



Hewlett Packard
Enterprise

Prototype NVDIMM-N _DSM Interface Example

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1. Revision History

Revision	Date	Notes
0.84s	3/7/15	Edited 0.84 draft for an externally publishable example.
0.84s update draft 1	8/23/16	Addressing internal review feedback on the published 0.84s document.
0.84s update 2	1/23/17	Finishing up the last of the comments on the existing text.
<u>0.85</u>	<u>5/16/17</u>	<u>Added support for failure counts to the SMART and Health information function.</u>
	<u>5/18/17</u>	<u>Added functions 21-24</u>
	<u>5/22/17</u>	<u>Standardized output buffers to include status in offsets</u>

2. References

- Advanced Configuration and Power Interface Specification, Version 6.1, January 2015
- DDR4 SPD Contents NVDIMM Revision 0.5
- I²C Bus Specification Revision 4
- NVDIMM DSM Interface Example, April 2015. Intel document
- Byte Addressable Energy Backed Interface, version 0.9, JEDEC Standard No. 2233-22

3. Terms and Definitions

3.1.1 Acronyms

DIMM	Dual In-line Memory Module
DDR4	Double Data Rate version 4
EEPROM	Electrically Erasable Programmable ROM
ES	Energy Source
I²C	Inter-IC
NVDIMM	Non-volatile Dual In-line Memory Module
NVDIMM-N	A type of NVDIMM. Refer to the NVDIMM-N term below.
NVM	Non-Volatile Memory
SDRAM	Synchronous Dynamic Random Access Memory
SPD	Serial Presence Detect

3.1.2 Terms

Abort: Operation that stops the currently running operation on the NVDIMM-N module.

ADR: Asynchronous DRAM Refresh is a hardware method, supported by Intel systems, designed to place the DRAM in self-refresh automatically under host conditions like power loss. For these systems, ADR can be used to trigger the Catastrophic Save operation on the NVDIMM-N module.

Arm: Operation that enables or disables trigger(s) for a Catastrophic Save operation on the NVDIMM-N module.

Backup: Process of saving SDRAM contents from the NVDIMM-N module SDRAM to the non-volatile memory. The current designs of NVDIMM-N modules support BIOS-controlled Backup and Restore operations, for example triggered by host power failures, and OS-controlled Backup and Restore operations at OS runtime.

BIOS: Basic Input/Output System. Host uses this code to initialize its hardware prior to loading and launching an operating system.

Catastrophic Save: Process of copying the SDRAM contents of the NVDIMM-N into non-volatile memory when power is lost. The Catastrophic Save operation is initiated when an enabled trigger occurs.

Device Managed Policy: Energy Source policy where the module manages the Energy Source used during the Catastrophic Save operation.

Energy Source: A device or host support that is capable of storing and providing energy to the NVDIMM-N module during a Catastrophic Save operation.

Erase: Operation that deletes the previously saved SDRAM content in the NVDIMM-N module non-volatile memory.

Factory Default: Operation that erases all non-volatile memory on the NVDIMM-N module and resets readable registers to its factory default value except the data needed to determine warranty compliance. This operation does not update the firmware on the module.

Firmware Operations: Operations that are related to updating the firmware on the NVDIMM-N module.

Host: The system in which the NVDIMM-N module is installed in.

Host Managed Policy: Energy Source policy where the Host manages the Energy Source used during the Catastrophic Save operation of the NVDIMM-N modules.

I²C Bus: A bidirectional 2-wire bus for efficient inter-IC control. The current designs of NVDIMM-N modules have I²C bus access.

Management Operations: Operations that either reset the controller on the NVDIMM-N module or clear its status register(s).

NAND Flash: Non-Volatile Memory on the NVDIMM-N module, used to store SDRAM content during a NVDIMM-N module Backup.

NVDIMM-N: A battery-backed DIMM with SDRAM and a Non-Volatile Flash device. Only SDRAM is addressable by Software and the Non-Volatile Media acts as a backup for DRAM in the event of a host server power disruption or a CPU reset.

Restore: Process of restoring previously saved SDRAM contents from non-volatile memory to the NVDIMM-N module SDRAM.

SDRAM Mode Registers: The registers on SDRAM that configures the SDRAM for operational use. Some of the mode registers are write-only registers.

Self-refresh: The SDRAM state that maintains data integrity without requiring any host interaction.

Set Energy Source Policy: Operation that configures the Energy Source to be used by the NVDIMM-N module in the Catastrophic Save operation.

Set Event Notification: Operation that either enables or disables notification support on the NVDIMM-N module when certain event occurs.

4. Introduction

This document describes an example of the _DSM interfaces associated with NVDIMM-N objects described in ACPI name space in terms of supporting NVDIMM-N modules with a generic interface.

The objectives with regards to the definitions of this example are:

1. Full compliancy to the JEDEC DDR4 NVDIMM-N specification defined as “SPD Annex L: Serial Presence Detect for DDR4 SDRAM, Release 3.
2. Support existing NVDIMM-N devices and the JEDEC TG456_2 specification for byte addressable energy backed interfaces v1.0 (JEDEC Standard No. 2233-22).
3. Support Region Format Interface Code 0x0101 NVDIMM-N modules in a generic _DSM interface, respecting the functionalities of the JEDEC byte addressable energy backed interface specification.
4. Definitions of the _DSM interface with as much commonality with Intel NVDIMM NFIT Region Format interface code 0x0201 _DSM proposal to ease the OSVs support of these new NVDIMM modules, acknowledging the precedence of the Intel NVDIMM NFIT RFIC 0x0201 definitions.

5. _DSM Interface for NFIT NVDIMM-N Device (non-root)

A platform that implements the _DSM interface outlined in this section can support a NVDIMM region with Region Format Interface Code of 0x0101 (per JEDEC SPD Annex L: Serial Presence Detect for DDR4 SDRAM DDR4 SPD Document Release 2).

Note that the _DSM methods defined in this section are implemented under NVDIMM devices that are child devices of NVDIMM object associated with _HID of ACPI0012 in ACPI name space hierarchy.

5.1 Input Parameters:

Arg0 – UUID (set to 9002C334-ACF3-4C0E-9642-A235F0D53BC6)

Arg1 – Revision ID (set to 1)

Arg2 – Function Index

Function Index	Function Name
0	Query command implemented per ACPI Specification
1	SMART and Health Information
2	Get SMART Threshold
4	Get OS Data Size
5	Get OS Data
6	Set OS Data
10	Get Identification
11	Get Energy Source Identification
12	Get Last Backup Information
13	Set NVM Lifetime Threshold
18	Query Error Injection Capabilities
19	Inject Error
20	Get Inject Error Status
<u>21</u>	<u>I2C Read</u>
<u>22</u>	<u>I2C Write</u>

<u>23</u>	<u>I2C Block Read</u>
<u>24</u>	<u>I2C Block Write</u>

Table 5-1 NFIT NVDIMM-N Device _DSM Functions

Arg3 – a package containing parameters for the function specified by the *UUID*, *Revision ID* and *Function Index*. The layout of the package for each command along with the corresponding output is illustrated in the following tables. The input and output packages are a list of bytes (Buffer).

5.2 _DSM function return Status codes:

This section adopts the following conventions for the _DSM function return Status codes:

Field	Byte Length	Byte Offset	Description
Status Code	2	0	0 - Success 1 - Not Implemented 2 - Invalid Input Parameters 3 - Operation Failed 4 - Vendor Specific Error Code 5 -FFFFh – Reserved
Vendor Specific Error Code	2	2	If Status Code is set to Vendor Specific Error Code, this value reports vendor specific error codes, including function specific error values. This specification will define the function specific error values for each function as needed.

Table 5-2 NFIT NVDIMM-N _DSM return Status Codes

5.3 NVDIMM-N Query command implemented per ACPI Specification (Function Index 0)

This function returns the functions supported by this interface version.

5.3.1 Input (Arg3)

None.

5.3.2 Output

A buffer containing one bit for each function index, starting with zero, as defined in Section 9.1.1 of the ACPI specification.

5.4 NVDIMM-N Get SMART and Health Information (Function Index 1)

This function provides SMART and Health related information.

5.4.1 Input (Arg3)

Input is a single buffer, where the buffer is formatted as shown in Table 5-3.

Field	Byte Length	Byte Offset	Description
Input Validation Flags	4	0	Input Validation Flags – if the corresponding input validation flag is set, operating system software expects the corresponding output buffer field to be reported. Bit 0 – set to 1 to indicate that Health Status Summary field should be reported Bit 1 – set to 1 to indicate that Current Temperature field should be reported Bit 2 – set to 1 to indicate that Spare Blocks field should be reported Bit 3 – set to 1 to indicate that Alarm Trips field should be reported Bit 4 – set to 1 to indicate that Percentage Used field should be reported Bit 5 – set to 1 to indicate that Last Shutdown Status field should be reported Bit 6 – set to 1 to indicate Statistics fields should be reported Bit 7 – set to 1 to indicate Health Status Detail fields should be reported

			<p>Bit 8 – set to 1 to indicate Energy Source Health fields should be reported</p> <p>Bit 9 – set to 1 to indicate that the Vendor Specific Data fields should be reported.</p> <p><u>Bit 10 – set to 1 to indicate that operations failure counts should be reported.</u></p> <p>Bits 30:11 – Reserved</p> <p>Bit 31 – set to 1 to indicate that platform firmware shall return information for fields <u>whose</u> changes caused an ACPI NFIT Health Event Notification for the NVDIMM device.</p> <p>An Input Validation Flags value sets to 0 or 0xFFFFFFFF means that the operating system software is requesting the default behavior <u>for the platform</u>.</p> <p>With a successful call, the Validation Flags of the output buffer provide the valid fields that the platform firmware has updated in the output buffer.</p>
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Table 5-3 SMART and Health Information – Input Format

5.4.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-4](#). Fields that are “lifetime” values are not affected if the device is reset to factory defaults.

Field	Byte Length	Byte Offset	Description
Status	4	0	<p>Bytes 1-0</p> <p>0 – Success</p> <p>1 – Not Implemented</p> <p>2 – Invalid Input Parameters</p> <p>3 – Operation Failed</p> <p>4 – Vendor Specific Error Code</p> <p>5-FFFFh - Reserved</p> <p>Bytes 3-2</p> <p>Vendor specific error value</p>

Field	Byte Length	Byte Offset	Description
Validation Flags	4	<u>4</u>	<p>Validation Flags – if the corresponding validation flag is not set in this field, it is indication to software that the corresponding field is not valid and must not be interpreted.</p> <p>Bit 0 – set to 1 to indicate that Health Status Summary field is valid</p> <p>Bit 1 – set to 1 to indicate that Current Temperature field is valid</p> <p>Bit 2 – set to 1 to indicate that Spare Blocks field is valid</p> <p>Bit 3 – set to 1 to indicate that Alarm Trips field is valid</p> <p>Bit 4 – set to 1 to indicate that Percentage Used field is valid</p> <p>Bit 5 – set to 1 to indicate that Last Shutdown Status field is valid</p> <p>Bit 6 – set to 1 to indicate Statistics fields are valid</p> <p>Bit 7 – set to 1 to indicate Health Status Detail fields are valid</p> <p>Bit 8 – set to 1 to indicate Energy Source Health fields are valid</p> <p>Bit 9 – set to 1 to indicate that the Vendor Specific Data fields are valid. If these field are not valid, software can ignore the vendor specific data fields.</p> <p><u>Bit 10 – set to 1 to indicate that operation failures counts are valid</u></p> <p>Bits 31:11 – Reserved. Unused bits will be set to zero.</p>
Health Status Summary	1	<u>8</u>	<p>Health Status Summary: Overall health status summary</p> <p>Bit 0 – Set to 1 to indicate Non-Critical condition, maintenance required but no data loss detected</p> <p>Bit 1 – Set to 1 to indicate Critical condition, features or performance degraded due to failures but no data loss detected</p> <p>Bit 2 – Set to 1 to indicate fatal condition, data loss is detected or is imminent</p> <p>Bits 7:3 - Reserved</p>
Current Temperature	2	<u>9</u>	<p>Current Temperature: Current Temperature of the NVDIMM device</p> <p>Bits 14:0 - Temperature in 1/16th Celsius resolution.</p> <p>Bit 15 - Sign bit for temperature (1 = negative, 0 = positive)</p>
Spare Blocks	1	<u>11</u>	<p>Spare Blocks: Remaining Spare Capacity as % of factory configured space</p> <p>Valid range 0 to 100. A value of 100 is a fully healthy state. Values from 101 to 255 are reserved.</p>

Field	Byte Length	Byte Offset	Description
Alarm Trips	2	<u>12</u>	Alarm Trips: Bits to signify if values have tripped their respective alarm thresholds Bit 0 - Temperature Trip - If set then the temperature value has reached the pre-programmed threshold limit Bit 1 - Spare Blocks Trip - If set then the spare block value has reached the pre-programmed threshold limit Bit 2 – Lifetime Warning Trip Bit 3 – Lifetime Error Trip Bit 4 – Energy Source Lifetime Warning Trip Bit 5 – Energy Source Lifetime Error Trip Bit 6 – Energy Source Temperature Warning Trip Bit 7 – Energy Source Temperature Error Trip Bits 15:8 - Reserved
Device Life	1	<u>14</u>	Percentage Used: Device life span as percentage, 100 = warranted life span of the device has been reached. Range 101 to 255 is reserved.
Last Shutdown Status	1	<u>15</u>	Last Shutdown Status: Bits to present the device operation status and state at the last host shutdown. Bit 0 - Reserved. Bit 1 – NVDIMM-N Save Operation Succeeded. Bits 7:2 - Reserved.
Last Save Operation Duration	2	<u>16</u>	Statistics: Last save operation duration, in seconds. A value of 0 means the duration is unknown. A duration that is less than 1 second should be rounded up to 1.
Last Restore Operation Duration	2	<u>18</u>	Statistics: Last restore operation duration, in seconds. A value of 0 means the duration is unknown. A duration that is less than 1 second should be rounded up to 1.
Last Erase Operation Duration	2	<u>20</u>	Statistics: Last erase operation duration, in seconds for last power-on. A value of 0 means the duration is unknown. A duration that is less than 1 second should be rounded up to 1.
Reserved	2	<u>22</u>	Reserved for future use.
Save Operations	4	<u>24</u>	Statistics: Number of save operations successfully completed since last power-on
Restore Operations	4	<u>28</u>	Statistics: Number of restore operations successfully completed since last power-on
Erase Operations	4	<u>32</u>	Statistics: Number of erase operations successfully completed since last power-on
Lifetime Save Operations	4	<u>36</u>	Statistics: Number of lifetime save operations successfully completed
Lifetime Restore Operations	4	<u>40</u>	Statistics: Number of lifetime restore operations successfully completed
Lifetime Erase operations	4	<u>44</u>	Statistics: Number of lifetime erase operations successfully completed

Field	Byte Length	Byte Offset	Description
Lifetime module Power cycles	4	<u>48</u>	Statistics: Number of NVDIMM-N module power cycles
Module Health Status	4	<u>52</u>	Health Status Detail: Module Health Status Bit 0 set to 1 indicates an Energy Source failure was detected. Persistency is lost for the device. Bit 1 set to 1 indicates a module controller failure. Access to the module device and its capabilities are lost. Bit 2 set to 1 indicates that the error was triggered by the count of DRAM uncorrectable ECC errors. Bit 3 set to 1 indicates that the error was triggered by the count of DRAM correctable ECC error above threshold events. Bit 4 set to 1 indicates the previous SAVE operation failed. Bit 5 set to 1 indicates the last RESTORE operation failed. Bit 6 set to 1 indicates the previous ARM operation failed. Bit 7 set to 1 indicates the previous ERASE operation failed. Bit 8 set to 1 indicates a platform detected configuration error, e.g. interleave set configuration error. Bit 9 set to 1 indicates a firmware error on the NVDIMM controller, e.g. corruption in the firmware image. Bit 10 set to 1 indicates a Vendor specific error. Bit 11 set to 1 indicates an Energy Source is charging but does not have sufficient charge to support a backup. Persistency is temporarily lost for the device. Bit 11 set to 0 indicates the Energy Source is sufficiently charged. Bits 31:12 – Reserved
Energy Source Health Check	4	<u>56</u>	Health Status Detail: Energy source health check frequency, in seconds. A value of 0 means that the energy source is host managed.
Energy Source Lifetime Percentage	1	<u>60</u>	Energy Source Health Status: Lifetime percentage. Valid range 0 to 100. A value of 100 means a fully health state. Values from 101 to 255 are reserved.
Energy Source Current Temperature	2	<u>61</u>	Energy Source Health Status: Current temperature, in Celsius. Bits 14:0 - Temperature in 1/16th Celsius resolution. Bit 15 - Sign bit for temperature (1 = negative, 0 = positive)
Reserved	1	<u>63</u>	Reserved
Energy Source Total Runtime	2	<u>64</u>	Energy Source Health Status: Total runtime, in hours. If the value hits its maximum (0xffff), it stays at that value. A value of 0 means the energy source is host managed.
Vendor Specific Data Size	2	<u>66</u>	Size of Vendor Specific Data. If set to 0, indicates that there is no vendor specific data that follows. Otherwise, indicates size of Vendor specific data that follows. The maximum size is 28 bytes.

Field	Byte Length	Byte Offset	Description
Vendor Specific Data	28	6 <u>8</u>	Vendor Specific Data. The size of this field is fixed but the amount of valid information it contains varies according to the Vendor Specific Data Size.
Failed Save count	8	9 <u>6</u>	Number of failed save operations since factory reset
Failed Restore count	8	10 <u>4</u>	Number of failed restore operations since factory reset
Failed Arm count	8	11 <u>2</u>	Number of failed arm operations since factory reset
Failed Flush count	8	12 <u>0</u>	Number of failed flush operations since factory reset

Table 5-4 SMART and Health Information – Output Format

5.5 NVDIMM-N Get SMART Thresholds (Function Index 2)

This function provides SMART related threshold information.

5.5.1 Input (Arg3)

None.

5.5.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-5](#).

Field	Byte Length	Byte Offset	Description
Status	4	0	<p>Bytes 1-0 0 – Success 1 – Not Implemented 2 – Invalid Input Parameters 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved</p> <p>Bytes 3-2 Vendor specific error value</p>
Threshold Alarm Control	2	<u>4</u>	<p>If a bit is set to 1, the specific alarm is enabled and the corresponding bit in the Alarm Trips field in the _DSM SMART and Health Information output payload will be set when a specific threshold outlined below has been reached.</p> <p>Bit 0 - Temperature Threshold Alarm Bit 1 - Spare Block Threshold Alarm Bit 2 – Lifetime Warning Threshold Alarm Bit 3 – Lifetime Error Threshold Alarm Bit 4 – Energy Source Lifetime Warning Threshold Alarm Bit 5 – Energy Source Lifetime Error Threshold Alarm Bit 6 – Energy Source Temperature Warning Threshold Alarm Bit 7 – Energy Source Temperature Error Threshold Alarm Bits 15:8 - Reserved</p>
Temperature Threshold	2	<u>6</u>	<p>Bits 14:0 - Temperature in 1/16th Celsius resolution. Bit 15 - Sign bit for temperature (1 = negative, 0 = positive) If “Temperature Threshold Alarm” bit is enabled and when the temperature goes above this value, the “Temperature Trip” bit will be set in the SMART and Health Information Data defined in Table 5-4.</p>
Spare Block Threshold	1	<u>8</u>	<p>Remaining Spare Capacity as % of factory configured space. Valid range 0 to 100. Range from 101 to 255 are reserved. If “Spare Block Threshold Alarm” bit is enabled and when the space block capacity goes below this threshold, the “Spare Blocks Trip” bit will be set in the SMART and Health Data structure defined in Table 5-4.</p>

Reserved	3	<u>9</u>	Reserved for future use.
Lifetime Thresholds	8	<u>12</u>	Bits 7:0 – Lifetime Warning Threshold Bits 15:8 – Lifetime Error Threshold Bits 63:16 - Reserved
Energy Source Thresholds	8	<u>20</u>	Bits 7:0 – Lifetime Warning Threshold Bits 15:8 – Lifetime Error Threshold Bits 23:16 – Temperature Warning Threshold Bits 31:24 – Temperature Error Threshold Bits 63:32 - Reserved
Reserved	8	<u>28</u>	Reserved for future support.

Table 5-5. Get SMART Thresholds – Output Format

5.6 NVDIMM-N Get OS Data Size (Function Index 4)

This function returns the size of the OS reserved region on the NVDIMM device.

This specification allows an OSPM to access and control an OS reserved region associated with the NVDIMM-N module.

5.6.1 Input (Arg3)

None.

5.6.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-6](#).

Field	Byte Length	Byte Offset	Description
Status	4	0	Bytes 1-0 0 – Success 1 – Not Implemented 2 – Invalid Input Parameters 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved Bytes 3-2 Vendor specific error value
Size of OS Data Area	4	4	Size Returned in bytes
Max OS Data Area Length	4	8	In bytes, Maximum size of the OS Data length supported by the platform in Get/Set OS Data functions

Table 5-6 Get OS Data Size – Output Format

5.7 NVDIMM-N Get OS Data (Function Index 5)

This function returns the content of the OS reserved region from the NVDIMM device.

This specification allows an OSPM to access and control an OS reserved region associated with the NVDIMM-N module.

5.7.1 Input (Arg3)

Input is a package containing a single buffer, where the buffer is formatted as shown in [Table 5-7](#).

Field	Byte Length	Byte Offset	Description
Offset	4	0	In bytes
Length	4	4	In bytes

Table 5-7 Get Volume Label Data – Input Format

5.7.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-8](#).

Field	Byte Length	Byte Offset	Description
Status	4	0	Bytes 1-0 0 – Success 1 – Not Implemented 2 – Invalid Input Parameters(Offset + Length is > size of OS Data Area) 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved Bytes 3-2 Vendor specific error value
Data in OS Data Area	Varies	4	Size of the output is equal to length in input if status is SUCCESS; otherwise, the contents of rest of the output buffer are not valid.

Table 5-8 Get OS Data – Output Format

5.8 NVDIMM-N Set OS Data (Function Index 6)

This function sets the content of the OS reserved region on the NVDIMM device

This specification allows an OSPM to access and control an OS reserved region associated with the NVDIMM-N module.

5.8.1 Input (Arg3)

Input is a package containing a single buffer, where the buffer is formatted as shown in [Table 5-9. Table 5-9 Set OS Data – Input Format](#)

Field	Byte Length	Byte Offset	Description
Offset	4	0	In bytes Indicates the offset, within the OS Data Area, to which the OS Data is to be written in the target NVDIMM-N module
Length	4	4	In bytes
OS Data	Varies	8	OS Data provided in Buffer. Size of the OS Data is as indicated by Length field above.

Table 5-9 Set OS Data – Input Format

5.8.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-10.](#)

Field	Byte Length	Byte Offset	Description
Status	4	0	Bytes 1-0 0 – Success 1 – Not Implemented 2 – Invalid Input Parameters(Offset + Length is > size of OS Data Area) 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved Bytes 3-2 Vendor specific error value

Table 5-10 Set OS Data – Output Format

5.9 NVDIMM-N Get Identification (Function Index 10)

This function returns the NVDIMM-N device information.

5.9.1 Input (Arg3)

None.

5.9.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-11](#).

Field	Byte Length	Byte Offset	Description
Status	4	0	Bytes 1-0 0 – Success 1 – Not Implemented 2 – Invalid Input Parameters 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved Bytes 3-2 Vendor specific error value
Specification Revision	1	4	JEDEC specification revision: [3:0] Minor Revision [7:4] Major Revision
Number of Standard Pages	1	5	Number of standard defined pages supported by the NVDIMM-N module.
Hardware Revision	4	6	Controller hardware revision: Implementation specific
Supported Backup Triggers	1	10	Bitmask of Backup triggers, includes ADR Triggers Bit 0 – CKE-Trigger: Set to 1 indicates that the NVDIMM-N device can have its backup triggered by the CKE signal going low. Bit 1 – External-Signal-Trigger – Set to 1 indicates that the NVDIMM-N device can have its backup triggered by an external signal connected to the device controller. Bit 2 – 12V-Trigger - Set to 1 indicates that the NVDIMM-N device can have its backup triggered by 12V rail falling below the trigger threshold. Bit 3 – I2C-Register-Trigger - Set to 1 indicates that the NVDIMM-N device can have its backup triggered by the host writing to the BACKUP register through I2C. Bit 4 – SAVE_n-Trigger – Set to 1 indicates that the NVDIMM-N device can have its backup triggered by asserting SAVE_n pin.

Field	Byte Length	Byte Offset	Description
			Bits 7:5 - Reserved
Maximum Operations Retries count	2	11	Maximum count of host operation retries, retries due to operation failures or exceeding the maximum timeout value for the operations. The field is defined as: Bits 3:0 – maximum number of SAVE retries Bits 7:4 – maximum number of RESTORE retries Bits 11:8 – maximum number of ERASE retries Bits 15:12 – maximum number of RESET retries
Reserved	3	13	Reserved
Backup Operation timeout	4	16	Save operation timeout, in milliseconds
Restore Operations timeout	4	20	Restore operation timeout, in milliseconds
Erase Operations timeout	4	24	Erase operation timeout, in milliseconds
Arm Operations timeout	4	28	Arm operation timeout, in milliseconds
Firmware Operations timeout	4	32	Firmware operations timeout, in milliseconds
Region Block Size	4	36	Region Block Size in Bytes
Minimum Operating Temperature	2	40	Minimum operating temperature, in Celsius. Bits 14:0 - Temperature in 1/16 th Celsius resolution. Bit 15 - Sign bit for temperature (1 = negative, 0 = positive)
Maximum Operating Temperature	2	42	Maximum operating temperature, in Celsius. Bits 14:0 - Temperature in 1/16 th Celsius resolution. Bit 15 - Sign bit for temperature (1 = negative, 0 = positive)
Current Firmware Slot	1	44	Slot number of the running firmware.
Reserved	1	45	Reserved for future use.
Number of Firmware Slots	2	46	Number of Firmware image slots on the NVDIMM-N module.
Firmware Slot revision	2*(number of firmware slots)	48	Firmware Revision of each supported firmware slot on the NVDIMM-N module. Firmware Revision is defined as: Byte 0 – LSB of the controller firmware revision. Byte 1 – MSB of the controller firmware revision.

Table 5-11 Get Identification function – Output Format

5.10 NVDIMM-N Get Energy Source Identification (Function Index 11)

This function provides the NVDIMM-N energy source information.

5.10.1 Input (Arg3)

None.

5.10.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-12](#).

Field	Byte Length	Byte Offset	Description
Status	4	0	Bytes 1-0 0 – Success 1 – Not Implemented 2 – Invalid Input Parameters 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved Bytes 3-2 Vendor specific error value
Energy Source Policy	1	4	0 – unknown 1 – device-managed 2 – host-managed 255-3: reserved
Attributes	1	5	Energy Source Attributes: Bit 0 – set to 1 indicates the Energy Source is on the NVDIMM-N module Bit 1 – set to 1 indicates the Energy Source is tethered to the NVDIMM-N module. Bit 2 – set to 1 indicates the Energy Source is used by more than one NVDIMM-N module. Bit 7:3 – Reserved Implementation Note: one or more bits might be set.
Technology	1	6	Energy Source Technology: Bit 0 – set to 1 indicates undefined, i.e. not defined in this specification Bit 1 – set to 1 indicates the Energy Source uses supercapacitor Bit 2 – set to 1 indicates the Energy Source uses battery

Field	Byte Length	Byte Offset	Description
			Bit 3 – set to 1 indicates the Energy Source uses hybrid capacitor Bit 7:4 – Reserved Implementation Note: one or more bits might be set.
Reserved	1	7	Reserved for future use.
Hardware Revision	2	8	Energy Source hardware revision: Implementation specific.
Firmware Revision	2	10	Energy Source firmware revision. The revision is defined as: Byte 0 – LSB of the Energy Source firmware revision. Byte 1 – MSB of the Energy Source firmware revision.
Charge Timeout	4	12	Worst case Energy Source charge time In milliseconds
Minimum Operating Temperature	2	16	In Celsius. Bits 14:0 - Temperature in 1/16 th Celsius resolution. Bit 15 - Sign bit for temperature (1 = negative, 0 = positive)
Maximum Operating Temperature	2	18	In Celsius. Bits 14:0 - Temperature in 1/16 th Celsius resolution. Bit 15 - Sign bit for temperature (1 = negative, 0 = positive)

Table 5-12 Get Energy Source Identification function – Output Format

5.11 NVDIMM-N Get Last Backup Information (Function Index 12)

This function returns information about the last initiated backup operation.

5.11.1 Input (Arg3)

None.

5.11.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-13](#).

Field	Byte Length	Byte Offset	Description
Status	4	0	Bytes 1-0 0 – Success 1 – Not Implemented 2 – Invalid Input Parameters 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved

Field	Byte Length	Byte Offset	Description
			Bytes 3-2 Vendor specific error value
Backup Image on NVM Media Status	1	<u>4</u>	!= 0 – valid data image in the NVDIMM-N NVM media
Backup Completion Status	1	<u>5</u>	!= 0 - Backup did not complete
Last Backup Initiation	1	<u>6</u>	Last Backup Initiation Bit 0 – SAVE_n initiated Backup Bit 1 – External signal of the NVDIMM-N device initiated Backup Bit 2 – CKE assertion initiated Backup Bit 3 – FW initiated Backup Bit 4 – RESET_n initiated Backup Bits 7:5 - Reserved
Controller Backup status	1	<u>7</u>	NVDIMM-N Controller Backup status: Bit 0 – Backup was initiated with Good To Go = 0 Bit 1 – Controller detected SDRAM Initialization Fault Bit 2 – Controller detected General Fault Bits 7:3 - Reserved

Table 5-13 Get Last Backup Information function – Output Format

5.12 NVDIMM-N Set NVM Lifetime Threshold (Function Index 13)

This function sets NVDIMM-N NVM lifetime threshold information.

5.12.1 Input (Arg3)

Input is a package containing a single buffer, where the buffer is formatted as shown in [Table 5-14](#).

Field	Byte Length	Byte Offset	Description
NVM Lifetime Warning Threshold	1	0	Value to set NVDIMM-N module NVM Lifetime Warning Threshold. The new value must be between 0 and 100.

Table 5-14 Set NVM Lifetime Threshold function – Input Format

5.12.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-15](#).

Field	Byte Length	Byte Offset	Description
Status	4	0	Bytes 1-0 0 – Success 1 – Not Implemented 2 – Invalid Input Parameters 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved Bytes 3-2 Vendor specific error value

Table 5-15 Set NVM Lifetime Threshold function – Output Format

5.13 NVDIMM-N Query Error Injection Capabilities (Function Index 18)

This function gets the NVDIMM-N error injection capabilities of the platform host and the memory device. This function can only be called in a special secure and protected mode. A “Not Implemented” Error will be returned if the error injection is locked.

5.13.1 Input (Arg3)

None.

5.13.2 Output

Returns status and a 32 byte buffer as shown in [Table 5-16](#), where each bit corresponds to error injection type supported (see [Table 5-17](#)).

Field	Byte Length	Byte Offset	Description
Status	4	0	Bytes 1-0 0 – Success 1 – Not Supported 2 – Invalid Input Parameters 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved Bytes 3-2 Vendor specific error value

Field	Byte Length	Byte Offset	Description
Error Injection Capabilities	32	4	Bitmask 32 byte buffer, where each bit corresponds to error injection type supported (see Table 5-17 for error injection types). For example, if bit 5 is set, then Uncorrectable Restore Error injection is supported.

Table 5-16 Get Error Injection Capabilities – Output Format

Error Type Number (Decimal)	Error
0	Reserved
1	Non Critical Device Error
2	Critical Device Error
3	Fatal Device Error
4	Uncorrectable error during backup operation from SDRAM to Flash
5	Uncorrectable error during restore operation from Flash to SDRAM
6	Uncorrectable error during erase Operation
7	Uncorrectable error during arm Operation
8	Bad Block in NVDIMM Region
9	Energy source error
10	Energy source not sufficiently charged
11	Energy source Thermal Warning
12	Energy source Thermal Error
13	Energy source Lifetime Warning
14	Energy source Lifetime Error
15	Lifetime Warning
16	Lifetime Error
17	Firmware Update error
18	Internal NVM controller error
19-127	Reserved
128-255	Vendor Defined

Table 5-17 Error Injection Types

5.14 NVDIMM-N Inject Error (Function Index 19)

This function injects NVDIMM-N standard errors to the memory device. This function can only be called in a special secure and protected mode. A “Not Implemented” Error will be returned if the error injection is locked.

This function can be used to inject and to clear error injection.

5.14.1 Input (Arg3)

Input is a package containing a single buffer, where the buffer is formatted as shown in [Table 5-18](#).

This function can only be called in a special secure and protected mode. A “Not Implemented” Error will be returned if the error injection is not enabled.

Field	Byte Length	Byte Offset	Description
Error Type	1	0	Integer representing the error type to be injected. See Table 5-17 for error injection types.
Options	1	1	The options are defined as follows: 0 – Single Injection 1 – Persistent Injection 2 – Clear pending or persistent error injection 3-127 – Reserved 128-255 – Vendor defined

Table 5-18 Inject Error – Input Format

5.14.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-19](#).

Field	Byte Length	Byte Offset	Description
Status	4	0	Bytes 1-0 0 – Success 1 – Not Implemented 2 – Invalid Input Parameters 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved Bytes 3-2 Vendor specific error value

Table 5-19 Inject Error – Output Format

5.15 NVDIMM-N Get Inject Error Status (Function Index 20)

This function returns the status of the error injection attempted. The injected status does not change after the error status has been read following a single injection.

5.15.1 Input (Arg3)

None.

5.15.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-20](#).

Field	Byte Length	Byte Offset	Description
Status	4	0	Bytes 1-0 0 – Success 1 – Not Implemented 2 – Invalid Input Parameters 3 – Operation Failed 4 – Vendor Specific Error Code 5-FFFFh - Reserved Bytes 3-2 Vendor specific error value
Error Injection Status Information	1	4	0 – No Error injection activity 1 – Injected 2 – Pending 3 – 255 – Reserved
Error Injection Type	1	5	Not valid if Status is 0. Reports last error type injected as defined in Table 5-17. Table 5-17 Error Injection Types
Error Injection Option	1	6	Not valid if Status is 0. 0 – Single 1 – Persistent All other values reserved

Table 5-20 Get Inject Error Status– Output Format

5.16 I2C Read (Function 21)

This function allows access to the NVDIMM-N pages and registers through an I2C-initiated function. This function reads a register. This function is only enabled in debug mode.

5.16.1 Input (Arg3)

Input is a package containing a single buffer formatted as shown in Table 5-21.

Field	Byte Length	Byte Offset	Description
Page	<u>1</u>	<u>0</u>	Descriptor of the Page containing the register
Offset	<u>1</u>	<u>1</u>	Offset of the register in the page

Table 5-21 I2C Read - Input Format

5.16.2 Output

Return value for this function is a buffer formatted as shown in Table 5-22.

Field	Byte Length	Byte Offset	Description
Status	<u>4</u>	<u>0</u>	Bytes 1-0 <u>0 – Success</u> <u>1 – Not Implemented</u> <u>2 – Invalid Input Parameters</u> <u>3 – Operation Failed</u> <u>4 – Vendor Specific Error Code</u> <u>5-FFFFh - Reserved</u> Bytes 3-2 <u>Vendor specific error value</u>
Register Value	<u>1</u>	<u>4</u>	<u>Value contained in the register</u>

Table 5-22 I2C Read - Output Format

5.17 I2C Write (Function Index 22)

This function allows access to the NVDIMM-N pages and registers through an I2C-initiated function. This function writes a register. This function is only enabled in debug mode.

5.17.1 Input (Arg3)

Input is a package containing a single buffer, where the buffer is formatted as shown in Table 5-23.

Field	Byte Length	Byte Offset	Description
-------	-------------	-------------	-------------

<u>Page</u>	<u>1</u>	<u>0</u>	<u>Descriptor of the Page containing the register</u>
<u>Offset</u>	<u>1</u>	<u>1</u>	<u>Offset of the register in the page</u>
<u>Value</u>	<u>1</u>	<u>2</u>	<u>Value to be written to the register</u>

Table 5-23 I2C Write – Input Format

5.17.2 Output

Return value for this function is a buffer formatted as shown in [Table 5-24](#).

<u>Field</u>	<u>Byte Length</u>	<u>Byte Offset</u>	<u>Description</u>
<u>Status</u>	<u>4</u>	<u>0</u>	<u>Bytes 1-0</u> <u>0 – Success</u> <u>1 – Not Implemented</u> <u>2 – Invalid Input Parameters</u> <u>3 – Operation Failed</u> <u>4 – Vendor Specific Error Code</u> <u>5-FFFFh - Reserved</u> <u>Bytes 3-2</u> <u>Vendor specific error value</u>

Table 5-24 I2C Write – Output Format

5.18 I2C Block Read (Function Index 23)

This function provides access to the NVDIMM-N pages and registers through an I2C-initiated function. This function reads a 32-byte block data specified by a data type, region ID, and block ID. This function is only enabled in debug mode.

5.18.1 Input (Arg3)

Input is a package containing a single buffer formatted as shown in [Table 5-25](#).

<u>Field</u>	<u>Byte Length</u>	<u>Byte Offset</u>	<u>Description</u>
<u>Data Type</u>	<u>1</u>	<u>0</u>	<u>The type of data, as defined in JEDEC TYPED_BLOCK_DATA (3, 0x04):</u> <ul style="list-style-type: none"> <u>0: Reserved</u> <u>1: Firmware image data</u> <u>2: Vendor Log Page</u> <u>3 to 200: Reserved</u> <u>201 to 255: Vendor Specific</u>
<u>Region ID</u>	<u>2</u>	<u>1</u>	<u>Region ID the data transfer is applicable to.</u>
<u>Block ID</u>	<u>1</u>	<u>3</u>	<u>Identification of the block being read inside the region.</u>

Table 5-25 I2C Block Read – Input Format

5.18.2 Output

Return value for this function is a buffer formatted as shown in [Table 5-26](#).

<u>Field</u>	<u>Byte Length</u>	<u>Byte Offset</u>	<u>Description</u>
<u>Status</u>	<u>4</u>	<u>0</u>	<u>Bytes 1-0</u> <u>0 – Success</u> <u>1 – Not Implemented</u> <u>2 – Invalid Input Parameters</u> <u>3 – Operation Failed</u> <u>4 – Vendor Specific Error Code</u> <u>5-FFFFh - Reserved</u> <u>Bytes 3-2</u> <u>Vendor specific error value</u>
<u>Data Value</u>	<u>32</u>	<u>4</u>	<u>Values contained in the read block</u>

Table 5-26 I2C Block Read – Output Format

5.19 I2C Block Write (Function Index 24)

This function provides access to the NVDIMM-N pages and registers through an I2C-initiated function. This function writes a 32-byte block data specified by a data type, region ID, and block ID. This function is only enabled in debug mode.

5.19.1 Input (Arg 3)

Input is a package containing a single buffer formatted as shown in [Table 5-27](#).

<u>Field</u>	<u>Byte Length</u>	<u>Byte Offset</u>	<u>Description</u>
<u>Data Type</u>	<u>1</u>	<u>0</u>	<u>Descriptor of the Page containing the register</u>
<u>Region ID</u>	<u>2</u>	<u>1</u>	<u>Region ID the data transfer is applicable to.</u>
<u>Block ID</u>	<u>1</u>	<u>3</u>	<u>Identification of the block being read inside the region.</u>
<u>Data</u>	<u>32</u>	<u>4</u>	<u>Values to be written to the block</u>

Table 5-27 I2C Block Write - Input Format

5.19.2 Output

Return Value for this function is a buffer formatted as shown in [Table 5-28](#).

<u>Field</u>	<u>Byte Length</u>	<u>Byte Offset</u>	<u>Description</u>
<u>Status</u>	<u>4</u>	<u>0</u>	<u>Bytes 1-0</u> <u>0 – Success</u> <u>1 – Not Implemented</u> <u>2 – Invalid Input Parameters</u> <u>3 – Operation Failed</u> <u>4 – Vendor Specific Error Code</u> <u>5-FFFFh - Reserved</u> <u>Bytes 3-2</u> <u>Vendor specific error value</u>

Table 5-28 I2C Block Write – Output Format