RELIABILITY ISSUES AND FAILURE MECHANISMS-Modelling failure rate

The reliability of a system is the consequence of the reliability of all its parts, electronic and mechanical, not forgetting the reliability of the solder joint itself. Although formal rigour is not normally commercially viable, making reliability predictions for systems is usually part of the military designer's mandate.

Figures for failure rate for the system (or for Mean Time To Fail, which can be derived from the failure rate) can in theory be predicted from failure rates for the individual components. MIL-HDBK-217F1 is an example of a specification which suggests how this might be done. Its failure rate models are specific to particular device types, but are generally of the form

$$\lambda_p = \lambda_b \pi_Q \pi_E \pi_A \ldots$$

where lp is the failure rate under the environmental conditions, lb is the base failure rate at the device temperature, and pQ, pE, pA, … are factors which take into account the quality screening level of the part, the equipment environment and the application severity.

1 This specification and its supplements are available for free download from a number of sites – we used the Society of Reliability Engineers' web site at http://www.sre.org/pubs/ – but even the PDFs total over 20MB, so make sure you have a fast connection.

MIL-HDBK-217 has formed the basis for many other published databases and methods for predicting the reliability of electronic systems. However, all these methods have been rightly criticised as a means of predicting system-level reliability, because of:

doubts as to the validity of the models used, in particular whether failure rate is in fact dependent on temperature

the belief that some of the multipliers used are not valid: for example, adverse effects of increasing device complexity have generally been counteracted by process improvement

the lack of any precise formula linking specific environments to failure rates, even though empirical relationships have been established between certain device failure rates and specific stresses, such as voltage and temperature

the omission of some factors that affect reliability, such as transient over-stress, temperature cycling, and control of assembly, test and maintenance the experience that only perhaps 1–10% of electronic system failures are due to components failing from internal causes

the experience that ‘higher-grade’ military components may no longer be more reliable than good commercial grade parts, following substantial improvements in manufacturing methods and control. Indeed, some would argue that, because commercial parts are made in much larger volumes, they are actually more reliable than military parts.

Of these criticisms, one of the most cogent is that MIL-HDBK-217 bases its relationship of failure rate to temperature on the Arrhenius model:

$$\lambda_T = K \cdot \exp(-E/kT)$$

where K is a constant, E the ‘activation energy’ for the process, k Boltzmann’s constant, and T the absolute temperature.

As O’Connor points out, the assumed temperature dependence on which much forecasting is based is probably no longer valid. This may well be the reason why the results of testing real products are so much better than those predicted by MIL-HDBK-217 (Figure 1).

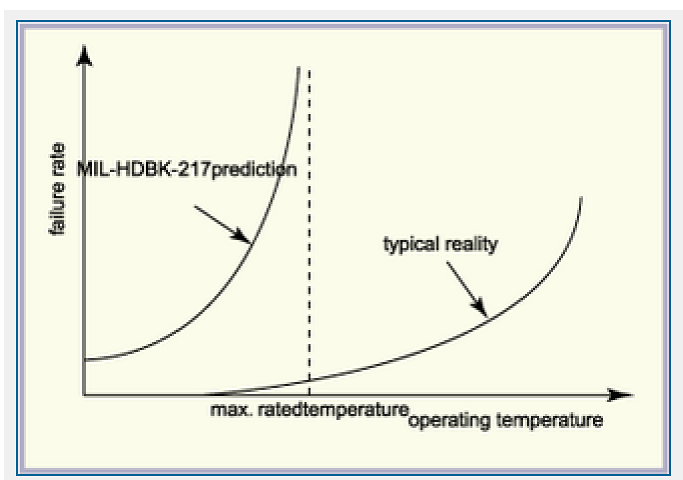

Figure 1: Failure rate plotted against temperature for electronic components

after O’Connor 2002

In practice, individual component (and joint) base failure rates are extrapolated from experimental data, and a model similar to MIL-HDBK-217 used to predict how the resulting system failure rate will change with operational conditions. The standards also embody some general pointers to good practice, or at least clear justifications for what many designers would consider common sense! For example:

The reliability of capacitors reduces sharply as the applied voltage nears the maximum rated voltage, and de-rating to 50% of maximum is desirable

The reliability of all components reduces markedly as they near their maximum operating temperature. It is prudent to keep power-dissipating components well clear of anything sensitive

In carrying out an MTTF calculation, it will often be found that the greatest contribution to unreliability will come from only a small number of components, and that improving their quality or reducing the stresses applied will be beneficial.

Another problem with reliability prediction is that it depends on the quality of the information. Many of the figures given in MIL-HDBK-217 are now incredibly conservative: combining this with acceleration factors that are also conservative will result in reliability estimates that are way off the mark – "it will never fly, Wilbur!" Nevertheless, carrying out this sort of exercise is worthwhile, because it highlights clearly which are the risk factors, and enables the designer to take avoiding action.

Yet another difficulty in performing reliability assessment is the lack of current information. Reliability testing is all about proving that the product is capable of meeting its intended goals. However, we cannot afford to carry out reliability testing on every product. We therefore need a test regime that can be applied across the board, to allow results to be compared, and to give a means of predicting reliability, based on experience with comparable products and similar designs. This becomes particularly important as the industry adopts alternative practices, such as lead-free soldering, in order to meet environmental objectives, and also develops new and smaller designs of package in order to meet market demands.

IPC-9701 has been developed to create specific test methods for evaluating performance and reliability for surface mount technology, and in particular the attachment of Chip Scale Packages. Its tests are designed to replicate actual use environments of the assemblies, and to give information on the reliability of solder attachment to a number of different circuit structures, embracing flexible and flex-rigid circuits as well as the more traditional rigid substrates. Expect to hear more about this standard!

Finally, be aware that a number of suppliers offer Reliability Prediction Analysis services aimed at helping designers make critical decisions on reliability, maintainability and quality. Examples of such companies are: MTain (http://www.mtain.com/relia/relpred.htm), Quanterion Solutions (http://quanterion.com/index.asp) and Relex (http://www.relexsoftware.com/). If you need to calculate reliability, then a number of software tools are available, some of which are available for trial download.

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