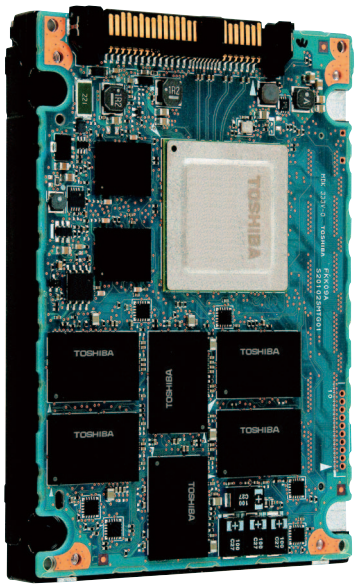
Technology of Enterprise Solid State Drive



Recently, large capacity and high-performance storages are highly required in the cloud computing and data center due to rapidly increasing amount of information and number of access. When many people heavily access to internet services such as social network service (SNS) or web search engine, they will always expect an instant response from the service. In the corporate on-premise network system and financial trading system, micro seconds range of the response time makes big difference to the business outcome. As an evolution of the enterprise server and storage system, more focus is placed on speed, response time and latency to support large number of SNS user accesses and time-critical business transactions. Then Solid State Drive (SSD) plays an important role for server system to make the transactions faster.

Enterprise class SSD is a storage device with NAND flash memories and required the design to store and retrieve data at very high speed under high duty operation conditions with reliable endurance performance.

It will be very beneficial for system managers to deploy SSD for boosting up computing process and storage access speed. By positioning between host processor and hard disk drive (HDD) storage pools as a large cache memory, SSD increases the system transaction speed.

SSD has also good points, in addition to higher performance, such as smaller footprint and lower power consumption.

Toshiba has matured leading edge technologies in the SSD as the first company developing NAND flash memory.

Interfaces

Depending on server / storage system configuration and the reliability requirement for storage devices to be adopted, variety of interfaces is being used.

The most commonly used in enterprise storage applications is SAS (Serial Attached Small Computer System Interface (SCSI). SAS interface has the features such as SCSI protocol, full duplex point-to-point connection, dual-port access which manages two independent paths, and Multi-Link access. Interface speed is being enhanced from 6Gbit/s to 12Gbit/s. Dual-Port feature is capable high availability with redundant path from host systems.

Though SATA (Serial Advanced Technology Attachment (ATA)) interface is the common interface for storage devices in the most of client PC, it is also widely used in low-end to mid-range server systems because of relatively lower cost and easier implementation. SATA interface has the features such as ATA protocol, point-to-point connection and 6Gbit/s interface speed.

SSD which has PCIe (Peripheral Component Interconnect (PCI) Express) interface are used for high performance application such as server-side cache or accelerator. PCIe interface speed is 1GB/s per 1lane in Gen3. The performance can be increased with multi lane. PCIe SSD also has better latency characteristics by direct connection to system bus. Current popular protocol of PCIe SSD is proprietary for enterprise segment and AHCI (Advanced Host Controller Interface) is popular for client application. NVMe (NVM Express) and SCSI over PCI / PCIe Queuing Interface (SOP-PQI) are being developed as standard protocol for PCIe SSD. NVMe is optimized protocol for SSD and SOP-PQI can utilize SCSI commands over PCIe Bus. NVMe and SOP-PQI are expected to be popular standard protocol for enterprise application in future.

Performance

SSD's read and write performance depends on the architecture of controller such as number of NAND flash memory channels and firmware algorithm, along with erase, program and read speed of the NAND flash memory itself. SSD has direct and fast access to NAND flash memory in writing and reading data without any mechanical movements to access like HDD. Multiple channels configuration being accessed in parallel achieves very high speed in data transactions compared to HDD. In addition, features such as log-structured algorithm, over provisioning, and Unmap/Trim commands are also important contributors to boost the random write performance.

In talking about NAND flash memory programming speed, Single Level Cell (SLC) is faster device compared to Multi Level Cell (MLC). Additionally, SLC has better endurance capability (write/erase cycle) than MLC. Therefore, for enterprise high speed applications, SLC NAND has been mostly used. However, since MLC has an

advantage in cost per capacity than SLC and as a result of improvements in the controller such as optimized programming algorithm, increased parallel access and enhanced error correction capability, MLC SSD can be adopted in the most enterprise applications recently.

Error Detection and Correction Technology

SSD controller should support error detection / correction function to improve data reliability. As generation of NAND flash memory is moving forward to narrower process rule definition, data detection and error correction code (ECC) technology has become more important for SSD. The ECC that are used for NAND flash memory are Hamming Code, Reed-Solomon Code, BCH (Bose-Chaudhuri-Hocquenghem) Code, LDPC (Low Density Parity Check) and such.

Hamming Code was often used at the early generation of NAND flash memory. Calculation of Hamming code is simple and often implemented by software.

Reed-Solomon Code handles multiple bits as one symbol, and error correction is performed in units of symbols. Error correction performed in units of symbols is suitable for burst bit error correcting.

BCH Code has flexibility for Block length and error correcting capability. And power consumption is small with respect to the error correction capability. BCH Code is the most popular ECC these days.

Error correction capability of LDPC is extremely high. But, considerations for power consumption and processing time are necessary.

In order to resolve the trade-off, Toshiba has developed original error detection and correction technique QSBC™ and utilized it on the SSD products.

Power Loss Protection

Zero down time is the fundamental requirement in mission critical enterprise systems such as server and storage system. Even in case of sudden power loss situation, SSD is required to protect and maintain data residing in the NAND flash memory, and furthermore to save all of the data inside in process onto NAND flash memory safely. On-board capacitors inside of SSD automatically supply enough electric power to complete data processing and saving, so-called power loss protection (PLP).

Encryption

Storing data in secure manner against theft or hacking is one of the most important features in enterprise server and storage systems. Today, storage devices have been required to store confidential (secret) data after encrypting it. Self-encrypting drive (SED) provides a means to encrypt all user data with AES encryption engine on the drive and protect user data. All user data in NAND flash memory are encrypted with a randomly generated encryption key. Encryption key, passwords, and other critical security parameters stored are protected securely.

SED drive also provides the Cryptographic Erase function. Unlike a lengthy over-write operation and a block erase operation, the Cryptographic Erase function simply regenerates the encryption key, effectively invalidating all previously stored user data. This allows SED drives to be quickly and securely sanitized before re-allocation, redeployment or retirement.

Toshiba enterprise SSD has a data encryption scheme with Trusted Computing Group (TCG) Storage Enterprise Security Subsystem Class (SSC) or OPAL SSC (SATA). Some models are also compliant with authorization of FIPS140-2.

References

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*QSBC: Quadruple Swing-By Code. QSBC is a trademark of Toshiba Corporation.

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