

QLC SSD: High Density, High Performance and Affordable Solution for Client PCs

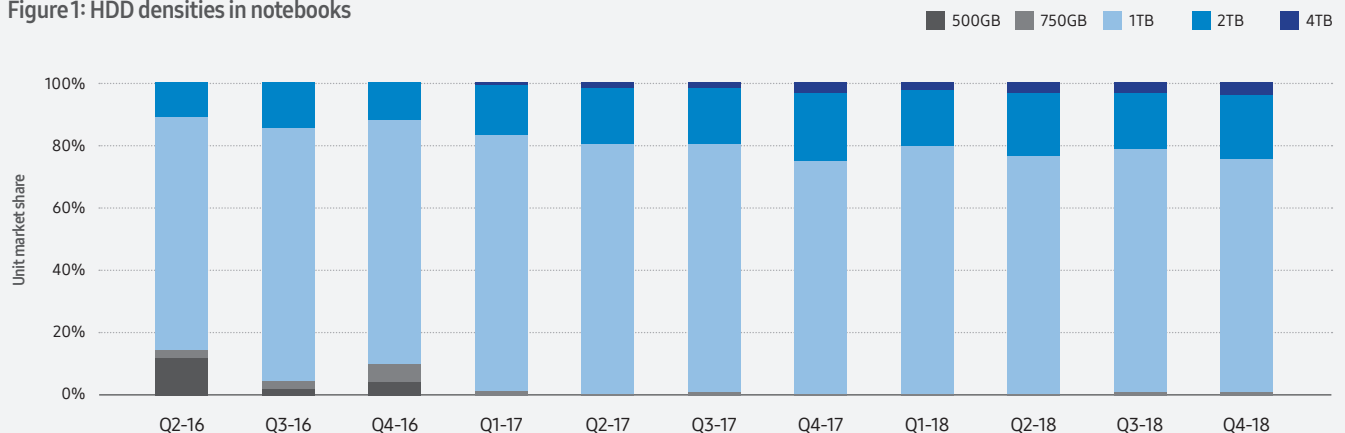
This white paper provides an overview of Samsung's first QLC (Quad-Level Cell, 4-bit MLC) NAND based Solid State Drive (SSD), the 860 QVO SSD. Samsung 860 QVO QLC SSD is based on Samsung's latest V-NAND technology which boasts outstanding performance standards, almost equivalent to those of the existing TLC (Triple-Level Cell, 3-bit MLC) based SSDs on the market. Samsung 860 QVO QLC SSD is expected to bring a new level of computing experiences to its end users.



Market Demand for Higher Capacity Storage

According to the market research in Q1 of 2018, the average HDD capacity for client PCs is approximately 1.2TB, and the usage rates of HDDs with capacities of 1TB or more has increased by over 80%. The PC market has been satisfying customers' storage capacity expectations with high-capacity HDDs. Meanwhile, SSD use has been expanding from ultra-slim notebooks to mainstream PCs thanks to its unique high-performance, low-power consumption, low failure rate, small form factor, and lightweight design. QLC SSDs can offer capacities of 1TB and higher at an affordable price to meet the PC market's high capacity storage needs.

Figure 1: HDD densities in notebooks



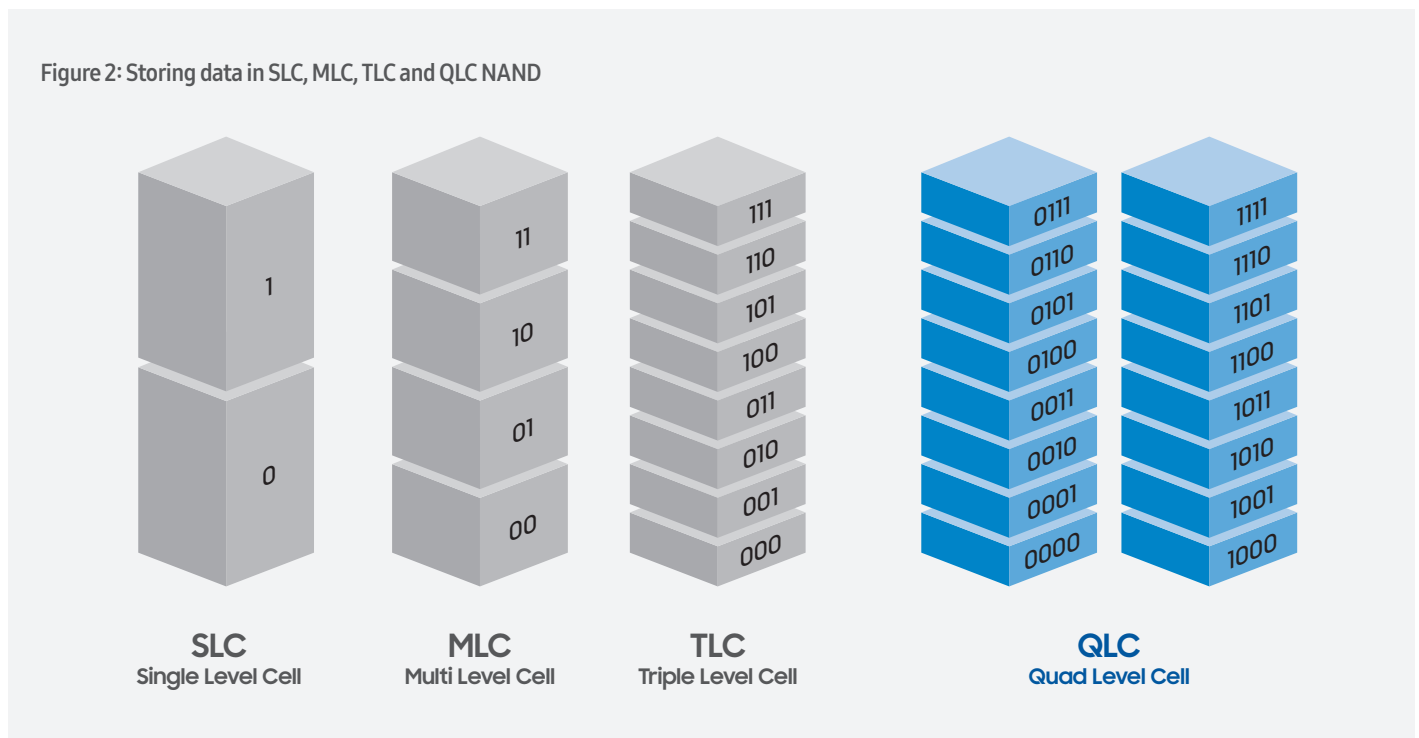
* Source: IHS Markit

What is QLC NAND?

QLC NAND stores four logical bits per physical cell, so this technology makes storage capacity denser and cheaper than TLC NAND which stores three logical bits per physical cell. Therefore, a QLC NAND can store 33% more data than TLC NAND within the same physical cell. Ideally, the QLC NAND should show a density increase of over 33% than TLC NAND.

How does QLC NAND store data?

QLC NAND holds 4-bits of information per NAND physical cell. This means the 16 voltage levels must be distinguishable in order to decipher the information held. (QLC NAND cells have a total of 16 possible states: 0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110, and 1111)



Samsung 860 QVO SSD: A Large Capacity SSD Solution

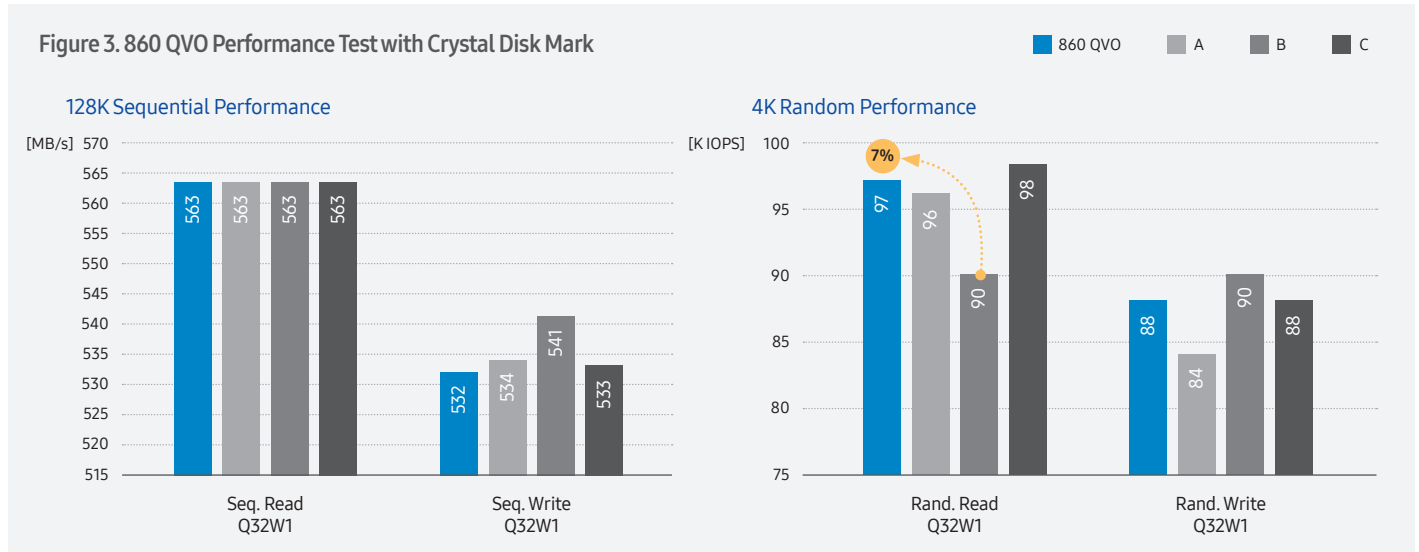
The 860 QVO SSD for client PCs is a SATA SSD based on QLC V-NAND, which provides high-performance, fast responsiveness, and high reliability. Consisting of 1TB, 2TB, and 4TB capacities, it has opened a new standard of TB (terabytes) for SSDs. With its 2.5-inch form factor and height of 7 mm, users can easily replace an HDD or an existing low-capacity SSD with this product. Model names and other product specifications are provided in the table below.

Table 1. Samsung 860 QVO QLC SSD products

	Host Interface	Form Factor	Capacity	Model Name
860 QVO	SATA3 6 Gbps	2.5-inch x 7mmT	1TB	MZ-76Q1T0
			2TB	MZ-76Q2T0
			4TB	MZ-76Q4T0

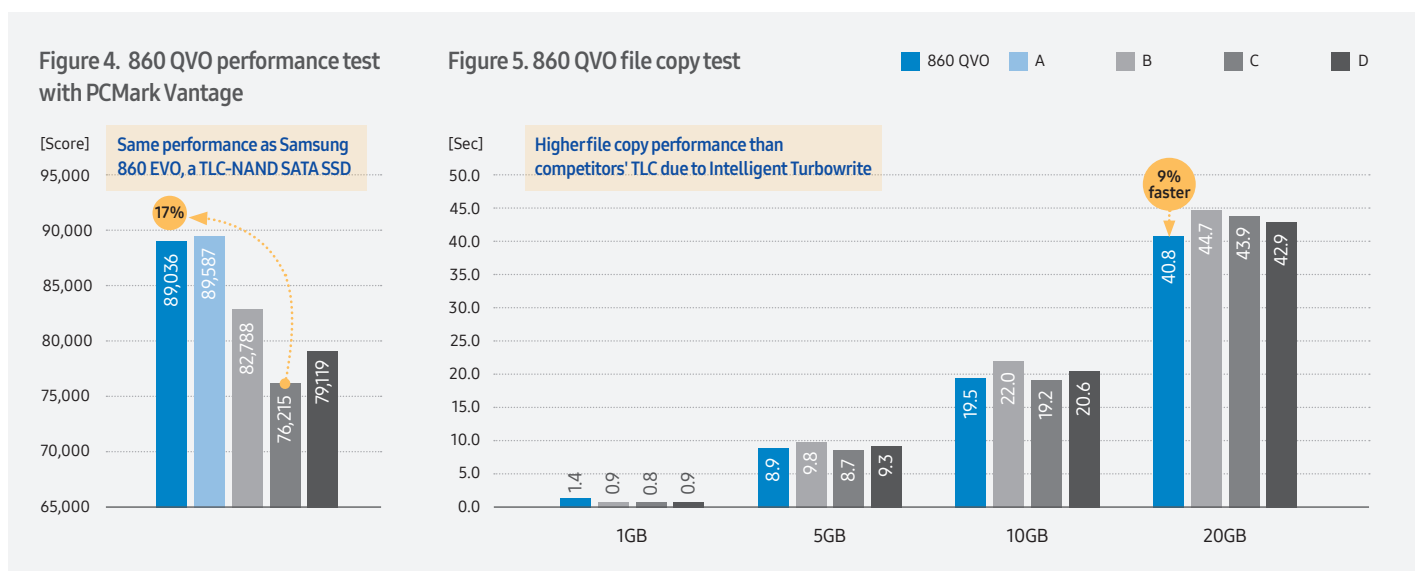
Performance of the Samsung 860 QVO SSD

The sequential read/write performance of storage is the basic performance measurement of an SSD. The performance results in Figure 3 below illustrate that the 860 QVO SSD delivers an equivalent performance to that of other brands' TLC-based SATA SSD. In addition, among the random quick response rate performances, the random read performance of the 860 QVO SSD surpasses one of the compared TLC products by 7%, demonstrating its high performance.



As shown in Figure 4 below, Samsung 860 QVO SSD demonstrates up to 17% higher performance than other brands' TLC-based SSDs in the PCMark Vantage test. The performance results were similar to Samsung's TLC based-SSD.

The below test results show that the 860 QVO SSD, which is designed with Samsung's V-NAND technology to provide optimized performance, is capable of providing excellent data-copying performance; a common operation in the user environment. According to the results of the four basic performance measurements, as well as the system environment of SSDs, the 860 QVO SSD's performance is equivalent to that of other brands' TLC SSDs. It provides its users with a high-capacity SSD product with a competitive price and high-performance levels.



Samsung's Intelligent TurboWrite Technology

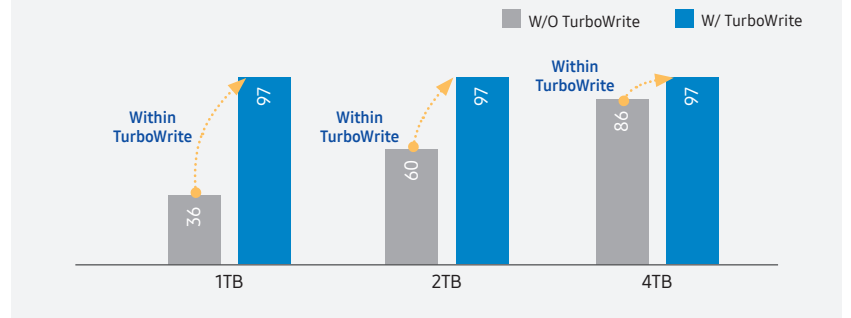
The 860 QVO SSD uses Intelligent TurboWrite to improve the user experience. SSDs are used in order to maintain high performance for long periods of time. To address this, Samsung used a variable SLC buffer. Intelligent TurboWrite technology allocates more SLC buffer to provide an optimal user experience, similar to that of the 860 EVO SSD.

TurboWrite affects not only sequential write but also random read performance due to QLC's characteristics (slower than TLC). The Iometer shows the same performance as Crystal Disk Mark—the simple synthetic benchmark test tool commonly used among users—within the TurboWrite region.

Table 2. TurboWrite buffer size

Capacity	Total Region	Default Region	Intelligent Region
1TB	42GB	6GB	36GB
2TB	78GB	6GB	72GB
4TB	78GB	6GB	72GB

Figure 6. Random read performance comparisons (in KIOPS)



Technologies to Improve Performance and Reliability

QLC NAND's endurance levels are inevitably lower than TLC's due to the control of its voltage level (16 level), which is much denser than that of TLC's (8 level) and results in faster cell wear-out. Despite being QLC-based, the 860 QVO SSD applies Samsung's proprietary V-NAND and controller technologies, such as Extreme ECC and State Shaping, to guarantee endurance and reliability levels similar to TLC SSD devices.

Table 3. Total Bytes Written (TBW) comparison - based on 1TB capacity

	Samsung 860 QVO	A	B	C	D
NAND Type	QLC	QLC	TLC	TLC	QLC
TBW	360TB	200TB	400TB	400TB	200TB

A. Extreme ECC Technology

By adopting the Extreme ECC technology, 860 QVO SSD improved error correction capabilities by 50% and enhanced reliability, making it equivalent to TLC SSDs. Maximizing the error correction capability requires an increase in data size for ECC (Error Correction Code) data processing. Samsung's unique SSD controller technology and multiple ECC data processing technologies are applied in the 860 QVO SSD to improve its error correction capabilities. In addition, both the power consumption and ECC operation time increase when errors are being corrected. These issues are improved by adopting an advanced algorithm that maintains stable power consumption in high-capacity SSDs.

B. V-NAND State Shaping Technology

The V-NAND State Shaping is a technology that reduces the occurrence of patterns which can affect the QLC V-NAND's reliability and increases NAND retention. In conjunction with Extreme ECC, it efficiently uses the NAND parity size to improve the reliability of QLC SSD.

C. Adaptive On-Chip AccuRead Technology™

Adaptive On-Chip AccuRead Technology is a data read control technology within QLC V-NAND that reduces error rates for boosted reliability. Within each NAND chip, it prevents data corruption by automatically reading scattered data with greater accuracy.

D. QLC TruPrecision Program™

Samsung's QLC TruPrecision Program boasts both robust reliability and superior performance. It programs data extremely quickly by first scanning data from QLC NAND at rapid speeds, and then reading it one more time to make vital adjustments. By making continuous adjustments, both the bit error rate and inter-cell interference are significantly lower while maintaining high programming speeds.

Key Takeaway

Samsung's 860 QVO SSD is designed to satisfy the client PC market that requires a high level of capacity, performance, and reliability. It provides higher capacities at lower prices while providing optimal performance in comparison with the current mainstream TLC NAND-based client SATA SSD. Despite a QLC NAND structure, Samsung's Intelligent TurboWrite and leading expertise in V-NAND and ECC technology enable the 860 QVO SSD to yield a higher, or equivalent, performance than other brands' TLC NAND-based SSDs. This satisfies the market's need to obtain high-capacity SSD storage devices at affordable prices.

SATA Interface-based SSDs are in high demand compared to NVMe SSDs as affordable high-capacity storage devices. Therefore, Samsung's 860 QVO SSD is expected to meet this demand and be a high-capacity storage device for laptop PCs, desktops, and workstations. One of the main benefits is that users can easily replace an existing HDD or low-capacity 2.5-inch SSD on a PC, opening a terabyte-SSD era for those demanding high-capacity storage.

Appendix

Test environments	
Motherboard	ASUS Z370A
CPU	i7-8700K
DRAM	8GB DDR4
OS	Windows10 RS3
Crystal Disk Mark	6.0
PCMark Vantage	Professional 64-bit Edition (1.2.0.0)

For more information about the Samsung SSD, visit samsung.com/ssd or samsungssd.com.

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