Technical Article

How to Use Slew Rate for EMI Control

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Many industrial and automotive applications use the synchronous buck converter power-supply topology; these applications also require low conducted and radiated emissions to ensure that the power supply does not interfere with other equipment sharing the same bus (input voltage [V_{IN}]). For example, in an automotive infotainment system, electromagnetic interference (EMI) could result in unwanted noise in the car stereo.

Figure 1 shows a synchronous buck-converter schematic, along with its switch-node waveform. The ringing on the peak of the switch-node waveform is a function of both the high-side MOSFET's switching speed and the high-side and low-side MOSFETs and printed circuit boards (PCB) stray inductance and capacitance. The ringing on the switch-node waveform is unwanted because it can increase the voltage stress on the low-side MOSFET and generate EMI.

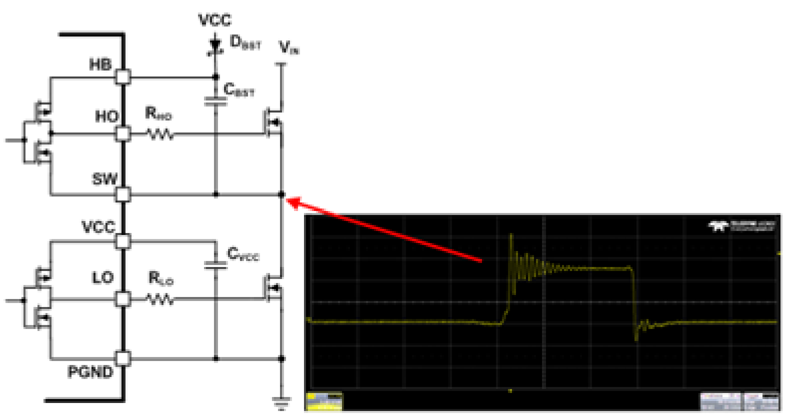

Figure 1. Synchronous Buck Converter

To determine the relationship between the switch-node ringing of the buck converter in Figure 1 and the EMI that it generates, I ran conducted emissions testing in accordance with Comité International Spécial des Perturbations Radioélectriques (CISPR) 25 Class 5. Figure 2 shows the results. The measured data shows that the buck converter's conducted emissions exceed Class 5 limits by 15dBμV in the 30MHz-108MHz frequency range.

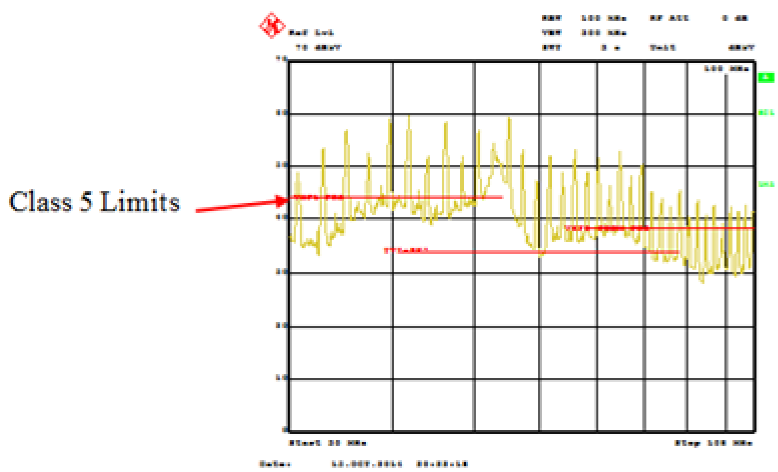

Figure 2. CISPR 25 Class 5, 30MHz-108MHz, Buck Converter v_{IN} = 12V, v_{OUT} = 3.3V, I_{OUT} = 5A

The first step to lower the EMI is to reduce the switch-node ringing. There are several methods: the first is to slow down the MOSFET's turn-on and turn-off time, which controls the rise and fall time of the switch node. You can do this by adding resistors in series (R_{HO} and R_{LO}) with the MOSFET's gate leads; see Figure 3. A second method step is to add a snubber (R_{SUB} and C_{SUB}) from the switch node to ground. The snubber circuit dampens the parasitic inductances and capacitances during switching transitions.

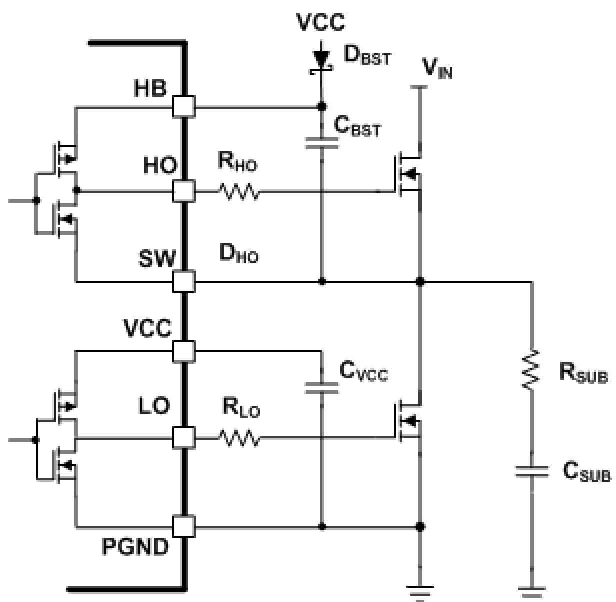

Figure 3: Turn-on and turn-off circuit

An alternative to using the methods describe above to reduce switch-node ringing is to use the LM5140-Q1 automotive-qualified synchronous buck controller. One of the key features of the LM5140-Q1 is slew-rate control. By pinning out the driver's source and sink leads, you can independently control the turn-on and turn-off time of both the high- and low-side MOSFETs.

During the period when the low-side bottom MOSFET is turning off and the high-side top MOSFET is turning on, the switch-node voltage rises from ground to V_{IN}. If the high-side top MOSFET turn-on time is too fast, there is a high overshoot in the switch-node voltage during this transition. Increasing the R_{HO} resistor decreases the drive current to the high-side MOSFET, slowing down this MOSFET's turn-on time and helping reduce switch-node ringing. Note that slowing down the high-side MOSFET's turn-off time will increase the switching losses. You will need to make a trade-off when selecting R_{HO} between low EMI and the high-side MOSFET's switching losses.

The losses in the low-side MOSFET include $R_{DS(ON)}$ losses, dead-time losses and losses in the MOSFET's internal body diode. During the dead time (when the high- and low-side MOSFETs are turned off) the low-side MOSFET's internal body diode conducts the inductor current. The MOSFET's internal body diodes typically have a high forward-voltage drop, so there can be a significant reduction in efficiency. Reducing the time that the low-side MOSFET's internal body diode conducts current improves efficiency.

Using slew-rate control, a resistor (R_{OL}) can be inserted between the LM5140-Q1 driver output (LO pin) and the low-side MOSFETs gate to increase the time that it takes for the low-side MOSFET to turn-off. Slowing down the turn-off time decreases the dead time between the low- and high-side MOSFETs' conduction, increasing buck-converter efficiency. When reducing the dead time for a synchronous buck, make sure that the high- and low-side MOSFETs never conduct at the same time.

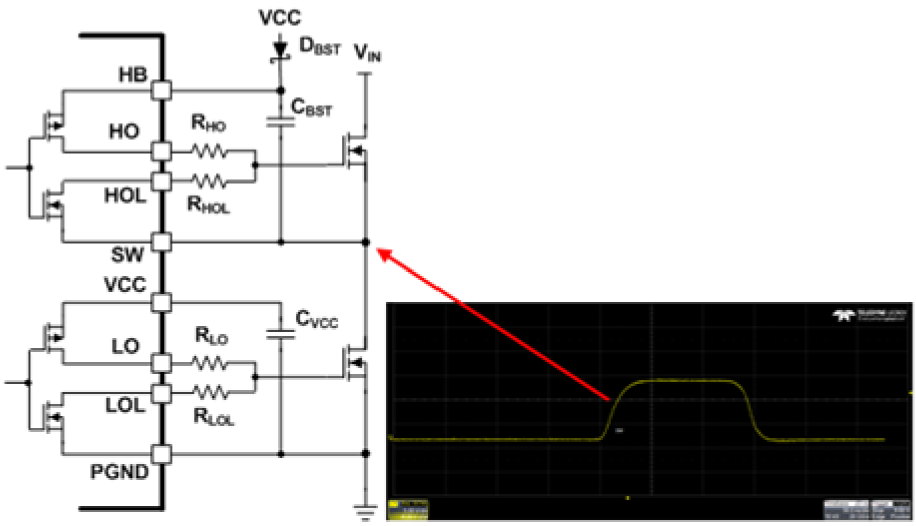

Figure 4: Buck converter switch-node waveform with slew-rate control

I modified the power supply shown in Figure 1 using the LM5140-Q1 controller (see Figure 4). Using slew-rate control optimizes the switch-node rise and fall time, eliminating switch-node ringing.

The next step is to run the CISPR 25 Class 5 conducted emissions. I chose these slew-rate control-resistor values: R_{HO} = 10Ω, R_{HOL} = 0Ω, R_{LO} = 10Ω and R_{LOL} = 10Ω. The resistors I selected for this application are a good startup point for any application where the output power is under 50W.

Figure 3 shows the results and summary of the conducted emissions testing.

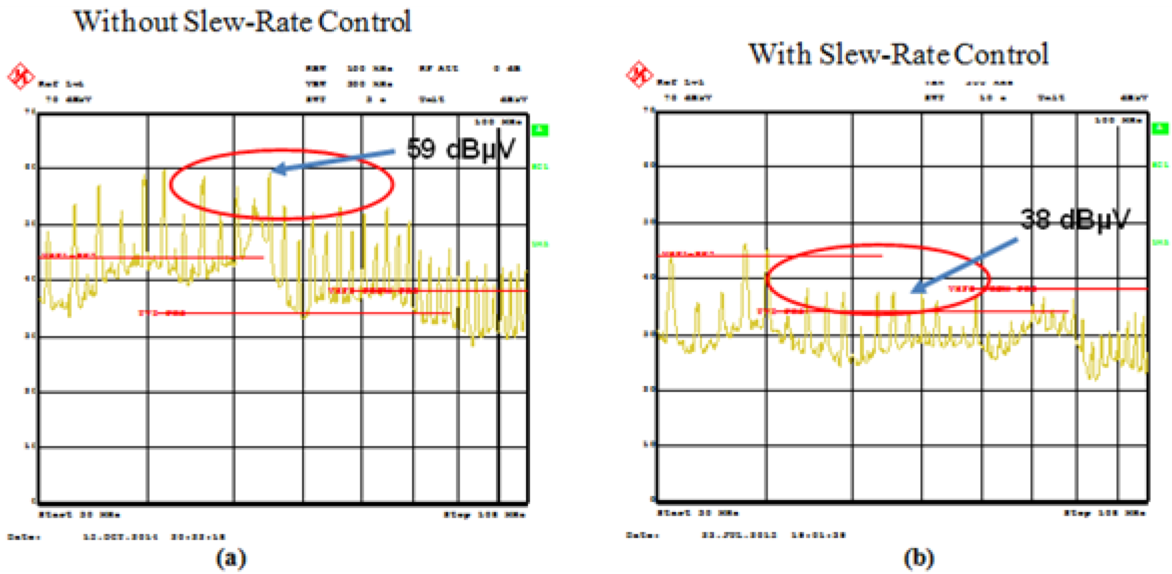

Figure 3. Slew-rate Control Comparison: CISPR 25 Class 5, v_{IN} = 12V, v_{OUT} = 3.3V, I_{OUT} = 5A, without Slew-rate Control (a) and with Slew-rate Control (b)

The buck converter using the LM5140-Q1 with slew-rate control reduced conducted emissions by 21dBµV. It also provided better control of the switch-node rise and fall and eliminated the need for a snubber circuit, which adds circuit complexity and cost.

By picking the correct values of slew-rate control resistors, not only can you reduce EMI; you can also improve system efficiency.

See a live demonstration of the LM5140-Q1 buck converter in TI's booth (No. 1617) at the Applied Power Electronics Conference (APEC), March 21-23 in Long Beach, California. Follow TI at www.ti.com/apec2016.

Additional Resources

- Watch the video "Engineer it: How to use slew rate control for EMI reduction."
- See the LM5140-Q1 data sheet.
- Open the "LM5140-Q1 Evaluation Module User's Guide."

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