DEVELOPMENTAL HALT Report
R-00000350

Product Tested:	UX4 and UX6 PowerPac Power Supplies XgA, XgB, XgC, XgD and XgL powerMods
Service Proposal #:	S00000350
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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 ruggedize 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 testing was performed on four Excelsys power supplies (UX4 by 2 and UX6 by 2). 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 7.0 for a detailed discussion of failures. The HALT exposed specific weaknesses, which need to be addressed:

2.1 Cold Thermal Step Stress

Both units (UX4 ad UX6) were continuously monitored throughout the test and operated at 10% loading and function tested during each dwell, and 100% loading after the units had stabilised for 10 minutes.
The units were tested at 10% of full load due to the heating effect of the unit. The chamber was unable to cool the unit sufficiently when running at 100%.

At -50°C it was discovered that the four individual loads could not be increased separately to 100% in sequential order as this caused the fourth load to go into current limit at 3A on the XGC 36V 5.56A. When all loads were reduced and increased together the maximum load of 100% was achievable.

At -60°C UX4 went into current limit while drawing 100% load. XGC PowerMod was identified as the problem and when the operating loading was reduced to 90% loading the UX4 passed function test.

At -70°C after a dwell of 30 min both UX4 and UX6 failed to operate at 100% load during a function test. It was found that it was possible to operate UX4 (80%) and UX6 at (1KW 80%) when their PowerMod modules were configured as follows UX4 (XGA, XGB, XGD were at 100% and XGC was at 1.5A.) and UX6 (XGL, XGA, XGB, XGD were at 100% and XGC was at 1.5A.) When both UX4 and UX6 were operated under 50% there were no issues. If XGC is reduced to 25% loading all other PowerMods can operate at 100%.

At -80°C UX4 starts to go out of regulation when loads greater than 10% are applied. UX6 can operate at 40% loading before it goes out of regulation at 50% of full power.

At -90°C UX4 shut itself off while operating at 10% load. UX6 was operating correctly at 10% but then shut down when increased to 50% loading.

When power cycled both units did not recover at -90°C or at -70°C, -60°C, -50°C, -40°C, -30°C, -20°C, -10°C, 0°C and +20°C. It was found that the C14 was damaged on the UX4 and after a period the UX6 recovered and operated without issue when the temperature stabilised at +20°C.

2.2 Hot Thermal Step Stress

Both units (UX4 ad UX6) were continuously monitored throughout the test and operated at 10% loading and function tested during each dwell at 100% loading after the units had stabilised for 10 minutes.

At +70°C power limiting occurred when the units were been tested at 100% load. Both units were ok at 10% load. The UX4 was then reduced to 400W and UX6 to 1000W and both units operated ok.

At +80°C both units were ok at 10% load and at reduced load (UX4 400W and UX6 1000W).
At +20°C Both UX4 and UX6 operating ok on return to +20°C

2.3 Rapid thermal transitions

Both units (UX4 ad UX6) were continuously monitored throughout the test and operated at 10% loading and monitored for any issues of which there were none noted.

2.4 Vibration Step Stress

Both units (UX4 ad UX6) were continuously monitored throughout the test and operated at 10% loading and functionally tested during each dwell at 100% loading after the units had stabilised for 10 minutes.

At 25G and 30G the UX6 XGC PowerMod appears to be dropping out of regulation intermittently but did not shut down. This was found to be a loose cable that was attached to the electronic load.

At end of the 50G dwell it was noticed that UX6 had no outputs but that the fans were still running. The unit was replaced with another UX6 for the remainder of the testing however no noticeable fault could be found other than a possible bad solder joint that could exist.

2.5 Combined Environmental Stress

Both units (UX4 ad UX6) were continuously monitored throughout the test and operated at 10% loading and monitored for any issues of which there were none noted.

3.0 Operating and Destruct Limits

Stress Type	Chamber Setpoint Level
Temp LOL	*-40ºC
Temp LDL	<-50ºC
Temp UOL	+60ºC**
Temp UDL	≥+80ºC
Thermal Transitions	-40ºC to +60ºC
Vibration OL	≥60G
Vibration DL	>60G
Combined OL	-40ºC to +60ºC and 50G
Combined DL	>-40ºC to +60ºC and 50G

* While destruct and operating limits were found it has been suggested by the customer that if the units were operating at higher load (>10%) these issues may not have occurred.

Table 1: Summary of Operating and Destruct Limits

Notes:

1. All temperature and vibration values are chamber setpoints. See Section 7 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 function but when the applied stress is increased, the product is no longer function.
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.

4.0 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:

5.0 Halt Setup

5.1 Product Identifiers

The serial number of the units subjected to the HALT process and the date these units were received are shown in table 2.

Unit	UX4 Type	UX4 Serial	Test	Date unit Received
1	PowerPac: PowerMod 1: XgD PowerMod 2: XgC PowerMod 3: XgB PowerMod 4: XgA	34061857 20130063 20130009 20130015 20130013	Cold Thermal Step Stress (Failed during -80°C Cold Step replaced with unit UX4 2)	21st Oct 2013
2	PowerPac: PowerMod 1: XgD PowerMod 2: XgC PowerMod 3: XgB PowerMod 4: XgA	34061855 20130041 20130030 20130060 20130018	Hot Thermal Step Stress Rapid Thermal Transitions Vibration Step Stress Combined Environment	22nd Oct 2013
	UX6 Type	**UX6 Serial**	**Test**	**Date unit Received**
1	PowerPac: PowerMod 1: XgL PowerMod 2: XgL PowerMod 3: XgD PowerMod 4: XgA PowerMod 5: XgB PowerMod 6: XgC	36007130 20096498 20096538 20130065 20130014 20130016 20130013	Cold Thermal Step Stress Hot Thermal Step Stress Rapid Thermal Transitions Vibration Step Stress (Failed at 50G Vibration Step replaced with UX6 unit 2)	21st Oct 2013
2	PowerPac: PowerMod 1: XgL PowerMod 2: XgL PowerMod 3: XgD PowerMod 4: XgA PowerMod 5: XgB PowerMod 6: XgC	36007129 20096558 20096500 20130064 20130021 20130034 20130024	Vibration Step Stress Combined Environment	25th Oct 2013

Table 2: Product Identifiers

5.2 Fixturing and Airflow

The units were placed in the environmental chamber and secured to the vibration plate using threaded bars vertical bars and horizontal bars secured with bolts.

Air from the chamber plenum was directed onto the unit. 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.

5.3 Test Setup

The units setup as follows;

The UX4 and UX6 PowerPac units were powered using 230VAC and contained 4 and 6 PowerMod modules respectively. Each PowerMod was attached to electronic loads which were located exterior to the chamber and were operational throughout the testing at 10% and increased to 100% for a function test.

The UX4 configuration comprised of;

- PowerPac:
- PowerMod 1: XgD
- PowerMod 2: XgC
- PowerMod 3: XgB
- PowerMod 4: XgA

The UX6 configuration comprised of;

- PowerPac:
- PowerMod 1: XgL
- PowerMod 2: XgL
- PowerMod 3: XgD
- PowerMod 4: XgA
- PowerMod 5: XgB
- PowerMod 6: XgC

The function test involved performing the following steps:

- Ensure the chamber has stabilised at the temperature / vibration level
- Observe any issues on any of the electronic loads at 10%
- Observe the unit inside the chamber
- Increase the operating load to 100%
- Observe any issues and record any issues noted
- Decrease the operating load to 10% and proceed to the next stage.

5.4 Description of Test Equipment

Description	Manufacturer	Model	S/N	Cal Due
Thermal & Vibration Test Chamber	QualMark	OVS 2.5 HP	2604980254	17th April 2014
Data Acquisition Unit	Hewlett Packard	34970A	US37022947	17th Jul 2014
Data Logger Thermocouple	RS	Type T	ANO1543	18th Apr 2014
Data Logger Thermocouple	RS	Type T	ANO1980	18th Apr 2014
Data Logger Thermocouple	RS	Type T	ANO1996	18th Apr 2014
Data Logger Thermocouple	RS	Type T	ANO1244	18th Apr 2014
Data Logger Thermocouple	RS	Type T	ANO1992	18th Apr 2014
Data Logger Thermocouple	RS	Type T	ANO1250	18th Apr 2014
Data Logger Thermocouple	RS	Type T	ANO2078	14th Dec 2013
Data Logger Thermocouple	RS	Type T	ANO1989	18th Apr 2014
Data Logger Thermocouple	RS	Type T	ANO2204	26th Aug 2014
Data Logger Thermocouple	RS	Type T	ANO1994	18th Apr 2014
Chamber Thermocouple	RS	Type T	ANO1576	18th Apr 2014
Chamber Thermocouple	RS	Type T	ANO1570	18th Apr 2014
Chamber Thermocouple	RS	Type T	ANO1571	18th Apr 2014
Accelerometer Voltage Mode	Dytran	3030C1	10119	13th Sep 2014
Cable Assembly	Dytran	6019B10	ANO0997	13th Sep 2014
Charge Amplifier	Dytran	4705M16	3569	13th Sep 2014
Spectrum Analyser	Data Physics	DP240D	20995	21st Dec 2013
Accelerometer	Dytran	3035B1G	6038	27th Mar 2014
Accelerometer	Dytran	3035B1G	3355	29th Apr 2014
Accelerometer	Dytran	3035B1G	7238	29th Apr 2014
Accelerometer	Dytran	3035B1G	3515	10th Dec 2013

Table 3: Test Equipment

6.0 Data Collection

Thermocouples were attached to various points on the device 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 section 10.0 for thermal graphs and section 11.0 for locations of thermocouples.

Accelerometers were placed at reference points on the product during vibration step stress. The product vibration response was recorded at each level of vibration stress.

Channel	Location or Description
1	Q10 (UX6)
2	Q5 (UX6)
3	Q17 (UX4)
4	Q4 XGD (UX6)
5	Q4 XGC (UX6)
6	Product (UX6)
7	Air (UX6)
8	Q4 (UX4)
9	Q5 (UX4)
10	C17 (UX4)

Table 4: Datalogger Channel Assignment

Channel	*Placement*
Product (control)	Internal PCB on UX6
Air	Internal air on UX6
Honeywell	Wall of chamber

Table 5: OVS Control System Thermocouple Placement

Channel	*Location*	*Axis*
1	Centre top of chassis UX6	Z
2	Qualmark Vibration Plate	Z
3	Side of chassis UX6	X
4	Front of Fan UX6	Y

Table 6: Accelerometer Placement

7.0 HALT Results

7.1 Thermal Step Stress

The test units were subjected to cold thermal step stress beginning at +20°C. The chamber was then ramped to -20°C and the temperature was decreased in 10°C increments. Once the thermocouples located on the units stabilized, the unit remained at that setpoint for a minimum of 15 minutes. A function test was performed at the end of each dwell. 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.

Hot thermal step stress began at a setpoint temperature of +20°C. The chamber was then ramped to 40°C with the temperature increasing in 20°C increments. Once the thermocouples located on the unit reached the setpoint temperature, the unit remained at that setpoint for 15 minutes.

The results of thermal testing are summarized in Table 7, 8, 9 and 10.

Setpoint	Function Test Results	Notes
+20°C	OK	1
-20°C	OK	1
-30°C	OK	1
-40°C	OK	1
-50°C	See Below	1,2
-60°C	See Below	1,3
-70°C	See Below	1,4,5,6
-80°C	See Below	1,7
-90°C	See Below	1,8
-70°C	See Below	9
-60°C	See Below	9
-50°C	See Below	9
-40°C	See Below	9
-30°C	See Below	9
-20°C	See Below	9
-10°C	See Below	9
+20°C	See Below	9,10,11

Table 7: Cold thermal Step Stress Results

While destruct and operating limits were found it has been suggested by the customer that if the units were operating at higher load (>10%) these issues may not have occurred.

Notes:

1. The units were powered throughout the testing and were attached to loads running at 10%, at the end of each dwell the loads were increased to 100% and the units were functionly tested.
2. At -50°C when the four individual loads were increased to 100% in sequential order that the fourth load went in to current limit at 3A on the XGC 36V 5.56A. When all loads were reduced and increased together maximum load of 100% was achieved and the units were function tested and passed.

3. At -60°C UX4 went into current limit while drawing 100% load. The XGC PowerPac was the problem. When reduced to 90% loading the UX4 passed function test ok. The UX6 unit did not have any issues while loaded at 100%.
4. At -70°C after a dwell of 30 min both UX4 and UX6 failed to operate at 100% load.
5. It was possible to operate UX4 (80%) and UX6 at (1KW 80%) when their PowerMod modules UX4 (XGA, XGB, XGD were at 100% and XGC was at 1.5A.) and UX6 (XGL, XGA, XGB, XGD were at 100% and XGC was at 1.5A.) When both UX4 and UX6 were operated under 50% there were no issues.
6. If XGC is reduced to 25% loading all other PowerMods can operate at 100%.
7. At -80°C UX4 starts to out of regulation when loads greater than 10% are applied. UX6 can operate at 40% loading before it goes out of regulation at 50% of full power.
8. At -90°C UX4 has shut itself off while operating at 10% load. UX6 was operating ok at 10% but shut down when increasing to 50% loading.
9. When power cycled units were found to be not responding. The chamber ramped to -70°C, -60°C, -50°C, -40°C, -30°C, -20°C, -10°C, 0°C and +20°C and the unit did not recover.
10. It was found that the C14 was damaged on the UX4. Another UX4 unit replace it for the remainder of the testing. The UX6 recovered operated without issue when the temperature stabilised.

Setpoint	Function Test Results	Notes
+20°C	OK	1
+40°C	OK	1
+60°C	OK	1
+70°C	OK	1,2
+80°C	OK	1,3,4
+20°C	See Below	1,5

Table 8: Hot Thermal Step Stress Results

Notes:

1. The units were powered throughout the testing and were attached to loads running at 10%, at the end of each dwell the loads were increased to 100% and the units were function tested.
2. At +70°C power limiting occurred when the units were been tested at 100% load. Units were ok at 10% load.
3. UX4 was reduced to 400W and UX6 to 1000W.
4. Units operated correctly at 10% load and at reduced load (UX4 400W and UX6 1000W).
5. Both UX4 and UX6 operating ok on return to +20°C

7.2 Rapid Thermal Transitions

The units under test was subjected to five and a half temperature cycles from +60°C to –40°C at an average thermal transition rate of 55°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.

Cycle	Setpoint	Function Test Results	Notes
1	20°C	OK	1
1	60°C	OK	1
1	-40°C	OK	1
2	60°C	OK	1
2	-40°C	OK	1
3	60°C	OK	1
3	-40°C	OK	1
4	60°C	OK	1
4	-40°C	OK	1
5	60°C	OK	1
5	-40°C	OK	1
5	60°C	OK	1
5	20°C	OK	1

Table 9: Rapid Temperature Transitions

Notes:

1. The units were powered throughout the testing and were attached to loads running at 10%. The units were monitored for any issues throughout the testing.

7.3 Vibration Step Stress

The device under test was subjected to vibration step stress beginning at a setpoint of 5 Grms with the vibration increasing in 5 Grms increments at 15 minute intervals. When the setpoint reached 30 Grms, tickle vibration was incorporated to detect any failures that were precipitated at the higher Grms level and went undetected. The results are summarized in Table 10.

Setpoint (G)	Function Test Results	Notes
5	OK	1
10	OK	1
15	OK	1
20	OK	1
25	See Below	1,2
30	See Below	1,3
35	OK	1
40	OK	1
45	OK	1
50	See Below	1,4
55	OK	1
60	OK	1
0	OK	1

Table 10: Vibration Step Stress Results

Notes:

1. The units were powered throughout the testing and were attached to loads running at 10%, at the end of each dwell the loads were increased to 100% and the units were function tested.
2. At 25G UX6 XGC PowerMod appears to be dropping out of regulation intermittently but did not shut down.
3. At 30G UX6 XGC repeated symptoms shown at 25G. Issue was found to be a loose cable attached to the electronic load.
4. At end 50G dwell it was noticed that UX6 had no outputs but that the fans were still running. Another UX6 unit replaced it for the remainder of the testing.

	Ch1		Ch2		Ch3		Ch4	
G-Level	10Hz-1Hz	10Hz-10KHz	10Hz-1Hz	10Hz-10KHz	10Hz-1Hz	10Hz-10KHz	10Hz-1Hz	10Hz-10KHz
5	6.39	7.34	4.00	6.15	1.74	4.25	0.86	14.12
10	25.46	27.01	10.22	15.28	4.94	10.42	2.33	41.42
15	35.01	37.36	14.54	23.52	6.75	15.61	4.85	48.36
20	43.45	45.56	18.31	30.68	8.69	20.19	6.31	55.00
25	55.10	58.88	21.75	37.26	10.72	24.54	7.82	58.36
30	61.97	66.74	25.23	44.70	11.93	28.83	9.95	65.72
35	56.74	62.85	25.05	44.75	11.35	28.20	8.43	42.74
40	74.08	80.74	31.96	56.92	13.72	35.92	12.57	76.14
45	77.81	85.95	37.66	63.74	14.39	38.96	14.54	83.98
50	81.86	91.39	39.67	68.41	15.20	41.85	15.88	95.62
55	99.75	103.20	49.78	79.36	17.01	46.89	13.43	64.66
60	99.50	109.70	9.53	14.57	15.10	57.86	18.81	58.89

Table 11: Vibration Levels Measured During Vibration Step Stress (Grms)

7.4 Combined Environment

The test unit was subjected to temperature cycles from +60°C to -40°C at an average transition rate of 55°C per minute combined with vibration. Vibration began at a setpoint of 10Grms and incremented by 10Grms at the end of each thermal cycle. The results are summarized in Table 12.

Cycle	Temp (°C)	Vibration (Grms)	Function Test Results	Notes
1	20	0	OK	1
1	60	10	OK	1
1	-40	10	OK	1
2	60	20	OK	1
2	-40	20	OK	1
3	60	30	OK	1
3	-40	30	OK	1
4	60	40	OK	1
4	-40	40	OK	1
5	60	50	OK	1
5	-40	50	OK	1
5	60	0	OK	1
5	20	0	OK	1

Table 12: Combined Environment Results

Notes:

1. The units were powered throughout the testing and were attached to loads running at 10%. The units were monitored for any issues throughout the testing.

8.0 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.

9.0 Vibration Template

9.1 5G Vibration Profiles

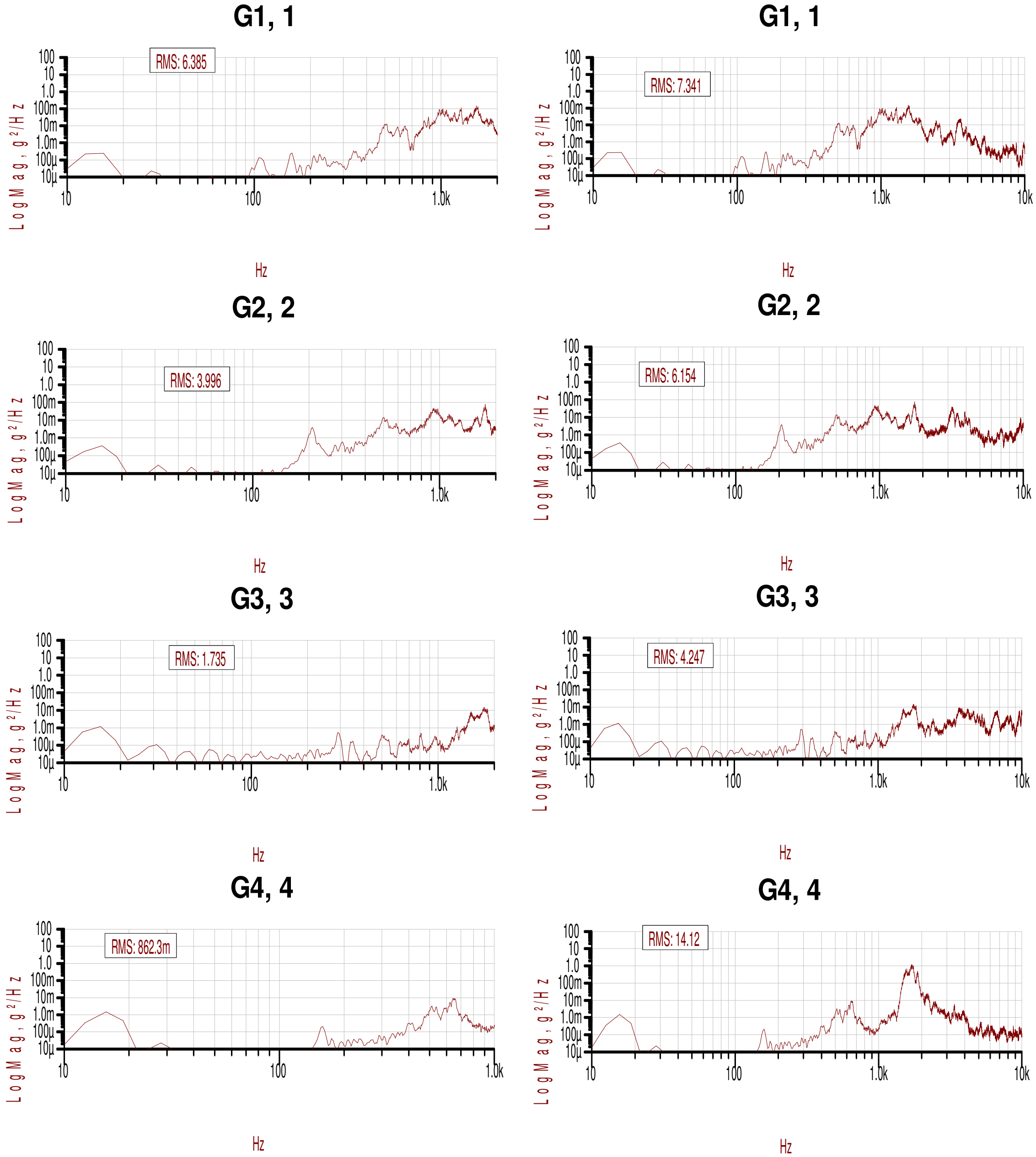
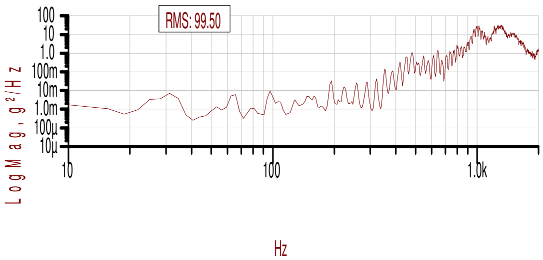


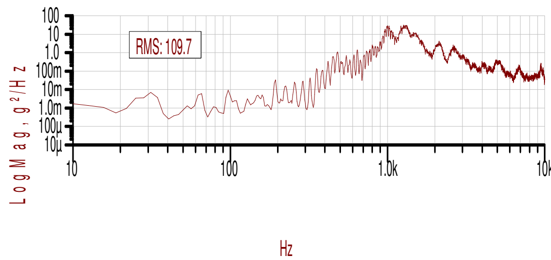
Figure 1 5G Vibration Profiles

9.2 45G Vibration Profiles

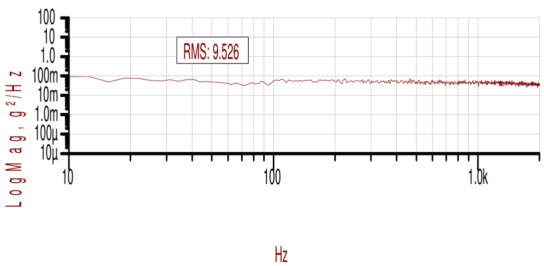
G1, 1



G1, 1



G2, 2



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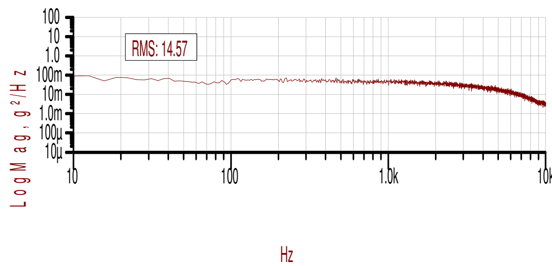
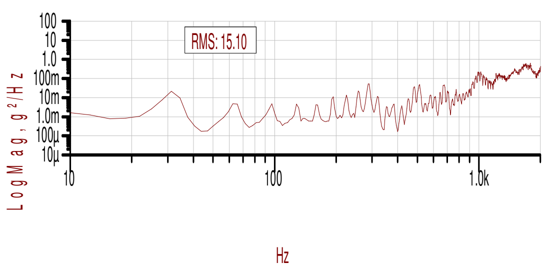
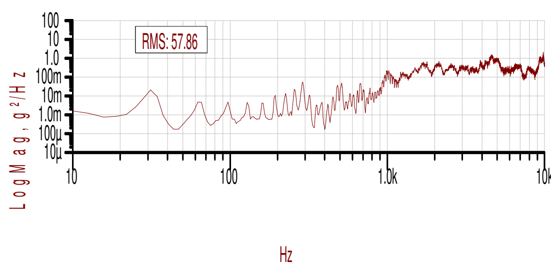


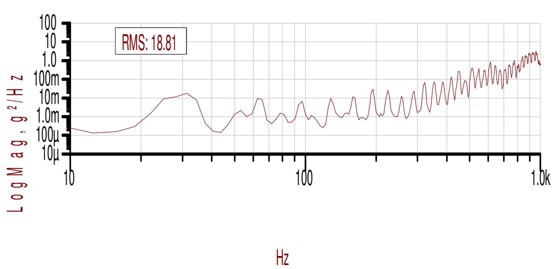
G3, 3



G3, 3



G4, 4



G4, 4

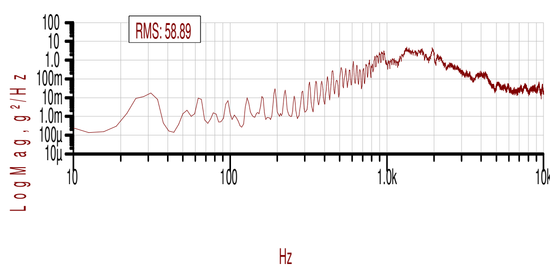


Figure 2 60G Vibration Profiles

10.0 Thermal and Vibration Graphs

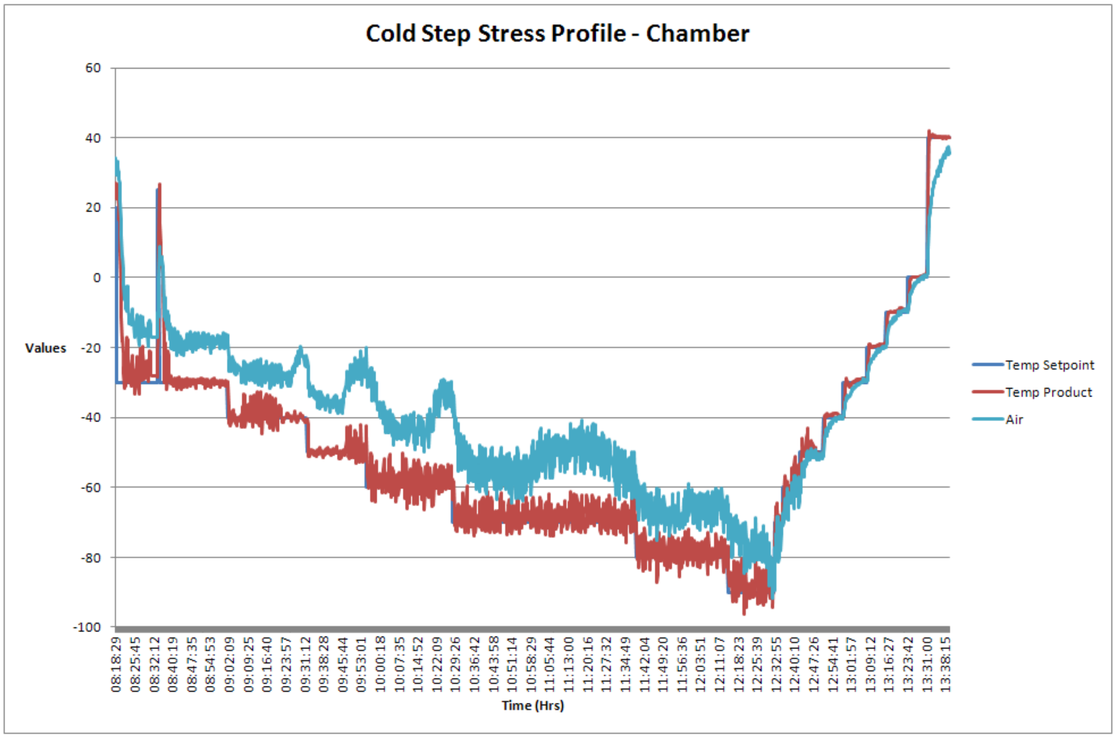


Figure 3 Cold Step Stress Profile from Chamber

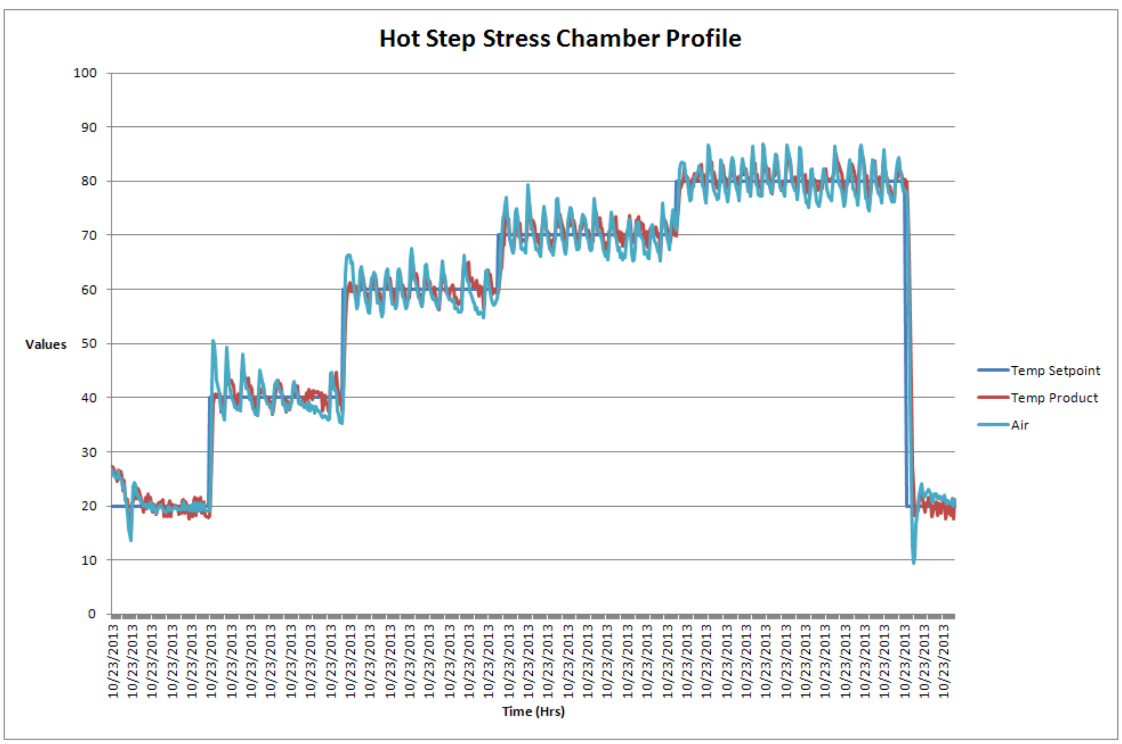


Figure 4 Hot Step Stress Profile from Chamber

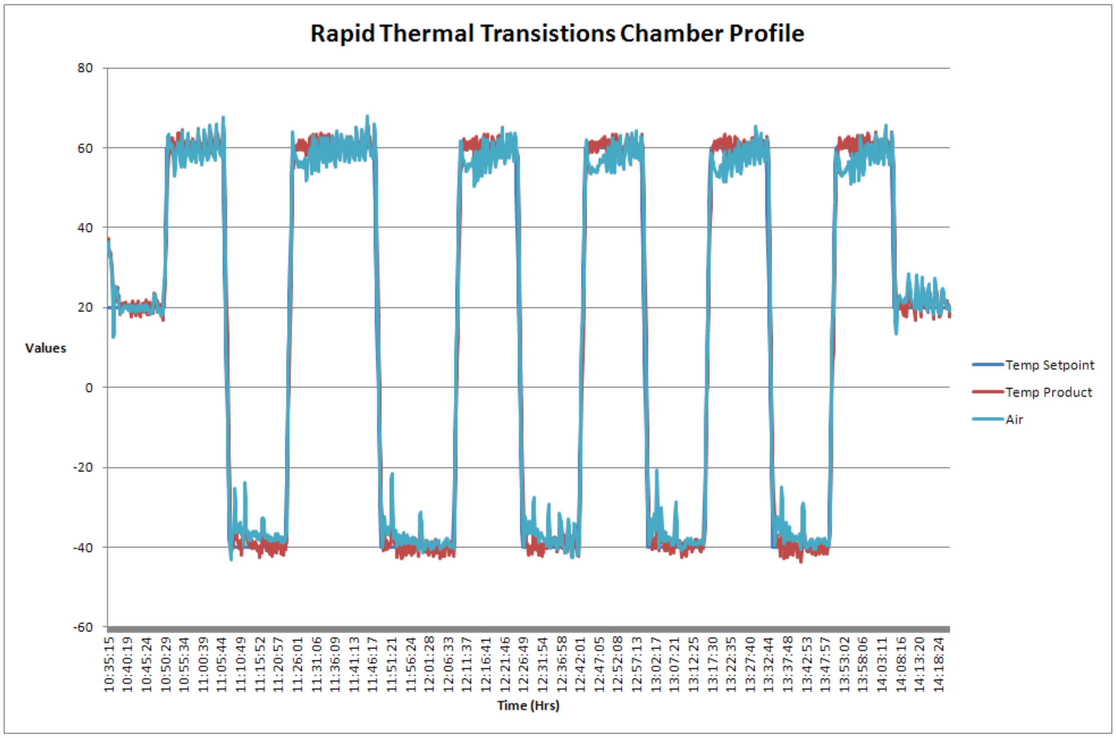


Figure 5: Rapid Thermal Transitions Chamber Profile

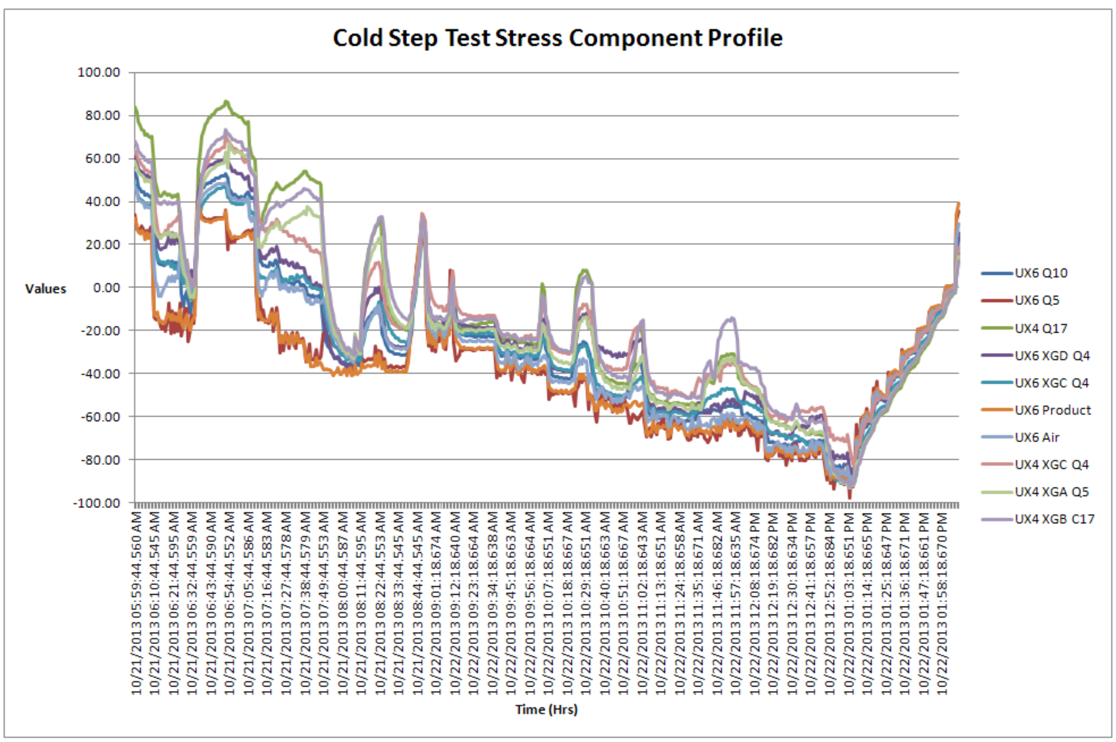


Figure 6: Cold Step Stress Component Profile

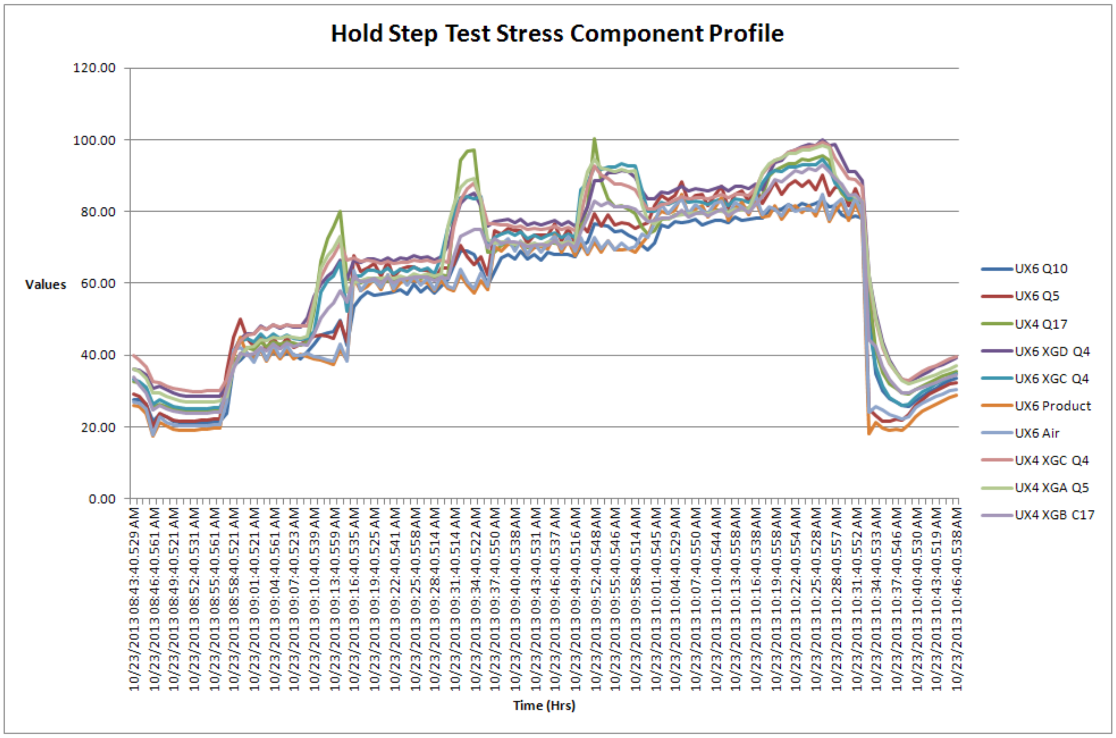


Figure 7: Hot Step Stress Component Profile

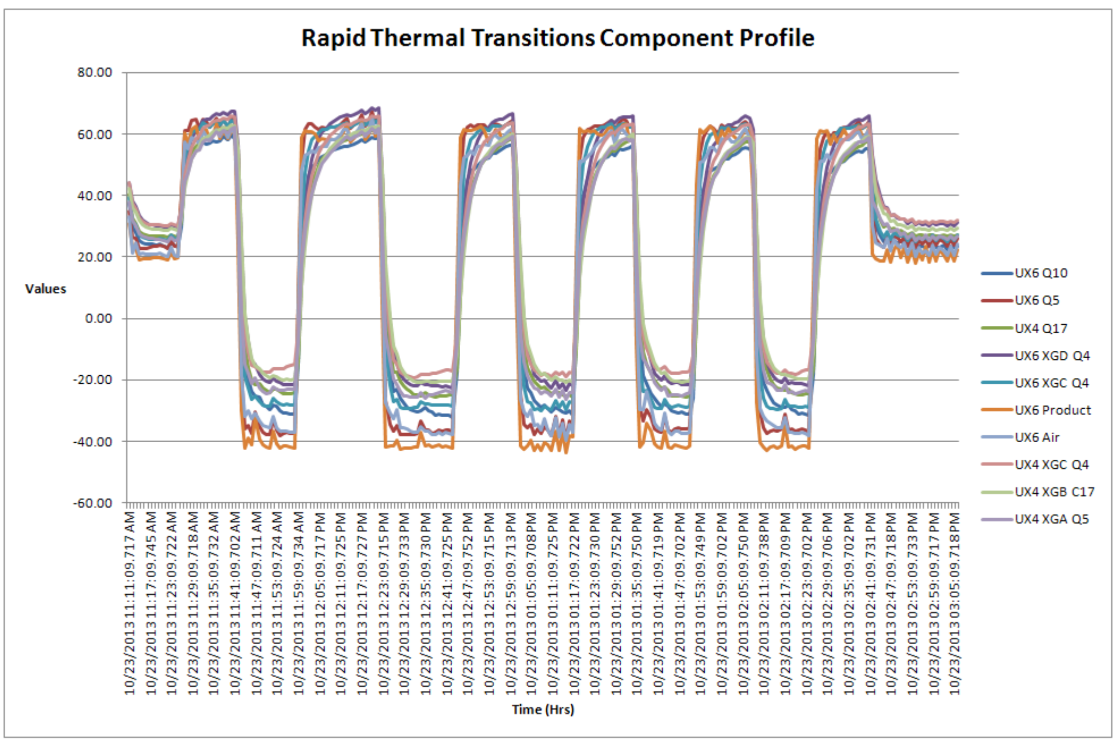


Figure 8: Rapid Temperature Transitions Component Profile

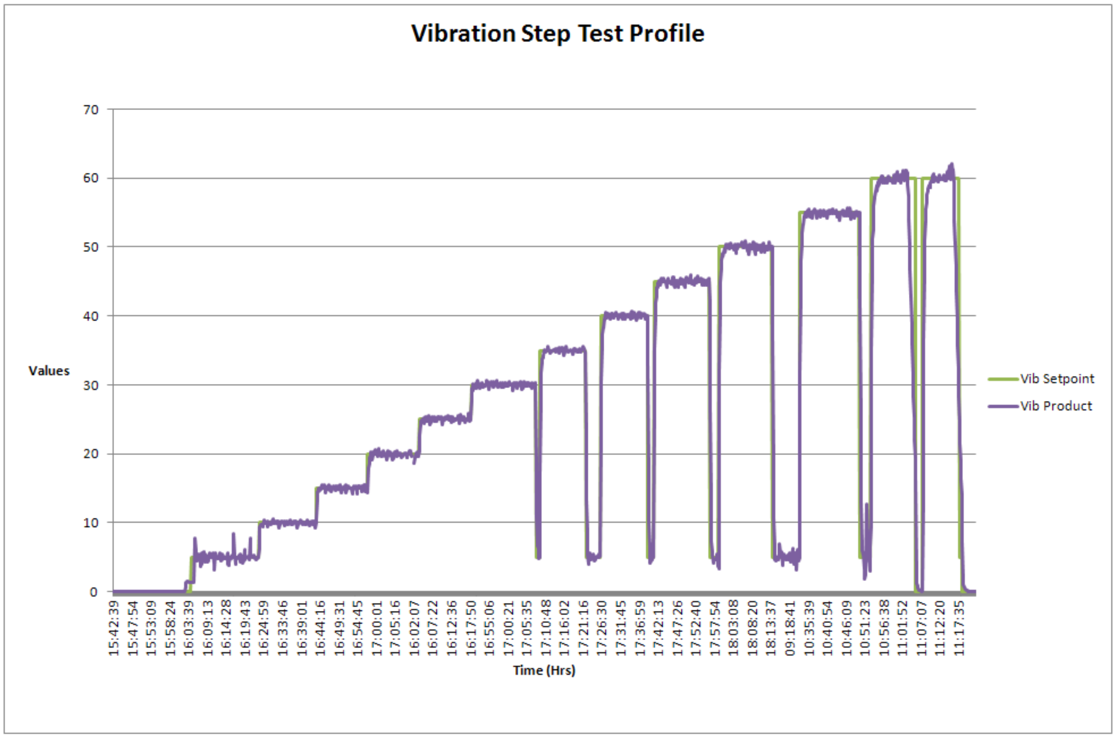


Figure 9: Vibration Step Stress Profile

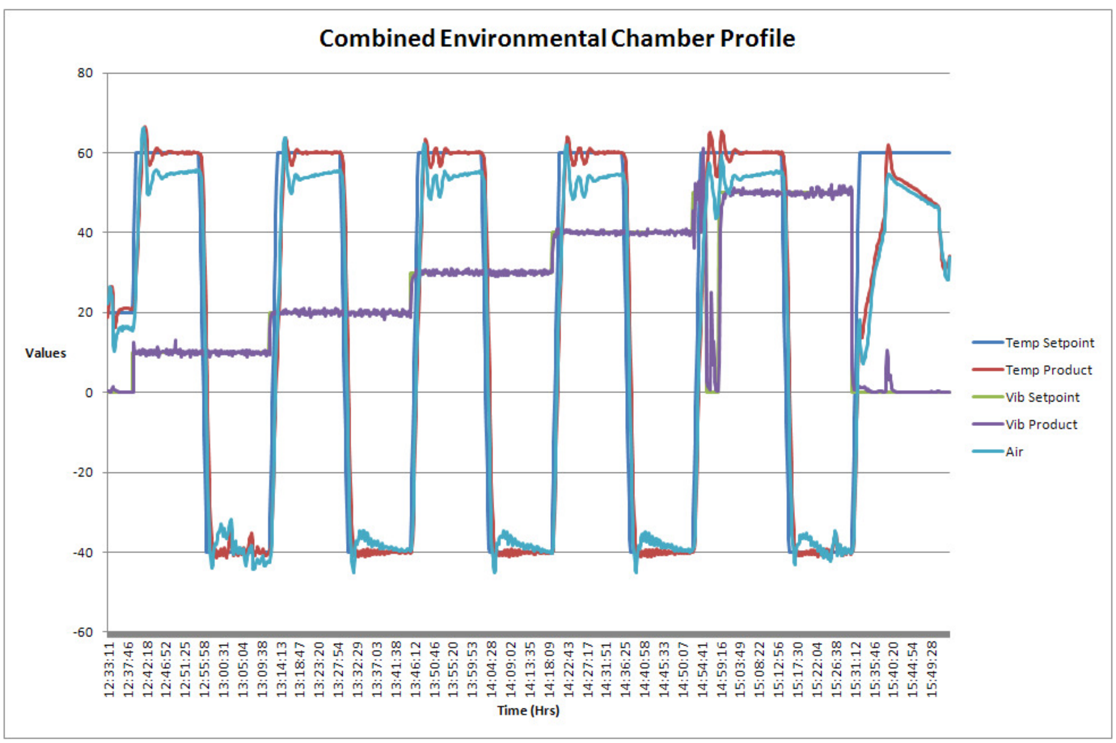


Figure 10: Combined Environmental Profile

11.0 Test Setup

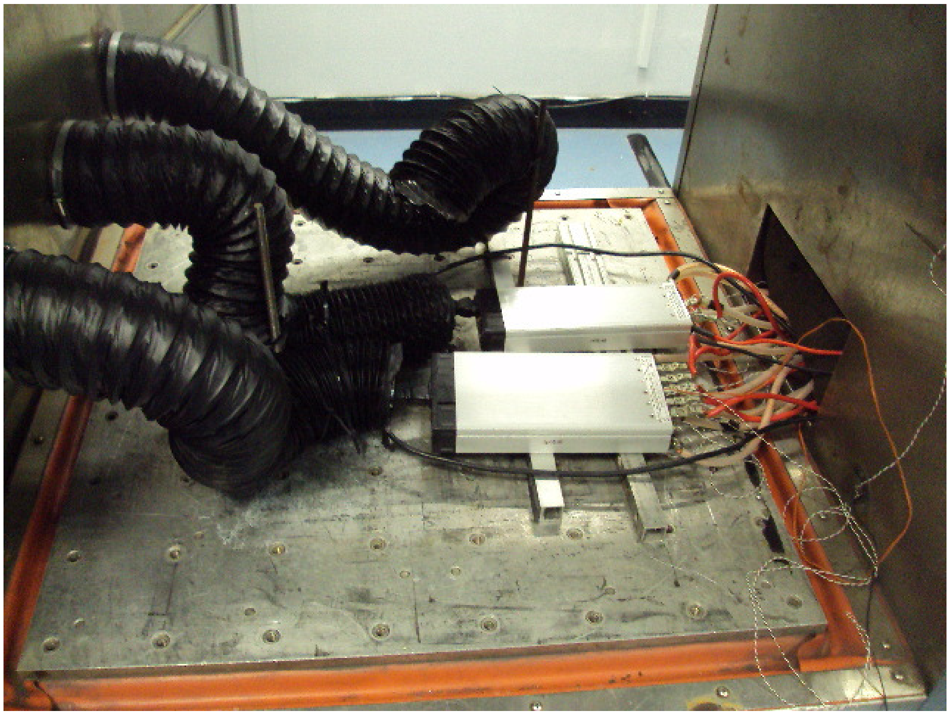


Figure 11: Thermal Setup

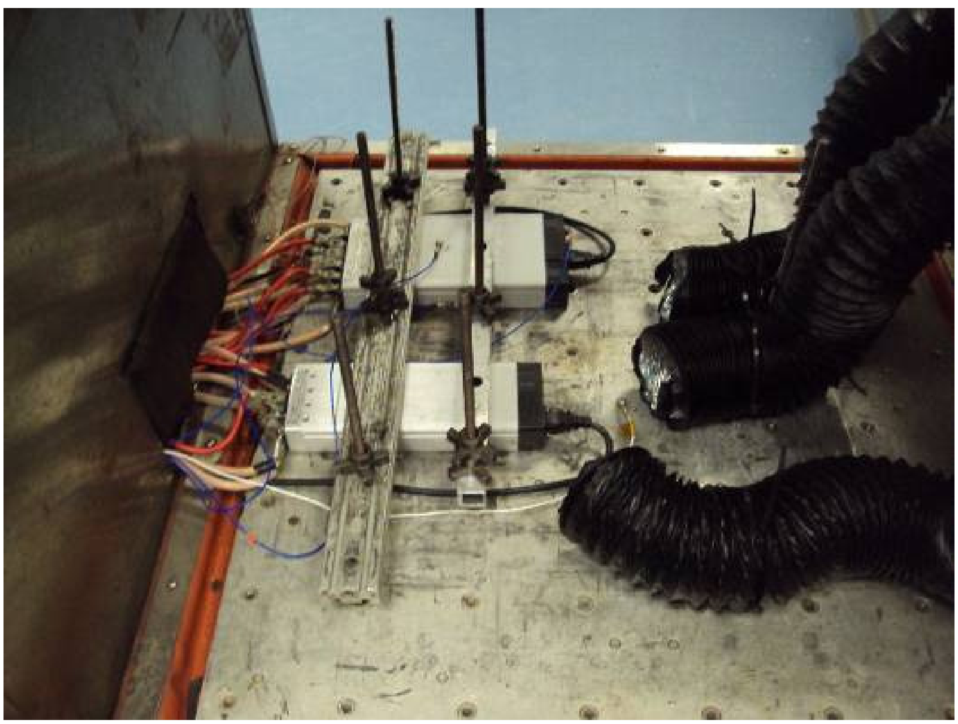


Figure 12: Vibration Setup

11.1 Component Setup

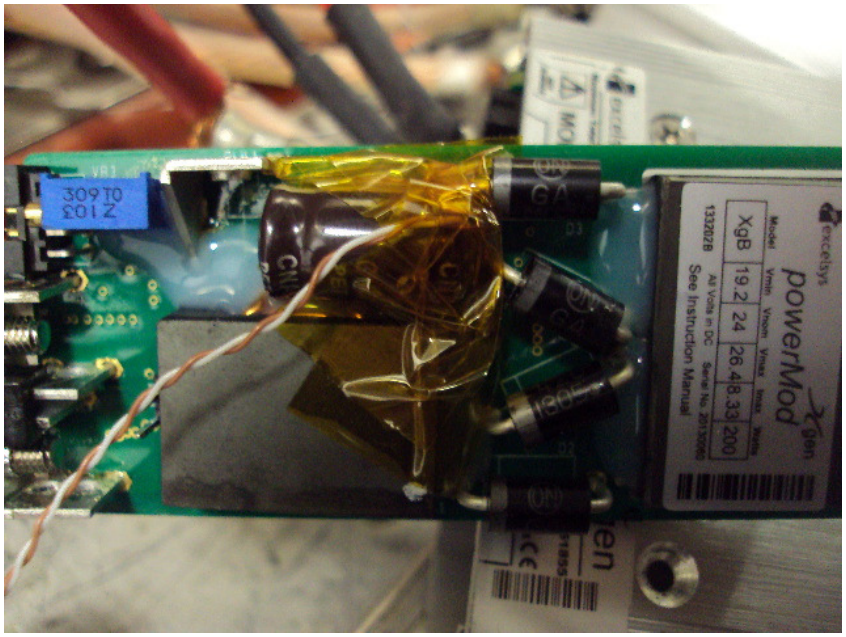


Figure 13: C17 UX4 XGB

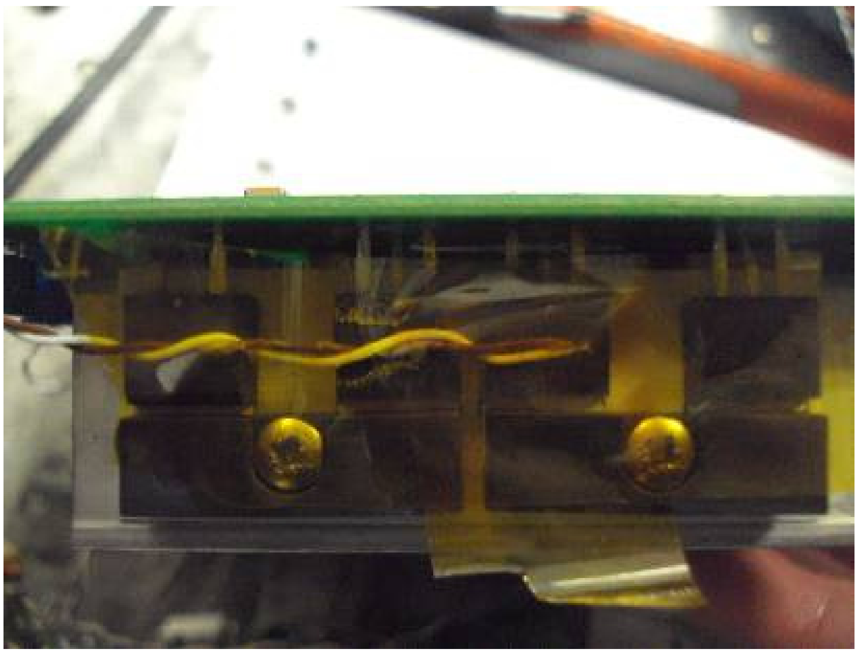


Figure 14: Q5 UX6

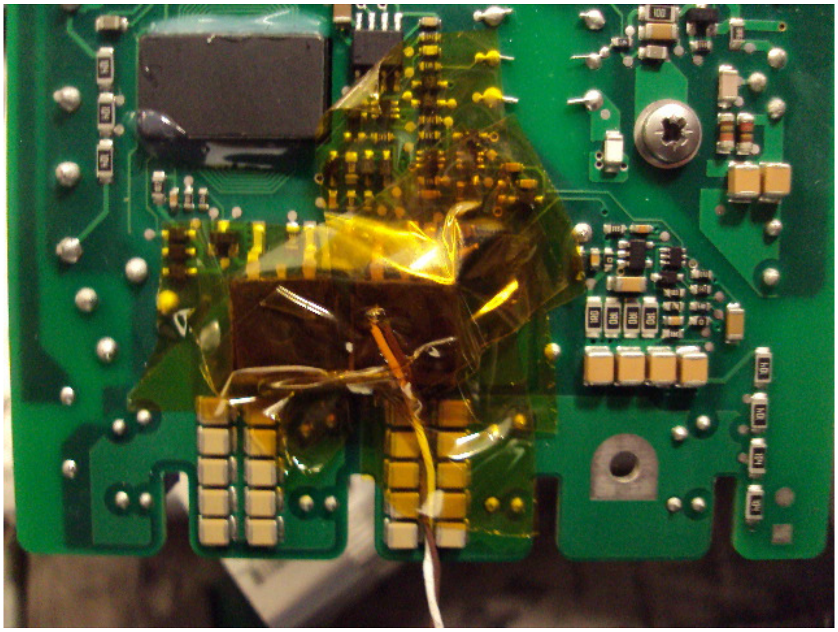


Figure 15: Q17 UX4 PowerPac

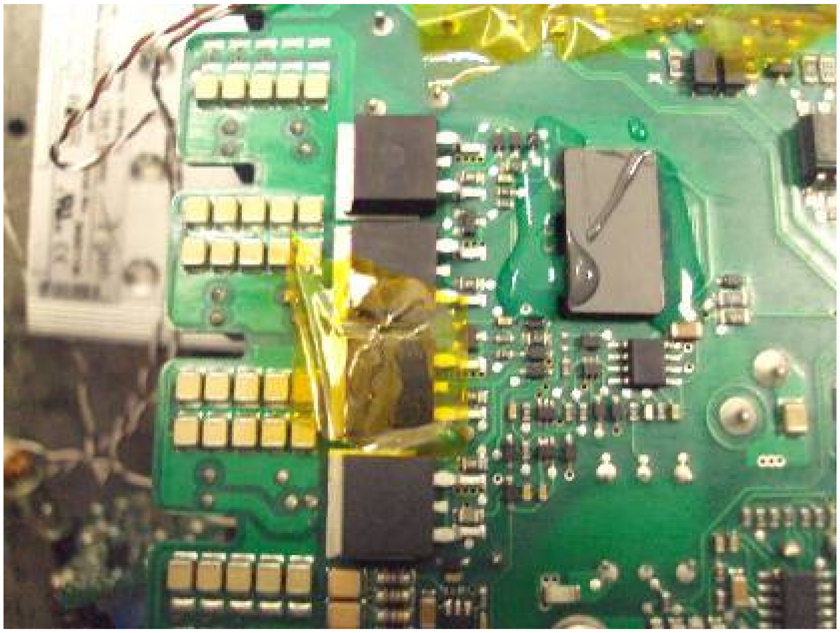


Figure 16: Q10 UX6 PowerPac

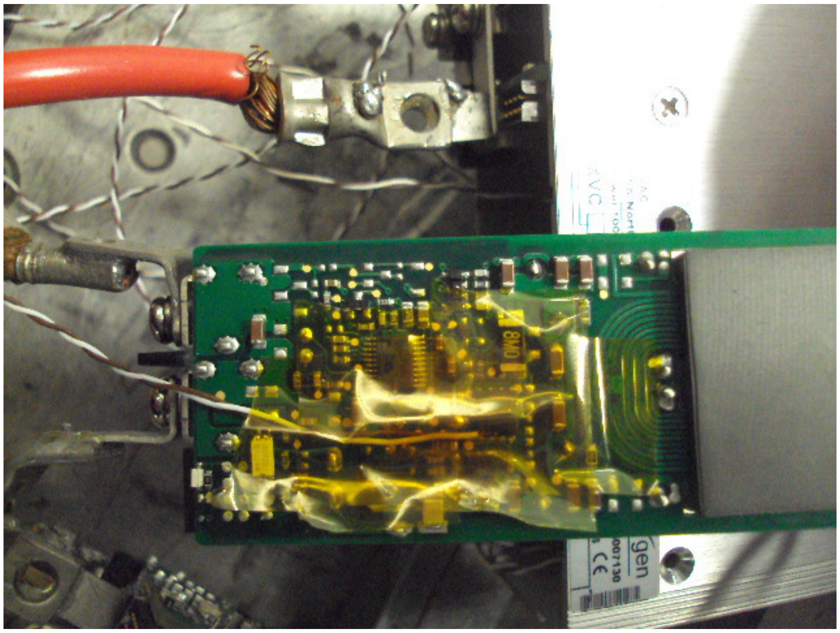


Figure 17: Q5 UX6 XGD

11.2 Accelerometer Setup

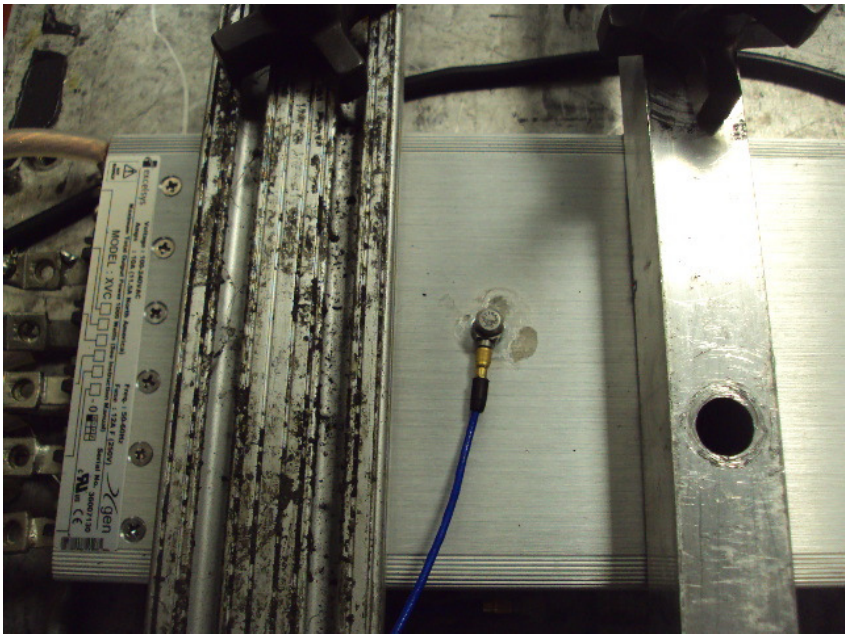


Figure 18: CH 1 Top of Chassis (Z)

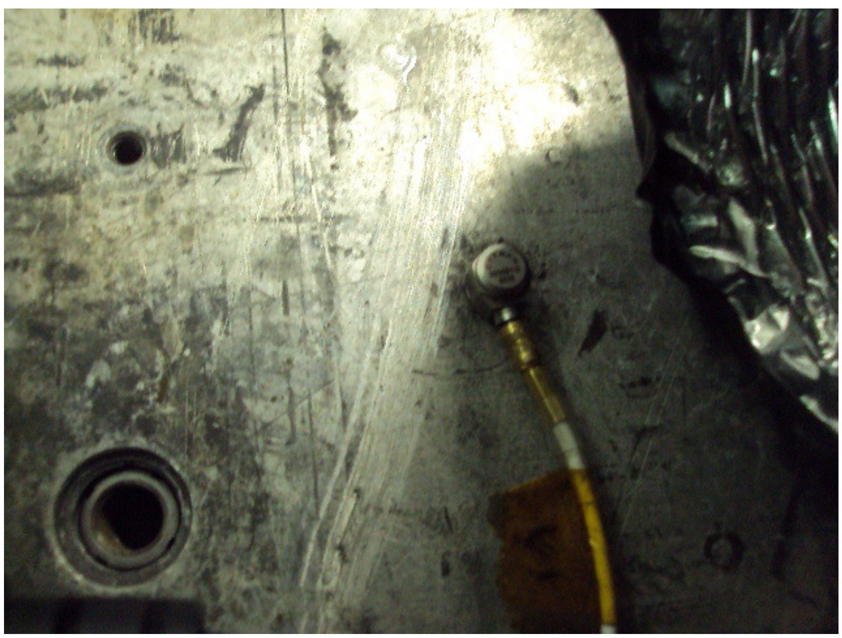


Figure 19: CH 2 Vibration Plate (Z)

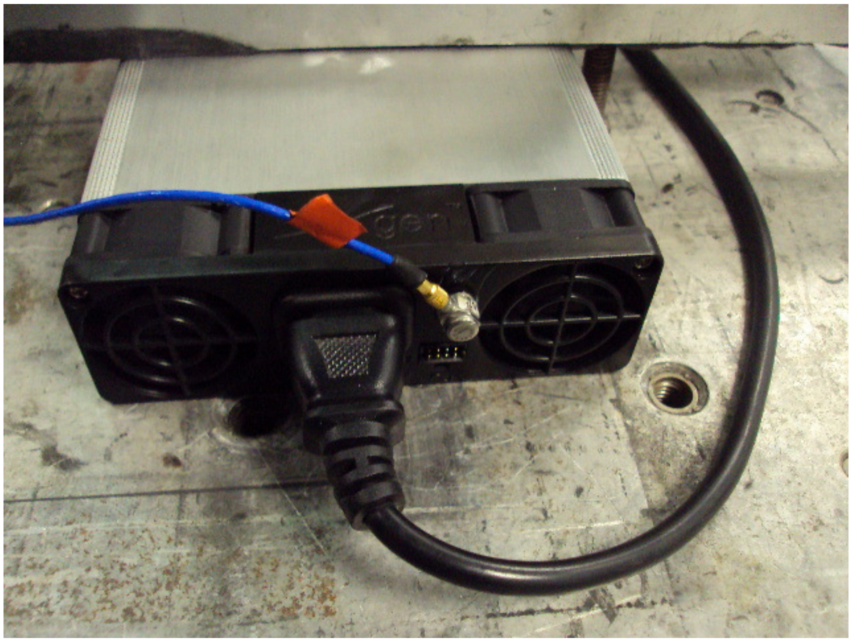


Figure 20: CH 4 Front of Fan (Y)

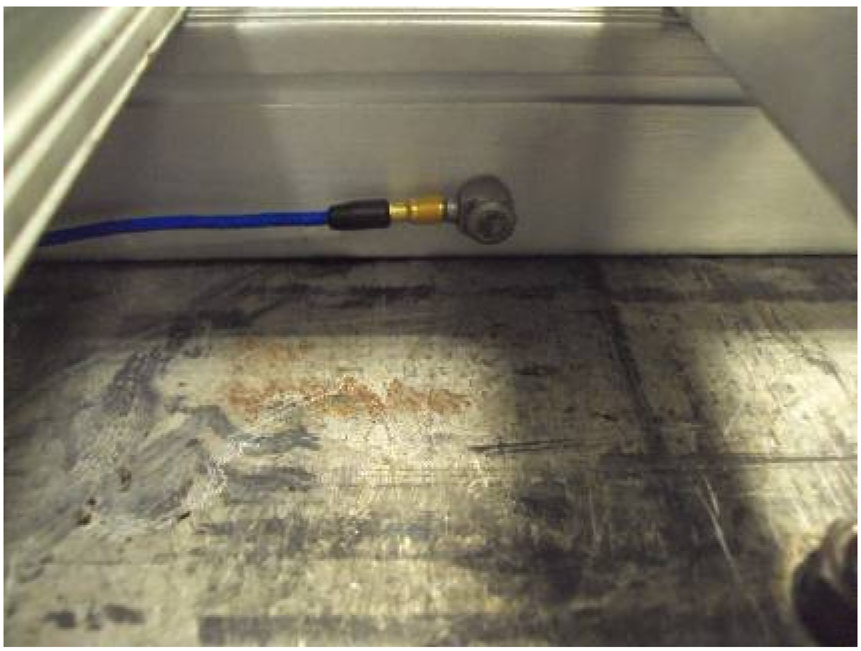


Figure 21: CH 3 Side of UX6 Chassis (X)