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Master's Degree in Mechatronic Engineering
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Master's Degree Thesis

Reliability and Criticality Analysis of Automotive Embedded Systems

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To those who accompanied
us in this journey

Summary

In the last decades the automotive field has become increasingly multidisciplinary. This has happened because of the outbreak of electronic components first, and software programming secondly, in the design of more modern vehicles. Therefore, the need for controlled and safe products, hence functional safety, has become more delicate and relevant. In particular, the commonly accepted standard is ISO 26262. This addresses the possible hazards that may arise due to malfunctioning electronic and electric components and proposes some safety measures to prevent, detect or control such situations. The subject of this work is the study of two electronic boards, conducted with two different perspectives: FIDES and FMECA. The integration between the two methodologies is efficient in time and effective in highlighting the most delicate failure modes, and thus identifying the most critical situations in a global scope. This is fundamental in preventing any kind of risk, caused by failures, that can bring damage to human activities.

Contents

List of Figures

List of Tables

Abbreviations

ADAS	Advanced Driver Assistance Systems
ASIL	Automotive Safety Integrity Level
CAN	Controller Area Network
COTS	Commercial Off-The-Shelf
ECU	Electronic Control Unit
EV	Electric Vehicle
FIT	Failure In Time
FMEA	Failure Mode and Effect Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
FMEDA	Failure Modes, Effects and Diagnostic Analysis
HARA	Hazard Analysis and Risk Assessment
H-SDF	Hyper-Spectral Data Fusion
IC	Integrated Circuit
ISO	International Standards Organization
I&M	Ideas&Motion
LVDS	Low Voltage Differential Signaling
PMSM	Permanent Magnet Synchronous Motor
PWM	Pulse Width Modulation
QA	Quality Assurance
QM	Quality Management
RH	Relative Humidity
SEooC	Safety Element out of Context
SPFM	Single Point Fault Metric

Introduction

The word "reliability" was coined by the poet Samuel T. Coleridge who started the English Romantic Movement. He used this word in some lines written in praise of his friend, the poet Robert Southey :

> “he bestows all the pleasures, and inspires all that ease of mind
> on those around him or connected with him, with perfect consistency, and
> (if such a word might be framed) absolute reliability.”

The modern concept of reliability began to develop with the rise of mass production and the relative need to deal with quality issues. Another contributing factor was the wider use of statistics in the applicative fields. The exploitation of the vacuum tube during World War II, which was one the most unreliable components used on the battlefield, was the driving event that led to the birth of Reliability Engineering, followed by the introduction of the transistors. [1]

In the 1950s the greater attention with regard to the reliability issue, mostly due to the involvement of the military, promoted the establishment of the Advisory Group on Reliability of Electronic Equipment (AGREE) formed by the department of defense and the American electronics industry. In 1957 the publication of the "Reliability of Military Electronic Equipment" report raised the awareness about the new discipline of Reliability Engineering.

In the 1960s Reliability Engineering development followed two directions: the first one was an increased specialization, the second one was a shift from component-level reliability to system-level reliability. These trends were correlated to the progressively more complex engineering systems. In 1967 sneak circuit analysis was developed by Boeing for NASA. This technique allows the identification of possible sneak or hidden paths in the circuit that may cause failures.

Reliability improvements were possible in the 1970s with the widespread use of transistors and the invention of new technologies, in particular the introduction of large scale integration (LSI) devices. Hence the ideation of new models for reliability prediction.

The 1980s witnessed the outbreak of computer systems, and with that the diffusion of reliability prediction programs, able to produce predictions, fault trees, failure modes and effects analyses (FMEA) and similar. Since the system reliability had increased, more attention was payed to human reliability. This subject was first studied in the 1960s but began to be more deeply analyzed in this decade. [2] [3]

From the 1990s onward the system complexity increased in a way such that the reliability analysis had to consider a more detailed and multileveled approach.

In this perspective performing the criticality analysis becomes nodal: firstly to obtain a more accurate and effective result in safety, secondly to balance the costs for the producer with the product requirements.

In this work the principles behind reliability and criticality are discussed and applied to the analysis of two electronic embedded automotive boards designed and produced by Ideas&Motion. The most critical one is the Dual Inverter board, followed by the Hyper-Spectral Data Fusion board.

The first part of the analysis revolves around reliability and is based on the FIDES methodology. Firstly, the life profile is defined depending on the operational situations of the item through time. Multiple factors are taken into account: number of hours working, physical stresses, human interactions and others. Secondly, each component is classified depending on its properties: principally component type, package and operating conditions. These data are combined by the FIDES analysis tool: the failure rates of each component and of the item are obtained, and the single influences of the phases and stresses may be observed.

The second part of the study involves criticality and focuses only on the Dual Inverter. The applied methodology is FMECA (Failure Mode, Effects and Criticality Analysis). The failure modes with their probabilities are classified according to the FMECA Manual of the Reliability Analysis Center and the effects on the functioning of the item are studied.

These data are combined with the previously obtained FIDES results to achieve a deeper understanding of the risks determined by the single components in the item. This step allows the identification of the most critical components and of the most hazardous failures.

Consequently, it is possible to determine the ASIL (Automotive Safety Integrity Level) of the electronic board taken into analysis. The determination of the ASIL level is described by the ISO 26262, the international standard for functional safety in the automotive field redacted by the International Organization for Standardization. The ASIL value is obtained by the combination of severity of the effects, exposure to operational situations that may be hazardous, and controllability of the vehicle in case of failure. This score represents the level of safety of the system considered.

Chapter 1

ISO 26262

The increasing complexity of the automotive systems, and thus the associated risks, over the last years led to a consequent evolution of the related standards. In particular, the functional safety aspects have gained more and more relevance. In this context a primary role is covered by ISO 26262, the standard for functional safety of electrical and electronic systems in production automobiles by the International Organization for Standardization (ISO). It was published in 2011 and its title is "Road vehicles – Functional safety". The previous reference standard was IEC 61508, issued between 1998 and 2000, and replaced because of the greater completeness of the new standard: specifically ISO 26262 includes the study of controllability and deals with more technical aspects.

1.1 Scope

The products covered by ISO 26262 are electrical/electronic systems on series production passenger cars with a maximum gross weight of 3500 kg. The purpose of the whole standard is to cover the possible hazards caused by malfunctions in the systems. [4]

When defining functional safety, firstly it is necessary to clarify the different concepts of safety. [5]

- Passive safety: its goal is to minimize the severity of the effects of an accident which is assumed inevitable. Some passive safety elements may be seatbelts and airbags.
- Active safety: its goal is to avoid accidents or at least minimize the consequences. Examples of active safety elements are ABS and traction control.
- Functional safety: its goal is to ensure the correct functioning of all the electrical and electronic items. The boards object of this work are an example of functional safety elements.

The latter is the one treated in ISO 26262, and focuses mainly on the risks related to random hardware failures, and systematic faults in system design, hardware development, software development and production. The standard provides requirements for the entire lifecycle of the electronic and electrical systems. Hence, it contains the diffusion of errors and helps the manufacturers finding the product issues earlier, potentially saving time, costs and lives.

1.2 Structure

The ISO 26262 standard is divided in ten parts, of which nine are normative and one is a guideline. The structure follows the V-Model for the different phases of the development.

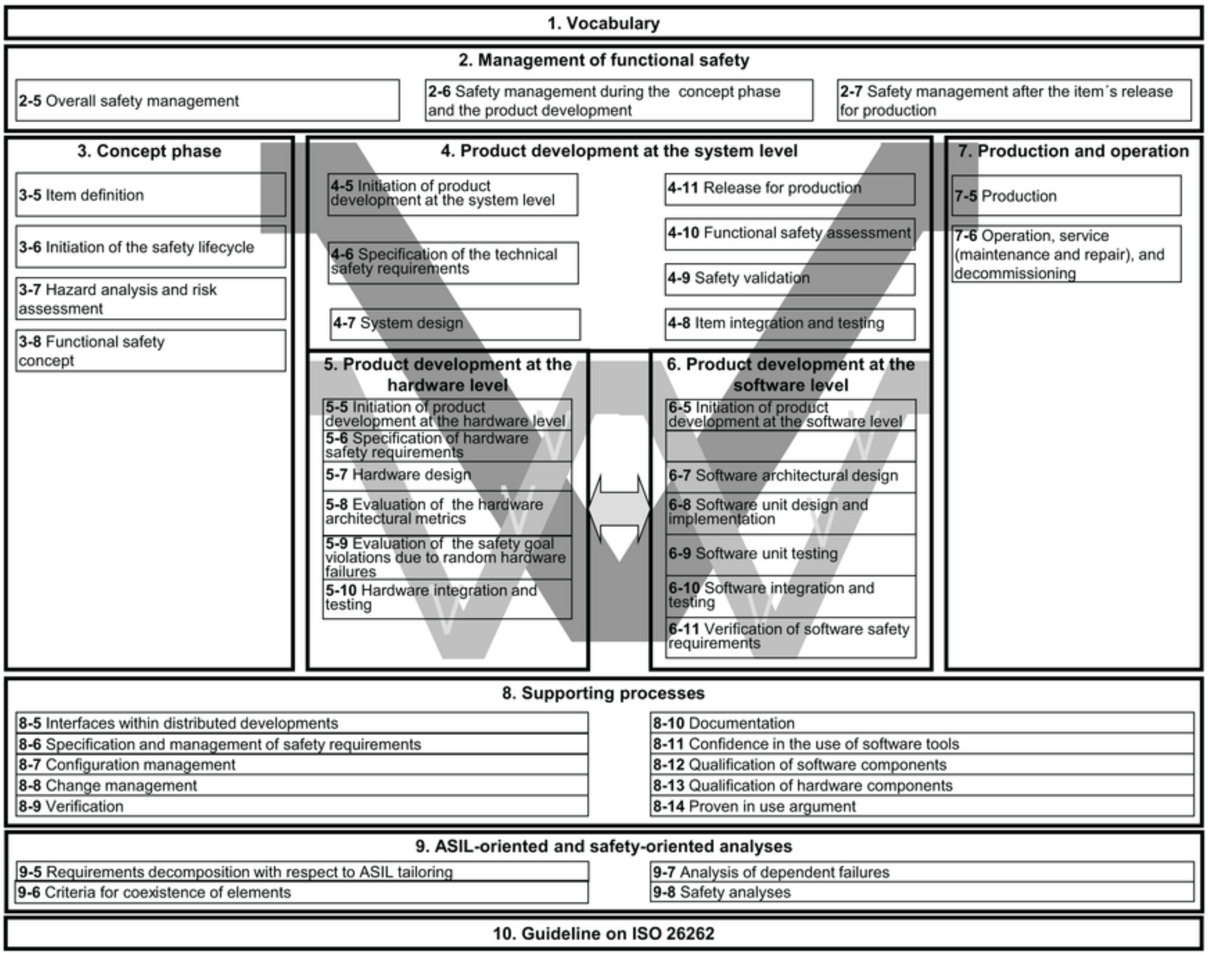

Figure 1.1: V-Model

The following list enumerates the parts of the standard.

1. **Vocabulary.** It states the terms, definitions and abbreviations used in the standard.

2. **Management of Functional Safety.** It focuses on the specification and management of safety requirements both project-specific and organizational.

3. **Concept phase.** It specifies the requirements for the concept phase, including

item definition, initiation of safety lifecycle, HARA, and Functional Safety concept.

4. **Product Development at System Level.** It involves detailed requirements analysis, system design, item integration and testing, evaluation, validation and verification.

5. **Product Development at Hardware Level.** It involves the hardware aspects of the system design and implementation.

6. **Product Development at Software Level.** It involves the software aspects of the system design and implementation.

7. **Production and Operation.** It revolves around the production, operation, service and decommissioning.

8. **Supporting Processes.** It provides requirements for processes that support the development, including change management, documentation, qualification of software and hardware components.

9. **ASIL-oriented and Safety-oriented Analysis.** It provides guidance in ASIL assessment.

10. **Guidelines on ISO 26262.** It is a guide to the application of the whole standard.

1.3 Safety Lifecycle

The goal of the safety lifecycle model applied to the life of a product is to set the stages of safety management and it represents the backbone of the standard itself. The safety requirements implemented following the procedure can be carried out individually on the single phases, and validated independently from functionality: this increases the reliability of the analysis. However, a global perspective must be considered, to maintain a coherent vision of the whole system.

The following list illustrates the sequence of steps of the safety lifecycle.

1. **Item definition.** Firstly, it is necessary to define and describe the item, and its interactions with the environment and other items. The relative requirements include: functionality, interfaces, operational and environmental conditions , legal requirements, known hazards and others.

2. **Initiation of the Safety Lifecycle.** It is then mandatory to distinguish between new and modified status of the item: in the latter, the areas affected by the modifications are identified and addressed.

3. **Hazard Analysis and Risk Assessment (HARA).** In this phase the hazards that may be triggered by the malfunctioning of the item are identified and classified. Thus, the safety goals are formulated in order to prevent and/or

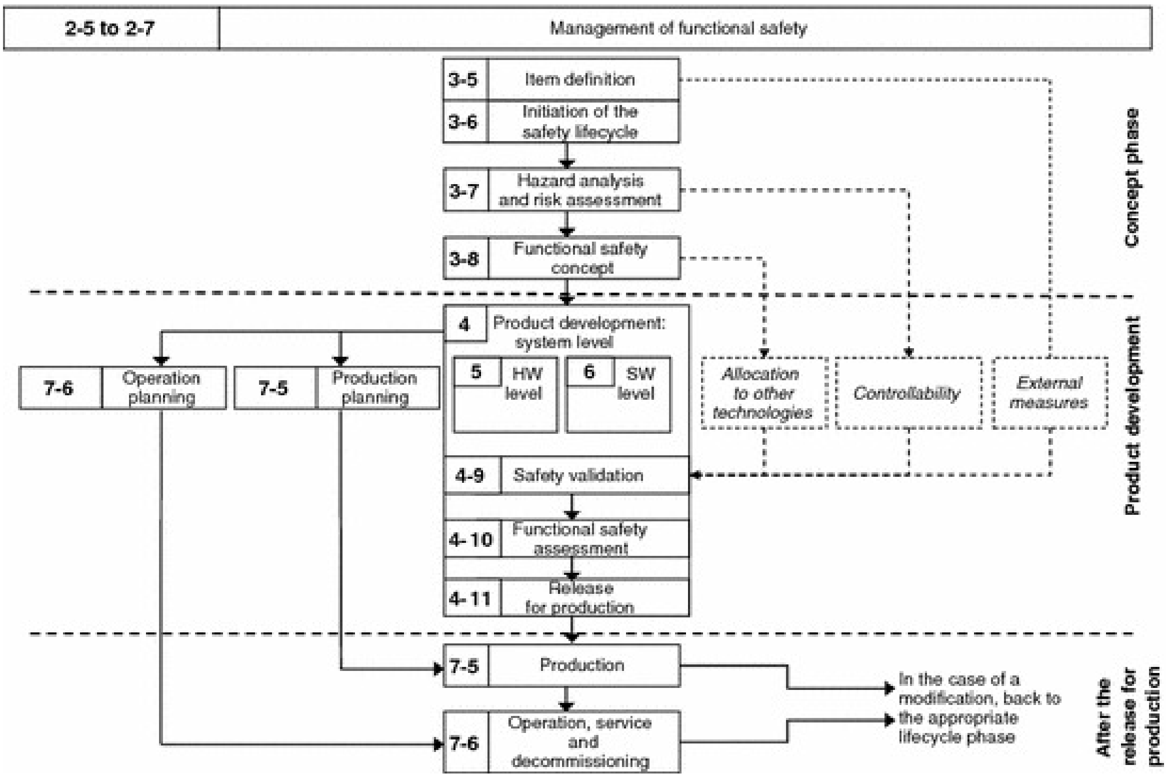

Figure 1.2: Safety lifecycle

mitigate the aforementioned events. With regard to this, the ASIL determination is performed by estimating the factors of severity, probability of exposure and controllability.

4. **Functional Safety concept.** Based on the previous point, the functional safety requirements are derived. The topics covered are fault detection and failure mitigation, transitioning to a safe state, fault tolerance mechanisms, driver warning.

5. **Product development. System level.** Having obtained the requirements, it is now possible to develop the item from a system-level perspective. This is carried out according to the V-model described above and considering the system architecture, design and implementation, and the integration, verification and validation.This method is applied both to the hardware and software level.

6. **Production planning.** Having designed the item, it is necessary to plan how to produce it. In particular, the following are taken into account: requirements for production, conditions of storage, transport and handling, the suitability of the whole production process, the competences of the personnel. The production plan shall describe the production steps, sequence and methods required to achieve the functional safety of the item, system or element.

7. **Operation planning.** After the item is produced the operation plan comes

in. This is conceived in parallel to the production plan and considers the requirements for maintenance and repair, the warning and degradation concept, the measures for field data collection and analysis, and the way the product is handled.

8. **Controllability.** This phase involves the ability of the driver to control hazardous situations that may arise, it is estimated during the HARA and undergoes the safety validation.

9. **External measures and other technologies.** The first refers to measures adopted outside the item to minimize as possible the hazardous effects that may occur because of the item itself. The second refers to non-electrical and non-electronic technologies, not treated in ISO 26262, that serve as safety measures as well.

10. **Production.** This phase actuates the requirements of the production plan. The aim is to develop and maintain a production process able to achieve functional safety.

11. **Operation Service, Decommissioning.** This step is connected to the operation planning. It provides the requirements necessary for repairing and disassembling the item. This includes the user manual and the performing of the maintenance work, all while considering the safety-related aspects.

1.4 How to determine ASILs

ASIL stands for Automotive Safety Integrity Level and is defined in part three. It serves as tool for risk classification, based on the safety goals, in automotive domains. The classifications are: QM (Quality Management), ASIL A, ASIL B, ASIL C, ASIL D (the most critical). The higher the score, the more rigorously the products will be tested.

The classification itself depends on three factors: severity, exposure and controllability.

The first parameter is severity, which is the measure of the gravity of the hazards (mostly revolving around humans) that would occur in case of failure.

- **S0.** No injuries.
- **S1.** Light and moderate injuries.
- **S2.** Severe and life-threatening injuries (survival probable).
- **S3.** Life-threatening injuries (survival uncertain), fatal injuries.

The second parameter is exposure, which is the probability of being in an operational situation that may be hazardous if coincident to a failure.

- **E0.** Incredible.
- **E1.** Very low probability.

- **E2.** Low probability.
- **E3.** Medium probability.
- **E4.** High probability.

The final parameter is controllability (introduced in ISO 26262 for the first time), which is the ability of the driver to avoid an hazard that is caused by a failure.

- **C0.** Controllable in general.
- **C1.** Simply controllable.
- **C2.** Normally controllable.
- **C3.** Difficult to control or uncontrollable.

Combining these three measures, it is possible to obtain the corresponging ASIL according to this formula:

$$ASIL = Severity \times Exposure \times Controllability$$

More intuitively, the following table can be used in order to find the correct ASIL from the parameters.

Severity class	**Probability class**	**Controllability class**		
		C1	**C2**	**C3**
S1	**E1**	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	A
	E4	QM	A	B
S2	**E1**	QM	QM	QM
	E2	QM	QM	A
	E3	QM	A	B
	E4	A	B	C
S3	**E1**	QM	QM	A
	E2	QM	A	B
	E3	A	B	C
	E4	B	C	D

Table 1.1: ASIL determination

Chapter 2

Automotive embedded boards: two case studies

"Transport of the mails, transport of the human voice, transport of flickering pictures — in this century, as in others, our highest accomplishments still have the single aim of bringing men together. Do our dreamers hold that the invention of writing, of printing, of the sailing ship, degraded the human spirit? It seems to me that those who complain of man's progress confuse ends with means. True, that man who struggles in the unique hope of material gain will harvest nothing worth while. But how can anyone conceive that the machine is an end?"

Antoine de Saint Exupéry

In an era in which new technologies are spreading in the most disparate applications in everyday life, the automotive field is on the frontline with the development of electric autonomous vehicles: environmental matters and safety issues are in the spotlight, and the automotive applications are particularly sensitive to such kind of topics.

Many questions have been raised around self-driving cars and it has become a largely debated subject. Some consider it an opportunity to create a safer, less stressful and more efficient society, others think that these benefits are utopic, and that instead it will cause a loss of control for humans over machines and it would reveal itself treacherous especially for safety.

In reality, a great deal of attention is given to safety in the automotive domain in order to minimize the possible risks associated with these innovations. This is an aspect that is often underestimated in the analysis about the future timeline of autonomous cars.

This work focuses on the safety analysis of two boards connected to the new concept of electric autonomous vehicle. In particular, the Dual Inverter board deals directly with the electric motor, and the Hyper-Spectral Data Fusion board deals directly with the autonomous driving. These boards can be both integrated on the same vehicle, but it will be possible to actually use the H-SDF only when self-driving cars of fourth and fifth generation (completely driverless) will be produced.

The two analysed boards were provided by Ideas&Motion, an innovational company based in Cherasco, near Turin, that engineers software and hardware solutions in automotive applications, and provides ECUs in peak technological applications.

2.1 Dual Inverter board

In an electric vehicle (EV), the propulsion system employs the electric motor to generate torque by converting electric energy into mechanical. The process is reversed during regenerative braking, where energy is recovered through the braking torque that decelerates the vehicle. Total requested torque represents a reference for the propulsion system control and is obtained from the driver hitting the accelerator and brake pedal. For in-wheel propulsion system, torque must be controlled for each driving wheel independently, whereas distribution of the torque between the driving wheels can be fixed or dynamic. The latter is used in the case of active propulsion systems with yaw control functions, torque vectoring, or anti-slip function. Active systems also employ steering wheel data as an additional reference for intended lateral motion from the driver. In this scenario the Dual Inverter plays a fundamental and very innovative role for active in-wheel propulsion systems.

In the following, the proposed project by Ideas&Motion is discussed.

2.1.1 Purpose

The Dual Inverter board is an electronic control unit designed to drive and control a 3-phase in-wheel electric motor inverter in an automotive system, representing an improvement in efficiency and accuracy. In particular a Permanent Magnet Synchronous Motor (PMSM) is controlled.

2.1.2 Structure

The Dual Inverter system is composed of a Logic Board and a Driver Board. The first one has external interface functionalities and internal functions related to the Power Board interface. In detail it integrates: a 3 Pulse-width modulation (PWM) command for the 3-phase power stage to drive the PMSM; digital outputs, two of which feature a diode in series for reverse battery polarity protection via an external relay; dedicated inputs to acquire the signal from the motor and the control shaft position sensors with the related sensor supply pins; other dedicated inputs to interface with an accelerator pedal sensor, a gear position sensor and a brake pedal sensor; four CAN lines for communication, two of which are isolated, and an internal Negative Thermal Coefficient (NTC) to monitor the Logic Board temperature. The computational core of the Logic Board is the Infineon TC277TF Microcontroller, specific for motor control applications. The logic power supply is based on a TLF35584 System Base Chips (SBC), supplying both the microcontroller and the external sensors, and supporting, together with the TC277TF, applications up to ASIL-D.

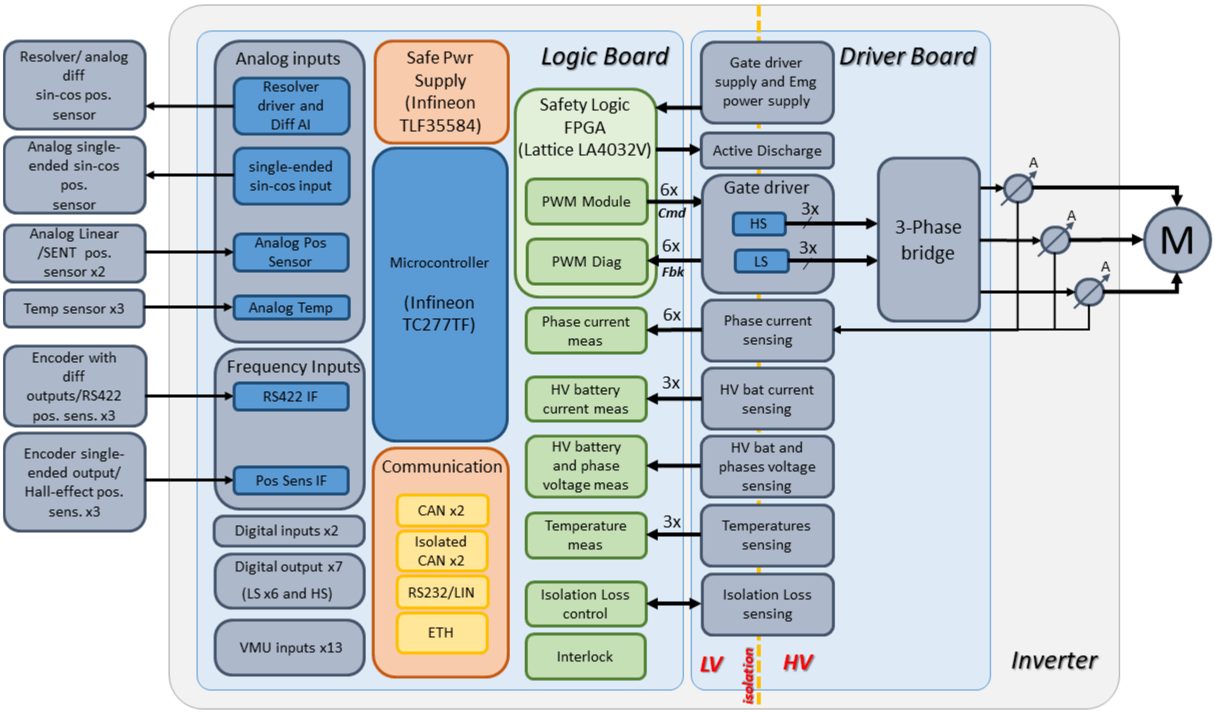

Figure 2.1: Dual Inverter block diagram

2.1.3 Implementation

In-wheel propulsion system with Dual Inverter can be implemented for a 2-wheel or 4-wheel drive electric vehicle with PMSM.

In-wheel propulsion systems are composed of Dual Inverter, in-wheel motors and position sensors, in particular main system elements are:

- Dual Inverter (INV),
- in-wheel motor (IWM),
- anti-lock braking system (ABS),
- vehicle control unit (VCU),
- electronic stability program (ESP),
- battery management system (BMS),
- power battery (BATT),
- inertial measurement unit (IMU).

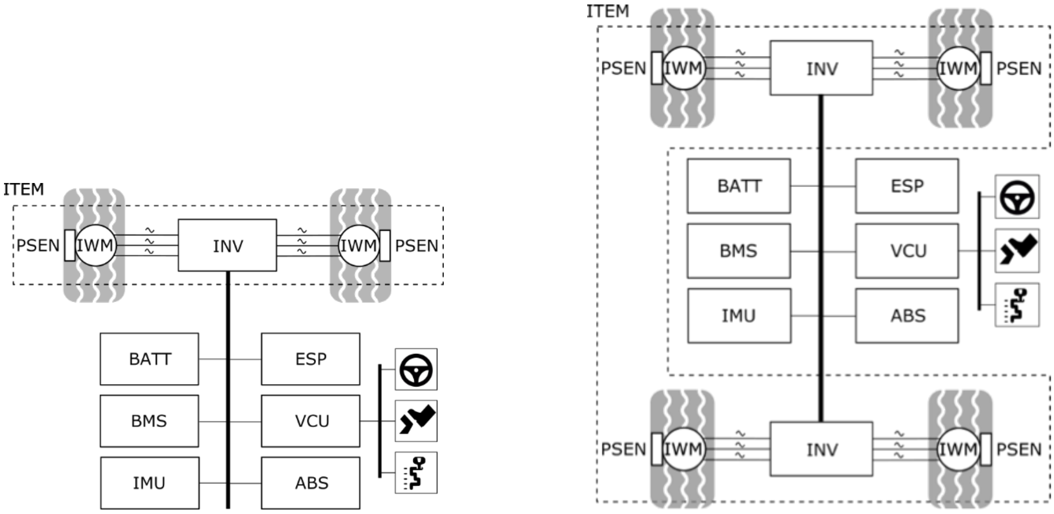

Figure 2.2: 2-wheel and 4-wheel drive electric vehicle

It is assumed that direct drive synchronous in-wheel electric motors (IWM) are used where torque and motor speed are equal to the wheel. Synchronous operation of the motors is achieved by the inverter (INV) with the help of position sensors (PSEN) that are integrated in the motors. It is also assumed that the Dual Inverter has two power outputs for driving two electric motors independently. It can switch to regenerative braking mode for additional deceleration when brake pedal is pressed and for providing drag torque when both pedals are released. Mechanical brakes are integrated into electric motors, however, this braking system is independent and is not part of the propulsion system in terms of functionality. Inverter processes steering wheel position, selected direction of movement, and position of accelerator and brake pedals. Typically these are obtained from the vehicle control unit (VCU). In case vehicle is equipped with ABS and ESP, inverter needs to know when they are activated in order to switch off regenerative braking and torque vectoring. Connection to the battery management system (BMS) gives information about the charge and discharge currents that are available. These currents limit maximum traction and regeneration torque. In case of torque vectoring, inertial measurement unit (IMU) is also needed.

2.2 Hyper-Spectral Data Fusion board

When thinking about completely autonomous driving, the first thing that comes to mind is the absence of the driver. Of course, this implies that some device must take the driver's place in order to inspect and recognize the surroungings. For this, multiple solutions have been proposed, among them RADARs, LIDARs and cameras. Since the detection of the obstacles and dangers on the path is crucial, just one of these is not sufficient. Thus, multiple types of sensors are used and their signals are fused in order to achieve a more precise and reliable picture of the situation in order to take a decision on how to control the vehicle.

In the following, the proposed solution by Ideas&Motion is discussed.

2.2.1 H-SDF as a SEooC

The Hyper-Spectral Data Fusion board is conceived to be used as a platform to develop applications. This means it has to be able to cope with different applications and it can be used in different ways. The final goal is to control the vehicle depending on the acquired data, independently from the way data are acquired. This makes the H-SDF a SEooC.

A Safety Element out of Context is a safety-related element which is not developed for a specific item. [6] It can be a software component, a hardware component, a subsystem, a system or an array of systems, but it cannot be an item, since the item needs, by definition, the final context in which it will be used. This means that the considered generic element is used for different applications by different customers. The latter require these elements to be developed by third parties. This is a trend that has been established in the last years in many fields because of the lower cost in production and certification: one of the most affected is the automotive domain.

While in classic items, changes are made on an already known version that needs improvement and recertification, SEooCs are applied to unknown (assumed) items in which they must be integrated. We can thus have two different possibilities: either changing the SEooC or changing the item. Changes lead to new versions of the item or the SEooC. This is the main problem of this type of objects, since every new version, at the present time, is almost as costly as developing an all-new product, but it is an issue that is being analysed and solved by many organizations.[7]

2.2.2 Purpose

The Hyper-Spectral Data Fusion is conceived to be used in ADAS (Advanced Driver-Assistance Systems) to improve the safety while driving. Its purpose is to collect the data from multiple sensors (RADARs, LIDARs, cameras, GPS, ultrasonic sensors...). The inputs coming from these instruments are not raw, though: they are pre-processed and contain informations about detected features and objects, position and speed informations, and similar. Eventually, there could be a further processing stage at which some data from different sensors are already combined before being transmitted. Starting from these acquisitions, the H-SDF board constructs a 2D or 3D model of the surroundings. This model is used by the decision making algorithm to find the most appropriate answer that guarantees reaching the target while avoiding all hazards and damages.

2.2.3 Structure

Since the board performs two major tasks (vision and decision making), it is divided into two parallel parts: this assures a better robustness to failures, and the two processors can be develeped separately, according to their own ASIL. The fusion processor manages the fusion of the data coming from the sensors, while the safe processor manages the decision making part.

The nodal issue with this board is that for the present state of technologies it is not possible to build a real-time model of the surroundings. Multiple reasons

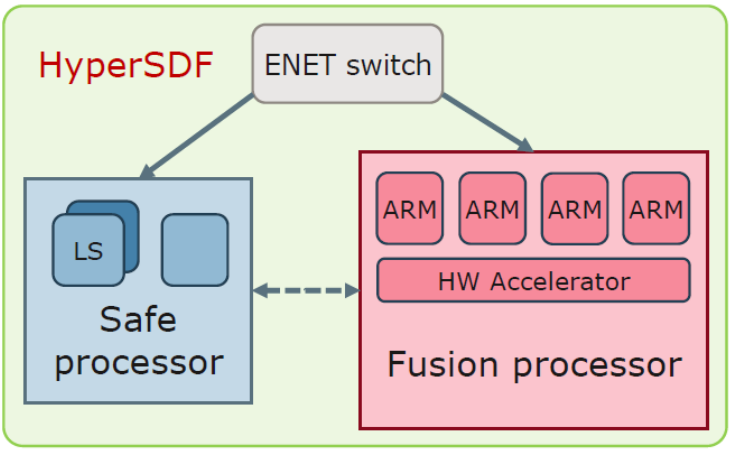

Figure 2.3: H-SDF processors

stand behind this. First of all, microcontrollers are not powerful enough to enable a centralized module to acquire data, perform signal processing and data fusion, and build a model of the surroundings. The second main reason is that even if that technology was sufficient, the components would produce a lot of heat: on an electric car it is unreasonable to exceed than 50W for thermal power on a single ECU.

As for literature, the vision is not safety-critical (if a single frame is missing, there will be another in about 33ms later, or other sensors will fill in the gap), so it is sufficient to guarantee the failures can be recovered. Decision making, on the other hand, is safety critical: a failure in controlling the vehicle could cause great harm to the people involved. The most straighforward method is to exploit redundancy and duplicate the H-SDF board: this way the ECU will be fail-operational (if one module is broken, the other takes its place). The alternative is not to duplicate the components, but to create a fail-silent product, that when not functioning sends a warning and switches to a safe state, and autonomous driving is disabled.

To sum up, the ASIL of the various components can be classified as such:

- Sensors are QM;
- Feature extraction is ASIL A;
- Object recognition is ASIL B;
- Modelling the environment, assessing the situation and taking functional decisions can be ASIL B or C;
- Arbitrating functional decisions, assessing the threats and taking actions to avoid/mitigate them (i.e. steering or braking) are ASIL D.

As it can be deduced, each level has more control over the previous one, and is able to recover possible failures produced previously: this is also a reason why the higher the step is, the more critical it is.

In the following figure, the fail-operational solution is shown.

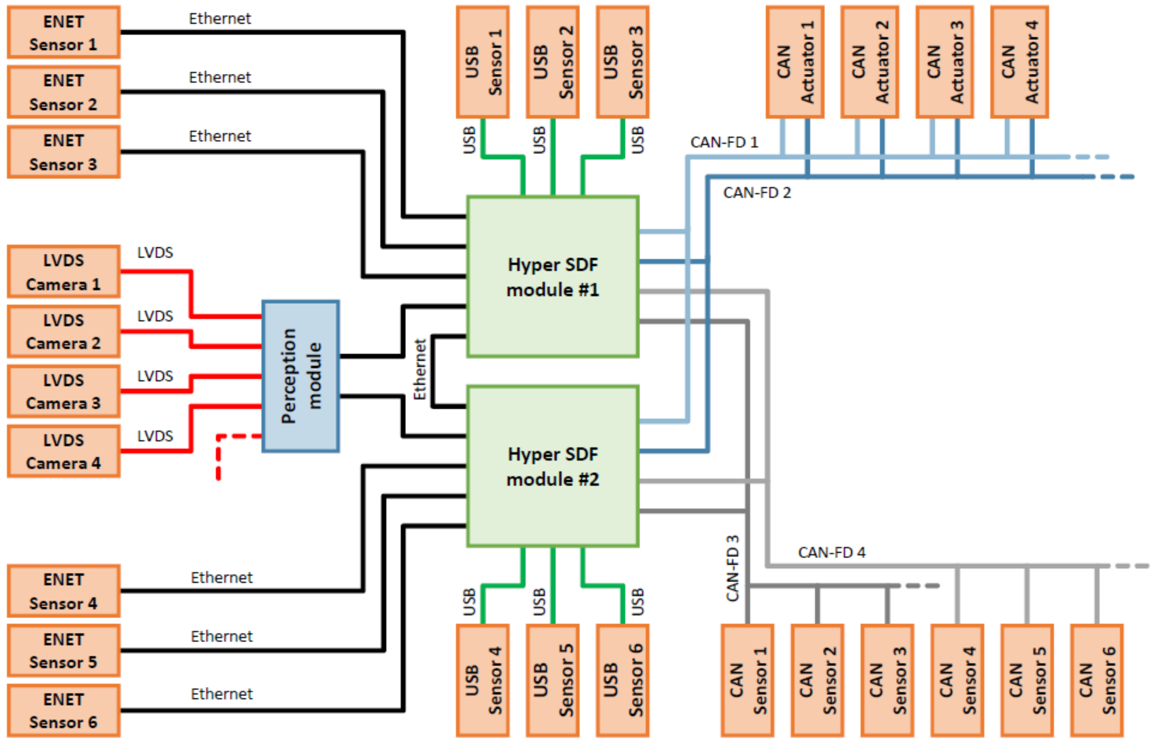

Figure 2.4: H-SDF fail-operational architecture

As it can be seen, multiple types of input provide data to the modules. Most of the signals are sent directly to the H-SDF boards, but a possibility for raw signals to be used is provided: the Low-Voltage Differential Signals coming from the cameras may be preprocessed and then forwarded via Ethernet.

As for outputs, the ECU controls the car both in its path and dynamics. The commands are typically issued via CAN (Controller Area Network bus). In order to achieve high reliability, the CAN lines to communicate with the actuators will be duplicated to guarantee transmission.

2.2.4 Implementation

The two parts of the board will revolve around the following components.

- The fusion processor is designed to be a powerful, ARM based, multi-core processor that will run the vision pipeline and perform sensor fusion, but with lower safety certification. For this purpose, NXP i.MX8 (Quad Max version) has been selected.

- The safe processor instead is a microcontroller developed for the powertrain domain, able to support ASIL D applications, take decisions and issue commands to the actuators. For this purpose the choice was IFX Aurix TC277, with its safe power supply TLF35584, together supporting up to ASIL D as a SEooC.

Due to the short duration of the project, however, the Hyper-Spectral Data Fusion did not include a board based on i.MX8 processor by NXP. Instead, it was developed connecting a i.MX8 QuadMax Evaluation board to a custom Aurix board developed by I&M via the B-connector of the evaluation board.

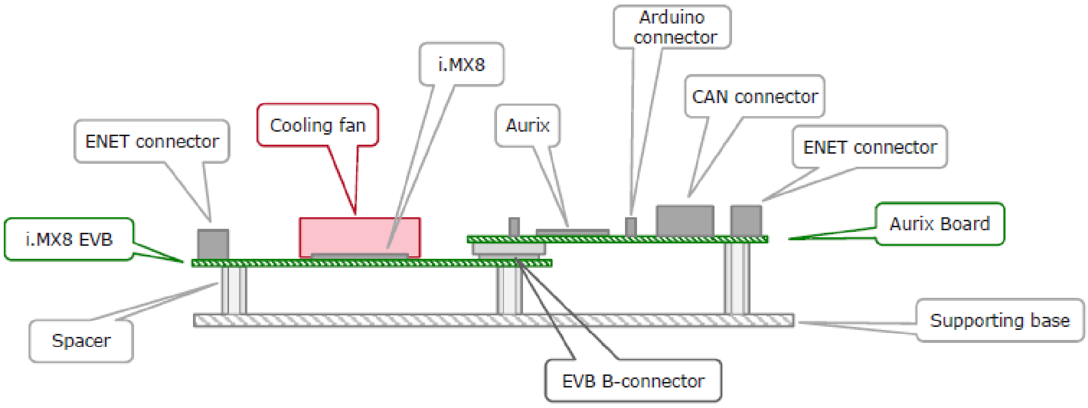

Figure 2.5: H-SDF with evaluation board

Furthermore, an Ethernet switch can be provided externally in order to increase the number of Ethernet connections available.

The Hyper-Spectral Data Fusion platform is not a finished project, though, and it will be re-implemented in the future following EU projects (AutoDrive), in order to be enclosed in a mechanical housing with proper connectors to be used in an ADAS vehicle. The i.MX8 board developed by I&M will be implemented, as well as the application board.

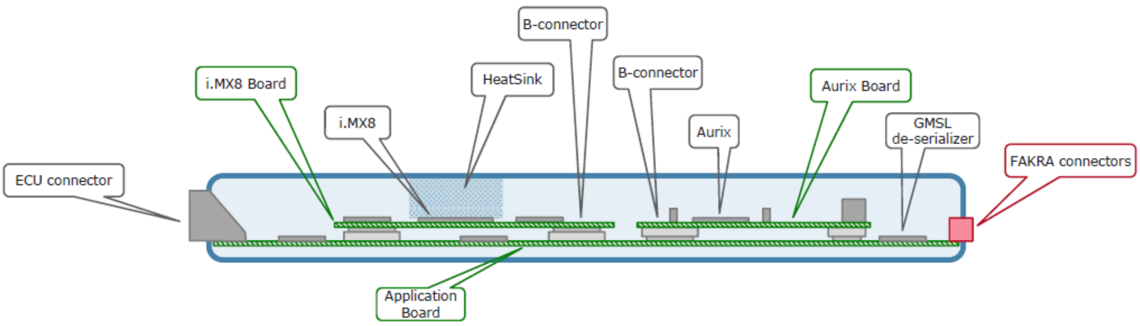

Figure 2.6: H-SDF as future implementation

Chapter 3

FIDES

FIDES (Latin: trust) is a guide allowing a realistic evaluation of the reliability of electronic components and systems, providing a specific tool for its construction and control. This guide provides reliability data for RAMS (Reliability, Availability, Maintainability, Safety) studies. In this work, FIDES methodology is applied to predict the reliability of two embedded automotive systems.

FIDES is a DGA (French armament industry supervision agency) study conducted from 2001 by a European consortium composed of eight Business magnates from the fields of aeronautics and Defence: AIRBUS France, Eurocopter, Nexter Electronics, MBDA France, Thales Systèmes Aéroportés SA, Thales Avionics, Thales Corporate Services SAS and Thales Underwater Systems. After the model was finalised, the methodology was calibrated making use of the experience of consortium members, in particular for process factors. The first FIDES Guide 2004 issue A "Reliability Methodology for Electronic Systems" was published in 2004. In 2005 the French standardization organization UTE (Union Technique de l'Electricité has accepted the FIDES publication with the reference UTE C 80 811, available in both French and English. Also an international normative reference extension (International Electrotechnical Commission) is planned for the future. [8]

3.1 Purpose

Reliability control, quantification and engineering, has become essential in projects. In fact reliability prediction calculations are usually performed in the first phases of the design.

The first aim of the FIDES project is to develop a new reliability assessment method applicable to COTS (Commercial Off-The-Shelf) items, specific parts, and new technologies, provided that their technical characteristics comply with the requirements described in the 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". In particular FIDES deals with: components such as printed circuit boards, discrete semiconductors circuits or passive components, subassemblies such as hard disks and screens, assembled COTS boards.

The global aim is to find a replacement to the existing prediction guide, the worldwide reference MIL-HDBK-217F, which is obsolete and has not been revised since 1995 (issue F notice 2). Moreover, the MIL HDBK 217F is very pessimistic for COTS components, which are more and more widely used in military and aerospace systems.

The second aim is to provide engineering process and tools to improve reliability in the development of new electronic systems, paying particular attention to the identification and control of factors that can influence it.

3.2 Methodology

The FIDES guide is composed of two different parts: the first one is a reliability calculation guide illustrating the general method, the factors involved and regarding main electronic component families and complete subassemblies; the second part is about control and audit of the reliability process, which is a tool to assess the reliability quality and technical know-how in the operating time of the studied product, operational specification and maintenance.

The FIDES reliability approach is based on the consideration of three aspects: one Technology, one Process and one Use. Technology regards the item itself and its integration into the product. Process considers all practices and the state of the 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.

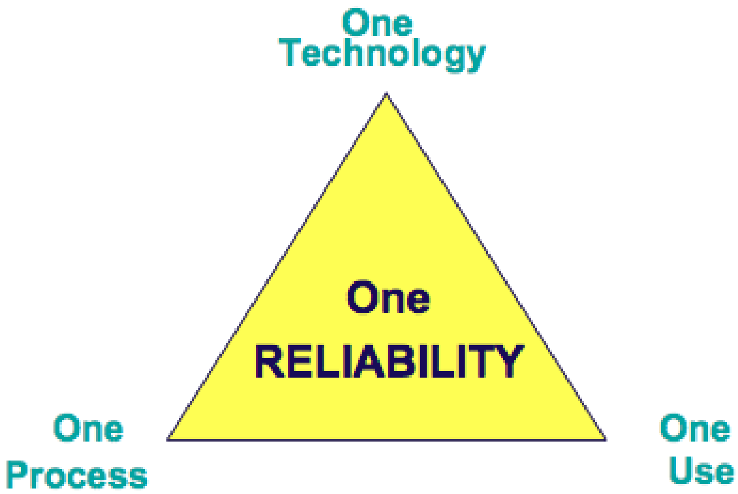

Figure 3.1: Reliability approach scheme

The three aspects are considered for the entire life cycle, from the product specification phase until the operation and maintenance phase.

The result of the application of the FIDES methodology is the failure rate denoted λ. According to experimental observations, the failure rate varies as a function of time. This behavior is represented by the “bathtub curve”.

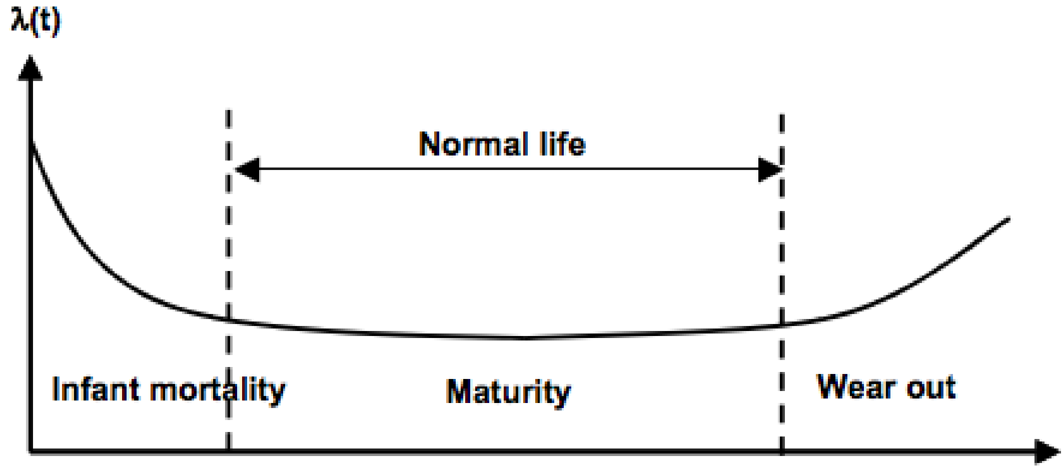

Figure 3.2: Bathtub curve

Hence the life of a product can be divided into three periods. The infant mortality period, in which the failure rate reduces with time and the reliability increases. It is characterized by early failures due to problems with setting up processes and debugging the design and components.

The second phase is the maturity period, the useful life period, represented by a constant failure rate, which is independent from the number of functioning hours of the product. This period is the reference case for electronics products.

The reliability decreases during the last life phase, the wear out period: the older the product, the more probable a failure becomes. The failure rate increases with the number of hours of functioning and this behavior is characteristic of items subject to wear or other progressive deterioration.

The FIDES methodology evaluates the reliability at a constant failure rate thus infant mortality and wear out periods are excluded from the prediction. The reason of this choice is that in the first period control over increasing reliability is a crucial step towards quickly obtaining good reliability. The wear out period is also excluded because it is sufficiently far in the future compared with the useful life of electronic systems covered by FIDES.

Moreover the dispersion of many failure mechanism is such that they can be considered constant, the accumulation of the large number and diversity of components will be close to a constant and the age differences between equipment in the same system or a stock of equipment will tend to make the failure rate constant. Therefore the best approach for estimating the product reliability of a system is the use of a constant failure rate.

The FIDES reliability prediction increases with the number of items considered in fact it is not applicable for a single item but it is recommended that the level considered should be at least the equipment level.

One of the main concepts of the FIDES method is that failures are very largely the consequence of life situations encountered by the product, hence confidence in the predicted reliability can never be better than confidence in the prediction of expected product life.

3.3 Life Profile

The building of the life profile of the item is crucial for reliability evaluation because it strongly influences the accuracy of predictions. Firstly it is important to identify: the precise type of platform when the product is integrated into a system, the location in the platform, the climatic region considered and the type of use.

The choice of phases that compose the life profile must be sufficient to describe the different usage situations as completely as possible. Every time that environmental conditions change significantly in terms of the stresses encountered, a specific phase has to be defined.

The life profile has a total duration of 1 year, namely 8760 hours: 24 hours per day, 730 hours per month. The duration of phases must be expressed in hours and shall be chosen to describe the product activity as realistically as possible.

At this purpose the FIDES methodology concerns four different physical contributing factors that allow to characterize all the possible applicability domains in which the component is qualified.

- **Temperature.** It considers temperature and thermo-electrical stresses. The theoretical temperature range allowed is -55°C$\leq T_{ambient} \leq$+125°C. For each phase considered, the ambient temperature and the state (operating or not) are required by the model. In general the ambient temperature is the temperature of the environment. For reliability evaluations at component level, the value to be considered is the temperature around the electronic board, in particular for a board integrated into equipment it is the temperature inside the equipment. In a functioning phase the ambient temperature must include the temperature rise due to heat dissipation from components.

- **Temperature cycling.** It considers thermo-mechanical stress in terms of temperature variations connected to the functional and dormant phases (on/off) and changes in the environment (day/night). The theoretical range of the temperature cycle allowed is $\Delta T_{cycling} \leq$180°C, $T_{max-cycling} \leq$125°C, temperature transition rate $\leq$20°C/ minute. For each phase considered it is necessary to specify: the amplitude of the temperature cycle ΔT (°C), the associated number of cycles over one year (quantity), the cycle duration θ_{cycle}(in hours) and the maximum temperature in the cycle (°C). It is mandatory that temperatures considered are the same temperatures described for the temperature aspect itself.

- **Relative humidity.** It represents the ratio (%) between the vapour pressure of water contained in the air and the saturating vapour pressure and characterizes the climate considered. The theoretical validity range is from 0% to 100% and condensation or icing are not considered. For each phase the input required are: the relative humidity RH (%), the ambient temperature T (°C) and the state (operating or not). The temperature must be the same as that described in the temperature section. Evaluating this feature it is necessary to take into account the hermeticity of the product, the use of drying measures or the presence of air conditioning. Relative humidity is inversely proportional to temperature and is a relevant factor in life profiles that include long storage periods where the influence of temperature is higher than functioning.

- **Vibration.** It regards the mechanical stress and for each phase it is expressed in G_{RMS}. The theoretical validity range is $G_{RMS} \leq 40$ G_{RMS} and the mechanical shock is not considered. The risk of failure in components and electronic boards is strictly connected to this factor because it increases as the vibration amplitude increases. Quantification of the vibration amplitude must be made from technical specifications, selecting non-accelerated and non-ruggedised endurance vibration amplitudes.

In some reliability models, the chemical stress represents an acceleration factor for other physical stresses.

3.4 General Model

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

$$\lambda = \lambda_{Physical} \cdot \Pi_{PM} \cdot \Pi_{Process} \tag{3.1}$$

Where

- $\lambda_{Physical}$ is the physical and technological contributing factor.
- Π_{PM} (PM for Part Manufacturing) denotes the quality and technical control over manufacturing of the item. The variation range varies from 0.5 (supplier better than the state of art) to 2 (the worst case). It must be set for active components and other components (including COTS and subassemblies).
- $\Pi_{Process}$ represents the maturity of the manufacturer on control over the development, manufacturing and usage process for the product containing the item. The variation range is from 1 (for the best process) to 8 (for the worst process). For a classical tin-lead solder process the failure rate is calculated according to the general model. For a lead-free process the failure rate is calculated as

  $$\lambda = \lambda_{Physical} \cdot \Pi_{PM} \cdot \Pi_{Process} \cdot \Pi_{LF}$$

  hence it is mandatory to define the transition factor to the lead-free process Π_{LF}. In case of microwave(HF) and radiofrequency(RF) products the $\Pi_{ProcessRFHF}$ factor must be compiled, it is complementary to the $\Pi_{Process}$ factor and the failure rate calculation is

  $$\lambda = \lambda_{Physical} \cdot \Pi_{PM} \cdot \Pi_{Process} \cdot \Pi_{ProcessRFHF}$$

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. Predicted failure rates are expressed in FIT (Failure In Time) where 1 FIT is equal to 1 failure per 10^9 hours. This measurement unit allows to create a fixed reference for the comparison failure rate values. When the product type is sufficiently well known, the magnitude of failure rate also indicates the severity of the life profile.

3.4.1 $\lambda_{Physical}$

The $\lambda_{Physical}$ value represents the physical stresses applied to the item during its operational use, including aspects related to the design.

$$\lambda_{Physical} = [\sum_{Physical_Contributions} (\lambda_0 \cdot \Pi_{acceleration})] \cdot \Pi_{induced}$$

λ_0 is the basic failure rate of the item, $\Pi_{acceleration}$ is an acceleration factor translating the sensitivity to usage conditions. These factors are broken down for each physical stress, in particular the $\Pi_{acceleration}$ differentiates in : $\Pi_{Thermal}$ for thermal stress, $\Pi_{Electrical}$ for electrical stress or for some item families they are combined in $\Pi_{Thermal-electrical}$, $\Pi_{Mechanical}$ for mechanical stress, Π_{RH} for humidity stress and $\Pi_{Chemical}$ for chemical stress.
$\Pi_{induced}$ factor represents the contribution of overstresses and is calculated for each phase in the life profile as:

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

$\Pi_{Placement}$ refers to the position of the item in the equipment or in the system, in particular if it is or not interfaced. $\Pi_{Application}$ represents the influence of the usage environment of the product that contains the item. $\Pi_{Ruggedising}$ represents the influence of the policy for taking account of overstresses in the product development. $C_{sensitivity}$ represents the coefficient of sensitivity to overstresses inherent to the item technology considered and i is the index of the phase considered.

3.4.2 $\Pi_{Application}$

The $\Pi_{Application}$ factor must be determined for each phase defined in the life profile by marking a series of criteria, in particular each one can have three levels: favourable, moderate or unfavourable situation.

Each level and each criterion has a particular weight, defined respectively as weighting of marks (P_{notes}) and Pos and illustrated in the last column of the following tables:

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

Table 3.1: Table of possible P_{notes} levels

Imposed Π application				
Detailled Π application				
User type in the phase considered	Represents the capability to respect procedures, facing operational constraints.	0: Favourable 1: Moderate 2: Unfavourable	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

Figure 3.3: $\Pi_{Application}$ table

For each phase this factor can be imposed or evaluated based on the levels assigned to each criterion in the table. It is important to carefully consider some criteria at a product level, others at a system level. The calculation engine will use the compulsory values first and foremost to obtain the $\Pi_{Application}$ factor:

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

Where $Pmarks_k$ correspond to levels assigned to each criterion (Figure 2.3) and Pos_k are weights for each criterion.

3.4.3 $\Pi_{Ruggedising}$

The $\Pi_{Ruggedising}$ factor regards all the phases of the life profile and can be imposed or determined assigning a satisfaction level for each recommendation:

- N1 = not applied → definite risks regarding reliability
- N2 = partially applied → potential risks regarding reliability
- N3 = globally (almost fully) applied → few risks regarding reliability
- N4 = fully applied and described in a procedure → control of the reliability

A mark corresponds to each level as follows:

Level	**Mark**
N1	0
N2	1
N3	2
N4	3

Table 3.2: Table of possible satisfaction levels

The following table illustrates the $\Pi_{Ruggedising}$ table with the weights associated to each recommendation

Imposed Π ruggedising	
Detailled Π ruggedising	
Recommendation	**Weight**
Check that environmental specifications are complete.	4
Provide training and manage operation and maintenance for implementation and maintenance of the product	7
Check that procedures specific to the product and rules specific to businesses are respected by an appropriate monitoring system	7
Design dependable electrical protection devices	4
Study and handle risks of the product under test being deteriorated by failures of its test or maintenance means.	4
Identify and use appropriate prevention means of preventing reasonably predictable aggressions (related to the weather)	4
Use appropriate prevention means to identify and handle reasonably predictable abnormal uses weather	4
Include production, storage and maintenance environments in the product environment specifications	4
Justify that environment specifications are respected	4
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
Perform an analysis of failure cases that could result in failure propagation.	4
Carry out a process analysis of implementation and maintenance operations	4
Carry out a review of maintenance operations done by the final user and deal with his recommendations	4
Write complete procedures for all product implementation and maintenance operations	7

Figure 3.4: $\Pi_{Ruggedising}$ table

Using the data in the table, the $\Pi_{Ruggedising}$ factor is calculated as follows:

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

where:

$$recom\_grade = \frac{1}{225}\sum_{i}^{Recommendation} Recom\_Weight_i \times Satisfaction\_mark_i$$

The recom_grade factor varies from 0 (worst case: no recommendation is applied) to 1 (best case). Recom_weight is the weight associated with a recommendation, Satisfaction_mark is the mark assigned to it (0,1,2 or 3).

3.5 Electronic Components

In all components the Π_{PM} and the $Pi_{Process}$ are respectively the quality and technical control over manufacturing of the item, and the quality and technical control over the development, manufacturing and usage process for the product containing the item. Both are calculated according to some characteristics of the components considered.

Placement

It is mandatory to define if the electronic component is treated as interface or non-interface. The choice depends on its position in the system, in particular it must be interface if the component is more exposed to accidental electrical aggressions such as the items which link the equipment with the external systems or often electrically close to a connector.
Moreover it is necessary to identify if the component has digital or analogue functions. In the latter the difference between analogue low level or analogue power must be made: the threshold corresponds approximately to a current of 1 A. Moreover the analogue low level functions are mainly discrete inputs/outputs, measurement signals and analogue logics, otherwise the analogue power functions are mainly power supplies or power transmissions.

PI_PART

The component manufactoring factor Π_{PM} must be set for active parts and other components. It follows a general model:

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

for active components:

$$Part\_Grade = [\frac{(QA_{manufacturer} + QA_{component} + RA_{component}) \times \epsilon}{36}]$$

for other components:

$$Part\_Grade = [\frac{(QA_{manufacturer} + QA_{component}) \times \epsilon}{24}]$$

The general formula can be made specific for each component choosing the right parameters according to the following tables.

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

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

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

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

3.5.1 Ceramic capacitors

The most produced and diffused type of capacitors is the ceramic capacitor. In this product the ceramic material behaves as the dielectric (the insulator between the two terminals).

To obtain the lambda factor of the ceramic capacitors the general formula (3.1) is applied, where:

$$\lambda_{physical} = \lambda_{0Capacitor} \times \sum_{i}^{Phases} (\frac{t_{annual}}{8760}) \times (\Pi_{Thermo-electrical} + \Pi_{Tcy} + \Pi_{Mechanical})_i \times (\Pi_{Induced})_i$$

Before defining the $\lambda_{0Capacitor}$, a definition of the classification of the capacitor depending on the CV product mus be given. Type I is a capacitor with defined temperature coefficient, type II has a non-defined temperature coefficient.

	Type I	**Type II**
Low CV product	Less than 1.0×10^{-9} VF	Less than 1.0×10^{-7} VF
Medium CV product	Between $1.0 \times 10^{-9}$and 1.0×10^{-7}VF	Between $1.0 \times 10^{-7}$and 1.0×10^{-5}VF
High CV product	Higher than 1.0×10^{-7}VF	Higher than 1.0×10^{-5}VF

Component description	$\lambda_{0Capacitor}$
Ceramic capacitor with defined temperature coefficient (Type I) with a low CV product	0.03
Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product	0.05
Ceramic capacitor with defined temperature coefficient (Type I) with a high CV product	0.40
Ceramic capacitor with non-defined temperature coefficient (Type II) with a low CV product	0.08
Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product	0.15
Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product	1.20
Ceramic capacitor with polymer terminations with non-defined temperature coefficient (Type II) with a low CV product	0.08
Ceramic capacitor with polymer terminations with non-defined temperature coefficient (Type II) with a medium or high CV product	0.15

3.5.2 Aluminium capacitors

This kind of capacitors is characterized by an anode made of metal (aluminium) whose oxide (Al_2O_3) layer forms the dielectric. It also offers a higher CV product for equal volume. However, when not used for long periods, anodization takes place and a SC forms. Also, these capacitors have a cathode and an anode: inverting the current may burn the component.

The lambda factor is obtained in the same way as for ceramic capacitors (3.1) and:

$$\lambda_{physical} = \lambda_{0Capacitor} \times \sum_{i}^{Phases} (\frac{t_{annual}}{8760}) \times (\Pi_{Thermo-electrical} + \Pi_{Tcy} + \Pi_{Mechanical})_i \times (\Pi_{Induced})_i$$

Component description	$\lambda_{0Capacitor}$
Aluminium liquid electrolyte capacitor	0.21
Aluminium solid electrolyte capacitor	0.40

3.5.3 Resistors

Fixed resistors are the most commonly used resistors and in general one of the most used electronic components. Fixed resistors are available mostly in surface mount packages or in more customized packages depending on their application. Fixed value resistors have a defined ohmic resistance and are not adjustable.

To obtain the lambda factor (3.1), $\lambda_{physical}$ is calculated as:

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

where $\lambda_{0\_Resistor}$ depends on the component type according to the following table:

Component description	$\lambda_{0\_Resistor}$
"Minimelf" common use (RC) high stability (RS) low power film resistor	0.1
Power film resistor	0.4
Low power wirewound accuracy resistor	0.3
Power wirewound resistor	0.4
Trimming potentiometer (CERMET)	0.3
Resistive chip	0.01
SMD resistive network	$0.01 \times \sqrt{N_R}$
High stability bulk metal foil accuracy resistor, SMD$<$ $10k\Omega$	0.18
High stability bulk metal foil accuracy resistor, $10k\Omega$ $<$SMD$<$ $100k\Omega$	0.21
High stability bulk metal foil accuracy resistor, SMD$>$ $100k\Omega$	0.14
High stability bulk metal foil accuracy resistor, through hole $10k\Omega$ $<$SMD$<$ $100k\Omega$	0.18
High stability bulk metal foil accuracy resistor, through hole $> 100k\Omega$	0.21

3.5.4 Connectors

The peculiarity of connectors is the fact they are not used in a "fixed" manner, but they are mobile, since they serve as joint between devices. In our case, they are used only for laboratory activities and not while mounted on the vehicle.

The failure rate of the connectors is calculated from (3.1) where

$$\lambda_{physical} = \lambda_{0Connector} \times \sum_{i}^{Phases} (\frac{t_{annual}}{8760}) \times (\Pi_{Thermal} + \Pi_{Tcy} + \Pi_{Mechanical} + \Pi_{RH} + \Pi_{Chemical})_i \times (\Pi_{Induced})_i$$

More specifically, $\lambda_{0Connector}$ is determined by multiple factors:

$$\lambda_{0Connector} = \lambda_{Type} \times \Pi_{Connection} \times \Pi_{Contact} \times \Pi_{Cycle}$$

Connector type	λ_{Type}
Circular and rectangular connectors	0.05
Coaxial connectors	0.07
Connectors for printed circuits (and similar)	0.10
Component supports	0.10

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

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

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

$$\Pi_{Cycle} = 0.2 \times (N_{AnnualCycles})^{0.25}$$

where $N_{AnnualCycles}$ is the number of cycles (one connection and one disconnection) per year: if $N_{AnnualCycles} < 1$, Π_{Cycle} is set to 0.2.

3.5.5 Integrated Circuits

Integrated circuits (ICs) are a keystone of modern electronics. An IC is a collection of electronic components such as resistors, transistors, capacitors and others, all packed into a small chip, and connected together to achieve a common goal. It functions as single-circuit logic gates, operational amplifier, oscillator, timer, voltage regulator, motor controller, microcontroller, microprocessor, FPGA or even computer memory. To calculate the failure rate of an integrated circuit, the (3.1) formula is the one used in general, where

$$\lambda_{physical} = \sum_{i}^{Phases} (\frac{t_{annual}}{8760}) \times (\lambda_{0TH} \times \Pi_{Thermal} + \lambda_{0TcyCase} \times \Pi_{TcyCase} + \lambda_{0TcySolderjoints} \times \Pi_{TcySolderjoints} + \lambda_{0RH} \times \Pi_{RH} + \lambda_{0Mechanical} \times \Pi_{Mechanical})_i \times (\Pi_{Induced})_i$$

The basic faliure rates asociated to the different physical stresses are obtained as:

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

where:

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

Description	Np	λ_{0RH}		λ_{0TCy_Case}		λ_{0TCy_Solder}		$\lambda_{0mechanical}$	
		a	**b**	**a**	**b**	**a**	**b**	**a**	**b**
Plastic Dual-In-line Package	8 to 68	5.88	0.94	9.85	1.35	8.24	1.35	12.85	1.35
Ceramic Dual-In-Line Package	8 to 20	$\lambda_{0RH} = 0$		6.77	1.35	5.16	1.35	8.38	1.35
	>20 to 48					4.47	1.35	7.69	1.35
Plastic Quad Flatpack. L lead	44 to 240	11.16	1.76	12.41	1.46	10.80	1.46	14.71	1.46
	>240 to 304					10.11	1.46	14.02	1.46
Plastic Shrink (thickness) Quad Flatpack. L lead Plastic Thin Quad Flatpack. L lead	32 to 120	7.75	1.13	8.57	0.73	6.96	0.73	11.57	0.73
	>120 to 208					5.57	0.73	10.18	0.73
Plastic Quad Flatpack with heat sink. L lead	160 to 240	14.17	2.41	15.11	1.96	13.50	1.96	17.41	1.96
	>240 to 304					12.81	1.96	16.72	1.96
CERPACK	20 to 56	$\lambda_{0RH} = 0$		12.41	1.46	10.80	1.46	14.02	1.46
Ceramic Quad Flat Pack	64 to 132	$\lambda_{0RH} = 0$		12.41	1.46	10.80	1.46	14.02	1.46
	>132 to 256					9.19	1.46	12.41	1.46
Plastic Leaded Chip Carrier J-Lead	20 to 52	9.36	1.74	18.52	3.15	16.91	3.15	21.11	3.15
	>52 to 84					15.52	3.15	19.72	3.15
J-Lead Ceramic Leaded Chip Carrier	4 to 32	$\lambda_{0RH} = 0$		8.07	0.93	6.46	0.93	9.68	0.93
	44					5.77		8.99	
	52					5.36		8.58	
	68					4.85		8.07	
	84					4.38		7.6	

Ceramic Leadless Chip Carrier	4	$\lambda_{0RH} = 0$		8.07	0.93	5.07	0.93	8.07	0.93
	20					4.51		7.51	
	32					4.38		7.38	
	44					4.26		7.26	
	52					4.26		7.26	
	68					4.16		7.15	
	84					4.16		7.15	
Plastic Small Outlines. J-lead	24 to 44	4.31	0.86	8.36	1.39	6.75	1.39	11.36	1.39
Plastic Small Outlines. L-lead	8 to 14	8.23	1.17	13.36	2.18	11.75	2.18	16.36	2.18
	16 to 18					11.06	2.18	15.66	2.18
	20 to 28					10.36	2.18	14.97	2.18
	32					10.14	2.18	14.75	2.18
Thin Small Outlines. leads on small edges. L lead Thin Small Outlines. leads on long edges. L lead	5 to 16	6.21	0.97	9.25	0.76	7.44	0.76	12.05	0.76
	>16 to 32					6.05	0.76	10.66	0.76
	>32 to 44					5.83	0.76	10.44	0.76
	>44 to 56					5.36	0.76	9.97	0.76
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
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
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

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
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
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
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
Ceramic Ball Grid Array	255 to 1156	11.78	1.72	15.37	1.87	11.56	1.87	14.56	1.87
Dimpled BGA	255 to 1156	11.78	1.72	15.37	1.87	12.15	1.87	15.15	1.87
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
Ceramic Pin Grid Array	68 to 250	$\lambda_{0RH} = 0$		8.07	0.93	5.77	0.93	8.76	0.93
	>250 to 655					4.85	0.93	7.85	0.93

Type	λ_{0TH}
FPGA, CPLD, FPGA Antifuse, PAL	0.0166
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

3.5.6 Discrete semiconductors

When dealing with semiconductors, two possible solutions exist: Integrated Circuits and discrete semiconductors. While the first ones are more complicated, the second ones implement just one function per device. These components include diodes, transistors and similars, mostly for regulation, rectifying and protection.

To calculate the failure rate of a discrete semiconductors, the formula (3.1) is the one used in general, where

$$\lambda_{physical} = \sum_{i}^{Phases} (\frac{t_{annual}}{8760}) \times (\lambda_{0TH} \times \Pi_{Thermal} + \lambda_{0TcyCase} \times \Pi_{TcyCase} + \lambda_{0TcySolderjoints} \times \Pi_{TcySolderjoints} + \lambda_{0RH} \times \Pi_{RH} + \lambda_{0Mechanical} \times \Pi_{Mechanical})_i \times (\Pi_{Induced})_i$$

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

Description	λ_{0RH}	$\lambda_{0TcyCase}$	$\lambda_{0TcySolderjoints}$	$\lambda_{0Mechanical}$
Through hole, small signal, plastic	0.0310	0.00110	0.0055	0.00011
SMD, small signal, L-lead, plastic	0.0055	0.00057	0.00285	0.000057
SMD, medium power, small heat sink, L-lead, plastic	0.0126	0.00091	0.00455	0.000091
Through hole, power, plastic	0.0589	0.00303	0.01515	0.0003
SMD, small signal, C-lead, plastic	0.0124	0.00091	0.00455	0.00009
SMD, power, large heat sink, L-lead, plastic	0.0335	0.00413	0.02065	0.00041
SMD, high power, screw, plastic	0.99	0.03333	0.16665	0.0033
SMD, Hermetically sealed glass	0	0.00781	0.03905	0.00078
Through hole, metal	0	0.0101	0.0505	0.00101

The table above however does not list all the possible choices for the descriptions. The following types are addressed in the IC analysis, since the packages are the same:

1. Thin Shrink Small Outlines, L-lead, plastic (TSSOP);
2. Thin Small Outlines, leads on long edges, L-lead, plastic (TSOP);
3. Plastic Small Outlines, L-lead, plastic (SO).

3.5.7 Light Emitting Diodes (LED)

The Light Emitting Diodes are p-n junction diodes that emit light when activated. Due to their small size, low energy consumption and longer durability with respect to other light sources, they are largely utilized in electronic components to signal the correct or uncorrect functioning of a component.

The failure rate is defined by (3.1), where

$$\lambda_{physical} = \sum_{i}^{Phases} (\frac{t_{annual}}{8760}) \times (\lambda_{0TH}\Pi_{Thermal} + \lambda_{0TCyCase} \times \Pi_{TCyCase}$$
$$+\lambda_{0TCySolderJoints}\Pi_{TCySolderJoints} + \lambda_{0RH} \times \Pi_{RH} + \lambda_{0Mech} \times \Pi_{Mech})_i \times (\Pi_{Induced})_i$$

Light Emitting Diode	λ_{0TH}
Colour	0.01
White	0.05

<table>
<tr><th>Direct current I_F max</th><th>SMD or Through hole</th><th colspan="2">Case type</th><th>N. of pins</th><th>λ_{0RH}</th><th>λ_{0TCyC}</th><th>λ_{0TCyS}</th><th>λ_{0Mech}</th></tr>
<tr><td rowspan="13">I_F<150mA</td><td rowspan="2">Through</td><td>T1-x</td><td rowspan="9">Plastic</td><td>2 to 4</td><td rowspan="13">0.0034</td><td rowspan="13">0.0104</td><td rowspan="8">0.0520</td><td rowspan="8">0.0052</td></tr>
<tr><td>High flux</td><td>4</td></tr>
<tr><td rowspan="11">SMD</td><td>Chip</td><td>2</td></tr>
<tr><td rowspan="5">PLCC</td><td>Min 2</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>6</td></tr>
<tr><td>Round</td><td>2</td><td>0.1560</td><td>0.0624</td></tr>
<tr><td rowspan="2">LGA</td><td>Plastic</td><td rowspan="2">2</td><td>0.2080</td><td>0.0832</td></tr>
<tr><td>Ceramic</td><td>0.3640</td><td>0.1820</td></tr>
<tr><td rowspan="2">Other</td><td>Plastic</td><td rowspan="2">Any</td><td>0.1560</td><td>0.0624</td></tr>
<tr><td>Ceramic</td><td>0.3640</td><td>0.1820</td></tr>
<tr><td rowspan="2">I_F ≥150mA</td><td rowspan="2">SMD</td><td colspan="2">Plastic</td><td rowspan="2">Any</td><td rowspan="2">0.0031</td><td rowspan="2">0.0042</td><td>0.0420</td><td>0.0064</td></tr>
<tr><td colspan="2">Ceramic</td><td>0.1470</td><td>0.0735</td></tr>
</table>

3.5.8 Magnetic Components: Inductors and Transformers

Transformers and inductors seem to have very similar construction but they have different applications and their own unique design and construction elements. The general model is (3.1), where $\lambda_{physical}$ is calculated as:

$$\lambda_{physical} = \lambda_{0\_Magnetic} \times \sum_{i}^{Phases} (\frac{t_{annual}}{8760})_i \times (\Pi_{Thermo-electrical} + \Pi_{TCy} + \Pi_{Mechanical})_i \times (\Pi_{induced})_i$$

where $\lambda_{0\_Magnetic}$ depends on the component type according to the following table:

Component description	$\lambda_{0\_Magnetic}$
Low current wirewound inductor (or Low level)	0.025
High current (or power) wirewound inductor	0.05
Multi-layer inductor	0.05
Transformer, Low Power (or Low Level)	0.125
Transformer, High Power	0.25

3.5.9 Piezoelectric Components: Oscillator and Quartz

The crystal oscillator is an electronic oscillator circuit that creates an electrical signal with a precise frequency to keep track of time, to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator used is the quartz crystal, so oscillator circuits incorporating them became known as crystal oscillators. To obtain the lambda factor (3.1), $\lambda_{physical}$ is calculated as:

$$\lambda_{physical} = \lambda_{0\_Piezoelectric} \times \sum_{i}^{Phases} (\frac{t_{annual}}{8760})_i \times (\Pi_{Thermo-electrical} + \Pi_{TCy} + \Pi_{Mechanical} + \Pi_{RH})_i \times (\Pi_{induced})_i$$

where $\lambda_{0\_Piezoelectric}$ depends on the component type according to the following table:

Component description	$\lambda_{0\_Piezoelectric}$
Quartz resonator (through hole HCxx type case)	0.82
Quartz resonator (surface mounted)	0.79
Quartz oscillator (through hole XO type case)	1.6
Quartz oscillator (surface-mounted XO, MCSO type case)	1.63

3.5.10 Printed circuit boards (PCBs)

When dealing with complex functions, hardware must be complex too, and the different components must be connected: PCBs mechanically support and electrically connect the elements that are present on it.

The failure rate is, as always, defined in (3.1), and

$$\lambda_{physical} = \lambda_{0PCB} \times \sum_{i}^{Phases} (\frac{t_{annual}}{8760}) \times (\Pi_{Tcy} + \Pi_{Mechanical} + \Pi_{RH} + \Pi_{Chemical})_i \times (\Pi_{Induced})_i$$

The λ_{0PCB} parameter is determined by multiple factors:

$$\lambda_{0PCB} = 5 \times 10^{-4} \times (N_{Layers})^{0.5} \times (\frac{N_{connection}}{2}) \times \Pi_{Class} \times \Pi_{TechnoPCB}$$

where N_{Layers} is the number of layers in the PCB and $N_{connection}$ is the number of connection points.

Printed circuit technology identification	$\Pi_{TechnoPCB}$
Through holes	0.25
Blind holes	0.50
Micro-via technology	1
Pad on via technology	2.5

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

Chapter 4

Failure Mode, Effects and Criticality Analysis

While dealing with products or processes, it is fundamental to identify the possible consequences that may arise when the item fails, since a failure may lead to harmful situations for humans. In order to understand the behaviour of a compromised item, an analysis must be performed.

The first appearance of FMECA (Failure Mode, Effects, and Criticality Analysis) was in 1949, by the U.S. military, in the military protocol MIL-P 1629, "Procedures for performing a failure mode, effects and criticality analysis". [9] A different form of it, FMEA, which will be discussed later on, was also adopted and they both began to be broadly used in the 1950s, mostly in U.S.A. and Japan, primarily in high risk applications such as aerospace, that needed to be highly reliable. In the 1970s this method began to spread in Europe, mostly in mechanical engineering and electronics. An increasing demand for more quality and reliable products made it commonly used since the 1980s.[10]

There are three different forms of FMEA (Failure Mode and Effects Analysis):

- FMEA
- FMEDA
- FMECA

FMEA

The FMEA methodology is a methodology used to identify potential failures and determine their effects on a greater scale, in order to define possible countermeasures. It is a bottom-up approach in which each element of the item is considered in its possible failure modes, and the failure propagation is analysed until its final effect. FMEA classifies the elements depending on the severity of the consequences in case of failure. Only one failure at a time is considered, and the worst possible scenario depending from that failure is evaluated for severity classification. This classification does not take into account the probability of such failure happening, so it is a qualitative analysis.

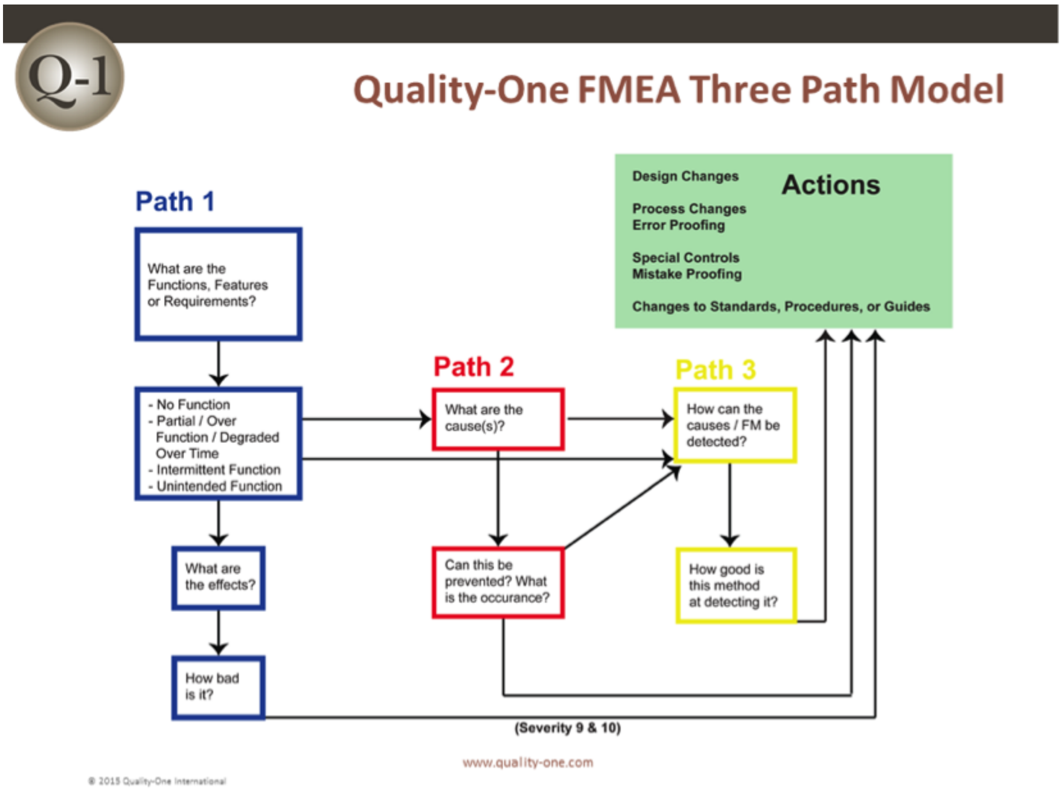

Figure 4.1: Path 1 represents FMEA, path 2 FMECA, path 3 FMEDA [11]

FMEDA

Failure Modes, Effects and Diagnostic Analysis is a more accurate method with respect to FMEA. It involves the evaluation of the possibility to detect a failure that may have effects on the correct functioning of the item. As in FMEA, all elements are considered, and the priority is given to the ones whose severity in case of failure is greater. Here too, only one failure at a time is taken into account. In addition to that, FMEDA also includes an analysis of the ability of any automatic diagnostic to detect the failure: the coverage factor is the parameter that indicates this ability. This is fundamental in signalling to the user that an element is not working, and it helps avoid damages, thus increasing the reliability. The only issue is that only known possible failures may be detected.

4.1 FMECA

The analysis considered in this work is the third one: Failure Modes, Effects and Criticality Analysis. This methodology has the same principles as FMEA, but a criticality analysis is added. Criticality is defined as a combination of severity and probability of a failure. In the following, the detailed methodology is described. The first part of the procedure is common to FMEA. The item must be considered in each of its components, and each part must be analysed from these points of view:

1. Functional descriptions;
2. Interfaces;
3. Interdependences;
4. Operational modes;
5. Mission phases.

For each component all failure modes must be identified, and their effects on the item must be examined. Each failure is assumed to be the only one in the item. For each failure the possible consequences are evaluated, and the worst one is taken into account. [12]

Each failure mode can be detected or undetected by the rest of the item. They can be identified by diagnostic testing, alarms, proof testing, human perception, and similar. Some failure modes are evident (detected), other are hidden (undetected). [13]

All the components are analysed following the previous guidelines, and the probability relative to each failure mode is calculated, which makes FMECA an improved version of FMEA. Each failure mode is also classified considering the consequences of its malfunctioning.

Depending on that, the failure modes can be classified as such:

- **Safe detected.** The failure is not critical (the hazards arising are not severe), and it is also detected.
- **Safe undetected.** The failure is not critical, but it is not detected unless a specific test is performed, not in operational mode.
- **Unsafe detected.** The failure may cause critical situations, but is detected by the item and corrective actions may be taken.
- **Unsafe undetected.** The most dangerous case, since the arising situation may be dangerous, and there is no way to detect it.

These types of failure modes contribute to the residual failure rate, since the undetected failures are not recovered, and the detected ones may not be completely compensated. At this point the $\lambda_{residual}$ can be obtained from the failure rates. The last three types of failures are taken into account in their entirety: the undetected because of the lack of compensations, the unsafe because of their effects. The safe detected failures, instead, are considered with an associated parameter: the coverage factor. It is a parameter that indicates how likely a failure is prevented from causing unwanted effects. It is indicated in percentual, and ranges from 0% (completely uncompensated component) to 100% (totally safe component). However, the last value is never used, because an unpredicted failure may always happen, so the maximum is set to 99.9%.

The $\lambda_{residual}$ is thus calculated according to this formula:

$$\lambda_{residual} = \lambda_{SafeUnd} + \lambda_{UnsDet} + \lambda_{UnsUnd} + \frac{(100 - Coverage) \times \lambda_{SafeDet}}{100}$$

The residual failure rate indicates the failure rate deriving from unwanted events that even if covered by safety mechanisms cause undesired effects. [14]

Hence, the Single Point Fault Metric (SPFM) can be calculated. It represents the proportion of hardware failures that do not directly cause the generation of unwanted effects, or, put in a simpler way, the robustness of the item. It depends both on the $\lambda_{residual}$ and on the $\lambda_{SinglePointFault}$, where a Single Point Fault (SPF) is a failure that directly causes an undesired outcome. The SPFM is calculated as following:

$$SPFM = \frac{\sum(\lambda_{SPF} + \lambda_{residual})}{\sum \lambda}$$

The acceptability of the result of this metric is linked to the ASIL of the item: the safer the item must be, the higher the SPFM must be. In particular, this table can be followed [15]:

	ASIL B	**ASIL C**	**ASIL D**
SPFM	>90%	>97%	>99%

Table 4.1: SPFM by ASIL

Chapter 5

Reliability Analysis of the boards

In this part the results obtained will be discussed. The failure rates of the boards were obtained compiling the template generated by the FIDES ExperTool version 2.6 (2012). The data regarding the circuits are inserted in a blank template generated by the program, after that this Excel file is used for computations, and a new Excel file is generated: this includes the original file and the result sheets. [16]

In the first part of this chapter the assumptions made about the two electronic boards will be discussed, while in the second part the results obtained from the FIDES analysis will be examined.

5.1 Assumptions

Both the Dual Inverter and the Hyper-Spectral Data Fusion boards are conceived to be integreted in an autonomous elecric car. The vehicle considered is used in car-sharing in an average european city, and when not used it is connected to a power network to recharge. Following the FIDES requirements, more specifical assumptions can be found below. Some parts share the same parameters for both boards, while in others the differences are explicited. Furthermore, it is assumed, as it is a standard practice, that the boards that are not functioning after the production, initial storage and transport are detected through testing and discarded, thus they are not mounted and do not need to be taken into account.

5.1.1 $\Pi_{Process}$ and Π_{PM}

Since the boards are manufactured in the most controlled and qualitative way, the best values for $\Pi_{Process}$ and Π_{PM} are chosen: 1 for the first type of parameters, 0.5 for the second.

ΠPROCESS	
Pi process	1
Pi LF Lead-free process factor	1
Pi process RF/HF	1

ΠPM (Part-Manufacturing)	
Active components	0,5
Other components (including COTS & SUBASSEMBLIES)	0,5

5.1.2 Time phases

The electronic boards are both working when the car is used. A car sharing autonomous vehicle in a European city is considered: the car is used 8 hours per day. If we assume it working 350 days per year, the boards will be working 2800 hours per year. Considering an average embedded automotive board has a lifespan of around 10 years, this means 28000 hours functioning in their lives. The boards are not used for 5600 hours a year, so 56000 hours in their lifetime. The remaining 15 days are used for maintenance: 360 hours a year, 3600 hours in their life.

At this point, the phases of a normal usage of the car and thus its equipment must be considered. Every time the vehicle is used, there will be these steps:

1. Key start;
2. Driving;
3. Key stop.

LIFE PROFILE

Standard life profile

Phase name	On / Off	Calendar time (hours)
Non-working day (maintenance)	OFF	72 h
Parking	OFF	5.792 h
Key start	ON	72 h
Driving mode	ON	2.751 h
key stop	OFF	72 h

Sum (1 year = 8760 h) ===>	8.760

Before and after these steps we have the parking periods in which everything is off and the charging of the car takes place: it can be considered a period of 16 hours a day. The number of times the working phase takes place can be determined on the basis of the assumptions previously made. Since a car-sharing scenario was considered, and 8 hours working, it can be reasonably stated an average utilization period of 40 minutes, from which it is assumed that 12 persons are going to use the car within a day. In the 40 minutes of usage, the key start step will occupy 1 minute, the driving phase will last 38 minutes, and finally the key stop will be 1 minute again. Now that the operational situations and their time distribution is defined, the stress analysis may be developed.

5.1.3 Physical factors

As stated in the chapter about FIDES, multiple stress factors are taken into account: temperature, temperature cycling, humidity, mechanical stresses (vibrations) and chemical stresses.

- **Temperature.** As we assumed the product will be used in a european city, an average of 20°C can be used for the calculations. The difference between the temperatures is present only in the key stop phase, in which it corresponds to the temperature reached while driving, so 55°C for the Dual Inverter and 70°C for the H-SDF. This because the first one is placed under the car (and thus has a higher dissipation), while the second one overheats more easily and is placed in the dashboard.

Temperature
Ambient temperature (°C)
20,00 °C
20,00 °C
20,00 °C
20,00 °C
55,00 °C

Temperature
Ambient temperature (°C)
20,00 °C
20,00 °C
20,00 °C
20,00 °C
70,00 °C

- **Temperature cycling.** In this case, the two boards will have different parameters. This is both because of the placing of the board inside the vehicle, and because of the proneness to heat production of the board. In the H-SDF board the maximum temperature, reached after the driving phase, is 70°C. In the Dual Inverter board instead it peaks at 55°C. For brief periods the circuit temperatures may exceed these values, but the boards can withstand a maximum temperature of 125°C, so these peaks over the assessed temperature are negligible. For both boards a temperature cycle from 15 to 25°C when in maintenance (protected environment), and a cycle from 10 to 30°C when parked where considered. Finally as it can be remarked, there is no cycling in key start nor in key stop because the inertia keeps the components to heat up or cool down in such a short period (1 minute). The number of cycles per phase in a year is obtained by multiplying the number of times a phase takes place in a day for the number of days corresponding to the phase.

Temperature cycling			
Δt (°C)	Cycle duration (hours)	Number of cycles (/phase)	Maximum temperature during cycling (°C)
10,00 °C	24 h	3	25,00 °C
20,00 °C	16 h	362	30,00 °C
0,00 °C	0 h	4344	20,00 °C
35,00 °C	1 h	4344	55,00 °C
0,00 °C	0 h	4344	55,00 °C

Temperature cycling			
Δt (°C)	Cycle duration (hours)	Number of cycles (/phase)	Maximum temperature during cycling (°C)
10,00 °C	24 h	3	25,00 °C
20,00 °C	16 h	362	30,00 °C
0,00 °C	0 h	4344	20,00 °C
50,00 °C	1 h	4344	70,00 °C
0,00 °C	0 h	4344	70,00 °C

- **Humidity.** For both the boards a default value of 70% of humidity was considered, and not changing between the phases because the item is isolated from the exterior.

Humidity
Relative humidity (%)
70
70
70
70
70

- **Mechanical.** The only phase in which both boards undergo mechanical stress is the driving phase. This wouldn't be the case if there was a combustion motor, since the ignition of the fuel, even at low power, causes vibrations. The electrical motor instead is not so noisy, and the only stress considered is the one due to the road profile. An estimated value of 2.0 Grms was placed.

Mechanical
Random vibrations (Grms)
0,00 Grms
0,00 Grms
0,00 Grms
2,00 Grms
0,00 Grms

- **Chemical.** The boards into study do not come into contact with saline pollution, nor are placed in the vehicle in proximity to damaging products, but they undergo some pollution stress from the environment of the city. Still, this polluting factor is indirect, since the products are hermetically sealed in a case.

Chemical			
Saline pollution	Environmental pollution	Application pollution	Protection level
Low	Moderate	Low	Hermetic
Low	Moderate	Low	Hermetic
Low	Moderate	Low	Hermetic
Low	Moderate	Low	Hermetic
Low	Moderate	Low	Hermetic

5.1.4 $\Pi_{Application}$ evaluation

In this section the $\Pi_{Application}$ of the items are analysed. Being mounted in different parts of the car (the Dual Inverter is under the vehicle, the H-SDF is inside the dashboard), some parameters differ.

1. **User type in the phase considered.** In both cases, the user is considered not completely reliable but neither is considered reckless, so a medium score is assigned. For the maintenance, it is assumed that the procedures in dealing with the vehicle are followed.

2. **User qualification level in the phase considered.** As before, the driver is considered with average skills in both cases, thus a medium qualification is assigned. Instead, during maintenance the scores are different: because of the more exposed position the Dual Inverter board may be unintentionally damaged while dealing with other problems, instead, the H-SDF is protected and cannot be touched unintentionally.

3. **System mobility.** Both boards undergo a movement only while in driving phase, and since an accident could potentially happen, the parameter is set to the most severe value.

Input of $\Pi_{application-i}$

Nota : The P application value can be imposed for each phase or can be computed from detailed data

					Non-working day (maintena	Parking	Key start	Driving mode	key stop
Imposed Π application									
Detailled Π application									
User type in the phase considered	Represents the capability to respect procedures, facing operational constraints.	0: Favourable 1: Moderate 2: Unfavourable	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	0, low level	1, medium level	1, medium level	1, medium level	1, medium level
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	2, high level	1, medium level	1, medium level	1, medium level	1, medium level
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	0, low level	0, low level	0, low level	2, high level	0, low level
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	1, medium level	0, low level	0, low level	0, low level	0, low level
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	0, low level	0, low level	1, medium level	1, medium level	1, medium level
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	2, high level	1, medium level	1, medium level	1, medium level	1, medium level
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	0, low level	0, low level	1, medium level	1, medium level	1, medium level
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	1, medium level	1, medium level	1, medium level	1, medium level	1, medium level

4. **Product manipulation.** In maintenance a risk for shocks while repairing or dealing with the vehicle may happen, for both the boards.

5. **Type of electrical network for the system.** Both the circuits are subject to the influence of electrical disturbances in the ON phases of the car, because of the proximity of multiple other circuits.

6. **Product exposure to human activity.** While being used or while the car is parked, the boards may be subject to damages of people moving around the vehicle, but it is improbable something really severe happens. For the maintenance period, being the Dual Inverter board more exposed, it may be easily affected by acivities on the vehicle. The H-SDF is instead isolated and not directly manipulated.

7. **Product exposure to machine disturbances.** While being used, the car is exposed to disturbances related to its own movements and operations.

8. **Product exposure to the weather.** In both cases while not in maintenance the exposure to bad weather is similar and indirect. For the maintenance phase the weather may still indirectly affect the Dual Inverter board because of its position, while the H-SDF would be protected.

Input of $\Pi_{application-i}$

Nota : The P application value can be imposed for each phase or can be computed from detailed data

					Non-working day (maintena	Parking	Key start	Driving mode	Key stop
Imposed Π application									
Detailled Π application									
User type in the phase considered	Represents the capability to respect procedures, facing operational constraints.	0: Favourable 1: Moderate 2: Unfavourable	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	**0, low level**	**1, medium level**	**1, medium level**	**1, medium level**	**1, medium level**
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	**0, low level**	**1, medium level**	**1, medium level**	**1, medium level**	**1, medium level**
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	**0, low level**	**0, low level**	**0, low level**	**2, high level**	**0, low level**
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	**1, medium level**	**0, low level**	**0, low level**	**0, low level**	**0, low level**
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	**0, low level**	**0, low level**	**1, medium level**	**1, medium level**	**1, medium level**
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	**1, medium level**	**1, medium level**	**1, medium level**	**1, medium level**	**1, medium level**
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	**0, low level**	**0, low level**	**1, medium level**	**1, medium level**	**1, medium level**
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	**0, low level**	**1, medium level**	**1, medium level**	**1, medium level**	**1, medium level**

5.1.5 $\Pi_{Ruggedising}$ evaluation

Since the boards are developed under the strict regulations of the automotive domain, it can be stated the all the recommendations concerning this part are fully applied and thus the score is "N4 - Recommendation is fully applied" for all the fields of the table.

Input of $\Pi_{ruggedising}$

Nota : The Π RUGGEDISING can be imposed for all phases or detailled.

Imposed Π ruggedising		
Detailled Π ruggedising		
Recommendation	**Weight**	**Level**
Check that environmental specifications are complete.	4	N4 - Recommendation is fully applied
Provide training and manage operation and maintenance for implementation and maintenance of the product	7	N4 - Recommendation is fully applied
Check that procedures specific to the product and rules specific to businesses are respected by an appropriate monitoring system	7	N4 - Recommendation is fully applied
Design dependable electrical protection devices	4	N4 - Recommendation is fully applied
Study and handle risks of the product under test being deteriorated by failures of its test or maintenance means.	4	N4 - Recommendation is fully applied
Identify and use appropriate prevention means of preventing reasonably predictable aggressions (related to the weather)	4	N4 - Recommendation is fully applied
Use appropriate prevention means to identify and handle reasonably predictable abnormal uses weather	4	N4 - Recommendation is fully applied
Include production, storage and maintenance environments in the product environment specifications	4	N4 - Recommendation is fully applied
Justify that environment specifications are respected	4	N4 - Recommendation is fully applied
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	N4 - Recommendation is fully applied
Perform an analysis of failure cases that could result in failure propagation.	4	N4 - Recommendation is fully applied
Carry out a process analysis of implementation and maintenance operations	4	N4 - Recommendation is fully applied
Carry out a review of maintenance operations done by the final user and deal with his recommendations	4	N4 - Recommendation is fully applied
Write complete procedures for all product implementation and maintenance operations	7	N4 - Recommendation is fully applied
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	N4 - Recommendation is fully applied
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	4	N4 - Recommendation is fully applied

5.1.6 Electronic components

In the analysis of the components, aside from the already present specifications obtained from the datasheets, for some of them a further classification depending on the positions of the components was performed.

- **Resistors.** They were divided into termination, pull-up, pull-down and others. Furthermore, they were divided into power components and non-power: the first ones were given a rating 0.85 for $P_{applied}/P_{rated}$ because of the direct link to the power supply, while the ones of the second type were given 0.5.

- **Capacitors.** Both types of capacitors were classified depending on their position, decoupling or other, and their voltage. When a voltage could not be specifically calculated a default value for $V_{applied}/V_{rated}$ was used. For capacitors not directly connected to a specific tension, the maximum voltage on that part of the circuit was used, to have a conservative estimate.

- **Discrete semiconductors.** Some types of semiconductors will require a specification about the ratio $V_{applied}/V_{rated}$, this is obtained as for capacitors.

In the following pages the tables about the analysed components are shown. Firstly, the ones about the Dual Inverter board, then the ones of the Hyper-Spectral Data Fusion. In particular, the list must be read three pages at a time: the first contains the components' names, types, and description appendices 1 and 2, the second contains the QA values, all set to the levevel corresponding to maximum reliability, and the third page contains the specific parameters required by that type of component.

Dual Inverter

Name	Component type	Description appendix 1	Description appendix 2
3.3V Automotive In-System Programmable CPLD (5V tolerant)	Integrated Circuits [ECIC]	TSQFP TQFP. VQFP.LQFP, Plastic Thin Quad Flatpack, L lead / >120 à 208 [ECIC_07]	FPGA, CPLD, FPGA Antifuse, PAL [ECIC_57]
32bit 200MHz Aurix Tricore	Integrated Circuits [ECIC]	PBGA CSP BT 0.8 et 0.75 mmPlastic Ball Grid Array with solder ball pitch = 0.8 mm et 0.75 mm / 48 à 384 [ECIC_44]	Microprocessor, Microcontroller, DSP [ECIC_59]
CAN-HSTransceiver 5VLogic U14,U15	Integrated Circuits [ECIC]	SO, SOP, SOL, SOIC, SOWPlastic Small Outlines, L lead / 8 à 14 [ECIC_28]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
CAN-HSTransceiver LocalWakeInput INHOutput LowPowerManagement	Integrated Circuits [ECIC]	SO, SOP, SOL, SOIC, SOWPlastic Small Outlines, L lead / 8 à 14 [ECIC_28]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
Buck/Boost/LDO/Tracker/Reference/Standby Safety PowerSupply	Integrated Circuits [ECIC]	QFN, DFN, MLFQuad Flat No lead (package without lead) / 28-56 [ECIC_42]	Microprocessor, Microcontroller, DSP [ECIC_59]
CeramicCapacitor C0G 1.0nF 100V 0603, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a high CV product [ECCC_03]	-
CeramicCapacitor C0G 1.0nF 100V 0603	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a high CV product [ECCC_03]	-
CeramicCapacitor C0G 100pF 50V 0402, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product [ECCC_02]	-
CeramicCapacitor C0G 220pF 50V 0402, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product [ECCC_02]	-
CeramicCapacitor C0G 3.3nF 50V 0603, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product [ECCC_02]	-
CeramicCapacitor C0G 330pF 100V 0603, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product [ECCC_02]	-
CeramicCapacitor C0G 47pF 50V 0402, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a low CV product [ECCC_01]	-
CeramicCapacitor C0G 47pF 50V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a low CV product [ECCC_01]	-
CeramicCapacitor C0G 5.6pF 50V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a low CV product [ECCC_01]	-
CeramicCapacitor C0G 680pF 100V 0603	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product [ECCC_02]	-
CeramicCapacitor C0G 680pF 100V 0603, decoupilng	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product [ECCC_02]	-
CeramicCapacitor C0G 68pF 100V 0603, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a low CV product [ECCC_01]	-
CeramicCapacitor X7R 100nF 100V 0603, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 100nF 100V 0603 SoftTermination	Ceramic capacitors [ECCC]	Ceramic capacitor with polymer terminations with non-defined temperature coefficient (Type II) with medium or high CV product [ECCC_08]	-
CeramicCapacitor X7R 100nF 16V 0402, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 10nF 50V 0402, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-

...ndix 2

Placement	Quantity	PI_PART	QA_ Manufacturer factor	QA_Component factor	RA_Manufacturer factor (IC&Discrete)	Experience factor : ε
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	28		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	10		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	6		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	9		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	6		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	13		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	118		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

ocess ASIC T_max manufacturer (piezo	N-layer (PCB)	N-connection (PCB)	N-contact (connectors)	N-annual_cycles (connecto	Np number of pins(IC & opt	Number of SMD Resistive r	Number of Discret Semiconductors or LED or optocouplers in case of sharing the same case.	Rise of temperature	P-applied / P-rated (Resisto	V-applied / V-rated (capacit	V-contact / V-nominal (rela	I-contact / I-nominal (relays)	U-nominal / U-coil (relays)	Limit and Manual action switch	Nbre of manœuvres /h (rela	I-output / I-max-output (piez	N DT (Switches & Relays)	N ST (Switches & Relays)	I-applied / I-rated (Fuses)
					144			35											
					60			35											
					8			35											
					14			35											
					48			35											
										0,5									
										0,05									
										0,5									
										0,5									
										0,1									
										0,5									
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										0,5									
										0,5									
										0,05									
										0,5									
										0,5									
										0,5									
										0,5									

CeramicCapacitor X7R 10uF 10V 0805, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 1nF 100V 0402, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 1uF 25V 0603, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 2.2uF 50V 1206, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 22uF 6.3V 1206, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 330nF 50V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 33nF 50V 0603, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 4.7uF 16V 0805, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 470nF 25V 0603, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7S 10uF 50V 1210 SoftTermination	Ceramic capacitors [ECCC]	Ceramic capacitor with polymer terminations with non-defined temperature coefficient (Type II) with medium or high CV product [ECCC_08]	-
CeramicCapacitor X7S 1uF 100V 0805 SoftTermination	Ceramic capacitors [ECCC]	Ceramic capacitor with polymer terminations with non-defined temperature coefficient (Type II) with medium or high CV product [ECCC_08]	-
Crystal 20MHz 8pFLoad 120OhmESR	Piezoelectric components: Oscillators and Quartz [ECPZ]	Crystal quartz oscillator (surface mounted, XO MCSO type Case) [ECPZ_04]	-
Crystal 25MHz 8pFLoad 100OhmESR	Piezoelectric components: Oscillators and Quartz [ECPZ]	Crystal quartz oscillator (surface mounted, XO MCSO type Case) [ECPZ_04]	-
Double SiliconRectifier 125mA 100V CommonCathodeConfiguration	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Signal diodes up to 1A (PIN, Schottky,signal, varactor) [ECDS_10]
Double SiliconRectifier 125mA 100V SeriesConfiguration	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Signal diodes up to 1A (PIN, Schottky,signal, varactor) [ECDS_10]
Double SiliconRectifier 125mA 90V CommonAnodeConfiguration	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Signal diodes up to 1A (PIN, Schottky,signal, varactor) [ECDS_10]
Dual buffer driver 3-state	Integrated Circuits [ECIC]	TSOP IThin Small Outlines, leads on small edges, L lead / 5 à 16 [ECIC_32]	Digital circuit (MOS, bipolar, BiCMOS) [ECIC_63]
Dual buffer/line driver 3-state	Integrated Circuits [ECIC]	TSOP IThin Small Outlines, leads on small edges, L lead / 5 à 16 [ECIC_32]	Digital circuit (MOS, bipolar, BiCMOS) [ECIC_63]
Dual Comparator RailToRail OpenDrainOutput	Integrated Circuits [ECIC]	TSSOP, MSOP, µSO, µMAX, TVSOPThin Shrink Small Outlines, L lead / 8 à 28 [ECIC_37]	Digital circuit (MOS, bipolar, BiCMOS) [ECIC_63]
Dual ESDProtection 60VClamping	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Protection diodes more than 3kW (in peak 10ms/ 100ms) (TVS) [ECDS_17]
Dual nMOS 120mOhm 40V Autoprotected	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Silicon MOS > 5 W [ECDS_22]
Dual nMOS 17mOhm 60V	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Silicon MOS > 5 W [ECDS_22]
Dual nMOS+pMOS 55mOhm+150mOhm 20V	Discrete semiconductors [ECDS]	SO - (Discrete/ IC) [ECIC_28]	Silicon MOS > 5 W [ECDS_22]
Dual OpAmp RailToRail LowOffset	Integrated Circuits [ECIC]	TSSOP, MSOP, µSO, µMAX, TVSOPThin Shrink Small Outlines, L lead / 8 à 28 [ECIC_37]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
ElectrolyticCapacitor Aluminum 220uF 35V d=10mm h=10mm SurfaceMount	Aluminum capacitors [ECAC]	Aluminum liquid electrolyte capacitor [ECAC_01]	-
ElectrolyticCapacitor Hybrid 270uF 35V d=10mm h=10mm SurfaceMount	Aluminum capacitors [ECAC]	Aluminum liquid electrolyte capacitor [ECAC_01]	-

1.0 - Non-interface digital function	7		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	60		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	17		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	6		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	11		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	16		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	24		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	6		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	11		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	10		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

											0,5	0,5													
0,5	0,5	0,5	0,5	0,5	0,5	0,1	0,5	0,5	0,5	0,5			0,05	0,05	0,5									0,5	0,5
													35	35	35	35	35	35	35	35	35	35	35		
													1	1	1				1	1	1	1			
																20	8	8				8	8		
											150	150													

eMGS625 - Programmable 6x Solenoid Controller	Integrated Circuits [ECIC]	SQFP, TQFP. VQFP.LQFP, Plastic Shrink (thickness) Quad Flatpack, L lead / 32 à 120 [ECIC_06]	Microprocessor, Microcontroller, DSP [ECIC_59]
FerriteBead 600Ohm@100MHz 1000mA	Magnetic Components: Inductors and Transformers [ECIN]	Multi-layer ceramic chip inductor [ECIN_03]	-
FixedResistor CurrentSense 47mOhm 1% 1W 2512	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 0.0Ohm 1% 100mW 0603	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 0.0Ohm 1% 100mW 0603, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 0.0Ohm 1% 125mW 0805 R11, pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 0.0Ohm 1% 62.5mW 0402, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 0.0Ohm 1% 62.5mW 0402, pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 0.0Ohm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 100mW 0603, pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 125mW 0805, pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 125mW 0805	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 250mW 0805	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 62.5mW 0402, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 62.5mW 0402, pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0MOhm 1% 100mW 0603	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.5kOhm 1% 100mW 0603, pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 100kOhm 1% 62.5mW 0402, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 100kOhm 1% 62.5mW 0402, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 100kOhm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 100Ohm 1% 62.5mW 0402, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 100Ohm 1% 62.5mW 0402, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 100Ohm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 10kOhm 1% 100mW 0402, pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-

1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	24		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	19		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	16		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	6		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	7		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	27		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	14		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	7		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

		0,5	0,5	0,5	0,85	0,5	0,85	0,5	0,85	0,85	0,5	0,85	0,5	0,85	0,5	0,5	0,5	0,85	0,5	0,5	0,5	0,5	0,5	0,85
35	35																							
64																								

FixedResistor E24Series 10kOhm 1% 250mW 1206	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 10kOhm 1% 62.5mW 0402, pull up	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 10kOhm 1% 62.5mW 0402, pull down	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 10kOhm 1% 62.5mW 0402	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 10Ohm 1% 62.5mW 0402	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 11kOhm 1% 100mW 0603, pull up	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 150kOhm 1% 100mW 0603	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 15kOhm 1% 100mW 0603, pull down	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 15kOhm 1% 100mW 0603	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 15kOhm 1% 125mW 0805	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 18kOhm 1% 100mW 0603, pull down	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 18kOhm 1% 100mW 0603, pull up	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 2.0kOhm 1% 125mW 0805, pull up	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 20.0kOhm 0.1% 100mW 0603, pull up	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 20.0kOhm 0.1% 100mW 0603, pull down	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 20.0kOhm 0.1% 100mW 0603	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 20.0kOhm 1% 62.5mW 0402, pull down	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 20.0kOhm 1% 62.5mW 0402, pull up	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 20.0kOhm 1% 62.5mW 0402	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 220Ohm 1% 62.5mW 0402, pull up	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 22kOhm 1% 100mW 0603, pull up	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 270kOhm 1% 62.5mW 0402	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 27Ohm 1% 62.5mW 0402	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-
FixedResistor E24Series 3.3kOhm 1% 250mW 1206	Resistors	[ECRE]	Resistive chip	[ECRE_06]	-

1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	23		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	19		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	25		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	13		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	49		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	21		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	11		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	38		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

0,5	0,85	0,5	0,5	0,5	0,85	0,5	0,5	0,5	0,5	0,5	0,85	0,85	0,85	0,5	0,5	0,5	0,85	0,5	0,85	0,85	0,5	0,5	0,5

FixedResistor E24Series 39kOhm 1% 100mW 0603, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 4.7kOhm 1% 62.5mW 0402, pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 4.7kOhm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 470kOhm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 47kOhm 1% 62.5mW 0402, pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 47kOhm 1% 62.5mW 0402, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 47kOhm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 49.9Ohm 1% 100mW 0603,pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 49.9Ohm 1% 100mW 0603, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 560Ohm 5% 125mW 0805	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 56kOhm 1% 62.5mW 0402, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 680Ohm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 680Ohm 1% 62.5mW 0402, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 7.5kOhm 1% 100mW 0603, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 750Ohm 1% 100mW 0603	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 8.2kOhm 1% 250mW 1206	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E96Series 2.49kOhm 1% 62.5mW 0402, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E96Series 4.87kOhm 1% 62.5mW 0402, pull down	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E96Series 5.76kOhm 1% 100mW 0603, pull up	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E96Series 60.4Ohm 1% 250mW 1206	Resistors [ECRE]	Resistive chip [ECRE_06]	-
GreenLED SurfaceMount 1206	Light Emitting Diode (LED) [ECLE]	SMD PLCC Plastic/ 2 pins [ECLE_05]	Color [ECLE_16]
Header CMC 64Ways 8PowerPin 56SignalPin J1	Connectors [ECCO]	Circular and rectangular connectors [ECCO_01]	Soldered (through-hole mount component) [ECCO_06]
LinearRegulator Fixed 4Vto5.5VInput 3.3V 1A	Discrete semiconductors [ECDS]	SOT223, SOT89… SMD, medium power, small heatsink, L-lead, plastic [ECDS_03]	Silicon bipolar > 5W [ECDS_21]

1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	9		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	32		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	21		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	36		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	6		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	8		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	12		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	6		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Fixed	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

									0,5										
									0,85										
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									0,5										
									0,85										
									0,5										
							1	35											
			8	5				35											
							1	35											

NTCThermistor 10k@25C 2% 0805	Resistors [ECRE]	Resistive chip [ECRE_06]	-
Oscillator 4MHz StopFunction	Piezoelectric components: Oscillators and Quartz [ECPZ]	Crystal quartz oscillator (surface mounted, XO MCSO type Case) [ECPZ_04]	-
PowerInductor Shielded 1uH 8.5A 4.06x4.45mm	Magnetic Components: Inductors and Transformers [ECIN]	High current (or power) wirewound inductor [ECIN_02]	-
PowerInductor Shielded 2.2uH 6A 4.06x4.45mm	Magnetic Components: Inductors and Transformers [ECIN]	High current (or power) wirewound inductor [ECIN_02]	-
PowerInductor Shielded 4.7uH 2A 5.3x4.2mm	Magnetic Components: Inductors and Transformers [ECIN]	High current (or power) wirewound inductor [ECIN_02]	-
PowerInductor Shielded 6.8uH 4.4A 6.5x6.9mm	Magnetic Components: Inductors and Transformers [ECIN]	High current (or power) wirewound inductor [ECIN_02]	-
RedLED SurfaceMount 1206	Light Emitting Diode (LED) [ECLE]	SMD PLCC Plastic/ 2 pins [ECLE_05]	Color [ECLE_16]
SchottkyBarrierRectifier 0.5A 40V	Discrete semiconductors [ECDS]	SOD6, SOD15 SMD, small signal, C-lead, plastic [ECDS_05]	Signal diodes up to 1A (PIN, Schottky,signal, varactor) [ECDS_10]
SchottkyRectifier 10A 100V	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Rectifying diodes > 3A [ECDS_15]
SchottkyRectifier 2A 100V	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Rectifying diodes 1A to 3A [ECDS_11]
SiliconRectifier 250mA 100V	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Signal diodes up to 1A (PIN, Schottky,signal, varactor) [ECDS_10]
Single 2-inputs AND gate	Integrated Circuits [ECIC]	SMD, small signal,L-lead, plastic (Discrete/ IC) [ECDS_02]	Digital circuit (MOS, bipolar, BiCMOS) [ECIC_63]
Single HighSideSwitch 200mOhm 52V Autoprotected DiagnosticFeedback	Integrated Circuits [ECIC]	SMD, small signal,L-lead, plastic (Discrete/ IC) [ECDS_02]	Digital circuit (MOS, bipolar, BiCMOS) [ECIC_63]
Single nMOS 25mOhm 60V	Discrete semiconductors [ECDS]	TSOP - (Discrete/ IC) [ECIC_32]	Silicon MOS > 5 W [ECDS_22]
Single NOT gate	Integrated Circuits [ECIC]	SMD, small signal,L-lead, plastic (Discrete/ IC) [ECDS_02]	Digital circuit (MOS, bipolar, BiCMOS) [ECIC_63]
Single OpAmp RailToRail LowOffset	Integrated Circuits [ECIC]	SMD, small signal,L-lead, plastic (Discrete/ IC) [ECDS_02]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
Single pMOS 18mOhm 60V	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Silicon MOS > 5 W [ECDS_22]
Single PNP 600mA 40V	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Silicon bipolar > 5W [ECDS_21]
ZenerDiode 47V 250mW	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Zener regulation diodes up to 1.5W [ECDS_12]
Dual Inverter PCB	Printed circuit board (PCB) [ECPC]	Through holes [ECPC_01]	100 / 100 [ECPC_11]

1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	10		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Fixed	1		3 -Higher	3 -Much Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

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125																0,5			
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Hyper-Spectral Data fusion

Name	Component type	Description appendix 1	Description appendix 2
CeramicCapacitor C0G 5.6pF 50V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a low CV product [ECCC_01]	-
CeramicCapacitor C0G 8.2pF 50V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a low CV product [ECCC_01]	-
FixedResistor E24Series 0.0Ohm 1% 62.5mW 0402, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 0.0Ohm 1% 62.5mW 0402, pullup	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 0.0Ohm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 0.0Ohm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 100Ohm 1% 62.5mW 0402, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 10kOhm 1% 62.5mW 0402, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 10kOhm 1% 62.5mW 0402, pullup	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 10kOhm 1% 62.5mW 0402, pulldown	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 10kOhm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 10Ohm 1% 62.5mW 0402, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 10Ohm 1% 62.5mW 0402, pullup	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 12kOhm 1% 62.5mW 0402, pulldown	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 15kOhm 1% 125mW 0805	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 62.5mW 0402, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 62.5mW 0402, pullup	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 62.5mW 0402, pulldown	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 1.0kOhm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 240Ohm 1% 62.5mW 0402, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 240Ohm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-

Placement	Quantity	PI PART	QA_Manufacturer factor	QA_Component factor	RA_Manufacturer factor (IC&Discrete)	Experience factor : ε
1.0 - Non-interface digital function	4		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	27		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	76		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	11		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	12		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	7		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	6		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

Π Process / SIC	T_max manufacturer (piez	N-layer (PCB)	N-connection (PCB)	N-contact (connectors)	N-annual_cycles (connect	Np number of pins(IC & op	Number of SMD Resistive	Number of Discret Semiconductors or LED or optocouplers in case of sharing the same case.	Rise of temperature	P-applied / P-rated (Resis	V-applied / V-rated (capac	V-contact / V-nominal (re	I-contact / I-nominal (relay	U-nominal / U-coil (relays)	Limit and Manual action switch	Nbre of manœuvres /h (re	I-output / I-max-output (pi	N DT (Switches & Relays)	N ST (Switches & Relays)	I-applied / I-rated (Fuses)
											0,5									
											0,5									
										0,5										
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FixedResistor E24Series 240Ohm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 2.2kOhm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
Dual nMOS 1.6Ohm 60V	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Silicon MOS > 5 W [ECDS_22]
CeramicCapacitor X7R 2.2uF 16V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 2.2uF 16V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 2.2uF 16V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
FixedResistor E96Series 33.2Ohm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
CeramicCapacitor X7R 470nF 25V 0603	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 470nF 25V 0603	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
FixedResistor E24Series 47kOhm 1% 62.5mW 0402, pullup	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 47kOhm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 4.7kOhm 1% 62.5mW 0402, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 4.7kOhm 1% 62.5mW 0402, pullup	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 4.7kOhm 1% 62.5mW 0402, pulldown	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 4.7kOhm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 560Ohm 1% 62.5mW 0402	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E24Series 5.1kOhm 1% 62.5mW 0402, termination	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E96Series 60.4Ohm 1% 250mW 1206	Resistors [ECRE]	Resistive chip [ECRE_06]	-
FixedResistor E96Series 6.49kOhm 1% 100mW 0603, pulldown	Resistors [ECRE]	Resistive chip [ECRE_06]	-
ShiftRegister 8-bit SerialIn Serial+ParallelOut 3-state	Integrated Circuits [ECIC]	TSSOP, MSOP, µSO, µMAX, TVSOPThin Shrink Small Outlines, L lead / 8 à 28 [ECIC_37]	Digital circuit (MOS, bipolar, BiCMOS) [ECIC_63]
Single Buffer OpenDrain LowPower Mixed3.3V-5V	Integrated Circuits [ECIC]	TSOP IThin Small Outlines, leads on small edges, L lead / 5 à 16 [ECIC_32]	Digital circuit (MOS, bipolar, BiCMOS) [ECIC_63]
Bus buffer/line driver; 3-state	Integrated Circuits [ECIC]	TSOP IThin Small Outlines, leads on small edges, L lead / 5 à 16 [ECIC_32]	Digital circuit (MOS, bipolar, BiCMOS) [ECIC_63]
1K Microwire Compatible Serial EEPROM	Integrated Circuits [ECIC]	TSSOP, MSOP, µSO, µMAX, TVSOPThin Shrink Small Outlines, L lead / 8 à 28 [ECIC_37]	Flash, EEPROM, EPROM [ECIC_60]
Double SchottkyRectifier 200mA 30V CommonAnodeConfiguration	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Protection diodes up to 3kW (in peak 10ms/100ms) (TVS) [ECDS_13]
Double SchottkyRectifier 200mA 30V CommonCathodeConfiguration	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Signal diodes up to 1A (PIN, Schottky,signal, varactor) [ECDS_10]
Double SiliconRectifier 125mA 75V CommonCathodeConfiguration	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Signal diodes up to 1A (PIN, Schottky,signal, varactor) [ECDS_10]

1.0 - Non-interface digital function	2		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	17		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	10		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher		3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

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								1	50		0,16									

Double SiliconRectifier 125mA 90V CommonAnodeConfiguration	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Signal diodes up to 1A (PIN, Schottky,signal, varactor) [ECDS_10]
FerriteBead 60Ohm@100MHz 500mA	Magnetic Components: Inductors and Transformers [ECIN]	Multi-layer ceramic chip inductor [ECIN_03]	-
Single nMOS 60mOhm 60V	Discrete semiconductors [ECDS]	TSOP - (Discrete/ IC) [ECIC_32]	Silicon MOS > 5 W [ECDS_22]
Single pMOS 7.5Ohm 50V	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Silicon MOS > 5 W [ECDS_22]
Dual nMOS+pMOS 55mOhm+150mOhm 20V	Integrated Circuits [ECIC]	QFN, DFN, MLFQuad Flat No lead (package without lead) / 8-24 [ECIC_41]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
CeramicCapacitor C0G 100pF 100V 0402, decoupling	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product [ECCC_02]	-
CeramicCapacitor C0G 100pF 100V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with defined temperature coefficient (Type I) with a medium CV product [ECCC_02]	-
Crystal 12MHz 8pFLoad 100OhmESR	Piezoelectric components: Oscillators and Quartz [ECPZ]	Crystal quartz oscillator (surface mounted, XO MCSO type Case) [ECPZ_04]	-
Crystal 20MHz 8pFLoad 100OhmESR	Piezoelectric components: Oscillators and Quartz [ECPZ]	Crystal quartz oscillator (surface mounted, XO MCSO type Case) [ECPZ_04]	-
Crystal 25MHz 8pFLoad 100OhmESR	Piezoelectric components: Oscillators and Quartz [ECPZ]	Crystal quartz oscillator (surface mounted, XO MCSO type Case) [ECPZ_04]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 16V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 10nF 50V 0402	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a low CV product [ECCC_04]	-
CeramicCapacitor X7R 1uF 25V 0603	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 1uF 25V 0603	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 1uF 25V 0603	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-

1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	10		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	33		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	24		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	7		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	32		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	6		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

								1	50		0,04									
									50											
						6		1	50											
								1	50											
						8			50											
											0,12									
											0,5									
	150																0,5			
	150																0,5			
	150																0,5			
											0,5									
											0,31									
											0,31									
											0,31									
											0,21									
											0,08									
											0,5									
											0,11									
											0,5									
											0,36									
											0,08									
											0,5									
											0,5									
											0,2									
											0,23									

CeramicCapacitor X7R 1uF 25V 0603	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 100nF 100V 0603	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 100nF 100V 0603	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a medium CV product [ECCC_05]	-
CeramicCapacitor X7R 10uF 10V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 10uF 10V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 10uF 10V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 10uF 10V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 4.7uF 16V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 4.7uF 16V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 4.7uF 16V 0805	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7S 4.7uF 50V 1206	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
CeramicCapacitor X7R 22uF 6.3V 1206	Ceramic capacitors [ECCC]	Ceramic capacitor with non-defined temperature coefficient (Type II) with a high CV product [ECCC_06]	-
Dual ESDProtection 60VClamping	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Protection diodes more than 3kW (in peak 10ms/ 100ms) (TVS) [ECDS_17]
GreenLED SurfaceMount 1206	Light Emitting Diode (LED) [ECLE]	SMD PLCC Plastic/ 2 pins [ECLE_05]	Color [ECLE_16]
RedLED SurfaceMount 1206	Light Emitting Diode (LED) [ECLE]	SMD PLCC Plastic/ 2 pins [ECLE_05]	Color [ECLE_16]
YellowLED SurfaceMount 1206	Light Emitting Diode (LED) [ECLE]	SMD PLCC Plastic/ 2 pins [ECLE_05]	Color [ECLE_16]
PowerInductor Shielded 6.8uH 4.4A 6.5x6.9mm	Magnetic Components: Inductors and Transformers [ECIN]	High current (or power) wirewound inductor [ECIN_02]	-
FerriteBead 30Ohm@100MHz 1500mA	Magnetic Components: Inductors and Transformers [ECIN]	Multi-layer ceramic chip inductor [ECIN_03]	-
LinearRegulator Fixed 6.5Vto12V Input 5V 1A	Discrete semiconductors [ECDS]	SOT223, SOT89… SMD, medium power, small heatsink, L-lead, plastic [ECDS_03]	Silicon bipolar < 5W [ECDS_20]
Double SchottkyRectifier 500mA 40V CommonCathodeConfiguration	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Signal diodes up to 1A (PIN, Schottky,signal, varactor) [ECDS_10]
Single pMOS 45mOhm 30V	Discrete semiconductors [ECDS]	SOT23-3, SOT363… SMD, small signal, L-lead, plastic [ECDS_02]	Silicon MOS > 5 W [ECDS_22]
32bit 200MHz Aurix Tricore ADASVersion HSM	Integrated Circuits [ECIC]	PBGA CSP BT 0.8 et 0.75 mmPlastic Ball Grid Array with solder ball pitch = 0.8 mm et 0.75 mm / 48 à 384 [ECIC_44]	Microprocessor, Microcontroller, DSP [ECIC_59]
HighSpeed HighDensity Male 500Pin TenRow SurfaceMount 1.27mmPitch	Connectors [ECCO]	Connectors for Printed circuits (and similar) [ECCO_03]	Soldered (SMD) [ECCO_07]
Octal Buffers and Drivers With 3-State Outputs	Integrated Circuits [ECIC]	TSSOP, MSOP, µSO, µMAX, TVSOPThin Shrink Small Outlines, L lead / 8 à 28 [ECIC_37]	Digital circuit (MOS, bipolar, BiCMOS) [ECIC_63]

1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	5		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	10		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Fixed	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

0,13	0,5	0,12	0,5	0,58	0,5	0,33	0,5	0,31	0,11	0,24	0,21								0,08				
												50	50	50	50	50	50	50	50	50	50	50	50
												1	1	1	1			1	1	1			
																					292		20
																						5	
																						500	

SchottkyRectifier 2A 30V	Integrated Circuits [ECIC]	SMD, power, large, heat sink, L-lead, plastic (Discrete/ IC) [ECDS_06]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
SchottkyRectifier 2A 100V	Integrated Circuits [ECIC]	SMD, power, large, heat sink, L-lead, plastic (Discrete/ IC) [ECDS_06]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
Buck/Boost/LDO/Tracker/Reference/Standby Safety PowerSupply	Integrated Circuits [ECIC]	QFN, DFN, MLFQuad Flat No lead (package without lead) / 28-56 [ECIC_42]	Microprocessor, Microcontroller, DSP [ECIC_59]
ElectrolyticCapacitor Aluminum 100uF 35V d=6.3mm h=7.7mm SurfaceMount	Aluminum capacitors [ECAC]	Aluminum solid electrolyte capacitor [ECAC_02]	-
PowerInductor Shielded 4.7uH 2A 5.3x4.2mm	Magnetic Components: Inductors and Transformers [ECIN]	High current (or power) wirewound inductor [ECIN_02]	-
FixedResistor CurrentSense 200mOhm 1% 250mW 1206	Resistors [ECRE]	High stability bulk metal foil accuracy resistor,SMD <10kΩ [ECRE_08]	-
PowerInductor Shielded 22uH 5A 6.4x6.6mm	Magnetic Components: Inductors and Transformers [ECIN]	High current (or power) wirewound inductor [ECIN_02]	-
Dual High Speed USB to Multipurpose UART/FIFO IC	Integrated Circuits [ECIC]	SQFP, TQFP. VQFP.LQFP, Plastic Shrink (thickness) Quad Flatpack, L lead / 32 à 120 [ECIC_06]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
10/100EthernetPHY MIIInterface	Integrated Circuits [ECIC]	QFN, DFN, MLFQuad Flat No lead (package without lead) / 28-56 [ECIC_42]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
Header Female Straight 16Pin DualRow 2.54mmPitch	Connectors [ECCO]	Connectors for Printed circuits (and similar) [ECCO_03]	Soldered (SMD) [ECCO_07]
Header Female Straight 20Pin DualRow 2.54mmPitch	Connectors [ECCO]	Connectors for Printed circuits (and similar) [ECCO_03]	Soldered (SMD) [ECCO_07]
Header Male Straight 10Pin DualRow SurfaceMount 1.27mmPitch Shrouded	Connectors [ECCO]	Connectors for Printed circuits (and similar) [ECCO_03]	Soldered (SMD) [ECCO_07]
Header Male Straight 4Pin DualRow 2.54mmPitch	Connectors [ECCO]	Connectors for Printed circuits (and similar) [ECCO_03]	Soldered (SMD) [ECCO_07]
Header Male Straight 8Pin DualRow 2.54mmPitch	Connectors [ECCO]	Connectors for Printed circuits (and similar) [ECCO_03]	Soldered (SMD) [ECCO_07]
CAN-FDTransceiver 3.3V/5VLogic	Integrated Circuits [ECIC]	SO, SOP, SOL, SOIC, SOWPlastic Small Outlines, L lead / 8 à 14 [ECIC_28]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
CAN-HSTransceiver LocalWakeInput INHOutput LowPowerManagement	Integrated Circuits [ECIC]	SO, SOP, SOL, SOIC, SOWPlastic Small Outlines, L lead / 8 à 14 [ECIC_28]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
Quad DAC 10Bit RailToRailOutput SPIInterface	Integrated Circuits [ECIC]	QFN, DFN, MLFQuad Flat No lead (package without lead) / 8-24 [ECIC_41]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
Dual supply translating transceiver; 3-state	Integrated Circuits [ECIC]	TSSOP, MSOP, µSO, µMAX, TVSOPThin Shrink Small Outlines, L lead / 8 à 28 [ECIC_37]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
Dual supply translating transceiver; 3-state U25-26-27	Integrated Circuits [ECIC]	SMD, small signal,L-lead, plastic (Discrete/ IC) [ECDS_02]	Analogue and Hybrid circuit (MOS, bipolar, BiCMOS) [ECIC_58]
PCB per SDFSafetyBoard_1.0	Printed circuit board (PCB) [ECPC]	Through holes [ECPC_01]	100 / 100 [ECPC_11]

1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	2		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Fixed	3		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Fixed	3		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Fixed	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Fixed	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Fixed	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	4		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	17		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Non-interface digital function	3		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered
1.0 - Fixed	1		3 -Higher	3 - Higher	3 - Very reliable level A	4 -Recognised manufacturer, Mature processes for the item considered

						2			50											
						2			50											
						48			50											
											0,34									
									50											
										0,5										
									50											
						64			50											
						32			50											
				16	5				50											
				20	5				50											
				10	5				50											
				4	5				50											
				8	5				50											
						8			50											
						14			50											
						10			50											
						8			50											
						6			50											
		8	1826																	

5.2 Results

The Excel file containing the results produced by FIDES ExperTool differs from the original file in the last sheets. These pages contain the output failure rates: the first divides them by type of stress, the second one by phase, the third one represents the distributions of failures through graphics, the fourth one is similar to the third one but uses percentages instead of graphics, the last one lists the components and their relative impact on the overall failure rate. The last two pages are not shown since the fourth is similar to the third and thus a repetition, and the fifth one includes results that are used in the FMECA later.

5.2.1 Dual Inverter board

The λ parameter, as already said, is expressed in FITs, Failures In Time: 1 FIT is 1 failure in 1 billion device-hours of operation.

Analyzing the results, it can be noticed that ceramic capacitors are the component type which gives the major contribution to the λ_{Total} of the item, because of the elevate thermal cycling and thermo-electrical stresses and because of the large amount of components. They are immediately followed by resistors, which are more numerous than capacitors and with a high thermal cycling stress. In third place there are piezoelectric components with their considerable thermal cycling stress.

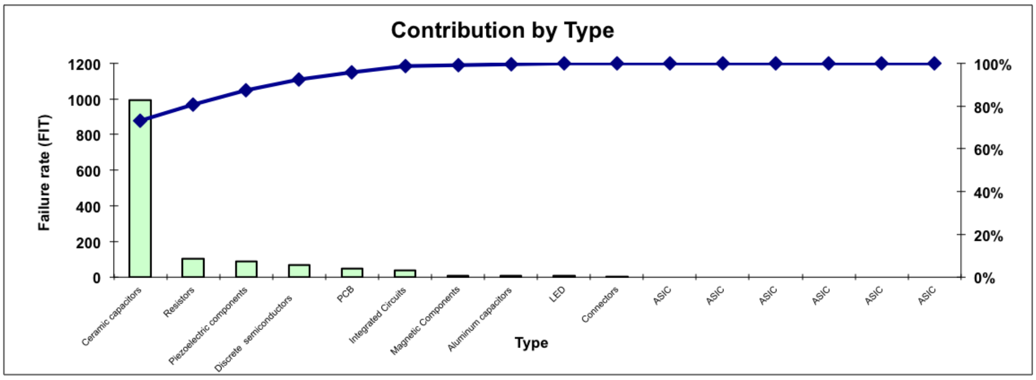
Analyzing the contribution by stress, as it is predictable, the largest failure rates are in the driving mode phase which is the main phase for the item in terms of hours, all the components are active and all the stresses concentrate.

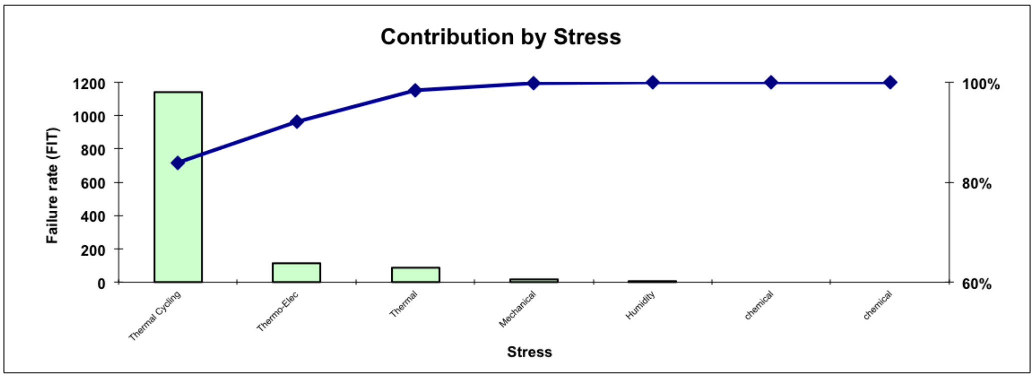
λ Total	1.359,08 FIT

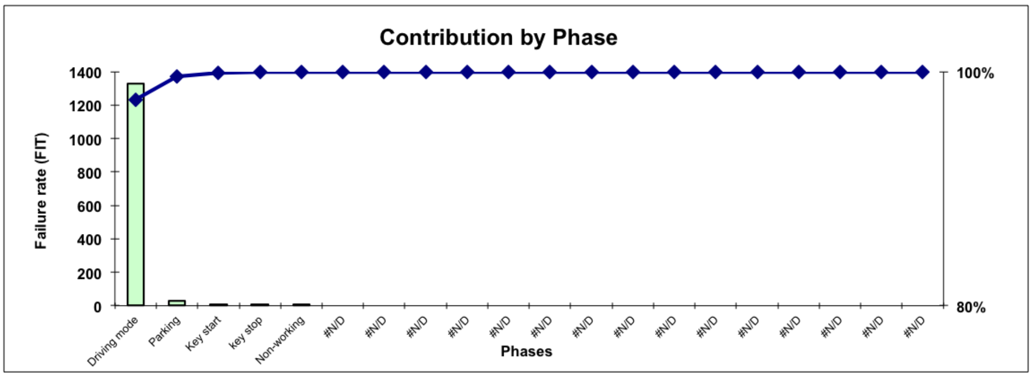
		Results			PHASES				
Model	Component type	λ Total	Quantity	λ Unitaire	Non-working day (maintenance)	Parking	Key start	Driving mode	key stop
Results by family of components		1359,081623	1100						
ELECTRONIC COMPONENT	ALUMINIUM CAPACITOR [ECAC]	5,851091886	8		0,000387376	0,112579651	0,01447486	5,723649999	0
ELECTRONIC COMPONENT	Ceramic capacitors [ECCC]	993,1279931	370		0,065370642	19,29757228	2,371610496	971,3934397	0
ELECTRONIC COMPONENT	Connectors [ECCO]	0,342985457	1		0,000402845	0,024910762	0,002179851	0,307285348	0,008206652
ELECTRONIC COMPONENT	Discrete semiconductors [ECDS]	68,60222386	80		0,006669033	0,443969766	1,299118309	66,65711501	0,195351739
ELECTRONIC COMPONENT	Integrated Circuits [ECIC]	39,14374948	41		0,009352921	0,64056598	0,550950794	37,68787794	0,255001841
ELECTRONIC COMPONENT	Light Emitting Diode (LED) [ECLE]	5,713190448	3		0,000350029	0,086167602	0,001442564	5,621172473	0,004057779
ELECTRONIC COMPONENT	Components: Inductors and Transformers [ECIN]	6,606403144	8		0,000494825	0,136680985	0,00170872	6,467518615	0
ELECTRONIC COMPONENT	ctric components: Oscillators and Quartz [ECPZ]	89,89720559	4		0,017436532	2,313034	0,022949488	87,24492561	0,298859958
ELECTRONIC COMPONENT	Printed circuit board (PCB) [ECPC]	45,79271224	1		0,012290951	1,366569761	0,005933495	44,2335007	0,174417332
ELECTRONIC COMPONENT	Resistors [ECRE]	104,0040673	584		0,008276573	2,421131394	0,001098711	101,5505599	0,023000797

		Results			STRESS					
Model	Component type	λ Total	Quantity	λ Unitaire	Thermal	Thermal Cycling	Mechanical	Humidity	Thermo-Elec	chemical
Results by family of components		1359,082	1100							
ELECTRONIC COMPONENT	ALUMINIUM CAPACITOR [ECAC]	5,851091886	8			5,114105382	0,062151539		0,674834965	
ELECTRONIC COMPONENT	Ceramic capacitors [ECCC]	993,1279931	370			869,5550024	13,60323493		109,9697558	
ELECTRONIC COMPONENT	Connectors [ECCO]	0,342985457	1		0,0854705	0,177814212	0,03776997	0,041930776		0
ELECTRONIC COMPONENT	Discrete semiconductors [ECDS]	68,60222386	80		59,36695674	8,696851971	0,015211238	0,523203912		
ELECTRONIC COMPONENT	Integrated Circuits [ECIC]	39,14374948	41		25,6470262	12,79319609	0,024097223	0,679429963		
ELECTRONIC COMPONENT	Light Emitting Diode (LED) [ECLE]	5,713190448	3		0,065481231	5,587685203	0,049135581	0,010888434		
ELECTRONIC COMPONENT	Magnetic Components: Inductors and Transformers [ECIN]	6,606403144	8			6,372897569	0,155114243		0,078391332	
ELECTRONIC COMPONENT	Piezoelectric components: Oscillators and Quartz [ECPZ]	89,89720559	4			86,07603987	1,935706713	0,790957583	1,094501418	
ELECTRONIC COMPONENT	Printed circuit board (PCB) [ECPC]	45,79271224	1			42,48903244	2,409836411	0,893843395		0
ELECTRONIC COMPONENT	Resistors [ECRE]	104,0040673	584			103,7108065	0,181733568	0,061754207	0,049773028	

In the graphics below, the lines indicate in an additive progressive way which factors are considered to reach 100% of the FITs.







5.2.2 Hyper-Spectral Data Fusion board

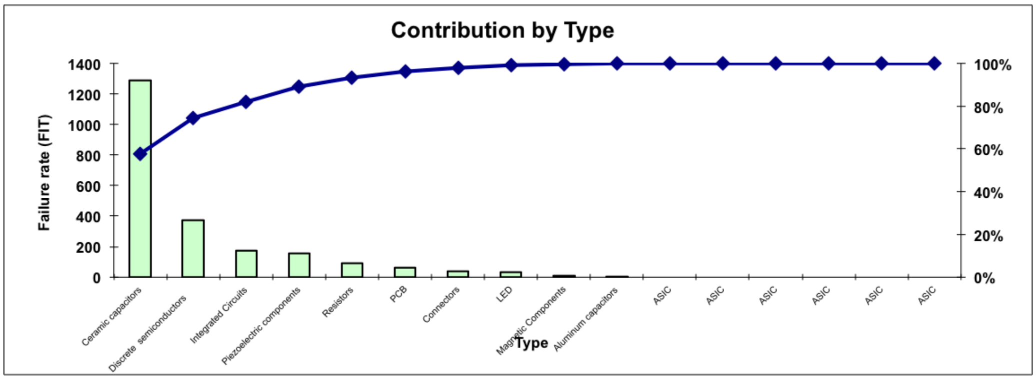
As it can be seen, more than half of the failure rate is due to the ceramic capacitors, both because of the large amount of such components and because a significant amount of them has a high CV product. Discrete semiconductors represent the second greatest contributor to the λ. It can be noticed that the thermal cycling is the major cause of failures, mostly because of the high increases in temperature and the number of repetitions per day. Furthermore, thermal cycling depends on capacitors, as it can be remarked. The high maximum temperature also determines the impact on the final result of the discrete semiconductors, for the thermal stress to which they are particularly sensitive. This holds true for the ICs too, since they are mostly encasing semiconductors.

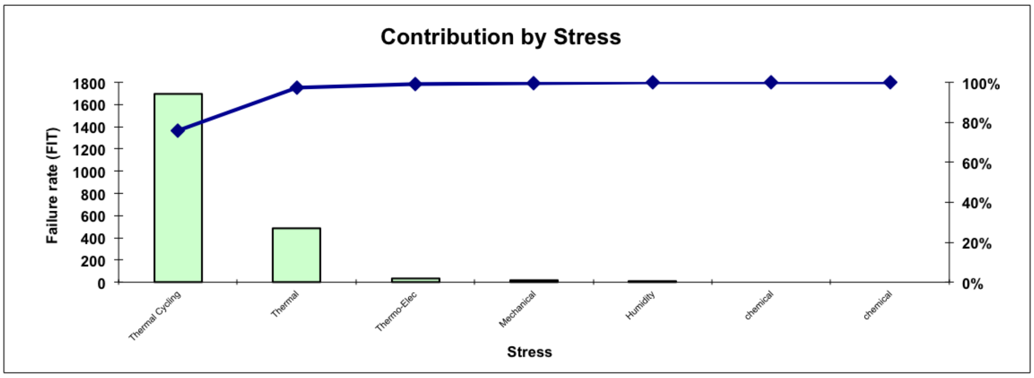
Analysing the results divided by phase it is clear that almost all of the FITs are caused by the driving period. This is quite obvious: in this phase all the components are turned on, and they also undergo thermal and mechanical stress. Furthermore, this is the moment in which the components are mostly put in danger and the phase has a large amount of hours per year. Non-working day on the other hand has almost no influence, because it lasts just 15 days a year, and the board is exposed to almost no stress.

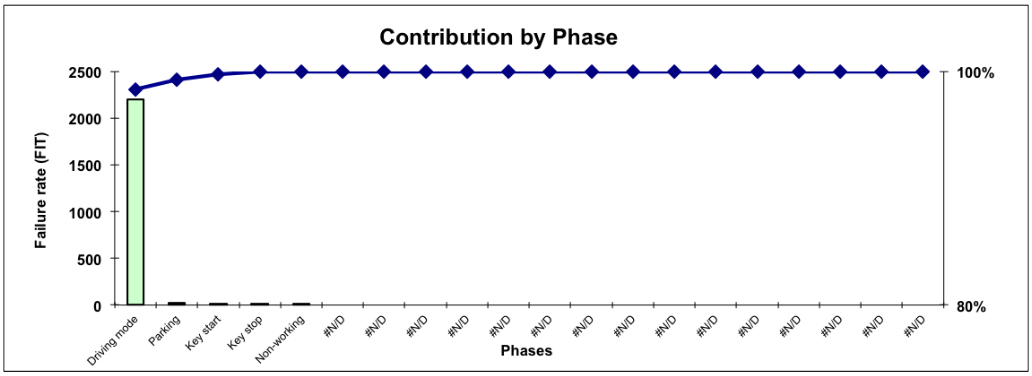
λ Total	2.238,87 FIT

Model	Component type	Results: λ Total	Results: Quantity	Results: λ Unitaire	PHASES: Non-working day (maintenance)	PHASES: Parking	PHASES: Key start	PHASES: Driving mode	PHASES: Key stop
Results by family of components		**2238,869965**	**488**						
ELECTRONIC COMPONENT	ALUMINIUM CAPACITOR [ECAC]	5,822111036	2		8,45441E-05	0,053609358	0,001628335	5,766788799	0
ELECTRONIC COMPONENT	Ceramic capacitors [ECCC]	1289,907321	180		0,018738487	11,78744858	0,75147093	1277,349663	0
ELECTRONIC COMPONENT	Connectors [ECCO]	40,51719033	10		0,014204218	1,63720938	0,164168062	36,84202198	1,859586682
ELECTRONIC COMPONENT	Discrete semiconductors [ECDS]	374,4091626	28		0,001220896	0,161291114	7,939176935	366,0191706	0,288303071
ELECTRONIC COMPONENT	Integrated Circuits [ECIC]	175,1932114	41		0,00457197	0,770594895	2,445168374	170,9276016	1,045274615
ELECTRONIC COMPONENT	Light Emitting Diode (LED) [ECLE]	34,14346443	5		0,000300429	0,14361267	0,00446427	33,96786869	0,027218367
ELECTRONIC COMPONENT	Components: Inductors and Transformers [ECIN]	8,827091642	6		0,000124052	0,079735764	0,002505938	8,744725887	0
ELECTRONIC COMPONENT	ctric components: Oscillators and Quartz [ECPZ]	155,1452095	3		0,005428659	1,7347755	0,017212116	152,4856949	0,902098317
ELECTRONIC COMPONENT	Printed circuit board (PCB) [ECPC]	62,08286041	1		0,003358095	0,819974206	0,003560238	60,89514733	0,360820538
ELECTRONIC COMPONENT	Resistors [ECRE]	92,82234202	212		0,00194516	0,951740106	0,000889138	91,75264917	0,115118444

Model	Component type	Results: λ Total	Results: Quantity	Results: λ Unitaire	STRESS: Thermal	STRESS: Thermal Cycling	STRESS: Mechanical	STRESS: Humidity	STRESS: Thermo-Elec	STRESS: chemical
Results by family of components		2238,870	488							
ELECTRONIC COMPONENT	ALUMINIUM CAPACITOR [ECAC]	5,822111036	2			5,716600175	0,029595971		0,075914889	
ELECTRONIC COMPONENT	Ceramic capacitors [ECCC]	1289,907321	180			1246,683974	8,378217714		34,84512942	
ELECTRONIC COMPONENT	Connectors [ECCO]	40,51719033	10		6,557300717	27,41338023	2,482354745	4,064154631		0
ELECTRONIC COMPONENT	Discrete semiconductors [ECDS]	374,4091626	28		362,8035801	11,19287085	0,00534521	0,407366513		
ELECTRONIC COMPONENT	Integrated Circuits [ECIC]	175,1932114	41		113,8237716	59,83249353	0,064121611	1,472824635		
ELECTRONIC COMPONENT	Light Emitting Diode (LED) [ECLE]	34,14346443	5		0,202643275	33,8204302	0,081892634	0,038498317		
ELECTRONIC COMPONENT	Magnetic Components: Inductors and Transformers [ECIN]	8,827091642	6			8,632890151	0,080533841		0,11366765	
ELECTRONIC COMPONENT	Piezoelectric components: Oscillators and Quartz [ECPZ]	155,1452095	3			151,6060788	1,451780034	1,266474673	0,820876063	
ELECTRONIC COMPONENT	Printed circuit board (PCB) [ECPC]	62,08286041	1			59,84737109	1,445958892	0,789530426		0
ELECTRONIC COMPONENT	Resistors [ECRE]	92,82234202	212			92,50938235	0,109686766	0,162538907	0,040733995	







It can thus be stated that in order to have better results, a cooling system would be beneficial, since the temperature cycle would not have such a wide range of temperatures, and lower CV products would have a positive impact on the failure rate, since a high CV product has a $\lambda_{0Capacitor}$ about ten times higher than one with medium CV product. The driving mode is still the most critical phase, since all types of hazards come into play.

Chapter 6

Criticality Analysis: Dual Inverter board

In this chapter, the Failure Modes, Effect and Criticality Analysis will be performed on the Dual Inverter board and discussed. The schematics were analysed component by component, and the failure modes of each were examined in their effects. The probability of failures happening was calculated, and the SPFM was calculated.

6.1 Compilation of the FMECA table

Firstly, an Excel file was created to contain the FMECA table. In this file, the components relative to nodal aspects of the circuit were examined (for example, the analog temperature sensors were not considered). For each component, its failure modes and their relative probability with respect to the probability of any failure was defined. These probabilities (α) were obtained from an FMECA manual[17] that in its appendix A shows a table containing all types of components, their failure modes and the aforementioned α.

For each failure mode, the α parameter was indicated and multiplied by the λ of that component obtained from the FIDES analysis. Thus, $\lambda\alpha$ indicates the overall probability for a failure of that specific type for that component: the value is expressed in FITs.

A further step in the analysis is taken considering the coverage. In the Dual Inverter board, the maximum hazard that may arise when a single malfunction occurs (as said in Chapter 4 FMECA considers only one failure at a time) is a loss of power for the motor, or the turning off of the car. Every other possibility is corrected or mitigated by redundancies or software checks and recovery. Thus, no really severe situation can take place, and the coverage is total. Still, as said before, there may be some non-considered behaviour, so the coverage is set to 99.9% for all the components in the board.

The last column of the table indicated the $\lambda_{residual}$ and is calculated as such:

$$\lambda_{residual} = \frac{(100 - Coverage) \times \lambda\alpha}{100}$$

In the following pages the FMECA tables are shown. In the analysed schematics some sheets had the same layout (for example, the current sensors circuits related to the phases), in those cases, the duplications were omitted.

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
C3	SC	0,49	0,54743	PosSensB-EncB1_IF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C4	SC	0,49	0,54743	PosSensA-EncA2_IF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C5	SC	0,49	0,54743	PosSensB-EncB2_IF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C6	SC	0,49	0,54743	PosSensSinP1_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C7	SC	0,49	0,54743	PosSensSinN1_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C8	SC	0,49	0,54743	PosSensSinP2_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C9	SC	0,49	0,54743	PosSensSinN2_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C10	SC	0,49	0,54743	EmgStopSw_ID doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C11	SC	0,49	0,54743	AccPedPos0_IA-IC-ID doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C12	SC	0,49	0,54743	StartSw_ID doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C13	SC	0,49	0,54743	GearPosSens0_IA-ID doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C14	SC	0,49	0,54743	Analog0_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C15	SC	0,49	0,54743	Analog1_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C16	SC	0,49	0,54743	KeySw_BS doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C17	SC	0,49	0,54743	cmdCoolPump_OF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C18	SC	0,49	0,54743	cmdRelay0Hs_OPH doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C19	SC	0,49	0,54743	cmdRelay0Ls_OPH doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C20	SC	0,49	0,54743	cmdRelay1Hs_OPH doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C21	SC	0,49	0,54743	cmdRelay1Ls_OPH doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C22	SC	0,49	0,54743	cmdRelay0_OD doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C23	SC	0,49	0,54743	cmdRelay1_OD doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C24	SC	0,49	0,54743	PwrGnd_BG doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C25	SC	0,49	0,54743	DirPwrSply_BS doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C26	SC	0,49	0,54743	PwrGnd_BG doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C27	SC	0,49	0,54743	SensSply2_SS doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C28	SC	0,49	0,54743	Sens1 IC-IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C29	SC	0,49	0,54743	PosSensC-EncIdx1_IF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C30	SC	0,49	0,54743	Sens2_IC-IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C31	SC	0,49	0,54743	PosSensC-EncIdx2_IF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C32	SC	0,49	0,54743	PosSensCosN1_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C33	SC	0,49	0,54743	PosSensCosP1_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C34	SC	0,49	0,54743	PosSensCosN2_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C35	SC	0,49	0,54743	PosSensCosP2_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C36	SC	0,49	0,54743	AccPedPosSw_ID doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C37	SC	0,49	0,54743	AccPedPos1_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399

Figure 6.1: Sheet 1

C38	SC	0,49	0,54743	SteeringSens_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C39	SC	0,49	0,54743	GearPosSens1_IF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C40	SC	0,49	0,54743	BrakePedPres_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C41	SC	0,49	0,54743	BrakePedSw_ID doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C42	SC	0,49	0,54743	SpareLS_OF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C43	SC	0,49	0,54743	cmdFanDriver_OF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C44	SC	0,49	0,54743	DigitalSpare2_IF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C45	SC	0,49	0,54743	DigitalSpare2_IF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C46	SC	0,49	0,54743	cmdRelay2Ls_OPH doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C47	SC	0,49	0,54743	cmdRelay2Hs_OPH doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C48	SC	0,49	0,54743	SensSply1_SS doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C49	SC	0,49	0,54743	SensGnd2_SG doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C50	SC	0,49	0,54743	SensGnd2_SG doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C51	SC	0,49	0,54743	SensGnd1_SG doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C52	SC	0,49	0,54743	Temp1_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C53	SC	0,49	0,54743	Temp2_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C54	SC	0,49	0,54743	RfGnd_BG doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C55	SC	0,49	0,54743	IntLock_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C56	SC	0,49	0,54743	IntLock_OD doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C57	SC	0,49	0,54743	RfGndIn_BG doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C58	SC	0,49	0,54743	SensGnd1_SG doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C59	SC	0,49	0,54743	Temp3_IA doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C210	SC	0,49	0,18248	CAN0L_BC doesn't work	0,37239896	99,9	0,00018248
	OC	0,22	0,08193	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,108	no effect	0,37239896	99,9	0,000108
C211	SC	0,49	0,18248	Rs232Tx_OC-LIN_BC doesn't work	0,37239896	99,9	0,00018248
	OC	0,22	0,08193	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,108	no effect	0,37239896	99,9	0,000108
C212	SC	0,49	0,18248	Rs232Rx_IC doesn't work	0,37239896	99,9	0,00018248
	OC	0,22	0,08193	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,108	no effect	0,37239896	99,9	0,000108
C213	SC	0,49	0,18248	CAN1H_BC doesn't work	0,37239896	99,9	0,00018248
	OC	0,22	0,08193	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,108	no effect	0,37239896	99,9	0,000108
C214	SC	0,49	0,18248	CAN1L_BC doesn't work	0,37239896	99,9	0,00018248
	OC	0,22	0,08193	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,108	no effect	0,37239896	99,9	0,000108
C293	SC	0,49	0,54743	PosSensA-EncA1_IF doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C321	SC	0,49	0,18248	CAN0H_BC doesn't work	0,37239896	99,9	0,00018248
	OC	0,22	0,08193	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,108	no effect	0,37239896	99,9	0,000108
C102	SC	0,49	0,54743	Interferent Grounds (R,D)	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C103	SC	0,49	0,54743	Interferent Grounds (R,D)	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C105	SC	0,49	0,54743	Interferent Grounds (R,D)	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
C106	SC	0,49	0,54743	Interferent Grounds (R,D)	1,11719688	99,9	0,00054743
	OC	0,22	0,24578	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,32399	no effect	1,11719688	99,9	0,00032399
R8	OC	1	0,17808	no effect	0,17807891	99,9	0,00017808
R9	OC	1	0,17808	no effect	0,17807891	99,9	0,00017808
J1	OC	0,61	0,20922	no signals transmitted	0,34298546	99,9	0,00020922
	Poor Contact Intermittent	0,23	0,07889	intermittent/no signals transmitted	0,34298546	99,9	7,8887E-05
	SC	0,16	0,05488	Microcontroller doesn't work	0,34298546	99,9	5,4878E-05
PCB	Not working	1	45,7927	Microcontroller doesn't work	45,7927122	99,9	0,04579271
							0,11799246

Figure 6.2: Sheet 1

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R155	OC	1	0,17807891	possible undefined output	0,178078906	99,9	0,00017808
R551	OC	1	0,17807891	no output:Microcontroller doesn't work	0,178078906	99,9	0,00017808
R552	OC	1	0,17807891	no output:Microcontroller doesn't work	0,178078906	99,9	0,00017808
R556	OC	1	0,17811235	possible undefined output	0,178112349	99,9	0,00017811
R554	OC	1	0,17811235	possible undefined output	0,178112349	99,9	0,00017811
R555	OC	1	0,17807891	possible undefined output	0,178078906	99,9	0,00017808
R550	OC	1	0,17807891	wrong output	0,178078906	99,9	0,00017808
R553	OC	1	0,17807891	wrong output	0,178078906	99,9	0,00017808
R626	OC	1	0,17807891	no output:Microcontroller doesn't work	0,178078906	99,9	0,00017808
R398	OC	1	0,17811235	possible undefined output	0,178112349	99,9	0,00017811
R399	OC	1	0,17811235	possible undefined output	0,178112349	99,9	0,00017811
R400	OC	1	0,17807891	wrong output	0,178078906	99,9	0,00017808
R401	OC	1	0,17807891	wrong output	0,178078906	99,9	0,00017808
R170	OC	1	0,17811235	possible undefined output	0,178112349	99,9	0,00017811
R634	OC	1	0,17807891	wrong output	0,178078906	99,9	0,00017808
R56	OC	1	0,17811235	possible undefined output	0,178112349	99,9	0,00017811
R666	OC	1	0,17811235	wrong threshold	0,178112349	99,9	0,00017811
R650	OC	1	0,17807891	wrong threshold	0,178078906	99,9	0,00017808
R169	OC	1	0,17811235	wrong threshold	0,178112349	99,9	0,00017811
R660	OC	1	0,17811235	wrong threshold	0,178112349	99,9	0,00017811
R690	OC	1	0,17807891	wrong threshold	0,178078906	99,9	0,00017808
R171	OC	1	0,17811235	wrong threshold	0,178112349	99,9	0,00017811
	SC	0,49	0,08786684	wrong output	0,179320077	99,9	8,7867E-05
C381	OC	0,22	0,03945042	no effect	0,179320077	99,9	3,945E-05
	Changing Value	0,29	0,05200282	no effect	0,179320077	99,9	5,2003E-05
	SC	0,49	0,08786684	wrong output	0,179320077	99,9	8,7867E-05
C382	OC	0,22	0,03945042	wrong output	0,179320077	99,9	3,945E-05
	Changing Value	0,29	0,05200282	wrong output	0,179320077	99,9	5,2003E-05
	SC	0,49	0,18247549	no output:Microcontroller doesn't work	0,372398962	99,9	0,00018248
C408	OC	0,22	0,08192777	no effect	0,372398962	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	no effect	0,372398962	99,9	0,000108
	SC	0,49	0,54742647	no output:Microcontroller doesn't work	1,117196885	99,9	0,00054743
C114	OC	0,22	0,24578331	no effect	1,117196885	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,117196885	99,9	0,00032399
	SC	0,49	0,54742647	no output:Microcontroller doesn't work	1,117196885	99,9	0,00054743
C113	OC	0,22	0,24578331	no effect	1,117196885	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,117196885	99,9	0,00032399
	SC	0,49	0,54742647	wrong output	1,117196885	99,9	0,00054743
C110	OC	0,22	0,24578331	no effect	1,117196885	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,117196885	99,9	0,00032399
	SC	0,49	0,54742647	wrong output	1,117196885	99,9	0,00054743
C245	OC	0,22	0,24578331	no effect	1,117196885	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,117196885	99,9	0,00032399
	SC	0,49	0,54742647	wrong output	1,117196885	99,9	0,00054743
C111	OC	0,22	0,24578331	no effect	1,117196885	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,117196885	99,9	0,00032399
	SC	0,49	0,54742647	wrong output	1,117196885	99,9	0,00054743
C115	OC	0,22	0,24578331	no effect	1,117196885	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,117196885	99,9	0,00032399
	SC	0,49	0,54742647	wrong output	1,117196885	99,9	0,00054743
C112	OC	0,22	0,24578331	no effect	1,117196885	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,117196885	99,9	0,00032399
	SC	0,49	0,54742647	wrong output	1,117196885	99,9	0,00054743
C116	OC	0,22	0,24578331	no effect	1,117196885	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,117196885	99,9	0,00032399
	SC	0,51	0,05840264	possible undefined output	0,114514973	99,9	5,8403E-05
DD3 (Diode, Rectifier)	OC	0,29	0,03320934	no output:Microcontroller doesn't work	0,114514973	99,9	3,3209E-05
	Parameter Change	0,2	0,02290299	possible undefined output	0,114514973	99,9	2,2903E-05
	SC	0,51	0,05840264	possible overload on Microcontroller	0,114514973	99,9	5,8403E-05
DD2	OC	0,29	0,03320934	no output:Microcontroller doesn't work	0,114514973	99,9	3,3209E-05
	Parameter Change	0,2	0,02290299	possible overload on Microcontroller	0,114514973	99,9	2,2903E-05
	SC	0,51	0,05840264	possible overload on Microcontroller	0,114514973	99,9	5,8403E-05
DD4	OC	0,29	0,03320934	no output:Microcontroller doesn't work	0,114514973	99,9	3,3209E-05
	Parameter Change	0,2	0,02290299	possible overload on Microcontroller	0,114514973	99,9	2,2903E-05
U22	Not working	1	1,1199467	no output:Microcontroller doesn't work	1,119946698	99,9	0,00111995
U24	Not working	1	1,1199467	no output:Microcontroller doesn't work	1,119946698	99,9	0,00111995
U35	Not working	1	0,1997931	no output:Microcontroller doesn't work	0,199793103	99,9	0,00019979
U41	Not working	1	0,1997931	no output:Microcontroller doesn't work	0,199793103	99,9	0,00019979
							0,01656971

Figure 6.3: Sheet 6

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R497	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R353	OC	1	0,17807891	no effect	0,17807891	99,9	0,00017808
R354	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R495	OC	1	0,17807891	no effect	0,17807891	99,9	0,00017808
R355	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R496	OC	1	0,17807891	no effect	0,17807891	99,9	0,00017808
C309	SC	0,49	0,54742647	no output	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C310	SC	0,49	0,54742647	no output	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C311	SC	0,49	0,54742647	no output	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
							0,00442006

Figure 6.4: Sheet 14

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R151	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R45	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R46	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R384	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R382	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R383	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R44	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R622	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R152	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R48	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R49	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R387	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R385	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R386	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R47	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R623	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
C401	SC	0,49	0,18247549	wrong output	0,37239896	99,9	0,00018248
	OC	0,22	0,08192777	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C400	SC	0,49	0,18247549	wrong output	0,37239896	99,9	0,00018248
	OC	0,22	0,08192777	wrong output	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	wrong output	0,37239896	99,9	0,000108
C359	SC	0,49	0,14644473	no output:Microcontroller doesn't work	0,2988668	99,9	0,00014644
	OC	0,22	0,0657507	no effect	0,2988668	99,9	6,5751E-05
	Changing Value	0,29	0,08667137	no effect	0,2988668	99,9	8,6671E-05
C108	SC	0,49	0,54742647	no output:Microcontroller doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C403	SC	0,49	0,18247549	wrong output	0,37239896	99,9	0,00018248
	OC	0,22	0,08192777	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C402	SC	0,49	0,18247549	wrong output	0,37239896	99,9	0,00018248
	OC	0,22	0,08192777	wrong output	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	wrong output	0,37239896	99,9	0,000108
C360	SC	0,49	0,14644473	no output:Microcontroller doesn't work	0,2988668	99,9	0,00014644
	OC	0,22	0,0657507	no effect	0,2988668	99,9	6,5751E-05
	Changing Value	0,29	0,08667137	no effect	0,2988668	99,9	8,6671E-05
U20	Not working	1	1,1199467	no output:Microcontroller doesn't work	1,1199467	99,9	0,00111995
							0,0071738

Figure 6.5: Sheet 20

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
U31	Not working	1	1,23516553	No output	1,23516553	99,9	0,00123517
U33	Not working	1	0,1997931	No outputs	0,1997931	99,9	0,00019979
U43	Not working	1	0,1997931	No output	0,1997931	99,9	0,00019979
R513	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R514	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R145	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R512	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R509	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R510	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R508	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R511	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R371	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R370	OC	1	0,17807891	no outputs:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R611	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R40	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R167	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R118	OC	1	0,17807891	no output:Microcontroller doesn't work	0,17807891	99,9	0,00017808
R610	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R41	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R616	OC	1	0,17811235	wrong threshold	0,17811235	99,9	0,00017811
R614	OC	1	0,17807891	wrong threshold	0,17807891	99,9	0,00017808
R606	OC	1	0,17811235	wrong threshold	0,17811235	99,9	0,00017811
R608	OC	1	0,17807891	wrong threshold	0,17807891	99,9	0,00017808
C94	SC	0,49	0,54742647	no output:Microcontroller doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C95	SC	0,49	0,54742647	no output:Microcontroller doesn't work	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C320	SC	0,49	1,39419362	wrong output	2,84529311	99,9	0,00139419
	OC	0,22	0,62596448	no effect	2,84529311	99,9	0,00062596
	Changing Value	0,29	0,825135	no effect	2,84529311	99,9	0,00082514
C319	SC	0,49	1,1080604	wrong output	2,26134775	99,9	0,00110806
	OC	0,22	0,4974965	wrong output	2,26134775	99,9	0,0004975
	Changing Value	0,29	0,65579085	wrong output	2,26134775	99,9	0,00065579
C345	SC	0,49	0,43933419	no output:Microcontroller doesn't work	0,89660039	99,9	0,00043933
	OC	0,22	0,19725209	no effect	0,89660039	99,9	0,00019725
	Changing Value	0,29	0,26001411	no effect	0,89660039	99,9	0,00026001
C96	SC	0,49	0,54742647	wrong output	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C97	SC	0,49	0,54742647	wrong output	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
							0,01566856

Figure 6.6: Sheet 25

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R107	OC	1	0,17807891	U16 doesn't work	0,17807891	99,9	0,00017808
R144	OC	1	0,17807891	Bus off	0,17807891	99,9	0,00017808
R471	OC	1	0,17807891	Bus off	0,17807891	99,9	0,00017808
R470	OC	1	0,17807891	Bus off	0,17807891	99,9	0,00017808
C91	SC	1	1,11719688	VS1 to Ground (U15,U16 doesn't work)	1,11719688	99,9	0,0011172
	OC	1	1,11719688	no effect	1,11719688	99,9	0,0011172
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C307	SC	0,49	0,54742647	VS1 to Ground (U16 doesn't work)	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C308	SC	0,49	0,54742647	Bus off	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	Bus off	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	Bus off	1,11719688	99,9	0,00032399
DD35 (Diode, General)	SC	0,49	5,98164275	No output	12,2074342	99,9	0,00598164
	OC	0,36	4,3946763	Overload of output CAN0H_BC	12,2074342	99,9	0,00439468
	Parameter Change	0,15	1,83111513	Possible overload	12,2074342	99,9	0,00183112
DD36	SC	0,49	5,98164275	No output	12,2074342	99,9	0,00598164
	OC	0,36	4,3946763	Overload of output CAN0L_BC	12,2074342	99,9	0,00439468
	Parameter Change	0,15	1,83111513	Possible overload	12,2074342	99,9	0,00183112
U16	Not working	1	1,22029007	no output:Microcontroller doesn't work	1,22029007	99,9	0,00122029
U15	Not working	1	4,63975955	no output:Microcontroller doesn't work	4,63975955	99,9	0,00463976
							0,03578001

Figure 6.7: Sheet 29

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R468	OC	1	0,17807891	Bus off	0,17807891	99,9	0,00017808
R469	OC	1	0,17807891	Bus off	0,17807891	99,9	0,00017808
C90	SC	0,49	0,54742647	VS1 to ground (U14 doesn't work)	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	No effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	No effect	1,11719688	99,9	0,00032399
C306	SC	0,49	0,54742647	Bus off	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	Bus off	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	Bus off	1,11719688	99,9	0,00032399
DD33	SC	0,49	5,98164275	No output	12,2074342	99,9	0,00598164
	OC	0,36	4,3946763	Overload of output CAN1H	12,2074342	99,9	0,00439468
	Parameter Change	0,15	1,83111513	Possible overload	12,2074342	99,9	0,00183112
DD34	SC	0,49	5,98164275	No output	12,2074342	99,9	0,00598164
	OC	0,36	4,3946763	Overload of output CAN1L	12,2074342	99,9	0,00439468
	Parameter Change	0,15	1,83111513	Possible overload	12,2074342	99,9	0,00183112
U14	Not working	1	1,14385439	no output:Microcontroller doesn't work	1,14385439	99,9	0,00114385
							0,02830568

Figure 6.8: Sheet 30

Component	Failure Mode	α	λα	Effect on the	λ	Coverage (%)	λres
R31	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R324	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R325	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R326	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R327	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R328	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R329	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R330	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R331	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R332	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R315	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R320	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R321	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R322	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R323	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R226	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R227	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R228	OC	1	0,17807891	No connectio	0,17807891	99,9	0,00017808
R216	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R217	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R218	OC	1	0,17807891	No connectio	0,17807891	99,9	0,00017808
R210	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R211	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R212	OC	1	0,17807891	No connectio	0,17807891	99,9	0,00017808
R213	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R214	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R215	OC	1	0,17807891	No connectio	0,17807891	99,9	0,00017808
R221	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R222	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R223	OC	1	0,17807891	No connectio	0,17807891	99,9	0,00017808
R32	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R316	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R317	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R318	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R314	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R33	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R334	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R335	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R336	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R333	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R225	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R224	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R220	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R219	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
C221	SC	0,49	0,18247549	no output	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C219	SC	0,49	0,18247549	no output	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C217	SC	0,49	0,18247549	no output	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C218	SC	0,49	0,18247549	no output	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C220	SC	0,49	0,18247549	no output	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C89	SC	0,49	0,54742647	U13 doesn't v	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C88	SC	0,49	0,54742647	U12 doesn't v	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
							0,01250572

Figure 6.9: Sheet 33

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R246	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R244	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R251	OC	1	0,17807891	no outputs	0,17807891	99,9	0,00017808
R193	OC	1	0,17807891	no output _FaultDrvULs_Idm	0,17807891	99,9	0,00017808
R247	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R243	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R252	OC	1	0,17807891	no outputs	0,17807891	99,9	0,00017808
R194	OC	1	0,17807891	no output _FaultDrvUHs_Idm	0,17807891	99,9	0,00017808
R245	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R242	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R253	OC	1	0,17807891	no outputs	0,17807891	99,9	0,00017808
R195	OC	1	0,17807891	no output _FaultDrvWLs_Idm	0,17807891	99,9	0,00017808
R249	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R240	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R256	OC	1	0,17807891	no outputs	0,17807891	99,9	0,00017808
R197	OC	1	0,17807891	no output _FaultDrvVLs_Idm	0,17807891	99,9	0,00017808
R250	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R239	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R255	OC	1	0,17807891	no outputs	0,17807891	99,9	0,00017808
R196	OC	1	0,17807891	no output _FaultDrvVHs_Idm	0,17807891	99,9	0,00017808
R248	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R241	OC	1	0,17807891	noise	0,17807891	99,9	0,00017808
R254	OC	1	0,17807891	no outputs	0,17807891	99,9	0,00017808
R198	OC	1	0,17807891	no output _FaultDrvWHs_Idm	0,17807891	99,9	0,00017808
C226	SC	0,49	0,18247549	no outputs	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C227	SC	0,49	0,18247549	no outputs	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C228	SC	0,49	0,18247549	no outputs	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C231	SC	0,49	0,18247549	no outputs	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C230	SC	0,49	0,18247549	no outputs	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C229	SC	0,49	0,18247549	no outputs	0,37239896	99,9	0,00018248
	OC	0,36	0,13406363	no effect	0,37239896	99,9	0,00013406
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
							0,0068213

Figure 6.10: Sheet 35

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R258	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R257	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R344	OC	1	0,17807891	no effect	0,17807891	99,9	0,00017808
R265	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R264	OC	1	0,17811235	noise	0,17811235	99,9	0,00017811
R266	OC	1	0,17807891	no effect	0,17807891	99,9	0,00017808
R263	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R267	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R268	OC	1	0,17807891	no effect	0,17807891	99,9	0,00017808
C351	SC	0,49	0,43933419	no output	0,89660039	99,9	0,00043933
	OC	0,36	0,32277614	no effect	0,89660039	99,9	0,00032278
	Changing Value	0,29	0,26001411	no effect	0,89660039	99,9	0,00026001
C166	SC	0,49	0,54742647	no output	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C354	SC	0,49	0,43933419	no output	0,89660039	99,9	0,00043933
	OC	0,36	0,32277614	no effect	0,89660039	99,9	0,00032278
	Changing Value	0,29	0,26001411	no effect	0,89660039	99,9	0,00026001
C355	SC	0,49	0,43933419	no output	0,89660039	99,9	0,00043933
	OC	0,22	0,19725209	no effect	0,89660039	99,9	0,00019725
	Changing Value	0,29	0,26001411	no effect	0,89660039	99,9	0,00026001
							0,00566082

Figure 6.11: Sheet 37

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R485	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R484	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R483	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R486	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R687	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R681	OC	1	0,17811235	wrong output	0,17811235	99,9	0,00017811
R86	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R125	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R680	OC	1	0,17811235	wrong output	0,17811235	99,9	0,00017811
R686	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R85	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R124	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R487	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R488	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R679	OC	1	0,17811235	wrong output	0,17811235	99,9	0,00017811
R685	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R84	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
R123	OC	1	0,17807891	wrong output	0,17807891	99,9	0,00017808
C424	SC	0,49	0,08771429	no output	0,17900875	99,9	8,7714E-05
	OC	0,22	0,03938193	no effect	0,17900875	99,9	3,9382E-05
	Changing Value	0,29	0,05191254	no effect	0,17900875	99,9	5,1913E-05
C425	SC	0,49	0,08771429	no output	0,17900875	99,9	8,7714E-05
	OC	0,22	0,03938193	no effect	0,17900875	99,9	3,9382E-05
	Changing Value	0,29	0,05191254	no effect	0,17900875	99,9	5,1913E-05
C426	SC	0,49	0,08771429	no output	0,17900875	99,9	8,7714E-05
	OC	0,22	0,03938193	no effect	0,17900875	99,9	3,9382E-05
	Changing Value	0,29	0,05191254	no effect	0,17900875	99,9	5,1913E-05
DD31	SC	0,51	0,06082077	possible wrong output	0,1192564	99,9	6,0821E-05
	OC	0,29	0,03458436	possible wrong output	0,1192564	99,9	3,4584E-05
	Parameter Change	0,2	0,02385128	possible wrong output	0,1192564	99,9	2,3851E-05
DD45	SC	0,51	0,05840264	possible undefined output	0,11451497	99,9	5,8403E-05
	OC	0,29	0,03320934	no output	0,11451497	99,9	3,3209E-05
	Parameter Change	0,2	0,02290299	possible undefined output	0,11451497	99,9	2,2903E-05
DD46	SC	0,51	0,05840264	possible undefined output	0,11451497	99,9	5,8403E-05
	OC	0,29	0,03320934	no output	0,11451497	99,9	3,3209E-05
	Parameter Change	0,2	0,02290299	possible undefined output	0,11451497	99,9	2,2903E-05
DD32	SC	0,51	0,06082077	possible wrong output	0,1192564	99,9	6,0821E-05
	OC	0,29	0,03458436	possible wrong output	0,1192564	99,9	3,4584E-05
	Parameter Change	0,2	0,02385128	possible wrong output	0,1192564	99,9	2,3851E-05
DD47	SC	0,51	0,05840264	possible undefined output	0,11451497	99,9	5,8403E-05
	OC	0,29	0,03320934	no output	0,11451497	99,9	3,3209E-05
	Parameter Change	0,2	0,02290299	possible undefined output	0,11451497	99,9	2,2903E-05
							0,0043246

Figure 6.12: Sheet 40

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
C185	SC	0,49	0,54742647	Tension to GND (no VCC)	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	No effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	No effect	1,11719688	99,9	0,00032399
C186	SC	0,49	0,54742647	Tension to GND (no VCC)	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	No effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	No effect	1,11719688	99,9	0,00032399
U53	Not working	1	0,31501194	No outputs	0,31501194	99,9	0,00031501
U49	Not working	1	0,47220515	Wrong input	0,47220515	99,9	0,00047221
U50	Not working	1	0,47220515	No outputs	0,47220515	99,9	0,00047221
							0,00349382

Figure 6.13: Sheet 44

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R644	OC	1	0,17807891	Battery malfunction	0,17807891	99,9	0,00017808
R702	OC	1	0,17807891	Battery malfunction	0,17807891	99,9	0,00017808
R643	OC	1	0,17807891	Battery malfunction	0,17807891	99,9	0,00017808
R701	OC	1	0,17807891	Battery malfunction	0,17807891	99,9	0,00017808
R642	OC	1	0,17807891	Battery malfunction	0,17807891	99,9	0,00017808
R453	OC	1	0,17807891	Battery malfunction	0,17807891	99,9	0,00017808
R695	OC	1	0,17807891	Battery malfunction	0,17807891	99,9	0,00017808
R699	OC	1	0,17811235	wrong signal	0,17811235	99,9	0,00017811
R659	OC	1	0,17811235	no output	0,17811235	99,9	0,00017811
R658	OC	1	0,17811235	no output	0,17811235	99,9	0,00017811
R645	OC	1	0,17807891	Battery malfunction	0,17807891	99,9	0,00017808
R646	OC	1	0,17807891	Battery malfunction	0,17807891	99,9	0,00017808
R700	OC	1	0,17807891	Battery malfunction	0,17807891	99,9	0,00017808
	SC	0,49	6,96553222	VPW to ground (U55 doesn't work)	14,2153719	99,9	0,00696553
C315	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
	SC	0,49	0,18247549	wrong signal	0,37239896	99,9	0,00018248
C445	OC	0,22	0,08192777	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
	SC	0,49	6,96553222	VPW to ground (U55 doesn't work)	14,2153719	99,9	0,00696553
C316	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
	SC	0,49	0,18247549	wrong signal	0,37239896	99,9	0,00018248
C442	OC	0,22	0,08192777	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
	SC	0,49	6,96553222	VPW to ground (U55 doesn't work)	14,2153719	99,9	0,00696553
C313	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
	SC	0,49	0,18247549	wrong signal	0,37239896	99,9	0,00018248
C441	OC	0,22	0,08192777	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
	SC	0,49	0,54742647	V5.0 to ground (U55 doesn't work)	1,11719688	99,9	0,00054743
C268	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
	SC	0,49	0,54742647	V5.0A to ground (U55 doesn't work)	1,11719688	99,9	0,00054743
C427	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
	SC	0,49	6,96553222	VBATT to ground (U55 doesn't work)	14,2153719	99,9	0,00696553
C312	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
	SC	0,49	6,96553222	SC between pins and ground	14,2153719	99,9	0,00696553
C428	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
	SC	0,49	6,96553222	SC between pins	14,2153719	99,9	0,00696553
C260	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
	SC	0,49	0,54742647	no output	1,11719688	99,9	0,00054743
C190	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
	SC	0,49	0,54742647	no output	1,11719688	99,9	0,00054743
C191	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
	SC	0,49	0,54742647	SC between pins	1,11719688	99,9	0,00054743
C430	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
	SC	0,49	0,54742647	SC between pins	1,11719688	99,9	0,00054743
C431	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
	SC	0,49	0,54742647	SC between pins	1,11719688	99,9	0,00054743
C432	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
	SC	0,49	0,54742647	SC between pins and ground	1,11719688	99,9	0,00054743
C433	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399

Figure 6.14: Sheet 47

C434	SC	0,49	0,54742647	SC between pins and ground	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C314	SC	0,49	6,96553222	VPW to ground (U55 doesn't work)	14,2153719	99,9	0,00696553
	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C440	SC	0,49	0,18247549	wrong signal	0,37239896	99,9	0,00018248
	OC	0,22	0,08192777	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
DS16	SC	0,51	0,70552333	Battery malfunction	1,38337908	99,9	0,00070552
	OC	0,29	0,40117993	Battery malfunction	1,38337908	99,9	0,00040118
	Parameter Change	0,2	0,27667582	Battery malfunction	1,38337908	99,9	0,00027668
DS5	SC	0,51	0,70552333	Battery malfunction	1,38337908	99,9	0,00070552
	OC	0,29	0,40117993	Battery malfunction	1,38337908	99,9	0,00040118
	Parameter Change	0,2	0,27667582	Battery malfunction	1,38337908	99,9	0,00027668
DS4	SC	0,51	0,09856561	Battery malfunction	0,19326591	99,9	9,8566E-05
	OC	0,29	0,05604711	Battery malfunction	0,19326591	99,9	5,6047E-05
	Parameter Change	0,2	0,03865318	Battery malfunction	0,19326591	99,9	3,8653E-05
DS7	SC	0,51	0,70552333	Battery malfunction	1,38337908	99,9	0,00070552
	OC	0,29	0,40117993	Battery malfunction	1,38337908	99,9	0,00040118
	Parameter Change	0,2	0,27667582	Battery malfunction	1,38337908	99,9	0,00027668
DS3	SC	0,51	0,09856561	Battery malfunction	0,19326591	99,9	9,8566E-05
	OC	0,29	0,05604711	Battery malfunction	0,19326591	99,9	5,6047E-05
	Parameter Change	0,2	0,03865318	Battery malfunction	0,19326591	99,9	3,8653E-05
DS8	SC	0,51	0,70552333	Battery malfunction	1,38337908	99,9	0,00070552
	OC	0,29	0,40117993	Battery malfunction	1,38337908	99,9	0,00040118
	Parameter Change	0,2	0,27667582	Battery malfunction	1,38337908	99,9	0,00027668
DS6	SC	0,51	0,09856561	Battery malfunction	0,19326591	99,9	9,8566E-05
	OC	0,29	0,05604711	Battery malfunction	0,19326591	99,9	5,6047E-05
	Parameter Change	0,2	0,03865318	Battery malfunction	0,19326591	99,9	3,8653E-05
M11 (Transistor, Bipolar)	SC	0,73	0,2012034	Battery malfunction	0,27562109	99,9	0,0002012
	OC	0,27	0,0744177	Battery malfunction	0,27562109	99,9	7,4418E-05
M8	SC	0,73	0,2012034	Battery malfunction	0,27562109	99,9	0,0002012
	OC	0,27	0,0744177	Battery malfunction	0,27562109	99,9	7,4418E-05
M7	SC	0,73	0,2012034	Battery malfunction	0,27562109	99,9	0,0002012
	OC	0,27	0,0744177	Battery malfunction	0,27562109	99,9	7,4418E-05
M10	SC	0,73	0,2012034	Battery malfunction	0,27562109	99,9	0,0002012
	OC	0,27	0,0744177	Battery malfunction	0,27562109	99,9	7,4418E-05
M9	SC	0,73	0,2012034	Battery malfunction	0,27562109	99,9	0,0002012
	OC	0,27	0,0744177	Battery malfunction	0,27562109	99,9	7,4418E-05
DZ1 (Diode, Zener, Voltage Reference)	Parameter Change	0,69	0,1222113	Battery malfunction	0,17711783	99,9	0,00012221
	OC	0,18	0,03188121	Battery malfunction	0,17711783	99,9	3,1881E-05
	SC	0,13	0,02302532	Battery malfunction	0,17711783	99,9	2,3025E-05
DZ2	Parameter Change	0,69	0,1222113	Battery malfunction	0,17711783	99,9	0,00012221
	OC	0,18	0,03188121	Battery malfunction	0,17711783	99,9	3,1881E-05
	SC	0,13	0,02302532	Battery malfunction	0,17711783	99,9	2,3025E-05
DZ3	Parameter Change	0,69	0,1222113	Battery malfunction	0,17711783	99,9	0,00012221
	OC	0,18	0,03188121	Battery malfunction	0,17711783	99,9	3,1881E-05
	SC	0,13	0,02302532	Battery malfunction	0,17711783	99,9	2,3025E-05
U55	Not working	1	1,55737246	no output:Microcontroller doesn't work	1,55737246	99,9	0,00155737
DD39 (Diode, Rectifier)	SC	0,51	0,06082077	Battery malfunction	0,1192564	99,9	6,0821E-05
	OC	0,29	0,03458436	Battery malfunction	0,1192564	99,9	3,4584E-05
	Parameter Change	0,2	0,02385128	Battery malfunction	0,1192564	99,9	2,3851E-05
DD40	SC	0,51	0,06082077	Battery malfunction	0,1192564	99,9	6,0821E-05
	OC	0,29	0,03458436	Battery malfunction	0,1192564	99,9	3,4584E-05
	Parameter Change	0,2	0,02385128	Battery malfunction	0,1192564	99,9	2,3851E-05
DD41	SC	0,51	0,06082077	Battery malfunction	0,1192564	99,9	6,0821E-05
	OC	0,29	0,03458436	Battery malfunction	0,1192564	99,9	3,4584E-05
	Parameter Change	0,2	0,02385128	Battery malfunction	0,1192564	99,9	2,3851E-05
							0,13587155

Figure 6.15: Sheet 47

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R113	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R102	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R103	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R104	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R105	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R106	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R95	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R96	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R97	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R98	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R99	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R100	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R101	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R134	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R135	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R136	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R137	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R138	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R139	OC	1	0,17807891	no signal	0,17807891	99,9	0,00017808
R164	OC	1	0,17807891	no signal	0,17807891	99,9	0,00017808
R13	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R93	OC	1	0,17807891	no signal	0,17807891	99,9	0,00017808
R94	OC	1	0,17807891	no signal	0,17807891	99,9	0,00017808
R141	OC	1	0,17807891	no signal	0,17807891	99,9	0,00017808
R142	OC	1	0,17811235	no signal	0,17811235	99,9	0,00017811
R140	OC	1	0,17811235	no signal	0,17811235	99,9	0,00017811
R20	OC	1	0,17807891	no signal	0,17807891	99,9	0,00017808
R452	OC	1	0,17807891	no effect	0,17807891	99,9	0,00017808
C73	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C253	SC	0,49	6,96553222	wrong signal	14,2153719	99,9	0,00696553
	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C254	SC	0,49	6,96553222	wrong signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C74	SC	0,49	0,54742647	noise	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no connection	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C75	SC	0,49	0,54742647	noise	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no connection	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C266	SC	0,49	0,10948529	Y1 doesn't work	0,22343938	99,9	0,00010949
	OC	0,36	0,08043818	Y1 doesn't work	0,22343938	99,9	8,0438E-05
	Changing Value	0,29	0,06479742	no effect	0,22343938	99,9	6,4797E-05
C267	SC	0,49	0,10948529	Y1 doesn't work	0,22343938	99,9	0,00010949
	OC	0,22	0,04915666	Y1 doesn't work	0,22343938	99,9	4,9157E-05
	Changing Value	0,29	0,06479742	no effect	0,22343938	99,9	6,4797E-05
C60	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C68	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C192	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246

Figure 6.16: Sheet 49

C193	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C65	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C66	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C67	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C62	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C63	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C64	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C61	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C69	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C261	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C70	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C71	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C242	SC	0,49	0,54742647	noise	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	wrong signal	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C72	SC	0,49	0,54742647	noise	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	wrong signal	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
DL1 (Optoelectronic, LED)	OC	0,7	1,33307777	uncorrect functioning	1,90439682	99,9	0,00133308
	SC	0,3	0,57131904	uncorrect functioning	1,90439682	99,9	0,00057132
L3 (Coil)	SC	0,42	0,42434078	no effect	1,0103352	99,9	0,00042434
	OC	0,42	0,42434078	no V1.3	1,0103352	99,9	0,00042434
	Changing Value	0,16	0,16165363	no effect	1,0103352	99,9	0,00016165
Y1	OC	0,89	20,0021282	no effect	22,4743014	99,9	0,02000213
	No Oscillation	0,11	2,47217315	no effect	22,4743014	99,9	0,00247217
M1 (Transistor, FET)	SC	0,51	0,09885546	no V1.3	0,19383423	99,9	9,8855E-05
	Output Low	0,22	0,04264353	no V1.3	0,19383423	99,9	4,2644E-05
	Parameter Chang	0,17	0,03295182	no V1.3	0,19383423	99,9	3,2952E-05
	OC	0,05	0,00969171	no V1.3	0,19383423	99,9	9,6917E-06
	Output High	0,05	0,00969171	no V1.3	0,19383423	99,9	9,6917E-06
Q4 (Transistor, bipolar)	SC	0,73	0,36387911	uncorrect functioning LED	0,49846454	99,9	0,00036388
	OC	0,27	0,13458543	uncorrect functioning LED	0,49846454	99,9	0,00013459
U2	Not working	1	1,99902131	no output:Microcontroller doesn't work	1,99902131	99,9	0,00199902
							0,1290022

Figure 6.17: Sheet 49

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R21	OC	1	0,17807891	no signal	0,17807891	99,9	0,00017808
R22	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R143	OC	1	0,17807891	wrong signal	0,17807891	99,9	0,00017808
R24	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R25	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R26	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R27	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R313	OC	1	0,17807891	no signal	0,17807891	99,9	0,00017808
R343	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R208	OC	1	0,17807891	no signal	0,17807891	99,9	0,00017808
R209	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R440	OC	1	0,17811235	uncorrect functioning LED	0,17811235	99,9	0,00017811
R342	OC	1	0,17811235	uncorrect functioning LED	0,17811235	99,9	0,00017811
R345	OC	1	0,17807891	no signal	0,17807891	99,9	0,00017808
R346	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R11	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
C275	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C288	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C297	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C276	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C289	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C298	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C78	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C255	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C256	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C243	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C244	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C76	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C264	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C265	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C273	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C274	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C194	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C195	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C269	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246

Figure 6.18: Sheet 50

C270	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C271	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C272	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C197	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C79	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C196	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C80	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C77	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C262	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,36	5,11753388	no effect	14,2153719	99,9	0,00511753
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C263	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C305	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,36	0,40219088	no effect	1,11719688	99,9	0,00040219
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C283	SC	0,53	0,38763484	no signal	0,73138649	99,9	0,00038763
	OC	0,35	0,25598527	no effect	0,73138649	99,9	0,00025599
	Electrolyte Leak	0,1	0,07313865	no effect	0,73138649	99,9	7,3139E-05
	Decrease in Capac	0,02	0,01462773	no effect	0,73138649	99,9	1,4628E-05
C284	SC	0,53	0,38763484	no signal	0,73138649	99,9	0,00038763
	OC	0,35	0,25598527	no effect	0,73138649	99,9	0,00025599
	Electrolyte Leak	0,1	0,07313865	no effect	0,73138649	99,9	7,3139E-05
	Decrease in Capac	0,02	0,01462773	no effect	0,73138649	99,9	1,4628E-05
L5	SC	0,42	0,42434078	no effect	1,0103352	99,9	0,00042434
	OC	0,42	0,42434078	no signal	1,0103352	99,9	0,00042434
	Changing Value	0,16	0,16165363	no effect	1,0103352	99,9	0,00016165
L5	SC	0,42	0,42434078	no effect	1,0103352	99,9	0,00042434
	OC	0,42	0,42434078	no VPRE	1,0103352	99,9	0,00042434
	Changing Value	0,16	0,16165363	no effect	1,0103352	99,9	0,00016165
DS1	SC	0,51	0,09856561	possible undefined signal	0,19326591	99,9	9,8566E-05
	OC	0,29	0,05604711	no connection	0,19326591	99,9	5,6047E-05
	Parameter Chang	0,2	0,03865318	possible undefined signal	0,19326591	99,9	3,8653E-05
DS2	SC	0,51	0,09856561	possible undefined signal	0,19326591	99,9	9,8566E-05
	OC	0,29	0,05604711	no connection	0,19326591	99,9	5,6047E-05
	Parameter Chang	0,2	0,03865318	possible undefined signal	0,19326591	99,9	3,8653E-05
DS14	SC	0,51	0,09466624	VPRE uncorrect functioning	0,18562007	99,9	9,4666E-05
	OC	0,29	0,05382982	VPRE uncorrect functioning	0,18562007	99,9	5,383E-05
	Parameter Chang	0,2	0,03712401	VPRE uncorrect functioning	0,18562007	99,9	3,7124E-05
DS15	SC	0,51	0,09466624	possible undefined signal	0,18562007	99,9	9,4666E-05
	OC	0,29	0,05382982	no connection	0,18562007	99,9	5,383E-05
	Parameter Chang	0,2	0,03712401	possible undefined signal	0,18562007	99,9	3,7124E-05
DL2	OC	0,7	1,33307777	uncorrect functioning	1,90439682	99,9	0,00133308
	SC	0,3	0,57131904	uncorrect functioning	1,90439682	99,9	0,00057132
DL3	OC	0,7	1,33307777	uncorrect functioning	1,90439682	99,9	0,00133308
	SC	0,3	0,57131904	uncorrect functioning	1,90439682	99,9	0,00057132
U8	Not working	1	0,31501194	no output	0,31501194	99,9	0,00031501
U6	Not working	1	1,50322448	no output:Microcontroller do	1,50322448	99,9	0,00150322
U3 (Diode, Zen	Parameter Chang	0,35	0,19942765	uncorrect functioning	0,56979328	99,9	0,00019943
	OC	0,45	0,25640698	Microcontroller doesn't worl	0,56979328	99,9	0,00025641
	SC	0,2	0,11395866	overload:Microcontroller do	0,56979328	99,9	0,00011396
U7	Parameter Chang	0,35	0,62500754	uncorrect functioning	1,78573582	99,9	0,00062501
	OC	0,45	0,80358112	Microcontroller doesn't worl	1,78573582	99,9	0,00080358
	SC	0,2	0,35714716	overload:Microcontroller do	1,78573582	99,9	0,00035715
							0,27334217

Figure 6.19: Sheet 50

Component	Failure Mode	α	λα	Effect on the system	λ	Coverage (%)	λres
R295	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R297	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R298	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R296	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R300	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R299	OC	1	0,17807891	no output	0,17807891	99,9	0,00017808
R66	OC	1	0,17811235	no power supply	0,17811235	99,9	0,00017811
R430	OC	1	0,17807891	possible undefined output	0,17807891	99,9	0,00017808
R67	OC	1	0,17807891	no input in Y3	0,17807891	99,9	0,00017808
R302	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
R301	OC	1	0,17811235	possible undefined output	0,17811235	99,9	0,00017811
C198	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C167	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C199	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C168	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C238	SC	0,49	0,18247549	no output	0,37239896	99,9	0,00018248
	OC	0,22	0,08192777	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C239	SC	0,49	0,18247549	no output	0,37239896	99,9	0,00018248
	OC	0,22	0,08192777	no effect	0,37239896	99,9	8,1928E-05
	Changing Value	0,29	0,1079957	no effect	0,37239896	99,9	0,000108
C208	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C201	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C173	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C200	SC	0,49	6,96553222	no signal	14,2153719	99,9	0,00696553
	OC	0,22	3,12738181	no effect	14,2153719	99,9	0,00312738
	Changing Value	0,29	4,12245785	no effect	14,2153719	99,9	0,00412246
C174	SC	0,49	0,54742647	no signal	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C169	SC	0,49	0,54742647	no power supply	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C170	SC	0,49	0,54742647	no power supply	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C171	SC	0,49	0,54742647	no power supply	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C172	SC	0,49	0,54742647	no power supply	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
C175	SC	0,49	0,54742647	no power supply	1,11719688	99,9	0,00054743
	OC	0,22	0,24578331	no effect	1,11719688	99,9	0,00024578
	Changing Value	0,29	0,3239871	no effect	1,11719688	99,9	0,00032399
L9	SC	0,42	0,11432231	no effect	0,27219597	99,9	0,00011432
	OC	0,42	0,11432231	no V3.3	0,27219597	99,9	0,00011432
	Changing Value	0,16	0,04355136	no effect	0,27219597	99,9	4,3551E-05
Y3	OC	0,89	20,0021282	no clock	22,4743014	99,9	0,02000213
	No Oscillation	0,11	2,47217315	no clock	22,4743014	99,9	0,00247217
U4	Parameter Chang	0,35	0,19942765	uncorrect functioning	0,56979328	99,9	0,00019943
	OC	0,45	0,25640698	Microcontroller doesn't work	0,56979328	99,9	0,00025641
	SC	0,2	0,11395866	overload:Microcontroller doesn't work	0,56979328	99,9	0,00011396
U44	Not working	1	5,45335559	no output	5,45335559	99,9	0,00545336
U46	Not working	1	0,32651532	no output: Microcontroller doesn't work	0,32651532	99,9	0,00032652
							0,09983345

Figure 6.20: Sheet 53

6.2 Single Point Fault Metric calculation

For each of the schematic's sheets analysed, the sum on the $\lambda_{residual}$ was calculated. As it can be remarked, all of the components have coverage set to 99.9%. This because all of their failures are detected, and none of them can cause critical situations (the maximum hazard would be the turning off, but not the braking, of the motor), since compensating mechanisms are applied through software checks or duplication of the hardware.

In an additional Excel page, these residual failure rates were summed, obtaining the $\lambda_{residualTot}$ that indicates the failure rate of non-covered faults. This factor was confronted with the λ_{Total} obtained from the FIDES analysis:

$$\lambda_{residual\%} = \frac{\lambda_{residualTot}}{\lambda_{Total}} \times 100$$

At this point, the SPFM corresponds to $100 - \lambda_{residual\%}$. As it can be remarked, its value is >99%, that is correct for an ASIL D.

λres.tot	**1,150069428**
λtot	**1359,081623**
λres%	**0,084621071**
SPFM	99,91537893

Figure 6.21: SPFM results

Conclusions

The aim of this thesis was to evaluate the reliability and criticality of the boards provided by Ideas&Motion applying a combination of FIDES and FMECA methodologies.

The FIDES analysis was born to be used in the aerospace field, but has been increasingly used over the last years by the automotive companies. The reason for this trend is its usability and comprehensiveness. In contrast to the use of FIDES, the failure rate would be obtained from the producers: in particular, this factor would be more precise for more complex components. The FIDES analysis, for example, doesn't take into account the internal structure of Integrated Circuits. The producing company would instead be aware of it and define a more accurate parameter. However, this provided λ would not consider the situations that the component would undergo, neither the design of the whole circuit. In FIDES the results are instead analysed depending on the stresses and on the phases related to the item, thus giving a visual on what are the most hazardous situations.

This procedure was applied to both boards to have an initial general framework of the reliabilities. The H-SDF has a failure rate much higher than the Dual Inverter, confirming its lower reliability. This board was conceived to be further developed in future projects, for nowadays the technologies are not advanced enough to allow the board to be integrated in real applications. On the contrary, the Dual Inverter board will be produced on the short term and is patent protected.

While FIDES is a quite recent methodology, FMECA is an established procedure used in many fields. This is why many manuals are quite dated, like the one referenced in this work. More recent data would be more accurate, but being often used in military applications, old handbooks have conservative measures that keep the analysis reliable. In this work, it was applied to the Dual Inverter board, which is the most critical one, having ASIL D. The previous FIDES results revealed themselves particularly useful and effective in finding the criticality of the board through the SPFM. In this analysis only the hardware failures were considered, but the coverage of the software part was taken into account when identifying the possible effects of the failure modes. Hence, the full application of ASIL D, having a SPFM >99%.

The obtained results mirror the assumptions about safety made on the two boards, and represent a confirmation about their feasibility. It can thus be stated that the union of FIDES and FMECA may represent a future solid procedure to be used in the automotive domain.

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