Advanced Energy

Power Supply Common Mode Noise

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Introduction

Noise in the electronics realm is a random or undesired fluctuation in the electrical signals or voltage source. It is often conducted through interconnect cables and conducting metal parts such as brackets, shields and chassis.

Radiated noise is a form of electromagnetic interference transmitted through the air by cables and components with AC voltages or currents. The radiated coupling can be very local, for example between a transformer and a nearby wire or PCB trace, and become conducted noise.

Industrial and medical instruments operate in a noisy environment and are prone to interference from common mode noise present as a result of lack of knowledge or understanding of the inference mechanisms.

Types of Noise and Coupling

Common mode noise currents often follow a large loop area which then radiate to the environment adding to the system electromagnetic emissions. It can also create spurious conducted signals within a system that causes communications errors and malfunctions due to signal disturbances. Sensitive measurement devices can malfunction or interpret the noise as data and result in erroneous data.

AC line transients, such as line surges due to lightning strikes, power switching from motor controls, circuit breakers or relays actuating, can cause both differential and common mode disturbances on the AC mains that propagate through the power supply to the electronics or is coupled across conductors and result in malfunctions or damage to the electronics.

Differential mode, also known as Normal mode noise is the ac voltage disturbance across signal or power lines or current through them. The noise follows the signal and power paths. This is what one would expect normally when reviewing a wiring diagram or schematic.

Common mode noise is the ac disturbance from one or more signal or power lines and an external conduction path, such as an earth ground or chassis or other conductive material not intended to conduct the power or signals (figure 1).

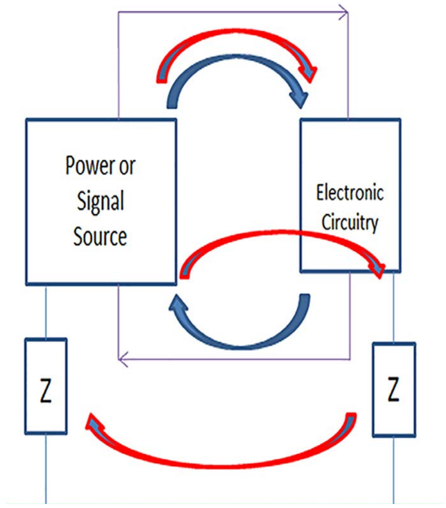

Figure 1. Common mode noise current is returned to the source through a different path from the normal signal or power path. Examples include chassis or earth ground and adjacent conductors. This is possible due to impendences to that conductor.

The noise source may be from the AC mains, the power supply or even the electronic circuitry being powered.

The parasitic impedance is often not obvious, but understanding it is essential to finding optimum mitigation methods. One also needs to be aware of the impedances to the common path may be components added to help filter noise.

Output common mode noise is often overlooked and not specified. Most of the attention is in the input EMI filter and output differential noise filtering. There is though, significant output common mode noise present due to conductive and radiated coupling to the output. In most applications, this is not an issue as the output is grounded either internally at the power supply or at the end application or significant capacitance to ground is added on the output to earth.

Noise Sources

A typical power supply consists of an AC/DC rectification stage followed by a high frequency DC/DC stage and control circuitry to regulate the output voltage.

Noise from the power supply mainly originates from the switching power semiconductors. Switch mode power supplies are much more efficient, smaller and more economical than linear power supplies they have displaced during the past few decades. Power supply designers have made improvements in reducing noise generated in the power supply from leaking out to connected or nearby equipment. However, noise is still a challenge and common mode noise is often overlooked, partially due to the lack of specifications defining a requirement for output common mode noise.

The nature of switching power supplies is that there are high dv/dt and di/dt circuits in order to achieve the high efficiency, reduced size and cost. With parasitic capacitance as part of the product due to the nature of physics of materials and electromagnetics, we have a natural high harmonic noise source that is heavily filtered within the power supply, but not perfect in containing it within the boundary of the power source.

Here we have a simplified diagram (figure 2) for a switch mode power supply. Only a few parasitic coupling paths are shown to illustrate the mechanism. Depending on the power conversion topology used, the dv/dt and di/dt generated in the power supply can vary greatly. Although filtering is used to reduce the amount of noise that is present at the output terminals, the amount of noise that conducts through the output cables depends on the load and its impedances, both from the differential and common mode perspective.

The point of interest here is to see what the voltage is between the output power or signals leads, and chassis or system ground. If the output is shorted to chassis or earth at the power supply, that eliminates the common mode voltage at that point. Depending on how the system electronics is configured, common mode noise could be generated at the system and coupled back to the power supply ground point. This forms a loop which can also be a source of conduct and radiated EMI and a path for noise currents that interferes with the system operation.

An understanding of the nature of the noise source goes a long way in determining how to mitigate its impact and also to define requirements. Noise can be low frequency, 50/60 line frequency coupled for example, or at the switching frequency of the power supply (typically in the 50-300kHz range) or high frequency of the switching transition of the power devices which can be in the megahertz range.

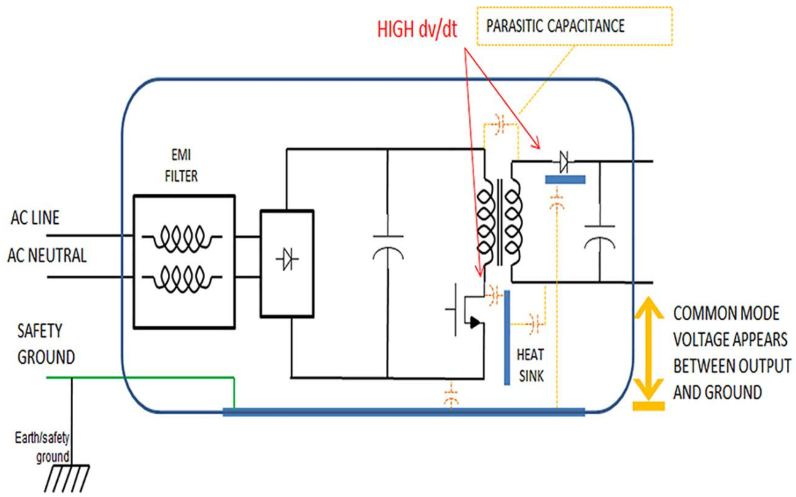

Figure 2. Switch mode power supply showing noise sources and paths. The switching modes generate high dv/dt or di/dt. Dv/dt couples through capacitances and di/dt through magnetic field coupling. This generates noise currents which find their way back to the source.

Understanding what your system may be sensitive too will help you determine acceptable solutions.

For instrumentation systems monitoring low frequency signals in the low Hz to a few 100 Hz and a floating power source, AC mains noise can be a significant problem in high impedance applications. The relatively small capacitive coupling between the AC mains and the output can be enough to generate 10's of volts of common mode noise.

In high impedance applications, where there is little to no capacitance to ground, a small ~ 10pf capacitance from AC input to an output forms a capacitive divider that generates almost 10VRMs at 265VAC. This is assuming 270pF for output to chassis/earth ground. While these are very high impedances for most applications, in sensitive high impedance systems, this can be a challenge.

Understanding the noise content and impedance of the noise source will provide good insight into ways to mitigate the impact of the noise.

When making measurements, you need to be aware of the potential impact the measurement method may have on the results. The measurement method may result in higher readings, due to long leads and loops for high frequencies for example. Or lower the reading by loading down the noise source due to probe impedance itself. Give some thought to what you're measuring. Try to distinguish between the noise frequencies that are causing the problem and other noise frequencies that are present and only masking the real noise issue. It can be advantageous to filter out frequency ranges in order to see noise of a particular frequency when the noise is a combination of low and high frequency.

A simple low pass and high pass filter can be made using an R-C network. This allows investigation of the frequencies of interest.

This is suitable for typical applications, but for systems having a very high impedance (> Meg ohms) requirement between the power supply and ground, than a high impedance active voltage probe will be needed to avoid loading down the measurement point.

To get an understanding of the noise source impedance, and hence an appreciation of what will be needed to filter it, measuring the open circuit voltage and short circuit current will be helpful.

Measure the open circuit voltage from the output return lead, or the other polarity, and the system or earth ground point. You can use an oscilloscope to do this being careful to keep the test lead short if measuring in the few megahertz and higher. You can also use a spectrum analyzer which will be more instructive in revealing the frequencies of the noise. This will be helpful to know so you can then select the proper component values needed if additional filtering is required. However, the input to a spectrum analyzer is usually 50 or 75 ohms so this could be loading down the noise source. You could monitor the same point with an oscilloscope to see how much it is being loaded.

Common Mode Noise Mitigation

Once you have a good idea of the noise frequency spectrum, source impedance and the frequencies that are an issue, you can make informed decisions on the ways to mitigate the noise issue:

- Ferrite material, clamp on cores, inductors, toroid's and the like are quiet effective at reducing offending currents if the proper material is selected. There are a number of manufacturers for ferrite material, and some provide excellent characterization data showing impedance verse frequency.

- For high frequency noise in the 10 – 20 MHZ and higher range, selecting a material with a high resistive characteristics is often more effective than materials with a reactive characteristics. The resistive element helps dampen and dissipate the energy, while reactive parts will present impedance, but may contribute to resonances depending on the capacitance of the network. However, at lower frequencies, having a higher reactive element may be better as the energy involved could be significant and just providing high impedance will reduce the current flow and reduce the common mode noise.

- When selecting capacitors, be aware of the tolerance variation of the materials over temperature and applied voltage. They can be very significant and be less effective over the operating temperature of the product. Also, select the value to coincide with its minimum impedance at the frequency of interest.

- Check for resonances when adding capacitance and inductance to your filter. The resonant frequency can be calculated and depending on the noise level and frequency, you may be able to measure the voltage if you're getting worse results after applying the filter components.

- Minimize capacitive coupling between noisy signals; separate power and signal lines, shield noisy cables.

- Minimize dv/dt; ground output return to chassis/earth ground near the power supply if possible, shunt noise to power supply chassis near power output.

- Decouple noise from source to load; add common mode inductor or ferrite cores on power cables. Select ferrite material that has a high impedance in the offending frequency range.

- Shield the noise source from sensitive circuitry.

- Select Power Supplies with acceptable common mode noise.

Summary

Common mode noise is present in power systems and can cause interference issues. The impact depends on the application. Always measure to understand the source well. Follow a structured approach to mitigation methods – measure, understand, apply and verify solutions.

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