EMI/RFI SHIELDING:
A DESIGNERS' GUIDE TO FOIL TAPES

The world has witnessed a dramatic evolution, proliferation and growing dependence on electronic equipment. Our increased reliance on such devices, however, has been accompanied by new problems. Along with advances in electronics technology, for example, there's been a corresponding growth in the potential for electronic or electrical "pollution."

The sun, cosmic rays, radio stars and other atmospheric phenomena can be sources of interference, but most EMI originates from communications electronics, power tools, ignition systems and numerous other industrial and consumer devices. EMI poses a distinct problem for electronics design engineers. They must prevent EMI as well as protect sensitive equipment from it.

Today, many firms produce a wide variety of products for shielding, containing, reflecting and absorbing EMI. This article addresses one type of shielding: copper and aluminum foil tapes with pressure-sensitive adhesives (Figure 1).

Let's examine EMI more closely in relation to the electronics design function.

EMI Background

Generally speaking, electromagnetic interference (EMI) is either radiated or conducted. Interference is most often caused by electric or magnetic components of a radiating electromagnetic field. Grounding and filtering techniques eliminate conducted interference and radiated emissions can be attenuated by using metallic/conductive materials.

If electronic equipment were always contained in a housing that ensured complete electrical continuity (i.e., no openings or "leak points"), most EMI effects would be eliminated. Unfortunately, most electronic systems are not that self-contained; instead, they usually consist of several functional/physical elements. The junctions or interfaces between these elements often are the leakage points where EMI emissions originate. Designers then, in addition to considering grounding schemes and filtering methods, must monitor potential EMI trouble spots when developing new equipment. Shielding against EMI emissions can be as simple as sealing the openings

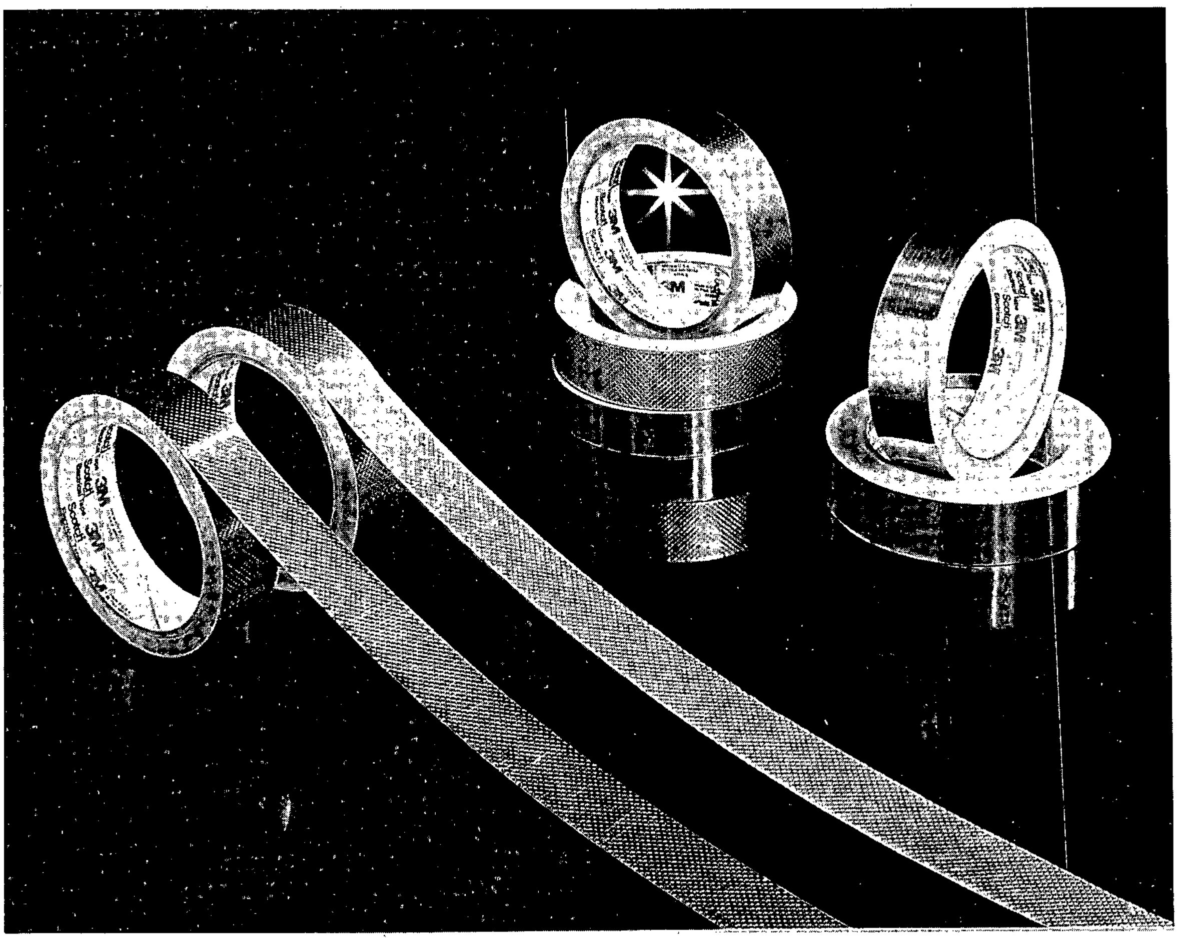


Figure 1 - Copper and aluminum foil tapes with pressure-sensitive adhesive.

in a motor enclosure with a metallic material. Other traditional shielding methods include welding; conductive gaskets, paints and epoxies; metal cable shields and other metal-to-metal contacts.

Unshielded EMI is most troublesome at shorter wave lengths (higher frequencies) above 1 GHz. At this level EMI can escape from very small openings and wreak havoc with nearby electronic equipment, such as television receivers, emergency vehicle receivers, alarm systems and garage door openers within range of the source.

New FCC Standards

The effects of EMI are almost inescapable, whether in the home, office or industrial facility. The seriousness of the EMI problem is indicated by the myriad of regulations that now exist on a worldwide basis. In the USA, manufacturers of digital electronic equipment must meet new, stringent design and performance guidelines. To ensure manufacturers' compliance, the Federal Communications Commission (FCC) established EMI emission limits, test procedures and formal definitions for several classes of devices (FCC Docket 20780).

Class A devices include those used in commercial, industrial or business environments, e.g., computers, machine tools, printing presses and electronic typewriters. Class B devices refer to those used in a home or residential environment, such as digital watches and clocks, pocket calculators and home computers. Implementation of the latest iteration of FCC rules began in 1981 and full compliance, including all Class A devices, will be required by the fall of 1983. The only items exempt under the present guidelines are certain types of medical equipment, industrial and commercial test equipment, transportation vehicles and a few microprocessor devices in home appliances.

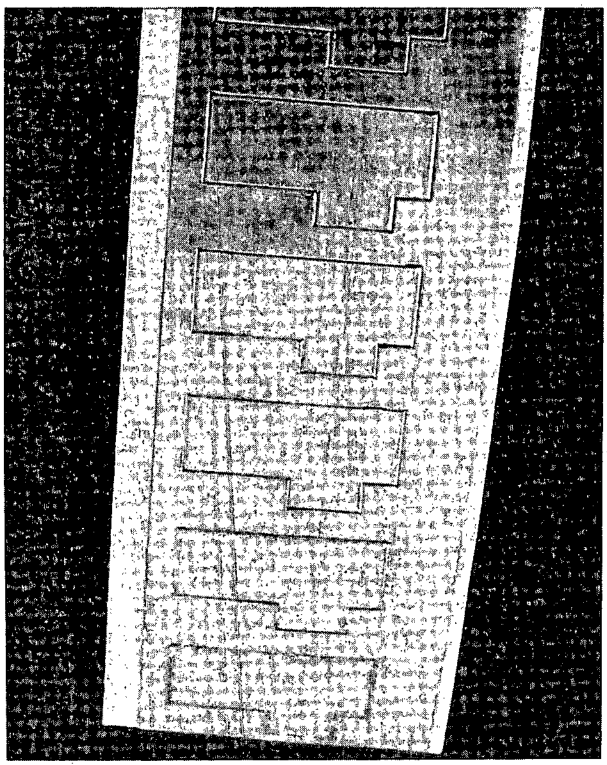


Figure 2 - Foil tapes can be die-cut to increase productivity when a large number of devices with complex shapes must be shielded.

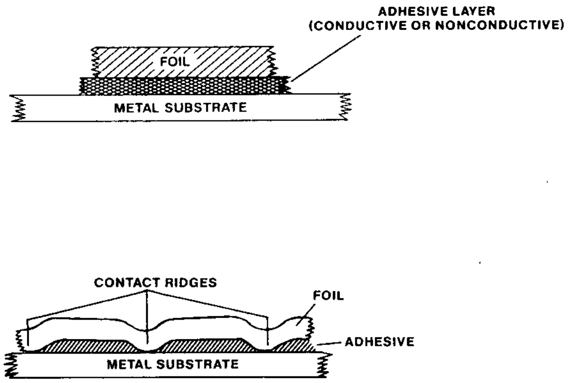


Figure 3 - The illustration shows typical foil tape construction/attachment to a metal substrate for EMI shielding or static drain.

While no one doubts the need for reducing the levels of EMI in the environment, implementation of the FCC regulations is already proving quite costly to electronics firms. Changes to existing designs, more materials and steps in processing, more time to install additional ground straps, screws and clamps ... all these things add up to higher manufacturing costs. Existing foil tape shielding technology offers a means of combating the added costs and hassles connected with today's EMI problems.

Foil Tape Construction

Foil tape for EMI shielding provides designers with great flexibility, literally and figuratively. Foil tape with a pressure-sensitive adhesive can be molded to conform to almost any shape for shielding motor housings, "black boxes," cables, connectors, transformers and other noise sources. In an assembly line setting, foil tape can be die-cut into individual custom shapes (still attached to the liner) in roll form to speed handling and increase productivity (Figure 2). These precut parts can be used as solder joint replacements, as customized runs of conductive material for static drain as well as for shielding purposes. Before we proceed further, let's examine the three basic types of foil tape (Figure 3).

In simplest form, foil tape consists of a metal foil layer (usually copper or aluminum) and a layer of nonconductive adhesive. Tape is also available with a conductive adhesive layer, which consists of a nonconductive matrix containing conductive particles.

The third type of foil tape is embossed. In this case, regularly spaced "ridges" of foil (dictated by the pattern of embossing) protrude through the nonconductive adhesive layer to contact the underlying substrate. In addition to providing good metal-to-metal contact with the substrate for shielding purposes, these embossed foil tapes are useful for static charge draining applications.

Foil tapes should have an electronic-grade, pressure-sensitive adhesive to prevent possible electrolytic corrosion of fine wires (18 AWG and smaller) in coils and transformers or thin copper strips on printed circuit boards.

Tape Shielding Effectiveness

Copper and aluminum foil tapes are effective shields across the range of EMI frequencies covered by the new FCC regulations. They combine properties of reflection and absorption (reflection predominates at lower frequencies, while absorption predominates at frequencies greater than 1 GHz). For low frequency magnetic fields up to 200 kHz, foil tapes are not effective. Rather, high permeability materials, such as iron and magnetic steel, are used (see section on Magnetic Shielding).

The amount of EMI leakage that will occur depends on the length of the opening through which the electromagnetic energy can escape, the wavelength of the energy and the impedance of the wave. If a foil tape with a nonconductive adhesive is used to cover an opening in an EMI source, shielding effectiveness will be limited because of the lack of electrical contact to the substrate. This factor is most important in the MHz range. Better shielding results are obtained when the continuous electrical contact is achieved around the opening by using embossed foil tape or a foil tape with a conductive adhesive layer. The amount of leakage then becomes a function of the thickness of the adhesive layer and amount of overlap beyond the opening. With embossed foil, the ridges reduce the adhesive gap to essentially zero.

The shielding effectiveness of different foil tapes were determined by exposing various substrate materials with samples of tape installed on their surfaces to known frequencies of EMI and measuring the insertion loss. In the test, nonconductive, conductive and embossed tape samples were installed on copper substrates and exposed to a simulated EMI frequency of 143 MHz (Figure 4). The minimum aging period was three months (for the conductive adhesive tape sample) and a full year for the other two foil tape samples (nonconductive adhesive tape and embossed foil tape). Clearly, embossed foil tape provided the most effective shield.

As a whole, foil tapes offer convenience, speed and low material cost in comparison to other shielding methods. They are easy to use in designing entirely new applications and are often an ideal remedy to persistent, existing EMI challenges. Foil tape can be used as a diagnostic tool, for example, to isolate EMI emission points by simply shielding portions of a system until an interference signal is eliminated. It can also be easily removed at any time without damage to the shielded equipment. Above all, it is ideal for use in the field for quick, permanent solutions to the knottiest EMI problems.

Foil Tape Applications

As mentioned previously, static drain is another application for the conductive adhesive and embossed foil tapes, particularly in computer electronics where built-up static charges (e.g., cathode ray tubes, keyboards and aerospace appliations) can greatly degrade performance or even destroy sensitive components.

Some computer manufacturers have selected foil tapes for device mainframes corrosion protection and

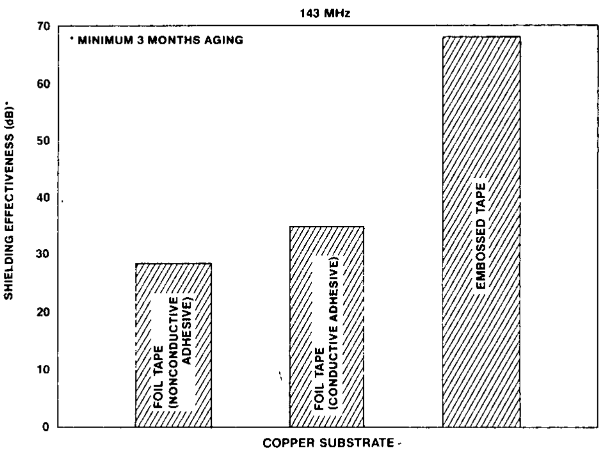
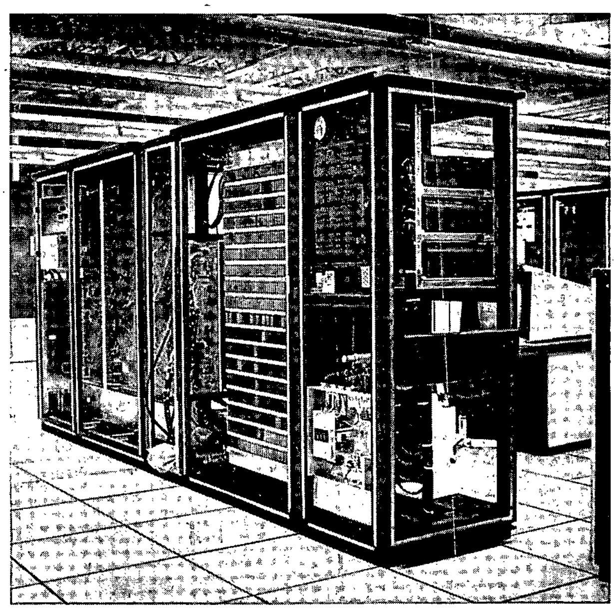


Figure 4 - The chart compared the shielding effectiveness of the three types of foil tape - embossed, conductive adhesive, nonconductive adhesive. Measurements were made with a minimum of three months aging to assure long-term stability.



Picture by Control Data Corporation

Figure 5 - Foil tape can provide EMI shielding between a computer frame and door. The tape protects the bare metal of the frame from corrosion.

RFI shielding (Figure 5). Transformer manufacturers find foil tape useful for a number of applications (Figure 6). In addition to controlling electrostatic coupling between windings, foil tape helps to attenuate radiated EMI from the windings.

There are also numerous uses for foil tape in cable assemblies and their associated connectors (Figure 7). By wrapping cable protected by a braided metal shield with half-lapped layers of foil tape, shielding effectiveness is greatly enhanced. In computer systems, foil tape can be used as ground planes or shields for ribbon cables. If desired, a small solder run can be used to connect a foil tape to the metal conector enclosure for complete electrical continuity in a cable assembly for shielding purposes. Again, the function can be twofold: static drain and shielding.

Other applications of foil tapes in the computer industry include wrapping cables/connectors, transformer shielding, static drain and providing a conductive path between the cabinet, doors, access panel and filters.

Figure 6 - Radiated EMI and electrostatic coupling between the windings of a transformer controlled with foil tapes.

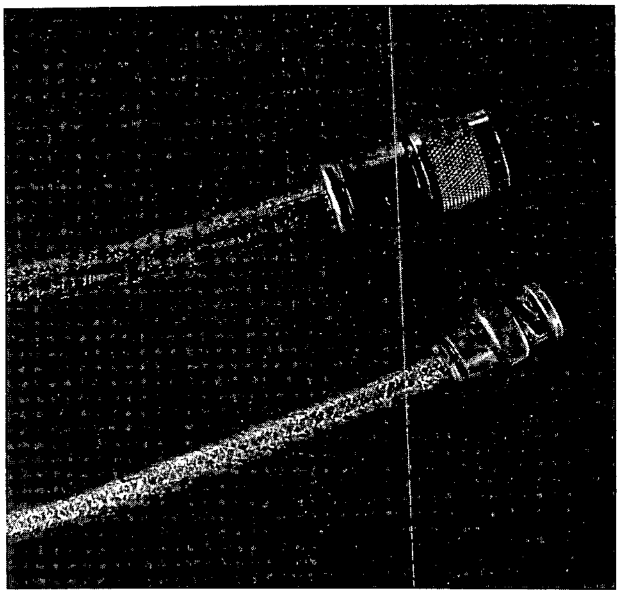


Figure 7 - Embossed foil tapes used for static draining and for shielding of cables and connectors.

In the cable television (CATV) industry, foil tape is useful for shielding oscillators, filters and coaxial relays. The electronic game industry uses foil tape for shielding integrated circuits, where it is a superior alternative to conductive plastic enclosures and conductive sprays.

Test equipment manufacturers solve numerous EMI problems with foil tape. Here the tape is used for transformer shielding, providing easily installed conductive paths between doors and panels and eliminating expensive redesign costs of temperature sensor circuits.

The military, too, benefits from the superior shielding characteristics of foil tape for shielding flat cable connectors and missile launcher circuits from EMI and providing static ground paths.

And the list of applications continues, including such diverse areas as microwave systems, conducting conductivity tests of paint, shielding security alarm systems from nuisance tripping and masking areas of printed circuit boards before the plating process is started.

The conductive tapes now available to the design engineer offer a viable, low-cost solution to the well-known problems of electromagnetic interference and static discharge.

This article was written for ITEM by John M. Magnusson, Applications Engineer, Shielding Products, 3M Industrial Electrial Products Div., St. Paul, MN.

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