

## Enmotus Endurance Document

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### Summary:

This paper documents the methods used to measure the Endurance of Enmotus' FuzeDrive SSD products and how this relates to real world applications and Personal Computer Systems. Through this testing we demonstrate how our new Intelligent SSD Technology can match the best Endurance levels of SSD's available using the JEDEC219 specs. JEDEC219 employs test patterns under strict lab conditions and this matches the theoretical calculations from the NAND specifications. Our Enmotus 1.6TB NVMe SSD employs 128GB of SLC and measured JEDEC219 endurance of 3.6PBW and our 900GB NVMe SSD with 24GB of SLC has a measured JEDEC219 endurance of 750TBW. (Although these seem like relatively high numbers, one should reflect that Intel's Optane Enterprise Devices, the P905 and P4800X have endurance levels as high as 17PBW due to their proprietary cell technology.) We will also lay out a case for the simplification of Client Classification of Endurance into Gold, Silver and Bronze Levels to make it easier for the customers to quickly understand their best choice of SSD Endurance for their applications and usage scenarios.

### Test System:

The following workstation was employed for use in the Endurance Testing due to its robust architecture and industrial strength bandwidth:

#### Lenovo P920

Processor Type	2 x Intel® Xeon® Gold 6254 (3.10GHz, 16 cores, 24.75MB Cache)
Processor Base Frequency	2694 MHz
Number of Physical Cores	36*
Number of Logical Cores	72*
Number of Threads per Core	2
BIOS Manufacturer	LENOVO
BIOS Name	S055613
BIOS Version	LENOVO - 1210
SMBIOS Version	S05KT33A
Memory Type	DDR3
Memory Speed	2666 MHz
Memory Size	96GB
Graphics Accelerator	NVIDIA Quadro K620
Graphics Driver Version	10.18.13.5330
Graphics Memory	2GB

## Software:

Windows 10 Pro (Workstation) OS (Updated to Version 2004)

Enmotus .103 Driver

Diskpart (from Windows 10)

Enmotus Proprietary MiDrive.exe Software

Phison Proprietary Software Tool

VDbench (for running the JEDEC219 Test Files)

Virtium (for competitive drive comparison data)

CrystalDiskInfo (used for taking read and write counter measurements at regular intervals)

## Methodology:

To ensure a known good starting point we used the following procedure to test the drive.

After physically installing the drive. We performed the following steps before each test run

- 1) Updated the driver to the Microsoft Inbox driver.
- 2) Used diskpart to clean the drive
- 3) Securely erased the drive using a Proprietary Phison Software Tool
- 4) Installed the Enmotus .103 driver
- 5) Disabled promotions using the midrive utility
- 6) Initialized the drive using disk manager.

Endurance tests were conducted using VDbench and the following JEDEC input parameters.

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```
data_errors=10
sd=sd1,lun=\\.\PhysicalDrive1,align=4k,threads=50
wd=wd1,sd=sd1,rdpct=0,seek=100,xfersize=(512,4,1k,1,1.5k,1,2k,1,2.5k,1,3k,1,3.5k,1,4K,67,8k,10,16k,7,32k,3,64k,3),range=(1,5),skew=100
rd=SSD_Sustain,wd=wd*,iorate=max,elapsed=24h,interval=60
```

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Chart #1: JEDEC219 Random Testing Script

Enmotus places the SLC portion of the drive at the beginning, starting at LBA=0. The range of the test of SLC should be 0-x% where x is the percent of the drive configured as SLC. (900 GB drive ~2.6%; 1.6Tb drive is ~9.5%). QLC tests also used 2.6% or 9.5% of the capacity respectively, starting at the 50% capacity point.

Logging was recorded in five-minute intervals using Crystal Disk Info and a Proprietary Enmotus (Dumpstat) tool to measure QLC and SLC endurance.

Tests were run until a 3% change in the life remaining/used values as reported by SMART. This allows the tester to identify beginning and end of one complete percent change with +/- 5-minute accuracy over runs of several hours. (This is as prescribed in the JEDEC219 Specification which notes that since these tests can be arduously long, that an estimate based upon a percentage of the drive being tested is adequate for measuring a drives total endurance.)

Although the JEDEC219 Specification allows for estimation, Enmotus suggest that because SMART counters do not always accurately reflect the true drive life (it underestimates it), to fully test to determine true life expectancy, a drive should be written to until the Available Spares start to decrement. This test can run for a thousand hours or more.

### Theoretical Calculation:

FuzeDrive	P200-900/24		P/E Cycles	Endurance	
SLC	25.78	GB <sup>1</sup>	30,000	773,094	GB
QLC	874.26	GB	600	525,557	GB
				1,297,651	GB
				1,297	TB
				1.29	PB

FuzeDrive	P200-1600/128		P/E Cycles	Endurance	
SLC	137.44	GB	30,000	4,123,169	GB
QLC	1462.73	GB	600	877,665	GB
				5,000,804	GB
				4,883	TB
				5.0	PB

WAF = 1

<sup>1</sup> Unformatted. 1 GB = 1 Billion Bytes.

## Practical Measurement:

SLC JEDEC Endurance test			QLC JEDEC Endurance test		
	GB Written	Life Used Percent (SLC)		GB Written	Life Used Percent (QLC)
Test Start GB	89,681	10%	Test Start GB	8,678	2%
Test End GB	109,084	13%	Test End GB	9,741	3%
Total GB Written	19,403	3%	Total GB Written	1,063	1%
GB Written per 1%	6,468		GB Written per 1%	1,063	
SLC TBW for 900 GB	647		QLC TBW for 900 GB	106	
SLC Calculated TBW for 1.6Tb drive	3,449		QLC Calculated TBW for 1.6Tb drive	195	
SLC Best Case Sequential (128k) test			QLC Best Case Sequential (128k) test		
	GB Written	Life Used Percent (SLC)		GB Written	Life Used Percent (QLC)
Test Start GB	158,347	20%	Test Start GB	184,582	31%
Test End GB	169,495	21%	Test End GB	185,558	32%
Total GB Written	11,148	1%	Total GB Written	976	1%
GB Written per 1%	11,148		GB Written per 1%	488	
SLC TBW for 900 GB	1,115		QLC TBW for 900 GB	488	
SLC Calculated TBW for 1.6Tb drive	5,946		QLC Calculated TBW for 1.6Tb drive	893	
Total Endurance					
SLC +QLC JEDEC endurance 900 GB	753	TBW			
SLC +QLC JEDEC endurance 1.6 TB	3,644	TBW			
SLC +QLC Best Case endurance 900 GB	1,603	TBW			
SLC +QLC Best Case endurance 1.6 TB	6,839	TBW			




See Appendix A/B for raw data JEDEC219 data (before/after) for the SLC Portion of the 900GB

## How to relate the results to the real world: Gold, Silver, Bronze:

Due to the multiple methods of displaying and revealing Solid State Drive Endurance such as Terabytes Written (TBW), Drive Writes per Day (DWPD) and Mean Time between Failure (MTBF) as well as the numerous ways of measuring these: JEDEC219, JEDEC218, Sequential Writes, Client Endurance, Enterprise Endurance etc...it has become too confusing (almost on purpose) for a simple or even well-educated technical person to decipher whether the SSD they are purchasing has the endurance that is right for their application. Enmotus has brought a new simple methodology using JEDEC219 for a consumer to be able to decide what the right endurance level is when they purchase a new SSD. By normalizing the measurements to three simple levels, Gold Endurance, Silver Endurance and Bronze Endurance, the consumer can quickly see on the packaging and product briefs whether the SSD product is the correct fit for their application.

### How these levels match to Applications:

- **Gold Endurance**
  - Built to withstand the most punishing video editing and heavy-duty 3D Rendering Tasks/High Performance Computing Tasks
  - Long Term Write Reliability and Performance
  - Important when there is only one M.2 SSD in a Notebook
- **Silver Endurance**
  - Built for gaming and professional PC usage as a Boot Drive
  - Long Term Client Read and Write Performance
- **Bronze Endurance**
  - Built mainly as a data drive, not recommended as the sole M.2 for Boot Drives

FUZE DRIVE		The World's Smartest SSD		
SSD Endurance Levels				
<b>ENDURANCE</b> (terabytes written/GB)	> 1 TBW per GB	0.5 TBW to 1TBW per GB	Less than 0.5 TBW per GB	

### Methodology and Table:

The method used to derive these three levels is derived from the JEDEC219 Client SSD Standard that is the most often used and accepted tests for SSD today. By normalizing the units of the test with the capacity of the drives, the unit of Terabyte Written per Gigabyte of Capacity can be used to separate the three levels of Endurance:

- Gold is greater than 1TBW/GB
- Silver is between 0.5 and 1 TBW/GB
- Bronze is less than 0.5TBW/GB

This method is easy to calculate and provides a guide to the consumer by distilling technical jargon and numbers to ease in choosing the appropriate SSD for the application.

Gold	Silver	Bronze
>1.0 TBW per GB	0.5-1.0 TBW per GB	< 0.5 TBW per GB
FuzeDrive SSD P200-900/128 Innodisk 3SE Samsung 970 Pro Mercury MSD128	FuzeDrive SSD P200-900/24	Sabrent Rocket Q Series Intel 660, 665, H10 Series Micron P1, P2 Series

*Table of SSD's classified by Manufacturer's Published Best Case Endurance*

## Appendix A: SLC JEDEC219 Data

### Beginning of test

Fast Tier		
Enmotus P200HEQ 23GiB		
	Reads	Writes
Host IOs	3	2,281,89,227
Host BLKs	18	3,479,216,946
Promote IOs	0	0
Promote BLKs	0	0
VMAP-Cnt IOs	114	2
VMAP-Cnt BLKs	5,070	4
Slow Tier		
Enmotus P200HEQ 814GiB:		
	Reads	Writes
Host IOs	0	0
Host BLKs	0	0
Promote IOs	0	0
Promote BLKs	0	0
Metadata IOs	15	0
Metadata BLKs	109	0
Host Total IOs by Size:		
Block Size	Reads	Writes
<=4K	2	177,146,107
<=8K	1	23,361,776
<=16K	0	16,354,291
<=32K	0	7,020,121
<=64K	0	7,023,537
<=128K	0	0
<=1M	0	0
>1M	0	0
SMART Data		
05	Percentage Used	10
07	Data Units Read	358,828
08	Data Units Written	188,073,020
09	Host Read Commands	7,523,509
0A	Host Write Commands	12,316,938,997
16	D3 Average Erase Count	63
18	D1 Average Erase Count	3,354
22	SSD Life Used Percent (SLC)	10

## Appendix B:SLC JEDEC219 Data

### End of test

Fast Tier		
Enmotus P200HEQ 23GiB:		
	Writes	Reads
Host IOs	3	2,824,712,727
Host BLKs	18	43,066,418,064
Promote IOs	0	0
Promote BLKs	0	0
VMAP-Cnt IOs	114	2
VMAP-Cnt BLKs	5070	4
Slow Tier		
Enmotus P200HEQ 814GiB:		
	Reads	Writes
Host IOs	0	0
Host BLKs	0	0
Promote IOs	0	0
Promote BLKs	0	0
Metadata IOs	15	0
Metadata BLKs	109	0
Host Total IOs by Size:		
Block Size	Reads	Writes
<=4K	2	177,146,107
<=8K	1	23,361,776
<=16K	0	16,354,291
<=32K	0	7,020,121
<=64K	0	7,023,537
<=128K	0	0
<=1M	0	0
>1M	0	0
SMART Data		
05	Percentage Used	15
07	Data Units Read	358,828
08	Data Units Written	228,763,296
09	Host Read Commands	7,523,509
0A	Host Write Commands	14,984,282,070
16	D3 Average Erase Count	93
18	D1 Average Erase Count	4,433
22	SSD Life Used Percent (SLC)	13