FIDES guide 2009
Edition A
September 2010

Reliability Methodology for Electronic Systems

AIRBUS France - Eurocopter
Nexter Electronics - MBDA France
Thales Systèmes Aéroportés SA - Thales Avionics
Thales Corporate Services SAS - Thales Underwater Systems

FOREWORD

The FIDES Guide 2009 was produced by companies in the FIDES Group, under the supervision of the DGA.
The FIDES Group is composed of AIRBUS France, Eurocopter, Nexter Electronics, MBDA France, Thales Systèmes Aéroportés SA, Thales Avionics, Thales Corporate Services SAS and Thales Underwater Systems.

SUMMARY AND RATIONALE FOR THE REVISION

The FIDES Guide 2009 replaces the FIDES Guide 2004 issue A (also published by the UTE under reference UTE-C 80811). This update was made in order to take into account the technological developments, to increase the coverage and to make improvements. A guiding principle of these changes was to achieve a document which use is as practical and universal as possible.

From the FIDES Guide 2004 issue A to the FIDES Guide 2009, all the chapters of the document are revised.
The FIDES Guide 2009 issue A, bring a series of minor improvements. These improvements mainly come from users' feedback and especially from members of the methodology's Maintenance and Development Structure, a Working Group of the Institut de Maîtrise des Risques (IMdR).The changes that are not a matter of form are listed in the change table.

COPYRIGHT

CONTACT

If you would like to get in touch with us, please register on the Internet site:

www.fides-reliability.org

WARNING

Companies in the FIDES Group have not planned any marking procedure equivalent to an approval indication and do not accept any responsibility for products declared conforming with this publication.

Companies in the FIDES Group, their administrators, employees, assistants or agents, including their private experts, cannot be held responsible for any prejudice caused in case of direct or indirect bodily injury or equipment damage or any other damage of any nature whatsoever, or be obliged to pay the costs (including legal costs) and expenditures resulting from the publication or the use of this publication or credit granted to it.

Attention is drawn to the fact that some elements in this publication may be the subject of intellectual property rights or similar rights. Companies of the FIDES Group cannot be held responsible for not having identified such copyright and not having notified its existence.

CHANGES TABLE

Pages	Paragraphs	Changes
33	1.9.3	Addition of an explanation on procurement
40	2.5.4	Addition of details about the absence of links a priori between the θ_{cycle} and the duration of the phase
85, 87 et 88	3.5	Corrections in the washing machine life profile. Most lines of the life profile are modified
89, 90	3.6	Addition of details on speed
93	3.7	Correction of day/night thermal cycling of the "tracked armoured vehicle" life profile.
95	3.7	Correction of the maximum cycle temperature of the "On" phase.
100	Induced Factor	Addition of qualitative criteria for the "user type" choice
102	Induced Factor	Addition of the sheet numbers in the $\Pi_{Ruggedising}$ table
104	$QA_{manufacturer}$ factor	Change in criterion for the "Equivalent" level
111, 120, 130, 146, 150	$QA_{component}$ factor	Change in criteria for the "Higher" and "Equivalent" levels
117	ASIC	Correction of the denominator of the Part_Grade calculation
155, 158	$QA_{component}$ factor	Change in criterion for the "Higher" level
165	H&MCM	Change in the equation for the λ_{chip}. Move of the "Humidity" paragraph
172	H&MCM	Change of the λ_{wiring} equation
173	H&MCM	Addition of the "Humidity" paragraph (moved with no change)
176	H&MCM	Addition of details on K calculation
195	Carte COTS	Addition of a remark on "induced' factor calculation
233	Parts count	Replacement of the FMG acronym
238	Families count	Replacement of the FMG acronym
251	Lead free factor	Correction of some sums and some criterion numbers
270+	V	Many wording corrections

Contents

I FIDES Guide presentation 9
1. Introduction 10
2. Warning about the FIDES methodology 11
3. Terminology 12
3.1. Acronyms 12
3.2. Definitions 13
4. References 15
5. Application field 16
5.1. Application domains 16
5.2. Model coverage 16
5.3. Nature of the prediction 17
5.4. Confidence in the prediction 19
5.5. Covered items 20

II Predicted reliability evaluation guide 21
1. Introduction to models 22
1.1. Origins of reliability data 22
1.2. FIDES approach 23
1.3. Complete method and simplified methods 23
1.4. Generic input data 24
1.5. General model 25
1.6. Life profile and time unit 26
1.7. Failure rate for an electronic product 27
1.8. Physical and technological contributing factors $\lambda_{physical}$ 28
1.9. Process contributing factors 31
2. Life profiles 34
2.1. Principles for construction of the life profile 34
2.2. Phase duration 35
2.3. Applicability domains 35
2.4. Temperature (temperature and thermo-electrical stresses) 36
2.5. Temperature cycling (thermo-mechanical stress) 38
2.6. Relative humidity 41
2.7. Vibration amplitude (mechanical stress) 44
2.8. Chemical stress 48
2.9. Application type 49
2.10. Data sources 50
2.11. Standard life profile 50

3. Examples of life profiles 53
3.1. Life profile of a navigation computer onboard a helicopter 53
3.2. Life profile of equipment (in avionics bay) mounted in a medium haul civil aircraft 71
3.3. Life profile of equipment (in avionics bay) mounted on a civil aircraft with turboprop engines 76
3.4. Life profile for industrial system type equipment 81
3.5. Washing machine life profile 85
3.6. Life profile for multi-role fighter aircraft external stores 89
3.7. Other examples 93

III Evaluation guide calculation sheets 96

Electronic components 97
Induced factor 98
Component manufacturing factor 104
Thermal resistance of components 106
Integrated circuits 111
Application Specific Integrated Circuit (ASIC) 117
Discrete semiconductors 120
Light emitting diodes (LED) 125
Optocouplers 128
Resistors 130
Fuses 133
Ceramic capacitors 135
Aluminium capacitors 138
Tantalum capacitors 140
Magnetic components: Inductors and Transformers 142
Piezoelectric components: Oscillators and Quartz 144
Monostable electromechanical relays 146
Switches 150
Printed circuit board (PCB) 155
Connectors 158

Hybrids and Multi Chip Modules 161
General model 162
Induced factor 163
H&M process factor 164
Microcomponents 165
Wiring, case, substrate, external connections 172
Physical stresses 178

Microwave (HF) and radiofrequency (RF) components 180
RF and HF process factor 181

RF HF integrated circuits **182**
RF HF discrete semiconductors **185**
RF HF passive components **188**

COTS boards **191**

General **192**
Induced factor **193**
Item manufacturing factor **194**
Onboard electronic functions **195**

Various subassemblies **201**

General **202**
Life **203**
Induced and item manufacturing factors **205**
LCD screens (TFT, STN) **206**
Hard disks (EIDE, SCSI) **209**
CRT screens **212**
AC/DC and DC/DC voltage converters **215**
Lithium and nickel batteries **217**
Fans **220**
Keyboards **223**

Parts count and families count reliability predictions **227**

General principles **228**
Parts count: Parameters **231**
Families Count: Parameters **241**

Handling the transition to lead-free **245**

Consequences on reliability **246**
Lead-free process factor **249**

IV Guide for control and audit of the reliability process **252**

1. Life cycle **253**
2. The process factor **254**
3. Trade recommendations – Reliability control **254**
4. Calculating the process factor $\Pi_{Process}$ **255**
4.1. Relative influence of phases in the life cycle 255
4.2. Recommendation satisfaction level 256
4.3. Calibration 257
4.4. Calculating the audit mark 258
4.5. Calculating the process factor 259
5. Audit guide **260**

5.1. Audit procedure 260
5.2. Identify the audit scope 261
5.3. Prepare the audit 264
5.4. Performing the audit 265
5.5. Processing collected information 265
5.6. Present the audit result 265
5.7. Positioning principle 266
5.8. Profile of audit participants 267

V Recommendations of the Reliability Process control and audit guide 269

Tables of recommendations with weightings 270

Specification 271
Design 273
Manufacturing of the board or subassembly 276
Integration into equipment 280
Integration into the system 284
Operation and maintenance 287
Support Activities 290
Ruggedising 292

Detailed datasheets for each recommendation 294

I
FIDES Guide presentation

1. Introduction

The FIDES global electronic reliability engineering methodology Guide, is composed of two parts:

- a predicted reliability evaluation guide,
- a reliability process control and audit guide.

The objectives of the FIDES Guide are firstly to make a realistic evaluation of the reliability of electronic products, including systems that encounter severe or non-aggressive environments (storage), and secondly to provide a specific tool for the construction and control of this reliability.

Its main characteristics are:

- The existence of models both for Electrical Electronic and Electromagnetic components, and for electronic boards or some subassemblies.
- Demonstration and taking account of all technological and physical factors that have an identified role in reliability.
- Precisely taking account of the life profile.
- Taking account of electrical, mechanical and thermal overstresses.
- Taking account of failures related to the development, production, operation and maintenance processes.
- The possibility of making a distinction between several suppliers of a single component.

The FIDES Guide can be helpful for taking action on definitions, and throughout the life cycle of products to improve and control reliability, through the identification of technological, physical or process factors contributing to reliability.

2. Warning about the FIDES methodology

The consortium that created the FIDES methodology is composed of companies from the aeronautical and defence domains. This consortium was created under the supervision of the DGA (Délégation Générale pour l'Armement - French Ministry of Defence).

The FIDES methodology is based on physics of failures and is supported by analyses of test data, feedback from operations and existing models. It is thus distinguished from former methods developed mainly from statistical interpretation of feedback from operations.

This method avoids predicted reliability results from being influenced by the industrial domains of methodology designers.

After the models had been finalised, the methodology was calibrated making use of the experience of consortium members, particularly for process factors.

3. Terminology

3.1. Acronyms

ASIC: Application Specific Integrated Circuit
BICMOS: Bipolar-CMOS
COTS: Commercial Off-The-Shelf
CMOS: Complementary Metal Oxide Semiconductor
CPLD: Complex Programmable Logic Device
CRT: Cathode Ray Tube
DDV: Durée de vie (Life)
DGA: Délégation Générale de l'Armement
DRAM: Dynamic Random Access Memory
EEE: Electrical, Electronic, Electromechanical
EEPROM: Electrically Erasable Programmable Read Only Memory
EIDE: Enhanced Integrated Drive Electronic
EOS: Electrical Overstress
EPROM: Erasable Programmable Read Only Memory
ESD: ElectroStatic Discharge
FIT: Failure In Time (1 fit is equal to 10^{-9} failures per hour)
RAMS: Reliability Availability Maintainability Safety
FPGA: Field Programmable Gate Array
G_{RMS}: G root mean square
LCD: Liquid Crystal Display
MOS: Mechanical Overstress (accidental overload)
MOS: Metal Oxide Semiconductor
PAL: Programmable Array Logic
PCB: Printed Circuit Board
RH: Relative Humidity
SCSI: Small Computer System Interface
SMD: Surface Mounted Device
STN: SuperTwisted-Nematic
SRAM: Static Random Access Memory
TCy: Thermal Cycling
TFT: Thin-Film Transistor
TOS: Thermal Overstress
TTF: Time To Fail

3.2. Definitions

Reliability
The capability of an item to perform a required function under given conditions, for a given time interval.
Reliability is usually expressed quantitatively by appropriate characteristics. In some applications, one of these characteristics is an expression of this capability by a probability, also called reliability.

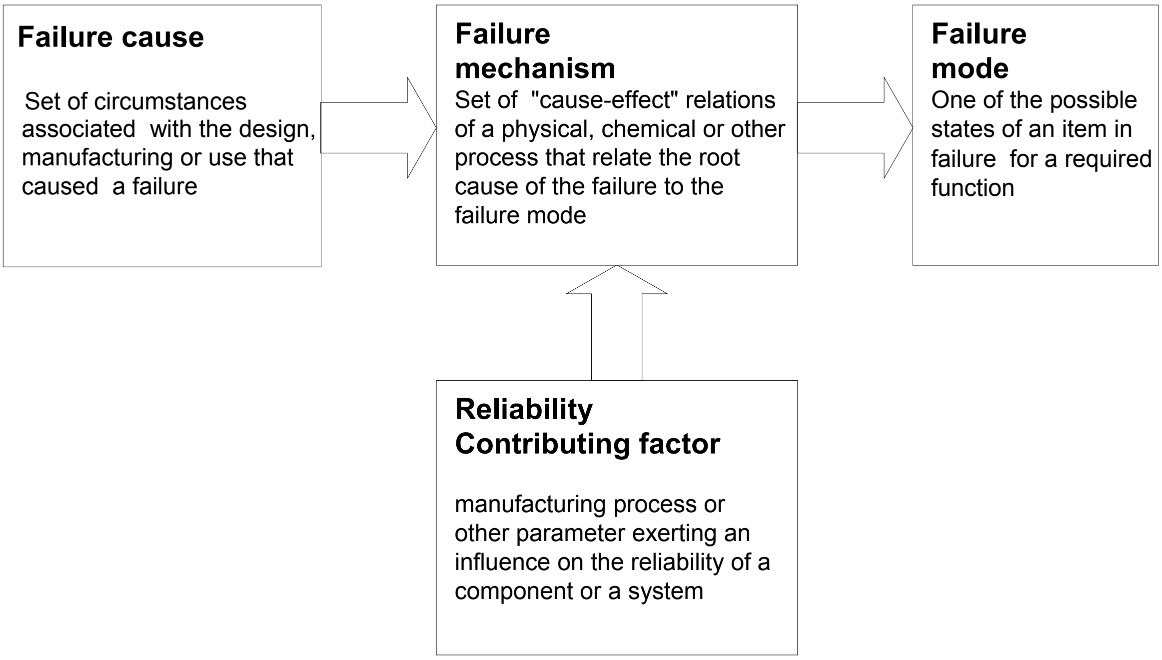
Failure mechanism
A set of "cause-effect" relations for a physical, chemical or other process that relates the root cause of the failure to the failure mode.

Failure mode
One of the possible states of an item in failure for a required function.

Cause of failure
A set of circumstances associated with design, manufacturing or use that led to a failure.

Reliability contributing factor – Factor influencing reliability
Technological, environmental, manufacturing process or other parameter exerting an influence on the reliability of a component or a system.

The logic sub-tending the above definitions can be summarised by the following diagram:



System
A set of equipment capable of making or supporting an operational role. A complete system includes all equipment, hardware, software, services and personnel necessary for its operation so that it is sufficient to itself in its usage environment. For example automobile, aircraft, microcomputer.

Subsystem
A set of equipment capable of performing an operational function of a system. The subsystem is a major subdivision of the system. The subsystem is often itself called a system. For example an ABS system in an automobile, a GPS system in an aircraft.

Equipment
Term denoting a group of items capable of performing a complete function. For example computer in the ABS system, screen in the GPS system.

Subassembly
Term denoting an item or an assembled group of items capable of performing a function of the equipment. For example electronic board in a computer, hard disk.

Electronic component
Term denoting an element that will be assembled with other elements in order to perform one or several electronic functions. For example transistor, resistor. This definition also includes the printed circuit board (PCB).

Product
This guide refers to the assembled entity for which reliability is being studied. Usually equipment.

Item
In this guide, an item refers to an elementary entity, not broken down, for which the reliability can be studied. Denotes a component or subassembly.

4. References

IEC 60050 (191) A1 (1999-03)
Electromechanical vocabulary - Chapter 191: operating dependability and service quality

MIL-HDBK-217F (+ notice 1 and 2)
Reliability prediction of electronic equipment

UTE C 80-810
RELIABILITY DATA HANDBOOK: RDF 2000 – A universal model for reliability prediction calculations for components, electronic boards and equipment

IEC 61709
Electronic components - Reliability – Reference conditions for failure rates and stress influence models for conversion

IEC 62308:2006
Equipment reliability – Reliability assessment methods

SSB-1.003
EIA Engineering Bulletin - Acceleration Factors - November 1999 and September 2002

JEDEC JEP122C
Failure Mechanisms and Models for Semiconductor Devices

5. Application field

5.1. Application domains

The FIDES methodology is applicable to all domains using electronics:

- Aeronautics.
- Navy.
- Military.
- Production and distribution of electricity.
- Automotive.
- Railway.
- Space.
- Industry.
- Telecommunications.
- Data processing, home automation, household appliances.
- Etc.

5.2. Model coverage

The FIDES methodology models failures with origins intrinsic to the studied items (item technology or manufacturing and distribution quality) and extrinsic (specification and design of the equipment, selection of the equipment procurement, production and integration system).

The methodology takes account of:

- Failures derived from development or manufacturing errors.
- Overstresses (electrical, mechanical, thermal) related to the application and not listed as such by the user (the occurrence of the overstress remained concealed).

Failures not dealt with by the methodology include:

- Software failures.
- Unconfirmed failures.
- Failures related to preventative maintenance operations that were not carried out.
- Failures related to accidental aggressions when identified or proven (failure propagations, use outside specifications, bad manipulations: the occurrence of the overstress is known).

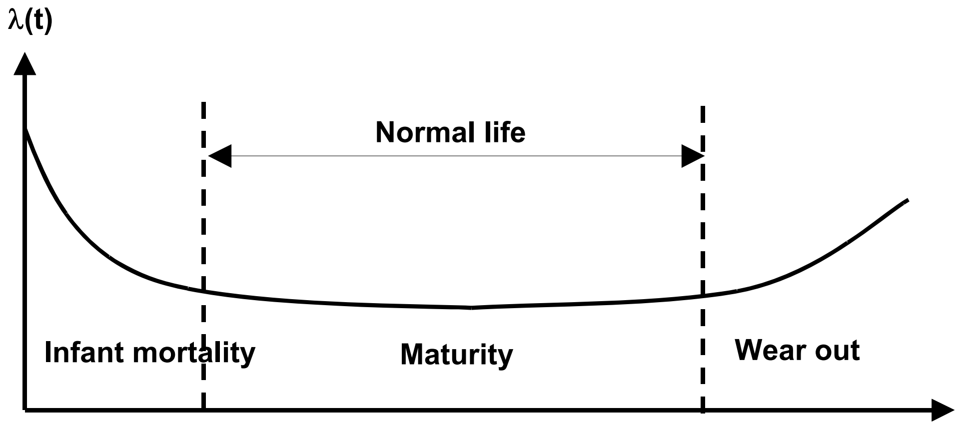
The FIDES methodology deals with non-functioning phases, either during dormant periods between use, or genuine storage.

5.3. Nature of the prediction

5.3.1. General case

Reliability predictions given by the FIDES methodology are failure rates denoted λ.

Experimental observations show that the way in which the failure rate varies as a function of time is usually represented by the following "bathtub curve".



Therefore the life of a product can be broken down into three periods:
- Infant mortality period, early failures.
- Period of useful life, approximately constant failure rate.
- Wear out period, wear failures.

The failure rate reduces during the infant mortality period. The reliability of a product increases with time. This is the period during which failures are due to problems with setting up processes and debugging the design and components.
The useful life period is represented by a constant failure rate. The failure rate is independent of the number of functioning hours of the product (this is why these failures are often described as random). This period is often non-existent for mechanical products, but is the reference case for electronics.
The reliability during the wear out period decreases with the number of hours of functioning; the older the product, the more probable a failure becomes. This type of behaviour is characteristic of items subject to wear or other progressive deterioration. Increasing failure rates occur during this period.

The FIDES evaluation method includes an evaluation of the reliability at constant failure rate (in fact, at an average failure rate). Infant mortality and wear out periods are excluded from the prediction (with a special case for some subassemblies). This is due to the following reasons:

- Firstly, the infant mortality period is representative of the development of an equipment or a system. Control over increasing reliability during this phase is a crucial step towards quickly obtaining good reliability.

- The wear out period is also excluded from FIDES because in principle it is sufficiently far in the future compared with the useful life of electronic systems covered by FIDES. However, checking this assumption during the design of the product is a key point. If items do not have a sufficiently long life, approaches other than predicted reliability alone must deal with this aspect, for example such as the definition of preventative maintenance.

- There is no doubt that microscopically, very few failure mechanisms strictly satisfy a "constant rate" type occurrence law. However:
  - The dispersion of many failure mechanisms, although they are accumulative and therefore increasing with time, is such that they can be deemed to be constant over the periods considered.
  - The accumulation of the large number and diversity of components, even on a single board, will be close to a constant.
  - Age differences between equipment in the same system or a stock of equipment will tend to make the rate constant for an observer at system level.

For these reasons, use of a constant failure rate is still the most relevant approach for estimating the predicted reliability of a system.

The physics of failures is used in some special cases to predict probabilistic life values (Time To Fail). This type of prediction is complementary to the reliability prediction, but cannot replace it.

5.3.2. Failures related to wear out in the case of subassemblies

In most cases, the life for electronic components is sufficiently long compared with the operational usage period and therefore its impact is negligible (reminder – verification of this assumption during the design of a product is a key point). But, for example, this is no longer the case in the presence of wear phenomena caused by moving mechanical parts.

Failures related to wear out of some subassemblies, for which the life is significantly shorter than the complete system, may make a non-negligible contribution to reliability. Particular modelling is proposed for these cases.

5.4. Confidence in the prediction

Evaluations made using the FIDES methodology are aimed at providing realistic values of reliability levels, similar to usually observed average values (and not pessimistic or conservative values).

One essential question after making an estimate of the predicted reliability is to know what confidence should be assigned to the estimate. This question is particularly important because users do not have confidence in raw results provided by previous methodologies and reliability control (quantification and engineering) in projects has become essential.

One of the objectives of the FIDES project is to build up this confidence. However, the accuracy of the prediction is not the only purpose of the FIDES methodology. Identification and control of factors influencing reliability may be considered as being even more important objectives.

As a general rule, an isolated estimate of the predicted reliability cannot be combined with a confidence interval in the same way as is possible when a failure rate is measured from feedback from operations. In the case of FIDES, while it might be possible to calculate a confidence interval on some basic failure rates, it is practically impossible to estimate confidence in all correcting parameters, even in the case of known and widely used physical acceleration laws.

It is important to bear in mind that reliability is a probabilistic concept.

The representativeness of the prediction increases with the number of items considered. Predictions are generally not applicable for a single item. It is recommended that the level considered should be at least the equipment level (set of electronic boards).

Note: The use of decimal values with several significant figures in the models gives no information about the expected accuracy of the results.

A comparison between a predicted reliability and a reliability measured from feedback from operations is always a difficult approach, because there are also uncertainties in measuring reliability in service. For example, these uncertainties are related to:

- The change in reliability with time.
- Poor knowledge of the real life of the product.
- The separation of failures that are due to the product from those that result from non-product sources.
- Cases of batch effects, which are difficult to take into account for the reliability calculation.

One prerequisite for the comparison between a predicted reliability and a reliability measured from feedback from operations is to assure that the life profile actually experienced by the product is sufficiently close to the life profile used to make the prediction. Otherwise, the comparison applies to the relative severity of the two life profiles (predicted and real) and not to the reliability itself.

One of the characteristics of the FIDES method is that it considers failures are very largely the consequence of life situations encountered by the product. Therefore confidence in the predicted reliability can never be better than confidence in the prediction of the expected product life.

5.5. Covered items

The FIDES methodology covers items varying from an elementary electronic component to a module or electronic subassembly with a well-defined function. Coverage of item families by FIDES is not absolutely exhaustive. However, the coverage is broadly sufficient to make a representative evaluation of reliability in most cases.

The methodology is applicable to COTS (Commercial Off-The-Shelf) items (for which it was initially developed), but also to special items provided that their technical characteristics comply with the technical characteristics described in this guide.

The COTS abbreviation denotes any item bought from a catalogue with a supplier reference and for which the customer has no control over the definition or production, and available on the domestic or foreign market. This item may be modified, and production or maintenance may be stopped without the customer having any control. A single supplier or several suppliers may be available for the same item.

FIDES deals with the following COTS:

- Components such as printed circuit boards, discrete semiconductor circuits or passive components.
- Subassemblies such as hard disks and screens.
- Assembled COTS boards.

II

Predicted reliability evaluation guide

1. Introduction to models

1.1. Origins of reliability data

Data used for the construction of models originate from:

- Failure analysis databases in the weapon systems domain and the civil aeronautical domain
- Reliability data for component and subassembly manufacturers.
- Existing reliability collections when they are relevant and can be used.

These data were used to develop and calibrate models, based on three methods:

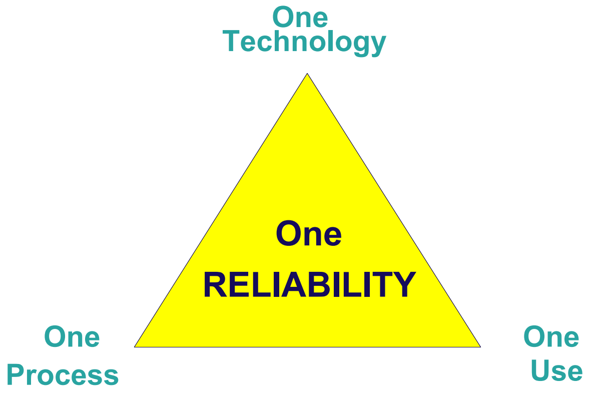
Method 1: Use of operational databases (aeronautical and military) on failure mechanisms.

Method 2: Use of test data from component and subassembly manufacturers (environmental tests, technological data, etc.).

Method 3: Use of mixed data (manufacturer data, feedback from operations, test results). This method is used mainly to build subassembly models.

1.2. FIDES approach

The FIDES reliability approach is based on the consideration of three components (Technology, Process and Use). These components are considered for the entire life cycle from the product specification phase until the operation and maintenance phase.



Technology covers the technology for the item itself and also for its integration into the product.
Process considers all practices and the state of art from the product specification until its replacement.
Use takes account of usage constraints defined by the product design and by operation at the final user.

These models consider a Technology faced with Usage constraints based on a failure mechanism approach and associated contributing factors. Those particularly balance the risk of failure by all Process contributing factors that can activate, accelerate or reduce these mechanisms.

1.3. Complete method and simplified methods

Reliability can be evaluated at different levels of detail to adapt to the project's progress:

- Detailed method, the most complete.
- Reliability counting method by item type.
- Reliability counting method by item family, which is the simplest to apply.

Reliability counting methods by item type and by item family are derived from the complete detailed method. All general models are applicable to the three methods in the same way, the only difference between the methods is in the level of information to be processed about the product.

1.4. Generic input data

Input data are as follows, generically:

Data on environments and product usage conditions.
These are typically:

- Operating temperature.
- Amplitude and frequency of temperature cycles.
- Vibration amplitude.
- Relative humidity.
- Ambient pollution level.
- Exposure to accidental overstress (application type).

These data should be broken down for each product life phase. The level of detail at which the product life profile is described within an operational system controls the accuracy of the reliability evaluation. Therefore, this step in the prediction analysis should be carried out with the utmost care.

Data on the product definition.
These are typically:

- Parts lists.
- Technical or technological characteristics of items derived from manufacturer datasheets.

Information related to the application shall be evaluated for each phase in the life cycle:

- Stress or overstress levels on items (dissipated powers, stress under power, etc.).
- Local aggravation (or moderation) to the temperature or another environmental parameter.

In practice, these data are often constant or assumed to be constant for all operating phases, but this is not always the case.

Data on the product life cycle.
These data must be collected through an audit of the process. This audit deals with the control of the reliability. It concerns the phase of specification, design, equipment manufacturing, integration into system, product operation, maintenance process and the support activities. Obviously, the thoroughness and extent of this audit shall be matched with the required reliability level.

Data on suppliers of items used in the product.
These data originate from the item supplier and the manufacturer's knowledge about his supplier.

1.5. General model

The FIDES general reliability model for an item is based on the following equation:

$$\lambda = \left(\sum \mathrm{Physical\_contributions}\right) \times \left(\prod \mathrm{Process\_contributions}\right)$$

Where:

- λ is the item failure rate.
- $\sum_{Physical\_contributions}$ represents a mainly additive construction term comprising physical and technological contributing factors to reliability.
- $\prod_{Process\_contributions}$ represents a multiplication term, that represents the impact of the development, production and operation process on reliability.

In practice, this equation becomes:

$$\lambda = \lambda_{\mathrm{Physical}} \cdot \prod_{\mathrm{PM}} \cdot \prod_{\mathrm{Process}}$$

Where:

- $\lambda_{Physical}$ represents the physical contribution.
- $\prod_{PM}$ (PM for Part Manufacturing) represents the quality and technical control over manufacturing of the item.
- $\prod_{Process}$ represents the quality and technical control over the development, manufacturing and usage process for the product containing the item.

1.6. Life profile and time unit

Failure rates predicted by the FIDES methodology are hourly failure rates expressed per calendar hour and based on the use of an annual life profile.

The failure rate for each phase is weighted by the duration of the phase:

$$\lambda_{\text{Physical}} = \sum_{i}^{\text{Phases}} \left(\frac{\text{Annual\_time}_{\text{phase-i}}}{8760} \cdot \lambda_{\text{phase-i}} \right)$$

A non-leap year contains 8760 calendar hours. All models are presented with this value of 8760 hours. Obviously, this method could be adapted if the life profiles considered can be better described over longer or shorter periods of time. The annual calculation is still recommended in general.

Predicted failure rates are expressed in FIT (1 FIT is equal to 1 failure per 10^9 hours).

Notes:

- The general equation does not deal with failure rates expressed per hour of operation, and this is one of the reasons why failure rates predicted by the FIDES methodology cannot be compared directly with results derived from different approaches.
- All that is necessary to calculate a failure rate for a period different from one year (for example a specific mission phase) is to substitute the value of the time weighting fixed at 8760 hours (1 year) in the formula by the effective duration of the period considered (caution is advised when using this approach when the time period is too short, to assure correct allocation of stresses, particularly temperature cycling).

Generalised use of the "calendar FIT" as a measurement unit for the failure rate enables the reliability manager to create a fixed reference for the comparison of failure rate values. Furthermore, when the product type is sufficiently well known, the magnitude of failure rate also indicates the severity of the life profile.

Despite the better universality of the failure rate expressed in calendar FIT, the failure rate sometimes has to be shown in the form of an "MTBF per mission hour". This calculation consists of allocating all failures to hours during which the product is considered to be "on-mission". The on-mission failure rate is calculated from the calendar failure rate as follows:

$$\lambda_{\text{mission}} = \lambda_{\text{calendar}} \times \frac{\text{Calendar duration}}{\text{Duration on-mission}}$$

1.7. Failure rate for an electronic product

The FIDES general model is used to calculate the failure rate of an electronic product before any redundancy or architectural consideration.

The global failure rate of the electronic product (usually equipment) is obtained by summating all failure rates for each of its constituent items.

$$\lambda_{\text{product}} = \left(\sum_{\text{Item}} \lambda_{\text{item}} \right)$$

Or in another form:

$$\lambda_{\text{product}} = \left(\begin{array}{l} \sum\limits_{\text{Components}} \lambda_{\text{Components}} \\ + \sum\limits_{\text{PCB}} \lambda_{\text{PCB}} \\ + \sum\limits_{\text{Boards}} \lambda_{\text{COTS boards}} \\ + \sum\limits_{\text{other\_S-A}} \lambda_{\text{Other\_subassemblies}} \end{array} \right)$$

1.8. Physical and technological contributing factors $\lambda_{\text{physical}}$

The physical contributing factor is itself broken down into different sub-contributing factors based on the following model:

$$\lambda_{\text{Physical}} = \left[\sum_{\text{Physical\_Contributions}} \left(\lambda_0 \cdot \Pi_{\text{acceleration}} \right) \right] \cdot \Pi_{\text{induced}}$$

Where:

- The term between brackets represents the contribution of normal stresses.
- Π_{induced} represents the contribution of induced factors (also called overstresses) inherent to an application field.

1.8.1. Real applied stresses

This element of the general model encompasses the basic failure rate assigned to the item, the contribution related to characteristics of the technology used, and acceleration factors to assign physical stresses applied to the item during its operational use.

$$\lambda_{\text{Physical}} = \left[\sum_{\text{Physical\_Contributions}} \left(\lambda_0 \cdot \Pi_{\text{acceleration}} \right) \right] \cdot \Pi_{\text{induced}}$$

Where:

- λ_0 is the basic failure rate of the item.
- $\Pi_{\text{acceleration}}$ is an acceleration factor translating the sensitivity to usage conditions.

The technological characteristics of an item are taken into account in the following way:

- Either directly by the choice of λ_0.
- Or by the presence of parameters in the expression of $\Pi_{\text{acceleration}}$.

These factors, and particularly the $\Pi_{\text{acceleration}}$ factor, are broken down for each physical stress. A physical stress is any stress normally applied to the product during its operational use, including for aspects related to the design. Physical stresses are grouped into different families:

• Thermal:	$\Pi_{Thermal}$
• Electrical:	$\Pi_{Electrical}$
• Temperature cycling:	Π_{TCy}
• Mechanical:	$\Pi_{Mechanical}$
• Humidity:	Π_{RH}
• Chemical:	$\Pi_{Chemical}$

Factors contributing to these physical stresses are usually additive. Thermal and electrical contributing factors for some item families are conjoint: $\Pi_{Thermal\text{-}electrical}$.

1.8.2. Overstresses: Π_{induced}

The induced factors considered are of mechanical (MOS), electrical (EOS) and thermal (TOS) origin.

The Π_{induced} factor represents the contribution of overstresses not listed as such. It is calculated for each phase in the life profile.

It is in the following form:

$$\Pi_{\text{induce-i}} = \left(\Pi_{\text{placement-i}} \times \Pi_{\text{application-i}} \times \Pi_{\text{ruggedising}}\right)^{0{,}511 \times \text{Ln}\left(C_{\text{sensibility}}\right)}$$

- $\Pi_{\text{Placement}}$ represents the influence of the item placement in the equipment or the system. In this case placement refers to the position of the item or the function in which it is integrated (particularly whether or not it is interfaced).

- $\Pi_{\text{Application}}$ represents the influence of the usage environment for application of the product containing the item. For example, exposure to a mechanical overstress is a priori more important in electronics integrated into a mobile system than in a fixed station system. This factor is variable depending on the life profile phase.

- $\Pi_{\text{Ruggedising}}$ represents the influence of the policy for taking account of overstresses in the product development.

- $C_{\text{sensitivity}}$ represents the coefficient of sensitivity to overstresses inherent to the item technology considered.

- i is the index of the phase considered.

The theoretical variation range of the Π_{induced} factor is from 1 (for the best case) to 100. However, only a small part of this range is reached in practice, since extreme cases are never encountered simultaneously.

1.9. Process contributing factors

1.9.1. The component manufacturing factor

The Π_{PM} factor (PM for Part Manufacturing) represents the item quality. The evaluation method varies depending on the nature of the item considered (EEE electronic component, board assemblies, other subassemblies).

It is in the following form:

$$\Pi_{PM} = e^{\delta_1 .(1-\text{Part\_Grade})-\alpha_1}$$

where:

$$\text{Part\_Grade} = \left[\frac{(QM_{\text{manufacturer}} + QA_{\text{item}} + RA_{\text{component}}) \times \varepsilon}{36} \right]$$

The evaluation method takes account of the manufacturer's quality assurance ($QM_{\text{manufacturer}}$) criteria, item quality assurance (QA_{item}) criteria and also the item purchaser's experience with his supplier (ε).

δ_1 and α_1 are correlation factors that determine the amplitude of the impact of Π_{PM} on the item reliability.

For active components, the principle used for evaluation of the Π_{PM} factor also takes account of qualification and periodic reliability monitoring tests for the case and for the active part; component reliability assurance, $RA_{\text{component}}$. These data are often found in Reliability Reports and audit results.

The variation range of the Π_{PM} factor varies from 0.5 (supplier better than the state of the art) to 2 (the worst case).

If Π_{PM} is not evaluated, a default value of 1.7 is used for active components and 1.6 for other components, COTS boards and various subassemblies. The use of a default value can reduce the accuracy of the final results.

1.9.2. The Π_{Process} factor

The Π_{Process} factor represents the quality and technical control over reliability in the product life cycle.
Its purpose is to globally evaluate the maturity of the manufacturer on control over his reliability engineering process.

It is in the form:

$$\Pi_{\text{Process}} = e^{\delta_2(1-\text{Process\_Grade})}$$

Where the *Process_grade* is the mark reflecting this process control, and δ_2 is a correlation factor that determines the variation range of the Π_{Process} factor.

The evaluation method is based on the level of application of recommendations that apply to the entire life cycle. The product life cycle is broken down as follows:
1. Specification.
2. Design.
3. Board or subassembly manufacturing (manufacturing).
4. Integration into equipment (manufacturing).
5. Integration into system (manufacturing).
6. Operation and maintenance.

A set of transverse activities has been added to these six phases that are sequential in time:
7. Support activities such as quality and human resources.

The recommendations are not intended to be exhaustive, they are more like a representative sample of good practice to improve the final reliability of products.

The variation range of the Π_{Process} factor is from 1 (for the best process) to 8 (for the worst process).

If Π_{Process} is not evaluated, a default value of 4.0 is suggested. The use of the default value can reduce the accuracy of the final results.

1.9.3. Comment on procurement

Procurement of an item corresponds to a life phase between the exit from the item manufacturing plant until the item is assembled in the product (for example assembly onto a board).

There is no factors specific to procurement in FIDES models.

The influence of the procurement phase on reliability is recognised as being dependent on:
- the company purchasing policy,
- the item selection policy (technological studies carried out beforehand),
- the item storage, debugging, manipulation and control policy.

These points are materialised in recommendations dependent on life cycle phases: *equipment support, design* and *production* (recommendations for which effects are considered in the evaluation of $\Pi_{Process}$) and in the choice of the ε factor in Π_{PM}.

The procurement policy has also an indirect influence on the other parameters of the Π_{PM}.

2. Life profiles

2.1. Principles for construction of the life profile

2.1.1. General

In producing a life profile for a reliability prediction, it is necessary to think about what causes product failures during its life. This is an engineering approach to reliability. It is crucial for reliability evaluations because it strongly influences the accuracy of predictions.

FIDES models have been designed to be sensitive to physical contributing factors. Choosing high or severe values when the life profile is being constructed so as to remain conservative, will eliminate a large proportion of the predictive value of the result.

The detail level and the accuracy of the description of the life profile can be limited to the accuracy level with which the product life can be predicted.

2.1.2. General description of the life profile

To enable the best use of the life profile, the first step is to describe it suitably from a qualitative point of view.

In particular, it is important to identify:
- The precise type of platform when the product is integrated into a system.
- The location in the platform if applicable.
- The geographic or climatic region considered.
- The type of use.

A customer or contractor project manager must build up a system level life profile, in opposition to an equipment level life profile. An equipment level life profile is derived by breaking down a system life profile to equipment level. The equipment life profile must take account of local conditions internal to the equipment and that cannot be generalised to other equipments of the system, including temperature increases due to the equipment itself, damping or amplification of vibration amplitudes, any drying measures taken, etc.

2.1.3. Choice of phases

The choice of phases must be sufficient to describe the different usage situations as completely as possible.

In order to enable a good understanding of a complex life profile, it may be useful to have a descriptive paragraph dedicated to each phase. It is essential to at least provide a clear title to each phase, to facilitate understanding.

A specific phase has to be determined every time that environmental conditions change significantly in terms of the stresses encountered. In this approach, the questionnaire on the application (relative to the induced factor) also has to be taken into account.

Usage situations need to be identified firstly at system level and not at the level of electronic equipment. Situation changes at system level usually have an impact on the equipment.
A priori, the equipment level life profile includes at least as many phases as the system level life profile. It is also possible that changes can occur in the equipment without there being any significant change at system level. In this case, the equipment level life profile will have more phases than the system life profile.

There is no universal method for breaking down into phases. It is usually relevant to perform the analysis by considering "typical product usage days".

It may be useful to make a distinction between seasons in some cases (an example is given in the VIP helicopter profile)

2.2. Phase duration

It is recommended that life profiles should be built up with a total duration of 1 year, namely 8760 hours. In the case of the FIDES method, all hours count, with 24 hours per day, 730 hours per month (average), and 8760 hours per year; and the term "calendar hour" is used to clarify matters.

The objective is to determine failure rates expressed in calendar FITs (1 FIT represents one failure per 10^9 hours), which are of the widest use. This choice is recommended rather than using the failure rate expressed "per hour of operation" or "per hour of mission", which can be misleading.

The duration of phases must be expressed in hours.

Durations shall be chosen to describe the product activity as realistically as possible.

2.3. Applicability domains

An applicability domain is proposed for each physical contributing factor processed by the FIDES method. The physical contributing factors concerned are:

- Temperature.
- Temperature cycling.
- Humidity.
- Vibration.

In general, the reliability prediction is only applicable in the environment domain for which the component is qualified. Qualification of a component for a given environment may either be guaranteed by the supplier or obtained by other means: in all cases, it is a prerequisite.

The proposed applicability domains are defined on a theoretical basis. The fact that the methodology is used within these domains does not provide any guarantee about the result. Furthermore, even within the applicability domain, the realism of predictions made with the FIDES method can be degraded for environmental conditions very different from the reference conditions.

2.4. Temperature (temperature and thermo-electrical stresses)

2.4.1. Physics of failures and models

The Arrhenius law is used to model the acceleration of some failure mechanisms due to temperature.

The acceleration factor is written as follows:

$$AF = e^{\frac{E_a}{K_B}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)}$$

Where:

- AF: acceleration factor;
- E_a: activation energy;
- K_B: Boltzmann's constant = 8.617 x 10^{-5} eV/K;
- T1: reference temperatures;
- T2: application temperatures.

Failure mechanisms activated by electrical operation of components are often taken into account by allowing for thermal dissipation in the calculation of the application temperature (for example junction temperature for active components) and by adding the ratio of the working voltage to the rated voltage, into the model. For example, the acceleration factor becomes:

$$AF = \left(\frac{1}{S_{\text{reference}}} \times \frac{V_{\text{applied}}}{V_{\text{rated}}}\right)^{p} e^{11604 \times Ea \times \left[\frac{1}{273+T_0} - \frac{1}{\left(T_{\text{ambient}}+273\right)}\right]}$$

Where:

- T_{ambient}: working temperature;
- T_0: reference temperature;
- V_{applied}: working voltage;
- V_{rated}: rated voltage;
- $S_{\text{reference}}$: reference level for the electrical stress;
- p: accelerating power for the electrical stress;
- The value of the activation energy Ea depends on the technology considered.

2.4.2. Reference conditions

Reference conditions are:

- Temperature T_0 20°C.
- An electrical stress level defined as a function of the technologies when necessary.

2.4.3. Applicability domain

The reliability prediction is only applicable in the range for which the component is qualified. The theoretical temperature range for which the FIDES Guide is applicable is: $-55°C \leq T_{ambient} \leq +125°C$.

2.4.4. Quantification of parameters

The following input data are required for each phase considered:

- The ambient temperature T (°C).
- The state (operating or not) (the thermal stress is usually not applicable during non-operation).

Even if temperature is a common factor with previous methods and particularly MIL-HDBK-217, it must not be estimated in the same way for FIDES and for MIL-HDBK-217.

For MIL-HDBK-217, the temperature was the only physical factor used. Consequently, for this methodology, temperature was often used to adjust the general severity of the environment.

The FIDES physical temperature model is usually more sensitive than models used in older methods. Therefore, a realistic temperature should be considered. The approach that consists of using a conservative fixed temperature inevitably leads to conservative estimates.

The temperature to be input into the model is the ambient temperature of the environment. In general, the temperature to be considered for this purpose is the temperature of the environment in which the studied item is located. When necessary, models explicitly allow for the temperature rise of the item relative to its environment (particularly for active components, for which the model considers the junction temperature).

For reliability evaluations at component level, the ambient temperature to be considered is the ambient temperature around the electronic board. For example, for a board integrated into equipment, the temperature to be considered is the ambient temperature inside the equipment. In a functioning phase, this temperature must include the temperature rise due to heat dissipation from components during this phase.

Thermal simulation tools can provide very good knowledge of temperatures in electronic equipment even during the preliminary phases of a development. Refinements can be made starting from such simulations. In particular, when the temperature in the equipment is not uniform, the temperature can be adapted depending on the zone by assuming a different temperature for each board, if this is consistent with the expected accuracy of the analysis. With this approach, FIDES can be used as a discriminating tool that is equally useful to design the internal layout of electronic equipment.

The same rule will be applied for reliability evaluations of the wired board. The ambient temperature in the environment should be considered for reliability evaluations of subassemblies other than boards. Information about temperature increases of subassemblies is usually not accessible directly and therefore models are designed to manage without them.

For a phase in which the temperature starts by changing and then stabilises (usual case of warming up after starting up), it is usually representative to assume that the temperature will be stable over the entire phase. The temperature to be considered for a phase during which the temperature is continuously changing and does not stabilise is not necessarily the average in time, due to the non-linear influence of temperature. In this case, the representative temperature will be higher than the average in time (an example is given in the VIP helicopter profile).

2.5. Temperature cycling (thermo-mechanical stress)

This stress is associated with temperature cycling of the product, regardless of whether it is in functional or dormant mode, considering temperature variations related to the functional and dormant phases (particularly on/off) and variations in its environment (for example day/night).

2.5.1. Physics of failures and models

The Norris-Landzberg model is used to model the acceleration on the fatigue mechanism due to temperature variations. This model is derived from the Coffin-Manson model usually used for thermo-mechanical fatigue. It takes account of the fact that slower temperature cycles are more damaging, due to activation of the creep phenomenon (for solder). The Norris-Landzberg model was specifically modified for the FIDES Guide, to convert the usual prediction of the model (a number of cycles) to an acceleration factor that can be used to modify a failure rate.

The acceleration factor is written:

$$\mathrm{AF} = \left(\frac{24}{N_0} \times \frac{N_{\mathrm{cy-annual}}}{t_{\mathrm{annual}}} \right) \times \left(\frac{\min(\theta_{\mathrm{cy}},2)}{\min(\theta_0,2)} \right)^{p} \times \left(\frac{\Delta T_{\mathrm{cycling}}}{\Delta T_0} \right)^{m} \times e^{1414 \times \left[\frac{1}{273 + T_0 + \Delta T_0} - \frac{1}{\left(T_{\mathrm{max-cycling}} + 273 \right)} \right]}$$

Where:

- $N_{\text{cy-annual}}$: Annual number of cycles;
- N_0: Number of reference cycles;
- t_{annual}: annual duration of the phase;
- θ_{cy}: cycle duration in hours;
- θ_0: reference cycle duration;
- $\Delta T_{\text{cycling}}$: thermal amplitude of the cycle;
- ΔT_0: reference thermal amplitude of the cycle;

- the constant 1414 corresponds to an activation energy of 0.122eV ; 1414= 0.122/KB, KB is the Boltzmann constant = 8.617 x 10^{-5} eV/K;
- $T_{max-cycling}$: The maximum temperature reached during the cycle;
- T_0: reference temperature;
- m: fatigue coefficient, for example m=1.9 for fatigue of SnPb solder;
- p=1/3, accelerating power of the duration factor;

The temperature cycling model does not deal with temperature shocks.

2.5.2. Reference conditions

Reference conditions are:

- A cycle amplitude ΔT_0 of 20°C.
- A cycle frequency N_0 of 2 cycles per day.
- A cycle duration θ_0 of 12 hours.
- A maximum temperature $T_{max-cycling}$ (namely $T_0+\Delta T_0$) of 40°C.

2.5.3. Applicability domain

The theoretical range of the temperature cycle for which the FIDES Guide is applicable is $\Delta T_{cycling} \leq 180°C$, $T_{max\_cycling} \leq 125°C$, temperature transition rate ≤ 20°C / minute.

2.5.4. Quantification of parameters

The following input data are required for each phase considered:

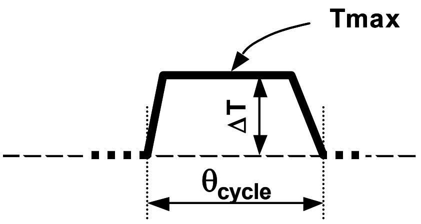
- The amplitude of the temperature cycle ΔT (°C).
- The associated number of cycles over one year (quantity).
- The cycle duration θ_{cycle} (in hours).
- The maximum temperature in the cycle (°C).

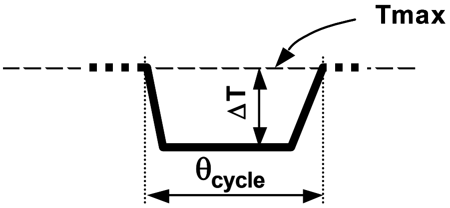
Temperatures considered for temperature cycling must be the same as the temperatures described for the temperature aspect itself.

The following rules should be applied to provide a representative reproducible description of temperature cycles:

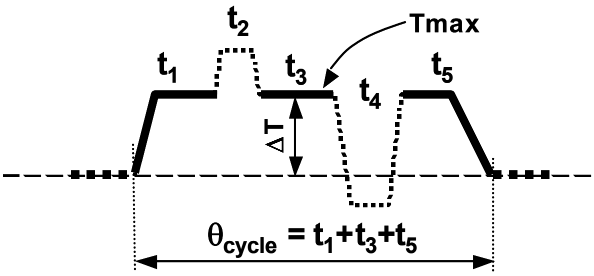
1. Cycles are evaluated from an initial equipment reference temperature; for example rest state (off).

2. A cycle usually corresponds to a temperature excursion, ΔT, measured toward the initial temperature; the cycle time θ_{cycle} is applicable until returning to the initial temperature.

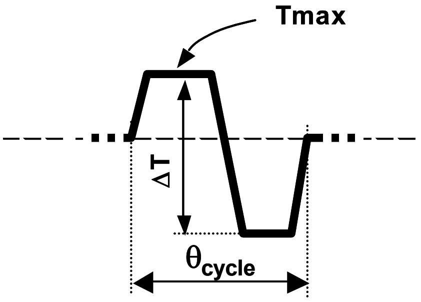




3. Other cycles may be superimposed on or inserted in a cycle, and in this case, sub-cycle times will be reflected on the primary cycle onto which they are superimposed.



4. In some special cases (low temperature amplitude), a cycle can be considered as a temperature variation around an average temperature (for example day/night cycling).



5. In many cases, $\theta_{\mathrm{Cycle}} = \dfrac{\text{Calendar time}}{\text{Annual number of cycles}}$, but this is generally a simplification (some examples are given in the VIP helicopter and the military portable radio profiles).

6. A temperature cycle must correspond to an identified phenomenon that generates the stress. For example switching on, increase in altitude, temperature

rise due to a system state. A cycle must be considered in an integrated manner and it must not be broken down into several arbitrary sub-cycles that do not correspond to any real time in a profile phase.

7. Several identical cycles may succeed each other in a single phase. In this case, the number of identical cycles will be counted.

The correct application of rules 3 and 6 mentioned above is particularly important. Simply reading the temperature profile of the product without taking account of rule number 6 can be misleading. Application of rule number 6 takes priority. Namely:

- Firstly identify the phenomenon that causes the temperature cycle. For example:
    - Switching on; therefore the end of the cycle must result in switching off.
    - Change in the operating phase; for example switching an additional load to a power supply.
    - Change in the environment temperature; for example day-night cycle.
    - Change due to the system being moved in its environment; for example movement from a zone that is air conditioned to a non-air conditioned zone, change of altitude for an aircraft.
- In examining the temperature profile as a function of time, it is important to identify the entire temperature cycle, including the temperature change phase that starts the cycle, and the return phase to the initial temperature. For nested cycles, take care not to associate a temperature transition cycle instead of a forward-return cycle.

- When temperature cycles are superimposed, apply the count principles in rule 3. It is then important to determine each temperature cycle independently, eliminating the other cycles. The constant temperature in the first temperature cycle becomes the reference temperature of the next one.

In general, there is usually a delay in the thermal cycling to the event that causes it (for example switching off does not cause an instantaneous return to ambient temperature). Depending on the cycle time being considered, it may be possible to ignore this effect.

2.6. Relative humidity

2.6.1. Physics of failures and models

The relative humidity (expressed as a %) is the ratio between the vapour pressure of water contained in the air and the saturating vapour pressure (that depends on the temperature of the air mass).

The Peck's model is used to model acceleration caused by the relative humidity-temperature combination on some failure mechanisms.

$$AF = \left(\frac{RH_{ambient}}{RH_0} \right)^p \times e^{11604 \times Ea \times \left[\frac{1}{273 + T_0} - \frac{1}{(T_{ambient} + 273)} \right]}$$

where:

- $RH_{ambient}$: relative humidity of the environment considered;
- RH_0: reference relative humidity;
- $T_{ambient}$: environment temperature considered;
- T_0: reference temperature;
- Ea: activation energy;
- p: accelerating power for this stress.

2.6.2. Reference conditions

Reference conditions are:

- Relative humidity RH_0 70% ;
- Ambient temperature T_0 20°C.

2.6.3. Applicability domain

The theoretical validity range is from 0% to 100%.
Cases of condensation or icing are not dealt with.

2.6.4. Quantification of parameters

The following input data are required for each phase considered:

- The relative humidity RH (%).
- The ambient temperature T (°C).
- The state (operating or not) (in most cases the humidity stress is not applicable during functioning).

The temperature is the same as that described in the temperature section.

Like temperature, relative humidity varies depending on the climate, it is important that the relative humidity assumed is representative of the climate considered.

The STANAG 2895 and GAM EG13 documents contain tables of minimum and maximum relative humidity values in different parts of the world and can be used if no better information is available.

In estimating relative humidity, it is important to take account of the relative humidity actually experienced by components. For example, the hermeticity of the product needs to be considered, with the possibility of moisture being trapped in a hermetically sealed case or the role of the drying measures that can significantly reduce the relative humidity applied to components, in comparison with the relative humidity of the environment.

Drying agents are sometimes used to reduce the relative humidity. For example if silica gel bags with a mass of about 1g are placed in a case containing less than 10L of air, the relative humidity usually reaches a value less than 10%. Document DIN 55474 suggests a method for calculating the quantity of drying agent as a function of the final tolerated humidity (and other different parameters). Dehydrating agents must be renewed when their absorption capacity is depleted.

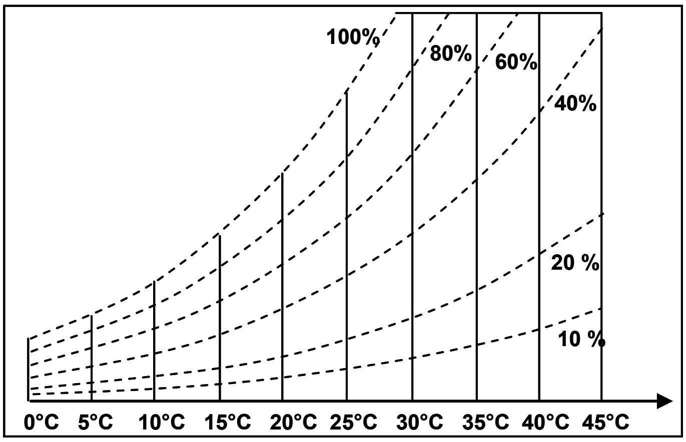
It may be necessary to take account of whether or not there is any air conditioning that will often dry air to below a relative humidity of 30% or 40% (the environment is not as comfortable for occupants below these values).

Change in humidity as a function of temperature: For a constant composition of the air, the humidity decreases as the temperature increases. Air inside functioning equipment is usually warmed up, which reduces the humidity experienced by components.

For a constant air composition in the lack of condensation, the variation of the RH as a function of the temperature can be calculated using the following formula:

$$\mathrm{RH}_{\mathrm{final}} = \mathrm{RH}_{\mathrm{initial}} \times e^{17.2694 \times \left[\frac{T_{\mathrm{initial}}}{238.3 + T_{\mathrm{initial}}} - \frac{T_{\mathrm{final}}}{238.3 + T_{\mathrm{final}}}\right]}$$

The change in the RH as a function of the temperature can also be read on a hygrothermal diagram.



Change in humidity as a function of the altitude : relative humidity varies as a function of the altitude. In general, as altitude increases relative humidity decreases, the relative humidity becoming zero beyond the troposphere. Nevertheless, this change is very irregular and difficult to predict. In particular, the relative humidity increases in cloud layers. It is simpler to assume an average humidity independent of the altitude.

This relative humidity factor may become preponderant in life profiles that include long storage periods. In such cases, special care has to be taken in determining the values for relative humidity and temperature.

Note: the influence of temperature is higher during storage (through the humidity) than when functioning.

2.7. Vibration amplitude (mechanical stress)

2.7.1. Physics of failures and models

Basquin's law provides a means of taking account of the fact that as the vibration amplitude increases, the risk of a failure in components and electronic boards also increases. There is a wide variety of failure mechanisms, and not all are fatigue mechanisms for which Basquin's law is usually used. In some cases, vibrations will reveal weaknesses such as, for example dry solder joints, cracks in parts (substrate, component cases, etc.), bond problems at interfaces (bonding defect, delamination, etc.) Where metallic particles are present in a hermetically sealed case, vibrations will increase the risk of a short circuit by moving these particles. Furthermore, if the failure mechanism is associated with mechanical fatigue, there is a wide variety of materials that can be degraded by fatigue or wear (aluminium, copper, silicon, epoxy, glass, ceramic, etc.).

$$AF = \left(\frac{G_{RMS}}{G_{RMS0}} \right)^{p}$$

Where:

- G_{RMS}: root mean square vibration amplitude in the environment considered;
- G_{RMS0}: reference vibration amplitude.
- p: accelerating power for the mechanical stress.

The coefficient of the acceleration law derived from Basquin's model for the FIDES model is chosen to be p=1.5. This value is fairly close to the bottom of the range of "fatigue coefficients" usually encountered for Basquin's law. Therefore, the use of the FIDES mechanical model combined with acceleration models used for tests must take account of this characteristic.

This mechanical model does not consider mechanical shocks.

2.7.2. Reference conditions

Reference conditions are:

- Vibration amplitude G_{RMS0} equal to 0.5 G_{RMS}.

2.7.3. Applicability domain

The theoretical validity range is $G_{RMS} \leq 40\ G_{RMS}$.
Mechanical shock is not considered.

2.7.4. Quantification of parameters

For each phase considered, the input data is:

- The random vibration amplitude expressed in G_{RMS}.

The vibration amplitude must be considered in the relevant frequency range for the product considered. Since frequencies to be taken into account are variable, the calculation must be made over a wide frequency band (20-2000 kHz). Electronic circuits are frequently most sensitive to vibration in the axis perpendicular to the plane of the board.

When considering the physics of failure under vibration conditions the vibration amplitude of the stressed element should be taken into account, for example:

- solder of a component on a board,
- pin of a through-hole component,
- solder of a strip inside a relay,
- gluing of a microcomponent within a hybrid.

But the vibration amplitude depends on a variety of factors:

- vibration amplitude at the input to the electronic board,
- amplification factor at the component position,
- frequencies of stresses in comparison with natural resonant modes of the board,
- the natural frequency of the stressed element (in some cases),
- etc.

Since it is unthinkable to consider all these parameters in a predicted reliability study, the model parameter setting will be made using the input level for the product (the level experienced by the equipment or the board). One means of controlling the reliability (process aspects) is to avoid placing the most sensitive components at the most severe locations on a board.

The level to be used shall be as close as possible to the level actually experienced in service.

Quantification of the vibration amplitude for reliability studies must often be made from technical specifications, before real in-service levels can be measured. Vibration amplitudes specified for the tests must be used with caution. These vibration levels are often either levels corresponding to accelerated or hardened tests, or extreme levels that the product may face. The correct levels to be selected are non-accelerated and non-ruggedised endurance vibration amplitudes.

Special attention is paid to the following confusions:

- Confusion between the vibration amplitude at the input and the amplified vibration at components on the electronic board.

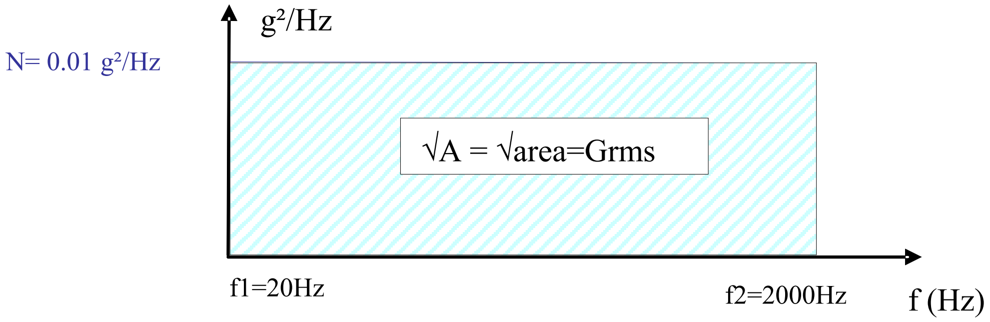
- Confusion between qualification levels (generally conservative since ruggedised) and typical in-service levels.
- Confusion between accelerated test levels (for example life) and nominal test levels.

Vibration amplitudes are usually given in the form of Power Spectral Density (PSD). In this case, the excitation level in G_{RMS} can be determined from this PSD. The G_{RMS} level is calculated as the square root of the area located under the curve of the PSD spectrum.

An example calculation is given in the following sections.

2.7.5. Calculate the G_{RMS} (rms acceleration) starting from the power spectral density

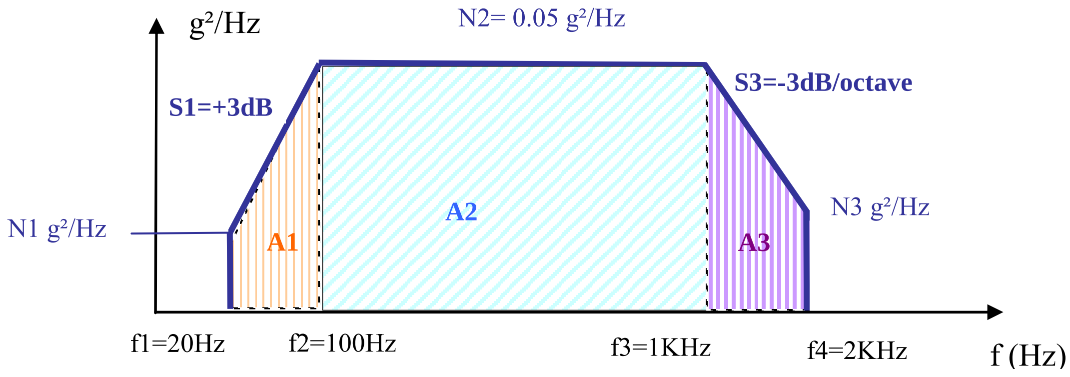
The area can be calculated directly if the excitation level is constant over the entire frequency band.



$$G_{RMS} = \sqrt{A}$$

$$G_{RMS} = \sqrt{19.8} = 4.45$$

In the case of a spectrum with different levels as a function of the frequency bands, the total area must be broken down as described in the example below.



When the slope is not equal to -3dB per octave:

$$A1 = \frac{3N2}{3+S1}\left(f2-\left(\frac{f1}{f2}\right)^{S1/3}\times f1\right) \text{ or } A1 = \frac{3N1}{3+S1}\left(\left(\frac{f2}{f1}\right)^{S1/3}\times f2 - f1\right)$$

$$A1 = \frac{3\times 0.05}{3+3}\left(100-\left(\frac{20}{100}\right)^{3/3}\times 20\right) = 2.4$$

When the level is constant on a frequency band:

$$A2 = N2(f3 - f2)$$

$$A2 = 0.05(1000-100) = 45$$

When the slope is -3dB per octave:

$$A3 = f3 \times N2 \times \ln\left(\frac{f4}{f3}\right) \text{ or } A3 = -f4 \times N3 \times \ln\left(\frac{f3}{f4}\right)$$

$$A3 = 1000 \times 0.05 \times \ln\left(\frac{2000}{1000}\right) = 34$$

If the slope S3 is not equal to -3dB per octave, A3 is calculated as A1:

$$A3 = \frac{3N3}{3+S3}\left(f4-\left(\frac{f3}{f4}\right)^{S3/3}\times f3\right)$$

Finally:

$$G_{RMS} = \sqrt{(A1 + A2 + A3)}$$

$$G_{RMS} = \sqrt{81.4} = 9$$

2.8. Chemical stress

2.8.1. Modelling

Chemical stress is modelled qualitatively, there is no physical model for this stress. In some models, the chemical stress becomes an acceleration factor for other physical stresses.

The chemical contribution to product reliability is expressed through four contributing factors related to the use of the product.

- In its environment:
  - Salinity of the environment (stronger salinity in coastal or marine environments).
  - Industrial or natural chemical environmental contribution (pollution).
- In its system:
  - Chemical contribution due to placement of the product in the system or the nature of the system (local pollution).
  - Product protection level within the system, hermetically sealed or not (warning, this is different from the hermeticity of component cases).

2.8.2. Quantification of parameters

The following tables describe the four criteria.

Saline pollution level	**Example**
Weak	Continental region
Strong	Coastal region

Environmental pollution level	**Example**
Weak	Rural region
Moderate	Urban region
Strong	Urban and industrial region

Application pollution level	**Example**
Weak	Inhabited or maintained zone
Moderate	Uninhabited zone or without maintenance
Strong	Engine zone

Product protection level	**Example**
Hermetic	Hermetic protection
Non hermetic	Other protections

2.9. Application type

This is a questionnaire used to determine the $\Pi_{application}$ parameter of the induced factor.

Different criteria are used to evaluate the severity of a usage phase in terms of exposure to overstresses. There are three levels per criterion. Evaluation of these levels provides a means of calculating the $\Pi_{application}$ parameter. The complete method is described in detail in the calculation sheets. The criteria are as follows:

- User type: Represents professionalism, respect of procedures, influence of operational stresses.
- User qualification: Represents the control level of the user or the operator in an operational context.
- System mobility: Represents problems related to the possibilities of moving the system.
- Product manipulation: Represents the risks of false manipulations, shocks, falls, etc.
- Power supply type: Refers to the level of electrical disturbance expected on power supplies and signals: power on, power supply switching, connection/disconnection.
- Exposure to human activity: Represents exposure to problems related to human activity: shock, change in the final use, etc.
- Exposure to machine disturbances: Represents problems related to functioning of machines, motors, actuators such as shocks, overheating, electrical disturbances, aggressive pollutants.
- Exposure to the weather: Represents exposure to rain, hail, frost, sandstorm, lightning, dust, etc.

A complete description of a life profile should include answers to these questions.

The main rule to be respected for answering these questions is to reply to the question with respect to the appropriate level, i.e. product level or system level..

The preferred point of view is shown in the following table.

Criterion	**Level**
User type in the phase considered	Complete system
User qualification level in the phase considered	Product user in the complete system
System mobility	Complete system
Product handling	Product
Type of electrical network for the system	System and product

Criterion	Level
Product exposure to human activity	Product in the complete system
Product exposure to machine disturbances	Product in the complete system
Product exposure to the weather	Product in the complete system

2.10. Data sources

There are many data sources for producing a life profile. The main sources are:

- Expression of the customer's or system assembler's requirements.
- Weather and climatic statistics.
- Standards.
- Feedback from operations.
- Test results, simulation results.

Difficulty in the interpretation of input documents can originate from the following confusions:

- Confusion between qualification levels (that are extremes) and typical levels (useful for reliability).
- Confusion between test levels and specified levels.
- Confusion between accelerated test levels (life) and nominal test levels.
- Heterogeneity (or even mismatch) between the different standard references.

2.11. Standard life profile

2.11.1. Principle

The standard life profile is intended to be used as it is, to give a reference reliability for a COTS product, equipment or subassembly.

This life profile resembles the life profile for the use of an electronic desktop equipment, but its objective is not to describe a real usage case. This profile is intended to be as close as possible to reference conditions for each physical contributing factor (it is impossible to be in reference conditions for all physical contributing factors at the same time). It describes a non-aggressive environment.

2.11.2. Description

This life profile corresponds to a product used 10 hours per day for 365 days per year (namely 3650 hours per year) under office or laboratory type usage conditions. The product is switched off when it is not being used (namely 14 hours per day, 5110 hours per year).
⇨ In a real life profile, the duration and the real number of power on operations should be considered.

When switched off, the average temperature of the product is 20°C and it is subjected to a moderate day/night temperature cycle representative of an office that is not air-conditioned (5°C around the average value of 20°C).
⇨ The appropriate weather conditions should be considered for a real life profile. When the not-operational time is dominant in the life profile, it is important to refine the level of day/night temperature cycle.

In the operating phase, the product considered is subject to a temperature increase of 20°C related to its dissipated power. Therefore its ambient temperature is fixed at 40°C and a temperature cycle with an amplitude of 20°C is assumed. The number of cycles corresponds to the number of power applications, which is 365 for this profile. Note: the operating time is superimposed on the duration of the day/night cycle.
⇨ The appropriate temperature rises should be considered in a real life profile.

The relative humidity is assumed to be 70% in ambient air at 20°C. Due to the temperature rise, the RH in a product in operation drops to 22%.
⇨ Appropriate weather conditions should be considered in a real life profile. When the non-operation time is dominant in the life profile, it is important to refine the RH level in storage.

The vibration amplitude is considered to be zero during non-operation and moderate during operation.
⇨ Appropriate vibration amplitudes should be considered in a real life profile. When the non-operation time is dominant in the life profile, it may be important to check if there is any residual vibration amplitude in this phase.

The pollution level for this product is assumed to be low. The system is not hermetically sealed and therefore the product is affected by a slight chemical stress.
⇨ In a real life profile, appropriate chemical stresses should be considered.

Exposure to overstresses is fixed as being very low for this reference life profile. Such a low level assumes in particular that the user is qualified and respects procedures.
⇨ The $\Pi_{\text{application}}$ factor plays a major role in the reliability evaluation. It is very important to evaluate it specifically for each life profile and to break it down for each phase.

2.11.3. Table

Standard life profile														
		Temperature and humidity			Temperature cycling				Mechanical	Chemical				Induced
Phase name	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
Stop	5 110	Off	20	70	5	365	14	23	0	Weak	Weak	Weak	Non hermetic	1
Start	3 650	On	40	22	20	365	10	40	0.5	Weak	Weak	Weak	Non hermetic	1.9

3. Examples of life profiles

The detail at which the life profile of the product is described in an operational system controls the accuracy of the evaluated reliability. Thus, this step in the prediction analysis must be carried out carefully. The examples of life profiles presented here illustrate the construction rules presented in previous chapter. They are not intended to be used directly. They must be considered as being starting points that need to be adapted.

3.1. Life profile of a navigation computer onboard a helicopter

There are different possible methods for producing a life profile. The example of the life profile of a navigation computer onboard a VIP (Very Important Person) helicopter gives a particular illustration of the "sequencing in typical days" method.

The example proposed herein also describes how to choose and build phases in the life profile starting from the life sequence of the system. This approach allows good reproducibility of the construction of the life profile, particularly for the determination of time and climatic aspects of the life profile.

3.1.1. Quantification of time data

Sequencing of a year

Principle: Identify different typical days experienced by the system and quantify their occurrence during the year.

The VIP helicopter experiences two different types of days:
- "Operating" day, 100 days per year.
- "Non-operating day", 265 days per year.

Note: The climate is a parameter that can play a role in this identification. Typical days can be differentiated as a function of the variation of the outside temperature, so as to increase the accuracy of the life profile and therefore the prediction. In this application case, assuming a temperate climate in which there are significant variations in the outside temperature and/or humidity during a year, it may be relevant to increase the accuracy of predictions by dividing each typical day into 3:
- an "operational - winter" day for 3 months, 100x3/12 = 25 d/year
- an "operational - spring or autumn" day, 6 months 100x6/12 = 50 d/year
- an "operational - summer" day, 25 d/year
- a "non-operational - winter" day, 265x3/12 = 66 d/year
- a "non-operational - spring or autumn" day, 133 d/year
- a "non-operational - summer" day, 66 d/year

This more detailed breakdown takes account of applied outside temperatures closer to reality. This may or may not be justified following a comparison in the final predictions between the detailed and simplified profiles.

Sequencing of days

Principle: Place each identified typical day into chronological steps in which each external stress (temperature, vibration, humidity, pollution, application type) may be assumed to be constant. This is done by identifying events during the day that generate change to these external stresses.

The day begins when the helicopter is in the "parking" phase. On average, a VIP helicopter performs two flights (an outbound and return flight) per day of operation. Each flight will include chaining of the following events:

- Event 1: "Start the navigation computer" (change to temperature stress)
- Event 2: "Start the engine" (change to vibration stress)
- Event 3: "Takeoff" (change to vibration and temperature stress)
- Event 4: "Landing" (change to vibration and temperature stress)
- Event 5: "Stop the engine" (change to vibration stress)
- Event 6: "Switch the computer off" (change to temperature stress)

And return to the parking phase.

Therefore there are 7 steps separated by the 6 events:

Event		**Step**	
1	Switch the navigation computer on	1	Parking
		2	Pre-flight tests of electronic systems
2	Start the engine	3	Preparation for takeoff
3	Takeoff	4	Outward flight
4	Landing	5	Ground - Engine On
5	Stop the engine	6	Post-flight tests of electronic systems
6	Switch the computer off	7	Parking

This chronology takes place twice per day of operation (Outward and return flights).

There are no events to be considered for "non-operation" days, except for the outside temperature variation during the day. Therefore, there is only one phase, the Parking phase.

Quantification of step durations

Principle: To collect or predict the average duration of each identified step.

Non-operating day:

Step		Duration
1	Parking	1440 minutes

Operating day:

Step		Duration
1	Parking	
2	Tests of electronic systems 1	1 minute
3	Preparation for takeoff 1	11 minutes
4	Flight 1	60 minutes
5	Ground - Engine On 1	3 minutes
6	Tests then Stop systems 1	1 minute
7	Parking	
8	Tests of electronic systems 2	1 minute
9	Preparation for takeoff 2	11 minutes
10	Flight 2	60 minutes
11	Ground - Engine On 2	3 minutes
12	Tests then Stop systems 2	1 minute
13	Parking	

Grouping of steps into phases

Principle: Steps are grouped into three phases.

1. Identification of usage cycles.
   The first step in doing this is to identify steps in which the equipment returns to its initial life situation, for each typical day. In general, the initial life situation corresponds to the system at rest.
2. Identification of external stress variations and causes of variations.
   For each step, the objective is to identify stress variations (thermal, vibration, humidity, chemical or application type) compared with stress variations in the initial life situation (that is the reference) and the causes that initiate them.
3. Identification of phases to be grouped.
   Phases to be grouped are phases inside a particular usage cycle and for which causes generating external stresses are identical.

Furthermore, two steps may be grouped (to simplify the life profile) if it can be anticipated that the impact on the final result of the prediction is not significant. This may be the case if:

- The difference between external stresses applied to the equipment in these two situations is small.
- The duration of one of the situations is sufficiently short so that the impact becomes negligible due to time weighting.

VIP helicopter:

1. Identification of usage cycles.
   The initial life situation of the equipment is the "Parking" step. In an operating day, there are three steps of this type that delimit usage cycles, namely steps 1, 7 and 13. Consequently, during this day, there are two usage cycles, including a first usage cycle from phase 2 to phase 6 (the first flight) and a second usage cycle from phase 8 to phase 12 (the second flight).

2. Identification of external stress variations and causes of these variations. The following table describes the variations and their causes for an operating day.

Step		Stress variation relative to the Parking phase	Cause of variation
1	Parking	None	None
2	Pre-flight tests of electronic systems 1	▪ Temperature ▪ Humidity	♦ Heat dissipation from equipment in the zone
3	Preparation for takeoff 1	▪ Temperature ▪ Humidity ▪ Vibrations	♦ Heat dissipation from equipment in the zone ♦ Vibrations generated by the engine (on the ground)
4	Flight 1	▪ Temperature ▪ Humidity ▪ Vibrations	♦ Heat dissipation from equipment in the zone ♦ Vibrations generated by the engine (in flight) ♦ Temperature drop due to increased altitude
5	Ground - Engine On 1	▪ Temperature ▪ Humidity ▪ Vibrations	♦ Heat dissipation from equipment in the zone ♦ Vibrations generated by the engine (on the ground)
6	Post-flight tests electronic systems 1	▪ Temperature ▪ humidity	♦ Heat dissipation from equipment in the zone
7	Parking	None	None
8	Pre-flight tests of electronic systems 2	▪ Temperature ▪ humidity	♦ Heat dissipation from equipment in the zone
9	Preparation for takeoff 2	▪ Temperature ▪ Humidity ▪ Vibrations	♦ Heat dissipation from equipment in the zone ♦ Vibrations generated by the engine (on the ground)
10	Flight 2	▪ Temperature ▪ Humidity ▪ Vibrations	♦ Heat dissipation from equipment in the zone ♦ Vibrations generated by the engine (in flight) ♦ Temperature drop due to increased altitude

Step		Stress variation relative to the Parking phase	Cause of variation
11	Ground - Engine On 2	▪ Temperature ▪ Humidity ▪ Vibrations	♦ Heat dissipation from equipment in the zone ♦ Vibrations generated by the engine (on the ground)
12	Post-flight tests of electronic systems 2	▪ Temperature ▪ Humidity	♦ Heat dissipation from equipment in the zone
13	Parking	None	None

The "humidity" stress varies with the "temperature" stress because an increase in the air temperature will reduced the relative humidity.

3. Grouping into phases.
Steps (2 and 6), (8 and 12), (3 and 5), (9 and 11) belong in pairs to the same operating cycle, and introduce identical causes of stress variations. Consequently, they must be grouped together. Similarly, the parking phases must be grouped together. It is then possible to build up the FIDES life profile composed of 8 phases as shown in the following tables.

Non-operating day:

Phase		Duration
1	Off-24h	1440 minutes

Non-operating day:

Phase		Duration
1-7-13	Parking operation	the rest
2-6	Tests of electronic systems 1	1 + 1 = 2 minutes
3-5	Preparation for takeoff 1	11 + 3 = 14 minutes
4	Flight 1	60 minutes
8-12	Tests of electronic systems 2	1 + 1 = 2 minutes
9-11	Preparation for takeoff 2	11 + 3 = 14 minutes
10	Flight 2	60 minutes

Furthermore, steps 2-6, and 8-12 are carried out during very short durations (2 minutes), it is therefore possible to anticipate the limited impact and group them together: step 2 into step 3 and step 8 into step 9.

Following this approach, phases for the simplified FIDES life profile are given in the table below.

Non-operating day:

Phase		Duration
1	Off-24h	1440 minutes

Operating day:

Phase		Duration
1	Off	1440 - 152 = 1288 minutes

Phase		Duration
3	Ground-On1	16 minutes
4	Flight1	60 minutes
9	Ground-On2	16 minutes
10	Flight2	60 minutes

Calculation of phase durations

The final step is to calculate the time spent per year (t_{annual_phase}) in each identified phase by multiplying the daily duration of phases by their annual occurrence.

Phase	Daily duration	No. of days per year	t_{annual_phase}
Off - 24h	1440 minutes	265	6360 h
Off	1288 minutes	100	2146 h
Ground-On1	16 minutes	100	27 h
Flight1	60 minutes	100	100 h
Ground-On2	16 minutes	100	27 h
Flight2	60 minutes	100	100 h

3.1.2. Quantification of temperature data

Component ambient temperatures are produced from daily equipment temperature graphs. This is achieved by using three types of input data:

- Climatic data: Temperature and humidity external to the system. These vary as a function of the climate in the geographic zone of operations.
- Zone data: data related to the location of the system containing the equipment used to determine temperature variations with respect to the outside temperature that will be applied to the zone during the different phases of the life profile.
- Equipment data: data related to the equipment to determine its internal temperature rise above the zone temperature due to its heat dissipation and/or where appropriate, its sensitivity to humidity and chemicals.

There are two possible cases for calculating $T_{ambient}$:

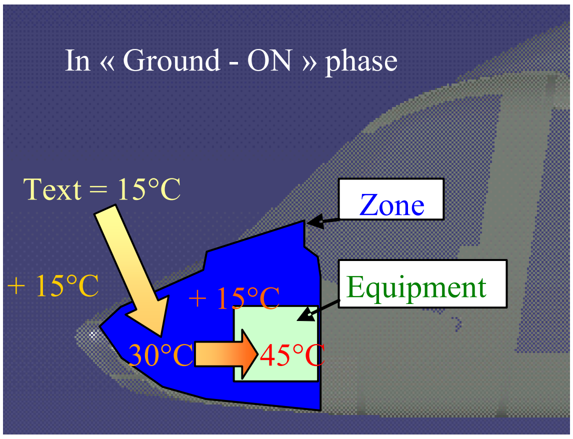
- Case 1: In the phase considered, the temperature varies from an initial temperature to a stable final temperature. The ambient temperature to be considered is then this final stable temperature. However, if the phase is too short for the temperature to have time to stabilise, the temperature to be considered may for example be estimated to be 70% of the final value reached during this phase (non-stabilised).
- Case 2: In the phase considered, the temperature varies around an average value. Thus the ambient temperature to be considered is this average temperature.

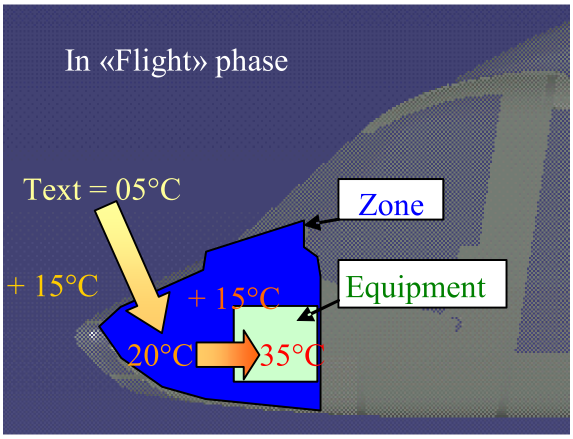
Note:

- The outside temperature varies as a function of the altitude.
- The temperature in the zone may be affected by kinetic heating.

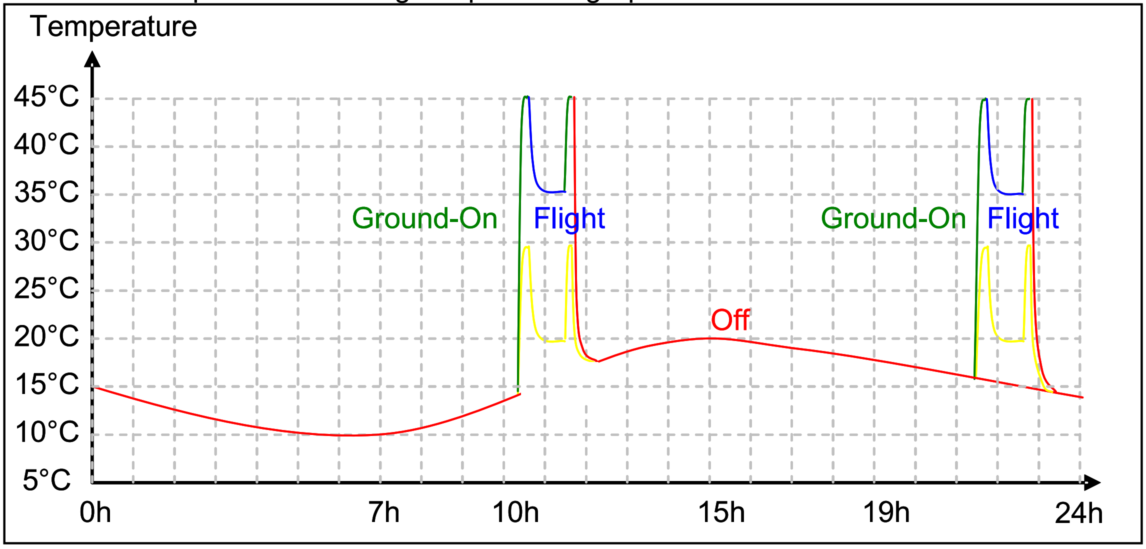
VIP helicopter:

- Climatic data: The average outside temperature considered is 15°C and the day/night variation is 10°C.
- Zone data: When the equipment in the zone containing the navigation computer is switched on, its total dissipation creates a temperature increase of 15°C in the zone that is reached in 5 minutes. Since the increase in altitude during flight is equal to 1500 m on average, this results in a cooler outside temperature and therefore cools the zone by 10°C. Kinetic heating is not significant.
- Equipment data: Dissipation specifically from the computer generates a temperature rise in the equipment equal to 15°C in 3 minutes.





That allows to plot the following temperature graph:



The red curve shows the ambient temperature external to the system during the parking phase.
The yellow curve shows the temperature in the system zone.
The other curves (green, blue) show the temperature inside the equipment during the different phases.

$T_{ambient}$ in each phase in the life profile can then be quantified:

- Parking (red curve): During 24h, the temperature varies from 10 to 20°C with an average of 15°C but never stabilises. In this case **T_{amb} = 15°C**.
- Ground-On 1 (green curve): The temperature starts at 15°C and increases by 30°C (+15°C zone and +15°C equipment) to tend towards 45°C. However, since the temperature does not have the time to become steady, the temperature considered for this phase is calculated as being 15°C + 0.70 x 30°C = 36°C. Therefore **T_{amb} = 36°C**.
- Flight (blue curve): The component temperature drops by 10°C due to the increased altitude and stabilises at 35°C. **Tamb = 35°C**.

3.1.3. Quantification of temperature cycling data

There are two steps in the calculation of temperature cycling data (ΔT, $T_{max\text{-}cycling}$, N_{cy} and θ_{cy}):

- Identification of temperature cycles. A temperature cycle begins with the occurrence of an initiating event that generates a temperature variation and terminates when the initiating activity no longer exists and return to its initial temperature value. Consequently, each temperature cycle corresponds to a phase in the life profile generated in §1.4.
- The plot of temperature cycles on temperature graphs is used to quantify temperature cycling data.

Notes:

- The time taken by the system to return to its initial temperature is accounted for within the cycle time: θcy. Consequently, the temperature cycle of a phase can overlap onto the next phase due to the thermal inertia of the system.
- It is possible that there is no temperature cycle for a particular phase in the life profile, if this phase is created due to a non-thermal cause. Temperature cycling data for this phase will therefore contain null values.

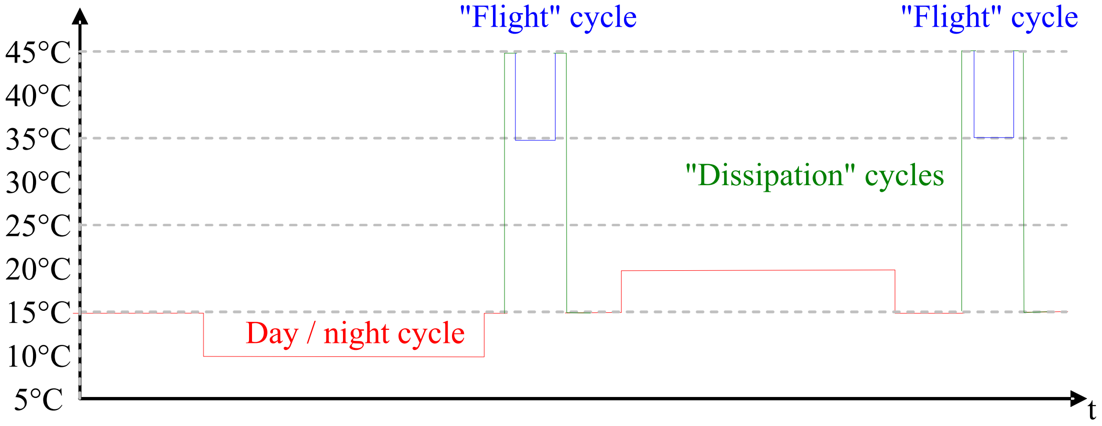
VIP helicopter:

1. Identification of temperature cycles.
   Temperature cycles associated with each phase in the life profile can be identified using the phase sequence formally defined in table below, but only keeping the causes of temperature variations.

Phase	Disturbing event generating a temperature cycle	Causes of temperature cycling
Off - 24h	Day / night variation	- Outside temperature rise due to the sun

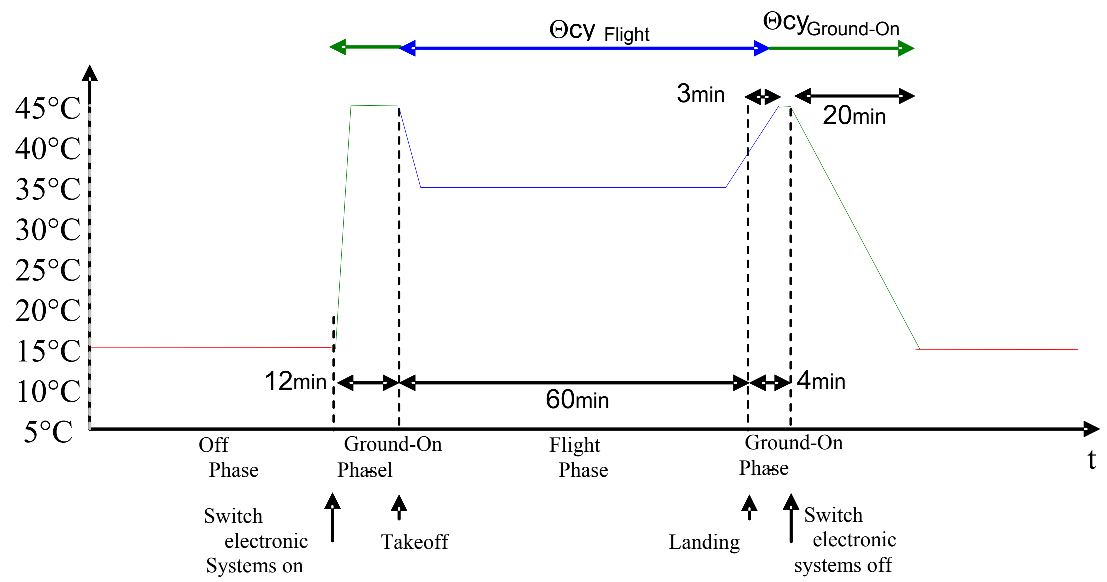
Phase	Disturbing event generating a temperature cycle	Causes of temperature cycling
Off	Day / night variation	- Outside temperature rise due to the sun
Ground-On1	Switching electronic systems on / off	- Heat dissipation from equipment
Flight1	Takeoff / landing	- Heat dissipation from equipment - Change in altitude
Ground-On2	Switching electronic systems on / off	- Heat dissipation from equipment
Flight2	Takeoff / landing	- Heat dissipation from equipment - Cooling due to increased altitude

2. Plot temperature cycles.
   Temperature cycles can be superimposed on the temperature spectrum for the "operating" day.



Thermal inertia data:

- Once on the ground, the time to return to the initial temperature of 45°C is estimated at 3 minutes.
- Once the equipment has been switched off, the time necessary to return to the initial temperature of 15°C is estimated at 20 minutes.



The duration of temperature cycles can be quantified: θcy.

This figure shows that durations of temperature cycles overlap onto the next phase, due to the time taken for the temperature to return to its initial value. Thus,
Θ_{cy} (Flight) = 60 + 3 = 63 min
Θ_{cy}(Ground-On) = 12 + 4 + 20 - 3 = 33 min

The "Flight" cycle shown in blue begins with the "takeoff" event. This cycle includes part of the time spent in "Ground-On" to warm up to 45°C because the cycle terminates when the temperature returns to the initial temperature.

- $T_{max\_cycling}$ = 45°C
- ΔT = Tmax-Tmin = 10°C
- N_{cy} = 100 cycles per year
- Θ_{cy} = 60 + 3 minutes = 63 minutes = 1.05 h (includes the time to return to 45°C in the Ground-On phase)

The "Dissipation" cycle begins with the "Switch electronic systems on" event and is interrupted by the "flight" cycle and then resumes until returning to its initial temperature of 15°C.

- $T_{max\_cycling}$ = 45°C
- ΔT = 30°C
- N_{cy} = 100 cycles per year
- Θ_{cy} = 12 + 4 + 20 - 3 = 33 min = 0.55 h (includes the time to return to 15°C in the parking phase, and does not include the 3 minutes absorbed by the "flight" cycle)

The "day / night" cycle in red forms the rest of the time.

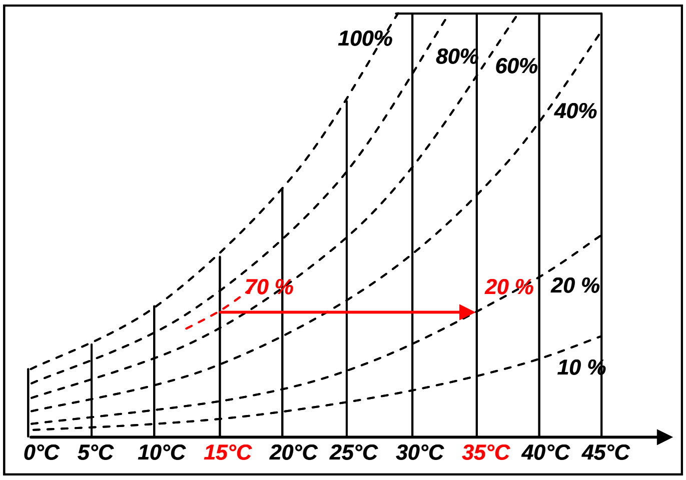
- $T_{max\_cycling}$ = 20°C
- ΔT = 10°C
- N_{cy} = 100 cycles per year
- Θ_{cy} = 24 - 2 x 1.05 - 2 x 0.55 = 20.8 h (the total time in the other 4 cycles considered is subtracted from the 24 hours)

3.1.4. Quantification of humidity data

The following must be known to calculate the relative humidity to be used in the FIDES life profile:

- The relative humidity outside the equipment.
- The temperature outside the equipment.
- The temperature rise inside the equipment.

VIP helicopter:
During the parking phase, the average relative humidity for a temperate climate is taken to be 70% at 15°C.
The ambient temperature due to warming up caused by dissipation from equipment is 36°C in the Ground-On phase and 35 °C in the Flight phase.
The nomogram below can then be used to calculate that the humidity resulting from this drying is 20%.



3.1.5. Exposure to overstresses (application factor)

The application factor was produced as follows:

Criterion	Level for the Parking phase	Level for Ground-On phases	Level for Flight phases
User type in the phase considered	Moderate (general respect of rules)	Moderate (general respect of rules)	Moderate (general respect of rules)
User qualification level in the phase considered	Moderate	Moderate	Favourable (pilot)
System mobility	Low	Low	Severe
Product handling	Favourable (product not handled)	Favourable (product not handled)	Favourable (product not handled)
Type of electrical network in the system	Favourable (not powered)	Severe (network disturbed)	Moderate (network slightly disturbed)

Criterion	**Level for the Parking phase**	**Level for Ground-On phases**	**Level for Flight phases**
Product exposure to human activity	Moderate (for example maintenance)	Low	Low
Product exposure to machine disturbances	Low	Moderate (indirect exposure)	Moderate (indirect exposure)
Product exposure to bad weather	Moderate (indirect exposure)	Moderate (indirect exposure)	Moderate (indirect exposure)
Value of $\Pi_{application}$	**2.33**	**2.71**	**2.51**

3.1.6. Simplification and finalisation of the FIDES life profile

Two lines in the life profile have the same impact on reliability if:

- They have the same physical stress values.
- They have the same chemical pollution criteria.
- They have the same values of $\Pi_{application}$.

Under these conditions, the two lines can be merged into a single line that will have

- Physical stress values common to the two merged lines or an average weighted by the duration (for small differences).
- For the cycle duration, the average weighted by the number of cycles (only if the differences are small, otherwise there is no reason for grouping them together).
- A $t_{annual\ phase}$ with a value equal to the sum of the two values of $t_{annual\ phase}$ of the merged lines
- An N_{cy} with a value equal to the sum of the two values of N_{cy} of the merged lines

VIP helicopter:
Considering a vibration amplitude of 0.5 Grms in Ground-On and 6 Grms in Flight, a $\Pi_{application}$ calculated under the conditions for a VIP helicopter, and the chemical level:

- Saline pollution: low,
- Environmental pollution: moderate
- Application pollution: moderate
- Equipment: non-hermetic

3.1.7. Table

Helicopter – Onboard navigation computer – VIP use														
		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
Off -24h	6360	Off	15	70	10	265	24	20	0	Low	Moderate	Moderate	Non Hermetic	2.33
Off	2146	Off	15	70	10	100	20,6	20	0	Low	Moderate	Moderate	Non hermetic	2.33
Ground-On 1	27	On	36	20	30	100	0,6	45	0,5	Low	Moderate	Moderate	Non hermetic	2.71
Flight 1	100	On	35	20	10	100	1.1	45	6	Low	Moderate	Moderate	Non hermetic	2.51
Ground-On2	27	On	36	20	30	100	0,6	45	0.5	Low	Moderate	Moderate	Non hermetic	2.71
Flight 2	100	On	35	20	10	100	1.1	45	6	Low	Moderate	Moderate	Non hermetic	2.51

The previous life profile may be simplified without making any significant modification to the final result by merging lines that describe similar stresses:

Helicopter – Computer in avionics bay - VIP use - Temperate climate (outside temperature of 15°C)														
		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{\text{application}}$
Off	8506	Off	15	70	10	365	23.1	20	0	Low	Moderate	Moderate	Non Hermetic	2.33
Ground-On	54	On	36	20	30	200	0.6	45	0.5	Low	Moderate	Moderate	Non hermetic	2.71
Flight	200	On	35	20	10	200	1.1	45	6	Low	Moderate	Moderate	Non hermetic	2.51

The principle used to create the previous life profile can be used to create life profiles for different equipment for different uses of the same helicopter.

Influence of the climate.
The following profile is applicable to the same product as above, but for a tropical climate. This profile breaks down the year into three seasons in order to emphasise the influence of climate

Helicopter - Computer in avionics bay - VIP use - Tropical climate

		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
Summer Off	2 127	off	30	90	12	91	23.1	36	0.0	Low	Low	Low	Non hermetic	2.33
Summer Ground-On	13	on	51	35	30	50	0.6	60	0.5	Low	Low	Low	Non hermetic	2.71
Summer Flight	50	on	50	35	10	50	1.1	60	6.0	Low	Low	Low	Non hermetic	2.51
Spring and Autumn Off	4 253	off	25	90	12	183	23.1	31	0.0	Low	Low	Low	Non hermetic	2.33
Spring and Autumn Ground On	27	on	46	35	30	100	0.6	55	0.5	Low	Low	Low	Non hermetic	2.71
I Spring and Autumn Flight	100	on	45	35	10	100	1.1	55	6.0	Low	Low	Low	Non hermetic	2.51
Winter Off	2 127	off	17	90	12	91	23.1	23	0.0	Low	Low	Low	Non hermetic	2.33
Winter Ground-On	13	on	38	35	30	50	0.6	47	0.5	Low	Low	Low	Non hermetic	2.71
Winter Flight	50	on	37	35	10	50	1.1	47	6.0	Low	Low	Low	Non hermetic	2.51

Influence of the location in the helicopter.
The following profile is applicable to the same VIP helicopter in a temperate climate, but is applicable for a product in the cockpit (no longer in the avionics bay).

Helicopter - Screen in Instrument Panel - VIP use - Temperate climate (outside temperature 15°C)

		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
Off	8 506	Off	15	70	10	365	23.2	20	0	Low	Moderate	Moderate	Non hermetic	2.33
Ground-On	54	On	24	40	10	200	0.4	25	0.5	Low	Moderate	Moderate	Non hermetic	3.21
Flight	200	On	25	40	0	200	1.1	25	3	Low	Moderate	Moderate	Non hermetic	3.28

Influence of the mission.

The following profile is applicable to the same product under the same climatic conditions as the initial example, but for a helicopter intended for another mission (in this case Transport).

Helicopter - Computer in avionics bay – Transport Use - Temperate climate (outside temperature of 15°C)

		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
Off	8 035	Off	15	70	10	365	21.5	20	0	Low	Moderate	Moderate	Non hermetic	2.33
Ground-On	125	On	36	20	30	600	0.5	45	0.5	Low	Moderate	Moderate	Non hermetic	2.71
Flight	600	On	35	20	10	900	0.7	45	6	Low	Moderate	Moderate	Non hermetic	2.51

Influence of the mission.

The following profile is applicable to the same product under the same climatic conditions as the initial example, but for a helicopter intended for another mission (in this case Offshore).

Helicopter - Computer in avionics bay - Offshore use- Temperate climate (outside temperature of 15°C)														
		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
Off	7 360	Off	15	70	10	365	19.7	20	0	Low	Moderate	Moderate	Non hermetic	2.33
Ground-On	200	On	36	20	30	500	0.6	45	0.5	Low	Moderate	Moderate	Non hermetic	2.71
Flight	1 200	On	35	20	10	1000	1.3	45	6	High	Low	Moderate	Non hermetic	2.51

3.2. Life profile of equipment (in avionics bay) mounted in a medium haul civil aircraft

3.2.1. Description of the profile as a number and duration of cycles

Profile definition

The "typical" life profile of equipment (in avionics bay) mounted on a medium haul civil aircraft is composed of the following phases:

- Operating phase on the ground when switching ON and OFF,
- Operating phase on the ground during stopovers (with the equipment remaining in the ON position),
- Taxiing phase (between the moment at which the aircraft leaves the boarding zone and the moment at which the aircraft is ready to takeoff),
- Flight phase, during takeoff (climb) and landing (descent),
- Stable flight phase (cruising speed),
- Non-operating phase on the ground: the equipment is on the OFF position (daily switching off and maintenance phases).
- It is assumed that a medium / long haul civil aircraft is operated at a daily rate of 3 flights per day with 2 intermediate stopovers (no or little change in time zones).

This type of aircraft is in service for 350 days per year, the remaining time possibly waiting on standby or in daily maintenance.

" Ground-Operation-ON/OFF" phase

The preparation time for the first flight of the day from when the aircraft is switched off after the last flight of the day (duration of the "Ground-Operation-ON/OFF" phase) is assumed to be 2 hours. This duration includes the first embarking and the last disembarking of the plane that takes place in parallel with service activities related to operation of the aircraft.
With 1 daily cycle, the total duration of the phase is 700 hours per year (2 x 350).

"Ground-Operation-Stopover" phase

The average duration of this phase (Turn Around Time) is assumed to be 2 hours (disembarking, cleaning, catering, reembarking).
With 2 cycles per day (between 3 flights), the total number of cycles is 700 per year (2 x 350). The total duration of the phase is 1400 hours per year (2 x 700).

"Ground-Taxiing" phase

The average taxiing duration is assumed to be 0.30 hours (18 minutes).
With a taxiing phase before and after each flight, the number of cycles is 6 per day, namely 2100 per year (2 x 3 x 350). The total duration of the phase is 630 hours per year (2100 x 0.30).

"Flight-Climb/Descent" phase

The duration of the "Flight-Climb/Descent" phase is assumed to be 1 hour/flight.
With 3 flights per day, the number of cycles is 1050 per year (3 x 350). The total duration of the phase is 1050 hours per year (1050 x 1).

"Stable flight " phase

The total duration of the average flight is assumed to be 4 hours, including 3 hours of "Stable flight".
With 3 flights per day, the number of cycles is 1050 per year (3 x 350). The total duration of the phase is 3150 hours per year (1050 x 3).

"Ground-Dormant" phase
This phase includes daily stops and the 15 days per year not in operation for which no special phase was created in this example.
The total duration of the phase is 1830 hours per year, so that the total duration of all phases is equal to 8760 hours per year (in other words 24 x 365). In this case, the cycle duration is 5.01 hours (1830 / 365).

3.2.2. Definition of the ON / OFF profile

For the most usual equipment in the avionics bay, it is assumed that the equipment is OFF during the "Ground-Dormant" phase and ON during all other phases.

3.2.3. Definition of the temperature profile and temperature cycling

The basic temperature cycle is day/night cycle during the "Ground-Dormant" phase. The ambient temperature is assumed to be 15°C with a cycling Delta T of 10°C and a maximum cycling temperature of 20°C (therefore the temperature varies between 10°C at night and 20°C during the day).

When the avionics bay is powered, the ventilation is started up. The transient phase from the beginning of start up (during which the computers start to warm up while ventilation has not reached its full efficiency) is neglected (furthermore, computers can start in a cold or warm ambient temperature before regulation takes place).

The internal temperature rise in the equipment is assumed to be 15°C (ambient temperature of components relative to the ambient temperature outside the equipment).
Furthermore, considering the effect of ventilation, the ambient temperature selected for the "Ground-Operation-ON/OFF" phase is equal to 40°C, which represents a cycling ΔT of 25°C relative to the ambient temperature in the "Ground-Dormant" phase (15°C). The maximum cycling temperature is equal to the ambient temperature (when ON).

The temperature is assumed to be constant for all the "Ground-Operation-ON/OFF" "Taxiing", "Climb/Descent" and "Stable-Flight" phases. The selected ambient temperature is 40°C, which represents a cycling Delta T of 0°C relative to the ambient temperature in the "Ground-Operation-ON/OFF" phase. The maximum cycling temperature is equal to the ambient temperature.

For the "Ground-Operation-Stopover" phase, it is assumed that there is a loss of efficiency in the temperature regulation caused by the aircraft doors being opened (passenger cabin and avionics bay). The ambient temperature considered (also the maximum cycling temperature) is 55°C, which represents a cycling Delta T of 15°C relative to the ambient temperature during the "Ground-Operation-ON/OFF", "Taxiing", "Flight-Climb/Descent" and "Stable-Flight" phases.

3.2.4. Definition of the humidity profile

When the equipment is OFF ("Ground-Dormant" phase), the average humidity is assumed to be of about 70%.

When the equipment is ON on the ground with the aircraft doors open ("Ground-Operation-ON/OFF" and "Ground-Operation-Stopover" phases), it is assumed that the internal temperature rise causes the relative humidity to change to 30%.

When the equipment is ON in flight ("Flight-Climb/Descent" and "Stable-Flight" phases or ON on the ground with the aircraft doors closed ("Ground-Taxiing" phase), it is assumed that the relative humidity drops to a level of about 10% (very dry air due to the ventilation system).

3.2.5. Definition of the vibration profile

The vibration stress level is assumed to be zero during the "Ground-Dormant" phase.

The vibration stress level is assumed to be very low during the "Ground-Operation-ON/OFF" and "Ground-Operation-Stopover" phases: 0.05 G_{RMS}.

The vibration stress during the "Taxiing" phase is assumed to 5 G_{RMS}.

The vibration stress during the "Climb/Descent flight" and "Stable-Flight" phases is assumed to be 0.6 G_{RMS}.

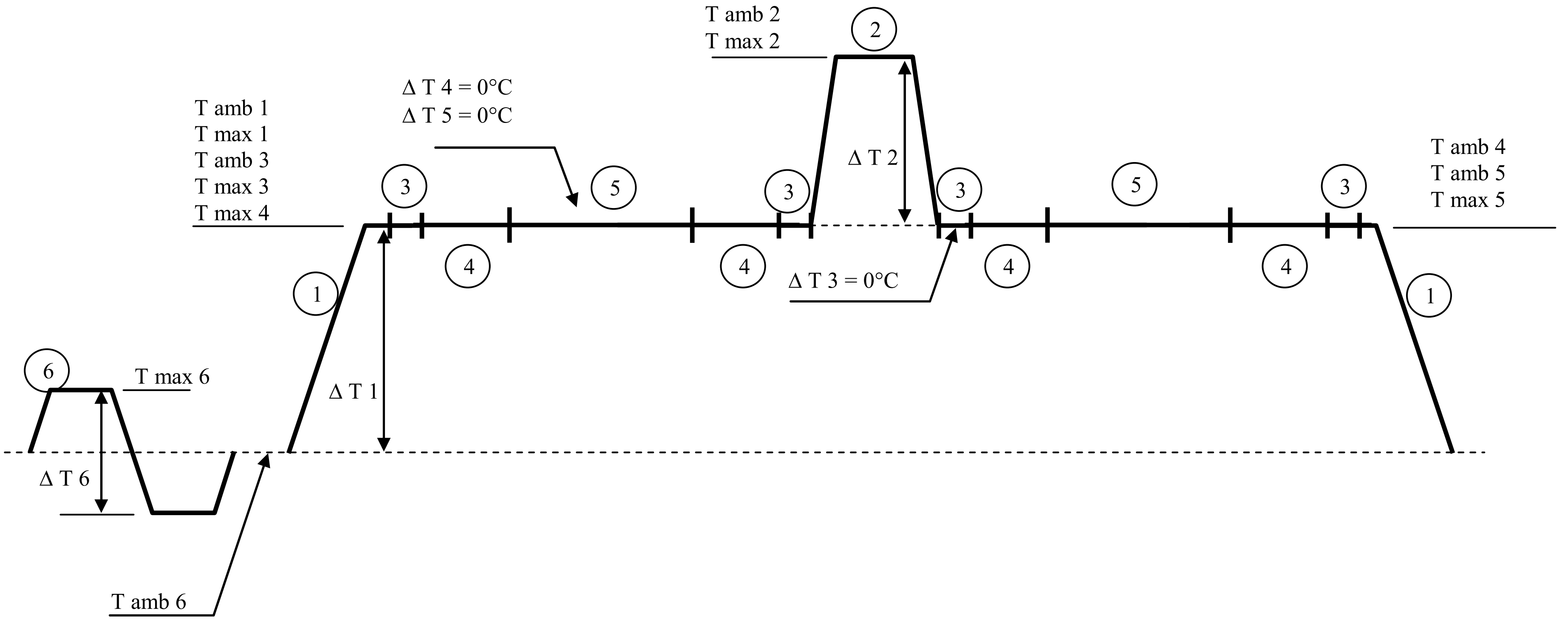
3.2.6. Definition of the chemical profile

The impact of the "environmental pollution" factor comes into play at the time that the aircraft is on the ground during the "Ground-Operation-ON/OFF", "Ground-Operation-Stopover" and "Ground-Dormant" phases. In these cases, the equipment can be directly subject to the outside environment in an airport type environment.

Concerning application pollution, only the "Ground-Dormant" phase might require action by persons close to equipment compartments.

3.2.7. Graph

The life profile is illustrated by the following diagram:



3.2.8. Table

Medium haul civil aircraft. computer in avionics bay														
		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{\text{application}}$
① Ground - Operation ON/OFF	700	On	40	30	25	350	2.00	40	0.05	Low	Moderate	Moderate	Non hermetic	4.8
② Ground - Operation Stopover	1400	On	55	30	15	700	2.00	55	0.05	Low	Moderate	Moderate	Non hermetic	2.0
③ Ground - Taxiing	630	On	40	10	-	2100	0.30	-	5	Low	Low	Moderate	Non hermetic	1.2
④ Flight - Climb/Descent	1050	On	40	10	-	1050	1.00	-	0.6	Low	Low	Moderate	Non hermetic	1.1
⑤ Stable - Flight	3150	On	40	10	-	1050	3.00	-	0.6	Low	Low	Moderate	Non hermetic	1.1
⑥ Ground - Dormant	1830	Off	15	70	10	365	5.01	20	-	Low	Moderate	Low	Non hermetic	3.3

3.3. Life profile of equipment (in avionics bay) mounted on a civil aircraft with turboprop engines

3.3.1. Description of the profile in number and duration of cycles

Definition of the profile

The "typical" life profile of equipment (in the avionics bay) installed on a civil turboprop aircraft is composed of the following phases:

- Operating phase on the ground when switching ON and OFF.
- Operating phase on the ground during stopovers (with the equipment remaining in the ON position).
- Taxiing phase (between the moment at which the aircraft leaves the boarding zone and the moment at which the aircraft is ready to takeoff).
- Flight phase, during takeoff (climb), stable flight (cruising speed), and landing (descent).
- Non-operating phase on the ground: the equipment is on the OFF position (daily switching off and maintenance phases).

It is assumed that a civil turboprop aircraft is operated at a daily rate of 4 flights per day with 2 stopovers (short distances). The aircraft is switched OFF after each cycle of 2 flights including one intermediate stopover (this cycle being repeated twice per day).
This type of aircraft is in service for 350 days per year, the remaining time possibly waiting on standby or in daily maintenance.

"Ground-Operation-ON/OFF" phase

This phase represents the preparation time for each flight (switching equipment ON: twice per day) and shutting the aircraft down (equipment switched OFF twice per day). The duration of this "Ground-Operation-ON/OFF" phase is assumed to be 0.6 hours (36 minutes). This duration includes aircraft embarking and disembarking phases done in parallel with service activities related to operation of the aircraft.
With 2 daily cycles, the total number of cycles is 700 per year (2 x 350). The total duration of the phase is 420 hours per year (0.6 x 700).

"Ground-Operation-Stopover" phase

The average duration of this phase (TAT) is assumed to be 0.5 hours namely 30 minutes (disembarking, cleaning, catering, reembarking).
With 2 cycles per day, the total number of cycles is 700 per year (2 x 350). The total duration of the phase is 350 hours per year (0.5 x 700).

"Ground-Taxiing" phase

The average taxiing duration is assumed to be 0.10 hours (6 minutes).
With a taxiing phase before and after each flight, the number of cycles is 4 per day, namely 2800 per year (2 x 4 x 350). The total duration of the phase is 280 hours per year (2800 x 0.10).

"Climb/Stable flight/Descent" phase

The total duration of the average flight is assumed to be 1.2 hours including about 0.2 hours (namely 12 minutes) of "Climb/Descent" and 1 hour of "Stable flight".
No precise distinction can be made between the "Climb/Descent" and "Stable flight" phases for a typical civil turboprop aircraft profile, and considering the durations

involved, it was decided to include a single phase called the "Climb /Stable flight/Descent".
With 4 flights per day, the number of cycles is 1400 per year (4 x 350). The total duration of the phase is 1680 hours per year (1400 x 1.2).

"Ground-Dormant" phase
This phase includes daily stops and the 15 days per year not in operation.
The total duration of the phase is 6030 hours per year so that the total duration of all phases is equal to 8760 hours per year (in other words 24 x 365). In this case, the cycle duration is 16.52 hours (6030 / 365).

3.3.2. Definition of the ON / OFF profile

For the most usual equipment in the avionics bay, it is assumed that the equipment is OFF during the "Ground-Dormant" phase and ON during all other phases.

3.3.3. Definition of the temperature profile and temperature cycling

The basic temperature cycle is day/night cycle during the "Ground-Dormant" phase. The ambient temperature is assumed to be 15°C with a cycling Delta T of 10°C and a maximum cycling temperature of 20°C (therefore the temperature varies between 10°C at night and 20°C during the day).

When the avionics bay is powered, the ventilation is started up. The transient phase from the beginning of start up (during which the computers start to warm up while ventilation has not reached its full efficiency) is neglected (furthermore, computers can start in a cold or warm ambience before the temperature is regulated).

The internal temperature rise in the equipment is assumed to be 15°C (ambient temperature of components relative to the ambient temperature outside the equipment).
Furthermore, considering the effect of ventilation, the ambient temperature selected for the "Ground-Operation-ON/OFF" phase is equal to 40°C, which represents a cycling ΔT of 25°C relative to the ambient temperature in the "Ground-Dormant" phase (15°C).
The maximum cycling temperature is equal to the ambient temperature (when ON).

The temperature is assumed to be constant for all the "Ground-Operation-ON/OFF" "Taxiing", and "Climb/Stable/Descent". The selected ambient temperature is 40°C, which represents a cycling Delta T of 0°C relative to the ambient temperature in the "Ground-Operation-ON/OFF" phase. The maximum cycling temperature is equal to the ambient temperature.

For the "Ground-Operation-Stopover" phase, it is assumed that there is a loss of efficiency in the temperature regulation caused by the aircraft doors being opened (passenger cabin and avionics bay). The ambient temperature considered (also the maximum cycling temperature) is 55°C, which represents a cycling Delta T of 15°C relative to the ambient temperature during the "Ground-Operation-ON/OFF", “Taxiing”, and "Climb/Stable flight/Descent".

3.3.4. Definition of the humidity profile

When the equipment is OFF (“Ground-Dormant" phase), the average humidity is assumed to be of the order of 70%.
It is assumed that the internal temperature rise makes the humidity change to 30% whenever the equipment is ON, when on the ground ("Ground-Operation-ON/OFF", "Ground-Operation-Stopover", and "Ground-Taxiing" phases) and when in flight ("Climb/Stable flight/Descent" phase).

3.3.5. Definition of the vibration profile

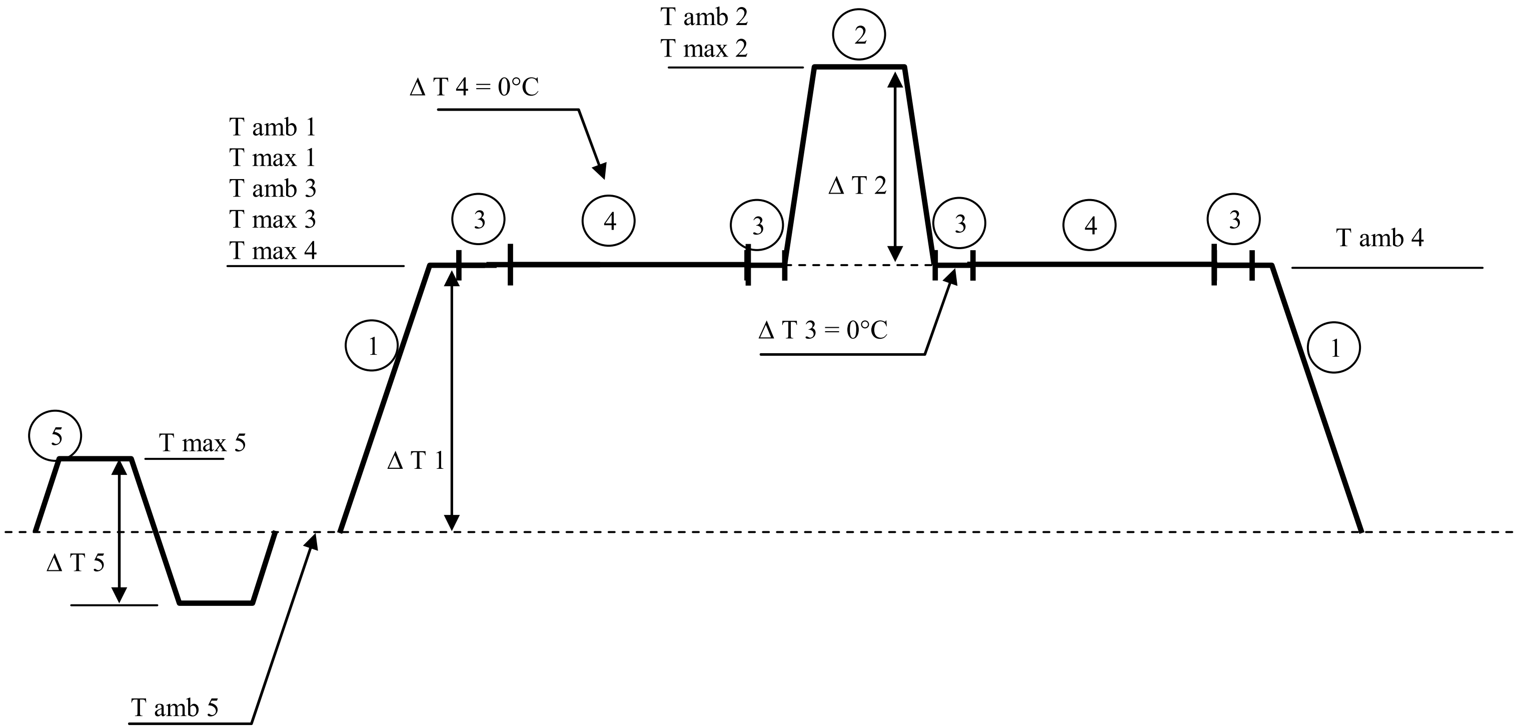
The vibration stress level is assumed to be zero during the "Ground-Dormant" phase.
The vibration stress level is assumed to be very low during the "Ground-Operation-ON/OFF" and "Ground-Operation-Stopover" phases: 0.05 G_{RMS}.
The vibration stress during the "Taxiing" phase is assumed to be 6 G_{RMS}.
The vibration stress during the "Climb/Stable/Descent" flight phases is assumed to be 1.2 G_{RMS}.

3.3.6. Definition of the chemical profile

The impact of the "environmental pollution" factor comes into play at the time that the aircraft is on the ground during the "Ground-Operation-ON/OFF", "Ground-Operation-Stopover" and "Ground-Dormant" phases. In these cases, the equipment can be directly subject to the outside environment in an airport type environment.
Concerning application pollution, only the "Ground-Dormant" phase might require action by persons close to equipment compartments.

3.3.7. Graph

The life profile is illustrated by the following diagram:



3.3.8. Table

Civil turboprop aircraft. Avionics bay														
		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
① Ground-Operation ON/OFF	420	On	40	30	25	700	0.60	40	0.05	Low	Moderate	Low	Non hermetic	4.8
② Ground – Operation Stopover	350	On	55	30	15	700	0.50	55	0.05	Low	Moderate	Low	Non hermetic	2.0
③ Ground - -Taxiing	280	On	40	30	-	2800	0.10	-	6	Low	Moderate	Low	Non hermetic	1.2
④ Flight - Climb/ Stable flight/ Descent	1680	On	40	30	-	1400	1.20	-	1.2	Low	Low	Low	Non hermetic	1.1
⑥ Ground - Dormant	6030	Off	15	70	10	365	16.52	20	-	Low	Moderate	Moderate	Non hermetic	3.3

3.4. Life profile for industrial system type equipment

3.4.1. Description of the profile in number and duration of cycles

Profile definition
The "typical" life profile of an industrial system type equipment is composed of the following phases:
"Control-Monitoring" phase that includes switching ON and OFF and control and monitoring between each effective operating phase,
Effective operating phase of the system in control mode,
Non-operating phase: the equipment is on the OFF position (daily stops and maintenance phases).
It is assumed that an industrial system type equipment (for example control/instrumentation module) is used at a daily working rate of 17 hours with two shifts one after the other during this period. The "Control-Distribution" phase actually occurs 4 times per day. The system is switched OFF at the end of each day.
This type of equipment is in service for 350 days per year, the remaining time possibly being spent on maintenance and/or work on the system.

"Control-Monitoring" phase
This phase represents the time to prepare the system in the morning (switching the equipment ON once per day) and switching it OFF at the end of each day (equipment switched OFF once per day). It also includes intermediate control and monitoring phases on equipment (between each "Control-Distribution" cycle).
The duration of this "Control-Monitoring" phase is assumed to be 7 hours total.
With 1 daily cycle, the total number of cycles is 350. The total duration of the phase is 2450 hours per year (7 x 350).

"Control-Distribution" phase
This phase represents effective operation of the system in control mode. The average duration of this phase is assumed to be 2.5 hours.
With 4 cycles per day, the total number of cycles is 1400 per year (4 x 350). The total duration of the phase is 3500 hours per year (2.5 x 1400).

"Dormant" phase
The number of cycles considered for this phase is 365 (day/night cycle over one year).
The total duration of the phase is 2810 hours per year, so that the total duration of all phases is equal to 8760 hours per year (in other words 24 x 365). In this case, the cycle duration is 7.7 hours (2810 / 365).

3.4.2. Definition of the ON / OFF profile

For this type of industrial equipment, it is assumed that the equipment is OFF during the "Dormant" phase and ON during all other phases.

3.4.3. Definition of the temperature profile and temperature cycling

The basic temperature cycle is the day/night cycle in the "Dormant" phase. The ambient temperature is taken to be 15°C with a cycling Delta T of 10°C and a maximum cycling temperature of 20°C (therefore the temperature varies between 10°C at night and 20°C during the day).

When the system is switched on, it can be assumed that its temperature is the workshop temperature, therefore approximately 15°C. The transient beginning of start up phase (during which the system begins to warm up) is neglected.

The internal temperature rise in the equipment is assumed to be 15°C (ambient temperature of components relative to the ambient temperature outside the equipment).

The ambient temperature selected for the "Control-Monitoring" phase is 30°C, which represents a cycling Delta T of 15°C relative to the ambient temperature of the "Dormant" phase (15°C). The maximum cycling temperature is equal to the ambient temperature (when ON).

The temperature rise for the "Control-Distribution" phase is assumed to be related to operational functioning of the control. The ambient temperature (also the maximum cycling temperature) is taken to be 55°C, which represents a cycling Delta T of 25°C relative to the ambient temperature in the "Control-Monitoring" phase.

3.4.4. Definition of the humidity profile

When the equipment is OFF ("Dormant" phase), it is assumed that the average humidity is of about 80% (equipment positioned in the workshop).

When the equipment is ON ("Control-Monitoring" and "Control-Distribution" phases), it is assumed that the internal temperature rise in the system reduces the humidity to 30%.

3.4.5. Definition of the vibration profile

The vibration stress level is assumed to be zero during the "Dormant" phase.

The vibration stress in the "Control-Monitoring", and "Control-Distribution" phases is assumed to be 0.1 G_{RMS}.

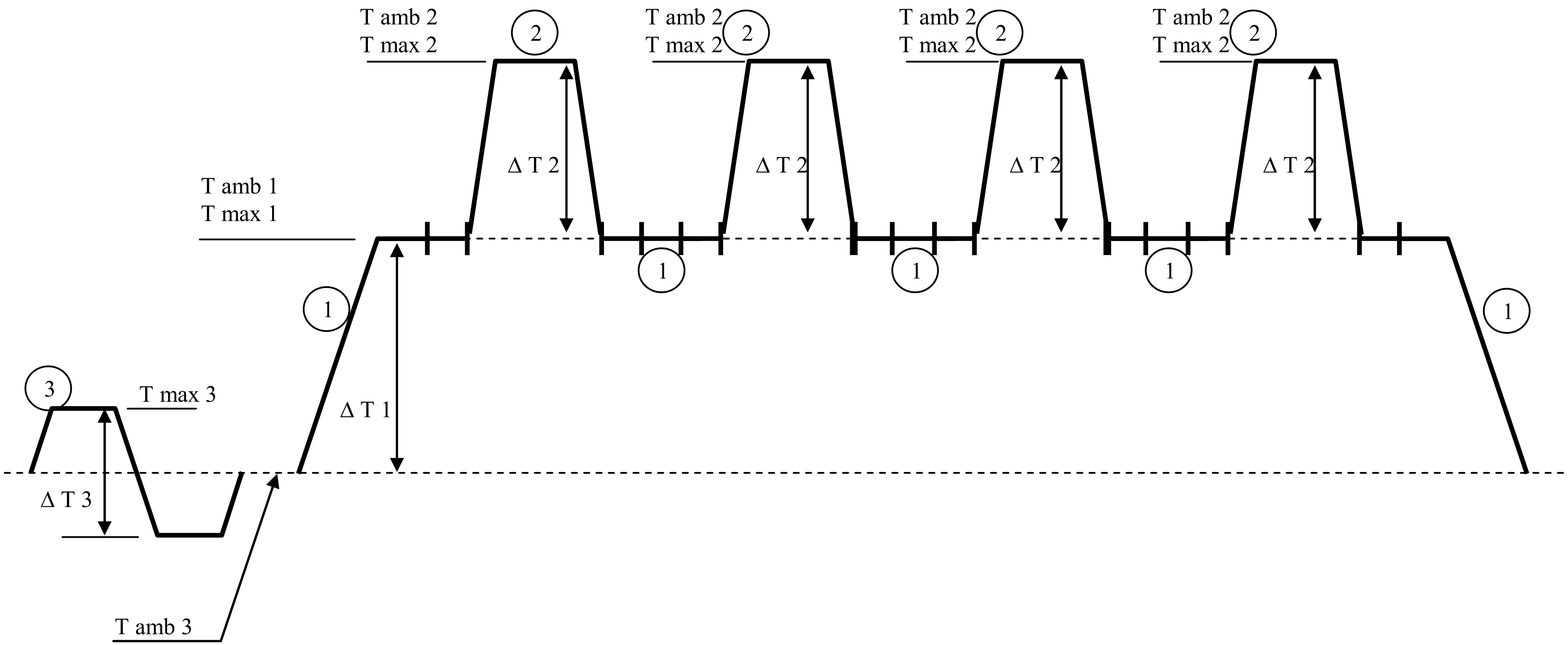
3.4.6. Definition of the chemical profile

When considering the equipment location in a production plant workshop, the impact of the "environmental pollution" factor acts on all 3 phases including "Control-Monitoring", "Control-Distribution" and "Dormant". Therefore the level is set to "high".

All 3 phases in the application zone may require action by persons on the equipment. Therefore the zone is set to "moderate".

3.4.7. Graph

The life profile is illustrated by the following diagram:



3.4.8. Table

Particular industrial system															
		Temperature and Humidity			Temperature cycling				Mechanical	Chemical				Induced
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
① Control-Monitoring	2450	On	30	30	15	350	7.00	30	0.1	Low	High	Moderate	Non hermetic	5.1
② Control-Distribution	3500	On	55	30	25	1400	2.50	55	0.1	Low	High	Moderate	Non hermetic	4.6
③ Dormant	2810	Off	15	80	10	365	7.70	20	-	Low	High	Moderate	Non hermetic	2.6

3.5. Washing machine life profile

3.5.1. Principle

This example life profile is intended to show that the FIDES methodology is applicable even in cases in which its definition appears complex due to the large number of phases to be defined (23 phases for this example). It was constructed by grouping elementary tasks for which physical stresses were identical based on the use of 150 washing cycles per year (nearly 3 weekly washings), distributed as follows:

- 17 "fragile washing" cycles or programs with a duration of 58.5 minutes.
    - Cold wash (30°C).
    - Rinse.
    - Short spin (include a rinse).
- 100 "normal program" cycles with a duration of 104 minutes.
    - Normal wash (50°C).
    - Two rinses.
    - Long spin (include a rinse).
- 33 "very dirty" cycles or programs with a duration of 136.5 minutes.
    - Pre-wash
    - Hot wash (80°C).
    - Two rinses.
    - Long and severe spin (include a rinse).

3.5.2. Parameter values

Temperatures, temperature cycles

The room in which the washing machine is located is assumed to be at 18°C on average, with a daily temperature cycle amplitude of 5°C.

Temperature values given in this profile correspond to the water temperature in the drum, which is not necessarily representative for the electronics in the washing machine. The creation of a realistic profile must take account of the temperature surrounding the electronic components, which may be influenced by factors other than the water in the drum.

The temperature cycling parameters are deduced from the temperature change in the drum between two steps of a wash:

- Heating, when the water is being heated.
- Cooling, when filling with water at 18°C.

Relative humidity

The washing machine in the example is assumed to be located in a laundry in which the humidity is normal during inactivity (70%) and is higher when washing is being done (85% at 18°C). Furthermore, the humidity close to the electronics is assumed to be influenced only by the air temperature.

Vibrations

The random vibration amplitude was generated using the rotation speed of the drum in the phase considered.

Pollution

The pollution level was determined as follows:

- No saline pollution: low level.
- Environmental pollution: moderate level corresponding to an urban zone.
- Application pollution: moderate level corresponding to an inaccessible zone.
- Protection level: non-hermetic (the machine water network itself is leakproof).

Exposure to overstresses (application factor)

The application factor was determined as follows:

Criterion	Level for the inactive phase	Level for operating phases
User type in the phase considered	Moderate, general public user	Moderate, general public user
User qualification level in the phase considered	Favourable, the product does not need qualification	Favourable, the product does not need qualification
System mobility	Favourable, the product is fixed	Favourable, the product is fixed
Product handling	Low, the product is not handled when not in operation	Moderate, the product is handled moderately for its use
Type of electrical network for the system	Favourable, the product is switched off during this phase	Moderate, the product is powered by a network with little disturbance
Product exposure to human activity	Moderate, there is activity close to the product even when it is not being used	Moderate, there is activity close to the product when it is being used
Product exposure to machine disturbances	Low when in non-operating phase	Moderate, during operating phase
Product exposure to the weather	Low, the product is in an indoor room	Low, the product is in an indoor room
Value of $\Pi_{\text{application}}$	**1.9**	**2.7**

3.5.3. Table

Washing machine														
		Temperature and Humidity			Temperature cycling				Mechanical	Chemical				Induced
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
Inactive	8 502.52	Off	18	70	5	365	23.29	20.5	-	Low	Moderate	Moderate	Non Hermetic	1.9
Filling 18°C (drum at 18°C)	21.65	On	18	85	0	433	0.05	18.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Filling 18°C (drum at 30°C)	2.50	On	18	85	0	50	0.05	30.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Filling 18°C (drum at 50°C)	5.00	On	18	85	0	100	0.05	50.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Filling 18°C (drum at 80°C)	1.65	On	18	85	0	33	0.05	80.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Rinsing	50.52	On	18	85	0	433	0.12	18.0	9.0	Low	Moderate	Moderate	Non Hermetic	2.7
Short spin, non-aggressive	0.99	On	18	85	0	17	0.06	18.0	14.0	Low	Moderate	Moderate	Non Hermetic	2.7
Long spin, non-aggressive	11.67	On	18	85	0	100	0.12	18.0	14.0	Low	Moderate	Moderate	Non Hermetic	2.7
Long, severe spin	3.85	On	18	85	0	33	0.12	18.0	16.0	Low	Moderate	Moderate	Non Hermetic	2.7
Wait to open	2.50	On	18	85	0	150	0.02	18.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Emptying (drum at 18°C)	21.65	On	18	85	0	433	0.05	18.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Emptying (drum at 30°C)	2.50	On	30	85	0	50	0.05	30.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Emptying (drum at 50°C)	5.00	On	50	85	0	100	0.05	50.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Emptying (drum at 80°C)	1.65	On	80	85	0	33	0.05	80.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Short wash (drum at 30°C)	6.67	On	30	85	0	50	0.13	30.0	9.0	Low	Moderate	Moderate	Non Hermetic	2.7

Washing machine														
		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
Normal wash (drum at 50°C)	33.33	On	50	85	0	100	0.33	50.0	9.0	Low	Moderate	Moderate	Non Hermetic	2.7
Normal wash (drum at 80°C)	11.00	On	80	85	0	33	0.33	80.0	9.0	Low	Moderate	Moderate	Non Hermetic	2.7
Short rest, drum full (drum at 30°C)	6.67	On	30	85	0	50	0.13	30.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Normal rest, drum full (drum at 50°C)	33.33	On	50	85	0	100	0.33	50.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Normal rest, drum full (drum at 80°C)	11.00	On	80	85	0	33	0.33	80.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Heating to 30°C	2.50	On	30	85	12	50	0.05	30.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Heating to 50°C	13.33	On	50	85	32	100	0.13	50.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7
Heating to 80°C	8.53	On	80	85	62	33	0.26	80.0	0.5	Low	Moderate	Moderate	Non Hermetic	2.7

To make the life profile easier to read, the number of cycles, the cycle duration and the maximum temperature parameters during the phase are completed in even when there is no temperature cycle. Filling the drum with cold water causes cooling but does not constitute a cycle; this cooling terminates the cycle that began with heating.

3.6. Life profile for multi-role fighter aircraft external stores

3.6.1. Principle

For products used on fighter aircraft, there is a calculation convention to calculate an MTBF per hour of flight in a daily mission profile that includes:

- One hour of flight per day.
- Half an hour aircraft maintenance per day.
- The remainder of the day switched off.

Using a conventional and therefore arbitrary life profile very often reduces the realism of the prediction. But it can be practical to compare predicted data with each other. In this case, it is obviously impossible to compare predicted reliability directly with observed reliability.

The profile given in this presentation as an example was forced to respect this convention while describing the various aircraft missions (a little shorter or longer than an hour). This profile was created based on the typical method described for the helicopter case.

3.6.2. Characteristics

Choice and duration of phases

There are several conventions for counting "hours of flight" for a fighter aircraft. These conventions more or less include the operating time on the ground. The convention selected here consists of counting "hours of flight" based on so-called "block to block" durations which include operating times on the ground (other than maintenance) in "flight times".

Three mission types are considered in this example.

- Patrol or escort mission, 1 hour flight (40% of the missions).
  - Wait on the ground.
  - Taxiing.
  - Climb.
  - Cruise (medium speed).
  - Descent.
  - Taxiing
  - Wait on ground.
- Low altitude mission, 1.5 hours flight (30%).
  - Wait on the ground.
  - Taxiing.
  - Climb.
  - Outbound cruise.
  - Low altitude mission (medium speed)
  - Return cruise
  - Descent.
  - Taxiing
  - Wait on ground.
- High altitude mission, 0.75 hours flight (30%).
  - Wait on the ground.

- Taxiing.
- Climb.
- High altitude mission (high speed).
- Descent.
- Taxiing
- Wait on ground.

Phase durations are chosen such that on average, the aircraft is subject to:

- One hour of flight per day.
- Half an hour maintenance per day.
- The reminder of the day stopped.

Therefore this life profile can be compatible with the convention in force. However, flights were broken down into 6 phases to suitably describe the different environment types. In particular, this breakdown reveals that some flight phases are characterised by high temperature stresses, and others by almost no temperature stress.

Temperature and temperature cycles

There are several temperature phenomena which are superimposed on each other. They are:

- Day / night temperature cycling.
- Heat dissipation from the product when powered up.
- Temperature variation with altitude (depending on the mission).
- Kinetic temperature rise (depending on aircraft speed and therefore the mission).

Humidity

The relative humidity is assumed to be 70% at 15°C on the ground. The only influence on humidity considered afterwards is the temperature.

Vibration

The vibration amplitude in flight and in taxiing is high. The vibration amplitude is assumed to be lower during the cruising phase.

Exposure to overstresses – application factor

This factor was determined as follows:

Criterion	**Level for the ground-off phase**	**Level for the taxiing and flight phases**	**Level for the maintenance phase**
User type in the phase considered	Unfavourable Military use: mission stresses take precedence over taking care of the equipment	Unfavourable Military use: mission stresses take precedence over taking care of the equipment	Unfavourable Military use: mission stresses take precedence over taking care of the equipment
User qualification level in the phase considered	Moderate	Favourable (pilot)	Moderate
System mobility	Low	High	Low
Product handling	Favourable (product not handled)	Favourable (product not handled)	Moderate (product sometimes handled)
Type of electrical network for the system	Favourable (not powered)	Severe (disturbed network)	Severe (disturbed network)
Product exposure to human activity	Moderate (for example at station)	Low	Moderate (for example maintenance)
Product exposure to machine disturbances	Low	Moderate (indirect exposure)	Low
Product exposure to the weather	Moderate (indirect exposure)	Moderate (indirect exposure)	Moderate (indirect exposure)
Value of $\Pi_{\text{application}}$	**4.4**	**5.0**	**5.5**

The case of the "Flight – Waiting powered up on the ground" phase that precedes taxiing has an application factor of 4.8.

3.6.3. Table

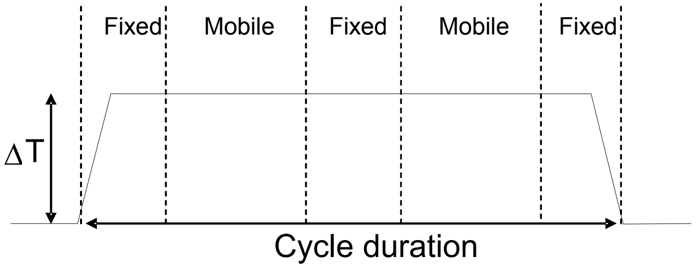
Fighter aircraft – Multi-role – External stores – Temperate climate														
		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
Ground – Not in operation	8 213	Off	15	70	10	365	22.50	20	0.01	Low	Moderate	Moderate	Non hermetic	4.4
Flight – Waiting powered up on the ground	37	On	35	20	20	365	0.10	35	0.50	Low	Moderate	Moderate	Non hermetic	4.8
Flight - Taxiing	37	On	35	20	-	-	-	-	8.00	Low	Moderate	Moderate	Non hermetic	5.0
Flight – Climb and descent	73	On	35	20	-	-	-	-	8.00	Low	Low	Moderate	Non hermetic	5.0
Flight - Cruising	131	On	- 2	90	37	219	0.80	35	4.00	Low	Low	Moderate	Non hermetic	5.0
Flight – Low altitude mission	37	On	50	10	52	73	0.50	50	8.00	Low	Low	Moderate	Non hermetic	5.0
Flight – High altitude mission	51	On	70	10	35	146	0.35	70	8.00	Low	Low	Moderate	Non hermetic	5.0
Ground - Maintenance	183	On	35	20	20	365	0.50	35	0.50	Low	Moderate	Moderate	Non hermetic	5.5

3.7. Other examples

Tracked armoured vehicle														
		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	Π application
Fixed and powered	152	On	50	40	35	48	5.06	50	0	Low	Low	Low	Non hermetic	6.2
Mobile and powered	91	On	50	40	-	-	-	-	4	Low	Low	Low	Non hermetic	6.7
Mobile not powered (logistics transport)	100	Off	15	70	-	-	-	-	0.5	Low	Low	Low	Non hermetic	5.2
Fixed not powered	8417	Off	15	70	10	365	23.06	20	0	Low	Low	Low	Non hermetic	7.5

Military portable radio														
		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
Day without use – Protected storage	3960	Off	20	37	5	165	24	23	0.01	Low	Low	Moderate	Hermetic	4.1
Operation – fixed Functioning	600	On	30	20	15	200	6	30	0.5	Low	Low	Moderate	Hermetic	5.6
Operation - mobile Functioning	600	On	30	20	-	-	-	-	1.5	Low	Low	Moderate	Hermetic	7.7
Operation – No fixed functioning	3200	Off	15	50	10	200	18	20	0.01	Low	Low	Moderate	Hermetic	4.3
Operation – No mobile functioning	400	Off	15	50	-	-	-	-	1.5	Low	Low	Moderate	Hermetic	7.7

This life profile describes a radio station used by an infantryman. It illustrates a case in which a phase includes a temperature cycle that lasts longer than the phase itself. In this life profile, the system is powered up while it is fixed ("Operation – Fixed functioning" phase). Therefore, this phase includes the power up temperature cycle. Once switched on, the system is transported, which is described in another phase ("Operation – Mobile functioning ") which does not cause a new temperature cycle but which induces a more severe vibration amplitude. The duration of the power up temperature cycle is then equal to the fixed functioning time plus the mobile functioning time.



Office automation personal computer

		Temperature and Humidity			**Temperature cycling**				**Mechanical**	**Chemical**				**Induced**
Phase title	Calendar time (hours)	On/Off	Ambient temperature (°C)	Relative humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)	Saline pollution	Environmental pollution	Application pollution	Protection level	$\Pi_{application}$
On	2860	On	50	10	30	220	13	50	0.1	Low	Moderate	Low	Non hermetic	3.1
Off	2420	Off	20	50	5	220	11	23	0.01	Low	Moderate	Low	Non hermetic	1.6
Day of inactivity	3480	Off	20	50	5	145	24	23	0.01	Low	Moderate	Low	Non hermetic	1.6

Life profile for an office automation personal computer used 220 days per year. The computer is not switched during days in which it is not used. When the computer is used, it is switched on manually at 9:00 in the morning and it switches itself off automatically at 22:00. The inside temperature rise during operation is 30°C. The room in which the computer is located is air conditioned during the day. The average temperature is 20°C with a daily temperature cycle of 5°C.

III

Evaluation guide calculation sheets

Electronic components

Induced factor

Factors contributing to overstresses

$$\Pi_{\text{induced}-i} = \left(\Pi_{\text{placement}} \times \Pi_{\text{application}-i} \times \Pi_{\text{ruggedising}}\right)^{0.511 \times \ln\left(C_{\text{sensitivity}}\right)}$$

The index i denotes the phase considered.

Contribution associated with the $C_{\text{sensitivity}}$ factor:

The $C_{\text{sensitivity}}$ factor is given in the datasheet specific to each item type.

Sensitivities related to EOS, TOS, MOS (Electrical OverStress, Thermal OverStress, Mechanical OverStress) are given for information to show the relative sensitivity of families to the different types of overstresses. They are not used in the calculations.

Contribution associated with the $\Pi_{\text{Placement}}$ factor:

	$\Pi_{\text{placement}}$
Digital non-interface function	1.0
Digital interface function	1.6
Analogue low level non-interface function	1.3
Analogue low level interface function	2.0
Analogue power non-interface function	1.6
Analogue power interface function	2.5

The $\Pi_{\text{Placement}}$ factor can be determined either at component level for a detailed study, or at board level for a faster study. The choice must be done according to the electronic function in which the article is implied and not according to the nature or the technology of the article himself.

To determine the $\Pi_{\text{Placement}}$ it is necessary to answer two questions.

1. Interface or non interface?

An interface is the junction that provides interconnection between two systems. The concept of interface must be considered from the electrical point of view. The concept is very dependent on the architecture in which the product is operated. An item shall be treated as “interface” if it is more exposed to accidental electrical aggressions because of its position in the system. The items which make the link between equipment and the external systems are interface functions.

Frequently, in an electronic assembly, interface components are categorised as protection (such as a transil or transorb), filters (such as inductors, resistors or capacitors) or insulation (such as optocouplers). The interface components are often electrically close to a connector.

2. Digital, analogue low level, analogue power?

Digital functions are usually easy to identify.

The threshold between analogue low level and analogue power corresponds approximately to a current of 1 A. But of other factors can influence for the choice of the $\Pi_{\text{Placement}}$, as the voltage and especially the function type:

- Within the FIDES guide, the analogue low level functions are mainly discrete inputs/outputs, measurement signals and analogue logics.
- The power functions are mainly power supplies, power transmissions.

Contribution associated with the $\Pi_{application}$ factor:

The $\Pi_{application}$ parameter is evaluated by marking a series of criteria. Each criterion can have three levels corresponding to a favourable, moderate or unfavourable situation. Each criterion has a particular impact on overstresses (P_{OS}):

$\Pi_{application}$: Table 1

Criterion	Description	Levels	Examples and comments	Weight P_{OS}
User type in the phase considered	Represents the capability to respect procedures, facing operational constraints.	0: Favourable 1: Moderate 2: Unfavourable	The product use and the respect of rules are globally driven by: 0: quality constraints (industrial) 1: cost of the product (general public) 2: success of the mission and operational context (military) Quality, cost, mission constraints exist in all application types, but with different priority.	20
User qualification level in the phase considered	Represents the level of control of the user or the worker regarding an operational context	0: Favourable 1: Moderate 2: Unfavourable	0: Highly qualified 1: Qualified 2: Slightly qualified or with little experience In some phases, the user to be considered is the person who does the maintenance or servicing	10
System mobility	Represents contingencies related to possibilities of the system being moved	0: Non-aggressive 1: Moderate 2: Severe	0: Few contingencies (fixed or stable environment) 1: Moderate contingencies 2: Severe contingencies, large variability (automobile)	4
Product manipulation	Represents the possibility of false manipulations, shocks, drops, etc .	0: Non-aggressive 1: Moderate 2: Severe	0: Not manipulated 1: Manipulation without displacement or disassembly 2: Manipulation with displacement or disassembly The severe level should be adopted if maintenance on the product is possible in the phase considered	15
Type of electrical network for the system	Represents the level of electrical disturbance expected on power supplies, signals and electrical lines: power on, switching, power supply, connection/disconnection	0: Non-aggressive 1: Moderate 2: Severe	0: Undisturbed network (dedicated regulated power supply) 1: Slightly disturbed network 2: Network subject to disturbances (onboard network) The network type is a system data but that can be broken down and related to specific products	4
Product exposure to human activity	Represents exposure to contingencies related to human activity: shock, change in final use, etc.	0: Non-aggressive 1: Moderate 2: Severe	0: Uninhabitable zone 1: Possible activity in the product zone 2: Normal activity in the product zone The product can be exposed to human activity even if it is not handled itself during normal use	8
Product exposure to machine disturbances	Represents contingencies related to operation of machines, engines, actuators: shock, overheating, electrical disturbances, pollutants, etc.	0: Non-aggressive 1: Moderate 2: Severe	0: Null (telephone) 1: Indirect exposure (product in compartment) 2: Strong or direct exposure (product in engine area)	3
Product exposure to the weather	Represents exposure to rain, hail, frost, sandstorm, lightning, dust	0: Non-aggressive 1: Moderate 2: Severe	0: Null (home) 1: Indirect exposure (compartment, station hall) 2: Outdoors (automobile engine)	2

Contribution associated with the $\Pi_{application}$ factor (continued).

Each criterion (user type, system mobility, etc.) must be answered to define a non-aggressive, moderate or severe level:

- It is important to determine the $\Pi_{application}$ for each usage phase. Exposure to overstresses can be very variable depending on the context. For example, it is useful to represent increased exposure during maintenance phases (when there are any).
- Some criteria are to be considered at product level (i.e. the entity for which the reliability is studied, in general an equipment) and others are to be considered at system levels (i.e. the assembly in which the product is integrated; for example an aircraft or a car). It is important to consider this carefully when evaluating the criteria.

Each level (benign, moderate or severe) is weighted specifically as defined in the following table:

$\Pi_{application}$: Table 2

Level	Weighting of marks (P_{notes})
0: Favourable or benign	1
1: Moderate	3.2
2: Unfavourable or severe	10

Starting from these tables and answers to the criteria, the $\Pi_{application}$ value is obtained by the following formula:

$$\Pi_{application} = \frac{1}{66} \cdot \sum_{k=Criteria} Pmarks_k \cdot Pos_k$$

Where:

$Pmarks_k$ are weighting factors corresponding to marks assigned to each criterion ($\Pi_{application}$: Table 2).

Pos_k are weights for each criterion ($\Pi_{application}$: Table 1).

Contribution associated with the $\Pi_{\text{Ruggedising}}$ factor

The $\Pi_{\text{Ruggedising}}$ factor is determined by considering the following questions.

The answers and the justifications provided by the audited person will be used to fix a ***satisfaction level*** for the recommendation (level N1 to N4):

- N1 = the recommendation is not applied → definite risks regarding reliability,
- N2 = the recommendation is only partially applied → potential risks regarding reliability,
- N3 = the recommendation is globally applied → few risks regarding reliability,
- N4 = the recommendation is fully applied and is described in a procedure → Control of the reliability.

Sheet	**Recommendation**	**Weight**
169	Write complete procedures for all product implementation and maintenance operations	7
157	Provide training and manage maintenance of skills for use and maintenance of the product	7
158	Check that procedures specific to the product and rules specific to businesses are respected by an appropriate monitoring system	7
168	Carry out a review of maintenance operations done by the final user and deal with his recommendations	4
156	Check that environmental specifications are complete. Verification criteria for completeness of specifications: analysis, tests, feedback from operations, respect of standards	4
164	Justify that environmental specifications are respected	4
165	Carry out a product improvement process (for example highly accelerated stress tests) so as to limit the product sensitivity to environmental constraints (disturbances, environments, overstress)	7
167	Carry out a process analysis of implementation and maintenance operations	4
170	Respect a standard dealing with power supplies (standard like EN2282 that defines possible disturbances and possible variations). The standard must be respected both for electricity generation and for electricity consumption.	4
166	Make an analysis of failure cases that could lead to a failure propagation	4
163	Include production, storage and maintenance environments in the product environments specifications	4
160	Study and handle risks of the product under test being deteriorated by failures of its test means. Criteria: Risks analysed in the design of the test means and the tested unit, set up adapted prevention means	4
162	Use appropriate prevention means to identify ant handle reasonably predictable abnormal uses.	4
161	Identify and use appropriate prevention means of preventing reasonably predictable aggressions (related to the weather)	4
159	Design dependable electrical protection devices: - identify electrical protection systems - make sure that they are testable and maintainable - integrate the case of these devices into the definition of the maintenance policy	4
171	Respect a standard dealing with conducted and radiated electromagnetic disturbances. This is equally applicable to the product and the system into which it is integrated	3

Detailed recommendations datasheets for the evaluation by audit of the $\Pi_{\text{Ruggedising}}$ are given with all the recommendations datasheets of the Reliability Process control and audit guide.

Contribution associated with the $\Pi_{\text{Ruggedising}}$ factor (continued)

The mark for each level is determined as follows:

Level	Mark
N1	0
N2	1
N3	2
N4	3

Each of the recommendations is weighted by a specific ***Recom_Weight***.

The $\Pi_{\text{Ruggedising}}$ factor is calculated as follows:

$$\Pi_{\text{ruggedising}} = e^{0.7\times(1-\text{recom}-\text{grade})}$$

where: $\text{recom\_grade} = \frac{1}{225}\sum_{i}^{\text{Recommendations}} \text{Recom\_Weight}_i \times \text{Satisfaction\_mark}_i$

Where:

- Recom_weight is the weight associated with a recommendation
- Satisfaction_mark is the mark obtained for this recommendation (0, 1, 2 or 3).

Notes:

- The **recom_grade** factor varies from 0 (worst case: no recommendation is applied) to 1 (best case).
- The "225" factor corresponds to the score obtained if the best mark is given to each recommendation. If one (or several) recommendations are considered to be inapplicable and not relevant for a given project, this total can be updated in the same way as is done for the calculation of the process factor.

If the $\Pi_{\text{Ruggedising}}$ factor is not evaluated, a default value of 1.7 is suggested. Use of the default value can reduce the accuracy of the final results.

Component manufacturing factor

General model associated with the component manufacturing factor Π_{PM}:

$$\Pi_{PM} = e^{1.39 \times (1 - \text{Part\_Grade}) - 0.69}$$

where for active parts (integrated circuits, discrete semiconductors, LED, optocouplers):

$$\text{Part\_Grade} = \left[\frac{(QA_{\text{manufacturer}} + QA_{\text{component}} + RA_{\text{component}}) \times \varepsilon}{36}\right]$$

and for all other items:

$$\text{Part\_Grade} = \left[\frac{(QA_{\text{manufacturer}} + QA_{\text{component}}) \times \varepsilon}{24}\right]$$

The general Π_{PM} calculation formula can be made specific and is then specified case by case.

Model associated with the $QA_{manufacturer}$ factor

This factor is common to all items.

Manufacturer quality assurance level	**Position relative to the state of the art**	**$QA_{manufacturer}$**
Certified ISO/TS16949 V2002	Higher	3
Certified according to one of the following standards: QS9000, TL9000, ISO/TS 29001, EN9100, AS9100, JISQ 9100, AQAP 2110, AQAP 2120, AQAP 2130, IRIS, IEC TS 62239, ESA/ECSS QPL, MIL-PRF-38535 QML, MIL-PRF-19500	Equivalent	2
ISO 9000 version 2000 certified	Lower	1
No information	Very much lower	0

Model associated with the $QA_{component}$ factor

The $QA_{component}$ factor is defined for each item family. It takes account mainly of the qualification methodology without considering the severity of the tests defined in the mentioned standards. Test severities for active components are taken into account by the $RA_{component}$ factor.

Component quality assurance level	**Position relative to the state of the art**	**$QA_{component}$**
Level criteria are defined for each item family	Higher	3
	Equivalent	2
	Lower	1
	Very much lower	0

Model associated with the $RA_{component}$ factor

The $RA_{manufacturer}$ factor is defined for integrated circuits and discrete semiconductors. It is quantified as a function of the results and the severity of tests performed by the manufacturer

	Risk $RA_{component}$
Very reliable level A	**3**
Very reliable level B	**2**
Reliable	**1**
Not reliable	**0**

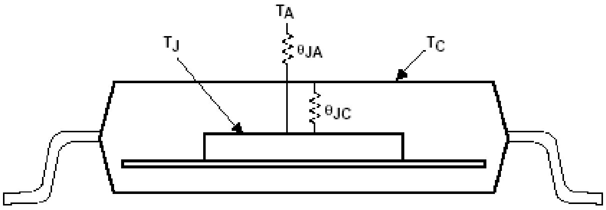
Model associated with the experience factor ε:

The experience factor, ε, must represent the component buyer's experience with his supplier. Therefore, this is a factor specific to each manufacturer. Its multiplication role in the model represents the importance of knowledge of suppliers in component reliability. This factor is common to all items, but in some cases specific indications are proposed for its determination.

Description of the risk related to use of this manufacturer	**Value of the ε factor**
Recognised manufacturer: Mature processes for the item considered	4
Recognised manufacturer – Processes not analysed or not mature for the item considered	3
Manufacturer not recognised (for example never audited or audited more than 6 years earlier) or small series productions	2
Previous disqualification or problem with feedback from operations	1

Thermal resistance of components

For active components, the temperature stress model uses the component junction temperature. This requires an evaluation of the increase in the junction temperature relative to the ambient temperature. This evaluation is usually made from the power dissipated by the component and its thermal resistance between the junction temperature and the ambient temperature. Thermal resistance data for components published by suppliers should be preferred wherever possible. A default method of evaluating thermal resistances for active components is proposed.



Integrated circuits

$$\boxed{R_{JA\_0m/s} = C_{type}.Np^{-0.58}.K}$$

$$\boxed{R_{JA\_2m/s} = \frac{R_{JA\_0m/s}}{1.5}}$$

R_{JA_V} = Junction-ambient thermal resistance, depending on the airflow speed
V = 0 m/s or 2 m/s = Airflow speed depending on environmental convection (0 m/s = natural convection)
C_{type} = Constant dependent on the case type
Np = Number of pins on the case; the same formula will be used for QFN cases, where Np = case area in mm².
K = Constant dependent on the value of thermal conductivity in the plane of the board (kx=ky)

Note:

- Low conductivity: $k_x \langle 15 \frac{W}{m.K}$
- High conductivity: $k_x \geq 15 \frac{W}{m.K}$

Case type	C_{type}	Variation range		
QFN (area in mm*mm)	223	3*3	<Area<	10*10
CerDIP / CDIP	320	8	< Np <	48
Power QFP (HQFP, RQFP...)	340	160	< Np <	304
PDIP	360	8	< Np <	68
PPGA	380	28	< Np <	447
PLCC	390	20	< Np <	84
SOIC	400	8	< Np <	32
SOJ	400	24	< Np <	44
CPGA	410	68	< Np <	655
SOP	410	8	< Np <	32
Power BGA-1.27mm (SBGA, TBGA…)	450	256	< Np <	956
J-CLCC	470	28	< Np <	84
CBGA	480	255	< Np <	1156
Cerpack	480	20	< Np <	56
TQFP, VQFP, LQFP	480	32	< Np <	208
PBGA-1.27mm	530	119	< Np <	729
Power BGA-1mm (SBGA, TBGA…)	550	256	< Np <	1508
SSOP	560	16	< Np <	64
CQFP	560	64	< Np <	256
PQFP	570	44	< Np <	304
TSSOP	650	8	< Np <	64
PBGA-1mm	670	100	< Np <	1156
PBGA-0.8mm	700	48	< Np <	484
TSOP	750	5	< Np <	56

Board thermal conductivity	K
Low conductivity	1.15
High conductivity	0.94

Considering the diversity of the possible shapes, it may be preferable to refer to the manufacturer's data for BGA type cases.

Discrete semiconductors

R_{JA} = Junction – ambient thermal resistance (model proposed for natural convection only, airflow speed = 0 m/s) in °C/W
R_{JC} = Junction – case thermal resistance in °C/W
Np = Number of pins on the case
kx = Thermal conductivity in the plane of the board (kx = ky) in W/m.K

Low conductivity: $k_x \langle 15 \frac{W}{m.K}$

& High conductivity: $k_x \geq 15 \frac{W}{m.K}$

Case type	Equivalent name	Np	R_{JA} Low conductivity	R_{JA} High conductivity	R_{JC}
DO15	DO-204AC	2	60	*42*	*5*
DO27	DO-201AA	2	41	*30*	*1*
DO35	DO-204AH	2	378	*241*	*134*
DO41	DO-204AL	2	73	*50*	45
DO92		3	195	*126*	150
DO220 *		3	65	*45*	4
DPAK *	TO-252AA, SC63, SOT428	4	97	71	4
D2PAK *	TO-263, SC83A, SMD-220	4	58	*40*	1
IPACK *	TO-251AA	3	96	50	3
I2PAK		3	63	*44*	1
ISOTOP *	SOT227, TO-244, Half-Pak	4	35	*26*	1
F126		2	40	*29*	*1*
SIL	SIL, ZIP	(See manufacturer's specification)			
SIP	SIL, ZIP	(See manufacturer's specification)			
SOD6	DO-214AA, SMB-J	2	88	*59*	27
SOD15	DO-214AB, SMC-J	2	67	*46*	2
SOD80	Mini-MELF, DO213AA	2	568	*361*	*172*
SOD87	DO-214AC, SMA-J	2	110	*73*	*41*
SOD110		2	315	*202*	*119*
SOD123		2	337	*216*	130
SOD323	SC76	2	428	*273*	*146*
SOD523	SC79	2	93	*62*	*31*
SOT23	TO-236AB	3	443	360	130
SOT23	SC74A, SOT25	5	285	136	106
SOT23	SC74, SOT26, SOT457	6	212	133	110
SOT82 *	TO225	3	100	*67*	8
SOT89	SC62, TO-243AA	4	142	125	100
SOT90B		6	500	*318*	*160*
SOT143	TO-253AA, SC61B	4	473	250	*155*
SOT223	SC73, TO261AA	4	84	57	21
SOT323	SC70	3	516	*328*	*164*
SOT343	SC82	4	215	*139*	*88*
SOT346	SC59, TO-236AA	3	500	*318*	*160*
SOT353	SC70-5, SC88A	5	358	229	144
SOT363	SC70-6, SC88	6	553	*351*	*164*

Case type	Equivalent name	Np	R_{JA} Low conductivity	R_{JA} High conductivity	R_{JC}
TO18	TO-71, TO-72, SOT31, SOT18	3	475	*302*	150
TO39	SOT5	3	219	*142*	58
TO92	SOT54, SC43, TO226AA	3	180	*117*	66
TO126	SOT32, TO-225AA	3	95	*64*	3
TO218 *	ISOWATT218	3	40	*29*	1
TO220 *	TO220-5, ISOWATT220, TO220XX	3	58	*40*	4
TO247 *	Max247, Super247, SOT429	3	47	*34*	1

Note:

1. *Data in italics* are orders of magnitude derived from regression analyses based on averages by case type.
   There are no standard tests for measuring thermal resistances of discrete cases; therefore thermal performances of these components depend only on the manufacturer. These *data in italics* are provided for information; for the cases types concerned, it is strongly recommended that reference should be made to manufacturer data referred to in specifications.

2. *: For power cases (type TO218, DPAK, ISOTOP, etc.), the thermal resistance "R_{JA}" should only be applied if the case is mounted directly on the board; otherwise (for example), when the case is screwed onto a metallic structure or if it is provided with a heat sink, it is recommended that the thermal resistance "R_{JC}" should be applied.

3. If the Delta_T of the component is very high (Delta_T = R_{JA} x $P_{Dissipated}$ > 150°C), it is preferable to look for thermal measurement conditions in the specification and apply the value of the thermal resistance "R_{JA}" supplied by the manufacturer, if it is less than that supplied by FIDES; otherwise, apply the thermal resistance "R_{JC}" (because it takes account of better metallisation under the component).

Light emitting diode (LED)

Considering the diversity of LED (Light Emitting Diode) sizes for each type of case, it is preferable to refer to manufacturer data. Ranges of values are given for information.

R_{JA} = Junction – ambient thermal resistance in °C/W
R_{JC} = Junction – case thermal resistance in °C/W

Maximum direct current DC	SMD or through hole	Case type	Number of pins	R_{JA} °C/W	R_{JC} °C/W
$I_F < 150\text{mA}$	Through hole	T1-x	2 to 4	300-500	160-290
		High flux	4	200	90-155
	SMD	Chip	2	450-800	260-450
		PLCC	Mini 2	460-580	230-330
			2	360-400	180-280
			3	270-290	130-190
			4	270-560	130-180
			6	210-500	130-160
		Round	2	420-530	250
		LGA	2	380-630	180-360
		Other	Indifferent	-	
$150\text{mA} \leq I_F < 300\text{mA}$	SMD		Indifferent	90-140	15-25
$300\text{mA} \leq I_F < 1\text{A}$				39-65	8-23
$I_F \geq 1\text{A}$				30-50	3-17

Integrated circuits

General model associated with the family

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$ where:

$$\lambda_{\text{Physical}} = \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \begin{pmatrix} \lambda_{0\,\text{TH}} \times \Pi_{\text{Thermal}} \\ + \lambda_{0\,\text{TCy Case}} \times \Pi_{\text{TCy Case}} \\ + \lambda_{0\,\text{TCy Solder joints}} \times \Pi_{\text{TCy Solder joints}} \\ + \lambda_{0\,\text{RH}} \times \Pi_{\text{RH}} \\ + \lambda_{0\,\text{Mech}} \times \Pi_{\text{Mech}} \end{pmatrix}_i \times (\Pi_{\text{Induced}})_i$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	$C_{\text{sensitivity}}$
Integrated circuit	10	2	1	6.30

Π_{PM}: Model associated with the $QA_{\text{component}}$ factor

Component quality assurance level	Position relative to the state of the art	$QA_{\text{component}}$
Qualification according to one of the following standards: AEC Q100, MIL-PRF-38535 class V , ESA ESCC 90xx, NASDA-QTS-xxxx class I , NPSL NASA level 1	Higher	3
Manufacturer qualification including tests conforming with standards JESD22, EIAJ-ED-4701, MIL-STD-883, IEC 68 with identification of "front-end" and "back-end" manufacturing sites; Qualification according to one of the following standards: MIL-PRF-38535 class Q, MIL-PRF-38535 class M , MIL-PRF-38535 class N , MIL-PRF-38535 class T, NASDA-QTS-xxxx class II , NPSL NASA level 2 & 3 , STACK-S0001	Equivalent	2
Qualification program internal to the manufacturer and unidentified manufacturing sites	Lower	1
No information	Much lower	0

Π_{PM}: Model associated with the $RA_{component}$ factor

Title of accelerated aging test	High Temperature Operating Life (HTOL)	Pre-conditioning before TC, THB or HAST	Temperature Cycling (TC)	Pressure Cooker Test (PCT)	Highly Accelerated Stressed Tests (HAST)	Temperature Humidity Biased (THB)	
Reference standards	EIA JESD-22-A108 A or equivalent	EIA JESD-22-A113A or equivalent	EIA JESD-22-A104 or equivalent	EIA JESD-22-A102 or equivalent	EIA JESD-22-A110 or equivalent	EIA JESD-22-A101 or equivalent	
	Test results						Risk $RA_{component}$
Very reliable level A	1000h, 125°C, Vmax, 231/0 (1) 1500/0*	done	1000 cycles -55°C /+150°C or 500 cycles -65°C/+150°C 231/0 or 1000 cycles -55°C/125°C 385/0	168 h at 121°C / 100%RH 231/0	168 h at 130°C/ 85%RH 231/0	168 h at130°C/ 85%RH 231/0	**3**
Very reliable level B	1000h, 125°C, Vmax, 154/0 (1) 900/0*	done	1000 cycles -55°C /+125°C, 154/0	96 h at 121°C / 100%RH, 154/0	96 h at 130°C/ 85%RH, 154/0	96 h at 130°C/ 85%RH, 154/0	**2**
Reliable	1000h, 125°C, Vmax, 77/0(1) 231/0*	done	500 cycles -55°C /+125°C 154/0	96 h at 121°C / 100%RH, 77/0	96 h at 130°C 85%HR, 77/0	1000 h at 85°C/85%RH, 154/0	**1**
Not reliable	Design below the reliable level	Not done	Design below the reliable level				**0**

Each box in the table contains a description of test conditions with the expected result in the form XXX/Y where XXX is the number of parts under test and Y is the number of defects (in practice Y=0)

(1): Applicable to a Front End item or process for a determined case
*: applicable to all Front End processes for a determined case.

If the levels in the different types of tests are not equal, the lowest level will be selected.

Basic failure rates associated with cases

The basic failure rates for the different physical stresses are obtained by the following equation:

$$\lambda_{0\_Stress} = e^{-a} \times Np^{b}$$

Where:

- a and b are constants that depend on the case type and the number of pins given in the following table.
- Np is the number of pins on the case.

Typical name	Description	Np	λ_{0RH}		λ_{0TCy_Case}		$\lambda_{0TCy\_Solder\ joints}$		$\lambda_{0\ mechanical}$	
			a	b	a	b	a	b	a	b
PDIP. TO116	Plastic Dual In line Package	8 to 68	5.88	0.94	9.85	1.35	8.24	1.35	12.85	1.35
CERDIP. CDIP	Ceramic Dual-In-Line Package	8 to 20 >20 to 48	λ_{0RH}=0		6.77	1.35	5.16 4.47	1.35 1.35	8.38 7.69	1.35 1.35
PQFP	Plastic Quad Flatpack. L lead	44 to 240 >240 to 304	11.16	1.76	12.41	1.46	10.80 10.11	1.46 1.46	14.71 14.02	1.46 1.46
SQFP **TQFP. VQFP. LQFP**	Plastic Shrink (thickness) Quad Flatpack. L lead Plastic Thin Quad Flatpack. L lead	32 to 120 >120 to 208	7.75	1.13	8.57	0.73	6.96 5.57	0.73 0.73	11.57 10.18	0.73 0.73
Power QFP (RQFP. HQFP. PowerQuad. EdQuad…)	Plastic Quad Flatpack with heat sink. L lead	160 to 240 >240 to 304	14.17	2.41	15.11	1.96	13.50 12.81	1.96 1.96	17.41 16.72	1.96 1.96
CERPACK		20 to 56	λ_{0RH}=0		12.41	1.46	10.80	1.46	14.02	1.46
CQFP. Cerquad	Ceramic Quad Flat Pack	64 to 132 >132 to 256	λ_{0RH}=0		12.41	1.46	10.80 9.19	1.46 1.46	14.02 12.41	1.46 1.46
PLCC	Plastic Leaded Chip Carrier J-Lead	20 to 52 >52 to 84	9.36	1.74	18.52	3.15	16.91 15.52	3.15 3.15	21.11 19.72	3.15 3.15
J-CLCC	J-Lead Ceramic Leaded Chip Carrier	4 to 32 44 52 68 84	λ_{0RH}=0		8.07	0.93	6.46 5.77 5.36 4.85 4.38	0.93	9.68 8.99 8.58 8.07 7.6	0.93
CLCC	Ceramic Leadless Chip Carrier	4 20 32 44 52 68 84	λ_{0RH}=0		8.07	0.93	5.07 4.51 4.38 4.26 4.26 4.16 4.16	0.93	8.07 7.51 7.38 7.26 7.26 7.15 7.15	0.93
SOJ	Plastic Small Outlines. J-Lead	24 to 44	4.31	0.86	8.36	1.39	6.75	1.39	11.36	1.39
SO. SOP. SOL. SOIC. SOW	Plastic Small Outlines. L lead	8 to 14 16 to 18 20 to 28 32	8.23	1.17	13.36	2.18	11.75 11.06 10.36 10.14	2.18 2.18 2.18 2.18	16.36 15.66 14.97 14.75	2.18 2.18 2.18 2.18
TSOP I **TSOP II**	Thin Small Outlines. leads on small edges. L lead Thin Small Outlines. leads on long edges. L lead	5 to 16 >16 to 32 >32 to 44 >44 to 56	6.21	0.97	9.05	0.76	7.44 6.05 5.83 5.36	0.76 0.76 0.76 0.76	12.05 10.66 10.44 9.97	0.76 0.76 0.76 0.76
SSOP. VSOP. QSOP	Plastic Shrink (pitch) Small Outlines. L lead	16 to 64	11.95	2.23	16.28	2.60	14.67	2.60	19.28	2.60

Typical name	Description	Np	λ_{0RH}		λ_{0TCy_Case}		λ_{0TCy_Solder} joints		λ_{0} mechanical	
			a	b	a	b	a	b	a	b
TSSOP. MSOP. µSO. µMAX. TVSOP	Thin Shrink Small Outlines. L lead	8 to 28	11.57	2.22	15.56	2.66	13.95	2.66	18.56	2,66
		>28 to 48					13.21	2.66	17.86	2,66
		56					12.56	2.66	17.17	2,66
		64					12.16	2.66	16.76	2,66
QFN. DFN. MLF	Quad Flat No lead (package without lead)	8-24	8.97	1.14	11.2	1.21	8.12	1.14	11.34	1,21
		28-56					7.90		11.12	
		64-72					7.71		10.93	
PBGA CSP BT 0.8 and 0.75 mm	Plastic Ball Grid Array with solder ball pitch = 0.8 mm and 0.75 mm	48 to 384	9.7	1.50	12.13	1.49	9.13	1.49	12.82	1,49
PBGA flex 0.8 mm	Plastic Ball Grid Array with solder ball pitch = 0.8 mm and 0.75 mm	48 to 288	9.7	1.50	12.13	1.49	8.57	1.49	12.26	1,49
PBGA BT 1.00 mm	Plastic Ball Grid Array with solder ball pitch = 1.0 mm	64 to 1156	6.2	0.81	10.89	1.00	7.67	1.00	11.36	1,00
PBGA 1.27mm	Plastic Ball Grid Array. with solder ball pitch = 1.27 mm	119 to 352	6.87	0.90	10.36	0.93	7.36	0.93	11.05	0,93
		>352 to 432					7.14	0.93	10.83	0,93
		>432 to 729					6.67	0.93	10.36	0,93
Power BGA (TBGA SBGA…)	Tape BGA. PBGA with heat sink. die top down pitch=1.27 mm Super BGA. PBGA with heat sink. die top down Pitch=1.27 mm	256 to 352	9.44	1.31	15.73	1.68	12.73	1.68	16.42	1,68
		>352 to 956					12.33	1.68	16.02	1,68
CBGA	Ceramic Ball Grid Array	255 to 1156	11.78	1.72	15.37	1.87	11.56	1.87	14.56	1,87
DBGA	Dimpled BGA	255 to 1156	11.78	1.72	15.37	1.87	12.15	1.87	15.15	1,87
CI CGA	Ceramic Land GA + interposer. Ceramic column GA	255 to 1156	11.78	1.72	15.37	1.87	11.81	1.87	14.81	1,87
CPGA	Ceramic Pin Grid Array	68 to 250	λ_{0RH}=0		8.07	0.93	5.77	0.93	8.76	0.93
		>250 to 655					4.85	0.93	7.85	0.93

Note:

- The failure rate of hermetically sealed cases due to a humid atmosphere is null (λ_{0RH}=0).
- Basic failure rates for solder joints were estimated based on assumptions about the type of printed circuit (the selected type is FR4), the difference in the coefficients of thermal expansion between the PCB and the component, the material used for the pins, curvature of CQFP pins, the CBGA, Flex BGA, PBGA substrate types. These parameters have an influence on the reliability but cannot usually be dealt with in a predictive reliability study.
- Some Discrete semiconductor cases are also used for Integrated Circuits. In particular, the "SMD, small signal, L-lead, plastic", "SMD, medium power, small heat sink, L-lead, plastic", "Through hole, power, plastic", "SMD, power, large heat sink, L-lead, plastic" types. Refer to the Discrete semiconductor components datasheet for failure rates of these cases.

Basic failure rates associated with the chip

Type	λ_{0TH}
FPGA, CPLD, FPGA Antifuse, PAL	0.166
Analogue and Hybrid circuit (MOS, bipolar, BiCMOS)	0.123
Microprocessor, Microcontroller, DSP	0.075
Flash, EEPROM, EPROM	0.060
SRAM	0.055
DRAM	0.047
Digital circuit (MOS, bipolar, BiCMOS)	0.021

Notes:

- Mixed = analogue and digital.
- For ASICs, refer to the ASIC model.

Information about the life profile

t_{annual}: time associated with each phase over a year (hours)
$RH_{ambient}$: humidity associated with a phase (%)
$T_{board-ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual-cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}: cycle duration (hours)
Grms: vibration amplitude associated with each random vibration phase (Grms)

Information about the application

$T_{J\_component}$: component junction temperature during an operating phase (°C)
$T_{J\_component} = T_{ambient} + R_{JA} \cdot P_{dissipated}$
$P_{dissipated}$: power dissipated by the component during the phase (W)

Factors contributing to Physical stresses

Π***Thermal_***	In an operating phase: $e^{11604 \times 0.7 \times \left[\frac{1}{293} - \frac{1}{\left(T_{j-component} + 273\right)}\right]}$ In a non-operating phase: $\Pi_{Thermal} = 0$
Π***TCy*** ***Case***	$\left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\Delta T_{cycling}}{20}\right)^{4} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{\left(T_{max-cycling} + 273\right)}\right]}$
Π***TCy*** ***Solder joints***	$\left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy}, 2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1,9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{\left(T_{max-cycling} + 273\right)}\right]}$
Π***Mech***	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π***RH***	$\left(\frac{RH_{ambient}}{70}\right)^{4,4} \times e^{11604 \times 0.9 \times \left[\frac{1}{293} - \frac{1}{\left(T_{board-ambient} + 273\right)}\right]}$ In operating phase: $\Pi_{RH} = 0$

Application Specific Integrated Circuit (ASIC)

General model associated with the family

$$\lambda_{\text{ASIC}} = \lambda_{\text{Physical}} \times \Pi_{\text{Process\_ASIC}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$$

ASICs are modelled in the same way as other integrated circuits together with the specificities described in this datasheet.

The $\lambda_{\text{Physical}}$ and Π_{Process} factors are the factors defined for the Integrated Circuits family. The λ_{0TH} value for the different types of ASIC are detailed below.

Model associated with the $\Pi_{\text{Process\_ASIC}}$ factor

The $\Pi_{\text{Process\_ASIC}}$ factor takes account of:

- The use of a formal development methodology (type DO254, COCISPER…) and the Project Manager's level of control over subcontractors, for a project set up involving several contributors (founder, assembler, test house, etc).
- Good control in production and appropriate monitoring during the ASIC manufacturing process.

$$\Pi_{\text{Process\_AS IC}} = e^{1.39 \times (1 - \text{ASIC\_Grade})}$$

The default value of 2.5 is proposed if $\Pi_{\text{Process\_ASIC}}$ is not evaluated. The use of the default value can reduce the accuracy of the final results.

The ASIC_Grade factor is calculated from a questionnaire about the ASIC development process.

$$\text{ASIC\_Grade} = \frac{\sum \text{Values in the following table}}{100}$$

No.	**Factors influencing the ASIC_grade**	**Value** (if true)	**Value** (if false)
Development and design: recommendations related to the ASIC design and project management			
1	Application of a formal methodology during the design phase (DO254, COCISPER, …)	10	0
2	Existence of a subcontractor control plan (participants in the project)	10	0
3	The subcontractor control plan covers all participants in the project (control over the entire life cycle)	10	0
4	Selection of subcontractors with experience in the target technology, functions and complexity level	10	0
5	Selection of experienced subcontractors to take account of the complexity of the industrial organisation of the project	5	0
6	Formal control (with reviews) by the design centre over subcontractors (founder, assembler and "test house")	5	0
7	Industrial organisation used in the past	5	0
8	No subcontractor with poor feedback from operations	5	0
Manufacturing: Recommendations for manufacturing and monitoring of the process ASIC manufacturing process			
9	Use of a mature non-aging technology	15	0
10	Use of Wafer annealing	10	0
11	Functional test of the ASIC at 3 temperatures	15	0

The variation range of the $\Pi_{\text{Process ASIC}}$ factor varies from 1 (for the best process) to 4 (the worst process).

Model associated with the Π_{PM} factor

$$\Pi_{PM} = e^{1.39\times(1-\text{Part\_Grade})-0.69}$$

$$\text{Part\_Grade} = \left[\frac{(QA_{\text{manufacturer}} + QA_{\text{component}} + RA_{\text{component}})\times\varepsilon}{36}\right]$$

The $QA_{\text{manufacturer}}$, $QA_{\text{component}}$ and $RA_{\text{component}}$ factors are as defined for the Integrated Circuits family.

Model associated with the experience factor ε

As for Integrated Circuits, the experience factor, ε, must represent the buyer's experience with his supplier. For ASICs, it is essential to take account of the case of manufacturers/founders who propose aging technologies, few updating, or too recent technologies. These cases will be treated like a "small series" (where $\varepsilon=2$).

Description of the risk related to use of this manufacturer/founder	ε
Recognised manufacturer: mature processes for the product considered	4
Recognised manufacturer: processes not analysed or not mature for the product considered	3
Manufacturer not recognised (for example never audited or audited more than 6 years earlier) or manufacturing of small series or aging or immature ASIC technology	2
Previous disqualification or major problem with feedback from operations	1

Basic failure rate associated with the chip

Technology type	**Type of ASIC function**	λ_{0TH}
MOS silicon	Digital ASIC, simple function	0.021
	Digital ASIC, complex function (with IP and/or µP core, memory blocks)	0.075
	Analogue, mixed ASIC	0.123
Silicon bipolar, BICMOS	Digital ASIC	0.021
	Mixed, analogue ASIC	0.123

Discrete semiconductors

General model associated with the family

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$ where:

$$\lambda_{\text{Physical}} = \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \begin{pmatrix} \lambda_{0\,\text{TH}} \times \Pi_{\text{Thermal}} \\ + \lambda_{0\,\text{TCyCase}} \times \Pi_{\text{TCyCase}} \\ + \lambda_{0\,\text{TCySolder joints}} \times \Pi_{\text{TCySolder joints}} \\ + \lambda_{0\,\text{RH}} \times \Pi_{\text{RH}} \\ + \lambda_{0\,\text{Mech}} \times \Pi_{\text{Mech}} \end{pmatrix}_i \times (\Pi_{\text{Induced}})_i$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	$C_{\text{sensitivity}}$
Discrete semiconductor circuit	8	2	1	5.20

Π_{PM}: Model associated with the $QA_{\text{component}}$ factor

Component quality assurance level	Position relative to the state of the art	$QA_{\text{component}}$
Qualification according to one of the following standards: AEC Q101, MIL-PRF-19500 JANS, ESCC 5xxxx level B , NASDA-QTS-xxxx class I	Higher	3
Manufacturer qualification including tests conforming with standards JESD22, EIAJ-ED-4701, MIL-STD-750 and identification of "front end" and "back end" manufacturing sites; Qualification according to one of the following standards: MIL-PRF-19500 JANTX or JANTXV, ESCC 5xxx level C, NASDA-QTS-xxxx class II	Equivalent	2
Qualification according to MIL-PRF-19500 JAN or qualification program internal to the manufacturer and unidentified manufacturing sites	Lower	1
No information	Much lower	0

Π_{PM}: Model associated with the $RA_{component}$ factor

Title of accelerated aging test	High Temperature Reverse Bias (HTRB)	High Temperature Gate Bias (HTGB)	Intermittent Operating Life(2) Or Power and Temperature Cycle (2)	Pre-conditioning before TC, THB or HAST	Temperature Cycling (TC)	Pressure Cooker Test (PCT)	High Humidity High Temperature Reverse Bias (H^3TRB)	
Reference standards	EIA JESD-22-A108 A or equivalent	EIA JESD-22-A108 A or equivalent	MIL-STD-750 Method 1037 EIA JESD22 A-105	EIA JESD-22-A113A or equivalent	EIA JESD-22-A104 or equivalent	EIA JESD-22-A102 or equivalent	EIA JESD-22-A101 or equivalent	
	Test results							$RA_{component}$ risk
Very reliable level A	1000h, 125°C, 80% to 100% of the rated voltage, 231/0(1) 1500/0*	1000h, 150°C, 80% to 100% of the rated voltage 231/0(1) 1500/0*	Ta=25°C biased component to obtain ΔTj ≥100°C (without reaching the absolute maximum ratings) 231/0(1) 1500/0*	done	1000 cycles -55°C /+150°C or 500 cycles -65°C/+150°C 231/0 or 1000 cycles -55°C/125°C 385/0	2000 h at 85°C/85% RH 154/0	168 h at 130°C/ 85%RH 231/0	**3**
Very reliable level B	1000h, 125°C, 80% to100% of the rated voltage, 154/0(1) 900/0*	1000h, 150°C, 80% to 100% of the rated voltage 154/0(1) 900/0*	Ta=25°C biased component to obtain ΔTj ≥100°C (without reaching the absolute maximum ratings) 154/0(1) 900/0*	done	1000 cycles -55°C /+125°C, 154/0	96 h at 121°C / 100%RH, 154/0	2000 h at 85°C/85%RH 154/0	**2**
Reliable	1000h, 150°C, 80% to100% of the rated voltage, 77/0(1) 231/0*	1000h, 150°C, 80 to 100% of the rated voltage, 77/0(1) 231/0*	Ta=25°C biased component to obtain ΔTj ≥100°C (without reaching the absolute maximum ratings), 77/0(1) 231/0*	done	500 cycles -55°C /+125°C, 154/0	96 h at 121°C / 100%RH, 77/0	1000 h at 85°C/85%RH, 154/0	**1**
Not reliable	Design below the reliable level			Not done	Design below the reliable level			**0**

Each box in the table contains a description of test conditions with the expected result in the form XXX/Y where XXX is the number of parts under test and Y is the number of defects (in practice Y=0)

(1): Applicable to a Front End item or process for a determined case.
(2): Test conditions as defined in AEC-Q101.
*: applicable to all Front End processes for a determined case.

If levels in different test types are different, the lowest level will be selected.

Basic failure rate associated with cases

Case	Equivalent name	Description	λ_{0RH}	λ_{0Tcy_Case}	$\lambda_{0Tcy\_Solder\ joints}$	$\lambda_{0\ Mechanical}$
CB417		Through hole, small signal, plastic	0.0310	0.00110	0.0055	0.00011
CB429						
DO13	DO202AA					
DO15	DO204AC					
DO27	DO201AA					
DO35	DO204AH					
DO41	DO204AL					
DO92						
F126						
SIL, SIP	SIL, SIP, ZIP					
TO92	SOT54, SC43, TO226AA					
TO126	SOT32, TO225AA					
TO202						
SOT23-3	TO236AB	SMD, small signal, L-lead, plastic	0.0055	0.00057	0.00285	0.000057
SOT23-5	SC74A, SOT25					
SOT23-6	SC74, SOT26, SOT457					
SOT143	TO253AA, SC61B					
SOT323	SC70					
SOT346	SC59, TO236AA					
SOT353	SC70-5, SC88A					
SOT363	SC70-6, SC88					
SOD123						
SOD323	SC76					
SOD523	SC79					
SOT223	SC73, TO261AA	SMD, medium power, small heat sink, L-lead, plastic	0.0126	0.00091	0.00455	0.000091
SOT243						
SOT343	SC82					
SOT89	SC62, TO243AA					
SOT194						
TO218	ISOWATT218	Through hole, power, plastic	0.0589	0.00303	0.01515	0.0003
TO220	TO220-5, ISOWATT220, TO220XX					
TO247	Max247, Super247, SOT429					
ISOWATT						
DO220						
IPACK	TO251AA					
SOT82	TO225					
SOD6	DO214AA, SMB-J	SMD, small signal, C-lead, plastic	0.0124	0.00091	0.00455	0.00009
SOD15	DO214AB, SMC-J					
DPAK	TO252AA, SC63, SOT428	SMD, power, large heat sink, L-lead, plastic	0.0335	0.00413	0.02065	0.00041
D2PAK	TO263, SC83A, SMD220					
D3PAK	TO268					
ISOTOP	SOT227, TO244, Half-Pak	SMD, high power, screw, plastic	0.99	0.03333	0.16665	0.0033
SOD80	Mini-MELF, DO213AA	SMD, Hermetically sealed glass	0	0.00781	0.03905	0.00078
SOD87	MELF, DO213AB					
TO18	TO71, TO72, SOT31, SOT18	Through hole, metal	0	0.0101	0.0505	0.00101
TO39	SOT5					
TO52						

Notes:

- The failure rate for hermetically sealed cases due to a humid atmosphere is zero.
- Some types of Integrated Circuit cases are also used for Discrete semiconductors. In particular, the "Thin Shrink Small Outlines, L lead, plastic (TSSOP)", "Thin Small Outlines, leads on long edges, L lead, plastic (TSOP)" and " Plastic Small Outlines, L lead, plastic

(SO)" types. Refer to the Integrated Circuit components datasheet for failure rates for these cases.

Basic failure rates associated with the chip

Low power diodes	λ_{0TH}
Signal diodes up to 1A (PIN, Schottky, signal, varactor)	0.0044
Rectifying diodes 1A to 3A	0.0100
Zener regulation diodes up to 1.5W	0.0080
Protection diodes up to 3kW (in peak 10ms/ 100ms) (TVS)	0.0210

Power diodes	λ_{0TH}
Thyristors, triacs more than 3A	0.1976
Rectifying diodes > 3A	0.1574
Zener regulation diodes more than 1.5W	0.0954
Protection diodes more than 3kW (in peak 10ms/ 100ms) (TVS)	1.4980

Low power transistors	λ_{0TH}
Silicon bipolar < 5W	0.0138
Silicon MOS < 5W	0.0145
Silicon JFET < 5W	0.0143

Power transistors	λ_{0TH}
Silicon bipolar > 5W	0.0478
Silicon MOS > 5W	0.0202
IGBT	0.3021

When N elements (diodes, transistors) are installed in a single case, the λ_{0TH} value must be multiplied by $\sqrt{N}$.

Information about the life profile

t_{annual}:	time associated with each phase over a year (hours)
$RH_{ambient}$:	humidity associated with a phase (%)
$T_{board-ambient}$:	average board temperature during a phase (°C)
$\Delta T_{cycling}$:	amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$:	maximum board temperature during a cycling phase (°C)
$N_{annual-cy}$:	number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}:	cycle duration (hours)

Information about the application

$T_{J\_component}$: component junction temperature during an operating phase (°C)

$T_{J\_component} = T_{ambient} + R_{JA} \cdot P_{dissipated}$

$P_{dissipated}$: power dissipated by the component during the phase (W)

$V_{applied}$: inverse voltage applied during the phase, for signal diodes only (V)

Information related to the technology

V_{rated}: rated inverse voltage (V), for signal diodes only

Factors contributing to Physical stresses

$\Pi_{Thermal}$	In an operating phase: $\Pi_{El} \times e^{11604 \times 0.7 \times \left[\frac{1}{293} - \frac{1}{(T_{j-component}+273)}\right]}$ For signal diodes up to 1A (PIN, Schottky, signal, varactor): $\Pi_{El} = \left(\frac{V_{applied}}{V_r}\right)^{2.4}$ if $\frac{V_{applied}}{V_{rated}} > 0.3$ $\Pi_{El} = 0.056$ if $\frac{V_{applied}}{V_{rated}} \leq 0.3$ For other item types: $\Pi_{El} = 1$ In a non-operating phase: $\Pi_{Thermal} = 0$
Π_{TCy} **Case**	$\left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\Delta T_{cycling}}{20}\right)^4 \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
Π_{TCy} **Solder joints**	$\left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
Π_{Mech}	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$\left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.9 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient}+273)}\right]}$ In an operating phase: $\Pi_{RH} = 0$

Light emitting diodes (LED)

General model associated with the family

ⓘ Warning: Limited life

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$ where:

$$\lambda_{\text{Physical}} = \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \begin{pmatrix} \lambda_{0\,\text{TH}} \times \Pi_{\text{Thermal}} \\ + \lambda_{0\,\text{TCy Case}} \times \Pi_{\text{TCy Case}} \\ + \lambda_{0\,\text{TCy Solder joints}} \times \Pi_{\text{TCy Solder joints}} \\ + \lambda_{0\,\text{RH}} \times \Pi_{\text{RH}} \\ + \lambda_{0\,\text{Mech}} \times \Pi_{\text{Mech}} \end{pmatrix}_i \times \left(\Pi_{\text{Induced}}\right)$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	**$C_{\text{sensitivity}}$**
Light Emitting Diode (LED)	7	2	3	4.85

Model associated with the component manufacturing factor Π_{PM}

The Π_{PM} factor is the same as for Discrete semiconductors.

Basic failure rate associated with cases

Direct current I_F maximum	SMD or Through hole	Case type		Number of pins	λ_{0RH}	λ_{0Tcy} Case	λ_{0Tcy} Solder joints	$\lambda_{0\ Mechanical}$
$I_F < 150mA$	Through	T1-x	Plastic	2 to 4	0.0034	0.0104	0.0520	0.0052
		High flux		4				
	SMD	Chip		2				
		PLCC		Min 2				
				2				
				3				
				4				
				6				
		Round		2			0.1560	0.0624
		LGA	Plastic	2			0.2080	0.0832
			Ceramic				0.3640	0.1820
		Other	Plastic	Indifferent			0.1560	0.0624
			Ceramic				0.3640	0.1820
$I_F \geq 150mA$	SMD	Plastic		Indifferent	0.0031	0.0042	0.0420	0.0064
		Ceramic					0.1470	0.0735

Basic failure rate associated with the chip

Light emitting diode (LED)	λ_{0TH}
COLOUR	0.01
WHITE	0.05

When N diodes (colour or white) are arranged in the same case, the λ_{0TH} value must be multiplied by $\sqrt{N}$. Some white diodes are composed of three colour diodes; for these white diodes, use the value of λ_{0TH} given in the table instead of calculating the individual λ_{0TH} from λ_{0TH} for the 3 colour diodes.

Information about the life profile

t_{annual}:	time associated with each phase over a year (hours)
$RH_{ambient}$:	relative humidity associated with a phase (%)
$T_{board-ambient}$:	average board temperature during a phase (°C)
$\Delta T_{cycling}$:	amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$:	maximum board temperature during a cycling phase (°C)
$N_{annual-cy}$:	number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}:	cycle duration (hours)

Information about the application

$T_{J\_component}$:	component junction temperature during an operating phase (°C)
$T_{J\_component} = T_{ambient} + R_{JA} \cdot P_{dissipated}$	
$P_{dissipated}$:	power dissipated by the component during the phase (W)
$V_{applied}$:	inverse voltage applied during the phase, for signal diodes only (V)

Factors contributing to Physical stresses

$\Pi_{Thermal}$	In an operating phase: $e^{11604 \times 0.4 \times \left[\frac{1}{293} - \frac{1}{(T_{j-component} + 273)}\right]}$ In a non-operating phase: $\Pi_{Thermal} = 0$
Π_{TCy} **Case**	$\left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\Delta T_{cycling}}{20}\right)^{4} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling} + 273)}\right]}$
Π_{TCy} **Solder joints**	$\left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy}, 2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling} + 273)}\right]}$
Π_{Mech}	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$\left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.9 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient} + 273)}\right]}$ In an operating phase: $\Pi_{RH} = 0$

Optocouplers

General model associated with the family

$\lambda = \lambda_{Physical} \times \Pi_{PM} \times \Pi_{Process}$ where:

$$\lambda_{Physical} = \sum_{i}^{Phases} \left(\frac{t_{annual}}{8760}\right)_i \times \left(\begin{array}{l} \lambda_{0\,TH} \times \Pi_{Thermal} \\ + \lambda_{0\,TCyCase} \times \Pi_{TCyCase} \\ + (\lambda_{0\,TCySolder\,joints} + \lambda_{0\,TCyChip}) \times \Pi_{TCySolder\,joints} \\ + \lambda_{0\,RH} \times \Pi_{RH} \\ + (\lambda_{0\,Case\,Mech} + \lambda_{0\,Chip\,Mech}) \times \Pi_{Mech} \end{array} \right)_i \times (\Pi_{Induced})_i$$

$C_{sensitivity}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	$C_{sensitivity}$
Optocoupler	8	2	1	5.20

Model associated with the component manufacturing factor Π_{PM}:

The factor Π_{PM} is the same as for discrete semiconductors.

Basic failure rate associated with the chip

Component description	Activation energy (eV)	λ_{0_Th}	$\lambda_{0\ TCY\_chip}$	$\lambda_{0\ chip\ MECH}$
Optocoupler with photodiode	0.4	0.05	0.01	0.005
Optocoupler with phototransistor	0.4	0.11	0.021	0.011

When N optocouplers are placed in a single case, the λ_{0_TH}, λ_{0TCY_chips}, and $\lambda_{0\ chip\ MECH}$ values must be multiplied by $\sqrt{N}$.

The values of $\lambda_{0\ Tcy\ Cases}$, $\lambda_{0\ Tcy\ Solder\ joints}$, $\lambda_{0\ Case\_mech}$ and $\lambda_{0\ RH}$ can be found in basic failure rate tables associated with integrated circuit cases or discrete semiconductors.

Information about the life profile

t_{annual} : time associated with each phase over a year (hours)
$RH_{ambient}$: humidity associated with a phase (%)
$T_{board\text{-}ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy} : cycle duration (hours)

Information about the application

$T_{J\_component}$: component junction temperature during an operating phase (°C)
$T_{J\_component} = T_{ambient} + R_{JA} \cdot P_{dissipated}$
$P_{dissipated}$: power dissipated by the component during the phase (W)

Factors contributing to Physical stresses:

$\Pi_{Thermal}$	In an operating phase: $e^{11604\times 0.7\times\left[\frac{1}{293}-\frac{1}{(T_{j-component}+273)}\right]}$ In a non-operating phase: $\Pi_{Thermal} = 0$
Π_{TCy} Case	$\left(\frac{12\times N_{annual\text{-}cy}}{t_{annual}}\right)\times\left(\frac{\Delta T_{cycling}}{20}\right)^{4}\times e^{1414\times\left[\frac{1}{313}-\frac{1}{(T_{max-cycling}+273)}\right]}$
Π_{TCy} Solder joints	$\left(\frac{12\times N_{annual\text{-}cy}}{t_{annual}}\right)\times\left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}}\times\left(\frac{\Delta T_{cycling}}{20}\right)^{1.9}\times e^{1414\times\left[\frac{1}{313}-\frac{1}{(T_{max-cycling}+273)}\right]}$
Π_{Mech}	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$\left(\frac{RH_{ambient}}{70}\right)^{4.4}\times e^{11604\times 0.9\times\left[\frac{1}{293}-\frac{1}{(T_{board-ambient}+273)}\right]}$ In an operating phase: $\Pi_{RH} = 0$

Resistors

General model associated with the family

$\lambda = \lambda_{Physical} \times \Pi_{PM} \times \Pi_{Process}$ where:

$$\lambda_{Physical} = \lambda_{0\_Resistance} \times \sum_{i}^{Phases} \left(\frac{t_{annual}}{8760}\right)_i \times \left(\Pi_{Thermo-electrical} + \Pi_{TCy} + \Pi_{Mechanical} + \Pi_{RH}\right)_i \times \left(\Pi_{Induced}\right)_i$$

$C_{sensitivity}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	$C_{sensitivity}$
“Minimelf" high stability (RS) common (RC) low power film resistor	5	2	4	3.85
Power film resistor	2	3	1	2.25
Low power wirewound accuracy resistor	2	1	3	1.75
Power wirewound resistor	2	3	1	2.25
Trimming potentiometer (CERMET)	1	5	2	2.50
Resistive chip	5	4	6	4.75
SMD resistive network	4	5	3	4.25
High stability bulk metal foil accuracy resistor	6	6	4	5.8

$QA_{component}$ factor

Component quality assurance level	Position relative to the state of the art	$QA_{component}$
Qualification according to one of the following standards: AEC Q200, MIL-PRF-xxxx level S, MIL-PRF-xxxx level R, MIL-PRF-xxxx level D, MIL-PRF- level C, ESCC 400x level B, NASDA-QTS-xxxx class I	Higher	3
Qualification according to one of the following standards: MIL-PRF-xxx level P, MIL-PRF-xxxx level B, ESCC 400x level C, NASDA-QTS-xxxx class II with identification of manufacturing sites for these standards	Equivalent	2
Qualification according to one of the following approved CECC standards: MIL-PRF-xxxx level M, or qualification program internal to the manufacturer and unidentified manufacturing sites	Lower	1
No information	Much lower	0

Note: This factor applies to all passive components. The MIL-PRF or NASDA-QTS standard appropriate for the item family concerned must be considered.

Basic failure rate associated with the component

Component description			$\lambda_{0\text{-Resistor}}$	**A (°C)**	$\gamma_{TH\text{-}EL}$	γ_{TCy}	γ_{Mech}	γ_{RH}
"Minimelf" common use (RC) high stability (RS) low power film resistor			0.1	85	0.04	0.89	0.01	0.06
Power film resistor			0.4	130	0.04	0.89	0.01	0.06
Low power wirewound accuracy resistor			0.3	30	0.02	0.96	0.01	0.01
Power wirewound resistor			0.4	130	0.01	0.97	0.01	0.01
Trimming potentiometer (CERMET)			0.3	65	0.42	0.35	0.22	0.01
Resistive chip			0.01	70	0.01	0.97	0.01	0.01
SMD resistive network			$0.01\times\sqrt{N_R}$	70	0.01	0.97	0.01	0.01
High stability bulk metal foil accuracy resistor	SMD	<10kΩ	0.18	85	0.14	0.53	0.07	0.26
		10kΩ <...< 100kΩ	0.21	85	0.10	0.54	0.06	0.30
		>100kΩ	0.25	85	0.07	0.55	0.05	0.33
	Through hole	<10kΩ	0.14	85	0.18	0.43	0.08	0.31
		10kΩ <...< 100kΩ	0.18	85	0.12	0.44	0.07	0.37
		>100kΩ	0.21	85	0.08	0.45	0.06	0.41

For resistive networks, N_R is the number of resistors in the network.

Information about the life profile

t_{annual}:	time associated with each phase over a year (hours)
$RH_{ambient:}$	relative humidity associated with a phase (%)
$T_{board-ambient}$:	average board temperature during a phase (°C)
$\Delta T_{cycling}$:	amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$:	maximum board temperature during a cycling phase (°C)
$N_{annual-cy}$:	number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}:	cycle duration (hours)
G_{RMS}:	vibration amplitude associated with each random vibration phase (Grms)

Information about the application

$P_{dissipated}$:	power dissipated by the component during the phase (W)

Information about technical characteristics

P_{rated}:	maximum allowable power by the component specified by the supplier (W)

Factors contributing to Physical stresses

Π***Thermo-electrical***	In an operating phase: $\gamma_{TH-EL} \times e^{11604 \times 0.15 \times \left[\frac{1}{293} - \frac{1}{\left(T_{board-ambient} + 273 + A \times \frac{P_{applied}}{P_{rated}}\right)}\right]}$ In a non-operating phase: $\Pi_{Thermo-electrical} = 0$
Π***TCy***	$\gamma_{TCy} \times \left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
Π***Mechanical***	$\gamma_{Mech} \times \left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π***RH***	$\gamma_{RH} \times \left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.9 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient}+273)}\right]}$ In an operating phase: $\Pi_{RH} = 0$

Fuses

Preliminary comment

Predicting the reliability of fuses is a unique problem. Unlike other components, there is very little correlation between replacement of a fuse and its failure. Usually, when a fuse opens and has to be replaced, it has performed its function satisfactorily. On the other hand, a fuse that has not opened when it should have opened will not necessarily have been diagnosed in failure. Therefore, care should be taken when predicting the reliability of a fuse.

General model associated with the family

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$ where:

$$\lambda_{\text{Physical}} = \lambda_{0\_\text{Fuse}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \left(\Pi_{\text{Thermo-electrical}} + \Pi_{\text{TCy}} + \Pi_{\text{Mechanical}} + \Pi_{\text{RH}} + \Pi_{\text{Chi}}\right)_i \times \left(\Pi_{\text{Induced}}\right)_i$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	**MOS**	**TOS**	**$C_{\text{sensitivity}}$**
Fuse	6	6	4	5.8

$QA_{\text{component}}$ factor

Component quality assurance level	**Position relative to the state of the art**	**$QA_{\text{component}}$**
Qualification according to MIL-PRF-23419 or equivalent	Higher	3
Certification according to IEC 60127 or equivalent	Equivalent	2
No information	Lower	0

Basic failure rate associated with the component

$\lambda_{0\_\text{Fuse}} = 0.5$

The λ_{0_Fuse} value shall be considered for all fuse types. This includes glass tube, ceramic tube, plug-in, through hole, SMD, chip (with FR4 or ceramic substrate) type fuses.

The model does not include a fuse holder (which can be modelled as a component support connector with 2 contacts).

Information about the life profile

t_{annual}: time associated with each phase over a year (hours)
$RH_{ambient}$: relative humidity associated with a phase (%)
$T_{board-ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual-cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}: cycle duration (hours)
G_{RMS}: vibration amplitude associated with each random vibration phase (Grms)
Pollution level (see tables)

Saline pollution level	Π_{sal}
Low	1
High	2

Product protection level	Π_{prot}
Hermetic	0
Non-hermetic	1

Application pollution level	Π_{zone}
Low	1
Moderate	2
High	4

Environmental pollution level	Π_{envir}
Low	1
Moderate	1.5
High	2

Information about the application

$I_{applied}$: Current in the fuse during the phase (A)

Information about technical characteristics

I_{rated}: Allowable rated current in the fuse without opening (A)

Factors contributing to Physical stresses

$\Pi_{Thermo-electrical}$	In an operating phase: $0.13 \times \left(\frac{1}{0.8} \times \frac{I_{applied}}{I_{rated}}\right)^{1.5} \times e^{11604 \times 0.15 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient}+273)}\right]}$ In a non-operating phase: $\Pi_{Thermo-electrical} = 0$
Π_{TCy}	$0.51 \times \left(\frac{12.N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
$\Pi_{Mechanical}$	$0.06 \times \left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$0.24 \times \left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.9 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient}+273)}\right]}$ In an operating phase: $\Pi_{RH} = 0$
Π_{CHI}	$0.06 \times \Pi_{Sal} \times \Pi_{Envir} \times \Pi_{Area} \times \Pi_{Prot}$

Ceramic capacitors

General model associated with the family

$$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$$

where:

$$\lambda_{\text{Physical}} = \lambda_{0\_\text{Capacitor}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \left(\Pi_{\text{Thermo-electrical}} + \Pi_{\text{TCy}} + \Pi_{\text{Mechanical}}\right)_i \times \left(\Pi_{\text{Induced}}\right)_i$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	$C_{\text{sensitivity}}$
Ceramic capacitor with defined temperature coefficient (Type I)	7	6	1	6.05
Ceramic capacitor with non-defined temperature coefficient (Type II)	7	6	1	6.05

Model associated with the $QA_{\text{component}}$ factor

This factor is determined in the same way as for resistors.

Basic failure rates associated with the component

Component description	$\lambda_{0\_Capacitor}$	Activation energy (eV)	$S_{reference}$	γ_{TH-EL}	γ_{TCy}	γ_{Mech}
Ceramic capacitor with defined temperature coefficient (Type I) with a low CV product	0.03	0.1	0.3	0.70	0.28	0.02
Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product	0.05	0.1	0.3	0.70	0.28	0.02
Ceramic capacitor with defined temperature coefficient (Type I) with a high CV product	0.40	0.1	0.3	0.69	0.26	0.05
Ceramic capacitor with non-defined temperature coefficient (Type II) with a low CV product	0.08	0.1	0.3	0.70	0.28	0.02
Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product	0.15	0.1	0.3	0.70	0.28	0.02
Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product	1.20	0.1	0.3	0.44	0.51	0.05
Ceramic capacitor with polymer terminations with non-defined temperature coefficient (Type II) with a low CV product	0.08	0.1	0.3	0.70	0.28	0.02
Ceramic capacitor with polymer terminations with non-defined temperature coefficient (Type II) with a medium or high CV product	0.15	0.1	0.3	0.70	0.28	0.02

CV product

	Type I	Type II
Low CV product	Less than 1.0 x 10^{-9} V.F	Less than 1.0 x 10^{-7} V.F
Medium CV product	Between 1.0 x 10^{-9} V.F and 1.0 x 10^{-7} V.F	Between 10 x 10^{-7} V.F and 1.0 x 10^{-5} V.F
High CV product	Higher than 1.0 x 10^{-7} V.F	Higher than 1.0 x 10^{-5} V.F

Information about the life profile

t_{annual}: time associated with each operating phase over a year (hours)
$T_{board\text{-}ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}: cycle duration (hours)
G_{RMS}: stress associated with each random vibration phase (Grms)

Information about the application

$V_{applied}$: voltage applied to the component during the phase (V)

Information about technical characteristics

V_{rated}: maximum voltage applied to the component specified by the supplier (V)

Factors contributing to Physical stresses

Π***Thermo-electrical***	In an operating phase: $\gamma_{TH-EL} \times \left(\frac{1}{S_{reference}} \times \frac{V_{applied}}{V_{rated}} \right)^3 \times e^{11604 \times Ea \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient} + 273)} \right]}$ In a non-operating phase: $\Pi_{\text{Thermo-electrical}} = 0$
Π***TCy***	$\gamma_{TCy} \times \left(\frac{12 \times N_{annual\text{-}cy}}{t_{annual}} \right) \times \left(\frac{\min(\theta_{cy}, 2)}{2} \right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20} \right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling} + 273)} \right]}$
Π***Mechanical***	$\gamma_{Mech} \times \left(\frac{G_{RMS}}{0.5} \right)^{1.5}$

Aluminium capacitors

General model associated with the family

ⓘ Warning: limited life

$$\lambda = \lambda_{\mathrm{Physical}} \times \Pi_{\mathrm{PM}} \times \Pi_{\mathrm{Process}}$$

where:

$$\lambda_{\mathrm{Physical}} = \lambda_{0\_\mathrm{Capacitor}} \times \sum_{i}^{\mathrm{Phases}} \left(\frac{t_{\mathrm{annual}}}{8760}\right)_i \times \left(\Pi_{\mathrm{Thermo-electrical}} + \Pi_{\mathrm{TCy}} + \Pi_{\mathrm{Mechanical}}\right)_i \times \left(\Pi_{\mathrm{Induced}}\right)_i$$

$C_{\mathrm{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	$C_{\mathrm{sensitivity}}$
Aluminium liquid electrolyte capacitor	7	7	1	6.40
Aluminium solid electrolyte capacitor	7	7	1	6.40

Model associated with the $QA_{\mathrm{component}}$ factor

This factor is determined in the same way as for resistors.

Basic failure rates associated with the component

Component description	$\lambda_{0\_\mathrm{Capacitor}}$	Activation energy Ea (eV)	$S_{\mathrm{reference}}$	$\gamma_{\mathrm{TH-EL}}$	γ_{TCy}	γ_{Mech}
Aluminium liquid electrolyte capacitor	0.21	0.40	0.5	0.85	0.14	0.01
Aluminium solid electrolyte capacitor	0.4	0.40	0.55	0.85	0.14	0.01

Information about the life profile

t_{annual} : time associated with each operating phase over a year (hours)
$T_{board-ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual-cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy} : cycle duration (hours)
G_{RMS} : stress associated with each random vibration phase (Grms)

Information about the application

$V_{applied}$: voltage applied to the component during the phase (V)

Information about technical characteristics

V_{rated}: maximum voltage applied to the component specified by the supplier (V)

Factors contributing to Physical stresses

$\Pi_{Thermo-electrical}$	In an operating phase: $\gamma_{TH-EL} \times \left(\frac{1}{S_{reference}} \times \frac{V_{applied}}{V_{rated}} \right)_i^3 e^{11604 \times Ea \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient} + 273)} \right]_i}$ In a non-operating phase: $\Pi_{Thermo-electrical} = 0$
Π_{TCy}	$\gamma_{TCy} \times \left(\frac{12.N_{annual-cy}}{t_{annual}} \right)_i \times \left(\frac{\min(\theta_{cy},2)}{2} \right)_i^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20} \right)_i^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling} + 273)} \right]_i}$
$\Pi_{Mechanical}$	$\gamma_{Mech} \times \left(\frac{G_{RMS}}{0.5} \right)_i^{1.5}$

Tantalum capacitors

General model associated with the family

$$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$$

where:

$$\lambda_{\text{Physical}} = \lambda_{0\_\text{Capacitor}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760} \right)_i \times \left(\Pi_{\text{Thermo-electrical}} + \Pi_{\text{TCy}} + \Pi_{\text{Mechanical}} \right)_i \times \left(\Pi_{\text{Induced}} \right)_i$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	**MOS**	**TOS**	$C_{\text{sensitivity}}$
Tantalum capacitor (solid or gel electrolyte)	8	7	1	6.95

Model associated with the $QA_{\text{component}}$ factor

This factor is determined in the same way as for resistors.

Basic failure rates associated with the component

Tantalum capacitor with gel electrolyte

Component description	$\lambda_{0\_\text{Capacitor}}$	Activation energy EA (eV)	$S_{\text{reference}}$	$\gamma_{\text{TH-EL}}$	γ_{TCy}	γ_{Mech}
Wet tantalum capacitor Silver case, sealed by elastomer	0.77	0.15	0.6	0.87	0.01	0.12
Wet tantalum capacitor Silver case, sealed by glass beads	0.33	0.15	0.6	0.81	0.01	0.18
Wet tantalum capacitor bead Tantalum case, sealed by glass beads	0.05	0.15	0.6	0.88	0.04	0.08

Tantalum capacitor with solid electrolyte

Component description	$\lambda_{0\_\text{Capacitor}}$	Activation energy EA (eV)	$S_{\text{reference}}$	$\gamma_{\text{TH-EL}}$	γ_{TCy}	γ_{Mech}
Dry tantalum capacitor Drop packaging	1.09	0.15	0.4	0.86	0.12	0.02
Dry tantalum capacitor SMD packaging	0.54	0.15	0.4	0.84	0.14	0.02
Dry tantalum capacitor Axial metal packaging	0.25	0.15	0.4	0.94	0.04	0.02

Notes:

- The default value for the wet tantalum capacitor will be a Silver case sealed by glass beads.
- The default value for the dry tantalum capacitor will be SMD packaging.

Information about the life profile

t_{annual} : time associated with each operating phase over a year (hours)
$T_{board-ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual-cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy} : cycle duration (hours)
G_{RMS} : stress associated with each random vibration phase (Grms)

Information about the application

$V_{applied}$: voltage applied to the component during the phase (V)

Information about technical characteristics

V_{rated}: maximum voltage applied to the component specified by the supplier (V)

Factors contributing to Physical stresses

Π***Thermo-electrical***	In an operating phase: $\gamma_{TH-EL} \times \left(\frac{1}{S_{reference}} \times \frac{V_{applied}}{V_{rated}}\right)_i^3 e^{11604 \times Ea \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient}+273)}\right]_i}$ In a non-operating phase: $\Pi_{Thermo-electrical} = 0$
Π***TCy***	$\gamma_{TCy} \times \left(\frac{12.N_{annual-cy}}{t_{annual}}\right)_i \times \left(\frac{\min(\theta_{cy},2)}{2}\right)_i^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)_i^{1.9} \times e^{1414\times\left[\frac{1}{313}-\frac{1}{(T_{\max-cycling}+273)}\right]_i}$
Π***Mechanical***	$\gamma_{Mech} \times \left(\frac{G_{RMS}}{0.5}\right)_i^{1.5}$

Magnetic components: Inductors and Transformers

General model associated with the family

$$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$$

where:

$$\lambda_{\text{Physical}} = \lambda_{0\_\text{Magnetic}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \left(\Pi_{\text{Thermo-electrical}} + \Pi_{\text{TCy}} + \Pi_{\text{Mechanical}}\right)_i \times \left(\Pi_{\text{Induced}}\right)_i$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	**MOS**	**TOS**	**$C_{\text{sensitivity}}$**
Low current wirewound inductor	5	2	6	4.05
High current (or power) wirewound inductor	10	7	1	8.05
Multi-layer inductor	4	6	1	4.40
Transformer, Low Power (or Low Level)	8	6	4	6.90
Transformer, High Power	8	6	3	6.80

Model associated with the $QA_{\text{component}}$ factor

This factor is determined in the same way as for resistors.

Basic failure rates associated with the component

Component description	$\lambda_{\text{0-Magnetic}}$	**Activation energies Ea (eV)**	$\gamma_{\text{TH-EL}}$	γ_{TCy}	γ_{Mech}	**ΔT (°C)**
Low current wirewound inductor (or Low level)	0.025	0.15	0.01	0.73	0.26	10
High current (or power) wirewound inductor	0.05	0.15	0.09	0.79	0.12	30
Multi-layer inductor	0.05	0.15	0.71	0.28	0.01	10
Transformer, Low Power (or Low Level)	0.125	0.15	0.01	0.73	0.26	10
Transformer, High Power	0.25	0.15	0.15	0.69	0.16	30

Information about the life profile

t_{annual} : time associated with each phase over a year (hours)
$T_{board\text{-}ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy} : cycle duration (hours)
G_{RMS} : stress associated with each random vibration phase (Grms)

Information about the application

ΔT : component temperature increase relative to ambient temperature (°C). The previous table gives typical values of ΔT to be used, if a better estimate is not available.

Factors contributing to Physical stresses

Π ***Thermo-electrical***	In an operating phase: $\gamma_{TH-EL} \times e^{11604 \times Ea \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient} + \Delta T + 273)}\right]_i}$ In a non-operating phase: $\Pi_{Thermo\text{-}electrical} = 0$
Π ***TCy***	$\gamma_{TCy} \times \left(\frac{12.N_{annual-cy}}{t_{annual}}\right)_i \times \left(\frac{\min(\theta_{cy},2)}{2}\right)_i^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)_i^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]_i}$
Π ***Mechanical***	$\gamma_{Mech} \times \left(\frac{G_{RMS}}{0.5}\right)_i^{1.5}$

Piezoelectric components: Oscillators and Quartz

General model associated with the family

$$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$$

where:

$$\lambda_{\text{Physical}} = \lambda_{0\_\text{Piezoelectric}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760} \right)_i \times \left(\Pi_{\text{Thermo-electrical}} + \Pi_{\text{TCy}} + \Pi_{\text{Mechanical}} + \Pi_{\text{RH}} \right)_i \times \left(\Pi_{\text{Induced}} \right)_i$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	**MOS**	**TOS**	**$C_{\text{sensitivity}}$**
Quartz resonator (through HCxx type case)	1	10	5	4.55
Quartz resonator (surface mounted)	1	10	5	4.55
Quartz oscillator (through XO type case)	8	10	2	8.10
Quartz oscillator (surface mounted XO, MCSO type case)	8	10	2	8.10

Model associated with the $QA_{\text{component}}$ factor

This factor is determined in the same way as for resistors.

Basic failure rates associated with the component

Component description	$\lambda_{\text{0-Piezoelectric}}$	$\gamma_{\text{TH-EL}}$	γ_{TCy}	γ_{Mech}	γ_{RH}
Quartz resonator (through hole HCxx type case)	0.82	0.16	0.46	0.27	0.11
Quartz resonator (surface mounted)	0.79	0.16	0.59	0.15	0.1
Quartz oscillator (through hole XO type case)	1.6	0.32	0.42	0.14	0.12
Quartz oscillator (surface-mounted XO, MCSO type case)	1.63	0.31	0.53	0.07	0.09

Information about the life profile

t_{annual} : time associated with each phase over a year (hours)
$RH_{ambient}$: humidity associated with a phase (%)
$T_{board-ambient}$: average board temperature during a phase (°C))
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual-cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy} : cycle duration (hours)
G_{RMS} : vibration amplitude associated with each random vibration phase (Grms)

Information about the application

I_{output} : current output by the component in operation in the application (A)

Information about technical characteristics

$I_{max-output}$: maximum current that the component can output in operation (A)
$T_{ambient-max\ manufacturer}$: maximum temperature specified by the manufacturer (°C)

Factors contributing to Physical stresses

Π***Thermo-electrical***	In an operating phase: $\gamma_{TH-EL} \times \Pi_{rating\_TH-i} \times \Pi_{rating\_EL-i}$ Description of usage conditions: Value of Π_{rating_TH} Tboard-ambient < (Tambient-max manufacturer - 40°C) 1 Tboard-ambient ≥ (Tambient-max manufacturer - 40°C) 5 Description of usage conditions: Value of Π_{rating_EL} Quartz resonator: 1 Oscillator : $I_{output} <$ 0.8 x $I_{max-output}$ 1 Oscillator : $I_{output} \geq$ 0.8 x $I_{max-output}$ 5 In a non-operating phase: $\Pi_{Thermo-electrical} = 0$
Π***TCy***	$\gamma_{TCy} \times \left(\frac{12.N_{annual-cy}}{t_{annual}}\right)_i \times \left(\frac{\min(\theta_{cy},2)}{2}\right)_i^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)_i^{1.9} \times e^{1414\times\left[\frac{1}{313}-\frac{1}{(T_{\max-cycling}+273)}\right]_i}$
Π***Mechanical***	$\gamma_{Mech} \times \left(\frac{G_{RMS}}{0.5}\right)_i^{1.5}$
Π***RH***	$\gamma_{RH} \times \left(\frac{RH_{ambient}}{70}\right)_i^{4.4} \times e^{11604\times 0.9\times\left[\frac{1}{293}-\frac{1}{(T_{board-ambient}+273)}\right]_i}$ In an operating phase: $\Pi_{RH} = 0$

Monostable electromechanical relays

General model associated with the family

ⓘ **Warning: limited life**

$\lambda = \lambda_{Physical} \times \Pi_{PM} \times \Pi_{Process}$ where:

$$\lambda_{Physical} = \lambda_{0\,Relay} \times \sum_{i}^{Phases} \left(\frac{t_{annual}}{8760} \right)_i \times \left(\Pi_{Thermal} + \Pi_{electrical} + \Pi_{TCy} + \Pi_{Mechanical} + \Pi_{RH} \right)_i \times \left(\Pi_{Induced} \right)_i$$

$C_{sensitivity}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	**MOS**	**TOS**	**$C_{sensitivity}$**
Electromechanical relay	7	10	2	7.55

$QA_{component}$ factor

Component quality assurance level	**Position relative to the state of the art**	**$QA_{component}$**
Qualification according to one of the following standards: ESCC 360x, MIL-PRF-39016 (or 83536 or 6106) level R, NASDA-QTS-xxxx,	Higher	3
Qualification according to one of the following standards: MIL-PRF-39016 (or 83536 or 6106) level P, NASDA-QTS-xxxx,	Equivalent	2
Qualified to the EIA, IEC, SAE, BS standards	Lower	1
No information	Much lower	0

Basic failure rates associated with the component

$\lambda_{0\_Relay} = 1.1$

Information about the use profile

T_{amb}:	item temperature associated with an operating phase (°C)
t_{annual}:	time associated with each phase over a year (hours)
$\Delta T_{cycling}$:	amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$:	maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$:	number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}:	cycle duration
G_{RMS}:	vibration amplitude associated with each random vibration phase (Grms)
$RH_{ambient}$:	humidity associated with a phase (%)

Pollution level in the phase (see tables)

Saline pollution level	π_{sal}
Low	1
High	2

Product protection level	π_{prot}
Hermetic	0
Non hermetic	1

Application pollution level	π_{zone}
Low	1
Moderate	2
High	4

Environmental pollution level	π_{envir}
Low	1
Moderate	1.5
High	2

Information about the application

$V_{contact}$:	Voltage at the contact terminals (V)
$I_{contact}$:	Current passing through a contact (A)
U_{coil}:	Relay control voltage (V)
ΔT_{relay}:	Temperature increase in the relay (°C). By default, for a continuously activated relay, use $\Delta T_{relay} = 45°C$.

Number of operations per hour in the phase (see table)
Load type (see table)

Information about technical characteristics

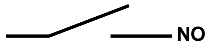
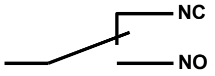
V_{rated}:	rated voltage specified at the terminals of a contact (V)
I_{rated}:	rated current specified at the terminals of a contact (A)
U_{reted}:	rated control voltage specified for the relay (V)
N_{ST}:	number of Single Throw (ST) poles, in which only the normally open contact (NO) is used
N_{DT}:	number of Double Throw (DT) poles, in which the normally open (NO) and normally connected (NC) contacts are used

Finish type of the relay contact (see table)
Relay breaking capacity (see table)
Relay hermeticity type (see table)

Technological attributes

$$\pi_{pole} = 1.25 \times N_{DT} + 0.5 \times N_{ST} + 0.5$$

Number of poles and contact type	π_{pole}
SPST	1
DPST	1.5
3PST	2
4PST	2.5
SPDT	1.75
DPDT	3
3PDT	4.25
4PDT	5.5
6PDT	8

Typical diagram of an ST pole with NO contact only	
Typical diagram of a DT pole with NO and NC contacts	

Load type	$\pi_{load\ type}$	S_V	S_I
Resistive	0.3	1	$\frac{I_{contact}}{I_{nominal}}$
Inductive	8	1	$\frac{I_{contact}}{I_{nominal}}$
Incandescent lamp	4	$\frac{V_{contact}}{V_{nominal}}$	$\frac{I_{contact}}{I_{nominal}}$
Capacitive	6	$\frac{V_{contact}}{V_{nominal}}$	1

$\frac{V_{contact}}{V_{nominal}}$	m_1
≤1	3
>1	8.8

$\frac{I_{contact}}{I_{nominal}}$	m_2
≤1	3
>1	5.9

Contact type	$\pi_{ME\ contact}$	$\pi_{RH\ contact}$
Gold plated contact	1.5	1
Silver contact	1	2

Breaking capacity	$\pi_{TH\ breaking}$	$\pi_{EL\ breaking}$	$\pi_{ME\ breaking}$
Breaking capacity <2A	1.8	1.5	3
Breaking capacity >2A	1.2	1.2	1

Number of manoeuvres per hour	$\pi_{manoeuvres}$
≤1	1
>1	$\sqrt{\text{Number of manoeuvres per hour}}$

Relay protection level	$\pi_{prot\ CHI}$	$\pi_{prot\ TCY}$
Hermetic	0.01	1
Sealed	0.6	3
Not sealed	1	3

Factors contributing to Physical stresses

Π Thermal	$0.29 \times (1+\Pi_{chemical}) \times \Pi_{manoeuvres} \times \Pi_{TH\ contact} \times \Pi_{TH\ breaking} \times e^{11604 \times 0.25 \left[\frac{1}{313} - \frac{1}{273+T'}\right]}$ If $T_{amb} + \Delta T_{relay} \le 125°C$ then $\pi_{contact\ TH} = 1$ If $T_{amb} + \Delta T_{relay} > 125°C$ then $\pi_{contact\ TH} = \pi_{ME\ contact\ type} \times \pi_{pole}$ In an operating phase: If $T_{amb} + \Delta T_{relay} \le 0°C$ then $T' = 40-85/55 \times (T_{amb} + \Delta T_{relay})$ If $0 < T_{amb} + \Delta T_{relay} \le 40°C$ then $T' = 40°C$ If $T_{amb} + \Delta T_{relay} > 40°C$ then $T' = T_{amb} + \Delta T_{relay}$ In a non-operating phase: $\Pi_{Thermal} = 0$
Π Electrical	In an operating phase: $0.55 \times \Pi_{pole} \times \Pi_{EL\ breaking} \times \Pi_{load\ type} \times \Pi_{manoeuvres} \times S_V^{m_1} \times S_I^{m_2} \times \left(\frac{U_{nominal}}{U_{coil}}\right)$ In a non-operating phase: $\pi_{electrical}=0$
Π TCy	$0.02 \times \Pi_{prot\ TCY} \times \left(\frac{12 \times N_{annual\text{-}cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy_i},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
Π Mechanical	$0.05 \times (1+\Pi_{chemical}) \times \Pi_{pole} \times \Pi_{ME\ contact} \times \Pi_{manoeuvres} \times \Pi_{ME\ breaking} \times \left[\left(\frac{G_{RMS}}{0.5}\right)\right]^{1,5}$
Π RH	$0.09 \times \Pi_{pole} \times \Pi_{chemical} \times \Pi_{RH\ contact} \times \left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.9 \left[\frac{1}{293} - \frac{1}{T_{amb}+273}\right]_{a}}$ $\Pi_{chemical} = \Pi_{sal} \times \Pi_{area} \times \Pi_{envir} \times \Pi_{prot} \times \Pi_{Prot\ CHI}$

Switches

General model associated with the family:

ⓘ **Warning: Limited life**

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$ where:

$$\lambda_{\text{Physical}} = \lambda_{0\,\text{Switch}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760} \right)_i \times \left(\Pi_{\text{Thermal}} + \Pi_{\text{electrical}} + \Pi_{\text{TCy}} + \Pi_{\text{Mechanical}} + \Pi_{\text{RH}} \right)_i \times \left(\Pi_{\text{Induced}} \right)_i$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	**MOS**	**TOS**	**$C_{\text{sensitivity}}$**
Load switches and switches	7	10	1	7.45

$QA_{\text{component}}$ factor

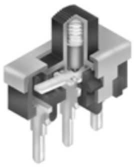
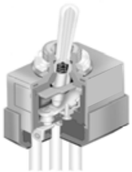
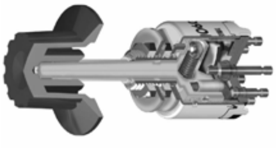
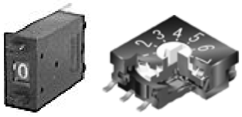
Component quality assurance level	**Position relative to the state of the art**	**$QA_{\text{component}}$**
Qualification according to one of the following standards: ESCC 370x level B, MIL-PRF-8805	Much higher	3
Qualification according to MIL-C-xxxx, MIL-PRF-24236, ESCC 370x level C	Higher	2
Conforming with one of the EIA, IEC, SAE, BS standards	Equivalent	1
No information	Lower	0

Basic failure rates associated with the component

Limit switch

Type	C_{TH}	C_{TCy}	C_{ME}	C_{RH}	C_{EL}	λ_{0_switch}
Limit switch, microcontacts	1	1	1	1	1	0.85

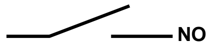
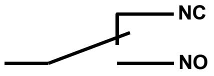
Manual action switch

Type	**Illustration**	C_{TH}	C_{TCy}	C_{ME}	C_{RH}	C_{EL}	λ_{0_switch}
Toggle		1.11	0.56	1.11	0.56	0.56	0.85
Slide		1.11	0.56	1.11	0.56	0.56	0.85
Lever		1.11	0.56	1.11	0.56	0.56	0.85
DIP		1.11	0.56	1.11	0.56	0.56	0.85
Rotary		1.78	1.19	1.78	1.19	1.19	0.85
Encoder wheel		1.78	1.19	1.78	1.19	1.19	0.85
Momentary push button (monostable)		1	1	1	1	1	0.85
Permanent push button (bistable)		1.11	0.56	1.11	0.56	0.56	0.85

Technological attributes

$\pi_{pole} = 1.25 \times N_{DT} + 0.5 \times N_{ST} + 0.5$

Number of poles and contact type	π_{pole}
SPST	1
DPST	1.5
3PST	2
4PST	2.5
SPDT	1.75
DPDT	3
3PDT	4.25
4PDT	5.5
6PDT	8

Typical diagram of an ST pole with NO contact only	
Typical diagram of a DT pole with NO and NC contacts	

Note: for rotating switches and encoder wheels, all poles should be counted as DT (Double Throw) regardless of the number of contacts per pole.

Load type	$\pi_{load\ type}$	S_V	S_I
Resistive	0.3	1	$\frac{I_{contact}}{I_{nominal}}$
Inductive	8	1	$\frac{I_{contact}}{I_{nominal}}$
Incandescent lamp	4	$\frac{V_{contact}}{V_{nominal}}$	$\frac{I_{contact}}{I_{nominal}}$
Capacitive	6	$\frac{V_{contact}}{V_{nominal}}$	1

$\frac{V_{contact}}{V_{nominal}}$	m_1
≤1	3
>1	8.8

$\frac{I_{contact}}{I_{nominal}}$	m_2
≤1	3
>1	5.9

Contact type	$\pi_{ME\ contact}$	$\pi_{RH\ contact}$
Gold plated contact	1.5	1
Silver contact	1	2

Breaking capacity	$\pi_{EL\ breaking}$	$\pi_{ME\ breaking}$
Breaking capacity <2A	1.5	3
Breaking capacity >2A	1.2	1

Number of manoeuvres per hour	$\pi_{manoeuvres}$
≤1	1
>1	$\sqrt{\text{Number of manoeuvres per hour}}$

Switch protection level	π_{prot_CHI}	π_{prot_TCY}
Hermetic	0.01	1
Sealed	0.6	3
Not sealed	1	3

Information about the life profile

T_{amb}:	item temperature associated with an operating phase (°C)
t_{annual}:	time associated with each phase over a year (hours)
$\Delta T_{cycling}$:	amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$:	maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$:	number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}:	cycle duration
G_{RMS}:	vibration amplitude associated with each random vibration phase (Grms)
$RH_{ambient}$:	humidity associated with a phase (%)

Pollution level in the phase (see tables)

Saline pollution level	π_{sal}
Low	1
High	2

Product protection level	π_{prot}
Hermetic	0
Non hermetic	1

Application pollution level	π_{zone}
Low	1
Moderate	2
High	4

Environmental pollution level	π_{envir}
Low	1
Moderate	1.5
High	2

Information about the application

$V_{contact}$:	voltage seen at the contact terminals
$I_{contact}$:	current passing through a contact

Number of operations per hour in the phase (see table)
Load type (see table)

Information about technical characteristics

V_{rated}:	rated voltage specified at the terminals of a contact
I_{rated}:	rated current specified at the terminals of a contact
N_{ST}:	number of Single Throw (ST) poles, for which only the normally open (NO) contact is used
N_{DT}:	number of Double Throw (DT) poles, for which the normally open (NO) and normally connected (NC) contacts are used

Finish type of the switch contact (see table)
Switch breaking capacity (see table)
Switch hermeticity type (see table)

Factors contributing to Physical stresses

Π_{Thermal}	$0.21 \times C_{TH} \times (1+\Pi_{\text{chemical}}) \times \Pi_{\text{manoeuvres}} \times \Pi_{\text{TH contact}} \times e^{11604 \times 0.25\left[\frac{1}{313}-\frac{1}{273+T'}\right]}$ If $T_{amb} \leq 125°C$ then $\Pi_{\text{TH contact}} = 1$ If $T_{amb} > 125°C$ then $\Pi_{\text{TH contact}} = \Pi_{\text{ME contact type}} \times \Pi_{\text{pole}}$ In an operating phase: If $T_{amb} \leq 0°C$ then $T' = 40-85/55 \times T_{amb}$ If $0 < T_{amb} \leq 40°C$ then $T' = 40°C$ If $T_{amb} > 40°C$ then $T' = T_{amb}$ In a non-operating phase: $\Pi_{\text{Thermal}} = 0$
$\Pi_{\text{Electrical}}$	In an operating phase: $0.59 \times C_{EL} \times \Pi_{\text{pole}} \times \Pi_{\text{EL breaking}} \times \Pi_{\text{load type}} \times \Pi_{\text{manoeuvres}} \times S_V^{m_1} \times S_I^{m_2}$ In a non-operating phase: $\pi_{\text{electrical}}=0$
Π_{TCy}	$0.02 \times C_{TCy} \times \Pi_{\text{pole}} \times \Pi_{\text{prot TCY}} \times \left(\frac{12 \times N_{\text{annual-cy}}}{t_{\text{annual}}}\right) \times \left(\frac{\min(\theta_{cy_i},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{\text{cycling}}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313}-\frac{1}{(T_{\text{max-cycling}}+273)}\right]}$
$\Pi_{\text{Mechanical}}$	$0.06 \times C_{MECH} \times (1+\Pi_{\text{chemical}}) \times \Pi_{\text{pole}} \times \Pi_{\text{ME contact}} \times \Pi_{\text{manoeuvres}} \times \Pi_{\text{ME breaking}} \times \left[\left(\frac{G_{RMS}}{0.5}\right)\right]^{1,5}$
Π_{RH}	$0.12 \times C_{RH} \times \Pi_{\text{pole}} \times \Pi_{\text{chemical}} \times \Pi_{\text{RH contact}} \times \left(\frac{RH_{\text{ambient}}}{70}\right)^{4.4} \times e^{11604 \times 0.9\left[\frac{1}{293}-\frac{1}{T_{amb}+273}\right]}$ $\Pi_{\text{chemical}} = \Pi_{\text{sal}} \times \Pi_{\text{area}} \times \Pi_{\text{envir}} \times \Pi_{\text{prot}} \times \Pi_{\text{Prot CHI}}$

Printed circuit board (PCB)

General model associated with the family

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$ where:

$$\lambda_{\text{Physical}} = \lambda_{0\,\text{PCB}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \left(\Pi_{\text{TCy}} + \Pi_{\text{Mechanical}} + \Pi_{\text{RH}} + \Pi_{\text{Chemical}}\right)_i \times \left(\Pi_{\text{Induced}}\right)_i$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	$C_{\text{sensitivity}}$
Printed circuit board (PCB)	4	10	8	6.5

$\Pi_{\text{Placement}}$ factor:

For PCBs the placement factor is fixed: $\Pi_{\text{Placement}} = 1$

$QA_{\text{component}}$ factor

Component quality assurance level	**Position relative to the state of the art**	$QA_{\text{component}}$
Qualification according to MIL-PRF-31032 (PCB), MIL-PRF-55110 (PWB), MIL-P-50884, MIL-S-13949, ECSS-Q-ST-70-10 (PCB)	Higher	3
Manufacturer qualification according to IPC-9701 including tests in standard IPC TM 650	Equivalent	2
Know-how approval made according to EN 123 xxx, CECC 23000, NBN EN 61189-1	Lower	1
No information	Much lower	0

Basic failure rates associated with the item

$$\lambda_{0\,\text{PCB}} = 5 \cdot 10^{-4} \times \left(N_{\text{layers}}\right)^{\frac{1}{2}} \times \left(\frac{N_{\text{connection}}}{2}\right) \times \Pi_{\text{Class}} \times \Pi_{\text{Techno-PCB}}$$

Information about technical characteristics

N_{layers}: Number of layers in the printed circuit board
$N_{\text{connection}}$: Number of connection points (surface mounted + through holes)

Printed circuit technology identification	**Value of $\Pi_{\text{Techno-PCB}}$**
Through holes	0.25
Blind holes	0.5
Micro-via technology	1
Pad on via technology	2.5

Minimum conductor width (µm) / Minimum spacing between conductors or pads (µm)	**Value of Π_{Class}**
800 / 800	1
500 / 500	1
310 / 310	2
210 / 210	3
150 / 150	4
125 / 125	5
100 / 100	6

For a multilayer PCB, the layer with the highest density should be considered. The area with the highest density should be considered in any one particular layer.

Information about the life profile

t_{annual}: time associated with each phase over a year (hours)
$RH_{ambient}$: humidity associated with a phase (%)
$T_{board\text{-}ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}: cycle duration (hours)
G_{RMS}: stress associated with each random vibration phase (Grms)
Pollution level (see tables)

Saline pollution level	Π_{sal}
Low	1
High	2

Product protection level	Π_{prot}
Hermetic	0
Non hermetic	1

Application pollution level	Π_{zone}
Low	1
Moderate	2
High	4

Environmental pollution level	Π_{envir}
Low	1
Moderate	1.5
High	2

Ambient temperature range	Π_{TV}
$T_{ambient\text{-}board} < 110°C$	1
$T_{ambient\text{-}board} > 110°C$	$e^{0.2\times(T_{board\text{-}ambient}-110)}$

Factors contributing to Physical stresses

Π_{TCy}	$0.6\times\Pi_{TV}\times\left(\frac{12\times N_{annual\text{-}cy}}{t_{annual}}\right)_i\times\left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}}\times\left(\frac{\Delta T_{cycling}}{20}\right)^{1.9}\times e^{1414\times\left[\frac{1}{313}-\frac{1}{(T_{max-cycling}+273)}\right]}$
$\Pi_{Mechanical}$	$0.2\times\Pi_{TV}\times\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$0.18\times\Pi_{TV}\times\left(\frac{RH_{ambient}}{70}\right)^{4.4}\times e^{11604\times0.8\times\left[\frac{1}{293}-\frac{1}{(T_{board\text{-}ambient}+273)}\right]}$
$\Pi_{Chemical}$	$0.02\times\Pi_{TV}\times\Pi_{Sal}\times\Pi_{Envir}\times\Pi_{Zone}\times\Pi_{Prot}$

Connectors

General model associated with the family

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$ where:

$$\lambda_{\text{Physical}} = \lambda_{0\_\text{Connector}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760} \right)_i \times \left(\Pi_{\text{Thermal}} + \Pi_{\text{TCy}} + \Pi_{\text{Mechanical}} + \Pi_{\text{RH}} + \Pi_{\text{Chemical}} \right)_i \times \left(\Pi_{\text{Induced}} \right)_i$$

Contribution associated with the $C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	**$C_{\text{sensitivity}}$**
Connectors	1	10	3	4.4

$\Pi_{\text{Placement}}$ factor:

For connectors, the placement factor is fixed: $\Pi_{\text{Placement}} = 1$

$QA_{\text{component}}$ factor

Component quality assurance level	**Position relative to the state of the art**	**$QA_{\text{component}}$**
Qualification according to one of the following standards: ESCC 340x level B, NASDA-QTS-xxxx class 1, …	Much higher	3
Qualification according to one of the following standards: Telcordia GR1217-CORE, MIL-C-xxxxx, MIL-DTL-xxxx ARINC 600 & 80x, AECMA,…	Higher	2
Conforming with one of the EIA, IEC, SAE, BS standards	Equivalent	1
No information	Lower	0

Basic failure rates associated with the item

$$\lambda_{0\_Connector} = \lambda_{Type} \times \Pi_{connection} \times \Pi_{contact} \times \Pi_{Cycle}$$

The presented model is applicable to a half-connector pair.

Information about technical characteristics

Connector type	λ_{type}
Circular and rectangular connectors	0.05
Coaxial connectors	0.07
Connectors for printed circuits (and similar)	0.1
Component supports	0.1

Connection type	Π_{report}
Insertion (press fit)	1
Soldered (through)	6
Soldered (SMD)	10
Wrapping (braid)	3
Wrapping (wire)	2

Number of contacts

$$\Pi_{Contact} = \left(N_{Contact}\right)^{0.5}$$

where $N_{contact}$ is the number of contacts on the connector.

Connection frequency

$$\Pi_{Cycles} = 0.2 \times \left(N_{Annual\text{-}cycles}\right)^{0.25}$$

Where $N_{Annual\text{-}cycles}$ is the number of cycles (one cycle includes one connection and one disconnection) per year. If $N_{annual\text{-}cycles} < 1$ per year, use $\Pi_{cycles} = 0.2$.

Insert temperature increase

Gauge	32	30	28	24	22	20	18	16	12
a	3.256	2.856	2.286	1.345	0.989	0.64	0.429	0.274	0.1

$\Delta T_{insert} = a \times I_{contact}^{1.85}$

Where $I_{contact}$ is the average current in a pin (in amperes).

Information about the life profile

t_{annual}: time associated with each phase over a year (hours)
$RH_{ambient}$: humidity associated with a phase (%)

Note: The relative humidity at connectors at an equipment interface may be different from the relative humidity at other items in the equipment.

$T_{board-ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$: maximum temperature during a cycling phase (°C)
$N_{annual-cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}: cycle duration (hours)
G_{RMS}: vibration amplitude associated with each random vibration phase (Grms)
Pollution level (see tables):

Saline pollution level	Π_{sal}
Low	1
High	2

Product protection level	Π_{prot}
Hermetic	0
Non hermetic	1

Application pollution level	Π_{zone}
Low	1
Moderate	2
High	4

Environmental pollution level	Π_{envir}
Low	1
Moderate	1.5
High	2

Information about the application

ΔT: Insert temperature increase

Factors contributing to Physical stresses

$\Pi_{Thermal}$	In an operating phase: $0.58 \times e^{11604 \times 0.1 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient} + \Delta T + 273)}\right]}$ In a non-operating phase: $\Pi_{thermal} = 0$
Π_{Tcy}	$0.04 \times \left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
$\Pi_{Mechanical}$	$0.05 \times \left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$0.13 \times \left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.8 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient}+273)}\right]}$
$\Pi_{Chemical}$	$0.20 \times \Pi_{Sal} \times \Pi_{Envir} \times \Pi_{zone} \times \Pi_{Prot}$

Hybrids and Multi Chip Modules

General model

Hybrids and Multi Chip Modules (MCMs) are miniaturised assemblies of components on different types of substrates with different types of encapsulations (moulding, case). The failure rate of a hybrid is calculated in a similar way to an electronic board. It is based on a list of microcomponents internal to the hybrid or the MCM and takes account of connections, wiring, encapsulation and different technological or process control attributes. Active components (integrated circuit, transistors, diodes) assembled in Hybrids and MCM can be bare chips or in micro-cases.

General model associated with the family

$$\lambda_{H\&M} = \sum_{\mu components} \left(\lambda_{\mu component} \times \Pi_{PM\_\mu component}\right) \times \Pi_{process\_H\&M} \times \Pi_{process}$$
$$+ \left(\lambda_{wiring} + \lambda_{Case+Substrate} + \lambda_{External\_connections}\right) \times \Pi_{process\_H\&M} \times \Pi_{process}$$

With the following for each basic element (microcomponent, wiring, case-substrate, external connections):

$$\lambda_{element} = \sum_{i}^{Phases} \left[\left(\frac{t_{annual}}{8760} \right)_i \times \left(\sum_{stresses} \left(\lambda_{0\,stress} \times \Pi_{stress} \right) \right)_i \times \left(\Pi_{induced} \right)_i \right]$$

The $\Pi_{Process}$ factor is the factor calculated for the product into which the hybrid or the MCM is integrated.

The $\Pi_{PM\_\mu component}$ factor is calculated using the calculation method described to determinate the Π_{PM} of the corresponding components (integrated circuits and discrete semiconductors, resistors, capacitors, inductors).

Induced factor

Factors contributing to overstresses

$$\Pi_{induced-i} = \left(\Pi_{placement} \times \Pi_{application-i} \times \Pi_{Ruggedising}\right)^{0.511 \times \ln(C_{sensitivity})}$$

The index i denotes the phase considered.

Contribution associated with the $C_{sensitivity}$ factor

A single $C_{sensitivity}$ factor for the entire Hybrid or MCM is defined as a function of the type of substrate and encapsulation.

	Relative sensitivity (mark out of 10)			
	EOS	**TOS**	**MOS**	**$C_{sensitivity}$**
Metal case, ceramic case, ceramic substrate	6	1	5	5.5
Glass-epoxy substrate with moulding	6	1	2	4.1
Glass-epoxy substrate without moulding	6	1	5	4.8

Sensitivities relating to EOS, TOS, MOS (Electrical Over-Stress, Thermal Over-Stress, Mechanical Over-Stress) are given for information to show the relative sensitivity of families to different types of overstresses. They are not used in the calculations.

Contribution associated with the $\Pi_{Placement}$ factor:

This contribution is determined in the same way as for components.
The placement to be considered is placement of the hybrid in the product.

	$\Pi_{placement}$
Digital non-interface function	1.0
Digital interface function	1.3
Analogue low level non-interface function	1.2
Analogue low level interface function	1.5
Analogue power non-interface function	1.3
Analogue power interface function	1.8

Contribution associated with the $\Pi_{application}$ factor

This contribution is determined in the same way as for components.

Contribution associated with the $\Pi_{ruggedising}$ factor

This contribution is determined in the same way as for components.

H&M process factor

The $\Pi_{Process\_H\&M}$ factor takes account of how control over design and manufacturing of the hybrid or the MCM influences reliability.

$$\Pi_{Process\_H\&M} = e^{1.39x(1-H\&M\_process\_grade)}$$

Where $H\&M\_process\_grade = \dfrac{\sum \text{values in the following table}}{140}$

	Value if true	Value if false
Application of a formal method[1] to take account of hybrid or MCM manufacturing means during the design	15	0
Application of a formal method[1] to take account of capacities to connect the hybrid or MCM onto the board	15	0
Previous experience in development of the hybrid and the MCM with good feedback from operations	10	0
Internal interconnection technology(ies) already used in a previous development	3	0
Case and substrate technology(ies) already used in a previous development	3	0
External interconnection technology(ies) already used in a previous development	4	0
Qualification of the line for space application (ESA/CNES) - (class K according to the MIL-PRF 38534F classification, or class I according to JESD93), or equivalent	30 See note 2	0
Qualification of the line for military application - (class H according to the MIL-PRF 38534F classification or class II according to JESD93), or equivalent	20 See note 2	0
Class G, E or D according to the MIL-PRF 38534F classification, or class lower than II according to JESD93, or qualification program internal to the manufacturer	10 See note 2	0
Application of three methods of improving reliability: 1. burn-in, 2. batch by batch DPA, 3. functional test at the 3 temperatures	30	0
Application of two out of three among 1. burn-in, 2. batch by batch DPA, 3. functional test at the 3 temperatures	20	0
Application of one out of three among 1. burn-in, 2. batch by batch DPA, 3. functional test at the 3 temperatures	10	0

Notes:
1. The formal method can be represented by the use of a guide or a specification that takes account of technical manufacturing capabilities.
2. These three cases are exclusive of each other.

The default value of 2.5 is proposed if there is no evaluation of $\Pi_{process\_H\&M}$. The use of the default value can reduce the accuracy of the final results.

Microcomponents

Failure rate associated with bare chips (integrated circuits, transistors, diodes, etc.)

$$\lambda_{\text{chip}} = \left(\lambda_{\text{0TH}} \times \Pi_{\text{Thermique}}\right) + \left(C_{\text{moulding}} \times C_{\text{chip\_area}} \times \lambda_{\text{0\_chip\_TCy}} \times \Pi_{\text{TCy\_case}}\right)$$

Thermal

For values of λ_{0TH} , refer to the basic failure rate associated with the chip for Integrated Circuits or Discrete Semiconductors.

Chip thermal cycling

This is the acceleration factor of thermal cycling $\Pi_{\text{TCy case}}$ (thermal amplitude to the power of 4) that is applicable for this stress on chips.

$$\lambda_{\text{0\_chip\_TCy}} = 0.011$$

	C_{moulding}
hermetic non-moulded circuit	1
moulded circuit silicone type embedding	1.4
moulded circuit polyurethane type embedding	1.6
moulded circuit epoxy type embedding	2

$$C_{\text{surface\_chip}} = \left(1 + S^{d}\right)$$

S: individual surface area of each chip en mm²

	d
Numeric Si integrated circuits (MOS, Bipolar and BiCMOS)	0.35
Analogue Si integrated circuits (MOS, bipolar and BiCMOS)	0.2
Discrete circuits	0.1

If the surface area of chips is not known, use the following default value for each chip:

	Chip_area (mm²)
Logical	75
Analogue	4
Weak signal discrete	0.8
Power discrete	3

Failure rate associated with components in micro-cases (integrated circuits, transistors, diodes)

$$\lambda_{\text{micro–boîtier}} = \begin{pmatrix} \lambda_{0\,\text{TH}} \times \Pi_{\text{Thermique}} + \lambda_{0\,\text{TCyCase}} \times \Pi_{\text{TCyCase}} \\ + C_{\text{moulding}} \times \lambda_{0\,\text{TCy Solder joints}} \times \Pi_{\text{TCy Solder joints}} \\ + C_{\text{hermeticity}} \times \lambda_{0\,\text{RH}} \times \Pi_{\text{RH}} \end{pmatrix}$$

<u>Thermal</u>

For values of $\lambda_{0\text{TH}}$ refer to the basic failure rate associated with chips for Integrated Circuits or Discrete Semiconductors.

<u>Thermal cycling</u>

The basic failure rate for solder joints is calculated as a function of the substrate type.

For IC cases, the basic failure rates are obtained using the following equation:

$$\lambda_{0\_\text{Stress}} = e^{-a} \times \text{Np}^{b}$$

Where:

- a and b are constants that depend on the type of case and the number of pins, given in the following table.
- Np is the number of pins in the case.

Case (usual designation)	**Description**	**Np**	$\lambda_{0\text{TCy\_Case}}$		$\lambda_{0\text{TCy\_Solder joints}}$			
					Glass-epoxy substrate		**Ceramic Substrate**	
			a	b	a	b	a	b
PQFP	Plastic Quad Flatpack. L lead	44 to 240	12.41	1.46	10.80	1.46	9.41	1.46
		>240 to 304			10.11	1.46	8.61	1.46
SQFP TQFP. VQFP. LQFP	Plastic Shrink (thickness) Quad Flatpack. L lead Plastic Thin Quad Flatpack. L lead	32 to 120	8.57	0.73	6.96	0.73	5.57	0.73
		>120 to 208			5.57	0.73	4.65	0.73
Power QFP (RQFP. HQFP. PowerQuad. EdQuad…)	Plastic Quad Flatpack with heat sink. L lead	160 to 240	15.11	1.96	13.50	1.96	12.11	1.96
		>240 to 304			12.81	1.96	11.31	1.96
CERPACK		20 to 56	12.41	1.46	10.80	1.46	10.8	1.46
CQFP. Cerquad	Ceramic Quad Flat Pack	64 to 132	12.41	1.46	10.80	1.46	10.8	1.46
		>132 to 256			9.19	1.46	10.8	1.46
PLCC	Plastic Leaded Chip Carrier J-Lead	20 to 52	18.52	3.15	16.91	3.15	16.91	3.15
		>52 to 84			15.52	3.15	15.52	3.15
J-LCC	J-lead Ceramic Leaded Chip Carrier.	4	8.07	0.93	6.46	0.93	6.46	0.93
		20			6.46	0.93	6.46	0.93
		32			6.46	0.93	6.46	0.93
		44			5.77	0.93	6.46	0.93
		52			5.36	0.93	6.46	0.93
		68			4.85	0.93	6.46	0.93

Case (usual designation)	**Description**	**Np**	λ_{0TCy_Case}		$\lambda_{0TCy\_Solder\ joints}$			
					Glass-epoxy substrate		**Ceramic Substrate**	
			a	b	a	b	a	b
CLCC	Ceramic Leadless Chip Carrier	4	8.07	0.93	5.07	0.93	6.46	0.93
		20			4.51	0.93	6.46	0.93
		32			4.38	0.93	6.46	0.93
		44			4.26	0.93	6.46	0.93
		52			4.26	0.93	6.46	0.93
		68			4.16	0.93	5.77	0.93
		84			4.16	0.93	5.77	0.93
SOJ	Plastic Small Outlines. J-Lead	24 to 44	8.36	1.39	6.75	1.39	4.96	1.39
SO. SOP. SOL. SOIC. SOW	Plastic Small Outlines. L lead	8 to 14	13.36	2.18	11.75	2.18	9.67	2.18
		16 to 18			11.06	2.18	9.45	2.18
		20 to 28			10.36	2.18	9.16	2.18
		32			10.14	2.18	9.45	2.18
TSOP I **TSOP II**	Thin Small Outlines. leads on small edges. L lead Thin Small Outlines. leads on long edges. L lead	5 and 6	9.05	0.76	7.44	0.76	7.44	0.76
		>6 to 16			7.44	0.76	6.34	0.76
		>16 to 32			6.05	0.76	5.13	0.76
		>32 to 44			5.83	0.76	5.14	0.76
		>44 to 56			5.36	0.76	5.14	0.76
SSOP. VSOP. QSOP	Plastic Shrink (pitch) Small Outlines. L lead	16 to 64	16.28	2.60	14.67	2.60	13.28	2.60
TSSOP. MSOP. µSO. µMAX. TVSOP	Thin Shrink Small Outlines. L lead	8 to 28	15.56	2.66	13.95	2.66	12.0	2.66
		>28 to 48			13.21	2.66	11.71	2.66
		56			12.56	2.66	11.64	2.66
		64			12.16	2.66	11.65	2.66
PBGA CSP BT 0.8 et 0.75 mm	Plastic Ball Grid Array with solder ball pitch = 0.8 mm and 0.75 mm	48 to 384	12.13	1.49	9.13	1.49	10.52	1.49
PBGA flex 0.8 mm	Plastic Ball Grid Array with solder ball pitch = 0.8 mm and 0.75 mm	48 to 288	12.13	1.49	8.57	1.49	9.82	1.49
PBGA BT 1.00 mm	Plastic Ball Grid Array with solder ball pitch = 1.0 mm	64 to 1156	10.89	1.00	7.67	1.00	7.67	1.00
PBGA 1.27mm	Plastic Ball Grid Array. with solder ball pitch = 1.27 mm	119 to 352	10.36	0.93	7.36	0.93	7.36	0.93
		>352 to 432			7.14	0.93	7.14	0.93
		>432 to 729			6.67	0.93	6.67	0.93
Power BGA (TBGA SBGA, etc.)	Tape BGA. PBGA with heat sink. die top down pitch=1.27 mm Super BGA. PBGA with heat sink. die top down Pitch=1.27 mm	256 to 352	15.73	1.68	12.73	1.68	12.51	1.68
		>352 to 956			12.33	1.68	12.18	1.68
CBGA	Ceramic Ball Grid Array	255 to 1156	15.37	1.87	11.56	1.87	13.76	1.87
DBGA	Dimpled BGA	255 to 1156	15.37	1.87	12.15	1.87	13.76	1.87
CI CGA	Ceramic Land GA + interposer. Ceramic column GA	255 to 1156	15.37	1.87	11.81	1.87	13.76	1.87

The following table gives basic failure rates for discrete semiconductor cases:

Case	Equivalent names	Designation	λ_{0Tcy_Case}	$\lambda_{0Tcy\_Solder\ joints}$	
				FR4	**Ceramic**
SOT23-3	TO236AB	SMD, small signal, L-lead, plastic	0.00057	0.00285	0.00285
SOT23-5	SC74A, SOT25				
SOT23-6	SC74, SOT26, SOT457				
SOT143	TO253AA, SC61B				
SOT323	SC70				
SOT346	SC59, TO236AA				
SOT353	SC70-5, SC88A				
SOT363	SC70-6, SC88				
SOD123					
SOD323	SC76				
SOD523	SC79				
SOT223	SC73, TO261AA	SMD, medium power, small heat sink, L-lead, plastic	0.00091	0.00455	0.0091
SOT243					
SOT343	SC82				
SOT89	SC62, TO243AA				
SOT194					
SOD6	DO214AA, SMB-J	SMD, small signal, C-lead, plastic	0.00091	0.00455	0.0091
SOD15	DO214AB, SMC-J				
DPAK	TO252AA, SC63, SOT428	SMD, power, large heat sink, L-lead, plastic	0.00413	0.02065	0.0413
D2PAK	TO263, SC83A, SMD220				
D3PAK	TO268				
ISOTOP	SOT227, TO244, Half-Pak	SMD, high power, screw, plastic	0.03333	0.16665	0.199
SOD80	Mini-MELF, DO213AA	SMD, Hermetically sealed glass	0.00781	0.03905	0.00781
SOD87	MELF, DO213AB				

Notes:

- Some Discrete Semiconductor cases are also used for Integrated Circuits.
- Some Integrated Circuit cases are also used for Discrete Semiconductors.
- Cases used in Hybrids and MCM are usually micro-cases. Nevertheless, the tables describe all the cases, even larger, which use in Hybrids or MCM is conceivable.

Humidity

For values of λ_{0RH} refer to basic failure rates associated with cases described in the Integrated Circuits or Discrete Semiconductors chapters.

	$C_{hermeticity}$
hermetic circuit (internal embedding or not)	0.05
sealed cavity circuit (non-hermetic)	0.5
moulded circuit	1

Failure rate associated with internal microcomponents: passive components (resistors, capacitors, inductors)

Factors common to all passive microcomponents

The influence of thermal cycling depends on the type of component connection:

Connection type	**Model of Π_{TCy}**
By gluing (conducting glue)	$\Pi_{TCy\ case}$
By soldering (brazing)	$\Pi_{TCy\ solder\ joints}$

Moulding factor

	$C_{moulding}$
hermetic non-moulded circuit	1
moulded circuit silicone type embedding	1.4
moulded circuit polyurethane type embedding	1.6
moulded circuit epoxy type embedding	2

Resistive chips (SMD)

$$\lambda_{resistor} = \lambda_{0\_resistor} \times C_{moulding} \times \Pi_{TCy}$$

Where:

$\lambda_{0\_resistor}$ = 0.01

Deposited resistors

$$\lambda_{deposited\_resistors} = \lambda_{0\_deposited\_resistors} \times C_{moulding} \times C_{tolerance} \times \Pi_{TCy}$$

Where:

$$\lambda_{0\_deposited\_resistors} = (0.01 \times R_e + 0.04 \times R_m)$$

R_e: number of deposited thick-layer resistors.
R_m number of deposited thin-layer resistors.

Tolerance	**$C_{tolerance}$**
Tolerance more than 5%	1
Tolerance from 1 to 5%	1.5 (default value)
Tolerance less than 1%	2

Resistive networks

$$\lambda_{\text{network\_resistance}} = \lambda_{\text{0\_network\_resistance}} \times C_{\text{moulding}} \times \Pi_{\text{TCy}}$$

Where:

$\lambda_{\text{0\_network\_resistance}}$ = 0.059

Capacitors

$$\lambda_{\text{capacitor}} = \lambda_{\text{0\_capacito r}} \times \left(C_{\text{moulding}} \times \gamma_{\text{TCy}} \times \Pi_{\text{TCy}} + \gamma_{\text{TH\_EL}} \times \Pi_{\text{Voltage}} \times \Pi_{\text{TH\_EL}}\right)$$

The Π_{TH_EL} factor to be taken into account should be selected for each capacitor as a function of the activation energy Ea.

Where:

Component description	$\lambda_{0\_Capacitor}$	**Activation energy (eV)**	$S_{reference}$	γ_{TH-EL}	γ_{TCy}
Ceramic capacitor with defined temperature coefficient (Type I) with a low CV product	0.03	0.1	0.3	0.70	0.28
Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product	0.05	0.1	0.3	0.70	0.28
Ceramic capacitor with defined temperature coefficient (Type I) with a high CV product	0.40	0.1	0.3	0.69	0.26
Ceramic capacitor without defined temperature coefficient (Type II) with a low CV product	0.08	0.1	0.3	0.70	0.28
Ceramic capacitor without defined temperature coefficient (Type II) with a medium CV product	0.15	0.1	0.3	0.70	0.28
Ceramic capacitor without defined temperature coefficient (Type II) with a high CV product	1.20	0.1	0.3	0.44	0.51
Ceramic capacitor with polymer terminations without defined temperature coefficient (Type II) with a low CV product	0.08	0.1	0.3	0.70	0.28
Ceramic capacitor with polymer terminations without defined temperature coefficient (Type II) with a medium or high CV product	0.15	0.1	0.3	0.70	0.28
Solid tantalum capacitor (SMD packaging)	0.54	0.15	0.4	0.85	0.15
Deposited capacitor	0.1	0.1	0.3	0.71	0.29

The ceramic capacitor datasheet contains data about the criterion for choosing a low, medium or high CV product.

$$\Pi_{\text{Voltage}} = \left(\frac{1}{S_{\text{reference}}} \times \frac{V_{\text{applied}}}{V_{\text{rated}}} \right)_i^3$$

The index i denotes the phase. The Π_{Voltage} factor should be calculated for each phase.
V_{applied} : voltage applied to the component in the phase (V)
V_{rated} : maximum voltage applicable to the component specified by the supplier (V)

Multilayer inductors

$$\lambda_{\text{inductor}} = \lambda_{0\_\text{inductor}} \times \left(C_{\text{moulding}} \times \gamma_{\text{TCy}} \times \Pi_{\text{TCy}} + \gamma_{\text{TH\_EL}} \times \Pi_{\text{TH\_EL}} \right)$$

Where:

	Ea (eV)	λ_0	γ_{TH_EL}	γ_{TCy}
Inductor	0.15	0.05	0.71	0.29

Other components

If other component type are present in the Hybrid or the MCM, the model of these components will be used, with the following adaptations:

Thermal cycling:

- If the model does not distinguish the case thermal cycling. The C_{moulding} factor will be applied in weighting of the Π_{TCY} factor, as for the other micro components. The acceleration law for thermal cycling will be selected according to the type of transfer (gluing or brazing). See the “Model of Π_{TCy}” table.
- If the model separates case thermal cycling from solder joint thermal cycling. The preceding rule will be applied only to the factor $\Pi_{\text{TCy\_solder\_joint}}$.

Humidity:
The $C_{\text{hermeticity}}$ factor will be applied in weighting of the Π_{RH} factor, like in the case of the micro-cases in order to take into account the protection against the moisture which the hermeticity of the Hybrid or MCM can bring.

Wiring, case, substrate, external connections

Failure rate associated with the wiring: internal wiring by wires (bonding), by bumps (flip-chip) or by strip wiring

$$\lambda_{\text{wiring}} = \begin{pmatrix} \lambda_{0\_\text{wiring}} \times \left(c_{\text{moulding}} \times \gamma_{\text{TCy}} \times \Pi_{\text{TCy}} + c_{\text{particle}} \times \gamma_{\text{ME}} \times \Pi_{\text{ME}}\right) \\ + \lambda_{0\_\text{RH}} \times C_{\text{hermeticity}} \times \Pi_{\text{RH}} \end{pmatrix}$$

Where:

$$\lambda_{0\_\text{wiring}} = 1.04 \cdot 10^{-4}\,\text{Nb}_{\text{wires}}{}^{0.93}$$

Nb_{wires}: Total number of wires, bumps or strips inside the hybrid or the MCM.

If the Nb_{wires} factor is not known, it can be estimated by default starting from the number $\text{Nb}_{\text{I/O}}$ of inputs / outputs of the hybrid or the MCM:

- For hybrids: $\text{Nb}_{\text{wires}} = \text{Max}(6.15 \times \text{Nb}_{\text{I/O}} - 24.55\,;\, \text{Nb}_{\text{I/O}})$
- For MCMs: $\text{Nb}_{\text{wires}} = 2.9 \times \text{Nb}_{\text{I/O}}$

$\gamma_{\text{TCy}} = 0.65$
$\gamma_{\text{ME}} = 0.35$

Wiring type	**Model of Π_{TCy}**
Wires and strips (aluminium and gold)	$\Pi_{\text{TCy case}}$
Bumps	$\Pi_{\text{TCy solder joints}}$

	C_{moulding}
hermetic non-moulded circuit	1
moulded circuit silicone type embedding	1.4
moulded circuit polyurethane type embedding	1.6
moulded circuit epoxy type embedding	2

	C_{particle}
moulded circuit or chip interconnection by Flip-Chip, with underfill	0
non-moulded hermetic circuit presence of particle trap and gold wire*	0.5
non-moulded hermetic circuit presence of particle trap and aluminium wire or chip interconnection by Flip-Chip without underfill	0.3
non-moulded hermetic circuit absence of particle trap and gold wire *	1.5
non-moulded hermetic circuit absence of particle trap and aluminium wire	1

(*): wire or strip

Humidity

$$\lambda_{0\_RH} = 7.01 \cdot 10^{-7} \times \mathrm{Nb}_{\mathrm{wires}}{}^{2.41}$$

Where
$\mathrm{Nb}_{\mathrm{wires}}$: Total number of wires, bumps or strips inside the hybrid or the MCM.

If the $\mathrm{Nb}_{\mathrm{wires}}$ is not known, it can be estimated by default starting from the number of inputs/output $\mathrm{Nb}_{\mathrm{I/O}}$ of the hybrid or the MCM:

- For hybrids: $\mathrm{Nb}_{\mathrm{wires}} = \mathrm{Max}(6.15 \times \mathrm{Nb}_{\mathrm{I/O}} - 24.55\ ;\ \mathrm{Nb}_{\mathrm{I/O}})$
- For MCMs: $\mathrm{Nb}_{\mathrm{wires}} = 2.9 \times \mathrm{Nb}_{\mathrm{I/O}}$

$\mathrm{Nb}_{\mathrm{I/O}}$: Number of pins on the hybrid or the MCM.

Remark: If a case has two different parts (by example one hermetic side and one without protection), each face has to be studied in the calculation.

$C_{\mathrm{hermeticity}}$ factor

	$C_{\mathrm{hermeticity}}$
hermetic circuit (internal embedding or not)	0.05
sealed cavity circuit (non-hermetic)	0.5
moulded circuit	1

Failure rate associated with the case and the substrate

$$\lambda_{BS} = \lambda_{0\_BS} \times \left(\gamma_{TCy} \times \Pi_{TCy\_case} + C_{ME} \times \gamma_{ME} \times \Pi_{ME} + \gamma_{RH} \times \Pi_{RH} + \gamma_{chemical} \times \Pi_{chemical}\right)$$

Where:

$$\lambda_{0\_BS} = \lambda_{0\_substrate} \times \left(N_{layers}\right)^{\frac{1}{2}} \times \left(\frac{N_{tracks}{}^{b}}{2}\right) \times \Pi_{Class} \times \Pi_{Techno-substrate}$$

N_{tracks} = number of tracks

Default value: N_{track} = (Nb_{wires} / 2)

For the default estimate of Nb_{wires}, refer to the proposed calculation starting from the number of inputs / outputs.

N_{layers} = number of layers

Substrate type	Technology	Value of $\Pi_{Techno\_substrate}$
Ceramic		0.25
Glass-epoxy	Through holes	0.25
	Blind holes	0.5
	Micro-via technology	1
	Pad on via technology	2.5

Minimum width of conductors (µm) / Minimum space between conductors or pads (µm)	Value of Π_{Class}
800 / 800	1
500 / 500	1
310 / 310	2
210 / 210	3
150 / 150	4
125 / 125	5
100 / 100	6

	$\lambda_{0\_substrat}$	b	γ_{TCy}	γ_{ME}	γ_{RH}	$\gamma_{Chemical}$	C_{ME}
Hermetic ceramic case (cofired MCM case, …)	$2.08\ 10^{-4}$	0.93	0.32	0.66	0.01	0.01	$1+0.1\sqrt{S_{case}}$
Alumina substrate in hermetic metal case	$2.08\ 10^{-4}$	0.93	0.32	0.66	0.01	0.01	$1+0.1\sqrt{S_{case}}$
Alumina substrate with moulding	$2.08\ 10^{-4}$	0.93	0.6	0.35	0.04	0.01	$1+0.1\sqrt{S_{case}}$
Alumina substrate, without case or moulding	$2.08\ 10^{-4}$	0.93	0.3	0.58	0.1	0.02	$1+0.1\sqrt{S_{case}}$
Organic substrate (glass-epoxy) with hermetic metal case	$5\ 10^{-4}$	1	0.48	0.5	0.01	0.01	$1+0.1\sqrt{S_{case}}$
Organic substrate (glass-epoxy) with moulding	$5\ 10^{-4}$	1	0.72	0.18	0.09	0.01	1
Glass-epoxy substrate, without case or moulding	$5\ 10^{-4}$	1	0.6	0.2	0.18	0.02	1

S_{case} = case surface area in cm²

For a Hybrid or a MCM with several types of substrate, "$\lambda_{0\_substrate}$" and "b" parameters of a "glass-epoxy" substrate shall be chosen for all the Hybrid or the MCM.

If the case has parts in different configurations (as, for example, a MCM with an hermetic side and the other side without protection), the weighted mean value of the failure rates for each parts (each side or each cavity) has to be considered, for which the S_{Case} parameter correspond to the surface area of the considered part. The model becomes:

$$\lambda_{BS} = \sum_{Cavities} \frac{\lambda_{0\_BS} \times S_{cavity}}{S_{total}} \times \left(\gamma_{TCy} \times \Pi_{TCy\_case} + C_{ME} \times \gamma_{ME} \times \Pi_{ME} + \gamma_{RH} \times \Pi_{RH} + \gamma_{chemical} \times \Pi_{chemical}\right)$$

And

$$C_{ME} = 1 + 0.1\sqrt{S_{cavity}}$$

Where
S_{cavity} = surface area of each cavity (part or side) in cm²
S_{total} = sum of the surface area of each cavity in cm²

Failure rate associated with external connections

$$\lambda_{\text{connections}} = \lambda_{0_{\text{TCy}}} \Pi_{\text{TCy\_solder\_joints}} + \lambda_{0_{\text{ME}}} \Pi_{\text{ME}}$$

Temperature cycling

$$\lambda_{0\,\text{TCy}} = 20.5 \cdot 10^3 \times (\text{K} \times (\text{D} \times \Delta\text{CTE})^2)^{1.1}$$

K: connection rigidity parameter

Mounting type	**K**
SMD component with soldered pins With copper or copper alloy pins	$\min\left(5000.({}^{\text{S}_{\text{pin}}}/_{\text{L}_{\text{pin}}} - 0.01), 200\right)$ if negative take K=0 (connexion not very rigid)
SMD component with soldered pins With Iron-Nickel alloy pins (alloy 42, Kovar, etc.)	$\min\left(6150.({}^{\text{S}_{\text{pin}}}/_{\text{L}_{\text{pin}}} - 0.01), 200\right)$ if negative take K=0 (connexion not very rigid)
Component with soldered through pins With copper or copper alloy pins	$\min\left(30.\left(\frac{\text{S}_{\text{pin}}}{0.196}\right)^{1.1}, 100\right)$
Component with soldered through pins With Iron-Nickel alloy pins (alloy 42, Kovar, etc.)	$\min\left(37.\left(\frac{\text{S}_{\text{pin}}}{0.196}\right)^{1.1}, 100\right)$
SMD component without soldered pin	500
Component without pin assembled by contact	5

S_{pin}: Pin cross section in mm²
L_{pin}: Pin length in mm
D: distance between the connections furthest from the module (in mm).
ΔCTE: is the difference between the coefficient of thermal expansion of the case and the coefficient of thermal expansion of the PCB

With the following default values:

	PCB	
Case nature	Printed circuit (FR4, polymide) **without** Cu/In/Cu*	Printed circuit (FR4, polymide) **with** Cu/In/Cu*
Metal (Kovar)	$\Delta\text{CTE} = 9 \cdot 10^{-6}$ /°C	$\Delta\text{CTE} = 7 \cdot 10^{-6}$ /°C
Ceramic (alumina or co-sintered)	$\Delta\text{CTE} = 8 \cdot 10^{-6}$ /°C	$\Delta\text{CTE} = 6 \cdot 10^{-6}$ /°C
Moulded (organic or ceramic substrate)	$\Delta\text{CTE} = 2 \cdot 10^{-6}$ /°C	$\Delta\text{CTE} = 4 \cdot 10^{-6}$ /°C

(*) The Cu/In/Cu (copper/Invar/copper) layers are deposited in the printed circuit, on external layers, so as to reduce the thermal coefficient of expansion at the surface.

Mechanical

$$\lambda_{0_{ME}} = \frac{1}{a} \times \left(7 \cdot 10^{-4} \times \frac{M^{1.6}}{S_{pin} . Nb_{pin}^{0.5}} + 1 \cdot 10^{-6} \times \frac{D^2}{S_{pin}} \right)$$

Where:

Fixing mode	**Example**	**a**
None (allows relative movement between the component and the printed circuit)	Component simply connected on the board	1
Flexible (allows limited movement of the component on its support)	Gluing	2
Rigid (allows no or only small relative movement between the component and the printed circuit)	Clamping Screwing	4

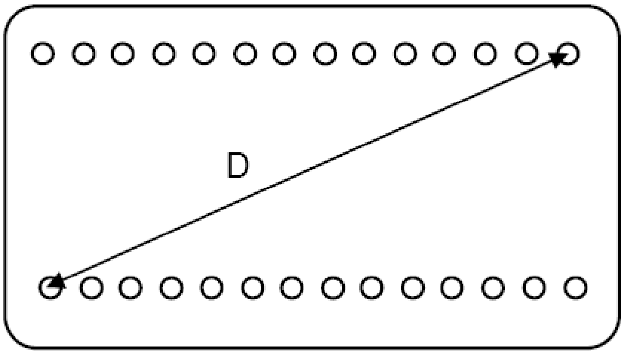
S_{pin}: Pin cross section in mm²

Nb_{pin}: Number of pins on the hybrid or the MCM

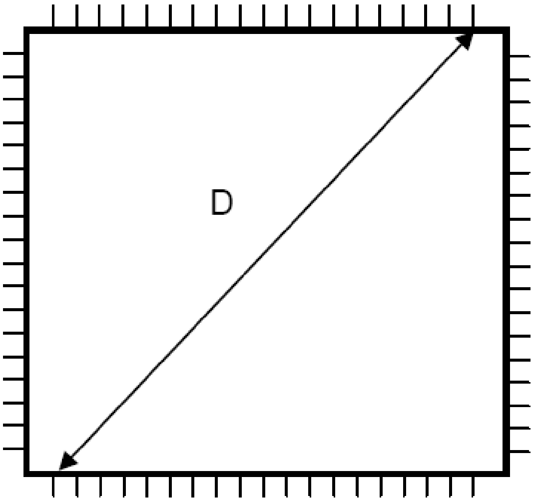
D: distance between the furthest connections of the module (in mm).
M: case mass (in grams)
If there is no information about the mass of the hybrid in a metal case, use:
M (gr) = 0.003 x Hybrid volume (mm^3)
If there is no information about the mass of the MCM in a ceramic case, use:
M (gr) = 0.004 x Substrate volume (mm^3)

Remark: the distance D between the furthest connections of the module are often close to the diagonal of the case as illustrated in the diagram below.

Example of a platform case:



Example of a QFP case:



Physical stresses

Information about the usage profile

t_{annual}: time associated with each phase over a year (hours)
$T_{board\ ambient}$: average board temperature during the phase (°C)

$RH_{ambient}$: relative humidity associated with a phase (%)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}: cycle duration (hours)
Grms: vibration amplitude associated with each random vibration phase (Grms)
Pollution level (see tables)

Saline pollution level	Π_{sal}
Low	1
High	2

System protection level	Π_{prot}
Hermetic	0
Non hermetic	1

Application pollution level	Π_{zone}
Low	1
Moderate	2
High	4

Environmental pollution level	Π_{envir}
Low	1
Moderate	1.5
High	2

Information about the application

$T_{H\&M}$: average temperature of the hybrid or the MCM during the phase (°C)
$T_{J\_component}$: junction temperature of the component during the phase (°C)
$P_{dissipated}$: power dissipated in the phase by the component, the hybrid, the MCM or the microcomponent depending on the case (W)

Calculation of component $T_{H\&M}$ and T_J for hybrids and MCM

$T_{J\_component} = T_{H\&M} + R_{JC} \cdot P_{\text{dissipated from the component}}$

$T_{H\&M} = T_{ambient} + R_{CA} \cdot P_{\text{dissipated from the H\&M}}$

Where:
R_{JC} is the thermal resistance between the junction and the substrate of the hybrid or the MCM.
R_{CA} is the thermal resistance between the hybrid or the MCM and ambient.

Factors contributing to Physical stresses

Π***Thermal*** *Active components*	In an operating phase: $\Pi_{El} \times e^{11604 \times 0.7 \times \left[\frac{1}{293} - \frac{1}{(T_{j-component}+273)}\right]}$ For signal diodes up to 1A (PIN, Schottky, signal, varactor): $\Pi_{El} = \left(\frac{V_{applied}}{V_{rated}}\right)^{2,4}$ if $\frac{V_{applied}}{V_{rated}} > 0.3$ $\Pi_{El} = 0.056$ if $\frac{V_{applied}}{V_{rated}} \leq 0.3$ For other item types: $\Pi_{El} = 1$ In a non-operating phase: $\Pi_{Thermal} = 0$
Π***Thermo-electrical*** *Ea = 0.1 eV* *Capacitors other than solid tantalum capacitors*	In an operating phase: $e^{11604 \times 0.1 \times \left[\frac{1}{293} - \frac{1}{(T_{H\&M}+273)}\right]}$ In a non-operating phase: $\Pi_{Thermo\text{-}electrical} = 0$
Π***Thermo-electrical*** *Ea = 0.15 eV* *Solid tantalum capacitor, inductors*	In an operating phase: $e^{11604 \times 0.15 \times \left[\frac{1}{293} - \frac{1}{(T_{H\&M}+273)}\right]}$ In a non-operating phase: $\Pi_{Thermo\text{-}electrical} = 0$
Π***TCy_solder_joints***	$\left(\frac{12 \times N_{annual\text{-}cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy}, 2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
Π***TCy_Case***	$\left(\frac{12 \times N_{annual\text{-}cy}}{t_{annual}}\right) \times \left(\frac{\Delta T_{cycling}}{20}\right)^{4} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
Π***Mechanical***	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π***RH***	$\left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.9 \times \left[\frac{1}{293} - \frac{1}{(T_{ambient}+273)}\right]}$ In an operating phase: $\Pi_{RH} = 0$
Π***Chemical***	$\Pi_{Sal} \times \Pi_{Envir} \times \Pi_{zone} \times \Pi_{Prot}$

Microwave (HF) and radiofrequency (RF) components

RF and HF process factor

$\Pi_{\text{process RFHF}}$ factor

The $\Pi_{\text{process RFHF}}$ factor takes account of how control over the life cycle of a radiofrequency (RF) or microwave (HF) product influences reliability.

When these data are not known, the default value is t $\Pi_{\text{process RFHF}} = 2.5$.

This factor is complementary to the Π_{process} factor that remains applicable for microwave and radiofrequency products.

The $\Pi_{\text{process RFHF}}$ factor is in the following form:

$$\Pi_{\text{ProcessRFHF}} = e^{1.39 \times (1 - \text{RFHF\_grade})}$$

Where RFHF_grade = Sum (Values in the following table) / (Maximum applicable mark)

No	Criterion	Value if true	Value if false
1	Confirmed experience of the manufacturer with the development of a board or a radiofrequency (or microwave) function with good feedback from operations about the reliability of the function produced	10	0
2	Presence of protections against disconnection of antennas around RF and HF amplifiers and power transistors	5	0
3	Presence of protections for EMC compatibility (check on out of band) around RF and HF amplifiers and power transistors. For example circulator, filter, etc.	5	0
4	Presence of protections against mismatch of load around RF and HF amplifiers and power transistors. For example, circulator, isolator, filter, etc.	5	0
5	Presence of protections against temperature overstresses around RF and HF amplifiers and power transistors.	5	0
6	Application of a formal method for taking account of thermal characteristics of the microwave function in the application.	5	0
7	Application of a formal method for validating the robustness of the circuit in its working environment (demonstrated margins from RF excursions, thermal overstress, compression, etc.)	10	0
8	Application of a formal method for taking account of specific features for transferring microwave components in the manufacturing chain due to specific features of cases	5	0

The maximum mark for a board comprising power components is 50. If the product only includes transistors and low level amplifiers, criteria 2, 3, 4 and 5 are not applicable and the maximum mark is 30.

RF HF integrated circuits

General model associated with the family

$$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}} \times \Pi_{\text{Process RFHF}}$$

Where:

$$\lambda_{\text{Physical}} = \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \begin{pmatrix} \lambda_{0\,\text{TH}} \times \Pi_{\text{Thermal}} \\ + \lambda_{0\,\text{TCy Case}} \times \Pi_{\text{TCy Case}} \\ + \lambda_{0\,\text{TCy Solder joints}} \times \Pi_{\text{TCy Solder joints}} \\ + \lambda_{0\,\text{RH}} \times \Pi_{\text{RH}} \\ + \lambda_{0\,\text{Mech}} \times \Pi_{\text{Mech}} \end{pmatrix}_i \times (\Pi_{\text{Induced}})_i$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	$C_{\text{sensitivity}}$
Si, SiGe integrated circuit	10	2	1	6.3
AsGa integrated circuit	10	4	5	7.4

Item manufacturing factor Π_{PM}

The Π_{PM} factor is determined in the same way as for Integrated Circuits other than HF and RF.

In choosing the ε factor, it is recommended that a value of 4 should be applied for large volume applications (telecommunication, general public) and a value of 2 should be applied for low volume applications (defence, industrial, aeronautical).

Basic failure rates associated with cases

Refer to the failure rates data given for integrated circuit cases other than HF or RF.

Basic failure rates associated with the chip

Basic material	Type	λ_{0TH}
AsGa	RF and HF Analogue Circuit (Power amplifier)	0.70
Si	RF and HF (MOS) Analogue Circuit (Power amplifier)	0.53
Si, SiGe, AsGa	Analogue and Mixed circuit (MOS, Bipolar, BiCMOS, MESFET, PHEMT, HBT) including RF and HF	0.19
Si, SiGe	RF and HF Digital Circuit (MOS, Bipolar, BiCMOS)	0.04

Notes:

- Mixed = analogue and digital.
- The following table shows the distinction between power and low level for amplifiers:

Family (chip with or without case)	Frequency	P1dB (dBm)
Power amplifiers & power transistor	<= 20 GHz	>= 30
Power amplifiers & power transistor	> 20 GHz	>= 20

Information about the life profile

t_{annual}:	time associated with each phase over a year (hours)
$RH_{ambient}$:	relative humidity associated with a phase (%)
$T_{board\text{-}ambient}$:	average board temperature during a phase (°C)
$\Delta T_{cycling}$:	amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$:	maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$:	number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}:	cycle duration (hours)
Grms:	vibration amplitude associated with each random vibration phase (Grms)

Information about the application

$T_{J\_component}$: component junction temperature during an operating phase (°C)

$T_{J\_component} = T_{ambient} + \Delta T$

$\Delta T = P_{dissipated} \times R_{JA}$

ΔT:	component temperature increase
R_{JA}:	junction-ambient thermal resistance
$P_{dissipated}$:	power dissipated by the component during the phase (W)

In the case of pulse operation, it is important to take account of the duty cycle in the calculation of $\Pi_{Thermal}$. For short pulses (pulse for which the duration is less than the thermal time constant of the chip), ΔT has to be determined using the thermal impedance Z instead of R_{JA}.

η: duty cycle during the phase

Factors contributing to Physical stresses

$\Pi_{Thermal\_}$	In an operating phase: $e^{11604 \times 0.7 \times \left[\frac{1}{293} - \frac{1}{\left(T_{j-component} + 273\right)}\right]}$ In a pulse operating phase: $\eta \times e^{11604 \times 0.7 \times \left[\frac{1}{293} - \frac{1}{\left(T_{j-component} + 273\right)}\right]}$ In a non-operating phase: $\Pi_{Thermal} = 0$
Π_{TCy} Case	$\left(\frac{12 \times N_{annual\text{-}cy}}{t_{annual}}\right) \times \left(\frac{\Delta T_{cycling}}{20}\right)^{4} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{\left(T_{max-cycling} + 273\right)}\right]}$
Π_{TCy} Solder joints	$\left(\frac{12 \times N_{annual\text{-}cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy}, 2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{\left(T_{max-cycling} + 273\right)}\right]}$
Π_{Mech}	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$\left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.9 \times \left[\frac{1}{293} - \frac{1}{\left(T_{board\text{-}ambient}\ 273\right)}\right]}$ In an operating phase: $\Pi_{RH} = 0$

RF HF discrete semiconductors

General model associated with the family

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}} \times \Pi_{\text{Process RFHF}}$ where:

$$\lambda_{Physical} = \sum_{i}^{Phases} \left(\frac{t_{annual}}{8760} \right)_i . \left(\lambda_{0_{TH}} .\Pi_{Therm.} + \lambda_{0_{TCy_{Case}}} .\Pi_{TCy_{Case}} + \lambda_{0_{TCy_{Solder\_joints}}} .\Pi_{TCy_{Solder\_joints}} + \lambda_{0_{RH}} .\Pi_{RH} + \lambda_{0_{mech}} .\Pi_{mech} \right)_i .\Pi_{Induced-i}$$

$C_{\text{sensitivity}}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	**MOS**	**TOS**	**$C_{\text{sensitivity}}$**
HF and RF Si and SiGe discrete semiconductor circuit	10	2	1	6.3
RF and HF AsGadiscrete semiconductor circuit	10	4	5	7.4

Item manufacturing factor Π_{PM}

The Π_{PM} factor is determined in the same way as for Discrete semiconductors other than HF and RF.

In choosing the ε factor, it is recommended that a value of 4 should be applied for large volume applications (telecommunication, general public) and a value of 2 for low volume applications (defence, industrial, aeronautical).

Basic failure rates associated with cases

Refer to the failure rates given for cases for Discrete semiconductors other than HF or RF.

Basic failure rates associated with the chip (rates built up from manufacturer tests)

Low power diodes	λ_{0TH}
PIN, Schottky, Tunnel, varactor diodes (RF HF)	0.0120

Low power transistors	λ_{0TH}
Silicon, bipolar < 5W. SiGe, bipolar <1W	0.0138
AsGa<1W	0.0488

Power transistors	λ_{0TH}
Silicon, bipolar > 5W	0.0478
Silicon, MOS > 5W	0.0202
AsGa>1W	0.0927

Information about the life profile

t_{annual}: time associated with each phase over a year (hours)
$RH_{ambient}$: humidity associated with a phase (%)
$T_{board\text{-}ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}: cycle duration (hours)
Grms: vibration amplitude associated with each random vibration phase (Grms)

Information about the application

$T_{J\_component}$: component junction temperature during an operating phase (°C)
$T_{J\_component} = T_{ambient} + \Delta T$
$\Delta T = P_{dissipated} \times R_{JA}$
ΔT: component temperature rise
R_{JA}: junction-ambient thermal resistance
$P_{dissipated}$: power dissipated by the component during the phase (W)
$V_{applied}$: inverse voltage applied during the phase, for signal diodes only (V)

In the case of pulse operation, it is important to take account of the duty cycle in the calculation of $\Pi_{Thermal}$. For short pulses (pulse for which the duration is less than the thermal time constant of the chip), ΔT has to be determined using the thermal impedance Z instead of R_{JA}.

η: duty cycle during the phase

Information related to the technology

V_{rated}: rated inverse voltage (V), for signal diodes only

Factors contributing to Physical stresses

$\Pi_{Thermal}$	In an operating phase: $\Pi_{El} \times e^{11604 \times 0.7 \times \left[\frac{1}{293} - \frac{1}{(T_{j-component}+273)}\right]}$ In a pulse operating phase: η x $\Pi_{El} \times e^{11604 \times 0.7 \times \left[\frac{1}{293} - \frac{1}{(T_{j-component}+273)}\right]}$ For signal diodes up to 1A (PIN, Schottky, signal, varactor): $\Pi_{El} = \left(\frac{V_{applied}}{V_{rated}}\right)^{2,4}$ if $\frac{V_{applied}}{V_{rated}} > 0.3$ $\Pi_{El} = 0.056$ if $\frac{V_{applied}}{V_{rated}} \leq 0.3$ For other item types: $\Pi_{El} = 1$ In a non-operating phase: $\Pi_{Thermal}$ = 0
Π_{TCy} Case	$\left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\Delta T_{cycling}}{20}\right)^{4} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
Π_{TCy} Solder joints	$\left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
Π_{Mech}	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$\left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.9 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient}+273)}\right]}$ In an operating phase: Π_{RH} = 0

RF HF passive components

General model associated with the family

$$\lambda = \lambda_{Physical} \times \Pi_{PM} \times \Pi_{Process} \times \Pi_{ProcessRFHF}$$

Where:

For specific HF and RF functions,

$$\lambda_{Physical} = \lambda_{0\_PassiveHF\,RF} \times \sum_{i}^{Phases} \left(\frac{t_{annual}}{8760} \right)_i \times \left(\Pi_{Thermo\text{-}electrical} + \Pi_{TCy} + \Pi_{Mechanical} + \Pi_{RH} \right)_i \times \left(\Pi_{Induced} \right)_i$$

For RF and HF SMD resistors, apply the calculation of $\lambda_{Physical}$ of resistive chips described in the resistors datasheet (other than HF and RF).

For RF and HF SMD ceramic capacitors, apply the calculation of $\lambda_{Physical}$ of ceramic capacitors with a defined temperature coefficient (type I) described in the ceramic capacitors datasheet (other than HF and RF).

For RF and HF inductors, apply the calculation of $\lambda_{Physical}$ of multilayer inductors described in the magnetic components datasheet (other than HF and RF).

$C_{sensitivity}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	**MOS**	**TOS**	**$C_{sensitivity}$**
Fixed passive components for microwaves: Attenuator, load (50 Ohm), filter, power divider (combiner, splitter)	2	4	1	2.6
Variable passive components for microwaves: variable attenuator, tuneable filter	2	4	1	2.6
Passive components with ferrites for microwaves, circulator, isolator, phase shifter	2	4	1	2.6
Passive components for microwaves: Surface wave filters	6	7	5	6.25

Item manufacturing factor Π_{PM}

The Π_{PM} factor is determined in the same way as for Discrete semiconductors other than HF and RF.

In choosing the ε factor, it is recommended that a value of 4 should be applied for large volume applications (telecommunication, general public) and a value of 2 for low volume applications (defence, industrial, aeronautical).

Basic failure rates associated with the component

Component description	$\lambda_{0\_passive\ HF\ RF}$	γ_{TH-EL}	γ_{TCy}	γ_{Mech}	γ_{RH}
Fixed passive components for microwaves: Attenuator, load (50 Ohm), filter, power divider (combiner, splitter)	0.5	0.01	0.67	0.30	0.02
Variable passive components for microwaves: Variable attenuator, tuneable filter	1	0.01	0.67	0.30	0.02
Passive components with ferrites for microwaves, circulator, isolator, phase shifter	1	0.01	0.69	0.30	0
Surface wave filters	3.75	0.01	0.67	0.30	0.02

Information about the life profile

t_{annual}:	time associated with each phase over a year (hours)
$RH_{ambient}$:	humidity associated with a phase (%)
$T_{board-ambient}$:	average board temperature during a phase (°C)
$\Delta T_{cycling}$:	amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$:	maximum board temperature during a cycling phase (°C)
$N_{annual-cy}$:	number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}:	cycle duration (hours)
Grms:	vibration amplitude associated with each random vibration phase (Grms)

Information about the application

$\Delta T = P_{dissipated} \times R_{CA}$

ΔT:	component temperature rise
R_{CA}:	component-ambient thermal resistance
$P_{dissipated}$:	power dissipated by the component during the phase (W)

In the case of pulse operation, it is important to take account of the duty cycle in the calculation of $\Pi_{Thermo-electrical}$. For short pulses (pulse for which the duration is less than the thermal time constant of the chip), ΔT has to be determined using the thermal impedance Z instead of R_{CA}.

η: duty cycle during the phase

Factors contributing to Physical stresses

Π ***Thermo-electrical***	In an operating phase: $\gamma_{TH-EL} \times e^{11604 \times 0.15 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient} + \Delta T + 273)}\right]}$ In a pulse operating phase: $\eta \times \gamma_{TH-EL} \times e^{11604 \times 015 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient} + \Delta T + 273)}\right]}$ In a non-operating phase: $\Pi_{Thermo-electrical} = 0$
Π ***TCy***	$\gamma_{TCy} \times \left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
Π ***Mechanical***	$\gamma_{Mech} \times \left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π ***RH***	$\gamma_{RH} \times \left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.9 \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient}+273)}\right]}$ In an operating phase: $\Pi_{RH} = 0$

COTS boards

General

The COTS board model is intended for off-the-shelf boards that perform standard electronic functions. This model is particularly useful to:

- Estimate the reliability of COTS boards for which the manufacturer has not given any reliability information.
- Estimate the reliability of COTS boards in environments other than those for which the manufacturer has given the reliability.
- Estimate the reliability of a set of COTS boards from different sources in a common frame of reference, knowing that when COTS board manufacturers provide any reliability information, they do not necessarily specify the source, or the conditions under which the information is applicable.

One of the practical objectives of this model is that it can be used starting from information directly available on the COTS board. In general, this is limited to the technical datasheet for the board. The level of detail contained within technical datasheets for COTS boards is often low. This creates some limits on this model of COTS boards:

- The proposed breakdown into electronic functions provides a means of describing boards that perform standard functions; it is not suitable for the description of specific boards that are not COTS boards.
- The realism of the prediction should be compared with the low level of information used.

It is recommended that COTS board manufacturers who would like to publish reliability information about their boards should use the component method rather than this board method.

Induced factor

Factors contributing to overstresses

$$\Pi_{\text{induced-i}} = \left(\Pi_{\text{placement}} \times \Pi_{\text{application-i}} \times \Pi_{\text{Ruggedising}}\right)^{0.511 \times \ln\left(C_{\text{sensitivity}}\right)}$$

The index i denotes the phase considered.

Contributions associated with the $\Pi_{\text{placement}}$ and $C_{\text{sensitivity}}$ factors

Common functions all boards	$\Pi_{\text{placement}}$	$C_{\text{sensitivity}}$
Common functions	1.3	6.1

Central digital functions	$\Pi_{\text{placement}}$	$C_{\text{sensitivity}}$
CPU function	1.0	6.1
FLASH memory Boot function (NOR)		
FLASH memory Storage function (NAND)		
DRAM memory function (DDR-SDRAM, SGRAM)		
L2, L3 cache or SRAM function		
SCSI controller function		
Chipset function (Northbridge, Southbridge)		

Peripheral digital functions	$\Pi_{\text{placement}}$	$C_{\text{sensitivity}}$
Ethernet control function (LAN)	1.3	6.1
Graphic control function (VGA)		
Fieldbus control function (CAN, ARINC, 1553)		
Wireless control function (Bluetooth, WIFI)		
Analogue / digital or digital / analogue conversion function		

Inputs outputs	$\Pi_{\text{placement}}$	$C_{\text{sensitivity}}$
Parallel bus digital line	1.6	6.1
Analogue or discrete line	2.0	
Serial peripheral line (RS232, RS485, RS422, USB, mouse, keyboard, ethernet)		
Serial bus line (CAN, ARINC, 1553)		
Input output isolation by optocoupling		
Input / output isolation or switching by the electromechanical relay		

Contribution associated with the $\Pi_{\text{application}}$ factor

This contribution is determined in the same way as for components.

Contribution associated with the $\Pi_{\text{ruggedising}}$ factor

This contribution is determined in the same way as for components.

Item manufacturing factor

Model associated with the Π_{PM} factor

$$\Pi_{PM} = e^{1.39\times(1-\text{Part\_Grade})-0.69}$$

Where:

$$\text{Part\_Grade} = \left[\frac{(QA_{\text{manufacturer}} + QA_{\text{item}})\times \varepsilon}{24}\right]$$

$QA_{manufacturer}$ factor

This factor is determined in the same way as for components.

QA_{item} factor

Item quality assurance level	**Position relative to the state of the art**	**QA_{item}**
Severe environments and accelerated stress tests performed	Higher	3
Known qualification / debugging procedure internal to the manufacturer	Equivalent	1
No information	Lower	0

Experience factor ε:

This factor is determined in the same way as for components.

Onboard electronic functions

General model associated with the family

$$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$$

Where:

$$\lambda_{\text{Physical}} = \sum_{i}^{\text{Phases}} \left(\left(\frac{t_{\text{annual}}}{8760} \right) \times \lambda_{\text{Board}} \right)_i$$

$$\lambda_{\text{Board}} = \lambda_{\text{common functions}} + \sum_{j}^{\text{Functions}} \lambda_{\text{function } j}$$

$$\lambda_{\text{common functions}} = \lambda_{0\,\text{common functions}} \times \sum_{k}^{\text{Stress}} \left(\gamma_{\text{ common functions}} \times \Pi_{\text{Acceleration}} \right)_k \times \left(\Pi_{\text{induced}} \right)_{\text{common functions}}$$

$$\lambda_{\text{function}} = \lambda_{0\,\text{function}} \times \sum_{k}^{\text{Stress}} \left(\gamma_{\text{function}} \times \Pi_{\text{Acceleration}} \right)_k \times \left(\Pi_{\text{induced}} \right)_{\text{function}}$$

Not : in the same way of the other models, $\left(\Pi_{\text{induced}} \right)_{\text{common functions}}$ and $\left(\Pi_{\text{induced}} \right)_{\text{function}}$ have to be calculated for each phase.

Determination of distribution factors by stress

Function type	γ_TH	γ_TCy Solder joints	γ_TCy Case	γ_Mech	γ_RH	γ_Chi
Common functions all boards	0.54	0.24	0.02	0.05	0.08	0.07
Central digital functions	0.38	0.50	0.04	0.03	0.05	0.00
peripheral digital functions	0.38	0.50	0.04	0.03	0.05	0.00
Input / output function						
• Input output line (parallel bus, serial bus, discrete or analogue line)	0.49	0.40	0.03	0.02	0.05	0.01
• Input output isolation by optocoupling						
• Input/output isolation or switching by electromechanical relay	0.60	0.23	0.02	0.05	0.10	0.01

Basic failure rates

Common functions all boards	λ_0 **function**
Common functions	155 x FF

Central digital functions	λ_0 **function**
CPU function	11
FLASH memory Boot function (NOR)	17 x D_flash_boot
FLASH memory Storage function (NAND)	19 x D_flash_stock
DRAM memory function (DDR-SDRAM, SGRAM)	23 x D_DRAM
L2, L3 cache or SRAM function	11 x D_SRAM
SCSI controller function	6
Chipset function (Northbridge, Southbridge)	16

Peripheral digital functions	λ_0 **function**
Ethernet control function (LAN)	12
Graphic control function (VGA)	24
Fieldbus control function (CAN, ARINC, 1553)	12
Wireless control function (Bluetooth, WIFI)	11
Analogue/digital or digital/analogue conversion function	10

Input output lines	λ_0 **function**
Parallel bus digital line	1,0 x $M_{parallel}$
Analogue line or discrete digital line	1,2 x M_{analog}
Serial peripheral line (RS232, RS485, RS422, USB, mouse, keyboard, ethernet)	2 x M_{series}
Serial bus line (CAN, ARINC, 1553)	3 x M_{series}
Input output isolation by optocoupling	1 x quantity
Input/output isolation or switching by electromechanical relay	3 x quantity

Determination of the shape factor FF

Board format	**Length (mm)**	**Width (mm)**	**FF**
Ipack	99	45	0.12
PC104	96	90	0.23
PMC	149	74	0.30
EPIC	165	115	0.51
3U	160	100	0.43
mini ITX	170	170	0.78
6U	233	160	1.00
Flex-ATX	228	190	1.16
micro ATX	244	244	1.60
ATX	304	244	2.00

$$FF = \frac{\text{Width} \times \text{Length}}{37280}$$

Where Width and Length are the main dimensions of the board in millimetres. If there is no available data about the size of the board, FF shall be set equal to 1.

Determination of the memory density factors D

Flash memory Boot NOR	
Size (Mb)	**D_flash_boot**
≤ 4	1.00
8	1.41
16	2.00
32	2.83
64	4.00
128	5.66

$D\_flash\_boot = 1$ if size ≤ 4Mb

$D\_flash\_boot = \left(\frac{Size(Mb)}{4}\right)^{\frac{1}{2}}$ if size > 4Mb

Flash memory Storage NAND	
Size (Mb)	**D_flash_stock**
≤ 512	1
1024	1.41
2048	2
4096	2.82

$D\_flash\_stock = 1$ if size ≤ 512Mb

$D\_flash\_stock = \left(\frac{Size(Mb)}{512}\right)^{\frac{1}{2}}$ if size > 512Mb

DRAM memory	
Size (Mb)	**D_DRAM**
≤ 256	1
512	1.41
1024	2
2048	2.82
4096	4

$D\_DRAM = 1$ if size ≤ 256Mb

$D\_DRAM = \left(\frac{Size(Mb)}{256}\right)^{\frac{1}{2}}$ if size > 256Mb

SRAM memory	
Size (Kb)	**D_SRAM**
≤ 512	1
1024	1.41
2048	2
4096	2.82

$D\_SRAM = 1$ if size ≤ 512Kb

$D\_SRAM = \left(\frac{Size(Kb)}{512}\right)^{\frac{1}{2}}$ if size > 512Kb

D will be equal to 1 if no technological data is available associated with the listed function.

Determination of the input/output line multiplicity factor M

In the case of parallel bus inputs/outputs: $M_{parallel} = \sum_{\text{Parallel bus}} (\text{Number of lines in the bus})^{1/2}$

If the number of parallel inputs/outputs is not available, $M_{parallel}$ will be equal to 4.

In the case of analogue inputs/outputs: $M_{analogue} = (\text{Number of lines})^{1/2}$

If the number of parallel inputs outputs is not available, M_{analog} will be equal to 3.

In the case of serial bus inputs/outputs: $M_{series} = \text{Number of serial bus interfaces}$

If the number of lines is not available, M_{series} will be equal to 2.
The number of serial bus interfaces must consider all protocols present.
For example, if the board has 3 CAN buses and one ARINC bus, the M_{series} to be considered will be 4.

Guide for listing and counting functions

The analysis used to identify electronic functions of the COTS board being studied must be based on the specifications given in manufacturer datasheets. The recommended process is as follows:

1	Identify the dimensions of the board being studied: calculate the shape factor **FF**
2	Identify central digital functions: these functions will necessarily be associated with the presence of components responsible for part of the architecture, on the board
3	Identify the technological generation of the various memory resources on the board being studied: calculate memory density factors **D**
4	Identify peripheral digital functions: these functions will necessarily be associated with the presence of components responsible for specific management of a communication or signal processing protocol, on the board
5	Identify the number of buses and the number of parallel bus input output lines: calculate the $M_{parallel}$ factor Example: for a board that manages 4 parallel buses with 16 lines each, $M_{parallel} = 4x(16)^{1/2} = 16$
6	Identify the number of analogue input output lines: calculate the factor $M_{analogue}$ Example: for a board managing 16 analogue inputs, $M_{analogue} = (16)^{1/2} = 4$
7	Identify the number of serial bus input output lines: calculate the factor M_{series} Example: a board managing 3 accesses to a CAN bus and one access to an ARINC bus will have a CAN controller and an ARINC controller (therefore 2 fieldbus control functions), 3 CAN serial bus lines and one ARINC serial bus line (M_{series} factor = 4)
8	Identify input output lines with isolation barriers (optocoupling or electromechanical) and add the failure rates at the input output lines concerned. Example: for a board with 1 switchable analogue input by 8 relays to 8 external sources, then $M_{analogue}$ = 1, plus 8 isolation barrier functions by electromechanical relays

Information about the life profile

t_{annual}: time associated with each phase over a year (hours)
$RH_{ambient}$: relative humidity associated with a phase (%)
$T_{board\text{-}ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$: number of cycles associated with each cycling phase during a year (cycles)
θ_{cy} : cycle duration (hours)
G_{RMS} : stress associated with each random vibration phase (Grms)

Pollution level (see tables)

Saline pollution level	Π_{sal}
Low	1
High	2

Product protection level	Π_{prot}
Hermetic	0
Non hermetic	1

Application pollution level	Π_{zone}
Low	1
Moderate	2
High	4

Environmental pollution level	Π_{envir}
Low	1
Moderate	1.5
High	2

Factors contributing to Physical stresses

$\Pi_{Thermal}$	In an operating phase: $e^{11604\times 0.45\times\left[\frac{1}{293}-\frac{1}{(T_{board-ambient}+273)}\right]}$ In a non-operating phase: $\Pi_{thermal}=0$
Π_{Tcy_solder} *joints*	$\left(\frac{12\times N_{annual-cy}}{t_{annual}}\right)\times\left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}}\times\left(\frac{\Delta T_{cycling}}{20}\right)^{1.9}\times e^{1414\times\left[\frac{1}{313}-\frac{1}{(T_{max-cycling}+273)}\right]}$
Π_{Tcy_cases}	$\left(\frac{12\times N_{annual-cy}}{t_{annual}}\right)\times\left(\frac{\Delta T_{cycling}}{20}\right)^{4}\times e^{1414\times\left[\frac{1}{313}-\frac{1}{(T_{max-cycling}+273)}\right]}$
$\Pi_{Mechanical}$	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH} - *Common functions* - *Input output line (parallel bus, discrete or analogue line, serial peripheral, serial bus)* - *Isolation or input output switching by electromechanical relay*	In a non-operating phase: $\left(\frac{RH_{ambient}}{70}\right)^{4.4}\times e^{11604\times 0.9\times\left[\frac{1}{293}-\frac{1}{(T_{board-ambient}+273)}\right]}$ In an operating phase: $0.6\times\left(\frac{RH_{ambient}}{70}\right)^{4.4}\times e^{11604\times 0.9\times\left[\frac{1}{293}-\frac{1}{(T_{board-ambient}+273)}\right]}$
Π_{RH} *other functions*	$\left(\frac{RH_{ambient}}{70}\right)^{4.4}\times e^{11604\times 0.9\times\left[\frac{1}{293}-\frac{1}{(T_{board-ambient}+273)}\right]}$ In an operating phase: $\Pi_{RH}=0$
$\Pi_{Chemical}$	$\Pi_{Sal}\times\Pi_{Indus}\times\Pi_{Area}\times\Pi_{Prot}$

Various subassemblies

General

Warning about the theoretical applicability domain

Considering the method of building some models of subassemblies presented in this chapter, their behaviour in extreme environments (severe or not at all aggressive, like storage) is not necessarily as representative as what is expected for the component models.

Consequently, these models should be used with caution in extreme environments (severe or not at all aggressive).

The following subassemblies are concerned:
- LCD screens
- Hard disks
- CRT screens
- Lithium and nickel batteries
- Fans
- Keyboards

Life

Modelling

The life that depends on aging phenomena is represented by an increase in the failure rate that can be modelled using a Weibull law.

$$\lambda_{\text{wear out}}(t) = \beta \cdot \frac{t^{\beta-1}}{\eta^{\beta}}$$

where:
t time,
β, shape factor
η, scale factor.

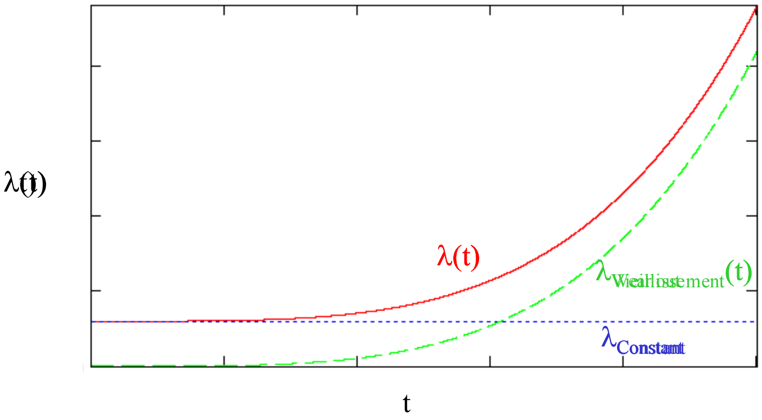
The life is usually expressed by means of the L10 parameter corresponding to the time at which 10% of wear out failures occur.

$$\lambda_{\text{wear out}}(t) = \beta \cdot \mathrm{Ln}\left(\frac{1}{0.9}\right) \cdot \frac{t^{\beta-1}}{L10^{\beta}}$$

These failures, $\lambda_{\text{wear out}}(t)$, are additional to so-called random failures modelled using an exponential law with a constant failure rate.

$$\lambda(t) = \lambda_{\text{Constant}} + \lambda_{\text{Wear out}}(t)$$

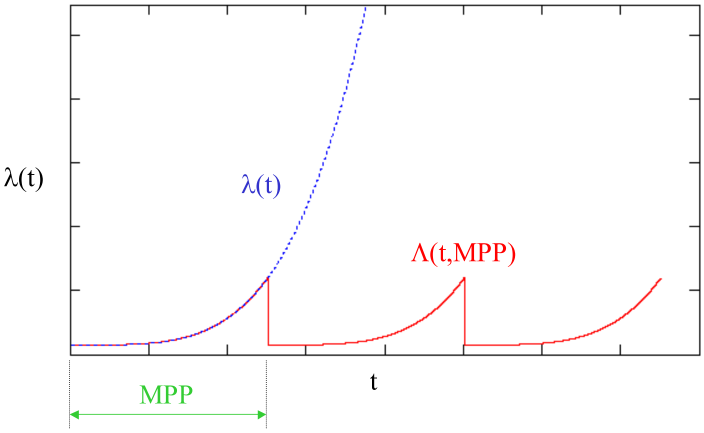
Which is shown in the following curve:



Prenventative maintenance

It is often useful to set up Periodic Prenventative Maintenance (MPP) at intervals, to prevent an avalanche of failures due to wear out.

The failure rate will then be represented as follows:



Once MPP has been determined, the case in which the subassembly has a longer life than the complete system must be considered (for example hard disk in an office computer). In this case, MPP will be limited to the life of the complete system.
MPP shall be considered as the interval after which the subassembly is replaced in the system. In this case, the subassembly itself is considered as a non-reparable item.

Average failure rate

Strictly speaking, a model of the failure rate as a function of time should be used. However, considering the requirements, it is much more practical to use an average failure rate.

$$\lambda = \lambda_{\mathrm{Constant}} + \mathrm{Ln}\left(\frac{1}{0.9}\right) \cdot \frac{\mathrm{MPP}^{\beta-1}}{\mathrm{L10}^{\beta}}$$

When the maintenance policy does not include any prenventative maintenance, the average failure rate is calculated over the average period MC between two corrective maintenance operations due to wear out failures.

$$\mathrm{MC} = \mathrm{L10} \cdot \left(\frac{-\mathrm{Ln}(0.5)}{\mathrm{Ln}\left(\frac{1}{0.9}\right)} \right)^{\frac{1}{\beta}}$$

Therefore some item models (subassemblies) will use the $\lambda_{\text{Wear out}}$ parameter that is built up using the principles described below.

Weibull shape factor β

The shape factor β is used to model the wear out type. A default value of β is suggested for each model with a $\lambda_{\text{Wear out}}$. When the subassembly supplier provides a value of β, this value will be preferred to the default value.

Induced and item manufacturing factors

Factors contributing to overstresses $\Pi_{Induced}$

The $\Pi_{Induced}$ factor is calculated in the same way as for components.
The $\Pi_{placement}$ parameter is determined as defined in each item datasheet.

Model associated with the item manufacturing factor Π_{PM}

The Π_{PM} factor is calculated for all subassemblies in the same way as for COTS boards.

LCD screens (TFT, STN)

General model associated with the family **ⓘ Warning: limited life**

$$\lambda = \lambda_{\mathrm{Cst}} + \lambda_{\mathrm{Wear\ out}}$$

where:

$$\lambda_{\mathrm{Cst}} = \lambda_{\mathrm{Physical}} \times \Pi_{\mathrm{PM}} \times \Pi_{\mathrm{Process}}$$

and:

$$\lambda_{\mathrm{Physical}} = \sum_{i}^{\mathrm{Phases}} \left(\frac{t_{\mathrm{annual}}}{8760}\right)_i \times \left(\lambda_{\mathrm{Thermal\_screen}} \times \Pi_{\mathrm{Thermal}} + \lambda_{\mathrm{Mechanical\_screen}} \times \Pi_{\mathrm{Mechanical}}\right)_i \times \left(\Pi_{\mathrm{Induced}}\right)_i$$

and:

$$\lambda_{\mathrm{wear\,out}} = 0.105 \cdot 10^9 \times \frac{\min(\mathrm{MPP},\mathrm{MC})^{\beta-1}}{\left(\frac{\mathrm{DDV}}{T_{\mathrm{usage}}}\right)^{\beta}}$$

where:

- DDV, life in operation (L10).
  The life of LCD screens is limited, particularly due to the back lighting lamp(s).
  If there is no manufacturer data, assume DDV = 40 000 hours of operation.

- MPP, average calendar time between 2 periodic prenventative maintenance operations.
  If the maintenance policy does not allow for any, assume MPP = MC.

- MC, average calendar time between 2 corrective preventative maintenance operations due to wear out failures alone: $\mathrm{MC} = \frac{\mathrm{DDV}}{T_{\mathrm{usage}}} \times 6.579^{\frac{1}{\beta}}$

- T_{usage}, usage rate during the duration of the life profile (sum of operating times divided by the total duration).

- β, Weibull shape factor, by default β = 3.

Contribution associated with the $C_{sensitivity}$ factor

		EOS	MOS	TOS	$C_{sensitivity}$
LCD screens	**TFT**	7	2	1	**2.40**
	STN	3	2	1	**1.80**

Contribution associated with the $\Pi_{placement}$ factor

		$\Pi_{placement}$
LCD screens	**Portable**	**1.6**
	Fixed	**1.0**

Failure rate associated with the subassembly

Subassembly description	$\lambda_{Mechanical\_Screen}$	$\lambda_{Thermal\_Screen}$	**Ea (eV) Activation energy**
TFT LCD screens	$\Pi c \times \left(126 \times D^{1.11}\right)$	$\Pi c \times \left(193 \times e^{\frac{P}{115}}\right)$	0.6
STN LCD screens	$\Pi c \times \left(11 \times D^{2.48}\right)$	$\Pi c \times \left(96.5 \times e^{\frac{P}{10.8}}\right)$	0.5

Information about technical characteristics

D: Screen size, diagonal (in inches). 6"< D_{TFT} < 70" and 6"< D_{STN} < 17"
P: Power (in Watts). P_{TFT} < 300W and P_{STN} < 40W
Note: If P is unknown, use $P(D) = 2.4 \times e^{0.18 \times D}$, for 6" < D < 20".

Determination of the class factor Π_c

Simplified classification according to ISO13406-2:

	Maximum number of pixels, sub-pixels or dead clusters per million pixels					
Class	**On pixels Type 1**	**Off pixels Type 2**	**Sub-pixels Type 3**	**Type 1 or 2 clusters**	**Type 3 clusters**	**Class factor Π_c**
I	0	0	0	0	0	2.48
II	2	2	5	0	2	1.00
III	5	15	50	0	5	0.46
IV	50	150	500	5	50	0.28

This table shows the number of defects beyond which a screen is considered to be defective. For example, a screen with only 2 bad pixels in class II will not be considered as being defective.

Information about the life profile:

t_{annual} : time associated with each phase over a year (hours)
$T_{ambient}$: average ambient temperature associated with a phase (°C)
G_{RMS} : stress associated with each random vibration phase (Grms)

Factors contributing to Physical stresses:

$\Pi_{Thermal}$	In an operating phase: $e^{11604 \times Ea \times \left[\frac{1}{293} - \frac{1}{(T_{ambient} + 273)}\right]}$ In a non-operating phase: $\Pi_{thermal} = 0$
$\Pi_{Mechanical}$	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$

Hard disks (EIDE, SCSI)

General model associated with the family: **ⓘ Warning: Limited life**

$$\lambda = \lambda_{Cst} + \lambda_{Wear\ out}$$

where:

$$\lambda_{Cst} = \lambda_{Physical} \times \Pi_{PM} \times \Pi_{Process}$$

and:

$$\lambda_{Physical} = \sum_{i}^{Phases} \left(\frac{t_{annual}}{8760}\right)_i \times \left(\lambda_{Thermal\_Hard\text{-}disk} \times \Pi_{Thermal} + \lambda_{Mechanical\_Hard\text{-}disk} \times \Pi_{Mechanical}\right)_i \times \left(\Pi_{Induced}\right)_i$$

and:

$$\lambda_{Wear\,out} = 0.105 \cdot 10^9 \times \frac{\min(MPP, MC)^{\beta-1}}{\left(\frac{DDV}{T_{usage}}\right)^{\beta}}$$

Where:

- DDV, life in operation (L10).
  The life of hard disks is limited, particularly due to the wear of mechanical moving parts.
  If there are no manufacturer data, assume DDV = 50 000 hours of operation.

- MPP, average calendar time between 2 periodic prenventative maintenance operations.
  If the maintenance policy does not allow for any, assume MPP = MC.

- MC, average calendar time between 2 corrective maintenance operations due to wear out failures alone: $MC = \frac{DDV}{T_{usage}} \times 6.579^{\frac{1}{\beta}}$

- T_{usage}, usage rate during the duration of the life profile (sum of operating times divided by the total duration).

- β, Weibull shape factor, by default β = 4.5.

Contribution associated with the $C_{sensitivity}$ factor

			EOS	*MOS*	*TOS*	$C_{sensitivity}$
Hard disks	Normal use	Protection against shocks/vibrations	*2*	*6*	*2*	4.00
		Qualification for shocks/vibrations	*2*	*8*	*2*	5.00
		Without particular protection or qualification	*2*	*10*	*2*	6.00
	Ventilated intensive use	Protection against shocks/vibrations	*2*	*6*	*5*	5.05
		Qualification for shocks/vibrations	*2*	*8*	*5*	6.05
		Without particular protection or qualification	*2*	*10*	*5*	7.05
	Non-ventilated intensive use	Protection against shocks/vibrations	*2*	*6*	*8*	6.10
		Qualification for shocks/vibrations	*2*	*8*	*8*	7.10
		Without particular protection or qualification	*2*	*10*	*8*	8.10

Contribution associated with the $\Pi_{placement}$ factor

		$\Pi_{placement}$
Hard disks	Portable or rack	2.5
	Fixed	1.8

Failure rate associated with the subassembly

Subassembly description	$\lambda_{Mechanical\_Hard\text{-}disk}$	$\lambda_{Thermal\_Hard\text{-}disk}$
IDE family hard disks (IDE, EIDE, E-IDE, ATA, SATA, S-ATA, Ultra ATA, DMA, Ultra DMA, etc.)	$\Pi_S \times [425 - 208 \times \ln(\mathrm{Ft})]$	$\Pi_S \times \left[5.2 + \left(\frac{\mathrm{Ta}}{9.6}\right)^{4.97}\right]$
SCSI family hard disks (SCSI-1, 2, 3, Ultra Wide SCSI 1, 2, 3, 4, SAS, etc.)	$\Pi_S \times [205 - 100 \times \ln(\mathrm{Ft})]$	$\Pi_S \times \left[2.5 + \left(\frac{\mathrm{Ta}}{11.1}\right)^{4.97}\right]$

Description of technological factors

Ft: Hard disk format (in inches). 1'' < Ft < 5.25''
Ta: Average access time (in ms). Ta < 20ms
Pc: Number of platters (Platter Count)

Note: if the Pc is unknown, use: $Pc = Integer\_part\left(\frac{1+Nt}{2}\right)$ where Nt = Number of heads.

Information about the application: Calculation of the load factor Π_S

$$\Pi_S(Pc, Dc) = \frac{Pc \times Dc + 3}{4}$$

Where:
Pc: Number of platters (Platter Count)
Dc: Duty Cycle defined by:

$$Dc = \frac{\left(\sum_a Access\_Time + \sum_b Read\_Time + \sum_c Write\_Time\right)}{Usage\_time}$$

However, in case of lack of data on the Duty Cycle, following default values can be used according to the type of use:

Type of use	**DC**
Office application or home application excluding high speed data transfers	10%
Net server (applications, data)	50%
High speed data transfers (server or client)	100%

Information about the life profile

t_{annual} : time associated with each phase over a year (hours)
$T_{ambient}$: average ambient temperature associated with a phase (°C)
G_{RMS} : stress associated with each random vibration phase (Grms)

Factors contributing to Physical stresses:

$\Pi_{Thermal}$	In an operating phase: $e^{11604 \times 0.785 \times \left[\frac{1}{293} - \frac{1}{(T_{ambient} + 273)}\right]}$ In a non-operating phase: $\Pi_{thermal} = 0$
$\Pi_{Mechanical}$	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$

CRT screens

General model associated with the family **ⓘ Warning: limited life**

$$\lambda = \lambda_{\text{Cst}} + \lambda_{\text{Wear out}}$$

where:

$$\lambda_{\text{Cst}} = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$$

and:

$$\lambda_{\text{Physical}} = \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \begin{pmatrix} \lambda_{\text{Thermal\_Screen}} \times \Pi_{\text{Thermal}} \\ +\lambda_{\text{Screen\_TCy}} \times \Pi_{\text{TCy}} \\ +\lambda_{\text{Mechanical\_Screen}} \times \Pi_{\text{Mechanical}} \\ +\lambda_{\text{Screen\_HR}} \times \Pi_{\text{HR}} \end{pmatrix}_i \times \left(\Pi_{\text{Induced}}\right)_i$$

and:

$$\lambda_{\text{Wear out}} = 0.105 \cdot 10^{9} \times \frac{\min(\text{MPP},\text{MC})^{\beta-1}}{\left(\dfrac{\text{DDV}}{T_{\text{usage}}}\right)^{\beta}}$$

where:

- DDV, life in operation (L10).
  The life of CRT screens is limited, particularly due to the loss of accuracy of electron bombardment and particularly deterioration to the phosphor layer.
  If there are no manufacturer data, assume DDV = 20 000 hours of operation.

- MPP, average calendar time between 2 periodic prenventative maintenance operations;

- If the maintenance policy does not allow for any, assume MPP = MC.

- MC, average calendar time between 2 corrective maintenance operations due to wear out failures alone: $\text{MC} = \dfrac{\text{DDV}}{T_{\text{usage}}} \times 6.579^{\frac{1}{\beta}}$

- T_{usage}, usage rate during the duration of the life profile (sum of operating times divided by the total duration).

- β, Weibull shape factor, by default $\beta = 2.5$.

Contribution associated with the $C_{sensitivity}$ factor

	EOS	MOS	TOS	$C_{sensitivity}$
CRT screens	2	5	1	3.15

Contribution associated with the $\Pi_{placement}$ factor

	$\Pi_{placement}$
CRT screens	1.4

Failure rate associated with the subassembly

$\lambda_{Mechanical\_Screen}$	λ_{Screen_TCy}	$\lambda_{Thermal\_Screen}$	λ_{Screen_RH}
$\left(262+e^{\frac{Pds-14.4}{3.97}}\right)$	$\left(524+e^{\frac{Pds-11.7}{3.97}}\right)$	$\left[13.6+\left(\frac{P}{40.7}\right)^{2.5}+\frac{215}{\sqrt{Fh}}\right]$	$\left(128+e^{\frac{D-16.9}{1.18}}\right)$

Description of technological factors

Pds: Weight of screen without casing (in kg): P < 40kg
D: Screen size, diagonal (in inches): D < 25’’
Fh: Maximum horizontal scanning frequency (in kHz): 30kHz < Fh < 150 kHz
P: Maximum operating power (in Watts): P < 200W

Note: If P unknown, use: $P(D) = 0.78 \times D^{1.72}$

Information necessary for the life profile

t_{annual}	: time associated with each phase over a year (hours)
$T_{ambient}$	: average ambient temperature associated with a phase (°C)
$RH_{ambient}$	: humidity associated with a phase (%)
G_{RMS}	: stress associated with each random vibration phase (Grms)

Information necessary for the application

π_{Prot}	: Subassembly protection level

Factors contributing to Physical stresses

$\Pi_{Thermal}$	In an operating phase: $e^{11604 \times 0.35 \times \left[\frac{1}{293} - \frac{1}{(T_{ambient} + 273)}\right]}$ In a non-operating phase: $\Pi_{thermal} = 0$
Π_{TCy}	$\left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling} + 273)}\right]}$
$\Pi_{Mechanical}$	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$\Pi_{Prot} \times \left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.8 \times \left[\frac{1}{293} - \frac{1}{(T_{ambient} + 273)}\right]}$ **Subassembly Protection level: Value of Π_{Prot}** Hermetic 0 Non hermetic 1

AC/DC and DC/DC voltage converters

General model associated with the family

$$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$$

where:

$$\lambda_{\text{Physical}} = \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760} \right)_i \times \begin{pmatrix} \lambda_{0_{\text{TH-TCy}}} \times \left(\gamma_{\text{TH}} \times \Pi_{\text{TH}} + \gamma_{\text{TCy}} \times \Pi_{\text{TCy}} \right) \\ + \ \lambda_{0_{\text{M-RH}}} \times \left(\gamma_{\text{M}} \times \Pi_{\text{M}} + \gamma_{\text{RH}} \times \Pi_{\text{RH}} \right) \end{pmatrix}_i \times \left(\Pi_{\text{Induced}} \right)_i$$

Contribution associated with the $C_{\text{sensitivity}}$ factor

	EOS	***MOS***	***TOS***	$C_{\text{sensitivity}}$
AC/DC and DC/DC converters	8.4	3.4	1	5.90

Contribution associated with the $\Pi_{\text{placement}}$ factor

	$\Pi_{\text{placement}}$
AC/DC and DC/DC converters	1.6

Basic failure rate associated with the subassembly

	$\lambda_{0\ \text{AC/DC}}$	$\lambda_{0\ \text{DC/DC}}$	γ_{TH}	γ_{TCy}	γ_{M}	γ_{RH}
$\lambda_{\text{oTH-TCY}}$	$\sqrt{1150 + 86 \cdot \sqrt{P} \cdot Ln(P)}$	$\left(3.4 + 0.27 \cdot \sqrt{P}\right)^2$	0.359	0.523		
$\lambda_{\text{oM-RH}}$	$\dfrac{1}{6.48 \cdot 10^{-3} + 0.296 \cdot \dfrac{Ln(Vol)}{Vol}}$	$6.4 \cdot Vol^{0.38} - 0.79$			0.090	0.028

Description of technological factors

	AC/DC	**DC/DC**
P: Output power (in W)	5 W < P < 7 000 W	0.5 W < P < 1 000 W
Vol: Volume in cm^3	25 cm^3 < Vol < 10 000 cm^3	0.5 cm^3 < Vol < 3 500 cm^3
If Vol unknown, assume	$\text{Vol}(\text{Pds}) = 1.4 \times \text{Pds}$	$Vol(Pds) = \left(\dfrac{Pds}{4.2}\right)^{1.3}$
where Pds: weighting	20 g < Pds < 7 000 g	10 g < Pds < 2 200 g

Information about the life profile

t_{annual} : time associated with each phase over a year (hours)
$RH_{ambient}$: relative humidity associated with a phase (%)
$T_{ambient}$: average temperature of the sub-assembly during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$: maximum temperature of the sub-assembly during a cycling phase (°C)
$N_{annual-cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy} : cycle duration (hours)
G_{RMS} : vibration amplitude associated with each random vibration phase (Grms)

Information related to the technology

Case type : Moulded case or other.

Factors contributing to Physical stresses

$\Pi_{Thermal}$	In an operating phase: $e^{11604\times 0.44\times\left[\frac{1}{293}-\frac{1}{(T_{ambient}+\Delta T+273)}\right]}$ with: moulded cases, $\Delta T=15°C$ other cases, $\Delta T=10°C$ In a non-operating phase: $\Pi_{Thermal}=0$
Π_{TCy}	$\left(\frac{12\times N_{annual-cy}}{t_{annual}}\right)\times\left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}}\times\left(\frac{\Delta T_{cycling}}{20}\right)^{2.5}\times e^{1414\times\left[\frac{1}{313}-\frac{1}{(T_{max-cycling}+273)}\right]}$
$\Pi_{Mechanical}$	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	In a non-operating phase: $\left(\frac{RH_{ambient}}{70}\right)^{4.4}\times e^{11604\times 0.6\times\left[\frac{1}{293}-\frac{1}{(T_{ambient}+273)}\right]}$ In an operating phase: $\Pi_{RH}=0$

Lithium and nickel batteries

General model associated with the family **ⓘ Warning: limited life**

$$\lambda = \lambda_{\mathrm{Cst}} + \lambda_{\mathrm{Wear\ out}}$$

where:

$$\lambda_{\mathrm{Cst}} = \lambda_{\mathrm{Physical}} \times \Pi_{\mathrm{PM}} \times \Pi_{\mathrm{Process}}$$

and:

$$\lambda_{\mathrm{Physical}} = \lambda_{\mathrm{0\_Battery}} \times \mathrm{N}_{\mathrm{cells}} \times \sum_{i}^{\mathrm{Phases}} \left(\frac{t_{\mathrm{annual}}}{8760} \right)_i \times \left(\Pi_{\mathrm{Thermal}} + \Pi_{\mathrm{TCy}} + \Pi_{\mathrm{Mechanical}} \right)_i \times \left(\Pi_{\mathrm{Induced}} \right)_i$$

and:

$$\lambda_{\mathrm{Wear\,out}} = 0.105 \cdot 10^9 \times \frac{\min(\mathrm{MPP},\mathrm{MC})^{\beta-1}}{\min(\mathrm{DDV}_1, \mathrm{DDV}_2)^{\beta}}$$

where:

- DDV_1, DDV_2, calendar life durations (L10).
  Batteries have a limited life (DDV_1) dependent on the number of charge/discharge cycles. The life (DDV_2) of lithium batteries is also limited in time independently of the number of charge/discharge cycles. As an estimation of the life duration, the failure criteria is generally a battery capability less than a specified threshold (usually between 60% and 80% of the initial capability).

  If there are no manufacturer data, use the following:

		Merit factor (Wh/Kg)	NbCD: No. of Charge/Discharge cycles	DDV_2 in calendar hours
Lithium	Li-ion Polymer	-	300	20 000
	Li-ion (1)	≤ 100	300	20 000
		100 < ≤ 200	500	
		> 200	1 000	
	Li-metal Phosphate	-	2 000	35 000
	Nano Titanium	-	10 000	150 000
Nickel	NiMH Metal Hydride (2)	≤ 50	300	NA
		> 50	1 000	
	Ni-Zn Zinc	-	1 000	
	Ni-Cd Cadmium	-	2 000	

(1) and (2): if the merit factor is not known, use NbCD = 500

$$\mathrm{DDV}_1 = \frac{\mathrm{NbCD}}{\mathrm{NbCD}_{\mathrm{Annual}}} \times 8760$$ (8760, number of hours per year for an annual life profile)

where $NbCD_{Annual}$: Number of charge/discharge cycles per year.

- MPP, average calendar time between 2 periodic prenventative maintenance operations. If the maintenance policy does not allow for any, assume MPP = MC.
- MC, average calendar time between 2 corrective maintenance operations due to wear out failures alone: $$MC = \min(DDV_1, DDV_2) \times 6.579^{\frac{1}{\beta}}$$
- β, Weibull shape factor, by default β = 5.0.

Contribution associated with the $C_{sensitivity}$ factor

	EOS	MOS	TOS	$C_{sensitivity}$
Lithium and Nickel batteries	7	7	1	6.40

Contribution associated with the $\Pi_{placement}$ factor

	$\Pi_{placement}$
Lithium and Nickel batteries	1.3

Basic failure rate associated with the subassembly

Subassembly description	$\lambda_{0\text{-Battery}}$	Activation energy (eV)	γ_{TH}	γ_{TCy}	γ_{Mech}
Nickel: NiMH Metal Hydride, Ni-Zn Zinc, Ni-Cd Cadmium Lithium: Li-ion, Nano Titanium	0.21	0.40	0.85	0.14	0.01
Lithium: Li-ion Polymer	0.29				
Lithium: Li-metal Phosphate	0.40				

N_{cell} is the number of the cells from which the battery is made. If N_{cell} is not known, assume N_{cell} = 1.

Information about the life profile

t_{annual} : time associated with each operating phase over a year (hours)
$T_{board-ambient}$: average board temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max-cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual-cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy} : cycle duration (hours)
G_{RMS} : stress associated with each random vibration phase (Grms)

Factors contributing to Physical stresses

$\Pi_{Thermal}$	In an operating phase: $\gamma_{TH} \times e^{11604 \times Ea \times \left[\frac{1}{293} - \frac{1}{(T_{board-ambient}+273)}\right]}$ In a non-operating phase: $\Pi_{Thermal} = 0$
Π_{TCy}	$\gamma_{TCy} \times \left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
$\Pi_{Mechanical}$	$\gamma_{Mech} \times \left(\frac{G_{RMS}}{0.5}\right)^{1.5}$

Fans

General model associated with the family **ⓘ Warning: limited life**

$$\lambda = \lambda_{\text{Cst}} + \lambda_{\text{Wear out}}$$

where:

$$\lambda_{\text{Cst}} = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$$

and:

$$\lambda_{\text{Physical}} = \lambda_{0\_\text{Fan}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760} \right)_i \times \left(\Pi_{\text{Thermo-electrical}} + \Pi_{\text{TCy}} + \Pi_{\text{Mechanical}} + \Pi_{\text{RH}} \right)_i \times \left(\Pi_{\text{Induced}} \right)_i$$

and:

$$\lambda_{\text{Wear out}} = 0.105 \cdot 10^9 \times \frac{\min(\text{MPP},\text{MC})^{\beta-1}}{\left(\text{DDV}_{\text{calendar}}\right)^{\beta}}$$

where:

- $\text{DDV}_{\text{calendar}}$, life in calendar hours.
  Fans have a limited life (DDV) mainly due to wear of bearings. Fan technologies may be very different, and this is why it is preferable to use manufacturer's data, usually accessible in the form of operating life (L10). This operating life is assumed to depend on the operating temperature. The life in calendar hours is deduced from the life in the different life phases using the following formula:

$$\text{DDV}_{\text{calendar}} = \left(\sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760} \right)_i \times \left(\frac{1}{\text{DDV}} \right)_i \right)^{-1}$$

Where:

$\left(\frac{1}{\text{DDV}} \right)_i = 0$ for non-operating phases.

For operating phases, $\left(\frac{1}{\text{DDV}} \right)$ will be calculated from the operating life (L10) given by the manufacturer, when this data is accessible. If there are no manufacturer data, use the following:

$$\text{DDV} = 79200 \times \Pi_{\text{Type}} \times \left[3.53 - 0.744 \times \text{Ln}(B) \right] \times e^{-Ea*11604*\left(\frac{1}{313} - \frac{1}{T+273} \right)} \times \left(\frac{V}{3000} \right)^{-m}$$

Where:

B, Noise in dBA	10 dBA < B < 90 dBA
V, Rotation speed in Revs/Minute (rpm)	1500 rpm < V < 5000 rpm
T, Temperature close to the bearing in the phase considered in °C	30°C < T < 90°C
If T unknown, use $T = 30°C$	for -40°C ≤ T_{amb} ≤ 16°C
And $T = 1.1 \times Tamb + 12.5$	for 16°C < T_{amb} ≤ 70°C

Where T_{amb} is the ambient temperature in the phase considered in °C

And:

Bearing type	Π_{type}		Ea	m
	AC	DC		
Sealed sleeve bearing	0.50	0.46	0.46	1.60
Single ball bearing (ball/sleeve) Hydrodynamic (hypro)	0.70	0.64	0.40	1.23
Ball bearing (dual)	1.0	0.92	0.28	0.93
Ceramic bearing	1.4	1.3	0.21	0.57

- MPP, average calendar time between 2 periodic prenventative maintenance operations.

  If the maintenance policy does not allow for any, assume MPP = MC.

- MC, average calendar time between 2 corrective maintenance operations due to wear out failures only:

- $$MC = DDV_{calendar} \times 6.579^{\frac{1}{\beta}}$$

- β, Weibull shape factor, by default β = 2.2.

The $C_{sensitivity}$ factor

	Relative sensitivity (mark out of 10)			
	EOS	MOS	TOS	$C_{sensitivity}$
Fan	3.7	9.1	2.4	5.5

Contribution associated with the $\Pi_{placement}$ factor

	$\Pi_{placement}$
Fan	1.6

Basic failure rate associated with the subassembly

Component description	$\lambda_{0\text{-}Fan}$	γ_{Th}	γ_{TCy}	γ_{Mech}	γ_{Rh}
Fan	0.17	0.51	0.31	0.08	0.11

Information about the life profile

t_{annual} : time associated with each phase over a year (hours)
$T_{ambient}$: average ambient temperature during a phase (°C)
$\Delta T_{cycling}$: amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$: maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$: number of cycles associated with each cycling phase over a year (cycles)
θ_{cy} : cycle duration (hours)
G_{RMS} : stress associated with each random vibration phase (Grms)
$RH_{ambient}$: humidity associated with a phase (%)

Factors contributing to Physical stresses

$\Pi_{Thermal}$	In an operating phase: $\gamma_{Th} \times e^{11604 \times 0.15 \times \left[\frac{1}{293} - \frac{1}{(T+273)}\right]}$ In a non-operating phase: $\Pi_{Thermal} = 0$ T: temperature close to the bearing during a phase (°C) If T unknown, use: For -40°C ≤ $T_{ambient}$ ≤ 16 $T = 30°C$ For 16°C < $T_{ambient}$ ≤ 70°C $T = 1.1 \times T_{ambient} + 12.5$
Π_{Tcy}	$\gamma_{Tcy} \times \left(\frac{12 \times N_{annual\text{-}cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling}+273)}\right]}$
$\Pi_{Mechanical}$	$\gamma_M \times \left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$\gamma_{Rh} \times \left(\frac{RH_{ambient}}{70}\right)^{4.4} \times e^{11604 \times 0.8 \times \left[\frac{1}{293} - \frac{1}{(T_{ambient}+273)}\right]}$

Keyboards

General **ⓘ Warning: limited life**

This model describes long or short press contact keyboards.

The keyboard model takes account of the mechanical part of the keyboard (keys) and the electrical keyboard board interface. Those two elements are separate in the model.

The keyboard model does not take account of the different possible options that may be included in some keyboards (card readers, wireless option, pointing device, etc.).

General model associated with the family

$$\lambda = \lambda_{\text{Cst}} + \lambda_{\text{Wear out}}$$

where:

$$\lambda_{\text{Cst}} = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$$

and:

$$\lambda_{\text{Physical}} = \lambda_{\text{Keyboard}} + \lambda_{\text{Board}}$$

$$\lambda_{\text{Keyboard}} = \lambda_{\text{0\_Keyboard}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760} \right)_i \times \begin{pmatrix} \Pi_{\text{Th\_Keyboard}} + \Pi_{\text{TCy\_Keyboard}} \\ + \Pi_{\text{Rh\_keyboard}} + \Pi_{\text{Mechanical\_Keyboard}} \end{pmatrix}_i \times \left(\Pi_{\text{Induced}} \right)_i$$

$$\lambda_{\text{Board}} = \lambda_{\text{0\_Board}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760} \right)_i \times \begin{pmatrix} \Pi_{\text{Th\_Board}} + \Pi_{\text{TCy\_Board}} + \Pi_{\text{Rh\_Board}} \\ + \Pi_{\text{Mechanical\_Board}} + \Pi_{\text{Chemical\_Board}} \end{pmatrix}_i \times \left(\Pi_{\text{Induced}} \right)_i$$

and:

$$\lambda_{\text{Wear out}} = 0.105 \cdot 10^9 \times \frac{\min(\text{MPP},\text{MC})^{\beta-1}}{\text{DDV}^{\beta}}$$

where:

- DDV, calendar life (L10).
  Keyboards have a limited life. It is always preferable to use manufacturer data, which is usually accessible. However, if there is no information, use:

  $$\text{DDV} = \frac{N_{\text{Presses}}}{\text{Frq}}$$

  where:
  - N_{presses}, Number of keyboard presses before failure.
  - Frq, Frequency of presses on the keyboard in Number of presses / calendar hour.
    If N_{presses} is not known, use:

    $$N_{\text{Presses}} = \left(0.69 + 0.34 \times \text{Weight}^{2.5}\right) \times \left(N_{\text{Keys}}\right)^{1-\frac{1}{\beta}} \times 10^6$$

    Where N_{Keys} is the number of keys on the keyboard.

- Weight, is the weight of the keyboard in kilograms. 0.1 kg < Pds < 2 Kg.
- β, Weibull shape factor, by default $\beta = 2.4$.

- MPP, average calendar time between 2 Periodic Prenventative Maintenance operations. If the maintenance policy does not allow for any, assume MPP = MC.

- MC, average calendar time between 2 Corrective Maintenance operations due to wear out failures only:

$$MC = DDV \times 6.579^{\frac{1}{\beta}}$$

Example: The desktop keyboard for which the average number of cycles before failure is $N_{Presses}=10^6$ presses is subjected to a press frequency of the order of 3000 characters per day, namely Frq=3000/24=125 characters per calendar hour. Its life is then $DDV=10^6/125=80000$ calendar hours.
The life of the same keyboard used at 180 strikes/minute for 2 hours/day, corresponding to a frequency Frq=900 presses per calendar hour, will be:
$DDV=10^6/900=11\ 000$ calendar hours

Contribution associated with the $C_{sensitivity}$ factor

	$C_{sensitivity}$
Keyboard	7.2
Keyboard board	4.7

Contribution associated with the $\Pi_{placement}$ factor

	$\Pi_{placement}$
Keyboard and Keyboard board	1.6

Basic failure rate associated with the <u>Keyboard</u> subassembly

Component description		$\lambda_{0\text{-Keyboard}}$	$\gamma_{Th\text{-}Keyboard}$	$\gamma_{TCy\text{-}Keyboard}$	$\gamma_{RH\text{-}keyboard}$	$\gamma_{Mech\text{-}Keyboard}$
Keyboard	Up to 20 keys	1.0	0.27	0.13	0.32	0.28
	From 20 to 70 keys	2.0	0.38	0.10	0.19	0.33
	From 70 to 95 keys	3.0	0.45	0.10	0.12	0.33
	From 95 to 120 keys	3.6	0.45	0.10	0.12	0.33
	More than 120 keys	4.5	0.45	0.10	0.12	0.33

Basic failure rate associated with the <u>Keyboard board</u> subassembly

Component description	**Phases**	$\lambda_{0\text{-Board}}$	$\gamma_{Th\text{-}Board}$	$\gamma_{Tcy\_B\text{-}Board}$	$\gamma_{Tcy\_JB\text{-}Board}$	$\gamma_{RH\text{-}Board}$	$\gamma_{Mech\text{-}Board}$	$\gamma_{Chem\text{-}Board}$
Keyboard board	ON	2.9	0.21	0.24	0.23	0.03	0.07	0.22
	OFF	2.9	0	0.24	0.23	0.24	0.07	0.22

Information about the life profile

t_{annual}:	time associated with each phase over a year (hours)
$T_{ambient}$:	average ambient temperature during a phase (°C)
$\Delta T_{cycling}$:	amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$:	maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$:	number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}:	cycle duration (hours)
G_{RMS}:	stress associated with each random vibration phase (Grms)
$RH_{ambient}$:	humidity associated with a phase (%)

Pollution level (see tables):

Saline pollution level	Π_{sal}
Low	1
High	2

Product protection level	Π_{prot}
Hermetic	0
Non-hermetic	1

Application pollution level	Π_{zone}
Low	1
Moderate	2
High	4

Environmental pollution level	Π_{envir}
Low	1
Moderate	1.5
High	2

Factors contributing to Physical stresses

ΠTh Keyboard	$\gamma_{\text{Th-Keyboard}} \times e^{11604 \times 025 \times \left[\frac{1}{293} - \frac{1}{(T_{\text{ambient}}+273)}\right]}$
ΠTcy Keyboard	$\gamma_{\text{Tcy-Keyboard}} \times \left(\frac{12 \times N_{\text{annual-cy}}}{t_{\text{annual}}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{\text{cycling}}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{\text{max-cycling}}+273)}\right]}$
ΠKeyboard Mechanical	$\gamma_{\text{keyboard-Mech}} \times \left(\frac{G_{\text{RMS}}}{0.5}\right)^{1.5}$
ΠRH Keyboard	$\gamma_{\text{RH-Keyboard}} \times \left(\frac{RH_{\text{ambient}}}{70}\right)^{4.4} \times e^{11604 \times 0.86 \times \left[\frac{1}{293} - \frac{1}{(T_{\text{ambient}}+273)}\right]}$
ΠTh Board	$\gamma_{\text{Th-Board}} \times e^{11604 \times 0.27 \times \left[\frac{1}{293} - \frac{1}{(T_{\text{ambient}}+273)}\right]}$ $\gamma_{\text{Th-Board}}$ is different in operating and non-operating
ΠTcy Board	$\Pi_{\text{TCy}} = \Pi_{\text{TCy\_B}} + \Pi_{\text{TCy\_JB}}$ $\Pi_{\text{TCy\_B}} = \gamma_{\text{TCy\_B-Board}} \times \left(\frac{12 \times N_{\text{annual-cy}}}{t_{\text{annual}}}\right) \times \left(\frac{\Delta T_{\text{cycling}}}{20}\right)^{1.27} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{\text{max-cycling}}+273)}\right]}$ $\Pi_{\text{TCy\_JB}} = \gamma_{\text{TCy\_JB-Board}} \times \left(\frac{12 \times N_{\text{annual-cy}}}{t_{\text{annual}}}\right) \times \left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{\text{cycling}}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{\text{max-cycling}}+273)}\right]}$
ΠMechanical Board	$\gamma_{\text{Mech-Board}} \times \left(\frac{G_{\text{RMS}}}{0.5}\right)^{1.5}$
ΠRH Board	$\gamma_{\text{RH-Board}} \times \left(\frac{RH_{\text{ambient}}}{70}\right)^{4.4} \times e^{11604 \times Ea \times \left[\frac{1}{293} - \frac{1}{(T_{\text{ambient}}+273)}\right]_i}$ $\gamma_{\text{RH-Board}}$ is different in operating and non-operating In an operating phase: Ea = 0.80 In a non-operating phase: Ea = 0.84
ΠChemical Board	$\gamma_{\text{Chem-Board}} \times \Pi_{\text{Sal}} \times \Pi_{\text{Envir}} \times \Pi_{\text{Zone}} \times \Pi_{\text{Prot}}$

Parts count and families count reliability predictions

General principles

The two calculation methods (parts count and families count) are simplified methods of evaluating reliability. They were produced using different parameters described in detail in component datasheets, and this is why the use of these simplified methods does not necessarily give pessimistic or conservative results. Values of failure rates obtained for a set of components will be particularly close to a detailed calculation if quantities and particularly the diversity of components used are high. Conversely, larger differences may occur in the case of an assembly comprised of a few different types of components. Stresses applied to components are almost always fixed by default, based on usually observed levels respecting standard practices.

The families count prediction method is particularly applicable during the earliest phases of the project. This method can be used to produce a reliability evaluation with the least amount of information about the product definition. In particular, the technological description of items is very much simplified and practically all application constraints are fixed at default values.

The parts count prediction method is similar to the families count method, but with a little more detail. It can provide a quick evaluation of reliability so that efforts to study and therefore construct reliability can be focussed on the more important areas. Therefore, this method is particularly useful for reliability studies on very large systems for which it is not necessary to describe millions of components in detail.

Note: These two methods should be fairly distinguished from the COTS board method that is still the most suitable for evaluations of COTS boards.

Life profile and physical stresses:

The life profile should be performed in the same way as for application of the detailed method. The only simplification made concerns information about chemical stresses where default values are used and do not need to be input.

Process audit, $\Pi_{process}$:

$\Pi_{process}$ should be considered in the same way as for complete application of the FIDES methodology. Use of the default value can reduce the accuracy of the final results.

Induced factor, $\Pi_{induced}$:

$\Pi_{induced}$ should be considered in the same way as for complete application of the FIDES methodology, except for $\Pi_{placement}$ that should be considered directly at the level of the object to be calculated rather than at component level. The C_sensitivity factor is specified by component family in counting by family and counting by type tables given below.

Item manufacturing factor Π_{PM}:

Π_{PM} is simplified and is used as a global approach for the choice of components to be considered globally and not by component family.

$$\Pi_{PM} = e^{1.39 \times (1 - \text{Part\_Grade}) - 0.69}$$

Where: $$\text{Part\_Grade} = \left[\frac{\left(AQ_{\text{manufacturer}} + AQ_{\text{component}} + AF_{\text{component}} \right) \times \varepsilon}{36} \right]$$

$QA_{manufacturer}$

The chosen Quality Assurance level of manufacturers is most often, for example	Position relative to the state of the art	*$QA_{manufacturer}$*
TS16949	Higher	3
ISO 9000 or MIL PRF 38535 or EN 9100 certified	Equivalent	2
STACK 0001	Lower	1
No information	Much lower	0

$QA_{component}$

The chosen Quality Assurance level of components is most often, for example	Position relative to the state of the art	*$QA_{component}$*
Qualification according to AEC Q100, Q101, or JESD47	Higher	3
Qualification according to standards JESD22, JEP143 or QML	Equivalent	2
Manufacturer qualification program, unidentified manufacturing sites	Lower	1
No information	Much lower	0

$RA_{component}$

The chosen level of tests carried out is most often, for example	Position relative to the state of the art	*$QA_{component}$*
Very severe tests are usually carried out	Very reliable - Level A	3
Severe tests are usually carried out	Very reliable - Level B	2
Tests are usually carried out	Reliable	1
No tests	Unreliable	0

Typical tests are given, for example, for integrated circuits in the detailed method.

Experience factor ε

Chosen manufacturers are usually	Position relative to the state of the art	Factor ε
Recognised with mature processes	Very low risk	4
Recognised with processes that have not been analysed or are not mature	Low risk	3
Not recognised	Risk	2
Previous disqualifications, problems observed, etc.	High risk	1

General model associated with all families

$\lambda = \lambda_{Physical} \times \Pi_{PM} \times \Pi_{Process}$ where:

$$\lambda_{Physical} = \sum_{i}^{Phases} \left(\frac{t_{annual}}{8760} \right) \times (\lambda_{ECU})_i + \sum_{i}^{Phases} \left(\frac{t_{annual}}{8760} \right)_i \times \begin{pmatrix} \lambda_{TH} \cdot \Pi_{Thermal} + \\ \lambda_{TcyB} \cdot \Pi_{TcyCase} + \\ \lambda_{TcyJB} \cdot \Pi_{TcySolder\_Joints} + \\ \lambda_{M} \cdot \Pi_{Mechanical} + \\ \lambda_{RH} \cdot \Pi_{RH} \end{pmatrix}_i \times (\Pi_{Induced})_i$$

The failure rate λ_{ECU} is the failure rate of the Electrical contribution (for relays and switches), Chemical and Wear out (Wear) contributions for which the variation as a function of environmental conditions is not considered or neglected in the case of reliability counting methods. However, λ_{ECU} is different during operation (switched on) and when not in operation (switched off).

Information about the usage profile

t_{annual}:	Time associated with each phase over a year (hours)
$RH_{ambient}$:	Relative humidity associated with a phase (%)
$T_{ambient}$:	Average temperature during a phase (°C)
$\Delta T_{cycling}$:	Amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$:	Maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$:	Number of cycles associated with each cycling phase during a year (cycles)
θ_{cy}:	Cycle duration (hours)
Grms:	Level of random vibrations associated with each phase (Grms)

Factors contributing to Physical stresses:

$\Pi_{Thermal}$	$e^{11604 \times Ea_{Th} \times \left[\frac{1}{To+273} - \frac{1}{\left(T_{ambient} + \Delta T \times e^{-\alpha \cdot T_{ambient}} + 273\right)} \right]}$
$\Pi_{TcyCase}$	$\left(\frac{12 \times N_{annual\text{-}cy}}{t_{annual}} \right) \times \left(\frac{\Delta T_{cycling}}{20} \right)^{m_B} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{\left(T_{max-cycling}+273\right)} \right]}$
$\Pi_{TcySolder\_Joints}$	$\left(\frac{12 \times N_{annual\text{-}cy}}{t_{annual}} \right) \times \left(\frac{\min(\theta_{cy},2)}{2} \right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20} \right)^{m_{JB}} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{\left(T_{max-cycling}+273\right)} \right]}$
$\Pi_{Mechanical}$	$\left(\frac{G_{RMS}}{0.5} \right)^{n}$
Π_{RH}	$\left(\frac{RH_{ambient}}{70} \right)^{4.4} \times e^{11604 \times Ea_{RH} \times \left[\frac{1}{293} - \frac{1}{\left(T_{ambient}+273\right)} \right]}$

Parts count: Parameters

Parameters associated with ON phases for parts count prediction

			ON phases: Average parameters by default by item type														Induced
			Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
			λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
Digital integrated circuit	**Hermetic**	**≤ 24 p**	0.021	0.7	20	3	0	0	0	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0.021	0.7	20	5	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0.021	0.7	20	7	0	0	0	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p	0.021	0.7	20	10	0	0	0	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p	0.021	0.7	20	14	0	0	0	0.034	4	0.96	1.9	0.043	1.5	0	6.3
	Non Hermetic	**≤ 24 p**	0.021	0.7	20	3	0	0	0	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0.021	0.7	20	5	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0.021	0.7	20	7	0	0	0	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p	0.021	0.7	20	10	0	0	0	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p	0.021	0.7	20	14	0	0	0	0.034	4	0.96	1.9	0.043	1.5	0	6.3
Memory integrated circuit	**Hermetic**	**≤ 24 p**	0.054	0.7	20	6	0	0	0	0.0020	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0.054	0.7	20	8	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0.054	0.7	20	12	0	0	0	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p	0.054	0.7	20	17	0	0	0	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p	0.054	0.7	20	24	0	0	0	0.034	4	0.96	1.9	0.043	1.5	0	6.3
	Non Hermetic	**≤ 24 p**	0.054	0.7	20	6	0	0	0	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0.054	0.7	20	8	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0.054	0.7	20	12	0	0	0	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p	0.054	0.7	20	17	0	0	0	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p	0.054	0.7	20	24	0	0	0	0.034	4	0.96	1.9	0.043	1.5	0	6.3
Micro*, DSP, simple ASIC integrated circuit	**Hermetic**	**≤ 24 p**	0.075	0.7	20	8	0	0	0	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0.075	0.7	20	11	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0.075	0.7	20	17	0	0	0	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p	0.075	0.7	20	23	0	0	0	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p	0.075	0.7	20	33	0	0	0	0.034	4	0.96	1.9	0.043	1.5	0	6.3

				ON phases: Average parameters by default by item type														Induced
				Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
				λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
	Non Hermetic	≤ 24 p		0.075	0.7	20	8	0	0	0	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p		0.075	0.7	20	11	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p		0.075	0.7	20	17	0	0	0	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p		0.075	0.7	20	23	0	0	0	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p		0.075	0.7	20	33	0	0	0	0.034	4	0.96	1.9	0.043	1.5	0	6.3
Analogue, Mixed FPGA, CPLD, complex ASIC integrated circuit	Hermetic	≤ 24 p		0.14	0.7	20	10	0	0	0	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p		0.14	0.7	20	15	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p		0.14	0.7	20	22	0	0	0	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p		0.14	0.7	20	30	0	0	0	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p		0.14	0.7	20	43	0	0	0	0.034	4	0.96	1.9	0.043	1.5	0	6.3
	Non Hermetic	≤ 24 p		0.14	0.7	20	10	0	0	0	0.020	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p		0.14	0.7	20	15	0	0	0	0.044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p		0.14	0.7	20	22	0	0	0	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p		0.14	0.7	20	30	0	0	0	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p		0.14	0.7	20	43	0	0	0	0.034	4	0.96	1.9	0.043	1.5	0	6.3
Diode	Non Hermetic	SMD	low power	0.0075	0.7	20	10	0	0	0	0.0008	4	0.0040	1.9	0.000080	1.5	0	5.2
			power	0.15	0.7	20	43	0	0	0	0.0041	4	0.021	1.9	0.00041	1.5	0	5.2
		TH	low power	0.0075	0.7	20	10	0	0	0	0.0011	4	0.0055	1.9	0.00011	1.5	0	5.2
			power	0.15	0.7	20	43	0	0	0	0.003	4	0.015	1.9	0.00030	1.5	0	5.2
	Hermetic	SMD		0.079	0.7	20	27	0	0	0	0.0078	4	0.039	1.9	0.00078	1.5	0	5.2
		TH		0.079	0.7	20	27	0	0	0	0.01	4	0.051	1.9	0.0010	1.5	0	5.2
Transistor	Non Hermetic	SMD	low power	0.014	0.7	20	10	0	0	0	0.0008	4	0.0040	1.9	0.00008	1.5	0	5.2
			power	0.034	0.7	20	43	0	0	0	0.0041	4	0.021	1.9	0.00041	1.5	0	5.2
		TH	low power	0.014	0.7	20	10	0	0	0	0.0011	4	0.0055	1.9	0.00011	1.5	0	5.2
			power	0.034	0.7	20	43	0	0	0	0.003	4	0.015	1.9	0.0003	1.5	0	5.2
	Hermetic	SMD		0.024	0.7	20	27	0	0	0	0.0078	4	0.039	1.9	0.00078	1.5	0	5.2
		TH		0.024	0.7	20	27	0	0	0	0.01	4	0.051	1.9	0.001	1.5	0	5.2
Optocoupler with Photodiode	Non Hermetic	SMD	low power	0.05	0.4	20	7	0	0	0	0.0008	4	0.014	1.9	0.0051	1.5	0	5.2
			power	0.05	0.4	20	29	0	0	0	0.0041	4	0.031	1.9	0.0054	1.5	0	5.2
		TH	low power	0.05	0.4	20	7	0	0	0	0.0011	4	0.016	1.9	0.0051	1.5	0	5.2

				ON phases: Average parameters by default by item type														Induced
				Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
				λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
			power	0.05	0.4	20	29	0	0	0	0.003	4	0.025	1.9	0.0053	1.5	0	5.2
	Hermetic	SMD		0.05	0.4	20	18	0	0	0	0.0078	4	0.049	1.9	0.0058	1.5	0	5.2
		TH		0.05	0.4	20	18	0	0	0	0.01	4	0.061	1.9	0.0060	1.5	0	5.2
Optocoupler with Phototransistor	Non Hermetic	SMD	low power	0.11	0.4	20	7	0	0	0	0.0008	4	0.025	1.9	0.011	1.5	0	5.2
			power	0.11	0.4	20	29	0	0	0	0.0041	4	0.042	1.9	0.011	1.5	0	5.2
		TH	low power	0.11	0.4	20	7	0	0	0	0.0011	4	0.027	1.9	0.011	1.5	0	5.2
			power	0.11	0.4	20	29	0	0	0	0.003	4	0.036	1.9	0.011	1.5	0	5.2
	Hermetic	SMD		0.11	0.4	20	18	0	0	0	0.0078	4	0.060	1.9	0.012	1.5	0	5.2
		TH		0.11	0.4	20	18	0	0	0	0.01	4	0.072	1.9	0.012	1.5	0	5.2
Potentiometer				0.13	0.15	20	33	0	0	0	0	1	0.11	1.9	0.066	1.5	0	2.5
Resistor		high dissipation		0.010	0.15	20	78	0	0	0	0	1	0.37	1.9	0.0040	1.5	0	2.3
		low dissipation		0.0050	0.15	20	12	0	0	0	0	1	0.19	1.9	0.0020	1.5	0	2.8
High stability bulk metal foil accuracy resistor				0.021	0.15	20	26	0	0	0	0	1	0.097	1.9	0.012	1.5	0	5.8
Resistive network, Resistive chip				0.00021	0.15	20	7	0	0	0	0	1	0.020	1.9	0.00021	1.5	0	4.5
Ceramic capacitor		moderate CV product		0.048	0.1	20	0	0	0	0	0	1	0.019	1.9	0.0014	1.5	0	6.1
		high CV product		0.12	0.1	20	0	0	0	0	0	1	0.075	1.9	0.0074	1.5	0	6.1
Aluminium capacitor				0.26	0.4	20	0	0	0	0	0	1	0.043	1.9	0.0031	1.5	0	6.4
Tantalum capacitor		gel		0.33	0.15	20	0	0	0	0	0	1	0.0043	1.9	0.052	1.5	0	7.0
		solid		0.54	0.15	20	0	0	0	0	0	1	0.072	1.9	0.013	1.5	0	7.0
Inductor				0.013	0.15	20	17	0	0	0	0	1	0.024	1.9	0.0043	1.5	0	5.5
transformer		low power		0.0013	0.15	20	10	0	0	0	0	1	0.091	1.9	0.033	1.5	0	6.9
		high power		0.038	0.15	20	30	0	0	0	0	1	0.17	1.9	0.040	1.5	0	6.8
Quartz resonator		through hole		0.23	0	20	0	0	0	0	0	1	0.37	1.9	0.22	1.5	0	4.6
		SMD		0.13	0	20	0	0	0	0	0	1	0.47	1.9	0.12	1.5	0	4.6
Quartz oscillator		through hole		1.65	0	20	0	0	0	0	0	1	0.68	1.9	0.22	1.5	0	8.1
		SMD		1.65	0	20	0	0	0	0	0	1	0.94	1.9	0.12	1.5	0	8.1
Relay ≤ 10 contacts	Resistive load	< 3 actuations/h		2.6	0.25	40	57	0.024	0.13	0.9	0	1	0.10	1.9	0.76	1.5	0.12	7.55
		≥ 3 actuations/h		26	0.25	40	57	0.024	0.13	0.9	0	1	0.10	1.9	7.6	1.5	1.2	7.55
	Non-resistive load	< 3 actuations/h		2.6	0.25	40	57	0.024	0.13	0.9	0	1	0.10	1.9	0.76	1.5	2.4	7.55
		≥ 3 actuations/h		26	0.25	40	57	0.024	0.13	0.9	0	1	0.10	1.9	7.6	1.5	24	7.55

			ON phases: Average parameters by default by item type														Induced
			Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
			λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
Relay > 10 contacts	Resistive load	< 3 actuations/h	6.2	0.25	40	57	0.024	0.31	0.9	0	1	0.24	1.9	1.8	1.5	0.28	7.55
		≥ 3 actuations/h	62	0.25	40	57	0.024	0.31	0.9	0	1	0.24	1.9	18	1.5	2.8	7.55
	Non-resistive load	< 3 actuations/h	6.2	0.25	40	57	0.024	0.31	0.9	0	1	0.24	1.9	1.8	1.5	5.7	7.55
		≥ 3 actuations/h	62	0.25	40	57	0.024	0.31	0.9	0	1	0.24	1.9	18	1.5	57	7.55
Push button, Switch, Inver. (< 4 pins)		Resistive load	0.45	0.25	40	52	0.024	0.070	0.9	0	1	0.041	1.9	0.32	1.5	0.030	7.45
DIP, Encoder wheel (from 4 to 10 pins)			0.88	0.25	40	52	0.024	0.14	0.9	0	1	0.081	1.9	0.63	1.5	0.058	7.45
Switch (> 10 pins)			1.9	0.25	40	52	0.024	0.30	0.9	0	1	0.18	1.9	1.4	1.5	0.13	7.45
Push button, Switch, Inver. (< 4 pins)		Non resistive load	0.45	0.25	40	52	0.024	0.070	0.9	0	1	0.041	1.9	0.32	1.5	0.59	7.45
DIP, Encoder wheel (from 4 to 10 pins)			0.88	0.25	40	52	0.024	0.14	0.9	0	1	0.081	1.9	0.63	1.5	1.2	7.45
Switch (> 10 pins)			1.9	0.25	40	52	0.024	0.30	0.9	0	1	0.18	1.9	1.4	1.5	2.6	7.45
Connector for printed circuit and printed circuit supports	soldered (PTH or SMD)	up to 20 contacts	0.29	0.1	20	5	0	0.066	0.8	0	1	0.020	1.9	0.025	1.5	0.22	4.4
		from 20 to 200 contacts	0.93	0.1	20	5	0	0.21	0.8	0	1	0.064	1.9	0.080	1.5	0.69	4.4
		More than 200 contacts	2.1	0.1	20	5	0	0.47	0.8	0	1	0.14	1.9	0.18	1.5	1.5	4.4
	wrapping or insertion	up to 20 contacts	0.073	0.1	20	5	0	0.016	0.8	0	1	0.0051	1.9	0.0063	1.5	0.055	4.4
		from 20 to 200 contacts	0.23	0.1	20	5	0	0.052	0.8	0	1	0.016	1.9	0.020	1.5	0.17	4.4
		More than 200 contacts	0.52	0.1	20	5	0	0.12	0.8	0	1	0.036	1.9	0.045	1.5	0.39	4.4
Other connector	soldered (PTH or SMD)	up to 20 contacts	0.18	0.1	20	5	0	0.039	0.8	0	1	0.012	1.9	0.015	1.5	0.13	4.4
		from 20 to 200 contacts	0.56	0.1	20	5	0	0.12	0.8	0	1	0.038	1.9	0.048	1.5	0.42	4.4
		More than 200 contacts	1.2	0.1	20	5	0	0.28	0.8	0	1	0.086	1.9	0.11	1.5	0.93	4.4
	wrapping or insertion	up to 20 contacts	0.044	0.1	20	5	0	0.010	0.8	0	1	0.0030	1.9	0.0038	1.5	0.033	4.4
		from 20 up to 200	0.14	0.1	20	5	0	0.031	0.8	0	1	0.010	1.9	0.012	1.5	0.10	4.4
		More than 200 contacts	0.31	0.1	20	5	0	0.070	0.8	0	1	0.021	1.9	0.027	1.5	0.23	4.4
Printed circuit, PTH		up to 2000 connections	0	0	40	0	0	0.090	0.8	0	1	0.30	1.9	0.10	1.5	0.022	6.5
		> 2000 connections	0	0	40	0	0	0.36	0.8	0	1	1.2	1.9	0.40	1.5	0.087	6.5
Printed circuit, SMD		up to 2000 connections	0	0	40	0	0	1.2	0.8	0	1	4.1	1.9	1.4	1.5	0.30	6.5
		> 2000 connections	0	0	40	0	0	4.9	0.8	0	1	16	1.9	5.5	1.5	1.2	6.5
Hard disk		EIDE	8.2	0.785	20	0	0	0	0	0	1	0	1	230	1.5	510	5.0
		SCSI	2.9	0.785	20	0	0	0	0	0	1	0	1	110	1.5	510	5.0

			ON phases: Average parameters by default by item type														Induced
			Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
			λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
LCD screen (Class III)	STN	up to 14"	449	0.5	20	0	0	0	0	0	1	0	1	3520	1.5	1167	1.8
		from 14" to 20"	713	0.5	20	0	0	0	0	0	1	0	1	5697	1.5	1167	1.8
	TFT		137	0.6	20	0	0	0	0	0	1	0	1	1346	1.5	1167	2.4
		larger than 20"	252	0.6	20	0	0	0	0	0	1	0	1	2156	1.5	1167	2.4
CRT screen	Up to 20"		42	0.35	20	0	0	64	0.8	0	1	526	1.9	263	1.5	2858	3.2
	larger than 20"		89	0.35	20	0	0	269	0.8	0	1	796	1.9	401	1.5	2858	3.2
AC/DC voltage converter	up to 500W		77	0.44	20	0	0	0	0	0	1	112	2.5	23	1.5	0	5.9
	more than 500W		142	0.44	20	0	0	0	0	0	1	207	2.5	26	1.5	0	5.9
DC/DC voltage converter	up to 50W		19	0.44	20	0	0	0	0	0	1	27	2.5	6.4	1.5	0	5.9
	more than 50W		47	0.44	20	0	0	0	0	0	1	68	2.5	12	1.5	0	5.9

SMD: Surface Mounted Device
TH: Through Hole
ECU = Electrical, Chemical, Wear

Parameters associated with OFF phases for parts count prediction

			OFF phases: Average parameters by default by item type														Induced
			Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
			λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
Digital integrated circuit	**Hermetic**	**≤ 24 p**	0	0	0	0	0	0	0.9	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0	0	0	0	0	0	0.9	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0	0	0	0	0	0	0.9	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p	0	0	0	0	0	0	0.9	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p	0	0	0	0	0	0	0.9	0.034	4	0.96	1.9	0.043	1.5	0	6.3
	Non Hermetic	**≤ 24 p**	0	0	0	0	0	0.011	0.9	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0	0	0	0	0	0.031	0.9	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0	0	0	0	0	0.072	0.9	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p	0	0	0	0	0	0.17	0.9	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p	0	0	0	0	0	0.45	0.9	0.034	4	0.96	1.9	0.043	1.5	0	6.3
Memory integrated circuit	**Hermetic**	**≤ 24 p**	0	0	0	0	0	0	0.9	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0	0	0	0	0	0	0.9	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0	0	0	0	0	0	0.9	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p	0	0	0	0	0	0	0.9	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p	0	0	0	0	0	0	0.9	0.034	4	0.96	1.9	0.043	1.5	0	6.3
	Non Hermetic	**≤ 24 p**	0	0	0	0	0	0.011	0.9	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0	0	0	0	0	0.031	0.9	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0	0	0	0	0	0.072	0.9	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p	0	0	0	0	0	0.17	0.9	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p	0	0	0	0	0	0.45	0.9	0.034	4	0.96	1.9	0.043	1.5	0	6.3
Micro*, DSP, simple ASIC integrated circuit	**Hermetic**	**≤ 24 p**	0	0	0	0	0	0	0.9	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0	0	0	0	0	0	0.9	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0	0	0	0	0	0	0.9	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
		from 144 to 288 p	0	0	0	0	0	0	0.9	0.016	4	0.30	1.9	0.011	1.5	0	6.3
		> 288 p	0	0	0	0	0	0	0.9	0.034	4	0.96	1.9	0.043	1.5	0	6.3
	Non Hermetic	**≤ 24 p**	0	0	0	0	0	0.011	0.9	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
		from 24 to 48 p	0	0	0	0	0	0.031	0.9	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		from 48 to 144 p	0	0	0	0	0	0.072	0.9	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3

				OFF phases: Average parameters by default by item type														Induced
				Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
				λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
			from 144 to 288 p	0	0	0	0	0	0.17	0.9	0.016	4	0.30	1.9	0.011	1.5	0	6.3
			> 288 p	0	0	0	0	0	0.45	0.9	0.034	4	0.96	1.9	0.043	1.5	0	6.3
Analogue, Mixed, FPGA, CPLD, complex ASIC integrated circuit	Hermetic		≤ 24 p	0	0	0	0	0	0	0.9	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
			from 24 to 48 p	0	0	0	0	0	0	0.9	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
			from 48 to 144 p	0	0	0	0	0	0	0.9	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
			from 144 to 288 p	0	0	0	0	0	0	0.9	0.016	4	0.30	1.9	0.011	1.5	0	6.3
			> 288 p	0	0	0	0	0	0	0.9	0.034	4	0.96	1.9	0.043	1.5	0	6.3
	Non Hermetic		≤ 24 p	0	0	0	0	0	0.011	0.9	0.002	4	0.012	1.9	0.00028	1.5	0	6.3
			from 24 to 48 p	0	0	0	0	0	0.031	0.9	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
			from 48 to 144 p	0	0	0	0	0	0.072	0.9	0.0084	4	0.11	1.9	0.0036	1.5	0	6.3
			from 144 to 288 p	0	0	0	0	0	0.17	0.9	0.016	4	0.30	1.9	0.011	1.5	0	6.3
			> 288 p	0	0	0	0	0	0.45	0.9	0.034	4	0.96	1.9	0.043	1.5	0	6.3
Diode	Non Hermetic	SMD	low power	0	0	0	0	0	0.01	0.9	0.0008	4	0.0040	1.9	0.000080	1.5	0	5.2
			power	0	0	0	0	0	0.034	0.9	0.0041	4	0.021	1.9	0.00041	1.5	0	5.2
		TH	low power	0	0	0	0	0	0.031	0.9	0.0011	4	0.0055	1.9	0.00011	1.5	0	5.2
			power	0	0	0	0	0	0.059	0.9	0.003	4	0.015	1.9	0.00030	1.5	0	5.2
	Hermetic	SMD		0	0	0	0	0	0	0.9	0.0078	4	0.039	1.9	0.00078	1.5	0	5.2
		TH		0	0	0	0	0	0	0.9	0.01	4	0.051	1.9	0.0010	1.5	0	5.2
Transistor	Non Hermetic	SMD	low power	0	0	0	0	0	0.01	0.9	0.0008	4	0.0040	1.9	0.00008	1.5	0	5.2
			power	0	0	0	0	0	0.034	0.9	0.0041	4	0.021	1.9	0.00041	1.5	0	5.2
		TH	low power	0	0	0	0	0	0.031	0.9	0.0011	4	0.0055	1.9	0.00011	1.5	0	5.2
			power	0	0	0	0	0	0.059	0.9	0.003	4	0.015	1.9	0.0003	1.5	0	5.2
	Hermetic	SMD		0	0	0	0	0	0	0.9	0.0078	4	0.039	1.9	0.00078	1.5	0	5.2
		TH		0	0	0	0	0	0	0.9	0.01	4	0.051	1.9	0.001	1.5	0	5.2
Optocoupler with Photodiode	Non Hermetic	SMD	low power	0	0	0	0	0	0.01	0.9	0.0008	4	0.014	1.9	0.0051	1.5	0	5.2
			power	0	0	0	0	0	0.034	0.9	0.0041	4	0.031	1.9	0.0054	1.5	0	5.2
		TH	low power	0	0	0	0	0	0.031	0.9	0.0011	4	0.016	1.9	0.0051	1.5	0	5.2
			power	0	0	0	0	0	0.059	0.9	0.003	4	0.025	1.9	0.0053	1.5	0	5.2
	Hermetic	SMD		0	0	0	0	0	0	0.9	0.0078	4	0.049	1.9	0.0058	1.5	0	5.2
		TH		0	0	0	0	0	0	0.9	0.01	4	0.061	1.9	0.0060	1.5	0	5.2

				OFF phases: Average parameters by default by item type														Induced
				Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
				λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
Optocoupler with Phototransistor	Non Hermetic	SMD	low power	0	0	0	0	0	0.01	0.9	0.0008	4	0.025	1.9	0.011	1.5	0	5.2
			power	0	0	0	0	0	0.034	0.9	0.0041	4	0.042	1.9	0.011	1.5	0	5.2
		TH	low power	0	0	0	0	0	0.031	0.9	0.0011	4	0.027	1.9	0.011	1.5	0	5.2
			power	0	0	0	0	0	0.059	0.9	0.003	4	0.036	1.9	0.011	1.5	0	5.2
	Hermetic	SMD		0	0	0	0	0	0	0.9	0.0078	4	0.060	1.9	0.012	1.5	0	5.2
		TH		0	0	0	0	0	0	0.9	0.01	4	0.072	1.9	0.012	1.5	0	5.2
Potentiometer				0	0	0	0	0	0.003	0.9	0	1	0.11	1.9	0.066	1.5	0	2.5
Resistor			high dissipation	0	0	0	0	0	0.014	0.9	0	1	0.37	1.9	0.0040	1.5	0	2.3
			low dissipation	0	0	0	0	0	0.0045	0.9	0	1	0.19	1.9	0.0020	1.5	0	2.8
High stability bulk metal foil accuracy resistor				0	0	0	0	0	0.064	0.9	0	1	0.097	1.9	0.012	1.5	0	5.8
Resistive network, Resistive chip				0	0	0	0	0	0.00021	0.9	0	1	0.020	1.9	0.00021	1.5	0	4.5
Ceramic capacitor			moderate CV product	0	0	0	0	0	0	0	0	1	0.019	1.9	0.0014	1.5	0	6.1
			high CV product	0	0	0	0	0	0	0	0	1	0.075	1.9	0.0074	1.5	0	6.1
Aluminium capacitor				0	0	0	0	0	0	0	0	1	0.043	1.9	0.0031	1.5	0	6.4
Tantalum capacitor			wet	0	0	0	0	0	0	0	0	1	0.0043	1.9	0.052	1.5	0	7.0
			solid	0	0	0	0	0	0	0	0	1	0.072	1.9	0.013	1.5	0	7.0
Inductor				0	0	0	0	0	0	0	0	1	0.024	1.9	0.0043	1.5	0	5.5
transformer			low power	0	0	0	0	0	0	0	0	1	0.091	1.9	0.033	1.5	0	6.9
			high power	0	0	0	0	0	0	0	0	1	0.17	1.9	0.040	1.5	0	6.8
Quartz resonator			through hole	0	0	0	0	0	0.094	0.9	0	1	0.37	1.9	0.22	1.5	0	4.6
			SMD	0	0	0	0	0	0.077	0.9	0	1	0.47	1.9	0.12	1.5	0	4.6
Quartz oscillator			through hole	0	0	0	0	0	0.19	0.9	0	1	0.68	1.9	0.22	1.5	0	8.1
			SMD	0	0	0	0	0	0.15	0.9	0	1	0.94	1.9	0.12	1.5	0	8.1
Relay ≤ 10 contacts	Resistive load		< 3 actuations/h	0	0	0	0	0	0.13	0.9	0	1	0.10	1.9	0.76	1.5	0	7.55
			≥ 3 actuations/h	0	0	0	0	0	0.13	0.9	0	1	0.10	1.9	7.6	1.5	0	7.55
	Non-resistive load		< 3 actuations/h	0	0	0	0	0	0.13	0.9	0	1	0.10	1.9	0.76	1.5	0	7.55
			≥ 3 actuations/h	0	0	0	0	0	0.13	0.9	0	1	0.10	1.9	7.6	1.5	0	7.55
Relay > 10 contacts	Resistive load		< 3 actuations/h	0	0	0	0	0	0.31	0.9	0	1	0.24	1.9	1.8	1.5	0	7.55
			≥ 3 actuations/h	0	0	0	0	0	0.31	0.9	0	1	0.24	1.9	18	1.5	0	7.55
	Non-resistive		< 3 actuations/h	0	0	0	0	0	0.31	0.9	0	1	0.24	1.9	1.8	1.5	0	7.55

			OFF phases: Average parameters by default by item type																	Induced
			Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
			λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
	load	≥ 3 actuations/h	0	0	0	0	0	0.31	0.9	0	1	0.24	1.9	18	1.5	0	7.55
Push button, Switch, Inver. (< 4 pins)		Resistive load	0	0	0	0	0	0.070	0.9	0	1	0.041	1.9	0.32	1.5	0	7.45
DIP, Encoder wheel (from 4 to 10 pins)			0	0	0	0	0	0.14	0.9	0	1	0.081	1.9	0.63	1.5	0	7.45
Switch (> 10 pins)			0	0	0	0	0	0.30	0.9	0	1	0.18	1.9	1.4	1.5	0	7.45
Push button, Switch, Inver. (< 4 pins)		Non resistive load	0	0	0	0	0	0.070	0.9	0	1	0.041	1.9	0.32	1.5	0	7.45
DIP, Encoder wheel (from 4 to 10 pins)			0	0	0	0	0	0.14	0.9	0	1	0.081	1.9	0.63	1.5	0	7.45
Switch (> 10 pins)			0	0	0	0	0	0.30	0.9	0	1	0.18	1.9	1.4	1.5	0	7.45
Connector for printed circuit and printed circuit supports	soldered (PTH or SMD)	up to 20 contacts	0	0	0	0	0	0.066	0.8	0	1	0.020	1.9	0.025	1.5	0.22	4.4
		from 20 to 200 contacts	0	0	0	0	0	0.21	0.8	0	1	0.064	1.9	0.080	1.5	0.69	4.4
		More than 200 contacts	0	0	0	0	0	0.47	0.8	0	1	0.14	1.9	0.18	1.5	1.5	4.4
	wrapping or insertion	up to 20 contacts	0	0	0	0	0	0.016	0.8	0	1	0.0051	1.9	0.0063	1.5	0.055	4.4
		from 20 to 200 contacts	0	0	0	0	0	0.052	0.8	0	1	0.016	1.9	0.020	1.5	0.17	4.4
		More than 200 contacts	0	0	0	0	0	0.12	0.8	0	1	0.036	1.9	0.045	1.5	0.39	4.4
Other connector	soldered (PTH or SMD)	up to 20 contacts	0	0	0	0	0	0.039	0.8	0	1	0.012	1.9	0.015	1.5	0.13	4.4
		from 20 to 200 contacts	0	0	0	0	0	0.12	0.8	0	1	0.038	1.9	0.048	1.5	0.42	4.4
		More than 200 contacts	0	0	0	0	0	0.28	0.8	0	1	0.086	1.9	0.11	1.5	0.93	4.4
	wrapping or insertion	up to 20 contacts	0	0	0	0	0	0.010	0.8	0	1	0.0030	1.9	0.0038	1.5	0.033	4.4
		from 20 up to 200	0	0	0	0	0	0.031	0.8	0	1	0.010	1.9	0.012	1.5	0.10	4.4
		More than 200 contacts	0	0	0	0	0	0.070	0.8	0	1	0.021	1.9	0.027	1.5	0.23	4.4
Printed circuit, PTH		up to 2000 connections	0	0	0	0	0	0.090	0.8	0	1	0.30	1.9	0.10	1.5	0.022	6.5
		> 2000 connections	0	0	0	0	0	0.36	0.8	0	1	1.2	1.9	0.40	1.5	0.087	6.5
Printed circuit, SMD		up to 2000 connections	0	0	0	0	0	1.2	0.8	0	1	4.1	1.9	1.4	1.5	0.30	6.5
		> 2000 connections	0	0	0	0	0	4.9	0.8	0	1	16	1.9	5.5	1.5	1.2	6.5
Hard disk		EIDE	0	0	0	0	0	0	0	0	1	0	1	230	1.5	0	5.0
		SCSI	0	0	0	0	0	0	0	0	1	0	1	110	1.5	0	5.0
LCD screen (Class III)	STN	up to 14"	0	0	0	0	0	0	0	0	1	0	1	3520	1.5	0	1.8
		from 14" to 20"	0	0	0	0	0	0	0	0	1	0	1	5697	1.5	0	1.8
	TFT		0	0	0	0	0	0	0	0	1	0	1	1346	1.5	0	2.4
		larger than 20"	0	0	0	0	0	0	0	0	1	0	1	2156	1.5	0	2.4

		OFF phases: Average parameters by default by item type															Induced
		Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
		λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
CRT screen	**Up to 20"**	0	0	0	0	0	64	0.8	0	1	526	1.9	263	1.5	0	3.2
	larger than 20"	0	0	0	0	0	269	0.8	0	1	796	1.9	401	1.5	0	3.2
AC/DC voltage converter	**Up to 500W**	0	0	0	0	0	7.1	0.6	0	1	112	2.5	23	1.5	0	5.9
	More than 500W	0	0	0	0	0	8.2	0.6	0	1	207	2.5	26	1.5	0	5.9
DC/DC voltage converter	**Up to 50W**	0	0	0	0	0	2.0	0.6	0	1	27	2.5	6.4	1.5	0	5.9
	More than 50W	0	0	0	0	0	3.7	0.6	0	1	68	2.5	12	1.5	0	5.9

SMD: Surface Mounted Device
TH: Through Hole
ECU = Electrical, Chemical, Wear

Families **Count: Parameters**

Parameters associated with ON phases for families count prediction

			ON phases: Average parameters by default by item family															Induced
			Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
			λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
Digital and memory integrated circuit	**≤ 84 p**	**Hermetic**	0.038	0.7	20	7	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		Non Hermetic	0.038	0.7	20	7	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
	> 84 p	**Hermetic**	0.038	0.7	20	14	0	0	0	0.016	4	0.3	1.9	0.011	1.5	0	6.3
		Non Hermetic	0.038	0.7	20	14	0	0	0	0.016	4	0.3	1.9	0.011	1.5	0	6.3
Other integrated circuit	**≤ 84 p**	**Hermetic**	0.11	0.7	20	14	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		Non Hermetic	0.11	0.7	20	14	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
	> 84 p	**Hermetic**	0.11	0.7	20	28	0	0	0	0.016	4	0.3	1.9	0.011	1.5	0	6.3
		Non Hermetic	0.11	0.7	20	28	0	0	0	0.016	4	0.3	1.9	0.011	1.5	0	6.3
Diode	**Non Hermetic**	**Low power**	0.0075	0.7	20	10	0	0	0	0.00095	4	0.0047	1.9	0.000095	1.5	0	5.2
		power	0.15	0.7	20	43	0	0	0	0.0036	4	0.018	1.9	0.00036	1.5	0	5.2
	Hermetic		0.079	0.7	20	27	0	0	0	0.0090	4	0.045	1.9	0.00090	1.5	0	5.2
Transistor	**Non hermetic**	**Low power**	0.014	0.7	20	10	0	0	0	0.00095	4	0.0047	1.9	0.000095	1.5	0	5.2
		power	0.034	0.7	20	43	0	0	0	0.0036	4	0.018	1.9	0.00036	1.5	0	5.2
	Hermetic		0.024	0.7	20	27	0	0	0	0.0090	4	0.045	1.9	0.00090	1.5	0	5.2
Optocoupler with Photodiode	**Non hermetic**	**Low power**	0.05	0.7	20	7	0	0	0	0.00095	4	0.0147	1.9	0.0051	1.5	0	5.2
		power	0.05	0.7	20	29	0	0	0	0.0036	4	0.028	1.9	0.0054	1.5	0	5.2
	Hermetic		0.05	0.7	20	18	0	0	0	0.0090	4	0.055	1.9	0.0059	1.5	0	5.2
Optocoupler with Phototransistor	**Non hermetic**	**Low power**	0.11	0.7	20	7	0	0	0	0.00095	4	0.0257	1.9	0.011	1.5	0	5.2
		power	0.11	0.7	20	29	0	0	0	0.0036	4	0.039	1.9	0.011	1.5	0	5.2
	Hermetic		0.11	0.7	20	18	0	0	0	0.0090	4	0.066	1.9	0.012	1.5	0	5.2
Potentiometer			0.13	0.15	20	33	0	0	0	0	1	0.11	1.9	0.066	1.5	0	2.5
Resistor			0.012	0.15	20	39	0	0	0	0	1	0.22	1.9	0.0059	1.5	0	3.6
Resistive network, Resistive chip			0.00021	0.15	20	7	0	0	0	0	1	0.02	1.9	0.00021	1.5	0	4.5
Ceramic capacitor			0.083	0.1	20	0	0	0	0	0	1	0.04726	1.9	0.0044	1.5	0	6.1
Aluminium capacitor			0.26	0.4	20	0	0	0	0	0	1	0.0427	1.9	0.0031	1.5	0	6.4

			ON phases: Average parameters by default by item family														Induced
			Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
			λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
Tantalum capacitor			0.43	0.15	20	0	0	0	0	0	1	0.0382333	1.9	0.032	1.5	0	7.0
Inductor			0.013	0.15	20	17	0	0	0	0	1	0.024	1.9	0.0043	1.5	0	5.5
Transformer			0.019	0.15	20	20	0	0	0	0	1	0.13	1.9	0.036	1.5	0	6.9
Quartz resonator			0.179	0	20	0	0	0	0	0	1	0.42	1.9	0.170	1.5	0	4.6
Quartz oscillator			1.7	0	20	0	0	0	0	0	1	0.8	1.9	0.17	1.5	0	8.1
Relay	**Resistive load**	**< 3 actuations/h**	4.4	0.25	40	57	0.024	0.22	0.9	0	1	0.17	1.9	1.3	1.5	0.20	7.55
		≥ 3 actuations/h	44	0.25	40	57	0.024	0.22	0.9	0	1	0.17	1.9	13	1.5	2.0	7.55
	Non-resistive load	**< 3 actuations/h**	4.4	0.25	40	57	0.024	0.22	0.9	0	1	0.17	1.9	1.3	1.5	4.1	7.55
		≥ 3 actuations/h	44	0.25	40	57	0.024	0.22	0.9	0	1	0.17	1.9	13	1.5	41	7.55
Push button, Switch, Inver. (< 4 pins)			0.45	0.25	40	52	0.024	0.070	0.9	0	1	0.041	1.9	0.32	1.5	0.31	7.45
DIP, Encoder wheel (from 4 to 10 pins)			0.88	0.25	40	52	0.024	0.14	0.9	0	1	0.081	1.9	0.63	1.5	0.61	7.45
Switch (> 10 pins)			1.9	0.25	40	52	0.024	0.30	0.9	0	1	0.18	1.9	1.4	1.5	1.3	7.45
Soldered connector (PTH or SMD)		**up to 20 contacts**	0.23	0.1	20	5	0	0.053	0.8	0	1	0.016	1.9	0.020	1.5	0.18	4.4
		from 20 to 200 contacts	0.74	0.1	20	5	0	0.17	0.8	0	1	0.051	1.9	0.064	1.5	0.55	4.4
		More than 200 contacts	1.7	0.1	20	5	0	0.37	0.8	0	1	0.11	1.9	0.14	1.5	1.2	4.4
wrapping or insertion connector		**up to 20 contacts**	0.059	0.1	20	5	0	0.013	0.8	0	1	0.004	1.9	0.0051	1.5	0.044	4.4
		from 20 to 200 contacts	0.19	0.1	20	5	0	0.042	0.8	0	1	0.013	1.9	0.016	1.5	0.14	4.4
		More than 200 contacts	0.42	0.1	20	5	0	0.093	0.8	0	1	0.029	1.9	0.036	1.5	0.31	4.4
Printed circuit, PTH		**up to 2000 connections**	0	0	40	0	0	0.090	0.8	0	1	0.3	1.9	0.10	1.5	0.022	6.5
		> 2000 connections	0	0	40	0	0	0.36	0.8	0	1	1.2	1.9	0.40	1.5	0.087	6.5
Printed circuit, SMD		**up to 2000 connections**	0	0	40	0	0	1.2	0.8	0	1	4.1	1.9	1.4	1.5	0.30	6.5
		> 2000 connections	0	0	40	0	0	4.9	0.8	0	1	16	1.9	5.5	1.5	1.2	6.5
Hard disk			5.5	0.785	20	0	0	0	0	0	1	0	1	170	1.5	510	5.0
LCD screen (Class III)		**STN**	581	0.5	20	0	0	0	0	0	1	0	1	4610	1.5	1167	1.8
		TFT	195	0.5	20	0	0	0	0	0	1	0	1	1750	1.5	1167	1.8
CRT screen			65	0.35	20	0	0	170	0.8	0	1	663	1.9	332	1.5	2858	3.2
AC/DC voltage converter			110	0.44	20	0	0	0	0	0	1	160	2.5	25	1.5	0	5.9
DC/DC voltage converter			33	0.44	20	0	0	0	0	0	1	48	2.5	9	1.5	0	5.9

Parameters associated with OFF phases for families count prediction

			Phases OFF: Average parameters by default by component family														Induced
			Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
			λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
Digital and memory printed circuit	**≤ 84 p**	**Hermetic**	0	0	0	0	0	0	0	0.004	4	0.041	1.9	0.0012	1.5	0	6.3
		Non Hermetic	0	0	0	0	0	0.031	0.9	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
	> 84 p	**Hermetic**	0	0	0	0	0	0	0	0.016	4	0.3	1.9	0.011	1.5	0	6.3
		Non Hermetic	0	0	0	0	0	0.17	0.9	0.016	4	0.3	1.9	0.011	1.5	0	6.3
Other integrated circuit	**≤ 84 p**	**Hermetic**	0	0	0	0	0	0	0	0.0044	4	0.041	1.9	0.0012	1.5	0	6.3
		Non Hermetic	0	0	0	0	0	0.031	0.9	0.004	4	0.041	1.9	0.0012	1.5	0	6.3
	> 84 p	**Hermetic**	0	0	0	0	0	0	0	0.016	4	0.3	1.9	0.011	1.5	0	6.3
		Non hermetic	0	0	0	0	0	0.17	0.9	0.016	4	0.3	1.9	0.011	1.5	0	6.3
Diode	**Non hermetic**	**Low power**	0	0	0	0	0	0.021	0.9	0.00095	4	0.0047	1.9	0.000095	1.5	0	5.2
		power	0	0	0	0	0	0.046	0.9	0.0036	4	0.018	1.9	0.00036	1.5	0	5.2
	Hermetic		0	0	0	0	0	0	0	0.009	4	0.045	1.9	0.0009	1.5	0	5.2
Transistor	**Non hermetic**	**Low power**	0	0	0	0	0	0.021	0.9	0.0010	4	0.0047	1.9	0.00010	1.5	0	5.2
		power	0	0	0	0	0	0.046	0.9	0.0036	4	0.018	1.9	0.00036	1.5	0	5.2
	Hermetic		0	0	0	0	0	0	0	0.009	4	0.045	1.9	0.0009	1.5	0	5.2
Optocoupler with Photodiode	**Non hermetic**	**Low power**	0	0	0	0	0	0.021	0.9	0.00095	4	0.0147	1.9	0.0051	1.5	0	5.2
		power	0	0	0	0	0	0.046	0.9	0.0036	4	0.028	1.9	0.0054	1.5	0	5.2
	Hermetic		0	0	0	0	0	0	0	0.009	4	0.055	1.9	0.0059	1.5	0	5.2
Optocoupler with Phototransistor	**Non hermetic**	**Low power**	0	0	0	0	0	0.021	0.9	0.0010	4	0.0257	1.9	0.011	1.5	0	5.2
		power	0	0	0	0	0	0.046	0.9	0.0036	4	0.039	1.9	0.011	1.5	0	5.2
	Hermetic		0	0	0	0	0	0	0	0.009	4	0.066	1.9	0.012	1.5	0	5.2
Potentiometer			0	0	0	0	0	0.003	0.9	0	1	0.11	1.9	0.066	1.5	0	2.5
Resistor			0	0	0	0	0	0.028	0.9	0	1	0.22	1.9	0.0059	1.5	0	3.6
Resistive network, Resistive chip			0	0	0	0	0	0.00021	0.9	0	1	0.02	1.9	0.0002	1.5	0	4.5
Ceramic capacitor			0	0	0	0	0	0	0	0	1	0.0472609	1.9	0.0044	1.5	0	6.1
Aluminium capacitor			0	0	0	0	0	0	0	0	1	0.0427	1.9	0.0031	1.5	0	6.4
Tantalum capacitor			0	0	0	0	0	0	0	0	1	0.0382333	1.9	0.032	1.5	0	7
Inductor			0	0	0	0	0	0	0	0	1	0.024	1.9	0.0043	1.5	0	5.5
Transformer			0	0	0	0	0	0	0	0	1	0.13	1.9	0.036	1.5	0	6.9

			Phases OFF: Average parameters by default by component family														Induced
			Thermal					Humidity		Temperature cycling				Mechanical		El.Ch.W	Csensitivity
			λTh	Ea_Th	To	ΔT	α	λRh	Ea_Rh	λTcy_B	m_B	λTcy_JB	m_JB	λM	n	λECU	
Quartz resonator			0	0	0	0	0	0.085	0.9	0	1	0.42	1.9	0.170	1.5	0	4.6
Quartz oscillator			0	0	0	0	0	0.17	0.9	0	1	0.8	1.9	0.17	1.5	0	8.1
Relay	Resistive load	< 3 actuations/h	0	0	0	0	0	0.22	0.9	0	1	0.17	1.9	1.3	1.5	0	7.55
		≥ 3 actuations/h	0	0	0	0	0	0.22	0.9	0	1	0.17	1.9	13	1.5	0	7.55
	Non resistive load	< 3 actuations/h	0	0	0	0	0	0.22	0.9	0	1	0.17	1.9	1.3	1.5	0	7.55
		≥ 3 actuations/h	0	0	0	0	0	0.22	0.9	0	1	0.17	1.9	13	1.5	0	7.55
Push button, Switch, Inver. (< 4 pins)			0	0	0	0	0	0.070	0.9	0	1	0.041	1.9	0.32	1.5	0	7.45
DIP, Encoder wheel (from 4 to 10 pins)			0	0	0	0	0	0.14	0.9	0	1	0.081	1.9	0.63	1.5	0	7.45
Switch (> 10 pins)			0	0	0	0	0	0.30	0.9	0	1	0.18	1.9	1.4	1.5	0	7.45
Soldered connector (PTH or SMD)		up to 20 contacts	0	0	0	0	0	0.053	0.8	0	1	0.016	1.9	0.020	1.5	0.18	4.4
		from 20 to 200 contacts	0	0	0	0	0	0.17	0.8	0	1	0.051	1.9	0.064	1.5	0.55	4.4
		More than 200 contacts	0	0	0	0	0	0.37	0.8	0	1	0.11	1.9	0.14	1.5	1.2	4.4
Wrapping or insertion connector		up to 20 contacts	0	0	0	0	0	0.013	0.8	0	1	0.004	1.9	0.0051	1.5	0.044	4.4
		from 20 to 200 contacts	0	0	0	0	0	0.042	0.8	0	1	0.013	1.9	0.016	1.5	0.14	4.4
		More than 200 contacts	0	0	0	0	0	0.093	0.8	0	1	0.029	1.9	0.036	1.5	0.31	4.4
Printed circuit, PTH		up to 2000 connections	0	0	0	0	0	0.090	0.8	0	1	0.3	1.9	0.10	1.5	0.022	6.5
		> 2000 connections	0	0	0	0	0	0.36	0.8	0	1	1.2	1.9	0.40	1.5	0.087	6.5
Printed circuit, SMD		up to 2000 connections	0	0	0	0	0	1.2	0.8	0	1	4.1	1.9	1.4	1.5	0.30	6.5
		> 2000 connections	0	0	0	0	0	4.9	0.8	0	1	16	1.9	5.5	1.5	1.2	6.5
Hard disk			0	0	0	0	0	0	0	0	1	0	1	174	1.5	0	5.0
LCD screen (Class III)		STN	0	0	0	0	0	0	0	0	1	0	1	4610	1.5	0	1.8
		TFT	0	0	0	0	0	0	0	0	1	0	1	1750	1.5	0	2.4
CRT screen			0	0	0	0	0	167	0.8	0	1	663	1.9	332	1.5	0	3.15
AC/DC voltage converter			0	0	0	0	0	7.6	0.6	0	1	160	2.5	25	1.5	0	5.9
DC/DC voltage converter			0	0	0	0	0	2.9	0.6	0	1	48	2.5	9	1.5	0	5.9

SMD: Surface Mounted Device
TH: Through Hole
ECU = Electrical, Chemical, Wear

Handling the transition to lead-free

Warning:

Rigorous reliability models based on the physics of failures cannot be produced on the date of publication of this guide, considering the state-of-the-art of the physics of failures and the short period during which lead-free assemblies have been used industrially. However, this chapter in the guide does propose an approach for the reliability assessment of electronic products with lead-free assemblies. Therefore, these results should be used with caution.

Consequences on reliability

The transition to lead-free assembly technologies can affect the reliability of systems due, firstly to the modification of manufacturing processes and materials, and secondly to a change in the acceleration of some failure mechanisms.

Variation of the physics of failures for lead-free assemblies

Fatigue mechanisms of solder connections between lead-free assemblies and tin-lead assemblies satisfy a priori different acceleration laws. The existing models in the FIDES Guide are based on the physics of failures of tin-lead solder assemblies. Therefore, the laws used to calculate acceleration factors applicable to thermo-mechanical and mechanical environments of lead-free solder assemblies should be modified accordingly.

It is also possible that sensitivity to different environments is modified for some component families, due to the probable change in the level of residual stress in lead-free solder assemblies induced by the increase in the solidification temperature, the reduction in stress relaxation at ambient temperature and the increased stiffness of solder joints. Therefore, basic failure rates and distributions of physical contributing factors of assembled lead-free solder components could also be modified and become different from values for assembled tin-lead solder components.

All these adaptations will only be possible when models validated by the scientific and industrial community become available. This is not available at the time of publication of this guide. It has not yet been formally demonstrated that the models described in this guide are applicable to the case of lead-free solder assemblies, and models will eventually have to be modified.

Despite these restrictions, this guide suggests that all proposed models should be applied in the same way, regardless of whether the assembly is lead-free or contains lead.

Variation of the risk of failure related to modifications to the component manufacturing process

Any variation of the risk of failure related to modifications to components (including PCBs) must be taken into account in the item manufacturing factor Π_{PM}, or in λ_0 values. In some cases, for components with plastic encapsulation supplied by major component manufacturers, the transition to lead-free has not induced any significant modification to the risk of failure. The most probable reason is that the modification to resins (embedding and glue) made to improve connectability by the increase in reflow profiles, will tend to improve the reliability of the case (lower sensitivity to humidity, and probably better bond of resins).

In other cases for manufacturing of low volume components, modifications to processes or materials will at best be technologically validated by tests on a limited number of parts that will not be capable of demonstrating dispersion of processes.

Consequently, the risk of increasing the failure rate, particularly due to process changes, is not considered more important than for any other change, and the criteria taken into account in the evaluation of Π_{PM} are sufficient to characterise it.

Variation of the risk related to changes in board manufacturing process

It is considered that any variation of the risk of failure related to modifications to the design and manufacturing of boards for the transition to lead-free can have a significant influence on the reliability of systems.

A change to manufacturing processes could create an isolated increase in failures related to lack of control over new processes. A modification to materials and processes resulting from the increase in the solder reflow temperature (an increase of about 35°C in the melting temperature of the solder alloy), has been subjected to a number of validations, with a varying extent. But it is highly probable that anomalies will occur despite these validations, for example due to unanticipated incompatibilities between processes and materials, poor knowledge of new equipment and processes by operators, or the co-existence of 2 processes (backward and full lead-free), etc.

The occasional increased in the risk of failure related to process changes alone will be taken into account by the introduction of a Π_{LF} (LF for Lead-free) factor, taking account of experience in design and manufacturing of lead-free electronic assemblies.

This factor represents the increase in the failure rate of the system related to the lead-free process. It will change over time as follows:

- The factor is equal to 1 as long as series manufacturing is carried out using the "controlled" tin-lead process.
- The factor becomes greater than 1 at the time of the transition and then reduces with time and experience.
- It returns to 1 when the lead-free process has become mature.

The model for estimating the Π_{LF} factor is given below.

Lead-free process factor

Model general form

The failure rate for a classical tin-lead solder process is calculated as follows:

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$

The failure rate for a lead-free process is calculated as follows:

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}} \times \Pi_{\text{LF}}$

Where Π_{LF} is the transition factor to the lead-free process.

$$\Pi_{\text{LF}} = 1 + \left(1 + 12 \times \text{LF\_grade} + C_Q \times Y\right)^{\frac{-1}{(3.1 - 2 \times \text{LF\_grade})}}$$

Where:

- Y (in years) is the number of complete years of effective production with a lead-free process. The factor Y must only be set equal to integer values (therefore the first year Y = 0).
- LF_grade is a process factor that measures the effort made to prevent defects related to the transition to lead-free processes. LF_grade varies from 0 (no precaution) to 1 (maximum precaution).
- C_Q is a factor that depends on the production quantity using a lead-free process.

The Π_{LF} factor varies from 1 (for a mature process) to 2 (for a process for which no precautions were taken). When the Π_{LF} factor becomes less than 1.1, there is no longer any need to take it into account.

Determination of the LF_grade factor

The LF_grade factor is determined using a questionnaire on lead-free processes.

$$\mathrm{LF\_grade} = \frac{\sum \text{Weight of satisfied criteria}}{\sum \text{Weight of applicable criteria}}$$

No.	Category	Criterion	Weight (if criterion satisfied)
1	Development	The LF status is identified in the components database.	8
2	Development	Compatibility of the component with the SnPb assembly process or with the lead-free process is identified in the components database.	8
3	Development	Compatibility between component finishes and lead-free or SnPb processes is defined in specific design documents. (this criterion is exclusive of the previous criterion)	4
4	Development	The lead-free status is clearly identified and taken into account in the design process.	8
5	Procurement, logistics, storage	Traceability: adapted labelling for identification of lead-free or ROHS components for the entire logistics chain.	10
6	Procurement, logistics, storage	Lead or lead-free components are clearly identified in the production database.	3
7	Procurement, logistics, storage	The need for lead or lead-free components is clearly identified in the order, with a request for particular marking on the delivery.	5
8	Procurement, logistics, storage	Lead or lead-free components are clearly identified at reception.	5
9	Procurement, logistics, storage	In storage, there is a physical separation between components used for the lead-free process and components used for the lead process.	5
10	Procurement, logistics, storage	Compatibility with the lead-free process is taken into account in the definition of component storage conditions (solderability).	4
11	Assembly process	The lead-free assembly status is clearly identified in the production file.	3
12	Assembly process	The lead-free series process is formally qualified (verification of the integrity of components and PCB after connection and metallurgical analysis)	20
13	Assembly process	The lead-free repair process is formally qualified (verification of the integrity of components and PCB after repair and metallurgical analysis)	20
14	Assembly process	One line is dedicated to each series process: lead and lead-free	8
15	Assembly process	One line is dedicated to each repair process: lead and lead-free	8
16	Assembly process	The lead-free or lead technology is marked unambiguously on the board	8

No.	Category	Criterion	Weight (if criterion satisfied)
17	Assembly process	Operators have received appropriate training on the lead-free aspect (new processes, compatibility, solder joint aspect, wiring, inspection, repair, etc.).	16
18	Reliability	The equipment manufacturer has carried out internal or outsourced studies concerning modelling of the reliability or the life of lead-free assemblies.	8
19	Reliability	The equipment manufacturer has carried out internal or external studies on qualification test conditions for lead-free boards or equipment.	8
20	Reliability	The equipment manufacturer has carried out internal or external tests concerning burning in of lead-free boards or equipment.	6
21	Reliability	The JEDEC JESD201 standard or equivalent care must be taken to avoid tin whiskers	5

Note:

- In the general case, the sum of the applicable criteria is 166.
- Criterion 3 is included in criterion 2, and only one of these two criteria must be counted as being satisfied at any one time (this is why the weight of criterion 3 is not included in the applicable total).
- The fact that a single component changes reference when it is modified to become lead-free is a sufficient identification (criteria 7 and 8).
- When lead-free processes do not cohabit with tin-lead processes, in other words there is no tin-lead manufacturing line and all procured components are actually lead-free, criteria 1, 2, 3, 4, 5, 6, 7, 8, 9, 14, 15, and 16 may be considered as being satisfied.
- Criteria 13 and 15 are not applicable for irreparable products. The sum of applicable criteria then becomes 138.

Determination of the factor C_Q

Accumulated number of components connected per week using the lead-free process	Series type	C_Q
Weekly quantity <100000	Small series	4
100000 ≤ Weekly quantity < 500000	Medium series	12
500000 ≤ Weekly quantity < 2000000	Large series	36
Weekly quantity ≥ 2000000	Very large series	108

IV
Guide for control and audit of the reliability process

1. Life cycle

The following table gives details of the complete life cycle followed by a product and that is used to determine its reliability. The FIDES methodology covers the evaluation and control of reliability throughout this life cycle.

Phase		Main activities	
1	SPECIFICATION	1.1	Expression of the need by the customer
		1.2	Formal definition of system requirements
		1.3	Definition of the architecture
		1.4	Allocation of system requirements
		1.5	Formal definition of subsystem, equipment requirements..
2	DESIGN	2.1	Feasibility / Preliminary studies
		2.2	Detailed design
		2.3	Tests and debugging
		2.4	Qualification
		2.5	Preparation for production / Industrialisation
		2.6	Preparation for Logistics Support
3	MANUFACTURING BOARD OR SUBASSEMBLY	3.1	Reception / Entry inspection
		3.2	Storage
		3.3	Assembly of board or subassemblies
		3.4	Tests (board or subassemblies)
		3.5	Integration into equipment
		3.6	Burning in (board or subassembly)
		3.7	Acceptance
		3.8	Delivery of board or subassembly
4	INTEGRATION INTO EQUIPMENT	4.1	Reception / Entry inspection
		4.2	Storage
		4.3	Equipment assembly
		4.4	Equipment tests
		4.5	Burning in (Equipment)
		4.6	Equipment acceptance
		4.7	Equipment delivery
5	INTEGRATION INTO SYSTEM	5.1	Reception / Entry inspection
		5.2	Storage
		5.3	System assembly
		5.4	System tests
		5.5	Burning in (System)
		5.6	System acceptance
		5.7	System delivery
6	OPERATION & MAINTENANCE	6.1	Transfer to the user
		6.2	Operational use
		6.3	Keeping in Operational Condition
7	SUPPORT ACTIVITIES	7.1	Management of subcontractors
		7.2	Management of reliability, procurements, incidents
		7.3	Management of the quality system, resources

2. The process factor

The process factor is denoted Π_{process} in the evaluation part of the guide.
Quantification is done in response to questionnaires about the development, manufacturing and operating process for the product. The audit guide formally describes the approach used to answer these questionnaires.

3. Trade recommendations – Reliability control

A set of recommendations about reliability is presented during each phase or activity in the life cycle.
Recommendations are either global and potentially able to affect all phases (they are then associated with the "Support activities" phase), or they are precise and recognised as affecting reliability during specific activities in one or several phases of the life cycle.

Taking these recommendations into consideration allows setting up reliability control actions (Reliability Engineering) and an evaluation of the reliability assurance level for each phase in the process. The reliability control approach consists of using a first evaluation result to modify activities that affect this result.

Recommendations in the Reliability Process guide are applicable mainly to procedures and the organisation throughout the life cycle. The purpose of the Reliability Process guide is not to give technological recommendations about the use of components, boards or subassemblies in electronic equipment.

4. Calculating the process factor $\Pi_{Process}$

$\Pi_{process}$ is based on a mark (***Process_Grade***) that represents the quality of the process, that is determined following an audit on the different phases of the life cycle.

4.1. Relative influence of phases in the life cycle

The 7 phases in the life cycle are as follows:

- Specification.
- Design.
- Manufacturing of the board or subassembly.
- Integration into equipment.
- Integration into the system.
- Operation and maintenance.
- Support Activities.

Each of these phases has a specific impact on the reliability. For quantification, each phase is assigned a scale factor so as to determine the relative weight of each phase. If the distribution specific to the audited manufacturer is already known, it can be taken into account.

The default distribution is as follows:

PHASE	Phase contribution %
Specification	8
Design	16
Manufacturing of board or subassembly	20
Integration into equipment	10
Integration into the system	10
Operation and maintenance	18
Support Activities	18
Total:	100

4.2. Recommendation satisfaction level

The audit is done by phase and evaluates the manner in which these activities are carried out by asking questions (about these recommendations).
The responses and demonstrations made by the audited person will be used to fix a **Satisfaction_*mark,*** to the recommendation (level N1 to N4):

- N1 = the recommendation is not applied → definite risks regarding reliability,
- N2 = the recommendation is only partially applied → potential risks regarding reliability,
- N3 = the recommendation is practically applied → few risks regarding reliability,
- N4 = the recommendation is fully applied → no significant risk regarding reliability.

The mark for each level is determined as follows:

Level	Mark
N1	0
N2	1
N3	2
N4	3

Each recommendation is weighted by a specific ***Recom_Weight***; for example:

- 1 → the recommendation associated with the question has little impact on reliability,
- 10 or more → the recommendation associated with the question has a strong impact on reliability.

The attached application tables give the list of recommendations for each phase (with the associated audit question) with the ***Recom_Weight*** specific to each recommendation. There is also a datasheet for each recommendation containing a precise description of it, and satisfaction criteria for each of the four satisfaction levels.

4.3. Calibration

The purpose of this step is to neutralise questions about activities that are not relevant for the product/process considered (these questions are said to be "non-applicable").

Therefore the first calculation step consists of producing the ***Max_Audit_Mark**$_j$* for each phase j.

The ***Max_Audit_Mark**$_j$* corresponds to a "perfect" audit, in which the satisfaction level is N4 for all selected questions.

Thus, for each recommendation i:

$$Max\_Weighted\_Points_i = Recom\_Weight_i \times 3$$

***Max_Audit_Mark**$_j$* is then calculated by summating values of ***Max_Weighted_Point**$_i$* on all recommendations applicable for the product/process considered (i=1 to n) for the complete phase j:

$$\text{Max\_Audit\_Mark}_j = \sum_{i=1}^{n} \text{Max\_Weighted\_Points}_i$$

4.4. Calculating the audit mark

This step consists of performing the FIDES audit itself with persons concerned in the different phases of the process, and defining the satisfaction level as a function of the proof provided. The approach to be applied is proposed in the Audit Guide chapter.

The work should be done in phases, answering each question i; the level of satisfaction to the question, marked **0**, **1**, **2** or **3,** multiplied by the weight of the recommendation, gives the ***Weighted_Points$_i$*** acquired for the question:

$$Weighted\_Points_i = Recom\_Weight_i \times Satisfaction\_Mark\ (0, 1, 2, 3)_{ij}$$

The ***audit_mark*** for phase j is equal to the sum of all ***Weighted_Points*** for recommendations i selected for the phase concerned:

$$\text{Audit\_Mark}_j = \sum_{i=1}^{n} \text{Weighted\_Points}_i$$

4.5. Calculating the process factor

The formula for the process factor is as follows:

$$\Pi_{\text{Process}} = e^{\delta_2 (1 - \text{Process\_Grade})}$$

The factor δ_2 fixes the variation range of the process factor. It was fixed at **2.079**, which gives a range of 1 to 8 for the process factor.

The ***Process_grade*** is calculated from ***Audit_Marks*** per phase, calculated previously and weighted by the **Contribution_Phase** for each phase such that:

$$\text{Process\_Grade} = \sum_{j=1}^{7} \left(\text{Contribution\_Phase}_j \times \frac{\text{Audit\_Mark}_j}{\text{Max\_Audit\_Mark}_j} \right)$$

The ***Process_grade*** will be a value between 0 and 1:

- **0** represents a process for which all audit questions are answered unsatisfactorily;

$$\rightarrow \Pi_{\text{Process}} = 8$$

- **1** represents a "perfect" process, for which all audit questions are answered satisfactorily;

$$\rightarrow \Pi_{\text{Process}} = 1$$

Note: a Process_Grade$_j$ specific to each phase j can be evaluated so as to determine the level of the phase:

$$\text{Process\_Grade}_j = \frac{\text{Audit\_Mark}_j}{\text{Max\_Audit\_Mark}_j}$$

5. Audit guide

This guide is used to make an audit on a company. Therefore, the audit approach is generic, so as to provide a certain degree of independence from the company.

The FIDES methodology identifies a list of recommendations which, if followed, will facilitate construction of a product reliability. This set of recommendations has been broken down into a set of questions.

The answers that a company gives to these questions provides:
- a measurement of its ability to make reliable products,
- a quantification of the process factors used in the calculation models,
- the possibility of identifying improvement actions.

5.1. Audit procedure

To control an audit, the auditor must:
- Identify the audit scope.
- Prepare the audit.
- Perform the audit.
- Collect proofs.
- Process the collected information.
- Draw conclusions.
- Write an audit report.
- Present the audit result.

5.2. Identify the audit scope

5.2.1. Identify the product being audited

Initially, it is important to identify exactly what product is to be audited.
Audit recommendations for the different phases of the life cycle must be oriented and adapted as a function of the product considered.

5.2.2. Selection of applicable phases

Concepts of integration into equipment and integration into system may be considered together for some products (equipment used alone, for example a radio station). In this case, we will only select the value for whichever of the two phases is most representative, and the weight of the two phases will be assigned to it.

For example:

PHASE	Phase contribution %
Specification	8
Design	16
Manufacturing of board or subassembly	20
Integration into equipment	*20 (instead of 10)*
Integration into system	*0 (instead of 10)*
Operation and maintenance	18
Support activities	18
Total:	100

In general, this contributions table will be adapted to cancel out the contribution of a phase that would not be at all applicable for a given product.
Warning: With this approach, it is important not to consider that a phase is "not applicable" just because someone other than the manufacturer who initiates the audit is responsible for it. For example, if a contractor has not given any commitment about operation and maintenance of products that he sells, this life phase very probably exists even so.

5.2.3. Taking account of the industrial breakdown

For an industrial breakdown, the life cycle is distributed into different organisations. For example, a single product may be specified by a project manager, designed at an equipment manufacturer, made at a subcontractor before being integrated and operated by a final manufacturer.

The important thing then is to evaluate the Π_{Process} factor, taking account of the process of each manufacturer concerned for the life cycle phases for which he is responsible.
When there is an industrial breakdown, it frequently happens that a single phase in the FIDES life cycle is shared between several manufacturers. For example, the specification activity can begin at system level and continue at equipment level and then subassembly level. In general, this is also the case for the "Support activities" part of the FIDES life cycle. In this case, the **Process_grade** factor of shared phases for

each manufacturer concerned needs to be evaluated, and the lowest mark should be used for the final calculation of $\Pi_{Process}$. Therefore, the selected $\Pi_{Process}$ will be the "worst case" (lowest mark). This is not a conservative approach; it is the weak link in the chain that is preponderant, therefore it is essential to take account of the worst observed practices, like in a quality audit.

If a phase in the life cycle cannot be evaluated, the $\Pi_{Process}$ factor can be calculated using a default value of Process_grade for the phase concerned. The default value of Process_grade is 0.33.

For manufacturers of COTS products (boards or equipment) who would like to publish reliability information on their products, it is recommended that the $\Pi_{Process}$ factor used in their evaluation should be specified, although a large part of the life cycle will have to be quantified by default in this case.

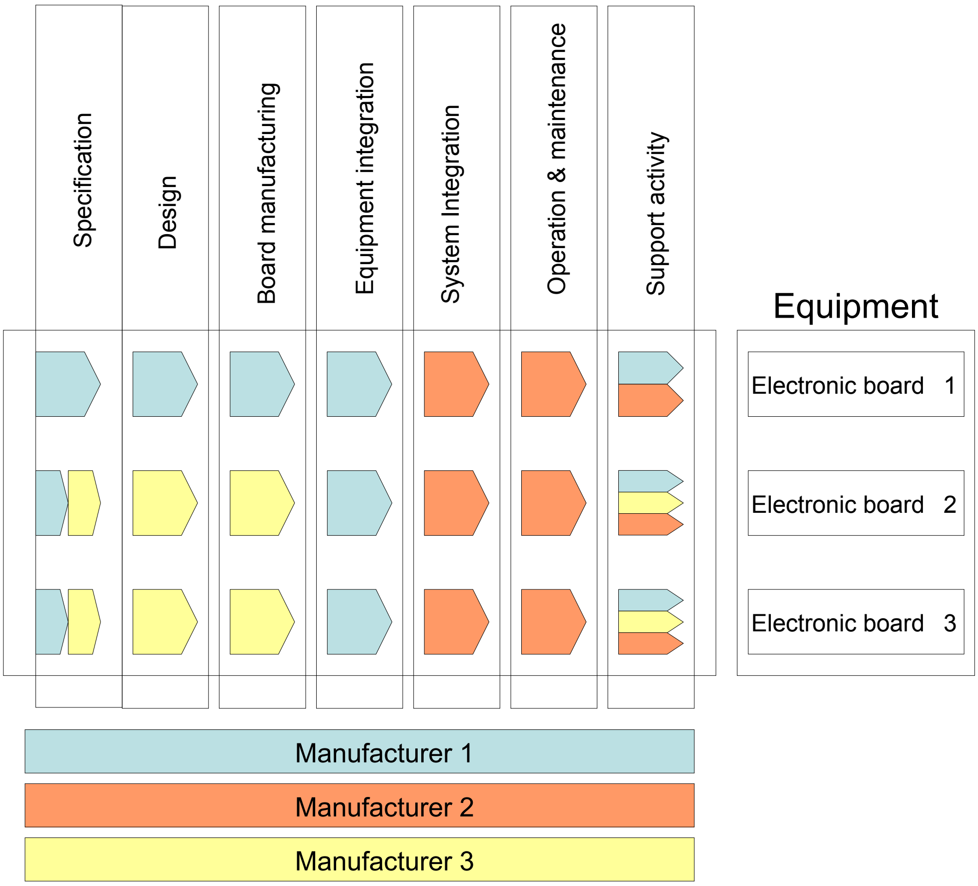
5.2.4. Large number of life cycles for a single product

If the product is a piece of equipment, it may be composed of boards or subassemblies that have not all followed the same life cycle. In this case the $\Pi_{Process}$ factor must be evaluated for each board or subassembly.

5.2.5. Example industrial breakdown

In the example shown on the diagram given below, three manufacturers contribute to defining and producing equipment composed of three electronic boards and integrated into a system.

In this breakdown, a first manufacturer is responsible for the development and manufacturing of the equipment, and a second manufacturer is responsible for its integration into the system and its operation. The first manufacturer subcontracts the design and manufacturing of two electronic boards to a third manufacturer.



For electronic board 1:
The process_grade of manufacturer 1 must be used for the "specification", "design", "board manufacturing" and "integration into equipment" phases of the life cycle. The process_grade of manufacturer 2 must be used for the "integration into system" and "operation and maintenance" phases. The worst of the two process_grade values for manufacturers 1 and 2 should be used for the "support activity" phase.

For electronic boards 2 and 3:
The worst of the two process_grade values for manufacturers 1 and 3 should be used for the "specification" phase, which is assumed to be distributed between the two. The process_grade of manufacturer 2 must be used for the "design" and "board manufacturing" phases of the life cycle. The process_grade of manufacturer 1 must be used for the "integration into equipment" phase. The process_grade of manufacturer 2 must be used for the "integration into system" and "operation and maintenance" phases. The worst of the three process_grade values among manufacturers 1, 2 and 3 must be used for the "support activity" phase.

Therefore in this example, the evaluation of the complete equipment reliability should be based on an audit of the three manufacturers (none being audited over the entire FIDES life cycle). The quantitative calculation must use two distinct Π_{Process} values, the first for electronic board 1 and the second for electronic boards 2 and 3.

5.3. Prepare the audit

The audit preparation consists of the following steps:

- Identify the scope of the audit (complete, partial, for a program applicable to certification, required information, duration, etc.).
- Identify context elements of the audit.
- Identify the right targets (FIDES targets specified in the following table).
- Identify the nature and scope of the audit.
- Produce an audit plan (planning with the milestones calendar, convening notes, preparation of data collection documents, prepare model output documents, involvement of the audit orderer and the organisation to be audited, calculate the maximum possible score for the audit considered, present the rules, etc.).
- Validate the auditor's audit plan (by the internal or external orderer of the audit and by the representative of the audited company).
- Initialise implementation of the audit plan (send convening note).
- Inform the audited party about the content of the audit in good time, knowing that if any proof is not provided, it will be assumed that there is no proof.

Obtaining good acceptance of the audit is a key point towards its success. The auditor can mention the following points in order to justify the benefits of a FIDES audit:

- Importance of the product reliability level.
  - A cost generator, a new key parameter for competition.
  - A specific objective to be achieved.
- The audit is a risk control tool, and in particular concerns:
  - the robustness of the product definition,
  - the environment of products in use,
  - actual acceptance of reliability throughout the entire life cycle.
- The FIDES audit is complementary to the ISO 9001 V2000 audit because it is more specific and more oriented towards operating dependability.
- The specific objectives in carrying out the FIDES audit:
  - Evaluation of a quantified Quality Indicator representative of the company's capability to control reliability of its products (process_grade factor or $\Pi_{Process}$).
  - Evaluation of a factor controlling reliability; calculate $\Pi_{Process}$.
  - Identification of the strengths and weaknesses of the company and formulation of targeted recommendations to improve the internal process.

5.4. Performing the audit

Performing an audit consists of:

- Presenting the audit (summary of objectives, its scope and rules). Ask questions (if applicable, ask further questions necessary to determine the actual level of the criterion reached).
- Mark the answers of audited targets for each question.
- Collect available proof immediately, so that it can be attached to the report.
- File proof collected during the audit.
- Take account of any additional proofs.

During the audit, the auditor will identify questions that are not relevant (in other words for which there is no need for process activities) if he had not already done so during the preparation: this operation will be used to recalculate the maximum score expected for the audit considered.

5.5. Processing collected information

Processing the information consists of evaluating the position of the audited entity relative to the criteria for each recommendation, using the answers given to the questions, the proofs collected to support these answers and the weightings associated with each recommendation.

The result of this processing will be used to:

- determine the reliability level to be associated with the audited entity,
- quantify the process factor (Π_{Process}) to be used,
- if applicable, identify lines of improvement for the audited entity.

5.6. Present the audit result

The auditor will present the result of the audit to the orderer and to the audited party after the audit is complete. This presentation will consider:

- the purpose of the audit,
- the audit plan & its implementation,
- the audit result,
- identified lines of improvement,
- conclusions.

The written audit report will subsequently be handed over to the orderer.

5.7. Positioning principle

The score of the audited organisation (process_grade for one or several phases and Π_{Process} for a complete life cycle) can be evaluated at the end of the audit, using answers to questions and the evaluation of answers with regard to the criteria and taking account of the weighting.

The minimum possible score applies to a process that does not satisfy any of the criteria. The FIDES methodology has not determined any rule fixing the minimum acceptable score so that the FIDES methodology is considered to be applicable. Such rules can only originate from practical use of the methodology in industry.

Depending on the position of this score (**process_grade**) relative to the maximum possible score, the audited entity may be considered to be at a "very high reliability", "high reliability", "standard" or finally "unreliable" level.

Level	Process	Π_{Process}	Process grade
Very high reliability	Process almost with no weakness	<1.7	> 75%
High reliability	Controlled process, reliability engineering	1.7 to 2.8	50% to 75%
Standard	Usual ISO 9001 version 2000 type quality procedures	2.8 to 4.8	25% to 50%
Unreliable	Reliability problems not taken into account	>4.8	<25%

5.8. Profile of audit participants

5.8.1. Profile of auditors

Auditors should:

- be engineers, executives or technicians with at least 5 years experience.
- be familiar with the ISO 9001 standard Version 2008 or 2000.
- have skills and theoretical and practical experience in reliability.
- be trained in carrying out audits.

These prerequisites will be completed by good knowledge of the FIDES methodology.

These skills can also be obtained by an audit team (typically an experienced auditor and a specialist in reliability).

5.8.2. Profile of audited parties

Audited parties can have different profiles, considering the diversity of organisations that could be audited.
However, they will be representatives of the population of the eighteen targets identified by FIDES. In a partial audit, the audited parties may be representative of a subset of these targets only.

N°	Target population	Description
1	Purchases	- Supervisors for the purchase process and documents reference system (creation, implementation). - Project buyer: responsible for negotiations about Technical Clauses / Costs and respect of commitments.
2	Design office / Design	- Analysis or production of requirement definitions, technical specifications and justification files, and traceability. - Set up the design, evaluation, approval, validation team. - Management of planning, reviews, indicators (costs, quality, etc.).
3	Customer (order giver)	- Person responsible for RAMS (Reliability, Availability, Maintainability, Safety) requirement specification and related specifications (life profiles, analysis baselines, etc.).
4	Site management	- Person responsible for management of global means on the site (design, production, industrialisation).
5	Documentation management	- Recording / archiving and viewing (providing) the archived documentation (definition files, specifications, purchase files, etc.). - Project documentation manager
6	Operation	- Person responsible for use: respect of recommendations, usage documentation, training of users. - Final users.

N°	Target population	Description
7	Industrialisation / Production / Integration: Management of methods and quality	- Traceability of products and production / industrialisation / integration files (Industrialisation Manager). - Control over the quality of services, fluids and the environment in the workplace. - Reference system (creation, implementation), inspections, etc.
8	Industrialisation / Production / Integration: Management of the site and means	- Control of inspection means (workshop supervisor). - Control of procedures and test and inspection reports.
9	Industrialisation / Production / Integration: Operational personnel	- Carrying out tests (means, planning, etc.).
10	Maintenance	- Manager of maintenance means and procedures, respect of recommendations, processing of anomalies (Keeping in Operational Condition service). - Maintenance technician.
11	Handling / Logistics	- Procedure trade and transport / handling / packaging / storage clauses.
12	Project	- Management and specification / creation of supplier or in-house clauses: - Summary of RAMS, Logistics Support, obsolescence, qualification, Quality, Handling / packaging / storage activities, etc., production, After sales service … - Risk management (technical, planning, nonconformity).
13	Quality	Description and implementation of processes: - Traceability of products in design, production, delivery and clientele. - Assure that trade and Quality reference systems are implemented and respected. - Monitoring of the treatment of anomalies or nonconformities.
14	Human resources	- Adaptation between workload / qualification / human resources and reuse of know how and experience.
15	After Sales Service, customer support	- Treatment of customer complaints and anomalies or nonconformities.
16	Components Service / Supplier qualifications / Technological monitoring / Procurement	- Reference system (creation, implementation) for inspections and qualifications (functional, technical) of purchased items.
17	Logistics support	- Project player for implementation of Support analyses. - Reference system (creation, implementation), for the Logistics Support process (description of the process, analyses and justification tests, qualification tests).
18	Operating dependability, RAMS (Reliability, Maintainability, Availability, Safety)	- Project controller for implementing the RAMS / reference system (resources, means), project monitoring (indicators, specifications, risk management, RAMS feasibility, etc) and increased awareness of other entities about RAMS. - Reference system (creation, implementation, production,).

V
Recommendations of the Reliability Process control and audit guide

1. Tables of recommendations with weightings.
2. Detailed datasheets for each recommendation.

Tables of recommendations with weightings

Specification

Number	Recommendation	Question	Weight
1	Assign resources in terms of personnel and means to reliability studies.	Is there a financing item for reliability studies? Have the necessary means and personnel been identified?	10.7
2	Allocate reliability requirements to subassemblies.	Are global reliability requirements allocated to subassemblies? What allocation method was used?	10.4
26	Completely describe the environment in which the product will be used and maintained.	Is there a description and characterisation of the environment in which the product will be stored, transported, used and maintained?	12.4
28	Define product failure.	What is considered as a product failure?	10.3
29	Define the method of demonstrating product reliability during operational phases.	How is it planned to demonstrate the product reliability?	9.8
31	Define the product life profile for which reliability performances are expected.	Is the usage profile of the product for which reliability performances are expected defined?	9.9
40	Define the context associated with the product reliability requirements.	What is the context associated with product reliability requirements?	8.1
53	Make use of feedback from operations.	Is feedback from operations used to maintain a good level of confidence in achieving reliability performances?	8.5
54	Get the Operating Dependability business to participate in the functional and organisational design of the product.	Are the reliability criteria taken into account in the architecture of the products, and design, industrialisation and support choices?	12.6
57	Quantitatively formulate the reliability requirement.	Is the reliability requirement expressed quantitatively?	8.2
62	Formally identify technical risks affecting reliability.	Have technical risks affecting the reliability been identified?	12.4
64	Identify the type of time measurement for reliability performances.	Has a type of time measurement (Hours of operation, Hours of flight, number of cycles, etc.) been identified for reliability performances?	6.6
65	Identify customer requirements.	Have customer requirements been identified, documented and traced?	7.3
103	Negotiate reliability requirements with the customer	Is the state-of-the-art of technology taken into account, and is the cost-performance of the product design optimised during negotiations of reliability requirements with the customer?	10.7
106	Organise a design review in which Reliability aspects are dealt with	Has a design review been organised in which Reliability aspects are dealt with?	10.3

Number	Recommendation	Question	Weight
107	Organise a product requirements review in which Reliability aspects will be dealt with.	Has a requirements review been organised dealing with reliability aspects?	10.3
117	Take account of the product maintenance policy (request from the customer).	How is the product maintenance policy (requested by the customer) taken into account?	5.8
122	Write a Reliability Plan	Has a Reliability Plan been written for the product?	7.6

Design

Number	Recommendation	Question	Weight
6	Ensure the completeness of information on subassemblies to establish (complete) subassemblies Test Manuals.	Are technical data for subassemblies available for development of the production test?	7.8
7	Implement corrective actions.	What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?	6.7
8	Implement prenventative actions.	Do procedures related to prenventative actions include: - The use of appropriate information sources? - Determination of appropriate steps? - Triggering of prenventative actions and application of control means? - A management review of corrective actions?	6.8
16	Make sure that a person responsible for logistics support, industrialisation, purchasing, development and RAMS (concurrent engineering) is involved at each step	Is the point of view of the different disciplines involved in engineering taken into account?	16.7
34	Have personnel qualified for test means, measurements and relevant standards.	What measures have been taken so that the person concerned is qualified for the test means, measurements and relevant standards?	5.8
36	Have a document justifying preliminary technical studies on reliability,	Is there a list of justification elements?	8
38	Assure that know-how is recorded by business procedures	Is there any management of business procedures?	13.8
39	Have and manage a table of skills required by activity, including names.	Is there any management of skills?	24.5
44	Write a collection of business recommendations dealing with manipulation and storage operations at the user, for use by Logistics Support.	Is there a collection of business recommendations for manipulation and storage operations at the customer?	7.7
48	Produce and maintain a preferred components list.	Is there a preferred components list?	8
50	Existence of a database summarising feedback from operations.	Has feedback from operations been used to improve future designs?	24.2
51	Existence of a database summarising the reliability evaluation studies.	Is there a database recording reliability evaluation studies?	10.6

Number	Recommendation	Question	Weight
52	Existence of a database on the history of definitions and definition justifications.	Is there a database on the history and definition justifications?	7.8
54	Get the Operating Dependability business to participate in the functional and organisational design of the product.	Are the reliability criteria taken into account in the architecture of the products, and design, industrialisation and support choices?	12.6
61	Identify and implement means of protecting subassemblies.	Have means of protecting subassemblies during some production activities been identified and implemented?	7.3
62	Formally identify technical risks affecting reliability.	Have technical risks affecting the reliability been identified?	21
83	Maximise test coverage based on the specification and justification.	Is there assurance that the test coverage is maximum, and that it is based on the specification? Is there a justification document?	6
86	Implement design verifications.	Are there any design verification procedures?	27.1
87	Implement a maintenance in logistics support concept.	Is there a maintenance concept?	5.4
106	Organise a design review in which Reliability aspects are dealt with	Has a design review been organised in which Reliability aspects are dealt with?	12.1
123	Write a management plan in which key skills (specialists) are identified.	Is there a reliability management plan in which key skills (specialists) are identified?	17.7
124	Write an acceptance procedure.	Is there an acceptance procedure for production tests?	7.8
130	Make sure that the analysis documentation necessary to evaluate reliability exists.	Is there any analysis documentation for evaluating the reliability?	7.5
131	Make sure that there are design rules to adapt the choice of a component for a given reliability.	Are there any design rules to adapt the choice of a component for a given reliability?	12.7
132	Make sure that there is a definition of production test points and that test recommendations are applied.	Are test points defined and are recommendations for production tests applied?	6
133	Make sure that there is a product / process qualification procedure.	Is there a qualification procedure for products and manufacturing process?	7.2
134	Make sure that there is a product/supplier qualification procedure.	Is there a product/supplier qualification procedure?	7.6
135	Make sure that there is a manufacturing qualification for the new component.	Are new components qualified before they are used?	7.2
137	Make sure that the predicted reliability calculation is made using a recognised tool (FIDES, adjusted MIL-HDBK-217, proprietary feedback from operations or other method).	Is there a tool for formally calculating the reliability? Is there a formal choice of the reliability compilation (FIDES, adjusted MIL-HDBK-217, proprietary feedback from operations or other method)?	7.7

Number	Recommendation	Question	Weight
147	Take account of the equilibrium between reliability and complexity of built-in tests.	Are choices related to test coverage documented?	10.2
150	Use of validated and recognised modelling means.	Are validated and recognised modelling means used?	13.8

Manufacturing of the board or subassembly

Number	Recommendation	Question	Weight
5	Improve the product final test seen in the design and specification to increase the test coverage and make a summary of the tests.	Is there a final product test? Are nonconforming test results treated: at the product, at the process? Are test results recorded?	6.6
7	Implement corrective actions.	What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?	15.4
8	Implement prenventative actions.	Do procedures related to prenventative actions include: - The use of appropriate information sources? - Determination of appropriate steps? - Triggering of prenventative actions and application of control means? - A management review of corrective actions?	15.6
17	Monitor inspection parameters during varnishing activity.	Are inspection parameters monitored during the varnishing activity?	9.9
18	Perform corrective maintenance as soon as an anomaly appears on production means or produced subassemblies.	Does corrective maintenance take place as soon as an anomaly appears on production means or produced subassemblies?	6.9
19	Perform prenventative maintenance to correct drifts to production means parameters.	Is prenventative maintenance planned to correct drifts to production means parameters?	4
21	Verify programming means periodically, so that the software loading operation is correctly performed.	Is there a periodic verification of programming means so that the software loading operation is done correctly?	4.1
22	Systematically audit final test operators for monitoring of skills.	Are the skills of final test operators systematically audited?	4.1
23	Automate manipulations to limit possible degradations on subassemblies.	Are production and manipulation of subassemblies automated?	6.5
25	Check and maintain data loaded in the programmable production means (by updating).	Are data loaded in programmable production means managed?	2.8
33	Delegate the general inspection of the subassembly varnishing operation, to optimise filtering before continuing doing the process.	Is the subassembly varnishing inspection done by someone other than the varnishing operator?	4.4

Number	Recommendation	Question	Weight
37	Have experienced personnel in the subassembly drying activity after varnishing.	Is the subassembly drying activity after varnishing carried out by experienced personnel?	5.6
41	Give instructions (protocol and particular instructions to be respected) to operators.	Are the instructions (protocol and particular instructions to be respected) given to operators?	7.4
42	Make records of temperature profiles for each program used in the soldering means to make sure that there is no aggression to the subassembly.	Are there any records of temperature profiles for each program used for the soldering means?	6.9
43	Eliminate all possibilities of ambiguous use of a tool to avoid inadequacy between the production means and the subassembly to which it is applied.	How is it assured that production means are adapted to elements to be produced?	7.2
46	Record problems that could require the application of corrective and/or prenventative actions (on an Anomaly datasheet).	How are technical events or anomaly reports recorded?	7.6
60	Manage priorities to be respected as a function of end of file dates.	How are priorities managed as a function of end of file dates?	3.1
61	Identify and implement means of protecting subassemblies.	Have means of protecting subassemblies during some production activities been identified and implemented?	7.3
77	Control changes to manufacturing processes.	How are changes to manufacturing processes controlled?	13.9
84	Measure contamination of baths by sampling (frequency to be defined) so as not to exceed the pollutant content during this activity.	Is contamination of solder baths measured by sampling (so as not to exceed the pollutant content during this activity)?	5.8
88	Implement self-checking to filter human errors that could reduce reliability of the subassembly.	Is a self checking system applied to filter human errors (that could reduce reliability of the subassembly)?	5.3
89	Set up indicators to verify that a good solder is obtained when components are transferred.	Are there any indicators to verify that a good solder is obtained when components are transferred?	6
90	Set up periodic inventories of stores.	Are checks made to assure that stock inventories are defined and respected	5.5
91	Set up protections against ESD for subassemblies during manipulations and storage.	Have you set up specific protections against ESD for subassemblies during manipulations and storage?	26
92	Set up periodic verifications for monitoring tools used for inspection of production means.	Are there any periodic verifications used to monitor tools used for inspection of production means?	4.9
93	Set up appropriate protections to avoid degrading subassemblies while cleaning.	Are there any appropriate protections to avoid degrading subassemblies while cleaning?	6

Number	Recommendation	Question	Weight
94	Set up a self-test of test tools to detect any anomalies.	Are there any self-tests of test tools in order to detect any anomalies before use on the subassembly ?	5.1
95	Set up a cross-check to optimise the final inspection of varnishing of subassemblies.	Is there a cross-check to optimise the final inspection of varnishing of subassemblies?	5.6
96	Set up a conformity check when putting into stock in stores (excluding non-conforming items).	Is there a conformity check when putting into stock in stores with the exclusion of non-conforming items?	6
97	Set up an SPC (Statistical Process Control) for the production process.	is there an SPC (Statistical Process Control) for the production process?	4.5
98	Give a detailed description of the varnishing protocol.	Is there a detailed description of the varnishing protocol?	5.8
99	Set up a label for identification and withdrawal of out-of-date consumables.	Is there a label for identification and withdrawal of out-of-date consumables?	6.4
100	Set up real time processing of test monitoring indicators so as to not to degrade the subassembly as soon as an anomaly appears.	Is there a real time processing of test monitoring indicators so as to not to degrade the subassembly as soon as an anomaly appears?	4.7
101	Set up prenventative maintenance by metrological monitoring to prevent the possibility of aggression to the subassembly.	is there a prenventative maintenance by metrological monitoring?	5.9
102	Do not validate and authorise operation of drying ovens, except by checking drifts and malfunctions (by probes and other monitoring systems).	Is a method used for checking drifts and malfunctions (by probes and other monitoring systems), and to validate or allow the operation of drying ovens?	6.1
112	Have high and low safety systems tied to inspection and monitoring means (systematically stop the cycle and have a technician carry out an analysis before restarting).	Are high and low safety systems provided tied to inspection and monitoring means (systematically stop the cycle and analysis by a technician before restarting)?	5.7
115	Possess a plan for qualification of a method of removing the masking varnishes used so as to avoid reducing the reliability of the subassembly.	Is there a qualification plan of the method of removing masking varnishes used so as not to reduce reliability of the subassembly?	6.5
120	Include an inspection step (even visual) to assure that the masking varnish placement activity takes place correctly before varnishing.	Is there an inspection step (even visual) to assure that the masking varnish placement activity takes place correctly before varnishing?	6.5
121	Provide prenventative maintenance to detect an anomaly if any, before using a production means on a subassembly.	Is there a prenventative maintenance to detect an anomaly, if there is one, before a production means is used on a subassembly?	4.7
125	Respect a rest time between each transfer phase to avoid overstressing the subassembly.	Is a rest time between each silk screen printing operation respected to avoid overstressing the subassembly?	6.4

Number	**Recommendation**	**Question**	**Weight**
126	Revise and increase the robustness of plans for maintenance of production means to eliminate any possibility of degradation to component connections.	Have plans for maintenance of production means been revised and made more robust to eliminate any possibility of degradation to component connections?	6.7
127	Make sure that the preparation (dosing) of varnish is controlled by a qualified procedure and test measurements.	Is the preparation (dosing) of varnish controlled by a qualified procedure and test measurements?	5.9
128	Make sure that operators well informed and study how to update their skills in real time.	Is there a procedure for assuring that operators are well informed and are studies done to determine how to update their skills in real time?	4.4
129	Make sure that the inspection on the final varnishing quality is effective, by strictly applying the inspection procedure.	Is it assured that the inspection on the final varnishing quality is effective, by strictly applying the inspection procedure.	5.2
136	Make sure that the procedure for implementing the means is known.	Is it checked that the procedure for implementing the means is known?	5.1
138	Make sure that the right software is loaded and keep the identification of its version.	Is it checked that the right software is loaded, and that its version is identified?	6.7
139	Make sure that means are maintained and that this maintenance is followed.	Is a check carried out to assure that means are maintained and that this maintenance is followed?	5.9
140	Make sure that the operator has received training (qualification), appropriate for the activity.	Is it checked that the operator has received training (qualification), appropriate for the activity?	8.5
141	Secure means (drying oven T°) through direct monitoring by probes and recordings, to prevent overstresses.	Are means secured (drying oven T°) through direct monitoring by probes and recordings, to prevent overstresses?	6.6
144	Increase personnel awareness about a visual verification of subassemblies after placement and before remelting.	Are personnel made aware about a visual verification of subassemblies after placement and before remelting?	5.9
145	Increase operators awareness about the verification of the quality of the soldering flux deposit (implementation of a verification action that must appear in the subassembly follower sheet).	Are operators made aware of the need to verify the quality of soldering flux deposit (implementation of a verification action that must appear in the subassembly follower sheet)?	5.9
153	Check conformity of purchased products.	Is the conformity of purchased products checked?	8.6
154	Perform an inspection action (barcode reading, reading the S/N) to verify that the right product is available before starting the test.	Is an inspection action (barcode reading, reading the S/N) performed to verify that the right product is available before starting the test?	6.1
155	Check that the test coverage during and after burn-in is formalised correctly.	Is it checked that the test coverage for burn-in is formalised correctly?	5.2

Integration into equipment

Number	Recommendation	Question	Weight
5	Improve the product final test seen in the design and specification to increase the test coverage and make a summary of the tests.	Is there a final product test? Are nonconforming test results treated: at the product, at the process? Are test results recorded?	6.6
7	Implement corrective actions.	What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?	15.4
8	Implement prenventative actions.	Do procedures related to prenventative actions include: - The use of appropriate information sources? - Determination of appropriate steps? - Triggering of prenventative actions and application of control means? - A management review of corrective actions?	15.6
9	Make the product traceable.	How is product traceability achieved?	16.5
10	Manage packaging.	Does the supplier control wrapping, packaging and marking processes to assure conformity with the specified requirements? Is there a list of equipment requiring packaging?	12.3
11	Manage storage.	Are there any designated storage areas or premises? Are they used to prevent damage or deterioration of the product? Are appropriate measures taken to enable reception and shipping in these areas?	10.8
12	Maintain delivery conditions.	Does the supplier take steps to maintain the product quality after the inspections and final tests? When specified in the contract, are these steps extended to include delivery for final use?	17.5
13	Perform inspections and tests during the phase.	Is there any risk that a product that has not satisfied inspections and tests specified during one phase will go on to the next phase without corrective action?	7.2
14	Perform final inspections and tests.	Have all final inspections and tests been carried out in accordance with the quality plan and/or written procedures?	7.9

Number	Recommendation	Question	Weight
15	Carry out inspections and tests specific to reception	Are appropriate inspections and tests carried out on incoming products before use?	6.7
18	Perform corrective maintenance as soon as an anomaly appears on production means or produced subassemblies.	Does corrective maintenance take place as soon as an anomaly appears on production means or produced subassemblies?	6.9
19	Perform prenventative maintenance to correct drifts to production means parameters.	Is prenventative maintenance planned to correct drifts to production means parameters?	4
21	Verify programming means periodically, so that the software loading operation is correctly performed.	Is there a periodic verification of programming means so that the software loading operation is done correctly?	4.1
22	Systematically audit final test operators for monitoring of skills.	Are the skills of final test operators systematically audited?	4.1
23	Automate manipulations to limit possible degradations on subassemblies.	Are production and manipulation of subassemblies automated?	6.5
25	Check and maintain data loaded in the programmable production means (by updating).	Are data loaded in programmable production means managed?	2.8
30	Define the degree of nonconformity.	Is the description of the accepted nonconformity or of the repairs performed recorded to indicate the product's real condition?	10.3
32	Define the means necessary for inspection and test of the product.	Are means necessary for inspections and tests of the product defined?	11.6
35	Have documents for performing incoming inspection on supplies.	Are there any documents for performing incoming inspection on supplies?	8.8
41	Give instructions (protocol and particular instructions to be respected) to operators.	Are the instructions (protocol and particular instructions to be respected) given to operators?	7.4
43	Eliminate all possibilities of ambiguous use of a tool to avoid inadequacy between the production means and the subassembly to which it is applied.	How is it assured that production means are adapted to elements to be produced?	7.2
46	Record problems that could require the application of corrective and/or prenventative actions (on an Anomaly datasheet).	How are technical events or anomaly reports recorded?	7.6
47	Produce procedures to assure that the product is conforming with specified requirements.	Are there any written procedures for assuring that products are conforming with specified requirements?	10.6
49	Examine and process nonconformities.	Has the responsibility for the examination and the decision to process the nonconforming product been defined?	13.6

Number	Recommendation	Question	Weight
60	Manage priorities to be respected as a function of end of file dates.	How are priorities managed as a function of end of file dates?	3.1
61	Identify and implement means of protecting subassemblies.	Have means of protecting subassemblies during some production activities been identified and implemented?	7.3
66	Identify means concerning special processes.	Are means concerning special processes identified?	13.1
67	Identify human resources concerning special processes.	Are human resources concerning special processes managed?	11.7
70	Control the product inspection and test documentation.	How is the product inspection and test documentation controlled?	9.3
71	Control documentation.	Is documentation well controlled? Does it take account of all equipment changes?	12.2
73	Make sure that inspection, measurement and test equipment is compatible with needs.	What steps are taken to control how inspection, measurement and test equipment is compatible with needs?	9.6
74	Control the environment of inspection, measurement and test equipment.	How is the environment of inspection, measurement and test equipment controlled?	7.9
75	Control the working environment.	How is the working environment controlled?	9.6
77	Control changes to manufacturing processes.	How are changes to manufacturing processes controlled?	13.9
78	Control handling methods.	Are handling and transport methods defined?	8.8
79	Control production means, tools and programmable machines.	How are production equipment, tools and programs for numerical control machine controlled?	10.5
80	Control handling, storage, packaging, preservation and delivery operations.	How are handling, storage, packaging, preservation, and delivery controlled?	6.5
81	Control special processes.	How are special processes controlled?	14.4
82	Control services and fluids in the working environment.	How are services and fluids in the working environment controlled?	10.1
88	Implement self-checking to filter human errors that could reduce reliability of the subassembly.	Is a self checking system applied to filter human errors (that could reduce reliability of the subassembly)?	5.3
91	Set up protections against ESD for subassemblies during manipulations and storage.	Have you set up specific protections against ESD for subassemblies during manipulations and storage?	26
92	Set up periodic verifications for monitoring tools used for inspection of production means.	Are there any periodic verifications used to monitor tools used for inspection of production means?	4.9

Number	Recommendation	Question	Weight
94	Set up a self-test of test tools to detect any anomalies.	Are there any self-tests of test tools in order to detect any anomalies before use on the subassembly?	5.1
99	Set up a label for identification and withdrawal of out-of-date consumables.	Is there a label for identification and withdrawal of out-of-date consumables?	6.4
100	Set up real time processing of test monitoring indicators so as to not to degrade the subassembly as soon as an anomaly appears.	Is there a real time processing of test monitoring indicators so as to not to degrade the subassembly as soon as an anomaly appears?	4.7
113	Possess inspection and test records.	Are records produced and kept to prove that the product has been inspected and/or tested in accordance with defined criteria? Are the records sufficient to identify the person who made the checks?	5.3
114	Possess an inspection file.	Is there an inspection file containing acceptance criteria, the sequential list of inspection and test operations, inspection result record documents, list of specific and non-specific inspection instruments?	5.7
116	Possess documentation specific to the nonconformity.	Is there any documentation specific to the nonconformity?	11.1
121	Provide prenventative maintenance to detect an anomaly if any, before using a production means on a subassembly.	Is there a prenventative maintenance to detect an anomaly, if there is one, before a production means is used on a subassembly?	4.7
136	Make sure that the procedure for implementing the means is known.	Is it checked that the procedure for implementing the means is known?	5.1
138	Make sure that the right software is loaded and keep the identification of its version.	Is it checked that the right software is loaded, and that its version is identified?	6.7
139	Make sure that means are maintained and that this maintenance is followed.	Is a check carried out to assure that means are maintained and that this maintenance is followed?	5.9
140	Make sure that the operator has received training (qualification), appropriate for the activity.	Is it checked that the operator has received training (qualification), appropriate for the activity?	8.5
153	Check conformity of purchased products.	Is the conformity of purchased products checked?	8.6

Integration into the system

Number	Recommendation	Question	Weight
7	Implement corrective actions.	What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?	15.4
8	Implement prenventative actions.	Do procedures related to prenventative actions include: - The use of appropriate information sources? - Determination of appropriate steps? - Triggering of prenventative actions and application of control means? - A management review of corrective actions?	15.6
9	Make the product traceable.	How is product traceability achieved?	16.5
10	Manage packaging.	Does the supplier control wrapping, packaging and marking processes to assure conformity with the specified requirements? Is there a list of equipment requiring packaging?	12.3
11	Manage storage.	Are there any designated storage areas or premises? Are they used to prevent damage or deterioration of the product? Are appropriate measures taken to enable reception and shipping in these areas?	10.8
12	Maintain delivery conditions.	Does the supplier take steps to maintain the product quality after the inspections and final tests? When specified in the contract, are these steps extended to include delivery for final use?	17.5
13	Perform inspections and tests during the phase.	Is there any risk that a product that has not satisfied inspections and tests specified during one phase will go on to the next phase without corrective action?	7.2
14	Perform final inspections and tests.	Have all final inspections and tests been carried out in accordance with the quality plan and/or written procedures?	7.9
15	Carry out inspections and tests specific to reception	Are appropriate inspections and tests carried out on incoming products before use?	6.7

Number	Recommendation	Question	Weight
30	Define the degree of nonconformity.	Is the description of the accepted nonconformity or of the repairs performed recorded to indicate the product's real condition?	10.3
32	Define the means necessary for inspection and test of the product.	Are means necessary for inspections and tests of the product defined?	11.6
35	Have documents for performing incoming inspection on supplies.	Are there any documents for performing incoming inspection on supplies?	8.8
47	Produce procedures to assure that the product is conforming with specified requirements.	Are there any written procedures for assuring that products are conforming with specified requirements?	10.6
49	Examine and process nonconformities.	Has the responsibility for the examination and the decision to process the nonconforming product been defined?	13.6
66	Identify means concerning special processes.	Are means concerning special processes identified?	13.1
67	Identify human resources concerning special processes.	Are human resources concerning special processes managed?	11.7
70	Control the product inspection and test documentation.	How is the product inspection and test documentation controlled?	9.3
71	Control documentation.	Is documentation well controlled? Does it take account of all equipment changes?	12.2
73	Make sure that inspection, measurement and test equipment is compatible with needs.	What steps are taken to control how inspection, measurement and test equipment is compatible with needs?	9.6
74	Control the environment of inspection, measurement and test equipment.	How is the environment of inspection, measurement and test equipment controlled?	7.9
75	Control the working environment.	How is the working environment controlled?	9.6
77	Control changes to manufacturing processes.	How are changes to manufacturing processes controlled?	13.9
78	Control handling methods.	Are handling and transport methods defined?	8.8
79	Control production means, tools and programmable machines.	How are production equipment, tools and programs for numerical control machine controlled?	10.5
80	Control handling, storage, packaging, preservation and delivery operations.	How are handling, storage, packaging, preservation, and delivery controlled?	6.5
81	Control special processes.	How are special processes controlled?	14.4
82	Control services and fluids in the working environment.	How are services and fluids in the working environment controlled?	10.1

Number	Recommendation	Question	Weight
88	Implement self-checking to filter human errors that could reduce reliability of the subassembly.	Is a self checking system applied to filter human errors (that could reduce reliability of the subassembly)?	5.3
91	Set up protections against ESD for subassemblies during manipulations and storage.	Have you set up specific protections against ESD for subassemblies during manipulations and storage?	18.4
99	Set up a label for identification and withdrawal of out-of-date consumables.	Is there a label for identification and withdrawal of out-of-date consumables?	6.4
113	Possess inspection and test records.	Are records produced and kept to prove that the product has been inspected and/or tested in accordance with defined criteria? Are the records sufficient to identify the person who made the checks?	5.3
114	Possess an inspection file.	Is there an inspection file containing acceptance criteria, the sequential list of inspection and test operations, inspection result record documents, list of specific and non-specific inspection instruments?	5.7
116	Possess documentation specific to the nonconformity.	Is there any documentation specific to the nonconformity?	11.1
136	Make sure that the procedure for implementing the means is known.	Is it checked that the procedure for implementing the means is known?	5.1
138	Make sure that the right software is loaded and keep the identification of its version.	Is it checked that the right software is loaded, and that its version is identified?	6.7
153	Check conformity of purchased products.	Is the conformity of purchased products checked?	8.6

Operation and maintenance

Number	Recommendation	Question	Weight
7	Implement corrective actions.	What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?	17.5
8	Implement prenventative actions.	Do procedures related to prenventative actions include: - The use of appropriate information sources? - Determination of appropriate steps? - Triggering of prenventative actions and application of control means? - A management review of corrective actions?	17.7
9	Make the product traceable.	How is product traceability achieved?	9.2
10	Manage packaging.	Does the supplier control wrapping, packaging and marking processes to assure conformity with the specified requirements? Is there a list of equipment requiring packaging?	13.8
11	Manage storage.	Are there any designated storage areas or premises? Are they used to prevent damage or deterioration of the product? Are appropriate measures taken to enable reception and shipping in these areas?	15.6
13	Perform inspections and tests during the phase.	Is there any risk that a product that has not satisfied inspections and tests specified during one phase will go on to the next phase without corrective action?	11.2
14	Perform final inspections and tests.	Have all final inspections and tests been carried out in accordance with the quality plan and/or written procedures?	10.4
20	Adopt a policy of control of risks associated with nonconformities.	Is a policy applied aimed at identifying, evaluating and managing potential risks associated with nonconformities, on products and also on all design, planning, manufacturing, assembly and inspection processes, etc?	16.3
30	Define the degree of nonconformity.	Is the description of the accepted nonconformity or of the repairs performed recorded to indicate the product's real condition?	12.8

Number	Recommendation	Question	Weight
32	Define the means necessary for inspection and test of the product.	Are means necessary for inspections and tests of the product defined?	14.3
35	Have documents for performing incoming inspection on supplies.	Are there any documents for performing incoming inspection on supplies?	9.9
47	Produce procedures to assure that the product is conforming with specified requirements.	Are there any written procedures for assuring that products are conforming with specified requirements?	6.8
63	Identify documentation for special processes.	Is there any documentation for special processes? Is this documentation kept up to date?	12.2
66	Identify means concerning special processes.	Are means concerning special processes identified?	13.1
67	Identify human resources concerning special processes.	Are human resources concerning special processes managed?	13.7
71	Control documentation.	Is documentation well controlled? Does it take account of all equipment changes?	5.6
72	Control product testability and maintainability.	How are product testability and maintainability controlled?	17.6
73	Make sure that inspection, measurement and test equipment is compatible with needs.	What steps are taken to control how inspection, measurement and test equipment is compatible with needs?	11.3
74	Control the environment of inspection, measurement and test equipment.	How is the environment of inspection, measurement and test equipment controlled?	11.7
75	Control the working environment.	How is the working environment controlled?	10.8
77	Control changes to manufacturing processes.	How are changes to manufacturing processes controlled?	13.9
78	Control handling methods.	Are handling and transport methods defined?	9.9
79	Control production means, tools and programmable machines.	How are production equipment, tools and programs for numerical control machine controlled?	11.3
80	Control handling, storage, packaging, preservation and delivery operations.	How are handling, storage, packaging, preservation, and delivery controlled?	11.3
81	Control special processes.	How are special processes controlled?	15.2
82	Control services and fluids in the working environment.	How are services and fluids in the working environment controlled?	12.2
91	Set up protections against ESD for subassemblies during manipulations and storage.	Have you set up specific protections against ESD for subassemblies during manipulations and storage?	17.4

Number	Recommendation	Question	Weight
114	Possess an inspection file.	Is there an inspection file containing acceptance criteria, the sequential list of inspection and test operations, inspection result record documents, list of specific and non-specific inspection instruments?	5.7
116	Possess documentation specific to the nonconformity.	Is there any documentation specific to the nonconformity?	11.1

Support Activities

Number	Recommendation	Question	Weight
3	Allocate the infrastructures necessary for correct execution of production operations.	Have the conclusions of reliability studies in terms of necessary infrastructures for production and integration been taken into account?	7.4
4	Continuously improve the company's Reliability engineering.	Are there any objectives to improve reliability engineering in the company? Are there any indicators about the current position relative to these objectives?	6.6
24	Collect customer comments about the product reliability during operational functioning.	Are customer comments about product reliability collected during operational functioning?	7.9
27	Describe the process to improve the product reliability and the associated objectives.	Are there any objectives to improve the process to construct product reliability?	6.3
45	Perform a company quality certification.	The company has one or several quality certifications, for example ISO 9001 Version 2000	6.5
55	Get the Operating Dependability business to participate in all phases of the project	Does the Operating Dependability business participate in all phases of the project?	8.8
56	Train personnel concerned by Reliability or use personnel qualified in Reliability.	Is training of persons working on reliability appropriate for the criticality of reliability performances expected for the product?	7.5
58	Supply resources necessary for reliability studies.	Are technical data necessary for reliability studies accessible? Are the necessary tools available? Have the necessary time and financing been allowed for?	8.3
59	Manage reliability study documents in configuration.	Are reliability study documents managed?	5.4
68	Identify risks related to Reliability at subcontractors.	Have risks related to reliability of products at subcontractors been identified?	7.2
69	Integrate reliability into the company's quality policy.	Is the reliability theme present in the company quality policy?	7.4
76	Control monitoring and measurement devices, metrology of measurement instruments and industrial means.	What procedure is there to control monitoring and measurement devices, the metrology of measurement instruments and industrial means?	7.8
85	Measure the reliability of products in operation.	Are product reliability measurements actually made in operation?	8
104	Appoint a person responsible for reliability studies.	Has a person responsible for reliability studies been appointed?	8.5
105	Organise periodic reliability meetings with the subcontractor.	Are periodic reliability meetings organised with the subcontractor?	5.7

Number	Recommendation	Question	Weight
108	Plan the sequence of tasks, and include reliability tasks.	Are tasks related to reliability taken into account in project plannings?	6.3
109	Plan the communication process with the subcontractor.	Are tasks related to reliability taken into account in project plannings?	4.1
110	Plan reliability activities including reliability improvement.	Are reliability activities including reliability improvement organised?	9.1
111	Plan reliability studies.	Are reliability studies planned?	7.3
118	Maintain the product reliability in production.	Are measures taken to maintain the product reliability in production?	8.1
119	Plan periodic consultations with customers related to reliability aspects.	Are there periodic consultations planned with customers related to reliability aspects?	7.3
142	Select the components used.	Are reliability criteria considered when selecting the components used?	12.9
143	Select component suppliers.	Are reliability criteria considered when selecting component suppliers?	10.8
146	Monitor and control corrective actions done by the subcontractor related to product reliability.	Are corrective actions done by the subcontractor related to reliability monitored	7.2
148	Deal with the reliability aspect in management reviews.	Is the reliability aspect dealt with in management reviews?	5.6
149	Deal with anomalies, using an Incident Processing and Corrective Action Logic	What process is set up to collect technical events, produce anomaly reports and measure improved reliability? How are hardware upgrades managed?	8.3
151	Use statistical methods adapted to the use of feedback from operations.	Are statistical methods adapted to the use of feedback from operations?	6
152	Validate the subcontractor's Reliability management baseline.	Has the reliability management baseline of the subcontractor been validated?	7.7

Ruggedising

Number	Recommendation	Question	Weight
156	Check that environmental specifications are complete.	How is it checked that environmental specifications are complete?	4
157	Provide training and manage maintenance of skills for implementation and maintenance of the product	Have users (for use and maintenance) received training on the product? Is this training repeated and updated to satisfy needs?	7
158	Check that procedures specific to the product and rules specific to businesses are respected by an appropriate monitoring system	Are inspection means (process, recording means) sufficient for the supplier to assure that rules for the use of the product are well respected by users?	7
159	Design dependable electrical protection devices.	How are electrical protection devices designed?	4
160	Study and handle risks of the product under test being deteriorated by failures of its test or maintenance means.	How are risks of the product under test being deteriorated by failure of its test means dealt with?	4
161	Identify and use appropriate prevention means of preventing reasonably predictable aggressions (related to the weather)	Are reasonably predictable aggressions (related to the weather) taken into account?	4
162	Use appropriate prevention means to identify and handle reasonably predictable abnormal uses	Are reasonably predictable abnormal uses taken into account?	4
163	Include production, storage and maintenance environments in the product environment specifications	How are production, storage and maintenance environments taken into account in the product environment specification?	4
164	Justify that environment specifications are respected	How is it justified that environment specifications are respected	4
165	Carry out a product improvement process (for example highly accelerated stress tests) so as to limit the product sensitivity to environmental constraints (disturbances, environments, overstress)	Is there a product improvement process to construct its robustness and accelerate its maturity?	7
166	Perform an analysis of failure cases that could result in failure propagation.	Have the possibilities of failure propagation been analysed?	4
167	Carry out a process analysis of implementation and maintenance operations	How are risks of errors in carrying out implementation and maintenance operations analysed?	4
168	Carry out a review of maintenance operations done by the final user and deal with his recommendations	Has a review of maintenance operations done by the user been organised?	4

Number	Recommendation	Question	Weight
169	Write complete procedures for all product implementation and maintenance operations	Is there any documentation that describes all product implementation and maintenance operations?	7
170	Respect a standard dealing with power supplies (standard that defines possible disturbances and possible EN2282 type variations). The standard must be respected both for electricity generation and for electricity consumption	Is there a standard on electrical power supplies applicable to the product and the system surrounding it? How is this standard applied?	4
171	Respect a standard dealing with conducted and radiated electromagnetic disturbances. This is equally applicable to the product and the system into which it is integrated	Is there a standard concerning conducted and radiated electromagnetic disturbances applicable to the product and the system that surrounds it? How is it applied?	3

Detailed datasheets for each recommendation

Recommendation Assign resources in terms of personnel and means to reliability studies.	**N°** 1
Phases in which the recommendation is applicable SPECIFICATION...	**Weight** 10.7
Further description Financing is assigned to the project's reliability manager. This is the subject of a separate item (at accounting level) in project management. Personnel and means necessary for carrying out Reliability studies satisfactorily are made available to the product reliability manager	
Audit question Is there a financing item for reliability studies? Have the necessary means and personnel been identified?	
Level 1	No specific resources are allocated to the reliability studies: integrated with other studies or a non formalised specific allocation.
Level 2	Resources allocated to reliability studies are identified at project management level and are formalised in a document .
Level 3	Resources allocated to reliability studies are identified at project management level and are formalised in a validated plan.
Level 4	Resources allocated to reliability studies are identified at project management level and are formalised in a validated plan. Proof of the real availability of resources is established .

Recommendation Allocate reliability requirements to subassemblies.	**N°** 2
Phases in which the recommendation is applicable **Weight** SPECIFICATION 10.4	
Further description The operating dependability (reliability) business participates in the allocation of requirements to subassemblies.	
Audit question Are global reliability requirements allocated to subassemblies? What allocation method was used?	
Level 1	There is not or will not be any allocation of reliability requirements to subassemblies.
Level 2	Persons responsible for reliability engineering have defined (or have participated in defining) the allocation of reliability requirements to subassemblies. No validated document certifies this allocation.
Level 3	Persons responsible for reliability engineering have defined (or have participated in defining) the allocation of reliability requirements to subassemblies. Validated documents certify this participation.
Level 4	Persons responsible for reliability engineering have defined (or have participated in defining) the allocation of reliability requirements to subassemblies. Validated documents certify this participation. This allocation is based on prior data dealing with similar equipment (technology, usage environment).

Recommendation
Allocate the infrastructures necessary for correct execution of production operations.

N°
3

Phases in which the recommendation is applicable **Weight**
SUPPORT PROCESS ACTIVITIES 7.4

Further description
Allocate the infrastructures necessary for production and integration operations to obtain the reliability level predicted by reliability studies during the product design (no degradation of reliability during these phases).
Perform the Process FMECA.
Examples: supply appropriate power networks, clean rooms, ergonomic buildings, application of 5S methods.
The improvement in the environment may consist of: Increasing the surface areas (easier manipulations), Improving lighting, Reducing operator fatigue, Imposing storage and cleanliness standards,
Improving the quality of tools,
Making personnel aware about reliability.

Audit question
Have the conclusions of reliability studies in terms of necessary infrastructures for production and integration been taken into account?

Level 1	No evaluation has been made of the impact, no specific systems to protect products.
Level 2	A few product protection systems have been set up (storage room), partial awareness of personnel.
Level 3	Workshops are provided with structures to provide protection against risks of damage to equipment caused by unsuitable infrastructures (for example electrostatic discharges), personnel have been trained in their use.
Level 4	Workshops are provided with structures to provide protection against risks of damage to equipment caused by unsuitable infrastructures (for example electrostatic discharges), personnel have been trained in their use. Formal studies have been carried out, to preserve the product in production (e.g. Process FMECA).

Recommendation Continuously improve the company's Reliability engineering.	**N°** 4

Phases in which the recommendation is applicable **Weight**

SUPPORT PROCESS ACTIVITIES 6.6

Further description

Set up Reliability engineering indicators.
Fix objectives to improve the company's Reliability engineering; Audit the company's Reliability engineering (get the reliability specialists to attend further training, make presentations in reliability conferences).

Audit question

Are there any objectives to improve reliability engineering in the company? Are there any indicators about the current position relative to these objectives?

Level 1	No indicator on Reliability engineering has been set up. No Reliability business actions are performed.
Level 2	No indicator on Reliability engineering has been set up, the company's baseline includes documents related to Reliability engineering.
Level 3	Some indicators have been set up (maintenance of performances, performances of prediction methods), the company's baseline includes documents related to Reliability engineering. Directives are regularly updated.
Level 4	Reliability engineering indicators have been set up. The company's baseline includes documents related to Reliability engineering: Regularly updated directives et guides. Objectives to improve the company's Reliability engineering have been fixed; the company's Reliability engineering is audited regularly (further training of personnel, presentations in reliability conferences).

Recommendation Improve the product final test seen in the design and specification to increase the test coverage and make a summary of the tests.	**N°** 5

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6.6
INTEGRATION INTO EQUIPMENT 6.6

Further description

The product final test and particularly the coverage level achieved by this test must be studied and defined with respect to the product. Specification and Design.
This test must check the product according to procedures in the System Testability Manual:
- Appropriate treatment in case of a nonconformity,
- Recording and saving results for monitoring of tests.

Audit question

Is there a final product test? Are nonconforming test results treated: at the product, at the process? Are test results recorded?

Level 1	No changes are made to the predefined test coverage rate.
Level 2	A summary of product tests can be made with the purpose of revising and improving the predefined coverage rate. However, no document formally describes related actions.
Level 3	Final product tests are regularly reviewed, even after specification and design. The purpose is to increase the predefined test coverage. Documents describe the procedure to be adopted.
Level 4	Final product tests are regularly reviewed, even after specification and design. The purpose is to increase the predefined test coverage. Documents describe the procedure to be adopted. These were validated by an authority independent from the operating entity.

Recommendation Ensure the completeness of information on subassemblies to establish (complete) subassemblies Test Manuals.	**N°** 6
Phases in which the recommendation is applicable DESIGN..........	**Weight** 7.8
Further description Obtain technical data for subassemblies in order to develop the production test.	
Audit question Are technical data for subassemblies available for development of the production test?	
Level 1	No technical data for subassemblies related to the test.
Level 2	Existence of non validated partially useable data.
Level 3	Existence of validated partially useable data for all subassemblies.
Level 4	Existing data are complete, validated and useable for all subassemblies

Recommendation	**N°**
Implement corrective actions.	7

Phases in which the recommendation is applicable	**Weight**
DESIGN	6.7
MANUFACTURING OF BOARD OR SUBASSEMBLY	15.4
INTEGRATION INTO EQUIPMENT	15.4
INTEGRATION INTO SYSTEM	15.4
OPERATION AND MAINTENANCE	17.5

Further description

Procedures related to corrective actions include:
- Effective processing of customer complaints and product nonconformity reports,
- The search for the causes of nonconformity related to the product, the process and the quality system, and recording the results of this search,
- Determining corrective actions necessary to eliminate the causes of nonconformity,
- Application of all means to measure the effectiveness of the corrective action.

Audit question

What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?

Level 1	There are no procedures related to corrective actions.
Level 2	Corrective actions are implemented following a customer complaint or a nonconformity report, but they are not formalised.
Level 3	Procedures related to corrective actions include at least: Effective processing of customer complaints and nonconformity reports on the product, The search for causes of nonconformity related to the product, the process and the quality system and recording the results of this search, Determination of corrective actions necessary to eliminate the causes of the nonconformity, These procedures do not define the application of control means to assure that the corrective action is implemented and that it produces the expected effect.
Level 4	Procedures related to corrective actions include: Effective processing of customer complaints and nonconformity reports on the product, The search for causes of nonconformity related to the product, the process and the quality system and recording the results of this search, Determination of corrective actions necessary to eliminate the causes of the nonconformity, Application of control means to assure that the corrective action is implemented and that it produces the expected effect.

Recommendation Implement preventive actions.	**N°** 8

Phases in which the recommendation is applicable **Weight**

Phase	Weight
DESIGN	6.8
MANUFACTURING OF BOARD OR SUBASSEMBLY	15.6
INTEGRATION INTO EQUIPMENT	15.6
INTEGRATION INTO SYSTEM	15.6
OPERATION AND MAINTENANCE	17.7

Further description

Procedures related to preventive actions include:

- The use of appropriate information sources such a processes and operations affecting the product quality, waivers, audit results, quality records, maintenance reports and customer complaints, so as to detect, analyse and eliminate the potential causes of nonconformities,
- Determination of appropriate steps to deal with any problem requiring preventive action,
- Triggering of preventive actions and the application of control means to make sure that they produce the expected effect,
- Assurance that relative information about actions implemented is submitted to the management review.

Audit question

Do procedures related to preventive actions include:

- The use of appropriate information sources?
- Determination of appropriate steps?
- Triggering of preventive actions and application of control means?
- A management review of corrective actions?

Level 1	No procedure for preventive actions is implemented
Level 2	Procedures for preventive actions do exist but they are incomplete
Level 3	Procedures for preventive actions do exist and are almost complete with regard to the mentioned criteria (there are possible minor nonconformities in the application or satisfaction of criteria)
Level 4	Procedures for preventive actions do exist, they are formalised and are complete with regard to the mentioned criteria

Recommendation Make the product traceable.	**N°** 9

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT 16.5
INTEGRATION INTO SYSTEM 16.5
OPERATION AND MAINTENANCE 9.2

Further description

When traceability is required, the system implemented must make it possible of:
- maintaining the product identification throughout the life cycle,
- knowing the history (definition file + changes) and the final use (deliveries, scrap) of all products manufactured from the same batch of raw material or from the same manufacturing batch,
- finding the identity of elements making up an assembly and the higher assembly,
- finding the sequential documentation on production (manufacturing, assembly, inspection) of a given product (e.g. configuration follower sheet including recording of actual operations and observed anomalies).

The traceability system must be capable of determining the product configuration ready for delivery, including variations between the real state and the agreed state.

Audit question

How is product traceability achieved?

Level 1	No product traceability during its life cycle, the product is distinguished only by its marking.
Level 2	Traceability is used to identify the product but not to determine its origin and its history.
Level 3	Traceability is used to identify and know the product history (Definition file + changes), However it is not sufficient to know the documentation associated with its life cycle (e.g. no configuration follower sheet containing records of operations carried out and anomalies observed).
Level 4	Traceability is used to identify and know the product history (Definition file + changes), including components, e. g. Date Code... It is sufficient to find the documentation associated with its life cycle (e. g. configuration follower sheet containing records of operations carried out and anomalies observed). Exhaustive application of the recommendation.

Recommendation Manage packaging.	**N°** 10

Phases in which the recommendation is applicable — **Weight**

INTEGRATION INTO EQUIPMENT 12.3
INTEGRATION INTO SYSTEM 12.3
OPERATION AND MAINTENANCE 13.8

Further description

Wrapping, packaging and marking processes must be controlled to assure conformity with specified requirements.
Define a list of equipment for which packaging is necessary.
Suggest a method of managing special packaging by product (dates, modes, duration).
Periodically check the quality of packaging.
Use appropriate packaging specific to the products.

Audit question

Does the supplier control wrapping, packaging and marking processes to assure conformity with the specified requirements? Is there a list of equipment requiring packaging?

Level 1	Product packaging is not defined, the materials used for this packaging are used depending on their availability. Information about packaging dates, management methods inspections to be carried out is not defined.
Level 2	Standard packaging is used for the products. Information about the packaging is given. No specific inspection of the packaging.
Level 3	Special product packaging is provided, and documentation is associated with it No specific inspection of the packaging.
Level 4	Special product packaging is provided, and documentation is associated with it. A specific regular inspection of the packaging is made A procedure regularly checks that periodic inspections are applied.

Recommendation Manage storage.	**N°** 11

Phases in which the recommendation is applicable **Weight**

Phase	Weight
INTEGRATION INTO EQUIPMENT	10.8
INTEGRATION INTO SYSTEM	10.8
OPERATION AND MAINTENANCE	15.6

Further description

Designated storage areas or premises must be used to prevent damage or deterioration of the product.
Appropriate measures are taken to allow reception in these areas and shipment from them.
The state of the product in stock must be evaluated at appropriate intervals to detect any deterioration.
Manage and control atmospheres in storage.
Tailor positioning in storage.
Manage periodic actions to maintain product characteristics in storage (powering on).

Audit question

Are there any designated storage areas or premises? Are they used to prevent damage or deterioration of the product? Are appropriate measures taken to enable reception and shipping in these areas?

Level 1	Product storage areas are not specific, the storage environment is not considered.
Level 2	Product storage areas are not specific, the storage environment is controlled and adapted to the stored products.
Level 3	Product storage areas are specific. The storage environment is controlled and adapted to the stored products. Storage positions are individually defined. Periodic actions are carried out to maintain product characteristics.
Level 4	Product storage areas are specific. The storage environment is controlled and adapted to the stored products. Storage positions are individually defined. Periodic actions are carried out to maintain product characteristics. The condition of products in stock is regularly inspected, the stock is verified and storage conditions are regularly optimised.

Recommendation Maintain delivery conditions.	**N°** 12

Phases in which the recommendation is applicable **Weight**
INTEGRATION INTO EQUIPMENT 17.5
INTEGRATION INTO SYSTEM 17.5

Further description

The supplier shall take measures to protect the product quality after inspections and final tests. When specified in the contract, this protection is extended to include delivery for final use.

The supplier makes sure that the accompanying documentation for the product as specified at the order is present at the time of the delivery, and that it is protected against loss and damage.

Audit question

Does the supplier take steps to maintain the product quality after the inspections and final tests? When specified in the contract, are these steps extended to include delivery for final use?

Level 1	Normal protections for products during delivery are not used
Level 2	Product quality protections are used during delivery to the customer. The supplier does not check that accompanying documents are present.
Level 3	Product quality protections are used during delivery to the customer. The supplier does check that accompanying documents are present, but does not protect them against loss and deterioration.
Level 4	The supplier takes measures to protect the product quality during delivery for its final use. He assures that the accompanying documentation for the product is present as specified at the time of the order, and that the documentation is protected against loss and deterioration.

Recommendation Perform inspections and tests during the phase.	**N°** 13

Phases in which the recommendation is applicable — **Weight**

Phase	Weight
INTEGRATION INTO EQUIPMENT	7.2
INTEGRATION INTO SYSTEM	7.2
OPERATION AND MAINTENANCE	11.2

Further description

During the phase, the product must be inspected and tests must be carried out in accordance with the quality plan and/or written procedures.

The product must remain blocked until the required inspections and tests are terminated, or until the necessary reports have been received and verified.

Audit question

Is there any risk that a product that has not satisfied inspections and tests specified during one phase will go on to the next phase without corrective action?

Level 1	No inspection or test during the phase.
Level 2	Inspections are carried out during the phase, but they are not formalised in the form of written procedures or quality plan.
Level 3	Inspections are carried out during the phase and are formalised in the form of written procedures or a quality plan. These inspections and test are not always complete.
Level 4	Inspections are carried out during the phase and are formalised in the form of written procedures or a quality plan. These inspections and tests are complete.

Recommendation	**N°**
Perform final inspections and tests.	14

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT 7.9
INTEGRATION INTO SYSTEM 7.9
OPERATION AND MAINTENANCE 10.4

Further description

Perform all final inspections and tests in accordance with the quality plan and/or written procedures.

The quality plan and/or procedures for final inspections and tests must require that all specified inspections and tests, including those defined for product reception, are carried out and that the results are conforming with requirements.
Before shipment, make sure that:
All activities specified in the quality plan and/or written procedures have been satisfactory accomplished,
The associated data and documentation are available and accepted.

Audit question

Have all final inspections and tests been carried out in accordance with the quality plan and/or written procedures?

Level 1	No final inspection or test.
Level 2	Final inspections and tests are carried out, but they are not described in strict procedures or in a quality plan.
Level 3	Final inspections and tests are carried out, They are described in strict procedures or in a quality plan. Application of these inspections and tests is not verified and validated.
Level 4	Final inspections and tests are carried out in accordance with the quality plan and/or written procedures. The quality plan and/or procedures for final inspections and tests require that all specified inspections and tests, including those specified for product reception or during its manufacturing, are done and that the results are conforming with the requirements. It is checked before shipment that: All activities specified in the quality plan and/or in written procedures have been satisfactorily accomplished Data and the associated documentation are available (follower sheet type document that records the configuration, operations carried out and observed anomalies) and accepted.

Recommendation Carry out inspections and tests specific to reception	**N°** 15

Phases in which the recommendation is applicable — **Weight**

INTEGRATION INTO EQUIPMENT 6.7
INTEGRATION INTO SYSTEM 6.7

Further description

Make sure that the incoming product is not used or implemented until it has been inspected or until its conformity with specified requirements has been verified in another way.

The check on conformity with specified requirements must be made in accordance with the quality plan and/or written procedures.

Inspections carried out in the premises of subcontractors and proofs of conformity provided must be taken into account to determine the importance and nature of inspections to be carried out on reception.

When the incoming product is released before it has been verified for reasons of urgency, it must be identified and this release shall be recorded.

Audit question

Are appropriate inspections and tests carried out on incoming products before use?

Level 1	No inspection or test on reception
Level 2	Inspections and tests are carried out on reception, but no procedure specific to these actions is described.
Level 3	Conformity with specified requirements is verified in accordance with a quality plan and/or written procedures. There is no monitoring of products allowed to enter without inspections in case of urgency.
Level 4	Conformity with specified requirements is verified in accordance with a quality plan and/or written procedures. Inspections carried out in subcontractor premises and proofs of conformity supplied are taken into account to determine the importance and nature of inspections to be carried out on reception. When the entering product is released before it has been verified for reasons of urgency, it is identified and this release is recorded.

Recommendation Make sure that a person responsible for logistics support, industrialisation, purchasing, development and RAMS (concurrent engineering) is involved at each step	**N°** 16

Phases in which the recommendation is applicable **Weight**

DESIGN..16.7

Further description

Make sure that a person responsible for logistics support, industrialisation, purchasing, development and RAMS is involved at every step.
Make sure that the baseline used allows simultaneous engineering. The contractor's organisation is based on permanent specialists of the function.

Audit question

Is the point of view of the different disciplines involved in engineering taken into account?

Level 1	The baseline does not impose any simultaneous engineering.
Level 2	There is a global instruction that does not specify the methods. No formal organisation.
Level 3	There is a procedure imposing simultaneous engineering but it is not adapted to the company organisation; positions responsible for logistics support, industrialisation, purchasing, development and RAMS are allocated independently from their businesses
Level 4	There is a procedure imposing simultaneous engineering. The organisation of the company is based on permanent specialists of the function.

Recommendation	**N°**
Monitor inspection parameters during varnishing activity.	17

Phases in which the recommendation is applicable	**Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY	9.9

Further description

The subassembly varnishing activity, that must result in immunity to a number of stresses that can reduce the reliability of the subassembly, must be carried out with a permanent inspection particularly dealing with monitoring of the main parameters that are:

- The humidity rate,
- The temperature,
- The quality of varnish constituents,
- The thickness of the varnish deposit.

The varnish viscosity must also be checked at least daily.

Audit question

Are inspection parameters monitored during the varnishing activity?

Level 1	No inspection parameters are monitored during the varnishing activity.
Level 2	The varnishing activity is monitored by supervision of a number of mentioned parameters at the stipulated frequency, but there is no formal documented monitoring and no study indicating their criticality for reliability of the subassembly.
Level 3	The varnishing activity is monitored by supervision of a number of mentioned parameters at the stipulated frequency. These parameters are monitored and derived from a critical analysis of the varnishing activity regarding the reliability of the subassembly. But this criticality plan was generated without being validated by an independent authority.
Level 4	The varnishing activity is monitored by supervision of a number of mentioned parameters at the stipulated frequency. These parameters are monitored and derived from a critical analysis of the varnishing activity regarding the reliability of the subassembly. This criticality plan was generated and then validated (parameters monitored and implemented) by an independent authority.

Recommendation Perform corrective maintenance as soon as an anomaly appears on production means or produced subassemblies.	**N°** 18

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6.9
INTEGRATION INTO EQUIPMENT 6.9

Further description

Maintenance procedures related to corrective actions in production must include:

- Effective processing of complaints and subassembly nonconformity reports,
- The search for causes of nonconformity related to the process and recording of the results of this search,
- Determination of corrective actions necessary to eliminate causes of nonconformity,
- Application of control means to assure that the corrective action is implemented and that it produces the required effect.

Audit question

Does corrective maintenance take place as soon as an anomaly appears on production means or produced subassemblies?

Level 1	There is no corrective maintenance after an anomaly appears on a production means or a subassembly.
Level 2	Corrective actions are made directly where the anomaly was observed, although a corrective maintenance plan was not set up.
Level 3	Real maintenance procedures related to corrective actions are implemented, a formal corrective maintenance procedure is applied for them but it has not been validated by an authority independent from the operating entity.
Level 4	Real maintenance procedures related to corrective actions are implemented, a formal corrective maintenance procedure is applied for them and has been validated by an authority independent from the operating entity.

Recommendation Perform preventive maintenance to correct drifts to production means parameters.	**N°** 19

Phases in which the recommendation is applicable **Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY 4
INTEGRATION INTO EQUIPMENT 4

Further description
Based on the defined preventive maintenance plan and after its production, a correction is made by:
redefining production means references,
replacement of consumables,
replacement of worn and therefore potentially defective parts (probes and inspection tools).

Audit question
Is preventive maintenance planned to correct drifts to production means parameters?

Level 1	There is no preventive maintenance to correct any drifts of production means.
Level 2	Preventive actions are carried out directly where the anomaly might be detected, although there no formal preventive maintenance plan is set up.
Level 3	Real maintenance procedures are implemented for preventive actions, there is a formal preventive maintenance plan for them but it has not been validated by an authority independent from the operating entity.
Level 4	Real maintenance procedures are implemented for preventive actions, there is a formal preventive maintenance plan for them and it has been validated by an authority independent from the operating entity.

Recommendation Adopt a policy of control of risks associated with nonconformities.	**N°** 20

Phases in which the recommendation is applicable **Weight**
OPERATION AND MAINTENANCE 16.3

Further description
A policy is applied aimed at identifying, evaluating and managing potential risks associated with nonconformities, non only on products but also on all design, planning, manufacturing, assembly, inspection processes, etc.
This policy must take account of potential risks associated with human factors.

Audit question
Is a policy applied aimed at identifying, evaluating and managing potential risks associated with nonconformities, on products and also on all design, planning, manufacturing, assembly and inspection processes, etc?

Level 1	No policy is applied to evaluate risks of nonconformity.
Level 2	There is a policy aimed at identifying, evaluating and managing potential risks associated with nonconformities only on products. But not on all design, planning, manufacturing, assembly, inspection processes, etc.
Level 3	There is a policy aimed at identifying, evaluating and managing potential risks associated with nonconformities, not only on products but also on all design, planning, manufacturing, assembly, inspection processes, etc. This policy does not take account of potential risks associated with human factors.
Level 4	There is a policy aimed at identifying, evaluating and managing potential risks associated with nonconformities, not only on products but also on all design, planning, manufacturing, assembly, inspection processes, etc. This policy takes account of potential risks associated with human factors.

Recommendation Verify programming means periodically, so that the software loading operation is correctly performed.	**N°** 21

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 4.1
INTEGRATION INTO EQUIPMENT 4.1

Further description

This verification is less complicated than a planned preventive maintenance action, and should be done by the user of the means (it forms part of the operator's training). Its purpose is to make sure that the operation will be done correctly and that it will provide the expected result (using the right loaded software or a correct configuration).
The frequency of the verifications (to be defined) may be systematic before each use or after a defined number of uses of the means.

Audit question

Is there a periodic verification of programming means so that the software loading operation is done correctly?

Level 1	There is no periodic verification of the programming means used to load software.
Level 2	A number of verifications are carried out on the production means. These verifications are brief and do not necessarily take account of all software loading rules. There is no clear formal definition of the procedure or the limits of these verifications.
Level 3	Planning of verifications has been studied, this planning is respected and a written document has been produced verifying all points (and way this was done).
Level 4	Strict planning of verifications has been studied, this planning is respected and a written document has been produced verifying all points (and way this was done). This document was produced taking account of the entire software loading process and was validated by an authority independent from the operating entity.

Recommendation Systematically audit final test operators for monitoring of skills.	**N°** 22

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 4.1
INTEGRATION INTO EQUIPMENT 4.1

Further description

This filter assures that the final test that forms the final verification milestone is carried out by a competent person and particularly a person whose skills are monitored to assure that the most recent requirements are taken into consideration.

The audit assures that the operator reviews control over procedures and critical points, to achieve perfect confidence in execution of the final test.

Audit question

Are the skills of final test operators systematically audited?

Level 1	No audit is done to monitor operator skills.
Level 2	The equivalent of an audit is done to monitor the skills of operators performing the final product test, but it is not formally defined.
Level 3	An audit is done to monitor the skills of operators performing the final product test and this audit follows an identified formal definition, although it has not been validated by an authority independent from the operating entity.
Level 4	An audit is done to monitor the skills of operators performing the final product test and this audit follows an identified formal definition, This audit has been validated by an authority independent from the operating entity.

Recommendation Automate manipulations to limit possible degradations on subassemblies.	**N°** 23

Phases in which the recommendation is applicable — **Weight**

Phase	Weight
MANUFACTURING OF BOARD OR SUBASSEMBLY	6.5
INTEGRATION INTO EQUIPMENT	6.5

Further description

It is important to perform the minimum number of manipulations of subassemblies during the production phase to limit risks of mechanical shocks and other overstresses.
Furthermore, the automation of manipulations between activities during the entire production provides a means of eliminating a large number of failures caused by human intervention.
This recommendation remains applicable to very small series

Audit question

Are production and manipulation of subassemblies automated?

Level 1	No manipulation of subassemblies is automated.
Level 2	A number of manipulations of subassemblies has been automated.
Level 3	Manipulations of subassemblies are automated. The level of automation was studied in a feasibility and result study. The whole procedure is formalised, although the study has not been validated by an authority independent from the operating entity.
Level 4	Manipulations of subassemblies are automated. The level of automation was studied in a feasibility and result study. The whole procedure is formalised, and has been validated by an authority independent from the operating entity.

Recommendation Collect customer comments about the product reliability during operational functioning.	**N°** 24
Phases in which the recommendation is applicable **Weight** SUPPORT PROCESS ACTIVITIES 7.9	
Further description Collect information about product reliability in its operational environment from customers and users of the product, and carry out associated action plans.	
Audit question Are customer comments about product reliability collected during operational functioning?	
Level 1	No information about the product reliability perceived by the customer is available.
Level 2	There is some available information about product reliability perceived by the customer.
Level 3	Customer satisfaction inquiries have been carried out dealing with the reliability aspect.
Level 4	Customer satisfaction inquiries have been carried out dealing with the reliability aspect, action plans aimed to improve the reliability have been set up, and the customer has seen the results.

Recommendation	**N°**
Check and maintain data loaded in the programmable production means (by updating).	25

Phases in which the recommendation is applicable	**Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY	2.8
INTEGRATION INTO EQUIPMENT	2.8

Further description
It is essential to specifically monitor and maintain (by updating) references coordinates, batch numbers, etc.) loaded in production tools, for the automation of tasks and for reliable execution of activities.

Audit question
Are data loaded in programmable production means managed?

Level 1	There is no check on maintenance of programming data in programmable production means.
Level 2	A check and/or maintenance of parameters loaded into programmable production means is/are done, but there is no formal definition of actions to be carried out to guarantee this maintenance.
Level 3	A check and maintenance of data programmed in production means are done, in accordance with an identified formal definition (document, inspection procedure, update procedure).
Level 4	A check and maintenance of data programmed in production means are done, in accordance with an identified formal definition (document, inspection procedure, update procedure). All documents have been validated by an authority independent from the operating entity.

Recommendation	**N°**
Completely describe the environment in which the product will be used and maintained.	26

Phases in which the recommendation is applicable **Weight**

SPECIFICATION..12.4

Further description

Describe the environment in which the product will be stored, transported, used and maintained.
Describe average and maximum quantitative values for the following characteristics:
Temperature,
Humidity
Shocks
Vibrations,
Pressure
Penetration/abrasion,
Ambient light,
Mounting position,
Weather (wind, rain, snow),
Operators' qualification level.

Audit question

Is there a description and characterisation of the environment in which the product will be stored, transported, used and maintained?

Level 1	The product environment is not known (or is hardly known), the manufacturer has not defined any formal assumption.
Level 2	The product environment is partially known (applicable parameters defined in the recommendation are partially known) but no document lists these parameters and complementary assumptions.
Level 3	The product environment is partially known (applicable parameters defined in the recommendation are partially known), the manufacturer has made complementary assumptions and formalised them in a document.
Level 4	The product environment is known perfectly (applicable parameters defined in the recommendation are known). A document lists all these parameters.

Recommendation Describe the process to improve the product reliability and the associated objectives.	**N°** 27
Phases in which the recommendation is applicable SUPPORT PROCESS ACTIVITIES	**Weight** 6.3
Further description Fix objectives for improving the company's reliability engineering annually.	
Audit question Are there any objectives to improve the process to construct product reliability?	
Level 1	There is no process for construction of reliability in the company.
Level 2	The reliability construction process is described.
Level 3	The reliability construction process is described, progress actions are defined informally.
Level 4	The reliability construction process is described, maintained and applied fully. Annual improvement objectives are fixed, action plans are defined and a summary of results obtained is made.

Recommendation Define product failure.	**N°** 28
Phases in which the recommendation is applicable — **Weight** SPECIFICATION 10.3	
Further description Precisely define what will be considered as a product failure (possibilities of acceptable degraded modes).	
Audit question What is considered as a product failure?	
Level 1	No description of the product failure was defined during the call for bids (or the contract). The customer has not given any list of feared events. The customer has not defined any degraded mode. The manufacturer has not defined these elements for his study.
Level 2	The manufacturer has produced the description of the product failure and (or) the list of feared events, and (or) product degraded modes without formal validation by the customer.
Level 3	The manufacturer has produced the description of the product failure and (or) the list of feared events, and (or) product degraded modes with formal validation by the customer.
Level 4	Product failures are perfectly identified in the call for bids (or the contract). The list of feared events is supplied in the call for bids (or the contract). Degraded modes are also described in the call for bids (or the contract).

Recommendation Define the method of demonstrating product reliability during operational phases.	**N°** 29

Phases in which the recommendation is applicable **Weight**

SPECIFICATION..9.8

Further description

Define the method of demonstrating the product reliability (this method must be accepted by the customer).

Clearly describe the method selected to demonstrate that the product is conforming with the specified reliability, particularly taking account of the real life profile, treatment of the early life period, the confidence level used for measurement (e.g. > high limit at 60%), failures due to reliability. For example, this can include classes C, E, F, V1 in the following classification of the origin of technical events.

C: Random failure of a component / E: Incomplete study (or defective design) / F: Manufacturing outside standard (or production defect) / M: Manipulation too severe (or failure to respect the user and maintenance documentation) / O: Special check (check correct operation) / P: Preventive maintenance / R: Application of a retrofit / S: Consequence of another failure (or secondary failure) / V: Aging of equipment (1 Unexpected wear, 2 life limits exceeded) / X: Use outside specifications / Y: Abnormal technical events (or unconfirmed anomaly) / ?: Undetermined origin or cause.

Measurement method: e.g. No. of hours of flight / No. of failures with determined causes. In general, conformity with a requirement can be verified by one of the following four methods depending on its nature:

· Inspection (I): Visual or dimensional verification of product constituents. The verification is based on human senses (view, touch) or uses simple measurement and manipulation methods. No stimulus is necessary. Passive means such as a measuring tape, microscope, gauge etc. can be used.

· Analysis (A) : Verification based on analytic proofs obtained by calculation, without any intervention on product constituents. The techniques used are modelling, simulation and prediction. E.g. predicted reliability calculation.

· Demonstration (D) : Verification of observable characteristics on product constituents while functioning, without the use of physical measurements. Examples: demonstration of a start sequence, functioning of a safety sequence, functioning of a built-in test device, etc.

· Test (T) : Verification of measurable characteristics, directly or indirectly accessible. Standard or specific test equipment is usually required. E.g. measurement of operational reliability.

Audit question

How is it planned to demonstrate the product reliability?

Level 1	The product environment is not known (or hardly known), the manufacturer has not produced any formal assumption.
Level 2	The call for bids (or the contract) includes a request to demonstrate reliability but does not contain any details about the measurement method.
Level 3	The call for bids (or the contract) includes a request for demonstration, but the description of the method to be used only partially satisfies the recommendation.
Level 4	The method of demonstrating the product reliability is defined perfectly in the call for bids or the contract (in accordance with the content of the recommendation).

Recommendation Define the degree of nonconformity.	**N°** 30

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT	10.3
INTEGRATION INTO SYSTEM	10.3
OPERATION AND MAINTENANCE	12.8

Further description

The description of the accepted nonconformity or repairs made is recorded to indicate the real condition of the product.
Written procedures are kept up to date defining at least:
The process for classification of nonconformities and control over the use of nonconforming components in finished products,
The formal authorisation process and the application field for personnel authorising the use of replacement materials and/or nonconforming products (waiver procedures),
The process for control of scrapped parts.

Audit question

Is the description of the accepted nonconformity or of the repairs performed recorded to indicate the product's real condition?

Level 1	There is no information about the degree of nonconformity of the product.
Level 2	The indication of the degree of nonconformity of the products is only used for information, its purpose is not to make a decision about whether or not to use the nonconforming equipment.
Level 3	The description of the accepted nonconformity or the repairs made is recorded to indicate the real condition of the product. Written procedures define the process for classification of nonconformities and control over the use of nonconforming components in finished products. The process for authorisation of personnel to use replacement materials and/or nonconforming products is not formalised.
Level 4	The description of the accepted nonconformity or the repairs made is recorded to indicate the real condition of the product. Written procedures are kept up to date defining: The process for classification of nonconformities and control over the use of nonconforming components in finished products. The formal process for authorisation and the application field for personnel authorising the use of replacement materials and/or nonconforming products. The process for control over scrapped parts.

Recommendation Define the product life profile for which reliability performances are expected.	**N°** 31

Phases in which the recommendation is applicable — **Weight**

SPECIFICATION..9.9

Further description

Define the life profile for the product (breakdown into operational scenarios for which reliability performances are expected).
Give successive phases for use of the product (environment/phase duration pair).
The description shall cover at least the following phases:
Storage (non-functioning, protected environment, small temperature variation, controlled humidity, etc.),
Non-functioning (the product possibly being in its operational environment),
Operational functioning (e.g. in flight, taxiing, navigation, etc.).

Audit question

Is the usage profile of the product for which reliability performances are expected defined?

Level 1	The life profile is not defined.
Level 2	The life profile is not provided in the specification, but it was defined completely or partially by the manufacturer with no validation by the customer.
Level 3	The life profile provided in the specification (contract) and that partially satisfies the recommendation or that was partially defined by the manufacturer and formally validated by the customer.
Level 4	The life profile provided in the specification (contract) satisfies the recommendation or was defined completely by the manufacturer and formally validated by the customer.

Recommendation Define the means necessary for inspection and test of the product.	**N°** 32

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT 11.6
INTEGRATION INTO SYSTEM 11.6
OPERATION AND MAINTENANCE 14.3

Further description

Product inspection and test procedures must specify resources (men, means), methods to be implemented, acceptance criteria and methods of recording the results.
These procedures must also define the training and if necessary require operators' qualification.

Audit question

Are means necessary for inspections and tests of the product defined?

Level 1	No product inspection or test procedure has been specified, there is no description of methods and acceptance criteria.
Level 2	Product inspection or test procedures are specified. Acceptance methods and criteria are described. The results are not kept.
Level 3	Product inspection or test procedures are specified. Acceptance methods and criteria are described. Results are not recorded and used for feedback from operations. Procedures also describe training and qualification of operators.
Level 4	Product inspection or test procedures are specified. Acceptance methods and criteria are described. Results are recorded and used for feedback from operations. Procedures also describe training and qualification of operators.

Recommendation Delegate the general inspection of the subassembly varnishing operation, to optimise filtering before continuing doing the process.	**N°** 33

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 4.4

Further description

Delegation of the general inspection assures objectivity making it possible to better filter any errors that could have occurred during processes used for varnishing of subassemblies and critical for reliability.

Filling in the follower sheet enables traceability of all operations and actions that occurred during this varnishing.

Audit question

Is the subassembly varnishing inspection done by someone other than the varnishing operator?

Level 1	No general inspection is carried out at the end of varnishing.
Level 2	A person other than the varnishing operator makes a general inspection of this operation, but this inspection is not based on any formal document describing the procedure.
Level 3	A person other than the varnishing operator makes a general inspection of this operation. This inspection is done according to a formalised procedure but this document has not been validated by an independent authority.
Level 4	A person other than the varnishing operator makes a general inspection of this operation. This inspection is done according to a formalised procedure described in a document that has been validated by an authority independent from the operating entity.

Recommendation Have personnel qualified for test means, measurements and relevant standards.	**N°** 34

Phases in which the recommendation is applicable **Weight**

DESIGN..5.8

Further description

Set up training courses so that the person is in full control of the test means, standards and interpretation of measurements: planned training and monitoring of skills

Audit question

What measures have been taken so that the person concerned is qualified for the test means, measurements and relevant standards?

Level 1	No training or monitoring of skills on these points
Level 2	There are training courses but not followed, no individualisation of training courses
Level 3	Training followed individually.
Level 4	Training followed individually with update. Skills are monitored for all personnel concerned

Recommendation Have documents for performing incoming inspection on supplies.	**N°** 35

Phases in which the recommendation is applicable	**Weight**
INTEGRATION INTO EQUIPMENT	8.8
INTEGRATION INTO SYSTEM	8.8
OPERATION AND MAINTENANCE	9.9

Further description

Purchasing documents must include the following when applicable:

The type, category and any other precise identification, the title or any other formal identification and the applicable edition of specifications, drawings, requirements for processes, inspection instructions and other relevant technical data, the title, identifier and edition of the quality system standard to be applied, purchasing document reviewed and approved before distribution to assure that they are capable of satisfying the requirements.

Documented procurement requirements must include the following when applicable:

Tests, examinations, inspections and acceptance conditions imposed by the customer, and any relevant instructions or requirements, requirements related to specimens (production method, number, storage conditions) for inspections, investigations or audits, requirements related to notification of anomalies, changes to the definition and approval of their processing.

Suppliers must be notified about customer requirements.

Audit question

Are there any documents for performing incoming inspection on supplies?

Level 1	No documentation specific to the incoming inspection on supplies.
Level 2	Product identification documents are the only documents used for the incoming inspection on supplies.
Level 3	Purchasing documents include a precise identification, the applicable edition of specifications, drawings, requirements in terms of process, inspection instructions and other relevant technical data, the title, identifier and edition of the quality system standard to be applied, purchasing documents reviewed and approved before distribution, to assure that they satisfy the requirements.
Level 4	Purchasing documents include a precise identification, the applicable edition of specifications, drawings, requirements in terms of process, inspection instructions and other relevant technical data, the title, identifier and edition of the quality system standard to be applied, purchasing documents reviewed and approved before distribution, to assure that they satisfy the requirements. Documented procurement requirements also include: Tests, examinations, inspections and customer acceptance conditions and any relevant instruction or requirements, requirements related to specimens (production method, number, storage conditions) for inspections, investigations or audits, requirements related to notification of anomalies, changes to the definition and approval of their processing The customer's requirements are forwarded to suppliers.

Recommendation Have a document justifying preliminary technical studies on reliability,	**N°** 36

Phases in which the recommendation is applicable **Weight**
DESIGN..8

Further description
Make sure that all data justifying the need are available and are validated in a preliminary reliability study document. A directive imposes that this document is written.

Audit question
Is there a list of justification elements?

Level 1	No justification document.
Level 2	There is an informal justification document.
Level 3	There is a formalised and identified document in the justification file, which assures that all requirements are satisfied.
Level 4	There is a formalised and identified document in the justification file, which assures that all requirements are satisfied. A directive imposes that this document is written.

Recommendation Have experienced personnel in the subassembly drying activity after varnishing.	**N°** 37

Phases in which the recommendation is applicable **Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY 5.6

Further description
The particular subassembly drying task within the varnishing activity requires know-how by the operator, who therefore needs to be experienced if it is required to avoid overstressing subassemblies. Reduced reliability due to an excessively high temperature, an excessively long application or imperfect drying, can cause serious degradations in the remainder of the process.

Audit question
Is the subassembly drying activity after varnishing carried out by experienced personnel?

Level 1	The subassembly is not dried by experienced personnel.
Level 2	Operators drying the subassembly are experienced. Their experience is based on activities very similar to drying subassemblies but no specific training has been given to them.
Level 3	Operators drying the subassembly are experienced. Their experience is proven in formal documents but not validated by an independent authority.
Level 4	Operators drying the subassembly are experienced. Their experience is based on similar drying activities. This experience is proven in formal documents validated by an independent authority.

Recommendation Assure that know-how is recorded by business procedures	**N°** 38
Phases in which the recommendation is applicable **Weight** DESIGN..13.8	
Further description Have a means of recording know how and technical standards through business procedures (information recording the designer's know how: guidelines, checklist, process, operating methods, etc.). Manage and monitor these procedures as a function of changes to techniques.	
Audit question Is there any management of business procedures?	
Level 1	No business procedures.
Level 2	Existence of incomplete procedures that are not managed.
Level 3	Existence of managed and validated procedures.
Level 4	Existence of managed and validated procedures covering all businesses, particularly reliability.

Recommendation Have and manage a table of skills required by activity, including names.	**N°** 39
Phases in which the recommendation is applicable **Weight** DESIGN..24.5	
Further description Make sure that the skills required for an activity are assigned by name in a regularly reviewed skills table and periodically verify that training is appropriate for the activities.	
Audit question Is there any management of skills?	
Level 1	No monitoring of suitability for training.
Level 2	There is a skills table but this table is not monitored in training.
Level 3	Training tables are regularly updated, but there is no periodic verification that training is suitable for the activities.
Level 4	There is a skills table and training is periodically monitored and updated. There are regular evaluations of the suitability of training to satisfy the company's objectives.

Recommendation Define the context associated with the product reliability requirements.	**N°** 40
Phases in which the recommendation is applicable **Weight** SPECIFICATION..8.1	
Further description The following essential elements must be taken into account in formulating the requirement for a reliability specification: - Quantitative formulation of the reliability requirement, - Complete description of the environment in which the system will be stored, transported, used and maintained, - Life profile of the product for which Reliability performances are expected, - Clear identification of the type of time measurement (Hours of operation, Hours of flight, cycles, etc), - Clear definition of what forms a failure, - Clear description of the method selected to demonstrate that the system is confirming with the specified reliability, - Associate penalties with a failure to satisfy reliability requirements.	
Audit question What is the context associated with product reliability requirements?	
Level 1	The customer did not take account of the recommendation and the necessary information (according to the recommendation) was not provided.
Level 2	Partial identification of customer reliability requirements as requested in the recommendation.
Level 3	Complete identification of customer reliability requirements as requested in the recommendation.
Level 4	Complete identification of customer reliability requirements as requested in the recommendation at the time of the call for bids

Recommendation Give instructions (protocol and particular instructions to be respected) to operators.	**N°** 41

Phases in which the recommendation is applicable **Weight**

Phase	Weight
MANUFACTURING OF BOARD OR SUBASSEMBLY	7.4
INTEGRATION INTO EQUIPMENT	7.4

Further description
Operators must be provided with a workstation datasheet or any other information means describing actions to be carried out and different instructions and protocols to be followed.

Audit question
Are the instructions (protocol and particular instructions to be respected) given to operators?

Level 1	There are no instructions for operators.
Level 2	A number of instructions are provided at the workstation, but they are not necessarily given to the operator.
Level 3	Instructions related to the activity to be performed do exist and are formalised in documents (workstation sheets, protocols, etc.). They are given to each operator responsible for carrying out an activity. These documents have not been validated by an authority independent from the operating entity.
Level 4	Instructions related to the activity to be performed do exist and are formalised in documents (workstation sheets, protocols, etc.). They are given to each operator responsible for carrying out an activity. These documents have been validated by an authority independent from the operating entity.

Recommendation Make records of temperature profiles for each program used in the soldering means to make sure that there is no aggression to the subassembly.	**N°** 42

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6.9

Further description

Take readings of temperature profiles for each program used with the soldering means to precisely determine levels that were applied (amplitude and duration so as to verify that values remain within the required range during execution of the activity).

Audit question

Are there any records of temperature profiles for each program used for the soldering means?

Level 1	No readings are taken during execution of the program.
Level 2	A number of readings are taken during execution of the activity and may be used to find levels applied on the subassembly. These readings are carried out sporadically and there is no precise formal definition for them.
Level 3	Readings are used to precisely know levels applied on subassemblies. They are done according to a predefined formal definition (document indicating the protocol, frequency, etc.), but they have not been validated by an authority independent from the operating entity.
Level 4	Readings are used to precisely know levels applied on subassemblies. They are done according to a predefined formal definition (document indicating the protocol, frequency, etc.), and these documents have been validated by an authority independent from the operating entity.

Recommendation	**N°**
Eliminate all possibilities of ambiguous use of a tool to avoid inadequacy between the production means and the subassembly to which it is applied.	43

Phases in which the recommendation is applicable	**Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY	7.2
INTEGRATION INTO EQUIPMENT	7.2

Further description

The description of actions to be carried out during application of a production tool on a subassembly must be sufficiently explicit to not allow interpretation by the operator that would result in accidental use of inappropriate means.

It must be assured that the reliability of subassemblies will not be reduced by the use of an unsuitable tool.

Audit question

How is it assured that production means are adapted to elements to be produced?

Level 1	There is no explicit description assuring that there will be no mismatch between production means and the subassembly.
Level 2	A number of criteria need to be verified to assure that the means are suitable for the subassembly, but they are not formally identified in a document.
Level 3	Each production means is accompanied by a description of a set of parameters to be verified before use on a subassembly. These are formally identified in a document that has not been validated by an authority independent from the operating entity.
Level 4	Each production means is accompanied by a description of a set of parameters to be verified before use on a subassembly. This description is sufficiently explicit so that the identified means match the subassembly. All parameters to be verified are formalised in a document that has been validated by an authority independent from the operating entity.

Recommendation Write a collection of business recommendations dealing with manipulation and storage operations at the user, for use by Logistics Support.	**N°** 44

Phases in which the recommendation is applicable **Weight**

DESIGN....................7.7

Further description

Make sure that there is a list of business recommendations on manipulation and storage operations at the user, for use by Logistics Support. This collection must be enriched by feedback from operations.

Audit question

Is there a collection of business recommendations for manipulation and storage operations at the customer?

Level 1	No collection of recommendations and no procedures for processing of feedback from operations.
Level 2	There is non formalised and unmanaged collection of recommendations. Feedback from operations is dealt but not systematically.
Level 3	There is a formalised collection of recommendations but it is not necessarily applicable to the project (not referenced to the project) and is not validated. Feedback from operations formalised in a base that is not managed and is not much used in design.
Level 4	Formalised collection of recommendations, validated and referenced to the project. Formalised and validated feedback from operations, referenced to the project, useable and acting as design input data to improve reliability.

Recommendation Perform a company quality certification.	**N°** 45

Phases in which the recommendation is applicable — **Weight**

SUPPORT PROCESS ACTIVITIES 6.5

Further description

Certify the company quality system according to ISO 9001 V2000

Audit question

The company has one or several quality certifications, for example ISO 9001 Version 2000

Level 1	The manufacturer has not set up a quality system.
Level 2	The manufacturer has set up a quality system but there is no standard quality certification for it, or the certification is more than a year old.
Level 3	The manufacturer has set up a quality system and has obtained a certification. For example ISO 9000 V2000.
Level 4	The manufacturer has set up a quality system and has obtained a certification. For example ISO 9000 V2000. He regularly audits his reliability activity internally (at least once every two years) to define progress actions.

Recommendation Record problems that could require the application of corrective and/or preventive actions (on an Anomaly datasheet).	**N°** 46

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 7.6
INTEGRATION INTO EQUIPMENT 7.6

Further description

Recording on an Anomaly datasheet type document facilitates monitoring of different malfunctions.
This anomaly datasheet is one of the main documents used to implement preventive and/or corrective maintenance actions.
The assembly contributes to traceability for management of nonconformities (products and means).

Audit question

How are technical events or anomaly reports recorded?

Level 1	No records are kept and there is no traceability of problems encountered during production.
Level 2	Critical points are identified and can be transmitted to initiate corrective actions, but no formal definition is made.
Level 3	Every production problem, regardless of its nature, is identified and recorded in a document provided for this purpose that can then be used for preventive and corrective maintenance. Nevertheless, this form of information recording has not been validated.
Level 4	Every production problem, regardless of its nature, is identified and recorded in a document provided for this purpose and following a predefined formal format. The complete system and more particularly the way in which information is recorded for reuse during preventive and corrective maintenance, has been validated by an authority independent from the operating entity.

Recommendation

Produce procedures to assure that the product is conforming with specified requirements.

N°
47

Phases in which the recommendation is applicable	**Weight**
INTEGRATION INTO EQUIPMENT	10.6
INTEGRATION INTO SYSTEM	10.6
OPERATION AND MAINTENANCE	6.8

Further description

Produce written procedures to assure that the purchased product is conforming with the specified requirements.
Define the terms and conditions for procurement and the responsibilities of all persons concerned.
Check that procedures are applied.

Audit question

Are there any written procedures for assuring that products are conforming with specified requirements?

Level 1	No procedures to assure that products are conforming with specified requirements. Nothing formal.
Level 2	Generic procedures (all products) are defined to assure conformity of the purchased product. There is a formal proof: e.g. note
Level 3	Procedures specific to the product are defined in a validated plan to assure conformity of the purchased product. Procurement conditions and the responsibilities of persons doing the work are not described.
Level 4	Procedures specific to the product are defined in a validated plan to assure conformity of the purchased product. Procurement conditions and the responsibilities of persons doing the work are described. Proofs that these procedures have been evaluated exist.

Recommendation Produce and maintain a preferred components list.	**N°** 48
Phases in which the recommendation is applicable **Weight** DESIGN..8	
Further description Produce and maintain a preferred components list taking account of reduced reliability characteristics.	
Audit question Is there a preferred components list?	
Level 1	No preferred components list.
Level 2	There is non formalised preferred components list, that has not been validated, and only contains technical characteristics.
Level 3	There is a managed and formalised preferred components list with standardisation objectives. It is validated by purchasing, methods and technical services and contains only technical characteristics.
Level 4	There is a managed and formalised preferred components list with standardisation objectives. It is validated by purchasing, methods and technical services and contains not only technical characteristics but also information about the reliability and failure methods of components.

Recommendation Examine and process nonconformities.	**N°** 49

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT 13.6
INTEGRATION INTO SYSTEM 13.6

Further description

The responsibility for examination and the decision to process the nonconforming product must be defined.
Written procedures must describe processing of nonconformities.
These procedures must predict that the nonconforming product can be:
reworked to satisfy the specified requirements,
accepted by waiver with or without repair.
declassified for other applications,
rejected or scrapped.
If required by the contract, the proposal for use or repair of the nonconforming product may be submitted to the customer.
The repaired and/or reworked product is inspected once again in accordance with the requirements in the quality plan and/or written procedures.

Audit question

Has the responsibility for the examination and the decision to process the nonconforming product been defined?

Level 1	The nonconforming product is not examined.
Level 2	The nonconforming product is examined and described but these actions are carried out with no written procedures.
Level 3	The nonconforming product is examined and described according to written procedures, but they do not allow for product modifications or acceptance without modification.
Level 4	The nonconforming product is examined and described according to written procedures. These specify that the product may be: Reworked to satisfy specified requirements. Accepted by waiver with or without repair. Declassified for other applications. Rejected or scrapped. If required by the contract, the proposal for use or repair of the non-conforming product is submitted to the customer. The repaired and/or reworked product is once again inspected in accordance with the requirements in the quality plan and/or the written procedures.

Recommendation Existence of a database summarising feedback from operations.	**N°** 50

Phases in which the recommendation is applicable **Weight**

DESIGN..24.2

Further description

Make sure that there is a methodology to:
gather technical events,
update,
operation.

Recording feedback from operations, with the objective of improving the reliability of future designs.

Make sure that feedback from operations is actually used by designers; existence of a usage methodology.

Audit question

Has feedback from operations been used to improve future designs?

Level 1	No recording methodology.
Level 2	Methodology initialised without update.
Level 3	Methodology updated but is unusable/not used (for example due to lack of information).
Level 4	Methodology updated, useable and used.

Recommendation Existence of a database summarising the reliability evaluation studies.	**N°** 51
Phases in which the recommendation is applicable DESIGN	**Weight** 10.6
Further description Make sure that there is centralised management of reliability evaluation studies to reuse previous calculations with stresses: clearly identified basic assumptions, data extractable and reusable by design businesses	
Audit question Is there a database recording reliability evaluation studies?	
Level 1	No database.
Level 2	There is a database but it is not centralised.
Level 3	There is a centralised database with no formal enrichment process.
Level 4	There is a centralised database with a formal and updated enrichment process.

Recommendation Existence of a database on the history of definitions and definition justifications.	**N°** 52

Phases in which the recommendation is applicable **Weight**
DESIGN..7.8

Further description

Make sure that the traceability and justification for the design are done with the objective of controlling definitions and changes.

Existence of a methodology to allow access to this information within the design office.

Audit question

Is there a database on the history and definition justifications?

Level 1	No database, nor personal expert knowledge.
Level 2	There is no explicit database but personal knowledge and experience of experts.
Level 3	Formal definition of knowledge and the history of the justification of definitions in a database, but with no procedures for updating and management of configuration monitoring.
Level 4	There are procedures for updating and management of the database.

Recommendation Make use of feedback from operations.	**N°** 53

Phases in which the recommendation is applicable **Weight**
SPECIFICATION..8.5

Further description

Make use of feedback from operations obtained from similar products used in similar environments so as to achieve a good level of confidence in maintenance of reliability performances.
Feedback from operations is also used to calibrate or check predictive reliability methods .
These studies require a large amount of time to collect operational data and precise recording of anomalies encountered.
Input data comprise
- records of observed anomalies,
- conditions for use of the product (life profile, operational environment, usage duration),
- analysis of the cause of the failure (that may or may not be due to the manufacturer).

Output data comprise:
Operational reliability that may be extrapolated for different environments and life profiles by models output from the system engineering.

Audit question

Is feedback from operations used to maintain a good level of confidence in achieving reliability performances?

Level 1	No feedback from operations is available (measurement of the operational reliability on previous projects).
Level 2	There is feedback from operations, but it is not used, nor formalised in one or more documents.
Level 3	The manufacturer's feedback from operations is used and formalised in a document. This feedback from operations does not precisely correspond to the technologies currently used. There is a validation or adjustment of predicted reliability methods.
Level 4	The manufacturer's feedback from operations is used and formalised in a document. This feedback from operations corresponds to technologies currently used in which formal similarity studies are carried out and formally defined to evaluate the differences (document). Predicted reliability methods are validated or adjusted, and regularly updated.

Recommendation Get the Operating Dependability business to participate in the functional and organisational design of the product.	**N°** 54

Phases in which the recommendation is applicable **Weight**

Phase	Weight
SPECIFICATION	12.6
DESIGN	12.6

Further description

Use reliability engineering to optimise product architecture, design choices. Give reliability engineering authority if a reliability performance is not reached

Audit question

Are the reliability criteria taken into account in the architecture of the products, and design, industrialisation and support choices?

Level 1	Reliability engineering does not make any contribution to product design.
Level 2	Participation in reliability engineering during the product design is sporadic and/or partial. The only contribution of reliability engineering is to evaluate reliability.
Level 3	Reliability engineering contributes to the design as certified in documents, but the company's baseline does not describe this participation.
Level 4	Reliability engineering contributes to the design and has the authority to make decisions if a reliability objective is not achieved. This is certified in documents. The company's baseline describes this participation. A reliability engineering guide like the FIDES Guide is applied

Recommendation Get the Operating Dependability business to participate in all phases of the project	**N°** 55
Phases in which the recommendation is applicable **Weight** SUPPORT PROCESS ACTIVITIES........8.8	
Further description The Operating Dependability (Reliability) business participates in all phases of the project, from phases before the development and until series production. The Functional Dependability business is also involved in production and operational monitoring	
Audit question Does the Operating Dependability business participate in all phases of the project?	
Level 1	No-one responsible for reliability engineering participates in the project.
Level 2	Persons responsible for reliability engineering participate partially (incomplete service according to the meaning in the recommendation) in the project, no document certifies this participation.
Level 3	Persons responsible for reliability engineering participate fully (complete service according to the meaning in the recommendation) in the project, but this participation is not formalised in a plan or procedure.
Level 4	Persons responsible for reliability engineering participate fully (complete service according to the meaning in the recommendation) in the project, and this participation is formally defined in documents.

Recommendation Train personnel concerned by Reliability or use personnel qualified in Reliability.	**N°** 56

Phases in which the recommendation is applicable **Weight**

SUPPORT PROCESS ACTIVITIES..7.5

Further description

Train personnel concerned with reliability, with training varying from awareness to expert refresher courses for reliability managers, depending on the criticality of reliability performances expected for the product.

Make production personnel aware about non-degradation of products.

Audit question

Is training of persons working on reliability appropriate for the criticality of reliability performances expected for the product?

Level 1	The reliability specialist has not received any specific training (initial or further training).
Level 2	No awareness actions have been undertaken in the company, but persons responsible for reliability studies have been trained.
Level 3	Awareness actions have been carried out for company personnel concerned by reliability (e.g. production personnel informed about non-degradation of products). Persons responsible for reliability studies have received training and are experienced.
Level 4	Awareness actions have been carried out for company personnel concerned by reliability (e.g. production personnel informed about non-degradation of products). Personnel are experienced, and business activities are organised in the company. The personnel participate in reliability conferences and present documents

Recommendation Quantitatively formulate the reliability requirement.	**N°** 57

Phases in which the recommendation is applicable **Weight**

SPECIFICATION..8.2

Further description

At least one of the following three types of specifications (or an equivalent) must be used for the specification of reliability performances (that must be quantitative):

The MTBF or the failure rate is a definition adapted to reparable systems with a long life and / or for which the life of missions is short relative to their MTBF. The validity of the assumed constant failure rate in time sometimes needs to be proven.

The probability of survival for a defined time period. For example, this specification is used when a high reliability level is required throughout the mission duration.

The probability of success independent of time for single use devices. It can also be used for devices with cyclic use.

These quantitative values shall be specified either as average values (design objectives) or minimum acceptable values below which the customer finds that the system is completely unsatisfactory with regard to his operational requirements. The objective type (design objective or minimum acceptable) shall be specified explicitly.

Audit question

Is the reliability requirement expressed quantitatively?

Level 1	No quantitative reliability requirement
Level 2	No quantitative reliability requirement, but a quantitative evaluation of reliability is required
Level 3	The specification contains one of the three types of performance specification (as defined in the recommendation). Some elements about the quantification are covered in non formalised assumptions.
Level 4	One of the three types of performance specification (as defined in the recommendation) is defined in the specification. All quantification assumptions are formally specified

Recommendation Supply resources necessary for reliability studies.	**N°** 58
Phases in which the recommendation is applicable **Weight** SUPPORT PROCESS ACTIVITIES 8.3	
Further description Allocate the necessary resources (hardware means, access to technical data, and time necessary to perform reliability studies).	
Audit question Are technical data necessary for reliability studies accessible? Are the necessary tools available? Have the necessary time and financing been allowed for?	

Level 1	No allocation of means is clearly attributed to reliability activities.
Level 2	Means are allocated to reliability activities, but insufficiently (competent personnel, adapted tools, time to perform under-sized studies).
Level 3	Means (human and equipment) are satisfactorily allocated to reliability activities.
Level 4	Means (human and equipment) are satisfactorily allocated to reliability activities, these means are described in a job management plan.

Recommendation Manage reliability study documents in configuration.	**N°** 59

Phases in which the recommendation is applicable **Weight**
SUPPORT PROCESS ACTIVITIES 5.4

Further description
Control of documentation related to reliability studies: recording, saving, archiving, validation, management of documents in configuration.

Audit question
Are reliability study documents managed?

Level 1	Reliability documents are not managed in configuration.
Level 2	Some documents are managed in configuration.
Level 3	Assumptions related to predicted calculations are specified in documents. Documentation related to reliability studies is controlled but not systematically: (Recording, saving, archiving, validation, management of documents in configuration not done systematically.
Level 4	Assumptions related to predicted calculations are specified in documents. Documentation related to reliability studies is controlled (recording, saving, archiving, validation, management of documents in configuration. Predicted reliability study documents are accessible for more than 5 years after they are produced (for comparative studies between predictions/operations).

Recommendation Manage priorities to be respected as a function of end of file dates.	**N°** 60

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY	3.1
INTEGRATION INTO EQUIPMENT	3.1

Further description

The different subassemblies are made and integrated starting from planned tasks that may correspond to simultaneous activities. Priorities have to be managed, so that only a minimum number of subassemblies needs to be stored (any time taken in routing production will require storage and additional manipulations of subassemblies), thus limiting ways in which the reliability of elements might be reduced.

Audit question

How are priorities managed as a function of end of file dates?

Level 1	No hierarchisation of priorities is done in production.
Level 2	According to production planning, some priority is given to subassemblies to minimise manipulations and storage. These priorities are not described in formal documents.
Level 3	A genuine priority management is set up as a function of end of file dates. This planning is based on formal documents that have not been validated by an authority independent from the operating entity.
Level 4	A genuine priority management is set up as a function of end of file dates. This planning is based on formal documents that have been validated by an authority independent from the operating entity.

Recommendation Identify and implement means of protecting subassemblies.	**N°** 61

Phases in which the recommendation is applicable **Weight**

Phase	Weight
DESIGN	7.3
MANUFACTURING OF BOARD OR SUBASSEMBLY	7.3
INTEGRATION INTO EQUIPMENT	7.3

Further description

List and implement protection means to avoid reducing the reliability of the subassembly.

Audit question

Have means of protecting subassemblies during some production activities been identified and implemented?

Level 1	No particular protection means is identified.
Level 2	Protection means are identified but are partially applied in different activities.
Level 3	Protection means are identified and their application is verified.
Level 4	Protection means are identified following a periodic analysis of observed anomalies and their application is verified.

Recommendation Formally identify technical risks affecting reliability.	**N°** 62
Phases in which the recommendation is applicable — **Weight** SPECIFICATION .... 12.4 DESIGN 21	
Further description Formally identify requirements and critical factors related to reliability. The risk management procedure will use this information. Mark and manage these risks. Existence of an action plan.	
Audit question Have technical risks affecting the reliability been identified?	
Level 1 No risk management is made regarding reliability performances.	
Level 2 An initial analysis of risks related to obtaining reliability performances has been made, but risk management is not formalised or is incomplete.	
Level 3 An initial analysis of risks related to obtaining reliability performances has been made. This is formalised, but risk management is not maintained in the long term: cooperation is set up between the equipment manufacturer and the system engineer to evaluate risks related to the product environment.	
Level 4 Risks related to obtaining reliability performances are perfectly identified. There is a procedure for management of these risks at the manufacturer and it is followed. Cooperation is set up between the equipment manufacturer and the system engineer to evaluate risks related to the product environment. A risk sheet is written and is kept up to date for each risk, in particular this sheet presents quantitative approaches towards risk probability, severity (cost, planning, performance), proposed solutions to reduce the risk and cost of solutions.	

Recommendation Identify documentation for special processes.	**N°** 63

Phases in which the recommendation is applicable **Weight**

OPERATION AND MAINTENANCE 12.2

Further description

Records concerning processes, products and personnel are kept up to date.

Audit question

Is there any documentation for special processes? Is this documentation kept up to date?

Level 1	No documentation concerning special processes.
Level 2	The associated documentation only deals with processes, the associated products or human resources are not taken into account.
Level 3	Records are provided for processes, products and personnel associated with special processes, but these procedures are not updated.
Level 4	Records for processes, products and personnel are updated.

Recommendation Identify the type of time measurement for reliability performances.	**N°** 64
Phases in which the recommendation is applicable **Weight** SPECIFICATION 6.6	
Further description Identify the type of time measurement for reliability performances (Hours of operation, Hours of flight, cycles, etc).	
Audit question Has a type of time measurement (Hours of operation, Hours of flight, number of cycles, etc.) been identified for reliability performances?	
Level 1	The type of time measurement is not fully defined in the call for bids or the contract and the manufacturer has not completed it.
Level 2	The type of time measurement is not fully defined in the call for bids (or the contract), but the manufacturer has completed these data by making assumptions, although these assumptions have not been validated by the customer.
Level 3	The type of time measurement is not fully defined in the call for bids (or the contract), but the manufacturer has completed these data by making assumptions validated by the customer.
Level 4	The type of time measurement is fully defined in the call for bids (or the contract).

Recommendation Identify customer requirements.	**N°** 65
Phases in which the recommendation is applicable **Weight** SPECIFICATION 7.3	
Further description Customer requirements must be identified, documented and traced with respect to input documents.	
Audit question Have customer requirements been identified, documented and traced?	
Level 1	Customer requirements related to reliability are not identified.
Level 2	Customer requirements related to reliability are identified and listed in a document with no revision index, there is no traceability of changes to these requirements (no justification or record in a document).
Level 3	Customer requirements related to reliability are identified and listed in a document (e.g. reliability plan) with revision index, there is no traceability of changes to these requirements (no justification or record in a document).
Level 4	Customer requirements related to reliability are identified and listed in a document and kept up to date (successive versions if justified) with their revision index, there is traceability of changes to these requirements (justification and record in a document).

Recommendation Identify means concerning special processes.	**N°** 66

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT 13.1
INTEGRATION INTO SYSTEM 13.1
OPERATION AND MAINTENANCE 13.1

Further description

Requirements for qualification of process operations including equipment and associated personnel, must be specified.

Audit question

Are means concerning special processes identified?

Level 1	Means concerning special processes are not formally identified.
Level 2	Documents identify technical means dedicated to special processes. Equipment and personnel associated with these processes are not defined
Level 3	Process operation qualification requirements, including associated equipment and personnel, are specified.
Level 4	Process operation qualification requirements, including associated equipment and personnel, are specified. Documents identifying these requirements are regularly updated.

Recommendation Identify human resources concerning special processes.	**N°** 67

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT 11.7
INTEGRATION INTO SYSTEM 11.7
OPERATION AND MAINTENANCE 13.7

Further description

Special processes must be done by qualified operators and/or are continuously monitored, with control over process parameters to assure conformity with requirements.

Audit question

Are human resources concerning special processes managed?

Level 1	Special processes are not associated with qualified human resources.
Level 2	Special processes are done by trained operators, but there is no regular check on their skills.
Level 3	Special processes are done by qualified operators, or they are continuously monitored.
Level 4	Special processes are done by qualified operators and they are continuously monitored.

Recommendation Identify risks related to Reliability at subcontractors.	**N°** 68

Phases in which the recommendation is applicable **Weight**
SUPPORT PROCESS ACTIVITIES 7.2

Further description
Before signing the contract (with the subcontractor) identify risks associated with the reliability of the subcontracted product.

Audit question
Have risks related to reliability of products at subcontractors been identified?

Level 1	No reliability risk analysis is made with the subcontractor before the contract is signed (no specific provision)
Level 2	No reliability risk analysis is made with the subcontractor before the contract is signed, but a risk identification was made during the job. These risks are not managed.
Level 3	The reliability risk analysis was made before the contract was signed and is described in a formal document. These risks are not managed.
Level 4	The reliability risk analysis was made before the contract was signed and is described in a formal document. Identified risks are described in risk sheets that are regularly updated.

Recommendation Integrate reliability into the company's quality policy.	**N°** 69

Phases in which the recommendation is applicable **Weight**
SUPPORT PROCESS ACTIVITIES..7.4

Further description
Integrate the Reliability theme in the company quality policy and breakdown this policy at levels concerned by reliability engineering.

Audit question
Is the reliability theme present in the company quality policy?

Level 1	The quality policy does not take reliability into account.
Level 2	Reliability is mentioned indirectly in quality policy objectives.
Level 3	Reliability is mentioned in the company's quality policy.
Level 4	Reliability is one of the major objectives of the quality policy.

Recommendation
Control the product inspection and test documentation.

N°
70

Phases in which the recommendation is applicable **Weight**

Phase	Weight
INTEGRATION INTO EQUIPMENT	9.3
INTEGRATION INTO SYSTEM	9.3

Further description
Written inspection and test procedures have to be produced and kept up to date, to verify that specified requirements for the product are respected.

Audit question
How is the product inspection and test documentation controlled?

Level 1	No documentation about product inspections and tests.
Level 2	The documentation for product inspections and tests is limited to the test program; it contains the reference to specifications of equipment to be tested, references of equipment to be tested, traceability of the test program, the test framework, functions to be tested. There is no formal definition for the test report.
Level 3	The documentation includes a program and a test report containing information about the test itself, and also all results with a list of anomalies remaining at the end of the test.
Level 4	The documentation includes the test program, the test report, specifications for test means, and the definition of test means.

Recommendation Control documentation.	**N°** 71

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT 12.2
INTEGRATION INTO SYSTEM 12.2
OPERATION AND MAINTENANCE 5.6

Further description

Store and keep product and process documentation available in the workshop.
Make a list of the documentation regularly.
Periodically update the documentation.
Train an entity among workshop personnel in the management of technical documentation.
Have technical documentation for products.
Have a documentation specific to the inspection and maintenance tests.
Associate this product technical documentation with implementation processes.
When documents are provided, analyse the validity of this product documentation.
Be in possession of process control documentation.
Specify technical documentation for each process.
Provide this technical documentation and make it useable.
Have a documentation specific to the inspection and tests .

Audit question

Is documentation well controlled? Does it take account of all equipment changes?

Level 1	No documentation specific to the products or processes, there are no plans to provide special documentation.
Level 2	Documentation specific to products and processes does exist, however it is not always effectively updated, there is no analysis about the validity of documents.
Level 3	Documentation specific to products and processes does exist, it is updated periodically in a planned manner, the validity of the documents used is not analysed.
Level 4	Documentation specific to products and processes does exist, it is updated periodically in a planned manner, the validity of the documents used is analysed. Precise procedures are applied for storage and preservation of the documentation.

Recommendation Control product testability and maintainability.	**N°** 72

Phases in which the recommendation is applicable **Weight**
OPERATION AND MAINTENANCE 17.6

Further description
Control the capability of products to detect failures, control failure detection means, facilitate maintenance.

Audit question
How are product testability and maintainability controlled?

Level 1	No built-in tests, maintenance is done when a failure appears
Level 2	There is a minimum surveillance by lights or alarms.
Level 3	Application of PBIT, CBIT, IBIT (Power up Built In Test, Continuous Built In Test, Initiated Built in test) type tests.
Level 4	Application of built-in tests (PBIT, CBIT, IBIT) and testability complements by one (or several) external test means.

Recommendation Make sure that inspection, measurement and test equipment is compatible with needs.	**N°** 73

Phases in which the recommendation is applicable **Weight**

Phase	Weight
INTEGRATION INTO EQUIPMENT	9.6
INTEGRATION INTO SYSTEM	9.6
OPERATION AND MAINTENANCE	11.3

Further description

Inspection, measurement and test equipment is used to assure that the measurement uncertainty is known and is compatible with the required measurement aptitude.

Test software or comparison references used as inspection means are verified before they are put into service to demonstrate that they are capable of checking that the product is acceptable.

Audit question

What steps are taken to control how inspection, measurement and test equipment is compatible with needs?

Level 1	There is no procedure that defines how to check that inspection, measurement and test equipment is compatible with needs.
Level 2	Procedures define how to check that inspection, measurement and test equipment is compatible with needs. There is no check to assure that they are used.
Level 3	Inspection, measurement and test equipment is used in such a manner that the measurement uncertainty is known and is compatible with the required measurement aptitude. There is no verification of inspection equipment before it is put into service.
Level 4	Inspection, measurement and test equipment is used in such a manner that the measurement uncertainty is known and is compatible with the required measurement aptitude. Test software or comparison references used as inspection means are verified before they are put into service to demonstrate that they are capable of checking if the product is acceptable. Systematic verification before use is industrially impossible but the use of a metrological procedure (Validation period and definition of the class of equipment in the test procedure), the class is defined in advance.

Recommendation Control the environment of inspection, measurement and test equipment.	**N°** 74

Phases in which the recommendation is applicable — **Weight**

Phase	Weight
INTEGRATION INTO EQUIPMENT	7.9
INTEGRATION INTO SYSTEM	7.9
OPERATION AND MAINTENANCE	11.7

Further description

Handling, preservation and storage of inspection and measurement equipment assures that precision and usability are maintained.

Inspection, measurement and test equipment, including the test benches and test software, are protected against manipulations that would invalidate calibration settings.

Audit question

How is the environment of inspection, measurement and test equipment controlled?

Level 1	The environment of inspection, measurement and test equipment is not taken into account.
Level 2	Inspection, measurement and test equipment is protected against aggression that could damage it.
Level 3	Inspection, measurement and test equipment is protected against aggression that could damage it, it is also protected against manipulations that would invalidate calibration settings. Handling, preservation and storage of inspection equipment are not defined by strict procedures.
Level 4	Inspection, measurement and test equipment is protected against aggression that could damage it, it is also protected against manipulations that would invalidate calibration settings. Handling, preservation and storage of inspection equipment are defined by strict procedures.

Recommendation Control the working environment.	**N°** 75

Phases in which the recommendation is applicable **Weight**
INTEGRATION INTO EQUIPMENT 9.6
INTEGRATION INTO SYSTEM 9.6
OPERATION AND MAINTENANCE 10.8

Further description
When the working environment is important for product quality, appropriate limits must be specified, controlled and verified (layout of the workshop, ergonomy of the workstation, etc).

Audit question
How is the working environment controlled?

Level 1	The layout of workshops is not designed as a function of the processed product.
Level 2	Workstations are specific to equipment. The working environment is controlled.
Level 3	Workstations are specific to equipment. The working environment is controlled and verified.
Level 4	Workstations are adapted to the specific needs of products. The working environment is controlled and verified. Workshop layouts are designed to optimise maintenance.

Recommendation Control monitoring and measurement devices, metrology of measurement instruments and industrial means.	**N°** 76

Phases in which the recommendation is applicable **Weight**
SUPPORT PROCESS ACTIVITIES..7.8

Further description
Control monitoring and measurement devices, the metrology of measurement instruments and industrial means. Control the verification, calibration and rating of measurement instruments and test and trial benches used by the company. APMs are tied to national standards.

Audit question
What procedure is there to control monitoring and measurement devices, the metrology of measurement instruments and industrial means?

Level 1	There is no verification, calibration and rating procedure for measurement instruments and test and trial benches in the company.
Level 2	There is a verification, calibration and rating procedure for measurement instruments and test and trial benches in the company, but it is not respected.
Level 3	There is a verification, calibration and rating procedure for measurement instruments and test and trial benches in the company, and it is applied.
Level 4	Verification, calibration and rating of measurement instruments and test and trial benches used by the company is controlled (accreditation, certification, etc.); APMs are tied to national standards.

Recommendation Control changes to manufacturing processes.	**N°** 77

Phases in which the recommendation is applicable | **Weight**

Phase	Weight
MANUFACTURING OF BOARD OR SUBASSEMBLY	13.9
INTEGRATION INTO EQUIPMENT	13.9
INTEGRATION INTO SYSTEM	13.9
OPERATION AND MAINTENANCE	13.9

Further description

A clear statement of persons authorised to approve process changes must be available.
These changes requiring acceptance by the customer must be identified before they are applied.
Any change affecting processes, production equipment, tools and programs, must be documented and must lead to a procedure to control its application.
Make sure that results of process changes produce the required effect and that the changes have not reduce the product quality.

Audit question

How are changes to manufacturing processes controlled?

Level 1	Process changes are made without being recorded, these modifications are not submitted for authorisation.
Level 2	Process changes are recorded and submitted for authorisation. These changes are not documented, and there is no procedure to control their application.
Level 3	Process changes are recorded, persons authorised to approve changes to production processes are clearly named. Changes requiring acceptance by the customer are identified before application. Any change affecting processes, production equipment, tools and programs is described in a document and a procedure must be produced to control its application. However, there is no systematic check that the results of changes to processes produce the required effect and that these changes have not modified the product quality.
Level 4	Process changes are recorded, persons authorised to approve changes to production processes are clearly named. Changes requiring acceptance by the customer are identified before application. Any change affecting processes, production equipment, tools and programs is described in a document and a procedure must be produced to control its application. Systematic checks are carried out to assure that the results of changes to processes produce the required effect and that these changes have not modified the product quality.

Recommendation Control handling methods.	**N°** 78
Phases in which the recommendation is applicable **Weight** INTEGRATION INTO EQUIPMENT .... 8.8 INTEGRATION INTO SYSTEM .... 8.8 OPERATION AND MAINTENANCE 9.9	
Further description Product handling methods and means are provided to prevent damage or deterioration to the product and include: - transport procedures, - handling methods specific to each product.	
Audit question Are handling and transport methods defined?	
Level 1	Handling methods are not defined. There are no specific means to prevent deterioration during manipulation.
Level 2	Handling methods are defined, but they are not specific to a product.
Level 3	Handling methods specific to the product are written down, specific means are provided to prevent any deterioration during manipulations. There is no verification about their application.
Level 4	Product manipulation procedures are specifically defined, and associated means prevent any deterioration to the product during manipulations. It is verified that these methods are applied.

Recommendation Control production means, tools and programmable machines.	**N°** 79

Phases in which the recommendation is applicable — **Weight**
INTEGRATION INTO EQUIPMENT 10.5
INTEGRATION INTO SYSTEM 10.5
OPERATION AND MAINTENANCE 11.3

Further description

Make sure that written procedures describe the following activities, for all production means, tools and programs:
validation before use,
maintenance,
periodic inspection according to written procedures.

Audit question

How are production equipment, tools and programs for numerical control machine controlled?

Level 1	Means and tools are not submitted for inspection and validation before use.
Level 2	Means and tools are submitted for inspection before use, but these inspections are not all formalised.
Level 3	The periodic inspection of means and tools is submitted for validation, formal procedures identify periodic inspections to be carried out.
Level 4	The periodic inspection of means and tools is submitted for validation, formal procedures identify actions and periodic inspections to be carried out. Formal procedures describe maintenance of tools.

Recommendation Control handling, storage, packaging, preservation and delivery operations.	**N°** 80

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT 6.5
INTEGRATION INTO SYSTEM 6.5
OPERATION AND MAINTENANCE 11.3

Further description

A procedure is necessary to take account of specific requirements for the following at the different production steps, if applicable in accordance with the manufacturer's recommendations and/or applicable regulations:

- cleaning,
- prevention, detection and removal of foreign bodies,
- handling adapted to sensitive products,
- marking and labelling, including safety marking,
- control of shelf life and stock rotation,
- dangerous equipment

Produce special management procedures for perishables.
Eliminate all products that have passed their useful life and unidentified products.
Suggest criteria for evaluating and analysing the quality of storage conditions.
List and analyse failures related to lack of quality in storage.

Audit question

How are handling, storage, packaging, preservation, and delivery controlled?

Level 1	Handling, storage, packaging, preservation and delivery conditions are not coded, and execution of these operations is not perfectly controlled.
Level 2	Handling, storage, packaging, preservation and delivery conditions are coded, there are procedures that can be adapted to all products. Execution of these operations is not specific to a product.
Level 3	Handling, storage, packaging, preservation and delivery conditions are coded, there are procedures specific to each product.
Level 4	Handling, storage, packaging, preservation and delivery conditions are coded, there are procedures specific to each product. Considerations such as expiration dates, sensitivity of products to stress, dangerousness of products are also coded and applied.

Recommendation	**N°**
Control special processes.	81

Phases in which the recommendation is applicable	**Weight**
INTEGRATION INTO EQUIPMENT	14.4
INTEGRATION INTO SYSTEM	14.4
OPERATION AND MAINTENANCE	15.2

Further description

When special processes are used (processes for which results cannot be fully verified a posteriori by an inspection or test of the product, and for which the consequences of deficiencies in application will not appear until this product is used, for example gluing, soldering:

The special processes to be implemented must be identified.

The supplier verifies that all parameters of special processes (for example materials, personnel, procedures and software) produce satisfactory results.

The supplier identifies and documents significant operations and process parameters to be controlled.

Any modification to these operations and parameters must be described in a proposal justifying this modification and guaranteeing that it does not introduce any harmful effect on the result of the process.

The supplier must verify special processes by making one or several typical parts under the conditions defined for the phase.

Special processes or subcontracted processes must be qualified before use.

The supplier must keep qualified special processes up to date.

Audit question

How are special processes controlled?

Level 1	Special processes are not identified.
Level 2	Special processes are identified. The parameters for these processes (materials, personnel, procedures and software) are evaluated. These processes are not documented, or not defined by strict procedures.
Level 3	Special processes are identified. The parameters for these processes (materials, personnel, procedures and software) are evaluated. Significant operations and parameters of the process to be controlled in production have been identified and documented. Any modification to these operations and parameters will be described in a proposal justifying this modification and guaranteeing that it does not introduce any harmful effect on the result of the process. Special processes have not been verified by making one or several typical parts under defined conditions.
Level 4	Same criterion as level 3 and also: It is verified that all parameters of special processes (for example materials, personnel, procedures and software) produce the expected results. Special processes are verified by making one or several typical parts under defined conditions. Special processes (subcontracted or not) are qualified before they are used and they are kept up to date.

Recommendation Control services and fluids in the working environment.	**N°** 82

Phases in which the recommendation is applicable **Weight**

Phase	Weight
INTEGRATION INTO EQUIPMENT	10.1
INTEGRATION INTO SYSTEM	10.1
OPERATION AND MAINTENANCE	12.2

Further description

When they have an influence on the quality and reliability of the product, services and supplies such as water, compressed air, electricity and chemicals used must be controlled and verified regularly to make sure that their effect on the process is constant.

Audit question

How are services and fluids in the working environment controlled?

Level 1	Services and supplies such as water, compressed air, electricity and chemicals are not verified.
Level 2	Services and supplies such as water, compressed air, electricity and chemicals are verified occasionally following a proven failure (see ISO 14000).
Level 3	Services and supplies such as water, compressed air, electricity and chemicals are controlled and verified periodically to make sure that their effect on the process is constant.
Level 4	Services and supplies such as water, compressed air, electricity and chemicals are controlled and verified continuously to make sure that their effect on the process is constant.

Recommendation Maximise test coverage based on the specification and justification.	**N°** 83

Phases in which the recommendation is applicable **Weight**
DESIGN..6

Further description
Make sure that the test coverage is maximum and is based on the specification. Justification of the coverage in a document.

Audit question
Is there assurance that the test coverage is maximum, and that it is based on the specification? Is there a justification document?

Level 1	No justification of the test coverage.
Level 2	The test coverage is evaluated and compared simply with the specification.
Level 3	The test coverage is evaluated and some actions are done to maximise performance. The performance justification is formalised .
Level 4	The test coverage is evaluated and actions are applied to maximise performance. The performance justification will assure that the coverage rate is maximum.

Recommendation Measure contamination of baths by sampling (frequency to be defined) so as not to exceed the pollutant content during this activity.	**N°** 84

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 5.8

Further description

Measure the bath contamination by sampling (frequency to be defined) so as not to exceed the allowable pollutant content during this activity.
Excess content of pollutant will increase the risks of reducing the reliability of the solder.

Audit question

Is contamination of solder baths measured by sampling (so as not to exceed the pollutant content during this activity)?

Level 1	The pollution content in the solder bath is not measured.
Level 2	The content of contaminating pollutant in the solder bath is measured. These measurements are sporadic and are not formalised in any way.
Level 3	The content of contaminating pollutant in the solder bath is measured. These measurements are made following an identified protocol and frequency. All these points to be respected are described in a document, but this document has not been validated by an authority independent from the operating entity.
Level 4	The content of contaminating pollutant in the solder bath is measured. These measurements are made following an identified protocol and frequency. All these points to be respected are described in a document that has been validated by an authority independent from the operating entity.

Recommendation Measure the reliability of products in operation.	**N°** 85

Phases in which the recommendation is applicable **Weight**

SUPPORT PROCESS ACTIVITIES..8

Further description

Make operational reliability measurements of products in operation (monitoring of technical events, analysis of causes of failure, allocation of the origin of failures, recording the real product usage profile, reliability evaluation, analysis of these measurements and take account of the result for studies on new products).

Audit question

Are product reliability measurements actually made in operation?

Level 1	No reliability evaluation by analysis of feedback from operations.
Level 2	Observation and collection of information dealing with product failure rates, the only feedback from operations relates to a reliability evaluation.
Level 3	Feedback from operations for evaluation of reliability data, analysis of causes of failure, allocation of the cause of failures, record of the real product usage profile. Role to observe feedback from operations, not used to quantify the reliability of new projects.
Level 4	Feedback from operations for evaluation of reliability data, analysis of causes of failure, allocation of the cause of failures, record of the real product usage profile. These measurements are analysed and the result is taken into account for new product studies.

Recommendation Implement design verifications.	**N°** 86

Phases in which the recommendation is applicable **Weight**

DESIGN..27.1

Further description

Implement design verifications: these procedures must be based on proof reading, approval circuit and reviews with the objective of making sure that the orientation actions, and elements chosen are correct.

Audit question

Are there any design verification procedures?

Level 1	No design verification procedures.
Level 2	There are no formalised verification procedures.
Level 3	There are formal verification procedures.
Level 4	There are formal verification procedures that are periodically revised, including peer reviews.

Recommendation Implement a maintenance in logistics support concept.	**N°** 87

Phases in which the recommendation is applicable **Weight**
DESIGN..5.4

Further description
Make sure that the maintenance concept is formalised and validated by the customer.
Example of documents to be presented in response to requirements of the concept: integrated logistics support plan, logistics supportability file.

Audit question
Is there a maintenance concept?

Level 1	No support requirements planned. The customer's organisation is not taken into account.
Level 2	There are support requirements but they are only partially formalised; They are isolated or even inconsistent and not broken down into subassemblies: No integrated logistics support organisation at the manufacturer.
Level 3	Support requirements formalised. Response to requirements formalised but not validated and considered as secondary. Partially justified requirements or requirements not satisfied.
Level 4	Support requirements formalised: maintenance concept . There is a project organisation at the manufacturer to satisfy customer requirements in the form of a logistics support plan . Support requirements are taken into account at the design stage, they are broken down into subassemblies, justified and validated in a supportability file . Elements in the support system (documents, training, spare parts batches, tools and test means, etc.) are available and are consistent and validated .

Recommendation Implement self-checking to filter human errors that could reduce reliability of the subassembly.	**N°** 88

Phases in which the recommendation is applicable **Weight**

Phase	Weight
MANUFACTURING OF BOARD OR SUBASSEMBLY	5.3
INTEGRATION INTO EQUIPMENT	5.3
INTEGRATION INTO SYSTEM	5.3

Further description
Set up self-checking to filter human errors that could reduce the reliability of the subassembly.

Audit question
Is a self checking system applied to filter human errors (that could reduce reliability of the subassembly)?

Level 1	No self-checking is done on the task .
Level 2	Self-checking is done at the end of the activity. However, it is not described in any formal document .
Level 3	Self-checking is done at the end of the activity. This is done in accordance with a predefined protocol formalised in a document.
Level 4	Self-checking is done at the end of the activity. This is done in accordance with a protocol that was validated by an authority independent from the operating entity. This protocol is formalised in a document .

Recommendation Set up indicators to verify that a good solder is obtained when components are transferred.	**N°** 89

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6

Further description

It must be impossible for reliability to be reduced due to nonconformity of soldering (missing, excess or offset) during electronic component transfer activities.

Indicators (deposited quantity, appearance after transfer, etc.) must be identified and they must be monitored (operator check, etc) to detect all causes of reduced reliability of subassemblies.

Audit question

Are there any indicators to verify that a good solder is obtained when components are transferred?

Level 1	There is no indicator to verify that good solder is obtained during the transfer.
Level 2	There are indicators to assure that a good solder has been achieved. However, these do not depend on a formal study or do not satisfy any formally expressed criteria.
Level 3	There are indicators to assure that a good solder has been achieved. These are based on a document giving their information level, however, no independent authority has validated this document.
Level 4	There are indicators to assure that a good solder has been achieved. These are based on a document giving their information level and the protocol to be followed. Furthermore, these documents have been validated by an authority independent from the operating entity .

Recommendation Set up periodic inventories of stores.	**N°** 90

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 5.5

Further description

Setting up periodic store inventories prevents the use of any elements that do not satisfy expiration criteria; correct name or identification, correct geographic location during storage).

Audit question

Are checks made to assure that stock inventories are defined and respected

Level 1	No periodic inventory is made and there is no automatic inventory reminder.
Level 2	Several inventories are made. However, there is no formal plan for the frequency of these inventories.
Level 3	Periodic inventories are made. If the date of an inventory is not respected, a reminder is systematically issued until a new inventory has been validated. Documents formally define actions to be done and the different monitoring forms to be updated.
Level 4	Periodic inventories are made. If the date of an inventory is not respected, a reminder is systematically issued until a new inventory has been validated. Documents formally define actions to be done and the different monitoring forms to be updated. It was validated by an authority independent from the operating entity.

Recommendation	**N°**
Set up protections against ESD for subassemblies during manipulations and storage.	91

Phases in which the recommendation is applicable — **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 26
INTEGRATION INTO EQUIPMENT 26
INTEGRATION INTO SYSTEM 18.4
OPERATION AND MAINTENANCE 17.4

Further description

Set up protections against ESD for subassemblies during manipulations and storage.

Audit question

Have you set up specific protections against ESD for subassemblies during manipulations and storage?

Level 1	There is no protection against ESD.
Level 2	Protection against ESD is subject to non formalised rules and practices.
Level 3	There are validated procedures for protection against ESD defining practices recognised as protecting the subassemblies.
Level 4	Protection against ESD is described in validated procedures and follow-up checks are made on these procedures.

Recommendation	**N°**
Set up periodic verifications for monitoring tools used for inspection of production means.	92

Phases in which the recommendation is applicable	**Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY	4.9
INTEGRATION INTO EQUIPMENT	4.9

Further description

A number of production means parameters are provided by test tools (probes, sensors, detectors, etc.).

These test tools need to be monitored periodically (frequency to be defined) to assure that the measurements made are reliable.

The delta between the stress actually applied by the production means and the measurement made of this stress must be minimal and perfectly measurable.

Audit question

Are there any periodic verifications used to monitor tools used for inspection of production means?

Level 1	There is no periodic verification for monitoring production means test tools.
Level 2	Tools and instruments used for inspection of production means are checked occasionally but without following a formal verification plan.
Level 3	Tools and instruments used for inspection of production means are periodically checked. These verifications (frequency and procedures) are formalised in documents, but there is no validation of these documents by an authority independent from the operating entity.
Level 4	Tools and instruments used for inspection of production means are periodically checked. These verifications (frequency and procedures) are formalised in documents and they have been validated by an authority independent from the operating entity.

Recommendation Set up appropriate protections to avoid degrading subassemblies while cleaning.	**N°** 93

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6

Further description

Set up suitable protections if necessary to avoid degrading subassemblies during this activity. The purpose of these protections is to isolate part of the subassembly, and it must be possible to verify that they were effective after the activity is complete (tests, measurements).

Audit question

Are there any appropriate protections to avoid degrading subassemblies while cleaning?

Level 1	No specific protection is used when cleaning subassemblies.
Level 2	A number of protections are set up during the subassembly cleaning activity. These protections may be specific to some subassemblies, but there are no formal documents for them.
Level 3	A number of protections are set up during the subassembly cleaning activity. Protections and appropriate procedures to be followed are formalised in one or several documents as a function of types of subassembly.
Level 4	A number of protections are set up during the subassembly cleaning activity. Protections and appropriate procedures to be followed are formalised in one or several documents as a function of types of subassembly, and these documents have been validated by an authority independent from the operating entity.

Recommendation Set up a self-test of test tools to detect any anomalies.	**N°** 94
Phases in which the recommendation is applicable **Weight** MANUFACTURING OF BOARD OR SUBASSEMBLY .... 5.1 INTEGRATION INTO EQUIPMENT 5.1	
Further description Set up a self-test of testers in order to detect any anomalies. It must be impossible to perform a test if the self-test is not conclusive or unless there is a traced waiver (authorisation to execute the test provided that the follower sheet is marked and signed and cannot be separated from the subassembly) accompanying the subassembly thus tested.	
Audit question Are there any self-tests of test tools in order to detect any anomalies before use on the subassembly ?	
Level 1	No self-test is done on the testers.
Level 2	A self-test is carried out on the testers. This self test is carried out without any formal document or study to determine the effectiveness and the limits.
Level 3	A self-test is carried out on the testers. This self test is described in documents used to determine the degree of effectiveness and the procedure. But these documents have not been validated by an authority independent from the operating entity.
Level 4	A self-test is carried out on the testers. This self test is described in documents used to determine the degree of effectiveness and the procedure. These documents have been validated by an authority independent from the operating entity.

Recommendation **N°** 95

Set up a cross-check to optimise the final inspection of varnishing of subassemblies.

Phases in which the recommendation is applicable	**Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY	5.6

Further description

This cross check filters nonconformities before the subassembly is continued in the production process.

The final inspection activity is the last level for identification of errors that could reduce the reliability of the subassembly caused by unreliable varnishing.

Audit question

Is there a cross-check to optimise the final inspection of varnishing of subassemblies?

Level 1	There is no cross-check at the final inspection of varnishing.
Level 2	A cross-check is done during the final inspection of the subassembly varnishing activity. However, this inspection method is not described in a formal document.
Level 3	A cross-check is done during the final inspection of the subassembly varnishing activity. The effectiveness of this method has been measured and the procedure and the scope of the inspection are formally described in documents.
Level 4	A cross-check is done during the final inspection of the subassembly varnishing activity. The effectiveness of this method has been measured and the procedure and the scope of the inspection are formally described in validated documents.

Recommendation Set up a conformity check when putting into stock in stores (excluding non-conforming items).	**N°** 96

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6

Further description

A so-called conformity check must be identified and must occur before every final entry of items into storage.
Check on reception that there is no non-conforming element that could potentially reduce reliability during the remainder of the process.

Audit question

Is there a conformity check when putting into stock in stores with the exclusion of non-conforming items?

Level 1	There is no conformity check before putting into stock in the stores.
Level 2	Some parameters are monitored when putting into stock in stores, but there is no formal definition of them.
Level 3	A real check on conformity of items is made before putting in stock in stores. This conformity check is formally described (parameters, special points, etc.) through a set of documents. However, no independent authority has validated these documents.
Level 4	A real check on conformity of items is made before putting in stock in stores. This conformity check is formally described (parameters, special points, etc.) through a set of documents. The relevance of the information in these documents and the manner in which they are broken down has been validated by an authority independent from the operating entity.

Recommendation Set up an SPC (Statistical Process Control) for the production process.	**N°** 97

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 4.5

Further description

Use of the statistical process control by making SPC (Statistical Process Control) cards verifies that some activities carried out at precise moments in the production phase take place correctly. The SPC is used for activities for which the risk (statistical) of having a nonconformity that reduces the reliability of the subassembly is highest.

Audit question

is there an SPC (Statistical Process Control) for the production process?

Level 1	There is no inspection of the production process using SPC cards.
Level 2	There is a means of inspecting the production process by SPC card or a similar method, but it is not formally described in a document.
Level 3	There is a means of inspecting the production process by SPC card. This statistical check is formalised and its efficiency for the process to be checked is known.
Level 4	There is a means of inspecting the production process by SPC card. This statistical check is formalised and its efficiency for the process to be checked is known. The complete system has been validated by an authority independent from the operating entity.

Recommendation Give a detailed description of the varnishing protocol.	**N°** 98
Phases in which the recommendation is applicable **Weight** MANUFACTURING OF BOARD OR SUBASSEMBLY 5.8	
Further description The special feature of the varnishing activity requires a precise description of the protocol and parallel actions to be followed to assure that it is done reliably.	
Audit question Is there a detailed description of the varnishing protocol?	
Level 1	There is no description of the varnishing procedure available to the operator.
Level 2	The different actions to be carried out to varnish the subassembly are known and are available through various documents. However, these documents are too dispersed for the operator to be able to see a clearly expressed protocol.
Level 3	The different actions to be carried out and the operations to be followed to varnish the subassembly are described in a document formally setting down the protocol to be respected. However, this document has not been validated by an authority independent from the operating entity.
Level 4	The different actions to be carried out and the operations to be followed to varnish the subassembly are described in a document formally setting down the protocol to be respected. This document has also been validated by an authority independent from the operating entity.

Recommendation Set up a label for identification and withdrawal of out-of-date consumables.	**N°** 99

Phases in which the recommendation is applicable — **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6.4
INTEGRATION INTO EQUIPMENT 6.4
INTEGRATION INTO SYSTEM 6.4

Further description

Accidental use of out-of-date consumables can have a negative influence on quality and consequently reliability, a number of suitable methods must be set up for preservation, identification and withdrawal of the products concerned if necessary.

Systematically reading labels before use to identify each product used and to obtain all information about expiration, reduces risks of using a product that would reduce reliability.

Audit question

Is there a label for identification and withdrawal of out-of-date consumables?

Level 1	No labels or signs provide any information about expiration dates of consumables.
Level 2	No labels or signs provide any information about expiration dates of consumables.
Level 3	Consumables are correctly identified by labelling. All information necessary for this identification is formally described in documents, but these documents have not been validated by an authority independent from the operating entity.
Level 4	Consumables are correctly identified by labelling. All information necessary for this identification is formally described in documents, and these documents have been validated by an authority independent from the operating entity.

Recommendation	**N°**
Set up real time processing of test monitoring indicators so as to not to degrade the subassembly as soon as an anomaly appears.	100

Phases in which the recommendation is applicable	**Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY	4.7
INTEGRATION INTO EQUIPMENT	4.7

Further description

This involves monitoring of test execution indicators to take immediate action with:

- a definition of envelope curves, outside which it can be deemed that there is no anomaly,
- an alarm as soon as an anomaly is detected,
- suspension of the current activity to avoid stressing the subassembly,
- compulsory action and correction of the anomaly before the activity can be resumed and continued.

Audit question

Is there a real time processing of test monitoring indicators so as to not to degrade the subassembly as soon as an anomaly appears?

Level 1	There are no test monitoring indicators.
Level 2	There are a number of indicators used to identify any anomaly that occurred during the test. These indicators are not subject to a formal plan and their processing is done later
Level 3	There is real time processing of test monitoring indicators. Documents formally describe the way in which these indicators are processed. However, these data have not been validated by an authority independent from the operating entity.
Level 4	There is real time processing of test monitoring indicators. Documents formally describe the way in which these indicators are processed. These documents have been validated by an authority independent from the operating entity.

Recommendation Set up preventive maintenance by metrological monitoring to prevent the possibility of aggression to the subassembly.	**N°** 101

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 5.9

Further description

This maintenance by metrological monitoring of production tool parameters must make it possible to eliminate the risk of degrading the reliability of an element by aggression of the subassembly (overstress). The use of parameters that are not precisely consistent with specified parameters (temperature too low, etc.) would make it impossible to assure that the operation is reliable.

Audit question

is there a preventive maintenance by metrological monitoring?

Level 1	No preventive maintenance measure by metrological monitoring has been set up.
Level 2	A number of metrology actions are done related to preventive maintenance.
Level 3	Real metrological monitoring is recorded in the preventive maintenance plan that is applied. One or several documents formally define these actions even if they have not been validated by an organisation independent from the operating entity.
Level 4	Real metrological monitoring is recorded in the preventive maintenance plan that is applied. One or several documents formally define these actions, and this preventive maintenance plan has been validated by an organisation independent from the operating entity.

Recommendation Do not validate and authorise operation of drying ovens, except by checking drifts and malfunctions (by probes and other monitoring systems).	**N°** 102

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6.1

Further description

The activity must be done under the permanent control of a number of fundamental parameters and it must be possible to determine if the subassembly was overstressed or affected by a malfunction during this activity.

Audit question

Is a method used for checking drifts and malfunctions (by probes and other monitoring systems), and to validate or allow the operation of drying ovens?

Level 1	No particular verification governs operation of the drying ovens.
Level 2	There are several malfunction indicators for the drying ovens. These can provide information for the operator who would like to oven dry a subassembly. Nevertheless, no formal document is used as a reference to pronounce any operating authorisation.
Level 3	The operator makes a real check on drifts and malfunction indicators . Documents are used as a reference to authorise the operation of drying ovens, even if they have not been validated by an authority independent from the operating entity.
Level 4	The operator makes a real check on drifts and malfunction indicators . Documents are used as a reference to authorise the operation of drying ovens. These documents have been validated by an authority independent from the operating entity.

Recommendation Negotiate reliability requirements with the customer	**N°** 103

Phases in which the recommendation is applicable **Weight**

SPECIFICATION 10.7

Further description

Reliability requirements must be negotiated to take account of the state-of-the-art of technology and to optimise the cost-performance of the product design and Reliability studies.
For an initial objective requested by the customer, a study by the project manager will evaluate the cost of achieving Reliability performances and propose alternatives so as to optimise the cost of achieving Reliability performances.
The results of the negotiations will be integrated into the final offer submitted to the customer.

Audit question

Is the state-of-the-art of technology taken into account, and is the cost-performance of the product design optimised during negotiations of reliability requirements with the customer?

Level 1	No Negotiation, fixed requirements.
Level 2	Informal negotiations, or negotiations after the contract has been signed.
Level 3	Negotiations with the customer leading to optimisation of costs / performances in achieving Reliability performances.
Level 4	Negotiations with the customer leading to optimisation of costs / performances in achieving Reliability performances, there is an official document describing this negotiation.

Recommendation Appoint a person responsible for reliability studies.	**N°** 104
Phases in which the recommendation is applicable **Weight** SUPPORT PROCESS ACTIVITIES 8.5	
Further description Appoint a person responsible for reliability for each project, who will guarantee that product reliability objectives are achieved. This person shall report on progress with studies and problems encountered.	
Audit question Has a person responsible for reliability studies been appointed?	

Level 1	No person responsible for reliability studies has been identified.
Level 2	There is a person responsible for reliability studies in practice, but no record of his appointment is available.
Level 3	A reliability study manager has been formally named, he has been trained and has experience in the reliability field.
Level 4	A reliability study manager has been named and integrated into the project, he is trained and has the required experience in the field. He makes regular reports on progress with studies in meetings or in reports.

Recommendation Organise periodic reliability meetings with the subcontractor.	**N°** 105
Phases in which the recommendation is applicable **Weight** SUPPORT PROCESS ACTIVITIES 5.7	
Further description Organise periodic meetings with the subcontractor, in which the reliability of subcontracted products will be systematically discussed.	
Audit question Are periodic reliability meetings organised with the subcontractor?	
Level 1 There are no planned periodic meetings with the subcontractor in which reliability aspects of the subcontracted product are systematically discussed, and no meetings have taken place.	
Level 2 Although they have not been planned, meetings with the subcontractor have taken place in which reliability aspects were dealt with.	
Level 3 Periodic meetings with the customer are defined in project plans, in which reliability aspects are dealt with. These are held sporadically.	
Level 4 Periodic meetings with the customer are defined in project plans, in which reliability aspects are dealt with, these take place in accordance with the plan / their planning.	

Recommendation Organise a design review in which Reliability aspects are dealt with		**N°** 106
Phases in which the recommendation is applicable SPECIFICATION DESIGN		**Weight** 10.3 12.1
Further description Organise a design review. Check that reliability requirements are respected. This review defines: - reliability allocations - conditions for use (life profile)		
Audit question Has a design review been organised in which Reliability aspects are dealt with?		
Level 1	No design review.	
Level 2	Organisation of a design review in which reliability aspects are dealt with incompletely or are handled by persons who are not reliability specialists.	
Level 3	Organisation of a design review in which reliability aspects are dealt with completely by persons who are reliability specialists.	
Level 4	Organisation of a design review in which reliability aspects are dealt with completely by persons who are reliability specialists. A procedure or plan imposes this review.	

Recommendation Organise a product requirements review in which Reliability aspects will be dealt with.	**N°** 107

Phases in which the recommendation is applicable **Weight**

SPECIFICATION 10.3

Further description

Organise a requirements review, check that all reliability requirements are identified and that the customer and the supplier understand each other. It must be possible to validate, achieve and verify these requirements (conformity means).

Audit question

Has a requirements review been organised dealing with reliability aspects?

Level 1	No requirements review.
Level 2	An informal requirements review has been set up (or is planned depending on progress with the project). There are no available records that persons responsible for reliability engineering participated in this review.
Level 3	An informal requirements review has been set up (or is planned depending on progress with the project). Persons responsible for reliability engineering were called upon to participate in the document review or validation, and records of this participation are available.
Level 4	An informal requirements review has been set up (or is planned depending on progress with the project). Persons responsible for reliability engineering were called upon to participate in the document review or validation, and records of this participation are available. A procedure or plan imposes this review

Recommendation Plan the sequence of tasks, and include reliability tasks.	**N°** 108
Phases in which the recommendation is applicable / **Weight** SUPPORT PROCESS ACTIVITIES 6.3	
Further description Include information about system engineering tasks in the various project plannings.	
Audit question Are tasks related to reliability taken into account in project plannings?	
Level 1 Reliability tasks are not planned.	
Level 2 Reliability tasks to be done are identified but are not described in a plan.	
Level 3 Reliability tasks are described and there is a planning for them.	
Level 4 Reliability tasks are described and there is a planning for them tied to other company plannings.	

Recommendation	**N°**
Plan the communication process with the subcontractor.	109

Phases in which the recommendation is applicable **Weight**

SUPPORT PROCESS ACTIVITIES 4.1

Further description

Include mechanisms for "communication on reliability aspects" with the subcontractor in the project management plan, and mentioning the frequency and nature of meetings, permanent agenda, content of minutes, reliability aspects of communications.

Audit question

Are tasks related to reliability taken into account in project plannings?

Level 1	There is no communication with the subcontractor dealing with reliability.
Level 2	There is a communication with the subcontractor dealing with reliability aspects.
Level 3	Requirements for the communication with the subcontractor dealing with reliability aspects are described in a project management plan, but only partial application of these requirements has been demonstrated.
Level 4	Requirements for the communication with the subcontractor dealing with reliability aspects are described in a project management plan, and are applied (proofs of this application).

Recommendation Plan reliability activities including reliability improvement.	**N°** 110
Phases in which the recommendation is applicable **Weight** SUPPORT PROCESS ACTIVITIES........9.1	
Further description Plan activities related to reliability improvement in the reliability plan. Describe fundamental activities related to reliability improvement in plans and perform them completely, with records of these actions.	
Audit question Are reliability activities including reliability improvement organised?	

Level 1	No activity has been planned or done related to product reliability improvement.
Level 2	There are activities related to reliability improvement but they do not appear in specific plans.
Level 3	Fundamental activities related to reliability improvement are described in plans and are done partially.
Level 4	Fundamental activities related to reliability improvement are described in plans and are done completely and records of these actions are produced.

Recommendation Plan reliability studies.	**N°** 111

Phases in which the recommendation is applicable **Weight**

SUPPORT PROCESS ACTIVITIES 7.3

Further description

Plan reliability studies to guarantee that product reliability objectives are achieved and to synchronise reliability studies and product design.

Audit question

Are reliability studies planned?

Level 1	No planning has been made for reliability studies.
Level 2	Although there is a calendar for reliability studies, they do not appear on a planning.
Level 3	Reliability studies appear on the project planning.
Level 4	Reliability studies appear on the project planning. There is a formal definition of synchronisation between execution of the project and reliability studies (milestones, stop points, etc.).

Recommendation Have high and low safety systems tied to inspection and monitoring means (systematically stop the cycle and have a technician carry out an analysis before restarting).	**N°** 112

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 5.7

Further description

Have high and low safety systems tied to inspection and monitoring means (systematically stop the cycle and have a technician carry out an analysis before restarting)

Audit question

Are high and low safety systems provided tied to inspection and monitoring means (systematically stop the cycle and analysis by a technician before restarting)?

Level 1	There is no value of inspection parameters causing a systematic stop of the activity when this value is reached.
Level 2	Inspection and monitoring means can stop the activity. However, there is no document indicating values beyond which a systematic stop is necessary.
Level 3	There are high and low safety systems on inspection and monitoring means. They are formally identified in a document and stop procedures specific to each means.
Level 4	There are high and low safety systems on inspection and monitoring means. They are formally identified in a document specific to each means. Furthermore, these documents and stop procedures have been validated by an authority independent from the operating entity.

Recommendation Possess inspection and test records.	**N°** 113

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT 5.3
INTEGRATION INTO SYSTEM 5.3

Further description

Records must be produced and kept to provide proof that the product has been subjected to inspections and/or tests in accordance with defined criteria.
Records must be sufficient to identify the person who performed the inspections and released the product.
Test records must indicate measured values when they are required by the specification or the acceptance plan.
If specified, the supplier must demonstrate the qualification of the product.

Audit question

Are records produced and kept to prove that the product has been inspected and/or tested in accordance with defined criteria? Are the records sufficient to identify the person who made the checks?

Level 1	Records of inspections and tests are produced but are not kept.
Level 2	Records of inspections and tests are produced and are kept but cannot be used to identify the source of the inspection (persons, machine).
Level 3	Records of inspections and tests are produced and are kept and can be used to identify the source of the inspection (persons, machine).
Level 4	Records prove that inspections and/or tests have been carried out on the product in accordance with defined criteria. The records are sufficient to identify the person who carried out the inspections and authorised release of the product. Test records indicate measured values when they are required by the specification or the acceptance plan.

Recommendation Possess an inspection file.	**N°** 114

Phases in which the recommendation is applicable **Weight**

INTEGRATION INTO EQUIPMENT 5.7
INTEGRATION INTO SYSTEM 5.7
OPERATION AND MAINTENANCE 5.7

Further description

The inspection file must contain:
criteria for acceptance and refusal,
a sequential list of inspection and test operations to be done,
inspection result record documents,
a list of specific and non-specific inspection instruments,
the documents associated with specific inspection instruments for their design, production, validation, management, use and maintenance .

Audit question

Is there an inspection file containing acceptance criteria, the sequential list of inspection and test operations, inspection result record documents, list of specific and non-specific inspection instruments?

Level 1	No inspection file.
Level 2	The inspection file is limited to the definition of acceptance or refusal criteria.
Level 3	The inspection file defines acceptance or refusal criteria, and the list of operations to be done. It proposes inspection result record documents.
Level 4	The inspection file contains: the definition of acceptance or refusal criteria, the sequential list of inspection and test operations to be carried out, inspection result record documents, the list of specific and non-specific inspection instruments, documents associated with specific inspection instruments for their design, production, validation, management, use and maintenance.

Recommendation Possess a plan for qualification of a method of removing the masking varnishes used so as to avoid reducing the reliability of the subassembly.	**N°** 115

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6.5

Further description

Possess a plan for qualification of a method of removing the masking varnishes used so as to avoid reducing the reliability of the subassembly.
Risks of the penetration of humidity affecting the reliability of the subassembly are strong if the operator does not take some precautions.

Audit question

Is there a qualification plan of the method of removing masking varnishes used so as not to reduce reliability of the subassembly?

Level 1	There is no plan specific to the method of removing masking varnishes.
Level 2	Masking varnishes are removed using a particular method but no formal document describes this method.
Level 3	Operators apply a qualification plan for the method of removing masking varnishes after varnishing of subassemblies. This plan is formally defined through specific documents.
Level 4	Operators apply a qualification plan for the method of removing masking varnishes after varnishing of subassemblies. This plan is formally defined through specific documents that have been validated by an authority independent from the operating entity.

Recommendation Possess documentation specific to the nonconformity.	**N°** 116

Phases in which the recommendation is applicable **Weight**

Phase	Weight
INTEGRATION INTO EQUIPMENT	11.1
INTEGRATION INTO SYSTEM	11.1
OPERATION AND MAINTENANCE	11.1

Further description

Nonconformity documents must specify:
the product identification,
the description of the nonconformity,
the cause of the nonconformity,
actions taken to prevent recurrence of the nonconformity,
reworking or repairs if necessary,
check of characteristics affected by the reworking or repairs,
the final decision.

Audit question

Is there any documentation specific to the nonconformity?

Level 1	There is no documentation specific to the nonconformity.
Level 2	Documentation specific to the nonconformity plays a unique role to identify the nonconforming product.
Level 3	Nonconformity documents specify the product identification, the description of the nonconformity and the cause of the nonconformity. However, there is no formal definition of actions to prevent recurrence of the nonconformity, reworking or repairs if necessary and checking of characteristics affected by the reworking or repairs.
Level 4	Nonconformity documents specify the product identification, the description of the nonconformity and the cause of the nonconformity. Actions are formalised to prevent recurrence of the nonconformity, reworking or repairs if necessary and checking of characteristics affected by the reworking or repairs.

Recommendation Take account of the product maintenance policy (request from the customer).	**N°** 117

Phases in which the recommendation is applicable **Weight**

SPECIFICATION..5.8

Further description

The maintenance policy requested by the customer should be taken into account in this activity to maintain product reliability in the long term.

Audit question

How is the product maintenance policy (requested by the customer) taken into account?

Level 1	The product maintenance policy is not defined.
Level 2	The maintenance policy is defined without taking account of reliability aspects.
Level 3	The maintenance policy is defined taking account of reliability aspects (identification and monitoring of critical elements).
Level 4	The product maintenance policy that maintains the product reliability in the long term is perfectly defined and is described in a document. Reliability managers participate in the definition of the maintenance policy (identification and monitoring of critical elements).

Recommendation Maintain the product reliability in production.	**N°** 118

Phases in which the recommendation is applicable	**Weight**
SUPPORT PROCESS ACTIVITIES	8.1

Further description
Maintain the product reliability in production: Analyse potential degradations that could occur during production and integration operations during the design phase (example Process FMECA).

Audit question
Are measures taken to maintain the product reliability in production?

Level 1	No analysis is made of potential degradations that could occur during production operations.
Level 2	Some isolated analyses of degradations that occurred during production operations are carried out so as to remedy observed defects.
Level 3	A Process FMECA was done at least once to evaluate and reduce risks of a reduction in the product reliability.
Level 4	A Process FMECA is done systematically to evaluate and reduce risks of degrading the reliability of new products or product ranges.

Recommendation Plan periodic consultations with customers related to reliability aspects.	**N°** 119

Phases in which the recommendation is applicable **Weight**

SUPPORT PROCESS ACTIVITIES 7.3

Further description

Consult customers regularly on operational reliability aspects and take their comments into account for the design of new products.

Audit question

Are there periodic consultations planned with customers related to reliability aspects?

Level 1	There is no available feedback from customers about the perception of product reliability.
Level 2	There is some available feedback from customers concerning reliability, but not much of it is used.
Level 3	There is some available feedback from customers concerning reliability, and it is used to improve the product design, development and production.
Level 4	The company regularly consults its customers about the reliability of its products (formal interviews or investigations by questionnaires). These feedbacks are used and are the subject of action plans, the results of which are distributed to the customer. The effectiveness of this process may be demonstrated by the customer's satisfaction.

Recommendation Include an inspection step (even visual) to assure that the masking varnish placement activity takes place correctly before varnishing.	**N°** 120

Phases in which the recommendation is applicable **Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY 6.5

Further description
Include an inspection step (even visual) to assure that the masking varnish is placed correctly before varnishing.

Audit question
Is there an inspection step (even visual) to assure that the masking varnish placement activity takes place correctly before varnishing?

Level 1	No particular visual inspection is done during the placement of masking varnish before varnishing.
Level 2	An inspection specific to the placement of masking varnish for varnishing is done, however no document describes the procedure to be followed for this inspection.
Level 3	An inspection step specific to the placement of masking varnish is done. This particular inspection is described in a correctly formalised procedure. However, these documents have not been validated by an independent authority.
Level 4	An inspection step specific to the placement of masking varnish is done. This particular inspection is described in a correctly formalised procedure. These documents have been validated by an independent authority.

Recommendation Provide preventive maintenance to detect an anomaly if any, before using a production means on a subassembly.	**N°** 121

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 4.7
INTEGRATION INTO EQUIPMENT 4.7

Further description

Provide preventive maintenance (by the use of a plan describing a maintenance strategy) to detect an anomaly, if there is one, before use on the subassembly.
This maintenance must be described in a maintenance plan describing intervals, parameters to be verified, critical levels, margins, etc.

Audit question

Is there a preventive maintenance to detect an anomaly, if there is one, before a production means is used on a subassembly?

Level 1	There is no preventive maintenance plan in production.
Level 2	A number of parameters need to be verified within the framework of preventive maintenance. These points are not exhaustive and there is no formal document for them.
Level 3	Preventive maintenance does exist on production means. This maintenance is broken down in a documented maintenance plan. Not all of this plan has been validated.
Level 4	Preventive maintenance does exist on production means. This maintenance is broken down in a documented maintenance plan that has been validated by an authority independent from the operating entity.

Recommendation Write a Reliability Plan	**N°** 122
Phases in which the recommendation is applicable **Weight** SPECIFICATION 7.6	
Further description A Reliability plan has been written, or there is a Development Plan that fully describes reliability aspects	
Audit question Has a Reliability Plan been written for the product?	
Level 1	No reliability plan has been written.
Level 2	The reliability plan has been written but has not been formalised.
Level 3	The reliability plan has been written and validated by the project. This document that was written at an early stage is not updated.
Level 4	The reliability plan has been written and validated by the project. This document is updated throughout the project as a function of events that might make it change.

Recommendation Write a management plan in which key skills (specialists) are identified.	**N°** 123

Phases in which the recommendation is applicable **Weight**
DESIGN..17.7

Further description

Make sure that adjustments to the baseline are specified in the management plan.
Make sure that skills are committed on the project in the management plan and that there is a planning.

Audit question

Is there a reliability management plan in which key skills (specialists) are identified?

Level 1	No management plan, and no planning describing tasks to be accomplished. No organisation set up.
Level 2	There is an incomplete management plan that does not specify any adjustments to the baseline. The planning describing tasks to be accomplished and the organisation set up is imprecise: incompatible with available resources.
Level 3	There is an incomplete management plan that does not specify any adjustments to the baseline. There is planning describing tasks to be accomplished and the organisation set up but it has not been validated.
Level 4	There is a complete management plan specifying any adjustments to the baseline. There is planning describing tasks to be accomplished and the precise and validated organisation set up; there is a good match with the company workload plan.

Recommendation Write an acceptance procedure.	**N°** 124
Phases in which the recommendation is applicable **Weight** DESIGN...7.8	
Further description Make sure that there is an acceptance procedure and that it is relevant. The acceptance procedure is written from a definition file and a test oriented manufacturing file describing adjacent cases, presenting a functional description, inputs/outputs, and key manufacturing points.	
Audit question Is there an acceptance procedure for production tests?	
Level 1	No acceptance procedure.
Level 2	There is an acceptance procedure but it is done in production independently of development teams.
Level 3	There is an acceptance procedure done during the development including configuration monitoring, but it has not been validated and it is not traced.
Level 4	The acceptance procedure is adapted to the product (proof of traceability of its application to the product and its configuration) and is validated.

Recommendation Respect a rest time between each transfer phase to avoid overstressing the subassembly.	**N°** 125

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6.4

Further description

Wait for the time necessary to reach thermal equilibrium between each transfer phase to avoid overstressing the subassembly.
A procedure must specify this need and describe the method.

Audit question

Is a rest time between each silk screen printing operation respected to avoid overstressing the subassembly?

Level 1	No particular timeout is respected between the different transfer phases on a subassembly.
Level 2	A number of measures are applied during the component transfer to respect the necessary waiting time between two transfer phases to avoid reducing reliability of the subassembly. However, these actions are not formally defined in a document.
Level 3	A document explicitly describes times and actions to be respected for the transfer of components. However, this document has not been validated by an authority independent from the operating entity.
Level 4	A document explicitly describes times and actions to be respected for the transfer of components. Furthermore, this document has been validated by an authority independent from the operating entity.

Recommendation Revise and increase the robustness of plans for maintenance of production means to eliminate any possibility of degradation to component connections.	**N°** 126

Phases in which the recommendation is applicable **Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY 6.7

Further description
All preventive and corrective maintenance operations for keeping production means and tools in condition, must be described in a plan revised periodically so as to prevent the use of any tool for which parameters have changed (drifts, etc.) and that could thus cause damage (physical deformations of component connections) during placement operations.

Audit question
Have plans for maintenance of production means been revised and made more robust to eliminate any possibility of degradation to component connections?

Level 1	There is no revision and record of the plan for maintenance of production means specifically applicable to manipulation of components.
Level 2	Plans for maintenance of production means are revised but there is no document that formally describes the frequency of these revisions, nor particular points that might change.
Level 3	Documentation describes points to be revised and to be made more robust regarding the maintenance of production means. The frequency of these revisions and all actions aimed at reducing possibilities of degradation due to parameter drifts, however, have not been validated by an authority independent from the operating entity.
Level 4	Documentation describes points to be revised and to be made more robust regarding the maintenance of production means. The frequency of these revisions and all actions aimed at reducing possibilities of degradation due to parameter drifts have been validated by an authority independent from the operating entity.

Recommendation Make sure that the preparation (dosing) of varnish is controlled by a qualified procedure and test measurements.	**N°** 127

Phases in which the recommendation is applicable **Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY 5.9

Further description
Make sure that varnish preparation (dosing) is controlled by a qualified procedure and measurements used for checking before use.

Audit question
Is the preparation (dosing) of varnish controlled by a qualified procedure and test measurements?

Level 1	There is no qualified procedure or inspection to guarantee the quality of the prepared varnish.
Level 2	The preparation of the varnish is controlled by making checks on a number of points. However, no document formally describes this verification.
Level 3	The preparation of the varnish is controlled by making checks on a number of points. These points and the procedure to be followed are formalised in a document.
Level 4	The preparation of the varnish is controlled by making checks on a number of points. These points and the procedure to be followed are formalised in a document that has been validated by an independent authority.

Recommendation Make sure that operators well informed and study how to update their skills in real time.	**N°** 128

Phases in which the recommendation is applicable **Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY 4.4

Further description
Make sure that the operators are well informed about final test activities and study how to update their skills in real time.

Audit question
Is there a procedure for assuring that operators are well informed and are studies done to determine how to update their skills in real time?

Level 1	No plan has been set up to inform operators and update their knowledge.
Level 2	Operators are informed about particular activities and their skills are updated occasionally. However, these actions have not been formalised in any document.
Level 3	Operators are informed about particular activities and their skills are updated occasionally according to needs. These actions are described in documents describing details of actions to be followed. But these documents have not been validated.
Level 4	Operators are informed about particular activities and their skills are updated occasionally according to needs. These actions are described in documents describing details of actions to be followed and these documents have been validated by an authority independent from the operating entity.

Recommendation Make sure that the inspection on the final varnishing quality is effective, by strictly applying the inspection procedure.	**N°** 129

Phases in which the recommendation is applicable — **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 5.2

Further description

Make sure that the final inspection of the varnishing is effective by strict application of the inspection procedure. This final inspection must verify that the subassembly has passed each elementary step and its associated inspection (check the various validations of documents attached to the subassembly), respecting a formalised procedure.

Audit question

Is it assured that the inspection on the final varnishing quality is effective, by strictly applying the inspection procedure.

Level 1	No procedure describes this final inspection.
Level 2	The final inspection of varnishing activities is made by reviewing a number of points considered to be critical, although no formal document is followed in carrying out these actions.
Level 3	The final inspection of varnishing activities is made by reviewing a number of points considered to be critical. The different actions to be carried out are described in a documented procedure.
Level 4	The final inspection of varnishing activities is made by reviewing a number of points considered to be critical. The different actions to be carried out are described in a documented procedure. This document has also been validated by an authority independent from the operating entity.

Recommendation Make sure that the analysis documentation necessary to evaluate reliability exists.	**N°** 130
Phases in which the recommendation is applicable **Weight** DESIGN.......... 7.5	
Further description Make sure that there is a project documentation to correctly evaluate the reliability.	
Audit question Is there any analysis documentation for evaluating the reliability?	
Level 1	The data used are not traced.
Level 2	The definition file (DD) contains studies, but they are not up to date (consistent with the rest of the file) and have not been validated.
Level 3	The definition file contains up-to-date studies, but they have not been validated.
Level 4	The definition file contains up-to-date and validated studies.

Recommendation Make sure that there are design rules to adapt the choice of a component for a given reliability.	**N°** 131
Phases in which the recommendation is applicable **Weight** DESIGN..12.7	
Further description Make sure that there is a design methodology obliging designers to apply rules aimed at improving reliability. Make sure that it is checked that rules are applied.	
Audit question Are there any design rules to adapt the choice of a component for a given reliability?	

Level 1	No reliability oriented design rules.
Level 2	There are rules but they are not formalised (nor updated nor validated) nor copied nor validated.
Level 3	There are formalised, updated rules, but they have not been validated.
Level 4	There are formalised, updated and validated rules.

Recommendation Make sure that there is a definition of production test points and that test recommendations are applied.	**N°** 132

Phases in which the recommendation is applicable **Weight**
DESIGN..6

Further description
Make sure that the developer includes test operation stresses specified by the test manager in the product definition.
There is a precise test methodology.

Audit question
Are test points defined and are recommendations for production tests applied?

Level 1	Production does not have any information about the method for applying the test on the product.
Level 2	The production manager is aware of the manner in which test operations will be carried out and participated in producing the test recommendations.
Level 3	The production manager is aware of the manner in which test operations will be carried out and participated in producing the test recommendations. There is a validated compilation of recommendations specifically describing the manner in which the tests are carried out, but with no guarantee about their application.
Level 4	Production managers participate in the definition of the production test. There is a validated compilation of recommendations specifically describing the manner in which the tests are carried out, and there is proof that the recommendations are applied.

Recommendation Make sure that there is a product / process qualification procedure.	**N°** 133
Phases in which the recommendation is applicable **Weight** DESIGN...7.2	
Further description Make sure that there is a product / process qualification procedure for manufacturing processes.	
Audit question Is there a qualification procedure for products and manufacturing process?	
Level 1	No product / process qualification procedure.
Level 2	Manufacturing processes are informally designed for the product. This is neither traced nor validated.
Level 3	Manufacturing processes are formally designed for the product, but have not been validated.
Level 4	The company reference documentation imposes a product / process qualification procedure.

Recommendation Make sure that there is a product/supplier qualification procedure.	**N°** 134
Phases in which the recommendation is applicable **Weight** DESIGN..7.6	
Further description Make sure that suppliers are qualified and follow up the following aspects: sustainability quality monitoring.	
Audit question Is there a product/supplier qualification procedure?	
Level 1	Suppliers are not qualified.
Level 2	Suppliers have been partially qualified informally.
Level 3	The company baseline requires that suppliers should be qualified based on the reliability (and / or the manufacturing quality) criterion, this qualification is effective and is based on an analysis of data provided by suppliers.
Level 4	The company baseline requires that suppliers should be qualified based on the reliability (and / or the manufacturing quality) criterion, this qualification is effective and is based on formal activities (interview with suppliers, analysis of previous services, audits, ISO certification).

Recommendation Make sure that there is a manufacturing qualification for the new component.	**N°** 135
Phases in which the recommendation is applicable **Weight** DESIGN........7.2	
Further description Make sure that there is a qualification procedure so as to evaluate risks related to the use of the new technology component (for example by extrapolation of use in a similar environment).	
Audit question Are new components qualified before they are used?	
Level 1	No procedure.
Level 2	There are informal rules.
Level 3	There is a procedure.
Level 4	There is a managed procedure that monitors technological change and validated by competent technical services.

Recommendation	**N°**
Make sure that the procedure for implementing the means is known.	136

Phases in which the recommendation is applicable	**Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY	5.1
INTEGRATION INTO EQUIPMENT	5.1
INTEGRATION INTO SYSTEM	5.1

Further description
Make sure that the person who will perform the task knows the procedure for implementing the means at a production workstation.

Audit question
Is it checked that the procedure for implementing the means is known?

Level 1	There is no procedure or the operator cannot access it from the workstation.
Level 2	There is a procedure explicitly describing implementation of production means at the workstation. However, the operator can implement the means with no assurance that he is familiar with it The proposed format is such that the operator will not systematically be familiar with the procedure.
Level 3	There is a procedure explicitly describing implementation of production means at the workstation. This is formalised in a manner that obliges the operator to be familiar with it before implementing the means (visual warning when starting up the means, etc).
Level 4	There is a procedure explicitly describing implementation of production means at the workstation. This is formalised in a manner that obliges the operator to become familiar with it before implementing the means (visual warning when starting up the means, etc). This formal definition has also been validated by an authority independent from the operating entity.

Recommendation Make sure that the predicted reliability calculation is made using a recognised tool (FIDES, adjusted MIL-HDBK-217, proprietary feedback from operations or other method).	**N°** 137

Phases in which the recommendation is applicable **Weight**

DESIGN..7.7

Further description

Make sure that the predicted reliability calculation is made using a recognised tool associated with the selected calculation methodology

Audit question

Is there a tool for formally calculating the reliability? Is there a formal choice of the reliability compilation (FIDES, adjusted MIL-HDBK-217, proprietary feedback from operations or other method)?

Level 1	Predicted reliability calculation methodology not controlled. Tool not recognised or validated
Level 2	Predicted reliability calculation methodology identified but not recognised (controversial relevance to the state-of-the-art) and not validated Tool not recognised or validated
Level 3	Predicted reliability calculation methodology identified and recognised and not validated Tool recognised but not validated
Level 4	Selection and validation of methods and tools used for predicted reliability calculations

Recommendation Make sure that the right software is loaded and keep the identification of its version.	**N°** 138
Phases in which the recommendation is applicable — **Weight** MANUFACTURING OF BOARD OR SUBASSEMBLY .... 6.7 INTEGRATION INTO EQUIPMENT .... 6.7 INTEGRATION INTO SYSTEM 6.7	
Further description Make sure that the right software is loaded and more particularly that it is the most recent version to be used in the subassembly. This identification information must also be traced in the remainder of the process.	
Audit question Is it checked that the right software is loaded, and that its version is identified?	

Level 1	No identification of the loaded software is made.
Level 2	After software has been loaded in a hardware subassembly, an identifier of the loaded software is provided, assuring that the software is conforming with the subassembly. However, no document precisely describes the format or logging of this identifier.
Level 3	Every time that software is loaded, the operator is informed of the software version to be used. An identifier of the version to be used is provided after the operation.
Level 4	Every time that software is loaded, the operator is informed of the software version to be used. An identifier of the version to be used is provided after the operation A cross verification is formalised.

Recommendation	**N°**
Make sure that means are maintained and that this maintenance is followed.	139

Phases in which the recommendation is applicable	**Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY	5.9
INTEGRATION INTO EQUIPMENT	5.9

Further description
Make sure that maintenance is done on production means and that this maintenance is followed, particularly to take account of the most recent nonconformities.

Audit question
Is a check carried out to assure that means are maintained and that this maintenance is followed?

Level 1	There is no monitoring of maintenance done on production means.
Level 2	Maintenance is provided for production means and this maintenance is followed. However, there is no formal documented maintenance plan indicating the frequency and compulsory application points for this maintenance.
Level 3	Real maintenance of the production means has been set up. It is monitored based on a plan describing all compulsory application points and the frequency of the different actions.
Level 4	Real maintenance of the production means has been set up. It is monitored based on a plan describing all compulsory application points and the frequency of the different actions. Furthermore, these documents have been validated by an authority independent from the operating entity.

Recommendation Make sure that the operator has received training (qualification), appropriate for the activity.	**N°** 140
Phases in which the recommendation is applicable — **Weight** MANUFACTURING OF BOARD OR SUBASSEMBLY .... 8.5 INTEGRATION INTO EQUIPMENT 8.5	
Further description Make sure that the operator has received training (qualification), appropriate for the activity.	
Audit question Is it checked that the operator has received training (qualification), appropriate for the activity?	

Level 1	There is no check that an operator has received appropriate training for the workstation to which he is posted.
Level 2	There is a verification to assure that the operator required to perform the task has actually previously received appropriate training.
Level 3	There is a verification to assure that the operator required to perform the identified task has actually previously received appropriate training. This verification follows a formal procedure for a complete review of the different points.
Level 4	There is a verification to assure that the operator required to perform the identified task has actually previously received appropriate training. This verification follows a formal procedure for a complete review of the different points. The procedure has been validated by an authority independent from the operating entity.

Recommendation Secure means (drying oven T°) through direct monitoring by probes and recordings, to prevent overstresses.	**N°** 141

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 6.6

Further description

All overstresses must be detectable and quantified (instant of occurrence stress level relative to required parameters).

It must be possible to display this detection in real time and not only after the activity, so that action can be taken during the application thus reducing the overstress on the subassembly and therefore limiting its degradation.

Audit question

Are means secured (drying oven T°) through direct monitoring by probes and recordings, to prevent overstresses?

Level 1	There is no particular safety system.
Level 2	There are monitoring systems or other indicators to determine that parameters to be applied by means on subassemblies are respected. However, there is no study or formal document dealing with these particular monitoring actions.
Level 3	There are monitoring systems or other indicators to determine that parameters to be applied by means on subassemblies are respected. Documents formally define the coverage level and setting up of these direct monitoring systems.
Level 4	There are monitoring systems or other indicators to determine that parameters to be applied by means on subassemblies are respected. Documents formally define the coverage level and setting up of these direct monitoring systems. The monitoring plan thus produced has been validated by an authority independent from the operating entity.

Recommendation Select the components used.	**N°** 142
Phases in which the recommendation is applicable **Weight** SUPPORT PROCESS ACTIVITIES 12.9	
Further description Select the components used, analyse the market, evaluate component reliability.	
Audit question Are reliability criteria considered when selecting the components used?	
Level 1	No components are selected.
Level 2	Components are selected informally based on the reliability (or manufacturing quality) criteria.
Level 3	The company baseline requires that components should be selected based on the reliability (and/or manufacturing quality) criterion without further clarification. This is effective but is based only on manufacturer data.
Level 4	The company baseline requires that components should be selected based on the reliability (and/or manufacturing quality) criterion. This is effective and is based on detailed analyses (use of manufacturer data, manufacturer audits, evaluation of the technologies used).

Recommendation Select component suppliers.	**N°** 143

Phases in which the recommendation is applicable — **Weight**

SUPPORT PROCESS ACTIVITIES.. 10.8

Further description

Select component suppliers, analyse the market. Evaluate how component reliability is taken into account.

Audit question

Are reliability criteria considered when selecting component suppliers?

Level 1	Component suppliers are not selected.
Level 2	A partial selection of component suppliers is made informally.
Level 3	The company baseline requires that component suppliers should be selected based on the reliability (and or manufacturing quality) criterion. This is effective and is based on an analysis of data provided by suppliers.
Level 4	The company baseline requires that component suppliers should be selected based on the reliability (and or manufacturing quality) criterion. This is effective and is based on formal activities: (interview with suppliers, analysis of previous services, audit, ISO certification).

Recommendation Increase personnel awareness about a visual verification of subassemblies after placement and before remelting.	**N°** 144

Phases in which the recommendation is applicable **Weight**
MANUFACTURING OF BOARD OR SUBASSEMBLY 5.9

Further description
It is important that the person responsible for this activity should be informed so as to reduce anomalies caused by human error (in this case visual inspection) not detected during the inspection, so as to minimise the risk due to human error or the failure to detect an anomaly.

Audit question
Are personnel made aware about a visual verification of subassemblies after placement and before remelting?

Level 1	No particular verification is done after components have been placed and before remelting.
Level 2	The operator may make a verification that the placement activity before remelting took place correctly. However, this verification is not formally described.
Level 3	The operator does make a verification that the placement activity before remelting took place correctly. This verification is done in accordance with a procedure (from mentioning a simple visual inspection to the description of points to be systematically verified).
Level 4	The operator does make a verification that the placement activity before remelting took place correctly. This verification is done in accordance with a procedure (from mentioning a simple visual inspection to the description of points to be systematically verified). Furthermore, this procedure has been validated by an authority independent from the operating entity.

Recommendation	**N°**
Increase operators awareness about the verification of the quality of the soldering flux deposit (implementation of a verification action that must appear in the subassembly follower sheet).	145

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 5.9

Further description

Increase operators awareness about the verification of the quality of soldering flux deposit.
Since this operation requires a special verification after it has been done, placement of an electronic barcode reading as verification phase must enable good monitoring of this inspection and the subassembly follower sheet must include a check that it has been done.

Audit question

Are operators made aware of the need to verify the quality of soldering flux deposit (implementation of a verification action that must appear in the subassembly follower sheet)?

Level 1	No particular verification is made to check that the soldering flux deposit took place correctly.
Level 2	The operator checks that the activity for the soldering flux deposit (quantity, appearance, etc.) took place correctly. However this verification is not formally described.
Level 3	The operator checks that the activity for the soldering flux deposit (quantity, appearance, etc.) took place correctly. This verification is done in accordance with a procedure enabling traceability (for example barcode reading of the manufacturing follower sheet).
Level 4	The operator checks that the activity for the soldering flux deposit (quantity, appearance, etc.) took place correctly. This verification is done in accordance with a procedure enabling traceability (for example barcode reading of the manufacturing follower sheet). Furthermore, these verification means and their placement have been validated by an authority independent from the operating entity.

Recommendation Monitor and control corrective actions done by the subcontractor related to product reliability.	**N°** 146

Phases in which the recommendation is applicable **Weight**

SUPPORT PROCESS ACTIVITIES 7.2

Further description

Monitor and control (plan, record) corrective actions done by the subcontractor related to product reliability.

Audit question

Are corrective actions done by the subcontractor related to reliability monitored

Level 1	No system has been set up for monitoring corrective actions that the subcontractor was asked to take.
Level 2	Corrective actions that the subcontractor was asked to take are monitored partially during meetings with the subcontractor.
Level 3	A system has been set up for periodic monitoring of corrective actions that the subcontractor has been asked to take, but it is not completely or satisfactorily controlled.
Level 4	A system has been set up for periodic monitoring of corrective actions that the subcontractor has been asked to take and there is proof demonstrating that this monitoring is effective.

Recommendation Take account of the equilibrium between reliability and complexity of built-in tests.	**N°** 147

Phases in which the recommendation is applicable **Weight**
DESIGN..10.2

Further description

Make a compromise between the complexity of built-in tests and the reliability of components used for the operational functions, in order to achieve an effective test coverage ratio.
Request a justification document on the subject.

Audit question

Are choices related to test coverage documented?

Level 1	The reliability calculations carried out do not establish the contribution of each function (including built-in test devices) to reliability.
Level 2	The influence of built-in test devices on reliability or complexity is taken into account informally
Level 3	There is a specified objective limiting the impact of built-in test devices on reliability. There is an a posteriori verification that this objective is achieved.
Level 4	There is a specified objective limiting the impact of built-in test devices on reliability. This objective is taken into account in the product design so as to optimise the design of built-in tests, and this procedure is traced. The verification of the objective is substantiated.

Recommendation Deal with the reliability aspect in management reviews.	**N°** 148

Phases in which the recommendation is applicable **Weight**

SUPPORT PROCESS ACTIVITIES 5.6

Further description

Deal with the theme of reliability in the agenda of management reviews (progress objective, action plan, measurement of the extent to which objectives are achieved, and reliability assessment of products at customers).

Audit question

Is the reliability aspect dealt with in management reviews?

Level 1	The Reliability of products is not discussed in the Management reviews.
Level 2	The reliability of products is discussed irregularly during Management Reviews.
Level 3	The reliability of products is systematically dealt with during Management Reviews.
Level 4	The reliability of products is systematically dealt with during Management Reviews, progress objectives are defined, and an evaluation about whether or not these objectives are achieved is made.

Recommendation Deal with anomalies, using an Incident Processing and Corrective Action Logic	**N°** 149

Phases in which the recommendation is applicable **Weight**

SUPPORT PROCESS ACTIVITIES 8.3

Further description

Set up an anomaly processing system that can cover the entire FIDES life cycle.
This system is intended to:

- record the circumstances of the anomaly,
- record references of the defective product,
- propose remedial action,
- analyse the causes of the anomaly,
- propose corrective/preventive actions,
- check the efficiency of the corrective/preventive actions.

Processing in this system is suitable for:

- quickly finding identical anomalies observed previously,
- producing statistics,
- use as feedback from operations.

Audit question

What process is set up to collect technical events, produce anomaly reports and measure improved reliability? How are hardware upgrades managed?

Level 1	There is no system for processing anomalies.
Level 2	The manufacturer has set up a system for processing anomalies, that partially satisfies the requirements of the recommendation. It is not fully applied to the project.
Level 3	The manufacturer has set up a system for processing anomalies, that partially satisfies the requirements of the recommendation. It is fully applied to the project.
Level 4	The manufacturer has set up a system for processing anomalies, that fully satisfies the requirements of the recommendation. It is fully applied to the project. Furthermore: - Indicators are available, - They are regularly interpreted to produce conclusions, - Benefits of the system set up are measured.

Recommendation Use of validated and recognised modelling means.	**N°** 150
Phases in which the recommendation is applicable **Weight** DESIGN... 13.8	
Further description Use of validated and recognised modelling means (particularly electrical, thermal, mechanical models). Demonstrate that tools are monitored and updated.	
Audit question Are validated and recognised modelling means used?	
Level 1	Modelling means are neither validated nor recognised.
Level 2	Modelling means are recognised and validated but not monitored.
Level 3	Modelling means are recognised, validated and monitored but no one is assigned to management of tools.
Level 4	Modelling means are recognised, validated and monitored. Managed monitoring.

Recommendation Use statistical methods adapted to the use of feedback from operations.	**N°** 151
Phases in which the recommendation is applicable **Weight** SUPPORT PROCESS ACTIVITIES..6	
Further description Use statistical methods adapted to the use of feedback from operations.	
Audit question Are statistical methods adapted to the use of feedback from operations?	
Level 1	Feedback from operations is neither observed nor recorded.
Level 2	Feedback from operations is recorded, but it is not used at all, or it is used with unsuitable statistical methods not formalised.
Level 3	Feedback from operations is recorded, it is used with suitable methods but they are not formalised (no generalised methods).
Level 4	Feedback from operations is recorded, it is processed using relevant statistical methods and it is distributed to users.

Recommendation Validate the subcontractor's Reliability management baseline.	**N°** 152

Phases in which the recommendation is applicable — **Weight**

SUPPORT PROCESS ACTIVITIES 7.7

Further description

Validate that the subcontractor has actually taken contract reliability requirements into account and that his project baseline takes them into account.

Audit question

Has the reliability management baseline of the subcontractor been validated?

Level 1	Contractual requirements about reliability are applicable but are not transmitted to the subcontractor.
Level 2	The manufacturer sends contractual requirements or internal requirements related to reliability to the subcontractor, but the subcontractor has not written any document guaranteeing that these requirements are applied.
Level 3	The subcontractor has produced a reliability management reference document (management plan or reliability plan), that repeats the original requirements of the prime contractor. The manufacturer does not verify that this baseline is applied.
Level 4	The subcontractor has produced a reliability management reference document (management plan or reliability plan), that repeats the original requirements of the prime contractor. The manufacturer validates that this baseline is applied (progress meeting, audit, etc.).

<u>Recommendation</u> Check conformity of purchased products.	**N°** 153

Phases in which the recommendation is applicable **Weight**

Phase	Weight
MANUFACTURING OF BOARD OR SUBASSEMBLY	8.6
INTEGRATION INTO EQUIPMENT	8.6
INTEGRATION INTO SYSTEM	8.6

Further description

Use measurements for verification of purchased products such as:
examination of the required documentation,
inspection and audit at the purchase source,
examination of products on delivery.

Audit question

Is the conformity of purchased products checked?

Level 1	There is no verification on the conformity of purchased products.
Level 2	Conformity of purchased products is only verified by examination of the required documentation.
Level 3	Conformity of purchased products is verified by examination of products on delivery and by examination of the required documentation.
Level 4	Conformity of purchased products is verified by examination of products on delivery, by examination of the required documentation and by inspection and audit of the purchase source.

Recommendation Perform an inspection action (barcode reading, reading the S/N) to verify that the right product is available before starting the test.	**N°** 154
Phases in which the recommendation is applicable **Weight** MANUFACTURING OF BOARD OR SUBASSEMBLY 6.1	
Further description Perform an inspection action (barcode reading, reading the S/N) to verify that the right product is available before starting the test.	
Audit question Is an inspection action (barcode reading, reading the S/N) performed to verify that the right product is available before starting the test?	

Level 1	No verification is made to assure that the right product is available for the test to be done.
Level 2	A verification of the product type for the test to be done might be made This verification is not formally described.
Level 3	The identification of the product to be tested is systematically verified. This is based on a documented procedure indicating the procedure to be followed (barcode reading of an identifier, etc.).
Level 4	The identification of the product to be tested is systematically verified. This is based on a documented procedure indicating the procedure to be followed (barcode reading of an identifier, etc.). This verification method has been validated by an authority independent from the operating entity.

Recommendation Check that the test coverage during and after burn-in is formalised correctly.	**N°** 155

Phases in which the recommendation is applicable **Weight**

MANUFACTURING OF BOARD OR SUBASSEMBLY 5.2

Further description

Check that the test coverage during and after burn-in is formalised correctly.

Audit question

Is it checked that the test coverage for burn-in is formalised correctly?

Level 1	No verification of the test coverage rate during burn-in is done.
Level 2	The test coverage rate during burn-in was verified when it was set up. No additional verifications have been done with regard to possible changes (new technologies, etc.) .
Level 3	The test coverage rate during burn-in is verified. A document describes changes requiring a verification and the procedure to be implemented.
Level 4	The test coverage rate during burn-in is verified. A document describes changes requiring a verification and the procedure to be implemented. This entire document has been validated by an authority independent from the operating entity.

Recommendation Check that environmental specifications are complete.	**N°** 156
Phases in which the recommendation is applicable **Weight** RUGGEDISING 4	
Further description Make sure that specifications are complete by using validation criteria: analysis, tests, feedback from operations, respect standards	
Audit question How is it checked that environmental specifications are complete?	
Level 1 No verification or insufficient verification of completeness.	
Level 2 Completeness of environmental specifications is based on at least 2 out of the 4 methods (Analysis, Experience, Tests, Standards).	
Level 3 Completeness of environmental specifications is based on at least 3 out of the 4 methods (Analysis, Experience, Tests, Standards).	
Level 4 Completeness of environmental specifications is based on all 4 methods (Analysis, Experience, Tests, Standards). The approach assuring the coverage is described in a formal procedure	

Recommendation Provide training and manage maintenance of skills for implementation and maintenance of the product	**N°** 157

Phases in which the recommendation is applicable **Weight**

RUGGEDISING 7

Further description

Train users to make sure that the product is always used and repaired correctly

Audit question

Have users (for use and maintenance) received training on the product? Is this training repeated and updated to satisfy needs?

Level 1	No training associated with the product
Level 2	There is some initial training or training of only some users
Level 3	There is a complete training but with no skills management
Level 4	There is a complete training. Skills management assures that all users have been trained and that the training is up to date

Recommendation Check that procedures specific to the product and rules specific to businesses are respected by an appropriate monitoring system	**N°** 158

Phases in which the recommendation is applicable **Weight**
RUGGEDISING 7

Further description
Implement means to supervise and control users in use and maintenance of the product, to be able to identify deviations and deal with them.

Audit question
Are inspection means (process, recording means) sufficient for the supplier to assure that rules for the use of the product are well respected by users?

Level 1	No inspection means
Level 2	Existence of a few monitoring and inspection means
Level 3	Existence of non-exhaustive or informally used inspection means. Deviations are not systematically dealt with.
Level 4	There are complete and formalised inspection means. Deviations are dealt with.

Recommendation Design dependable electrical protection devices.	**N°** 159
Phases in which the recommendation is applicable — **Weight** RUGGEDISING 4	
Further description Identify protection needs Design electrical protection devices Make sure that they are testable and maintainable Include the case of these devices in the definition of the maintenance policy	
Audit question How are electrical protection devices designed?	

Level 1	Operating dependability principles are not applied to electrical protection devices
Level 2	Operating dependability principles are applied to electrical protection devices in some cases
Level 3	Operating dependability principles are applied to electrical protection devices. There are verifications that these devices are operating correctly throughout the life of the product.
Level 4	Operating dependability principles are applied to electrical protection devices. There are verifications that these devices are operating correctly throughout the life of the product. This approach is described in a procedure.

Recommendation Study and handle risks of the product under test being deteriorated by failures of its test or maintenance means.	**N°** 160

Phases in which the recommendation is applicable **Weight**
RUGGEDISING..4

Further description
Minimise the risk of deterioration by taking it into account in the design of the test means and the tested unit, develop appropriate prevention means.

Audit question
How are risks of the product under test being deteriorated by failure of its test means dealt with?

Level 1	No study of failures of the test and maintenance means
Level 2	Some known failures are taken into account
Level 3	These risks are analysed in the design of the test means and unit tested. Appropriate prevention means are set up.
Level 4	These risks are analysed in the design of the test means and unit tested. Appropriate prevention means are set up. This approach is described in a procedure.

Recommendation Identify and use appropriate prevention means of preventing reasonably predictable aggressions (related to the weather)	**N°** 161

Phases in which the recommendation is applicable **Weight**
RUGGEDISING 4

Further description
Search and prevent effects of reasonably predictable aggressions (related to the weather) (UV, hail, condensation, etc.)

Audit question
Are reasonably predictable aggressions (related to the weather) taken into account?

Level 1	Aggressions related to the weather are not taken into account
Level 2	Well known aggressions related to the weather are taken into account
Level 3	Aggression cases (related to the weather) are searched for and are taken into account
Level 4	Aggression cases related to the weather are searched for and are taken into account. This approach is described in a procedure or a standard

Recommendation Use appropriate prevention means to identify and handle reasonably predictable abnormal uses	**N°** 162
Phases in which the recommendation is applicable **Weight** RUGGEDISING 4	
Further description Search for and prevent reasonably predictable abnormal uses: misuse of the product, installation backwards et cetera	
Audit question Are reasonably predictable abnormal uses taken into account?	
Level 1	Abnormal uses are not taken into account
Level 2	Well known abnormal uses are taken into account
Level 3	A search is made for cases of abnormal uses and they are taken into account.
Level 4	A systematic search is made for cases of abnormal uses and they are taken into account. This approach is described in a procedure.

Recommendation Include production, storage and maintenance environments in the product environment specifications	**N°** 163
Phases in which the recommendation is applicable **Weight** RUGGEDISING 4	
Further description Extend environment specifications so that they also cover production, storage and maintenance situations (and not only usage cases). The controlling parameter for storage (for example spare parts) could be the duration.	
Audit question How are production, storage and maintenance environments taken into account in the product environment specification?	
Level 1	Production, storage and maintenance environments are not specified
Level 2	Production, storage and maintenance environments are taken into account if they are known
Level 3	Production, storage and maintenance environments are taken into account in environment specifications
Level 4	Production, storage and maintenance environments are systematically taken into account. Environments are formalised in a documentation

<u>Recommendation</u> Justify that environment specifications are respected	**N°** 164

Phases in which the recommendation is applicable	**Weight**
RUGGEDISING	4

Further description
Set up a procedure to justify that environment specifications that guarantee completeness are respected

Audit question
How is it justified that environment specifications are respected

Level 1	No formal demonstration that environment specifications are respected
Level 2	There is a formal justification that the main environment specifications are respected
Level 3	There is a formal justification that all environment specifications are respected
Level 4	There is a formal justification that all environment specifications are respected. The justification approach identifies margins on the need. The justification process is described in a formal procedure

Recommendation Carry out a product improvement process (for example highly accelerated stress tests) so as to limit the product sensitivity to environmental constraints (disturbances, environments, overstress)	**N°** 165
Phases in which the recommendation is applicable **Weight** RUGGEDISING 7	
Further description Carry out a product improvement process during development and production to avoid delivering an immature product (presence of infancy defects) or a product with weaknesses (burn-in). Aggravated HALT (Highly Accelerated Life Test) type tests are mentioned as an important tool towards meeting this objective	
Audit question Is there a product improvement process to construct its robustness and accelerate its maturity?	

Level 1	No procedure for improvement of robustness and maturity
Level 2	Some measures are taken to improve robustness and maturity
Level 3	Implementation of a procedure to improve robustness and maturity
Level 4	Implementation of a procedure to improve robustness and maturity. This approach is systematic and is described in a formal procedure

Recommendation Perform an analysis of failure cases that could result in failure propagation.	**N°** 166
Phases in which the recommendation is applicable **Weight** RUGGEDISING..4	
Further description Analyse possibilities of failure propagation to limit the effects and to limit unnecessary removals, particularly using an FMECA (Failure Modes, Effects and Criticality Analysis)	
Audit question Have the possibilities of failure propagation been analysed?	
Level 1	No analysis of failure propagation
Level 2	Some failure propagation cases are taken into account
Level 3	Risks of failure propagation are taken into account in the design and when doing FMECAs. These cases are dealt with by choices of protections or architectural choices.
Level 4	Risks of failure propagation are taken into account in the design and when doing FMECAs. These cases are dealt with by choices of protections or architectural choices. This approach is described in a procedure.

Recommendation Carry out a process analysis of implementation and maintenance operations	**N°** 167
Phases in which the recommendation is applicable / **Weight** RUGGEDISING 4	
Further description Carry out a process FMECA (Failure Modes, Effects and Criticality Analysis) for implementation and maintenance operations	
Audit question How are risks of errors in carrying out implementation and maintenance operations analysed?	
Level 1 No analysis of risks of errors in carrying out operations	
Level 2 Well known anomalies and drifts are collected and used in the design of the product or its maintenance	
Level 3 The process FMECA for implementation and maintenance operations is done in some cases and is used for the product design or its maintenance	
Level 4 The process FMECA for implementation and maintenance operations is systematically done and is used for the product design or its maintenance	

Recommendation Carry out a review of maintenance operations done by the final user and deal with his recommendations	**N°** 168
Phases in which the recommendation is applicable RUGGEDISING	**Weight** 4
Further description Take account of user recommendations in the design of product maintenance after a review	
Audit question Has a review of maintenance operations done by the user been organised?	
Level 1	No review with the user
Level 2	User recommendations are taken into account informally, or there is paper review with no operation on a product
Level 3	Organisation of a maintenance procedures review with the user that includes performing operations on the equipment
Level 4	Organisation of a maintenance procedures review with the user that includes performing operations on the equipment. The review process is described in a plan or a formalised procedure

Recommendation Write complete procedures for all product implementation and maintenance operations	**N°** 169
Phases in which the recommendation is applicable **Weight** RUGGEDISING..7	
Further description Provide users and maintenance with documentation describing procedures to be applied for each situation	
Audit question Is there any documentation that describes all product implementation and maintenance operations?	
Level 1	No documentation, or superficial documentation
Level 2	There is documentation covering some of the needs
Level 3	There is complete documentation, but its exhaustiveness cannot be proven
Level 4	The documentation exists and is complete. The composition of the documentation is described in a procedure that guarantees that it is complete

Recommendation Respect a standard dealing with power supplies (standard that defines possible disturbances and possible EN2282 type variations). The standard must be respected both for electricity generation and for electricity consumption	**N°** 170

Phases in which the recommendation is applicable **Weight**

RUGGEDISING 4

Further description

Apply a standard on all electrical interfaces to guarantee their operating conditions and predictable extreme situations.

It is also recommended that the person responsible for the system into which the product is integrated should guarantee that the standard is respected for the entire system. The same applies for respecting the standard for the generation of electricity that powers the product

Audit question

Is there a standard on electrical power supplies applicable to the product and the system surrounding it? How is this standard applied?

Level 1	No standard for electrical power supplies
Level 2	There is a standard used as a guide to define electrical interfaces
Level 3	There is a standard applied for all electrical interfaces of the product
Level 4	There is a standard applied for all electrical interfaces of the product. A formal justification is provided that the standard is respected.

<table>
<tr><td colspan="2"><u>Recommendation</u>
Respect a standard dealing with conducted and radiated electromagnetic disturbances. This is equally applicable to the product and the system into which it is integrated</td><td>N°
171</td></tr>
<tr><td colspan="3">Phases in which the recommendation is applicable Weight
RUGGEDISING .... 3</td></tr>
<tr><td colspan="3">Further description
Apply a standard on conducted and radiated electromagnetic disturbances</td></tr>
<tr><td colspan="3">Audit question
Is there a standard concerning conducted and radiated electromagnetic disturbances applicable to the product and the system that surrounds it? How is it applied?</td></tr>
<tr><td>Level 1</td><td colspan="2">No standard for conducted and radiated electromagnetic disturbances</td></tr>
<tr><td>Level 2</td><td colspan="2">There is a standard used as a guide for the definition of tolerances to conducted and radiated electromagnetic disturbances</td></tr>
<tr><td>Level 3</td><td colspan="2">A standard is applied to define the tolerance of the product to conducted and radiated electromagnetic disturbances</td></tr>
<tr><td>Level 4</td><td colspan="2">A standard is applied to define the tolerance of the product to conducted and radiated electromagnetic disturbances. There is a formal substantiation that the standard is respected.</td></tr>
</table>