A Short Guide to
Quality and Reliability Issues
In Semiconductors
For High Rel. Applications

Issue 1.0 Jan 2002

"It is impossible to test Quality or Reliability into a product. It is, however, quite practical to assess both Quality and Reliability by judicious testing."

Introduction.

When designed, built and used with long life in mind, the modern semiconductor is one of the most reliable of man's inventions. Indeed, under close to optimum conditions, such devices have a virtually infinite life with the elements around them usually causing ultimate failure of the equipment. Such failures are caused, more often than not, by failing jointing methods and other forms of fatigue. Only with the need for faster processing speeds and more features in "Consumer" products has this reliability issue changed in recent years. This note describes briefly the screening and actions that can be applied to suitably constructed products in order to guarantee long life with extremely high levels of reliability.

Quality and Reliability Issues.

There are many issues that affect the perceived quality and reliability of a product that is delivered to a customer. For the Semiconductor manufacturer, the "rules" have changed quite radically with time. In the early stages and well up into the 1970s, the Military users dominated the main markets. The major quest for the suppliers was to produce devices, which were constructed with intrinsically high reliability, which could then be proved and assured by reliability testing, conformance testing, whole batch life testing etc.
Today, the High Reliability sector accounts for about 0.3% of the whole market. Different forces now apply which demand more and more performance for less and less financial cost. Many of the end equipments that the components go into have quite short lives (mobile telephones, PCs, Satellite receivers etc.). It is therefore possible to reduce the long term requirement in the design of any semiconductor and assume that a "wear out" mechanism is acceptable in return for this lower cost, higher performance, more features or any mix of these. What is not acceptable is that the semiconductor has a high or poor initial and "first year of life" reliability figure of merit.
The philosophy used in the design of High-Rel devices and those intended for "consumer" applications can therefore be very different.

Product Construction.

Products can be designed to be intrinsically safe over very long periods of time when used within their specified ratings – but ---

Many modern products have been compromised in their design and construction in order to give very high performance and/or features at low cost for use in Consumer (limited life expectancy) equipment. The design of such products is such that the reliability "out of the box" is extremely high. This is achieved by good design and tight control over the production process. Indeed, on high volume lines, the use of techniques such as SPC (statistical process control) allows potential problems to be identified and rectified before any material change is seen at the end of the production line or by the customer. Indeed, early failures seldom occur using this technique. The fabled very low failure PPM (parts per million) are usually generated this way. SPC gives rapid feedback from the back-end of the production process to the front end of any potential drift in characteristics that would ultimately result in failures. Corrections are applied before such failures are allowed to occur.

The use of SPC and the very low PPM figures that are achieved on a commercial high volume production line have led many to think that such products must be acceptable for use in Military/Hi-Rel applications. This is not necessarily so. The lifetime design objectives do not necessarily correspond.

Unfortunately, devices intended for use in Military and Hi-Rel equipments are usually required in penny numbers. SPC and similar techniques do not work at all well when only 1000 pieces or less are needed. The techniques that have to be used here to control quality and life expectancy have to be different.

The first issue is to design a product that has inherently high reliability built in. This means avoiding all the elements that would contribute to a wear-out mechanism in the product. Starting with the design of the Silicon Die itself, this requires that the build up of materials throughout the design be compatible with the long life use to which the device would ultimately be put. Examples:- the die attach method frequently needs to be more complex to remove Metal Fatigue features, thicker and/or more robust metal interconnects on the chip itself in order to overcome metal migration effects, removal of contact between dissimilar metals which produce corrosion within the device and hence open circuits etc, etc.

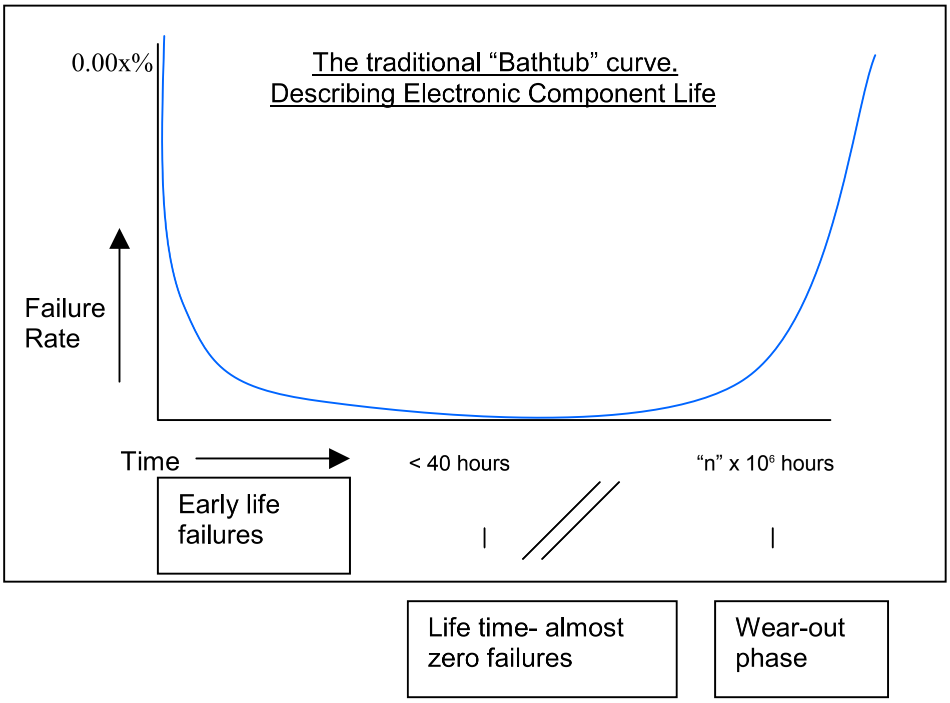
The second issue is to control thoroughly all the materials used to ensure that every element in the design meets the minimum level of performance and "toughness" before building into the final product.

Thirdly –the assembly process has to be tightly controlled and inspected for compliance. SPC does not work here, so more traditional techniques of control are required.

If all the above elements are considered properly, then testing and especially reliability assessment become confirmatory processes.

Reliability Assessment - Introduction

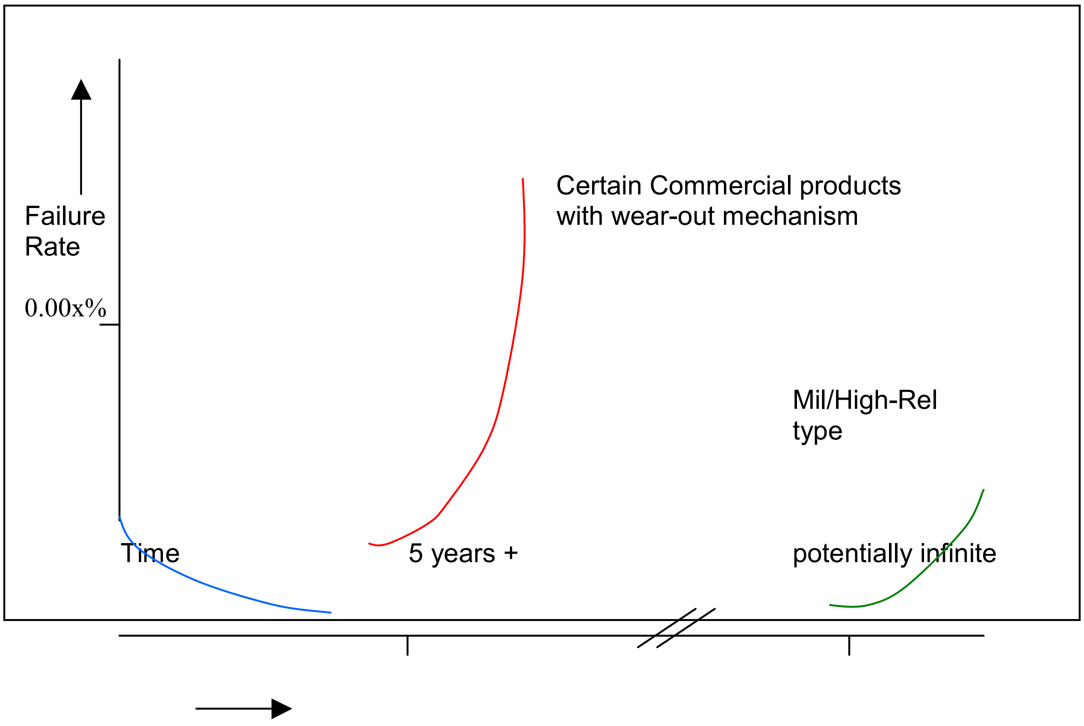
Traditionally, the failure rate of an electronic component has been well described by the "Bath Tub Curve".



Modern Commercial Semiconductors	Military / High-Rel Semiconductors
Initial Phase • Achieves very high level of acceptance with very low failures "out of the box" as a result of the use of SPC (or similar techniques) on high volume lines.	**Initial Phase** • Achieves a very low level of failure due to careful design, selection of materials and construction and control.
Life Phase • During life, failures, when used with specified limits are generally very low to non-existent.	**Life Phase** • During life, failures are exceptionally low, especially for products fully engineered for Space and similar applications.
Wear-out Phase • This can be reached in as little as 5 years where products have a known or inadvertent built in wear-out mechanism. Other more conservative designs could have an almost limitless life dependant upon use in a benign environment.	**Wear-out Phase** • Life is usually infinite when used within the design parameters. Equipment life is usually determined by other components drifting out of tolerance and mechanical failure of joints etc.

Semelab Plc
Tel: + 44 (0) 1455 556565 Fax: +44 (0)1455 552612 E-mail: sales@ semelab.com
Web: www.semelab.com

Graphically, life differences can be summarised: -



Screening for long and reliable life is not very effective on those short life products since all that would happen would be to remove the small number of "infant mortality" cases and to shorten the life of the product by the "burn-in" time.

Screening on devices designed for long term use is particularly valuable since not only infant mortality failures are removed but also products and batches showing sustained adverse characteristic drift can be detected and quarantined. Only good products with a potential for a long trouble free life are accepted.

Reliability Assessment – Screening of High-Rel Products

Screening of products consists of electrical testing of the devices followed by a series of electrical and mechanical stress tests followed by further electrical tests. Burn-in and Life Tests are generally designed to expose the weaknesses of the technologies used. For many ICs, modules and arrays, life tests are designed to fully exercise the product by being dynamic.

Semelab Plc
Tel: + 44 (0) 1455 556565 Fax: +44 (0)1455 552612 E-mail: sales@ semelab.com
Web: www.semelab.com

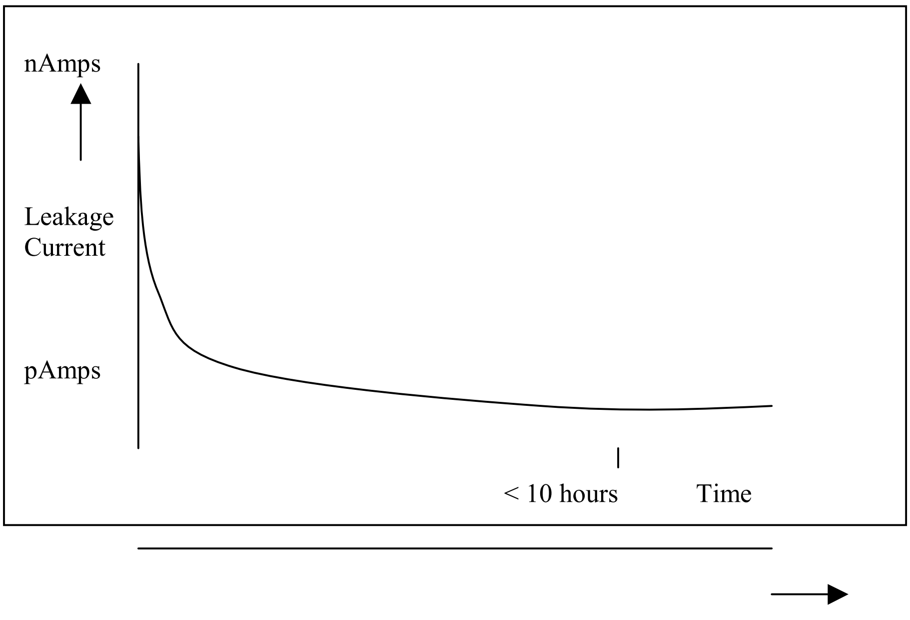
Devices can fail the tests by either catastrophic means or by excessive drift in one of the key parameters for that device.

The severity of the tests extend from the lowest level of environmental tests on a sample from a homogenous production batch to qualify that batch (Conformance Testing) tests designed to qualify devices for Space Level use – the highest levels currently in common use.

Space Level Screening calls for each device to be serial numbered and put through a stringent series of environmental tests. All the key characteristics of each device are recorded before, during and after testing with any drift noted. Excessive drift is cause for the product and frequently the batch to be scrapped.

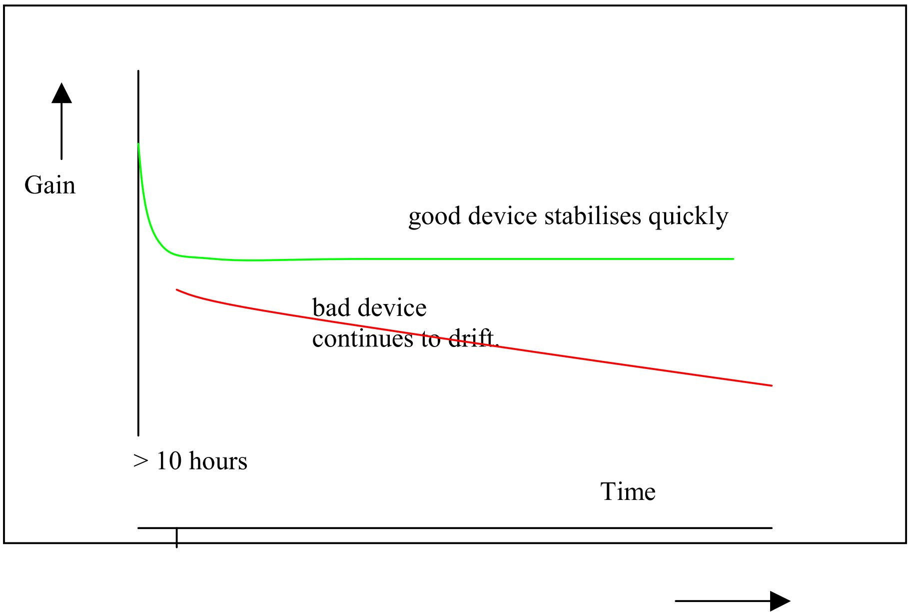
Drift.

All products, when first switched on exhibit a period of settling down – or stabilisation. This usually occurs during the first few hours of life. The manifestation of this is that the leakage of the product drops, the gain stabilises etc. For a transistor, the curve of leakage should look like this: -



Good devices stabilise out very quickly – poor devices frequently show an increase in leakage or do not stabilise at all.

Similarly with the gain characteristics: -



These examples relate to a single transistor. In Integrated circuits, the same actions take place except that on several hundred devices (in a simple IC) through to a few million devices (complex circuit). Drift of characteristic within and IC usually means that it will cease to function after a while (usually within the first 10 hours under stress).

Lot Acceptance Tests and Screening are designed to trap such batches and prevent them being shipped to the Equipment Maker.

High Reliability Product - Initial Material Screening

All material intended for use in High reliability Semiconductors is screened before being built into the device. The active die is assembled into known good headers and subjected to life tests and other electrical and physical tests to assure that the die is more than adequate for the final use.

Mechanical piece parts are similarly screened before use.

High Reliability Product – Assembly

Fully qualified personnel build all products on fully qualified assembly lines. Qualification lapses if the operator has not performed a specific function for more than a certain period of time. The strictest rules apply in the assembly of Space and similar quality level of device.

High Reliability Product – Test.

Electrical tests are carried out 100% on the assembled products. Dependant upon the specification, the product may be subjected to other tests not foreseen with normal commercial types.

High Reliability Product – Conformance Tests.

A series of tests referred to as Group A, Group B and Group C tests are carried out on samples from all batches made. A batch is defined as one group of devices built from a homogeneous set of input materials by the same group of operators in a continuous time frame.

Group A tests – Electrical. Samples from the main production batch are subjected to electrical tests by the Quality department – using different equipment, test programs and personnel to those used for the original tests so as to trap any errors that may have been made. The sample size and the AQL (Acceptable Quality Level) are determined by the sample plan required by the order.

Group B tests – Mechanical plus electrical endurance. A series of mechanical tests are made to establish that there is no fault in the mechanical usability of the device. Additionally, electrical endurance tests are carried out to establish that the products do not exhibit any significant parametric drift or failures. Any such large drift would cause the whole batch of products to be rejected.

Group C tests – these are carried out periodically (typically every 3 months). The aim of the tests is to stress the products in several different ways to prove that the products perform as they should within the data sheet (or specifications) over a long period of time. Typically, longest of these tests last for 8000 hours.

Group A test double checks the production testing

Group B establishes that there are no mechanical defects and also that the product is stable under life conditions.

Group C verifies the long-term ability of the product to continue to meet specification.

In all instances, the sample sizes are determined by the sample plan called up by the order.

Typical product designation for this group of devices is CECC, JAN etc.

High Reliability Product – Additional Screening.

Orders for High reliability products for use in severe or critical applications usually have screening called up as an addition to the above.

For CECC, BS, JAN/TX/TXV and DSCC products, the breakdown is basically as follows: -

Sequence A Screening – relates to JANTXV and is the most severe level of screening outside of full Space Level. It follows that it is expensive to perform. All products are subject to Life Tests with before and after "test and record" results compiled.

Sequence B – similar to JANTX is the most common form requested. All products are subject to life Tests with before and after electrical testing.
Linear products conforming to MIL 883B fall into this groups as do discrete products such as 2N3055CECC-B.

Sequence C and D are reduced versions of Sequence B and are little used.

For a full explanation of the screening programs used by SEMELAB, please see the booklet "High Reliability and Screening Options" – now at issue 6.

Do not confuse Quality and Reliability Screening with Up-Screening (re-rating products beyond the original Manufacturer's published limits).

Up-Screening should in no circumstances be confused with "Screening" (reliability testing).

Up-Screening is carried out on a product in order to attempt to qualify that product for use under different environmental and / or electrical conditions than it was designed and / or sold for.

Up-Screening has to be used as an absolute last resort when no other solution can be found. Up-Screened products should never be designed into new equipments and should only be used in emergency for repairs to existing equipment and even then, with extreme caution.

Products to be up-screened are generally commercial parts that are being stretched from the 0 to 70 degree range to cover anything up to –55 to +200 degree range. Without a complete knowledge of the construction and the design of the product, this is an extremely dangerous procedure. Even if the devices function electrically over the extended range, most commercial products will fail (quite some time after the traditional life test periods) due to the construction and materials used. Frequently, the designer never envisaged or provisioned for extended temperature ranges.

Very often, ICs intended for use in Commercial equipment are designed to operate over a limited temperature range only. Outside this, the product is not guaranteed and can perform erratically or shut down completely. Timing delays through the different channels within the IC can reverse producing interesting effects, which frequently are only found when used in equipment some time in the future.

Typical failures will be mechanical disintegration (mechanical fatigue cause by temperature cycling). Inter-metallic corrosion which accelerates very significantly at the higher temperatures. Greater risk of metal migration leading to internal open circuits developing. Ion and other chemical migration from the plastic encapsulant attacking the die and metal interconnects greater risk of "trapped charges" – etc. Marginal electrical operation at the extended temperatures leading to increased risk of unquantified "races" in ICs and random malfunctions etc. It is unusual for an organisation performing the up-screening to have sufficient detailed knowledge of the original design and construction of the device to know how such a device will operate outside its normal design envelope.

Any of the newer Commercial products that have a limited life because of design choices will have considerably shorter life and possibly unstable performance if operated over extended temperatures.

No original Semiconductor manufacturer will condone the practice of up-screening – some taking legal action against companies offer this service. The reasons are that the risk of failure and consequent lawsuits is very high.

The original Semiconductor Manufacturer immediately disowns any up-screened product and any guarantee associated with it if up-screened. Any product liability is borne entirely by the house that up-screened that device and/or any organisation instigating such actions. Frequently, such houses are small and have little insurance to cover the eventuality that a major failure takes place.

Up-Screening – don't do it unless absolutely necessary.