Smart sensors for transportation

Automotive motion sensors for smart driving

Finite State Machine and Machine Learning Core

Use cases and demo (Stationary / Motion / Jack detection)

GitHub examples, evaluation kits

life.augmented

Automotive sensors for smart driving

6 axis IMU and Accelerometers

- Miniaturization and low power features
- Stability and low noise contribution
- High accuracy and linearity over temperature and time
- Embedded smart features, including Machine Learning algorithms

MEMS Application Examples

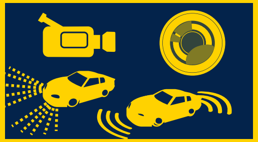
Applications


Key Fob


Active Suspension

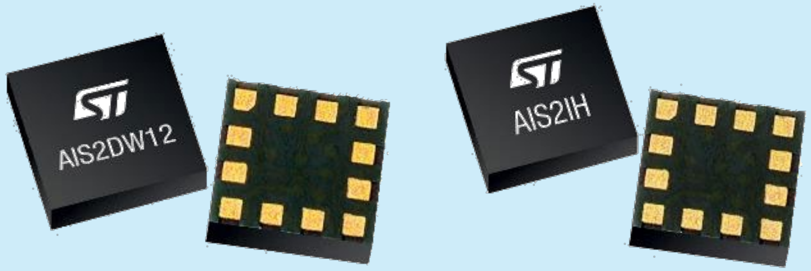

RNC


Navigation Precise Positioning


ADAS i.e. Image Stabilization

Motion MEMS sensors

3-axis accelerometers:

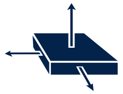


6-axis Inertial Measurement Unit (accelerometer + gyroscope):

3-axis Accelerometers for smart driving

In-Vehicle Infotainment

AIS3624DQ

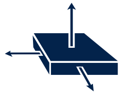


4 x 4 x 1.8 mm

FS: up to 24 g
Specific for e-Call

- 3 axis digital
- **Mid-g range axel: FS: up to 24 g**
- Extended top: -40°C +105°C
- QFN package

AIS2IH



2 x **2** x **0.93 mm**

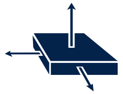
High performance & versatility:
Ultralow power & high resolution / high performance modes

Ideal for navigation, antitheft, TBOX

- FS: ±2g / ±4g / **±8g / ±16g**
- ODR 1.6 Hz to 1.6 kHz
- **Extended top: -40°C +115°C**
- **LGA package with wettable flanks**

Passive keyless entry (PKE)

AIS2DW12



2 x 2 x 0.93 mm

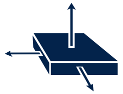
Ultralow power 3-axis digital accelerometer

Superior robustness to mechanical shock and drops

- Cur Cons: 0.67 µA @3 V @1.6Hz
- FS: ±2g / ±4g
- ODR 1.6 Hz to 100 Hz
- **LGA package**

Road noise canceling

AIS25BA



2.5 x 2.5 x 0.86 mm

Audio accelerometer

- **High and flat bandwidth (min 2 kHz)**
- **Low noise (< 2.4 mg_{RMS})**

- FS ±4g / ±8g
- TDM time-division multiplexing interface

life.augmented

6-axis IMU for smart driving

Navigation & In-Vehicle Infotainment

ASM330LHH

2.5 x 3 x 0.86 mm

Auto NON-SAFETY
AEC-Q100 qualified
Low AVAR (ARW, BI)
High stability over temperature

- Extended temp. range: -40 °C to 105 °C
- High stability

ASM330LHHX

2.5 x 3 x 0.86 mm

Auto NON-SAFETY
Low Power Modes
Embedded Finite State Machine (FSM) and Machine Learning Core (MLC)

- Extended temp. range: -40 °C to 105 °C
- Low power mode:
  - Accelerometer 32 µA (typ)
  - Combo 520 µA (typ)

ADAS – Chassis & safety

ASM330LHB

2.5 x 3 x 0.86 mm

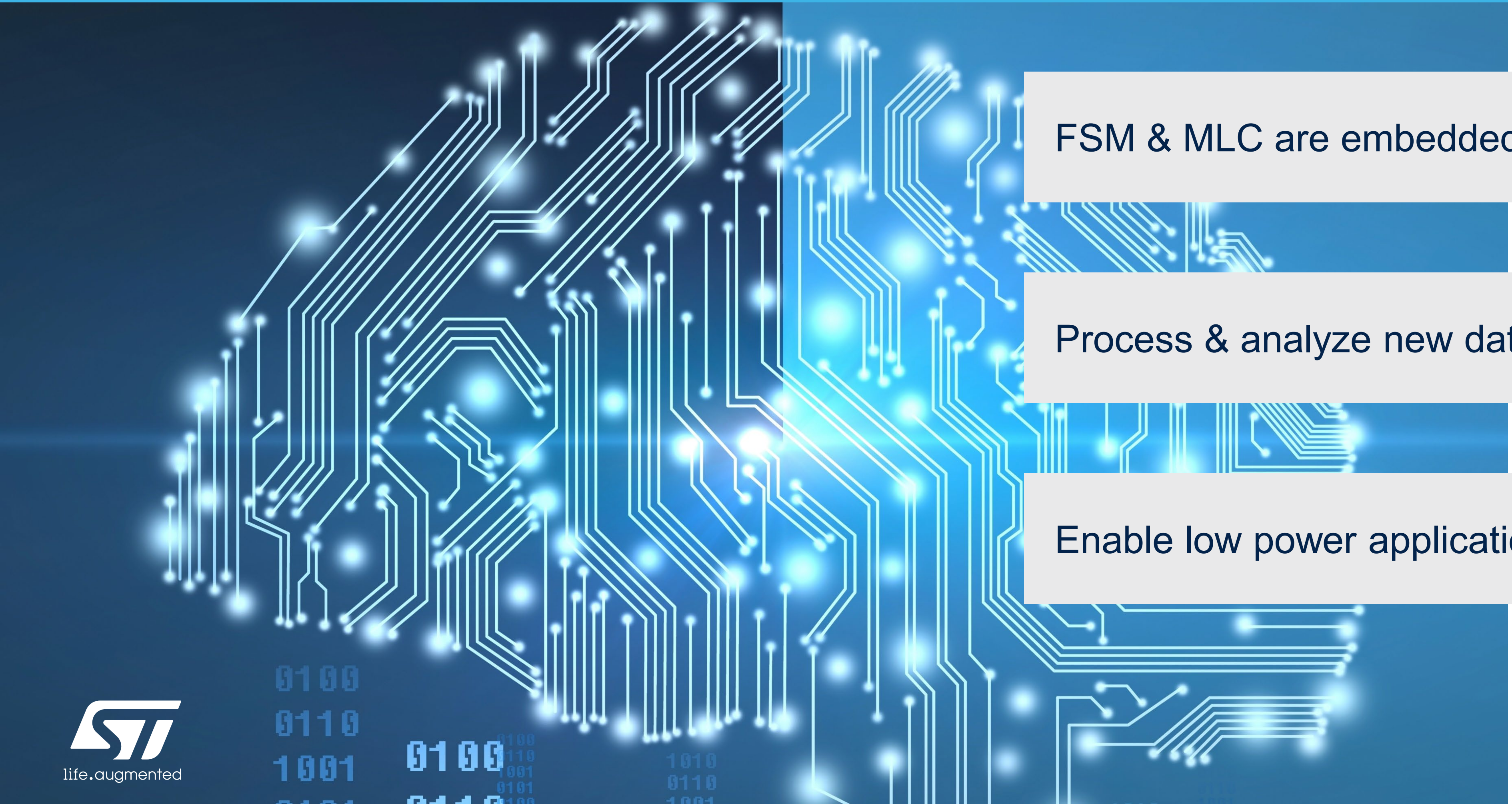
6-axis IMU + SW
solution for ASIL-B systems Embedded FSM & MLC

- Extended temp. range: -40 °C to 105 °C
- Low power mode:
  - Accelerometer 32 µA (typ)
  - Combo 520 µA (typ)
- Offered with specific library to be compatible for ASIL-B systems

AVAR: **A**llan **Var**iance
ARW: **A**ngular **R**andom **W**alk
BI: **B**ias **I**nstability

Finite State Machine and Machine Learning Core

FSM & MLC description and use cases



- FSM & MLC are embedded in the sensor
- Process & analyze new data using trained model
- Enable low power applications

Finite State Machine

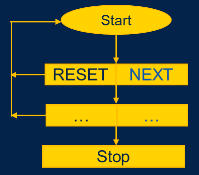
FSM is an in-sensor behavioral model composed of a finite number of states and transitions between states

Motion sensing

External sensors

Finite State Machine

Sensor Data	Signal Conditioning	FSM block
Accelerometer	Sensitivities	Data Sections
Gyroscope	Norm	Instruction Sections



Main processor

FSM is able to generate interrupt signals activated by user-defined motion patterns

Machine Learning Core

MLC is an in-sensor classification engine based on a decision tree logic

Motion sensing

External sensors

Machine Learning Core

Sensor Data
- Accelerometer
- Gyroscope

Computation Block
- Filters
- Digital Pre-defined Features

Decision Tree
- Meta-classifier
- Results

Main processor

MLC is able to **increase accuracy** with a **better context detectability**, **offloading the main processor** while the built-in sensors identify motion data

From a low power sensor to a low power system

FSM & MLC enable low power data processing and reduced interactions with MCU

Machine Learning
microcontroller

Sensing

Raw data

Full activity monitoring processing

Power optimization at system level

Machine Learning
sensor

Sensing
+
FSM & MLC algo

ML data

High-level processing

FSM
up to 16

MLC
up to 8

- Higher computation power at sensor level
- Lower power consumption at system level

Example of sensors MLC programming

Energy saving by running MLC on sensor vs. MCU / AP, unique features such as vehicle stationary versus moving condition

How it works in 5 simple steps and with an intuitive use case:

1

User defines **Classes** to be recognized

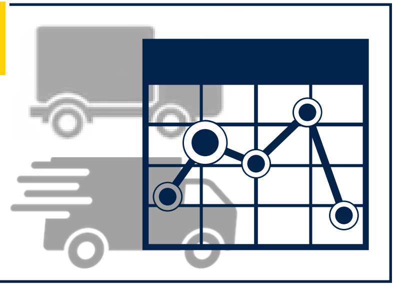
Capture data

2

Label data and select **filters and features**

Label data

3



Build the decision tree based on a wide range of SW tools.

Build decision tree

4

Program the decision tree into the MLC enabled Sensor

Embed decision tree

5

Run the MLC model and process incoming data in real time

Process new data

Use case demo implementation

Demo: Low power MLC implementation

1. Vehicle is stationary: no movement

2. Vehicle is moving forward / backward

3. Vehicle is being jacked up

How is this achieved?

MLC implementation using data from accelerometer and gyro

- **Accelerometer** and **Gyroscope** running at 26 Hz (low power mode)
- **MLC** at 26 Hz: 1 decision tree, 3 outputs

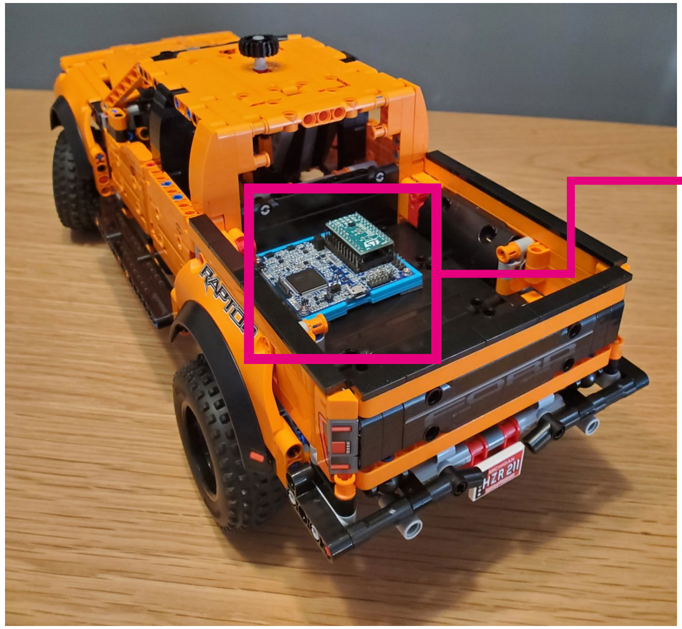
Total Current Consumption: ~475 uA
Model Performance: 97.02% accuracy, RMSE error of 0.1386

In real use case scenarios MLC detection logic can run while the vehicle is turned off

life.augmented

Demo setup & tools

Evaluation board and UNICO GUI with MLC support

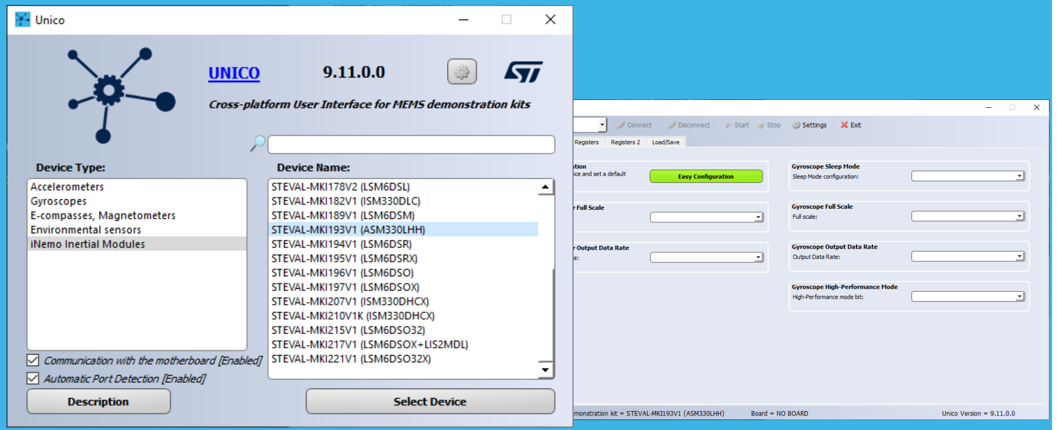


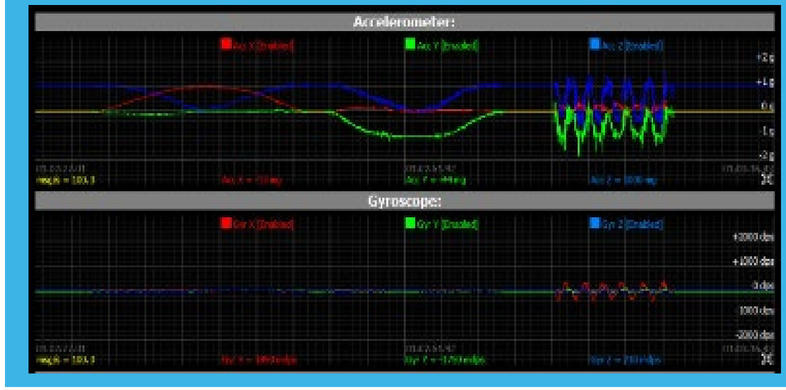
Mother board
STEVAL-MKI109V3

ASM330LHHX Daughter Board

Unico Graphical User Interface

Device selection, configuration and evaluation





MLC on ST's GitHub
Automotive use case examples

LINK

Car motion

- Detection with MLC filters
- Logic is monitoring motion and stationary status
- Detections for all three axes

Accel, (4g, 52Hz)
Gyro (500dps, 52Hz)
→
MLC Features:
- Mean
- Variance
- Energy
- Peak-to-peak
- Min
- Max

→
MLC Output:
- 0 = Motion
- 4 = Stationary

Sensors configuration: 520 uA, MLC 3.1 uA

Tow detection

- Detection with MLC filters
- Logic is monitoring for two different vehicle towing styles:
  - Front/back wheel lift
  - Forward/backward lift with flatbed

Accel, (4g, 12.5Hz)
→
MLC Features:
- Mean on bandpass XL individual axis
- Peak-to-peak on XL individual axis
- Zero-crossing on XL individual axis

→
MLC Output:
- 0 = No event
- 4 = Front/back wheel lift
- 8 = Forward and backward lift with flatbed

Sensors configuration 11.5 uA , MLC 3.1 uA

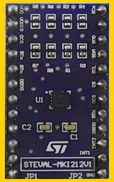
Key Advantage

Detection logic can **run** while **vehicle** is turned **off** → Wake up system & alert user upon event detection

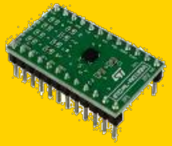
Evalboards based on mother board STEVAL-MKI109V3 and GUI

Mother board
STEVAL-MKI109V3

Daughter boards



ASM330LHHX: STEVAL-MKI212V1



ASM330LHH: STEVAL-MKI193V1

AIS2DW12: STEVAL-MKI206V1

AIS2IH: STEVAL-MKI218V1

Note: any DIL-24 board compatible

Unico Graphical User Interface
Device selection, configuration and evaluation