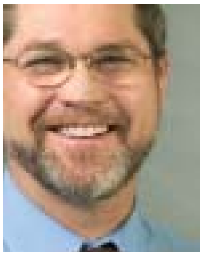

BY HOWARD JOHNSON, PhD

Voltage-regulator droop

The circuit model in **Figure 1** captures the important low-frequency behavior of most voltage regulators (**Reference 1**). Parameters C_2, R_2, and L_2 represent a typical bulk decoupling-capacitor array. To model the response below 100 kHz, you can set L_2 to 0. Parameter R_1 models the regulation resistance, or stiffness, of a small switching-regulator module. Parameter L_1 models the response time.

Now try something outrageous. Add series resistance to the regulator output, effectively increasing the value of R_1.

When the load draws current, the new, larger value of R_1 increases the droop measured at V_{CC}. That scenario sounds bad, but in some special circumstances, it is actually good for your circuit.

Figure 2 shows the regulator-voltage response for values of R_1 from 3 to 12 mΩ. The circuit is subject to an 8A step load with a maximum dI/dt of 2.5A/µsec. The plot shows the load current at the bottom and the collection of response curves at the top. It offsets each curve horizontally to visually separate them.

Concentrate on the red waveform (minimum value of R_1). Beginning from rest at Point A, the V_{CC} output sits at its nominal, midlevel value. When the load turns on, V_{CC} responds with a downward glitch.

Only components C_2 and R_2 limit the initial amplitude of this glitch, because the regulator can't respond instantaneously; it takes a few switching cycles to respond.

Once the regulator wakes up, it drives the voltage back to a new operating Point B. The sluggish response of the regulator mimics the action of an inductor, which is why **Figure 1** makes such an effective model.

When the load switches off, the response pops back high at Point C. (Inductors do that.) The overall peak-to-peak response of the red waveform equals nearly twice the amplitude of the initial glitch.

Now, increase R_1 to 0.012Ω and reapply the load. The black waveform goes down and stays down, displaying more long-term droop because of its larger series resistance. When the load cuts off, the positive glitch that inductor L_1 causes begins at a lower level. Beginning lower, this glitch does not reach as high as the glitch on the red waveform. As a result, you obtain the smallest peak-to-peak response with R_1=0.012Ω.

If you use this method, offset the resting voltage of your regulator toward the high end of its range to best center the overall step-response waveform.

Some switching regulators let you lower the gain of the control loop, effectively increasing the regulation resistance, R_1, without dissipating additional power. This cool trick does not work for linear regulators.

Whatever you do, beware of the tolerances associated with all components in this circuit. Do not design something so tricky and intricately balanced that small changes in component values throw the system out of whack. EDN

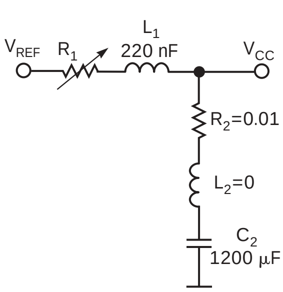

Figure 1 Some regulators provide adjustable droop.

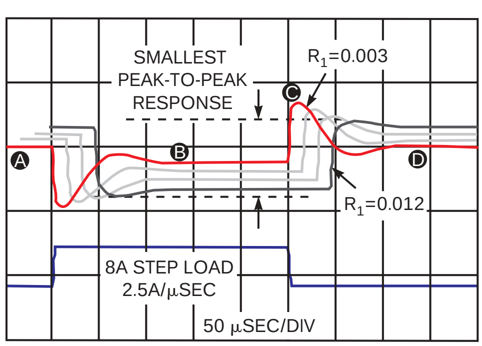

Figure 2 Adjusting R_1 changes the peak-to-peak response.

REFERENCE

1. Johnson, H, "Voltage-regulator model," *EDN*, Aug 17, 2006, pg 22, www.edn.com/article/CA6360320.

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