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Assessing Point-Of-Load Regulators Using Non-Invasive Techniques

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Evaluating the stability of a Point-Of-Load ("POL") regulator can be performed using both traditional Bode plot and output impedance measurement techniques. Measuring output impedance has an advantage over the Bode plot in some cases as the output impedance test can be non-invasive.[3] With the right equipment, the non-invasive measurement does not require access to the control loop, such as an injection resistor or transformer. The test techniques used to make these measurements are generic and apply to any control loop (e.g. switching regulators, LDOs, filters, etc.).

The stability of a POL regulator is shown in the Bode plot in Fig. 1 . The gain-phase information for the POL regulator is also shown, using the same data, in a Nyquist plot (Fig. 2).

Specific points along the Nyquist curve can be used to evaluate the effective circuit Q via the proximity to the singular unstable point (1,0).

These calculations indicate that the stability of the POL is significantly worse at 109.9kHz than at the POL bandwidth of 90kHz. This performance degradation is primarily due to the rapid phase rolloff from the sampling effects of the switching.

Output Impedance

There is no distinction as the non-invasive measurement reflects the closest point to the singular unstable point (1,0) encompassing both in a single measurement, while the Bode plot attempts to determine stability from two points on the gain vector. A 2-port shunt through VNA measurement is used to determine the output impedance with the switching regulator in a powered state (solid line) and an unpowered state (dashed line) in Fig. 3 . This measurement is only valid from very low impedances to approximately a few ohms. The unpowered state allows us to measure the output capacitors. Selecting the point at 1 Ω and 10kHz allows us to calculate the capacitor's output capacitance; 16µF. This is consistent with other measurements of X5R capacitors, which are typically 80% of stated value (which is 2 x10 µF on this board) in an unbiased state. The output capacitance then falls rapidly as the DC bias is applied.

Non-Invasive Measurement

The impedance measurement was also repeated using the Picotest J2111A Current Injector in a non-invasive phase margin measurement. The Current Injector, a voltage controlled current source, is driven by the VNA's oscillator, resulting is an ac current that is in parallel with the normal circuit load. The stimulus and the results measurement are non-invasive to the circuit performance. The output impedance plot, along with the corresponding group delay plot using the J2111A is shown in Fig. 4 .

Note that the peak in impedance and group delay occur very close to the mathematical result of 110kHz with a corresponding Q of 3.3. The resulting phase margin can be mathematically derived from the group delay. It is shown for this example as the Bode 100 cursor measurement, indicating an effective phase margin of 17.6 degrees at 111 kHz.

The traditional Bode plot and the non-invasive measurement would reveal the same result if the crossover frequency was the most unstable point of the system. In such cases, the non-invasive measurement indicates the least stable point, which may be more valuable than the crossover frequency and associated phase margin.

References

1. “New Technique for Non-Invasive Testing of Regulator Stability”, Steven Sandler and Charles Hymowitz, AEi Systems, Power Electronics Technology, September 2011

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3. “When Bode Plots Fail Us”, Steve Sandler, Picotest and Paul Ho and Charles Hymowitz, AEi Systems, Power Electronics Technology, May 2012.

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