How to Effectively Measure High Performance eGaN® FETs in Applications

Motivation

Advancements in eGaN FET-based converters' in-circuit capability drives high performance measurement requirements. This article compares various measurement techniques and technologies' capability of accurately evaluating high performance eGaN FETs in applications.

Impact of bandwidth on measurement

When evaluating an eGaN FET based converter such as a half-bridge, typical waveform measurements of the drain and gate include rise and fall times, peak overshoot, undershoot and overshoot ringing frequency. The choice of system bandwidth impacts these measurements directly. Typically, the measurement system has a low-pass characteristic as shown in figure 1. The position of the ringing frequency of the measured waveform with respect to the system bandwidth decides the accuracy of the measurements. This is shown in figure 2 for low (500 kHz) and high (10 MHz) switching frequency prototypes, that can be measured using a 2 GHz bandwidth MSO5204 and 1 GHz TPP1000 probe from Tektronix. Most of the parameters are measurable for the low frequency board, even with reduced system bandwidth, however only dead time is partially measurable for the high frequency board, and only under high system bandwidth setting (500 MHz and 1 GHz).

Impact of measurement techniques

To capture a reliable and high-fidelity waveform, it is important to use a proper probing technique together with a probe having low input capacitance and a short ground loop connection feature. While a long ground lead is convenient because the user can make one ground connection and probe many test points within the range of the ground lead, it has distributed inductance which interferes with overshoot and ringing frequency measurement. The impact of using a long ground lead (alligator clip) over a short one (spring clip) is illustrated in figure 3. The short ground lead provides a much cleaner waveform with a measurable ringing frequency. While the relative position between the probe leads is important, i.e., short ground loop, the absolute position of the leads does not impact the measurement as much. The "far point" in figure 3 is farther away from the eGaN FETs than the "near point", but with the short ground loop, the corresponding waveforms are almost identical.

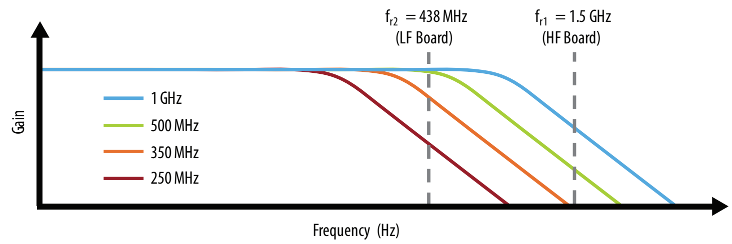
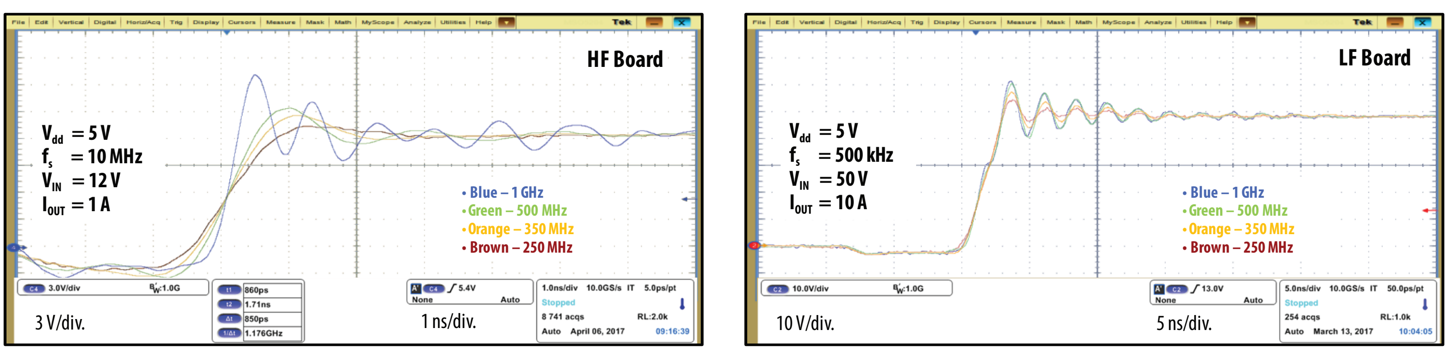


Figure 1: Low-pass characteristic of a typical scope + probe system



System Bandwidth	250 MHz	350 MHz	500 MHz	1 GHz
Dead time	×	×	✓	✓
Ringing frequency	×	×	×	×
Overshoot	×	×	×	×
Rise time	×	×	×	×

System Bandwidth	250 MHz	350 MHz	500 MHz	1 GHz
Dead time	✓	✓	✓	✓
Ringing frequency	✓	✓	✓	✓
Overshoot	×	×	✓	✓
Rise time	✓	✓	✓	✓

Figure 2: Impact of measurement system bandwith on switch node measurements

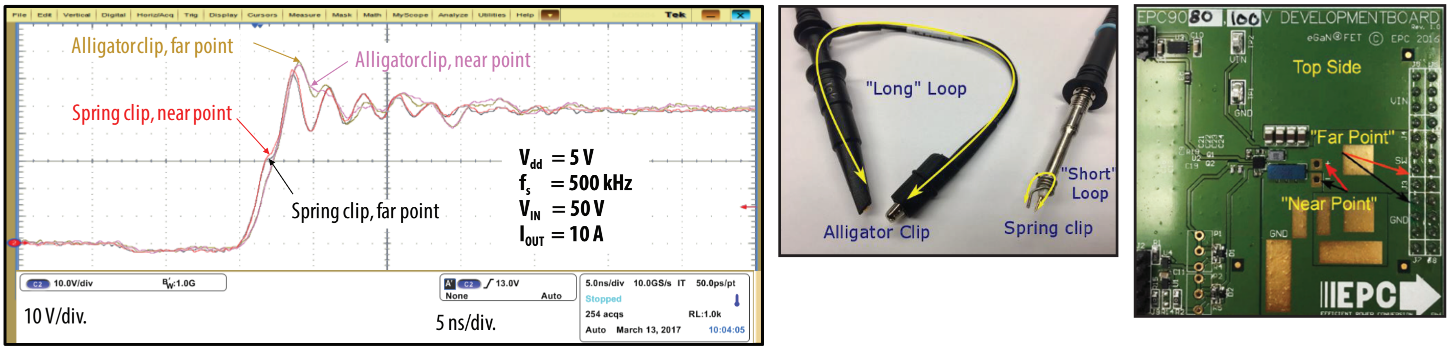


Figure 3: Effect of measurement techniques and choice of measurement point

Differential measurements with high common mode signals

In many eGaN FET based power electronic circuits such as a half-bridge, high common-mode differential voltage measurements are critical, such as the gate-source of the high side switches. The reference node in this case switches between low and high common-mode voltage, and ordinary differential probes do not have sufficient common mode rejection ratio (CMRR) to capture this waveform correctly. Using the math mode in an oscilloscope is one method of measuring these waveforms indirectly, but suffers from channel mismatch, poor CMRR and common mode voltage overdrive on the oscilloscope inputs. Isolated optical measurement systems, such as the Tektronix IsoVu TIVM1, which boast of high bandwidth (1 GHz), extremely good CMRR (>120 dB @ 100 MHz) and large input impedance, can mitigate these measurement issues. Figure 4 shows the advantage obtained when using these measurement systems compared to using two probes and subtracting one from the other using the oscilloscope's math function.

Conclusion

Various measurement considerations for eGaN FET based power converter designs have been described in this article. The impact of bandwidth, probing techniques and appropriate use of high-bandwidth isolated probes have been covered.

Typically, as shown in Table 1, current state-of-the-art measurement systems (Bandwidth ~1 GHz) are adequate for characterizing the majority of eGaN FET based converter designs. Additionally, it is important to use a probe with low input capacitance and short ground loop in order to make these measurements accurately. Combining better measurement technologies and techniques with improved understanding of the requirements of the measurement system for a specific application, circuit designers can better optimize their high performance eGaN FET based designs.

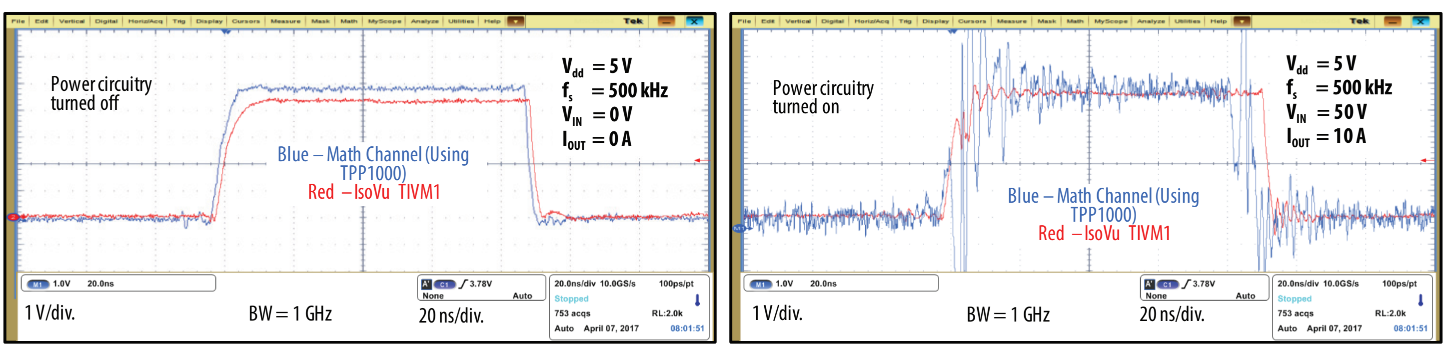


Figure 4: Impact of high common mode switching signals on differential voltage of a high side device: comparison of two probes using the Math Mode vs. IsoVu TIVM1

Die Size	Part Number	C_{oss} (pF)	Q_{gd} (nC)	$R_{DS(on)}$ (mΩ)	Min BW (GHz)	$t_{rise/fall, system}$ (ns)
Small	EPC8010	25	0.06	160	> 1	< 0.25
Medium	EPC2016C	210	0.55	16	0.5-1	1.5 - 2
Large	EPC2001C	430	1.2	7	0.5	2 - 3
XL	EPC2022	840	2.4	3.2	0.5	3 - 4

Table 1: Estimation of system requirements based on eGaN FET size