Automotive In-cabin Sensing Solutions

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Drowsiness responsible for 20% to 25% of car crashes in Europe (INVS/AFSA)
Driver distraction is highly implicated in accidents. Young drivers are particularly affected.

Mobile used during driving:
About 50% drivers are texting, while on the road.

Mental distraction lasts long after the eye distraction time.

~50% of drivers text. Cars have features close to smartphones.

→ Drivers are much more distracted than before.
## Human Machine Drive

### Levels

<table>
<thead>
<tr>
<th>Levels</th>
<th>0 Human only</th>
<th>1 Assisted driving</th>
<th>2 Partial automation</th>
<th>3 Conditional automation</th>
<th>4 High automation</th>
<th>5 Full automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot off</td>
<td>No</td>
<td>Temporary</td>
<td>Temporary</td>
<td>Temporary</td>
<td>Temporary Within use cases</td>
<td>Always</td>
</tr>
<tr>
<td>Hands off</td>
<td>No</td>
<td>No</td>
<td>Temporary</td>
<td>Temporary</td>
<td>Temporary Within use cases</td>
<td>Always</td>
</tr>
<tr>
<td>Eyes off</td>
<td>No</td>
<td>No</td>
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<td>Temporary</td>
<td>Temporary Within use cases</td>
<td>Always</td>
</tr>
</tbody>
</table>

### Human Machine

**Who drives?**

- **1 driver**
- **2 drivers for the same car!**
- **1 driver**

**Driver Monitoring is key for a safe co-driving**

Ultimately both type of car would co-exist for a long time.

**Who drives?**

- **1 driver**
- **2 drivers for the same car!**
- **1 driver**

**Driver Monitoring**

*a Must Have for Car Automation*
The Machine must sense the Human driver to understand his behavior, release the car control upon driver request, while keeping safety assistance.
Effective driver monitoring will also be a prerequisite for automated driving, to make sure that, where needed, control can be handed back to a driver who is fit and able to drive the vehicle.

**Driver Monitoring - DMS**
- Attention, distraction, drowsiness
- Health status, heart rate, breathing
- Gaze direction
- Head orientation
- Identification (immobilizer)
- Hands position
- Recording (legal aspect)
- ADAS interaction management

**Cabin Monitoring - CM**
- Passengers detect/classify
- Passenger/child surveillance
- Airbags adaptation
- Passengers identification
- Autonomous taxi
- Accident recording
- Intruder detection, recording
- Left child detection

**Comfort Functions - CF**
- Gestures driver and passengers
- Air condition
- Personalization
- Head up display eye box adjustment
- Display interactions, smart dashboard

- Video conferencing
- Speaker detection
- Remote Cabin monitoring, lost items
- Cabin light management
HDR Global Shutter
Perfectly fitting with applications
- Head pose detection
- Eyelids analysis
- Accurate gaze direction
- Immune to ambient
- AEC-Q100 grade 2 and ASIL-B

Disruptive sensor technology
- 1.6Mpixels & 2.3Mpixels
- 98dB High Dynamic Range
- Background removal
- High effective resolution and contrast at near IR 940nm
- Very low noise at high temperature

Perfect use in a 3D sensing system
- Using Stereo or Structured Light
- Robust driver identification
- Head distance to dashboard
- Head position confirmation

Perfect for 2D + 3D depth map
- 2D High resolution
- Accurate Depth Map
- HDR Global Shutter
- With Stereo or Structured Light
In-cabin Sensing
Near-IR Camera System

Global Shutter HDR sensor

- GS HDR pixel array
- Dual ADC
- ISP<sub>HDR</sub>
- CPU: Strobe, Power, Thermal sensor, Safety, Host I/F
- Mipi: Parallel

- 8 to 16 bits
- Computer vision
- Sensor control
- Safety manager
- Host SoC

Light power driver
Near-IR Illumination
Rolling Shutter

Near-IR light is ON for a much **longer** amount of time:

→ With this example, NIR Light is ON for 10x longer than exposure time
Near-IR light is ON for a much **shorter** amount of time:

→ Much **lower power consumption** of the Near-IR light and less tiring for human eyes, with Global Shutter.
Near-IR Illumination
HDR Global Shutter

ST 3.2um Global shutter stores two different values, without delay:
→ Enabling in-pixel HDR mode and background removal
• Disruptive dual memory 3.2um Global Shutter
• HDR or background removal computed internally
• No trade-off on the frame-rate, thanks to the dual pipe
• From 8 to 16-bit output to match with various Host SoC
Driver Monitoring
the Need for HDR Sensor, Even at 940nm Pass Only

Even with 940nm only, Sun energy is very high: in-cabin is a strong HDR case

- Images acquired with a 940nm narrow pass light filter
- Same tone mapping applied to both image only for human to see the 15-bits data
- No tone mapping required for Computer Vision, linear data preferred
ST Automotive 3.2um Global Shutter

Background Removal

Sensor outputs only information from the local zone lightning
ST Automotive 3.2um Global Shutter

Background Removal

Only the light from the illumination is kept in the sensor output image.

This feature enables **Background Subtraction**

- Only the local zone illuminated by the NIR light is sent to the host SoC
- Avoiding the Host SoC to analyze irrelevant part of the scene
ST In-pixel Background Removal

No impact on the frame-rate, and no need for external processing
ST 3.2um Automotive Global Shutter
a Unique Disruptive Technology

- **ST high density storage in-pixel**
- **Low total noise at high temperature**
- **Very good intrinsic Dynamic range**
- **Linear HDR mode**

### Dynamic Range @ 60°C

<table>
<thead>
<tr>
<th></th>
<th>2x 8.3ke-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Full Well</td>
<td></td>
</tr>
<tr>
<td>Usable Full Well</td>
<td>2x 7.1ke-</td>
</tr>
<tr>
<td>Total Noise</td>
<td>2.75e-</td>
</tr>
<tr>
<td>Temporal noise + FPN</td>
<td>2.35e- @ 25°C</td>
</tr>
</tbody>
</table>

#### Dark current @ 60°C

<table>
<thead>
<tr>
<th></th>
<th>Memory zone</th>
<th>Photodiode zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory zone</td>
<td>5 e-/s</td>
<td>22 e-/s</td>
</tr>
<tr>
<td>PRNU</td>
<td>0.4%</td>
<td></td>
</tr>
</tbody>
</table>

#### Dynamic Range

- **Dynamic Range @ 60°C**: 68.2dB
- **Dynamic range Ratio long/short @ 60°C**
  - 4: 80dB
  - 8: 86dB
  - 16: 92dB
  - 32: 98dB

Above ratios are examples, any long/short integration times can be used within their ranges.

- **Very low noise**
- **Very low dark current robust to high temperature**
- **High intrinsic dynamic range**
- **In-pixel linear HDR mode or Background removal mode**
Competition

ST sensor

Useable Signal

Cross-talk

Useable Signal

Signal swing of sensor with same QE or sensitivity

Competition

ST sensor

• Low crosstalk is key for computer vision
• Crosstalk can be considered as a ‘noise’

Increases the QE is not good if it increases the crosstalk significantly

Pixel to Pixel Crosstalk

Crosstalk is worst in Near-IR

Charges
Charge creation from photon happens deeper in the photodiode

...Limiting the crosstalk is much more difficult with Near-IR wavelengths than with visible light

Blue
Green
Red
Near-IR

Pixels

Photons
Lower Sensor Crosstalk → Higher MTF

What is MTF?
- Modulation
- Transfer
- Function

Input scene
From left to right, low to high spatial frequency

Image sampled by the sensor

Data of one line
With spatial frequency increasing, the details of the image are attenuated. The low number of details is lowering the easiness for computer vision to detect and understand the scene.

MTF is a measure of contrast loss:
- 100% → no contrast attenuation;
- 0% → not any contrast/details remaining
ST Global Shutter pixel approaches the max theoretical limit with outstanding MTF, up to 940nm.

Quantum Efficiency: \(QE_{505\text{nm}} = 73\%,\)  \(QE_{850\text{nm}} = 20\%,\)  \(QE_{940\text{nm}} = 9.3\% @ 60^\circ C\)
Very high sensor sharpness and contrast, even at 940nm
In-cabin 3D Sensing

Global Shutter Image Sensor
- High NIR MTF/QE
- Ultra-low crosstalk
- High frame rate

SoC image Processing
- 2D image
- Depth map

Power driver

2D X & Y
3D X, Y & depth

Flash light for 2D image
Patterned light for depth map

Structured Light requires very high MTF at 940nm

This enables both a high resolution 2D and an accurate depth image
ST Automotive GS Sensor
Engineered for in-cabin Computer Vision

High resolution
Enabling better detections

<table>
<thead>
<tr>
<th>Resolution</th>
<th>1.6Mbp</th>
<th>2.3Mbp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio</td>
<td>4:3</td>
<td>16:9</td>
</tr>
<tr>
<td>Format</td>
<td>1/3”</td>
<td>1/2.5”</td>
</tr>
<tr>
<td>Array diagonal</td>
<td>5.9mm</td>
<td>7.3mm</td>
</tr>
<tr>
<td>Width</td>
<td>1464</td>
<td>1944</td>
</tr>
<tr>
<td>Height</td>
<td>1104</td>
<td>1204</td>
</tr>
</tbody>
</table>

High frame-rate
Enabling lower latencies

1.6Mbp sensor

<table>
<thead>
<tr>
<th>Frame Rate</th>
<th>Resolution</th>
<th>Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 fps</td>
<td>1.6Mbp</td>
<td>2x11 bits</td>
</tr>
<tr>
<td>100 fps</td>
<td>1.4Mbp</td>
<td>2x10 bits</td>
</tr>
<tr>
<td>120 fps</td>
<td>1.0Mbp</td>
<td>2x11 bits</td>
</tr>
<tr>
<td>200 fps</td>
<td>0.6Mbp</td>
<td>2x10 bits</td>
</tr>
<tr>
<td>300 fps</td>
<td>0.1Mbp</td>
<td>2x10 bits</td>
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2.3Mbp sensor

<table>
<thead>
<tr>
<th>Frame Rate</th>
<th>Resolution</th>
<th>Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 fps</td>
<td>2.3Mbp</td>
<td>2x11 bits</td>
</tr>
<tr>
<td>75 fps</td>
<td>1.9Mbp</td>
<td>2x11 bits</td>
</tr>
<tr>
<td>100 fps</td>
<td>1.4Mbp</td>
<td>2x11 bits</td>
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Features full
Enabling powerful system

- 2 programmable light strobes
- 4 light strobes output pins
- 4 frames contexts linkable
- Each frame context includes exposure, strobes, modes, ROI…
- 8 Regions Of Interest

- AEC-Q100 grade 2
- ASIL B support
  Some features seen with higher ASIL level, like dual lock steps CPU, full L/Mbist, ECC,…

Highly Automotive
Enabling high Safety grades

1.6Mbp & 2.3Mbp sensors sampling from Q1’2018
Thank You