Open Vault Storage Hardware V0.85 OR-draco-bueana-0.85

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1 Scope

This document describes the technical specifications used in the design of the storage unit for the Open Compute Project, known as the Open Vault.

2 Contents

3 Overview

When data center design and hardware design move in concert, they can improve efficiency and reduce power consumption. To this end, the Open Compute Project is a set of technologies that reduces energy consumption and cost, increases reliability and choice in the marketplace, and simplifies operations and maintenance. One key objective is openness -- the project is starting with the opening of the specifications and mechanical designs for the major components of a data center, and the efficiency results achieved at facilities using Open Compute technologies.

A main component of this project is the Open Vault storage server. The Open Vault is a simple and cost-effective storage solution with a modular I/O topology that's built for the Open Rack. The Open Vault offers high disk densities, holding 30 drives in a 2U chassis, and can operate with almost any host server. Its innovative, expandable design puts serviceability first, with easy drive replacement no matter the mounting height.

3.1 License

4 Open Vault Storage Unit Overview

The Open Vault storage unit is a 2U-30HDD storage enclosure, consisting of two identical 1U high HDD trays with 15 x 3.5" HDDs and slots for two SAS expander boards on each, one fan control board, and six redundant fan modules mounted externally in the rear of the chassis. An Open Vault storage server fits into the Open Compute Project Open Rack.

Each HDD tray contains one drive plane board, one power transition board and two SAS expander boards, interfaces external to one or more separate server(s) via x4 SAS 6G link(s). Each SAS expander board and HDD tray can be extracted and serviced independently without impact to the other connected tray. This provides for the easy replacement of one SAS expander board or the replacement of a single HDD while keeping the whole system running. Each fan module is hot pluggable and field replaceable from the rear of the chassis. There are bus bar clips to the Open Rack bus bars so that the 12.5V main power from the Open Rack can feed into the Open Vault enclosure.

For the purposes of this specification, "front" refers to the cold aisle side of the chassis, which is where all service (except fan module removal and replacement) occurs; "rear" refers to the hot aisle side of the chassis, which is where the fan module service occurs; "SEB" refers to the SAS expander board, "DPB" refers to the drive plane board, "PTB" refers to the power transition board and "FCB" refers to the fan control board.

Figure 1 and Figure 2 show an overview of the Open Vault storage unit.

Figure 1 Open Vault Storage Unit Overview

Figure 2 Open Vault Detail Showing the Hinged Disk Drive Tray

4.1 Open Vault Front View

The equipment accessible from the front of the Open Vault, as shown in Figure 3, includes:

- Two (2) HDD trays
- Up to four (4) SAS expander boards; default is two (2) SEBs, one for each tray
- Up to four (4) external mini-SAS connectors, with status LED
- Up to eight (8) internal mini-SAS connectors, with status LED
- Up to four (4) enclosure status LEDs, one on each SEB
- Up to four (4) debug headers, one on each SEB

Figure 3 Open Vault Storage Unit Front View

4.2 Open Vault Rear View

The equipment accessible from the rear of the Open Vault, as shown in Figure 4, includes:

- One (1) pair of bus bar clips
- Six (6) fan modules, each with a status LED

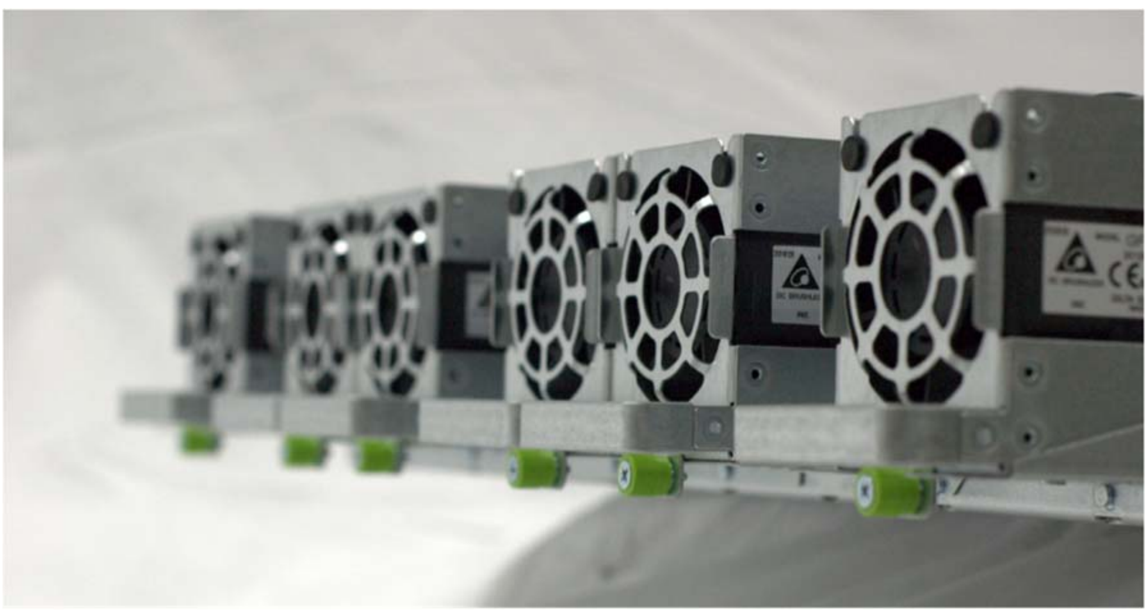

Figure 4 Open Vault Storage Unit Rear View

4.3 System Component Layout

Figure 5 shows the layout from overhead of the Open Vault's major system components.

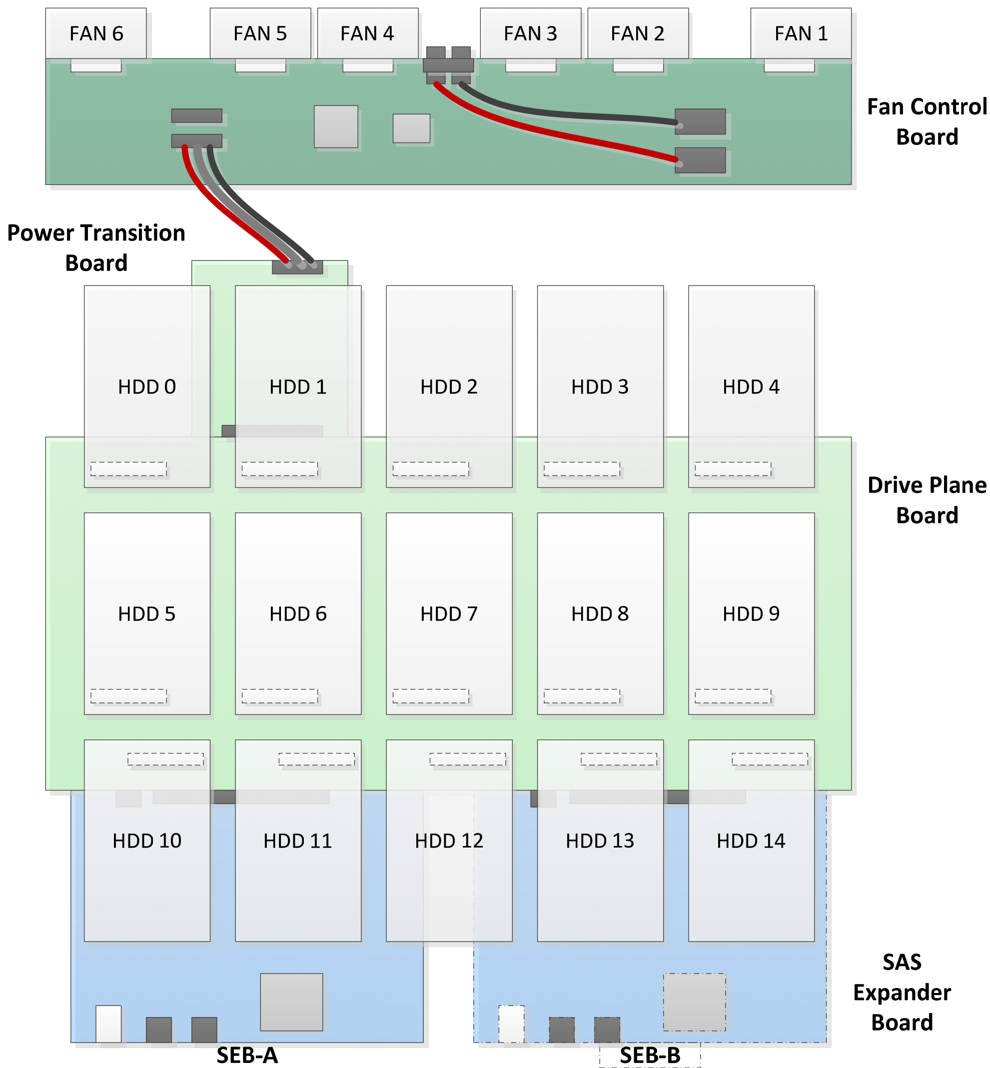

Figure 5 Open Vault System Components Layout

4.4 System Block Diagram

Figure 6 shows the system block diagram for the Open Vault, mainly addressing SAS data paths. Each SAS expander board has:

- One external mini-SAS port to the host RAID or HBA card
  - Using external mini-SAS cable
  - Max cable length: 7m
- Up to two internal mini-SAS ports to cascaded Open Vault trays
  - Using internal mini-SAS cable located outside the chassis
  - Max cable length: 1.5m

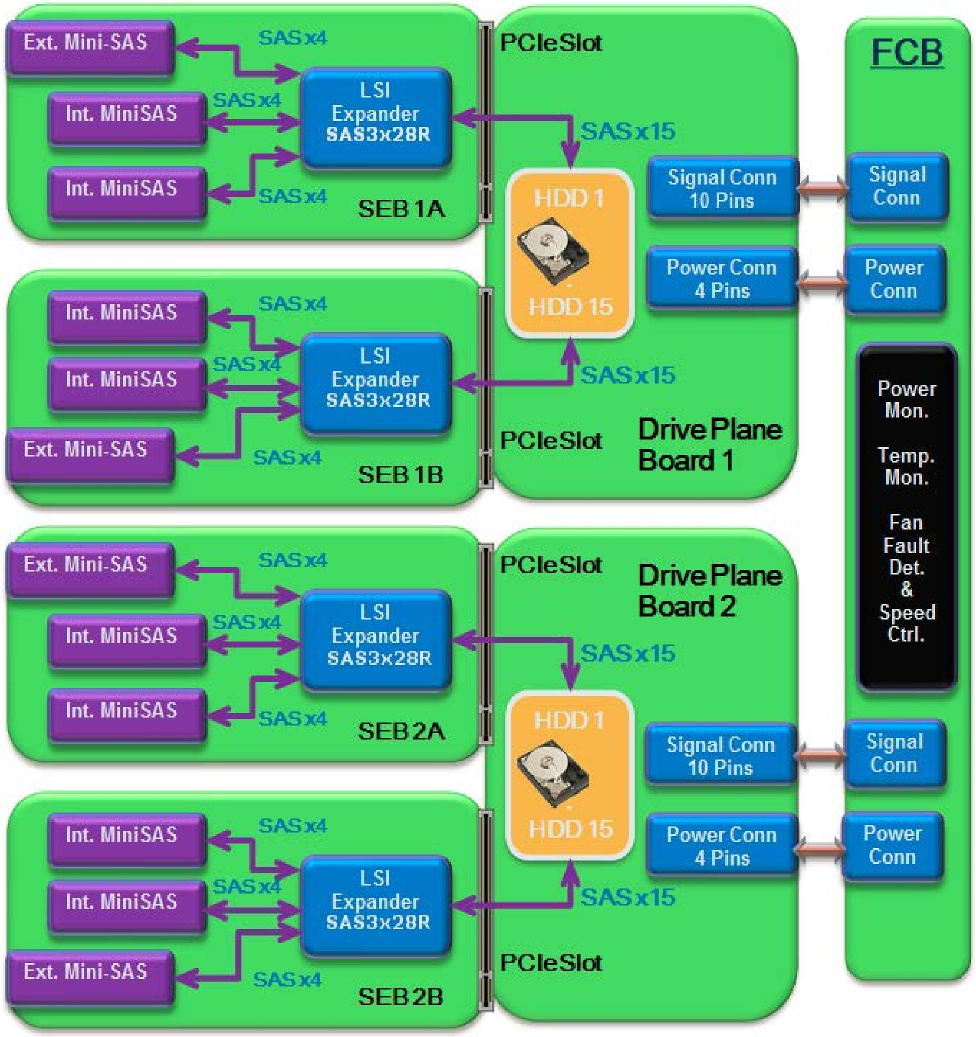

Figure 6 Open Vault System Block Diagram

4.5 System I2C Topology

Figure 7 shows the system I2C topology of the Open Vault. It reflects the enclosure management structure of the Open Vault.

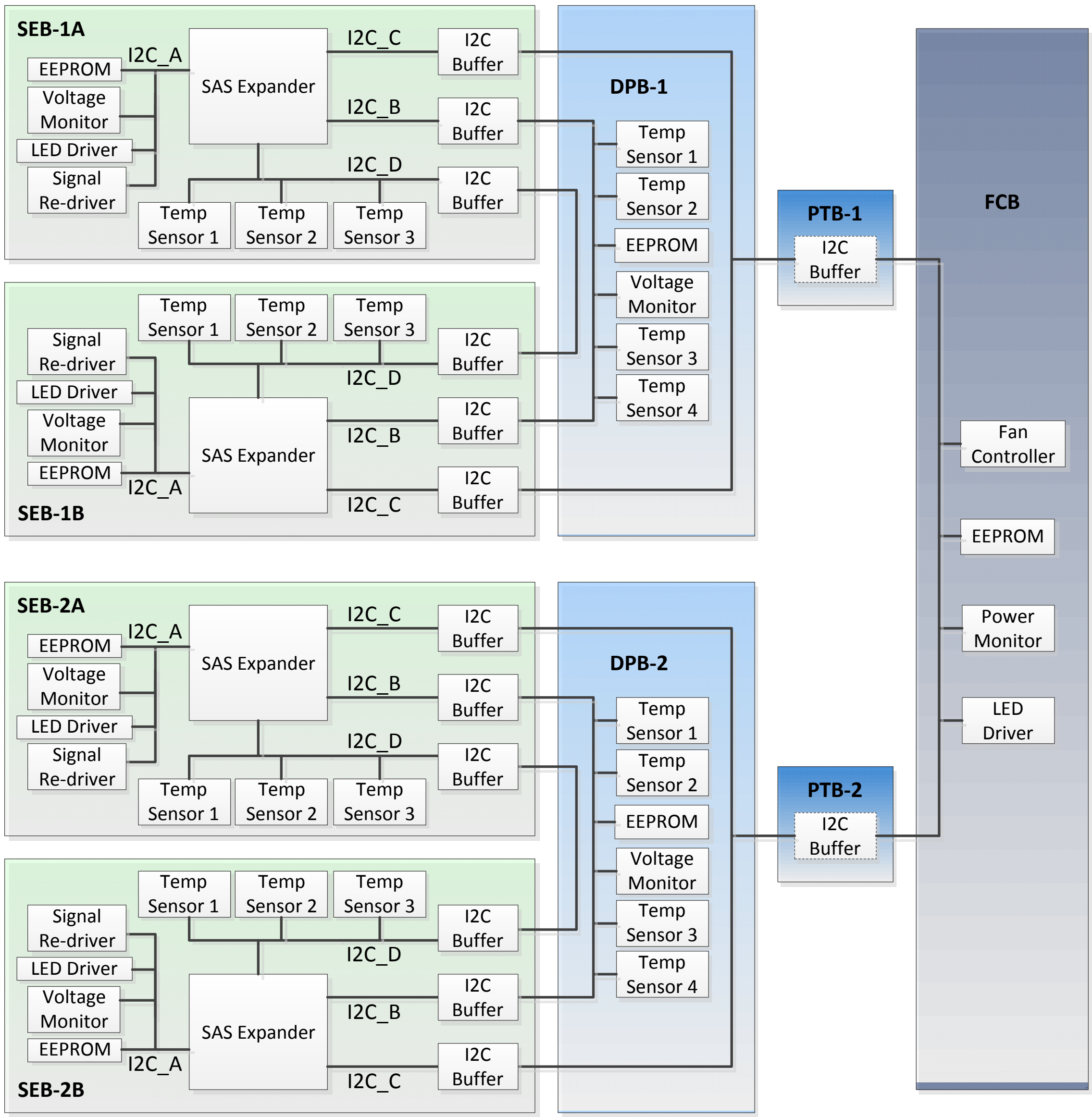

Figure 7 Open Vault System I2C Topology

5 Open Vault SAS Expander Board

5.1 Functional Block Diagram

Figure 8 illustrates the functional block diagram of the Open Vault SAS expander board (SEB), utilizing an LSISAS3x28R 12G SAS expander.

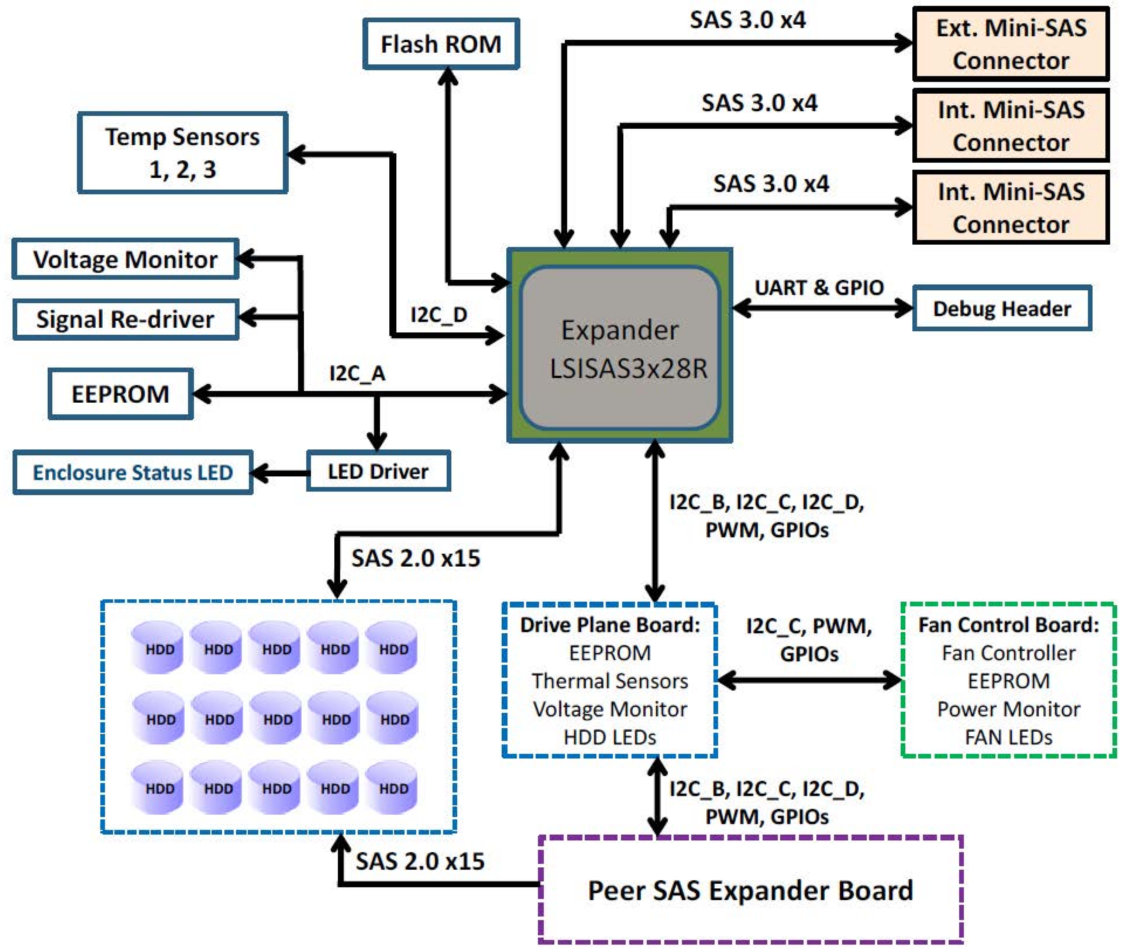

Figure 8 Open Vault LSISAS2108 Block Diagram

5.2 SEB Placement and Form Factor

The SAS expander board (SEB) form factor is 235mm x 195mm. Figure 9 illustrates the board placement. The following devices are placed as close as possible to the front of the SEB for easy access from the front:

- External mini-SAS connector
- Internal mini-SAS connector
- Status LEDs
- Debug header

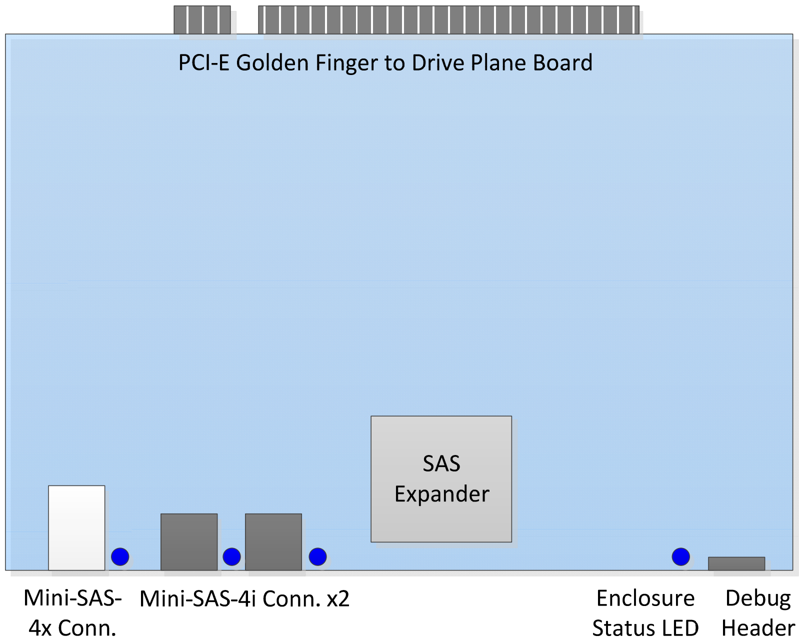

Figure 9 Open Vault SAS Expander Board Placement

5.3 SAS Expander IC

The Open Vault SAS expander board contains a single 12G SAS expander IC, part number LSISAS3x28R. The board design is compatible with LSISAS3x36R and LSISAS3x24R under different configurations.

5.4 Voltage Monitor

A voltage monitor is required for the Open Vault SAS expander board in order to ensure proper operation of all power rails at all times. The voltages are reported as part of the enclosure status as described in section 10.1. The power rails to be monitored are shown in Figure 10.

Power Rail	Voltage
VDDIO33	3.3V
VDDIO	1.8V
VDD	0.9V
VCC for signal re-driver	1.2V

Figure 10 Monitored Power Rails on SEB

5.5 SAS Signal Re-driver

The longest PCB traces are around 600mm (23.7 inches) that connect the SAS expander on the SEB to the farthest two HDDs on the DPB. In order to guarantee signal quality, a signal re-driver may be necessary.

5.6 Connectors

Sections 5.6.1 through 5.6.4 describe the connectors that reside on the Open Vault SAS expander board.

5.6.1 Signal Connector to Drive Plane Board

The Open Vault SAS expander board is designed as a field replaceable unit that interfaces to the drive plane board through an OCP-defined pin-out. The drive plane board-side connectors are two standard straddle-type PCI-E connectors for each SAS expander board. One is an x16 connector (164 pin) and the other is an x1 connector (36 pin), together they provide up to 200 pins. These connectors are mated with 1mm pitch gold finger contacts on the SAS expander board side. The design is capable for 6G SAS signals.

Figure 11 shows the PCI-E 1mm edge golden figures, using 164 pins for the x16 connection as an example. The full connector pin is defined in section 14.1.

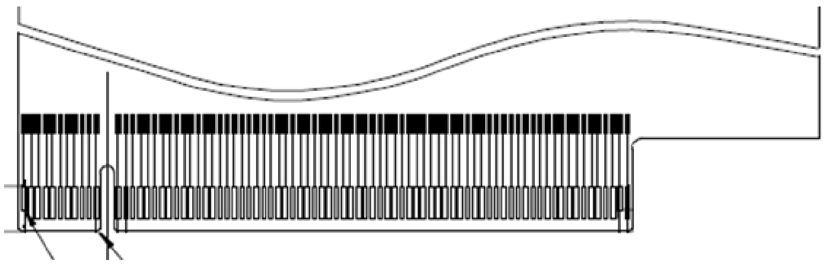

Figure 11 PCI-E 1mm Edge Golden Fingers

5.6.2 External Mini-SAS Connector and Cage

The Open Vault SAS expander board interfaces with a server head node via one external mini-SAS connector. It has an SFF-8088 standard form factor, and is referred to as a Mini-SAS-4x connector. Its part number is G40BR261BEU from AMPHENOL. The connector pin-out is shown in Figure 12.

Pin	Assignment	Pin	Assignment
A1	GND	B1	GND
A2	Rx0P	B2	Tx0P
A3	Rx0N	B3	Tx0N
A4	GND	B4	GND
A5	Rx1P	B5	Tx1P
A6	Rx1N	B6	Tx1N
A7	GND	B7	GND
A8	Rx2P	B8	Tx2P
A9	Rx2N	B9	Tx2N
A10	GND	B10	GND
A11	Rx3P	B11	Tx3P
A12	Rx3N	B12	Tx3N
A13	GND	B13	GND

Figure 12 Mini-SAS-4x Connector Pin-Out

The corresponding EMI cage for Mini-SAS connector is MOLEX 74548-0211, or equivalent part from other vendors.

5.6.3 Internal Mini-SAS Connector

Open Vault SAS expander board can also interface with an upper or lower level cascaded Open Vault (node) via two internal mini-SAS connectors. They are SFF-8087 standard form factor, or referred to as Mini-SAS-4i connectors. The part number is 75783-0012 from Molex. The connector pin-out is shown in Figure 13.

Pin	Assignment	Pin	Assignment
A1	GND	B1	GND
A2	Rx0P	B2	Tx0P
A3	Rx0N	B3	Tx0N
A4	GND	B4	GND
A5	Rx1P	B5	Tx1P
A6	Rx1N	B6	Tx1N
A7	GND	B7	GND
A8	NC	B8	NC
A9	NC	B9	NC
A10	NC	B10	NC
A11	NC	B11	NC
A12	GND	B12	GND
A13	Rx2P	B13	Tx2P
A14	Rx2N	B14	Tx2N
A15	GND	B15	GND
A16	Rx3P	B16	Tx3P
A17	Rx3N	B17	Tx3N
A18	GND	B18	GND

Figure 13 Mini-SAS-4i Connector Pin-Out

5.6.4 Debug Header

The SAS expander board includes a debug header on the front side. It supports hot plugging for an existing debug card. The card is used in Open Compute servers and contains the following functionality:

- Two 7-segment LED displays: Show firmware POST information and system error codes.
- One RS-232 serial connector: Provides console redirection.
- One reset switch: Triggers a system reset when pressed.

The connector for the debug header is a 14-pin, shrouded, right-angled, 2mm pitch connector. Figure 14 shows an illustration. The debug card has a key to match with the notch to avoid pin shift when plugging it in.

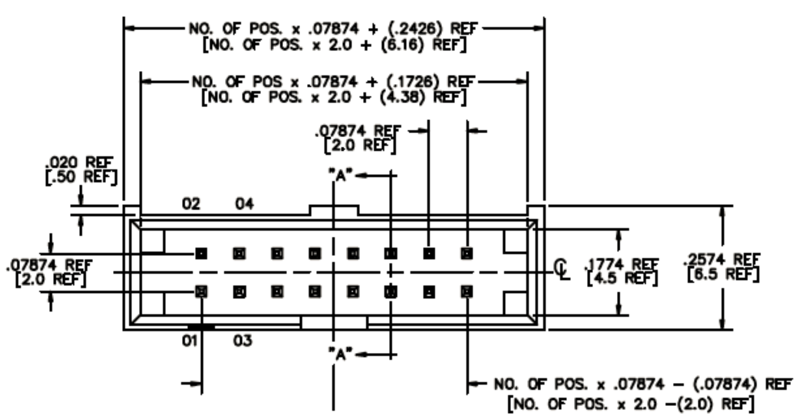

Figure 14 Debug Header

Figure 15 lists the pin definition of the debug header:

Pin (CKT)	Function
1	Low HEX character [0] least significant bit
2	Low HEX character [1]
3	Low HEX character [2]
4	Low HEX character [3] most significant bit
5	High HEX character [0] least significant bit
6	High HEX character [1]
7	High HEX character [2]
8	High HEX character [3] most significant bit
9	Serial Transmit
10	Serial Receive
11	System Reset
12	Serial Port Select (1=Console; 0=Debug)
13	GND
14	VCC (5VDC)

Figure 15 Debug Header Pin-out

5.7 LEDs

The SAS expander board has several LEDs on its front edge to display various types of information:

- One (1) bi-color (blue/red) for enclosure status
- One (1) bi-color (blue/red) for each mini-SAS port link status

Figure 16 and Figure 17 summarize the behavior of the LEDs.

Enclosure Status	Blue LED	Red LED
Normal system operation	ON	OFF
Any fault in whole enclosure	OFF	ON
Tray Identify	Flashing	OFF
Reserved for future use	OFF	Flashing

Figure 16 Front Panel LED for Enclosure Status

Mini-SAS Port Link Status	Blue LED	Red LED
SAS links (x4) health	ON	OFF
Loss of SAS links (x1 ~ x 3)	OFF	ON
No SAS links	OFF	OFF

Figure 17 Front Panel LED For Mini-SAS Port Links

5.8 PCB Stack-up

The PCB stack-up and impedance control for the SAS expander board are defined in Figure 18 and Figure 19 below.

Layer	Plane Description	Copper Weight (oz)	Thickness (mil)	Dielectric (er)

		Solder Mask		0.5	3.8
L1	TOP	Signal	0.5 + 1.0	1.9	
		PrePreg		2.7	3.5
L2	GND1	Ground	2.0	2.6	
		Core		4.0	3.7
L3	IN1	Signal	1.0	1.3	
		PrePreg		13.6	4.4
L4	VCC1	Power	2.0	2.6	
		Core		4.0	4.1
L5	VCC2	Power	2.0	2.6	
		PrePreg		13.6	4.4
L6	IN2	Signal	1.0	1.3	
		Core		4.0	3.7
L7	GND2	Ground	2.0	2.6	
		PrePreg		2.7	3.5
L8	BOT	Signal	0.5 + 1.0	1.9	
		Solder Mask		0.5	3.8
		Total		62.4	Tolerance: +/-6mil

Figure 18 PCB Stack-up for SAS Expander Board

Trace Width (mil)	Air Gap Spacing (mil)	Impedance Type	Layer	Impedance Target (ohm)	Tolerance (+/- %)
4.0		Single	1, 8	50	15.0
4.0	9.0	Differential	1, 8	100	15.0
4.5		Single	3, 6	50	10.0
4.0	8.0	Differential	3, 6	100	10.0

Figure 19 PCB Impedance Control for SAS Expander Board

6 Open Vault Drive Plane Board

6.1 Functional Block Diagram

Figure 20 illustrates the functional block diagram of the drive plane board (DPB).

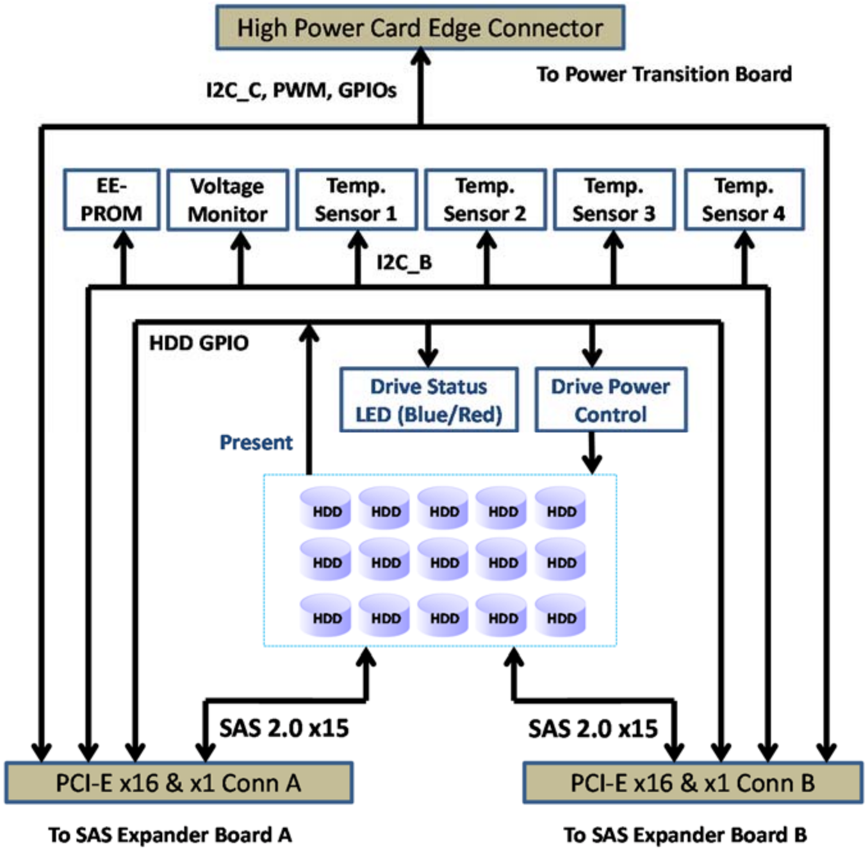

Figure 20 Open Vault Drive Plane Board Block Diagram

6.2 DPB Placement and Form Factor

The drive plane board form factor is 270mm x 510mm. Figure 21 illustrates the board placement.

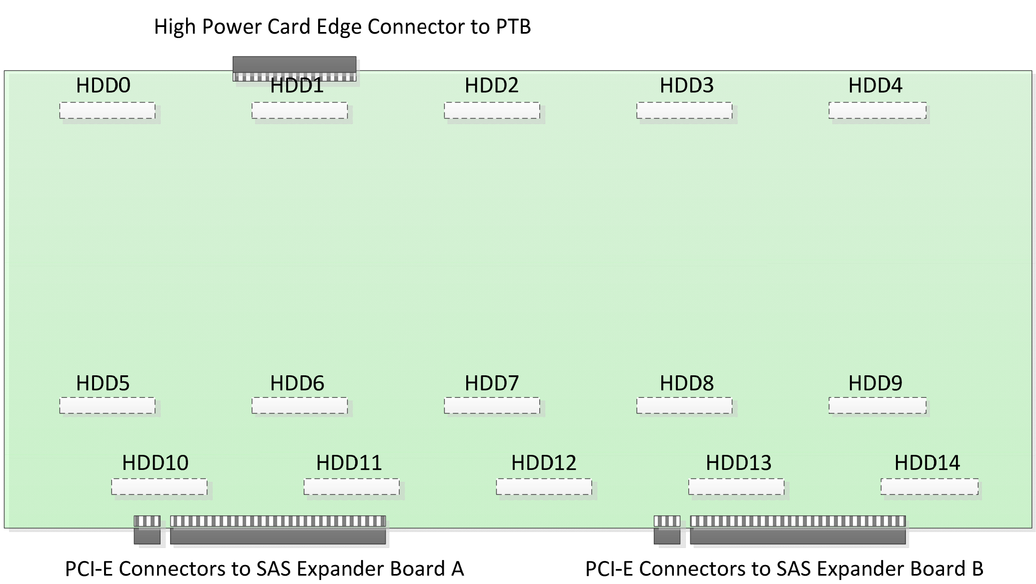

Figure 21 Open Vault Drive Plane Board Placement

6.3 DPB HDD Port Mapping

The HDD port mapping is the correlation between physical HDD slot number on DPB and the logic number of SAS expander Phy from SEB. This is determined by two factors: 1), pin definition on PCI-E connectors between SEB and DPB; 2), layout implementation or PCB trace routing on DPB. Figure 22 shows the HDD port mapping from SEB A side, Figure 23 shows the SEB B side.

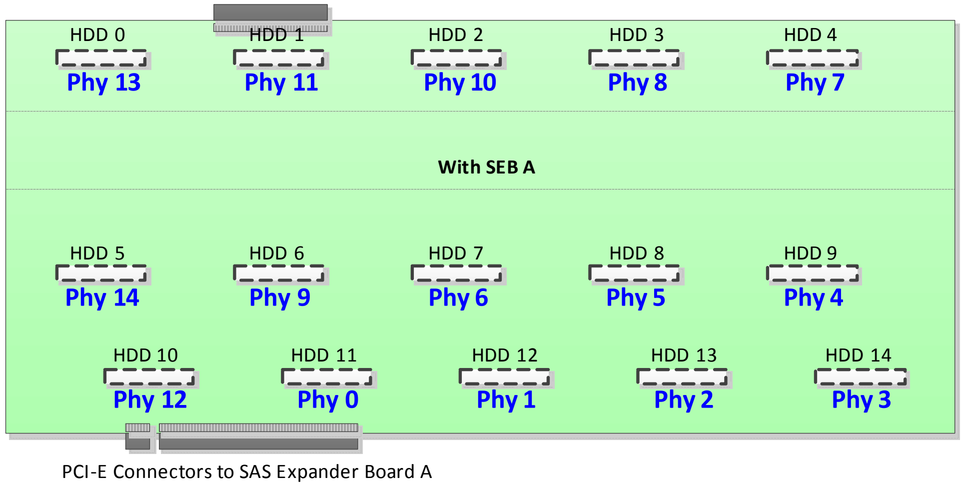

Figure 22 Open Vault DPB HDD Port Mapping on A-side

Figure 23 Open Vault DPB HDD Port Mapping on B-side

6.4 12.5V to 5V Buck Converter

In order to provide a 5V power rail to the hard disk drives, there is one 12.5V to 5V buck converter on the drive plane board for each group of 5 HDDs. Its efficiency is 93% at nominal load. For more information about the HDD power design, see section 9.3.

6.5 Disk Drive Power Control

Both 12V and 5V power rails to each disk drive are independently controlled through management software. For more information, see section 9.4.

6.6 Voltage Monitor

A voltage monitor ensures proper operation of all power rails at all times. The voltages are reported as part of the enclosure status as described in section 10.1. The voltage rails that are monitored are shown in Figure 24.

Power Rail	Voltage
5V to HDD group A	5V
5V to HDD group B	5V
5V to HDD group C	5V
12V to all HDDs & SEBs	12V

Figure 24 Monitored Voltage Rails on DPB

6.7 Connectors and Cables

Sections 6.7.1 through 6.7.3 describe the connectors and cables that reside on the Open Vault drive plane board.

6.7.1 Signal Connector to SAS Expander Board

The interfaces from the SAS expander board to the drive plane board are through two PCI-E connectors: one is an x16 connector (164 pin from Amphenol, part number G630HAA12248EU), and the other is an x1 connector (36 pin from Amphenol, part number G630H3612248EU). These straddle-type connectors are mated with 1mm pitch gold finger contacts on the SAS expander board side and are PCI-E Gen3 capable.

Due to the large number of signals, the full connector pin definition is provided in 14.2.

6.7.2 Power and Signal Connector to Power Transition Board

A high power card edge connector on the drive plane board receives 12.5V power from the power transition board. To minimize contact resistance, 36 power contacts are applied. It also contains 24 signal pins that are used for I2C, PWM and other GPIOs. The part number is GPCE54362413HR from Amphenol. Figure 25 and Figure 26 show the pin-out.

Pin	Assignment	Pin	Assignment
P1	12.5V	P19	GND
P2	12.5V	P20	GND
P3	12.5V	P21	GND
P4	12.5V	P22	GND
P5	12.5V	P23	GND
P6	12.5V	P24	GND
P7	12.5V	P25	GND
P8	12.5V	P26	GND
P9	GND	P27	GND
P10	GND	P28	GND
P11	GND	P29	12.5V
P12	GND	P30	12.5V
P13	GND	P31	12.5V
P14	GND	P32	12.5V
P15	GND	P33	12.5V
P16	GND	P34	12.5V

P17	GND	P35	12.5V
P18	GND	P36	12.5V

Figure 25 Drive Plane Board Power and Signal Connector Pin-out, Power Portion

Pin	Assignment	Pin	Assignment
S1	GND	S13	GND
S2	3.3V	S14	Self SEB A Heart-beat
S3	3.3V	S15	Self SEB B Heart-beat
S4	Peer Tray Present	S16	Tray ID
S5	PWM from expander B	S17	FCB Hardware Revision
S6	Self Tray Present	S18	Shutdown Latch Release
S7	PWM from expander A	S19	GND
S8	GND	S20	Peer SEB A Heart-beat
S9	I2C_C SDA	S21	Peer SEB B Heart-beat
S10	GND	S22	GND
S11	I2C_C SCL	S23	GND
S12	GND	S24	5V (Reserved)

Figure 26 Drive Plane Board Power and Signal Connector Pin-out, Signal Portion

6.7.3 SAS HDD Connectors

The Open Vault drive plane board supports hot plugging of hard disk drives using a blind mate, standard SAS interface, right-angle connector (an SMT connector from Molex, part number 87945-0001). The mating height is standard (7.07mm) according to the Open Vault HDD tray design.

Pin	Assignment	Pin	Assignment
P1	3.3V_Precharge	S1	GND
P2	3.3V	S2	Tx1P
P3	3.3V	S3	Tx1N
P4	GND	S4	GND
P5	GND	S5	Rx1N
P6	GND	S6	Rx1P
P7	5V_Precharge	S7	GND
P8	5V	S8	GND
P9	5V	S9	Tx2P
P10	GND	S10	Tx2N
P11	Ready_LED	S11	GND
P12	GND	S12	Rx2N
P13	12V_Precharge	S13	Rx2P
P14	12V	S14	GND
P15	12V		

Figure 27 SAS HDD Connector Pin-out

6.8 LEDs

On the drive plane board, each hard disk drive has one bi-color LED to indicate its status, both driven by SAS expander chip:

- When the HDD is online and healthy, the blue LED turns on;
- When any fault for the HDD occurs, the red LED turns on;
- When the HDD is not inserted, both LEDs turn off;
- When HDD is powered off, toggle the LED between blue and red.

Each drive's LEDs are located near the corresponding drive's cage and clearly visible from the top when HDD tray is pulled out. If needed, an optical path for the drive status LEDs can be provided for easy access by users.

Figure 28 summarizes the conditions the LEDs are to represent:

Disk Drive Status	Blue LED	Red LED
No Drive Inserted	OFF	OFF
Drive Online and Healthy	ON	OFF
Drive Failure	OFF	ON
Drive Power Off	Toggle	Toggle

Figure 28 Drive Plane Board LED for HDD Status

6.9 PCB Stack-up

The PCB stack-up and impedance control for drive plane board are defined in Figure 29 and Figure 30 below.

Layer	Plane Description		Copper Weight (oz)	Thickness (mil)	Dielectric (er)
		Solder Mask		0.5	3.8
L1	TOP	Signal	0.5 + 1.0	1.9	
		PrePreg		2.7	3.5
L2	GND1	Ground	2.0	2.6	
		Core		4.0	3.7
L3	IN1	Signal	1.0	1.3	
		PrePreg		13.6	4.4
L4	VCC1	Power	2.0	2.6	
		Core		4.0	4.1
L5	VCC2	Power	2.0	2.6	
		PrePreg		13.6	4.4
L6	IN4	Signal	1.0	1.3	
		Core		4.0	3.7
L7	GND2	Ground	2.0	2.6	
		PrePreg		2.7	3.5
L8	BOT	Signal	0.5 + 1.0	1.9	
		Solder Mask		0.5	3.8
		Total		85.2	Tolerance: +/-8mil

Figure 29 PCB Stack-up for Drive Plane Board

Trace Width (mil)	Air Gap Spacing (mil)	Impedance Type	Layer	Impedance Target (ohm)	Tolerance (+/- %)
4.0		Single	1, 8	50	15.0
4.0	9.0	Differential	1, 8	100	15.0
4.5		Single	3, 6	50	10.0
4.0	8.0	Differential	3, 6	100	10.0

Figure 30 PCB Impedance Control for Drive Plane Board

7 Open Vault Power Transition Board

The Open Vault power transition board (PTB) is located on the rear side of the HDD tray. It is connected to the drive plane board by a high powered card edge connector. Another power and signal connector connects the PTB to the fan control board (FCB). Tray pull-out detection circuits are located on the rear side of the PTB.

7.1 Functional Block Diagram

Figure 31 illustrates the functional block diagram of the power transition board.

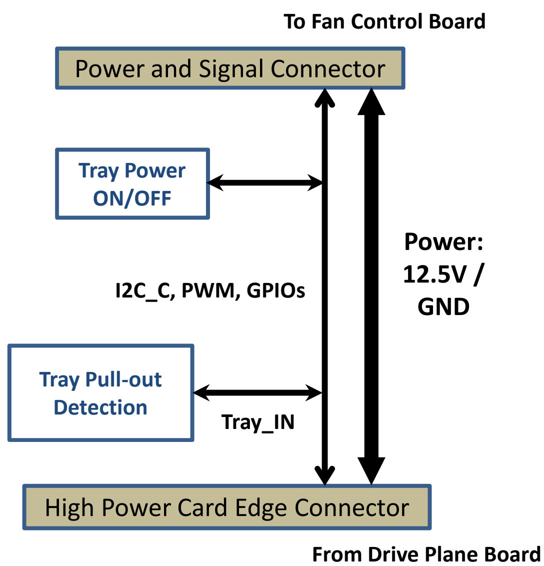

Figure 31 Power Transition Board Functional Block Diagram

7.2 PTB Placement and Form Factor

The power transition board form factor is 120mm x 175mm. Figure 32 illustrates the board placement.

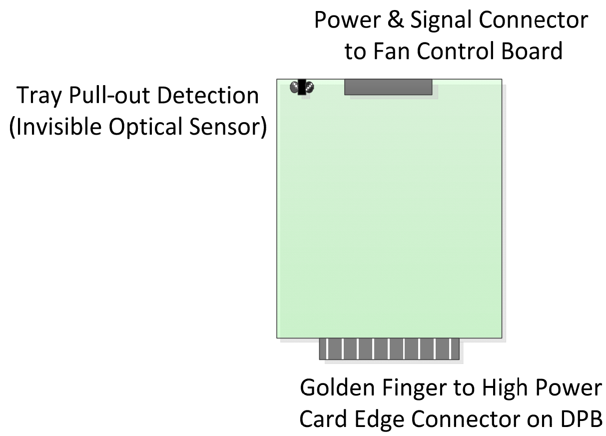

Figure 32 Open Vault Power Transition Board Placement

7.3 Tray Pull-out Detection

A pair of invisible-light optical sensors is used for tray pull-out detection, together with a mechanical flag in between. Related circuits are shown in Figure 33 below. The emitter is SFH426 from OSRAM; and the detector is SFH325 also from OSRAM.

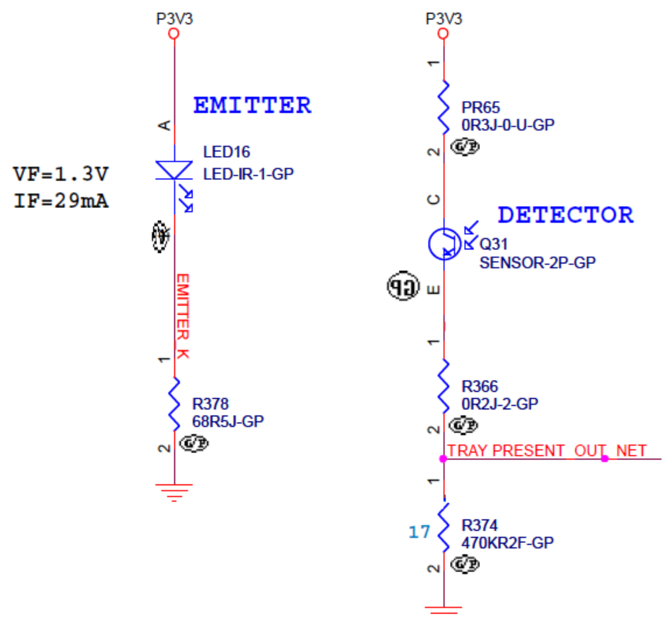

Figure 33 Circuits of Tray Pull-out Detection

7.4 Connectors and Cables

7.4.1 Golden Finger to High Power Card Edge Connector on Drive Plane Board

Golden fingers are designed on the PTB to mate with the high power card edge connector on the DPB. They total 36 power contacts and 24 low speed signals. Figure 34 shows the PCB footprint. For detailed pin definition, refer to 6.7.2.

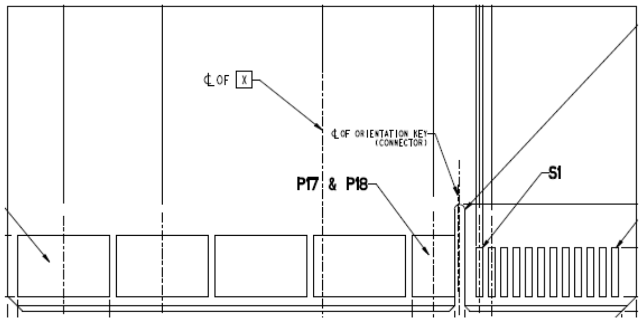

Figure 34 Golden Finger on PTB to DPB

7.4.2 Power and Signal Connector to Fan Control Board

A power blade type connector is used for the power and signals between the PTB and the FCB. It contains four power blades and 20 signal pins. A latch secures the connectors and cables on both ends. The part number of this right-angled power and signal connector on the PTB is 51939-689 from FCI. Figure 35 to Figure 37 show the pin-out.

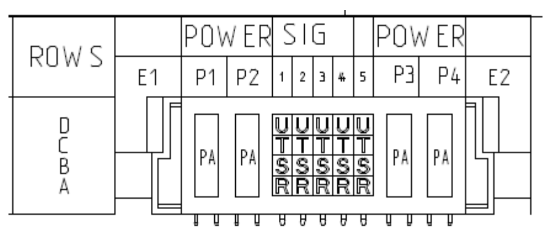

Figure 35 Power and Signal Connector Pin Assignment

Pin	Description
P1	12.5V
P2	12.5V
P3	GND
P4	GND

Figure 36 Power and Signal Connector Pin Definition on PTB, Power Portion

Pin	Assignment	Pin	Assignment
A1	I2C_C SDA	C1	Tray Power Enable_1
A2	GND	C2	Tray Power Enable_2
A3	I2C_C SCL	C3	Self SEB A Heart-beat
A4	GND	C4	Peer SEB A Heart-beat
A5	PWM from expander B	C5	Peer SEB B Heart-beat
B1	GND	D1	Peer Tray Present
B2	PWM from expander A	D2	Tray ID
B3	GND	D3	FCB Hardware Revision
B4	Self SEB B Heart-beat	D4	Shutdown Latch Release
B5	GND	D5	Self Tray Present

Figure 37 Power and Signal Connector Pin Definition on PTB, Signal Portion

7.4.3 Power and Signal Cable to Fan Control Board

Between the PTB and FCB there are 4 power cables (12 AWG) and 20 signal cables (26 AWG). The cable assembly part number is 10080594-3KC0382LF from FCI.

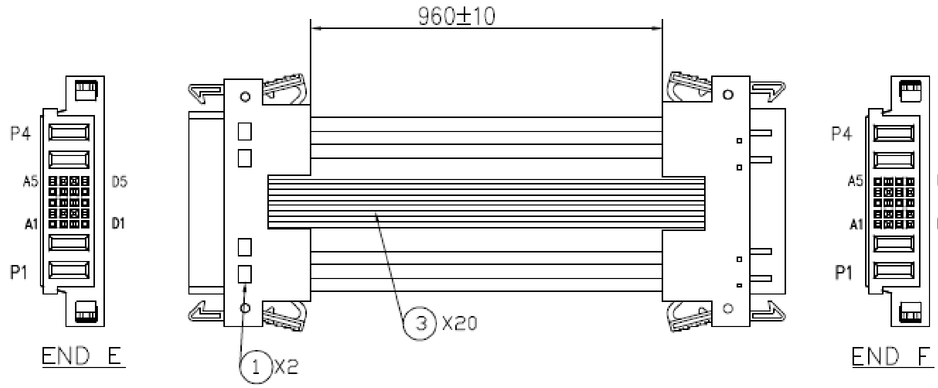

Figure 38 Power and Signal Cable from PTB to FCB

7.5 PCB Stack-up

The PCB stack-up and impedance control for power transition board are defined in the following figures.

Layer	Plane Description		Copper Weight (oz)	Thickness (mil)	Dielectric (er)
		Solder Mask		0.5	3.4
S1	TOP	Signal	0.5 + 1.0	1.7	
		PrePreg		3.5	3.7
P2	PLANE	Power / GND	2.0	2.6	
		Core		47.0	4.2
P3	PLANE	Power / GND	2.0	2.6	
		PrePreg		3.5	3.7
S4	BOT	Signal	0.5 + 1.0	1.7	
		Solder Mask		0.5	3.4
		Total		63.6	Tolerance: +/-6 mil

Figure 39 PCB Stack-up for Power Transition Board

Trace Width (mil)	Air Gap Spacing (mil)	Impedance Type	Layer	Impedance Target (ohm)	Tolerance (+/- %)
5.5		Single	1, 4	50	15.0

Figure 40 PCB Impedance Control for Power Transition Board

8 Open Vault Fan Control Board

The Open Vault fan control board (FCB) is fixed and located at the rear of the system. A pair of bus bar clips connects the Open Vault to the bus bar from the Open Rack, to feed in the main 12V power rail to the fan control board via FusionLug cables. Another connector conducts the 12V power to the power transition board through a high strand power cable. A hardware monitor and PWM comparator work together with control signals from the SAS expander(s) for the fan speed control, according to the cooling requirements of the whole storage enclosure.

8.1 Functional Block Diagram

Figure 41 illustrates the functional block diagram of the fan control board (FCB).

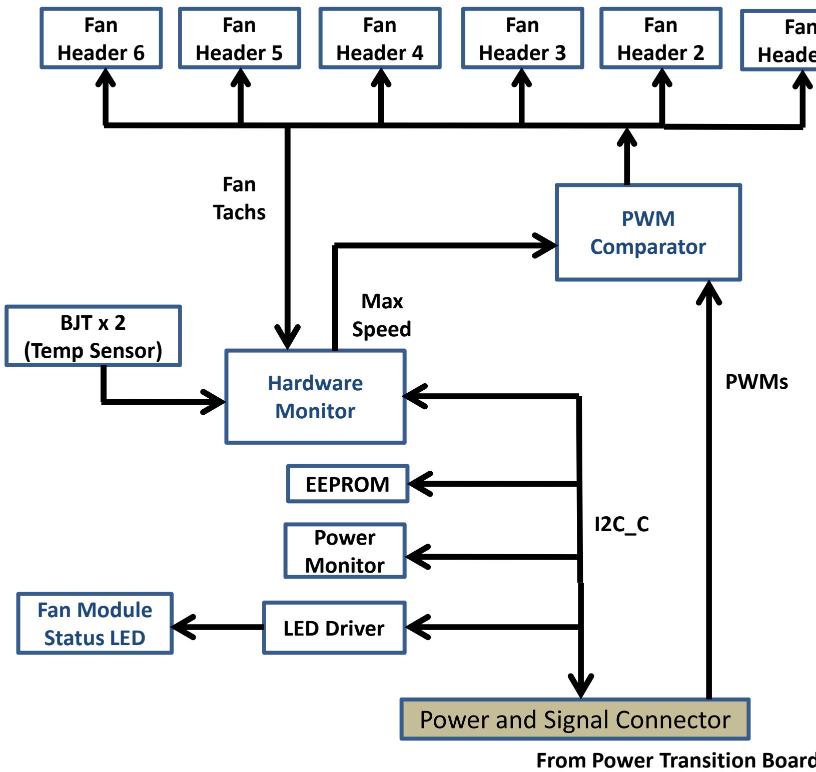

Figure 41 Fan Control Board Functional Block Diagram

8.2 FCB Placement and Form Factor

The fan control board (FCB) form factor is 500mm x 51mm. Figure 42 illustrates the board placement. The ODM is responsible for complete component placement.

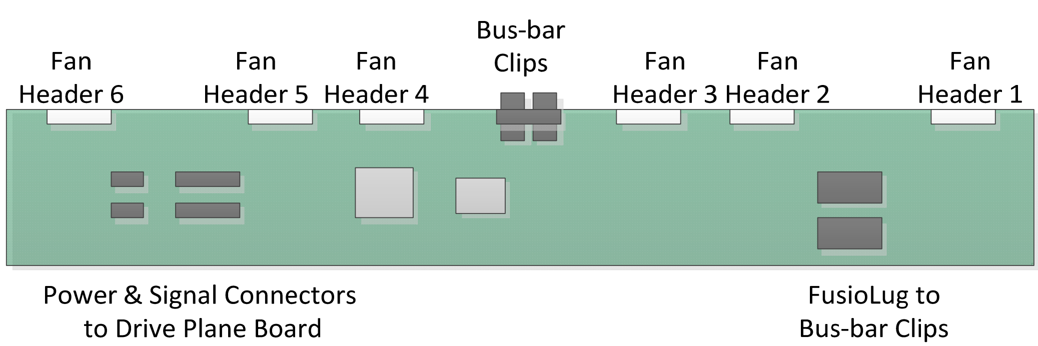

Figure 42 Open Vault Fan Control Board Placement

8.3 Embedded Fan Controller

An embedded fan controller is installed on the fan control board. Its part number is NCT7904D from Nuvoton. The main features of this fan controller are:

- Monitors fan tachometer signals;
- Monitors the local temperature of the FCB;
- Monitors the voltage rails on FCB, as Figure 43 shows.

Power Rail	Voltage
V12_input	12V
V12_upper_tray	12V
V12_lower_tray	12V
V3.3_FCB	3.3V

Figure 43 Monitored Voltage Rails on the FCB

8.4 Input Power Monitor

There is an input power monitor on the fan control board. It monitors the input current and voltage, reporting input power numbers to the SAS expander chip via the I2C interface. It also protects the system from over current, over voltage and under voltage cases. The monitor is part number ADM1276 from Analog Devices.

8.5 Connectors

8.5.1 Power and Signal Connector to Power Transition Board

Power and signals to the power transition board from the fan control board are conducted via a power plus signal cable assembly; the vertical connector on the fan control board is from FCI, part number 51952-220. A latch secures the connectors and cables on both ends. The pin count is 4 for power and 20 for signals. Detailed definitions are listed in Figure 44 and Figure 45.

Pin	Assignment on Upper Tray	Assignment on Lower Tray
A1	I2C_C SDA	I2C_C SDA
A2	GND	GND
A3	I2C_C SCL	I2C_C SCL
A4	GND	GND
A5	PWM from expander 1B	PWM from expander 2B
B1	GND	GND
B2	PWM from expander 1A	PWM from expander 2A
B3	GND	GND
B4	SEB 1B Heartbeat	SEB 2B Heartbeat
B5	GND	GND
C1	Upper Tray Power Enable_1	Lower Tray Power Enable_1
C2	Upper Tray Power Enable_2	Lower Tray Power Enable_2
C3	SEB 1A Heartbeat	SEB 2A Heartbeat
C4	SEB 2A Heartbeat	SEB 1A Heartbeat
C5	SEB 2B Heartbeat	SEB 1B Heartbeat
D1	Lower Tray Present	Upper Tray Present
D2	1 (for Upper Tray ID)	0 (for Lower Tray ID)

D3	FCB Hardware Revision	FCB Hardware Revision
D4	Shutdown Latch Release	Shutdown Latch Release
D5	Upper Tray Present	Lower Tray Present

Figure 44 Pin-out of Connectors from FCB to PTBs, Signal Portion

Pin	To Upper Tray	To Lower Tray
P1	12.5V	12.5V
P2	12.5V	12.5V
P3	GND	GND
P4	GND	GND

Figure 45 Pin-out of Connectors from FCB to PTBs, Power Portion

8.5.2 Bus Bar Clips to Open Rack Bus Bar

The bus bar clip assembly comprises a floating carrier plate, allowing for lateral and vertical (X and Y directions as viewed from the cold aisle) misalignment of the chassis and bus bars. This carrier plate is connected to the fan control board (FCB) by a pair of 6AWG cables. The bus bar clip is part number C5313-07352-00107 from Methode.

The connector matches the bus bar on the Open Rack.

The bus bar clip assembly is shown in Figure 46, and its pin definition is in Figure 47.

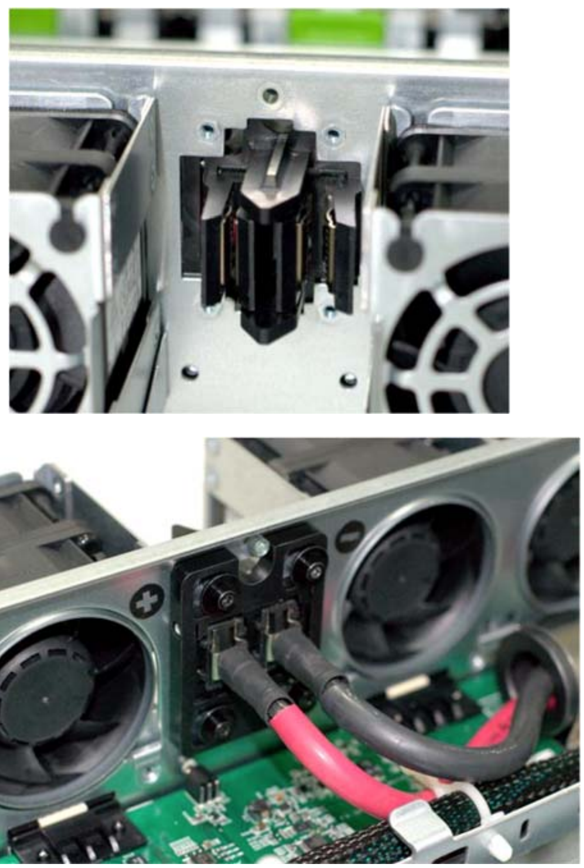

Figure 46 Bus Bar Connector to Open Rack

Pin	Description
1	12.5V
2	GND

Figure 47 Pin-out of Bus Bar Connector to Open Rack

8.5.3 Fan Module Connector

Each Open Vault fan control board is connected to 6 fan modules. Each fan module contains one dual rotor fan. One hot-pluggable right angle 2.54mm pitch connector is used (the pin definition is in Figure 48). Its part number is 22-05-1052 from Molex.

Pin	Description
1	Tachometer 1
2	PWM
3	Tachometer 2
4	12VDC
5	GND

Figure 48 Fan Connector Pin-out

8.6 LEDs

The fan control board has six bi-color LEDs on its edge to display the fan module status, one for each fan module and fault.

Fan Module Status	Blue LED	Red LED
Normal operation	ON	OFF
Fan module fault	OFF	ON

Figure 49 Rear Panel LED for Fan Module Status

8.7 PCB Stack-up

The PCB stack-up and impedance control for the fan control board are defined in the following tables.

Layer	Plane Description		Copper Weight (oz)	Thickness (mil)	Dielectric (er)
		Solder Mask		0.5	3.4
S1	TOP	Signal	0.5 + 1.0	1.7	
		PrePreg		3.5	3.7
P2	PLANE	Power / GND	2.0	2.6	
		Core		47.0	4.2
P3	PLANE	Power / GND	2.0	2.6	
		PrePreg		3.5	3.7
S4	BOT	Signal	0.5 + 1.0	1.7	
		Solder Mask		0.5	3.4
		Total		63.6	Tolerance: +/-6 mil

Figure 50 PCB Stack-up for Fan Control Board

Trace Width (mil)	Air Gap Spacing (mil)	Impedance Type	Layer	Impedance Target (ohm)	Tolerance (+/- %)
5.5		Single	1, 4	50	15.0

Figure 51 PCB Impedance Control for Fan Control Board

9 Open Vault Power System

9.1 System Power Budget

Overall power consumption of the Open Vault storage system is approximately 600W:

- In full-load operation under maximum ambient temperature (35°C) with automatic fan speed control, Open Vault continuous power consumption is approximately 500W.
- In idle operation and room temperature, Open Vault continuous power consumption is approximately 300W.
- During system startup, with HDDs in a grouped spin-up strategy (in 5 groups for example), Open Vault transitory power consumption is about 400W.
- In the extreme worst case (for example, all 30 HDDs fully stressed and all six fans running at maximum speed), the maximum continuous power consumption of Open Vault is around 600W.

Figure 52 shows the Open Vault system power budget calculation in full-load operation, based on each module.

Item	Quantity in 1 System	Power Consumption/ Module (W)	Subtotal for All Modules (W)	Derating %	Power Consumption after Derating (W)
HDD	30	14	420	90%	378
Drive Plane Board	2	9	18	90%	16.2
SAS Expander Board	2	15.6	54	90%	48.6
Fan Control Board	1	6	6	90%	5.4
Fan Module	6	18	108	55%	59.4
Total			606		507.6

Figure 52 Open Vault System Power Budget in Full Load

Figure 53 shows the Open Vault system power budget calculation in idle mode, based on each module.

Item	Quantity in 1 System	Power Consumption/ Module (W)	Subtotal for All Modules (W)	Derating %	Power Consumption after Derating (W)
HDD	30	7.5	225	100%	225
Drive Plane Board	2	9	18	60%	10.8
SAS Expander Board	2	27	54	70%	37.8

Fan Control Board	1	6	6	60%	3.6
Fan Module	6	18	108	30%	32.4
Total			411		309.6

Figure 53 Open Vault System Power Budget in Idle Mode

9.2 SEB Bulk Converter Solutions

Both the 12V to 3.3V and the 12V to 0.9V buck converters residing on the SAS expander board have 93% efficiency under normal load. The ODM determines their components.

9.3 Hard Drive 5V Power Design

9.3.1 Hard Drive 5V Power Requirements

The drive plane board passes through the system power (nominal 12VDC) to the hard disk drives. It also contains voltage regulators to generate 5VDC for the HDDs from 12VDC. The total 5V current for each HDD tray is about 18A maximum. In order to improve reliability, the 15 HDDs on each drive tray are divided into three groups, as shown in Figure 54.

A VR generates 5VDC for each HDD group and maximizes the efficiency of the drive plane board. The output current of each VR is about 6A.

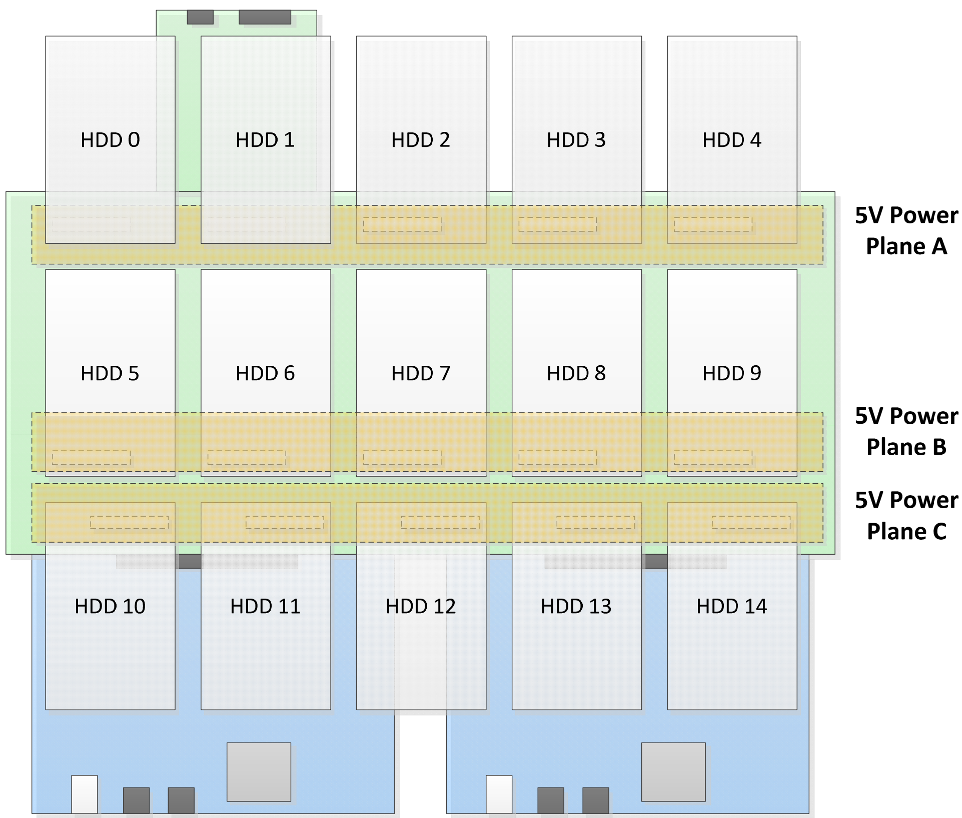

Figure 54 5V Power Rail Design on Fan Control Board

The drive plane board design ensures that the PCB traces and power planes are wide/thick enough to support the required continuous power as well as the inrush current to start the drive from idle. The 5VDC regulator supports the additional inrush current required by each drive as well.

9.3.2 5V Output Protection

The 5V output power regulator protects against shorts and overload conditions. The protection mode is achieved using a constant current system.

9.3.3 12V to 5V Bulk Converter

The 5V buck converter residing on the fan control board has 93% efficiency under normal load. The ODM determines their components.

9.4 Disk Drive Power Control

In order to control both 12V and 5V power rails to each hard disk drive independently through a GPIO, proper MOSFETs (metal-oxide semiconductor field-effect transistors) and related circuits are included. The ODM is responsible for the implementation details and ensures the reliability.

9.5 Power-on Sequencing

The SAS expander chips power on in sequence without any violations, and ensure power cycling with adequate reliability.

The use of a power button is not required to power on. The system always resumes operation upon restoration of power during a power failure event.

10 Enclosure Management Firmware

The ODM is responsible for creating and supporting the firmware to execute all enclosure management features described in the following sections. The ODM is also responsible for creating a set of diagnostic commands that is capable of providing status summary and device information details to a user terminal.

10.1 Enclosure Service Functionalities

Listed below is a high-level enclosure service functional specification of the Open Vault. Refer to section 10.2 for more information.

- External management interfaces:
  - SES commands
  - Diagnostics CLI
- I/O connectivity and PHY control / monitoring:
  - SMP functions
  - PHY error counters
  - Topology discovery and routing table management
  - Staggered disk drive spin-up
- General enclosure management features:
  - Redundant enclosure service processes
  - Power monitoring and control
  - Intelligent cooling fan control scheme
- Reliability, availability and serviceability:
  - Power on self-test
  - Enclosure event log
  - EEPROM contents update for each field replaceable unit

- o Firmware in-system upgrade for each SAS expander
- o One command / script to upgrade firmware for all HDDs

10.2 Enclosure Status Output File

A SCSI Enclosure Service (SES) is the service that establishes the mechanical environment, electrical environment, and external indicators and controls for the proper operation and maintenance of devices within an enclosure. SES data is transported in-band to and from the application client.

SES pages are accessed via the SCSI commands SEND DIAGNOSTICS (control pages) and RECEIVE DIAGNOSTIC RESULTS (status pages).

The Open Vault JBOD ("just a bunch of drives") system applies a standalone enclosure service process model that can be accessed by an external host directly via the data channel. Management software running on the host uses "polling" as the reporting method when managing the Open Vault JBOD system. Asynchronous event notification is **not** supported.

Please refer to Figure 55 for supported SES pages and Figure 56 for supported SMP functions. The ODM is responsible for more detailed design specifications, such as SES element definition, and so forth.

Page Code	Page Name
00h	Supported Diagnostic Pages
01h	Configuration
02h	Enclosure Control
	Enclosure Status
04h	String Out
	String In
05h	Threshold Out
	Threshold In
07h	Element Descriptor
0Ah	Additional Element Status
0Eh	Download Microcode Control
	Download Microcode Status

Figure 55 Supported SES Pages

SMP Function	Function Field Code
Report general	00h
Report manufacturing information	01h
Discover	10h
Report PHY error log	11h
Report PHY SATA	12h
PHY control	91h

Figure 56 Supported SMP Functions

10.3 Fan Speed Control

The Open Vault enclosure thermal management system supports two schemes:

- One scheme is to control fan power management by each SAS expander chip itself with thermal sensors; a PWM comparator on the FCB selects the maximum PWM value from the four SAS expanders and drives the fans.
- The other scheme is each expander chip only reports all temperature values to the host server; the host server calculates suitable PWM numbers and controls fan speed via SES commands sent to the SAS expander(s).

Figure 57 shows the temperature sensors' location within the Open Vault system.

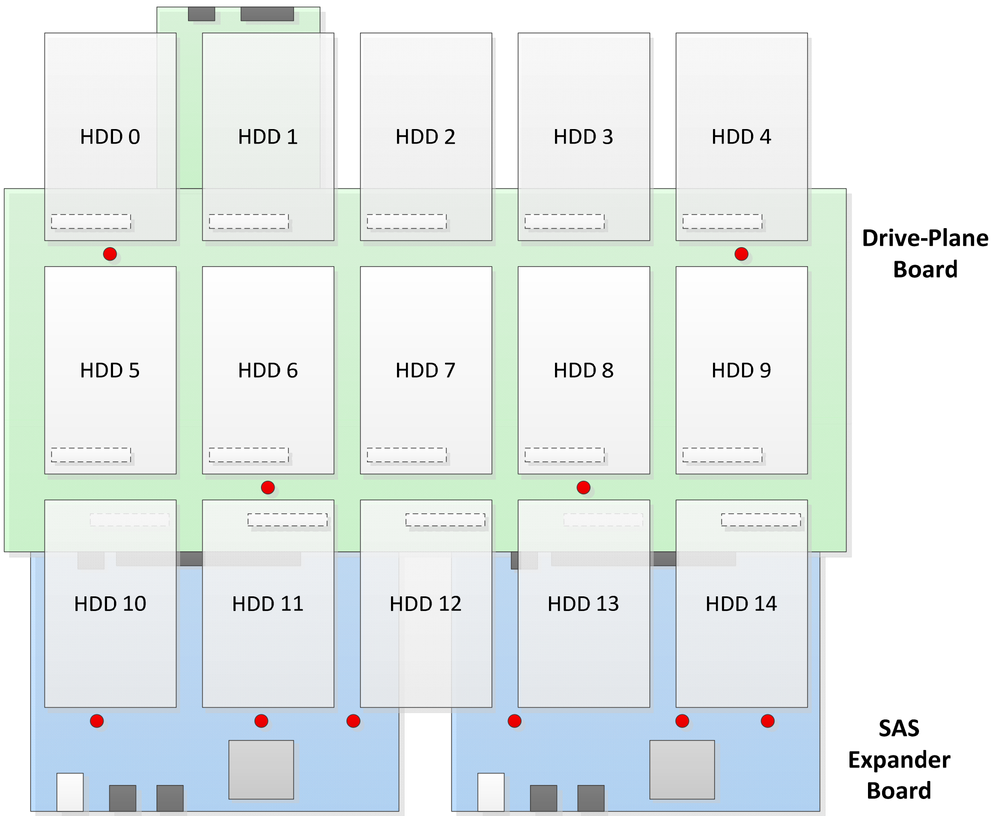

Figure 57 Open Vault System Thermal Sensor Locations

The ODM provides a detailed implementation of the fan speed control requirements. Figure 58 shows the high-level strategy of Open Vault fan speed control executed by firmware in each SAS expander.

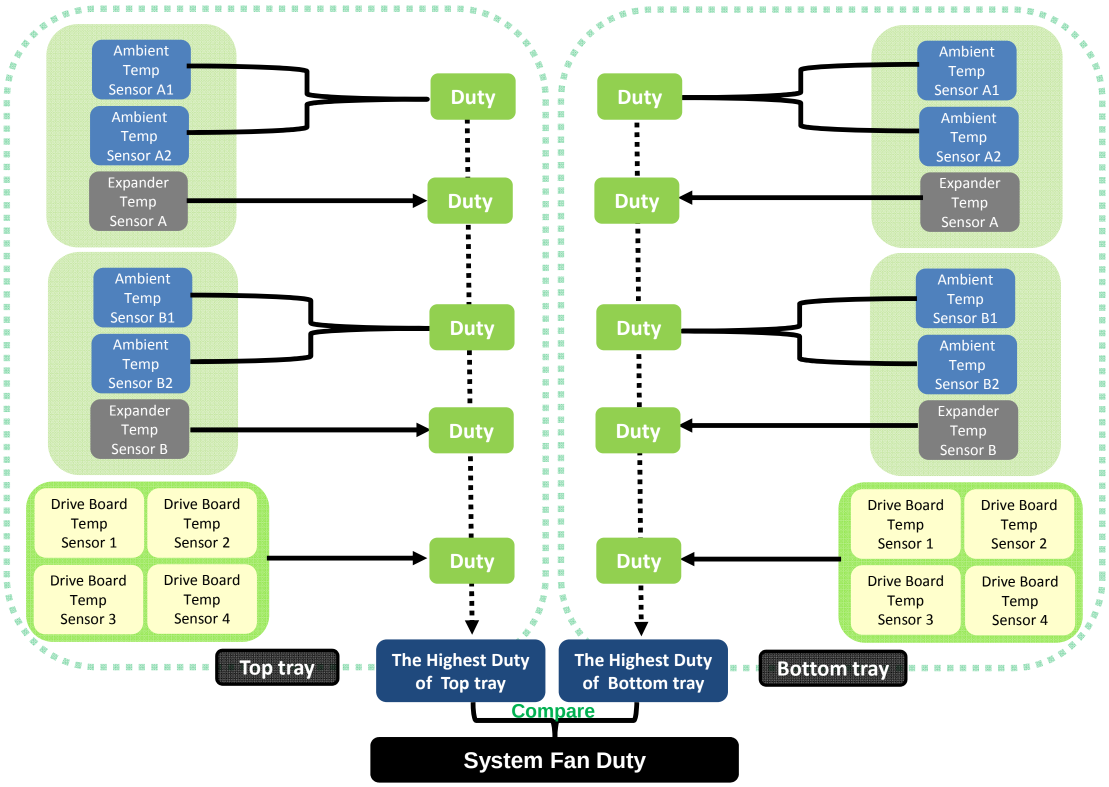

Figure 58 Open Vault System Fan Speed Control Strategy

10.4 Thermal Protection

There are different levels of consideration of system / hardware thermal protection for the Open Vault system. They include:

- Setting a **Warning** level for each monitored parameter (including all temperatures, voltages and input power). When any one of the parameters reaches its warning value, the firmware should report an **ALARM** status to the host server. The host server can predictively perform some actions to avoid actual (both hardware and software) protection in advance.
- Setting a **Software Protection** level for each monitored parameter. When one parameter reaches this level, the related fault LED will light, an error code will be generated, and the firmware should report a **CRITICAL** status to the host server. The host server takes suitable actions to protect the system, such as setting maximum speed to the fan or power off the related HDDs.
- Setting a **Hardware Protection** level. When some parameters reach this level or meet a set of pre-defined conditions, hardware protection actions will be taken to prevent system damage or reduce the cost of more power and more airflow.

10.5 HDD Spin-up Control

When an HDD spins up after power on, it draws excessive current on both 12V and 5V. Especially for the 12V rail, the peak current may reach 1.5A ~ 2A range, which is 2 ~ 3 times the maximum current during normal operation. And the duration could last around 5 to 15 seconds. To minimize the impact on the system power budget, the hardware design supports a staggered power-on feature, and the enclosure management firmware implements a grouped spin-up control mechanism.

- The group definition of hard disk drives follows the SAS expander chip vendor's strategy.
- The ODM defines the quantity of hard disk drives in each group.
- The ODM defines the delay interval between each group.

10.6 HDD Spin-down Control Support

To be aligned with a power saving strategy in future data center operations, the Open Vault design also supports a spin-down control. Both the hardware design and enclosure management firmware implementation support such a feature.

10.7 HDD Presence Detect

The enclosure management firmware reports when it detects the presence of an HDD.

10.8 HDD Status LED

The enclosure management firmware supports control of the HDD status LED as depicted in Figure 28. The LED turns on blue when the HDD is working normally. It turns on red when either of the two PHYs in an HDD reports a fault status.

10.9 Error Code Display on Debug Card

The error codes displayed on the debug card are defined in the table below. The error codes are detailed in chapter 15.

00	**No Error**
01-02	Critical Crash - Expander
03-06	Critical Crash - I2C Bus
07-10	*Reserved*
11-22	Fan Fault Critical
23-30	*Reserved*
31-42	Temperature Sensor Critical
43-44	*Reserved*
45-48	Voltage & Current Sensor Critical
49	*Reserved*
50-64	HDD SMART Temp Critical
65-66	Expander Internal Temp Critical
67-69	*Reserved*
70-84	HDD Fault
85-89	*Reserved*
90-92	Mini-SAS Link Error
93-94	Tray Pulled-out
93-99	*Reserved*

Figure 59 Proposed Open Vault Error Codes

11 Mechanical

11.1 External Chassis

The overall dimensions of the chassis are: 536mm wide x 94.5mm tall x 878mm deep.

The individual HDD trays may be carried fully loaded. The chassis may be carried with 2 fully loaded HDD trays. The main chassis has a cover for airflow management and to improve stiffness. The cover is removed by releasing 2 thumbscrews at the rear, when it is not installed in the rack.

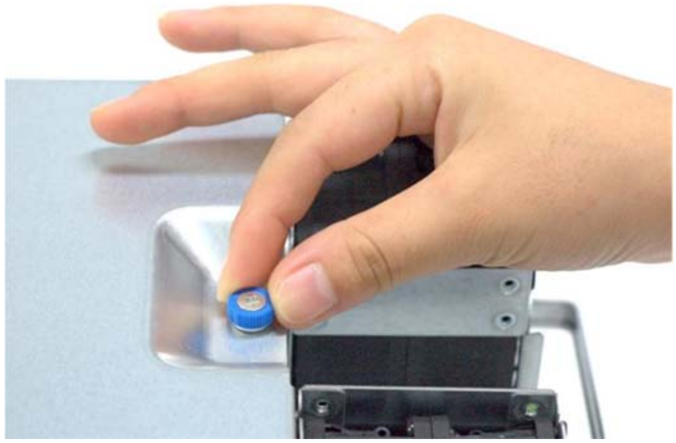

Figure 60 Chassis Cover Thumbscrew

11.1.1 Serviceability

Most service is from the front of the chassis, which is defined as the "cold aisle" or intake end of the chassis. Fan service is performed from the rear or "hot aisle" end of the chassis. All FRU removal, replacement and service is tool-less.

11.1.2 Rack Interface/Slides

The rack upon which the chassis is mounted is the Open Rack design as published at http://opencompute.org.

The main chassis is mounted in the rack by sliding it onto the rack's horizontal rails and engaging the cam levers mounted to the front of the HDD trays. The levers engage holes in the rack to hold the chassis and HDD trays in place.

Figure 61 HDD Tray/Chassis Cam Latches

11.2 HDD Tray

The HDD tray comprises a primary tray, drive plane and SAS expander boards, which are mounted to the underside of the tray. The expander boards are removable from the front of the tray. Each tray holds 15x HDDs horizontally, engaging right angle connectors on the drive plane board.

The HDD tray slides in and out of the chassis from the cold aisle. It rolls on multiple roller bearings for smooth movement. It has hard stops with deceleration features at the rear and front of its travel, to minimize operational shock. When it reaches the end of its travel outside the chassis, it may be tilted downward by 30 degrees for easier service. The HDD is easily removable without tools, for replacement. See section 11.2.1.

The entire HDD tray may be removed for service or replacement by releasing the HDD tray release levers at the rear of the tray. The HDD tray is retained in the chassis by left and right side cam latches. The tray's drop rate is controlled by its pair of friction hinges in such a manner as to avoid HDD damaging deceleration. The power and signal cables to each tray may be released, and the supporting cable arm is released by unscrewing the cable arm thumbscrew (Figure 65). The HDD tray may then be removed for service.

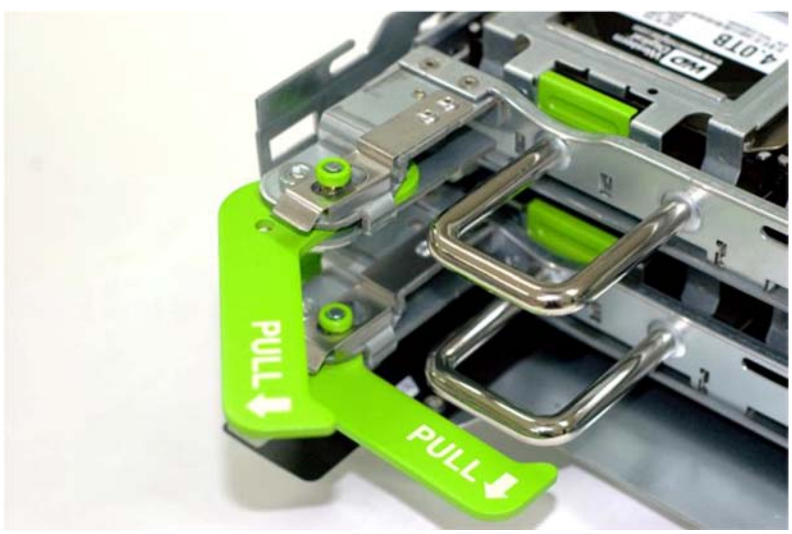

Figure 62 HDD Tray During Service

Figure 63 Front View of HDD Tray in Service

Figure 64 HDD Tray Release Lever

Figure 65 Cable Arm Release

11.2.1 Removing HDDs for Service

1. Press the HDD latch release (green).

2. Lift the latch upwards, slide the HDD forward, then lift the HDD out of the bay.

3. To install, slide the new HDD into the bay (press horizontally into the connector), and press the latch downwards until it latched in place.

Figure 66 Hard Disk Drive Removal

11.3 SAS Expander Board Tray

Each SAS expander board is hot-pluggable and can be serviced in the field. The HDD tray doesn't need to be extended for access to the expander boards.

Figure 67 SAS Expander Board

11.4 Power Distribution to Drive Plane Boards/Cable Arm

Power from the fan control board is delivered by high strand count power cables. High strand count wires are used to allow maximum flexibility. The power and signal cables are bundled together and are supported by a cable arm, which allows the HDD trays to translate forward and rearward. The cable arm is released and the cable unplugged for HDD tray removal. See Figure 65 and below.

Figure 68 HDD Tray Cable Arm

11.5 Fan Module

There are six fan modules mounted to the hot aisle end of the chassis.

Each fan module carries one dual-rotor fan, 60mm x 56mm size or equivalent, mounted to individual fan carriers via elastomeric isolators in order to minimize vibration transmitted to the main chassis. The fans are retained by panel-mounted thumbscrews in each fan carrier. The carriers are installed onto individual trays, horizontally onto guide pins.

Installing the fan module involves simply pushing the fan carrier directly into the rear of the chassis, then engaging the thumbscrew. Removing the fan is done by reversing these steps.

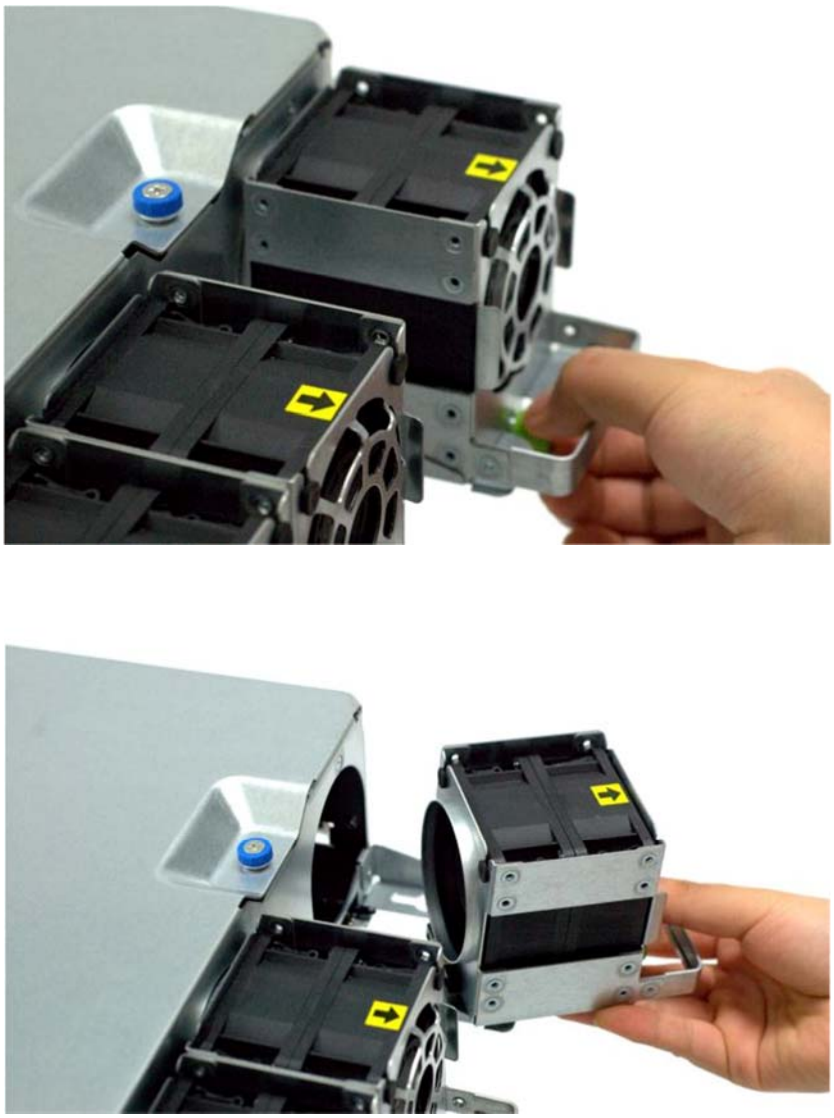

Figure 69 Fan Module Installation/Removal

12 Environmental

12.1 Environmental Requirements

The Open Vault storage system meets the following environmental requirements:

- Gaseous contamination: Severity Level G1 per ANSI/ISA 71.04-1985
- Ambient operating temperature range for system without HDD: -5°C to +45°C
- Ambient operating temperature range for system with HDD: +5°C to +35°C
- Operating and storage relative humidity: 10% to 90% (non-condensing)
- Storage temperature range: -40°C to +70°C
- Transportation temperature range: -55°C to +85°C (short-term storage)

In addition, the full Open Vault storage system has an operating altitude with no de-ratings of 1000m (3300 feet).

12.2 Vibration and Shock

The Open Vault PCBs meet shock and vibration requirements according to the following IEC specifications: IEC78-2-(*) & IEC721-3-(*) Standard & Levels. The testing requirements are listed in Figure 70.

	Operating	Non-Operating
Vibration	0.4g acceleration, 5 to 500 Hz, 10 sweeps at 1 octave/minute per each of the three axes (one sweep is 5 to 500 to 5 Hz)	1g acceleration, 5 to 500 Hz, 10 sweeps at 1 octave/minute per each of the three axes (one sweep is 5 to 500 to 5 Hz)
Shock	6g, half-sine 11mS, 5 shocks per each of the three axes	12g, half-sine 11mS, 10 shocks per each of the three axes

Figure 70 Vibration and Shock Requirements

13 Prescribed Materials

13.1 Sustainable Materials

Wherever possible and practical, and where cost or performance are not compromised, environmentally sustainable materials and finishes are used. This includes the use of non-hexavalent metal finishes, recycled and recyclable base materials and materials made from renewable resources, with associated material certifications.

13.2 Disallowed Components

The following components shall not be used in the design of the motherboard:

- Components disallowed by the European Union's Restriction of Hazardous Substances Directive (RoHS 6)
- Trimmers and/or potentiometers
- Dip switches

13.3 Capacitors and Inductors

The following limitations shall be applied to the use of capacitors:

- Only aluminum organic polymer capacitors from high-quality manufacturers are used; they must be rated 105°C

- All capacitors have a predicted life of at least 50,000 hours at 45°C inlet air temperature, under worst conditions
- Tantalum capacitors are forbidden
- SMT ceramic capacitors with case size > 1206 are forbidden (size 1206 still allowed when installed far from PCB edge, and with a correct orientation that minimizes risks of cracks)
- Ceramics material for SMT capacitors must be X7R or better material (COG or NP0 type should be used in critical portions of the design)

Only SMT inductors may be used. The use of through-hole inductors is disallowed.

13.4 Component De-Rating

For inductors, capacitors, and FETs, de-rating analysis should be based on at least 20% de-rating.

14 Open Vault Interconnect Pin Definitions

Below are the full interconnected pin definitions between the SAS expander board and drive plane board. The connectors are placed such that Pin1 is towards the right side of the chassis.

14.1 Pin Definitions on the SAS Expander Board

Below listed are the pin definitions on the SAS expander board to the drive plane board.

A1	GND	SAS_PRE15	B1
A2	SAS0_RX+	FCB_HW_REV	B2
A3	SAS0_RX-	GND	B3
A4	GND	SAS0_TX+	B4
A5	GND	SAS0_TX-	B5
A6	SAS1_RX+	GND	B6
A7	SAS1_RX-	GND	B7
A8	GND	SAS1_TX+	B8
A9	GND	SAS1_TX-	B9
A10	SAS2_RX+	GND	B10
A11	SAS2_RX-	DPB_HW_REV	B11
Key	Key	Key	Key
A12	Tray_ID	SAS2_TX+	B12
A13	GND	SAS2_TX-	B13
A14	SAS3_RX+	GND	B14
A15	SAS3_RX-	GND	B15
A16	GND	SAS3_TX+	B16
A17	GND	SAS3_TX-	B17
A18	SAS4_RX+	GND	B18
A19	SAS4_RX-	GND	B19
A20	GND	SAS4_TX+	B20
A21	GND	SAS4_TX-	B21

A22	SAS5_RX+	GND	B22
A23	SAS5_RX-	GND	B23
A24	GND	SAS5_TX+	B24
A25	GND	SAS5_TX-	B25
A26	SAS6_RX+	GND	B26
A27	SAS6_RX-	GND	B27
A28	GND	SAS6_TX+	B28
A29	GND	SAS6_TX-	B29
A30	SAS7_RX+	GND	B30
A31	SAS7_RX-	GND	B31
A32	GND	SAS7_TX+	B32
A33	GND	SAS7_TX-	B33
A34	SAS8_RX+	GND	B34
A35	SAS8_RX-	GND	B35
A36	GND	SAS8_TX+	B36
A37	GND	SAS8_TX-	B37
A38	SAS9_RX+	GND	B38
A39	SAS9_RX-	GND	B39
A40	GND	SAS9_TX+	B40
A41	Shutdown_Release	SAS9_TX-	B41
A42	SAS1_FLT	GND	B42
A43	SAS0_FLT	SAS9_FLT	B43
A44	SAS2_FLT	SAS10_FLT	B44
A45	SAS3_FLT	SAS11_FLT	B45
A46	SAS4_FLT	SAS12_FLT	B46
A47	SAS5_FLT	SAS13_FLT	B47
A48	SAS6_FLT	GND	B48
A49	SAS7_FLT	SAS10_TX+	B49
A50	SAS8_FLT	SAS10_TX-	B50
A51	GND	GND	B51
A52	SAS10_RX+	SAS14_FLT	B52
A53	SAS10_RX-	SAS15_FLT	B53
A54	GND	SEB_HTBT_OUT	B54
A55	SCL_C	SEB_HTBT_IN	B55
A56	SDA_C	SCL_B	B56
A57	SCL_D	SDA_B	B57
A58	SDA_D	SEB_ID	B58
A59	GND	PWM_OUT	B59
A60	SAS11_RX+	PEER_SEBA_HB	B60
A61	SAS11_RX-	GND	B61
A62	GND	SAS11_TX+	B62
A63	GND	SAS11_TX-	B63

A64	SAS12_RX+	GND	B64
A65	SAS12_RX-	GND	B65
A66	GND	SAS12_TX+	B66
A67	GND	SAS12_TX-	B67
A68	SAS13_RX+	GND	B68
A69	SAS13_RX-	GND	B69
A70	GND	SAS13_TX+	B70
A71	GND	SAS13_TX-	B71
A72	SAS14_RX+	GND	B72
A73	SAS14_RX-	GND	B73
A74	GND	SAS14_TX+	B74
A75	GND	SAS14_TX-	B75
A76	SAS15_RX+	GND	B76
A77	SAS15_RX-	GND	B77
A78	GND	SAS15_TX+	B78
A79	PEER_SEBB_HB	SAS15_TX-	B79
A80	12V	GND	B80
A81	12V	GND	B81
A82	12V	GND	B82

Figure 71 Pin Definition from SEB to DPB – I (164 Pin Connector to Drive Plane Board)

A1	SAS_PRE0	SAS_PWR0	B1
A2	SAS_PRE1	SAS_PWR1	B2
A3	SAS_PRE2	SAS_PWR2	B3
A4	SAS_PRE3	SAS_PWR3	B4
A5	SAS_PRE4	SAS_PWR4	B5
A6	SAS_PRE5	SAS_PWR5	B6
A7	SAS_PRE6	SAS_PWR6	B7
A8	SAS_PRE7	SAS_PWR7	B8
A9	SAS_PRE8	SAS_PWR8	B9
A10	SAS_PRE9	SAS_PWR9	B10
A11	SAS_PRE10	SAS_PWR10	B11
Key	Key	Key	Key
A12	SAS_PRE11	SAS_PWR11	B12
A13	SAS_PRE12	SAS_PWR12	B13
A14	SAS_PRE13	SAS_PWR13	B14
A15	SAS_PRE14	SAS_PWR14	B15
A16	SELF_TRAY_IN	SAS_PWR15	B16
A17	PEER_TRAY_IN	PCIe_MATED	B17
A18	GND	PEER_SEB_IN	B18

Figure 72 Pin Definition from SEB to DPB – II (36 Pin Connector to Drive Plane Board)

14.2 Drive Plane Board Pin Definitions

The following table lists the pin definitions on the drive plane board to both the SAS expander board A and SAS expander board B.

164 Pin Connector to SEB A					164 Pin Connector to SEB B			
A1	GND	HDD_PRE15	B1		A1	GND	HDD_PRE15	B1
A2	HDD11_RX+	FCB_HW_REV	B2		A2	HDD14_RX+	FCB_HW_REV	B2
A3	HDD11_RX-	GND	B3		A3	HDD14_RX-	GND	B3
A4	GND	HDD11_TX+	B4		A4	GND	HDD14_TX+	B4
A5	GND	HDD11_TX-	B5		A5	GND	HDD14_TX-	B5
A6	HDD12_RX+	GND	B6		A6	HDD4_RX+	GND	B6
A7	HDD12_RX-	GND	B7		A7	HDD4_RX-	GND	B7
A8	GND	HDD12_TX+	B8		A8	GND	HDD4_TX+	B8
A9	GND	HDD12_TX-	B9		A9	GND	HDD4_TX-	B9
A10	HDD13_RX+	GND	B10		A10	HDD9_RX+	GND	B10
A11	HDD13_RX-	DPB_HW_REV	B11		A11	HDD9_RX-	DPB_HW_REV	B11
Key	Key	Key	Key		Key	Key	Key	Key
A12	Tray_ID	HDD13_TX+	B12		A12	Tray_ID	HDD9_TX+	B12
A13	GND	HDD13_TX-	B13		A13	GND	HDD9_TX-	B13
A14	HDD14_RX+	GND	B14		A14	HDD3_RX+	GND	B14
A15	HDD14_RX-	GND	B15		A15	HDD3_RX-	GND	B15
A16	GND	HDD14_TX+	B16		A16	GND	HDD3_TX+	B16
A17	GND	HDD14_TX-	B17		A17	GND	HDD3_TX-	B17
A18	HDD9_RX+	GND	B18		A18	HDD2_RX+	GND	B18
A19	HDD9_RX-	GND	B19		A19	HDD2_RX-	GND	B19
A20	GND	HDD9_TX+	B20		A20	GND	HDD2_TX+	B20
A21	GND	HDD9_TX-	B21		A21	GND	HDD2_TX-	B21
A22	HDD8_RX+	GND	B22		A22	HDD8_RX+	GND	B22
A23	HDD8_RX-	GND	B23		A23	HDD8_RX-	GND	B23
A24	GND	HDD8_TX+	B24		A24	GND	HDD8_TX+	B24
A25	GND	HDD8_TX-	B25		A25	GND	HDD8_TX-	B25
A26	HDD7_RX+	GND	B26		A26	HDD7_RX+	GND	B26
A27	HDD7_RX-	GND	B27		A27	HDD7_RX-	GND	B27
A28	GND	HDD7_TX+	B28		A28	GND	HDD7_TX+	B28
A29	GND	HDD7_TX-	B29		A29	GND	HDD7_TX-	B29
A30	HDD4_RX+	GND	B30		A30	HDD1_RX+	GND	B30
A31	HDD4_RX-	GND	B31		A31	HDD1_RX-	GND	B31
A32	GND	HDD4_TX+	B32		A32	GND	HDD1_TX+	B32
A33	GND	HDD4_TX-	B33		A33	GND	HDD1_TX-	B33
A34	HDD3_RX+	GND	B34		A34	HDD0_RX+	GND	B34
A35	HDD3_RX-	GND	B35		A35	HDD0_RX-	GND	B35
A36	GND	HDD3_TX+	B36		A36	GND	HDD0_TX+	B36
A37	GND	HDD3_TX-	B37		A37	GND	HDD0_TX-	B37

A38	HDD6_RX+	GND	B38		A38	HDD13_RX+	GND	B38
A39	HDD6_RX-	GND	B39		A39	HDD13_RX-	GND	B39
A40	GND	HDD6_TX+	B40		A40	GND	HDD13_TX+	B40
A41	SD_Release	HDD6_TX-	B41		A41	SD_Release	HDD13_TX-	B41
A42	HDD12_FLT	GND	B42		A42	HDD4_FLT	GND	B42
A43	HDD11_FLT	HDD6_FLT	B43		A43	HDD14_FLT	HDD13_FLT	B43
A44	HDD13_FLT	HDD2_FLT	B44		A44	HDD9_FLT	HDD6_FLT	B44
A45	HDD14_FLT	HDD1_FLT	B45		A45	HDD3_FLT	HDD5_FLT	B45
A46	HDD9_FLT	HDD10_FLT	B46		A46	HDD2_FLT	HDD10_FLT	B46
A47	HDD8_FLT	HDD0_FLT	B47		A47	HDD8_FLT	HDD11_FLT	B47
A48	HDD7_FLT	GND	B48		A48	HDD7_FLT	GND	B48
A49	HDD4_FLT	HDD2_TX+	B49		A49	HDD1_FLT	HDD6_TX+	B49
A50	HDD3_FLT	HDD2_TX-	B50		A50	HDD0_FLT	HDD6_TX-	B50
A51	GND	GND	B51		A51	GND	GND	B51
A52	HDD2_RX+	HDD5_FLT	B52		A52	HDD6_RX+	HDD12_FLT	B52
A53	HDD2_RX-	HDD15_FLT	B53		A53	HDD6_RX-	HDD15_FLT	B53
A54	GND	SEB_HTBT_OUT	B54		A54	GND	SEB_HTBT_OUT	B54
A55	SCL_C	SEB_HTBT_IN	B55		A55	SCL_C	SEB_HTBT_IN	B55
A56	SDA_C	SCL_B	B56		A56	SDA_C	SCL_B	B56
A57	SCL_D	SDA_B	B57		A57	SCL_D	SDA_B	B57
A58	SDA_D	SEB_ID	B58		A58	SDA_D	SEB_ID	B58
A59	GND	PWM_OUT	B59		A59	GND	PWM_OUT	B59
A60	HDD1_RX+	PEER_SEBA_HB	B60		A60	HDD5_RX+	PEER_SEBA_HB	B60
A61	HDD1_RX-	GND	B61		A61	HDD5_RX-	GND	B61
A62	GND	HDD1_TX+	B62		A62	GND	HDD5_TX+	B62
A63	GND	HDD1_TX-	B63		A63	GND	HDD5_TX-	B63
A64	HDD10_RX+	GND	B64		A64	HDD10_RX+	GND	B64
A65	HDD10_RX-	GND	B65		A65	HDD10_RX-	GND	B65
A66	GND	HDD10_TX+	B66		A66	GND	HDD10_TX+	B66
A67	GND	HDD10_TX-	B67		A67	GND	HDD10_TX-	B67
A68	HDD00_RX+	GND	B68		A68	HDD11_RX+	GND	B68
A69	HDD00_RX-	GND	B69		A69	HDD11_RX-	GND	B69
A70	GND	HDD0_TX+	B70		A70	GND	HDD11_TX+	B70
A71	GND	HDD0_TX-	B71		A71	GND	HDD11_TX-	B71
A72	HDD5_RX+	GND	B72		A72	HDD12_RX+	GND	B72
A73	HDD5_RX-	GND	B73		A73	HDD12_RX-	GND	B73
A74	GND	HDD5_TX+	B74		A74	GND	HDD12_TX+	B74
A75	GND	HDD5_TX-	B75		A75	GND	HDD12_TX-	B75
A76	HDD15_RX+	GND	B76		A76	HDD15_RX+	GND	B76
A77	HDD15_RX-	GND	B77		A77	HDD15_RX-	GND	B77
A78	GND	HDD15_TX+	B78		A78	GND	HDD15_TX+	B78

A79	PEER_SEBB_HB	HDD15_TX-	B79		A79	PEER_SEBB_HB	HDD15_TX-	B79
A80	12V	GND	B80		A80	12V	GND	B80
A81	12V	GND	B81		A81	12V	GND	B81
A82	12V	GND	B82		A82	12V	GND	B82

Figure 73 DPB to SEB Interconnect Pin Definition – I

36 Pin Connector to SEB A					36 Pin Connector to SEB B			
A1	HDD_PRE11	HDD_PWR11	B1		A1	HDD_PRE14	HDD_PWR14	B1
A2	HDD_PRE12	HDD_PWR12	B2		A2	HDD_PRE4	HDD_PWR4	B2
A3	HDD_PRE13	HDD_PWR13	B3		A3	HDD_PRE9	HDD_PWR9	B3
A4	HDD_PRE14	HDD_PWR14	B4		A4	HDD_PRE3	HDD_PWR3	B4
A5	HDD_PRE9	HDD_PWR9	B5		A5	HDD_PRE2	HDD_PWR2	B5
A6	HDD_PRE8	HDD_PWR8	B6		A6	HDD_PRE8	HDD_PWR8	B6
A7	HDD_PRE7	HDD_PWR7	B7		A7	HDD_PRE7	HDD_PWR7	B7
A8	HDD_PRE4	HDD_PWR4	B8		A8	HDD_PRE1	HDD_PWR1	B8
A9	HDD_PRE3	HDD_PWR3	B9		A9	HDD_PRE0	HDD_PWR0	B9
A10	HDD_PRE6	HDD_PWR6	B10		A10	HDD_PRE13	HDD_PWR13	B10
A11	HDD_PRE2	HDD_PWR2	B11		A11	HDD_PRE6	HDD_PWR6	B11
Key	Key	Key	Key		Key	Key	Key	Key
A12	HDD_PRE1	HDD_PWR1	B12		A12	HDD_PRE5	HDD_PWR5	B12
A13	HDD_PRE10	HDD_PWR10	B13		A13	HDD_PRE10	HDD_PWR10	B13
A14	HDD_PRE0	HDD_PWR0	B14		A14	HDD_PRE11	HDD_PWR11	B14
A15	HDD_PRE5	HDD_PWR5	B15		A15	HDD_PRE12	HDD_PWR12	B15
A16	SELF_tray_IN	HDD_PWR15	B16		A16	SELF_tray_IN	HDD_PWR15	B16
A17	PEER_tray_IN	PCIe_MATED	B17		A17	PEER_tray_IN	PCIe_MATED	B17
A18	SEB_A_INS (G)	SEB_B_INS	B18		A18	SEB_B_INS (G)	SEB_A_INS	B18

Figure 74 DPB to SEB Interconnect Pin Definition – II

15 Open Vault Error Code Definitions

The table below lists the full definitions of Open Vault error codes. These codes get displayed on the debug card and are stored in system event log.

Error Code	Description	Error Code	Description
00	No error	50	HDD0 SMART temp critical
01	Expander A fault	51	HDD1 SMART temp critical
02	Expander B fault	52	HDD2 SMART temp critical
03	I2C bus A crash	53	HDD3 SMART temp critical
04	I2C bus B crash	54	HDD4 SMART temp critical
05	I2C bus C crash	55	HDD5 SMART temp critical
06	I2C bus D crash	56	HDD6 SMART temp critical
07	Reserved	57	HDD7 SMART temp critical
08	Reserved	58	HDD8 SMART temp critical

09	Reserved	59	HDD9 SMART temp critical
10	Reserved	60	HDD10 SMART temp critical
11	Fan 1 front fault	61	HDD11 SMART temp critical
12	Fan 1 rear fault	62	HDD12 SMART temp critical
13	Fan 2 front fault	63	HDD13 SMART temp critical
14	Fan 2 rear fault	64	HDD14 SMART temp critical
15	Fan 3 front fault	65	Expander A Internal temp critical
16	Fan 3 rear fault	66	Expander B Internal temp critical
17	Fan 4 front fault	67	Reserved
18	Fan 4 rear fault	68	Reserved
19	Fan 5 front fault	69	Reserved
20	Fan 5 rear fault	70	HDD0 fault
21	Fan 6 front fault	71	HDD1 fault
22	Fan 6 rear fault	72	HDD2 fault
23	Reserved	73	HDD3 fault
24	Reserved	74	HDD4 fault
25	Reserved	75	HDD5 fault
26	Reserved	76	HDD6 fault
27	Reserved	77	HDD7 fault
28	Reserved	78	HDD8 fault
29	Reserved	79	HDD9 fault
30	Reserved	80	HDD10 fault
31	Drive board temp sensor 1 critical	81	HDD11 fault
32	Drive board temp sensor 2 critical	82	HDD12 fault
33	Drive board temp sensor 3 critical	83	HDD13 fault
34	Drive board temp sensor 4 critical	84	HDD14 fault
35	Expander temp sensor A critical	85	Reserved
36	Expander temp sensor B critical	86	Reserved
37	Ambient temp sensor A1 critical	87	Reserved
38	Ambient temp sensor A2 critical	88	Reserved
39	Ambient temp sensor B1 critical	89	Reserved
40	Ambient temp sensor B2 critical	90	External Mini-SAS Link Error
41	BJT temp sensor 1 critical	91	Internal Mini-SAS 1 Link Error
42	BJT temp sensor 2 critical	92	Internal Mini-SAS 2 Link Error
43	Reserved	93	Self-Tray Pulled-out
44	Reserved	94	Peer Tray Pulled-out
45	Expander voltage sensor critical	95	Reserved
46	Drive plane board voltage sensor critical	96	Reserved
47	Fan Control Board voltage sensor critical	97	Reserved
48	Fan Control Board current sensor critical	98	Reserved
49	Reserved	99	Firmware and Hardware Mismatch

Figure 75 Error Code Definition

16 Revision History

Version	Changes
0.5	Initial public version.
0.6	• Replaced most drawings with photographs. • Added license information. • Added SAS signal re-driver section. • Added power transition board section. • Greatly expanded section on HDDs, including descriptions of serviceability, SAS expander board tray, power distribution cabling, and the fan module. • Added IC pin definitions and error code definitions.
0.7	• Updated images and board layouts. • Added tray pullout detector part information. • Updated HDD mechanical section.
0.8	• Added HDD port mapping for DPB (from HDD slot to SAS expander Phy). • Corrected system power budget for idle mode. • Added error code 99 definition.
0.85	• Page 5 - added LSI Corporation OWF CLA information • Page 9 - altered expander part number in figure 6 • Page 11 - altered expander part number in figure 8 and in text to 12Gb version. Changed references from 6Gb to 12Gb. • Page 12 - Section 5.3 - changed expander part number. Section 5.4 - modified voltage table for VDD of 0.9V. Section 5.5 - changed text to re-driver may be required. • Page 30 - Power table values changed for SAS Expander Board. Totals updated. • Page 31 - Figure 51 totals updated. Section 9.2 - Buck converter voltage now 0.9V • Page 53 - Added revision entry to History Note: These Version 0.85 revisions constitute LSI Corporation's sole contribution to this specification. Furthermore, the SAS specification is a normative reference. As such, it is merely referenced in this revision and therefore falls within the exception set forth in the Granted Claims definition of Section 10.5 of the Open Web Foundation Contributor License Agreement. Additionally, hardware components (such as, but not limited to the SAS expanders: LSI SAS3x28R, LSI SAS3x36R, and LSI SAS24R), and their associated functionality, fall within the merely referenced exception set forth in the OWF CLA Granted Claims definition.