The Prevention and Control of Electrostatic Discharge (ESD) (AN-40-005)

An Introduction to ESD

We experience occurrences of static electricity everyday. For example, walking along a carpeted floor in a heated room during winter generates sufficient static electricity to give us a rather shocking experience when we touch the door knob. While this sudden discharge of static electricity does not result in any harm to the human body, it can be very damaging to electronic devices which are sensitive to electrostatic discharge (ESD). It is possible for electronic devices to be damaged by ESD that is imperceptible to the human body. This document is intended to shed some light on the sources of ESD and provides guidelines on the prevention and control of ESD.

What are the common sources of static electricity?

The following table shows a sample list of sources of static electricity.

Object or process	*Material or activity*
Work surfaces	Waxed, painted or plastic surfaces.
Floors	Waxed, common vinyl tiles, sealed concrete
Clothes	Common smocks, non-conductive shoes, synthetic materials (e.g. nylon)
Chairs	Vinyl, fiber-glass, finished wood
Packaging	Common plastic bags, foam, trays, tote boxes
Assembly area	Spray cleaners, heat guns, blowers, plastic tools (e.g. solder suckers, brushes) cathode ray tubes.

What are typical examples of static charge inducing situations? Does humidity have any effect on the induced static charge?

The following table shows some typical situations. Please note that humidity has a significant effect on the induced charge. It is not recommended to have relative humidity (RH) that is too low, say, below 30%. ESD control becomes especially challenging at low RH levels. A relative humidity between 40% to 60% is recommended for the typical assembly area.

Means of static generation	*RH 10-20%*	*RH 65-90%*
Walking across a carpet	35,000 V	1,500 V
Walking on a vinyl tile floor	12,000 V	250 V
Vinyl envelopes for work instructions	7,000 V	600 V
Worker at bench	6,000 V	100 V

How does damage from ESD happen?

When a statically-charged person or object touches an electrostatic discharge sensitive (ESDS) device, there is a possibility that the electrostatic charge could be drained through sensitive circuitry in the device. If the electrostatic discharge possesses sufficient energy, damage could occur in the device due to localized overheating. Generally, devices with finer geometries are more susceptible to damage from ESD.

The modes in which ESD damage occurs are:

- Discharge to the device
- Discharge from the device
- Field-induced discharge.

What are the classifications of ESD sensitivity?

Electrostatic discharge sensitive (ESDS) parts are commonly characterized to three defined models:

- Human Body Model (HBM)
- Machine Model (MM)
- Charged Device Model (CDM)

Based on the models used, the ESDS parts can be classified in accordance with the following table (per MIL-STD-1686C, with HBM subgroups per ESD STM5.1-2001). It should be noted that the HBM, MM and CDM voltage levels do not correlate with each other.

ESD Model	ESD Classification	Voltage Range
Human Body Model (HBM)	0	0V – 249V
	1A	250V – 499V
	1B	500V – 1999V
	1C	1000 – 1999V
	2	2000 – 3999V
	3A	4000 – 7999V
	3B	>= 8000V
Machine Model (MM)	M1	0V – 100V
	M2	101V – 200V
	M3	201V – 400V
	M4	401V – 800V
	M5	>800V
Charged Device Model (CDM)	C1	0V – 124V
	C2	125V – 249V
	C3	250V – 499V
	C4	500V – 999V
	C5	1,000V – 1,499V
	C6	1,500V – 2,999V
	C7	>= 3,000V

What damage does ESD cause in an electronic device?

There are basically two categories of damage from ESD:

- *Catastrophic damage* – the electronic device is rendered inoperable immediately after the ESD event. A semiconductor junction or a connecting metallization could have been damaged by the electrostatic discharge.
- *Latent damage* – the electronic device appears to be working fine following the ESD event. However, the sensitive circuitry has been damaged and could fail to operate properly at some time in the future.

Detection of static charges in the work area.

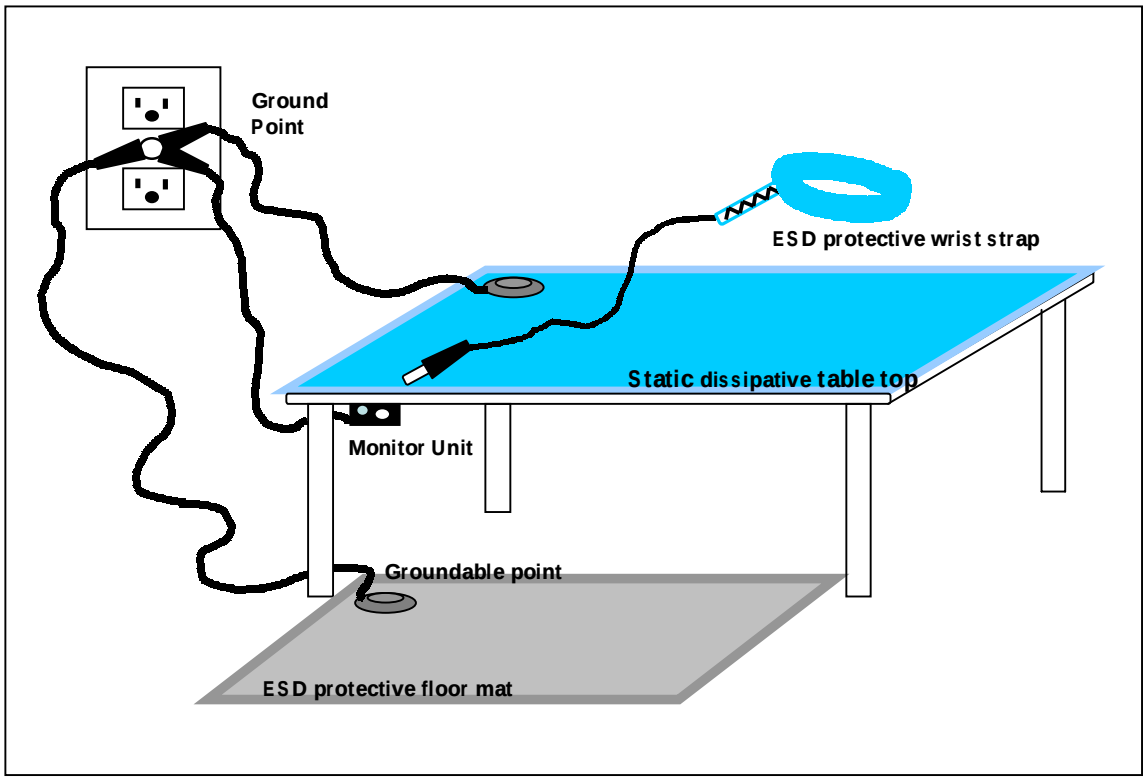
A commonly used tool for the detection of static charges is the electrostatic field meter. This tool, when used in conjunction with regular audits on the production floor, is very effective in detecting the presence and magnitude of static charges. Care should be exercised to ensure adherence to the measurement distance as the meter is calibrated to specific distances from the measuring plane. Please consult the user's guide on the correct measuring distance for the specific electrostatic field meter model that is being used.

Protection for Electrostatic Discharge Sensitive (ESDS) devices.

- Work area:
  - It is essential to handle ESDS devices at static-safe workstations. This will prevent yield loss (through catastrophic damage) or, worse, potential reliability failures in the field (through latent damage).
  - Where it is impractical or impossible to use antistatic wrist-straps or remove items that are composed of insulative materials at a static-safe workstation, use an air ionizer designed to neutralize electrostatic charges or apply topical antistats to control generation and accumulation of static charges.
  - When an air ionizer is utilized, it is vital that maintenance procedures and schedules are adhered to in order to ensure that ions generated by the ionizer are sufficiently balanced.
  - Avoid bringing sources of static electricity (as shown in page 1) within 1 meter of a static-safe work bench.
  - Where it is necessary to use air-guns, use special models that do not generate static charges in the air stream.
- Personnel:
  - Any accumulated charge on the body of the human operator should be discharged first before opening the protective container with ESDS devices inside. The discharge can be accomplished by putting a hand on a grounded surface or, ideally, by wearing a grounded antistatic wrist-strap.
  - The use of an antistatic smock for each worker is highly recommended.
  - Education and training on ESD preventive measures is invaluable.
  - A regular audit is also helpful in supporting an ESD program.
- Packaging and Transportation:
  - ESDS devices should be contained in a static protective bag or container at all times during storage or transportation.

Static-safe work bench.

The diagram below shows a typical static-safe work bench. The table top is covered by a static dissipative mat which is grounded through a 1 Meg-ohm resistor. This resistor is required in order to protect the users of the static-safe work bench – in the event that the ground becomes electrically live, the resistor will prevent electrical shock at the work bench. The same safety requirement holds true for the antistatic wrist-strap as well.



What materials are suitable for dissipating static electricity?

It is recommended that static dissipative materials are used as the medium (e.g. mats, containers) for discharging static charge to ground. These materials have the following properties:

Surface resistivity: 1 x 10^5 to 1 x 10^{12} ohms/sq
Volume resistivity: 1 x 10^4 to 1 x 10^{11} ohm-cm

Cautionary note: Materials which are conductive (e.g. stainless steel surfaces) are not recommended for use as a static-safe work surface; the low electrical resistance could result in a transient-like (surge) discharge of static electricity. A rapid discharge is far more damaging to the electronic device than a gradually paced discharge through a static dissipative material.

An example of a static-safe work bench (at Electrical Test).

The picture below shows an example of a static-safe work bench. It is vitally important that the wrist-strap and the table mat are securely grounded (through the 1 Meg-ohm safety resistor). In addition, all other materials with which the products come into contact must also be static-safe. The use of an antistatic floor further enhances the protective capabilities of a static-safe work environment. The worker should also wear an antistatic smock.

An example of a Static Control Test Station.

The picture shows an example of a test station used to determine whether antistatic wrist-straps or antistatic shoes are working properly.

A green test indicator light means the wrist-strap is worn properly and is working as intended. This picture shows the configuration for testing wrist-straps. The test station can also be configured to test antistatic footwear.

Antistatic footwear.

Where a wrist-strap is impractical, e.g. the job requires the worker to walk from one location to another, it is recommended that antistatic footwear such as antistatic shoes or heel-straps are worn. The picture on the right shows an example of an antistatic heel-strap with the grounding cord running into the socks to make contact with the skin. It is also necessary to use an antistatic floor (e.g. conductive floor tiles) to work together with the antistatic footwear.

Labels to identify electrostatic discharge sensitive (ESDS) devices.

The following labels are commonly used on containers and packaging to alert anyone who handles the ESDS devices on the need to use static-safe procedures before handling the devices. The one on the left is preferred.

The following verbiage should be placed beside the label:

CAUTION
Contains parts and
assemblies susceptible to damage by
Electrostatic Discharge (ESD)

References

ANSI/ESD S8.1-1993
"ESD Awareness Symbols"

ANSI/ESD S20.20
"ESD Association Standard for the Development of an Electrostatic Discharge Control Program"

ESD STM5.1-2001
"Electrostatic Discharge Sensitivity Testing -- Human Body Model (HBM) Component Level"

MIL-HDBK-263
"Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding electrically-initiated explosive devices)"

MIL-STD-1686C
"Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding electrically-initiated explosive devices)"

JESD625-A
"Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices."