INTRODUCTION

Editor's Note: *In recognition of the increasing significance of the ESD threat and its relationship to EMI, both as phenomenon and for control techniques, this ESD Section has been expanded considerably from the 1982 Edition. It is anticipated that ITEM will continue to address ESD in keeping with its importance as an EMI phenomenon.*

This issue of ITEM contains some noteworthy articles on a subject that should be of considerable interest to the EMI community. Particular attention is given to the subject of Electrostatic Discharge (ESD) in this updated and expanded ESD section. ESD and EMI have much in common, from both standpoints of design and control technology. The subject of ESD has been gaining prominence in recent years, largely due to the emergence of increasingly sophisticated electronics equipment, and corresponding heightened malfunction/ vulnerability factors associated with ESD.

Although for ten years now our focus has centered on the human body discharge, other forms of ESD-related failure have a commensurate destructive potential. A high percentage of integrated circuits will fail at voltage levels far below the human body's sensitivity threshold of approximately 4,000 volts — many are reluctant to recognize this "invisible threat."

The so-called "hard" failures are simpler to detect. Decreased factory yields have an immediate visibility, whereas subtle parametric degradation and temporary upsets (hiccups) do not.

The concept of latent ESD failures has been a long-standing controversy within the industry. Can a part (or assembly) fail at a later time, the result of an earlier electrostatic discharge that did not produce an immediately detectable failure? Recent research, under well-controlled conditions, has given some credence to the delay factor in ESD-related failure — thereby giving ESD greater consequence as a reliability threat.

The "charged device" presents another menace. Integrated circuits accumulate an electrostatic charge as they slide down a dual-in-line-package (DIP) tube. Such a charged device can often destroy itself if suddenly discharged after this triboelectric accumulation in material handling processes. Printed circuit boards and hybrid assemblies are susceptible to these accumulations as well. Insulator-induced charges on a conductor pose a further ESD threat.

Clearly, ESD is as much an environmental consideration as EMI. Control methods include personnel and equipment grounding, protective packaging, antistatic treatments, and awareness training. Product design needs to concentrate on developing built-in static immunity.

There is an excitement in industry's response to the ESD problem, and the momentum is building. The Annual Electrical Overstress/Electrostatic Discharge (EOS/ESD) Symposium has provided an excellent forum of information. The Fifth Annual EOS/ESD Symposium will be held in September in Las Vegas. (For information, contact Tom Speakman, General Chairman, at Western Electric, P.O. Box 241, Reading, PA 19603.)

ESD awareness was also increased substantially by the release of DOD-STD-1686 and the associated MIL-HDBK-263 in May of 1980. Even where not invoked contractually, these documents have been widely used as control guidelines. (For information, contact Commander, Naval Sea Systems Command, Attn.: Code 3112, Washington, DC 20362.)

Lastly, the newly-formed EOS/ESD Association now boasts 375 members dedicated to scientific, literary, and educational endeavors related to the design-hardening and preventive aspects of electrical overstress, with particular emphasis on ESD control standards. (For information, write to: EOS/ESD Association, P.O. Box 298, Westmoreland, NY 13490.)

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ELECTRIC FIELDS, STATIC DAMAGE, AND SHIELDING

Electrostatic Shielding

One of the most important laws in electrostatics is Gauss' Law, which states that the *net* outward (inward) electrostatic field flux density through any closed surface is equal to the *net* positive (negative) charge enclosed by that surface. The use of the word net cannot be overemphasized. Gauss' Law means that a closed surface containing equal positive and negative charges, regardless of their distribution, will have no *net* flux through it. Furthermore, the net flux is dependent only upon the net algebraic sum of positive and negative charge enclosed by the surface, once again regardless of their distribution. From Gauss' Law, the electric field E, very near the surface of a charged conductor can be given by Equation 1:

$$E = \frac{\sigma}{\epsilon_0}$$

where: σ = surface charge density
ϵ_0 = permittivity of free space (Eqn. 1)

Although the potential of a charged conductor is constant over its entire surface, the charge density is not necessarily uniform over the conductor's surface. Charge density is high at locations having a small area such as points, corners, and edges, and therefore, the electric field will be high at such locations.

One consequence of Eqn. 1 is that the electric field due to a given amount of charge can be changed by changing the area the charge occupies. In effect the charge's capacitance is changed, and the field from the charge changes inversely with the change in capacitance.

At a point in an electric field, E is the negative derivative of the potential with respect to r as given by Equation 2:

$$E = \frac{-dV}{dr}$$

(Eqn. 2)

Macroscopically, the electric field is given by Equation 3:

$$E = \frac{-\Delta V}{r}$$

(Eqn. 3)

where ΔV is the difference in voltage between two points separated by a distance r. The negative sign means that the potential decreases as the distance along r increases. The electric field is, therefore, also called a potential gradient. The most significant aspect of Equation 3 is that if ΔV is zero, E must be zero. These equations are often stated in two ways:

An electric field exists only between two points at different potentials.

An electric field does not exist between two points at the same potential.

If E is zero, no net inductive force of attraction or repulsion exists. Because inductive effects arise from electric fields, there will be no inductive effects in regions where E is zero. A region in which E remains at zero regardless of external field conditions is said to be shielded.

There are several important corollaries of Gauss' Law:

(Cor. 1) *There can be no net charge within the material of a conductor. Therefore, the induced charge or net charge of a charged conductor lies only on the conductor's surface.*

(Cor. 2) *Every point on a conductor, whether it is charged or uncharged, or in an electric field or not, is at the same potential. The surface of a conductor is therefore, an equipotential surface.*

(Cor. 3) *The electric field at any point on a conductor's surface is normal to the surface. There is no electric field within the conductor's material.*

(Cor. 4) *Charge outside a hollow conductor cannot produce an electric field inside the cavity.*

(Cor. 5) *Charge placed in the cavity of a hollow conductor will result in equal induced charge on the conductor's outer surface.*

Although these corollaries and previous equations are true under equilibrium or electrostatic conditions, they do not necessarily hold under non-equilibrium conditions; e.g. changes in charge distribution where the amount or position of charge changes suddenly, or changes in electric field conditions. Under non-equilibrium conditions in a conductor, electric fields and forces will exist until free charge in the conductor relocates itself into positions such that the fields of the charges themselves neutralize the cause of the non-equilibrium. How field-induced charge redistribution relates to device damage and shielding ability will be discussed next.

Static Damage to Electronic Devices

Static damage to electronic devices has been considered mostly due to a rapid discharge through a device from a charged conductor, typically a person. The discharge is a transient surge of large current through small, resistive regions of the device, which causes overheating and even melting of the semiconductor material. This mechanism occurs principally in bipolar devices and film resistors and will continue to cause damage unless it is prevented from happening. The passage of the discharge current through a device can be prevented by wrapping the device in an insulator such as plastic. Even if charged, the plastic could not discharge its energy through a device because plastic is a nonconductor. However,because charged insulators emanate an electric field and do not shield, the use of insulators could allow damage to devices which are not purely current sensitive. Such devices are called electric field sensitive and comprise most of the modern microelectronic and integrated circuits (ICs) in use today.

During the advancement in the 1970's of MOS integrated circuits, it was found that devices having MOS structures were very sensitive to static damage, even at levels unnoticed by people. Because such devices have enormously large input resistance (10^9 ohms and greater), they should inherently prevent any sizeable transient current. Failure analysis results indicated that the likely mechanism of failure was dielectric breakdown of the insulating oxide layer under the gate metallization. Dielectric breakdown is a field induced and not a current induced phenomenon.

Dielectric breakdown occurs in insulators when an induced internal electric field exceeds the electric field between nuclei and the electrons which bond the nuclei together. In conductors not all an atom's electrons are needed to create chemical bonds. The "left-over" electrons are free to move under the influence of an external electric field without damaging the bonds and thus disrupting the integrity of the material. In an insulator, however, all the electrons of each atom are necessary to form the bonds that hold the material together. Consequently, when the induced internal field "wins the tug of war" over the nuclei for the bonding electrons, some electrons break loose from their atoms. These initially freed electrons create an internal current, causing an avalanche effect as they move through the insulator. The material, in effect, "falls apart" in the region of the insulator where the breakdown occurs, often creating a channel through the insulator.

If a charged conductor contacts a device's lead, the conductor's charge will transfer to the conductive areas of the device chip creating very high electric fields because of the very small capacitance (e.g., 1 pF or less) of these internal areas. After breakdown is initiated,the conductor's charge will add to the induced internal current, thereby causing substantial heating of the conducting path. Often there is sufficient heat to melt some of the metallization and spew it along the surface of the breakdown channel, causing the often-referred-to "gate short" to the semiconductor substrate in a MOSFET.

The foregoing explains how physical contact of a charged conductor with a device lead can cause internal field induced breakdown and damage. However, it is not necessary that a charged body, conductor or insulator, contact a device in order to similarly cause damage. The basis for non-contact field induced damage is shown in Figure 1. In Figure 1 a potential difference exists between A and B. Assume A, a conductor or insulator, is uniformly charged positively to 5,000 volts, with B at ground.

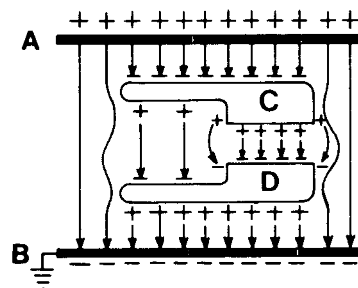


Figure 1. Two uncharged conductors, C and D in the electric field between A and B. A is a positively charged object, conductor or insulator, and B is grounded.

Since A is at 5,000 volts and B is at zero, the potential of vertical points between A and B must be some nonzero value (Eqn. 3). The potential of C and D must be between 0 and 5,000 volts, depending on their distance from A (Eqn. 3, Cor. 2). If C and D are at different vertical positions between A and B, each will be at a different potential from the other. A potential difference will exist between C and D even though each one is neither grounded nor charged. Although the potential difference between C and D is constant (Cor. 2), the electric field between them is not constant because the distance between their surfaces varies (Eqn. 3). The field will be highest in the regions of closest proximity. Also, the induced charge density will be higher at locations of smaller area, and therefore the electric field will be higher between the smaller areas of C and D (Eqn. 1). If the field is high enough, the medium between C and D can undergo dielectric breakdown.

Applying the concept of Figure 1 to a situation with a MOS device between A and B, let A be a charged insulator or a charged person's hand; B be a grounded work bench top; C be the device's gate lead and metallization; and D be the device's substrate lead, metallization, and substrate. The induced charge condition for this situation is qualitatively illustrated in Figure 2. It must be emphasized that the device's leads and chip structure are not to scale.

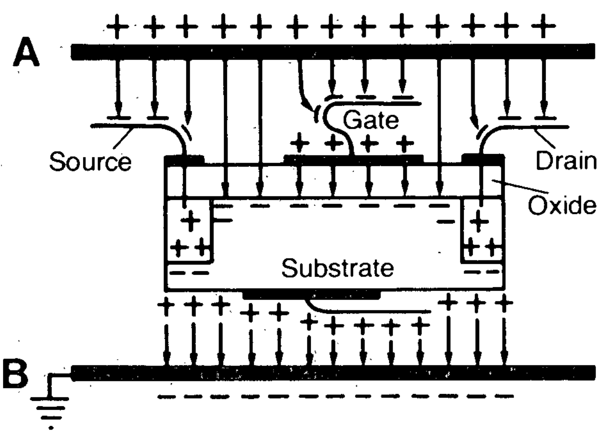


Figure 2. Induced charge redistribution on MOS device in an electric field.

There is no *net* charge on any part of the MOS device, nor is there an electric field within any lead or the substrate (Cor. 1 and 3). However, an induced electric field from the induced, high charge density on the gate metallization can exist within the oxide layer because it is an insulator and has no free charge to move and neutralize the field from the gate. If this induced field exceeds the breakdown strength of the oxide, the oxide will rupture resulting in either a self-healing breakdown [1], degradation [2], or catastrophic failure. It is not necessary that charge transfers from A to the device for this breakdown to occur. The breakdown of the oxide layer does not depend on whether the positive charge on the gate metallization is there from charging by direct contact, or from induction. The field has virtually the same effect on the oxide layer as the field due to direct charging, and thus an external electric field can induce dielectric breakdown.

The breakdown strength of pure silicon dioxide is almost 10 MV/cm, which means at least 10 million volts are needed to "punch through" one cm. Although this voltage is extremely high, less voltage is necessary if the oxide is thinner. In common MOS ICs, oxide layers are only about 1,000 angstroms thick. Ten MV/cm corresponds to 0.1 volt per angstrom so that a potential difference across the oxide of only 100 volts could cause breakdown. Many VLSICs today have oxide layers less than 500 angstroms thick so they are extremely vulnerable to the electric fields of static electricity.

This failure mechanism is not limited only to the gate oxide region of MOS devices. It can occur in any device where two conductive areas are separated by a thin insulator. One example is a discrete capacitor in an op-amp [3]. A second example is the region between two metallization runs in adjacent layers separated by an insulating layer (4). This region is sometimes called a metallization crossover, and it is merely a small capacitor. Such crossovers exist in both bipolar and MOS ICs. A third example is devices which have very narrow conductive line spacings in the same chip layer. A line spacing of one micron in silicon dioxide would "arc over" at about 1,000 volts, which, although seemingly large, is so small for static voltages that a person can't even sense it. As device density increases, layer thicknesses and line widths will decrease to a point where induced potential differences of only tens of volts to a few hundred volts will cause breakdown failure. This failure mechanism can occur in both bipolar and MOS ICs because the failure can occur in the chip's structure instead of only the semiconductor element. Thus input protection schemes will not provide adequate protection because they are typically designed to protect circuit elements but not the IC structure. Today's and future microelectronic devices, therefore, need shielding to prevent static damage.

Static Shielding Evaluation

Devices sensitive to electric fields and dielectric breakdown can be shielded if they are surrounded by a closed, conductive material (Cor. 4), provided the magnitude and duration of the electric field in the material's interior during induced charge redistribution does not exceed the sensitivity of the device. The charge in a material need be only mobile enough to move faster than the charge or changing electric fields in the environment in order for the material to be shielding. When charge in a material moves slower than field producing external charge, the response of the device enclosed by that material to the penetrating field will determine whether that device is damaged before charge redistribution is complete. Thus, the dynamic response of the shielding container to changing, external fields must be sufficient to ensure that any penetrating field will not exceed the sensitivity of an enclosed device.

There are several methods for evaluating the static shielding ability of electronic component carriers. However, some methods have significant limitations which must be considered when interpreting their results. One convenient method is to place a small, electrostatic field meter entirely in the container and rapidly unroll some tape outside the container in front of the meter's sensor. A deflection of the meter indicates an electric field within the container. This method is principally qualitative but is semiquantitavie in that a large meter deflection can mean a large penetrating field. More important, however, is the response of the container to actual contact by a static charged object because the container must be contacted sometime in order to move it. At contact, fields in the container will be greatest, from Eqn. 3, since r becomes small while ΔV remains constant. Damage to the container's contents are most likely to occur at contact so that a more sensitive evaluation of the container's shielding ability is to have the meter close to the container's surface and actually touch the container's outside in front of the meter with the tape or, even better, with a charged finger.

Antistatic bags and tote boxes can provide actual observation of the time dependent charge redistribution mechanism. If tape is unrolled in front of an antistatic bag or tote box with a meter in it as just described and then held steady, the meter usually deflects positively and then returns to zero in a few seconds because equilibrium has been reached. That negative charge on the bag's surface has been drawn toward the positively charged tape is shown by quickly removing the tape. The meter will deflect negatively and then return to zero. Thus, close encounters of charged objects with antistatic containers can produce a significant exposure by both polarities of an electric field to the contents of the container. A shortcoming of this method is that although a deflection of the meter indicates the presence of an electric field, no deflection does not mean there was no penetrating field. If the penetrating field was below the meter's sensitivity and inertial response, its occurence would not be indicated. Since dielectric breakdown in devices occurs in nanosecond times, the inadequacy of this method is apparent. A meaningful test method must be both sensitive and responsive.

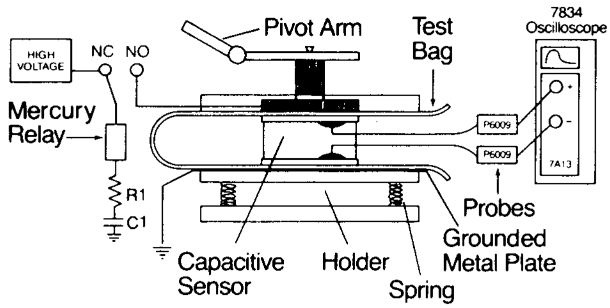
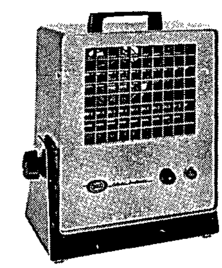


Figure 3. Shielding/discharge test apparatus.

A test method that is graphically quantitative and functional has been reported [4] and is illustrated in Figure 3. This method, using a high speed storage oscilloscope and a capacitive sensor, detects the transient potential difference due to a penetrating electric field inside a bag or tote box when an electronically simulated discharge occurs at the container's outside surface. The method evaluates well the shielding ability of various, commonly used containers. It does have some experimental considerations, however. First, the probes must be balanced to produce no differential signal from a common input signal. Secondly, the common mode rejection (CMR) of the differential amplifier will limit the shortness of pulses that can be meaningfully observed. With a Tektronix 7A13 differential amplifier, the CMR ratio is at least 10,000:1 at 1 MHz. Materials which are conductive enough to permit pulses so short that their duration is beyond a MHz bandwidth capability are sufficiently conductive to provide static shielding. Accurate measurements, therefore, require the determination of a reference pulse from a common input pulse with characteristics similar to the pulse to be measured. Pulses observed from this method correlate highly with material resistivity and static protection to devices [4].

Since the previous method shows that shielding is a function of the resistivity of the container's material, resistivity and resistance measurements can be used for shielding evaluation. The previous method showed that a high level of static shielding is provided by surface-only conductive materials with a surface resistivity less than 10 ohms/square and by volume conductive materials with a volume resistivity less than 10 ohm-cms per mil thickness. Surface resistivity measurements can be made according to ASTM D-257, and volume resistivity can be measured according to ASTM D-991. The recommended test apparatus for ASTM D-991 can also be used for surface resistivity for reasonably conductive materials but not antistatic materials. Resistivity measurements are usually destructive tests because sample material must be cut from the container. They typically require several pieces of equipment and are, therefore, not convenient for *in situ* evaluation.

Resistance measurements are more convenient than resistivity measurements and can be meaningful if interpreted properly. As discussed by Norman [5, Chap. 2], contact effects can be significant when measuring conductive plastics so that high voltage (≥ 100 volts) ohmmeters might be necessary. A shielding tote box of carbon-loaded material with a volume resistivity less than 100 ohm-cm according to ASTM D-991 shows an end-to-end resistance of about 100 kilohms at 250 volts using alligator clip leads. The readings of a given ohmmeter and probes must be correlated with the material's resistivity measured according to an accurate method in order for this method to be meaningful.



A method utilizing a changing electric field can be used to evaluate the static shielding ability of materials provided that the rate of change in the electric field is similar to that produced in the work environment by charged people and insulators as they move in relation to sensitive components. An apparatus useful for such a method was shown in ASTM F 365-73T. This ASTM method was only tentative and apparently was not adopted. It is, however, a good method in principle. The apparatus of this method consists of an isolated parallel plate capacitor placed inside a horizontally split, hollow metal cylinder such that each capacitor plate is in each half of the cylinder, equidistant from the plane of the opening. This apparatus is shown in Figure 4.

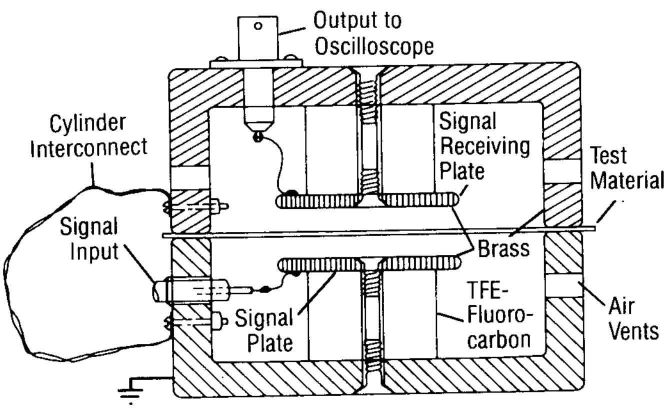


Figure 4. Illustration of ASTM F 365-73T shielding test apparatus.

A sheet of the material to be tested is placed between the halves of the cylinder. Both halves are grounded; a sine wave is then applied to one (signal) plate of the capacitor, and an oscilloscope is attached to the other (receiver) plate of the capacitor. The principle of the method is based on Eqn. 3. Charge placed on the signal plate emanates a field which will raise the potential of the receiver plate to some value above ground. If the material placed between these plates is sufficiently conductive, charge can move from the grounded metal cylinder across the material fast enough to shield the receiver plate. A limitation of this method is that the conductive part of the material must make electrical contact with the cylinder's edges.

Because the voltage of the receiver plate is usually only several volts even when the signal plate is a few hundred volts, a signal frequency must be used which reasonably simulates the rate of change of the electric fields in a work area as static charged objects move near or contact a container. For example, consider a situation in which a charged person picks up a bag with components or a PC board in it. Let the person be charged to 5,000 volts, and the rate of approach of his/her hand be 1 foot/sec., or 30 cm/sec. Assuming the hand behaves as a parallel plate capacitor, the rate of change of the electric field between the hand and table top, dE/dt, can be determined from Eqn. 3. The rate of change of the field near the bag's surface (1 cm from the table top) would be 150 KV/cm-sec. For an induced 3 volt amplitude on the receiver plate, the rate of field change corresponding to the moving hand would be produced at a frequency of about 32 KHz.

The ratio of the observed voltage with no material in place to the voltage with the material is a measure of the shielding ability of the material. The shielding ability, S, can be expressed in decibels (dB) according to Equation 4:

$$S = 20 \log (V_o/V_m) \text{ dB} \qquad \text{(Eqn. 4)}$$

where: V_m = the voltage amplitude on the oscilloscope with the material in place.
V_o = the voltage amplitude with no material

This method shows different shielding abilities for antistatic, carbon loaded, and transparent metal vapor coated packaging materials, as illustrated in Figures 5, 6, and 7, respectively. Antistatic plastic provides little shielding because its response is too slow due to its high surface resistivity. Although antistatic plastic can respond within several seconds, its response time is orders of magnitude slower than the response of oxide layers to overstress by electric fields. Carbon loaded plastic is not as good a shield as the metal coated plastic, but it is far more shielding than antistatic plastic. The shielding ability of the metal vapor coated material is so high that the signal at the receiver plate is below the system noise level of 0.1 millivolts. The shielding ability of these materials determined by this method corresponds to the pulses observed in bags of these materials from the previous oscilliscope method. [4].

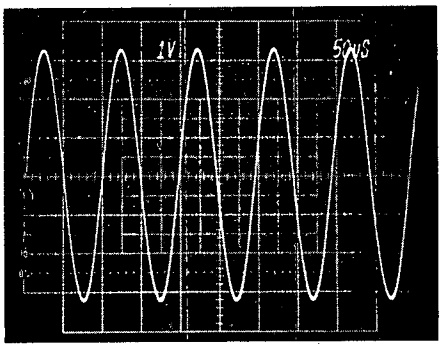


Figure 5. Signal (Vm) with antistatic polyethylene. Vm = 6.5 volts; shielding, S = 0 dB. Material's surface resistivity = 10^{12} ohms/sq.

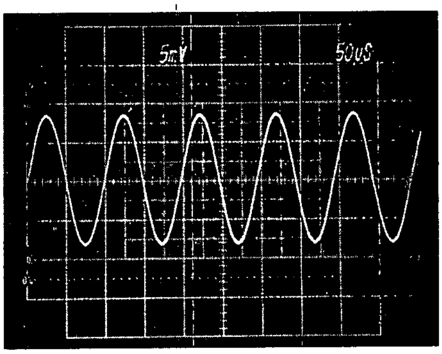


Figure 6. Signal (Vm) with carbon loaded plastic. Vm = 17 mV; shielding, S = 51.6 dB. Material's volume resistivity = 175 ohm-cms.

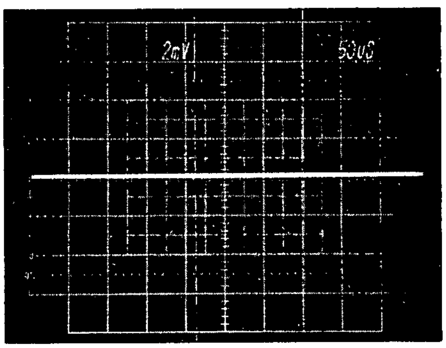


Figure 7. Signal (Vm) with metal vapor coated film. Vm <0.1mV (noise level); shielding, S >96 dB. Material's surface resistivity = 100 ohms/sq.

Static Protection in Practice

Devices and PC boards are shielded by complete enclosure in a conductive bag, tote box, or shipping tube. From Corollary 4, the components would not be subjected to an electric field. However, the author has seen handling methods which used conductive materials improperly and therefore had possibly damaging short-comings. One approach to protect chips in plastic "waffle packs" is to place a thin sheet of metal between the chips and the pack's lid. It was thought that the metal would shield the chips if any charge was on the lid due to a charged person touching it or triboelectric charging of the lid itself. The fallacy is that an isolated sheet of metal does not shield. It simply re-emanates the field. There can be some "pseudo-shielding" in this approach, although it is highly dependent upon how much static charge the area of the lid is exposed to. The best circumstance for shielding is a small area of charge such as might be caused by contact of the non conductive lid with a single finger of a charged person as shown in Figure 8.

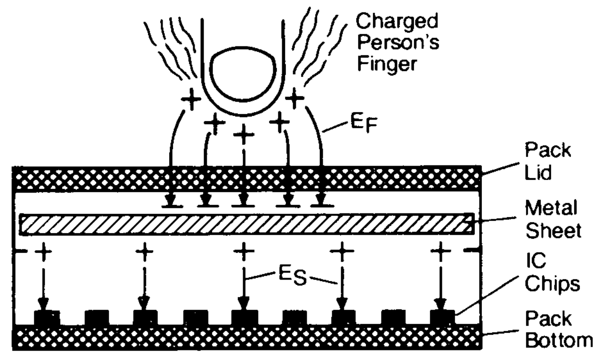


Figure 8. Different electric fields due to different charge densities.

The electric field from the charged finger, E_F, can be high because the charge density at the finger tip is large (Eqn. 1). The positive charges on the finger tip induce an equal number of negative charges on the metal sheet's top surface and create a field E_F between them. In turn, an equal number of positive charges are induced on the bottom surface of the metal sheet. These induced positive charges will spread out across the sheet's bottom surface creating a new field E_S, which will be smaller than E_F, because the charge density on the sheet's bottom is smaller than on the sheet's top surface (Eqn.1). Alternatively, the capacitance of the induced positive charge can be thought of as larger than the capacitance of the induced negative charge. It is important to realize that although the charge on the finger created the negative and positive charges on the sheet by induction, the charges on the sheet's bottom behave independently of the other charges because no electric field "connects" the bottom charges to the other charges through the metallic sheet (Cor, 3). In a worst case where the pack's lid is entirely covered by a charged hand or sheet of charged insulator, the metal sheet provides little benefit. This method has similarly been used in shipping where sheets of conductive plastic are laid over components or subassemblies in a box, and static generating, loose-fill foam packing is poured on top. It is a risky approach that can be avoided by putting the pack in a static shielding container.

A second handling oversight involves the use of conductive tote boxes without lids. Although the box's contents are shielded from the side and bottom, the contents are not shielded from fields from above. Often plastic job sheet holders are placed on top of PC boards in the tote box. If the holders are charged, they can induce damage to field sensitive components on the boards. The solder runs on the board can transmit induced charge to devices which aren't near the plastic holder. The possibility for such static damage can be eliminated by using a conductive lid that electrically contacts the tote box. The conductive lid provides a secondary protective function in a situation where a person wants to remove the box's contents. If the person is charged, and there is no lid, a discharge through the components could occur upon contacting them. If, however, the box is grounded and has a lid, a charged person would discharge to ground in removing the lid. Even if the box was not grounded, the person and tote box would come to the same potential so that the components could be safely removed. However, setting that component down safely might present a problem. This latter problem would be avoided by using a properly conductive, grounded table top. The possibility of incomplete shielding due to the openings of bags and shipping tubes can also be minimized. The end of a bag can be folded over, and conductive plugs can be inserted in the ends of a shipping tube. However, the openings of bags and tubes are far less a problem than open tote boxes.

Another handling oversight with conductive tote boxes can arise if the tote box becomes charged and is placed on a table top which does not acutally drain the charge from the tote box. In such a case [6] and although the box might be a perfect shield, damage to the box's components can occur if they are touched by a person. Though there is no electric field in the conductive box even if it has no lid, the inside and outside of the box are at the same potential (Cor. 2 and 3). Contact of the parts by a person places the parts between the potential difference of the box and the person, creating the possibility for damage. These possibilities for damage do not mean the use of conductive tote boxes is a poor method of safe handling. To the contrary, their use is a very safe method, but the proper use of the product in conjunction with other properly designed static control products is necessary for maximum static damage prevention.

A common static protection method is lead shorting or shunting. However, many methods of shunting are not absolutely safe. A popular method of shunting DIPs is to insert them in conductive foam. In such a condition the DIPs are not immune to static damage, although they are substantially safer than without the foam. Static charge on the lid of a DIP can cause an arc between the lid's inside surface and the chip's top surface similarly as in the waffle pack. Such a mechanism has already been reported [7, 8]. It is not that conductive foam is inadequately conductive because the same result would happen even if the DIP's leads were shunted with soldered wire. The possibility for damage arises because the DIP's lid is a non-shielding insulator. Lead shorting can be very effective with "metal can" devices where the can is connected to a lead, so that the entire device will be at the same potential. Conductive foam's principal function is to provide a safe means to handle or carry devices rather than touching the devices directly. The foam also protects the device's leads and provides cushioning.

This argument applies similarly to PC boards with edge shunts. A charged object contacting an edge-shunted PC board where the devices are exposed, can damage the devices in the area of contact and possibly others via the solder runs. The user must realize that some static control approaches have some limitations which dictate proper use for maximum benefit. Since the shortcomings of some of these approaches arise from lack of complete shielding, the most reliable approach is the proper use of shielding containers (bags, tote boxes, and tubes) for handling and transporting.

SUMMARY

Modern microeletronic devices can be damaged by the electric fields from charged conductors or insulators without their physically contacting the devices. A device is best shielded by containers which provide a continuously conductive layer surrounding the device. The shielding ability of containers can be evaluated by several methods. The most accurate methods usually require sophisticated equipment such as an oscilloscope. Users of such containers can evaluate them with common instruments such as an electrostatic field meter or ohmmeter provided their poper use and limitations are realized. The evaluation of available packaging materials by instrumental methods and device testing has shown that highly conductive materials are necessary to shield devices against commonly encountered static fields. However, effective static protection requires not only a properly designed product, but also the proper use of the product.

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