Managing for Quality in the Electronics Industry

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Abstract

The quality of electronic products is a combination of numerous attributes, including defect level, reliability, availability, appearance and ease of use. Product developers and manufacturers strive to maximize the performance level for the quality attributes that are most critical for a product's intended applications, while optimising the overall product quality. This paper will discuss methodologies used to achieve high quality electronic products, and the measurements used to define and distinguish product quality levels.

I. Product Quality

Many different attributes are used to describe the quality of a product. A customer with a new electronic product may place their attention initially on whether the product is defect free and has no cosmetic flaws. Next the attention is on how easy the product is to use and whether the product functions correctly. As time passes, a customer will add reliability and availability to their assessment of the product's quality level. If the product does fail, the timeliness of repair is yet another quality factor. All of these attributes contribute to the overall quality experience.

A. Quality Life Cycle

The typical life cycle of an electronic product can be expressed as follows: design, manufacture, deployment, useful life and end of service. During the design, manufacture and deployment phases, defect prevention and elimination are essential so that the product can enter the useful life phase as defect free as possible. During the useful life phase, the product must demonstrate levels of reliability and availability necessary for success in the application where the product is used. The product also needs to remain reliable for the expected life span, through the end of service phase.

This paper will introduce the reliability, availability and defect level quality attributes that are key factors during the product's life cycle. How these quality attributes are interrelated, metrics used to assess performance, and methods to drive improvement will also be discussed.

II. Reliability

Reliability is an expression of the probability that a part or system will function without failure in a defined environment for a designated period of time. The objective is to design and manufacture products that will continue to function with minimal failures for the intended life span of the product.

A. Reliability Metrics

The failure rate of a product model or grouping is the average number of failures per unit of time. The mean time between failures (MTBF) is the reciprocal of the failure rate, or the average amount of time between each failure. Failure rate and mean time between failures are usually applied to products that will be repaired and returned to service after a failure.

Mean time to failure (MTTF) is a better metric for a product that is usually not repaired upon failure, such as a light bulb. MTTF indicates the average amount of time a product will function before failing.

B. Return Rate Trends

Many types of electronic products will have a failure rate versus time trend that approximately fits the standard bathtub curve. The bathtub curve portrays that a product tends to have a higher failure rate initially, followed by a steady state failure rate during the bulk of the product lifetime, with an increasing failure rate due to wear-out late in the product's life. Because of the declining return rate during the early stage of the product's life, the observed MTBF appears to increase as time goes by. Early life failures resulting from the presence of latent defects contribute to the higher initial return rate, while the inherent failure rate and inherent MTBF tend to remain relatively steady over time. If the product is designed with sufficient operating margin and is manufactured defect free, then the latent defects are minimized and the observed failure rate will approach the inherent failure rate much sooner.

When tracking actual return rate trends, the observed return rate and MTBF often do not accurately represent the inherent MTBF of the product. Because of the effects of escaping defects, application problems, material variability, etc., the observed product return rate is higher than the inherent failure rate. By taking steps to prevent and eliminate product defects, the observed failure rate can be significantly lowered, often with no change in design.

C. *Reliability Testing*

Since it will often take years of actual field usage to demonstrate a product's reliability, developers and manufacturers have created tests to check the reliability of their products. Accelerated life test (ALT) is a process by which products are subjected to stress factors to simulate normal product life, but in a highly compressed time period. By exposing the product to extremes in temperature, humidity, voltage, vibration, etc., combined with power cycling and other operating tests, several years of normal product life can be compressed into a period of weeks.

By defining acceleration factors, such as 1 week of ALT testing simulates 1 year of normal product life, an ALT test cycle can be structured to provide a demonstrated level of expected product reliability, or MTBF. ALT reliability prediction accuracy and effectiveness is improved over time by correlating the ALT results with actual observed field reliability. The ALT test conditions are adjusted to best match the tested and field results, and also to better expose reliability problems that may have passed prior versions of the test cycle.

Environmental design validation testing (DVT) is similar to ALT. The intent is to stress a product using extreme environmental conditions in order to expose potential design, manufacturing, or material deficiencies. Environmental DVT is used to validate and improve the product, but is often not used to predict a specific reliability level.

III. AVAILABILITY

Availability is the probability that a product is operational at a given time. Availability is often expressed as a number of nines, such as 5NINES, or 99.999%.

A. *Availability Metrics*

Under steady state conditions, availability can be calculated by taking the mean time between failures divided by the sum of mean time between failures and the mean time to repair (MTTR).

Availability = MTBF / (MTBF + MTTR)

This relationship can be plotted as shown in Figure 1. This graph shows that in order to increase the availability of a product or system, either the average time between failures must increase or the average time to repair a failure must decrease.

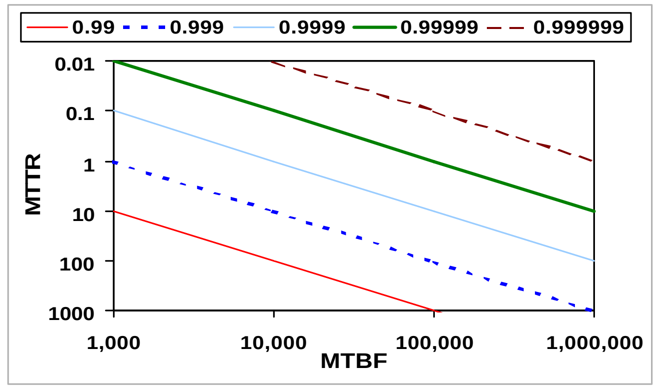

Figure 1: Number of Nines Availability

B. *Improving Availability*

The most obvious means of increasing product availability is to increase the reliability of the product. But even with very high reliability products, this alone may not be sufficient or the most cost-effective means of achieving a targeted availability level. For example, assume a complex system has 50 major modules, such as circuit boards, power supplies, fans, hard drives, etc. If each module has an expected MTBF of 500,000 hours, the overall system MTBF drops all the way down to 10,000 hours.

One approach to drive the system MTBF up to much higher levels is to design in redundancy, such as using 3 cooling fans when 2 fans are sufficient to maintain system operation. With this redundancy, if a single fan fails, the overall system does not fail. As long as the faulty fan module is replaced prior to a second fan failure, the system remains operational. Therefore, the system is fault resilient to that failure mode and the system level MTBF is greatly increased.

Another means of increasing availability is to design the product so that repair can happen in a short time period. Referencing Figure 1, the plot shows that for a given MTBF, the lower the MTTR, the higher the availability (number of nines). For example, using the system product previously noted, if the faulty fan replacement can be done with a brief power down and reboot cycle, then the time the system is unavailable may be only 10 to 20 minutes. However, if the fan can be replaced with the system still operational, or hot-swapped, the unavailable time may approach zero.

IV. DEFECT LEVEL

Electronic product developers and manufacturers strive to design, manufacture and deliver defect free product. In this section, the focus will be on the prevention and elimination of defects during the manufacturing cycle.

A. Defect Metrics

An excellent metric for tracking product quality through the manufacturing process is total defects per unit (TDU). Total defects account for all defects found throughout the entire manufacturing process and the number of units is the quantity of product manufactured.

TDU = Total Number of Defects / Number of Units

B. Delivered Defects

Tests and inspections are not 100% effective in finding every defect. When products contain defects as a result of variability in the materials used to build the products or variability in the manufacturing processes, most of these product defects will be detected by effective test and inspection, while some of the defects will escape the manufacturing process and be delivered to customers.

Delivered defects are proportional to the total defects found during the manufacturing process. By reducing the variability in manufacturing, the number of defects created is reduced, which will also reduce the number of delivered defects. Reducing the number of delivered defects will reduce the early life failures, which will lower the return rate and increase the observed product reliability.

C. Variability

Design for Manufacturability (DFM) is a method used jointly by designers and manufacturers to ensure that a product can be consistently manufactured. By knowing the normal variation within manufacturing processes, designers can create products that have adequate design margin so the product can be manufactured with fewer defects and lower cost. Statistical Process Control (SPC) is widely used to track process variation and facilitate efforts to reduce the variation. Reducing the process variation improves the ability to manufacture defect free product.

V. SUMMARY

Managing for quality in the electronics industry spans the entire life cycle of the product. Figure 2 shows a common product life cycle and how the quality elements fit together across the life cycle. Start with a robust product design that is manufacturable, reliable and repairable. Reduce variability in the materials and manufacturing processes to ensure consistent results and to eliminate latent defects and early life failures. Plan to achieve availability targets through a combination of reliability, fault resiliency, redundancy and repair time management. Use quality metrics to track performance throughout the life of the product and continuously drive for improvement.

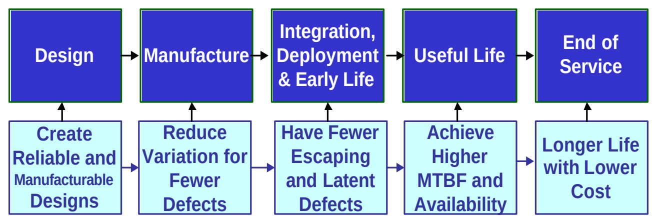

Figure 2: Quality Life Cycle

In summary, the overall quality objective is to provide the customer a defect free product that is available for use throughout the intended life span of the product. To accomplish this objective, product designers, manufacturers and service providers use a wide range of quality techniques to improve product quality and metrics to assess quality performance.