

Noise Defined

When evaluating the performance of a power filter/surge protector, it is important to understand the definition of “noise” and the noise filtering capability of the power filter being evaluated.

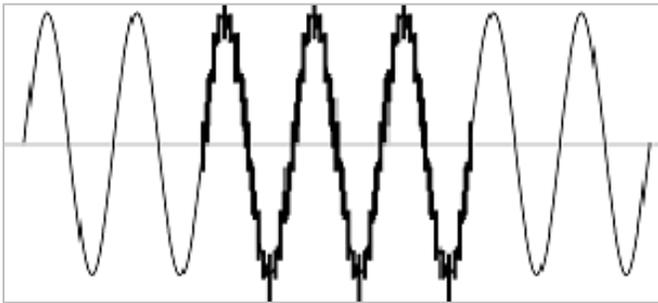


Figure 1. Typical EMI/RFI Noise

Noise is defined as a high-frequency electrical distortion of the voltage waveform. It is comprised of unwanted and interfering voltages and currents generated by motors, office equipment, industrial equipment, etc. It is commonly referred to as conducted (EMI/RFI).

Noise can be further broken down into three types: Line to Neutral, Line to Ground, and Neutral to Ground. Line to Neutral noise is called normal mode, and Line to Ground/Neutral to Ground is called common mode.

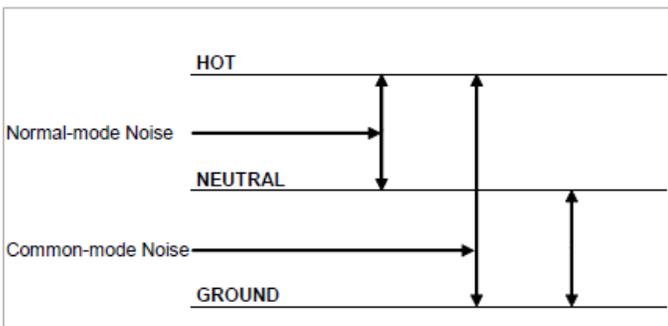


Figure 2. Typical Noise Paths

Power filters designed for office equipment must address all of these modes, but the reduction of high frequency noise referenced to ground (common mode) is the most important. The ground connection serves as the logic reference throughout the electronic network. Since common mode noise is referenced to ground, it can disrupt the clocking frequencies and logic circuits in sophisticated digital equipment, causing lock-ups and equipment malfunctions. ANSI/IEEE C62.41-1991 describes this phenomenon as “system upset” with respect to low voltage, high frequency power signals that can interfere with sensitive electronics:

Upset: This consequence can be a self recoverable upset by design of the software and therefore not immediately apparent, or may be a permanent upset requiring operator intervention or programmed automatic action occurring after some time delay.

Conducted high frequency noise is any signal of greater than 1000 times the fundamental power frequency of 60Hz. Based on further information derived from IEEE Std. 1100-1999, it can be determined that the typical range for AC mains conducted EMI/RFI is from 60kHz to approximately 10MHz. Table 4-3 of this standard defines typical voltage levels of 10V up to 200kHz and lower voltages at higher frequencies.

Noise in the Real World

A copy machine, for example, uses a switched-mode power supply to convert 120 Vac power into secondary DC voltages (5V or 3.3V used for logic circuits). The transformer contained in the power supply also serves to provide isolation from primary voltage rails to secondary voltage rails. It should be noted that low frequency (60Hz) noise/voltage between neutral and ground is not visible to the secondary side. High frequency noise however, can travel across parasitic capacitance in the transformer.

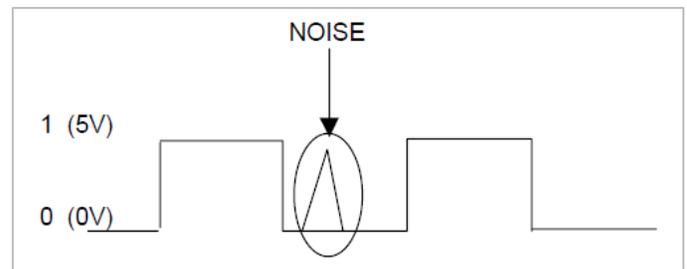


Figure 3. High frequency noise in a 4.77 MHz, 5 Volt system

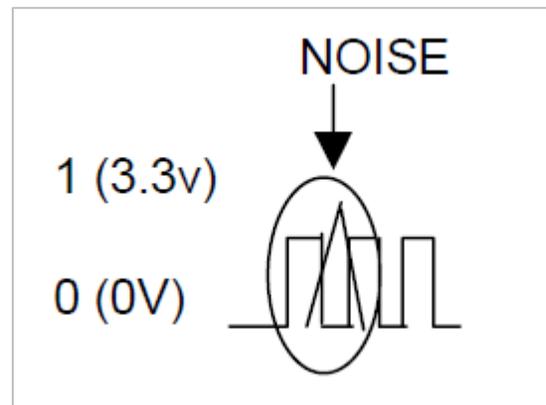


Figure 4. High frequency noise in a 50 MHz, 3.3 Volt system

Figures 3 and 4 indicate what happens when high frequency noise gets to the secondary voltages. Figure 3 shows how older systems are less susceptible to noise due to lower clocking frequencies and higher voltage levels for a logic 1. Figure 4 shows how new, faster systems are affected by the same noise. The higher clocking speeds and lower voltages for a logic 1 mean that high frequency noise levels as low as 0.5V can cause erroneous logic transitions resulting in error codes, data corruption, etc.

Equipment manufacturers specify that Neutral to Ground noise should not exceed 0.5 volts in order to avoid performance problems. Information regarding frequency is not provided, and endusers often assume that this voltage can be measured at a wall outlet using a multi-meter or other low-end power monitoring equipment. While it is possible to achieve a Neutral to Ground voltage of 0.5 volts at high frequencies, it is virtually impossible to measure this voltage without negating the effects of the voltage drop at the AC power frequency of 60Hz (refer to Figure 5). The performance characteristics of filtering devices can only be evaluated in a well equipped laboratory utilizing high frequency test equipment.



Figure 5. Instruments such as the SureTest 61-165 are often improperly used to measure high frequency noise. They are only capable of measuring low frequency, non-disruptive noise at the AC power frequency of 60Hz.

Common mode, high frequency noise is defined over a range of frequencies (60kHz-10MHz), and the remaining voltage (noise) after filtering is dependent upon both the frequency and the input voltage. For example, given a particular power filter with a performance curve as defined in Figure 6, an input voltage (noise) of 10 volts at 100kHz is attenuated by -50dB, resulting in a final voltage of 0.03 volts. Using a different filter performance curve from the same Figure 6, this same 10 volt input at 100kHz is attenuated by only -10dB, resulting in a final voltage of 3.16 volts (more than enough to disrupt equipment logic circuits). Power filter manufacturers often state that their filters reduce common mode noise to 0.5 volts or less, but closer examination of their specifications shows that this may only be true at one particular frequency, or over a very small range of frequencies.

Figures 6 illustrates the response performance of various surge/filter products. Using a simple dB/voltage calculator, it is possible to

determine the correct attenuation required to reduce noise to a safe level of 0.5 volts or less. In order to satisfy this requirement, calculations show that a power filter should provide at least -26dB of attenuation over the entire range from 60kHz to 10MHz. It is also important to note that some of the performance curves show attenuation levels greater than -26dB at certain frequencies. More, however, is not necessarily better, since noise reduced to levels below the 0.5 volt requirement is inconsequential.

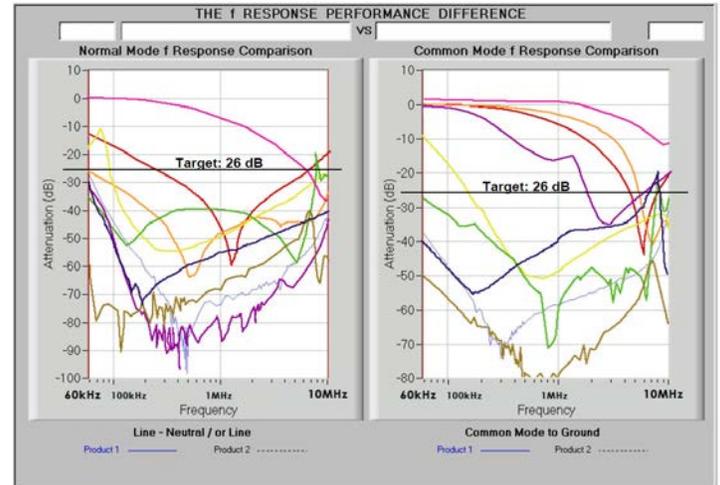


Figure 6. Filter performance curves.

Evaluating Power Filter Performance

When evaluating the filtering capability of a power filter it is important to remember some of the key points covered above:

- Noise is defined by common mode and normal mode noise.
- Normal mode noise can cause some harm to equipment power supplies, but is generally not disruptive or destructive to sensitive electronic components beyond the power supply.
- Common mode noise poses a greater threat to sensitive electronic equipment because it is present on the ground plane.
- High frequency noise is defined to be in the range from 60kHz to 10MHz, with typical voltage levels of 10 volts up to 200kHz, and less at higher frequencies.
- Some equipment manufacturers have specified that Neutral to Ground noise levels must be 0.5 volts or less to prevent lock-ups, data disruption, and component damage.
- A power filter should provide at least -26dB of attenuation over the entire range, from 60kHz to 10MHz in order to reduce noise to safe levels.
- More attenuation is not necessarily better since noise reduced to levels below the 0.5 volt requirement is inconsequential.