10 Commandments

The Key to Mastering EMI Protection

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I. Abstract

Electromagnetic Compatibility (EMC) is the ability of a system, equipment, or device that uses electromagnetic energy to operate in its intended environment without suffering or causing unacceptable degradation. EMC is critical for ensuring modern electronic equipment operates reliably in an increasingly connected environment. Connectivity also provides a means of unwanted energy to be exchanged through conducted or radiated means and creates emission or immunity issues for a system. Any switching power supply, motor, processor, or transmitter is a potential source of Electromagnetic Interference (EMI). Using simple techniques, EMC issues can be mitigated early in the design process, avoiding costly late-stage implementation hurdles. The technique called the 10 commandments of EMC is used as a best practice early-stage design principle approach.

II. Introduction

The trend toward higher frequency operation is largely driven by the demand for increased data throughput and enhanced performance in communication and signal processing applications. As semiconductor technologies continue to evolve, integrated circuits are capable of operating at once unattainable frequencies. This push for higher frequencies is critical for applications ranging from high-speed data communication networks to advanced radar and sensing systems, where faster signal processing directly translates to improved accuracy and efficiency. Operating at higher frequencies also introduces new design challenges particularly, in managing signal integrity and mitigating electromagnetic interference (EMI). As circuits operate at these elevated frequencies, even minor parasitic elements or layout imperfections can lead to significant distortions, phase shifts, or signal losses. Consequently, engineers must adopt advanced techniques such as precision impedance matching, careful component placement, and enhanced filtering to ensure reliable performance. This rigorous focus on design not only ensures that the circuit performs as intended but also that it complies with increasingly strict electromagnetic compatibility standards.

III. Ten Commandments overview

I. Know the EMI profile and specifications

II. Proper filter placement

III. Tailor the filter response

IV. Consider system impedances

V. Shield of noisy components

VI. Grounding techniques

VII. Utilization of Common Mode Ferrites

VIII. Twisted pair

IX. Openings and apertures

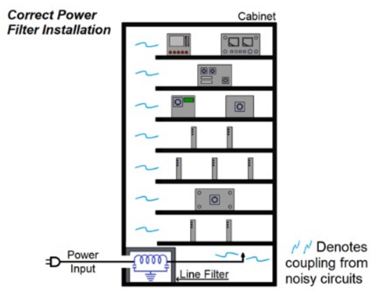
X. Transients

IV. The Ten Commandments

i. Know your EMI profile and EMI specifications

1. **Governing Specifications:** Depending on the industry, all have a governing specification for emissions and immunity. The Military uses Mil-STD-461 for Conducted and Radiated testing. Other Industries like Commercial/Industrial, Medical, and Automotive have specifications written for levels and frequencies of interest for their specific industries.

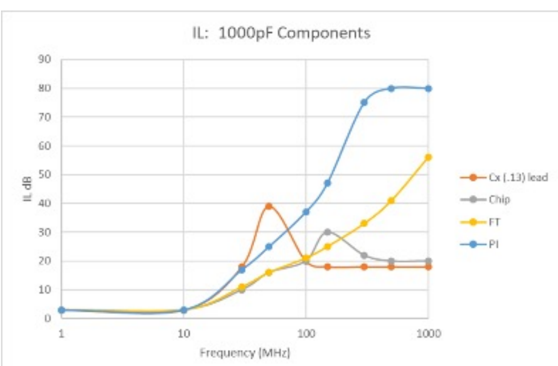
2. **Noise Analysis:** Once the test plan is created and the profile is established, filtering and shielding solutions can be achieved based on the emissions and susceptibility results achieved. The earlier the testing is done during the design cycle, the more options are available to mitigate EMI.



ii. Filter placement

1. **Immediate POE Filtering:** The best place for an EMI filter is in the interface to the hardware on the chassis wall where the power and signal enter the system. This reduces the coupling of the energy onto critical paths of the circuit. Even if the type of filter is correct, deploying it in an incorrect fashion may render it ineffective.

2. **Filtering between functional compartments:** Filtering between critical circuit sections is also important. In some cases, it may be important to isolate internally to the system to prevent noise from coupling between functional parts of a system. Some sections may emit, others may be susceptible to EMI influences.



iii. Filter design

1. **Low Pass Filter Design:** The filter needs to be designed to allow the fundamental frequency of a circuit to perform its intended function and the reject band to be as broadband as possible. Switch-mode power supplies, processors, and DC motors are all sources of EMI. Low pass filters are effective solutions to reduce noise produced by circuit harmonics.

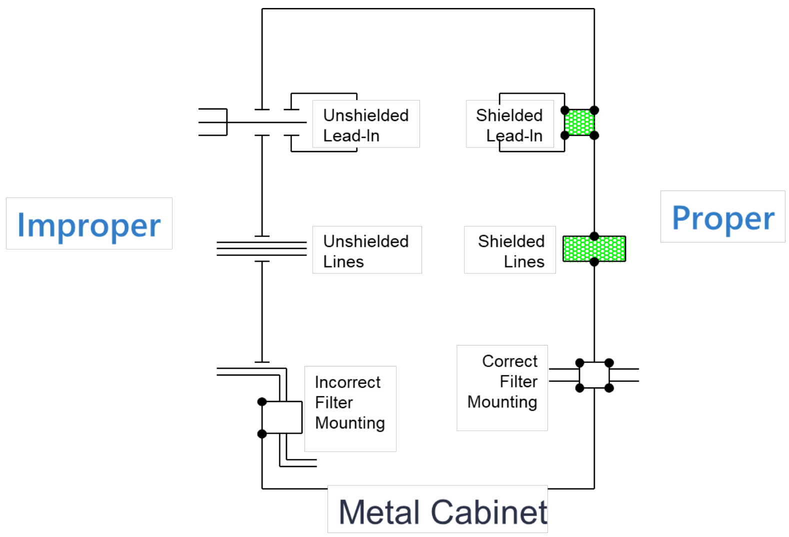
2. **Filter Reject Frequencies:** The filter effectiveness is defined as the Insertion Loss of the filter. The IL (in dB) = 20*Log(V1/V2). The slope of the filter increases as the number of poles increases (i.e. 3 pole filter increases 3*20 / decade).

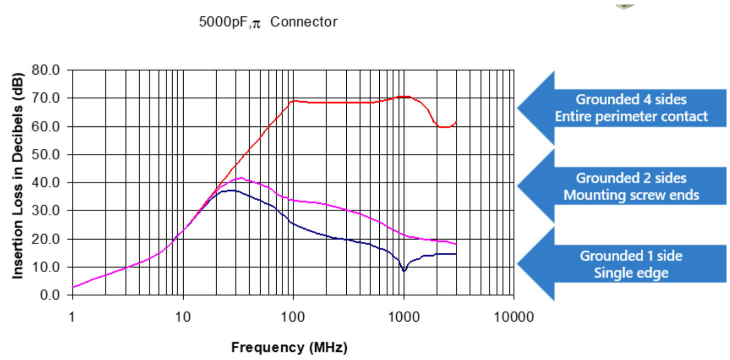
3. **Filter Construction:** The type of components used in the filter also influences the performance. A coaxial capacitor provides the best broadband and high frequency performance due to the lower parasitic influences as the frequency increases, then a chip style capacitor, reducing filter circuit resonances.

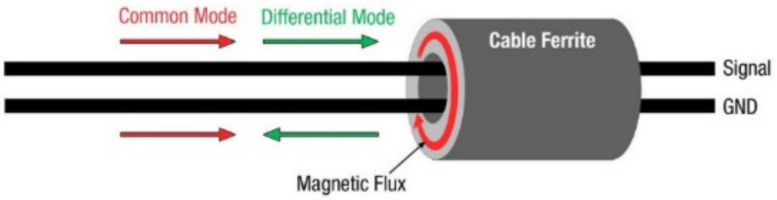
iv. Impedance considerations

1. **Filter Impedance Matching:** Although in most circuit designs it is desirable to have matched impedances, for low impedance Power and Control lines, a high impedance filter helps improve stability of the low impedance lines by reducing noise and ripple.

2. **Impedance Balancing:** Impedance balance pairs to avoid additional differential issues from common mode interference.







v. **Shielding**

1. **I/O Shielding:** Ensure any I/Os passing through a chassis use shielding and are grounded at the chassis. Do not leave a power or signal carrying conductor exposed to a noise source, allowing it to be conducted through the chassis.
2. **Board level shielding:** Use dedicated ground layers on boards to isolate signal and power circuits. Provide as many points of contact to chassis ground from board ground. If a noisy component is identified on a PCB, consider discrete shielding of the device.
3. **Proximity Effects:** Avoid long cable connections to eliminate ground loops in systems. Separate input and output cables to reduce potential coupling within the chassis.

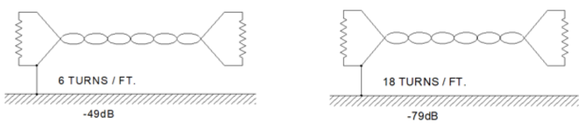
vi. **Grounding**

1. **Surface Finish:** Surface conductivity is important for effective grounding. To facilitate EMI current dissipation, a low impedance path to ground is highly desirable. A good rule of thumb is 3 milliohms/sq cm. High frequency EMC compliance requires highly conductive surfaces.
2. **Interface Installation:** Although interconnects are provided with some type of mounting flange and interface hardware. Grounding 360-degree or many point contact to the grounding surface creates the best EMI solution.
3. **Ground/Filter Best Practice:** The best EMI solution uses many points of contact to ground with a highly conductive surface. In connectors with coaxial capacitors, the performance approaches that of the theoretical calculation.

vii. **Common mode techniques: Ferrites**

1. **Complex component:** Ferrite beads/sleeves are typically placed on lines that are susceptible to EMI pick-up. Ferrite beads/sleeves provide a simple common mode element with a lossy component that damps high frequency emanations.
2. **High Frequency Signals:** Ferrites are also good for circuits that cannot tolerate traditional filter design methods, like Ethernet, USB, or HDMI. They also work particularly well when only a few dB of attenuation is needed at higher frequencies.

viii. Twisted pairs



1. **Noise Cancellation**: The use of twisted pairs allows for reduced crosstalk, better signal integrity, and interference cancellation due to the signal in the opposing wire.

2. **Properties:** Twisted pairs allow for better isolation from outside influences and improved dielectric properties with a higher twist rate.

ix. Openings and apertures

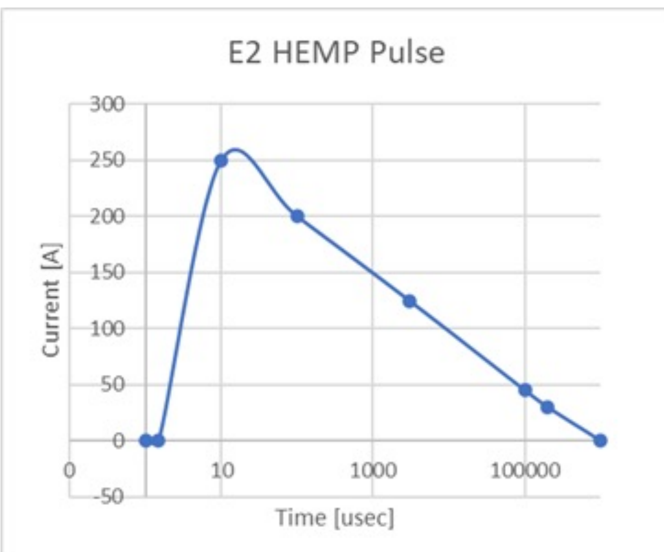
Frequency	Maximum gap
120MHz	4.92 inch
600MHz	0.98 inch
1.5GHz	0.394 inch
3GHz	0.197 inch

Equation:
[(3x10^8)*39.4] / (f) = lambda
Lambda / 20 = aperture max.
Simplified 591/f(MHz) = aperture max. inch

1. **Chassis Design:** Shielding effectiveness of a chassis is based on the largest opening size, independent of the shape. A careful survey of the metalwork is essential to ensure minimal leakage occurs for emission and immunity compliance.

2. **Aperture Design:** The size of the opening or aperture [inches] should be kept under Lambda/20, where lambda is the wavelength at the frequency [f] of interest. Lambda = [3E8*39.4] / [f].

x. Transients



1. **Pulsed Energy:** EMC is the ability of a system or device that uses electromagnetic energy to operate in its intended environment without suffering or causing unacceptable degradation. EMI is not only caused by the presence of RF noise, but higher energy RF pulses. These pulses can be in the form of ESD, Lightning, Spurious Discharges, or even EMP. EMI Filters may be required to survive or suppress the pulse, depending on the application.

2. **Suppression Devices:** Understanding the waveshape of the transient and the correct suppression device to be used requires knowledge of the transient and operating parameters of the system. The speed, amplitude, and allowable parasitics of the suppressor are all design considerations.

3. **Pulse Characteristics:** Understanding the differences between E2 (energy pulse similar to a lightning strike) and E3 (long duration pulse) events allows designers to tailor protection measures appropriately.

Incorporating transient protection is essential for ensuring that both the system and its components are safeguarded against unexpected high-energy events.

V. Conclusion

In modern electronic system design, EMC is a multifaceted challenge that demands careful planning and execution. By following the "10 Commandments of EMC Design," engineers can create systems that not only meet regulatory requirements but also achieve optimal performance under adverse electromagnetic conditions. From understanding the EMI profile to managing transients, every step in the design process contributes to a more robust and reliable system. As technology continues to evolve, the principles outlined in this white paper will remain foundational for overcoming EMI challenges in a diverse range of applications.