

INTERNATIONAL STANDARD



**Semiconductor devices – Mechanical and climatic test methods –
Part 28: Electrostatic discharge (ESD) sensitivity testing – Charged device
model (CDM) – device level**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2017 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.



IEC 60749-28

Edition 1.0 2017-03

INTERNATIONAL STANDARD



**Semiconductor devices – Mechanical and climatic test methods –
Part 28: Electrostatic discharge (ESD) sensitivity testing – Charged device
model (CDM) – device level**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.080.01

ISBN 978-2-8322-4139-4

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	8
3 Terms and definitions	8
4 Required equipment	9
4.1 CDM ESD tester	9
4.1.1 General	9
4.1.2 Current-sensing element.....	10
4.1.3 Ground plane.....	10
4.1.4 Field plate/field plate dielectric layer.....	10
4.1.5 Charging resistor	11
4.2 Waveform measurement equipment	11
4.2.1 General	11
4.2.2 Cable assemblies	11
4.2.3 Equipment for high-bandwidth waveform measurement	11
4.2.4 Equipment for 1,0 GHz waveform measurement	11
4.3 Verification modules (metal discs).....	11
4.4 Capacitance meter.....	11
4.5 Ohmmeter.....	12
5 Periodic tester qualification, waveform records, and waveform verification requirements	12
5.1 Overview of required CDM tester evaluations.....	12
5.2 Waveform capture hardware	12
5.3 Waveform capture setup	12
5.4 Waveform capture procedure	12
5.5 CDM tester qualification/requalification procedure	13
5.5.1 CDM tester qualification/requalification procedure	13
5.5.2 Conditions requiring CDM tester qualification/requalification.....	13
5.5.3 1 GHz oscilloscope correlation with high bandwidth oscilloscope	14
5.6 CDM tester quarterly and routine waveform verification procedure	14
5.6.1 Quarterly waveform verification procedure	14
5.6.2 Routine waveform verification procedure	14
5.7 Waveform characteristics	14
5.8 Documentation.....	16
5.9 Procedure for evaluating full CDM tester charging of a device	16
6 CDM ESD testing requirements and procedures	17
6.1 Device handling	17
6.2 Test requirements	17
6.2.1 Test temperature and humidity	17
6.2.2 Device test	17
6.3 Test procedures.....	17
6.4 CDM test recording / reporting guidelines	18
7 CDM classification criteria	18
Annex A (normative) Verification module (metal disc) specifications and cleaning guidelines for verification modules and testers.....	19

A.1	Tester verification modules and field plate dielectric	19
A.2	Care of verification modules.....	19
Annex B (normative)	Capacitance measurement of verification modules (metal discs) sitting on a tester field plate dielectric	20
Annex C (informative)	CDM test hardware and metrology improvements.....	21
Annex D (informative)	CDM tester electrical schematic	23
Annex E (informative)	Sample oscilloscope setup and waveform	24
E.1	General.....	24
E.2	Settings for the 1 GHz bandwidth oscilloscope.....	24
E.3	Settings for the high-bandwidth oscilloscope.....	24
E.4	Setup.....	24
E.5	Sample waveforms from a 1 GHz oscilloscope	24
E.6	Sample waveforms from an 8 GHz oscilloscope	25
Annex F (informative)	Field-induced CDM tester discharge procedures.....	27
F.1	General.....	27
F.2	Single discharge procedure.....	27
F.3	Dual discharge procedure	27
Annex G (informative)	Waveform verification procedures	29
G.1	Factor/offset adjustment method.....	29
G.2	Software voltage adjustment method.....	32
G.3	Example parameter recording tables	34
Annex H (informative)	Determining the appropriate charge delay for full charging of a large module or device.....	36
H.1	General.....	36
H.2	Procedure for charge delay determination.....	36
Annex I (informative)	Electrostatic discharge (ESD) sensitivity testing direct contact charged device model (DC-CDM).....	38
I.1	General.....	38
I.2	Standard test module.....	38
I.3	Test equipment (CDM simulator).....	38
I.3.1	Test equipment design.....	38
I.3.2	DUT (device under test) support	38
I.3.3	Metal bar/board	39
I.3.4	Equipment setup.....	39
I.4	Verification of test equipment.....	39
I.4.1	General description of verification test equipment.....	39
I.4.2	Instruments for measurement	41
I.4.3	Verification of test equipment, using a current probe	41
I.5	Test procedure.....	42
I.5.1	Initial measurement	42
I.5.2	Tests	42
I.5.3	Intermediate and final measurement	43
I.6	Failure criteria.....	43
I.7	Classification criteria.....	43
I.8	Summary	43
Bibliography.....		44
Figure 1 – Simplified CDM tester hardware schematic		10

Figure 2 – CDM characteristic waveform and parameters	16
Figure D.1 – Simplified CDM tester electrical schematic	23
Figure E.1 – 1 GHz TC 500, small verification module	25
Figure E.2 – 1 GHz TC 500, large verification module	25
Figure E.3 – 8 GHz TC 500, small verification module (oscilloscope adjusts for attenuation)	26
Figure E.4 – GHz TC 500, large verification module (oscilloscope adjusts for attenuation)	26
Figure F.1 – Single discharge procedure (field charging, I_{CDM} Pulse, and slow discharge).....	27
Figure F.2 – Dual discharge procedure (field charging, 1st I_{CDM} pulse, no field, 2nd I_{CDM} pulse)	28
Figure G.1 – An example of a waveform verification flow for qualification and quarterly checks using the factor/offset adjustment method	30
Figure G.2 – An example of a waveform verification flow for the routine checks using the factor/offset adjustment method	31
Figure G.3 – Example of average I_{peak} for the large verification module – high bandwidth oscilloscope	32
Figure G.4 – An example of a waveform verification flow for qualification and quarterly checks using the software voltage adjustment method	33
Figure G.5 – An example of a waveform verification flow for the routine checks using the software voltage adjustment method	34
Figure H.1 – An example characterization of charge delay vs. I_p	37
Figure I.1 – Examples of discharge circuit where the discharge is caused by closing the switch	39
Figure I.2 – Verification test equipment for measuring the discharge current flowing to the metal bar/board from the standard test module	40
Figure I.3 – Current waveform.....	40
Figure I.4 – Measurement circuit for verification method using a current probe	41
Table 1 – CDM waveform characteristics for a 1 GHz bandwidth oscilloscope.....	15
Table 2 – CDM waveform characteristics for a high-bandwidth (≥ 6 GHz) oscilloscope.....	15
Table 3 – CDM ESDS device classification levels	18
Table A.1 – Specification for CDM tester verification modules (metal discs).....	19
Table G.1 – Example waveform parameter recording table for the factor/offset adjustment method	35
Table G.2 – Example waveform parameter recording table for the software voltage adjustment method	35
Table I.1 – Dimensions of the standard test modules	38
Table I.2 – Specified current waveform	40
Table I.3 – Range of peak current I_{p1} for test equipment.....	41
Table I.4 – Specification of peak current I_{p1} for the current probe verification method	42

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SEMICONDUCTOR DEVICES –
MECHANICAL AND CLIMATIC TEST METHODS –****Part 28: Electrostatic discharge (ESD) sensitivity testing –
Charged device model (CDM) – device level**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60749-28 has been prepared by IEC technical committee 47: Semiconductor devices in collaboration with IEC technical committee 101: Electrostatics.

This standard is based on ESDA/JEDEC Joint Standard ANSI/ESDA/JEDEC JS-002 which resulted from the merging of JESD22-C101 and ANSI/ESD S5.3.1). It contains the essential elements from both standards. The co-operation of ANSI/ESDA/JEDEC is gratefully acknowledged.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
47/2362/FDIS	47/2379/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60749 series, published under the general title *Semiconductor devices –Mechanical and climatic test methods*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The earliest electrostatic discharge (ESD) test models and standards simulate a charged object approaching a device and discharging through the device. The most common example is IEC 60749-26, the human body model (HBM). However, with the increasing use of automated device handling systems, another potentially destructive discharge mechanism, the charged device model (CDM), becomes increasingly important. In the CDM, a device itself becomes charged (e.g. by sliding on a surface (tribocharging) or by electric field induction) and is rapidly discharged (by an ESD event) as it closely approaches a conductive object. A critical feature of the CDM is the metal-metal discharge, which results in a very rapid transfer of charge through an air breakdown arc. The CDM test method also simulates metal-metal discharges arising from other similar scenarios, such as the discharging of charged metal objects to devices at different potential.

Accurately quantifying and reproducing this fast metal-metal discharge event is very difficult, if not impossible, due to the limitations of the measuring equipment and its influence on the discharge event. The CDM discharge is generally completed in a few nanoseconds, and peak currents of tens of amperes have been observed. The peak current into the device will vary considerably depending on a large number of factors, including package type and parasitics. The typical failure mechanism observed in MOS devices for the CDM model is dielectric damage, although other damage has been noted.

The CDM charge voltage sensitivity of a given device is package dependent. For example, the same integrated circuit (IC) in a small area package can be less susceptible to CDM damage at a given voltage compared to that same IC in a package of the same type with a larger area. It has been shown that CDM damage susceptibility correlates better to peak current levels than charge voltage.

SEMICONDUCTOR DEVICES – MECHANICAL AND CLIMATIC TEST METHODS –

Part 28: Electrostatic discharge (ESD) sensitivity testing – Charged device model (CDM) – device level

1 Scope

This part of IEC 60749 establishes the procedure for testing, evaluating, and classifying devices and microcircuits according to their susceptibility (sensitivity) to damage or degradation by exposure to a defined field-induced charged device model (CDM) electrostatic discharge (ESD). All packaged semiconductor devices, thin film circuits, surface acoustic wave (SAW) devices, opto-electronic devices, hybrid integrated circuits (HICs), and multi-chip modules (MCMs) containing any of these devices are to be evaluated according to this document. To perform the tests, the devices are assembled into a package similar to that expected in the final application. This CDM document does not apply to socketed discharge model testers. This document describes the field-induced (FI) method. An alternative, the direct contact (DC) method, is described in Annex I.

The purpose of this document is to establish a test method that will replicate CDM failures and provide reliable, repeatable CDM ESD test results from tester to tester, regardless of device type. Repeatable data will allow accurate classifications and comparisons of CDM ESD sensitivity levels.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

CDM ESD

charged device model electrostatic discharge

electrostatic discharge (ESD) using the charged device model (CDM) to simulate the actual discharge event that occurs when a charged device is quickly discharged to another object at a lower electrostatic potential through a single pin or terminal

3.2

CDM ESD tester

charged device model electrostatic discharge tester

equipment that simulates the device level CDM ESD event using the non-socketed test method

Note 1 to entry: "Equipment" is referred to as "tester" in this document.