IEC 62435-2

Edition 1.0 2017-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Electronic components – Long-term storage of electronic semiconductor devices –
Part 2: Deterioration mechanisms

Composants électroniques – Stockage de longue durée des dispositifs électroniques à semiconducteurs –
Partie 2: Mécanismes de détérioration

IEC 62435-2:2017-01(en-fr)

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ELECTRONIC COMPONENTS – LONG-TERM STORAGE OF ELECTRONIC SEMICONDUCTOR DEVICES –

Part 2: Deterioration mechanisms

FOREWORD

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

FDIS	Report on voting
47/2327/FDIS	47/2350/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 62435 series, published under the general title *Electronic components – Long-term storage of electronic semiconductor devices*, 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- withdrawn,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.

INTRODUCTION

This document applies to the long-term storage of electronic components.

This is a document for long-term storage (LTS) of electronic devices drawing on the best long-term storage practices currently known. For the purposes of this document, LTS is defined as any device storage whose duration can be more than 12 months for product scheduled for long duration storage. While intended to address the storage of unpackaged semiconductors and packaged electronic devices, nothing in this standard precludes the storage of other items under the storage levels defined herein.

Although it has always existed to some extent, obsolescence of electronic components and particularly of integrated circuits, has become increasingly intense over the last few years.

Indeed, with the existing technological boom, the commercial life of a component has become very short compared with the life of industrial equipment such as that encountered in the aeronautical field, the railway industry or the energy sector.

The many solutions enabling obsolescence to be resolved are now identified. However, selecting one of these solutions should be preceded by a case-by-case technical and economic feasibility study, depending on whether storage is envisaged for field service or production, for example:

- remedial storage as soon as components are no longer marketed;
- preventive storage anticipating declaration of obsolescence.

Taking into account the expected life of some installations, sometimes covering several decades, the qualification times, and the unavailability costs, which can also be very high, the solution to be adopted to resolve obsolescence should often be rapidly implemented. This is why the solution retained in most cases consists in systematically storing components which are in the process of becoming obsolescent.

The technical risks of this solution are, a priori, fairly low. However, it requires perfect mastery of the implemented process and especially of the storage environment, although this mastery becomes critical when it comes to long-term storage.

All handling, protection, storage and test operations are recommended to be performed according to the state of the art.

The application of the approach proposed in this standard in no way guarantees that the stored components are in perfect operating condition at the end of this storage. It only comprises a means of minimizing potential and probable degradation factors.

Some electronic device users have the need to store electronic devices for long periods of time. Lifetime buys are commonly made to support production runs of assemblies that well exceed the production timeframe of its individual parts. This puts the user in a situation requiring careful and adequate storage of such parts to maintain the as-received solderability and minimize any degradation effects to the part over time. Major degradation concerns are moisture, electrostatic fields, ultra-violet light, large variations in temperature, air-borne contaminants, and outgassing.

Warranties and sparing also present a challenge for the user or repair agency as some systems have been designated to be used for long periods of time, in some cases for up to 40 years or more. Some of the devices needed for repair of these systems will not be available from the original supplier for the lifetime of the system or the spare assembly may be built with the original production run but then require long-term storage. This document was developed to provide a standard for storing electronic devices for long periods of time.

For storage of devices that are moisture sensitive but that do not need to be stored for long periods of time, refer to IEC TR 62258-3.

Long-term storage assumes that the device is going to be placed in uninterrupted storage for a number of years. It is essential that it is useable after storage. Particular attention should be paid to storage media surrounding the devices together with the local environment.

These guidelines do not imply any warranty of product or guarantee of operation beyond the storage time given by the manufacturer.

The IEC 62435 series is intended to ensure that adequate reliability is achieved for devices in user applications after long-term storage. Users are encouraged to request data from suppliers to these specifications to demonstrate a successful storage life as requested by the user. These standards are not intended to address built-in failure mechanisms that would take place regardless of storage conditions

These standards are intended to give practical guide to methods of long-duration storage of electronic components where this is intentional or planned storage of product for a number of years. Storage regimes for work-in-progress production are managed according to company internal process requirements and are not detailed in this series of standards.

The overall standard includes a number of parts. Parts 1 to 4 apply to any long-term storage and contain general requirements and guidance, whereas Parts 5 to 9 are specific to the type of product being stored. It is intended that the product specific part should be read alongside the general requirements of Parts 1 to 4.

Electronic components requiring different storage conditions are covered separately starting with Part 5.

The structure of the IEC 62435 series as currently conceived is as follows:

Part 1 – General

Part 2 – Deterioration mechanisms

Part 3 – Data

Part 4 – Storage

Part 5 – Die and wafer devices

Part 6 – Packaged or finished devices

Part 7 – MEMS

Part 8 – Passive electronic devices

Part 9 – Special cases

ELECTRONIC COMPONENTS – LONG-TERM STORAGE OF ELECTRONIC SEMICONDUCTOR DEVICES –

Part 2: Deterioration mechanisms

1 Scope

This part of IEC 62435 is related to deterioration mechanisms and is concerned with the way that components degrade over time depending on the storage conditions applied. This part also includes guidance on test methods that may be used to assess generic deterioration mechanisms. Typically, this part is used in conjunction with IEC 62435-1 for any device long-term storage whose duration may be more than 12 months for product scheduled for long duration storage. Mechanisms that apply to specific component types are detailed in IEC 62435-5 to IEC 62435-9 (proposed)[1].

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60749-20-1, *Semiconductor devices – Mechanical and climatic test methods – Part 20-1: Handling, packing, labelling and shipping of surface-mount devices sensitive to the combined effect of moisture and soldering heat*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms, definitions and abbreviated terms 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 Terms and definitions

3.1.1
storage environment
specially controlled storage area, with particular control of temperature, humidity, atmosphere and any other conditions depending on the product requirements

3.1.2
long-term storage
LTS
planned storage of components to extend the life-cycle for a duration with the intention of supporting future use

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[1] Under preparation.

3.1.3

MBB

moisture barrier bag

storage bag manufactured with a flexible laminated vapour barrier film that restricts the transmission of water vapour

Note 1 to entry: Refer to IEC 60749-20-1 for packaging of moisture sensitive products.

3.2 Abbreviated terms

BGA	ball grid array
ES	electro-static
ESD	electro-static discharge
MSD	moisture sensitive device
PWB	printed wiring board
rH	relative humidity

4 Principles of deterioration

4.1 General

In determining the deterioration mechanisms for products stored under LTS, it is important to consider not only the deterioration of the product itself (see Annex A) but also any deterioration mechanism that can affect the subsequent processing and use of the product.

4.2 Solderability and oxidisation of lead finishes

Device surfaces that will be soldered to another surface using reflow and/or wave soldering operations should join successfully. Solderability determines whether the surfaces intended to be joined metallurgically can perform as expected. Failure to form a complete metallurgical joint can result in conditions known as non-wets or de-wets; oxides typically contribute to solderability degradation. LTS factors that can impact the ability for a part to form a good metallurgical joint include humidity, oxygen exposure, cleanliness, foreign material, and contamination.

4.3 Popcorning

Moisture content within a material when heated rapidly results in expansion of the moisture in form of vapour. This vapour occupies greater space than the moisture from which it was derived. If this vapour is not allowed to dissipate, then the materials within which it is contained will increase in size and exceed the strength or ability of the material to contain the vapour. Subsequently an electronic device that was manufactured correctly (i.e., all materials were properly adhered) may then develop a loss of adhesion. This may lead to interface delamination, package blistering, cracking, and bubbling.

4.4 Delamination

Delamination can occur when moisture accumulates in the materials, voids or at the interface between layers. Subsequent exposure to cycling or thermal processing can cause a separation of materials. Dies with organic passivation, organic substrates, polymer encapsulants, and PWBs tend to absorb moisture which could subsequently outgas during high-temperature processing. The primary failure mode is interfacial disbanding and cohesive separation.

4.5 Corrosion and tarnishing

Corrosion is a chemical reaction that results in the oxidation and/or structural decomposition of metals. Metal migration is also a form of corrosion. Moisture, chemical attack and contamination enhances corrosion mechanisms; contaminants (including fluorine and chlorine) may be hydrated with atmospheric moisture or pollutants during shipment, handling and ambient storage and act as corrosion catalyst. Eliminating the moisture is key to inhibiting corrosion. Corrosion can lead to opens, shorts, dendrites, and discoloration.

Tarnishing of some metal finishes can lead to solderability issues, notably the tarnishing of silver and silver alloys predominantly caused by chemical reaction to oxygen and/or sulphur.

4.6 Electrical effects

Conductive or electro-static (ES) dissipative materials should be used when required for ESD protection. ESD may be caused by using inappropriate packing materials, too low relative humidity (rH), or proximity to ES field sources. This may lead to p-n junction damage, oxide breakdown/puncturing, or other sensitive parameter effects.

4.7 High-energy ionizing radiation damage

Where the product is known to be susceptible to damage caused by ionizing radiation (e.g., as from x-rays or other high energy radiation sources), exposure to such radiation shall be qualified and quantified to understand the potential damage. Some die types can be particularly sensitive to damage and parameter drift caused by radiation. Care should be taken to ensure protection from ionizing radiation sources for those products that are sensitive.

4.8 Storage temperature risks to semiconductor devices

Exposure to heat over time can accelerate some semiconductor failure mechanisms, including stress voiding in metallization and data loss in some non-volatile memory cell types that have been written to a desired state prior to storage. Refer to JEP-122 for further details on such mechanisms..

4.9 Noble metal finishes

No failure mechanisms have been identified that would compromise the reliability of plastic encapsulated solid state devices with lead finishes containing Au or Pd owing to storage. The best practise for long-duration storage is associated with a warehouse environment as described in IEC 60721-3-1 and as required by IEC 60749-20-1.

4.10 Matte tin and other finishes

Assuming proper MSD protection for the term of storage, lead finishes not containing Au or Pd may require tests such as solderability on aged units to confirm long-term storage integrity.

Consideration should be given to the likelihood of the creation of tin whiskers and oxide degradation that gives rise to solderability issues. Refer to lead finish guidelines in IEC 60749-21.

4.11 Solder ball and solder bump

Assuming proper MSD protection for the term of storage and that the solder balls or bumps are fully reflowed, no failure mechanisms have been identified that compromise the reliability of solder balled or bumped BGA packages stored for extended periods of time in a warehouse environment per IEC TR 62258-3. However, if the solder balls or bumps are not reflowed but are attached with an adhesive or a solder paste that has a lower melting point, the solder balls or bumps shall be examined for oxide growth that could affect adhesion or solderability. Surface analysis of the balls/bumps and solderability testing on aged units can be required to confirm acceptance for attach of the next level of assembly after long-term storage.

4.12 Devices containing programmable memory – flash, programmable logic and other devices containing non-volatile memory cells

Devices that contain memory cells may contain certain locations that are factory programmed. These may be used to contain identification information and code that the device uses during normal component use or user programming. It is important to check that these types of components will not lose essential data during storage which can render the component non-functional after storage. The original component manufacturer may recommend special storage conditions, such as temperature maxima and minima to ensure that this data is not corrupted.

Subject to original component manufacturers' recommendations, it is recommended that such devices are stored in the un-programmed state. However, care should be taken to ensure that equipment to programme the devices will also be available when the components are taken out of storage. This may require storage of special programming equipment.

Where programmable devices are stored in the programmed state, then removal from storage should also include a test to check that the programming is not corrupted.

5 Technical validation of the components

5.1 Purpose

The purpose of the technical validation of the components with a view to their storage is to detect *a priori* the batches which do not offer proper reliability and life-time guarantees.

In designing the tests, consideration should be given to the application mission profile and the storage mission profile.

5.2 Test selection criteria

The first thing to be taken into account to select the tests to be implemented for storing components is to have these components previously qualified, depending on the profile of their expected mission.

In addition, in the case of multiple-source components, the selection of the sources shall have been validated by a method capable of evidencing "false" second sources.

The selection of the required tests and measurements will depend on the storage strategy adopted. It can cover a range from a minimal utilization with no tests to a maximal utilization, where all tests described in Table 1 would be performed.

As a whole, the technical validation of the components requires the following items to be checked:

a) compliance with the visual inspection criteria;
b) solderability checking;
c) sealing/hermeticity checking (for components with hermetic packages);
d) compliance with the electrical specifications in the temperature range;
e) checking of manufacturing control (technological analysis);
f) checking the supplied batch reliability.

The criteria for sanctions and the number of tested components may vary depending on the requirements and level of reliability, as well as the data collected from the original component manufacturer. At the end of the technical validation, a status is established for this batch in order to decide on its storage capability.

5.3 Measurements and tests

5.3.1 Assessment of the supplied batch reliability

All failures affecting electronic components initiate originally from a mechanism of a mechanical, chemical, electrical type, or a combination of the three types.

Any failure mechanism, as soon as the process has started, can be accelerated by a constraint adapted to the nature of the failure:

- temperature for chemical corrosion;
- temperature associated to a potential difference for an electrolytic migration.

The component environment varies depending on the application.

It is important to be able to estimate the impact of the constraints on the failure mechanisms in order to determine any possible induced acceleration (for example, humidity).

Depending on the defects and efficiency expected, and according to the technical means available as well as the affordable costs, various test methods may be used.

5.3.2 List of test methods

Table 1 describes the main test methods, the nature of the defects, the relative cost and their efficiency, as well as the test conditions and average times.

Table 1 – List of tests

Operation	Defects concerned	Efficiency	Relative cost	Criteria/ duration	Remarks
Rapid temperature variations (RTV)	– Packaging – Sealing – Electrical connections – Chip crack – Differential expansion	Good	Very low	Min. T = −55 °C Max. T = +125 °C N = 500 to 1 000 cycles 30 min/30 min	One of the most efficient for chips mounted with aluminium connecting wires and power components (diodes, transistors, etc.)
High-temperature storage power off	– Jitter – Bonding – Corrosion – Substrate	Good	Very low	125 °C or 150 °C depending on the component 1 000 h or 2 000 h	Good method
High-temperature storage with static operation	– Bonding – Substrate – Oxide films – Inversion layer – Design – Contamination	Good	High	125 °C or 150 °C depending on the component 1 000 h or 2 000 h	Efficient method, especially for MOS technology
High-temperature storage with dynamic operation	– Bonding – Substrate – Oxide films – Inversion layer – Design – Contamination	Very good	High	Generally 125 °C or as per T_j 1 000 h or 2 000 h	Very efficient method
High-temperature storage with reverse bias	– Inversion layer – Contamination	Good	High	125 °C or 150 °C 1 000 h or 2 000 h	Efficient for discrete components