ESD – BOOK

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ESD BOOK

Protection from electrostatic discharges in the electronic environments

Preface

This publication is intended to help users in understanding and prevent the Electrostatic Discharges Phenomena, it is not a substitute for reference to the ESD or Safety Standards The information given in this ESD BOOK is based on CEI/IEC 61340-5-1: 1998 and CEI/IEC 61340-5-2/TS:1999 published by the International Electrotechnical Commission, 3, rue de Varambe, Geneva, Switzerland. (www.iec.ch).

It is recommended to buy the IEC 61340-5-1 Technical Report and IEC 61340-5-2 Technical Specification, or their national versions, as IEC documents, they have world-wide applicability.

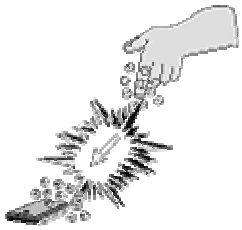
Standards

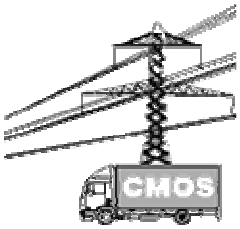
IEC 61340-5-1:	Protection of electronic devices from electrostatic phenomena – General requirements (1999)
IEC 61340-5-2:	Protection of electronic devices from electrostatic phenomena – User Guide (1999)
IEC 61340-4-1:	Electrical resistance of floor coverings and installed floors
ANSI/ESD S20.20-1999:	Protection of Electrical and Electronic Parts, Assemblies and Equipment USA 1999 (download free in pdf format, source www.esda.org)
ANSI/ESD S541-2003:	Packaging Materials for ESD Sensitive Items USA - 2003 (download free in pdf format, source www.esda.org)

What is ESD?

Electrostatic discharge is defined as the transfer of charge between bodies at different electrical potentials. The electrostatic charge occurs when two different materials rub or slide together or are separated.
Examples are: walking over synthetic floors, rubbing of synthetic garments, shifting of plastic boxes, unrolling of PVCadhesive tape, moving of conveyor belt

When two objects with different charges get closer, electrons can suddenly flow from one object to the other.





ESD can also occur when a high electric field develops between two objects in close proximity.

ESD can results in:

Static generation typical voltage levels		
Means of generation	10-25% RH	65-90% RH
Walking across carpet	35000 Volt	1500 Volt
Walking across vinyl tile	12000 Volt	250 Volt
Worker at bench	6000 Volt	100 Volt
Poly bag picked up from bench	20000 Volt	1200 Volt
Chair with urethane foam	18000 Volt	1500 Volt

Device type	ESD susceptibility
CMOS	250 - 3000 Volt
OP-AMP	190 - 2500 Volt
VMOS	30 - 1800 Volt
MOSFET	100 - 200 Volt
GaAsFET	100 - 300 Volt
EPROM	100 Volt
JFET	140 - 7000 Volt
BI-POLAR TRANSISTOR	380 - 7000 Volt
SCHOTTKY DIODES	300 - 2500 Volt
SCHOTTKY TTL	1000 - 2500 Volt

Materials

For ESD purposes, many materials are classified by their resistance or resistivity characteristics.

Shielding materials	from 0 to 10^3 Ω
Conductive materials	from 0 to 10^5 Ω
Static-Dissipative materials	form 10^5 to 10^12 Ω
Insulative materials	> 10^12 Ω

Surface resistance measurements are not always appropriate to establish the effectiveness of the materials, where resistance is higher than 10^10 Ω, or where the material is of non-homogeneous woven it is mandatory to measure the “decay time of the generated charge”

SHIELDING MATERIALS: providing a Faraday cage protection, limit the passage of current and attenuate the energy resulting from an electrostatic discharge. Most static shielding materials include a conductive (less than 10^3 Ω) metal or carbon element that suppresses the field, attenuates, or reflects field energy.

CONDUCTIVE MATERIALS: characterised by a low electrical resistance (less than 10^5 Ω), allow the charge to quickly distribute itself throughout the material. If the conductive material is connected to ground, all charge will flow away. Some examples of conductors are metals, carbon and the human body's sweat layer.

STATIC-DISSIPATIVE MATERIALS: are defined as those having a surface resistance greater than 10^5 Ω but less than 10^12 Ω. Charges will flow to ground slower than with conductive materials, reducing its destroying potential.

INSULATIVE MATERIALS: are defined as those having a surface resistance of at least 10^12 Ω. Insulative materials have a high electrical resistance and are difficult to ground. Static charges remain in place on these materials for a very long time. This property make insulators a hazard that must be controlled as part of an ESD program. Some examples of insulators are common plastics, glass and air.

Controls

ESD damage can occur at any time:

GOODS INPUT
ACCEPATANCE
PRODUCTION
ASSEMBLY
TESTING
STORING
PACKING
SHIPPING
MAINTENANCE

Basic ESD controls:

GROUNDING
SHIELDING
NEUTRALIZATION (ionizers)

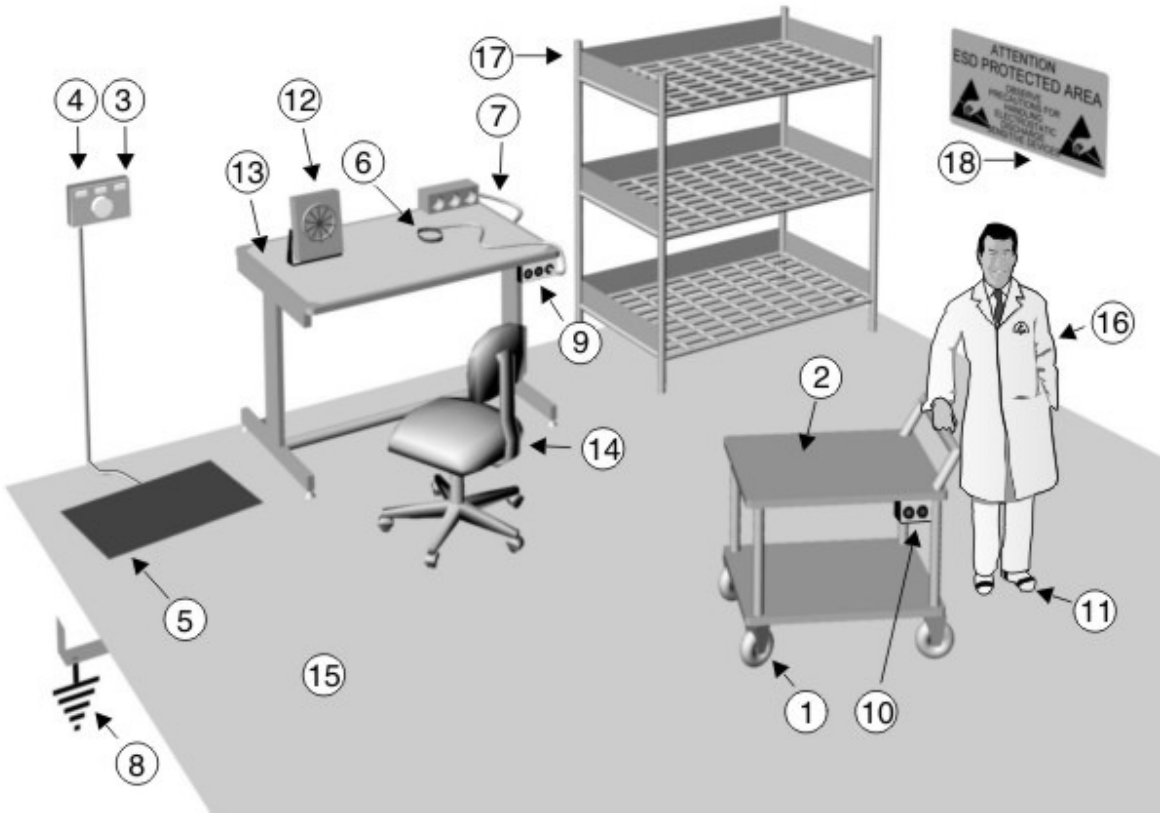
4 gold rules:

1. Assume that all active components are sensitive to ESD
2. Handle electronic components only in the ESD protected area (EPA) and only when you are properly grounded.
3. Store and transport the ESD-sensitive items in ESD protective containers.
4. Check regularly the ESD protection system, internal and external (suppliers)

Take in evidence the principle "No Charge/No discharge", the elimination of charge build-up is obtained by using conductive and dissipative materials that have less tendency to generate static charges. All equipment must be free of moving parts that may generate charges, e.g., rubber rollers, plastic stoppers, etc. Things which the devices may come in contact with or get transported onmust also be antistatic or conductive. The use of ionizers to neutralize newly generated charges will also prevent charge build-up. The minimization of movements in the work area, as well the use of ESD-safe equipment, will help in minimizing static charges generated by personnel.

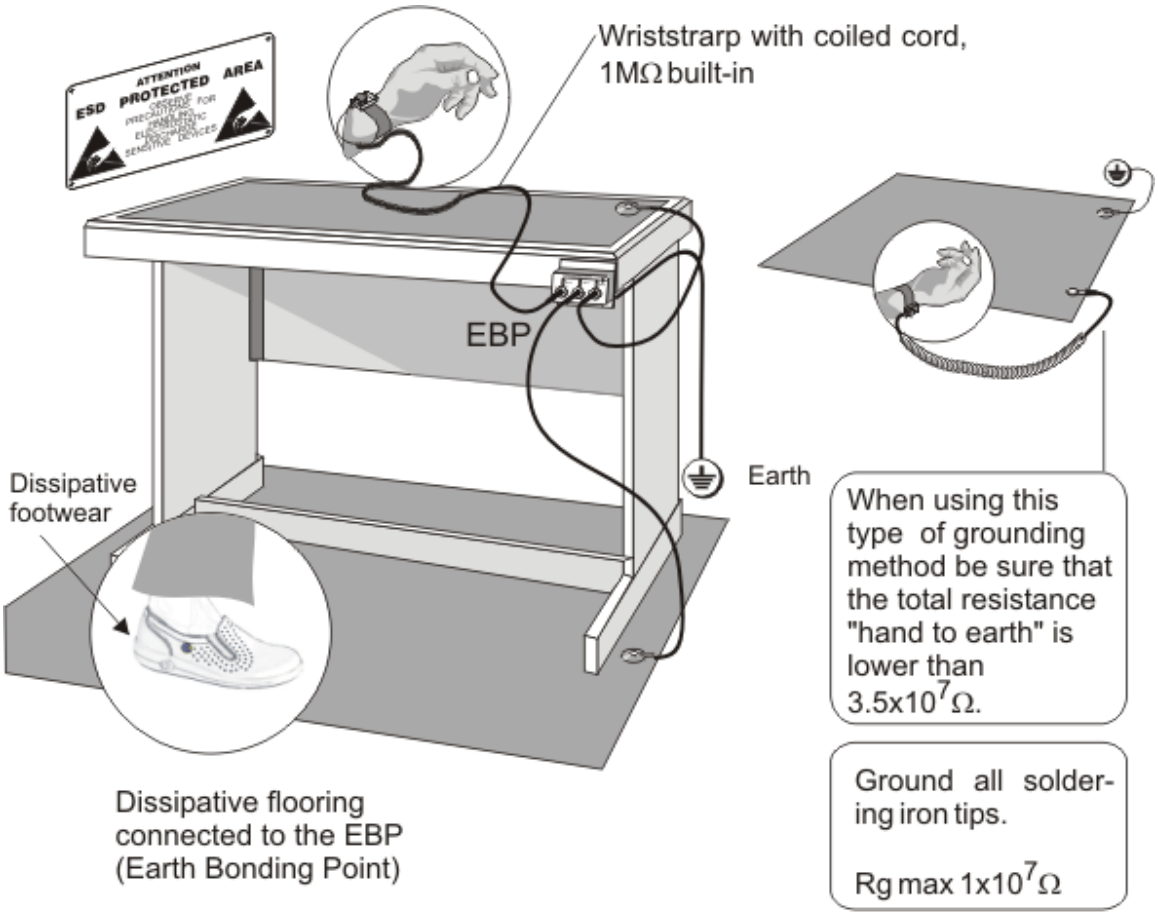
EPA area

An EPA (ESD Protected Area) is a defined space where no items or activity are able to cause damage to a sensitive device.
In the simplest case - a field work station - it may consist of a dissipative mat, a wrist strap and common grounding facility for both.



1) Groundable castors
2) Groundable surface
3) Wrist-strap tester
4) Footwear tester
5) Footwear foot plate
6) Wrist cord and wrist band
7) Ground cord
8) Ground
9) Earth Bounding Point (EBP)
10) Groundable point of trolley
11) Toe and heel strap (footwear)
12) Ionizers
13) Static-dissipative working surface
14) Seat with groundable feet and pads
15) Static-dissipative floor
16) Low charging garments
17) Shelvings with grounded surfaces
18) EPA sign

Typical workstation:



– Remove all extraneous materials from the workstation (food, beverages, combs, bags, clothing etc).

– Test the wrist strap/operator daily or install constant monitors.

– Inspect theESDgrounding connections, the mats, the EBP,weekly.

– Clean the surfaces with purpose-made antistatic cleaner, do not use commercial products, the cleanersmay leave a residue insulative layer.

Grounding

People are the primary source of electrostatic charges

The elimination of charge build-up is obtained by using conductive and dissipative materials that have less tendency to generate static charges. Grounding systems shall be used to ensure that components, personnel and any other conductors are at the same electrical potential. For proper and safe grounding the ESD ground must be tied directly to and at the same potential as the building or "green/yellow" ground.

Personnel grounding devices:

WRIST-STRAP	The wrist strap is the most used device to ground personnel, it will safely and effectively drain static charges from the body. Someone offers ESD Wrist straps without cord (cordless), we can assure that are ineffective.
FOOTWEAR	In some locations, such as stores and around equipment, conductive shoes or foot grounders are used. Foot grounders should be worn on both feet to ensure constant contact to ground floor or floor mat. Foot grounders will not function properly if used on surfaces which are insulative or improperly grounded.
GARMENTS	The main purpose for wearing conductive smocks is to suppress static fields on employee clothing. The conductive fibers woven into the material provide a Faraday cage that prevents dangerous fields from extending to and damaging sensitive products. There shall be electrical conductivity between all parts of the garment.
GLOVES	ESD sensitive device can experience a damaging discharge if touched by a person, even if that person is properly grounded. Increasing the electrical path's contact resistance is one way to control the speed of the discharge. A good way to accomplish this is by wearing static dissipative cots and gloves.
CHAIRS	The resistance to ground from any part of the seat which may have contact with personnel, must be less than 10^10 Ω. At least two castors or feet must provide a path to ground.

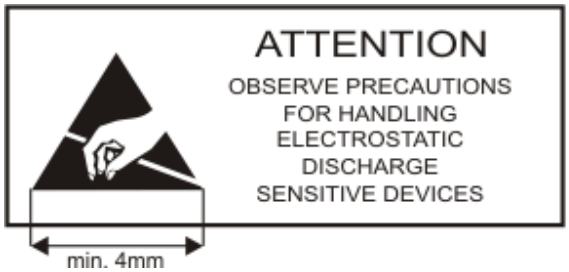
Labels

Basic symbol
The basic symbol consists of a yellow hand within a black triangle. It is intended to identify devices and assemblies which are ESD sensitive.

Protection symbol
Used to designate all ESD protective products such as bags, boxes, garments. A letter is added under the symbol to indicate the primary function:

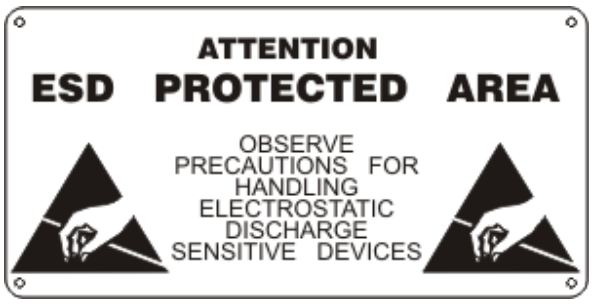
C	Conductive
D	Dissipative
S	Shielding
L	Low charging

EPA Symbol
Used to designate EPA equipments such as tables, trolleys, chairs.

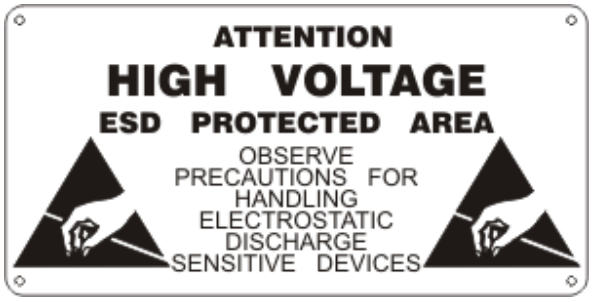


EPA cautionary symbol

Earth Bonding Point (EBP)



EPA warning sign



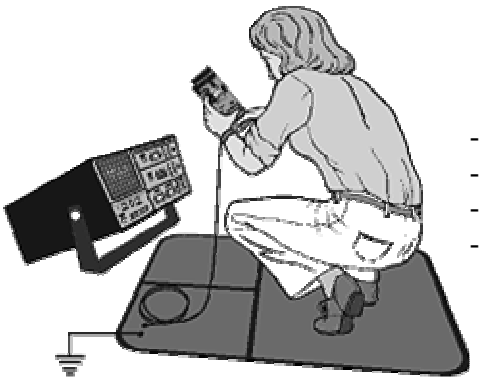
EPA which contain high voltage

The signs are designed to attract attention and deliver a clear message to personnel and visitors before they enter the EPA.
Where high voltages greater than 250VAC or 500VDC are present, use proper warning signs.

Field works

Field work is perhaps the most risky situation of handling ESD sensitive devices, it is also often the most neglected aspect of ESD damage prevention. The situation is risky as there are usually many potential ESD sources in the environment. Spare parts should be transported inside static shielding bags or containers . Where modules have to be worked on in an exposed state, staticdissipative
matting should be bonded to the product's electrostatic bonding point, and to the ground to act as awork surface.

Typical field service kit:



- Wriststrap with 1MΩ resistor w. coiled cord
- Static dissipative mat
- Grounding cord with 1MΩresistor built-in
- Lay ESD sensitive devices only on the mat

Packaging

The aim of ESD protective packaging is to prevent a direct electrostatic discharge to the ESDS item contained within and allow for dissipation of charge from the exterior surface. Packaging material will also often provide mechanical protection and protection against contamination by dust or humidity.

IEC 61340-5-1 defines three levels of packaging:

INTIMATE	in contact with the ESDS.
PROXIMITY'	does not make contact with the ESDS, but may enclose one or more ESDS
SECONDARY	mainly used to give physical protection, is kept away from ESDS and is not allowed in the EPA

	INSIDE TEH EPA		OUTSIDE THE EPA	
	INTIMATE	PROXIMITY'	INTIMATE	PROXIMITY'
ESDS	Either low charging and conductive or low charging and static-dissipative (for powered ESDS only low charging and static-dissipative above 1GΩ shall be used)	Low charging and electrostatic shielding or low charging and conductive or static-dissipative.	As for inside EPA	Electrostatic shielding
NOT ESDS	Dissipative or low charging		No requirements	

Note: where surface resistance >10^10 Ω is used, the material shall be procured with a T1000 < 2 sec

Caution in purchasing:
some packaging materials may be humidity dependent and may have limited shelf life, some other may contaminate or shed particles that cause production-related problems. (example: a too brittle hard foam).

Bags

Bags are classified in:

ANTISTATIC (low charge)
Use: Within the EPA for packing non-ESD sensitive items
Cost: Low.
Appearance: Clear or tinted (pink, blue, green)
Material: Polyethilene mono or multilayer.
Characteristics: 10^10 - 10^12 Ω. - T1000 < 2sec a 50% rH e 22°C
Shelf-life: Generally 1 year.

CONDUCTIVE
Use: Good degree of protection for many ESD sensitive items. Don't use with powered devices.
Cost: Medium.
Appearance: Black.
Material: Polyethilene with carbon added.
Characteristics: 10^3 - 10^5 Ω.
Shelf-life: More than 5 years.

SHIELDING
Use: For intimate packaging of all ESD sensitive items
Cost: High.
Appearance: Metallized semi-transparent.
Material: Generally a vacuum deposited aluminium between layers of polyesther and polyethilene film
Characteristics: Shielding bags meet the two main requirements: "low charging" and "electrostatic discharge shielding barrier"
Shelf-life: More than 2 years.

Ionization

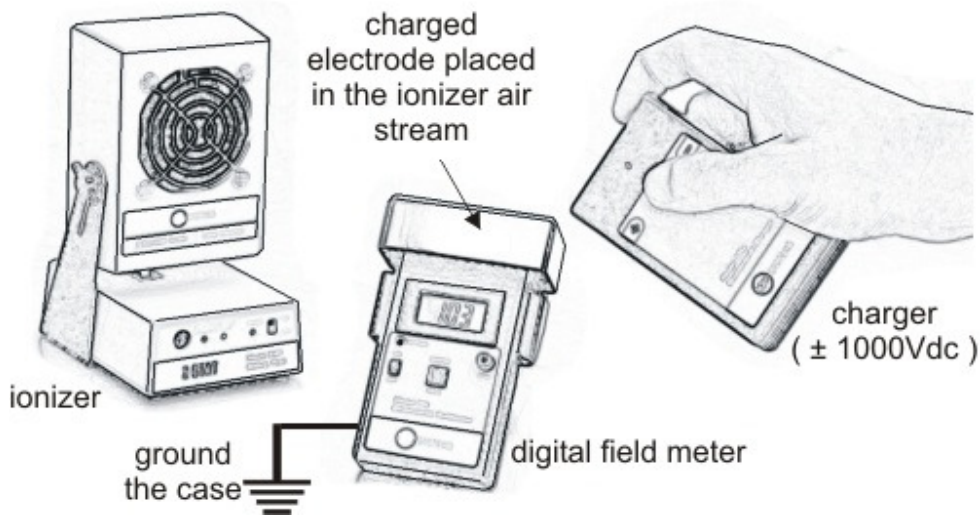
Where grounding of some equipment or parts of it through the traditional earthing techniques is impractical and where it is impossible to exclude all charging materials from the working area, the use of suitable ionizers is highly.
Air Ionization systems work by flooding the atmosphere with positive and negative ions. When the ionized air comes in contact with a charged surface, the surface attracts ions of the opposite polarity.As a result the static electricity that has built up on products and equipment is neutralised. Ions do remove small particles or smoke and pollens from the air, and subjective research suggest that peopleworking in ionized area are happier.

NUCLEAR: High maintenance required
AC: Low discharge time when using high volume blowers
DC: Very Lowdischarge time.

LOCAL (little ares): bench Ionizers, Ionizing bars, Ionizing guns.
COMPLETE (whole room): Manual Environmental Control and Automatic Environmental Control

Maximum Ozone generation accepted by law: 0.2 mg/m^3 (0.1ppm)
DC Ionizers with balanced ions emission are the best solution for local protection.

An ionization test kit can very quickly verify the proper functioning of an ionizer. The ionization test kit should be grounded and placed in the ionized airflow to measure the decay time and the balance of air ionization equipment, the charger is used to charge an isolated plate applied on the field-meter.



Humidity

The most significant environmental factor in ESD Control is the relative humidity (Rh).

When humidity in the working environment decreases, the human body and other insulators can easily charge with static electricity due to friction. The air itself, being dry, becomes a part of the electrostatic build-up mechanism, every time an air flow(wind, air conditioning, blower) come over an insulated surface. Relative Humidity shall be maintained over 30%.
Below that value it is recommended the use of ionization.

Environmental Monitoring.
Each EPA area shall be equipped with a Humidity / Temperature meter to record these data.These informations are useful to establish the distribution through the time ofESDrelated failures (needed to the "Failure Process Analysis").

Monitoring

ESD protection systems as wrist straps, foot grounders, work surfaces and floors need to be checked on a regular basis. This is an important requirement of the ESD standard IEC 61340-5-1.

PERSONNEL TESTING
The personnel grounding tester is a wrist strap and/or footwear tester to check personnel grounding systems before entering an EPA.
Check wrist straps and footwear twice a day.

FOR STANDING OPERATIONS
ESD flooring used with approved footwear,may be an alternative to the wrist strap system, in this case the standard is more restrictive and one of the following conditionsmust be met:
- the resistance of the person to the ground must be less than 3.5x10^7 Ω
- the maximum body voltage generation must be less than 100 volts.

It is easier to check the first condition, we suggest to use a Megaohmmeter with one lead attached to the ground and one electrode held by the person wearing ESDfootwear standing on the factory's protective floor.

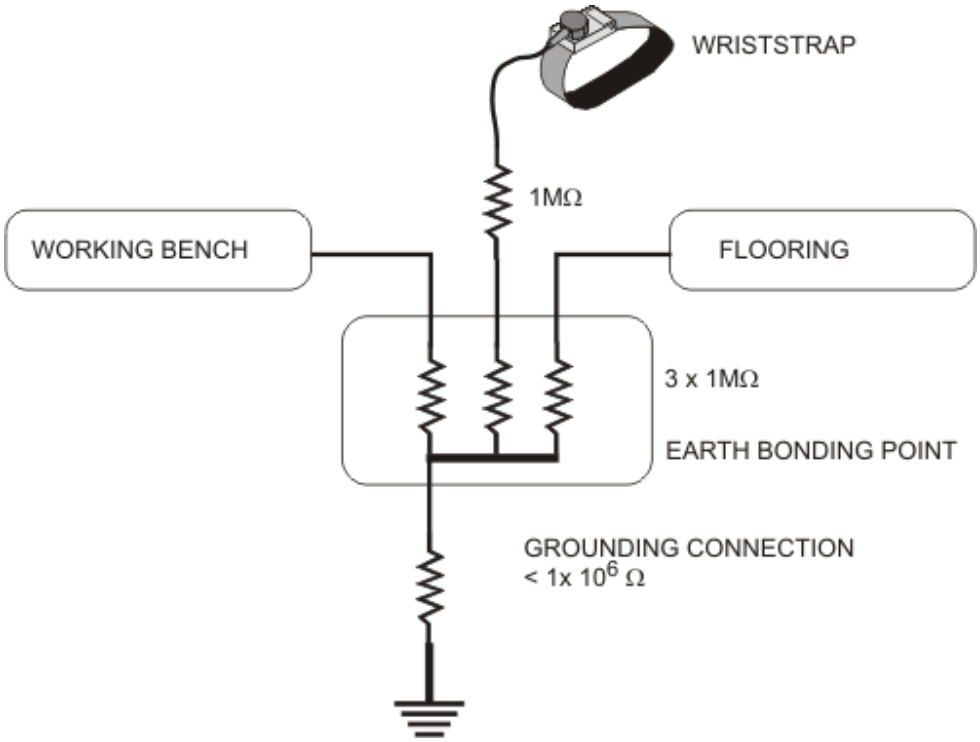
GARMENTS
Rsup < 10^12 Ω and charge decay T1000 < 2sec

GLOVES AND FINGER COATS AS WORN
750 KΩ < Rg < 10^12 Ω

EPA TESTING
Worksurface: 750 KΩ < Rg < 10^9 Ω
Floors: Rg < 10^9 Ω
Chairs: Rg < 10^10 Ω
Tools: Rg < 10^12 Ω

Safety

Before we get to the key issues of ESD control, it is important to note that personnel safety is paramount. In no way should an ESD control program replace or supersede any requirements for personnel safety.
In the factory, grounding personnel around the AC power line is a possible hazard. Personal grounding should not be used when working around voltages greater than 250VAC.
Although personal grounding items must include a 1MΩ resistor to limit current to less than 0.25 mA, ground fault circuit interrupters should be used.
Where high voltages greater than 250VAC or 500VDC are present, use proper warning signs.



Training

STANDARDS: purchase, read and get familiar with the IEC 61340-5-1 Standards

ESD TEAM: establish and organise an ESD Team responsible for the ESD control program.

TRAINING: train the operators to the use and check of personal protection, handling, etc. Sub/contractors and visitors shall be made aware of local ESD procedures.

VIDEO: some video training on ESD event, cause and effect, examples, demonstration, will get everyone aware of this important problematic.

SIGNALING: clear signs to identify the Electrostatic Protected Area or any ESD hazard, shall be widely and properly used to alert operators, or to draw their attention over protection.

DISCIPLINE: manager and technicians shall always respect the standards and quality procedure so as to give a good example to the operators.

Visitors

Visitors entering the EPA shall behave properly to prevent any ESD damage or danger. In case of a conductive floor they shall wear ESD heel and toe grounder, which also exist in the economic disposable version. It is recommended to wear an antistatic overall, and also a connected wrist-strap in case ofPCBor component manipulation.