ESD protection while handling LEDs

Application Note

Published by ams-OSRAM AG
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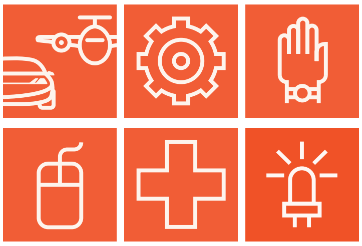
Application Note No. AN020



Valid for:
all products

Abstract

This application note gives a first idea of the extensive ESD protection topic. Because of the enormous scope and the complexity of the topic only some aspects could be essentially described and illustrated.

The application note provides information on where to get further and more detailed information on ESD protection. It is recommended to consult and use the appropriate standards, as well as the literature and the publications of the approved associations and committees.

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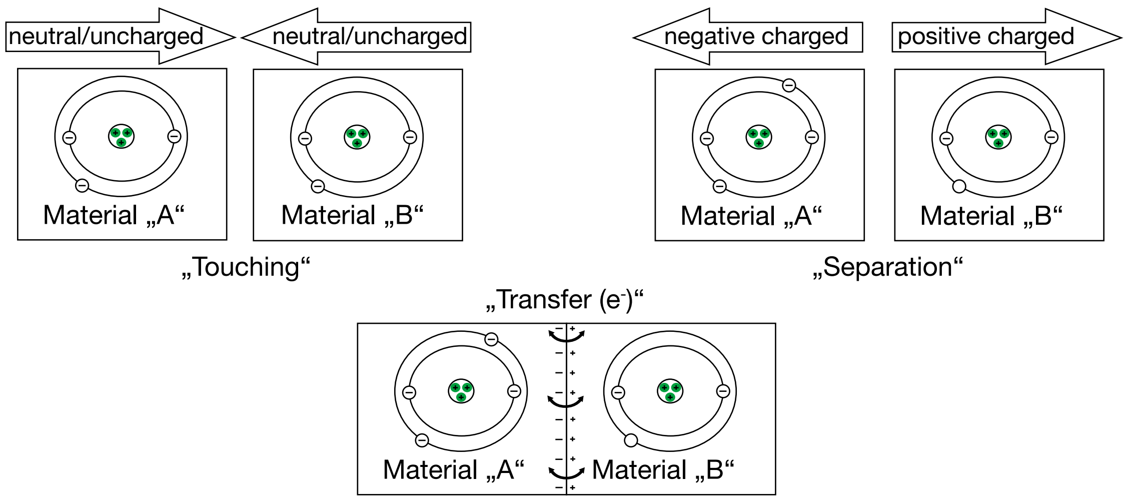
1 Fundamentals of ESD

As LED's become more efficient and more compact their sensitivity to ESD events is also increasing in most cases. Despite a great deal of effort in the semiconductor industry in the past decade, ESD still affects production yields, manufacturing costs, product quality, product reliability, and profitability of all semiconductor devices, including LED's. The cost of the damaged device itself is often negligible, but if associated costs like repair and rework, shipping, labor, and overhead are included, clearly there is a need to understand how to handle and process devices which are sensitive to ESD.

Controlling electrostatic discharge begins with understanding how electrostatic charge occurs in the first place. Electrostatic charge is most commonly created by the contact and separation of two materials, which is known as "tribo-electric charging" (see Figure 1).

It involves the transfer of electrons between materials. When two materials are placed in contact and then separated, negatively charged electrons are transferred from the surface of one material to the surface of the other material. Which material loses electrons, and which gains electrons will depend on the nature of the two materials. The material that loses electrons becomes positively charged, while the material that gains electrons is negatively charged.

Figure 1: Principle of triboelectric



For example, a person walking across the floor generates static electricity as shoe soles contact and then separate from the floor surface. An electronic device sliding into or out of a bag, magazine or tube generates an electrostatic charge as the device's housing and metal leads make multiple contacts and separations with the surface of the container. While the magnitude of electrostatic charge may be different in these examples, static electricity is indeed generated.

Table 1: Typical voltage spike levels by different means of generation

Means of generation	10-25 % REL. Humidity	65-99 % RH
Walking across carpet	35,000 V	1,500 V
Walking across vinyl tile	12,000 V	250 V
Worker at bench	6,000 V	100 V
Poly bag picked up from bench	20,000 V	1,200 V
Chair with urethane foam	18,000 V	1,500 V

This process of material contact, electron transfer and separation is in reality a more complex mechanism than described here. The amount of charge created by tribo-electric generation is affected by the area of contact, the speed of separation, relative humidity, and other factors. Once the charge is created on a material, it becomes an “electrostatic” charge. This charge may be transferred away from the material, creating an electrostatic discharge (ESD) event (Voltage spike). Additional factors such as the resistance of the actual discharge circuit and the contact resistance at the interface to the contacting surfaces also affect the actual charge that can cause damage. Table 1 shows typical voltage spike levels by different means of generation and relative humidity levels.

ESD damage is usually caused by one of three events: direct electrostatic discharge to the device, electrostatic discharge from the device or field-induced discharges. Damage to an ESDS (electrostatic discharge sensitive) device by the ESD event is determined by the device's ability to dissipate the energy of the discharge or withstand the voltage levels involved. This is known as the device’s “ESD sensitivity”.

1.1 Discharge to the device

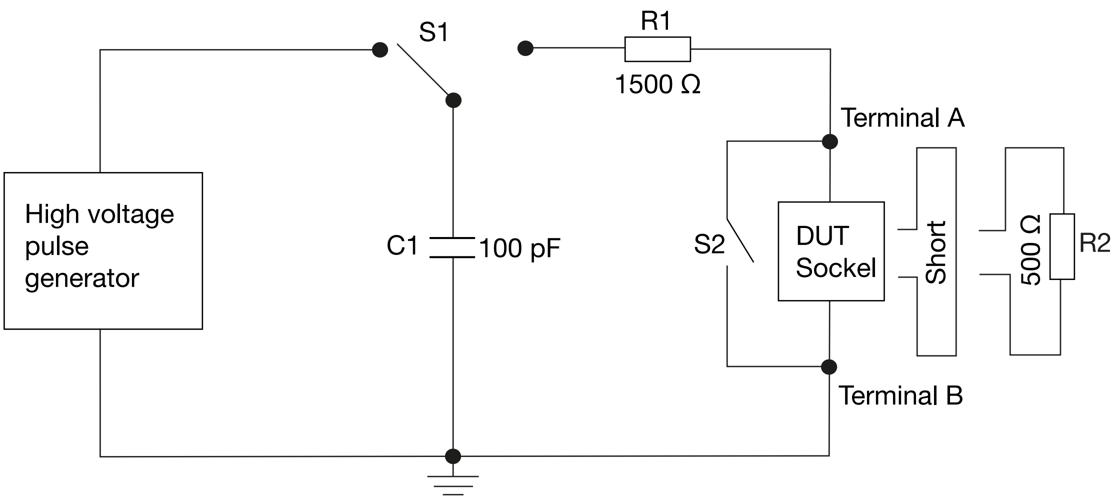
An ESD event can occur when any charged conductor (including the human body) discharges to an ESDS device. The most common cause of electrostatic damage is the direct transfer of electrostatic charge from the human body or a charged material to the electrostatic discharge sensitive (ESDS) device. The model used to simulate this event is the Human Body Model (HBM).

A similar discharge can occur from a charged conductive object, such as a metallic tool or fixture. The model used to characterize this event is known as the Machine Model (MM)

1.1.1 Human Body Model (HBM)

The Human Body Model is the most commonly used model for classifying device sensitivity to ESD and used by ams-OSRAM to classify their devices, according to ANSI/ESDA/JEDEC JS-001-2017. The HBM testing model represents the discharge from the fingertip of a standing individual delivered to the device. It is modeled by a 100 pF capacitor (C1) discharged through a switching component (S1) and a 1.5 kΩ series resistor (R1) into the component. A typical Human Body Model circuit, as described in ANSI/ESDA/JEDEC JS-001-2017, is shown in Figure 2.

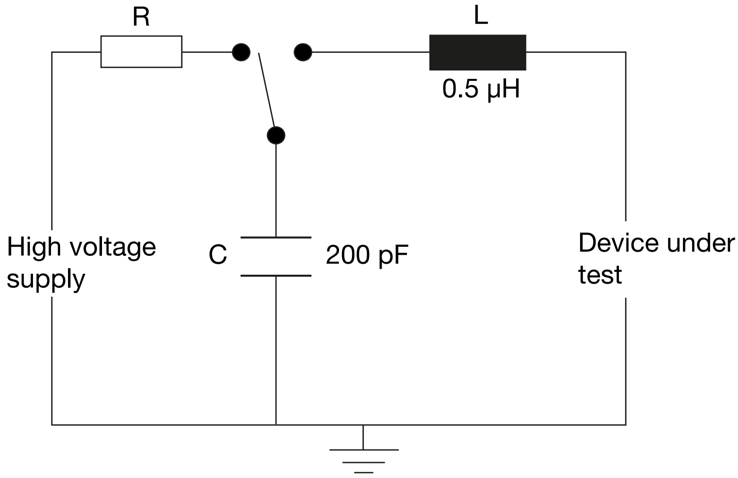
Figure 2: Typical equivalent HBM ESD circuit



1.1.2 Machine Model (MM)

A discharge similar to the HBM event also can occur from a charged conductive object, such as a metallic tool or fixture. Originating in Japan as the result of trying to create a worst-case HBM event, the model is known as the Machine Model (MM). This ESD model consists of a 200 pF capacitor discharged directly into a component with no series resistor (Figure 3).

Figure 3: Typical machine model circuit diagram



As a worst-case human body model, the Machine Model may be over severe. However, there are real situations that this model represents, for example the rapid discharge from a charged board assembly or from the charged cables of an automatic tester. The MM version does not have a 1.5 kΩ resistor, but otherwise the test board and the socket are the same as for HBM testing. The series inductance, as shown in Figure 3, is the dominating parasitic element that shapes the oscillating machine model wave form.

1.2 Discharge from the device

The transfer of charge from an ESDS device is also an ESD event. Static charge may accumulate on the ESDS device itself through handling or contact with packaging materials, working surfaces or machine surfaces. This frequently occurs when a device moves across a surface or vibrates in a package. The model used to simulate the transfer of charge from an ESDS device is referred to as the Charged Device Model (CDM). The capacitance and energies involved are different from those of a discharge to the ESDS device. In some cases, a CDM event can be more destructive than the HBM for some devices. that components may be more sensitive to damage when assembled by automated equipment.

1.2.1 Charged Device Model (CDM)

The transfer of charge from an ESDS device is also an ESD event. A device may become charged, for example, from sliding down the feeder in an automated assembler. If it then contacts the insertion head or another conductive surface, a rapid discharge may occur from the device to the metal object. This event is known as the Charged Device Model (CDM). For further information please refer to ANSI/ESDA/JEDEC JS-002-2014.

1.2.2 Field induced discharges

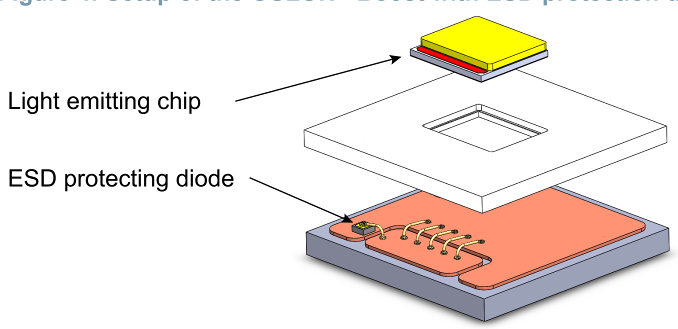
Another event that can directly or indirectly damage devices is termed Field Induction. As noted earlier, whenever any object becomes electro-statically charged, there is an electrostatic field associated with that charge. If an ESDS device is placed in that electrostatic field, a charge may be induced on the device. If the device is then momentarily grounded while within the electrostatic field, a transfer of charge from the device occurs as a CDM event. If the device is removed from the region of the electrostatic field and grounded again, a second CDM event will occur as charge (of opposite polarity from the first event) is transferred from the device.

2 ESD sensitivity of products

The portfolio mix of ams-OSRAM represents everything from products for low power applications to LEDs and LED modules for high power demanding applications. For details, please refer to the latest product catalogue.

Those larger packages usually have chip sizes larger than 500 µm and are often incorporating an ESD diode to provide ESD withstand voltage protection up to 8 kV, according to ANSI/ESDA/JEDEC JS-001. As an example, Figure 4 shows the OSLON® Boost package including the ESD protection diode.

Figure 4: Setup of the OSLON® Boost with ESD protection diode

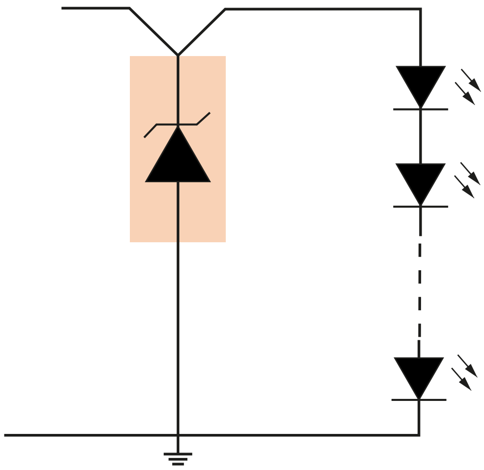


For some of the LED devices it is impossible to incorporate an ESD protection diode, e.g., due to the package space restrictions. Those devices can have a much lower ESD withstand voltage, which can be as low as JEDEC JS-001 Class 0 (HBM). For details, please refer to the corresponding devices data sheet.

3 Considerations of circuit design

Most LEDs are capable of withstanding ESD voltage from 2 kV up to 8 kV in compliant with ANSI/ESDA/JEDEC JS-001. To further enhance the protection grade in module design, the following scheme instantiates an application of light bar with a few considerations against system-level ESD. Designer should be aware of, but not limited to, factors below.

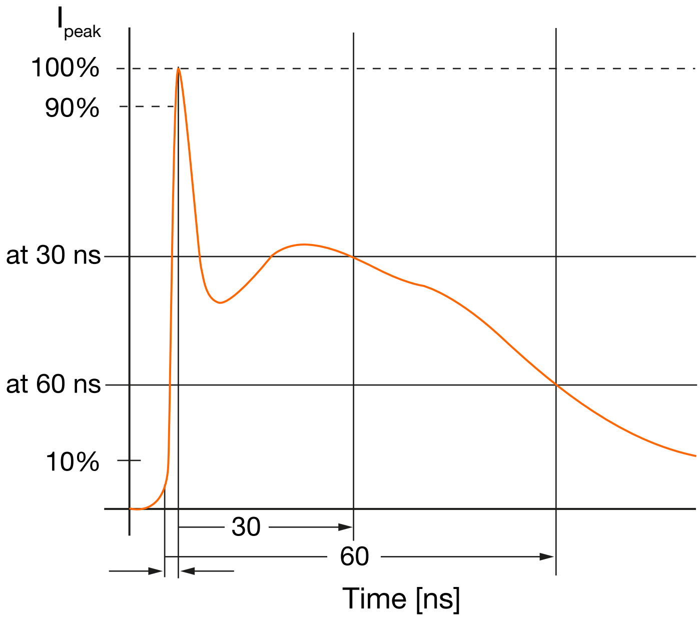
Figure 5: Adopting a reversed Zener diode in parallel with LED string



3.1 Breakdown voltage

When a surge occurs (see Figure 6) and exceeds the maximum ratings of the LED, the Zener diode provides an alternative path to channelize the current.

Figure 6: The most commonly used waveform of ESD discharge defined by IEC 61000-4-2 [4]



A significant parameter, breakdown voltage (VBR), is required to be higher than the total forward voltage of LEDs to ensure the functionality of the circuitry under normal circumstances.

3.2 Response time

The response time of dedicated protection diode must be faster than the LEDs. Thus, the mechanism can work effectively before a pulse might cause any damage to the LEDs. Due to the short switching time of LEDs, the response time of protection device is supposed to be in the range of nanoseconds or less. Note that this characteristic must be considered in both directions from anode to cathode, and vice versa.

3.3 Placement

An ESD protection device ought to be placed near by the power input in order to protect the whole module from incoming surges of power supply. However, to prevent damage which occurs from other sources, for instance by touching the PCB, the most applicable location should be placed the closest to the protected circuitry, i.e., LEDs. An appropriate way to locate the component therefore would vary from one case to another. Designer must first identify where the most potential damage could come from.

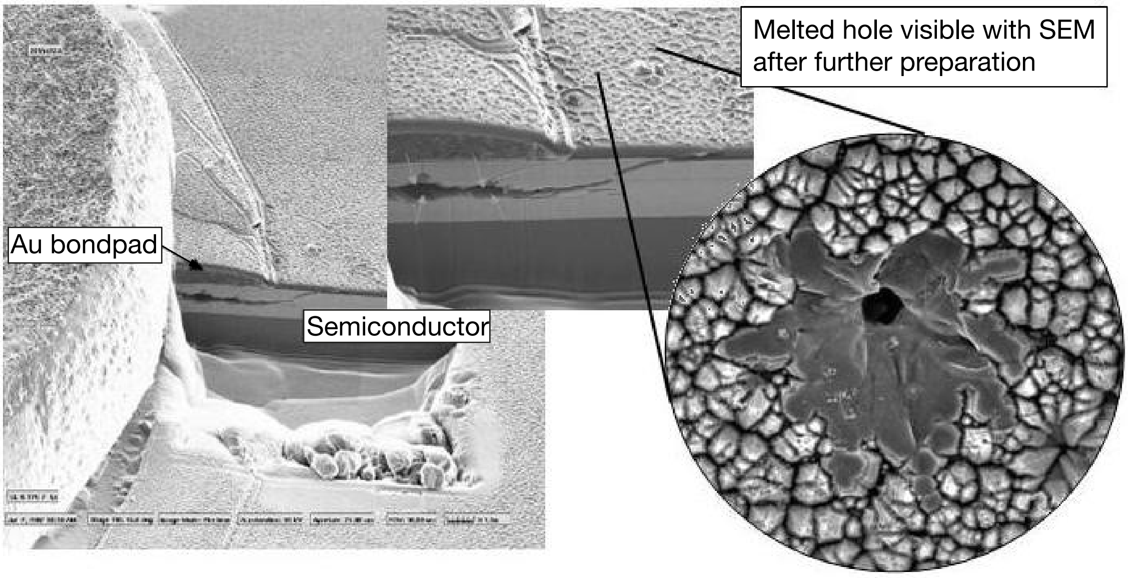
The above-mentioned precautions should be pre-examined before any designer going about selecting the appropriate protective devices.

4 Typical symptoms of ESD / EOS damage

ESD damage is typically created by short pulses of high power with a pulse length below 100 ns. The energy deposition in the structure due to the discharge (ESD event) engenders melting holes in the semiconductors. Resulting from the thermal impact this is sometimes combined with small crack lines up to the surface of the LED die (Figure 7).

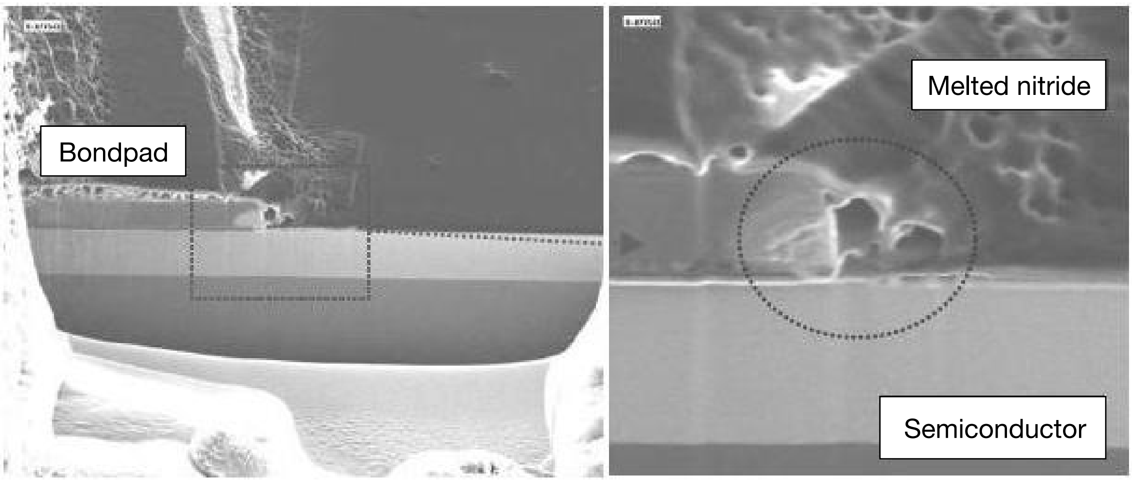
Therefore, the ESD event is not always visible on the surface of the chip but can be seen from the electrical characteristic of the LED.

Figure 7: Typical failure of ESD impairment (3 kV, analysis with FIB and SEM)



Massive surface destruction, such as melting of gold (Au) or nitride, may be caused by electrical overstress (EOS), and can be mainly observed at the edge of the bond pad (see Figure 8). Contrary to ESD an EOS damage relays on comparatively long pulses (ms) of lower power but high energy.

Figure 8: Typical failure of EOS deterioration (analysis with FIB and SEM)



However, it is often impossible to clearly detect and differentiate between both effects since they can crop up combined or caused by ambiguous power levels or pulse lengths.

The possible causes of static discharges are almost always associated with people, the type of material/clothes that people wear and/or the handling equipment.

Analytical techniques to detect such damage are:

- Electrical characterization — Curve tracer
- Optical detection — Optical microscopy
- Physical identification — Scanning electron microscope

5 Recommendations for ESD control

5.1 Take care of ESD

Everyone who is handling ESD sensitive devices must be aware of ESD protection and must take care of suitable measures in order to prevent ESD.

ESD protection is mandatory for all departments where ESD sensitive devices are handled:

- Incoming inspection
- Manufacturing line
- Testing / Outgoing inspection
- Packaging
- Storage / Warehouse
- Shipping department

5.2 Grounding / bonding systems

Grounding / bonding systems shall be used to ensure that ESDS items, personnel, and any other conductors (e.g., mobile equipment) are at the same electrical potential. As a minimum, ESDS items, personnel and other related conductors shall be bonded or electrically interconnected. Please pay attention that the ESD grounding is not the common hard earthing (protective earth PE).

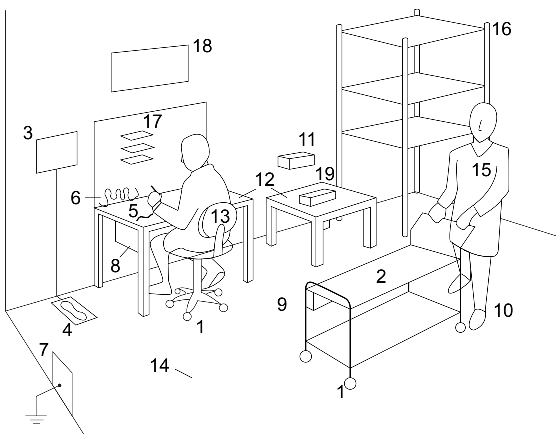
5.2.1 Personal grounding

All personnel shall be bonded or electrically connected to the ground or contrived ground when handling ESD sensitive items. When personnel are seated at ESD protective workstations, they shall be connected to the common point ground via a wrist strap system.

5.3 Protected areas

Handling of ESDS parts, assemblies and equipment without ESD protective covering or packaging shall be performed in a protected area (Figure 9). Caution signs indicating the existence of the ESD protected area (EPA) shall be posted and clearly visible to personnel prior to entry to the protected area. ESDS items shall be packaged in ESD protective packaging while not in a protected area. Access to the protected area shall be limited to personnel who have completed appropriate ESD training. Trained personnel shall escort untrained individuals while in a protected area. All nonessential insulators, such as those made of plastics and paper (e.g., coffee cups, food wrappers and personal items) must be removed from the workstation. Ionization or other charge mitigating techniques shall be used at the workstation to neutralize electrostatic fields on all process essential insulators (e.g., ESDS device parts, device carriers and specialized tools) if the electrostatic field is considered a threat.

Figure 9: Example of an ESD protection area



1. Groundable wheels
2. Groundable surface
3. Wrist band and footwear tester
4. Footwear footplate
5. Wrist band and grounding cord
6. Grounding cord
7. Ground
8. Earth bounding point (EBP)
9. Groundable point of trolley
10. Toe and heel strap (footwear)
11. Ionizer
12. Dissipative surfaces
13. Seating with groundable feet and pads
14. Floor
15. Garments
16. Shelving with grounded surfaces
17. Groundable racking
18. EPA sign
19. Machine

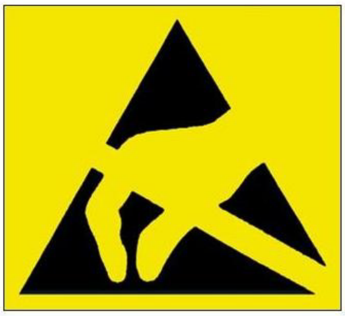
5.4 Packaging

ESD protective packaging and package marking shall be in accordance with the recommendation of the standards. For smooth business processes ESD protective packaging can be defined and fixed in the contract, purchase order, drawing or other documentation. Packaging shall be defined for all material movement within protected areas, between job sites and field service operations.

5.5 Marking

ESDS assemblies and equipment containing ESDS parts and assemblies should be marked with an ESD caution symbol, (i.e., EOS/ESD S8.1). The symbol should also be located on equipment in a position readily visible to personnel. In addition, the symbol should be located in a position readily visible when an ESDS assembly is incorporated into its next higher assembly.

Figure 10: ESD caution symbols



ESD Susceptibility

ESD Protective

5.6 Equipment

AC powered tools

The working part of AC powered tools should be capable of providing a conductive path to ground. New powered hand tools such as soldering irons typically should have a tip to ground resistance of less than 1.0 Ω. Note — This resistance may increase with use but should be less than 20.0 Ω for verification purposes.

Battery powered and pneumatic hand tools

Battery powered and pneumatic hand tools while being held should have a resistance to ground of less than 1×10^{12} Ω.

Automated handlers

All conductive or static dissipative components of automated handling equipment should provide a continuous conductive path to ground, whether stationary or in motion. The equipment should minimize charge generation of the ESDS items that are handled. Where insulating materials are necessary in the device path, they should be designed to minimize electric fields and the charge imparted to devices being handled.

5.7 Handling

ESD protective handling procedures shall be established, documented, and implemented. Handling procedures are required for all areas where ESDS items are manually or machine processed. When outside their protective covering or packaging, ESDS items shall be handled only in a protected area.

Table 2: Recommendation for the use of ESD control products

	Wrist bands	Worksurface mats	Floor mats	Shoe grounders	Clothing	Shielding bags	Conductive foam	Conductive containers	Field service kit/mat	Ionizers
Receiving & incoming inspection	•	•	•	•	•	•		•		•
Stores & storage	•		•	•	•	•	•	•		
Kitting	•	•	•	•	•	•	•	•		•
Automatic insertion			•							•
Manual Inspection	•	•	•	•	•	•	•	•	•	•
Wave soldering			•	•				•		•
Board testing rework	•	•	•	•	•	•	•	•		•
Equipment assembly	•	•	•	•	•	•		•		
Packaging & shipping	•	•	•	•		•	•			
Field service	•	•				•	•	•	•	•

6 ESD control checklist

6.1 Grounding / general ESD controls

1. Is there a common ESD ground for the entire plant?

2. Is ESD protective flooring used in ESD controlled areas where the personnel are mobile while handling ESD sensitive items?

3. Where ESD protective flooring is used, is the flooring grounded to the plant's common ESD ground?

4. Is the ESD protective flooring grounded properly at prescribed intervals?

   M1) Measure the resistivity of the ESD protective flooring; Spec: 0 — 1E5 Ω/Square

   (M2) Measure field voltages at different areas of the floor; Spec: < 200 V

   (M3) Measure the resistance between a flooring ground point and the common ESD ground; Spec: < 1 Ω

5. Where ESD protective flooring is used for personnel grounding, are foot grounding devices or conductive footwear worn?

6. Where conductive footwear is used, do personnel check continuity to ground upon entering the area?

   (M4) Measure the resistivity of the conductive shoes; Spec: 0 — 1E5 Ω/Square

7. Are the ground points of all workstations grounded to the common ESD ground of the plant?

   (M5) Measure the resistance be-tween a workstation ESD ground point and the common ESD ground; Spec: < 1 Ω

8. Are personnel wearing grounded wrist straps at the ESD-protected work-stations?

9. Are personnel checking their wrist straps for continuity at regular intervals and are the results

of these checks logged consistently and kept?

10. Where used, are continuous ground monitors checked and maintained periodically?

11. Are the wrist strap /conductive footwear checkers checked and maintained regularly?

12. Do wrist straps and foot grounders fit correctly?

13. Are wrist straps and foot grounders working properly?

14. Are disposable foot grounders limited to one-time use?

15. Do personnel wear ESD protective garments or smocks in ESD controlled areas?

16. Are ESD protective garments correctly worn?

    (M6) Measure the resistivity of the ESD protective garment/smock; Spec: 0 — 1E5 Ω/Square

17. Are the ground points of all equipment grounded to the common ESD ground of the plant?

    (M7) Measure the resistances between equipment ESD ground points and the common ESD ground; Spec: < 1 Ω

    (M8) Measure field voltages around the equipment; Spec: < 200 V

18. Are non-grounded personnel at least 4 feet away from any ESD sensitive area?

19. Are charge-generating equipment at least 4 feet away from any ESD sensitive area?

20. Is the surface of the worktable where ESD-sensitive devices are handled covered with a static dissipative mat?

21. Is the static dissipative mat on the table properly grounded to the ESD common ground at prescribed intervals?

    (M9) Measure the resistivity of the worktable surface; Spec: 1 E5 — 1E9 Ω/Square

    (M10) Measure the resistance of the dissipative mat ground point to the common ESD ground; Spec: < 1 Ω

    (M11) Measure field voltages at different areas of the worktable surface; Spec: < 200 V

22. Are the ground points of workstations and equipment properly labeled as such?

23. Does the plant have a prescribed procedure and frequency for cleaning their ESD protective flooring/surfaces to maintain their conductive /dissipative properties?

24. Are there any non-essential personal items in the ESD controlled areas?

(M12) Measure field voltages around any non-essential personal items; Spec: < 200 V

25. Are there any insulating materials in ESD controlled areas, e.g., plastic bags, plastic envelopes, plastic folders, boxes?

26. Where insulating materials are present in ESD controlled areas, are ionizers in use?

27. Where ionizers are in use, are these ionizers properly positioned and distributed to provide adequate ESD protection?

28. Where ionizers are in use, are these ionizers being checked and maintained regularly?

(M13) Measure field voltages around any insulating / triboelectric items in the workplace; Spec: < 200 V

29. Is the RH of ESD controlled areas maintained above 40 % and is the RH in these areas monitored?

6.2 Storage / stationing/ transfer of materials

30. Are storage racks or cabinets conductive, but covered with dissipative liners in areas contacting ESD sensitive items?

31. Are the conductive storage racks or cabinets individually grounded to the common ESD ground?

(M14) Measure the resistance of the rack/cabinet ground point to the common ESD ground; Spec: < 1Ω

32. Is each level of a storage rack or cabinet grounded to the other levels?

33. Are the trays or boxes used in storing ESD sensitive materials on dissipative racks/cabinets also dissipative?

(M15) Measure field voltages around the storage racks and cabinets Spec: < 200 V

34. Do personnel ground themselves first before handling ESD sensitive items that are stored on racks or in cabinets?

35. Are carts used for transporting ESD sensitive materials grounded to the ESD protective flooring with a drag chain or conductive wheels?

36. Is each level of a multi-level cart grounded to the other levels?

37. Are boards / units being transported in dissipative containers with dissipative lids to shield them from electric fields?

38. Are the carts properly grounded to the common ESD ground when not in transit?

(M16) Measure field voltages around the carts while stationary and while in transit;
Spec: < 200 V

39. Are the dissipative containers of transported boards / units allowed to discharge through a dissipative mat on the worktable before they are opened?

40. Do personnel ground themselves first before handling ESD sensitive items from a cart / container or on the worktable?

6.3 Plant ESD control program

41. Is there a person, entity, or group owning the overall ESD control program of the plant?

42. Does the plant have a metric or indicator that pertains to the level of success of their ESD control program?

43. Is there a system in place for continuously reviewing and improving the plant's ESD control program?

44. Is there a system for conducting regular ESD control audits in the plant?

45. Is there a standard checklist used during ESD audits?

46. Does the ESD audit checklist include actual measurement of resistivity and field voltages?

47. Does the plant have a resistivity meter and a field meter for actual measurement of resistivity and voltage build-ups during audits?

48. Is there a system for tracking and closing open action items generated by the internal ESD audits?

49. Are ESD control requirements imposed on visitors?

50. Is there a system for monitoring employee violations of ESD controls?

51. Is there a system for correcting system issues that lead to ESD control violations?

52. Is there a system for implementing disciplinary actions on personnel who commit ESD violations?

6.4 ESD control training / certification

53. Are all employees in the plant trained on ESD awareness and control?

54. Is there a record of all employees' ESD training history?

55. Is there a standard training module used for training new employees on ESD control?

56. Are all personnel working in ESD controlled areas trained and certified on ESD?

57. Are the ESD instructors trained and certified as such?

58. Is there a system for identifying employees that need to undergo ESD training or recertification?

59. Is there a central repository of ESD training materials and references?

7 Monitoring an ESD control program

Once an ESD control program has been implemented, it is necessary to routinely monitor the program to make sure every element is working properly.

Table 3 gives recommendation for the time intervals for ESD monitoring.

Table 3: Time intervals for ESD monitoring

Product	Test-equipment	Testing interval
ESD protect area	Visual	Daily
Packaging	Visual	Daily
Wrist bands	Ground Check Grounding tester	Daily
Shoe grounder	Ground Check Grounding tester	Daily
Shoes	Ground Check Grounding tester	Daily
Work surfaces	Surface resistivity meter	Monthly
Field surface kit	Surface resistivity meter	Monthly
Flooring	Surface resistivity meter	Monthly
Chairs	Chair Check	Monthly
Ionizers	Ionizer performance analyzer	Monthly
Clothing	Resistivity meter	Semi-annual

Table 4 shows the ESD classification criteria according to ANSI/ESDA/JEDEC JS-001 (HBM).

Table 4: ESD classification criteria according to ANSI/ESDA/JEDEC JS-001 (HBM)

Classification level	Classification test condition
Class 0	Any part that fails after exposure to an ESD pulse of 250 V or less.
Class 1A	Any part that passes after exposure ton an ESD pulse of 250 V, but fails after exposure to an ESD pulse of 500 V.
Class 1B	Any part that passes after exposure to an ESD pulse of 500 V, but fails after exposure to an ESD pulse of 1,000 V.
Class 1C	Any part that passes after exposure to an ESD pulse of 1,000 V, but fails after exposure to an ESD pulse of 2,000 V.
Class 2	Any part that passes after exposure to an ESD pulse of 2,000 V, but fails after exposure to an ESD pulse of 4,000 V.
Class 3A	Any part that passes after exposure to an ESD pulse of 4,000 V, but fails after exposure to an ESD pulse of 8,000 V.
Class 3B	Any part that passes after exposure to an ESD pulse of 8,000 V.

Table 5 depicts the ESD classification criteria according to ANSI/ESDA/JEDEC JS-002 (CDM).

Table 5: ESD classification criteria according to ANSI/ESDA/JEDEC JS-002 (CDM)

Classification level	Classification test condition
Class 0a	Any part that fails after exposure to an ESD pulse of 125 V or less.
Class 0b	Any part that passes after exposure ton an ESD pulse of 125 V, but fails after exposure to an ESD pulse of 250 V.
Class 1	Any part that passes after exposure ton an ESD pulse of 250 V, but fails after exposure to an ESD pulse of 500 V.
Class 2a	Any part that passes after exposure ton an ESD pulse of 500 V, but fails after exposure to an ESD pulse of 750 V.
Class 2b	Any part that passes after exposure ton an ESD pulse of 750 V, but fails after exposure to an ESD pulse of 1,000 V.
Class 3	Any part that passes after exposure to an ESD pulse of 1,000 V.

8 References

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[12] Stat-X Deutschland GmbH, www.stat-x.biz/en/expertise/standards/

ABOUT ams OSRAM Group (SIX: AMS)

The ams OSRAM Group (SIX: AMS) is a global leader in optical solutions. By adding intelligence to light and passion to innovation, we enrich people's lives. This is what we mean by Sensing is Life. With over 110 years of combined history, our core is defined by imagination, deep engineering expertise and the ability to provide global industrial capacity in sensor and light technologies. Our around 24,000 employees worldwide focus on innovation across sensing, illumination and visualization to make journeys safer, medical diagnosis more accurate and daily moments in communication a richer experience. Headquartered in Premstaetten/Graz (Austria) with a co-headquarters in Munich (Germany), the group achieved over EUR 5 billion revenues in 2021. Find out more about us on https://ams-osram.com

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Published by ams-OSRAM AG
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