What is EMI and How is it Propagated

EMI (Electro-Magnetic Interference) is unwanted electrical noise created by various AC sources such as motors, variable frequency drives (VFDs), solid state and mechanical relays, but a major and common source is switched mode power supplies. EMI can wreak havoc on electrical systems compromising their safety and performance.

The propagation of EMI can take two forms, conducted and radiated.

Conducted EMI, whether sourced or created by an external device, travels through conductors, such as traces on PCB boards, electrical components, power line cords, and AC systems. If not attenuated, it can cause the electrical equipment to malfunction or behave erratically.

Radiated noise, aka RFI, is propagated through free space as radio waves. Much like conducted EMI, it can interfere with internal systems when absorbed. One of the most significant contributors to radiated RFI from electronic equipment is the AC power cord. The power cord is often an efficient antenna since its length approaches a quarter wavelength for the RFI frequencies present in digital equipment and switching power supplies.

Regulation of EMI

EMI is unwanted but common, so what? Manufacturers of electronic devices take great care to ensure their devices work in the desired application across many different environments and that means operating properly with EMI levels below defined limits. Conversely, their equipment is a creator of EMI noise as well and attenuation of all of the EMI would be costly and highly illogical. Instead, manufacturers design their systems to meet FCC and EN standards so they can focus on EMI elimination that is more specific to the intended uses of the equipment.

The FCC Part 15 and the European Standards EN55011 and EN 55022 have established the same conducted emission limit for EMI and are broken down to Class "A" for commercial, industrial, or business environments and Class "B" for residential environments. Class "B" is the more stringent of the requirements and the frequency range is between 150 kHz and 30 MHz (see figure 1). Class A and most Class B equipment must be verified but no forms need to be filled with the FCC. In most cases, manufacturers will have test labs perform the conducted emission analysis or work with an EMI filter supplier who has an RFI chamber to identify, analyze, and test a specifically chosen EMI filter solution.

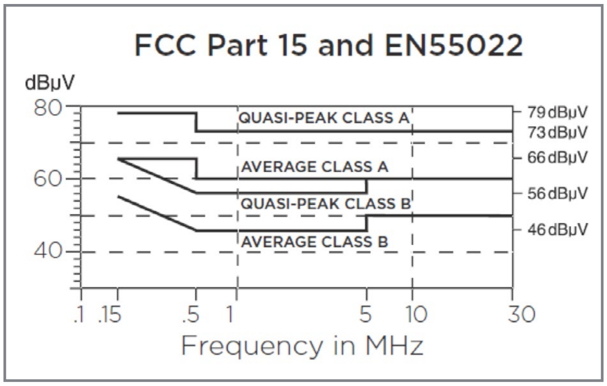

Figure 1.

What is an EMI Filter

An EMI filter in its most basic configuration is an L-C circuit made up of the passive components of inductors and capacitors. It's a low-pass filter that attenuates EMI noise typically higher than 10kHz. The role of the EMI filter is to squelch EMI conducted noise before it leaves the electronic device and to act as a barrier to EMI noise coming in on the power line side to the electronic device.

How to measure EMI Filter Performance

EMI filter performance can be affected by many variables such as impedance mismatching, installation location, length of leads at source and load, and more. Designers need a specification to compare filters in order to narrow down the types of filters used in the analysis.

Insertion loss is a common specification used by EMI filter manufactures to describe the performance of attenuating EMI in a controlled circuit, commonly utilizing 50ohm resistive loads at the source and the load. Insertion loss data is typically shown in the form of graphs or tables (See Figure 2) that describe how well it attenuates the EMI noise.

Minimum Insertion Loss

Measured in closed 50 Ohm system

Common Mode / Asymmetrical (Line to Ground)

Current Rating	Frequency – MHz .03	.1	.15	.5	1	3	5	10	30
S Models									
3A	7	17	21	27	33	40	44	50	32
6A	-	8	12	17	23	32	36	44	30
10A	-	3	5	10	13	23	27	35	27

Differential Mode / Symmetrical (Line to Line)

Current Rating	Frequency – MHz .10	.15	.5	1	3	5	10	30
S Models								
3A	2	4	12	15	30	48	50	45
6A	2	4	12	15	22	42	55	45
10A	2	4	12	15	22	42	55	45

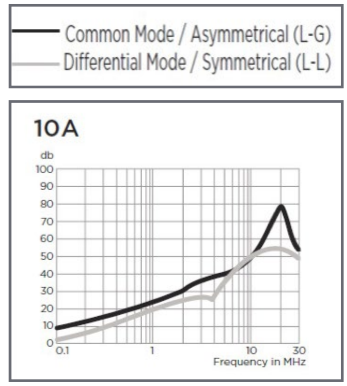

Figure 2: Insertion Loss Data for Corcom, 10A P Series Power Entry Modules

Insertion loss thus is the ratio (expressed in dB) of the signal voltage transferred from source to load with and without a filter. The two modes that an EMI filter works in are common and differential mode.

Common Mode/Asymmetrical (CM) – represents EMI filtered on the line or neutral with respect to ground. Filtering is typically accomplished by series inductors on each power line and by Y-caps going from line/neutral to ground.

Differential Mode/Symmetrical (DM) – represents EMI filtered on the line with respect to neutral. This line-to-line noise is 180° out of phase with itself and is typically filtered with X-caps between the Line and Neutral conductors.

Medical applications and their unique EMI filtering needs

Designing and manufacturing medical electronic equipment for compliance with product safety standards is no easy task. The goal is to ensure that patients or caregivers never serve as a current path to ground due to faulty insulation or faulty grounding within a product.

The medical electrical equipment standard, IEC 60601, regulates the international medical device market; and specifies leakage current, fusing, and the use of specific switches in medical electronic equipment.

When a filter uses capacitors between the conductors and ground, small amounts of current 'leak' through the filter to ground. This leakage current contributes to the performance of any filter. However, should there be a faulty ground in the system, this current can take an alternative path to ground and can result in an electrical shock. The potential for shock is of little concern for most applications, but presents particular risk in medical applications – especially in those systems with direct patient contact. Therefore, devices intended for medical application must limit their leakage current to no more than 100uA. That is the total allowable leakage current for the device and an EMI filter is but one component in the device that contributes to the total so an end-user should search or work with an experienced EMI filter manufacturer to select the correct filter with the least amount of leakage current.

Two additional requirements. Double fusing and the use of DPST switches are specified by the standard in order to minimize the risk of shock to the patient or operator of said equipment in case of faulty wiring. The double fusing and the DPST ensure the Hot lead is always "broken" when a fault is presented or the unit is switched off.

End-Customer Investigation

Armed with a basic understanding of EMI noise and filtering a customer can begin to search for filters by answering these questions.

1. What are the operating specs of the device, voltage, current, temp?
   a. If power line is it AC, single phase, three phase or DC
2. What frequency are you having problems?
3. Do you need a power line or power entry module?
   a. If a power entry module what functions are needed?
4. Is this for a medical or low leakage current application?
5. How much spacing is allowed for the filter?
6. Will the system be sold in Europe?
7. How much insertion loss margin is needed?
8. Do you have a system scan that can be reviewed by EMI filter manufacturers?

Keys to selecting a hi-quality EMI filter

As mentioned previously, EMI filter performance can be influenced by many different factors so it's important to select a brand with UL recognized EMI filters that have a broad selection of filters with different current and voltages, terminations, and filter performances. Selecting and qualifying the proper EMI filter for your device will require some analysis with different filters in order to identify the optimal solution. There are many EMI manufacturers who have a good selection of filters but having a local expert is invaluable. The local expert can provide guidance on proper EMI filter, help with the testing and analysis, and use experience to advise on mounting and termination solutions. The local EMI expert should also have the proper equipment, e.g. RFI shielded room (to allow measurement with minimal background interference), spectrum analyzer, and line impedance stabilization networks (LISN) to evaluate customer designs before going to the test houses.

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