

HARDWARE RELIABILITY ASSURANCE AND FIELD EXPERIENCE IN A TELECOM ENVIRONMENT

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SUMMARY

This paper gives an overview of some methods and procedures used to assure product reliability within Ericsson Telecom AB. The main focus in this paper is on hardware (HW) reliability at board and component level. The evolution of customer-vendor relations over the years is addressed. Some new concepts in complex component reliability assurance are described. Experience from field service is summarized.

This information is open and may be subject to change at any time.

KEY WORDS Reliability Qualification Improvement Zero defect Time dependency Feedback

INTRODUCTION

The reliability of telephones and exchanges has always been a major design parameter. As old mechanical systems have been able to serve for several decades, the electronic systems of today have to be similarly long lived.

Ericsson Telecom AB is a company within the Ericsson Group. Our market is world-wide and our telephone exchanges are found in over 100 different countries. Competent customers around the world are developing modern quality and reliability requirements where one key element is improvement of these factors.

Also, the management's interest is focused on improvement activities, such as shorter development times, reduced failure costs, cost of ownership, whole life costs etc.

A large number of new complex components and package types are needed in the new systems that are being developed. This implies that a qualification strategy has to be defined in line with the latest developments in process and packaging technology.

In this summary we will review some of the methods used to assure the required quality and reliability of our products all the way through component testing and board manufacturing to the final use by the end customer. Results from several years of field service are reviewed and summary statistics are given.

PRODUCT RELIABILITY ASSURANCE

Quality requirements

As a manufacturer to a world-wide market we need to cope with many and different quality specifications from a number of competent customers. Thus it makes sense to define a set of internal quality

requirements that cover those of our customers. We also often review customer specifications to give our comments before a new revision is released.

Product reliability

The word 'product' is generally used for any type of product used or produced by Ericsson. However, in this paper we will make a distinction between components and products, the latter then being the finished goods such as printed circuit boards, assembled and sold by Ericsson.

Keeping this in mind we can note that product reliability is a result of several factors and activities, such as

- (a) design process, design manuals etc.
- (b) the complexity of the product
- (c) board manufacturing processes
- (d) the application and the environmental stress
- (e) materials and component reliability properties
- (f) testability and fault coverage of the product.

Time dependency

Failures are detected at different points in time. This depends either on the time it takes to develop a fault, or on the time it takes to realize that there is a fault. It can also be a combination of the two.

The time dependencies of the different contributions to board failures are also different.

The board manufacturing process may, for instance, result in different types of processing faults. The major portion of these are found during the board test; see Figure 1. A small additional part is found during operating heat testing. In field use only about 0.5 per cent of all failures are due to the board manufacturing process.

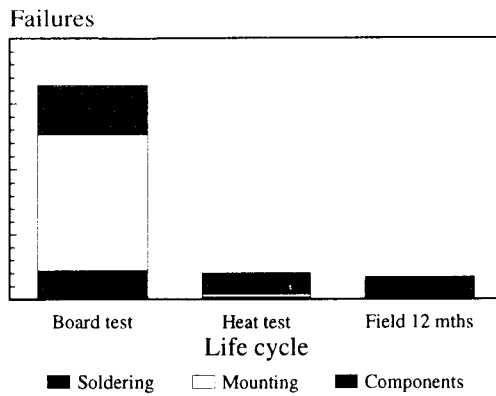


Figure 1. Board failures vs life cycle

The application and environmental stress in use adds failures during the use time. These failures can be either constant in time or vary according to the time of the year. Failures due to thunderstorms, for example, appear to peak in July–August in the Northern hemisphere.

Component failure rates normally constitute a major part of the board failure rates. Figure 2 shows the time dependence of field reliability data of printed board assemblies (an average picture). This shows that the average failure rate decreases by a factor of more than two during the first few years.

Test-related failures are also very important. Some of these may show up as so-called 'no failure found' (NFF) boards, i.e. no failure is found when the returned board is tested at the repair centre. NFFs seem to have the same time dependency as verified failures, so it is likely that some of them are caused by component or processing faults. In-depth analyses of NFFs often reveal additional HW or component failures. However, the board exchange and failure verification procedures may also cause boards to be returned without being proved faulty. The quality of the test system on site is very important.

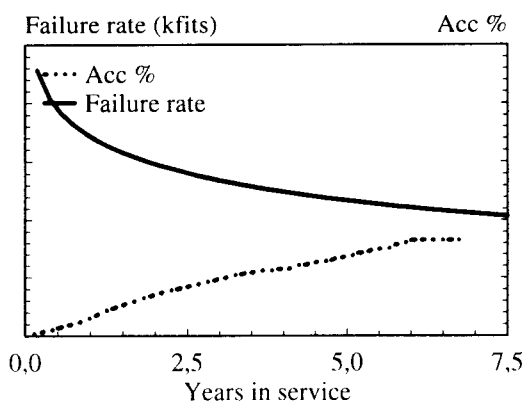


Figure 2. Time dependence of field reliability characteristics for the average printed board assembly

Board Testing

One of the most important forms of board testing is to verify that the board will work in the application environment. The board specification tries to cover most of the known, formal requirements. It is often difficult to write a test specification that covers all application cases in use. Therefore we need to perform a number of tests to verify its function.

Board verification testing. Initially the board is measured and verified against all detailed specified functional and environmental requirements. This is done before production release on a small sample. The verification can be repeated periodically.

Operating heat test. Boards are kept operating in a heated environment for a specified time. This test is normally a 100 per cent screening activity. Owing to the intensive testing this screening is very effective and normally sorts out a failure amount that is comparable to the failure level that is added during the next 12 months of use in the field.

Prolonged operating heat test. Some major board types undergo, on a sample basis, prolonged operating heat testing as a quality monitor. This gives early information on the field reliability and simulates several years of normal field use. This activity also includes operating tests at low temperature.

Field trial. New generations of major board types may be put into a controlled field trial. This is a form of detailed follow-up of the performance in a specific telephone exchange for a specified period of time.

Field use analysis. Once the board has been released for production we will be able to follow the field performance through statistics from our repair centres.

Failure codes, failure dates, replaced components and even component positions on the board are data that can be retrieved for performance analysis.

Quality control in production

All factories within Ericsson Telecom AB are supporting quality improvements. This applies both to their internal production processes, such as soldering, assembly etc., and to the individual product types.

New board types that are going to be high volume runners are run through an industrialization project. During that period all failure in production and field trial tests are analysed, and corrective actions are initiated. Fixed yield targets are defined that have to be met before the project is closed.

Quality control includes the same types of statistical process control as has been used for semiconduc-

tor manufacturing for a long time now. This means that data from individual process steps are continuously analysed and fed back to control the process.

Product improvement

Even after that the product has reached its initial production yield targets there is good economy in further improvements. As the production volume is increasing even small improvements add up to large savings, so called quality profit. An improvement manager may be appointed to support this work.

COMPONENT RELIABILITY ASSURANCE

Some facts

Our component purchase represents a large value every year.

A typical AXE exchange contains about half a million components including 100,000 microcircuits.

An IC field failure return level of only 30 ppm per year still generates a lot of repair costs, as the accumulated amount of ICs in AXE field use today is of the order of 700,000,000.

Every year we are introducing well over 200 new component type numbers or manufacturers to our standard component base.

Requirements

Our internal quality and reliability requirements are based on customer requirements and our expectations for the near future.

Requirements are split into two parts:

- (a) procedures and methods for reliability assurance
- (b) requirements on component manufacturers.

In terms of electronic components reliability we want to see both a low initial failure rate and a demonstrated long life, 20 years at use conditions.

Component evaluation

New components are primarily brought into the system after requests from various design projects. The following investigations are performed as a base for the final approval.

Datasheet evaluation. Component engineers evaluate the component regarding specified data, but the design team is responsible to make sure that the component fits the application requirements.

Process evaluation. It is common that one IC manufacturing process is used for several components, such as ASICs. Therefore it makes sense to base the technology qualification on general test results including reliability tests performed on specific test structures for this process. Inherent process

reliability characteristics such as electromigration or thin oxide breakdown must not cause field failures within twice the expected normal operating time, i.e. 2×20 years.

It is normally easy to perform tests on special structures to simulate very long times and also to reach the wear-out phase for each individual inherent process.

However, it may be difficult to simulate the full use time for some types of components. A power device may require more than 5000h of life test to simulate 20 years use.

Package evaluation. Again, one single package type is often used for many individual component types. Specific tests are designed to verify the quality and reliability of new package types. Test results on a test device in a defined semiconductor process will be used as a base to qualify other devices in the same process and package (family qualification).

Package evaluation may have to be repeated for certain increments of chip sizes.

Component reliability evaluation. The reliability evaluation is either performed by us or by the manufacturer. In the latter case the manufacturer has to report the results to us. The trend is to base most of the reliability qualifications directly on data provided by the manufacturer. Sometimes we provide software to support and facilitate the reporting and to unify the methods of calculation.

A series of ASICs may get their reliability qualification based on the generic process qualification, the generic package qualification(s) and some additional tests on representative ASIC types having different chip sizes.

The same principles may be used for component families such as 74HC.

Application testing. There is a trend to require a formally reported and approved application testing of new complex components. This is due to the difficulties in getting a component specification that fully covers all possible application vectors.

High frequency applications can normally not be simulated in standard life-test equipment, but need separate verification tests in real systems.

Qualification

The formal component qualification is documented in a product certificate that gives reference to all relevant component evaluation reports including an input to vendor assessment reports.

The qualification is approved by the relevant component manager. Our general data network is then used to provide the information on those component types and suppliers that are released for production.

Future qualifications may also be based on evalu-

ation of individual transistor data and defect statistics.

Improvements

Although a component is qualified there is normally room for quality improvement. In order to support that process a number of steps are taken.

Components that are strategic from an economic or reliability point of view must be covered by some form of quality maintenance program by the manufacturer. Results from these periodic tests are summarized and given to us for evaluation every quarter.

Incoming inspection statistics from our factories are compiled, and a zero defect process is continuously carried out to improve the quality. Failure reports are sent back to the manufacturers for comments and corrective actions. Owing to the improved quality and quality assurance programmes more and more of the deliveries are accepted by sample testing or even in some case accepted for direct ship to stock or line. Figure 3 shows the development of the average failure level and the sample test acceptance ratio of microcircuit lots delivered to our factories over the past years.

Component failures in production and system testing of stratic board types are summarized continuously, and component engineers with access to the data network will initiate actions when needed. Information on production and system test component failures may also be fed back to the manufacturer.

Field failure statistics on components are based on board repair statistics. Figure 4 shows the field reliability data of integrated circuits on average. The average failure rate is also decreasing by a factor of two within a few years in use. Analysis of the component reliability may show different results from one application to an other. In that case one might suspect a design problem rather than a component problem.

The statistics, including some typical field failures,

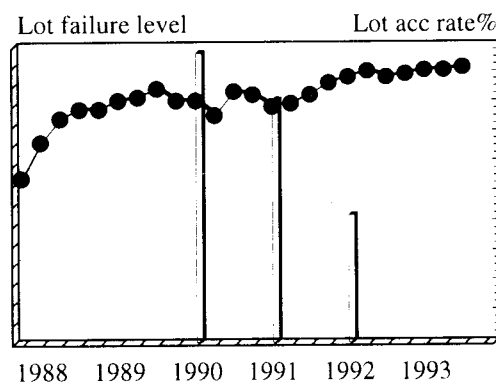


Figure 3. The evolution of failure levels and sample testing acceptance rates of microcircuits at incoming inspection. A result from the zero defect process

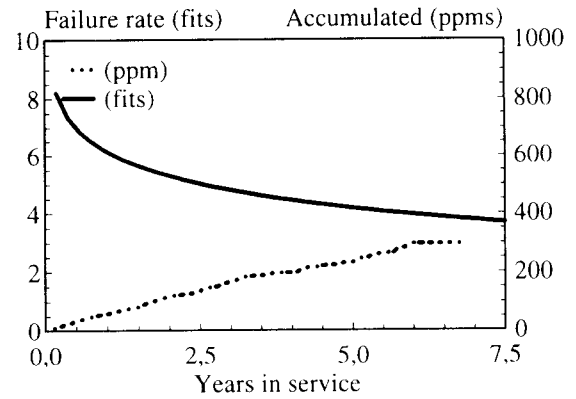


Figure 4. Field reliability trends for the average microcircuit, not including hybrids or ASICs

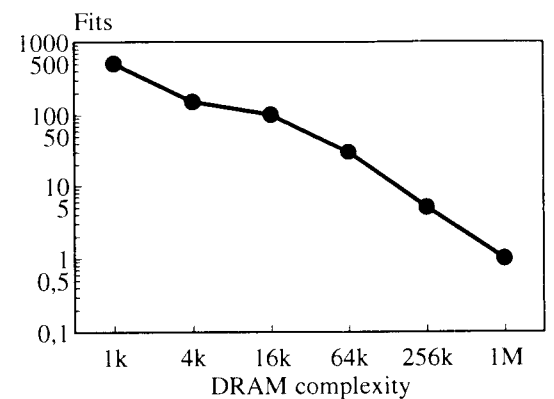


Figure 5. The improvement of DRAM reliability versus complexity evolution over the years 1975-1993. The plot gives the average failure rate during the first year

are sent to the component manufacturer for comments and analysis if agreed upon.

Figure 5 shows the remarkable improvement of the field reliability of DRAMs over the past 20 years.^{1,2} Although the complexity has increased by a factor of over 1000 the failure rate per DRAM component has been reduced by a factor of near 500 times. On a bit level this is equal to an improvement of 500,000 times.

Temperature dependence

An analysis of the failure rate of different microcircuits vs estimated average chip temperature did not show any clear correlation at all. See Figure 6, which may explain why there are different opinions on this matter.

VENDOR RELATIONSHIP

A large number of vendors are used to satisfy our production needs. Depending on the importance and degree of co-operation we classify the vendors as

- (a) general suppliers
- (b) strategic suppliers

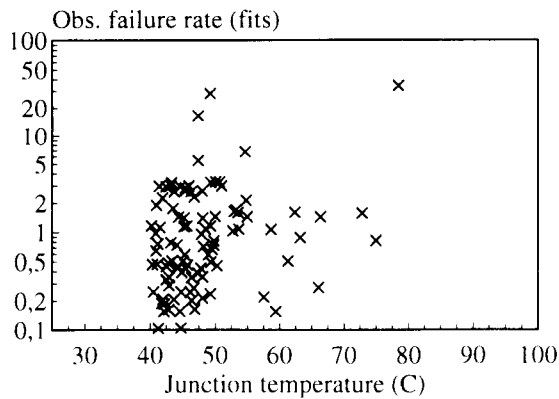


Figure 6. Scatter diagram showing the lack of correlation between observed failure-rate and junction temperature of (different types of) bipolar logic ICs

(c) partners.

Strategic suppliers and partners are evaluated from a general point of view, not only from the quality of their products at a specific time. Basically three areas are investigated:

Technology level and standard

This is based on a technical review of one or more factories of interest to us. The review is not formal but rather technical in its nature. A recommendation is given by a technical expert in the relevant field.

Quality system standard

The base for this assessment is ISO 9001-9002. The trend is to rely more and more on third party assessments as the base for a quality system base approval. This gives us the possibility to better use our resources in the continuous work for improvements also regarding the quality system beyond the requirements of ISO 9001.

Commercial status

Strategic suppliers are evaluated by our purchasing organization from a financial and commercial point of view.

Quality agreements

In addition to normal purchasing agreements separate quality agreements can be signed between Ericsson Telecom AB and a strategic supplier. The following items are covered in such an agreement:

1. Relevant specifications.
2. Applicable components.
3. Quality system certification.
4. Process and product qualification.
5. Process control.
6. Change and problem management.
7. Feedback and corrective actions.

8. Improvement plan.
9. Zero defect process.

A common structure is used for the different quality agreements. A stand-alone frame text can be used within all of the Ericsson Group. Separate agreements make use of this frame text. Finally, lists of applicable components and contact persons are defined when needed while referring to the relevant quality agreement.

STRATEGIES FOR THE FUTURE

Product quality assurance

The product quality must be measured as the total performance through purchase of piece parts, the production process and the service performance in field use.

Failure costs must be measured and used within the improvement process. The reduction of failure costs will then convert into quality profit for the company.

Production quality feedback

Production quality feedback is an important tool for the product improvement process and must be an integral part of the total quality feedback system.

Component qualification

The process and package qualifications will form the base for the individual component type certifications.

The tests will be performed by the manufacturers and reported to us according to more or less uniform procedures.

Strategic suppliers may become qualified to perform the formal qualification of new parts according to release procedures outlined in mutual quality agreements. This would be similar to the QML principles (QML = Qualified Manufacturers Line³).

As component complexity increases, application evaluation will become more important and a formal requirement for qualification.

Improvement management

It is necessary to use quality information from all steps of the product life cycle for optimum product improvement. Our total quality feedback (TQF) system covers three major loops:

- TQF-1: supplier quality feedback, ZDP.
- TQF-2: production quality feedback.
- TQF-3: field service feedback.

Key products may get their own improvement managers appointed to support the continuous improvement process for that product.

Supplier relationship

The general trend is to concentrate on fewer suppliers and instead develop a close co-operation or even partnership with these suppliers. It is, though, important to watch out so that one supplier is not overloaded with partners, whereas another good supplier is forced out of business. Here a co-operation between purchasing organizations is essential.

Quality agreements that include improvement goals will replace or add to the older quality specifications that were more static in nature.

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Authors' biographies:

Örjan Hallberg is currently managing a project on quality information feedback and product improvement within Ericsson Telecom AB, Local Switching. He received an M.Sc. degree in Electrical Engineering in 1966 from Chalmers' University of Technology, Gothenburg, Sweden. He then joined the Swedish Telecommunications Administration, working with component evaluation and standardization. Between 1971 and 1981 he was managing the quality and reliability evaluations of electronic components within ELLEMTEL. Between 1981 and 1987 he worked as quality manager within RIFA AB. Since 1987

he has been with Ericsson Telecom AB, being responsible for qualification and vendor assessment activities.

He has published papers about reliability models, field use reliability data, step stress testing, test structures and acceleration factors.

At present he is also a member of the European Steering Committee for the ESREF94 conference.

Bo Eriksson was born in 1959 and gained an M.Sc. degree at Linköping in 1983. He has been working with product and process engineering in semiconductor manufacturing and also been managing component reliability engineering for pacemakers. Since 1990 he has been handling IC qualifications at Ericsson Telecom AB and is especially interested in ASIC and process qualification methods.

René Francis joined Ericsson in 1986. He has a B.Sc. background in telecom technology. The main part of his work has been devoted to the quality improvement process (OIP) within the area of incoming inspection of electronic components. He is appointed manager and coordinator of a corresponding zero defect programme.

Royne Hjortendal joined Ericsson in 1960 as a design engineer in switching electronics. He has been involved in the design of all versions of line circuit boards for AXE within Ericsson Telecom AB. The work includes all specific ASICs that were designed for the boards. He has also been responsible for developing a test philosophy and design verification strategy at both the component and the board level. He is at present managing the telecom component engineering activities.

Lars Inge Lindberg was born in 1950 and joined Ericsson in 1972. His career has been within different production facilities within Ericsson and has involved international contracts. During 1985-1986 he managed the incoming inspection facility in Mexico. In 1987 he developed and managed the incoming inspection at the factory in England and was during 1990-1991 the quality manager of the factory in Algeria. Since 1992 he has been involved in several major industrialization projects of high volume products in Sweden.

Bernt Sävström started his career at Ericsson in 1963 and soon came to the component development organization. He has been involved in component reliability testing and investigations for the whole period since then. During the last ten years he has been responsible for reliability testing of microcircuits and the development and maintenance of the reliability prediction system that is used within Ericsson Telecom AB.