Testing a power supply - Noise (Part 2)

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Read the introduction to this series in Part 1, and the conclusion in Part 3, which covers stability.

This is Part 2 of a three-part series which discusses how to properly test a DC/DC power supply to ensure it works reliably over various operating conditions. The series is intended to provide the design engineer with a sufficient understanding about some, but not necessarily all, of the testing needed to verify a reliable power supply design.

Part 1 covers the fundamentals about testing, including the necessary equipment and how to prepare a circuit for testing. Part 1 covers how to accurately measure start-up time, current limit, and power supply efficiency.

In Part 2, we discuss how to measure various sources of noise and output voltage errors found in a switch-mode power supply. We also discuss good oscilloscope probing techniques to help ensure accurate measurements.

Video 3: Power supply noise

Good probing technique for measuring noise

When measuring noise with an oscilloscope, be careful to ensure what you see is actually noise from the circuit - not noise being coupled into the scope probe. For an accurate measurement, use the shortest ground stub available with your passive probe, or use an active/differential probe with probe pins. An active probe generally provides the best results, yet many have voltage limits that are below the voltage you might be measuring. Also, some active probes have limited AC coupling capability, resulting in difficulty when measuring noise. Reference the operating manual for the specific active probe before attempting to use it for power supply testing (Figure 1).
Figure 1. When measuring noise do not use long ground wires

Noise

Power supply noise can be generated from many different sources. Like any amplifier, all power supplies generate low levels of noise, such as thermal noise, while switch-mode power supplies generate noise from their inherent switching. While linear regulators also produce noise, that topic will not be discussed here.

For best results use an oscilloscope with appropriate bandwidth and sample rate. As discussed earlier, be sure to use a good passive or active probe for these measurements. Otherwise, ambient noise can be picked up and cause false readings. If a passive probe is used, a short ground spring or ground stub is needed. Place it directly across an output capacitor. Be careful to avoid placing the probe or probes ground wire near any inductor or transformer as this may cause magnetic coupling into the probe, again, resulting in false readings. Basic switch-mode power supply noise can be separated into two different types: ripple, and transient switch noise.

Measuring Load transient performance

Load transients are the droop and/or overshoot, which take place on the power supply output when an instantaneous change in load current takes place on its output (Figure 2).
Figure 2. Load transients are caused by a fast change in load current.

The transient amplitude is a function of many variables, including the regulation circuit. The actual load current change and rate of change has a significant effect on the transient’s magnitude. For proper testing, a worst case load step and slew rate must be defined.

1. Before connecting the DC power supply to your power circuit, set the proper input voltage and verify correct polarity.
2. Connect the dynamic load to the power supply output. Set electronic load to provide a switching load from 10 to 90 percent of maximum output current (or pre-determined levels determined to be realistic limits for the specific system). Set the switch duty cycle to 50 percent and frequency of switching to a few hundred Hz. Set slew rate on the electronic load as appropriate for the load being driven, or per the system specification.
3. Connect an oscilloscope across the output capacitor using a very short ground spring or wire ground stub. Set the oscilloscope for AC coupling or DC coupling with appropriate offset. Using normal trigger mode, set bandwidth limiting on the oscilloscope to help provide a cleaner waveform, resulting in easier measurements.
4. Connect the power supply to the input.
5. Apply power, adjust the vertical gain on the scope to measure the positive and negative transient spikes. With normal trigger mode, set a positive slope to capture the overshoot (when the load is reduced). Set a negative slope trigger to measure undershoot and droop (when load is increased).
6. Note the peak voltages and the time it takes to settle back to within 10 percent of the nominal output voltage. Note: Though not necessary, it may be useful to trigger the oscilloscope off the electronic load’s trigger output, if provided.
Measuring line transient performance

Line transients are the droop and/or overshoot that takes place on the output of a power supply when an instantaneous change in input voltage takes. The transient amplitude is a function of many variables including the regulation circuit. The actual line voltage change and the change rate have a significant effect on the magnitude of the transient. For proper testing the worst case line voltage-step and slew rate must be defined.

1. Connect a dynamic load to output wires. Set the electronic load to the maximum output current expected.
2. Set the DC power supply to switch between the minimum and maximum input voltage expected (manual or automatically, if the power supply is capable).
3. Connect the power supply to the input.
4. Connect the oscilloscope across the output capacitor using a very short ground spring or wire stub. Set oscilloscope for AC coupling (or DC coupling with appropriate offset voltage) with normal trigger. Bandwidth limiting may be enabled on the oscilloscope to help provide a cleaner waveform resulting in easier measurements.
5. Apply power, adjust the vertical gain on the scope and measure the positive and negative transient spikes. Set the scope to normal trigger mode with positive slope for to capture the overshoot, and set to negative slope to measure undershoot and droop.

Note the peak voltages and the time it takes to settle back to within 10 percent of the nominal output voltage.

Switching ripple noise

Switching ripple noise is created when a switch-mode power supply and associated load charges and discharges the output capacitor, respectively, during every cycle of the pulse-width modulator (PWM) engine. The frequency will be that of the PWM oscillator and often looks like a triangle wave (Figure 3).
Figure 3. Switching power noise shown without bandwidth limiting.

Figure 4. Use bandwidth limiting to make it easier to measure switching ripple noise.

1. Before connecting the DC power supply to your power circuit, set the proper input voltage and
verify correct polarity.
2. Connect the DC power supply to the input.
3. Set the electronic load to the maximum load expected and connect it to the output.
4. Set the oscilloscope to bandwidth limit to avoid measuring the transient noise (Figure 4).
5. Oscilloscope may be set to AC or DC coupling with an appropriate offset voltage as needed.
6. Turn on the input power from the DC power supply.
7. Connect an oscilloscope probe with a short ground stub directly across the output capacitor and set the scope to normal trigger mode with the trigger level at midpoint of the waveform.
8. Measure and log the peak-to-peak value of the waveform disregarding any high frequency spikes (they will be measured in the next section).
9. Log the frequency of the waveform.

Switching transient noise

Switching transient noise is the noise generated when the PWM switches change state. The transient spike is a higher frequency spike or a sequence of spikes often in the form of a damped sine wave (Figure 3). This transient noise can cause high frequency interference internal to a system and/or cause EMI issues, which will not be discussed in this series.

Be aware that an electronic load may generate noise internally, adding to the output noise of the circuit under test. Also, the output wires may pick-up noise resulting in higher noise measurements than in reality. For this reason you may want to verify the switching transient noise measurements using a load resistor with very short leads. Keep in mind that if the system load is disconnected, you may be measuring noise higher than when a load is connected with high-frequency decoupling capacitors.

1. Before connecting the DC power supply to your power circuit, set the proper input voltage and verify correct polarity.
2. Connect the DC power supply to the input.
3. Set the electronic load to the maximum load expected and connect it to the output.
4. Turn on the input power.
5. Connect the oscilloscope probe with a short ground stub directly across the output capacitor and set the scope to normal trigger mode with the trigger level at midpoint of the waveform. (Ensure NO bandwidth limiting is enabled on the oscilloscope.)
6. Measure and log the maximum and minimum value (positive trigger for maximum and negative trigger for minimum).

Be aware that even with the best probes and probing techniques, some amount of high frequency noise will be coupled into the probe, resulting in a measurement worse than that actually in the circuit.

Switching waveform

It is always a good idea to observe the switch node of a switch-mode power supply. Verify that the switch voltage is not above a predetermined maximum or below a minimum value. Usually the limit
is determined by either the power IC or, in the case of a power controller, the external transistor(s).

1. Before connecting the DC power supply to your power circuit, set the proper input voltage and verify correct polarity.
2. Connect the oscilloscope probe ground to the appropriate reference point being sure to isolate the load from the oscilloscope, if that point is not at ground potential. It’s always best to use a very short ground connection to ensure best accuracy. See earlier section on good probing technique.
3. Turn on the DC power supply.
4. Set the oscilloscope to trigger on the positive edge and turn off any bandwidth limiting.
5. Observe and log the most positive voltage on the node.
6. Set the oscilloscope to trigger on the negative edge.
7. Observe and log the most negative voltage on the node.

**Thermal testing**

Thermal testing and management deserves a thorough explanation of its own. Here are some basic methods of testing component temperature within a power supply: Thermal probes: Thermal bimetal probes with a meter can be used for accurate thermal measurements. A probe along with thermal grease allows measurement in the normal system operating conditions. Normally this can be performed with minimal changes to the mechanical structures of the system enclosure. Specifics should be obtained within the meter’s user’s manual.

Thermal IR probes: IR thermal probes are a cost-effective tool for gaining insight into the rough temperature of a circuit. For precise accuracy it may be necessary to use a thermal bi-metal probe or a thermal imager.

Thermal imaging: Thermal imagers may cost more yet provide a clear picture of the temperatures on a circuit board. Thermal imagers are the best way to get a feel for the hot spots on a PCB. However, they cannot be used when the board is inside an enclosure. For an accurate measurement inside an enclosure, a thermal probe is often the best approach.

In Part 3 of this series, we will discuss stability of a power supply and how to measure it. We will also discuss phase and gain margins in a control loop and how to read it from a bode plot. Read the introduction to the series in Part 1.

Join the conversation about testing power supplies on TI’s E2E™ Community: www.ti.com/engineer56-ca.

**References**

For more information: www.ti.com/power-ca; www.ti.com/webenchcenter-ca.

**About the author**
Robert M. Hanrahan currently is Member Group Technical Staff at TI where he is involved with analog field applications. He has more than 20 years of experience in digital and analog design, applications engineering, and management. Robert has published numerous application notes and articles in electronics and aviation trade magazines and has a patent in his name. His degrees include a BS from The University of the State of New York, and he holds a commercial pilot and flight instructor certificate, as well as a ham radio license. Robert can be reached at ti_rhanrahan@list.ti.com.