IEC 60749-18

Edition 2.0 2019-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Semiconductor devices – Mechanical and climatic test methods –
Part 18: Ionizing radiation (total dose)

Dispositifs à semiconducteurs – Méthodes d'essais mécaniques et climatiques –
Partie 18: Rayonnements ionisants (dose totale)

IEC 60749-18:2019-04(en-fr)

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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.
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International Standard IEC 60749-18 has been prepared by IEC technical committee 47: Semiconductor devices.

This second edition cancels and replaces the first edition published in 2002. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) updates to subclauses to better align the test method with MIL-STD 883J, method 1019, including the use of enhanced low dose rate sensitivity (ELDRS) testing;
b) addition of a Bibliography, which includes ASTM standards relevant to this test method.

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

FDIS	Report on voting
47/2539/FDIS	47/2554/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.

SEMICONDUCTOR DEVICES – MECHANICAL AND CLIMATIC TEST METHODS –

Part 18: Ionizing radiation (total dose)

1 Scope

This part of IEC 60749 provides a test procedure for defining requirements for testing packaged semiconductor integrated circuits and discrete semiconductor devices for ionizing radiation (total dose) effects from a cobalt-60 (^{60}Co) gamma ray source. Other suitable radiation sources can be used.

There are four tests presented in this procedure:

a) a standard room temperature irradiation test;

b) an irradiation at elevated temperature/cryogenic temperature test;

c) an accelerated annealing test;

d) an enhanced low dose rate sensitivity (ELDRS) test.

The accelerated annealing test estimates how dose rate ionizing radiation effects on devices is important for low dose rate or certain other applications in which devices can exhibit significant time-dependent effects. The ELDRS test determines if devices with bipolar linear components exhibit sensitivity to enhanced radiation-induced damage at low dose rates.

This document addresses only steady-state irradiations, and is not applicable to pulse type irradiations.

It is intended for military- and aerospace-related applications.

This document can produce severe degradation of the electrical properties of irradiated devices and thus is considered a destructive test.

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
ionizing radiation effects, pl
changes in the electrical parameters of a device or integrated circuit resulting from radiation-induced charge

Note 1 to entry: These are also referred to as total dose effects.

3.2
in-flux test
electrical measurements made on devices during irradiation exposure

3.3
internal dose pattern
logic condition of all elements within a logic circuit during radiation exposure

3.4
non in-flux test
electrical measurements made on devices at any time other than during irradiation

3.5
remote test
electrical measurements made on devices that are physically removed from the radiation location

3.6
time-dependent effect
TDE
significant degradation in electrical parameters caused by the growth or annealing, or both, of radiation-induced trapped charge after irradiation

Note 1 to entry: Similar effects also take place during irradiation.

Note 2 to entry: This note applies to the French language only.

3.7
accelerated annealing test
procedure utilizing elevated temperature to accelerate time-dependent effects

3.8
enhanced low dose rate sensitivity
ELDRS
part that shows enhanced radiation-induced damage at dose rates below 0,5 Gy(Si)/s

Note 1 to entry: This note applies to the French language only.

3.9
overtest
factor that is applied to the specification dose to determine the test dose level that the samples have to pass to be acceptable at the specification level

Note 1 to entry: An overtest factor of 1,5 means that the parts should be tested at 1,5 times the specification dose.

3.10
parameter delta design margin
PDDM
design margin that is applied to the radiation-induced change in an electrical parameter

Note 1 to entry: For a PDDM of 2 the change in a parameter at a specified dose from the pre-irradiation value is multiplied by two and added to the pre-irradiation value to see if the sample exceeds the post-irradiation parameter limit. For example, if the pre-irradiation value of base current I_b is 30 nA and the post-irradiation value at 200 Gy(Si) is 70 nA (change in I_b is 40 nA), then for a PDDM of 2 the post-irradiation value would be 110 nA (30 nA + 2 x 40 nA). If the allowable post-irradiation limit is 100 nA, the part would fail.

4 Test apparatus

4.1 Choice of apparatus

The apparatus shall consist of the radiation source, electrical test instrumentation, test circuit board(s), cabling, interconnect board or switching system, an appropriate dosimetry measurement system, and an environmental chamber (if required for time-dependent effects measurements). Adequate precautions shall be observed to obtain an electrical measurement system with sufficient insulation, ample shielding, satisfactory grounding, and suitable low noise characteristics.

4.2 Radiation source

The radiation source used in the test shall be the uniform field of a ^{60}Co gamma ray source. Uniformity of the radiation field in the volume where devices are irradiated shall be within ±10 % as measured by the dosimetry system, unless otherwise specified. The intensity of the gamma ray field of the ^{60}Co source shall be known with an uncertainty of no more than ±5 %. Field uniformity and intensity can be affected by changes in the location of the device with respect to the radiation source and the presence of radiation absorption and scattering materials.

4.3 Dosimetry system

An appropriate dosimetry system shall be provided that is capable of carrying out the measurements called for in 5.3 (see Bibliography).

4.4 Electrical test instruments

All instrumentation used for electrical measurements shall have the stability, accuracy, and resolution required for accurate measurement of the electrical parameters. Any instrumentation required to operate in a radiation environment shall be appropriately shielded.

4.5 Test circuit board(s)

Devices to be irradiated shall either be mounted on or connected to circuit boards together with any associated circuitry necessary for device biasing during irradiation or for in situ measurements. Unless otherwise specified, all device input terminals and any others which can affect the radiation response shall be electrically connected during irradiation, i.e. not left floating.

The geometry and materials of the completed board shall allow uniform irradiation of the devices under test. Good design and construction practices shall be used to prevent oscillations, minimize leakage currents, prevent electrical damage and obtain accurate measurements. Only sockets that are radiation resistant and do not exhibit significant leakages (relative to the devices under test) shall be used to mount devices and associated circuitry to the test board(s).

All apparatus used repeatedly in radiation fields shall be checked periodically for physical or electrical degradation. Components which are placed on the test circuit board, other than devices under test, shall be insensitive to the accumulated radiation or they shall be shielded from the radiation. Test fixtures shall be made such that materials will not perturb the uniformity of the radiation field intensity on the devices under test.

Leakage current shall be measured outside the field of radiation. With no devices installed in the sockets, the test circuit board shall be connected to the test system such that all expected sources of noise and interference are operative. With the maximum specified bias for the test device applied, the leakage current between any two terminals shall not exceed 10 % of the lowest current limit value in the pre-irradiation device specification.

Test circuit boards used to bias devices during accelerated annealing shall be capable of withstanding the temperature requirements of the accelerated annealing test and shall be checked before and after testing for physical and electrical degradation.

4.6 Cabling

Cables connecting the test circuit boards in the radiation field to the test instrumentation shall be as short as possible. If long cables are necessary, line drivers can be required. The cables shall have low capacitance and low leakage to ground, and low leakage between wires.

4.7 Interconnect or switching system

This system shall be located outside the radiation environment location, and provides the interface between the test instrumentation and the devices under test. It is part of the entire test system and subject to the limitation specified in 4.5 for leakage between terminals.

4.8 Environmental chamber

The environmental chamber for time-dependent effects testing, if required, shall be capable of maintaining the selected accelerated annealing temperature within ±5 °C.

4.9 Irradiation temperature chamber

The irradiation temperature chamber, if required for elevated temperature irradiation should be capable of maintaining a circuit under test at 100 °C ± 5 °C while it is being irradiated. The chamber should be capable of raising the temperature of the circuit under test from room temperature to the irradiation temperature within a reasonable time prior to irradiation and cooling the circuit under test from the irradiation temperature to room temperature in less than 20 min following irradiation. The irradiation bias shall be maintained during the heating and cooling. The method for raising, maintaining and lowering the temperature of the circuit under test can be by conduction through a heat sink using heating and cooling fluids, by convection using forced hot and cool air, or other means that will achieve the proper results. For cryogenic temperature irradiations, the chamber should be capable of maintaining the test device/unit at the required cryogenic temperature within ±5 °C (e.g., liquid helium or liquid nitrogen) while it is being irradiated. The chamber should be capable of maintaining the cryogenic temperature of the test device/unit during post-irradiation electrical testing.

5 Procedure

5.1 Test plan

The test devices shall be irradiated and subjected to accelerated annealing testing (if required for time-dependent effects testing) as specified by a test plan. This plan shall specify the device description, irradiation conditions, device bias conditions, dosimetry system, operating conditions, measurement parameters and conditions and accelerated annealing test conditions (if required).

5.2 Sample selection and handling

Only devices that have passed the electrical specifications as defined in the test plan shall be submitted to radiation testing. Unless otherwise specified, the test samples shall be randomly selected from the parent population and identically packaged. Each part shall be individually identifiable to enable pre- and post-irradiation comparison. For device types that are electrostatic discharge (ESD)-sensitive, proper handling techniques shall be used to prevent damage to the devices.

5.3 Burn-in

For some devices, there are differences in the total dose radiation response before and after burn-in. Unless it has been shown by prior characterization or by design that burn-in has a negligible effect (parameters remain within post-irradiation specified electrical limits) on the total dose radiation response, then one of the following functions shall take place:

a) the manufacturer shall subject the radiation samples to the specified burn-in conditions prior to conducting total dose radiation testing; or

b) the manufacturer shall develop a correction factor, (which is acceptable to the parties to the test) taking into account the changes in total dose response resulting from subjecting the product to burn-in. The correction factor shall then be used to accept the product for total dose response without subjecting the test samples to burn-in.

5.4 Dosimetry measurements

The radiation field intensity at the location of the device under test shall be determined prior to testing by dosimetry or by source decay correction calculations, as appropriate, to ensure conformance to the test level and uniformity requirements.

The dose applied to the device under test shall be determined in one of two ways:

a) by measurement during the irradiation with an appropriate dosimeter; or

b) by correcting a previous dosimetry value for the decay of the ^{60}Co source intensity in the intervening time. Appropriate correction shall be made to convert from the measured or calculated dose in the dosimeter material to the dose in the device under test.

5.5 Lead/aluminium (Pb/Al) container

Test specimens shall be enclosed in a Pb/Al container to minimize dose enhancement effects caused by low-energy scattered radiation. A minimum of 1,5 mm of lead (Pb), surrounding an inner shield of at least 0,7 mm aluminium (Al) is required. This Pb/Al container produces an approximate charged particle equilibrium for Si and for thermoluminescence dosimetries (TLDs) such as CaF2. The radiation field intensity shall be measured inside the Pb/Al container (1) initially, (2) when the source is changed, or (3) when the orientation or configuration of the source, container or test-fixture is changed. This measurement shall be performed by placing a dosimeter (e.g. a TLD) in the device-irradiation container at the approximate test-device position. If it can be demonstrated that low energy scattered radiation is small enough that it will not cause dosimetry errors due to dose enhancement, the Pb/Al container may be omitted.

5.6 Radiation level(s)

The test devices shall be irradiated to the dose level(s) specified in the test plan within ±10 %. If multiple irradiations are required for a set of test devices, then the post-irradiation electrical parameter measurements shall be performed after each irradiation.

5.7 Radiation dose rate

5.7.1 Radiation dose rate determination

The radiation dose rate for bipolar and BiCMOS linear or mixed-signal parts used in applications where the maximum dose rate is below 0,5 Gy(Si)/s shall be determined as described in 5.14. Parts used in low dose rate applications, unless they have been demonstrated to not exhibit an ELDRS response shall use condition C, condition D, or condition E.

A flow diagram for ionizing test procedures for MOS and digital bipolar devices is shown in Figure 1. A flow diagram for ionizing radiation test procedure for bipolar (or BiCMOS) linear or mixed-signal devices is shown in Figure 2.

NOTE Devices that contain both MOS and bipolar devices can require qualification to multiple subconditions to ensure that both ELDRS and traditional MOS effects are evaluated.

5.7.2 Condition A

For condition A (standard condition), the dose rate shall be between 0,5 Gy(Si)/s and 3 Gy(Si)/s for integrated circuits and between 0,5 Gy(Si)/s and 20 Gy(Si)/s for discrete semi-conductor devices. The dose rates may be different for each radiation dose level in a series; however, the dose rate shall not vary by more than ±10 % during each irradiation.

5.7.3 Condition B

For condition B, for MOS devices only, if the maximum dose rate is less than 0,5 Gy(Si)/s in the intended application, the parties to the test can agree to perform the test at a dose rate greater than or equal to the maximum dose rate of the intended application. Unless the exclusions in 5.13.2 b) are met, the accelerated annealing test of 5.13.3 shall be performed.

5.7.4 Condition C

For condition C, (as an alternative) the test may be performed at the dose rate of the intended application if this is agreed to by the parties to the test. Where the final user is not known, the test conditions and results shall be made available in the test report with each purchase order.

5.7.5 Condition D

For condition D, for bipolar or BiCMOS linear or mixed-signal devices only, the parts shall be irradiated at less than or equal to 0,1 mGy(Si)/s.

5.7.6 Condition E

For condition E, for bipolar or BiCMOS linear or mixed-signal devices only, the parts shall be irradiated with the accelerated test conditions determined by characterization testing as discussed in 5.14.3. The accelerated test may include irradiation at an elevated temperature.

5.8 Temperature requirements

5.8.1 Room temperature radiation

Since radiation effects are temperature dependent, devices under test shall be irradiated in an ambient temperature of 24 °C ± 6 °C as measured at a point in the test chamber in close proximity to the test fixture. The electrical measurements shall be performed in an ambient temperature of 24 °C ± 6 °C. If devices are transported to and from a remote electrical measurement site, the temperature of the test devices shall not be allowed to increase by more than 10 °C from the irradiation environment. If any other temperature range is required, it shall be specified.

Caution: Annealing at ambient temperatures above the irradiation temperature can be significant, especially for the extended times allowed for the time between irradiations at low dose rate (condition D). It is important to ensure that the temperature of the parts is maintained within the above stated requirements to minimize annealing.

5.8.2 Elevated temperature irradiation

For bipolar or BiCMOS linear or mixed-signal devices irradiated using the condition E elevated temperature irradiation test, devices under test shall be irradiated in an ambient temperature determined by characterization testing (see 5.14.3) as measured at a point in the test chamber in close proximity to the test fixture (see 4.8 for details on raising and lowering the irradiation temperature).