Sensing solutions with Machine Learning capabilities

ISM330DHCX with embedded AI

MLC for AI ready

SensorTile.box for AI & Software Libraries

High accuracy & Low power sensors

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ISM330DHCX
6-axis IMU with Machine Learning Core

Industrial Automation, Dynamic Inclinometer and Stability Control

- **Configurability**
  - Angular rate range: from ±125dps up to ±4000 dps
  - Axel Full Scale: from ±2g up to ±16g
  - Low power and high-performance modes
- **High Accuracy, Stability and linearity over temperature and time**
  - Gyro Offset vs T ±0.005 dps/°C (typ)
  - Gyro Bias Instability 3°/hr (typ)
  - Rate Noise Density 5 mdps/√Hz (typ)
  - Axel Noise Density 60 µg/√Hz (typ) – ODR up to 6.6kHz
- **Programmability & digital features**
  - Programmable Machine Learning Core & Finite State Machines to integrate AI algorithms
  - 9 kB Embedded FIFO
  - Sensor Hub
- **Extended operating temperature range** from -40 to +105 °C

LGA 14L
2.5x3x0.86 mm

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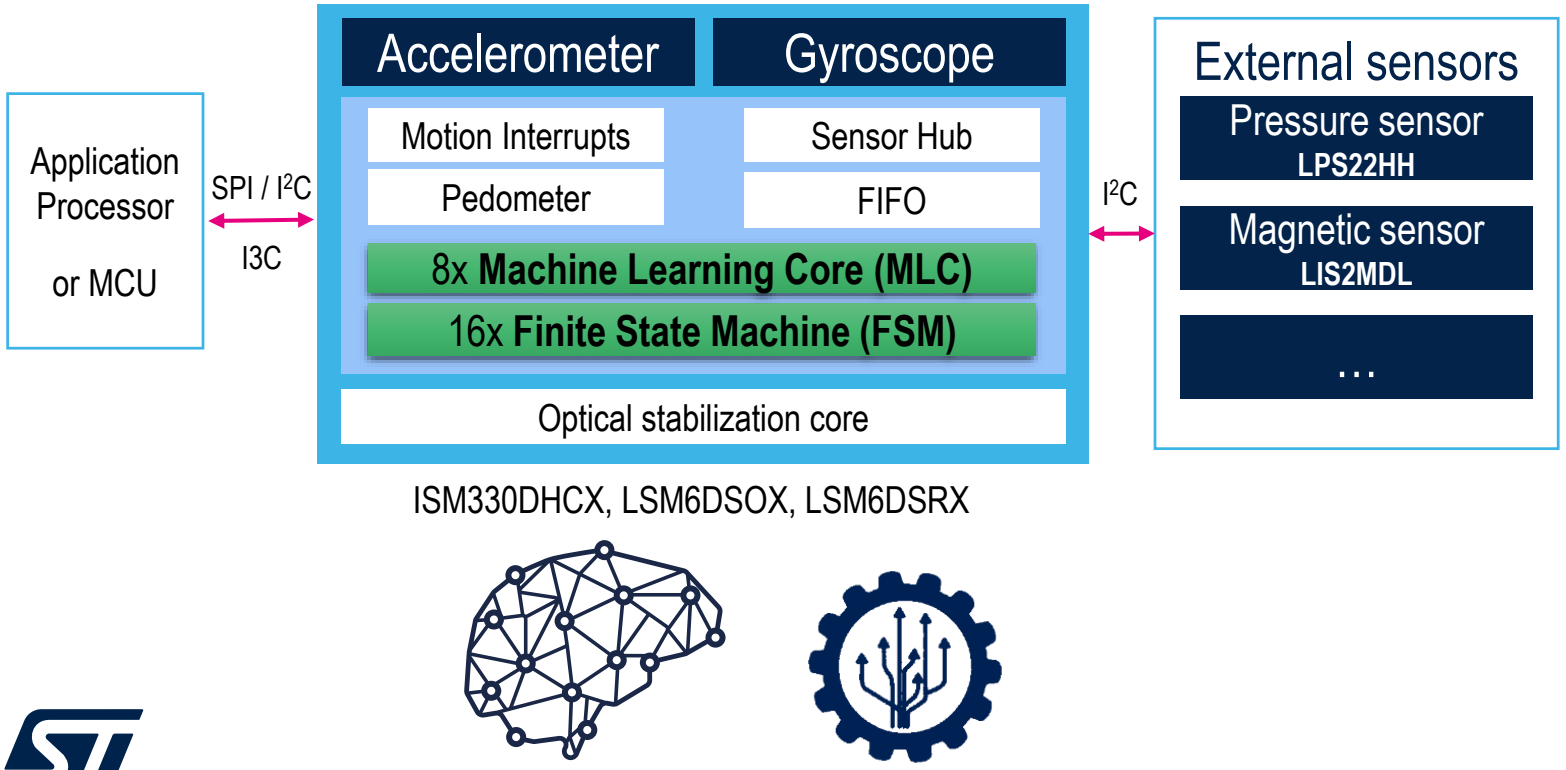
6-axis IMUs with Machine Learning Core

From low power sensor to low power system

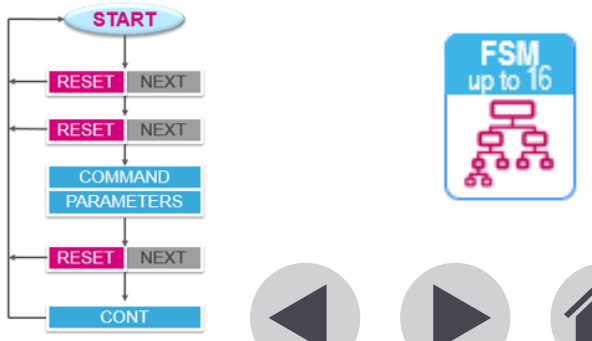
Advanced Features



Embedded AI

MLC with embedded Decision Trees

Finite State Machine



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AI with MLC – the X products

LSM6DSOX, LSM6DSRX, ISM330DHCX (IMUs), IIS2ICLX (Inclinometer)

4x products with MLC

We create the new generation of **sensors**
to allow **developers** exploiting their potential
by improving the overall system **efficiency**

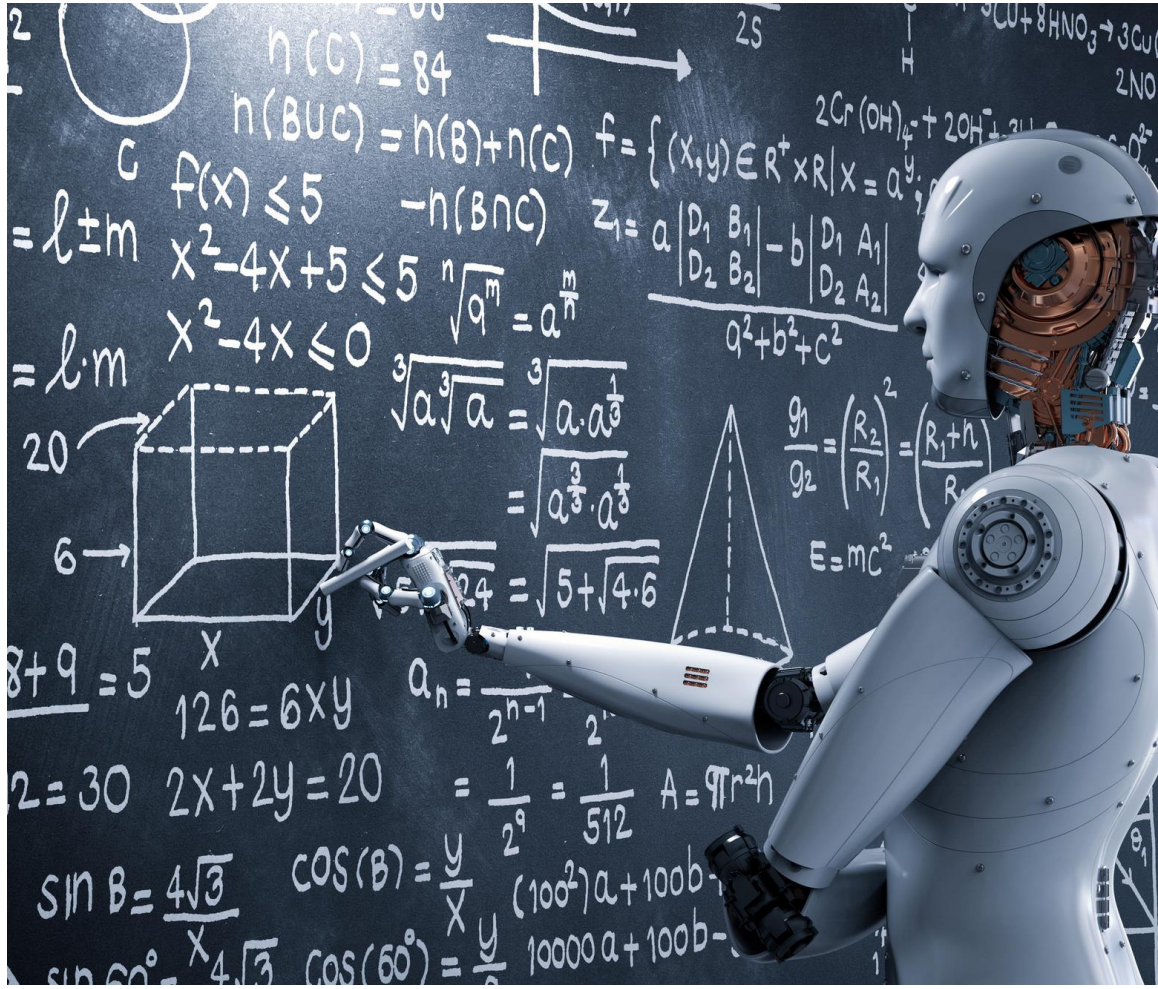
thanks to:

- Reduced power consumption (both sensor and system)
- Increased accuracy (context detectability)
- Real edge computing

And we do this by leveraging Machine Learning techniques

Machine Learning, why do we need it?

When a complex task or problem involves a large amount of data and lots of variables**, but no existing formula or equation can solve it**



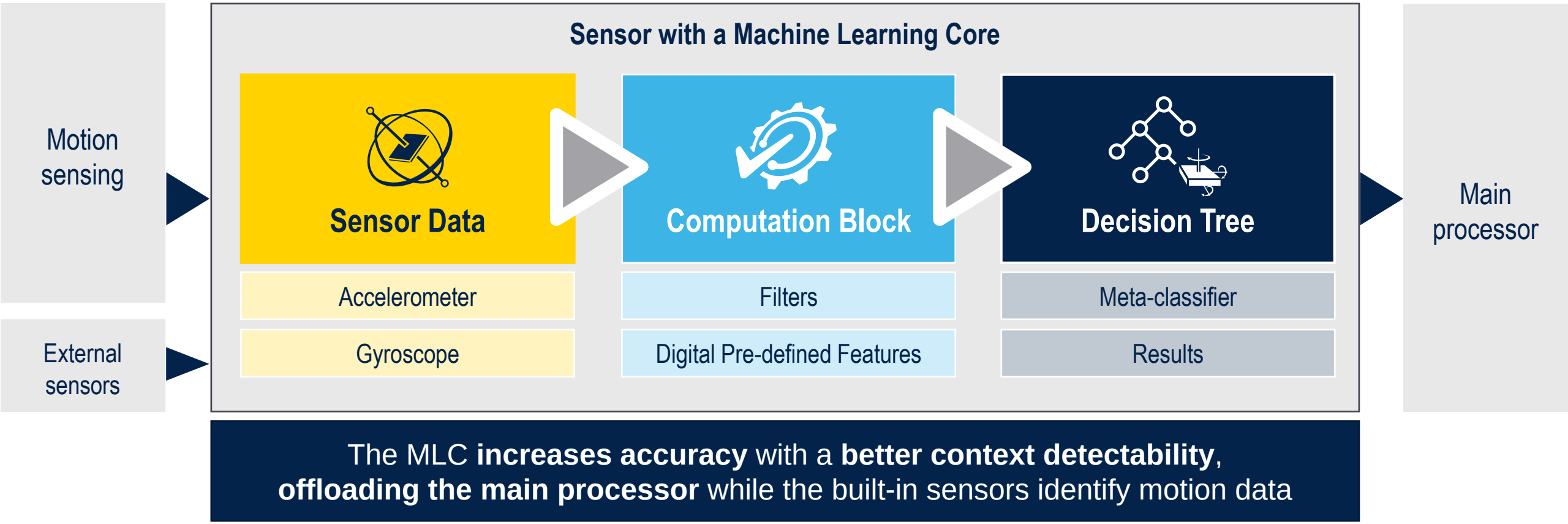
An example of difficult program:

How to recognize the handwritten digits?

- Very difficult to define the rules!
- What makes all these numbers to be identifiable?
- Is there a pattern?
- What is it that makes a 2 to be identified as a 2?

Machine Learning Core (MLC) Definition

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



The MLC **increases accuracy** with a **better context detectability**, **offloading the main processor** while the built-in sensors identify motion data

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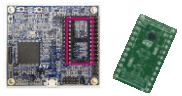
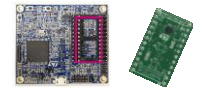
MLC process example for ISM330DHCX

WHAT

Capture data	Label data	Build decision tree	Embed decision tree	Process new data
Accelerometer	Filters	Classification	DT implementation	Real-time test
Gyroscope	Features	Results		
External sensors				

HOW

	Capture data	Label data	Build decision tree	Embed decision tree	Process new data
HW	Unicleo-GUI 				Unicleo-GUI 
SW	Unico-GUI 				Unico-GUI  AlgoBuilder

Unico GUI*

*** External tools for building decision tree:**
Weka, RapidMiner, MATLAB, Python

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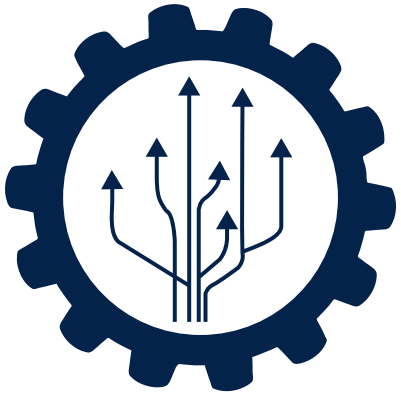
Get inspired

MLC examples are available online at the dedicated **GitHub project for Machine Learning Core**



- Consumer
  - 6D position recognition, Activity recognition, Gym activity recognition, Head gestures
- Industrial
  - 6D position recognition, Motion intensity, Vibration monitoring
- Automotive
  - Vehicle stationary detection

github.com/STMicroelectronics/STMems_Machine_Learning_Core

… and more to come!

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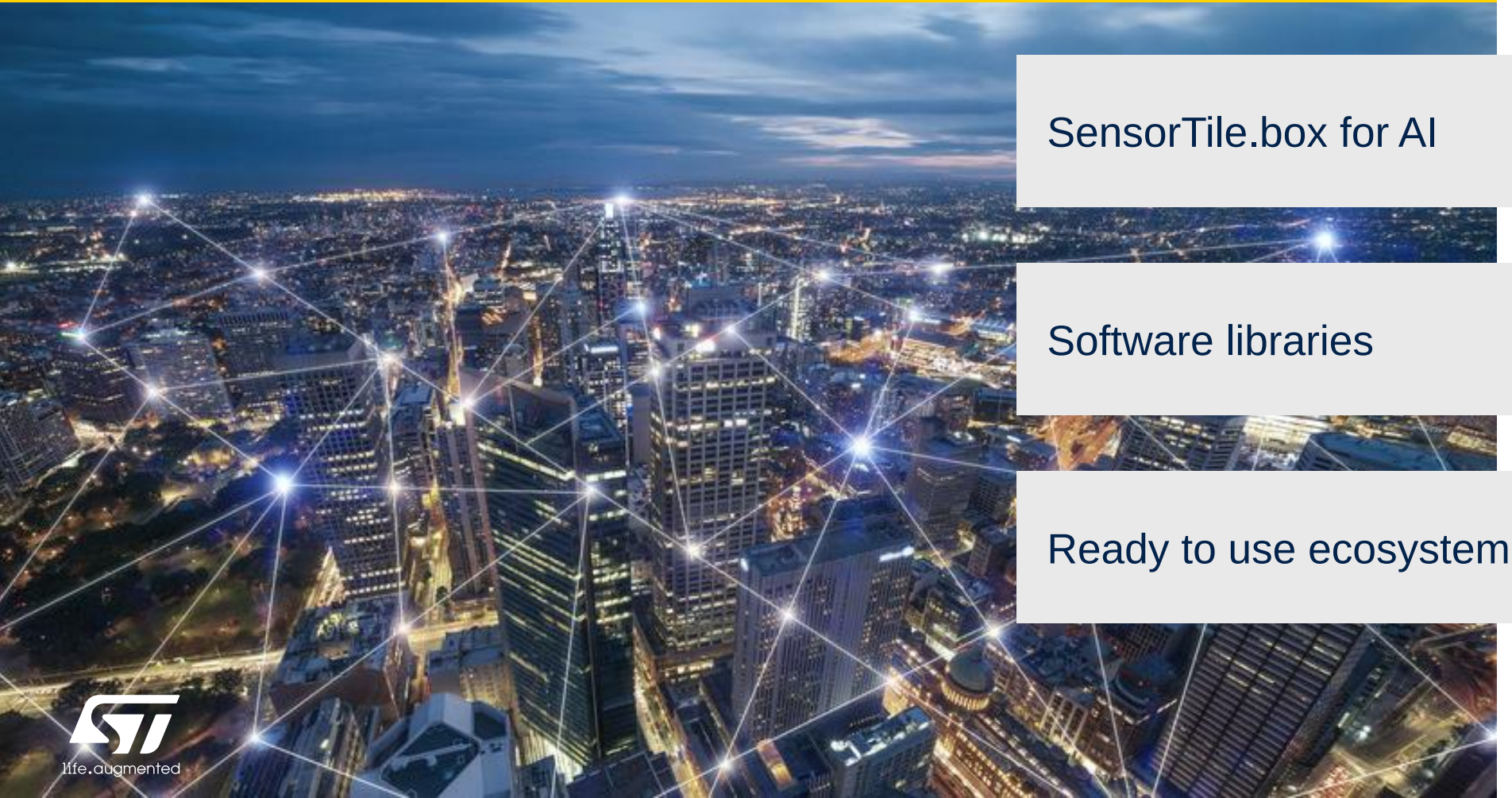
SensorTile.box & Software Libraries

Complete suit of sensor solutions



SensorTile.box for AI

Software libraries

Ready to use ecosystem

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The easiest way to run AI on ST sensor SensorTile.box

The solution for a quick prototype

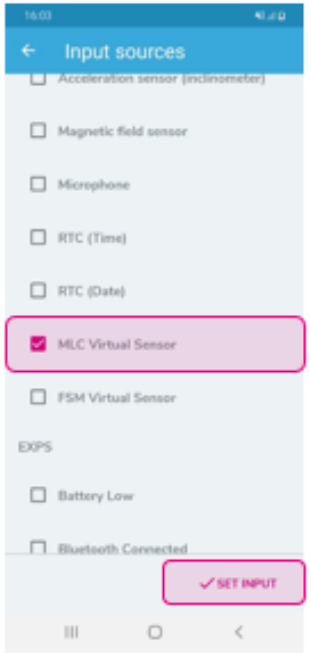
SensorTile.box

SensorTile.box
STEVAL-MKSBOX1V1

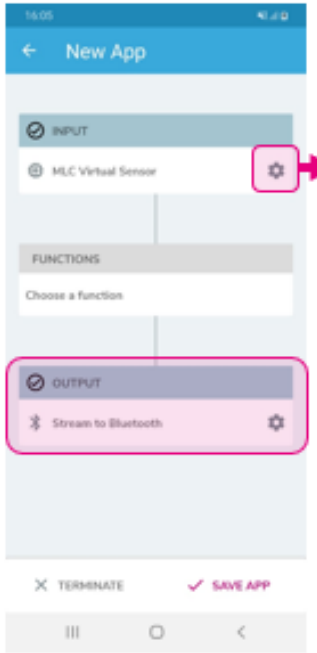
Software package:
STBLESensor mobile app
UNICLEO GUI
UNICO GUI for MLC development

Embed LSM6DSOX

Select "MLC Virtual Sensor"

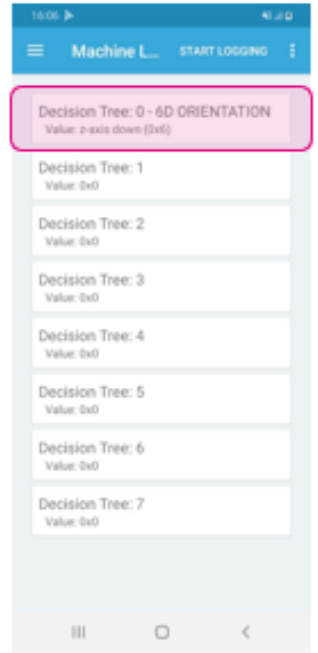


Select output and touch gearbox button on MLC input



Select .ucf file to be used; label outputs

Upload the program and see results



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The easiest way to run AI on ST sensor SensorTile.box

Your entry point to ST MEMS sensors

- Barometer and Temp/Humidity
- Compass & Level
- Pedometer (step counter)
- Sensor Fusion (quaternions)
- Data recorder (on SD card)
- Baby crying detection — NN based
- Vibration monitoring and Training
- Human Activity Recognition — MLC based

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Find SensorTile.box on st.com

Software libraries for industrial applications

Accuracy Calibration

- Accelerometer calibration
- Gyroscope calibration
- Magnetometer calibration
- Sensor fusion

Measuring Monitoring

- Static tilt measure
- Dynamic tilt measure
- FFT & vibration monitoring

Positioning Tracking

- Sensor fusion
- Tilt measure
- Take-off / landing
- Vertical context
- eCompass

Healthcare

- Activity monitoring
- Pedometer
- Pose estimation
- Sleep monitoring
- Fall detection
- Standing vs. sitting

All libraries are available in X-CUBE-MEMS1 package / FP-IND-PREDMNT1 package

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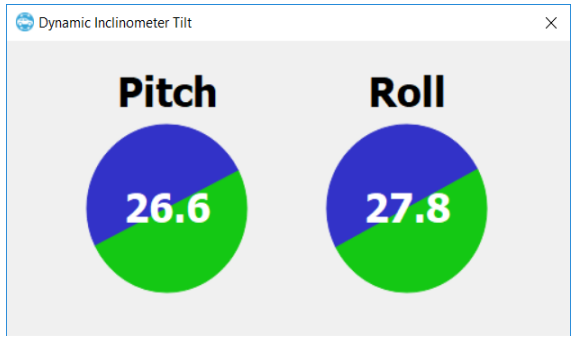
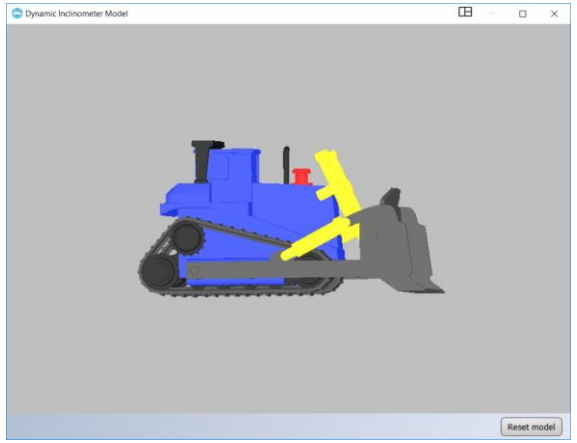
Dynamic Inclinometer Library MotionDI

- MotionDI is a library that provides real-time motion-sensor data fusion and tilt information - accurate estimation of device orientation even in presence of vibrations and motion
- The MotionDI sensor fusion library features:
  - Input data: accelerometer, gyroscope
  - Output data: rotation vector, quaternions, gravity and linear acceleration data
  - Real-time 6-axis motion-sensor data fusion
  - Gyroscope bias calibration
  - Accelerometer bias and scale calibration
- Knobs available for configuration:
  - Calibration frequency: NONE, ONETIME, COUNTINUOUS
  - Thresholds to optimize the performance for various vibration levels.
- Available for ARM Cortex-M3/M4/M7 architectures
- User manual UM2724





Resources requirements:
48.7 kB of code and 6.2 kB of data on Cortex-M4
Note: Real size might differ for different IDEs (toolchain)

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Complete ecosystem offering by ST

All building blocks for IoT devices

- Microcontrollers
- Secure solutions
- Sensors & actuators
- Connectivity solutions
- Power management
- Motor control
- Analog components

Lower barriers for developers getting started

Stackable boards & modular SW

STM32 Nucleo Development & Expansion Boards

Form-factor boards

Discovery Kit IoT Node

SensorTile Wireless Industrial Node

NFC Dynamic Tag Sensor Node

SensorTile.box

Lower barriers from prototyping to first product

Pre-integrated software for vertical applications

Smart Things

Smart Home & City

Smart Industry

Development ecosystem

Code generators

Prototyping software

Development environments

Artificial Intelligence toolbox

Debug solutions

Simulation and analysis tools

On-line design tools

Enable product & service commercialization

Integration of Cloud Provider SDKs

Partner Program and ST community

Partner Program

ST Community

Educational Platforms

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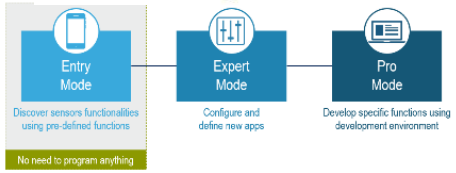
Most powerful ecosystem for sensors

HW



STEVAL-MKSBOX1V1

SensorTile.box

STEVAL-STWINKT1

STWIN

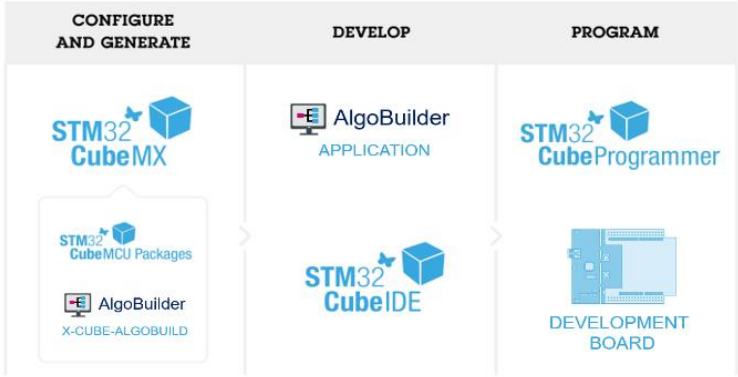
Consumer sensors
X-NUCLEO-IKS01A3

Industrial sensors
X-NUCLEO-IKS02A1

Analog WB Microphones
X-NUCLEO-AMICAM1

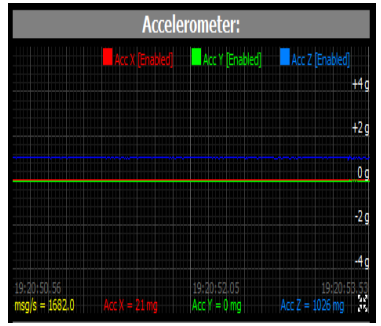
X-Nucleo expansions

SW



AlgoBuilder

Unico GUI



Unicleo-GUI

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High accuracy & low power sensors

Continuous improvement

- Better accuracy, better performance
- Lower power consumption
- Technology

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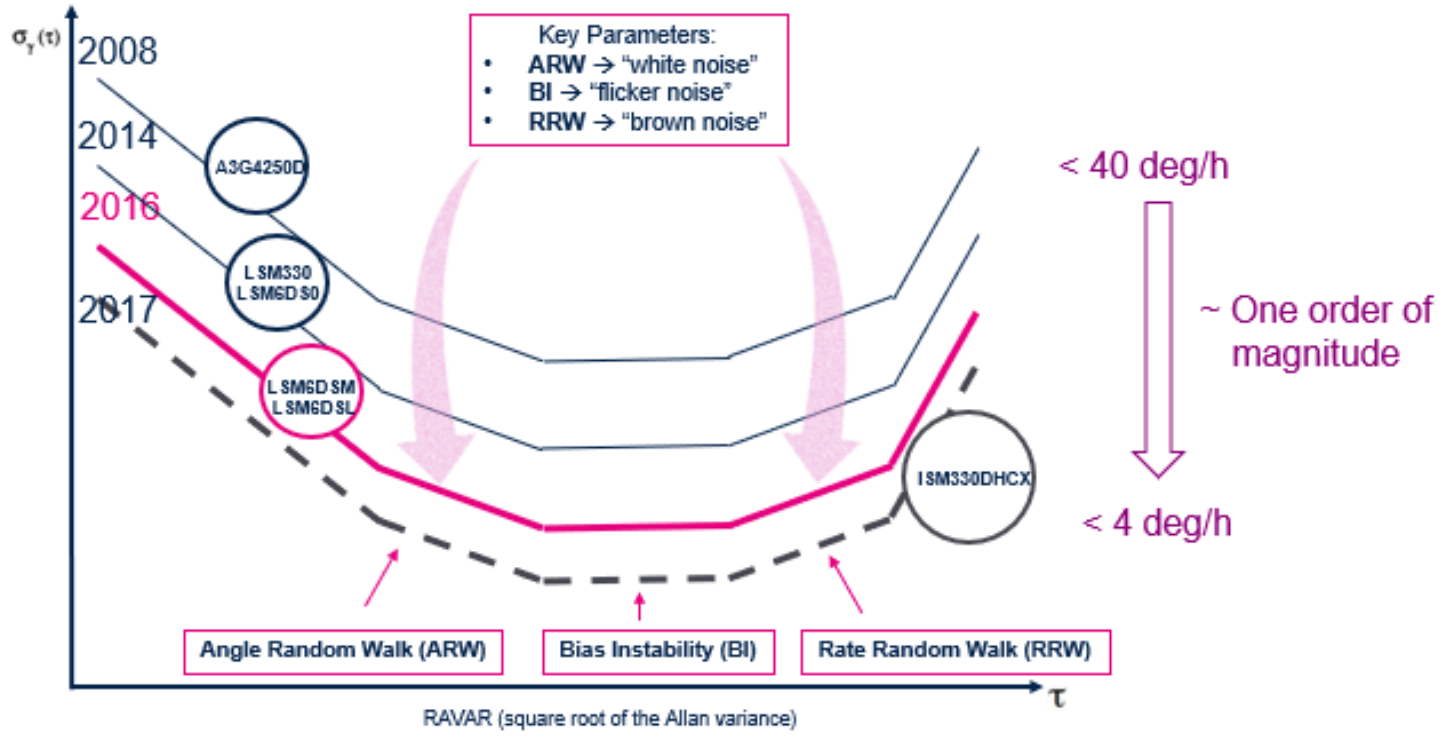
Accuracy improvements for ISM330DHCX

Industrial IoT

Smart antennas	Industrial IoT	Dynamic inclinometers
Antenna condition monitoring	Industrial automation	Dynamic inclinometers for industrial vehicles

Example with Allan Variance (AVAR) is the analysis of stability in time and noise contribution



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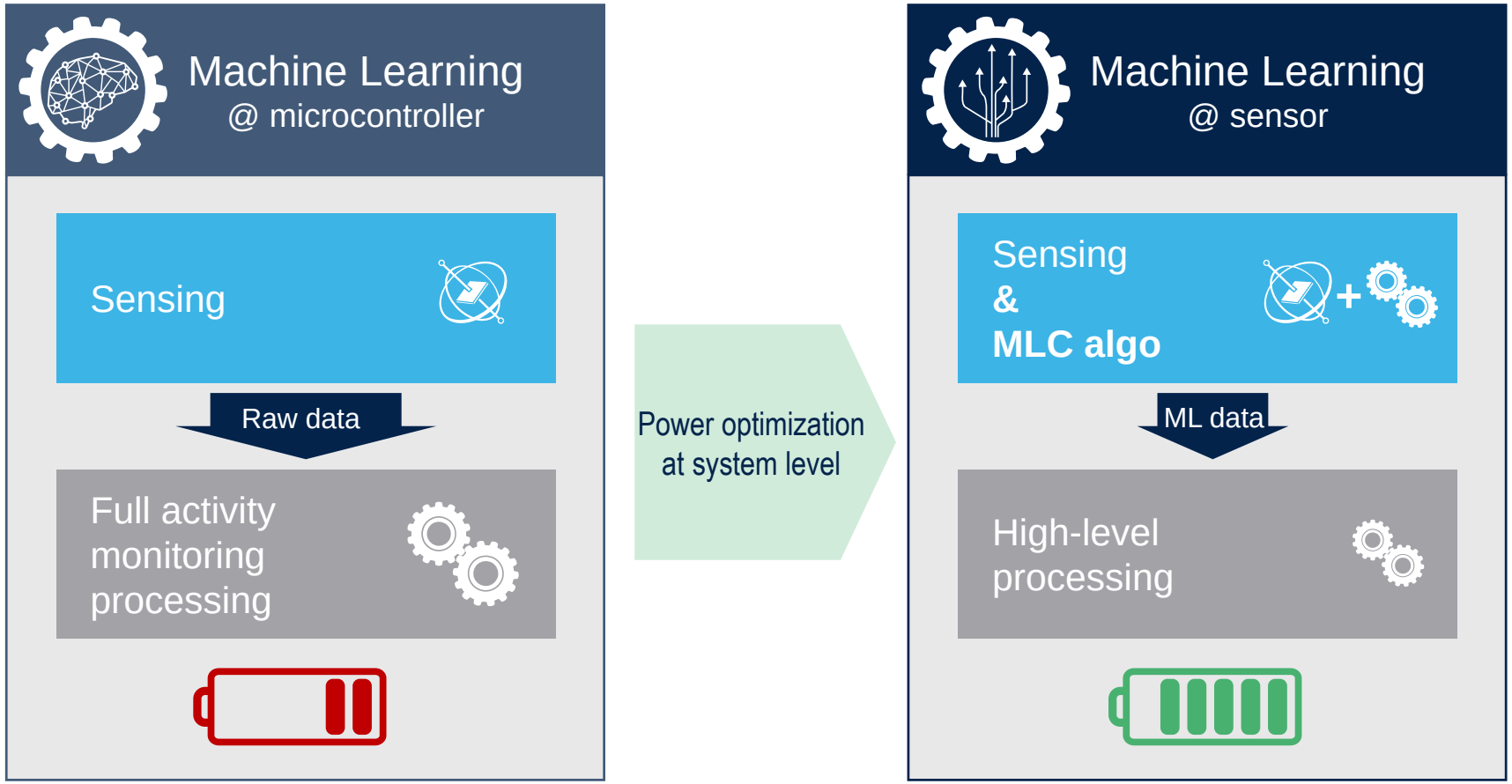
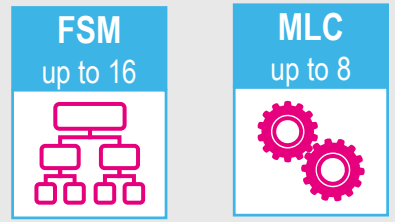
Power consumption improvement at system level

Machine Learning (ML) for real edge computing enables high system flexibility





- Higher computation power in sensor level
- Lower power consumption in system level
- Cost optimized solution

This is the added value!

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AI with MLC Sensors: Current consumption improvements

Only 4 µA additional current consumption to run Activity Recognition with MLC

Activity recognition library (MotionAR) running **in SW in MCU**

LSM6DSOX Sensor	Sensor Current consumption
Sensor Core	15 µA
MLC – not used	0 µA

MCU	Wake-up rate	MCU Current consumption
STM32L476RG	1/16 = 63ms	51 µA

Total: **66µA**

Activity recognition algorithm running **inside LSM6DSOX**

LSM6DSOX Sensor	Sensor Current consumption
Sensor Core	15 µA
MLC	4 µA

MCU	Wake-up rate	MCU Current consumption
	1 s	2.8 µA
STM32L476RG	30 s	0.65 µA
	100 s	0.59 µA

Total: **20µA**
3x power saving

In both scenario the ODR of the sensor is set in the same condition (ODR 26Hz, LP mode) and same sampling time window.

In the first scenario the microcontroller wakes up to read all new sensor data, in the second scenario the microcontroller wake ups only when a new class is detected.
From system power consumption point of view, the second scenario brings significant power consumption improvement since the microcontroller is less active.

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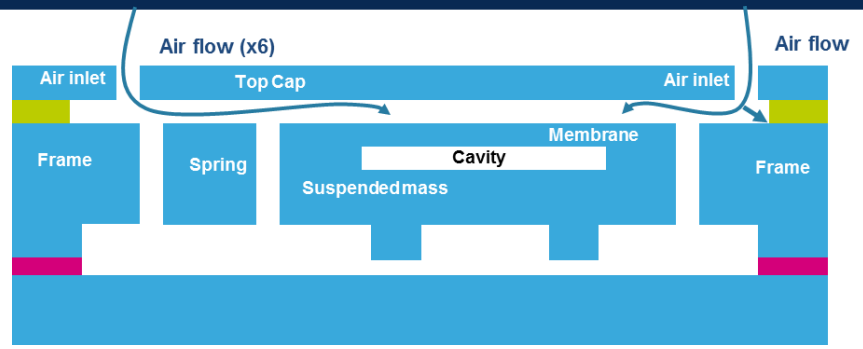
ST Unique Pressure Sensor Package Patented Technology for LPS22HH

ST full molded package

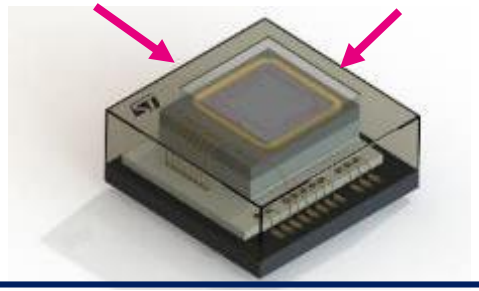
Unique advantages

- Improved shock and vibration suppression
- Improved reliability and moisture resistance
- Ultra-thin package

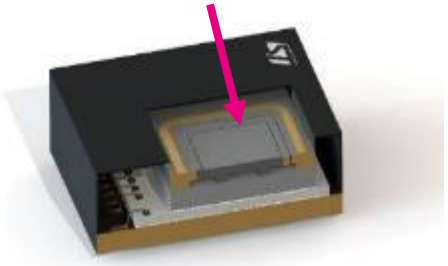


Full molded package

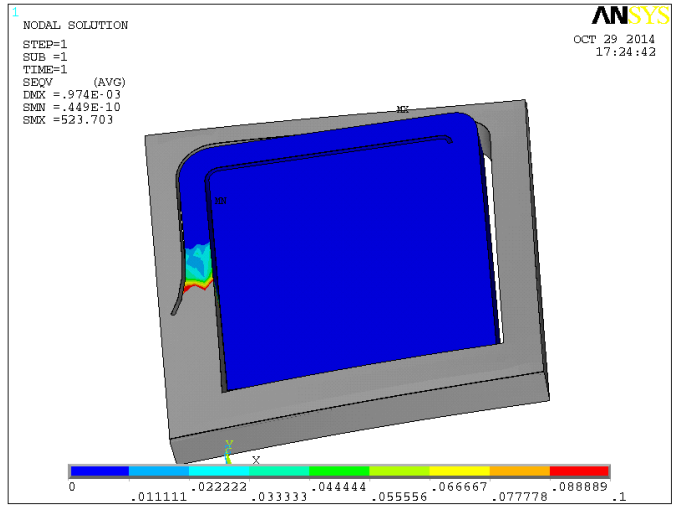
Silicon cap



Suspended membrane



Better behavior stress simulation



Full molded package for a better robustness, better resistance to dust contamination

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Water resistant and waterproof Pressure sensors

LPS22HH

Water resistant

- 2x2 mm, HLGA - 10L – **Fully Molded**
- 260 to 1260 mbar absolute pressure
- Absolute accuracy 0.5hPa, Noise RMS ±0.65Pa

LPS33W

Water resistant

- 3.3x3.3x2.9 mm, CCLGA - 10L - **IPx8**
- O-ring shaped PKG with full metal lid
- 15µA (HPM), 4µA (LPM) @1Hz

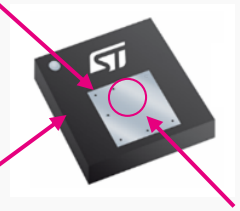
LPS27HHW & LPS27HHTW

Water Proof

- 2.7x2.7x1.7mm
- O-ring shaped PKG with full metal lid
- **10ATM resistant (90m)**
- Absolute accuracy ±2hPa
- Temp Accuracy: ±1.5'C @ 25~65°C (T version)
- Noise RMS [HP] - 0.7Pa
- 13µA (HPM), 4µA (LPM) @1Hz, 0.9µA PDM

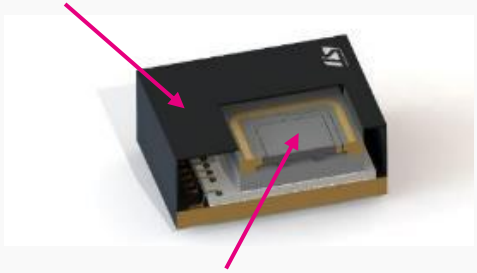
Package structure

Small vent holes: 6x holes for redundancy & small hole to avoid contamination inside IC



Full-molded package

Silicon cap



Suspended membrane : To be robust to thermal / external stress