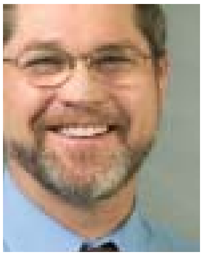

BY HOWARD JOHNSON, PhD

Voltage-regulator model

I love switching-regulator modules. They are efficient, you can configure them for many uses, and you can easily model them.

Figure 1 shows a typical characterization test for a regulator module—a Texas Instruments PTH08T220W switching-regulator module. The module is subject to an 8A step load, with a maximum dI/dt of 2.5V/μsec. The plot shows the load current at the bottom and the voltage-regulator response to this current at the top.

To build a circuit model for this voltage regulator, you need no additional information about the insides of the regulator. The step-response test reveals enough information to form a simple circuit model (**Figure 2**). The circuit model assumes a perfect voltage source, V_{REF}, connected through components R_1 and L_1 to your V_{CC} plane. Components R_1 and L_1 represent the action of the regulator.

Component C_2, along with R_2 and L_2, represent the bulk capacitor (or array of bulk capacitors) in your application.

If, by looking at the data sheet, you can discover values for R_1 and L_1, then you can build a circuit model such as the one in **Figure 2** for any application of the regulator.

The most straightforward parameter in this circuit is R_1. Over a time period of more than 100 μsec, the circuit comes to rest at a steady-state dc operating condition. After that time, capacitor C_2 draws no appreciable steady-state current, so you may replace it with an open circuit. Similarly, replace inductor L_1 with its dc equivalent: a short. The only operative component remaining in the circuit is resistor R_1, which directly controls the output droop, or steady-state dc offset. The value of R_1 equals the ratio of droop to load current.

Over a medium scale of time, components C_2 and L_1 come into play, creating a damped sinusoidal response. The application note for this component shows a typical step-response waveform with 1200 μF of output capacitance. Given that data point, you just set C_2 equal to 1200 μF and adjust L_1 to match the width of the sinusoidal glitch. Now you know L_1!

Last, given R_1, C_2, and L_1, adjust R_2 until you match the damping factor of each sinusoidal pulse. Now you know what ESR (equivalent series resistance) that manufacturer used when it snapped the step-response picture.

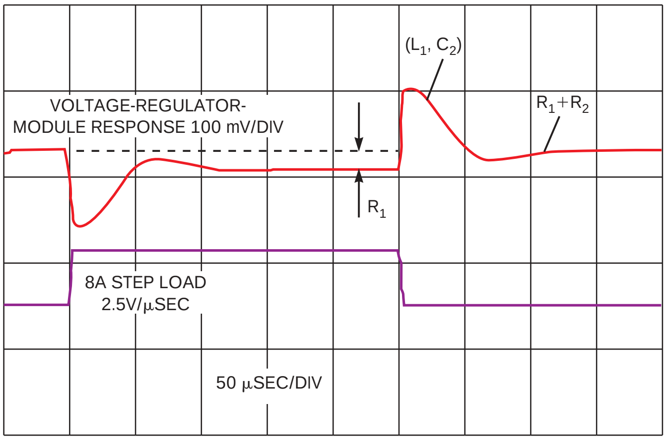

Figure 1 Four parameters control the low-frequency step response.

This simple circuit mimics the performance of the regulator at frequencies from dc to approximately 100 KHz. Above that range, the ESL (equivalent series inductance) of capacitor C_2 comes into play, but this low-speed step-response test doesn't provide enough information to determine L_2. For a low-speed model, just leave L_2 at zero.

This simple circuit model works for any voltage regulator with dominant-pole feedback, meaning that the regulator does not use a multipole phase-compensating feedback structure. (Most don't.)

Always follow the manufacturer's guidelines for minimum capacitance and minimum ESR in your output capacitors. Failure to do so can produce unstable oscillations in the feedback circuit, destroying your circuit. **Figure 2** does *not* model that aspect of regulator behavior. EDN

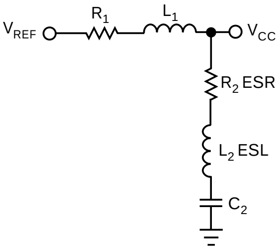

Figure 2 Most voltage regulators behave like this simple circuit.

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