G1 Basics of Static Electricity: Sources, Damage, Prevention

CONTENTS

Background

Almost everyone is aware of the effects of static electricity in general terms. If you comb dry hair with a plastic comb, the hair will stand up. Scuffing your shoes on carpet and touching a person or door knob produces a spark and brief shock. Drying synthetic clothing in a dryer will often produce "static cling." These happenings are common place and most are unaware that similar events can damage or destroy modern electronic components.

Static and its companion ESD (electrostatic discharge), damage electronic circuits every day. While an individual IC may not appear to cost a lot, the costs incurred when a system that uses that damaged IC fails, can be extraordinary. Consider the costs if a mainframe computer fails due to a damaged IC. The user of the computer cannot do business. The computer maker or service organization must rush to diagnose and repair the system. Worse, if care is not taken while testing circuit boards and transporting new circuit boards, even more damage could be done while trying to fix the problem.

Whether the effected system is a telephone, vending machine, copier, or an airplane, direct financial costs associated with failures due to static damage demand that we try to understand the basics of static and how to reduce its influence.

HISTORY

The phenomenon of static electricity and its effects have been known by man since the time of the ancient Greeks, but did not receive much serious attention until the 17th and 18th centuries. Just before and during the industrial revolution (steam engine times) static electricity was described, tested and measured. Many early scientists, including Voltaire, experimented with accumulating charge, storing charge and igniting things with sparks. When sustained current became available from Voltaire's pile (a battery), interest and study of static declined.

Static was generally viewed as nuance. With mechanization came high speed machines and belts generating large amounts of static electricity. Static sparks were blamed for fires in paper and cotton mills, and explosions in mines and munitions factories. Shocks delivered to workers could cause injury.

ElectroStatic Discharge

Later, static would be put to productive use in industries of photocopying, painting and cleaning. With the 1950's dawned the age of plastics. Plastics generally carry a static charge that attracts dirt, and caused new manufacturing difficulties.

The 1960's brought the wide spread use of the transistor and the first major need, in electronics, for awareness and precautions regarding static electricity. While the early devices were relatively large and robust, miniaturization in military and space applications created sensitive devices. During this time the military created specifications for handling and packaging static sensitive devices.

The 1970's saw the Integrated Circuit (IC), where hundreds or thousands of transistors were placed on a single device. As device size was substantially reduced, sensitivity was increased. In 1979, the EOS/ESD Association was founded to explore static issues and provide education.

Static Control Components developed this Technical Bulletin to assist users with understanding, acquiring, and implementing static control measures. Bulletin G1 summarizes the basic science of ESD, device damage, and damage prevention. Further technical support can be obtained from other Tech Bulletins, Product Data Sheets, and Static Control Components' Technical Staff.

The 1980's introduced still smaller devices and new processing technologies. Thousands of gates were placed on a single chip. Electronic control systems proliferated through consumer goods and industry. Computers became standard to business applications and found access to the home.

Today, hundreds of thousands of transistors may be placed in a single IC and multiple IC's may be placed into one super-dense module. The future will bring even smaller circuit sizes, creating devices that are even more susceptible to static and ESD.

BASICS

Static electricity is electrical charge at rest. We can compare static or unmoving charge with dynamic or moving charge as found in direct current (DC) flowing through wires from a battery.

Charge

Atoms have protons, electrons, and neutrons. Protons have a positive charge, electrons a negative charge, and neutrons no charge. When an atom has the same number of electrons and protons, the atom has no net charge. This is because the positive and negative charges balance each other. If an atom gains an electron, it gains negative charge. If an atom loses an electron, it becomes positively charged. (See Figure 1.)

We can summarize by saying that positive and negative charges are due to a lack or overabundance of electrons orbiting the nucleus of an atom.

Fields

Charges on objects can affect other charges over a distance. We call this force a field.
Visualize a field as a group of lines reaching out in all directions looking for a charge that is opposite to grasp. Remember that like charges repel each other and opposite charges attract each other. (See Figure 2.) This is a result of the electric field acting on an object. All charged objects have a field around them.

Example: Combing hair with a plastic comb. Both the hair and the comb become charged. It is possible to move the hair by bringing the comb close to the hair.

HOW OBJECTS BECOME CHARGED

Triboelectrification

Most static electricity is generated by Tribocharging. Tribocharging occurs when two materials contact each other and are then separated. Charges (electrons) are exchanged by the materials, leaving one material with a positive charge and the other with a negative charge. (See Figure 3). Since an object has many billions of electrons, charge on objects grow to significant amounts. This is the most common way static charge is accumulated.

Example: Walking is one of the biggest sources of tribocharging. Shoe soles contact and then separate from the floor or carpet effectively leaving both person and floor charged. Conveyer belts and other moving machinery are also sources of tribocharging.

Polarization

Polarization occurs when the charges on an object are redistributed from a mixed state to a segregated state, where all positive charges are in one area and all negative charges are in a different area. The object must be a conductor and must be ungrounded.

Example: This process has several steps (Figure 4). First, an ungrounded,conductive material (a), (an IC for example) is moved into the field of a charged object(Styrofoam cup) (b). This polarizes the charges on the IC . While still in the field, the IC contacts

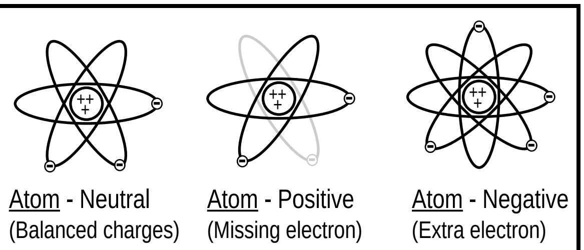


Figure 1. Charged

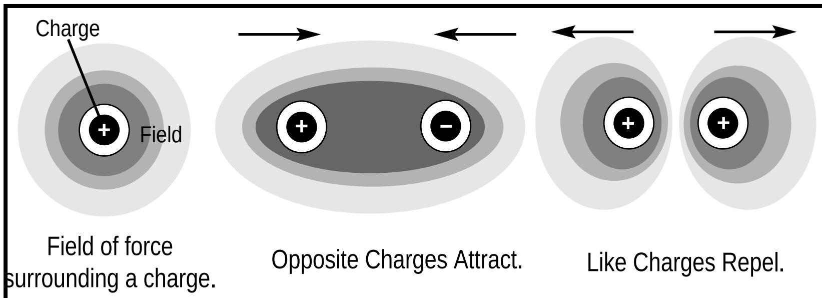


Figure 2. Fields

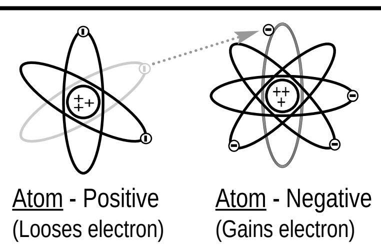


Figure 3. Tribocharging- Charge transfer

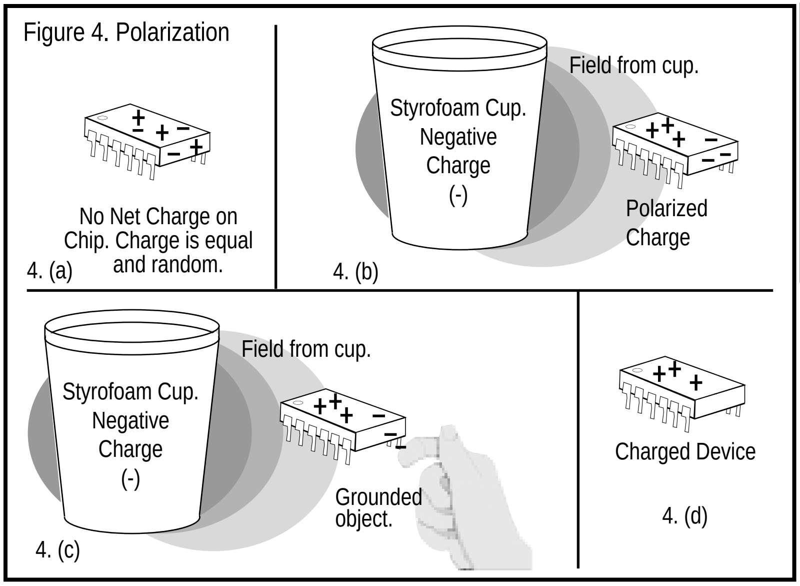


Figure 4. Polarization

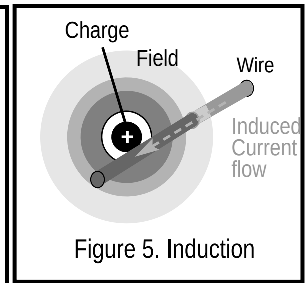


Figure 5. Induction

ground (a person with a wrist strap) or an object with different potential (c). The polarized charge transfers to ground . The IC is left with an imbalance of charge. (d)

Some refer to the process of "*polarization*" as "*induction*." While incorrect, the terms are less important than the ideas.

Induction

Induction is the process by which a charge's field establishes a charge in a nearby conductive object without physical contact. When a conductor cuts across a field at a right angle, a current is generated in the conductor (Figure 5). Induction is how generators turn mechanical motion into electricity.

Conduction

Conduction is the transfer of charge through direct contact. Conduction occurs when a charged object directly contacts an object with a different charge. There must be a conductive path between the objects.

Material Properties

Materials for static control purposes reside in one of three classes: Conductive, Dissipative, and Insulative. These material properties govern what happens to charge after the material is charged.

Conductive Materials

Conductive materials allow charge (electrons) to move freely across their surface or through their volume. Charge placed in one spot on a conductive object will flow around the object so that all parts of the object share the same charge. If a charged conductor is grounded, charges will recombine (move to ground) until the object has no charge. See Figure 6a. Conductive materials have a low resistance to current flow.

Dissipative Materials

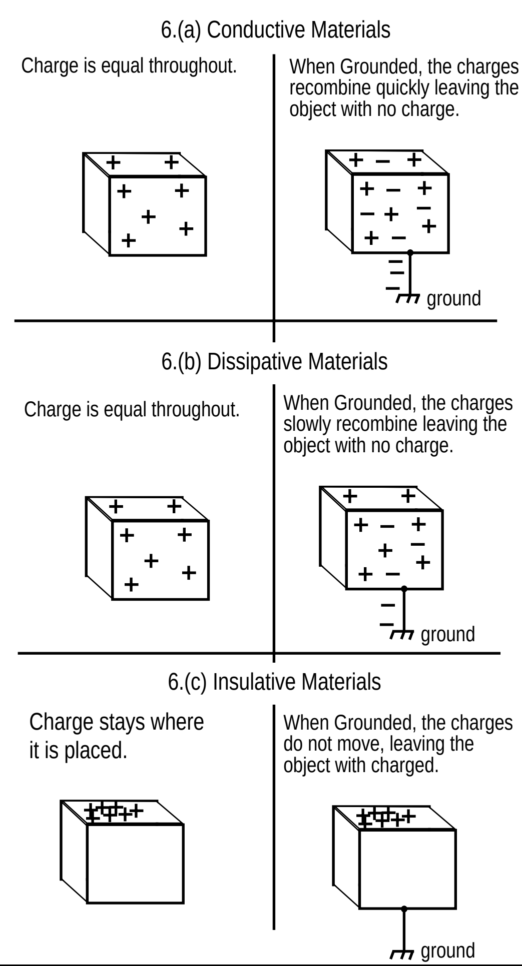
Dissipative Materials allow charge (electrons) to move more slowly across their surface or through their volume. Charge placed in one spot on a dissipative object will flow around the object so that all parts of the object share the same charge.

If a charged dissipative material is grounded, charges will recombine at a slower rate until the object has no charge. See Figure 6b. Dissipative materials have resistance to current flow that is greater than conductors but less than insulators.

Insulative Materials

Insulative Materials do not allow charge (electrons) to move across their surface or through their volume. Charge placed in one spot on an insulative object will stay in that location. If a charged insulator is grounded, charges will not move to ground. See Figure 6c. Insulators can have both negatively and positively charged areas on the same object. Because

Figure 6. Material Properties



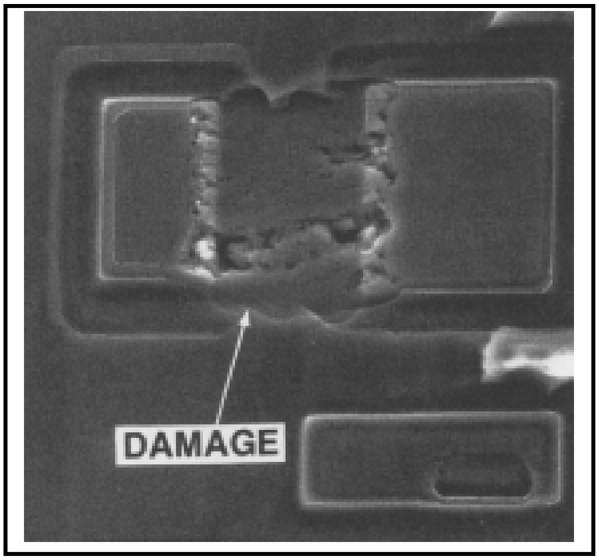


Figure 7. Damage from ESD

insulators do not allow charge (electrons) movement, they can accumulate massive amounts of charge. Insulative materials have a very high resistance to current flow.

Static (charge) Damages Electronic Devices

Electronic devices are damaged by static charge in two primary ways, direct discharge and field induced damage.

Discharge

When two objects with different charges (numbers of electrons) are brought together, the charges move between the objects until both objects have the same charge. We say that the objects have discharged.

The small amount of energy produced by an electrostatic discharge (ESD) can destroy the intricate pathways and gates inside an integrated circuit (IC). See Figure 7.

To feel the ESD 'shock' when 'sparking' to a door knob after tribocharging, requires more than 3500 volts. It takes only a few hundred volts to damage many ICs'.

Fields

Previously we discussed how fields from charged objects can charge other objects. IC damage from fields occurs from either current induced into the circuit or from discharge occurring from a charged object after polarization.

How a Damaged Device Behaves

Damaged devices are placed into two categories: Catastrophic Failure, and Latent Damage.

Catastrophic Failures are relative easy to find because the damage is so severe that the device does not function. Latent Damage is much more difficult to detect because the device will still work at some reduced level. The "Walking Wounded" device may pass final card tests only to, fail in the field under long term operating stresses.

More Science? *(Not now, Thanks)*

At this point we could discuss potential, capacitance, circuit models of ESD events, and types of semiconductor failures. However that would require more space and science than allowed. For the interested reader I suggest the ESD Association's Handbook, or for the more technically inclined, papers by W.D. Greason "ESD: A charge driven phenomenon" EOS/ESD Symposium Proceeding 1991, J.R. Huntsman "Triboelectric Charge" EOS/ESD Symposium 1984, Appendix A., and MIL-HDBK-263.

Which Electronic Devices Need Protecting

The short answer is "protect everything until the part is inside its final static tested enclosure."

To be more specific, the card, module, or assembly should be protected so that the most sensitive part on the card is safeguarded. To avoid applying maximum static-safe handling techniques to a card, you must determine the sensitivity of each component on the card, and design custom protective schemes for each card. This is usually cost prohibitive and virtually impossible to implement in a production environment.

Specific Device Sensitivity
Please note that the susceptibility of IC chips changes when place on a board. Many ASIC's have not been tested for sensitivity. Also this data is from simulations that may not always mirror reality.

MIL-HDBK-263 classifies devices as:
CLASS 1 Susceptible to ESD from 0 to 1999 volts.
Example: Discrete MOSFET, SAW, JFET, CCD

CLASS 2, 2000 to 3999 volts.
Example: OP AMPS, ICS, VHSIC, MOSFETS,

CLASS 3, 4000 to 15999 volts.
All microcircuits not in 1 or 2, SCR.

"*ESD Susceptibility of Electronic Devices*", better known as the VZAP, is a listing of voltage sensitivities for IC chips. Contact Reliability Analysis Center, Rome Air Development Center, Griffiss Air Force Base, NY 13441 for more information.

Protecting Electronic Devices

There are hosts of products, materials, and strategies for protection and static elimination. The would-be user can be easily overwhelmed by complexities of static control and the sometimes conflicting advice of product sales associates. As you wade through the sales pitches and product performance claims, stay focused on the goal of controlling static.

First, most static control strategies can be reduced to simple terms.

a. If a material is conductive, then ground it.
b. If a material is insulative, remove it from the production area or make it conductive and ground it.
c. If it cannot be made conductive or remove it, then shield it.
d. Control the charge on people because people are the most common source of charge and ESD.

The general idea is to remove sources of static. Insulative materials, when rubbed, accumulate static charge. Some insulators have a charge by their nature. Conductive materials can hold a charge only when they are not grounded. So by grounding them we remove any charge. When a source of static cannot be removed, a machine for example, a shield of conductive material (usually metal) can protect an area or products from the static charge. Shields work best when grounded.

Secondly, understand that all static control products function in one of three ways.

1. Reduce charge accumulation. ('generation')
2. Provide a path for the static charge to move away from the electronics. (Grounding)
3. Shield the electronics from static fields or charges.

Protective Products

There are many products to help control static. We will examine some of them and how they work.

Wrist Straps
People are the greatest source of static charge. Always moving and moving things around us, we cause more ESD and problems than anything else. Since removing people from manufacturing is not practical and since people are conductive, we can be grounded.

A wrist strap connects a person to ground. Wrist bands are commonly made of elastic nylon fabric that has conductive fibers on the inside surface. These conductive fibers connect the skin with a coiled cord. The coil cord snaps to the wrist band and plugs into a ground point. A 1 megohm (1,000,000) resistor is included in the cord to prevent accidental shock to the wearer. The wrist band can also be made of metal, similar to a watch band, or hook and loop (Velcro) material.

Features include size adjustment, color, cord length, snaps, clips and buckles. The key items to look for are a comfortable fit on employees, a good strain relief at the cord's bending points, and that the wrist strap and cord set meets EOS/ESD Standard 1. (See SCC Bulletins W1, W2, and W3 for more information)

Worksurfaces
The surface that sensitive electronics are placed on should dissipate charge. Soft mats and Hard laminates are the primary worksurface categories. The choice is based on a how the surface is used and the user's preferences. Soft mats are flexible, easy to install, provide a variety of features, and can be cut to size or precut. Hard laminates provide durability and are usually higher priced. Hard mats are precut to size and can be placed on any bench to provide a static work area.

There are many types, colors, sizes and costs associated with worksurfaces. Worksurfaces should meet the EOS/ESD Standard 4.1. Sometimes users install an expensive hard work surface only to purchase an inexpensive material to place over it for protection from cuts and abuse. Consider what work will be performed on the worksurface before buying. (See SCC Bulletins W1, W2, and W4 for more information)

Flooring
Static flooring is used to reduce charging and ground any charges generated. Floor tile, carpeting, epoxy coatings, and mats should be considered. Large new buildings may install static flooring as a 'built-in' protection scheme. Floor run-

ners and mats may provide the same effect in other factories.

There are many styles and types of flooring and mats. Heel grounders need to be worn be all personnel if flooring is to be of much use. As of yet, no comprehensive standard for flooring exists. Some EOS/ESD Standard 4 techniques apply. Cost, durability, maintenance, and installation time are the primary issues to consider. (See SCC Bulletins W1, and W3 for more information)

Heel Grounders

This strap connects a person to a grounded mat or floor. The conductive sole is placed under the heel (or toe on a toe grounder). A tab is placed in the shoe and the moisture in the shoe makes electrical connection between the body and the tread. A dissipative or conductive mat (or floor) is needed for the heel grounder to work. One grounder should be worn on each shoe so that ground connection is maintained while walking.

Options on heel and toe grounders include color, size, body connection, and resistor. Durability of the sole is also a consideration. The grounders should only be worn in the factory to reduce wear.

Grounding Cords

Worksurfaces, wrist straps, and other static control products need to be connected to ground. Ground cords are wires with various type snaps, clips or eyelets for connection to the product and to ground. Many ground cords include a 1 meg resistor. A Common Grounding Cord allows several products to be grounded to the same point. (See SCC Bulletins W1, W2 and W4 for more information)

Air Ionizers

Ionizers neutralize a charge on the surface of a material by blowing air filled with an equal number of negative and positive ions across the material. Ionizing systems can be fitted to entire rooms or to a small bench top unit. Units differ in charge neutralization ability, power consumption, particle generation, and out of balance sensors. Ozone generation was a substantial concern. Newer designs should eliminate most issues.

Ionizers should be considered as a secondary grounding system to reduce charge on items that cannot be grounded. Maintenance is a primary concern with ionizers. If amounts of negative charge and positive charge are equal, charges are neutralized. However, if more of one charge is coming from the ionizer, the surface of the object is charged up instead of being neutralized. A regular program of maintenance is needed. EOS/ESD Standard 3 will provide guidance.

Field Service Kits

Often when a service person goes to repair an electronic device, they have no static protective workstation with a worksurface and wrist strap. A portable field service kit consists of a flexible mat, a ground cord, and a wrist strap. The mat folds to contain the cords and fit into a pocket or work case. Field service organization should consider using these kits.

Furniture

Furniture includes work tables, chairs, carts, desks, racks, and stands designed to be static safe when grounded. These items provide convenience and easy of use because they are constructed with static safety in mind. They also provide a positive appearance.

Monitors/Testers

There is a monitor or tester for almost every protective product. Wrist Strap Checkers test the connection between the cord, the strap and the person. Constant monitors continuously check that the correct resistance or capacitance is maintained without interrupting work. Resistance meters check a material's ability to move a charge across the surface. Resistance meters can be used to check packaging, flooring and worksurfaces. The general idea is to insure that the products are doing what they are designed to do and to replace the product when it fails.

Packaging

Packaging probably has the most options and choices of style and performance. When selecting packaging keep in mind these goals: Static protection, ease of use, cost, reuse, physical protection, and customer requirements.

Bags

Bags provide a convenient, economical method of static safe storage and protection.
The MIL-B-81705C military material specification describes material TYPES.

TYPE I. MOISTURE BARRIER EMI/RFI/ STATIC SHIELDING.
TYPE II. TRANSPARENT, STATIC DISSIPATIVE.
TYPE III. TRANSPARENT, STATIC SHIELDING.

Moisture Barrier bags (Type I) are opaque, usually white or silver, and stop moisture and static from entering the bag. Dissipative bags ('pink poly' Type II) are clear, pink or blue, and will not accumulate charge but will not stop static from penetrating the bag. Shield bags (type III) are gray/silver, and stop static from getting inside the bag.

Bags work by using a chemical antistat to enable plastic to dissipate charge and not accumulate charge. Moisture barrier and shielding bags use a layer of metal to shield their contents from fields and charges. Metal on barrier bags is thicker or in multiple layers to stop both moisture and static. The 'poly' bags (type II) use only the antistat.

Bags Uses

Barrier bags are generally used for long term storage and maximum protection. Surface mount electronics are sensitive to moisture and are packaged in moisture barrier bags.

Pink poly bags are generally used for non static sensitive parts like screws, plastic cases, or assembly parts.

Shield bags are used to protect electronic parts during production, storage and shipping. These bags do not accumulate charge and the metal shield stops static fields and charge from damaging the electronics inside the bag. (See bulletins P1, P2, P3, and P4)

Tote Boxes

Tote boxes are made from plastics or paper that is coated or loaded with antistat or carbon black. The carbon black makes the box conductive. Boxes are made in all shapes and sizes and may include slots for cards. Tote boxes are used to move electronic assembles, cards, etc, through a manufacturing operation. Some are fitted to work on a conveyor system or with robots.

Plastic Tote boxes can be injection molded or vacuum formed. Injection molded boxes usually have better tolerances and if purchased in standard sizes, are less expensive. They are made from polyethylene, ABS, and PVC. Conductive boxes provide some measure of shielding. A test method has not yet been established.

Semi-Rigid (Clamshells)

Thin plastic sheets are vacuum formed into shapes that hold electric parts. Examples include IC chip trays and clam shells. The plastic is usually clear PVC or PETG that is coated and/or loaded with an antistat. These containers provide a nonaccumulating package that provides good physical protection. These containers do not provide static shielding.

Antistats

Antistats are chemical mixtures that will make the surface of a material able to conduct static and reduce static accumulation through tribocharging. Antistats work by attracting moisture to the surface of the material. Moisture becomes the conductor. Some antistat bring there own water along and are active at low relative humidities. Antistats can be applied to a surface or incorporated into plastic and eventually need replacing. Two common chemical bases are amines and amides. Amines got a bad name by causing stress cracking of some plastics.

Other Products

There are many other products available for static control. Gloves, smocks, lab coats, drapes, lotion, tools, cleaners, tape, tape dispensers, paint, laboratory test equipment, product test services, wafer boats, labels, cabinets, and others.

MINIMUM ESSENTIALS

After reading about static, how it damages electronics, and static control products, you probably want a simple check list of what is required. Unfortunately, it is not that easy. Each facility needs to evaluate its specific needs. However, there are some common essentials. (See also EIA 625 and STATech W1)

Equipment:

Wrist Straps.
Worksurfaces for tables.
Grounding cords.
Packaging.
Wrist Strap Checker.

A minimal work station consists of a worksurface, a wrist strap and coil cord, and a grounding cord. Correct packaging is critical. A tester for the wrist strap is needed to make sure that the products are installed correctly. (See bulletins W1, W2, W3, and W4)

Training:

Management (For support)
Engineering (Specifying materials for new products)
Purchasing(Keep products in inventory)
Receiving (Handle sensitive produces correctly. Do no accept shipments incorrectly packaged)
Stock Room (Handling, and transporting electronics safely)
Production (Handling, working, transporting.)
Shipping (Handling, packaging, transporting.)

Training and motivating people to use the static control products is the biggest challenge. Static control is an ongoing task. Straps break, worksurfaces wear out, people short cut static control procedures. Unfortunately damage can occur if only one area in the electronics manufacturing area does not do its part.

For more information about installing static control programs I suggest MIL-STD-1686, MIL-HDBK-263, or "ESD Program Management," G.T. Dangelmayer, from Van Hostrand Reinhold.

RESULTS

The first level of static protection installed in most companies will yield substantial savings in rework or debugging of final electronic products. I have seen some process where static is responsible for 60% of defect rates. Many companies are so impressed by their results that they require their suppliers undertake static control programs.

Many programs reach a point where the first 'round' of the program is installed and complete. Because of the success, more protective products are purchased and put in place. While some improvement is observed, the amount is usually much less than the first 'round'.

The lesson is that many big static offenders can be subdued with a moderate amount of investment in protective products and programs.

by
Brent Beamer - SCC

References

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W.D. Greason "ESD: A charge driven phenomenon" EOS/ESD Symposium Proceeding 1991.

J.R. Huntsman "Triboelectric Charge" EOS/ESD Symposium 1984, Appendix A.

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ESD Association Advisory: Handbook, ESD-ADV-2.0-1994. Electrostatic Discharge Association, Rome NY.

STATIC Q AND A

The science of static can get very complex and cumbersome. We will try to keep this Q and A short and simple.

What is Static Electricity? Electric Charge that is not moving. Static meaning still as opposed to dynamic or moving. An analogy would be the rock sitting up on a hill (static.) verses a rock rolling down the hill (dynamic). For an object to get and hold a static charge, it must be an insulator or an ungrounded conductor.

What is ESD- Electrostatic Discharge? The transfer of electric charge between two objects. We use the term discharge because the electricity generally moves from one object to another. ESD is the technical term for static "spark."

What is an Electric or Static Field? When an object is charged, it has invisible lines of force surrounding it. These invisible "hands" can grab for things or push them away.

How does an object accumulate static charge? There are three ways.

Rubbing or "Tribocharging": When two materials contact and then separate they exchange electric charge. One material will end up with a negative charge and the other with a positive charge.

Polarization: When an ungrounded conductive material is in the electric field from another object, it becomes polarized. This means that one part of the object is negative and another part is positive. When this polarized object is grounded, while still in the field, it retains a static charge.

Conduction: When charge is transferred to an object by near or direct contact with a charged material. ESD could be considered conduction.

Why does ESD (spark) occur? Nature likes everything to be at the same charge level. So when two objects with different electrical charge levels come close together the static charge becomes dynamic and the charge "leaps" from one object to the other. This leaves the two objects with the same charge.

What are some examples of how all of this happens in a production area? Tribocharging happens as you walk across the carpet or floor. The soles of your shoes contact and separate with the carpet transferring charge. In essence, your body accumulates this charge. When you touch an object with your hand, your body and the object you touched swap charge and electrostatic discharge (ESD, a spark) occurs.

Polarization (Induction) is sometimes hard to visualize. Here is an example: An ungrounded circuit card is sitting on a table and next to it is a charged Styrofoam cup. The field from the charged cup is polarizing the electronic device. If a person picks up the device they effectively ground it. This leaves a charge on the card. When the card is placed back on a table, the charge on the card transfers (ESD) to the table.

Why are ESD and Static bad for electronics?
An electronic integrated circuit (IC) has extremely small wires and structures inside. These small conductive parts cannot take much electrical power. When ESD occurs it's like a small lightening strike hitting the structure. The wires and structures melt like a fuse blowing.

Also, there is insulation between these small wires and conductive structures. If too much power is placed on the wire, the insulation may breakdown. This causes a short in the circuit and the circuit does not work.

What is the difference between Conductive and Dissipative Materials?
For static control purposes, Conductive materials are defined as having resistance less than 10^5 (100,000) ohms. Dissipative materials have resistance greater than 10^5 but less than 10^{12} ohms.

However, often the terms are used in generic ways. Conductive can mean 'able to carry a charge'. Insulative means 'not able to carry a charge'. Dissipative can mean able to decay (carry to ground) a charge.

What is the difference between Antistatic and Antistat?
Antistatic means that a material will not charge up when rubbed. An antistat is a chemical that makes things antistatic. The antistats work in two ways. First they attract moisture from the air to a surface. This moisture makes a material able to dissipate a charge to ground. Antistats also reduce the charge accumulated from rubbing materials.

What is ground?
For static purposes ground is a conductive connection with the earth that allows us to dissipate static charges. Green wire building ground wire in the AC power system is generally used for grounding. Some people use a metal rod driven into several feet of earth as an ESD ground point. However, this must be tested and connected to the AC power system ground.

Static Stats

Basic Static Control Strategies:

a. If a material is conductive, then ground it.
b. If a material is insulative, remove it from the production area or make it conductive and ground it.
c. If it cannot be made conductive or removed, then shield it.
d. Control the charge on people, because people are the most common source of charge and ESD.

Three ways static control products work:

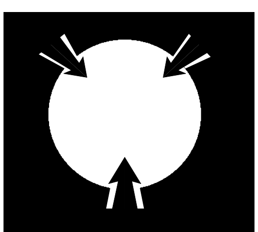
1. Reduce charge accumulation. (Tribocharging)
2. Provide a path for the static charge to move away from the electronics. (Grounding)
3. Shield the electronics from static fields or discharges.

Surface Resistance Range (ohms)

Exponent	Number of ohms	
$1x10^2$	100	Conductive
$1x10^3$	1000	Conductive
$1x10^4$	10000	Conductive
$1x10^5$	100000	Conductive
$1x10^6$	1000000	Dissipative
$1x10^7$	10000000	Dissipative
$1x10^8$	100000000	Dissipative
$1x10^9$	1000000000	Dissipative
$1x10^{10}$	10000000000	Dissipative
$1x10^{11}$	100000000000	Dissipative
$1x10^{12}$	1000000000000	Insulative

Resistance for ESD products is usually stated in exponents. Be aware that an increase of one exponent is actually 10 times more resistance.


Military Symbol
from MIL-STD-129M


Obsolete Military Symbol


EIA 471 and JESD 42


EOS/ESD S8.1 Protective


EOS/ESD S8.1 ESD Sensitive

Static Warning Symbols

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ESD Products Division

US and Canada **800.356.2728** Fax 800.356.2729
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