

PMA2 Software Option

Operator's Guide

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INTRODUCTION TO PMA2

The Tools and What They Do

When combined with a LeCroy digital storage oscilloscope (DSO) and current and differential measurement tools, the PowerMeasure Analysis 2 (PMA2) software package provides a complete set of hardware and software tools for the design and analysis of power conversion circuits, as well as current and differential voltage measurement tools. PMA2 consists of three major measurement areas:

Power Device Analysis – This area covers measurements made on power switching devices used in power conversion products, such as power supplies, electronic motor drives (adjustable-speed drives), or high-efficiency lighting circuits. Measurements covered include device instantaneous power, safe operating area (SOA), saturation voltage, and dynamic on-resistance. With PMA2, these device measurements can be made either on a test stand or in circuit while the devices are operating in a power conversion system.

Modulation Analysis – This area covers the acquisition and analysis of information contained in a power conversion circuit's modulated control signal. It analyzes modulation changes in pulse width (PWM), duty cycle, frequency, or period as the circuit responds to changes in line and/or load, as well as during start-up and shut-down.

Line Power Analysis – This area covers the measurement of line voltage and current applied to an off-line power conversion device. Real power, apparent power, power factor, and line harmonics are measured. Analysis of line harmonic content is included to assist the design and evaluation engineer in designing for pre-compliance to EN 61000-3-2 requirements.

Equipment Required

DSO

PowerMeasure Analysis 2 software operates on any LeCroy X-Stream DSO. For analysis of phenomenon requiring the acquisition of many cycles, a DSO with a minimum memory of 1 Mpt per channel should be used. Steady-state analysis can be accomplished with shorter record lengths. Two acquisition channels are adequate for most measurements, but a four-channel DSO is required if you want to analyze multiple devices or to use complex triggering.

Voltage Probes

Since most voltage signals associated with power conversion circuits are not ground related, differential measurement capability is required. To carry out all the measurements covered in Using Power Device Analysis the CMRR, CMR, Overdrive Recovery, and compensation flatness performance of the LeCroy DA1855A differential amplifier and its associated DXC series passive differential probes are required. The measurements in Using Modulation Analysis and Using Line Power Analysis can be made with medium-performance differential probes.

Current Probes

The measurements described in Using Power Device Analysis

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require precision wide-bandwidth current probes with DC measurement capability. The LeCroy AP015 DC-to-50 MHz current probe is recommended. Other, higher current probes are also available from LeCroy.

Deskew Signal Source

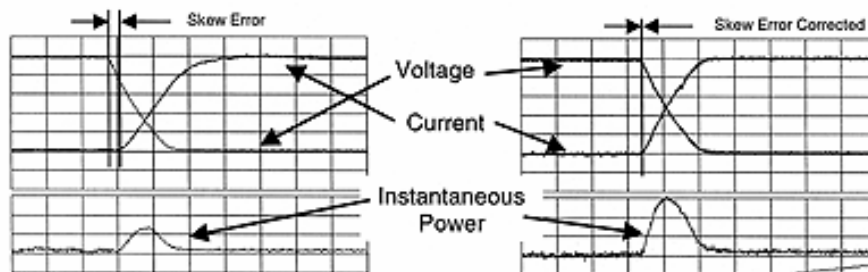
A source of time-coincident voltage and current signals is required to allow the propagation delay differences in the voltage and current signals to be matched. The LeCroy DCS015 Deskew Calibration Source is provided for this purpose.

Note: The time delay of a DA1855/DXC100 (A or non-A versions) connected to the DSO with a 1.2 m 50 coaxial cable is the same as the AP015 Current Probe's delay, and no deskew adjustment is required.

DESKEWING VOLTAGE AND CURRENT

Matching the Time Delay in Your Measurement System

Because the signals associated with power devices are relatively fast, it is important to determine whether the time delay for the current and voltage signal paths are the same. Signal delay characteristics of the voltage and current probes, as well as the distance the signals must travel from the probe tips to the input of the DSO, can cause time-coincident points on the voltage and current signals to be sampled by the DSO at different times. A small time difference can cause significant errors to occur in the measurements.



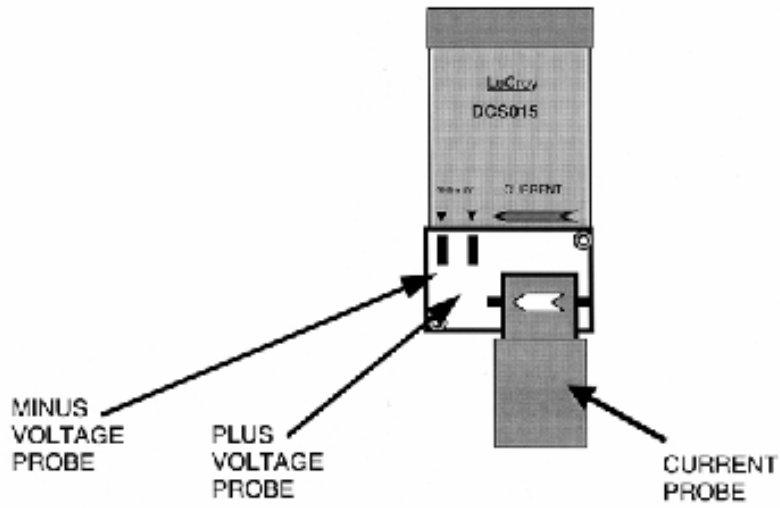
Significant error occurs in an instantaneous power measurement when the current signal takes longer than the voltage signal to reach the DSO because of a longer signal path. This error can be corrected by matching the delay of the voltage and current signal paths using the Deskew adjustment

It is advisable to use the Deskew adjustment to check and match, if necessary, the time delay of the current and voltage channels. This is very important if these signals are going to be used to make Instantaneous Power, Safe Operating Area, or Dynamic On-Resistance measurements.

Checking Channel-to-Channel Time Skew

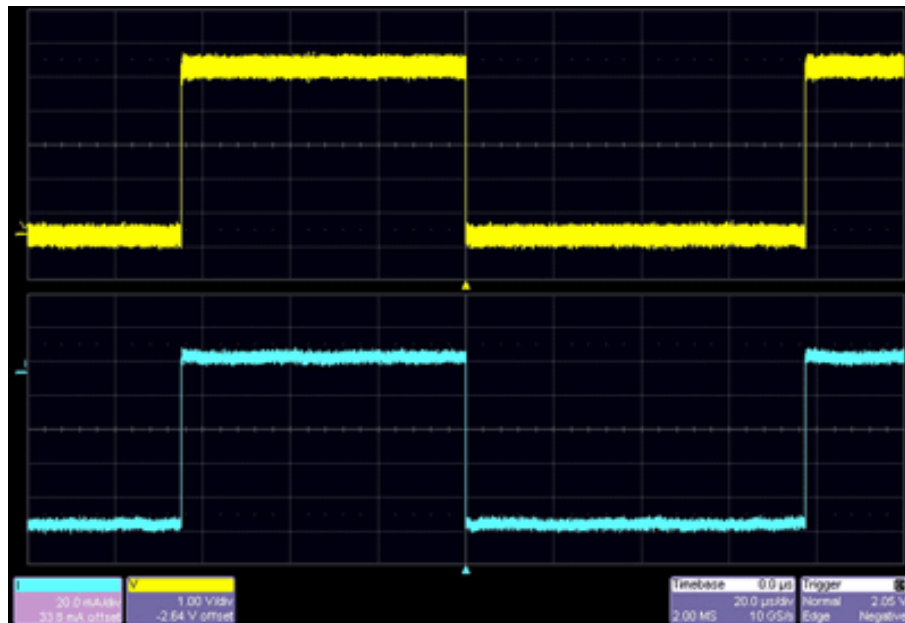
Decide which DSO channels are to be used as the voltage and current inputs, and connect the voltage and current probes to those channels. Connect the DCS015 Deskew Calibration Source to the DSO's calibrator output or to one of the unused channels.

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Connect the voltage and current probes to the DCS015 as shown. Be sure to observe polarity on the current and voltage signals.

Initial Setup



Set the time/div, trigger delay, trigger level, voltage, and current channel coupling to obtain the display shown above. It is important to trigger on the negative slope of the voltage waveform. In the Utilities Preferences Setup Offset/Delay dialog, set the Delay Setting Constant to **Div**. Position both traces around center screen, and set the trigger level and delay as shown.

Note: The choice of which channel to use for current and voltage is arbitrary. For consistency, all examples use Channel 2 for voltage and Channel 3 for current.

Deskew Setup

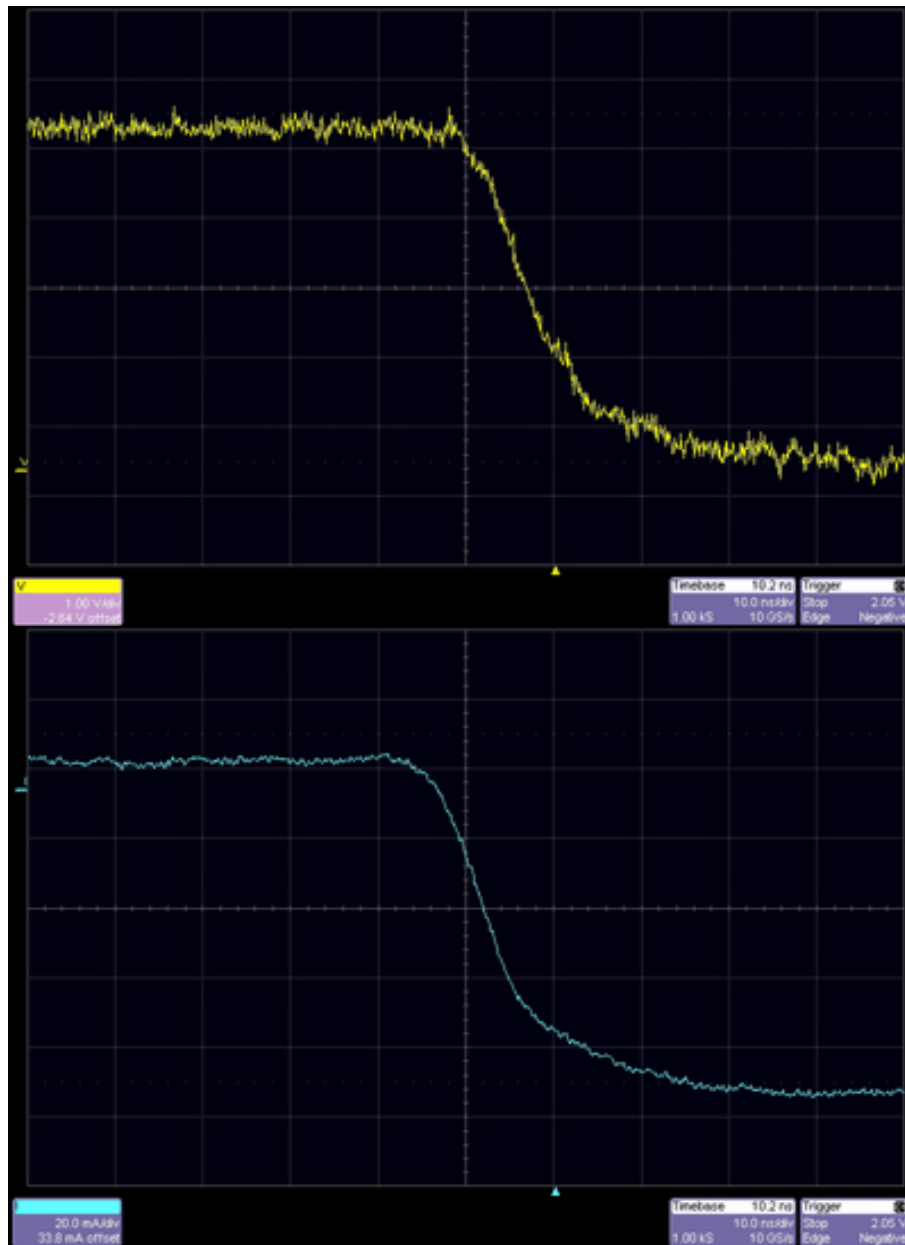
Once the DCS015's voltage and current waveforms are properly displayed, use the PMA2 software to match the time delay in the voltage and current channels.

1. From the menu bar, select **Analysis**, then **PowerMeasure** from the drop-down menu; the "PowerMeasure" dialog opens.
2. Touch the **Voltage** tab, then touch inside the **Source** field and select a channel, memory, or math trace from the pop-up menu.
3. Touch the **Current** tab, then touch inside the current **Source** field and select a channel from the pop-up menu.

Note: The channel selected as the Current Input channel will be assigned Ampere units even if a voltage or non-ProBus-compatible current probe is used.

4. Touch the **Timebase** descriptor label; the "Horizontal" dialog opens. Set the Time/Division to 10 ns.
5. The voltage and current displays should look similar to this:

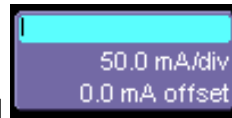
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Channel-to-Channel Propagation Delay (Skew) Matching

After the voltage and current channels are properly set up, proceed as follows to deskew the voltage and current signals. Be sure to deskew on the negative edge:

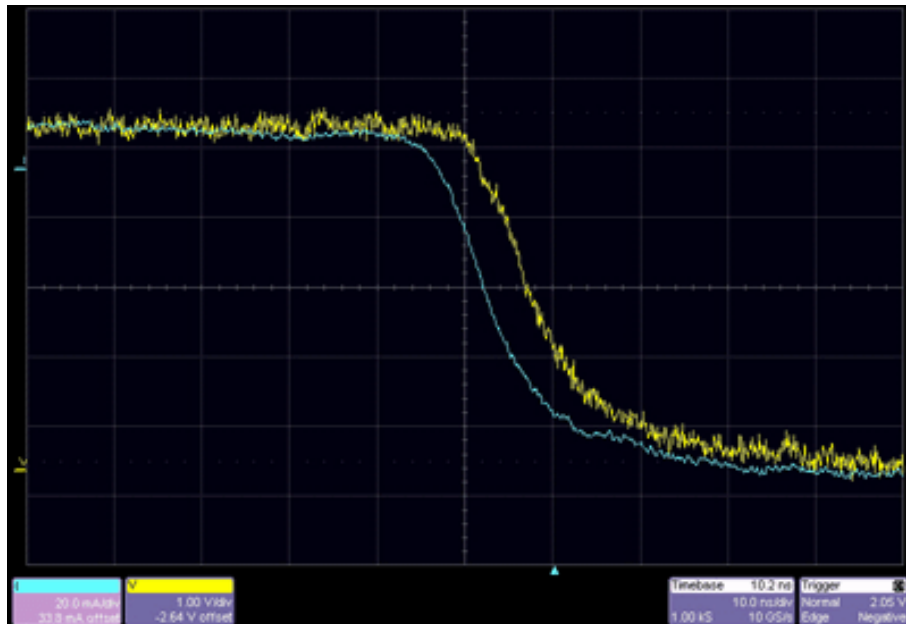
1. Touch the **Timebase** descriptor label to open the "Horizontal" setup dialog; then touch the **Set To Zero** button under "Delay" to zero any delay. In this same dialog, touch the **SMART Memory** tab, then the **Fixed Sample Rate** button. Lower the **Sampling Rate** to around 100 kS/s to speed up processing.
2. Press the front panel channel button for the voltage channel. The "Vertical Adjust" dialog opens. Touch inside the **Averaging** field and set a value of approximately 5 sweeps to remove noise from the trace. Then press the front panel channel button for the current channel and do the same for that trace. This will make it easier to align the traces for deskewing.



3. Touch the **Current** descriptor label, then touch inside the **Deskew** field.

Note: Be sure to deskew in the PowerMeasure dialog and NOT in the Vertical (channel) setup dialog.

4. Enter a time value, using the pop-up keypad, or turn the Adjust knob to set a value.



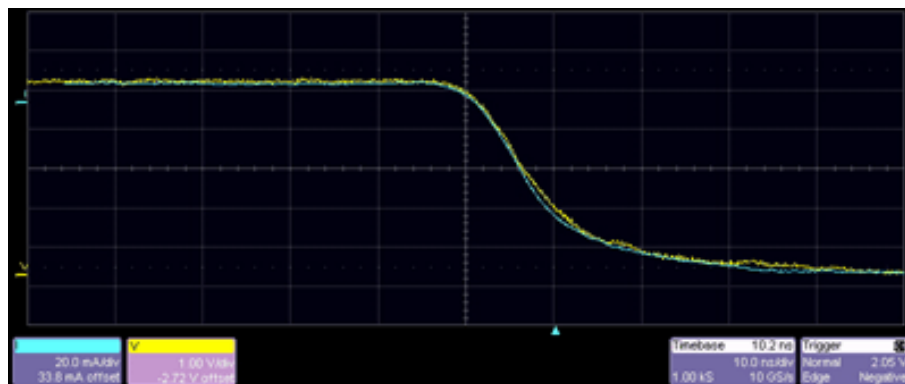
The signal time skew will be shown as delay difference between the voltage and current waveform. By changing the value of deskew (either by directly entering a number using the pop-

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up keypad or by adjusting the number with the Adjust knob), the current waveform will be moved to the right (positive deskew) or left (negative deskew) to a maximum of +/- 100 ms. In this example the delay difference (time skew) is a little more than 10 ns. The amount of delay will depend on which voltage and current probes are used, as well as on the length of the probes and the coaxial cable used to connect the DA1855A to the DSO.

Note: When a DA1855A Differential Amplifier (connected by a 1.2 m coaxial cable), DXC100A Differential Passive Probe Pair, and AP015 Current Probe are used, the time delay is matched and no deskew adjustment is needed.



1. Adjust the deskew value until the current waveform coincides with the voltage waveform. If the current waveform's fall time is slower than that of the voltage, align the beginning of the waveforms (alignment point).
2. Turn the Adjust knob until the knee of the current and voltage waveforms are aligned.



Use the Fine button under the **Adjust** knob to make small adjustments.

- The time delays of these two channels are now matched, and they can be used to make accurate measurements that require precise time alignment of the current and voltage waveforms. This deskew value is only valid for this particular setup. Changing probes or bandwidth for either the current or voltage channel requires the channel's time-delay difference to be checked and possibly corrected. This process can be used to characterize and correct the delay difference between more than one current and one voltage channel. For instance, if the user plans to use one voltage channel and alternate measurements between two current channels, the relationship between the voltage channel and each of the current channels can be characterized. The amount of deskew required for each combination should be recorded for later use.
- Proceed directly to the power device measurement section by touching **Analysis** in the menu bar, then **PowerMeasure** in the drop-down menu. Alternatively, touch one of the



PowerMeasure descriptor labels

Clearing the Deskew Setup

If you are not going to be using the PMA2 application immediately, you should turn it off so as to undo modifications made during the deskew process.

- Touch **Analysis** in the menu bar, then **PowerMeasure** in the drop-down menu. Alternatively, touch one of the PowerMeasure descriptor labels



- Under "Analysis," touch the **Off** button.

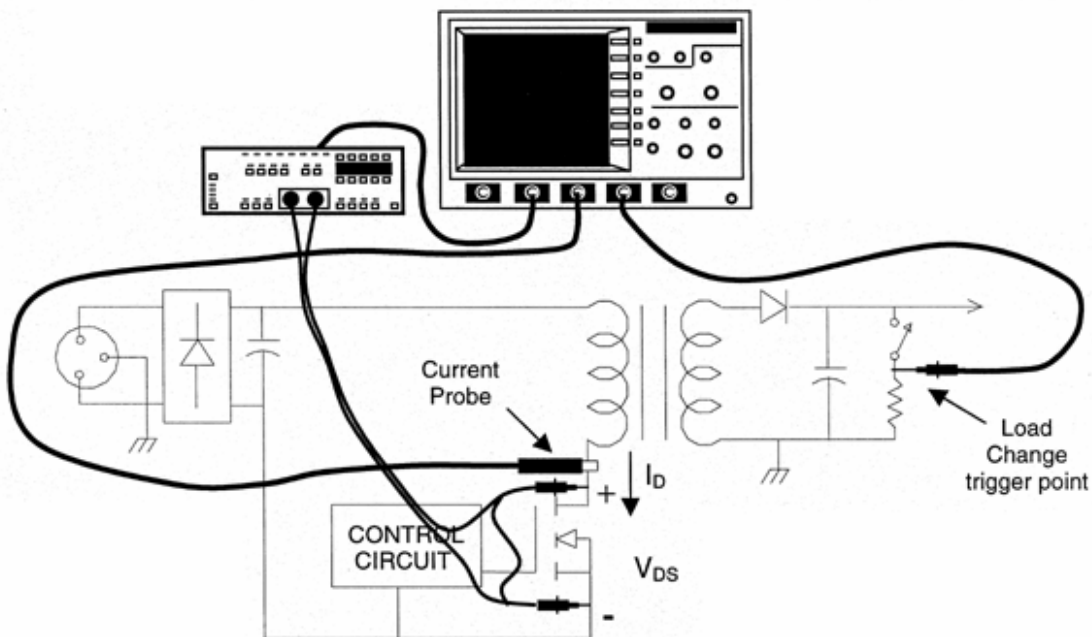
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USING POWER DEVICE ANALYSIS

Setup and Configuration for Power Device Analysis

The Power Device Analysis portion of PMA2 lets you make difficult measurements on the devices while they operate in circuit. The exact setup for each measurement will differ depending on what device type is to be analyzed and where it is located in the circuit. It will make the setup easier if the measurements are planned in advance. If possible, obtain representative waveforms of the voltage, current, and trigger inputs before invoking PMA2 software.

The following diagram shows a typical setup used to analyze the power FET in an off-line switching power supply. A differential amplifier is used to acquire the voltage across the device, and a current probe is used to acquire the current through it.



Typical Connections to a Circuit under Test Required to Make Instantaneous Power, Safe Operating Area, Saturation Voltage, and Dynamic On-resistance Measurements

The circuit shown is an off-line flyback power supply. Examples in this section are based on connections to a circuit of this type. Measurements also can be made on devices such as power transistors, snubber diodes, or similar devices in other topologies.

Configuring for Device Measurements

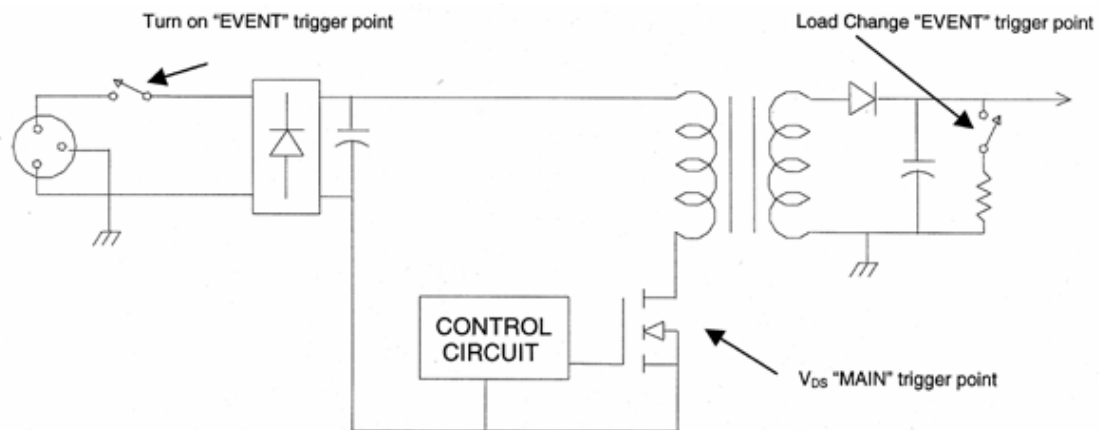
1. Select which DSO channels are to be used as voltage and current inputs. Follow the procedure contained in the Matching the Time Delay in Your Measurement System to

correct any delay between the current and voltage.

2. Connect the voltage and current probes to the appropriate points in the circuit under test. The figure above can be used as a guide. If measurements are to be made on the device as a function of an event such as load change or start-up, select a signal to be used as a trigger for this event. The example in the figure uses the DSO's Channel 4 to acquire a trigger signal indicating when the load changes from maximum to minimum. The DSO's EXT trigger input also could be used.

Preliminary Trigger Setup

Before you enter the PowerMeasure software menu, it is important to determine the source and setup of the triggers. Identify the signal on which the main measurement will be triggered, as well as the signal on which the acquisition of an extended measurement record is to be triggered. The main trigger can be the device's voltage or current signal while the event trigger is usually associated with load change or turn-on and turn-off. Establish the event trigger first (if required), then set up the main trigger. Choose the desired trigger signal and establish a stable display.

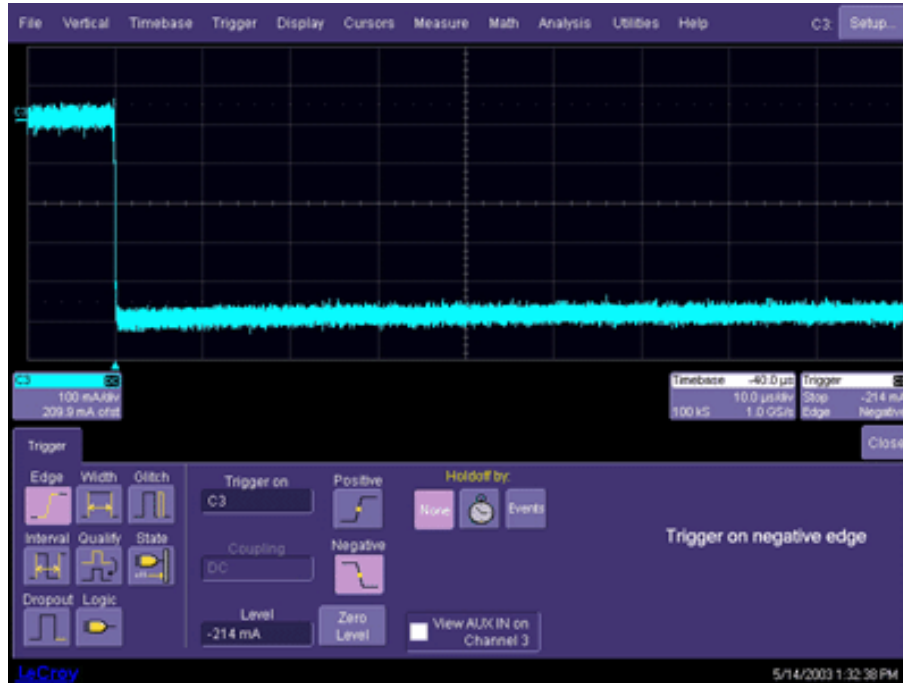


Typical Connections to Circuit under Test for MAIN and EVENT Triggers

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Initial Setup (Optional Event Trigger)

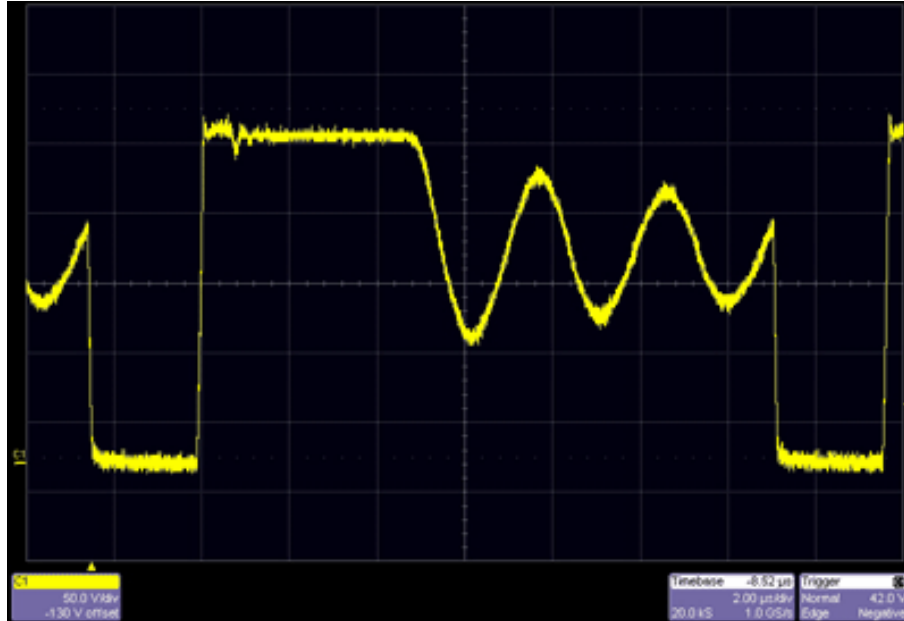
Determine the event whose change in operation requires the recording of an extended data record. Examples of such an event include the change from maximum to minimum load, and start-up. Presetting the trigger of such an event will make the final power measurement setup easier.



In this example, Channel 4 is used to acquire a signal that indicates the power supply load's changing from maximum to minimum. Set up the trigger so the acquisition of a record can be initiated from this event. The Load Change "EVENT" trigger shown in the figure above was used for this example. The event you need to trigger on may be different.

Initial Setup (Main Trigger)

The following example uses the power transistor's drain-to-source voltage as a trigger source. This is the same signal that will be used to measure the device's instantaneous power loss or safe operating area performance.



Set the time/div, trigger delay, trigger level, and voltage channel coupling to obtain a display similar to that shown above. It is usually desirable to trigger on the negative slope of the voltage waveform. But you should set your trigger on either the voltage (shown) or current waveform in order to obtain a stable display.

Setup for Power Device Analysis

After the measurement is planned, the voltage and current channels are identified and deskewed, and preliminary triggering is established, use the PMA2 software to finish the setup and make the measurements.

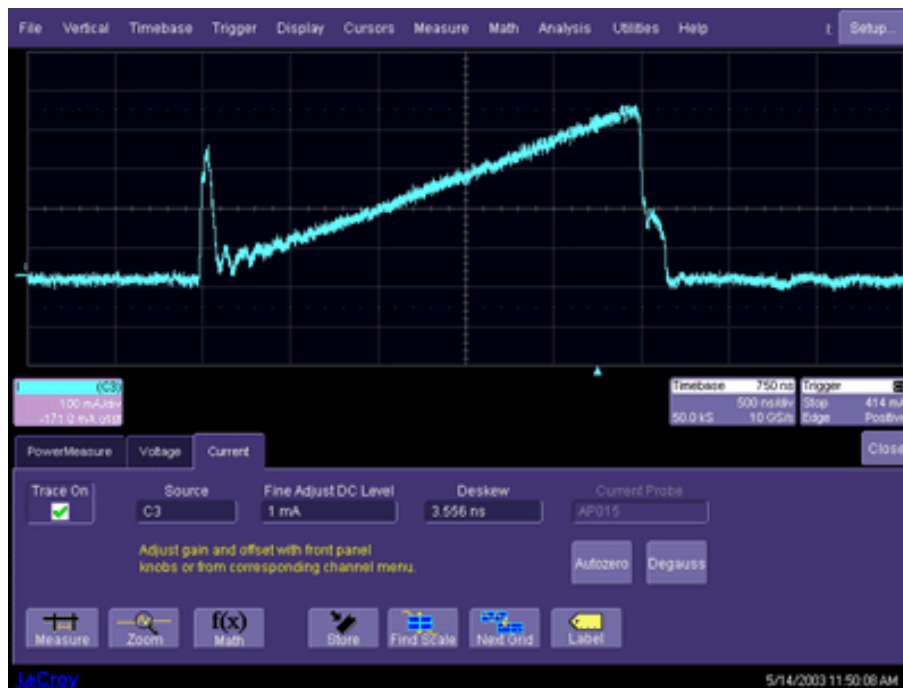
Power Device Analysis Setup

1. From the menu bar, select Analysis, then PowerMeasure from the drop-down menu; the "PowerMeasure" dialog opens.
2. Touch the **Voltage** tab, then touch inside the voltage **Source** field and select a channel, memory, or math trace from the pop-up menu.
3. Using the Horizontal and Vertical front panel buttons, adjust the time/division and volts/division to obtain a stable display of at least one cycle of the voltage signal across

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the device.

4. Touch inside the **Fine Adjust DC Level** field and enter a value, using the pop-up keypad. The Fine Adjust DC Level controls correct small DC offset errors in the voltage and current probes without your having to remove the voltage or current probe from the circuit. You can use the pop-up keypad to zero the offset for each control.
5. Touch inside the **Attenuation** field and select an attenuation factor from the pop-up menu.
6. Touch the **Current** tab, then touch inside the current **Source** field and select a channel, memory, or math trace from the pop-up menu.
7. Touch inside the **Fine Adjust DC Level** field and enter a value, using the pop-up keypad.
8. Touch inside the **Current probe type** field and make a selection from the pop-up menu. The display should appear similar to this:



Note: It is important to set V/div to allow the largest expected voltage excursion to remain on screen during all conditions of the test. If the voltage signal goes off screen during the test, erroneous results will be obtained.

9. It is good practice to balance the DC offset of the voltage probe at this point. Press the DA1855A's Autozero button to autobalance the amplifier.

Note: The channel selected as the Current Input channel will be assigned Ampere units even if a voltage or non-ProBus-compatible current probe is used.

10. It is also good practice to degauss the current probe at this point. Remove the current probe from the circuit under test, close the probe and press Degauss.
11. Reconnect the current probe to the circuit under test.

Power Device Analysis Setup (Deskew Value Check)

After the voltage and current channels are assigned, the value of time delay correction required between the two can be set by touching inside the **Deskew** field in the "Current" dialog.

The deskew value can be changed in this dialog by turning the front panel Adjust knob



or by using the pop-up keypad.

Note: The deskew value should not be changed in this dialog unless the correct value is known. Voltage and current signals that occur in the circuit under test may not be properly phase related, and using them for deskew purposes can cause major errors to occur in the measurements. Time-coincident voltage and current signals such as those provided by the DCS015 Deskew Calibration Source should be used.

Power Device Analysis Measurements

Note: The previous sections should be completed before you make these measurements.

After the channel-to-channel propagation delay is matched and the previous measurement setup is completed, measurements on the device under test can proceed.

1. From the menu bar, select **Analysis**, then **PowerMeasure** from the drop-down menu; the "PowerMeasure" dialog opens.
2. Touch the **Device** button. The choices of measurement are as follows:
 - **Instantaneous Power** measures the instantaneous power loss in the power FET.
 - **Safe Operating Area** measures the power FETs safe operating area.
 - **Dynamic On-Resistance** measures the power FETs saturation voltage and its dynamic on-resistance.
 - **DV/DT** measures the derivative of the voltage.
3. Touch the **Voltage** tab, then touch inside the **Fine Adjust DC Level** field. This field enables you to correct small DC offset errors without having to remove the probe from the circuit. Enter a value, using the pop-up keypad, or use the fine adjust front panel knob

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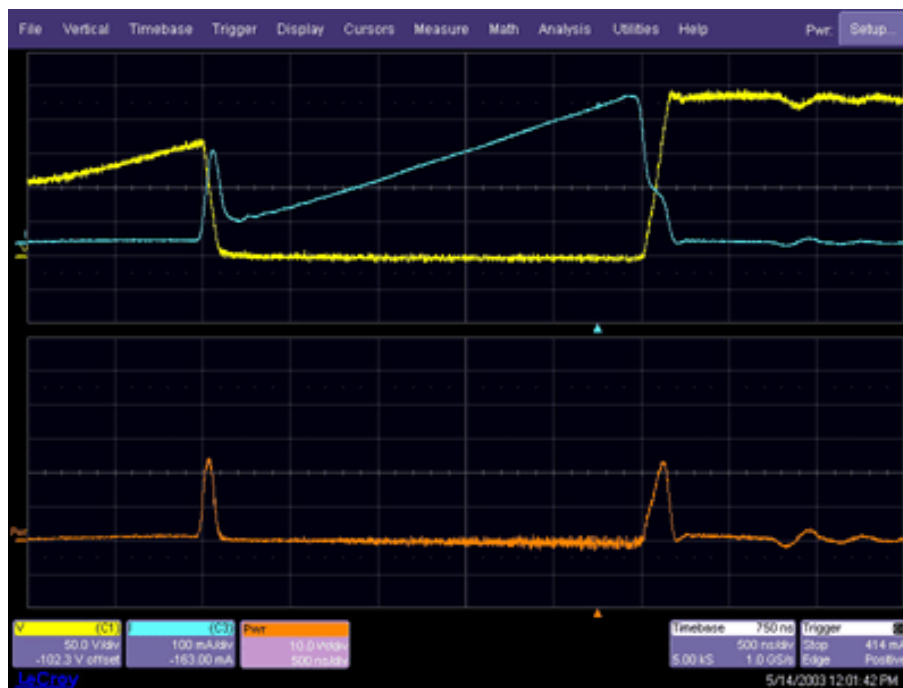


4. Touch the **Current** tab; perform the same DC offset correction, as necessary.

Instantaneous Power Measurement – Steady State

Note: The previous sections should be completed before you make these measurements.

Selecting **Instantaneous Power** from the **Analysis** menu brings up the following display:



- The deskewed current waveform (I) and the voltage waveform (V) are displayed in the first grid.
 - The instantaneous power waveform (Pwr) is displayed in the second grid.
1. **Fine Adjust DC Level** for both voltage and current are provided to allow you to

compensate for any residual DC offset that the voltage and current probes may exhibit. Because the magnitude of residual DC offset error is usually unknown, use of these adjustments requires that you know something about the waveforms.

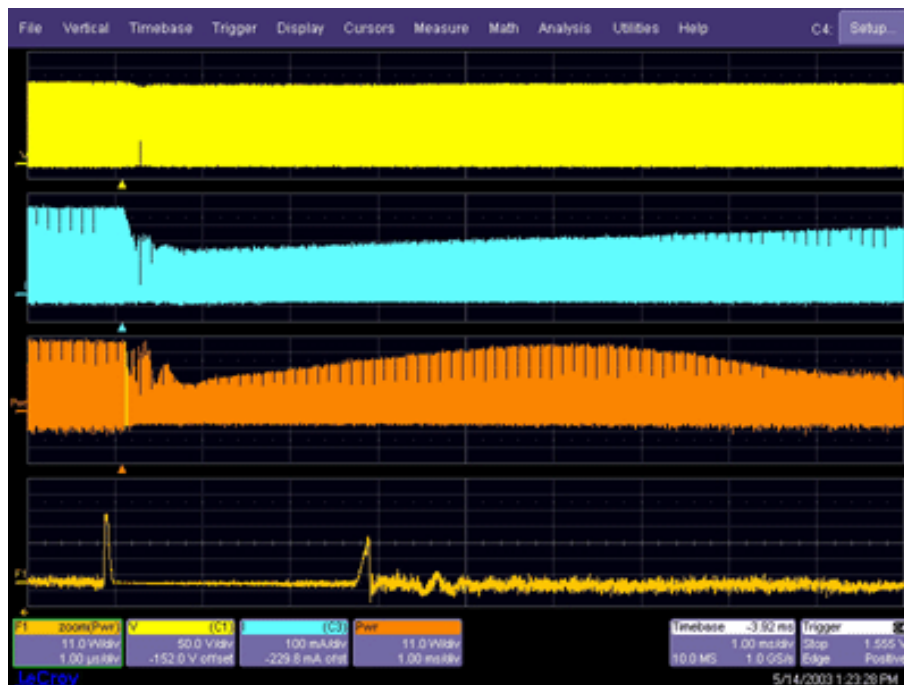


2. Press the **FINE** button, then turn the **ADJUST** knob to set the DC offset level.
3. For a detailed explanation of how to adjust the DC offset level, see “Fine DC Level Adjustment” below.

Instantaneous Power Measurement – Event Triggered

Note: The previous sections should be completed before you make these measurements.

To analyze the instantaneous power of the power device during transitions such as turn-on and load change, trigger the acquisition on an "event" trigger:



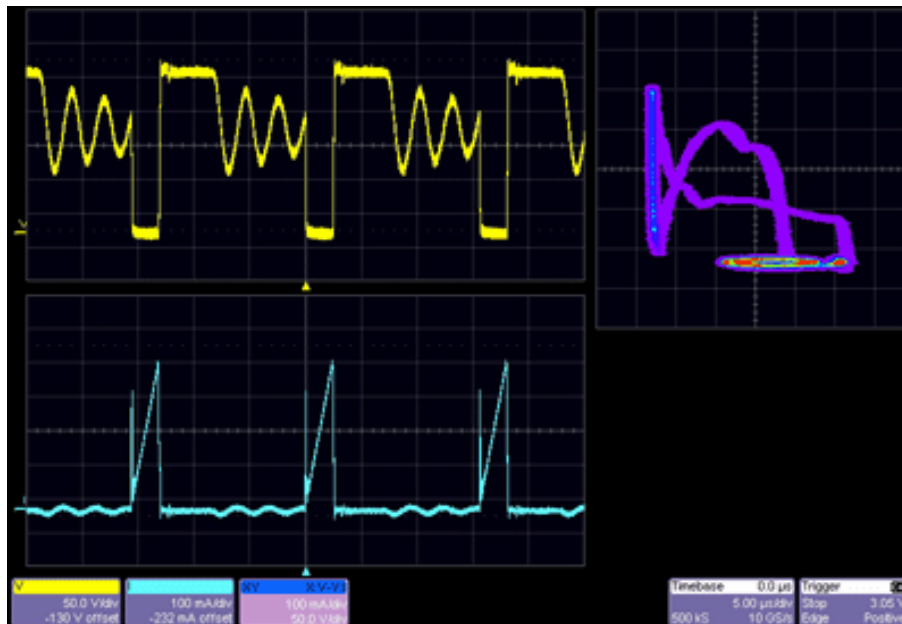
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The above is a 10 ms window of a power FETs drain-source voltage, drain current (deskewed), and instantaneous power dissipation that occurs during the circuit's transition from maximum to minimum load. The zoom of the instantaneous power waveform (F1) is used to examine the instantaneous power dissipation during one cycle in trace Pwr. In this case, the acquisition of the 10 ms record was triggered by the "event" trigger previously set up on Channel 4.

Safe Operating Area Measurement – Steady State

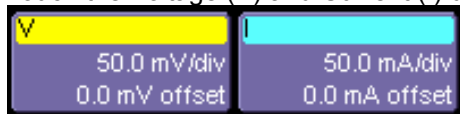
Note: The previous sections should be completed before you make these measurements.

Selecting **Safe Operating Area** in the "Functions" menu brings up the following display. The voltage waveform (**V**) is displayed in the first grid and the deskewed current waveform (**I**) is displayed in the second grid. In the XY plot, voltage points are plotted on the horizontal axis, while current is plotted on the vertical. The delay between the voltage and current samples have been removed by the deskew function.



Fine Adjust DC Level fields for both voltage and current are provided to allow you to compensate for any residual DC offset that the voltage and current probes may exhibit. Because the magnitude of residual DC offset error is usually unknown, use of these adjustments requires that you know something about the waveforms.

1. Touch the Voltage (**V**) and Current (**I**) descriptor labels



in turn to open the setup dialogs for each.

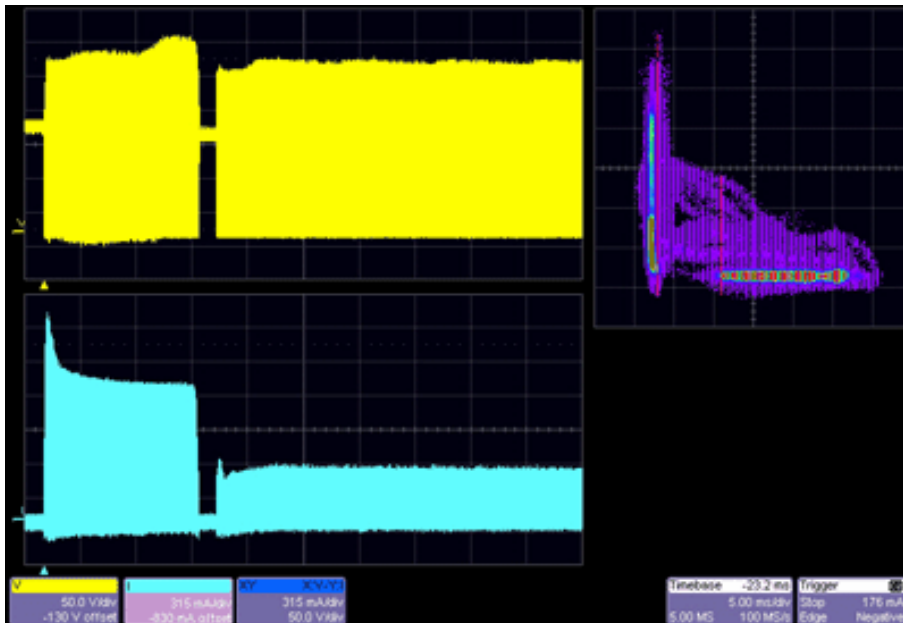


2. Press the Fine button, then turn the front panel **ADJUST** knob to set the DC Offset Level.
3. For a detailed explanation of how to adjust the DC Offset Level, see “Fine DC Level Adjustment” below.

Safe Operating Area Measurement – Event Triggered

Note: The previous sections should be completed before you make these measurements.

To analyze the safe operating area performance of the power device during a transition, such as turn-on or load transition, trigger the acquisition on an "event" trigger.



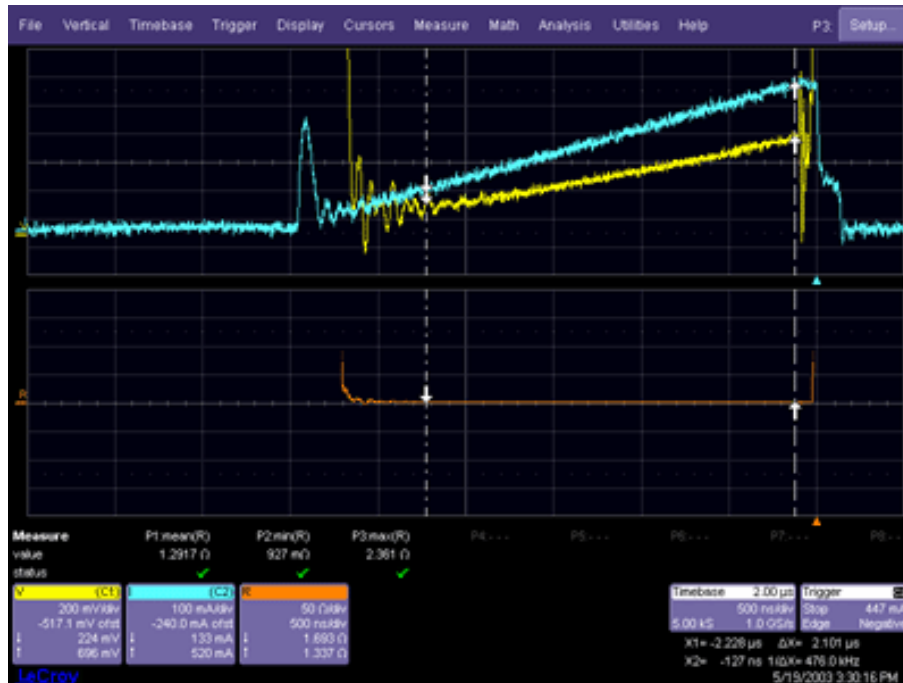
The above is a 10 ms window of a Power FET's drain-source voltage, drain current (deskewed), and safe operating area measurement that occurs during the circuit's transitioning from maximum to minimum load. In this case, the acquisition of the 10 ms record was triggered by the "event" trigger previously set up on Channel 4.

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Note: When a power mode button is selected, a great many calculations are performed by the scope. A brief interval is required, therefore, before the new display appears.

Saturation Voltage and Dynamic On-resistance Measurement

Note: The previous sections should be completed before you make these measurements.



Selecting **Dynamic On-Resistance** in the Functions menu brings up the above display. The deskewed voltage (V) and current (I) waveforms are displayed in the first grid. The delay between the voltage and current waveforms has been removed by the deskew function. By changing the DSO's V/div setting and adjusting the trigger level, the voltage waveform displayed is the device saturation voltage. (A DA1855A differential amplifier and DXC100A passive differential probe pair is required to make this measurement.) The voltage waveform is divided by the deskewed current waveform, and the resulting resistance waveform is displayed in the second grid (R).

Because the device saturation voltage waveform (R) is off screen during the non-saturation portion of the waveform, the math-generated resistance waveform should be ignored during this time.

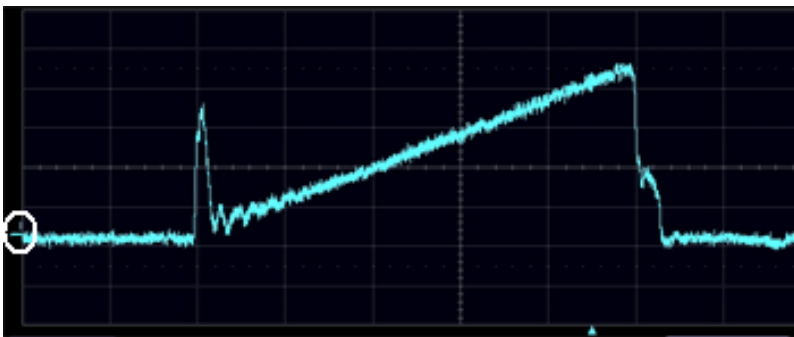
1. **Fine Adjust DC Level** for both voltage and current are provided to allow you to compensate for any residual DC offset that the voltage and current probes may exhibit. Because the magnitude of residual DC offset error is usually unknown, use of these adjustments requires that you know something about the waveforms.

2. Press the **FINE** button, then turn the adjust knob to set the DC Offset Level.
3. For a detailed explanation of how to adjust the DC Offset Level, see Fine DC Level Adjustment, next.

Fine DC Level Adjustment

Measurement errors caused by channel-to-channel time delay differences can be corrected using PMA2's deskew capability. Another major cause of errors is DC offset in the measurement equipment. Minor DC offset errors in the current or voltage channel can cause major errors in power calculations. Because it is not possible to design amplifiers and current probes with zero DC offset, PMA2 provides fine DC offset adjustments to correct for these offsets in both the current and voltage channels.

To use these adjustments, it is necessary to know where zero is on a current or voltage waveform. The following illustrates how to compensate for residual DC offset in a current probe when the zero current point on the waveform is known.



1. Press the **FINE** front panel button.
2. Turn the **ADJUST** knob so that the underscore under **I** (the zero level indicator) becomes level with the zero current level of the waveform.

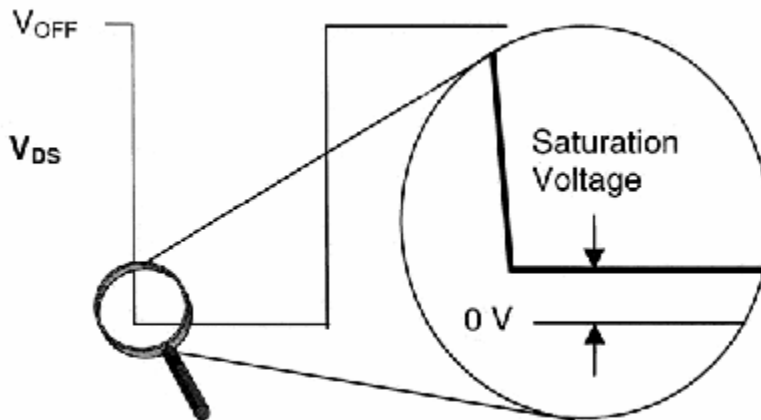
Adjustment of the Fine Adjust DC Level for voltage operates in the same fashion. Placing the voltage plus and minus differential probes on the same point in the circuit will provide a zero voltage reference point for the adjustment.

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Effects of Probe Compensation on Saturation Voltage Measurements

To measure a switching device's saturation voltage while the device is operating in circuit requires a combination of several capabilities in the measurement system. Differential voltage measurement is needed because the measurements are not ground referenced. Also, the amplifier must be able to quickly recover from overdrive. And the amplifier, as well as the probes, must have negligible high-frequency aberrations.

Example:



To measure the saturation voltage of a device to 100 mV accuracy when the off voltage is 400 V requires 250 ppm measurement capability.

The DSO input, or an input preamplifier such as the DA1855A, needs to recover and settle to a value greater than 250 ppm before the measurement can be made. The DA1855A is designed with this capability.

From this example, it is clear that high-frequency performance from the probe is required for this measurement.

Less obvious is how the probe's LF compensation adjustment can have a large effect on the accuracy of device saturation voltage measurement. Most DSO users are familiar with the requirement of adjusting passive probes for low-frequency compensation. Under normal usage, the entire waveform is on screen when a passive voltage probe's low-frequency compensation is adjusted, which is usually adequate for most measurements.

However, when a signal's amplitude is greatly magnified, as it is during a saturation voltage measurement, a small error in the LF compensation flatness can cause a major error in the saturation voltage measurement. The following figures illustrate how this seemingly minor adjustment can make the saturation voltage's DC level appear to be incorrect.

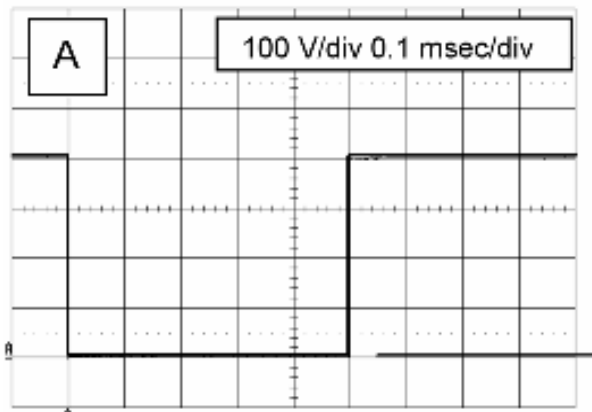


Figure A: The voltage probe appears to be properly compensated on a 400 V square wave when viewed at 100 V/div.

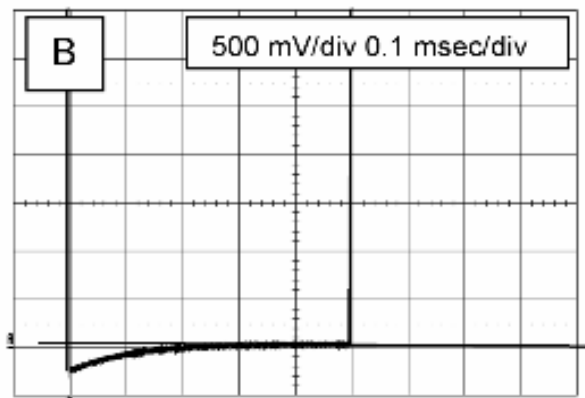


Figure B: When viewed at 500 mV/div, the same 400 V square wave shows the probe compensation to be slightly peaked.

PMA2 Option

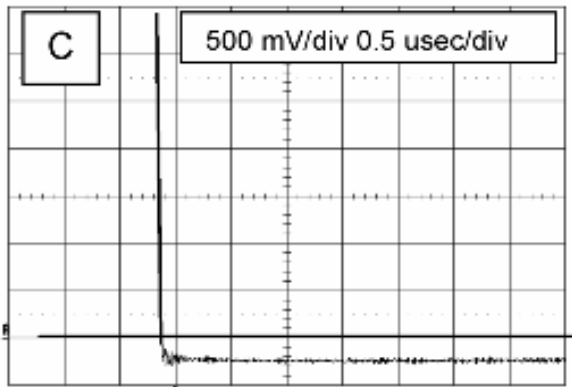


Figure C: When the horizontal time per division is decreased to a value normally used to view 20 to 150 kHz switchmode power conversion circuits, the slightly peaked LF compensation appears as a DC level shift.

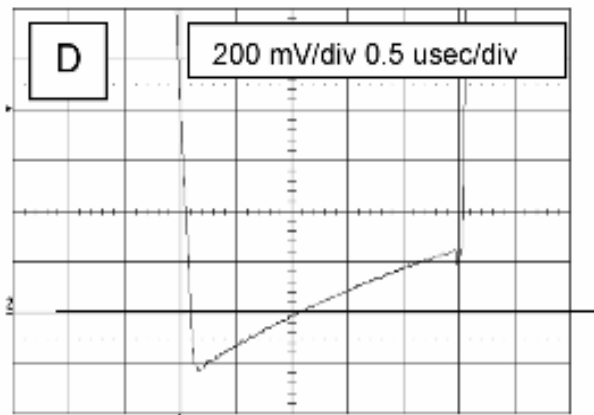


Figure D: Viewing a power FET's saturation voltage with the slightly peaked LF compensation makes the voltage appear to go negative. In this example, the repetition rate of the power supply is 60 kHz.

Clearing the Power Device Analysis Setup

To Exit PMA2

1. Touch the **Power Measure** tab.
2. Under "Analysis," touch the **Off** button.

Measuring Device dv/dt

The speed of a power device's dv/dt during turn-on and turn-off can be measured using PMA2's derivative math function.

Note: It is recommended that you lower the sampling rate to around 1 GS/s to speed up processing.

To Access dv/dt

1. Under "Functions," touch the **dv/dt** button. The derivative of your voltage waveform will be displayed with a cursor that you can click and drag.
2. Touch the **dv/dt** tab if you want to zoom in on the derivative.



- In the example above, a power device's Drain-to-Source Voltage (VDS) signal (V) is displayed in the first grid.
- In the second grid, the derivative of the waveform's dv/dt is displayed. The dv/dt waveform shown is a zoom of the dv/dt function.
- You can use cursors to find the signal's dv/dt at any point.

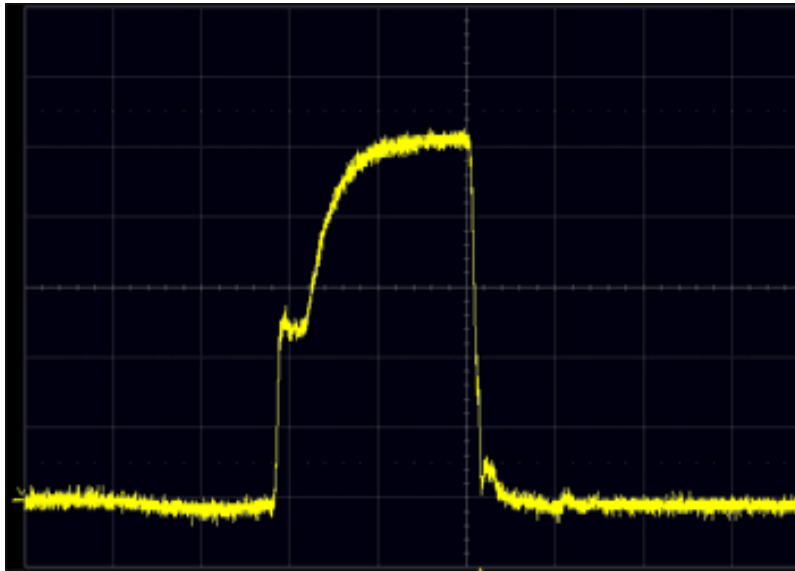
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USING MODULATION ANALYSIS

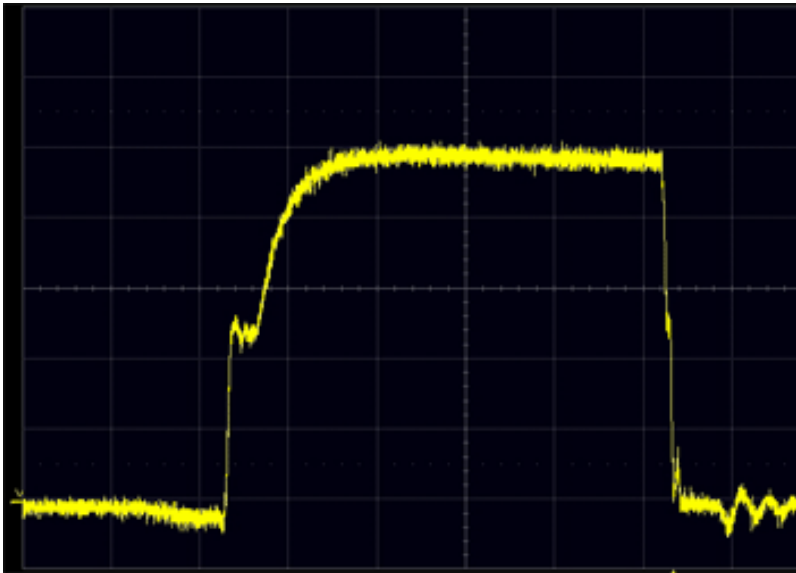
How Modulation Analysis Works

Switchmode power conversion circuits use some method of transferring energy from an unregulated source to regulated outputs on a cycle-by-cycle basis. Output regulation is achieved by modulating the amount of energy transferred in each cycle. The most common modulation method used is Pulse Width Modulation (PWM).

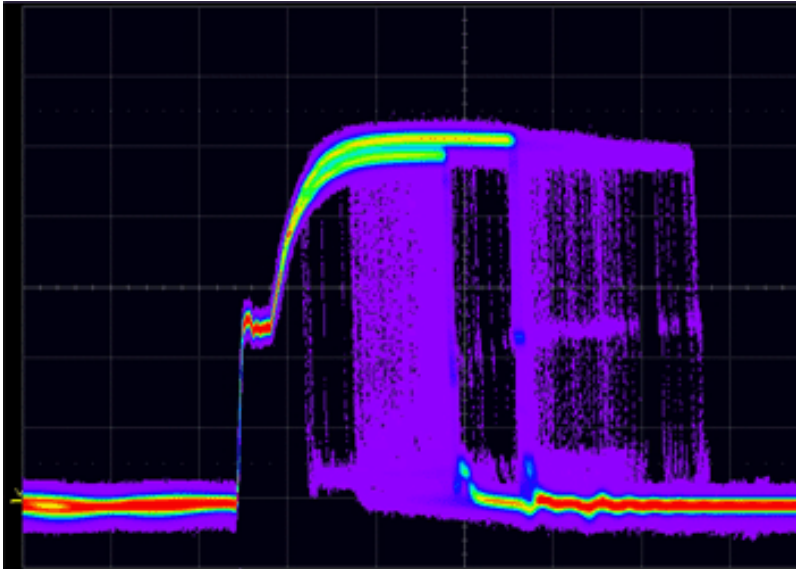
The Modulation Analysis section of PMA2 provides you with tools to view the information contained in the control circuit's modulated signals. The most common method of controlling the energy-per-cycle transfer in power conversion circuits is through the use of PWM. Other methods (such as frequency modulation) are also used. But no matter which method is used, it is difficult to view and analyze the modulation.



(A) Gate drive pulse width at minimum load



(B) Gate drive pulse width at full load



(C) Analog Persistence display shows pulse widths at minimum and maximum load, as well as other pulse widths that occur during load transition

When operating in steady state, a power supply's pulse width will be narrow during periods of low load, and wider when the load is higher. This difference is easy to see on a DSO in the Analog Persistence display mode. What happens to the pulse width during a change in load or some other EVENT is much harder to see. The use of Analog Persistence mode yields more

PMA2 Option

information about the supply's step response, but does not display the change in width as a function of elapsed time.

Modulation Analysis provides you with a method of seeing the information contained in the modulated signal. It does this by taking the time (width) information in the modulated signal that is normally displayed on the horizontal axis, along with elapsed time, and displays it on the vertical axis.



Example of how Modulation Analysis measures the width of individual pulses and displays their value on the vertical axis.

As the number of pulses per division increases, the display of their individual widths forms a “waveform” that represents the change in pulse width as a function of elapsed time. This “waveform” can be used to gain valuable information about the power supply's response to various events, such as load change (step response) or its soft-start performance.

The Modulation Analysis Display



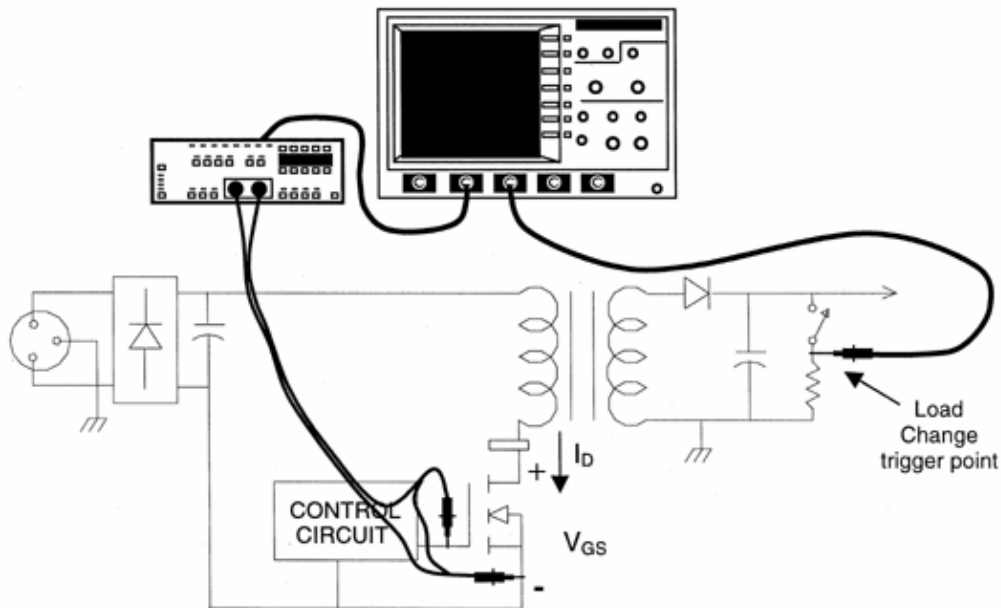
Modulation Analysis displays a PWM circuit's step response as the output load changes from maximum to minimum. In this example, over 1000 gate drive pulses are recorded in the first grid [V], and a record of their individual widths is displayed in the second grid [Mod].

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Configuration for Modulation Analysis

The Modulation Analysis portion of PMA2 lets you capture and analyze information contained in the power conversion circuit's modulation. The exact setup for this measurement may be different depending on the specific circuit topology and where in the circuit under test the modulation signal is to be acquired.

The following diagram shows a typical setup used to acquire the modulated signal at the power FET's gate in an off-line switching power supply. The LeCroy DA1855A Differential Amplifier is used to acquire the device's gate drive signal.



Typical connections to a circuit under test needed to acquire the power device's gate drive signal from which the circuit's Pulse Width Modulation can be obtained.

The circuit shown is an off-line flyback power supply. Examples in this section are based on connections to a circuit of this type. Other signals in the circuit can be used to measure the modulation, but the gate drive signal is usually a good place to acquire a relatively noise-free signal.

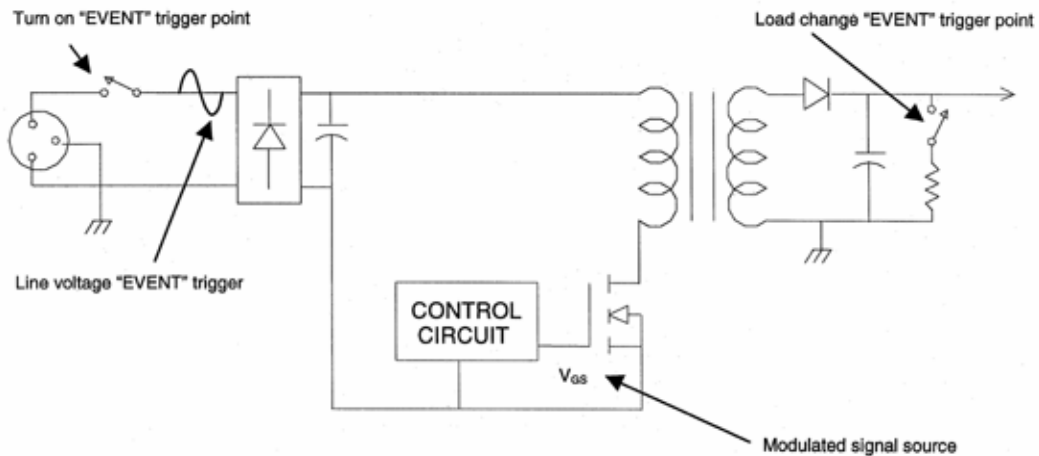
Setup for Modulation Analysis Measurements

Modulated Signal and Trigger Setup

Modulation analysis measurements usually are made to find the circuit's response to some event. Identify which signal in the circuit is to be used as a source of modulation information (modulated signal) and a signal "event" that can be used to trigger the acquisition of the record of the

modulated signal. Connect the differential probes to the appropriate points in the circuit under test to acquire the modulated signal. An event such as turn-on, turn-off, line trigger, or load change can be used to trigger the modulated signal record acquisition. In the figure above, the power transistor's gate drive signal is used as the source of modulation information, and a load change on the output is used as the "EVENT" Trigger.

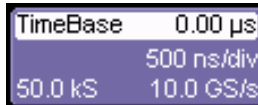
IMPORTANT! If possible, establish a stable display of the modulated signal and determine the source of the event trigger before entering the PowerMeasure software dialog.



Typical connections to the circuit under test for acquiring a source of the feedback modulation and various EVENT trigger sources.

Trigger Setup – The Event Trigger

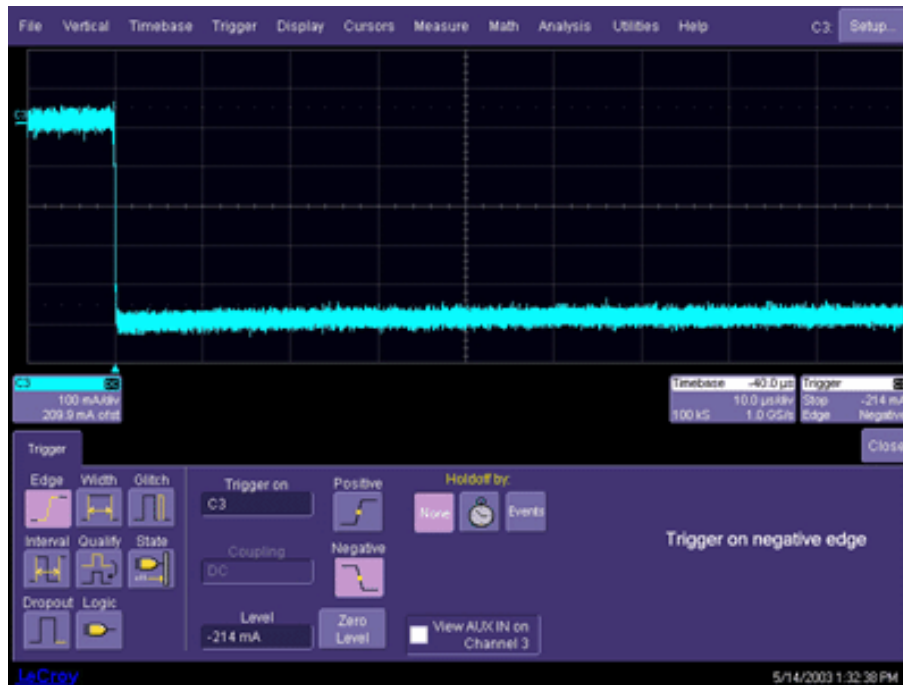
1. Determine the event around which the acquisition of an extended signal modulation record will be required. Triggering the acquisition of the modulated signal on these events can test the circuit's response to events such as line voltage change, turn-on, turn-off, and load change. Typical trigger points are illustrated in the figure above. In the example used here, the acquisition is triggered as the power supply's 5 V supply load changes from maximum to minimum. Presetting the trigger of such an event will make the final modulation measurement setup easier.



2. Touch the **Timebase** descriptor label and set the time/division, trigger delay, and trigger level for the event trigger channel to obtain a display similar to that shown above. If the modulated signal is to be acquired as the result of a one-time event such as turn-on, test the event trigger for satisfactory operation in SINGLE trigger

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mode.



3. In this example, Channel 3 is used to acquire the load change signal, and the DSO is set up to trigger from this channel. Other channels or the DSO's EXT trigger input also could be used for this purpose.

Initial Setup – The Modulated Signal

1. Set up a stable display of the signal that will be used as the source of the modulation information. Ensure that a clean signal can be acquired that will allow the signal's width (or other characteristic) to be readily measured. The following example uses the power transistor's gate-to-source voltage as a modulation signal source.
2. Set the time/division, trigger delay, trigger level, and voltage channel coupling to obtain a display similar to that shown above.

Finishing the Setup and Making Modulation Measurements

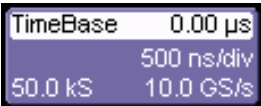
1. After the measurement is planned, the modulated signal channel is identified, the probes are connected to the proper point in the circuit under test, and preliminary triggering is established, use the PMA2 software to finish the setup and measure the signal's modulation.
2. Change the trigger source to the event trigger previously set up (Channel 3 in the example). If the event is repetitive, the DSO's **Normal** trigger can be used. For events

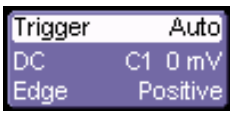
that occur only once, such as start-up, **Single** trigger should be used.

Activating the Modulation Analysis Menu

1. Touch **Analysis** in the menu bar, then **PowerMeasure** in the drop-down menu.
2. In the **PowerMeasure** dialog, touch the **Modulation** button.
3. Touch the **Voltage** tab to select the previously set up modulated signal voltage channel.
4. Touch the **Modulation** tab, then the **Width** button.
5. Touch the **Trace On** checkbox.


Modulation Analysis Controls

1. Touch the **Timebase** descriptor label , and change the horizontal **Time/Division** to a value that will allow the capture of a modulated signal record sufficiently long to cover the time of interest.

2. Touch the Trigger descriptor label , and select **Positive** slope



to measure the width between a positive-going edge and the next falling edge.

3. Touch either the voltage or current descriptor label  to get back to the "PowerMeasure" dialog, then touch the **Modulation** tab.
4. Touch inside the **Level Is** field and select either **Absolute** or **Percent**. Then touch the **Find Level** button to find the 50% level of the modulated signal's width.
5. Turn the front panel Adjust knob to set the voltage level on the modulated signal at which the width is to be measured. Set this to a level on the modulated signal where both the rising and falling edges are free of noise. When measuring the modulation of the gate drive signal, it is best to avoid placing the level around the pedestal.

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6. Press the **Find Scale** button to find the range of the modulated signal's width.

Optimizing the Display



Using the Zoom mini-dialog to the right of the screen, optimize the display.

The modulated signal (**V**) is displayed in the first grid (the gate drive voltage waveform in this example). The waveform that results from measuring the width of each pulse (**Mod**) is displayed in the second grid, and zoom traces (**F1**) and (**F2**) of the modulated signal (**V**) are displayed in the third and fourth grids. These grids are used to expand waveform **V** so that individual cycles of a multiple-cycle record can be viewed.

Clearing the Modulation Analysis Setup

1. Touch the **PowerMeasure** tab.
2. Touch the **Off** button.

USING LINE POWER ANALYSIS

Line Power Analysis Overview

The Line Power Analysis section of PMA2 provides you with tools to measure 50 and 60 Hz line voltage (V_{rms}), line current (I_{rms}), Apparent Power (VA), Real Power (Watts), and Power Factor ($\cos \theta$). It also enables you to evaluate harmonic currents injected into the power line. Harmonic measurements are made in accordance with the requirements of standard EN 61000-3-2, *Harmonic Current Emissions*.

EN 61000-3-2, Harmonic Current Emissions

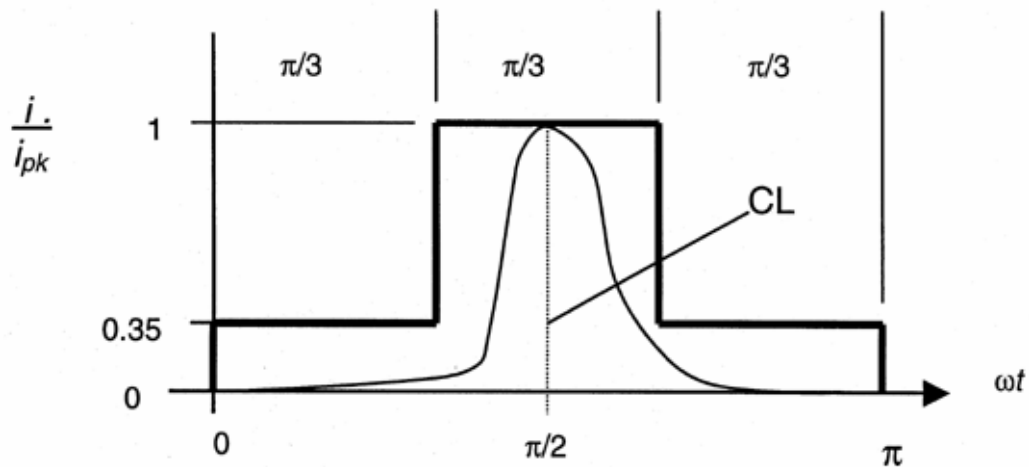
LeCroy encourages you to refer to the latest version of EN 61000-3-2 for full definitions and limits set forth by the standard. The following information is abstracted for your convenience.

Classification of Equipment

For purposes of harmonic current limitation, EN 61000-3-2 classifies equipment as follows:

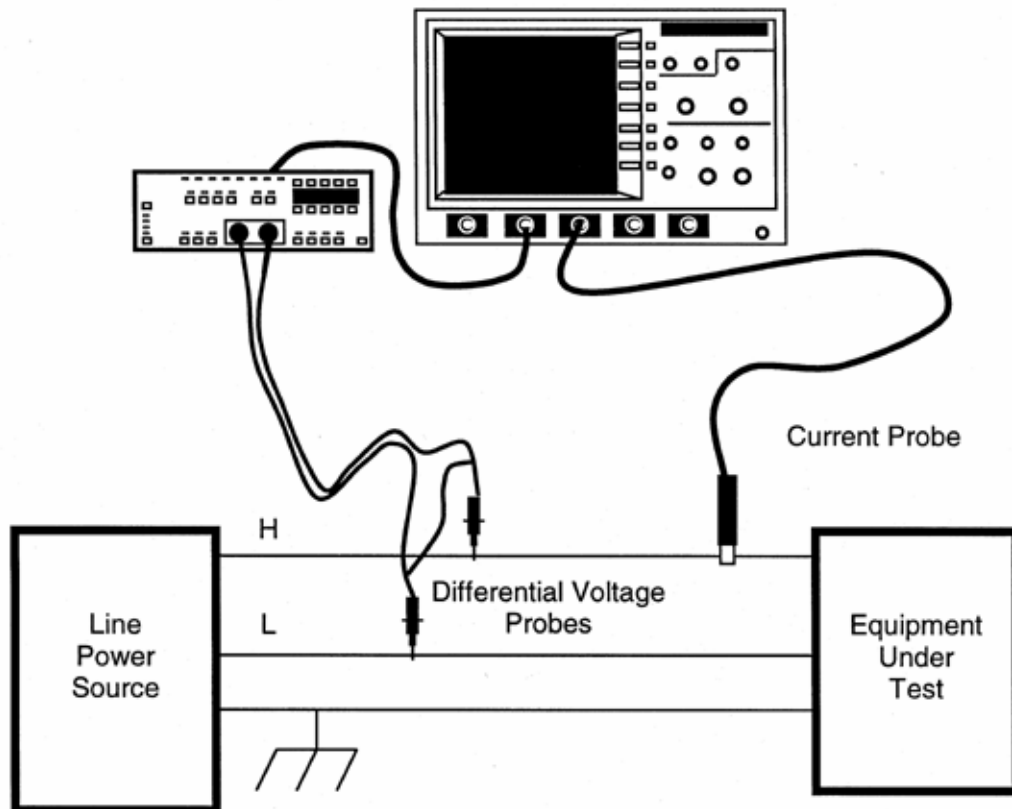
Class A	Balanced three-phase equipment and all other equipment, except that stated in one of the following classes
Class B	Portable tools
Class C	Lighting equipment, including dimming devices
Class D	Equipment not in Classes B, C, or motor driven and having an input current with a “special wave shape” as defined in the following figure: Equipment is deemed to be Class D if the input current wave shape of each half-period is within the figure’s envelope for at least 95% of the time. The input current’s peak value defines the envelope’s centerline, CL.

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Configuration for Line Power Analysis

SETUP: To make line power analysis measurements, the equipment should be set up as shown here. In the examples below, Channel 2 is used for voltage and Channel 3 is used for current. But any channel can be used for voltage or current. In the case of 3-phase systems, multiple voltage and/or current channels can be set up before analysis is started.



EQUIPMENT UNDER TEST: The equipment being tested for power consumption and line harmonics.

LINE POWER SOURCE: The power source should be low distortion. EN 61000-3-2 specifies maximum crest factor and harmonic distortion for the power source while it is connected to the equipment under test. The test can be run with the available power line, but the distortion in the source will directly affect the quality of the measurements.

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Setting Up the Line Voltage and Current Signals

The screenshot shows the main display of a LeCroy oscilloscope with a yellow sine wave. Below the display, the 'Trigger' menu is open, showing settings for 'C1'.

Channel C1: 50.0 V/div, 11.3 V offset

Timebase: -40.2 ms, 10.0 ms/div, 10.0 kS

Trigger: Auto, 2.5 V, Edge, Positive

Trigger Menu Settings:

- Edge: (Selected)
- Width:
- Glitch:
- Interval:
- Quality:
- State:
- Dropout:
- Logic:
- Trigger on: C1
- Coupling: DC
- Level: 2.5 V
- Holdoff by: None
- Zero Level:
- View AUX IN on Channel 3:

LeCroy logo and timestamp: 5/14/2003 1:50:57 PM

The screenshot shows the 'C1 Vertical Adjust' menu for channel C1 on a DA1855A oscilloscope.

Differential Amplifier: Automatic Gain

Bandwidth Limit: Upper, Full

Gain: x1

Attenuator: +10

Effective Gain: +1000

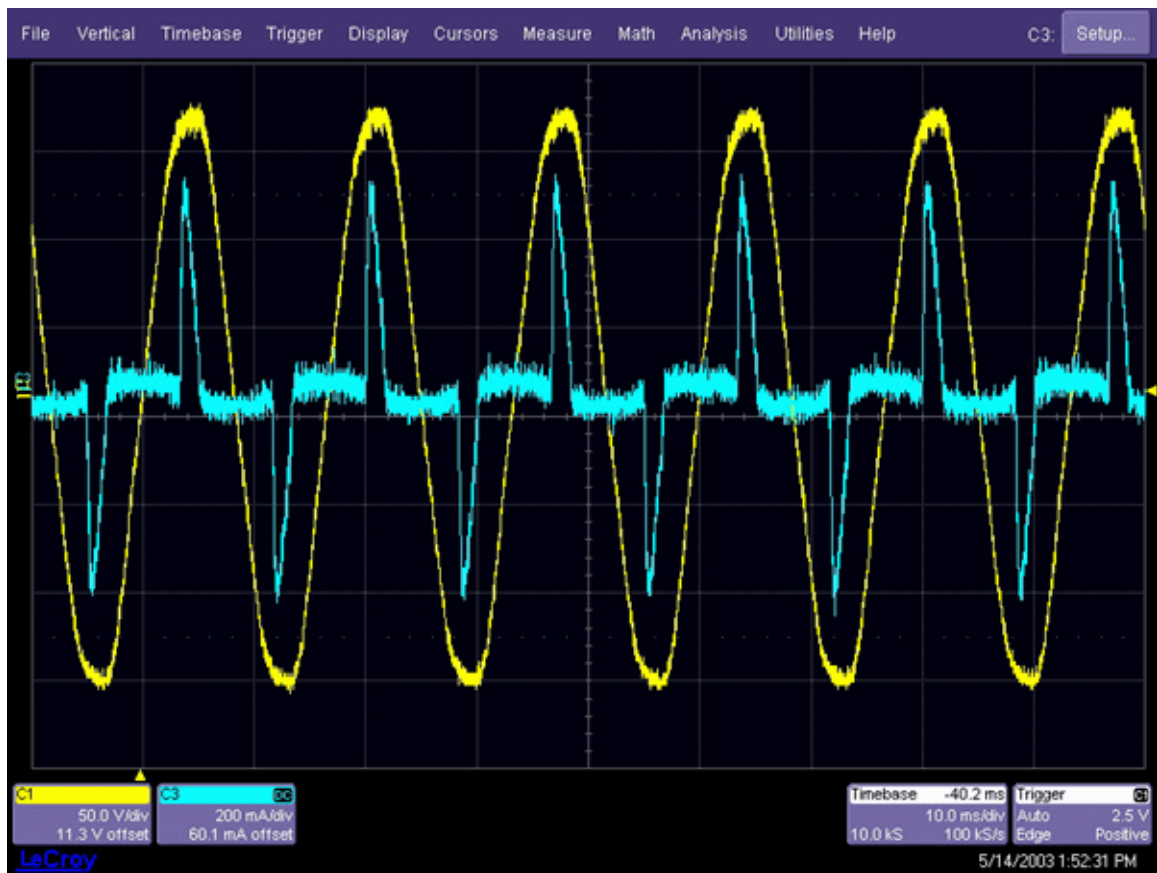
AutoZero:

Positive Coupling: AC, Off, DC

Negative Coupling: AC, Off, DC

Input Resistance: 1M Ω , 100M Ω , 100M Ω (Selected)

Precision Voltage Generator: PVG Mode: Differential, Precision Voltage: -11.2 V, Zero Offset:



1. Set up a stable display of the line voltage and current signals similar to those shown.
2. Set the time/division, trigger delay, trigger level, and voltage channel coupling to obtain a display similar to that shown above.
3. Polarity of the current waveform must match that of the voltage waveform. Make sure that your current probe is connected so that this is the case.

Activating the Line Power Analysis Menu

1. Touch **Analysis** in the menu bar, then "PowerMeasure" in the drop-down menu.
2. In the "PowerMeasure" dialog, touch the **Line Power** button under "Analysis," then touch the **Power** button just to the right of that.
3. Touch the **Voltage** tab and select the previously set up modulated signal voltage channel. Then touch the **Trace On** checkbox.
4. Touch the **Current** tab and select the previously set up line current signal channel. Then

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touch the **Trace On** checkbox. The channel selected as the Current channel will be assigned Ampere units even if a voltage or non-ProBus probe is used. Remove and degauss the current probe. The polarity of the current probe should match the voltage waveform.

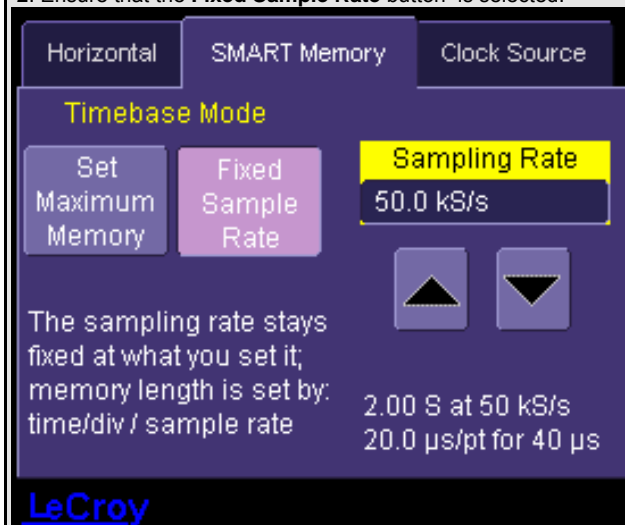
After the Voltage and Current selections have been made, the display screen shows the line voltage and current waveform, as well as the power and energy waveforms. Parameters displayed are apparent power (apwr) and power factor (pf).

Line Harmonics Measurement

Note: To speed up processing, it is recommended that you set the sampling rate to 50 kS/s. This is because the highest frequency we need to measure is 40 times the fundamental line frequency (50, 60 Hz). The maximum frequency to be captured, therefore, is 2.4 kHz. A sampling rate of 50 kS/s is sufficient for that frequency.

To set the sampling rate,

1. Touch the **Timebase** descriptor label, then touch the **SMART Memory** tab.
2. Ensure that the **Fixed Sample Rate** button is selected:



3. Touch inside the **Sampling Rate** field and set a value of 50 kS/s.



1. In the PowerMeasure dialog, touch the **Harmonics** button, then the **Harmonics** tab. Menu selections are provided to select the class of the equipment under test (EN 61000 A, B, C, or D classification) and the line frequency at which it is operating (50, 60 Hz).
2. Touch inside the **Class** field and select an EN 61000 classification: A, B, C, or D from the pop-up menu.
3. Touch inside the **Frequency** field and select a power line frequency from the pop-up menu.
4. Touch inside the **Units** field and select Amps or dBuA (decibels referred to one microAmp).
5. Touch the **Line Harmonics Table** tab to the right of the main dialog to display results in tabular form.
6. Turn the front panel Cursor knob to move the cursor along the harmonics. (You should stop acquisition by pressing the front panel Stop trigger button before you use the cursor).

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A zoomed-in view of the 'Line Harmonics Table' window. The window has a title bar with 'Zoom', 'Line Harmonics Table', and 'Close' buttons. The table contains the following data:

No	Freq	Limit	Measured P/F
		[mA]	[mA]
3	180.0	2300.00	106.75 OK
5	300.0	1140.00	78.30 OK
7	420.0	770.00	12.95 OK
9	540.0	400.00	7.23 OK
11	660.0	330.00	6.97 OK
13	780.0	210.00	5.57 OK

The date and time '4/29/2003 9:21:34 AM' are displayed at the bottom of the window.

USING NON-PROBUS PROBES

PMA2 Dialog Overview

PMA2 dialogs give you maximum flexibility by providing the correct units and scaling for power measurements. When LeCroy probes equipped with the ProBus interface are used, correct units and scaling are automatic. When non-ProBus current or voltage probes are used, PMA2 software provides methods to enter the correct units and scaling for a variety of current and voltage probes.

Units

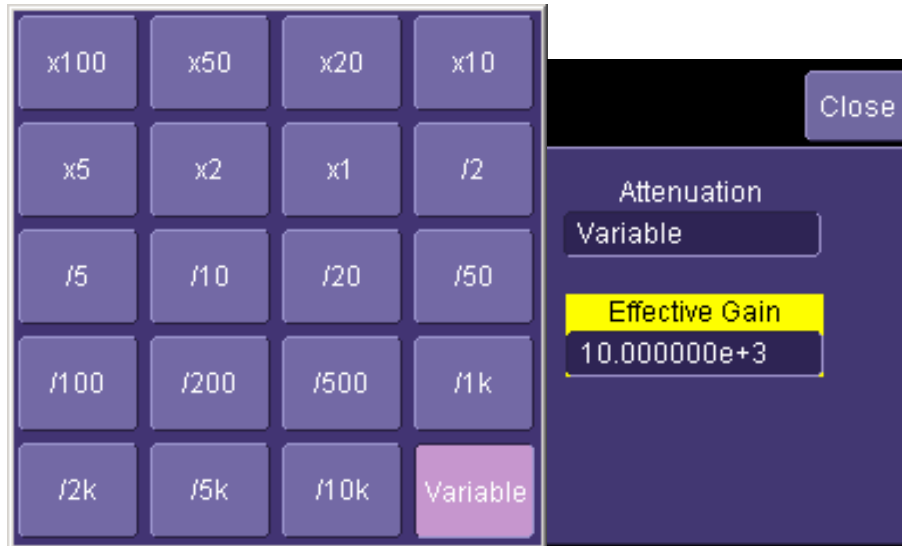
When a channel is selected as the current input in the PMA2 setup dialogs, its units are automatically changed to Amperes. After the assignment is made, data acquired through the channel is treated as current in any math function. Therefore, multiplying a current channel waveform by a voltage waveform results in watts, dividing a voltage waveform results in resistance, etc. This allows the proper units to be displayed even when a shunt resistor and a voltage probe are used to measure current.

Scaling

When a channel is selected as a current input or voltage input in the PMA2 setup dialogs, its scale can be set to take into account the non-ProBus probe's overall effective gain. This includes gain as well as attenuation factors. For non-normalizing current and voltage probes, the attenuation or gain can be set from /10,000 to X100 in a 1-2-5 sequence. There is also a Variable selection, which allows you to set an effective gain.

For current or voltage probes with normalizing amplifiers, special factors can be applied so that the amplifier's readout can be entered directly into the dialog.

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Effective gain of a voltage or current probe can be set from /1000 attenuation to X10,000 gain.

Current Input Setup Menus

Adjusting Current with No Amplifier Normalization Factor

When a non-ProBus current probe is used that has no normalization factor, proceed as follows:

1. Touch the **Current** tab.
2. Touch inside the **Current probe type** field and select **Probe** from the pop-up menu.
3. Touch inside the **Attenuation** field and select **Variable** from the pop-up menu.
4. Determine the probe's effective gain factor, then touch inside the **Effective Gain** field. Enter that value using the pop-up keypad.
5. If the current probe's DC offset cannot be adjusted to zero on the probe, use the **Fine Adjust DC Level** to correct the level.

Adjusting Current When the Current Probe Has an Amplifier with a 10 mV/div Normalization Factor

This setup is useful for the AM503 amplifier and its family of current probes.

1. Touch the **Current** tab.
2. Touch inside the **Current probe type** field and select **Amplifier 10mV/div** from the pop-up menu; the **Amps/div** field appears.
3. Touch inside the **Amps/div** field and enter a value, using the pop-up keypad.

4. If the current probe's DC offset cannot be adjusted to zero on the probe, use the **Fine Adjust DC Level** to correct the level.

Adjusting Current When the Current Probe Has an Amplifier with a 50 mV/div Normalization Factor

This setup is useful when the DA1855 Differential Amplifier is used to measure the voltage across a resistor shunt.

1. Touch the **Current** tab.
2. Touch inside the **Current probe type** field and select **Amplifier 50mV/div** from the pop-up menu; the **Amps/div** field appears.
3. Touch inside the **Amps/div** field and enter a value, using the pop-up keypad.
4. If the current probe's DC offset cannot be adjusted to zero on the probe, use the **Fine Adjust DC Level** to correct the level.

Adjusting Current When Using a Shunt Resistor

1. Touch the **Current** tab.
2. Touch inside the **Current probe type** field and select **Shunt resistor** from the pop-up menu; the **Shunt resistor** field appears.
3. Touch inside the **Shunt resistor** field and enter the value (in ohms) of the shunt, using the pop-up keypad.
4. Use the **Fine Adjust DC Level** to zero the level.

Voltage Input Setup Menus

This setup is useful when a non-ProBus voltage probe is used on the voltage input channel, and when a non-A model LeCroy DA1855 Differential Amplifier is used to measure the voltage. It also can be used for other voltage probes and amplifiers.

1. Touch the **Voltage** tab.
2. Touch inside the **Attenuation** field and select Variable from the pop-up menu.
3. Touch inside the **Effective Gain** field and enter a value, using the pop-up keypad.
4. If the probe's DC offset cannot be adjusted to zero on the probe, use the **Fine Adjust DC Level** to correct the level.

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