Ansys

BOSTON ENGINEERING™

The Definitive Guide to an Electronic Assembly Design Review

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Executive Summary

A **design review** is a comprehensive assessment of the design of a product with reliability as the driving factor. Undergoing a design review in the initial stages of product development is essential to ensure a product is fully operable prior to the final stages of development. This conserves business' resources, reduces cost, and, most importantly, expedites time to market.

You cannot achieve these business goals without a design review methodology in place that ensures your product — from its initial stages to the final stage — functions as planned. Therefore, the design review should occur as early in the design stage as possible to eliminate any need for redesign, retooling or rework later in the design process or after the product has already gone to prototype.

This guide is designed to provide businesses — particularly within electronic and manufacturing industries — insight into the design review process, Ansys' approach to design reviews and how you can overcome common product design flaws for electronic hardware.

"The goal of a world-class company is to produce a product or service that offers customers the highest quality at the lowest cost in the shortest amount of time."

/ Takashi Ichida

How Does a Design Review Work?

The main purpose of a design review is to predict potential risks and failures of a specific product or component. For example, a typical design review should begin with finding out as much information as possible about the product in question. This includes determining the user of your product, the conditions the product will be subjected to, how the product is expected to perform, its desired life expectancy and more. This information will inform and facilitate your design review process and clarify the conditions that the product will likely encounter throughout its life cycle.

The design review process typically follows a series of nine steps:

1. Establish a reliability goal
2. Quantify the use environment
3. Circuit analysis
4. Bill of Material (BOM) component stress review
5. Printed circuit board (PCB) analysis
6. Design for manufacturability (DfM)
7. Sherlock Automated Design Analysis (ADA)
8. Reliability test plan development
9. Failure analysis

Once these steps are complete, the client receives an analysis of the conditions causing failure. Potential solutions for that failure will also be provided such as revised parts placement, new materials selection and more.

/ The Design Review Process

The design review process follows a series of nine steps that are used to determine the reliability of a product design. Let's go into further detail about each step:

1 Establishing a Reliability Goal

Establishing a product reliability goal must be exhaustive in the sense that your product's desired life expectancy, its operating functions and its performance objectives should be identified clearly and with specificity to business goals.

You need to do more than state that your product's reliability goal is to be 'better than last year's product', or 'have a 5-year lifespan'. Reliability goals must be robust and detailed, including past products' field performance, market positioning, cost of failures, technical capabilities and more.

Establishing a Reliability (cont.)

Best practices include:

- Set reliability goals based on survivability. This is often bound by confidence levels, such as 95% reliability with a 90% confidence level over 15 years.
- Avoid mean time to failure (MTTF) and mean time between failures (MTBF) which do not measure reliability. Historically, MTBF has been calculated using empirical prediction handbooks, which assume a constant failure rate that is not always correct.
- Employ physics of failure (PoF) to acquire a deeper understanding of how your product's desired lifetime and environment affect its design. This takes substantial effort, but you receive a valuable return on investment.

What is Physics of Failure (PoF)?

The knowledge and understanding of the processes and mechanisms that induce failure to predict reliability and improve product performance.

What is Mean Time to Failure (MTTF)?

The length of time a device or other product is expected to last in operation.

What is Mean Time between Failure?

The predicted elapsed time between inherent failures of a mechanical or electronic system during normal system operation.

2 Quantify the Use Environment

Quantifying the use environment remains a key step for ensuring product reliability. Design engineers must examine all the possible use scenarios and environmental stressors the product will likely encounter, including thermal and mechanical conditions, such as temperature and humidity, as well as shock and vibration, drops and mechanical bending and product storage and housing.

For example, if a manufacturer develops a smartphone, they must take into account that the product will likely experience greatly varying temperatures, suffer a number of drop shocks throughout its lifecycle and endure rugged environmental conditions, including submersion. Quantifying these potential scenarios and use environments will be essential to develop a reliable product and effectively evaluate a product design.

3 Circuit Analysis

Often a customer requests a detailed review of their schematic as part of the design review. At Ansys, we begin by reviewing product specifications to fully understand the requirements and environments. We often ask questions like:

- Do we have a sufficient operating temperature range?
- Are there appropriate standards and high enough levels?
- Are shock and vibration involved environments?

A circuit analysis includes an assessment to ensure the circuit will function as intended. Electromagnetic capability (EMC) and electrostatic discharge (ESD) risks are identified and the derating of the components are verified by assessing power dissipation, voltage ratings, dV/dt ratings for field effect transistors (FETs), Vgs breakdown of FETs and the temperature rating of the parts.

To examine circuit stability, engineers check feedback loop circuitry, low dropout regulators (LDOs) and capacitor configurations. Electrolytic capacitors are known to be a weak link in designs, particularly the power supply, so life expectancy is assessed as a function of circuit stress levels. Magnetics are also assessed by looking at saturation currents and core loss.

As a result of this analysis, components are flagged that exhibit a risk. The analysis then looks at component placement for inclusion in the design for manufacturing (DfM) analysis.

4 BOM (Component) Stress Review

Before subjecting an assembly to tests and evaluation, you should know how individual components perform under stress. Are all components of a board compatible? Are there any components you can eliminate from consideration from the start? Similar to establishing reliability goals, a component stress review represents a small step that helps your design review operate smoothly and quickly.

This step involves examining data sheets for every component that comprises your assembly. This enables you to:

- Determine your components' operating temperature range to identify the part(s) that have the least amount of margin with respect to the operating conditions.
- Identify a replacement part with better margins.
- Analyze the materials used in your components' manufacturing, as different materials have different compatibilities within the circuit board.
- Examine critical components — including optoelectronics, custom parts, memory devices, electro-mechanical components and ceramic MLCC capacitors — to ensure product life expectancy will be met.
- Evaluate new technology devices (e.g., small device features) to determine if the new, finer geometries will function for the intended duration of operation. All components in the BOM are examined for derating criteria, moisture sensitivity level (MSL) and temperature sensitivity level (TSL). This analysis often identifies parts where extreme care must be undertaken in manufacturing to ensure no moisture penetration occurs.

4 BOM (Component) Stress Review (cont.)

Often a tin whisker analysis may also be performed. At Ansys, we explore the finish on the component leads and printed wiring board (PWB) surface finish to assess susceptibility. Whiskering occurs because of the presence of a compressive stress (or, more accurately, a stress gradient) within the tin deposit. This compressive stress drives the preferential diffusion of tin atoms.

Electrostatic discharge (ESD) susceptibility must also be examined. We recommend that the user know the ESD rating for each part and select parts (when possible) to achieve the best ESD rating. The designer should identify all ESD sensitive parts on drawings and mark locations of ESD sensitive parts on the board with the ESD symbol. Finally, the user must be aware that part location, particularly with respect to I/O signals, drives the appropriate ESD rating.

5 PCB Analysis

As the speed and complexity of electronic components continues to climb, the importance of a detailed PCB analysis in the overall design process has become more and more important. The common practice of leaving the vital PCB stack-up design in the hands of the PCB fabrication company's fabrication engineers carries with it significant hazards. A much better approach includes empowering the design team to provide the fabricator with all the information necessary for creating a printed wiring board (PWB) that is fully compliant with the specifications

For example, depending on the product, designers may need to consider the surface finish attributes applied by a circuit board fabricator. The surface finish influences the process yield, the amount of rework necessary, field failure rate, the ability to test, the scrap rate, and of course, the cost. Designers can be led astray by selecting the lowest cost surface finish only to learn that the total design cost is much higher. The selection of a surface finish should be completed with a holistic approach that considers all important aspects of the assembly, including:

- Cost sensitivity
- Volume of product (finish availability)
- Tin lead solder (SnPb) or load finish (LF) processes
- Shock/drop concerns
- Cosmetics concerns
- User environment (corrosion concerns)
- Fine pitch assembly (<0.5 mm)
- Wave solder required (PCB > 0.062")
- High yield in-circuit test (ICT)

5 PCB Analysis (cont.)

This table provides helpful information when you consider surface finish attributes and their performance based on the intended use. The table reveals positives and negatives associated with each finish. Additionally, the application environment and operating conditions must also be considered to ensure the best surface selection.

Surface Finish	Cost	Corrosion Resistance	ICT	Hole Fill	Fine Pitch	Cosmetics	Comments
Imm Silver	Low	Poor	Good	Mod	Good	Poor	Good surface finish for soldering and testing, tarnish & creep corrosion are the weaknesses
HST OSP	Low	Mod	Poor	Poor	Good	Mod	Required pasting of test pads/vias. Difficult to achieve LF hole fill, especially on >0.062 boards.
LF HASL	Low	Good	Good	Good	Mod	Good	Phenolic laminate recommended. New equipment required. Flatness is better than SnPb.
Imm Tin	Mod	Good	Good	Mod	Good	Mod	Solderability/hole-fill may be a problem on double sided PCBs. Shelf life.
ENIG	High	Mod	Good	Good	Good	Good	Galvanic driven creep corrosion canoccur if Cu is exposed. Ni-Sn interface is brittle with LF. Black pad issues remain.

6 Design for Manufacturability (DfM)

When striving for optimal reliability, design engineers must consider the manufacturer's abilities and limitations. Engineers can simulate, test and design for the perfect product, but if the manufacturer cannot produce the completed design or procure optimal materials, design engineers may design a product that cannot be constructed or falls short of reliability expectations.

The DfM review assesses the pad geometries used in the layout to determine long-term reliability. Component placement ascertains the potential for shadowing during either the reflow operation or conformal coating. This action involves analyzing the proximity of parts to PCB edges, press fit connectors and the potential effects of improper ICT fixturing.

Measurement of trace separation assures that the voltage levels applied comply with IPC-2221. Cleanliness and contamination are examined by looking at the fluxes, handling procedures and any other potential source of contamination.

IPC-2221 is a generic standard for printed circuit board design established in 1998. This standard includes requirements intended to establish design principles and recommendations for PCB design.

6 Design for Manufacturability (DfM) (cont.)

Finally, the DfM analysis examines the manufacturing flow by asking several questions:

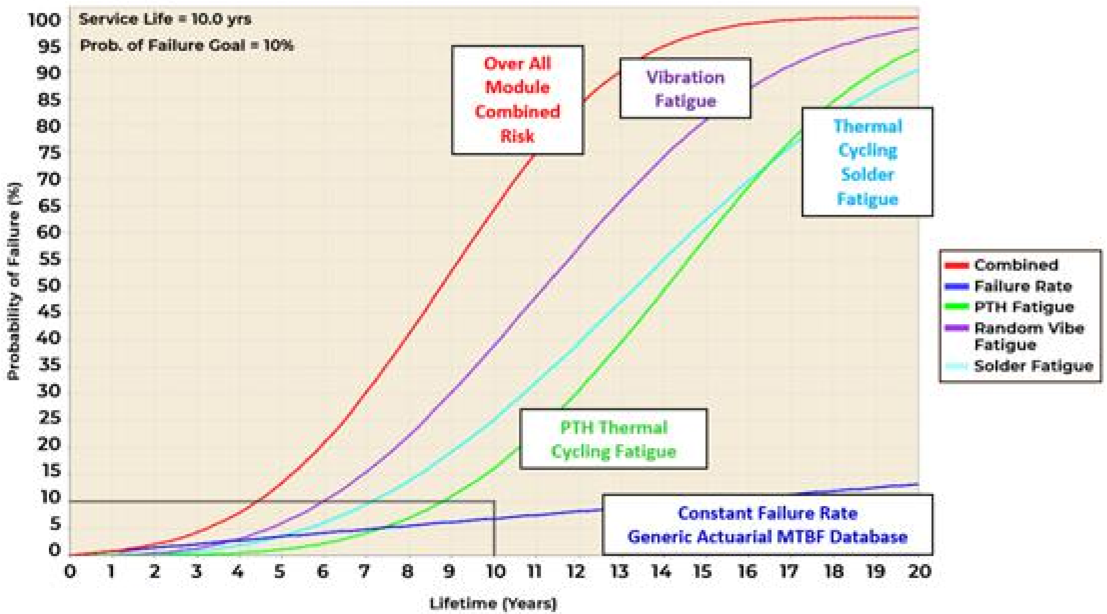
- Does the board use single- or double-sided surface mount technology (SMT)?
- Are through-hole parts used?
    - Are they wave or selective soldered?
- Are any parts hand soldered?
- Are we employing no-clean processing?
- Does the assembly require conformally coating?
    - What type of coating?
    - How does it compare to different thermal environments?
    - Are caustic chemicals in the use environment?
    - How can we apply the coating?

7 Sherlock Automated Design Analysis (ADA)

Virtual qualification evaluates the functional and reliability performance of the product design without physical testing of your product. Specifically, virtual qualification uses computer-aided engineering (CAE) and simulation based on reliability physics analysis (RPA) to model how a product will function under specific load applications.

You can leverage Ansys Sherlock (ADA) at this point in your design review. Sherlock uses a three-phase approach consisting of:

- Data input
- Analysis
- Reporting and recommendations



7 Sherlock Automated Design Analysis (ADA) (cont.)

Sherlock models your product, simulates specified environments to determine potential failures and provides actionable data to improve your product design.

Physical testing often consumes budgets and development time. Simulation allows design teams to understand the functionality of a design without wasting physical components or overusing testing material and equipment. Simulation does not entirely replace physical testing, rather, it limits the dreaded cycle of “test-fail-fix-repeat.”

PoF (Physics of Failure):
A failure analysis typically performed in a research format to identify the ultimate root cause mechanisms and processes that may result in the failure of materials, components and systems.

VS

RPA (Reliability Physics Analysis):
An engineering product development methodology that applies failure mechanisms models and knowledge developed by PoF research to produce failure-free product and systems.

Ansys Sherlock automated design analysis (ADA) software is the only reliability physics/physics of failure (PoF)-based electronics design software that provides fast and accurate life predictions for electronic hardware at the component, board and system levels in early design stages.

8 Reliability Test Plan Development

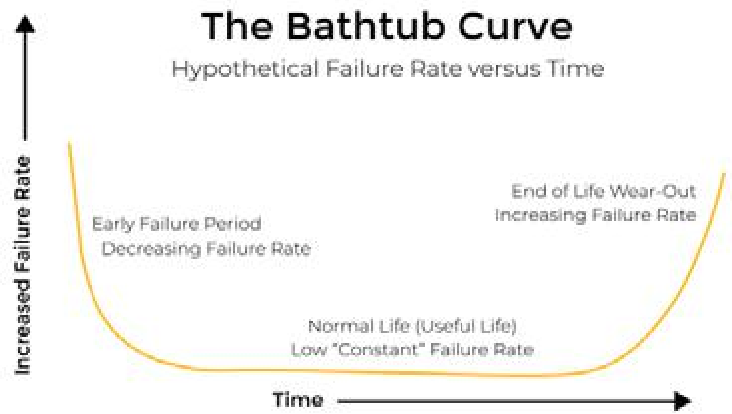
Stress testing assesses your product's ability to maintain a certain level of functionality under unfavorable conditions, such as extreme temperatures or other environmental/physical stressors. Stress tests include highly accelerated life testing (HALT), highly accelerated stress screen (HASS), mechanical shock, vibration, etc., which uncovers weaknesses within a product design much quicker than in the field.

When using stress tests to define operating margins, measurements are taken of operating temperatures (or other specified stress risks) and compared to the ratings of the individual components. If individual components are operating close to their upper limits, then a variety of parts will be tested at various capacities to determine which part will sustain enough margin to prevent early failure.

8 Reliability Test Plan Development (cont.)

Stress tests are important as they can be initiated relatively quickly to assess life expectancy (temperature cycling) and performance under humidity (temperature-humidity-bias) by utilizing a stress level with an acceleration factor that can be translated to the use environment. For example, 168 hours (1 week) of thermal cycling may equate to three years in a field environment. If you complete the 168 hours successfully, you can report that your product will also meet the three-year life expectancy.

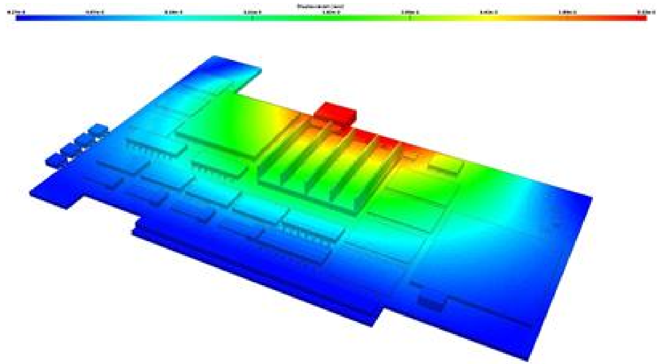
Other tests such as mechanical shock, vibration, salt fog, humidity testing, etc. may also be involved in the development of the test plan portion of the review.



168 hours (1 week) of thermal cycling may equate to three years in a field environment. Using stress tests as part of the design review can significantly reduce time in test and time to market

9 Perform Failure Analysis on Test Failures and Field Returns to Initiate Feedback Loop

When performing failure analysis, it is important to not limit the analysis to assemblies that failed preliminary tests. In such a scenario, the test would only determine what does not work before the product ever hits the field, when your ultimate goal is to determine the reliability of a product in its use environment. Failure analysis should include studying test failures, as well as field returns (if they exist), to accurately understand field environments as well as exhaustively identify use cases that may not have been considered in initial reliability qualifications.



In a design review, failure history can often provide significant insight into the root cause of failure. For example, if failures occur quickly in the field, the root cause may be linked to a manufacturing-related issue. Similarly, if dendritic failures are encountered, it may be a cleaning or handling issue in manufacturing or an environmental exposure issue.

Failures during a testing protocol need to be analyzed so that the root cause can be ascertained and acted upon. For example, HALT testing searches for failure, fixes it and resumes the test. Doing so helps determine the design's margins with respect to the test parameters.

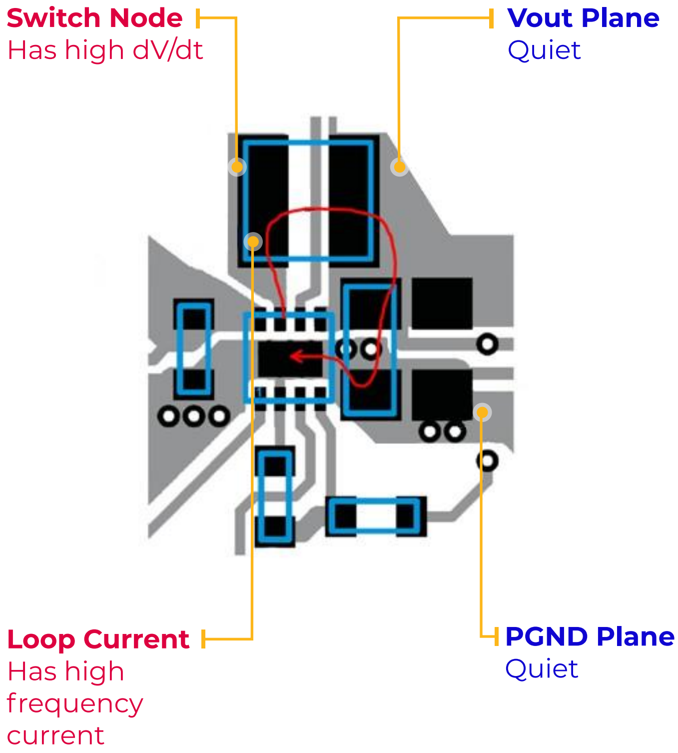
Design Review Examples

Example 1

Ansys has worked with numerous companies to provide design reviews of electronic products and components that help our customers revise their design plans to create highly successful products with longer life cycles.

For example, in the adjacent figure, Ansys determined that a switch node within a client's PCB would capacitively couple to any nearby traces, planes and even the chassis. This occurs when the digital ground plane resides under the switch node, resulting in current that will flow into the digital plane and back to the ground on the power supply integrated circuit (IC), causing the digital ground to be noisy. In addition, the node may magnetically couple into circuits, causing disruption.

Our design review helped our client determine design errors that would potentially lead to product failure. Additionally, we provided key recommendations for improving the overall design plan and circuit layout which included ground plane and signal layer configuration to obviate the crosstalk.



Design Review Examples

Example 2

Also, in another example, we reviewed a circuit board and noticed a number of issues in component placements and material selection, including a solder fillet touching a component body. We do not recommend this as it could lead to non-optimal solder joints and potential component damage during rework. In addition, in Figure A, we do not recommend the use of a glass body MELF due to its tendency to shift and its overall fragility.

The design review helped our client determine whether they would continue using this particular supplier or move to other options.

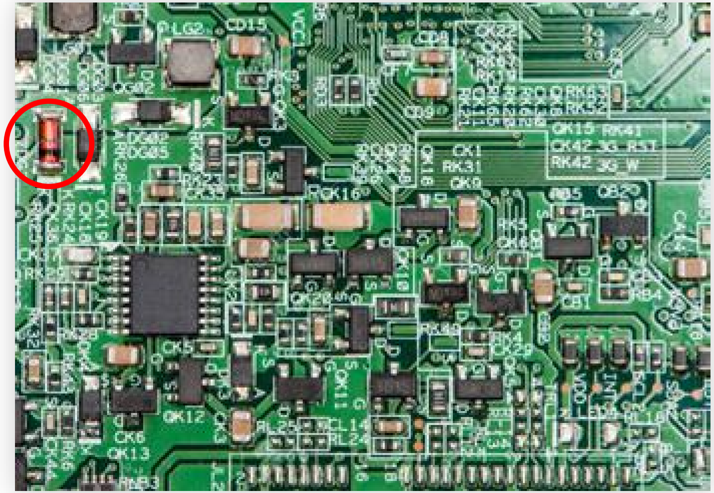
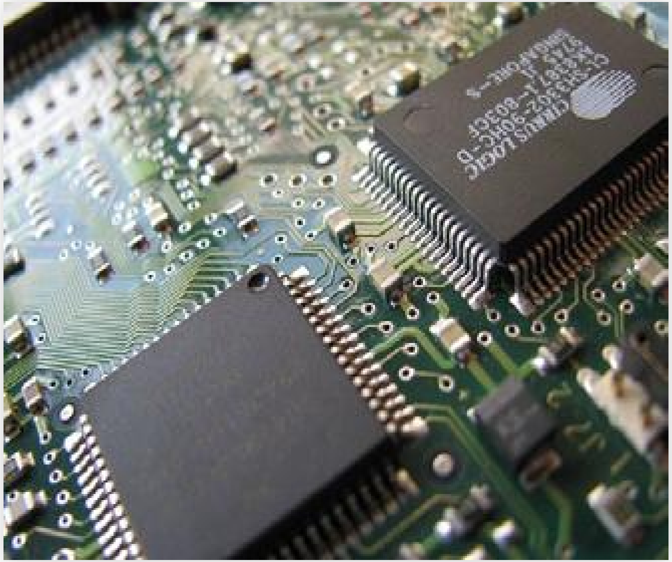


Figure A

Common Design Flaws and Recommendations

Ansys continues to remain at the forefront of the design for reliability sector for over twenty years. As such, we have discovered reoccurring design flaws that impact product reliability.



Common issues include:

- Poor parts procurement
- The BOM review is lacking
- Unreliable derating

Poor Parts Procurement

To achieve a good parts procurement, we recommend observation of ESD component susceptibility in the BOM prior to procurement. This especially applies to the active components on the BOM.

The following should be addressed during the component procurement process:

- Know the ESD rating for each part and select parts (when possible) for the best ESD rating.
- Identify all ESD sensitive parts on drawings.
- Mark locations of ESD sensitive parts on the board with the ESD symbol.
- Be aware that the appropriate ESD rating will be driven by part location.

Common Design Flaws and Recommendations (cont.)

The BOM Review is Lacking

In addition, when examining the BOM, it is important to note if any of the various device types have known reliability issues. For example, parts like capacitors are known to have significantly higher failure rates that the same value-part dielectrics. Similarly, when parts are used in either a calibration or sensing circuit, we often recommend changing resistors when resistance levels are greater than 1 megohm per 1 or more low resistance components..

Unreliable Derating

Finally, Ansys recommends reliable derating for different device types. For example, resistors should be aggressively derated regarding power dissipation, especially for the higher power (1/4W, 1/8W, and 1W) components. We recommend the following: derate to 60% of maximum applied voltage, 70% of steady state power, 80% of peak power and 20C below peak operating temperature to maximize reliability.

/ Conclusion

For a product to be fully reliable, communication up and down the supply chain remains essential. Following industry best practices and knowing reliability standards and specifications continues to be the first step to manufacture a product that will be successful from early design stages to the final product set to go to market.

Performing a formal design review as early in the design phase as possible will drive overall product reliability. The steps provided in this ebook provide insight into the basic design review workflow.

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