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ABSTRACT

The reduction of electromagnetic interference (EMI) is an inherent issue in all electronic systems as a result of either electromagnetic *radiation* or electromagnetic *conduction*. EMI management is one of the most difficult challenges in switch-mode power supply (SMPS) systems due to the switching actions of the power MOSFETs and resulting discontinuous currents. This application report will focus on understanding the noise origins, the effective construction of TI's Power Modules to help with noise reduction, and how the spread spectrum technique helps reduce EMI emissions.

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1 Noise Origin

We tend to associate EMI with wireless interference but there is also an interference that travels through a conducted path instead of the air. Conducted EMI is a form of conduction coupling generated via cabling, PCB traces, parasitic elements, or power and ground planes. Radiated EMI is the coupling of unwanted signals from radio transmissions due to the elements of conducting materials. Every conductor has characteristics of an antenna that is capable of both transmitting and receiving signals.

1.1 Parasitic Elements

Most of the problems encountered with SMPS and noise are related to the parasitic components in the design. Parasitic elements are unavoidable. They can come in forms of resistance, inductance, or capacitance. For example, a capacitor has a nominal capacitance but also comes with unwanted electrical elements of equivalent series resistance (ESR) and equivalent series inductance (ESL). In a buck switching regulator (step-down converter), as the high-side and low-side MOSFETs alternate in switching, noise from the input source of the converter and the parasitic inductance in the high di/dt loop appears on the switch node. The noise on the switch node is then be coupled and distributed onto the output voltage through the parasitic capacitance associated with the inductor, package, and PCB layout.

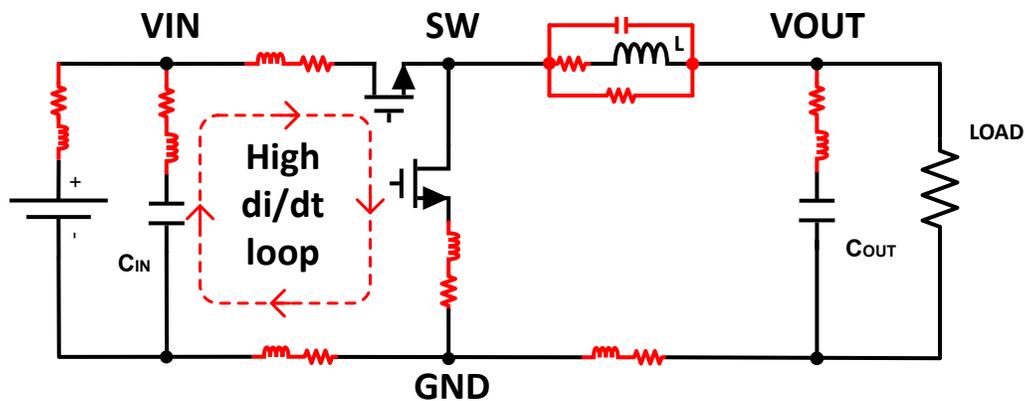


Figure 1-1. Buck Converter With Parasitic Elements

1.2 High Frequency Noise and Low Frequency Ripple

The noise elements that are coupled onto the output voltage are high-frequency noise and low-frequency ripple. The low frequency ripple is a byproduct of the inductor ripple current and output capacitor(s) impedance. The high frequency noise is generated by the high di/dt current and any inductance in its path (input capacitor and power switches).

2 Effective Construction of a Power Module

A DC/DC power module integrates the controller, power MOSFETs, inductor and other passive components into a single package. Texas Instrument’s power module family spans isolated and non-isolated architectures as well as step-up, step-down, and inverting topologies. See [TI’s DC/DC power modules broad portfolio](#) for more information.

2.1 Noise Reduction

Most power modules integrate a high frequency input capacitor and a shielded inductor. It’s important to note that the integrated input capacitor greatly reduces the area of the high di/dt loop. A smaller loop area creates a lower ringing on the switch node; lowering the ringing on the switch node will therefore lower the output noise. Also, since the switch node is inside the package and has been further reduced, the potential parasitic capacitance to the other nodes is limited. Although reduced, there are still some parasitic elements present in the power module.

TI’s Enhanced HotRod™ QFN package technology offers the best in class EMI performance by the removal of the wire bonds, which contribute significantly to the parasitic inductance of the power loop (MOSFETs gate loop), and the optimized pin-out of the device to further reduce the parasitic loop inductance. In summary, Enhanced HotRod QFN technology leverages the noise improvements of a flipped chip on lead-frame (FCOL) package and thermal advantages of the standard QFN package. For a deeper understanding of Enhanced HotRod QFN package technology see [Enhanced HotRod QFN Package](#).

2.2 TPSM5601R5H Step-Down Power Module

The TPSM5601R5H power module is a highly integrated 1.5-A power solution that operates from a 4.2-V to 60-V supply voltage with power MOSFETs, a shielded inductor, and passives in a thermally enhanced QFN package. The QFN package uses Enhanced HotRod QFN technology for enhanced thermal performance, small footprint, and low EMI. [Figure 2-1](#) illustrates radiated emission performance of the evaluation module (EVM) board [TPSM601R5HEVM](#) passing CISPR 11 Class B. Additionally, the TPSM5601R5HS offers frequency spread-spectrum operation to further mitigated EMI noise.

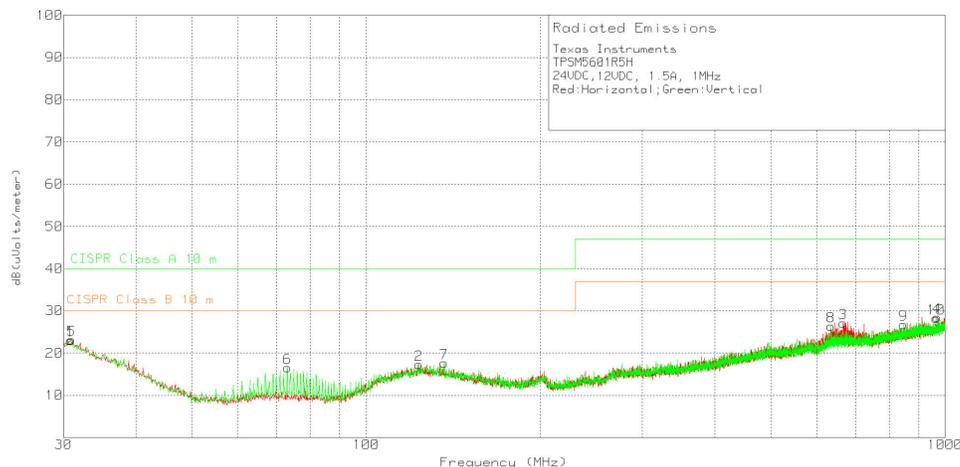


Figure 2-1. Radiated Emissions 24-V Input, 12-V Output, 1.5-A Load

3 Spread Spectrum

Spread Spectrum techniques (or “dithering”) are commonly found in switch-mode power supply systems to reduce the effect of EMI that SMPS generate.

3.1 Concept

Spread Spectrum is used to reduce the effect of EMI by converting a narrowband signal into a wideband signal, which will spread the energy across multiple frequencies. In the context of switching regulators, the switching frequency set by the oscillator is manipulated to reduce the peak energy and is distributed to other frequencies and their harmonics. [Figure 3-1](#) illustrates how manipulating the clock frequency over time has the effect spreading energy generated by a switching power supply.

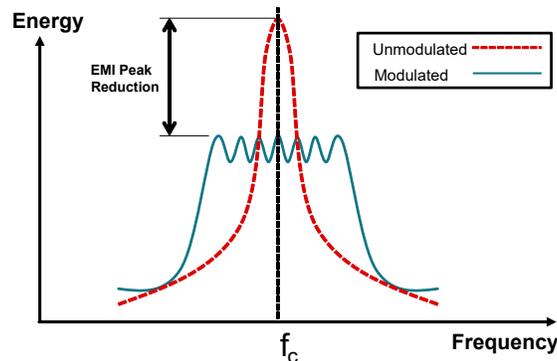


Figure 3-1. EMI Reduction by Spread Spectrum, Frequency Modulation

There are many ways to implement spread spectrum; different techniques, such as triangular analog dither, Pseudo-random, adaptive random spread spectrum (ARSS), dual random spread spectrum (DRSS) and many other techniques. Each of these techniques will typically perform better at either low frequencies or high frequencies. Note that the total EMI energy is unchanged, since there is no attenuation. Instead, the spread spectrum technique alters the shape of the conducted and radiated interfering power spectrum, reducing the level of peak emissions.

3.2 Tradeoffs

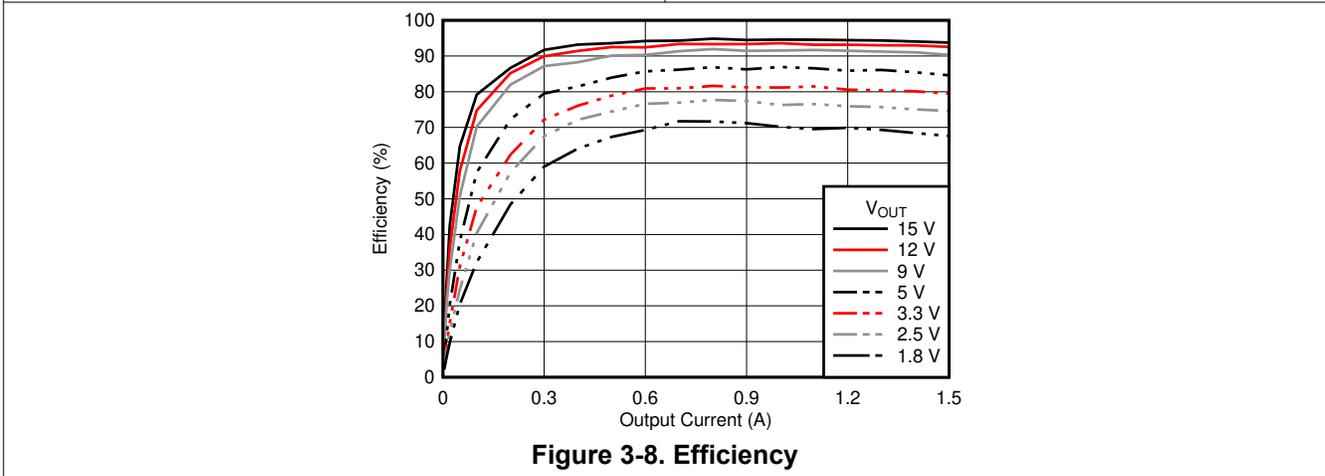
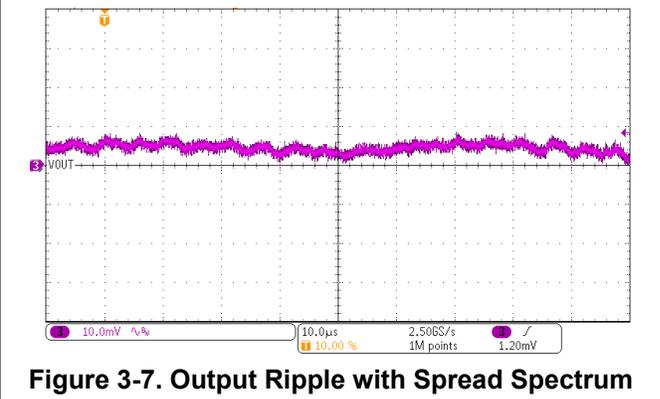
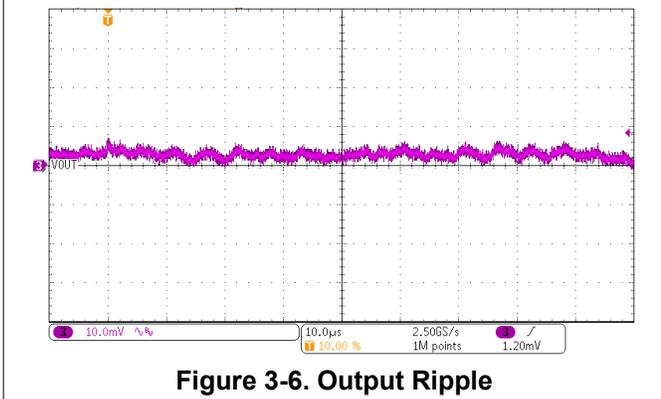
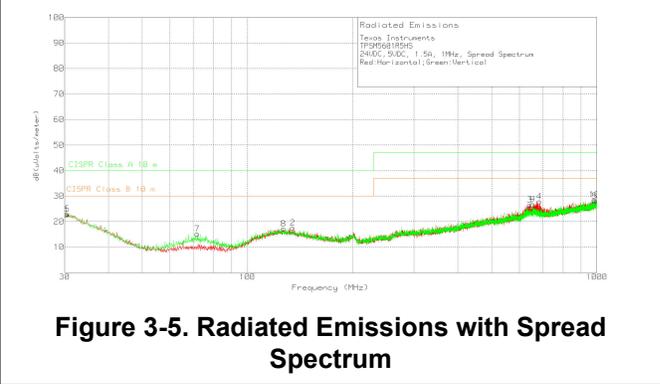
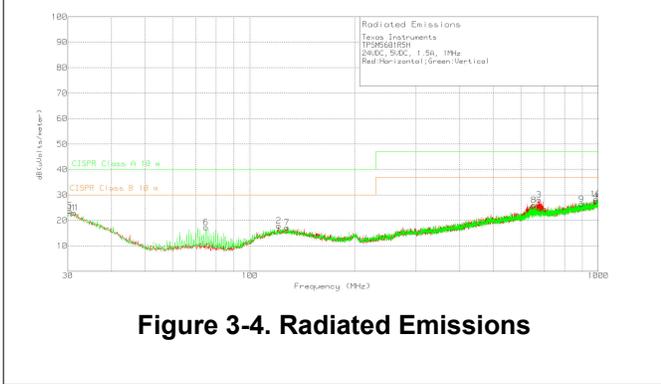
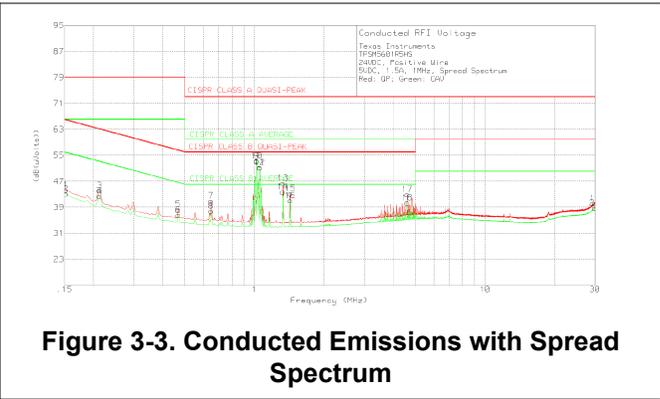
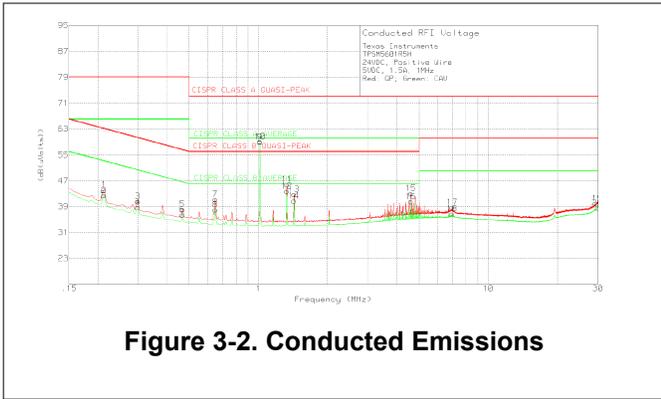
When optimizing spread spectrum, the most important factor is the modulation index. The larger the modulation index, the more distributed the spectrum becomes; however, there are limits when spreading in a switching-regulator application. Modulation index is a factor of the energy spread and the resulting fundamental/harmonics. Note the switching frequency of the converter is the fundamental frequency of the voltage ripple. Therefore, as the switching frequency deviates from the fundamental frequency it can increase the output ripple, create large variations in the inductor current ripple and can start spreading energy into bands where it is not desired.

3.3 Other EMI Mitigation Techniques

There are many more proposed solutions to mitigate EMI besides the spread spectrum technique. Some of the techniques available to help reduce EMI emissions in SMPS are by implementing additional input filter designs and PCB layout improvements. For more details on these techniques, see [EMI Mitigation Techniques Using the LMZM23601](#).

3.4 EMI Results

Spread spectrum technique offers a simple and cost effective solution for the average EMI noise reduction. [Figure 3-2](#) through [Figure 3-5](#) show the conducted and radiated EMI results (CISPR 11) for TPSM5601R5H and TPSM5601R5HS for a 24-V input, 5-V output, and 1.5-A Load. Emission tests were performed on the default evaluation board for both devices. As expected, the EMI results show that implementing the spread-spectrum technique reduced peak emissions while efficiency and output ripple did not have an impact. Note, both TPSM5601R5H and TPSM5601R5HS are compliant with EN55011 Class-B radiated emissions.



4 Summary

EMI can enter a system (or device) through either conduction or radiation, or both. Conducted EMI occurs from the normal operation of switching circuits. The ON and OFF actions of the power switches generate large discontinuous currents and pass noise to the output as low frequency ripple and high frequency noise. In EMI-sensitive applications it is important to begin the design with components that have great EMI performance. Texas Instrument's Enhanced HotRod package technology and power modules are great solutions when it comes to EMI performance.

To further optimize EMI performance, implementing spread-spectrum architecture offers a simple and cost effective solution for the average EMI noise reduction by reducing harmonic peaks and spreading the noise energy. As a result, the measured radiated and conducted peak emissions are reduced, however, the total-noise energy is unchanged and other bands can be negatively affected depending on the application.

5 References

- Texas Instruments, [Enhanced HotRod QFN Package: Achieving Low EMI Performance in Industry's Smallest 4-A Converter](#) application report.
- Texas Instruments, [EMI Mitigation Techniques Using the LMZM23601](#) application report.
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