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Process management for avionics – Use of semiconductor devices outside manufacturers' specified temperature range

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROCESS MANAGEMENT FOR AVIONICS – USE OF SEMICONDUCTOR DEVICES OUTSIDE MANUFACTURERS' SPECIFIED TEMPERATURE RANGE

FOREWORD

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IEC 62240, which is a technical report, has been prepared by IEC Technical Committee 107: Process management for avionics.

This Technical Report cancels and replaces IEC/PAS 62240 published in 2001. This first edition constitutes a technical revision.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
107/33/DTR	107/36/RVC

Full information on the voting for the approval of this technical report 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.

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- withdrawn;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.

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

INTRODUCTION

Traditionally, industries that produce electronic equipment for rugged applications have relied on the military specification system for semiconductor device standards; and upon manufacturers of military-specified devices as device sources. This assured the availability of semiconductor devices specified to operate over the temperature ranges required for electronic equipment in rugged applications. Many device manufacturers have exited the military market in recent years, resulting in decreased availability of devices specified to operate over wide temperature ranges. Following are some typical ambient temperature ranges at which devices are marketed:

Military:	–55 °C to +125 °C
Automotive:	–40 °C to +125 °C
Industrial:	–40 °C to +85 °C
Commercial:	0 °C to +70 °C

If there are no reasonable or practical alternatives, then a potential response is for equipment manufacturers to use devices in temperature ranges that are wider than those specified by the device manufacturer. This practice, properly documented and controlled, is used by electronic equipment manufacturers to meet the design goals of their equipment.

This technical report gives practices and procedures to select semiconductor devices; to assess their capability to operate; and to assure their intended quality in the wider temperature ranges. It also reports the documentation of such usage.

PROCESS MANAGEMENT FOR AVIONICS – USE OF SEMICONDUCTOR DEVICES OUTSIDE MANUFACTURERS' SPECIFIED TEMPERATURE RANGE

1 Scope

This technical report reports processes that exist for using semiconductor devices in wider temperature ranges than those specified by the device manufacturer.

This technical report reports on applications in which only the performance of the device is an issue. Even though the device is used at wider temperatures, the wider temperatures will be limited to those that do not compromise the system performance or application-specific reliability of the device in the application. Specifically, this technical report does not report on applications that require the device to function beyond the absolute maximum rating limits of the component specified by the manufacturer and with a margin to be considered.

NOTE Alternate means of thermal uprating may have been performed prior to the implementation reported in this technical report by the equipment manufacturer. Rationale for decisions made may have been valid considering the application, semiconductor market conditions, experience with the particular component manufacturer, etc. at the times these decisions were made. Field performance using these methods also may validate their use, however, their continued use should take into account the risk of changes to the subject devices such as feature size reductions, material changes, etc.

2 Normative references

The following referenced documents are indispensable for the application of this technical report. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62239, *Process management for avionics – Preparation of an electronic components management plan*

3 Terms and definitions

For the purposes of this technical report, the following terms and definitions are used herein and/or should be used when using devices outside the manufacturers' specified temperature ranges.

NOTE The terms *uprating* and *thermal uprating* are being used increasingly in avionics industry discussions and meetings, and clear definitions are included in this clause. They were coined as shorthand references to a special case of methods commonly used in selecting components for circuit design. This technical report describes the methods and processes for implementing this special case. All of the elements of these processes employ existing, commonly used engineering practices. No new or unique engineering knowledge is required to follow these processes: only a rigorous application of the overall approach.

3.1
absolute maximum ratings
limiting values of operating and environmental conditions applicable to any semiconductor device of a specific type as defined by its published data, which should not be exceeded under the worst possible conditions. These values are chosen by the device manufacturer to provide acceptable serviceability of the device, taking no responsibility for equipment variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and all other electronic devices in the equipment

[IEC 60134:1961, Clause 4, modified]

3.2
ambient temperature
temperature of the environment in which a semiconductor device is operating

3.3
case temperature
temperature of the surface of a semiconductor device package during operation

3.4
circuit element functional mode analysis
documented analysis that determines minimum ranges and maximums of all functional characteristics of the assembly with respect to the related functional parameters of devices being uprated

3.5
device capability assessment
process of demonstrating that the device design is capable of providing the specified functionality, over the wider temperature range, for the required length of time. It assumes that the device has been qualified to operate within its specified temperature range, and includes additional testing or analysis to evaluate expected performance at the wider temperature range. Device capability assessment includes both performance and application-specific reliability

3.6
device quality assurance over the wider temperature range
additional testing or analysis required to assure that each individual device is capable of operating successfully in the required wider temperature range

3.7
ECMP
Electronic Components Management Plan

3.8
semiconductor devices
electronic devices that are not subject to disassembly without destruction or impairment of design use. They are sometimes called *electronic parts* or *piece parts*. Examples are diodes, integrated circuits, and transistors

3.9
electronic equipment
any item, for example, end item, sub-assembly, line-replaceable unit, shop-replaceable unit, or system produced by an electronic equipment manufacturer

3.10
junction temperature
temperature of the active region of the device in which the major part of the heat is generated

[International SEMATECH Official Dictionary, Rev 5.0, modified]

3.11
manufacturer-specified parameter limits
electrical parameter limits that are guaranteed by the device manufacturer when a device is used within the recommended operating conditions (see *Rating*)

3.12
manufacturer-specified temperature range
operating temperature range over which the component specifications, based on the component data sheet, are guaranteed by the component manufacturer (see *Rating*)

NOTE Manufacturer-specified temperature range is a subset of the recommended operating conditions.

3.13
may
indicates a course of action which is permissible within the limits of this technical report

3.14
parameter conformance assessment
process for thermal uprating in which devices are tested to assess their conformance to the manufacturer-specified parameter limits over the target temperature range

3.15
parameter characterisation
process of determining the typical and limiting values of electrical parameters by testing representative samples at room and extreme temperatures over the manufacturer's specified temperature range

3.16
parameter re-characterisation
process for thermal uprating in which the device parameters are characterised over the target temperature range, leading to a possible re-specification of the manufacturer-specified parameter limits

3.17
rating
value that establishes either a limiting capability or a limiting condition for a semiconductor device

3.18
recommended operating conditions
conditions for use of the component for which the component specifications, based on the component data sheet, are guaranteed by the component manufacturer (see *Rating*)

3.19
shall
indicates a mandatory requirement to be followed in order to conform to this technical report

3.20
should
indicates that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain course of action is deprecated but not prohibited

3.21
stress balancing
process for thermal uprating in which at least one of the device's electrical parameters is kept below its maximum allowable limit to reduce heat generation, thereby allowing operation at a higher ambient temperature than that specified by the device manufacturer

3.22
target temperature range
operating temperature range of the device in its required application

3.23
thermal uprating
process to assess the capability of a part to meet the performance requirements of the application in which the device is used outside the manufacturer's specified temperature range (see *Uprating*)

3.24
uprating
process to assess the capability of a device to meet the performance requirements of the application in which the device is used outside the manufacturer's specification range

NOTE Terms such as "upscreening", "retest", "up-temperature testing" and other similar variations are all deemed to be subsets of or encompassed by the overall uprating process.

3.25
wider temperature range
target temperature range outside the manufacturer-specified temperature range. It may include temperatures that are higher or lower than the manufacturer-specified temperature range, or both

3.26
will
expresses a declaration of intent

4 Objectives

The objectives of this technical report are:

– to ensure that device usage outside the manufacturers' specified temperature ranges is done only with appropriate justification; and

– to ensure that, if it is necessary to use devices outside the manufacturers' specified temperature ranges, it is done with documented and controlled processes that assure the integrity of the equipment.

5 Using devices outside the manufacturer's specified temperature ranges

Devices used outside the manufacturers specified temperature range **shall** be selected (5.1), their capability assessed (5.2), and their quality assured (5.3), and documented (5.4), as illustrated by the flow chart of Figure 1.

NOTE The headings of this clause are keyed to the actions and decisions of Figure 1.

5.1 Device selection, usage and alternatives

The equipment manufacturer **shall** design so that, initially and throughout life, no absolute-maximum value for the intended service is exceeded for any device under the worst probable operating conditions with respect to supply voltage variation, equipment device variation, equipment control adjustment, load variations, signal variation, environmental conditions, variation in characteristics of the device under consideration and of all other electronic devices in the equipment.

5.1.1 Alternatives

A review of alternatives **shall** be carried out prior to using a device outside the manufacturer's specified temperature range. If an alternative can be shown to be reasonable and practical then it **shall** be selected. The results of the evaluation **shall** be documented.

Examples of potential alternatives include:

– using a device specified over the required temperature range, with the identical function, but from a different manufacturer;

– using a device specified over the required temperature range, with the identical function, but a wider specified temperature range;

– using a device specified over the required temperature range, with the identical function, but a different package;

– using a device specified over the required temperature range, that has slightly different specified parameter limits, but which still meets the equipment design goals;

– using a device with the identical function, but a specified temperature range that still meets the application requirement;

– using a device specified over the required temperature range, but a different function, and compensating by making changes elsewhere in the equipment design;

– modifying the device's local operating environment, for example, adding cooling, etc.;

– modifying the equipment specified ambient temperature requirement, in co-operation with the customer;

– modifying the equipment operating or maintenance procedures, in co-operation with the customer; and

– negotiating with the device manufacturer to provide assurance over the wider temperature range.

For most applications, the preferred device for use in a wider temperature range should be the one for which the extension beyond the specified range is least.

NOTE As an example of this requirement, consider the case in which the required ambient temperature is 92 °C, and no device specified to operate above 85 °C is available. If the two available devices have specified maximum ambient temperatures of 70 °C and 85 °C, then the 85 °C device should, in the absence of other factors, be given preference regarding temperature.

5.1.2 Device technology

The technology of a device and its package **shall** be identified and understood in sufficient detail to assess the likelihood and consequences of potential failure mechanisms. It is recommended that the device manufacturer be consulted when a device is proposed for use outside manufacturers' specified temperature range. If the device manufacturer discourages the uprating process arguing technical reasons, the user needs to assess the impact of those reasons against the user's specific application.

5.1.3 Compliance with the Electronic Component Management Plan

All devices considered for use in wider temperature ranges **shall** be compliant with the equipment manufacturer's ECMP. It is necessary for ECMP requirements to be met only for the temperature range over which the device is specified, since requirements for wider temperatures are provided in this technical report.

NOTE IEC 62239 is recommended as a resource for an ECMP.

The use of devices outside the temperature ranges specified by the device manufacturer is discouraged; however, such usage may occur if other options prove to be impossible, unreasonable, or impractical. Justification for such usage may be based on availability, functionality, or other relevant criteria. In no case will such usage result in a design that:

– requires the device to operate at an operating or environmental stress level that significantly increases the risk of unstable device operation or loss of equipment function; or
– requires the device to operate beyond the device's maximum junction temperature or any other limiting temperature, as specified by the device manufacturer, or calculated directly from parameters specified by the device manufacturer.

5.2 Device capability assessment

The assessment of device capability needs to assure that not only are device parametrics acceptable, but also that device functionality and functionality of the related circuit are acceptable as well. Therefore, functional testing at the application or circuit level and higher levels as well is recommended.

5.2.1 Device package and internal construction capability assessment

Device qualification test data and other applicable data when available **shall** be analyzed to assure that they support the operation of the device over the end use temperature range and that the package and internal construction type used in device qualification is the same as that to be used in the end application.

Device qualification test data and other applicable data when available **shall** be analyzed to assure that the package and internal construction can withstand the stresses resulting from wider temperature cycling ranges, and that the package materials do not undergo deleterious phase changes or changes in material properties in the wider temperatures.

If this data is not available, then relevant testing based on the application should be considered.

5.2.2 Risk assessment (assembly level)

A preliminary risk assessment is prudent at this point to help guide decisions regarding the method(s) of capability assessment to be used, as well as how and when they should be applied. Understanding the risks on an application-specific basis enables "risk informed" decision-making and thereby a prediction of the impact of critical decisions.

The process for assessing risks should consider applicable factors associated with the use of devices beyond the manufacturers specified temperature range. Risk factors in this assessment may include:

– application criticality into which the device will be used;
– consequences of failure at device, circuit and system level;
– type or technology of device under consideration;
– manufacturer data available for the device;
– quality/reliability monitors employed by the manufacturer;
– comprehensiveness of production assembly-level screens performed at extended temperature;
– identification of both managed and unmanaged risks and cost models for each.