

Qualification Test Report
for the
Heat Dissipation Capability
of the
3U and 6U Conduction-Cooled Mechanical Housing Assembly

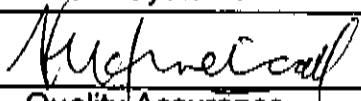
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CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page iii of vii

Contents

1. Introduction and Scope	1
1.1 Introduction	1
1.2 Scope	2
1.3 Applicable and Reference Documents	2
1.3.1 Specifications	2
1.3.2 Reference Documents	2
2. Test Objectives	3
3. Test Methodology	4
4. Preparation and Test Procedure	5
4.1 Heat Sources	5
4.2 Cold Plate	6
4.3 Temperature Measurement	7
5. Formulae and Derivations	8
5.1 Average Rib Temperature	8
5.2 Normalisation	8
5.3 Resultant Rib Temperature at 25 C Cold Plate Temperature	8
5.4 Resultant Cold Plate Temperature at 85 C Rib Temperature	9
6. Test Results	10
6.1 Detailed Results	10
6.2 Graphical Results	10
6.2.1 6U MHA Results Normalised for 25 C Cold Plate	11
6.2.2 6U MHA Power Dissipation	11
6.2.3 3U Housing Normalised for 25 C Cold Plate	12
6.2.4 3U MHA Heat Dissipation	12
7. Analysis of Test Results and Graphs	13
7.1 Resultant Temperatures Vs Distribution of Heat Sources	13
7.2 Heat Dissipation	13
8. Conclusions	14
8.1 6U MHA	14
8.1.1 6U Housing with Cold Plate with Conduction-Cooling Only	14
8.1.2 6U Housing with Cold Plate with Conduction-Cooling Only	14
8.2 3U MHA	14
8.2.1 3U Housing with Cold Plate with Conduction-Cooling Only	14
8.2.2 3U MHA with Forced-Air Cooling	14

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page iv of vii

8.3	General	14
8.3.1	Resultant Temperatures Vs Distribution of Heat Sources	14
8.3.2	Distribution of Source of Heat	15
8.3.3	Derating for Higher Cold Plate Temperature	15
8.3.4	3U vs 6U Heat Dissipation Performance with Forced-Air Cooling	15
9.	Recommendations	16
9.1	Distribution of Sources of Heat	16
9.2	Optimisation of Heat Flow	16
9.3	Testing for User-Specific Configurations	16
9.4	Redesign of 6U MHA Fan Enclosure	16

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page v of vii

List of Figures

Figure 1 : 6U Conduction-Cooled MHA	1
Figure 2 : 3U Conduction-Cooled MHA	2
Figure 3 : Heat Sources - Power Resistors on Wedgelock Frames	5
Figure 4 : MHA Mounted on Representative Cold Plate	6
Figure 5 : Normalisation Process - Cold Plate	8
Figure 6 : Normalisation Process - Rib	9

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page vi of vii

Abbreviations and Acronyms

C	Celsius
CC	Conduction-Cooled
MHA	Mechanical Housing Assembly
SEA	Simulated Electronic Assembly
W	Watt

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page vii of vii

1. Introduction and Scope

1.1 Introduction

Conduction-Cooling (CC) is required in situations where it is necessary to protect electronic equipment from harsh environments, for example dust or salt laden air. The heat that is generated by the electronics must be removed by conduction through the walls of the housing either to the surrounding air or to a heat sink (cold plate) to which the housing is mounted.

For any given enclosure it is important to know the heat transfer characteristics to determine operational parameters. The objective is to determine the maximum ambient or cold plate temperature that can be tolerated for a given heat load in the enclosure.

CCII Systems (Pty) Ltd has produced two new Conduction-Cooled (CC) Mechanical Housing Assemblies (MHA) in 3U and 6U variants, for use where computer systems in VME, Compact PCI, VPX and other formfactors need to be housed in an IP-65 enclosure.



Figure 1 : 6U Conduction-Cooled MHA

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 1 of 21

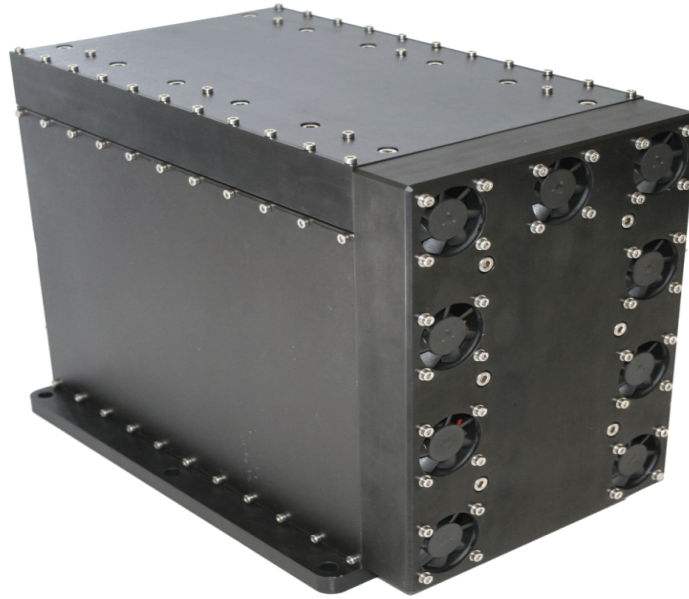


Figure 2 : 3U Conduction-Cooled MHA

1.2 Scope

A comprehensive set of tests were conducted to determine the Power Dissipation capabilities of both the 3U and 6U variants of the MHA.

This document describes the test methodology and records the results of these tests.

1.3 Applicable and Reference Documents

1.3.1 Specifications

CCII/MHA/6-PS/001 *Shortform Specification for 6U CC MHA* Version 1.1

CCII/MHA/6-PS/002 *Shortform Specification for 3U CC MHA* Version 1.1

1.3.2 Reference Documents

None.

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 2 of 21

2. Test Objectives

The generally accepted standard for ruggedised COTS environments is that the rib temperature of any CC assembly can reach a maximum of 85 C in operation.

The generally accepted standard for ruggedised MOTS environments is that the rib temperature of any CC assembly can reach a maximum of 125 C in operation.

The objectives of these qualification tests are to determine the heat dissipation capabilities of the 3U and 6U MHAs, specifically whether they can achieve an acceptable maximum internal temperature for given amounts of internally injected heat values, so that the housed electronics can operate reliably for extended periods of time in the environment experienced by industrial and military systems.

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 3 of 21

3. Test Methodology

- Generate incremental controlled heat in order to simulate the heat created by electronic assemblies during normal operation by using Simulated Electronic Assemblies (SEA) made up with power resistors mounted in Conduction-Cooling Wedgelock Frames;
- Measure the temperature at the rib of the SEA and at the base of the MHA;
- Calculate the Temperature Differential;
- Use this Temperature Differential to calculate the Rib Temperature of the SEA for a given Cold Plate Temperature;
- In a similar way calculate the maximum allowed Cold Plate Temperature required to keep the Rib Temperature below 85 C.

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 4 of 21

4. Preparation and Test Procedure

4.1 Heat Sources

Simulated Electronic Assemblies (SEA) were made by fitting power resistors onto copper clad fibreglass sheets mounted in Conduction-Cooling Wedgelock Frames for both 6U and 3U MHAs. These each simulate a typical electronic assembly within the MHA radiating heat into the housing frame. One, three or five of these heat sources at a time were inserted into the MHA under test. All interface points were coated with thermal paste to aid heat flow.

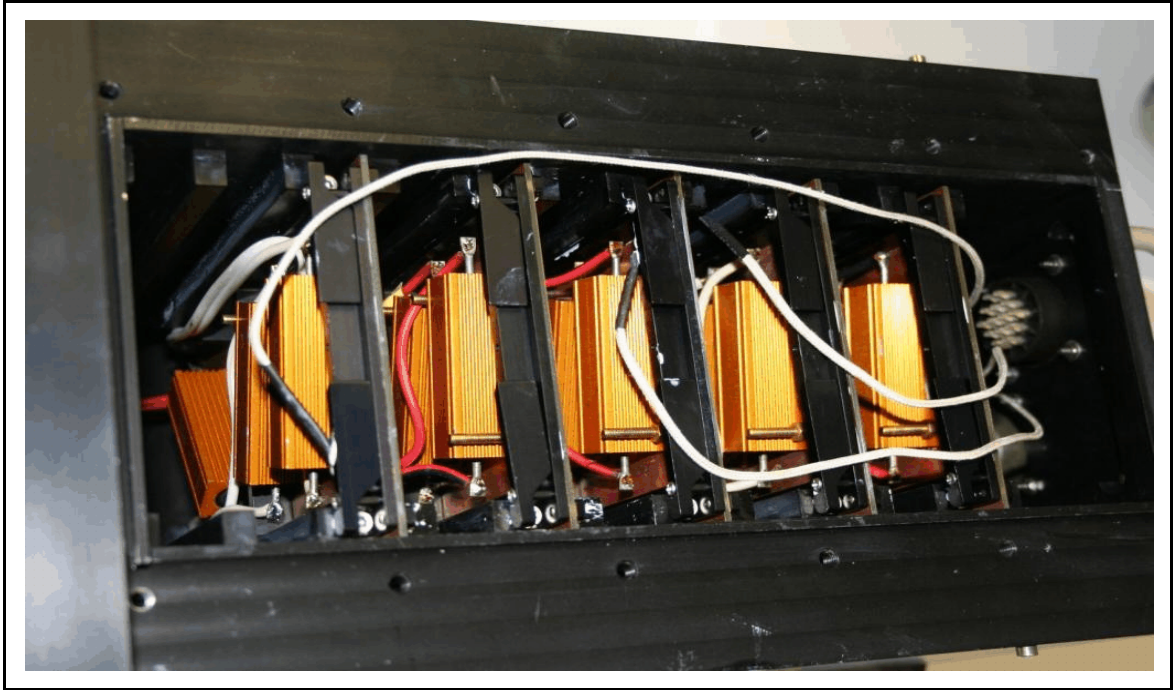


Figure 3 : Heat Sources - Power Resistors on Wedgelock Frames

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 5 of 21

4.2 Cold Plate

Typically the technique of conduction-cooling employs the dissipation of heat by thermal conduction through the ribs of the internal components of the assembly to the ribs and walls of the mechanical housing and then by conduction through a Cold Plate on which the MHA is mechanically mounted and finally by thermal convection to the external environment (usually the atmosphere or sea).

A representative cold plate was made using an 8 mm aluminium plate with a fabricated water chamber through which chilled water could be circulated.

At the higher injected powers during these tests the cold plate temperature was reduced by circulating chilled water through it using a variable speed submersible pump.

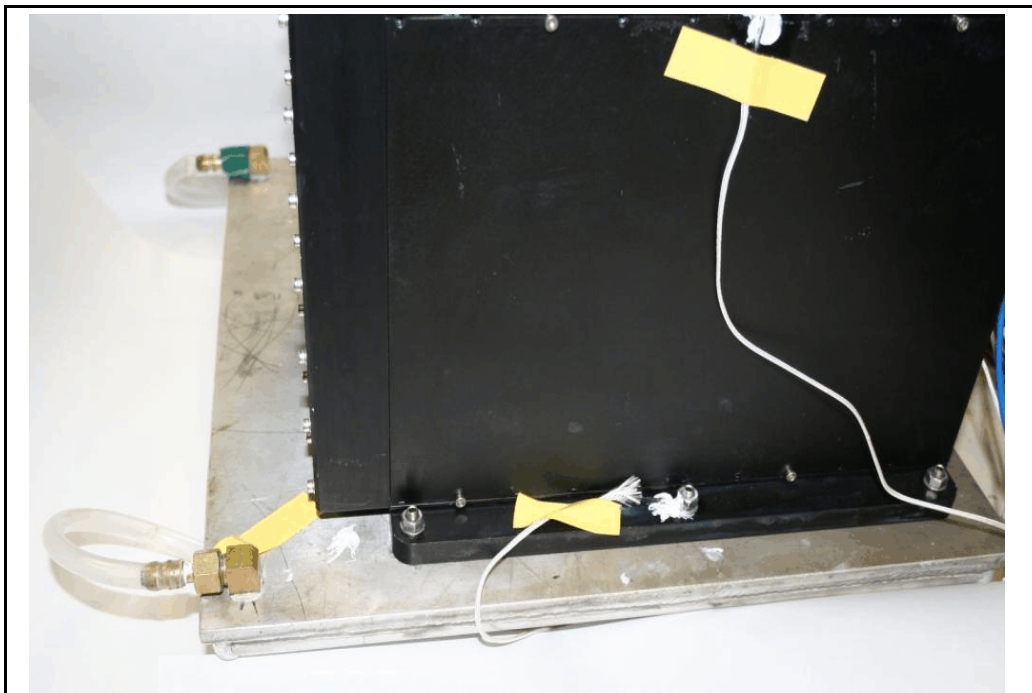


Figure 4 : MHA Mounted on Representative Cold Plate

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 6 of 21

4.3 Temperature Measurement

Temperature was measured using thermocouple digital thermometers and manually recorded at each power increment after allowing a short time to stabilise.

Temperature was measured at the following points :

- card rib of the SEA heat source nearest the centre of the MHA;
- fin inside the MHA closest to this SEA;
- card rib of the SEA heat source nearest one end of the MHA;
- fin on the outside of the MHA directly in line with the fin measured on the inside;
- base of the 3U or 6U MHA;
- Cold Plate.

The positions of the thermocouples used for temperature measurement are also shown in the figure above.

The card ribs of the two SEA were the most important measurements as in practical operation the temperature must not exceed 85 C at these points.

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 7 of 21

5. Formulae and Derivations

5.1 Average Rib Temperature

The measured rib temperatures varied because of the positions of the power resistors relative to the measurement point. If a resistor close to a measurement point was powered as opposed to one located further away it had more effect on the measured value. To eliminate this effect the average temperature of two Wedgelock Frame ribs was determined and used in the calculations.

5.2 Normalisation

It is not possible to hold the Cold Plate at an absolutely stable temperature. In order to be able to compare the measured temperatures at the various heat loads to one another, these measurements have to be referenced to a common baseline. For the purpose of this trial two baselines were selected, namely :

- 25 C Cold Plate Temperature
- 85 C Rib Temperature

5.3 Resultant Rib Temperature at 25 C Cold Plate Temperature

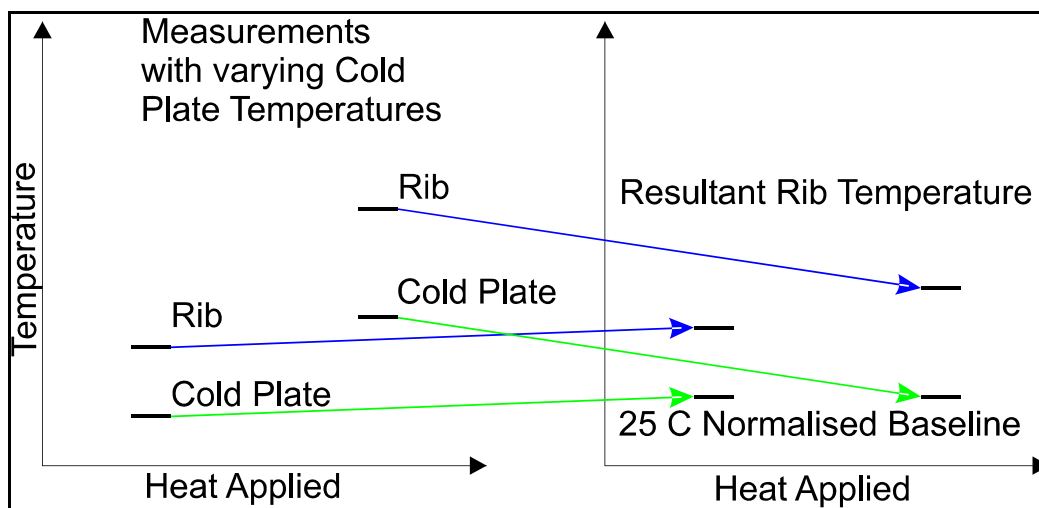


Figure 5 : Normalisation Process - Cold Plate

The Temperature Differential from the Cold Plate to the Average Rib Temperature was calculated for each power setting. and then the rib temperature was normalised to a 25 C Cold Plate Temperature by the formula :

$$\text{Resultant Rib Temperature at 25 C Cold Plate} = (25 - \text{Cold Plate Temperature}) + \text{Temperature Differential}$$

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 8 of 21

5.4 Resultant Cold Plate Temperature at 85 C Rib Temperature

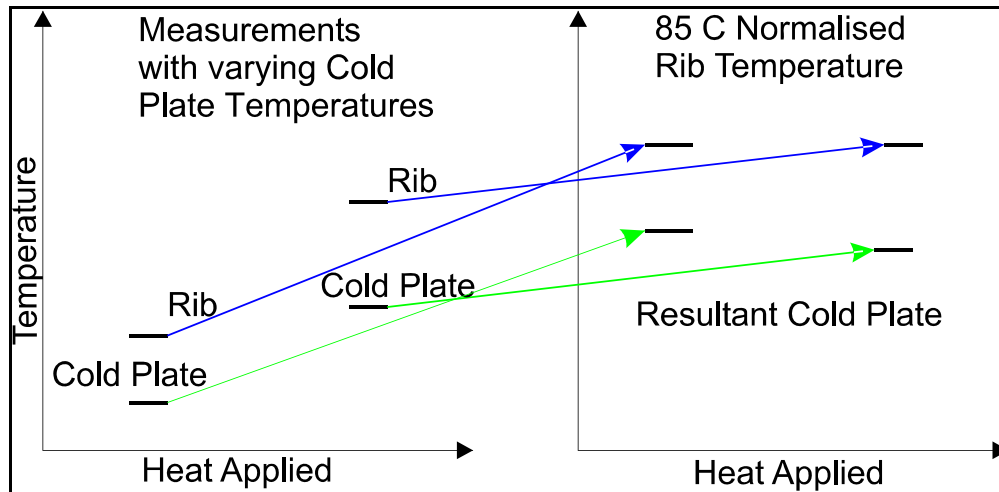


Figure 6 : Normalisation Process - Rib

Similarly in order to calculate the maximum allowed Cold Plate Temperatures required to keep the Rib Temperature at 85 C for any given power dissipation the formula becomes :

$$\text{Resultant Cold Plate Temperature at 85 C Rib} = 85 - \text{Temperature Differential}$$

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 9 of 21

6. Test Results

6.1 Detailed Results

Detailed results are given in tabular form in the Annexure.

Raw measured data as recorded is given in each table, followed by the calculated values.

The first column shows applied power evenly distributed over all the SEAs.

The next six columns show the raw measured recorded temperatures.

Average Rib Temperature was calculated and from this the Temperature Differential to the Cold Plate was calculated.

Using this Temperature Differential the Resultant Rib Temperature can be determined for any Cold Plate Temperature.

Alternatively using the Temperature Differential the maximum allowable Cold Plate Temperature in order to hold the Rib Temperature at or below 85 C can be determined.

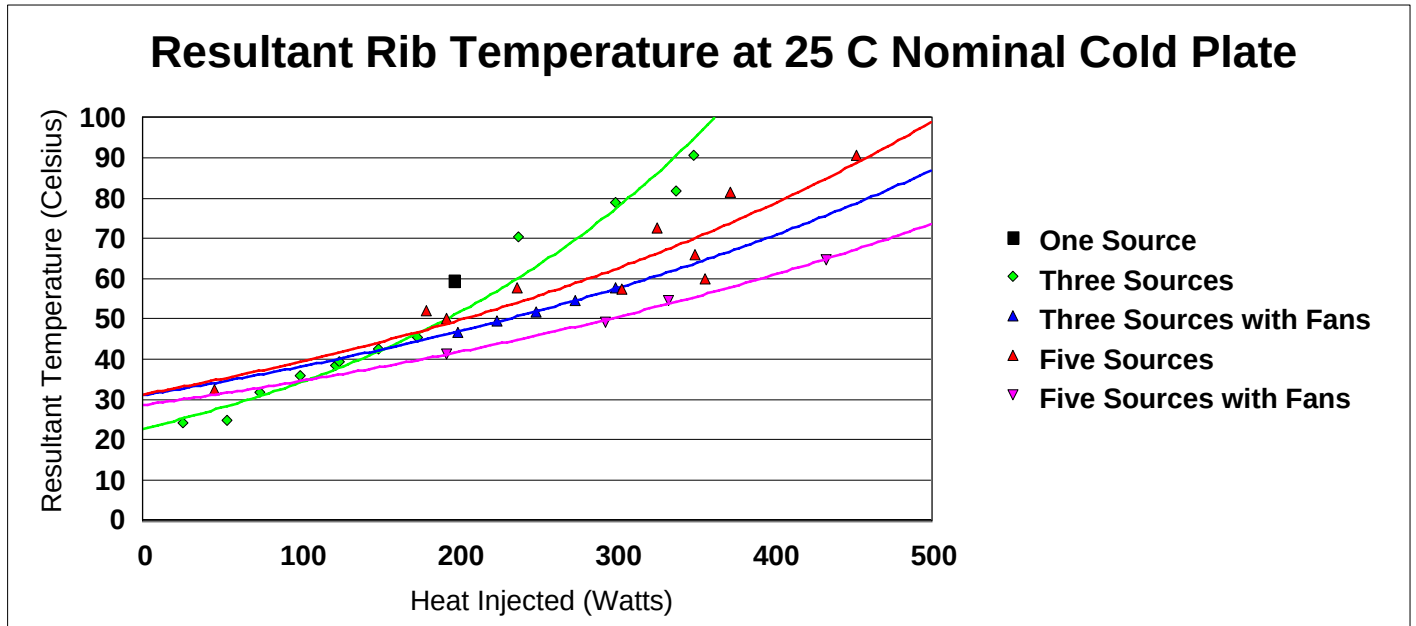
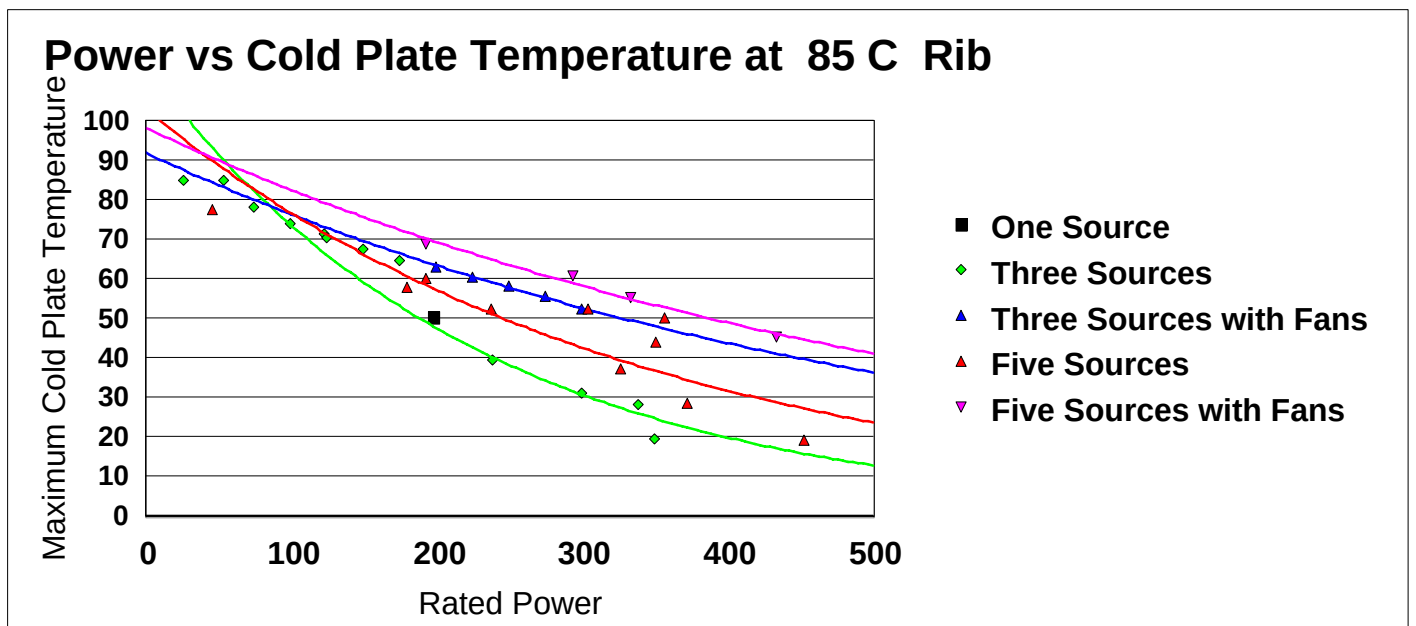
These values are given in the "Calculated Values" section of each table.

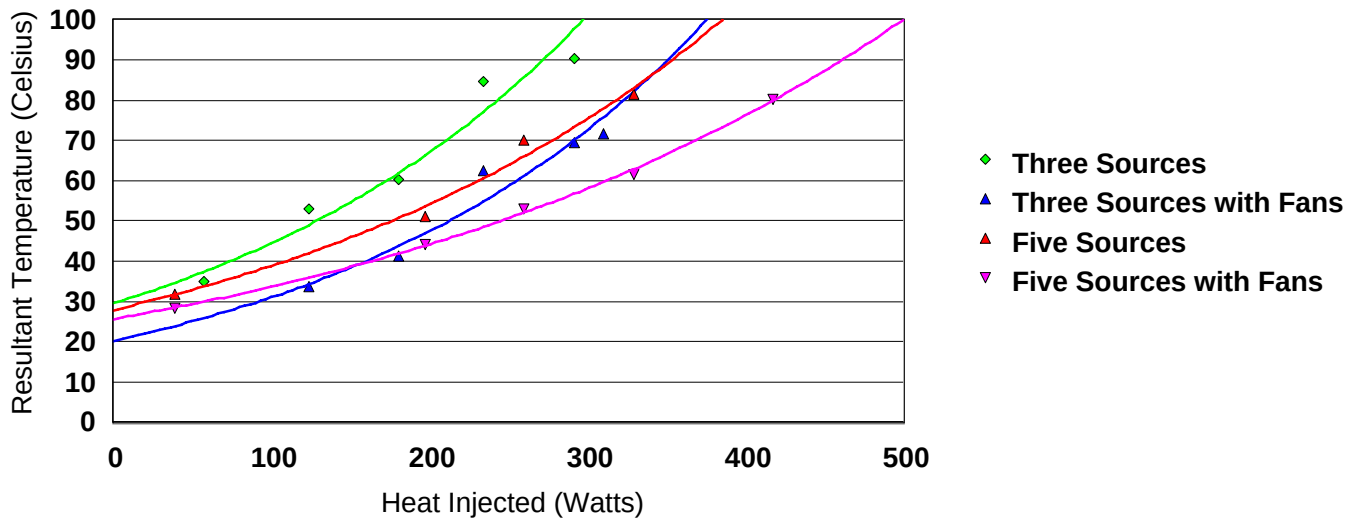
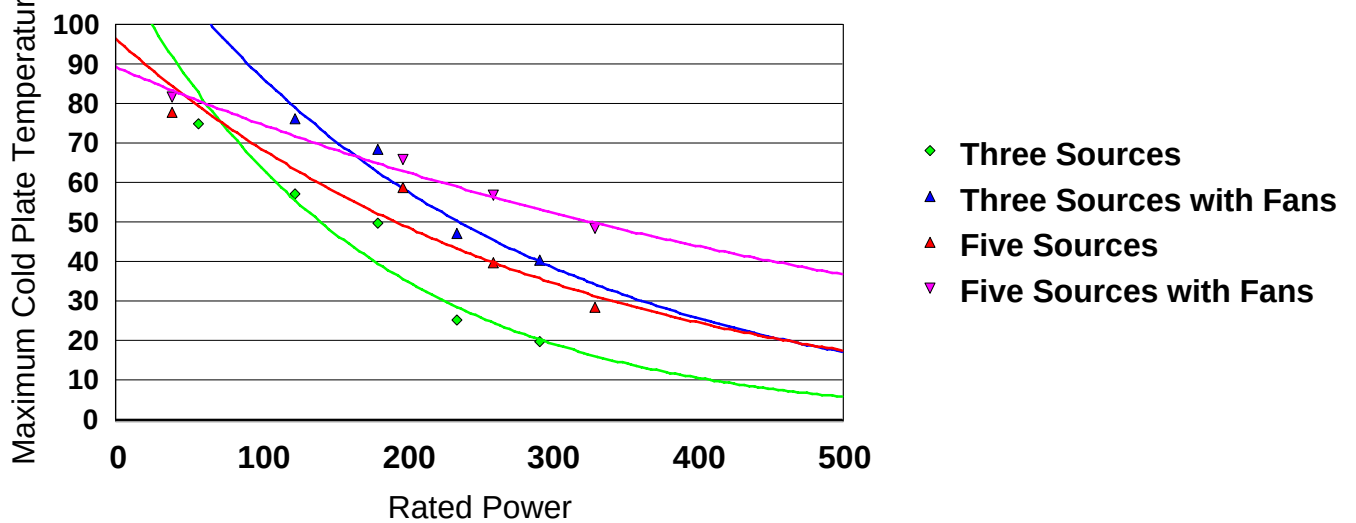
6.2 Graphical Results

The processed test results are summarised in the following graphs.

The Graphs were plotted using 25 C as the nominal Cold Plate Temperature and 85 C as the Rib Temperature.

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 10 of 21

6.2.1 6U MHA Results Normalised for 25 C Cold Plate6.2.2 6U MHA Power Dissipation

6.2.3 3U Housing Normalised for 25 C Cold Plate**Resultant Rib Temperature at 25 C Nominal Cold Plate**6.2.4 3U MHA Heat Dissipation**Power vs Cold Plate Temperature at 85 C Rib**

7. Analysis of Test Results and Graphs

7.1 Resultant Temperatures Vs Distribution of Heat Sources

The graphs clearly show the improved dissipation achieved by distributing the heat source(s) over more slots.

7.2 Heat Dissipation

In many applications it will not be possible to maintain a fixed Cold Plate Temperature.

The Heat Dissipation Graphs show the Cold Plate Temperatures that can be accepted in order to dissipate a required power.

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 13 of 21

8. Conclusions

8.1 6U MHA

8.1.1 6U Housing with Cold Plate with Conduction-Cooling Only

The 6U MHA will safely (i.e. < 85 C Rib Temperature using a 25 C Cold Plate Temperature) dissipate up to 450 W if the heat sources can be spread over 50% or more of the available slots.

The 6U MHA dissipates more heat if the sources can be spread over more slots as shown by comparing the results achieved with three and five heat sources.

It may be possible to dissipate more heat if a particular application utilises even more boards on Wedgelock Frames.

8.1.2 6U Housing with Cold Plate with Conduction-Cooling Only

The 6U MHA will safely dissipate up to 500 W with additional forced-air cooling if the heat sources can be spread over 50% or more of the available slots.

8.2 3U MHA

8.2.1 3U Housing with Cold Plate with Conduction-Cooling Only

The 3U MHA will safely (i.e. < 85 C Rib Temperature using a 25 C Cold Plate Temperature) dissipate up to 340 W if the heat sources can be spread over 50% or more of the available slots.

As with the 6U MHA, the 3U version also dissipates more heat if the sources can be spread over more slots.

It may be possible to dissipate more heat if a particular application utilises even more boards on Wedgelock Frames.

8.2.2 3U MHA with Forced-Air Cooling

The 3U MHA will safely dissipate up to 430 W with forced air if the sources can be spread over 50% or more of the available slots.

8.3 General

8.3.1 Resultant Temperatures Vs Distribution of Heat Sources

The heat sources within the MHA should be distributed as widely as possible throughout the volume of the MHA and over as many card slots as possible.

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 14 of 21

8.3.2 Distribution of Source of Heat

If power dissipation is required to be effected using fewer slots the power dissipation figure may have to be reduced if the heat source cannot be very well thermally coupled into the body of the MHA.

8.3.3 Derating for Higher Cold Plate Temperature

If it is not possible in a practical application to maintain a low Cold Plate Temperature the power dissipation will be less.

Both MHAs still dissipate heat successfully at higher Cold Plate Temperatures and if the power dissipation is derated according to the information in the graphs should operate acceptably.

8.3.4 3U vs 6U Heat Dissipation Performance with Forced-Air Cooling

The 3U MHA fan enclosure was a later design and appears to be more efficient than that of the 6U version. This is understandable noting that the fans are positioned in line with the cooling fins thereby achieving a smoother air flow.

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 15 of 21

9. Recommendations

9.1 Distribution of Sources of Heat

The tests show there is merit in spreading the heat generated over as many slots as possible.

In practice this would generally be the case.

9.2 Optimisation of Heat Flow

There may be some advantage in thickening the wall material near the base of the sides of the MHA in order to improve the heat flow in this area for pure Cold Plate use.

9.3 Testing for User-Specific Configurations

During the higher power sections of the tests over 100 W of heat was applied per slot. Modern Conduction-Cooled Intel i-7 Quad Core Processor Boards dissipate around 60 W, which is why the 100 W limit was chosen as a practical upper limit. If the planned application is going to approach or exceed 100 W in a single slot further testing would be advisable.

While the heat dissipation capability tests documented here are comprehensive, it is not practical to test or simulate every possible user configuration. Therefore, and especially if the intention is to operate the MHAs near their specified limits, it is advisable to perform testing for the specific User Configuration either with Heat Sources sized and positioned as closely as possible to the real configuration, or possibly with the real actual internal heat generating components.

9.4 Redesign of 6U MHA Fan Enclosure

CCII Systems should consider redesigning the 6U MHA fan enclosure to be similar to the 3U version. This will reduce the overall size of the MHA and should increase its Power Dissipation Capability when using forced-air cooling.

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 16 of 21

Annexure A

Heat Input vs Temperature

Notes

1. Applied Power in Watts.
2. Temperatures in Celsius.

1. 6U MHA - Three Heat Sources

Applied Power	Temperature									
	Measured Values						Calculated Values			
	Rib 1	Inside Fin	Rib 2	Outside Fin	MHA Base	Cold Plate	Average Rib	Resultant Rib at 25 C Cold Plate	Differential	Resultant Cold Plate at 85 C Rib
26	22	22	22	22	21	23	22	24	0	85
54	23	23	22	22	22	23	23	25	0	85
75	34	23	28	26	23	24	31	32	7	78
100	42	34	35	32	27	28	39	36	11	74
123	41	39	43	38	30	29	42	39	14	71
125	51	43	47	42	35	35	49	40	15	70
150	59	50	55	49	40	39	57	43	18	67
175	67	57	61	54	43	43	64	45	20	65
239	71	50	77	46	33	29	74	71	46	39
300	86	70	86	66	36	32	86	79	54	31

Table A1 : 6U MHA - Three Heat Sources

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 17 of 21

2. 6U MHA - Three Heat Sources with Fans

Applied Power	Temperature									
	Measured Values						Calculated Values			
	Rib 1	Inside Fin	Rib 2	Outside Fin	MHA Base	Cold Plate	Average Rib	Resultant Rib at 25 C Cold Plate	Differential	Resultant Cold Plate at 85 C Rib
200	71	64	69	62	49	48	70	47	22	63
225	78	70	75	67	53	52	76	49	24	61
250	82	80	86	77	60	57	84	52	27	58
275	87	84	93	81	62	60	90	55	30	56
300	92	89	98	84	65	63	95	58	33	52

Table A2 : 6U MHA - Three Heat Sources with Fans

3. 6U MHA - Five Heat Sources

Applied Power	Temperature									
	Measured Values						Calculated Values			
	Rib 1	Inside Fin	Rib 2	Outside Fin	MHA Base	Cold Plate	Average Rib	Resultant Rib at 25 C Cold Plate	Differential	Resultant Cold Plate at 85 C Rib
46	39	33	34	32	28	29	36	32	7	78
180	71	46	55	49	35	36	53	52	27	58
193	49	46	59	44	31	29	54	50	25	60
238	58	52	65	49	30	29	61	58	33	52
304	87	61	67	58	46	45	77	57	32	53
327	72	56	79	53	33	28	76	73	48	37
351	100	71	82	69	53	50	91	66	41	44
357	75	60	66	56	37	36	70	60	35	50
373	85	62	85	58	36	28	85	82	57	28
453	95	70	93	65	39	28	94	91	66	19

Table A3 : 6U MHA - Five Heat Sources

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 18 of 21

4. 6U MHA - Five Heat Sources with Fans

Applied Power	Temperature									
	Measured Values						Calculated Values			
	Rib 1	Inside Fin	Rib 2	Outside Fin	MHA Base	Cold Plate	Average Rib	Resultant Rib at 25 C Cold Plate	Differential	Resultant Cold Plate at 85 C Rib
193	54	35	35	32	28	28	44	41	16	69
294	58	39	47	35	29	28	63	49	24	61
334	71	38	45	34	30	28	58	55	30	55
434	78	43	58	39	31	28	68	65	40	45

Table A4 : 6U MHA - Five Heat Sources with Fans

5. 3U MHA - Three Heat Sources

Applied Power	Temperature									
	Measured Values						Calculated Values			
	Rib 1	Inside Fin	Rib 2	Outside Fin	MHA Base	Cold Plate	Average Rib	Resultant Rib at 25 C Cold Plate	Differential	Resultant Cold Plate at 85 C Rib
58	38	34	40	32	28	29	39	35	10	75
124	66	46	48	41	31	29	57	53	28	57
181	78	63	49	49	32	28	64	60	35	50
235	91	65	86	57	33	29	88	85	60	25
292	90	71	97	62	34	29	94	90	65	20

Table A5 : 3U MHA - Three Heat Sources

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 19 of 21

6. 3U MHA - Three Heat Sources with Fans

Applied Power	Temperature									
	Measured Values						Calculated Values			
	Rib 1	Inside Fin	Rib 2	Outside Fin	MHA Base	Cold Plate	Average Rib	Resultant Rib at 25 C Cold Plate	Differential	Resultant Cold Plate at 85 C Rib
124	38	36	37	29	28	28	37	34	9	76
181	44	40	46	30	27	28	45	41	16	69
235	67	44	65	33	28	28	66	63	38	47
292	71	47	74	37	28	28	73	69	44	41
311	72	49	78	38	29	28	75	72	47	38

Table A6 : 3U MHA - Three Heat Sources with Fans

7. 3U MHA - Five Heat Sources

Applied Power	Temperature									
	Measured Values						Calculated Values			
	Rib 1	Inside Fin	Rib 2	Outside Fin	MHA Base	Cold Plate	Average Rib	Resultant Rib at 25 C Cold Plate	Differential	Resultant Cold Plate at 85 C Rib
39	35	30	31	30	26	26	33	32	7	78
198	48	42	62	41	30	29	55	51	26	59
260	70	57	78	56	34	29	74	70	45	40
330	85	65	85	63	35	29	85	81	56	29

Table A7 : 3U MHA - Five Heat Sources

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 20 of 21

8. 3U MHA - Five Heat Sources with Fans

Applied Power	Temperature									
	Measured Values						Calculated Values			
	Rib 1	Inside Fin	Rib 2	Outside Fin	MHA Base	Cold Plate	Average Rib	Resultant Rib at 25 C Cold Plate	Differential	Resultant Cold Plate at 85 C Rib
39	34	28	28	27	26	28	31	28	3	82
198	39	33	53	32	27	27	46	44	19	66
260	53	38	58	36	28	27	55	53	28	57
330	66	42	63	40	29	28	64	62	37	49
418	88	53	78	49	32	28	83	80	55	30

Table A8 : 3U MHA - Five Heat Sources with Fans

CCII/MHA/6-RPT/001	2014-01-23	Issue 1.0
R:\MHA\TECH\RPT\CMHRPT01.wpd		Page 21 of 21