What is a Product's Reliability Strength?

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What is a Product's Reliability Strength?

- Too strong = waste of money, uneconomic.
- Better than just good enough = medium risk, Fit-for-purpose.
- Today's ceramic hermeticity can be just below good enough.
- Most of today's standard commercial components are better than good enough, some are not.

The challenge is to distinguish which and this requires evidence.

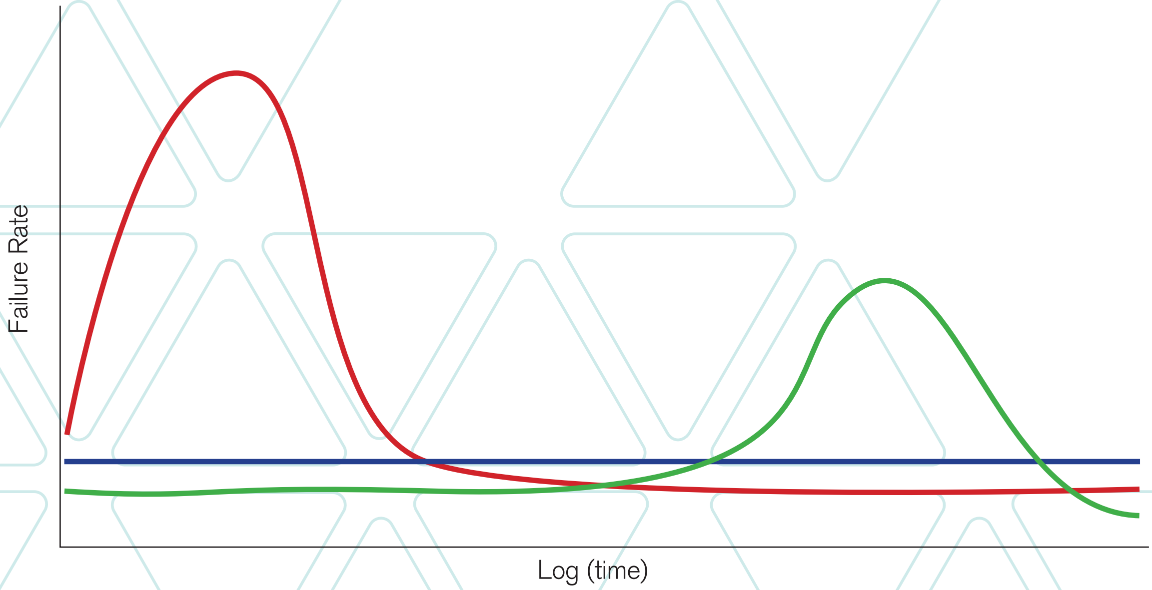
The following Brief Tutorial helps guide us towards the answer:

The reliability of electronic equipment has improved many fold over four decades. It is now so good that many take the continuous functioning of equipment for granted. Good reliability has not come about by accident, but by intelligent work by many engineers and scientists. Continuous improvements and controls are required to ensure that reliability levels continue to improve, and not deteriorate. However, occasional failures do still happen, and means to predict reliability, analyse failures, and reduce the failure rate, while still producing product economically, is vital. Reliability and reliability engineering is one of the primary means of achieving these capabilities.

Reliability Regimes: refer to the different (and independent) failure rate behaviour obtained over the whole life of a system. Acceptable levels are dependent on the requirements placed on component reliability at each stage of the system life cycle. The failure regimes are: Infant Mortality, Random Failure and Wearout.

RELIABILITY REGIMES

Reliability testing and/or modelling is required to assess either component or equipment reliability and feed back information either for corrective action in design or manufacturing, or forward to system design to estimate system reliability. Different types of testing are required to obtain information on the different reliability regimes.



Infant Mortalities (red curve) arise due to weaknesses or faults in manufacturing processes. Early detection and feedback should be applied to improve manufacture. Infant mortalities are least expensive to repair if detected prior to installation in equipment or deployment in the field, each of which can be detected by "burn-in" and "environmental stress screening" (ESS) respectively. Failing adequate detection of faults at the component or board level, the cost of repair would be orders of magnitude greater at the system level.

Because burn-in has no defined acceleration equation, the only genuine 'acceleration' of infant mortalities is achieved by using the worst case operating stress conditions for a suitable short duration. Typically, burn-in for Hi-Rel is conducted at 125ºC for 168 hours. Continuous measurement during burn-in provides many advantages including: comprehensive diagnostic testing, soft error screening, and tailored burn-in. ESS for circuit board assemblies for Hi-Rel is typically conducted by thermal cycling for 20 cycles from -10ºC to +70ºC ramped at ±10ºC/min for 20 cycles.

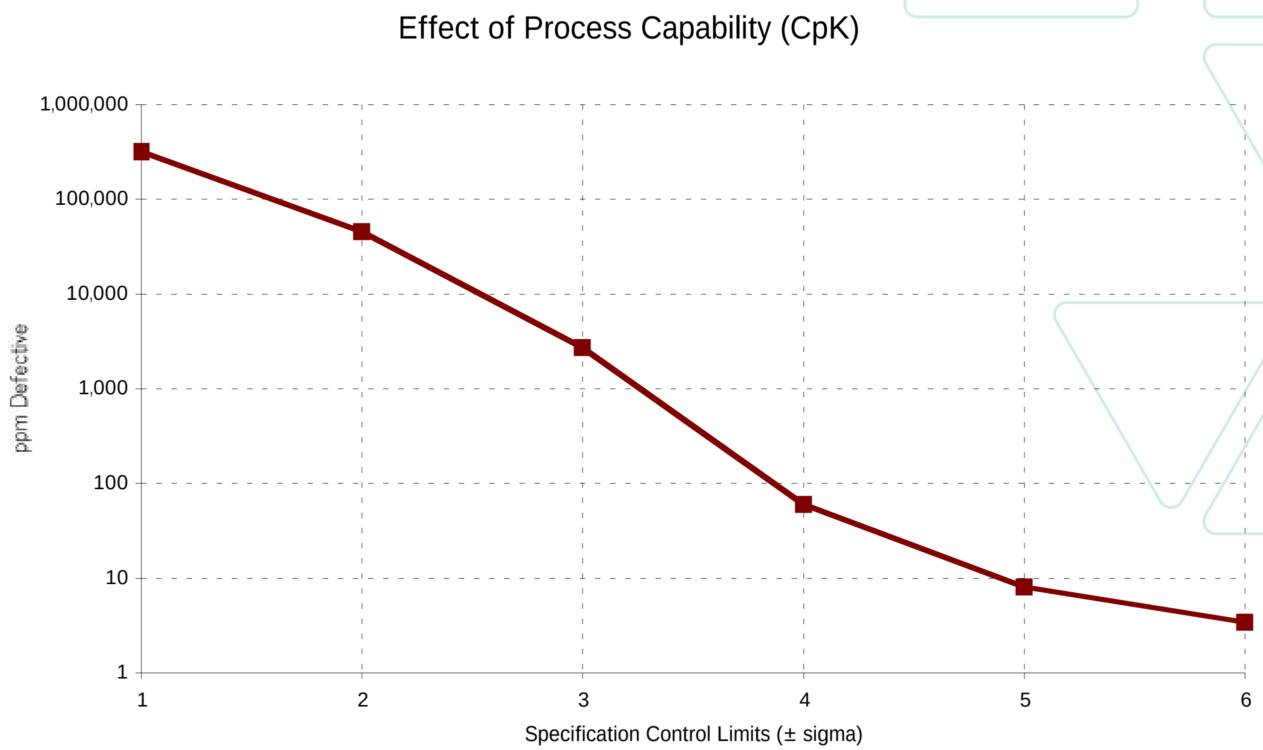
Random Failures (blue curve) arise from random weaknesses in process control. They occur throughout the life of a system, and at one time placed the greatest logistic burden on field maintenance for terrestrial systems because the component failure rates were measured in percentages. Indeed the "lot acceptance" and AQL (acceptable quality levels) approaches were contributory to this problem by failing to strive for higher standards. At that time, component defect levels of 8,000 ppm required massive support with many repair sites, people and fleets of vehicles. The high materials, people and logistics costs were major contributors to operating costs. Therefore, technology solutions — to modernise — and radically new relationships with suppliers to deliver high reliability solutions, were necessary to remain competitive and also increase market opportunities.

Acceptable random failure rates are specified by major electronics systems and service providers, such as BT, and are based on economic operational and maintenance costs. These are calculated on the basis of cost effective service provision and requisite maintenance operations. [Having massively reduced its maintenance workforce, the UK telecommunications company initially calculated its component reliability requirement from its assessment of the target system reliability of its modern electronics switching and transmission systems and the maintenance logistics costs (diagnostics, repair or replacement)]. In common with other modern electronics systems requirements, the required failure rate for high reliability (Hi-Rel) is less than 10 FITS (failure unit; 1 FIT = 1 failure in 109 hours) corresponding to a Mean Time To Failure (MTTF) of 10^8 hours. In order to generate statistically meaningful data, it is necessary to obtain failure rate data from 10^{10} device hours. Such data may not be generated in laboratories, because of the prohibitive costs of the components, equipment and duration. Such data is only obtained where such numbers of devices and durations are combined, i.e. in operational use in the field.

Already, infant mortalities are down to 50 ppm and 1 year warranty field failures are down to 10 ppm. TVs now have 5 year warranties, cars have 15,000 km intervals between services and are responding to legislation requiring 10 year lifetimes (no more built in obsolescence and consequent environmental pollution), telecommunication companies procure to legal contracts embodying performance based requirements, and have halved the number of their maintenance personnel. The latest approaches are based on service levels to be provided to the customers, which necessitate the calculation and specification of required system failure rates, with the onus of obtaining components of acceptable reliability now placed squarely on the equipment manufacturers. The random failure regime is bounded by infant mortalities, which have a decreasing failure rate, and wearout failures which have an increasing failure rate leading ultimately to total system failure. These boundaries determine the "Useful Life" of a system which is specified by the service provider to be the duration during which the failure rate is below the Required Failure Rate. Thus, by definition, the random failure rate must be below the required failure rate.

Wearout (green curve) is inevitable, although failure due to basic silicon inter-diffusion mechanisms in active devices may take millions of years at room temperature. Component wearout is dependent on the design and choice of materials and technologies, which can contribute to longevity either by prolonging or shortening life. For example, silicone encapsulation chemisorbed onto an IC surface can safeguard reliability by preventing leached contaminants and moisture forming ionic monolayers of water at the surface of the semiconductor. Silicones add further benefits for space and terrestrial applications by attenuating alpha particles. Wearout failures can either be catastrophic or be defined as 'the onset of the failure rate which exceeds the "Required Level"' when the system becomes non-maintainable or, in the case of a space system, when the safeguards themselves will have worn out. If the random failure rate is required to be below 10 FITS, then the wearout lifetime can be defined as the time at which component failures reach 10 FITS. Typical lifetimes are now 5 years for consumer, 12 years for industrial and 20 years for Hi-Rel applications.

Both infant mortalities and random failure rates benefit from good quality control practices. Advanced statistical process control (SPC) methods at the component level result in a high yield and improvements also in random failure rates. Improved automation and the use of in-line vision systems in board level processing and assembly also results in improved product quality and lowered infant mortalities.



However, wearout failures are more dependent on technology choices and design rules. For example, 6 sigma controlled semiconductor production of device designs which permit current densities exceeding $10^9 A.m^{-2}$ may deliver high quality and low infant mortality components and yet result in electromigration failures later in life. Another example is that low cost encapsulation with good process control to encapsulate with silicone applied to a fully activated clean silicon IC surface can safeguard the reliability of the IC for more than 100 years in harsh tropical climates.

Such high reliability (Hi-Rel) has been engineered in the past by co-operative development between Hi-Rel users and the manufacturers of the materials and components. Today the ball is firmly in the court of the equipment manufacturers to understand Reliability Engineering, build and verify adequate reliability in their products and accept whole life responsibility for the products. It is alarming to observe that some companies (or the inexperienced newly promoted managers therein) no longer understand reliability engineering and rely on non-verified desk-based computer modelling [Model Based Reliability (MBR)] to check out the durability of the product. This is particularly dangerous when today's products may be used anywhere on the globe and the hazards of tropical use can be 20 times greater than the hazards in temperate climates of the developed world where current experience (or instinct) has been gained. The route to reliability assurance has been considerably streamlined compared with the ponderous former Mil-Standards practices. The valid route is through evidence. Evidence Based Reliability (EBR) has rapid evaluation methods and is already used to verify reliability in temperate, tropical and hazardous environments. EBR methods also show how Commercial-off-the-Shelf (COTS) components may be used in the severe climates of aerospace and terrestrial Hi-Rel applications.

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