Magnetic Shielding Basics

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Growing complexity in electronics heightens the need for magnetic shielding.

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Without magnetic shielding, much of today's sophisticated electronic gear would be larger, less efficient, and in some magnetic environments, completely non-functional. Today's complex components are extremely sensitive, and miniaturization and dense packaging mean greater vulnerability to electromagnetic interaction. This dramatic upswing in component vulnerability can cause even the best engineered layouts to fail.

Origins of Electromagnetic Interference

Electromagnetic interference originates from many sources. In some instances, even the magnetic field of the Earth itself can affect proper functioning. The background radiation of the Earth is, of course, all pervasive, but is not always taken into account in design of electronic systems and components. Man-made sources of EMI-RFI include permanent magnets or electromagnets; coil components such as transformers, solenoids and reactors; AC or DC motors and generators; and improperly grounded cables carrying large DC or AC current at power frequencies. These cables can act as antennas that switch transients onto power lines. The resulting conducted interference indicates that unwanted energy from electromagnetic fields has coupled into the calibrated circuits. Another troublesome field includes the electromagnetic pulses of wide dynamic range that can be caused by severe local thunderstorms.

Some comparatively new hazards to optimum electronic equipment functioning are still largely unrecognized. One such hazard involves the low ceilings in modern concrete structures reinforced with steel beams. The metal in the ceilings is much closer to sensitive equipment than was the case in older buildings with high ceilings. The resulting magnetic disturbance is substantially greater than 150 Gamma/cm, a typical magnetic field gradient in older reinforced concrete industrial buildings.

The Need for Magnetic Shielding

Unfortunately, when electronic equipment intended to handle certain precise levels of input, whether logic or continuous signal, picks up undesired inputs at operating, triggering, or higher levels, a dysfunction can occur. For example, clear, sharp CRT readouts are vital in many applications. Yet, without magnetic shielding at the tube neck, this ideal cannot be achieved. In electron microscopes, resolution deterioration can be caused by beam scattering, bending or displacement from normal optimum focus position. Complex, high resolution video recorder head assemblies must be shielded from a wide range of magnetic field interferences that may prevent full operational capability in recording/playback applications in TV studio/mobile, closed circuit, professional home and other video display systems. There are also hazards when analog or digitized data on magnetic tape or cassettes are stored or transported. The fidelity of vital recorded information may be distorted or even partially erased by unforeseen external magnetic fields, or by the carelessness of unheeding or uninformed personnel—or by deliberate vandalism with powerful permanent magnets.

Aircraft electronics provides just one crucial example of the potential for EMI problems. Instrumentation in aircrafts is packaged tightly together because of space restraints. The performance of an aircraft radar tube can be visibly distorted by nearby tachometers that may radiate a rotating magnetic field. The radar display is subject to some position shift each time the aircraft changes direction or attitude relative to the earth's field.

Using Magnetic Shielding to Foil EMI

To assure optimum performance, stray magnetic fields must be directed around critical electronic components as a rock in a river diverts running water. Sometimes, the undesired source is obvious and can be subjected to line filtering or shielding suitable to the frequency and intensity encountered. However, unexpected and unpredicted sources and combinations may not be analyzed so easily.

Shielding is accomplished by placing a special material between the field source and the sensitive components affected. Such material must be both conductive to prevent passage of electric fields and permeable enough to prevent passage of magnetic fields. The "permeabilities" of commonly used shielding materials range from 300 to over 500,000 depending on flux density.

Once the offending field source is identified, one practical approach in determining needed shielding is to order a small quantity of heat-treated ready-to-use magnetic shielding foil from a shielding manufacturer. It is available for immediate delivery in various convenient widths, lengths and shielding strengths for high or low permeability requirements with a range of electrical conductivities. Foil is easily, quickly cut with ordinary scissors and can then be hand-shaped to the desired outline. It is ideal for R/D, hard-to-get-at places, or for small quantity or extremely compact applications. With foil, many shielding problems thus can be resolved quickly.

After hand shaping around the component to be shielded, the foil can be held in place with simple adhesive tape. Thickness and number of layers can be determined by ordinary trial and error procedure, or a formula to follow may be requested from the manufacturer. Begin by using a single layer and then add layers until the desired shielding effect is achieved.

When using multiple layers in steady fields and at low frequencies, the low permeability layer should be closest to the field source. This arrangement tends to increase the flux density shielding capabilities. The low permeability layer diverts the major portion of the field, permitting the high permeability layer, or layers, to operate in a lower reluctance mode. In experimentation or where relatively few shields are needed, foil is the swift, economical solution.

Once foil shielding is functioning satisfactorily in either experimental or production applications, it is time to evaluate the economics. The cost of foil versus prefabricated shields for that particular application should be compared. A prefabricated shield is less costly in larger quantities and for certain complex applications. For designing and manufacturing prefabricated magnetic shields in-house, sheet stock can be ordered. Sheet stock may be formed by bending, stamping, or drawing on ordinary sheet metal equipment. It is then finished by plating, MIL spec painting, etc. For optimum magnetic shielding characteristics, shields must be heat-treated after all forming, welding, and machining operations.

A shielding supplier will provide guidance in the use of the various available kinds of heat treatments—such as the one which permits ease of forming (mill annealed) or the treatments which assure the maximum mechanically stable permeability or absolute maximum permeability (which are not necessarily stable mechanically or thermally in some high nickel alloys).

Shielding Effectiveness

The high electrical conductivity and high magnetic permeability cited above both contribute to the effectiveness of thin foils in fast-rising pulse shielding by reducing the skin depth. Lately, distinctions have been drawn between cases where the foil thickness exceeds the skin depth and where it is greater. This type of shielding against pulse-type interference achieves the highest order of shielding effectiveness generally obtained by any means. Attenuations between 300 dB and 1000 dB are not unusual. Low frequency magnetic shielding effectiveness is directly proportional to shield thickness because the shield's reluctance to magnetic flux is inversely proportional to its thickness. It is essential to minimize joints or air gaps that can reduce shielding effectiveness by causing both the leakage of magnetic interference and a significant alteration of the path's reluctance, resulting in a lower effective permeability.

The degree of shielding achieved by a given total thickness of material can be increased by dividing the material into two or more concentric shields separated by at least the thickness of the material. In such cases, a medium permeability material should be used for one layer and a high permeability material for the other layer. The lower permeability material should be located closest to the field source. Thus, the medium permeability laminate acts as a buffer that sufficiently diverts the magnetic field to enable the lower reluctance (higher permeability) material to attain the required attenuation. When the external field is strong enough to cause the medium permeability material to approach saturation, an additional diverting shield of low permeability, high flux carrying capability may be needed. At high frequencies, shielding via enhancing skin effect offers a considerable degree of shielding from a thin, compact layer.

Conclusion

Magnetic shielding provides the solution to the EMI problems explored above.. It protects sensing devices such as the magnetic sensors used for signature recognition and proximity sensing in a wide variety of industrial, military, and commercial security operations. It shields complex, high resolution video head assemblies to guarantee full operability in recording/playback applications in television studios, closed circuit networks, and video display systems. In the crucial example of aircraft, a magnetic shield for aviation radar tubes minimizes interference and supports the positioning of the tube, In short, magnetic shielding helps create an economical, replicable, controlled magnetic environment vital to today's complex electronics.

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