IEC 60749-38

Edition 1.0 2008-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Semiconductor devices – Mechanical and climatic test methods –
Part 38: Soft error test method for semiconductor devices with memory**

**Dispositifs à semiconducteurs – Méthodes d'essais mécaniques et climatiques –
Partie 38: Méthode d'essai des erreurs logicielles pour les dispositifs à semiconducteurs avec mémoire**

IEC 60749-38:2008

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: 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.

- Catalogue of IEC publications: www.iec.ch/searchpub

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 It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

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

- Electropedia: www.electropedia.org

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

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:
Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,…). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:
Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

IEC 60749-38

Edition 1.0 2008-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Semiconductor devices – Mechanical and climatic test methods –
Part 38: Soft error test method for semiconductor devices with memory

Dispositifs à semiconducteurs – Méthodes d'essais mécaniques et climatiques –
Partie 38: Méthode d'essai des erreurs logicielles pour les dispositifs à semiconducteurs avec mémoire

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX **M**

ICS 31.080.01
ISBN 2-8318-9615-0

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES – MECHANICAL AND CLIMATIC TEST METHODS –

Part 38: Soft error test method for semiconductor devices with memory

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 provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.

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 60749-38 has been prepared by IEC technical committee 47: Semiconductor devices.

The text of this standard is based on the following documents:

FDIS	Report on voting
47/1943/FDIS	47/1951/RVD

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

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

A list of all the parts in the IEC 60749 series, 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 publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

SEMICONDUCTOR DEVICES – MECHANICAL AND CLIMATIC TEST METHODS –

Part 38: Soft error test method for semiconductor devices with memory

1 Scope

This part of IEC 60749 establishes a procedure for measuring the soft error susceptibility of semiconductor devices with memory when subjected to energetic particles such as alpha radiation. Two tests are described; an accelerated test using an alpha radiation source and an (unaccelerated) real-time system test where any errors are generated under conditions of naturally occurring radiation which can be alpha or other radiation such as neutron. To completely characterize the soft error capability of an integrated circuit with memory, the device must be tested for broad high energy spectrum and thermal neutrons using additional test methods. This test method may be applied to any type of integrated circuit with memory device.

2 Terms and definitions

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

2.1
single-event upset
SEU
soft error caused by the transient signal induced by a single energetic-particle strike

2.2
soft error
erroneous output signal from a latch or memory cell that can be corrected by performing one or more normal functions of the device containing the latch or memory cell

NOTE As commonly used, the term refers to an error caused by radiation or electromagnetic pulses and not to an error associated with a physical defect introduced during the manufacturing process.

2.3
single-event hard error
SHE
irreversible change in operation resulting from a single radiation event and typically associated with permanent damage to one or more of the device elements (e.g. gate oxide rupture)

2.4
static soft error
soft error that is not corrected by repeated reading but can be corrected by rewriting without the removal of power

2.5
transient soft error
soft error that can be corrected by repeated reading without rewriting and without the removal of power

2.6
soft error, power cycle
PCSE
soft error that is not corrected by repeated reading or writing but can be corrected by the removal of power

2.7
single event functional interrupt
SEFI
soft error that causes the component to reset, lock-up, or otherwise malfunction in a detectable way, but does not require power cycling of the device (off and back on) to restore operability, unlike single-event latch-up (SEL), or result in permanent damage as in single-event burnout (SEB)

2.8
multiple bit upset
MBU
multiple-cell upset in which two or more error bits occur in the same word

2.9
single event latch up
SEL
abnormal high-current state in a device caused by the passage of a single energetic particle through sensitive regions of the device structure and resulting in the loss of device functionality

NOTE 1 SEL may cause permanent damage to the device. If the device is not permanently damaged, power cycling of the device (off and back on) is necessary to restore normal operation.

NOTE 2 An example of SEL in a CMOS device is when the passage of a single particle induces the creation of parasitic bipolar (p-n-p-n) shorting of power to ground.

2.10
flux (of particle radiation)
time rate of flow of particles emitted from or incident on a surface, divided by the area of that surface

NOTE The flux is usually expressed in particles per square centimeter second (N/cm^2s) or particles per square centimeter hour (N/cm^2h).

2.11
alpha source activity
number of alpha particle decays in the alpha source per unit time

NOTE The preferred SI unit is the Becquerel (Bq); to convert from the Curie, multiply by $3,7 \times 10^{10}$ (exactly).

2.12
soft error rate
SER
rate at which soft errors occur

2.13
failures in time
FIT
the number of failures in 10^9 device-hours

2.14
multiple-cell upset
MCU
single event that induces several bits in an IC to have a soft error at one time

NOTE The bits are usually, but not always, adjacent.

3 Test apparatus

3.1 Measurement equipment

The equipment shall be capable of measuring the functions of the integrated circuit devices, and capable of measuring the time taken for the change of stored data by the exposure to energetic particles, such as alpha radiation to take place (i.e. the generation of a soft error). Alternatively, the test equipment (memory tester etc.) shall have the capability of counting the number of soft errors in unit time.

3.2 Alpha radiation source

3.2.1 Background information

Uranium and thorium impurities found in trace amounts in the various production and packaging materials emit alpha particles. Alpha particles are strongly ionizing, so those that impinge on the active device create bursts of free electron-hole pairs in the silicon. Different types of alpha sources can be used to simulate the alpha emission from uranium and thorium impurities. Sources that emit alpha particles with energy spectra similar to uranium and thorium impurities simulate the radiation environment of wirebonded components encapsulated in moulding compound. Sources that emit alpha particles with similar energy spectra to ^{210}Po are used for simulating components in a flip-chip arrangement with solder bumps. The source should provide an alpha particle spectrum similar to that encountered in the actual component.

3.2.2 Preferred sources

^{238}U or ^{232}Th are the preferred sources for inducing SER in mould-resin compounds. ^{241}Am and ^{210}Po sources can be used as substitutes.

3.2.3 Variation in results

Results will differ depending on the source used due to spectral variations. Alpha particle sources available on the market are usually only classified by their activities in μCi (rather than in the preferred unit, Bq, see 2.11) and the emission rates of alpha particle are seldom indicated.

The emission rate cannot be determined simply from the activities because of the effects of absorption of alpha particle in the source itself and its situation. For example, the activity of 1μCi is $3{,}7 \times 10^4$ decays/s. However, the alpha emission rate from the source would be less than $3{,}7 \times 10^4$ alpha/s.

Therefore, a measurement of the alpha emission rate of the source which is used in the SER test is recommended.

As a consequence, the energy spectrum of the alpha radiation source shall be confirmed because different test values can result from differing energy spectra even if the alpha radiation sources have the same level of radioactivity.

NOTE If ^{241}Am or ^{210}Po are used, this should be documented in a report along with the statement that results can differ if other sources have been used, due to energy spectra variations.

3.2.4 Effect of high radiation levels

In cases where the dose concentration delivered to the test sample is high, consideration shall be given to the effect of multiple hits.

3.2.5 Measurement accuracy

If the emission area of the alpha radiation is significantly smaller than the chip area, absorption of the alpha radiation through the atmosphere and the chip protection film and incident angle effects will contribute to give erroneous values. Therefore, to perform the test accurately, the emission area of the alpha radiation shall not be significantly smaller than the chip area and, preferably, shall be larger. In Figure 1, the curves apply for devices of about 10 mm diameter. Dimension "*d*" should be scaled up or down in proportion for devices with a different diameter (for more information, see Bibliography).

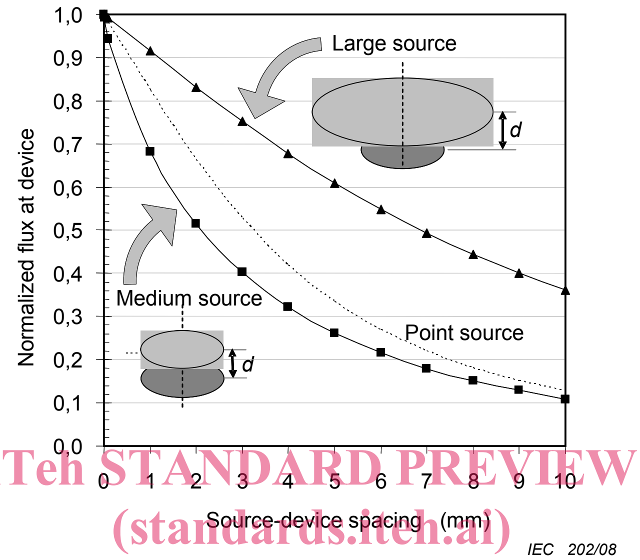

Figure 1 – Effect of source-device spacing on normalized flux at device

3.3 Test sample

Any type of integrated circuits with memory may be tested. The device parameters (capacitance of the memory cell in the DRAM etc.) which can affect the soft error rate shall be well understood.

4 Procedure

4.1 Alpha radiation accelerated soft error test

4.1.1 Surface preparation

The surface of the sample shall be suitably prepared before irradiation. For accelerated alpha particle testing, the surface of the sample shall be exposed using a method which does not affect the electrical characteristics. When, however, the purpose of the test is to evaluate the effect of chip coating, the chip coating shall not be removed.

NOTE As an example, the upper side of the package can be cut with a small knife or the moulding resin on the upper surface of the chip can be dissolved chemically etc. Unless otherwise specified, chip coatings should be removed because alpha radiation from an ^{241}Am source (peak energy 5 MeV approximately) is absorbed by the chip coating. Alpha radiation of higher energy can occur in the package materials or as natural radio-activity.

4.1.2 Power supply voltage

This shall be set at the minimum voltage of the recommended operating condition (when required, the supply voltage dependence on failure rate shall be measured). For latch up testing, the voltage shall be set at the minimum and maximum voltage of the recommended operating condition.

4.1.3 Ambient temperature

The ambient temperature shall be room temperature and, for latch up, at the manufacturer's maximum recommended operating temperature.

4.1.4 Core cycle time

The core cycle time is dependent on the samples under test and shall be set to the manufacturer's recommended value (when required, the core cycle time dependence shall be measured).

4.1.5 Data pattern

This is dependent on the samples under test. Data pattern shall be reported (a checker board, all '0/1'-read/write pattern, etc.).

4.1.6 Distance between chip and radiation source

The actual value used shall be documented in the report.

NOTE The distance between the chip and radiation source should be 1 mm or less. Excessive distance between the source and the chip will cause attenuation of the alpha flux, unless the test is performed in a vacuum. Operators should be careful to avoid touching the chip or wirebonds with the radiation source.

4.1.7 Number of measurement samples

Multiple samples shall be measured to take into account measurement variation.

4.2 Real-time soft error test

4.2.1 General

In this method, the samples are mounted on memory boards of a system machine which has a similar function to that of the test equipment. The soft errors are generated under similar conditions to those of the actual use environment, without the use of an external alpha source to provide error rate acceleration. The radiation is that which occurs naturally, consisting of alpha, neutron and other energetic particles.

4.2.2 Power supply voltage

Power supply voltage shall be set at nominal voltage so that the reported SER will be related to in-use conditions, unless otherwise specified.

4.2.3 Ambient temperature

The ambient temperature shall be from room temperature to the maximum temperature of recommended operating condition. The ambient temperature shall be reported.

4.2.4 Operating frequency

The operating frequency is dependent upon the samples used but the evaluation is recommended to be performed at the intended operating core frequency and it shall be reported. No frequency or voltage accelerations are permitted.

4.2.5 Data pattern

This is dependent on the samples under test. Data pattern shall be reported. Dependent upon the detail specification, all or some of the following data patterns shall be used with equal duration: all 1, checkerboard pattern, the complementary checkerboard pattern and all zeros. In cases where dynamic patterns are used to consider mechanisms that can not be identified with static patterns, the duty cycle shall be reported. As a special case, in the data retention test for SRAM etc., a data pattern of all '1' is written in the test samples initially. The test samples are left in the battery back-up mode and the evaluation by reading out is performed at predetermined intervals.

4.2.6 Test time

Test time shall be related to system SER requirements and shall be detailed in the relevant specification.

NOTE A test time of 1 000 h may be used.

4.2.7 Number of test samples

Sample size shall be related to system SER requirements.

NOTE A sample size of 1 000 test pieces may be used.

4.2.8 Environmental neutron testing

Neutron flux depends on the location. Therefore, the evaluation shall take into account the environment as follows:

Altitude

Region/Latitude

Room/Outdoor

The altitude and location of the test shall be reported.

Where the evaluation takes place in a building, the structure, floor, thickness and material of building shall be reported.

4.3 Neutron radiation accelerated soft error test

Where this test is required, three methods of neutron accelerated soft error test are available. These are the thermal neutron-induced soft error test, the (quasi)-mono energy test and the white neutron test, all as nuclear spallation reactions. The neutrons are generated by a nuclear reactor or accelerator. One or more methods shall be selected to satisfy the requirement. For neutron radiation accelerated soft error testing, the facilities where the test can be performed are restricted. Refer to the bibliography for the detail of the methods and facility information.

NOTE White neutron test is a radiation test using a neutron simulator that has a flux-versus energy spectrum similar to that of the naturally occurring atmospheric neutron radiation from sea level to 60 000 feet (18 290 m) altitude.

5 Evaluation

5.1 Alpha radiation accelerated soft error test

The soft error rate (SER) is calculated by the following equation.