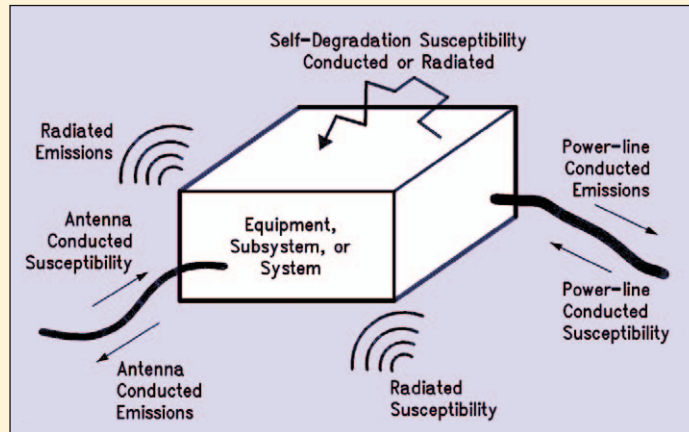


# Noise Suppression and Intra-System EMI-Control Techniques

EMI control techniques involve both hardware implementations and methods and procedures. They may also be divided into intra-system and inter-system EMI control. Our major concern in this Application Note is intra-system EMI control, however, an overview of each may be appropriate at this time.



The Figure above illustrates the basic elements of concern in an intra-system EMI problem. The test specimen may be a single box, an equipment, subsystem, or system (an ensemble of boxes with interconnecting cables). From a strictly near-sighted or selfish point-of-view, the only EMI concern would appear to be degradation of performance due to self-jamming such as suggested at the top of the figure. While this might be the primary emphasis, the potential problems associated with either

- susceptibility to outside conducted and/or radiated emissions or
- tendency to pollute the outside world from its own undesired emissions, come under the primary classification of intra-system EMI.

Corresponding EMI-control techniques, however, address themselves to both self-jamming and emission/susceptibility in accordance with applicable EMI specifications. The techniques that will be discussed include filtering, shielding, wiring, and grounding.

## Inter-System EMI

Inter-system EMI distinguishes itself by interference between two or more discrete and sepa-

rate systems or platforms which are frequently under independent user control. Culpit emissions and/or susceptibility situations are divided into two classes:

- antenna entry/exit and
- back-door entry/exit

More than 95% of inter-system EMI problems involve the antenna entry/exit route of EMI. We can group inter-system EMI-control techniques by four fundamental categories: frequency management, time management, location management, and direction management. The first step in locating a solution is to identify the problem as either an inter-system or intra-system EMI situation. Generally, if the specimen has an antenna and the problem develops from what exits or enters the antenna from another specimen or ambient, then the problem is identified as an inter-system EMI one. Otherwise, it is an intra-system

EMI situation which we will discuss now.

## Shielding

Shielding is used to reduce the amount of electromagnetic radiation reaching a sensitive victim circuit. Shields are made of metal and work on the principle that electromagnetic fields are reflected and/or attenuated by a metal surface. Different types of shielding are needed for different types of fields. Thus, the type of metal used in the shield and the shield's construction must be considered carefully if the shield is to function properly. The ideal shield has no holes or voids, and, in order to accommodate cooling vents, buttons, lamps, and access panels, special meshes and "EMI-hardened" components are needed.

Once a printed-circuit board design has been optimized for minimal EMI, residual interference can be further reduced if the board is placed in a shielded enclosure. A box's shielding effectiveness in decibels depends on three main factors: its skin, the control of radiation leakage through the box's apertures or open areas (like cooling holes), and the use of filters or shields at entry or exit spots of cables.

A box skin is typically fabricated from sheet metal or metallized plastic. Normally sheet metal skin that is 1 mm thick is more than adequate; it has a shielding effectiveness of more than 100

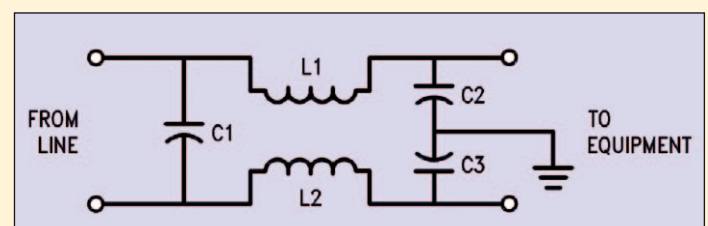
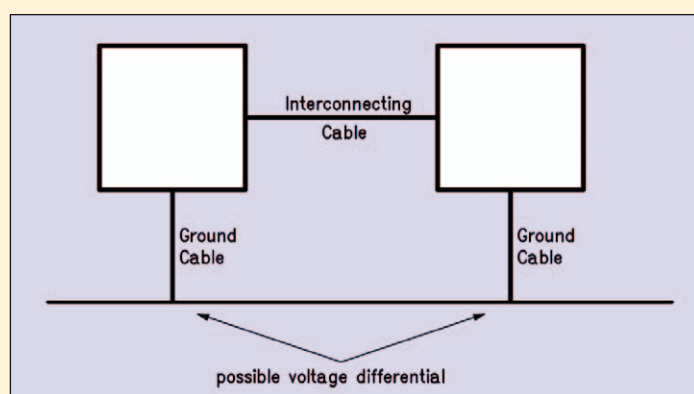
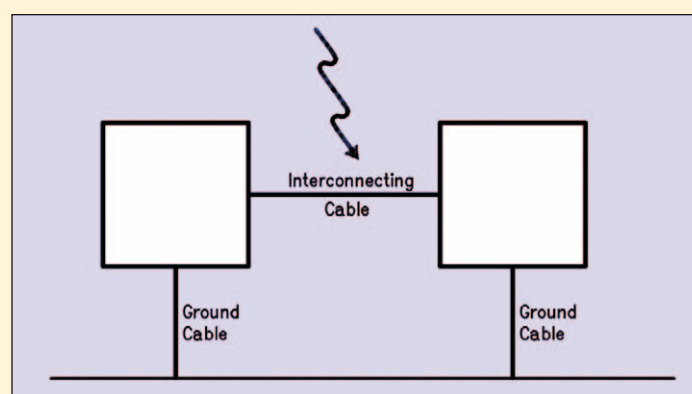


Figure 1: Filtering

Quelle:  
Texas Instruments, Application  
Report AN-643, EMI/RFI  
Board Design, Chapter 11 &  
12, [www.ti.com](http://www.ti.com)



**Figure 2. Common Ground Impedance Coupling**



**Figure 3. Common-Mode, Radiated Field-to-Cable Coupling**

dB throughout the high-frequency spectrum from 1 MHz to 20 GHz. Conductive coatings on plastic boxes are another matter. Table 1 shows that at 10 MHz the shielding effectiveness can be as low as 27 dB if a carbon composite is used, or it can run as high as 106 dB for zinc sprayed on plastic by an electric arc process. Plastic filled materials or composites having either conductive powder, flakes, or filament are also used in box shielding; they have an effectiveness similar to that of metallized plastics.

In many cases shielding effectiveness of at least 40 dB is required of plastic housings for microcontroller-based equipment to reduce printed-circuit board radiation to a level that meets FCC regulations in the United States or those of the VDE in Europe. Such skin shielding is easy to achieve. The problem is aperture leakage. The larger the aperture, the greater its radiation leakage because the shield's natural attenuation has been reduced. On the other hand, multiple small holes matching the same area as the single large aperture can attain the same amount of cooling with little or no loss of attenuation properties.

## Filtering

Filters are used to eliminate conducted interference on cables and wires, and can be installed at either the source or the victim. Figure 1 shows an AC power-line filter. The values of the components are not critical; as a guide, the capacitors can be

between 0.01 and 0.001  $\mu\text{F}$ , and the inductors are nominally 6.3  $\mu\text{H}$ . Capacitor C1 is designed to shunt any high-frequency differential-mode currents before they can enter the equipment to be protected. Capacitors C2 and C3 are included to shunt any common-mode currents to ground. The inductors, L1 and L2, are called common-mode chokes, and are placed in the circuit to impede any common-mode currents.

## Wiring

Now that the equipment in each box can be successfully designed to combat EMI emission and susceptibility separately, the boxes may be connected together to form a system. Here the input and output cables and, to a lesser extent, the power cable form an "antenna farm" that greatly threatens the overall electromagnetic compatibility of the system. Most field remedies for EMI problems focus on the coupling paths created by the wiring that interconnects systems. By this time most changes to the individual equipment circuits are out of the question.

Let us address five coupling paths that are encountered in typical systems comprised of two or more pieces of equipment connected by cables. These should adequately cover most EMI susceptibility problems. They are:

- A common ground impedance coupling – a conducting path in which a common impedance is shared between an

undesired emission source and the receptor.

- A common-mode, radiated field-to-cable coupling, in which electromagnetic fields penetrate a loop formed by two pieces of equipment, a cable connecting them, and a ground plane.
- A differential-mode, radiated field-to-cable coupling, in which the electromagnetic fields penetrate a loop formed by two pieces of equipment and an interconnecting transmission line or cable.
- A crosstalk coupling, in which signals in one transmission line or cable are capacitively or inductively coupled into another transmission line.
- A conductive path through power lines feeding the equipment.

The first coupling path is formed when two pieces of equipment are connected to the same ground conductor at different points, an arrangement that normally produces a voltage difference between the two points. If possible, connecting both pieces

of equipment to a single-point ground eliminates this voltage. Another remedy is to increase the impedance along a loop that includes the path between the ground connections of the two boxes. Examples include the isolation of printed-circuit boards from their cabinet or case, the use of a shielded isolation transformer in the signal path, or the insertion of an inductor between one or both boxes and the ground conductor. The use of balanced circuits, differential line drivers and receivers, and absorbing ferrite beads and rods on the interconnecting cable can further reduce currents produced by this undesirable coupling path. Figure 2 illustrates common ground impedance coupling.

A balanced circuit is configured so its two output signal leads are electrically symmetrical with respect to ground, as the signal increases on one output the signal on the other decreases. Differential line drivers produce a signal that is electrically symmetrical with respect to ground

## Electromagnetic Interference Fixes

1. Insert Filter in Signal Source
2. Insert Filter in Signal Receptor
3. Insert Filter in Power Source
4. Insert Filter in Power Receptor
5. Twist Wire Pair
6. Shield Cable
7. Use Balanced Circuits
8. Install Differential Line Drivers and Receivers
9. Float Printed Circuit Board(s)
10. Separate Wire Pair
11. Use Ferrite Beads
12. Use a Multilayer Instead of a Single-Layer Printed Circuit Boards

Shielding Material	Surface Resistance Ohms/Square	Shielding Effectiveness, dB		
		at 10 MHz	100 MHz	1000 MHz
Silver Acrylic	0.004	67	93	97
Paint Silver Epoxy	0.1	59	81	87
Paint Silver	0.05	57	82	89
Deposition Nickel	3.0	35	47	57
Composite Carbon	10.0	27	35	41
Composite Arc-Sprayed	0.002	106	92	98
Zinc Wire Screen (0.64 mm Grid)	N.A.	86	66	48

**Table 1: Effectiveness of shielding materials with (1) 25- $\mu$ m thickness and for frequencies for which the largest dimension of the shielding plate is less than a quarter of a wavelength**

from a single-ended circuit in which only one lead is changing with respect to ground. Ferrite beads, threaded over electrical conductors, substantially attenuate electromagnetic interference by turning radio-frequency energy into heat, which is dissipated in them. In the second coupling path, a radiated electromagnetic field is converted into a common-mode voltage in the ground plane loop containing the interconnect cable and both boxes. This voltage may be reduced if the loop area is trimmed. Figure 3 illustrates common-mode, radiated field-to-cable coupling.

The third coupling path produces a differential-mode voltage that appears across the input terminals of the EMI receptor. One way of controlling this is to cancel or block the pickup of differential-mode radiation. In a balanced transmission line, this is done by use of twisted-wire pairs and a shielded cable. As for crosstalk, the fourth coupling path – the reduction of capacitive coupling can be achieved by the implementation of at least one of these steps:

- Reducing the spacing between wire pairs in either or both of the transmission lines.
- Increasing the separation between the two transmission lines.
- Reducing the frequency of operation of the source, if possible.
- Adding a cable shield over either or both transmission lines.

- Twisting the source's or receptor's wire pairs.
- Twisting both wire pairs in opposite directions.

The fifth coupling path conductively produces both common-mode and differential-mode noise pollution on the power mains. Among several remedies that can suppress the EMI here are the filters and isolation transformers. There are only about 50 common practical remedies that can be used in most EMI situations. Of these, about 10 suffice in 80 percent of the situations. Most engineers are aware of at least some of these remedies – for example, twisting wires to reduce radiation pickup.

In order to attack the EMI problem, one can make use of the information contained in Table 2. First, decide what coupling path has the worst EMI interference problem. From the 11 most common coupling paths listed at the top of the table, find the problem coupling path. Using the numbers found in that table entry, locate the recommended remedy or remedies from the 12 common EMI fixes identified at the bottom of the table. This procedure should be repeated until all significant coupling paths have been properly controlled and the design goal has been met.

## Inter-System EMI Control Techniques

There are many EMI controls that may be carried out to enhance the chances of inter-

system EMC. They can be grouped into four categories which we will discuss briefly. The following discussion is not intended to be complete but merely provide an overview of some EMI control techniques available to the intersystem designer and user.

Frequency management suggests both transmitter emission control and improvement of receptors against spurious responses. The object is to design and operationally maintain transmitters so that they occupy the least frequency spectrum possible in order to help control electromagnetic pollution. For example, this implies that long pulse rise and fall times should be used. Quite often one of the most convenient, economic and rapid solutions to an EMI problem in the field, is to change frequency

of either the victim receiver or the culprit so

In those applications where information is passed between systems, a possible time management technique could be utilized where the amount of information transferred is kept to a minimum. This should reduce the amount of time that the receptor is susceptible to any EMI. In communication protocols, for example, essential data could be transmitted in short bursts or control information could be encoded into fewer bits.

Location management refers to EMI control by the selection of location of the potential victim receptor with respect to all other emitters in the environment. In this regard, separation distance between transmitters and receivers is one of the most significant forms of control since interfering source emissions are reduced greatly with the distance between them. The relative position of potentially interfering transmitters to the victim receiver are also significant. If the emitting source and victim receiver are shielded by obstacles, the degree of interference would be substantially reduced.

Direction management refers to the technique of EMI control by gainfully using the direction and attitude of arrival of electromagnetic signals with respect to the potential victim's receiving antenna. ◀

Radiated Field to Interconnecting Cable CM	2, 7, 8, 9, 11
Radiated Field to Interconnecting Cable DM	2, 5, 6
Radiated Field to Box	12, 13
Box to Radiated Field	12, 13
Interconnecting Cable to Radiated Field CM	1, 3, 9, 11
Interconnecting Cable to Radiated Field DM	1, 3, 5, 6, 7
Box-to-Box Radiation	12, 13
Box-to-Box Conduction	1, 2, 7, 8, 9
Cable-to-Cable Crosstalk	1, 2, 3, 4, 5, 6, 10, 11
Power Mains to Box Conduction	4, 11
Box to Power Mains Conduction	4

**Table 2: Electromagnetic interference coupling paths (CM Common-Mode, DM Differential-Mode)**