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Mastering RFID Label Converting

Where Understanding Static Control Can Help Prevent RFID Transponder Failures.

By Mark Blitshteyn, Ion Industrial

Introduction

Static electricity generation is virtually unavoidable during the manufacture of RFID labels, even with the most advanced converting equipment. When a discharge of static electricity, or Electrostatic Discharge (ESD), travels through the transponder antenna into the RFID chip, permanent chip failure and loss or corruption of stored data can occur. From the lamination process to the final product at the end user, each step in the RFID label manufacturing process exposes the RFID inlay to electrostatic charges and discharges that can cause the chip to fail.

Studies show that 1%-5% of RFID labels fail during the converting phase with electrostatic discharge being a key cause. Specifications for the sensitivity of electronic devices, including RFID chips, are based on well-researched and proven test methods developed by the electronics industry. However, no RFID label processing standards have yet been developed and little guidance is available to RFID tag converters.

This article analyzes existing ESD control standards and interprets them for RFID label converting. In addition, available static control methods in RFID converting are examined along with a case study for static control on an RFID tag insertion module for a narrow-web press.

RFID Transponder Chips are ESD Sensitive Devices

What do printers and converters today have in common with the high-tech manufacturers of electronic devices? More than you might think if converting of RFID labels is involved.

In the electronics industry, a controlled manufacturing environment is critical for successful production. For example, manufacturers of semiconductors, flat panel displays, and mass storage devices rely on production in cleanrooms to control airborne contamination, and on stringent static control practices to eliminate unwanted ESD. Lack of proper static control reduces production yields and creates conditions for catastrophic failures, or result in “latent defects” where ESD-damaged parts pass production testing, but fail prematurely in use.

Now within the converting industry, a delicate, micro-thin, integrated circuit (IC) known as a “RFID chip,” is being applied to webs within a much less-controlled environment. Though dust is not an issue in RFID label converting, electrostatic discharge is a serious problem -- one that must be addressed to achieve the highest yields and required product reliability.

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Analysis of RFID production results (Table 1) has revealed two distinctive chip failure modes. One mode was mechanical stress; the other was electrostatic discharge [1].

Table 1. Typical failure rate for RFID levels in key supply chain phases

Phase/Failure Rate				
	IC/Inlay Manufacturing	Converting	Packaging/Delivery	Application/Use
Range	1%-30%	1%-10%	1%-6%	1%-30%
Typical	5%-6%	4%-5%	3%-4%	5%-6%

The failure rate numbers in Table 1 presume no anti-static measures in the converting phase. The exact breakdown of the failures attributable to mechanical stress and those attributable to ESD is not available.

The AIM Global RFID Guideline ToR13 [2] warns that static electricity can be generated during many stages of the converting process, such as separating a passive RFID label from the release liner. Discharge of static electricity through the transponder antenna into the RFID chip can cause permanent chip failure, or loss or corruption of the stored data. The quoted Guideline does not provide any failure statistics.

Technical literature and failure analysis data exist which indicate ESD failures are due to a complex series of interrelated effects. Every electronic device can be damaged by electrostatic discharge at some level. Damage to an ESD-sensitive device by the ESD event is determined by the device's ability to *dissipate* the energy of the discharge or *withstand* the current levels involved. This is known as device “ESD sensitivity” or “ESD susceptibility.”

The ESD sensitivity of the device (defined in volts), is determined by using any of the defined models explained in the side bar “ESD Models.” Testing according to the models provides ESD sensitivity levels for the comparison of devices using defined parameters.

The Human Body Model (HBM) is the oldest and most commonly used model for classifying device sensitivity to ESD [3]. This model, which dates from the nineteenth century, was developed for investigating explosive gas mixtures in mines. It was adopted by the military in MIL-STD-883 Method 3015. Here the source of the ESD is the charged human body, as modeled by HBM standards by a 100 pF capacitor discharged through a switching component and 1,500 ohm series resistor into the device under test.

Table 2 shows a classification system for defining the component’s sensitivity to the Human Body Model. This classification system allows easy grouping and comparing of components according to their ESD sensitivity. The classification gives you an indication of the level of ESD protection that is required for the component. The higher the reported HBM voltage level, the more robust the device and the less sensitive it will be to electrostatic discharges.

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Table 2. ESDS Component Sensitivity Classification - Human Body Model
(Per ESD STM5.1-2001)

Class	Voltage Range
Class 0	<250 volts
Class 1A	250 volts to <500 volts
Class 1B	500 volts to < 1,000 volts
Class 1C	1000 volts to < 2,000 volts
Class 2	2000 volts to < 4,000 volts
Class 3A	4000 volts to < 8000 volts
Class 3B	>= 8000 volts

Surprisingly, we have been unable to find the information on ESD sensitivity of RFID chips and inlays in the data sheets or application notes for RFID chips available on web sites of the largest RFID IC and inlay manufacturers. We have eventually obtained the information from one manufacturer defining their RFID chips ESD sensitivity as “HBM Class 1B.” According to the classification in Table 2, that translates into the ability of the chips to withstand up to 1000V direct HBM discharge.

The ESD Association, however, offers a word of caution to use these classification systems as guides and not as absolutes. The true utility of the data is in comparing one device with another and to provide a starting point for developing your ESD control programs. That is why it is important for the RFID label converters to obtain the ESD sensitivity data from their inlay suppliers.

RFID Labels —Construction and Insertion

An RFID inlay, also known as an RFID transponder or RFID tag, consists of an RFID chip attached to an antenna. A typical antenna for a high frequency “smart label” is a printed or etched conductive pattern affixed to a plastic substrate, usually PET. The RFID chip houses the data with the product-related information. These components are then placed onto either a pressure-sensitive label stock or film carrier material. See Figure 1. While the illustration in Figure 1 shows the older-design HF label, this general construction is used for newer UHF inlays.

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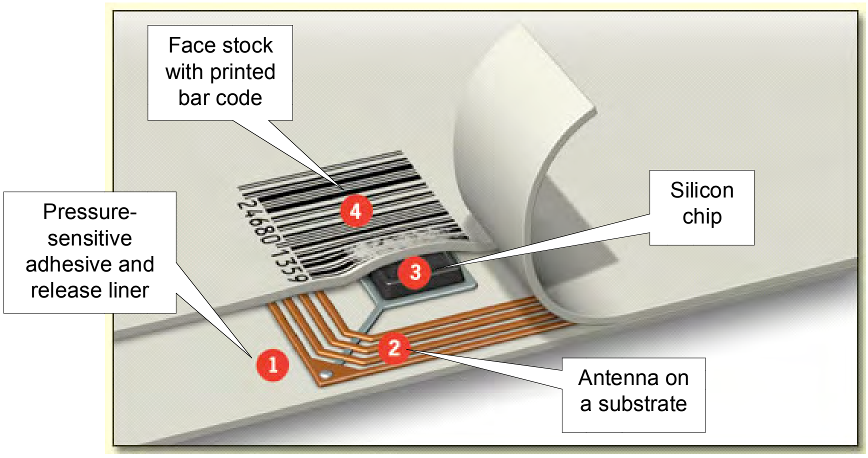

Image courtesy of Appleton®, manufacturer of technologically advanced label face stocks .

Figure 1 – Typical construction of a RFID label on a label stock with release liner.

Inlays on a film carrier are typically packaged in a roll form and delivered to smart-label converting companies that will insert the RFID inlays into a pressure-sensitive adhesive label stock. The smart-label converter then cuts the labels into the appropriate sizes and winds them into smaller rolls specific to the printer used in the end-product application.

For the purpose of illustrating this converting process on advanced converting machinery, the P500 RFID Inserter Module manufactured by Tamarack Products Inc. of Wauconda, Illinois, is shown below (see Figure 2). This inserter module was designed for in-line installation on new or existing label presses producing smart labels.

Label face stock is printed, then delaminated from the release liner and routed to the inserter module. A roll of transponders is unwound and fed into the vacuum applicator and cut-off unit. The vacuum cylinder also serves as the anvil for the cut-off. This assures that the cut transponder is joined to the face stock at matching speed to achieve the required registration.

The liner web can receive a continuous coating of hot melt adhesive, or a pattern coating of adhesive, to eliminate a void in the area of the transponder. The label webs are relaminated and routed to the press finishing section. At the end of the process, each label is tested. Defective tag removal is optional.

Triboelectric charging in the RFID label processing

It is not entirely surprising that ESD is being attributed as a cause of RFID tag failures. Insulating materials are an integral part of RFID label manufacturing, and virtually all insulating materials can be electrostatically charged from contact and separation with other surfaces. Creating electrostatic charge by contact and separation of materials is known as “triboelectric charging.” It involves the transfer of electrons between materials.

The atoms of a material with no static charge have an equal number of positive (+) protons in their nucleus and negative (-) electrons orbiting the nucleus. When the 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.

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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. The level of charge is affected by material type, speed of contact and separation, pressure, tension, humidity, and several other factors [4].

Triboelectric charging takes place in several locations on a press with an RFID tag applicator. On the Tamarack® P500 RFID Insertion Module for example, the five general areas where charge generation can take place are identified with letters A through E in Figure 2.

A – at the inlay unwind area where a web of inlays is unwound from a roll.
B – after the feed rollers where the inlay web goes through a nip including a rubber-coated roller.
C – at the vacuum applicator and cut-off unit where inlays are applied to the face stock (another nip including a rubber coated roller).
D – after another nip including a rubber coated roller feeding relaminated facestock and liner construction, now with inlays.
E – after the last nip before the rewinder.

There are two additional areas, identified in Figure 2 with letters F and G, where static charges generated on the face stock and release liner webs during delamination can potentially cause RFID chip damage. In area F, the face stock with inlays is relaminated with the release liner. The static charge on the surface of the release liner can cause an ESD event in that area. In the rewind at the end of the process, (area G), even a small surface charge could add up to a significant electrostatic potential as the winding roll grows in diameter, leading to an ESD event.

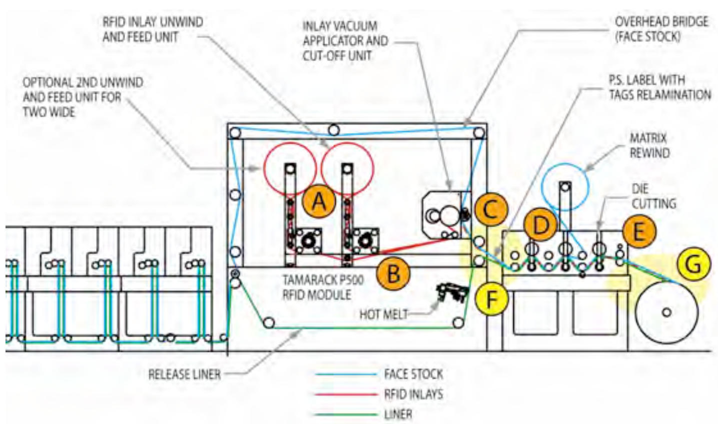

Figure 2 –Areas of possible static generation on an RFID inserter module.

There is little doubt that static electricity is present in RFID label converting. But is that static charge sufficient to damage the transponders? And does it warrant protective measures be taken by converters?

There is clear evidence that converting processes can generate electrostatic charges beyond the tolerances of an RFID IC. It is also clear that most label converters lack the knowledge and test equipment for analyzing IC failures. Logic suggests that successful converters must assume a defensive position and prudently protect their RFID ICs from unwanted ESD threats. Finally, delivering higher quality products manufactured using the minimum required protection will inevitably strengthen customer relationships.

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In addition, can anyone accurately predict whether the components of the next RFID generations will be more or less sensitive to ESD? UHF tags are considered more sensitive than VHF. It has also been suggested that Gen 2 inlays will contain design improvements to render inlays more robust against ESD. In the absence of any published ESD sensitivity data, all of that remains a speculation. And while most machines now run webs with RFID inlays at 150 fpm or slower, when production speeds reach 500 fpm, the charge generation will increase dramatically.

Also, ESD events generate electro-magnetic interference (EMI) that appears as signals in the radio-frequency spectrum. Typically in the range of 100 MHz to 2 GHz, ESD events are in the same frequency range as the UHF inlay operating frequency (approx 915 MHz). Because EMI propagates through both radiation and conduction, an ESD event in one piece of equipment may affect the nearby equipment or devices, making the source of the problem difficult to locate [6]. (At the time of this writing, we have not found any published data on this aspect of ESD-related failures of UHF labels.

In summary:

- ESD can create catastrophic or latent failures in RFID ICs.
- ESD can occur throughout the manufacturing, testing, shipping, handling or converting processes.
- Component damage can occur as the result of a direct discharge to the component.
- Components can vary significantly in their sensitivity to ESD [4].

With this basic understanding of ESD and its impact on your environment, you can now begin to develop an effective ESD control program.

Developing the ESD Protection Program

The two published documents with guidelines for RFID use [2, 5] devote significant attention to the ESD problem. They specifically point to several sources of static electricity, such as peeling the RFID transponders label from the release liner, charging of rubber conveyor belts, charge generation in unwinding or unstacking the face stock, and others.

These guidelines, however, do not mention several other ESD risks that we have already identified in this article. And while the quoted guidelines instruct users to deal with the ESD problems, they do not offer any specific solutions.

In the absence of specific ESD prevention standards, we suggest that RFID label converters and the user community utilize the experience of manufacturers and users of integrated circuits, such as board assemblers, who have been dealing with the issues of ESD control for several decades and have developed many valuable standards and guidelines.

A comprehensive program for ESD protection consists of these four steps:

1. Design immunity into the devices
2. Protect ESD sensitive devices
3. Eliminate and reduce static charge generation
4. Dissipate and neutralize static charge

1. Design Immunity in the Devices. Manufacturers of the RFID chips and inlays are responsible for designing them to be as immune as is reasonable from the effects of ESD. They recognize their responsibility expecting also that the other players in the chain will do their part. In their

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"Tag-it™ HF-I Transponder Inlays Reference Guide" [7], Texas Instruments warns that electronic devices can be destroyed by electrostatic energy. They also indicate that for the proper operation of the machine it is necessary to ionize the foil to remove the electrostatic charge. *(Author's note: We assume that the "machine" reference in the Guide means "RFID label converting equipment" and the "foil" reference means the "inlay carrier material".)*

2. Protect ESD Sensitive Devices. On the most basic level, the converter must protect ESD sensitive devices in handling from the time they are received in to the time they are shipped out.

First and foremost, containers with ESD sensitive devices must carry the ESD Susceptibility Symbol (Figure 3). The symbol literally translates to "ESD sensitive contents, don't touch without taking the necessary precautions."

Figure 3--ESD Susceptibility Symbol

Direct protection of ESD sensitive devices from electrostatic discharge is provided by ESD-protective packaging materials such as bags, corrugated, and rigid or semi-rigid packages during shipping and by ESD-protective tote boxes and other containers for protection during inter- or intra-facility transport [4]. The main ESD function of these packaging and material handling products is to limit the possible impact of ESD from triboelectric charge generation, direct discharge, and electrostatic fields. ESD protective packaging and handling materials should be appropriately labeled to indicate their function.

3. Eliminate and Reduce Static Charge Generation. The measures for eliminating or reducing static charge generation in *production* and *handling* of RFID chips can take many forms. Fewer options are available to achieve that goal in the RFID label *converting* process. In one such attempt to reduce static charge generation, film-based label stock with antistatic qualities is used, such as Appleton's SmartStrate® product [1],. The protective effect of the antistatic layer in the label stock was rather limited during the RFID label converting phase due to the presence of other non-conductive and static-prone layers.

Also, other production considerations may go against the ESD control requirements. For instance, to reduce the RFID label unit cost, printing antennae may become the preferred process. To ensure that conductive inks adhere to plastic base materials such as PET and PP, corona or plasma treatment is required. While such treatment is necessary, there is increased propensity o for electrostatic charging of the film.

Relative humidity also influences the level of electrostatic charges. When humidity is low, higher static charges are generated. Humidity levels of over 50% limit static build-up since surface moisture makes material more conductive. At the same time, relative humidity over 60% can be uncomfortable to workers, can cause equipment problems, and introduce contaminants into your system. In the early 80s, relative humidity was one of the accepted means of controlling static electricity in the electronics industry until two Honeywell scientists decisively demonstrated that

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room ionization is a better alternative [8]. After that, the electronics industry never looked back. While maintaining relative humidity at 50% remains a viable method of controlling static electricity, RFID label converters should not overlook the experience of the electronics industry.

4. Dissipate and Neutralize Static Charge. When charge generation is unavoidable, the emphasis switches to dissipation and neutralization of static charges. This part of the program is most critical and covers controlling electrostatic charges on both operators and material.

In many facilities, people are one of the primary generators of static electricity. For example, the simple act of walking around can generate several thousand volts on the human body. Even in highly automated assembly and test processes, people still handle static sensitive devices in the warehouse, in repair, in the lab, in transport. For this reason, static control programs place considerable emphasis on controlling operator-generated electrostatic discharge [4].

According to the Proposed Guidelines for the Use of RFID-Enabled Labels in Military Logistics [5], to avoid build-up of static charge which may discharge through the RFID-enabled label as it is removed from the printer or applied to the carton or asset, labeling operators should work in antistatic [ESD-protective] environments and wear antistatic [static dissipative] clothing and protective gear. Conductive or static dissipative floors and mats, as well as conductive footwear, are some of the solutions employed to continually dissipate electrostatic charges from operators.

While a direct connection to ground is the primary method of static charge control for conductors and operators, air ionization is more frequently used to neutralize static charges on insulators that cannot be grounded, such as webs of non-conductive plastic and coated paper. Air ionization is based on charging the molecules of the gases of the surrounding air. Any static charge present on objects in the work environment will be neutralized by attracting opposite polarity charges from the air.

Selecting static neutralizers for RFID label converting

The ANSI/ESD S20.20-1999 Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment [3] is a very useful standard for specifying ionizing performance requirements. This Standard defines an ESD protected area as a single workstation (fixed or portable), laboratory, room, building or any other area with pre-designated boundaries that contains materials and equipment designed to limit electrostatic potentials. In the protected area, all process essential insulators that have electrostatic fields exceeding 2,000 volts should be kept at a minimum distance of 12 inches from ESDS items. This limit is set for 100V HBM sensitive devices.

Based on the 2000 volt maximum allowable electrostatic potential, all non-conductive webs and rolls in the RFID label converting machinery should not have an electrostatic potential higher than 2000 volts if they are within 12 inches of the RFID devices. The web *carrying the RFID devices* must be neutralized at any given point of charge generation to a potential less than 1000 volts. (*Note that an electrostatic potential on a web is not equivalent to a 1000 volt ESD sensitivity limit per the HBM standard.*)

Charge generation takes place on the press with the RFID applicator at every location shown in Figure 2. The solution quickly becomes clear that multiple static neutralizers are needed on RFID label and application machinery. Figure 4 shows the recommended locations for static neutralization on the P500 Module.

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On the Tamarack RFID label inserter module, ionizers are placed in every location where charge generation takes place and where inlays can be exposed to ESD. Ionizers 1 and 2 neutralize the charge generated when unwinding a roll with transponder chips. Ionizer 3 neutralizes the charge on the web where inlays exit feed rollers. Ionizers 4 and 5 neutralize the charge on the label face stock and release liner. Ionizer 6 neutralizes the charge on the facestock with the inlays coming out off the nip after the vacuum applicator and cut-off unit. Ionizer 7 neutralizes the charge where the inlays on the facestock are relaminated with the release liner. Ionizer 8 neutralizes the charge where relaminated facestock with inlays and liner pass through the final nip in the finishing section of the press. Ionizer 9 neutralizes the charge in the rewind.

The illustration in Figure 4 is not intended to suggest that neutralizers are required in every shown location. Users can judge where neutralizers are needed by monitoring charge levels. (Measuring and monitoring charges is a complex issue that goes beyond the scope of this article.)

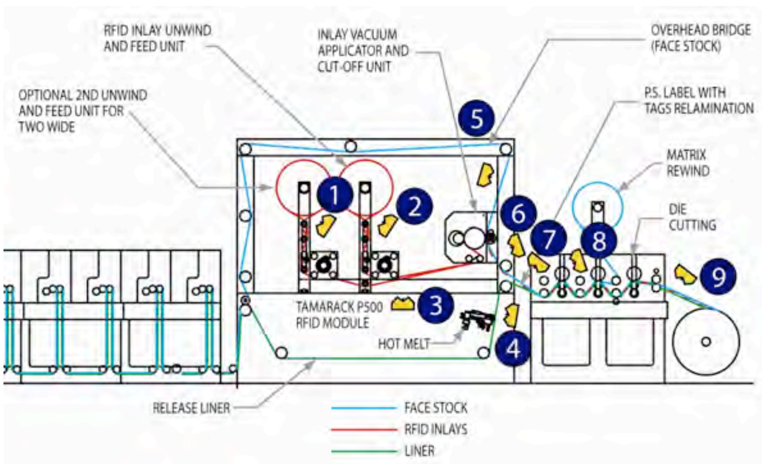

Figure 4 – Recommended locations for static neutralizers in an RFID inserter module.

There are three basic types of ionizers which are commercially available: passive neutralizers, such as tinsel and string, ionizing air blowers, and ionizing bars with and without air assist.

A recently published article [9] correctly rules out passive eliminators for protection of RFID tags. Although passive devices are used to reduce static charges in some converting applications, the passive ionizer *does not start ionizing until the potential on the material exceeds its ionizing threshold*, typically 2000 to 5000 volts -- a static charge that could exceed the level considered hazardous for RFID tags.

Most ionizing air blowers will reliably neutralize a slow-moving web (up to 100 fpm), but at faster speeds they will become ineffective [10]. Also, the majority of the commercially-available ionizing air blowers do not include monitoring circuitry to assure that the blowers are functioning properly. Another potential problem with ionizing air blowers is their need for maintenance, including cleaning the ionizing electrodes and replacing the air filters. Given the fact that multiple neutralizers might be necessary in RFID applications, the ionizing air blowers may not be practical.

The third choice of ionizers for RFID applications is static neutralizing bars, especially those with a long neutralizing range requiring no air assist. Such bars rely on the field of the charges on the material to attract only the ions (positive or negative) necessary to neutralize the charge. These

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devices provide the accurate and measured amount of ions necessary to reduce the static charges quickly to levels that are no longer dangerous to the RFID tags.

When researching static neutralizing solutions, users will encounter a menagerie of ionizer products and technologies along with the varying claims of their manufacturers. These include conventional AC, TrueAC™, Virtual AC™, Pulsed DC, and steady-state DC. All these products and technologies have their advantages and valuable features. A review of different ionizers and ionizing technologies could be a subject of another paper.

Regardless which technology you consider, the selected static neutralizers should meet all of the following criteria:

- Long neutralizing range *without air assist* to "reach" out toward the charge generation areas (web release points from nip rollers, etc.)
- High-reliability design providing years of trouble-free service
- System diagnostics and performance displays, and analog or digital interface
- Modular construction for daisy-chain configuration.

Systems with diagnostics and performance displays provide direct and real-time feedback about the performance of the neutralizers. Systems with analog or digital interface make it possible to integrate the neutralizers into the machine controls for operator interface and record keeping.

In the past five to six years, the converting and plastic industry has moved from simplistic static control devices such as tinsel and conventional static eliminators, and turned to the advanced static control solutions offering system diagnostics and performance monitoring [11]. Many narrow-web converters and printers getting involved in RFID label processing in the coming years will need to address ESD prevention issues. It would be in their best interests to avoid the lure of "cheap" and simplistic static controls. The economics of RFID label converting should justify using the best static neutralizing equipment – especially when considering the high cost of inlays.

Modular systems that allow static neutralizing bars to be connected in a daisy-chain configuration are ideal for RFID applications where a number of static neutralizers are required. Some neutralizing bar designs allow as many as fifteen bars to be connected together to a single power supply with monitoring circuitry [12]. A typical daisy-chain arrangement of the static bars is shown in Figure 5. Such an expandable configuration provides a highly efficient and reliable arrangement, as well as one of the most economical.

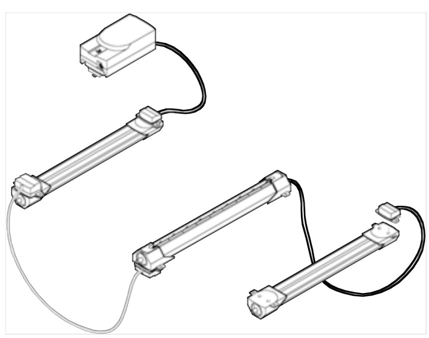

Figure 5 – Daisy-chain arrangement of static neutralizing bars for multi-spot RFID label applications.

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An advanced seven-bar static neutralizing system with a single power supply and monitoring circuitry was used on the Tamarack Products Inc. model R500 RFID Module installed on a Mark Andy model 2200 13″ label press. See Figure 6.

Figure 6 – Placement of static neutralizing bars on an RFID inserter module.

Three of the seven static neutralizing bars (yellow and blue devices) are visible in the photo. One at the inlay reel unwind, the second after the RFID feed station, and the third bar (in the upper right corner of the photo) against the face stock web. The other bars are installed to neutralize the liner at the relamination point and in the press's finishing section, including the final product rewind.

According to David Steidinger, President of Tamarack Products Inc., based on the experience of his company and other RFID label converters, "unexplained" and presumed converting damage to RFID chips is about 1% on the machines and presses equipped with anti-static systems.

Areas for further work

- RFID chip manufacturers must start including the ESD sensitivity information in the data sheets for RFID ICs, inlays and labels; and the converters need to be educated as to the meaning of this information. This will enable the design of an appropriate static control program.
- Methods of in-house data gathering that show the effect of static control methods must be developed and implemented. This will allow converters to determine the impact of their static control methods.
- The effect of the antennae on the ESD sensitivity of RFID ICs needs to be studied.
- The effect of electro-magnetic interference (EMI) generated by ESD events on the UHF inlays, RFID production, and test equipment needs to be studied.

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Conclusions

There is a more than adequate body of work showing the necessity of providing the static control measures during RFID label converting. Confronting ESD failures is analogous of fighting an invisible enemy – you need the best defense you can afford. Every RFID label converter needs to develop and implement an effective ESD prevention program. The converters will need technical support in the design of the processes and implementation of the program. Comparing RFID inlay yield before and after the converting process, and RFID label yield with and without static control procedures will help determine if the static control measures have successfully increased production yields.

Author

Mark Blitshteyn is general manager for Ion Industrial, a division of Ion Systems providing static control solutions for high-tech electronics manufacturing. Mark has over twenty-five years experience in industrial control applications and *holds a degree in electrical engineering from Leningrad Avionics Institute (Technical University) and an MBA from Rutgers University. He holds 12 U.S. patents and has authored 20 publications, many in the area of industrial static control and surface treatment. He can be reached at (860) 292-6847, or email: markblit@ion.com* (888-310-3334

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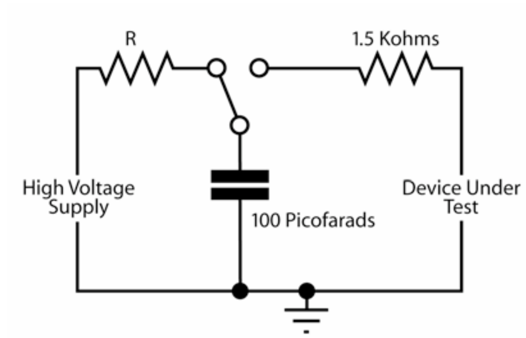
Side bar – ESD Sensitivity Test Models. Source: http://www.esda.org/esdbasics5.htm

Human Body Model Sensitivity:
A source of ESD damage is the charged human body, as modeled by HBM standards. This testing model represents the discharge from the fingertip of a standing individual delivered to the conductive leads of the device. It is modeled by a 100 pF capacitor discharged through a switching component and 1,500 ohm series resistor into the device under test. The discharge itself is a double exponential waveform with a rise time of 2-10 nanoseconds and pulse duration of approximately 150 nanoseconds.



Typical Human Body Model Circuit

Machine Model Sensitivity:
A source of damage for the MM is a rapid transfer of energy from a charged conductor to the conductive leads of the device. This ESD model is a 200 pF capacitor discharged through a 500 nH inductor directly into the device with no series resistor. In the real world this model represents a rapid discharge from items such as, charged board assembly, charged cables, or the conduction arm of an automatic tester. The discharge itself is a sinusoidal decaying waveform with a rise time of 5-8 nanoseconds and a period of approximately 80 nanoseconds.

Charged Device Model Sensitivity:
A source of damage for the CDM is the rapid discharge of energy from a charged device. The ESD event is totally device dependent, but its location relative to ground can influence the failure level in the real world. The assumption for this test model is that the device itself has become charged and rapid discharge occurs when the charged device's conductive leads contact a metallic surface, which is at a different potential. The waveform rise time is often less than 200 picoseconds. The entire event can take place in less than 2.0 nanoseconds. Although very short in duration, current levels can reach several tens of amperes during discharge.

Table 2 - ESD Susceptibility Test References for Devices

ESD MODEL	ESD Standards and Methods for Susceptibility Testing of Devices
HBM	ESD STM5.1 MIL-STD-883 Method 3015 MIL-STD-750 Method 1020 MIL-PRF-19500 MIL-PRF-38535 JEDEC JESD 25
MM	ESD-STM5.2 JEDEC JESD 25
CDM	ESD STMS5.3.1 JEDEC JESD 25

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