DEVELOPMENTAL HALT REPORT

R-00000279

Product Tested:	**1200W power supply XVD754321-00**
Service Proposal #:	**S-0000279**
Job #:	**4148-3578**
Test Dates:	**19/02/2008 to 21/02/2008**
Report Date:	**18/03/2008**

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1.0 Objective

Poor reliability, low MTBF, frequent field returns, high in-warranty costs, and customer dissatisfaction are often the result of design and/or process weaknesses, even if a product has successfully passed qualification tests and burn-in.

The product was subjected to the HALT process to uncover design and/or process weaknesses. During the HALT process, the product was subjected to progressively higher stress levels brought on by thermal dwells, vibration, rapid temperature transitions and combined environments.

Throughout the HALT process, the intent was to subject the product to stimuli well beyond the expected field environments to determine the operating and destruct limits of the product. Failures, which typically show up in the field over a period of time at much lower stress levels, are quickly discovered while applying high stress conditions over a short period of time.

HALT is primarily a margin discovery process. In order to ruggedise the product, the root cause of each of failure needs to be determined and the problems corrected until the fundamental limit of the technology for the product can be reached. This process will yield the widest possible margin between product capabilities and the environment in which it will operate, thus increasing the product's reliability, reducing the number of field returns and realizing long-term savings.

The operating and destruct limits discovered during HALT on these units could be used to develop an effective Highly Accelerated Stress Screen (HASS) for manufacturing which will quickly detect any process flaws or new weak links without taking significant life out of the product. The HASS process will ensure that the reliability gains achieved through HALT will be maintained in future production.

2.0 Executive Summary

HALT was performed using one sample. During the HALT process, our goal was to find the operating and destruct limits for the units tested using thermal step stress, vibration step stress, and combined environment of temperature and multi-axis, 6 degree-of-freedom vibration. Once these limits were determined, our goal was to fix the weak links and stress even further to expand the limits as much as possible. The operating and destruct limits are summarized in Table 1. See Section 5.0 for a detailed discussion of failures. The HALT exposed specific weaknesses, which need to be addressed:

2.1 Cold step stress

The unit began to go into power limiting due to tolerances in the power limit circuit when the ambient temperature was decreased below -26℃. When the output power was reduced to 1kW the unit operated correctly down to -80℃ when testing was stopped.

2.2 Hot step stress

At +65℃ the Xg5 module began to go into current limiting, the current was reduced to 5A and testing continued. The Xg4 module began current limiting at +85℃ but recovered when the current on Xg4 was reduced to 4A. The PSU shut down when the temperature reached +90℃ and testing was stopped.

2.3 Rapid thermal transitions

There were no issues found during the rapid temperature cycling profile with dwells at +60℃ and -20℃ and transition rates of 60℃/min.

2.4 Vibration Step Stress

At 45G the Xg3 module began to intermittently lose output regulation and at 50G the problem got worse. After replacing the Xg3 module testing resumed at 45G.
At 55G Xg4 began to lose output occasionally and continued to do so at 60G, testing stopped at 60G.

2.5 Combined Environment Stress

The unit began power limiting during the 2nd cycle at 15G and temperature of -20℃, the power output was reduced to 1157W and the test continued with the unit operating correctly. The unit shut off during the dwell at +60℃ and 40G on the 7th cycle.

Table 1 - Summary of PSU Operating and Destruct Limits

Stress Limit	***Chamber Setpoint Level***
Temp LOL	-26ºC
Temp LDL	<-80ºC
Temp UOL	+60ºC
Temp UDL	>+90ºC
Thermal Transitions	-20ºC to +60ºC
Vibration OL	40G
Vibration DL	>60G
Combined OL	< -20ºC to +60ºC and 15G
Combined DL	< -20ºC to +60ºC and 40G

Notes:

1. All temperature and vibration values are chamber setpoints. See Section 5 and the Appendix for product levels.
2. LOL / LDL = Lower Operating / Destruct Limit. UOL / UDL = Upper Operating / Destruct Limit. For vibration there is an upper limit only.
3. <u>Operating Limit</u> is defined as the point at which the product is still fully functional but when the applied stress is increased, the product is no longer functional.
4. <u>Destruct Limit</u> is defined as the point at which the product still returns to full operation when the applied stress is decreased to within the operating limit but when the applied stress is increased the unit fails to return to operation when the applied stress is returned to within the operating limit.
5. When the limit is preceded by a ">" or "<" sign it indicates that we stopped prior to a failure, either because of a limitation of the chamber, the test setup, or per customer request.
6. The limits shown are the worst case limits. In other words, the limits for the product that had the lowest limits of all units tested under that stress. These limits reflect the product limits before any modifications.

3.0 HALT Process

The test procedure followed is outlined in the ARTC Service Proposal noted on the front page of this report. Any deviations from this procedure are noted below:

- During each dwell the system was functionally tested.

4.0 HALT Setup

4.1 Fixturing and Airflow

The product was tested one unit at a time. The product under test was secured using two bars of aluminium U-channel and all-thread to clamp the metal chassis to the vibration table. Air from the chamber plenum was directed onto the units. The fixture was designed to maximize both transmission of energy from the vibration table to the product and thermal transition rates, as well as to help maintain consistent temperatures on all the components inside the test units. Pictures illustrating the fixturing and arrangement of test units in the test chamber are presented in Appendix A.

4.2 Description of Test Equipment

Table 2 - Anecto Test Equipment

Description	*Manufacturer*	*Model*	*S/N*	*Cal Due*
Thermal & Vibration Test Chamber	QualMark	OVS 2.5 HP	2604980254	15/02/09
Data logger	Hewlett Packard	34970A	U537037399	14/08/08
Data logger Thermocouples	Omega	TT-T-30	N/A	N/A
Chamber Thermocouples	Omega	C03-T-60	N/A	N/A
Spectrum Analyzer	Data Physics	Dp430	3869	N/A
Accelerometer	Dytran	3035B1G	3355	14/03/08
Accelerometer	Dytran	3035B1G	3514	11/09/08
Accelerometer	Dytran	3035B1G	3455	15/03/08

Table 2b – PSU Details

	Temperature Unit:	Vibration Unit:
PowerPak:	#36002644	#36002642
PowerMod XG1:	#20062668	#20062199
PowerMod XG2:	#20066035	#20066073
PowerMod XG3:	#20060967	#20064600
PowerMod XG4:	#20069143	#20068975
PowerMod XG5:	#20065839	#20065045
PowerMod XG7:	#30012132	#30002832

4.4 Data Collection

Thermocouples were attached to various points on the devices under test using kapton tape. These thermocouples remained in place throughout thermal step stress and rapid thermal transitions. The product thermal response at each thermocouple location was recorded at each level of thermal stress. See appendix B for thermal graphs.

Table 3 - Data logger Channel Assignment Temperature

Channel	*Location or Description*
101	Q10 PB
102	Q17 PB
103	Bridge PB
104	L4 PB
105	Q4 PB
106	D1 PB
107	Xg5 Q11/Q13 HS
108	Xg5 Sync FETs HS
109	Xg7 U8 HS
110	Xg7 Diode
111	Xg4 Q9/Q10 HS
201	Xg3 Sync FETs HS
202	Xg3 Q5/Q6 HS
203	Xg2 Sync FETs HS
204	Xg2 Q1/Q2 HS
205	Xg1 Sync FETs HS
206	Xg1 Q1/Q2 HS
208	Xg4 Sync FETs HS

Table 4 - OVS Control System Thermocouple Placement

Channel	***Placement***
Product (control)	PSU chassis
Air	Above chassis
Honeywell	Wall of chamber

4.5 Test Routine

The device under test was connected to external equipment and was functionally tested throughout the HALT.

Correct operation of the PSU was verified by monitoring the current and voltage output.

5.0 HALT Results

5.1 Thermal Step Stress

The test unit was subjected to cold thermal step stress beginning at +20°C, with the temperature decreasing in 10°C increments as far as -80℃ and from -25℃ to -27℃ in 1℃ steps. Once the thermocouples located on the units stabilized, the unit dwelled at that setpoint for 10 minutes. Once cold thermal step stress was completed, the unit was returned to +20°C and remained there until the thermocouples located on the unit stabilized. Once the unit reached +20°C, it was tested to ensure it was still fully functional. Hot thermal step stress began at a setpoint temperature of +30°C with the temperature increasing in 10°C increments as far as +50℃ and 5℃ steps thereafter. Once the thermocouples located on the unit reached the setpoint temperature, the unit dwelled at that setpoint for 10 minutes. The results of thermal testing are summarized in Tables 5 and 6.

Table 5 – Cold Thermal Step Stress Results (°C)

Setpoint	***Functional Test Results***	***Notes***
+20	OK	1
+10	OK	1
0	OK	1
-10	OK	1
-20	OK	1
-25	OK	1
-26	OK	1
-27	See notes below	1,2
-30	See notes below	1,2,3
-40	OK	1,3
-50	OK	1,3
-60	OK	1,3
-70	OK	1,3
-80	OK	1,3
+20	OK	1

Notes:

1. The system was functionally tested during each dwell.
2. The unit began to go into power limiting due to tolerances in the power limit circuit when the ambient temperature was decreased from -20℃ to -30℃ but recovered when the temperature was increased to -25℃. The temperature was then stepped down in 1℃ increments to find the operational limit which was found to be -26℃.
3. The output power was then reduced to 1kW and the unit operated correctly down to -80℃ when testing was stopped.

Table 6 – Hot Thermal Step Stress Results (°C)

Setpoint	***Functional Test Results***	***Notes***
+30	OK	1
+40	OK	1
+50	OK	1
+55	OK	1
+60	OK	1
+65	See notes below	1,2
+70	See notes below	1,3
+75	See notes below	1,3
+80	See notes below	1,3
+85	See notes below	1,3,4
+90	See notes below	1,3,4,5
+30	See notes below	1,6

Notes:

1. The system was functionally tested during every dwell.
2. At +65℃ the Xg5 module began to go into current limiting and began to lose regulation intermittently, the Xg5 was replaced with a new module which also began current limiting at +65℃.
3. The current on Xg5 was reduced to 5A and testing continued.
4. The Xg4 module began current limiting at +85℃ but recovered when the current on Xg4 was reduced to 4A.
5. The PSU shut down when the temperature reached +90℃ and testing was stopped.
6. The unit recovered when the temperature was reduced below +90℃ but was non functional after ramping back to ambient, later analysis showed the Xg4 module was causing the problem.

5.2 Rapid Thermal Transitions

The device under test was subjected to five and a half temperature cycles from +60°C to –20°C at an average thermal transition rate of 60°C per minute. The average thermal transition rate is computed from the average transition of all the product temperature response thermocouples. The rate is computed through the centre region of the entire transition, which discounts 20% at each end of the transition. Air temperature limits were set to +100°C and –60°C to prevent excessive overshoot. The results of rapid thermal transitions testing is summarised in Table 7.

Table 7 - Rapid Thermal Transition Results (°C)

Cycle	*Setpoint*	*Functional Test Results*	*Notes*
1	+60	OK	1
1	-20	OK	1
2	+60	OK	1
2	-20	OK	1
3	+60	OK	1
3	-20	OK	1
4	+60	OK	1
4	-20	OK	1
5	+60	OK	1
5	-20	OK	1
6	+25	OK	1

Notes:

1. The system was functionally tested during every dwell. No issues were found.

5.3 Vibration Step Stress

The device under test was clamped firmly to the vibration table to maximise energy transmission and subjected to vibration step stress beginning at a setpoint of 5 Grms with the vibration increasing in 5 Grms increments at 10 minute intervals. Tickle vibration was introduced at each dwell from 30G onwards. The results are summarized in Table 8.

Table 8 - Vibration Step Stress Results

Setpoint	*Functional Test Results*	*Notes*
5	OK	1
10	OK	1
15	OK	1
20	OK	1
25	OK	1
30	OK	1
35	OK	1
40	OK	1
45	See notes below	1,2
50	See notes below	1,2
55	See notes below	1,3
60	See notes below	1,3

Notes:

1. The system was functionally tested and during every dwell.
2. At 45G the Xg3 module began to intermittently lose output regulation and at 50G the problem got more pronounced. After replacing the Xg3 module testing resumed at 45G and the unit functioned correctly at 45G and 50G.
3. At 55G Xg4 began to lose output regulation occasionally and continued to do so at 60G, testing stopped at 60G.

5.4 Combined Environment

The device under test was subjected combined environment testing incorporating a temperature profile of seven and a half cycles from +60°C to –20°C at an average thermal transition rate of 60°C per minute and the introduction of increasing levels of vibration starting at 10G and increasing in 5G steps at the end of each hot/cold cycle. The results are summarized in Table 10.

Table 10 - Combined Environment Results

Cycle	*Temp (°C)*	*Vibe (Grms)*	*Functional Test Results*	*Notes*
1	+60	10	OK	1
1	-20	10	OK	1
2	+60	15	OK	1
2	-20	15	See notes below	1,2
3	+60	20	See notes below	1,2
3	-20	20	See notes below	1,2
4	+60	25	See notes below	1,2
4	-20	25	See notes below	1,2
5	+60	30	See notes below	1,2
5	-20	30	See notes below	1,2
6	+60	35	See notes below	1,2
6	-20	35	See notes below	1,2
7	+60	40	See notes below	1,3
7	-20	40	not completed	na
8	+60	40	not completed	na
8	+20	0	See notes below	1,3

Notes:

1. The system was functionally tested during every dwell.
2. The unit began power limiting during the 2nd cycle at 15G and temperature of -20°C, the power output was reduced to 1157W and the test continued with the unit operating correctly.
3. The unit shut off during the dwell at +60°C and 40G on the 7th cycle and the test was stopped. The unit failed to recover after the environmental stress was removed and analysis showed that a FET/s had blown on the primary board.

6.0 Synopsis

Each of the failures found during the HALT process (see section 2.0) needs to be examined and the root cause of the failure determined. Once the root cause of each failure is determined, engineering judgment is used to determine whether corrective action should be taken to fix the problem. The product should then undergo a verification HALT to ensure that the design margins have been increased to the fundamental limit of technology and that the fixes made did not induce new failure modes. The ruggedisation of the product will not be increased unless each of the failures found during the HALT process are taken to root cause and corrective action implemented.

Appendix A – Photographs

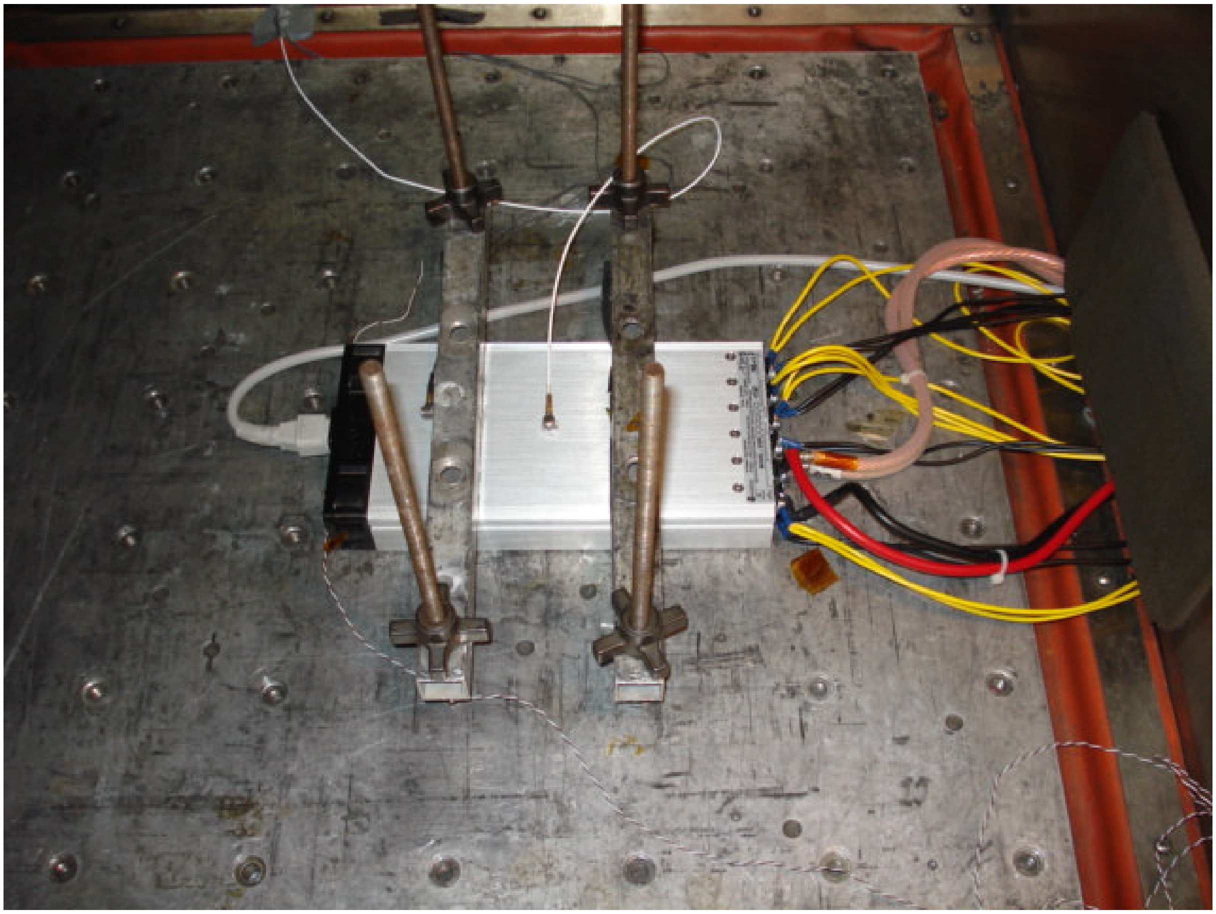
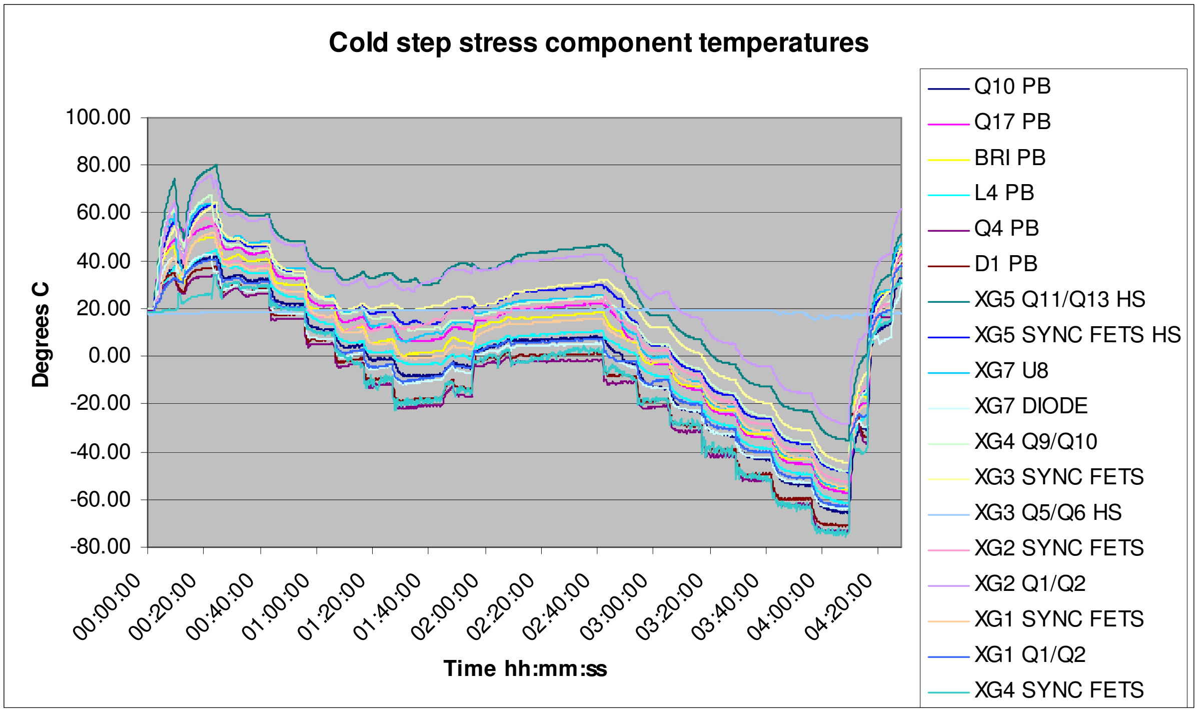
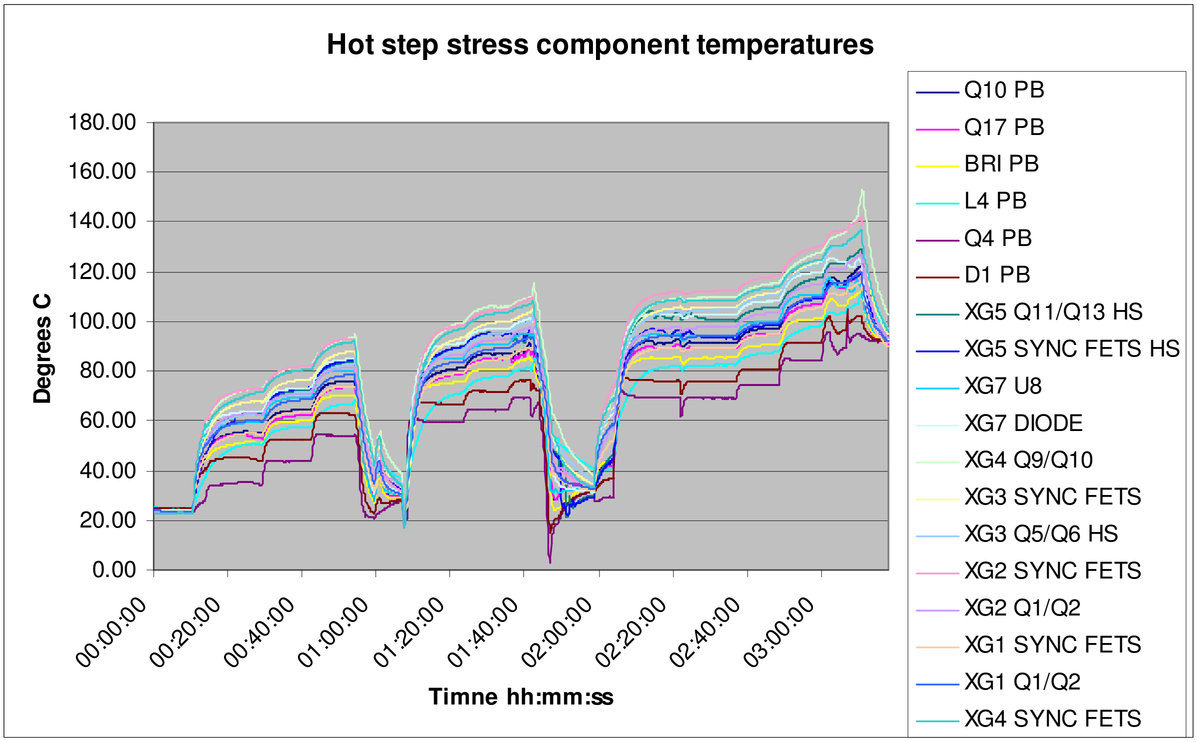
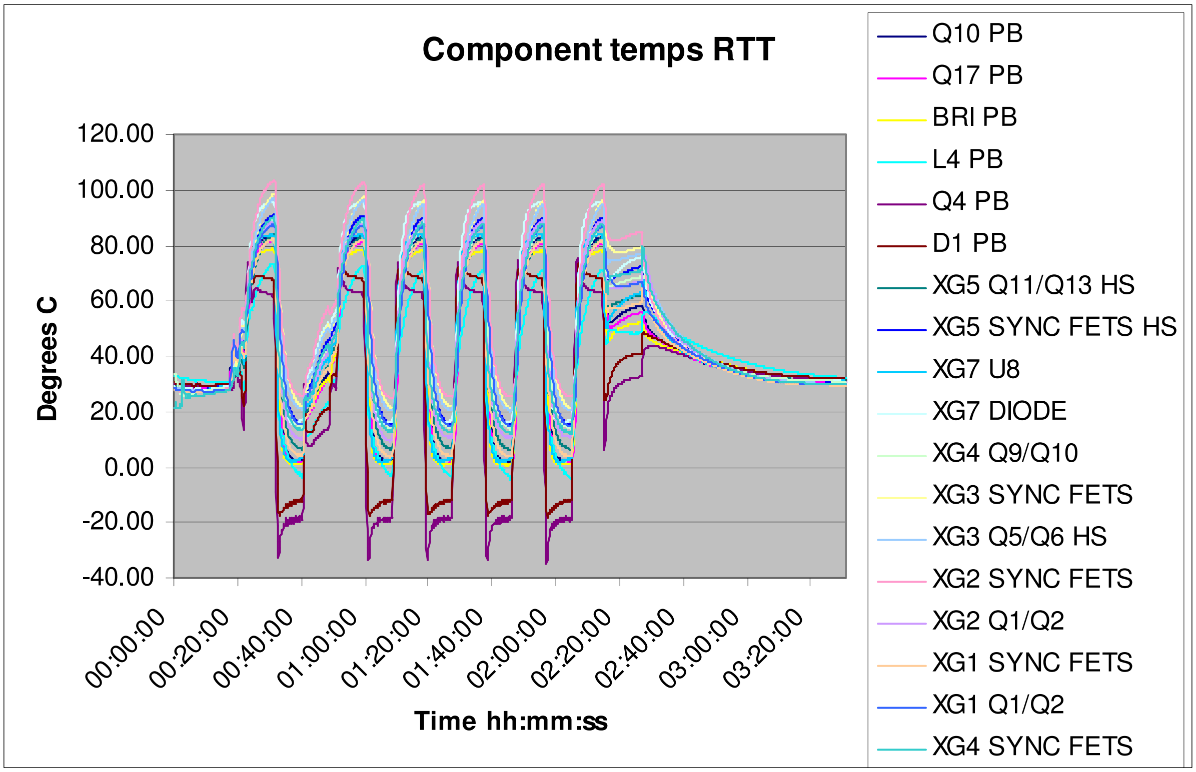


Figure 1 – Thermal and vibration Set-up

Appendix B – Thermal and Vibration Graphs






Component temps RTT
Degrees C
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100.00
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
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00:20:00
00:40:00
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02:00:00
02:20:00
02:40:00
03:00:00
03:20:00
Time hh:mm:ss
Q10 PB
Q17 PB
BRI PB
L4 PB
Q4 PB
D1 PB
XG5 Q11/Q13 HS
XG5 SYNC FETS HS
XG7 U8
XG7 DIODE
XG4 Q9/Q10
XG3 SYNC FETS
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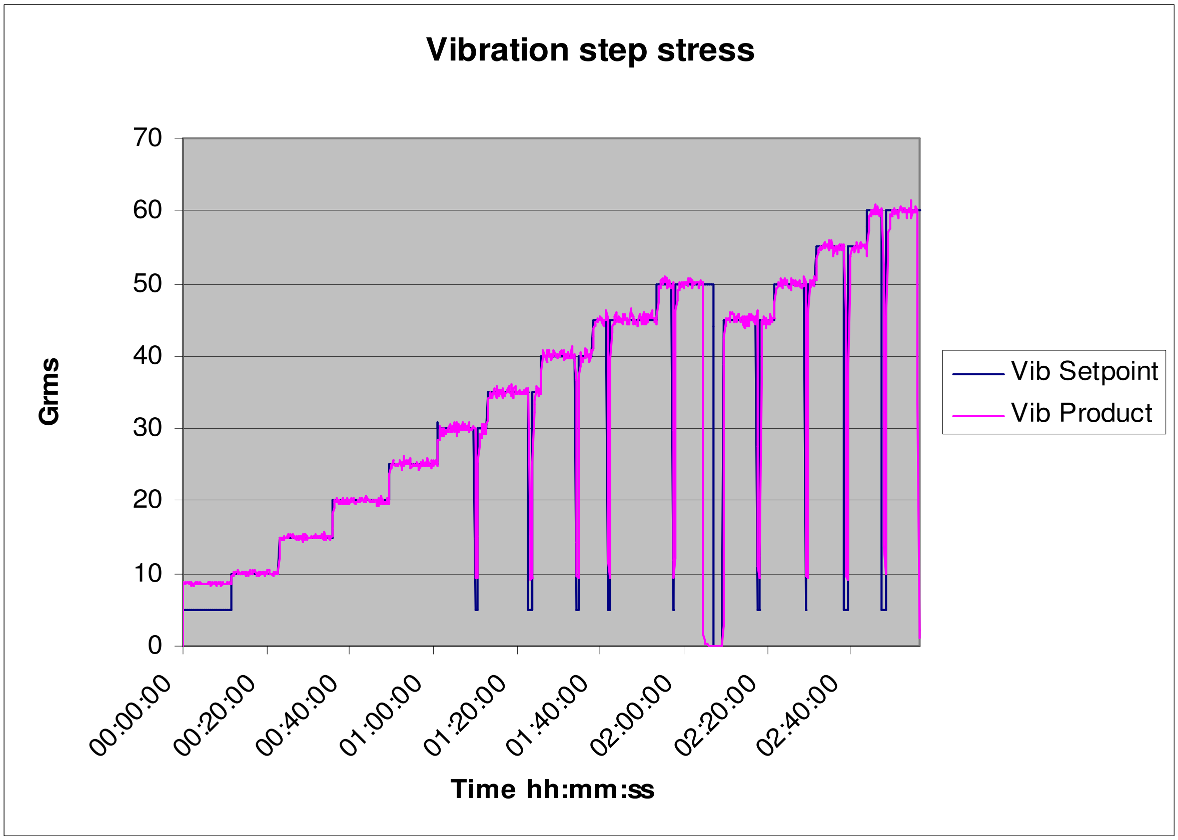
XG1 Q1/Q2
XG4 SYNC FETS


Vibration step stress
Grms
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60
50
40
30
20
10
0
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00:20:00
00:40:00
01:00:00
01:20:00
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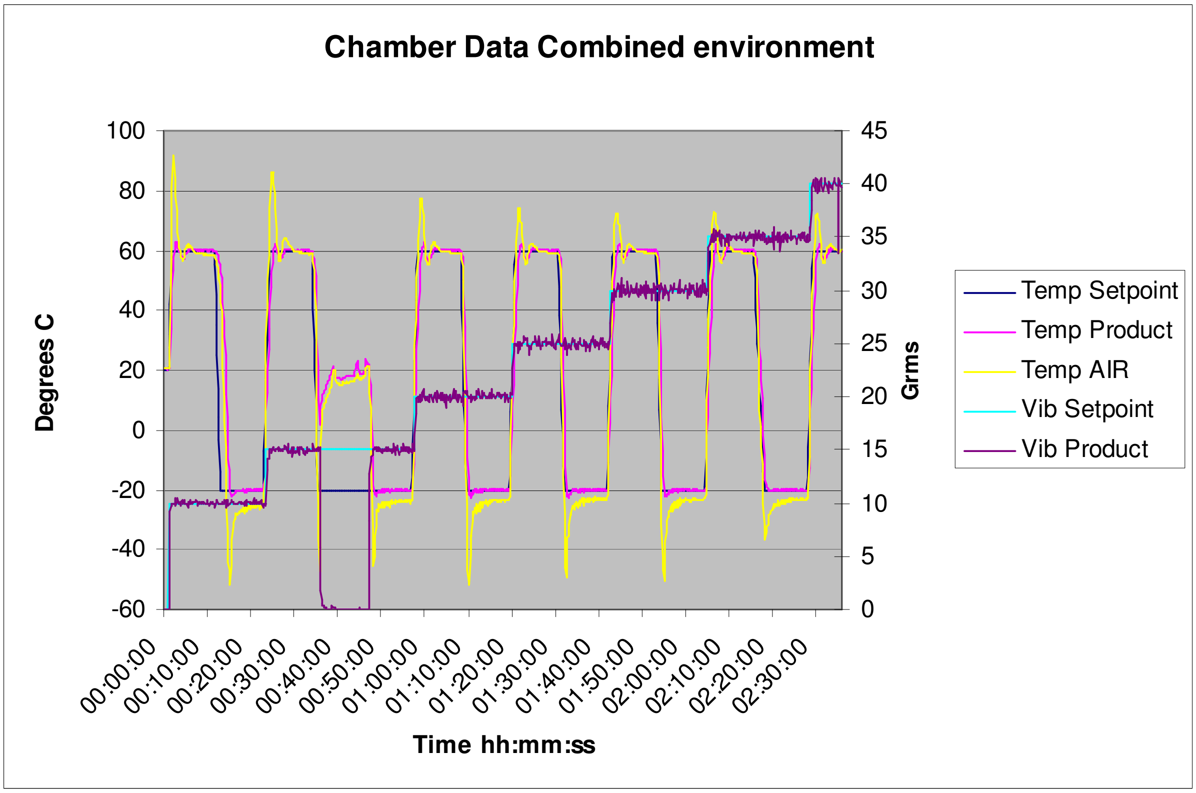
02:00:00
02:20:00
02:40:00
Time hh:mm:ss
Vib Setpoint
Vib Product


Chamber Data Combined environment
Degrees C
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80
60
40
20
0
-20
-40
-60
Grms
45
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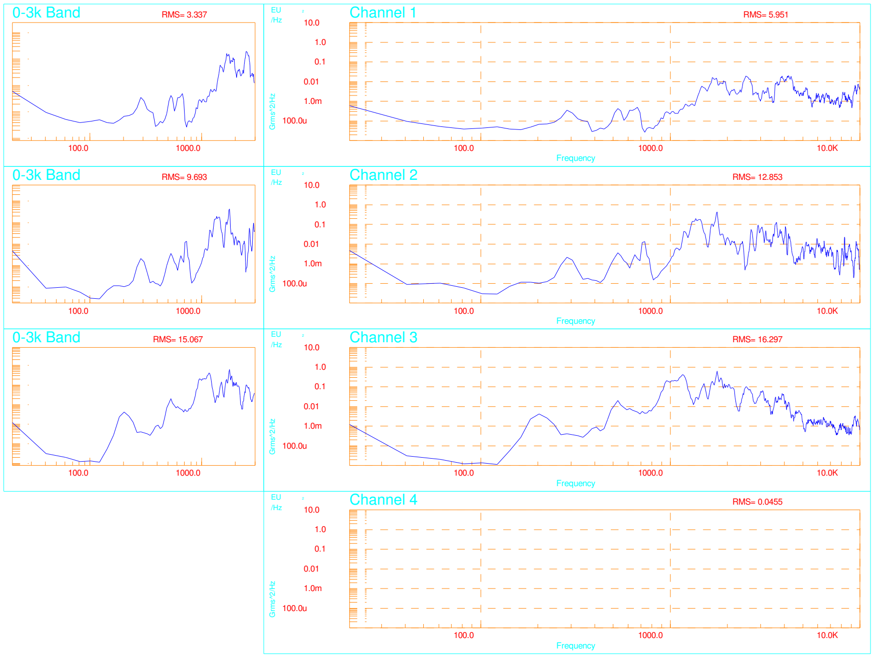
01:50:00
02:00:00
02:10:00
02:20:00
02:30:00
Time hh:mm:ss
Temp Setpoint
Temp Product
Temp AIR
Vib Setpoint
Vib Product

Appendix C – Vibration Plots

5 Grms



60 Grms