SLC | MLC | TLC | ULTRA MLC

Selecting the Right NAND flash for your Applications

A Guidebook for Designers, by Designers

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What is Flash Memory?

Understanding the technology and different forms of flash available will effect your deployment strategies

As technology continuously advances, the demands for greater density and better performance with flash memory become dominant as well. Each NAND flash type has its own advantages and disadvantages; therefore, engineers often encounter difficulty in selecting the right flash type for their application.

The purpose of this playbook is to provide an overview on the difference of NAND flash types for SLC, MLC, & TLC comparison and also Advantech's Ultra MLC

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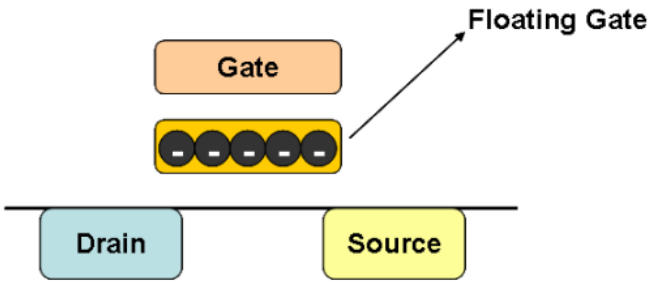
What's NAND Flash Memory

NAND flash memory is built up of many cells that hold bits, and those bits are either turned on or off through an electric charge. How those on/off cells are organized represents the data stored on the SSD.

NAND flash memory is categorized into three types:

- **SLC** (single-level cell)
- **MLC** (multi-level cell)
- **TLC** (triple-level cell)

Basis Structure of a Memory Cell



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Single-Level Cell (SLC) Flash

SLC flash stores one bit value per cell, which basically is a voltage level. The bit value is interpreted as “0” or a “1”.

Value	State
0	Programmed
1	Erased

Table1: SLC Levels

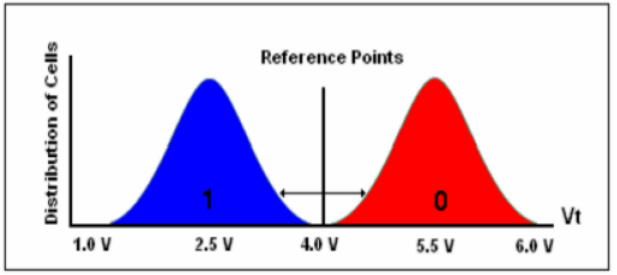

Figure 1: Voltage Reference for SLC

Pros:

- Long lifespan and charge cycles
- Reliable smaller room for read/write error
- Operate in a broader temperature range

Cons:

- Uneconomical
- Smallest capacity support among all flash types

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Multi-Level Cell (MLC) Flash

MLC flash stores multi bits of data on one cell. The value can be interpreted as 4 distinct stages: 00,01,10,11.

Value	State
00	Fully Programmed
01	Partially Programmed
10	Partially Erased
11	Fully Erased

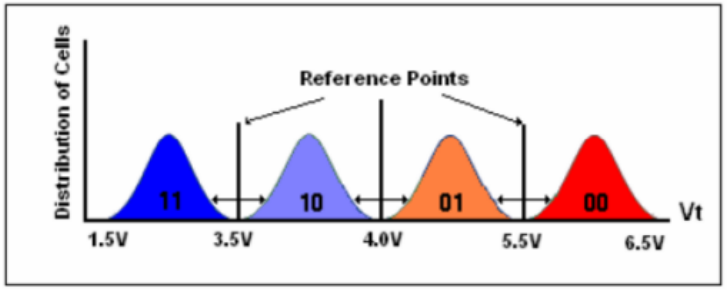

Figure 2: Voltage Reference for MLC

Pros:
Lower production costs because some costs are passed onto consumers

Cons:
Not as durable and reliable as SLC

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Triple-Level Cell (TLC) Flash

TLC Flash stores 3 bits of data per cell. The value can be interpreted as 8 distinct stages: 000,001,010, and 111.

Pros:
The most cost effective form of flash to manufacture

Cons:
Cells have less read/write cycles so TLC flash is only suitable for for consumer usage

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SLC/MLC/TLC Comparison Summary

As the levels of voltage increase, error, misjudge and bad block are more likely to occur. Therefore, the performance and reliability will decrease from SLC to MLC then to TLC.

It's critical to select the right Flash type for your application

	SLC	MLC	TLC
Bits per cell	1	2	3
P/E Cycles	100,000	3,000	1,000
Read Time	25 µs	50 µs	~75 µs
Program Time	200-300 µs	600-900 µs	~900-1350 µs
Erase Time	1.5-2 ms	3 ms	4.5 ms

Higher density / Lower cost

Higher performance and endurance

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Challenges in selecting a flash type

SLC flash is more durable and provides high performance, but it's uneconomical. MLC flash offers high density and lower bit-cost but it requires greater power consumption. TLC flash is only suitable for end consumer use. Can we have a flash type that delivers greater performance and endurance, but yet at the same time, is an economical solution?

It is

Ultra MLC Flash

Ultra MLC

#1: Higher Performance Enhancement

Ultra MLC is an extended version of MLC, which consists of a number of fast and slow pages. However, only fast pages are used for programing to obtain better performance and endurance . Ultra MLC delivers 3 key advantages:

#1-Higher Performance Enhancement: only fast pages are programed with Ultra MLC flash in result to improving write performance

MLC Flash	
1st Bit (Fast)	2nd Bit (Slow)
1	1
1	0
0	1
0	0

→

Ultra MLC Flash	
1st Bit (Fast)	2nd Bit (Slow)
1	1
1	0
0	1
0	0

↔

SLC Flash
Bit
1
0

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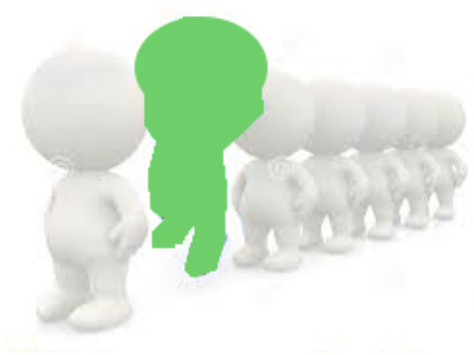
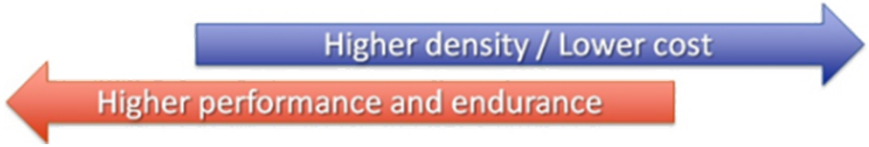
Advantages of Ultra MLC

#2: Longer Lifespan Extension



	SLC	uMLC	MLC	TLC
Bits per cell	1	1	2	3
P/E Cycles	100,000	30,000	3,000	1,000
Read Time	25 µs	~42 µs	50 µs	~75 µs
Program Time	200-300 µs	~450 µs	600-900 µs	~900-1350 µs
Erase Time	1.5-2 ms	~4.5 ms	3 ms	~4.5 ms

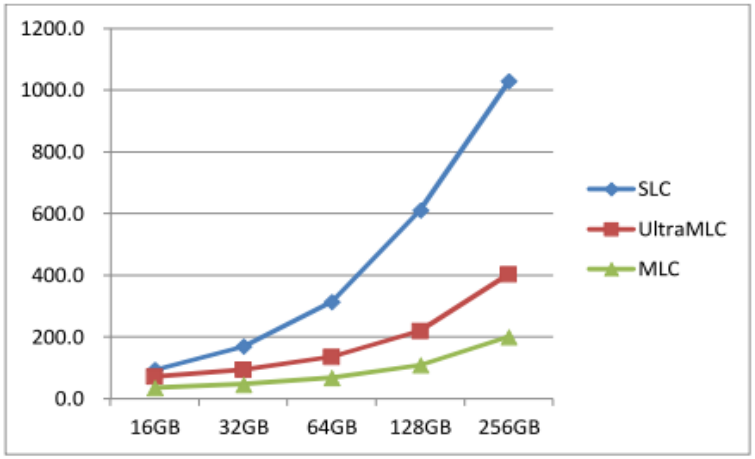


Ultra MLC outperforms MLC in terms of withstanding a greater amount of usage. Ultra MLC's endurance is at least 10X than MLC.

Advantages of Ultra MLC

#3: Better Cost Savings

Ultra MLC is using MLC flash but sacrifices 50% of the storage capacity to greatly increase the durability . The cost is about x2 times of MLC but still more economical solution cost-wise compared to SLC flash.



Cost estimation with different capacities

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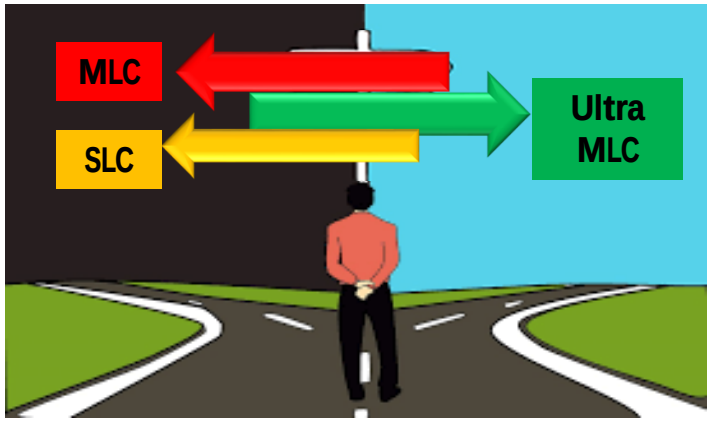
What NAND Flash type is suitable for your application?



Choosing the right flash type for you application can be challenging, our experts at Advantech have intensively studied features and capabilities of each flash type. It's recommended that engineers should check their application behavior in order to choose the most suitable flash type for their industry.

Application Behavior	Suggested Flash Type	Industries Examples
High Writing Frequency	SLC	Machine Automation, Data I/O, Applications with massive logging
High Writing Intensity	Ultra MLC	Video Recording, Multimedia Rendering, Applications with non-stop big block data writing
General Usage	MLC	POS, ATM, KIOSK, neither frequently nor continuously data writing

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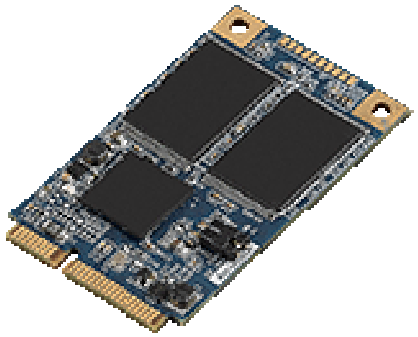
Ultra MLC Use Case



- Compliant with SATA III and SATA v 3.0 standard
- Supports 72 bit ECC correct per 1K Byte data
- Support hardware write protect
- Supports Fragment Writing Technology and Flush Manager
- Shock resistance, anti-vibration and low power consumption
- GUI management tool & software API package

Application

Image server for MRI

Product

SQFlash 630 Series mSATA Ultra MLC with AES

Project Information

The image server stores patients MRI images which in taking hundreds of photo per hour and the photo size could up to gigabytes. Ultra MLC provides 10x better endurance than commercial SSD that realizably records all of the medical data.

In terms of patient privacy, SQFlash offers internal AES 256-bit encryption that secures data from unauthorized duplication. When the disk needs to be erased for equipment maintenance, AES enabled disk provides the possibility of Quick Erase that completely wipes data within 10 milliseconds.

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Conclusions

Depend on needs, you can choose the right flash type for your application. However, Ultra MLC is considered the most economical alternative for industrial flash applications when it comes to stable and cost efficiency requirements.

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Ask the Expert with Pres Lee

SQFlash Product Manager, Advantech

What is your top tip for design engineers selecting storage?

It depends on the application. Since we offer a wide range of storage options, you have to first look at what your end goal is and make your selection with the longest lasting effect.

What key features should engineers consider when selecting a flash type for their application?

SSD performance nowadays can achieve quite high no matter flash type. So the most important guideline of selecting NAND Flash is always endurance. The more frequent writing behavior or the more volume of writing needs a higher tier of Flash IC.

What applications/industries are using Ultra MLC flash?

Although Ultra MLC has 10x endurance than MLC, but due to bigger page size compare with SLC flash, Ultra MLC is better fitting larger file size intensive writing. Such as multimedia editing, medical image, scientific graphic, DVR, or video recording. For frequent small file (several KB or even smaller) accessing, SLC is still better.

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MONITORING

- Data access control
- Write & Read Protect
- Emergency Erase within 10 milliseconds

Commitment to Premium Quality & Longevity

SQFlash was verified with all Advantech platforms and fully tested in rugged environments to ensure its high compatibility and reliability. It provides 3-year longevity and at least 15-month lifecycle information to service long design-in schedules for embedded projects.

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