車用電力電子產品設計驗證與可靠度評估

Edward Su 台達電子

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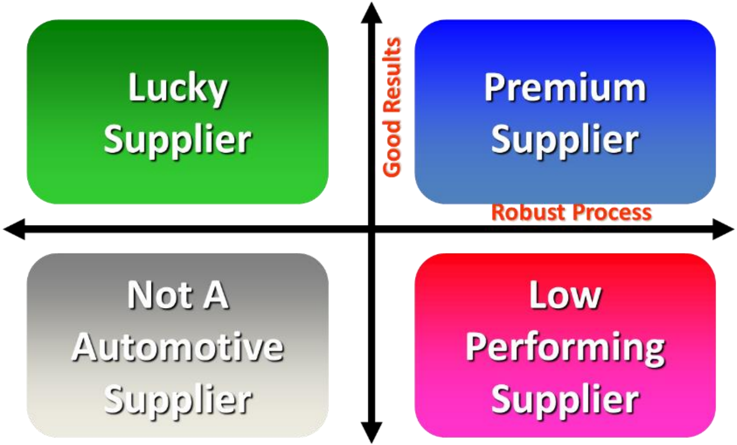
寬能隙半導體之設計及雙脈衝測試研討會

System Reliability

- No perfect hardware part
- No perfect software quality
- So, a systematic method should be developed!!

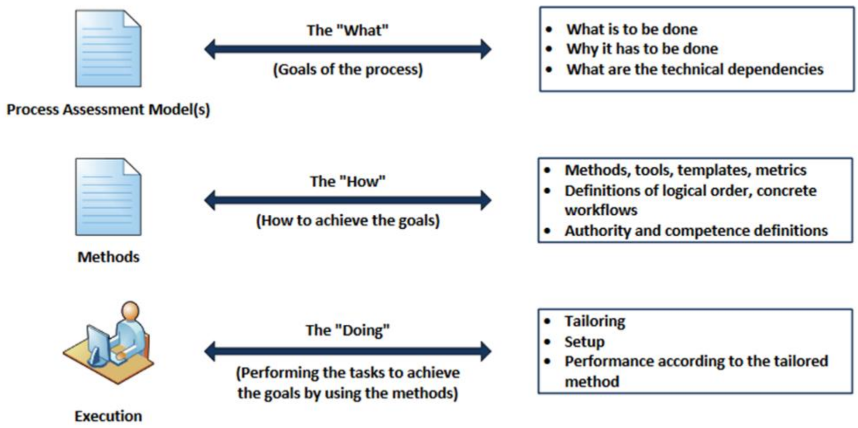
Source: SGS

Letting Nothing Managed by Chance!!



Source: Volvo Supplier Quality Assurance Manual

Process Concept



Product Development Process

Concept

- Item Definition
- Distributed Interface Agreement (DIA)
- Safety Program Planning
- Functional Safety Concept
- Sub-system / component HARA (if applicable)
- Hardware analysis
- Single point fault analysis

Requirements

- Requirements refinement
- System interface analysis
- Requirements traceability
- V&V Plan (includes fault injection testing)

Design / Development

- System DFMEA
- Software DFMEA (if applicable)
- Fault Tree Analysis (FTA)
- Diagnostics Coverage Assessment
- Common Cause Fault Analysis
- Technical Safety Concept

Integration

- V&V Plan Update
- Safety assessment in vehicle
- Finalizing safety work products

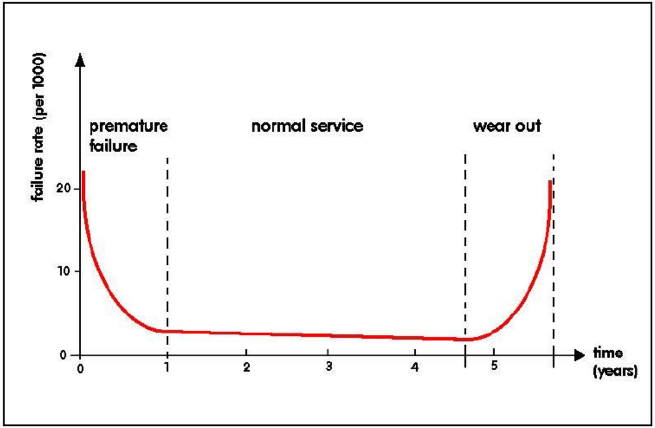
Validation

- Execution of final validation plan (test reports)
  - Software
  - Hardware
  - Sub-system
  - System
  - Vehicle
- Safety Case Compilation

ISO/IEC/IEEE Standards

- ISO/IEC/IEEE 16085:2021 **RISK MANAGEMENT**
- ISO/IEC/IEEE 16326:2019 **PROJECT MANAGEMENT**
- ISO/IEC/IEEE 29148:2018 **REQUIREMENTS ENGINEERING**
- ISO/IEC/IEEE 24748-1:2018 **LIFE CYCLE MANAGEMENT** — PART 1: GUIDELINES FOR LIFE CYCLE MANAGEMENT
- ISO/IEC/IEEE 24748-2:2018 LIFE CYCLE MANAGEMENT — PART 2: GUIDELINES FOR THE APPLICATION OF ISO/IEC/IEEE 15288 (SYSTEM LIFE CYCLE PROCESSES)
- ISO/IEC/IEEE 24748-5:2017 LIFE CYCLE MANAGEMENT — PART 5: SOFTWARE DEVELOPMENT PLANNING
- ISO/IEC TS 24748-6:2016 LIFE CYCLE MANAGEMENT — PART 6: SYSTEM INTEGRATION ENGINEERING
- ISO/IEC/IEEE 15939:2017 **MEASUREMENT PROCESS**
- ISO/IEC/IEEE 26531:2015 **CONTENT MANAGEMENT FOR PRODUCT LIFE-CYCLE**, USER AND SERVICE MANAGEMENT DOCUMENTATION
- ISO/IEC/IEEE 42010:2011 **ARCHITECTURE** DESCRIPTION
- ISO/IEC/IEEE 15026-1:2019 **SYSTEMS AND SOFTWARE ASSURANCE** — PART 1: CONCEPTS AND VOCABULARY
- ISO/IEC/IEEE DIS 15026-2 SYSTEMS AND SOFTWARE ASSURANCE — PART 2: ASSURANCE CASE
- ISO/IEC/IEEE 29119-1:2013 **TESTING** — PART 1: CONCEPTS AND DEFINITIONS
- ISO/IEC/IEEE 29119-2:2013 TESTING — PART 2: TEST PROCESSES
- ISO/IEC/IEEE 29119-3:2013 TESTING — PART 3: TEST DOCUMENTATION
- ISO/IEC/IEEE 29119-4:2015 TESTING — PART 4: TEST TECHNIQUES
- ISO/IEC/IEEE 29119-5:2016 TESTING — PART 5: KEYWORD-DRIVEN TESTING
- ISO/IEC TR 29119-6:2021 TESTING — PART 6: GUIDELINES FOR THE USE OF ISO/IEC/IEEE 29119 (ALL PARTS) IN AGILE PROJECTS

Reliability & The Bathtub Curve



Source: https://www.design1st.com

Reliability & The Bathtub Curve

Life phase	Cause of failure	Prevention / remedy
Premature failures	Component is good but inappropriately installed.	Installation method is part of design responsibility.
Premature failures	Component is damaged during product assembly.	Liaison with production management – change component design or assembly method.
Premature failures	Component is damaged during product maintenance.	Adjust design according to field data. Adopt 'design for maintainability'.
Premature failures	Overall product design is poor and introduces unnecessarily high stress levels throughout.	Back to the drawing board.
Normal service phase (random) failures	Careless handling. Accidents.	Ruggedize, examine product with respect to shock and vibration.
	Severe natural phenomena (lightning, freak weather, sun-storms, meteorites). Acts of War.	Ruggedization, otherwise no economic remedy.
Wear-out failures	Mechanical wear. Component wears out at the end of its declared life (through abrasion or material depletion). E.g. tires	Consider product maintenance or disposal. E.g. replace tires
	Component wears out before reaching its intended life.	Increase specification, ruggedize, reduce stress environment, revise target life

Source: https://www.design1st.com

Design for Reliability

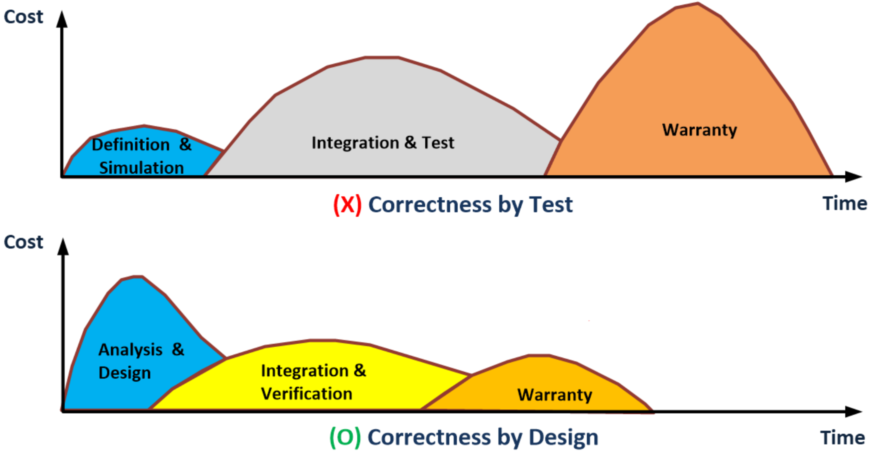
Design → Test ⇒ **Verification & Validation → Design**

- **Conventional Methodology**
  - ✓Define several product concepts
  - ✓Select the one that has the most promise
  - ✓Draw up specifications and divide them into subsystems;
  - ✓Subsystems are designed, built and rolled up for system testing.
  - ✓Failures? Rework the specs and the designs accordingly (non-optimized and confusing endeavor)

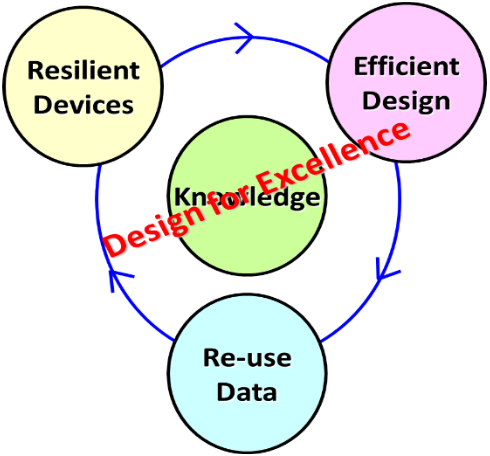
- **New Methodology**
  - ✓Efforts concentrated at lowest possible design level
  - ✓Focus on learning as much as possible
  - ✓Use of that knowledge to develop a stream of excellent products
  - ✓Thorough understanding of the technology of a subsystem so it can be used appropriately in future designs

Engineers test at the fundamental knowledge level so they don't have to test at the later, more expensive stages of design and prototyping

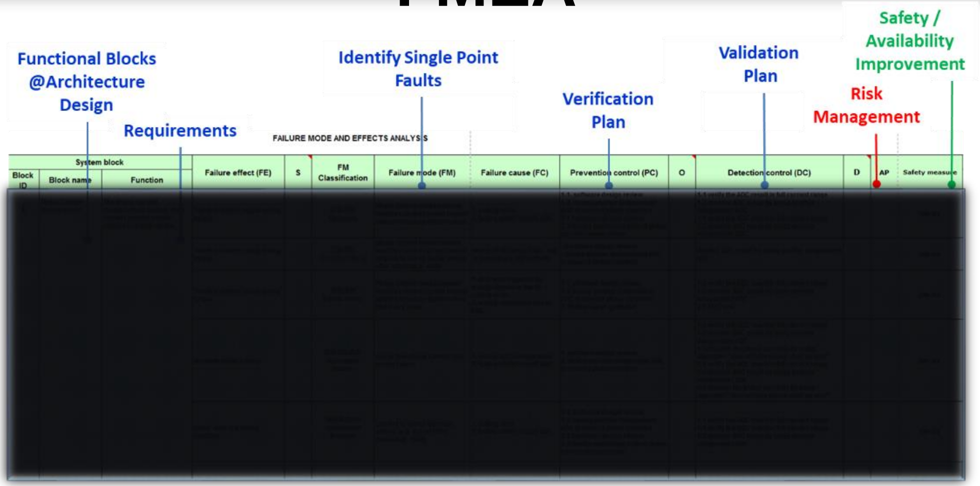
Processed Based Development



Reliability Knowledge Framework



Design Verification / Analysis - FMEA



System block			Failure effect (FE)	S	FM Classification	Failure mode (FM)	Failure cause (FC)	Prevention control (PC)	O	Detection control (DC)	D	AP	Safety measure
Block ID	Block name	Function											
[redacted]													

fppt.com

Robust Design Concept

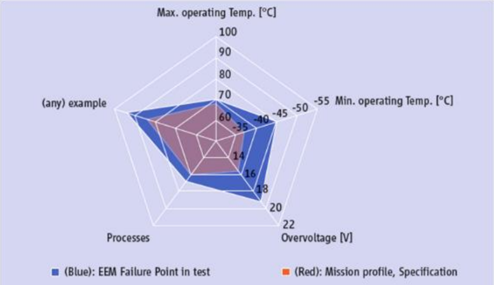
Robust Design relies on :

1) **knowledge-based modeling simulation and analysis methods** to develop a highly capable design prior to building and testing physical parts;

2) test-to-failure (or acceptable degradation) and failure / defect susceptibility testing to confirm or identify **Robustness Margins**, to enable failure prediction and verify that manufacturing processes produce defect free parts.

Environmental and Functional Load Stress Factors

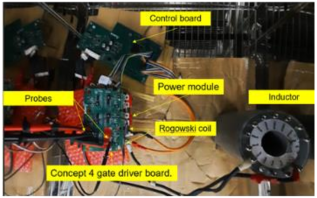
Environmental Loads ✓ Thermal ✓ Mechanical ✓ Radiation ✓ Dust ✓ Humidity ✓ Water ✓ Chemical ✓ Electromagnetical (EMC)	**Interaction**	**Functional Loads** ✓ Usage profiles ✓ Mechanical operation ✓ Emitted radiation ✓ Electrical operation
Assembly Requirements		**Shipping and Service**



Double Pulse Test

Purpose :

1) Make sure power module **operate safety** at all operation conditions.
2) Achieve **max. efficiency** of invertor.
3) As a **base for switch loss (Eon+Eoff+Err) & thermal simulation**.



Consider factors:

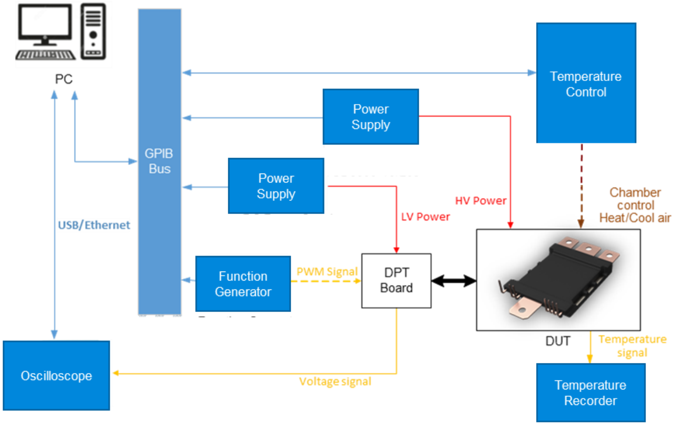
1) Motor output current
2) HVDC voltage
3) Ambient temperature
4) Gate on/off resistor
5) Passive components

Process :

Item	Content	Temperature	Current	Voltage	Time	Note
1	Fine tune **on & off** Rg	Min. & Max.	Max.	Max.	4 days	@Different batch
2	DPT @ different current	Room	Min ~ Max	Nominal	2 days	Around 10 currents
3	DPT @ different HVDC	Room	Min ~ Max	Nom. ~ Max	3 ~ 4 days	2 ~ 3 voltage
4	DPT @ different ambient	Min, room, & Max	Min ~ Max	Max.	4 ~ 5 day	3 temperature

Time = 30 days (item 1 + 2 * 3 * 4)

DPT Automation



The tasks included:

- Integrate and control different equipment to realize automatic double pulse test.
- Test procedures standardization.
- Create the database for power module thermal simulation.
- Build up the switching loss calculation method(tool coupling).

Thanks for Your Attention!