A Very Low-Power Human-Machine Interface Using ToF Sensors and Embedded AI

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Agenda

- Introduction to ams OSRAM & 7 Sensing Software
- ams OSRAM TMF882X ToF sensor
- Human-Machine Interface (HMI) applications
- Power of embedded AI
- Conclusion

Introduction to ams OSRAM & 7 Sensing Software

ams OSRAM and 7 Sensing Software

ams OSRAM

- Top 3 global optical semiconductor player
- Market leader in light emitters, sensors, optical modules, sensor interface ICs and algorithms

7sensing SW (an ams OSRAM company)

- Mix of AI, Computer Vision and Embedded Software experts
- Building AI solutions optimized for processing on Edge Platforms

7 Sensing Software
Application areas

AR/VR

- Depth-map densification
- Eye-tracking

Imaging

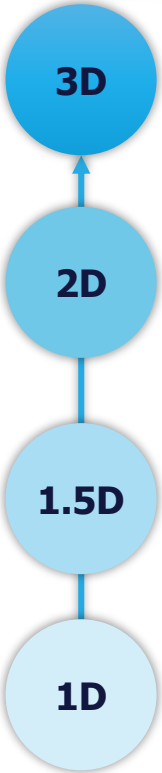
- Spectral-sensor-based AWB
- AI-accelerated image sensor

Human Machine Interface

- Human presence detection
- Gesture recognition
- Head and body pose

Vital Sign

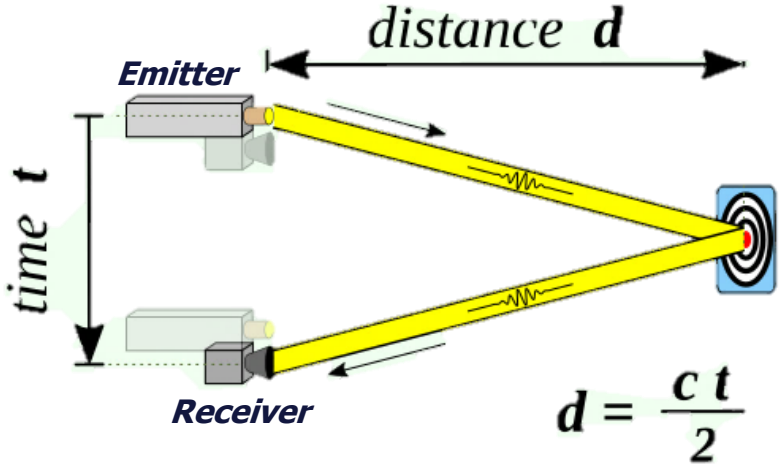
- Blood pressure
- Respiratory rate

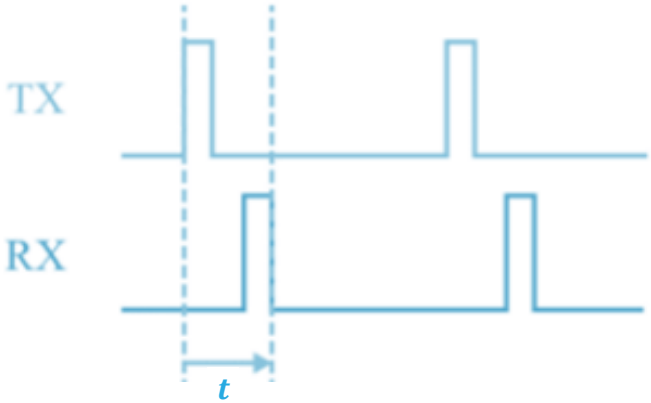


ams OSRAM TMF882X ToF Sensor

What is a Time-of-Flight (ToF) Sensor?

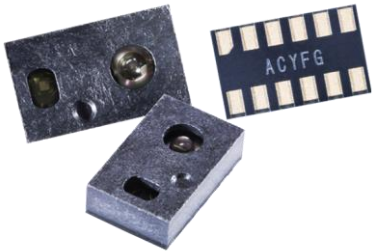
Distance estimation based on time-of-flight of a light pulse reflecting off a target.





ams OSRAM TMF882X ToF Sensor

- Family of multi-zone ToF sensors
- Capture up to 2 distances per zone
- Low power consumption
  (141 mW @ 30 Hz operation)
- Privacy-safe (no biometric data)
- Class 1 eye safe: 940 nm VCSEL
- Distance range: 1 cm to 5 m



2.0 x 4.6 x 1.4 mm

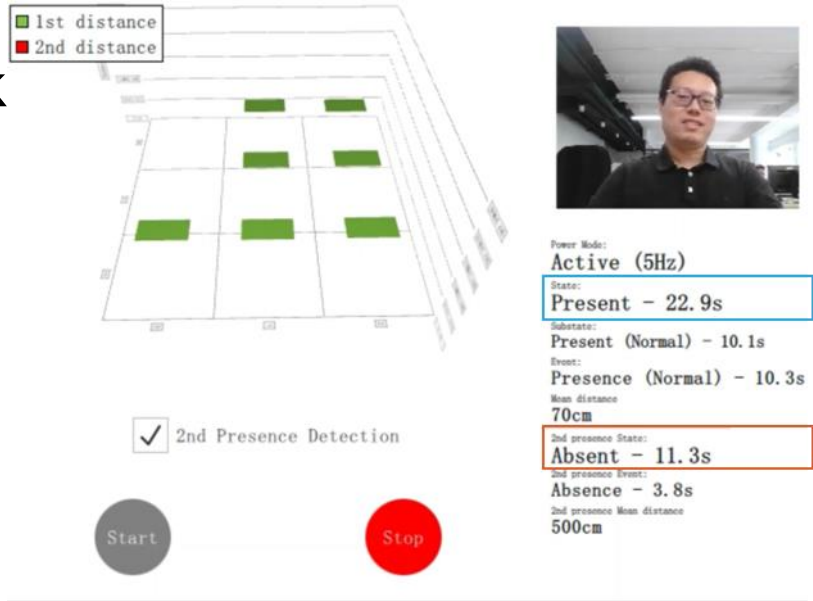
- Configurable Resolution:

	3x3	4x4	8x8
TMF8820	Yes	No	No
TMF8821	Yes	Yes	No
TMF8828	Yes	Yes	Yes

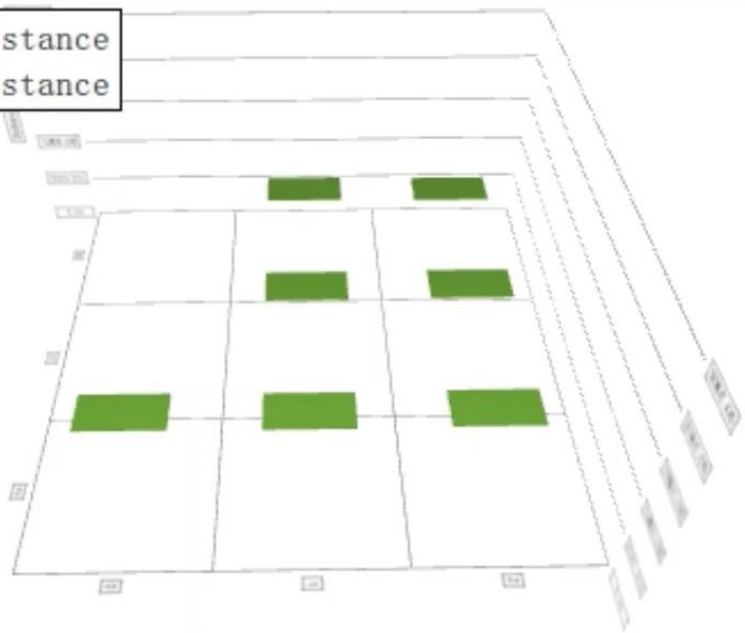
Human-Machine Interface (HMI) Applications

Human Presence Detection

- Target market: Laptop
- Use case: Smart wake-up & leave-lock
- Algorithm capability:
  - Detect user presence
  - Discriminate between still human and inanimate object
  - Detect and warn shoulder surfing
- ToF sensor resolution: 3x3 or 4x4



1st distance
2nd distance



Power Mode:
Active (5Hz)

State:
Present - 22.9s

Substate:
Present (Normal) - 10.1s

Event:
Presence (Normal) - 10.3s

Mean distance
70cm

2nd presence State:
Absent - 11.3s

2nd presence Event:
Absence - 3.8s

2nd presence Mean distance
500cm

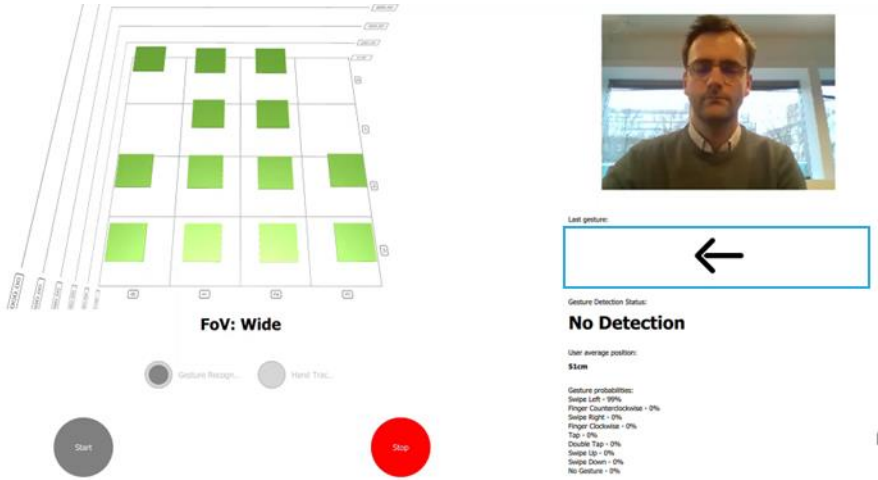
☑ 2nd Presence Detection

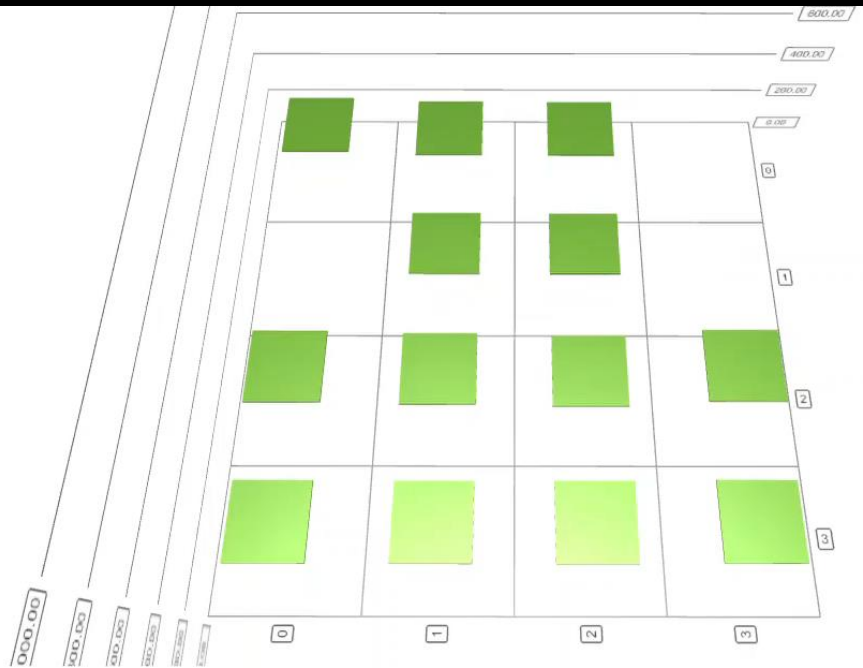
Start

Stop

Gesture Recognition

- Target markets: Laptop, AR glasses
- Use case: Touchless user interface
- Algorithm capability:
  - Recognize up to 9 gestures
  - Robust to long-distance gestures (up to 1.8 m)
- ToF sensor resolution: 4x4





FoV: Wide

Gesture Recogn...

Hand Trac...

Start

Stop

Last gesture:

Gesture Detection Status:

No Detection

User average position:

51cm

Gesture probabilities:
Swipe Left - 99%
Finger Counterclockwise - 0%
Swipe Right - 0%
Finger Clockwise - 0%
Tap - 0%
Double Tap - 0%
Swipe Up - 0%
Swipe Down - 0%
No Gesture - 0%

Cursor Tracking & Tap

- Target markets: Laptop, in-vehicle
- Use case: Touchless user interface
- Algorithm capability:
  - Track hand position
  - Detect hand click / tap
- ToF sensor resolution: 8x8

Start

Stop

User Position

Validity: Valid

User distance: 647 mm

Hand Position

Status: Hand Not Detected

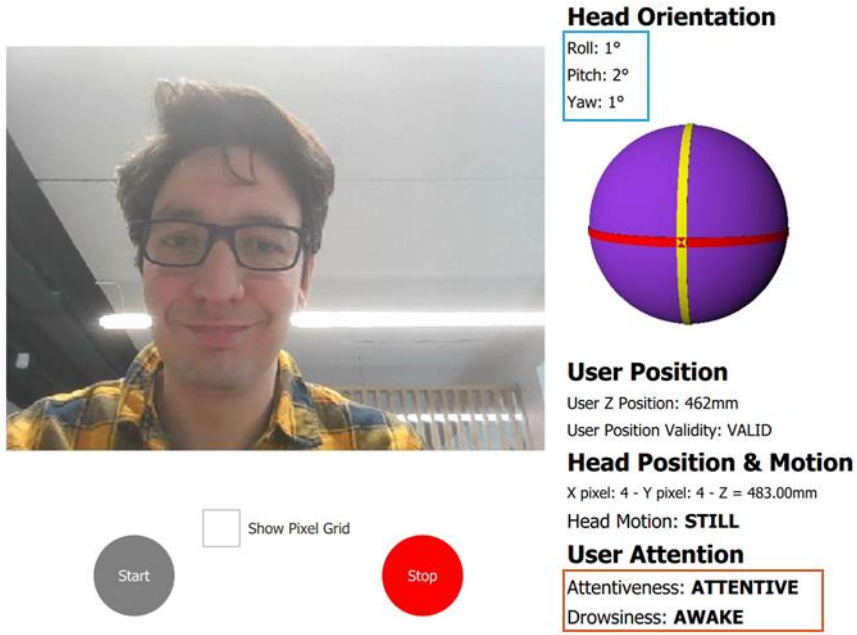
(X, Y, Z): (0.00, 0.00, 0.00 mm)

Click

status Click Not Detected

Head Pose Estimation

- Target markets: In-vehicle, laptop
- Use case: Attentiveness detection
- Algorithm capability:
  - Head orientation angles (roll, pitch, yaw)
  - User attentiveness and drowsiness
- ToF sensor resolution: 8x8



Show Pixel Grid

Start

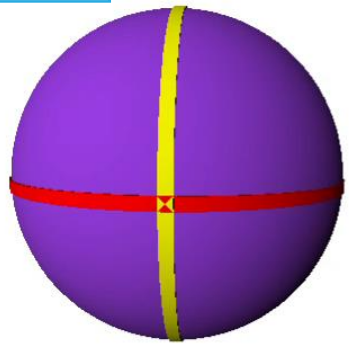
Stop

Head Orientation

Roll: 1°

Pitch: 2°

Yaw: 1°



User Position

User Z Position: 462mm

User Position Validity: VALID

Head Position & Motion

X pixel: 4 - Y pixel: 4 - Z = 483.00mm

Head Motion: **STILL**

User Attention

Attentiveness: **ATTENTIVE**

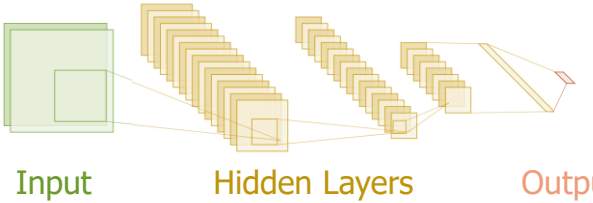
Drowsiness: **AWAKE**

Power of Embedded AI

Inside Our AI Algorithms

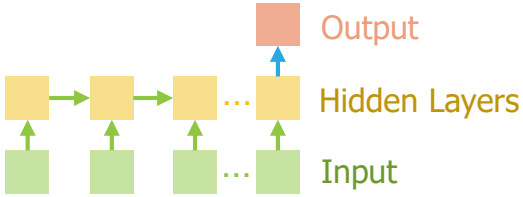
Deep Learning (DL) models:

- Tailor-made for multi-zone ToF sensor data (e.g., 3x3 time series)
- Trained with augmented data to address real-life diversity
- Optimized performance & model footprint



Convolutional Neural Network (CNN)

- Human Presence Detection
- Head Pose Estimation



Long Short Term Memory

- Gesture Recognition

Embedding Our AI Algorithms

- Our AI algorithms are portable to any **microcontroller** (MCU)
  - No need for AI acceleration
- They are based on our **Deep Learning Integration Framework**
  - ✓ Written in **C** with static memory allocation
  - ✓ Compatible with most deep learning operations/layers
- Example: Embedded in laptop's sensor-hub microcontrollers (e.g., ARM Cortex M4 @ 64 MHz)
  - ✓ Low latency: **~19 ms** for one gesture recognition
  - ✓ Small memory footprint: **16 KB** RAM + **58 KB** Flash

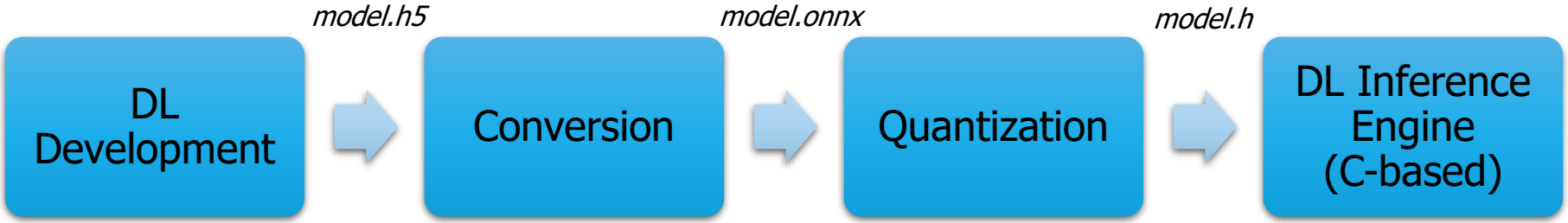
Our Deep Learning Integration Framework

Convert DL model (ONNX) to **C code**
DL Inference Engine specifically for **MCU** (C-based engine)

Support common DL **operators**: CNN, RNN, BatchNorm…
Support common DL architectures: ResNet, DenseNet...

Support 8-bit, **16-bit and 8/16-bit hybrid** quantization,
Optimize footprint/latency while preserving accuracy

Our Deep Learning Integration Framework
Workflow for deployment on the edge



- Train DL model (Keras, Tensorflow, Pytorch…)
- Optimization

- Convert DL model to ONNX

- 8-bit
- 16-bit
- 8/16-bit hybrid

- Run on all MCU platforms
- Low latency / memory footprint

Conclusion

To Summarize

- We developed multiple HMI applications using low-power and low-resolution ToF sensors, preserving privacy.
- Our embedded AI technology makes ToF sensors smart, enabling them to achieve accuracy and robustness.
- We deployed our deep learning based algorithms on MCUs, such as ARM Cortex-M4/M33, Intel and ITE Sensor Hubs.

Resources

More about us

ams OSRAM:
https://ams-osram.com

7 Sensing Software:
https://7sensingsoftware.com

TMF882X ToF Sensors:
https://ams.com/time-of-flight

2023 Embedded Vision Summit

Please check our booth **1102** for more information on our solutions:

- Low Power Human-Machine Interface
- Synthetic Human Dataset for AI training
- Light Sense solution for hyper realistic AR
- Edge AI Solution Services