Using Common Mode Chokes to Reduce EMI/RFI in Off Line Switching Power Supplies

Ongoing advances in semiconductor technology and the migration to higher switching frequencies has allowed off line switch mode power supply (SMPS) designers to offer products that deliver ever higher levels of efficiency in a shrinking footprint. But these advantages come at a cost. Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) are natural byproducts of SMPS design. Much of this noise is generated as a direct result of a switching process that produces large voltage swings caused by short-duration charging and discharging in the power supply circuitry. These undesirable emissions can interfere with both the internal circuits in the power supply and external electronic equipment located nearby. As a result efficient and cost-effective filtering technology placed between the electrical equipment and the power line is essential to reducing noise and meeting increasingly stringent regulatory requirements.

Power supply designers can use any of a number of filtering techniques to control EMI/RFI. One of the more effective ways to reduce common mode noise is to place a Common Mode Choke (CMC) after the AC line full-wave diode rectifier. This white paper will look at the role CMCs play in achieving that goal and how designers can optimize the use of CMCs to ensure regulatory compliance.

The Regulatory Landscape

To manage the EMI/RFI generated by SMPS, regulatory agencies in various markets around the world have developed a series of rules and regulations that define electromagnetically compatible (EMC) power supplies. In the U.S., the Federal Communications Commission (FCC) is responsible for regulating EMI emissions. Part 15 of the FCC's rules specifies that any spurious signal generating more than 10 kHz be subject to regulation. It also specifies the frequency bands in which those spurious emissions must be controlled by type of emission. Radiated emissions must be controlled between 30 MHz and 1000 MHz, while conducted emissions must be controlled in the frequency band between 0.45 MHz and 30 MHz.

The regulatory agency overseeing electromagnetic compatibility in Europe is the International Special Committee on Radio Interference or CISPR. The committee's third edition of CISPR, Pub 22, known as CISPR 22 or EN55022, defines those regulations and has been adopted by much of the European community.

Today conducted and radiated emission limits specified in FCC Part 15 and CISPR 22 are within a few dB of each other over prescribed frequencies ensuring that using either regulation will not compromise the accuracy of the measurement or certification process.

Common Mode Chokes

Many electronic circuits require the use of common mode chokes to filter out conducted switching and RF noise coming from switched mode power supplies (SMPS) or other live power outlets. This high frequency

noise can adversely impact the performance of electronic devices connected to the same power source. In some cases it can cause system failures.

A common mode choke is used to filter out noise that is common to, or coupled to, the power and network lines. A CMC features two identical windings with the current in each winding flowing in the opposite direction of the other. The live and return currents are of the same magnitude since they are from the same power source. But the direction of the magnetic flux lines created by the current flowing into the first winding is opposite the flux lines created by the return current in the second winding. These two magnetic pluses cancel each other out creating a theoretical net flux of zero.

As a result the choke presents little inductance or impedance to the differential-mode currents. This means the CMC's core will not saturate due to the amplitude of the main currents. High frequency noise currents, however, which are of much lower amplitude, will see a high impedance due to the common inductance of the windings and will be severely attenuated or filtered out.

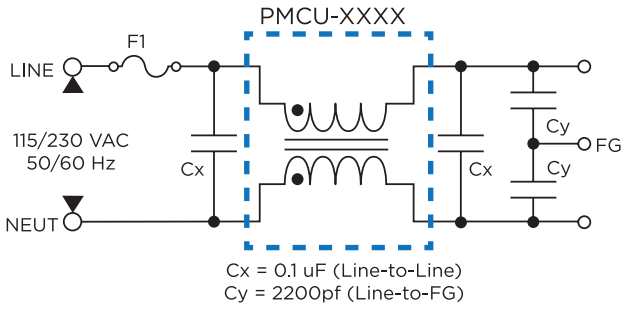


Figure 1 - Typical Application Circuit

Premier Magnetics has developed a comprehensive line of transformers and inductors that are either specifically designed for or include common mode filters to block EMI and RFI in power supply applications. The diagram above illustrates a typical low profile, common mode filter for low to medium power applications.

Key Component Selection Considerations

Often power supply designers decide to rely on discrete inductors and capacitors in front end filtering solutions instead of CMCs. These components do offer a small but attractive cost advantage. In many cases, however, that cost advantage may be more than offset by a requirement for flux bands or shields on the main transformer that significantly increase design complexity and transformer cost. For example, adding a flux band or shield to a typical 30 to 50W SMPS transformer will increase component cost by 20 to 30 percent. Common mode currents can pass through a transformer due to the parasitic capacitance between the primary and secondary coils. This is why a CMC or flux band can help reduce common mode noise.

By avoiding use of a CMC, power supply designers may not only require a more complex transformer, they also must add inductors and/or capacitors to filter the power lines. This design strategy drives up system cost and complexity. Moreover, this approach may result in less than optimum FCC compliance. Furthermore, relatively powerful power line filters are often required to meet conducted noise specifications. Yet safety regulations limit the size of the capacitors fitted between the supply line and ground plane. This limitation can often result in a filtering solution that is inadequate for the common-mode interference problem it is attempting to address.

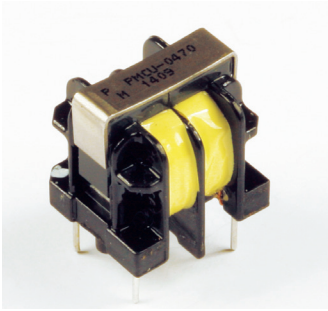
Designers who opt to add capacitors for filtering can face additional issues. Electrolytic capacitors used after the rectifier diodes are more likely to fail from overvoltage, heat or other factors. Film capacitors are also undesirable because of UL/CE requirements and their loss of capacitance over time.

For designers opting to use CMCs to reduce common mode noise, Toroids (Ferrite) offer the most

effective core shape. Their continuous unbroken path maximizes magnetic coupling between windings and minimizes leakage inductance. However, the core material, the high number of windings and the use of a plastic mounting base make toroids a more expensive option. Furthermore, isolation between windings is typically limited to < 1500V which may limit their use in some applications.

A typical toroidal CMC offered by Premier Magnetics

Designers looking for an optimal combination of efficient filtering and low cost will find CMCs with E or U ferrite core shapes offer the best bet in a wide range of applications. These devices offer isolation between the two windings up to 3000V which helps meet UL and other safety agency requirements while ensuring FCC compliance.



E or U ferrite core CMCs deliver efficient filtering at low cost.

Designers can also use this style of component as an output filter. Long cable runs that are connected to a safety ground act like antennas when common mode currents flow through them. A PMCU filter can be used to limit radiated EMI wherever long output cables are used and the output return is connected to safety earth ground.

Conclusion

Common mode noise, which is generated through the power line and returns to the source through some type of ground path, is a key problem in SMPS design. Managing these emissions is crucial to meeting worldwide regulatory requirements. By using a new generation of CMCs, designers can build highly efficient and cost-effective filtering solutions that optimize power supply performance while ensuring regulatory compliance.

About the Author

Jim Earley is president and founder of Premier Magnetics. He has spent the majority of his career actively involved in the design, sale and manufacture of magnetic components.

Premier Magnetics Common Mode Products

Part Number	Series Type	Rating Range	Feature / Application
PMCU-XXXX	Common Mode Filter	11.5VA - 287.5VA	Low profile; 3750Vrms isolation; low-medium power
PMCE-XXXX	Common Mode Filter	86VA - 805VA	Low profile; 3750Vrms isolation; medium-to-high power
PM-Omxx	Common Mode Inductor	1.8A - 6.0 A / 120/ 240 Vac	Vertical mount toroid; 1250 Vrms isolation; high frequency power
LF-668	Line Filter	3.3 mH - 68 mH @ 10 kHz	Low DC Resistance; DC/DC, AC/DC line noise suppression

About Premier Magnetics

Incorporated in 1991, Premier Magnetics is a leading, multinational company specializing in power (switch-mode) magnetics. In addition, Premier produces and markets a broad range of magnetics components, including communication and networking magnetics, data bus MIL-1553 military magnetics and DC/DC converters. Committed to providing the highest quality products available – within the shortest cycle times and at the most competitive cost–Premier's products span the communications, computer, industrial, commercial, medical, defense and avionics industries.

Premier Magnetics provides world-class design and engineering expertise for custom design requirements as well as an extensive offering of standard products. Sample and prototype manufacturing takes place in the company's California design lab, while high-volume quantities are produced at facilities based in China. Premier's sales and distribution offices are located worldwide. For more information, please go to: www.premiermag.com.

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