The Electrostatic Discharge (ESD) Packaging Dilemma

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Improper packaging of ESD sensitive (ESDS) components, assemblies and equipment resulting in hard and soft failures has cost both manufacturers and users millions, possibly even billions of dollars. This is because most suppliers and end users do not understand how (ESDS) items fail. When Unger, etal. [1] demonstrated that devices could fail from sliding in a plastic shipping tube, then dropping with pins hitting a grounded metal table, some were in disbelief. How could this happen? This was the Charged Device Model (CDM) in action. What made the CDM so devastating was the speed of the discharge (sub-nanoseconds) with a peak current of amperes. As a matter of fact, when the component's pins touched the metal table, only the charge on the metal leads was discharged. The trapped charged on the insulating parts of the package remained and could re-induce the charge to the metal parts of the component. So, if the component was not damaged the first time it's pins touched the metal table it could still be damaged when picked up and dropped a second time even by a person holding the plastic shipping tube wearing a grounded wrist strap.

What are the ESD Damage Models?

In order to understand the importance of packaging to protect an item from ESD, manufacturers and users need to understand the different ESD models. For years many thought that all ESD damage came from charged persons discharging to or inducing charge in ESDS items. This is known as the Human Body Model (HBM). Unfortunately, even with the knowledge of how to control it, the HBM is still a major cause of ESD failures. Today, machines do much of the handling of ESDS items and their role in causing ESD failures is far more complicated than the HBM and needs to be understood. Most testing of complicated digital signal processors is done with automatic test handlers. Every time an item slides, contacts and separates from a surface it can become charged. This is called triboelectric charging and its theory is not yet well understood, in particular for organic materials such as plastic packaging [2]. In the past there were serious problems with components sliding on insulating surfaces in an automatic test handler, becoming charged and then being discharged in the test head by the CDM. Therefore, contact electrification or tribocharging must also be considered when choosing packaging.

Every time a component or assembly is placed-in or removed from a package, whether slid into a static shielding bag, placed in a plastic clamshell or a corrugated container it can become charged. If already charged, it can also discharge. It once was thought that a conductive container was the final answer to ESD control. It would be the perfect shield from direct ESD events and the ultimate ESD protector. At this time, no one understood that if this conductive container resided on an insulated surface and became charged, the <u>first</u> pins of a neutral item could have this charge induced onto them possibly causing CDM ESD damage. Conversely, if a charged item was placed into a grounded conductive container, again CDM damage could occur. In addition, an assembly or circuit card could be triboelectrically or inductively charged when removed from an isolated conductive container and then cause a CDM discharge when the card was inserted into a grounded equipment rack.

A package was needed that was not conductive or insulative. The answer was a partially resistive package that slowed the charging and discharging process. Consequently, this led to the development of the static dissipative package.

Static dissipative material is currently defined as material having a surface resistance (measured using ESD Association [3, 4] ESD ANSI S11.11 of 1×10^4 Ohms to 1×10^{11} Ohms) or a volume resistance (measured using ESD ANSI S11.12 of 1×10^4 Ohms to 1×10^{11} Ohms. Packaging materials with surface and/or volume properties in this range were then thought to afford protection from all ESD events. Unfortunately again, this was not always the case except when the package and its contents could be kept at an equipotential level at all times. In the case of a direct discharge to a package where the contents and package are in intimate contact the static dissipative container may not protect at all. However, it has been shown that sufficient air gaps between the surface of the package contents and its outside walls will attenuate a direct ESD discharge [5].

A static dissipative container such as a plastic bag incorporating a conductive layer in the bag can attenuate a direct ESD discharge. The static shielding plastic bag has become a popular way to package assemblies and components. Since it has limited mechanical protection it must be transported in a ridged container such as a corrugated box. Paperboard and plastic container manufacturers have also incorporated conductive layers in their containers that are effective shields. Today, there are many new ways to make plastics static dissipative and even conductive. These include the incorporation of powdered metals, mixed-metal oxides, polymers and permanent coatings [6].

What Do Users Require in a ESD Protective Package?

This was a question asked by the Telephone Companies and in early 1992 the Bell Operating Companies - Bellcore (now Telcordia Technologies) ESD Team published an ESD packaging wish list [7]. This list contained thirteen features or characteristics thought necessary to protect circuit-packs, (also called plug-ins or circuit card assemblies) from ESD degradation, mechanical damage and contamination. The first of these was the totally enclosed container. For years many telephone circuit packs were shipped in open-ended sleeves with extra open slots to scan bar codes. They continue to be used today by some telecommunications companies who are willing to take the risk of having a direct ESD event occur through these openings. Typically, for this type of container the outside surface is static dissipative and the inside surface is conductive. All static shielding packaging using a conductive layer should have static dissipative inner and outer surfaces. With the very expensive assemblies of today, it makes very little sense not to incorporate the most effective ESD packaging.

Another totally enclosed container is the plastic clamshell. For years the almost clear antistat treated plastic clamshell has been used to ship electronic parts and assemblies. Because it is usually thermoformed both its optical and resistive properties are degraded from the starting plastic sheet. Typically, the plastic is coated with a topical antistat. This coating can vary greatly with relative humidity. At low humidities the coated plastic may loose all its ESD protective properties. Loading plastic with carbon is a relatively inexpensive way to add ESD protection, but when plastic is carbon loaded it becomes opaque, so the package would have to be opened to verify its contents. UNSEALED packages have an unknown history, therefore, packages should remain sealed until its contents are ready to be removed.

The industry generally wants packaging to retain its ESD protective properties over a specified period of time in order for it to be reusable. After the useful life period ends, the package should be recyclable. Users want the packaging to incorporate a way of reading the assembly, circuit pack or plug-in card bar code without having to open the container. Users do not want to pay for a static-shielding container if it is not necessary. Users do not want to have over-packs for shipping unless absolutely necessary. Obviously, over-packs will be required for shipping plastic bags and plastic clamshells. All packaging must have an ESD label and a seal. Users also want containers to be stackable. So what types of packaging fit these requirements?

It would seem that the corrugated container with a removable window fits most requirements. It can also have a conductive layer in the corrugated for shielding if required. Can the other packaging schemes meet the user criteria? The plastic bag and clamshell will always need an over-pack and a paper label adhered to the bag will make it unrecyclable. Bar codes are often difficult to read through a thermoformed plastic clamshell and impossible to read through a static shielding bag. Bags are often not reusable because the bag is punctured by the sharp cut-off component leads protruding from the assembly solder side. The clamshell is reusable assuming that its static dissipative properties can be maintained. Clamshells can be designed to be stackable, but bags are not. A plastic bag can be designed to be a moisture barrier, but corrugated packaging always contains some moisture.

How Can ESD Protective Packaging be Specified?

The ESD Association has issued ANSI/ESD S20.20, ESD Standard for the Development of an Electrostatic Discharge Program for the {Protection of Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices). This document has been adopted by many manufacturers and users, including the military and government. In addition, the ESD Association is in the process of updating EIA-541-1988, Packaging Material Standards for ESD Sensitive Items to ESD S-541 [8]. This revised document is designed to complement ANSI/ESD S20.20 in providing packaging guidelines for both manufacturers and users. The document is now been issued for industry review and can be obtained from ESD Association [4].

In summary, in order to specify the packaging needed for components, assemblies and systems, an understanding of the ESD damage models, the ESD sensitivity of the items and the trade-offs associated with various types of packaging are required. The plastic clamshell may be satisfactory for those applications where items are sufficiently hardened to withstand indirect ESD events and contact electrification. For most ESDS items a static dissipative corrugated container should afford enough protection. For highly sensitive ESDS items a static-shielding bag plus a rigid box may be required.

Every year there are significant materials and factory issue papers published in the EOS/ESD Symposium Proceedings. An index of these papers can be found on the Web Site: www.netlabs.net/hp/echase.

References

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