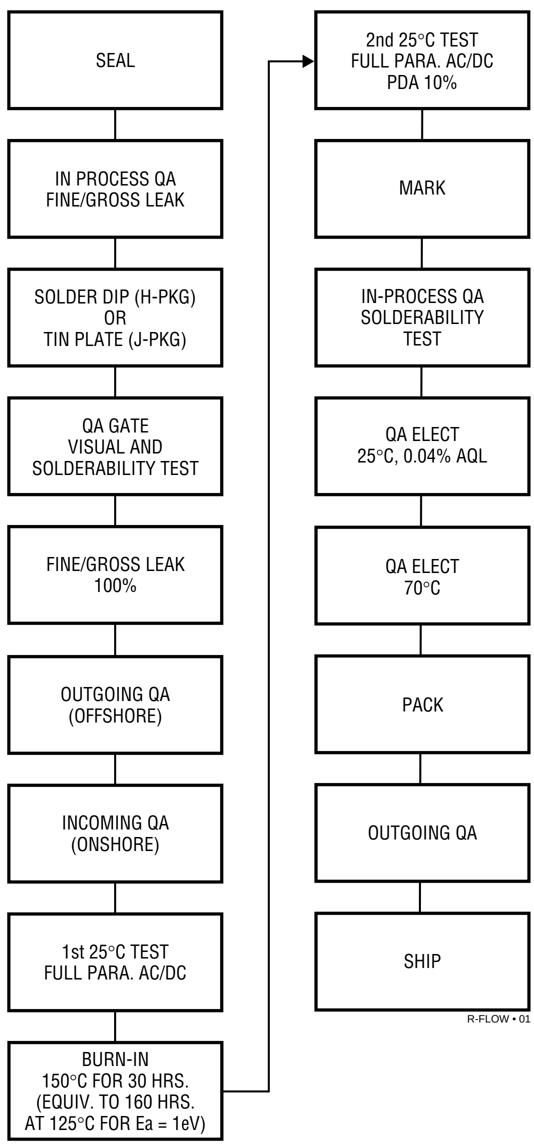
Linear Technology Corporation R-Flow

Reliability has been a key focal point at Linear Technology Corporation (LTC) since its inception in 1981. Our standard product reliability is monitored closely and we have generated an extensive reliability database for both hermetic and plastic devices. This data is published on a quarterly basis and we are seeing very low reliability failure rates in the under 1 FIT range at 55°C.*

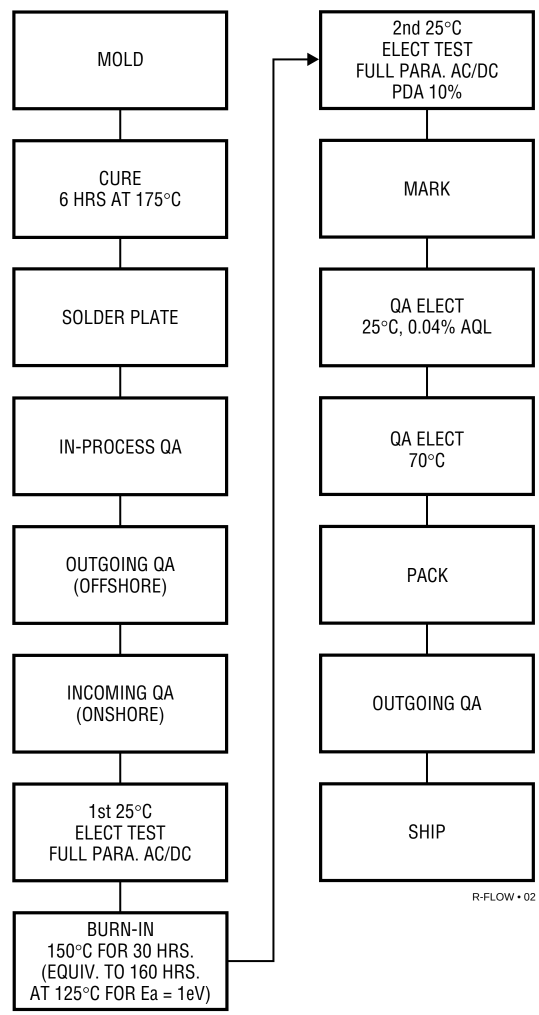
In response to customer requests, we have added an even higher level of reliability screening for commercial hermetic and plastic components. LTC's R-Flow adds a burn-in equivalent to 160 hours at 125°C to the standard commercial process flow. Following burn-in, a 100% room temperature test is performed and a 10% PDA (Percent Defective Allowed) is applied. This PDA limit affords an additional level of insurance on a lot-by-lot basis and prevents the occasional disparate lot from being shipped for critical applications. The additional room temperature insertion also decreases the probability of any electrical defectives in the R-Flow lot.

*1 FIT = 1 failure in 10^9 device hours.

R-Flow for TO-5 and CERDIP Packages



R-Flow for Plastic Dual-In-Line Packages



Introduction

As integrated circuit technologies achieve higher speed, smaller geometries, lower power and lower voltage, there is a trend toward greater ESD (Electrostatic Discharge Damage) susceptibility. State-of-the-art CMOS ICs can be susceptible to as little as 50V, a static level that is way below the 500V to 15,000V commonly found in an ESD unprotected work environment. As these state-of-the-art ICs get designed into systems, the ESD susceptibility of system hardware also increases proportionately. Industry estimates of losses due to ESD are in the range of a few billion dollars annually.

It has now become increasingly more important for all semiconductor manufacturers and users of semiconductors and other electronic components to fully understand the nature of ESD, the sources of ESD, and its impact on quality and reliability, to effectively deal with this *silent chip killer*.

Linear Technology Corporation (LTC) has successfully undertaken a simple but effective ESD Protection Program as part of an overall program designed to enhance product quality and reliability. Described in this section are the key points of this program.

This objective is to provide increased ESD awareness by showing the sources of ESD in the work environment, and to recommend key points for the successful implementation of an ESD program on a company-wide basis.

The end result of a successful ESD program would be the reduction of line failures, final inspection failures and field failures, improved manufacturing yields, improved product quality and reliability and lower warranty costs. We hope that this will help to convince the reader that an ESD Protection Program must be an integral part of every electronic company's product quality and reliability program.

Key Elements of a Successful ESD Protection Program

Recent improvements in failure analysis techniques to correctly identify ESD failures together with an increase in ESD related information from technical publications, EOS/ESD symposiums and vendors have significantly helped to increase ESD awareness.

The ESD Protection Program at LTC was successfully launched in 1983 when production of ICs was first started. A constant upgrading of the program is still underway. During the ongoing efforts to improve product quality and reliability, previously unrecognized ESD related problems have been brought to light and corrected.

An effective ESD Protection Program must start at product design, and encompass all manufacturing and handling steps up to and including field service and repair. Our design goal is to achieve an ESD susceptibility level of 2,000V or greater.

Since the sources of static in any work environment are similar, key elements of the program successfully implemented at LTC can also be applied to all users of electronic components. Where these key elements apply, static controls generic to an electronic systems manufacturer are included.

The key elements of a successful ESD Protection Program include:

1. Understanding static electricity.
2. Understanding ESD related failure mechanisms.
3. ESD sensitivity testing.
4. Establishing an ESD task force to outline the requirements of the program, sell the program to management, implement the program, review progress against milestones, and follow up to ensure the program is continuously improved and upgraded. Selecting an ESD coordinator to interface with all departments affected.
5. Conducting a facility evaluation to help identify the sources of ESD and establish static control measures.
6. Setting up an audit program.
7. Selecting ESD protective materials and equipment.
8. Establishing a training and ESD awareness program.

What is Static Electricity?

Lightning and sparks from a metallic doorknob during a dry month are examples of static electricity. The magnitude of static charge is dependent on many variables, among them the size, shape, material composition, surface characteristics and humidity. There are basically three primary static generators: triboelectric, inductive and capacitive charging.

Triboelectric Charging

The most common static generator is triboelectric charging. It is caused when two materials (one or both of which are insulators) come in contact and are suddenly separated or rubbed together, creating an imbalance of electrons on the materials and thus static charge.

Some materials readily give up electrons whereas others tend to accumulate excess electrons. The Triboelectric Series lists materials in descending order from positive to negative charging due to this triboelectric effect. A sample triboelectric series is shown here. A material that is higher on the list, e.g., a human body, will become positively charged when rubbed with a material, e.g., polyester, that is lower on the list, due to the transfer of electrons from the human body to the polyester material.

Triboelectric Series

	Human Body
Positive +	Glass
	Mica
	Nylon
	Wool
	Fur
	Silk
	Aluminum
	Paper
	Cotton
	Steel
	Wood
	Hard Rubber
	Orlon
	Polyester
	Polyethylene
Negative –	PVC (Vinyl)
	Teflon

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Inductive Charging

Static can also be caused by induction, where a charged surface induces polarization on a nearby material. If there is a path to ground for the induced charge, an ESD event may take place immediately. An example of an induced charge is when the plastic portion of a molded IC package acquires a charge either through triboelectric charging or other means, produces an electrostatic field and induces a charge on the conductive leads of the device. When the device leads are grounded, a short duration damaging static pulse can take place.

Capacitive Charging

The capacitance of a charged body relative in position to another body also has an effect on the static field. To see that this is true, one need only look at the equation $Q = CV$ (charge equals capacitance times voltage). If the charge is constant, voltage increases as capacitance decreases to maintain equilibrium. As capacitance decreases the voltage will increase until discharge occurs via an arc. A low voltage on a body with a high capacitance to ground can become a damaging voltage when the body moves away from the ground plane. For example, a 100V charge on a common plastic bag lying on a bench may increase to a few thousand volts when picked up by an operator, due to a decrease in capacitance.

These sources of static can be found almost anywhere in an unprotected work environment, on personnel wearing synthetic clothing and smocks, on equipment with painted or anodized surfaces, and on materials such as carpets, waxed vinyl floors, and ungrounded work surfaces.

Understanding the Failure Mechanisms

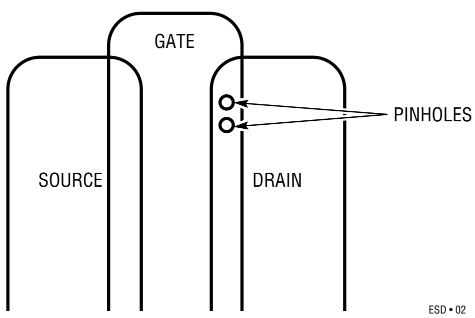
In the past, analysis of electrical failures to pinpoint ESD as a cause was often difficult. But with a better understanding of failure mechanisms and their causes, and the use of more sophisticated techniques like scanning electron microscopy (SEM), pinpointing ESD failures can now be part of a routine failure analysis.

Parametric or functional failure of bipolar and MOS ICs can occur as a result of ESD.

The primary ESD failure mechanisms include:

1. **Dielectric Breakdown:** This is a predominant failure mechanism on MOS devices when the voltage across the oxide exceeds the dielectric breakdown strength. This failure mechanism is basically voltage dependent where the voltage must be high enough to cause dielectric breakdown. As such, the thinner the oxide, the higher the susceptibility to ESD. MOS device failures are characterized by resistive shorts from the input to V_{DD} or V_{SS}.

MOS Transistor Structure Showing ESD Included Pinholes at Gate Oxide



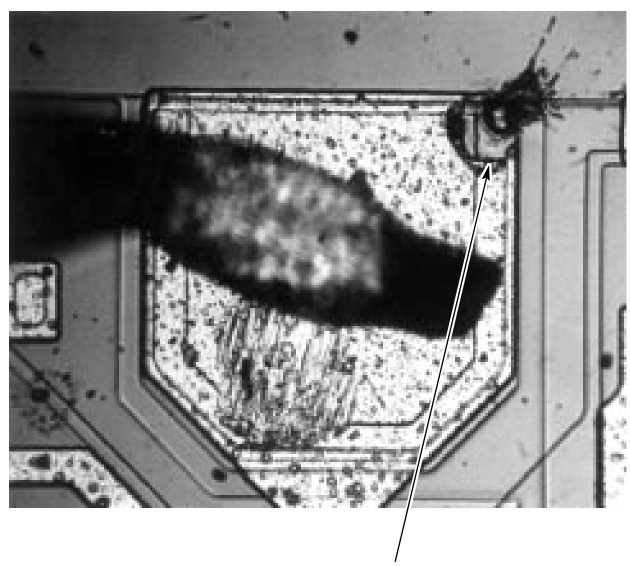
This failure mechanism can also be found on bipolar ICs which have metallization runs over active semiconductor regions separated by a thin oxide. Device failures are characterized by resistive or high leakage paths.

2. **Thermal Runaway (Second Breakdown):** This failure mechanism results in junction melting when the melting temperature of silicon (1415°C) is reached. This is basically a power dependent failure mechanism; the ESD pulse shape, duration and energy can produce power levels resulting in localized heating and eventually junction melting, even though the voltage level is below that required to cause dielectric breakdown. Breakdown of the emitter-base junction of a NPN transistor is a common ESD related failure mode on bipolar ICs, since the highest current density occurs on the smallest current carrying area which is typically the emitter-base junction. Low current gain (h_{FE}) is very sensitive indicator of emitter-base junction damage on bipolar linear ICs.

3. **Parametric Degradation:** On precision, high speed ICs (e.g., bipolar operational amplifiers with a typical input bias current of 10pA and low input offset voltage of typically 50μV) ESD can cause device degradation, besides functional failures. This can impact electrical performance and adversely affect device reliability.

   This degradation in device parametric performance is far more difficult to pinpoint as an ESD related failure mode. It is also the least understood among the failure modes. The extent of this degradation is dependent on the number of ESD pulses and the level of damage sustained. The first ESD pulse may not cause an IC to fail the electrical data sheet limits but with each subsequent ESD pulse, the parametric performance can degrade to the point where the device no longer meets the data sheet limits.

   There is a great deal of current research focused on ESD induced latent failures, and there now appears to be more evidence of this type of failure mechanism.



RESISTIVE SHORT ON A METALLIZATION STRIP OVER A THIN OXIDE N + REGION ON A BIPOLAR IC

ESD Failure Analysis Program

ESD defect identification must be an integral part of a failure analysis program. The key objectives are to help identify the ESD failure mechanism, isolate the cause for failure, and implement corrective action to prevent recurrence. All devices suspected of being damaged by ESD after initial electrical verification, should be failure analyzed.

An ESD failure analysis program is outlined below.

1. Initial electrical test verification.
2. Review device history to determine if there are any similar failures in the past. Review ESD sensitivity data if available.
3. Investigate conditions in any area that can potentially cause ESD damage.Common potential problem areas include:
   - Proper grounding procedures not being followed (e.g., conductive table/floor mats not grounded, personnel not wearing wrist strap, etc.)
   - Improper handling (e.g., handling devices at non-ESD protected station)
   - Transporting devices in unapproved containers (e.g., in common plastic bags/tubes/tote boxes)
   - Changes in procedures or operation
   - Changes in equipment
   - Design deficiencies
4. Failure analysis sequence:
   - Bench testing and curve tracer analysis
   - Pin-to-pin analysis
   - Internal visual (10× to 1000×)
   - Liquid crystal hot spot detection
   - Scanning electron microscopy (SEM), secondary ion mass spectrometry (SIMS), energy dispersive X-ray analysis (EDX), scanning auger microprobe (SAM), radiography, voltage contrast, electron beam induced current (EBIC)
   - Plasma/chemical etching
   - Special fault decoration
   - Micro-sectioning
   - Documentation

   An excellent failure analysis manual is published by the Rome Air Development Center titled *Failure Analysis Techniques—A Procedural Guide*.
5. Duplication of failure by stressing identical devices. The same or similar electrical failure mode is a good indicator of an ESD induced failure mode.
6. Implement corrective action to prevent recurrence. Corrective action may include:
   - Component, board, sub-system or system level re-design
   - Improve ESD controls
   - Improve part handling
   - Improve ESD awareness
   - Improve compliance with ESD protection procedures
   - Increase audit frequencies
   - Improve packaging materials and procedures

Corrective action taken by the end user should include a thorough review of electrical and mechanical packaging designs. In addition the end users should consult with the IC manufacturer on their findings, request failure analysis of suspected ESD failures if needed and require the IC manufacturer to take appropriate corrective action on any confirmed ESD failure.

ESD Sensitivity (ESDS) Testing

ESDS testing is crucial in helping the IC designer and the end user evaluate the ESD susceptibility of a particular device. At LTC, ESDS testing is incorporated into the failure analysis program and is performed on each device as part of the product characterization program. The ESDS testing is also part of new product qualification. LTC performs this ESDS testing according to MIL-STD-883 Method 3015.

The ESDS testing provides immediate feedback to the IC designer on any weakness found in the design and permits design correction before product release. The ESDS data collected is also used as baseline data to evaluate the effect of any future design changes on the ESDS testing performance, and to help ensure that the final packaging methods meet MIL-PRF-38535, Appendix A requirements. Devices are categorized as either Class One, Class Two or Class Three, each with a susceptibility range from 0V to 2000V, above 2000V but below 4000V, and above 4000V respectively. Topside marking with equilateral triangles is specified by MIL-PRF-38535, Appendix A.

Since people are considered to be a prime source of ESD, the ESDS test circuit is based on a human ESD model. A 1500Ω resistor and a 100pF capacitor are used in the test circuit. Human capacitance is typically 50pF to 250pF, with the majority of people at 100pF or less, and human resistance ranges from 1000Ω to 5000Ω. An ESD failure is defined as a voltage level which causes sufficient damage to the device such that it no longer meets the electrical data sheet limits.

After initial ESDS testing, it is important that ESDS test monitoring be performed periodically on devices from various lots to determine lot-to-lot variation. The VZAP-2 report titled "Electrostatic Discharge (ESD) Susceptibility of Electronic Devices" published by the Reliability Analysis Center, Rome Air Development Center, contains a wealth of information on ESDS testing data on devices of different process technologies from many manufactures. The data in this report clearly indicates a large lot-to-lot variation relating to ESD susceptibility on the same device.

Design for ESD Protection

ESD protection designs employed on LTC devices include:

1. Input clamp diodes
2. Input series resistors to limit ESD current in conjunction with clamp diodes
3. New ESD structures
4. Eliminating metallization runs over thin oxide regions when they are tied directly to external pins

ESD Task Force

An ESD task force should consist of members from each effected department to do the foundation work, sell the program to management, and implement the program with the following objective:

1. Develop, approve and implement an ESD control specification covering all aspects of design, ESD protected materials and equipment, and manufacturing
2. Raise the level of ESD awareness
3. Develop a training and certification program
4. Work with all departments on any ESD questions or problems
5. Develop a program to educate and assist sales personnel, distributors and customers to minimize ESD
6. Review and qualify new ESD protective materials and equipment, and keep specification and training program upgraded
7. Measure the cost-to-benefit ratio of the program

Facilities Evaluation

The ESD task force should be responsible for facility evaluation. This evaluation should be guided by the ESD coordinator. The ESD coordinator should be chosen for strong knowledge of ESD controls and for the ability to effectively interface with all effected departments. The primary objective of the task force is to pinpoint areas that represent the source of static electricity and potential yield losses due to ESD.

A representative, preferably the engineering or production manager, from each of the key manufacturing areas should be represented on this task force. At LTC this effort is headed by the Quality Assurance Manager and the Package Engineering Manager. The balance of the ESD task force members are the Test Engineering, Product Engineering and Production Managers.

The only equipment needed for this survey is a field static meter which measures static up to a level of 50kV. Both nuclear and electronic type static meters are available from manufactures like 3M, Simco, Wescorp, Scientific Enterprises, Voyager Technologies and ACL.

Regardless of area classification, all manufacturing areas can be broken down into the following categories for evaluation purposes.

1. **Personnel:** Personnel represents one of the largest source of static, form the type of clothing, smocks and shoes that they wear (for example, polyester or nylon smocks).
2. **The Environment:** The environment includes the room humidity and floors. Relative humidity plays a major part in determining the level of static generated. For example, at 10% to 20% RH a person walking across a carpeted floor can develop 35kV versus 1.5kV when the relative humidity is increased to 70% to 80%. Therefore the humidity level must be controlled and should not be allowed to fluctuate over a broad range.

   Floors also represent one of the greatest contributors of static generation on personnel, moving carts or equipment because of movement across its surface. Carpeted and waxed vinyl floors are prime static generators.

3. **Work Surfaces**: Painted or vinyl-covered table tops, vinyl-covered chairs, conveyor belts, racks, carts and shelving are also static generators.
4. **Equipment**: Anodized surfaces, plexiglass covers, ungrounded solder guns, plastic solder suckers, heat guns and blowers are also static generators.
5. **Materials**: Look out for common plastic work holders, foam, common plastic tote boxes and packaging containers.

Examples of typical static levels are shown in the table below.

	RELATIVE HUMIDITY	
ESD SOURCE	**10% ~ 20%**	**70% ~ 80%**
Walking across a carpeted floor	35kV	1.5kV
Walking across a vinyl floor	12kV	0.3kV
Picking up a common plastic bag	15kV	0.5kV
Sliding plastic box over bench/conveyor	15kV	2.0kV
Ungrounded solder sucker	8kV	1.0kV
Plastic cabinets	8kV	1.0kV

This ESD survey should include all direct and support manufacturing areas where semiconductor and other electronic components are handled and should be extended to cover distribution offices. Once the facility evaluation is completed, the results are reviewed by the ESD task force, and controls are selected to combat each potential ESD problem area.

The ESD Protection Program

The degree of static control should be determined by the most static sensitive device or assembly in the operation. Top management support and implementing the same basic controls in all areas with no double standards will help to ensure success.

The basic concept of complete static protection is the prevention of static buildup, the removal of any already existing charges, and the protection of electronic components from induced fields. The first and foremost line of defense is the personnel wrist strap together with grounded conductive or static dissipative table tops, and conductive heel straps and grounded conductive or static dissipative floor mats.

To increase ESD awareness at LTC, all ESD Protection Areas are marked by an identifying label (for example, label shown below). This label alerts all personnel that ESD protection procedures are enforced in the area.

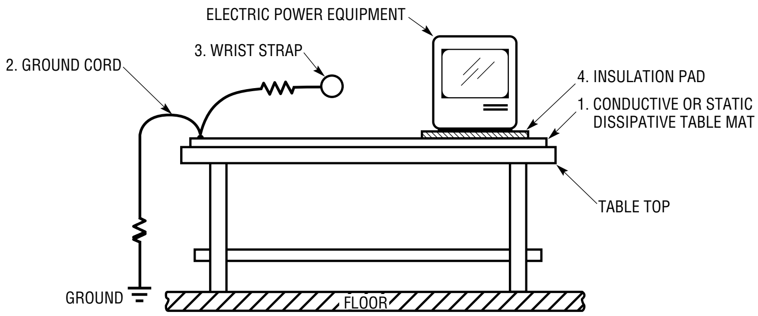
ESD • 04

ESD Protected Workstation

Example of ESD Protected Workstations are shown in Figures 1 and 2.

Option 1 (Figure 1): All electronic components, subassemblies and assemblies must be handled at an ESD protected workstation only. The figure illustrates an ESD protected workstation consisting of a static dissipative table mat grounded to earth or electrical ground through a $1M\Omega$ series resistor, with the requirement that the operator wears a grounded insulated conductive wrist strap with a $1M\Omega$ series resistor. This $1M\Omega$ series resistor protects the operator from electrical shock, should the operator come in contact with a potentially lethal voltage. Option 1 should be used where the operator does not require a large degree of freedom, e.g., during product inspection, etc.

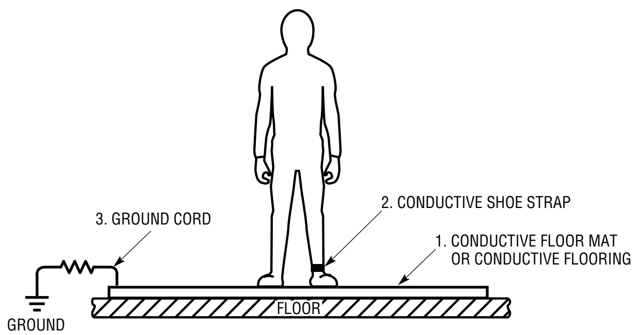
Option 2 (Figure 2): Shows an alternate installation method for an ESD protected workstation. It consists of a conductive or static dissipative floor mat grounded to earth or electrical ground through a $1M\Omega$ series resistor with the operator wearing a conductive shoe strap. This installation is typically used where the operator needs freedom of movement over a large area, e.g., environmental chamber loading and unloading, electrical testing, etc. To be effective the conductive shoe strap must make contact with the wearer's foot or thin sock and be attached to the wearer's shoe to maximize contact between the strap and the conductive or static dissipative floor.



MATERIALS:
1. 1/16" THICK CONDUCTIVE OR STATIC DISSIPATIVE TABLE MAT WITH SURFACE RESISTIVITY OF $\leq 10^8 \Omega$ PER SQUARE.
2. INSULATED CONDUCTIVE GROUND CORD WITH A SERIES RESISTOR OF 1/2W MINIMUM, 1M $\Omega \pm 10\%$, AND 18AWG OR LARGER INSULATED WIRE.
3. INSULATED CONDUCTIVE WRIST STRAP WITH 1/4W MINIMUM, 1M $\Omega \pm 10\%$ AND 20AWG OR LARGER INSULATED WIRE. THE CURRENT LIMITING 1M Ω RESISTOR MUST B LOCATED RIGHT NEXT TO THE WRIST TO PREVENT THE POSSIBILITY OF SHUNTING THE RESISTOR.
4. POWER TEST EQUIPMENT MUST BE CHASSIS GROUNDED VIA A 3-PRONG PLUG, AND PLACED ON AN INSULATION PAD MADE OF FORMICA, FIBERGLASS OR EQUIVALENT MATERIAL.

ESD F01

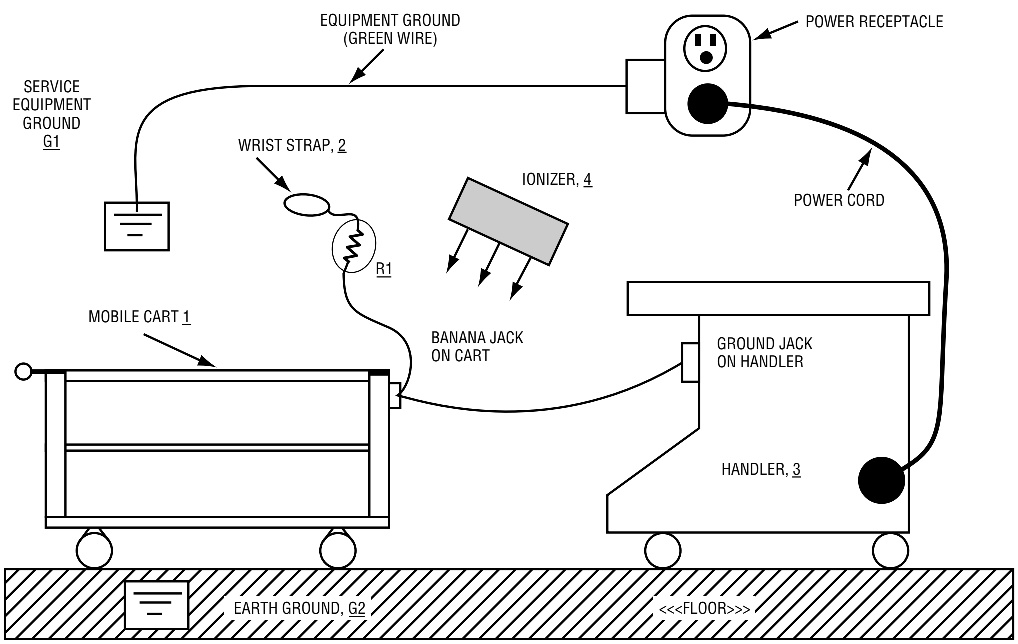
Figure 1



MATERIALS:
1. OPTIONAL 1/8" THICK CONDUCTIVE OR STATIC DISSIPATIVE MAT OR CONDUCTIVE FLOORING (e.g., CONDUCTIVE FLOOR TILES) WITH A SURFACE RESISTIVITY OF $\leq 10^8 \Omega$ PER SQUARE.
2. CONDUCTIVE SHOE STRAP WITH A SURFACE RESISTIVITY OF $\leq 10^8 \Omega$ PER SQUARE.
3. INSULATED CONDUCTIVE GROUND CORD WITH A SERIES RESISTOR OF 1/2W MINIMUM, 1M $\Omega \pm 10\%$, AND 18AWG OR LARGER INSULATED WIRE.

ESD F02

Figure 2



MATERIALS:
1. MOBILE CART WITH CONDUCTIVE TABLE TOP AND SURFACE RESISTIVITY OF $\leq 10^{10} \Omega$ PER SQUARE. HIGHLY CONDUCTIVE WORK SURFACES (E.G. STAINLESS STEEL, COPPER) SHALL BE CONNECTED DIRECTLY TO EQUIPMENT GROUND, WITH NO LIMITING RESISTOR.
2. INSULATED CONDUCTIVE WRIST STRAP WITH 1/4 WATT MINIMUM, 1M $\Omega \pm 10\%$ RESISTOR, R1, AND 20 AWG OR LARGER INSULATED WIRE. THE R1 RESISTOR MUST BE LOCATED RIGHT NEXT TO THE WRIST TO PREVENT THE POSSIBILITY OF SHUNTING THE RESISTOR.
3. POWER HANDLER EQUIPMENT MUST BE CHASSIS GROUNDED VIA A THREE-PRONGED PLUG.
4. IONIZER DIRECTED AT WORK IN PROGRESS.

NOTE: G1 (SERVICE EQUIPMENT GROUND) OR G2 (EARTH GROUND) IS ACCEPTABLE FOR ESD GROUND. WHERE BOTH GROUNDS ARE USED, THEY SHALL BE CONNECTED (BONDED) TOGETHER.

ESD F03

Figure 3. ESD Protected Mobile Cart as Work Station

Option 3: Utilizes the same conductive or static dissipative floor mat installation as Option 2 with the exception that the operator is grounded via a wrist strap through the equipment ground instead of a conductive shoe strap. It is utilized where an operator is working with a piece of freestanding equipment and does not require a great deal of freedom of movement.

Handling

At LTC all products are handled, transported and staged in volume conductive tote boxes. This offers maximum protection to the components from triboelectrically generated and inductive static charges. The rule is — under no circumstances should components be removed from their approved containers except at an ESD protected workstation.

Final Packaging

Only antistatic, static dissipative and conductive final packaging containers (for example, antistatic or conductive dip tubes, volume conductive carbon loaded plastic bags or metallic film laminate bags, foil lined boxes) are used. Filler (dunnage) material used should be antistatic, noncorrosive, and should not crumble, flake, powder, shred or be of fibrous construction. Conductive packing materials are preferred since they not only prevent buildup of triboelectric charge, but also provide shielding from external fields.

Other ESD Preventative Measures

- Where possible, ban all static bearing materials, e.g., common plastics, styrofoam from the work environment.
- Use only synthetic material smocks with 1% to 2% interwoven steel.
- Ensure all electronic and electromechanical equipment is chassis grounded, including conveyor belts, vapor degreasers and baskets, solder pots, etc.
- Tips of hand soldering irons are to be grounded.
- All parts of hand tools (e.g., pliers, etc.) which can be expected to come in contact with electronic components are to be made of conductive material and grounded.
- Conductive shorting bars are to be installed on all terminations for PC boards with electronic components during assembly, loading, inspecting, repairing, soldering, storing and transporting.
- All PC boards with electronic components are not to be handled by their circuitry, connector points or connector pins.
- High velocity air movement is to be delivered through a static neutralizer.
- Air ionizers are to be employed in neutralizing static buildup on insulators if they have to be used or as an extra precautionary measure for extremely sensitive devices.
- Do not slide electronic components over a surface.

Air ionizers come in three basic types: nuclear, AC and pulsed DC. These ionizers can neutralize static charges on nonconductive materials by supplying the materials with a stream of both positive and negative ions.

The advantage of the AC or pulsed DC type air ionizer is that there is no recurring annual replacement cost. The disadvantages are: it emits ozone which can damage rubber in equipment; EMI (Electro Magnetic Interference); and an imbalance in the stream of ions if not properly maintained, therefore necessitating frequent preventive maintenance.

The advantages of the nuclear type air ionizer are low maintenance, no ozone, no EMI and no imbalance problems. The disadvantages are that it requires careful handling because of the radioactive source and the annual recurring cost to replace the radioactive source.

The selection of air ionizers must be done with care and with awareness of the above limitations. The squirrel cage ionized air blower has been proven to produce a significantly more even distribution of ion patterns than does a conventional fan blower design.

Maintenance

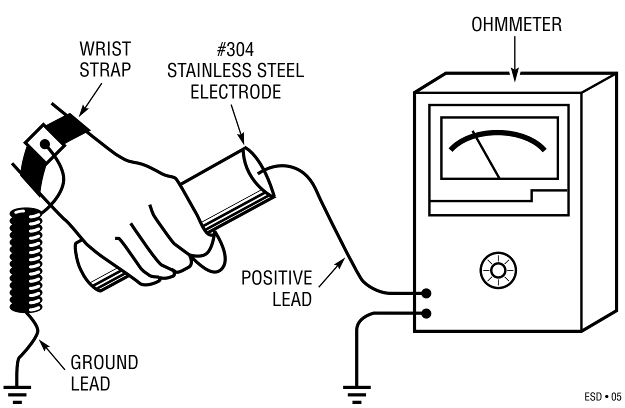
ESD protective floor and table coverings must be properly maintained. Do not wax them. Cleaners must not degrade their electrical properties. Vacuum to remove loose particles, followed by a wet mop with a solution of mild detergent and hot water.

Periodic Audits

At LTC periodic audits are conducted to check on the following:

- Compliance with ESD control procedures.
- Ensure that the conductive ground cord connection is intact by measuring the series resistance to ground with an ohmmeter.
- Ensure that wrist straps are still functional by measuring the resistance from the person to ground. The ground lead of the ohmmeter is connected to the ground connection of the wrist strap, and the positve lead is connected to a stainless steel electrode (one inch in diameter and three inches long #304 stainless steel) which is held by the person. This test method not only checks the resistance of the series resistor, but also resistance through the ground cord and any contact resistance between the wrist strap and the person's skin. This test procedure is required when wrist straps with an elastic nylon band with interwoven metallic strands are used, since the metallic strands break down with prolonged use. This monitor frequency may be shortened depending on audit results.
- Measure the surface resistivity of conductive or static dissipative table tops once every quarter using ASTM-F-150-72, ASTM-D-257 or ASTM-D-991 test methods as appropriate.

Wrist Strap Resistance Test Setup



Materials Selection and Specification

Based on the tremendous amount of ESD protective materials available, it is important that materials are selected based on a stringent qualification. Once the materials have been selected and specifications defined, a material procurement specification needs to be initiated that defines the materials and quality requirements to the vendor. One of the major pitfalls is to procure material in haste, e.g., a wrist strap, only to find out it does not perform reliably.

The SOAR-1 report titled "ESD Protective Material and Equipment: A Critical Review" published by the Rome Air Development Center is an excellent reference on the various types of ESD protective materials available.

At LTC a minimum of three manufacturing lots from a potential vendor are subjected to qualification testing per the requirements of the material procurement specification for ESD protective materials. The vendor is considered qualified only when all three lots are found to be acceptable. Once vendors have been qualified, all incoming ESD protective materials are subjected to a stringent incoming inspection.

The following table summarizes a sample material and test specification for ESD protective materials.

MATERIAL	PROPERTIES/DESCRIPTION	TEST METHODS
Wrist Strap	• Insulated coil cord with a 1MΩ ±10%, 1/4W minimum series resistor molded into snap fastener (at wrist end), and an elastic wrist band with inner metallic filaments and insulative exterior	Measure series resistance with ohmmeter. Apply normal tug to both ends of strap and remeasure series resistance. Resistance must be between 0.8MΩ to 1.2MΩ.
Conductive or Static Dissipative Table and Floor Coverings, Conductive Tote Boxes, Conductive Shoe Straps	• Must not shed particles • Must not support bacterial or fungal growth • Conductive: surface resistivity < 10^5Ω/square, Static Dissipative: surface resistivity > 10^5 < 109Ω/square	Test per ASTM-F-150-72, ASTM-D-257, ASTM-D-991 (for surface resistivity < 10^6Ω/square).
Conductive Foam	• Shall not contain more than 30ppm Cl, K, Na when a quantitative chemical analysis is performed • Must not support bacterial or fungal growth	With devices inserted into the foam, the foam must not cause lead corrosion after a 24-hour 85°C/85% RH temperature/humidity storage.
Antistatic and Conductive Dip Tubes	• Must not exhibit an oily film	Must meet an Electrostatic Decay test per Federal Test Method Standard 101 Test Method 4046. Material charged to 5000V must be discharged to 1% of its initial value (50V) in 2 seconds after a 24-hour conditioning at 15% relative humidity.
Antistatic and Conductive Bags	• Antistatic bags must meet MIL-B-81705 type . • Conductive bags must meet MIL-B-117 and sealing requirements of MIL-B-81705 • Must not support bacterial or fungal growth	Test method for antistatic bags same as for antistatic/ conductive dip tubes. Test method for conductive bags same as for conductive table/floor coverings.
Static Eliminators/Ionized Air Blowers	• Ozone level: 0.1ppm maximum for 8-hour exposure • Noise: 60dB maximum • EMI: nondetectable when measured 6 inches away	Voltage Decay test: A nonconductive sheet of material charged to 5kV must be discharged to 1% of its initial value (50V) in 2 seconds at a distance of 2 feet from the ionizer or larger distance if application calls for a larger distance.

Training and Certification Program

The training program should be developed to increase ESD awareness and to assist all personnel in complying with the ESD control specification. The program should include:

1. A discussion on “What is Static Electricity?”
2. How ESD affects ICs
3. Estimated cost of ESD related losses
4. Materials and equipment for controlling static
5. The importance of wearing the wrist strap
6. The importance of an audit program
7. Encourage floor personnel to alert the ESD task force to any ESD potential areas

ESD training should be incorporated into the personnel training and certification program. At LTC only fully trained and certified personnel are allowed to do actual production work. To help increase ESD awareness, it is often a good idea to show ESD awareness films and video tapes which are available from a variety of sources (Reference 3 provides a list of films and video tapes). Personnel are retrained and recertified at a minimum frequency of once per year.

Measuring the Benefits

Where possible, the benefits of an ESD Protection Program should be tracked and quantified. The two yardsticks used at LTC are final test yields and QA electrical average outgoing quality (AOQ). Since the implementation of this program, there has been a significant improvement in final test yields especially on static sensitive CMOS devices. With the elimination of ESD as a potential failure cause, the electrical AOQ has averaged well under 100ppm for all products combined. Improvements such as this help to provide positive feedback to manufacturing and support personnel on the importance of an ESD Protection Program, and also help to ensure its continuing success.

References

1. MIL-STD-1686 — *Electrostatic Discharge Control Program for Electrical and Electronic Parts, Assemblies and Equipment*
2. MIL-HDBK-263 — *Electrostatic Discharge Control Handbook for Electrical and Electronic Parts, Assemblies and Equipment*
3. SOAR-1 — *State-of-the-Art Report ESD Protective Materials and Equipment: A Critical Review*, published by the Rome Air Development Center
4. VZAP-90 — *Electrostatic Discharge (ESD) Susceptibility Data*, published by the Rome Air Development Center
5. EOS-1, EOS-2, etc. — *Electrical Overstress/Electrostatic Discharge Symposium Proceedings, 1979 to Current Year*
6. MIL-STD-883 — *Test Methods and Procedures For Microelectronics*
7. MIL-PRF-38535 — *General Specification for Integrated Circuits (Microcircuits) Manufacturing*
8. MIL-M-55565 — *Microcircuits, Packaging of*
9. MIL-B-81705 — *Barrier Materials, Flexible, Electrostatic* — Free, Heat Sealable
10. FED-STD-101 — *Preservation, Packaging and Packing Materials Test Procedures; Test Methods, 4046: Electrostatic Properties of*
11. EIA-625 — *Requirements for Handling Electrostatic Discharge-Sensitive (EDSS) Devices*