THE DRAWING BOARD

Increasing current-handling capability of regulators

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THE TREND IN MODERN LOGIC FAMILIES IS to make them operate with smaller and smaller amounts of power. (I suppose the ultimate goal is the family that can run on potential energy!) Lower power-requirements get rid of the necessity for wrist-thick cables and glass insulators, but there's an even more important benefit. Lower power means smaller, and less complicated, regulator circuits. Some IC's even have the regulator circuitry built onto the chip's substrate. Less current-draw means that the layout of the + V run on printed-circuit boards is much simpler. Remember that when heavy amounts of current are running through a trace on a board, a potentially troublesome voltage drop will be generated because of the resistance (however small) of the copper trace. That can lead to inductive oscillation and other nightmares.

That "low power" side benefit, however, can tend to make you a bit forgetful when you're developing a power supply. LED's, relays, and other things can still gobble up current at an alarming rate. A power supply that can deliver half an amp may seem perfectly adequate for, say, a CMOS circuit—and it is. Unfortunately, when we start asking the circuit to turn something on or light something up, the current draw is going to increase dramatically and our half-amp supply is rapidly going to drop dead.

The voltage-regulator circuit that we've been developing over the past few months can so far safely supply about a half amp over its full range, but it's a smart move to design it so that it can provide a lot more. Since the internal circuitry of the 7805 is limited to less than one amp, it's obvious that we're going to need some other device to provide the additional current.

Adding a pass transistor

In Fig. 1, we've added a transistor and a resistor to take care of the additional current. For simplicity's sake I haven't drawn in the rest of the circuit we've developed so far. All the current that goes into the regulator has to pass through R_B since it's in series with the regulator input. Ohm's law tells us that as the current flow through a resistor increases, so does the voltage developed across it. The base-emitter junction of Q1, a PNP transistor, is in parallel with R_B. As long as the current flowing through the resistor is below a certain level, just about all that's going to happen is that the resistor will get a little warm. At some point, however, the voltage drop across R_B is going to get high enough to turn on the transistor, which will start to pass current through its collector. That current is added to the current supplied by the regulator and allows the draw on our power supply to be increased by the amount that the Q1 can handle without blowing up.

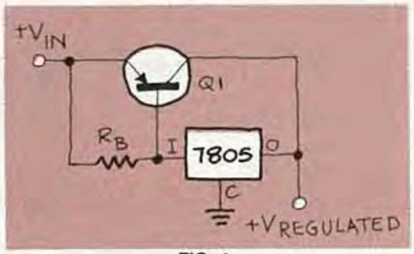

FIG. 1

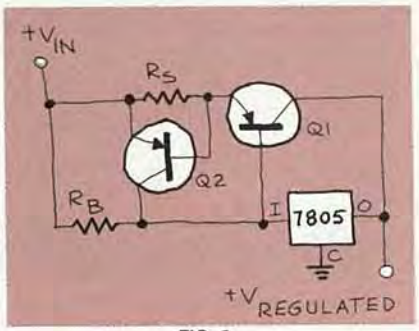

FIG. 2

Transistor Q1, then, is used as a switch that senses when the regulator output is near some limit and turns on to provide the extra current that the regulator can't handle. The turn-on point of Q1 is determined by the value of R_B and the base-emitter voltage of Q1. One other thing to be aware of is that the difference between the input and output voltages is going to change. Since Q1 and R_B are in series with the regulator input, the voltage drop across them has to be added to the inherent 2-volt drop of the regulator. That is important to remember when we're figuring out how much voltage we need at the output of the rectifier.

Short-circuit protection

Before we start doing any arithmetic to calculate the value of R_B we have to add some short-circuit protection to the circuit. I know you're thinking that we took care of that earlier, but we've now added active components to the input. If the output is shorted now, all our earlier protection springs into action—but it only takes care of the regulator. The collector of Q1 is going to be shorted out and the transistor is going to start passing current through the short. It will rapidly exceed its maximum collector-current rating, and all you'll be able to do is administer the last rites.

That is, to say the least, an undesirable state of affairs. In Fig. 2 we've added a safety net for Q1 in the form of Q2 and R_S. Those of you with sharp eyes will recognize that those two new components form a switch in exactly the same manner as R_B and Q1. The same sort of analysis also applies.

All the current that flows through Q1 has to pass through R_S. When a certain point is reached, the emitter-base junction of Q2 is going to conduct and the transistor will turn on. When it does, it will lower the voltage across R_B and turn Q1 off. Since Q2 isn't going to turn on until the power supply is providing really large amounts of current, we need a hefty transistor there. It has to handle pretty close to the sum of the short-circuit currents of both the 7805 and Q1.

Since there are more components connected in the circuit between the base and emitter of Q1, the math needed to calculate the values of the two resistors is going to be more complicated. Rather than going through it however, let's make a few intelligent assumptions and see if we can make life easier.

If we use silicon transistors for Q1 and Q2, we know that the base-emitter voltage is going to be about .65 volts when the transistor is turned on. As long as the voltage is below that, the transistor will be turned off.

Now let's look at Fig. 1 again and assume that Q1 isn't there. The 7805 needs about 8 mA to operate—the rest of the current it passes is available to whatever circuit it's powering. The regulator can handle half an amp without any problem, but let's be on the safe side and arrange for Q1 to turn on when the regulator draw exceeds 250 mA. Since the turn-on voltage for the transistor is 0.65 volts, calculating the value of R_B is a snap: $R_B = E/I = .65/.250 = 2.6$ ohms

Now, it's true that the emitter-base junction of Q1 is in parallel with R_B so that bunch of arithmetic isn't strictly correct. Remember, though, that the apparent resistance of the junction when the transistor is in cutoff is pretty high. It's not really accurate to talk about the resistance of a transistor (or any semiconductor, for that matter), because they're dynamic devices and we should more properly refer to their "impedance." That's the DC resistance coupled with an AC component. For our "real world" circuit, however, the difference doesn't amount to much and we can ignore it.

If you look at Fig. 2, you'll see that we have to go a little farther in figuring the value of R_B. Since both R_B and R_S are across the emitter-base junction of Q1, both their values have to be taken into account when we figure the trip point of Q1. Once again, the "resistance" of Q2 in cutoff is high enough for us to ignore it and just work with the resistor values.

Since R_S has to pass all the current that flows through Q1, we have to decide what we're going to let the maximum current be. Five amps is a good value for our regulator circuit—more than that will cause design problems we don't want to get involved with. Just as was the case with Q1, Q2 will start conducting when its emitter-base voltage reaches 0.65 volts. If we want that to happen when Q1 is passing 5 amps, R_S has to be on the order of 0.13 ohms. The total resistance we need to turn on Q1 is 2.6 ohms. Since R_S must be .13 ohms, the new value of R_B will be 2.47 ohms.

Now, I'm the first to admit that those are pretty oddball values for resistors. You can't exactly amble down to your local resistor store and buy a 2.47 ohm resistor. There are ways around that, though.

Next month we'll take care of all the unfinished business and complete our regulator. We'll consider choices for Q1, Q2, and the proper wattage for the resistor. Not only all that, but, since we've all been working so hard we'll find ourselves treated to a surprise in the circuit that's not only useful, but that's one we get for free. **R-E**

"I'm not too thrilled with its aesthetic value, but I sure dig the variety of channels I can get."