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Open Vault Storage Hardware V0.5

Authors:

Mike Yan, Engineer

Jon Ehlen, Engineer

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 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 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 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 trays. 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. Also there are power connecter(s) to the Open Rack bus bars so that the 12V main power from the Open Rack can be fed 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 tray 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, and "FCB" refers to the fan control board.

3.1 Open Vault Front View

The equipment visible from the front of the Open Vault includes:

- Two (2) HDD trays
- Four (4) SAS expander boards
- Four (4) external mini-SAS connectors, with status LED
- Eight (8) internal mini-SAS connectors, with status LED
- Four (4) enclosure status LEDs
- Four (4) debug headers

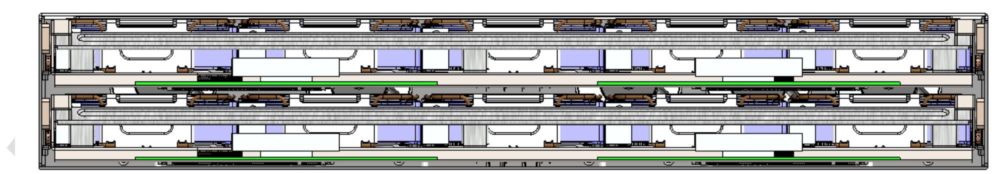

Figure 1 Open Vault Storage Unit Front View

3.2 Open Vault Rear View

The equipment visible from the rear of the Open Vault includes:

- Two (2) bus bar connectors
- Six (6) fan modules, with status LED

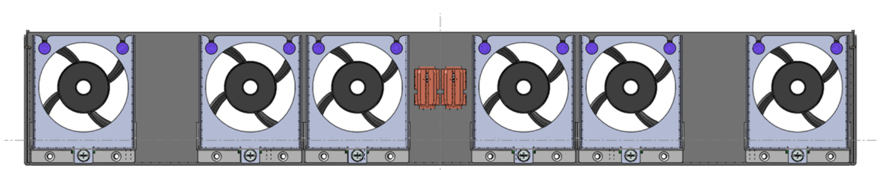

Figure 2 Open Vault Storage Unit Rear View

3.3 System Component Layout

Figure 3 shows the layout from overhead of the Open Vault's major system components.

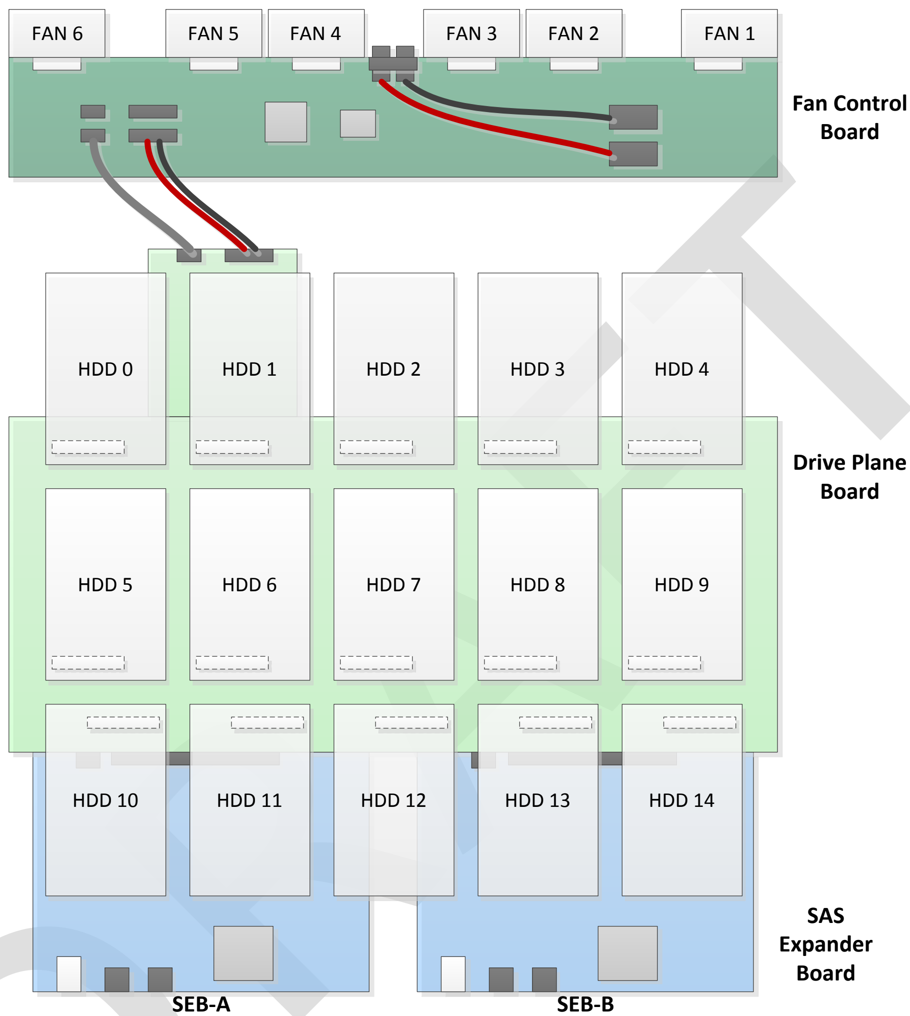

Figure 3 Open Vault System Components Layout

3.4 System Block Diagram

Figure 4 shows the system block diagram for 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: 10m
- Two internal mini-SAS ports to cascaded Open Vault trays
  - Using internal mini-SAS cable located outside the chassis
  - Max cable length: 1.5m

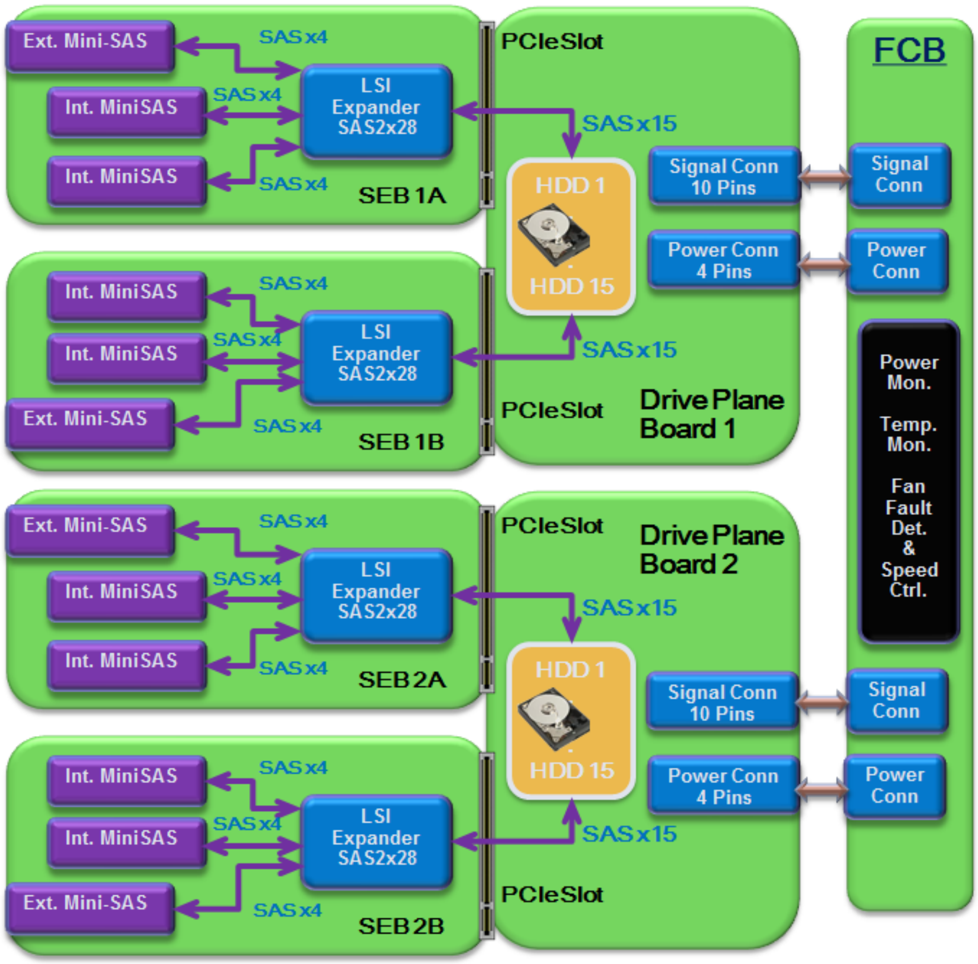

Figure 4 Open Vault System Block Diagram

3.5 System I2C Topology

Figure 5 shows the system I2C topology of Open Vault. It reflects the enclosure management structure of Open Vault.

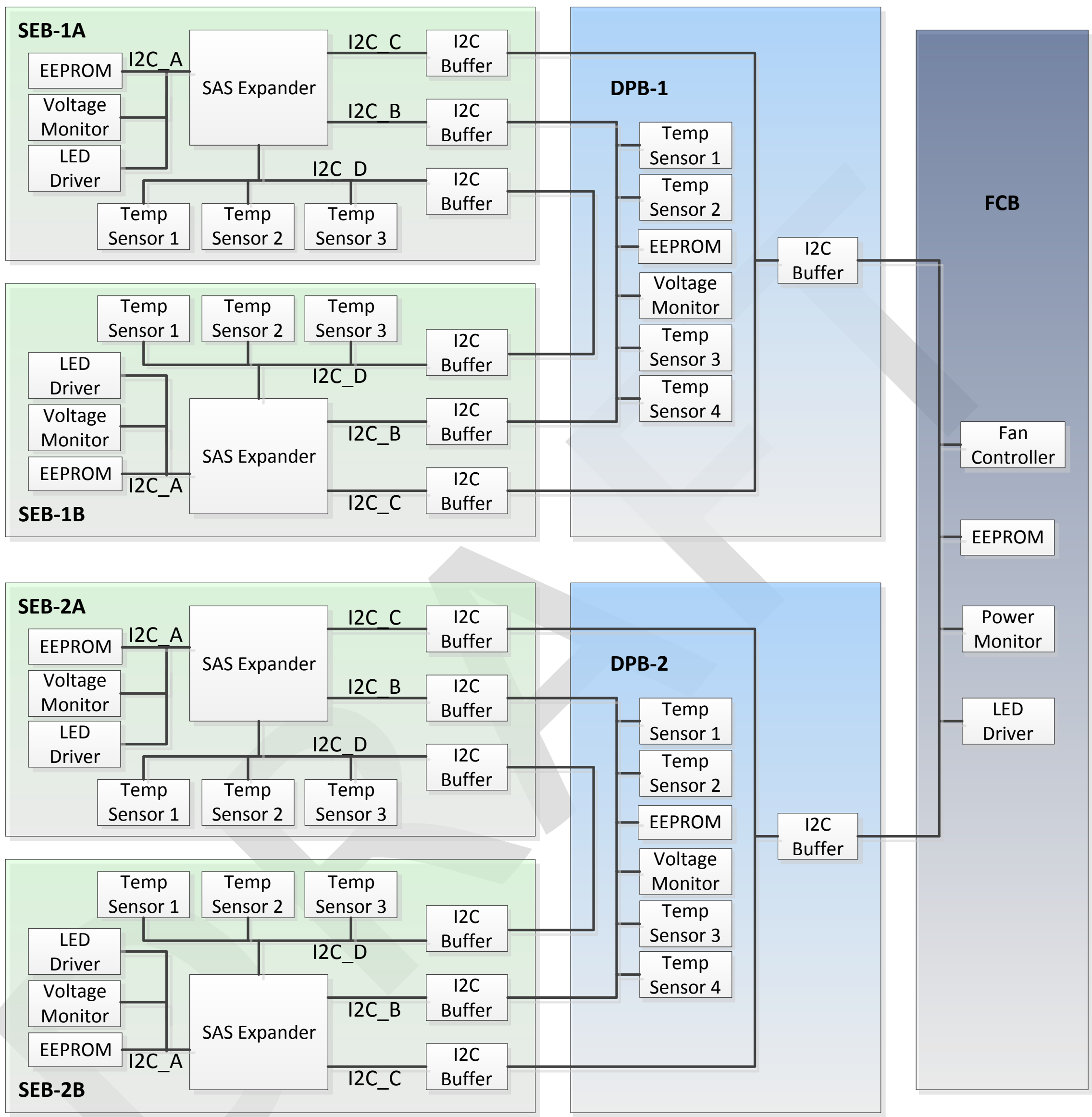

Figure 5 Open Vault System I2C Topology

4 Open Vault SAS Expander Board

4.1 Block Diagram and Configurations

Figure 6 illustrates the functional block diagram of the Open Vault SAS expander board (SEB), utilizing an LSISAS2x28 6G SAS expander.

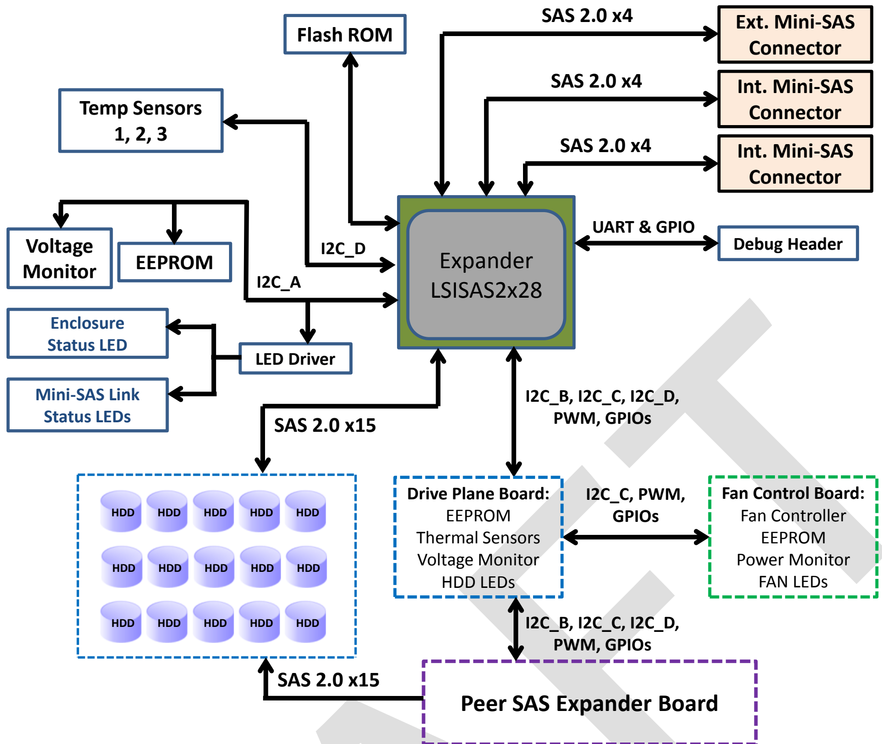

Figure 6 Open Vault LSISAS2108 Block Diagram

4.2 SEB Placement and Form Factor

The SAS expander board (SEB) form factor is 235mm x 195mm. Figure 7 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

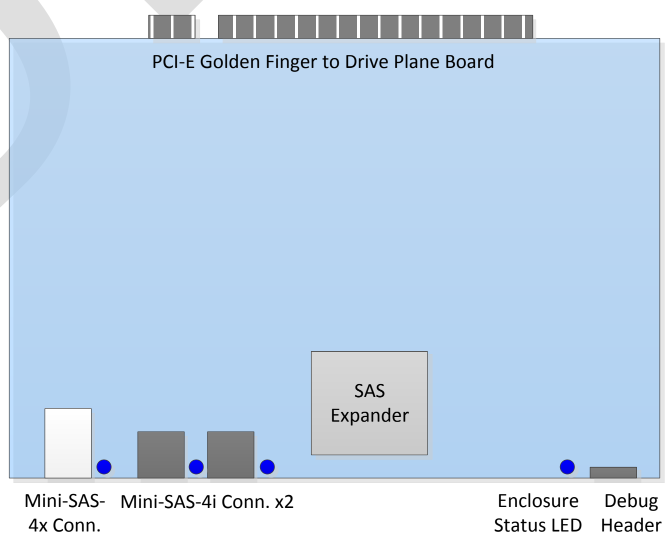

Figure 7 Open Vault SAS Expander Board Placement

4.3 SAS Expander Chip

The Open Vault SAS expander board contains a single 6G SAS expander, part number LSISAS2x28. The board design is compatible with LSISAS2x24 and LSISAS2x20 under different configurations.

4.4 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 8.1. The power rails to be monitored are shown in Figure 8.

Power Rail	Voltage
VDDIO33	3.3V
VDDIO	1.8V
VDD	1.0V
VCC for signal re-driver	1.2V

Figure 8 Monitored Power Rails on SEB

4.5 Connectors

Sections 4.5.1 through 4.5.4 describe the connectors that reside on the Open Vault SAS expander board.

4.5.1 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 x16 connector (164 pin) and the other is x1 connector (36 pin), together to provide up to 200 pins. These connectors will be mated with 1mm pitch gold finger contacts on the SAS expander board side. The design should be capable for 6G SAS signals with reliable margin.

Figure 9 shows the PCI-E 1mm edge golden figures, using 164 pins for x16 connection as an example. The full connector pin definition should be provided by the ODM.

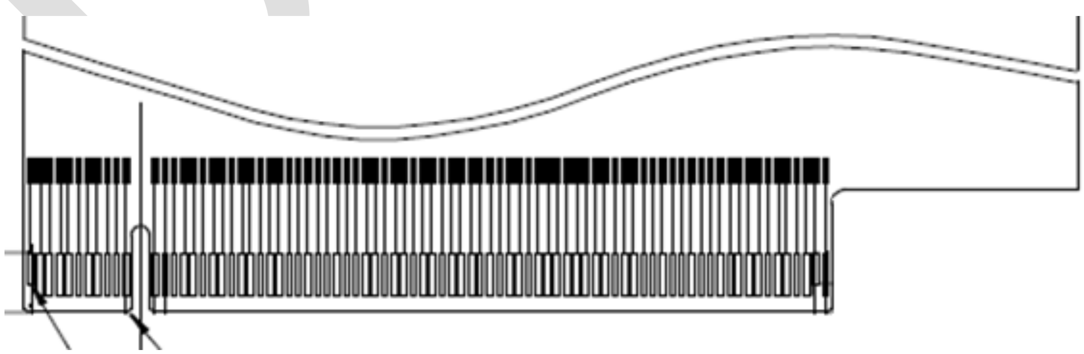

Figure 9 PCI-E 1mm Edge Golden Fingers

4.5.2 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, referred to as a Mini-SAS-4x connector. Its part number is G40BR261BEU from AMPHENOL. The connector pin-out is shown in Figure 10.

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 10 Mini-SAS-4x Connector Pin-Out

4.5.3 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're SFF-8087 standard form factor, or referred as mini-SAS-4i connectors. The part number is 75783-0012 from Molex. The connector pin-out is shown in Figure 11.

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 11 Mini-SAS-4i Connector Pin-Out

4.5.4 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 has been 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 12 shows an illustration. The debug card has a key to match with the notch to avoid pin shift when plugging it in.

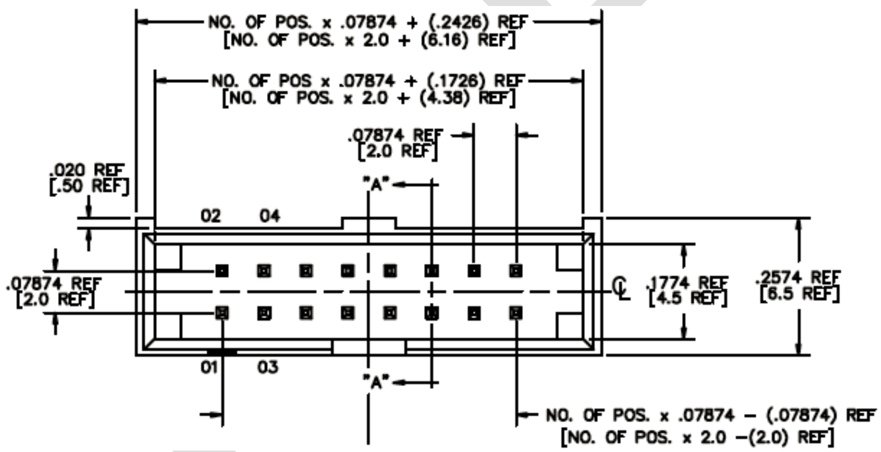

Figure 12 Debug Header

Figure 13 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 13 Debug Header Pin-Out

4.6 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 14 and Figure 15 summarize the conditions and actions the LEDs present.

Enclosure Status	Blue/Red LED
Normal system operation	Blue on
Any fault in whole enclosure	Red on

Figure 14 Front Panel LED for Enclosure Status

Mini-SAS Port Link Status	Blue/Red LED
SAS links (x4) health	Blue on
Loss of SAS links (x1 ~ x 3)	Red on
No SAS links	Both off

Figure 15 Front Panel LED For Mini-SAS Port Links

4.7 PCB Stack-up

The PCB stack-up and impedance control for the SAS expander board are defined in Figure 16 and Figure 17 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	GND	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	GND3	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 16 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 17 PCB Impedance Control for SAS Expander Board

5 Open Vault Drive Plane Board

5.1 Block Diagram

Figure 18 illustrates the functional block diagram of the drive plane board (DPB).

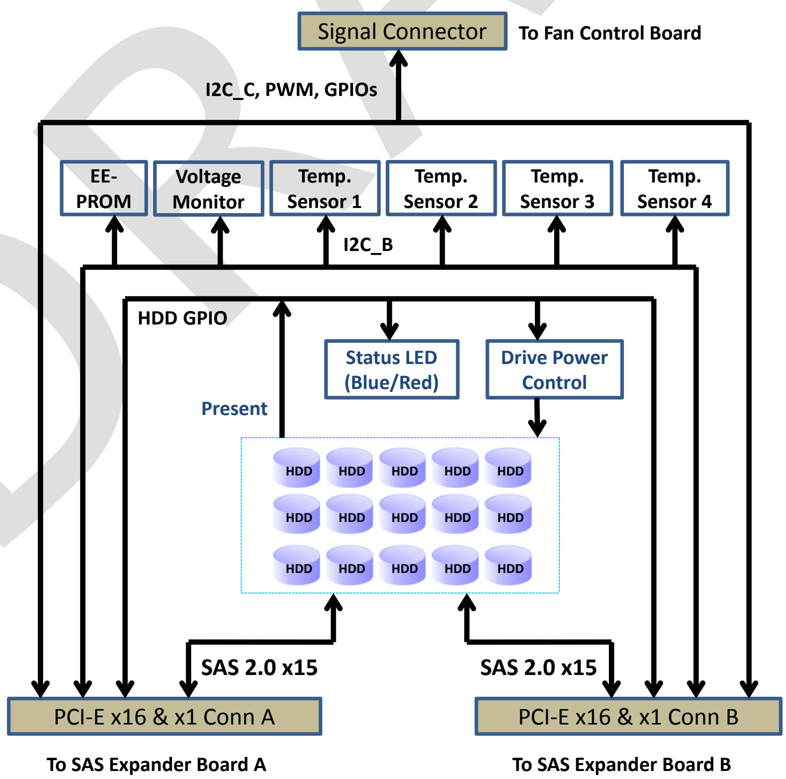

Figure 18 Open Vault Drive Plane Board Block Diagram

5.2 DPB Placement and Form Factor

The drive plane board form factor is 450mm x 510mm. Figure 19 illustrates board placement.

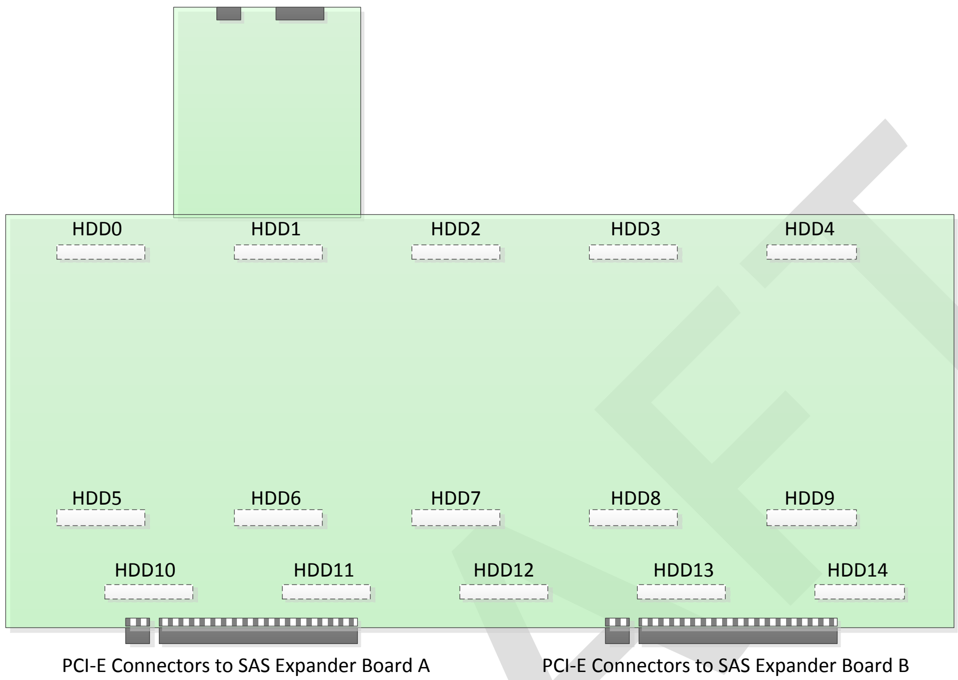

Figure 19 Open Vault Drive Plane Board Placement

5.3 12.5V to 5V Buck Converter

In order to provide a 5V power rail to the hard disk drives, one 12.5V to 5V buck converter will be implemented on the drive plane board for each group of 5 HDDs. It must be 93% efficient at nominal load. For more information, see section 7.3.

5.4 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 7.4.

5.5 Voltage Monitor

A voltage monitor is required for the Open Vault drive plane 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 8.1. The power rails to be monitored are shown in Figure 20.

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

Figure 20 Monitored Power Rails on DPB

5.6 Connectors

Sections 5.6.1 through 5.6.4 describe the connectors on the Open Vault DPB.

5.6.1 Signal Connector to SAS Expander Board

The interfaces from the SAS expander board to the drive plane board are through an OCP-defined pin-out. The DPB-side connectors are two standard PCI-E connectors for each SAS expander board:

- PCI-E x16, 164 pin, straddle type, part number G630HAA12248EU from Amphenol.
- PCI-E x1, 36 pin, straddle type, part number G630H3612248EU from Amphenol.

The connectors are PCI-E Gen3 capable.

The ODM should provide the full connector pin definition.

5.6.2 Signal Connector to Fan Control Board

Signals from the drive plane board to the fan control board mainly contain the I2C bus, PWMs and some GPIOs. Use an FFC/FPC cable between these two boards. The connector part number is 196360-10041-3 from P-Two. The pin count is 10, and signals are listed in Figure 21.

Pin	Assignment
1	SEB Heartbeat out
2	I2C_C SCL
3	I2C_C SDA
4	GND
5	PWM from expander A
6	GND
7	PWM from expander B
8	GND
9	Tray present out
10	Tray present in

Figure 21 Pin-Out of Signal Connector from DPB to FCB

5.6.3 Power Connector to Fan Control Board

A four-pin connector from Molex receives 12V power from the drive plane board via a high-strand power cable. Part number of this right angle connector is PLA04F4BN0A1 from Positronic. Figure 22 shows the pin-out.

Pin	Description
1	12.5V
2	12.5V
3	GND
4	GND

Figure 22 Drive Plane Board Power Cable Connector Pin-Out

5.6.4 SAS HDD Connectors

The Open Vault drive plane board supports hot plugging of hard disk drives. The drives are connected via a blind mate, standard SAS interface, right-angle connector (an SMT connector from Molex, part number 87945-0001). The mating height is also 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 23 SAS HDD Connector Pin-Out

5.7 LEDs

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

- When the HDD is online and healthy, the blue LED turns on;
- When any HDD fault occurs, the red LED turns on.

Each drive's LEDs are located near the corresponding drive's cage and are clearly visible from the top when HDD tray is pulled out. An optical path for drive status LEDs can be implemented for easy access.

Figure 24 summarizes the conditions the LEDs present:

Disk Drive Status	Blue/Red LED
Drive online and healthy	Blue on
Drive failure	Red on

Figure 24 Drive plane board LED for HDD Status

5.8 PCB Stack-up

The PCB stack-up and impedance control for the DPB are defined in Figure 25 and Figure 26.

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	GND	Ground	2.0	2.6	
		Core		4.0	3.7
L3	IN1	Signal	1.0	1.3	
		PrePreg		25.0	4.4
L4	VCC1	Power	2.0	2.6	
		Core		4.0	4.1
L5	VCC2	Power	2.0	2.6	
		PrePreg		25.0	4.4
L6	IN4	Signal	1.0	1.3	
		Core		4.0	3.7
L7	GND3	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 25 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 26 PCB Impedance Control for Drive Plane Board

6 Open Vault Fan Control Board

The Open Vault fan control board 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 drive plane board through 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.

6.1 Block Diagram

Figure 27 illustrates the functional block diagram of the fan control board (FCB).

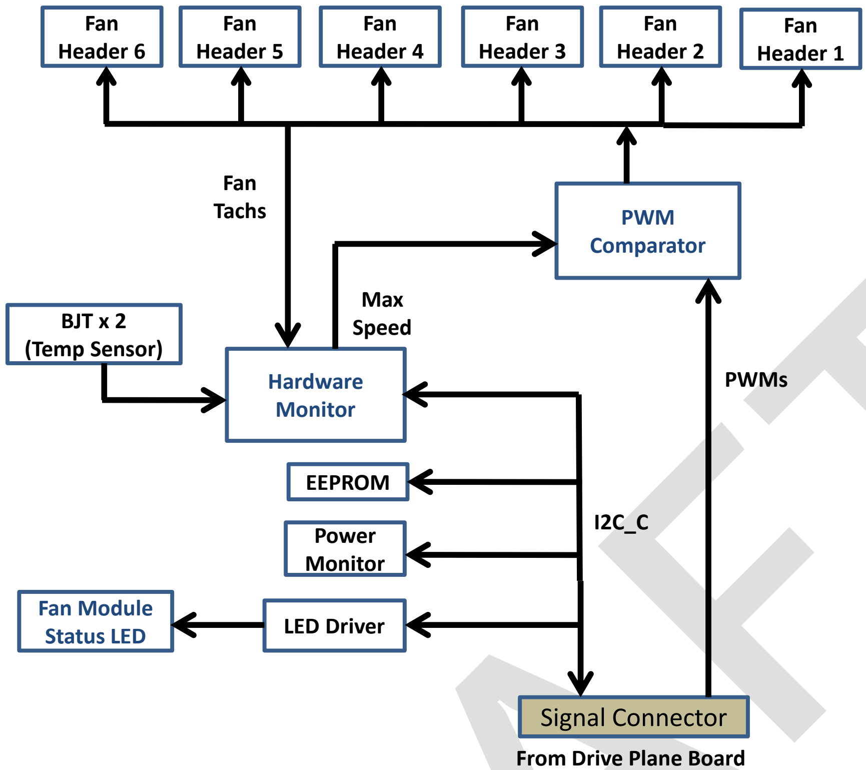

Figure 27 Fan Control Board Functional Block Diagram

6.2 FCB Placement and Form Factor

The fan control board form factor is 480mm x 65mm. Figure 28 illustrates the board placement. The ODM is responsible for complete component placement.

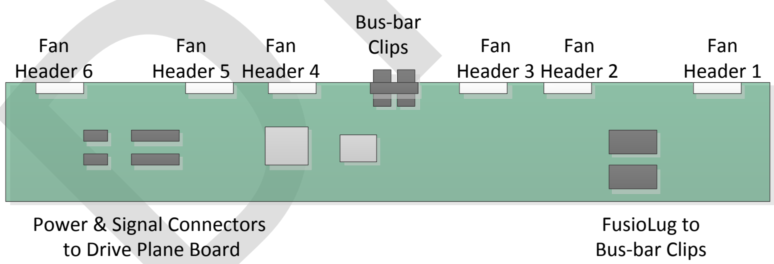

Figure 28 Open Vault Fan Control Board Placement

6.3 Embedded Hardware Monitor

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

- Monitors fan tachometer signals;
- Monitors the local temperature of the fan control board;
- Monitors the voltage rails on fan control board, as Figure 29 shows.

Power Rail	Voltage
V12_input	12V
V12_upper_tray	12V
V12_lower_tray	12V

Figure 29 Monitored Power Rails on FCB

6.4 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. The monitor is part number ADM1276 from Analog Devices.

6.5 Connectors

6.5.1 Signal Connector to Drive Plane Board

Signals from the drive plane board to the fan control board primarily contains the I2C bus, power monitors and some GPIOs. The connector between these two boards is an FFC/FPC cable, part number 6712K-F10M-02L from Entery. The pin count is 10, and the signals are listed in Figure 30.

Pin	Assignment on Upper Tray	Assignment on Lower Tray
1	Upper tray heartbeat out	Lower tray heartbeat out
2	I2C_C SCL	I2C_C SCL
3	I2C_C SDA	I2C_C SDA
4	GND	GND
5	PWM from expander 1A	PWM from expander 2A
6	GND	GND
7	PWM from expander 1B	PWM from expander 2B
8	GND	GND
9	Upper tray present out	Lower tray present out
10	Lower tray present to upper	Upper tray present to lower

Figure 30 Pin-Out of Signal Connector from FCB to DPB

6.5.2 Power Connector to Drive Plane Board

The 4-pin vertical connector part number is PLA04F3N0A1 from Positronic. The 12V and 5V power rails are carried by high strand power cable. Figure 31 shows the pin-out.

Pin	Description
1	12.5V
2	12.5V
3	GND
4	GND

Figure 31 Fan Control Board Power Cable Connector Pin-Out

6.5.3 Power Connector to Open Rack Bus Bar

The bus bar connector assembly comprises a floating self-aligning carrier plate, allowing for lateral (X direction 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 short cables. One qualified connector is part number C5313-07301-00107 from Methode.

The connector matches the bus bar on the Open Rack.

The connector is shown in Figure 32, and its pin definition is in Figure 33.

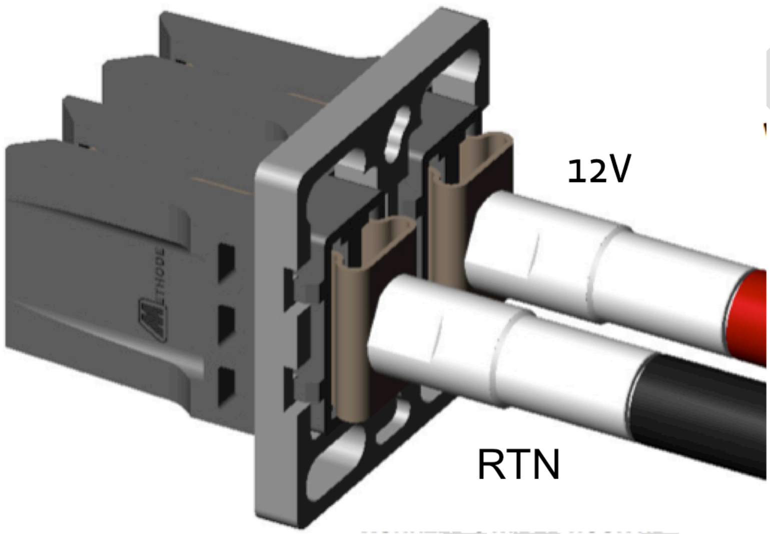

Figure 32 Bus Bar Connector to Open Rack

Pin	Description
1	12V
2	RTN

Figure 33 Pin-Out of Bus Bar Connector to Open Rack

6.5.4 Fan Module Connector

Each Open Vault fan control board is connected to 6 fan modules. Each fan module contains one dual rotor fan. One right angle 2.54mm pitch connector is used, with the pin definition in Figure 34. The connector's part number is 22-05-1052 from Molex.

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

Figure 34 Fan Connector Pin-Out

6.6 LEDs

The fan control board has six LEDs on its edge to display fan module status, one for each fan module.

Fan Module Status	Blue/Red LED
Normal operation	Blue On
Fan module fault	Red On

Figure 35 Rear Panel LED for Fan Module Status

6.7 PCB Stack-up

The PCB stack-up and impedance control for the SAS expander board are defined in the following figures. Total thickness is 62 mils +/-10%.

			Thickness (mil)
L1	TOP		1.7
		PP	3.5
L2	GND/VCC		1.2
		Core	49.0
L3	GND/VCC		1.2
		PP	3.5
L4	Bottom		1.7

Figure 36 PCB Stack-up for Fan Control Board

Impedance Request List		
Spec \ Layer	L1	L4
Single Ended Type (Trace width : mil)		
50Ω	5.5	5.5

Figure 37 PCB Impedance Control for Fan Control Board

7 Open Vault Power System

7.1 Power Budget

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

- In full-load operation, Open Vault system continuous power consumption is approximated 570W.
- In the extreme worst case, the maximum power consumption of Open Vault system won't exceed 650W.

Figure 38 shows the Open Vault system power budget in full-load operation, based on each module.

Item	Qty in one System	Power Consumption of each module (W)	Sub-total for all modules (W)	Derating by percentage	Power Consumption after derated (W)
HDD	30	14	420	90%	378
Drive Plane Board	2	9	18	90%	16.2
SAS Expander Board	4	15.6	62.4	90%	56.16
Fan Control Board	1	2	2	90%	1.8
Fan Module	6	24	144	80%	115.2
Total			646.4		567.36

Figure 38 Open Vault System Power Budget in Full Load

7.2 SEB Bulk Converter Solutions

Both the 12V to 3.3V and the 12V to 1.0V buck converters residing on the SAS expander board have a 93% efficiency target under normal load. The ODM determines their components.

7.3 Hard Drive 5V Power Design

7.3.1 Hard Drive 5V Power Requirements

The drive plane board passes through the system power (nominal 12VDC) to the hard disk drives. It also contains power regulators to generate 5VDC from 12VDC for HDDs. The total 5V current for each HDD tray is about 18A maximum. In order to improve reliability, the 15 HDDs are divided into three groups. A VR is required to generate 5VDC for each HDD group. The output current of each VR is about 6A.

The drive plane board design ensures that the PCB traces and power planes are wide/thick enough to support 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.

7.3.2 5V Output Protection

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

7.3.3 5V Bulk Converter

The 5V buck converter residing on the fan control board must be designed with a 93% efficiency target for normal load. The ODM determines their components.

7.4 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.

7.5 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.

8 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.

8.1 Enclosure Service Functionalities

Listed below is a high-level enclosure service functional specification of the Open Vault. Refer to SCSI Enclosure Services and SMP Functions (section 8.2) 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
  - Firmware in-system upgrade for each SAS expander
  - One command/script to upgrade firmware for all HDDs

8.2 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.

The Open Vault JBOD system applies a standalone SES model that can be accessed by 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.

Please refer to Figure 39 for supported SES pages and Figure 40 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 39 Supported SES Pages

SMP Function	Function Field Code
Report general	00h
Report manufacturing information	01h
Report broadcast	06h
Discover	10h
Report PHY error log	11h
Report PHY SATA	12h
PHY control	91h

Figure 40 Supported SMP Functions

8.3 Fan Speed Control

The Open Vault enclosure thermal management supports two schemes:

- One scheme is to control fan power management by each SAS expander chip itself, with environment thermal sensors and HDD S.M.A.R.T. temperature information; a power management comparator on the FCB selects the maximum power management 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 power management numbers and controls fan speed via SES commands sent to the SAS expander(s).

Figure 41 shows the temperature sensors' location within the Open Vault system.

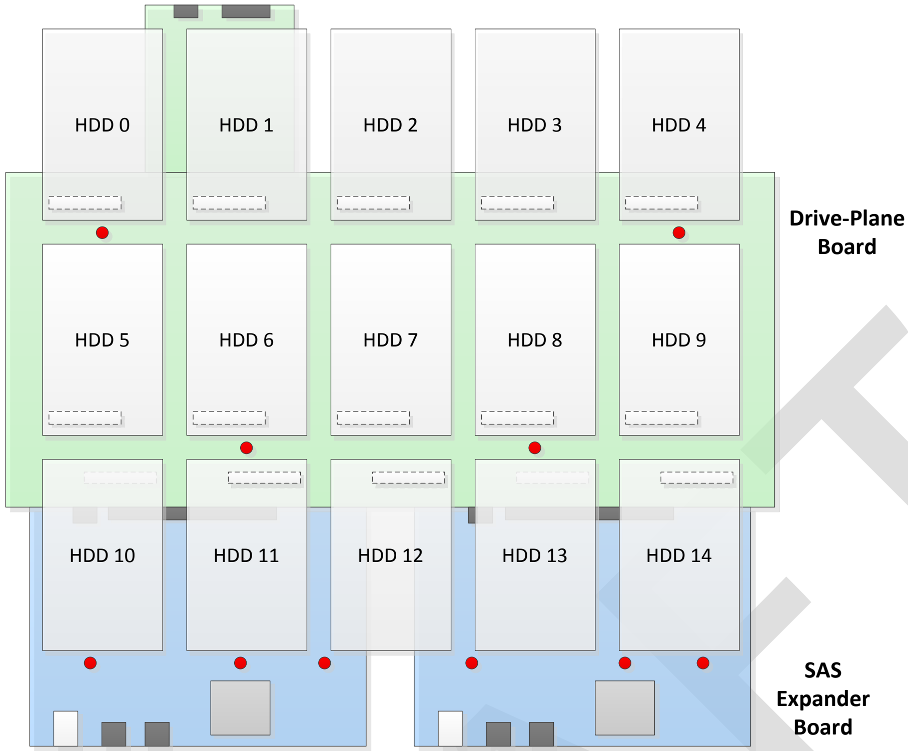

Figure 41 Open Vault System Thermal Sensor Locations

The ODM provides a detailed implementation of the fan speed control requirements. Figure 42 shows the high-level strategy of Open Vault fan speed control executed by firmware in each SAS expander.

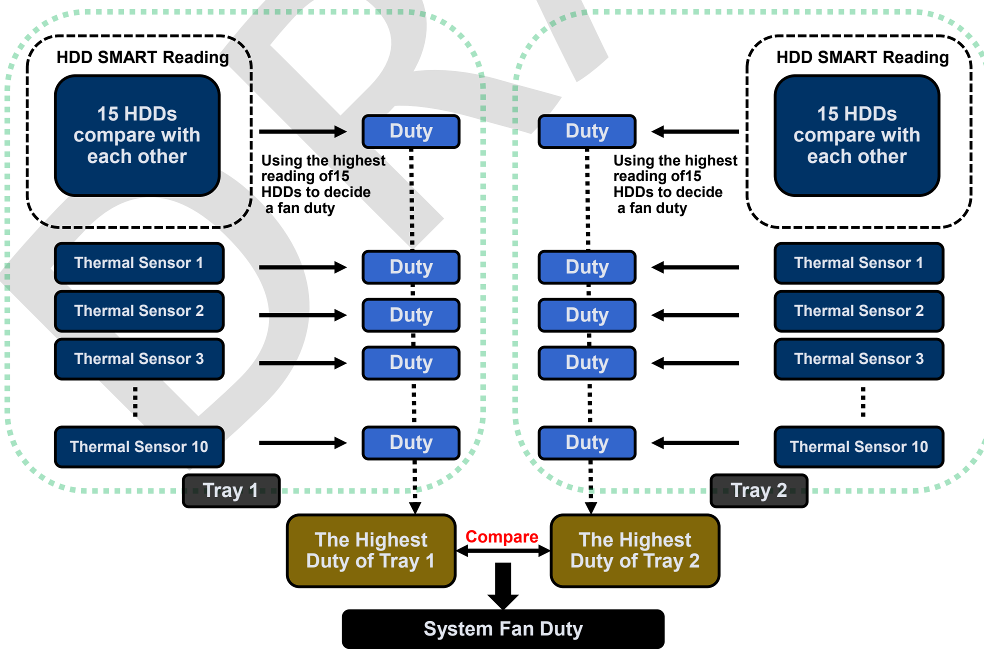

Figure 42 Open Vault System Fan Speed Control Strategy

8.4 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.

8.5 HDD Spin-up Control

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 will follow the SAS expander chip vendor's strategy.
- Details of group spin-up will be decided by ODM, such as quantity of hard disk drives in each group, and delay interval between each group.

8.6 HDD Spin-down Control Support

To be aligned with 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.

8.7 HDD Presence Detect

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

8.8 HDD Status LED

The enclosure management firmware supports control of the HDD status LED as depicted in Figure 24. 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.

8.9 Error Code Display on Debug Card

The error codes displayed on the debug card can be defined by the ODM.

9 Mechanical

9.1 External Chassis

The overall dimensions of the chassis are: 536mm wide x 88.9mm tall x 878mm deep.

The chassis is designed to use welding and rivets or other approved methods, but not screws. The individual HDD trays are stiff enough to be carried fully loaded. The chassis should be capable of being carried fully loaded with 2 loaded HDD trays. The main chassis has a cover for airflow management and to improve stiffness.

9.2 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.

9.3 Rack Interface/Slides

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

10 Environmental

10.1 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).

10.2 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 43.

	Operating	**Non-Operating**
Vibration	0.5g 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 43 Vibration and Shock Requirements

11 Prescribed Materials

11.1 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

11.2 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.

11.3 Component De-Rating

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