ESD FOR
(AND BY)
THE LAYPERSON

AN EXPLANATION OF ELECTROSTATIC DISCHARGE
AND WHY IT CONCERNS MANUFACTUERS OF A.T.E.

Dedication

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Unlike stupidity which is terminal, ignorance is curable and education is the miracle cure.

From one who is a little less ignorant and a little more educated because he was challenged to all those who have challenged him.

Notice

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The sale of AT9000™ for use in a vacuum actuated test fixture is restricted to users who are licensed by Everett Charles Technologies.

FROM THE EDITOR:

A challenge ignored is an opportunity lost while a challenge accepted is sometimes a hell of a lot of work! In the winter of 1992 a customer asked me to explore the possibility of making an electrostatic dissipative material suitable for use as probe and diaphragm plates that is electrostatic dissipative. As if that were not enough of a challenge, he added almost parenthetically “It can’t be painted on … It must be an integral part of the surface.” My education began.

Fortunately, my superior officer in the Air National Guard, Major Dean Plowman who was also my partner in a software business venture is a degreed Electrical Engineer and has extraordinary patience and a passion for educating the ignorant. Dean pounded in just enough basic knowledge into the gray matter between my ears to enable me to ask the correct questions of several smart people in the industry. These customers and friends were the underlying and driving forces that helped me develop AT9000™, the G10/FR4 with an integral electrostatic dissipative surface.

Now, I not only ask the right questions (sometimes) but, I can even understand the mumbo jumbo responses of my learned colleagues of the EE persuasion (sometimes). Here is some of the really neat stuff I’ve learned:

Peter DeSimone

What is electricity?

For the purposes of our discussion, we will say that electricity is energy. It is an invisible force that has the *ability* to do work. If for example that ability is applied to an appliance like a motor or a heater it becomes real and measurable for us. It becomes work.

What about static electricity? What is it and how does it work?

Static electricity is electricity at rest. It is therefore also energy at rest. This energy has the ability to move from place to place but before it can, it must overcome the resistance that surrounds it. Think of static electricity and the work that it can do as you would think of a powerful man-eater tiger lying in a circus cage peering hungrily through the bars at you. He sure would like to get at you and he certainly has the fangs, claws and muscle to do you some serious harm but before he can, he must first get by those thick iron bars in his cage. The stronger the bars that surround this terrible beast, the safer you may feel. But, you would not feel so safe if for instance the bars in the tiger cage were made of wood instead of iron and, perish the thought, if the bars were made of rubber, you could soon be history, technically El Gonzo!

The measurement of an electrical charge's ability to do work is called (amongst other things) *volts*. So, the more volts contained in an electrical charge the greater its potential to do work.

In the simplified example above, the reclining tiger represents the *static electric* charge, its strength would represent *volts* and the bars would be *resistance*. If the tiger were stronger or if the bars weaker you could be *shocked* by the results.

What does ESD stand for?

Electrostatic Discharge (ESD) is the transfer of a static electric charge between two objects at different *potentials.* This is “sorta” like you after you scuff across the rug and touch the door knob – El Zappo!! (See Figure 1).

What is meant by different potentials?

Again, for the purpose of our discussion we can think of potential as the differences in voltage between two objects. Whenever an electric charge can reach out to an object with a lesser charge there is a transfer of energy from the greater to the lesser. The greater the difference is the more violent the transfer of energy. You get zapped when you touch a door knob or other conductive surface because you body became charged from walking over the carpet. The charge is hundreds of volts more than the door knob’s charge which in this case may be zero, so as your hand approaches the door knob the charge you hold reaches out to the object with less of a charge and just when it can overcome the resistance between you and the door know - *ZAP!* - The greater the difference the greater the zap.

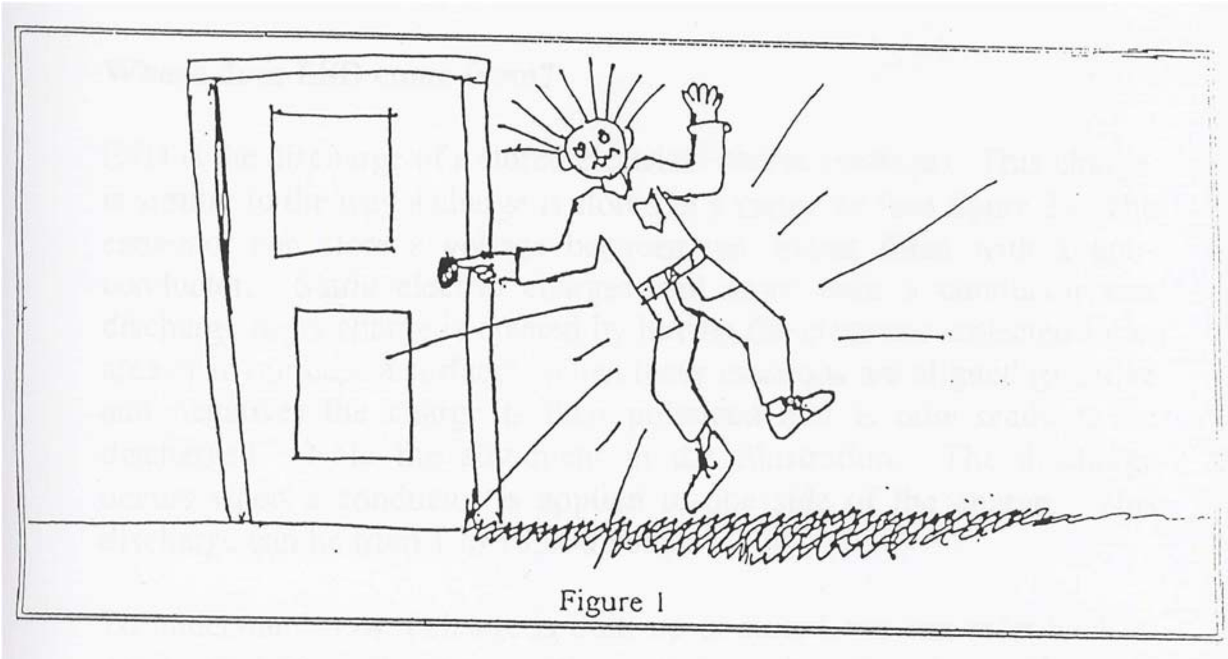

Figure 1

So, what's the big deal about ESD and incircuit testing?

Most electronic designs use integrated circuits (ICs) and silicon/germanium devices. These little suckers are soldered into printed circuit (PC) boards that are usually made of a fiberglass type of material not too unlike the material used on your probe and diaphragm boards. Many sensitive electronic devices can be destroyed by having a voltage from 30 to 7,000 volts discharged through them on their way to the place of least electrical charge, "ground".

Where does ESD come from?

ESD is the discharge of a stored electrical charge (voltage). This charge is stored in a capacitor (see figure 2). The capacitor can store a voltage between two plates filled with a non-conductor. Static electric charges will store until a conductor can discharge it. A charge is created by having the electrons collected in an area or in our case a surface. When these electrons are aligned (positive and negative) the charge is then polarized and is now ready to be discharged. Note the alignment in the illustration. The discharge occurs when a conductor is applied to one side of the charge. This discharge can be from 1 to 15,000 volts!

To understand how a charge is built up or stored, we can refer back to our example of walking across the carpet. The carpet is usually made up of plastic fibers, like polyester. Like most plastic materials polyester has a high resistivity (electricity does not pass through or over it easily) and because of this resistivity, the carpet cannot by itself dissipate an electrical charge. When you walk across the carpet you create friction between the carpet and your feet. This friction aligns the electrons (and wears out your Xmas slippers and the carpet – but that's another problem. The charge is then created (see figure 3).

A high potential (more than 1,000 volts) can be produced. When you touch an object that has a lower resistivity (more easily conducts electricity) the charge is dissipated from your hand to that item. The aforementioned El Zappo!

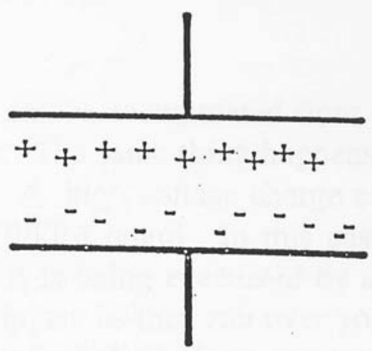

Figure 2

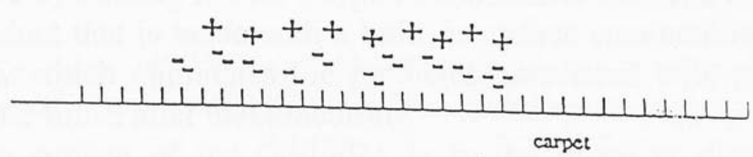

Figure 3

An electrostatic charge can be accumulated from as small as one volt to as high as 15,000 volts. The same thing happens with any surface that has a high resistivity. A high voltage charge can build and be stored on the surface of a G10/FR4 board. In this case air rushing over the surface of the board as it is being evacuated by a vacuum actuated test fixture acts like your slippers as they rub over your carpet. Any device with a lower resistivity, including electronic boards and devices, will discharge the high voltage pop!, there goes another unit under test (and sometimes a customer)!

What can be done to prevent ESD?

One way of preventing the build up of dangerously high voltages is by reducing the resistivity of the surface. This is usually done by making the surface more conductive. A surface can be made more conductive by coating it with a type of conductive material or you may use a product that is made with a built in surface conductivity like our AT9000™ which eliminates the problems associated with applying a less durable finish after manufacturing. When the surface of the G10/FR4 is in the range to dissipate any charges, ESD is prevented.

Dissipative surfaces are not however the only way to prevent damage of components from discharging electrostatic charges which build on the surface of the probe and diaphragm boards. Another way to avoid damaging electrostatic dissipation is to condition the air (ionization) before it rushes over the surfaces. This works but is very costly and we’re very cheap!

Everett Charles Technologies developed a process to reduce the resistivity by coating the surface of their test fixture. When they finished the design, their surfaces measured 10^5 to 10^{10} ohms (a measure of resistance to the conducting of an electrical charge) per square. They patented the process of coating test fixtures.

Surface resistive ranges (in general; from EIA 541 and Mil-HDBK-263) in general, the *higher* the ohm value, the *less* conductive it is. If the ohm value becomes too large, the surface is able to hold an electronic charge.

Simply, (and *I am* an expert on *SIMPLY*) less than 10^5 is too conductive for our purposes and higher than 10^{10} is too resistant to conductivity for us.

AT7000™, "The G10/FR4 made especially for A.T.E." has a surface resistivity of approximately 10^{13} and is therefore dielectric or resistant to conductivity while AT9000™ the ESD G10/FR4 has a surface resistivity between 10^7 and 10^9 therefore will safely conduct electricity to ground before it builds to damaging proportions (scientifically pre - El Zappo).

While insulating materials – having more than 10^{12} ohms/square should not be used with sensitive electrostatic devices, dissipating materials – having more than 10^4 and less than 10^{11} ohms-cm/square should be used for intimate contact with materials. Conductive materials have less than 10^3 ohms-cm.

Volume resistivity ranges (in general; from EIA 541 and Mil-HDBK-263)

Volume resistivity is just a different way of measuring the surface of resistivity. The higher the ohm value, the less conductive the surface is.

What does $10^{5 \text{ or } 10 \text{ or???}}$ mean?

The scientific notation after the whole number represents the number of zeros that follow that number. So, 10^5 is the scientific way of expressing 10 followed by 5 zeros or 1000000 or more correctly 1,000,000. So, for our purposes, if a material has a surface resistivity of 10^5 ohms it will resist the conductivity of electric charge until that charge can overpower one million ohms of resistance.

How can we measure surface resistivity?

Resistivity or resistance is usually measured with the resistance scale of a multimeter. This method is good for a quick test of resistivity when the field you want to test is point to point because the test probes are sharp and pointed. But surface resistivity to the degree that interests us can only be measured accurately with a surface resistivity meter or officially a megohmeter, the test points called bi-electrode sensors are narrow bars 2 to 6 inches long and they measure the change in current between the two bars or surface resistivity per square.

What is acceptable as a reading for our purposes and what are the consequences of having too much or too little surface resistivity?

The two extremes are too much static electricity flow – *conductive surface.* When this happens the electricity can flow into our test area and cause shorts or false readings. On the other side of the scale too little static electricity flow or an *insulative* surface allows the static charge to build to a point when it may have enough energy to jump from the surface of your test fixture to the unit that is being tested and burn out components.

In the range which we consider (10^5 to 10^{10}), 10^5 to 10^6 may allow too much static electricity flow – too conductive, and above 10^9 may not allow enough static electricity to flow and therefore be insulative. Although other variables may come into play in determining the ideal surface resistivity generally any reading between 10^7 and 10^9 is acceptable.

References / Specifications (in order of importance)

DOD-STD-1686A "ESD Control Program"
EIA 541 "Packaging Material Standards for ESD Sensitive Items"
MIL-HDBK-263
MIL-B-81705C "Barrier Materials, Flexible, Electrostatic Protective, Heat Sealable"
Compliance Engineering Magazine – various articles

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