How AC Powerline Filtering Can Assist Factory Automation Systems In Meeting EMI/EMC Requirements

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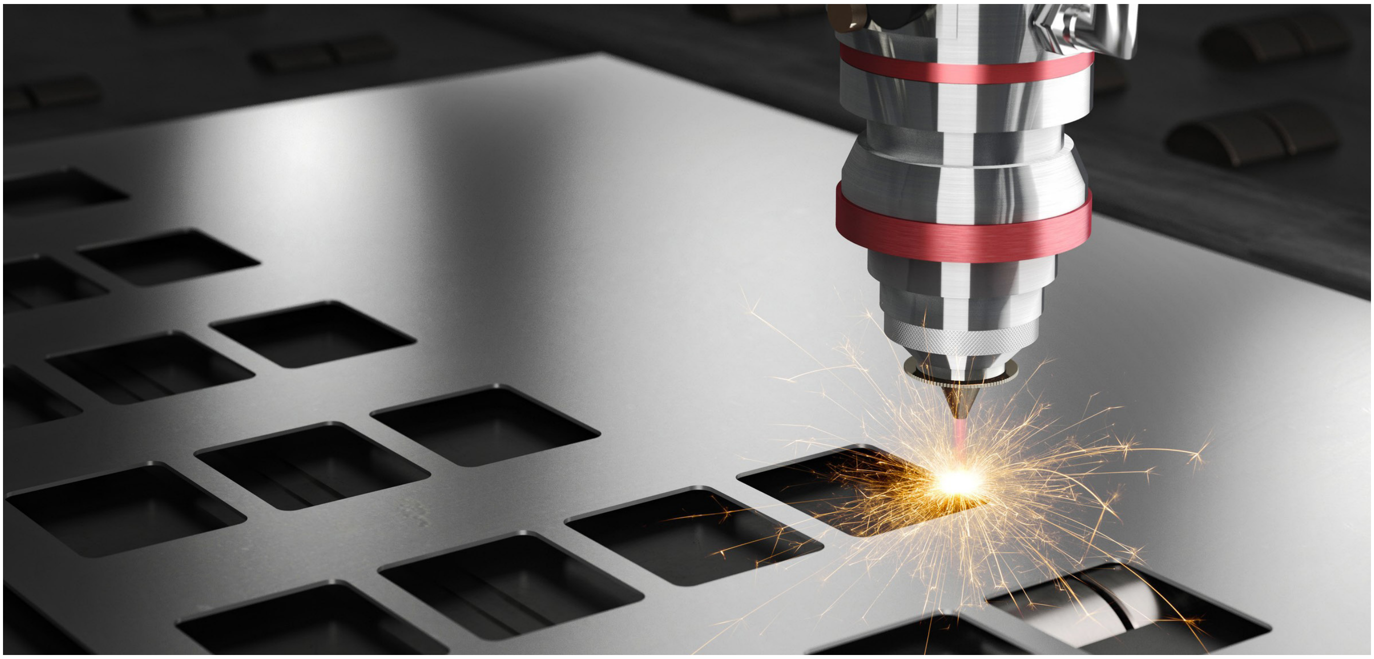

Increased electromagnetic interference, or EMI, can adversely affect system efficiency and increase downtime by interfering with analog control signals and industrial communications between devices/systems. So, as inter- and intra-communication networks expand on the factory floor, adequate electromagnetic compatibility or EMC design objectives need to be addressed. Keep in mind that "downtime" means loss of manufactured products and hence loss of revenue. Detecting EMI can be difficult and time consuming at the system level, therefore, time and trouble can be saved if proper noise mitigation solutions are implemented into the design process at the beginning. Many times, control/signal cables placed in control panels can disrupt communications and control functions of an entire automation system and cause the failure of the installation.

Potential Sources of EMI

Some industrial sources of noise can be servo drives, variable frequency drives, switching power supplies, inductive loads, lighting fixtures, and static electricity. Rotating machinery can generate a significant amount of electrical noise. Servo drives can also create noise due to voltage dips and spikes caused by switching current flow on and off at high frequencies. Switching power supplies can also emit EMI and at a much higher level than linear power supplies. Turning inductive loads on and off rapidly can produce a spark across an electrical contact which can generate EMI. This arcing and sparking can cause a wide bandwidth of EMI. Even lighting fixtures can generate EMI, in this case due to quick changes in voltage or current or even from the fluorescent bulbs. Another source of EMI is static electricity (human or machine generated) and related electrostatic discharge. Nylon or other polymer-based conveyor belts often are used to move material in industrial facilities and can generate high amounts of static electricity. Keep in mind that any length of wiring can and usually will act as an antenna which includes the AC power wiring. A simple rule of thumb is the longer a wire is, the better an antenna it becomes.

Encoders rely on low-level signals from rotating machinery and can be especially susceptible to EMI. Sources of electrical noise near sensitive analog signals and measurement instrumentation often can cause symptoms such as unexpected voltage spikes and ripple or jitter causing incorrect or non-repeatable readings. With communication networks such as Ethernet links, electrical noise symptoms usually include loss of communication or errors in data. And with programmable logic controllers (PLCs) and other microprocessor-based components, symptoms can include not only a loss of communications, but also faults or failure in the PLC or processor, unexpectedly triggering, and reporting of incorrect values.

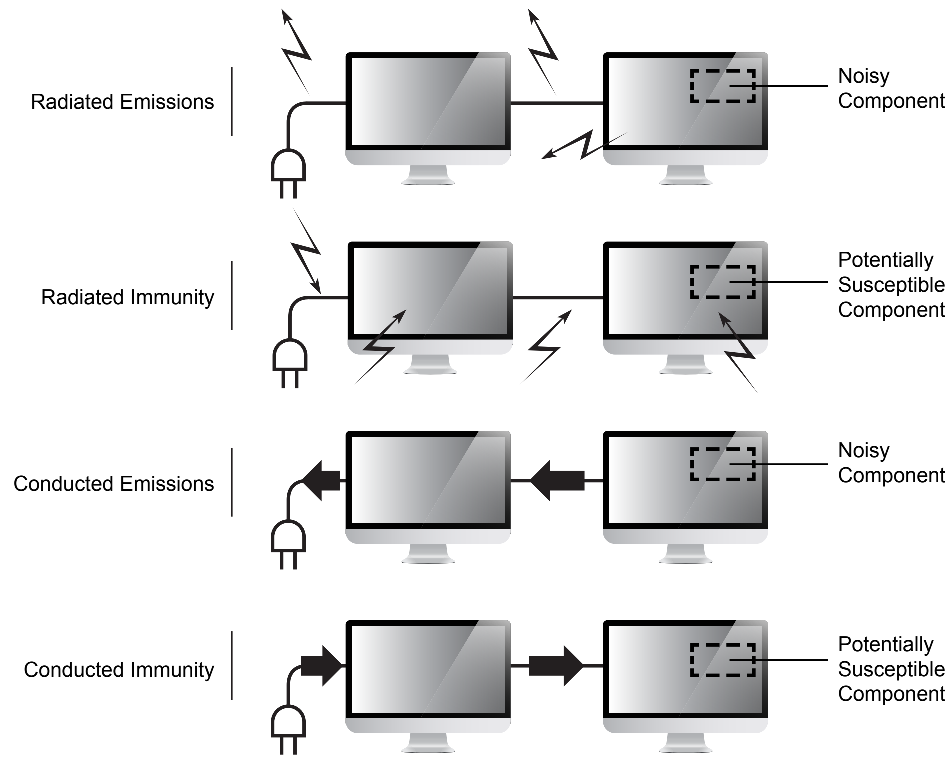

Figure 1. Noise Paths.

What Can We Do? How Can an AC Powerline EMI Filter Help?

Unfortunately, EMC is typically the last step in a design. When all the other product features have been implemented and the functionality is established, any EMC problems are then solved. At this point, EMC becomes expensive, time-consuming and difficult to handle. Manufacturers should therefore always start thinking about EMC in the early stages of product design. This thought process pertains to the EMI power input filter as well.

Designers often forget that an EMI filter can assist not only with conducted emissions, but also in meeting immunity and fast transients requirements along with radiated emissions.

A power line or mains EMI filter is placed at the power entry point of the equipment it is being installed in to prevent EM noise from exiting or entering the equipment. Refer to *Figure 1* to see how the AC mains power cable (on the left side of the diagrams) is a common element in the potential path for the device's electromagnetic emission and immunity paths.

So, the AC main power filter could be a key component to resolving or preventing both emissions and/or immunity electromagnetic noise issues. The design parameters for selecting an appropriate EMI filter include the attenuation or insertion loss, rated current, rated voltage, and regulatory approval requirements specified by the user.

There are many other parameters that should be or must be considered to get the most efficiency, reliability, and proper operation from the filter especially in a potentially noisy environment of a factory floor. The intent of the remainder of this article is to present what some of the more important filter parameters are, and should be considered. EMI is a difficult issue to harden a network against. Proper design methods will significantly aid in producing a clean RF environment.

In order to access global market, EMC filters must meet relevant safety requirements. For EU market CE and ENEC marks, for North America CSA and UL marks and for China CQC mark are some of the main examples. ENEC is the harmonized European safety approval accepted by all EU members. The CE mark signifies that the product is safe in accordance with appropriate European directives such as LVD and ROHS.

Electrical Design Parameters

Electrical Filter Design Parameters. Essentially, an AC power or mains EMI filter is a low pass filter that blocks the flow of "noise" while passing the desired input 50/60 Hertz power frequency. An ideal EMI filter will reduce the amplitude of all frequency signals greater than the filter cut-off frequency.

The measure of a filter's ability to reduce a given signal level is insertion loss or attenuation. Filters are not only for conducted emissions, but also help in meeting radiated emissions levels and also helps in immunity issues and fast transients like electrical fast transients (EFT) as shown in the previous *Figure 1*. In all circuits, both common-mode (CM) and differential-mode (DM) currents are present. There is a difference between the two types of noise and filtering configuration. Given a pair of transmission lines and a return path, one or the other mode will exist, usually both.

Differential-mode signals carry data or a signal of interest (information). Common-mode is an undesired side effect from differential-mode transmission and is most troublesome for EMC. Common-mode filtering involves capacitors to ground and/or a common mode inductor in series with both side of the line or lines (Reference *Figure 2*).

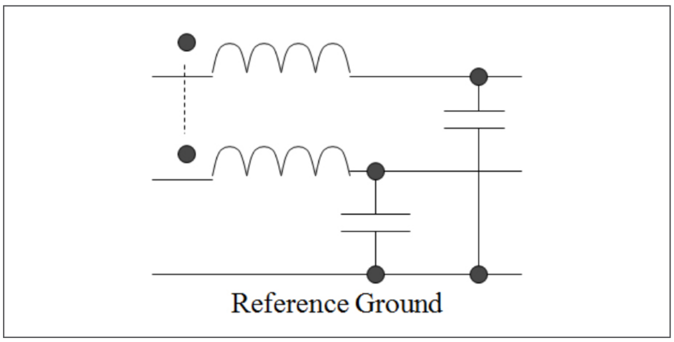

Figure 2. Common Mode Filtering.

Differential-mode filtering involves placing capacitors between lines and/or an inductor in series with either the high or low side of the line (Reference *Figure 3*).

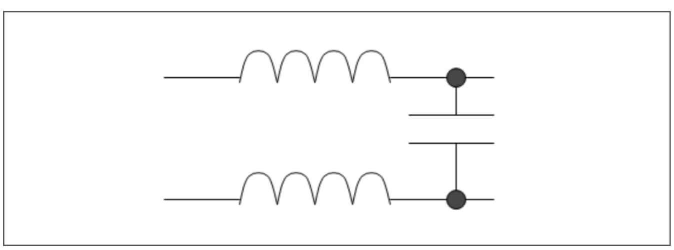

Figure 3. Differential Mode Filtering.

To design a good filter for factory automation systems usage, more than just insertion loss or attenuation needs to be considered. Some other filter parameters that should be considered and typically are not are mentioned below. Many times, reliability is essential for components used in these systems since down-time can be costly and critical to schedule impacts. Unless the design engineer has experience in filter designing, it is recommended that such assistance be called upon from a potential filter manufacturer like Schaffner EMC, Inc. EMI test laboratories can also provide many filter choices.

NO LOAD/FULL LOAD

The filter's insertion loss or attenuation characteristics should be verified not just at the "no load", but for the "full load" current levels as well.

RATED CURRENT/CURRENT OVERLOAD

Rated Current – The rated current should be equal to the maximum input current to be drawn from the device being filtered.

Current Overload – Current overload characteristic of a filter demonstrates the filter's ability to withstand the heat dissipated by the filter's components when subjected to a higher than rated current of the filter.

RATED VOLTAGE/VOLTAGE DROP/OVERSHOOTS

Rated Voltage – The rating voltage should be equal to or greater than the maximum input voltage to be supplied to the device being filtered. The rated voltage of the filter defines the maximum continuous operating voltage, i.e., the maximum voltage at which the filter could be used continuously.

Voltage Drop – The impedance of the filter is measured at the relevant power network frequency, i.e., 50 Hz for European applications and 60 Hz for North American applications. This is performed at a defined temperature, such as 25 °C. Current flowing through this impedance, of course, will cause a voltage drop across the filter resulting in a change in the voltage seen at the load end of the filter.

Overshoots – Voltage overshoots and voltage peaks can come with high dv/dt values but are also a problem on their own. The inductance of the filter acts like a choke according to the energy storage principle. If chokes are subject to voltage pulses, voltage peaks occur every time switching on or off takes place.

Safety Design Perameters

LEAKAGE CURRENT

During normal operation of electrical equipment, some current flows to earth. Such currents, called leakage currents, pose a potential safety risk to the user and are therefore limited by most current product safety standards. For EMI filters it is common to calculate the leakage currents based on the capacitor values against earth and other parasitic components. This leakage current is limited by the international safety agencies to prevent a danger to personal safety.

DIELECTRIC WITHSTAND (HI-POT)

Dielectric testing, sometimes referred to as Hi-Pot testing, demonstrates the ability of the filter capacitors to ensure higher than rated voltage. In filters, components are used that are connected between the phases of the supply network or between one phase and earth. It is therefore important to determine how well filters resist high voltages.

A dielectric withstand test is performed for this reason by applying a voltage between enclosure and phase or between two connectors for a defined time. The current flowing between the same points is measured. Current flow means that the insulation is broken; the equipment fails the test.

During approval procedures, the test is usually performed over a longer period (typically one minute) with a defined voltage. Many safety standards require the testing to be performed on 100 % of all units, but to save time, a test with higher voltage but reduced time is accepted. It should be noted that repeated high-voltage testing can lead to a damage of the insulation.

Please note that this test is a high-stress test for the capacitors inside the filter. Each additional test stresses the capacitors again and leads to a reduction of lifetime. Schaffner recommends keeping the number of tests to a minimum and never test the filters at higher than the indicated voltages.

INSULATION RESISTANCE

Insulation resistance indicates quality of the filter capacitor construction and filter insulation system. Low insulation resistance may indicate a condition which may lead to possible deterioration over time. Sometimes this can be calculated from measurements of the DC leakage current at the specified voltage.

Conclusion

Schaffner not only can provide off the shelf EMC filter solutions but also support manufacturers with their EMC layout from the early stages of new product ideas or designs. Schaffner can also offer custom made solutions to help manufacturers meet any unique electrical, mechanical or EMC challenge. Contact your nearest Schaffner representative for assistance.

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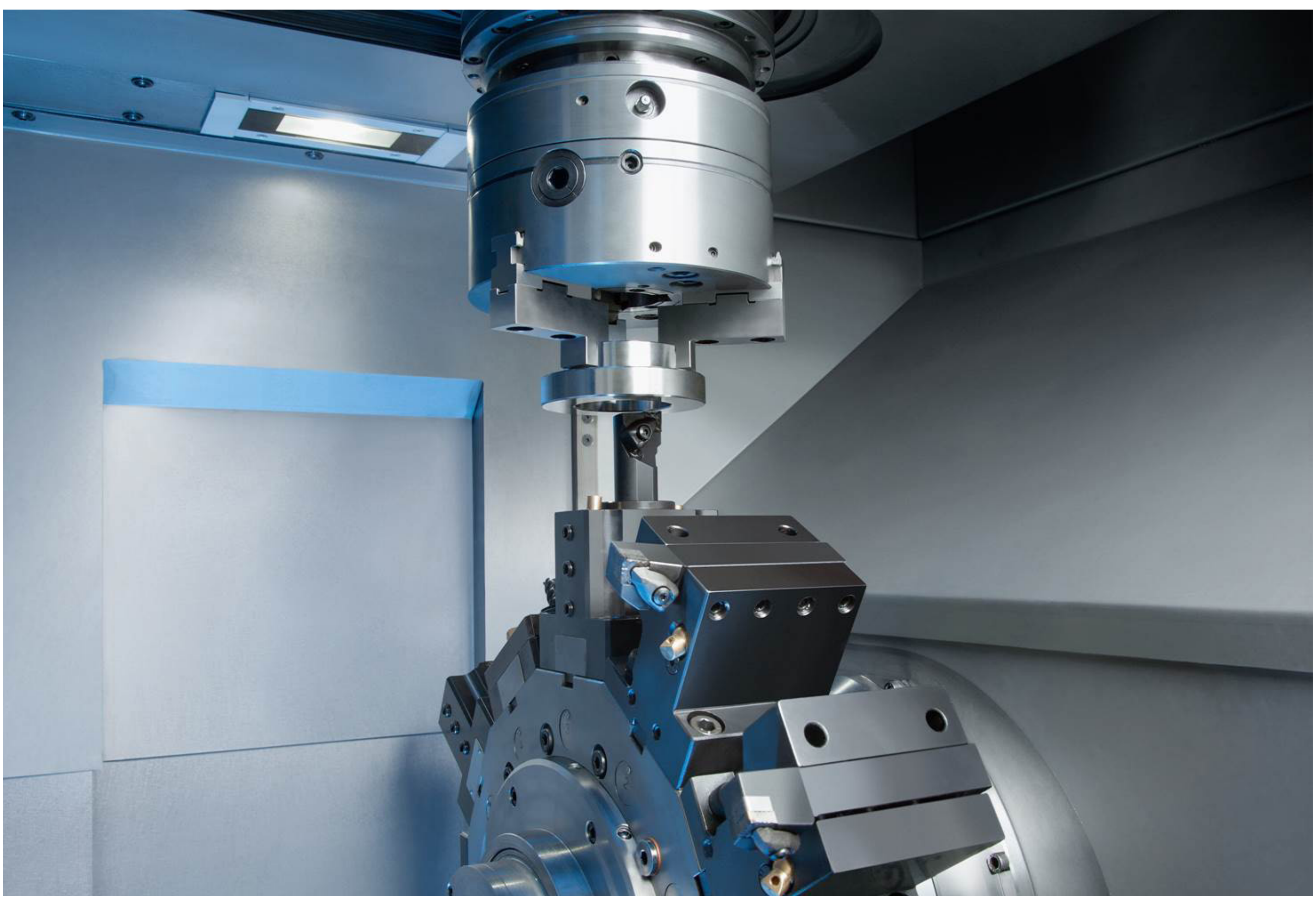

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