Solid State Drive for Client Applications

The laptop PC is evolving with thin and lightweight design, long battery life and high-performance processing capability. In particular, great efforts are being devoted to enhancing operability so as to realize a more responsive user experience on portable PCs from the human-interface viewpoint. In order to support from ultra-sleek clamshell laptop PCs to keyboard-detachable tablets, storage devices need to offer faster transfer rates, shorter access latency, a variety of small form factors, and greater efficiency (lower power consumption) as well as larger capacity.
Solid State Drive (SSD) with NAND flash memory is the most suitable storage device for integration on such laptop PC platforms. SSD provides very fast access speed in writing and reading as well as low power consumption. SSD is also thin, compact and very robust against the shock and vibration to which portable PCs are likely to experience during operation.
As the first company to develop NAND flash memory, Toshiba has been a leader in the SSD market with its high technologies.

Interfaces

As it is for Hard disk drive (HDD), the Serial AT Attachment (SATA) interface is also widely used in SSD for client applications such as laptop PCs and other industry equipment.
The SATA interface has the following features: Point-to-point connection, ATA command set, and 6 Gbit/s interface speed.
For some high-performance PC models, SSD with PCIe (PCI Express) interface has started to be used. The PCIe interface currently uses ATA command set over AHCI (Advanced Host Controller Interface) protocol. NVM Express (NVMe) optimized for data access to SSD may be used as a popular protocol in the future.

Form Factors

There are several form factors in SSD.
The 2.5-inch compatible with HDD is widely used. The size is 69.85 mm x 100.0 mm and the thickness is 9.5 mm and 7.0 mm.
Besides, there is also the 1.8-inch form factor that is smaller than the 2.5-inch and compatible with HDD. The size is 54.0 mm x 78.5 mm and the thickness is 5.0 mm.
Additionally, there is a smaller and lighter form factor for SSD called the mSATA™ (or mini-SATA) module (Figure 1) and its size is as small as 30.0 mm x 50.95 mm and the thickness is 4.85 mm.
A newly developed form factor in practical use is the M.2 type with various sizes. There are Type 22110, 2280, 2260, 2242 and 2230 in the M.2 type form factor for SSD (Figure 2).

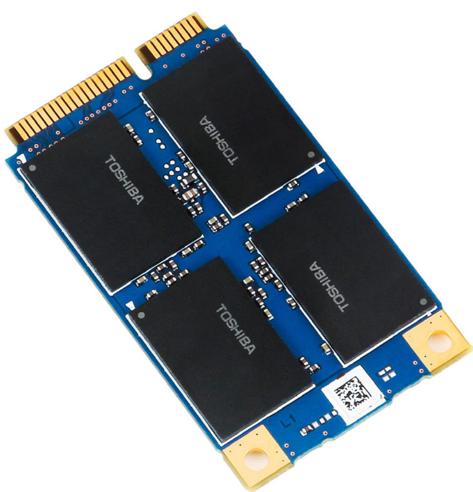

Figure 1: mSATA™ module

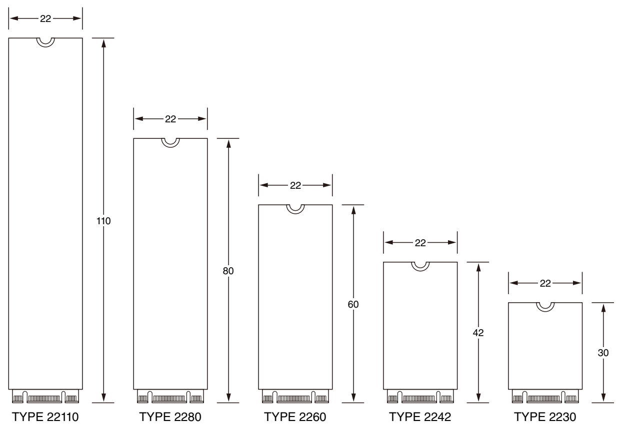

Figure 2: PCI Express M.2 Specification

Performance

SSD requires only electrical operation, and a read and write operation to access data through NAND flash memory although HDD requires the mechanical operation to access data.
Additionally, the multiple access to NAND flash memory is the most important feature, realizing, compared to HDD, very high speed in data transactions. The data transfer rate is more than 500 MB/s for recent client SSD with 19nm NAND flash memory.
The random access speed is about 80,000 Input Output Per Second (IOPS) for 4 KiB data transactions.
Turning to NAND write/read speed, Single Level Cell (SLC) storing 1 bit in a cell is the fastest NAND device, followed by Multi Level Cell (MLC) storing 2 bits in a cell. For client applications, MLC has been mostly used because MLC is more cost effective than SLC.
Recently Triple Level Cell (TLC) storing 3 bits in a cell has been introduced in the client SSD market.

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Error Detection and Correction Technology

The SSD controllers offer an error detection/correction function to improve data reliability.
As the NAND flash memory generation advances toward fine process, error detection and error correction code (ECC) technologies have become more important for SSD.
The ECC used for NAND flash memory is Hamming Code, Reed-Solomon Code, Bose-Chaudhuri-Hocquenghem Code (BCH), and Low Density Parity Check (LDPC). They are used in accordance with characteristics of NAND flash memory and usage of SSD products.
Hamming Code was often used in the early generations of NAND flash memory. Calculation of Hamming code is simple and can be implemented by software.
Reed-Solomon Code handles multiple bits as one symbol. Error correction, which is performed in units of symbols, is suitable for burst bit error correction.
BCH Code has flexibility for block length and error correction capability, and its power consumption is small compared with other technologies. BCH Code is the most popular ECC in today's SSD.
Error correction capability of LDPC is extremely high, however, its power consumption and processing time may be considered when it is applied.
In addition to the above, Toshiba has developed QSBC, the original error detection and correction technique, and utilized it for Toshiba's SSD products.

Power Failure Management (PFM)

If Power supply to SSD is lost unexpectedly during data write operation, the power failure might corrupt system information that manages data allocation in NAND flash memory, resulting in the loss of user data already stored in NAND flash memory. To prevent such a worst-case incident, Toshiba's client SSD has a mechanism to keep the data safe. This power failure protection for SSD is called Power Failure Management (PFM).

Encryption

Keeping data stored inside a portable PC system secure from theft is one of the key features. Nowadays, storage devices are often required to store personal data after encrypting it. A self-encrypting drive (SED) provides a mechanism to encrypt all user data with AES encryption hardware engine on the drive and thus protect user data [(1)]. All user data in NAND flash memory is encrypted with a randomly generated encryption key. Encryption key, passwords, and other critical security parameters stored are protected securely.
SED also provides the Cryptographic Erase function. Unlike a lengthy over-write operation or a block erase operation, the Cryptographic Erase function simply regenerates the encryption key, effectively invalidating all previously stored user data. This allows SED to quickly and securely sanitize the recorded data before reutilization or disposal of SSD.
Toshiba client SSD has lined up a model compatible with Trusted Computing Group (TCG) Opal. Some models also provide Toshiba's innovative "Wipe Technology"[(2)] function. Wipe technology can automatically execute the Cryptographic Erase when SSD is connected to an unauthorized host.

References

1) YAMAKAWA Teruji, et al., Implementation of Security Functions in Storage Devices, *TOSHIBA Review* 69, 1, 2014, PP.18-21.
2) Toshiba Wipe Technology: Better Data Security for the Digital Age White Paper, June 2014

* mSATA™ is a trademark of Serial ATA International Organization.
* Maximum read and write speed may vary depending on the host device, read and write conditions, and file size. For purposes of measuring read and write speed in this context, 1 megabyte or MB = 1,000,000 bytes.
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