DESIGN CONSIDERATIONS: Conductive Plastics in Computer Housings

Over the past several years, interest in electrically conductive plastics has been growing rapidly. The driving force for this interest is the electronics industry and its insatiable need for conductive materials which can 1) dissipate static electricity, and 2) provide high levels of EMI/RFI attenuation. The topic of radio-frequency emission gained considerable attention when the Federal Communication Commission issued strict regulations.[1] As a result, advancements have been made in the technology of conductive plastics from the standpoint of new fillers and additives,[2,3,4] semiconducting polymer molecules[5,6] and improved processing methods.

Metal oxide semiconductor (MOS) chips are the key elements in intelligent electronic devices—e.g., computers, cash registers, electronic toys, office equipment, control instrumentation and appliances. Because they are high impedance devices, these ultra-thin MOS elements are inherently sensitive to electrostatic fields and electromagnetic radiation, which can result in degradation or catastrophic failure. Several failure mechanisms have been determined and are summarized in references 7 and 8. In every stage from manufacture through end-use, MOS devices must be protected by some static dissipating mechanism, as well as from radiated fields.

In addition to the need for protection of MOS devices from degradation, there is a need to prevent spurious fields from interfering with the data function itself. In MOS devices, minute signals or micro-amps, are being processed and amplified to useful levels. Therefore, any noise from electrostatic discharge (ESD), lightning, secondary induced fields and other emitting devices must be shielded to prevent interference.

Engineers responsible for the design of housings for microelectronic systems should consider the performance of the housing in both electromagnetic and electrostatic fields. Electromagnetic radiation considerations encompass the susceptibility of the microelectronic system to functional interference as well as the emission of radiation into the environment. The protection of microelectronic systems from functional interference caused by static electricity has been approached primarily by protecting the workplace environment—i.e., antistatic carpeting, chairs, chair mats and topical antistatic agents.

This article will review the requirements for the use of *electrically conductive plastics* in housings for protection from electrostatic discharge and radiated electromagnetic energy.

Requirements For Electromagnetic Shielding

When impinging upon the interface of a computer housing, electromagnetic energy can be reflected, transmitted or absorbed (Figure 1). The shielding effectiveness of a material is a measure of its ability to attenuate electromagnetic radiation. The total shielding effectiveness is the sum of its absorption component and its reflection component, expressed in decibels (dB).[10,11]

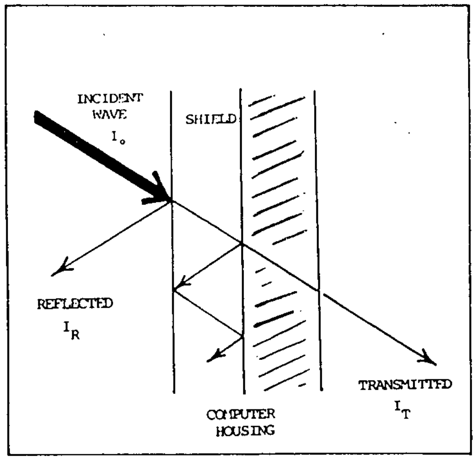

Figure 1. Requirements for Shielding.

Shielding Effectiveness, SE = Absorption, A + Reflection, B

The absorption attenuation, A is given by:

$$A = 3.34\sqrt{\mu f G}\ (\text{dB})$$

The reflection component, R, is given by:

$$R = 20\log\left[\frac{Z_w}{4}\sqrt{\frac{G}{2\pi\mu f}}\right]\ (\text{dB})$$

where, t = shield thickness in mils
μ = relative magnetic permeability of shield
f = frequency in MH_z
G = shield conductivity relative to copper in MHOS/meter
Z_w = wave impedance at shield
$= \frac{\text{E Field Intensity}}{\text{H Field Intensity}}$ (ohms)

The above relationships attest to the fact that shielding effectiveness is a complex function of thickness, frequency, magnetic permeability, wave impedance and conductivity. From the standpoint of this discussion, it is important to note that both the absorption and reflection attenuation increase with increasing electrical conductivity of the housing material.

How much attentuation by the housing is necessary to protect against RF emission, as well as EM susceptibility? The only satisfactory method of obtaining this answer is to perform in-format testing on actual systems. At a given attenuation level, the actual quantity of EM energy which will penetrate the shield will depend upon the initial intensity, I_o, of radiation. In addition to radiated energy attenuation, total shielding considerations involve the manifold aspects of circuit design, mechanical design, grounding, and coupling. Figure 2 compares the attenuation of a shield as a function of surface resistivity. To function as a minimum shield, surface resistivities of less than one (1) ohm per square and attenuation greater than 25 dB are commonly used.

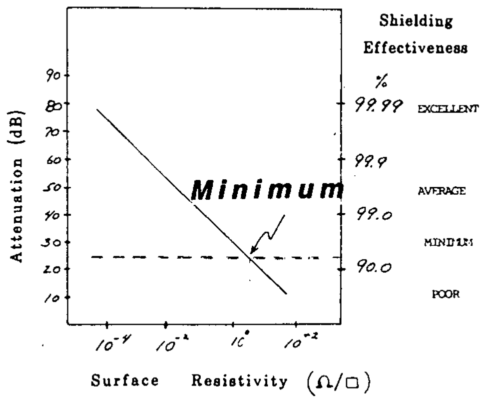

Figure 2. Attenuation of a Shield as a Function of Surface Resistivity.

Requirements for Protection Against ESD

ESD concerns for computer housings are divided into three categories:

1) prevention of charge accumulation

2) drainage of electrostatic charge from the housing material and from the operating personnel under controlled conditions to prevent corona discharge, and

3) Faraday cage shielding against ESD, and grounding of the electronic system.

Several test methods have been developed to study the decay of electrostatic charge as a function of time. In a typical charge-decay test[12] (i.e. FED-STD-101B, Test Method 4046) a material is charged to ±5000 volts and grounded. The voltage discharge as a function of time is recorded. If the voltage decays to zero (0) within 2 seconds, the material conforms to the requirements of MIL-B-81705B. If the voltage discharges to 10% of its initial value (500 volts) within 0.5 seconds, the material meets the requirements of the National Fire Prevention Association NFPA #56A. This is represented by the curves of Figure 3. These test methods attempt to define acceptable rates of voltage decay in a pragmatic sense. Decay times which are too slow permit the accumulation of electrical charge on a surface. On the other hand, decay times which are excessively rapid result in electrostatic discharge (ESD), dielectric breakdown of air manifested as sparking. Similar to natural lightning, ESD is a source of electromagnetic interference which must be dealt with by Faraday cage shielding.

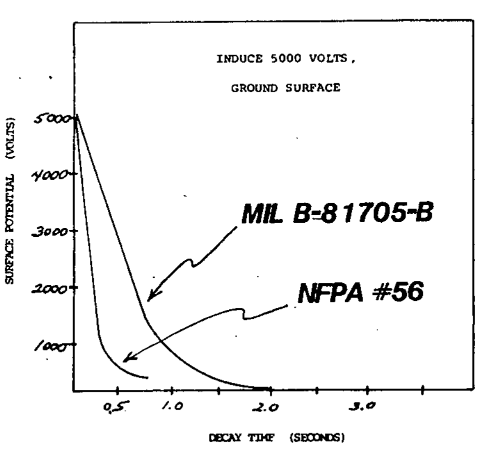

Figure 3. Electrostatic Charge as a Function of Time.

Static charge decays either by conduction through the surface of the solid or by radiation from the surface of the solid to the environment. A variety of materials and coatings have been used in static control applications to accelerate this decay. These include: 1. Topical and Internal Antistatic Agents, 2. Conductive Coatings, 3. Semiconductive Polymers, 4. Surface Treatments, 5. Conductive Plastic Composites and 6. Vapor Deposited Metals and Metal Oxides.

To the extent that most ESD interference problems are associated with high levels of static charge on personnel using the computer equipment, it is the drainage of this charge under rapid, controlled conditions which is to be achieved.

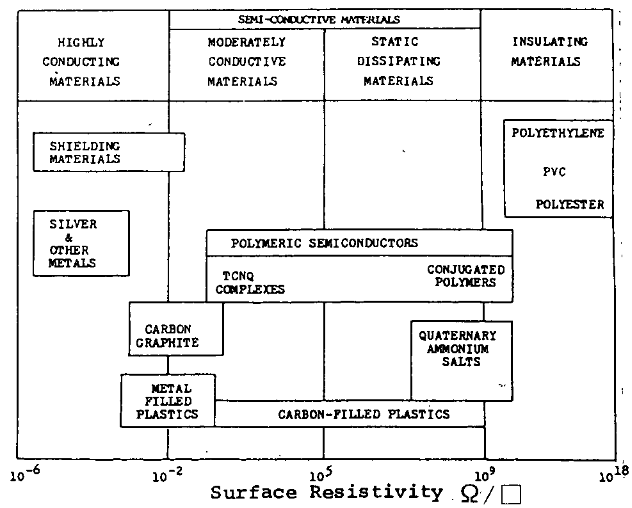

Figure 4. Materials Arranged According to their Surface Resistivity.

Discussion

Materials can be arranged on a spectrum according to their surface resistivity, ρ, as shown in Figure 4. The spectrum spans the range from highly conducting material such as silver ($\rho = 10^{-6}$ ohms per square) to dielectric materials typified by polyethylene ($\rho \approx 10^{+17}$ ohms per square). Surface resistivity is a measure of the restraint to a current passing across the surface under the influence of an impressed potential difference. In the test method commonly employed to measure ρ, a circular guarded electrode contacts the surface to be measured, as defined in ASTM-D257.[12]

Electrical conductivity can be imparted to plastics by the incorporation of conductive fillers—carbon black, graphite, aluminum, aluminumized glass, or stainless steel fiber into the resin material. In order for current to flow in a filled system, electronic transmission must occur from conductive aggregate to aggregate. It has been shown that aggregate size, shape, porosity and surface chemistry effect the resulting conductivity. In general, small, highly structured, high aspect-ratio porous aggregates provide greater conductivity for a given weight percent loading. Figure 5 shows the relation of carbon loading to the resultant volume resistivity for three commercial carbon blacks.

Structural properties can be enhanced by the incorporation of conductive pitch and polyacrylonitrile graphitized fibers in nylon, polycarbonate, polyacetal, ABS, Noryl, polysulfone and other engineering thermoplastics. Processing by extrusion, injection molding, calendering, vacuum forming and blow molding is readily accomplished with attention to several details. The resins must be thoroughly dried before processing; also high shear, high temperatures and long residence times must be avoided. Even though this represents good practice for plastics in general, it is essential for carbon filled systems.

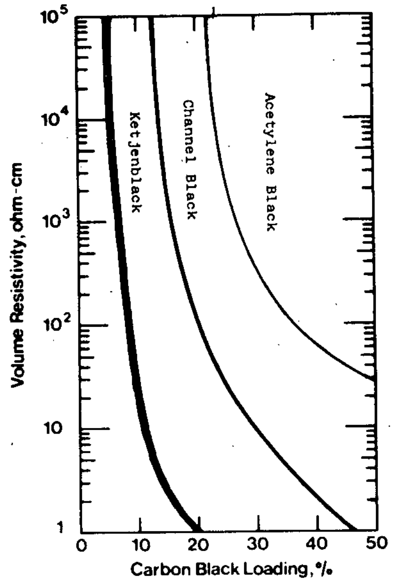

Figure 5. Volume Resistivity vs. Carbon Black Loading.

The surface of carbon black is extremly active and can serve as a catalytic site for the degradation or crosslinking of the polymer chain. Furthermore, the incorporated surface area is very large and readily absorbs stabilizers and processing aids. Formulations must be carefully optimized for thermal stability and processability. The incorporation of carbon black also demands that the use of regrind be carefully controlled. During compounding a nitrogen blanket is recommended in order to prevent oxidation.

According to the Department of Defense (DOD-HDBK-263, 2 May 1980) materials whose surface resistivities fall within the range of 10^5 to 10^9 ohms per square are classified as static dissipative and it is this range which is generally considered appropriate for controlled drainage of electrostatic charge.

Materials whose surface resistivities fall within the range of 10^9 to 10^{14} ohms per square are classified as antistatic and will resist the generation of electrostatic surface charge on the computer housing. However, antistatic materials are generally considered ineffective in providing static dissipation from personnel, especially above 10^{10} ohms per square. Moving towards the other end of the spectrum, materials having surface resistivities below 10^5 ohms per square are classified as conductive per DOD-HDBK-263 and are likely to discharge static electricity catastrophically by spark generation, resulting in EMI. From the perspective of ESD too much conductivity can be as detrimental as too little conductivity for housing materials.

From the previous discussion, a dilemma exists in that one material cannot function for both requirements of static control and shielding. Static control requires that the outside surface of the housing is static dissipative, 10^5 to 10^9 ohms per square. EMI shielding necessitates the use of a continuous conductive Faraday cage with a minimum surface resistivity of one (1) ohm per square.

Two solutions are available to the design engineer responsible for ESD and EMI protection. In the first approach, a two-layered housing structure can be fabricated having the outside plastic surface in the static dissipating range (10^5 to 10^9 ohms per square) and an inside highly conductive layer having a surface resistivity of less than one (1) ohm per square. Representative of this approach would be housings of static dissipative formulations of ABS, Noryl, Polycarbonate, or impact styrene, coated internally with nickel acrylic paint,[14] arc sprayed zinc,[15] thick film vapor deposited aluminum[16] or electroless nickel. These few examples are meant only to be representative and a more complete treatment of existing technology can be found in references 17, 19, and 21. The second approach would come from the position that the more effective the *total* EMI/RFI shielding protection (from all considerations—radiation, grounding, coupling, circuit design, mechanical design), the less influence ESD would have on the system.[20] In the extreme, a perfectly shielded microelectronic system would be insensitive to ESD.

References

1. Milton Mobley, "FCC and EMC: Origin and Development of the Equipment Authorization Program," *ITEM 1983.*
2. P. Datta et al., "Surface Modification of Conductive Carbon Filler by Graft Polymerization of Vinyl Monomers," 1979 *SPE37th ANTEC Proceedings.*
3. D. G. Bodnar and B. M. Jenkins, "Use of Internal Shielding Materials for Electromagnetic Shielding of Structural Foams, "Georgia Institute of Technology, Final Technical Report EES/GIT Project A-161, April 1979.
4. D. M. Bigg, "Conductive Polymeric Compositions," *Polymer Engineering and Science,* Vol. 17, No. 12, December 1977.
5. Joel S. Miller, *Extended Linear Chain Compounds,* Plenum Press, 1982.
6. "Organic Superconductors," *Scientific American,* July 1982.
7. Tarak N. Barr, Edward G. McMahon, *Electrostatic Discharge Control,* Hayden Book Co., 1982.
8. "DOD HDBK 263, Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment," May 1980, pg. 12.
9. M. E. Baird, *Electrical Properties of Polymeric Materials,* The Plastics Institute, London, England, 1973.
10. Donald R. J. White, *Handbook on Electromagnetic Shielding Materials and Performance,* 2nd Edition, 1980.
11. *Electromagnetic Shielding Principles; Vol. 1,* Rensalaer Polytechnic Institute, Troy, N.Y. 1956.
12. James R. Huntsman, Donald M. Yenni, Jr., "Test Methods for Static Control Products," presented at the 1982 EOS/ESD Symposium, Orlando, Florida.
13. "D-C Resistance or Conductance of Insulating Materials," ANSI/ASTM D-257-76.
14. Joseph Kosiarski, "The Use of Electrically Conductive Organic Surface Coatings for Shielding and Grounding of Plastic Enclosures," *Polym. Plast. Technol. Eng.* 13 (2), 183-195 (1979).
15. Portable Metallizing System Provides EMI Shielding Using Thermal Spraying Technique, *Plastic Design & Processing,* April 1978.
16. W. A. Schaller, "Conductive Coating By Vacuum Metalization, *ITEM 1983.*
17. "Shielding Against Electromagnetic Interference," *Plastics Design Forum,* March/April 1979.
18. Jay L. Rogers, "Antistatic Tests and Agents for Plastics: Part 1 and 2; *SPE Journal,* Jan. and Feb., 1973.
19. Norman E. Fowler, "The Processing and Testing of Filled Conductive Plastic Materials," (Masters Thesis) University of Lowell, 1980.
20. "Deadline Passes as Products Meet Compliance," *Interface: Data General News Letter,* October 1983.
21. Michael E. Gordon, "Conductive Plastics in Static Control and EMI/RFI Shielding," Presentation at Circuit Expo 1982.

This article was written for ITEM '84 *by Dr. Michael E. Gordon, President, Plastic Systems, Inc., Marlboro, MA.*

SEE ADVERTISEMENT ON PAGE 202