Technology White Paper

Technical Considerations for Controlling ESD in Electronics Manufacturing

Overview of ESD, Associated Risks and Prevention Measures

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Technical Considerations for Controlling ESD in Electronics Manufacturing

As device geometries get smaller and processing speeds grow faster, their ESD sensitivity increases. Designers face the challenge of fitting more active component features into smaller chip territory, often at the expense of on-chip protection devices. The trade off is greater risk for ESD damage. This white paper gives an overview of ESD, the associated risks and recommended measures for ESD prevention.

- *The Cost of ESD*
- *What Is ESD?*
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- *Preventing ESD Buildup*
- *ESD Measurement Tools*
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- *Evaluating ESD Handling Capabilities*

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Mastering ESD control has always been critical to achieving high production yields, and it will become even more important in the next few years. While the industry has a solid understanding of ESD safety in manual operations involving personnel, there is room for improvement in automated applications. To be effective, ESD control programs must ensure that automated handling equipment is capable of handling tomorrow's highly sensitive devices.

The Cost of ESD

ESD impacts productivity and product reliability in virtually every aspect of electronic environment. Despite the effort made over the past decade, ESD still costs the electronics industry billions of dollars every year. Industry experts attribute an estimated 8 to 33% of all product losses to be caused by ESD.[1] The individual cost of these devices themselves range from a few cents for a simple diode to several hundred dollars for complex hybrids. However, ESD damage affects more than just the loss of devices. It affects production yields, manufacturing costs, product quality and reliability, customer relationships, and ultimately, profitability.

For today's automated facilities, conventional methods of ESD control must be re-examined and new methods applied. Automated assembly equipment is capable of processing 4,000 to 20,000 components an hour.[2] At these speeds, poorly designed equipment that is allowed to charge devices can damage large amounts of components in a very short amount of time. Perhaps even more importantly, an ESD event can in turn damage the automated equipment.

ESD generates a significant amount of electromagnetic interference (EMI). The EMI resulting from an ESD event is often powerful enough to interrupt the operation of the production equipment. Equipment controlled by microprocessors is especially susceptible to damage as they operate in the same frequency range as the EMI from ESD events. Often mistaken for a software error or glitch in the system, EMI can cause a variety of equipment operating problems, such as stoppages, software errors, testing, and calibration inaccuracies as well as mishandling. All can cause significant physical component damage and affect production yields. The affects of EMI tend to be random in nature and can affect equipment across the room, but leave the equipment where the ESD event occurred untouched. This can make the location of the ESD event difficult to locate.

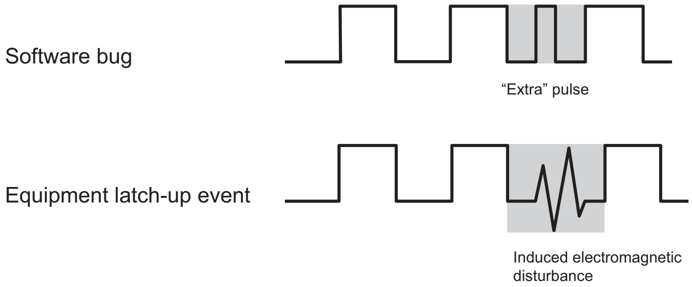

Figure 1: *EMI resulting from ESD is often mistaken for a software glitch.*[3]

What is ESD?

ESD, simply stated, is the rapid transfer of an electrostatic charge between two objects. ESD happens when two objects of different potentials come into direct contact with each other. Charging results when one object's surface gains electrons to become negatively charged and another object loses electrons from its surface to become positively charged. Triboelectric charging occurs when an electron transfer results from two objects coming into contact with each other and then separating. One of three events is usually the cause of ESD damage to devices: direct electrostatic discharge to the device; electrostatic discharge from the device; or field induced discharges. There are several models used to characterize how devices are damaged – the Human Body Model (HBM), the Machine Model (MM), the Charged Device Model (CDM), and the effect of electric fields on devices. In an automated assembly facility, the last three models or modes are the largest cause of concern.

MM damage is what happens when a machine component discharges through a device. Automated assembly equipment uses a variety of methods such as conveyors to move and guide devices through the assembly process. Poor equipment design can cause the handling systems to accumulate significant charges that will eventually discharge through the devices.

CDM damage occurs when the device discharges to another material. When a charge builds up in a device, it will dissipate through a conductor on the device when the device is placed in contact with a surface with a lesser charge.

Influence of Electric Fields (E-Fields), or the space surrounding an electrical charge, can cause a charged device to polarize. Polarization creates a difference of potential, which may cause the device to discharge to an opposite charge, causing two discharges or equalization events.

Identifying ESD

While a great deal of attention is spent on preventing ESD caused by the HBM, recent studies have indicated that less than 0.10% of all documented damage actually resulted from ungrounded personnel touching ESD-sensitive (ESDS) products. The studies concluded that 99.9% of ESD damage originated from the other models, specifically CDM.[4]

ESD control embedded into machinery is essential but problematic. To effectively control static buildup, both MM and CDM ESD events must be prevented. The first step in developing an ESD control program is to identify exactly where ESD events occur or are likely to occur. A good place to start is to ask two primary questions: first, is the equipment properly grounded; and second, does it handle devices in such a way that they do not generate static charge above an acceptable level?
To be fully prepared for handling devices of the future, equipment should be capable of handling components with an ESD tolerance as little as 50 V. The following is a list of documented areas known to charge devices, increasing the likelihood of a CDM ESD event.

IC Handlers. ICs typically become highly charged as they pass through the equipment and are subsequently discharged as a part of normal operation. According to recent studies, IC handlers have caused considerable yield losses due to CDM.[5]

Tape-and-Reel Components. Problems have been documented with components charging while they are on the reels.

Gel Packs. If the proper ESD control methods are not in place, IC chips can become highly charged as they are lifted off of the sticky bottom liner and then immediately discharged by the collets removing them.

PCBs Mounted in Plastic Panels. The plastic panels regularly used for housing PCBs can routinely charge to very high levels when handled, subsequently charging the PCBs themselves. The assemblies are subsequently discharged during normal operator handling.

Test Sockets. Normal operation can cause test sockets to charge and then discharge into devices.

Plastic Covers Over Test Sockets. The fields from the large plastic covers required to shield operators during high voltage tests often are strong enough to damage the devices under test.

Preventing ESD Buildup

In preventing or reducing MM damage, it is critical that equipment is properly grounded while in motion. All equipment parts that come into contact with the static-sensitive devices must have a sufficient grounding path to dissipate accumulated charge. Proper grounding of conductive and dissipative surfaces prevents the buildup of static charge on machine components and eliminates them as a source of charge-creating ESD events.

Grounding alone, however, will not prevent all CDM ESD events from occurring. Component charging is a much more challenging problem to solve, primarily because most electronic components contain insulators as part of their design. Insulating materials

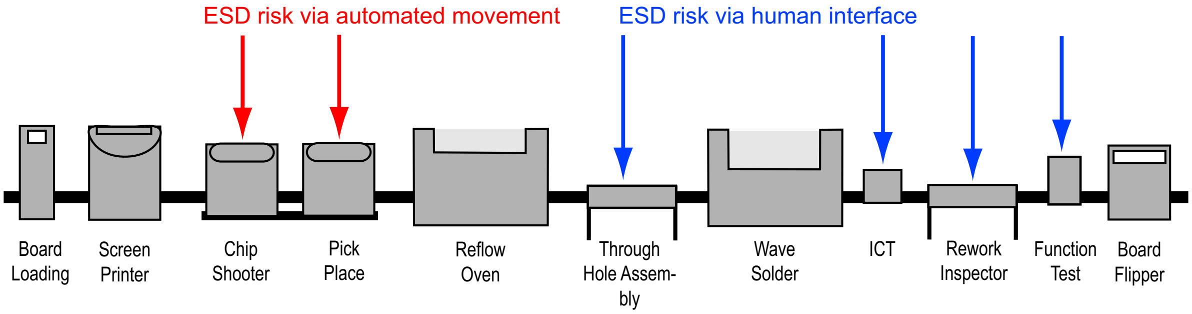

Figure 2: *Common locations of ESD risk in automated assembly.*

naturally accumulate a charge and grounding the materials does not remove or reduce the static charge. When the charge cannot be removed or avoided, air ionization is often the most effective method of neutralizing the charge on insulators or isolated conductors. In the case of automated equipment, air ionizers can be mounted inside the process chambers. Creating mini environments by enclosing specific machines and mounting ionizers inside is another option.

ESD Measurement Tools

Once ESD countermeasures are in place, it is important to verify that they are working properly. Continuous process monitoring is recommended over periodic audits of the ESD program because ESD countermeasures will often fail. For this reason, if and when failure does occur, it should be identified as soon as possible to prevent ESD damage.

Several test methods exist to validate the integrity of the ground path to equipment parts and measure whether machines are charging devices. When selecting the best measurement instruments, consider the safe charge level to be measured and select an instrument that can measure within that range. Note the size of the area to be measured and whether the spacing is fixed between the surface of the object to be measured and the instrument.

Identifying and measuring static charge inside automated equipment presents specific challenges. The problem with most conventional methods is that they are not particularly suited to automated equipment. Most require direct contact with the charged object or require the device to be removed from the object, making it necessary to take the equipment offline to do the testing. To avoid lost production time, alternative solutions are necessary for measuring charges inside the equipment.

To measure static charge without disrupting equipment operation, assemblers can mount sensors or probes inside the equipment or mount static event detectors (SED) on the devices themselves. Two options for mounting instruments inside equipment include static sensors and special electrostatic voltmeters and electrostatic fieldmeters with small probes. Static sensors incorporate very high input impedance circuitry and can be mounted inside automated equipment. This allows them to measure the field generated by a charged part as it moves through the process. Ideally, the sensor should be mounted as close to the part as possible. Since it does not require the nullification of existing fields, it is ideal for measuring charges on parts moving through high throughput machines.[6]

Electrostatic voltmeters and electrostatic fieldmeters with small probes offer an alternative option for monitoring inside equipment. The probes are small enough that they can be placed in critical locations to measure the charge on components as they pass by. However, care must be taken when mounting them to ensure that they take accurate measurements and do not interfere with the operation of the equipment. Several factors can affect the accuracy of their measurements, including orientation of the charged surface with respect to the probe as well as the size, speed and distance of the part from the probe.
SEDs are tiny sensors small enough to fit on a circuit board. They are designed to measure the current pulse in an ESD event and can be monitored optically as they pass through operating equipment. SEDs are ideal for verifying whether the equipment is generating dangerous static-charge levels. Several different types are available, each with varying features. However, many must be removed from the device and placed into separate instrumentation to ascertain whether an ESD event actually occurred.

Automated Tracking in an ESD Environment

If an ESD event does occur, the data provided from a device tracking system can help assemblers quickly identify damaged components and contain the impact. In a device tracking system model, a bar code reader is installed at various points throughout the manufacturing process to read the bar codes (or 2D codes) applied to the devices. Typically, bar code readers scan the bar codes on the device before the device enters a station and again after it exits. This documents the type of procedure that was performed, the equipment that performed it and attaches a time/date stamp for when it occurred.

While ESD monitoring instruments output all types of data, the bar code reader provides the only link between each device’s serial number and the data supplied from the instrument. For example, when equipment calibration is altered due to EMI from an ESD event, the data generated from the device tracking system can help identify specifically which boards were damaged after the equipment’s calibration was altered. It is no longer necessary to pull, scrap, or rework entire lots because of insignificant data.

When selecting a bar code reader, careful consideration should be made to ensure that it does not introduce additional risk for ESD events. Printed circuit boards, integrated circuits, and other electrically sensitive components typically use small, high-density bar codes to conserve space, making it difficult for some readers to scan from a distance. When close-proximity scanning is employed, the bar code reader may build up a static charge depending on whether it is used on a non-conductive surface. If the reader itself has built up a charge and is brought into close proximity with a sensitive component, an ESD event could occur, potentially damaging the component. Some manufacturing environments utilize a workaround by mounting the scanner after applying a special anti-static spray, which is not without its own risk.

First, the coating must completely cover the area for maximum effectiveness; uncovered areas remain at risk. In addition, anti-static sprays can wear off over time and require timely replacing. Without an accurate measure of a spray’s efficacy period, companies either waste money by applying too much, or put their components at risk by using them in an unprotected environment.
As an alternative solution, miniature bar code readers are now available with a unique nickel coating and ESD resistant labels for maximum ESD safety. These units are rated for discharges up to 8kV and feature a surface resistivity of less than 10 * 10-9 Ω/inch^2.

Evaluating ESD Handling Capabilities

According to the ESD Association's Technology Roadmap released in 2005, sensitivity levels to ESD in devices are expected to drop so low, that assemblers must act quickly to ensure they will be able to handle the new levels.[7] Assemblers certified to the ANSI/ESD S20.20, the ESD Association Standard for the Development of an Electrostatic Discharge Program, already have done much of the work in preparing for tomorrow's sensitive devices. For those manufacturers that are unsure of the voltage capabilities of their automated equipment, the ESD roadmap provides direction:

- Determine the ESD-control capabilities of the facility's handling processes.
- Ensure all conductive fixtures or tooling that contact sensitive devices are grounded.
- Ensure that maximum voltage induced on devices is kept below 50 V.

Following the requirements outlined in S20.20 will help managers assess the sensitivity levels of the components being assembled in their facility and identify ESD issues at each stage in the process, from receiving and inventory through assembly, test, rework and shipping. By using the appropriate ESD countermeasures, managers will have the data available to them to articulate their facility's capabilities by voltage level.

Figure 3: *Quadrus MINI ESD Safe is nickle coated to safely read codes on ESD sensitive parts and components.*

Conclusion

The consumer electronics industry has witnessed phenomenal growth over the past few years. Industry analysts have attributed this growth in part to the convergence of previously separated markets of digital-based audio, video and information technology to create state of the art electronic devices. As these devices rapidly gain new capabilities, they are increasing their ESD sensitivity almost as quickly. To be competitive in electronics manufacturing tomorrow, facilities must work towards mastering ESD control today.

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