



# NVMe IP for Gen4/NVMeG4-IP demo instruction

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# 1 Overview

This document provides instructions for running NVMe-IP for Gen4/NVMeG4-IP demo on FPGA development boards, which involves accessing an NVMe Gen4 SSD. The demo supports seven commands: Identify, Write, Read, SMART, Flush, Secure Erase, and Shutdown. User can control the test operation through the FPGA console.

To get started, user must first follow the “dg\_nvmeip4ip\_fpgasetup” document to set up the FPGA board. Once the board setup is completed, the welcome screen is displayed, revealing the IP name and IP version number upon the IP’s successful initialization.

When utilizing the NVMe-IP, 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.

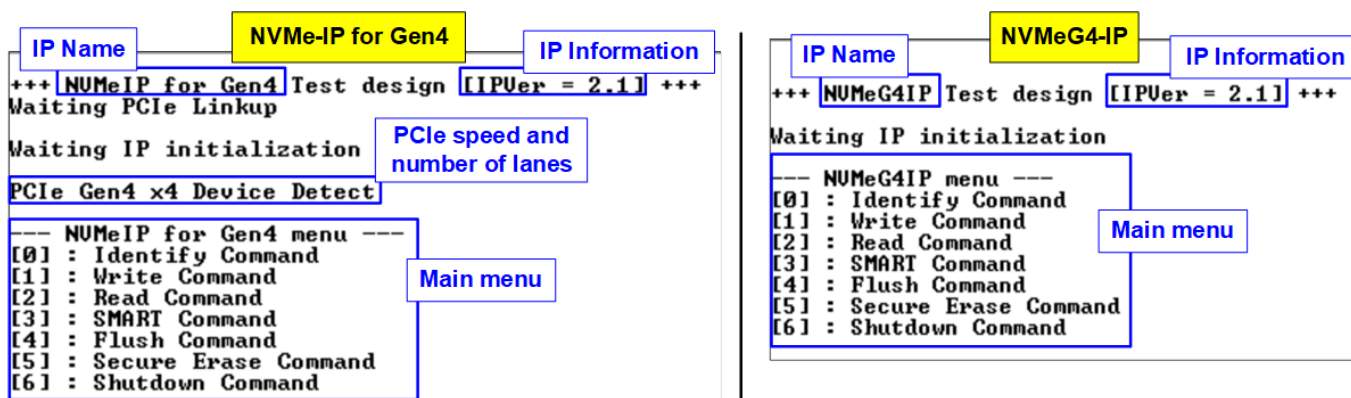


Figure 1-1 Main menu after finishing initialization

## 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 +++
Model Number      : Samsung SSD 990 PRO 1TB
SSD Capacity      = 1000[GB]
Data size per LBA = 512[Byte]
Secure Erase Command : Support

--- NVMG4IP menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command
  
```

Model name, SSD Capacity, LBA unit and Secure Erase Command Support (Output from Identify command)

Figure 2-1 Test result when running Identify command

- 1) SSD model number : This value is decoded from Identify controller data.
- 2) SSD capacity : This value is signal output from NVMe(G4)-IP.
- 3) Data size per LBA : This value is signal output from NVMe(G4)-IP. Two values are supported: 512 bytes and 4 KB.
- 4) Secure Erase Command Support: This value is decoded from the Identify controller data to show whether the SSD supports the Secure Erase command.

## 2.2 Write Command

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

```

+++ Write Command selected +++
Enter Start Address (512 Byte) : 0 - 0x74706DAF => 0
Enter Length (512 Byte) : 1 - 0x74706DB0 => 0x8000000
Selected Pattern [0]Inc32 [1]Dec32 [2]A11_0 [3]A11_1 [4]LFSR=> 4
 6.938 [GB]
13.904 [GB]
20.872 [GB]
27.803 [GB]
34.767 [GB]
41.702 [GB]
48.656 [GB]
55.596 [GB]
62.564 [GB]
Total = 68.719 [GB] , Time = 9887[ms] , Transfer speed = 6950[MB/s]
--- NUMeG4IP menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command
  
```

Figure 2-2 Input and test result when running Write command (IP using 1MB buffer)

The user needs to input three parameters as follows.

- 1) Start Address: Specifies the start address to write the SSD 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. When the LBA unit of SSD is 4 KB, this input must align 8.
- 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. When the LBA unit of SSD is 4 KB, this input must align 8.
- 3) Test pattern: Used to select the test data pattern for writing to the SSD. The user can choose from five patterns, i.e., 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: 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*

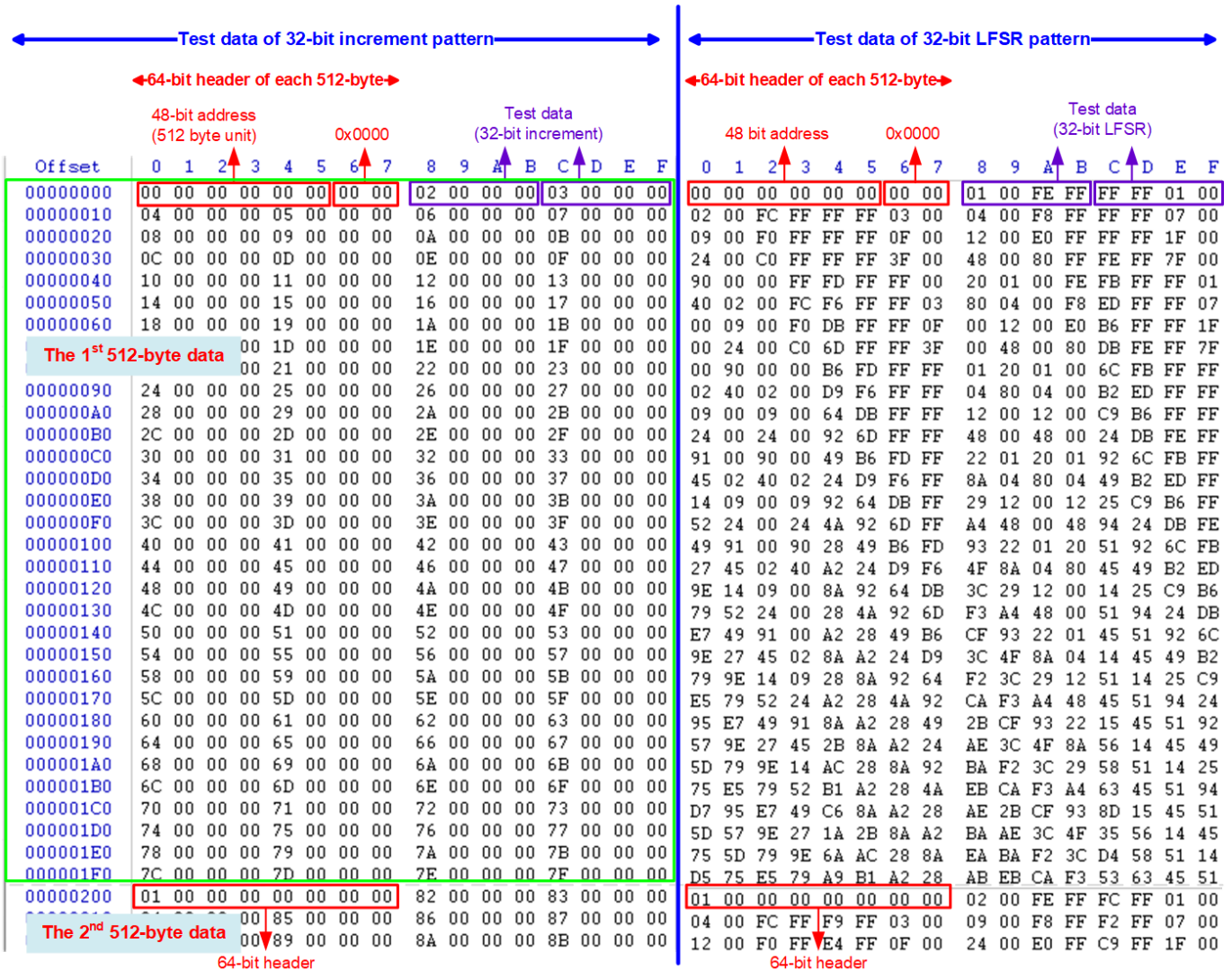


Figure 2-3 Example Test data of the 1st and 2nd 512 byte by using increment/LFSR pattern

Test data in SSD is divided into 512-byte unit. For incremental, decremental, and LFSR pattern, each 512-byte data has a unique 64-bit header that consists of a 48-bit address (in 512-byte units) and a 16-bit zero value. The data following the 64-bit header is the test pattern selected by the user.

The left window of Figure 2-3 shows an example when using 32-bit incremental pattern while the right window shows an example when using a 32-bit LFSR pattern. The unique header is not included when running all-0 or all-1 pattern.

When user runs the Write or Read command with a 4KB LBA SSD, a message is displayed on the console to show the input limitation, which must be aligned to 8, as shown in Figure 2-4. If the input is not aligned to 8, the console displays “Invalid input”, and the operation is cancelled.

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

```

LBA alignment error
Recommended message when LBA unit = 4 KB
+++ Write Command selected +++
Please input [Start Address] and [Length] in unit of 8
Enter Start Address (512 Byte) : 0 - 0x74706DAF => 0
Enter Length (512 Byte) : 1 - 0x74706DB0 => 7
Invalid input
--- NVMG4IP
[0] : Identif
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command
    
```

When LBA unit = 4 KB and length is not aligned to 8, error message is displayed.

Figure 2-4 Error message when the input is unaligned for SSD with 4KB LBA unit

```

Error input
Out of range address
+++ Write Command selected +++
Enter Start Address (512 Byte) : 0 - 0x74706DAF => 0xFFFFFFFF
Invalid input

Out of range Length
+++ Write Command selected +++
Enter Start Address (512 Byte) : 0 - 0x74706DAF => 0
Enter Length (512 Byte) : 1 - 0x74706DB0 => 0xFFFFFFFF
Invalid input

Invalid pattern
+++ Write Command selected +++
Enter Start Address (512 Byte) : 0 - 0x74706DAF => 0
Enter Length (512 Byte) : 1 - 0x74706DB0 => 0x4000000
Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR=> 5
Invalid input
    
```

Figure 2-5 Error message from the invalid input

## 2.3 Read Command

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

```

+++ Read Command selected +++
Enter Start Address (512 Byte)      : 0 - 0x74706DAF => 0
Enter Length (512 Byte)           : 1 - 0x74706DB0 => 0x80000000
Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR=> 4
  7.522 [GB]
 15.048 [GB]
 22.574 [GB]
 30.099 [GB]
 37.625 [GB]
 45.151 [GB]
 52.676 [GB]
 60.202 [GB]
 67.727 [GB]
Total =      68.719 [GB] , Time = 9131[ms] , Transfer speed = 7525[MB/s]
--- NUMeG4IP 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 running Read Command

The user needs to input three parameters as follows.

- 1) Start Address: Specifies the start address to read the SSD 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. When the LBA unit of SSD is 4 KB, this input must align 8.
- 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. When the LBA unit of SSD is 4 KB, this input must align 8.
- 3) Test pattern: Select test data pattern for reading and verifying data from the SSD. 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 SSD. 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.

If any of the inputs are invalid or 8-byte unalignment (for 4KB LBA SSDs), the console displays the message “Invalid input” and cancels the operation.

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 finished. 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.

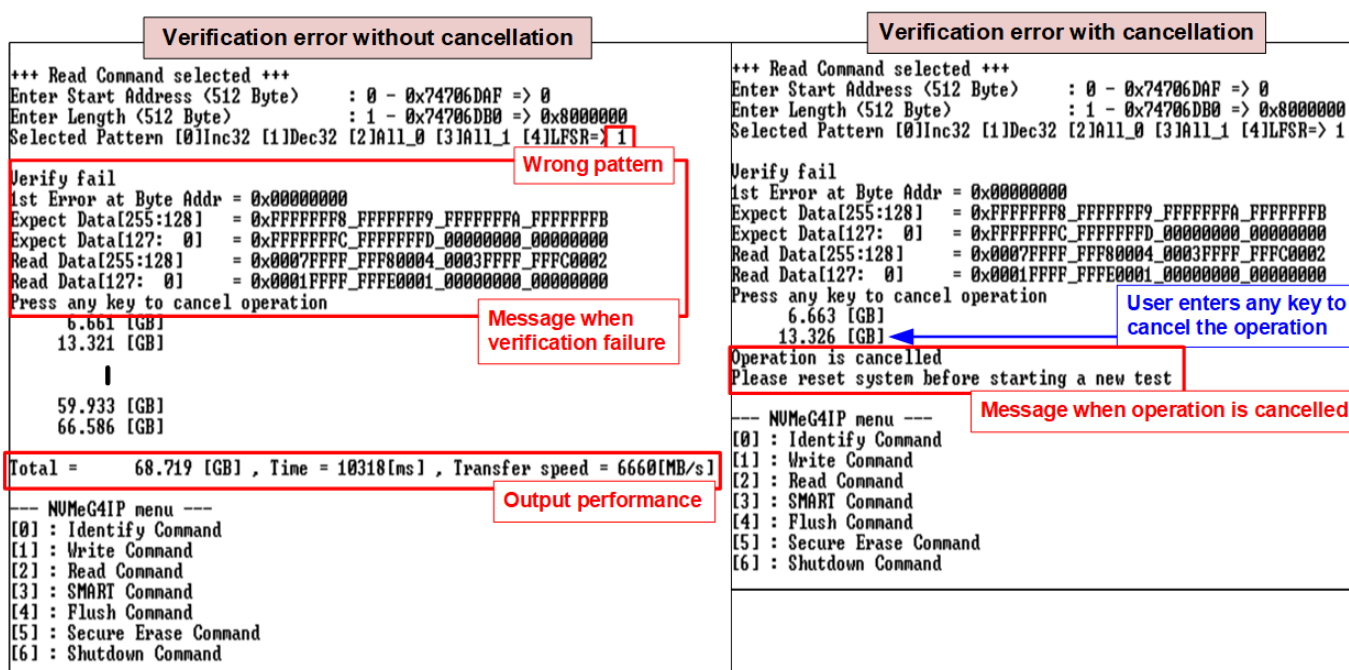


Figure 2-7 Data verification is failed



The user should note that the IP achieves the best performances when using 1 MB buffer in High-Speed mode. However, the performance apparently decreases when a 256 KB buffer is applied in Small-Buffer mode, especially in Read commands as shown in Figure 2-8.

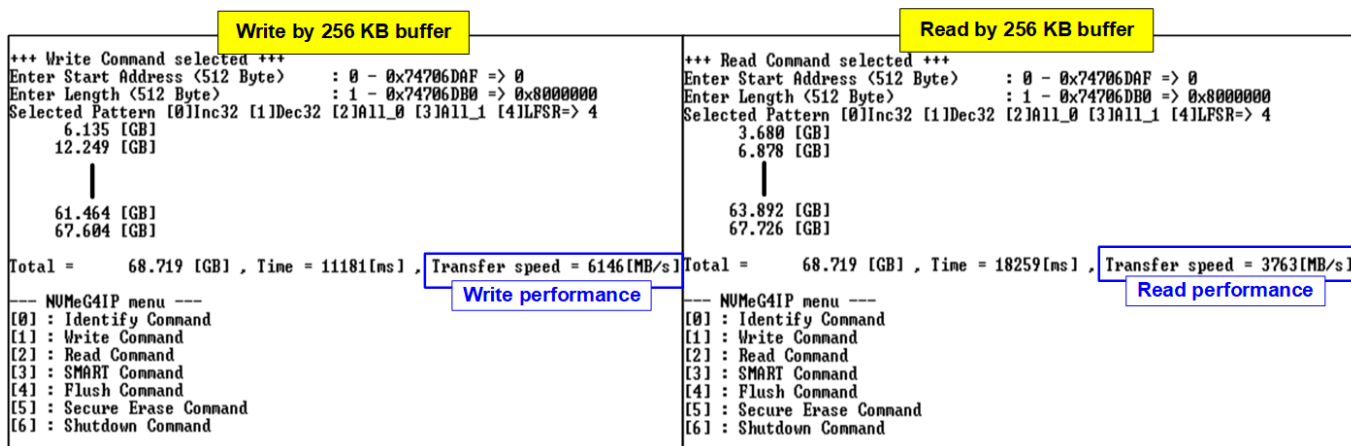


Figure 2-8 Test results when running Write-Read command by 256KB buffer

## 2.4 SMART Command

Select '3' to send a SMART command to the NVMe SSD. After the operation is completed, the console will display the SMART/Health Information output (see Figure 2-9). This information includes both the Health status and SMART log information.

```

+++ SMART Command selected +++
<< Health Status >>
Remaining Life : 91%

<< SMART Log Information >>
Percentage Used : 9%
Temperature : 31 Degree Celsius
Total Data Read : 106162 GB
Total Data Read <Raw data> : 0x00000000_00000000_00000000_0C5BAFAD
Total Data Written : 58540 GB
Total Data Written <Raw data> : 0x00000000_00000000_00000000_06D0888D
Power On Cycles : 328 Times
Power On Hours : 37 Hours
Unsafe Shutdowns : 142 Times

SMART Command Complete

--- NUMeG4IP menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command

```

Data output decoded from SMART command

Figure 2-9 Test result when running 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 Read: 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 Written: 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 NVMe SSD, 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
--- NUMeG4IP menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command
  
```

Figure 2-10 Test result when running 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 NVMe SSD. 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.

```

+++ Secure Erase Command selected +++
Are you sure to erase all Data ?
Press 'y' to confirm : y
Secure Erase Command Complete
--- NUMeG4IP menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Secure Erase Command
[6] : Shutdown Command
  
```

Figure 2-11 Test result when running 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 Shutdown command to NVMe SSD.

```

--- NUMeG4IP 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 the IP and SSD are inactive

Figure 2-12 Shutdown Command with confirmation

The confirmation message is 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
1.07	15-Dec-23	Add Secure Erase command
1.06	13-Jul-23	Update all performance
1.05	3-Aug-22	Update read performance by 1 Mbyte buffer
1.04	14-Sep-21	Support NVMe-IP for Gen4
1.03	20-Jul-21	Update SMART info and test performance
1.02	21-Dec-20	Remove FPGA setup from the document
1.01	20-Apr-20	Remove power adapter cable from AB18
1.00	29-Jan-20	Initial version release