EMI Generation, Propagation, and Suppression in Automotive Electronics (Part I)

In the automotive industry, stringent electromagnetic interference (EMI) requirements are necessary for safety but create design challenges for engineers (see Figure 1). To reduce EMI, it is necessary to model and analyze various EMI problems. This article provides modeling and suppression methods to reduce EMI in non-isolated converters, such as buck, boost, and buck-boost converters.

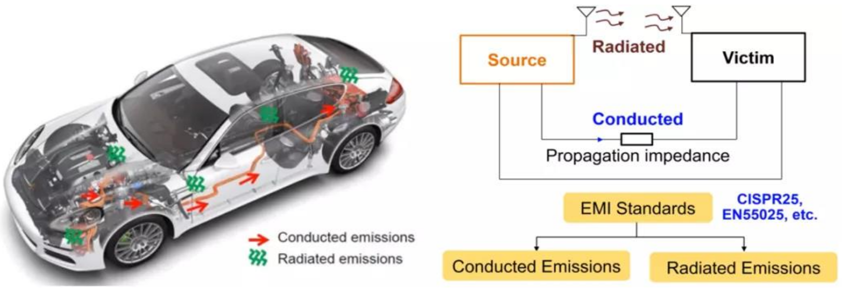

Figure 1: Conducted and Radiated EMI in Automotive Electronics

Many components in power electronics systems (e.g. MOSFETs and diodes) produce high dV/dt nodes and high dI/dt loops during high-frequency switching. These high dV/dt and dI/dt values are the root causes of EMI. EMI is divided into conducted EMI noise and radiated EMI noise. Conducted EMI is caused by the physical contact between conductors, while radiated EMI is caused by induction, and occurs when the conductors are not in contact. Based on these key differences in the propagation path for both types of EMI, conducted EMI noise and radiated EMI noise must be discussed separately. This article will discuss conducted EMI, while Part II will discuss radiated EMI.

Conducted EMI

Conducted EMI is divided between differential mode (DM) and common mode (CM). Accordingly, DM noise and CM noise should be modeled separately to account for their different propagation paths and suppression mechanisms. Noise separators can be used to obtain measurements and distinguish between whether DM or CM causes the majority of the EMI.

DM noise mainly flows between two lines, while CM current flows to the ground in the form of displacement current. This displacement current goes through the capacitor connected from the device to ground, then returns to the grid (see Figure 2).

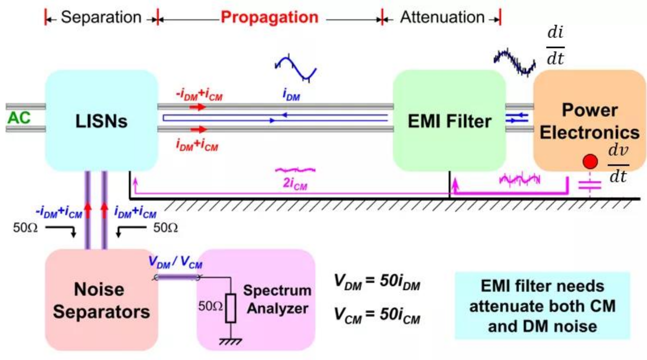

Figure 2: CM and DM Noise in Conducted EMI

The first step in EMI modeling uses the switch as an equivalent current or voltage source, after which the current and voltage remain the same throughout the circuit. Then the overlay theorem can be used to analyze the impact of each source in detail. Figure 3 shows how to simplify the DM model for a buck converter. Note that it is also possible to have models for other non-isolated converters.

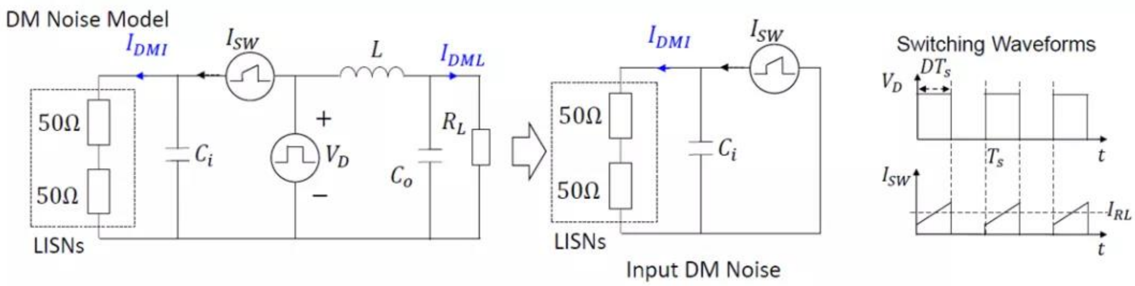

Figure 3: DM Noise Model and Typical Switching Waveforms of a Buck Converter

Figure 4 shows how to simplify the CM model for a buck converter.

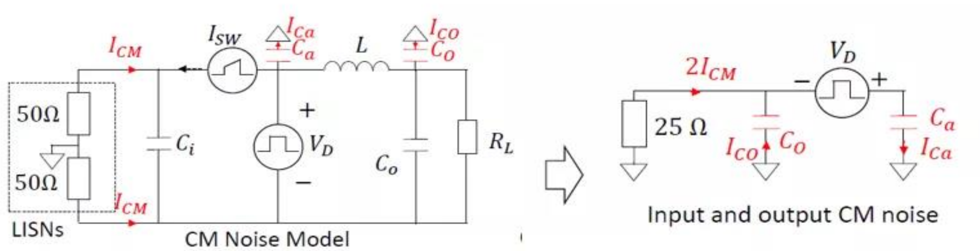

Figure 4: CM Noise Model and Typical Switching Waveforms of a Buck Converter

Reduce DM noise in the buck converter by carefully selecting the input capacitor and input filter; reduce CM noise by minimizing the switching node’s area with a filter.

Figure 5 shows the results when a buck converter’s DM noise and CM noise are separated and measured. In this example, DM noise causes the majority of EMI.

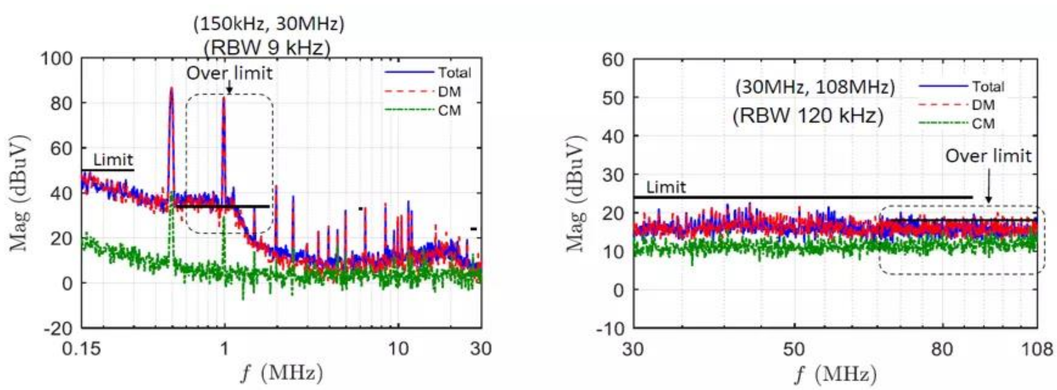

Figure 5: Overall DM and CM Noise Measurements of a Buck Converter

To reduce EMI, the DM filter was increased, and the resulting noise measurements indicated that EMI had been reduced successfully (see Figure 6). This logic can be extended to other converters that have excessive DM noise.

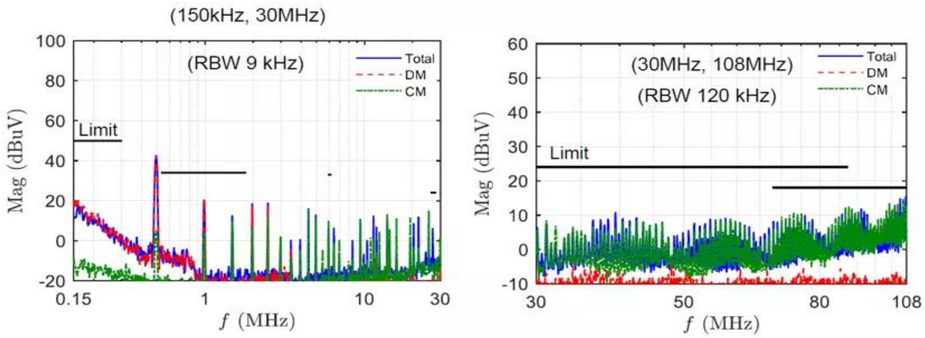

Figure 6: Noise Reduction for a Buck Converter

Automotive Buck Converters with Reduced EMI

An example of a buck converter with reduced conducted EMI is the [MPQ4423C-AEC1](), a synchronous, rectified step-down switch-mode converter. This device is available with Wettable flanks, integrated power MOSFETs, and synchronous mode operation for improved efficiency across the output current.

When operating in forced pulse-width modulation (PWM) mode, the MPQ4423C-AEC1 maintains low conducted EMI emissions (see Figure 7).

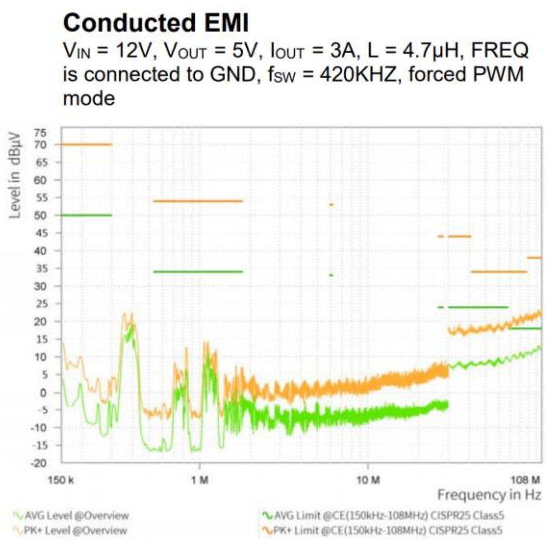

Figure 7: Conducted EMI with the MPQ4423C-AEC1

A second example is the [MPQ8873-AEC1](), a four-switch buck-boost converter that is well-suited for automotive applications. The MPQ8873-AEC1 features configurable parameters, including an adjustable frequency spread spectrum (FSS) that can periodically dither the switching frequency (f_{SW}) to improve EMI performance. A dedicated register allows designers to enable FSS, adjust the FSS modulation range, and set the FSS modulation frequency. Figure 8 shows the results of the average conducted EMI.

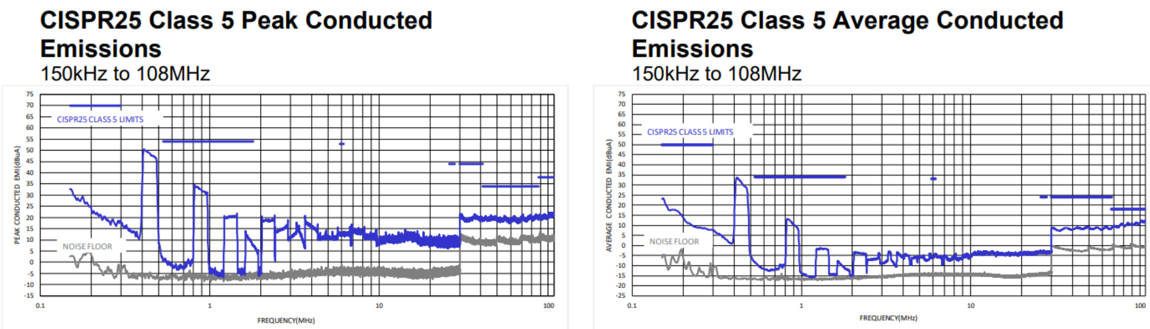

Figure 8: Conducted EMI with the MPQ8873-AEC1

Conclusion

In this article, we reviewed methods for controlling conducted EMI noise from exceeding the standard requirements. These methods included modeling DM noise and CM noise separately and addressing each to reduce EMI for different applications, as well as highlighting automotive devices that can control conducted EMI for peak efficiency.

Part II will dive into more detail on radiated EMI problems using Thevenin's Theorem, which models the converter and antenna to control EMI noise.