Samsung Solid State Drive
TurboWrite Technology

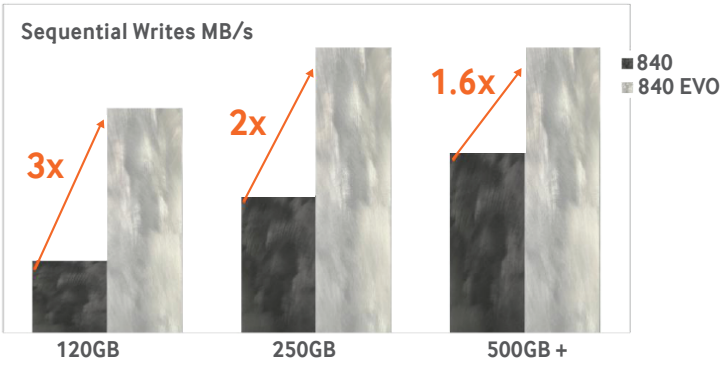
White Paper

Faster Sequential Write Performance with TurboWrite Technology

Accelerated sequential write speeds

To improve on the previous generation 840 Series SSD, Samsung developed an evolutionary TurboWrite technology for the 840 EVO. This new firmware technology, delivers much faster sequential write speeds, which are so crucial for large file transfers – more than tripling performance for the 120GB drive and more than doubling performance for the 250GB drive.

Performance Comparison		840			840 EVO		
		120GB	250GB	500GB	120GB	250GB	500GB/ 750GB/ 1TB
Sequential (MB/s)	Read	530	540	540	540		
	Write	130	250	330	410	520	520

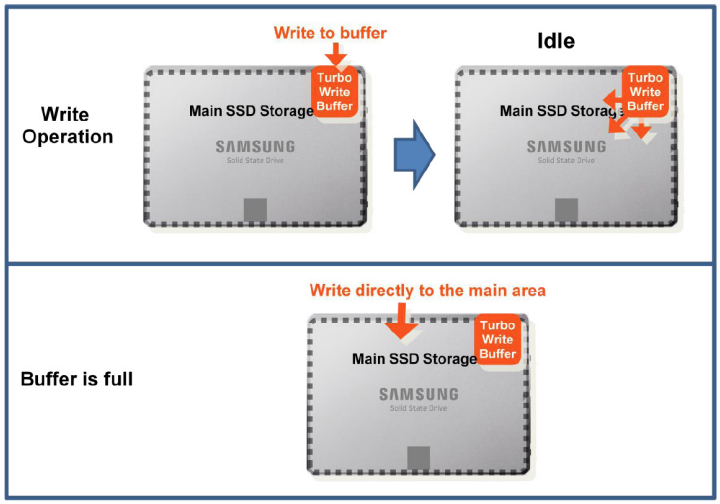


To achieve these remarkable improvements, the development team had to fundamentally re-think the way data is written to NAND Flash.

What is TurboWrite Technology?

As you recall, 3-bit MLC NAND write speeds are slower because the additional "bit(s)" require more signal processing and error correction during writing (programming). To overcome this, the 840 EVO simulates faster SLC NAND on a portion of the drive to achieve much higher performance.

The following figure shows how the TurboWrite Technology works.



[Figure. 1] TurboWrite Technology algorithm

TurboWrite Technology creates a high-performance write buffer area within the drive that simulates high-performance SLC. During write operations, data from the host system is first transferred/written to the high-performance buffer at accelerated speeds and then during the idle periods, the data is moved from the buffer to primary storage region. With this technology, the user experience is improved as they only "feel" the accelerated performance of the initial writes.

The buffer size is shown in the below table and it varies based on the capacity of the SSD. The minimum buffer size is 3GB, which through Samsung's extensive testing is considered to be large enough for all everyday performance scenarios. Note that the buffer size is defined in SLC terms, therefore the physical capacity will be 3x greater in 3-bit MLC capacity.

[Table.1] TurboWrite buffer size

SSD Capacity	120GB	250GB	500GB	750GB	1TB
Buffer Size (SLC-mode base)	3GB	3GB	6GB	9GB	12GB

Under consecutive write operations with no idle time, the buffer will eventually become full. At this point, the transfer will exit TurboWrite and write data directly to the main storage area of the drive at 3-bit MLC performance.

[Table.2] Sequential Write Performance by cases

SSD Capacity		120GB	250GB	500GB	750GB	1TB
Sequential (MB/s)	TurboWrite	410	520	520		
	Exit TurboWrite	140	270	420		

The TurboWrite buffer size also determines the maximum duration of TurboWrite, i.e. the longest period of contiunuous write operations at accelerated speeds. Below table shows the migration time(required idle time) to empty the whole buffer.

[Table.3] Required idle time to empty TurboWrite Buffer

SSD Capacity	120GB	250GB	500GB	750GB	1TB
Migration Time (sec)	28.2	18.5	32.5	44.9	55

One common question is where is the physical area for the TurboWrite buffer, since the over-provisioning area is not large enough to cover this buffer completely. To explain this, one must understand the IDEMA (International Disk Drive Equipment and Material Association) capacity definitions. IDEMA defines a calculation method to determine a drive's capacity and the corresponding number of LBAs (Logical Block Address) which is slightly different from the user accessible area. This is a common industry occurrence and you may have seen the capacity difference between what is stated on a drive label vs. user accessible area shown in the OS. The TurboWrite buffer then, is created from the excess capacity that comes from (a) the default overprovisioning area and (b) the "extra" area that results from IDEMA's specification.

LBA counts = 97,696,368 + (1,953,504 x (Capacity(GB)-50))

Capacity	OP(GB)	# of LBAs	User accessible area(GB)	Remained area(GB)	OP+Remained Area(GB)
120GB	8GB	234441648	111.8	8.2	16.2
250GB	6GB	488397168	232.9	17.1	23.1
500GB	12GB	976773168	465.8	34.2	46.2
750GB	18GB	1465149168	698.6	51.4	69.4
1TB	24GB	1953525168	931.5	68.5	92.5

"TurboWrite buffer (SLC-buffer) is in this area"

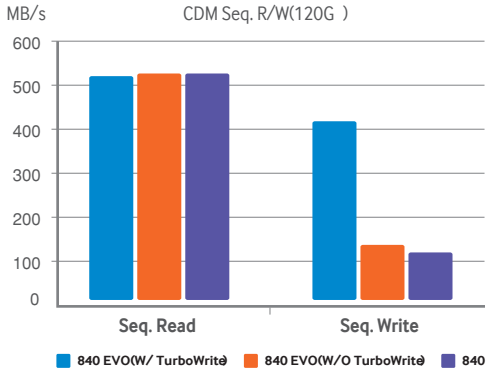
Benefit of TurboWrite Technology

TurboWrite delivers a better PC experience as you can enjoy much faster sequential write speeds. Though the buffer size has a limit, Samsung has carefully selected the optimal size to ensure that most everyday usage scenarios can experience accelerated writes. To test TurboWrite performance is in real life, Samsung analyzed SSD users' workloads and the result is shown below:

Workload	OP(GB)	# of LBAs
5GB and above	12.32	5.5
4GB	3.45	4.8
3GB	2.42	9.8
2GB	1.41	31.1
1GB	0.74	33
500M	0.41	10.6
300M	0.23	4.2
100M and below	0.05	0.9
Average	1.17	

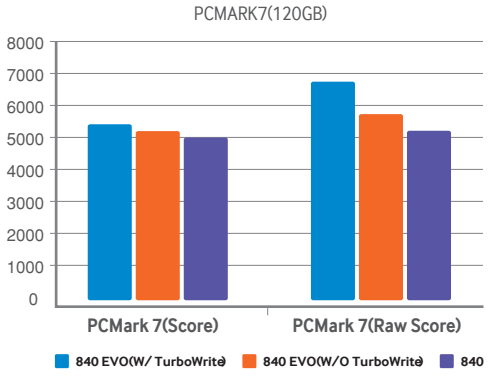
[Table.4] SSD user workload analysis

As seen above table, the averagePC user writes 1.17GB of data per hour and more than 90% users' average workload was under 3GB – the minimum size of the buffer (120/250GB). Therefore, the PC users will experience accelerated speeds for most workloads. The chart below shows the performance benefit of TurboWrite Technology. Sequential write performance improves significantly with TurboWrite. The performance was measured by CrystalDiskMark benchmark tool which is the most commonly used program.



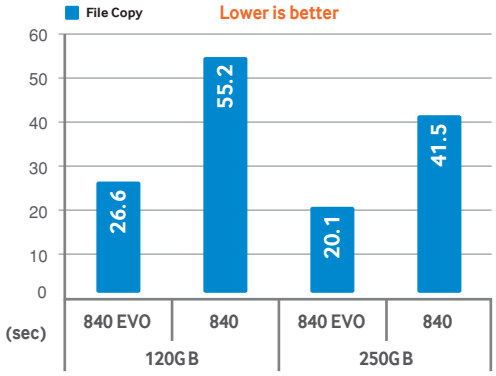
[Figure. 2] TurboWrite Performance benefit (CDM)

PCMark7 benchmark, which reflects real-life usage environments, shows a 7% system performance improvement and 15% SSD storage performance (raw score) with TurboWrite. This result implies that TurboWrite Technology has performance benefit not only for sequential write alone, but in various real-life use scenarios.

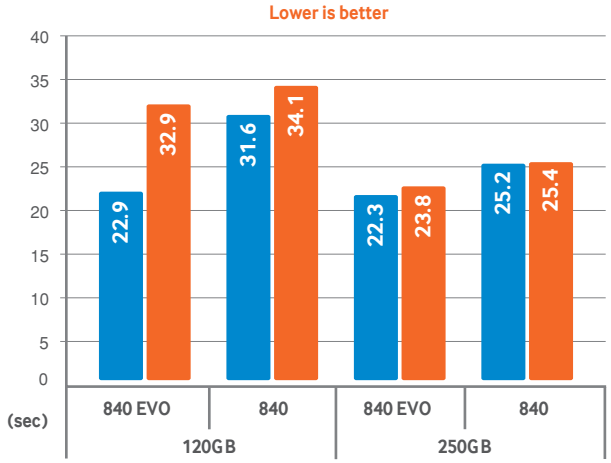


[Figure. 3] TurboWrite Performance benefit (PCMark7)

For example, when transferring large files or using photoshop, both scenarios which mostly consist of sequential writes, the 840 EVO(with TurboWrite) completed the tasks faster than 840 Series (without TurboWrite) - almost 52% less time when copying files and 27%(120GB) and 12%(250GB) when using photoshop.



[Figure.4] Benefit of TurboWrite Technology - File Copy



[Figure.4] Benefit of TurboWrite Technology – Using Photoshop

Closing Thoughts

Samsung is proud to introduce the evolutionary technology that allows the 840 EVO to surpass the traditional 3-bit MLC's performance limit. Samsung's new TurboWrite Technology delivers significantly faster sequential write performance and offers a significant upgrade over the previous 840 Series.

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