Applications

INTRODUCTION

Some parts of a power supply operation, such as saturation voltage, upper gate drive, loop response etc, have been difficult to perform without the proper accessories to expand the measurement capabilities of oscilloscopes. To obtain accurate voltage and current waveforms is a necessity before any waveform analysis can occur.

VOLTAGE MEASUREMENTS

A significant limitation in power supply characterization is that many of the signals of interest are referenced to voltages other than ground. Several techniques have been tried to overcome this measurement limitation.

The most frequently used — and probably the worst one – is floating the oscilloscope by disconnecting the ground wire in the power-line cable. This allows the chassis of the oscilloscope to float to the potential to which the probe ground lead is connected. The most obvious danger is electrical shock. When an oscilloscope is floated to hazardous voltages, accidental contact with any metal component of the oscilloscope chassis can seriously injure or even kill the operator. Another problem when floating a scope is the inability to externally trigger the oscilloscope, or the waveform distortion that may occur when high slew rates appear on the ground lead.

Another technique used for measuring voltages not referenced to ground is quasi-differential or channel A minus Channel B. Even though this technique is safe, the oscilloscope is still grounded, it is still limited to measurements where the differential mode (signal of interest) is approximately the same amplitude or larger than the common mode signal (signal being rejected). A major problem however is the limited CMRR (Common Mode Rejection Ratio) caused by gain mismatches between the two input channels.

The best solution for measuring voltages that are not referenced to ground is to use a differential amplifier. The DA1855 is ideally suited for these measurements.

MEASURING CURRENT

Current can be measured either by using a shunt resistor or by using a current probe. Adding a shunt resistor requires cutting the current carrying conductor. Shunt resistors will add a resistance to the circuit that can affect the operation. It is difficult to obtain accurate resistors with low resistance and low inductance values necessary to measure large dynamic currents.

Current probes overcome these problems. Some models have a jaw that can be opened to install around conductors without the need to cut them. They come in two different types, AC and DC. The DC types can measure from DC to higher frequencies with relative flat frequency response. AC current probes have both a low frequency and a high frequency response. Many AC current probes have a low frequency cut-off of 40 Hz or higher, eliminating the ability to measure power at line frequencies

SETUP AND CONFIGURING FOR POWER DEVICES ANALYSIS

The following example uses the power transistor's drain to source voltage of a flyback type switching power supply as a trigger

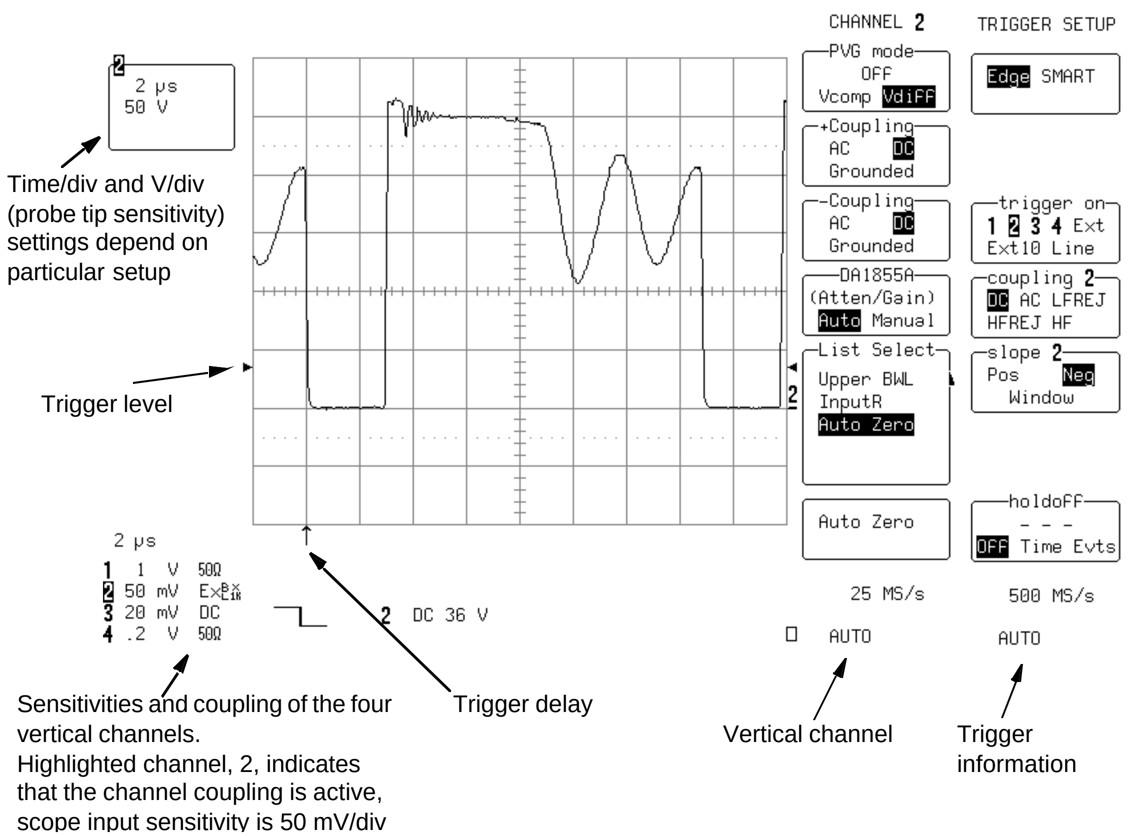

Figure 5-1. Oscilloscope Screen information.

signal as well as the signal to be used to measure the device's dynamic saturation voltage.

EFFECTS OF PROBES ON SATURATION VOLTAGE MEASUREMENTS

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

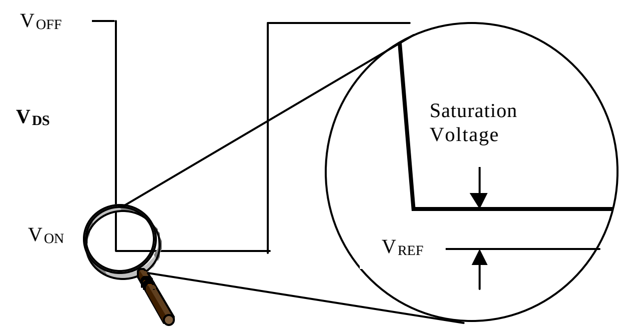

Figure 5-3. Saturation Voltage

The most obvious problem with this measurement is the signal's wide dynamic range. The voltage across the device can be several hundred Volt when the device is off and then drop to less than a Volt as the device turns on (Figure 5-3).

To measure the saturation voltage of a device to 100 mV accuracy when the OFF voltage is 400 Volt requires 250 ppm measurement capability. To accurately view the device's approximately 1 Volt ON-voltage with an oscilloscope, the vertical sensitivity must be set to 200 to 500 mV/div. Almost all of the signal will be off-screen. Also this voltage change occurs in a fraction of a microsecond. This means that the oscilloscope must be able to accurately display sub-1 Volt signal less than a microsecond after being overdriven by several hundred divisions. It is obvious that the oscilloscope input or an input preamplifier such as the DA1855A needs to recover and therefore that a probe with high frequency performance is required.

To overcome the overdrive problem is to use a specially designed fast clipping circuit to limit the magnitude of the signal at the oscilloscope's input to a value within the linear range and to turn ON and OFF fast enough so not to compromise the measurement integrity. Another solution is to use a differential pre-amplifier specifically designed to recover from being overdriven and to cleanly clip the signal so the oscilloscope is not overdriven. Of equal importance to the amplifier's overdrive recovery performance is the oscilloscope or differential amplifier's probe performance. Probes play an important role in device ON-voltage measurements. They attenuate the voltage's magnitude as well as provide a convenient way of connecting to the device under test. in addition to attenuating the input signal they also attenuate the rate of change of the oscilloscope or differential amplifier's input signal. A ÷100 passive probe will attenuate a 400 Volt signal with a dv/dt of 10 V/nsec to a 4 Volt signal with a dv/dt of 0.1 V/nsec.

Less obvious is the effect of a probe's low frequency compensation adjustment on the measurement accuracy of device saturation voltage. Most oscilloscope 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 made with the entire waveform visible on screen is usually adequate for most measurements.

However when a signal's amplitude is greatly magnified as can be the case when using a differential amplifier, a small error in the low frequency compensation flatness can cause major error in voltage measurements, especially when measuring saturation voltages.

The following figures 5-4A through 5-4D illustrate how this seemingly minor adjustment can make the saturation voltage's DC level appear to be incorrect.

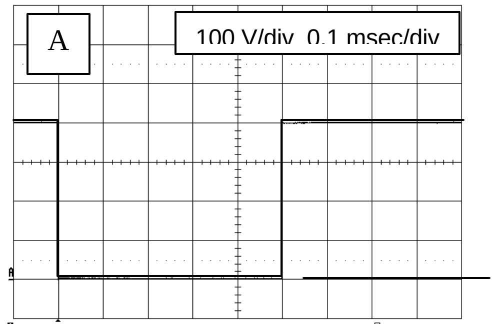

Figure 5-4A. A voltage probe appears to be properly compensated on a 400 V square wave when viewed at 100 V/div.

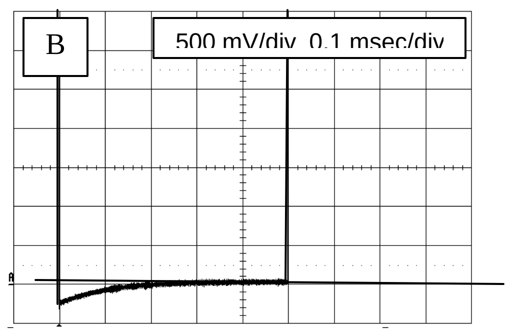

Figure 5-4B. When viewed at 500 m/div, the same 400 V square wave shows the probe compensation to be slightly overpeaked.

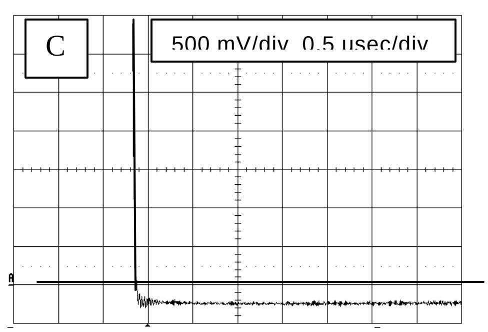

Figure 5-4C. when the time/div is decreased to value normally used to view 20 to 150 kHz switchmode power conversion circuits, the slightly peaked LF compensation appears as a DC level shift.

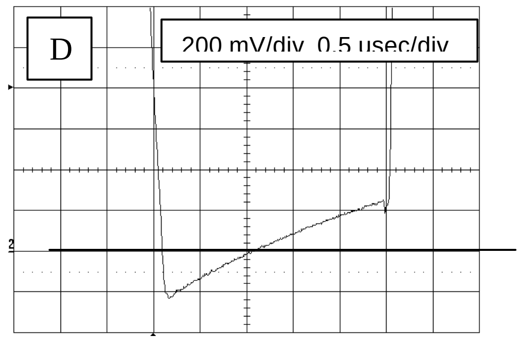

Figure 5-4D. Viewing a power FET's saturation voltage with the slightly peaked LF compensation makes the voltage appear to go negative. In this example the repetition rate of the power supply is 60 kHz.

SATURATION VOLTAGE MEASUREMENT

To measure the saturation voltage of a power device in a flyback type switching power supply, connect the **+INPUT** probe to the drain and the –**INPUT** probe to the source of the switching device (Refer to figure 4-1). There is no need to 'float' the oscilloscope. The probe connected to the –**INPUT** becomes the reference lead (same as black lead on a DMM). The DA1855A will reject the power line portion (common mode part) of the signal and allows us to see the actual signal of interest. Set the **VOLTS/DIV** to 50 mV/div and adjust the **OFFSET** to read 00.000 on the DA1855A front panel indicator. Press the Autozero button to autobalance the amplifier.

Refer to figure 5-5 where the start of the saturation voltage measures close to 0.0 Volt since the switching device is OFF and ramps up due to the increase in current through the primary of the transformer. If this starting point does not come close to the 0 Volt line, then it could indicate an incorrect low frequency adjustment of the probes.

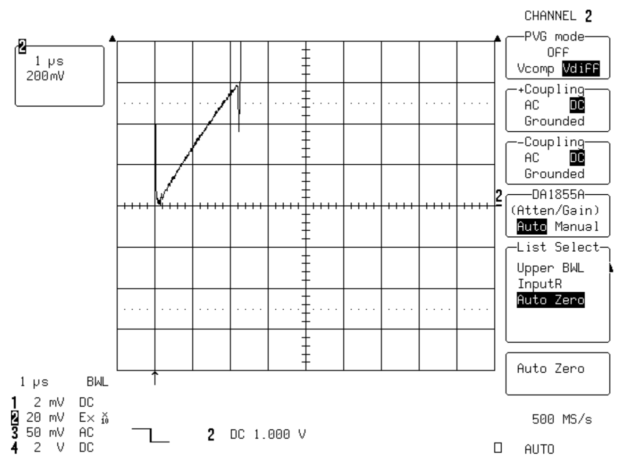

Figure 5-5 Saturation Voltage

GATE DRIVE VOLTAGE

The main reason to measure the gate drive voltage is to assure rapid turn-on and turn-off and to assure that the transistor is fully saturated.

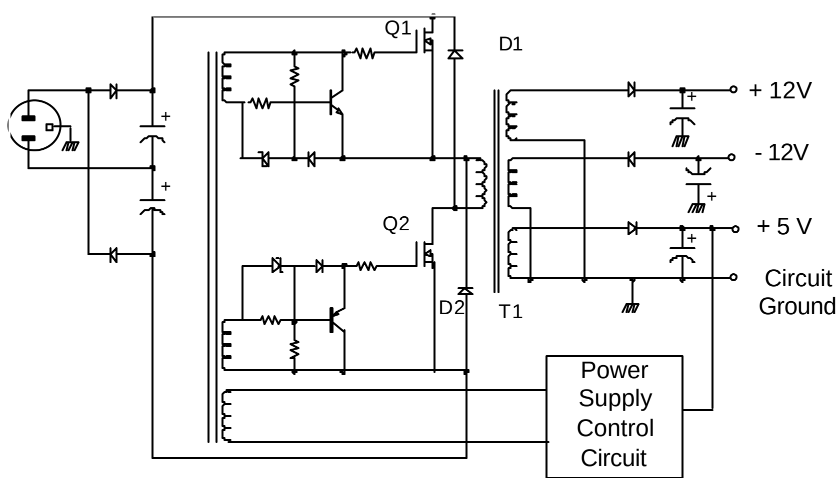

Figure 5-6 Switching power supply with upper and lower FET drive.

Care must be taken when acquiring the switching's device gate drive signal. In off-line switching power supplies, the switching devices are elevated to line potential. The DA1855A is ideally suited for this application with its high CMRR.

The following discussion demonstrates how the DA1855A Differential Amplifier and a XC100 Differential Probe are used to make measurements such as upper gate drive signal on a switching power supply. A simplified schematic of such a flyback type power supply is shown in figure 5-6. In this circuit both Q1 and Q2 are ON at the same time. D1 and D2 limit the voltage caused by the primary's leakage reactance to the rail voltages.

Figure 5-7 shows the signal on the drain of Q2 with respect to ground as measured by a ground referenced oscilloscope. This signal is the combination of line voltage and the drain to source voltage.

By using the DA1855A and the XC100 probe, the signal reference point can be changed to any point in the circuit. To select the source of Q2 as the reference point, connect the **–INPUT** probe to that point. To acquire the drain to source signal of Q2 place the **+INPUT** probe on the drain of Q2 and select DC coupling on both inputs. The amplifier will reject the power line portion (common mode) of the signal and allows us to see the drain to source signal.For this measurement, the XC100 is set to ÷100 and the DA1855A is set for ÷10 attenuation and a gain of X1. The total attenuation from probe tip to the oscilloscope is 1000.

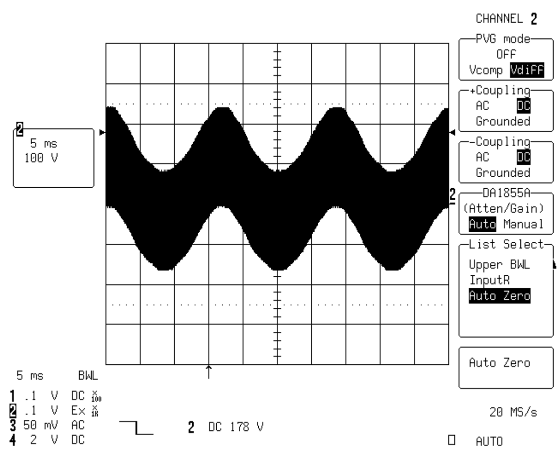

Figure 5-7. Signal at Q2 drain with respect to ground.

This value is displayed on the front panel **EFFECTIVE GAIN** indicators as well as EX 1K on the oscilloscope screen next to the highlighted channel to which the amplifier is connected.

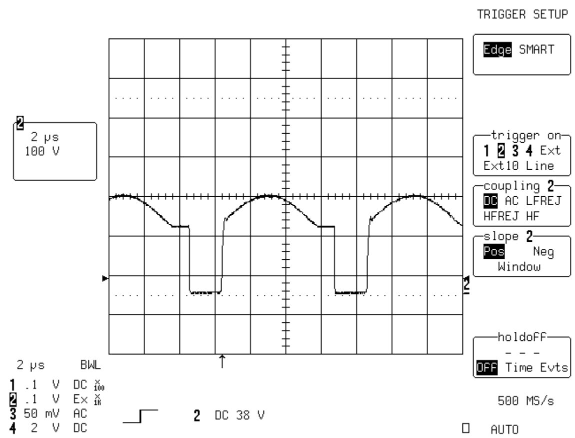

Figure 4-8. Q2 Drain to Source voltage

Selecting the differential mode by selecting $\mathbf{V_{DIFF}}$ on the PVG mode menu section and setting the **OFFSET** to 245 Volt, will move the trace down about 2½ divisions. Figure 5-8. This means that the drain voltage with respect to the source is 245 Volt when the top part crosses the oscilloscope's screen horizontal center line.

Rejecting the AC line voltage was no real challenge, but rejecting the drain to source signal is a real measure of system ability. As can be seen from figure 5-9, the drain to source voltage rises over 245 Volt when the FET turns OFF. The maximum rate of rise of this signal is about 15 V/nsec followed by a ring at the bottom of the waveform. It will be necessary to adequately reject this signal if upper gate signal is the be measured accurately.

UPPER AND LOWER GATE DRIVE

To examine the gate drive signal on the upper FET's Q1, the **–INPUT** probe will be connected to the source of Q1 and the **+INPUT** probe to the gate of Q1. The XC100 probes are set for an attenuation of ÷100 and the DA1855A for an attenuation of ÷1 and a gain of X1. The **EFFECTIVE GAIN** indicator should read an overall gain of ÷100. To make room for other traces, the **OFFSET** control on the oscilloscope was set to –5.0 Volt, moving the trace up one division. Figure 5-9.

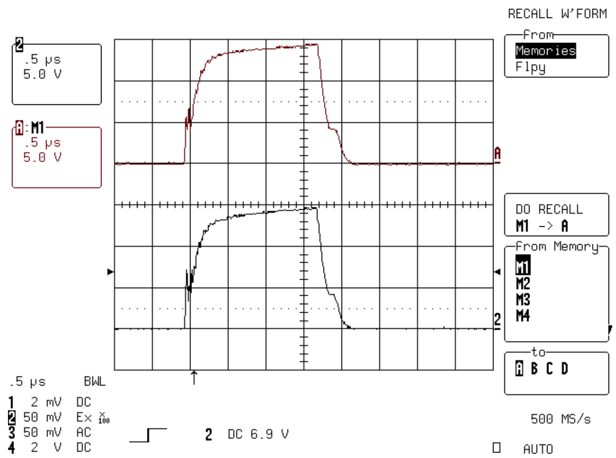

Figure 5-9. Comparison of Upper and Lower Gate to Source Voltages.

The same procedure is repeated for Q2 gate drive where the result is shown in figure 5-10 where the **OFFSET** is set to +15 V to move the trace down by 3 divisions. By setting the m**VOLT/DIV** to a more sensitive setting, small details of these signals can be examined

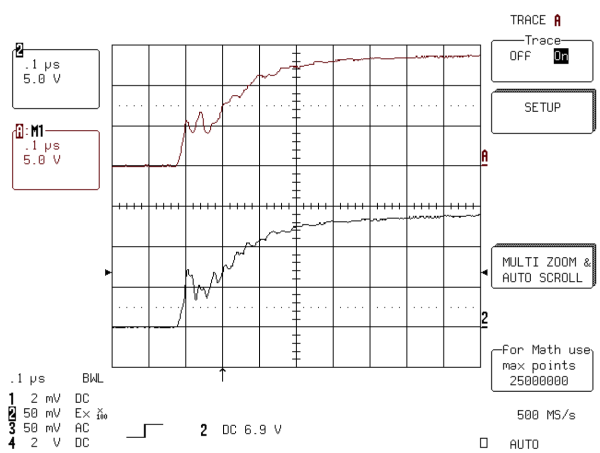

Figure 5-10. Comparison of Upper and Lower Gate to Source Voltages with expanded time/div setting.

AVOIDING MEASUREMENT ERRORS

The math capabilities in modern digital oscilloscopes can save time and effort. Both scalar measurements and waveform math provide direct answers for measurements that used to require considerable computation and analysis.
This functionality can cost time when erroneous results lead the user astray. The cause of erroneous results are:

- Errors in conditioning the input signal, such as clipping or bandwidth limiting.
- Limitation in the acquisition process, such as sample rate, resolution and record length.
- Limitation in the computational algorithms.

The most common source of error in power measurements results from the time delay (skew) between the voltage and current waveforms. The propagation delay through the current probe and the voltage probe plus differential amplifier are almost never equal. To eliminate resulting error in power waveforms, it is necessary to deskew the input signals. Some oscilloscopes have a deskew function that can be used to shift the time reference of one of the waveforms relative to the other.

Another error to be concerned with is the phase shift in the probes or instrument. As the rise time of the input signal approaches the rise time of the current probe or amplifier, the phase shift will create an amplitude error in the power waveform.

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