

# raNVMe-IP Demo Instruction

Rev1.4 29-Jun-23

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# 1 Overview

This document describes the instruction to run raNVMe-IP demo on FPGA development board for accessing one NVMe SSD. The demo is designed to run Identify, Write, Read, SMART, Flush, and Shutdown command. User controls test operation via FPGA console.

After user finishes FPGA board setup following "dg\_nvmeip\_fpgasetup" document, main menu is displayed and the user sets the input to the console for selecting test operation.

	ID Information	
	IP Information	
+++ raNUMeIP Test design [IPVer =	2.0] +++	_
Waiting PCIe Linkup		
Waiting IP initialization		
PCIe Gen3 x4 Device Detect		
raNUMeIP menu		
[0] : Identify Command		
[1] : Write Command		
[2] : Read Command		
[2] - CMODT Command Main menu		
LOJ • OHHNI GUMManu		
L4J : Flush Command		
15] : Shutdown Command		
Figure 1-1 raNVMe-IP 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.

DG

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# 2 Test Menu

#### 2.1 Identify Command

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

+++ Identify Command select Model Number : INTEL S SSD Capacity = 800[GB]	ed +++ SDPF21Q800GB
raNVMeIP menu [Ø] : Identify Command [1] : Write Command [2] : Read Command [3] : SMART Command [4] : Flush Command [5] : Shutdown Command	Model name and SSD Capacity (Output from Identify command)
iqure 2-1 Test result when run	ning Identify command

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

- 1) SSD model number: This value is decoded from Identify controller data.
- 2) SSD capacity: This value is signal output from raNVMe-IP.

Main menu [0] : Identify Command [1] : Write Command [2] : Read Command									
[3] : SMART Command [4] : Flush Command [5] : Shutdown Command	Error message when LBA un detected does not support								
+++ Identify Command selected +++									
Error Detect	Error Detect								
ErrorType = 0×00010000									
ErrorType[16]: LBA does not support PCIe Status = 0x0F2D TestPin = 0x000001F									
Figure 2-2 Error when LBA unit does not support									

When the SSD operates in LBA unit which is not equal to 512 bytes, the error message is displayed on the console, as shown in Figure 2-2. After that, the system stays inactive status and user needs to reset the system to restart the demo.



A : Llear input

### 2.2 Write Command

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

Sequential Write		Random Write	◆: User output
+++ Write Command selected +++ Please input [Start Address] and [Length] in unit of 8 Select Transfer Mode : [0] Sequential [1] Random => $0$ Enter Start Address (512 Byte) : $0 \times 0$ - $0 \times 5D26CEB8 => 0$ Enter Length (512 Byte) : $0 \times 8 - 0 \times 5D26CEB0 => 0 \times 4000000(3)$ Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR => 4	+++ Write Command selected Please input [Start Addres Select Transfer Mode Enter Start Address (512 B Enter Length (512 Byte) Selected Pattern [0]Inc32	++++ s] and [Length] in : [0] Sequ yte) : 0x0 - 0x : 0x8 - 0x [1]Dec32 [2]All_0 [	unit of 8 ential [1] Random =>[1] 5D26CEB8 => 0 5D26CEB0 => 0x4000000 3JAll_1 [4]LFSR => 4
In Progress Status 100% Iotal = 34.359 [GB], Time = 11904[ms] Iransfer speed = 2886 [MB/s], 704K [IOPS]	In Progress 100% Iotal = 34.359 [GB] , Tim Iransfer speed = 2886 [MB/	our e = 11904[ms] 's], 704K [IOPS]	tput performance
raNUMeIP menu [0] : Identify Command [1] : Write Command [2] : Read Command [3] : SMARI Command [4] : Flush Command [5] : Shutdown Command	raNUMeIP menu [0] : Identify Command [1] : Write Command [2] : Read Command [3] : SMARI Command [4] : Flush Command [5] : Shutdown Command		
Figure 2-3 Test result whe	en running Write c	ommand	

There are four input parameters for running Write command, described as follows.

 Transfer Mode: Select address mode of the transfer. There are two modes supported -Sequential and Random mode. The first address is assigned by Start Address input while the next address can be generated by using two equations. First is sequential mode which creates the next address by adding by 8 (4 Kbyte) to store data in contiguous area. Another is the random mode which creates the next address by LFSR equation. <u>Note</u>: The test data stored to the SSD in each address is similar for both Sequential mode

and Random mode. The different point is the order of the address that stores the data. Therefore, if the transfer length is less than full-disk capacity, the free area that is not accessed in Random mode depends on the start address value.

- 2) 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. This input must be aligned to 8 for 4-Kbyte alignment.
- 3) 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. This input must be aligned to 8 for 4-Kbyte alignment.
- 4) 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.

When all inputs are valid, the operation begins. While the command is operating, the progress of transfer in percentage unit is displayed on the console every second. Finally, total size, total time usage, and test speed are displayed on the console as a test result.

<u>Note</u>: Most SSD shows better write performance when using Sequential addressing, comparing to Random addressing.



•		-Te	st d	ata	of 3	2-bit	t inc	rem	ent p	atte	rn—					•		•				Test	dat	a of	32-1	bit LF	SR	pat	ern				-
	<b>4-6</b> 4	l-bit	hea	der o	of ea	ch 4	Kby	te->										<b>4-6</b> 4	-bit	hea	der o	of ea	ch 4	Kby	te-								
	48-bit address (512 byte unit) 0x0000					Test data (32-bit increment)						64-bit header (Same value for every pattern)							Test data (32-bit LFSR)														
Offset	0	1	2	3	4	5	6	7	8	9	A	в	С	D	E	F		0	1	2	3	4	5	6	7	8	9	A	в	С	D	Е	F
0000000000	00	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
0000000010	04	00	00	00	05	00	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
0000000020	08	00	00	00	09	00	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
0000000030	0C	00	00	00	0D	00	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
0000000040	10	00	00	00	11	00	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
0000000050	14	00	00	00	15	00	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
0000000060	18	00	00	00	19	00	00	00	14	00	00	00	1B	00	00	00		93	24	49	00	27	49	92	00	4F	92	24	01	9E	24	49	02
0000000070	10	00	00	00	1D	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
0000000080	20	00	00	00	21	00	00	00	22	00	00	00	23	00	00	00		CF	93	24	49	9E	27	49	92	3D	4F	92	24	74	9E	24	49
0000000090	24	00	00	00	25	00	00	00	26	00	00	00	27	00	00	00		F5	30	49	92	EB	79	92	24	D7	F3	24	49	AE	E7	49	92
UAUUUUUUUUU	28	00	00	00	29	00	00	00	2A	00	00	00	2B	00	00	UU		5D	CF	93	24	BA	9E	27	49	75	3D	4F	92	EB	7A	9E	24
0x0000 – 0x	0x0000 – 0x0FFF : The 1 <sup>st</sup> 4Kbyte data																																
0000000FC0	FO	03	00	00	F1	03	00	00	F2	03	00	00	F3	03	00	00		76	15	F4	90	EC	2A	E8	21	D8	55	DO	43	B1	AB	ΑO	87
0000000FD0	F4	03	00	00	F5	03	00	00	F6	03	00	00	F7	03	00	00		62	57	41	0F	C4	ΑE	82	1E	89	5D	05	ЗD	12	BB	0A	7A
0000000FE0	F8	03	00	00	F9	03	00	00	FA	03	00	00	FB	03	00	00		24	76	15	F4	48	EC	2Å	E8	91	D8	55	DO	23	B1	ΑB	AO
0000000FF0	FC	03	00	00	FD	03	00	00	FE	03	00	00	FF	03	00	00		47	62	57	41	8F	C4	ΑE	82	1F	89	5D	05	3F	12	BB	OA
0000001000	08	00	00	00	00	00	00	00	02	04	00	00	03	04	00	00	Ι	08	00	00	00	00	00	00	00	11	00	00	00	22	00	00	00
0000001010	04	04	00	00	05	04	00	00	06	04	00	00	07	04	00	00		44	00	00	00	89	00	00	00	12	01	00	00	24	02	00	00
0000001020	08	04	00	00	09	04	00	00	OA	04	00	00	0B	04	00	00		49	04	00	00	92	08	00	00	24	11	00	00	49	22	00	00
			64	-bit h	nead	er																											
0x1000 – 0	x1FF	F:	The	2 <sup>nd</sup>	4Kb	yte	data	1																									

#### Figure 2-4 Example Test data of the 1<sup>st</sup> and 2<sup>nd</sup> 4Kbyte data by using incremental/LFSR pattern

Test data in SSD is split into 4096-byte (4-Kbyte) unit. For incremental, decremental, and LFSR pattern, each 4-Kbyte data has a 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.

I

The left window of Figure 2-4 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.



Figure 2-5 shows the example error message when the input from the user is invalid which may be caused from out-of-range or not aligned to 8. "Invalid input" is displayed as the error message and the operation is cancelled before returning to the main menu.

	Error input		
+++ Write Command selected +++		J	Invalid input
Please input [Start Address] ar Select Transfer Mode Invalid input	nd [Length] : [Ø] S	in uni Sequent	it of 8 tial [1] Random => <mark>6</mark>
+++ Write Command selected +++ Please input [Start Address] ar Select Transfer Mode Enter Start Address (512 Byte) Invalid input	nd [Length] : [0] S : 0x0 -	in uni Seguent - <mark>Øx5D2</mark>	Out of range address tial [1] Random => 0 26CEA8 => ØxFFFFFFFF
+++ Write Command selected +++			Caution message
Please input [Start Address] ar	nd [Length]	in uni	it of 8
Select Transfer Mode	: [0] S	Geguent	tial [1] Random => 0
Enter Start Address (512 Byte)	: UxU -	- Øx5D2	26CEA8 => 0
Enter Length (S12 Byte)	- 9×9 -	- 9x5D2	
		A	Address or Length alignment error

Figure 2-5 Error message from the invalid input

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## 2.3 Read Command



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

There are four or five inputs parameters for running Read command, described as follows.
1) Transfer Mode: Select address mode of the transfer. There are two modes supported -Sequential and Random mode. The first address is assigned by Start Address input while the next address can be generated by using two equations. First is sequential mode which creates the next address by adding by 8 (4 Kbyte) to store data in contiguous area. Another is the random mode which creates the next address by LFSR equation.

<u>Note</u>: The test data stored to the SSD in each address is similar for both Sequential mode and Random mode. The different point is the sequence of the address that stores the data.

2) Enable Data Verification: Select to enable or disable data verification for verifying the data.

<u>Note</u>: When the user enables data verification with Random mode and transfer length is not full-disk capacity, start address of Read command must be the same as Write command and transfer length must be less than or equal to transfer length in Write command.

- 3) 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. This input must be aligned to 8 for 4-Kbyte alignment.
- 4) 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. This input must be aligned to 8 for 4-Kbyte alignment.
- 5) Test pattern: This input is available only when data verification is enabled. Select test data pattern for verifying to SSD. There are five patterns, i.e., 32-bit incremental, 32-bit decremental, all 0, all 1, and 32-bit LFSR counter.



Similar to Write command menu, the progress of transfer in percentage unit is displayed on the console every second. Finally, total size, total time usage, and test speed are displayed on the console as a test result.

<u>Note</u>: The read performance of most SSD when using Sequential addressing is better than Random addressing.

Figure 2-7 shows the error message when data verification is failed. "Verify fail" is displayed with the information of the 1<sup>st</sup> 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 +++ Please input [Start Address] and [Length] in unit of 8 Select Transfer Mode : [0] Sequential [1] Random => 0 Enable Data Verification : [0] Disable [1] Enable => 1 Enter Start Address (512 Byte) : 0x0 - 0x5D26CEA8 => 0 Enter Length (512 Byte) : 0x8 - 0x5D26CEB0 => 0x4000000 Selected Pattern [0]Inc32 [1]Dec32 [2]All\_0 [3]All\_1 [4]LFSR => 1 Enable data verification with wrong pattern In Progress Message when data verification is failed Verify fail Verity fall 1st Error at Byte Addr = 0x00000000 Expect Data[127: 0] = 0xFFFFFFC\_FFFFFFD\_000000000\_00000000 Read Data[127: 0] = 0x00000002\_00000001\_00000000\_00000000 Press any key to cancel operation 100% [Caution] The performance may be drop from the maximum due to firmware responses could not catch up with the IP Output performance Total = 34.359 [GB] , Time = 10609[ms] Transfer speed = 3238 [MB/s], 790K [IOPS] Verification error with cancellation +++ Read Command selected +++ Please input [Start Address] and [Length] in unit of 8 Select Transfer Mode : [0] Sequential [1] Random => 0 Enable Data Verification : [0] Disable [1] Enable => 1 Enter Start Address (512 Byte) : 0x0 - 0x5D26CEA8 => 0Enter Length (512 Byte) : 0x8 - 0x5D26CEB8 => 0x400000Selected Pattern [0]Inc32 [1]Dec32 [2]All\_0 [3]All\_1 [4]LFSR => 1  $0 \times 0 - 0 \times 5D26CEA8 => 0$  $0 \times 8 - 0 \times 5D26CEB0 => 0 \times 4000000$ In Progress Verify fail 1st Error at Byte Addr = 0x00000000 Expect Data[127: 0] = 0xFFFFFFC\_FFFFFFD\_00000000\_0000000 Read Data[127: 0] = 0x00000002\_00000001\_00000000\_00000000 Press any key to cancel operation User enters some keys 47% to cancel the operation Operation is cancelled Please reset system before starting a new test Message when operation is cancelled --- raNUMeIP menu ---[0] : Identify Command [1] : Write Command [2] : Read Command [3] : SMART Command [4] : Flush Command [5] : Shutdown Command Figure 2-7 Data verification is failed



In some conditions, CPU handles too much tasks until the speed to generate the command request is less than transfer performance of raNVMe-IP. Therefore, the test performance on the console is limited by CPU, not by raNVMe-IP and SSD. In this case, the caution message is displayed on the console, as shown in Figure 2-8.

```
+++ Read Command selected +++
Please input [Start Address] and [Length] in unit of 8
Select Transfer Mode : [0] Sequential [1] Random => 0
Enable Data Verification : [0] Disable [1] Enable => 1
Enter Start Address (512 Byte) : 0x0 - 0x5D26CEA8 => 0
Enter Length (512 Byte) : 0x8 - 0x5D26CEB0 => 0x4000000
Selected Pattern [0]Inc32 [1]Dec32 [2]All_0 [3]All_1 [4]LFSR => 1
In Progress
Verify fail
1st Error at Byte Addr = 0x000000002_00000000_0000000
Read Data[127: 0] = 0xFFFFFFC_FFFFFD_00000000_0000000
Press any key to cancel operation
100%
[Caution] The performance may be drop from the maximum
due to firmware responses could not catch up with the IP
Iotal = 34.359 [GB], Time = 10609[ms]
Transfer speed = 3238 [MB/s], 790K [IOPS]
--- raNUMeIP menu ----
[0] : Identify Command
[1] : Write Command
[2] : Read Command
[3] : SMARI Command
[5] : Shutdown Command
```

Figure 2-8 Caution message when the performance is dropped from the firmware responses



## 2.4 SMART Command

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

+++ SMART Command selected +++	Data output decoded							
<< Health Status >> Remaining Life : 100% << SMART Log Information >> Percentage Used Temperature Total Data Read Total Data Read (Raw data) Total Data Written	from SMART command : 0% : 30 Degree Celsius : 15334 GB : 0×00000000_00000000_00000000_01C8FA81 : 19677 GB							
Fotal Data Written (Raw data) Power On Cycles Power On Hours Unsafe Shutdowns	: 0x0000000_0000000_00000000_024A6748 : 119 Times : 11 Hours : 12 Times							
SMART Command Complete								
[0] : Identify Command [1] : Write Command [2] : Read Command [3] : SMART Command [4] : Flush Command [5] : Shutdown Command								

#### Figures 2-9 Test result when running SMART command

After finishing the operation, SMART/Health Information (output from SMART command) is be displayed as shown in Figures 2-9. 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 by 32 digits of hex number (128 bits). 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 by 32 digits of hex number (128 bits). 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.

Flu	sh	Command Complete	Message after
 ГØ 1	r	aNUMeIP menu Identify Command	finishing the operatio
[1] [2]	i	Write Command Read Command	
[3] [4]	ł	SMART Command Flush Command	
[5]	:	Shutdown Command	

Figure 2-10 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.

	<ul><li>♦ : User input</li><li>♦ : User output</li></ul>
raNUMeIP menu [Ø] : Identify Command [1] : Write Command [2] : Read Command [3] : SMART Command [4] : Flush Command [5] : Shutdown Command	Confirmation massage
+++ Shutdown Command selected + Are you sure you want to shutdo Press 'y' to confirm : y	++ wn the device now ? Press 'y' to confirm
Shutdown command is complete The device has turned off La IP	st message before the and SSD are inactive
Figure 2-11 Test result when runn	ing 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
1.4	7-Nov-22	Update raNVMe-IP version and performance
1.3	16-Jun-22	Update SMART info and test performance
1.2	12-Jan-21	Correct IOPs value
1.1	22-Dec-20	Update test result by new SSD model
1.0	11-Aug-20	Initial version release