Tektronix

TDS3000 Series
Digital Phosphor Oscilloscopes

500 MHz, 300 MHz, and 100 MHz Bandwidths

Sample Rates up to 5 GS/s

2 or 4 Channels

Full VGA Color LCD on all Models

Built-in Floppy Disk Drive For Easy Storage and Documentation

Centronics Port Standard on all Models for Quick, Convenient Hardcopies

9-Bit Vertical Resolution

Multi-Language User Interface

QuickMenu User Interface Mode for Quick, Easy Operation

Optional Modules for RS-232, GPIB, or VGA Communication Ports

Connection to Local Area Network with AD007 GPIB to LAN Adapter

Advanced Triggers, such as, Glitch, Width, and Logic Standard on 4 Channel Models

Fast Fourier Transform (FFT) for Frequency and Harmonic Analysis Standard on 4 Channel Models

Extended Video Application Module, Provides Features, such as Custom Video Trigger, Line Count Trigger and NTSC, PAL, SECAM Display Graticules

Support for Active Probes, Differential Probes, and Current Probes that Provide Automatic Scaling and Units

Optional Battery Power for Convenient Use in the Field or Away from the Bench

The TDS3000 Series of Digital Phosphor Oscilloscopes

The TDS3000 oscilloscopes are the lowest priced, most portable Digital Phosphor Oscilloscopes (DPOs). Now every design engineer and technician can take advantage of the tremendous benefits of DPOs. DPOs deliver a new level of insight that makes dealing with complex signals simple. DPOs display, store, and analyze, in real-time three dimensions of signal information: amplitude, time, and distribution of amplitude over time.

Benefits of DPO

DPOs have an intensity graded color display that provides information about the frequency of occurrence of signal amplitudes and widths. This helps the user locate and characterize waveform anomalies that can be elusive on traditional Digital Storage Oscilloscopes. The fast update rate of DPOs also makes it easier to capture and display infrequent waveforms or waveform variations.

Flexible Features for Every Application

The portable form factor allows the instrument to go wherever it is needed. The Communication and Application Modules enable the instrument to be configured for specific applications or upgraded without returning it to the manufacturer. The TekProbe® Level II interface provides power to a range of application specific accessories.

Quick to Learn and Quick to Use

The TDS3000 Series graphical user interface offers a new operating mode called QuickMenu. This quick access user interface makes the main oscilloscope controls accessible with a push of a single button. Included with every scope is an On-Line Tour disk that runs in the oscilloscope. This disk gives an overview of the product's operation and capabilities.

TDS3000 Series Electrical Characteristics

	TDS3012	TDS3032	TDS3052	TDS3014	TDS3034	TDS3054
Bandwidth	100 MHz	300 MHz	500 MHz	100 MHz	300 MHz	500 MHz
Channels	2	2	2	4	4	4
Sample Rate on Each Channel	1.25 GS/s	2.5 GS/s	5 GS/s	1.25 GS/s	2.5 GS/s	5 GS/s
Maximum Record Length	10K points on all models					
Vertical Resolution	9-bits on all models					
Vertical Sensitivity (/div)	1 mV-10 V on all models					
Vertical Accuracy	±2% on all models					
Max Input Voltage (1 MΩ)	150V RMS CAT I on all models					
Position Range	± 5 div on all models					
BW Limit	20 MHz	20, 150 MHz	20, 150 MHz	20 MHz	20, 150 MHz	20, 150 MHz
Input Coupling	AC, DC, GND on all models					
Input Impedance Selections	1 MΩ in parallel with 13 pF, or 50 Ω					
Time Base: Range (/div) Accuracy	 4 ns – 10 s/div 200 ppm	 2 ns – 10 s/div 200 ppm	 1 ns – 10 s/div 200 ppm	 4 ns – 10 s/div 200 ppm	 2 ns – 10 s/div 200 ppm	 1 ns – 10 s/div 200 ppm
Display Monitor	Color LCD					

TDS3000 Series Characteristics

ACQUISITION MODES

Peak Detect – High frequency and random glitch capture. Captures glitches as narrow as 1 ns.

Sample – Sample data only.

Envelope – Max/Min values acquired over one or more acquisitions.

Average – Waveform data from 2 to 572 (selectable) acquisitions is averaged.

Single Sequence – Use SINGLE SEQUENCE button to capture a single triggered acquisition sequence at a time.

TRIGGER SYSTEM

Main Trigger Modes – Auto (supports Roll Mode for 40 ms/div and slower), Normal.

B Trigger – Trigger after time or events.

Trigger After Time Range – 13.2 ns to 50 s.

Trigger After Events Range – 1 to 9,999,999 events.

External Trigger Input (available on TDS 30X2 only) – >1 MΩ in parallel with 17 pF; Max input voltage is 150V RMS.

TRIGGER TYPES

Edge – Conventional level-driven trigger. Positive or negative slope on any channel. Coupling selections: DC, noise reject, HF reject, LF reject.

Video – Trigger on all lines, odd/even, or all fields. See TDS3VID for Extended Video triggering and measurement features.

Logic – (Standard on TDS30X4, must purchase TDS3TRG for TDS30X2)
PATTERN: Specifies AND, OR, NAND, NOR when true or false for a specific time.
STATE: Any logic state. Triggerable on rising or falling edge, of a clock..

Note: Logic triggers can only be used on combinations of 2 inputs.

Pulse – (Standard on TDS30X4, must purchase TDS3TRG for TDS30X2)
WIDTH (or GLITCH): Trigger on pulse width less than, greater than, equal to, or not equal to a selectable time limit ranging from 39.6 ns to 50s.
RUNT: Trigger on a pulse that crosses one threshold but fails to cross a second threshold before crossing the first again.
SLEW RATE: Trigger on pulse edge rates that are either faster or slower than a set rate. Edges can be rising, falling, or either.

MEASUREMENT SYSTEM

Automatic Waveform Measurements – Period, Frequency, +Width, –Width, Rise Time, Fall Time, +Duty Cycle, –Duty Cycle, +Overshoot, –Overshoot, High, Low, Max, Min, Pk-Pk, Amplitude, Mean, Cycle Mean, RMS, Cycle RMS, Burst Width.
Display any four measurements from any combination of waveforms.

Thresholds – Settable in percentage or voltage.

Gating – Measurements can be gated using the screen or vertical cursors.

TDS3000 Series Characteristics

WAVEFORM PROCESSING

Deskew – Channel to channel deskew may be manually entered for better timing measurements and more accurate math waveforms.

Arithmetic Operators – Add, Subtract, Multiply, Divide.

Autoset – Single-button, automatic setup on selected input signal for vertical, horizontal, and trigger systems.

DISPLAY CHARACTERISTICS

Graticules – Full, grid, cross-hair, frame, NTSC, PAL and SECAM (with TDS3VID optional application module).

Format – YT and XY.

I/O INTERFACE

Hardcopy Port (standard) – Centronics-type parallel.

TDS3GM Communications Module –
GPIB (IEEE –488.2) Programmability: Full talk/listen modes; Control of all modes, settings, and measurements.
RS-232-C Interface Programmability: Full talk/listen modes; Control of all modes, settings, and measurements. Baud Rate up to 38,400. DB-9 male connector.
Programmer Manual: (071-0381-00).
Note: For Ethernet/LAN connection use this module with the AD007 GPIB to LAN adapter.

TDS3VM Communications Module –
VGA: Monitor output for direct display on large VGA-equipped monitors. DB-15 female connector, 31.6 kHz sync rate, EIA RS-343A compliant.
RS-232-C Interface Programmability: same as TDS3GM.
Programmer Manual: same as TDS3GM.

Note: Only one Communication Module may be installed at a time.

HARD COPY CAPABILITY

Graphics File Formats – Interleaf (.img), TIF, PCX (PC Paintbrush), BMP (Microsoft Windows), and Encapsulated Postscript (EPS).

Printer Formats – Thinkjet, Deskjet, Laserjet, Epson (9&24 pin).

ENVIRONMENTAL AND SAFETY

Temperature – +5 to +50°C (operating), –20 to +60°C (non-operating).

Humidity – 20% to 80% RH below 32°C, derate to 30% RH at 45°C (operating), 5% to 90% RH below 41°C, derate to 30% RH at 60°C (non-operating).

Altitude – to 3,000 m (operating), 15,000 m (non-operating).

Electromagnetic Compatibility – Meets or exceeds EN55011 Class A Radiated and Conducted Emissions; EN50082-1; FCC 47 CFR, Part 15, Subpart B, Class A; Australian EMC Framework; Russian GOST EMC regulations.

Safety – UL3111-1, CSA 22.2 No. 1010.1, EN 61010-1/A2:1995.

PHYSICAL CHARACTERISTICS

Instrument

Dimensions	mm	in.
Width	375.0	14.8
Height	176.0	6.9
Depth	149.0	5.9

Weight	kg	Lbs.
Instrument Only	3.2	7.0
W/ battery	5.2	11.5

Ordering Information TDS3012, TDS3014, TDS3032, TDS3034, TDS3052, TDS3054

Standard Accessories

Probes: 2 each P3010 10X passive probes (TDS3012), 4 each P3010 10X passive probes (TDS3014), 2 each P6139A 10X passive probes (TDS3032, TDS3052), 4 each P6139A 10X passive probes (TDS3034, TDS3054).

Documentation: Quick Reference Manual, User Manual, On-line Tour Disk, Front panel overlay for non-English languages.

Application Modules (TDS3014, TDS3034, TDS3054 only): TDS3FFT, TDS3TRG.

Power Cord.

Accessory Tray.

Protective Front Cover: has holder for reference manual and/or 3.5" floppy disks.

NIST-Traceable Certificate of Calibration.

Warranty Information

Three year warranty covering all labor and parts, excluding probes.

International Power Plug Options

Standard – US (161-0230-01).

Opt. A1 – Universal Euro 220V, 50 Hz (161-0104-06).

Opt. A2 – United Kingdom 240V, 50 Hz (161-0104-07).

Opt. A3 – Australia 240V, 50 Hz (161-0104-05).

Opt. A5 – Switzerland 220V, 50 Hz (161-0167-00).

Opt. A6 – Japan 3 to 2 wire adapter (013-0310-00).

International User Manuals (TDS3000 Series, TDS3FFT, TDS3TRG, TDS3VID)

Standard – English.

Opt. L1 – French.

Opt. L2 – Italian.

Opt. L3 – German.

Opt. L4 – Spanish.

Opt. L5 – Japanese.

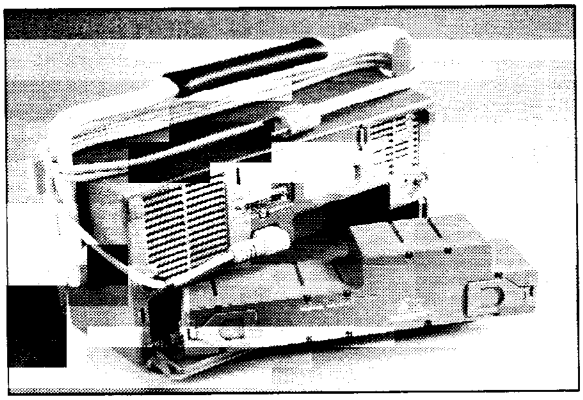
Opt. L6 – Portuguese.

Opt. L7 – Simplified Chinese.

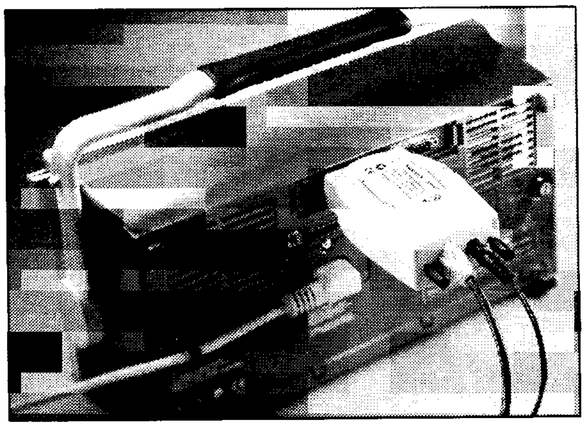
Opt. L8 – Traditional Chinese.

Opt. L9 – Korean.

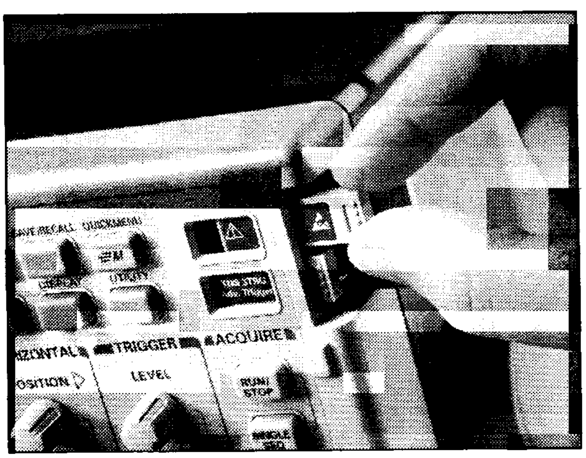
Opt. LR – Russian.



TDS3BAT – Battery Pack being installed.



AD007 – GPIB to LAN adapter attached to Instrument.



TDS3FFT – Application Module being installed.

Instrument Accessories

TDS3FFT – FFT Application Module (standard on TDS30X4). Adds FFT measurement capabilities in dB or linear RMS scales. A selection of four FFT windows (Rectangular, Hamming, Hanning, and Blackman-Harris) are provided.

TDS3TRG – Advanced Trigger Application Module (standard on TDS30X4). Adds Logic and Pulse triggering described under Trigger Types (page 2).

TDS3VID – Extended Video Application Module. Adds line count triggering, custom video scan and field rates, readout in mV or IRE units, and includes 75 Ω terminator.

TDS3GM – GPIB and RS232 interfaces.

TDS3VM – VGA port and RS232 interface.

TDS3BAT – Battery pack for up to 2 hours continuous operation without line power. Note: the instrument must be grounded at all times.

TDS3CHG – Fast charger for battery pack.

AC3000 – Soft case for carrying instrument.

RM3000 – Rackmount kit.

AD007 – GPIB to LAN adapter.

Service Manual (TDS3000 Series) – English Only (071-0382-00).

TDS3GM and TDS3VM Programmers Manual – English Only (071-0381-00).

WSTRO – Software for Oscilloscopes for Windows 95/NT.

Probes

ADA400A – 100X, 10X, 1X, 0.1X High gain differential amplifier.

P6243 – 1 GHz, ≤1pF input C 10X active probe.

P6246 – 400 MHz differential probe.

P5205 – 1.3 kV, 100 MHz high voltage differential probe.

P5210 – 5.6 kV, 50 MHz high voltage differential probe.

P5100 – 2.5 kV, 100X high voltage passive probe.

TCP202 – 15 A, DC + Peak AC 50 MHz AC/DC current probe.

For further information, contact Tektronix:

Worldwide Web: for the most up-to-date product information visit our web site at: www.tektronix.com

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ISO 9001 CE

Tektronix

11/98 HB/XBS 3GW-12482-1

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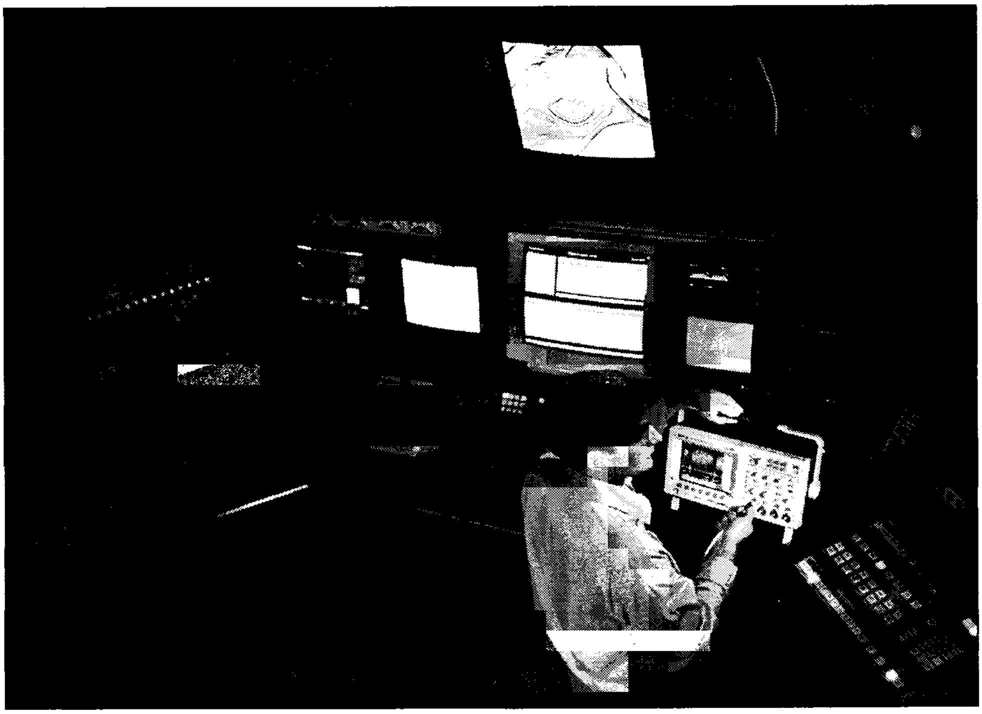
Application Note

Using the TDS3000 DPO for Video Maintenance and Service Measurements



Tektronix' new TDS3000 Digital Phosphor Oscilloscopes (DPOs) are uniquely suited to video applications. They offer the real-time intensity-graded display that's so important for video measurements, and they include the full feature set of a digitizing oscilloscope. With a DPO, the NTSC baseband waveform appears with the familiar brightened areas on the signal peaks and the sync burst. When viewing a full-frame test signal, the DPO displays the color bar waveforms with smooth, level tops, undistorted by digital aliasing. The TDS3000 Series DPOs deliver uncompromised analog-style signal viewing for video measurements, as well as advanced digital measurement and analysis features.

The TDS3000 Series also offers the compelling advantages of compact footprint combined with exceptional measurement performance. Bandwidths from 100 MHz to 500 MHz are available. The instruments are light (only 3.2 kg) and small. Optional battery power provides completely untethered operation. This makes the TDS3000 an ideal choice for video maintenance work in remote trucks and helicopters, or even those "behind the console" video checks in the broadcast studio.

"Signal Present" Check Is the Most Basic

Undoubtedly, the most common video "measurement" is the live video check. It's mainly intended to confirm that the video signal is present at a given test point, say, the output of a switcher. But it can also reveal irregularities that affect picture quality.

The live video check is a basic horizontal-rate display of the signal amplitude vs. time. Using a TDS3000 equipped with the optional video module, the video check is as simple as a continuity test. Both the IRE graticule and the video triggering controls appear on the QuickVideo menu. The Video Autoset function automatically adjusts vertical, horizontal, and trigger settings to bring up a waveform immediately (if there is one!). Figure 1 shows an NTSC video waveform captured in this manner. With the TDS3000, the whole process takes only a few seconds.

The TDS3000's standard video trigger makes it easy to synchronize on Odd, Even, All Fields, or All Lines of the signal (NTSC, PAL, or SECAM). These are standard selections under the TRIGGER TYPE menu. Since the video check is mainly a "signal present" test, it's often unnecessary to measure IRE or mV units. Thus, the conventional oscilloscope graticule is adequate for routine live video checks.

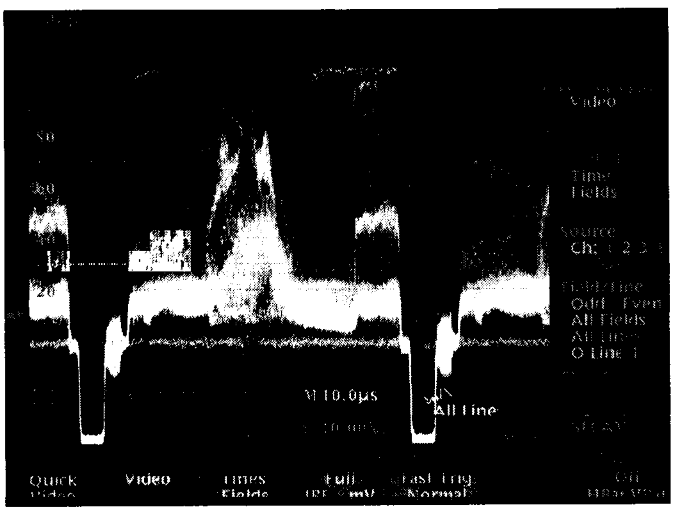


Figure 1. DPO technology brings out vivid waveform detail on the IRE graticule (available with video module).

Line Count Triggering

Sometimes it's necessary to view a single line of the video waveform. For example, the programming information in the NTSC signal is sometimes found on Line 20. To see this data, you must isolate that line.

The optional Video Application Module expands the TDS3000's video triggering flexibility. While the standard instrument can trigger on All Fields or on All Lines, the video module adds menu selections to trigger on any specific line number in an NTSC, PAL, or SECAM system.

Line Number triggering is a first-level QuickVideo menu selection on a video module-equipped instrument. Choosing "Line Number" sets up the general-purpose knob to scroll through the line numbers: 1 through 263 (Odd Lines) or 1 through 262 (Even Lines) for NTSC; 1 through 625 for PAL and SECAM. In this example, line 17 on an NTSC was chosen. The line number is displayed prominently on the screen, as shown in Figure 2.

Automating Everyday Measurements

The TDS3000 makes routine video amplitude and timing measurements easy. Using the IRE graticule provided by the video module, it's a simple matter to display any part of a video waveform and visually measure the amplitude levels. Unlike an analog oscilloscope, there's no need to convert voltage readings to IRE levels.

Video cursors hasten the process and provide improved accuracy. The CURSOR button brings up a menu to select horizontal bars for amplitude measurements. The general-purpose knob positions the cursors individually to bracket the desired waveform points. Whenever the active cursor moves, the change in the amplitude reading appears automatically on the screen. When the IRE or mV graticule is selected, the amplitude readout is expressed in the respective units. Figure 3 shows the cursors and the readout. A pair of vertical bars is also available for timing measurements.

Lastly, the TDS3000 can perform automated measurements. This function is very useful for repetitive measurements. To measure sync width, for example, trigger on the video waveform, then expand the vertical and horizontal scales such that the

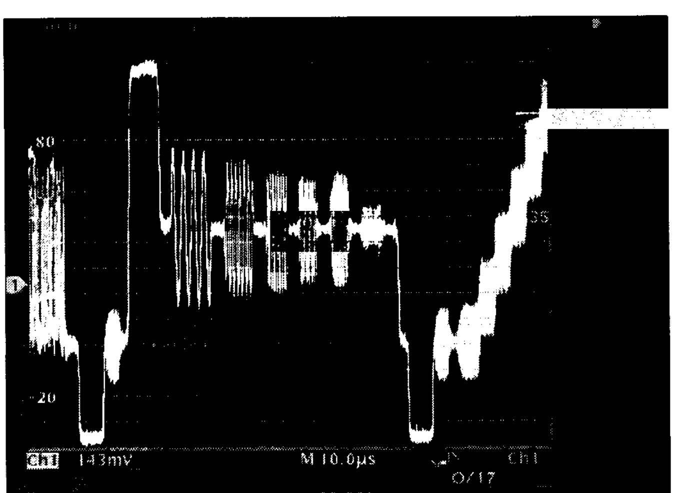


Figure 2. Line count triggering finds line 17 on an NTSC broadcast video signal.

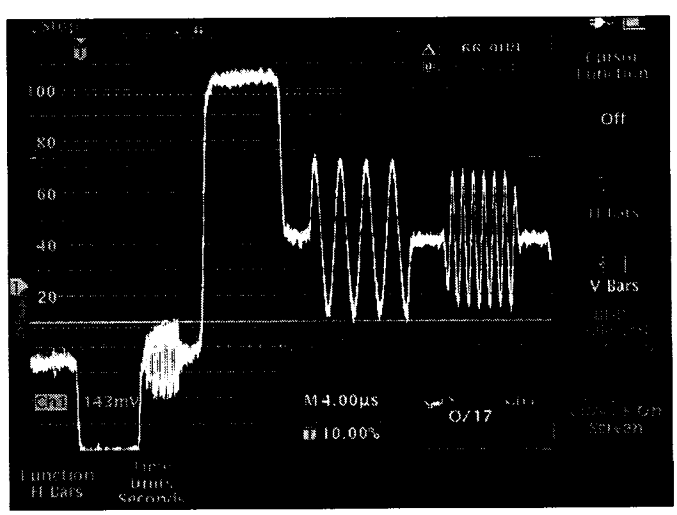


Figure 3. Cursor measurements allow accurate digital readout on both vertical and horizontal signal details.

sync pulse fills most of the screen. Select the automatic Negative Pulse Width measurement in the measurement menu which is activated by the MEASURE button.

Triggering for Other Standards

Obviously, not every video system conforms to the NTSC, PAL, or SECAM formats. As a rule, computer video monitors, medical displays, security cameras, and other self-contained systems aren't designed to interface directly with broadcast video equipment. These, therefore, may not adhere to the normal 525- or 625-line standards. Thus it is sometimes necessary to use an oscilloscope to determine the line rate.

The TDS3000 offers an easy solution. The first step is to capture a stable video waveform on the screen using the oscilloscope's Edge trigger (not Video trigger, since that function is set up for standard line rates). Then use the Vertical Bars cursors (accessed by pressing the CURSOR button) to measure the time between sync pulses. The Time Units menu button lets you select the reciprocal (1/time) of the reading. Next, press the trigger MENU button. Select Type>Video and then select Standard>Custom as shown in Figure 4. When this selection is made, the Scan Rate will appear as a menu option. In this case, select Rate 3 (25 to 35 kHz) as the scan rate. Scan rates up to 65 kHz can be selected.

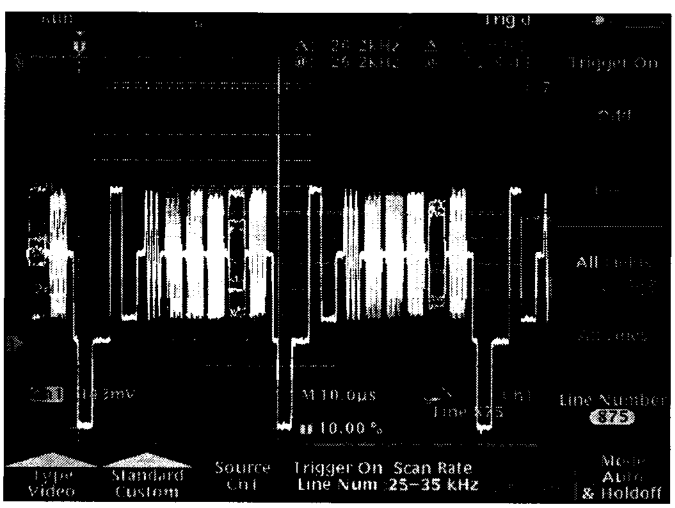


Figure 4. Custom video trigger allows the TDS3000 to trigger on standards such as RS343 (26.2 kHz scan rate).

Video Recorder "Tape Run" Adjustments

Helical-scan video tape recorders (VTRs) are a cornerstone of both professional and consumer video applications. But they can be a maintenance challenge. Even the humble VHS machine's front panel masks a surprisingly complex electromechanical system.

A video recorder reads the signal from the video tape by means of a rotary scanner that houses two playback heads which contact the tape. The scanner's rotation causes the two heads to read alternating interleaved tracks of information stored in a helical pattern on the tape.

Aligning a VTR is a matter of physically adjusting the tape path so that the tape passes across the scanning heads in perfect orientation. Improper adjustment can cause line dropouts – vertical striations in the video image. In professional video equipment, this may be corrected to some degree by a dropout compensation circuit, but in any event, dropouts are undesirable.

Adjustments are made by positioning a series of tape guides while viewing the effect on an RF signal from the video heads. Typically an exhaustive alignment is necessary only when the VTR has been damaged, or if the upper drum of the scanner assembly has been newly replaced.

The alignment procedure requires an oscilloscope and an alignment tape. Some professional VTR manufacturers offer an optional adjustment tool for setting the tape guide screws.

TIP: *It's wise to run a "known-good" tape through the machine before starting the actual adjustments. When a new scanner assembly is installed, the tape path can be grossly out of alignment – to the point where the first tape that goes through the machine gets wrinkled or scored. Protect your costly alignment tapes; start the alignment procedure by running a tape you can afford to lose! Make your initial coarse adjustments with this tape.*

To set up the TDS3000 for head alignment, start the calibration tape and connect Channel 2 to the head switching pulse. This becomes the trigger source. Connect Channel 1 to the output of the high-level RF amplifier receiving the signal from the video heads. It's best to set the time base so that two, and only two, cycles of the signal are visible on-screen. The "thicker" portions of the waveform are the areas of head switching. The screen image should be centered on one of these events. Figure 5a shows the result.

In Figure 5a the heads are out of adjustment. There are "pinched" areas in the waveform. The ideal is to set the alignment screws so the waveform peaks are relatively consistent across the top and bottom. There should be no gross variations in amplitude. The alignment screws are interactive, though, so it's usually necessary to do the adjustment cycle several times, making small changes each time. Figure 5b shows the waveform after the procedure is finished.

Interestingly, it's usually better not to strive for perfectly flat waveform peaks with uniform amplitude throughout. A small amount of variation actually improves the portability (interchangeability) of tapes recorded on the machine.

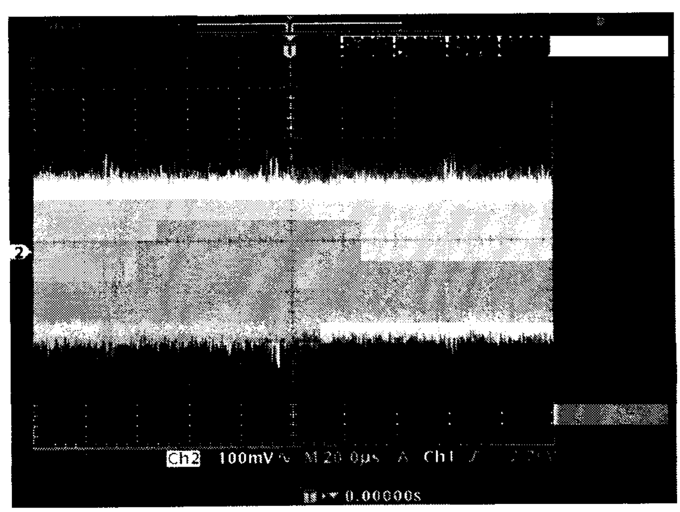
The TDS3000 DPO makes an ideal oscilloscope platform for VTR head alignments. Unlike any other type of digitizing oscilloscope, the TDS3000's analog-like real-time intensity grading can display the familiar RF signal envelope seen in every VTR service manual. Without intensity grading, the waveform in Figures 5a and 5b would appear as a pair of indistinct lines, almost useless for the alignment procedure.

The TDS3000 provides tactile feedback during the procedure. The instrument's extraordinary waveform capture rate ensures that the display immediately tracks any changes as adjustments are made. A continuous adjustment, therefore, appears as a continuous change in the waveform – not a series of abrupt jumps from one increment to the next.

Conclusion

The TDS3000 DPO is a versatile tool for all kinds of television and video measurements. Its unique intensity-graded display surpasses even analog oscilloscopes in legibility, responsiveness, and ease of interpretation. Standard digital oscilloscope features, as well as video-specific functions included in the optional video measurement module, make the TDS3000 an ideal tool for video service and maintenance applications.

(A)



(B)

Figure 5. Digital Phosphor technology makes video head alignment as fast and easy as using an analog oscilloscope for the job. a) RF envelope before adjustment; b) After adjustment.

For further information, contact Tektronix:

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ISO 9001

11/98 TD/XBS 3GW–12450–1

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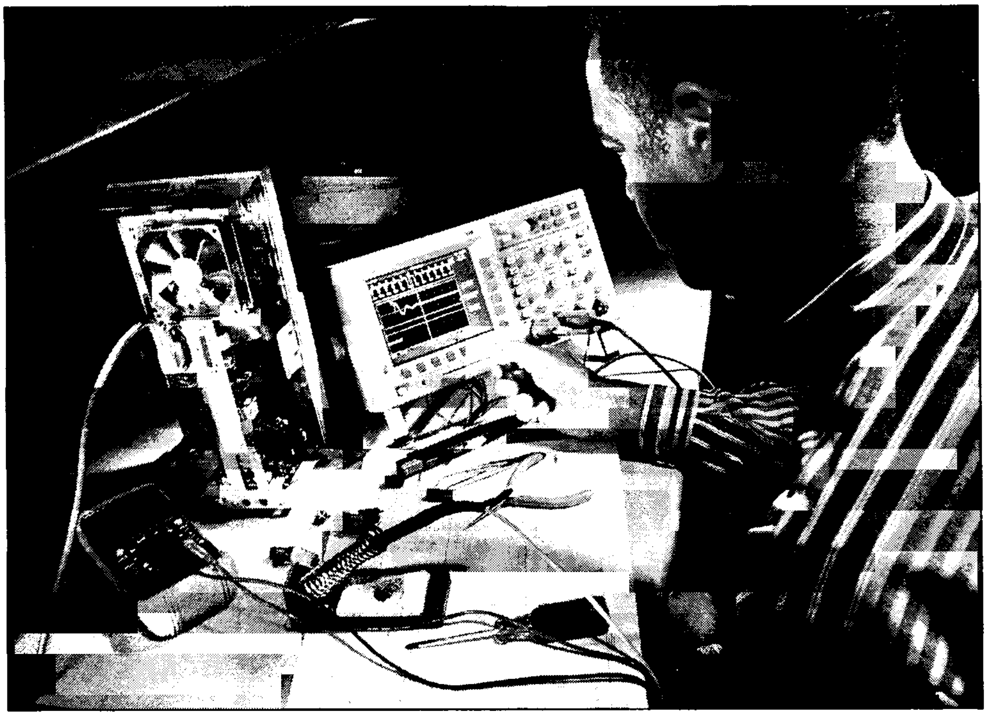
Application Note

TDS3000 DPO Answers Today's Power Measurement Problems



The definition of "power measurements" has changed in recent years, and with it the number of design applications that require such measurements. It's all due to the industry-wide shift to switching power supplies, which have become a near-standard part of consumer electronics, computers, and even household appliances. Where once the designer simply confirmed that his or her power supply provided adequate ripple-free voltage and current, now the engineer must characterize power levels, output purity, and harmonics fed back into the power line. Today, a power supply must deliver performance and reliability, and just as important, compliance with national and regional power quality standards (such as the IEEE 519-1992 specification in the United States). The designer must be prepared to measure high-frequency switching device outputs, noise levels, power characteristics, and more.

With all these diverse requirements, the oscilloscope has become a favored tool for power supply design and troubleshooting. But not every oscilloscope is adequately equipped for power measurements. Can the instrument measure voltage, current, and power with equal ease? Can it measure floating voltages safely? Can it provide harmonic measurements? Does it make the user's job easy and safe? These challenges, and more, must be considered when choosing a solution for power measurements.

The new TDS3000 Series Digital Phosphor Oscilloscopes (DPOs) address all of these concerns. 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.).

Power harmonic measurements require a tool that can display the signal's various spectral components. The harmonic display reveals the relative magnitude of the harmonics to the fundamental frequency. An optional FFT Application Module equips the TDS3000 oscilloscopes for this type of reading. It provides advanced analysis features that convert a timedomain acquisition into a true harmonic display. This is essential for harmonic measurements on 50 and 60 Hz lines.

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 – and the transients that also can occur – calls for ample bandwidth and 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).

TDS3000 DPO models range in bandwidth from 100 MHz to 500 MHz, sufficient for even the fastest power supply switching frequencies. The TDS3000 instruments also offer a waveform capture rate that surpasses digital storage oscilloscopes. Transients are, therefore, much more likely to be acquired; moreover, the DPO's intensity-graded digital phosphor display highlights the most frequently-occurring areas of the signal. This makes it easy to distinguish an occasional transient from the characteristics of the background waveform.

Measuring Instantaneous Power with the TDS3000

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 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 TDS3000's TekProbe interface is compatible with the P5205 High-Voltage Differential Probe and the TCP202 Current Probe (among many others). 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 TDS3000, like most oscilloscopes, is not designed to measure floating signals directly. A differential probe is required for making safe floating measurements with the TDS3000. 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 TDS3000 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 TDS3000 can be used to set up the initial waveform display. Autoset automatically adjusts the range and scaling to bring the waveforms into view. The TDS3000'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.

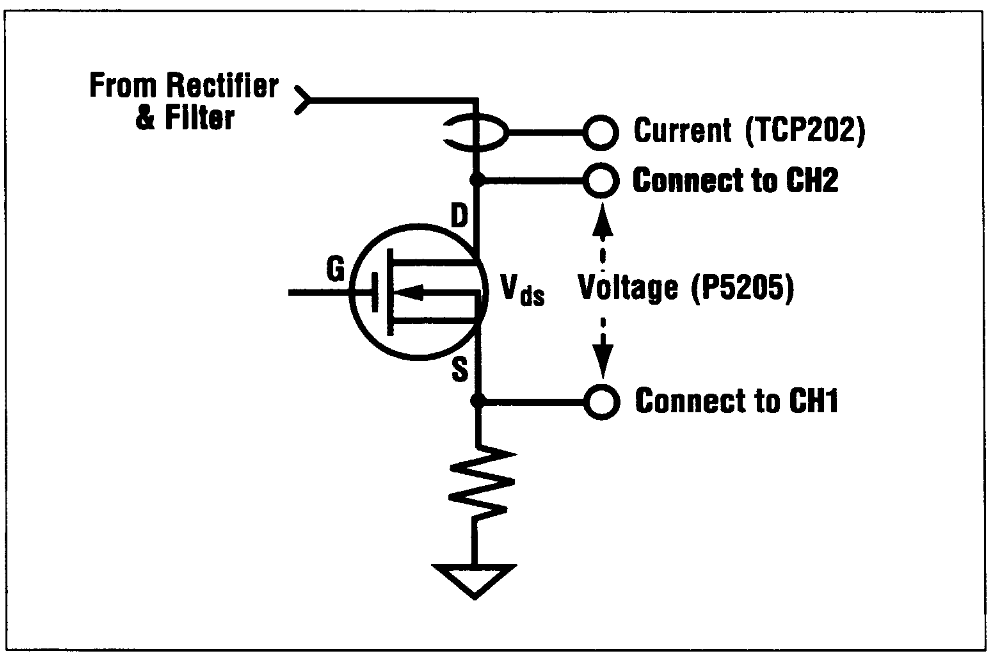


Figure 1. Connecting a differential probe to a power MOSFET.

The power waveform is simply a point-by-point multiplication of the voltage and current waveforms (CH1 x CH2). The TDS3000'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 TDS3000's digital phosphor display makes a big difference when troubleshooting, especially when identifying excessive modulation effects in a switching power supply.

The TDS3000 has a waveform capture rate that is fifty times higher than that of a DSO. This provides two advantages when investigating modulation effects. First, the TDS3000 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 TDS3000'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.

Viewing modulation effects with the TDS3000 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.

Capturing Transients with the TDS3000 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 TDS3000'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 optional FFT application module (TDS3FFT), the TDS3000 is an excellent tool for harmonic analysis. An oscilloscope with FFT capability is

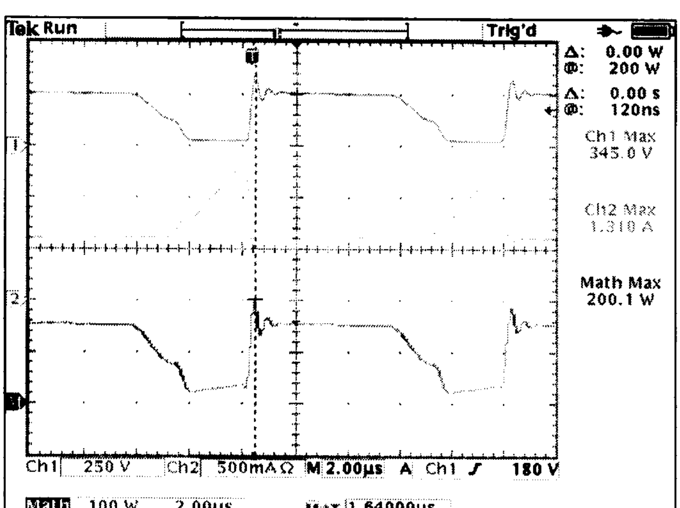


Figure 2. Power Measurement Screen shows volts, amps, and power waveform in correct units.

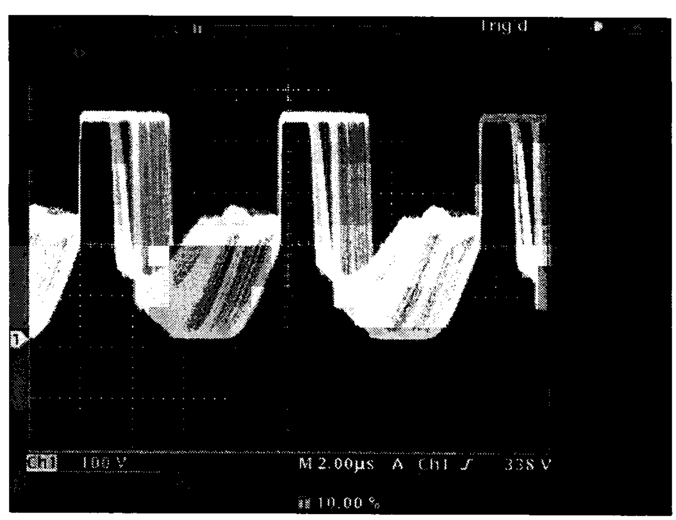


Figure 3. Modulation effects on a power supply control loop.

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 TDS3000 FFT 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 FFT 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.

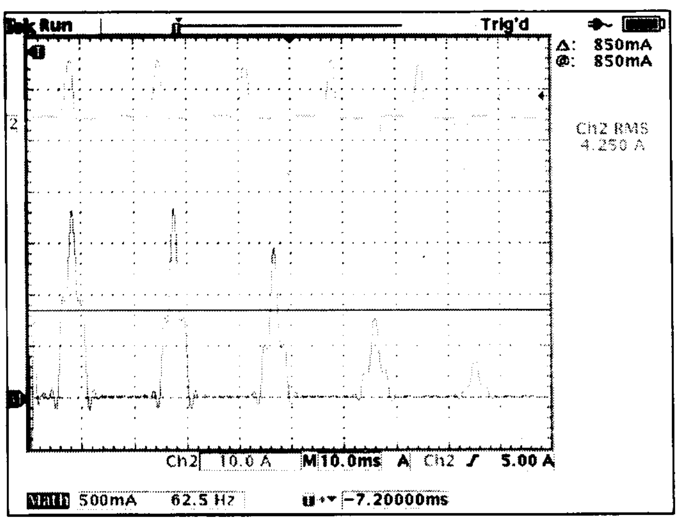


Figure 4. TDS3000 shows the harmonic analysis of a 250 W class D power supply. The cursor shows that the 3rd harmonic (at 180 Hz) exceeds the 850 mA limit per IEC61000-3-2.

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 TDS3000'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 TDS3000'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 TDS3000 offers a full range of storage and printing capabilities to aid in this effort. A dedicated HARD COPY button reproduces the screen image on an inkjet or laser printer connected to the TDS3000'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 TDS3000 Digital Phosphor Oscilloscope, when equipped with the FFT 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.

For further information, contact Tektronix:

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Application Note

TDS3000 DPO Keeps Pace with Changing Digital Troubleshooting Needs

Digital circuitry is no longer confined to cutting edge, high-end products; it's now ubiquitous in toys, toasters, table radios, and other commodity consumer products. Today's automobile contains multiple microprocessors, as do household security systems, VCRs, and so on. In most instances, a product's digital content includes a microprocessor or microcontroller. Digital devices are doing more of the work in all kinds of products, and, as in the case of the automobile air bag controller, people entrust their lives to the controller's reliability. These devices may even include functions such as memory, A/D converters, line drivers, and more. In addition, the operating speeds of these devices are faster.

It all adds up to an increasingly complex and critical troubleshooting task for the engineer or technician developing common consumer and industrial products. New digital designs often confront designers with new problems to find: race conditions, transients, signal aberrations, bus contention problems, etc. And of course, competitive time-to-market pressures dictate that troubleshooting must be completed quickly and accurately.

It's a scenario that calls for measurement and troubleshooting tools, particularly oscilloscopes, that can meet the challenges of new digital-intensive products. More than just a matter of basic bandwidth, these oscilloscopes must help the engineer solve problems quickly. In other words, they must first help the user establish that a problem exists, then capture the problem accurately, then analyze it to determine the root cause.

Introducing the New TDS3000 DPO

The TDS3000 Digital Phosphor Oscilloscope (DPO) family brings important new capabilities to the task of digital troubleshooting. The TDS3000's digital phosphor display gives it superior ability to accurately represent digital signals and intermittent faults with real-time intensity-graded detail, much like an analog oscilloscope. The TDS3000 family's bandwidth (models range from 100 MHz to 500 MHz) provides ample headroom for working with today's commodity microprocessors.

Getting the signal to the oscilloscope is the first important step in any measurement. The TDS3000 carries its performance all the way to the unit-under-test by means of the versatile TekProbe® interface. The interface mates to a broad selection of active high-frequency probes, current and differential probes. A properly-chosen probe is essential for high-speed measurements on digital circuits, since it minimizes circuit loading and ensures that the signal is not distorted by the probe itself.

After discovering a digital design problem with the help of the DPO's real-time intensity grading, the engineer can use the TDS3000's advanced triggers to isolate the fault and track down its origins. An optional user-installed module adds a wealth of advanced triggers to the TDS3000, including runt triggers, state triggers, width triggers, and more.

To Solve a Problem, First You Have to See It

Many oscilloscopes lack the performance and features to stay abreast of digital evolution. Consider, for example, a common digital design problem: a narrow, occasional transient that affects circuit operation. The analog oscilloscope is unable to display it with sufficient brightness, and is prone to flickering; the (much brighter) main waveform obscures it. Moreover, the analog oscilloscope provides no means of storing and analyzing the waveform, or capturing the glitch alone. The DSO may capture the transient, but cannot display it in real-time distinctly from the main, repetitive waveform. The transient looks like it occurs as often as the main trace.

The TDS3000 DPO brings a new dimension to signal viewing with a digitizing oscilloscope. First, its waveform capture rate is 50 times faster than that of a DSO with comparable performance. This provides advantages when looking for transients. Its acquisition system is active much more of the time, so the DPO has hundreds of times more opportunities to capture glitches and infrequent events.

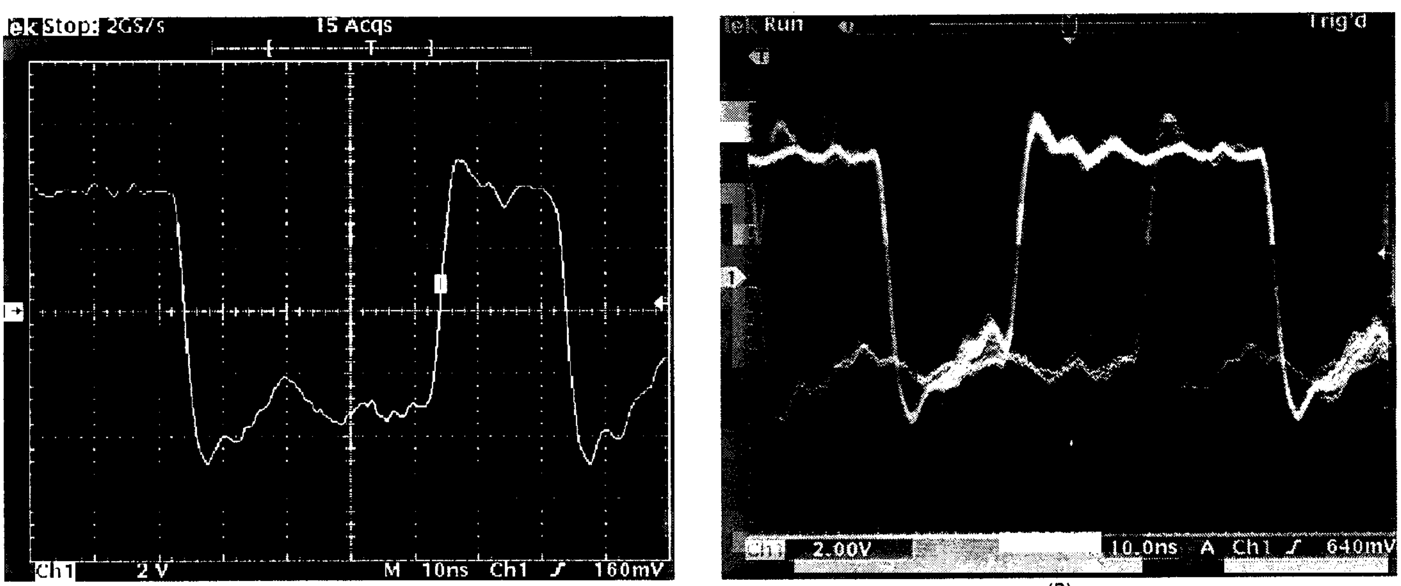
Secondly, the TDS3000's real-time intensity grading exposes the details about the "history" of a signal's activity as they accumulate. The digital phosphor display makes it easier to understand the characteristics of the transients you've captured. It intensifies the areas where the signal trace crosses more frequently, much like an analog oscilloscope. An infrequent transient is dimmer than the main waveform that repeats continuously, yet it's still very visible and distinguishable. Changes are seen as they occur.

Figures 1a and 1b show how intensity grading can help you understand what's going on in your circuit.

Extending DPO Performance to the Unit-Under-Test

An often-overlooked aspect of any digital measurement is the oscilloscope probe's effect on the signal. As clock speeds and edge rates increase, ordinary passive probes begin to degrade the signal, adding overshoot to transitions, and slowing down edges. Moreover, passive probes can load down the circuit. "Problems" appear that aren't really problems at all, while the real problem – a glitch or a delayed edge – may go unnoticed.

Often, the best solution is an active probe. An active, or FET, probe has a buffer circuit built into the tip to isolate the signal from the inductive and capacitive effects of the probe cable and oscilloscope input. Active probes require DC power, which is supplied directly by the TDS3000's own probe interface.



(A) (B)

Figure 1. a) Typical DSO can only display one event at a time; b) DPO reveals what the signal really looks like.

The P6243 active probe is recommended for high-speed digital measurements with the TDS3000 oscilloscope. The P6243 provides a system bandwidth of 500 MHz when used with the TDS3054. The TekProbe interface ensures correctly scaled readings from the P6243 and other compatible active probes. The P6243's ≤1 pF input capacitance keeps loading to a minimum, and its small physical size works well with tiny Surface Mount Devices (SMD).

Triggering Helps Isolate Offending Signals

A broad selection of triggering conditions is indispensable when troubleshooting. The TDS3000 offers an optional trigger set that supplements the oscilloscope's basic edge triggering capabilities. Added triggering functions include State, Pulse Width, Runt Pulse, Slew Rate, and more. With the right trigger setup, you can quickly isolate a problem and perform root-cause analysis.

Race conditions are a common occurrence in new digital designs, especially as clock speeds increase and timing tolerances get more critical. One result of a race condition is a transient, a pulse that's much narrower than the normal data-carrying signals in the circuit. Most digital systems specify a minimum pulse width for valid data, and it's necessary to eliminate pulses narrower than the specifications. The TDS3000 Pulse Width (PW) trigger is a powerful tool for finding transients.

The PW trigger allows you to set source, polarity (slope), and level as explained above. In addition, it provides a "Trigger When" menu from which you select one of four timing conditions: Less Than (the specified pulse width), Greater Than, Equal, or Not Equal. Typically you will use the Less Than condition. When the oscilloscope triggers, it exposes the pulses that are narrower than the specification. Figure 2 shows a pulse of this type.

State triggering is ideal for tracking events that result (or should result!) from the occurrence of a "clock" pulse. State triggering helps you confirm that the data on synchronous signals is arriving in the proper sequence. The trigger system monitors two inputs: a "state," or data, input, and the clock (which doesn't have to be a clock pulse; just a transition that enables data to move into the device). In Figure 3, for example, the Write Enable (WE) signal is used as the "clock." The TDS3000 is set to trigger when Data is true (1) and Write Enable makes a transition from 0 to 1. Is Write Enable occurring when the Data signal is valid? In this instance, yes. The arrival of Write Enable prompts the oscilloscope to check the Data input, which is found to be valid at the time of the WE transition. The instrument triggers and displays the two signals.

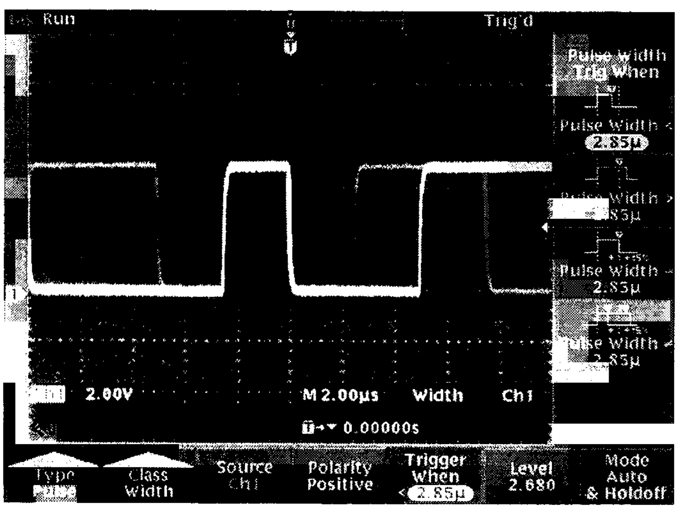


Figure 2. Pulse Width triggering captures a pulse that is not wide enough to be a valid state.

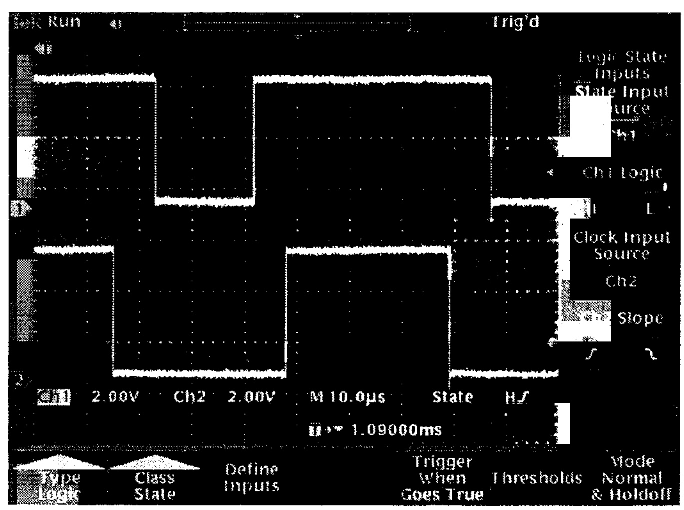


Figure 3. State triggering confirms that this Write Enable signal (bottom) is occurring when data (top) is valid.

When two I/O devices are trying to send data across a bus at the same time, erratic conditions can result. One of the transmitters might try to force a "1" at the same time the other is driving a "0." A common effect of this bus contention is a "runt" pulse – a signal that is neither 1 nor 0, but somewhere in between. Unlike the logic problems described previously, the runt pulse is an amplitude problem, not a timing problem.

The TDS3000's Runt Pulse trigger detects attenuated signals immediately. It looks for a pulse that crosses the first of two threshold levels but fails to cross a second threshold. Imagine, for example, setting up to detect a bus contention problem on a GPIB bus. The first threshold is set at 800 millivolts, the second at 2.80 volts. The thresholds can be set to detect either positive-going or negative-going pulses. Pulse width conditions can also be specified. Figure 4 depicts the resulting screen capture. With this triggering method, it's possible to trigger on the bad pulse and use a second channel to track down the logic conditions that caused it.

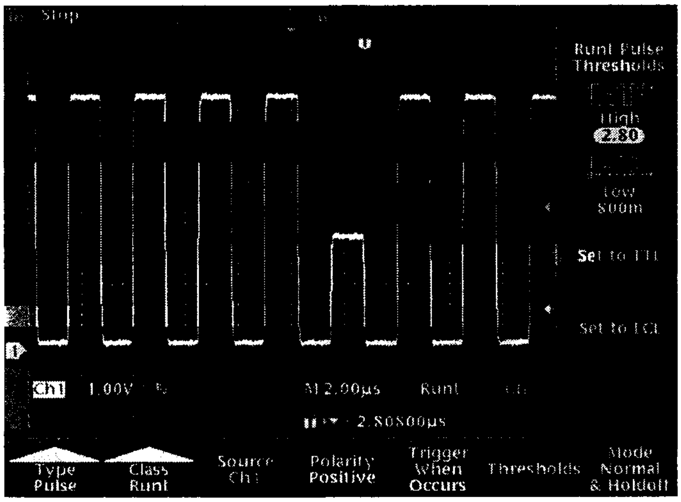


Figure 4. Runt Pulse trigger finds attenuated signals on an I/O bus.

Conclusion

Today's digital circuits present an increasingly difficult challenge to conventional measurement tools. Clock speeds, circuit density, and functional complexity are all on the way up. Fortunately the Tektronix TDS3000 Series DPO has advanced with these needs. The TDS3000 simplifies design and troubleshooting tasks wherever digital measurements are needed.

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