



NVMe-IP DDR Demo Instruction

Rev1.2 29-Jun-23

1	Overview	2
2	Test Menu.....	3
2.1	Identify Command.....	3
2.2	Write Command.....	4
2.3	Read Command.....	11
2.4	SMART Command.....	16
2.5	Flush Command	17
2.6	Shutdown Command	17
3	Revision History	18

NVMe-IP DDR Demo Instruction

Rev1.2 29-Jun-23

1 Overview

This document describes the instruction to run NVMe-IP with DDR demo on FPGA development board. The demo is designed to test Write or Read command with one NVMe SSD as sustain rate. The user can set DDR size usage for transferring the data as sustain rate to check the minimum memory size requirement to run the SSD. Also, the other commands that are supported by NVMe-IP can be run in the demo - Identify, SMART, Flush, and Shutdown command. User controls test operation via FGPA console.

After user finishes FPGA board setup following “dg_nvmeip_fpgasetup” document, main menu is displayed and then user can set the input to the console for selecting the test operation.

```

+++ NvMeIP DDR Test design [IPVer = 4.3] +++
Waiting PCIe Linkup
Waiting IP initialization
PCIe Gen3 x4 Device Detect
--- Main menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Shutdown Command
  
```

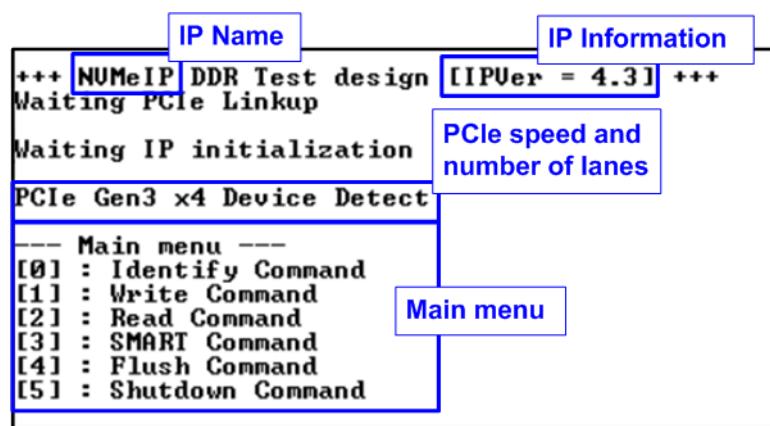


Figure 1-1 NVMe-IP with DDR main menu

On welcome screen, IP name and IP version number are displayed. The PCIe speed and number of PCIe lanes are displayed in the next message. Finally, the test menu is displayed on the console.

2 Test Menu

2.1 Identify Command

Select '0' to send Identify command to NVMe SSD.

```

+++ Identify Command selected +++
Model Number      : Samsung SSD 970 PRO 512GB
SSD Capacity     = 512[GB]
Data size per LBA = 512[Byte]

--- Main menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Shutdown Command

```

Model name, SSD Capacity, and LBA unit
(Output from Identify command)

Figure 2-1 Test result when running Identify command

After finishing the operation, the SSD information output from Identify command is displayed. The console shows three values.

- 1) SSD model number: This value is decoded from Identify controller data.
- 2) SSD capacity: This value is signal output from NVMe-IP.
- 3) Data size per LBA: This value is signal output from NVMe-IP. Two values are supported – 512-byte and 4-Kbyte.

2.2 Write Command

Select '1' to send Write command to NVMe SSD.

```

+++ Write Command selected +++
Enter Start Address (512 Byte)      : 0 - 0x3B9E1230 => 0
Enter Length (512 Byte)            : 0x80 - 0x3B9E12B0 => 0x3b9e12b0
Selected Pattern [0]Inc32 [1]Dec32 [2]A11_0 [3]A11_1 [4]LFSR => 4
Sustain rate = (NMT/DMT)x4000 MB/s
Enter Numerator ratio (NMT)       : 1 - 15 => 8
Enter Denominator ratio (DMT)    : 8 - 15 => 14
Sustain rate = 2285MB/s
Selected buffer size : 0 (64 [KB]) - 15 (2 [GB]) => 15
Buffer size = 2 [GB]
  2.286 [GB]
  4.572 [GB]
  6.859 [GB]
  |
505.292 [GB]
507.578 [GB]
509.864 [GB]
Total = 512.110 [GB] , Time = 223[s] , Transfer speed = 2286[MB/s]
Max buffer usage = 8.526 [MB]
--- Main menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Shutdown Command

```

Figure 2-2 Test result when running Write command

User inputs six parameters as follows.

- 1) Start Address: Input start address to write SSD as 512-byte unit. The input is decimal unit when user enters only digit number. User can add "0x" to be prefix for hexadecimal unit. When LBA unit of SSD is 4 Kbyte, this input must be aligned to 8.
- 2) Transfer Length: Input total transfer size as 512-byte unit. The input is decimal unit when user enters only digit number. User can add "0x" to be prefix for hexadecimal unit. When LBA unit of SSD is 4 Kbyte, this input must be aligned to 8.
- 3) Test pattern: Select test data pattern for writing to SSD. There are five patterns, i.e., 32-bit incremental, 32-bit decremental, all 0, all 1, and 32-bit LFSR counter.
- 4) Numerator ratio (NMT): Input numerator of transfer rate ratio. Valid value is 1 to 15.
- 5) Denominator ratio (DMT): Input denominator of transfer rate ratio. Valid value is NMT input to 15. The equation to set the transfer rate is as follows.

$$\text{Transfer rate (MB/s)} = (\text{NMT/DMT}) \times 4000 \text{ (250 MHz} \times \text{128-bit)}$$

Note: 4000 is the test data performance in the hardware which uses 250 MHz for transferring 128-bit data. Therefore, the maximum rate is 250 MHz x 128-bit = 4000 MB/s.

Thus, when NMT=8 and DMT=14, the transfer rate is 8/14 x 4000 = 2285 MB/s.

- 6) Buffer size: Input buffer size to use in this transfer. Valid value is 0-15. The details to set the buffer size is shown as below.

Table 2-1 Buffer size setting

Set value	Buffer size
0	64 KB
1	128 KB
2	256 KB
3	512 KB
4	1 MB
5	2 MB
6	4 MB
7	8 MB
8	16 MB
9	32 MB
10	64 MB
11	128 MB
12	256 MB
13	512 MB
14	1 GB
15	2 GB

Note: KB-1024 bytes, MB-1024x1024 bytes, and GB-1024x1024x1024 bytes

When all inputs are valid, the operation begins. While writing data, current transfer size is displayed on the console every second to show the progress of the test. Finally, total size, total time usage, test speed, and maximum buffer usage are displayed on the console as test result.

As shown in Figure 2-2, writing data at 2285 MB/s with full disk size can be done without error when setting 2-GByte buffer size. However, the result shows the maximum buffer usage while running the test is about 8.526 MB. Thus, it is expected that the user can re-run the test by reducing the buffer size to 16 MB (Set value=8) and the test should be run successfully.

Typically, the buffer size usage is reduced when the transfer speed is reduced. Also, it depends on SSD characteristic. Most enterprise SSDs show more stable performance than the consumer SSDs.

Offset	Test data of 32-bit incremental pattern																Test data of 32-bit LFSR pattern															
	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
00000000	00	00	00	00	00	00	00	02	00	00	00	03	00	00	00	00	00	00	00	00	00	00	00	01	00	00	00	02	00	00	00	
00000010	04	00	00	00	05	00	00	06	00	00	00	07	00	00	00	04	00	00	00	09	00	00	00	12	00	00	00	24	00	00	00	
00000020	08	00	00	00	09	00	00	0A	00	00	00	0B	00	00	00	49	00	00	00	92	00	00	00	24	01	00	00	49	02	00	00	
00000030	0C	00	00	00	0D	00	00	0E	00	00	00	0F	00	00	00	92	04	00	00	24	09	00	00	49	12	00	00	92	24	00	00	
00000040	10	00	00	00	11	00	00	12	00	00	00	13	00	00	00	24	49	00	00	49	92	00	00	92	24	01	00	24	49	02	00	
00000050	14	00	00	00	15	00	00	16	00	00	00	17	00	00	00	49	92	04	00	92	24	09	00	24	49	12	00	49	92	24	00	
00000060	18	00	00	00	19	00	00	1A	00	00	00	1B	00	00	00	93	24	49	00	27	49	92	00	4F	92	24	01	9E	24	49	02	
The 1 st 512-byte data	00 1D 00 00 00 00 00							1E 00 00 00 1F 00 00 00							3C 49 92 04 79 92 24 09							F3 24 49 12 E7 49 92 24										
	00 21 00 00 00 00 00							22 00 00 00 23 00 00 00							CF 93 24 49 9E 27 49 92							3D 4F 92 24 7A 9E 24 49										
00000090	24	00	00	00	25	00	00	26	00	00	00	27	00	00	00	F5	3C	49	92	EB	79	92	24	D7	F3	24	49	AE	E7	49	92	
000000A0	28	00	00	00	29	00	00	2A	00	00	00	2B	00	00	00	5D	CF	93	24	BA	9E	27	49	75	3D	4F	92	EB	7A	9E	24	
000000B0	2C	00	00	00	2D	00	00	2E	00	00	00	2F	00	00	00	D7	F5	3C	49	AE	EB	79	92	C1	D7	F3	24	B8	AE	E7	49	
000000C0	30	00	00	00	31	00	00	32	00	00	00	33	00	00	00	70	5D	CF	93	E0	BA	9E	27	C1	75	3D	4F	83	EB	7A	9E	
000000D0	34	00	00	00	35	00	00	36	00	00	00	37	00	00	00	07	D7	F5	3C	0E	AE	EB	79	1D	5C	D7	F3	3B	B8	AE	E7	
000000E0	38	00	00	00	39	00	00	3A	00	00	00	3B	00	00	00	77	70	5D	CF	EE	E0	BA	9E	DC	C1	75	3D	B8	83	EB	7A	
000000F0	3C	00	00	00	3D	00	00	3E	00	00	00	3F	00	00	00	70	07	D7	F5	E0	0E	AE	EB	C1	1D	5C	D7	83	3B	B8	AE	
00000100	40	00	00	00	41	00	00	42	00	00	00	43	00	00	00	07	77	70	5D	0E	EE	E0	BA	1C	DC	C1	75	39	B8	83	EB	
00000110	44	00	00	00	45	00	00	46	00	00	00	47	00	00	00	73	70	07	D7	E6	E0	0E	AE	CD	C1	1D	5C	9A	83	3B	B8	
00000120	48	00	00	00	49	00	00	4A	00	00	00	4B	00	00	00	34	07	77	70	68	0E	EE	E0	D1	1C	DC	C1	A3	39	B8	83	
00000130	4C	00	00	00	4D	00	00	4E	00	00	00	4F	00	00	00	47	F3	70	07	8E	E6	E0	0E	1D	CD	C1	1D	3A	9A	83	3B	
00000140	50	00	00	00	51	00	00	52	00	00	00	53	00	00	00	74	34	07	77	E9	68	0E	EE	D3	D1	1C	DC	A6	A3	39	B8	
00000150	54	00	00	00	55	00	00	56	00	00	00	57	00	00	00	4C	47	73	70	98	8E	E6	E0	31	1D	CD	C1	63	3A	9A	83	
00000160	58	00	00	00	59	00	00	5A	00	00	00	5B	00	00	00	C6	74	34	07	8D	E9	68	0E	1B	D3	D1	1C	37	A6	A3	39	
00000170	5C	00	00	00	5D	00	00	5E	00	00	00	5F	00	00	00	6E	4C	47	73	DC	98	8E	E6	B8	31	1D	CD	70	63	3A	9A	
00000180	60	00	00	00	61	00	00	62	00	00	00	63	00	00	00	E1	C6	74	34	C3	8D	E9	68	86	1B	D3	D1	0D	37	A6	A3	
00000190	64	00	00	00	65	00	00	66	00	00	00	67	00	00	00	1A	6E	4C	47	34	DC	98	8E	68	B8	31	1D	D0	70	63	3A	
000001A0	68	00	00	00	69	00	00	6A	00	00	00	6B	00	00	00	A0	E1	C6	74	41	C3	8D	E9	83	86	1B	D3	06	0D	37	A6	
000001B0	6C	00	00	00	6D	00	00	6E	00	00	00	6F	00	00	00	0C	1A	6E	4C	18	34	DC	98	30	68	B8	31	60	D0	70	63	
000001C0	70	00	00	00	71	00	00	72	00	00	00	73	00	00	00	C0	A0	E1	C6	81	41	C3	8D	03	83	86	1B	07	06	0D	37	
000001D0	74	00	00	00	75	00	00	76	00	00	00	77	00	00	00	0F	0C	1A	6E	1F	18	34	DC	3F	30	68	B8	7F	60	D0	70	
000001E0	78	00	00	00	79	00	00	7A	00	00	00	7B	00	00	00	FF	C0	A0	E1	FF	81	41	C3	FE	03	83	86	FD	07	06	0D	
000001F0	7C	00	00	00	7D	00	00	7E	00	00	00	7F	00	00	00	FA	0F	0C	1A	F4	1F	18	34	E9	3F	30	68	D3	7F	60	D0	
00000200	01	00	00	00	00	00	00	82	00	00	00	83	00	00	00	01	00	00	00	00	00	00	00	02	00	00	00	04	00	00	00	
The 2 nd 512-byte data	00 85 00 00 00 00 00							86 00 00 00 87 00 00 00							09 00 00 00 12 00 00 00							24 00 00 00 49 00 00 00										
	00 89 00 00 00 00 00							8A 00 00 00 8B 00 00 00							92 00 00 00 24 01 00 00							49 02 00 00 92 04 00 00										

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

Test data in SSD is split into 512-byte unit. For incremental, decremental, and LFSR pattern, each 512-byte data has unique 64-bit header consisting of 48-bit address (in 512-byte unit) and 16-bit zero value. The data after 64-bit header is the test pattern which is selected by user.

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

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

```

LBA alignment error
Recommended message
when LBA unit = 4 Kbyte
+++ Write Command selected +++
Please input [Start Address] and [Length] in unit of 8
Enter Start Address (512 Byte) : 0 - 0x3B9E1230 => 8
Enter Length (512 Byte) : 0x80 - 0x3B9E12B0 => 7
Invalid input
--- Main menu
[0] : Identif
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : 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

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

Error input	
<pre>+++ Write Command selected +++ Enter Start Address (512 Byte) : 0 - 0x3B9E1230 => 0x3B9E1230 Invalid input</pre>	Out of range address
<pre>+++ Write Command selected +++ Enter Start Address (512 Byte) : 0 - 0x3B9E1230 => 0 Enter Length (512 Byte) : 0x80 - 0x3B9E12B0 => 0x40 Invalid input</pre>	Out of range length
<pre>+++ Write Command selected +++ Enter Start Address (512 Byte) : 0 - 0x3B9E1230 => 0 Enter Length (512 Byte) : 0x80 - 0x3B9E12B0 => 0x10000000 Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR => 5 Invalid input</pre>	Invalid pattern
<pre>+++ Write Command selected +++ Enter Start Address (512 Byte) : 0 - 0x3B9E1230 => 0 Enter Length (512 Byte) : 0x80 - 0x3B9E12B0 => 0x10000000 Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR => 4 Sustain rate = (NMT/DMT)x4000 MB/s Enter Numerator ratio (NMT) : 1 - 15 => 0 Invalid input</pre>	Out of range NMT
<pre>+++ Write Command selected +++ Enter Start Address (512 Byte) : 0 - 0x3B9E1230 => 0 Enter Length (512 Byte) : 0x80 - 0x3B9E12B0 => 0x10000000 Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR => 4 Sustain rate = (NMT/DMT)x4000 MB/s Enter Numerator ratio (NMT) : 1 - 15 => 1 Enter Denominator ratio (DMT) : 1 - 15 => 16 Invalid input</pre>	Out of range DMT
<pre>+++ Write Command selected +++ Enter Start Address (512 Byte) : 0 - 0x3B9E1230 => 0 Enter Length (512 Byte) : 0x80 - 0x3B9E12B0 => 0x10000000 Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR => 4 Sustain rate = (NMT/DMT)x4000 MB/s Enter Numerator ratio (NMT) : 1 - 15 => 8 Enter Denominator ratio (DMT) : 1 - 15 => 14 Sustain rate = 266MB/s Selected buffer size : 0 (64 [KB]) - 15 (2 [GB]) => 18 Invalid input</pre>	Out of range buffer size

Figure 2-5 Error message from the invalid input

When the write rate is too high until the SSD pauses data transmission for long time, the buffer in the test system will be overflow. Some SSDs has a cache that can support the very fast write speed. However, when the internal cache in the SSD is full, finally the SSD pauses data transmission from the host.

```

Buffer underflow from transfer rate
+++ Read Command selected +++
Enter Start Address (512 Byte)      : 0 - 0x3B9E1230 => 0
Enter Length (512 Byte)            : 0x80 - 0x3B9E12B0 => 0x3b9e12b0
Selected Pattern [0]Inc32 [1]Dec32 [2]A11_0 [3]A11_1 [4]LFSR => 4
Sustain rate = (NMT/DMT)x4000 MB/s
Enter Numerator ratio (NMT)       : 1 - 15 => 13
Enter Denominator ratio (DMT)    : 13 - 15 => 15
Sustain rate = 3466MB/s
Enter Ddr Read Threshold : 0 (64 [KB]) - 14 (1 [GB]) => 11
Read Threshold size = 128 [MB]
Buffer size must be more than Ddr Read Threshold
Selected buffer size : 12 (256 [MB]) - 15 (2 [GB]) => 15
Buffer size = 2 [GB]
3.328 [GB]
ERROR: Buffer UnderFlow
Please wait 2 sec for monitoring NUMe status
No NUMe error
Operation is cancelled
  
```

More than SSD read performance

Error message when buffer is underflow

Check that underflow error is not caused by NVMe-IP

Figure 2-6 Buffer overflow from too high transfer rate

Figure 2-6 shows error message when buffer is overflow when the write rate is higher than the SSD performance. The maximum buffer size is applied in this case. Therefore, the user should reduce the transfer rate and tune the value until the buffer is not overflow. As shown in Figure 2-2, this SSD can run correctly when the write speed is 2285 MB/s.

The next issue that can be caused the overflow problem is setting too low buffer size, as shown in Figure 2-7.

```

Buffer overflow from buffer size
+++ Write Command selected +++
Enter Start Address (512 Byte)      : 0 - 0x3B9E1230 => 0
Enter Length (512 Byte)            : 0x80 - 0x3B9E12B0 => 0x3b9e12b0
Selected Pattern [0]Inc32 [1]Dec32 [2]A11_0 [3]A11_1 [4]LFSR => 4
Sustain rate = (NMT/DMT)x4000 MB/s
Enter Numerator ratio (NMT)       : 1 - 15 => 8
Enter Denominator ratio (DMT)    : 8 - 15 => 14
Sustain rate = 2285MB/s
Selected buffer size : 0 (64 [KB]) - 15 (2 [GB]) => 6
Buffer size = 4 [MB]
2.286 [GB]
4.572 [GB]
|
301.803 [GB]
304.089 [GB]
ERROR: Buffer OverFlow
Please wait 2 sec for monitoring NUMe status
No NUMe error
Operation is cancelled
  
```

Buffer size is not enough

Buffer is overflow

Figure 2-7 Buffer overflow from too less buffer size

In Figure 2-2, this SSD can be written at 2285 MB/s with full disk size correctly by using 8.526 MB buffer size. In Figure 2-7, only 4 MB buffer size is set, so it is not enough for storing the write data while the SSD is busy. Finally, the buffer is overflow. Typically, the buffer usage is increased when the write rate is increased. Thus, the user needs to determine the target write performance and the buffer size requirement in the system.

Besides, if the NVMe-IP detects some errors while operating with the SSD, the data will be stopped. After that, the buffer will be overflow. Therefore, the test console shows 2-sec waiting time (Timeout value of NVMe-IP setting in HDL code of the reference design) after buffer overflow is found. This step is designed to confirm that the buffer overflow is not caused by NVMe-IP error. "No NVMe Error" is shown when there is no error from NVMe.

When error is found, the operation of previous command in NVMe SSD does not finish in a good sequence. It is recommended to power-off/on the adapter board and press "RESET" button to restart the system. For the next trial after buffer overflow, please set the lower transfer rate or larger buffer size to solve the problem before running the test.

2.3 Read Command

Select '2' to send Read command to NVMe SSD.

◆ : User input
◆ : User output

```

+++ Read Command selected +++
Enter Start Address (512 Byte)      : 0 - 0x3B9E1230 => 0 ①
Enter Length (512 Byte)            : 0x80 - 0x3B9E12B0 => 0x3b9e12b0 ②
Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR => 4 ③
Sustain rate = (NMT/DMT)x4000 MB/s
Enter Numerator ratio (NMT)       : 1 - 15 => 9 ④
Enter Denominator ratio (DMT)    : 9 - 15 => 11 ⑤
Sustain rate = 3272MB/s ④
Enter Ddr Read Threshold : 0 (64 [KB]) - 14 (1 [GB]) => 11 ⑥
Read Threshold size = 128 [MB] ⑥
Buffer size must be more than Ddr Read Threshold
Selected buffer size : 12 (256 [MB]) - 15 (2 [GB]) => 15 ⑦
Buffer size = 2 [GB] ⑦
3.142 [GB]
6.416 [GB]
9.690 [GB]
|
504.018 [GB]
507.292 [GB]
510.565 [GB]
Total = 512.110 [GB] , Time = 156[s] , Transfer speed = 3272[MB/s]

--- Main menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Shutdown Command
    
```

Figure 2-8 Test result when running Read command

User inputs seven parameters as follows.

- 1) Start Address: Input start address to read SSD as 512-byte unit. The input is decimal unit when user enters only digit number. User can add "0x" to be prefix for hexadecimal unit. When LBA unit of SSD is 4 Kbyte, this input must be aligned to 8.
- 2) Transfer Length: Input total transfer size as 512-byte unit. The input is decimal unit when user enters only digit number. User can add "0x" to be prefix for hexadecimal unit. When LBA unit of SSD is 4 Kbyte, this input must be aligned to 8.
- 3) Test pattern: Select test data pattern to verify data from SSD. Test pattern must be matched with the pattern using in Write Command menu. There are five patterns, i.e., 32-bit incremental, 32-bit decremental, all-0, all-1, and 32-bit LFSR counter
- 4) Numerator ratio (NMT): Input numerator of transfer rate ratio. Valid value is 1 to 15.
- 5) Denominator ratio (DMT): Input denominator of transfer rate ratio. Valid value is NMT input to 15. The equation to set the transfer rate is as follows.

$$\text{Transfer rate (MB/s)} = (\text{NMT/DMT}) \times 4000 \text{ (250 MHz} \times \text{128-bit)}$$

Note: 4000 is the test data performance in the hardware which uses 250 MHz for transferring 128-bit data. Therefore, the maximum rate is 250 MHz x 128-bit = 4000 MB/s.

Thus, when NMT=9 and DMT=11, the transfer rate is $9/11 \times 4000 = 3272$ MB/s.

- 6) Ddr Read Threshold: The minimum data size is stored in DDR before starting reading data from DDR to verify at sustain rate. Valid value is 0 – 15. The mapped table from the set value to buffer size is shown Table 2-1.
- 7) Buffer size: Input buffer size to use in this transfer. Valid value is 0-15. The mapped table from the set value to buffer size is shown Table 2-1. This value must be more than Ddr Read Threshold.

Similar to Write command menu, test system reads data from SSD when all inputs are valid. While reading data, current transfer size is displayed on the console every second to show the progress of transferring. Total size, total time usage, and test speed are displayed after finishing the operation.

“Invalid input” is displayed when some inputs are invalid or unaligned to 8 (when connecting to 4-KB LBA SSD).

Figure 2-9 shows error message when data verification is failed. “Verify fail” is displayed with the information of the 1st failure data, i.e., the error byte address, the expected value, and the read value.

User can press any key(s) to cancel read operation. Otherwise, the operation is still run until finishing Read command. After that, the output performance is displayed on the console.

When cancelling the operation, the read command still runs as the background process and may not finish in a good sequence. It is recommended to power-off/on FPGA board and adapter board (if connected).

Verification error without cancellation

```

+++ Read Command selected +++
Enter Start Address (512 Byte)      : 0 - 0x3B9E1230 => 0
Enter Length (512 Byte)            : 0x80 - 0x3B9E12B0 => 0x40000000
Selected Pattern [0]Inc32 [1]Dec32 [2]A11_0 [3]A11_1 [4]LFSR => 0
Sustain rate = (NMT/DMT)x4000 MB/s
Enter Numerator ratio (NMT)        : 1 - 15 => 9
Enter Denominator ratio (DMT)      : 9 - 15 => 11
Sustain rate = 3272MB/s
Enter Ddr Read Threshold : 0 (64 [KB]) - 14 (1 [GB]) => 11
Read Threshold size = 128 [MB]
Buffer size must be more than Ddr Read Threshold
Selected buffer size : 12 (256 [MB]) - 15 (2 [GB]) => 15
Buffer size = 2 [GB]

Verify fail
1st Error at Byte Addr = 0x00000000
Expect Data           = 0x000000003_00000002_00000000_00000000
Read Data             = 0x000000002_00000001_00000000_00000000
Press any key to cancel operation

 3.142 [GB]
 6.416 [GB]
 9.690 [GB]
 |
26.058 [GB]
29.332 [GB]
32.605 [GB]

Total = 34.359 [GB] , Time = 10535[ms] , Transfer speed = 3261[MB/s]

```

Wrong pattern

Message when verification is failed

Output performance

Verification error with cancellation

```

+++ Read Command selected +++
Enter Start Address (512 Byte)      : 0 - 0x3B9E1230 => 0
Enter Length (512 Byte)            : 0x80 - 0x3B9E12B0 => 0x40000000
Selected Pattern [0]Inc32 [1]Dec32 [2]A11_0 [3]A11_1 [4]LFSR => 0
Sustain rate = (NMT/DMT)x4000 MB/s
Enter Numerator ratio (NMT)        : 1 - 15 => 9
Enter Denominator ratio (DMT)      : 9 - 15 => 11
Sustain rate = 3272MB/s
Enter Ddr Read Threshold : 0 (64 [KB]) - 14 (1 [GB]) => 11
Read Threshold size = 128 [MB]
Buffer size must be more than Ddr Read Threshold
Selected buffer size : 12 (256 [MB]) - 15 (2 [GB]) => 15
Buffer size = 2 [GB]

Verify fail
1st Error at Byte Addr = 0x00000000
Expect Data           = 0x000000003_00000002_00000000_00000000
Read Data             = 0x000000002_00000001_00000000_00000000
Press any key to cancel operation
 3.142 [GB]
Operation is cancelled
Please reset system before starting a new test

```

User enters some keys to cancel the operation

Message when operation is cancelled

Figure 2-9 Data verification is failed

When the read rate is too high until the SSD cannot fill the new data to the buffer in time, the buffer in the test system will be underflow. The SSD may pause data transmission in Read command while transferring data for long time. Finally, the buffer is underflow when the pause time is long.

```

    Buffer underflow from transfer rate

    +++ Read Command selected +++
    Enter Start Address (512 Byte)      : 0 - 0x3B9E1230 => 0
    Enter Length (512 Byte)            : 0x80 - 0x3B9E12B0 => 0x3b9e12b0
    Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR => 4
    Sustain rate = <NMT/DMT>x4000 MB/s
    Enter Numerator ratio (NMT)        : 1 - 15 => 13
    Enter Denominator ratio (DMT)      : 13 - 15 => 15
    Sustain rate = 3466MB/s
    Enter Ddr Read Threshold : 0 (64 [KB]) - 14 (1 [GB]) => 14
    Read Threshold size = 128 [MB]
    Buffer size must be more than Ddr Read Threshold
    Selected buffer size : 12 (256 [MB]) - 15 (2 [GB]) => 15
    Buffer size = 2 [GB]
    3.328 [GB]

    ERROR: Buffer UnderFlow
    Please wait 2 sec for monitoring NUMe status
    No NUMe error
    Operation is cancelled
  
```

More than SSD read performance

Error message when buffer is underflow

Check that underflow error is not caused by NVMe-IP

Figure 2-10 Buffer underflow from too high transfer rate

Figure 2-10 shows error message when buffer is underflow when the read rate is higher than the SSD performance. The maximum buffer size is applied in this case. Therefore, the user should reduce the transfer rate and tune the value until the buffer is not underflow. As shown in Figure 2-8, this SSD can run correctly when the write speed is 3272 MB/s.

Similar to Write command, if the user sets too low buffer size, the underflow can be found, as shown in Figure 2-11.

```

    Buffer underflow from buffer size

    +++ Read Command selected +++
    Enter Start Address (512 Byte)      : 0 - 0x3B9E1230 => 0
    Enter Length (512 Byte)            : 0x80 - 0x3B9E12B0 => 0x3b9e12b0
    Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR => 4
    Sustain rate = <NMT/DMT>x4000 MB/s
    Enter Numerator ratio (NMT)        : 1 - 15 => 9
    Enter Denominator ratio (DMT)      : 9 - 15 => 11
    Sustain rate = 3272MB/s
    Enter Ddr Read Threshold : 0 (64 [KB]) - 14 (1 [GB]) => 14
    Read Threshold size = 128 [KB]
    Buffer size must be more than Ddr Read Threshold
    Selected buffer size : 2 (256 [KB]) - 15 (2 [GB]) => 2
    Buffer size = 256 [KB]
    3.142 [GB]

    ERROR: Buffer UnderFlow
    Please wait 2 sec for monitoring NUMe status
    No NUMe error
    Operation is cancelled
  
```

Buffer size is not enough

Figure 2-11 Buffer underflow from too less buffer size

If the NVMe-IP detects some errors while operating with the SSD, the data will be stopped. After that, the buffer will be underflow. Therefore, the test console shows 2-sec waiting time (Timeout value of NVMe-IP setting in HDL code of the reference design) after buffer underflow is found. This step is designed to confirm that the buffer underflow is not caused by NVMe-IP error. “No NVMe Error” is shown when there is no error from NVMe.

When error is found, the operation of previous command in NVMe SSD does not finish in good sequence. It is recommended to power-off/on the adapter board and press “RESET” button to restart the system. For the next trial after buffer underflow, please set the lower transfer rate or larger buffer size to solve the problem before running the test.

2.4 SMART Command

Select '3' to send SMART command to NVMe SSD.

```

+++ SMART Command selected +++
<< Health Status >>
Remaining Life : 97%

<< SMART Log Information >>
Percentage Used           : 3%
Temperature               : 30 Degree Celsius
Total Data Read           : 40797 GB
Total Data Read (Raw data) : 0x00000000_00000000_00000000_04BFC85B
Total Data Written        : 50853 GB
Total Data Written (Raw data) : 0x00000000_00000000_00000000_05EB7281
Power On Cycles           : 1411 Times
Power On Hours            : 102 Hours
Unsafe Shutdowns         : 735 Times

SMART Command Complete

--- Main menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Shutdown Command

```

Data output decoded
from SMART command

Figure 2-12 Test result when running SMART command

After finishing the operation, SMART/Health Information (output from SMART command) is displayed as shown in Figure 2-12. The console shows Health status and SMART log information. Health status shows the remaining life of the SSD in percent unit which is calculated from Percentage Used in the SMART log information.

The SMART log information shows seven parameters as follow.

- 1) Percentage used: Display SSD usage in percent unit.
- 2) Temperature in °C unit.
- 3) Total Data Read decoded as GB/TB unit. Also, raw data without decoding is displayed as 128-bit hexadecimal unit. The unit size of raw data is 512,000 bytes.
- 4) Total Data Written decoded as GB/TB unit. Also, raw data without decoding is displayed as 128-bit hexadecimal unit. The unit size of raw data is 512,000 bytes.
- 5) Power On Cycles: Display the number of power cycles.
- 6) Power On Hours: Display the period of time in hours to show how long the SSD has been powered on.
- 7) Unsafe Shutdowns: Display the number of unsafe shutdowns of SSD.

2.5 Flush Command

Select '4' to send Flush command to NVMe SSD.

```

+++ Flush Command selected +++
Flush Command Complete
--- Main menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : Shutdown Command
  
```

Message after finishing the operation

Figure 2-13 Test result when running Flush command

“Flush Command Complete” is displayed after finishing Flush operation.

2.6 Shutdown Command

Select '5' to send Shutdown command to NVMe SSD.

```

--- Main menu ---
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMART Command
[4] : Flush Command
[5] : 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...
  
```

◆ : User input
◆ : User output

Confirmation message

Press 'y' to confirm

Last message before NVMe-IP and SSD are inactive status

Figure 2-14 Test result when running Shutdown command

The confirmation message is displayed on the console. User enters 'y' or 'Y' to continue the operation or enters other keys to cancel the operation.

After finishing Shutdown operation, “Shutdown command is complete” is displayed on the console as the last message. Main menu is not displayed anymore. User needs to power off/on test system to start new test operation.

3 Revision History

Revision	Date	Description
1.2	4-Aug-22	Support buffer size setting
1.1	25-Mar-21	- Remove FPGA setup from the document - Add SMART, Flush, and Shutdown command
1.0	19-Apr-18	Initial version release