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Automotive MEMS sensors for transportation

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MEMS and Sensors Marketing

Agenda

1. Introduction: ST MEMS sensors
2. ST MEMS sensors for automotive
3. Application examples based on ST MEMS
4. Finite state machine (FSM) & machine learning core (MLC)
5. Portfolio & roadmap
6. Key takeaways
7. Q&A

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ST MEMS and sensors 2022 focus products

Accelerometers / inclinometers

- LIS2DE12
- LIS2DH12
- LIS2DW12 / LIS2DTW12
- H3LIS331DL
- LIS2DU12
- IIS2DLPC
- IIS3DHHC
- IIS2ICLX
- IIS3DWB
- AIS2DW12
- AIS2IH

Magnetometers / e-Compass

- LIS2MDL
- LSM303AGR / LSM303AH
- IIS2MDC
- ISM303DAC

6-axis IMUs

- LSM6DSO / LSM6DSOX
  LSM6DSO32 / LSM6DSO32X
- LSM6DSR / LSM6DSRX
- ISM330DHCX
- ASM330LHH/ASM330LHHX

Environmental

- STLM20 / STTS751
- STTS22H
- LPS22HH / LPS22DF
- LPS27HH(T)W / LPS28DFW
- ILPS22QS

Microphones

- MP23ABS1 / IMP23ABSU
- MP34DT05-A / IMP34DT05
- MP34DT06J
- MP23DB01HP

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Consumer

Industrial

Automotive AEC-Q100

Vehicles of the future

In a deeply evolving automotive scenario, major trends are already underway

Propulsion

From gasoline to electricity

Electronics architecture

From traditional to domain based

Mobility habits

From personal to shared vehicles

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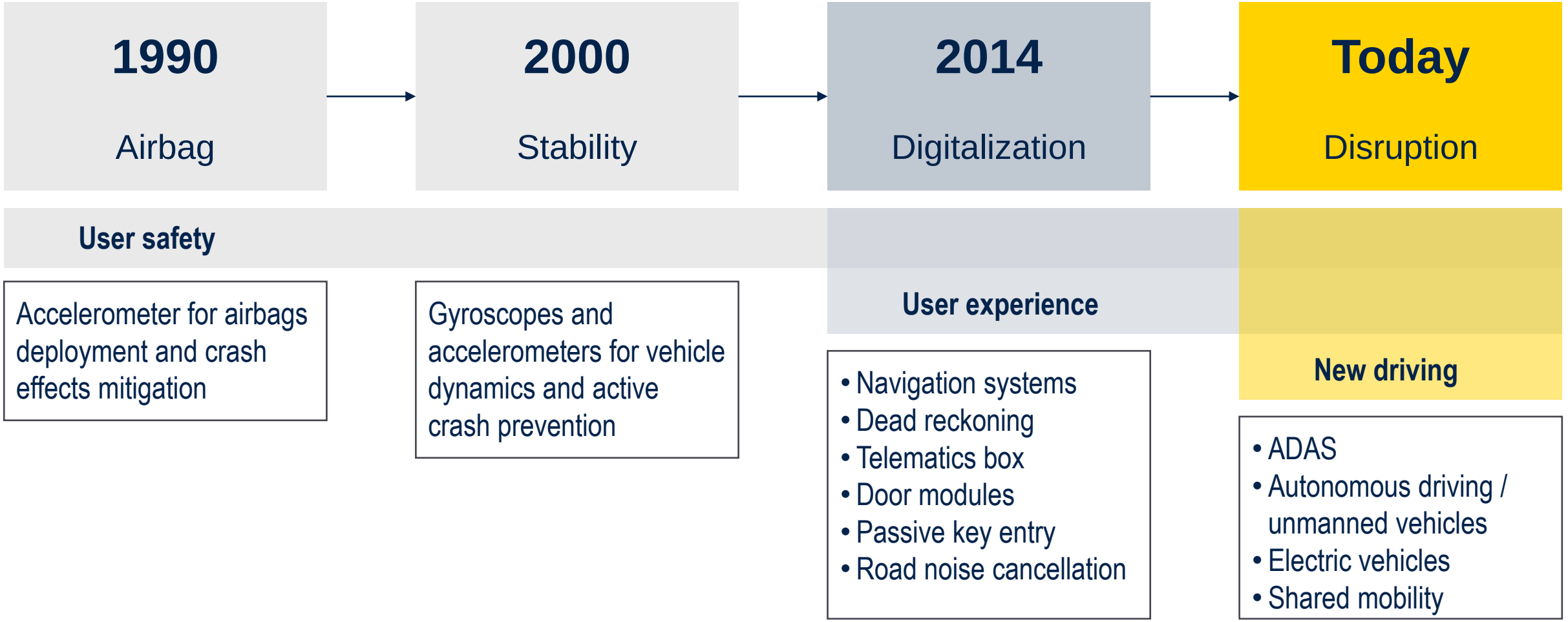
Use of MEMS sensors in vehicles



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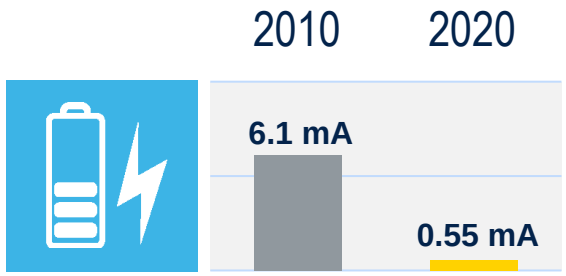
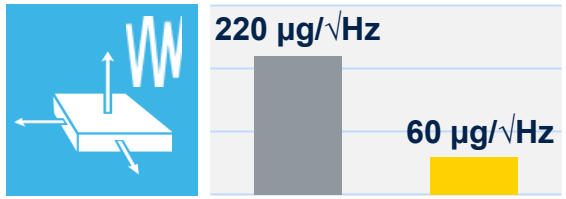
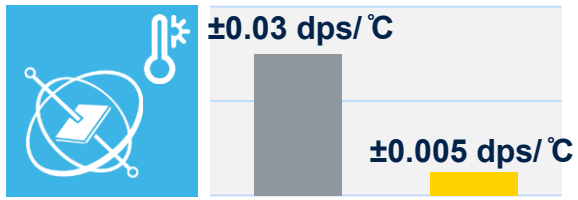
Sensor evolution over a 10-year period



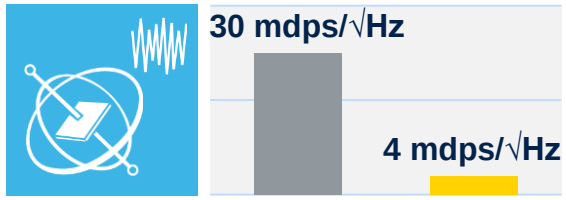
91%
Power reduction



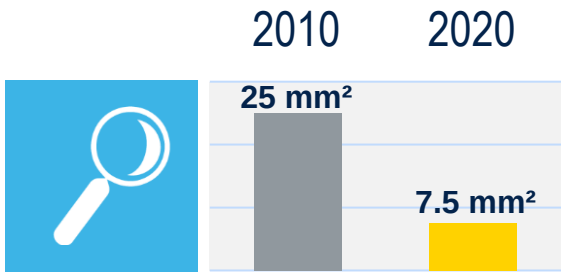
73%
Accelerometer noise reduction



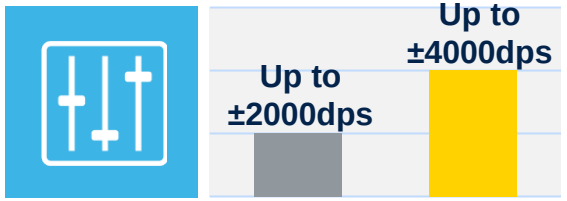
83%
Temperature stability improvement for gyroscope



87%
Gyroscope noise reduction



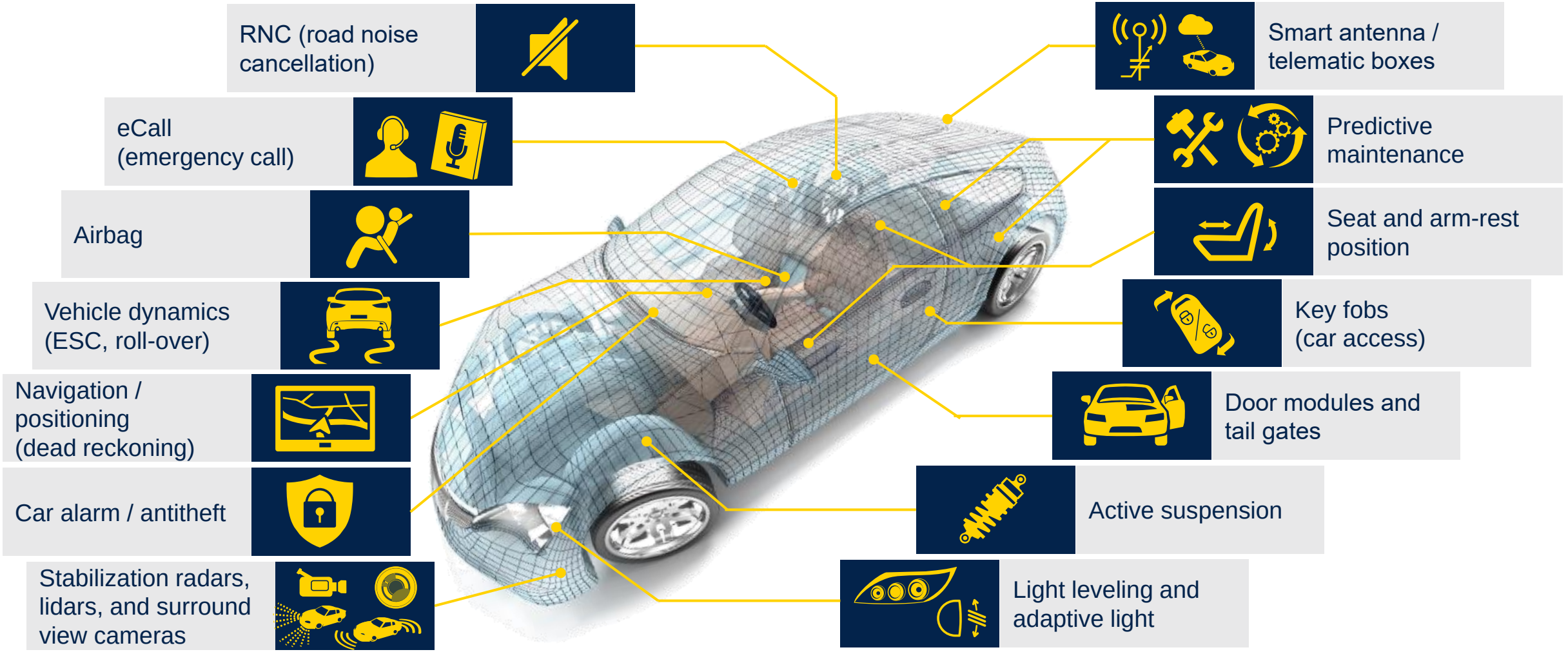
70%
Size reduction



100%
Increase in full-scale Range

Embedded finite state machine and machine learning core

Sensors in vehicles



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ST MEMS sensors for automotive

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Addressing applications with sensors

AI enhancing all applications

Electrification

- Road noise canceling
- Battery monitoring
- Condition monitoring
- Door modules

Connectivity

- Navigation / V2X
- Telematics boxes
- TPMS
- PKE (passive keyless entrance)

ADAS

- Navigation (Level2)
- Precise positioning (level2+ & Level3)
- INS modules (level2+ & Level3)

Shared mobility

- Precise positioning (level2+ ,Level3 and above)
- INS modules (level2+ and Level3)

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Broad ST sensor range

Electrification

AIS3624DQ / AIS2120SX
High-g accelerometers

AIS25BA
Wide band accelerometer

ASM330LHHX
High-performance IMU

MP23DB01HP
High-performance microphone

Connectivity

AIS2DW12
Ultralow power accelerometer

AIS2IH
High-perf. accelerometer

ASM330LHH
High-performance IMU

MP23DB01HP
High-performance microphone

ADAS

ASM330LHH
High-performance IMU

ASM330LHB
High-perf. IMU–ASIL-B

Shared mobility

ASM330LHB
IMU–ASIL-B or more

Coming soon

Electrification

Vehicle electrification is increasing rapidly, driven by the availability of higher performance, more cost-effective battery technologies, and improved mileage vehicles, as well as ecological awareness, government incentives, and regulation

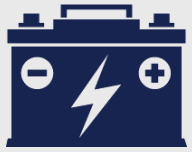
Road noise canceling

Enabling a silent vehicle cockpit

AIS25BA
Wide band accelerometer to sense wheels vibration

MP23DB01HP
Hi-fidelity microphone to enable noise canceling

Battery



Monitor battery safety and condition

AIS3624DQ
3-axis accelerometer for shock detection (±24 g)

AIS2120SX
High-g accelerometer for shock detection (±120 g)

Condition monitoring

Vibration monitoring to assess electric motor condition

ASM330LHH
Wide band 6-axis IMU for vibration analysis

AIS25BA
Wide band accelerometer for vibration analysis

Door module

Enabling smart feature of door (wake up, opening velocity, door lock)

ASM330LHHX
High performance 6-axis IMU with machine learning core for door movement detection

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Connectivity

Devices in an automobile that connect devices to other devices in the vehicle and/or external devices, networks, and services in other cars, homes, offices, and infrastructure

Navigation / V2X

Accurate navigation systems and V2X positioning

ASM330LHH
High performance 6-axis IMU for door movement detection

ASM330LHHX
High performance 6-axis IMU with low power mode and MLC to support always ON and AI

Telematics

DVR, insurance boxes, onboard diagnostic

AIS2DW12
Low power 3-axis accelerometer for battery operated devices

AIS2IH
High perf. accel. for shock detection, inclination, antitheft

MP23DB01HP
Hi-fidelity microphone to support emergency calls

TPMS

Monitor the internal pressure of the tires

SK95*
±480 g accelerometer MEMS for TPMS application

Key-Fob

Enable passive key entry

AIS2DW12
Low power 3-axis accelerometer for battery operated devices

*Contact ST sales

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Application examples based on ST MEMS

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Application examples based on ST MEMS

Navigation / V2X

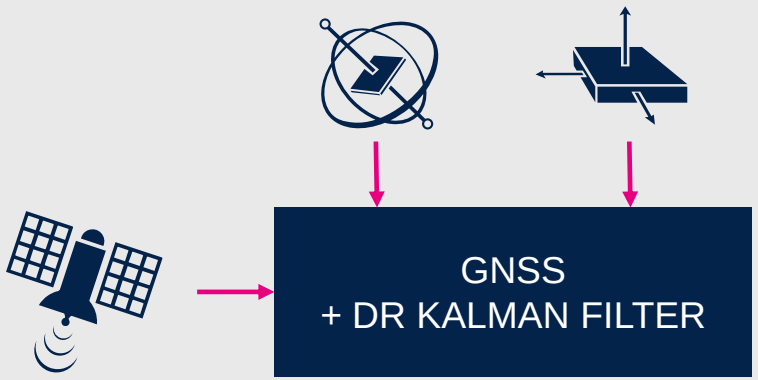
ASM330LHH

A3G4250D

AIS2IH

3 + 3 axis solution

6DOF IMU as GNSS assistant for inertial navigation system



Telematics

On board diagnostic	ASM330LHH	Driving style
Insurance boxes / DVR	AIS3624DQ AIS2IH	Shock detection
Antitheft	AIS2IH	Inclination
eCall	MP23DB01HP	Voice

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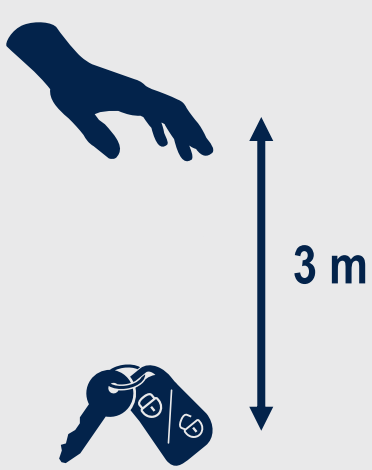
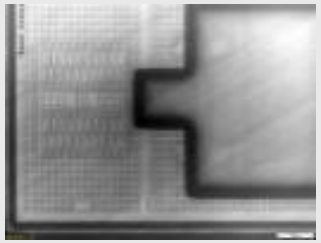
ST AIS2DW12 for key fobs

Robustness

Mechanical shock
(10000g, 0.2 ms; 3000g, 0.5 ms) fully compliant





Drop test successfully **PASSED** in customers test without ANY structure damage

Power consumption

AIS2DW12 is 3x better than competitor

AIS2DW12	
ODR (Hz)	Power consumption (µA)
100	**5**
50	**3**
12.5	**1.3**
1.6	**0.38**

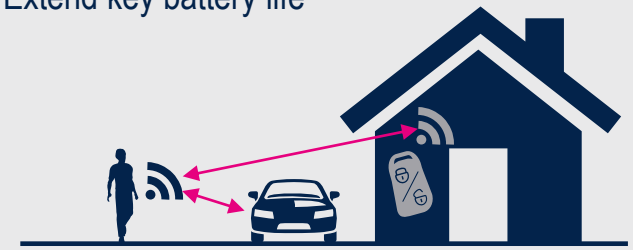
Competitor	
ODR (Hz)	Power consumption (µA)
91	15
38	6.9
10	3.3
2	2.3
1	2.1

Improved security

Standard key communication always ON in LF

AIS2DW12 disabled LF interface when key out from car and no motion detection

- Blocking radio bridge tampering
- Extend key battery life



Thief cloning–key inside home (always transmitting)

No cloning possible–key inside home (RF disabled)

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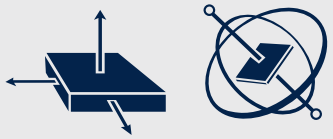
Automotive 6-axis sensors for smart driving

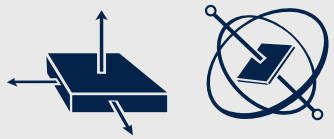
6-axis IMU

- ASM330LHH
- Extended temp. range: -40°C to 105°C



6-axis IMU

- ASM330LHHX
- High performance and low power modes



Key benefits and features

- AEC-Q100 qualified
- Low AVAR (ARW, BI)
- High stability over temperature
- LGA-14L package: 2.5 x 3 x 0.86 mm

Key benefits and features

- Low power mode:
  - Accelerometer 32 µA (typ.)
  - Combo 520 µA (typ.)
- Embedded FSM and MLC

MLC: **Machine learning core**
FSM: **F**inite **state machine**
AVAR: **A**llan **variance**

ARW: **A**ngular **random walk**
BI: **B**ias **instability**

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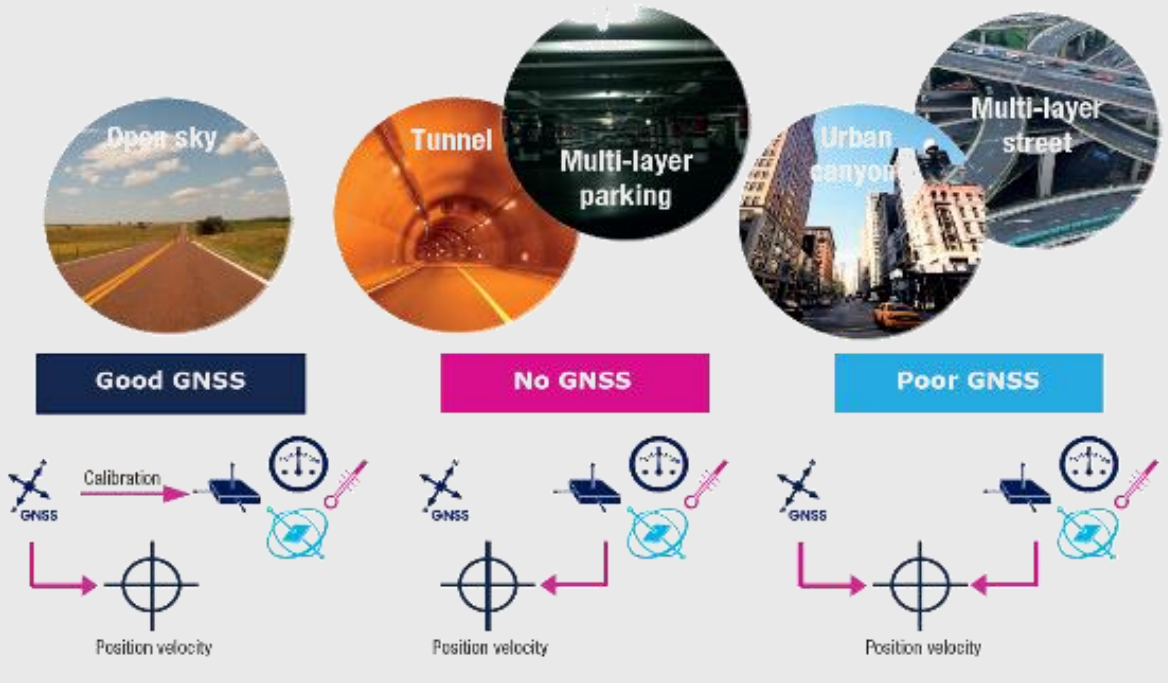
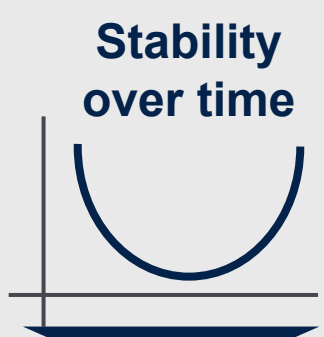
ASM330LHH 6-axis IMU for precise positioning

Navigation application description

Inertial measurement unit for
positioning in dead reckoning



Key application requirements



	Bias instability	Zero rate level over T	Low gyroscope noise
ASM330LHH	3°/h	±0.005 dps/°C	5 mdps/√Hz

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Automotive 6-axis sensors for smart driving

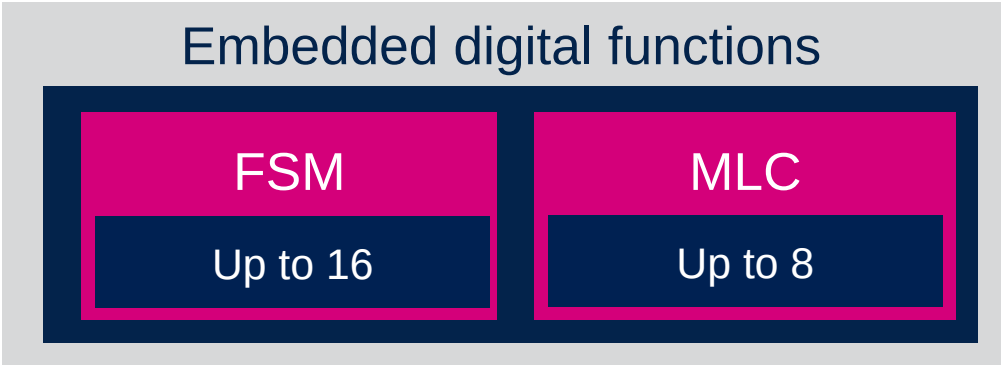
ASM330LHH & ASM330LHHX key specs

- Mechanical characteristics

Allan variance		
Accelerometer	VRW–typ.	0.03 m/sec/√h
	BI–typ.	40 µg
Gyroscope	ARW–typ.	0.21 °/√h
	BI–typ.	3 °/h

VRW: Velocity **random walk**
ARW: **A**ngular **random walk**
BI: **B**ias **instability**

- Smart functions (ASM330LHHX only)



MLC: **Machine learning core**
FSM: **F**inite **state machine**

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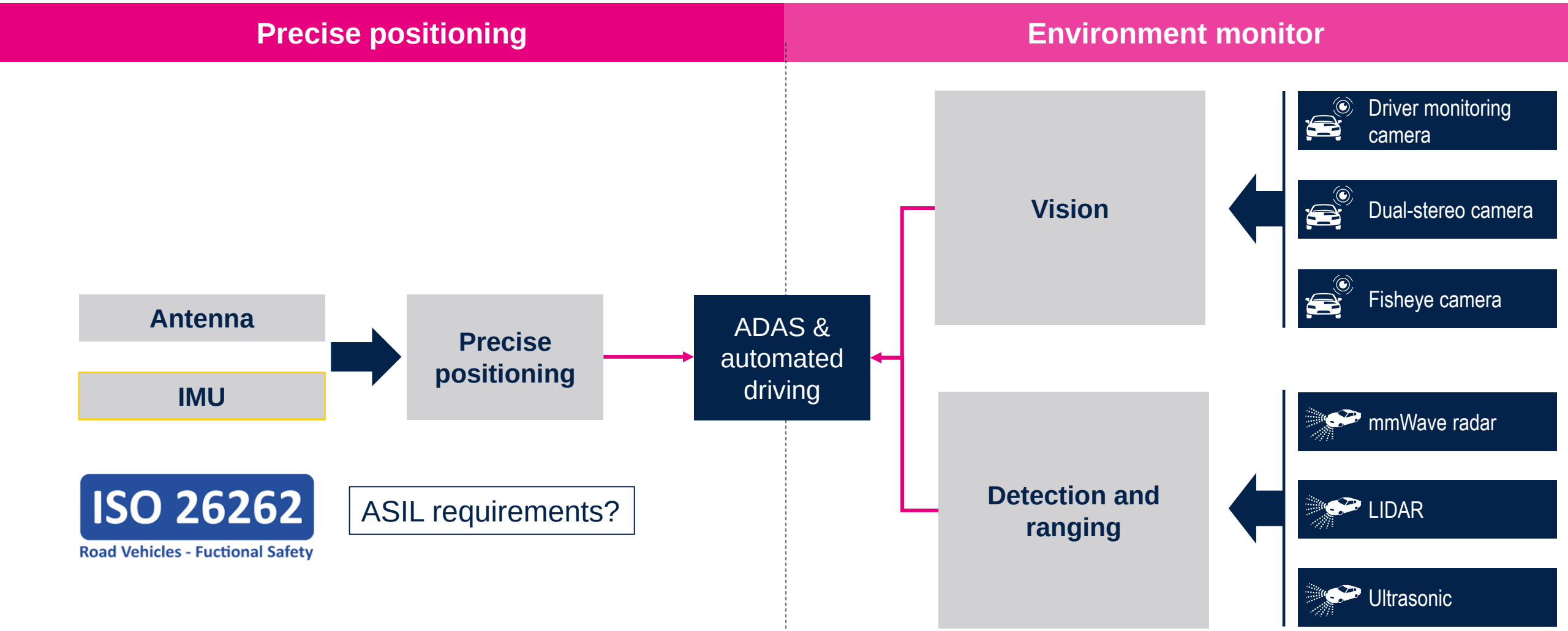
L2+, L3 application partitioning

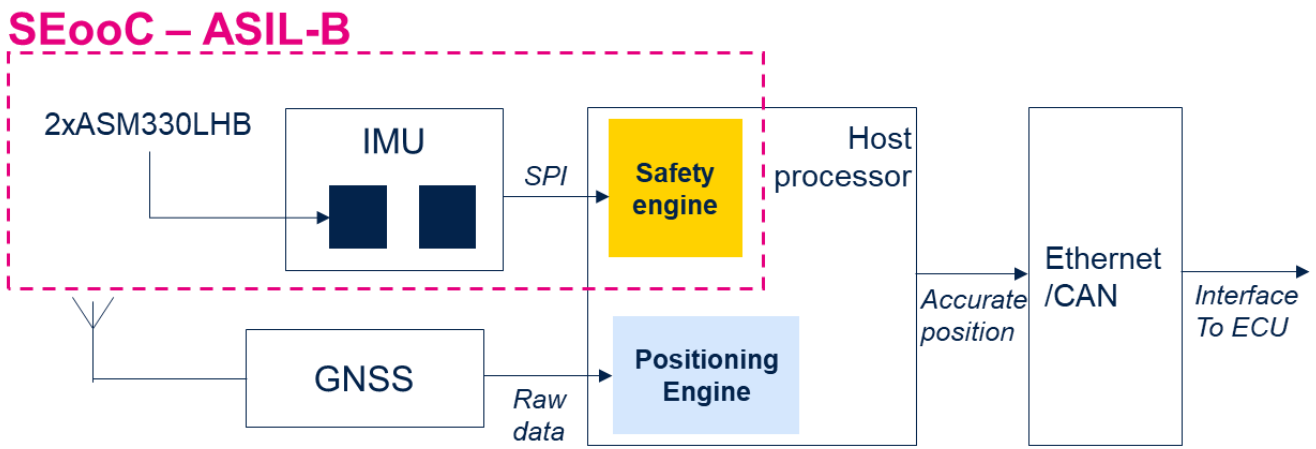


ASIL: Automotive Safety Integrity Level

ST ASIL-B solution overview

Solution

- Solution proposed to customers is based on two devices and a SW library implementing safety requirements:



Navigation control unit

Deliverables

- Define and implement the software library (safety engine) embedding the safety mechanism
- Produce all missing ISO26262 processes and collaterals
- ASIL-B assessment report
- Safety manual for end-customer solution integration

3rd party for ASIL certification

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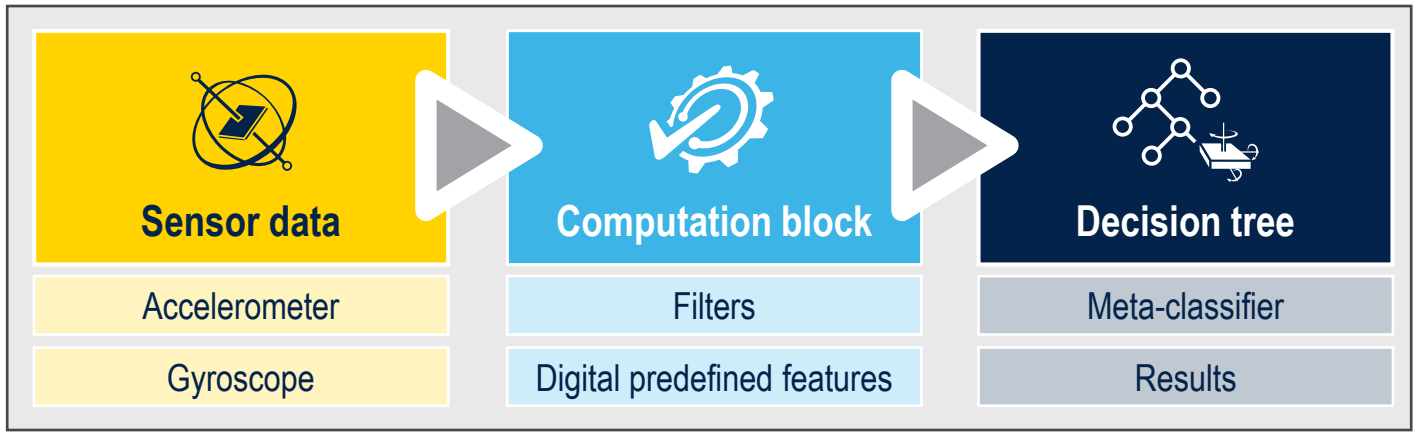
ASM330LHHX 6-axis inertial module with machine learning core and dual operating modes

Customers are adding features such as antitheft or other smart functions **requiring low power operative mode to be supported in always-on**

ASM330LHHX offers **extended voltage range & low power operative mode** together with digital blocks such as FSM and MLC to support developers in the **artificial intelligence and machine learning** domains.

ST offers 3 features enabled with MLC / FSM for automotive applications:

- Vehicle stationary detection
- Detection of vehicle driving on straight line versus turning / curved roads
- Basic driver monitoring (quality of driving) *(in progress)*



An **interrupt** is generated when the decision tree result indicates that the vehicle is stationary.

This interrupt triggers **self-test** functionality in ASM330LHHX driver.

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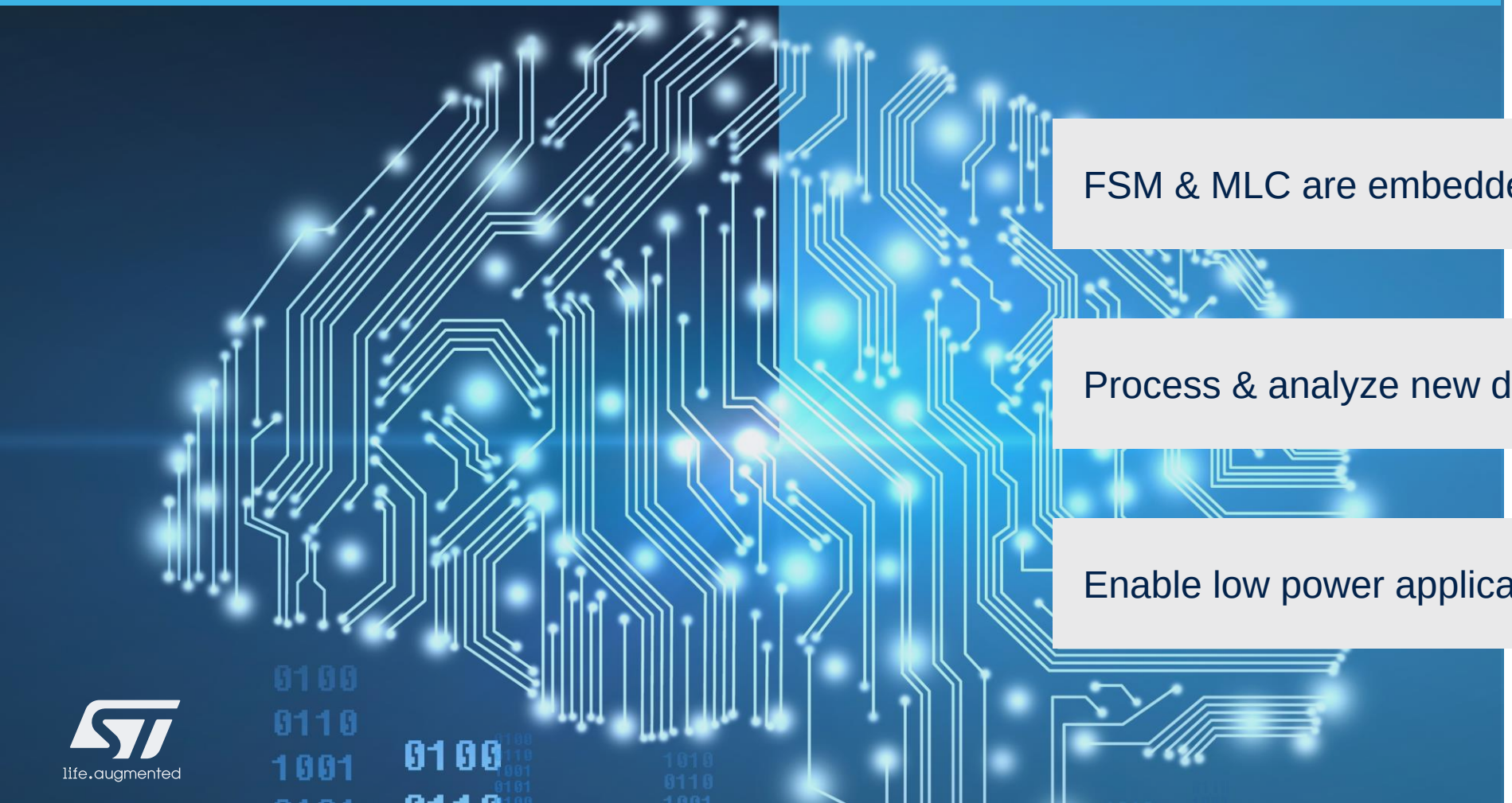
Finite state machine and machine learning core

FSM & MLC description and use cases



FSM & MLC are embedded in the sensor

Process & analyze new data using trained model

Enable low power applications.

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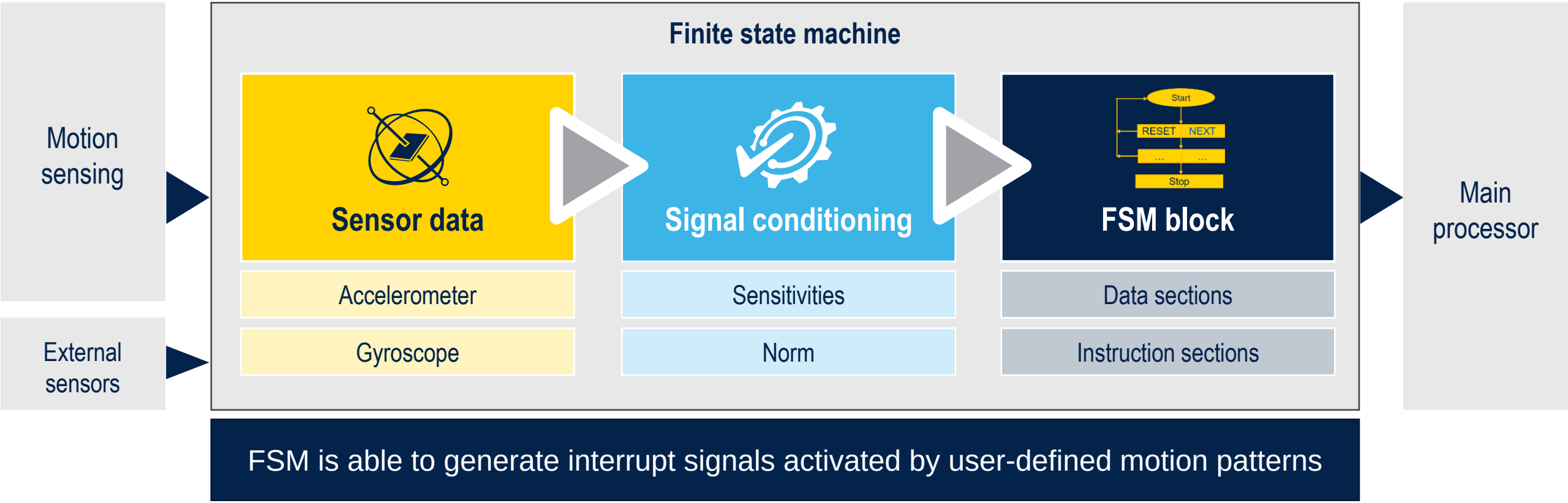
Finite state machine

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



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

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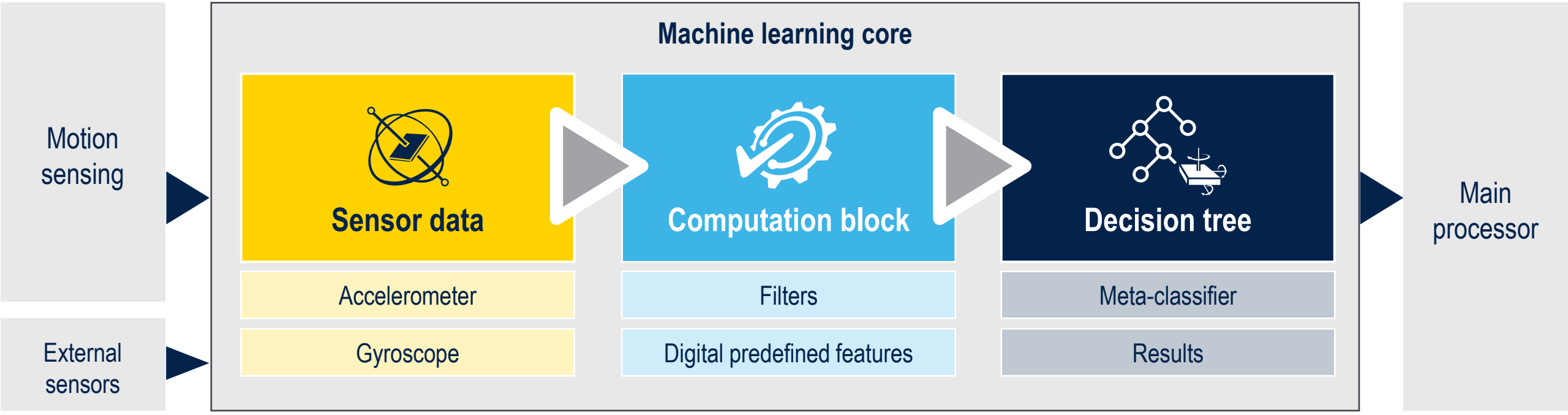
Machine learning core

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



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

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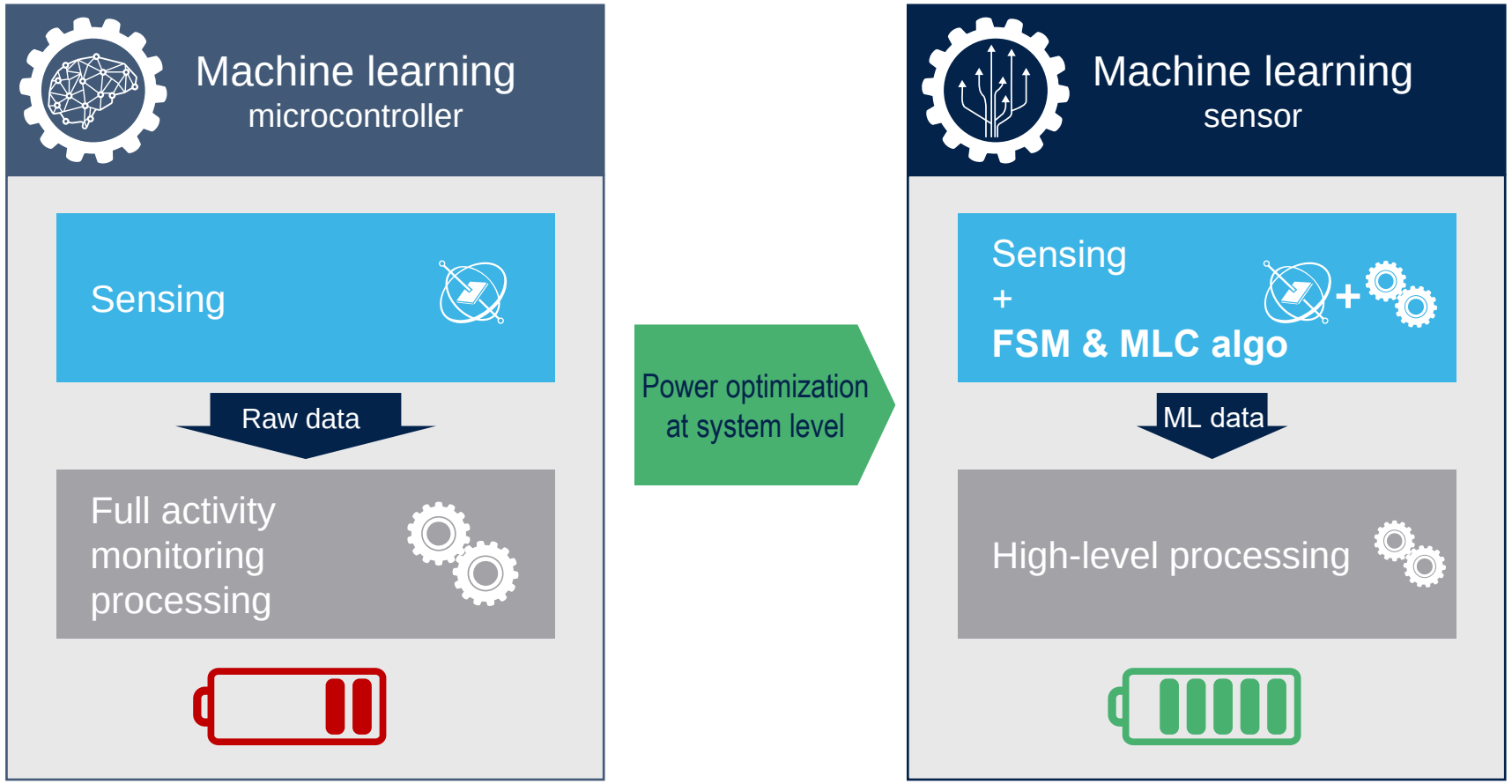
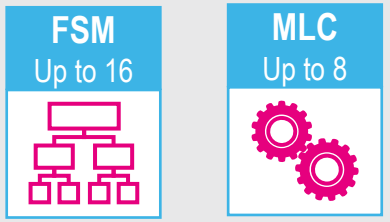
From a low power sensor to a low power system

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





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

Example of sensor 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:

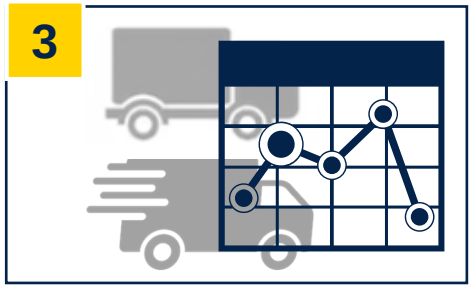
1

User defines **classes** to be recognized

2

Label data and select **filters and features.**

3



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

4

Program the decision tree into the MLC enabled sensor

5

Run the MLC model and process incoming data in real time

Capture data

Label data

Build decision tree

Embed decision tree

Process new data

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Portfolio & Roadmap

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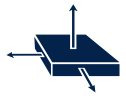
3-axis accelerometers for smart driving

Navigation / TBOX / antitheft / eCall

AIS328DQ



4 x 4 x 1.8 mm

Ideal for navigation and antitheft

MP

- 3 axis digital
- Extended top: -40°C +105°C
- QFN package

AIS3624DQ

4 x 4 x 1.8 mm

FS: up to 24 g
Specific for e-Call

MP

- 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

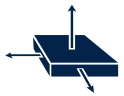
Ideal for navigation, antitheft, TBOX

MP

- 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

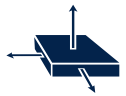
Superior robustness to mechanical shock and drops

MP

- 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})**

MP

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

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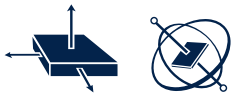
6-axis IMU evolution

ASM330LHH



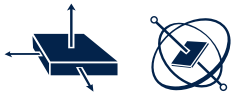
2.5 x 3 x 0.86 mm

Auto non-safety
6-axis IMU

MP

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

ASM330LHHX



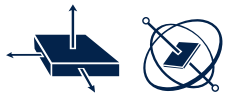
2.5 x 3 x 0.86 mm

Auto non-safety
6-axis IMU with LPM & machine learning core

MP

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

ASM330LHB



2.5 x 3 x 0.86 mm

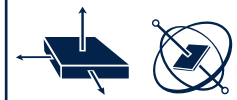
6-axis IMU + SW solution for ASIL-B systems

MP

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

AEC-Q100 grade1

ASM330LHBG1



2.5 x 3 x 0.86 mm

6-axis IMU + SW solution for ASIL-B systems

Q4 ’22

- Extended temp. range: **-40 °C to 125 °C**
- Low power mode:
  - **Accelerometer 32 µA (typ)**
  - **Combo 520 µA (typ)**
- Embedded **FSM and MLC**
- **Offered with specific library to be compatible for ASIL-B systems**

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MLC use case examples on ST GitHub space

LINK

Car motion

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

Accel, (4g, 52Hz) Gyroscope (500dps, 52Hz) → MLC features: Mean, Variance, Energy, Peak-to-peak, Min, Max → MLC output: 4 = motion, 0 = stationary

Sensors Config 520µA, MLC 3.1µA

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 Config 11.5µA, MLC 3.1µA

Key advantage

Detection logic

Can **run** while **vehicle** is turned **off** ➡ Wake up system & alert user upon event detection

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STEVAL-MKI109V3 evaluation motherboard 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

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MEMS brochures and applications notes

Brochure automotive MEMS

Application notes

Product-specific application notes:

- AN5777: ASM330LHHX application note
- AN5826: ASM330LHHX finite state machine
- AN5781: ASM330LHHX machine learning core
- AN5296: ASM330LHH application note
- AN5326: AIS2DW12 application note
- AN5538: AIS2IH application note

General application notes for use of accelerometers and gyroscopes:

- AN5353: How to use a sensor on a DIL 24 socket in X-CUBE-MEMS1 package applications.
- AN4508: Parameters and calibration of a low-g 3-axis accelerometer.
- AN4509: Tilt measurement using a low-g 3-axis accelerometer.
- AN5551: Precise and accurate tilt sensing in industrial applications.
- DT0060: Exploiting the gyroscope to update tilt measure and e-compass.
- DT0140: Tilt computation using accelerometer data for inclinometer applications.

Package and PCB assembly application notes:

- TN0018: Surface mounting guidelines for MEMS sensors in an LGA package.

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And many more on our website www.st.com

Takeaways

ST is #1 in the market for motion MEMS in consumer and automotive non-safety applications.

ST provides **MEMS and sensors** for automotive market.

- AEC-Q100 certification
- Best in class power consumption
- Advanced features like MLC
- 10-year longevity or more

ST provides **development kits** to help with the evaluation of the sensors and quick proof of concept vehicles.

Broad ecosystem of **tools and partners** to enable the use of **machine learning techniques** with ST dev kits and products

Our technology starts with You

Find out more at www.st.com/mems

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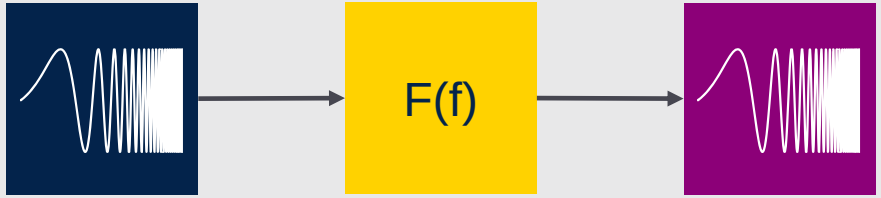
Backup Slides

Road noise canceling

Essential to electric vehicles comfort. Mitigate the only remaining noise source. Achieved withh audio & motion fusion

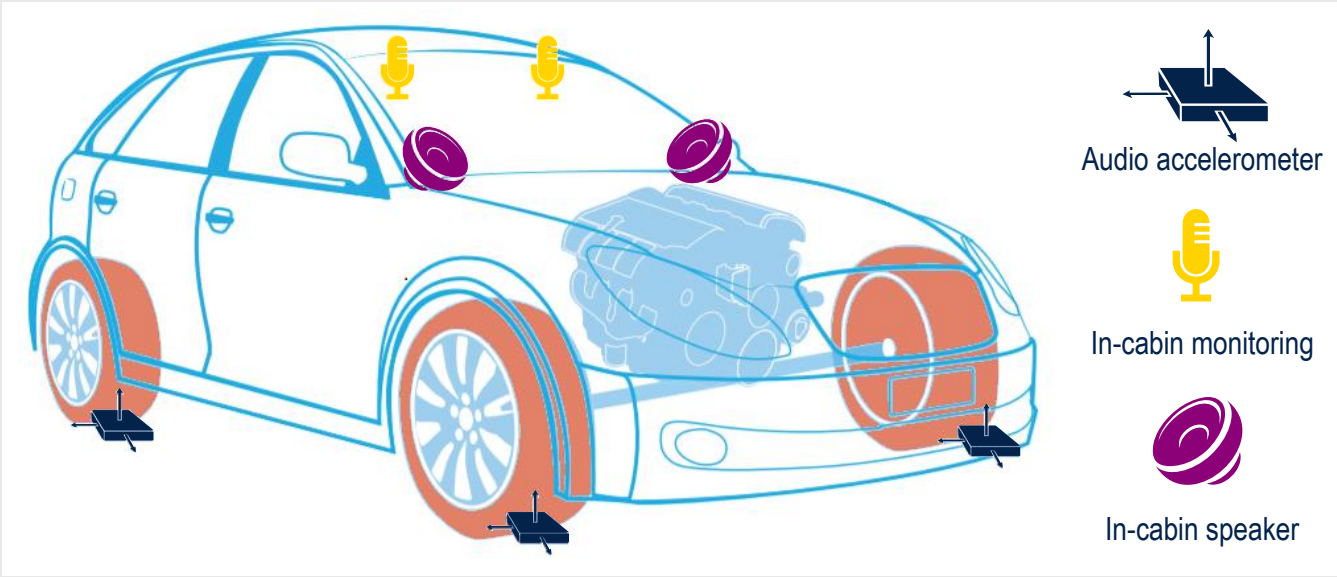
Road noise is picked up by accelerometer and microphones allow the engine to estimate the transfer function from vibration to noise into the cabin. 180° shifted signal is finally injected into the cabin to cancel the noise.



Accelerometers pick the road noise.

Microphones listen in-cabin residual noise.

Speakers play 180° shifted noise.



Product requirements

AIS25BA	Accelerometer with wide bandwidth and low noise
MP23DB01HP	High SNR, High AOP microphone

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Shared mobility