The overwhelming majority of modern power supplies are switch-mode devices. Power is controlled via a series of gate-drive pulses that control the switching power devices. When the load is large and more power is needed, the feedback loop, which monitors the output voltage, adjusts the gate-drive pulses to make them wider. When the load decreases, so does the pulse width. There are a variety of tests that engineers perform on power supplies and power conversion devices. These include Safe Operating Area (SOA), power losses, high-side gate drive, dynamic on resistance, control-loop response, output ripple, line current harmonics, power factor, real/apparent power and a variety of others.

**Measuring Response to a Change in Load**

One of the most common concerns, both for a power supply designer and for an engineer who is incorporating a power device into another product, is the response of a power supply to a change in load. Figure 1 shows an analysis of power supply performance when the load is reduced. The technique is the same for a step-up in load. The time-base descriptor in the lower right corner shows a time/division setting of one millisecond. Because there are 10 divisions on the screen, it also shows that the scope is capturing ten milliseconds of data and the sampling rate is 1.0 GS/s – more than enough to capture the signals of interest. When sampling at this rate for 10 milliseconds, the scope fills 10 megasamples of memory (“10MS” in the descriptor box).

The top grid of the oscilloscope screen in Figure 1 shows the capture of the gate drive pulses starting from about 1 millisecond prior to the change in load and continuing for about nine milliseconds afterwards. Note the yellow triangle below this trace. That is the trigger point. Slightly before the trigger and about half a horizontal division after the trigger there are short highlighted portions of the trace. The red colored highlight is shown as a zoomed detail in the third grid on the screen, while the purple highlighted portion is shown as a zoom detail on the bottom grid. In these zoomed portions, the scope displays the gate-drive pulses which were occurring prior to the change in load (red) and about half a millisecond after the change (purple). Even an “eye-ball” view of the zooms reveals the power supply was putting out more power (wider pulses) for the larger load prior to the step, and less power (narrow pulses) for the smaller load after the step.
Figure 1: Ten msec of gate drive pulses are captured in the top trace. The second trace tracks all the values of those pulse widths. The third trace is a zoomed detail prior to the change in load and the bottom trace is a zoom after the step change.

Though the insights discussed above are useful, the deeper picture of the power supply’s response to a change in load is contained in the second (blue) trace in Figure 1. This trace is a track of all the values of the gate-drive pulse widths. Digital oscilloscopes are very good at showing a series of numbers versus time. However, those numbers do not have to be voltages or currents. In this example what the engineer really wants to know is, “How does the power supply’s control loop respond to a change in load?” This question is answered by the blue trace. At the beginning of that trace, the gate pulse widths are wide (large numbers), followed by a rapid, sharp drop in pulse widths when the load changes. Next, the pulse widths go up to a small peak, and then go down a bit before slowly rising to a pulse-width value that corresponds to steady-state operation with the new load. The engineer can use the measurement capabilities of the scope on the track of gate-drive pulse widths. For example, the scope can measure the fall time of the edge or the minimum value of the trace. If the engineer wants to tune the response of the power supply to a change in load he can save this set of traces, tweak the power supply design and then repeat the measurements. If desired, he can subtract the two “blue” traces from before and after his “tweak” to see exactly what the differences are. This is a very good technique for quickly visualizing the closed-loop response of a power switching section to a step change in load as well as for performing precise measurements to characterize the performance.

**Measuring Safe Operating Area**

Both the designers of power devices and engineers who are incorporating those devices into other products want to make sure that the power device will stay in its safe operating area under various conditions. They also want to ensure that the device being powered is not subjected to any large current/voltage spikes. The engineer may
also want to confirm the snubber diode is limiting the turn-off voltage as expected. For an SOA measurement, one channel of the oscilloscope captures the voltage of the power supply switching device while at the same time a second channel of the scope captures the current flow through it. The objective is to capture both the voltage vs. time and current vs. time waveforms and plot them on a XY plot as shown in Figure 2. To produce the XY plot, the first value of the voltage trace is paired up with the first value of the current trace. This XY pair is plotted. Then the same is done for each of the other 2 million samples in the voltage and current waveforms. Note that the timebase descriptor box in Figure 2 says the two waveforms are each shown at 2 msec/div (a total of 20 msec), and that 2 MS (megasamples) of memory were captured on each trace using a sampling rate of 100 MS/s.

![XY Plot Example](image)

**Figure 2:** The upper, yellow trace is voltage vs time. The blue trace below it is current. The XY plot in the upper right uses the voltage values as horizontal coordinates and the current value taken at the same point in time as the vertical coordinate.

When performing an SOA measurement, the “dangerous” part of the XY plot are points that fall toward the upper right. Those points have high values for both voltage and current. When using a LeCroy instrument for this measurement, a scope user can place a cursor on the XY plot and move it around to any points of interest. The cursor will also appear on the voltage vs. time and current vs. time waveforms on the left side of the screen. This unique feature of LeCroy oscilloscopes is very useful in troubleshooting SOA problems. The instrument will show whether the worrisome points of the SOA plot come immediately at the start of the measurement, possibly indicating a problem with inrush current; or whether they come later, which could mean a problem related to step response for a change in load.
Additional Measurements

It is beyond the scope of this Technical Brief to show examples of every type of measurement for power devices. More examples can be found at www.lecroy.com. These include measurement of instantaneous power, total power dissipation, dynamic on resistance, real/apparent power, line-current harmonics (compared to standard templates for EN 61000-3-2 Class A, B, C, or D equipment), how to use the type of pulse width modulation analysis shown in Figure 1 to test power supply soft start and a variety of additional measurements.

All these measurements involve the capture of voltage and current signals from power devices. One of the more important factors in making accurate – and safe – measurements is the use of proper probes. LeCroy offers a wide range of current probes (up to 500 amps) and voltage probes (up to 20 kV). In some applications, it is desirable to measure voltages without a reference to ground. For these measurements the ADP300 (20 MHz bandwidth) and ADP305 (100 MHz) are well suited. Both of those active differential probes are rated to 1.4 kV. In some cases the most difficult part of the measurement is to capture, view and measure small signals in the presence of much larger voltage swings. In those cases a differential amplifier is required. The LeCroy DA1855A offers industry-leading 100,000:1 CMRR and very fast overdrive recovery.

Summary

Designing power devices requires many different types of measurements. Engineers who need to incorporate such devices into their products also need to perform a subset of these tests. Using the tools in LeCroy oscilloscopes can make this process much faster and easier. All engineers want to get their product to market quickly – but not if a fault has been overlooked in the power supply. Using the right probes and characterizing device performance using in-circuit tests can give the engineer much more confidence in the robustness of a design.