Hi-Rel DC/DC Converter
Environmental Stress Screening Grades

1- General

An environmental Stress Screening Program (ESS) is a process in which environmental stimuli (such as thermal cycling and random vibration) are applied to electronic items in order to precipitate defects to early failure. Manufacturing techniques for modern electronics consist of hundreds of operations and processes through which defects can be introduced into the products.
Many of these defects can be detected without the need for an environmental stress screening program by use of visual inspections, functionnal tests and other conventionnal quality assurance procedures. The other defects remain undetected and will eventually manifest during product use : these are called latent defects. Environmental Stress Screening is the vehicle by which latent defects are accelerated to early failure in the factory.

2- Referenced Documents

2-1 Government Standards

- MIL-STD-781 Reliability Testing for Engineering Development, Qualification, and Production
- MIL-STD-785 Reliability Program for Systems and Equipment Development and Production
- MIL-STD-883 : Test Method and Procedures for microcircuits
- MIL-HDBK-217 Reliability Prediction of Electronic Equipement
- MIL-HDBK-344 Environmental Stress Screening for Electronic Equipment

2-2 Air Force & Navy Publications

- AFP 800-7 USAF R&M 2000 Process
- RADC-82-87 Stress Screening for Electronic Hardware
- RADC-TR-86-149 Environmental Stress Screening
- RL-TR-91-300 Evaluation of Quantitative Environmental Stress Screening Methods
- NAVMAT P-9492 Navy Manufacturing Screening Program

2-3 other Publications

- IES (Institute for Environmental Science) : Environmental Stress Screening Guidelines for Assemblies.

3- ESS Approach

Basically there are 2 basic approaches to the application of ESS program.
In the first approach, a Government Agency explicitely specifies the ESS program and screening parameters to be used. These approaches are described in different standards such as :
- MIL-STD-883C for microelectronics
- RADC-TR-82-87 for USAF equipments
- AMC Reg 702-25 for the Army equipments
- NAVMAT P-9492 for Navy equipments

The second approach is to have contractors propose an ESS program which is tailored to their products and manufacturing process.

4- ESS Methodology

Maintaining an ESS program needs a dynamic method and has to be considered as a closed loop system to measure and optimize it's efficiency. The 3 major steps in this dynamic methods are :
- set-up an initial ESS program
- measure the results and efficiency
- optimize the ESS program

4-1 Set-up an initial ESS Program

Establishing an ESS program is linked to express quantitatively an objective to reduce the number of latent deffects in a production lot to an acceptable level by use of cost effective screening methods.
The MIL-HDBK-344 document defines a mathematical model to achieve ESS objectives.

4-2 Measurement of Efficiency

All defects measured during the ESS program need to be recorded together with field returns analyzed and compared to the initial ESS program objectives.

4-3 Optimize ESS Program

Optimize the ESS program according to results.

5- Set-up of an ESS Program

5-1 General

A basic premise of an ESS program is that under specific screening stresses applied over time, the failure rates of defective units are accelerated from that which would occur under normal field operation.

By subjecting electronic items to accelerate stresses, latent defects are thus precipitated to early failure.

5-2 Stress Screens Contributors

Results of the Institute of Environmental Sciences (IES Environmental Stress Screening Guidelines for Assemblies) pointed-out that vibration screens (and particularly random vibrations) and thermal screens are the 2 major contributors to precipitate latent defects into early failure.

The 2 screens are not equally effective to precipitate the same defect type and the following table provides a list of latent defect types versus stress screening contributors.

Defect Type	Thermal screen	Vibration screen
Deffective part	X	X
Broken part	X	X
Solder connection	X	X
Pcb etch, short and open	X	X
loose contact	X	
wire insulation	X	
loose wire termination	X	X
improber crimp or mating	X	X
parameter drift	X	

To characterize stress screening contributors, the following parameters are necessary :

- **Thermal cycle screen parameters :**
  - maximum temperature (Tmax) to which the electronic has to be exposed during a certain time t1 (commonly referenced as dwell)
  - minimum temperature (Tmin) to which the electronics has to be exposed during a certain time
  - temperature rate change from Tmax to Tmin
  - number of cycles

- **Vibration screen parameters :**
  - Grms level for random vibration
  - spectrum shape for random vibration
  - duration
  - axis of vibration

Care should be exerciced to ensure that hardware responses are large enough to generate an effective screen while not exceeding design capabilities.

5-3 Stress Screen Efficiency : Precipitation Efficiency

A stress screen can be characterized by a measurement of it's efficiency. The MIL-HDBK-344 Handbook proposes a theorical approach to measure a stress screen efficiency : the Precipitation Efficiency.

The Precipitation Efficiency (P_e) of a screen is expressed as the probability that the screen will precipitate a defect to a detectable state given that the defect susceptible to the screen is present. The precipitation efficiency of a screen must be independant of the number of defects and when the screen is performed. Mathematically this can be satisfied if the defects are exponentially distributed in time as follow :

$$P_e = 1 - \exp(-kt)$$

where(k) is a stress factor dependant of each screen.

The document RADC-TR-86-14 proposes an approach to calculate the stress factor as follow :

- **for temperature cycling :** the stress constant k can be determined with the following formula :

  $$k = 0.00017(Tmax-Tmin+0.6)^{0.6}(In(Rate+2.718)^{3}$$

- **for vibrations** : the stress constant k is determined by different formulas :
  for random vibration : $k = 0.0046G^{1.71}$
  for swept sine vibration : $k = 0.000727G^{0.863}$
  for fixed sine vibration : $k = 0.00047G^{0.49}$
  When selecting and modeling a vibration sensitivity, the precipitation efficiency is given by axis sensitivity factor.

5-4 Power-On testing versus Power-Off

Application of power, exercising and monitoring equipment performance contineously during the screen will greatly enhance defect detection. Subtile defects, such as contact intermittences or temperature sensitive parts can only be detected with powered and monitored screens.

Power-On/Power-Off testing will determine a detection efficiency during a screen.

5-5 Stress Screen Detection : Detection Efficiency

The RADC-TR-86-14 document proposes an approach to determine the detection efficiency of a screen. The detection efficiency is sensitive to 3 factors and must be estimated accordingly : the detection efficiency is the product of these 3 factors.

Screening	Detection Efficiency
Type of testing performed Functionnal test only Functionnal and parametric	 0.5 to 0.8 0.8 to 1
Environmental conditions during testing : under ambient conditions only concurrently with stress	 0.2 to 0.6 1
Ability to observe and isolate defect and the probability to removed the defect without introducing another	0.8 to 1

6-ESS Objective: A Theorical Quantitative Approach

6-1 General

A quantitative approach to an ESS program enables the establishement of explicit quantitative objectives and provides a basis for monitoring and controlling the ESS program to meet these objectives.

The fundamental objective of an ESS program is to reduce the number of latent defects in a production lot to an acceptable level by use of cost effective methods. As basic principles, one would like to be able to use strong screens and efficient tests, which have a high probability of precipitation and detection defects. To transform these principles into quantitative objectives is is necessary to define various measures and their relationship to the screen process. This section describes briefly a mathmatical model (MIL-HDBK-344A document) for an ESS program quantitative approach.

6-2 Key Parameters for quantitative approach

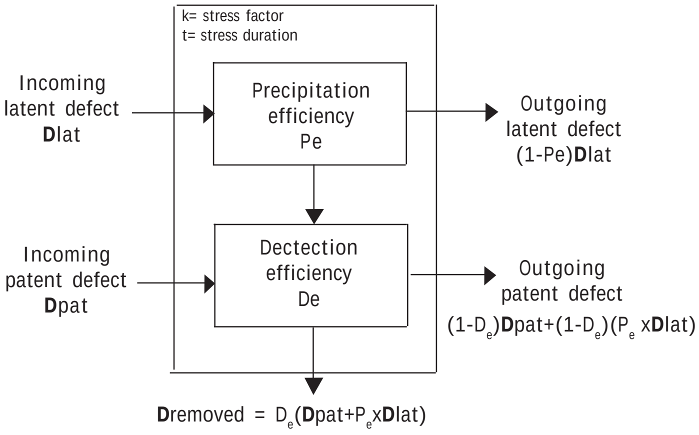
The following key parameters are explained as follow :

- **D**in **:** incoming defect density is the average number of defect per item which enters into the screen.
- **D**out **:** outgoing defect density is the average number of defect per item which comes out the screen
- **D**Lat **:** latent defect density is the average number of latent defect per item which will precipitate in failure under the screening program
- **D**pat **:** patent defect density is the average number of effective defect detected per item
- **D**remain **:** remaining defect density is the average number of defect per item which remains after the ESS program
- **D**remov **:** removed defect density is the average number of defect per item removed during the ESS program

these measures are related together as follow :

$$\mathbf{D}\text{in} = \text{Latent defect } (\mathbf{D}\text{lat}) + \text{Patent defect } (\mathbf{D}\text{pat})$$

Latent vs Patent deffects : for ESS purposes deffects are divided into latent deffect i.e an inherent or induced weakness that will manifest in a failure at some time in the future in operation and patent defects.



6-2 Mathematical Model

From the mathematical formula in section 5-3 related to precipitation efficiency and section 6-1 the remaining and removed defect density is given as follow :

$$\mathbf{D}\text{remain} = (1-D_e)\ \mathbf{x}\ \mathbf{D}\text{pat} + (1-D_e)\ \mathbf{x}\ \mathbf{D}\text{lat}(1-e^{-kt}) + \mathbf{D}\text{lat}(1-e^{-kt})$$

$$\mathbf{D}\text{removed} = D_e\ \mathbf{x}\ \mathbf{D}\text{pat} + D_e\ \mathbf{x}\ \mathbf{D}\text{lat}(1-e^{-kt})$$

6-3 Quantitative Objectives

The quantitative approach to an ESS program is based on a statistical mathematical model described by a bionomial probability distribution that can be approximated by a Poisson distribution.

The probability that an item is deffective (i.e contains one or more defects) is given by : $P(D) = 1 - e^{(-\mathbf{D})}$

The probability that an equipment will pass the screening tests is called the yield. Because not all remaining defects fail during the screen, the yield is expressed as :

$$\text{Yield} = e^{(-\mathbf{D}\text{removed})}$$

This yield can be used as an objective to plan an ESS program and subsequently monitor and control it.

6-4 ESS Program to Field Reliability

The MIL-HDBK-344 document proposes a theoretical approach to relate the remaining defect density to the field failure rate. From the remaining defect density after the screen a correlation can be done with the field failure rate by 2 adjusting factors :

- **SAF :**stress adjustment factor. Obtaining an initial estimate defect density for an item must take into account the field operation environment to which this item will be exposed during product life. Since the field operating stress levels are different from the ESS program, the model should incorporate a stress adjustment factor defined as :

$$\text{SAF} = \text{Defect Density (in field)} / \text{defect density (in ESS)}$$

- **CFR :** Constant failure rate. The field reliability is determined by the latent defect remaining at the time of shipment and the existance of a non-screenable defect that result in a constant failure rate due to limiting MTBF. This CRF constant should also be incorporated to the model

With these 2 factors the field reliability can be determined as follow :

$$\text{Average Field Failure Rate} = (\text{Total failures in time } t) / t = S((1-D_e)\mathbf{D}\text{pat} + (1-D_e)\mathbf{SAFD}\text{lat}(1-e^{-kt}) + \mathbf{D}\text{lat}(1-e^{-kt}) + t\text{xCRF}) / t$$

Using this relationship, the required field failure rate can be used to determine the requirements for remaining defect density at ESS level and consequently used to establish goals for an ESS program.

6-5 Fatigue Life : Damage Index

The ESS program induce stresses on the item, it is usefull to ensure that the ESS is not too stressfull. The MIL-HDBK-344 document proposes a theorical approach by calculating a damage index ratio from the equations :

$$\text{fatigue life } D = NS^B \ \& \ \text{life consumed ration} = De/DI$$

where De is the fatigue life during ESS program and DI is the fatigue life during life of the item and N=stress duration, S=stress level, B=fatigue exponent.

For temperature cycling : N is the number of cycles, S the temperature range and coefficiant B=2,5

7- Typical ESS Programs

Typical ESS programs have been elaborated for various type of applications and products; the most popular are :

7-1 The MIL-STD-883C/D ESS Program

US Government has elaborated a screen profile for microelectronics (monolithics, multichips, hybrid microcircuits, ..) components that include different screens among which some of them are as follow :

ESS Program	Screen Parameters
Thermal screen Burn-in (method 1015.1) Temperature cycle (method 1010) Steady stade life (method 1005) Stabilization bake (method 1008)	Various levels
Vibration screen Constant acceler. (method 2001) Mechanical shock (method 2002) Vibration fatigue (method 2005) Vibration noise (method 2006)	Various levels

7-2 The R&M2000 Initial ESS Program

The USAF in the above document recommends an initial ESS program for boards which has a high precipitation efficiency :

ESS Program	Screen Parameters
Thermal screen	
Temperature range	-54°C to 71°C
Temperature rate of change	30°C/min
Temperature cycles	25
Power On/Off	Off
Vibration screen	
Spectral density	6 Grms
Frequency limit	100- 1.000 Hz
Duration	10 min/axis
Power On/Off	On

7-3 Typical NAVMAT P-4855-1A ESS Program

The Navy in the above standard document is recommended for an ESS program the following levels :

ESS Program	Screen Parameters
Thermal screen	
Temperature range	-55°C to 55°C
Temperature rate of change	>5°C/min
Temperature cycles	12
Power On/Off	On and Off
Vibration screen	
Spectral density	6 Grms
Frequency limit	20- 2.000 Hz
Duration	10 min/axis
Power On/Off	On

8- GAIA Converter ESS Programs

GAIA Converter has elaborated an environmental stress screening program adapted for it's DC/DC Converters and manufacturing profile.
This ESS program is referenced as an option (/S) and exists for each GAIA Converter DC/DC Hi-Rel modules and accessories.
GAIA Converter has also set up a screen to verify the suitability for -55°C start up operation; this screen is referenced as /T option.
Screening profile are described in the following sections.

8-1 (/T) Screening Program

GAIA Converter proposes a (/T) option for applications that need to operate and start up at low temperature conditions of -55°C. The table hereafter describes the process to screen standard Hi-Rel converters to -55°C operation.

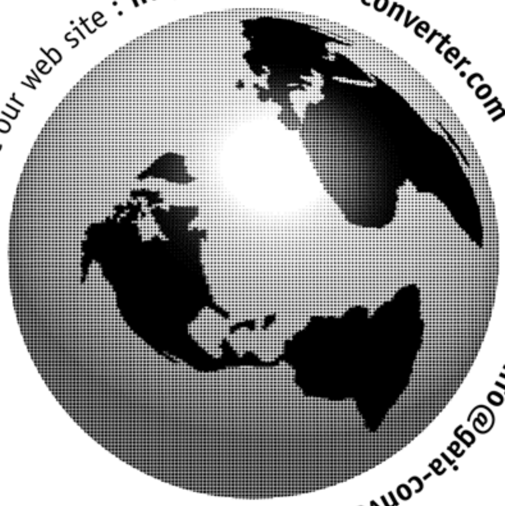
Screening	Test Procedures
-55°C start up screening	t = 2 hrs at -55°C power on/off : 5 cycles Start up time measurements

8-2 (/S) Screening Program

GAIA Converter proposes a (/S) option for applications that need to be screened according to an Environmental Stress Screening Program.
This ESS program covers the following steps :

Screening	Test Procedures and Screen Parameters
Precap before encapsulation	100%
Serialisation of each module	Yes
Electrical test after encapsulation	100% at 25°C
Stabilization bake	Duration : 96 hrs Temperature : 105°C Profile : power off
Temperature cycling	Number of cycles : 30 cycles Temperature : -40/+85°C (105°C case) Transfert time : 3°C / min Stabilization time : 10 min Profile : power on
Burn-in	Duration : 160 hrs Temperature : 85°C (105°C Case) profile : power on
Electrical test data report	100% at : low temperature ambient temperature 25°C high temperature

Visit our web site : **http://www.gaia-converter.com** • Write to us at : **info@gaia-converter.com**



For more detailed specifications and applications information, contact :

International Headquarters
GAÏA Converter - France
ZI de la Morandière
33185 LE HAILLAN - FRANCE
Tel. : + (33)-5-57-92-12-80
Fax : + (33)-5-57-92-12-89

North American Headquarters
GAÏA Converter Canada, Inc
4038 Le Corbusier Blvd
LAVAL, QUEBEC - CANADA H7L 5R2
Tel. : (514)-333-3169
Fax : (514)-333-4519

Represented by :

Printed in France by GAIA Converter Gaia Converter FC97-039.08/04 Revision E. Graphisme : Philippe Clicq