SLC NAND gains momentum in Autonomous Driving camera applications

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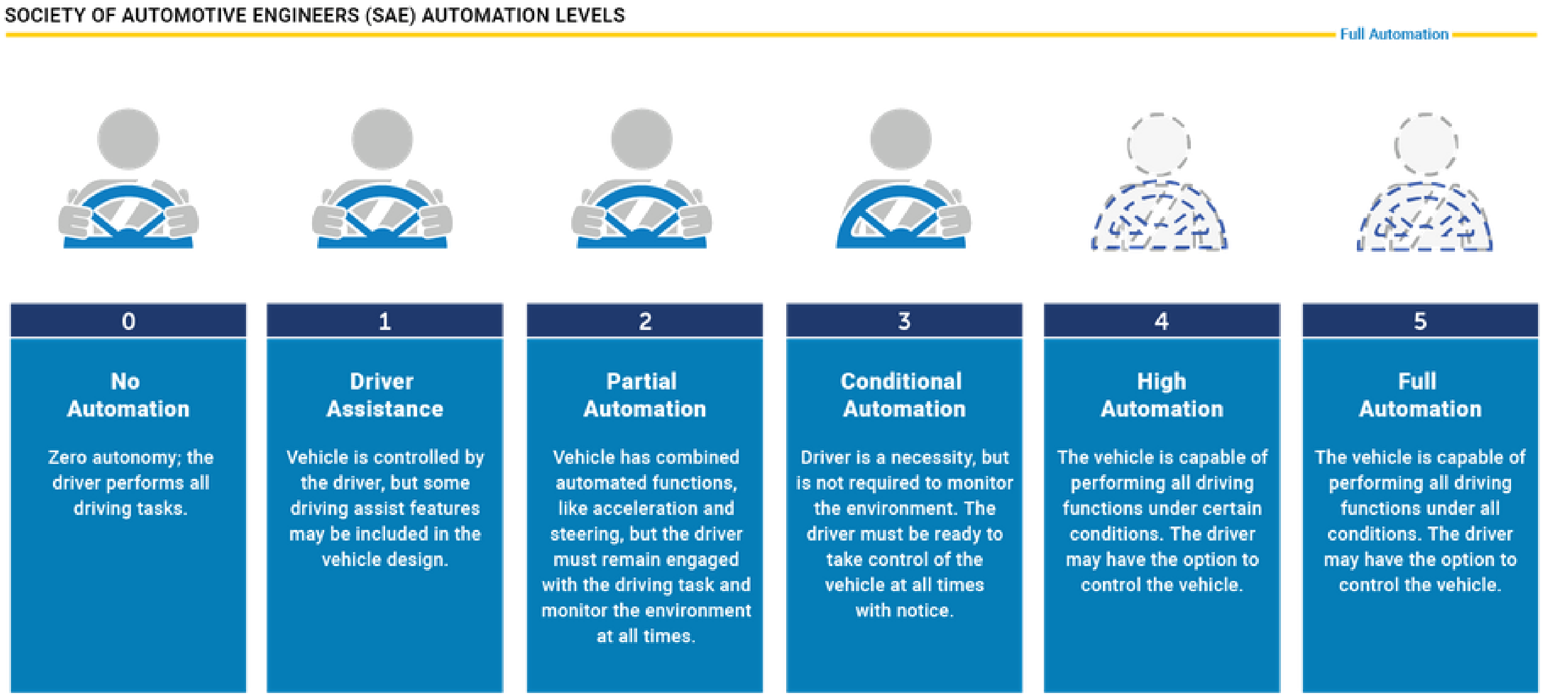
Overview of Automation Levels as per SAE (Society of Automotive Engineers)



Reference: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

Flash density requirement in front camera explodes to 1Gb~4Gb:
Level 4 and Level 5 Autonomous Driving

<u>LEVEL 3</u>
Automated driving in certain conditions – but driver may be alerted to take charge

→

<u>LEVEL 4</u>
Automated driving under normal conditions (e.g. under normal weather)

→

<u>LEVEL 5</u>
Automated driving under all conditions

- About decade ago, Flash density requirement for front camera was only about 64Mb
  - Driver assistance systems merely offered “emergency break” in close rear end
- Flash density requirement in front camera has exploded now to 1Gb~4Gb and higher
  - Tier-1 and OEM are developing level 4 and 5 “Autonomous Driving” systems
  - Front Camera: Application code in Flash long/complex + occasional update OTA
- NOR was good choice to 256Mb - but System Architects considering SLC NAND now

<u>Note</u>: Level 3/4/5 above are only illustrative examples, and may not always apply literally

SLC NAND offers cost effective solution at 1Gb~4Gb densities:
4X-nm NAND offers lower cost & Quality comparable to advanced NOR

Flash Memory Summit

- SLC NAND offers lower cost: NOR cell size ~10F^2 whereas SLC NAND cell size 4F^2
  - NOR process scaling started to slow down at 65nm and stalling at 4X-nm
  - SLC NAND process migration continued from 4X-nm to 3X-nm, and 2X-nm NOW
- SLC NAND at 2X-nm NOW - but prev. 4X-nm can offer Quality similar to 4X-nm NOR
  - Boot is possible from NAND, but some legacy applications require NOR for boot
- Good Arch choice: 1. SLC NAND: Application/OS/Data; 2. Small NOR: Boot (optional)
  - New SoC can support boot from Serial NAND

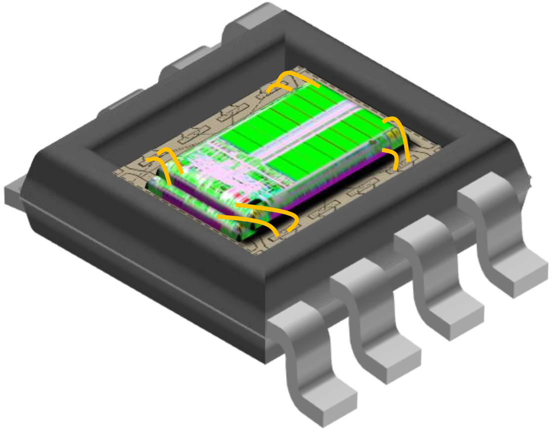
➢ Flash density increase in Front camera due to long and complex Application code

Comparing SPI Flash solutions at 1Gb: same footprint/pin-out

Fast write thru-put of SLC NAND key advantage in SW update OTA

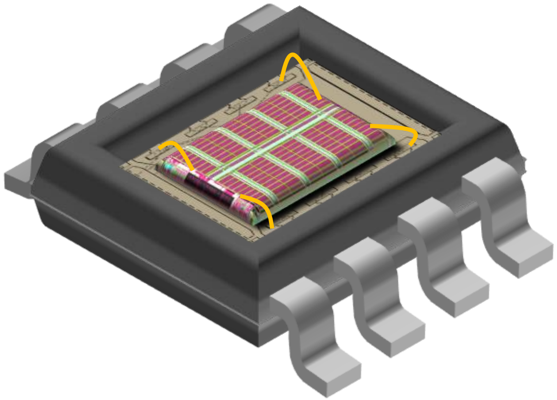
Flash Memory Summit

Relative cost: 2X (cell size: $10F^2$)	Relative cost: 1X (cell size: $4F^2$)	Relative cost: 1.25X+
Relative write thru-put: 1X	Relative write thru-put: 10X+	Relative write thru-put: 10X+



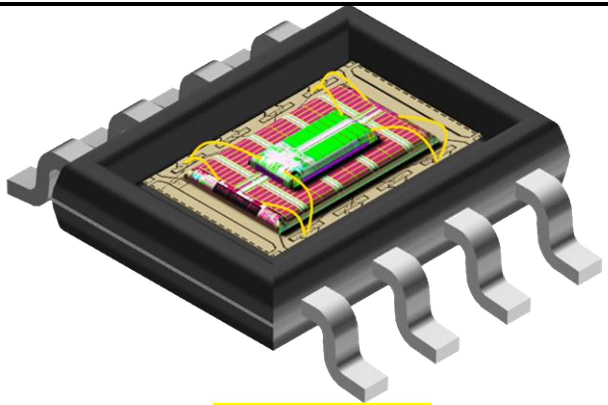
1Gb SPI NOR: 2 X 512Mb die Stack

- **Boot code, App, OS, Data**



1Gb Serial SLC NAND: 1-die

- **Boot code, App, OS, Data**



SpiStack™:

1Gb Serial NAND + 16Mb SPI NOR

- **NAND: App/OS/Data, NOR: Boot**

- Serial NAND based solutions offers fast write thru-put for SW update OTA & low cost

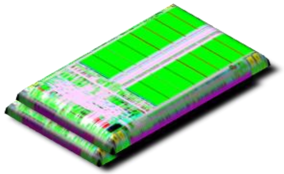
Note: Relative cost and write thru-put are illustrative examples, and actual values may vary

3 attributes of SLC NAND on 4X-nm w.r.t NOR on advanced tech:
1. Lower cost, 2. Comparable Quality, and 3. Very fast write thru-put

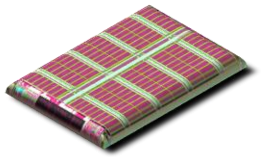
Flash Memory Summit

1. SLC NAND offers lower cost than NOR Flash at higher densities (e.g. 1Gb~4Gb)

- NOR Flash bit cell size ~$10F^2$, whereas SLC NAND bit cell size $4F^2$
- 1Gb NOR: 2-die stack (512Mb NOR: single die); but 1Gb Serial NAND: single die
- Cost of 1Gb Serial NAND ~ ½ cost of 1Gb SPI NOR



1Gb SPI NOR: 2 X 512Mb SPI NOR stack



1Gb Serial NAND: Single die

➢ SLC NAND offers lower cost solution as density increases to 1Gb~4Gb due to application code

3 attributes of SLC NAND on 4X-nm w.r.t NOR on advanced tech:

1. Lower cost, 2. Comparable Quality, and 3. Very fast write thru-put

2. 4X-nm SLC NAND offers comparable Quality to advance NOR tech in production (4X-nm)[1]

- Notion NOR high Quality, in part, since NOR (4~6X-nm) lag SLC NAND Tech (2~3X-nm) by 2 gen
- Prev gen 4X-nm SLC NAND can support good DR (data retention) and cyc, as in Winbond 46nm:

No. of P/E cycle	Un-cycled	10K P/E cycle
Data Retention	> 20 years @85C	> 15 years @70C
Application	Suitable for code - not frequently updated	Suitable for frequent writes

- ➢ 4X-nm SLC NAND can provide good "Code Storage Flash" solution at 1Gb~4Gb densities
- ➢ 1Gb~4Gb 4X-nm SLC NAND offers high Quality to store application code in front camera

Ref (1): Automotive-grade SLC High Quality NAND Flash ICs provide new pathway to higher density at lower cost for application code storage, Anil Gupta, Winbond Electronics Corp, EETimes, Mar 21, 2018

3 attributes of SLC NAND on 4X-nm w.r.t NOR on advanced tech:
1. Lower cost, 2. Comparable Quality, and 3. Very fast write thru-put

3. Very fast write thru-put of SLC NAND w.r.t. NOR key for SW update OTA applications
   - Serial NAND write thru-put about 25X times faster than SPI NOR, as in Winbond products:

		SPI Quad Interface; 6 signals (/CS, SCK, and 4 I/Os)	
		SPI NOR: W25Q256JW	Serial NAND: W25N01GW
Process		**58nm**	**46nm**
Density, VCC		**256Mb, 1.8V**	**1Gb, 1.8V**
Program	**Spec**	**800us**	**250us**
	Size	**256 Byte**	**2,048 Byte**
	MB/s	**0.32 MB/s**	**8.2 MB/s**

➢ SLC NAND fast write thru-put key to SW update OTA - large application code sometime needs update

Summary

1. Cost of Serial NAND ~½ compared to SPI NOR at 1Gb and higher densities, since:
   - NOR & SLC NAND cell size ~$10F^2$ and $4F^2$, and NOR process stalls to scale at 45nm
   - SLC NAND Technology has continued scaling to 3X-nm and even down to 2X-nm
2. Quality of 4X-nm NAND comparable to advanced NOR technology in production (4X-nm)
   - Notion NOR more robust, in part, due to Tech gap: NOR 4~6X-nm & NAND 2~3X-nm
   - Electron count/cell drops on advance Tech, prev. gen 4X-nm NAND chosen for high Quality
3. Write thru-put (programming): SLC NAND>10X fast write than NOR; Erase time >100X fast
   - Fast write thru-put by Serial NAND very important for SW update OTA applications

➢ SLC NAND suited for high density Flash in Front Camera: due to cost, Quality, and write thru-put

Thanks