

TDS3000B DPO Solves Today's Power Measurement Problems



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▶ Meets Power Supply Design, Troubleshooting, and Testing Needs

Due to the industry-wide shift to switching power supplies, the definition of “power measurements” has changed, and with it, the number of design applications that require such measurements.

Today, a power supply must deliver performance and reliability, and equally important, compliance with national and regional power quality standards (such as the IEEE 519-1992 specification in the United States). The engineer must characterize power levels, output purity, and harmonic feedback into the power line and be prepared to measure high-frequency switching device outputs, noise levels, power characteristics, and more.

The oscilloscope has become a favored tool for power supply design and troubleshooting because it easily meets these diverse requirements. The TDS3000B oscilloscope:

- ▶ Measures voltage, current, and power with equal ease
- ▶ Measures floating voltages safely
- ▶ Provides harmonic measurements
- ▶ Makes the user's job easy and safe

The TDS3000B Digital Phosphor Oscilloscope Advantage

The TDS3000B Series digital phosphor oscilloscopes (DPOs) equipped with the Fast Fourier Transform Application Module (TDS3FFT) has the bandwidth, waveform capture rate, and advanced analysis capability to meet today's power measurement, design, troubleshooting, and testing requirements. In addition, they are compatible with a wide range of probe types, including passive (voltage), active FET, current, differential, and high-voltage probes. This latter type of probe provides a safe means of connecting to ungrounded (floating) circuits. The built-in TekProbe® interface simplifies power measurement by providing correctly-scaled readings automatically, in proper units (volts, milliamperes, etc.).

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Harmonic measurement and display

Power harmonic measurements require a tool that can display the signal's various spectral components. The TDS3000B's harmonic display reveals the relative magnitude of the harmonics to the fundamental frequency. The optional Fast Fourier Transform Application Module (FFT) equips the TDS3000B oscilloscopes for this type of reading. It provides advanced analysis features that convert a time-domain acquisition into a true harmonic display, which is essential for harmonic measurements on 50 and 60 Hz lines.

Bandwidth to handle the fastest frequencies

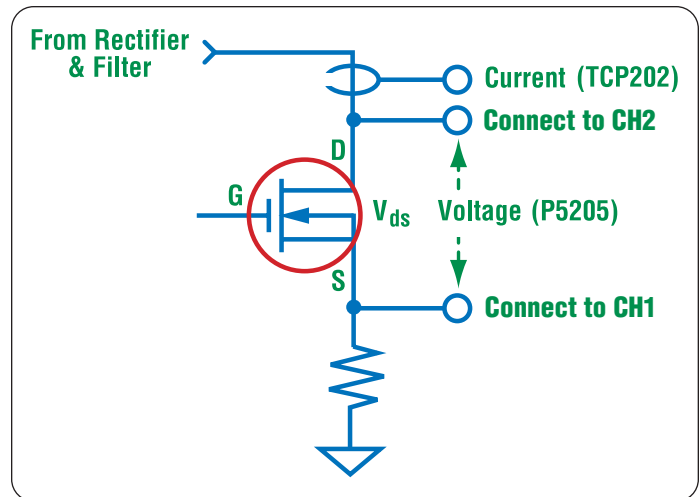
Switching transistor and IGBT circuits, noise, and transients all make demands on an oscilloscope's ability to capture power supply signals accurately and reliably. Switching frequencies are increasing with each new generation of power supplies. Viewing these signals calls for ample bandwidth. TDS3000B DPO models range in bandwidth from 100 MHz to 500 MHz, sufficient for even the fastest power supply switching frequencies.

DPO dependably captures and displays transients

Along with bandwidth, an oscilloscope's waveform capture rate – the number of times per second the instrument can trigger, compile the waveform, draw a fresh display, and re-arm for the next trigger – determines how reliably transients are acquired. The TDS3000B instruments offer a waveform capture rate that far surpasses digital storage oscilloscopes, which means that transients are much more likely to be acquired. It is easy to distinguish an occasional transient from the characteristics of the background waveform because the DPO's intensity-graded digital phosphor display highlights the most frequently-occurring areas of the signal.

Measuring Instantaneous Power with the TDS3000B

Characterizing the instantaneous power dissipation in switching transistors is part of almost every power supply design project. It's key to choosing a component (such as the power MOSFET in Figure 1) that is



► **Figure 1.** Connecting a differential probe to a power MOSFET.

both cost-effective and reliable under the stresses of worst-case operation. The procedure involves making a floating measurement simultaneously with a current measurement. The TDS3000B's TekProbe interface is compatible with the P5205 High-Voltage Differential Probe and the TCP202 Current Probe; other current probes are available for higher current measurements. This pairing provides exceptionally accurate results.

The high-voltage differential probe is necessary because the voltage of interest (V_{ds} on the MOSFET circuit) is across the drain-to-source terminals of the transistor, and neither is grounded. The TDS3000B, like most oscilloscopes, is not designed to measure floating signals directly. A differential probe is required for making safe floating measurements with the TDS3000B. The P5205 accepts the ungrounded signal and delivers a single-ended, grounded signal to the scope input.

Before making power measurements, it may be necessary to equalize the delay between the voltage and current probes using a procedure known as "deskewing." The P5205 and the TCP202 are inherently matched to within ± 2 ns, minimizing delay errors, but other probe combinations will need to be deskewed. This step is of critical importance, since a small offset in the timing of the voltage and current traces can cause a large error in the instantaneous power reading.

The TDS3000B has a deskew memory that stores the delay differentials between probes. To deskew a pair of probes, drive both with the same pulse and use cursors to measure the time difference. Then enter this information into the *deskew memory* (accessible via the Vertical MENU). This procedure stores the delay value for the pair of probes being used.

With the probes deskewed, connect them as shown in Figure 1 (a power MOSFET circuit of the type found in switching power supplies).

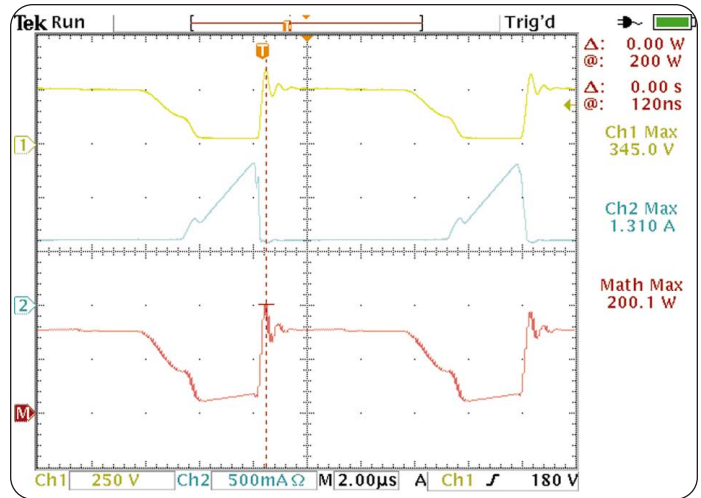
The *Autoset* function on the TDS3000B can be used to set up the initial waveform display. Autoset automatically adjusts the range and scaling to bring the waveforms into view. The TDS3000B's color LCD displays the voltage, current, and power waveforms in different colors, eliminating a common source of confusion. Thanks to the TekProbe interface, the numeric readout and scaling of all three waveforms is accurate – no interpretation is required.

The power waveform is simply a point-by-point multiplication of the voltage and current waveforms (CH1 x CH2). The TDS3000B's waveform *MATH* button gives you access to math operations that use the two waveforms as variables. Figure 2 shows the result. The voltage, current, and power waveforms are displayed in the correct units. The maximum instantaneous voltage, current, and power can be displayed with the Max measurement function accessed by pressing the *MEASURE* button.

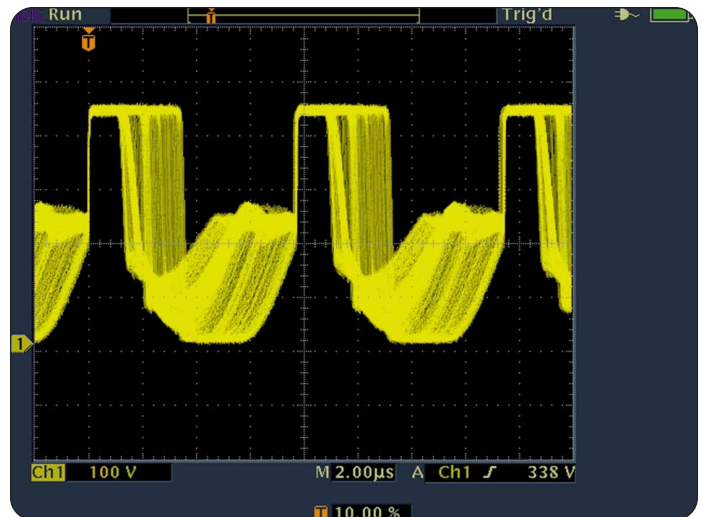
Troubleshooting Power Supplies

Digitizing oscilloscopes are common in the power measurement field, but the TDS3000B's digital phosphor acquisition technology makes a big difference when troubleshooting, especially when identifying excessive modulation effects in a switching power supply.

The TDS3000B has a waveform capture rate that is fifty times higher than that of a typical digital storage oscilloscope (DSO). This provides two advantages when investigating modulation effects. First, the TDS3000B is active much more of the time, and less time is spent processing waveforms for display. Thus the scope has hundreds of times more opportunities to capture the modulation. Secondly, the digital phosphor display makes it easier to see the modulated waveforms in real time. The TDS3000B's display intensifies the areas where the signal trace crosses most frequently, much like an analog scope. The modulation is dimmer than the main waveform that repeats continuously.



▶ **Figure 2.** Power Measurement Screen shows volts, amps, and power waveform in correct units.



▶ **Figure 3.** Modulation effects on a power supply control loop.

Viewing modulation effects with the TDS3000B is extremely simple. Figure 3 shows the modulated signal controlling the output of a current-mode control loop on a power supply. Modulation is important in a feedback system to control the loop. However, too much modulation can cause the loop to become unstable. Notice that the waveform is dimmer in regions where the modulation is less frequent.

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Capturing transients with the TDS3000B is also simple. Its *Edge Trigger* function gives you all the flexibility you need to set up the slope, level, coupling, and trigger delay. If the power supply under test is already integrated into a system, it may be desirable to trigger on the "problem" signal elsewhere in the system and monitor a test point on the power supply to see if there is a transient that occurs at the same time.

Of course, the power supply's DC output needs to be clean and free of transients also. The TDS3000B's *ROLL mode*, combined with the *Peak Detect* feature, is the best tool for viewing aberrations on slow signals or DC levels. *ROLL mode* simply scrolls the trace slowly from right to left, much like a strip chart recorder. It produces a clear, bright trace at very slow sweep speeds. *Peak Detect* lets the oscilloscope capture glitches as narrow as 1 ns, even at slow sweep speeds. Combining the two features produces a steady, legible trace that immediately reveals transients.

Measuring Line Harmonics

Measuring line harmonics is a critical task for today's designs. Switching power supplies tend to generate odd-order harmonics, which can find their way back into the power grid. The effect is cumulative; as more and more switching supplies are connected to the grid (for example, as an office adds more desktop computers), the total percentage of harmonic distortion returned to the grid can rise. Since this distortion causes heat buildup in the cabling and transformers of the power grid, it's necessary to minimize harmonics. Regulatory standards such as IEC1000-3-2 are in place to oversee power quality.

When fitted with the TDS3FFT application module, the TDS3000B is an excellent tool for harmonic analysis. An oscilloscope with FFT capability is far more cost effective than buying a specialized harmonic analyzer,

and it permits you to use a familiar instrument to do yet another job. The TDS3FFT module uses a Fast Fourier Transform (FFT) algorithm to provide spectrum-analyzer-style display of signal-frequency components. It's even possible, and often helpful, to display both the signal waveform and its frequency-domain equivalent on the screen at the same time.

The TDS3FFT module makes available an *FFT-specific menu* that simplifies setup and measurement. The *FFT menu* resides under the *MATH button menu*. The FFT can be performed on active signals or stored waveforms that have been recalled.

The procedure is no more difficult than taking an ordinary waveform measurement. Since the signal in this case is a repeating periodic waveform (as opposed to a transient of some kind), it's a simple matter to trigger and display it. Pre-compliance testing for IEC61000-3-2 is performed on the current waveform. At least five cycles should be displayed to ensure good frequency resolution, and the vertical scale must be set such that the full signal amplitude appears on-screen.

The TDS3000B's user-configured parameters include the vertical scaling and the FFT window format. Rectangular, Hamming, Hanning, and Blackman-Harris windows are available, each suited to a particular type of signal. For a periodic repeating signal like the one in this example, the Hamming window usually is best.

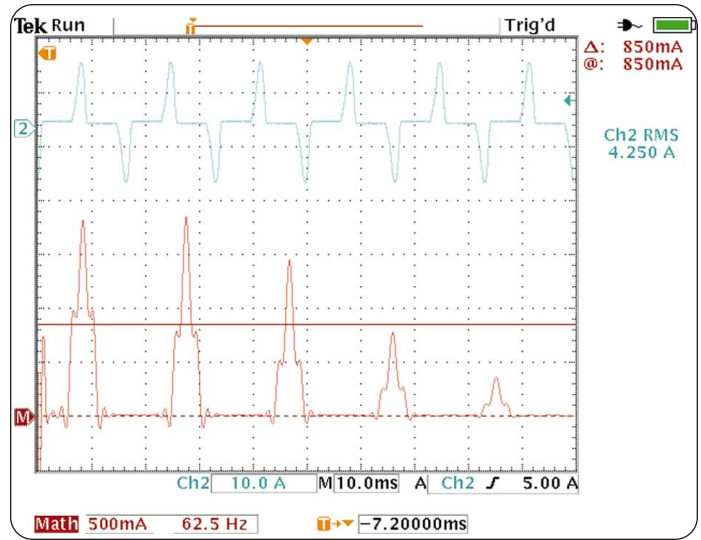
Vertical scaling for the FFT display may be either linear or logarithmic. Linear scaling is more commonly used in power measurements.

Figure 4 shows the result of a harmonic analysis on the power supply's load current. You can use the TDS3000B's cursors to measure either the magnitude of individual frequency components, or their frequency. The *ZOOM* function is also available to expand the FFT for closer scrutiny. Using *ZOOM* does not affect the acquisition itself (trigger or time base settings, etc.); only the display.

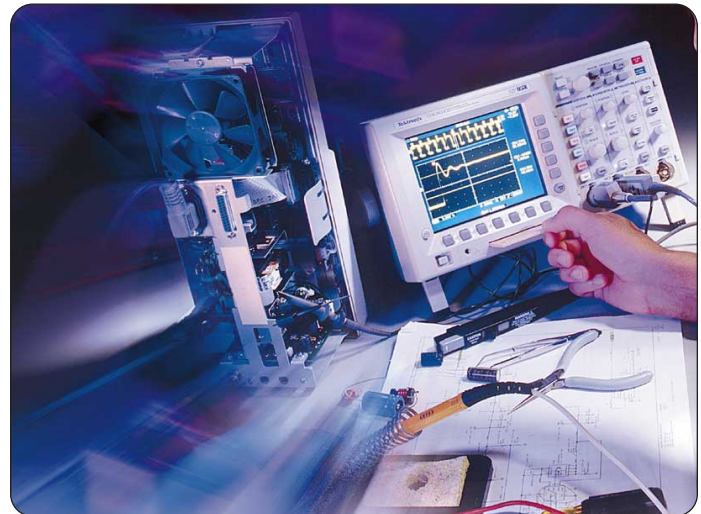
Proof of compliance with power-quality regulations is an important part of many power supply design projects. The TDS3000B offers a full range of storage and printing capabilities to aid in this effort. A dedicated *HARD COPY* button reproduces the screen image on the optional plug-in printer, or on an inkjet or laser printer connected to the TDS3000B's standard parallel port. Similarly, the image can be stored on a floppy disk in publishable formats including .BMP, .EPS, .TIF, and more. These are compatible with leading word processing, page layout, and office presentation programs.

Conclusion

Power measurements are no longer the province of dedicated tools such as power meters and harmonic analyzers. The TDS3000B digital phosphor oscilloscope, when equipped with the TDS3FFT application module, is ready to handle voltage, current, power, and harmonic measurements, and also serves as a versatile troubleshooting tool for power supply design and troubleshooting.



▶ **Figure 4.** TDS3000B shows the harmonic analysis of a 250 W class D power supply. The cursor shows that the 3rd harmonic (at 180 Hz) exceeds the 850 mA limit per IEC61000-3-2.



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- **The TDS3PRT Plug-in Printer** provides instant portable documentation of your work.



- **The TDS3FFT Module** adds FFT measurement capabilities in dB or linear RMS scales. A selection of four FFT windows (Rectangular, Hamming, Hanning, Blackman-Harris) are provided.



- **The P5205 Probe** is a 200 MHz active differential probe capable of measuring fast risetimes of signals in floating circuits.



- **The TCP202 DC Coupled Current Probe** is used for displaying and measuring current in electronic circuits. It is ideal for power supply and motor drive design and device testing.

For Further Information

Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology.

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ASEAN Countries (65) 356-3900

Australia & New Zealand 61 (2) 9888-0100

**Austria, Central Eastern Europe,
Greece, Turkey, Malta & Cyprus** +43 2236 8092 0

Belgium +32 (2) 715 89 70

Brazil and South America 55 (11) 3741-8360

Canada 1 (800) 661-5625

Denmark +45 (44) 850 700

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Hong Kong (852) 2585-6688

India (91) 80-2275577

Italy +39 (2) 25086 501

Japan (Sony/Tektronix Corporation) 81 (3) 3448-3111

Mexico, Central America, & Caribbean 52 (5) 666-6333

The Netherlands +31 23 56 95555

Norway +47 22 07 07 00

People's Republic of China 86 (10) 6235 1230

Republic of Korea 82 (2) 528-5299

South Africa (27 11) 254 8360

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Sweden +46 8 477 65 00

Switzerland +41 (41) 729 36 40

Taiwan 886 (2) 2722-9622

United Kingdom & Eire +44 (0)1344 392000

USA 1 (800) 426-2200

For other areas, contact: Tektronix, Inc. at 1 (503) 627-1924



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