ANSI/ESD S20.20-1999

ESD association standard

for the Development of an Electrostatic Discharge Control Program for –

Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

ANSI/ESD S20.20-1999

Electrostatic Discharge Association
7900 Turin Road, Bldg 3, Ste 2
Rome, NY 13440-2069

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Approved May 16, 1999

ESD ASSOCIATION ™

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Foreword

This standard covers the requirements necessary to design, establish, implement, and maintain an Electrostatic Discharge (ESD) Control Program for activities that: manufacture, process, assemble, install, package, label, service, test, inspect or otherwise handle electrical or electronic parts, assemblies and equipment susceptible to damage by electrostatic discharges greater than or equal to 100 volts Human Body Model (HBM). When handling devices susceptible to less than 100 volts HBM, more stringent ESD Control Program Technical Requirements may be required, including adjustment of program Technical Element Recommended Ranges. This document covers the control program requirements and offers guidance to protect and handle ESD sensitive (ESDS) items, based on the historical experience of both military and commercial organizations. References include, ESD Association, US Military and ANSI approved standards for material properties and test methods. The fundamental ESD control principles that form the basis of this document follow:

A. All conductors in the environment, including personnel, must be bonded or electrically connected and attached to a known ground or contrived ground (as on shipboard or on aircraft). This attachment creates an equipotential balance between all items and personnel. Electrostatic protection can be maintained at a potential above a “zero” voltage ground potential as long as all items in the system are at the same potential.

B. Necessary non-conductors in the environment cannot lose their electrostatic charge by attachment to ground. Ionization systems provide neutralization of charges on these necessary non-conductive items (circuit board materials and some device packages are examples of necessary non-conductors). Assessment of the ESD hazard created by electrostatic charges on the necessary non-conductors in the work place is required to ensure that appropriate actions are implemented, commensurate with risk.

C. Transportation of ESDS items outside an Electrostatic Protected Area (hereafter referred to as “Protected Area”) requires enclosure in static protective materials, although the type of material depends on the situation and destination. Inside a Protected Area, low charging and static dissipative materials may provide adequate protection. Outside a Protected Area, low charging and static discharge shielding materials are recommended. While these materials are not discussed in the document, it is important to recognize the differences in their application.

Any relative motion and physical separation of materials or flow of solids, liquids, or particle-laden gases can generate electrostatic charges. Common sources of ESD include personnel, items made from common polymeric materials, and processing equipment. ESD can damage parts by direct contact with a charged source or by electric fields emanating from charged objects that induce a charge on grounded or capacitively coupled to ground sensitive items. It is possible to determine device and item susceptibility by exposure to simulated electronic equivalent discharge circuits. The level of sensitivity determined by test using these models may not necessarily relate to the level of sensitivity in a real life situation. However, they are used to establish a baseline of susceptibility data for comparison of devices with equivalent part numbers from different manufacturers. Three different models are used for characterization of electronic components - Human Body Model (HBM), Machine Model (MM), and Charged Device Model (CDM). It is important to recognize that these models, if used alone, are difficult to apply in terms of specification setting activities. Examples of ESDS parts are microcircuits, discrete semiconductors, thick and thin film resistors, hybrid devices and piezoelectric crystals.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to:

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PROTECTION OF ELECTRICAL AND ELECTRONIC PARTS, ASSEMBLIES AND EQUIPMENT (EXCLUDING ELECTRICALLY INITIATED EXPLOSIVE DEVICES)

1. PURPOSE

The purpose of this Standard is to provide administrative and technical requirements, as well as guidance for establishing, implementing and maintaining an ESD Control Program (here after referred to as the "Program").

2. SCOPE

This document applies to activities that: manufacture, process, assemble, install, package, label, service, test, inspect or otherwise handle electrical or electronic parts, assemblies and equipment susceptible to damage by electrostatic discharges greater than or equal to 100 volts Human Body Model. This document does not apply to electrically initiated explosive devices, flammable liquids and powders.

3. REFERENCED PUBLICATIONS

Unless otherwise specified, the following documents of the latest issue, revision or amendment, form a part of this standard to the extent specified herein.

EOS/ESD ADV 1.0 EOS/ESD Association Glossary of Terms[1]

ESD S1.1 ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items - Wrist Straps[1]

ESD ADV 2.0 ESD Association Advisory for the Protection of Electrostatic Discharge Susceptible Items – Handbook[1]

ESD STM 2.1 ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items – Garments[1]

ANSI EOS/ESD S 3.1 EOS/ESD Association Standard for the Protection of Electrostatic Discharge Susceptible Items - Ionization[1]

ESD S 4.1 ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items - Worksurfaces - Resistive Characterization[1]

ESD STM 4.2 ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items - Worksurfaces - Charge Dissipation Characteristics[1]

ESD STM 5.1 ESD Association Standard for Electrostatic Discharge (ESD) Sensitivity Testing - Human Body Model (HBM) Component Level[1]

ESD STM 5.2 ESD Association Standard for Electrostatic Discharge (ESD) Sensitivity Testing - Machine Model (MM) Component Level[1]

ESD DS 5.3.1 ESD Association Standard for Electrostatic Discharge (ESD) Sensitivity Testing - Charged Device Model (CDM) Component Level[1]

ANSI EOS/ESD S 6.1 EOS/ESD Association Standard for the Protection of Electrostatic Discharge Susceptible Items - Grounding - Recommended Practice[1]

ANSI/ESD S 7.1 ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items - Resistive Characterization of Materials - Floor Materials[1]

EOS/ESD S 8.1 EOS/ESD Association Standard for the Protection of Electrostatic Discharge Susceptible Items - Symbols - ESD Awareness[1]

ESD S 9.1 ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items - Footwear - Resistive Characterization[1]

ESD DSP 10.1 ESD Association Draft Standard for Protection of Electrostatic Discharge Susceptible Items – Automated Handling

ANSI/EOS/ESD S 11.11 EOS/ESD Association Standard for the Protection of Electrostatic Discharge Susceptible Items - Surface Resistance Measurement of Static Dissipative Planar Materials[1]

[1] ESD Association, 7900 Turin Road, Bldg 3, Ste 2, Rome, NY 13440-2069, 315-339-6937

ESD DS 11.12 ESD Association Standard for the Protection of Electrostatic Discharge Susceptible Items - Volume Resistance Measurement of Static Dissipative Planar Materials[1]

ESD ADV 11.2 ESD Association Advisory for the Protection of Electrostatic Discharge Susceptible Items - Triboelectric Charge Accumulation Testing[1]

ANSI/ESD S 11.31 ESD Association Standard for Evaluating the Performance of Electrostatic Discharge Shielding Materials - Bags[1]

ESD STM 12.1 ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items - Seating - Resistive Characterization[1]

ESD DS 13.1 ESD Association Standard for Measuring Electrical Potential from Soldering/ Desoldering Hand Tools[1]

ESD ADV 53.1 ESD Association Advisory for the Protection of Electrostatic Discharge Susceptible Items - ESD Protective Workstations[1]

ESD STM 97.1 ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items - Floor Materials and Footwear - Resistance Measurement in combination with a Person[1]

ESD STM 97.2 ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items - Floor Materials and Footwear - Voltage Measurement on a Person[1]

ANSI C63.16 "American National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment"

IEC 1000-4-2, "Electromagnetic Compatibility for Industrial Process Measurement and Control Equipment, Part 2; Electrostatic Discharge Requirements"

IEEE STD C62.38, "IEEE Guide on ESD: ESD Withstand Capability Evaluation Methods (for Electronic Equipment Subassemblies)"

MIL-STD-750 Method 1020, Military Standard, Test Methods for Semiconductors Devices, Electrostatic Discharge Sensitivity (ESDS) Classification[2]

MIL-STD-883 Method 3015, Department of Defense, Test Method Standard, Microcircuits, Electrostatic Discharge Sensitivity Classification[2]

MIL-STD-2073-1 Department of Defense, Standard Practice for Military Packaging[2]

MIL-PRF-19500 Performance Specification, General Specification for Semiconductor Devices[2]

QML-19500 Qualified Manufacturers List of Products Qualified Under Military Specification MIL-PRF-19500, General Specification for Semiconductor Device[2]

MIL-PRF-38535 Performance Specification, General Specification for Integrated Circuits (Microcircuits) Manufacturing[2]

QML-38535 Qualified Manufacturers list of Advanced Microcircuits Qualified Under Military Specification MIL-PRF-38535, General Requirements for Microcircuits Manufacturing[2]

VZAP, Electrostatic Discharge Susceptibility Data[3]

4. DEFINITIONS

The terms used in the body of this document are in accordance with the definitions found in EOS/ESD Association Glossary of Terms, EOS/ESD ADV 1.0.

5. PERSONNEL SAFETY

The Procedures and equipment described in this document may expose personnel to hazardous electrical conditions. Users of this document are responsible for selecting equipment that complies with applicable laws, regulatory codes and both external and internal policy. Users are cautioned that this document cannot replace or supersede any requirements for personnel safety.

Ground fault circuit interrupters (GFCI) and other safety protection should be considered wherever personnel might come into contact with electrical sources.

Electrical hazard reduction practices should be exercised and proper grounding instructions for equipment must be followed.

6. ESD CONTROL PROGRAM

6.0.1. ESD Control Program Requirements

The Program shall include both Administrative and Technical Requirements as described herein. The

[2] Defense Printing Service Detachment Office, Bldg 4D (NPM-DODSSP), 700 Robbins Ave., Philadelphia, PA 19111-5094, 215-697-5164

[3] IIT Research Institute, 201 Mill, Rome, NY 13440, 315-336-2359

most sensitive level of the items to be handled in accordance with the Program shall be documented. The Organization shall establish, document, implement, maintain and verify the compliance of the Program in accordance with the requirements of this document.

6.0.2. ESD Control Program Guidance

The primary objective of a Program is to provide continuous ESD protection. Electrostatic control and protection entails implementation of Program requirements during design, production, inspection, test, storage, shipment, installation, use, maintenance, replacement and repair functions.

6.0.3. Tailoring

This document, or portions thereof, may not apply to all applications. Tailoring is accomplished by evaluating the applicability of each requirement for the specific application. Upon completion of the evaluation, requirements may be added, modified or deleted. Tailoring decisions, including rationale, shall be documented in the ESD Control Program Plan (hereafter referred to as the "Plan").

6.1 ESD CONTROL PROGRAM ADMINISTRATIVE REQUIREMENTS

6.1.1 ESD Control Program Plan

6.1.1.1. ESD Control Program Plan Requirement

The Organization shall prepare an ESD Control Program Plan that addresses each of the requirements of the Program. Those requirements are: The Plan, Training, Compliance Verification and ESD Control Program Plan Technical Requirements. The Plan is the principal document for implementing and verifying the Program. The goal is a fully implemented and integrated Program that conforms to internal quality system requirements. The Plan shall address the requirements as described herein and shall apply to all applicable facets of the Organization's work. The Plan shall contain the specific requirements for the organization and be evolutionary as technologies, processes or procedures change. If there is a contractual requirement for device or assembly testing, options for determining ESD Sensitivity include QPL-19500, QML-38535, VZAP data or manufacturer's data sheets. Efforts to identify and eliminate defects, and prevent their introduction, shall be a component of the Plan to reduce the cost and risk associated with ESD damage.

6.1.1.2. ESD Control Program Plan Guidance

The Plan should describe the scope of the Program; describe the tasks, activities, and procedures necessary to protect ESD sensitive items at or above a specified sensitivity level; identify organizational responsibilities for the tasks and activities; and list directive or supportive documents used in the Program. The Plan should include a listing of the specific type of ESD protective materials and equipment used in the Program. A major element in an effective Plan is the assessment of the ESD susceptibility of parts, assemblies and equipment and their required protection levels. A common method for establishing ESD sensitivity limits is to use one or more of the three ESD models used for characterization of electronic items. These are HBM, MM, and CDM (see Appendix A). The selection of specific ESD control procedures or materials is at the option of the Plan preparer and should be based on risk assessment and the established electrostatic discharge sensitivities of parts, assemblies, and equipment. The Plan should ensure that the Organization and suppliers of ESD sensitive items have established and implemented a Program in accordance with this document.

6.1.2. Training Plan

6.1.2.1 Training Plan Requirement

Initial and recurrent ESD awareness and prevention training shall be provided to all personnel who handle or otherwise come into contact with any ESDS items. The type and frequency of ESD training for personnel shall be defined in the Training Plan. The Training Plan shall document the procedures for recording this training in personnel training records. Training methods and the use of specific techniques are of the Organization's option. The option that is selected shall include an objective evaluation technique to ensure trainee comprehension and training adequacy.

6.1.2.2. Training Plan Guidance

Recurrent ESD training for personnel is an integral part of the Program. ESD training includes initial and recurrent training required to reinforce program requirements and modifications based upon lessons-learned. New technologies and correction of deficiencies identified during reviews and audits should also be part of the training process. The training requirements should be developed in conjunction with the Organization's handling procedures for ESDS parts, assemblies and equipment.

6.1.3. Compliance Verification Plan

6.1.3.1 Compliance Verification Plan Requirement

A Compliance Verification Plan shall be established to ensure the organization's compliance with the requirements of the Plan. Formal audits or certifications shall be conducted in accordance with

a Compliance Verification Plan that identifies the requirements to be verified, and the frequency at which those verifications must occur. Test equipment shall be selected to make measurements of appropriate properties of the technical requirements that are incorporated into the ESD program plan.

6.1.3.2. Compliance Verification Plan Guidance

In addition to internal audits, external audits (Organization and supplier of ESDS items) should be performed to ensure compliance with planned requirements. Verifications should include routine checks of the Technical Requirements in the Plan. The frequency of verification checks should be based on the control item usage, its durability and associated risk of failure.

6.2. ESD CONTROL PROGRAM PLAN TECHNICAL REQUIREMENTS

Table 1 identifies and describes key Technical Requirements used in the development of a Program and Plan. Note that for each Technical Requirement there are required or optional implementing processes or methods (shown with an "R" or "O" in Table 1) from which to fulfill each Technical Requirement. In a case where there is a required implementing process or method within the Technical Requirements, the implementing process or method shall be used. If there are additional optional elements, they may or may not be implemented in the Plan. If a Technical Requirement only contains optional elements, (shown with an "O") then at least one of the options must be implemented by the Plan. The Plan shall include test methods, acceptance limits and periodic testing intervals. Area 1 shown on Table 1 is intended to designate permanent ESD controlled areas such as manufacturing, production or distribution facilities. Area 2 shown on Table 1 is intended to designate temporary ESD controlled areas such as field service or other remote locations that are not normally equipped as a Protected Area. Test methods used by the organization that differ from the test method or reference in Table 1 shall be documented. Additional guidance may be obtained in ESD ADV 2.0 ESD Association Advisory for the Protection of Electrostatic Discharge Susceptible Items – Handbook

6.2.1. Grounding / Bonding Systems

6.2.1.1. Grounding / Bonding Systems Requirements

Grounding/Bonding Systems shall be used to ensure that ESDS items, personnel and any other conductors (e.g. mobile equipment) are at the same electrical potential. As a minimum, ESDS items, personnel and other related conductors shall be bonded or electrically interconnected.

6.2.1.2. Grounding / Bonding Systems Guidance

In most cases, the third wire (green) AC equipment ground is the preferred choice for ground[4]. When the third wire AC equipment ground is not available or impractical to use, personnel should be bonded or electrically connected to a conductive element of the ESDS item using a wrist strap or other grounding system to ensure that all elements are at the same electrical potential.

6.2.2. Personnel Grounding

6.2.2.1. Personnel Grounding Requirements

All personnel shall be bonded or electrically connected to ground or contrived ground when handling ESD sensitive items. When personnel are seated at ESD protective workstations, they shall be connected to the common point ground via a wrist strap system.

> NOTE: The Organization must be aware of local safety laws and/or codes when grounding personnel while working with energized equipment.

6.2.2.2 Personnel Grounding Guidance

The personnel grounding system in all cases includes the person, the control item(s) and connection to ground. A log should be maintained which verifies that personnel have tested their personal grounding devices. Personnel should check constant monitoring devices (when used) to ensure that they are functional and operating before ESDS products are handled. In addition, constant monitoring devices should be functionally checked periodically to ensure that they are operating as designed. ESD protective flooring, used with approved footwear, may be used as an alternative to the wrist strap system for standing operations. Footwear includes foot grounders, shoes or booties. When equipment ground or auxiliary ground systems are not available, bonding or electrical connections (contrived ground) may be used.

6.2.3. Protected Areas

6.2.3.1. Protected Areas Requirement

Handling of ESDS parts, assemblies and equipment without ESD protective covering or packaging shall be performed in a Protected Area. Caution signs indicating the existence of the Protected Area shall

[4] The color of third wire equipment ground can vary with local, national or international electric codes.

be posted and clearly visible to personnel prior to entry to the Protected Area. ESDS items shall be packaged in ESD protective packaging while not in a Protected Area. Access to the Protected Area shall be limited to personnel who have completed appropriate ESD training. Trained personnel shall escort untrained individuals while in a Protected Area. All nonessential insulators, such as those made of plastics and paper (e.g. coffee cups, food wrappers and personal items) must be removed from the workstation. Ionization or other charge mitigating techniques shall be used at the workstation to neutralize electrostatic fields on all process essential insulators (e.g. ESDS device parts, device carriers and specialized tools) if the electrostatic field is considered a threat.

6.2.3.2. Protected Areas Guidance

A Protected Area may be 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. Humidity control may be a key element in an ESD control program. Propensity for charge generation and accumulation increases with a reduction in humidity.

All process essential insulators that have electrostatic fields that exceed 2,000 volts should be kept at a minimum distance of 12 inches from ESDS items. 2,000 volts is a measure of the electrostatic field at the point of measurement and is not necessarily directly related to the electrical potential of the item. The accurate measurement of electrostatic fields requires that the person making the measurement is familiar with the operation of the measuring equipment. Most hand held meters require that the reading be taken at a fixed distance from the object. Equipment manufacturers typically specify that the object being measured needs to have certain minimum dimensions. Objects smaller than the minimum dimensions may not provide an accurate reading. Additional guidance related to Protected Areas may be obtained in ESD ADV 2.0.

6.2.4. Packaging

6.2.4.1. Packaging Requirements

ESD protective packaging and package marking shall be in accordance with the contract, purchase order, drawing or other documentation. When the contract, purchase order, drawing or other documentation does not define ESD protective packaging, the Organization shall define ESD protective packaging requirements for ESDS items within the Plan. Packaging shall be defined for all material movement within Protected Areas, between job sites and field service operations.

6.2.4.2. Packaging Guidance

ESD protective packaging techniques vary widely. Some of these types and techniques include low charge generating bags and wraps, air space, dissipative wrap, static shielding, conductive shunts and the use of EMI/RFI shielding. All or some of these packaging types may be used in conjunction with one another to achieve a level of protection commensurate with the item being protected. If the user does not know the sensitivity of the items being used, static shielding packaging should be used. Materials include topically treated polyethylene sheets and film, specially coated corrugated cartons, carbon-loaded plastics, metalized plastic film and various foils. The objective of ESD protective packaging is to prevent a direct electrostatic discharge to the ESDS item contained within and allow for dissipation of charge from the exterior surface. In addition, the packaging should minimize charging of the ESDS item in response to an external electrostatic field and triboelectrification. Users should be aware that some packaging materials may be humidity dependent and may have limited shelf life. They may also lose static shielding properties by crumpling, puncturing and folding. Packaging materials may outgas, contaminate or shed particles that may cause production-related problems. It is important that the Organization evaluate ESDS protective packaging materials for process, storage and environmental compatibility.

6.2.5. Marking

6.2.5.1. ESDS Assemblies and Equipment

ESDS assemblies and equipment containing ESDS parts and assemblies should be marked with an ESD caution symbol, (i.e., EOS/ESD S8.1). The symbol should also be located on equipment in a position readily visible to personnel. In addition, the symbol should be located in a position readily visible when an ESDS assembly is incorporated into its next higher assembly.

6.2.5.2. Packaging

ESD protective packaging should be marked in accordance with EOS/ESD S8.1 or MIL-STD-2073-1 for Military applications.

6.2.6. Equipment

Further guidance regarding equipment can be found in ESD-ADV-2.0.

6.2.6.1. AC Powered Tools

The working part of AC powered tools should be capable of providing a conductive path to ground. New powered hand tools such as soldering irons

typically should have a tip to ground resistance of less than 1.0 ohm.

Note - This resistance may increase with use but should be less than 20.0 ohms for verification purposes.

6.2.6.2. Battery Powered and Pneumatic Hand Tools

Battery powered and pneumatic hand tools while being held should have a resistance to ground of less than 1 X 10^{12} ohms.

6.2.6.3. Automated Handlers

All conductive or static dissipative components of automated handling equipment should provide a continuous conductive path to ground, whether stationary or in motion. The equipment should minimize charge generation of the ESDS items that are handled. Where insulative materials are necessary in the device path, they should be designed to minimize electric fields and the charge imparted to devices being handled.

6.2.7. Handling

6.2.7.1. Handling Procedure Requirements

ESD protective handling procedures shall be established, documented, and implemented. Handling procedures are required for all areas where ESDS items are manually or machine processed. When outside their protective covering or packaging, ESDS items shall be handled only in a Protected Area.

6.2.7.2. Handling Procedure Guidance

Handling procedures should address all operations and locations where ESDS items will be handled in protected and unprotected areas.

Table 1- ESD Control Program Technical Requirements Summary

(See paragraph 6.2 for further guidance regarding alternate test methods.)

Technical Requirement	Reference Paragraph	Implementing Process or Method	Area 1 Mfg.	Area 2 Field	Test Method, *Standard or Advisory*	Recommended Range[5]
Grounding / Bonding Systems	6.2.1				ANSI EOS/ ESD S 6.1	
		Equipment Ground	R	O	ANSI EOS/ ESD S 6.1	< 1.0 ohm AC Impedance
		Auxiliary Ground	O	O	ANSI EOS/ ESD S 6.1	< 1.0 ohm AC Impedance
		Equipotential Bonding	O	O	ESD ADV 2.0	< 1.0 X 10^9 ohm[6]
		Common Point Ground	R	O	ANSI EOS/ ESD S 6.1	< 1.0 ohm AC Impedance
Personnel Ground	6.2.2					
		Wrist Strap System			ESD S 1.1	< 35 X 10^6 ohm[7]
		Seated Operations	R	R		
		Standing Operations	O	O		
		Flooring – Footwear System	O	O	ESD STM 97.1 or ESD STM 97.2	< 35 X 10^6 ohm[6] or < 100 Volts[6]
Protected Area	6.2.3					
		Work Surface	O	O	ESD S 4.1	< 1 X 10^9 ohm
					ESD STM4.2	< 200 Volts[6]
		Wrist Strap Cord	O	O	ESD S 1.1	0.8 X 10^6 to 1.2 X 10^6 ohm
		Footwear	O	O	ESD S 9.1	< 1 X 10^9 ohm[7]
		Flooring	O	O	ANSI ESD S 7.1	< 1 X 10^9 ohm[7]
		Seating	O	O	ESD STM 12.1	< 1 X 10^9 ohm[7]
		Ionization (other than room systems)	O	O	ANSI EOS/ESD S 3.1	< ±50 Volts Voltage Offset[6]
		Ionization (room systems)	O	O	ANSI EOS/ESD S 3.1	< ±150 Volts Voltage Offset[5]
		Shelving	O	O	ESD ADV 53.1	< 1 X 10^9 ohm[7]
		Mobile Equipment	O	O		< 1 X 10^9 ohm[6]
		Continuous Monitors	O	O	Manufacturer Specification	N/A

[5] The values in the Recommended Range are obtained by using the Test Method, Standard or Advisory provided in this table. See paragraph 6.2 for further guidance regarding alternate test methods.
[6] This is a proposed value that has not been substantiated by any standard.
[7] This value differs from the value in current standards. There is work in progress to harmonize the value.

Technical Requirement	Reference Paragraph	Implementing Process or Method	Area 1 Mfg.	Area 2 Field	Test Method, Standard or Advisory	Recommended Range[5]
		Signs	R	O	N/A	
	6.2.4	ESDS Item Packaging	R	R	See ESD Packaging Technical Requirement	N/A
	6.2.6	Equipment			ESD ADV 2.0	
	6.2.6.1	AC Powered Tools	O	O	ESD DS 13.1	< 1.0 ohm[6]
	6.2.6.2	Battery Powered and Pneumatic Hand Tools	O	O		< 1 X 10^{12} ohms[6]
	6.2.6.3	Automated Handlers	O	O	ESD DSP 10.1	
		Garment	O	O	ESD STM 2.1	1 X 10^{5} to 1x10^{11} ohms
		Protective Material Marking	O	O	ESD S8.1	
		Humidity	O	O	N/A	> 30% Rh < 70%[6]
ESD Packaging	6.2.4					
		Conductive	O	O	EOS/ESD S11.11	< 1 X 10^{4} ohms
		Dissipative	O	O	EOS/ESD S11.11 ESD DS11.12	≥ 1 X 10^{4} to < 1 X 10^{11} ohms
		Shielding	O	O	ESD S11.31	< 50 nJ[6]
		Low Charging	O	O	ESD ADV 11.2	
		Protective Material Marking	O	O	EOS/ESD S8.1	

R-Required implementing process or method
O- Optional implementing process or method

7. APPENDIX A - SENSITIVITY TESTING

7.1. ESD Sensitivity Testing

Technical literature and failure analysis data exist that indicates ESD failures are due to a complex series of interrelated effects. Some of the factors that influence ESD sensitivity include the ESD current and energy envelope, the rise time of the ESD event, device design, fabrication technology and device package style. Energy sensitive devices are damaged by currents through the resistance of a bipolar junction, protection resistor, or protection MOS transistor. Voltage sensitive devices are damaged when the breakdown voltage is exceeded. ESD Sensitivity Testing of devices, whether performed using the Charged Device Model (CDM), Machine Model (MM) or the Human Body Model (HBM), provide ESD sensitivity levels for the comparison of one device to another using defined parameters. The ESD sensitivity of the device (defined in volts), as determined by using any of the defined models, may not be the actual failure voltage level in the manufacturing, process or user environment. Table 2 provides a reference for various standards and test methods for ESD sensitivity testing.

7.1.1. 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 a pulse duration of approximately 150 nanoseconds. The use of a 1,500 ohm series resistor means this model approximates a current source. All devices should be considered as HBM sensitive. The HBM ESD sensitivity of devices may be determined by testing the device using one of the referenced test methods. HBM sensitivities can be found in RAC VZAP, Qualified Manufacturers, List of Products (QML-19500) or Qualified Manufacturer List (QML-38535).

7.1.2. 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. Due to the lack of a series current limiting resistor, this model approximates a voltage source. 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.

7.1.3. 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. A major issue with the preparation of a CDM test standard is the availability of suitable instrumentation to measure the discharge event. 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
MM	ESD-STM5.2
CDM	ESD DS5.3.1

7.2. Assembly, Equipment and Design Hardening

7.2.1. Assembly, Equipment and Design Hardening Guidance:

Assemblies and equipment should have protective circuitry or techniques to meet the desired design goals. Determining the ESD susceptibility of assemblies and equipment may be based on simulation modeling, or actual testing. Table 3 provides a quick reference for various test methods associated with assembly and equipment susceptibility testing.

7.2.2. Direct Contact, Non-Operating Assembly, Body/Finger or Hand/Metal Tests:

This model can be used to verify that assemblies will not be damaged during non-operating conditions by direct contact to input, output and interface connections. This threat applies to all types of assemblies, see Table 3.

7.2.3. Direct Contact Operating Equipment Hand/Metal Test:

This model can be used to verify that operating equipment will not be damaged (or non-recoverable faults will not be injected) by direct contact to operator accessible points and exposed surface areas during the normal maintenance process. This threat is limited to equipment subject to operator adjustments or maintenance activities during operation, see Table 3.

7.2.4. Indirect Contact, Operating Equipment Furniture Model Test:

This model can be used to verify that operating equipment in a home or office environment will not be damaged (or non-recoverable faults will not be injected) by indirect contact during normal activities performed within the proximity of the equipment. This threat applies to all electronic equipment in a home or office environment. *See* Table 3

Table 3 - ESD Susceptibility Test References for Assemblies and Equipment

ESD Assembly/Equipment Model	ESD Test Standard or Method
Body/Finger HBM	IEEE STD C62.38 (Sub-Assembly)
Hand/Metal HBM	IEC 1000-4-2 ANSI C63.16 (Equipment)
Furniture Model	ANSI C63.16 (Equipment)

8. APPENDIX B - RELATED DOCUMENTS

The following documents are listed for further reference. Some documents may be canceled. However, this listing provides a reference of documents reviewed during the preparation of this standard.

8.1. Military/U.S. Government:

FED-STD-101, "Federal Test Method Standard"

MIL-B-117, "Bags, Sleeves and Tubing--Interior Packaging"

MIL-PRF-81705, "Barrier Materials, Flexible, Electrostatic Free, Heat Sealable"

MIL-E-17555, "Electronic and Electrical Equipment, Accessories, and Provisioned Items (Repair Parts): Packaging of"

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

MIL-M-38510, "General Specification for Military Microcircuits"

MIL-P-82646, "Plastic Film, Conductive, Heat Sealable, Flexible"

MIL-PRF-87893, “Workstations, Electrostatic Discharge (ESD) Control”

MIL-STD-129, "Marking for Shipment and Storage"

MIL-STD-1285, "Marking of Electrical and Electronic Parts"

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

MMA-1985-79, Revision 3, “Standard Test Method for Evaluating Triboelectric Charge Generation and Decay”

8.2. Industry Standards:

ANSI/IEEE-STD-142, "IEEE Green Book (IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems)"

ANSI/EIA-625, "Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices"

ANSI/EIA-541, “Packaging of Electronic Products for Shipment”

ANSI/EIA-583, “Packaging Material Standards for Moisture Sensitive Items”

ESD-ADV3.2, “Selection and Acceptance of Air Ionizers”

ESDSIL, "Reliability Analysis Center (RAC) ESD Sensitive Items List"

EIA-471, “Symbol and Label for Electrostatic Sensitive Devices”

IEC 61340-5-1, “Protection of Electronic Devices from Electrostatic Phenomena – General Requirements”

EN 100015-1, “Basic Specification: Protection of Electrostatic Devices - Part 1 General Requirements”