Virtium
Solid State Storage and Memory

Application Note

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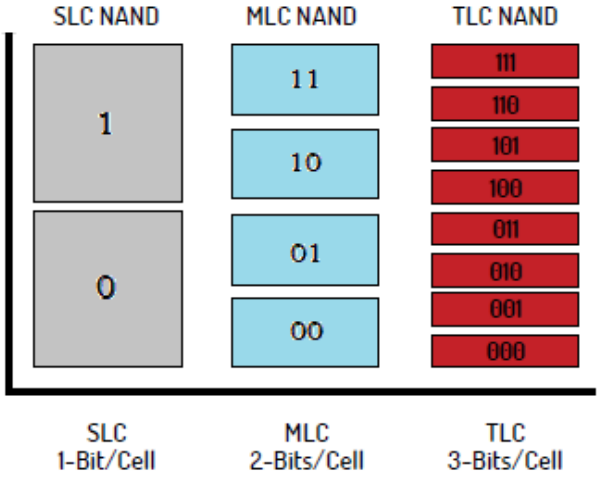
Virtium CE, XE and PE Industrial SSD Comparisons

Introduction

Solid state drives are the dominant choice for storage because of their superior performance over rotating media hard drives. They are based on various types of NAND Flash as discussed in this paper. In basic terms, the data stored in NAND flash is represented by electrical charges that are stored in each NAND cell.

Solid state drives designed for and used in the industrial and enterprise space have traditionally used NAND Flash based on two technologies, SLC (Single-Level Cell) and MLC (Multi-Level Cell), and most recently TLC (Triple-Level Cell). This paper outlines the features and differences of each as well as advanced NAND programming methods to greatly enhance the endurance of MLC/TLC NAND, commonly referred to as pSLC (pseudo-SLC).

SLC stores bits only as 2 voltage levels, a "1" or "0.", thus only one bit is stored per cell. It has very high endurance, up to 100,000 PE (Program/Erase) cycles, relatively fast read and write capabilities, and its error correction algorithms are relatively simple. It performs and maintains endurance well at higher industrial temperatures, and its die technology changes only once every 4-5 years, reducing the frequency of customer revalidation. Because it stores only one bit of data per cell however, it‘s acquisition cost is typically higher when compared to other MLC/TLC NAND technologies, though SLC’s endurance and resilience to extreme temperatures often justifies the added cost, especially in mission-critical and high service-level environments where downtime cannot be tolerated.



In contrast, MLC and TLC NAND stored charge has four and eight possible voltage levels respectively, and 2-3 bits are stored in each cell resulting in 2 to 3 times the capacity of SLC NAND in the same size die. The diagram above depicts the comparison among SLC, MLC and TLC NAND, neglecting the guard band. In the MLC, four different voltage levels can be stored, resulting in 2 bits per cell of stored data. Subsequently, TLC NAND can store and recognize 3 bits per cell, requiring eight distinct voltage states. Consequently, the voltage must be programmed and read more precisely (TLC even more precise than MLC), thereby reducing its performance compared to the SLC NAND. Since the maximum voltage in each cell is about the same, the SLC cells have more guard band than the MLC /TLC. It is this advantage that the SLC NAND is cable of withstanding temperatures and other adverse effects, such as circuit parasitics and layouts much better than the MLC or TLC NAND.

The higher bits-per-cell density in MLC/TLC results in significant reduction in cost-per-bit but it also comes at the cost of lower endurance, typically 3,000 PE cycles, as well as slightly reduced performance, and more complex ECC algorithms. It also has more frequent changing die technology, 12-18 months on average, and its data retention capability is reduced at higher temperatures, relatively dramatically at the high ends of the industrial temperature range. Still MLC (and now TLC) NAND has traditionally represented the lion's share of all NAND Flash shipments as its disadvantages are often overlooked in favor of its significant cost advantages over SLC.

As there is a wide gap in endurance and cost between SLC and MLC/TLC, many designers have had a need for a middle ground between the technologies, one that offers better endurance and temperature performance than MLC or TLC but not as high as SLC's price premium. A technology commonly referred to as pseudo-SLC (pSLC) has thus been created by Flash industry - which is a hybrid of 2-bit per cell MLC using firmware to emulate the storage states of 1-bit per cell SLC. The result is increased endurance – up to 30,000 PE cycles - over MLC's 3,000 PE cycles as well as much better data retention performance at higher temperatures, yet at a fraction of the cost as compared to SLC. In the case of TLC; while pSLC is an option, the reduction in capacity of 66% (from 3-bits to 1-bit) results in a potentially unfavorable tradeoff in capacity versus cost. In this case, specialty high-endurance 3D TLC can be used to enhance endurance up to three times over standard TLC. For industrial computing this offers a great middle ground when cost and reliability are of equal importance.

Virtium Solutions

In its lineup of StorFly solid state drives, Virtium offers SSDs based on all three of the above technologies: CE class - MLC and TLC based drives and pSLC based drives in the XE class family of solid state drives. Virtium's pSLC method improves upon baseline pSLC technology by using proprietary firmware techniques such as extra programming/read commands inserted during each cycle. These enhancements, combined with writing to only one page gives pSLC a much better distribution of the programming levels within the page than simply writing to one page as in the case of standard pSLC. The chart below illustrates the main differences among each of the above device families.

Product Class	CE (good)	XE (better)	PE (best)
NAND Technology	MLC / TLC	pSLC / iMLC	SLC
Capacities	30GB to 1920GB	16GB to 960GB	8GB to 256GB
Read/Write (MB/s) Read/Write (IOPS)	530 / 380 69,000 / 10,000	540 / 460 64,000 / 10,000	540 /470 72,000 / 6,100
NAND Program Erase	3,000	up to 30,000	up to 100,000
Warranty	3 Years	up to 5 Years	5 years
Use Case	High read, low write OS boot, code storage, application serving, crash dump / backup	Balanced read/write OS boot + light data logging / recording; better data retention than CE	High read/write Heavy data logging / recording, ideal for temperature extremes with longest data retention

Please note that the performance numbers in the above are relative values and vary based on each density and product class as related to type of NAND, number of channels on the drive, etc. As with the rest of Virtium's StorFly industrial SSDs, the XE Class features vtGuard™ power fail protection, vtSecure™ security features, as well as vtView™ software for precise performance and life/health monitoring. All Virtium StorFly SSDs carry a warranty up to five years. For further information and technical details please contact your Virtium representative.

Virtium manufactures memory and storage solutions for the world's top industrial embedded OEMs. For two decades we have designed, built and supported our products in the USA - fortified by a network of global locations. Our world-class technology and unsurpassed support provide a superior customer experience that continuously results in better industrial embedded products for our increasingly interconnected world.

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