



# 2-Ch RAID0 (NVMe IP for Gen 4/NVMeG4-IP)

## Demo Instruction

Rev1.3 26-Dec-23

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# 1 Overview

This document describes the instruction to run 2-ch RAID0 demo by using NVMe-IP for Gen4 or NVMeG4-IP. The demo is run on FPGA development board to access two NVMe Gen4 SSDs in a RAID0 configuration. There are seven test menus for executing each command - Identify, Write, Read, SMART, Flush, Secure Erase, and Shutdown command. The user can control the test operation through FPGA console.

Before proceeding with the demo, please ensure that the FPGA board has been completely setup according to the “dg\_nvmeip\_raid0x2\_fpgasetup” document, which can be found at the following link.

[https://dgway.com/products/IP/NVMe-IP/dg\\_nvmeip\\_raid0x2\\_fpgasetup\\_xilinx\\_en/](https://dgway.com/products/IP/NVMe-IP/dg_nvmeip_raid0x2_fpgasetup_xilinx_en/)

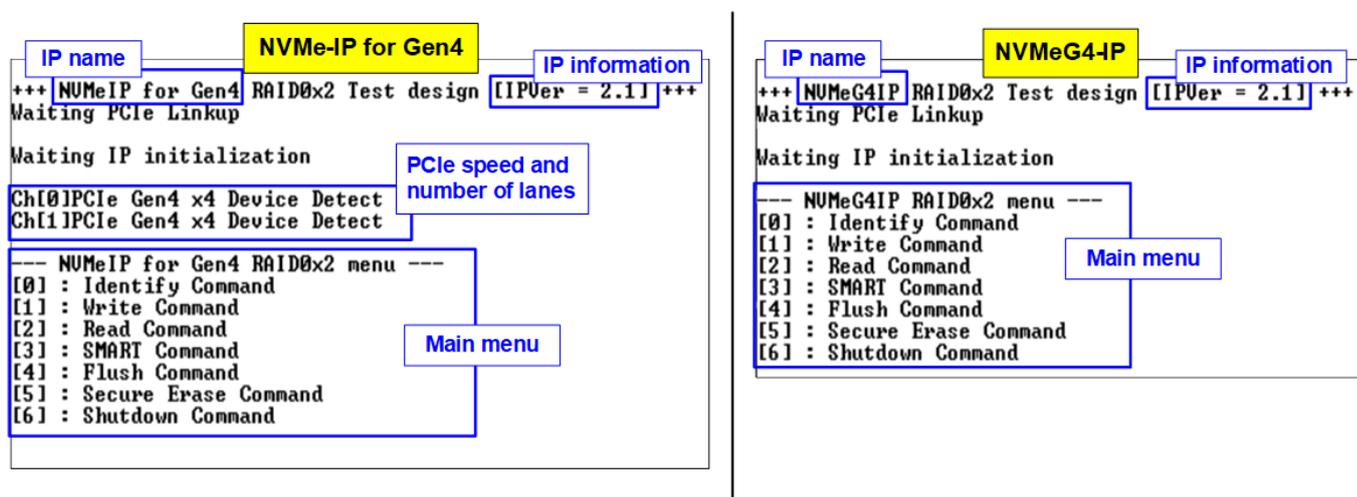


Figure 1-1 RAID0x2 menu after finishing initialization

On welcome screen, the IP name and version number are displayed. When utilizing the NVMe-IP for Gen4, the console will also present details regarding the PCIe speed and the number of PCIe lanes. However, the NVMeG4-IP does not provide these details as it is specifically designed to connect with a 4-lane PCIe Gen4 SSD only.

Subsequently, the test menu will be displayed on the console, enabling users to select their desired test operation by setting the input via the console.

## 2 Test Menu

### 2.1 Identify Command

The Identify command is used to retrieve information about the NVMe SSD. To send the Identify command, select '0' from the console menu. Once the command operation is completed, the console displays the following three pieces of information.

```

+++ Identify Command selected +++
Ch[0]Model Number : Samsung SSD 990 PRO 1TB
Ch[1]Model Number : addlink M.2 PCIE G4x4 NVMe
RAID Capacity= 2000[GB]
Secure Erase Command : Support

--- NVMeIP for Gen4 RAID0 ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command
  
```

Model name, RAID0 capacity, and Secure Erase Command support

Figure 2-1 Test result when executing Identify command

- 1) SSD model number : This value is decoded from Identify controller data of each SSD.
- 2) RAID capacity : This value is calculated by multiplying device capacity in channel#0 by 2. Therefore, it is recommended to connect two SSDs for RAID0.  
*Note: If the connected SSDs have different capacities, it is recommended to connect the SSD with smaller capacity to Ch#0.*
- 3) Secure Erase Command Support: This value is decoded from the Identify controller data to show whether the SSD supports the Secure Erase command.

The RAID0 design supports only the SSD LBA Size of 512 bytes. If the connected SSDs use different LBA Size values, a warning message shown in Figure 2-2 will be displayed. In such cases, RAID0 controller hardware in HDL code must be modified.

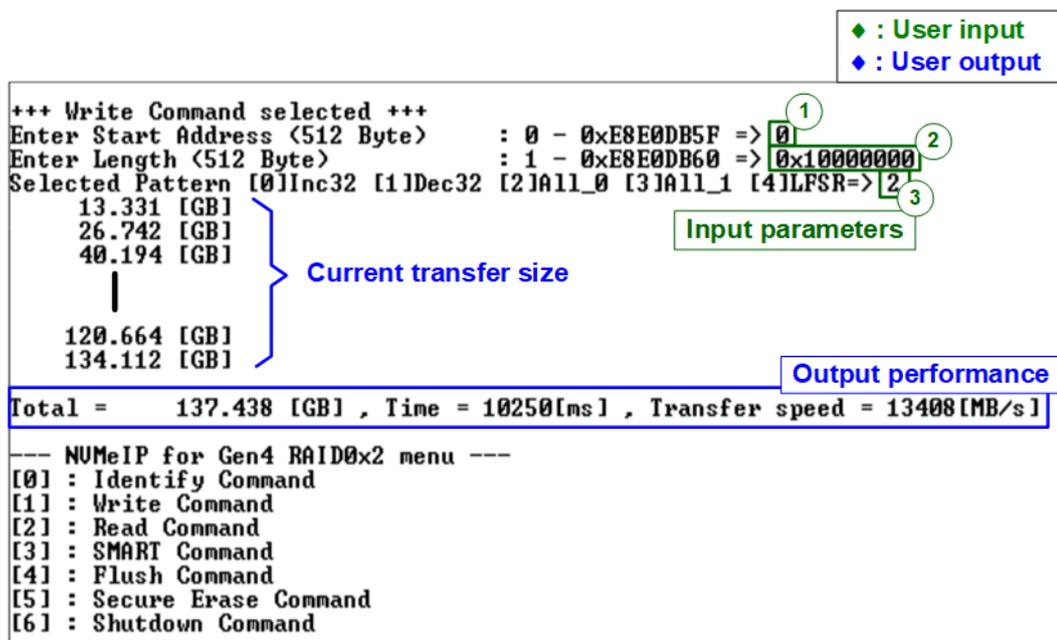
```

Unsupported LBA size is detected
Warning : LBA Size Not Support!
Please Check Devices
  
```

Figure 2-2 Error message when LBA size does not support

## 2.2 Write Command

The Write command is used to write data to the RAID0. To execute the Write command, select '1' from the test menu.



```

+++ Write Command selected +++
Enter Start Address (512 Byte)      : 0 - 0xE8E0DB5F => 0
Enter Length (512 Byte)            : 1 - 0xE8E0DB60 => 0x10000000
Selected Pattern [0]Inc32 [1]Dec32 [2]A11_0 [3]A11_1 [4]LFSR=> 2
  13.331 [GB]
  26.742 [GB]
  40.194 [GB]
  |
 120.664 [GB]
 134.112 [GB]
} Current transfer size

Total = 137.438 [GB] , Time = 10250[ms] , Transfer speed = 13408[MB/s]

--- NUMeIP for Gen4 RAID0x2 menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command
  
```

Figure 2-3 Input and test result when executing Write command

The user needs to input three parameters.

- 1) Start Address: Specifies the start address to write the RAID0 as a 512-byte unit. The input is in decimal unit when the user inputs only digits. The user can add "0x" as a prefix for hexadecimal units.
- 2) Transfer Length: Specifies the total transfer size as a 512-byte unit. The input is in decimal unit when the user inputs only digits. The user can add "0x" as a prefix for hexadecimal units.
- 3) Test pattern: Used to select the test data pattern for writing to the RAID0. The user can choose from five patterns, including 32-bit incremental, 32-bit decremental, all 0, all 1, and 32-bit LFSR counter.

Once all input parameters are validated, the write operation begins. The console displays the current amount of written data every second to indicate that the system is still running. Upon completion, the console shows the total size of data, time usage, and test speed as the test results.

**Note:**

1. The performance of RAID0x2 is approximately twice that of a single SSD. To achieve optimal performance, it is recommended to use the same SSD model for all SSD channels. However, if different SSD models are used in the system, the RAID0x2 performance is limited to two times of the performance of slower SSD.
2. The write performance of SSDs may decrease after long data transfer. In certain cases, the performance can be restored by executing the Secure Erase command.

Offset	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0000000000	00	00	00	00	00	00	00	00	FF	FF	00	00	FF	FF	FF	00	01	00	00	00	00	00	00	00	FE	FF	00	00	FE	FF	FF	00
0000000010	01	00	00	00	FF	01	00	00	FF	FF	01	00	FE	FF	FF	01	02	00	00	00	FC	01	00	00	FC	FF	01	00	FD	FF	FF	01
0000000020	02	00	00	00	FF	03	00	00	FF	FF	03	00	FD	FF	FF	03	04	00	00	00	F9	03	00	00	F9	FF	03	00	FB	FF	FF	03
0000000030	04	00	00	00	FF	07	00	00	FF	FF	07	00	FB	FF	FF	07	09	00	00	00	F2	07	00	00	F2	FF	07	00	F6	FF	FF	07
0000000040	09	00	00	00	FF	0F	00	00	FF	FF	0F	00	F6	FF	FF	0F	12	00	00	00	E4	0F	00	00	E4	FF	0F	00	ED	FF	FF	0F
0000000050	12	00	00	00	FF	1F	00	00	FF	FF	1F	00	ED	FF	FF	1F	24	00	00	00	C9	1F	00	00	C9	FF	1F	00	DB	FF	FF	1F
0000000060	24	00	00	00	FF	3F	00	00	FF	FF	3F	00	DB	FF	FF	3F	49	00	00	00	92	3F	00	00	92	FF	3F	00	B6	FF	FF	3F
0000000070	49	00	00	00	FF	7F	00	00	FE	FF	7F	00	B6	FF	FF	7F	92	00	00	00	24	7F	00	00	25	FF	7F	00	6D	FF	FF	7F
0000000080	92	00	00	00	FF	FF	00	00	FD	FF	FF	00	6D	FF	FF	FF	24	01	00	00	49	FE	00	00	4B	FE	FF	00	DB	FE	FF	FF
<b>SSD#0</b>																<b>SSD#1</b>																
00000001D0	F3	24	49	12	C9	B6	FF	FF	25	C9	B6	FF	28	92	A4	ED	E7	49	92	24	DD	DB	24	C9	31	A4	6D	C9	3C	FF	7F	DB
00000001E0	E7	49	92	24	92	6D	FF	FF	4A	92	6D	FF	51	24	49	DB	CF	93	24	49	BA	B7	49	92	62	48	DB	92	79	FE	FF	B6
00000001F0	CF	93	24	49	24	DB	FE	FF	94	24	DB	FE	A3	48	92	B6	9E	27	49	92	75	6F	93	24	C5	90	B6	25	F2	FC	FF	6D
0000000200	02	00	00	00	00	00	00	00	FD	FF	00	00	FD	FF	FF	00	03	00	00	00	00	00	00	00	FC	FF	00	00	FC	FF	FF	00
0000000210	04	00	00	00	FA	01	00	00	FA	FF	01	00	FB	FF	FF	01	07	00	00	00	F9	01	00	00	F9	FF	01	00	F8	FF	FF	01
0000000220	09	00	00	00	F4	03	00	00	F4	FF	03	00	F6	FF	FF	03	0F	00	00	00	F2	03	00	00	F2	FF	03	00	F0	FF	FF	03
0000000230	12	00	00	00	E9	07	00	00	E9	FF	07	00	ED	FF	FF	07	1F	00	00	00	E4	07	00	00	E4	FF	07	00	E0	FF	FF	07
0000000240	24	00	00	00	D2	0F	00	00	D2	FF	0F	00	DB	FF	FF	0F	3F	00	00	00	C9	0F	00	00	C9	FF	0F	00	C0	FF	FF	0F
0000000250	49	00	00	00	A4	1F	00	00	A4	FF	1F	00	B6	FF	FF	1F	7F	00	00	00	92	1F	00	00	92	FF	1F	00	80	FF	FF	1F
0000000260	92	00	00	00	49	3F	00	00	49	FF	3F	00	6D	FF	FF	3F	FF	00	00	00	24	3F	00	00	24	FF	3F	00	00	FF	FF	3F
0000000270	4	01	00	00	92	7E	00	00	93	FE	7F	00	DB	FE	FF	7F	FF	01	00	00	49	7E	00	00	48	FE	7F	00	00	FE	FF	7F
0000000280	49	02	00	00	24	FD	00	00	26	FD	FF	00	B6	FD	FF	FF	FF	03	00	00	92	FC	00	00	90	FC	FF	00	00	FC	FF	FF

Figure 2-4 Example Test data of the 1<sup>st</sup> 512-byte of each SSD by using LFSR pattern

In the 2-ch RAID0 demo, the stripe size of RAID0 is set to 512 bytes. When using incremental, decremental, and LFSR pattern, each 512-byte data block has a unique 64-bit header which consists of a 48-bit address (in 512-byte unit) and a 16-bit zero value. Following the header, the data block contains the test pattern selected by the user. When using all-0 or all-1 pattern, the unique 64-bit header is not included.

In the RAID0 configuration, the first stripe is mapped to the first 512-byte of SSD#0, while the second stripe of RAID0 is mapped to the first 512-byte of SSD#1, as shown in Figure 2-4.

```

Error input
+++ Write Command selected +++
Enter Start Address (512 Byte) : 0 - 0xE8E0DB5F => 0xFFFFFFFF
Invalid input Out of range address

+++ Write Command selected +++
Enter Start Address (512 Byte) : 0 - 0xE8E0DB5F => 0
Enter Length (512 Byte) : 1 - 0xE8E0DB60 => 0xFFFFFFFF
Invalid input Out of range length

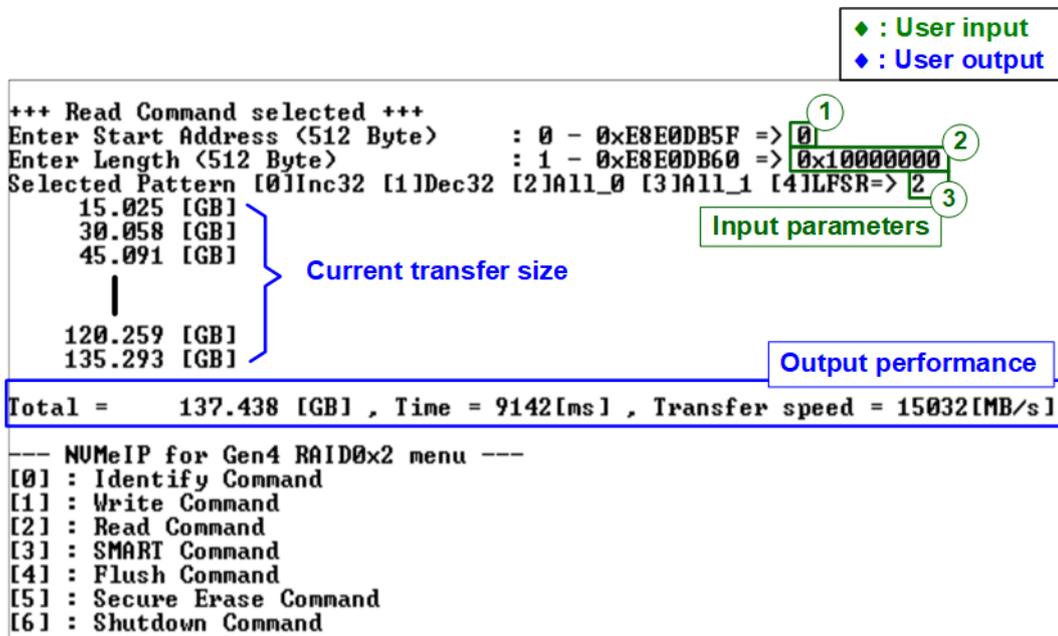
+++ Write Command selected +++
Enter Start Address (512 Byte) : 0 - 0xE8E0DB5F => 0
Enter Length (512 Byte) : 1 - 0xE8E0DB60 => 0x80000000
Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR => 7
Invalid input Invalid pattern
    
```

Figure 2-5 Error message from the invalid input

Figure 2-5 shows an example when the input is out-of-range from the recommended range for each parameter. The console displays “Invalid input”, and then the operation is cancelled.

## 2.3 Read Command

The Read command is used to read data from the RAID0. To execute the Read command, select '2' from the test menu.



```

+++ Read Command selected +++
Enter Start Address (512 Byte)      : 0 - 0xE8E0DB5F => 0
Enter Length (512 Byte)            : 1 - 0xE8E0DB60 => 0x10000000
Selected Pattern [0]Inc32 [1]Dec32 [2]A11_0 [3]A11_1 [4]LFSR=> 2
  15.025 [GB]
  30.058 [GB]
  45.091 [GB]
      |
 120.259 [GB]
 135.293 [GB]
      } Current transfer size

Total =      137.438 [GB] , Time = 9142[ms] , Transfer speed = 15032[MB/s]

--- NUMeIP for Gen4 RAID0x2 menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command
  
```

Figure 2-6 Input and test result when executing Read command

The user needs to input three parameters.

- 1) Start Address: Specifies the start address to read the RAID0 as a 512-byte unit. The input is in decimal unit when the user inputs only digits. The user can add "0x" as a prefix for hexadecimal units.
- 2) Transfer Length: Specifies the total transfer size as a 512-byte unit. The input is in decimal unit when the user inputs only digits. The user can add "0x" as a prefix for hexadecimal units.
- 3) Test pattern: Used to select the test data pattern for reading and verifying data from the RAID0. The test pattern must match the one used in the Write command menu. There are five available patterns: 32-bit incremental, 32-bit decremental, all 0, all 1, and 32-bit LFSR counter.

If all inputs are valid, the test system reads data from the RAID0. While the operation is in progress, the console displays the current amount of read data every second to indicate that the system is still running. When the operation is completed, the console shows the total size of data, time usage, and test speed.

Note:

1. The performance of RAID0x2 is approximately twice that of a single SSD. To achieve optimal performance, it is recommended to use the same SSD model for all SSD channels. However, if different SSD models are used in the system, the RAID0x2 performance is limited to two times of the performance of slower SSD.
2. It is found that some SSDs shows varying performance characteristic when different test patterns are utilized. For instance, the read performance is better when using all-zero pattern compared to using an LFSR pattern.

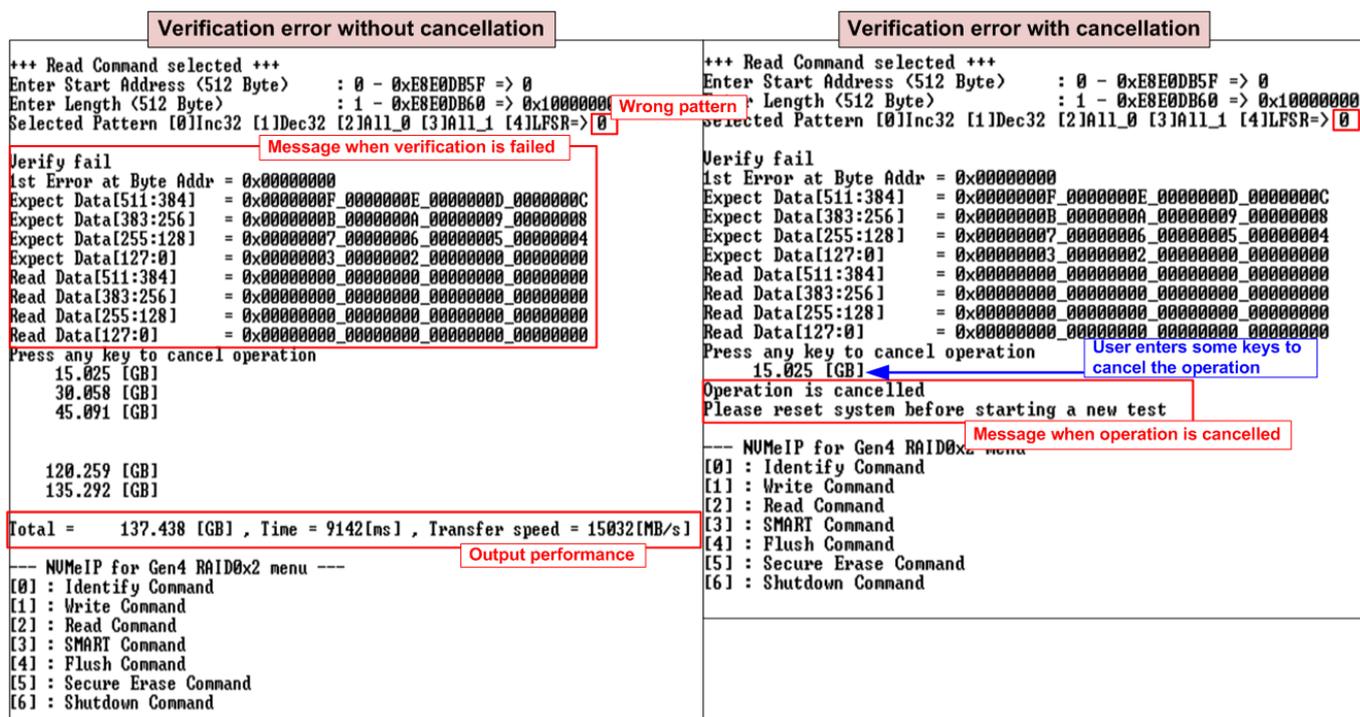


Figure 2-7 Data verification fails

In case of a failed data verification during Read command, an error message is displayed on the console, as shown in Figure 2-7. The message “Verify fail” is displayed with information about the first failure data, such as the error byte address, the expected value, and the read value.

To cancel the Read operation, the user can press any key(s). However, if the operation is not cancelled, it will continue running until it finishes. Once it has finished, the output performance is displayed on the console.

Though the operation is cancelled, the Read command continues running as a background process and may not finish in a proper sequence. Therefore, it is recommended to power off and then power on both the FPGA board and adapter board (if connected) after cancelling the operation.

## 2.4 SMART Command

Select '3' to send a SMART command to the RAID0. After the operation is completed, the console will display the SMART/Health Information output (see Figure 2-8). This information includes both the Health status and SMART log information.

```

+++ SMART Command selected +++
++ ch[0]
<< Health Status >>
Remaining Life : 90%
<< SMART Log Information Ch[0] >>
Percentage Used : 10%
Temperature : 30 Degree Celsius
Total Data Read : 118857 GB
Total Data Read (Raw data) : 0x00000000_00000000_00000000_0DD6029F
Total Data Written : 59747 GB
Total Data Written (Raw data) : 0x00000000_00000000_00000000_06F47E5A
Power On Cycles : 338 Times
Power On Hours : 39 Hours
Unsafe Shutdowns : 142 Times
SSD#0

++ ch[1]
<< Health Status >>
Remaining Life : 78%
<< SMART Log Information Ch[1] >>
Percentage Used : 22%
Temperature : 24 Degree Celsius
Total Data Read : 223247 GB
Total Data Read (Raw data) : 0x00000000_00000000_00000000_19FCDD8A
Total Data Written : 252162 GB
Total Data Written (Raw data) : 0x00000000_00000000_00000000_1D5A8EDE
Power On Cycles : 1209 Times
Power On Hours : 246 Hours
Unsafe Shutdowns : 641 Times
SSD#1

SMART Command Complete

```

Figure 2-8 Test result when executing SMART command

The Health status displays the remaining life of the SSD as a percentage, which is calculated from the Percentage Used value in the SMART log information. The SMART log information displays the following seven parameters.

- 1) Percentage Used: The percentage of the SSD's lifespan that has been consumed.
- 2) Temperature: The temperature of the SSD in degree Celsius.
- 3) Total Data: The total amount of data that has been read from the SSD, displayed in GB/TB units. Additionally, the raw data without decoding is displayed as a 32-digit hex number (128 bits). The unit size of raw data is 512,000 bytes.
- 4) Total Data: The total amount of data that has been written to the SSD, displayed in GB/TB units. Additionally, the raw data without decoding is displayed as a 32-digit hex number (128 bits). The unit size of raw data is 512,000 bytes.
- 5) Power On Cycles: The number of times the SSD has been powered on.
- 6) Power On Hours: The total amount of time in hours that the SSD has been powered on.
- 7) Unsafe Shutdowns: The number of times the SSD has experienced an unsafe shutdown.

## 2.5 Flush Command

To initiate a Flush command on the RAID0, select option '4' from the menu. The Flush command ensures that all modified data in the cache memory is written to Flash memory in the SSD.

```

+++ Flush Command selected +++
Flush Command Complete
--- NUMeIP for Gen4 RAID
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command
  
```

Figure 2-9 Test result when executing Flush command

Once the Flush operation is completed, the console will display the message “Flush Command Complete”.

## 2.6 Secure Erase Command

Select option '5' to initiate a Secure Erase command to the RAID0. Before the operation starts, a confirmation message is displayed on the console, requesting the user to confirm the command. The user must enter 'y' or 'Y' to continue with the operation or any other key to cancel.

```

◆ : User input
◆ : User output

+++ Secure Erase Command selected
Are you sure to erase all Data ?
Press 'y' to confirm : y
Secure Erase Command Complete
--- NUMeIP for Gen4 RAID0x2 m
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command
  
```

Figure 2-10 Test result when executing Secure Erase command

Once the Secure Erase command is completed, the console displays the message “Secure Erase Command Complete”.

## 2.7 Shutdown Command

Select '6' to send the Shutdown command to RAID0.

◆ : User input  
◆ : User output

```

--- NUMeIP for Gen4 RAID0x2 menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command

+++ Shutdown Command selected
Are you sure you want to shutdown the device now ?
Press 'y' to confirm : y
Shutdown command is complete
The device has turned off...
        
```

Confirmation message

Press 'y' to confirm

Last message before RAID0  
and all SSDs become inactive

Figure 2-11 Test result when executing Shutdown command

A confirmation message will be displayed on the console, and the user will need to enter 'y' or 'Y' to proceed with the operation. Press any other key to cancel the operation

Once the Shutdown operation is completed, "Shutdown command is complete" will be displayed as the final message. The console becomes inactive. To begin a new test operation, the user will need to power off and on the test system.

### 3 Revision History

Revision	Date	Description
1.3	26-Dec-23	Update performance and add Secure Erase Command
1.2	3-Aug-22	Support NVMe-IP for Gen4
1.1	20-Jul-21	Remove FPGA setup topic and update test result
1.0	8-May-20	Initial version release