*PCB007* ***QuietPower*** *columns*

# Cable Quality Matters

Istvan Novak, Oracle, September 2013

In a recent column we looked at the importance of properly terminating cables connecting a measuring instrument to our device under test [1]. We may be surprised to see that even if we use the correct termination at the end of the cable, the measured waveform may depend on what quality cable we use.

To illustrate the point, we use the same DC-DC converter evaluation board with an LTM4604 buck converter. To eliminate any possibility of ground loops, the converter is powered from a small battery pack with three AA batteries. The load is a small incandescent bulb, taking approximately 1A DC current from the output. We use a 50-ohm coaxial cable with BNC connectors at both ends. One end of the cable is connected to CH1 input of a Tektronix TDS540B oscilloscope. The input is switched to 50-ohm input impedance. The other end of the cable is connected to the BNC socket on the evaluation board, which directly monitors the output voltage. The setup is shown in *Figure 1*.

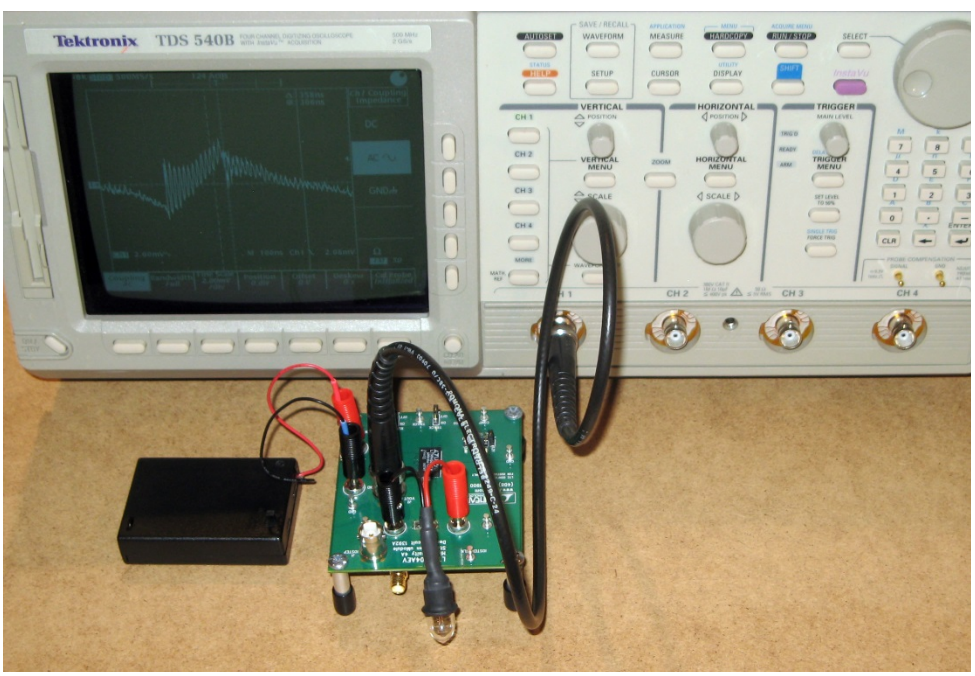


***Figure 1:*** *A DC-DC converter evaluation module is connected to an oscilloscope input with a BNC-BNC coaxial cable.*

On the photo you can see the output ripple waveform, which also shows the ringing when we do not terminate the cable at the oscilloscope. *Figure 2* shows the ripple waveform when the cable is properly terminated.

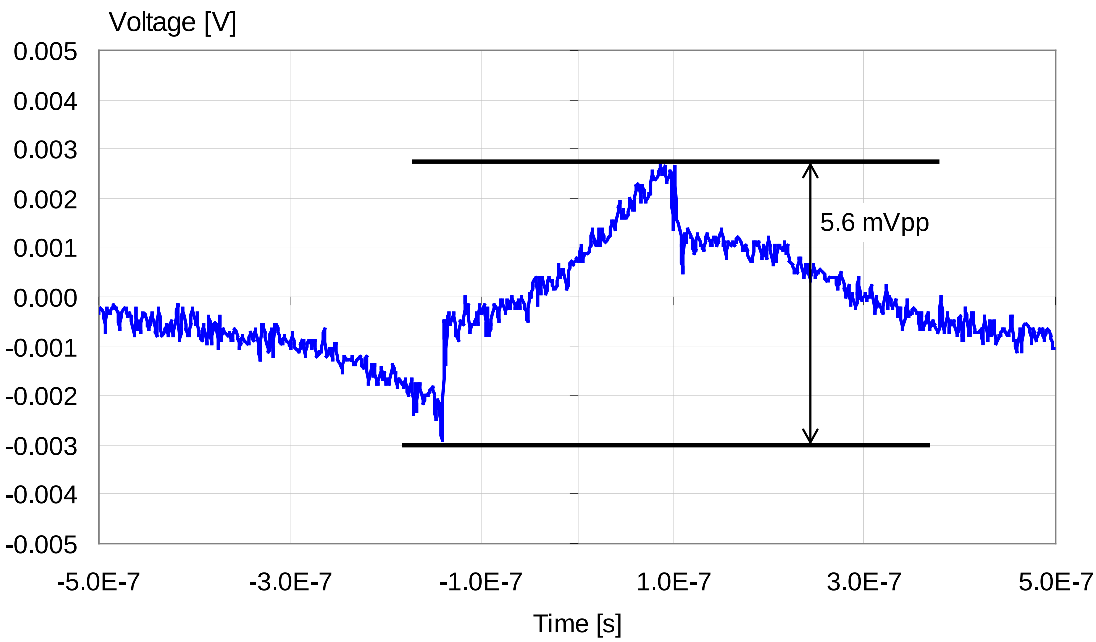


***Figure 2:*** *Switching ripple measured with the cable shown in Figure 1. The cable is terminated in 50 ohms.*

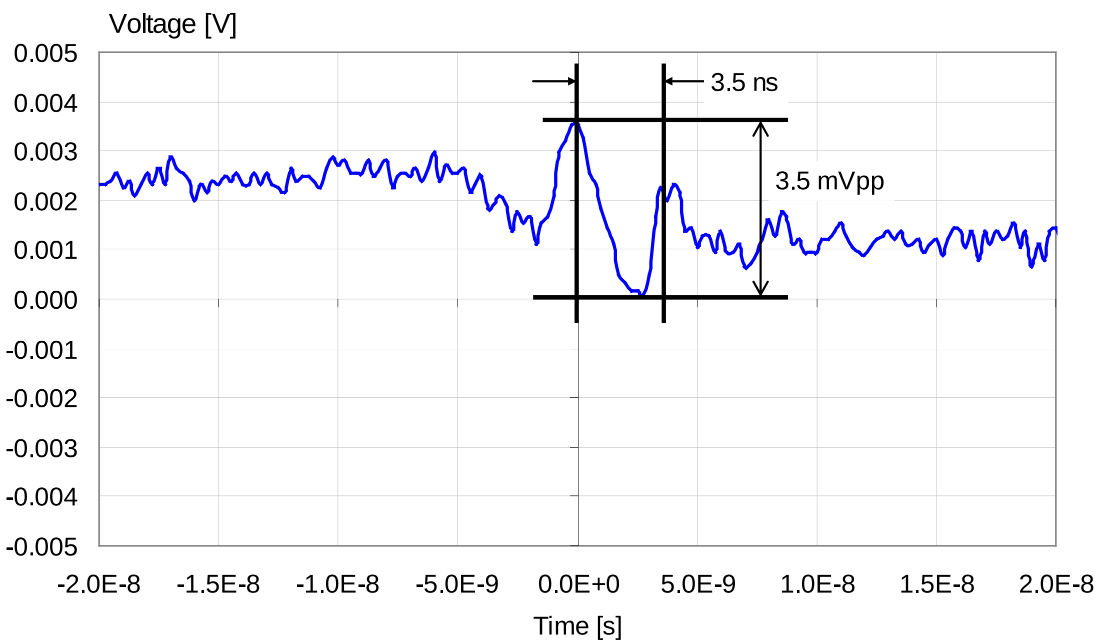


***Figure 3:*** *Waveform zoomed around the turn-off time: there is a 3.5 mVpp 3.5 ns period ringing on the falling edge.*

The single period shown on the plot has an output ripple of 5.6 mVpp.  We can also zoom on the edges to check for additional ringing.  *Figure 3* shows the ringing on the falling edge, at the moment when the high-side FET turns off.

Now we change the cable and use a smaller diameter RG178 coaxial cable.  The setup is shown in *Figure 4*.

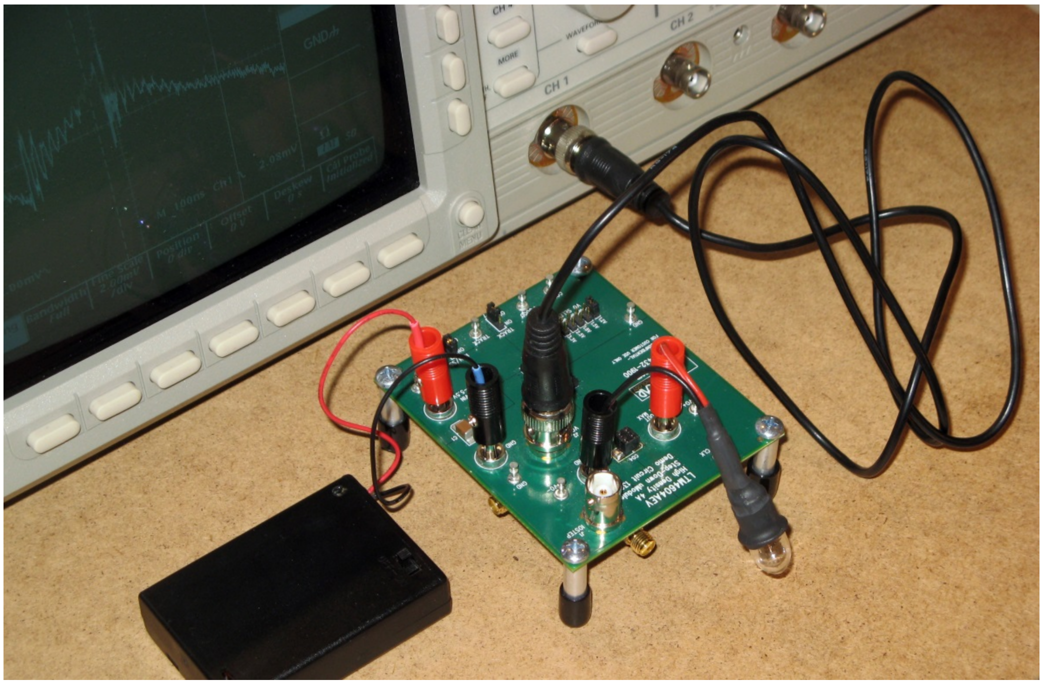


***Figure 4****: Setup with an RG178 50-ohm coaxial cable.*

Note that the DUT and oscilloscope settings are left exactly the same as before.  The full-period waveform is shown in *Figure 5*.  The waveform looks very similar to what we saw in *Figure 2*.  The measured peak-to-peak output ripple is 5.3 mV, which is 5% lower than what we measured before.  Since we measure just a few millivolts and use no bandwidth limiting or averaging, this difference can be easily explained by the trace noise.  As a result, if we re-measure these plots, the peak-to-peak values will vary by a few percent.  More alarming is the difference if we zoom on the turn-off edge.  The waveform is shown in *Figure 6*.  We do see a ringing similar to the one seen in *Figure 3*, but its peak-to-peak value is now 16% lower and the ringing signature is almost masked out by noise.

Why do we get different results with different cables?  A simple test gives us the clue.  We can measure the residual reading in the same exact setup, with the two different cables, when the DUT is not working.  The cables are still connected at both ends, the oscilloscope end of the cable having terminated in 50 ohms by the oscilloscope input.

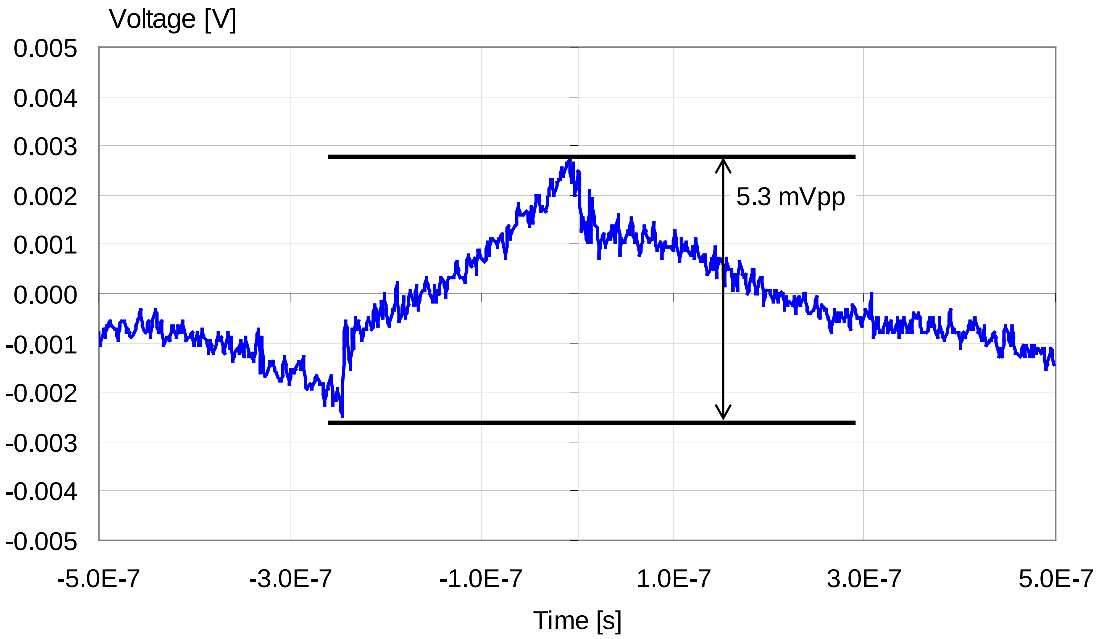


***Figure 5:*** *Switching ripple measured with the cable shown in Figure 4. The cable is terminated in 50 ohms.*

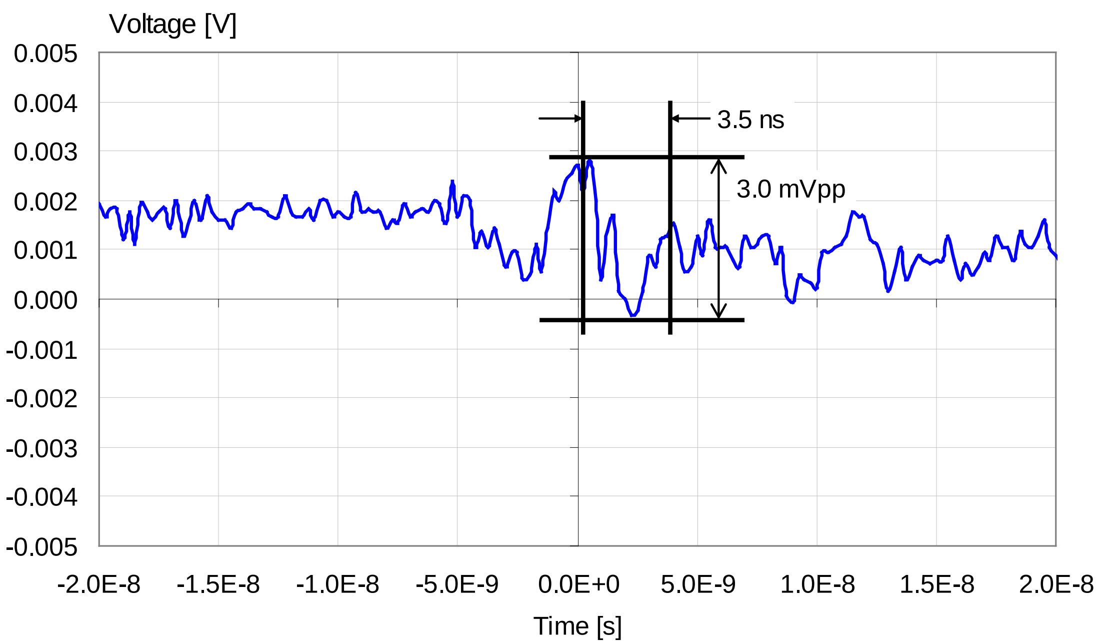


***Figure 6:*** *Waveform of Figure 5 zoomed around the turn-off time. A very noisy 3.0 mVpp 3.5 ns period ringing is seen.*

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The residual noise reading with the two cables is shown in *Figure 7*, where both oscilloscope output traces were copied into the same plot. We get the blue trace with the cable used for *Figures 1* through *3*, and get the red trace with the cable we used for *Figures 4* through *6*. The difference between the two traces is the noise pickup of the cable through its shield braid from the air. Both cables have braided shield, with single-braid coverage. I bought the first cable from a well-respected cable vendor. The second cable came from an unknown manufacturer as a cheap alternative. At first it may be surprising that we saw the correct DUT signature with the second cable, when just from the air it picks up a bigger signal than what we wanted to measure: the peak-to-peak signal level of the red trace is 8.5 mV, bigger than the output ripple of the converter. The reason why we still saw the correct signature –though distorted- in *Figures 5* and *6*, is because the noise is asynchronous to the measured DUT signal. The noise does not have the same repetition frequency as the DUT switching, so when we measure with a real-time oscilloscope, the degree of noise contamination depends on the timing between the noise and our DUT signal. If we are lucky, we may get little distortion, but if the noise peak lines up in time with the data set we capture from our DUT, it may completely mask out our signal.

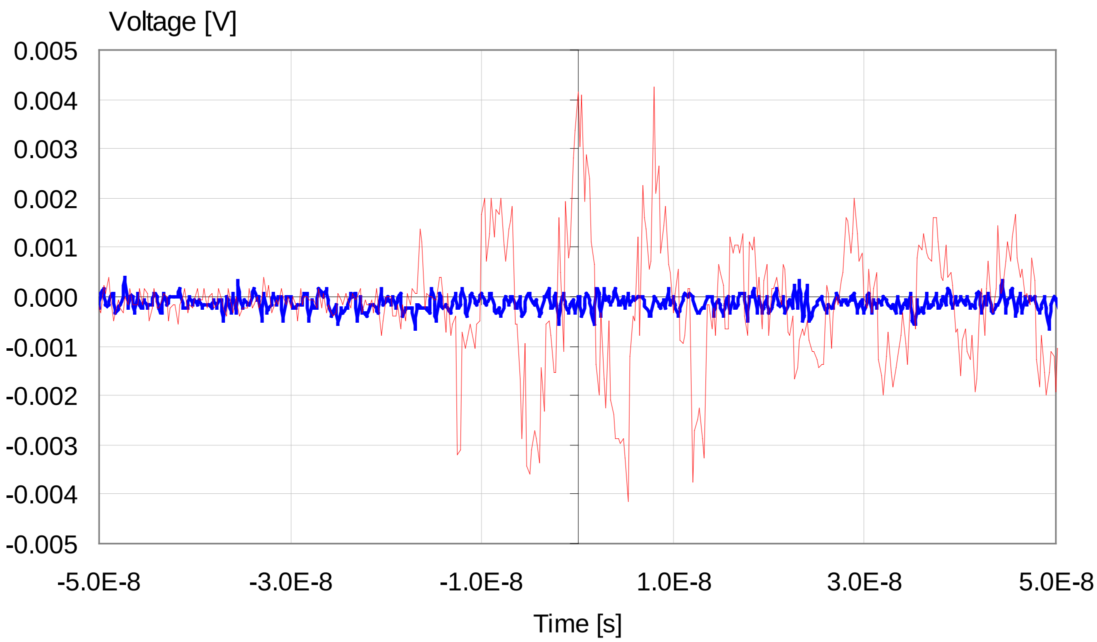


***Figure 7:*** *Voltage measured with two different cables at the DUT BNC connector, with the DUT turned off.*

In one of the future columns we will show the construction of these cables and look at various options to check the quality of the cable shield. Until then: be aware of cheap cables, especially when you need to measure a few millivolts of PDN voltage in a noisy lab.

**References:**

[1] “Don’t Forget to Terminate Cables,” QuietPower column, http://www.magazines007.com/emag/pub/PCBD Aug2013/fscommand/PCBDesign-Aug2013.pdf