ELECTRONIC COMPONENTS: RELIABILITY STRESS SCREENING

Key words: RSS - Reliability stress screening, ESS - Environmental stress screening, early failures, components

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1 SCOPE

In an electronic product there always are some weak points (flaws) such as insufficient solder joints or bonded joints in a semiconductor, which can be the cause of an equipment failure during early field operation. Before delivery to customer these flaws can be transformed into permanent faults, the faults located and the electronic unit repaired and delivered as a strong unit. This is done by a method called Reliability Stress Screening, RSS. By use of this method the reliability of an electronic equipment in the initial time of field operation is improved. As the cause of the weak point is disclosed and corrective action is taken, this also results in reliability growth of the product.

The RSS can be performed at different levels of the product structure such as: system level, sub-unit level, printed wiring assembly (PWA) level or component level. Generally, RSS performed at a lower product level is less expensive than RSS performed at a higher level. The efficiency of RSS performed at component level is also higher because higher stress levels can be used. The disadvantage is that flaws introduced (even in the components) during production of the final product could...
require RSS at higher product levels. The selection of these levels and their cost optimization is not dealt with further in this method.

A method for the design and performance of RSS at PWA level is described in Nordtest method NT ELEC 018, Ref. 1.

This document deals with RSS at component level and is written as a guide, in the first hand for the component user = equipment manufacturer. To keep the method itself as short as possible some background information which is not indispensable for the design and performance of the RSS is given in a separate report: SP report 1994:31, Ref. 4.

The possible product manufacturing phases at which component stress screening can be applied are indicated in Figure 1. If the user considers screening at component level he can either specify screening to be performed by the component manufacturer or he can perform the screening himself after receipt of the component delivery.

In some standards (e.g. MIL-STD-833) a certain method is specified for the actual component type. These methods are not flexible and optimized for the current situation and may give a too severe or a too mild environmental screen and are often too costly. It is also important to have a flexible RSS method to adapt to changed conditions e.g. after corrective actions.

RSS is performed only as long as the level of early failures is unacceptably high and the implementation of a corrective action is cost effective. When optimizing the method the quality and the features of the component type, the application and screening case shall be considered.

Components can in many cases be purchased to different quality levels. Some component types can be purchased screened. Specific problems for the user arise when it comes to application specific components, normally manufactured in small series, especially types which are manufactured with new processes.

Another problem for the equipment manufacturer arises when a component type in a screened version is not available, or is too costly and the component is to be used in a high reliability application.

A third problem is when a secondary component parameter is essential for its designed application. This parameter can be dependent on environmental stress e.g. temperature. Different cases are defined regarding the different aims of the screening, see Paragraph 5.1.

RSS is defined as a screening process which is in principle performed on all items in a population (100 %). To apply this method for the relevant screening activities lot screening i.e. screening based on a sample is included. This means that destructive methods can be used in the screening program and the results can be the basis for approval or reject of a component lot. Hence, this method also includes Lot Acceptance Tests ("LAT").

The application of the method will enhance good cooperation between component supplier/manufacturer and user.

2 FIELD OF APPLICATION

The aim of this Nordtest method is to give guidance for component users on how to design and perform RSS of components in the most efficient and economical way without a significant reduction of useful life for good components. In some cases a lot acceptance procedure is adequate and for these cases RSS is performed on relevant samples from the lot.

The method is especially applicable for:

- application specific or small series manufactured components which can be screened at the component manufacturers, alternatively at the equipment manufacturers premises, or
- standard, large series manufactured components intended for use in high reliability applications where the equipment manufacturer in most cases performs the screening
- parameter selection.

Besides the general procedure for the design, performance and analysis of screening results, the method describes environmental stress types and generally how these are to be selected together with stress levels and screening duration to
be as efficient and economical as possible in transforming flaws into faults. Some of these selections and methods are based on statistics. The method further describes equipment for the performance of screening.

The ultimate selection of stress types and levels is dependent on the component type, its design, possible failure modes and screening case. Examples are given for some generic component families (ASIC’s, power semiconductors, transformers, connectors) in the method. Possible failure modes for these families are given in annexes to the method as well as efficient screening methods for each failure mode.

The selection of these component families is based on a questionnaire reported in Ref. 1, where these families were identified as being the component families having the highest failure rate in RSS at higher product levels. Flaws introduced in components during the assembly process shall be considered for RSS at printed wiring board level.

This RSS method makes use of methods defined in document IEC 1163: “Reliability Stress Screening of Repairable Items manufactured in lots” (Ref. 2) with extended application including Lot Acceptance Tests.

3 REFERENCES
1 Nordtest method: NT ELEC 018. Printed Wiring Assemblies: Reliability Stress Screening.
2 IEC 1163. Reliability Stress Screening of Repairable Items manufactured in lots.

4 DEFINITIONS
With the exception of terms defined below, general reliability terms used in this publication are defined in IEV 191 (Ref. 3).

4.1 Reliability improvement
“A process undertaken with the deliberate intention of improving the reliability performance by eliminating causes of systematic failures and/or by reducing the probability of occurrence of other failures”. (IEV 191-17-05)

Additional note: Reliability stress screening reduces the probability of occurrence of other failures. The systematic failures are principally catered for by a reliability growth programme, but some may appear during reliability screening.

4.2 Reliability Screening
Reliability Screening is a process of detection of flaws and removal and repair of weak items for the purpose of reaching rapidly the reliability level expected during the useful life.

Note 1: In this Nordtest method RSS is extended to include removal of weak lots and subsequent minimisation of the occurrence of weak lots.

Note 2: IEV-191 defines in Clause 17-02 the term “burn-in”. This term, however, is used by many manufacturers to describe a so-called “soak test”, which is only one of many possible ways of screening. Furthermore “burn-in” may include ageing, the purpose of which is to stabilise parameters, and where in many cases no failures occur.

Note 3: IEV-191 defines in Clause 14-09 the term “screening test”. This term, however, is defined too broadly to be applicable in the present context because it encompasses screening for any types of nonconformities. Furthermore, reliability screening is a process, not a test.

4.3 Reliability Stress Screening
A reliability stress screening process using environmental and/or operational stress as a means of detecting flaws by precipitating them into detectable failures.

Note: The reliability stress screening is designed with the intention of precipitating flaws into detectable failures. An ageing process designed with the intention of stabilising parameters is not a reliability stress screening process and therefore outside the scope of this publication.

4.4 Item
“Any part, component, device, subsystem, functional unit, equipment or system that can be individually considered” (IEV 191-01-01).

Note 1: An item may consist of hardware, software or both, and may also in particular cases include people.

Note 2: A number of items e.g. a population of items or a sample, may itself be considered as an “item”.

Additional note: In the context of reliability screening only the hardware part of an item is relevant. Current examples are electronic components, assemblies, equipment and hardware parts of systems.

4.5 Weak item
An item which has a high probability of failure early in life due to a flaw.

4.6 Component
A single item which is not intended to be repaired.

Note: Even though components are defined as non-repairable a component may be repaired by the component manufacturer as part of his manufacturing process.
4.7 Weakness
Any imperfection (known or unknown) in an item, capable of causing one or more weakness failures.

Note: Each type of weakness is assumed to be statistically independent of all other such types.

4.8 Weakness failure
“A failure due to weakness in the item itself when subjected to stress within the stated capability of the item” (IEV 191-04-06).

Note: A weakness may be either inherent or induced.

4.9 Flaw
A weakness in hardware, which gives rise to early weakness failures.

Note: A flaw is localised in a component or is attributed to an interaction between components with characteristics close to the margins of the design requirements.

4.10 Inherent flaw
A flaw in an item related to its technology and manufacturing process.

4.11 Induced flaw
A flaw in an item related to assembling, testing, handling or other manipulation of the item after it has been manufactured.

Note: The induction may take place at the component manufacturers plant, during transportation or at the equipment manufacturer’s plant.

4.12 Flaw density
The average number of flaws per hardware (component, assembly, subsystem or system) under consideration.

4.13 Early failure period
“That early period, if any, in the life time of an item, beginning at a given instant of time and during which the instantaneous failure intensity for a repaired item or the instantaneous failure rate for a non-repaired item is considerably higher than that of the subsequent period” (IEV 191-10-07).

Additional note: The early failure period is the period where the weak items fail.

4.14 Screening Strength
A measure of the capability of a screening process, designed with specified parameters, to precipitate flaws into failures.

Note: The screening strength is a function of the type of screening as well as the specification of the screening parameters.

4.15 Screening Relevant Failure
A failure which is a result of one or more flaws brought about by the screening process.

4.16 Indicator Screening
A screening method, where other parameters than the functional parameters of the components are used as decision parameters (indicators) for acceptance or rejection of the components.

4.17 Freak
A component containing one or more inherent flaw(s). Freak components fail typically after a few thousand hours of operation under normal working conditions.

4.18 Lot Acceptance Test (LAT)
A sample test consisting of destructive and/or non-destructive tests. Results of the test are applied for the decision of acceptance or rejection of the lot.

5 SAMPLEING

5.1 Different cases of RSS
Sampling for an RSS process for components depends on the aim of the RSS and the type of component.

As a systematic approach the following cases are defined and discussed in this method:

Case 1
The delivered component lot is known to contain some ‘freak’ components, but the lot cannot be rejected, as the components are required in production.

Case 2
The user wants to use a component in such a way that one or more secondary parameters are primary parameters for the circuit design or he wants a closer tolerance than specified for one or more parameters. The user wants to have one or more component lots screened for this (these) parameter(s).

This case is applicable for companies producing according to the 6-sigma philosophy which want a higher margin between component parameter value and the functional limit of designed circuit.

Case 3
The user wants to use a standard component but the reliability level is unknown or is known to be too low for the intended application.
Case 4
A user or sub-supplier of small lots of customer specified components wants some assurance that the delivered components have a reliability high enough to meet the requirements of the design. Users or sub-suppliers of these components often lack the expertise of the large component suppliers.

This case includes ASIC's (Application Specific Integrated Circuits) and MCM's (Multichip Modules).

Case 5
The user wants to make sure that lots with "flaws" are not used in his production process. This can be the case when producing highly reliable equipment, or when producing according to the 6 sigma philosophy.

5.2 Considerations for the selection of 100 % RSS or sampling

Generally the following applies:

In Case 1 the lot shall be screened 100 %. The components are in their finished condition, i.e. sealed and ready for use.

In Case 2 a sample RSS or a 100 % RSS may be applicable. This is dependent on the parameter to be screened, the required assurance for not having a "freak" in the accepted lot and the results of the performed RSS (margin to the required limit). The decision from the result of a sample RSS may be to use the whole lot as it is, reject the whole lot or screen the lot 100 %.

For a 6 sigma computation the distribution of the parameters has to be logged, not just pass or reject. This is a requirement which can be specified by the user (e.g. by special agreement with the component manufacturer or screening laboratory for sampling and data logging).

In Case 3 the same situation as in Case 2 applies. 100 % RSS is more common in this case since there is a small number of "freaks", but a sample could also be used in some tests such as Destructive Physical Analysis (DPA).

In Case 4 it may be possible to perform screening and inspection before the components are fully assembled e.g. performance of a "precap-inspection". The RSS can be a mixture of sampling and 100 % screening.

In Case 5 the RSS will usually be performed on a sample of each manufacturing lot. The RSS may have to be of short duration when the company is producing according to "Just-In-Time".

In the decision whether to use sampling or 100 % RSS the character of the RSS process shall be considered. If the RSS process, or a part of it, is destructive, e.g. pull tests of bond wires, the RSS (or a part of it) must of course be performed on a sample basis. In some cases a test unit can be included e.g. an extra bond wire loop just for the purpose of testing.

5.2.1 Sample RSS

Sample RSS is efficient if there is confidence that the suspected "flaws" exist in a significant part of a lot e.g. in more than 5 % of the components. Efficiency of sampling increases dramatically as the percentage of "freak" components approaches 100 %.

If we can be certain that the character of the flaw is such that either 100 % of the lot contain the flaw, or none have it, a sample of one unit is sufficient to check for the flaw. This can be the case where a process e.g. a bonding process is set up incorrectly from the start of the lot, or a wrong material or a contaminated bath or oven is used.

Even though all the components in the batch contain the flaw it does not necessarily mean that they all fail in field use. The number of failures also depends on the environment of operation. If the flaw requires moisture to cause a failure it may not show up at all in an equipment running 24 hours a day in a humidity regulated area.

A special case is measurement of a number of parameters in a sample in order to estimate the parameters for a distribution describing the variations of the component parameter. Knowledge of these distribution parameters allows tolerance computations and e.g. evaluation of the components according to the 6 sigma philosophy.

"Flaws" forming a continuous distribution of the component parameter from the nearly perfect to reject are rare (Fig. 2A). Often there is one distribution of parameters around the "perfect value" and another small distribution formed by components containing "flaws" (Fig. 2B).

Since the number of "flaws" is usually a very low percentage, items belonging to the small "flawed" distribution will frequently be absent from the sample and are accordingly not detected. Occasionally only one single "outlying" value is seen (Fig. 2C).

In a sample of 50 components containing 1 % "flaws" there is 70 % probability that no flawed component is found in the sample!

Some flaws can only be precipitated by a time period with stress. The result of such a time dependent RSS process is described in Fig. 3.

The percentage of freaks, p(w) may be treated as a failure percentage for the sample. How to decide on the risk of accepting a bad lot, and decide when to reject it based on a sample, is described in 6.1.11.
5.2.2 100 % RSS

Sampling can not be used if the percentage of "flaws" that occur at random during the process is low, which is often the case. Examples of such flaws are: random contamination, local flaws in material or random human error. In this case a 100 % screening has to be performed in order to make sure that all freak components are caught. If such component flaws range from 100 ppm in one lot up to 0,1 to 2 % in other lots this means that most lots may be perfect, while some lots are unacceptable (contain a level of 0,1 to 2 % flaws).

Example: an equipment contains 34 components of the same type. This component type contains 0,5 % flaws. This results in early failures for 17 % of all finished equipment on average. This is enough to cause a major problem on the market.

For RSS based on 100 % sampling the decision whether to accept or reject the lot is simple. The flawed components should have failed during the RSS and are discarded. The rest of the lot should be accepted. Even if parameters are measured and the components do not fail functionally, the components that have exceeded one or more parameter limits are regarded as failed.

6 METHOD OF RSS

6.1 Principle

It is not possible to make a catalogue of RSS processes for each component type as there are so many different component types and versions (component values, sizes, packages etc.). Further, as described above, the aims of the RSS are different.

What can be described, however, is the procedure on how to design a tailored RSS process for a particular component type and application, the criteria for a good RSS process, how to optimize the RSS process, and how to discontinue the RSS process when it is no longer needed.

The following step-by-step procedure for setting up and running an RSS process is recommended:

Step 1: The aim of the RSS
Step 2: The role of the component manufacturer
Step 3: Possible flaws and failure modes
Step 4: Selection of stress types
Step 5: Selection of stress levels
Step 6: Selection of stress sequence
Step 7: Determination of duration: RSS test definition
Step 8: Determination of duration: Failure analysis
Step 9: Determination of duration: Mathematical analysis of RSS test result
Step 10: Performance of the RSS process
Step 11: Approval or rejection of a component lot (in relevant cases)
Step 12: Feedback to the RSS process
Step 13: Feedback to component manufacturer
Step 14: Discontinuance of the RSS process

The steps should be performed in the given order, but normally some iterations are necessary with feedback to any of the preceding steps.

In the following each step is discussed. In 6.3 there are examples of how an RSS process could be designed for different component types. These examples should not be used uncritically for RSS of components of the same family, but regarded only as illustrations of the described step by step procedure.
6.1.1 The aim of the RSS

First it shall be clarified why an RSS is really needed. No RSS should be made as a routine. There shall be a clear economical reason why RSS is chosen and the quality and cost gains with the RSS shall be evaluated against the drawbacks such as: increase in production time, investment costs, quality risks.

An RSS involves a lot of component handling during which there are probabilities that failures caused by this operation can even outnumber the failures caused by inherent flaws. These quality risks include risks of: destruction of hermeticity, bending of terminals, loss of solderability and most of all: risks of destruction or latent failures due to ESD (Electrostatic Discharges) damage or other voltage overstress.

Also the test equipment (and the measuring equipment) constitute threats to the components by the risks of voltage spikes and intermittent contacts/interruptions.

In some cases a qualification test of a component related to the actual application can be performed and information based on the result of this test used for the decision whether or not to perform RSS. The information is also of value for the design of the RSS.

An RSS at component level is almost always more efficient than an RSS at higher product levels due to the higher stress levels that can be used at component level. But it should be remembered that RSS on components will only find flaws which originate from the component manufacturing and not the flaws added during the equipment assembly processes.

The aim of the RSS shall be classified in accordance with 5.1.

6.1.2 The role of the component manufacturer

It is strongly recommended that before an RSS process is started the component manufacturer is always contacted. The reasons for doing so are several:

- Since the component manufacturer may already perform screening of the component type, or a similar type, he is probably willing to perform RSS and can do so very easily and therefore less expensively than if the user set up his own RSS scheme.

If it is decided at this point that the component manufacturer will perform the RSS the user shall include the RSS process in his purchase specification. In this preparation the component manufacturer shall take part. The preparation can follow the discussion as described below.

In some cases the component manufacturer will be able to do the screening without application of stress since many flaws can be found by simple means such as inspection or simple screening during the production process. On a finished component these flaws could require extensive RSS to be disclosed.

- If the component type is an ASIC and especially if it is a full-custom ASIC the cooperation with the component manufacturer is of major importance. The component user designs and specifies the electrical functions of the component and (often) supplies the component manufacturer with test programs. The component manufacturer supplies the basic elements for the design and the manufacturing process. Both parties contribute to the quality of the component.

- Even if the component manufacturer is not willing to perform the screening, or this alternative is too costly or impractical, the component manufacturer should be able to give valuable information for the design of the RSS e.g. the maximum stress levels that can be used. The manufacturer knows all the processes used for producing the component, and he also knows the potential flaws and how to detect and avoid them. This is part of the component manufacturers know-how, and it should not be expected that he will reveal it in detail.

- To gain a reliability growth of the component type (or family) which is of interest for both component user and manufacturer it is important that the communication between them is good. Examples of information to be exchanged are: results of RSS and failure modes revealed, component design changes, specification changes, field failure rate and modes, decision about feedback to RSS process.

6.1.3 Possible flaws and failure modes

A list of the components potential flaws should then be made up. Together with the information obtained from the contacts with the component manufacturer the basis for the evaluation could be Annex 1 which can be used as a check list. The annex shows potential flaws for different generic component families and technologies. If experience from failure analysis of failed components exists, this gives important information about possible flaws. This is often the case in RSS Case 1.

When the potential flaws have been listed an evaluation should be made whether the identified potential flaws develop into a failure in the environment of the finished product. E.g. if a flaw requires moisture to cause a failure it may not show up at all if the equipment runs 24 hours a day in a humidity regulated area. Further, the aim of the RSS process as determined in Step 1 should be taken into account.

This evaluation ends up with a list of potential flaws that the RSS process shall find and remove.

6.1.4 Selection of stress types

The aim of this step is to select stress types that are the most efficient in precipitating the listed flaw types. Different types of stress and needed equipment are described in 6.2.

When performing this analysis one should look for the stress types that are most efficient for a given flaw type. Annex 2 which lists efficient stress types versus failure mechanisms is a good basis for this discussion. The check lists shall, however, be supplemented with knowledge of the actual component and its possible flaws. Again information obtained from the component manufacturer is valuable.
Annex 2 can also be used to select efficient analysis methods in cases where screening with stress is not needed.

Not only the most efficient stress types should be considered. To cover all of the relevant flaw types with a manageable number of stress types it is necessary in some cases to select the second or third most efficient stress type.

Other factors which shall be taken into account are:
- which stress type can be used with the highest stress level if comparable stress types exist?
- which stress types are most easy to set up and require less investment (availability of equipment)?

Annex 3 lists the most common specifications for different stress types.

6.1.5 Selection of stress levels

The maximum level of stress that can be used without significantly reducing the life time of the good and sound (unflawed) components shall be chosen.

If no special information is available from the component manufacturer, the maximum storage temperature for the component type should be chosen when no voltage is applied and maximum operating temperature when the RSS is performed under electrical voltage.

It is nearly always possible to use higher stress levels than what is possible for an RSS at higher product level or stress levels that the component experiences when it is mounted in the final product.

The chosen stress levels must not destroy good unflawed components. For mechanical vibration the method of Nordtest NT ELEC 018, Annex 5 (Ref. 1) can be used for a check.

6.1.6 Selection of stress sequence

In some cases the stress types are applied separately in sequence. The order of the sequence can be of major importance. E.g. if a temperature cycling creates cracks between mechanical integrity parts a mechanical stress should be performed after the temperature cycling instead of the opposite.

The same applies for dry heat, which should be applied after mechanical stress in order to oxidize possible wear surfaces.

In other cases it is efficient to combine stress types e.g. cold and shock/vibration and heat and moisture (85 °C/85 %RH; 125 °C/85 %RH etc.). These stresses with high levels both of humidity and temperature are called “Highly Accelerated Stress Tests” (HAST).

Stress from operational load or from specially applied electric voltage as for example reverse voltage can be combined with thermal load.

Annex 4 contains some examples of stress sequences for different component families.

6.1.7 Determination of duration: RSS test definition

In order to find the optimum RSS duration an initial RSS test should be performed. A sample of the components is exposed to the selected stress sequence with the selected stress levels.

When the result of this initial RSS test is analysed the required duration of the RSS process can be selected. It is usually much shorter than the duration of the initial RSS test.

The number of components for the RSS test shall be chosen so high that at least 4 failures can be expected with 90 % confidence. The computation of the required number is shown in Annex 5.

The duration of the initial RSS test should be made so long that all expected flaws have failed in the test. Many flaws do not fail until 1000-3000 hours in field operation. The selected stress levels in 6.1.5 are normally much higher than stress levels in field use. To get a rough idea of the time needed to transform flaws into failures equations and data according to Annex 6 can be used.

When using the Arrhenius equation according to Annex 6, an activation energy valid for the actual expected failure modes and valid for the temperature interval between the operating temperature and the RSS temperature shall be used.

The RSS test should be performed over such a long period that a fair degree of confidence is reached that all flaws have failed during the test.

The computed duration is not used to define the duration of the RSS process. It is used only to make certain that the initial RSS test has a duration long enough to precipitate all relevant flaws into failures. It also gives an idea of the duration of the RSS at chosen stress levels to be able to calculate the cost and time consequences.

6.1.8 Determination of duration: Failure analysis

All failures observed during the initial RSS test should be analysed in order to determine the failure mechanisms and to determine whether or not the failure was a relevant screening failure (caused by a flaw).

Unflawed components destroyed by the test can give an indication that the chosen stress level is too high.

It is also very important to note any flaws that are caused by the handling during the RSS process (ESD damage, cracks around leads etc.).

The failure analysis may confirm the expected flaw types, but may also reveal some added types. However one can not be certain that a particular failure mode is absent just because it does not show up in the test. It may be absent due to statistical variations (good or bad luck) or it may be absent in the particular lot due to good process control or again due to luck.

The identified flaw types may however have consequences on the selection of the stress types and sequences, and therefore a feedback to these decisions should be considered.
6.1.9 Determination of duration: Mathematical analysis of RSS test result

The results from the initial RSS test are analysed mathematically using Weibull probability paper. The plotted failure points are analysed using the method described in Annex 5 together with Figures 8 and 9. More information may be found in IEC 1163 Annex F (Ref. 2).

It is very important to make sure that the curve really has levelled out, i.e. it is approximately horizontal. If in doubt one may add a hypothetical failure 1 hour after the test was finished. If the curve has still levelled off in this worst case situation it is fairly certain that all flawed components have failed. There are cases where more than one type of flaw is present and where the curve levels off in two or more steps. Therefore the initial RSS test should be performed as long as is practically possible.

If it is in question whether the component failures observed really are relevant screening failures this is normally determined by the failure analysis. This failure analysis may be supplemented by a statistical analysis using the Bayes method as described in Annex 7.

From the Weibull plot it is possible to determine the percentage of flawed components ($p_w$) and their characteristic lifetime ($\eta_w$), and the duration of the RSS can be computed as described in Annex 5.

Sequences of stress conditions and combined stress conditions are usually arranged as cyclic sequences. Such cycles are normally analysed with the number of cycles along the abscissa (corresponding to the time scale). In cases where the stress sequence is not cyclic but each stress step is applied only once the following procedure can be applied:

1. Each stress (combination) step is analysed separately and its optimum duration computed. This requires that the components are functionally tested during the RSS process or tested between each stress (combination) step.

2. The stress sequence is considered as a sequence of non-separable stress steps. Here the duration of each step of the sequence can be shortened or prolonged proportionally according to the RSS test results and depending on observed failure modes.

After evaluation of the results of the RSS test a feedback to the selected stress level and sequence shall be considered. E.g. if the screening is too time consuming a change of stress type or an increase of stress level could be necessary.

6.1.10 Performance of the RSS process

When all parameters for the performance of the RSS are set as described above, possibly after some iteration, the process can be introduced as a production step.

Depending on the identified RSS case (6.1.1) a 100% RSS or an RSS based on sampling is chosen.

Normally the components are produced in lots so that a statistical analysis can be performed on each lot. Alternatively statistics should be computed for each day or week or production.

The following discusses how to monitor the 100% RSS process.

The statistics should include the failure level found in the functional test before the RSS process and the failure level found in the functional test immediately after the RSS process. The last level should be closely monitored.

In order to determine when a significant change in the failure level has occurred a statistical process control chart (p-chart) should be employed.

Before the components are scrapped, rejected or repaired a failure analysis should be performed in order to determine the cause of the failure. It is especially important to determine whether or not the failure is a relevant screening failure (caused by a flaw). Unflawed components that failed due to the RSS process may indicate that stress levels are too high. Also failures identified as dependent on handling during the RSS process should be identified.

6.1.11 Approval or rejection of a component lot

In cases where the result of the RSS is used as the basis for the approval or rejection of the whole component lot (Lot Acceptance) the decision can alternatively be based on different decision rules:

A. The number of failures observed in the sample.
B. The percentage of flaws estimated in the lot.
C. The percentage of components with parameter value outside the limit.
D. The margin from the parameter distribution to the functional limit (e.g. 6 sigma).

Instead of rejecting the whole lot an alternative decision is to screen the lot 100% (when possible) and to scrap the components found to be outside the specification.

The procedures in arriving at the decision for the four alternatives are described in Annex 8.

6.1.12 Feedback to the RSS process

The RSS process shall always be subjected to changes in a running production. The initiators for changes are:

- Increase or decrease of failure rate in the RSS process
- Changed flaw types
- Field failures due to flawed components

If the function of the components is monitored continuously during the RSS process it is recommended that the information is used to change the process e.g.:
If the RSS is performed on sample basis this should be re-
vealed early in the process. Even if no significant changes are indicated the RSS test should be re-
peated when failures related to freak components are observed in the equipment in its field
use. The RSS test should always be significantly longer (3-5 times) than the RSS process in order to detect if early failures occur after termination of the RSS process.

To perform an RSS test takes some time and until its results have been evaluated the following actions should be taken:

- If significant increase of the failure level occurs in the RSS process the duration of the RSS process should immedi-
ately be doubled.
- If the RSS is performed on sample basis this should be increased to a 100 % RSS if the RSS is non-destructive.

For destructive steps the sample size should be doubled in number.

6.1.13 Feedback to component manufacturer

As discussed in 6.1.2 it is important that results from RSS, even the failure analysis, are reported to the component manu-
facturer. Even if no formal cooperation agreement exists with the manufacturer most manufacturers are happy to receive such information.

The purpose of this feedback is to enable the component manufacturer to improve his production processes and com-
ponent design.

This cooperation will of course be more efficient if a formal agreement on cooperation exists.

If the component manufacturer performs the RSS to a specifi-
cation issued by the component user it is vital that the outcome of the RSS is reported by the component manufacturer to the component user so that changes in the specification are introduced when it is appropriate.

6.1.14 Discontinuation of the RSS process

Where the RSS process is necessary because a secondary parameter is used as a primary parameter (Case 2), or a component need to be screened for a higher reliability (Case 3), the RSS process must naturally continue as long as the component type is used.

In the other cases the RSS process should never be a routine. The ultimate goal of the RSS is its discontinuation.

When 100 % RSS is no longer needed, RSS on a sample of each component lot could be used as a safeguard against lots containing freak components. Even though a long RSS pro-
cess may be needed in order to remove all freaks in the lot (100 % RSS), an RSS process on a sample of the lot may in shorter time be able to give information that the component lot contains freak components. See example in Nordtest method NT ELEC 018, Annex 2 (Ref. 1).

6.2 Applicable inspections, stress types and apparatus

Examples of standards for the following stress types can be found in Annex 3.

6.2.1 Internal inspections

Although not an environmental stress, visual inspection is a very viable step in an RSS sequence either to reveal flaws directly or after a preceding environmental stress step.

A visual inspection can be performed before the active parts of the component are packaged in a hermetic case or moulded in, called “Pre-cap visual inspection”. To perform this inspec-
tion a microscope is used. The magnification is selected to suit the component type and its structure.

Requirements can be found in different standards, see Annex 3. The user can also specify his own requirements in the component specification.

The method can reveal all kinds of deviations which are detectable at the magnification used provided that the inspec-
tor is well trained.

The inspection performed in full for e.g. complex multichip modules is very costly and is not recommended but for a specific suspected flaw type it can be cost effective, e.g. inspection of internal solder joints for transformers. It is of course most applicable for RSS Case 4.

For hermetically packaged semiconductors an option is to perform almost the same type of inspections after packaging by delidding the components. This screening which is called DPA (destructive physical analysis) is destructive and must, of course, be performed on a sample base. Special, not expen-

tive, equipment is needed for the delidding procedure.

Components with other types of packages can also be in-
spected by DPA, but here more sophisticated methods have to be applied, e.g. chemical stripping off of moulds and different mechanical actions.

If the internal visual inspection is performed before sealing or as a DPA it is possible also to perform mechanical tests of joints and attachments e.g. bond strength, die attachment.

For components, mainly ceramic multilayer capacitors, where it is imperative that no voids are present in the component
structure a Scanning Acoustic Microscope (SAM) can be used. This is a non-destructive inspection but it needs a very expensive equipment and it needs training to handle it and to interpret the results.

For components packaged in all kinds of packages it is possible to perform a non-destructive internal visual inspection by using different X-ray equipment. By using modern equipment for X-ray microscopy, which can offer magnification, very accurate inspections are possible. The equipment is very expensive and a full inspection is time consuming. Less expensive X-ray equipment can successfully be used for internal inspection of e.g. short-circuits between wires in transformers, bond wires, etc.

Internal visual inspection is applicable for RSS Cases 1, 3 and 4. DPA is very often used as a part of a Lot Acceptance Test.

The weaknesses of all types of visual inspections are that the real effects of the disclosed deviation in field use can often be questioned and that the inspector is not able to find all weak points. Destructive inspections suffer from the suspicion that the deviation, the flaw, has been caused during the preparation, delidding etc. Some methods also suffer from the problem of interpretation of the results.

6.2.2 Temperature cycling

Temperature cycling is a very viable method to reveal weak joints between combinations of material such as: solder joints, chip attachment to header, moulding compound to lead frame, bondings, welding joints and weak conductive areas such as: chip metallisation faults, bond wire nicks and also to reveal weakened insulation.

The stress is performed as a cycling between the highest and the lowest rated storage temperature in an air-to-air system. An equipment built with one or two chambers can be used. A two-chamber equipment has an elevator system by which the components are transported between the high and the low temperature chambers. The transfer time is specified to e.g. one minute.

A one-chamber equipment has the capability to change temperature fast between the two extremes. Normally the temperature gradient is specified as 5 to 10 °C/min. The severity is increased with increased temperature gradient.

The two-chamber method should however not be regarded as more severe than the one-chamber method as it depends on the cooling and heating capacity of the equipment and on the thermal mass of the components.

Normally this stress is performed without any voltage or power stress, but for certain components, e.g. power semiconductors an active temperature cycling by switching power on/off can be very effective as the thermo-mechanical tensions can be much higher e.g. for the chip attachment. This type of temperature cycling will of course be more complicated due to the needed component sockets, wiring and instrumentation.

6.2.3 Thermal shock

A simple kind of temperature cycling can be achieved by using two liquids e.g. two containers, one with ice water and the other with boiling water. The components are transported between these two containers with a defined transfer time, e.g. 10 seconds. Other liquids to get another temperature range can be used.

The method is applicable mainly for small components which have a small thermal capacity. When suspecting e.g. glass feed-throughs as weak points this method could well be used.

The stress type is very severe as the temperature gradient is high but the temperature range is limited. The use of liquids may be deleterious for the components. The method is slow as not as many components at a time can be tested. Due to this fact and due so questionable (sometimes inconsistent) results the method can not be recommended other than in special cases where it should have been well evaluated in advance.

6.2.4 High temperature

High temperature stress can be applied for several reasons:
- to stress flaws to failures (RSS Cases 1, 3, 4)
- to screen out components which do not work in their intended application if parameters are outside defined acceptance limits (RSS Case 2)
- to screen out components which are outside defined acceptance limits for the application of the 6-sigma quality system (RSS Case 5).

The latter two cases mean short time stress at a defined temperature with defined electrical stimuli. This type of stress can be performed in a temperature chamber but it needs cabling that can be complex and the measurement may be disturbed by long cabling. A better way could be, especially for small components like IC’s, semiconductors, to use a local heating/cooling system which blows the heated/colloed air on to the component which is mounted in a fixture connected to the measuring equipment.

This kind of equipment is fairly moderate in cost. The instrumentation for parameter measurement can be much more expensive.

If the aim of the high temperature stress is to precipitate flaws to failures this stress can be performed without voltage (e.g. "Stabilisation bake"), with voltage applied ("High temperature reverse bias", "Steady state, forward bias", etc) or with power applied ("Power burn-in", "Excitation", etc.). It can be performed with or without monitoring of the function during screening.

The choice of method shall depend on the type of the expected flaws. Generally, the application of voltage enhances failures which are related to contaminations. If power is applied the increase in temperature could preclude these failures. For semiconductors the stress of the reversed biased pn-junctions
can be more efficient than a forward biasing with power. Hence there are some technical reasons not to use power during screening. Otherwise the reason for not using power is the higher costs associated with the fixturing, instrumentation and cabling and also the risks of damage due to voltage overstress and failures in the fixtures.

For power components it can be very efficient to use power applied, possibly switched on-off as discussed in 6.2.2. Here again the cost for fixturing, instrumentation, etc. is high.

When power is applied during screening it is especially important to monitor the temperature on a well selected place in the temperature chamber and to have an even temperature over the whole of the chamber space.

6.2.5 Low temperature

The application of low temperature as a stress screen can, as the high temperature screen, be applied for the following reasons:

- to stress flaws to failures (RSS Cases 1, 3, 4)
- to screen out components which do not work in their intended application if parameters are outside defined acceptance limits (RSS Case 2)
- to screen out components which are outside defined acceptance limits for the application of the 6-sigma quality system (RSS Case 5).

For the latter two cases the same applies as is said about high temperature in 6.2.4.

Low temperature is very seldom used as stress type for the precipitation of failures. If failures occur during low temperature stress the failures are related to thermomechanical mismatch of different materials for which a more suitable stress type is temperature cycling. However, these failures are most often disclosed at the low temperature.

A very special kind of low temperature stress is the “dew point test” which can be applicable for semiconductors packaged in cavity-type packages. For the test the component is placed in a fixture and a parameter e.g. a leakage current, is continuously monitored. The component is then brought to a low temperature, e.g. -65 °C and then the temperature is raised. If a sharp discontinuity is observed in the measured parameter during the temperature fall or rise this is assumed to be the dew point for the enclosed environment. A too high dew point indicates high humidity which can be caused by a leak or by high humidity in the enclosed air during manufacture. This high humidity could lead to e.g. corrosion in field use of the component.

6.2.6 Constant acceleration

This type of stress can be used for components with a cavity such as: hermetically sealed IC’s, MCM’s, hybrids etc. It is effective in revealing insufficient attachments of (especially large) chips and substrates. It can also reveal loose, or loosely, fixed particles such as weld splashes and solder balls. Wires placed too close to each other or to the case may be revealed. Its efficiency regarding weak bondings is not that good due to the low mass of the wire, especially aluminum wires.

The stress level is high: 5 000 to 30 000 g. The level has to be matched to the mass of the component parts and to the expected strength of the attachments.

There is a risk in using this method for large packages as there may be mechanical bending of the case or the header that can destroy the seal.

The equipment for this type of stress is simply a centrifuge capable of achieving the needed number of revolutions per time. Special fixtures are needed for the actual package. The equipment is of moderate cost.

6.2.7 Mechanical shock

This type of stress can be used for all kind of components which have a cavity. The aim of the stress is to reveal the same type of weaknesses as constant acceleration does. The g-levels are much lower, up to 3 000 g. The frequency response spectrum in the shock is wide which may be very effective for some flaws.

The shock which is normally a half-sine pulse shall be applied so that the suspected flaws (joints or attachments) are stressed as much as possible. That means normally perpendicular to the substrate or chip surface.

The cost of the equipment is moderate. The cost of the performance of the stress may be more costly than the performance of a constant acceleration stress as not so many components can be stressed at the same time.

6.2.8 Vibration

This type of stress can be applied on all components with a cavity. The stress is most applicable for larger components as the applied stress levels are so low that low-weight parts of a component such as bond wires, chips etc. are not influenced. Badly flawed attachments and joints may however be broken due to fatigue as the stress is applied for many cycles.

The vibration can be applied as a sine signal with a fixed or swept frequency or as a random (noise) signal. Random vibration is often more efficient as possible resonance frequencies are present during the whole testing time while they are passed a certain number of times if a swept sine signal is used.

The equipment for vibration: vibrator, amplifier, control and monitoring system is expensive. The performance of the stress screening may also be expensive due to limited space on the vibrator for simultaneous screening of many components.
6.2.9 Particle impact noise detection (PIND)

This process is performed by putting one component at a time on a vibration shaker and vibration (10 to 20 g) and shock pulses (1 000 g, 100 µs) in sequence are applied. The instrumentation indicates any acoustical noise in the system during this agitation. Detected noise indicates that something is loose, or that there is impact between parts in the cavity.

This type of stress is efficient in getting e.g. small solder balls or weld splash balls loose and indicating their presence.

The equipment is of low cost. The stress can be applied to only one component at a time. Even if the test itself is fast it can be time-consuming for a whole lot of components.

The method is often used for Lot Acceptance Tests.

6.2.10 Sealing

Sealing tests are not normally environmental stresses and therefore they do not in fact fit into the definition of stress screening. The use of sealing tests is however very useful for indication of leaks directly or after a preceding stress. It can also be used as a replacement for an environmental stress e.g. humidity, which should otherwise have been needed to weed out a certain type of flaw.

The test is only applicable for components with a cavity.

A lot of different sealing tests exists. The most common sealing tests are the tests used mainly for all kind of semiconductor components: “Fine leak test” and “Gross leak test”.

One example of fine leak test (MIL-STD-883D, Method 1014, cond. A1) is performed as below:
- the component is placed in a chamber
- the chamber is pressurised with helium gas for a prescribed time and pressure
- the component is removed from the chamber and leak tested by a mass spectrometer type leak detector.

One example of a gross leak test is performed by the use of a transparent container filled with a heated liquid (e.g. water). The component is immersed into the warm liquid. Any leak is detected as bubbles or a stream of bubbles.

The equipment for fine-leak test is rather expensive while the equipment for the above simple gross leak test (“bubble test”) is cheap.

6.2.11 Humidity

For cavity-type components there are stress types more efficient than humidity stress. These are defined above, e.g. seal tests.

For moulded-in components it is very difficult to find methods to screen out components with weak packages, e.g. insufficient adhesion between mould to terminals which creates channels along the terminals through which humidity can penetrate to the chip and cause corrosion. At the same time the moulding compound in itself can create a threat to the chip by containing humidity and/or contaminations.

Unfortunately humidity tests take a long time and are destructive. To screen out lots which contain components with weak packaging humidity test on a sampling basis can be performed. The humidity test is often a “Highly accelerated stress test” (HAST) at 85 %RH and 85 or 130 °C which considerably reduces the time needed to reveal flaws. The test is comparative with the aim to disclose lots with flaws.

The equipment for this type of stress is expensive. As the time for the test is long, the lot must often be released for manufacturing before test results are available. This reduces the usefulness of the stress type.

As an alternative to humidity stress regarding the quality of the moulding compound, manufacturers can perform analysis of the moulding compound (e.g. purity and glass transition temperature) and verify compliance with earlier deliveries. The problem is to evaluate the implications of a deviation.

An intimate and trustful cooperation with a highly professional component supplier is recommended in all cases as the best alternative.

6.2.12 Electrical

Electrical stress is discussed in 6.2.2 and 6.2.4. The electrical stress can of course also be performed at ambient room temperature with less efficiency than combined with temperature cycling or high temperature. However, it offers a less expensive alternative.

The types of possible electrical stress correspond to those described in the above clauses.

Equipment for running an electrical stress screen shall be evaluated for their stability and reliability to avoid possible destruction of the components due to electrical overstresses such as voltage spikes.

The fixturing is also very important. The connections have to be very reliable and, in the case of applied environmental stress, they must be very durable regarding that type of stress. Intermittent failures during RSS that could be caused by an intermittent interruption in the components contact to the fixture are very time consuming and costly to analyse and the evaluation of the RSS result is erratic.

6.2.13 Combinations and sequences

As described in the text above combinations of stresses are possible and efficient, e.g. electrical and temperature. Other types of combinations are possible but in general they tend to be costly and should be avoided unless a failure mode is found easy to be revealed efficiently in the combined stress.

Sequences, on the other hand, can be very efficient and are very commonly used for all kinds of component families. The
The application of the different screening steps in a sequence plays a vital role in the overall screening efficiency.

The most well-known and widely used standard screening sequences are specified in US military standards such as MIL-STD-883, which is applicable for IC's. In Annex 4 some examples of standardised screening sequences are given.

As mentioned earlier these standardised sequences are normally used without tailoring to the current application and aim. The individual stress types, however, may be used to different extents and in different sequences for different component types and screening aims. In the examples in 6.3 some tailored stress types and sequences are given for some component types and RSS cases.

### 6.3 Applications of the RSS process

Examples presented in this clause represent different RSS cases and component families. They are all fictive.

On the basis of only the identified failure mechanisms and experiences stated in Annexes 1 and 2, it is not possible to give a generalised RSS method. The RSS shall be designed individually for each component type according to information given in this method and consideration shall also be given to the application and aim of the RSS. In this clause the application of the method is described and discussed based on information collected from literature and assumptions regarding other parameters.

#### 6.3.1 Power transistor

**6.3.1.1 The aim of the RSS**

Component type: Bipolar silicon power transistor (standard, catalogue product)

The application of the component requires the turn-on time to be ≤ 0.5 µs and turn-off time to be ≤ 1.0 µs at Ic = 2 A. According to components data sheet the times are specified as typical data at Ic = 5 A.

The use of this component type, with the special performance regarding the switching (pulse response) data, gives the equipment top performances and it will be competitive on the market.

During prototype manufacturing it was possible to select useable components from a delivery lot.

This discussion leads to the decision to perform RSS which corresponds to RSS Case 2.

**6.3.1.2 The role of the component manufacturer**

When the component manufacturer is contacted he cannot give any advice regarding the expected outcome of a screening operation and he is not aware of anyone else who performs this kind of selection. He is not willing to perform the screening as the requested quantity is too low and any special arrangement during manufacturing to increase the ratio of "good components is not possible for technical reasons.

The times appropriate for the selection decrease with increasing temperature. The temperature coefficient is not well defined. As the parameter is not measured in the outgoing control and it has not been measured in type tests nothing can be predicted with certainty about the stability over time.

No reject from the user is accepted by the component manufacturer regarding components with parameters outside the users criteria. Rejects are accepted only if specified data are outside the manufacturers specified limit.

**6.3.1.3 Possible flaws and failure modes**

This step is not applicable for this RSS case.

**6.3.1.4 Selection of stress types**

From the contact with the component manufacturer it is obvious that the screening should be performed by measuring the pulse response times at a low temperature and also after some time in a high temperature operation screening.

The measurement will be performed in accordance with MIL-STD-750, method 3251 at Ic = 2 A and at Vcc and other data as in the current application.

The high temperature screening will be performed in accordance with MIL-STD-750, method 1039, test cond. B, with specified power applied.

**6.3.1.5 Selection of stress levels**

The highest ambient temperature at the current position in the equipment is measured in prototypes and calculated to be +70 °C. This is lower than the specification value of 125 °C. Specified maximum power shall be applied during screening to raise the junction temperature and increase the time acceleration.

The specified lowest ambient temperature is 0 °C and the time measurements shall therefore be performed at this temperature.

**6.3.1.6 Selection of stress sequence**

It is of course of vital interest to know the temperature coefficient of the parameter and also the stability over time. It is therefore the baseline to perform the following sequence initially:

- measurement and logging of the parameters at 0 °C ambient temperature
- measurement and logging of the parameters at room temperature
- high temperature operation screening at 125 °C
- measurement and logging of the parameters at room temperature.
It is however kept in mind that if the temperature coefficient and the stability could be ensured the sequence could be reduced to measurement at room temperature only. It is therefore decided not to obtain a full set of screening and test equipment before the RSS test is performed.

6.3.1.7 Determination of duration: RSS test definition

The duration should be long enough to ensure the stability of the parameter during the required life of the equipment. For the current application it is calculated using the expected operation profile for the equipment and acceleration formulas and activation energies given in Annex 6 that the required life corresponds to 1000 hours at 125 °C ambient temperature. It is then decided to perform an initial test screening according to the baseline sequence to possibly find the stability and the influence of the temperature. Intermediate measurement at room temperature will be performed at 100, 200 and 500 hours.

Components for this RSS test are selected from different delivery lots from different dates of manufacture and also from two alternative sources (component manufacturers). 25 to 50 components of each batch and each source are used. 300 components are used in total.

6.3.1.8 Determination of duration: Failure analysis

No physical failure analysis was performed.

6.3.1.9 Determination of duration: Mathematical analysis of RSS test result

The results of the RSS test show that:

- the stability of the parameters is generally good (within ± 10 % as 3-sigma values), but one manufacturing lot had a large drift >100 % after 100 hours for 50 % of the population. The drift after 1000 hours was < 20 % for 90 % of the population.
- the temperature coefficient is generally very low, the individual spread is also very low. It can be taken care of by a further small reduction of the acceptance criteria, to: 0.4 µs and 0.9 µs respectively.

6.3.1.10 Performance of the RSS process

Taking the results from the RSS test into account it was decided to perform the screening according to the following sequence:

- Measurement of the parameter at room temperature. Logging of data. Components outside the (reduced) acceptance criteria are discarded.
- High temperature operation screening at 125°C ambient temperature during 96 hours.
- Measurement of the parameters at room temperature. Logging of data. Components with a drift more than 50 %, or outside acceptance criteria are discarded. Delivery lots with a reject rate >10 % are discarded.

All measured data for the parameter is logged and the drift is calculated. The reject rate for each delivery lot is also calculated.

6.3.1.11 Approval or rejection of a component lot

As defined above, all delivery lots with a reject rate >10 % are discarded.

6.3.1.12 Feedback to the RSS process

The results of the RSS test made it possible to reduce the time for the high temperature screening and measurement at 0°C could be deleted.

If experiences from equipment manufacturing or from field use of the equipment show that the parameters increase more with time than experienced during the RSS test the time for the screening should be increased or possibly the criteria for lot reject. Evaluation of the results of an RSS test has to be performed before a decision.

6.3.1.13 Feedback to component manufacturer

Information about the outcome of the test screening is given to the component manufacturer. He is also informed about the design of the screening sequence and of the reject criteria. After some negotiation he agrees to accept lot rejects if they are based on the criteria chosen (lots with a rate of >10 % of components with a drift >50 % of the parameter).

The component manufacturer is also informed about the results of the continued screening. He has no obligation to react but the information could be valuable as it is of common interest to supply components to a tighter specification and the user would expect higher rates of good components in the deliveries. (On the other hand competitors of the component user would also have access to the improved components).

6.3.1.14 Discontinuance of the RSS process

As soon as confidence is reached that no delivery lots with insufficient stability are received the high temperature operation screening could be discontinued.

Only if a very high degree of confidence is reached that no components are delivered with parameters outside acceptance criteria can the measurement of the parameters be discontinued as the values of the parameters are not guaranteed by the component manufacturer.

6.3.2 Thyristor

6.3.2.1 The aim of the RSS

Component type: Thyristor, 10 A, TO220 (plastic).

The component will be applied in an equipment which has high reliability requirements. Thyristors are known by experience of the user to have a high rate of early failures. The prediction of the reliability for the equipment in accordance with MIL-HDBK-217F shows that the theoretical failure rate (in the best period)
for the thyristor is sufficiently low. The problem is hence the expected early failures before the best period.

It is not possible to obtain this component type to an “assured failure rate or to a specified screening level as a standard, catalogue product.

6.3.2.2 The role of the component manufacturer

The component manufacturer does not perform any screening on any component type, but has a large type test program going for different power semiconductors. He admits the existence of early failures, but has no figure to present for the rate. He has some ideas of possible flaws.

He does not want to perform the screening and will not accept rejects from the users screening. As the component type is manufactured in large quantities he is not willing to perform any special inspections or tests or measurements in the production line.

6.3.2.3 Possible flaws and failure modes

Based on information in Annex 1, users own experience and the component manufacturers information the following flaws are considered the most plausible:

- flaws related to moulding: contamination, cracks, insufficient adhesion of mould to terminals
- insufficient chip attach.

6.3.2.4 Selection of stress types

Based on information in Annexes 1 and 2 the following stress types were selected as the baseline:

- Temperature cycling. As the component user has a two-chamber temperature cycling equipment available he chooses to perform the screening according to IEC 68-2-14 test Na.

- High temperature operation. AC blocking voltage is applied as defined in MIL-STD-750, method 1040 test cond A. Via a transformer from the 50 Hz mains the rated peak reverse blocking voltage and the rated peak forward blocking voltage is applied alternately. The components are attached to a thermal (cooling) plate.

6.3.2.5 Selection of stress levels

The storage temperature range for the component is -40 to +150 °C. These temperatures are chosen for the screening. The exposure time shall be so long that all of the components reach the extreme temperature. With consideration given to the thermal capacity of the chamber and the amount of components per screening 30 minutes is chosen as exposure time.

The junction temperature during high temperature operation screening should be +150 °C. With conservative calculations this means an ambient temperature of +125 °C at the current operation. Highest specified junction temperature is +125 °C but the higher temperature is checked with the component manufacturer.

6.3.2.6 Selection of stress sequence

It is obvious that the temperature changes shall be performed before the high temperature operation screening as the temperature cycling shall first open up possible cracks and the latter confirm these by precipitating them to failures.

After the two screening steps a parameter measurement will be performed.

6.3.2.7 Determination of duration: RSS test definition

Theoretically the sequence should be repeated until a flattening is observed in the curve of accumulated failures versus number of RSS cycles. As it can not be precluded that the high temperature RSS once performed influences the outcome of the next sequence it was decided to perform the RSS test according to the following:

lot 1: 10 temperature cycles + high temperature operation until flattening out.
lot 2: 20 temperature cycles + high temperature operation until flattening out.
lot 3: 50 temperature cycles + high temperature operation until flattening out.

To get enough confidence 100 components were used in each lot (see Annex 5).

6.3.2.8 Determination of duration: Failure analysis

The component user is not equipped to be able to strip-off the moulding, and the failure analysis is therefore reduced to electrical measurements and outer visual inspection with a microscope. Failed components from the RSS test were analysed and some cracks could be seen. Also high forward-on voltage was indicated. Failure mode for some catastrophic failures could not be established. These results were, however, considered as enough indication that the failures were of the expected types and no changes had to be made regarding the selection of stress types.

6.3.2.9 Determination of duration: Mathematical analysis of RSS test result

The results of the RSS test show that the fastest flattening out of the curve plotted on a Weibull diagram occurred for 50 temperature cycles but the difference was very small compared to the 20 cycle lot. The duration of the high temperature operation RSS was defined as shown in Ref. 2 (IEC 1163 Annex F).
6.3.2.10 Performance of the RSS process

Based on the outcome of the RSS test it was decided to perform the RSS as: 20 temperature cycles followed by high temperature operation 120 hours.

As the function of the components is not monitored during the performance of the RSS the only data from the RSS is the number of rejects. This number should, however, be continuously recorded and analysed.

It was also decided to perform failure analysis only if the results of the RSS indicate changes. In these cases a full strip-off and internal visual inspection (possibly SEM) could be foreseen. In these cases an outside supplier of the service or the component manufacturer would be used.

6.3.2.11 Approval or rejection of a component lot

This step is not applicable for this RSS case.

6.3.2.12 Feedback to the RSS process

If a clear increase of the failure rate after the RSS is observed a failure analysis should be performed. While this is performed the cycles and times respectively for both steps of the RSS shall be doubled.

6.3.2.13 Feedback to the component manufacturer

A continuous reporting to the component manufacturer of the outcome of the RSS is of benefit for both parties. The manufacturer will be aware of the users “control” and could use the result as an incentive for improvements. He will also get a feedback of any problem in his production.

6.3.2.14 Discontinuance of the RSS process

When the reject rate is at low level, enough to balance the costs of the performance of the screening and the cost of failures during manufacture of the equipment and in field use of the same the RSS should theoretically be discontinued. However, the expected flaws (at least failures regarding the moulding: contaminations etc.) are such that they can affect one manufacturing lot and leave other lots with no failures. Some control, e.g. sampling RSS is recommended even if the criteria for discontinuance are fulfilled.

6.3.3 Plastic encapsulated ASIC

6.3.3.1 The aim of the RSS

A product manufacturer has decided to introduce a new ASIC into his product. This ASIC is plastic encapsulated. As part of the qualification of the ASIC, which he performs before implementation, he carries out tests concerning the robustness of the package. He knows that the ASIC has to be assembled by soldering and furthermore, he wants to ensure that rework is possible.

The qualification plan, which he chooses concerning the package robustness, includes logistic related aspects (different storage conditions and rework), pick and place operation, IR-soldering, temperature cycling, and Highly Accelerated Stress Test (HAST). The robustness of the tested devices is monitored by electrical testing, non-destructive analysis such as: X-ray and Scanning Acoustic Microscopy (SAM) and finally by destructive analysis such as: decap, internal visual inspection, and Scanning Electron Microscopy (SEM).

The qualification tests disclose that some of the devices show a tendency to popcorn defects. The component manufacturer is contacted and states that one specific lot of the devices, which has been delivered, had increased moisture content in the plastic encapsulation. The device manufacturer also proved that when he has optimized materials and component design, no further problems related to thermal mechanical defects will occur if the device is mounted in dry condition.

Based on this experience the product manufacturer decides to perform a lot acceptance screening concerning package robustness for all plastic encapsulated ASIC’s used in future production.

6.3.3.2 The role of the component manufacturer

In this case the RSS is performed by the product manufacturer or by a subsupplier.

6.3.3.3 Possible flaws and failure modes

Based on the results of the qualification tests the failure mechanisms were popcorn defects.

6.3.3.4 Selection of stress types

Heat from the soldering process was selected.

6.3.3.5 Selection of stress levels

The maximum specified soldering temperature and time were selected together with the shortest specified preheat time.

6.3.3.6 Selection of stress sequence

Not relevant in this case.

6.3.3.7 Determination of duration: RSS test definition

The duration was selected as the maximum allowed soldering time, so it was not necessary to perform an RSS test.

6.3.3.8 Determination of duration: Failure analysis

Not relevant in this case.

6.3.3.9 Determination of duration: Mathematical analysis of RSS test results

Not relevant in this case.
6.3.3.10 Performance of the RSS process
The continuous monitoring of the lot quality was performed by assembling and soldering a device sample followed by SAM/X-ray and internal visual inspection.

6.3.3.11 Approval or rejection of a component lot
It was decided that one device with detectable popcorn defect in a sample of 50 components would mean that the lot was rejected.

6.3.3.12 Feedback to the RSS process
Not relevant in this case.

6.3.3.13 Feedback to component manufacturer
The results of each test together with failure analysis reports were mailed to the component manufacturer.

6.3.3.14 Discontinuance of the RSS process
The screening was performed on all lots produced before the component manufacturers optimizing of the materials and component design (see 6.3.3.1).

6.3.4 Transformer
6.3.4.1 The aim of the RSS
The transformer is custom made by a small manufacturer for a specific product. Since the production volume is low the reliability of the transformer can not be assured and it is therefore decided to use component RSS on 100 % basis. This corresponds to RSS Case 4.

6.3.4.2 The role of the component manufacturer
As the transformer is custom made cooperation between the transformer manufacturer and user is intimate. However, the user generally has greater experience of RSS and it will therefore be performed by him.

6.3.4.3 Possible flaws and failure modes
The transformer core is made of thin sheets of metal. There is a possibility that a wrong type of metal is used, or that the magnetic properties of the metal are damaged by the winding process or by the heat treatment. This will, however be found when measuring the no load current. The major problem is known to be acoustical noise from the C-core. After the production the core is cut, polished and reassembled around the windings. This can produce acoustical noise if there are flaws in the polishing and reassembly process.

For the windings a wrong type of wire (primarily wrong diameter) is a possibility. This failure will normally be found during measurement of the electrical resistance of the winding.

The number of windings may be wrong. This will be found when measuring the voltage/transformer ratio.

The most dangerous flaw in the windings is damage to the insulation, wrong insulation lacquer (wrong temperature characteristics) and nicks and damage to the wires.

6.3.4.4 Selection of stress types
In order to check for the acoustical noise either mechanical vibration or bump/shock can be used to check if the two parts can get loose. This stress should be followed by an acoustical noise test in cold and in hot condition.

Alternatively thermal cycling of the transformer can be performed together with continuous acoustical noise monitoring.

As acoustical noise test and monitoring direct listening could be used, but that requires each transformer to be checked individually in an anechoic chamber. An alternative can be to listen to each transformer with the aid of a stethoscope.

Another possibility is a microphone or accelerometer combined with a frequency analyser.

To precipitate the possible winding flaws the finished transformer can be placed in a hot chamber, loaded electrically to its maximum rating, and the temperature of the windings measured (IEC 185, Clause 13). This will find possible flaws in the lacquer (damaged or wrong type). It will also find any nicks of the wire. Alternatively a thermovision picture of the wire can be used to indicate local hot spots caused by short circuits or nicks in the wire.

Some damage to the lacquer and insulation will be found during the high voltage test that is required for safety reasons (IEC 185, Clause 17).

Bump followed by high temperature stress are the selected stresses at this point.

6.3.4.5 Selection of stress levels
For the vibration and bump/shock very large values can be chosen due to the mechanical robustness of the transformer. Care must however be taken for plastic parts and terminals. A vibration level of 4 to 7 g or a bump level of 10 g can be used without overstress.

The temperature level shall be the maximum operating temperature of the lacquer minus the expected temperature rise in the transformer at full load. The transformer shall be operated at full load in the chamber.

6.3.4.6 Selection of stress sequence
The sequence is defined as:
- halfsine bumps: 10 g, 16 ms long pulse according to IEC 68-2-29
- acoustical noise measurement
- high temperature stress, 2 h at maximum operating temperature (80 °C) minus expected temperature rise at full load (computed to 18 °C) which gives 60 °C. The transformer shall be loaded during the stress.

- functional test including high voltage test of the insulation.

6.3.4.7 Determination of duration: RSS test definition

The RSS test is performed on 100 transformers and the number of failures noted as a function of the duration of the temperature soak and the number of bumps.

It is decided to keep the duration of the temperature soak at 2 hours.

6.3.4.8 Determination of duration: Failure analysis

The failures found are analysed. It turns out that there are nicks in the wire and damage to the insulation. Both of these failures are caused by burrs on the C-core.

High noise is measured on some transformers. This is found to be caused by bad assembly of the C-core.

6.3.4.9 Determination of duration: Mathematical analysis of RSS test result

The Weibull plot of the bump test is shown in Fig. 4. This plot shows that the number of bumps can be reduced to 500 since 90 % of the failures occur during the first 300 bumps.

6.3.4.10 Performance of the RSS process

After the RSS test the process is defined as:

- 500 half sine bumps: 10 g, 16 ms long pulse according to ICE 68-2-29
- acoustical noise measurement
- high temperature stress, 2 h at maximum operating temperature (80 °C) minus expected temperature rise at full load (computed to 16 °C) which gives 60 °C. The transformer shall be loaded during the stress.
- functional test including high voltage test of the insulation.

The RSS process is performed on all delivered transformers (100 % basis).

6.3.4.11 Approval or rejection of a component lot

Acoustical noise measurement and functional test after temperature soak is initially made 100 % and failed items are scrapped.

6.3.4.12 Feedback to the stress screening process

See 6.3.3.13.

6.3.4.13 Feedback to component manufacturer

The results of the RSS test including the failure analysis gave cause for a discussion with the component manufacturer about process improvements.

The problem with burrs on the C-core could be eliminated by a deburring step in the production.

The problem with the noise could be eliminated by a more precise specification of the torque, and a new tool.

These actions solved the problem to a degree that the bump test and the noise measurement could be reduced to a sample based RSS. The temperature stress was kept for safety reasons.

By the implementation of RSS on sample basis it was also specified that if one or more failures were observed in the sample of 20 transformers, 100 % bump and acoustical noise measurement should be reimplemented for the lot concerned.

6.3.4.14 Discontinuance of the RSS process

The high temperature stress was kept for safety reasons and should not be reduced. The sample based RSS of the rest of the RSS steps could be reduced further when experience had been gained.

6.3.5 Connector

6.3.5.1 The aim of the RSS

An equipment manufacturer has received a delivery lot of crimp connectors where the pull test used in production to verify the adjustment of the crimping tool shows a small but significant percentage that does not pass the required pull test (80 % of the tensile strength of the wire). As the connectors are urgently needed in production the performance of an RSS is decided. This corresponds to RSS Case 1.

6.3.5.2 The role of the component manufacturer

Contact with the manufacturer confirms that the problem is caused by the connectors. Due to variations in a lot of raw material (rolled metal plate) the tolerances of the stamped and bent connector vary and the yield strength of the material also varies.

As the connectors are needed urgently the fastest way for the equipment manufacturer is to perform the RSS himself.

6.3.5.3 Possible flaws and failure modes

The flaw is known to be a deviation of the size of the connector and variations in the properties of the metal. This causes variations in the crimping force resulting in risk of corrosion (oxidation and corrosive gases may penetrate the crimp) which causes a high resistance and even intermittent connection.

This effect, which is time dependent, is especially pronounced in a hot and corrosive environment. Vibrations accelerate the process.
The connectors shall be used in an electronic equipment for ship, so both vibration and corrosive environment will be present.

6.3.5.4 Selection of stress types

Dry heat, corrosive gases and vibrations could be used to precipitate the flaws, but this would take too long.

Instead it was decided to employ the pull test as a screening process. The equipment is available to the equipment manufacturer so the screening can start immediately.

6.3.5.5 Selection of stress levels

Since a good, i.e. gas tight crimp connection is able to withstand 80 % of the tensile strength of the wire itself this can be used as the stress level. For a good crimp connection the test is not destructive.

6.3.5.6 Selection of stress sequence

It is decided to perform the pull test immediately after the crimp process.

6.3.5.7 Determination of the duration: RSS test

In this case the duration was given (one pull per wire). However the statistical distribution of the failures is important as the acceptance limit for the pull test could be influenced.

A sample of 50 connectors were taken and pull test was performed. The force at which the wire was pulled out of the crimp of the wire was logged. During the pull test the force was limited to 80 % of the tensile strength of the wire.

The result was that 18 % of the connectors failed. They all failed at a force that was between 10 and 50 % of the tensile strength of the wire. Therefore it was decided to use the 80 % as the RSS and acceptance level.

6.3.5.8 Determination of duration: Failure analysis

A failure analysis of the failed connectors confirms that the structure and strength of the base metal of the connector element does not comply with the specified material.

6.3.5.9 Determination of duration: Mathematical analysis of RSS test result

The pull out forces of the sample were plotted on Weibull paper to find the strength parameters of the weak population, see Fig. 5. It can be concluded that there are two distinct distributions and that all of the connectors in the weak distribution are removed by the 80 % pull test.

6.3.5.10 Performance of the RSS process

The pull test was performed on all connectors (100 %) crimped during 2 days. During these days it turned out that the flawed connectors were found more or less in sequence in the packages. Due to this experience it was decided to reduce the pull test to one out of 10 connectors. If a failure is observed the next connectors are pull tested 100 % until 20 connectors in sequence are approved after which sampling is continued.

6.3.5.11 Approval or rejection of a component lot

This step is not applicable for this example. The lot is rejected from the beginning, but a selection by RSS is decided.

6.3.5.12 Feedback to the stress screening process

See 6.3.5.10.

6.3.5.13 Feedback to component manufacturer

The percentage of failures was reported to the component manufacturer who was able to locate more closely the freak connectors in the manufacturing lots. Therefore it was possible to release parts of the manufacturing lots for normal production, with a pull test only on the first and the last connectors in each box.

6.3.5.14 Discontinuance of the RSS process

The RSS was from the beginning limited to one current lot. The connector manufacturer was soon able to send a new lot without any flawed connectors and the RSS process was discontinued. However the pull test each day to check the adjustment of the crimping tool was maintained, as before the current situation.
Figure 5. Weibull plot of a pull test as RSS on connector cramped.
THE MOST POSSIBLE POTENTIAL FLAWS FOR SOME COMPONENT FAMILIES

In this annex the most potential flaws are estimated for some selected component families. These families are chosen because they were pointed out as the component families giving the highest failure rate during RSS on PWA or higher level.

The following are extracts from literature, personal experiences and communication with component specialists.

1 POWER SEMICONDUCTORS

- Contaminations on chip surface
- Metallisation defects
- Corroded metallisation or bonds
- Chip cracks
- Defect die attach
- Weak bonds or damaged bond wires
- EOS/ESD latent failures

Hermetic packages:
- Loose particles
- Enclosed humidity
- Cracks or voids in the lid joint
- Cracks in feed-throughs
- Outgassing polymers

Plastic packages (no cavity):
- Cracks or voids in the encapsulation material
- Insufficient adhesion of mould to terminals
- Contaminated moulding compound
- Thermal mismatch effects e.g. between moulding compound and chip or wire bonds

2 ASIC'S

The manufacturing technology as well as the encapsulation technology is basically the same as for power semiconductors.

The voltage, current and temperature are lower for ASIC components but the physical dimensions of the semiconductor elements (conductor width, dielectric thickness etc.) are also smaller. The possible potential flaws are therefore the same as listed in Clause 1 above.

3 TRANSFORMERS

- Magnetic properties of core material, deformation, heat treatment
- Wire: thickness variations and nicks
- Wire insulation: temperature class, thickness variations, pinholes and damage
- Terminals: solderability, fastening
- Potting material: mechanical stresses, voids, distribution, adhesion to housing and core/windings
- Insulation material: positioning, pinholes and damage
- Housing: strength, cracks, mechanical stresses, voids and tolerances
- Fastening points: strength, cracks, friction coefficient.

4 CONNECTORS

- Spring material: mechanical properties, tolerances and cracks
- Plating material: thickness, pinholes and contamination
- Terminals: solderability, mechanical properties, tolerances, plating
- Housing: mechanical stresses, tolerances, voids and cracks
- Insulation: tightness, contamination.
EFFICIENT STRESS TYPES VERSUS FAILURE MECHANISMS

This annex indicates efficient stress types for potential failure mechanisms for some component families. These families are chosen because they were pointed out as the component families giving the highest failure rate during RSS at PWA or higher level. The assessment of the efficiency is based on literature studies, personal experience and discussions with component specialists.

1 POWER SEMICONDUCTORS

<table>
<thead>
<tr>
<th>Failure mechanism</th>
<th>Efficient stress types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contaminations on chip surface</td>
<td>HTRB</td>
</tr>
<tr>
<td>Metallisation defects</td>
<td>Temp cycling, HAST</td>
</tr>
<tr>
<td>Corroded metallisation or bonds</td>
<td>Temp cycling</td>
</tr>
<tr>
<td>Chip cracks</td>
<td>Temp cycling, constant acceleration, HAST for plastic encapsulated comp.</td>
</tr>
<tr>
<td>Defect die attach</td>
<td>Temp cycling, constant acceleration, HAST for plastic &amp;capsulated comp.</td>
</tr>
<tr>
<td>Weak bonds</td>
<td>Temperature, HTRB (?)</td>
</tr>
<tr>
<td>ESD/EOS latent failures</td>
<td>PIND, vibration</td>
</tr>
<tr>
<td>Loose particles in hermetic packages</td>
<td>Low temp, temp cycling</td>
</tr>
<tr>
<td>Enclosed humidity</td>
<td>Temperature shocks, hermeticity</td>
</tr>
<tr>
<td>Cracks in feed-throughs</td>
<td>HTRB, high temperature</td>
</tr>
<tr>
<td>Outgassing polymers</td>
<td>Humidity, visual insp, X-ray</td>
</tr>
<tr>
<td>Cracks in encapsulation material</td>
<td>Humidity</td>
</tr>
<tr>
<td>Bad adhesion to terminals</td>
<td>Temp cycling</td>
</tr>
<tr>
<td>Thermal mismatch</td>
<td></td>
</tr>
</tbody>
</table>

2 ASIC’S

The manufacturing technology as well as the encapsulation technology are basically the same as for power semiconductors. The voltage, current and temperature are lower for ASIC components but the physical dimensions of the semiconductor elements (conductor width, dielectric thickness etc.) are also smaller. Since the possible potential flaws are the same as for power semiconductors the efficient stress types versus failure mechanisms are the same as for power semiconductors listed in Clause 1 above.

3 TRANSFORMERS

<table>
<thead>
<tr>
<th>Failure mechanism</th>
<th>Efficient stress types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deformation, heat treatment core material</td>
<td>No load testing</td>
</tr>
<tr>
<td>Wire, thickness variations and nicks</td>
<td>High temperature, full load</td>
</tr>
<tr>
<td>Wire insulation: temperature class, thickness variations, pinholes or damage</td>
<td>High temperature, full load, high voltage</td>
</tr>
<tr>
<td>Terminals: solderability</td>
<td>Dry heat, moisture</td>
</tr>
<tr>
<td>Terminals fastening</td>
<td>Shock, pull test</td>
</tr>
<tr>
<td>Potting material: mechanical stresses, voids, distribution, adhesion to housing and core/winding</td>
<td>High temperature, full load, shock and bump, cyclic moisture</td>
</tr>
<tr>
<td>Insulation material: positioning, pinholes and damage</td>
<td>Moisture, high voltage</td>
</tr>
<tr>
<td>Housing: strength, cracks, mechanical stresses, voids and tolerances</td>
<td>Shock test, high temperature, temperature cycling</td>
</tr>
<tr>
<td>Fastening points: strength, cracks, friction coefficient</td>
<td></td>
</tr>
</tbody>
</table>

4 CONNECTORS

<table>
<thead>
<tr>
<th>Failure mechanism</th>
<th>Efficient stress types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring material: mech. properties, tolerances, cracks</td>
<td>Shock, bump, vibration, pull test</td>
</tr>
<tr>
<td>Plating material: thickness, pinholes, contamination</td>
<td>Dry heat, moisture, corrosive gases</td>
</tr>
<tr>
<td>Terminals: solderability, mechanical properties, tolerances, plating</td>
<td>Dry heat, moisture, shock, bump, vibration, pull test</td>
</tr>
<tr>
<td>Housing: mechanical stresses, tolerances, voids, cracks</td>
<td>High temperature, shock, bump, vibration</td>
</tr>
<tr>
<td>Insulation: tightness, contamination cyclic moisture</td>
<td>High temperature, temperature cycling</td>
</tr>
</tbody>
</table>
### SOME EXAMPLES OF STANDARDS FOR DIFFERENT STRESS TYPES

<table>
<thead>
<tr>
<th>Stress type</th>
<th>Standard, method (application)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal inspection (precap)</strong></td>
<td>MIL-STD-750, 2069 (Power MOSFET)</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-750, 2072 (Transistor)</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-750, 2037 (Bond strength)</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 2010 (Monolithic IC)</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 2017 (Hybrids)</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 2023 (Non-destructive bond pull)</td>
</tr>
<tr>
<td></td>
<td>MIL-C-38999 (Connector)</td>
</tr>
<tr>
<td><strong>DPA</strong></td>
<td>MIL-STD-750, 2075</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 2013</td>
</tr>
<tr>
<td><strong>Radiographic inspection</strong></td>
<td>MIL-STD-750, 2076</td>
</tr>
<tr>
<td><strong>Temperature cycling</strong></td>
<td>IEC 68-2-14, Na, Nb</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-750, 1051</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 1010</td>
</tr>
<tr>
<td><strong>Thermal shock</strong></td>
<td>IEC 68-2-14, Nc</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-750, 1056</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 1011</td>
</tr>
<tr>
<td><strong>High temperature</strong></td>
<td>IEC 68-2-2, B</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-750, 1031 (non-operating)</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-750, 1036 (intermittent operation)</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-750, 1039 (burn-in, transistor)</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 1008 (stabilisation bake, IC)</td>
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<tr>
<td></td>
<td>MIL-STD-883, 1015 (burn-in, IC)</td>
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<tr>
<td></td>
<td>IEC 185 (transformer)</td>
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<tr>
<td><strong>Low temperature</strong></td>
<td>IEC 68-2-1, A</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-750, 1066 (dew point)</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 1013 (dew point, IC)</td>
</tr>
<tr>
<td><strong>Constant acceleration</strong></td>
<td>IEC 68-2-7, G</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-750, 2006</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 2001</td>
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<tr>
<td><strong>Mechanical shock</strong></td>
<td>IEC 68-2-27, Ea</td>
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<tr>
<td></td>
<td>MIL-STD-883, 2002</td>
</tr>
<tr>
<td></td>
<td>MIL-C-38999 (connector)</td>
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<tr>
<td><strong>Vibration</strong></td>
<td>IEC 68-2-6, Fc (sinusoidal)</td>
</tr>
<tr>
<td></td>
<td>IEC 68-2-64, Fh (random)</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-750, 2056</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 2026</td>
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<tr>
<td><strong>PIND</strong></td>
<td>MIL-STD-750, 2052</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-883, 2020</td>
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<tr>
<td><strong>Seal</strong></td>
<td>IEC 68-2-17, Q</td>
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<tr>
<td></td>
<td>MIL-STD-750, 1071</td>
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<tr>
<td></td>
<td>MIL-STD-883, 1014</td>
</tr>
<tr>
<td></td>
<td>MIL-STD-1344 (connector)</td>
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<tr>
<td><strong>Humidity</strong></td>
<td>IEC 68-2-6, Ca (steady state)</td>
</tr>
<tr>
<td></td>
<td>IEC 68-2-30, Db (cyclic)</td>
</tr>
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<td></td>
<td>MIL-STD-883, 1004</td>
</tr>
<tr>
<td></td>
<td>IEC 749 (HAST)</td>
</tr>
<tr>
<td><strong>Corrosion</strong></td>
<td>ISO 4524 (connector)</td>
</tr>
<tr>
<td></td>
<td>IEC 68-2-42, Test Kc (SO₂)</td>
</tr>
<tr>
<td></td>
<td>IEC 68-2-43, Test Kd (H₂S)</td>
</tr>
</tbody>
</table>
### SOME EXAMPLES OF STANDARDISED SCREENING SEQUENCES

#### 1 POWER SEMICONDUCTORS

**1.1 Thyristor, 2N6605JANTX. MIL-S-19500/513**

<table>
<thead>
<tr>
<th>No</th>
<th>Screening type</th>
<th>MIL-STD-750 Method</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High temp. storage</td>
<td>&gt;48 h at 150°C</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Thermal shock (Temp. cycling)</td>
<td>1051</td>
<td>F. (-65 to +150 °C) 10 cycles, &gt;15 min at extreme temperatures</td>
</tr>
<tr>
<td>3</td>
<td>Acceleration</td>
<td>2006</td>
<td>Y1-direction. 20 000 g</td>
</tr>
<tr>
<td>4</td>
<td>Hermetic seal fine leak gross leak</td>
<td>1071</td>
<td>G or H</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1071</td>
<td>A, C, D, F</td>
</tr>
<tr>
<td>5</td>
<td>Measurement of specified parameters. (Pre burn-in test)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Burn-in</td>
<td>&gt; 72 at 125 °C</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Measurement of specified parameters. (Post burn-in test)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**1.2 Diode, 1N5614JANTX. MIL-S-19500/427C**

<table>
<thead>
<tr>
<th>No</th>
<th>Screening type</th>
<th>MIL-STD-750 Method</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High temperature</td>
<td>1032</td>
<td>(340 h, max temp.) Optional</td>
</tr>
<tr>
<td>2</td>
<td>Temperature cycling</td>
<td>1051</td>
<td>c. (-55 to +175°C, 20 c)</td>
</tr>
<tr>
<td>3</td>
<td>Hermetic seal fine leak gross leak</td>
<td>1071</td>
<td>G or H</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1071</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>High temperature reverse bias</td>
<td>1038</td>
<td>A (48 h)</td>
</tr>
<tr>
<td>5</td>
<td>Interim electrical and delta parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Power bum-in</td>
<td>1038</td>
<td>96h, 25°C, f=60Hz, 1 ADC</td>
</tr>
<tr>
<td>7</td>
<td>Final electrical test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Hermetic seal fine leak gross leak</td>
<td>1071</td>
<td>Optional as step 3 or 8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1071</td>
<td></td>
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</tbody>
</table>
### 1.3 FET, P-channel, 2N6849JANTX. MIL-S-19500/564B

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<th>Condition</th>
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<tbody>
<tr>
<td>1</td>
<td>High temperature</td>
<td>1032</td>
<td>(340 h, max temp.) Optional</td>
</tr>
<tr>
<td>2</td>
<td>Temperature cycling</td>
<td>1051</td>
<td>F, (+150 °C), T low = -55 °C, 20 cycles</td>
</tr>
<tr>
<td>3</td>
<td>Hermetic seal fine leak</td>
<td>1071</td>
<td>G or H</td>
</tr>
<tr>
<td></td>
<td>gross leak</td>
<td>1071</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Unclamped inductive switching</td>
<td>3470</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Thermal response measurements</td>
<td>3161</td>
<td>(ΔVSD measurements)</td>
</tr>
<tr>
<td>6</td>
<td>Gate stress test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>High temperature reverse bias</td>
<td>1040</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>a Interim electrical and delta parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Power burn-in</td>
<td>1042</td>
<td>240 h, +25 °C, +10 °C, -5 °C, Tj = 140 °C</td>
</tr>
<tr>
<td>10</td>
<td>Final electrical test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Hermetic seal fine leak</td>
<td>1071</td>
<td>Optional as step 3 or 11</td>
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<tr>
<td></td>
<td>gross leak</td>
<td>1071</td>
<td></td>
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### 1.4 FET, N-channel, 2N6788JANTX. MIL-S-19500/555C

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<tbody>
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<td>1032</td>
<td>(340 h, max temp.) Optional</td>
</tr>
<tr>
<td>2</td>
<td>Temperature cycling</td>
<td>1051</td>
<td>F, (+150 °C), T low = -55 °C, 20 cycles</td>
</tr>
<tr>
<td>3</td>
<td>Hermetic seal fine leak</td>
<td>1071</td>
<td>G or H</td>
</tr>
<tr>
<td></td>
<td>gross leak</td>
<td>1071</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Unclamped inductive switching</td>
<td>3470</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Thermal response measurements</td>
<td>3161</td>
<td>(ΔVSD measurements)</td>
</tr>
<tr>
<td>6</td>
<td>Gate stress test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>High temperature reverse bias</td>
<td>1042</td>
<td>B (160 h)</td>
</tr>
<tr>
<td>8</td>
<td>Interim electrical and delta parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Power burn-in</td>
<td>1042</td>
<td>A(48h at 150°C)</td>
</tr>
<tr>
<td>10</td>
<td>Final electrical test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Hermetic seal fine leak</td>
<td>1071</td>
<td>Optional as step 3 or 11</td>
</tr>
<tr>
<td></td>
<td>gross leak</td>
<td>1071</td>
<td></td>
</tr>
</tbody>
</table>
### 1.5 Transistor, PNP, 2N5958JANTX. MIL-S-19500/450A

<table>
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<th>Screening type</th>
<th>MIL-STD-750 Method</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High temperature storage</td>
<td></td>
<td>&gt;24 h at +200 °C</td>
</tr>
<tr>
<td>2</td>
<td>Thermal shock (temperature cycling)</td>
<td>1051</td>
<td>C (-55 to +175 °C), 10 cycles, &gt;15 minutes at each temp. extreme</td>
</tr>
<tr>
<td>3</td>
<td>Constant acceleration</td>
<td>2006</td>
<td>5000 g, Y₁ only</td>
</tr>
<tr>
<td>4</td>
<td>Hermetic seal fine leak gross leak</td>
<td>1071</td>
<td>G or H A, C, D or F</td>
</tr>
<tr>
<td>5</td>
<td>Reverse bias burn-in</td>
<td></td>
<td>48 h at +150°C</td>
</tr>
<tr>
<td>6</td>
<td>Pre burn-in measurements</td>
<td>3041 3076</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Burn-in</td>
<td></td>
<td>Tᵢ=200°C, Vᵦ=10-25V</td>
</tr>
<tr>
<td>8</td>
<td>Post burn-in measurements</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 1.6 Transistor, NPN, 2N6338JANTX. MIL-S-19500/509A

<table>
<thead>
<tr>
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<th>Screening type</th>
<th>MIL-STD-750 Method</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High temperature</td>
<td>1032</td>
<td>(340 h, max temp.) Optional</td>
</tr>
<tr>
<td>2</td>
<td>Temperature cycling</td>
<td>1051</td>
<td>c (-55 to +175 °C), 20 c</td>
</tr>
<tr>
<td>3</td>
<td>Hermetic seal fine leak gross leak</td>
<td>1071 1071</td>
<td>G or H</td>
</tr>
<tr>
<td>4</td>
<td>Interim electrical parameters</td>
<td></td>
<td>ICEX₁</td>
</tr>
<tr>
<td>5</td>
<td>High temperature reverse bias</td>
<td>1039</td>
<td>A (48 h at 150°C)</td>
</tr>
<tr>
<td>6</td>
<td>Interim electrical and delta parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Power burn-in</td>
<td>1039</td>
<td>Tᵢ=187°C, 160h</td>
</tr>
<tr>
<td>8</td>
<td>Final electrical test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Hermetic seal fine leak gross leak</td>
<td>1071 1071</td>
<td>Optional as step 3 or 9</td>
</tr>
</tbody>
</table>

### 1.7 Transistor, high power, NPN, 2N2812JANTX. MIL-S-19500/415

<table>
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<tr>
<th>No</th>
<th>Screening type</th>
<th>MIL-STD-750 Method</th>
<th>Condition</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>High temperature storage</td>
<td></td>
<td>&gt;24 h at +200 °C</td>
</tr>
<tr>
<td>2</td>
<td>Thermal shock (temperature cycling)</td>
<td>1051</td>
<td>C (-55 to +175 °C), 10 cycles, &gt;15 minutes at each temp. extreme</td>
</tr>
<tr>
<td>3</td>
<td>Constant acceleration</td>
<td>2006</td>
<td>10 000g, Y₁</td>
</tr>
<tr>
<td>4</td>
<td>Hermetic seal fine leak gross leak</td>
<td>1071</td>
<td>G or H A, C, D or F</td>
</tr>
<tr>
<td>5</td>
<td>Reverse bias burn-in</td>
<td></td>
<td>48 h at +150 °C no heat sink</td>
</tr>
<tr>
<td>6</td>
<td>Pre burn-in measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Burn-in</td>
<td></td>
<td>168 h at Tᵢ=100°C, 50W</td>
</tr>
<tr>
<td>8</td>
<td>Post burn-in measurements</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1.8 Other quality levels

For higher quality levels: JANTXV and JANS, typical additional screening steps are:

- Pre-cap visual inspection, methods: 2069, 2070, 2072, 2073, 2074
- Particle impact noise detection (PIND), method: 2052
- Radiography, method 2076
- External visual inspection, method 2071.

2 ASIC’S

2.1 Monolithic, hermetic ASIC, MIL-M-38510

The following RSS program shall be performed for devices conforming to group 1 (which corresponds to the lowest $\Pi_Q$) according to MIL-HDBK-217F.

For compliance to group 2 step no. 4 or 5 is deleted.

<table>
<thead>
<tr>
<th>No</th>
<th>Screening type</th>
<th>MIL-STD-883 Method</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Temperature cycling</td>
<td>1010</td>
<td>Minimum B</td>
</tr>
<tr>
<td>2</td>
<td>Constant acceleration</td>
<td>2001</td>
<td>E, Y₁-orientation</td>
</tr>
<tr>
<td>3</td>
<td>Visual inspection</td>
<td></td>
<td>Optional</td>
</tr>
<tr>
<td>4</td>
<td>Burn-in</td>
<td>1015</td>
<td>160 h, 125 °C</td>
</tr>
<tr>
<td>5</td>
<td>Final electrical test at temp. extremes</td>
<td></td>
<td>Applicable device specification</td>
</tr>
<tr>
<td>6</td>
<td>Seal</td>
<td>1014</td>
<td>A, B or C</td>
</tr>
<tr>
<td>7</td>
<td>External visual</td>
<td>2009</td>
<td></td>
</tr>
</tbody>
</table>

For compliance to group 3 the following screening program is required.

<table>
<thead>
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<th>MIL-STD-883 Method</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Temperature cycling</td>
<td>1010</td>
<td>Minimum B</td>
</tr>
<tr>
<td>2</td>
<td>Constant acceleration</td>
<td>2001</td>
<td>E, Y₁-orientation</td>
</tr>
<tr>
<td>3</td>
<td>Visual inspection</td>
<td></td>
<td>Optional</td>
</tr>
<tr>
<td>4</td>
<td>Burn-in</td>
<td>1015</td>
<td>160 h, 125 °C</td>
</tr>
<tr>
<td>5</td>
<td>Final electrical test at temp. extremes</td>
<td></td>
<td>Applicable device specification</td>
</tr>
<tr>
<td>6</td>
<td>Seal</td>
<td>1014</td>
<td>A, B or C</td>
</tr>
<tr>
<td>7</td>
<td>External visual</td>
<td>2009</td>
<td></td>
</tr>
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</table>

2.2 Power hybrid for space use

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<th>MIL-STD-883 Method</th>
<th>Condition</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre burn-in electricals</td>
<td>Applicable device specification</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Burn-in</td>
<td>1015</td>
<td>160 h, 125 °C</td>
</tr>
<tr>
<td>3</td>
<td>Final electricals test at temperature extremes</td>
<td>Applicable device specification</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Seal</td>
<td>1014</td>
<td>A, B or C</td>
</tr>
<tr>
<td>5</td>
<td>External visual</td>
<td>2009</td>
<td></td>
</tr>
</tbody>
</table>
Lot Acceptance Test (56 pcs for a lot of 1000 pcs):
- Environmental/mechanical tests (16 pcs):

<table>
<thead>
<tr>
<th>No</th>
<th>Screening type</th>
<th>MIL-STD-883 Method</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shock</td>
<td>2002</td>
<td>B</td>
</tr>
<tr>
<td>2</td>
<td>Vibration</td>
<td>2007</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>Constant acceleration</td>
<td>2001</td>
<td>E</td>
</tr>
<tr>
<td>4</td>
<td>Thermal shock</td>
<td>1011</td>
<td>C</td>
</tr>
<tr>
<td>5</td>
<td>Moisture</td>
<td>1004</td>
<td>10 cycles, 24 h</td>
</tr>
<tr>
<td>6</td>
<td>Seal test</td>
<td>1014</td>
<td>C</td>
</tr>
<tr>
<td>7</td>
<td>External visual inspection</td>
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</tbody>
</table>

- Endurance 15 pcs:

<table>
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<th>Condition</th>
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</thead>
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<td>1</td>
<td>Operating life</td>
<td>1005</td>
<td>125°C/1000 h</td>
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</table>

- Electrical 25 pcs.
- Others 10 pcs:

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<th>Screening type</th>
<th>MIL-STD-883 Method</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solderability</td>
<td>2003</td>
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<td>2</td>
<td>Terminal strength</td>
<td>2004</td>
<td>B2</td>
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</table>

3 TRANSFORMERS
According to IEC 185 clause 16 to 23

<table>
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<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Verification of terminal marking</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>Power frequency test</td>
<td>IEC 60, IEC 44-4</td>
<td>Table II</td>
</tr>
<tr>
<td>3</td>
<td>Intertum insulation</td>
<td>IEC 60, IEC 185</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Chopped lightning impulse test</td>
<td>IEC 185</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Measurement of dielectric dissipation factor</td>
<td>Schering bridge or equivalent</td>
<td>10°C &lt; temp. &lt; 30°C</td>
</tr>
</tbody>
</table>
## 4 CONNECTORS

### 4.1 Connectors according to CECC 75200

<table>
<thead>
<tr>
<th>No</th>
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<th>Condition</th>
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<tbody>
<tr>
<td>1</td>
<td>Examination</td>
<td>IEC 512-2</td>
<td>Test 1</td>
</tr>
<tr>
<td>2</td>
<td>Engaging and separating forces</td>
<td>IEC 512-7</td>
<td>Test 13a</td>
</tr>
<tr>
<td>3</td>
<td>Contact resistance</td>
<td>IEC 512-2</td>
<td>Test 2a or 2b</td>
</tr>
<tr>
<td>4</td>
<td>Insulation resistance</td>
<td>IEC 512-2</td>
<td>Test 3a</td>
</tr>
<tr>
<td>5</td>
<td>Voltage proof</td>
<td>IEC 512-2</td>
<td>Test 4a</td>
</tr>
<tr>
<td>6</td>
<td>Termination test such as solderability</td>
<td>IEC 512</td>
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</table>

### 4.2 Military connectors (example from literature)

<table>
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<th>Condition</th>
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<tbody>
<tr>
<td>1</td>
<td>Measurement of spec. parameters</td>
<td>MIL-STD-202, method 110</td>
<td>Air velocity 175 fps, 2 minutes</td>
</tr>
<tr>
<td>2</td>
<td>Sand and dust</td>
<td>MIL-C-38999, p. 4.7.7</td>
<td>250 cycles</td>
</tr>
<tr>
<td>5(4)</td>
<td>Fluid immersion</td>
<td>MIL-STD-1344, method 1016</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Temperature, altitude, humidity</td>
<td>MIL-STD-81 OC, method 518</td>
<td>Ozone: method 1007, 38 °C, 95 %RH 6 h, 60 000 ft, −40 °C, 2.5 h, repeat 3 times</td>
</tr>
<tr>
<td>7</td>
<td>Standard shock</td>
<td>MIL-C-38999</td>
<td>p. 4.7.23.1</td>
</tr>
<tr>
<td>8</td>
<td>Random vibration</td>
<td>MIL-C-38999</td>
<td>p. 4.7.22.1</td>
</tr>
<tr>
<td>9</td>
<td>Installation/removal tool abuse</td>
<td>MIL-C-38999</td>
<td>p. 4.7.32</td>
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<tr>
<td>10</td>
<td>Repeat 1</td>
<td>MIL-C-25769</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Repeat 2, 3, 4, 5, 6, 7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 4.3 Porosity test for connectors

(Western Electric test for gold plated connector elements)

<table>
<thead>
<tr>
<th>No</th>
<th>Screening type</th>
<th>Method</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Degrease connector</td>
<td>Trichloroethylene</td>
<td>Over conc. nitric acid, 1 h</td>
</tr>
<tr>
<td>2</td>
<td>Place connector in desiccator</td>
<td></td>
<td>Over conc. nitric acid, 1 h</td>
</tr>
<tr>
<td>3</td>
<td>Dry connector</td>
<td></td>
<td>30 min at 100 °C</td>
</tr>
<tr>
<td>4</td>
<td>Inspection</td>
<td>10 x magnification</td>
<td>Count pinholes in contact area</td>
</tr>
</tbody>
</table>
DESIGN AND EVALUATION OF AN RSS TEST

First we compute the required number of components to be used in the RSS test. We guess that the level of weak components may be approximately 5%. In order to draw a reasonable S-curve at least 4 failures are required. If the level of weak components is 5% we want 90% probability of having at least 4 failures. This means that the probability of having 3 or fewer failures is 10%.

In Fig. 6 we draw a line from the scale to the left p = 5% to P = 0.10 on the right hand scale (P = 0.10 = 1-0.90). Since the probability P = 0.10 is for 3 or fewer failures we look where the line crosses the failure line c = 3 in the center curves. From this point we follow the sample size line and read the sample size n = 130.

We must have at least 130 components in the RSS test in order to get at least 4 failures with 90% probability provided that the level of weak components is 5%. If the level of weak components is lower, a higher sample size is required. If the percentage of weak components is larger than 5% then a smaller sample can be used. Computations for other combinations of expected level of weak components can be made using the diagram in Fig. 7.

When the RSS test has been performed the data is plotted on a Weibull probability paper. We have the number of components in the test n and the number of failures observed r. Further we have noted the operating time to each failure t,

where 0 < i ≤ r.

The Weibull probability paper has a logarithmic scale on the x-axis and a highly unlinear y-axis. The x-axis is used for the operating time or the number of RSS cycles. We can choose the numbers on the x-axis freely as long as we remember that it is a logarithmic scale. The y-axis has fixed numbers usually from 0.1 to 99.9% failures of the total population.

We first write the failures in sequence after the time or number of RSS cycles. From the earliest failure to the last failure. These operating times, or cycles to each failure are the x-coordinate. The median rank can be found in tables or be the first part of an S, levelling off as a “knee”. If the curve does not have this shape the reason may be:

- The RSS test was too short. Not all weak components in the sample have failed during the test.
- The stress level chosen for the RSS test is too low. All the weak components in the sample have not failed in the test.
- The RSS stress level is too high. There are no weak failures, all failures are failed strong components (a failure analysis will in this case show no “flaws” in the failed components.
- There may be some failure free time before the first weak components fail. (In this case the shape of the curve will be more like a U than an S).

When in doubt the Bayes method described in Annex 7 can be used.

Following the failure analysis it can be useful to plot each failure mode separately using the method of suspended items described in the literature.

When we have drawn the best smooth curve and found the “knee” of the curve we can find the percentage of weak components p as the y-coordinate of the “knee”, the point where the curve “levels off” and becomes more or less horizontal.

We can now estimate the Weibull parameters of the weak population by multiplying p by 0.63 and with this y ordinate enter the Weibull paper. Where this percentage intersects the curve we go vertically down to the x-axis, where we find the characteristic lifetime of the weak components η1.

In order to find the shape parameter for the weak components we draw a line that represents the slope of the first part of the S-curve up to the “knee”. This slope is shifted parallel until it crosses the point with the coordinates (2.72, 0.63). This point is often marked with a circle on the probability paper.

The line representing the slope is now drawn through (2.72, 0.63). Where this line intersects the x-coordinate line 1 we draw a horizontal line out through the margin of the probability paper. In a scale in the margin we read the value minus β1. In this way we find the β-value for the weak components.

It can be difficult to find the x = 1 line, but the line is the x = 1 on the same scale as where we found x = 2.72.

When we have found this data we have all we need for the design of the duration of an optimized RSS process.

We plot the weak failures separately and are now able to read the number of RSS hours or RSS cycles needed to remove any percentage of the weak components. We can choose to remove 90%, 95% or 99% of the weak components. On this line we can get a more precise estimate of β1 and η1.

In some cases we want to estimate the percentage of failures caused by the RSS process on the strong components. In this case we need to find the parameters for the strong population.
This can only be done if we have at least two failures from the strong population.

We have then to plot the weak failures in one plot and the strong failures in another plot. Remember that the sample size \( n \) for the weak components in this case is equal to the number of weak failures, and the sample size for the strong components is the rest of the original sample \( n \). For this plot we might need the Bayes method (see Annex 7) to distinguish between the weak and the strong failures.

**Example:**

We assume that we have made an RSS test with \( n = 23 \) components.

We have observed 5 failures, at 60, 140, 230, 420 and 980 hours respectively.

We now compute the median ranks for the Weibull plot:

<table>
<thead>
<tr>
<th>Failure No.</th>
<th>Time to failure ( t(i) )</th>
<th>Median rank (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>3.0</td>
</tr>
<tr>
<td>2</td>
<td>140</td>
<td>7.3</td>
</tr>
<tr>
<td>3</td>
<td>230</td>
<td>11.5</td>
</tr>
<tr>
<td>4</td>
<td>420</td>
<td>15.8</td>
</tr>
<tr>
<td>5</td>
<td>980</td>
<td>20.1</td>
</tr>
</tbody>
</table>

We now plot the failures as shown in Fig. 8 (and Fig. 9).

We draw a smooth line through the points and find that the “knee” is at approximately 18 % weak components. \( \beta_1 \) is estimated to 1.0. We further compute 18 % \( \times 0.63 = 11.3 \) % and find at this ordinate the \( x \)-value of the smooth curve to be 230 hours. \( \eta_1 \) is therefore estimated to 230 hours.

We further plot the first 4 failures separately to determine the parameters for the weak population. Their \( x \)-coordinates are the same. Their \( y \)-coordinates are:

<table>
<thead>
<tr>
<th>Failure No.</th>
<th>Time to failure ( t(i) )</th>
<th>Median rank (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>140</td>
<td>39</td>
</tr>
<tr>
<td>3</td>
<td>230</td>
<td>61</td>
</tr>
<tr>
<td>4</td>
<td>420</td>
<td>84</td>
</tr>
</tbody>
</table>

Draw a straight line to represent the first 4 failures (the weak). See Figure 9. The slope of this line is equal to a \( \beta \) of 1.2.

The Weibull parameters for the weak distribution are therefore \( \beta_1 = 1.2 \) and \( \eta_1 = 250 \) hours. This more exact \( \eta_1 \) is found on the plot of the weak population alone.

We are not able to draw the curve for the strong population since we only have one strong failure, but we may, however, estimate the percentage of strong components that have failed at 120 hours to be 1 out of 23 - 4 = 19 strong components i.e. 5.3 %.

We want to remove 99 % of the weak components in the test and, looking at the plot of the weak components alone (Figure 9), we find that the optimum duration of the RSS process will be 900 hours. Since this time is lower than 980 hours the probability of a strong component failing is much less than 5.3 %. A good conservative estimate assuming constant failure intensity will be: \((900/980) \times 5.3 = 4.9 \%\).
Figure 6. Determination of number of components for an RSS test.

Figure 7. Nomogram for the binomial distribution.
Figure 9. Weibull plot of an RSS test (example in Annex 5).
ESTIMATION OF ACCELERATION FACTORS

It is difficult to compute the acceleration factor for an RSS process. We therefore use statistical methods that are independent of the acceleration factor (see Annexes 5, 7 and 8).

To estimate the acceleration factor of the RSS process for determination of the duration of the initial RSS test the following equations can be used.

1 TEMPERATURE ACCELERATION FACTORS

The Arrhenius equation allows us to estimate the acceleration factor caused by an increased temperature. Due to the higher rate of chemical reactions at higher temperature a small number of hours at high temperature is equivalent to a larger number of hours at low temperature. The equation reads:

\[
\frac{t_1}{t_2} = e^{(E_A/k (1/T_2 - 1/T_1))}
\]

In this equation:

- \(t_2/t_1\) is the acceleration factor, i.e. the proportion between the time at low temperature \(T_2\) and the time at high temperature \(T_1\)
- \(T_2\) is the low temperature and \(T_1\) the high temperature both measured in Kelvin (absolute temperature)
- \(k\) is Boltzmann’s constant \(k = 0.00008617\) eV/K
- \(E_A\) is a constant called the activation energy. It is measured in electron volts (eV).

Each failure mechanism has a specific activation energy, and we therefore can either make the computation for one failure mechanism at a time or use an average activation energy for a number of failure mechanisms. Unfortunately the mixture of the failure mechanisms varies with the absolute temperature, so the activation energy is not constant with temperature.

Great care must therefore be used when using the Arrhenius equation for a large temperature difference (more than 30 °C).

Since the equation is exponential a small error in the activation energy will result in a large error in the acceleration factor. We should therefore whenever possible use the activation energy for the actual failure mechanism (chemical reaction). If this is not possible we can be forced to use the average activation energy for the component type in the actual temperature interval.

As a rough guidance the following values can be given for the activation energy under normal conditions of use:

<table>
<thead>
<tr>
<th>Generic component family</th>
<th>(E_A) (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital bipolar</td>
<td>0.4</td>
</tr>
<tr>
<td>Digital MOS</td>
<td>0.7</td>
</tr>
<tr>
<td>Linear bipolar</td>
<td>0.9</td>
</tr>
<tr>
<td>Microprocessor (MOS)</td>
<td>0.7</td>
</tr>
<tr>
<td>Transistors</td>
<td>0.2</td>
</tr>
<tr>
<td>Diodes, signal, rectifier, power</td>
<td>0.15</td>
</tr>
<tr>
<td>Diodes, Zener</td>
<td>0.12</td>
</tr>
<tr>
<td>Capacitors, electrolytic</td>
<td>0.17</td>
</tr>
<tr>
<td>Capacitors, non-electrolytic</td>
<td>0.25</td>
</tr>
<tr>
<td>Resistors, carbon comp.</td>
<td>0.36</td>
</tr>
<tr>
<td>Resistors, carbon film, metal film</td>
<td>0.12</td>
</tr>
<tr>
<td>Resistors, wire wound</td>
<td>0.10</td>
</tr>
<tr>
<td>Resistor array</td>
<td>0.36</td>
</tr>
</tbody>
</table>

These values for activation energies are computed based on data from SAE 870050.

2 VIBRATION ACCELERATION FACTORS

For computing the acceleration factor for an ASD or PSD specified random vibration the following equation is used:

\[
W_2 = W_1 \cdot \left(\frac{t_1}{t_2}\right)^{1/M}
\]

\(M\) = material constant (slope of Wöhler curve of the relevant material). Typical value is 4 for metal which according to MIL-STD-810E, method 514 can also be used in general for electronic equipment

\(W_2\) = acceleration density (ASD or PSD) for RSS random vibration spectrum

\(W_1\) = acceleration density (ASD or PSD) for random vibration under operating conditions

\(t_1\) = duration of vibration under operating or transport conditions

\(t_2\) = time for the RSS random vibration

If this equation is used for calculations for sine vibration, \(W\) represents peak g values and \(M = 6\) in general case for electronics and \(M = 2.5\) in the case of electronic boards. (MIL-STD-810E, method 514).

If the vibration level is specified using the RMS values the following equation is used:

\[
W_2 = W_1 \cdot \left(\frac{t_1}{t_2}\right)^{1/2M}
\]

\(M\) = material constant (slope of Wöhler curve of the relevant material). Typical value is 4 for metal, which according to MIL-STD-810E, method 514 can also be used in general for electronic equipment

\(W_2\) = RMS value for RSS random vibration spectrum

\(W_1\) = RMS value for random vibration under operating conditions

\(t_1\) = duration of vibration under operating or transport conditions

\(t_2\) = time for the RSS random vibration
Bayesian Method

When we are analyzing RSS test data (see Annex 5), it is usually fairly easy to draw the S-curve and to find the point where the curve levels out. But in some cases it can be difficult to see which failures belong to the weak, and which to the strong population, especially in cases where several failure modes are competing and the “knee” of the curve is not well defined.

The following technique based on Bayesian inference theory overcomes this problem.

A distribution that consists of a weak and a strong population can be described as a bimodal Weibull distribution, with the following equation:

\[ F(t) = pF_1(t) + (1-p)F_2(t) \]

In this equation:

- \( F(t) \) is the accumulated percentage of failures
- \( p \) is the percentage of weak components
- \( F_1(t) \) is the accumulated percentage of failures in the weak population
- \( F_2(t) \) is the same for the strong population.

In the RSS test we have observed \( r \) failures. The failure number \( i \) is a number between 1 and \( r \).

Bayes theorem computes the probability of an event based on a previous assumption, updated with recent information.

When we observe a failure we do not know if the failed component belongs to the weak or to the strong part of the population. It will therefore be reasonable to assume that the probability is 50%.

Adding the information from the test we may now compute the revised probability that failure number \( i \) belongs to the weak population as:

\[ p_i = \frac{(f_1(t_i))}{(f_1(t_i)) + (f_2(t_i))} \]

In order to compute the revised probability we need the values of \( f_1(t_i) \) and \( f_2(t_i) \). These can be computed using the equations:

- \( f_1(t_i) = \frac{\beta_1}{\eta_1} \cdot \exp \left[ - \left( \frac{t_i}{\eta_1} \right)^{\beta_1} \right] \cdot \left( \frac{t_i}{\eta_1} \right)^{\beta_1-1} \)
- \( f_2(t_i) = \frac{\beta_2}{\eta_2} \cdot \exp \left[ - \left( \frac{t_i}{\eta_2} \right)^{\beta_2} \right] \cdot \left( \frac{t_i}{\eta_2} \right)^{\beta_2-1} \)

- \( t_i \) is the time to the failure \( i \) where we want an estimate of the probability that this failed component belongs to the weak population.
- \( \beta_1 \) is the shape parameter
- \( \eta_1 \) is the characteristic life of the weak components.

These parameters can fairly easily be estimated from a Weibull plot of the observed failures.

- \( \beta_2 \) is the shape parameter
- \( \eta_2 \) is the characteristic life time of the strong components.

These parameters can not usually be estimated from the test, but we can set \( \beta_2 \) equal to 1 (exponential failure distribution, constant risk). For \( \eta_2 \) a predicted MTBF value of the strong components at the stress level of the RSS process can be used. Alternatively large number as for example 10 000 hours can be used. It has been shown that the results are very sensitive to \( \beta_1 \) and \( \eta_1 \) but not very sensitive to \( \beta_2 \) and \( \eta_2 \).

Example:

We have made an RSS test with 23 components and 5 failures were observed. The failures were plotted on a Weibull paper (Figures 6 and 7). The data is the same as in the example in Annex 5.

From the probability paper we estimate that the percentage of weak components (p) is 18% and \( \beta_1 \) is 1 and \( \eta_1 \) is 230 hours (see Fig. 6).

We have no estimates for the parameters of the strong population, but we assume \( \beta_2 \) to be = 1. We make the calculation assuming \( \eta_2 \) to be 10 000 hours and 30 000 hours in order to demonstrate that the method is not very sensitive to a correct estimate of the parameters of the strong population.

The results are shown in the table below.

Bayes analysis of RSS results shown in Figures 6 and 7. Input parameters for the analysis are: \( \beta_1 = 1.0, \eta_1 = 230 \) hours, \( \beta_2 = 1.0 \) and \( \eta_2 \) alternatively 10 000 hours or 30 000 hours as shown.

<table>
<thead>
<tr>
<th>Failure No.</th>
<th>Time-to-failure (hours)</th>
<th>Median rank (%)</th>
<th>Probability of the failure belonging to the weak population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>3.0</td>
<td>0.97</td>
</tr>
<tr>
<td>2</td>
<td>140</td>
<td>7.3</td>
<td>0.96</td>
</tr>
<tr>
<td>3</td>
<td>230</td>
<td>11.5</td>
<td>0.94</td>
</tr>
<tr>
<td>4</td>
<td>420</td>
<td>15.8</td>
<td>0.88</td>
</tr>
<tr>
<td>5</td>
<td>980</td>
<td>20.1</td>
<td>0.40</td>
</tr>
</tbody>
</table>
PROCEDURES FOR DECISION OF THE ACCEPTANCE OF A COMPONENT LOT

The decision whether or not to accept a lot can be based on different rules. In 6.1.11 these cases are defined. In this annex the procedure in arriving at the decision is explained.

CASE A

Rule: The lot is accepted or rejected based on the number of failures in the sample.

Example:
We want to run a risk of maximum 10 % for accepting a lot of components that contains >1 % weak components.

We decide that we will not allow any weak components in the sample.

We now draw a line on the binomial distribution nomogram (Fig. 4) from 1 % on the p scale (far left scale) to the 10 % on the PA scale (far right scale). This is the probability that we will accept a lot even though it contains 1 % failures. This can happen when, due to random variations, we do not find any weak component in the sample. The probability that we find zero weak components in the sample for p = 1 % must therefore be less than 10 %. This means that c = 0 in the nomogram.

We now follow the line c = 0 since we will reject the lot if there is only 1 weak component in the sample. Where the line crosses the straight line between p = 1 % and PA = 10 % we find the required sample size n = 250.

The sample size for the RSS process therefore shall be 250, and we will reject the whole lot if there is one or more weak components in the sample.

We can also see in the nomogram that the probability of accepting a lot that contains 3 % weak components is less than 0.1 %.

We may decide that we would be willing to accept 1 weak component in the sample. In that case our sample size n should be 375 in order to have the same confidence level.

If we want higher or lower confidence level we may repeat the computation in the nomogram or compute using the binomial distribution.

CASE B

Rule: The lot is accepted or rejected based on the percentage of flaws estimated in the sample.

Example:
In this case we plot the result of the RSS performed on the sample using Weibull paper (see Annex 5 for description of the method). From the Weibull paper we read the best estimate of the percentage of weak components pw in the sample. In this example (Fig. 10) pw = 2.5 %.

If we have decided that the maximum allowed percentage of failures is 1 % then the lot has to be rejected.

The advantage of this method is that even though strong components may fail in the accelerated RSS process we only make our decision based on the weak components. The disadvantage of the method is that it requires a number of failures (at least 4).

If it is difficult to distinguish between weak and strong failed components the Bayes method can be used (see Annex 7).

CASE C

Rule: The lot is accepted or rejected based on the percentage of components with parameter value outside a certain limit.

Example:
During the RSS process, or after the RSS process one or more parameters of the component is measured. If we want to measure the parameter under stress we measure during the RSS process. If we are interested in the value after the RSS process we measure when the components are removed from the process.

A special case is where we measure the change in the parameter from before to after the RSS process, and plot this change.

In Fig. 11 one of the parameters for a component is plotted in a histogram. We can clearly see that most of the component values form a nice Gaussian distribution, but two components in the sample are clearly outside the distribution. These components must be characterised as flawed components.

If we allow maximum 1 flawed component in the sample we shall reject the lot.

We decide on the number of flawed or weak components that we will accept using the method described for case A above.

CASE D

Rule: The lot is accepted or rejected based on the margin from the distribution to the functional limit.

Example:
In this case we measure one or more parameter values as described in Case C above. But instead of plotting the parameters as a histogram we plot them on a probability paper, e.g. a Gaussian probability paper or a Weibull probability paper.
Figure 10: Decision for acceptance of a component by using a Weibull plot.
Figure 11. Decision for acceptance of a component lot using a histogram.

Figure 12. Decision for acceptance of a component lot using Gauss probability paper.
In Fig. 12 one of the parameters is plotted on a Gaussian probability paper. We can see that the data may, with a fair degree of approximation, be modelled by a Gaussian distribution.

From the Gaussian plot we find the mean value of the parameter to 10.32 and the standard deviation to 0.17. The computed standard deviation is our best estimate of the variance of this parameter in the whole lot. This value is called sigma (σ). Sigma for the parameter in the lot is estimated to 0.17.

The company that performs the RSS test is running a 6-sigma program and therefore requires that the distance from the parameter’s mean value to the functional limit of the circuit is > 6-sigma, or in this case $6 \times 0.17 = 1.02$.

The functional limit of the circuit is 9.5 and the distance from the mean to the functional limit is therefore 0.82 which is smaller than 1.02.

The component lot shall therefore be rejected, even though we have no parameter values lower than 9.9.

The company will state that the reason for this decision is that the safety margin is not large enough to guarantee trouble free production and operation.