Summary

This technical note focuses on the uses of digital scopes for measuring power supply characteristics. Examples are given of measuring power supply turn-on, hold-up time when AC power fails, in rush current and ripple/noise. Examples are given of pass/fail testing and power calculation. There is also a brief discussion of triggering and of the possibility of storing test sequences.

Introduction

The last decade has seen dramatic improvements in power supplies, and particularly in switch-mode power supplies. Due to improvements in power MOSFETs, in regulators and in control circuitry, switching power supplies are becoming smaller with power densities already greater than one watt per cubic inch, and with efficiencies reaching 90%.

As with many other technologies, the product life cycle is shortening rapidly, and manufacturer competition is becoming tougher. When the designs are very similar, a shorter time-to-market (for a new product), or a shorter production cycle, can make the winning difference. Test time, for instance, can now be reduced by using the latest developments in digital oscilloscopes. In the following we will describe a number of applications where digital oscilloscopes can considerably shorten design and test times.

Benefit of DSOs

As with analog oscilloscopes, the primary job of a digital oscilloscope is to display the input waveforms. Unlike analog oscilloscopes, the technique used to achieve this is to sample the input waveforms at regular intervals. The sampled analog values are then converted into digital numbers which in turn are stored into an internal memory. An input waveform is stored in the scope as a sequence of numbers, as many as the memory length. The waveform display is done by retrieving these numbers and representing them on the screen.

The use of this digital technology has many implications. Those which affect power supply testing include the following:

* **Multi-channel single-shot capture**: A DSO can capture single shot phenomena like power ON/OFF or failure conditions synchronously on up to four channels at the same time.
Waveform processing: Since the DSO internally uses a microprocessor, it can also perform various types of processing on the acquired waveform. For example, automatic calculation of pulse parameters and basic waveform mathematics (sum, difference, product, ratio) are standard features of all LeCroy oscilloscopes. Options are available for the 9300 series scopes to perform more complex mathematics like integral, derivative, exponential, logarithm, extended averaging, digital filtering, extreme values, Fast Fourier Transform and more.

Data storage and archiving: LeCroy DSOs have built-in memories which can store reference waveforms. They also offer DOS-compatible memory card, portable hard drive and floppy-disk options for non-volatile mass storage. The scopes can be easily interfaced to a large variety of plotters and printers for high quality hardcopies. The user can download the data and screen graphics as TIFF files directly into WordPerfect or other publishing software.

More trigger possibilities: DSOs also offer a wealth of trigger capabilities not found in analog oscilloscopes. For instance it is possible to trigger on faulty conditions and look at pre-trigger data to understand the history leading to the fault.

Stored test sequences: All LeCroy oscilloscopes offer the facility to store entire instrument setups in internal non-volatile memories. Many more setups can be stored onto memory cards, portable hard drive, or floppy disks, depending on what mass storage option is installed. These setups can be easily recalled either manually or under computer control. The user can then recall these predefined setups as part of a fully automatic (or semi-automatic) test sequence, eliminating the need for time consuming manual adjustments.

Automatic PASS/FAIL testing: LeCroy DSOs provide two kinds of automatic testing. The user can define a mask waveform and specify that any input waveform must be contained within the mask. Alternatively, the user can select a set of waveform parameters, which will be automatically calculated, and compare them to predetermined limits. If the waveform or the parameters fall outside the desired limits, a number of actions can be taken, including: freezing of the display (for visual inspection); screen-dump to a printer or waveform storage to disk, portable hard drive or memory card; send an interrupt to a computer; produce an audible alarm. The DSO tracks the statistics of passing and failing events.

Monitoring at Power-On

Figure 1 shows the Power-On transitions in a multi-voltage power supply. The simultaneous monitoring of all these transitions is useful to verify that any phase shifts are within acceptable limits. In fact, any voltage imbalances could be damaging to the load circuits. The switching time can also be automatically calculated, as shown in the figure.

Figure 1: Switch-on transition of a dual output power supply (+5 V and -5 V). Symmetric behavior of the two voltages is often required. The automatic calculation of pulse parameters (rise and fall times in this case) simplify this test.

Hold-Up Time

The hold-up time is the time for which the output voltage remains stable, at full load, after the loss of AC power. A digital oscilloscope is the ideal instrument for measuring this because of both the powerful trigger system and the single shot capture capability. (An oscilloscope with deep memory is normally required.)
Figure 2 shows such a hold-up time. The trigger condition used is LeCroy’s "Dropout" trigger. As shown at the bottom of the display, the scope triggers when the pulse train on channel C (the AC line) disappears for longer than 25 msec. The trigger conditions are also shown on the trigger setup menu, at the right of the display. The cursors positioned on the waveforms measure a hold-up time of about 70 msec.

![Figure 2: Measurement of the hold-up time. LeCroy's "Dropout" trigger mode is used, causing the scope to trigger on the mains drop which occur at the left of the lower trace.](image)

**In-Rush Current**

At power-on, the input current absorbed by the power supply has a spike which should not exceed the maximum allowable input current. The upper trace in Figure 3 shows an example of In-Rush current. The lower trace shows the simultaneously acquired input voltage.

![Figure 3: The in-rush current of a switching power supply (upper trace) is shown together with the input voltage. LeCroy’s "Bi-slope" trigger is used to trigger on current transitions of any slope.](image)

The oscilloscope used, a Model 9314AM, utilizes a bi-slope trigger, as shown in the trigger icon, at the bottom of the screen. That is, the oscilloscope would trigger on Channel 1 for whatever slope of the input pulse, provided it exceeds +0.5 V. The oscilloscope can test the In-Rush current automatically and in two different ways. It can calculate the current peak value and verify that it is smaller than a preset limit. Alternatively it can compare the full current waveform with a reference mask (as required by the European Telecommunication Draft Standard pr ETS 300 132). If the test fails, that is, if the in-rush current exceeds the set limits, several actions can be taken.

**Power Calculation**

The oscilloscope can be used to compute power. This is shown in Figure 4 where the two upper waveforms are respectively voltage and current at the input of a power supply. These two waveforms are multiplied point-by-point to provide the power waveform at the bottom.

![Figure 4: The power supply input voltage and input current (upper traces) are multiplied to provide the input power (lower trace).](image)

Figure 5 shows again the same power waveform together with the mean value of the power automatically calculated below the grid. The ratio of the output power (a DC value) to the mean value of the input power, would provide the power supply efficiency.
Ripple and Noise

Figure 6 shows an example of ripple measurement, (i.e., a measurement of the remaining AC component on the output). The displayed trace is obtained using LINE trigger, and averaging the input waveform on Channel 1 a thousand times, to remove the asynchronous noise. The scope automatically calculates the peak-to-peak ripple value of 2.5 mV, which is displayed below the grid.

Figure 7 shows a single-shot measurement of the high frequency switching noise (upper trace). The bottom trace shows an optional feature which can be added to all LeCroy oscilloscopes, that is the possibility of calculating the Fourier Transform of the input waveform even though this was taken as a single shot. The frequency analysis of the output noise can give valuable information about the origin of the noise.

Safe Operating Area

In a switching power supply the switching transistor(s) is probably the most stressed component and it is often important to verify that its working points lie inside the Safe Operating Area. The upper trace in Figure 8 shows the collector-to-emitter voltage of a switching transistor, while the middle trace is the emitter current. The bottom trace is the product of the previous two traces and it shows therefore the power dissipated inside the transistor. The two horizontal cursor lines show the limits imposed by the Safe Operating Area.

Figure 8: Voltage and current across the switching element. The product of the two gives the power waveform at the bottom. The oscilloscope can perform a PASS/FAIL test on the peak power, alerting the operator when violations of the Safe Operating Area are found.
Automatic Pass/Fail Testing

The Safe Operating Area test just described can also be done completely automatically. The user selects the "Peak-to-Peak" parameter and applies it to the third (dissipated power) trace of Figure 8. He can then specify that this pk-pk power must be, for instance, smaller than 400 V2. If the test fails, the scope can stop the acquisition, store the failing waveform on paper or on the memory card, "beep" and/or send an interrupt to the computer.

Another approach to the automatic test is shown in Figure 9.

Figure 9: Automatic PASS/FAIL test on the PWM waveform. The scope automatically tests that any input signal (inner waveform) lies inside the two outer waveforms (reference mask). Actions can be taken in case of failure.

The two outer traces shown constitute a Test Mask for the Pulse Width Modulated waveform on the collector of the switching transistor. They represent the maximum excursions that the upper trace in Figure 8 is allowed to have. (This mask may be generated automatically inside the scope. The user simply takes an acquired waveform and then specifies the desired tolerances.) When the test is activated, the scope will verify that all input waveforms fall inside the mask. In case of failure, the same actions mentioned previously can be taken.