

REQUIREMENTS ON A CLASS “0” EPA – BASICS, STANDARDS, ESD EQUIPMENTS AND MEASUREMENTS

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INTRODUCTION

Lately, more and more publications report about ESD requirements for an EPA „class 0“. What does this mean? This point is not described in the ESD standards ANSI/ESD S20.20 and the IEC standard IEC 61340-5-1. The electronic industry follows these rules when it comes to the protection of electronic components and assemblies against electrostatic discharges. Only one standard divides electronic components into certain hazard classes, the HBM standard IEC 61340-3-1 (ANSI/ESDA/JEDEC JS-001-2012).

Table 1. Classification

Classification	Voltage range (volt)	Notes
0A	< 125	
0B	125 to < 250	
1A	250 to < 500	
1B	500 to < 1,000	
1C	1,000 to < 2,000	
2	2,000 to < 4,000	
3A	4,000 to < 8,000	
3B	≥ 8,000	

According to this classification, class “0A” means a maximum electrostatic voltage of 125 volt. Class “0B” means an electrostatic voltage between 125 and 250 volt. The typical requirement for an EPA according to the ESD standards (ANSI and IEC) is a maximum electrostatic voltage of 100 volt. At the moment, the requirements for the electronic industry are higher than for other industries. Most of the EPAs meet these requirements.

Some semiconductor manufacturers demand a voltage of 0 volt for their electronic components within the handling area of an EPA. Is it possible to implement such requirements? Most of the ESD equipment on the market only grants the requirements up to 100 volt. Thus, how does the material have to be developed? Currently, only special ionizers are suitable to meet the target. Typical ionizers only guarantee a minimum of 100 volt, high specialized ones 10 volt (residual charge or balance). An optimized ESD Control System for machines with focus on cost-effectiveness is presented later.

All electronic components and assemblies are exposed to risks of electrostatic discharges. Producers, suppliers, distributors and users have to perform the ESD control system during the whole manufacturing process, the measurements as well as during the applications. All active electronic components, beginning with simple diodes, transistors or complex inner circuits, require an external ESD control system. In the next step, SMD resistors and condensers, and prospectively NEMS and MEMS are included in this danger category. Tests show that these passive components can be damaged through electrostatic discharges.

The structures of electronic components become smaller and smaller. 5 volt of an electrostatic charge are already enough to change the structures in small electronic components. The structures will achieve such small dimensions, so that electrostatic charges can cause permanent damages. In the year 2024 the sizes of the electronic components will be less than 10 nm. Then, electrostatic charges of 0.1 nC and electrostatic fields of 10 volt /cm (or 1000 volt /m) will be enough to damage ESDS permanently.

BASICS

The person is the greatest danger for electronic components. Electrostatic charges of a person are typically higher than 100 volt. The best way to reduce the electrostatic charge of a person is grounding. We have two ways for personal grounding: wrist straps and ESD shoes. The wrist strap contact with the skin of the person directly. So, the final charge of a person can be smaller than 100 volt. Many companies use ESD shoes for grounding. In figure 1, the grounding resistance is shown depending on the body voltage. Typical values for system resistance are higher than 10 MOhm. This means that the body voltage is higher than 100 volt.

The first and best way for grounding is the connection with ESD equipment of personnel grounding. Grounding only by table mats and floor materials is not enough. Staff is uncontrollable and workstations are ESD conform. Nevertheless, how do machines, automated handling systems, packaging systems etc. work and which requirements they have to meet?

REQUIREMENTS ON ESD - MATERIAL AND DEVICES

Requirements for a Person

Persons have to be equipped with ESD required shoes and a conductive garment. The most important measure is the wristband.

The figure 1 shows the important relationship between the body voltage or electrostatic charge of a person and the resistance to ground. So, if we estimate a lower level for electrostatic charge, we need a lower limit for the maximum resistance between the person and the floor grounding connection. Figure 1 also shows that we need an alternate grounding path from the person to the floor grounding connection in the future. If the resistance between person and shoes becomes smaller ($< 1 \times 10^6 \Omega$), the total resistance between person-shoes-floor material is going to be smaller at all ($< 1 \times 10^6 \Omega$).

Table 2. Requirements for personnel equipment

Step	Requirements R_A		Notes
	Today	Future	
Wristband	$< 3.5 * 10^7 \Omega$	$1 * 10^6 \Omega ?$	
Shoes	$< 1.0 * 10^8 \Omega$ ($3.5 * 10^7 \Omega$)	$1 * 10^6 \Omega ?$	Higher requirements are necessary, when the grounding happens exclusively over the floor. Is the maximum resistance from $3.5 * 10^7 \Omega$ to high? Yes, the system resistance must be smaller than $1 * 10^7 \Omega$.
Working clothes	$< 1.0 * 10^9 \Omega$?	The first value can only determinate the surface resistance. The second important value is the charge decay time or charge distribution time from the surface. The charge decay time must be smaller than 2 s (from 1000 v to 100 v) ¹ .
Note: A new measurement method has to be developed to measure the static decay time of working clothes. The existing methods are not adequate any more.			

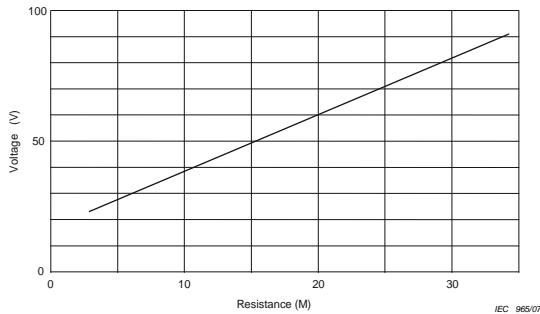


Figure 1. Body voltage relating to resistance to ground (IEC 61340-5-2 Ed. 1.0 TR, 2007)

Only a wristband can guarantee a permanent discharge of personal charge to a grounding point. Persons are connected by their wristband, so, no electrostatic charge can be generated. If a person has to walk around permanently because of his/her activity, the discharge can be performed through the shoes. In fact, the floor must be conductive. The shoes must have a defined resistance to ground (see table 2). Garments prevent the transfer of all electrostatic charges from normal daily clothes. If these measures are realized persons/employees are equipped against ESD.

Requirements for Working Places

Working places must be constructed like in the table 3 shown below. If it is constructed like this, no electrostatic charge can be developed. Furthermore, working place surfaces must guarantee that electrostatic charges can be eliminated safely. Additionally, working places must be equipped with a central grounding point like earth bonding points and earth bonding boxes. The resistance to ground of the working surface has a limited area. Table 3 shows different requirements for working places.

The resistance should not be too small. If it is too small a hard discharge (CDM method) can happen suddenly, which can damage ESDS. The limit of the upper resistance is defined in accordance to the fast and controlled, but still safe, discharge of electrostatic charge. At the same time the decay time is determined.

Table 3. Requirements for working place surfaces

Step	Requirements R_A		Notes
	Today	Future	
Working place surface	$> 7.5 * 10^5 \Omega$ and $< 1 * 10^9 \Omega$	$< 1 * 10^6 \Omega$?	$1 * 10^9 \Omega$ is too high and produce more than 1000 volt of electrostatic voltage. Surfaces with a resistance to ground about $< 1 * 10^6 \Omega$ lead to electrostatic charges higher than 100 v. Additionally, the discharge behavior of the surfaces have to be determined.
Decay time	$< 2s$ (from 1000 volt to 100 volt)	$< 2s$ (from 100 volt to 10 volt)	at a resistance value higher than $1 * 10^9 \Omega$ The measurement of the static decay time is necessary at $1 * 10^6 \Omega$.

Requirements for Floors

The floor is an important part of an ESD area. It is necessary for persons who do not wear any conductive shoes and whose discharge mostly happens over the floor. The electrical characteristics are shown in table 4. There are many experiences with conductive floors. Basically, conductive coverings are suitable because hard coatings (epoxy) have additional problems with the contact

resistance between person-shoes-floors is decisive. The reason for it is the basic principle of the discharge of charged persons. Tests with different floor materials showed that only a few of them are suitable. [2]

The additional measurements of the decay time are urgently necessary to qualify the material completely.

Table 4. Requirements for floors

Step	Requirements R_A		Notes
	Today	Future	
Floor	$< 1 * 10^9 \Omega$	$1 * 10^6 \dots 1 * 10^7 \Omega$	The system resistance is the most important value in the future for personnel grounding.
Higher requirements	$< 3.5 * 10^7 \Omega$?	Today: at a maximum electrostatic charge of 100 volt from a person, 10 volt will be the maximum in the future.
Decay time	$< 2 s$ (from 1000 volt to 100 volt)	$< 2 s$ (from 100 volt to 10 volt)	The measurement of the static decay time is required above a resistance from $1 * 10^6 \Omega$.

behavior. Some materials are not suitable. Previous tests made many questions like: Do the measurement probes and sample are suitable at all? Do the probes really establish the contact person-shoes-floor? Is the contact material of the probe maybe incorrect? Some interested parties have the opinion that contact material on probes do not agree with the reality. Other assumes that probes are not the reflection of the contact person-shoes-floor. A further question cause quite a stir: Can a person be standardized? Additional tests have been realized and will be realized in the future [1].

The basic requirements to conductive floors are not influenced through the tests. Electrostatic charges should be discharged over a conductive floor.

Extensive attempts show, that higher requirements have to be fulfilled at working places, where people work by standing. A higher resistance ($> 3.5 * 10^7 \Omega$) would develop electrostatic charge higher than 100 volt. There are different types of floors – floor coverings and floor coatings, which can be thin or thick. But the contact

Requirements for an EPA

For having an optimized protection of ESDS, ESD working places and working areas are necessary. The basic equipment: an ESD working place, which contains a conductive surface covering, a wristband and a grounding system. All equipment must be connected with a grounding point. That grounding point guarantees the same potential at all points of the working place.

The installation of ESD areas (EPA) is wiser. Because of the design of all materials and equipment, electrostatic potential above 100 volt cannot be developed. Nevertheless, if some should be developed caused by unsuitable packaging materials, one can discharge them without any danger.

After having equipped everything according to the ESD requirements - all persons, working places and so on - new sources of electrostatic charge will be seen. Persons and working places must be handled like the ESD requirements. The charges can be controlled.

Requirements for Packaging Material

The packaging requirements correlate with the IEC 61340-5-1 [4] (enumeration according to the standard) and will be introduced in the new packaging standard IEC 61340-5-3 (see table 5 and table 6).

concept guarantee a safe ESD control system as well as the protection of ESDS against electrostatic charges. We cannot find enough information and requirements for the machines in the existing standards.

Table 5. Packaging material inside and outside of an EPA

6.1 Inside an EPA	6.2 Outside an EPA
Packaging used within an EPA (that satisfies the minimum requirements of ANSI/ESD S20.20) shall be: <ol style="list-style-type: none"> 1. Low charge generation. 2. Dissipative or conductive materials for intimate contact. Items sensitive to < 100 volt Human Body Model may need additional protection depending on application and program plan requirements.	Transportation of sensitive products outside of an EPA shall require packaging that provides: <ol style="list-style-type: none"> 1. Low charge generation. 2. Dissipative or conductive materials for intimate contact. 3. A structure that provides electrostatic discharge shielding.
Notes: If electric field shielding materials are used to provide discharge shielding, a material that provides a barrier to current flow (insulator) must be used in combination with the electric field shielding material. Where this standard does not provide a test method, the user must determine the electrostatic discharge shielding properties of the packaging. See Appendix G for guidance about determining discharge shielding properties.	

Table 6. Requirements for packaging material

Material property	Resistance limits	Charge decay time	Requirements for class zero	Notes
Electrostatic conductive	$1 \times 10^2 \Omega \leq R_S < 1 \times 10^5 \Omega$	-	$(1 \times 10^2 \Omega) \leq R_S < 1 \times 10^4 \Omega$	Lower resistance range, add charge decay time
Electrostatic dissipative	$1 \times 10^5 \Omega \leq R_S < 1 \times 10^{11} \Omega$	$(> 1 \times 10^9 \Omega)$ $< 2 \text{ s}$	$1 \times 10^4 \Omega \leq R_S < (1 \times 10^{11} \Omega)$	Lower resistance range, add charge decay time
Electrostatic shielding	$< 50 \text{ nJ}$	-		Shielding or field shielding properties
Note: R_S ... surface resistance (IEC 61340-2-3)				

A third requirement is the question of tailoring. In the future, companies will have more responsibility for the art of the packaging material.

ESD Control Program

The introduction and the control of these 5 steps were already described last year in the concept "5 Steps Plan of an ESD Control System" [1]. The result is the following ESD control system:

1. Analysis of ESDS, their damage limits and the existing manufacturing process.
2. Creation of a program and the introduction steps of the ESD control system.
3. Personnel training
4. Introduction of the ESD control systems
5. Control and certification of the introduced ESD control systems.

The introduction of this ESD control system is more complex than the single system requirements of the IEC 61340-5-1 and the control program of the ANSI/ESD S20.20. Only both standards and the additional existing

Requirements for Machines

The first and only requirements are demands for a grounding of all metal parts as well as for the avoidance of plastic usage, which could generate electrostatic charges and fields. Experiences show that this is not enough for the protection of ESDS in automated handling machines and systems. ESDS will not be damaged by the operator, but by machines. The transport operation of an ESDS in a machine can happen as following:

1. Removal of the ESDS out of packaging is the first sub-process. The ESDS has an isolating case, so it will be electrostatically charged during the removal out of the reel or the tray.
2. The electrostatically charged ESDS will be transported to the PCB. Thereby a further electrostatic charge can develop. The movement at high speed Pick-and-Place System should be enough of the generation of electrostatic charges.
3. By placing it on the PCB, different potential between the ESDS and the PCB exist. So, the potential

difference leads to a discharge, which will damage the ESDS.

These examples show that electrostatic charges always develop when ESDS are parted or transported. Electrostatic charges will always generate because of the reason that components as well as PCBs are made of an insulating material. Other acts and production steps show, that this is not the only possibility for the generation of electrostatic charges in a production process. Further critical steps are for example: the printing of PCBs, the labeling of PCBs and assemblies as well as test constructions.

Manual handling of individual components is not common anymore. PCB assemblies are handled mainly by equipment and the final phases of mechanical assembly are done by both humans and robots. In consequence of this the Human Body Model (HBM) is not valid ESD simulation model as much as previous. The main electrostatic risk during automated manufacturing is with Charged Device Model (CDM) type of electrostatic discharges. The additional model, but not standardized yet, is the Charged Board Model (CBM).

In the CBM type of ESD the assembled Printed Wiring Board (PCB) or some of the mechanics parts can be charged during handling. The discharge to ground or between the objects can happen at the same time. CBM type of discharge is typically more seriously than other models for components due to high capacitance and high stored charge of PCB assemblies or mechanics.

There are some main ESD control principles which are important in ESD Protected Area (EPA) as well as in automated process equipment:

1. All conductive and dissipative items are grounded.
2. Materials or parts which are in contact with ESDS must be made of electrostatic dissipative material.
3. Non-essential insulating materials are excluded.
4. Where insulating materials or parts are needed, the possible charges must be minimized by special measures, like ionization, shielding or coating.

Enclosures of machines are normally made of conductive material. The conductive enclosure should have a straight and reliable connection to ground and the distance of the insulating parts should be long enough in order not to create high electrostatic fields close to ESDS. Special attention should be paid on grounding of parts which are separated from the enclosure or are movable, like adjustable conveyor.

There are a lot of materials which can be in contact with ESDS items. Components to be placed are stored in reels with plastic tapes covered and nozzle picks the component from reel. Components are placed on the PCB and PCB is

contacted with conveyor belts and possible support pins, gripper, clamps etc. All these materials should be made of electrostatic dissipative material at least in contact area and a resistance to ground value should be between $1 * 10^6 \Omega$ and $1 * 10^9 \Omega$.

Components and PCB material have plastic, insulating material and they can become charged by tribocharging, e.g. by rubbing against conveyor belt, touching on other product parts or in routing process. The charged ESDS item can subject to CDM or CBM risk. All rotating and sliding elements form an ESD risk. The tribocharging during automated manufacturing should be minimized and metal contact to ESDS should be prevented. Normally, these preventions are not enough. Thus, an ionizer should be installed in the area of rotating material.

Ionizers are applied sometimes to remove electrostatic charges from machines. Electronic components and PCBs cannot be grounded. Thus, ionization is the only method minimizing electrostatic charges at the moment. Intelligent ionizers are able to detect electrostatic charges in machines and to generate equivalent charges for their decrease either.

Requirements/Questions for an ESD control program for machines:

1. Are all parts grounded?
2. Is there no plastic material charged? Is only ESD plastic material used?
3. How does delivery of ESDS and PCBs happen?
4. Is the packaging material ESD conform?
5. How are the requirements for the packaging material for non ESDS defined?
6. How is the transport der ESDS inside of the machine defined?
7. If non ESD material is used (i.e. for high voltage wires), do the transportation ways of the ESDS have enough distance from this?
8. Are the PCB and the ESDS of the same potential when they get in contact? (i.e. in a pick-and-place-machine)
9. Are the PCB and the ESDS discharged enough?
10. Are the transport conveyors, belts and systems between the machines on the same electric potential?

Based on these questions, ESD requirements will be created for machines.

MEASUREMENTS

The most instruments on the market for measure electrostatic voltage, electrostatic charge and for resistance are not qualified for these correct measurements. Only special contact volt meters (CVM) or electrostatic static volt meters (EVM) are able to measure this very small electrostatic charge.

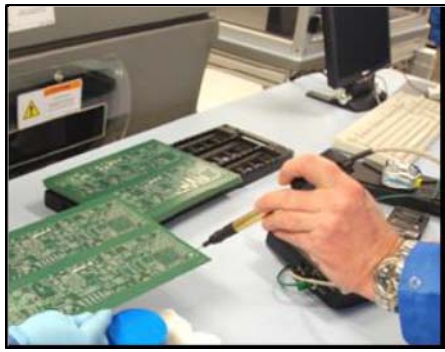


Figure 2. Measuring PC conductor with high an impedance contact volt meter [13]

The first step is the measurement with a contact volt meter. Furthermore, high sensitive electrostatic volt meter can be used. They do not damage ESDS during the measurement.

CONCLUSIONS

The requirements “0 volt” can be achieved, when die maximum value will be required. Unfortunately, today we do not have any ESD material, which requires these limits.

The biggest problems are machines and automated handling equipment (AHE), because very small charges are generated in these machines, independent from persons. These small and fast discharge procedures are energy-intensive. They cause damages of electrostatic sensitive devices and assemblies. The grounding of all metal parts does not suffice. New processes, which either discharge very small electrostatic charges fast or prevent these discharges, have to be developed.

The only way to meet such requirements is precision-ionization. All other ESD equipment have more than 0 volt. Even with a limit value of 125 volt (Level 0A) it is hard to find suitable ESD material. A further attempt is to classify ESD control areas in different zones.

1. Basic control requirements
2. Advanced control requirements
3. Extended control requirements

Until now, there are not any different requirements for these areas, defined in an ESD control program.

REFERENCES

[1] H. Berndt, Five Steps for the Introduction of an ESD Control System, Proceedings APEX 2004, Anaheim, CA, U.S.A.
[2] H. Berndt, A study of the Variables of Electrodes used in the Measurement of Table and Floor Materials and How They Affect the Test Results, 23. EOS/ESD-Symposium 2001, Portland, OR

[3] H. Berndt; VDE-Schriftenreihe - Normen verständlich - Band 71 Elektrostatik - Ursachen, Wirkungen, Schutzmaßnahmen, Messungen, Prüfungen, Normung, VDE-Verlag, 3. Auflage, 2009
[4] IEC 61340-5-1 Electrostatics - 08.2007: Part 5: Specification for the protection of electronic devices from electrostatic phenomena, Section 1: General requirements
[5] IEC 61340-5-2 Electrostatics - 08.2007: Part 5: Specification for the protection of electronic devices from electrostatic phenomena, Section 2: User guide
[6] ANSI/ESD S20.20-2007 ESD Association Standards for the Development of an Electrostatic Discharge Control Program for – Protection of Electrical and Electronic Parts, Assemblies and Equipment’s
[7] ANSI/ESD SP10.1-2007 ESD Association Standard practice for Protection of Electrostatic Discharge Susceptible Items – Automated Handling Equipment (AHE)
[8] A. Olney, B. Gifford, J. Guravage, A. Righter, Real-World Charged Board Model (CBM) Failures, 25. EOS/ESD Symposium 2003, Las Vegas, NV
[9] JEDEC Standard JESD22-C101-E, Field Induced Charged Device Model Test Method for Electrostatic-Discharge-Withstand; Thresholds of Microelectronic Components, December, 2009
[10] D.L. Lin, FCBM – A Field-Induced Charged-Board Model for Electrostatic Discharges,” IEEE Transactions on Industry Applications, Vol. 29, No. 6, pp. 1047-1052, November/December 1993.
[11] International Technology Roadmap for Semiconductors (ITRS), Factory Integration, Update 2011
[12] H. Berndt, Electrostatic Discharge (ESD) and the Technology Roadmap to 2020, Pan Pacific Microelectronic Symposium, January 2008
[13] White Paper 2: A Case for Lowering Component Level CDM ESD Specifications and Requirements, April 2010