Application Note

COMPUTING
COMMUNICATIONS
VIDEO

# Sophisticated Power Loss Analysis Using A Digital Phosphor Oscilloscope

## Quickly Locate Power Dissipation in Switching Power Supplies

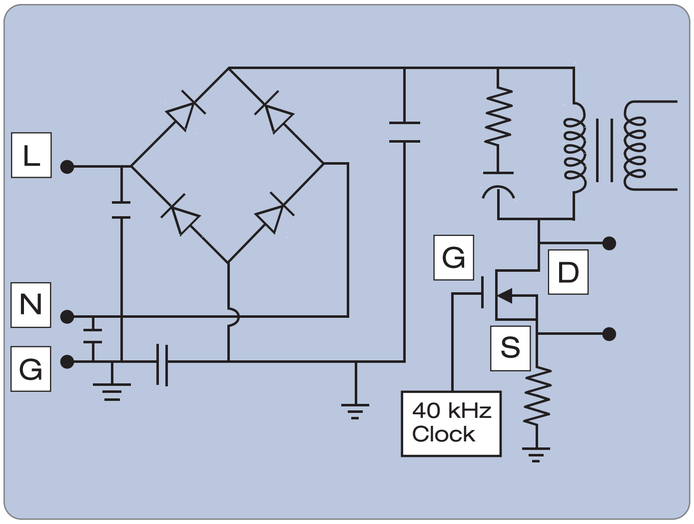
With demand for power driving architectural changes to switching power systems, the ability to measure and analyze the power dissipation in next-generation switch mode power supplies is critical. This is easily accomplished using a TDS5000 or TDS7000 Series digital phosphor oscilloscope with TDSPWR2 power measurement software.

New Switch Mode Power Supply (SMPS) architectures with much higher data speeds and GHz-class processors that need higher current and lower voltages are creating new pressures for power supply designers in the areas of efficiency, power density, reliability and cost. To address these demands, designers are adopting new architectures like synchronous rectifiers, active power filter correction and higher switching frequencies. These techniques bring unique challenges like high power dissipation at the switching device, thermal run-away and excessive EMI/EMC.

During the transition from an “off” to an “on” state, the power supply experiences higher power loss. (The power loss at the switching device while in an “on” or “off” state is less because the current through the device or the voltage across the device is quite small.) The inductors and transformers isolate the output voltage and smooth the load current. The inductors and transformers are also subjected to switching frequencies, resulting in power dissipation and occasional malfunctioning because of saturation.



Tektronix
Enabling Innovation




▶ ***Figure 1.*** *Simplified circuit for the inside switcher.*

Because the power dissipated in a switch mode power supply determines the overall efficiency of, and the thermal effect on, the power supply, the measurement of power loss at the switching device and inductor/transformer assumes great importance. This measurement indicates power efficiency and thermal runaway.

The challenges faced by designers who need to accurately measure and analyze instantaneous power loss for different devices are:

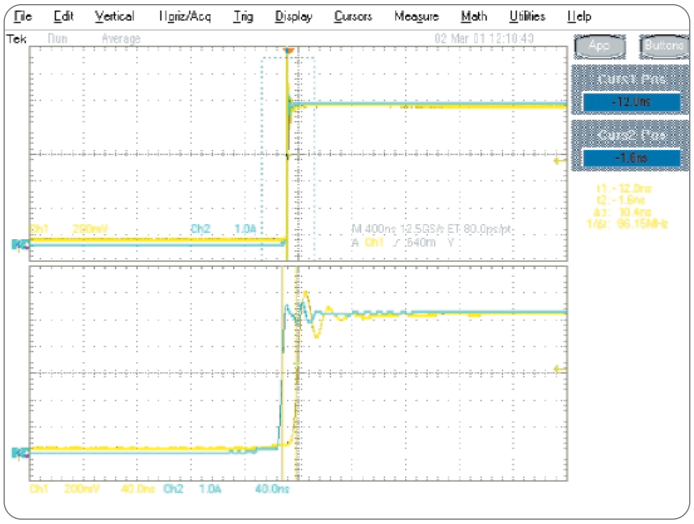
- Test setup for accurate power loss measurement
- Correcting errors caused by voltage and current probe propagation delay
- Computing power loss at a non-periodic switching cycle
- Analyzing power loss while load is changing dynamically
- Computing core loss at inductor or transformer

## Test Set Up for Accurate Power Loss Measurement

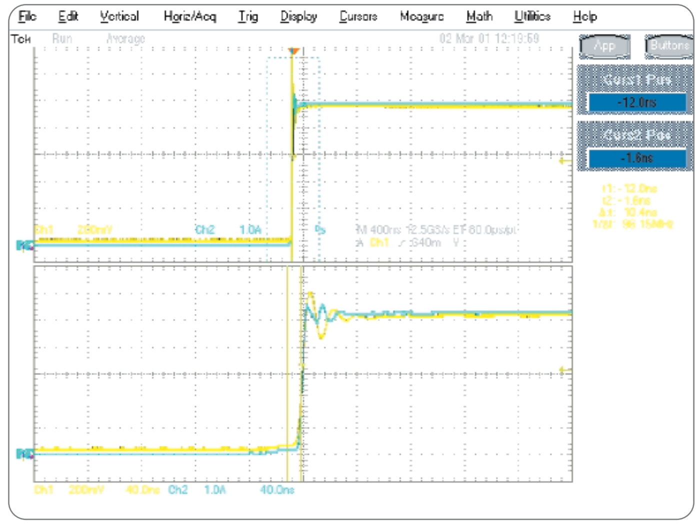
Figure 1 shows a simplified circuit for the inside switcher. The metal-oxide semiconductor field effect transistor (MOSFET), driven by a 40 kHz clock, controls the current. The MOSFET in Figure 1 is not connected to the AC main ground or to the circuit output ground. Therefore, taking a simple ground referenced voltage measurement with the oscilloscope would be impossible because connecting the probe's ground lead to any of the MOSFET's terminals would short circuit that point to ground through the oscilloscope.

Making a differential measurement is the best way to measure the MOSFET's voltage waveforms. With a differential measurement, you can measure voltage drain-to-source (VDS) – the voltage across the MOSFET's drain and source terminals. VDS can ride on top of a voltage ranging from tens of volts to hundred of volts, depending upon the range of the power supply. There are several methods to measure VDS:

- Float the oscilloscope's chassis ground. This is not recommended because it is highly unsafe and endangers the user, the device under test and the oscilloscope.
- Use the two conventional passive probes with their ground leads connected to each other and use the oscilloscope's channel math capability. This measurement is known as quasi-differential. However, the passive probes in combination with the oscilloscope's amplifier lack the Common Mode Rejection Ratio (CMRR) to adequately block any common mode voltages. This setup cannot measure the voltage accurately, but you can use the probes you probably already have.
- Use a commercially available probe isolator to isolate the oscilloscope's chassis ground. The probe's ground lead will no longer be at ground potential, and you can connect the probe directly to a test point. Probe isolators are an effective solution, but are expensive, costing two to five times as much as differential probes.
- Use a true differential probe on a wideband oscilloscope. A differential probe will let you measure VDS accurately.




▶ ***Figure 2.*** *Propagation delay for a voltage and current signal.*




▶ ***Figure 3.*** *The signal shown in Figure 2 after the Auto Deskew operation using TDSPWR2 power measurement and analysis software.*

For current measurements through the MOSFET, clamp on the current probe. Then, fine tune the measurement system. Many differential probes have built-in DC Offset trimmers. With the device under test turned off and the oscilloscope and probes fully warmed, set the oscilloscope to measure the mean of voltage and current waveforms. Use sensitivity settings that will be used in the actual measurement. With no signal present, adjust the trimmer to null mean value for each waveform to 0 V. This step minimizes the chance of a measurement error which results from quiescent voltages and current in the measurement system.

## Correcting Errors Caused by Voltage and Current Probe Propagation Delay

Before making any power loss measurement in a switch mode power supply, it is important to synchronize the voltage and current signals to eliminate propagation delay. This process is called “deskewing”. The traditional method calls for calculating the skew between the voltage and current signal, and then manually adjusting the skew using the oscilloscope’s deskew range. However, this is a tedious process.

It is simpler to use a deskew fixture and a TDS5000 Series oscilloscope. To deskew, connect the differential voltage probe and the current probe to the deskew fixture’s test point. The deskew fixture is driven by either the Auxiliary output or Cal-out signal of the oscilloscope. If desired, the deskew fixture can be driven by an external source.

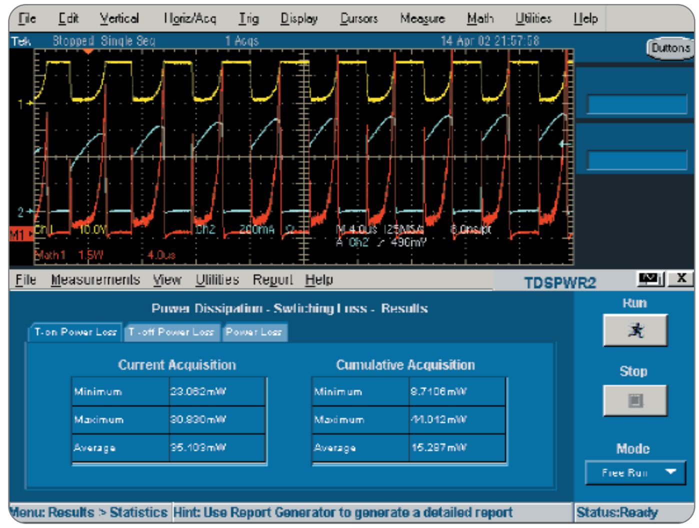
The deskew capability of TDSPWR2 software will automatically set up the oscilloscope and calculate the propagation delay caused by the probing. The deskew function then uses the oscilloscope’s deskew range and automatically offsets for skew. The test setup is now ready for accurate measurements. Figures 2 and 3 show the current and voltage signal before and after deskew.

## Computing Power Loss at a Non-periodic Switching Signal

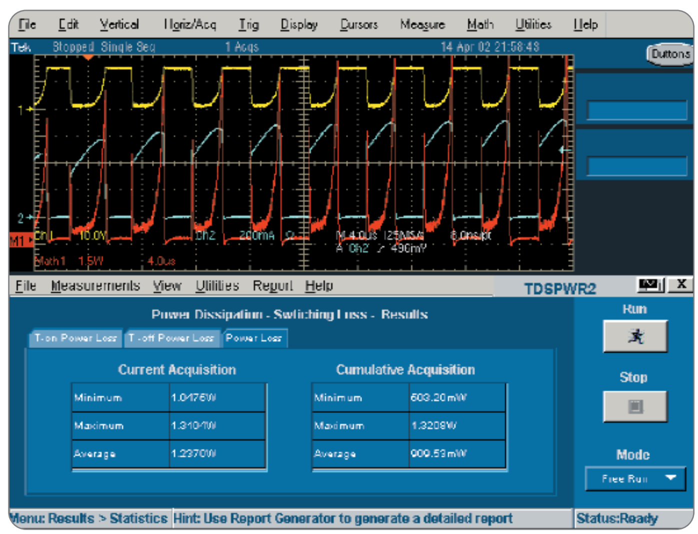
Measuring the dynamic switching parameter is simple if the emitter or the drain is grounded. But on a floating voltage, you need to measure a differential voltage. To accurately characterize and measure a differential switching signal, use a differential probe. Hall effect current probe allows you to view the current through the switching device without breaking the circuit. Use the Auto Deskew feature of TDSPWR2 to eliminate the propagation delay caused by the probes as explained earlier.

The "switching loss" feature in TDSPWR2 automatically computes the power waveform and measures minimum, maximum and average power loss at the switching device for the acquired data. This will be presented as Turn on Loss, Turn off Loss and Power Loss, as shown in Figure 4. This is useful data when analyzing power dissipation at the device. Knowing power loss at turn on and turn off enables you to work on voltages and current transitions to reduce the power loss.

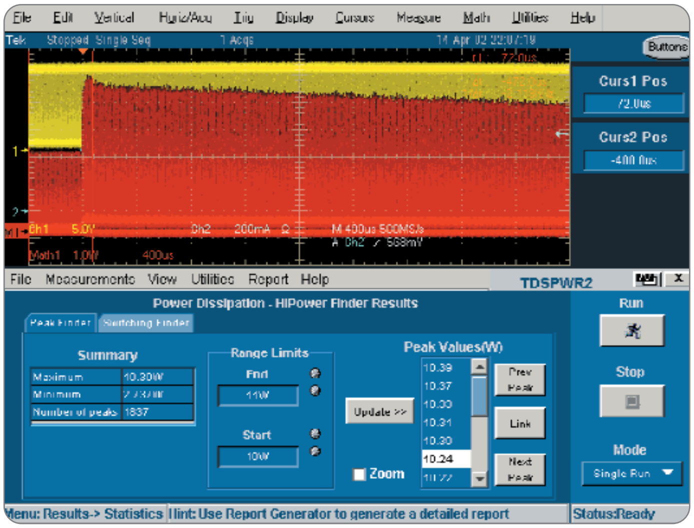
During the load change, the control loop of SMPS changes the switching frequency to drive the output load. Figure 5 shows a power waveform when the load is switched. Note that the power loss at the switching device also changes as the load is switched. The resulting power waveform will be non-periodic in nature. Analyzing the non-periodic power waveform can be a tedious task. However, the advanced measurement capabilities of TDSPWR2 automatically compute the min power loss, max power loss and average power loss, offering information about the switching device.




▶ ***Figure 4.*** *Min, max and average power loss during turn on time at switching device.*




▶ ***Figure 5.*** *Min, max and average power loss at switching device during the load change.*




▶ ***Figure 6.*** *The result of HiPower Finder: power waveform at the switching device at load change.*


▶ ***Figure 7.*** *HiPower Finder and scope zoom can be used for further analysis.*

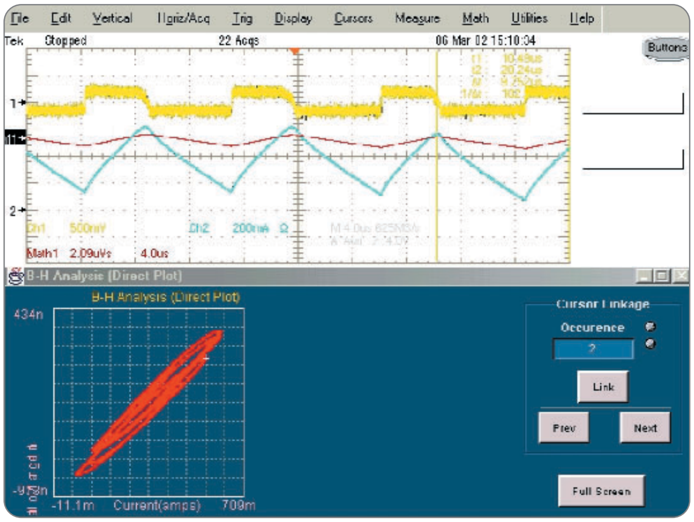
## Analyzing Power Loss While Load is Changing Dynamically

In a real-world environment, the power supply is continuously subjected to a dynamic load. Figure 5 shows that power loss at switching also changes during the load change. It is very important to capture the entire load-changing event and characterize the switching loss to make sure it doesn't stress the device.

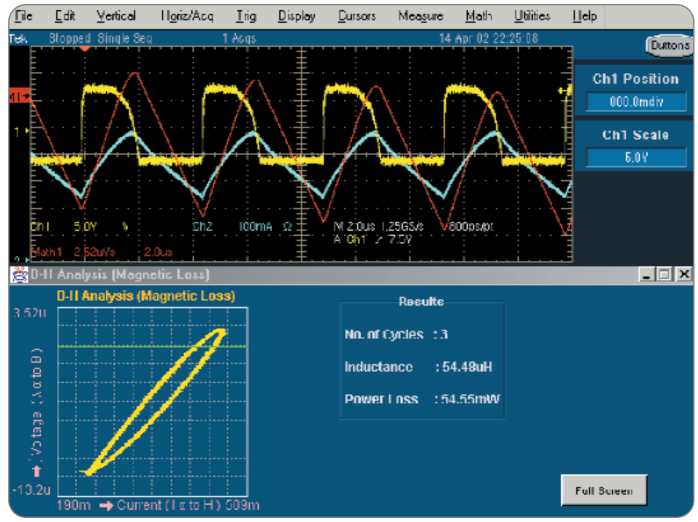
Today, most designers use an oscilloscope with deep memory (2 MB) and a high sampling rate to capture events in the required resolution. However, this presents the challenge of analyzing a huge amount of data for the switching loss points, which stresses the switching device.

The "HiPower Finder" feature of TDSPWR2 eliminates this challenge of analyzing the deep memory data. A typical result of power waveform using HiPower Finder at switching device is shown in Figure 6.

Figure 7 demonstrates the unique capabilities of HiPower Finder. The results show a summary of the number of switching events and max/min switching loss in the acquired data. You can then view the desired switching loss points by inputting your range of interest. Simply choose the point of interest within the range and ask the HiPower Finder to locate it within the deep memory data. The cursor will link to the requested area. On locating the point, the TDSPWR2 will allow you to zoom in around the cursor location and see the activity in more detail. This, combined with the previously mentioned capabilities of switching loss, quickly and effectively analyzes the power dissipation at the switching device.




▶ ***Figure 8.*** *The instantaneous B-H plot for the acquired waveform, showing cursor linkage.*




▶ ***Figure 9.*** *Power loss and inductor value.*

## Computing Power Loss at the Magnetic Component

Another way to reduce power dissipation comes in the core area. From the typical AC/DC and DC/DC circuit diagram, the inductor and transformer are the other components that will dissipate power, thereby affecting power efficiency and causing thermal runaway.

Typically, inductors are tested using an LCR meter. The LCR uses a test signal, which is a sine wave. In a switched power supply the inductors will be subjected to high voltage, high current switching signals, which are not sinusoidal. As a result, power supply designers need to monitor the inductor or transformer behavior in a live power supply. Testing with LCRs may not reflect a real-life scenario.

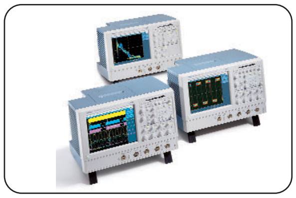
The most effective method of monitoring the behavior of the core is through the B-H curve, because the B-H curve quickly reveals inductor behavior in a power supply. TDSPWR2 enables quick B-H analysis using your oscilloscope in the lab without the need for expensive and dedicated tools.

The inductor and transformer will have different behavior during the turn-on time and steady state of the power supply. In the past, to view and analyze B-H characteristics designers have had to acquire the signals and conduct further analysis on a PC. TDSPWR2 enables you to do the B-H analysis directly on the oscilloscope, for instantaneous viewing of inductor behavior. For further analysis, TDSPWR2 provides cursor linkage between the B-H plot and acquired data in the oscilloscope (see Figure 8).

The B-H analysis capability of TDSPWR2 also automatically measures power loss and inductor value in a real-world, SMPS environment. To derive core loss at the inductor or transformer, make power loss measurements at the primary and also at secondary. The difference of these results is the power loss (core loss) at the core. Also, at a no-load condition, power loss at primary is a total power loss at the secondary including the core loss. These measurements can reveal information on the power dissipation area.

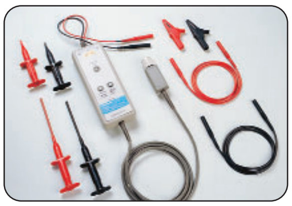
## Conclusion

Key features of the TDSPWR2 power measurement and analysis software, including the power loss at switching device, HiPower Finder and B-H analysis, provide fast measurements of switch mode power supplies. When used with a TDS5000 Series, TDS7054 or TDS7104 digital phosphor oscilloscope, you can quickly locate the power dissipation area and view the behavior of power dissipation in a dynamic situation.



### TDS5000 Series DPO

The TDS5000 Series oscilloscope's fast waveform capture rate, live analog-like display, dedicated video triggers, and long record length make it the ideal solution for video design and development.



### The P5205 Probe

The P5205 is a 100 MHz active differential probe capable of measuring fast risetimes of signals in floating circuits.

### The TCP202 DC Coupled Current Probe

The TCP202 is used for displaying and measuring current in electronic circuits. It is ideal for power supply and motor drive design and device testing.

**Contact Tektronix:**
**ASEAN / Australasia / Pakistan** (65) 6356 3900
**Austria** +43 2236 8092 262
**Belgium** +32 (2) 715 89 70
**Brazil & South America** 55 (11) 3741-8360
**Canada** 1 (800) 661-5625
**Central Europe & Greece** +43 2236 8092 301
**Denmark** +45 44 850 700
**Finland** +358 (9) 4783 400
**France & North Africa** +33 (0) 1 69 86 80 34
**Germany** +49 (221) 94 77 400
**Hong Kong** (852) 2585-6688
**India** (91) 80-2275577
**Italy** +39 (02) 25086 1
**Japan** 81 (3) 3448-3010
**Mexico, Central America & Caribbean** 52 (55) 56666-333
**The Netherlands** +31 (0) 23 569 5555
**Norway** +47 22 07 07 00
**People's Republic of China** 86 (10) 6235 1230
**Poland** +48 (0) 22 521 53 40
**Republic of Korea** 82 (2) 528-5299
**Russia, CIS & The Baltics** +358 (9) 4783 400
**South Africa** +27 11 254 8360
**Spain** +34 (91) 372 6055
**Sweden** +46 8 477 6503/4
**Taiwan** 886 (2) 2722-9622
**United Kingdom & Eire** +44 (0) 1344 392400
**USA** 1 (800) 426-2200
**USA** (Export Sales) 1 (503) 627-1916
For other areas contact Tektronix, Inc. at: 1 (503) 627-7111
Updated 20 September 2002

For the most up-to-date product information
visit our web site at www.tektronix.com

ISO 9001



10/02 OA/PG 55W-15754-1

Tektronix
Enabling Innovation