Technical Notes

THE CAUSES AND CURES:

With the proliferation of power electronics and frequent switching of power supplies, electromagnetic compatibility problems have become almost unavoidable. Personal computers, digital pagers, cellular phones, and other wireless and hand-held devices have all become more prevalent and norm in today's society. However, these devices have also created a greater opportunity for increased electromagnetic interference.

Radio frequency waves, which are used to carry the signals of cell phones, televisions, and radio broadcasts are energies transmitted through space. This energy is comprised of the alternating waves of electric and magnetic fields. While the electric field is associated with voltage, the magnetic field is associated with current. The energy comprised of electric and magnetic fields is called "electromagnetic energy" (E and H Waves). However, even though most of the transmissions are achieved under controlled conditions, it is this transmitted energy that creates interference producing phenomenon that may affect the performance of many electronic devices.

The frequency levels of these sources range from the very low frequencies to very high frequency range (approximately 10 KHz through Megahertz and even into the Gigahertz range) with the generation of multiple frequencies simultaneously, called Harmonic frequencies or simply harmonics. Radio Frequency Interference refers to noise over the part of the spectrum used specifically for broadcasting.

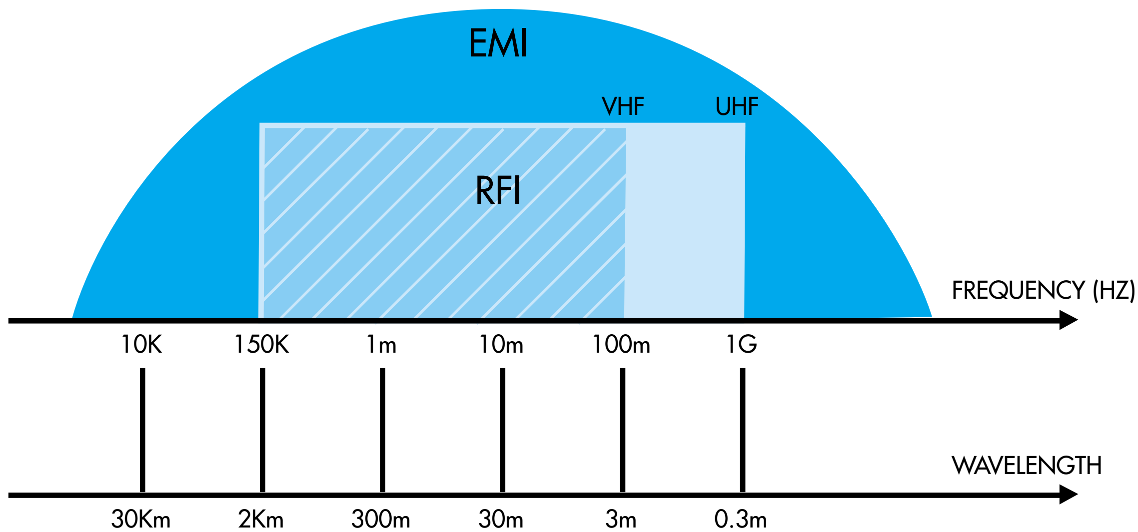

Fig.1.0 Frequency range for EMI and RFI

Good engineering design practice needs to be adapted to tame EMI noise. The engineer needs to be able to identify the source and the path of noise whether it is radiated or conducted. This is usually achieved by a combination of filtering conducted EMI and shielding against radiated EMI.

Radiated and conducted EMI cannot be thought of as totally separate problems because noise conducted along a cable acts as an antenna and radiation will increase as the cable length becomes comparable to the wavelength of the noise. The cable can also act as a receiving antenna and pick up radiated interference.

Generally, for radiated noise, one can use a shield that is placed around either a susceptible device or a radiating source of EMI. It can also be minimized as a result of the layout and wiring practices. As far as filtering is concerned, conducted interference can be attenuated to satisfactory levels with the inclusion of a power line filter. It will also reduce susceptibility to incoming power line noise as well.

Generally, the performance of a given filter is quantified in terms of attenuation or insertion loss. However, PDI strongly recommends that a customer actually perform filter selection testing to the required level of performance.

Appendix B

SELECTION OF A FILTER

Filters operate on the principal of introducing an impedance mismatch between a circuit's source and load impedances. The magnitude of the voltage or noise transfer from source to load can be minimized by inserting a series filter (Zs) with impedance much greater than 50 ohms at the noise frequency. This is created by series inductance and shunt capacitances. If the load impedance is unknown, one should not use a filter based on the insertion loss table given at fixed 50-ohm termination as a true indication of filter performance. A test must be performed to verify that EMI has been eliminated or minimized to acceptable levels.

In most applications, power line impedance is almost always low, but the equipment impedance may or may not be low depending upon the device. Switching regulators or power supplies are low impedance loads while linear power supplies may represent high impedance. To obtain mismatch, a filter must present high series impedance or inductance to the power line and a low shunt impedance or large capacitance to a high impedance load. If the equipment impedance is low, the filter must also present a high series inductance between line and load.

Therefore, for high equipment impedance, use capacitance to load See Fig, 2.1. For low equipment impedance, use inductance to load & Line. See Fig, 2.2.

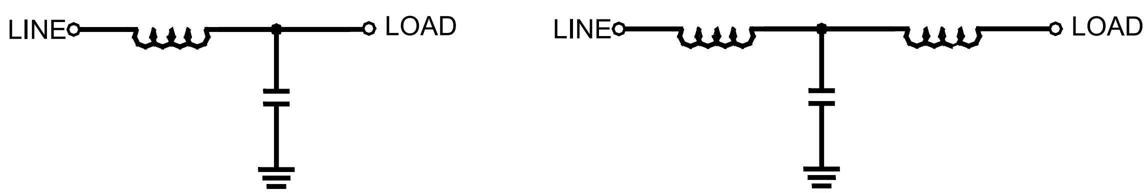

Fig. 2.1 and 2.2 Capacitive and Inductive Loads

Also, remember few key points:

1) In case of possible infiltration of high voltage surge or impulse, use the surge absorber in front of the noise filter to maximize the effects.

2) The noise filter should be mounted as close as possible to the equipment. The input and output wires should not be bound together for the best attenuation characteristics of the noise filter.

3) Try to keep the operating voltage of the noise filter lower than the voltage of the filter printed in the datasheet and avoid capacitor/filter failure.

4) Make sure that the noise filter satisfies the operating current. The noise filter of higher rated current than the actual operating current will cause the attenuation characteristics to deteriorate and increase in size and cost. The lower one will do harm to its reliability and eventually turn out to be dangerous. Accordingly, you should select the one with the same or 10% higher than the actual operating current.

5) Identify the frequency of the noise. Check whether the frequency of the noise to be reduced is below 1MHz (low frequency),or higher than 1Mhz (high frequency), or the vast domain.

6) Identify the property of the noise. Check whether the property is the Differential mode or common mode.

7) One should not use a filter based on the insertion loss table given at fixed 50 Ohm termination as a true indication of filter performance. The 50Ohm is used for Reference purposes only.

8) Solid metal conduit can be used to shield the wires. Shielded power cable can be used at a considerably higher cost.

See next page for various options available for Power Entry Modules:

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POWER ENTRY MODULE OPTIONS:

PDI filter modules are available in various feature combinations depending on customer's requirements. Various features include:

AC Power Inlet: AC Power inlet is an IEC 60320 with various C-connector configurations. The most popular connector is the C-14 configuration. (See Table below.)

IEC 60320 CONFIGURATIONS:

CONNECTOR	CURRENT RATING	TEMP. RATING	EQUIP. CLASS	CONNECTORS	CURRENT RATING	TEMP. RATING	EQUIP. CLASS	CONNECTOR	CURRENT RATING	TEMP. RATING	EQUIP. CLASS
C1/C2	25	70°C	II	C13/C14	10/15	70°C	II	C19/C20	16/20	70°C	I
C5/C6	25	70°C	I	C15/C16	10/15	120°C	I	C21/C22	16/20	155°C	I
C7/C8	25	70°C	II	C15A/C16A	10/15	155°C	I	C23/C24	16/20	70°C	II
C9/C10	6	70°C	II	C17/C18	10/15	70°C	II				

On/Off Switch: These "double pole single throw" switches are for easy on/off operations. Switches break both sides of the line and are printed with the I/O markings.

Fuse Holder: The selectable fuse holder allows use of single or dual European 5 x 20mm fuses, or a single North American 3 AG (1/4 X 1 1/4 inches) fuse.

Voltage Selector: The voltage selector provides a simple means to change transformer primary connections, and it is available in 4-voltage configurations (110V, 120V, 220V, & 240V). By changing the selection, one can define the correct input voltage.

Filter: Various filter circuits are available for variety of applications for the electronic and medical industry. Filters can be enclosed fully or partially with metal housing to prevent input of high frequency noise.

Mounting: Various standard and custom mounting options are available. Standard options are Snap-in & Screw mount (Flange Mount). For custom mounting options, please contact PDI.

Terminals: Various standard and custom terminal options are available. Standard options are Quick-connect and Solder terminals. The layout can be right angle, straight or sideways.

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GENERAL CIRCUIT CONFIGURATIONS:

PDI offers various circuit configurations described by their series inductance and ground capacitors for single line arrangements. See figure 3.0, shown below. Some of the standard configurations available are:

PI Filter: It presents capacitive characteristics with inductive source and load

LC Filter: It is suited for mating capacitive sources and inductive load

CL Filter: It is suited for mating inductive sources and capacitive load

T Filter: It is suited for inductive sources and inductive load.

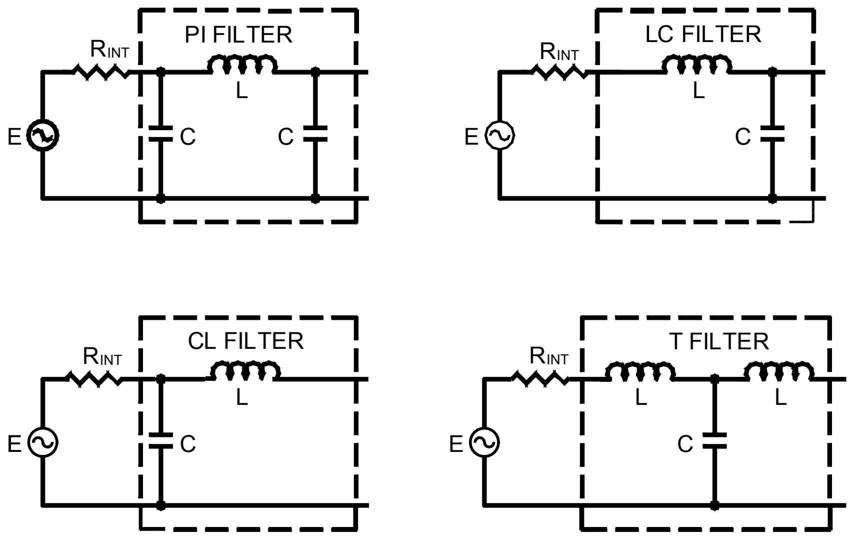

Fig. 3.0 Different circuit configurations

The three phase configurations described by their line configurations are shown in figure 4.0 (see below.) Some of the standard configurations available are:

Delta Filter: Three phase power system, 120 degrees out of phase with respect to each other, without a neutral line.

Wye Filter: Three phase power system, 120 degrees out of phase with respect to each other, with a neutral line.

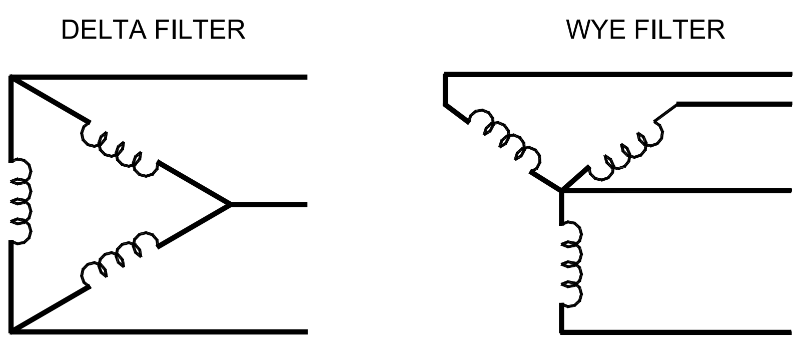

Fig. 4.0 Three Phase configurations.

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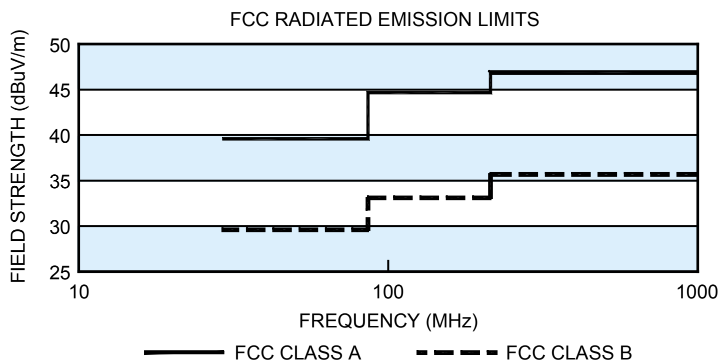
TESTING AND REGULATORY AGENCIES:

There are several national and international regulatory agencies that impose strict regulations to control interference.

FCC: One of the most important guidelines in US are set by the Federal Communications Commission (FCC). FCC docket (20780, Part 15, Subpart J) mandates the maximum EMI voltage that digital equipment with operating frequencies above 10KHz can generate in both residential and commercial environments (See Chart). Class B equipment must be certified by submitting emission test data results to the FCC for type approval, while class A equipment requires a verification of compliance by the manufacturer.

APPLICATION	FCC	EMI LIMITS	CERTIFICATION
RESIDENTIAL	CLASS B	RESTRICTIVE	DATA SUBMITTAL TYPE APPROVAL
COMMERCIAL	CLASS A	LIBERAL	SELF

The chart 1.0 depicts the FCC standard for maximum allowable radiated emissions in the frequency range between 30 to 1000MHz and on the maximum allowable conducted emissions on the AC power line in the frequency range of 0.450 to 30MHz.



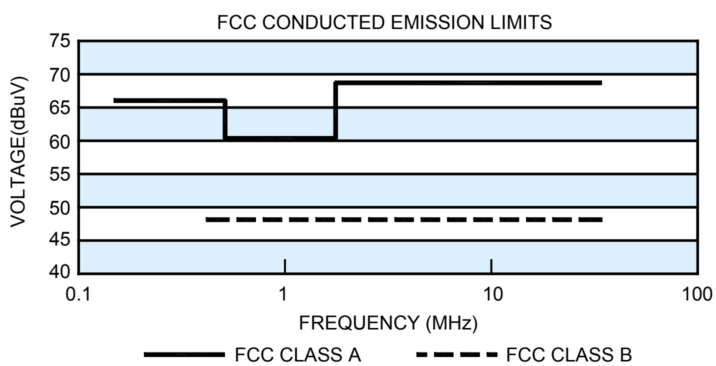


Chart 1.0 FCC Standards for maximum allowable radiated emissions

MIL-STD-461/462: The Department of Defense (DoD) of The United States defines all aspects of electromagnetic compatibility in a series of standards titled MIL-STD-461/462.

FDA: At present, there are no regulations in the United States addressing the electromagnetic emissions of medical equipment. In recent years, the Food and Drug Administration (FDA) has required EMC test data to accompany an application for FDA approval for specific medical devices. FDA reviews and examines more closely the electromagnetic compatibility specifications of devices such as respiratory equipment, cardiac pacemakers, defibrillators, and other critical medical devices.

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CISPR: The International Special Committee on Radio Interference (CISPR) regulates the international community. Its standards have been accepted by most European nations. It specifies the limits of radio frequency emissions which appliances and other electrical equipment are allowed.

The chart 2.0 depicts the CISPR standard for maximum allowable radiated emissions in the frequency range between 30 to 1000MHz and on the maximum allowable conducted emissions on the AC power line in the frequency range of 0.450 to 30MHz.

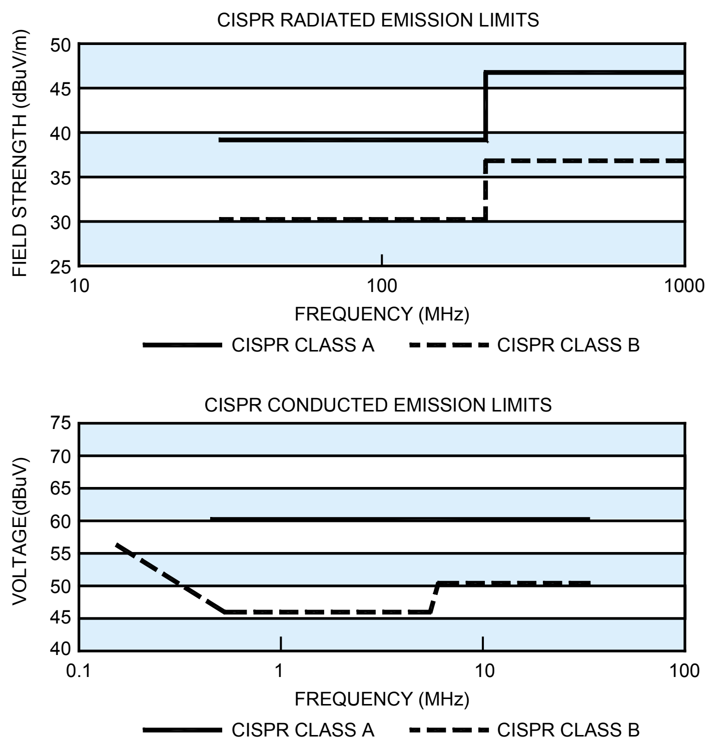

Chart 2.0 CISPR Standards for maximum allowable emissions

IEC 601 (EN60601): The International Electrotechnical Commission is the international standards and conformity assessment body for all fields of electro technology. It has developed and published various standards for the electronic and medical industries.

ISO: The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from 140 countries. The name ISO has become very popular among the manufacturers worldwide. The specific standards that world manufactures pride themselves on maintaining include ISO 9001, 9002 and 9003, etc.

UL: Underwriters Laboratory (UL) is a testing and certification agency. It is a private agency that developed more than 800 Standards for Safety. This Certification mark is a manufacturer's declaration that the products are of good quality have been evaluated for public safety. Millions of products and their components are tested to UL's rigorous safety standards with the result that consumers live in a safer environment than they would have otherwise. Some of the UL standards are like UL1283, UL544, 2601.

Note: UL 544 specification is for Medical and Dental Equipment. This specification is broken down to two categories: Patient Care Equipment (maximum leakage current of 100uA at 120VAC,60Hz) and Non-Patient Equipment (maximum leakage current of 500uA at 120VAC,60Hz).

As of January 1, 2003, all new Medical and Dental equipment must comply with UL2601 specification. Like UL544, UL2601 has also been broken down to two categories: Patient Care Equipment and Non-Patient Equipment. However, the Leakage current requirement for Patient Care Equipment has been increased to 300uA from 100uA. This will allow more line-to-ground capacitance.

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VDE: Verband Deutscher Electrotechniker (VDE) 0871 and 0875 impose requirements (like FCC in USA) on many European equipment manufacturers. For any manufacturer to sell its products in EU, they must meet VDE requirements. See Chart 3.0

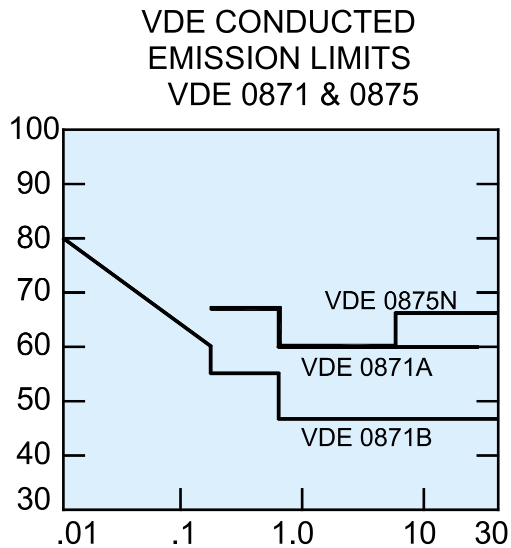

Chart 3.0 VDE Standards for maximum allowable emissions

CSA: Canadian Standard Association (CSA) is a testing and certification agency in Canada. Electronic products sold in Canada must have a marking of CSA. This certification mark is a manufacturer's declaration that the product has been evaluated by a formal process-involving examination, testing and follow-up inspection and that it complies with applicable standards for safety and performance.

UL and CSA: UL and CSA have cross-licensing agreement to provide testing and certification per each other's standards. This means that CSA can test and certify a product on behalf of UL and vice versa. Such a product would bear a mark "cUL."

CE: The letters "CE" are the abbreviation of French phrase "Conformité Européene" which means "European Conformity". CE Marking on a product is a manufacturer's declaration that the product complies with the essential requirements related to health, safety and environmental protection. In practice, by many of the so-called product directives that contains the "essential requirements" and/or "performance levels" and "harmonized standards" to which the products must conform. Products that bear the CE marking can be freely traded to and from European countries.

TÜV: TÜV is a safety-testing laboratory with headquarters in Germany. TÜV can test products for compliance with IEC or VDE requirements.

Others: Other agencies include **ANSI, IEEE, AAMI, NEMA, CENELEC, ISM, CISPR, SEMCO, NEMCO, FIMCO, KEMA, CEBEC, SEV,** etc.