ACNODES

White Paper

SLC vs MLC: Considering the Most Optimal Storage Capacity

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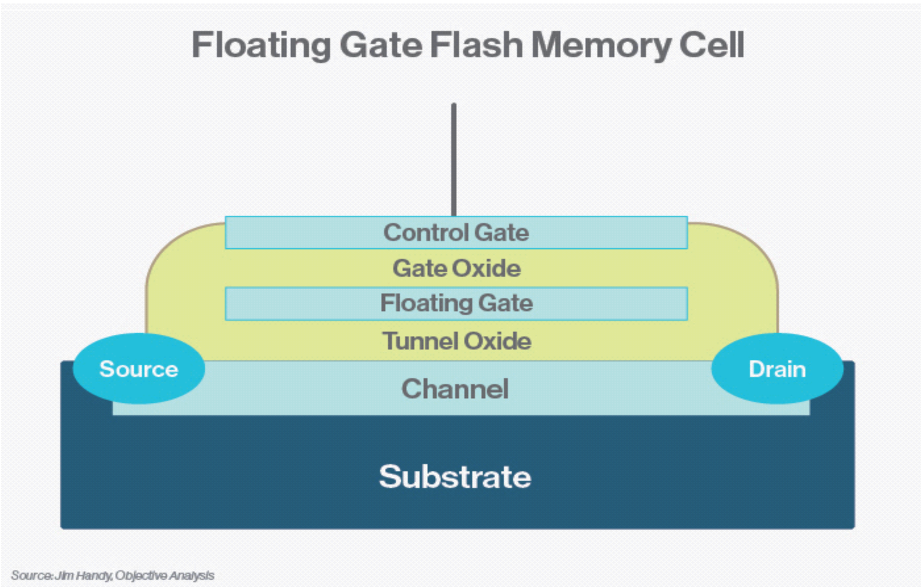
Introduction

Proficiency should be a priority for the storage in computers. The importance of NAND flash technologies is its ability to increase its chip capacity while efficiently reducing the cost per bit What keeps this machine going is its individual storage cells. Moreover, flash vendors increase the bit count in storage memory cells. These storage technologies are known as single-level cells (SLC) and multi-level cells (MLC). Both of these technologies should be considered as essential assets for industrial, commercial, or military applications. In datacenters, the things that usually go bad are bad fans and hard disks mainly because of its moving parts. Industrial applications like these require solid-state drives, that is, no moving parts, one of the major advantages over regular hard drives. However, it is crucial to acknowledge the advantages of what these different types of storage technologies comprise of for your specific applications.

Overview of NAND Flash Memory



It is necessary to examine the components of what exactly flash memory is. Flash cells or flash memory is a nonvolatile memory. This type of memory means that it does not need its own elements to be regularly refreshed. Flash memory cells compose of a transistor, and a floating

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gate that stores electrons. That means that any of these charges that are around the floating gate will actually stay there for a long period of time. The electrons undergo a process call Fowler-Nordheim tunneling that withdraws the electrons from the floating gate and through the channel. This turns the electrons from a negative to a positive charge. However, the reverse process can also occur where the electrons are trapped in the floating gate.

When the gate has a high charge it is written as “0” and when it has a lower charge, “1”. When the charge is at “0”, a higher voltage is needed compared to a bit value of “1”. For writing to occur in flash memory, these charges need to be transported into the oxide layer, as seen in the diagram above. Because there is no electrical contact at the floating gate, a process called quantum tunneling is present that allows those waves to pass through the gate (Nordheim equation). The voltage difference and the voltage source is what decides the amount of charge on the gate (threshold voltage). When more and more electrons get trapped, the conductivity between programmed and erased states will reduce. More bits per cell allows for higher storage density but because the charge states are closer together, more tolerance is needed. That is where considering between integrating SLC or MLC is important. The importance of NAND flash memory is its ability to not require any power to preserve data. The two types of cells are known as single layer (SLC) and multi-layer cells (MLC).

SLC vs MLC

The chart below analyzes the differences of advantages and disadvantages between single-level and multi-level cells. Performance wise, you can see that SLC delivers the fastest rate and the more bits per cells seems to slow performance down. We can also see with endurance, SLC holds the longest to, and MLC slows down a little bit. Although MLC is further back from SLC from performance and endurance levels, it wins by capacity. So the more bits per cell definitely increases capacity in NAND-Flash technologies.

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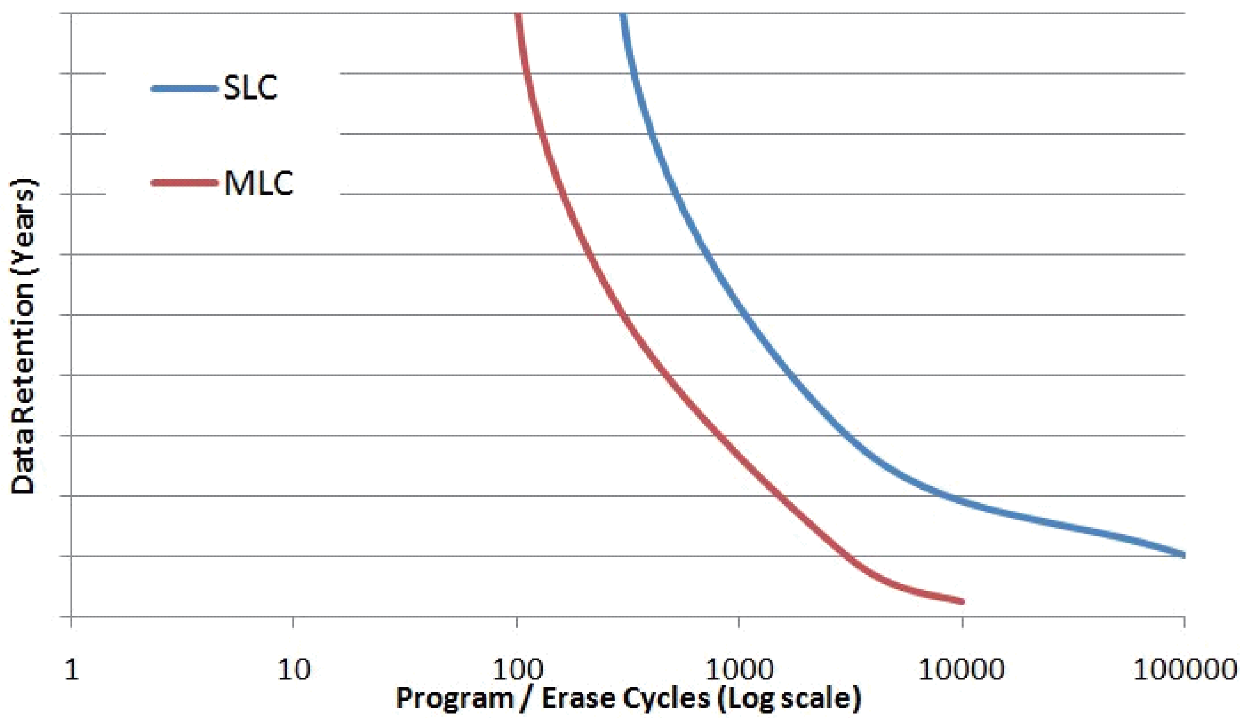
	SLC	MLC-2	MLC-3	MLC-4
Bits per cell	1	2	3	4
Performance	Fastest	⟷		Slowest
Endurance	Longest	⟷		Shortest
Capacity	Smallest	⟷		Largest
Error Prob.	Lowest	⟷		Highest
Price per GB	Highest	⟷		Lowest
Applications	Enterprise	Mostly Consumer	Consumer	Consumer

To make industrial applications relevant toward these technologies is to examine the endurance power between SLC and MLC. Single-cells advance in endurance up to thirty more times than that of multi-level cells. Considering levels of endurance plays well in a wide range of temperatures to consider for industrial applications. For more mission-critical tasks, SLC technology provides more endurance as seen in the graph below.



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Error Rates

MLC's as seen on the previous chart, shows signs of higher error rates. This makes sense because more bits per cells are added. To solve this problem, MLC uses more error corrections problems. MLC incorporates more than 2 charge states, bits per floating gate transistors that increases higher storage density. But because these charge states are more close together then SLC, more tolerance is needed and ultimately leads to more errors. One of the main mechanisms that can affect the reliability of data is something called program disturb. Program disturb is caused by cells not being programmed and as a result elevate their voltage stress. This is not a problem for SLC flash memory, but for MLC. When there is a voltage difference, the problem is called a "read disturb". There is debate on whether SLC or MLC is more suitable for industrial applications. The next problem will help address this issue. Leakage is a problem seen more in MLC that limits how much data can be kept. This is why MLC should be more for commercial use and why SLC is more suitable for mission critical tasks with large temperature ranges. These problems are more present in multi-level cells. One final crucial error to consider is called charge trapping. Within the erase cycles, you always get electrons without the energy you that is up to the task, therefore those electrons will get trapped between the channel and gate. And ultimately this can do some major perpetual damage to the cell.

Conclusion

Single-level cell (SLC) is more expensive than multi-level cells (MLC). The question is which one is better. There is no definitive answer between these two because different technologies have its own specific purposes. This article addressed many advantages and disadvantages between SLC and MLC and concluded that for commercial grade applications with a normal range of temperature, MLC should be considered. However, for those mission critical, military, and industrial applications that require a large range of operating temperatures, SLC would be the most reliable for maximizing efficiency.

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