# EMI Management for Board-Mounted Power Modules

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## Introduction

Board-mounted power modules offer a convenient and compact solution to system power-supply challenges. However, any switched-mode power converters can be a source of electromagnetic interference (EMI), which needs to be correctly managed.

This paper examines EMI noise in and around board-mounted power. It also outlines steps to mitigate any risks associated with both radiated and conducted EMI.

Switched-mode power conversion is essential for almost every electronic system. Board-mounted power (BMP) modules offer a proven and effective method to quickly and easily provide power conversion in units with compact form factors to generate useful voltages. However, switched-mode power conversion is also a source of electromagnetic interference (EMI) in the form of radiated and conducted noise. While soft-switching techniques and optimized layout go some way to reduce interference, additional steps must be taken to minimize EMI when deploying BMP modules.

Mitigating both radiated noise with shielding and conducted noise through the insertion of suitable filters in power lines and connections ensures that the final product functions correctly and meets stringent electromagnetic compatibility (EMC) regulations, such as EN 55022 Class B.

## How Can BMP Modules Be a Source of EMI?

To achieve a compact footprint and meet power density goals, DC-DC module designers often turn to planar transformers. The transformer windings are created as tracks in the BMP's PCB and the core of the component is clipped around these traces to complete the magnetic circuit (Figure 1).

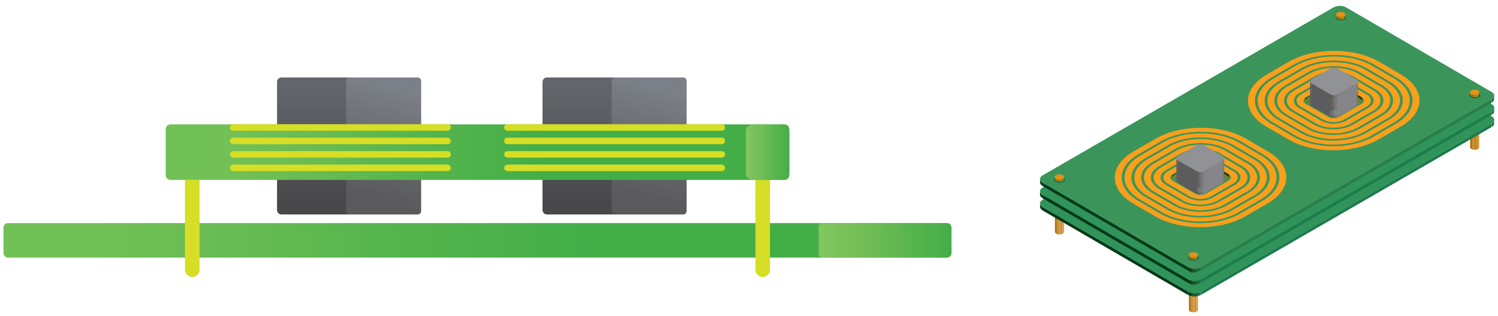


Figure 1. Transformer windings are a source of noise in BMP modules

The windings of the transformer and inductor, as the principal magnetic components, are effectively un-shielded. Therefore, they provide an effective antenna for transmitting radiated emissions at the switching frequency and at the switching frequencies' harmonic frequencies. The cores of the magnetics are also unscreened and will produce emissions at these frequencies. In addition, the PCB traces that carry the power and switching waveforms effectively act as antennas that contribute to the emissions from the module.

While a six-sided metal casing could prevent EMI from radiating from the module, these are seldom used. A full metal casing would tend to drive up the module's cost, is not beneficial in increasing power-conversion density (W/cu-in), and is largely not necessary, because EMC regulations apply only at the system level, not at module level. From this standpoint, an open power module is satisfactory if the complete system is housed in a metal enclosure (Figure 2).

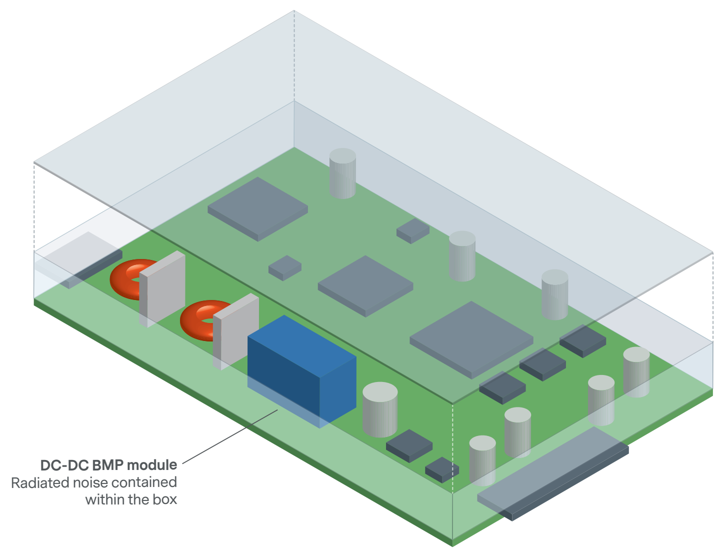



Figure 2. The casing of the final product provides the screening and contains any radiated EMI generated by the module

## Radiated and Conducted EMI

Radiated emissions occur at the fundamental frequency (converter switching frequency) and its associated harmonics. Specifications, such as the CISPR series, that apply to all electronic equipment including domestic appliances, power tools, computers, and televisions reference the norms stated in EN 55022 class B. For radiated emissions, EN 55022 class B considers noise in the frequency range from 30 MHz to 1 GHz.

The radiated EMI field from the module is emitted in all directions, although the predominant effect to the application is usually vertically above and below. Naturally, the field intensity is highest near the module and decreases moving farther away, although the distances involved can be many times the dimensions of the DC-DC converter itself.

Any tracks or wires close to the input side of the module will pick up the noise and this will manifest itself as conducted emissions on the input to the application. If tracks or components are placed under the BMP module, these can be particularly affected (Figure 3).

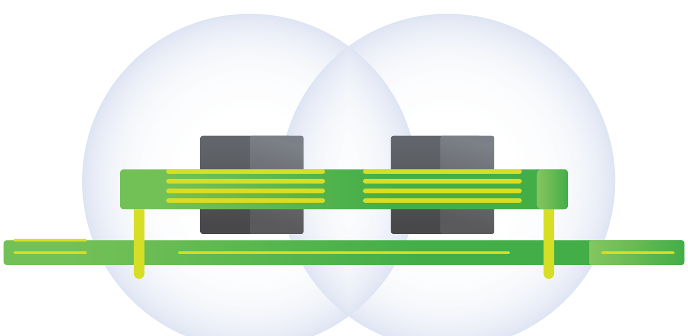


Figure 3. Radiated emissions from an unshielded BMP can affect circuit elements

Some BMP modules contain a conductive metal plate that is designed to connect to ground, and although the primary reason for the baseplate to be present is to manage the thermal dissipation from the module (if the module is bonded to a chassis or has a heatsink fitted), it has the effect of inhibiting much of the spectrum in the vertical direction. In conjunction with this shield, as per figure 4, designing the upper layer of the PCB with a large copper area directly beneath the BMP module and connected to ground prevents emitted radiation from entering the PCB to interfere with the circuit tracks and components.

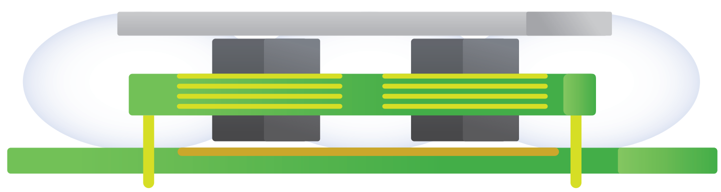


Figure 4. Grounded module top plate and PCB-plane block radiated EMI

AC-DC BMPs deserve special consideration, as the module is likely located close to the input connections for an application. A lack of shielding and consideration of the EMI radiation from the module can allow radiated interference to induce conducted noise in these connections. Typically, plastic module enclosures fail to address or affect any screening of those emissions, but the use of case kits may be an option. Advanced Energy's AC-DC BMPs (for example the AIF-500) are available with case kits that can be easily and quickly applied to prevent emissions of AC-DC modules that are coupled into the power supply conductors (Figure 5).


Figure 5. Advanced Energy case kit for AIF AC-DC modules

When it comes to conducted emissions, the input-pins of the module are considered to be the noise-generator. EN 55022 class B considers conducted emissions in the frequency range of 150 kHz to 30 MHz. It also specifies that no items of equipment are allowed to affect other equipment connected to the same power supply. So, any noise generated by the BMP module must be prevented from feeding back into the application power source. This necessitates an input EMI filter, which is implemented in the application, as there is usually no room to accommodate the components inside the BMP module. The filter must be placed externally to the module on the host PCB.

The design of the filter, including component types and values, is driven by factors such as the module's switching frequency and power rating. Designers may elect to build their own filters from discrete components or source a standard or custom filter from third parties. Figure 6 shows a typical input filter schematic and bill of materials.

Proper filter design should consider more issues than schematic and component values. Selection of component types and the layout and realization of the filter are critically important to the successful operation and effectiveness of the filter. Some guidelines include placing capacitors for high-frequency decoupling near to the module, the use of surface-mount components to minimize aerial effects, and deploying toroidal inductors to keep the field within core.

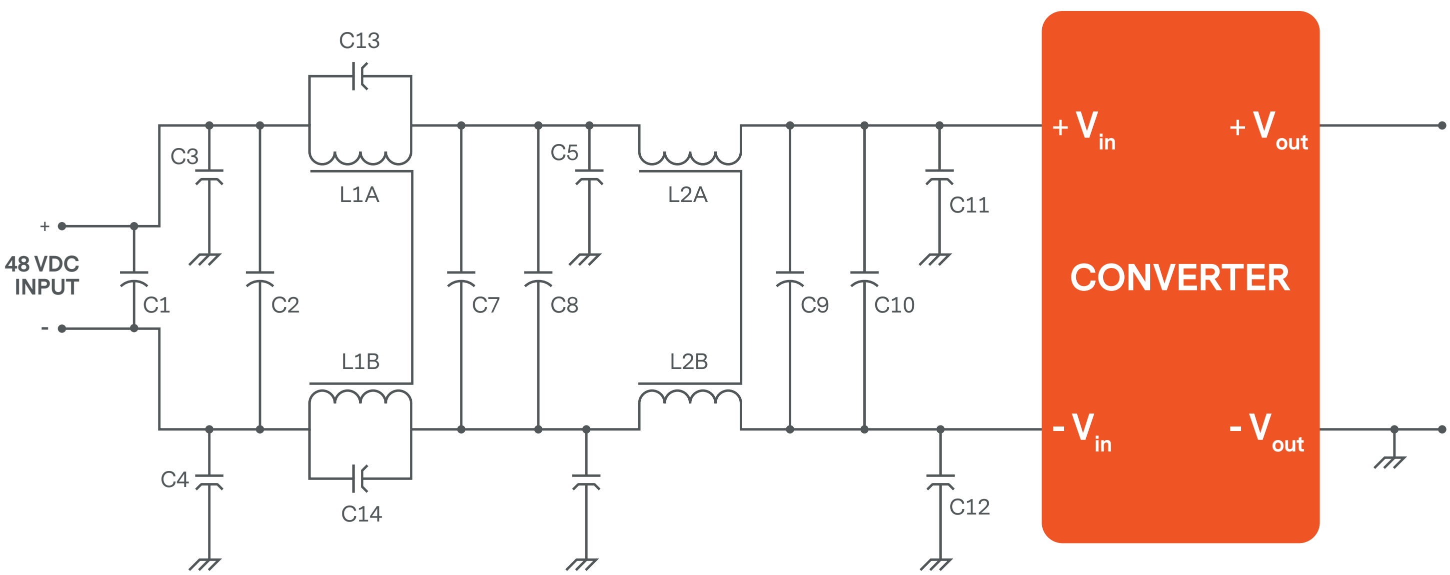



Figure 6. Generic EMI filter design

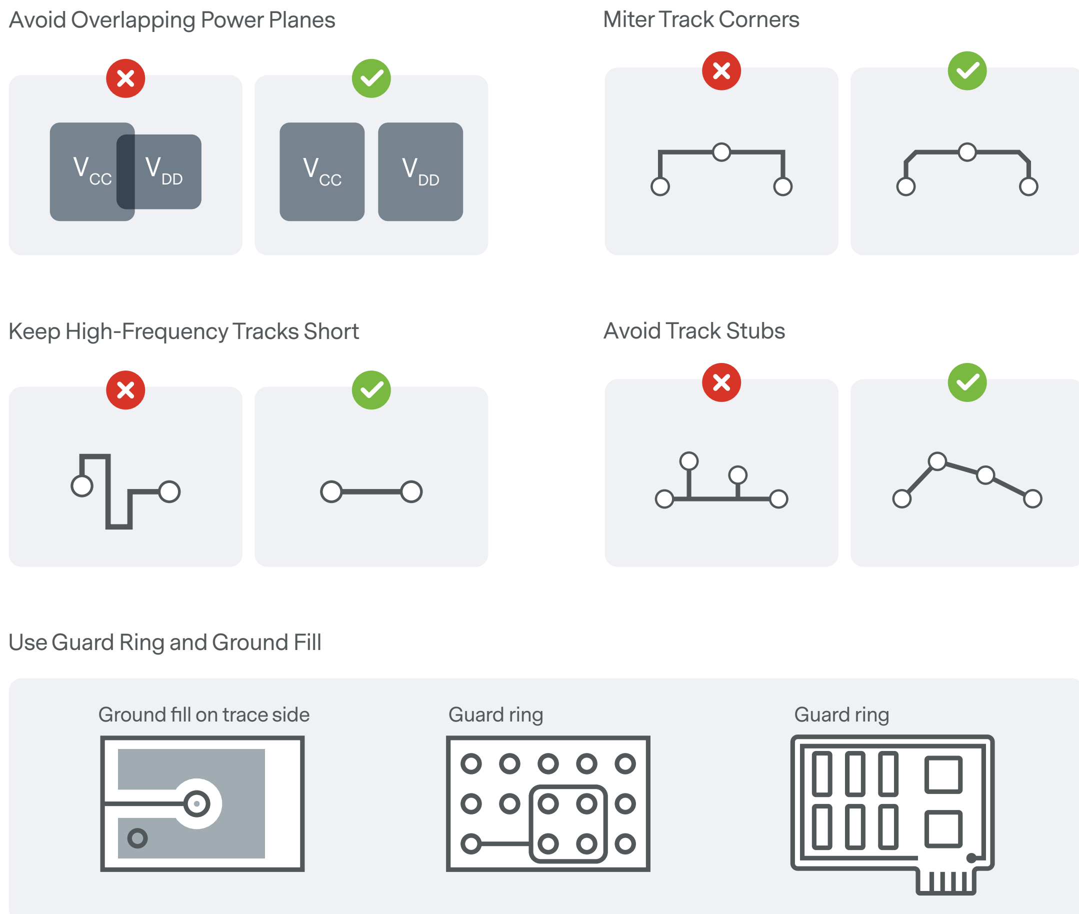



Figure 7.

Common-mode chokes should also be placed between current carrying and signal lines. Using RC snubbers is also an effective technique to dampen ringing.

Track shapes need to have curved corners to prevent unnecessary and easily avoided emissions, and careful layout to force noise-carrying conduction paths past de-coupling capacitors is critical to performance.

To reduce cost, it may be possible to use one filter with two BMP modules. This is particularly easy to accommodate if multiple instances of the same module are used in a current sharing or redundant arrangement. Figure 8, for example, shows a reference design developed by Advanced Energy's engineering team to combine a single surge suppressor and EMI filter with two AIF-500 AC-DC BMP modules. This reference design is backed up with a holdup calculator that can assist with selection, depending on the specific BMP module and other system requirements.

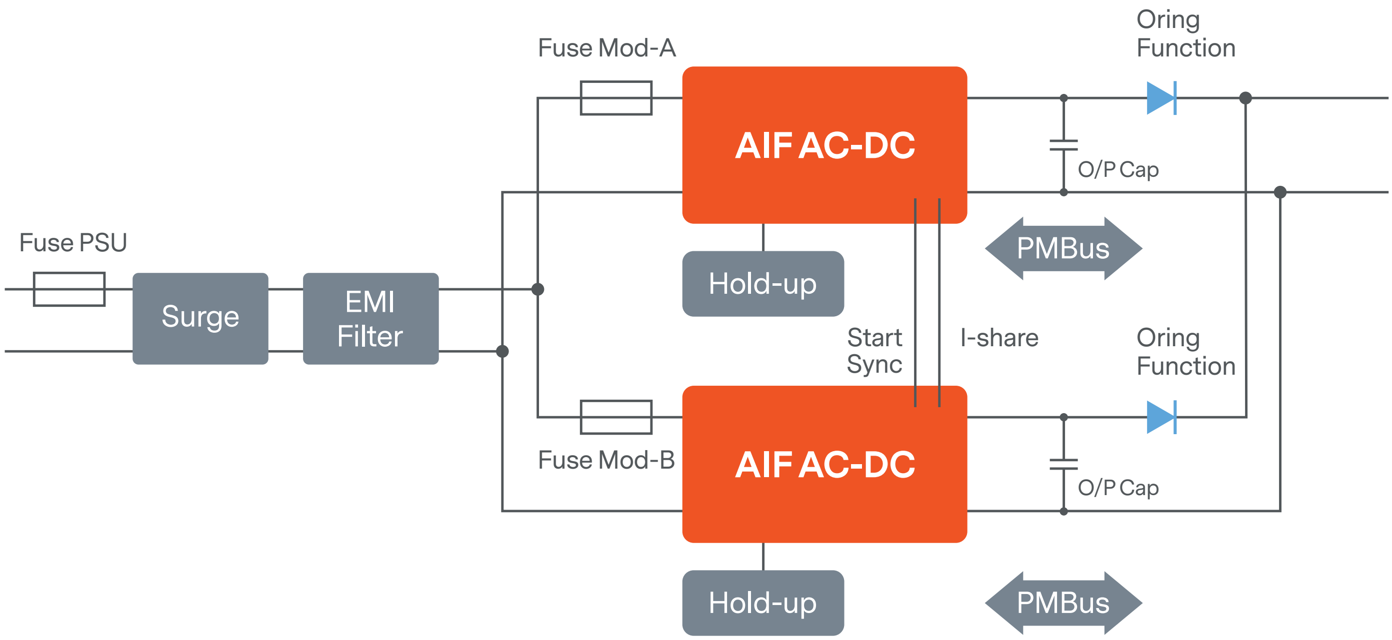



Figure 8. Sharing an EMI filter with two or more BMP modules

## Conclusion

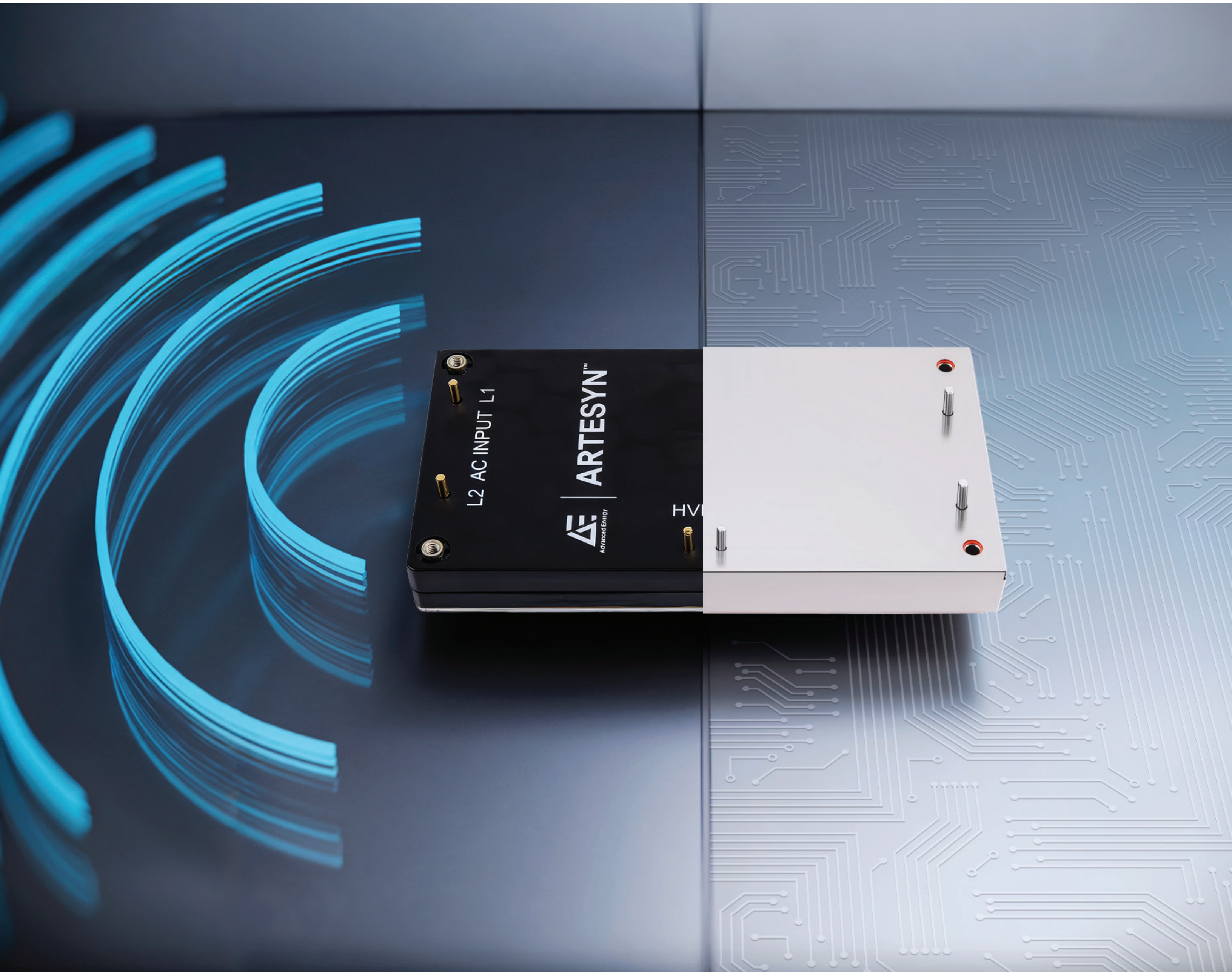
Integrating switched-mode power converters into any system requires effective EMI management to mitigate noise generated at the converter switching frequency and associated harmonics. Designing for EMC ensures both optimized system operation and compliance with key regulations such as EN 55022 class B related to conducted and radiated emissions.

To effectively manage EMI, the process begins with identifying the source of the interference. This source typically operates at the same frequency or shares a fundamental or harmonic frequency with the affected system. Once identified, the source should be suppressed using both mechanical and electrical methods. Mechanically, this involves implementing shielding, minimizing loop areas through careful layout, eliminating common impedances, and utilizing a solid ground plane. Electrically, suppression techniques include minimizing voltage and current transients (dv/dt and di/dt), using snubber circuits on switches, damping tuned circuits, decoupling power supplies, and applying bypass techniques. In parallel, it is crucial to identify the receivers or victims of the interference — often, nearly every component can act as a receiver, and some may even re-transmit the interference. To mitigate this, receivers should be desensitized. Mechanically, this again involves shielding, minimizing loops, eliminating shared impedances, and ensuring a robust ground plane. Electrically, damping circuits, decoupling, and bypass techniques are employed to reduce susceptibility to EMI.

In addition to supplying converters, module manufacturers can help designers with this task by providing accurate information on module noise performance and offering complementary products and design services.

As a leading supplier of DC-DC and AC-DC BMP modules, Advanced Energy has many years of experience in this area and provides extensive support to OEMs when it comes to meeting EMC requirements. This support includes complementary products such as case kits for EMI reduction, reference designs and calculator tools for filtering, and end-to-end engineering support throughout system design, testing and approval.

**To learn more about Advanced Energy AC-DC BMP module offerings, visit: AC-DC BMP.**



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