OPEN

Compute Project

Open Vault Storage
SAS Expander Firmware
Specification V1.0

Contents

1 Scope

This document describes the technical SAS Expander firmware specifications used in the Open Vault storage unit for the Open Compute Project.

2 Overview

This document mainly describes the Open Vault SAS expander firmware and SES management specification developed by Wiwynn Corporation. The Knox storage unit is a 2U-30HDD storage enclosure, consisting of two identical 1U high HDD trays with 15 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. Knox storage unit will fit into the Open Rack. Each HDD tray is connected externally to almost any host server via x4 SAS cable through SAS RAID or HBA cards.

The SAS expander firmware supports the SSP/STP/SMP protocols and the routing management to discover the topology of SAS storage network. And, the SAS expander firmware developed by Wiwynn Corporation provides complete enclosure management functions including, for example, HDD and enclosure system LED definition and control, current/voltage monitor, fan reading and fan control based on thermal profile.

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[1] INCITS SCSI Primary Commands - 3 (SPC-3). Revision 18 April 25, 2004

[2] INCITS SCSI-3 Enclosure Services Command Set 2(SES-2). Revision 20 May 12, 2008

[3] INCITS Serial Attached SCSI – 2 (SAS-2). Revision 16 April 18, 2009

[4] Open Compute Project Open Vault Storage Specification v0.7

[5] LSI Expander Tools (Xtools) User Guide Preliminary, Version 1.3 February 2011

[6] LSI 6Gb/s SAS/SATA Expander SDK Programming Guide Version 2.5 February 2011

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3 Open Vault Storage System Overview

3.1 System Block Diagram

Figure 3-1 shows the overview of system block diagram for Knox, mainly addressing SAS data paths.

On each SAS Expander Board:

- One external mini-SAS port to host RAID or HBA card
  - Using External Mini-SAS cable
  - Max cable length: 7m

- Up to two internal mini-SAS ports to cascade Knox trays
  - Using internal mini-SAS cable located outside the chassis
  - Max cable length: 1.3m

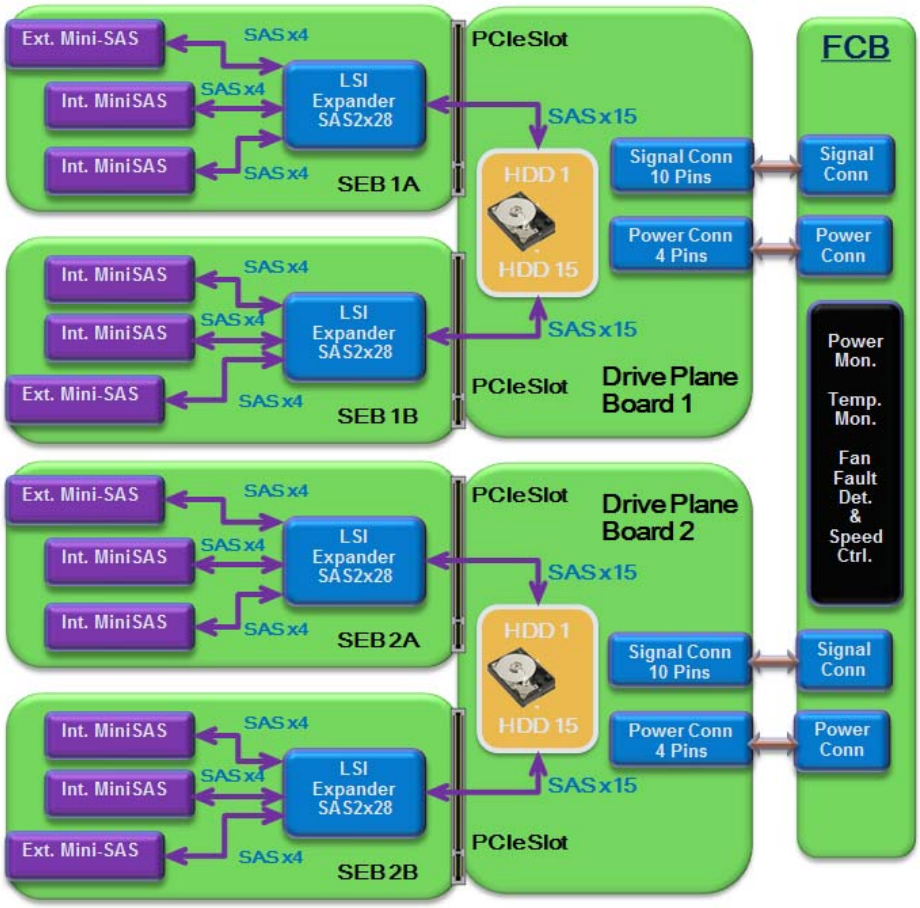


Figure 3-1 Knox System Block Diagram

3.2 System I2C Topology

Figure 3-2 shows the system I2C topology of Knox. This mainly reflects the enclosure management structure of Knox.

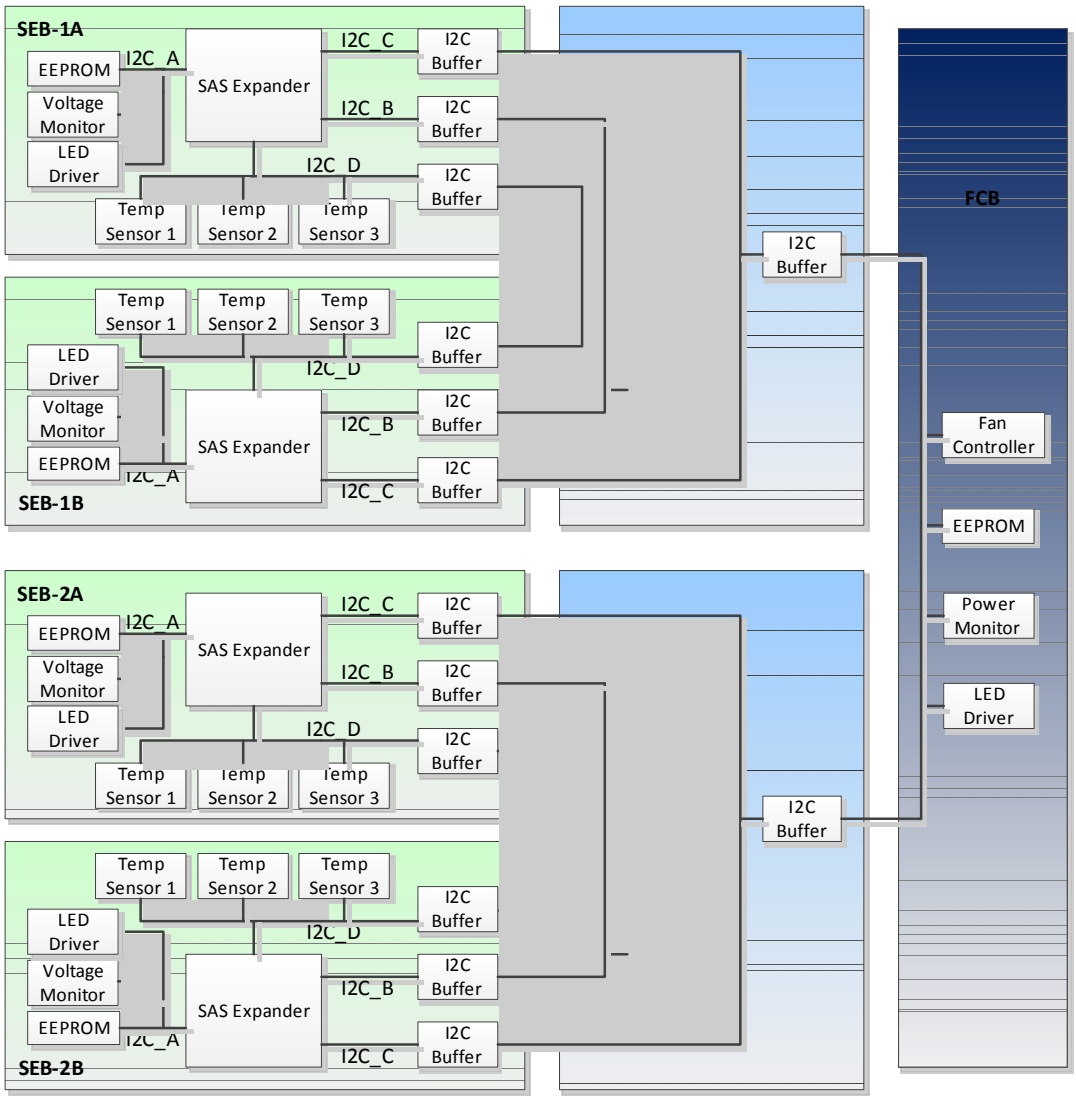


Figure 3-2 Knox System I2C Topology

3.3 Knox SAS Expander Board

Figure 3-3 illustrates the functional block diagram of the Knox SAS expander board (SEB), utilizing LSISAS2x28 6G SAS expander.

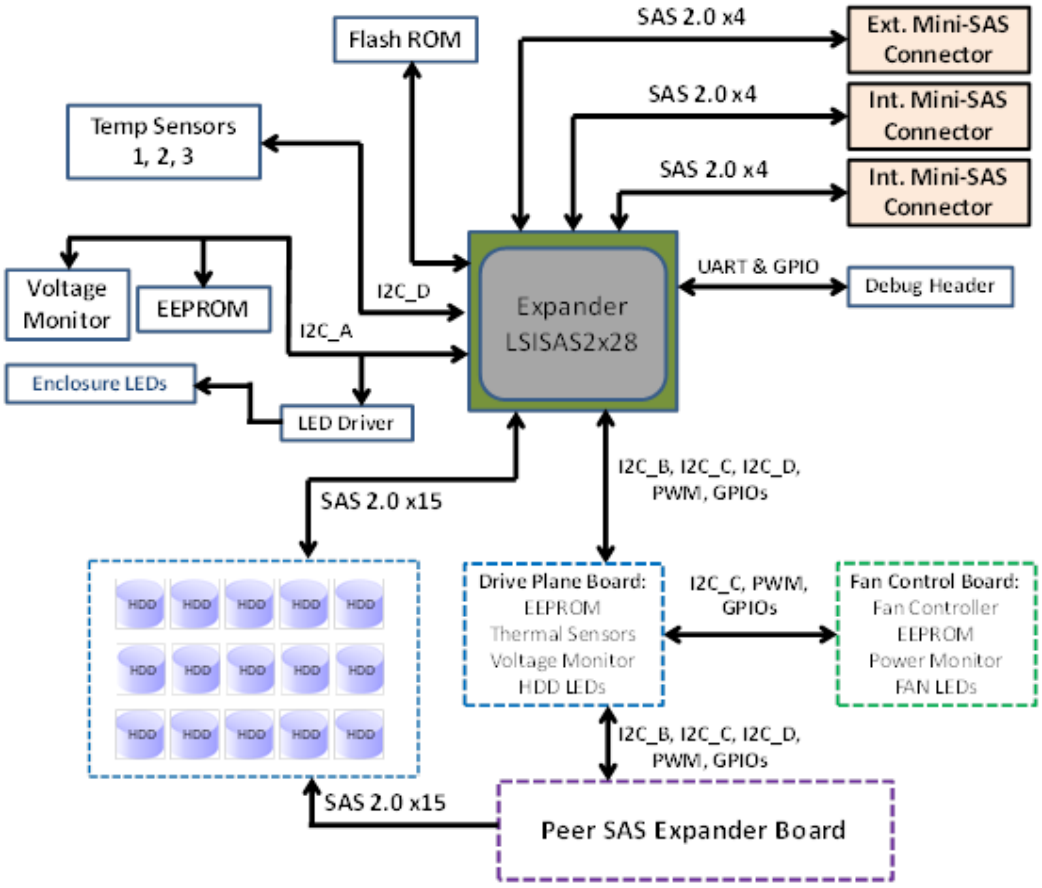


Figure 3-3 Knox SAS Expander Board Block Diagram

3.4 Knox Drive Plane Board

Figure 3-4 illustrates the functional block diagram of the drive plane board (DPB).

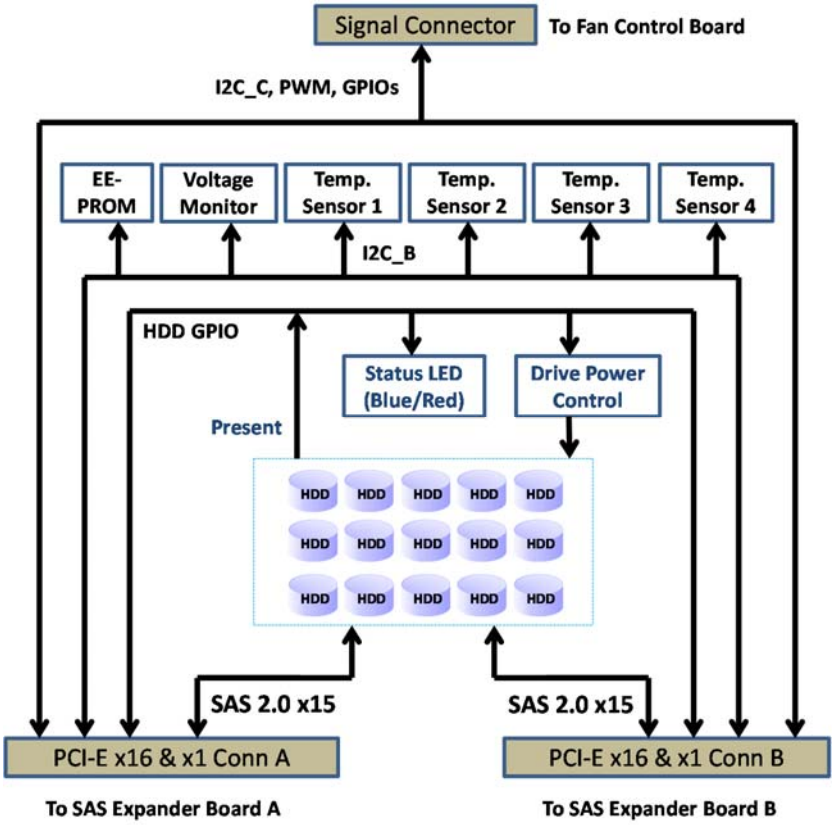


Figure 3-4 Knox Drive Plane Board Block Diagram

3.5 Knox Fan Control Board

Knox fan control board (FCB) is fixed on the rear side of the system. A pair of connector is used to connect Knox to the bus-bar from the Open Rack, to feed in the main +12V power rail. Another pair of connector conducts the +12V power to the drive plane board through high strand power cable. Hardware monitor and PWM comparator co-work with control signals from SAS expander(s) for the fan speed control according to cooling requirements of the whole storage enclosure.

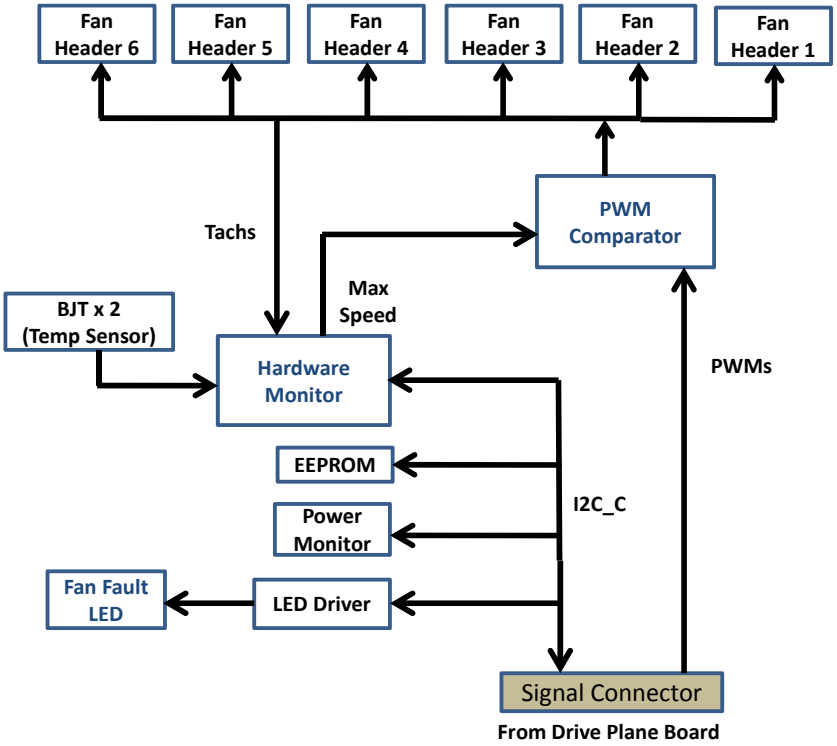


Figure 3-5 Fan Control Board Functional Block Diagram

3.6 System Component Layout

Figure 3-6 shows the major system components layout from top view of Knox.

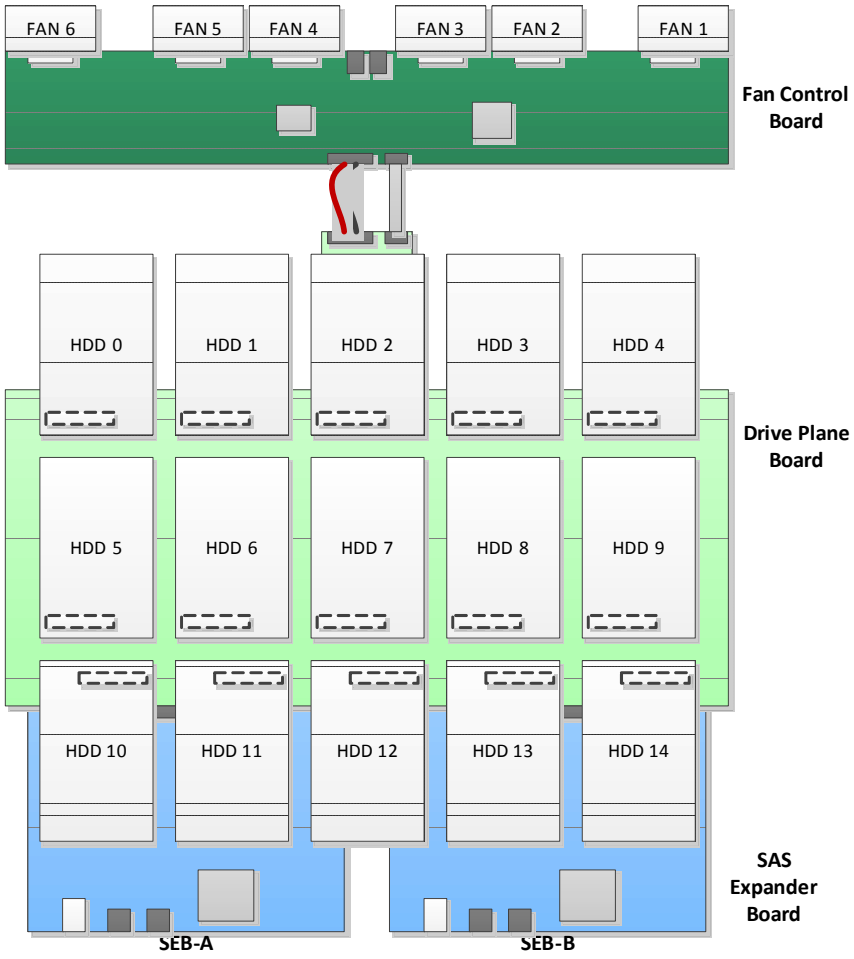


Figure 3-6 Knox System Component Layout

4 Feature

This subsection describes the expander firmware features.

- Support the SAS protocol described in the Serial Attached SCSI (SAS) Standard, version 2.0
- Support Zoning for drive partitioning
- Support hard drive presence detection
- Support tray pulling out detection
- Support expander crash detection
- Provide individual hard drive power On/Off control
- Support hard drive staggered spin-up
- Provide I2C interfaces to monitor current/voltage/temperature/fan speed sensors, control LED driver and access EEPROMs
- Support SAS hard drive SMART temperature monitoring
- Support flexible thermal profile settings and fan curves for fan PWM control
- Support fault indicators on different boards
- Support cascade function, allow user to cascade expander subsystem
- Support SES2 for standard enclosure management for environmental monitoring
- Support EEPROM contents update for each Field Replaceable Unit
- Support enclosure event log
- Support firmware in-system upgrade for each SAS expander
- Support command line interface for diagnostic

5 Expander Firmware Functionalities

Here are several sections to describe the detailed firmware operation. And the expander firmware is also responsible for enclosure management including reporting expander events, current, voltage sensors' state, temperature sensors' state, and the fans' state and controlling LEDs. The detailed information is described in the following section.

5.1 Zoning

The expander firmware supports both T-10 and Phy-Based Zoning. SAS zoning is implemented by a set of zoning expander devices with zoning enabled that define a zoned portion of a service delivery subsystem (ZPSDS). The zoning expander devices control whether a phy is permitted to participate in a connection to another phy.

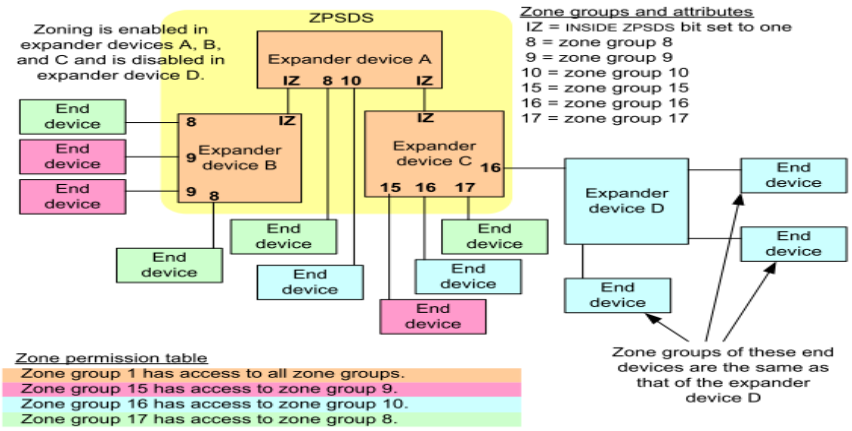


Figure 5-1 Show an example of zoning

5.1.1 T-10 Based zoning

The expander supports T10-Based Zoning. This is a zoning method defined in the SAS2 specification that allows for efficient management of access control between SAS devices across an entire SAS domain. The expander supports the standard "*Inside ZPSDS"* modes.

5.1.2 Phy-Based zoning

The expander implements Phy-Based Zoning using a permission table that

controls which phys can connect with each other. A valid permission table must be symmetric; that is, if PHY[x] can access PHY[y], PHY[y] can also access PHY[x]. Phy-Based Zoning divides an expander into separate logical zones. All phys in a wide port must have the same permissions.

5.2 HDD Presence Detection

The Knox expander hardware design can support HDD presence detection via GPIO pins. The expander firmware will configure LED pins as GPIO pins for HDD presence detection. And the LED pins definitions are proposed as Figure 5-2.

Activity LED Group	Signal Name
LED0	HDD_Presence 0
LED1	HDD_Presence 1
LED2	HDD_Presence 2
LED3	HDD_Presence 3
LED4	HDD_Presence 4
LED5	HDD_Presence 5
LED6	HDD_Presence 6
LED7	HDD_Presence 7
LED8	HDD_Presence 8
LED9	HDD_Presence 9
LED10	HDD_Presence 10
LED11	HDD_Presence 11
LED12	HDD_Presence 12
LED13	HDD_Presence 13
LED14	HDD_Presence 14

GPIO Value	Presence
Low	HDD Presence
High	No HDD Presence

Figure 5-2 LED Pins for HDD Presence Detection and Definition

5.3 Tray Pulling Out Detection

The Knox system hardware design can support tray pulling out detection via two GPIO pins. There are upper tray and lower tray in one Knox system. The expander firmware will determine does tray been pulled out or not via GPIO pins. And the GPIO pins definitions are shown as Figure 5-3. Firmware will support a fan control mechanism when detect a tray (upper or lower tray) have pulled out. After firmware detect any one of tray have pulled out, firmware will show error code on debug board and turn on the enclosure red LED. And firmware will record event log when tray pulled out and pushed in.

Expander GPIO5	Description
Low	Self tray pulling out
High	Self tray not pulling out

Expander GPIO6	Description
Low	Peer tray pulling out
High	Peer tray not pulling out

Figure 5-3 GPIO Pins for Tray Pulling Out Detection

5.4 Expander Crash Detection

The Knox hardware design can support expander crash detection via monitor the heartbeat of the other side SEB. The GPIO pins definitions for expander crash detection are proposed as Figure 5-4.

GPIO Pin	GPIO vaule	Description
SEB Heartbeat Out (GPIO2)	PWM signal	Connect to the other side SEB Heartbeat IN GPIO
Peer SEB Presence (GPIO10)	High	Another SEB not present
	Low	Another SEB present
SEB Heartbeat In (GPIO4)	High	Another SEB alive
	Low	Another SEB crash

Figure 5-4 GPIO Pins for Expander Crash Detection

5.5 HDD Power On/Off Control

The expander hardware design can support HDD power on/off control via GPIO pins. The expander firmware will configure LED pins as GPIO pins for HDD power on/off control. And the LED pins definitions are given as Figure 5-5.

Status LED Group	Signal Name
LED72	HDD_Power 0
LED73	HDD_Power 1
LED74	HDD_Power 2
LED75	HDD_Power 3
LED76	HDD_Power 4
LED77	HDD_Power 5
LED78	HDD_Power 6
LED79	HDD_Power 7
LED80	HDD_Power 8
LED81	HDD_Power 9
LED82	HDD_Power 10
LED83	HDD_Power 11
LED84	HDD_Power 12
LED85	HDD_Power 13
LED86	HDD_Power 14

SEB A GPIO Value	SEB B GPIO Value	HDD Power Status
High	High	HDD Power On
Low	High	HDD Power Off
High	Low	HDD Power Off
Low	Low	HDD Power Off

Figure 5-5 LED Pins for HDD Power On/Off Control and Definition

5.6 HDD Staggered Spin-Up

The expander hardware supports drive spin-up and sequencing control to optimize power usage across large topologies. User can set the time interval between drive spin-up and maximal number of drives to simultaneously spin up.

- The group definition of hard disk drives will follow SAS expander chip vendor's strategy.
- Quantity of hard disk drives in each group is 3 HDDs.
- Delay Interval between each group is 15 second.

5.7 Hardware Monitoring Sensors

According to the I2C topology in Figure 3-2, the firmware will automatically monitor the fans via hardware monitor chip and voltages, temperature, and current sensors via I2C bus. The following diagram indicates the sensor type and the respective sensor number as follows.

Sensor Type	Sensor Number
Temperature sensors in DPB(Drive Plane Board)	4
Temperature sensors in HDDs	15
Temperature sensors in SEB(SAS Expander Board)	4
Thermal diodes in FCB(Fan Controller Board)	2
Voltage sensors in DPB(Drive Plane Board)	4
Voltage sensors in SEB(SAS Expander Board)	4
Voltage sensors in FCB(Fan Controller Board)	4
Current monitor in FCB(Fan Controller Board)	1
Fan Tach in 2U System	12

Figure 5-6 Hardware Monitor Sensor Type and Number

5.7.1 Temperature Sensor Monitoring

The firmware will periodically read the values of temperature sensors in Knox and host can get these temperature sensor statuses via SES. The required thermal sensor locations and numbers are listed below and shown in Figure 5-7, 5-8, 5-9, 5-10.

Location of Thermal Sensors	# of Thermal Sensors
SAS Expander Board A	4
SAS Expander Board B	4
Drive Plane Board	4
HDD SMART temperature	15
Thermal diodes in Fan Controller Board	2

Figure 5-7 List of Knox System Thermal Sensors

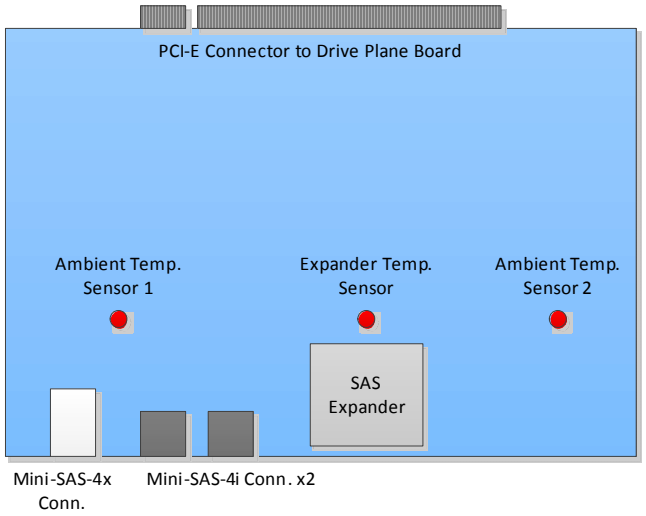


Figure 5-8 Thermal Sensor Locations and Names on SAS Expander Board

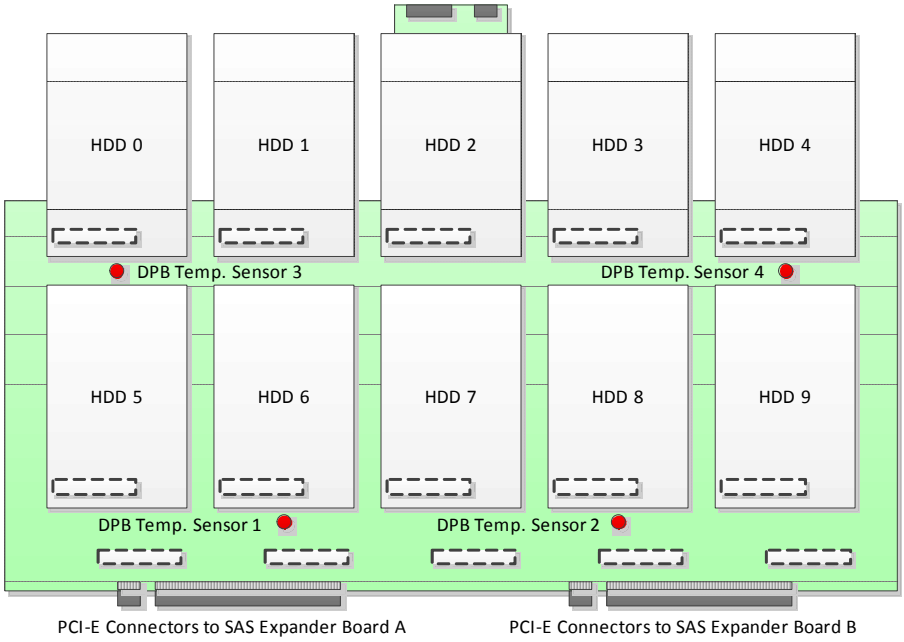


Figure 5-9 Thermal Sensor Locations and Names on Drive Plane Board

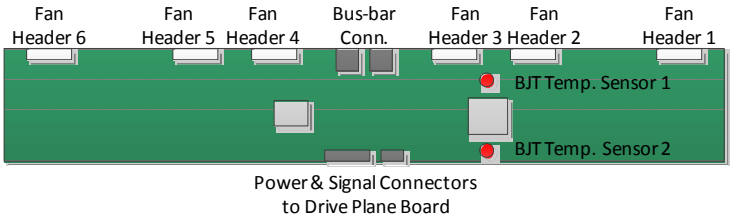


Figure 5-10 Thermal Locations and Names on Fan Control Board

5.7.2 Current Sensor Monitoring

There is only one current sensor in Knox system. The firmware will periodically read the value of current sensor and host can get status of current sensor via SES. The current sensor on FCB is shown in Figure 5-11.

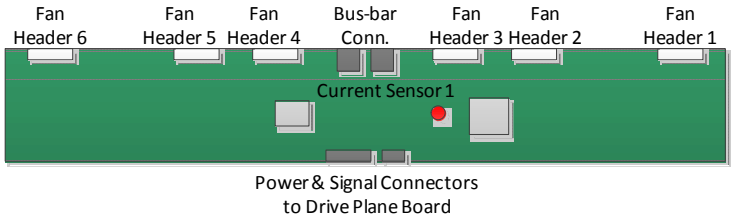


Figure 5-11 Current Sensor Location and Name on Fan Control Board

5.7.3 Voltages Sensor Monitoring

There are 12 voltage sensors in the tray. The firmware will periodically read the values of voltage sensors in the tray and host can get statuses of voltage sensors via SES. The voltage sensor locations and numbers are listed below and shown in Figure 5-12.

Power Rail	Voltage	Location	Number
VDDIO33	3.3V	SAS Expander Board	1
VDDIO	1.8V	SAS Expander Board	1
VDD	1.0V	SAS Expander Board	1
VCC for signal re-driver	1.2V	SAS Expander Board	1
Input and To HDDs	12.5V	Drive Plane Board	1
To HDDs	5V	Drive Plane Board	3
Input and To HDDs	12.5V	Fan Control Board	3
VDDIO33	3.3V	Fan Control Board	1

Figure 5-12 Listing of Voltage Sensors Monitored on SEB Board

5.7.4 Fan Speed Control and Monitoring

Figure 5-13 illustrates the board placement. An embedded fan controller will be implemented, to monitor fan tachometer signals and local temperature of the fan control board. The solution is a hardware monitor chip from Nuvoton, P/N is NCT7904D. The firmware will implement the fan speed monitoring features via NCT7904D shown in Figure 5-14.

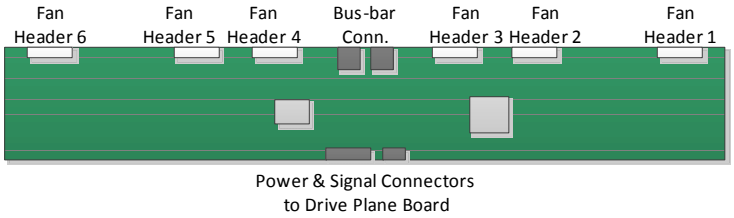


Figure 5-13 Knox Fan Control Board Placements

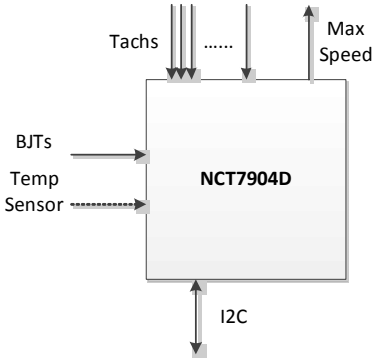


Figure 5-14 Embedded Fan Controller Block Diagram

Knox enclosure fan speed control will support two schemes:

One scheme is to control fan PWM by each SAS expander chip itself, with environmental thermal sensors temperature information; a PWM comparator on fan control board (FCB) will select the maximal PWM value from the four SAS expanders and drive the fans.

The other scheme is each expander chip only reports all temperature values to host server; the host server will calculate suitable PWM numbers and control fan

speed via SES commands sent to SAS expander(s).

For the first scheme, the Knox fan speed control algorithm ensures that all devices in the system (with primary focus on HDDs and SAS expander) are kept under their maximal specified operating temperatures. The fan control logic has the capability to adjust all parameters pertinent to providing optimal cooling within Facebook's contained "hot aisle" datacenter environment. The fan control strategy is designed based on the readings from various thermal sensors in the system, where cooling is designed for the system components to operate closest to their maximal temperature ratings.

The temperature sensor and HDD S.M.A.R.T. threshold settings are assigned for each individually based on thermal simulation. Expander firmware has the ability to read assigned threshold settings for a specific system configuration and thermal settings to implement the fan speed control algorithm accordingly. Figure 5-15 shows the temperature sensors' location within a Knox tray.

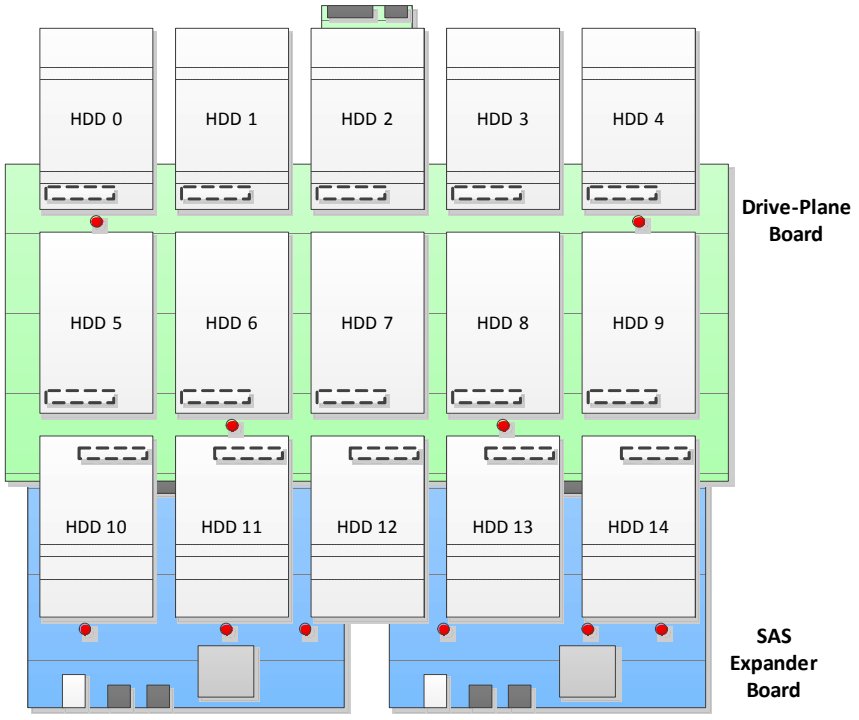


Figure 5-15 Knox System Thermal Sensor Locations

5.7.5 Thermal Protection

There will be different levels' consideration of system and hardware thermal protection for Knox system.

- **Thermal Warning**
  - Set high and low **Warning** thresholds in SES Threshold Pages of the SES elements (including all temperatures). When any SES element is over/under its high/low threshold, firmware will send out BROADCAST SES primitive to inform host server.

- **Thermal Software Protection**
  - Set a high and low **Critical** threshold in SES Threshold Pages of the SES elements (including all temperatures) as **Software Protection** level. When any SES element is over/under its high/low threshold value, firmware will send out BROADCAST SES primitive to host server. The related fault LED is on, error code is shown on debug board and event log is logged.

- **Thermal Hardware Protection**
  - When all heartbeats of SAS expander in Knox are gone, hardware design mechanism will drive fan speed to the maximum.

  - Firmware sets a temperature threshold in NCT7904 register. If temperature value of any BJT on fan control board reaches the 60 degree threshold, NCT7904 will disable the Enable Pin on hot-swap controller on FCB to shut down the whole Knox system.

5.7.6 Hardware Monitor Sensor Threshold and Offset

Figure 5-16 shows the thermal sensor threshold of each temperature sensor. Figure 5-17 shows the BJT temperature sensor and HDD S.M.A.R.T. temperature offset implement in SEB firmware. Figure 5-18 shows the voltage and current threshold of each voltage sensor and current sensor. The SEB firmware will use these thresholds to report warning or critical condition in each SES element.

Sensor Name	Low (in Celsius)		High (in Celsius)	
	Warning	Critical	Warning	Critical
Ambient Temp. Sensor A1	5	0	45	50
Ambient Temp. Sensor A2	5	0	45	50
Ambient Temp. Sensor B1	5	0	45	50
Ambient Temp. Sensor B2	5	0	45	50
Expander Temp. Sensor A	10	5	50	55
Expander Temp. Sensor B	10	5	50	55
DPB Temp. Sensor 1	10	5	50	55
DPB Temp. Sensor 2	10	5	50	55
DPB Temp. Sensor 3	10	5	50	55
DPB Temp. Sensor 4	10	5	50	55
BJT Temp. Sensor 1	10	5	50	55
BJT Temp. Sensor 2	10	5	50	55
HDD S.M.A.R.T.	10	5	60	65
Expander Internal Temp. A	10	5	105	110
Expander Internal Temp. B	10	5	105	110

Figure 5-16 Thermal Sensor Thresholds

Sensor	Offset
BJT Temp. Sensor 1	0
BJT Temp. Sensor 2	-2
HDD SMART Temp.	0

Figure 5-17 Thermal Sensor Offset

Sensor Name	Low		High	
	Warning	Critical	Warning	Critical
SEB Voltage 1.2V	5%	10%	5%	10%
SEB Voltage 3.3V	5%	10%	5%	10%
SEB Voltage 1.8V	5%	10%	5%	10%
SEB Voltage 1.0V	5%	10%	5%	10%
DPB Voltage 5V_1	5%	10%	5%	10%
DPB Voltage 5V_2	5%	10%	5%	10%
DPB Voltage 5V_3	5%	10%	5%	10%
DPB Voltage 12.5V	5%	10%	5%	10%
FCB Voltage 12.5V_1	5%	10%	5%	10%
FCB Voltage 12.5V_2	5%	10%	5%	10%
FCB Voltage 12.5V_3	5%	10%	5%	10%
FCB Voltage 3.3V	7%	10%	7%	10%
Current Sensor 1 (Reference base is 60A)	N/A	N/A	20%	30%

Figure 5-18 Voltage and Current Sensor Thresholds

5.8 LEDs

In Knox hardware design, the expander firmware supports fault indicators in SEB, DPB and FCB. This subsection describes the LED behavior.

5.8.1 Front Edge LEDs

The SEB has several LEDs on its front edge to display various statuses:

- One (1) bi-color (Blue/Red) for Enclosure status,
- One (1) bi-color (Blue/Red) for each Mini-SAS port link status.

The following Figure 5-19 shows the LED locations and Figure 5-20, 5-21 summarizes the conditions and the related LED behaviors.

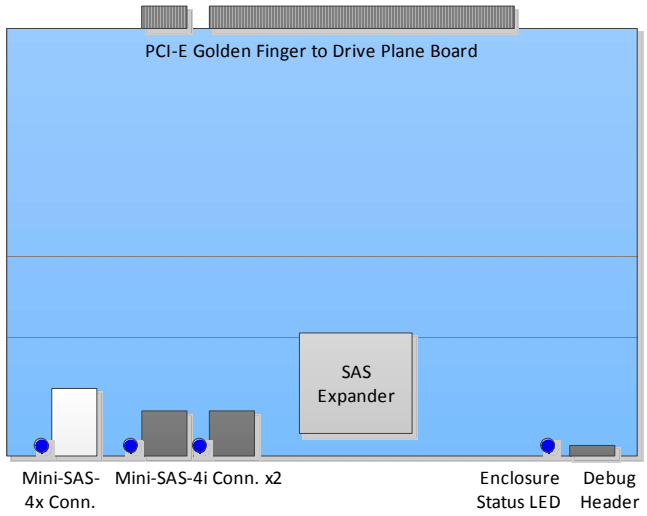


Figure 4-19 Front Edge LEDs

Enclosure Status	Blue LED	Red LED
Normal System Operation	ON	OFF
Any Fault in whole Enclosure	OFF	ON
Reserve for future use	OFF	Flashing

Figure 5-20 Enclosure Status LED on Front Panel

The SAS expander board fault status LED is designed to meet the following scenarios:

- If expander FW hangs, the enclosure fault LED (Red) will be turned ON.
- If expander FW runs normally, it will turn on the Enclosure fault LED for any SES element fault within the whole system.

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 5-21 Mini-SAS Port Link Status LED on Front Panel

5.8.2 Disk Drive Status LEDs

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

- When the HDD is online and healthy, turn on the Blue LED;
- When there's any fault for the HDD, turn on the Red LED.

Each drive's LED is located near the corresponding drive's cage and clearly visible from the top when HDD tray is pulled-out. Figure 5-22 summarizes the behaviors of the disk drive status LED:

Disk Drive Status	Blue LED	Red LED
Drive Online	ON	OFF
Drive Failure	OFF	ON
Drive Not Presence	OFF	OFF
Drive Power Off	Toggling (ON for 3s then OFF for 1s)	Toggling (OFF for 3s then ON for 1s)
Drive Identify	Toggling (ON for 1s then OFF for 3s)	Toggling (OFF for 1s then ON for 3s)

Figure 5-22 Disk Drive Status LED on Drive Plane Board

Note:
"Drive Failure" means the "FAULT REQSTD" bit is set to "1" in any SES Array Device Slot status elements
"Not Presence" means that the drive slot is empty
"Drive Power Off" mean the "DEVICE OFF" bit is set to "1" in any SES Array Device Slot status elements

“Drive Identify” mean the “IDENT” bit is set to “1” in any SES Array Device Slot status elements

5.8.3 Fan Control Board LED

The FCB has six bi-color LEDs on its edge to display the statuses of fan modules

- One bi-color LED for a fan module status

Fan Module Status	Blue LED	Red LED
Normal Operation	ON	OFF
Fan Module Fault	OFF	ON

Figure 5-23 Fan Module Status LED on Rear Panel

5.8.4 Error Code display on Debug Card and Event Log

Figure 5-24 shows the error codes to be displayed on the debug card. For details of each specific error code and event log, please refer to Section 12, Appendix A.

00	No Error
01-02	Critical Crash – Expander
03-06	Critical Crash – I2C Bus
07-10	Reserved
11-22	Fan Fault Warning
23-30	Reserved
31-42	Temperature Sensor Warning
43-44	Reserved
45-47	Voltage Sensor Warning
48	Current Sensor Warning
49	Reserved
50-64	HDD SMART Temp Warning
65	Expander A Internal Temp Warning
66	Expander B Internal Temp Warning
67-69	Reserved
70-84	HDD Fault
85-89	Reserved
90-92	Mini-SAS Link loss Warning
93	F/W detect self tray be pulled out
94	F/W detect peer tray be pulled out
95-98	Reserved
99	Firmware and hardware not match

Figure 5-24 Error Code for Knox

6 Serial Management Protocol (SMP)

Serial Management Protocol (SMP) is used to discover and configure expanders in the SAS topology. Each expander device contains at least one SMP target port for management purposes. The SMPT module responds to a standard set of SMP requests for tasks such as reporting an expander's self-configuration status, controlling phys, testing phys, reporting topology (discovery).

6.1 Supported Standard SMP Requests

The SMP module in the expander supports the standard SMP requests, as defined by the SAS specification (SAS-2, Revision 16). Figure 6-1 lists all supported SMP functions.

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 6-1 The Supported SMP Functions

7 SCSI Enclosure Services (SES)

7.1 Enclosure Management

The Knox expander firmware can support enclosure management function. According to the hardware design, the expander board can read all sensor data (including temperature sensors, fans speed, and current/voltage sensors in the system) and control front edge LED and HDD LED via SES. In the diagram, user applications can leverage LSI utilities or open source Linux utilities like sg3_utils to fetch status diagnostic pages from, and send control pages to, a SCSI Enclosure Services (SES) device, i.e. LSISAS2x28 expander.

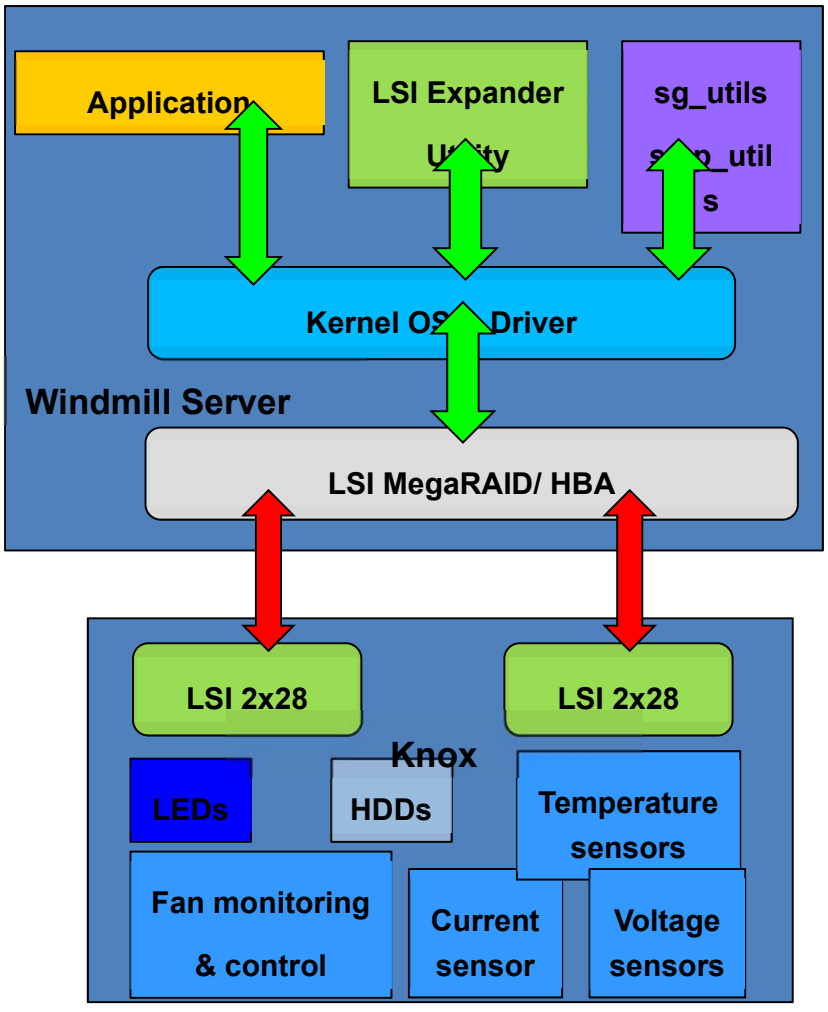


Figure 7-1 Knox Enclosure Management

As for the smp_utils in the diagram, it's a package of utilities that sends Serial

Attached SCSI (SAS) Management Protocol (SMP) requests to a device (typically a SAS expander) and decodes the response. The primary role of SMP is to monitor and control SAS expanders. Most SAS Host Bus Adapters (HBAs) and RoC contain a SMP initiator through which SMP requests are sent and responses received. SAS expanders contain SMP targets that respond to SMP requests.

7.2 SCSI command for SES

The SES Standard defines a common interface for accessing the elements in the enclosure. All SES communications are done via the SCSI SEND DIAGNOSTIC and RECEIVE DIAGNOSTIC RESULTS commands using SES “diagnostic pages”. The following sections will give great detail about SES pages supported by expander firmware.

7.3 Status Diagnostic Page

The following pages are defined in the SES-2 standard and will be supported in this expander firmware.

7.3.1 Supported Diagnostic Page (page code : 00h)

The Support Page List is a list of all diagnostic page codes implemented by the device server listed in ascending order starting with PAGE CODE 00h. See the details in Figure 7-2.

Figure 7-2 Supported Diagnostic Page

Bytes/Bits	7	6	5	4	3	2	1	0
0	Page Code (00h)							
1	Reserved (0)							
2~3	Page Length (8)							
4	00h							
5	01h							
6	02h							
7	04h							
8	05h							
9	07h							
10	0Ah							

11	0Eh

7.3.2 Configuration Diagnostic Page (page code : 01h)

The enclosure service configuration page will return a list of elements. The element list shall include all elements with defined element status or control and any other element in enclosure. It provides enclosure descriptor information and parameters. The configuration page is read by RECEIVE DIAGNOSTIC RESULTS command. See the details in Figure 7-3. The strings in the Figure 7-3 are padded with spaces up to the specified length if needed.

Figure 7-3 Configuration Diagnostic Page

Bytes/Bits	7	6	5	4	3	2	1	0
0	Page Code (01h)							
1	Number Of Sub-Enclosures (00h)							
2~3	Page Length (340)							
4~7	Generation Code (00h)							
	Enclosure Descriptor Header							
8~11	Reserved							
	Sub Enclosure Identifier (00h)							
	Number of Type Descriptor Header Supported (08h)							
	Enclosure Descriptor Length (44)							
	Enclosure Descriptor							
12~19	Enclosure Logical Identifier (WWN) (SAS Address of SEB)							
20~27	Enclosure Vendor Identification (“Wiwynn”)							
28~43	Product Identification (“Knox2U”)							
44~47	Vendor Firmware Revision Info (4 bytes) (“0e00”)							
48~55	Vendor Specific Data (8 bytes)							
	Type Descriptor Header #1							
56~59	Element Type (17h – Array Device Slot)							
	Number of Possible Elements (15)							
	SUB-Enclosure Identifier (0)							
	Type descriptor Text Length (32)							
	Type Descriptor Header #2							
60~63	Element Type (19h – Connector Element Slot)							
	Number of Possible Elements (20)							
	SUB-Enclosure Identifier (0)							
	Type descriptor Text Length (32)							
	Type Descriptor Header #3							

64~67	Element Type (03h –Cooling)
	Number of Possible Elements (12)
	SUB-Enclosure Identifier (0)
	Type descriptor Text Length (32)
	Type Descriptor Header #4
68~71	Element Type (04h – Temperature Sensor)
	Number of Possible Elements (29)
	SUB-Enclosure Identifier (0)
	Type descriptor Text Length (32)
	Type Descriptor Header #5
72~75	Element Type (12h – Voltage Sensor)
	Number of Possible Elements (12)
	SUB-Enclosure Identifier (0)
	Type descriptor Text Length (32)
	Type Descriptor Header #6
76~79	Element Type (13h – Current Sensor)
	Number of Possible Elements (1)
	SUB-Enclosure Identifier (0)
	Type descriptor Text Length (32)
	Type Descriptor Header #7
80~83	Element Type (0Eh – Enclosure)
	Number of Possible Elements (1)
	SUB-Enclosure Identifier (0)
	Type descriptor Text Length (32)
	Type Descriptor Header #8
84~87	Element Type (18h – SAS Expander)
	Number of Possible Elements (1)
	SUB-Enclosure Identifier (0)
	Type descriptor Text Length (32)
	Type Descriptor Text #1
88~119	“ArrayDevicesInSubEnclsr0”
	Type Descriptor Text #2
120~151	“ConnectorsInSubEnclsr0”
	Type Descriptor Text #3
152~183	“CoolingElementInSubEnclsr0”
	Type Descriptor Text #4
184~215	“TempSensorsInSubEnclsr0”

	Type Descriptor Text #5
216~247	“VoltageSensorsInSubEnclsr0”
	Type Descriptor Text #6
248~279	“CurrentSensorsInSubEnclsr0”
	Type Descriptor Text #7
280~311	“ EnclosureElementInSubEnclsr0”
	Type Descriptor Text #8
312~343	“SAS Expander”

7.3.3 Enclosure Status Page (page code : 02h)

The Enclosure Status page returns the status information for all elements in the enclosure in the order defined in the Configuration page. See the details in Figure 7-4.

Figure 7-4 Enclosure Status Page

Bytes/Bits	7	6	5	4	3	2	1	0
0	Page Code (02h)							
1	Status							
2~3	Page Length (400)							
4~7	Generation Code (00h)							
8~11	Overall Array Device Slot Status							
	Array Device Slot 1 Status							
12~15	Common Status							
	OK	RSVD DEVICE	HOT SPARE	CONS CHK	IN CRIT ARRAY	IN FAILED ARRAY	REBUILD/REMAP	R/R ABORT
	APP CLIENT BYPASSED A	DO NOT REMOVE	ENCLOSURE BYPASSED A	ENCLOSURE BYPASSED B	READY TO INSERT	RMV	IDENT	REPORT
	APP CLIENT BYPASSED B	FAULT SENSED	FAULT REQSTD	DEVICE OFF	BYPASSED A	BYPASSED B	DEVICE BYPASSED A	DEVICE BYPASSED B
16~71	Array Device Slot 2 Status ~ Array Device Slot 15 Status							
72~75	Overall Connector Element Slot Status							
	Connector Element Slot 1 Status							
76~79	Common Status							
	IDENT	Connector Type						
	Connector Physical Link							
	Reserved	Fail	Reserved					
80~155	Connector Element Slot 2 Status ~ Connector Element Slot 20 Status							
156~159	Overall Cooling Status							
	Fan 1 Status							
160~163	Common Status							
	IDENT	Reserved				ACTUAL FAN SPEED (MSB)		
	ACTUAL FAN SPEED (LSB)							
	HOT SWAP	FAIL	RQSTED ON	OFF	Reserved	ACTUAL SPEED CODE		
164~207	Fan 2 Status ~ Fan 12 Status							
208~211	Overall Temperature Sensor Status							
	Temperature Sensor 1 Status							
212~215	Common Status							

	IDENT	FAIL	Reserved				
	Temperature						
	Reserved			OT FAILURE	OT WARNING	UT FAILURE	UT WARNING
216~327	Temperature Sensor 2 Status ~ Temperature Sensor 29 Status						
328~331	Overall Voltage Sensor Status						
	Voltage Sensor 1 Status						
332~335	Common Status						
	IDENT	FAIL	Reserved	WARN OVER	WARN UNDER	CRIT OVER	CRIT UNDER
	Voltage (MSB)						
	Voltage (LSB)						
336~379	Voltage Sensor 2 Status ~ Voltage Sensor 12 Status						
380~383	Overall Current Sensor Status						
	Current Sensor 1 Status						
384~387	Common Status						
	IDENT	FAIL	Reserved	WARN OVER	Reserved	CRIT OVER	Reserved
	Current (MSB)						
	Current (LSB)						
388~391	Overall Enclosure Element Status						
	Enclosure Element 1 Status						
392~395	Common Status						
	IDENT	Reserved					
	TIME UNTIL POWER CYCLE					FAILURE INDICATION	WARNING INDICATION
	REQUESTED POWER OFF DURATION					FAILURE REQUESTED	WARNING REQUESTED
396~399	Overall SAS Expander Status						
	SAS Expander 1 Status						
400~403	Common Status						
	IDENT	FAIL	Reserved				
	Reserved						
	Reserved						

7.3.4 String In Page (page code: 04h)

The String In diagnostic page transmits an enclosure dependent binary string from the enclosure services process of the expander to the application client. The format of the binary string is vendor specific. The String In diagnostic page is read by the RECEIVE DIAGNOSTIC RESULTS command and a PAGE CODE field set to 04h. Figure 7-5 give an example for define the String In diagnostic page.

Figure 7-5 String In Diagnostic Page

Byte\Bits	7	6	5	4	3	2	1	0
0	Page Code (04h)							
1	00h							
2~3	Page Length (n – 3)							
4~n	Enclosure String In Data							

7.3.5 Threshold In Diagnostic Page (page code: 05h)

The Threshold In diagnostic page is transmitted from the enclosure services process to the application client to report the actual threshold values for those elements that have limited sensing capability (e.g., temperature sensors, voltage sensors, and current sensors). The Threshold In diagnostic page is read by the RECEIVE DIAGNOSTIC RESULTS command with a PCV bit set to one and a PAGE CODE field set to 05h. See the detail in Figure 7-6.

Figure 7-6 Threshold In Page

Bytes/Bits	7	6	5	4	3	2	1	0
0	Page Code (05h)							
1	Reserved			INVOP	Reserved			
2~3	Page Length (400)							
4~7	Generation Code (00h)							
8~11	Overall Array Device Slot Threshold Status Element							
12~71	Array Device 1 ~ Array Device 15 Threshold Status Element							
72~75	Overall Connector Threshold Status Element							
76~155	Connector 1 ~ Connector 20 Threshold Status Element							
156~159	Overall Fan Threshold Status Element							
160~207	Fan 1 ~ Fan 12 Threshold Status Element							
208~211	Overall Temperature Threshold Status Element							
	Temperature 1 Threshold Status Element							
212~215	High Critical Threshold							
	High Warning Threshold							
	Low Warning Threshold							
	Low Critical Threshold							
216~327	Temperature 2 Threshold Status Element ~ Temperature 29 Threshold Status Element							
328~331	Overall Voltage Threshold Status Element							
	Voltage Sensor 1 Threshold Status Element							
332~335	High Critical Threshold							
	High Warning Threshold							
	Low Warning Threshold							
	Low Critical Threshold							
336~379	Voltage 2 Threshold Status Element ~ Voltage 12 Threshold Status Element							
380~383	Overall Current Threshold Status Element							

	Current 1 Threshold Status Element
384~387	High Critical Threshold
	High Warning Threshold
	Low Warning Threshold
	Low Critical Threshold
388~391	Overall Enclosure Threshold Status Element
392~395	Enclosure 1 Threshold Status Element
396~399	Overall SAS Expander Threshold Status Element
400~403	SAS Expadner 1 Threshold Status Element

7.3.6 Element Descriptor Diagnostic Page (page code : 07h)

The Element Descriptor diagnostic page returns a list of vendor-specific, variable-length ASCII strings, one for each element in the Enclosure Status diagnostic page. The Element Descriptor diagnostic page is read by the RECEIVE DIAGNOSTIC RESULTS command with a PCV bit set to one and a PAGE CODE field set to 07h. See the detail in Figure 7-7. The strings in the Figure 7-7 are padded with spaces up to the specified length if needed.

Figure 7-7 Element Descriptor Diagnostic Page

Bytes/Bits	7	6	5	4	3	2	1	0
0	Page Code (07h)							
1	Reserved							
2~3	Page Length (3568)							
4~7	Generation Code (00h)							
Array Device Element Overall Descriptor								
8~9	Reserved							
10~11	Descriptior Length (32)							
12~43	“ArrayDevicesInSubEnclsr0”							
Array Device Element 1 Descriptor								
44~45	Reserved							
46~47	Descriptor Length (32)							
48~79	“ArrayDevices00”							
80~583	Array Device Element 2 ~ 15 Descriptor							
SAS Connector Element Overall Descriptor								
584~585	Reserved							
586~587	Descriptor Length (32)							
588~619	“ConnectorsInSubEnclsr0”							
SAS Connector Element 1 Descriptor								
620~621	Reserved							
622~623	Descriptior Length (32)							
624~655	“Connector00”							
656~1339	SAS Connector Element 2 ~ 20 Descriptor							
Cooling Element Overall Descriptor								
1340~1341	Reserved							
1342~1343	Descriptor Length (32)							

1344~1375	“CoolingElementInSubEnclsr0”
Cooling Element 1 Descriptor	
1376~1377	Reserved
1378~1379	Descriptor Length (32)
1380~1411	“Fan 1 Front”
Cooling Element 2 Descriptor	
1412~1413	Reserved
1414~1415	Descriptor Length (32)
1416~1447	“Fan 1 Rear”
1448~1807	Cooling Element 3~12 Descriptor
Temperature Sensor Element Overall Descriptor	
1808~1809	Reserved
1810~1811	Descriptor Length (32)
1812~1843	“TempSensorsInSubEnclsr0”
Temperature Sensor Element 1 Descriptor	
1844~1845	Reserved
1846~1847	Descriptor Length (32)
1848~1879	“DPB Temp. Sensor 1”
1880~1987	Temperature Sensor Element 2~4 Descriptor
Temperature Sensor Element 5 Descriptor	
1988~1989	Reserved
1990~1991	Descriptor Length (32)
1992~2023	“Expander Temp. Sensor A”
Temperature Sensor Element 6 Descriptor	
2024~2025	Reserved
2026~2027	Descriptor Length (32)
2028~2059	“Expander Temp. Sensor B”
Temperature Sensor Element 7 Descriptor	
2060~2061	Reserved
2062~2063	Descriptor Length (32)
2064~2095	“Ambient Temp. Sensor A1”
Temperature Sensor Element 8 Descriptor	
2096~2097	Reserved
2098~2099	Descriptor Length (32)
2100~2131	“Ambient Temp. Sensor A2”
Temperature Sensor Element 9 Descriptor	
2132~2133	Reserved

2134~2135	Descriptor Length (32)
2136~2167	“Ambient Temp. Sensor B1”
Temperature Sensor Element 10 Descriptor	
2168~2169	Reserved
2170~2171	Descriptor Length (32)
2172~2203	“Ambient Temp. Sensor B2”
Temperature Sensor Element 11 Descriptor	
2204~2205	Reserved
2206~2207	Descriptor Length (32)
2208~2239	“BJT Temp. Sensor 1”
Temperature Sensor Element 12 Descriptor	
2240~2241	Reserved
2242~2243	Descriptor Length (32)
2244~2275	“BJT Temp. Sensor 2”
Temperature Sensor Element 13 Descriptor	
2276~2277	Reserved
2278~2279	Descriptor Length (32)
2280~2311	“HDD SMART Temp. 00”
2312~2815	Temperature Sensor Element 14~27Descriptor
Temperature Sensor Element 28 Descriptor	
2816~2817	Reserved
2818~2819	Descriptor Length (32)
2820~2851	“Expander Internal Temp. A”
Temperature Sensor Element 29 Descriptor	
2852~2853	Reserved
2854~2855	Descriptor Length (32)
2856~2887	“Expander Internal Temp. B”
Voltage Sensor Element Overall Descriptor	
2888~2889	Reserved
2890~2891	Descriptor Length (32)
2892~2923	“VoltageSensorsInSubEnclsr0”
Voltage Sensor Element 1 Descriptor	
2924~2925	Reserved
2926~2927	Descriptor Length (32)
2928~2959	“SEB Voltage 1.2V”
Voltage Sensor Element 2 Descriptor	
2960~2961	Reserved

2962~2963	Descriptor Length (32)
2964~2995	“SEB Voltage 3.3V”
Voltage Sensor Element 3 Descriptor	
2996~2997	Reserved
2998~2999	Descriptor Length (32)
3000~3031	“SEB Voltage 1.8V”
Voltage Sensor Element 4 Descriptor	
3032~3033	Reserved
3034~3035	Descriptor Length (32)
3036~3067	“SEB Voltage 1.0V”
Voltage Sensor Element 5 Descriptor	
3068~3069	Reserved
3070~3071	Descriptor Length (32)
3072~3103	“DPB Voltage 5V_1”
Voltage Sensor Element 6 Descriptor	
3104~3105	Reserved
3106~3107	Descriptor Length (32)
3108~3139	“DPB Voltage 5V_2”
Voltage Sensor Element 7 Descriptor	
3140~3141	Reserved
3142~3143	Descriptor Length (32)
3144~3175	“DPB Voltage 5V_3”
Voltage Sensor Element 8 Descriptor	
3176~3177	Reserved
3178~3179	Descriptor Length (32)
3180~3211	“DPB Voltage 12.5V”
Voltage Sensor Element 9 Descriptor	
3212~3213	Reserved
3214~3215	Descriptor Length (32)
3216~3247	“FCB Voltage 12.5V_1”
Voltage Sensor Element 10 Descriptor	
3248~3249	Reserved
3250~3251	Descriptor Length (32)
3252~3283	“FCB Voltage 12.5V_2”
Voltage Sensor Element 11 Descriptor	
3284~3285	Reserved
3286~3287	Descriptor Length (32)

3288~3319	“FCB Voltage 12.5V_3”
Voltage Sensor Element 12 Descriptor	
3320~3321	Reserved
3322~3323	Descriptor Length (32)
3324~3355	“FCB Voltage 3.3V”
Current Sensor Element Overall Descriptor	
3356~3357	Reserved
3358~3359	Descriptor Length (32)
3360~3391	“CurrentSensorsInSubEnclsr0”
Current Sensor Element 1 Descriptor	
3392~3393	Reserved
3394~3395	Descriptor Length (32)
3396~3427	“Current Sensor 1”
Enclosure Element Overall Descriptor	
3428~3429	Reserved
3430~3431	Descriptor Length (32)
3432~3463	“EnclosureElementInSubEnclsr0”
Enclosure Element 1 Descriptor	
3464~3465	Reserved
3466~3467	Descriptor Length (32)
3468~3499	“Knox Enclosure”
SAS Expander Element Overall Descriptor	
3500~3501	Reserved
3502~3503	Descriptor Length (32)
3504~3535	“SAS Expander”
SAS Expander Element 1 Descriptor	
3536~3537	Reserved
3538~3539	Descriptor Length (32)
3540~3571	“Top ExpanderX” (X : A/B) Or “Bottom ExpanderX” (X : A/B) Note : Top or Bottom is depend on Tray ID

7.3.7 Additional Element Status Diagnostic Page (page code: 0Ah)

The Additional Element Status diagnostic page provides additional information about:

1. Array Device Slot elements
2. SAS Expander elements

The Additional Element Status diagnostic page is read by the RECEIVE DIAGNOSTIC RESULTS command with a PCV bit set to one and a PAGE CODE field set to 0Ah. A PAGE CODE field set to 0Ah in the parameter list for a SEND DIAGNOSTIC command is an invalid field error. See the detail in Figure 7-8.

Figure 7-8 Additional Element Status Diagnostic Page

Bytes/Bits	7	6	5	4	3	2	1	0
0	Page Code (0Ah)							
1	Reserved							
2~3	Page Length (616)							
4~7	Generation Code (00h)							
Additional Element Status descriptor 1 (Array Device 1)								
8	Invalid	Reserved		EIP (1b)	Protocol Identifier (6h)			
9	Additional Element Status Descriptor Length (34)							
10	Reserved							
11	Element Index (0)							
12	Number of Phy Descriptor							
13	Descriptor Type (00b)	Reserved						Not All Phys
14	Reserved							
15	Device Slot Number (0)							
16	Reserved	Device Type			Reserved			
17	Reserved							
18	Reserved				SSP Initiator Port	STP Initiator Port	SMP Initiator Port	Reserved
19	SATA Port Selector	Reserved			SSP Target Port	STP Target Port	SMP Target Port	SATA Device

20~27	Attached SAS Address			
28~35	SAS Address			
36	Phy Identifier			
37~43	Reserved			
44~547	Additional Element Status descriptor 2~15 (Array Device 2~15)			
Additional Element Status descriptor 1 (SAS Expander)				
548	Invalid	Reserved	EIP (1b)	Protocol Identifier (6h)
549	Additional Element Status Descriptor Length (70)			
550	Reserved			
551	Element Index (0)			
552	Number of Expander Phy Descriptors (28)			
553	Descriptor Type (01b)	Reserved		
554~555	Reserved			
556~563	SAS Address			
Expander Phy descriptor 1				
564	Connector Element Index			
565	Other Element Index			
566~619	Expander Phy descriptor 2~28			

7.3.8 Download Microcode Status Diagnostic Page (page code : 0Eh)

The Download Microcode Status diagnostic page transmits information about the status of one or more download microcode operations to the application client. See the detail in Figure 7-9 and Figure 7-10.

Figure 7-9 Download Microcode Status Diagnostic Page

Bytes/Bits	7	6	5	4	3	2	1	0
0	Page Code (0Eh)							
1	Number of Secondary Subenclosures (00h)							
2~3	Page Length (n-3)							
4~7	Generation Code							
Download microcode status descriptor list								
8	Download microcode status descriptor (primary subenclosure)							
23								
(N-15)	Download microcode status descriptor (last subenclosure)							
N								

Figure 7-10 Download Microcode Status Descriptor Format

Bytes/Bits	7	6	5	4	3	2	1	0
0	Reserved							
1	SubEnclosure Identifier							
2	SubEnclosure Download Microcode Status							
3	SubEnclosure Download Microcode Additional Status							
4~7	SubEnclosure Download Microcode Maximun Size							
8~10	Reserved							
11	SubEnclosure Download Microcode Expected Buffer ID							
12~15	SubEnclosure Download Microcode Expected Buffer Offset							

7.4 Control Diagnostic Page

7.4.1 Enclosure Control Diagnostic Page (page code: 02h)

The Figure 7-11 shows the way that SAS RoC uses SES to control LEDs behind an expander. The Enclosure Control Diagnostic Page provides access to the control elements identified by the Configuration Diagnostic Page. The Enclosure Control Diagnostic Page is written by the SEND DIAGNOSTIC command and the PAGE CODE field is set to 02h. See the details in Figure 7-12.

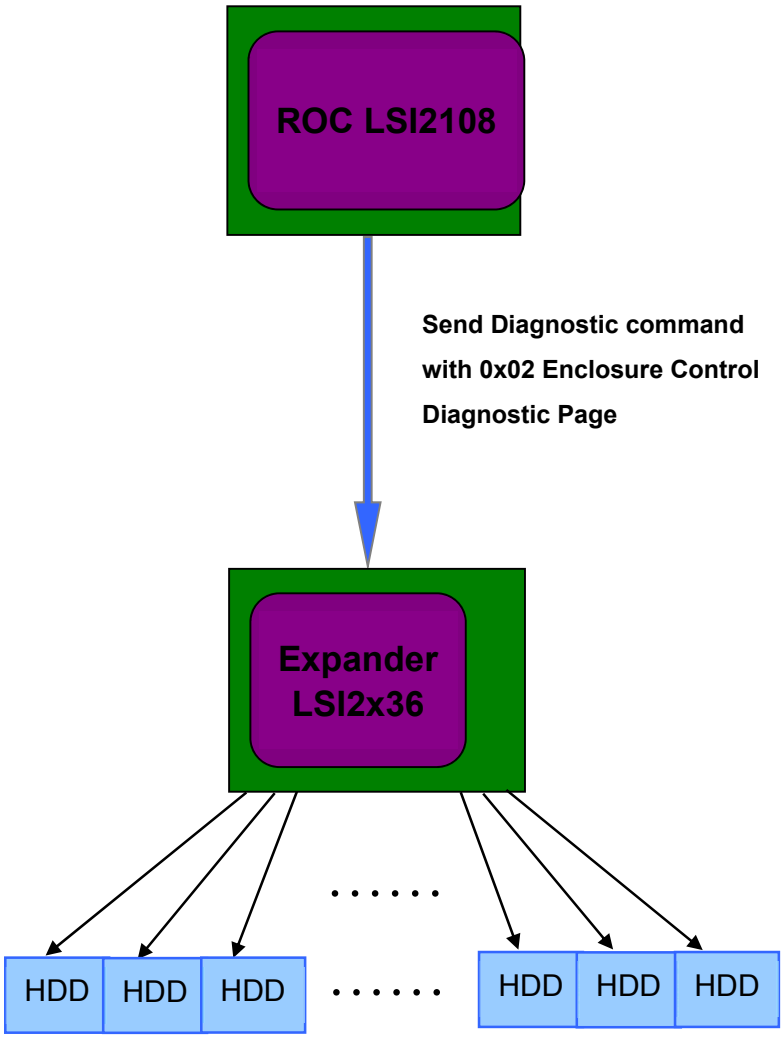


Figure 7-11 The SAS ROC uses SES to control HDD LEDs

Figure 7-12 Enclosure Control Diagnostic Page

Bytes/Bits	7	6	5	4	3	2	1	0

0	Page Code (02h)							
1	Control							
2~3	Page Length (400)							
4~7	Generation Code (00h)							
8~11	Overall Array Device Slot Control							
	Array Device Slot 1 Control							
12~15	Common Control							
	RQST OK	RQST RSVD DEVICE	RQST HOT SPARE	RQST CONS CHECK	RQST IN CRIT ARRAY	RQST IN FAILED ARRAY	RQST REBUILD/REMAP	RQST R/R ABORT
	RQST ACTIVE	DO NOT REMOVE	Reserved	RQST MISSING	RQST INSERT	RQST REMOVE	RQST IDENT	Reserved
	Reserved		RQST FAULT	DEVICE OFF	ENABLE BYPASSED A	ENABLE BYPASSED B	Reserved	
16~71	Array Device Slot 2 Control ~ Array Device Slot 15 Control							
72~75	Overall Connector Element Slot Control							
	Connector Element Slot 1 Control							
76~79	Common Control							
	RQST IDENT	Reserved						
	Reserved							
	Reserved	RQST FAIL	Reserved					
80~155	SAS Connector Element 2 Control ~ SAS Connector Element Slot 20 Control							
156~159	Overall Cooling Control							
	Fan 1 Control							
160~163	Common Control							
	RQST IDENT	Reserved						
	OEM REQUESTED PWM							
	Reserved	RQST FAIL	RQST ON	Reserved	REQUESTED SPEED CODE			
164~207	Fan 2 Control ~ Fan 12 Control							
208~211	Overall Temperature Sensor Control							
	Temperature Sensor 1 Control							
212~215	Common Control							
	RQST IDENT	RQST FAIL	Reserved					
	Reserved							
	Reserved							
216~327	Temperature Sensor 2 Control ~ Temperature Sensor 29 Control							
328~331	Overall Voltage Sensor Control							
	Voltage Sensor Element 1 Control							
332~335	Common Control							
	RQST	RQST	Reserved					

	IDENT	FAIL			
	Reserved				
	Reserved				
336~379	Voltage Sensor Element 2 Control ~ Voltage Sensor Element 12 Control				
380~383	Overall Current Sensor Control				
	Current Sensor 1 Control				
384~387	Common Control				
	RQST IDENT	RQST FAIL	Reserved		
	Reserved				
	Reserved				
388~391	Overall Enclosure Element Control				
	Enclosure Element 1 Control				
392~395	Common Control				
	RQST IDENT	Reserved			
	POWER CYCLE REQUEST	POWER CYCLE DELAY			
	POWER OFF DURATION			REQUEST FAILURE	REQUEST WARNING
396~399	Overall SAS Expander Control Element				
	SAS Expander Element 1 Control				
400~403	Common Control				
	RQST IDENT	RQST FAIL	Reserved		
	Reserved				
	Reserved				

7.4.2 String Out Page (page code: 04h)

The String Out Diagnostic Page transmits an enclosure dependent binary string from the application client to the enclosure services process of the expander. The format of the binary string is vendor specific. The String Out Diagnostic Page is written by the SEND DIAGNOSTIC command and the PAGE CODE field is set to 04h. See the details in Figure 7-13.

Figure 7-13 String Out Diagnostic Page

Byte\Bit	7	6	5	4	3	2	1	0
0	Page Code (04h)							
1	00h							
2~3	Page Length (n – 3)							
4~n	Enclosure String Out Data							

7.4.3 Threshold Out Diagnostic Page (page code : 05h)

The Threshold Out Diagnostic Page is transmitted to the enclosure services process to establish threshold values for those elements that have limited sensing capability (e.g., temperature sensors, and voltage sensors). The Threshold Out diagnostic page is written by the SEND DIAGNOSTIC command and the PAGE CODE field is set to 05h. See the details in Figure 7-14.

Figure 7-14 Threshold Out Diagnostic Page

Bytes/Bits	7	6	5	4	3	2	1	0
0	Page Code (05h)							
1	Reserved							
2~3	Page Length (400)							
4~7	Expected Generation Code (00h)							
8~11	Overall Array Device Slot Threshold Control Element							
12~71	Array Device 1 ~ Array Device 15 Threshold Control Element							
72~75	Overall Connector Threshold Control Element							
76~155	Connector 1 ~ Connector 20 Threshold Control Element							
156~159	Overall Fan Threshold Control Element							
160~207	Fan 1 ~ Fan 12 Threshold Control Element							
208~211	Overall Temperature Threshold Control Element							
	Temperature 1 Threshold Control Element							
212~215	Requested High Critical Threshold							
	Requested High Warning Threshold							
	Requested Low Warning Threshold							
	Requested Low Critical Threshold							
216~327	Temperature 2 Threshold Control Element ~ Temperature 29 Threshold Control Element							
328~331	Overall Voltage Threshold Control Element							
	Voltage 1 Threshold Control Element							
332~335	Requested High Critical Threshold							
	Requested High Warning Threshold							
	Requested Low Warning Threshold							
	Requested Low Critical Threshold							
336~379	Voltage 2 Threshold Control Element ~ Voltage 12 Threshold Control Element							
380~383	Overall Current Threshold Control Element							

	Current 1 Threshold Control Element
384~3387	Requested High Critical Threshold
	Requested High Warning Threshold
	Requested Low Warning Threshold
	Requested Low Critical Threshold
388~391	Overall Enclosure Threshold Control Element
392~395	Enclosure 1 Threshold Control Element
396~399	Overall SAS Expander Threshold Control Element
400~403	SAS Expander 1 Threshold Control Element

7.4.4 Download Microcode Control diagnostic page (page code: 0Eh)

The Download Microcode Control Diagnostic Page transmits a vendor-specific microcode (i.e., firmware) image to the control memory space of the enclosure services process. The image may be saved to flash ROM. The Download Microcode Control Diagnostic Page is written by the SEND DIAGNOSTIC command and the PAGE CODE field is set to 0Eh. The microcode image may be sent using one or more SEND DIAGNOSTIC commands. See the details in Figure 7-15.

Figure 7-15 Download Microcode Control Diagnostic Page

Bytes/Bits	7	6	5	4	3	2	1	0
0	Page Code (0Eh)							
1	Subenclosure Identifier							
2~3	Page Length (n – 3)							
4~7	Expected Generation Code							
8	Download Microcode Mode							
9~10	Reserved							
11	Buffer ID							
12~15	Buffer Offset							
16~19	Microcode Image Length							
20~23	Microcode Data Length (m – 23)							
24~m	Microcode Data							
(m+1)~n	PAD(if needed)							

8 Diagnostic and Manufacturing Support

8.1 Enclosure EEPROM Content and Manipulation

There are 7 EEPROMs in one Knox system. And the firmware will provide functions to read/write information from/to the EEPROM. The contents in EEPROM will include:

- Manufacturing records
  In factory, we will record “Board S/N”, “Board P/N”, “Chassis S/N”, Chassis P/N”, “Tray S/N” and “Tray P/N” in manufacturing process

- Customer information
  This region will include “FB P/N”, “FB Asset Tag”, and “FB RACKPOS Chassis”.

- SAS Expander Parameters
- Based on the design selection, SAS Address and other parameters may be stored in EEPROM.
- Stage and Revision Signature

This region will contain the stage and 59revision signature

Basically, the firmware supports this feature via different OEM Buffer IDs of SCSI Read/Write Buffer command. See the detail in Figure 8-1 ~ Figure 8-4.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Bh)							
1	MODE SPECIFIC			MODE (00001b)				
2	BUFFER ID							
3	BUFFER OFFSET							
4								
5								
6	PARAMETER LIST LENGTH							
7								
8								
9	CONTROL							

Figure 8-1 WRITE BUFFER Command

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Ch)							
1	Reserved				MODE (00001b)			
2	BUFFER ID							
3	BUFFER OFFSET							
4								
5								
6	ALLOCATION							
7								
8	LENGTH							
9	CONTROL							

Figure 8-2 READ BUFFER Command

BUFFER ID	EEPROM LOCATION
20h	SAS Expander Board
30h	Drive Plane Board
40h	Fan Control Board

Figure 8-3 Buffer ID Definition

BUFFER OFFSET START ADDRESS	Area Name
0000h	Board P/N (11 Chars.)
0100h	Board S/N (11 Chars.)
0200h	WW Chassis P/N (11 Chars.) (on FCB) or WW Tray P/N (11 Chars.) (on DPB)
0300h	WW Chassis S/N (13 Chars.) (on FCB) or WW Tray S/N (12 Chars.) (on DPB)
0400h	FB P/N (only on FCB)
0500h	FB Asset Tag (on SEB, DPB and FCB)
0600h	Rack Position of the Chassis (on FCB)
1000h	SAS Expander Parameters
1F00h	Signature (2 Chars.) on SEB, DPB and FCB

Figure 8-4 Buffer Offset Definition

8.2 Power Reading Support

There is a digital power monitor chip ADM1276 in Knox system. And the firmware provide power reading function to read information of input power.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Ch)							
1	Reserved			MODE (00001b)				
2	BUFFER ID(41h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	ALLOCATION LENGTH(4h)							
7								
8								
9	CONTROL(0h)							

Figure 8-5 READ BUFFER Command For Power Reading

Bytes/Bits	7	6	5	4	3	2	1	0
0	Reserved							
1	Reserved							
2	Input Power Information							
3								

Figure 8-6 Response of Power Reading

8.3 General Purpose Input Status Reading Support

The firmware support read the GPI pins of SEB.

Purpose	Pin	Type
Expander ID	GPIO_0	IN
Debug board detection	GPIO_1	IN
Peer SEB Heartbeat Detection	GPIO_4	IN
Pulling Out Detection For Self Tray	GPIO_5	IN
Pulling Out Detection For Peer Tray	GPIO_6	IN
Peer SEB Detection	GPIO_10	IN
FCB HW Revision	LED52	IN
DPB HW Revision	LED53	IN
Peer Tray SEB A Heartbeat Detection	LED54	IN
Peer Tray SEB B Heartbeat Detection	LED55	IN

Figure 8-7 GPI Pins Table

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Ch)							
1	Reserved				MODE (00001b)			
2	BUFFER ID(70h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	ALLOCATION LENGTH(Fh)							
7								
8								
9	CONTROL(0h)							

Figure 8-8 READ BUFFER Command For GPI Status Reading

Bytes/Bits	7	6	5	4	3	2	1	0
0	GPI 0 (Expander ID – 0 : Expander A, 1 : Expander B)							
1	GPI 1 (Tray ID – 0 : Bottom Tray, 1: Top Tray)							
2	Reserved (0)							
3	Reserved (0)							
4	GPI 4 (The Same Tray Peer SEB Heartbeat Detection – 0 : No Heartbeat, 1: Heartbeat alive)							
5	GPI 5 (Pulling Out Detection For Self Tray – 0 : Tray not pull out, 1 : Tray is pulled out)							
6	GPI 6 (Pulling Out Detection For Peer Tray – 0 : Tray not pull out, 1 : Tray is pulled out)							
7	Reserved (0)							
8	Reserved (0)							
9	Reserved (0)							
10	GPI_10 (The Same Tray Peer SEB Detection – 0 : Peer SEB attached, 1: Peer SEB not attached)							
11	LED52 (FCB HW Revision – 0 : For normal storage 1: For cold storage)							
12	LED53 (DPB HW Revision – 0 : No interconnection, 1: x1 SAS interconnection)							
13	LED54 (Peer Tray SEB A Heartbeat Detection – 0: No Heartbeat, 1: Heartbeat alive)							
14	LED55 (Peer Tray SEB B Heartbeat Detection – 0: No Heartbeat, 1: Heartbeat alive)							

Figure 8-9 Response of GPI Status Reading

8.4 Heartbeat Control

The firmware support control SEB heartbeat via in-band.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Bh)							
1	MODE SPECIFIC			MODE (00001b)				
2	BUFFER ID(74h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	PARAMETER LIST LENGTH(4h)							
7								
8								
9	CONTROL(0h)							

Figure 8-10 WRITE BUFFER Command For Heartbeat Control

After issue this command:

1. If heartbeat status is alive, then SEB will stop generating heartbeat signal.
2. If heartbeat status is stop, then SEB will start to generate heartbeat signal.

8.5 SEB, FCB and 7 Segment LED Support

The firmware support control and monitor the SEB, FCB and 7 segment LED via in-band.

Use READ BUFFER command can get back the status of LEDs on SEB and FCB.

Also the 7 segment LED status.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Ch)							
1	Reserved			MODE (00001b)				
2	BUFFER ID(75h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	ALLOCATION							
7								
8	LENGTH(11h)							
9	CONTROL(0h)							

Figure 8-11 READ BUFFER Command For LEDs and Debug Board Status Reading

Bytes/Bits	7	6	5	4	3	2	1	0
0	Debug On/Off (0x01 : Debug On, 0x00 : Debug Off)							
1	Ext. Mini SAS Red LED (0x00 : LED Off, 0x01 : LED On)							
2	Ext. Mini SAS Blue LED (0x00 : LED Off, 0x01 : LED On)							
3	Int. Mini SAS 1 Red LED (0x00 : LED Off, 0x01 : LED On)							
4	Int. Mini SAS 1 Blue LED (0x00 : LED Off, 0x01 : LED On)							
5	Int. Mini SAS 2 Red LED (0x00 : LED Off, 0x01 : LED On)							
6	Int. Mini SAS 2 Blue LED (0x00 : LED Off, 0x01 : LED On)							
7	Enc. Status Red LED (0x00 : LED Off, 0x01 : LED On)							
8	Enc. Status Blue LED (0x00 : LED Off, 0x01 : LED On , 0x02 : Blinking)							
9	Fan Module 1 Red LED (0x00 : LED Off, 0x01 : LED On)							
10	Fan Module 2 Red LED (0x00 : LED Off, 0x01 : LED On)							
11	Fan Module 3 Red LED (0x00 : LED Off, 0x01 : LED On)							
12	Fan Module 4 Red LED (0x00 : LED Off, 0x01 : LED On)							
13	Fan Module 5 Red LED (0x00 : LED Off, 0x01 : LED On)							
14	Fan Module 6 Red LED (0x00 : LED Off, 0x01 : LED On)							
15	Reserved							
16	Show 7 Segment LED Status							

Figure 8-12 Response of LEDs and Debug Board Status Reading

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Bh)							
1	MODE SPECIFIC			MODE (00001b)				
2	BUFFER ID(75h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	PARAMETER LIST LENGTH(11h)							
7								
8								
9	CONTROL(0h)							

Figure 8-13 WRITE BUFFER Command For LEDs Control

Bytes/Bits	7	6	5	4	3	2	1	0
0	Debug On/Off (0x01 : Debug On, 0x00 : Debug Off)							
1	Ext. Mini SAS Red LED (0x00 : LED Off, 0x01 : LED On)							
2	Ext. Mini SAS Blue LED (0x00 : LED Off, 0x01 : LED On)							
3	Int. Mini SAS 1 Red LED (0x00 : LED Off, 0x01 : LED On)							
4	Int. Mini SAS 1 Blue LED (0x00 : LED Off, 0x01 : LED On)							
5	Int. Mini SAS 2 Red LED (0x00 : LED Off, 0x01 : LED On)							
6	Int. Mini SAS 2 Blue LED (0x00 : LED Off, 0x01 : LED On)							
7	Enc. Status Red LED (0x00 : LED Off, 0x01 : LED On)							
8	Enc. Status Blue LED (0x00 : LED Off, 0x01 : LED On ,0x02 : Blinking)							
9	Fan Module 1 Red LED (0x00 : LED Off, 0x01 : LED On)							
10	Fan Module 2 Red LED (0x00 : LED Off, 0x01 : LED On)							
11	Fan Module 3 Red LED (0x00 : LED Off, 0x01 : LED On)							
12	Fan Module 4 Red LED (0x00 : LED Off, 0x01 : LED On)							
13	Fan Module 5 Red LED (0x00 : LED Off, 0x01 : LED On)							
14	Fan Module 6 Red LED (0x00 : LED Off, 0x01 : LED On)							
15	Reserved							
16	7 Segment LED Control (Range : 0x00 ~ 0xFF)							

Figure 8-14 Data Format of LEDs Control

8.6 Fan Speed Control Profile Index Support

The firmware support different FSC profile selection via in-band.

Use READ BUFFER command can get back the index of FSC record on FCB EEPROM.

Use WRITE BUFFER command can select index of FSC and record it on FCB EEPROM.

(Note : After select new FSC index, reset SEB to make new FSC index work)

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Ch)							
1	Reserved				MODE (00001b)			
2	BUFFER ID(44h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	ALLOCATION							
7								
8	LENGTH(01h)							
9	CONTROL(0h)							

Figure 8-15 READ BUFFER Command For FSC Index Reading

Bytes/Bits	7	6	5	4	3	2	1	0
0	Current FSC Profile Index Value							

Figure 8-16 Response of FSC Index Reading

FSC Index	FSC Profile
00h	SAS 3TB HDD
01h	SAS 4TB HDD
Others	Reserved

Figure 8-17 FSC Profile Index Table

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Bh)							
1	MODE SPECIFIC			MODE (00001b)				
2	BUFFER ID(44h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	PARAMETER LIST LENGTH(01h)							
7								
8								
9	CONTROL(0h)							

Figure 8-18 WRITE BUFFER Command For FSC Profile Selection

Bytes/Bits	7	6	5	4	3	2	1	0
0	FSC Profile Index Value							

Figure 8-19 Data Format of FSC Profile Index Control

8.7 Error Code Array Reporting Support

The firmware support read back debug board error array via in-band.
Use READ BUFFER command can get back the error code array and user can check which error code is on or off on debug board.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Ch)							
1	Reserved				MODE (00001b)			
2	BUFFER ID(76h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	ALLOCATION							
7								
8	LENGTH(64h)							
9	CONTROL(0h)							

Figure 8-20 READ BUFFER Command For Error Code Array Reading

Bytes/Bits	7	6	5	4	3	2	1	0
0	01h : Error Code 00 is on, 00h : Error Code 00 is off							
1	01h : Error Code 01 is on, 00h : Error Code 01 is off							
.....	.....							
93	01h : Error Code 93 is on, 00h : Error Code 93 is off							
94	01h : Error Code 94 is on, 00h : Error Code 94 is off							
95	00h							
96	00h							
97	00h							
98	00h							
99	00h							

Figure 8-21 Response of Error Code Array Reading

8.8 PHY Information Reading Support

The firmware support read back expander PHY information via in-band.
Use READ BUFFER command can get back the PHY information and user can check this information to determine the SI situation in each PHY of expander.
Use WRITE BUFFER command can clear information of all of expander PHYs.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Ch)							
1	Reserved			MODE (00001b)				
2	BUFFER ID(77h)							
3	BUFFER OFFSET(XXh) (Note : Use this value as PHY Number 00h~1Bh)							
4								
5								
6	ALLOCATION							
7								
8	LENGTH(10h)							
9	CONTROL(0h)							

Figure 8-22 READ BUFFER Command For Epxnader PHY Information Reading

Bytes/Bits	7	6	5	4	3	2	1	0
0~3	INVALID_DWORD COUNT							
4~7	RUNNING_DISPARITY COUNT							
8~11	LOSS_OF_DWORD_SYNC COUNT							
12~15	PHY RESET COUNT							

Figure 8-23 Response of Expander PHY Information Reading

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Bh)							
1	MODE SPECIFIC			MODE (00001b)				
2	BUFFER ID(77h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	PARAMETER LIST LENGTH(00h)							
7								
8								
9	CONTROL(0h)							

Figure 8-24 WRITE BUFFER Command For Clear PHY Information

8.9 PWM Reading Support

The firmware can support to report the current PWM reading (Fan duty cycle) and it is dominated by which Temperature sensor ID.

Use READ BUFFER command to get the current PWM value and dominant Temperature sensor ID via in-band.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Ch)							
1	Reserved			MODE (00001b)				
2	BUFFER ID(50h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	ALLOCATION LENGTH(2h)							
7								
8								
9	CONTROL(0h)							

Figure 8-25 READ BUFFER Command for PWM Reading

Bytes/Bits	7	6	5	4	3	2	1	0
0	Dominant Temperature Sensor ID (Note: 0xFF means manual control)							
1	PWM Value (Note: PWM value from 0 to 100)							

Figure 8-26 Response of PWM Reading

8.10 Reset Expander

The expander firmware supports to reset expander via SCSI Write Buffer command with buffer ID 0xE9.

There are two reset modes: hard-reset and watchdog reset.

For expander hard-reset, both of expander firmware and SAS Phy link connections will be reset.

For expander watchdog reset, only expander firmware will be reset but SAS Phy link connections won't.

Use WRITE BUFFER command to reset expander including hard-reset and watchdog reset as follows.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Bh)							
1	MODE SPECIFIC			MODE (00001b)				
2	BUFFER ID(E9h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	PARAMETER LIST LENGTH(03h)							
7								
8								
9	CONTROL(0h)							

Figure 8-27 WRITE BUFFER Command for resetting expander

Bytes/Bits	7	6	5	4	3	2	1	0
0	00h: Hard-reset, 01h: Watchdog reset.							
1	XXh: Time delay in milliseconds before reset (MSB)							
2	YYh: Time delay in milliseconds before reset (LSB)							

Figure 8-28 Data Format of Number of resetting expander

8.11 HDD Temperature Polling Interval

The firmware will poll HDD SMART periodically but the default is disabled. The interval between HDD temperature polls is configurable from 1 minute to 60 minutes as the following figures showed as below. It means15 HDDs in the same sub-enclosure share a configurable polling interval, from 1 minute to 60 minutes. The HDD temperature polling interval setting value will be saved in EEPROM or Flash.

[Note]: HDD Temperature polling only supports for SAS HDD, not for SATA HDD.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Ch)							
1	Reserved				MODE (00001b)			
2	BUFFER ID(72h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	ALLOCATION							
7								
8	LENGTH(4h)							
9	CONTROL(0h)							

Figure 8-29 READ BUFFER Command for HDD Temperature Polling Interval

Bytes/Bits	7	6	5	4	3	2	1	0
0 ~ 2	Reserved							
3	Polling Interval value (00h: disable polling; 01h~3Ch: 1~60 minutes; >3Ch: 60 minutes)							

Figure 8-30 Response of HDD Temperature Polling Interval

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Bh)							
1	MODE SPECIFIC			MODE (00001b)				
2	BUFFER ID(72h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	PARAMETER LIST LENGTH(4h)							
7								
8								
9	CONTROL(0h)							

Figure 8-31 WRITE BUFFER Command for HDD Temperature Polling Interval

Bytes/Bits	7	6	5	4	3	2	1	0
0 ~ 2	Reserved							
3	Polling Interval setting value (00h: disable polling; 01h~3Ch: 1~60 minutes; >3Ch: 60 minutes)							

Figure 8-32 Data Format of HDD Temperature Polling Interval

9 Enclosure Event Log

Except LSI SDK original event log, the firmware will support OEM event log based on hardware design. Enclosure events will be logged based on LSI expander SDK Event Logging APIs and the event error codes are defined in the "Error Code" table in Appendix A.

9.1 Event Log Format

Use READ BUFFER command to get event log from Expander via in-band.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Ch)							
1	Reserved				MODE (00001b)			
2	BUFFER ID(E5h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	ALLOCATION							
7	LENGTH(XXh)							
8	(Note : Set this value as the multiple of 64, maximum is 8192)							
9	CONTROL(0h)							

Figure 9-1 READ BUFFER Command for Event Log

Figure 9-2 shows the event log format. Each log is 64 bytes in length and includes a header and log data. The first four Dwords contain the header. See the event log format description below.

Bytes/Bits	31~24	23~16	15~8	7~0
0~7	TimeStamp			
8~11	Reserved			
12~15	LogEntryQualifier		LogSequence	

16~63	LogData

Figure 9-2 Enclosure Event Log Format

- **TimeStamp[63:0]**

This field indicates the number of elapsed milliseconds since the expander was reset.

- **LogEntryQualifier[31:16]**

This field specifies the type of event that occurred. The value in this field defines the contents of the 48-byte LogData field.

- **LogSequence[15:0]**

This field specifies the chronological order for the particular log event.Greater LogSequence values represent more recent error events. The host must properly interpret the LogSequence if this field rolls over.

- **LogData[351:0]**

This field contains 48 bytes of additional data for the log entry. It contain a "Log Data Header" and "String", the "String" will be filled with strings in the event log field of "Error Code" Table in Appendix A

Figure 9-3 shows the "LogData" format in event log. Each log is 64 bytes in length and includes a header and log data. The first four Dwords contain the header. See the event log format description below.

Bytes/Bits	31~24	23~16	15~8	7~0
0~3	LogCode (00000000h)			
4~7	Log Class (01h)	Argument Type (00h)	Locale (0009h)	
8~47	String (See the detail "Event Log" Table in Appendix A)			

Figure 9-3 LogData Format

Use WRITE BUFFER command to clear all event logs on Expander via in-band.

Bytes/Bits	7	6	5	4	3	2	1	0
0	OPERATION CODE (3Bh)							
1	MODE SPECIFIC			MODE (00001b)				
2	BUFFER ID(E5h)							
3	BUFFER OFFSET(0h)							
4								
5								
6	PARAMETER LIST LENGTH(01h)							
7								
8								
9	CONTROL(0h)							

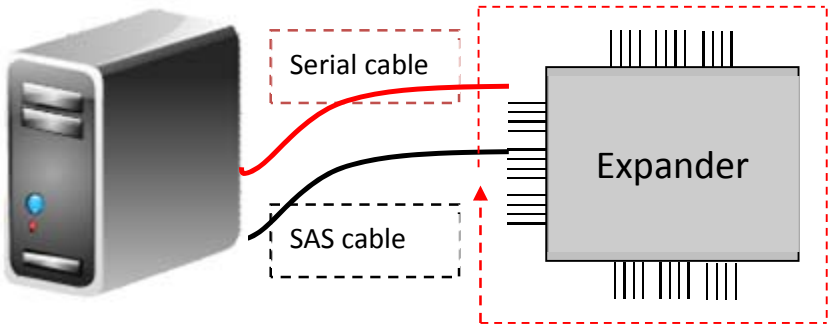
Figure 9-4 WRITE BUFFER Command for Event Log

Bytes/Bits	7	6	5	4	3	2	1	0
0	Any value (the data in the data buffer is ignored)							

Figure 9-5 Data Format of Clearing Event Log

10 Firmware Upgrade Mechanism

The expander firmware can support to upgrade the expander firmware in-band via SAS or out-of-band via serial (UART baud rate: 38400, 8n1) using LSI Expander Tools (Xtools).



10.1 LSI Expander Tools

The LSI Expander tools (Xtools) utilities provide a library of low-level functions which are designed to interface with an expander through either a serial interface, or SAS interface. The Xtools utilities contain the following command line interface (CLI) utilities:

- **Xflash, the Expander Flash utility**
- **Xmfg, the Expander Manufacturing Image Customizer utility**
- **Xutil, the Expander Diagnostics utility**
- **Xip, the Expander IP configuration utility**

The following figure shows the Xtools architecture.

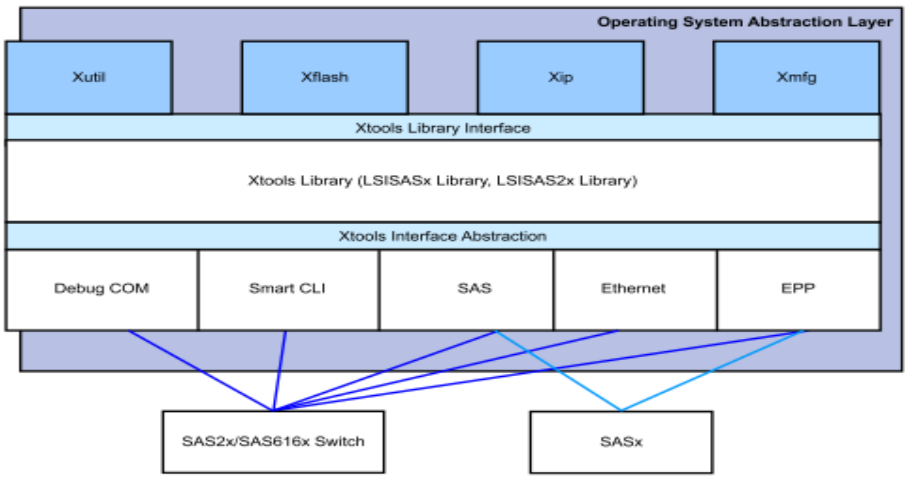


Figure 9-1 Xtools Architecture

For the firmware upgrade via in-band SAS or out-of-band serial interface, please see the detail information in “LSI Expander Tools User Guide”.

10.2 Product ID Checking Before Firmware Download Into Flash

To avoid expander firmware and hardware not match. Expander firmware implements a firmware header checking mechanism before firmware download into flash. The product id is “17” for Knox product. If the product id in firmware header is not “17” the upgrade procedure will fail.

Due to LSI limitation, this mechanism only applies to upgrade the expander firmware in-band via SAS and not apply to upgrade the expander firmware out-of-band via serial.

Below table shows the rule of firmware version:

Product ID	LSI Expander SDK Version		Revison
17	14	00	XX

11 Command Line Interface (CLI)

The CLI is designed to be a diagnostic utility. It provides an interface to the expander for debugging and downloading firmware. CLI interface is supported over the UART. The CLI module performs the following functions:

- Display a CMD> command prompt at the terminal
- Support a set of basic commands

11.1 CLI Command Set

This section list a part of command set of CLI.

- help: Display current available commands and their prototype.
- mr8: Memory read byte.
- mw8: Memory write byte.
- iicr: Read from an ISTWI slave.
- iicw: Write to an ISTWI slave.
- iicwr: Write and read data on a specified ISTWI channel.
- thread: Display thread information.
- rev: Display firmware revision information.
- sasaddr: Display SAS address of the expander.
- showlogs:Output the current log buffer to the CLI.
- clearlog: Clear the log buffer.
- counters: Display or clear phy count register values.
- phyinfo: Display information about all phys (physical and virtual) of the expander.
- regerase: Erase the specified flash region ID.
- phyop: Perform a given phy operation on agiven PHY index.
- showmfg: Display version-related information.
- showpost: Display the power-on self-test(POST) status of various peripherals.

Please see the complete information about very CLI command in “LSI 6Gb/s Expander SDK Programming Guide.

12 Appendix A: Error Code and Event Log Definition

Below listed is the full definition of Knox Error Code. It will be displayed on the Debug Card as well as stored in system event log.

Error Code	Description	Condition	Event Log
00	No error		
01	Expander A fault	Expander A heartbeat stop	Critical-Expander ID 0 HB Stop
02	Expander B fault	Expander B heartbeat stop	Critical-Expander ID 1 HB Stop
03	I2C bus A crash	Can not query I2C device in I2C bus A	Critical-I2C Bus ID 0 Crash
04	I2C bus B crash	Can not query I2C device in I2C bus B	Critical-I2C Bus ID 1 Crash
05	I2C bus C crash	Can not query I2C device in I2C bus C	Critical-I2C Bus ID 2 Crash
06	I2C bus D crash	Can not query I2C device in I2C bus D	Critical-I2C Bus ID 3 Crash
07	Reserved		
08	Reserved		
09	Reserved		
10	Reserved		
11	Fan 1 front fault	Can not query fan speed in fan module 1 front	Critical-Cooling ID 0 Fail,X(RPM)
12	Fan 1 rear fault	Can not query fan speed in fan module 1 rear	Critical-Cooling ID 1 Fail,X(RPM)
13	Fan 2 front fault	Can not query fan speed in fan module 2 front	Critical-Cooling ID 2 Fail,X(RPM)
14	Fan 2 rear fault	Can not query fan speed in fan module 2 rear	Critical-Cooling ID 3 Fail,X(RPM)
15	Fan 3 front fault	Can not query fan speed in fan module 3 front	Critical-Cooling ID 4 Fail,X(RPM)
16	Fan 3 rear fault	Can not query fan speed in fan module 3 rear	Critical-Cooling ID 5 Fail,X(RPM)
17	Fan 4 front fault	Can not query fan speed in fan module 4 front	Critical-Cooling ID 6 Fail,X(RPM)
18	Fan 4 rear fault	Can not query fan speed in	Critical-Cooling ID 7

		fan module 4 rear	Fail,X(RPM)
19	Fan 5 front fault	Can not query fan speed in fan module 5 front	Critical-Cooling ID 8 Fail,X(RPM)
20	Fan 5 rear fault	Can not query fan speed in fan module 5 rear	Critical-Cooling ID 9 Fail,X(RPM)
21	Fan 6 front fault	Can not query fan speed in fan module 6 front	Critical-Cooling ID 10 Fail,X(RPM)
22	Fan 6 rear fault	Can not query fan speed in fan module 6 rear	Critical-Cooling ID 11 Fail,X(RPM)
23	Reserved		
24	Reserved		
25	Reserved		
26	Reserved		
27	Reserved		
28	Reserved		
29	Reserved		
30	Reserved		
31	DPB temp. sensor 1 warning	Temperature over critical threshold	Critical-Temp. ID 0 Fail,Temp=X(C)
32	DPB temp. sensor 2 warning	Temperature over critical threshold	Critical-Temp. ID 1 Fail,Temp=X(C)
33	DPB temp. sensor 3 warning	Temperature over critical threshold	Critical-Temp. ID 2 Fail,Temp=X(C)
34	DPB temp. sensor 4 warning	Temperature over critical threshold	Critical-Temp. ID 3 Fail,Temp=X(C)
35	SEB temp. sensor A warning	Temperature over critical threshold	Critical-Temp. ID 4 Fail,Temp=X(C)
36	SEB temp. sensor B warning	Temperature over critical threshold	Critical-Temp. ID 5 Fail,Temp=X(C)
37	Ambient temp. sensor A1 warning	Temperature over critical threshold	Critical-Temp. ID 6 Fail,Temp=X(C)
38	Ambient temp. sensor A2 warning	Temperature over critical threshold	Critical-Temp. ID 7 Fail,Temp=X(C)
39	Ambient temp. sensor B1 warning	Temperature over critical threshold	Critical-Temp. ID 8 Fail,Temp=X(C)
40	Ambient temp. sensor B2 warning	Temperature over critical threshold	Critical-Temp. ID 9 Fail,Temp=X(C)
41	BJT temp. sensor 1	Temperature over critical	Critical-Temp. ID 10

	warning	threshold	Fail,Temp=X(C)
42	BJT temp. sensor 2 warning	Temperature over critical threshold	Critical-Temp. ID 11 Fail,Temp=X(C)
43	Reserved		
44	Reserved		
45	SEB voltage sensor warning	Voltage over or under critical threshold	Critical-Voltage ID ? Fail,V=X(mV) (ID : Voltage sensor on SEB)
46	DPB voltage sensor warning	Voltage over or under critical threshold	Critical-Voltage ID ? Fail,V=X(mV) (ID : Voltage sensor on DPB)
47	FCB voltage sensor warning	Voltage over or under critical threshold	Critical-Voltage ID ? Fail,V=X(mV) (ID : Voltage sensor on FCB)
48	FCB current sensor warning	Current over or under critical threshold	Critical-Current ID 0 Fail,I=X(mA)
49	Reserved		
50	HDD0 SMART temp. warning	HDD0 Temperature over critical threshold	Critical-Temp. ID 12 Fail,Temp=X(C)
51	HDD1 SMART temp. warning	HDD1 Temperature over critical threshold	Critical-Temp. ID 13 Fail,Temp=X(C)
52	HDD2 SMART temp. warning	HDD2 Temperature over critical threshold	Critical-Temp. ID 14 Fail,Temp=X(C)
53	HDD3 SMART temp. warning	HDD3 Temperature over critical threshold	Critical-Temp. ID 15 Fail,Temp=X(C)
54	HDD4 SMART temp. warning	HDD4 Temperature over critical threshold	Critical-Temp. ID 16 Fail,Temp=X(C)
55	HDD5 SMART temp. warning	HDD5 Temperature over critical threshold	Critical-Temp. ID 17 Fail,Temp=X(C)
56	HDD6 SMART temp. warning	HDD6 Temperature over critical threshold	Critical-Temp. ID 18 Fail,Temp=X(C)
57	HDD7 SMART temp. warning	HDD7 Temperature over critical threshold	Critical-Temp. ID 19 Fail,Temp=X(C)
58	HDD8 SMART temp. warning	HDD8 Temperature over critical threshold	Critical-Temp. ID 20 Fail,Temp=X(C)
59	HDD9 SMART temp. warning	HDD9 Temperature over critical threshold	Critical-Temp. ID 21 Fail,Temp=X(C)
60	HDD10 SMART temp.	HDD10 Temperature over	Critical-Temp. ID 22

	warning	critical threshold	Fail,Temp=X(C)
61	HDD11 SMART temp. warning	HDD11 Temperature over critical threshold	Critical-Temp. ID 23 Fail,Temp=X(C)
62	HDD12 SMART temp. warning	HDD12 Temperature over critical threshold	Critical-Temp. ID 24 Fail,Temp=X(C)
63	HDD13 SMART temp. warning	HDD13 Temperature over critical threshold	Critical-Temp. ID 25 Fail,Temp=X(C)
64	HDD14 SMART temp. warning	HDD14 Temperature over critical threshold	Critical-Temp. ID 26 Fail,Temp=X(C)
65	Expander A Internal temp. warning	Expander A Internal Temperature over critical threshold	Critical-Temp. ID 27 Fail,Temp=X(C)
66	Expander B Internal temp. warning	Expander B Internal Temperature over critical threshold	Critical-Temp. ID 28 Fail,Temp=X(C)
67	Reserved		
68	Reserved		
69	Reserved		
70	HDD0 fault	HDD0 Array Device Element status fault	Critical-HDD Slot 0 Status Fault
71	HDD1 fault	HDD1 Array Device Element status fault	Critical-HDD Slot 1 Status Fault
72	HDD2 fault	HDD2 Array Device Element status fault	Critical-HDD Slot 2 Status Fault
73	HDD3 fault	HDD3 Array Device Element status fault	Critical-HDD Slot 3 Status Fault
74	HDD4 fault	HDD4 Array Device Element status fault	Critical-HDD Slot 4 Status Fault
75	HDD5 fault	HDD5 Array Device Element status fault	Critical-HDD Slot 5 Status Fault
76	HDD6 fault	HDD6 Array Device Element status fault	Critical-HDD Slot 6 Status Fault
77	HDD7 fault	HDD7 Array Device Element status fault	Critical-HDD Slot 7 Status Fault
78	HDD8 fault	HDD8 Array Device Element status fault	Critical-HDD Slot 8 Status Fault
79	HDD9 fault	HDD9 Array Device Element status fault	Critical-HDD Slot 9 Status Fault

80	HDD10 fault	HDD10 Array Device Element status fault	Critical-HDD Slot 10 Status Fault
81	HDD11 fault	HDD11 Array Device Element status fault	Critical-HDD Slot 11 Status Fault
82	HDD12 fault	HDD12 Array Device Element status fault	Critical-HDD Slot 12 Status Fault
83	HDD13 fault	HDD13 Array Device Element status fault	Critical-HDD Slot 13 Status Fault
84	HDD14 fault	HDD14 Array Device Element status fault	Critical-HDD Slot 14 Status Fault
85	Reserved		
86	Reserved		
87	Reserved		
88	Reserved		
89	Reserved		
90	External Mini-SAS link error	Loss of SAS links (x1~x3)	Critical-Connector ID 16 Loss Link(s)
91	Internal Mini-SAS 1 link error	Loss of SAS links (x1~x3)	Critical-Connector ID 20 Loss Link(s)
92	Internal Mini-SAS 2 link error	Loss of SAS links (x1~x3)	Critical-Connector ID 24 Loss Link(s)
93	Self tray be pulled out	F/W detect self tray be pulled out	Critical-Self Tray Be Pulled Out
94	Peer tray be pulled out	F/W detect peer tray be pulled out	Critical-Peer Tray Be Pulled Out
95	Reserved		
96	Reserved		
97	Reserved		
98	Reserved		
99	Firmware and hardware not match	Only show this error code when FW initialization and then FW will hang	N/A
N/A	Self tray be pushed in	F/W detect self tray be pushed in	Infomation-Self Tray Be Pushed In
N/A	Peer tray be pushed in	F/W detect peer tray be pushed in	Information-Peer Tray Be Pushed In

13 Revision History

Revision Number	Description	Date
1.0	Initial public version.	2015/07/23

14 Reference

[1] INCITS SCSI Primary Commands - 3 (SPC-3). Revision 18 April 25, 2004

[2] INCITS SCSI-3 Enclosure Services Command Set 2(SES-2). Revision 20 May 12, 2008

[3] INCITS Serial Attached SCSI – 2 (SAS-2). Revision 16 April 18, 2009

[4] Open Compute Project Open Vault Storage Specification v0.7

[5] LSI Expander Tools (Xtools) User Guide Preliminary, Version 1.3 February 2011

[6] LSI 6Gb/s SAS/SATA Expander SDK Programming Guide Version 2.5 February 2011