TEXAS INSTRUMENTS

Electrostatic Discharge (ESD)

Application Report

1999

TI Semiconductor Group

SSYA008

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Electrostatic Discharge (ESD)

Introduction

In recent years, the semiconductor industry has made great strides in developing faster, lower-powered, and smaller devices. During the 1990s, many devices are produced with minimum structure feature size on the silicon chip of 0.25 micron. To put this size in perspective, a typical human hair is about 75 microns in diameter. However, as feature sizes get smaller and smaller, the ESD sensitivity (voltage level at which the device sustains damage) gets lower. Therefore, ESD protection and ESD handling procedures are becoming even more important in preventing ESD damage.

All semiconductor devices have an ESD voltage threshold above which they sustain damage. While circuit designers can provide some on-circuit ESD protection (typically in the 2,000 V to 4,000 V range for the human body model and in the 200 V to 300 V range for the machine model), this is well below the static voltage levels found in work areas without ESD protection. Proper ESD handling and packaging procedures must be used throughout the processing, handling, and storing of unmounted integrated circuits (ICs) and ICs mounted on circuit boards.

What is ESD and How Does It Occur?

A static charge is an unbalanced electrical charge at rest. A static discharge is created when insulator surfaces rub together or pull apart. One surface gains electrons while the other surface loses electrons. This results in an unbalanced electrical condition recognized as static charge.

When a static charge moves from one surface to another, it is called ESD. ESD is a miniature lightning bolt of static charge that moves between two surfaces that have different potentials. ESD only occurs when the voltage differential between the two surfaces is sufficiently high to break down the dielectric strength of the medium separating the two surfaces. When a static charge moves, it becomes a current that damages or destroys oxides, metalizations, and junctions. ESD can occur in one of four different ways: a charged

body can touch an IC, a charged IC can touch a grounded surface, a charged machine can touch an IC, or an electrostatic field can induce a voltage across a dielectric that is sufficient to break it down.

Latent Defects

Devices with latent ESD defects are devices that have been degraded by ESD but not destroyed. This occurs when an ESD pulse is not strong enough to destroy a device but causes damage. Often, the device suffers junction degradation through increased leakage or a decreased reverse breakdown, but the device still functions and is still within data-sheet limits. A device can be subjected to numerous weak ESD pulses, with each one further degrading a device before it finally becomes a catastrophic failure. There is no known practical screen for devices with latent ESD defects. To avoid this type of damage, devices must be continually provided with ESD protection as outlined later.

What Voltage Levels of ESD are Possible?

It has been shown that human beings can be charged up to 38,000 volts just by walking across a rug on a low-humidity day. In order for an ESD pulse to be seen, felt, or heard, it must be in the range of 3000–4000 volts. Many devices can be damaged well below this threshold. ESD damage can be seen in the failure analysis photographs shown in Figure 1.

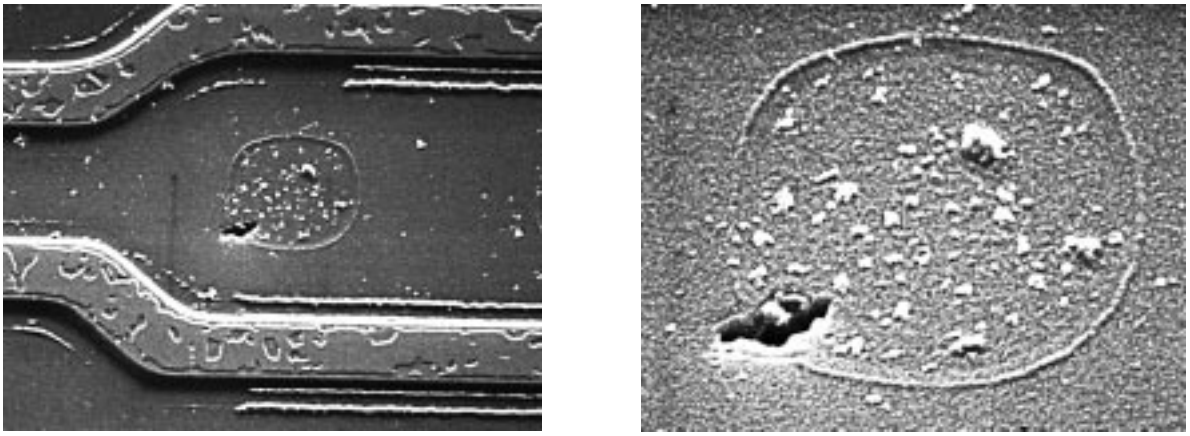


Figure 1. Punctured Barrier Junction After ESD Test at 4000 V

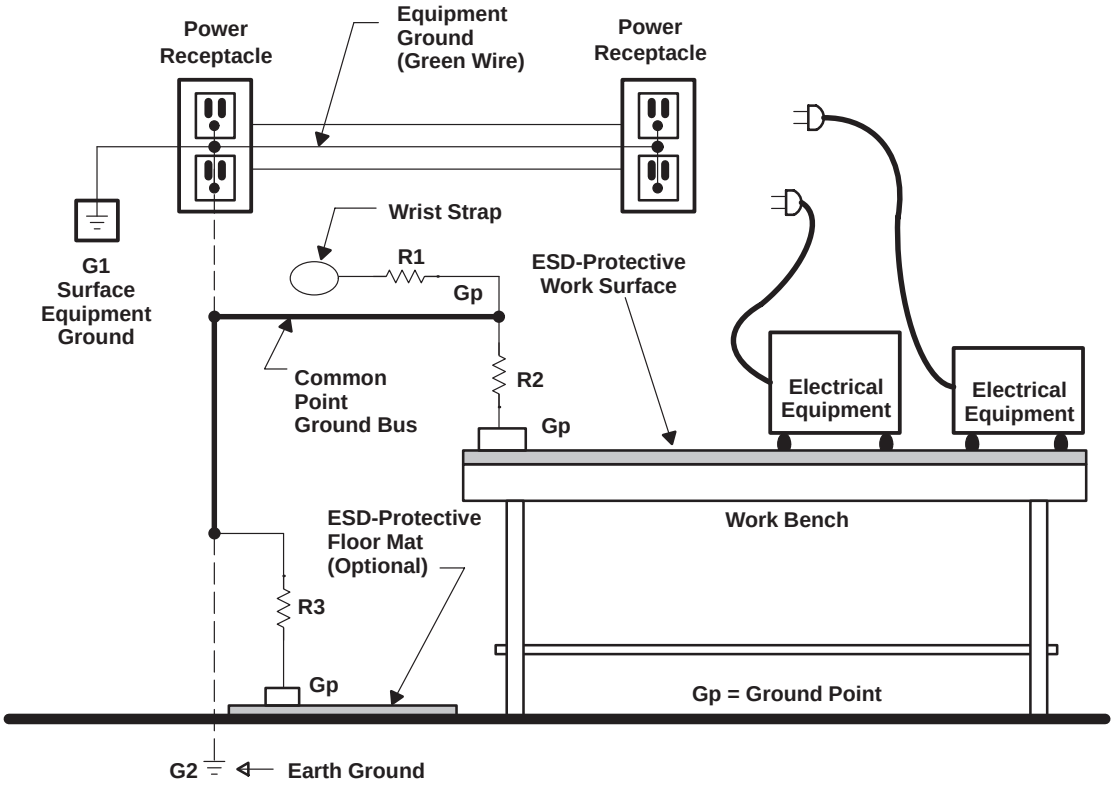
How to Avoid ESD Damage to ICs

The best way to avoid ESD damage is to keep ICs at the same potential as their surroundings. The logical reference potential is ESD ground. The first and most important rule in avoiding ESD damage is to keep ICs and everything that comes in close proximity to them at ESD ground potential. There are four supplementary rules that support this first rule.

- Any person handling the ICs should be grounded either with a wrist strap or ESD-protective footwear used in conjunction with a conductive or static-dissipative floor or floor mat.
- The work surface where devices are placed for handling, processing, testing, etc., must, be made of static-dissipative material and be grounded to ESD ground.

- All insulator materials must either be removed from the work area or must be neutralized with an ionizer. Static-generating clothing must be covered with an ESD-protective smock.
- When ICs are being stored, transferred between operations or workstations, or shipped, they must be kept in a Faraday shield container with inside surfaces (surfaces touching the ICs) that are static-dissipative.

Figure 2 shows an ESD-protected workstation.



NOTES: A. G1 (surface equipment ground) or G2 (earth ground) is acceptable for ESD ground. Where both grounds are used, they are connected (bonded) together.
B. R1 is mandatory for all wrist straps.
C. R2 (for static-dissipative work surfaces) and R3 (for ESD-protective floor mats) are optional. ESD-protective flooring are connected directly to the ESD ground without R3.
D. This ESD-protected workstation complies with JEDEC Standard No. 42.

Figure 2. ESD-Protected Workstation (Side View)

Humidity

Humidity is a very important factor in the generation of static electricity. This is especially true when insulators are present. Humidity affects the surface resistivity of insulator materials. As humidity increases, the surface resistivity decreases. This means that insulator materials rubbed together or pulled apart in a humid environment generate lower static charges than the same materials rubbed together or pulled apart in a dry environment. It is recommended that relative humidity be maintained between 40% and 60%. Humidity

above 60% is uncomfortable for humans. Humidity below 40% increases the risks of static generation from insulators. Humidity is a supplementary control and is not sufficient by itself to reduce static voltages to safe levels.

Training

All personnel who must come in close proximity to ESD-sensitive ICs must have received ESD training. These personnel should be retrained at least once per year. No ESD program can be successful unless the people who handle the ICs understand the need for ESD controls.

ESD Specification

Each area handling ESD-sensitive devices is operated in accordance with the established ESD Handling Procedure. The latest version of this controlled document is maintained in each area and is accessible to all area personnel.

ESD Coordinator

The ESD coordinator has overall responsibility for the ESD program. The ESD coordinator is responsible for ESD training, material evaluation, and writing and updating of the ESD Handling Procedure.

Audits

Periodic audits ranging from daily to yearly are held to ensure that all ESD handling procedures are being followed and that all ESD materials (wrist straps, heel straps, ionizers, table mats, floor mats, etc.) are functioning properly.

TI ESD Handling Procedure

The TI Worldwide ESD Handling Procedure is available to customers upon request.

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