TransGuard®
AVX Multilayer Ceramic Transient Voltage Suppressors
Application Notes: The Impact of ESD on Insulated Portable Equipment

The purpose of this discussion is to recap the impact ESD has on portable, battery powered equipment. It will be shown that ESD can cause failures in "floating ground systems" in a variety of ways. Specifically, ESD induced failures can be caused by one or more of its complex components:

Predischarge - Corona Generated RF

Predischarge - E Field

Discharge - Collapsing E Field

Discharge - Collapsing H Field

Discharge - Current Injection...Voltage...Additional Fields

With this in mind it will be shown that the only way to insure equipment survivability to ESD is to use a Transient Voltage Suppressor (in addition to proper circuit layout, decoupling, and shielding).

In order to get a better understanding of what happens in an ESD event the charge developed by a human body should be defined. The ESD schematic equivalent of the human body model is shown in Figure 1. Typically, the charge developed on a person can be represented by a 150pF capacitor in series with a resistance of 330 ohms. The energy of an ESD waveform generated from this model is $Q = 1/2\ CV^2$ where Q = total energy in Joules, C = capacitance of the human body model in farads and V = charging voltage in volts.

Voltages can be as high as 25 kV, however typical voltages seen are in the 8 to 15 kV regions.
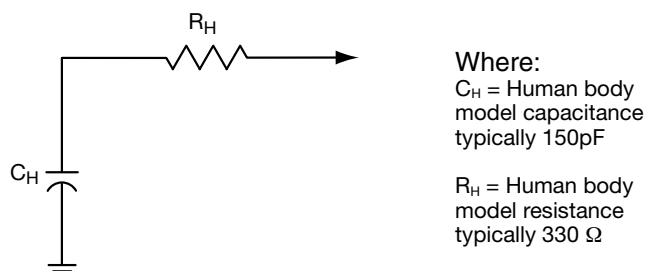

Where:
C_H = Human body model capacitance typically 150pF

R_H = Human body model resistance typically 330 Ω

Figure 1. Human Body Model

PREDISCHARGE E FIELD FAILURES

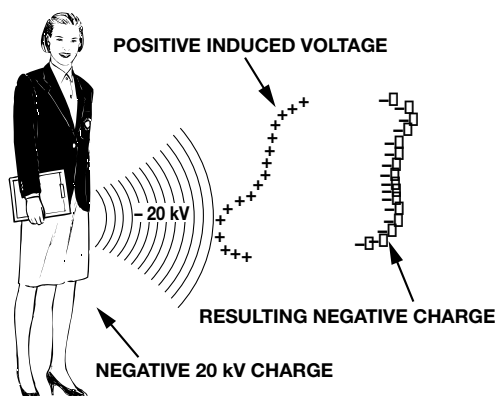Now that we have a definition of the basic ESD human body model we can discuss the predischarge E field failure mode.

POSITIVE INDUCED VOLTAGE

– 20 kV

RESULTING NEGATIVE CHARGE

NEGATIVE 20 kV CHARGE

Figure 2. Pre-Discharge Scenario

In the predischarge scenario (Figure 2) a human charged to –20 kV may approach a battery powered "system" on a table. As the person reaches toward the system electrostatics dictate that the system will have an equal and opposite charge on the system's surface nearest to the person. SInce the system we are approaching is isolated from ground, the charge is only redistributed among the device. (If the system were grounded a current would be generated by the loss of electrons to ground. The system would then become positive relative to ground). The rate of approach of the human body model affects the charging current to a small extent. However, most importantly, it is the electrostatic field and the unequal voltages which developed across the equipment that cause the destruction of components within the system. In general, unprotected IC's (particularly CMOS) are susceptible to damage due to induced E field v o l t a g e s . This problem is further complicated by the device type and complexity and the fact that the breakdown voltage of a generic IC will vary greatly from manufacturer to manufacturer (Figure 3). This brief discussion should be adequately convincing that electrostatically induced E field can impact system reliability. IC protection can be achieved by placing a transient suppressor on the most susceptible
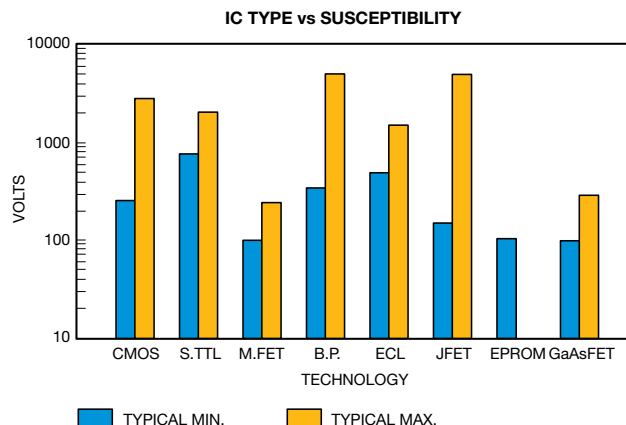

Figure 3. IC Type E Field Susceptibility

pins of the sensitive IC's (e.g., Vcc and I/O pins, etc.).

CONTACT DISCHARGE FAILURES

As the charged person gets closer to the system, the situation is more complex. First a much more detailed human body model is needed to represent the complex transmission line which will transport energy to the system (see Figure 4). In this discussion we will only consider the case of a single contact discharge. In the real world, however, multiple discharges will likely occur (possibly caused by a person's hand reacting to an ESD spark and then touching the system again, etc.).

In contact discharge, when a charged person approaches the system, E fields are induced. As the person gets closer to the system, the field intensity becomes greater, eventually

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reaching a point large enough to draw an arc between the person and the system. In contrast to the noncontrast E field example, the speed of approach is of great importance in the contact discharge model. A fast approach causes a more intensive discharge and faster current rise times and peaks.

The model shown on Figure 4 can be broken up into 4 sections for the sake of simplification. The first section is the human body model input voltage. This section is identical to the simplified human body model shown in Figure 1.

Section 2 takes into account how the human body model gets the energy to the system. This section considers the inductance, resistance and capacitance of the human's arm and finger and its capacitance relative to ground and the system.

The third section is the inductance and resistance of the arc which is created as section 2 approaches the system (Section 4).

Section four is the system itself.

The combination of the capacitances and inductances in these sections form a complex network of LC tank circuits which will inject a variety of waveforms (transients) into the system. These waveforms will range in frequency from very high (5 GHz) to high (100 MHz) to low (20-50 MHz) plus a variety of under damped and over damped waveforms.

Finally, in addition to current/voltage injection occurring as a result of the discharge, there will be collapsing E and H fields and significant high frequency RF waveforms. Many times these waveforms propagate into shielded equipment and cause system/device failures.

Figure 4. Contact Discharge Model

SUMMARY

Designers may be inclined to think that E field variation due to near field electrostatics (as in the person being close to the system but not touching it) can be eliminated by shielding. This is usually not the case because it is difficult to get a tight columbic shield around internal circuitry without incurring significant additional manufacturing costs. Additionally, the shielding will likely have seams, ventilation holes, or I/O ports which represent a significant portion of a wavelength (at 5 GHz). Therefore, E fields and corona generated RF can be a problem. Finally, if the system has I/O connectors, keyboards, antennas, etc., care must be taken to adequately protect them from direct/and indirect transients. The most effective resolution is to place a TransGuard[®] as close to the device in need of protection as possible.These recommendations and comments are based upon case studies, customer input and Warren Boxleitner's book *Electrostatic Discharge and Electronic Equipment - A Practical Guide for Designing to Prevent ESD Problems.*
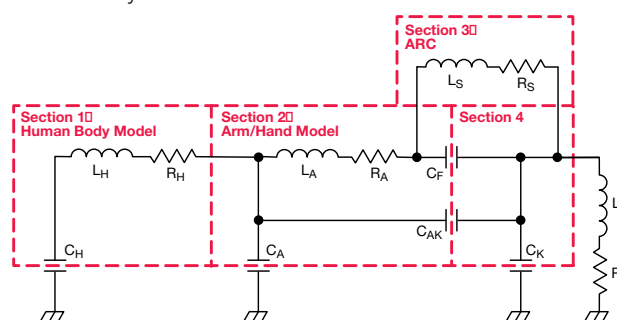
Where:
C_H = Lumped capacitance between the human body and earth

R_H = Lumped resistance of the human body

L_H = Lumped inductance of the human body

C_A = Lumped capacitance between the person's arm and earth

C_{AK} = Lumped capacitance between the person's arm (and near portions of the body) and the keyboard

R_A = Lumped resistance of the person's arm's discharge path

L_A = Lumped inductance of the person's arm's discharge path

C_F = Capacitance between person's finger, hand, and the keyboard

C_K = Lumped capacitance of the keyboard to earth

R_K = Lumped resistance of the keyboard earth ground path

L_K = Lumped inductance of the keyboard earth ground path