Data Bulletin

Digital Power Filter
Balanced Common Mode Filtration

Power line filters for digital imaging devices should address all modes of the power system, e.g., Line to Neutral, Line to Ground, and Neutral to Ground. Filtering on both the Line and Neutral in respect to ground is referred to as common mode. Line to Neutral filtering is referred to as normal or differential mode.

While it is important to filter all modes of operation, reducing or eliminating the high frequency noise referenced to ground is most important. The ground connection is not only the safety ground for the electrical system but also serves as the logic reference throughout the electronic network. High frequency noise is common to both the Line and Neutral with respect to ground (hence the “common mode” reference). Since this common mode noise is referenced to ground, it can interfere with the clocking frequencies and logic signals within the imaging device. These interruptions lead to equipment malfunction, quality problems and system lock up.

A copy machine, for example, takes the 120 Vac power into its power supply and converts this power to what is called “secondary voltages” i.e., 5 volt logic. This power supply consists of a transformer that accomplishes two tasks: 1) Convert high AC voltage to low DC voltage (120 Vac to 5 Vdc) and 2) Provide isolation from primary voltage rails to “secondary” voltage rails. The “isolation” means that low frequency (60Hz) noise/voltage between Neutral and Ground is not visible to the secondary side, but high frequency noise can ride across what is termed parasitic capacitance in the transformer.

The transformer’s construction provides a leakage path from primary to secondary through a capacitance that is formed across the windings. Differential noise is more easily filtered in front of the transformer, but common mode noise is the culprit as it rides on both conductors equally. Once the noise gets to the secondary voltages it can cause a host of problems. The 5 volt logic levels have been replaced by 3.3 volt logic, and in some cases 2.7 volt logic. These lower voltages mean that there is a smaller difference from a logic 0 to a logic 1, so high frequency noise levels of 0.5 volts can cause erroneous logic transitions.

Unfortunately, some manufacturers mistakenly attempted to specify their filtering performance with a voltage measurement from Neutral to Ground of less than 0.5 volts. This voltage measurement is generally made with a voltmeter that reads 60Hz voltages. Since this measurement is made with no load and at low frequencies, it completely misses the higher frequency voltages that can pass through the power supply. The Neutral to Ground voltage measurement represents the common mode noise which will also be found on the Line to Ground mode. The reason some manufacturers have focused on this measurement is because of the mistaken idea that the voltage at Neutral to Ground is zero volts without noise. Thus, any voltage measurement will be caused by noise.

The Neutral to Ground voltage at the AC power frequency depends on the load current flowing through the neutral wire and the distance between the AC power service entrance and the filter device. Under normal conditions, with a typical load on the filter device, the voltage drop on the neutral wire would be 2 volts or greater. This would completely overwhelm any noise measurement that could be made with a typical meter providing a single measurement (i.e. digital voltmeter). The reader can confirm this by

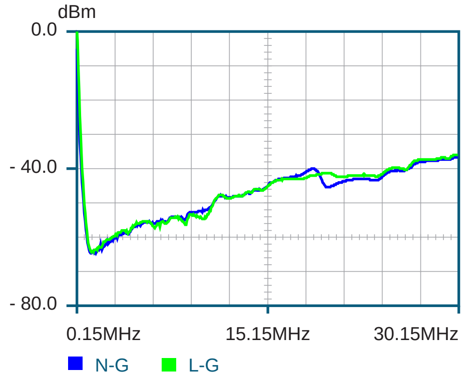

Figure 1: EFI Digital Power Filter Common Mode Filter Curves

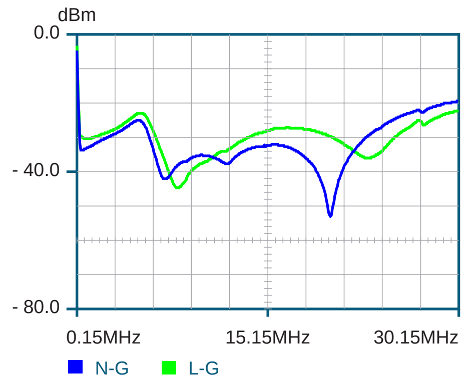

Figure 2: Competor Porduct Common Mode Filter Curves

measuring Neutral to Ground voltages with a 60Hz volt meter at different locations in his facility. A meaningful measurement would have to be made with an instrument capable of providing a reading over the frequency spectrum of concern (e.g., a spectrum analyzer).

While the 0.5 volt magnitude of Neutral to Ground voltage is reasonable to obtain with high frequency noise measurements, it will be difficult, if not impossible, to obtain without filtering out the voltage drop at the AC power frequency of 60Hz. The proper way to evaluate and compare the characteristics of filter devices is in a well-equipped laboratory with high frequency test equipment.

Some manufacturers' products were designed to short, or switch in a capacitor, between the Neutral to Ground within the filter device under certain operating conditions. While this can force the voltage to go to zero or very close to it, this solution is unsafe and not in accordance with accepted codes and standards. The NEC allows Neutral to Ground bonding only at the service entrance to a facility or at the secondary of a separately derived system, i.e., at the secondary of an isolation transformer. Switching in capacitors, large enough to reduce the 60 Hz Neutral to Ground voltage, can introduce leakage currents large enough to exceed safety limits set by UL.

In addition to the NEC code and safety violations, this practice causes the common mode filtering circuit to become unbalanced, causing more differential mode noise. Bonding Neutral to Ground only seems to make the noise voltage low by shorting the voltage drop across the neutral wire with the ground which is unsafe and does not get rid of the high frequency noise on the system. The Neutral to Ground voltage at AC power frequency is of no concern to the protected device because there is a UL specified level of isolation required between Neutral and Ground of 1000V or higher, depending on the system. Therefore, 0.5V at the power frequency (60 Hz) is of no concern.

In order to provide the best overall filtration, the common mode filter should be designed such that the Line to Ground and Neutral to Ground filters exhibit the same attenuation characteristics over the widest possible frequency range. See Figure 1 for curves on the EFI Filter. These curves show the matching of the Line to Ground and Neutral to Ground filter characteristics with a maximum attenuation of 65 dB occurring at 0.15 MHz. This relates to an attenuation of 0.0006 which says that a 50 volt noise signal will be reduced to 0.03 volts at 0.15 MHz. Also, the attenuation at 15 MHz is approximately 46 dB, thus reducing a 50 volt noise signal to approximately 0.25 volts.

By comparison, a competitor's common mode filter characteristics are shown in Figure 2. You will note the differences between the common mode filter characteristics over the frequency range, as well as the smaller attenuation of 34 dB at 0.15 MHz which indicates that a 50 volt noise signal will be reduced to approximately. 1 volt. At 15 MHz, this filter would also reduce a 50 volt noise signal to about 1 volt.

Good noise filtering is important for digital imaging equipment. The best noise filter will demonstrate balanced common mode attenuation curves. The 0.5 ohm Neutral to Ground test misleads customers into believing that this measurement is a valid form of noise measurement.

EFI Electronics Corporation
1751 South 4800 West
Salt Lake City, UT 84104
1-800-877-1174
www.efinet.com