HIRDLS

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

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Subject / Title: HIRDLS - PCU Thermal Analysis

Contents / Description / Summary:

This document detailed the thermal analysis performed on the PFM Power Converter Unit.

Key Words: PCU Thermal Analysis

Purpose (20 characters maximum): Thermal analysis of the PFM PCU.

Approved By:

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Rutherford Appleton Laboratory
Chilton, Didcot
Oxfordshire
OX11 0QX, United Kingdom

EOS

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0. SCOPE

This document describes the thermal analysis performed on the HIRDLS Power Converter Unit (PCU) of the Power Subsystem (PSS).

1. APPLICABLE DOCUMENTS

1.1 Thermal Interface Requirements Document SP-HIR-111, L Osborne
Lockheed Martin Missiles & Space (LMMS), 23 April 1999

1.2 SP-HIR-036, Draft A2, S Jaroslawski
Rutherford Appleton Laboratory (RAL), 14 May 1999

1.3 Maximum Temperatures for HIRDLS EEE parts, A P Preece
Document TC-RAL-143, Rutherford Appleton Laboratory (RAL), 29 June 1999

2. INTRODUCTION

The current report contains the geometric and thermal mathematical models of the PCU, the assumptions made during the modelling and the results obtained.

CDR Action Item #048 requested predictions for all components of the electronic box.

The thermal model limits oneself to the main power dissipating components (filters, converters, current limit transistors, current limit resistors, 25A main power relays, linear regulators) so as to get the temperature of each of the aforementioned components.

Nevertheless, others electronics parts (such as control logic PCBs and latching relays mounted on side panels) have not been modelled in this way. Indeed, most of these electronics produce little heat and it seemed impractical to devote the effort to do this considering the number of components involved.

Case temperature of all the electronics has also been considered as the point reference temperature, instead of junctions temperatures, to work out the difference between predicted temperatures and case temperature limits.

The model has regularly been updated in respect to recent changes of the design.

Boundary conditions regarding survival are still to be defined by LMMS.

3. PCU TEMPERATURE REQUIREMENTS

PCU temperatures requirements will be published in SP-HIR-188, the Environmental Requirements Document, which has not yet been released. This will include all temperature ranges including operation, survival, and test.

4. THERMAL DESIGN

Thermal control of the PCU is achieved through the use of passive elements such as radiator on the +Y side of the box, surface finishes and thermal gaskets, given the thermal environment specified by LMMS and the PCU power dissipation budget that has been set up by RAL.

5. GEOMETRIC AND MATHEMATICAL MODEL

5.1 Geometry

A geometric mathematical model of the HIRDLS has been created using ESARAD software.

The model includes all external and internal walls of the PCU, as well as all :

- PCBs,
- converters and filters on both radiator (+Y side) and bottom plate (- Z side),
- 25A relays close to the rear panel (-Y side),
- latching and CSS relays on side panels (+X and -X sides),
- sense resistors and current limit transistors screwed on a front panel perpendicular to -Y side.

External surfaces of the PCU are inactive as the thermal environment has been defined for each external surfaces by LMMS.

Some of the thermal interface requirements have been updated in the last Thermal Interface Requirements Document (SP-HIR-111 dated 23 April 1999).

A picture showing the overall model is given in **Figure 5.1** with the electronics inside the box shown in **Figure 5.2**.

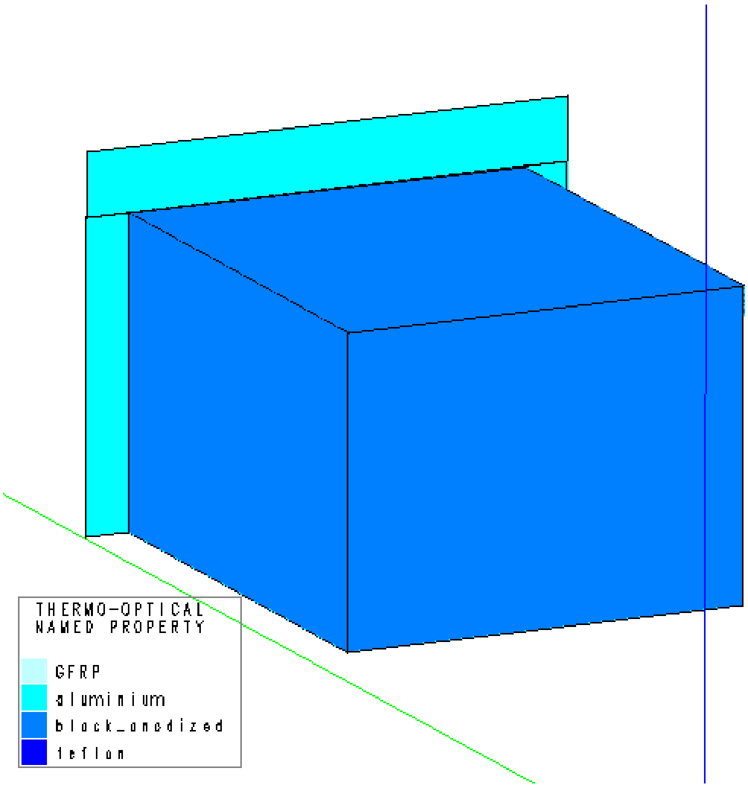

Figure 5.1 Overall Model

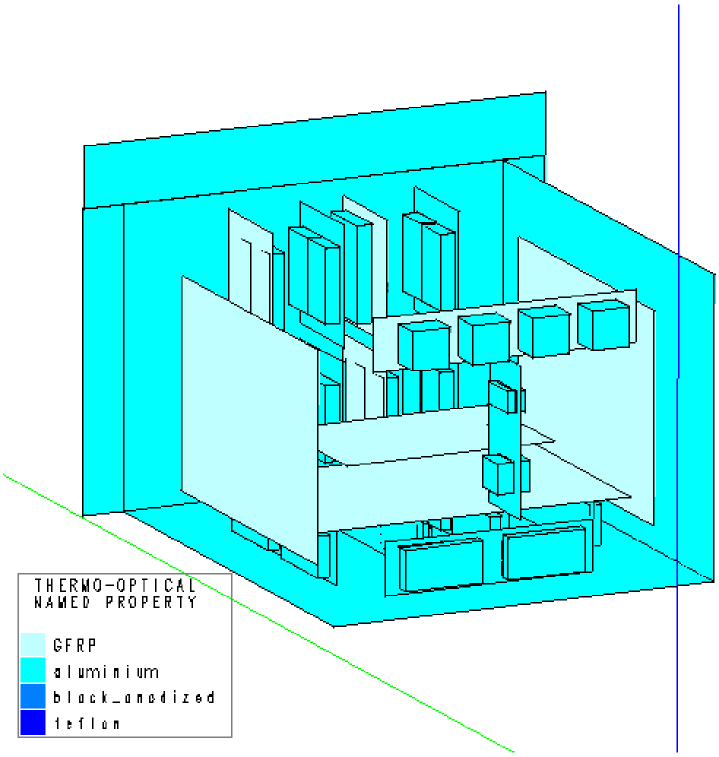

Figure 5.2 PCU Electronics

The PCU required radiator on the +Y surface, with the total area to be at least 6.8E4 mm2. The current thermal model includes a radiator area of 7.76 E4 mm2 as given in **Table 5.1**.

Node Number	Description	Area, mm2
41	PCU +Y	5.30 E4
43	PCU +Y	0.57 E4
45	PCU +Y	1.32 E4
47	PCU +Y	0.57 E4
		Total Area = 7.76 E4

Table 5.1 - Radiator Discretisation

5.*2 Thermo-Optical Properties*

BOL and EOL values for silverized FEP Teflon and black anodized surfaces were given by LMMS and are described in **Table 2a**.

Material	α_s		ε_{IR}	
	EOL	BOL	EOL	BOL
Silverized FEP Teflon	0.18	0.07	0.80	0.80
Black Anodized Aluminium	0.78	0.78	0.78	0.78

Table 2a - Thermal-Optical Surface Properties - Originator : LMMS

BOL and EOL values for all other surface finishes are taken from RAL's thermal database and are described in **Table 2b**.

Material	α_s		ε_{IR}	
	EOL	BOL	EOL	BOL
GFRP	0.72	0.72	0.89	0.89
Aluminium 6068	0.14	0.14	0.09	0.09

Table 2b - Thermal-Optical Surface Properties - Originator : RAL

Assumptions regarding thermal control surfaces :

- External surfaces of the box and the radiator are black anodized aluminium
- Internal surfaces of the box and the radiator are untreated aluminium

6. THERMAL MODEL

6.1 Nodal Discretisation

The model consists of 76 diffuse nodes and 6 boundary nodes representing the spacecraft and the Electronics Unit (EU) cavity mezzanine where the PCU is mounted.

Some of them referring to the surfaces of the box are shown in **Fig. 6**. A full node listing is given in **Table 6.1** describing the nodal distribution as well as locations and surface properties of each node.

Sides of the radiator have been discretised into four nodes in order to increase accuracy of the thermal model.

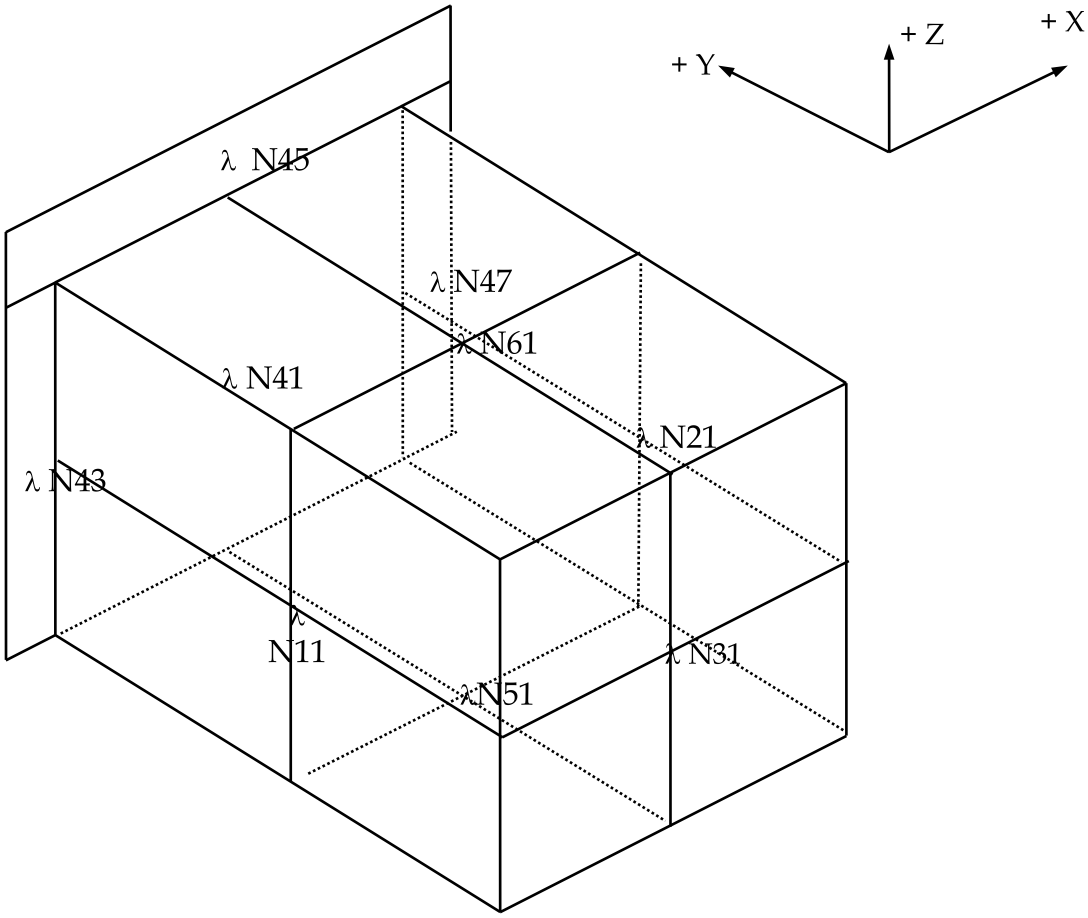

Fig. 6 - Node Map

The module temperatures of each side of the box, as well as each component inside the box, are then calculated within ESATAN.

Node Number	Node Type	Items	Location	Surface
11	D	-X surface	-	black (out) / aluminium (in)
21	D	+X surface	-	black (out) / aluminium (in)

31	D	-Y surface	-	black (out) / aluminium (in)
41	D	+Y surface	-	teflon (out) / aluminium (in)
43	D	+Y surface	-	teflon (out) / aluminium (in)
45	D	+Y surface	-	teflon (out) / aluminium (in)
47	D	+Y surface	-	teflon (out) / aluminium (in)
51	D	-Z surface	-	black (out) / aluminium (in)
61	D	+Z surface	-	black (out) / aluminium (in)
101	D	25 A Relays ON	Front panel	aluminium
102	D	Sense resistors ON	Front panel perpendicular	aluminium
103	D	Current limit transistors ON	Front panel perpendicular	aluminium
104	D	PCU filters ON	+Z surface	aluminium
105	D	PCU convs. ON	+Z surface	aluminium
106	D	SPU +15V convs. ON	+Z surface	aluminium
107	D	SPU -15V convs. ON	+Z surface	aluminium
108	D	SPU +5V convs. ON	+Z surface	aluminium
109	D	SPU filters ON	+Z surface	aluminium
110	D	SYS +5V convs. ON	Radiator	aluminium
111	D	SYS +5V filters ON	Radiator	aluminium
112	D	SYS +15V convs. ON	Radiator	aluminium
113	D	SYS +15V filters ON	Radiator	aluminium
114	D	SYS -15V convs. ON	Radiator	aluminium
115	D	SYS -15V filters ON	Radiator	aluminium
116	D	SYS +28V convs. ON	Radiator	aluminium
117	D	PCB_PX	+X surface	GFRP
118	D	PCB_MX	-X surface	GFRP
119	D	'PCB1_MZ'	-Z surface	GFRP
120	D	'PCB2_MZ'	-Z surface	GFRP
121	D	SYS +28V filters ON	Radiator	aluminium
122	D	Linear regulator ON	-Z surface	aluminium
123	D	Linear regulator ON	-Z surface	aluminium
201	D	Connectors panel parallel	-Y surface	GFRP
202	D	Connectors panel perpendicular	-Y surface	aluminium
204	D	L section	-Z surface	aluminium
206	D	L section	-Z surface	aluminium
208	D	L section	-Z surface	aluminium
210	D	SYS +5V convs. on MFL	Radiator	aluminium
212	D	SYS +15V convs. on MFL	Radiator	aluminium
214	D	SYS -15V convs. on MFL	Radiator	aluminium
216	D	SYS +28V convs. on MFL	Radiator	aluminium

Node Number	**Node Type**	**Items**	**Location**	**Surface**
301	D	25 A Relay OFF	-Y surface	aluminium
401	D	25 A Relay OFF	-Y surface	aluminium
501	D	25 A Relay OFF	-Y surface	aluminium
302	D	Sense resistors OFF	Connector panel per.	aluminium
303	D	Current limit transistors OFF	Connector panel per.	aluminium
304	D	PCU filters OFF	+Z surface	aluminium

305	D	PCU convs. OFF	+Z surface	aluminium
306	D	SPU +15V convs. OFF	+Z surface	aluminium
307	D	SPU -15V convs. OFF	+Z surface	aluminium
308	D	SPU +5V convs. OFF	+Z surface	aluminium
309	D	SPU filters OFF	+Z surface	aluminium
310	D	SYS +5V convs. OFF	Radiator	aluminium
311	D	SYS +5V filters OFF	Radiator	aluminium
312	D	SYS +15V convs. OFF	Radiator	aluminium
313	D	SYS +15V filters OFF	Radiator	aluminium
314	D	SYS -15V convs. OFF	Radiator	aluminium
315	D	SYS -15V filters OFF	Radiator	aluminium
316	D	SYS +28V convs. OFF	Radiator	aluminium
321	D	SYS +28V filters. OFF	Radiator	aluminium
322	D	Linear regulator OFF	-Z surface	aluminium
406	D	L section	-Z surface	aluminium
408	D	L section	-Z surface	aluminium
410	D	MFL bracket	Radiator	aluminium
412	D	MFL bracket	Radiator	aluminium
414	D	MFL bracket	Radiator	aluminium
416	D	MFL bracket	Radiator	aluminium
510	D	Power card	Radiator	GFRP
512	D	Power card	Radiator	GFRP
514	D	Power card	Radiator	GFRP
516	D	Power card	Radiator	GFRP
710	D	Power card	Radiator	GFRP
712	D	Power card	Radiator	GFRP
714	D	Power card	Radiator	GFRP
716	D	Power card	Radiator	GFRP
1000	B	-X Surface Sink T	-X Surface Sink T	-
2000	B	+X Surface Sink T	+X Surface Sink T	-
3000	B	-Y Surface Sink T	-Y Surface Sink T	-
4000	B	+Y Surface Sink T	+Y Surface Sink T	-
5000	B	-Z Surface Sink T	-Z Surface Sink T	-
6000	B	+Z Surface Sink T	+Z Surface Sink T	-

Table 6.1 - Node listing

6.2 Boundary conditions

Boundary conditions have been provided by LMMS for BOL operation (extreme cold case) and EOL operation (extreme hot case). These data include:

- Sink temperatures and corresponding radiative exchange factors from each side of the box
- Interface conductance with an interface temperature during normal operation

All the related values are summarised in **Table 6.2**.

	BOL Operation		**EOL Operation**	
	Sink T °C	Radk to Sink T (e x F x Area), cm2	Sink T °C	Radk to Sink T (e x F x Area), cm2
+X surface	-15.6	396.2	16.0	396.2
-X surface	-6.9	295.5	23.6	295.5
+Y surface	-72.2	829.9	-43.3	829.9
-Y surface	-13.3	415.5	18.9	415.5
+Z surface	-25.9	457.3	7.0	457.3
-Z surface	NA	NA	NA	NA
	* Mount G = 0.39 W/K, Interface T = -3.8 °C		* Mount G = 0.39 W/K, Interface T = 27.7 °C	

Table 6.2 - LMMS BOL and EOL Operation Data

6.3 Power Dissipation

The operational power distribution is defined according to the power and is depicted in **Table 6.3**, assuming 75 % converter efficiency. Figures have been drawn up from the SP-HIR-036 document.

Location	Items	Node Number	Dissipation (W)	Number of components	Number of components on simultaneously [1]	Min / Max case temperature (°C)	Max junction temperature (°C)
Front panel	25 A Relays	101,301 401,501	2.6 @ 25 °C	4	1 (101)	-55 / 125	-
Front panel per.	Sense resistors	102,302	0.23 average	4	2 (102)[2]	-55 / 103	-
Front panel per.	Transistor s	103,303	0.23 average	4	2 (103)[3]	-55 / 103	-
-Z surface	PCU converter s	104,304	3.0 average	2	1 (104)	-55 / 85	100
-Z surface	PCU filters	105,305	0.03 average	2	1 (105)	-55 / 85	100
-Z surface	SPU +15V convs.	106,306	4.3 average 6.1 peak	2	1 (106)	-55 / 85	100
-Z surface	SPU -15V convs.	107,307	1.9 average 2.7 peak	2	1 (107)	-55 / 85	100
-Z surface	SPU +5V convs.	108,308	0.8 average 1.1 peak	2	1 (108)	-55 / 85	100
-Z surface	SPU filters	109,309	0.35 average	2	1 (109)	-55 / 85	100
Radiator	SYS +5V convs.	110,310	4.4 average	2	1 (110)	-55 / 85	100
Radiator	SYS +5V filters	111,311	0.22 average	2	1 (111)	-55 / 85	100
Radiator	SYS +15V convs.	112,312	4.4 average 5.0 peak	2	1 (112)	-55 / 85	100
Radiator	SYS +15V filters	113,313	0.22 average	2	1 (113)	-55 / 85	100
Radiator	SYS -15V convs.	114,314	3.84 average 4.43 peak	2	1 (114)	-55 / 85	100
Radiator	SYS -15V filters	115,315	0.19 average	2	1 (115)	-55 / 85	100
Radiator	SYS +28V convs.	116	2.28 average 14.0 peak	1	1 (116)	-55 / 85	100
Radiator	SYS +28V filters	121	0.11 average	1	1 (121)	-55 / 85	100

Table 6.3a - HIRDLS Power Budget

[1] In brackets are the components which are on.
[2] Node 102 stands for 2 components
[3] Node 103 stands for 2 components

Location	Items	Node Number	Dissipation (W)	Number of components	Number of components on simultaneously	Min / Max case temperature (°C)	Max junction temperature (°C)
-Z surface	Control logic PCB	117	1.45	1	1 See note 1	-55 / 85	100
-Z surface	Control logic PCB	118	insignificant	1	1	-55 / 85	100
-X surface	Control logic PCB	119	insignificant	1	1	-55 / 85	100
+X surface	Control logic PCB	120	insignificant	1	1	-55 / 85	100
-X surface +X surface	Latching relays	-	0.004 each 0.180 in the whole	45	45 (equally distributed across -X and +X surface)	See note 2	See note 2
+X surface	CSS relays	-	0.75	4	1 (equally distributed across +X surface)	See note 2	See note 2
-Z surface	Linear regulator	122, 322 422, 522	2.9	4	1	-55 / 85	93.5

Table 6.3b - HIRDLS Power Budget

Notes :

1. Microcircuits mounted PCB have not been modelled individually, since they turn out to be too numerous. However, related dissipated power (1.45 W) has been included as source in the model.

2. Latching and CSS relays dissipate little power when in operation. Consequently, they have not been analysed to the same level of detail of other electronics. Like the control logic PCB, their dissipated amount of power has nevertheless been taken into account and included as source in the model.

6.4 Environmental Loads

BOL and EOL environmental have been defined by LMMS and consist essentially of environmental heat flux on the +Y side of the unit. Usually, these loads include solar constant, albedo and earth effective blackbody temperature.

	Environmental Q Watts **BOL Operation**	Environmental Q Watts **EOL Operation**
+X surface	0	0
-X surface	0	0
+Y surface	2.19	2.59
-Y surface	0	0
+Z surface	0	0
-Z surface	0	0

Table 6.4a - HIRDLS Environmental Loads

NB:

The sum of environmental loads, noted Qe, and internal loads, noted Qi, gives the total amount of power applied to the box, noted Qt, given hereafter:

	BOL Operation	**EOL Operation**
Qe (W)	2.19	2.59
Qi (W)	34.43	34.43
Qt (W)	36.62	37.02

Table 6.4b - HIRDLS Total Loads

7. RADIATIVE COUPLINGS

Radiative couplings between the various components inside the box have been calculated in ESARAD.

Radiative couplings between external surfaces of the box and the PCU environment have been given by LMMS. In regard to the radiator, radiative couplings are inferred from LMMS values taken into account its area discretisation. These values are all summarised in **Table 7**.

Node Number	Node Number	Radiative Coupling (e x F x Area), m2
41	4000	566.8 E-4
43	4000	60.6 E-4
45	4000	141.9 E-4
47	4000	60.6 E-4
		Σ = 829.9 E-4

Table 7 - Radiative Couplings to Sink Temperatures

8. CONDUCTIVE COUPLINGS

Conductive couplings have been calculated by hand. The interface coupling between the PCU assembly and the shelf (i.e. between N51 and N5000) has been defined by LMMS.

Node Number	Node Number	Coupling Type	Conductance (W/K)
21	61	8 × M 2.5	0.2628
61	11	8 × M 2.5	0.2628
11	51	8 × M 2.5	0.2628
51	21	8 × M 2.5	0.2628
21	31	6 × M 2.5	0.1502
31	11	6 × M 2.5	0.1502
11	41	6 × M 2.5	0.1651
41	21	6 × M 2.5	0.1651
41	43	-	0.5024
41	45	-	0.8032
41	47	-	0.5024
61	41	7 × M 2.5	0.2279
41	51	7 × M 2.5	0.2279
51	31	7 × M 2.5	0.2114
31	61	7 × M 2.5	0.2114
51	5000	-	0.39

Table 8.1a - Conductive couplings

Node Number	Node Number	Coupling Type	Conductance (W/K)
101	31	4 × M 3	0.5457
102	202	2 × M 2.5	0.2227
103	202	4 × M 2.5	0.4258
104, 105	204	2 × M 3	7.6219 *
106, 107	206	2 × M 3	7.6219 *
108, 109	208	2 × M 3	7.6219 *
204, 206, 208	51	-	2.0615 *
110, 111	210	2 × M 3	6.9372 *
112, 113	212	2 × M 3	6.9372 *
114, 115	214	2 × M 3	6.9372 *
116, 121	216	2 × M 3	11.7584 *
210, 212, 214, 216	41	3 × M 2.5	0.6252 *
119	206, 208, 406, 408	8 × M 2.5	0.0008
120	208, 408	2 × M 2.5	0.0010
122, 123	222	1 × M 2.5	0.5637 *
222	51	2 × M 2.5	0.8397 *
301, 401, 501	31	4 × M 3	0.5457
302	202	2 × M 2.5	0.2227
303	202	4 × M 2.5	0.4258
304, 305	204	2 × M 3	7.6219 *
306, 307	406	2 × M 3	7.6219 *
308, 309	408	2 × M 3	7.6219 *
310, 311	410	2 × M 3	6.9372 *
312, 313	412	2 × M 3	6.9372 *
314, 315	414	2 × M 3	6.9372 *
316, 321	416	2 × M 3	11.7584 *
410, 412, 414, 416	41	3 × M 2.5	0.6252 *
210, 212, 410, 412	216, 214, 416, 414	3 × M 2	0.1041
210, 212, 410, 412	510, 512, 514,516	4 × M 3	0.4008
410, 412, 414, 416	710, 712, 714, 716	4 × M 3	0.4008

Table 8.1b - Conductive couplings

Thermal gasket (thermally conductive rubber silicon STYCAST 4952) – 0.25 mm thickness together with a conductivity of 1.872 W/(m.K) have been assumed for this binder.

9. STEADY STATE ANALYSIS

Because junction-to-case thermal resistances were not known with sufficient accuracy for every electronic part of HIRDLS, margins have been worked out with case temperatures as temperature reference points. In other words, every predicted temperature gives the temperature of the case it refers to.

9.1 BOL steady-state operational case

Node Number	Description	T (°C)
11	PCU -X	3
21	PCU +X	2
31	PCU -Y	4
41	PCU +Y	2
43	PCU +Y	0
45	PCU +Y	-1
47	PCU +Y	0
51	PCU -Z	10
61	PCU +Z	-2

Table 9.1a - Predicted Node Temperatures - Steady State Case - BOL Operational

Node Number	Description	T (°C)	T min (°C)	ΔT = T - Tmin (°C)
101	25 A Relays ON	9	-55	64
102	Sense resistors ON	10	-55	65
103	Transistors ON	9	-55	64
104	PCU filters ON	12	-55	67
105	PCU convs. ON	12	-55	67
106	SPU +15V convs. ON	14	-55	69
107	SPU -15V convs. ON	14	-55	69
108	SPU +5V convs. ON	11	-55	66
109	SPU filters ON	11	-55	66
110	SYS +5V convs. ON	10	-55	65
111	SYS +5V filters ON	9	-55	64
112	SYS +15V convs. ON	10	-55	65
113	SYS +15V filters ON	9	-55	64
114	SYS -15V convs. ON	9	-55	64
115	SYS -15V filters ON	9	-55	64
116	SYS +28V convs. ON	7	-55	62
117	PCB_PX	3	-55	58
118	PCB_MX	4	-55	59
119	'PCB1_MZ'	13	-55	68
120	'PCB2_MZ'	8	-55	63
121	SYS +28V filters ON	7	-55	62
122	Linear regulator ON	17	-55	72
123	Linear regulator ON	16	-55	71
201	Connectors panel parallel	5	-55	60
202	Connectors panel perpendicular	8	-55	63
204	L section	12	-55	67
206	L section	13	-55	68
208	L section	11	-55	66
210	SYS +5V convs. on MFL	9	-55	64
212	SYS +15V convs. on MFL	9	-55	64
214	SYS -15V convs. on MFL	9	-55	64
216	SYS +28V convs. on MFL	6	-55	61
222	L section	14	-55	69
301	25 A Relay OFF	4	-55	59
401	25 A Relay OFF	4	-55	59
501	25 A Relay OFF	4	-55	59

Table 9.1b - Predicted Node Temperatures - Steady State Case - BOL Operational

Node Number	Description	T (°C)	T min (°C)	ΔT = T - Tmin (°C)
302	Sense resistors OFF	8	-55	63
303	Transistors OFF	8	-55	63
304	PCU filters OFF	12	-55	67
305	PCU convs. OFF	12	-55	67
306	SPU +15V convs. OFF	10	-55	65
307	SPU -15V convs. OFF	10	-55	65
308	SPU +5V convs. OFF	10	-55	65
309	SPU filters OFF	10	-55	65
310	SYS +5V convs. OFF	2	-55	57
311	SYS +5V filters OFF	2	-55	57
312	SYS +15V convs. OFF	2	-55	57
313	SYS +15V filters OFF	2	-55	57
314	SYS -15V convs. OFF	2	-55	57
315	SYS -15V filters OFF	2	-55	57
316	SYS +28V convs. OFF	2	-55	57
321	SYS +28V filters. OFF	2	-55	57
322	Linear regulator OFF	11	-55	66
406	L section	10	-55	65
408	L section	10	-55	65
410	SYS +5V convs. OFF MFL	2	-55	57
412	SYS +15V convs. OFF MFL	2	-55	57
414	SYS -15V convs. OFF MFL	2	-55	57
416	SYS +28V convs. OFF MFL	2	-55	57
510	SYS +5V convs. ON PB	9	-55	64
512	SYS +15V convs. ON PB	9	-55	64
514	SYS -15V convs. ON PB	8	-55	63
516	SYS +28V convs. ON PB	6	-55	61
710	SYS +5V convs. OFF PB	2	-55	57
712	SYS +15V convs. OFF PB	2	-55	57
714	SYS -15V convs. OFF PB	3	-55	58
716	SYS +28V convs. OFF PB	2	-55	57

Table 9.1c - Predicted Node Temperatures - Steady State Case - BOL Operational

9.2 EOL steady-state operational case

Node Number	Description	T (°C)
11	PCU -X	28
21	PCU +X	27
31	PCU -Y	30
41	PCU +Y	24
43	PCU +Y	21
45	PCU +Y	20
47	PCU +Y	21
51	PCU -Z	37
61	PCU +Z	23

Table 9.2a - Predicted Node Temperatures - Steady State Case - EOL Operational

Node Number	Description	T (°C)	T max (°C)	ΔT = Tmax - T (°C)
101	25 A Relays ON	35	125	90
102	Sense resistors ON	36	103	67
103	Current limit transistors ON	35	103	68
104	PCU filters ON	39	85	46
105	PCU convs. ON	38	85	47
106	SPU +15V convs. ON	40	85	45
107	SPU -15V convs. ON	40	85	45
108	SPU +5V convs. ON	37	85	48
109	SPU filters ON	37	85	48
110	SYS +5V convs. ON	31	85	54
111	SYS +5V filters ON	31	85	54
112	SYS +15V convs. ON	32	85	53
113	SYS +15V filters ON	31	85	54
114	SYS -15V convs. ON	31	85	54
115	SYS -15V filters ON	30	85	55
116	SYS +28V convs. ON	28	85	57
117	PCB_PX	28	85	57
118	PCB_MX	29	85	56
119	'PCB1_MZ'	36	85	49
120	'PCB2_MZ'	32	85	53
121	SYS +28V filters ON	28	85	57
122	Linear regulator ON	44	85	41
123	Linear regulator ON	42	85	43
201	Connectors panel parallel	30	85	55
202	Connectors panel perpendicular	34	85	51
204	L section	38	85	47
206	L section	40	85	45
208	L section	37	85	48
210	SYS +5V convs. on MFL	31	85	54
212	SYS +15V convs. on MFL	31	85	54
214	SYS -15V convs. on MFL	30	85	55
216	SYS +28V convs. on MFL	28	85	57
222	L section	40	85	45
301	25 A Relay OFF	30	125	95
401	25 A Relay OFF	30	125	95
501	25 A Relay OFF	30	125	95

Table 9.2b - Predicted Node Temperatures - Steady State Case - EOL Operational

Node Number	Description	T (°C)	T max (°C)	ΔT = Tmax - T (°C)
302	Sense resistors OFF	34	85	51
303	Transistors OFF	34	85	51
304	PCU filters OFF	38	85	47
305	PCU convs. OFF	38	85	47
306	SPU +15V convs. OFF	37	85	48
307	SPU -15V convs. OFF	37	85	48
308	SPU +5V convs. OFF	37	85	48
309	SPU filters OFF	37	85	48
310	SYS +5V convs. OFF	24	85	62
311	SYS +5V filters OFF	24	85	61
312	SYS +15V convs. OFF	24	85	61
313	SYS +15V filters OFF	24	85	61
314	SYS -15V convs. OFF	24	85	61
315	SYS -15V filters OFF	24	85	61
316	SYS +28V convs. OFF	24	85	61
321	SYS +28V filters. OFF	24	85	61
322	Linear regulator OFF	40	85	45
406	L section	37	85	48
408	L section	37	85	48
410	SYS +5V convs. OFF MFL	24	85	61
412	SYS +15V convs. OFF MFL	24	85	61
414	SYS -15V convs. OFF MFL	24	85	61
416	SYS +28V convs. OFF MFL	24	85	61
510	SYS +5V convs. ON PB	30	85	55
512	SYS +15V convs. ON PB	31	85	54
514	SYS -15V convs. ON PB	30	85	55
516	SYS +28V convs. ON PB	28	85	57
710	SYS +5V convs. OFF PB	24	85	61
712	SYS +15V convs. OFF PB	24	85	61
714	SYS -15V convs. OFF PB	24	85	61
716	SYS +28V convs. OFF PB	24	85	61

Table 9.2c - Predicted Node Temperatures - Steady State Case - EOL Operational

Peak temperatures correspond to peak power dissipation in one component, with nominal averaged power dissipation in all others. They are given in **Table 9.3a** along with nominal temperatures and for three different value of η, the power converter efficiency. Power dissipation versus efficiency are described in **Table 9.3b** for of each component.

		η = 85 %		η = 75 %		η = 70 %	
Node Number	Description	T (°C) Peak	T (°C) Nom	T (°C) Peak	T (°C) Nom	T (°C) Peak	T (°C) Nom
101	25 A Relays ON	-	31	-	35	-	37
102	Sense resistors ON	-	32	-	36	-	38
103	Current limit transistors ON	-	31	-	35	-	37
104	PCU filters ON	-	32	-	39	-	42
105	PCU convs. ON	-	31	-	38	-	42
106	SPU +15V convs. ON	34	32	43	40	49	45
107	SPU -15V convs. ON	33	32	41	40	47	45
108	SPU +5V convs. ON	31	30	39	37	42	41
109	SPU filters ON	-	30	-	37	-	41
110	SYS +5V convs. ON	20	19	28	31	34	38
111	SYS +5V filters ON	-	19	-	31	-	38
112	SYS +15V convs. ON	20	19	33	32	41	39
113	SYS +15V filters ON	-	19	-	31	-	38
114	SYS -15V convs. ON	20	19	32	31	40	38
115	SYS -15V filters ON	-	19	-	30	-	37
116	SYS +28V convs. ON	33	18	56	28	70	34
117	PCB_PX	-	23	-	28	-	31
118	PCB_MX	-	24	-	29	-	32
119	'PCB1_MZ'	-	30	-	36	-	39
120	'PCB2_MZ'	-	26	-	32	-	35
121	SYS +28V filters ON	-	18	-	28	-	34
122	Linear regulator ON	-	37	-	44	-	47
123	Linear regulator ON	-	36	-	42	-	46

Table 9.3a - Predicted Peak Temperatures – EOL Operational

		η = 85 %		η = 75 %		η = 70 %	
		average dissipation	peak dissipation	average dissipation	peak dissipation	average dissipation	peak dissipation
104	PCU converters	3.0	-	3.0	-	3.0	-
105	PCU filters	0.03	-	0.03	-	0.03	-
106	SPU +15V convs.	2.23	3.23	4.30	6.10	5.53	7.84
107	SPU -15V convs.	1.01	1.43	1.90	2.70	2.44	3.47
108	SPU +5V convs.	0.41	0.56	0.77	1.07	0.99	1.37
109	SPU filters	0.18	0.26	0.35	0.49	0.45	0.63
110	SYS +5V convs.	2.31	1.64	4.37	3.10	5.61	3.99
111	SYS +5V filters	0.12	0.08	0.22	0.16	0.28	0.20
112	SYS +15V convs.	2.33	2.65	4.40	5.00	5.66	6.43
113	SYS +15V filters	0.12	0.13	0.22	0.25	0.28	0.32
114	SYS -15V convs.	2.03	2.35	3.84	4.43	4.93	5.70
115	SYS -15V filters	0.10	0.12	0.19	0.22	0.25	0.29
116	SYS +28V convs.	1.21	7.41	2.28	14.0	2.93	18.0
121	SYS +28V filters	0.06	0.37	0.11	0.70	0.15	0.90

Table 9.3b - Power dissipation versus efficiency

10. HEAT DISSIPATION VALUES OUT OF EACH BOX SIDE

BOL - Minimum Operation					
		Gr = e.F.A x 10e-4 (m^2)	Ti (K)	To (K)	Qrad (W)
	-X surface	295.5	276	266.1	1.32
	+X surface	396.2	274	257.4	2.80
	-Y surface	415.5	277	259.7	3.15
	+Y surface	829.9	274	200.8	18.87
	+Z surface	457.3	271	247.1	4.32
		Gc (W/K)	Ti (K)	To (K)	Qc (W)
	- Z surface	0.39	283	269.2	5.38
					Qtot = 35.84

EOL - Maximum Operation					
		Gr = e.F.A x 10e-4 (m^2)	Ti (K)	To (K)	Qrad (W)
	-X surface	295.5	301	296.6	0.79
	+X surface	396.2	300	289.0	2.53
	-Y surface	415.5	303	291.9	2.75
	+Y surface	829.9	297	229.7	23.51
	+Z surface	457.3	296	280.0	3.97
		Gc (W/K)	Ti (K)	To (K)	Qc (W)
	- Z surface	0.39	310	300.7	3.63
					Qtot = 37.18

- Qrad = e.F.A.σ. $(T_i^4 - T_o^4)$

e, emissivity
F, shape factor
A, area of surface (m^2)
σ, Stefan-Boltzmann constant, σ = 5.67.10e-8 $W / (m^2 . K^4)$
Ti, surface temperature (K)
To, sink temperature (K)
Qrad, radiation heat dissipation (W)

- Qc = Gr.(Ti -To)

Gc, conductive coupling (W/K)
Ti, surface temperature (K)
To, sink temperature (K)
Qc, conduction heat dissipation (W)

- Qtot = Qrad + Qc

Qtot values are consistent with the total loads assumed for the box given in section 6.4.

CONCLUSION

The thermal model has been updated to be consistent with new environmental boundary conditions that have been issued in the last Thermal Interface Requirements Document (SP-HIR-111).

Recent design changes have also been incorporated in the model, as follows:

- SPU/PCU filters/converters are mounted on L sections on the -Z surface of the box
- side panels no longer exist and relays are directly mounted on each side of the box
- there are four control logic PCBs, one dissipating 1.45W

Analysis of the current thermal design was based upon passive thermal control through the use of a radiator (+Y side) and thermal gaskets at the most critical components level giving higher thermal conductivity to improve heat transfer between electronics and their mounts.

Results show that both in BOL and EOL operational case, all electronic equipment items will be working within their functional limitations and reliability requirements.

However, thermal paths might be improved to avoid undesirable temperature increases for units mounted on the bottom plate, which turn out to have the highest temperature values during EOL operational (i.e. 42°C and 44°C for the two linear regulators ON), by one of the following approaches:

a- to mount linear regulator separately
b- to thickener L bracket sections on which the hottest components are supposed to be mounted
c- to improve thermal conductivity between the box and the shelf
d- to improve thermal conductivity to the spacecraft