Achieving EMC for Dc-Dc Convertors

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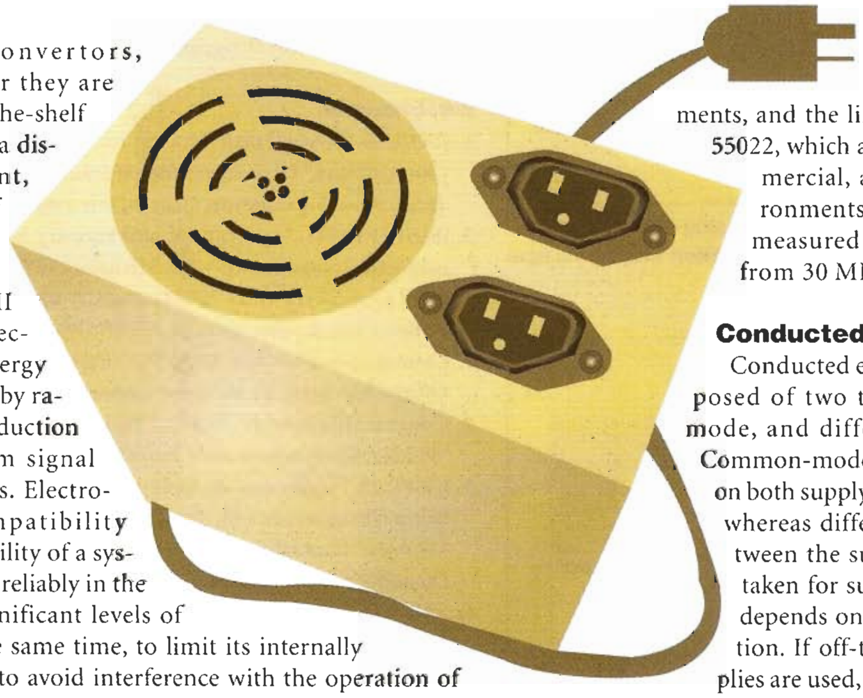
For dc-dc convertors, selecting suitable parts and designing effective layouts are crucial to meeting electromagnetic compatibility requirements.



Dc-dc convertors, whether they are an off-the-shelf brick design or a discrete equivalent, are a source of electromagnetic interference (EMI). EMI is unwanted electromagnetic energy that propagates by radiation and conduction through system signal and power lines. Electromagnetic compatibility (EMC) is the ability of a system to function reliably in the presence of significant levels of EMI and, at the same time, to limit its internally generated EMI to avoid interference with the operation of other systems around it. Whichever approach is used to meet system requirements, it is certain that some filtering will be required on the input power lines.

EMC Regulations

There are a number of EMC regulations concerned with all aspects of EMC, whether it is conducted or radiated emissions, electrostatic discharge (ESD), electromagnetic field, or surge immunity. Looking primarily at emissions requirements, international standards are prepared by the Comité International Spécial des Perturbations Radioélectriques (CISPR)—International Special Committee on Radio Interference—and adopted by regional authorities. In Europe, the applicable standard for dc-dc convertors is EN 55022. In the United States, FCC Part 15 is the applicable regulation.

Figure 1 shows the emissions limits for EN 55011 and EN 55022. The conducted emissions are measured at frequencies between 150 kHz and 30 MHz. The limit for Curve A is for EN 55011, which applies to industrial environments, and the limit for Curve B is for EN 55022, which applies to residential, commercial, and light industrial environments. Radiated emissions are measured over the frequency range from 30 MHz to 1 GHz.

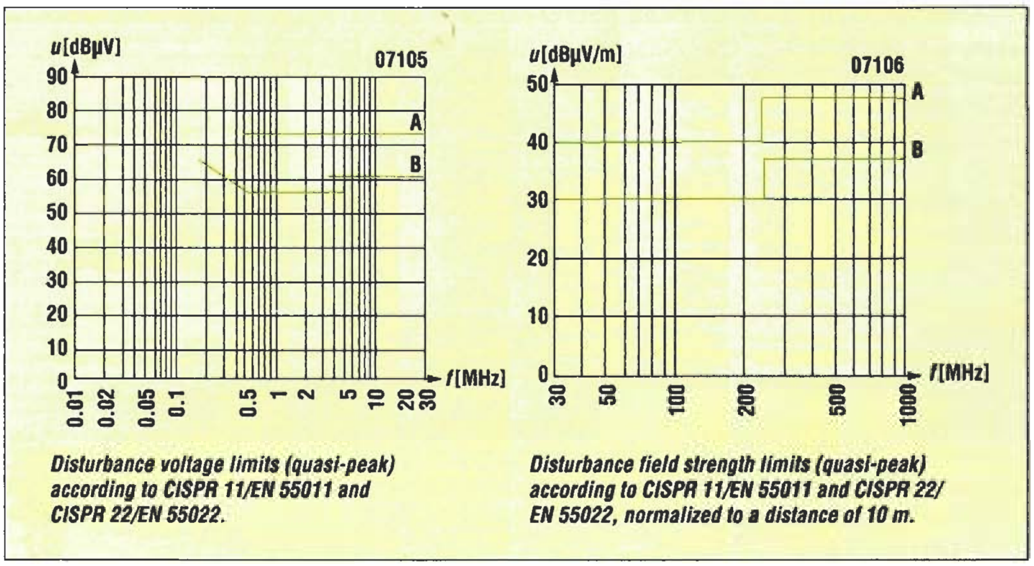
Conducted Emissions

Conducted emissions are usually composed of two types of noise: common mode, and differential or series mode. Common-mode noise appears as a voltage on both supply lines with respect to earth, whereas differential noise appears between the supply lines. The approach taken for suppressing these emissions depends on the dc-dc convertor solution. If off-the-shelf brick power supplies are used, then only external filtering is required. If a discrete solution is being employed, then the first step is to suppress the noise at its source.

There are two main areas of noise generation in a dc-dc convertor. The first area is associated with the switching frequency of the power supply. Obviously, the power supply switching frequency is an integral part of its operation, and there are limited steps that can be taken to suppress noise caused at this frequency and its harmonics. Switching-frequency noise is both common mode and differential. The differential noise can be reduced by placing a decoupling capacitor across the dc line local to the main switching element.

Common-mode noise is injected into the earth of the power supply via the parasitic capacitance between switching devices, such as transistors and diodes, and the chassis to which they are mounted. Using an electrostatic screen between the device and chassis can reduce noise levels, but this tends to hinder the thermal performance. In practice, a filter is usually placed on the input line to deal with the common-mode element of this noise. Implementation of modern circuit designs that use soft-switching techniques can greatly reduce both the common- and differential-mode noise associated with the switching frequency. This in turn allows the use of simpler and cheaper input filter designs.

The second aspect of dc-dc convertor noise is associated with the fast switching edges. These edges will tend to overshoot and ring, causing high-frequency noise. The normal way of dealing with this type of noise is to fit a snubber circuit, typically in a resistor-capacitor-diode (RCD) configuration, in parallel with the switching device in order to damp the ringing.



Disturbance voltage limits (quasi-peak) according to CISPR 11/EN 55011 and CISPR 22/EN 55022.

Disturbance field strength limits (quasi-peak) according to CISPR 11/EN 55011 and CISPR 22/EN 55022, normalized to a distance of 10 m.

Figure 1. EN 55011 and EN 55022 limits for conducted and radiated emissions.

EMI Filters

EMI filters have two functions. First, they attenuate noise generated within the power supply, preventing it from getting onto the supply lines. Second, they prevent noise on the supply lines from interfering with the power supply operation. The filter circuit shown in Figure 2 is the basic design required to attenuate differential-mode noise.

At the power supply switching frequency, which can be anything from 50 kHz to 1 MHz, the inductance in the line appears as high impedance. As a result, most of the noise current will flow through the low impedance of the capacitor fitted across the lines; this capacitor is referred to as an X capacitor. The inductor can be two separate parts, one in each line, or alternatively, a coupled inductor can be used. The advantage of coupled inductors is that two serially connected windings on the same core will give four times the inductance of a single winding. This means that, in general, a coupled inductor will be cheaper than two single inductors and require less circuit board space while achieving the same results.

Figure 3 shows the basic filter circuit required to attenuate common-mode noise. The inductor presents a high-frequency high impedance in the line, and the capacitors, which are referred to as Y capacitors, provide a low-impedance path for the noise current to earth.

Common-mode inductors are constructed with two windings on one core. These windings are connected in the circuit in antiphase, with one in each line. The effect is that the current in each winding is equal and opposite, resulting in no peak flux in the core and allowing common-mode chokes to be constructed using relatively small core sizes for their rated current.

In practice, a combination of both common-mode and differential-mode filters is required. For a modern dc-dc brick power supply design that uses soft switching, the filter

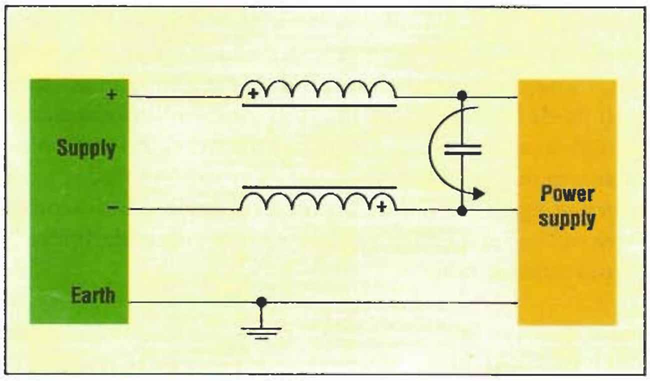


Figure 2. Differential-mode noise filter.

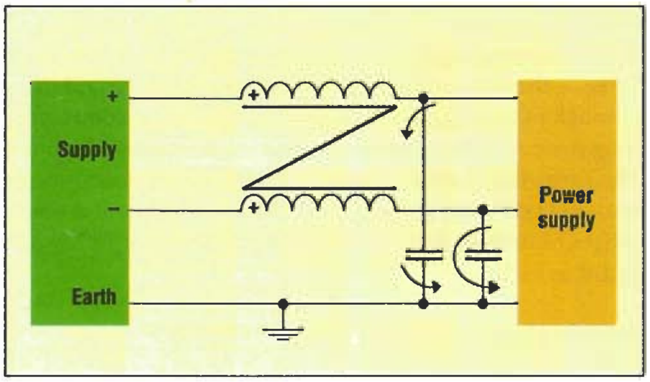


Figure 3. Common-mode noise filter.

will look something like the example in Figure 4.

The inductance L_x is the leakage inductance of the common-mode inductor. In many applications, this is large enough to filter the differential-mode noise when used in conjunction with a relatively large value of capacitance across the line. Capacitor C_4 is fitted to filter any noise on the supply line and prevent it from interfering with the power supply operation. Typical components for a nominal 48-V input, 30-W output dc-dc convertor with a 250-kHz switching frequency might be as follows:

- L_1: 780 µH, 1.2 A, Coiltronics CMS3-11, with L_x = 5.1 µH.
- C_1 and C_4: 1 µF, 100 V, AVX MR081C105J.
- C_2 and C_3: 4.7 nF, 1.5 kV, AVX 1812SC472KA1.

With these values, the common-mode switching-frequency noise will be attenuated by –20 dB, and differential noise will be attenuated by –28 dB.

For applications that require greater attenuation, multistage filters can be used. This can involve adding a differential-mode inductor or an extra common-mode choke. Figure 5 shows a three-stage filter that employs both of these additional components.

Typical components for a 48-V input, 15-W output dc-dc convertor with a 250-kHz switching frequency might be as follows:

- L_1: 15 µH, 1 A, Coiltronics CTX15-1A (this coupled inductor has an effective circuit inductance of 60 µH).
- L_2: 1.6 mH, 0.75 A, Coiltronics CMS3-14, with L_x = 9.6 µH.
- L_3: 840 µH, 0.8 A, Coiltronics CMS2-11, with L_x = 5.0 µH.
- C_1, C_2, and C_3: 1 µF, 100 V, AVX MR081C105J.
- C_3, C_4, and C_5: 2.2 nF, 1.5 kV, AVX 1812SC222KA1.

With these values, the common-mode switching-frequency noise will be attenuated by –35 dB, and the differential noise will be attenuated by –90 dB.

Layout and Positioning

The layout and positioning of the filter is critical to achieving optimum performance. Figure 6 shows an example layout for a simple filter. X capacitors are fitted directly across the input power lines, with the common-mode choke located directly in line. Similarly, Y capacitors are fitted on both of the power lines to ground.

The filter should be positioned as close as possible to the power inlet. Ideally, the filter should be mounted on the wall of the housing to prevent noise pickup in the power lines between the inlet and the filter. It is also common practice, although not always essential, to screen the filter and any cabling there may be between the inlet and the filter. Screened filters are often used to prevent high-frequency noise greater than 30 MHz from getting on to the power lines and being radiated. For this sort of screen to be effective, it must be connected to earth.

Conclusion

Whatever approach is used to meet dc-dc power requirements, it is certain that dc line filtering will be required. Whether it is a modern convertor topology using soft switching or a more traditional design, the basic requirements are the same. Selecting the correct parts to provide the required attenuation, along with designing a good layout, will bring switching-frequency and switching-frequency-harmonic noise levels within regulatory limits. When used with an off-the-shelf dc-dc brick solution, the addition of a filter should be enough to achieve regulatory EMC. However, discrete solutions will require more work; the filter will be relatively ineffective against noise at higher frequencies, and a lot of work will be required to resolve these issues for both conducted and radiated noise.

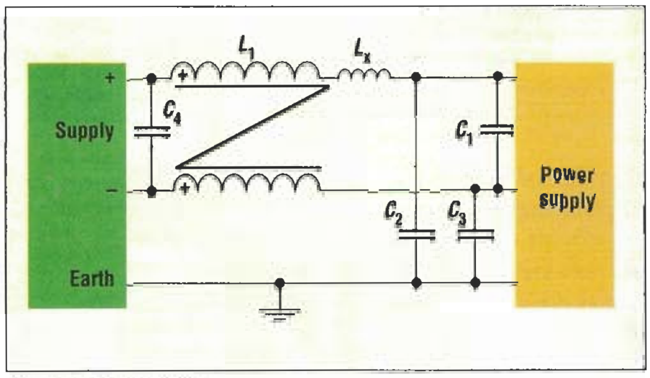


Figure 4. Simple filter.

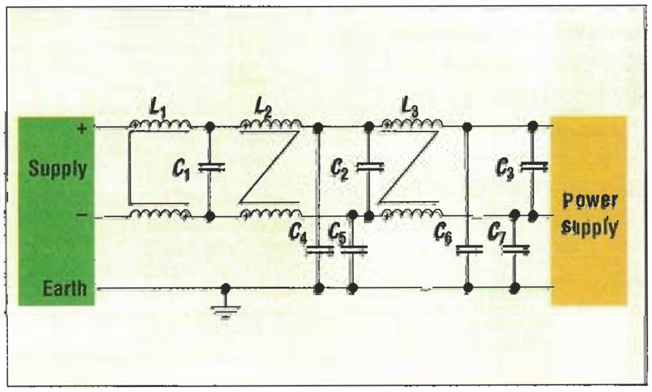


Figure 5. Three-stage filter.

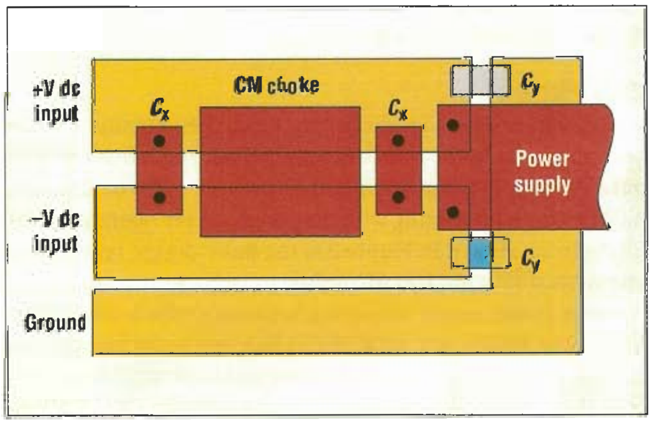


Figure 6. Input filter layout.

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