ADCs for Autonomous Driving

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Seamless Microsystems Background

LiDAR and RADAR in cars

Wireless and Wireline Comm.

Consumer Medical Imaging

SM250M  SM250M  SM250M  SM400M
Silicon Valley Traffic
Tesla Autopilot! Available now!
Works most of the time, but...
Why Tesla’s autopilot might be failing?

Tesla’s autopilot only uses cameras and radar for sensing.

High resolution RADAR vs LiDAR:
- 15 feet?
- 17 feet
## Comparison of sensors in various environments

<table>
<thead>
<tr>
<th>Sensor</th>
<th>RADAR</th>
<th>Camera/Vision</th>
<th>LIDAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
<td>✔</td>
</tr>
<tr>
<td>Range resolution</td>
<td>✔</td>
<td>-</td>
<td>✔ ✔ ✔</td>
</tr>
<tr>
<td>Angular resolution</td>
<td>-</td>
<td>✔</td>
<td>✔ ✔ ✔</td>
</tr>
<tr>
<td>Works in bad weather</td>
<td>✔ ✔ ✔</td>
<td>✗</td>
<td>-</td>
</tr>
<tr>
<td>Works in dark</td>
<td>✔ ✔ ✔</td>
<td>✗ ✗</td>
<td>✔ ✔ ✔</td>
</tr>
<tr>
<td>Works in bright light</td>
<td>✔ ✔ ✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Radial velocity</td>
<td>✔ ✔ ✔</td>
<td>✗</td>
<td>✗ ✗</td>
</tr>
<tr>
<td>Color/contrast</td>
<td>✗ ✗</td>
<td>✔ ✔ ✔</td>
<td>-</td>
</tr>
</tbody>
</table>
Most autonomous cars now use all three sensors:

- **LiDAR**
- **Camera**
- **RADAR**

(usually mounted behind body panels)
Time-of-Flight LiDAR Systems

Full waveform capture LiDAR Rx

Geiger/Single-Photon LiDAR Rx

Laser

PIN APD

SPAD array

A

ADC

Detection

Estimation

12Gb/s

300Mb/s

3-D Point Cloud

3-D Point Cloud

OPTICAL ANALOG DIGITAL

12Gb/s 300Mb/s
## Comparison of LiDAR receiver techniques

<table>
<thead>
<tr>
<th>LiDAR Receiver Technique</th>
<th>Geiger Mode</th>
<th>Full-Waveform Capture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing simplicity/power consumption</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Range/Resolution</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Quick Object Classification (reflectance data)</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Multi-return echo detection (ie foliage, poles/wires)</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Error-free from other LiDARs (interference)</td>
<td></td>
<td>✔</td>
</tr>
</tbody>
</table>
Current LiDAR solutions use discrete chips

$1600 for ADCs alone (8 channels)
ADCs in LiDAR Are Bulky and Expensive

Very hard to build

Large footprint

Speed | Resolution | Power/ch.
--- | --- | ---
0.9 GHz | 10-bits | 1W
LiDAR Receive Pulse Digitization

**LiDAR ADC Requirements**
- Sampling speed > 0.5GHz
- Resolution > 10-bits

**LiDAR Received Pulse**
- Pulse + Noise
- Bandwidth > 250MHz

**RX Chain**
- LPF
- ADC

**Time domain**
- Pulse
- Noise
- 4ns

**Frequency domain**
- Amplitude dB
- Frequency Hz
Problem 1: Power Hungry LPF

- Significant SNR degradation due to noise aliasing
- Requires expensive LPF to minimize noise aliasing
  - 8th order LPF
  - 4x AD8099 chips @ $14
  - 600mW

**Power hungry (600mW/ch.) and expensive ($14/ch)**
Problem 2: Poor Jitter Tolerance

- Very accurate clock source requirement for ADC sampling
- <300fs rms jitter requirement for LiDAR ADCs
- Expensive
  - On-board clock generators: TI LMK61A2-100M00SIAT ~ $7.00
  - On-chip (inside ADC) clock generators
    - Large Silicon area
    - Large cost
Problem 3: Power-Hungry ADC Input Driver

- Switched-capacitor input interface is hard to drive
  - Needs power hungry buffer
- ADC input driver ~ 20% ADC power consumption
Best ADCs for LiDAR: Continuous-time $\Delta \Sigma$ ADCs

- Low-pass filtering using integrators before sampling

- High speed sigma delta ADCs
  - Enabled by SMI’s patented technology

- Inherent over-sampling
  - No requirement for anti-alias filter

- Resistive input impedance
  - Low power ADC driver

- Simple digital calibration
ISO 26262 IP/Chip Requirements

All IP/SoCs must meet functional safety requirements

*Synopsys white paper – Data converters IP for Automotive SoCs

SM250M
4 channel ADC
With 1 redundant testing channel
IP or Chiplets?

- Digital will be a large portion of the SoC
  - Done in lower CMOS nodes for power/cost savings
- ADCs as chiplets
  - Does not need to be in same process as digital
  - Can be ISO 26262 qualified independently to reduce time-to-market
Conclusions

• For autonomous driving sensors, high bandwidth and high resolution ADCs will be needed
  • LiDAR/RADAR will definitely be used
  • Full-waveform capture needed for long range
• Automotive components have long lead time
  • Products need to be done quickly so exhaustive tests can begin sooner
  • ISO 26262 compliance is easier if every component is already qualified