Phase Node Measurement Techniques

Introduction

In a fast switching converter, the high slew rates of voltage transient (dv/dt) and current transient (di/dt) results in high conducted and radiated EMI due to the loop parasitic [1]. These electromagnetic emissions must be within the limit for the product to meet the regulatory compliance. Thus, one of the important goals of a design engineer is to optimize the power loop to minimize the parasitic.

The power loop inductance comprises of the series inductance of the input capacitor, PCB traces, and package inductance (drain, source inductances) of the power MOSFETs. The phase node waveform characteristics, such as the ringing, overshoot, and ground bounce, are the result of the parasitic energy stored in the loop.

In a DC/DC converter as shown in Figure 1, the phase node experiences voltage overshoot and ringing especially during the switching transient between the turn off the HSFET (M1) and turn on of the LSFET (M2). The magnitude of the ringing is highly dependent on the high-side MOSFET's switching speed and the stray inductances in the loop. The ringing will be gradually damped by the ac resistance in the loop. It is possible to estimate the loop parasitic damping factor at the resonance by capturing the phase node waveform accurately [2].

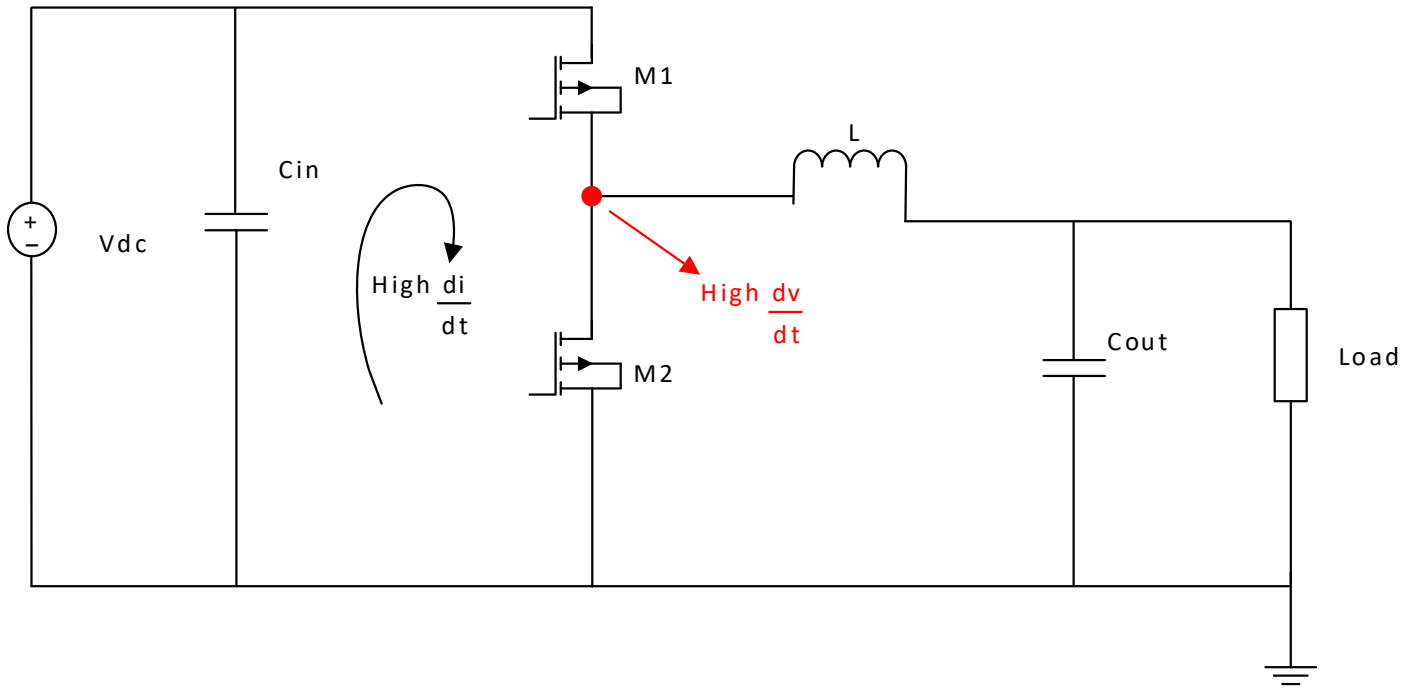

Figure 1: Schematic of a DC/DC converter

Methods to measure the phase node waveform

The stray inductance in the loop can easily estimate if the phase node waveform is accurately measured. To ensure that the actual stress on the device is seen accurately in the captured waveform, it is vital to place the probe tips as close as possible to the device.

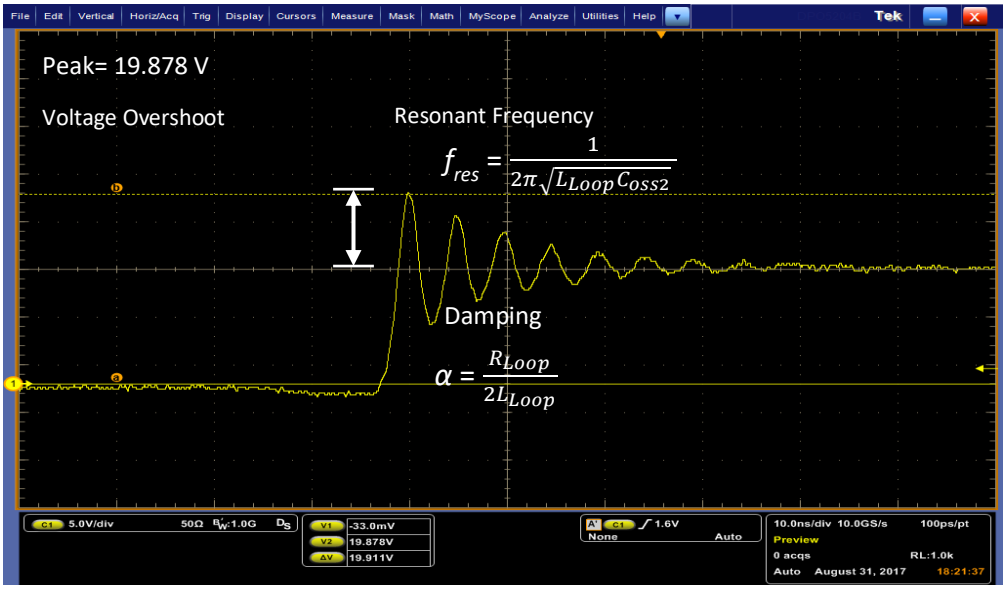

Figure 2: Phase node waveform observed with Tek IsoVu Probe

IsoVu probe

The Tektronix IsoVuTM probe, as shown in Figure 3, is considered one of the best in class probes due to the high CMRR of 120 dB from DC to 100 MHz and 80 dB rejection at 1 GHz [3]. The waveform thus measured from the IsoVu probe is taken as reference to find the best phase node measurement technique. The peak voltage observed in the waveform is 19.88 V. We will consider this voltage as a reference for our comparison.

Figure 3: Tek IsoVu Differential probe

Single ended measurement with 3-inch ground loop wire

In the single ended measurement, placement of the passive probe tip is at the phase node pin and the 3-inch wire ground tip, located at the ground test point on the board. The measured phase node pin is shown in Figure 5.

The peak observed in the waveform is 21.67 V and is 1.79 V higher than the actual ringing observed with IsoVu probe, shown in Figure 4.

The long wire loop acts as an antenna by picking up any radiated noise emitted by the evaluation board and yields a higher value of switch node voltage ringing than what is seen by the device.

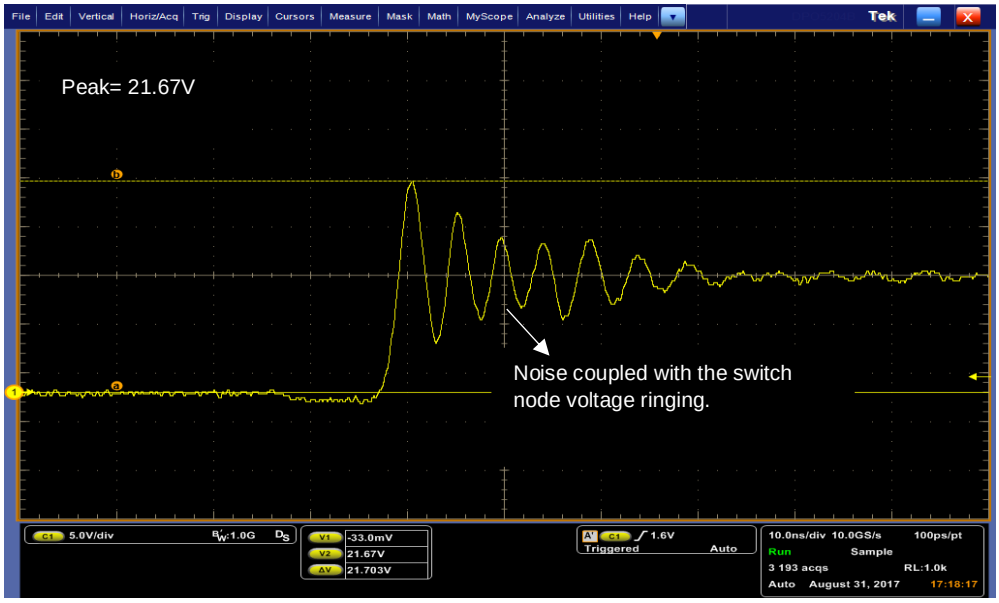

Figure 4: Phase node waveform observed with single ended measurement and 3-inch group loop wire

Figure 5: Passive probe with 3-inch group loop wire

SMD test point measurement

The SMD test point setup is comprised of two test points as shown in Figure 7: An SMD test point to place the probe tip and a through hole test point to provide the ground connection. This arrangement reduces a lot of noise in the phase node waveform due to the reduction in the ground loop. The setup is flexible enough to accommodate many different manufacturer's oscilloscope probes.

The waveform shown in Figure 6 is captured from the test point measurement. The peak observed in the waveform is 19.78 V as shown in Figure 6 and is quite close to the voltage observed with the IsoVu probe.

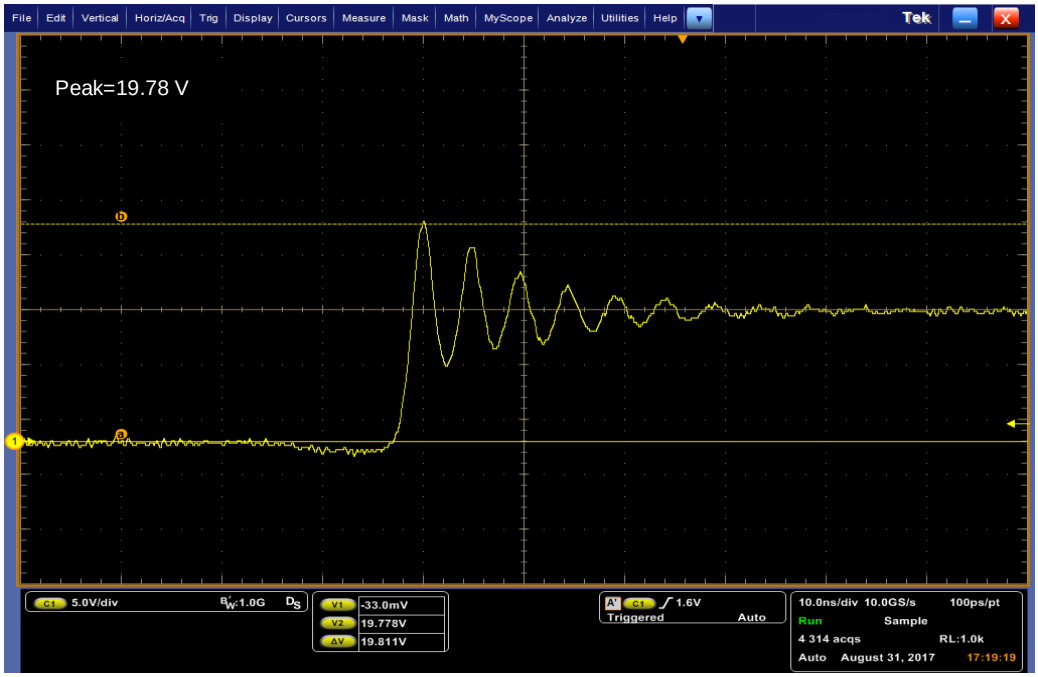

Figure 6: Phase node waveform observed SMD test point

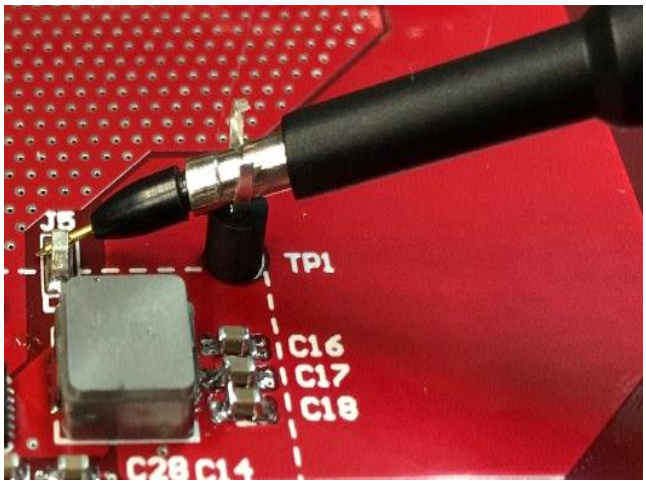

Figure 7: Passive probe with SMD test point and test point used for short ground loop

Pig tail method

Pig tail method is another way of measuring the phase node waveform accurately. The setup uses a pig tail bus wire for ground connection which is soldered to a ground point closest to the node of interest as shown in Figure 9.

The peak observed using this method is 19.98 V as shown in Figure 10 and is close to the value recorded from the IsoVu probe.

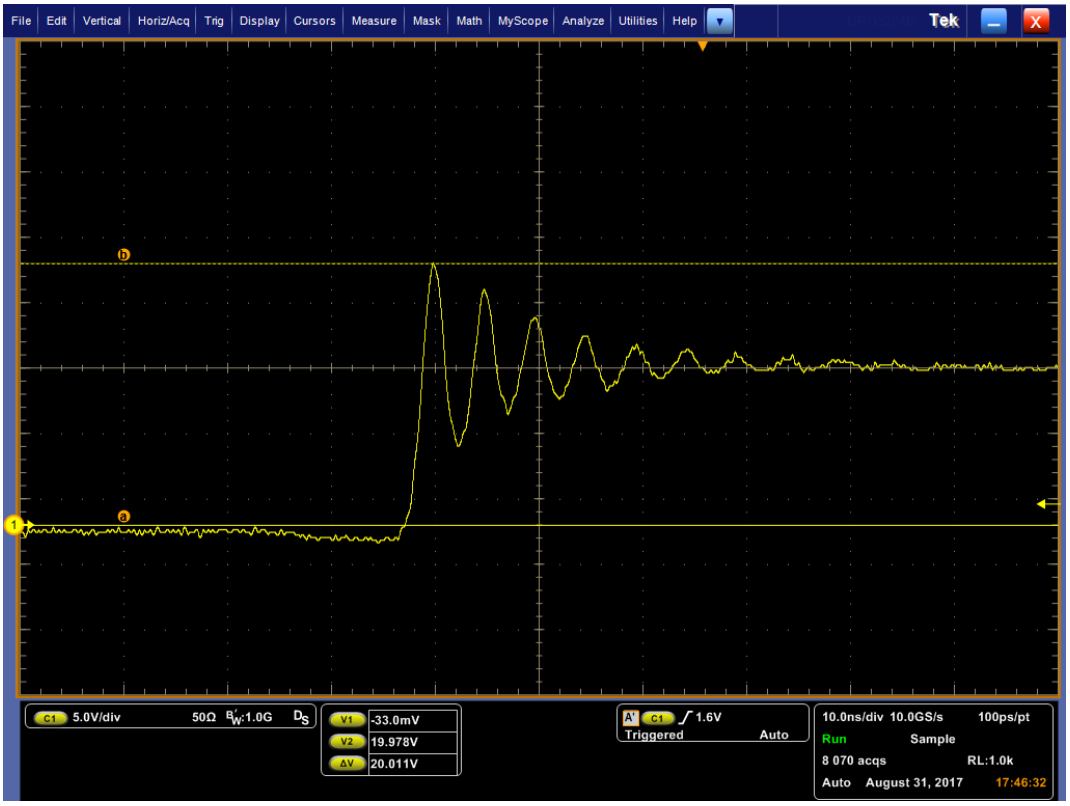

Figure 8: Phase node waveform observed SMD test point

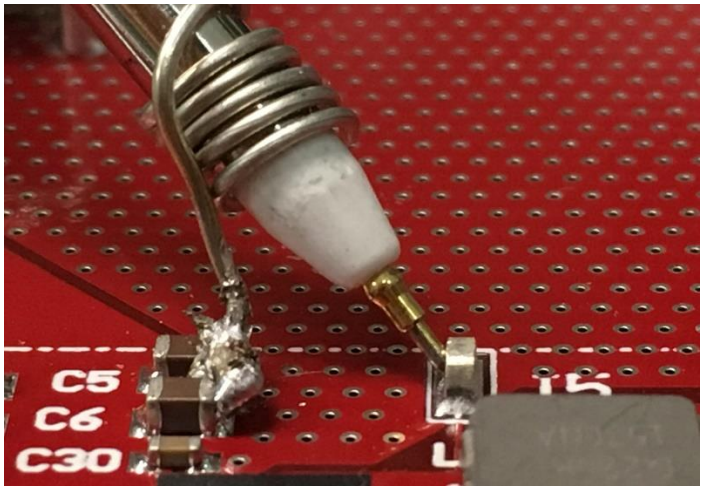

Figure 9: Passive probe with Pig tail ground

Conclusion:

The data collected infers that the probe with the standard 3-inch wire for the ground measurement is an incorrect way of measuring the phase node waveform due to the coupled noise. The data obtained from the SMD test point and pig tail method is like the one observed with the IsoVu probe as shown in Figure 10. From this waveform, we can estimate the loop parasitic by damping resistance in the circuit and optimize our board layout to minimize the loop parasitic.

As discussed, our goal is to reduce the parasitic energy stored in the stray inductances in the loop. This is done by pushing the resonance to a higher frequency by reducing the inductance in the power loop. Additionally, having the resonance at a higher frequency will damp the ringing oscillations faster due to an increase in the AC resistance because of Skin effect.

References:

[1]. J. Wang and H. Shu-Hung, “Impact of parasitic elements on the spurious triggering pulse in synchronous buck converter.” IEEE Trans. on Power Electronics, December 2010, pp. 6672-6685.

[2]. “Ringing Reduction Techniques for NexFETTM High Performance MOSFETs.” Texas Instruments Application Report SLPA010 – November 2011.

[3]. “Tektronix IsoVu Measurement System”, White paper, Tektronix - March 2016.

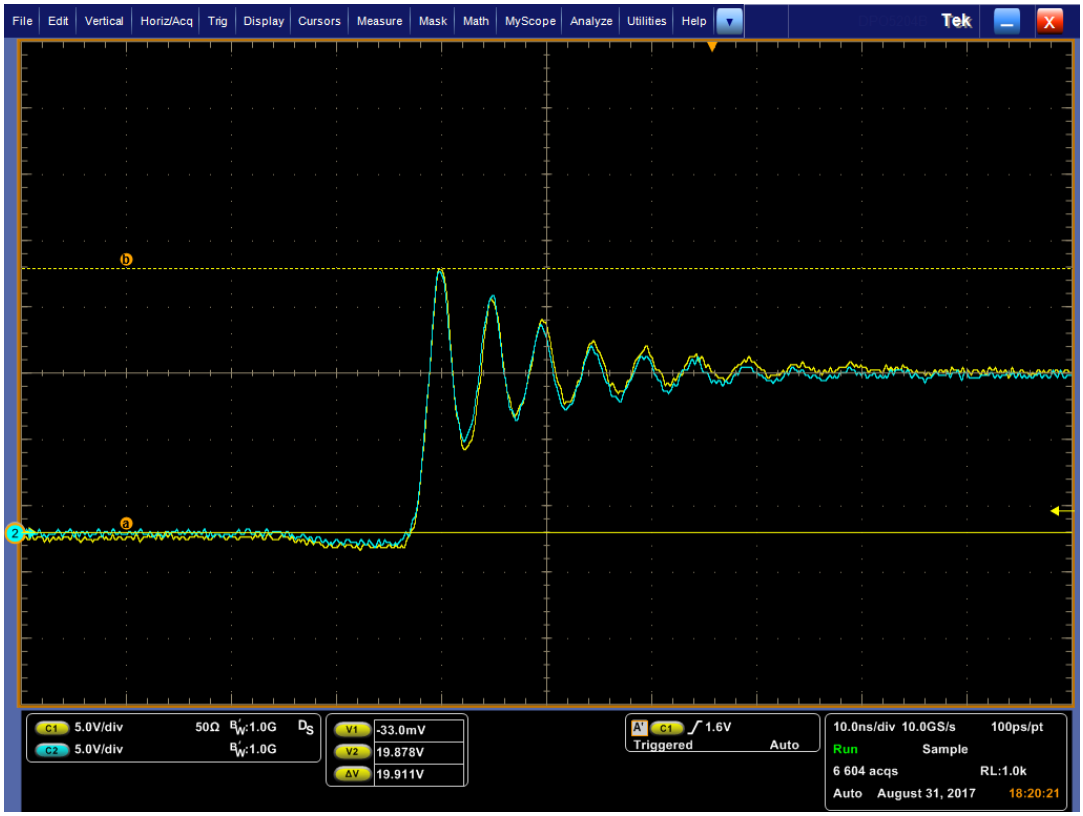

Figure 10: Phase node with Pig tail method and IsoVu probe measurement

Revision History

Date	Revision	Notes	Author
March 7, 2018	1.0	Initial Release	RS
July 3, 2019	2.0	Text edits. Update headers/footers and update to new logo.	CR