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Connections to Evaluation Boards

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In many measurements, connections to the Device Under Test (DUT) is very important and can fundamentally determine whether the data we get is correct or not. This article highlights some useful items to consider. To illustrate the points, we use examples with DC-DC converter evaluation boards.

If our circuit will be part of a bigger system, laid out on a printed circuit board, chances are that all connections will be on the printed circuit board itself in form of traces, planes and vias. Occasionally we may have connectors in our final applications, but there is a high likelihood that the connector chosen by the evaluation board designer is different from what we end up using. So what should we expect from the connectors and connections on an evaluation board? What are the 'good' connectors and connections for an evaluation board?

One thing is for sure: we should not expect the kind of connections and connectors that we would use in our application, simply because there are many possible applications, potentially each requiring different solutions. Instead, the evaluation board should focus on the needs of the circuit to be demonstrated. As an illustration, first we look at the power input and power output connections on the DC-DC converter evaluation board in *Figure 1*, which are little turrets.

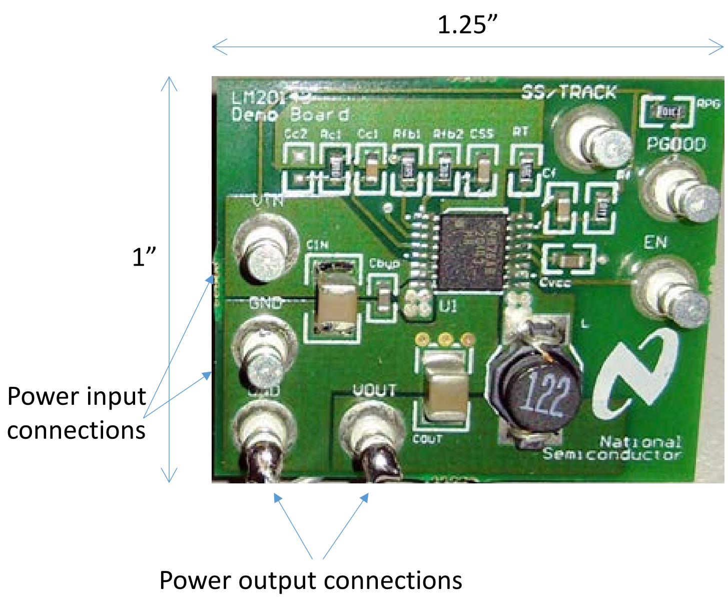

***Figure 1**: Evaluation board of a 3A DC-DC converter (courtesy of Texas Instruments).*

We can make connections to them by soldering wires or by using crocodile clips. The switch-mode DC-DC converter has a maximum output current of 3A. The entire circuit is laid out on a 1" x 1.25" (approximately 25 mm x 32 mm) printed circuit board. The low current does not require, and the very small board size does not allow, the use of large connectors. On this evaluation board the choice was made to use the same little metal turrets for all connections: along the left edge and bottom edge there are two turrets each for power input and power output and the three turrets on the upper right are signal connections: they are the Enable, PowerGood and SoftStart/Track pins. As it was illustrated in [1], these connections are well suited for attaching the power source, the load and even the vector network analyzer to measure the output impedance of the regulator up to a few MHz frequency. If we wanted to measure the output voltage ripple across the power connections, the same turrets can be used. Alternately, we can also measure across the 1210-size 47uF ceramic capacitors next to the turrets. However, in this latter case we need to accept distortion and we need to understand how to interpret the data properly [2].

As an illustration, *Figure 2* compares the output ripple waveform measured simultaneously across the output turrets (blue trace) and across the output capacitor (red trace). We can switch the cables and/or the oscilloscope inputs and we can convince ourselves that the difference in the measured magnitude is real, showing that across the output capacitor we measure much lower ripple voltage. Note that this measurement intentionally does not show the high-frequency burst noise on the output, because the measurement bandwidth was limited to approximately 20 MHz. As it was explained in [2], the parasitics around a capacitor create a filter with the rest of the plane structure, and dependent on the relative position of the switching frequency and impedance minimum of the output capacitor(s), we could get a wide range of amplification or attenuation. In this particular case we get a significant attenuation, because as it is shown in *Figure 3*, the 1.5 MHz switching frequency is above the impedance minimum.

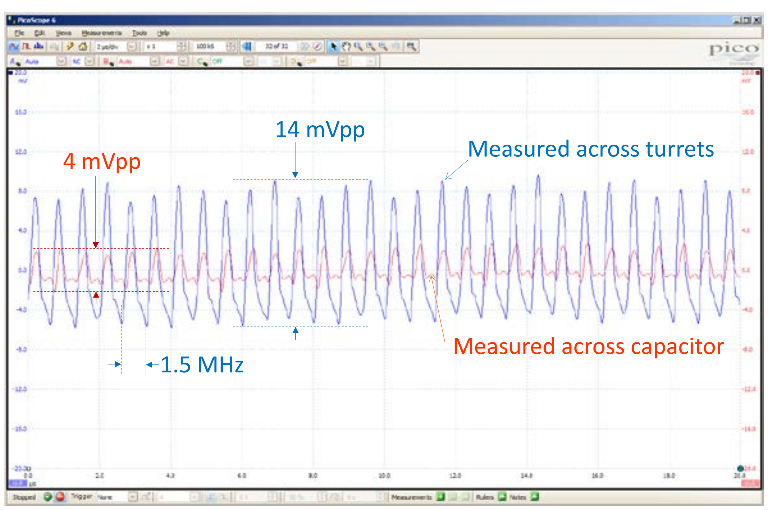

Figure 2*: Output ripple voltage measured at two different locations.*

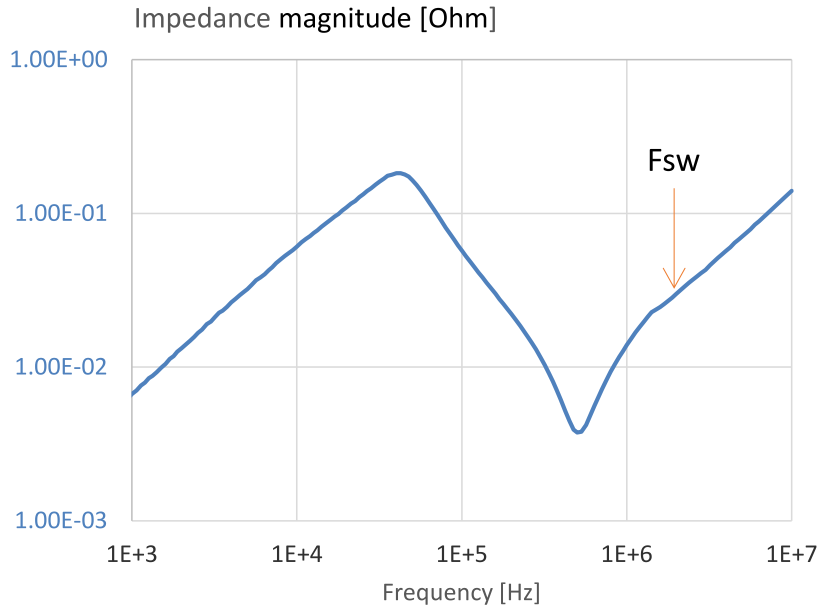

Figure 3: *Measured output impedance of the converter, with the switching frequency marked.*

For output impedance measurements on low-current DUTs, the turrets provide a convenient connection because at the turrets we can solder wires and cables on both sides of the board. We also need to decide: what is the frequency range of our measurement? For DC-DC converters we need to look at the frequency range that is determined by the converter. If we extend the measurement frequency range up to about ten times the switching frequency, we should be covered for most practical applications. Extending the frequency range does not really make sense because our final stackup and layout will be different and those have a big impact on the impedance at high frequencies.

Figure 4 shows the setup for output ripple voltage measurements. The DUT is powered from a battery pack with three AA batteries. The load is provided by an adjustable home-made current sink, where a voltage proportional to the current is shown on the digital multi-meter. The oscilloscope is a USB powered four-channel data-acquisition box. The input and output power connections and the coaxial cable for output ripple measurements are all soldered to the little metal turrets. The same setup was used to measure the output impedance data shown in *Figure 3*, with the difference that a second coaxial cable was also soldered to the output connections and the oscilloscope was replaced with a Vector Network Analyzer.

There are a few measurements that –if we want to perform them- may require some changes to the evaluation board. A simple modification that we might want to do is adjusting the output voltage to a different value. Some evaluation boards have jumper-selectable output voltage setting, for instance an example is shown in *Figure 5*. The board shown in *Figure 1* does not offer this option, but we can still change the output voltage by changing the resistance in the output voltage divider. This small evaluation board also lacks connections for measuring the loop stability. To add this feature, we can hand-solder pin-header sockets at the appropriate location. The result with a header with 100-mil pin-to-pin spacing is shown in *Figure 6*.

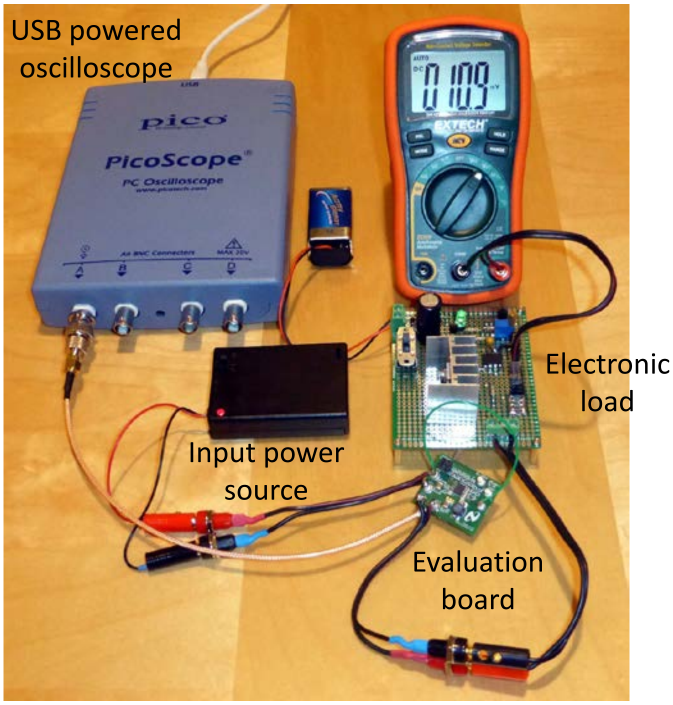

Figure 4*: Setup and connections for measuring the output ripple across the metal turrets.*

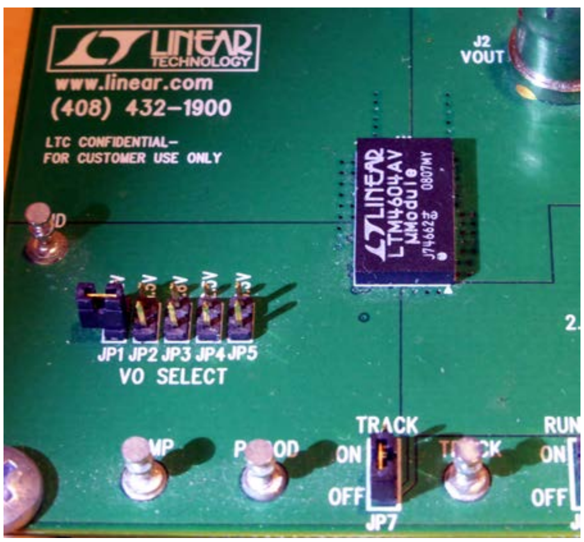

Figure 5*: Jumper-selectable output voltage.*

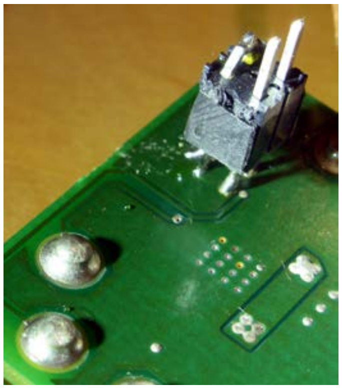

Figure 6*: Pin-header sockets soldered on the evaluation board for gain-phase loop stability measurements.*

Figure 7 shows a representative Gain-phase plot measured on the DUT shown in *Figure 1* with the modifications shown in *Figure 6*. The blue trace is the gain magnitude with the left vertical axis; the red trace is the phase with the right vertical axis. The two colored dots show the crossover frequency (37,752 Hz) and the phase margin (44.2 degrees).

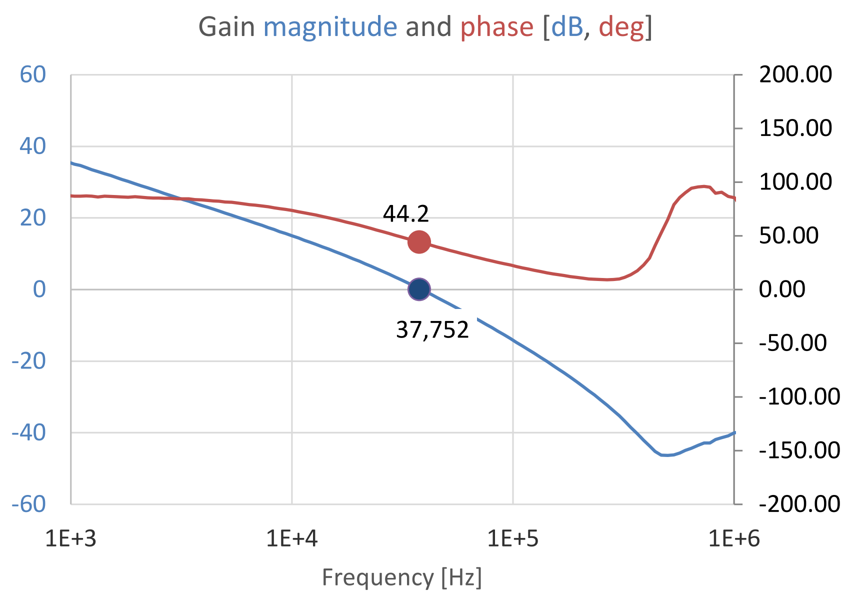

Figure 7*: Gain-phase loop stability plot measured with 4.5V input voltage, 1.2V output voltage and 1A DC load current.*

The frequency range of the measurement is 1 kHz to 1 MHz, which is limited by several factors. First and foremost, we don't really need the plot where the gain magnitude is very high or very low. From a stability point of view the unity gain (zero dB) is the most important. Usually at low frequencies the gain magnitude is high and well above the crossover frequency the gain is (should be) very low.

If we are thinking about measuring the performance of the evaluation board at higher frequencies as well, coaxial connectors would provide the required repeatability and stability. However, as it was pointed out above, the high-frequency behavior would very seldom represent our user geometry and therefore it is not essential for the evaluation.

References:

[1] "Evaluating Evaluation Boards!" Quietpower column, http://www.electrical-integrity.com/Quietpower_files/Quietpower-37.pdf

[2] "Do not measure PDN noise across capacitors!," Quietpower column, http://www.electrical-integrity.com/Quietpower_files/ Quietpower-23.pdf