HAL COMMUNICATIONS CORP.

ELECTROSTATIC DISCHARGE (ESD)

CONTROL PROGRAM

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1.0 INTRODUCTION

1.1 Scope

This Program is established for the purpose of protecting sensitive components and subassemblies from the harmful effects of static electricity discharge during design, production, inspection, test, storage, shipment, installation, maintenance, and repair.

Static electricity discharge has been shown to have very damaging effects to metal oxide semiconductors (MOS) and other semiconductor devices. Trends in technology are towards greater complexity, increased packaging density, and thinner dielectrics between active elements. This results in parts becoming even more sensitive to static electricity discharge.

Protection of parts sensitive to electrostatic discharge (ESD) is possible through the implementation of ESD controls. These controls should be implemented in every phase of a manufacturing process, from design to shipment. Indeed, HAL Communications Corp. has been implementing ESD controls since the early 1980's.

This Program provides a formal compilation of the controls to be used and how those controls are implemented at HAL Communications Corp.

1.2 Applicable Standards and Documents

This Program is established in accordance with:

MIL-STD-1686A - Electrostatic Discharge Control Program
for Protection of Electrical and
Electronic Parts, Assemblies, and
Equipment (Excluding Electrically
Initiated Explosive Devices)

This Program employs many of the recommendations and procedures of:

MIL-HDBK-263 - Electrostatic Discharge Control
Handbook for Protection of Electrical
and Electronic Parts, Assemblies, and
Equipment (Excluding Electrically
Initiated Explosive Devices)

1.3 Definitions

The following terms are defined as used in referring to Electrostatic Discharge (ESD) and protection from ESD.

Antistatic material. ESD protective material having a surface resistivity greater than 10E9 but not greater than 10E14 ohms per square.

Conductive material. ESD protective material having a surface resistivity of 10E5 ohms per square, maximum.

Decay time. The time for a static charge to be reduced to a given percent of the charge's peak voltage.

Electrical and electronic part. A part such as a microcircuit, discrete semiconductor, resistor, capacitor, thick or thin film device, or piezoelectric crystal.

Electrostatic Discharge (ESD). A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.

ESD protective material. Material capable of one or more of the following: limiting the generation of static electricity, rapidly dissipating electrostatic charges over its surface or volume, or providing shielding from ESD spark discharge or electrostatic fields. ESD protective materials are classified in accordance with their surface resistivity (or alternate conductivity) as conductive, static dissipative, or anti-static.

ESD protective packaging. Packaging with ESD protective materials to prevent ESD damage to ESDS items.

ESD Sensitive (ESDS) items. Electical and electronic parts, assemblies, and equipment that are sensitive to ESD voltages of less than 15,000 volts.

Electrostatic field. A voltage gradient between an electro-statically charged surface and another surface of a different electrostatic potential.

Ground. A mass such as earth, a ship, or vehicle hull, capable of supplying or accepting large electrical charge.

Hard ground. A connection to ground either directly or through a low impedance.

Handled or handling. Actions in which items are hand manipulated or machine processed during actions such as inspections, manufacturing, assembling, processing, testing, repairing, reworking, maintaining, installing, transporting, failure analysis, wrapping, packaging, marking, or labeling.

Insulative material. Material having surface resistivities greater than 10E14 ohms per square.

Protected area. An area which is constructed and equipped with the necessary ESD protective materials and equipment to limit ESD voltages below the sensitivity level of ESDS items handled therein.

Protective handling. Handling of ESDS items in a manner to prevent damage from ESD.

Soft ground. A connection to ground through an impedance sufficiently high to limit current flow to safe levels for personnel (normally 5 milliamperes). Impedance needed for a soft ground is dependent upon the voltage which could be contacted by personnel near the ground.

Static dissipative materials. ESD protective materials having surface resistivities greater than 10E5 but not greater than 10E9 ohms per square.

Surface resistivity. Surface resistivity is an inverse measure of the conductivity of a material and equal to the ratio of the potential gradient to the current per unit width of the surface, where the potential gradient is measured in the direction of current flow in the material.

(Note: Surface resistivity of a material is numerically equal to the surface resistance between two electrodes forming opposite sides of a square. The size of the square is immaterial. Surface resistivity applies to both surface and volume conductive materials and has the value of ohms per square.)

Volume resistivity. The volume resistivity is an inverse measure of the conductivity of a material and is equal to the ratio of the potential gradient to the current density, where the potential gradient is measured in the direction of current flow in the material.

(Note: In the metric system, volume resistivity of an electrical insulating material in ohm-cm is numerically equal to the volume resistance in ohms between opposite faces of a 1 cm cube of the material. Volume resistivity in ohm-meters has a value of 0.01 times the value in ohm-cm.)

2.0 CAUSES AND EFFECTS OF STATIC ELECTRICITY

2.1 Nature of Static Electricity

Static electricity is electrical charge at rest. This electrical charge is created by the interaction of bodies which causes electrons to be transferred from one body to another.

When a body charged with static electricity comes in contact with sensitive or delicate electrical or electronic components, severe damage may be done to the components. A discharge of static electricity is lightning on a small scale, which may be powerful enough to do severe damage to the interior thin films of components.

Damage from electrostatic dischages can be caused by direct contact between a charged body and a sensitive device, or by the Electromagnetic Pulse (EMP) caused by a nearby electrostatic discharge.

2.2 Triboelectric series

The generation of static electricity caused by rubbing two substances is called the triboelectric effect. A triboelectric series is a list of substances in order of positive to negative charging as a result of the triboelectric effect. A sample triboelectric series is shown in Table 1.

A substance higher on the list is positively charged when rubbed with a substance lower on the list. This is due to the fact that substances higher on the list have more free electrons compared to substances lower on the list. The degree of separation of substances in the series does not necessarily indicate the magnitude of the charges created by triboelectric effect.

In addition to the actual rubbing of two different substances, high electrostatic charges can also be generated when two pieces of the same material, especially common plastic, in intimate contact, are separated, for example, when unrolling plastic film or when opening plastic bags.

The triboelectric series is presented here to aquaint all personnel with the variety of different substances which can contribute to buildup of static electricity in the workplace.

+
Positive Air

Human Hands

Asbestos

Rabbit Fur

Glass

Mica

Human Hair

Nylon

Wool

Fur

Lead

Silk

Aluminum

Paper

Cotton

Steel

Wood

	Amber
	Sealing Wax
	Hard Rubber
	Nickel, Copper
	Brass, Silver
	Gold, Platinum
	Sulfur
	Acetate Rayon
	Polyester
	Celluloid
	Orlon
	Polyurethane
	+Polyethylene
	Polypropylene
	PVC (Vinyl)
	KEL F
	Silicon
Negative -	Teflon

Table 1. Sample Triboelectric Series

2.3 Prime sources of Static Electricity

Typical prime charge sources commonly encountered in a production facility are listed in Table 2. These prime sources are essentially insulators and are usually synthetic materials. Electrostatic voltage levels generated with these insulators can be extremely high since they are not readily distributed over the entire surface of the substance or conducted to another contacting substance. The conductivity of some insulative materials is increased by absorption of moisture under high humidity conditions onto the otherwise insulating surface. This creates a slightly conductive sweat layer which tends to dissipate static charges over the material surface. The generation of 15,000 volts from common plastics in a typical manufacturing facility is not unusual. Table 3 shows typical electrostatic voltages generated by personnel in a manufacturing facility.

Again, Tables 2 and 3 are presented to aquaint personnel with the
variety of materials which can contribute to static buildup and to the possible voltage levels which static electricity can attain in the normal work environment.

Object or Process	Material or Activity
Work Surfaces	Waxed, painted, varnished surfaces
	Common vinyl or plastics
Floors	Sealed concrete
	Waxed, finished wood
	Common vinyl tile or sheeting
Clothes	Common clean room smocks
	Common synthetic personnel garments
	Non-conductive shoes
	Virgin cotton (below 30% humidity)
Chairs	Finished wood
	Vinyl
	Fiberglass
Packaging and Handling	Common plastic bags, wraps
	Common bubble pack, foam
	Common plastic trays, plastic tote boxes, vials, parts bins
Assembly, Cleaning, Test and Repair Areas	Spray cleaners
	Common plastic solder suckers
	Solder irons with ungrounded tips
	Synthetic bristle solvent brushes
	Cleaning or drying by fluid or evaporation
	Temperature chambers
	Cryogenic sprays
	Heat guns and blowers
	Sand blasting
	Electrostatic copiers

Table 2. Typical Prime Charge Sources

Means of Static Generation	Electrostatic Voltages	
	10 to 20 % rel. humidity	65 to 90% rel. humidity
Walking across carpet	35,000	1,500
Walking over vinyl floors	12,000	250
Worker at bench	6,000	100
Vinyl envelopes for work instructions	7,000	600
Common poly bag picked up from bench	20,000	1,200
Work chair padded with polyurethane foam	18,000	1,500

Table 3. Typical Electrostatic Voltages

One can see by Tables 2 and 3 that the sources of static electricity are everyday items. The voltages which can be created can be extremely high, especially in conditions of low relative humidity. It is important, therefore, to always be conscious of the effects of electrostatic discharge and take the required precautions as specified in this program document.

3.0 SUSCEPTIBILITY OF ITEMS TO ESD

3.1 Classes of ESD Sensitivity

Various electrical and electronic parts are sensitive to ESD to differing degrees. The accepted definitions of the different classes of ESD sensitivity, according to MIL-HDBK-263, is as follows:

Class 1 - Most sensitive, can be harmed by discharges in the range of 0 to 1,999 Volts

Class 2 - Sensitive, can be harmed by discharges in the range of 2,000 to 3,999 Volts

Class 3 - Least sensitive, can be harmed by discharges in the range of 4,000 to 14,999 Volts

Class N - Not ESD sensitive, will not be harmed by static discharges of less than 15,000 Volts

Electrostatic Discharge Sensitivity (ESD) levels of components can be determined by manufacturer's data, individual parts testing in accordance with paragraph 6 of MIL-HDBK-263, or by reference to the latest VZAP manual available from the Relaibility Analysis Center, P.O Box 4700, Rome, NY 13440-8200, under contract to Rome Air Development Center, Griffiss Air Force Base, Rome, NY.

3.2 General Categories of Typical ESD Sensitive parts

Class 1 - MOS devices, Surface Acoustic Wave (SAW) devices, Op Amps with unprotected MOS capacitors, JFETs, SCRs with Io< 0.175 amperes at 100 degrees Celcius, precision voltage regulator microcircuits with regulation <0.5%, Microwave and UHF semiconductors and microcircuits (f> 1 gigahertz), thin film resistors (Type RN), LSI Micro-circuits including microprocessors and memories without protective circuits, hybrids using class 1 parts.

Class 2 - MOS devices with class 2 protective circuitry, Schottky diodes, precision resistor networks (type RZ), high speed ECL Microcircuits with propagation delays $\leq$1 nanosecond, TTL microcircuits, Op Amps with MOS

capacitors having class 2 protection, LSI with input protection to class 2, hybrids using class 2 parts.

Class 3 - Low power chopper resistors, resistor chips, small signal diodes with power $\leq$1 watt excluding zeners, general purpose silicon rectifier diodes and fast recovery diodes, low power silicon transistors with power $\leq$5 watts at 25 degrees C, all other micro-circuits not included in class 1 or class 2, piezo-electric crystals, hybrids using class 3 parts.

Subassemblies which are not protected by an outer cabinet are classified the same as the most sensitive part used in the subassembly.

Finished equipment enclosed in a metal cabinet is considered non-ESD sensitive.

3.3 Failure Mechanisms

ESD related failure mechanisms typically include:

a. Thermal secondary breakdown - causing actual melting or near melting of junctions within a device.
b. Metallization melt - melting or fusing of metal sections or bond wires.
c. Dielectric breakdown - actual puncturing of a dielectric region due to high voltage.
d. Gaseous arc discharge - vaporization and associated metal movement within devices with closely spaced electrodes.
e. Surface breakdown - localized avalanche process caused by narrowing of the junction space charge layer at the surface.
f. Bulk breakdown - changes in junction parameters due to high temperatures within the junction area.

Mechanisms a, b, and f are power dependent while mechanisms c, d, and e are voltage dependent. All of these failure mechanisms are applicable to microelectronic and semiconductor devices. For more detailed discussions of each of

these failure mechanisms, consult paragraph 5.3 of MIL-HDBK-263. Detailed discussions of parts consitituents and their susceptibility to ESD are included in paragraph 5.4 of MIL-HDBK-263.

It is important to emphasize that ESD may cause deterioration of parts without immediate failure. This deterioration will usually cause shortened life or inferior performance of the part in the future. Consequently, not all ESD damage is readily apparent.

4.0 ESD PROTECTIVE MATERIALS

4.1 Primary Properties of ESD Protective Materials

The primary protective properties of ESD protective materials include:

a. Protection against triboelectric generation.

b. Protection from electrostatic fields.

c. Protection against direct discharge from contact with charged people or charged objects.

Protection against the generation of electrostatic charges is the best method of ESD control. If materials do not generate electrostatic charges, no further action is required.

Conductivity is a prime characteristic for providing protection against stationary or approaching charged bodies and their associated electrostatic fields. A polarization occurs gradually as the charged body approaches. In conductive materials, electrons move rapidly and dissipate this polarization resulting in a very low voltage being applied across the ESD protective material.

Complete shielding from electrostatic fields or ESD high voltage spark induced EMP requires enclosing the item in a conductive material. Normally, the greater the conductivity of the enclosure, the greater the attenuation of the electrostatic field and ESD high voltage spark-induced EMP within the enclosure.

4.2 Types of ESD Protective Materials

ESD Protective materials can be classified in three categories. These are:

Antistatic
Static Dissipative
Conductive

4.2.1 Antistatic Materials

Antistatic materials as defined in 1.3 are materials which have somewhat conductive surfaces. They

use moisture in the air to maintain higher conductivity and thereby reduce the buildup of static electricity through distribution of electrical charge over the surface. Many of the shipping tubes used for IC's are made of antistatic material.

Antistatic materials provide good protection against the buildup of static electricity and a fair degree of protection against nearby discharges. The primary caution in using antistatic materials is to avoid very low humidities. At low humidity levels (on the order of 10 to 20% relative humidity), antistatic materials become much less effective due to a decrease in surface conductivity. Antistatic materials are best suited to protection of moderately sensitive ESDS items from moderate ESD voltages.

4.2.2 Static Dissipative Materials

Static dissipative materials are more conductive than antistatic materials. They provide a higher rate of dissipation of static electricity and are more suited to protection of highly sensitive ESD items from moderate voltages.

Unlike antistatic materials, static dissipative materials will continue to function well at lower humidities.

4.2.3 Conductive Materials

Conductive materials provide the best protection for ESDS items in that they dissipate charge rapidly and prevent damage from nearby high voltage discharges. They are suitable for protection of highly sensitive items from high voltages.

There are cautions which should be observed when using conductive materials, however. Because of their high rate of static dissipation, they can cause sparking if a highly charged body is brought near. Also, if hard grounded, conductive materials provide a direct path to ground if touched by a person. Extreme caution should be used in the presence of high voltages and hard grounded conductors.

5.0 ESD CONTROL PROCEDURES

5.1 General Procedures

In order to control the generation of static electricity in the workplace, humidity shall be maintained at a level that reduces the possibility of static discharge. The recommended level of DOD-HDBK-263 is in the range of 40 to 60% relative humidity, as long as these levels do not result in accelerating rust formation or result in other detrimental effects such as circuit board delamination during soldering. Further, all persons should be alert to situations which may cause unnecessary generation of static electricity and should report any suspected ESD hazards to their supervisor. An example of an ESD hazard is plain plastic bags being used at a workstation where ESDS components are being handled.

5.2 ESD Protected Workstations

ESD protective floor mats and table mats will be installed in all locations where ESDS parts, subassemblies, or open units will be handled. These protective mats will be soft grounded to an earth ground using current limiting resistors of approximately 1 M ohm to provide maximum current of 5 mA at up to 5000 volts. ESD protective mats shall not be connected in series from one workstation to the next. Each workstation shall be directly connected to the ground bus through the current limiting resistor. The diagram of a typical ESD protected workstation is shown on page 44 of DOD-HDBK-263.

Skin contact wrist straps connected directly to the table mat being used will be worn by all personnel prior to and during the handling of any ESDS devices while they are out of their protective materials. In wearing the skin contact wrist strap, the wearer must assure that good contact is made between the metal conductor of the wrist strap and the person's skin. If the forearms and wrist are extremely hairy, it may be necessary to wear the wrist strap so that the metal conductor of the strap is on the inside of the wearer's wrist.

Equipment used to test or process ESDS devices will be hard grounded to earth ground or power line ground. Equipment metal cases should not rest on the ESD protective mats as this will provide a direct hard ground to any person working at that ESD protective mat. This would eliminate the safety protection factor of the installed current limiting resistors in the protective mat wiring.

5.3 ESD Handling Procedures

These handling procedures are to be used by all departments at HAL Communications Corp. for the handling of ESD sensitive parts, devices, and assemblies.

a. All ESD sensitive parts, devices, and assemblies shall be kept in approved ESD protective packaging. Approved ESD protective packaging includes:

Conductive foam
Antistatic or conductive storage tubes
Antistatic or conductive plastic bags
Black conductive parts bins

b. When necessary for work, ESD sensitive parts, devices, and assemblies may be removed from their protective packaging, but only by a properly grounded person at an approved ESD work station.

c. Special parts bins are provided for temporarily holding ESDS items at approved ESD workstations. These parts bins are conductive and are black in color.

d. Power shall not be applied to equipment or assemblies while ESDS items are being removed or inserted.

e. All test equipment used at an approved ESD workstation must be properly grounded. Insure that the test equipment metal cabinet does not come in direct contact with the table mat of theESD workstation, thereby eliminating the safety factor provided by the current limiting resistor of the workstation. Also, the ground lead of test equipment should be connected to the equipment under test before any measurements are made.

f. Work instructions, test procedures, drawings, and similar documents used at ESD workstations should not be covered in common plastic sheeting.

g. Drawings for ESDS items should be marked with the ESD sensitive electronic symbol and warnings as necessary.

h. Personnel handling ESDS items should avoid physical activities which are static producing in the vicinity of ESDS items. Such activities include wiping feet or putting on smocks.

i. When maintenance is necessary and equipment must be opened away from an approved ESD

workstation, the maintenance person must first ground himself through the equipment cabinet before touching or removing any ESD sensitive device or assembly.

5.4 Departmental Procedures

5.4.1 Research and Development Procedures

a. Equipment design shall be based on sound engineering practice in order to minimize the effects of ESD on equipment.

b. Further recommendations on designs employing ESDS items are contained in DOD-HDBK-263, paragraphs 8 and 9.

c. Parts and assembly drawings and other related documents shall include ESD markings as appropriate, using the MIL-STD-129 ESD symbol. This is to alert employees that ESD parts are being used and ESD handling procedures are required.

d. Employ proper ESD handling procedures in R&D department to include ESD protected workstations and ESD protective packages for ESDS parts and subassemblies. Follow the other ESD handling procedures of 5.3.

5.4.2 Purchasing Procedures

a. Incorporate ESD control program requirements on all acquisitions related to design and handling of ESDS items.

b. Work with engineering and receiving to ensure that subcontractors and suppliers comply with ESD control program requirements.

c. Maintain listing of supply sources of ESD protective equipment and materials.

5.4.3 Receiving Inspection Procedures

a. Be aware of all ESDS items to be delivered by vendors.

b. Remove the unit package of an ESDS item from the outer shipping container. Do not open the unit package. Examine the item for proper labeling and ESD protective packaging.

c. Reject any ESDS items not packaged in ESD protective packaging. Mark these items as rejected and follow standard receiving procedures for rejected items.

d. If necessary, open the unit package and inspect or test the parts ONLY at an approved ESD workstation. Follow the handling procedures of 5.3.

e. Repackage ESDS items in ESD protective packaging and place in inventory.

5.4.4 Inventory Procedures

a. Transport ESDS items to and from the storeroom in ESD protective packaging.

b. Store ESDS items only in ESD protective packaging.

c. Do not open unit packages of ESDS items for count issuance or kitting unless required. When required, opening of unit packages of ESDS items should be preformed only at approved ESD workstations following the handling procedures of 5.3.

d. ESDS items removed from their protective packaging for counting must be returned to protective packaging before issue.

5.4.5 Production and Production Test Procedures

a. Accept ESDS parts from Inventory only in ESD protective packaging.

b. Perform production and test operations on ESDS parts and assemblies only at approved ESD workstations following the handling procedures of 5.3.

c. Remove ESDS parts from protective packaging only when necessary for work, and only after grounding yourself properly at the ESD workstation.

d. Use only conductive parts bins (black) for temporary storage of ESDS parts at the ESD workstation.

e. Always return ESDS parts and assemblies to ESD protective packaging after processing.

5.4.6 Quality Assurance Procedures

a. Transport ESDS items only in ESD protective packaging.

b. Remove ESDS items from protective packaging only at an approved ESD workstation.

c. Follow the general handling procedures of 5.3.

d. Place covers over external connectors as required to protect against contact with charged

bodies.

e. When other QA processes are complete, and equipment cabinet is secure, afix any applicable ESD warning labels to finished equipment.

5.4.7 Shipping Procedures

a. Transport ESDS items only in ESD protective packaging.

b. Remove ESDS items from protective packaging only at an approved ESD workstation.

c. Follow the ESD Handling Procedures of 5.3.

d. Package ESDS items for shipment first in ESD protective unit packaging before placing in shipping container. Label unit packs with appropriate ESD warning labels. Label shipping containers of ESD items with appropriate markings.

e. For finished equipment protected by a metal cabinet, any special coverings or markings required should be in place before placing the unit in its surface protective plastic bag. Exterior carton ESD markings are not required for finished equipment enclosed in metal cabinets.

6.0 ESD TRAINING AND CERTIFICATION

6.1 Personnel Training and Certification

Each employee of HAL Communications Corp. who is responsible for any phase of design, procurement, receiving, inventory, production, test, quality assurance, repair, packaging, or shipping of any products containing ESD sensitive items shall undergo recurring training in ESD awareness and handling procedures.

Upon employment with HAL Communications Corp. and prior to any responsibility concerning ESD items, employees shall read this ESD Program document and shall be given additional oral review in the applicability of ESD handling procedures and their necessity.
Each employee shall sign a statement in the Employee ESD Training Log that he/she has read this ESD Control Program document and is familiar with the need and procedures for proper handling of ESD sensitive items.

At intervals of at least once each year, employees shall review with their supervisor proper ESD handling procedures and all new information on ESD which has been added to the program. Dates of these yearly reviews shall be recorded in the Employee ESD Training Log by the employee's supervisor.

At any time that vital new information is available concerning ESD handling procedures, this information shall be provided to each employee as soon as possible and an appropriate entry shall be made in the Employee ESD Training Log. This new information shall be incorporated into the ESD Control Program for future employees and for review purposes.

6.2 ESD Workstation and Materials Certification

ESD Workstation materials and handling materials shall be purchased from reputable firms which can certify to the ESD protective properties of their materials. Records shall be maintained in the normal purchasing records of the source of supply of ESD materials.

ESD Workstations at HAL Communications Corp. shall be inspected by the plant ESD administrator or his assignee. ESD Workstations shall be inspected at least once every 6 months for proper materials, wiring, grounding, and wear. Records of these inspections shall be kept in the ESD Workstation Inspection Log. Upon inspection, a sticker shall be placed on the workstation table mat indicating the date of inspection.

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Employee ESD Training Log

Each employee certifies by signing below that he/she has read the document entitled "HAL Communications Corp. ESD Control Program" and understands proper handling procedures for ESD items and the reason for those handling procedures.

Employee Signature	Date	Dates of ESD Reviews

_____

_____

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_____

Page _____

Electrostatic Discharge (ESD) Protected Workstation
Inspection Log
(Updates required, 6 mo. intervals.)

Workstation No.	Equip. Condition	Resistance Mat to W.Strap	Mat to Gnd	Initials	Date

_____

_____

_____

_____

_____

_____

_____

_____