Understanding why taking precautions against uncontrolled electro-static discharge (ESD) is necessary.

Many electronic circuit board assemblies contain both active and passive components; some of these components, particularly semiconductors, may be sensitive to damage from static electricity, while some other components may not be. Still, where one static sensitive device is included in a circuit assembly, the whole circuit assembly should be treated as static sensitive. The purpose of this tutorial is to introduce a few of the many sources of static electricity, and the effect of electrostatic fields on static sensitive electronic components.

Advances in semiconductor integrated circuit (IC) technology over the last several decades have lead to micro electronic devices that are smaller, faster, and cheaper to produce than ever before. As new devices continue to shrink in size, we're also seeing higher circuit density, increases in clock speeds and lower power requirements to operate them. Semiconductors and the processes to manufacture them have evolved drastically since the invention of the first bi-polar transistors and diodes. With the advent of the high tech IC's used widely today, such as complementary metal oxide semiconductor (CMOS) integrated circuits, silicon circuit chips have become so small that they are necessarily manufactured with processes and materials which make the devices sensitive to the invisible forces and effects of static electricity.

While some amount of static electricity always surrounds us, the amount of static in our environment is highest on days of low humidity. Static electricity is easily generated by friction on carpets, tile flooring, clothing, hair, fabrics, plastics, rubber, adhesive tapes, etc. The friction of moving air alone will charge suspended dust particles and cause the build up of static electrical charges on people and objects in our environment.

The build up of static charges on furniture, tools, work surfaces, and objects all around us makes it impractical to avoid or control static electricity without taking special measures.
Grounded antistatic work mats used with antistatic wrist straps or heel straps provide the most basic means for the controlled discharge of electrostatic charges. Grounded mats and antistatic straps also stop static damage by *preventing the build-up* of electrostatic charges and fields. Mats and straps are the most common and affordable tools used to deal with static electricity in a work environment. At a very minimum, professionals or hobbyists who work with static sensitive components or materials should use these basic static protection items.

The simple act of walking around can generate large static charges that will build up and be stored on clothing. On a dry day, a person can easily generate and carry 40,000 volts of static around on their clothes. To a novice, it may sound incredible that such a high voltage doesn't kill. The high "static" voltage won't cause serious harm to people because the amount of electric current in a static electric discharge is very low. For example, due to the very low static current, it takes a minimum static charge of about 20,000 volts just to begin to feel the discharge "zap" on the tip of the finger when a door knob is touched. It's only becomes possible to see that little discharge spark at the tip of the finger when the static voltage begins to approach about 40,000 volts.

(DON'T confuse static voltage with other high voltage power sources which CAN provide enough current to harm or kill, such as AC wall outlets, step-up transformers and other power source equipment. The danger of high voltage "power sources" must always be respected).

A crucial point to understand when working with static sensitive electronics such as CMOS semiconductors is that it's not even necessary to touch an IC in order for static discharge to damage an IC chip. This is because static electricity generates an electrostatic "field" surrounding the source of the charge that can extend outward up to several feet all directions. Exactly how far an electrostatic field may extend around people or any other charged object depends on the static voltage level at the source of the static charge. The strength of the invisible field can be measured with an electrostatic field meter, and this static field strength increases as the source of static charge is approached.

When unprotected CMOS devices are exposed to a strong electrostatic field, the microscopic oxide insulator layers embedded within the chip circuitry are overcome by the high static *voltage potentials* within *the static field*. To explain this in another way, the thin insulating barriers sandwiched between the conductors inside the IC become unable to resist the flow of static current through or around the insulator, similar to an overcharged capacitor. At the critical break-down point, a small static current will break through an insulating layer between two or more conductors within the silicon. This totally unseen "short circuit" burst of static discharge current may last only a micro-second, but it will leave behind microscopic holes or paths where it burned through the oxide insulator. In fact, many such static damage events may occur at the weakest points within the IC oxide layers from a single exposure to a strong electrostatic field.

If this damage occurs especially at a critical spot in the IC circuitry, the chip is left with a permanent (and un-designed) opening in the insulation layer between two or more adjacent conductors within the IC. The unseen damage event typically goes completely unnoticed until normal power is applied to the circuitry, when the normally higher circuit power currents may easily leak through the new "holes" in the insulator. This undesired "short circuit" path is permanent damage within the IC circuitry, essentially altering the circuit design at random and potentially rendering the circuit partially or completely non functional.

Even though the static damage event is unknown and initially undetected, the IC may appear to function normally for a while, but it will likely continue to function for only a limited time and the normal life span of the IC will be greatly reduced. While the normal circuit power is turned on, some amount of leakage current will be continuously exchanged between conductors through the hole damage in the insulator existing between them. At first the leakage may be very small, and may not seem to affect the operation of the circuit. But through a process known as "electro-migration", the electrons leaking through the insulator will slowly pull some of the conductor material (atoms) through the hole damage in the insulator. Like a "via" in a circuit board, these conductor atoms will be deposited on the inside surface of the hole through the insulator. If this electro-migration were watched through a microscope over time, the conductors in the IC would appear to "grow" together through the hole damage in the insulator. Over time, the electro-migration growth of these conductors through the damaged insulator will further decrease the resistance of the insulator, causing an even further increase in the amount of leakage current, thus further increasing the electro-migration between the conductors. This cycle of damage continues and accelerates, until a critical un-designed short circuit is effectively created through the oxide insulator barrier, and the IC will cease to function normally, or may suddenly and completely fail altogether.

To a hobbyist or handyman building or repairing an electronic "toy", the damage caused by static electricity may seem trivial, (if they don't mind doing a lot of avoidable, unnecessary, trouble shooting and repairs).
But for commercial electronics manufacturers and professionals, static electricity damage can have huge consequences if their product is part of a medical life support instrument, a military weapon system, computers, cell phones, commercial appliances, or anything else where the highest possible degree of reliability is demanded and expected by the consumer.

Static electrical discharges can be a major concern for industries outside the field of electronics as well. For business that deal with flammable chemicals, natural gas, fireworks or pyrotechnics, spray painting, or anything else involving explosive dust or fumes, a static discharge spark in the wrong place at the wrong time can mean disaster.

If you or your company have reasons to be concerned about preventing damage caused by static electricity, a small amount of money, time and effort invested in doing so is very worth while. The small investment will more than pay for itself in the long run.