3D NAND Flash with Advanced ECC Technology for Industrial Applications

A Guidebook for Designers- by Designers

ADVANTECH
Enabling an Intelligent Planet

What Are The Key Technologies of Current Storage Devices?

Learn about 3D NAND flash technology to help build a system of superior performance, ultra-scalability, and cost efficiency.

To achieve faster performance, ultra-scalability, and better cost efficiency, advanced 3D NAND flash technology was introduced onto the market in recent years.

The purpose of this playbook is to provide an overview of 3D NAND flash technology, its advanced Error Correcting Code (ECC) technology, and low-density parity-check (LDPC) code for endurance and reliability improvements.

ADVANTECH
Enabling an Intelligent Planet

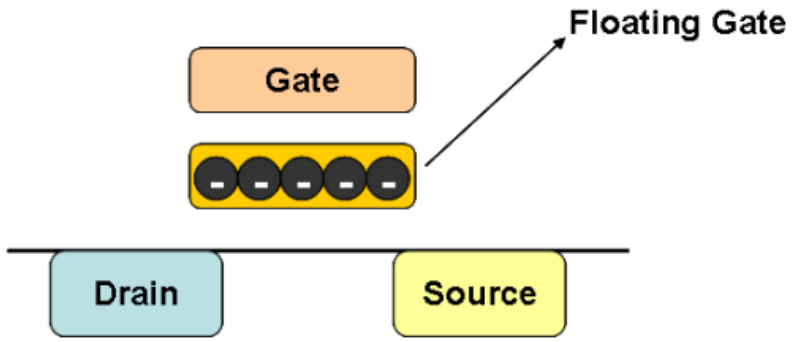
What's NAND Flash Memory?

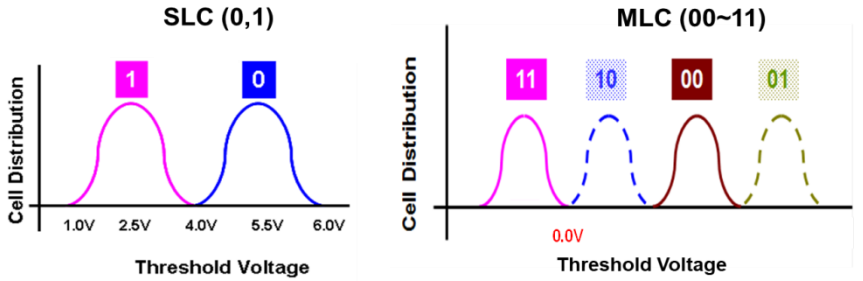
NAND flash memory is built up of many cells that hold bits, and those bits are either turned on or off through an electric charge. How those on/off cells are organized represents the data stored on the SSD.

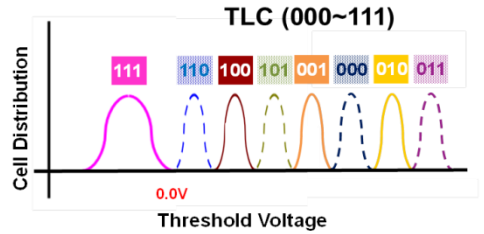
NAND flash memory is categorized into three types:

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

Basis Structure of a Memory Cell



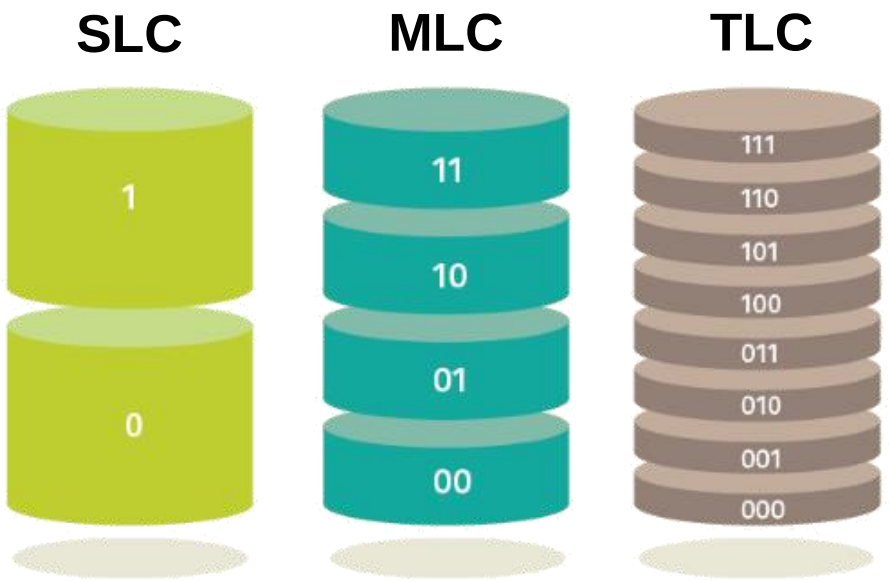




ADVANTECH
Enabling an Intelligent Planet

NAND (SLC/MLC/TLC) Comparison

As the number of levels in a cell increases, more data can be stored on a single die for lower bit-cost. However, the trade-off for cost-saving is greater power consumption and lower endurance, due to more voltage levels required and technology limitations.



Flash Type	SLC	MLC	TLC
Storage	1 bits / cell	2 bits / cell	3 bits / cell
Program / Erase Cycle	100,000+	3,000+	500 ~ 1,000
Write Performance	Highest	High	Low
Cost-per-bit	Highest	High	Low
Power Consumption	Lowest	Middle	Highest
Application	Often Used in Industrial Grade Storage		Used More in Consumer Electronics

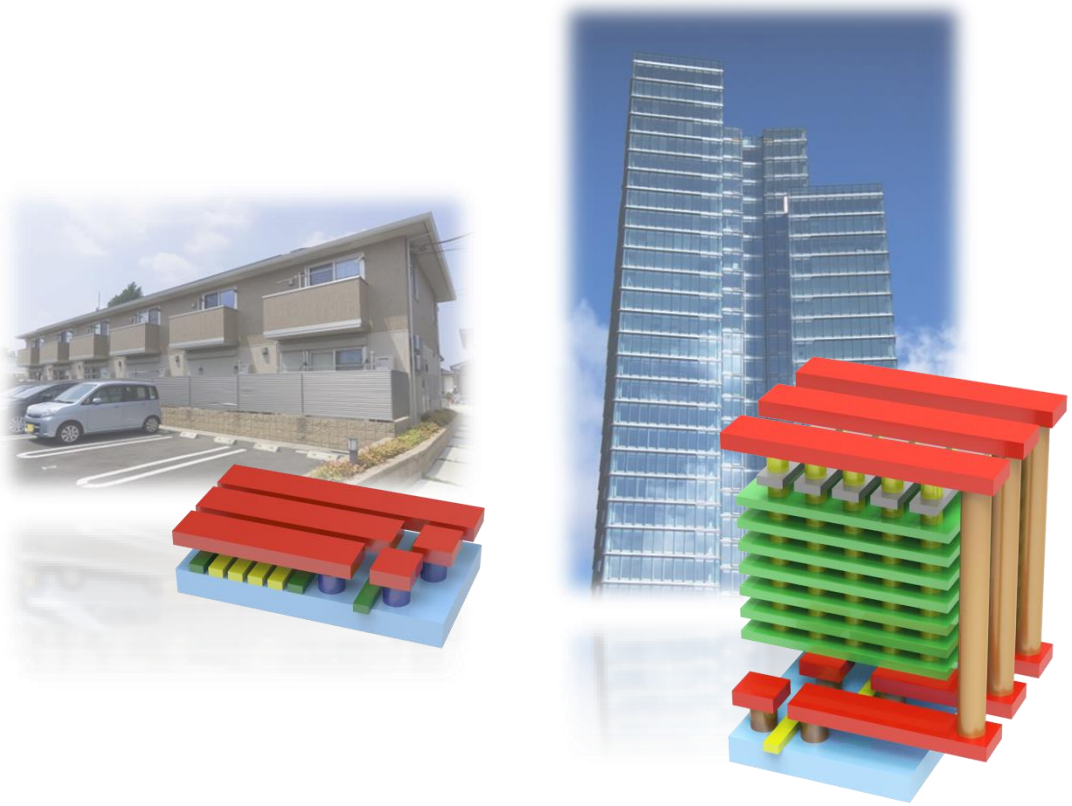
ADVANTECH
Enabling an Intelligent Planet

What is 3D NAND?

NAND Flash technology has been advancing to achieve higher storage density and lower bit-cost. However, in the planar process, individual cells interfere with each other in a space that is too narrow, so the 3D process was developed by scientists.

3D NAND is a precise process of vertically integrating NAND strings in a series. Memory transistors change from floating-gate types to trapped charge types.

3D NAND technology breaks the limitations of the 2D process by vertically stacking. By stacking more layers, 3D NAND can increase the unit density of storage



ADVANTECH
Enabling an Intelligent Planet

What Are the Benefits of 3D NAND?

Higher Capacity

By stacking more layers, 3D NAND can achieve higher storage density and ultra-scalability.

Reliable

P/E cycle count and data retention are higher than those of 2D TLC. With proper setting, the endurance level can reach 2D MLC grade.

Less Power

Less cell-to-cell program interference leads to lower power consumption.

Saving TCO

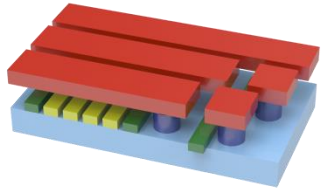
Higher capacity and lower power consumption bring greater cost efficiency.

ADVANTECH
Enabling an Intelligent Planet

Differences Between 2D NAND and 3D NAND

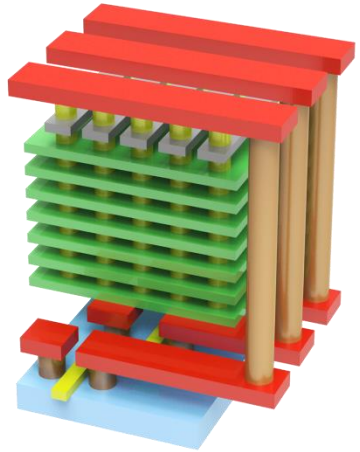
2D NAND Flash

15nm floating gate is approaching the physical limitation that pushes new lithography techniques to take over.



3D NAND Flash (BiCS)

Enlarged capacity within limited space provides good fab re-use by using existing lithography tools.



Flash Type	SLC	MLC	TLC	3D TLC (BiCS 3)
Storage	1 bits / cell	2 bits / cell	3 bits / cell	3 bits / cell
Program / Erase Cycle (ECC: BCH)	100,000+	3,000+	500 ~ 1,000	1,000 ~ 1,500
Write Performance	Highest	High	Low	Middle
Cost-per-bit	Highest	High	Low	Lowest
Power Consumption	Lowest	Middle	Highest	High

Better than 2D TLC but not good enough for industrial grade

ADVANTECH
Enabling an Intelligent Planet

How to Improve Endurance of 3D NAND Flash?

High Performance ECC Helps Data Accuracy and Improves Endurance

Error Correction Code (ECC) technology

Bose, Chaudhuri, and Hocquenghem (BCH)

Traditional algebraic coding method can correct up to a specified, fixed number of errors.

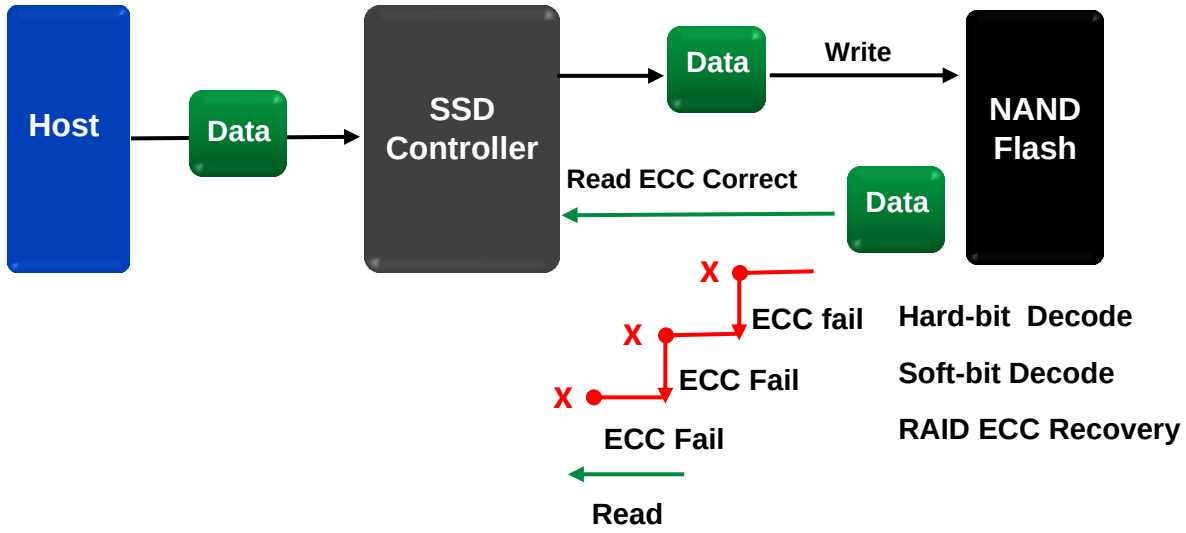
Low-Density Parity-Check (LDPC)

Using hard-bit (binary) and soft-bit (probabilities of bits) decode is 2~3x better performance over BCH.

RAID ECC

By identifying the RAID ECC parity between page and page, the performance can be enhanced more.

ECC Coding + RAID ECC

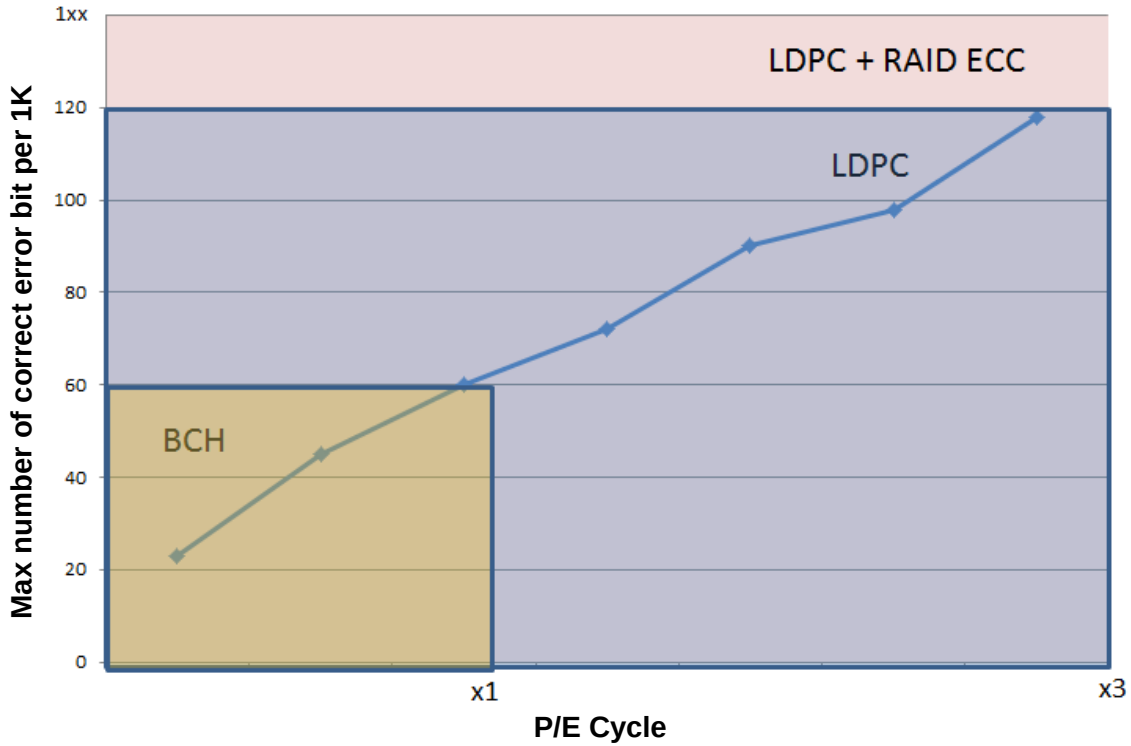


ADVANTECH
Enabling an Intelligent Planet

Can 3D NAND Flash (BiCS 3) Achieve Industrial Grade?

ECC Technology	BCH	LDPC	LDPC+RAID ECC
Decoding Algorithm	Algebraic Based	Probability Based	Probability Based
Performance of Hard-bit Decode	Fixed	1.3X BCH	1.3X BCH
Performance of Soft-bit Decode	-	2X~3X than BCH	3X+ than BCH
Decoding Complexity	Low	Mid	High
Die Cost	Low	High	High

Winner



With LDPC + RAID ECC, BiCS 3 boosts P/E cycles to over 3,000 times (originally 1000~1500 times with BCH) into industrial grade.

ADVANTECH
Enabling an Intelligent Planet

NAND Flash Types in Industrial Application

SLC, MLC, and ultra MLC[1] SSD are still the mainstream for industrial applications due to their high reliability, high endurance and stable performance features.

Note1: Ultra MLC acts as SLC based on MLC structure

3D TLC (BiCS 3) SSD is new technology that is easier to adapt in commercial/industrial applications such as POS, Kiosks, and data centers due to its cost-effective and large capacity features.

Fan-less / Embedded System

Surveillance and Automation Machine / Write-Intensive Application

POS, Kiosk and Data Center / Read Intensive Application

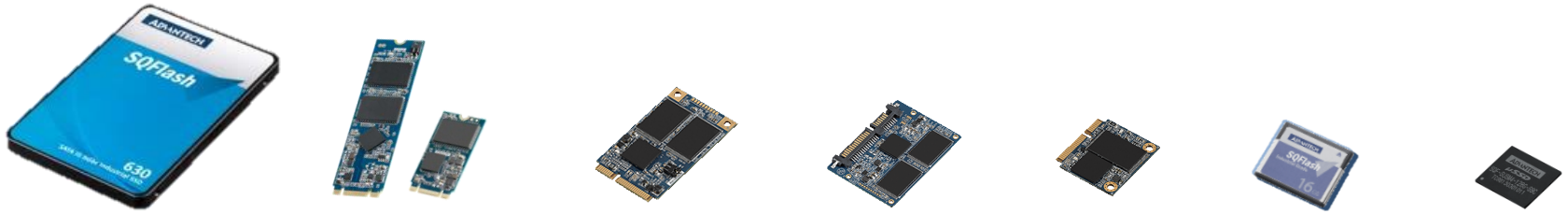
ADVANTECH
Enabling an Intelligent Planet

Conclusions

From 2D NAND flash to 3D NAND flash, higher storage density devices have emerged quickly in recent years. However, while eager to pursue cost-effectiveness, it is likely that endurance, reliability, and/or performance will be sacrificed.

LDPC ECC with RAID ECC technology could enhance the P/E cycle two- or three-fold, which enables 3D NAND flash (BiCS 3), to achieve MLC-level endurance that meets industrial-grade requirements for 3D NAND technology.

SATA 640 – Embedded Series



Product Series	Embedded 2.5” SSD	Embedded M.2 SSD	Embedded Modules				
Model Name	SQF-S25	SQF-SM8 / SQF-SM4	SQF-SMS	SQF-SLM	SQF-SHM	SQF-S10	SQF-SUS
Transfer Protocol	SATA 6Gb/s						
Connector	7 + 15 pin SATA	M.2 B + M Key	Mini PCIe with SATA pin-out	7 + 15 pin SATA	Mini PCIe with SATA pin-out	CFast Type-I	Onboard
Flash Vendor	Toshiba						
Flash Type	Ultra MLC / MLC / 3D NAND						Ultra MLC / MLC
Capacity	16GB ~ 1TB (SM4SHM/S10 and SUS up to 256GB)						
ECC	LDPC with advanced ECC						
Add-on	Hardware write protect					N/A	
Op. Temp.	0 ~ 70° C / -40 ~ 85° C						
SQFlash Utility	GUI management tool & SW API pack						

SATA 840 – Enterprise Series

Product Series	Industrial 2.5” SSD	Industrial M.2 SSD
Model Name	SQF-S25	SQF-SM8
Transfer Protocol	SATA 6Gb/s	
Connector	7 + 15 pin SATA	M.2 B + M Key Mini PCIe with SATA pin-out
Flash Vendor	Toshiba	
Flash Type	3D NAND BiCS 3	
Capacity	256GB ~ 8TB	256GB ~ 2TB
ECC	LDPC, RAID ECC	
New Tech.	Global Fragment Writing, Flush Manager, Thermal Throttling	
Op. Temp.	0 ~ 70° C / -40 ~ 85° C	0 ~ 70° C / -40 ~ 85° C
SQFlash Utility	GUI management tool & SW API pack	

SQF 710 & 920 series – NVMe SSD

Embedded NVMe 710 series	Product Series	Enterprise NVMe 920 series
SQF-CM8 → M.2 2280 (B-M key) SQF-CM3 → M.2 2230 (A-E key) SQF-CMS → Full-size MiniPCIe	**Form Factor**	SQF-C25 → U.2 2.5” SSD (SFF-8639) SQF-CM8 → M.2 2280 (M key)
PCIe Gen3 x2, 2-lane	**Transfer Protocol**	PCIe Gen3 x4, 4-lane
Support[1]	**AES256**	Support
TCG-OPAL	**SED feature**	TCG-OPAL / TCG-Enterprise
128GB ~ 1TB	**Capacity[2]**	256GB ~ 8TB
Read: up to 1,600 MB/s Write: up to 1,100 MB/s Random 4K R/W: up to 240K/ 200K IOPS	**Performance[3]**	Read: up to 3,200 MB/s Write: up to 2,600 MB/s Random 4K R/W: up to 600K/ 600K IOPS
SmartECC	**ECC mode**	LDPC + RAID ECC
0 ~ 70° C / -40 ~ 85° C	**Op. Temp.**	0 ~ 70° C / -40 ~ 85° C

1. The SQF-CM8 of 710 series supports AES256.
2. The max. capacity of SQF-CM3 710 series upto 256GB. The SQF-CM8 920 series up to 4TB.
3. The speed result is max. capacity model.