Sales and Service Throughout the World

Corporate Headquarters

700 Chestnut Ridge Road
Chestnut Ridge, NY 10977
USA
http://www.lecroy.com

LeCroy Sales Offices:

Asia: Hong Kong
Phone (852) 2836 7361
FAX (852) 2836 7007

France: Les Ulis
Phone (33) 1 69 18 83 20
FAX (33) 1 69 07 40 42

Germany: Heidelberg
Phone (49) 6221 827 00
FAX (49) 6221 834 655

Italy: Venice
Phone (39) 41 456 97 00
FAX (39) 41 456 95 42

Japan: Osaka
Phone (81) 6 6396 0961
FAX (81) 6 6396 0962

Japan: Tokyo
Phone (81) 3 3376 9400
FAX (81) 3 3376 9587

Japan: Tsukuba
Phone (81) 298 41 5810
FAX (81) 298 41 5830

Korea: Seoul
Phone (82) 2 3452 0400
FAX (82) 2 3452 0490

Switzerland: Geneva
Phone (41) 22 719 2228
FAX (41) 22 719 2230

U.K.: Abingdon
Phone (44) 1235 536 973
FAX (44) 1235 528 796

U.S.A.: Chestnut Ridge
Phone (1) 914 578 6020
FAX (1) 914 578 5985

AN29
0499
5M MTECH

LeCroy

LeCroy Digital Oscilloscopes

Get The Complete Picture

Accurate Instantaneous Power Measurements

LeCroy

Reprinted with permission from an article published in PCIM Magazine, September 1998.

INTRODUCTION

Almost all electronic equipment utilizes a power conversion circuit to convert the AC line voltage to regulated DC voltages required by the electronics.

Power transistors used in these circuits can dissipate more power during turn-on and turn-off transitions than they do during saturation, so it is important to know the instantaneous power loss during this period. Accurate measurement of instantaneous power loss in power switching transistors requires very sophisticated instrumentation to acquire data, as well as software tools to analyze that data.

One approach is to use a Digital Storage Oscilloscope (DSO) with waveform math processing to acquire the signal and display the power loss. It does this by multiplying the data points making up the collector (or drain) current and voltage waveforms.

Before the DSO can accurately perform the required waveform math, both the current through the device and the voltage across it need to be accurately measured. Also, time-delay differences must be removed between the voltage and current measuring channels.

Engineers needing to make these measurements on power supplies or their component parts will appreciate the ease, accuracy, and completeness of LeCroy's new PowerMeasure System. The system starts at the probe tip with high-performance current and differential voltage probes. It includes a low-noise differential amplifier equipped with a matched pair of passive probes, a current probe, a deskew accessory that removes interchannel timing differences, and a choice of 500 MHz or 200 MHz color digital oscilloscopes. The scopes are customized with specific measurement capabilities for the power device designer.

The LeCroy PS344L PowerMeasure System.

Measurement Methodology

The most useful information about a device's power loss is obtained while it is functioning in its normal operating environment. This often means the measurements need to be made on transistors located in a line-referenced power supply's primary circuit. Therefore, the instruments must be able to safely measure signals riding at line voltage levels, without adding common-mode voltage signal corruption.

It is therefore necessary to use high-performance current and differential voltage acquisition systems to acquire the current and voltage waveforms of the power-switching transistor. Both the current and voltage channels should have upper bandwidth capabilities beyond the highest frequency contained in signals being measured.

Dividing 0.35 by the risetime of the fastest voltage waveform to be measured will give a good estimate of its bandwidth. The instrumentation should exceed this bandwidth by a factor of three. Equally important is the ability to measure DC levels of the current and voltage signals.

The waveform measurements described below were made using the PS344L LeCroy PowerMeasure System. This complete and affordable system includes these LeCroy components: The DA1855A, which is a DC-100 MHz differential amplifier, a DXC100A pair of matched probes; the AP015 DC-50 MHz current probe; the DCS015 deskew calibration source; and the LT344L *Waverunner*™, a DC-500 MHz digital oscilloscope equipped with PMA1 PowerMeasure Analysis software. These instruments have sufficient upper-bandwidth capabilities to make these power supply measurements.

The DA1855A differential amplifier and its matched differential voltage probes can accurately and safely measure various power supply signals located in the primary circuit, while minimizing circuit loading. The AP015 current probe provides the DC reference required for the current measurement, while also providing circuit isolation.

After the current and voltage waveforms are acquired, the *Waverunner* scope performs a multiplication function (I x V) to yield a waveform that represents power. To accomplish this, *Waverunner* multiplies the value of each acquired point on the voltage waveform by the value of the current waveform that it acquired at the same time.

Due to differences in the voltage and current signal path lengths and delays introduced by the current probe and differential amplifier, the current waveform data can be time-skewed in relation to the voltage waveform. When this occurs, the scope does not multiply time-coincident data pairs; therefore, the resulting power waveform is incorrect.

Small time differences can result in substantial errors in the instantaneous power waveform. For this reason, the measurement system must provide some method for correcting this time skew problem.

Deskew

Since the voltage and current probes' bandwidths are higher than the highest frequency of interest in the signals they acquire, the difference in the data points can be treated as a simple time skew.

Few DSOs provide a method to deskew the time differences between channels. Those that do use different methods and offer differing amounts of deskew range. The deskew feature in some oscilloscopes is intended for digital timing measurements and can lack the range necessary for instantaneous power measurements.

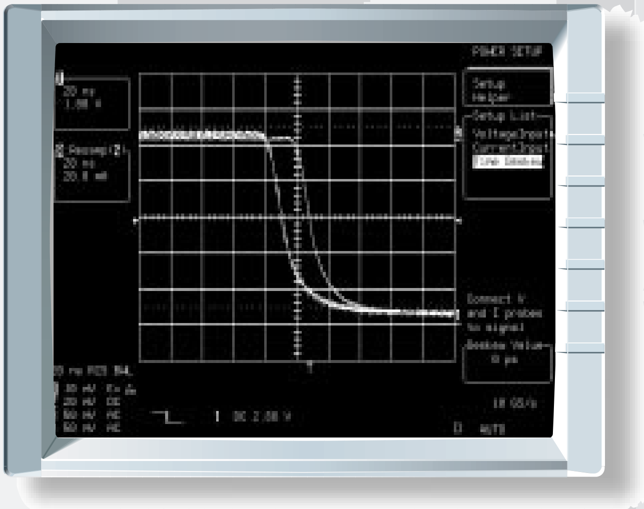


Figure 2: Measurement of the same signal indicates about an 18 ns delay difference between the current and voltage channels.

Time Deskew Function

The LeCroy *Waverunner* oscilloscope used for these measurements uses a deskew method in which the data points in an acquired waveform are "resampled" and displayed as a standard math function called "resample" with delay correction set by the user. The time relationship between the acquired and resampled waveforms can be skewed up to plus and minus 2 us with a 10 ps resolution. This is more than adequate to handle the time skew introduced by a wide range of current and voltage probes.

After any time skew has been compensated for, the data points in the resampled (deskewed) current waveform are multiplied by the voltage waveform to yield an accurate representation of the instantaneous power waveform.

To determine the amount of deskew required, the current and voltage probes need to be connected to time coincident voltage and current signals. The DSC015 included in the LeCroy PowerMeasure System provides fast rise voltage and current signals for this purpose. The DSC015 output signal risetimes are fast enough to allow accurate and easy waveform matching.

Figure 1 shows the current and voltage waveforms measured at the DCS015's output. This measurement indicates that the voltage signal is delayed by about 18 ns with respect to the current signal. In this particular setup, this delay difference is caused by the length of coaxial cable used to connect the external DA1855A differential amplifier to the input of the *Waverunner* oscilloscope.

To correct for the time skew difference between the current and voltage channels, we used *Waverunner*'s resample function to adjust the delay of the voltage probe waveform to match that of the current probe. The resample function creates a new waveform that is a "resampled" version of the voltage probe waveform. This function is automatically selected when the user selects the time deskew adjustment in the setup menu of the PMA1's Instantaneous Power measurement.

This new waveform differs from the original waveform only by the amount of delay set in the resample control. By adjusting the amount of resample delay, we can match the delay of the voltage channel to that of the current channel (Figure 2) for any acquisitions done with this system (the scope plus the differential and current probes).

After the two waveforms are matched, the scope's "delay" parameter indicates that the time-delay difference between the current and voltage channels is 17.18 ns. Using the resample function to delay the current waveform by this amount, we can now make accurate measurements that depend on the

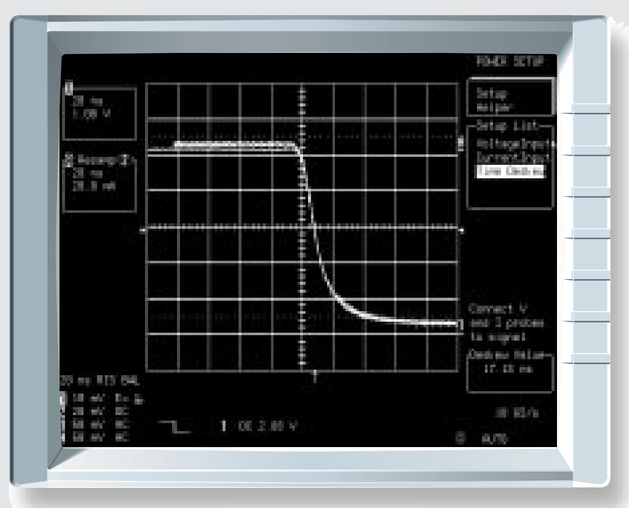
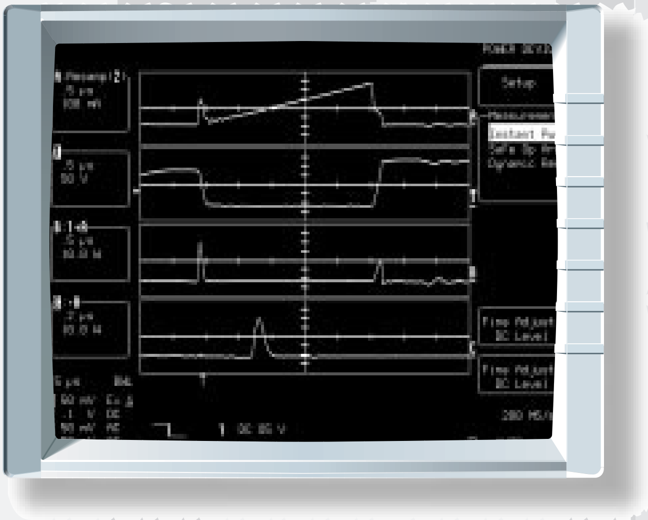
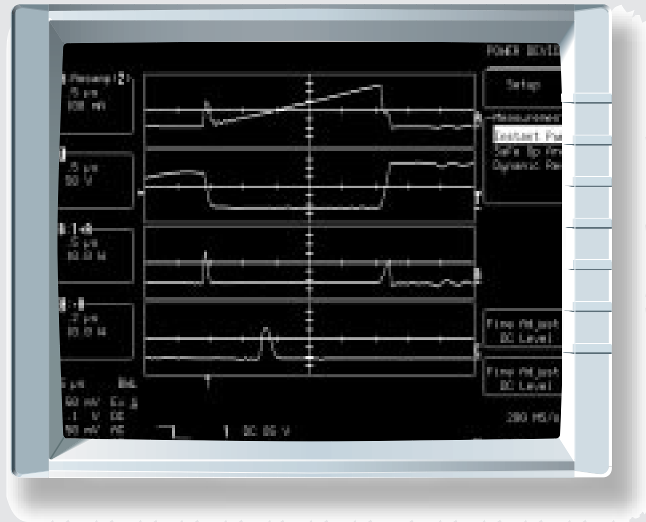


Figure 1: The resample function is used to correct the current and voltage channels' 17.18 ns delay difference. In this case the slower waveform (current) is moved forward in time by entering a positive delay.





Figures 3A & 3B: Comparison of instantaneous power measurements before and after channel time skew correction.

correct timing matchup of corresponding voltage and current samples. The timing adjustment (17.18 nsec in this example) will be performed “live” every time the scope triggers. Two power circuit measurements that require accurate timing matchup of voltage and current waveforms are instantaneous switching power losses and safe operating area (SOA), both of which are available as standard measurements in PMA1.

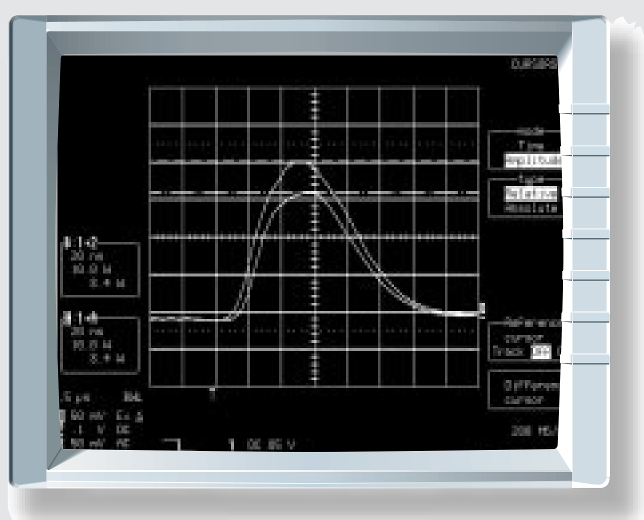
To illustrate the importance of signal deskew when designing snubber circuits, we can look at the current and voltage waveforms associated with the switching FET in a 25 W off-line flyback power supply. The snubber circuits are added to decrease radiated EMI by slowing the FET’s turn-off dv/dt. The challenge is to design a snubber circuit that allows the power supply to meet EMI requirements while introducing minimal power losses.

Figure 3A shows the FET’s voltage (CH 1) and current (CH 2) waveforms and the instantaneous power waveform that results from multiplying channels 1 and 2. This display is automatically set after selecting the PMA1’s Instantaneous Power measurement. Trace A at the top of the screen is the resampled/ repositioned current waveform (Channel 2). In Figure 3A, no deskew timing adjustment has been made.

In Figure 3B the resample function is used to correct the 17.18 ns time-delay difference between the current and voltage channels. When we compare the resulting power waveforms in Figures 3A and 3B, we can see the difference in the indicated amount of instantaneous power dissipation.

The two instantaneous power waveforms in Figure 4 are shown expanded around the transistor’s turn-on time. Using *Waverunner*’s cursors, we can see there is a substantial error (8.4 watts) in the non-deskewed instantaneous power waveform.

Figure 4: Cursors indicate an error of 8.4 W peak in the turn-on instantaneous power waveform when the current and voltage channel delay is not corrected.



Figures 5A & 5B: Comparison of Safe Operating Area (SOA) measurements before and after channel time-skew correction.

After the snubber circuits are designed, the safe operating area of the power transistor can be accurately checked using the PowerMeasure System's dedicated SOA function. This function setup is done by pushing a single button. The accuracy of SOA measurements also depends on the plotted current and voltage points being time-correlated. To obtain accurate results, it is necessary to use the resampled (deskewed) form of the voltage waveform. Figures 5A and 5B compare the same SOA measurement, with and without correcting the delay difference between the voltage and current channels.