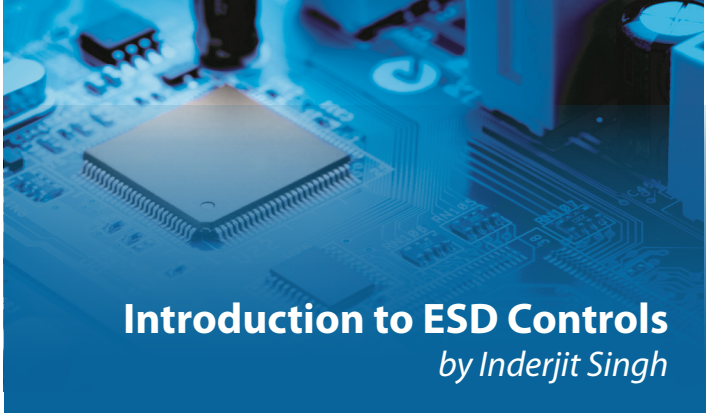


Introduction to ESD Controls

by Inderjit Singh

Introduction

This is an informative article on the various ESD controls that need to be implemented within an EPA (ESD Protected Area), the relevant standards / technical reports that will help and the verification needed afterwards to show continued compliance . After performing a basic Level 1 type ESD assessment of your manufacturing or production or assembly environment or lab – one has to then establish some or all of the necessary ESD controls within the defined EPAs . ESD controls include the following :

- Workstation / Worksurfaces / Wrist Strap System
- Grounding
- Static Control Garments (with Footwear)
- Seating
- Flooring (Wall)
- Hand Tools (incl Handling)
- Marking of EPA
- ESD Awareness Symbols (Signage)
- Packaging
- Transportation / Storage
- Ionization
- Automated Handling Equipment (AHE)

Refer to Figure 1 .

Figure 1 : ESD Controls

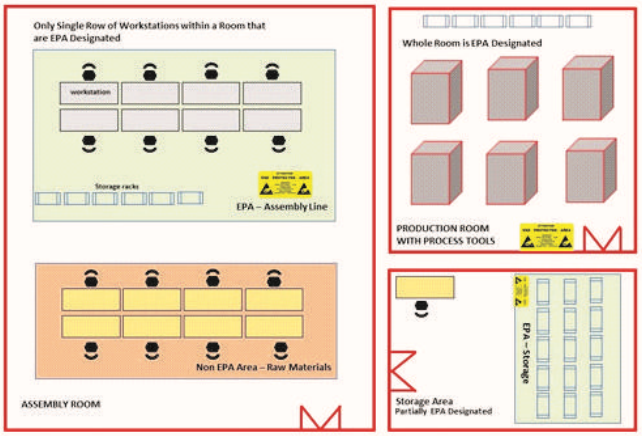
What is EPA (ESD Protected Area) ?

EPA refers to a defined location with the necessary materials, tools, and equipment capable of controlling static electricity to a level that minimises damage to ESD susceptible items . The level, type & criticality of the ESD controls to be implemented within the EPA will depend on the damage threshold of the ESD sensitive device being handled within each specific EPA . It is possible to determine the sensitivity of devices to each individual threat through specific experimentation . Refer to Figure 2 for an Example of EPA set up . The 2 models recognized widely today are

- Human Body Model (HBM) for simulation of discharges from personnel (especially for operations where operators handle the products directly)
- Charged Device Model (CDM) for simulation of discharges from charged devices including discharges caused by static induction – very common failure mode these days in most automated production floors

Having established the damage threshold, the relevant ESD controls can then be selected based on the criticality of each EPA wrt ESD damage based on HBM or CDM or both models, at each station or process line .

Figure 2 : Example of EPA



Personnel & Workstation

(Wrist Strap, ESD Mat, Continuous Monitor, Garments, Seating)

Worksurface / Wrist Strap & Continuous Monitors

The very basis first step is to ensure the worktable or workstation is at least static dissipative with resistance of less than 1GΩ . This can be achieved with a static dissipative laminate or by using an ESD mat (either vinyl or rubber) . Next step is to ensure that the operator working at a designated workstation within the EPA is appropriately grounded via a wrist strap . It is recommended to use a dual conductor type wrist strap plugged into a continuous workstation monitor . Depending on the type of monitor chosen - the continuous monitor can continuously not only monitor the wrist strap but also the ESD mat and other soft (<1GΩ) or hard grounds (< 10Ω though < 1Ω is preferred) . There are cheaper single wire type capacitive workstation monitors available as well which can be chosen though these types are less reliable and have their limitations on the number of operators or grounds these types can monitor .

Garments

Garments must all be static safe and choice of garments will also depend on whether the work is being performed in a cleanroom or just a controlled environment . Either a cleanroom coverall (jumpsuit) or smock type garment can be chosen . Grounding of the coverall type garment can be made via the footwear (assuming the flooring is ESD safe) but for those wearing the smock – the smock should be connected to a groundable point or workstation monitor though this might prove a safety issue as the movement of the operator might be restricted and could cause possible tripping or other hazard (proper safety evaluation has to be done before implementing smock grounding) . Alternatively the operator wearing the garment can be grounded via the static safe seating (chair, stool etc) when performing seated operations and/or assembly work . Similarly the garments should have a resistance of < 1 GΩ, though upto $1x10^{11}$ Ω is still acceptable for most applications . Footwear like shoes, booties are especially important for grounding especially when working on static control flooring and especially when walking within the production facility & within the EPA . The soles (inner and outsole) of the footwear are especially important and must be well maintained and clean to provide adequate grounding especially when a wrist strap cannot be used . It is preferred to have footwear with a resistance to ground (inner sole to floor) of between 1 MΩ ~ 1 GΩ (lower range is preferred) . Gloves should also be static safe and appropriately selected to have a resistance of less than 1 GΩ (the ESDA Standard Practice SP15.1 can be referenced to evaluate the resistance of gloves).

Seating

The chair or stool chosen should be static safe with preferably conductive castors so that the chair can be grounded via the flooring . Grounding chains are not preferred as these only make a very small surface area contact with the flooring . The chosen seating should also be comfortable even for the operator . Full stainless steel chairs or stools are fine but the hard seat will be very uncomfortable for the operators . The Point to Point Seat, Back Rest & Leg Rest resistance (PTP) and the Resistance to Ground (RTG) should also preferably be < 1 GΩ .

Equipment
(Ionizers, Hand Tools, Automated Handling Equipment)

Ionizers

Ionizers should be appropriately chosen to neutralise process insulators or isolated conductors and to keep the charge levels well below the susceptibility levels of the product(s) being assembled or handled . The types of ionizers to be chosen (refer to Figure 3) will depend on the following :

- Effective coverage area required (the type of ionizer selected will depend on the area to be effectively covered by ionization)
- Purpose of having ionization (Contamination control , ESD control or for other issues for eg : microprocessor lock up)
- Specification of ionizers in terms of balance/Offset voltage, decay times (1000V to 100V or 1000V to 50V decay) - This depends a little on the damage threshold of the part or component based on the human body model or charged device model
- Environmental conditions like Temperature, RH (the lower the RH , the higher the static charge build up)
- Ease of maintenance

Generally for fast neutralization a fan type ionizer is required, especially for general assembly workstations / tools / process equipment . If there is sufficient external HEPA/ULPA filtered airflow, especially, in cleanrooms and clean air benches or mini environments – bar type or ceiling ionizers can be used .

Generally the offset voltage should be kept below ±35V as recommended by ESDA S20.20 but this should not be blindly followed as the offset voltage is inversely proportional to the decay time especially for bar type and ceiling ionizers . In areas where fan type ionizers cannot be used like in unidirectional airflow type cleanrooms and clean benches (minienvironments), as turbulence might be created, using a bar type ionizer will be ideal but the balance and decay times will generally be higher unless an air assisted type ionizing bar (using CDA/ N2) is used . Generally for bar type and ceiling ionizers - if the offset voltage is low and there is very little external airflow then the decay times will generally be higher. However if one can explain via risk assessment that the work area and product is still appropriately covered & protected with ionization at an offset voltage of greater than then ±35V – then this is acceptable – be proactive and provide justification when specifications are a little different from the standards or reference documents .

Figure 3 : Types of Ionizers

Hand Tools

Hand tools like battery powered or electric screw drivers, torque wrenches, soldering irons, pneumatic tools and even tweezers should be selected such these are static safe and do not create unnecessary charges during use via tribocharging . For battery or electric powered tools like soldering irons, these need to be assessed for electrical leakage and have to be well grounded with a tip to ground resistance of less than 2Ω . Hand tools that are not electrically powered like tweezers, pliers, wire cutters etc need to be grounded thro' the ESD worksurface and the (grounded) person using the ESD safe (either conductive or static dissipative) tools . There are continuous monitors available that be used to monitor the resistance of the soldering iron / electric screwdrivers, if required .

Automated Handling Equipment (AHE)

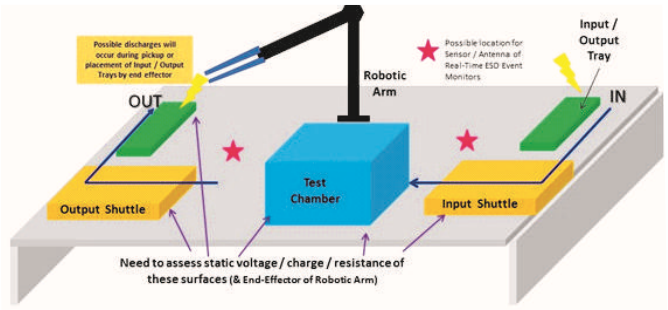
AHEs like IC Test handlers, Pick & Place tools, Wafer / Reticle Handling & process tools need to be tested to ensure the product (or DUT – Device Under Test) is well protected as it is processed within the AHE . The following measurements should be made with reference to Figure 4 :

- Resistance Measurement of machine components (using a ohmmeter or ground integrity meter for resistance to ground measurements and megohmmeter for conductive or static dissipative materials incorporated within the tool)
- Voltage measurements (either non-contact measurement using a voltmeter & probes or contact measurements using a HIDVM, High Impedance Contacting Digital Voltmeter) . Non contact measurements can be done via static field probes and contact measurements can be made on the pins of the DUT at different stages of the device path within the AHE and/or on the machine components that make contact with the DUT .

The AHEs should be designed with the following considerations :

- equipment or machine components are made of static dissipative or conductive materials and grounded – especially if these are within 15cm (6") of a static sensitive device's critical path
- all insulative materials within 15cm (6") of the the same device's critical path should be shielded, coated, plated or otherwise rendered static safe – this includes product transfer systems such as conveyors / robotic arms etc
- where possible all machine components that contact device leads should be static dissipative and grounded so as to prevent CDM (Charge Device Model) type damage
- all device pick up mechanisms such as vacuum cups, grippers or nozzles should be conductive or static dissipative and grounded
- all designated ground points should all be directly connected to the EGC (Equipment Grounding Conductor) with resistance of < 1ohm or less
- all machine conductors like wires & components that are relied upon to provide a ground path should be connected to the tool's EGC
- All surfaces where static sensitive devices need to be placed – should be made of static dissipative materials and grounded
- Ionizers should be incorporated where necessary to keep static levels and charges at manageable levels . The specifications of ionizers will depend on the ESD damage threshold of the sensitive items handled

Figure 4 : Schematic of a AHE, showing possible measurement locations



Besides making resistance and voltage measurements – an ESD event monitor with a calibrated antenna can be used to determine the number of ESD events occurring and the captured discharge voltages above the set threshold level as determined based on CDM model . Depending on the type of ESD event monitor selected – antennae should be placed at different locations of the AHE and events monitored in dynamic mode and recorded via an appropriate monitoring software on a laptop while the AHE is operating over a period of time . The antennae can be located at load / unload and pick / place areas, amongst other tool-specific locations .

Environment
(Flooring, Marking, Signage)

Flooring

One of the most important ESD controls is static safe flooring . Having a static control flooring (either conductive or static dissipative), in my opinion, is the first step towards establishing an optimal EPA . Contact & separation of (personnel) footwear on the floor can cause several thousand volts to develop on the personnel – therefore the need to

have an ESD safe floor . Having a static control (ESD-safe) flooring will enable easy grounding of personnel via the footwear, storage racks, mobile equipment, seating amongst others . Static control flooring can be in the form of epoxy / polymeric flooring, vinyl / rubber tiles and laminated raised (access) flooring amongst others . Static control flooring can be expensive and in some instances if the flooring has already been done and is insulative, then other options like floor mats & static control coverings at specific EPA workstations can be explored . Take note that in seated operations the operator still needs to wear wrist straps per ESDA S20.20 requirement, even though there is static control flooring installed .

Marking & Signage

Ensure that the EPA is clearly marked out on the floor using approved (ailse) marking tape with the proper ESD symbols . For signages there are actually three specific signs / symbols that apply for ESD controls, ESDS sensitive devices and common point ground points .
Refer to Figure 5 .

- ESD Susceptibility Symbol :
  Used on assemblies & devices that have a sensitivity to ESD events (classification can be incorporated in symbol eg : 1A …) – can be feature on signs signifying ESD safe environments or rooms and pasted on entrance to rooms or on stickers used to close or seal ESD packaging to indicate that materials inside the package are ESD susceptible
- ESD Protective Symbol :
  Used to identify items that are specifically designed to provide ESD protection for ESDS assemblies & devices – eg : this symbol is used on static shielding / dissipative bags, chairs, garments, workstation equipment etc
- ESD Common Point Ground Symbol :
  To indicate an ESD common point ground, defined by EOS/ESD S6.1 as a grounded device where 2 or more conductors are bonded

Figure 5 : ESD Signages / Marking Tape

Transportation & Packaging

(Packaging, Racks, Mobile Equipment)

Packaging

The purpose of having proper packaging is to provide physical / environmental protection, security & ESD protection of the ESD sensitive device as these are transported between the different assembly & final packaging location . Packaging involves Tapes, Labels, Bags (Shielding / Moisture Barrier), Totes / Boxes, Cushioning Foam, Air Bubble wrap, Injection Molded Trays, Stretch wrap & Shrink wrap – basically anything used in transportation . ESD Protective packaging has properties that prevent static electricity from damaging the packaged items – there are three broad categories defining ESD safe packaging :

Low Charging (Antistatic) Material Property

- Basically having a resistance that falls on the high end of the static dissipative range and only helps in reducing amounts of charge accumulation or tribocharging.

Resistance Material Property

- Using packaging that has resistance that is either conductive ($< 1x10^4$ ohms) or static dissipative where the resistance is $\geq 1x10^4$ ohms but less than $1x10^{11}$ ($1x10^4 \leq R \leq 1x10^{11}$ ohms). This type provides better control of charge accumulation.

Static Discharge Shielding Property

- Prevent fields and/or static discharge from reaching an item
- Uses a combination of conductive & dielectric materials to form a barrier (this is called "discharge shield")
- Most ESD sensitive items are packaged in these shielding bags at the Final packaging stations before leaving the facility

Transportation of ESD sensitive items outside an EPA requires enclosure in static protective materials, although the type of material depends on the situation and destination. Inside an EPA, low charging and static dissipative materials may provide adequate protection. Outside an EPA, low charging and static discharge shielding materials are recommended.

Storage Racks

ESD sensitive products & devices are to be stored on shelving that are constructed of conductive or static dissipative material and are to be properly grounded, either via the ESD safe flooring or directly to a groundable point . ESD sensitive and non-ESD sensitive parts should not be placed on the same shelving . All packaged ESD sensitive parts should not be opened within the shelves but at the appropriately grounded EPA workstation . Ensure that the different shelving storage tiers are grounded thro the connectors (metal or conductive type spacers) or via a metal plate or wire that connects all the different tiers to the rack's groundable point . ESD-sensitive parts in ESD protective packaging (ie, packed and sealed in appropriately selected ESD-shielding bags) need not be placed on grounded racks though such a practice of grounding these racks is a good insurance against ESD damage .

Mobile equipment

Same methodology of tier to tier grounding applies to mobile equipment like trolleys, carts, mechanised skids, storage carts with castors / wheels . The preferred method of grounding of these mobile equipment, if ESD safe flooring is present, is through at least two conductive castors OR a "fifth" ESD safe conductive, rack-grounder wheel if the castors are made of insulative materials . The contact surface area of the castors to the flooring is much larger than drag (SST) chains (eliminate the use of drag chains, if possible). If the production / transport area does not have ESD flooring in place then :

- Ensure that ESD sensitive parts/products are transported in ESD safe boxes/totes
- Ionizers are installed along the product travel / transport path
- Mobile equipment are physically connected to ground via a wire connected to an ESD grounding system prior to product loading / unloading at all workstations
  (NB : These applies to product transfer between EPA and non-EPA areas without ESD safe flooring as well)

Grounding

Grounding / Equipotential Bonding Systems shall be used to ensure that ESD Sensitive (ESDS) items, personnel and any other conductors that come into contact with ESDS items are at the same electrical potential. Besides personnel grounding via wrist straps as explained in an earlier section – all worksurfaces, flooring, walls, mobile equipment, racks, tools & equipment, product transfer mechanisms and items as mentioned in the preceding paragraphs – all have to be properly grounded and labeled . Poor or faulty grounding may result in personnel exposure to dangerous voltages, equipment malfunction or lockup, damage to sensitive components, high resistance and slow charge dissipation . All of the grounding conductors from each of the ESD Controls (ie, all of the items, materials, devices, tools & equipment used within an EPA for the control of static electricity) shall be terminated at the same electrically equivalent point – more commonly refered to as the ESD Common Point Ground and labeled. The ESD Common Point Ground could be a terminal strip or a bus bar . This will help to ensure that there is Equipotential bonding amongst the ESD control items which will ensure safe handling of ESD susceptible items as there would be no difference in the electrical potential between interconnected items . The ESD Common Point ground should then be connected to an Auxillary (Separate or Supplemental) Ground System or directly to the AC Equipment Ground . All Auxillary ground systems should be connected to the AC Equipment Ground wherever possible or else there might be significant different electrical potentials that could have an effect on safe handling of ESD sensitive items and proper operation of certain tools (electrical noise could be another consequence of this) . Ground cables should be kept as short as

possible and not coiled or bundled . Choose ground cables that show very little resistance increase vs length (18AWG ground cables are ideal) . Also do not conceal ground cables with high voltage or power cables . Refer to Figures 6 & 7 showing Workstation Grounding and a Basic EPA Grounding System with Common Point Ground Flowchart respectively .

Figure 6 : Example of Workstation Grounding

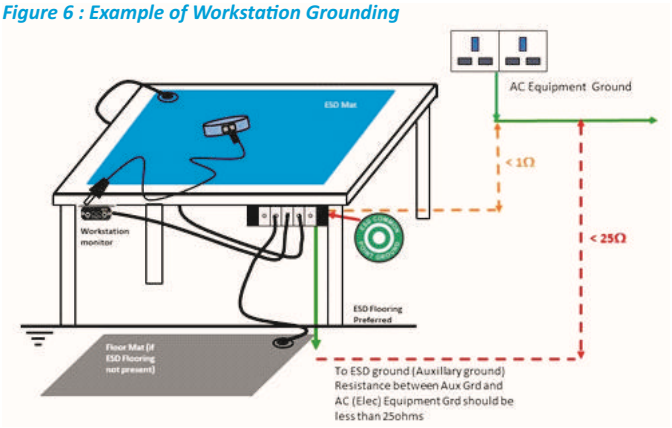
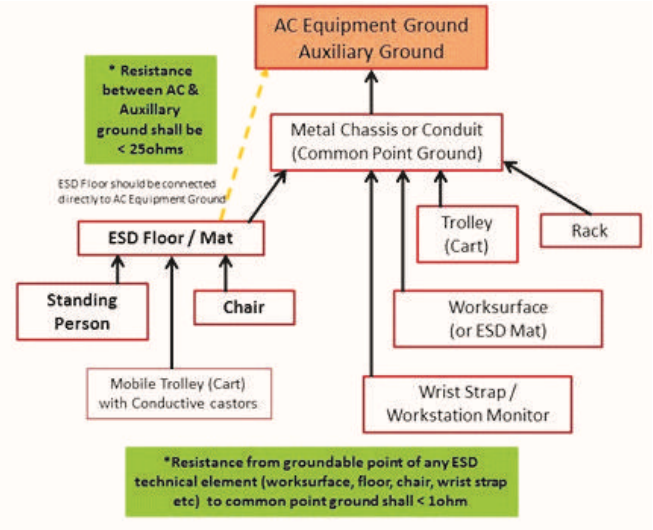


Figure 7 : Basic EPA Grounding System with Common Point Ground



Recommended Ground Resistance values :

- *Resistance between Auxillary Ground & AC equipment Ground : < 25ohms*
- *Resistance of conductor from ESD Common Point Ground to AC Equipment Ground : < 1 ohm*
- *Resistance of the Conductor from the groundable point of an ESD Control Item (eg : worksurface, floor, workstation monitor, hand tool, etc) to the ESD Common Point Ground : < 1 ohm*

Standards

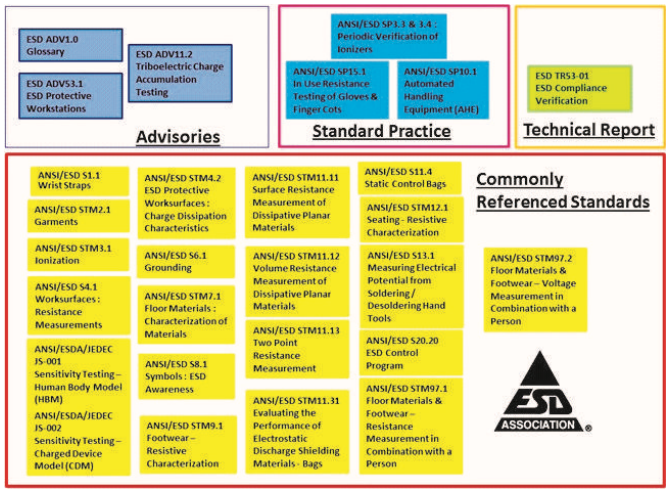
There are Official Standards, Standard Practices & Technical reports from the ESD Association (USA) that cover almost all ESD Controls as shown in Figure 8 .

Additionally for formulation of ESD Control Program Plan the following standards can be referenced :

- ANSI/ESD S20.20-2014 : Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
- IEC-61340-5-1 Protection of Electronic Devices from Electrostatic Phenomena – General requirements

These standards cover the requirements necessary to design, establish, implement and maintain an Electrostatic Discharge (ESD) Control Program for activities that manufacture, process, assemble, install, package, label, service, test, inspect or otherwise handle electrical or electronic parts, assemblies and equipment susceptible to damage by electrostatic discharges greater than or equal to 100 volts Human Body Model (HBM), 200 volts Charged Device Model (CDM) & 35V on Isolated conductors .

Figure 8 : ESD Standards, Advisories, Standard Practices & Technical report from ESDA



Compliance Verification (ESD TR53)

As with all organisation wide programs and plans, compliance verification is necessary to ensure continued compliance with all technical requirements and should cover field testing procedures, frequency of testing & measurement limits (acceptance criteria) . A good document that helps with this necessary compliance verification is the following technical report from the ESD Association :

- *ESD TR53 : Compliance Verification of ESD Protective Equipment & Materials*

This technical report covers the compliance verification testing for the following ESD Protective Equipment & Materials :

- Grounding / Bonding Systems
- Worksurfaces
- Wrist straps
- Footwear
- Flooring
- Seating
- Air Ionizers
- Mobile Equipment
- Electrical Soldering / Desoldering Hand Tools
- Constant (Continuous) Monitors
- Garments
- Packaging
- Process Required Insulators
- Isolated Conductors

Conclusion

Establishing ESD controls is the first step in formulating a decent ESD Control Program plan . Next step involves assessment & measurement of the ESD controls, correcting any faulty ESD controls and then re-assessing again . Once corrected and implemented, the next step is to establish a compliance verification plan and then training to ensure continued compliance to the implemented factory wide ESD control program plan. Continuous monitoring of the EPAs to ensure compliance can be done via the implementation of ESD event monitors, ionization monitors, workstation monitors, ground monitors, to mention a few, and other notable antennae and sensors to ensure that all the ESD controls are working well and your EPA is well protected . Any excursions will be flagged instantly and remedial action can be taken swiftly and effectively . This kind of a continuous monitoring program is part of the Industry 4.0 solution . This is the way forward …

About the Author :
Inderjit Singh is the Managing Director of Innospectra (Asia) Pte Ltd which provides static (ESD) & contamination control products, solutions and services for controlled environments . He is a ESD Certified Professional Program Manager (#081), iNARTE Certified ESD Engineer (#328) & NEBB Certified CPT Professional (CP-21477) with close to 30yrs of experience in the field of ESD and Microcontamination control .