EMI, SI, and PI: Overcoming Common Challenges in the Design of Power Electronics

Introduction

Every electronic device will need some sort of power source, whether it be the electrical grid, batteries, or a simple bench-top power supply. Today's advanced power electronics in industries like automotive and green energy face significant challenges resulting from power conversion, where low noise and thermal management are needed to ensure reliability and stable power delivery, and thus electrical performance throughout a system. In addition to low noise, heat management, and stable power, modern power electronics require higher power factors in more compact form factors, which pushes traditional designs to their limits. Prominent examples are found in automotive power management, green energy systems, and telecom equipment to support 5G rollouts.

The traditional solutions involving inductor coils and filtering for reducing EMI are often unable to meet the current demand for low noise, thermally stable electronics while also ensuring high power density delivered in a compact form factor. Designers are forced to either compromise on form factor or power delivery to ensure products have sufficiently low noise, or they risk creating a low-profile product with excessive noise that won't pass EMC testing requirements. SI, PI, EMI, and thermal management in power electronics and the systems they power are all interrelated, but success in these areas begins with high-efficiency, low-noise power conversion.

To help ensure success in these areas, more designers are looking to advanced material platforms, unique power regulator topologies, and higher operating frequencies and inductances in power conversion systems. Newer GaN FETs are enabling higher frequency operation, which can compound EMI problems that are already present at higher frequencies. To ensure these more advanced power systems can meet conducted EMI limits without compromising form factor, designers need to take a comprehensive approach and consider EMI suppression techniques at all levels of a design.

Major SI, PI, and EMI Challenges in Power Systems

Power systems are subject to multiple design challenges primarily in three areas: EMI suppression (especially common-mode), high-efficiency power delivery with high power density, and ensuring small form factor. Solving these challenges can help ensure power and signal integrity in the system that receives power, as well as ensure a system is reliable and compliant with EMI limits.

Conducted EMI Suppression

Most designers who have taken a power product to market should be familiar with FCC and CISPR limits on EMI. Regarding conducted EMI (common + differential mode noise) in power systems, regulatory limits reach as low as mV levels, depending on frequency. While typically solved with ferrites and possibly some EMI filter circuits, smaller form factors in modern electronics create additional challenges with common-mode noise due to parasitic coupling and feedback.

This noise component produces radiated EMI that is 100x more intense than differential mode noise, requiring common-mode chokes that can suppress noise. Noise suppression also occurs on the output from regulator stages through the use of high-inductance coils. Multiple ferrite components are needed in various stages in a design to address these noise problems and ensure stable DC power delivery with low conducted EMI.

High Power Density Designs
Power electronics can't be built with just any off-the-shelf components. Current and voltage ratings must be carefully considered when selecting components, including ferrites for noise suppression and filtering. High power designs carry thermal management requirements as heat accumulation and high temperature can reduce product lifetime or lead to failure, and components must be selected for their ability to operate with extended lifetimes in such harsh conditions. In addition, high power designs can be challenging for ferrites as hysteresis and flux saturation can occur in ferrite cores, leading to nonlinear behavior and harmonic generation at high power.

Thermal challenges, the need for higher power density, and ensuring small form factors has motivated several changes in modern power electronics. These include:

- Implementation of more complex switching regulator topologies, such as mullti-level, multiphase regulator designs
- Running regulators and converters at higher switching frequencies to reduce ripple in DC power conversion
- The use of more advanced semiconductor material platforms, such as GaAs and GaN-SiC, which can operate reliably at higher frequencies and power densities

While these changes have helped make today's power conversion more efficient, there is still a need for high inductance components in power electronics designs to ensure regulation, provide filtering, and stabilize DC power. High-current ferrites are needed in these applications in order to enable high power densities.

Form Factor
Smaller form factor designs already have problems with parasitic coupling and feedback as mentioned above, but this is made more difficult in power electronics. Power regulators, transformers, filter circuits, and other stages in a power system require high inductance components to ensure high-precision regulation and noise suppression. A unique set of high inductance ferrite components can provide solutions without compromising form factor. Some example components include SMD ferrite beads, high-mu inductor or transformer cores, and cable cores to address multiple sources of noise through a design.

Ferrites Provide Solutions in Power Electronics

The common thread in the above list of power electronics challenges is the need for high inductance ferrites that have low profile and can operate at high power densities. All of these areas should be addressed with a comprehensive, customized solution; there is no single ferrite component that can address all these areas simultaneously. Instead of defaulting to a simple ferrite cable core on input mains power, multiple ferrite components may be needed through a design to solve the aforementioned challenges in power electronics. Components that are suitable for high performance applications require broadband reliability, high power density limits, and small form factor.

Ideal Ferrites for Power Electronics
The ideal small form factor ferrites are placed on a PCB or cable assembly with the goal of ensuring high power conversion efficiency over a broad frequency range. Some ideal products targeting noise and SI/PI in power systems include:

- **Ferrite cable cores** – These components come in multiple form factors, offering designers the flexibility they need to implement the right core into their cable assembly
- **High-mu ferrite beads** – These SMD components can be implemented in regulator circuits and provide inductance that is comparable to some physically larger inductors, making them ideal for smaller, low-current regulator stages
- **Inductor cores and balun cores** – These components can use the same ferrite materials as other ferrite products, providing high inductance to enable high-efficiency power conversion and power transfer, as well as lower weight than iron-core components

- **Power ferrite chokes** – These components address noise and harmonics on input lines in power systems, which is particularly important in industrial settings

Approach EMI From Multiple Angles

Each of the above ferrite components can be implemented in different portions of a system to address specific EMI problems. In power conversion and regulation systems, it is often the case that multiple EMI problems are present alongside thermal challenges in the regulator, as well as SI/PI problems seen at the load. The above list of components gives designers options to mix and match components and implement board-level solutions as a first step to solving EMI challenges.

Should these steps prove insufficient at addressing heat and EMI, especially radiated EMI, additional shielding materials and thermal materials can be used on the board and enclosure. In cases where ferrites are unable to sufficiently reduce noise, or when power densities are large enough to create additional thermal problems, these materials can be added to a PCBA, enclosure, or both. Most vendors cannot provide solutions in all of these areas, and affected designers need to work with the right application engineering partner to implement these measures in their designs.

As power electronics designs become more complex, engineers will continue looking to companies like Laird™ Steward™ to offer flexible solutions that can be easily implemented in their designs. Instead of working through repeated changes to your enclosure or layout, take advantage of Steward’s line of power ferrites, advanced materials, and deep experience crafting custom solutions for challenging designs. Steward’s flexible options let you create a custom solution that provides reliable, high-efficiency power electronics systems without compromising form factor.

Contact Steward today to learn more.