ELECTROSTATIC DISCHARGE SUSCEPTIBILITY DATA
1995

(Ordering No.: VZAP-95)

Preface

The purpose of this document is to make available electrostatic discharge (ESD) susceptibility test and classification data. This data is much needed by industry and government equipment designers to enable them to assess their equipment's' vulnerability to the ESD threat, to assist in the establishment of ESD control programs, and to comply with such requirements as MIL-STD-1686B, "Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosives Devices)."

This document was prepared as part of the Reliability Analysis Center's effort to provide its user community with new and needed information in the field of electronic device reliability.

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1.0 INTRODUCTION

This databook is a cumulative compendium of Electrostatic Discharge (ESD) susceptibility test data residing in the RAC database. It was collected from a variety of sources and consists of data on integrated circuits, discrete semiconductors and resistors.

The introductory material of this publication is not intended to provide a tutorial on ESD testing or the physics of ESD failures, but rather to provide enough information to allow the user of this document to effectively interpret the presented data. This information will also give the user some insight into the usefulness and limitations of the data.

1.1 Background

When the first in a series of ESD data compendiums (VZAP-1) was published in 1983, ESD was a relatively immature field with a serous lack of standardization, especially in the area of ESD susceptibility testing. Much of the VZAP-1 data was taken with non-standard ESD simulator circuits that deviated from the use of a 100pF, 1500 ohm discharge model. Additionally, it was discovered subsequent to VZAP-1 that many of these simulators, either commercially available or built in-house, have low degrees of repeatability due to many uncontrolled variables. Although many of the reasons for this nonrepeatability have been studied, understood, and corrected, there potentially still are sources for large degrees of variation in the test results. A discussion of typical variability that exist in test results is given in Section 1.5.

VZAP-95 is the fifth version of this data compendium and includes data on approximately 150% more parts than VZAP-91 (published in 1991). All of the new data was taken with the standard 100pF, 1500 ohm discharge model, much of it in accordance with MIL-STD-883, Method 3015.7. Method 3015.6 was the first version of the MIL-STD-883 methods to require waveform verification to ensure consistency in test results.

1.2 Document Organization

This document is organized into the following section:

Section 1 contains background data, information on use and interpretation of the data presented, data conversion algorithms, and variability inherent in the data.

Section 2 contains profiles illustrating the relative susceptibility of various technologies and device types.

Sections 3 through 5 contain susceptibility data sorted by part number (not including letter prefixes), manufacturer, and device data code. Therefore parts 10501 and MC 10501 will appear in succession in the manual with each specific manufacturer and device data code listed on a separate line.

For ease of use to those who are familiar with VZAP-91, the following information is noted:

- *Parts included in this document but not limited in VZAP*-91 are flagged with a "*" prior to the part number.
- Parts changing classification since VZAP-91 are flagged with a "-" prior to the part number.

Section 3 contains detailed susceptibility test data on microcircuit devices.

Section 4 contains detailed susceptibility test data on discrete semiconductor devices.

Section 5 contains detailed susceptibility test data on passive devices.

Section 6 contains brief descriptions of the various data sources used in this publication.

Section 7 contains document references.

Slash# Index contains an integrated index of all slash numbers for Microcircuit, Discrete, and Passive Devices. The index includes the part number, (MIL-M-38510 & MIL-S-19500) slash number, manufacturer, device date code, susceptibility classification, test method used to classify the part, and reference pages (from Sections 3 through 5).

1.3 Use of this Data

MIL-STD-1686B covers the requirements for the establishment and implementation of an ESD control program, including identification of ESD Sensitive (ESDS) parts, assemblies, and equipment. Any organization that designs, tests, inspects, services, manufacturers, processes, assembles, installs, packages, labels, or otherwise handles electronic parts, assemblies, and equipment susceptible to ESD damage should consider implementation of an ESD control program. The RAC has also published a document "ESD Control in the Manufacturing Environment" to address these issues. At the time of this writing, MIL-STD-1686B was the current version. The "C" version of the standard is in preparation and will contain significant changes. However, the remainder of this discussion is based on the "B" version.

The first consideration in establishing an ESD control program in a specific application is the identification of the susceptibility levels of the specific parts being used. This is true whether the program is being implemented as a result of MIL-STD-1686B or not. Based on this information, an effective program can then be designed and implemented without expensive overkill.

MIL-STD-1686B, Paragraph 5.2 states, "The contractor shall identify each ESD Sensitive (ESDS) part, assembly, and equipment applicable to the contract as Class 1 or 2." In some cases Class 3 parts must also be identified. Paragraph 5.2.1.1 further states:

> "ESD sensitivity classification for parts shall be determined as follows:
>
> (a) ESD sensitivity as specified in the applicable part specification, or
> (b) ESD sensitivity in accordance with Appendix A (of MIL-STD-1686B) test data contained in the Reliability Analysis Center (RAC) ESD Sensitive Items List (ESDSIL), or
> (c) Classified in accordance with Appendix B (of MIL-STD-1686B0, or,
> (d) When specified, or at the option of the contractor when not specified, determine sensitivity by test (See Appendix A of MIL-STD-1686B). ESD sensitivity test data reporting shall be in accordance with the data ordering document included in the contract or order (See 6.2).

The data contained in this databook is essentially a compilation of ESD test data taken from a wide variety of sources. The ESDSIL database referred to in item (b) above is entitled the "Electrostatic Discharge Sensitive Items List." The intent of the ESDSIL database is to be a central repository of data taken as a result of the requirements of MIL-STD-1686B and Data Item Description (DID-RELI-80670). The classification test procedure in Appendix A of MIL-STD-1686B requires the use of the test circuit of MIL-STD-883, Method 2015. At the time MIL-STD-1686B was issued the MIL-STD-883 test method in effect was Method 3015.6. Since much of the data collected and included in this publication was performed in accordance with Method 3015.6 and 3015.7, most of this new data fulfills the requirements of (b).

The older data in this publication that does not fulfill (b) is however more desirable than the use of (c) above which generically classifies components based on part type. Since 3015.6 was the first MIL-STD-883 ESD test method to ensure reasonable confidence in test waveform characteristics, it is the most desirable test data available. The data types, in order of preference, can be summarized as follows:

(1) MIL-STD-883, Method 3015.6 or later
(2) MIL-STD-883, Method 3015.5 or earlier, or other 100pF, 1500ohm Human Body Model (HBM) tests, such as DOD-STD-1686
(3) Non 100pF, 1500 ohm HBM tests converted to an ESD susceptibility level consistent with the 100pF, 1500 ohm model
(4) Electromagnetic Pulse (EMP) data converted to an ESD susceptibility level..

There is data contained in this document from all four items listed above although item 1 is the most predominant. This is also the order of preference which as used in determining the ESD classification of each part listed. A more detailed description of the test method used or each data entry is given in the remarks field of Section 3 through 5 of this document.

In this publication unique devices are individually classified. The criteria RAC used to define a unique device is a unique combination of part number, manufacturer and date code. For this reason, there are separate classifications for the same part number from a particular manufacturer if in one case the date code was known and in another case it was not known. This uniqueness criteria was chosen since the susceptibility may be dependent on date of manufacture for a particular part if design or process changes were made.

Before the updates of DOD-STD-1686 to MIL-STD-1686A and MIL-STD-883 Method 3015.5 to 3015.6, there were inconsistencies between DOD-STD-1686 and MIL-STD-883 method of reporting ESD test results. Specifically, the voltage susceptibility ranges were different, making it impossible to cross-correlate test data. Both MIL-STD-1686A and MIL-STD-883, Method 3015.6 have been coordinated, thereby making data taken from either useable for either purpose. In fact MIL-STD-1686A invokes the procedure of MIL-STD-883 Method 3015. The classifications and their associated susceptibility ranges are as follows:

Class 1	0-1999V
Class 2	2000-3999V
Class 3	4000-15999V

This is the classification scheme that is used in this publication. In addition to these, RAC has defined Class N to mean devices susceptible to levels above 15999 volts.

Since some of the older data in this publication was obtained from tests performed not in accordance with MIL-STD-1686A or MIL-STD-883, classification in accordance with these standards becomes difficult. For example, if testing was performed that yielded devices passing a test at 1000 volts but failing the test at 3000, although it is known that the susceptibility level is 1000-3000 volts, the MIL-STD-1686A classification cannot be precisely determined. In this example it is not known whether the device is Class 1 or 2. The classification criteria used in this publication was to use the lowest failure voltage or the highest voltage at which the device passed if no failure data existed. For example, if a device was observed to fail when tested at 2000 volts only, it was classified as Class 1 since the actual threshold voltage is between 1 and 2000 volts.

As stated previously, all data present in this document as not taken from specific test methods, such as Method 3015 of MIL-STD-883 but rather from a variety of test methods. Contained in this document are the results of tests done in accordance with MIL-STD-883, Test Method 3015; tests similar to MIL-STD-883 Method 3015 but not strictly in accordance with it; tests using nonstandard simulation models and methods; and EMP data that was converted to reflect ESD susceptibility levels. The EMP data was only used for classification purposes in the cases in which there was no other empirical ESD susceptibility data. The methodology used to convert EMP data to ESD susceptibility levels is given in Section 1.5.

It should be noted that there could be significant differences in ESD susceptibility data between test taken in accordance with Method 3015.6 and earlier versions in which the waveform was not tightly controlled. Data taken from circuits in which the high frequency (i.e. > 100 HMz) performance has not been characterized will lower failure thresholds. This potential exists due to the fact that there can exist high frequency, high amplitude oscillations in some circuits which yield higher stressing amplitudes than that of the ideal RC discharge waveform.

Additionally, there is a limited amount of Charged Device Model (CDM) test results. Even though CDM tests are not yet incorporated into the ESD testing standards, there has been some data included in this publication from tests performed with this model. Although the device classification schemes are only applicable for the HBM, the CDM data that was available is included for completeness, considering that conventional classifications with CDM data cannot be done.

Individuals or firms testing devices for ESD susceptibility are encouraged to submit the resulting data to the Reliability Analysis Center for Inclusion into the database. If desired, the source of data will be held proprietary by RAC. This data does not need to be taken in accordance with the MIL-STD-883 test method, but can be any empirical ESD susceptibility data. A recommended format for this data is shown in Table 1-1. Table 1-2, The Data Item Description (DID) DI-RELI-80670 called out in MIL-STD-1686A for submission of ESD sensitivity data is also provided.

TABLE 1-1. DEFINITION OF VZAP TEST PARAMETERS

Field Description

SOURCE

Name - Information pertaining to the company and person responsible for performing/ compiling the results of ESD simulation. (Address, Phone Number)

TESTER

Manufacturer - Manufacturer of the ESD simulator being used

Model Number - Model number and any revision information about the ESD simulator being used

MIL-STD-883, Method 3015 version if applicable

TEST SPEC. METHOD (The test method by which ESD simulation was performed)

Test Method - If MIL-STD-883 Method 3015 was used, the version of 3015.X will be printed. Otherwise the resistance (in ohms) used in the simulation and the capacitance (in farads) used in the simulation will be noted

Voltage Step Levels - For step stress testing, the voltage step levels used, for go/no-go testing, the voltage applied

# of Pulses Per Level - For step stress enter the total number of pulses applied at the maximum failed voltage applied

Test Date - Date testing was performed

DEVICE

Part Number - Full device part number, prefix and suffix. In situations of drawing or in-house part numbers, the generic number when available. If parts are MIL-M-38510 or MIL-S-19500, slash numbers should also be provided

Description - Full device description of component

Manufacturer - Manufacturer of device being tested

Date Code - Date code as found on device

TEST RESULTS

Pass or Fail - Results of the ESD simulation for each device tested

# of Devices Tested - Number of devices tested

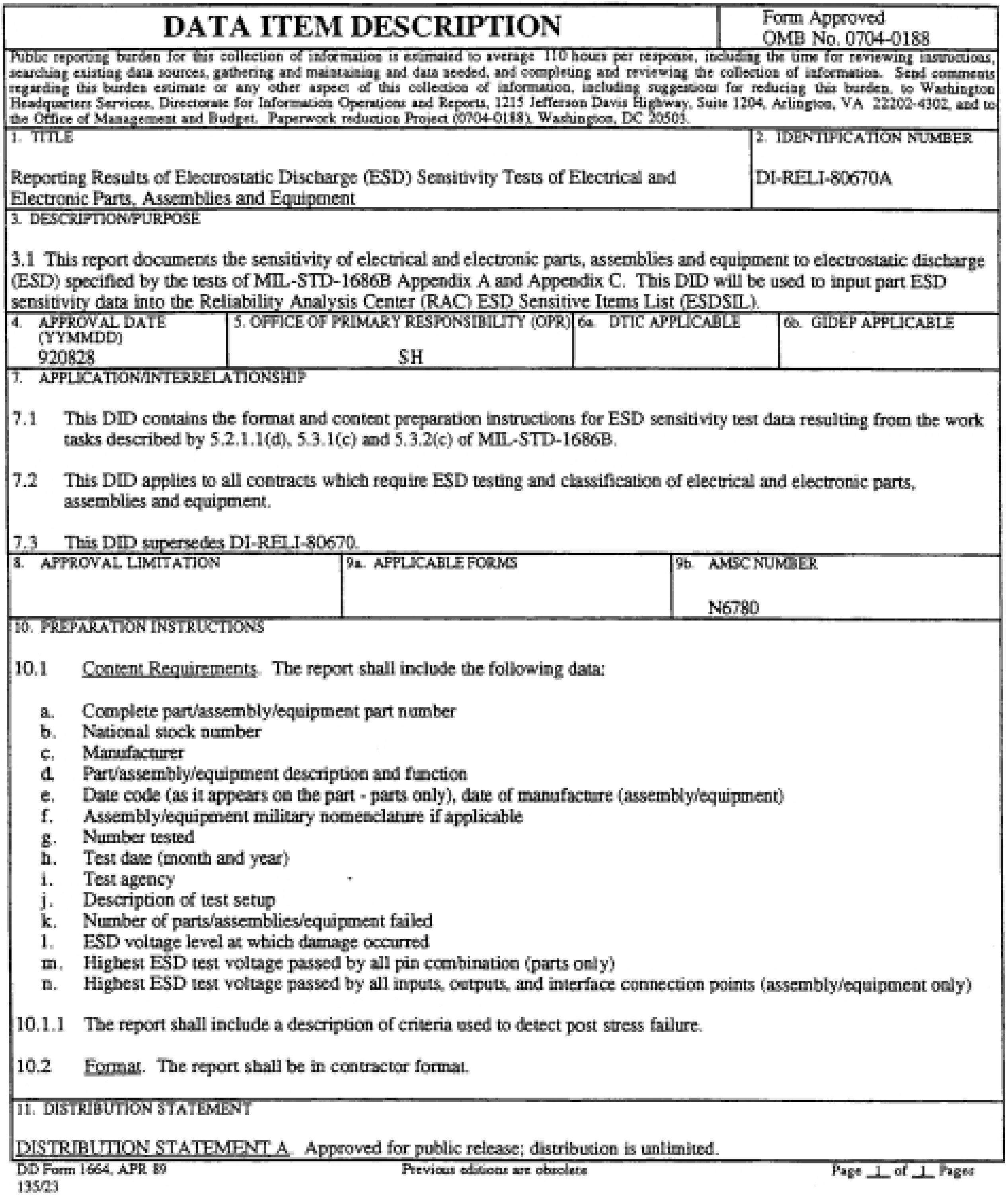
Failure Voltage - The voltage at which the device met failure criterion

Voltage Polarity The polarity of the failed voltage reported

Fail Pin Combination - The pin combination for which each test was performed and note which combination yielded a failure

Failure Criterion - Explanation of what criterion was used to determine a failure

TABLE 1-2. DATA ITEM DESCRIPTION - DI-RELI-80670



DATA ITEM DESCRIPTION

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 110 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining and data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget. Paperwork reduction Project (0704-0188), Washington, DC 20505.

1. TITLE Reporting Results of Electrostatic Discharge (ESD) Sensitivity Tests of Electrical and Electronic Parts, Assemblies and Equipment	2. IDENTIFICATION NUMBER DI-RELI-80670A

3. DESCRIPTION/PURPOSE

3.1 This report documents the sensitivity of electrical and electronic parts, assemblies and equipment to electrostatic discharge (ESD) specified by the tests of MIL-STD-1686B Appendix A and Appendix C. This DID will be used to input part ESD sensitivity data into the Reliability Analysis Center (RAC) ESD Sensitive Items List (ESDSIL).

4. APPROVAL DATE (YYMMDD) 920828	5. OFFICE OF PRIMARY RESPONSIBILITY (OPR) SH	6a. DTIC APPLICABLE	6b. GIDEP APPLICABLE

7. APPLICATION/INTERRELATIONSHIP

7.1 This DID contains the format and content preparation instructions for ESD sensitivity test data resulting from the work tasks described by 5.2.1.1(d), 5.3.1(c) and 5.3.2(c) of MIL-STD-1686B.

7.2 This DID applies to all contracts which require ESD testing and classification of electrical and electronic parts, assemblies and equipment.

7.3 This DID supersedes DI-RELI-80670.

8. APPROVAL LIMITATION	9a. APPLICABLE FORMS	9b. AMSC NUMBER N6780

10. PREPARATION INSTRUCTIONS

10.1 Content Requirements. The report shall include the following data:

a. Complete part/assembly/equipment part number
b. National stock number
c. Manufacturer
d. Part/assembly/equipment description and function
e. Date code (as it appears on the part - parts only), date of manufacture (assembly/equipment)
f. Assembly/equipment military nomenclature if applicable
g. Number tested
h. Test date (month and year)
i. Test agency
j. Description of test setup
k. Number of parts/assemblies/equipment failed
l. ESD voltage level at which damage occurred
m. Highest ESD test voltage passed by all pin combination (parts only)
n. Highest ESD test voltage passed by all inputs, outputs, and interface connection points (assembly/equipment only)

10.1.1 The report shall include a description of criteria used to detect post stress failure.

10.2 Format. The report shall be in contractor format.

11. DISTRIBUTION STATEMENT

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

DD Form 1664, APR 89
135/23

Previous editions are obsolete

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1.4 Interpretation of Data

The data contained herein is intended to present the results of empirical tests performed. Ideally, in addition to voltage susceptibility levels, one would like to know specific failure mechanisms that caused the device to fail. While manufacturers typically know the manner in which their part will fail when exposed to an ESD transient, this data is not normally available to outside organizations. Therefore, the specific failure mechanisms are not known. What is usually known is the failure mode (that is, the measurable effect of damage), since in any ESD test there must be a means of detecting failure. The failure criteria in the data contained herein is coded in field number 16 in Section 3 through 5 and detailed in Appendix B.

The failure criterion used in establishing an ESD failure is critical to the outcome of the testing. This may be illustrated by the use of two examples. In the first example, let us assume that the failure criterion for a bipolar device is defined as a certain percentage change in leakage current. This may be a difficult failure criterion to implement, because the relationship of leakage current versus stress voltage itself is not well defined. In the second example, let us assume that the leakage current specification limits are used as the failure criterion for the parts. The device which we are testing is relatively tolerant to ESD and remains within the specification limits when stressed with a pulse well below the damage threshold. Nevertheless, there is a measurable change in the leakage current (i.e., the device has been degraded; however, it does not exceed the specification until it is subsequently pulsed with a much higher energy pulse). Since we know that some degradation has occurred, we can measure the degradation, but, because of the failure criterion, the device is not considered susceptible to ESD damage at the lower level. For this reason, the criterion used to detect device failure must also be selected in accordance with the device operating characteristics and the manner in which the device is designed into a circuit; that is, if a certain circuit configuration can tolerate a parameter shift or even an out-of-specification condition of this component. Since it is impractical to require unique failure criteria based on the manner in which the part is used in the circuit, MIL-STD-883 Method 3015 states that devices shall be tested for failure following stressing by performing room temperature DC parametric and functional tests. Performing both parametric and functional tests should identify any degradation or failure of the device.

It is also recognized that failure modes and mechanisms are highly dependent on the simulation circuit used to stress the device. There are various circuits being used in industry to simulate different ESD scenarios. The most standard of these is the Human Body Model, in which a charge capacitance is discharged through a resistor to the device under test. This Human Body Model is the most commonly used simulation model and is specified in MIL-STD-1686B and MIL-STD-883 Method 3015. The resistance and capacitance values specified in these standards are 100 pF and 1500 ohms, respectively. Other values are often used and some data in this publication use these values. The values used are listed in the detailed data (Section 3 through 5). It should be noted that devices could exhibit different susceptibility characteristics depending on the values used. Since there is a need to classify devices in a consistent manner, the RAC derived a conversion method for data that was taken using a Human Body Model with resistance and capacitance values other than 100 pF, 1500 ohms.

Using empirical methods, the RAC has established the following algorithm for the conversion:

$$V_1 = V_2(3.87)\sqrt{\frac{C_2}{R_2}}$$

where:

V_1 = standard human body model damage threshold
R_2 = nonstandard value of resistance used (in ohms)
C_2 = nonstandard value of capacitance used (in pF)
V_2 = measured damage threshold using C_2 and R_2

The derivation of this equation may be found in Table 1-3.

This method is only used so that a classification in accordance with the susceptibility levels of MIL-STD-1686B can be made. The data in Section 3 through 5 presents both the classification of each part and the data as it was obtained (i.e., the failure voltages of the actual model used during testing).

The purpose of this publication is not to provide background on the physics of ESD failures, as this has been done extensively in the literature, but rather to present the data collection by RAC and give the reader enough information so that the limitations of the data are fully understood. If further information is required, consult MIL-HDBK-263A, "Electrostatic Discharge Control Handbook for the Protection of Electrical and Electronic Parts, Assemblies, and Equipment (excluding Electrically Initiated Explosive Devices)" and the proceedings of the Annual EOS/ESD Symposium.

1.5 Conversion of EMP Overstress Test Data to the ESD Human Body Model

A vast amount of electrical overstress data has been compiled from Electromagnetic Pulse (EMP) studies. By knowing certain parameters of a device, a theoretical ESD failure voltage can be estimated using the Wunsch-Bell model (Reference 28) as the starting point. The following equation has been established to convert EMP overstress data to the ESD Human Body Model equivalent:

$$V = \left[\frac{-2V_D + \sqrt{4V_D{}^2 + 1200K_1\left(7.675\times10^{-7}\right)^{-K_2}}}{60}\right]1530 + V_D$$

The derivation of this equation may be found in Table 1-3.

To estimate the precision of the calculated ESD levels presented in this publication, data was compared for specific devices which had both empirical ESD threshold data and ESD threshold levels calculated from EMP data. The log of the ratio of ESD to EMP failure voltages was plotted such that a given percentage of discrepancy (i.e., if the EMP level was the same percentage higher or lower than the ESD level) would be equidistant from the 0 line. Figure 1-1 is a histogram illustrating the relationship between the log (EMP/ESD) and frequency of occurrence. If the datapoints were randomly distributed about the 0 line and the data did not show a shift in distribution against any parameter, it could be concluded that the failure levels obtained from EMP data were a fairly good indication of the actual susceptibility levels of the devices (not taking into account random variations and noise in the data for any given device). Analysis of this data however, indicated that the log (EMP/ESD) datapoints were not randomly distributed but rather correlated to the susceptibility level. This indicates that the conversion algorithm is not perfectly accurate.

TABLE 1-3: DERIVATION OF DATA CONVERSION FORMULAE

The derivation of two data conversion methodologies are presented here:

Part I Conversion of failure voltages using a nonstandard human body model to a theoretical failure voltage consistent with the standard model (100 pF, 1500 ohm). This is only used for calculating a failure voltage consistent with the 100 pF, 1500 ohm model so that a classification can be derived in accordance with MIL-STD-1686A and MIL-HDBK-263.

Part II Conversion of empirical EMP overstress data to a theoretical ESD failure voltage.

Part I: Derivation of Nonstandard Human Body Model Test Data Conversion Formula

Since there is much data on parts using a discharge model other than the standard 100 pF, 1500 ohm, a method to convert the failure voltage to a level consistent with the 100 pF, 1500 ohm model for classification purposes is necessary. One way this can be accomplished is via a method similar to the EMP-to-ESD conversion method described in Part II of this table. However, for this method to work, one must know certain parameters of the device, namely the bulk resistance and breakdown voltage. Unfortunately, these parameters are seldom available, especially given the fact that for ICs the failure site is often not known.

A more direct conversion technique was therefore needed which could convert data without knowing these device parameters. Since the failure voltage of a device (the voltage on the capacitor) is proportional to the series resistance in the stressing circuits and inversely proportional to the capacitance in the circuit, the failure voltage, resistance, and capacitance can be approximately related as follows:

$$V = A\sqrt{\frac{R}{C}}$$

Here A is a constant dependent on the device parameters. Therefore, the ratio of failure voltages for two different RC models is in the general form:

$$\frac{V_1}{V_2} = \frac{A\sqrt{\frac{R_1}{C_1}}}{A\sqrt{\frac{R_2}{C_2}}} = \sqrt{\frac{R_1 C_2}{C_1 R_2}}$$

where:

V_2 = observed failure voltage using C_2 and R_2
C_2 = capacitance used in nonstandard model (in pF)
R_2 = resistance used in nonstandard model (ohms)
V_1 = converted failure voltage
C_1 = capacitance of model failure voltage is to be converted to (in pF)
R_1 = resistance of model failure voltage is to be converted to (ohms)

Therefore, when using 100 pF and 1500 ohm for C_1 and R_1 respectively, the following conversion equation is obtained:

$$V_1 = V_2\,(3.87)\sqrt{\frac{C_2}{R_2}}$$

The relationship of V, C, and R was obtained through empirical methods (regression analysis) by reviewing data in which a device was tested with different C, R models and threshold voltages obtained for each model (Ref. 10, 14, 16, 17, 19, 25).

It must also be stressed that this relationship of V, C and R indicates an energy-dependent failure mechanism. This may not be an adequate assumption, if the failure mechanisms does not follow the Wunsch Bell Model (Ref. 28). Since the failure mechanism for a particular device is rarely known, this data conversion methodology is necessarily very approximate. Adding to this uncertainty is the fact that the failure mechanism characteristics can change with various RC values.

For this reason this conversion was used to classify devices only in those cases where failure data from the 100pF, 1500 ohm model was not available. This method is approximate and was used in the classification of devices only if data using the standard human body model was not available.

Part II: Derivation of EMP-to-ESD Conversion Formula

By knowing certain parameters of a device, a theoretical ESD failure voltage can be calculated. The parameters needed for conversion of EMP overstress failure to a theoretical ESD failure voltage are (Reference 25):

R_B = Bulk resistance of the device
V_D = Breakdown voltage of device
K_1 = Failure constant 1
K_2 = Failure constant 2

The basic equation used for this conversion is: $P_{AV} = K_1\, t^{-K_2}$

where:

P_{AV} = average power required for failure
t = pulse width
p = $V_D\, i + R_B\, i^2$ (time dependent power)
where i = time dependent current
p = $V_D I_P\, e^{\frac{t}{\tau}} + R_B I_P^2\, e^{\frac{t}{\tau}}$
where τ = RC time constant of discharge

Integrating and averaging the power over 5 time constants yields:

$$P_{AV} = \frac{1}{5\tau}\int_0^{5\tau} V_D I_P\, e^{\frac{-t}{\tau}}\,dt + \frac{1}{5\tau}\int_0^{5\tau} R_B I_P^2\, e^{\frac{-2t}{\tau}}\,dt$$

$$= \frac{V_D I_P}{5}(1 - e^{-5}) + \frac{R_B I_P^2}{10}(1 - e^{-10})$$

$(e^{-5}$ and $e^{-10} \ll 1)$

therefore:

$$P_{AV} = \frac{V_D I_P}{5} + \frac{R_B I_P^2}{10}$$

$$K_1\, t^{-K_2} = \frac{V_D I_P}{5} + \frac{R_B I_P^2}{10}$$

Using the quadratic equation solution to solve for I_P:

$$I_P = \frac{-2V_D + \sqrt{4\,V_D^2 + 40\,R_B\,(K_1 t^{-K_2})}}{2\,R_B}$$

$$I_P = \frac{V - V_D}{R + R_B} \quad \text{(general equation for } I_P\text{)}$$

(V = voltage on capacitor)

$$V = I_P\,(R + R_B) + V_D \quad \text{(R = source resistance of model)}$$

Assuming $t = 5\tau = 5RC = 7.675 \times 10^{-7}$ for conversion to voltage level consistent with a 100 pF, 1500 ohm model and a nominal value of 30 ohms for R_B yields:

$$V = \left[\frac{-2V_D^2 + \sqrt{4V_D^2 + 1200K_1\,(7.675 \times 10^{-7})^{-K_2}}}{60}\right] 1530 + V_D$$

Based on this information, it should be emphasized that the ESD susceptibility levels obtained from EMP data are necessarily only approximate values. It can be seen from Figure 1-1 that the EMP to ESD levels can differ by as much as a factor of 10. There are various sources of error in converting EMP data to ESD data. Two of these error sources are the uncertainty in the damage constants and the uncertainty in the device parameters (bulk resistance and breakdown voltage). These uncertainties can stem from normal lot to lot variations and differences among manufacturers. Additionally, it is known that damage from EMP test pulses may manifest itself as different failure mechanisms than damage from an ESD pulse. This is due to the fact that an ESD pulse may be a shorter duration, higher current pulse relative to an EMP event. These variations can easily cause a factor of 10 difference in the susceptibility levels. For this reason, EMP data is used in the publication for classification purposes only in those cases where ESD data is not available. The EMP data is identified as such in the remarks field (field no. 16) of the detailed data section.

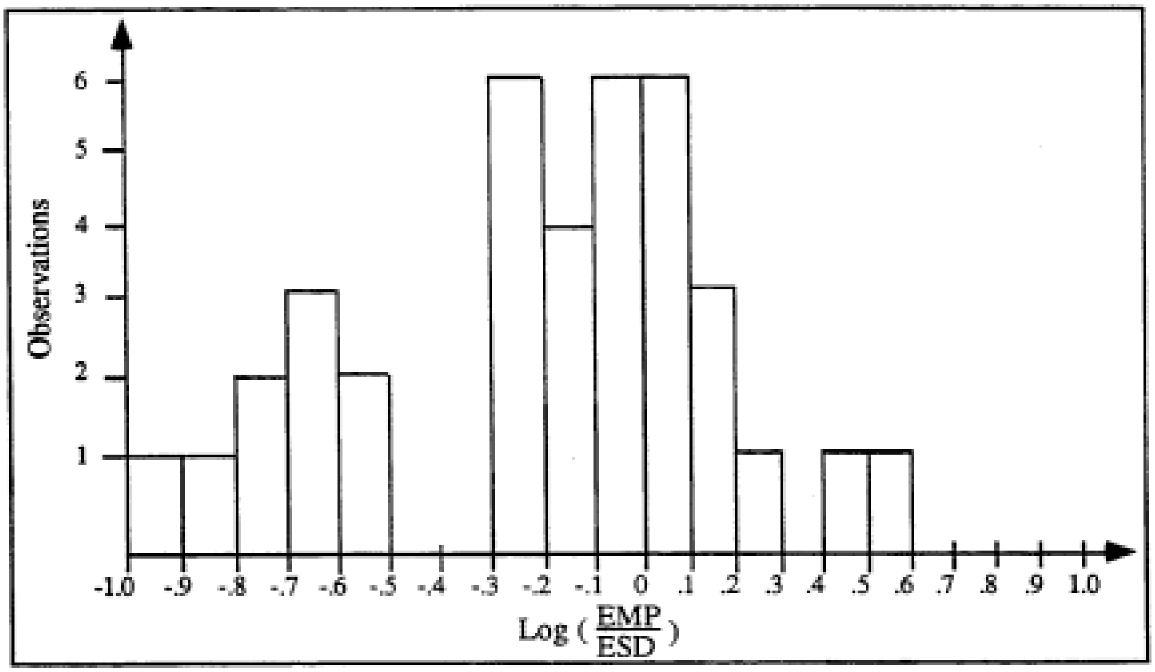

FIGURE 1-1. EMP VS. ESD DATA

1.6 Variability Associated with Conventional Test Methods

Since ESD testing began, it has been recognized that there was a certain degree of variability in test results due to the test apparatus itself. These variations were attributed to:

- Arcing of the high voltage switching relay
- Errors in calibration of the test voltages
- Leakage of the capacitor
- Parasitic inductances and capacitances
- Inconsistencies in the criteria used to detect failure
- Incomplete characterization of worst case pin combinations

Conventional ESD simulators probably effectively simulate a real ESD event from a charged person or object, since a real ESD would have many of the parasitic R, L, and C values similar to that of the simulator (Reference 8). The problem is, however, that the discharge waveform produced is uncontrolled and cannot be used to obtain repeatable results. Many of these problems have been alleviated with the release of Method 3015.6, however, since much of the data contained herein is from methods previous to 3015.6, it is important to understand the repeatability and variability of test results taken previous to 3015.6. To illustrate this, Figures 1-2 and 1-3 present the data RAC has taken from two different conventional ESD simulators. A sampling of 74LS08 devices were obtained of the same date code, attempting to minimize variations in the device under test population. The most susceptible pin was found by step stressing a small sample of devices on each pin until failure and detecting failures with a curve tracer.

Once the most susceptible pin was found, a sampling of 30 devices were step stressed to failure on this pin for each of the two simulators. Voltage step increments of 25 volts were used to maximize the resolution of failure voltage distributions. The intent of the study was to:

1. Determine the failure voltage distribution of a typical device stressed with a conventional test apparatus.
2. Identify differences in these distributions between two typical simulators.

Another study (Reference 26) with similar objectives yielded even a higher degree of variability. In this study, a sampling of 74F04 and 74F175 devices were tested by three independent test labs. Figures 1-4 and 1-5 summarize these results.

These results were taken when ESD testing technology was less mature and testers were being built with little regard for the subtleties involved in making an accurate and repeatable test circuit. Since the data contained in this publication was obtained from a variety of testers, it is apparent that this inherent variability is present in it.

In addition to the inherent variation in test apparatus and devices themselves, there can also exist large variations between manufacturers. This is due to the fact that each manufacturer employs his own unique methodologies and circuitry to protect devices, each with his own protection capability. If the manufacturer was known, it is reported in the detailed data section of this publication.

1.7 Summary and Conclusions

This publication presents the most comprehensive compendium of electrostatic discharge susceptibility test data currently available. This data is useful (and mandated by MIL-STD-1686B) for the establishment of ESD control procedures based on the susceptibility of devices being handled, assembled, stored, etc. It is important for the users of this information to understand the limitations of the data contained herein. To accomplish this, previous discussions have addressed the different types of data included in this publication as well as the variation inherent in it.

RAC also strongly encourages anyone performing ESD susceptibility tests to submit the results of those tests to RAC for inclusion in the database and dissemination in future editions of this publication. If tests are performed in accordance with MIL-STD-1686B, the results are required to be submitted to RAC as outlined in the Data Item Description DI-RELI-80670 (given in Table 1-2). Table 1-1 provides a format for submitting data if not done in accordance with a specific test method.

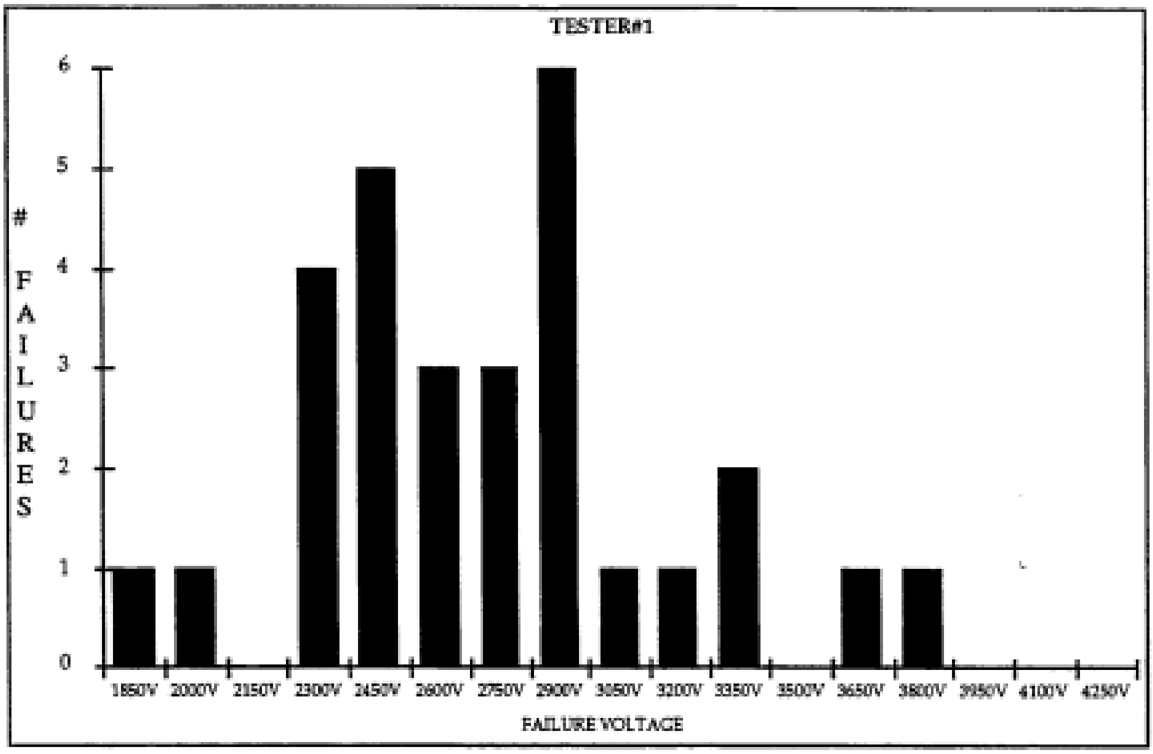

FIGURE 1-2. FAILURE DISTRIBUTION FOR TESTER #1

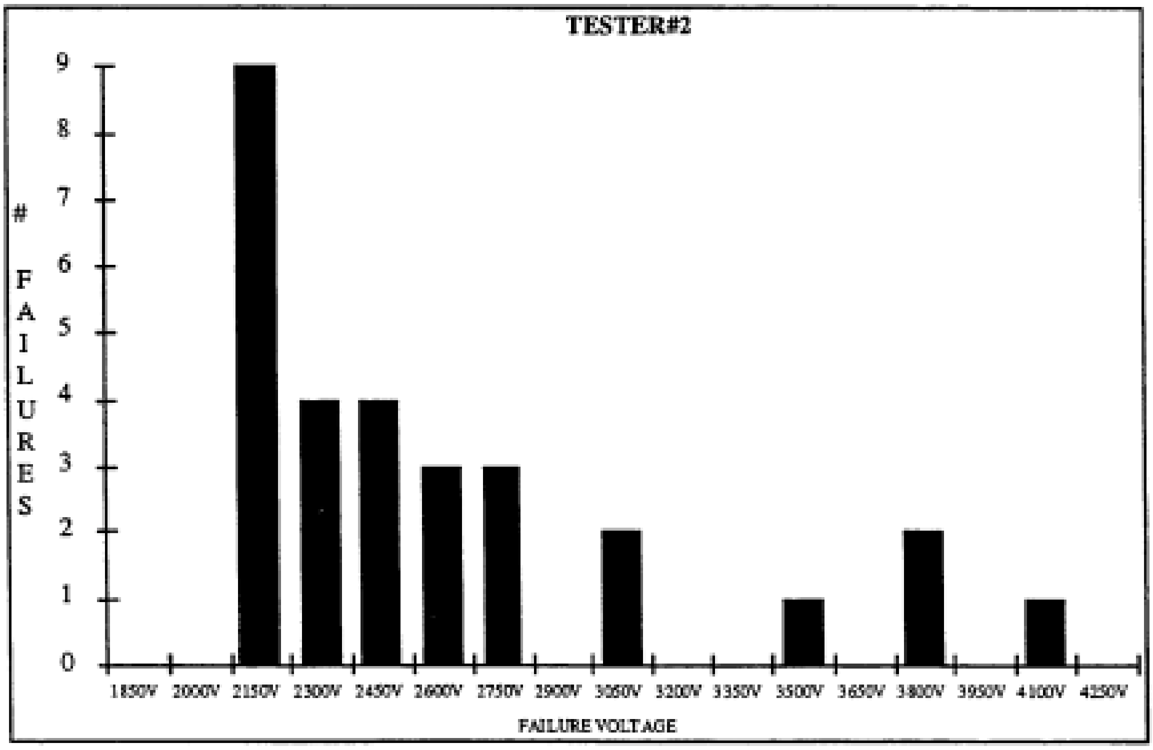

FIGURE 1-3. FAILED DISTRIBUTION FOR TESTER #2

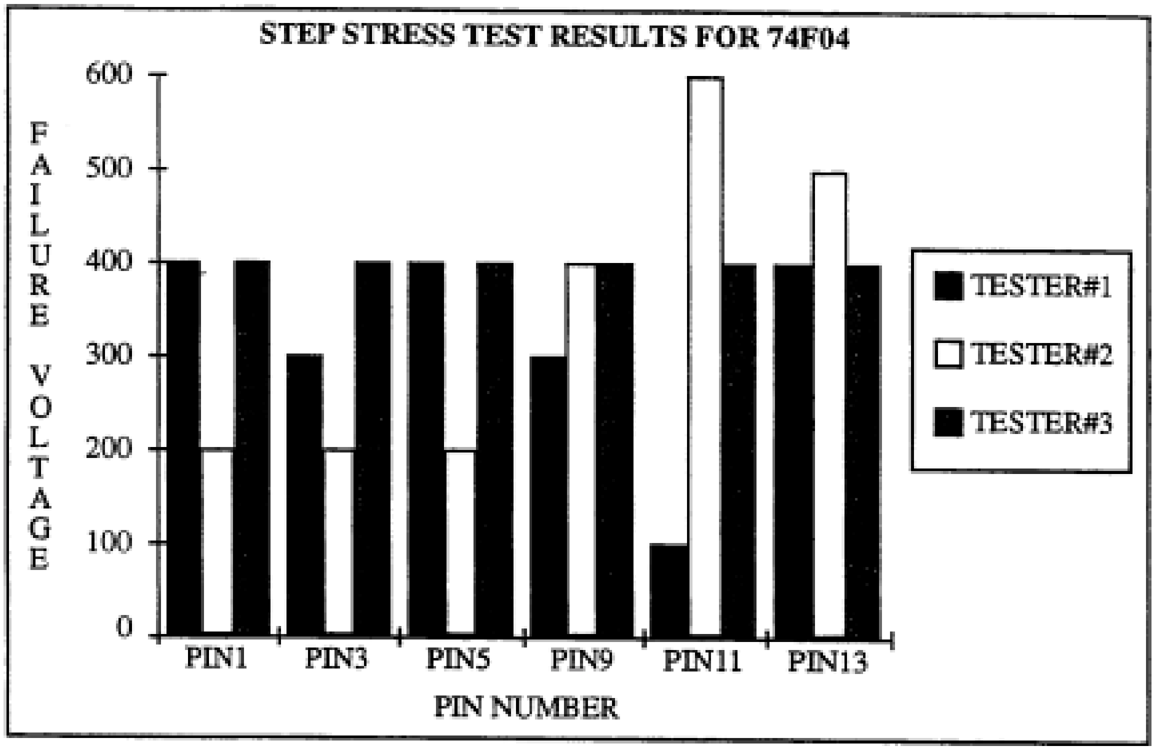

FIGURE 1-4: STEP-STRESS RESULTS FOR 74F04

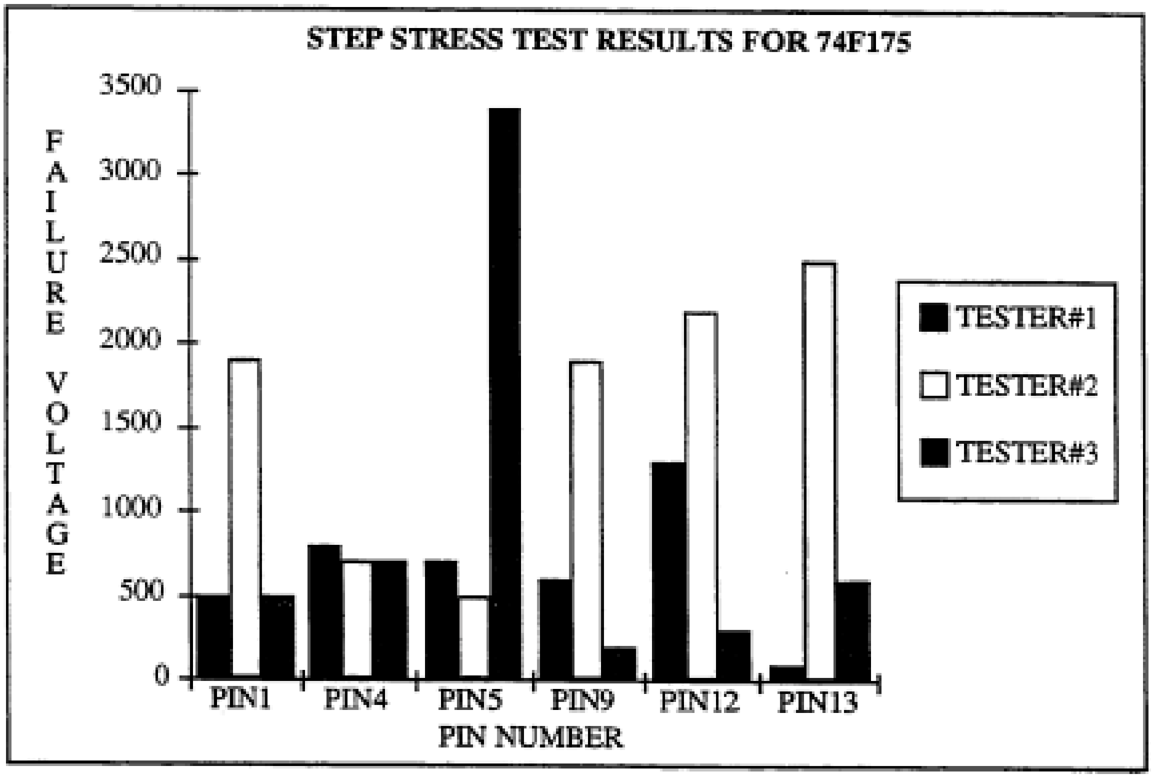

FIGURE 1-5. STEP-STRESS RESULTS FOR 74F175