SLC NAND gains momentum in Autonomous Driving camera applications

Anil Gupta
Technical Executive
Winbond Electronics Corporation
## Overview of Automation Levels as per SAE (Society of Automotive Engineers)


<table>
<thead>
<tr>
<th>Level</th>
<th>Automation Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>Zero autonomy; the driver performs all driving tasks.</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
<td>The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.</td>
</tr>
</tbody>
</table>
Flash density requirement in front camera explodes to 1Gb~4Gb:
Level 4 and Level 5 Autonomous Driving

• 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

Note: 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

- 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

<table>
<thead>
<tr>
<th>Relative cost: 2X (cell size: 10F^2)</th>
<th>Relative cost: 1X (cell size: 4F^2)</th>
<th>Relative cost: 1.25X+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative write thru-put: 1X</td>
<td>Relative write thru-put: 10X+</td>
<td>Relative write thru-put: 10X+</td>
</tr>
</tbody>
</table>

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

1. SLC NAND offers **lower cost** than NOR Flash at higher densities (e.g. 1Gb~4Gb)
   • NOR Flash bit cell size \(\sim 10F^2\), 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 \(\sim \frac{1}{2}\) cost of 1Gb SPI NOR

- 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)\textsuperscript{1}
   - Notion NOR high Quality, in part, since NOR (4\textemdash6X-nm) lag SLC NAND Tech (2\textemdash3X-nm) by 2 gen
   - Prev gen 4X-nm SLC NAND can support good DR (data retention) and cyc, as in Winbond 46nm:

<table>
<thead>
<tr>
<th>No. of P/E cycle</th>
<th>Un-cycled</th>
<th>10K P/E cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Retention</td>
<td>&gt; 20 years @85C</td>
<td>&gt; 15 years @70C</td>
</tr>
</tbody>
</table>

- 4X-nm SLC NAND can provide good “Code Storage Flash” solution at 1Gb\textemdash4Gb densities
- 1Gb\textemdash4Gb 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:

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:

<table>
<thead>
<tr>
<th></th>
<th>SPI Quad Interface; 6 signals (/CS, SCK, and 4 I/Os)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPI NOR: W25Q256JW</td>
</tr>
<tr>
<td>Process</td>
<td>58nm</td>
</tr>
<tr>
<td>Density, VCC</td>
<td>256Mb, 1.8V</td>
</tr>
<tr>
<td>Program</td>
<td>Spec: 800us</td>
</tr>
<tr>
<td></td>
<td>Size: 256 Byte</td>
</tr>
<tr>
<td></td>
<td>MB/s: 0.32 MB/s</td>
</tr>
</tbody>
</table>

- SLC NAND fast write thru-put key to SW update OTA - large application code sometime needs update.
1. **Cost** of Serial NAND ~½ compared to SPI NOR at 1Gb and higher densities, since:
   - NOR & SLC NAND cell size ~10\(F^2\) and 4\(F^2\), 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