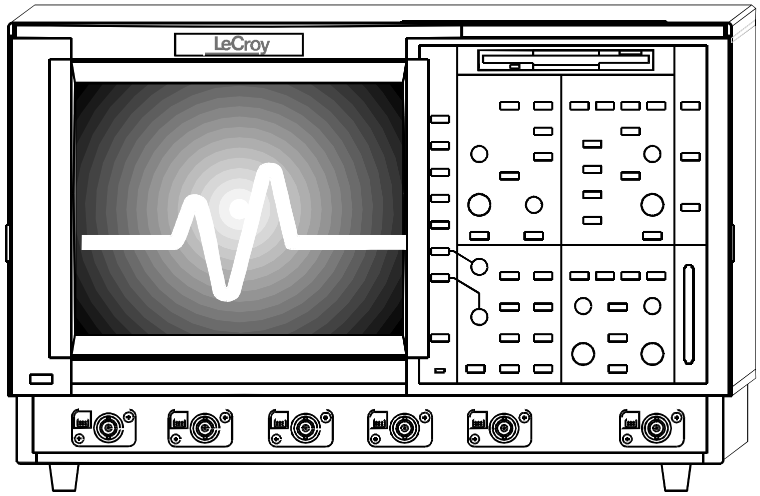

Operator's Manual

PMA1 Software
for LeCroy
Digital Oscilloscopes

Revision A — June 1999

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Chapter 1 - The PowerMeasure™ PMA1 Software

The Tools and the Work They Do

The PowerMeasure Analysis (PMA1) software package — when combined with a LeCroy digital storage oscilloscope (DSO), and current and differential measurement tools — provides a complete set of hardware and software tools for the design and analysis of power conversion circuits. PMA1 consists of three major measurement areas:

Power Device Analysis: This section 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 PowerMeasure Analysis, these device measurements can be made either on a test stand or while the devices are operating in a power conversion circuit.

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

Line Power Analysis: This section covers the measurement of line voltage and current applied to an offline power conversion device. Real power, apparent power, power factor, and line harmonics are measured. Analysis of line harmonic content is covered to assist the design and evaluation engineer in designing for pre-compliance to EN61000-3-2 requirements.

Equipment Required

DSO: PowerMeasure Analysis software operates on any LeCroy LC, 9300C, or LT (*Waverunner*) Series DSO. For analysis of phenomenon requiring the acquisition of many cycles, a DSO with a minimum of 1 mpoint per channel should be used. Steady state analysis can be accomplished with shorter record length. Two acquisition channels are adequate for most measurements, but a four-channel DSO is required if analysis of multiple devices or complex triggering is desired.

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 the Power Device Analysis section, the CMRR, CMR, Overdrive Recovery, and compensation flatness performance of the LeCroy DA1855A differential amplifier and its associated DXC series passive differential probes is required. The measurement requirement in the Modulation and Line Power Analysis sections can be made with medium-performance differential probes.

Current Probes: The Power Device Analysis section requires precision wide-bandwidth current probes with DC measurement capability. The LeCroy AP015 DC to 50 MHz current probe is recommended.

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.

Chapter 2 – Using Power Device Analysis

Matching the Time Delay in Your Measurements 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.

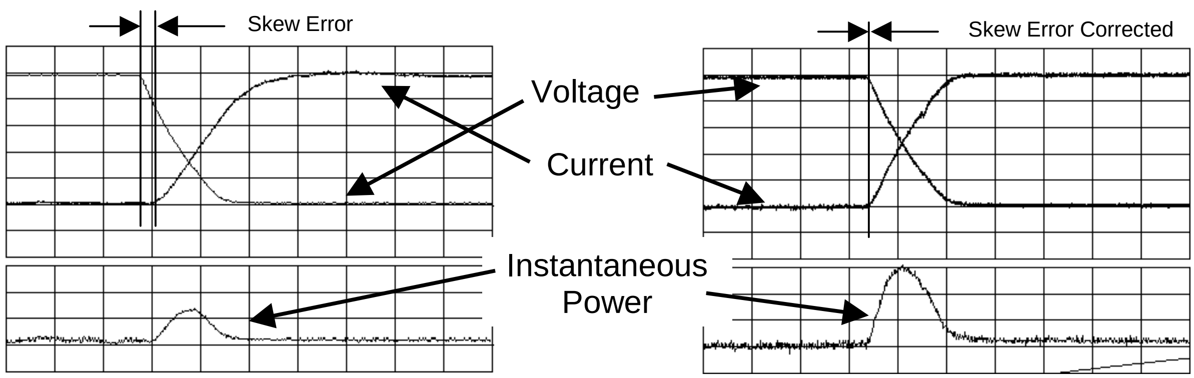


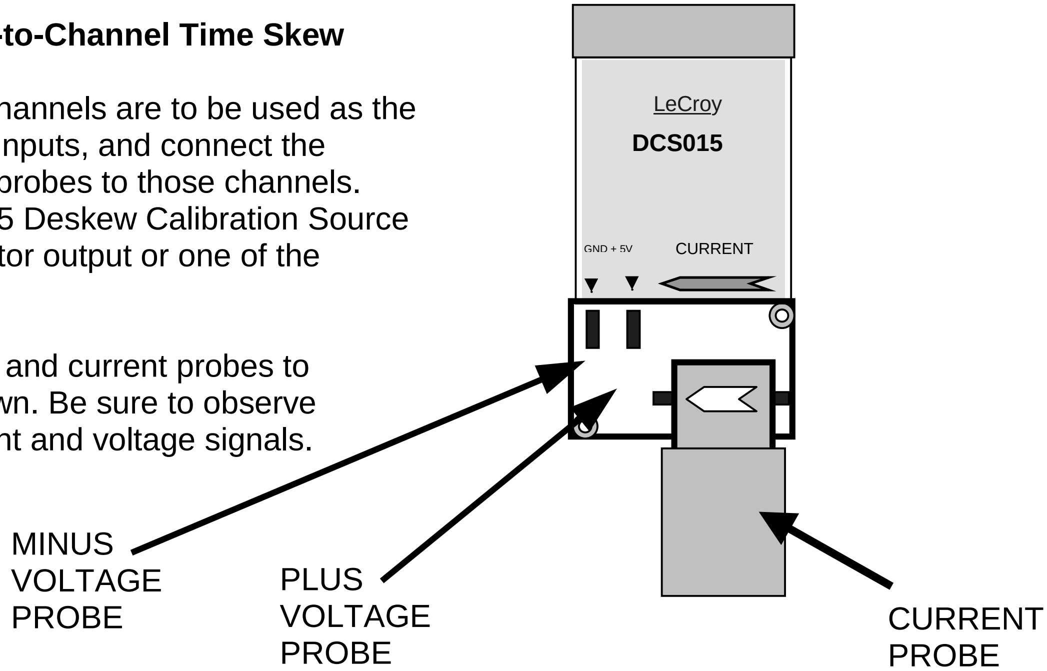
Figure 2.1: *Significant error occurs in an instantaneous power measurement when the current signal takes longer than the voltage signal to get to the DSO, because the current's signal path is longer. This error can be corrected by matching the delay of the voltage and current signal paths using the deskew function.*

It is advisable to use the deskew function 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.

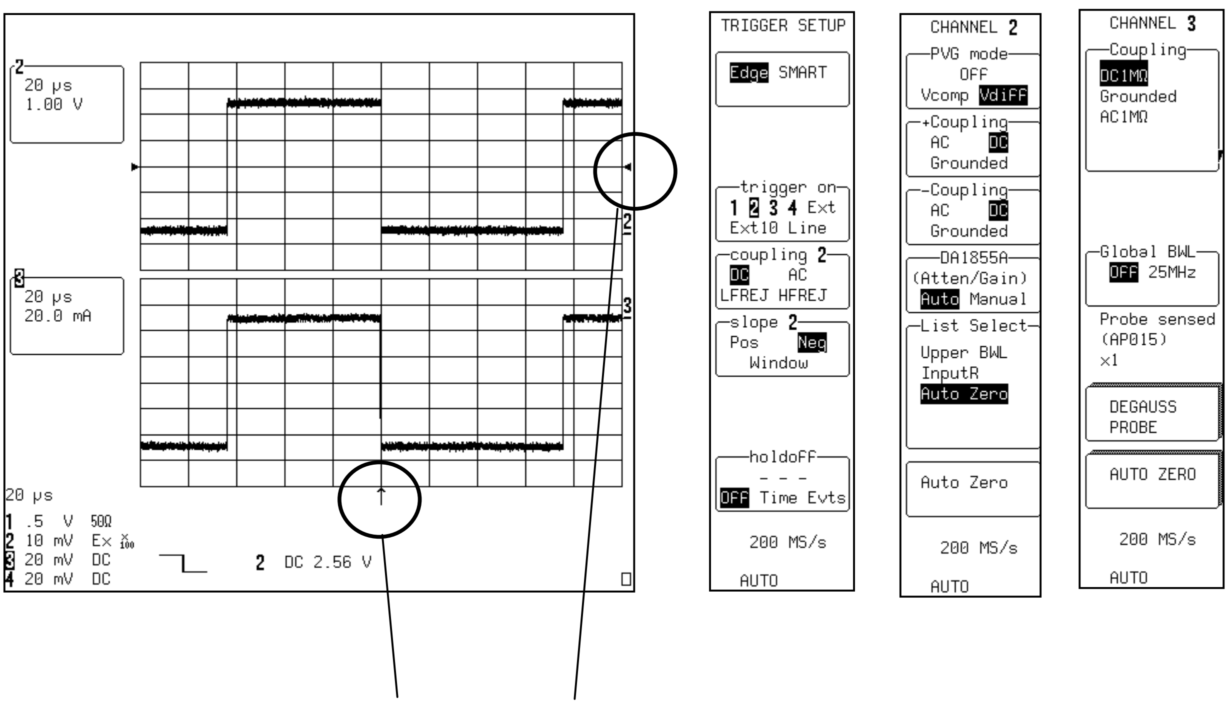
Checking Channel-to-Channel Time Skew

Select 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 one of the unused channels.

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



INITIAL SETUP



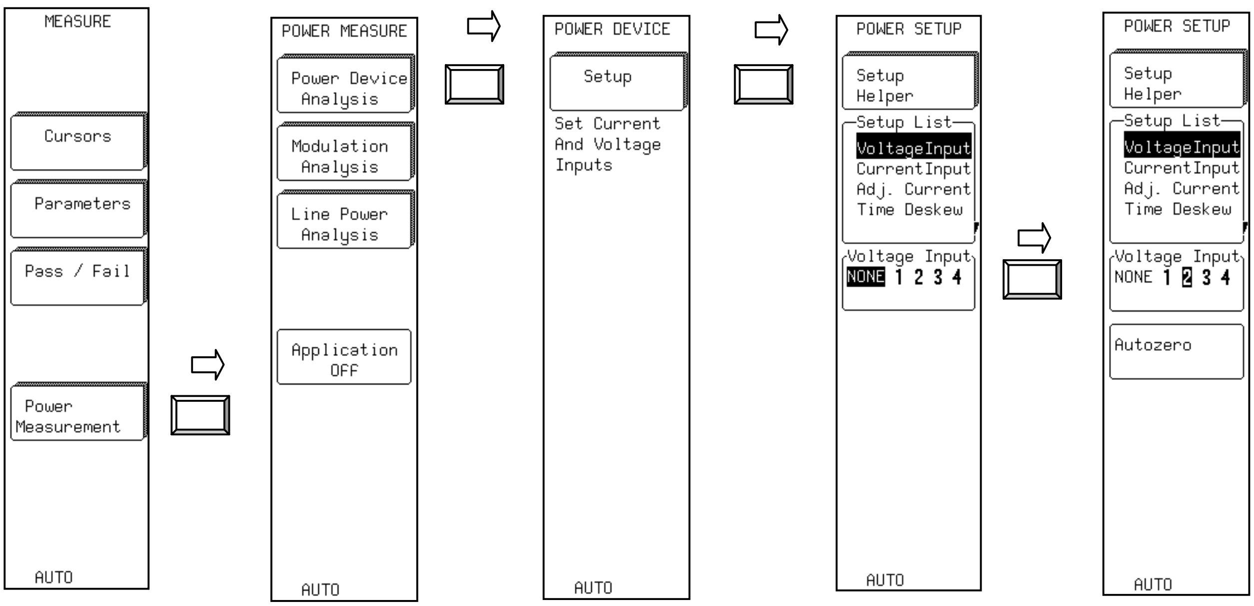
Set the time/div, trigger delay, trigger level, voltage, and current channel coupling to obtain the display as shown above. It is important to trigger on the negative slope of the voltage waveform. Position both traces around the center screen, and set the trigger level and delay as shown. **Note**: 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 (Voltage Channel)

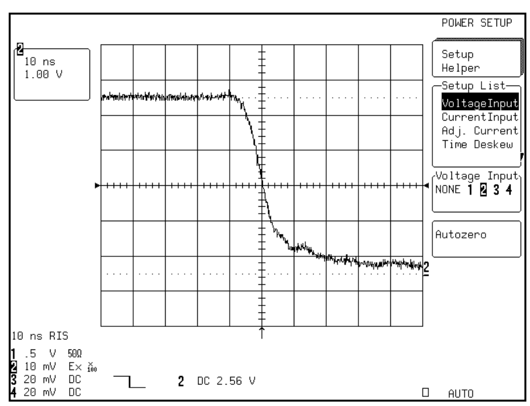
Once the DCS015's voltage and current waveforms are properly displayed, use the PMA1 software to match the time delay in the voltage and current channels.

Press the **MEASURE TOOLS** (LT Series) or **CURSORS/MEASURE** (LC Series) button on the DSO front panel to bring up the ***MEASURE*** menu, which includes the ***Power Measurement*** selection.

Follow the menu sequence given below:



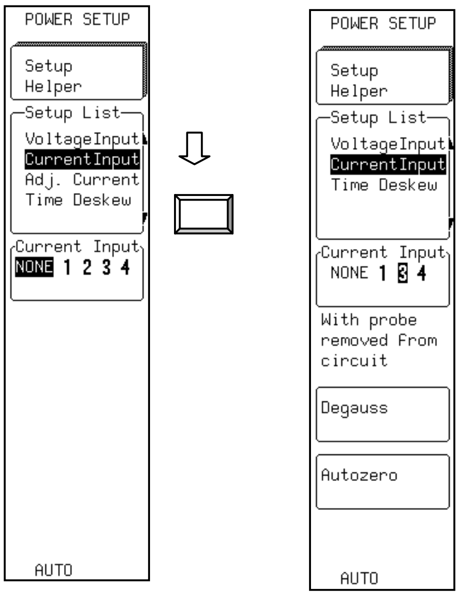
Change the horizontal time/division to 10 nsec/div.

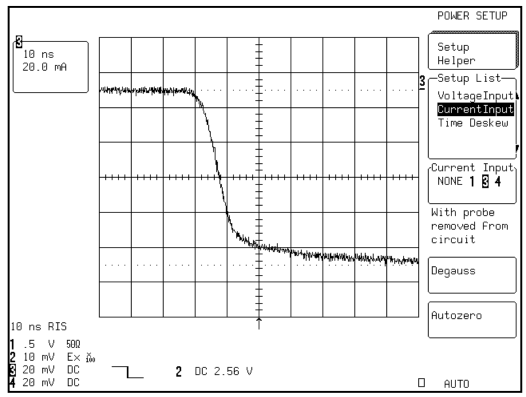


The display should appear similar to this.

Deskew Setup (Current Channel)

After the voltage channel is properly set up, follow the menu sequence given below to set up the current channel:



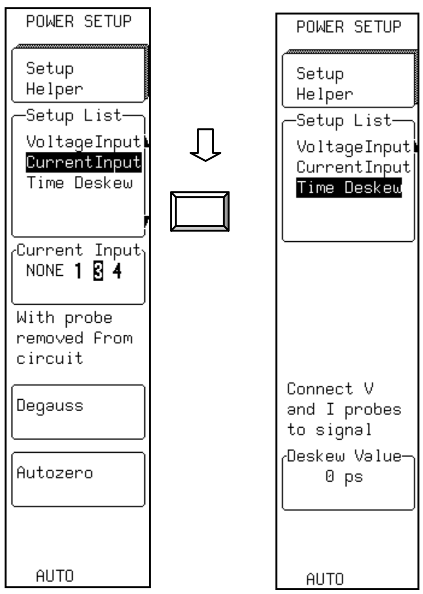


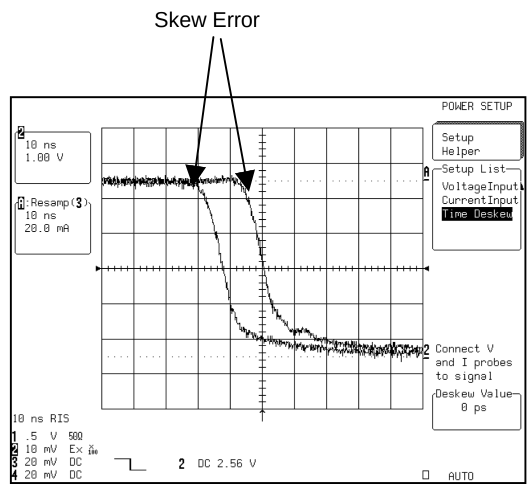
Display should appear similar to this.

The channel selected as the ***Current Input*** channel will be assigned Ampere units even if a voltage or nonProBus®-compatible current probe is used.

Channel-to-Channel Propagation Delay (Skew) Matching

After the voltage and current channels are properly set up, follow the menu sequence given below:



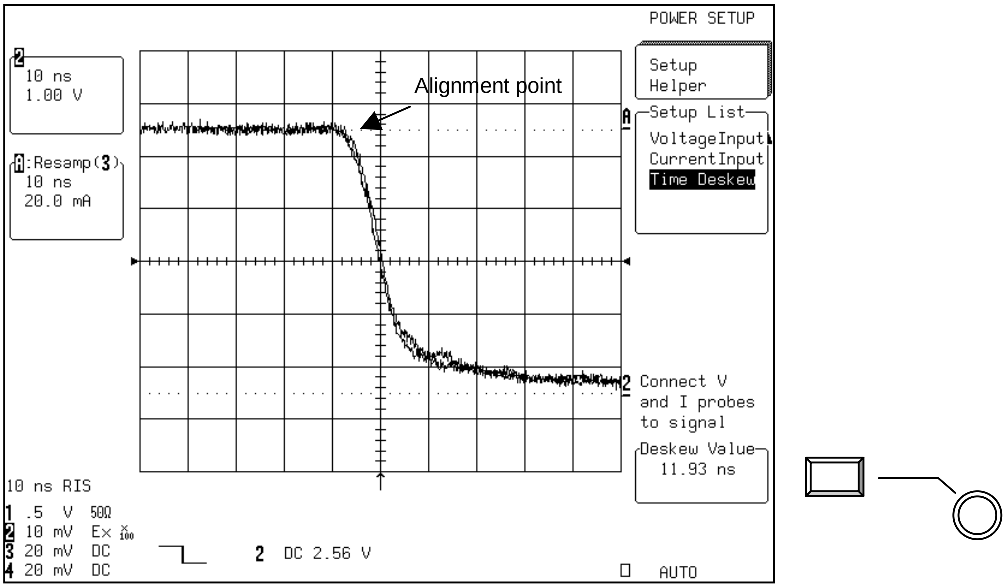


The display should appear similar to this.

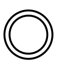
The signal time skew will be shown as delay difference between the voltage and current waveform. The original current waveform is replace by a “resampled” math waveform that can be delayed up to ± 2 msec. In this example the delay difference (time skew) is a little more than one 10 nsec per division. The amount of delay will depend on which voltage and current probes are used, as well as the length of the probes and the coaxial cable used to connect the DA1855A to the DSO.

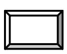
When the DA1855A Differential Amplifier (connected with a 1.2 m coaxial cable), DXC100A Differential Passive Probe Pair, and AP015 Current Probe are used, the time delay is matched and no deskew adjustment is needed.

Channel-to-Channel Propagation Delay (Skew) Matching - continued



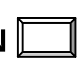
Adjust the deskew value until the current waveform coincides with the voltage waveform. If the current waveform's fall time is slower than that of the voltage, align the beginning of the wavefroms (alignment point).

Turn the  until the alignment points on the current and voltage waveforms coincide.

Pressing the  will return the ***Deskew Value*** to zero.

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 be checked and possibly corrected.

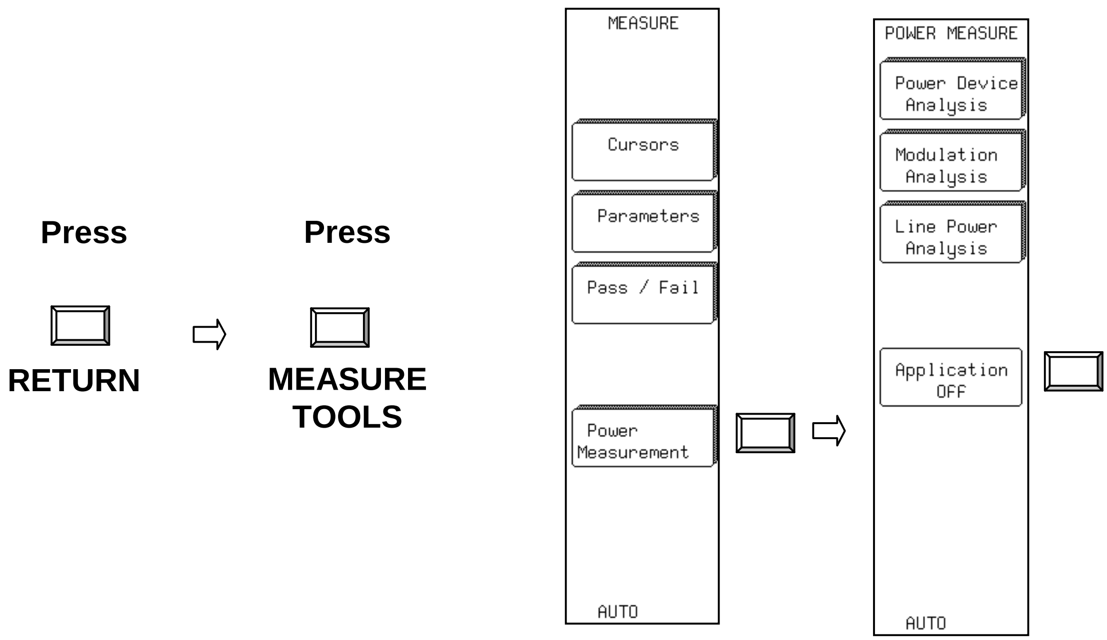
This process can be used to characterize and correct the delay difference between more than one current and one voltage channel. For instance, if the user plans to use one voltage channel and alternate measurements between two current channels, the relationship between the voltage channel and each of 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 pressing the **RETURN**  **(**See page 2-8.) If the Power Measurement Application is not going to be used immediately, it should be turned off by following the instructions on the next page.

Clearing the Deskew Setup

If no immediate use of the PMA1 software is planned, the channel assignments and other alterations made during the deskew process should be cleared.

Press the **RETURN** until the on-screen menu is cleared. Then press the **MEASURE/TOOLS** to bring up the ***MEASURE*** menu.



Selecting ***Application OFF*** in the Power Measure menu changes the ***Voltage Input*** and ***Current Input*** assignments to ***NONE***. The ***Deskew Value*** remains unchanged. The assignment of Ampere units to the channel selected as the ***Current Input*** channel will be removed.

Setup and Configuring for Power Device Analysis

The Power Device Analysis portion of PMA1 lets the user make difficult device 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 and set up in advance. If possible, obtain representative waveforms of the voltage, current, and trigger inputs before evoking PMA1 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.

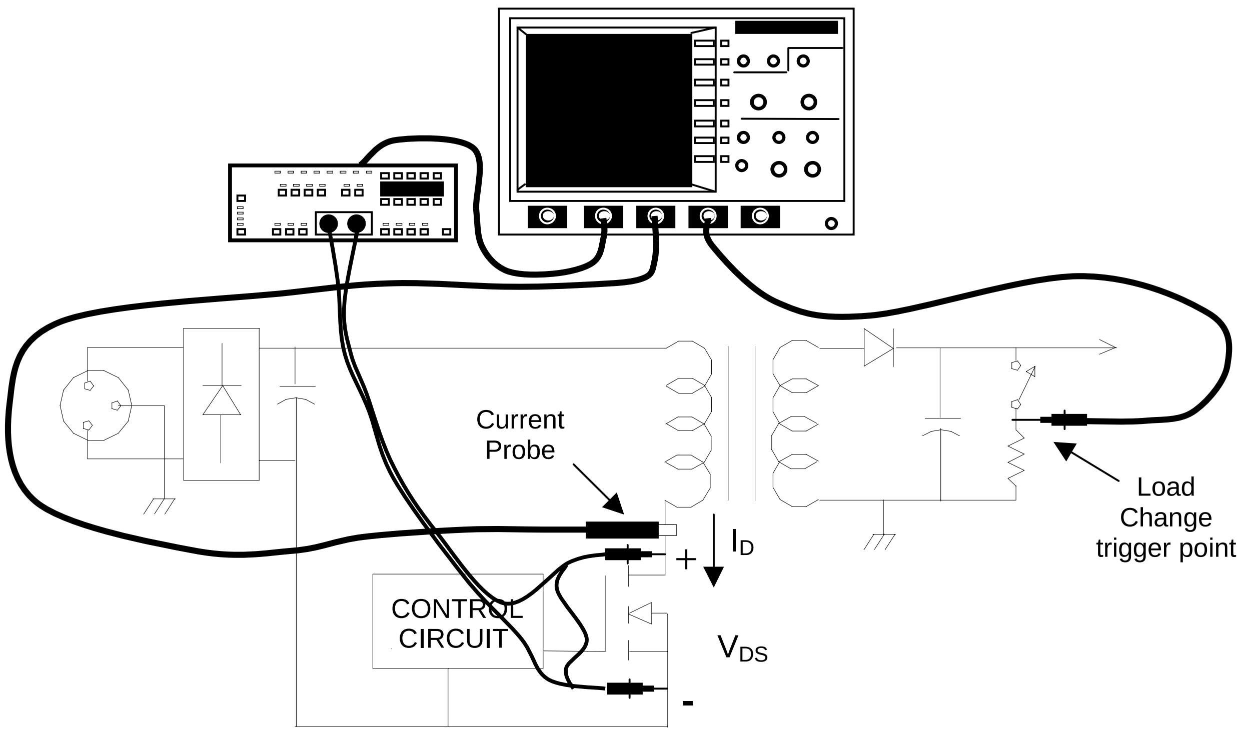


Figure 2.2: *Typical connections to a circuit under test required to make instantaneous power, safe operating area, saturation voltage, and dynamic on-resistance measurements.*

The circuit shown is an off-line flyback power supply. Examples in this section are based on similar 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.

Configure for Device Measurements

Plan the measurement in advance and do a preliminary setup before evoking the PMA1 Power Measurement menus. This will minimize the number of times it is necessary to leave the menu structure.

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*** section to correct any delay difference between the current and voltage.

Connect the voltage and current probes to the appropriate points in the circuit under test. Figure 2.2 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 Figure 2.2 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 entering the Power Measurement 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.

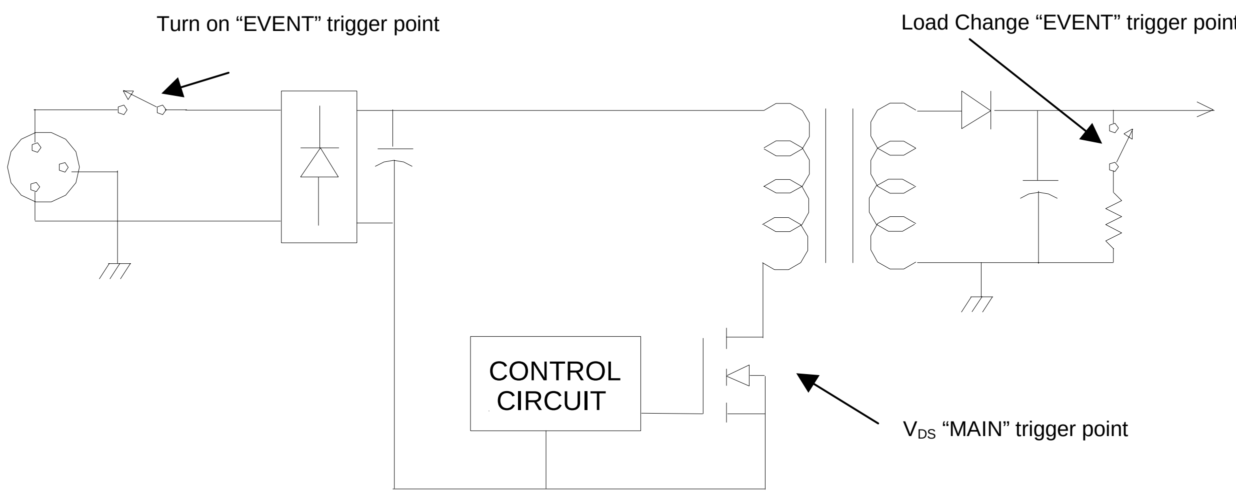
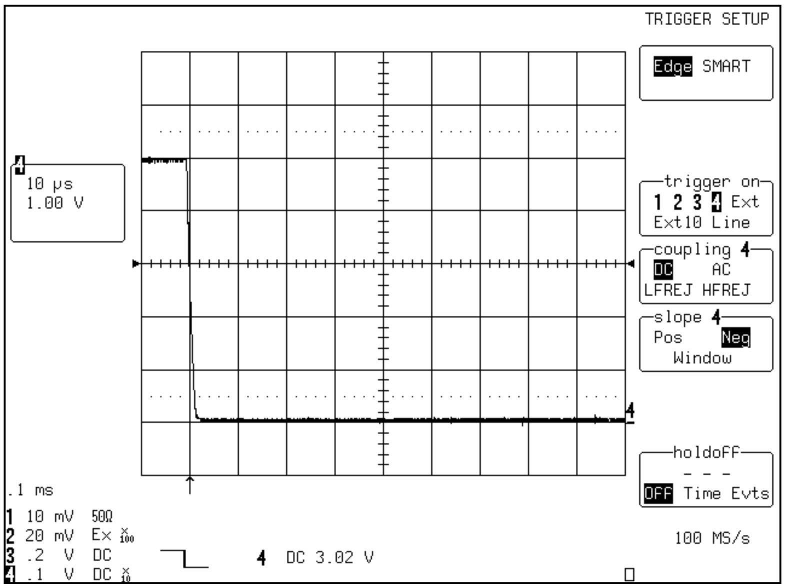


Figure 2.3: *Typical connections to circuit under test for MAIN and EVENT triggers.*

INITIAL SETUP (Optional Event Trigger)

Determine the event around which a change in the operation requires recording an extended record of information. 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.

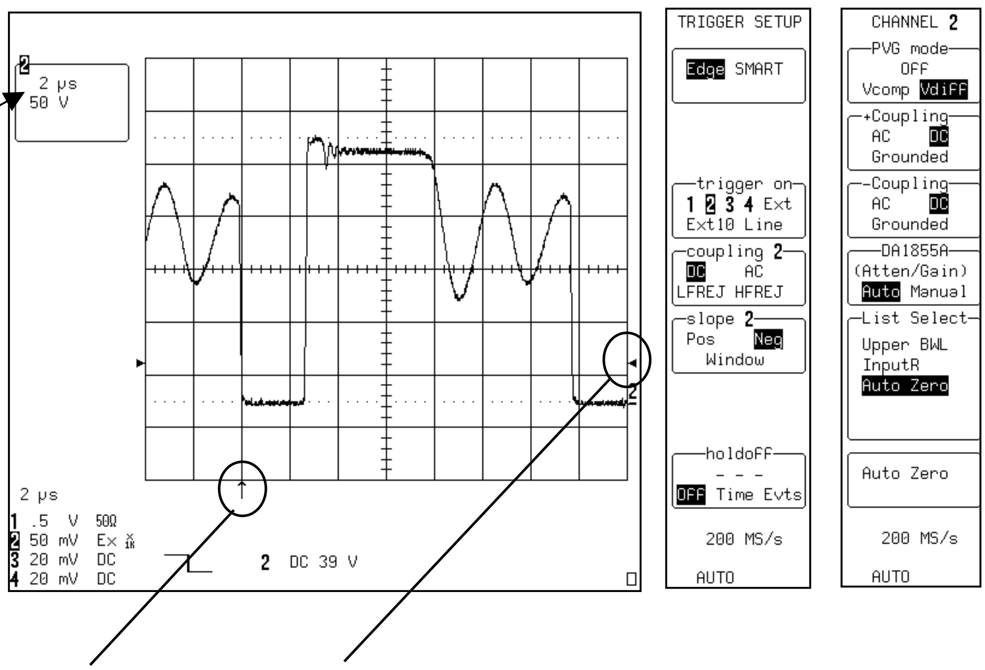


In this example, Channel 4 is used to acquire a signal that indicates the power supply’s load changes from maximum to minimum. Set up the trigger so the acquisition of a record can be initiated from this event. The Load Change “EVENT” trigger shown in Figure 2.3 was used in this example. The event you want 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.

V/div and time/div settings will depend on the particular circuit under test.



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.

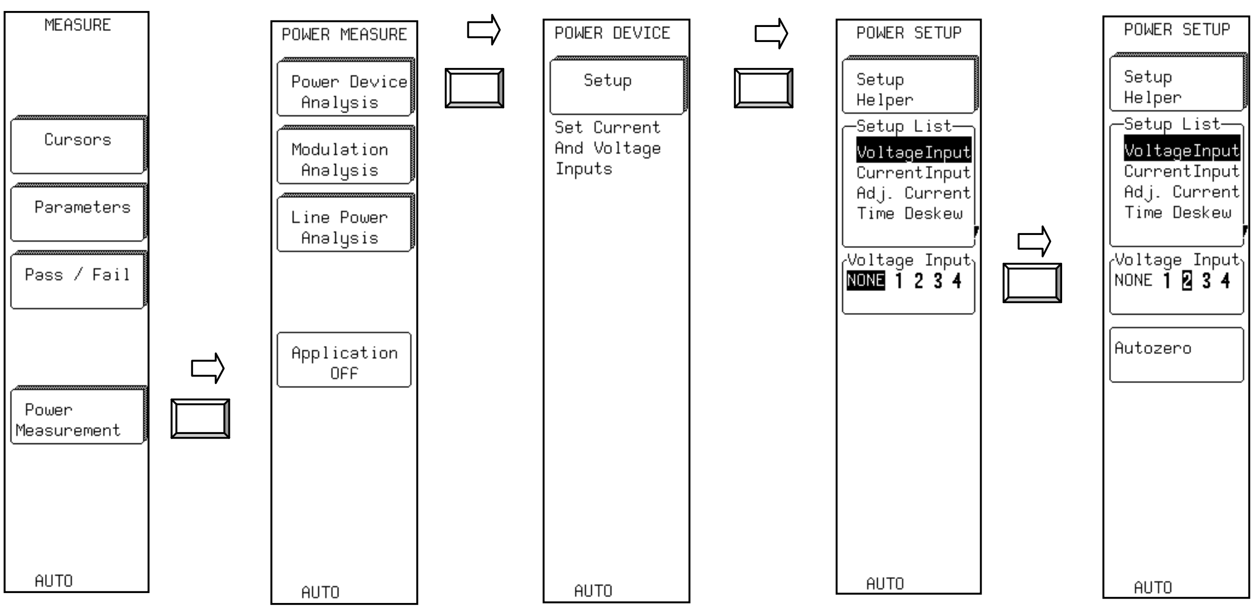
Setup for Power Device Analysis

After the measurement is planned, the voltage and current channels are identified and deskewed, and preliminary triggering is established, use the PMA1 software to finish the setup and make the measurements.

Power Device Analysis Setup

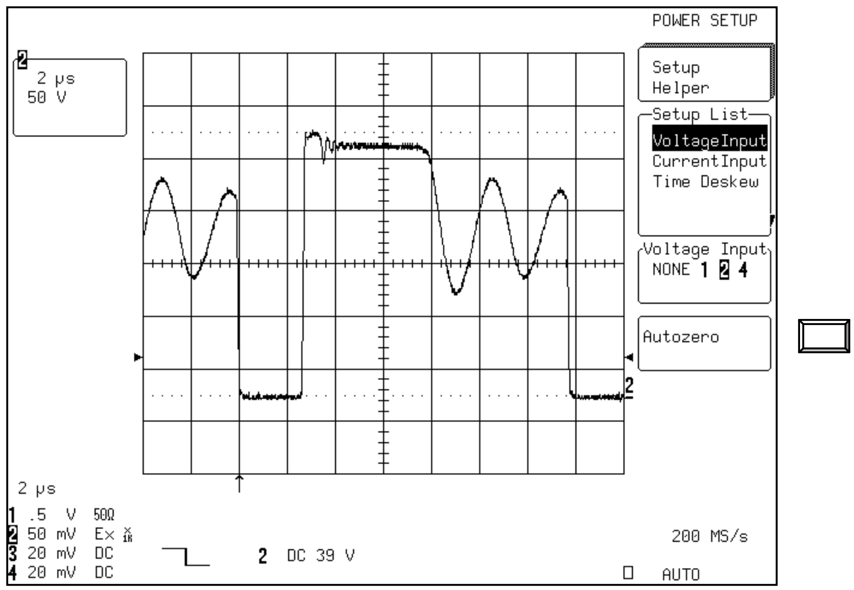
Press the **MEASURE TOOLS** (LT Series) or **CURSORS/MEASURE** (LC Series) button on the DSO front panel to bring up the ***MEASURE*** menu, which includes the ***Power Measurement*** selection.

Follow the menu sequence given below:



Power Device Analysis Setup - continued

In the ***Setup List*** menu, select the channel that is connected to the voltage measurement point. In the example, it is Channel 2. Adjust the volts/div and time/div to obtain a stable display of at least one cycle of the voltage signal across the device.



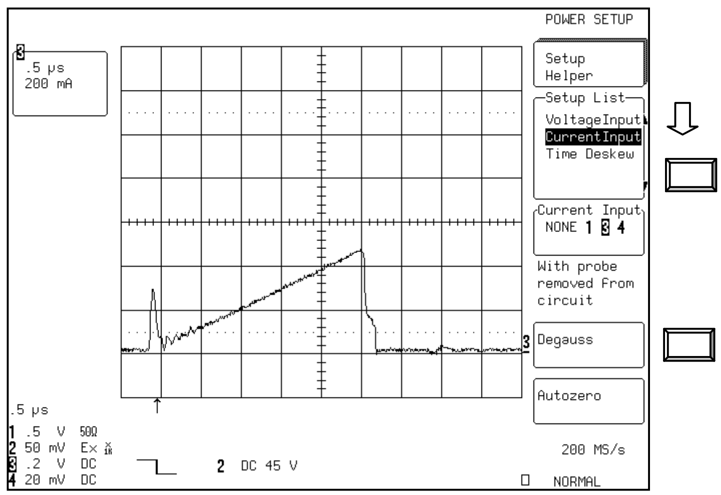
The display should appear similar to this.

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

It is good practice to balance the DC offset of the voltage probe at this step. Press the ***Autozero*** to autobalance the DA1855A amplifier.

Power Device Analysis Setup - continued

In the ***Setup List*** menu, select ***Current Input***. Select the channel that is connected to the current measurement point. In the example, it is Channel 3. Adjust the A/div and time/div to obtain a stable display of at least one cycle of the current signal through the device.



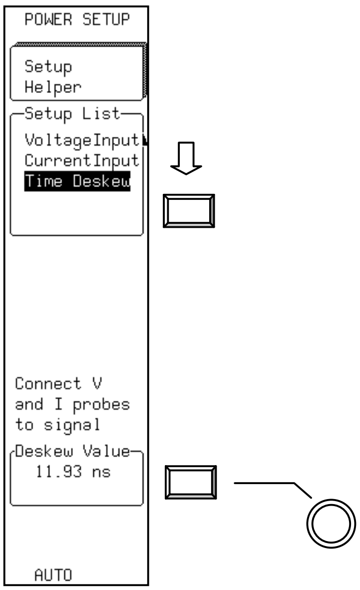
The display should appear similar to this.

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

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

It is good practice to degauss the current probe at this step. Remove the current probe from the circuit under test, close the probe and press the ***Degauss*** . Return 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 checked by selecting ***Time Deskew*** from the ***Setup List*** menu. If the deskew value was set using the process on page 2-5, that value will be displayed in the ***Deskew Value*** menu readout.

The deskew value can be changed in this menu by turning the . Pressing the will return the value to zero.

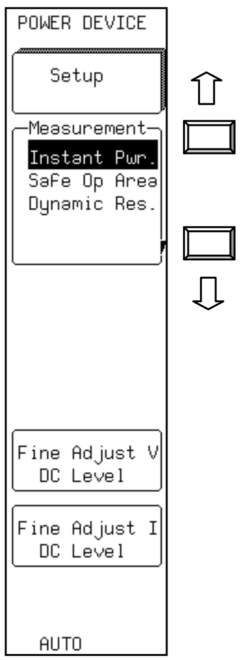
NOTE: The deskew value should not be changed in this menu unless the correct value is known. Voltage and current signals that occur in the circuit under test may not be properly phase-related, and using them for deskew purposes can cause major errors to occur in the measurements. Time-coincident voltage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

Power Device Analysis Measurements

Note: The previous sections should be completed before making 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.

Press the **RETURN** to bring up the following menu:



Select ***Instant Pwr*** to measure the instantaneous power loss in the power FET.

Select ***Safe Op Area*** to measure the power FET's Safe Operating Area.

Select ***Dynamic Res***. to measure the power FET's saturation voltage and its dynamic on-resistance.

The ***Fine Adjust V DC Level*** and ***Fine Adjust I DC Level*** knobs corrects small DC offset errors in the voltage and current probes without removing the voltage or current probe from the circuit. Pressing either returns the respective offset to zero.

NOTE: The ***Measurement*** menu selections ***Instantaneous Pwr***, ***Safe Op Area***, and ***Dynamic Res.*** will not be available unless both voltage and current channels were assigned in the ***Setup*** menu. Press the ***Setup*** in the Power Device menu to return to the ***Setup*** menu to assign the voltage and current channels or to change them.

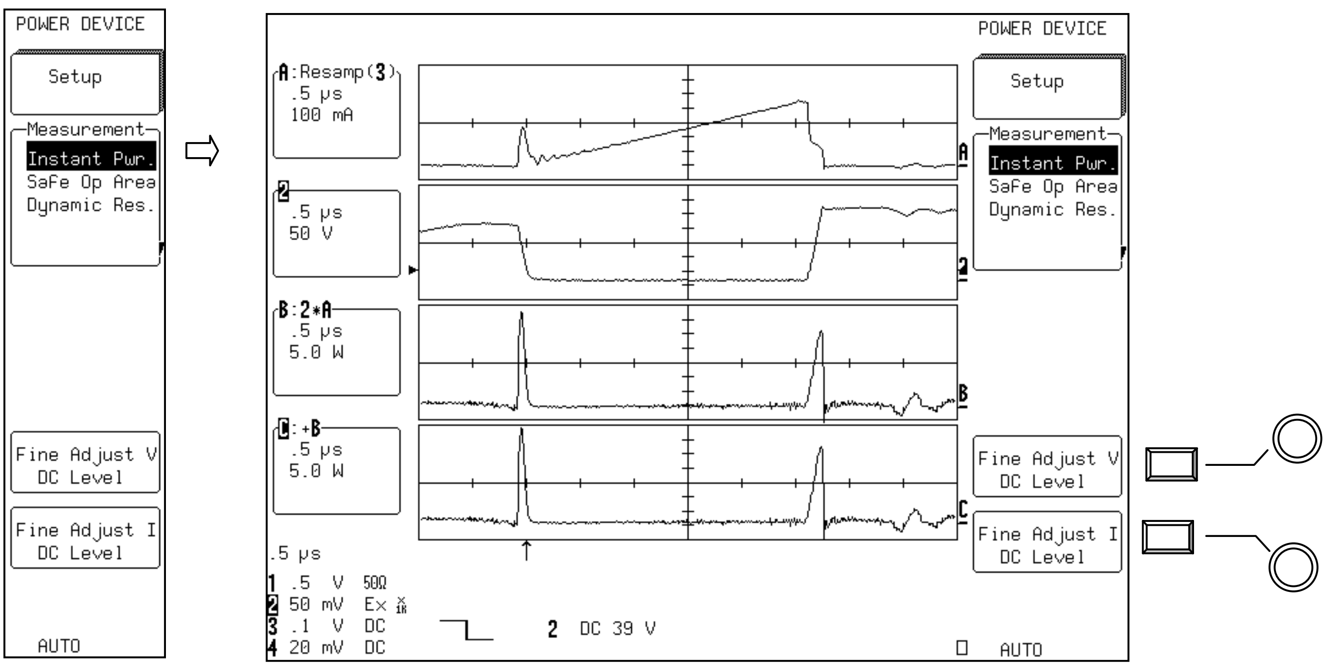
Instantaneous Power Measurement – Steady State

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

Selecting ***Instant Pwr.*** in the ***Measurement*** menu brings up the following display. The deskewed current waveform (**A**) is displayed in the first grid, and the voltage waveform (**2**) is displayed in the second.

The instantaneous power waveform (**B**) is displayed in the third grid. Use the DSO's **ZOOM + MATH** position and zoom controls to obtain the desired display.

The fourth grid (**C**) displays a copy of the instantaneous power waveform (**B**) and is used to expand the waveform B so individual cycles of a multiple cycle record can be viewed.



Fine Adjust V DC Level and ***Fine Adjust I DC Level*** are provided to allow the user 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 user knowledge of the waveforms.

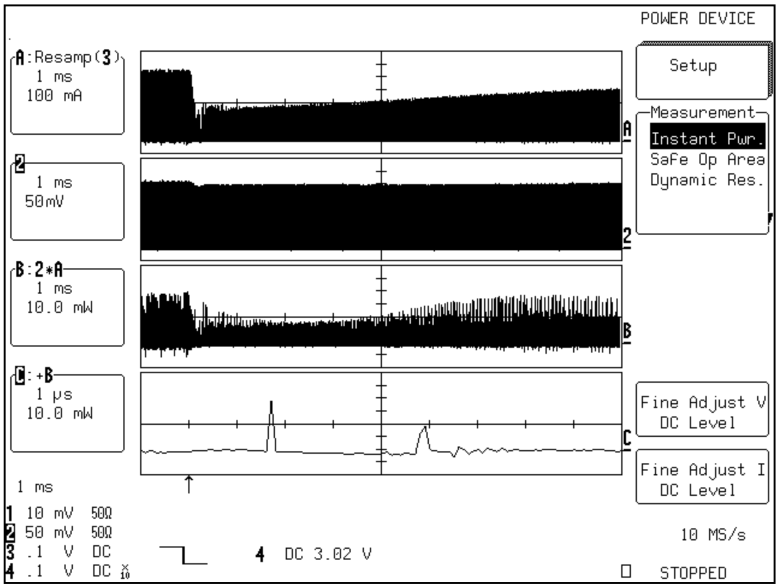
Turn the ◯ to adjust the DC Offset Level to the desired level. Pressing ▭ the will return the offset to zero.

For a detailed explanation on how to adjust the DC Offset Level, see page 2-22.

Instantaneous Power Measurement – Event Triggered

Note: The previous sections should be completed before making 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.

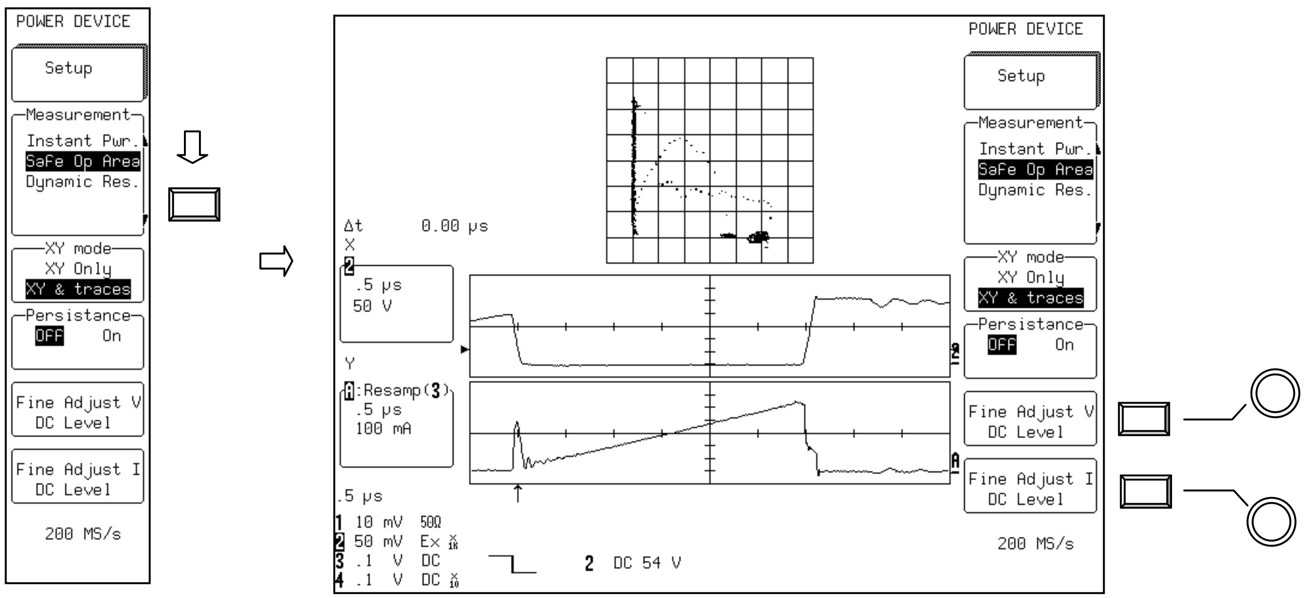


The above is a 10 msec window of a power FET’s drain-source voltage, drain current (deskewed), and instantaneous power dissipation that occurs during the circuit’s transition from maximum to minimum load. The ZOOM of the instantaneous power waveform (**B**) is used to examine the instantaneous power dissipation during one cycle in trace (**C**). In this case, the acquisition of the 10 msec 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 making these measurements.

Selecting ***Safe Op Area*** in the ***Measurement*** menu brings up the following display. The voltage waveform (**2**) is displayed in the first grid and the deskewed current waveform (**A**) 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 difference between the voltage and current samples have been removed by the deskew function.



Fine Adjust V DC Level and ***Fine Adjust I DC Level*** are provided to allow the user 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 user knowledge of the waveforms.

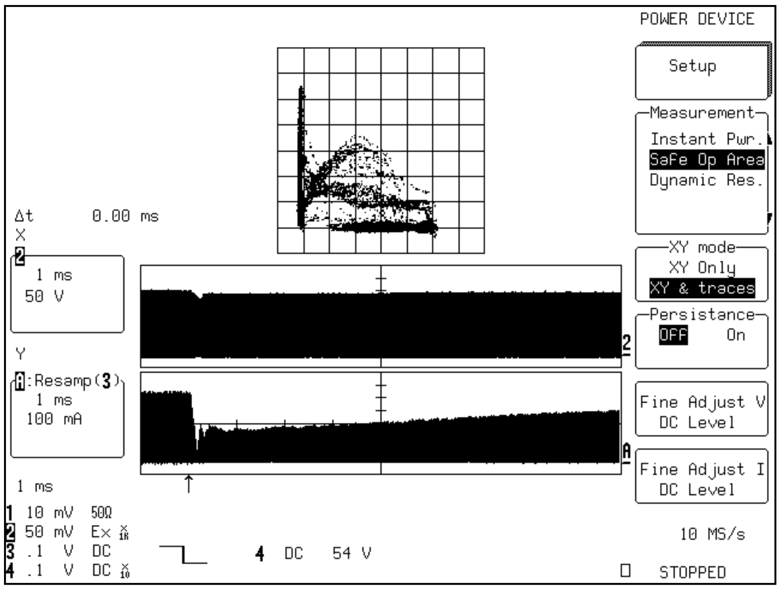
Turn the to adjust the DC Offset Level to the desired level. Pressing the will return the offset to zero.

For a detailed explanation on how to adjust the DC Offset Level, see page 2-22.

Safe Operating Area Measurement – Event Triggered

Note: The previous sections should be completed before making 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.



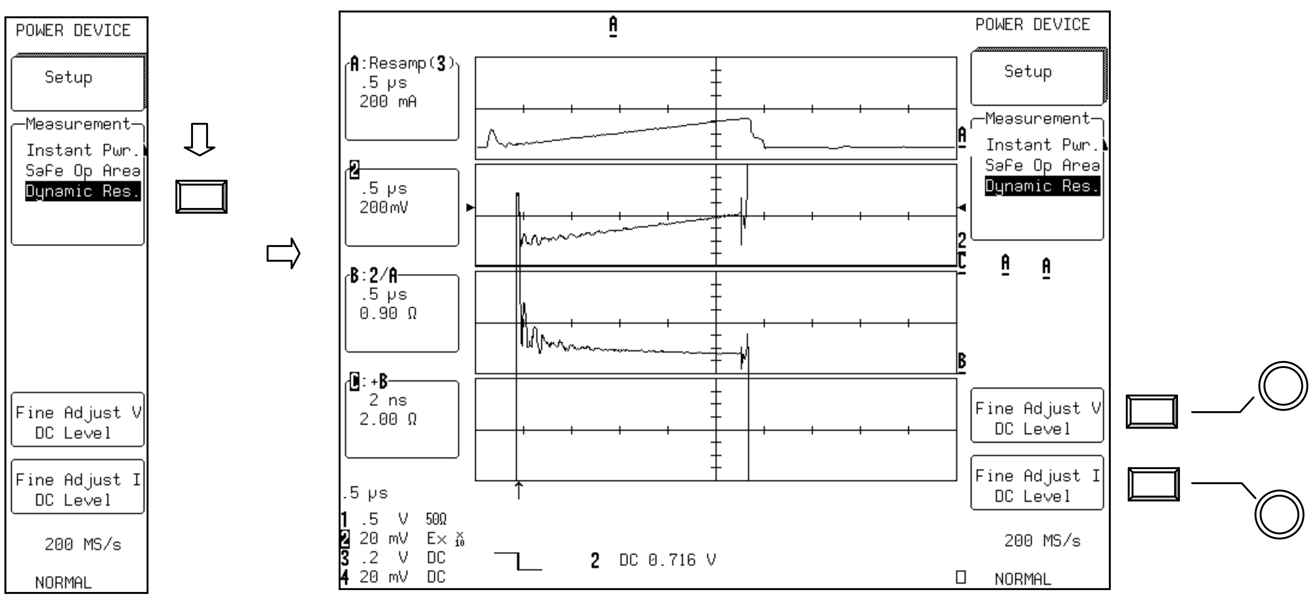
The above is a 10 msec window of a Power FET’s drain-source voltage, drain current (deskewed), and safe operating area measurement that occurs during the circuits transition from maximum to minimum load. In this case, the acquisition of the 10 msec record was triggered by the “EVENT” trigger previously set up on Channel 4.

Saturation Voltage and Dynamic On-resistance Measurement

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

Selecting ***Dynamic Res.*** in the ***Measurement*** menu brings up the following display. The deskewed current waveform (**A**) is displayed in the first grid and the voltage waveform (**2**) is displayed in the second grid. The delay difference between the voltage and current samples have 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. [**Note**: A DA1855(A) differential amplifier and DXC100A 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 third grid (**B**). Trace (**C**) is a ZOOM of the resistance trace (**B**) to be used to examine detail.

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



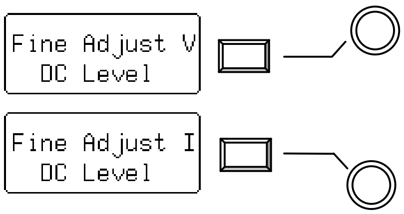
Fine Adjust V DC Level and ***Fine Adjust I DC Level*** are provided to allow the user to compensate for any residual DC offset that the voltage and current probes may exhibit. Because the magnitude of residual DC offset error is usually unknown, use of these adjustments requires user knowledge of the waveforms.

Turn the to adjust the DC Offset Level to the desired level. Pressing the will return the offset to zero.

For a detailed explanation on how to adjust the DC Offset Level, see page 2-22.

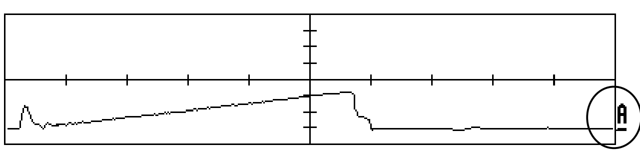
Fine DC Level Adjustment

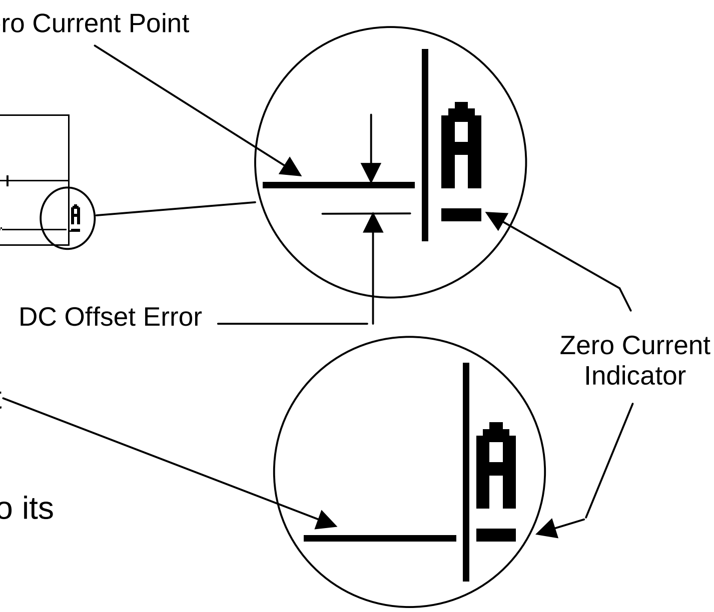
Measurement errors caused by channel-to-channel time-delay differences can be corrected using PMA1’s deskew capability. Another major cause of errors is DC offset in the measurement equipment. Minor DC offset errors in the current or voltage channel can cause major errors in power calculations. Because it is not possible to design amplifiers and current probes with zero DC offset, PMA1 provides fine DC offset adjustments to correct these errors 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.

To set the ***Fine Adjust I DC Level***:





Turn the until the zero current point aligns with the zero current indicator.

Pressing the will return the offset to its pre-adjusted state.

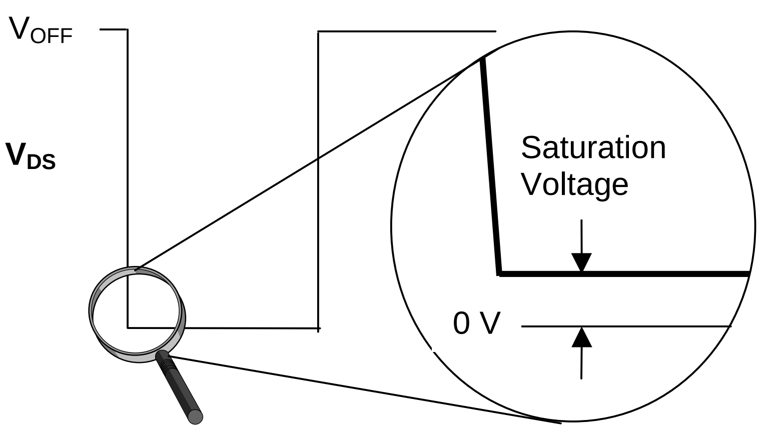
Adjustment of the ***Fine Adjust DC V Level*** operates in the same fashion. Placing the voltage plus and minus differential probes on the same point in the circuit will provide a zero voltage reference point for the adjustment.

NOTE: These adjustments remain in effect until ***Application Off*** is pushed (see page 2-25). Failure to turn this function off after using PMA1 can cause errors in subsequent measurements.

Effects of Probe Compensation on Saturation Voltage Measurements

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

An example:



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

It is obvious that 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, the probe's high-frequency performance required for this measurement is clear.

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. A low-frequency compensation adjustment made with the entire waveform on-screen 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.

Effects of Probe Compensation on Saturation Voltage Measurements - continued

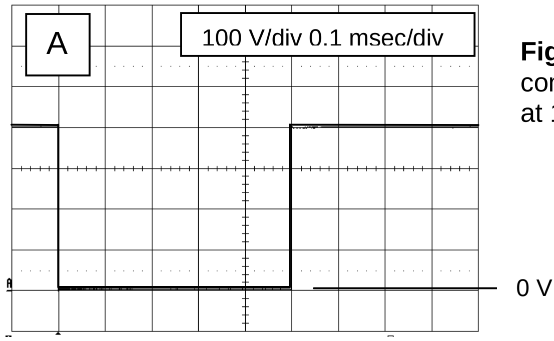


Figure A: A voltage probe appears to be properly compensated on a 400 V squarewave when viewed at 100 V/div.

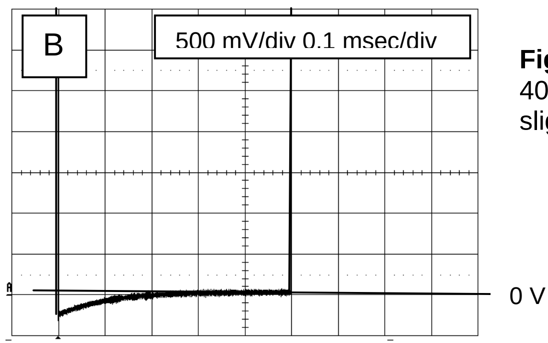


Figure B: When viewed at 500 mV/div, the same 400 V squarewave shows the probe compenstion is slightly peaked.

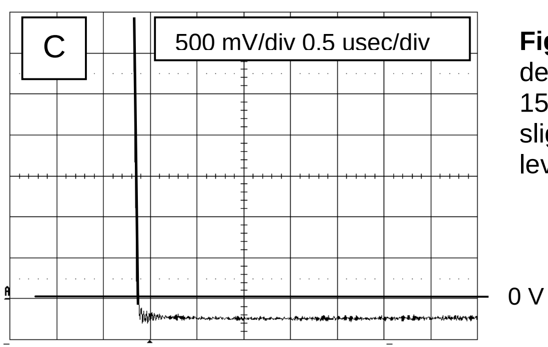


Figure C: When the horizontal time per division is decreased to a value normally used to view 20 to 150 kHz swictchmode power conversion circuits, the slightly peaked LF compensation appears as a DC level shift.

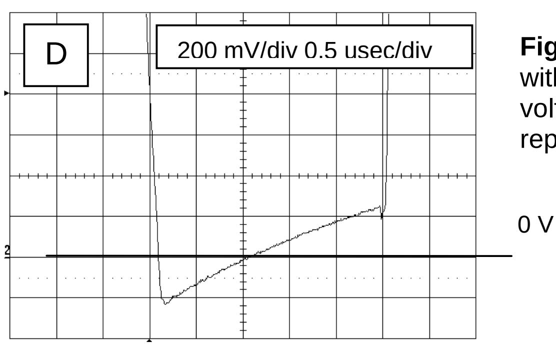
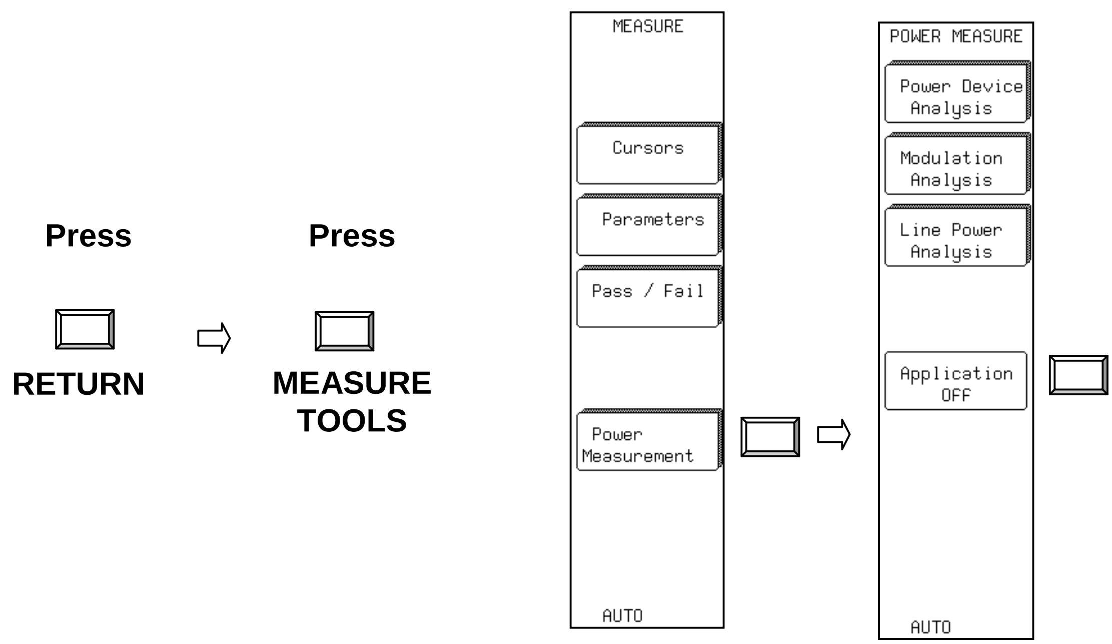


Figure D: Viewing a power FET’s saturation voltage with the slightly peaked LF compensation makes the voltage appear to go negative. In this example, the repetition rate of the power supply is 60 kHz.

Clearing the Power Device Analysis Setup

After using PMA1's Power Device Analysis section, it is important to clear the channel assignments and other alterations that were made while making power device measurements. Press the **RETURN** until the onscreen menu is cleared. Then press the **MEASURE/TOOLS** to bring up the ***MEASURE*** menu.

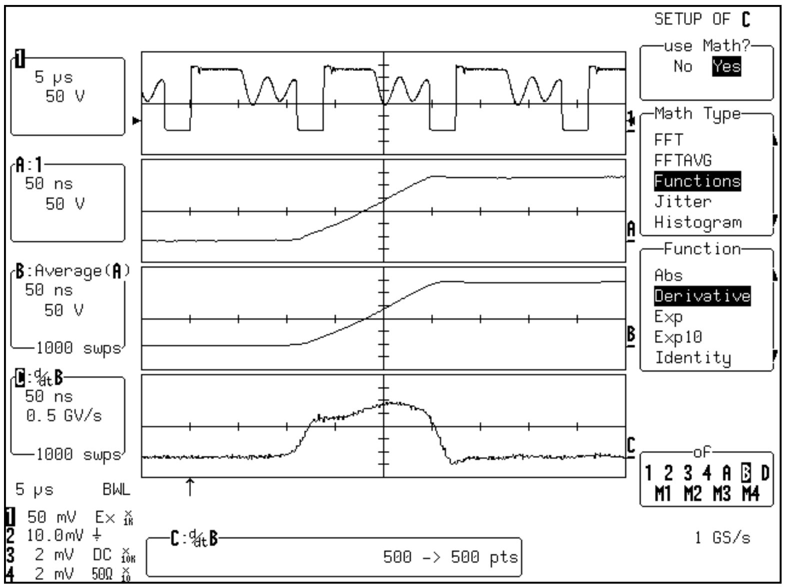


Selecting ***Application OFF*** in the Power Measure menu changes the ***Voltage Input*** and ***Current Input*** assignments to ***NONE*** and removes any DC offset adjustment made while using the ***Fine Adjust V DC Level*** and ***Fine Adjust I DC Level*** features. Any ***Deskew Value*** set while deskewing channel-to-channel delay remains unchanged. The assignment of Ampere units to the channel selected as the ***Current Input*** channel will be removed.

Measuring Device dv/dt

The speed of a power device's dv/dt during turn-on and turn-off can be measured using PMA1's derivative math function.

Note: This measurement does not require the use of the PMA1 menus.



In the example above, a power device's Drain to Source Voltage (V_{DS}) signal (**1**) is set up to be displayed in the first grid.

Math Channel A is used as a ZOOM of the Drain to Source voltage (**A**), and the trace is ZOOMed to 50 ns/div showing the voltage change as the device turns from on to off.

In the third trace (**B**), math Channel B is used to average trace A to remove noise from the V_{DS} signal before its derivative is taken.

In the fourth trace (**C**), math Channel C uses the derivative math function to display the waveforms dv/dt.

Cursors can be used to find the signal's dv/dt at any point.

Chapter 3 – Using Modulation Analysis

How Modulation Analysis Works

Switchmode power conversion circuits use some method of transferring energy from an unregulated source to a regulated output(s) 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 **P**ulse **W**idth **M**odulation (**PWM**).

The Modulation Analysis section of PMA1 is intended to provide the user 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) also are used, but no matter which method is used it is difficult to view and analyze the modulation.

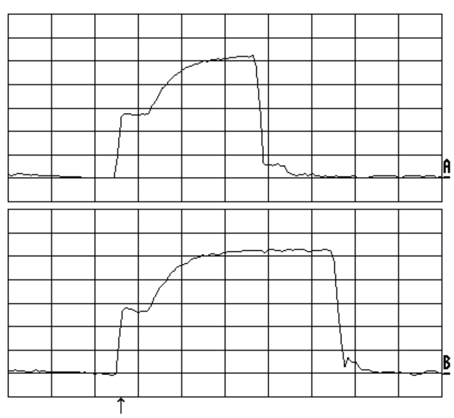


Figure 3.1:
(A) *Gate drive pulse width at minimum load*
(B) *Gate drive pulse width at full load*

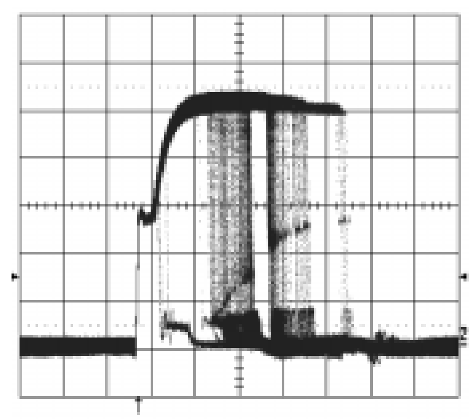


Figure 3.2: *Analog Persistence™ display shows pulse widths at minimum and maximum load, as well as other pulse widths that occur during load transition.*

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

Modulation Analysis provides the user 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.

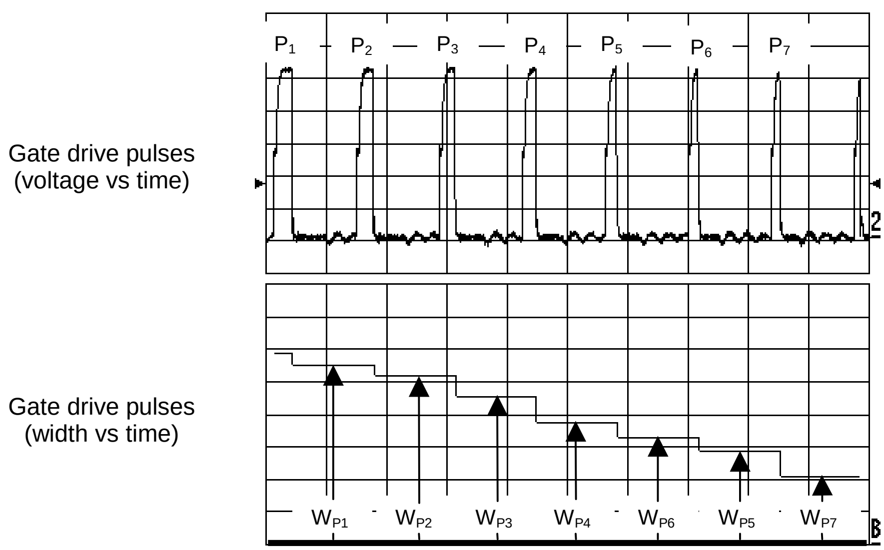


Figure 3.3: *Example of how Modulation Analysis measures the width of individual pulses and displays their value on the vertical axis.*

As the number of pulses increase per division, 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

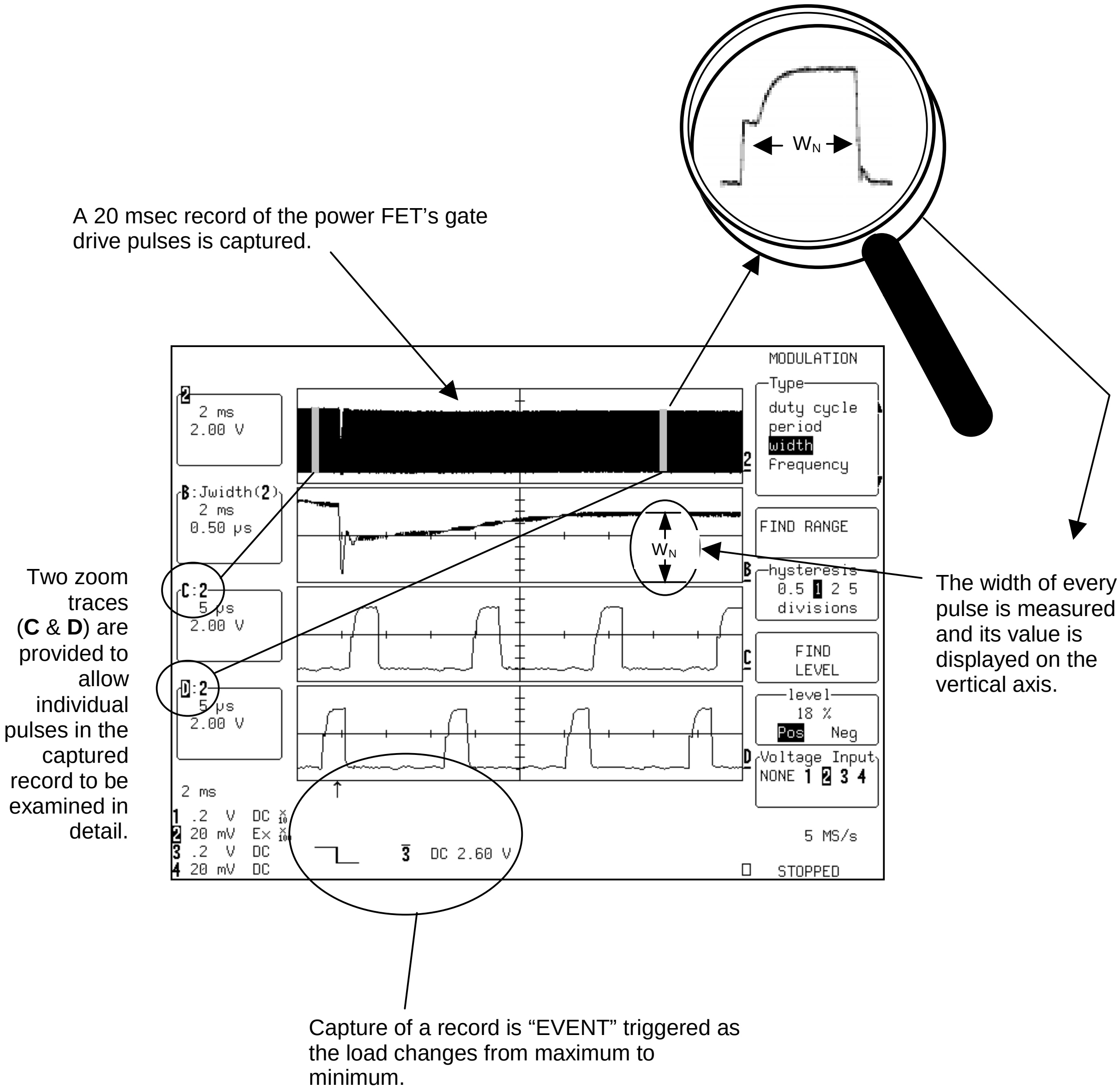


Figure 3.4: *Modulation Analysis displays a PWM circuit's step response as the output load changes from maximum to minimum. In this example, over 1000 gate drive pulses are recorded in the first grid [**2**], and a record of their individual widths is displayed in the second grid [**B**: Jwidth (**2**)].*

Configuring for Modulation Analysis

The Modulation Analysis portion of PMA1 lets the user capturie 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.

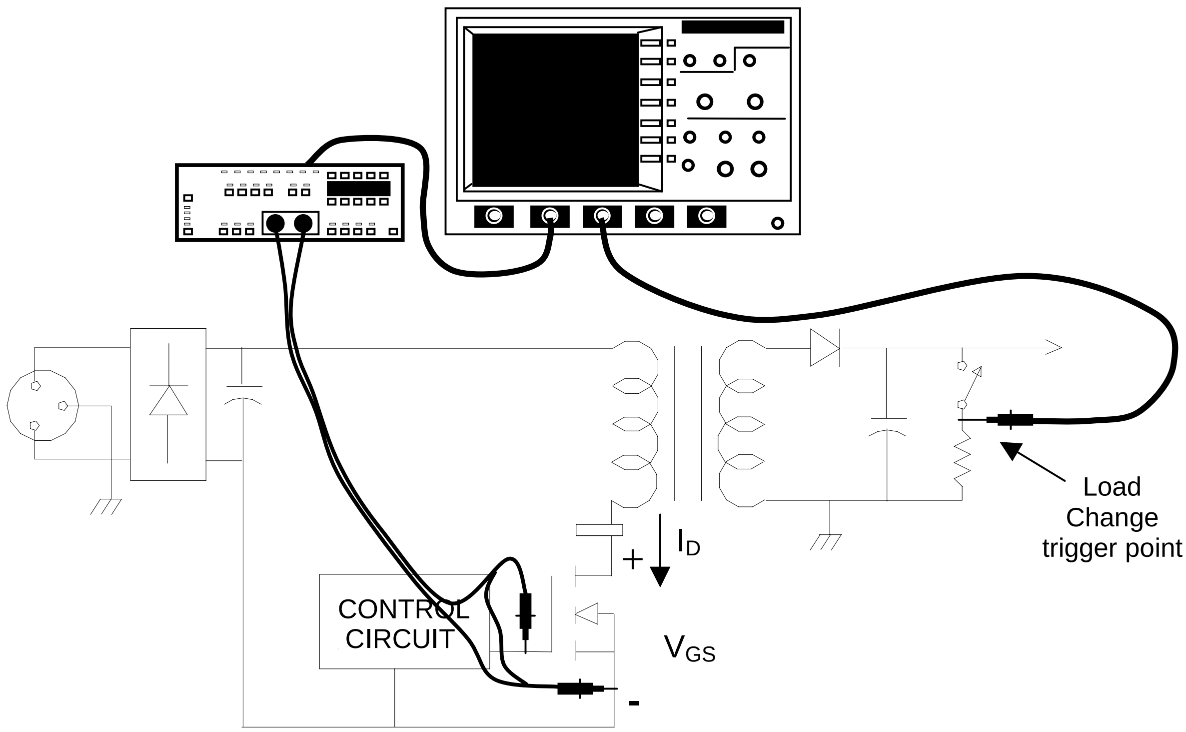


Figure 3.5: *Typical connections to a circuit under test needed to acquire the power device's gate drive signal from which the circuit's Pulse Width Modulation can be obtained.*

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

Plan the measurement in advance and do a preliminary setup before evoking the PMA1 Power Measurement menus. This will minimize the number of times it is necessary to leave the menu structure.

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 Figure 3.3, 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 menu.

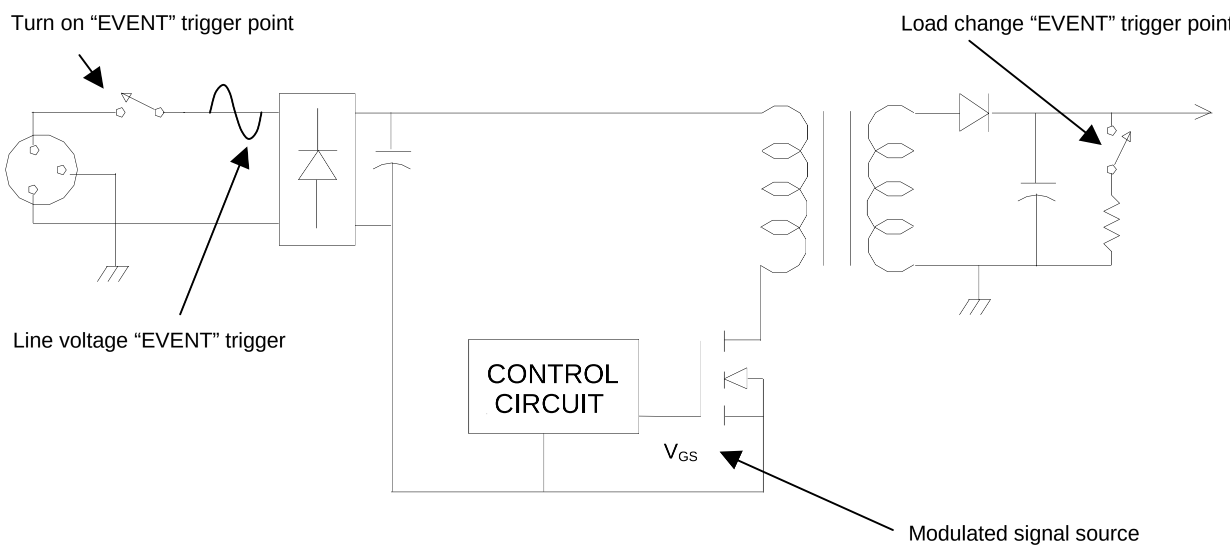
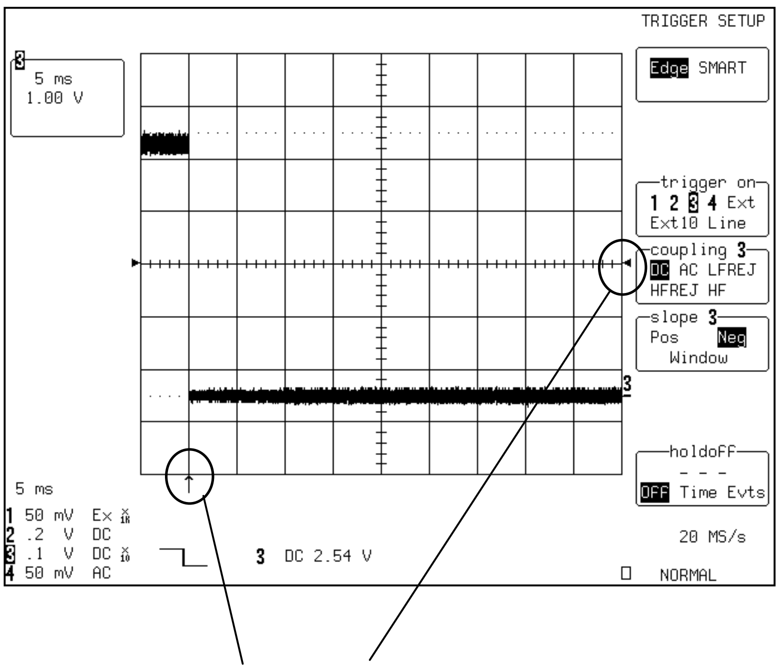


Figure 3.4: *Typical connections to the circuit under test for acquiring a source of the feedback modulation and various EVENT trigger sources.*

Trigger Setup – The Event Trigger

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 Figure 3.4.

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.



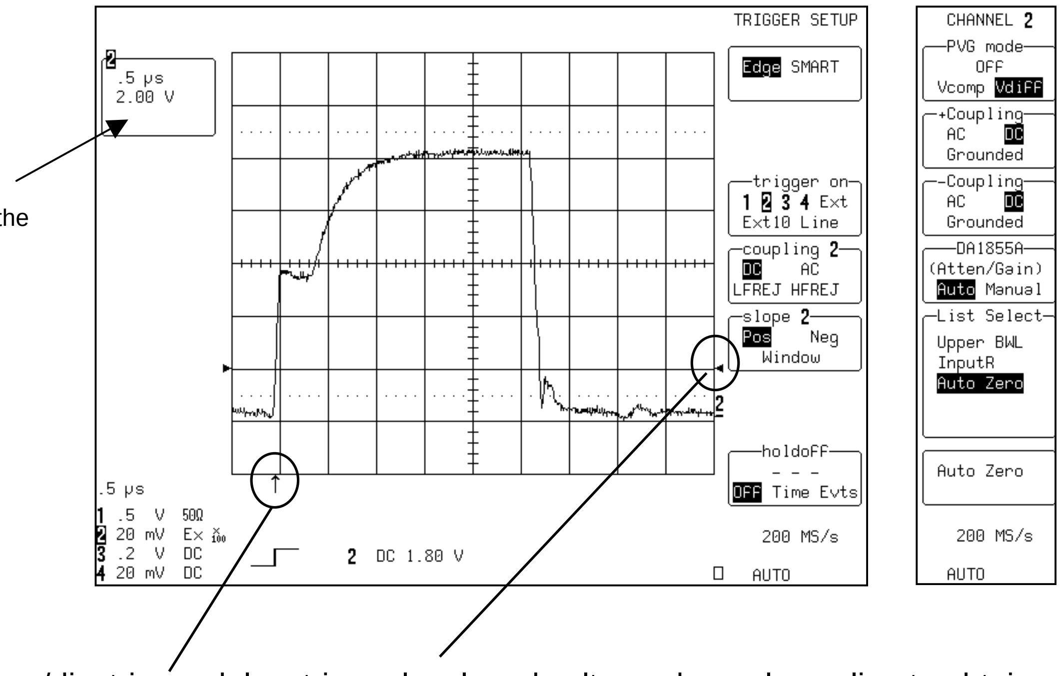
Set the time/div, trigger delay, and trigger level for the "EVENT" trigger channel to obtain a display similar to that shown above. If the modulated signal is to be acquired as the result of a one-time event such as turn-on, test the "EVENT" trigger for satisfactory operation in SINGLE trigger mode.

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

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.

V/div and time/div settings will depend on the particular circuit.



Set the time/div, trigger delay, trigger level, and voltage channel coupling to obtain a display similar to that shown above.

Finishing the Setup and Making Modulation Measurements

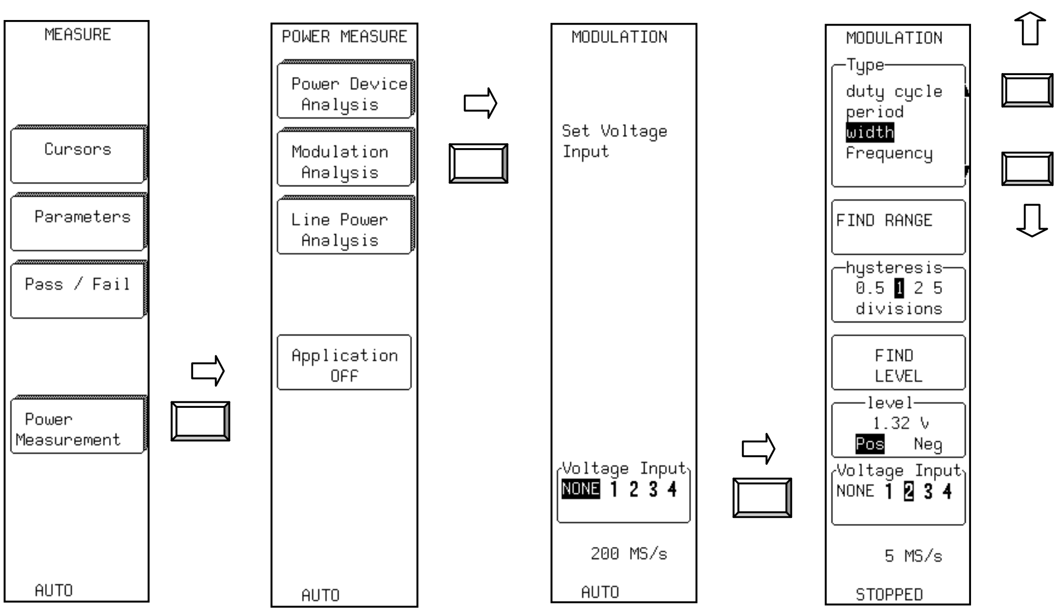
After the measurement is planned, the modulated signal channel is identified, the probes are connected to the proper point in the circuit under test, and preliminary triggering is established, use the PMA1 software to finish the setup and measure the signal's modulation.

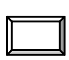
Change the trigger source to the "EVENT" trigger previously set up (Channel 3 in the example). If the event is repetitive, the DSO's **NORMAL** trigger can be used. For events that occur only once, such as start-up, **SINGLE** trigger should be used.

Activating the Modulation Analysis Menu

Press the **MEASURE TOOLS** (LT Series) or **CURSORS/MEASURE** (LC Series) button on the DSO front panel to bring up the ***MEASURE*** menu, which includes the ***Power Measurement*** selection.

Follow the menu sequence given below:

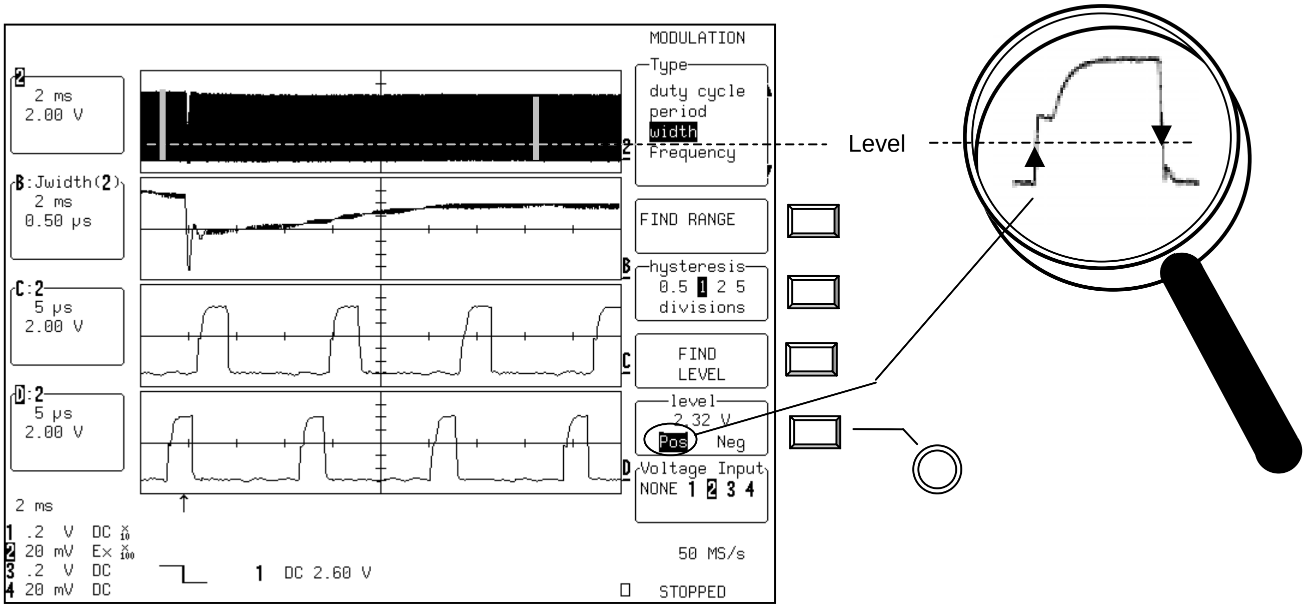


Press the ***Voltage Input***  to select the previously set up modulated signal voltage channel.

In the ***Type*** menu, select the form of modulation to be analyzed. ***Width*** is selected for this example and is the selection that is used for PWM modulation analysis.

Modulation Analysis Controls

Change the horizontal time/div to a value that will allow the capture of a modulated signal record sufficiently long to cover the time of interest and use the pre-selected “EVENT” trigger to acquire a record.



Press the ***POS*** in the ***level*** menu to measure the width between a positive-going edge and the next falling edge.

Press the ***FIND LEVEL*** to find the 50% level of the modulated signal’s width.

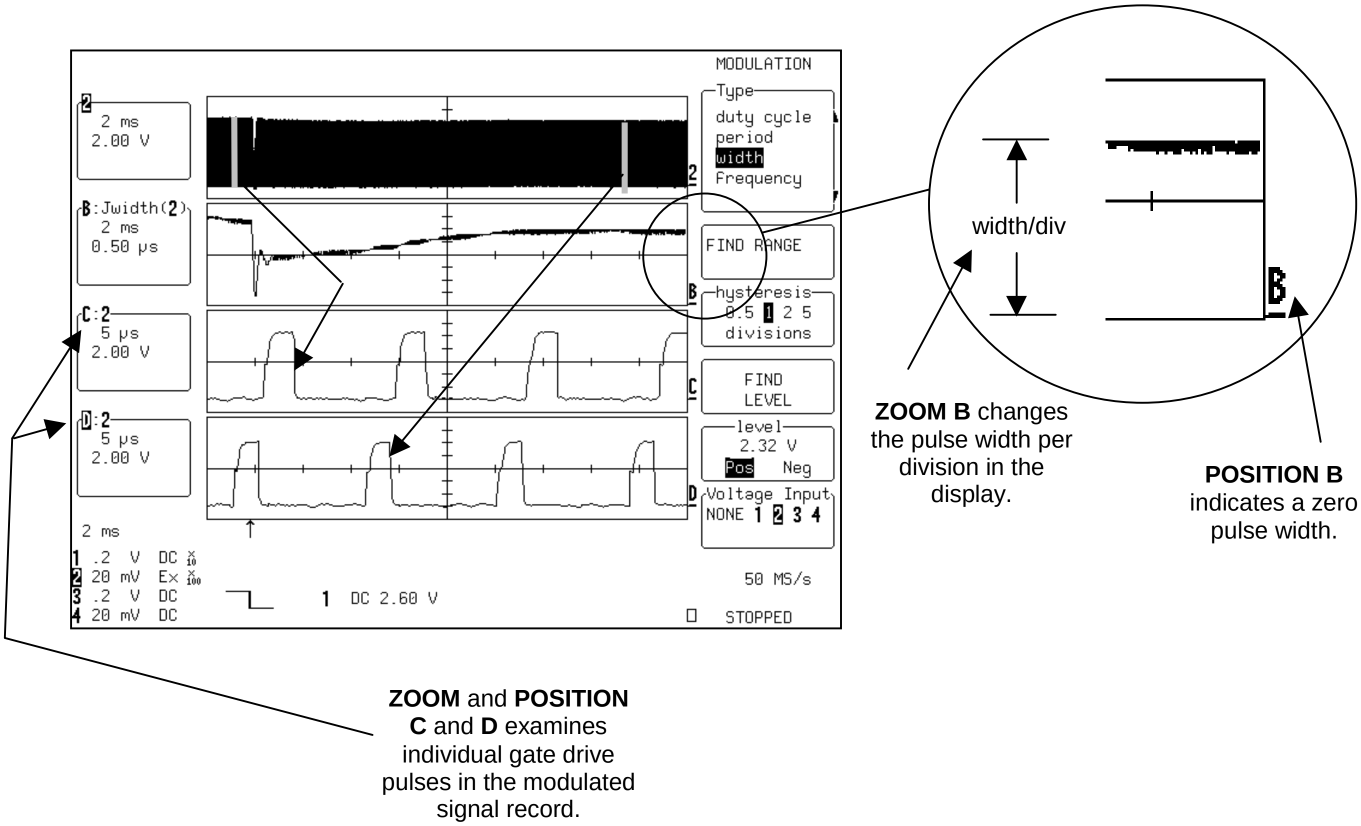
Turn the ***level*** knob to set the voltage level on the modulated signal at which the width is to be measured. Set this to a level on the modulated signal where both the rising and falling edges are free from noise. When measuring the modulation of the gate drive signal, it is best to avoid placing the level around the pedestal.

Press the ***hysteresis*** to select the number of divisions the modulated signal must change before a slope change is recognized.

Press the ***FIND RANGE*** to find the range of the modulated signal’s width.

Optimizing the Display

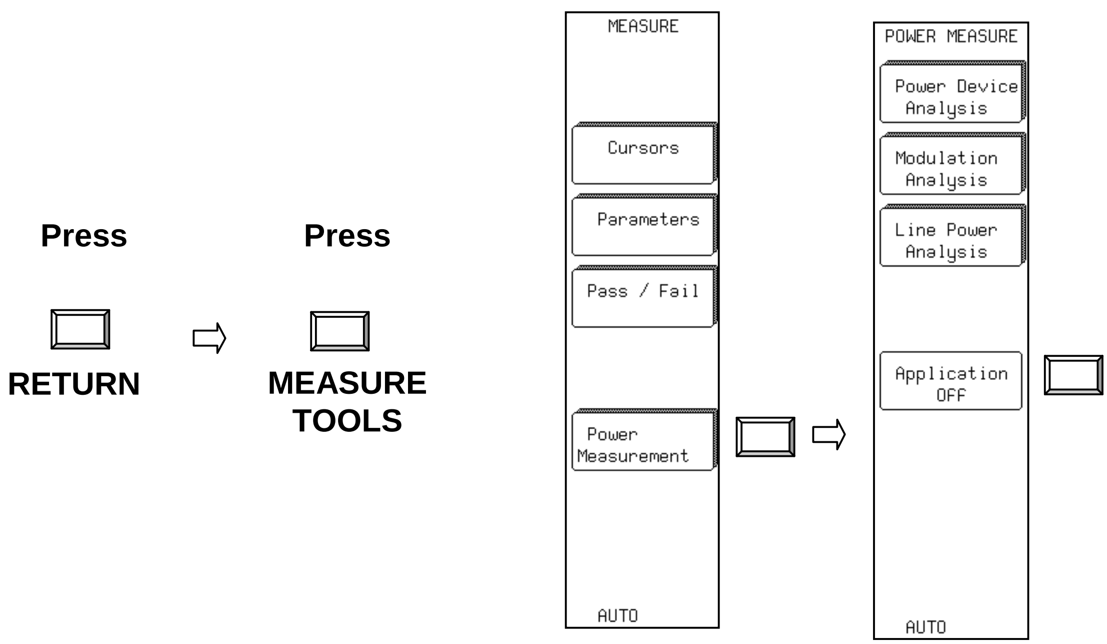
Use the DSO's **ZOOM + MATH** position and zoom controls to optimize the display.



The modulated signal (**2**) 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 (**B**) is displayed in the second grid, and zoom traces (**C**) and (**D**) of the modulated signal (**2**) are displayed in the third and fourth grids. These grids are used to expand the waveform B so individual cycles of a multiple-cycle record can be viewed.

Clearing the Modulation Analysis Setup

After using the Modulation Analysis section of PMA1, it is important to clear the channel assignments and other alterations that were made while making measurements. Press the **RETURN** until the on-screen menu is cleared. Then press the **MEASURE/TOOLS** to bring up the ***MEASURE*** menu.



Selecting ***Application OFF*** in the Power Measure menu changes the ***Voltage Input*** assignment to ***NONE***.

Chapter 4 – Using Line Power Analysis

Line Power Analysis Overview

The Line Power Analysis section of PMA1 provides the user 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 0), as well as evaluate harmonic currents injected into the power line. Harmonic measurements are made in relationship to the requirements of standard EN60001-3-2.

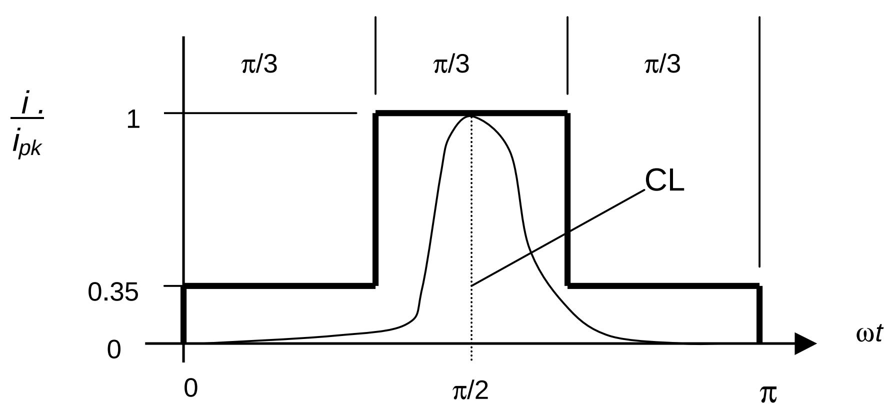
EN61000-3-2

The user is encouraged to refer to the latest version of EN61000-3-2 for full definitions and limits set forth by the standard. The following is provided for convenience.

Classification of Equipment:

For purposes of harmonic current limitation, EN61000-3-2 classifies equipment as follows:

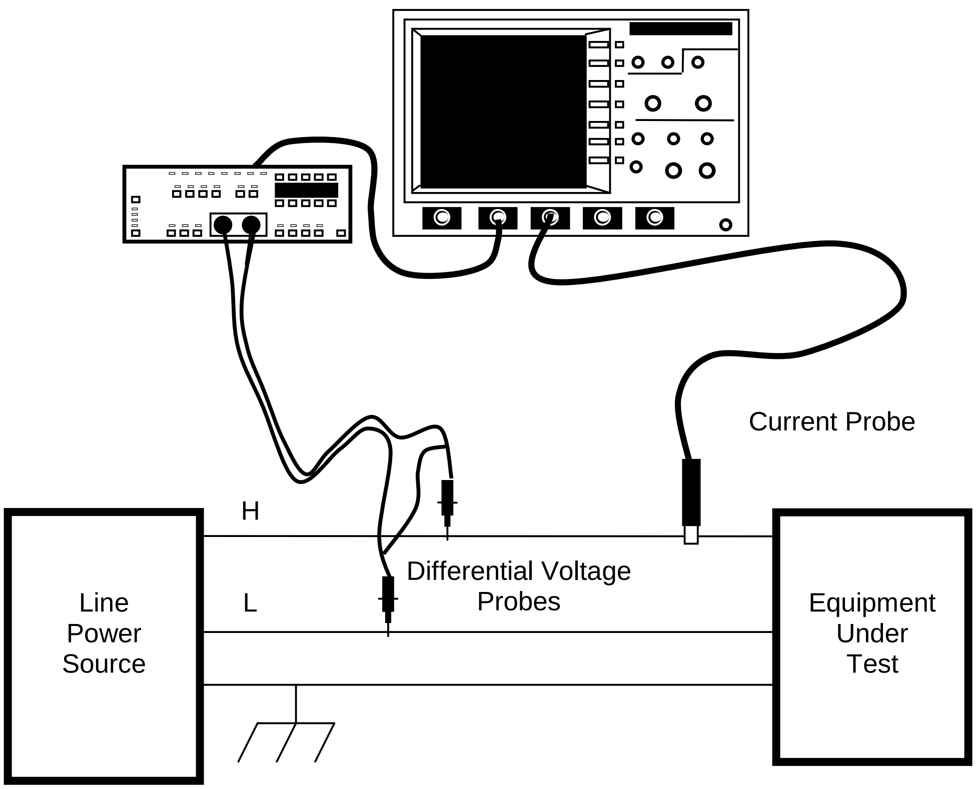
Class A: Balanced three-phase equipment and all other equipment, except that stated in one of the following classes.
Class B: Portable tools.
Class C: Lighting equipment, including dimming devices.
Class D: Equipment not in Classes B, C, or motor driven and having an input current with a “special wave 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.

Configuring for Line Power Analysis

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



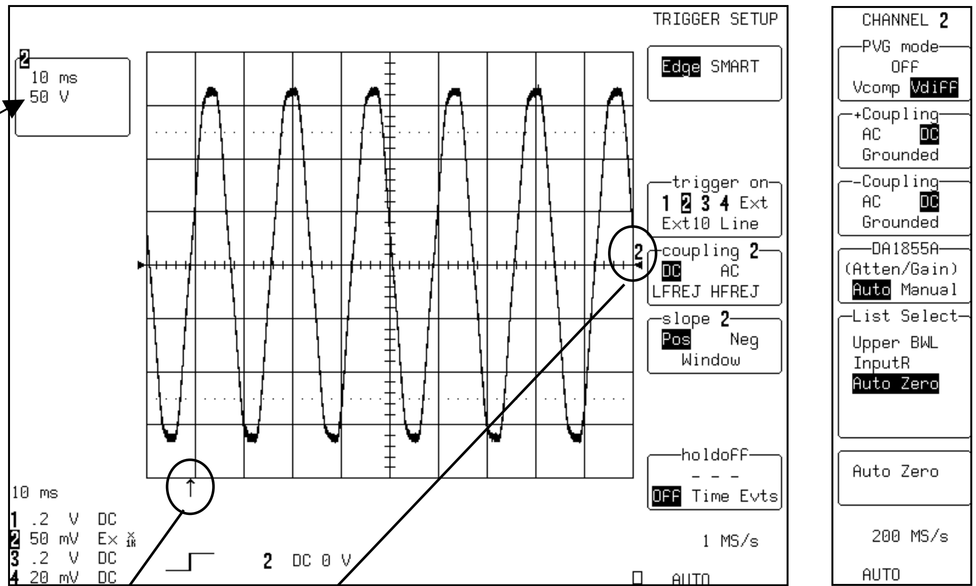
EQUIPMENT UNDER TEST: The equipment being tested for power consumption and line harmonics.

LINE POWER SOURCE: The power source should be low distortion. EN61000-3-2 specifies maximum crest factor and harmonic distortion for the power source while it is connected to the EUT. The test can be run with the available power line, but the distortion in the source will directly affect the quality of the measurements.

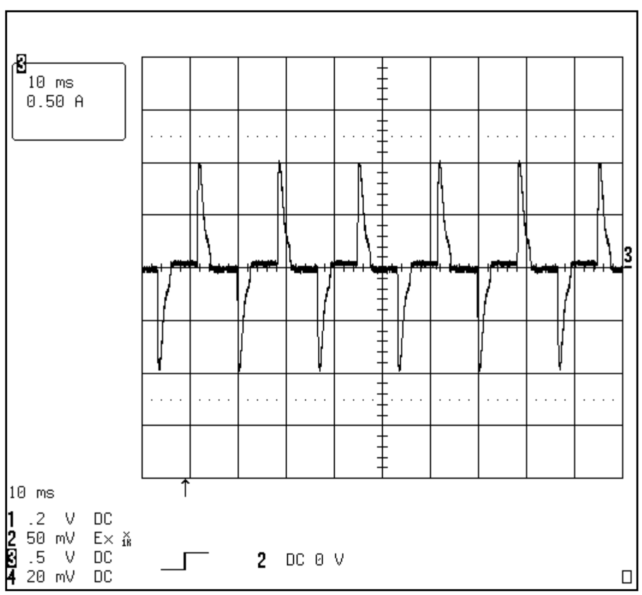
Initial Setup – The Line Voltage and Current Signals

Set up a stable display of the line voltage and current signals similar to those shown.

V/div setting will depend on the particular line voltage being tested.



Set the time/div, trigger delay, trigger level, and voltage channel coupling to obtain a display similar to that shown above.



Polarity of the current waveform must match that of the voltage waveform.

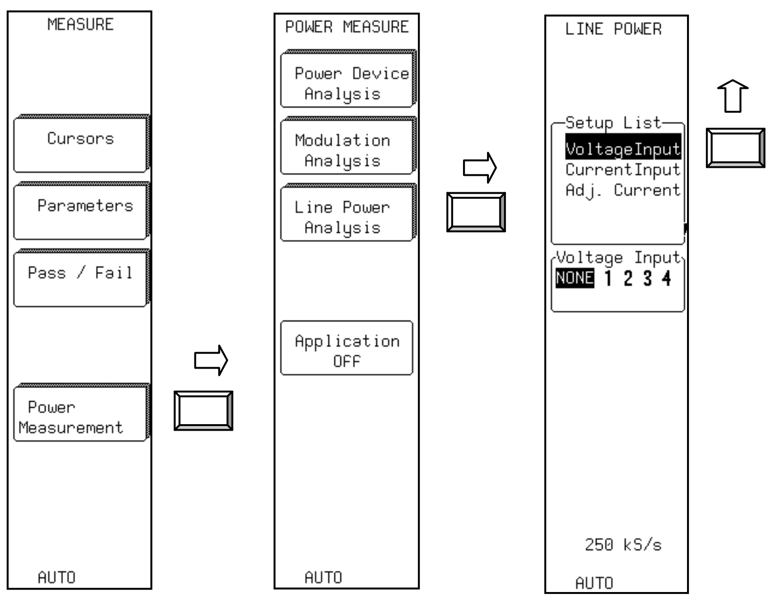
Finishing the Setup and Making Line Power Measurements

After the measurement is planned and the voltage and current channels are connected and preliminarily set up, use the PMA1 software to finish the setup and make the line power measurements.

Activating the Line Power Analysis Menu

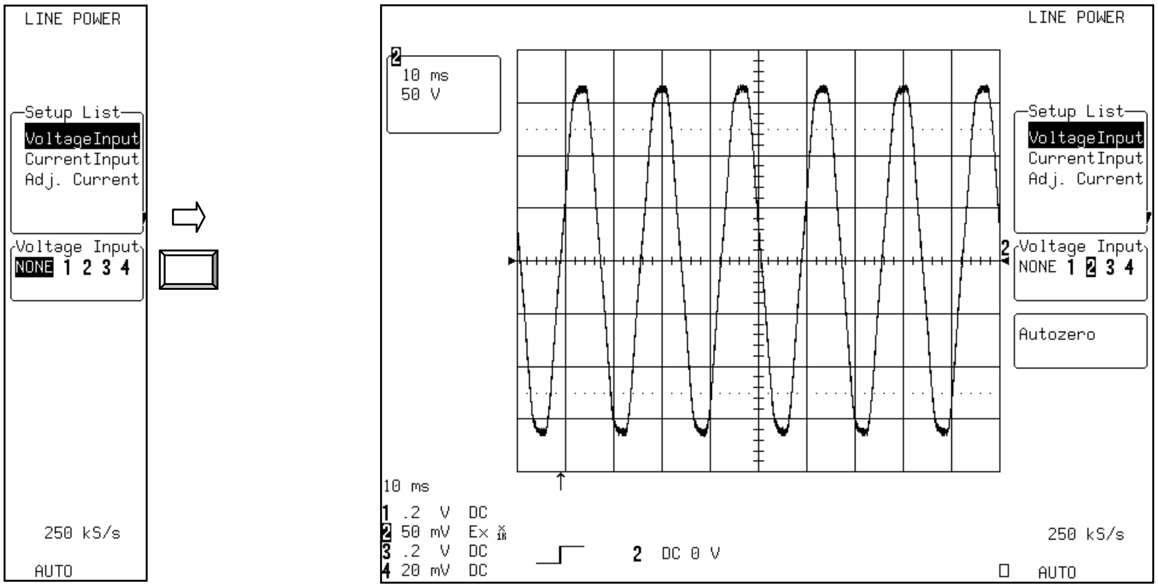
Press the **MEASURE TOOLS** (LT Series) or **CURSORS/MEASURE** (LC Series) button on the DSO front panel to bring up the ***MEASURE*** menu, which includes the ***Power Measurement*** selection.

Follow the menu sequence given below:

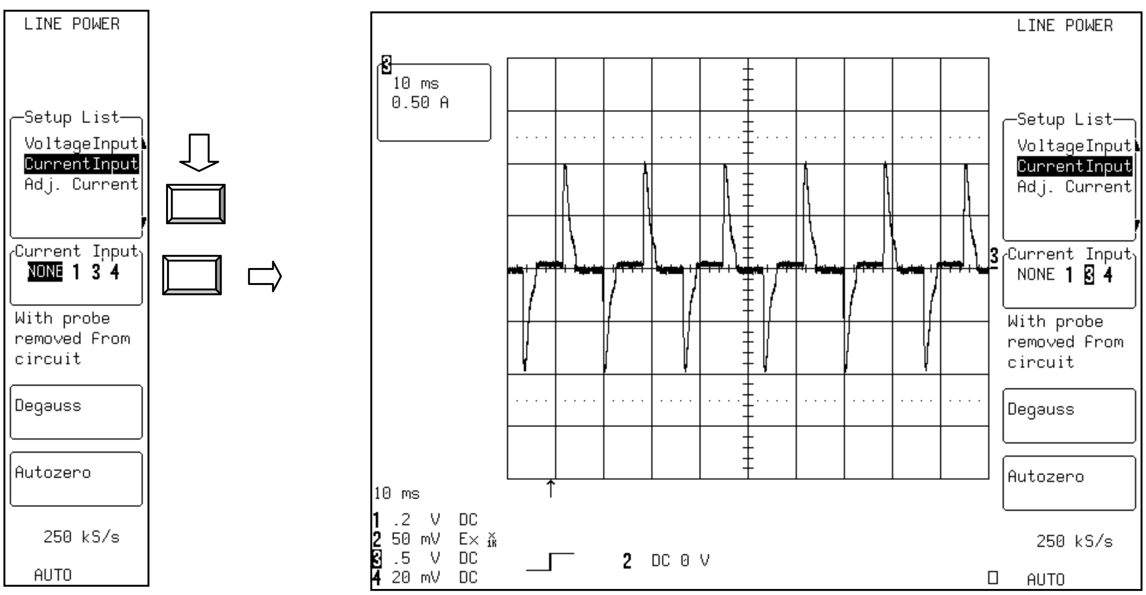


In the ***Setup List*** menu, select ***Voltage Input***.

Selecting the Voltage and Current Channels



Press the **Voltage Input** to select the previously set up line voltage signal channel.

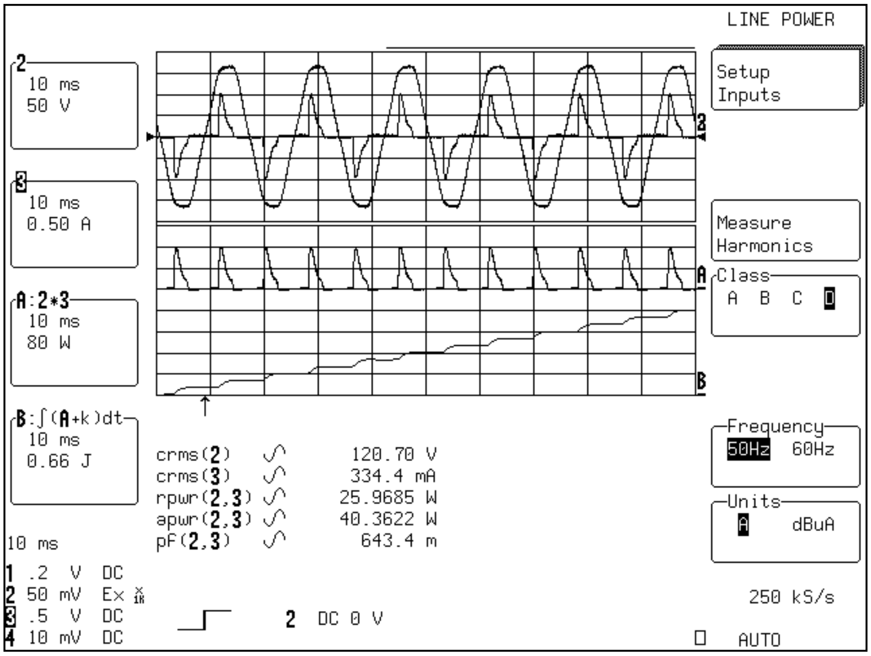


In the ***Setup List*** menu, select ***Current Input***.

Press the **Current Input** to select the previously set up line current signal channel. The channel selected as the ***Current Input*** channel will be assigned Ampere units even if a voltage or nonProBus-compatible current probe is used. Remove and degauss the current probe. Polarity of the current probe should match the voltage waveform.

Line Power Measurement

After the Voltage Input and Current Input selections have been made, press the **RETURN** on the DSO front panel to bring up the following display:



This display screen shows the line voltage and current waveform, as well as the power and energy waveforms.

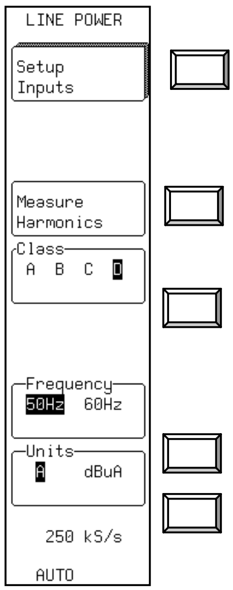
Parameters displayed are:

Line Voltage {*crms* (2)}
Line Current {*crms* (3)}
Real Power {*rpwr* (2,3)}
Apparent Power {*apwr* (2,3)}
Power Factor {*pf* (2,3)} (readout is in milli-units)

Menu selections are provided for the user to select the class of the equipment under test (EN61000 A, B, C, or D classification) and the line frequency at which it is operating (50 or 60 Hz).

Line Harmonics Measurement

Before evoking the **Measure Harmonics** menu selection:



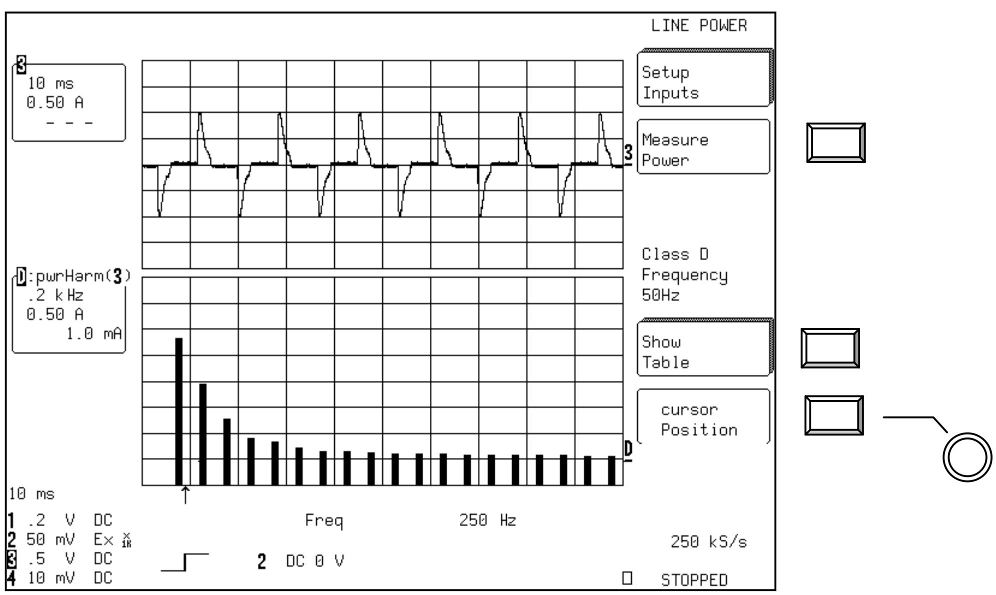
Press the ***Class*** to select the proper EN61000-3-2 equipment class.

Press the ***Frequency*** to select the line frequency (50 Hz or 60 Hz) upon which the equipment under test is operating.

Press the ***Units*** to select Amps or dBuA units for the harmonic displays.

If changes are needed in the voltage or current input setups, pressing the ***Setup Inputs*** will return to the previous menu where the selections can be changed.

After the above selections are made, press the ***Measure Harmonics*** to bring up the following display:

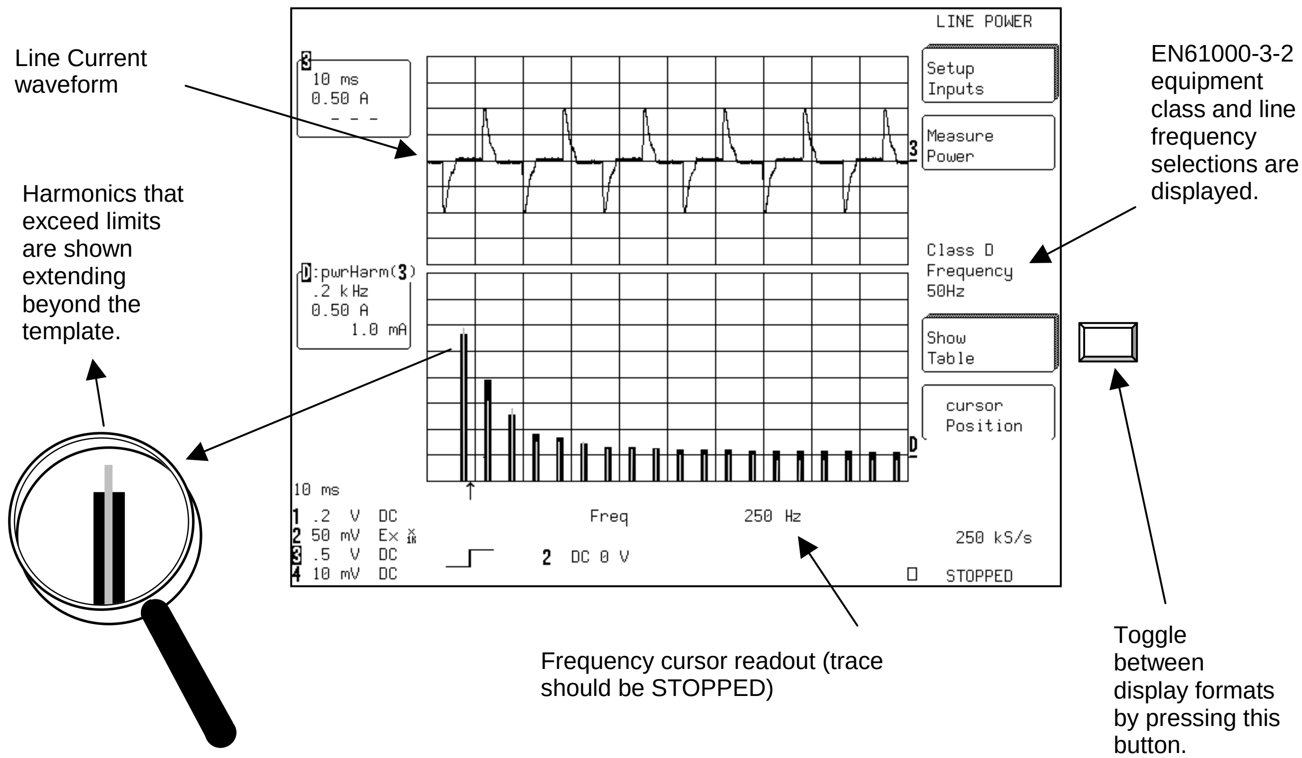


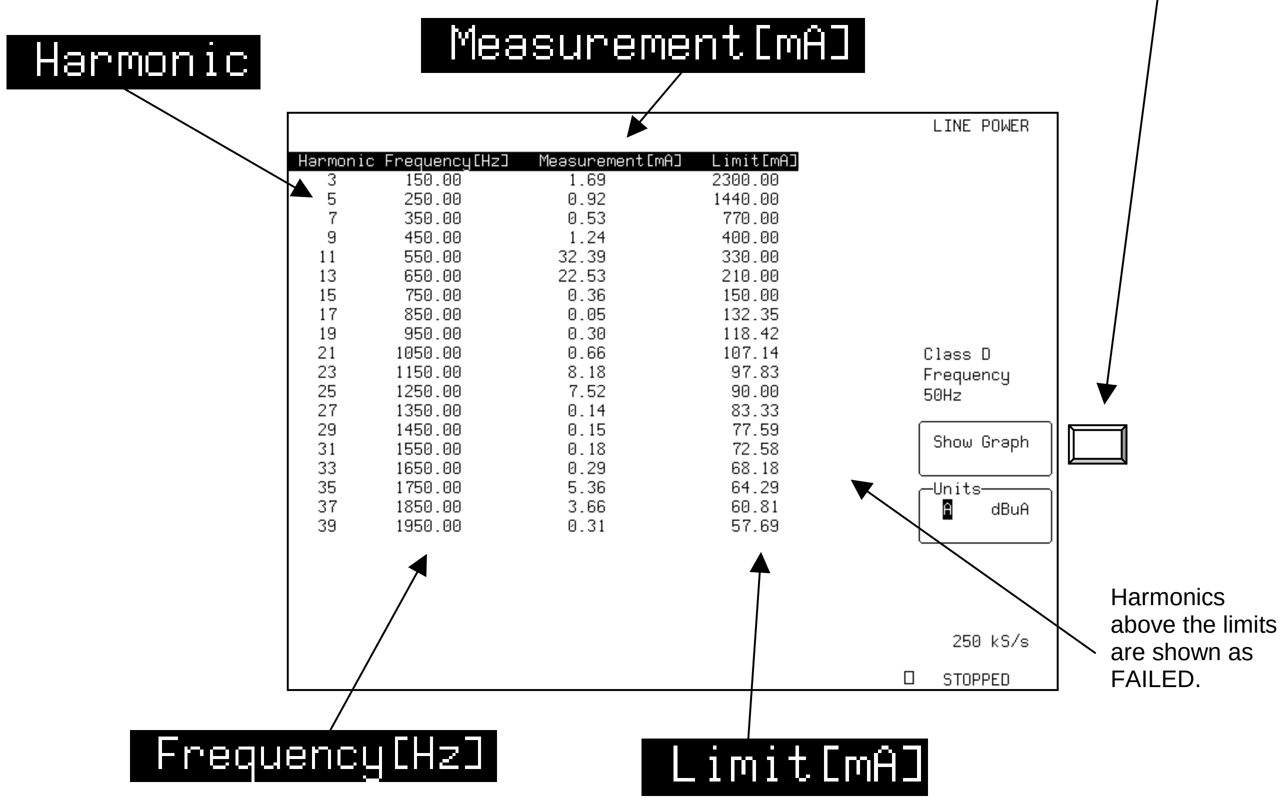
Press the ***Measure Power*** to return to the Measure Power Display (changes in class and line frequency can be made there).

Press the ***Show Table*** to change to the tabular display.

Turn the ***cursor Position*** to move the cursor along the harmonics (trace should be stopped before using the cursor).

The Measure Harmonics Displays

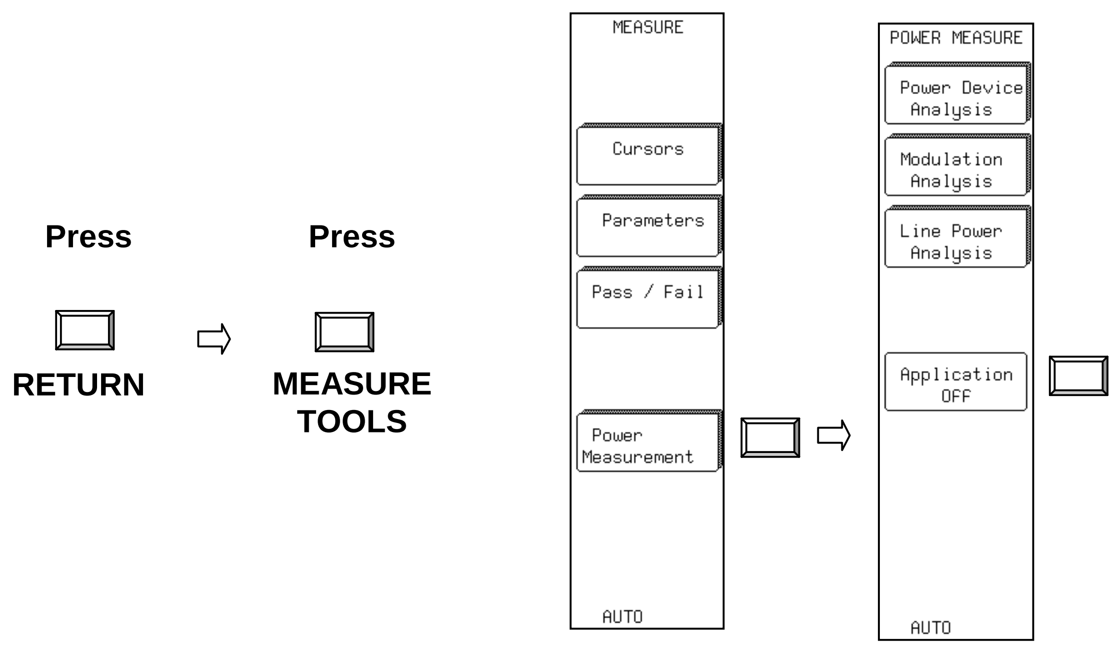




Harmonic	Frequency[Hz]	Measurement[mA]	Limit[mA]
3	150.00	1.69	2300.00
5	250.00	0.92	1440.00
7	350.00	0.53	770.00
9	450.00	1.24	400.00
11	550.00	32.39	330.00
13	650.00	22.53	210.00
15	750.00	0.36	150.00
17	850.00	0.05	132.35
19	950.00	0.30	118.42
21	1050.00	0.66	107.14
23	1150.00	8.18	97.83
25	1250.00	7.52	90.00
27	1350.00	0.14	83.33
29	1450.00	0.15	77.59
31	1550.00	0.18	72.58
33	1650.00	0.29	68.18
35	1750.00	5.36	64.29
37	1850.00	3.66	60.81
39	1950.00	0.31	57.69

Clearing the Line Power Analysis Setup

After using the Modulation Analysis section of PMA1, it is important to clear the channel assignments and other alterations that were made while making line power measurements. Press the **RETURN** until the on-screen menu is cleared. Then press the **MEASURE/TOOLS** to bring up the ***MEASURE*** menu.



Selecting ***Application OFF*** in the Power Measure menu changes the ***Voltage Input*** and ***Current Input*** assignments to ***NONE***. The assignment of Ampere units to the channel selected as the ***Current Input*** channel will also be removed.

Chapter 5 – Using NonProBus Probes

PMA1 Menu Overview

PMA1 menus give the user maximum flexibility by providing the correct units and scaling for power measurements. When LeCroy probes equipped with the ProBus interface are used, correct use of units and scaling is automatic. When nonProBus current or voltage probes are used, PMA1 software provides methods of entering the correct units and scaling for a variety of current and voltage probes.

Units

When a channel is selected as a ***Current Input*** in the PMA1 setup menus, 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.

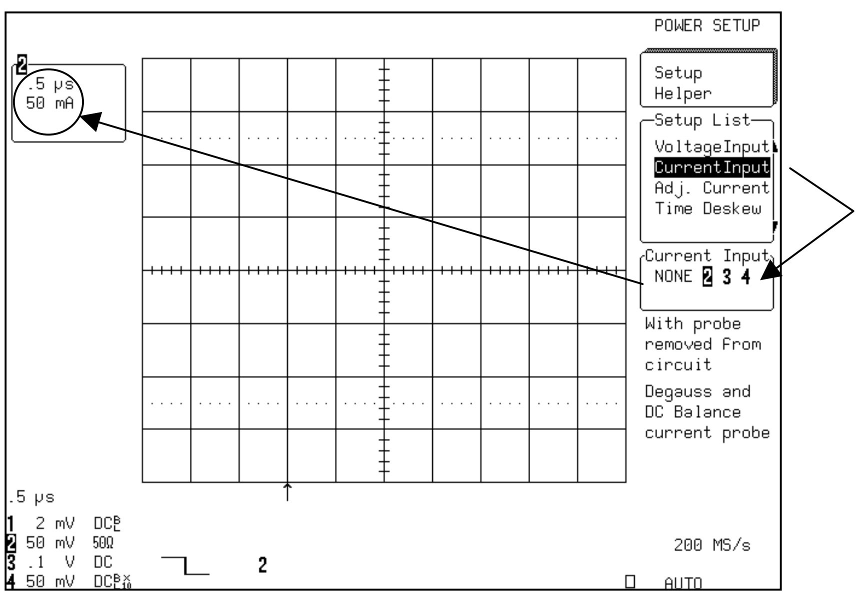


Figure 5.1: Ampere units are applied when Channel 2 is assigned as a current channel.

Scaling

When a channel is selected as a ***Current Input*** or ***Voltage Input*** in the PMA1 setup menus, 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 between ÷10,000 attenuation to X1000 gain in a 1-2-5 sequence. 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 menu system.

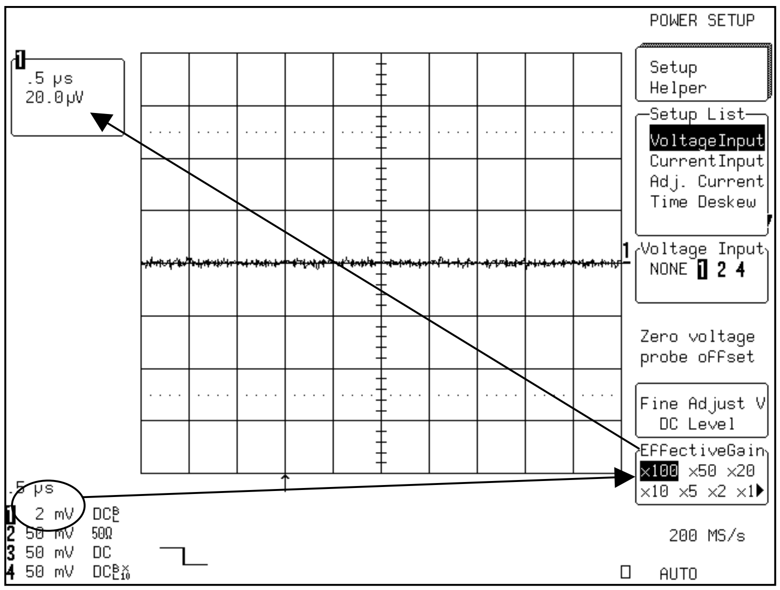
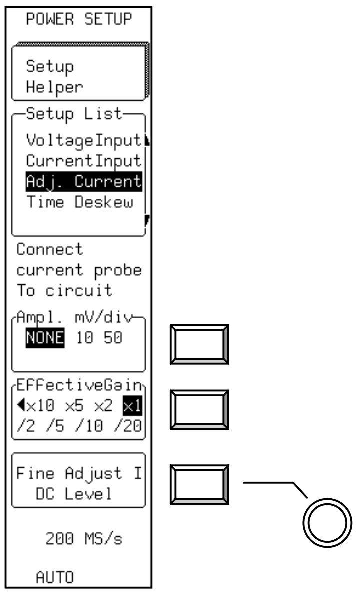


Figure 5.2: Effective gain of a voltage or current probe can be set from ÷10,000 attenuation to X1000 gain.

Current Input Setup Menus

Adj. Current menu with no amplifier normalization factor.

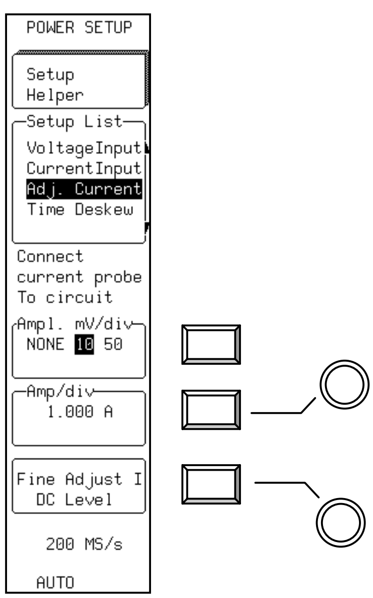


When an non-ProBus current probe is used that has no normalization factor, press the to select ***NONE*** in the **Ampl. mV/div** menu.

Determine the probe's effective gain factor and press the to enter that value in the ***Effective Gain*** menu.

If the current probe's DC offset cannot be adjusted to zero on the probe, use the ***Fine Adjust I DC Level*** to correct the level. Press the to reset the offset adjustment to its pre-adjusted value.

Adj. Current menu when the current probe has an amplifier with a 10 mV/div normalization factor. This menu is useful with the AM503 amplifier and its family of current probes.

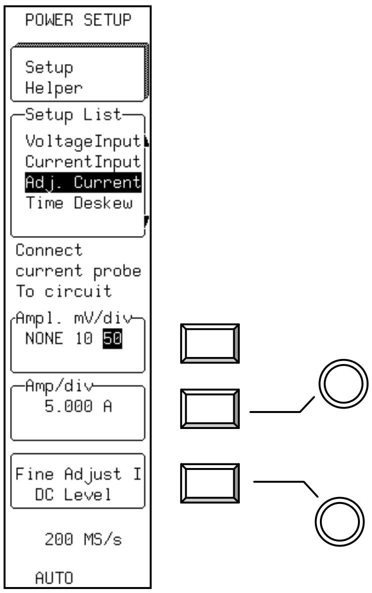


When a nonProBus current probe is used that has a 10 mV/div normalization factor, press the to select ***10*** in the **Ampl. mV/div** menu. When this selection is made, the ***Amp/div*** menu will appear.

Set the probe amplifier to the desired amp/div setting and turn the until the proper Amp/div factor appears in the ***Amp/div*** window.

If the current probe has DC offset that cannot be adjusted to zero on the probe, use the ***Fine Adjust I DC Level*** to correct the level. Press the to reset the offset adjustment to its pre-adjusted value.

Adj. Current menu when the current probe has an amplifier with a 50 mV/div normalization factor. This menu is useful when the DA1855 Differential Amplifier is used to measure the voltage across a resistor shunt.



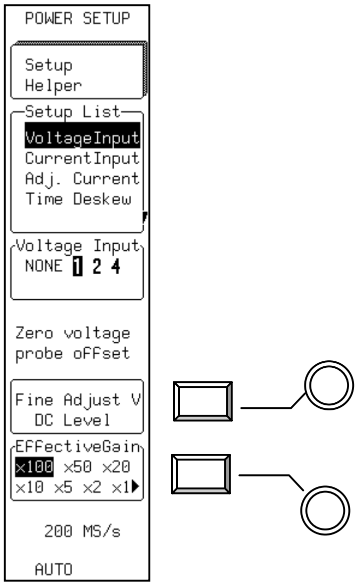
When a nonProBus differential voltage amplifier is used that has a 50 mV/div normalization factor, press the button to select ***50*** in the **Ampl. mV/div** menu. When this selection is made, the ***Amp/div*** menu will appear.

Set the differential amplifier to the desired effective gain setting and turn the knob until the proper Amp/div factor appears in the ***Amp/div*** window.

If the differential amplifier has a DC offset that cannot be adjusted to zero, use the ***Fine Adjust I DC Level*** knob to correct the level. Press the button to reset the offset adjustment to its pre-adjusted value.

Voltage Input Setup Menus

Voltage Input menu when the nonProBus voltage probe is used on the voltage input channel. This menu is useful when a non-A LeCroy DA1855 or Preamble Instruments 1855 Differential Amplifier is used to measure the voltage. It also can be used for other voltage probes and amplifiers.

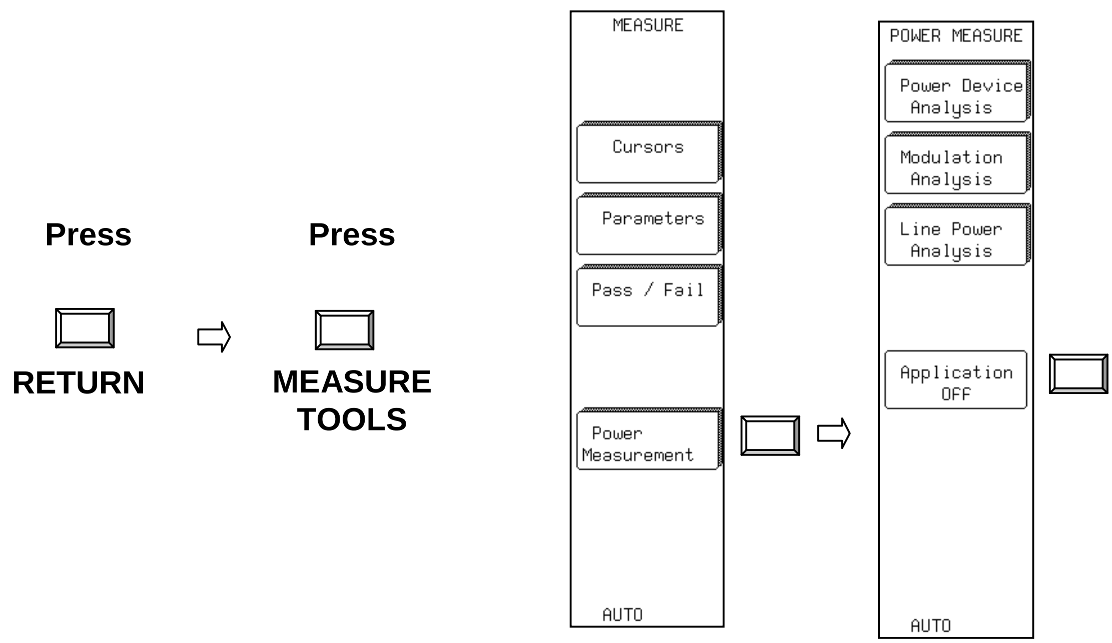


If the differential amplifier has a DC offset that cannot be adjusted to zero, use the ***Fine Adjust V DC Level*** to correct the level. Press the to reset the offset adjustment to its pre-adjusted value.

Set the differential amplifier to the desired effective gain setting and turn the until the proper effective gain factor appears in the ***Effective Gain*** window.

Clearing the Channel Assignments and DC Offsets

After using any section of PMA1, it is important to clear the channel assignments and other alterations that were made while making measurements. Press the **RETURN** until the on-screen menu is cleared. Then press the **MEASURE/TOOLS** to bring up the ***MEASURE*** menu.



Selecting ***Application OFF*** in the Power Measure menu changes the ***Voltage Input*** and ***Current Input*** assignments to ***NONE*** and removes any DC offset adjustments made while using the ***Fine Adjust V DC Level*** and ***Fine Adjust I DC Level*** features. Any ***Deskew Value*** set while deskewing channel-to-channel delay remains unchanged. The assignment of Ampere units to the channel selected as the ***Current Input*** channel will be removed.