FAILURE FREE ELECTRONICS - A RELIABILITY CHALLENGE

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Recent development in tools and methodologies for the analysis of field failure statistics has given new insights into the trends of AXE systems hardware reliability. This paper gives a brief introduction to this development and also some examples of results found. For over 20 years reliability objectives for hardware (components and printed circuit boards e.g.) have been based on a database of component reliability figures, implying that these can be regarded as inherent characteristics.

The new insight gathered instead calls for research on the real cause for field failures and to evaluate how far we may stretch the reliability limits for our products that already today have a reputation of being among the most reliable hardware for telecom application. In the future we might see 'failure free electronics'.

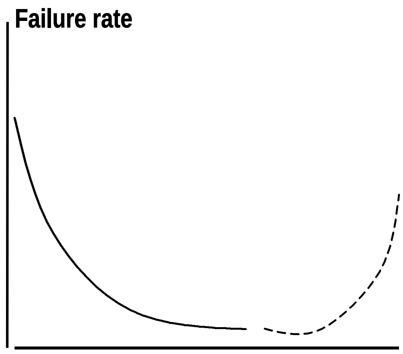

Figure 1. The classical 'bath tub' curve; normally only the first part is noticed in field reliability measurements.

Introduction

Since 1995 two new software tools have been developed that strengthen our power to analyze the field performance of our products. One is called ***EriView 2000***[1]. This tool finds a life distribution that gives an optimum fit to reported field failures, knowing the installation base, by parametric optimisation. An other tool is called ***MYFY*** and makes use of information on the manufacturing dates and the failure dates of returned goods. This tool gives immediately a graphical report on the failure rates development for any product and its manufacturing year as a function of field use time.

Examples from the use of the tools will be given. The analysis indicates that normally there is a clear trend of improvement by field use time as well as by manufacturing year. In many cases the failure rate virtually vanish after about 4 years of use. After that time there are many board types that may be regarded as 'failure free'. In rare cases signs of 'wear-out' (increasing failure rates) may also be detected, figure 1. By using these analysis methods such problems may be detected much earlier than previously thought possible.

Product Performance - a key issue

AXE10 is a complex product and its total performance is measured by our customers and operators in terms of availability and service quality.

Such measures may be frequency and duration of Complete Exchange Failures (CEF) or the average Line Down Time (LDT) measured per market or application release. It is known that the software quality plays an important role in determining the product performance. However, the hardware quality and reliability is also a very important factor that has an influence on maintenance costs and on the long-term profitability of the equipment.

Hardware failure costs can be identified at several steps along the life cycle such as during board manufacturing, in the final system testing and during installation and field service. Obviously the cost for a hardware failure will increase along this line. See also figures 2 and 3.

Within our department for Hardware Performance a great deal of effort has been put into analyzing quality properties of the hardware that goes into the AXE10 systems. The collection and analysis of failure data from manufacturing and system testing is important to give input to manufacturing process improvements and to correct design related problems.

Further more, there seems to be a good correlation between system test results and the field performance of the same product[2]. This makes it possible to develop new methods for product reliability prediction.

Field failure statistics can be used for many different purposes. One is to verify that design objectives are met. An other may be to estimate future guarantee costs in connection with sales and marketing to new customers. A third area may be to continuously scan the world wide installed base of hardware for any sign of wearing out. Other reasons are to analyze the performance of different products in order to identify clear improvement objects or even to find examples of extremely reliable products to serve as benchmarks for new designs.

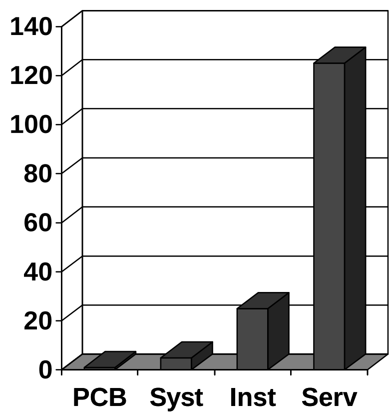

Figure 2. The relative cost per failure will increase as failures are detected later on along the life cycle. (Example)

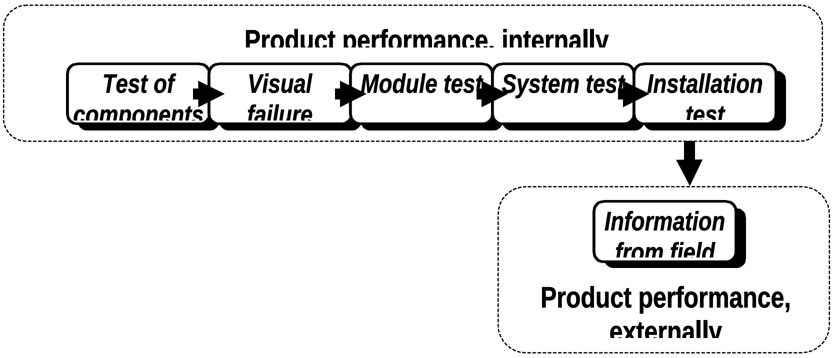

Figure 3. The product performance is measured at different points along the product life cycle.

By identifying the good properties of the 'failure free' boards we may improve future design work by developing even more robust board types. This will reduce the costs for board repair and replacements in the production as well as in the field use. Reduced failure levels will open up for less costly testing procedures such as sampling testing etc. Reduced field failure levels will also enhance customer satisfaction and add to our competition strength.

Reliability trends, history

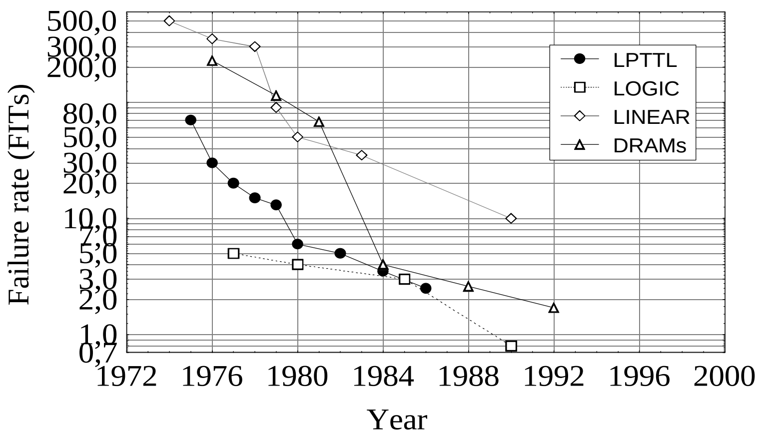

Figure 4. The measured field failure rate of different component types vs. time[3]

Component manufacturing quality has improved drastically over the years. Figure 4 shows that the improvement on microcircuits is approaching 100 times during the past 20 years.

There are some conclusions that might be drawn from this reliability trend:

Firstly, the trend is likely to continue due to the economic impact from high yields and low failure rates.

Secondly, as the component failure rates are dropping their role in electronic equipment field failure rates will be reduced. Other reasons to field returns will become more important and will need attention in order to address further improvement at equipment level.

Constant failure rate modeling

Traditionally, most reliability prediction of electronic equipment has been performed by assuming constant failure rates of its component parts. There are a few draw-backs related to this methodology.

Spare part estimation usually tend to give too large amounts of spares that will not be consumed in a reasonable time, thus adding to the inventory costs.

The need for future repair service and maintenance staff will be overestimated if the general improvement trends are not taken into account.

The idea itself, that the components have intrinsic characteristics called 'failure-rates' is basically unsound. It will lead to acceptance of certain failure levels and to conservation of old test philosophies. The possibilities offered that by drastically improved equipment reliability might never become investigated.

Stress - strength modeling

Component failure-rates are normally caused by a small fraction of weak parts while the rest are good and long-lived. If the weak sub-population is large enough it is possible to characterize it in terms of its own life distribution[1]. As the weak parts are weeded out and replaced by better parts the average failure rate of the installed base will improve by time.

If there is a strict sub-population that is causing field failures, then the reported field return rate will improve faster if the stress is higher - in contrary to what is normally assumed. A study[3] of the average field failure rate vs. chip temperature of logic IC's did not show any correlation at all and this might be due to this effect.

Similar trends can be seen on the field performance at printed board assembly level. The amount of components that really fail, or die, in service is normally fairly small. The reason why electronics still is being returned from field service can be due to different things, e.g.:

- There may be external disturbances i.e. thunder storms that gives failure peaks in the late summer time.
- The design has been centered around some nominal characteristics. If there is a certain possibility that component data spread (strength) and application stress will overlap then this may affect the functional performance of the board.

The last point is very important. If this is the main reason for field failures then one should expect to see a clear improvement in field failure rates over time, as the marginal boards successively are being replaced by more robust ones into the installed base of equipment.

Classic strength - stress analysis[4] (see figure 5) states that if there is a wide enough margin between the strength and the applied stress then there should only be the 'intrinsic failure-rate' to account for.

If the only failure generator is a marginality weakness, then one would expect to see close to 'failure-free' products in service after a certain period of use.

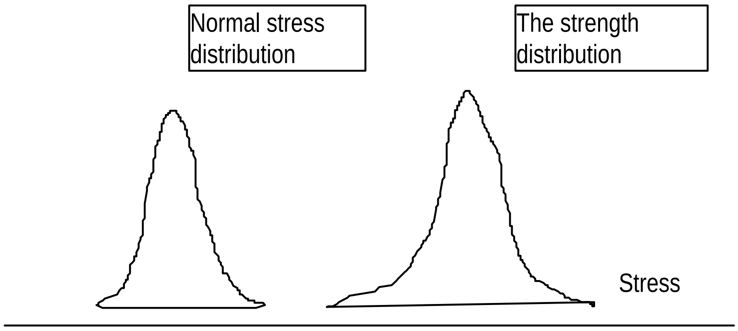

Figure 5. An example of a product having a safe window between strength and stress distributions leading to a virtually 'failure free' product.

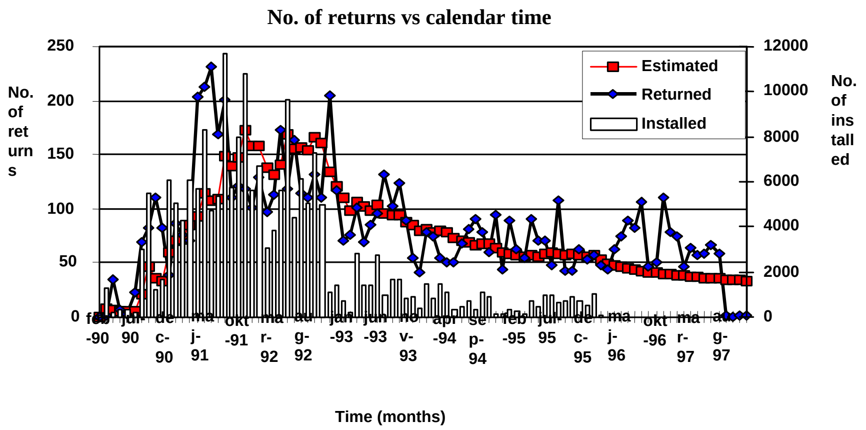

Figure 6. Measured and calculated returns per quarter of one board type, mainly installed during 1990-1993. The calculation is done after an ***EriView*** optimization.

Development of software tools

Several tools have been developed at Ericsson Telecom AB in order to support the collection and analysis of product quality data. One object common to all these tools, was giving the designers the possibility to monitor the performance of their own products and to support the improvement work.

EriView 2000 [1]

The central point in this software is to find a life distribution that best fits to the measured field performance. It makes use of an optimization algorithm that determines this life distribution based on two sets of data that normally are available. The optimization is done by varying parameters in the expressions for the life distributions.

The required input for the parametric optimization method is:

- The number of products put into service each time period (month, year etc)
- The number of products failed in service each time period.

The exact information about ***when*** and ***where*** a failed product was put into service is not necessary in this analysis. This makes it possible to analyze time dependencies from repair statistics, medical survival data or e.g. traffic accident statistics in a way that earlier might have been regarded as difficult or even impossible. An example of such an analysis is given in figure 6.

The tool is of general nature and gives many possibilities for the analysts. There are four different basic life distributions to choose from (exponential, normal, lognormal and Weibull). It is also possible to take into account the influence from up to 3 mixed sub-populations. Products with fixed service time, e.g. 20 years, can also be modeled.

MYFY

In most markets information on the number of products manufactured and installed each year is available. If each failure report in such a market gives the manufacturing date of the returned product, an other form of analysis is possible. This method is called '**MYFY**' as it is based on the **M**anufacturing **Y**ear and the **F**ailure **Y**ear information.

The basic idea behind MYFY is that fresh, new manufactured boards most likely will be put into service after a relatively short time, say three months. The installed base of boards may thus be approximated by the manufactured lot, delayed by this time

In order to calculate failure levels and failure rates one must recognize this delay and take into account the ramp-up of products installed over the manufacturing year and the year thereafter. Figure 7 gives a graphical picture of this flow. It may be the case that out of all products manufactured one year only 75% will come into service sometimes during that year.

The MYFY-application

In order to make the best use of the simple algorithm for MYFY-calculations a Windows application has been designed. The application allows the user to choose the market and product of interest, after which you immediately get a graphical report of the failure rate and the accumulated failures per manufacturing year versus field use time.

Figure 8 gives a view of the front-page of this application. It has been installed as a network product giving authorized personnel access to all available field reliability information for their own improvement work.

Figure 9 gives an example of a MYFY-analysis of one product. The plot shows the general good trend of accumulated failure levels by field use time for each manufacturing year for that market. The graph also shows the general good trend of annual improvements each manufacturing year. Much of this annual improvement is due to production, testing and design improvements

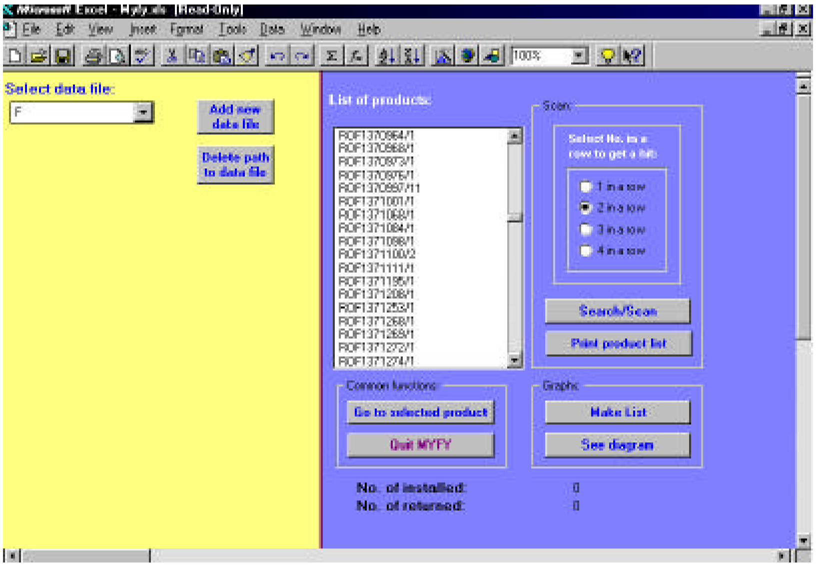

Figure 8. The front page of the MYFY application where market and product of interest can be specified

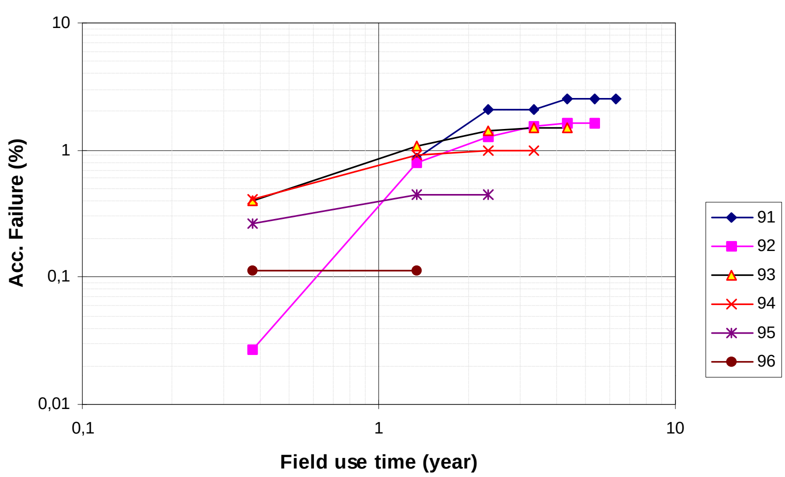

Figure 9. An example of a MYFY-analysis showing the accumulated failure levels of different manufacturing years of one board type

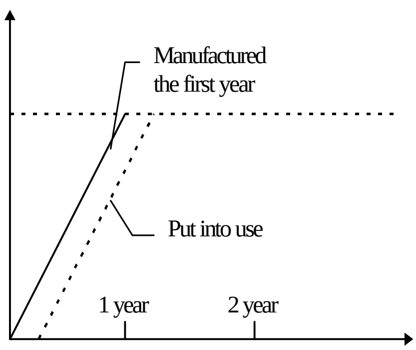

Figure 7. The ramp up of manufactured and installed boards from one manufacturing year

Results and general findings

Time dependent failure rates

One general conclusion that can be drawn is that the return rate of hardware from the field drops by the time in service. This is a natural result from the fact that the 'weak' parts having component failures or very small margins will be detected early and replaced by products that on average are much more robust.

The question about time dependent failure rates has for many years been a source of controversy. Today, we can see by ourselves that the failure rates normally are not constant in time. See figure 10.

Improvements by manufacturing year

An other good trend that we can see is that the hardware quality per product type in general improves from one year to the next by a factor of 1,5 in terms of accumulated failure level after, say 5 years.

This improvement trend is mainly due to process improvements in the manufacturing line, and is also due to design improvements (product revisions). An example showing both these trends is given in figure 10 where the average return rate of all printed board assemblies within one market has been compiled.

Failures free electronics?

Figures 10-11 give the impression that the board returns rate after four or even two years of use is dropping to very low levels. A study was undertaken on 20 volume produced board types that showed a very low field return rate (figure 11). The object was to see if there was any common factor behind the good results obtained.

The main conclusion is that these board types have been designed in a robust way, using good margins and well known components of high quality for their design. The boards were of normal complexity ranging from simple strap boards to complex multilayer board types equipped with ASIC components.

Obviously, it is possible to design and produce hardware that shows a very low failure rate, even further reduced by service time. This shows that we should not expect a minimum level due to inherent component failure rates. Further failure cost reductions can be expected by developing even more robust designs.

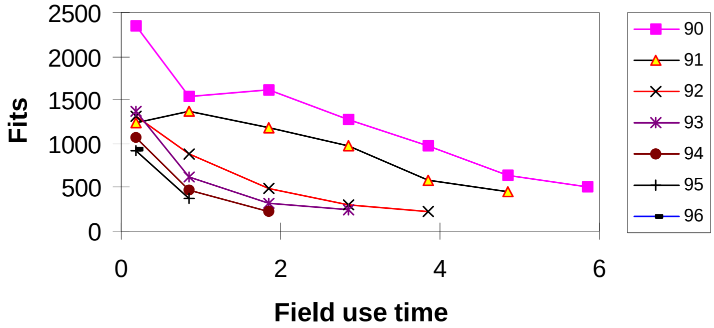

Figure 10. The failure-rate development for all boards manufactured in one market

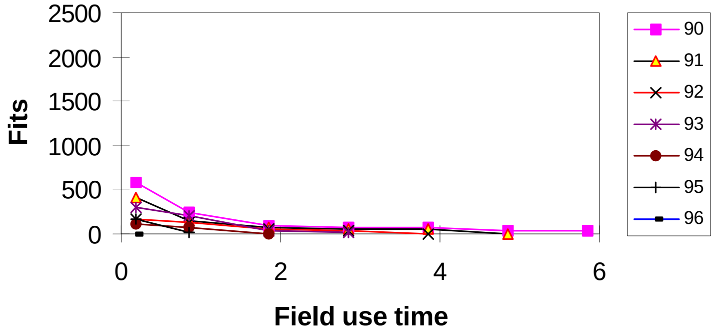

Figure 11. The failure-rate development for 20 high-quality volume board types, in total 110 000 boards in use.

Improvement activities

A continuous improvement of the methods and routines for the collection and analysis of repair- and installation data is necessary. A TQF-network (**T**otal **Q**uality **F**eedback) of reliability engineers and experts in this field has been formed over the past five years. This network is arranging annual meetings to inform about advances in the field and to promote improvements in analysis, data collection and corrective actions.

A major challenge is now to coordinate and standardize all reliability databases within Ericsson and to use that data to give feedback to designers and subcontracted manufacturers for their improvement work.

The concept of 'robust design' will be further developed and applied in general design work.

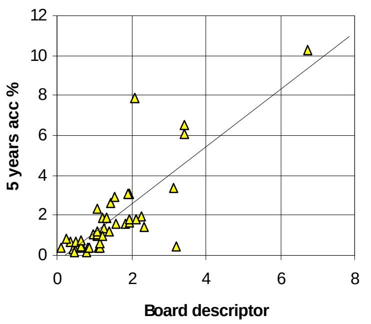

Figure 12. A positive correlation was noted between system test results and field performance. (From ref. 2)

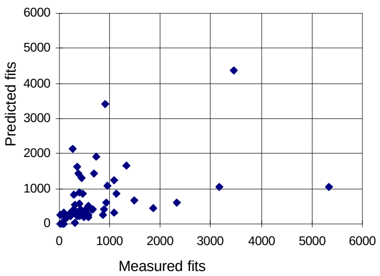

Figure 13. Predicted and measured failure rates of volume boards. Predicted by summing up component failure rates

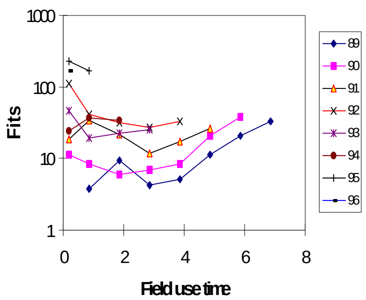

Figure 14. An example of increasing return-rates of one component type due to a technical problem

A simple improvement model

The results obtained from the field studies may justify a model based on one fixed, constant failure intensity and on top of that a dependency of both field use time and the maturity (manufacturing years since start). A model of this type is being tested at present in order to improve the prediction of field returns over time.

$$Y=C*b(m)*(exp(a*t) + 0,1) \qquad (1)$$

where a = -1

C = asymptotic fit value for the third manufacturing year

and b(m)= a factor that is reduced by each manufacturing year

Correlation between system test results and field failure rates

We have found that in general there exists a positive correlation between the failure levels in system testing and the field failure rates. Figure 12 is taken from ref. 2. Such a correlation may be used as a base for field reliability prediction of new board types when only quality information from manufacturing and system testing is available.

The traditional way of reliability prediction based on a set of standardized component failure rates gives normally a relatively poor correlation. See figure 13.

Are there any signs of wear-out?

The new tools developed for the analysis of field service performance may also give indications of deteriorating quality, i.e. increasing failure rates.

The MYFY-application has an option that automatically makes a search for products and manufacturing years that show 2, 3 or 4 consecutive years with increasing return rates. Once these products have been identified one may search for more detailed data for further analysis. The individual plot of the failure rate graphs is given by pushing the 'See diagram' knob (Figure 9).

Figure 14 shows such an example of increasing failure rates, in this case also for early failures.

Application in current AXE hardware evolution

The latest advances in hardware technology have brought into the AXE system dramatic improvements in such characteristics as floor space, power consumption, system handling, and cost of ownership. Backward compatibility has been maintained to the greatest possible extent, in order to protect previous investments in AXE.

For the same functionality the footprint has been reduced by 70%, the power consumption by 60% and the number of different board types by 65%.

The introduction of the robust design concept in combination with the latest advancements in manufacturing process control will assure further reliability enhancements, both as measured per product and certainly per function.

Summary

This paper has focused on hardware reliability. We can notice that there is a general good trend in reliability performance. It is possible to further improve product reliability by developing design methods and manufacturing processes towards a high level of inherent robustness.

The failure costs and test costs can be further reduced. If we can obtain virtual 'failure free' electronics we might take another look at the need for duplication or triplication of hardware that always has been necessary due to the traditional high failure rates predicted and/or measured.

References

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