



Output Voltage Ripple Measurements

Application Note 01-08-01 Rev. 01

Summary:

This application note explains why some customers occasionally see the existence of high frequency noise spikes when measuring the output voltage ripple on a SynQor converter. The paper details how to solve this measurement issue with the proper test set-up and termination methods.

Introduction

A common question from SynQor customers is, "Why do I see large high frequency noise spikes on my oscilloscope when testing the output ripple of a SynQor converter?" Customers often worry that these large spikes will cause their digital circuitry to malfunction, either because of absolute voltage deviation or because of noise coupling to adjacent circuitry. Fortunately this noise spike is largely a measurement artifact and does not reflect the actual voltage deviation between the power planes. With some simple test set-up changes, a much more accurate measurement is possible.

Measuring Output Voltage Ripple

Many SynQor customers evaluate our dc/dc converters using the SynQor Evaluation Board. Other customers prefer to make electrical characteristic measurements using their own evaluation boards or test them directly on prototype or pre-production load boards. Regardless of the method of evaluation, we have found that in many cases when measuring the output voltage ripple, the converter under test can exhibit large high frequency noise spikes on the oscilloscope.

It is widely recognized that large noise spikes can be caused by magnetic coupling through a scope probe ground loop. This source of noise can be eliminated by using a BNC cable, since the area of this ground loop is greatly reduced. It is not widely recognized that if the BNC cable is unterminated, then spikes will be created at the scope end of the cable, with amplitudes larger than those present on the circuit side of the cable.

A BNC cable is a transmission line with a 50 ohm impedance. At the circuit end of the cable, there is a very small amount of high frequency differential mode noise. This high frequency noise resonates and reflects from one end of the cable to the other. The high Q of the cable actually makes the peak noise higher than the actual noise source. To eliminate reflections, the transmission line must be terminated either with a 50 ohm resistor from signal to ground at the scope (referred to as parallel or end termination), or with a 50 ohm resistor in series with the signal on the eval board end (referred to as source termination). A diagram showing proper evaluation test set-up and termination is shown in Figure 6 on page 3.

An astute reader may ask whether the addition of a 50 ohm resistor in itself will filter out a presupposed noise spike. Figure 4 (page 2) shows that when a 50 ohm resistor is placed in circuit, but at the wrong end of the cable, that the noise spike is exactly the same amplitude as with no 50 ohm resistor.

Examining the Data

There are many other mechanisms that could theoretically cause this noise spike, such as near-field magnetic coupling or common-mode noise. To demonstrate that transmission line integrity is the primary effect, SynQor experimented by collecting the data shown on page 2. All of the scope plots are at a 500 MHz bandwidth limit and have a scale of 20mV per division.

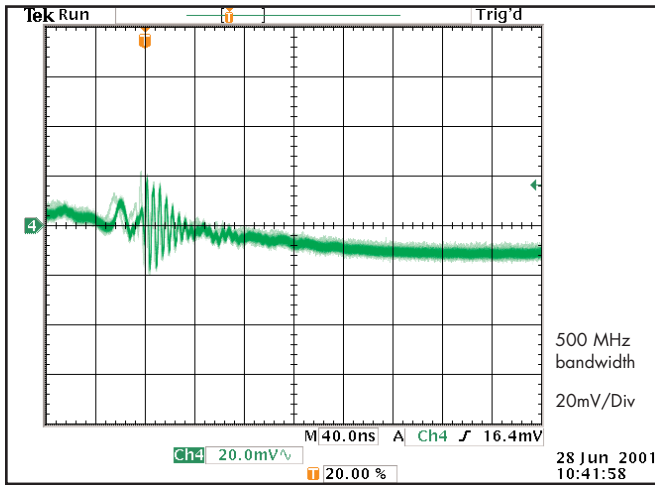


Figure 1: Noise spike amplitude measured on SynQor evaluation board with a 50 ohm parallel termination resistor at the correct end of the cable (at scope).

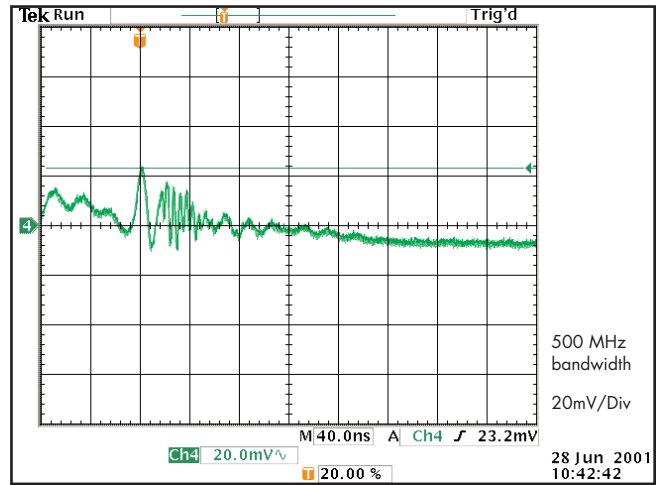


Figure 2: Noise spike amplitude measured on SynQor evaluation board with a 50 ohm source termination resistor in series with the signal at the eval board end of the cable.

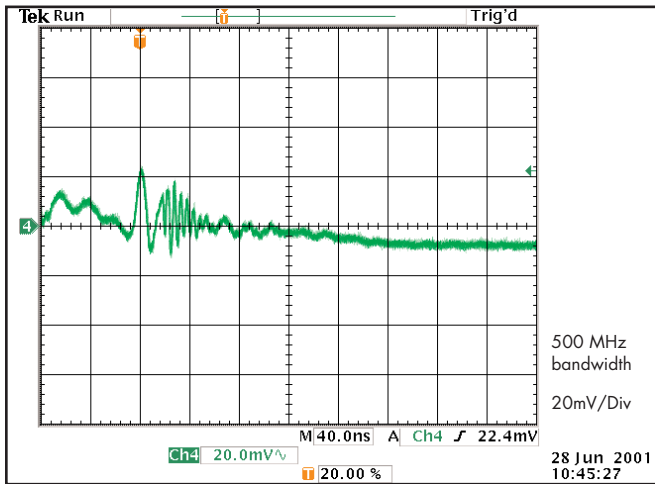


Figure 3: Noise spike amplitude measured on SynQor evaluation board with a 50 ohm source termination resistor and a common mode choke on the input voltage lines.

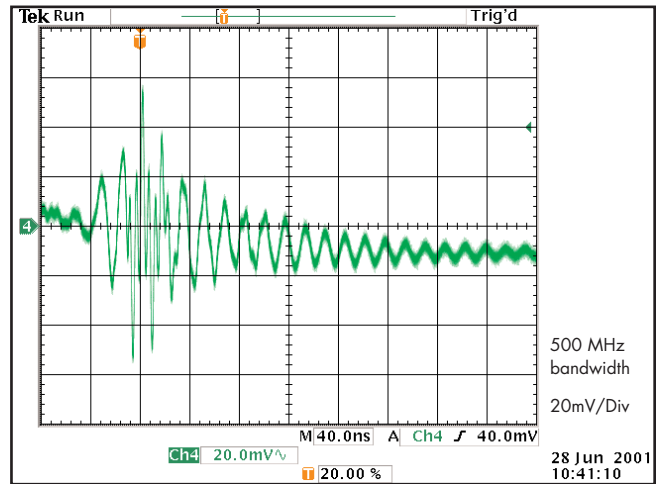


Figure 4: Noise spike amplitude measured on SynQor evaluation board with a 50 ohm parallel termination resistor at the wrong end of the cable (at eval board).

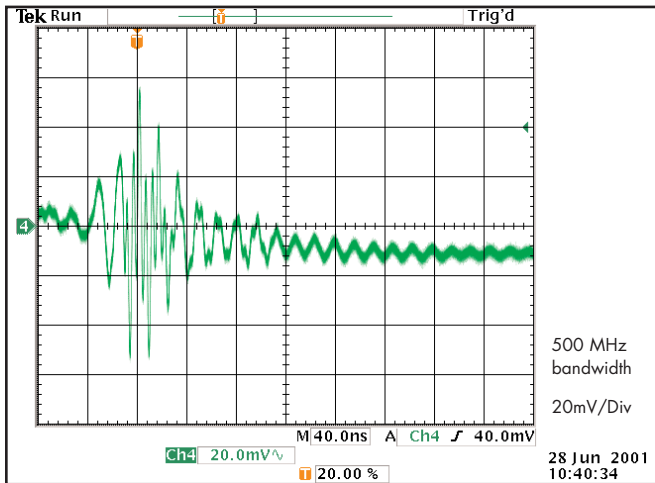


Figure 5: Noise spike amplitude measured on SynQor evaluation board with no termination. This is how eval board is currently wired.

Figure	Termination Method	Noise Spike Amplitude
1	50 ohm parallel termination at correct end (scope)	40 mV
2	50 ohm source termination in series with signal at eval board end of cable	35 mV
3	50 ohm source termination and common mode choke on input voltage lines	35 mV
4	50 ohm parallel termination at wrong end (eval board)	115 mV
5	No Termination (current evaluation board wiring)	110 mV

Table 1: Summary of measurements of noise spike amplitude under various termination methods.

Review of Termination Methods

It is clear from the data presented that proper termination makes a major difference in the output voltage ripple measurements. The reason for the slight difference between the source termination and the end termination results is that the two BNC connectors were physically separated on the test board. For all intents and purposes, either termination method will yield the same results. The choice between source and end termination involves some tradeoffs as indicated in Table 2 shown below.

Factor	Source Termination	End Termination
Power Dissipation	No DC power dissipation	0.5W at 5V _{out} 4.5W at 15V _{out}
Scope Location	Scope must be at the end of a single cable	Scope can be in the middle of a string of cables

Table 2: Summary of tradeoffs involved with measurements using source termination versus end termination.

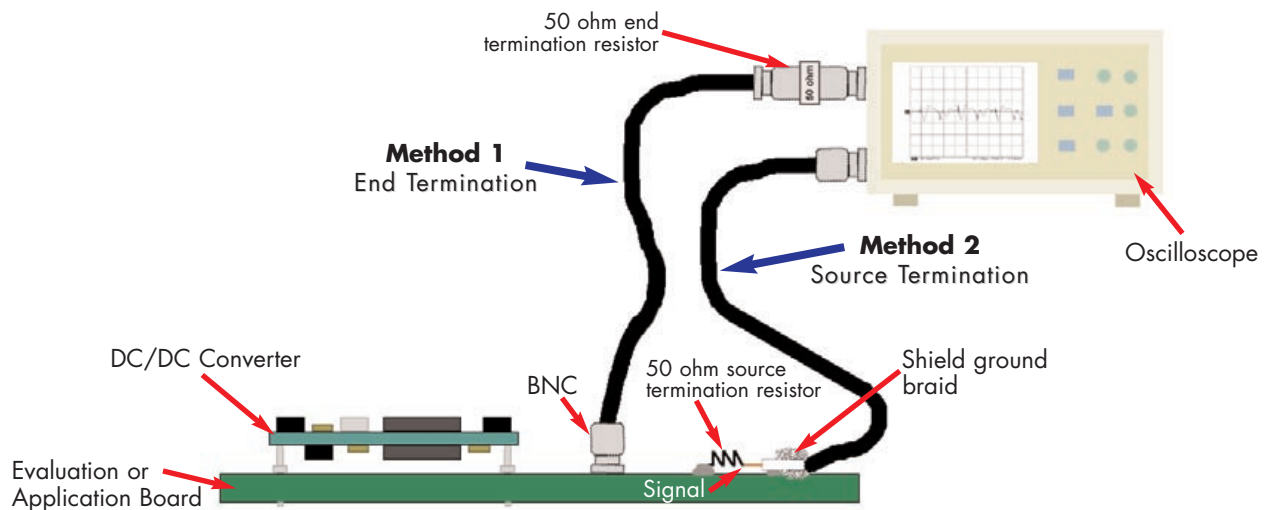


Figure 6: Diagram showing dc/dc converter under test with proper termination methods to oscilloscope (source termination and end termination).

Conclusion

Large high frequency noise spikes experienced while measuring the output voltage ripple do not necessarily indicate a problem with the dc/dc converter under test. Using improper termination methods introduces reflections in the transmission line that are not inherent to the converter being evaluated. When tested using the proper termination methods detailed in this paper, a true and accurate ripple measurement will be seen on the scope.

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