

How to Improve your Electronic Product Reliability



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Terminology

- **Durability** = *ability to withstand stresses*
- **Reliability** = *ability to keep achieving an objective (e.g. to function, to avoid getting broken, to avoid showing signs of wear & tear, and/or other similar objectives) based on a designated use case in a designated environment, for an intended period of time.*
- *In this memo, “reliability plan” and “reliability testing” include both durability and reliability.*

0. Introduction

1. What work is involved before creating a reliability plan?
2. During development of a new product: plan for reliability from the start
3. Testing the reliability of a product once its development is near finished
4. Testing the reliability of a product once it is in production
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How to improve product reliability (step-by-step)

Whether you are developing a new product, or you are buying a product manufactured by your supplier, you want to make sure your product doesn't get broken, doesn't show signs of wear & tear, or doesn't fail in its functions, early in its life. That means you need a plan for reliability and durability.

The purpose of this guide is to explain some basic concepts, so you can make the right choices.

1. What work is involved before creating a reliability plan?

Simply said, your product may be in one of these states:

1. Are there any specific, mandated standards to comply with? For instance, you intend to sell mobile phones to carriers (AT&T, Verizon, T Mobile). Those carriers have their own standards (typically 400-page requirements document). You will know what tests to run and what the pass/fail criteria are.
2. Are there international standard(s) to use as guidelines? If you are lucky, some existing standards make sense for your product, such as documents published by ASTM, IEC, ISO, JST, or as a MIL-STD. (Note: not all standards make sense for your application – see [Limitations Of Common Reliability And Safety Testing Standards](#) for an explanation). Again, you know what tests are best to run for your product and what the pass/fail criteria should be. But don't follow an available standard blindly. Modify it to suit your product and use case environment.
3. There is no international standard for some of your testing needs? In this case, you must work with an experienced reliability engineer or an engineering service provider that has their own library of standards and or can develop a customized reliability test case to meet specifically your product's testing needs.
4. Your product is new and unique? In this case, there may be no standards available to use as a guideline for reliability testing. Therefore, there is no other option but to have the reliability engineering team create a reliability test plan from scratch.

Are you in situation number 3 or 4 above?

In cases 3 and 4, you need to do some work:

- Describe the environment(s) in which the product will be used – for example “all over the USA, from Florida to New Mexico to Alaska, and it will be used outdoors in all 4 seasons”.
- Describe the use case(s) environment and conditions – for example “the automatic lawn mower will be stored in a garage; it will be deployed on average 40 times during the year, to mow a lawn covering up to 3,000 square feet all in 1 go each time; the grass will not be taller than 5 inches; the terrain will be flat with a few holes and bumps of up to 1 inch.
- Be as specific as possible, this way the test plan’s pass/fail criteria will be appropriate for your product.

(Note: We have worked on a template for collecting the basic information required. Please ask us for that template, if that would be helpful to you.)

Having had the required information, a reliability engineering service provider can then work on customizing an overall plan (including a test plan) specific to your product needs. For more details, see [Do You Need a Customized Reliability Test Plan?](#)

2. During development of a new product: plan for reliability from the start

Many design teams focus on getting to their next milestone ASAP – for example “getting to a functional prototype”. This is sometimes at the detriment of product reliability and product compliance.

For example, skipping reliability testing altogether or forgetting reliability test cases that reveal the most important failure modes critical to reliability. They might also pick Critical to Quality components without asking for reliability test results, or without looking for pre-certified parts, or without running a pilot run that includes the new unique components. When is the right time to start testing components, and the whole product, for reliability? Testing usually makes sense once a functional Proof of Concept (POC) prototype is ready.

The idea, at this stage, is generally to test to failure to evaluate the design limitations (including the components and material, the manufacturing process, the product features...).

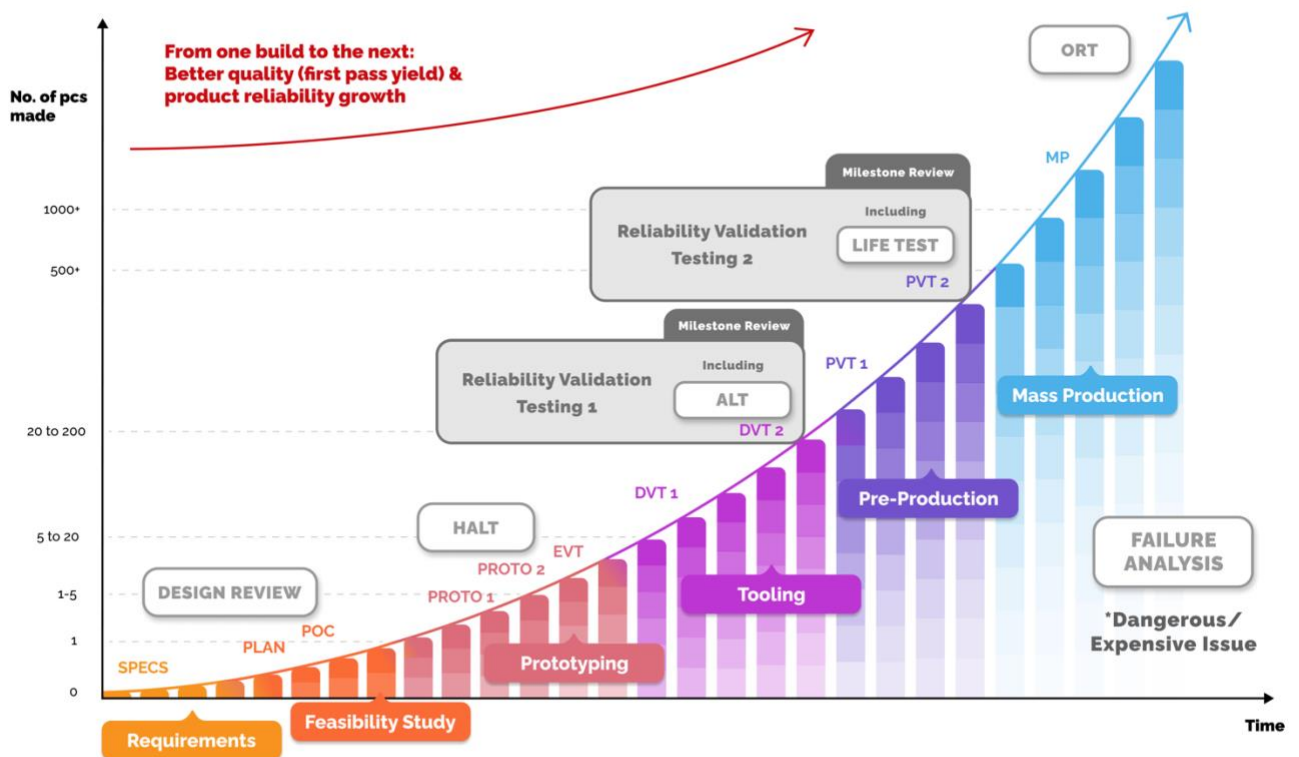
A detailed and thorough reliability growth program will consider all aspects of reliability, including quality. This would, for example, include but not be limited to DFMEA (risk analysis on the design), DFX reviews during design, Reliability Test Case development and Reliability Test Plan Creation; Reliability Life analysis, MTBF and Weibull analyses, Reliability Block Diagram, Reliability Allocation, Parts Count, Reliability Prediction, Availability Analysis, Warranty Analysis, CTQ Components Reliability Test and supplier audits and qualifications, etc.

These are just a few of the services that may be available from a reliability engineering service provider to consider. Some of the tests that may be very useful are HALT/HASS, Controlled and Random Drop Test, Temperature and Humidity and Vibration tests, among others. A good reliability engineering service provider has experience with various product types and they understand how to, for example, determine what temperature or what vibration level (gRMS) or what number of drops is suitable for your product to reveal issues in design or manufacturing, so that you can produce your product knowing that at least your product design is solid and it was designed with reliability in mind.

To simplify, there are two ways to do this. Design teams generally pick one of them.

Comparison of typical reliability tests during the NPI process

Test Approach	Highly Accelerated Life Test (HALT)	Accelerated Life Test (ALT)	Life Testing
Summary	Applying high levels of stress to learn quickly about the limits of the product	Relatively quick accelerated test with high stresses	Broader test that is relatively representative of expected usage
Typical duration	24 hours per sample	1 to 10 days	3 to 15 days
Main objective(s)	Find the product design limitations relatively early so that the design can be improved as necessary	Check if there are still high-impact failures (e.g. safety issues), quickly, before shipping the production	Understand the way the product will behave in normal operating conditions (i.e. expected usage)
Often used when	Early prototyping stage, on components or on the complete product, to find design deficiencies or component latent failures	Product design is past the early prototyping stage but is less mature (early DVT)	Product design is near maturity (late DVT and/or PVT)
Can estimate MTBF?	Usually not.	No straight relationship between the parameters of this test and the length of time of expected usage by real users	Yes, leads to an estimate of the average time to failure; typically requires many samples
Price for simple products	About 150 USD per part per hour per sample	500 to 2,000 USD typically (for a whole product)	2,500 to 8,000 USD typically, and more samples needed



a) HALT (Highly Accelerated Life Test)

HALT testing is a very common test for electronics. It includes a combination of temperature & humidity cycling, vibrations, and other stresses relevant to the product use case & environment. HALT is used to find a product’s limits concerning temperature, humidity, vibrations, over voltage and over current conditions, and any combination of those stress factors.

The objective is to find the deficiencies of the design, so that the next iteration and the next build are more reliable. The HALT test would not necessarily be appropriate for products, for example, the size of a pen or a pencil; although you may be able to vary the vibration frequency to check for issues resulting from resonant frequency. Typically, HALT is best for products as big as a mobile phone or larger; best for products with multiple PCBAs and modules and many components.

b) ALT (Accelerated Life Test)

ALT is a reliability engineering technique used to predict a product's lifespan by exposing it to extreme operating conditions. The goal is to identify potential failure modes, estimate product reliability, and ensure it meets its expected service life under normal conditions.

Purpose of ALT

- Identify Failure Mechanisms: Helps detect weaknesses in design, materials, or manufacturing processes.
- Predict Product Lifespan: Can estimate the Mean Time to Failure (MTTF) or Mean Time Between Failures (MTBF).
- Reduce Testing Time: Instead of waiting years for natural failures, ALT accelerates the process in weeks or months.
- Optimize Maintenance & Warranty Planning: Provides data for proactive maintenance schedules and warranty policies.

c) Life Testing: to estimate the MTBF (Mean Time Between Failures¹) value

It includes several tests, and it typically lasts for about 1 month to gather enough reliability data to calculate the reliability life and MTBF estimate. The more samples are tested, the more realistic the information would be. Best sample size would be 100 units, but we all know this is not always possible.

Reliability life testing is a very detailed experiment, and it requires a dedicated test team and dedicated lab equipment for a long period. For example, a 500-hour test will take 20 days plus 10 days in between for various tasks; it also includes preparation for the test, reviewing results every day, tracking results, and reporting results.

This is an expensive test. However, the results could be extremely useful for certain products, for example, medical devices, military products, automobile components, or wherever critical failure cannot be allowed in the product's life.

The main objective is to provide an estimate of the average lifetime of the product. If that average lifetime is not satisfactory, the design team needs to implement changes in design and hopefully, the next build of the product will be more reliable (as shown by a new set of reliability tests).

It is important to keep in mind that to have a reliable product, you must have a reliable design. Reliability tests can only expose reliability issue(s) but will not fix those issues. Design and development teams must evaluate all reliability failures in detail and make a decision based on the product and customer requirements, if any or all of the failures need to be fixed before high volume production.

¹ Assuming no repair, this is the average duration of use until failure occurs.

3. Testing the reliability of a product once its development is near finished

Once you are near the end of the development phase of the product, for example, the last build before production, you need to do one final reliability check on the product. This is typically called Reliability Validation Test (and some companies may also call it Reliability Verification Test). At this stage of the development process, you are trying to confirm that the product meets the intended reliability goal.

The focus switches from “how to improve the design, while we are still working on prototypes?” to “let’s make sure there won’t be serious issues once we work with components made with the same processes as mass production”.

The typical approach at this stage is to make sure that you do reliability testing on the whole product. The validation test is different from earlier testing. There are no tests to failures. There are no component tests.

At this stage you want to purely test the product against its performance specifications and reliability goals. The reliability standards used, the number of samples tested, and the custom test cases that were designed make up the final validation results, which, if done correctly, should deliver results near the target goal(s).

Of course, if you do NOT meet the reliability goal at this stage near the start of production, that is not a good thing. In this case, you must look into certain things:

- First, look for changes in the test process, which may have led to not meeting the reliability goals. Were any test cases changed? Have the conditions in the test cases changed? Was the test equipment or the procedure changed?
- Next, you need to check if any supplier components or other supplier quality issue was the root cause of the poor results.
- Last, was there a manufacturing issue that prevented the reliability goal from being met?

Do not move forward until these questions are answered. Then, decide if there is time to fix before moving to production, or phase in the changes as the production continues.

If there were NO reliability tests done during the development and the product is already in production, then it is expected that you will see a certain amount of production failures and perhaps returns from customers.

Most often is the case where you try hard to conduct a sustaining effort on the returns, which is a very costly thing to do, but you would have no other choice at that point if you need to continue the production.

Let's take an example. Let's say that a product needs to be designed for 3 years of life (or Warranty limit) to be able to survive in a specific use case environment. That's the reliability goal that was set during the development.

In the product development phase, engineers created specific test cases based on certain assumptions (such as how many cycles of usage per year, what heat and humidity, on what terrain, and so on). Now, we will test the product for the lifetime of 3 years while replicating the specific use case environment to ensure what was planned as a reliability goal is now achieved.

For many of these test cases, there is a need to have clear pass/fail criteria so that the reliability team understands what a failure is clearly. If a failure is unclear or there is a borderline failure, the engineering team needs to make a decision.

In many cases, there is an international standard, and it may make sense to follow it. Here are some examples:

- The artificial sweat test can be done as per ISO 3160, which calls for 24 hours of exposure of the product to the test chemical.
- An abrasion test can follow the ASTM F 2357 standard, which calls for 200 cycles.
- Some other test protocols are based on industry experience – that's typical of temperature & humidity cycling tests.

In all these cases, it is of course possible to run the tests for longer than the international standards call for, but it is generally not necessary, at least for consumer goods or other products that don't call for very high reliability. Remember, the objective is to detect serious issues in this phase. This is not lifetime testing as described in the previous section of this memo.

4. Testing the reliability of a product once it is in production

Once development is over and mass production starts, the focus switches from “let’s try and catch any serious issues on this design as it goes into mass production in general” to “in this specific batch, in case there are variations in some of the components or processes that can lead to very serious issues, let’s try to catch them early before shipping the product”.

This type of reliability testing is called **Ongoing Reliability Test (ORT)**.

The samples picked for ORT are tested to spec, not to failure. Special effort is given to reducing the sample size, to limit the cost of this testing, but also to increase the speed of screening production units for reliability since this is carried out during each production batch.

If a reliability plan was developed during the product development, and there is a change in a component or a process, it may call for an adjustment to the on-going reliability plan. In most cases, running ORT again is sufficient to provide assurance about the subsequent production batches.

5. In the long term, keep refining your reliability plans

Established brands that take reliability seriously tend to refine their own standards, based on data:

- 1) They collect statistics about complaints, returns, and other feedback from the market, such as online review scores.
- 2) They classify that feedback by nature of the problem, and they study the trends:
 - a) Is the proportion of reliability-related issues going up or down?
 - b) Which of our products seem to have the most reliability-related issues? Why? (It may be due to a different marketing positioning where customers have higher expectations.)
 - c) How do the numbers vary by geographical area, by segment of customer...?
- 3) They do a triage on the returns, categorize them, and understand if most of the failures are related to design, component/supplier or manufacturing issues. A sustaining team typically is dedicated to resolving the field-related returns issues, which includes RMA and customer feedback.
- 4) They compare the reliability test results to the market feedback, and they decide if the test standards are adequate or if they need to be modified.

If, for example, they keep getting returns based on a specific failure, let's say products fail in Hawaii, but work fine in Alaska. In this case, they may need to review the product temperature and humidity testing from the development history and determine if the temperature and humidity limits set were appropriate for operational environments for *both* Hawaii (Hot and Humid) and Alaska (Cold).

6. Special case: Starting to work on reliability for a product which is already produced

This is not an ideal situation, but reliability planning & testing can still be of great help.

If NO test to failure (TTF) was done during the development on components and or on the whole product, and if the product was not designed with reliability in mind (DFR), then it could have an impact on product reliability in production.

In this context, reliability test results will show what users are likely to experience in the first few years of use of the product, but they will NOT be able to confirm how long the product will last.

When there is no history of reliability testing during the development, it is very difficult if not impossible to predict what the product performance will be in the field, unless you do a lengthy and expensive test (see “life testing” in a previous section), you gather data and determine if the current product is in line with the product reliability goals.

For example, let’s say no test to failure was done. Now, the product is in production, and the team finds out that the color changes on the painted covers when exposed to relatively high temperatures. Or a certain component from a certain supplier fails. Or a plastic part starts cracking in the field within a few months.

All of these can be prevented if a detailed reliability testing was conducted during the development phase.

Reliability Testing Plan for a Fully Developed Product in Production

Given that no reliability testing was conducted during development, we must take a proactive approach to evaluate and improve the product's field performance.

The goal is to identify weaknesses, estimate failure rates, and implement corrective actions to extend the product's lifespan and reduce failures in the field.

Step 1: Establish Baseline Reliability Metrics

Before starting tests, collect and analyze existing field data to understand common failure modes:

- Warranty claims & repair data
- Customer complaints & returns
- Failure analysis from defective units

If no structured field data exists, start tracking failures now to measure Failure Rate.

Step 2: Reliability Testing for the Existing Product

1. Test to Failure (TTF) – We are trying to discover weak points

Since no TTF was done in development, conduct accelerated stress testing to identify primary failure mechanisms.

Tests you can run:

- Highly Accelerated Life Testing (HALT) – Push the product beyond normal operating limits (temperature, vibration, voltage) to uncover weak points.
- Accelerated Stress Testing (AST) – Similar to ALT, however with higher stresses - Expose the product to stress levels expected over years of use in a short timeframe.
- Step-Stress Testing – Incrementally increase stress (e.g., temperature, load) until the product fails to determine weak components.

This will help you:

- Find failure thresholds
- Identify design or material weaknesses
- Prioritize improvements to increase field reliability

2. Environmental & Mechanical Stress Testing – Identify Real-World Issues

If the product is exposed to extreme temperature, humidity, or mechanical stress, run the following:

- Temperature Cycling

- Thermal Shock
- Vibration & Shock Testing
- Drop & Impact Testing

3. Component-Level Reliability & Supplier Quality Validation

If certain components are failing in the field, conduct supplier and component quality verification tests:

- Solder Joint Fatigue Testing
- Material Degradation Testing – Check plastics, paints, adhesives under UV, high humidity, chemical exposure to replicate long-term degradation.
- Accelerated Aging & Corrosion Testing

If failures are component-related, then:

- Audit suppliers
- Set minimum component qualification criteria
- Enforce strict incoming inspection processes

4. Functional & Electrical Reliability Testing such as:

- Electrical Overstress
- Over voltage and over current tests

5. Field Failure Replication Testing

If customers report specific failures, replicate them in a controlled environment to find root cause.

Examples:

- If a painted cover fades under high temperature, conduct UV & heat exposure tests to accelerate wear.
- If a plastic part cracks, use tensile testing & thermal cycling to evaluate material durability.
- If a circuit fails after months in use, conduct HALT and burn-in testing on returned units.

Step 3: Implement Corrective Actions

1. Design Improvements

- Reinforce weak materials
- Modify PCB layout
- Add conformal coatings

2. Manufacturing Process Improvements

- Tighter quality control on suppliers
- Enhanced soldering & assembly processes
- Automate functional testing

3. Proactive Field Monitoring & Data Collection

- Collect and analyze customer complaints in real-time.
 - Track RMA trends
-

7. FAQs about reliability for developed products in production

Here are frequently asked questions about this special case.

a) Is it still possible to calculate an estimate of the average lifetime of the product?

Yes, lifetime testing with an MTBF calculation is possible at this stage. As we wrote above, it is expensive and necessitates many samples.

b) We buy an ODM product, we ask the supplier to make slight changes on the product. The supplier gives us no information about reliability. What to do?

You can still run reliability validation tests, with the limitation that we mentioned earlier in this section. If there was no history of development reliability, then there is always a risk that the reliability validation tests done at this stage during production, can be too hard and produce more failures or cause false failures than acceptable, or be too passive and not catch any of the potential problems.

Only an experienced reliability engineering team can develop a reliability test plan that is appropriate for the product with a certain confidence level.

And you can still run lifetime testing with an MTBF calculation, and it tends to be much more expensive, as we mentioned in a previous paragraph.

c) What if we observed relatively high (i.e. good) product reliability when it was made by factory A, and now we have decided to change the production to factory B, with possibly some changes in components and processes. How will this impact the reliability of the product in factory B?

Every time you have made any major changes to components or manufacturing processes, the newly produced product by factory B must be retested to ensure that the main performance specifications are still within acceptable specification limits.

Next, the reliability and compliance team must retest the full product to the exact same test plan that the previous factory A product was tested for to ensure there were no failures as a result of these changes (we described the Reliability Validation Test in a previous section).

Finally, all those failures must be analysed at the root and all failures must be fixed to return the product to its acceptable performance and acceptable reliability status.

d) What if we observed relatively low (i.e. bad) product reliability when it was made by factory A, and now we have switched the production to factory B, with new components and/or processes, to improve product reliability?

In this case, you are doing the right thing. Unfortunately, the product reliability

implementation may take a while until decisions are made and design has been modified and components and suppliers have been changed or improved; by then you have either decided to shut down production until these changes are finalized, or you are still producing and will still have returns and customer dissatisfaction. (Or you are screening all products before shipping, which is very costly.)

e) What if we want to compare our product to a key competitor's product, as far as reliability is concerned?

This is good practice, to give you an idea of how your product compares in performance and reliability. However, you must be able to create a reliability test plan that keeps in mind the best-in-class performance in reliability and test accordingly.

Only under those conditions, you may find out that perhaps your product performance in reliability is better than your competition.

Case in point, recently we created a detailed reliability test plan for an electronic router product, and we also tested similar samples from their competition. The results surprised our client, as their improved product performed much better than their competition under the same reliability test conditions.

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