GigaDevice Semiconductor Inc.

ESD Static Protection Manual

Application Note
AN055

Table of Contents

List of Figures

List of Tables

1. Prevention of ESD/EOS

Electrostatic discharge ESD is a phenomenon in which electrostatic charge is rapidly transferred between objects with different potentials generated by two electrostatic sources. Electrostatic charges can cause damage to electrostatically sensitive devices when they come into contact with or near them.

Electrical overstress EOS is an inherent result of component damage caused by harmful electrical energy effects. There are many sources of EOS damage, such as: large current and high voltage caused by lightning strikes/surges, ESD generated by electrical equipment or operation/processing.

ESD-sensitive components are those that are susceptible to such high-energy discharges. The relative sensitivity of components to ESD depends on their process. The smaller the technologies of the component, the faster the operation speed, and the more serious the ESD sensitivity. For example, The high-speed IO and RF pins of MCU are easily damaged by ESD.

Improper operating or handling can result in failure of ESD sensitive components or changes in device performance. These failures may occur immediately or latently. Immediate failure results can be individually tested, reworked, or scrapped. The consequences of latent failure are the most serious. That is, the product has passed inspection and functional testing. It is still possible that it will expire after delivery to the customer.

It is important to protect ESD sensitive components in circuit designs and packaging. Some unprotected electronics/fixtures are often used in manufacturing and assembly areas to connect ESD sensitive devices. Remember that ESD sensitive chips can only be removed from the antistatic packaging on an EOS/ESD safe operating platform in the ESD protected area EPA. This article will detail how to operate safely as a protected electronic assembly.

1.1. Electrostatic Discharge ESD

If ESD damage does occur, the best protection method is to prevent static electricity from being generated, and the second is to eliminate static electricity. The principles of all ESD protection technologies and products are based on either or both of the above.

ESD damage is the result of the charge generated by electrostatic sources approaching or touching ESD-sensitive components, which can be seen everywhere around us. The strength of static electricity depends on the characteristics of the electrostatic source, and the generation of static electricity requires the relative motion of objects, such as contact, separation, and friction of objects.

The culprit for electrostatic discharge is the insulating material, because the insulating material collects the electrostatic charge generated or acquired without allowing it to diffuse from the surface of the material, refer to ***Table 1-1. Common Static Sources***. Common materials such as plastic bags or Styrofoam containers can generate severe static electricity and are not suitable for use in operating areas, especially ESD protected area (EPA). The act of peeling tape from a roll of tape can generate 20,000 volts. Even compressed air blowing on insulating surfaces can generate static charges.

Table 1-1. Common Static Sources

Things	Electrostatic material
Working desk	Waxed, paint or paint surface
	Untreated polyethylene or plastic
	Glass
Floor	Potting concrete
	Waxed or finished wood
	Floor tiles and carpets
Clothing and person	Non-ESD protective clothing
	Synthetic material
	Non-ESD protective shoes
	Hair
Seat	Finished wood
	Polyethylene material
	Glass fiber
	Insulated wheels
Packaging and Handling materials	Plastic bags, packaging, envelopes
	Foam bag, foam plastic
	Polystyrene plastic
	Non-ESD protective boxes, trays, containers
Assembly tools and materials	Pressure injection
	Compressed air
	Synthetic brush
	Heat gun, hair dryer
	Copier printer

Destructive electrostatic discharges are often initiated by adjacent conductors, such as human skin, and onto the conductors of the assembly. This happens when a human body with electrostatic charges comes into contact with a printed board assembly. Electronic components are destroyed when static electricity is discharged through the conductive pattern to ESD-sensitive components. Much lower than the electrostatic discharge that the human body can feel (less than 3500 volts), it can still damage ESD sensitive components. Typical electrostatic voltage generation strengths are shown in ***Table 1-2. Common Behavior Electrostatic Strength***.

Table 1-2. Common Behavior Electrostatic Strength

Source	Electrostatic Voltage (V)	
	10-20% Relative Humidity	65-90% Relative Humidity
Walking on the carpet	35000	1500
Walk on polyethylene floor	12000	250
Staff on seat	6000	100
Polyethylene envelope (work instruction booklet)	7000	600
Pick up the plastic bag from the work surface	20000	1200
Work seat with foam pad	18000	1500

1.2. Electrical Overstress EOS

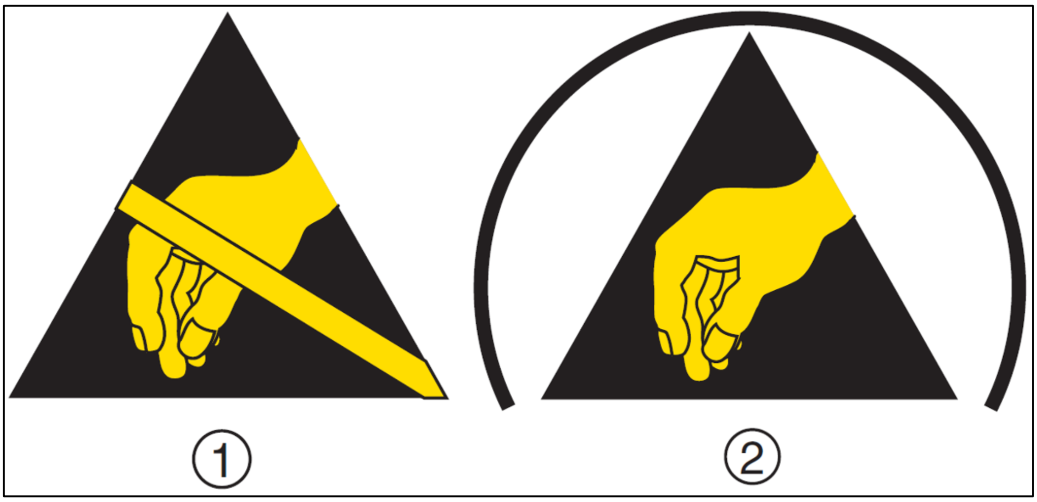
Electronic components can be damaged by many different sources of harmful electrical energy, either from ESD voltages or from electrical spikes generated by human-operated tools such as soldering irons, solder extractors, test instruments, or other electronic equipment. Some devices are more sensitive than others. Sensitivity was originally an indicator of device functional design. In general, faster, smaller devices have higher sensitivity than their slower, larger predecessors. The use or type of device plays a decisive role in sensitivity. This is because some devices are designed to respond to small electrical signals or over a wide frequency range. With the reduction of the process technologies, the problem of EOS will become more and more serious.

When considering the sensitivity of a product, we must look at the sensitivity of the most sensitive components in the assembly. Harmful electrical energy is conducted or processed as normal signals are applied to the circuit. Periodic testing of equipment, as required by most ESD specifications, prevents damage from degraded performance over time. Since both EOS damage and ESD damage are destructive consequences of harmful electrical energy, they are very similar in nature.

1.3. Warning Signs

Warning signs can be hung and posted on plants, components, assemblies, equipment and packaging to alert people that they may be damaged by static electricity or electrical overloading of the components they operate. ***Figure 1-1. ESD Sensitive Symbols and ESD Protective Symbols*** list the more common markings.

Figure 1-1. ESD Sensitive Symbols and ESD Protective Symbols



Symbol (1) ESD sensitive symbol. Inside the triangle is a hand drawn with a slash to touch. This symbol is used to indicate that the electronic or electrical device or assembly is susceptible to damage by an ESD event.

Symbol (2) ESD protection symbol. Unlike the ESD sensitive symbol, there is an arc surrounding the triangle, and there is no slash on the hand. It is used to identify appliances designed to provide ESD protection for ESD sensitive components and devices.

Symbols (1) and (2) are used to identify devices or assemblies containing ESD sensitive devices, which must be handled differently. These symbols were proposed by the ESD Association and described in EOS/ESD Standard S8.1, Electronic Industries Association (EIA) Standard EIA-471 and IEC/TS 61340-5-1 and other standards.

Note: The absence of an ESD warning label does not necessarily mean that the component is ESD insensitive. When the electrostatic susceptibility of a component is suspected, it must be treated as a sensitive device before conclusions can be drawn.

1.4. Protective Materials

When in non-EPA, ESD sensitive devices must be protected from electrostatic sources. Protective measures include conductive electrostatic shielding boxes, protective covers/bags/packaging, etc. **Only in EPA, ESD-sensitive devices can be removed from ESD-protective packaging.**

Learn the difference between three different types of protective packaging: static shielding materials, antistatic materials, and static dissipative materials.

Static shielding packaging: The barrier layer of the packaging will prevent electrostatic discharge from penetrating the packaging and entering the internal components and causing damage.

Antistatic material: Low electrification material, which can be used as a cheap shock absorption material for ESD sensitive devices, generally used as an intermediate layer material for packaging. Antistatic materials do not generate electrical charges when in motion or when rubbed. But if electrostatic discharge occurs, ESD can penetrate the package, causing ESD/EOS for ESD sensitive devices.

Static dissipative materials: Parts with sufficient conduction properties to allow the charge to dissipate through the surface of the material and leave the EOS/ESD protected work area must be packaged with static shielding materials, usually with static dissipative materials and antistatic materials sandwiched in the middle of the package.

Some static shielding and antistatic materials, as well as some topical antistatic agents, may affect the solderability of components, components, and materials in the process. Care should be taken to select packaging and handling materials that do not contaminate the product, and to follow the manufacturer's instructions for use. Solvents that clean the surfaces of static dissipative or antistatic materials can reduce their ESD protection properties. It is necessary to follow the manufacturer's recommendations for cleaning.

2. ESD Protected Area EPA

ESD/EOS safety benches prevent damage to sensitive components from electrostatic discharges and spikes generated during operation. The safety workbench should have the protection function against EOS damage and avoid the spikes pulse generated by test equipment such as maintenance, production, and testing. Soldering irons, tweezers, and test equipment can generate enough power to destroy extremely sensitive components and degrade the performance of other components.

In order to be ESD protected, a ground path must be provided to neutralize static charges, which can otherwise discharge on devices and assemblies and cause damage. Therefore, the ESD safe workbench EPA also has a grounded static dissipative or antistatic surface. It also provides a grounding path for the operator's skin to eliminate static electricity generated on the skin and clothes. Generally, it is suggested to wear an anti-static wristband.

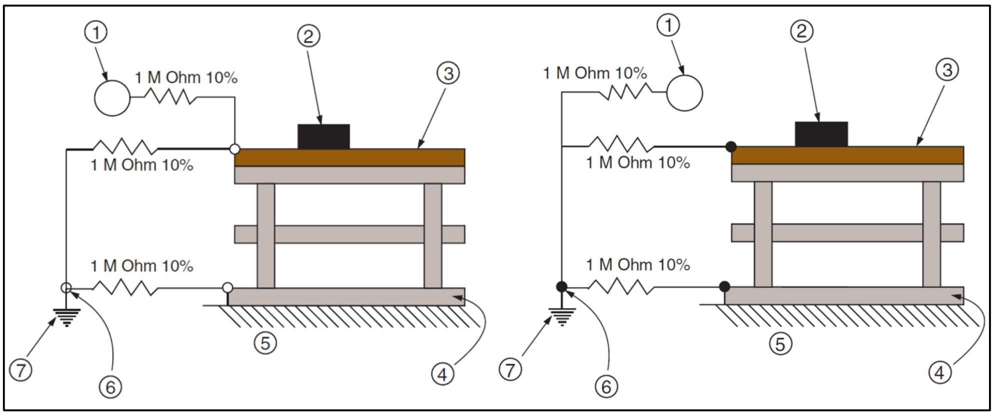
Measures must be taken in the grounding system to prevent damage to the operator's body and the chip due to the current generated by carelessness or equipment failure. Generally, a resistor is connected to the ground path. Changing the resistor will slow down the decay time and prevent current spikes from electrostatic sources. In addition, the power supply voltage used must be checked, and appropriate protection should be considered on the workbench to prevent personnel from being injured by electrical overstress. The maximum grounding resistance and discharge time allowed for electrostatic safe operation, please refer to ***Table 2-1. Maximum Ground Resistance and Discharge Time Allowed for Electrostatic Safe Operation***.

Table 2-1. Maximum Ground Resistance and Discharge Time Allowed for Electrostatic Safe Operation

Operators to the ground through the medium	Maximum allowable resistance	Maximum acceptable discharge time
From floor mat to ground	1000MΩ	< 1s
From desk mat to ground	1000MΩ	< 1s
From wristband to ground	100MΩ	< 0.1s

An example of an acceptable workbench is shown in ***Figure 2-1. Series connection and parallel connection of anti-static wristbands***. When necessary, an air ionizer may be required in more sensitive applications. The selection, placement and use of the ionizer must ensure its effectiveness.

Figure 2-1. Series connection and parallel connection of anti-static wristbands



① anti-static wristband
② ESD protection plate, static dissipative container, ion fan
③ ESD protection desktop
④ ESD protective floor/floor mat/epoxy floor
⑤ Building concrete floor
⑥ Common ground point
⑦ Protect the ground

Keep static dissipative and antistatic surfaces free of static sources of materials such as Styrofoam, plastic tin absorbers, paper packaging bags, plastic or paper notebook folders, and personal employee items.

Periodically check the bench/ESD protected area EPA to ensure its effectiveness. Improper grounding or oxidation of the ground may cause damage to the EOS/ESD equipment and personnel. Tools and equipment must also be regularly inspected and maintained to ensure proper functioning.

3. Operating Precautions

3.1. Guidelines

Avoid contaminating the pad surface before soldering. Anything that comes into contact with these surfaces must be cleaned. Be very careful when removing the PCB from its protective packaging. Only touch the edge of the board away from the edge connector. Gloves that meet EOS/ESD requirements may be required when mechanical assembly requires a firm grip on the board. The above principles are especially important when using a no-clean process.

During assembly and acceptability checks, care must always be taken to ensure product integrity.

1. Keep the workbench clean and tidy. There should be no food, beverages or tobacco in the work area.
2. Minimize hand-held chips or PCBs to prevent damage.
3. Gloves need to be replaced in time to prevent contamination caused by glove stains.
4. Do not touch PCB pads and chip pins or pads with bare hands or fingers. Human finger grease and salt can reduce solderability, increase corrosion and solder dendrite growth, and lead to poor adhesion of subsequent coatings or encapsulations.
5. Do not use hand creams and hand sanitizers containing silicon components. Chemical agents containing silicon components will cause solderability and coating adhesion problems.
6. The PCB test board or chip cannot be stacked. The stack is susceptible to physical damage, delineate a specific assembly area in the test area, use specific ESD racks for temporary storage.
7. Even if there is no ESD mark on the chip and PCB packaging, the chip or PCB to be operated should be the ESD sensitive device or component by default.
8. Testers must be trained in ESD protection and follow appropriate ESD regulations and procedures.
9. For the mailing and transportation of ESD sensitive devices, appropriate ESD protective packaging must be used, otherwise it cannot be packaged.

PCBs and common plastic chips have different levels of moisture absorption and release. During the soldering process, heat accumulation causes moisture expansion, which can damage the material and fail to meet the performance requirements of the product. This type of damage is hidden damage, such as cracks, internal delamination, and popcorn phenomena, which are difficult to observe with the naked eye, but occur during initial welding and rework operations.

If the humidity of the environment is unknown, the PCB should be baked to reduce the internal moisture and prevent the PCB from over-wetting the laminate. The selection of the baking temperature and the baking time should be controlled during the baking process to prevent the reduction of solderability due to the growth of intermetallic compounds, surface oxidation or damage to other internal components.

Moisture sensitive components (classified in accordance with IPC/JEDEC J-STD-020, ECA/IPC/JEDEC J-STD-075 or their equivalents) shall operate in accordance with IPC/JEDEC J-STD-033 or their equivalents Provisions for documented procedures. IPC-1601 provides guidelines for moisture control, operating, and packaging of PCBs.

3.2. Physical Damage

Irregular operations can easily damage the chip and the PCB test board, such as component pins/pads, cracked/shattered/broken connectors, bent or broken terminals, and severe scratches on the board surface and conductor pads. In addition, chip-level ESD caused by inattentive ESD protection causes chip circuit P-N junction damage, oxide layer breakdown/penetration, and sensitive parameter drift.

3.3. Pollution

Mostly products are contaminated through carelessness or improper handling during the manufacturing process, leading to soldering and coating problems. Human salts and oils, as well as unapproved hand creams, are typical sources of contamination. Body oils and acids can reduce solderability and increase corrosion and dendrite growth. It can also lead to poor adhesion of subsequent coatings or encapsulations. Ordinary cleaning methods cannot remove all contamination. It is therefore important to minimise the chance of contamination. The best solution is prevention, frequent washing, and only taking the edge of the board without touching the connectors or pads will help reduce contamination. When required, using pallets and brackets will also help reduce contamination during assembly.

The use of gloves or finger cots can often give the illusion of protection and can be more contaminated than bare hands for a brief period of time. When using gloves or finger cots, they should be discarded and replaced frequently. Gloves and finger cots must be carefully selected and used appropriately.

3.4. Electronic Components

Even if the components do not have the ESD sensitive marking on them, they still need to be treated as ESD sensitive components. In any case, ESD sensitive components and electronic assemblies need to have appropriate EOS/ESD markings for easy identification, refer to ***Figure 1-1. ESD Sensitive Symbols and ESD Protective Symbols***. Many sensitive components will also have their own logo, usually on the edge connector. In order to prevent ESD and EOS from damaging sensitive components, all operations, unpacking, assembly and testing should be carried out on an electrostatic protection workbench, refer to ***Figure 2-1. Series connection and parallel connection of anti-static wristbands***.

3.5. After Soldering

Even after soldering and cleaning operations, handling of electronic components requires great care. Fingerprints are extremely difficult to remove, and the conformal coated boards show fingerprints after humidity or environmental testing. Gloves or other protective equipment can be used to prevent such contamination. Use ESD fully protected mechanical racks or wash baskets during cleaning operations.

3.6. Gloves and Finger Cots

To prevent contamination of components and assemblies, the contract may provide for the use of gloves or finger cots. Gloves and finger cots with EOS/ESD protection must be carefully selected.

4. ESD Protection Check List

Table 4-1. Check List

Project	Questions	Responds
Control	How is the environment of the work area controlled?	
	Is the work area suitable for the chip product being used?	
Temperature	What is the allowable temperature range?	
Relative humidity	What is the allowable humidity range?	
Normal operations	Are the operating methods used suitable for chip products?	
	What special precautions are taken when handling high performance/RF chip products?	
Anti-static shoes	Have worn anti-static shoes?	
	Changing frequency	
Anti-static clothing	Have worn anti-static clothing?	
	Is it fully covered with clothing?	
	Changing frequency	
	What material was used?	
Operating area management requirements	What management requirements are implemented?	
	Which clause covers the activity management of products and people?	
	Are they displayed and visible?	
Choose tool and suction pen	What wafer or die choose tool was used?	
	Are they ESD safe?	
	How and when to check them for damage?	
	What cleaning program is used?	
Tweezers	Which step do you use tweezers for?	
	How to prevent wafer or chip from being damaged?	
ESD requirements	What are the requirements for ESD control in the chip product operating area?	
Ionizer	What type of ionizer to use?	
	Where is it placed in relation to the operating chip or wafer facility?	
	How to clean and maintain? Detection cycle?	
Hazards and sources of chemical	How to protect chip products from chemical damage and contamination?	

contamination		
ESD effects	What measures are taken to protect against ESD damage?	
	Are there any local sources of electromagnetic or electrostatic fields that could damage the product?	
Radiation	What measures are taken to protect against radiation damage?	
	How to limit nearby radiation sources, such as mobile phones, WiFi, microwave ovens, etc.?	

5. Revision history

Table 5-1. Revision history

Revision No.	Description	Date
1.0	Initial release	Apr.20, 2022

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