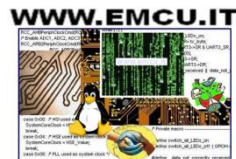




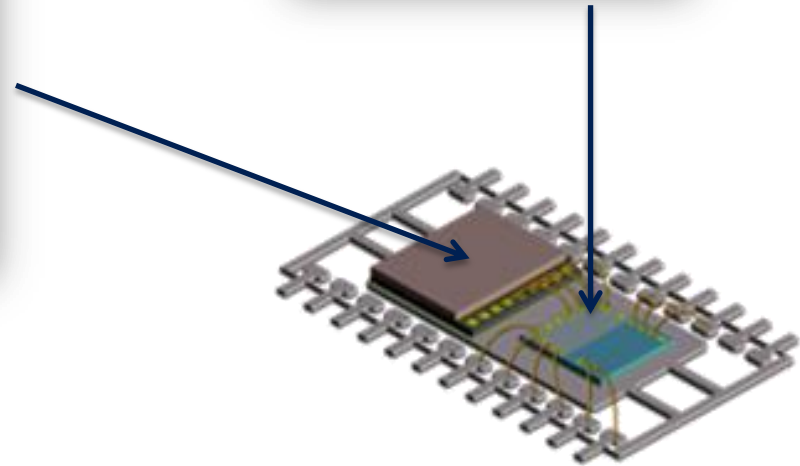
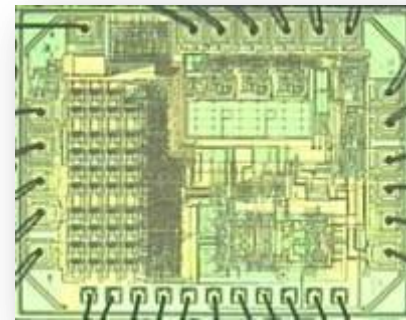
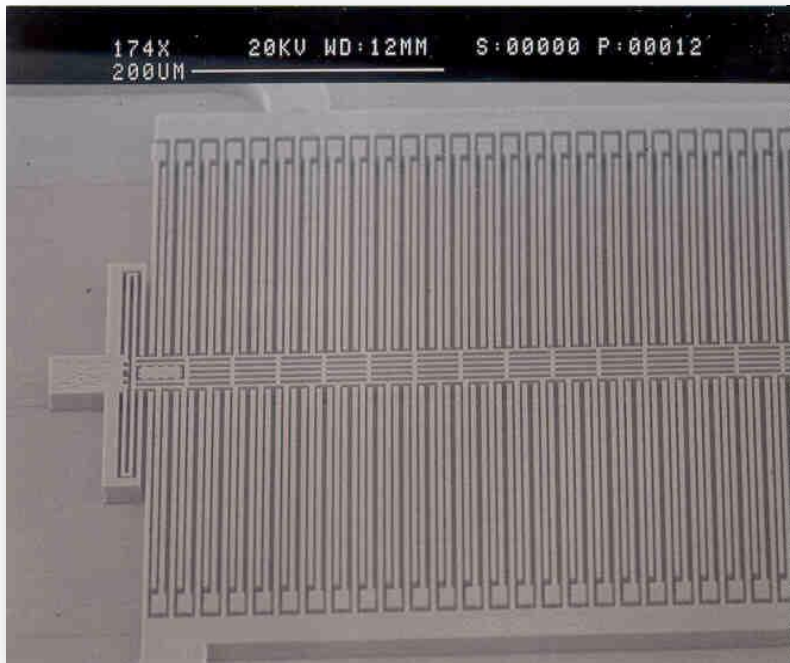
# MEMS & Sensor

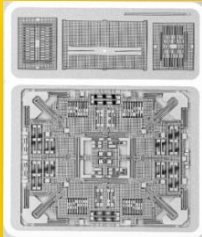
[www.emcu.it](http://www.emcu.it)



# What are MEMS?

- MEMS is an acronym for **M**icro **E**lectro **M**echanical **S**ystems





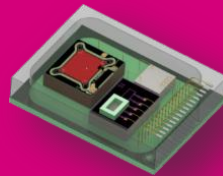
## MOTION MEMS

Accelerometers  
Gyroscopes  
Magnetometer  
E-Compass  
I-Nemo M1



## ACOUSTIC MEMS

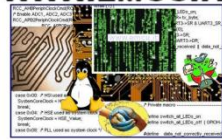
Microphones



## ENVIRONMENTAL MEMS

Pressure  
Temperature  
Humidity

# Accelerometers



# 3x3 Accelerometer – LIS3DH & LIS3DSH

LIS3DH



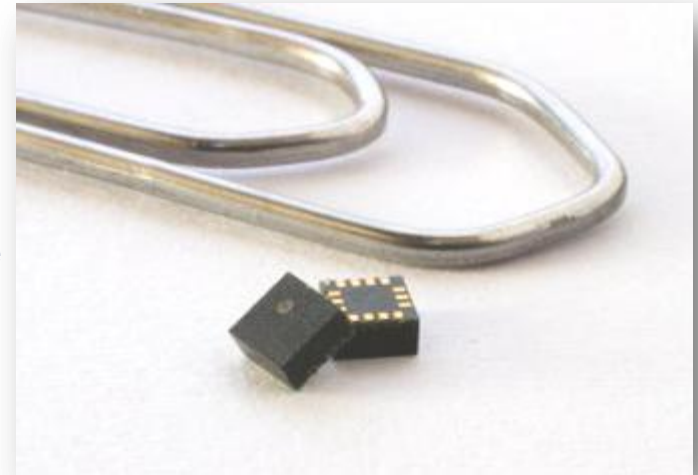
LIS3DSH

- 3-Axis Digital SPI/I2C Accelerometer
- 4 selectable Full Scales:  $\pm 2$ , 4, 8 and 16g
- Up to **12 bit** resolution
- Interrupt Generation (Wake Up/Free Fall Event)
- Very low power consumption: 2 $\mu$  in Low Power mode (1Hz) , 11 $\mu$ A in Normal mode (50Hz) and 0.5 $\mu$ A in Power down mode

- 3-Axis Digital SPI/I2C Accelerometer
- 5 selectable Full Scales:  $\pm 2$ , 4, 6, 8, 16g
- 2 programmable **finite-state machines** for interrupt generation
- Very High Resolution (up to **14 bit**) and low noise (**150 $\mu$ g/ $\sqrt{Hz}$** )
- P2P compatible with LIS3DH
- Power consumption: 11 $\mu$ A in Active mode (3.1Hz) and 2 $\mu$ A in Power down mode

# 2x2 Accelerometers - LIS2DH & LIS2DH12

- 3-Axis Accelerometer
- Up to 12 bit resolution
- Full-scale ranges of  $\pm 2g/\pm 4g/\pm 8g/\pm 16g$
- **FIFO and Temperature sensor**
- Programmable **interrupt signals** that enable immediate notification of motion detection, click/double-click events, and other conditions
- **Small size & Low power** targeted applications



LIS2DH: 2x2x1 LGA-14  
LIS2DH12\*: 2x2x1 **LGA-12**

**Key Features**

2x2 package

Power consumption down to  $2\mu A$

LIS3DH Register structure

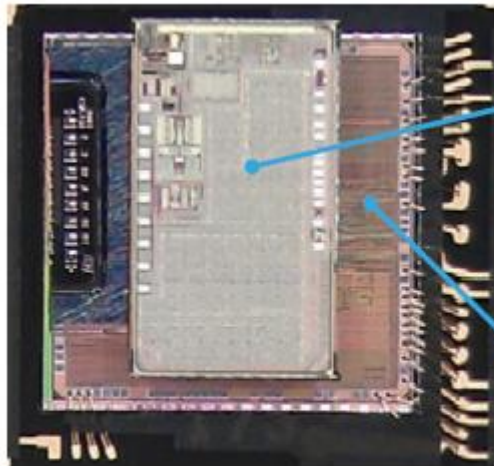
# Accelerometer High-g – H3LIS331

- 3-Axis Digital Accelerometer
- 3 selectable Full Scales:  $\pm 100$ , 200, 400g
- **12bit resolution**
- Low power: 300 $\mu$ A in Active mode, **10 $\mu$ A in low power** and 1 $\mu$ A in Power down mode
- ODR user selectable: from 0.5 to 1000 Hz
- Targeted applications:
  - **Impact measurements in sports** (American football, hockey, boxing, ....) to monitor events that could determine a concussion,
  - **Shock detection in tools**, equipment, portable instrumentation (like medical instruments, laptops, tablets, ...)
  - **Parcel Monitoring** for insurance purposes





# Smart sensor - LIS331EB



3x3x1 LGA-16

## LIS3DSH:

- Low-power mode down to 10  $\mu$ A
- $\pm 2g/\pm 4g/\pm 6g/\pm 8g/\pm 16g$  full-scale
- Data rate: 3Hz to 1.6kHz
- 16 bit data output
- Low noise 150 $\mu$ g/vHz
- Embedded FIFO and State Machine
- 10000 *g* high shock survivability

**Accelerometer**

## Embedded BRAIN:

- Cortex-M0 core - 72MIPS@80Mhz
- 80 MHz / 32 KHz RC / External crystal oscillator
- 64KB Flash Memory
- 128KB RAM memory
- 2x I2C (1 Master, 1 Slave)
- SPI Master/Slave
- JTAG/SWD
- 7 Programmable GPIOs
- Embedded WDG (32Khz)
- Embedded Timers/Event Counters
- Low power features

**MCU – M0**

## Key Features

**High Perf Accel + High Perf  
MCU Cortex M0**

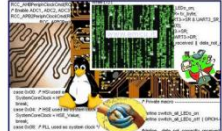
**9-axis SW Fusion available**



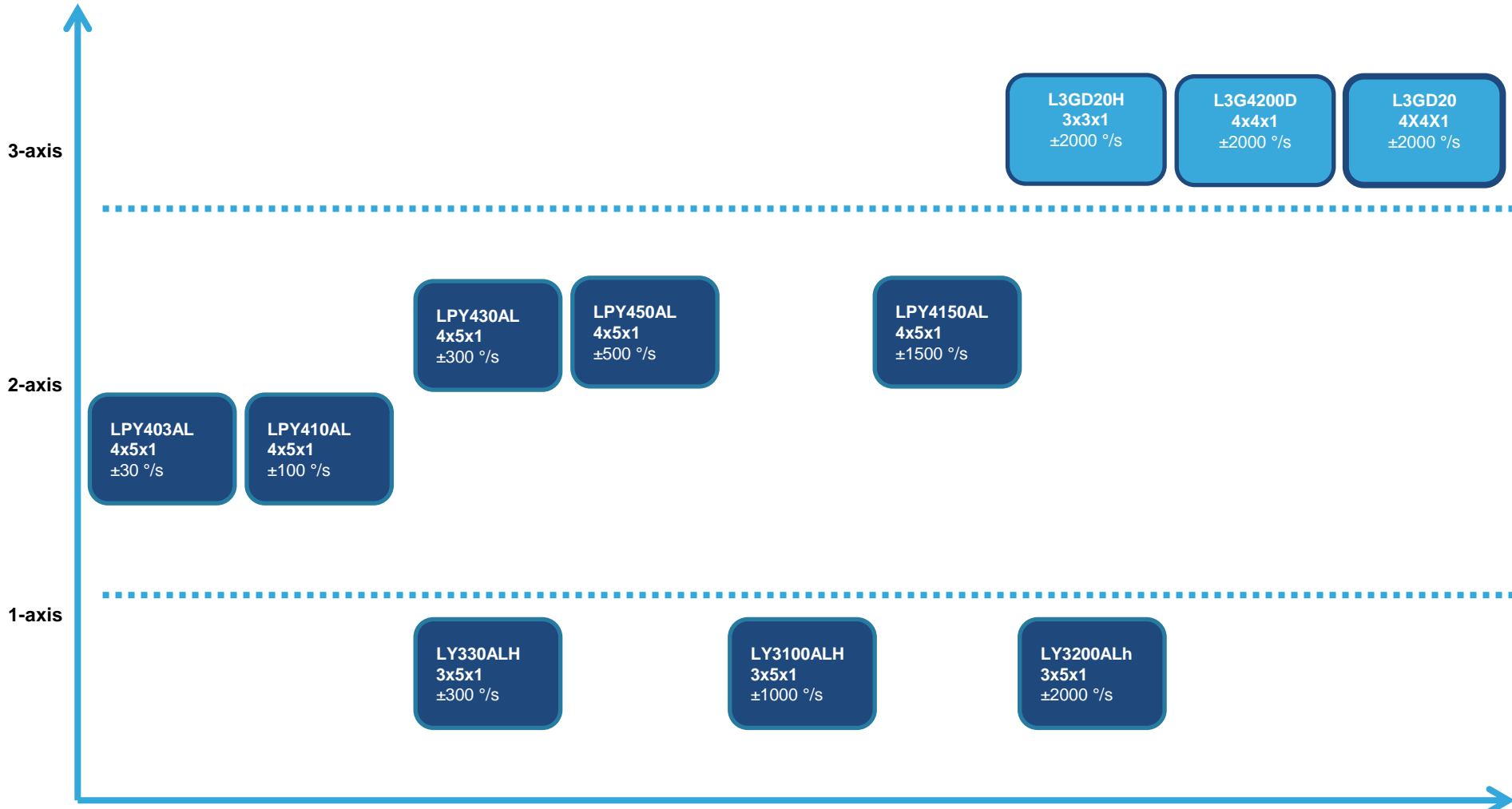
# MEMS Gyroscopes



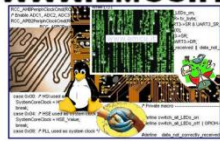
WWW.EMCU.IT



# 3-axis Gyroscopes Portfolio

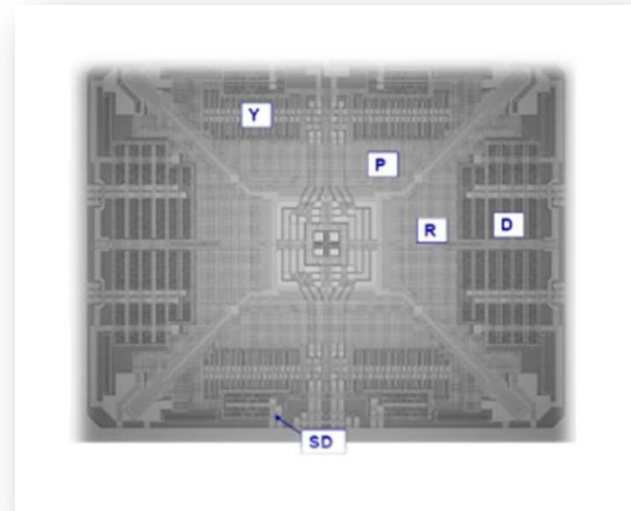
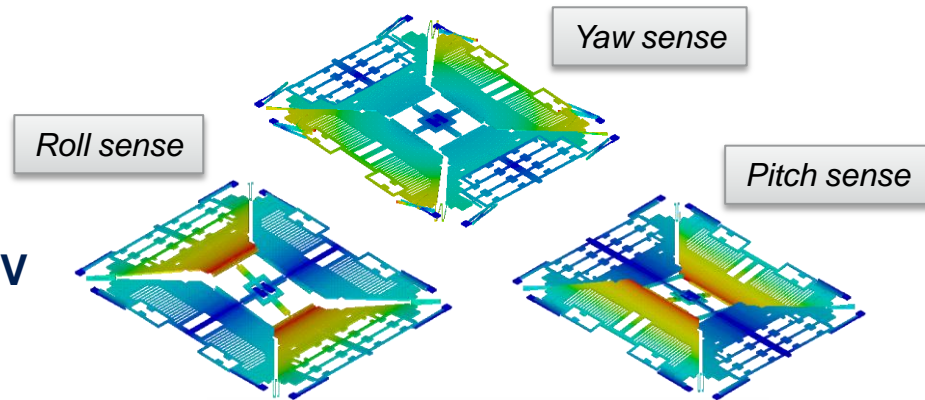


Full Scale ([WWW.EMCU.IT](http://WWW.EMCU.IT))

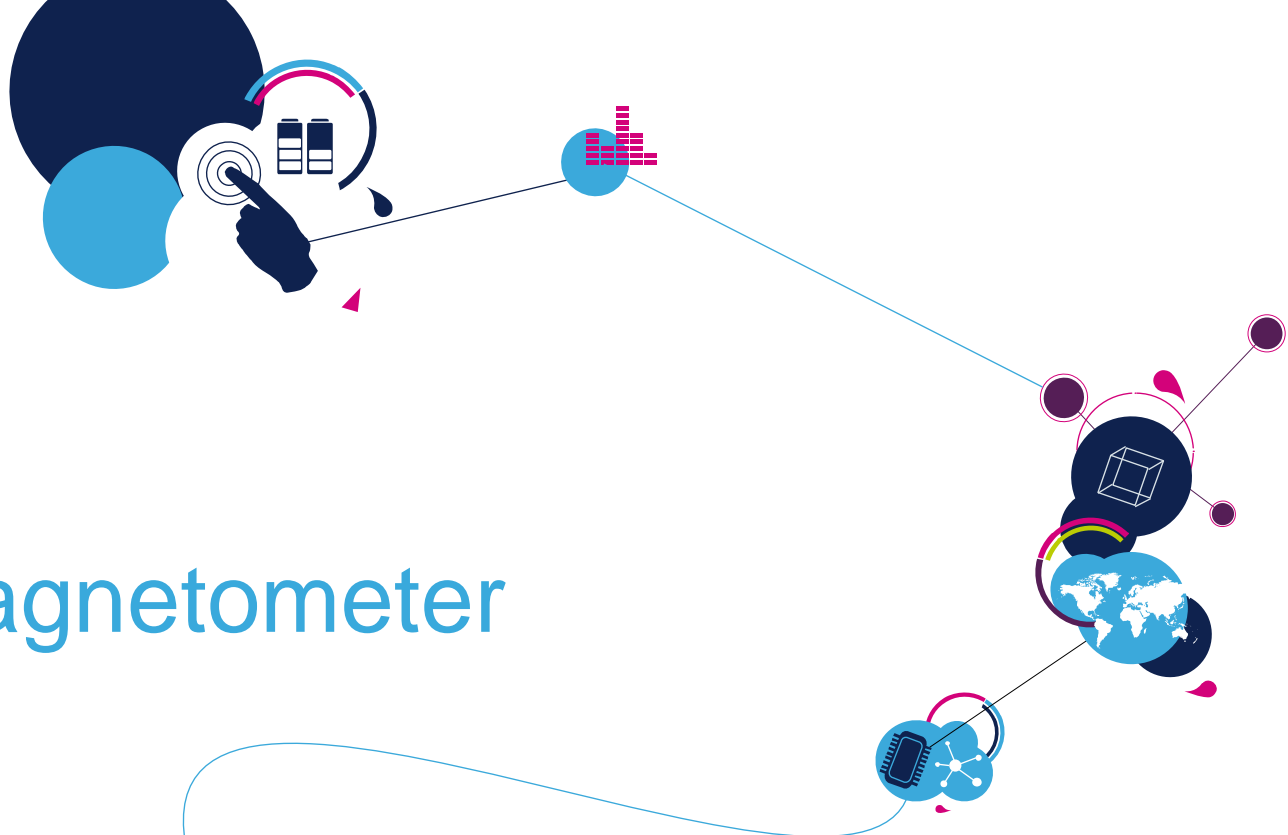


# Gyroscope – L3GD20

- **Selectable Full Scale** from  $\pm 250$  up to  $\pm 2000$  dps
- Any supply voltage over the range of **2.4 to 3.6V**
- Programmable interrupts
- **Digital** SPI/I2C output
- Embedded Power-down and sleep modes
- Embedded FIFO
- It integrates low- and high-pass filters with user selectable bandwidth
- Temperature sensor
- LGA Package 4x4x1mm

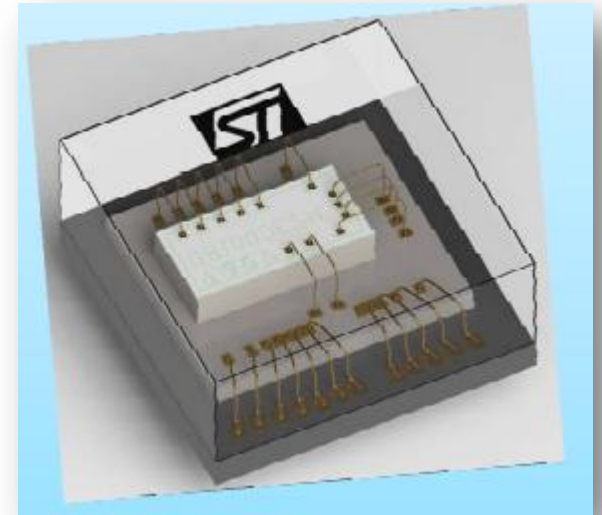


# MEMS Magnetometer

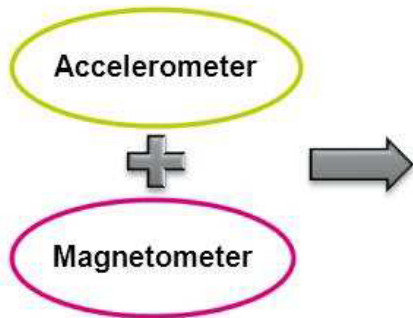


# 3-axis Magnetometer - LIS3MDL\*

- 3-axis standalone digital magnetometer:
- FS  $\pm 4/\pm 8/\pm 10/\pm 12$  gauss
- Typical resolution  $\sim 3$  mGauss RMS
- ODR on single mode operation from .625 to 80 Hz
- I2C/SPI
- Vdd from 1.9 V to 3.6 V
- Power consumption (@ODR=20Hz):
  - 270  $\mu$ A in High resolution
  - 40  $\mu$ A in Low power
  - 1  $\mu$ A in Power down
- LGA-12 Package, 2x2x0.7



# Digital Compass – LSM303\*



	LSM303DLHC	LSM303D
		
Accelerometer full-scale	±2g/±4g/±8g/±16g	±2g/±4g/±8g/±16g
Acceleration Noise density	220 µg	150 µg
Magnetic field full-scale	From ±1.3 to ±8.1 gauss	From ±2 to ±12 gauss
Magnetometer Sensitivity drift over temperature compensation	✓	✓
Magnetometer Offset bridge compensation	✓	✓
Two independent programmable interrupt generators	✓	✓
Digital interfaces	I <sup>2</sup> C	SPI / I <sup>2</sup> C
Embedded FIFO	✓	✓
Supply Voltage 2.16V to 3.6V	✓	✓
Package size	3x5x1 LGA-14	3x3x1 LGA-16

# 9 axis solution fully integrated: LSM9DS0

- LSM9DS0 – 9 axis - **accelerometer, gyroscope & magnetometer**
- Main features:
  - 3A+3G +3M
  - Digital interface
  - Package 4x4x1 mm
- **3A:**  $\pm 2/\pm 4/\pm 6/\pm 8/\pm 16g$  Full Scale
- **3M:**  $\pm 2/\pm 4/\pm 8/\pm 12$  gauss magnetic Full Scale
- **3G:**  $\pm 245/\pm 500/\pm 2000$  dps angular rate Full Scale
- Planning:
  - Product in Mass Production
  - **Available NOW**



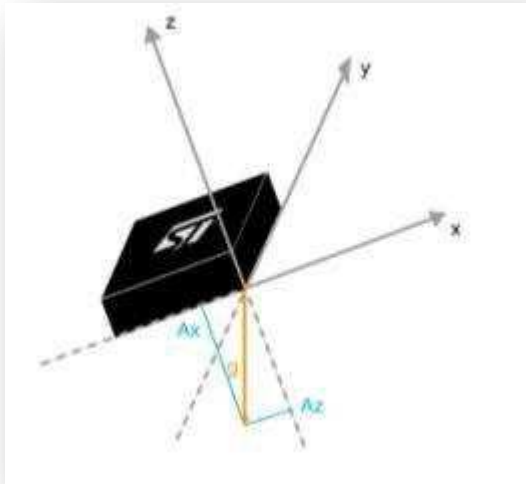
**Key Features**

**9 Axis: 3A+3G+3M**

*Integrated solution in : 4x4x1 mm*



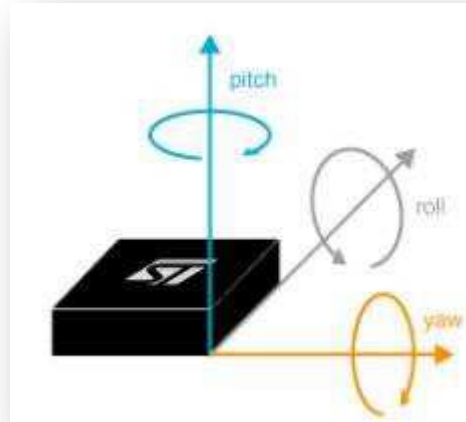
# Why 9-DoF and Sensor Fusion are needed



## Accelerometer

*tracks the direction of gravity*

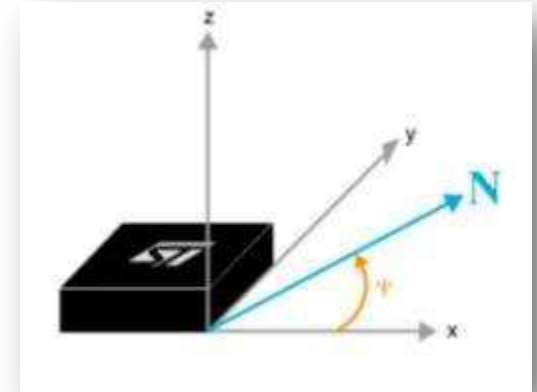
- + has absolute reference (Gravity)
- susceptible to acceleration, vibration



## Gyroscope

*tracks heading, pitch and roll*

- + Not influenced acceleration, vibration, or changing magnetic fields
- Does not have absolute reference and has an intrinsic drifts over time



## Magnetometer

*tracks the direction of Earth's magnetic field*

- + has absolute reference (Earth's magnetic field)
- susceptible to magnetic interference

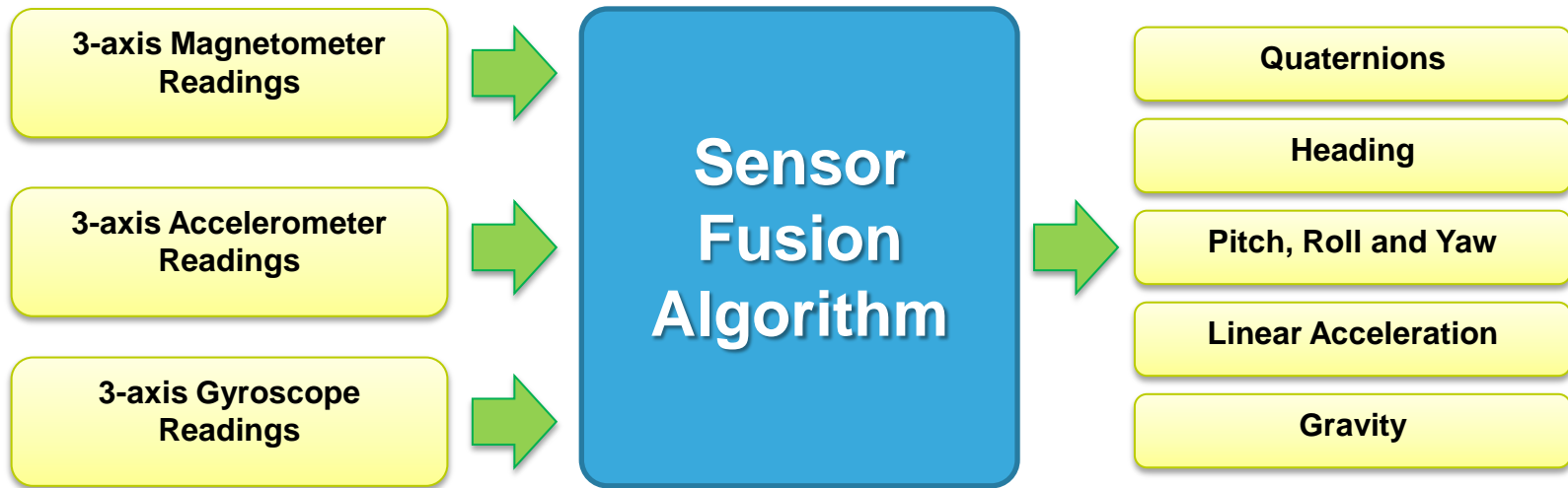
The proper combination of the gyroscope with the magnetometer and accelerometer provides all the benefits of each of the three types of sensors, while eliminating their respective weaknesses.

# 9-Axis iNEMO Module

17

- Compact design: 13 x 13 x 2 mm
- **L3GD20**: 3-axis digital gyroscope
- **LSM303DLHC**: 6-axis geomagnetic module
- **STM32F103REY**: WLCSP, ARM®-based 32-bit MCU
- **LDS3985M33R**: ultra low drop-low noise voltage regulator.
- Flexible interfaces: **CAN, USART, SPI** and I<sup>2</sup>C serial interfaces; full-speed USB 2.0
- Free **ADC channels** for external inputs





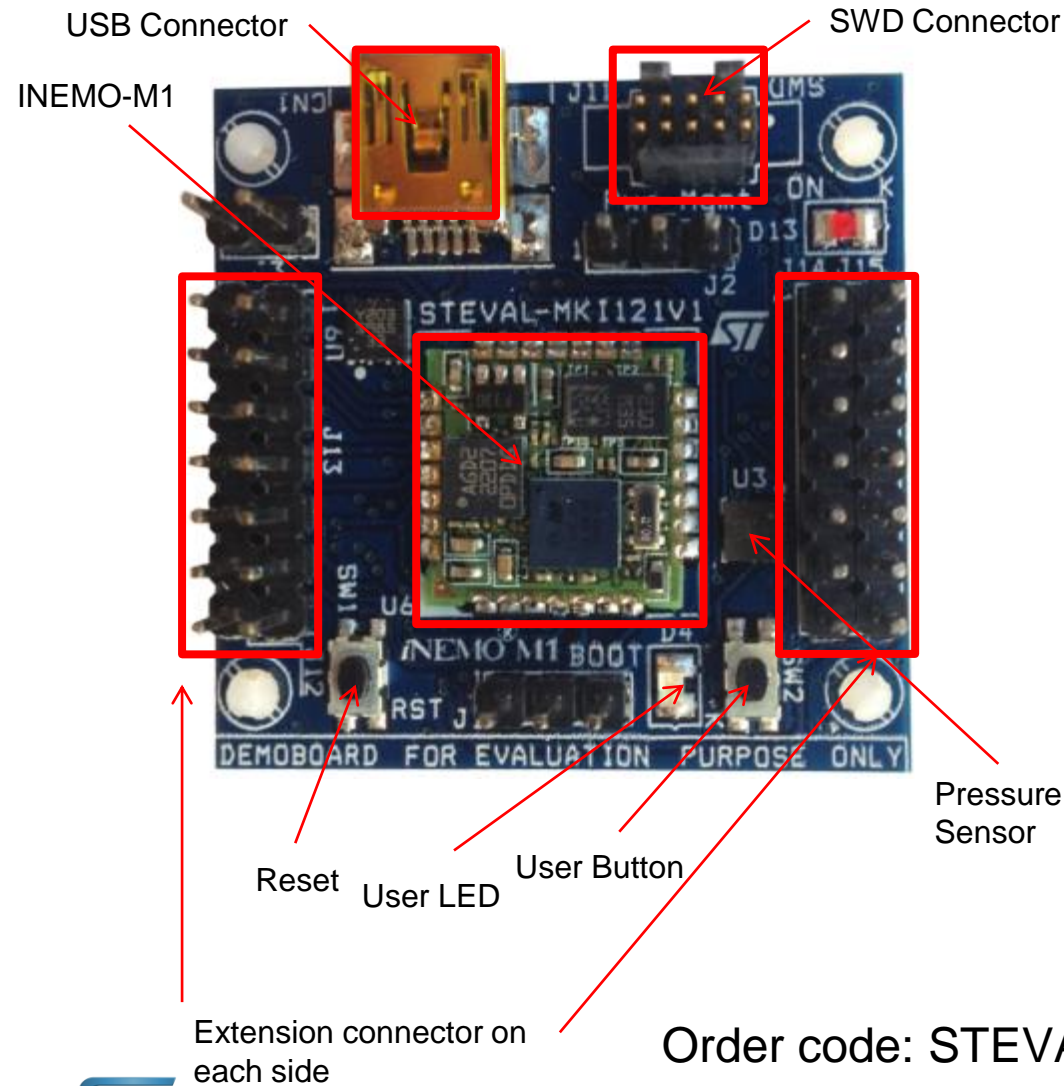
Availability of iNEMO software libraries, based on the Kalman's filter theory:

- *iNEMO Engine Lite*: a **free source code** software library for motion-detection system evaluation
- *iNEMO Engine Pro*: a **compiled software** library with high performance and high precision data-fusion algorithms for multiple sensors fields.

# STEVAL-MKI121V1 - Discovery-M1

## Main Features

- A compact “10DoF in one board 35x35 mm<sup>2</sup>
- INEMO-M1
- Integrated pressure sensor LPS331AP
- USB connector
- SWD connector for debugging and programming
- Several power supply options (5V via USB or 2.4V to 3.6V DC via external supply)
- The extension connector will all INEMO-M1 pins enable building more complex applications by using an extension board
- User LED and User button



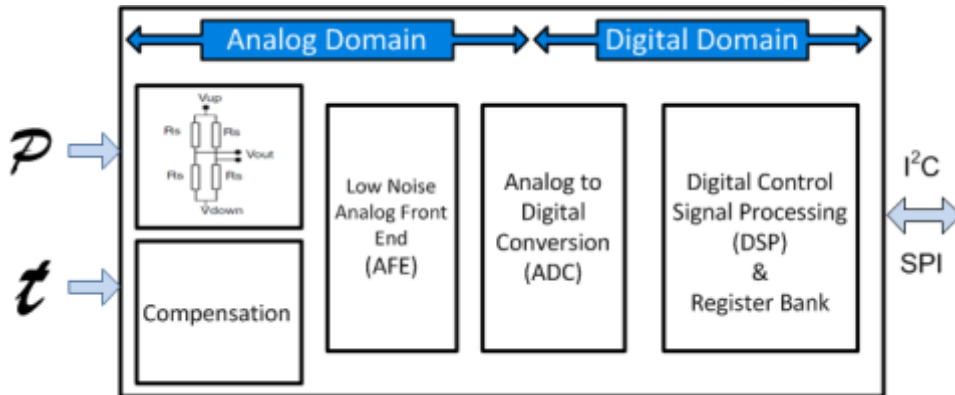
Order code: STEVAL-MKI121V1

# MEMS Environmental Sensor: Pressure Sensor



# LPS331AP Key Features

## Barometric Sensor



- Pressure and Temperature inputs
- Analog to Digital Conversion (ADC)
- Embedded Filtering & Compensation
- I<sup>2</sup>C or SPI Digital output

## Factory calibrated System on a Chip!

### Key Features

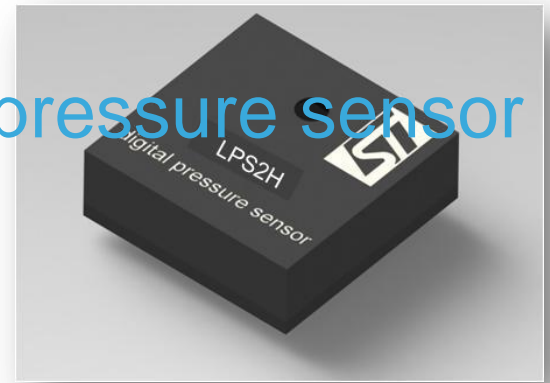
Dimension	3x3x1mm
Pressure range	260-1260 mbar
Overpressure / Shock	> 20 bar / 10,000G
ADC resolution	24 bits
Supply Voltage	1.71 to 3.6 V
Power consumption	Less than 1 $\mu$ A (stby) 5.5 $\mu$ A (low res) @ 1Hz ODR 30 $\mu$ A (high res.) @ 1Hz ODR
Pressure noise	0.060 mbar rms (0.5 meter)
Relative Accuracy over temperature (0÷80°C)	Quadratic : $\pm$ 1 mbar Linear embedded : $\pm$ 2 mbar
Other features	Auto zero One Shot mode ODR selectable up to 25Hz

### Digital features

Compensation	Linear Embedded Quadratic external SW
Offset management	Embedded temperature and Embedded 3 point calibration



# LPS25H High performances pressure sensor



- Package Dimension: 2.5 x 2.5 x 1.0 mm
- Power consumption: 25uAmp @ 1Hz
- Pressure noise:
  - 30 uBar rms
  - 10 uBar rms Internal filter
- Accuracy (pressure)
  - 0.2 mbar (between 0°C ÷ 60°C)
- Conversion time
  - 40 msec (max resolution)
- Embedded temperature compensation
  - Fully compensate internally
  - No need of external compensation software

## Key Features

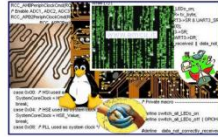
260 to 1260 hPa absolute pressure range  
High-resolution mode: 1 Pa RMS  
Low power consumption:  
Low resolution mode: 4 µA  
High resolution mode: 25 µA  
High overpressure capability: 20x full scale  
Embedded temperature compensation  
Embedded 24-bit ADC  
Selectable ODR from 1 Hz to 25 Hz  
SPI and I<sup>2</sup>C interfaces  
Embedded FIFO  
Supply voltage: 1.7 to 3.6 V  
High shock survivability: 10,000 g



# MEMS Environmental Sensor: Humidity Sensor



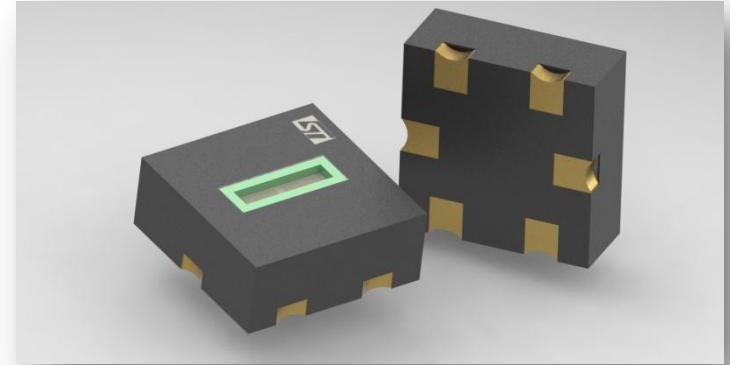
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# HT221 Humidity sensor

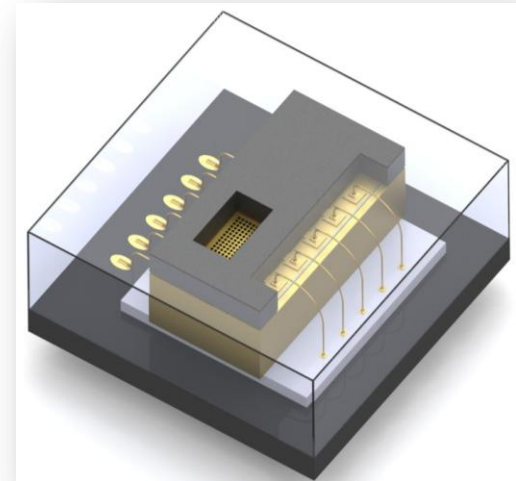
- HT221 main features

- Full molded package
- Small package dimension 2x2x0.9mm
- Digital out (I2C)
- Embedded temperature sensor



- Target spec

- Humidity accuracy: +/-4%RH (between 20-80 %RH)
- Humidity range 0 – 100%RH
- Temperature accuracy: +/-0.5°C (between 0-80°C )



# Tools, SW & Evaluation Kits



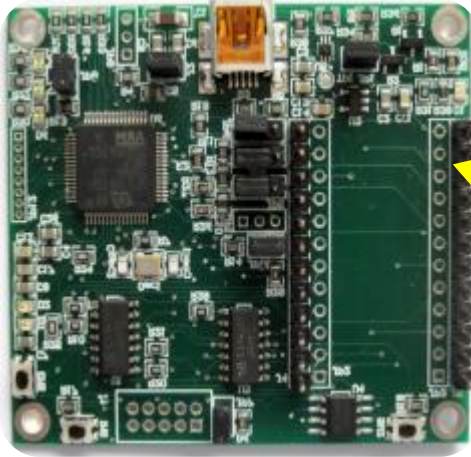
[WWW.EMCU.IT](http://WWW.EMCU.IT)



# MEMS support tools

eMotion: STEVAL-MKI109V2

- Possible Daughter boards:



**LIS3DH**  
MKI105V1  
**LIS3DSH**  
MKI134V1



**LSM303DLHC**  
MKI106V1  
**LSM303D**  
MKI133V1



**L3GD20**  
MKI107V2



**LSM303DLHC**  
+  
**L3GD20**  
MKI108V2



**LPS331AP**  
MKI120V1

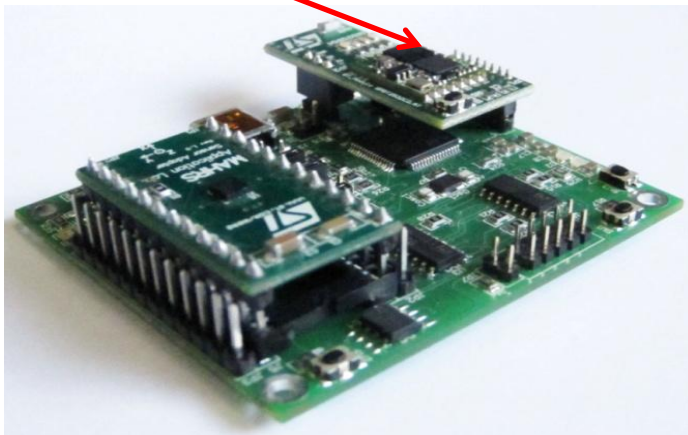
STM32-based MEMS motherboard compatible with ST MEMS adapters



## eMotion BT - STEVAL-MKI115V

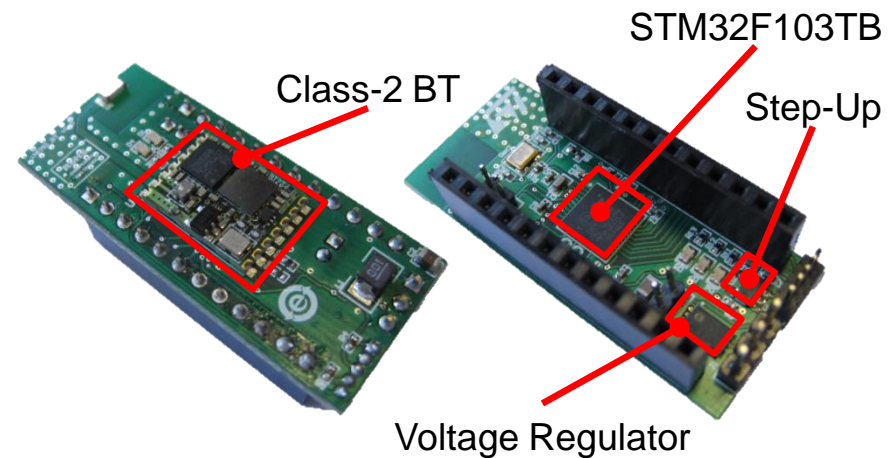
- Cable replacement BT module for eMotion
- Fully compatible with Unico SW

BlueTooth Class 2

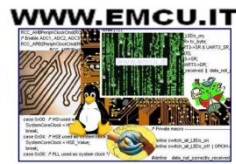


## BlueMotion - STEVAL-MKI132V1

- Compatible with all DIL24 MEMS adapter boards
- Compatible with Unico SW
- Battery powered down to 1.5V
- Ready for connection with any BT dongle

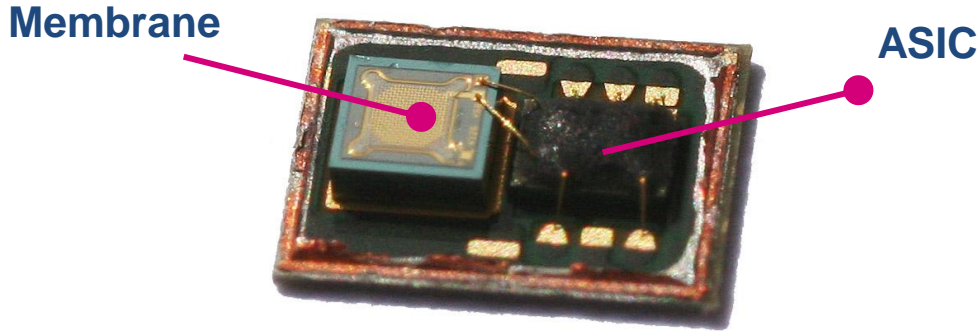


# MEMS Microphones



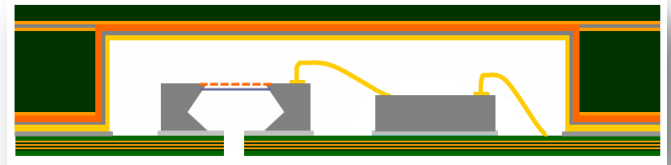
# MEMS microphones

## Today: state-of-the-art packaging process



MEMS mics are built of two parts. The membrane and the ASIC.

### Bottom port structure



### Top port structure

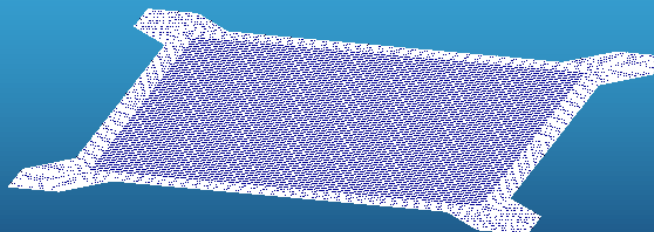
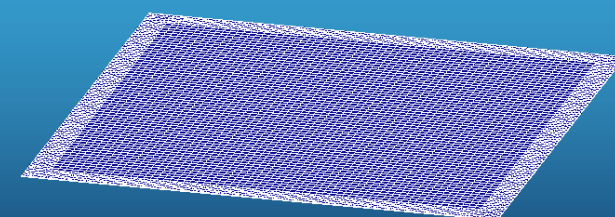


- **Top port performances equal bottom port ones**
  - Bottom port performances are better than top port due to membrane positioning closer to the acoustic inlet
  - ST technology allows to place MEMS membrane closer to the inlet also in top port mics
  - Top port SNR = 63dB as in bottom port



# Ultra-flat frequency response

## State-of-the-art membrane

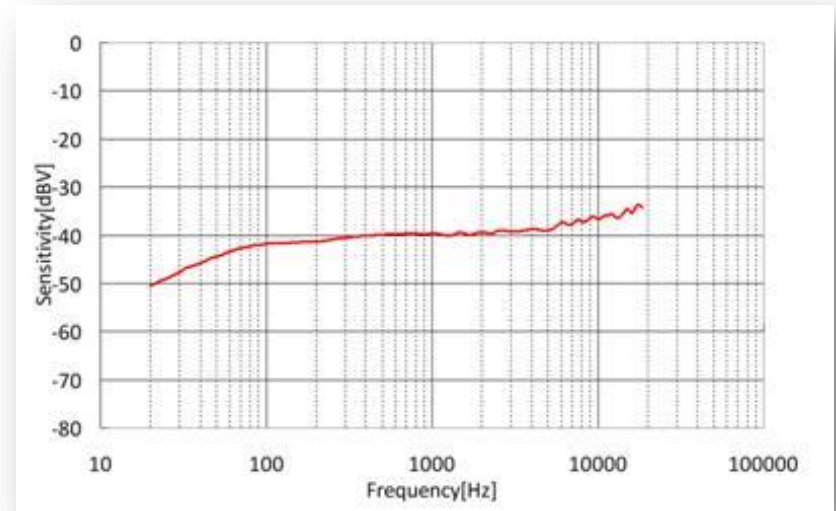
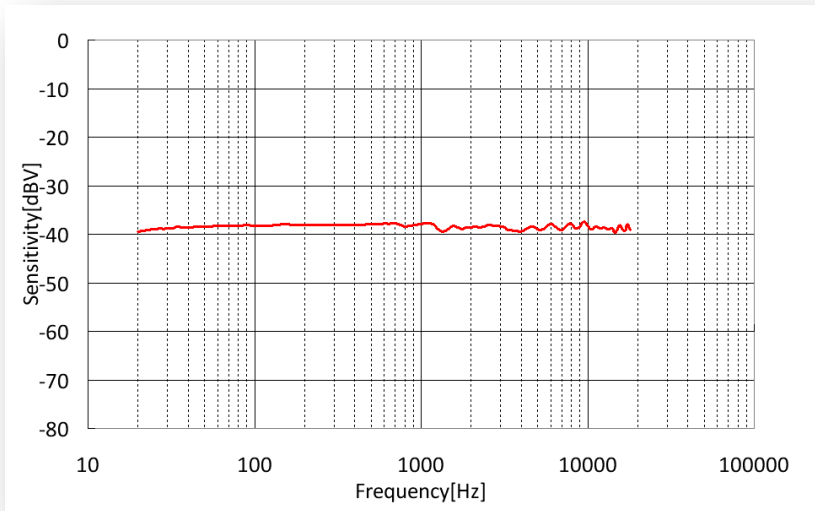
Simulating Vibrating membrane	<p>Current Design</p>  <p>4 point support</p>	<p>Others</p> <p>ANSYS</p>  <p>Conventional style Supporting all round structure</p>
	Sensitivity	Good

**OUR 4 ANCHOR POINT MEMBRANE DESIGN ALLOW US TO GET HIGH SENSITIVITY WITH MINIMAL CHIP AREA AT ANY FREQUENCY**

# Frequency response comparison



## #1 COMPETITOR

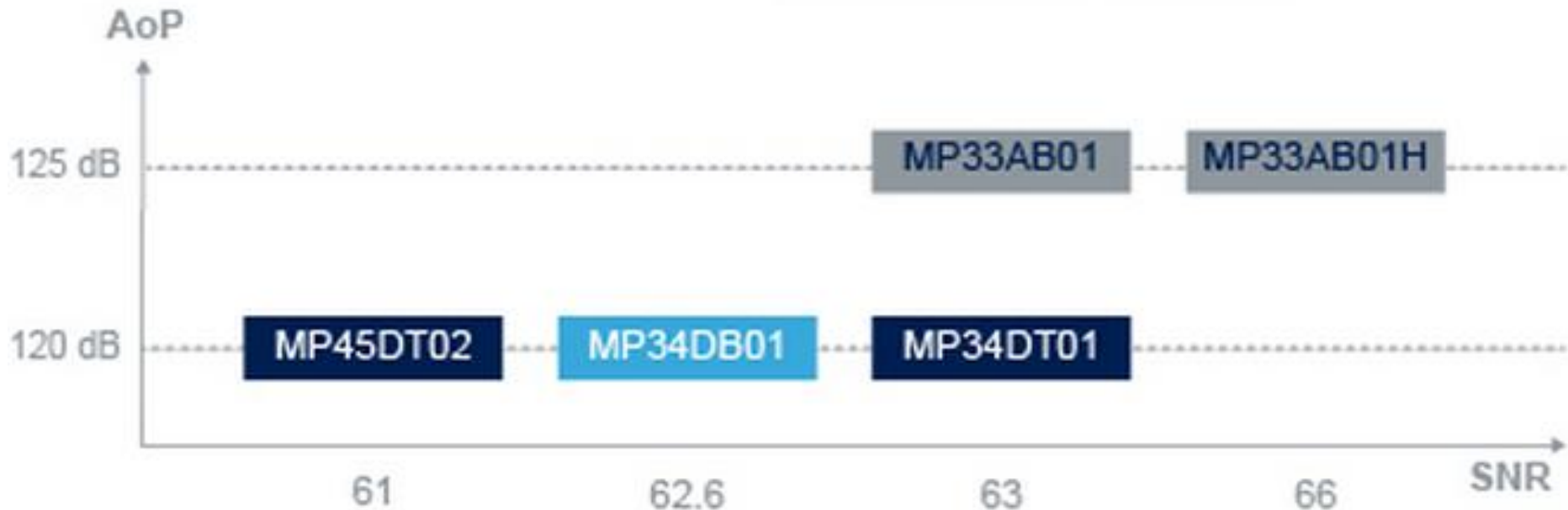


**ST MEMS MICROPHONES  
GUARANTEE AN HIGH FIDELITY  
SENSING IN THE WHOLE ABW**

**COMPETITORS PERFORMANCES  
ARE NOT UNIFORM AND  
DEPEND ON THE FREQUENCY**

# MEMS microphones family

- Best-in-class audio performance
- Ultra-miniaturized packages
- Simplified board design with top-port devices
- Same performances obtained with bottom- and top-port devices



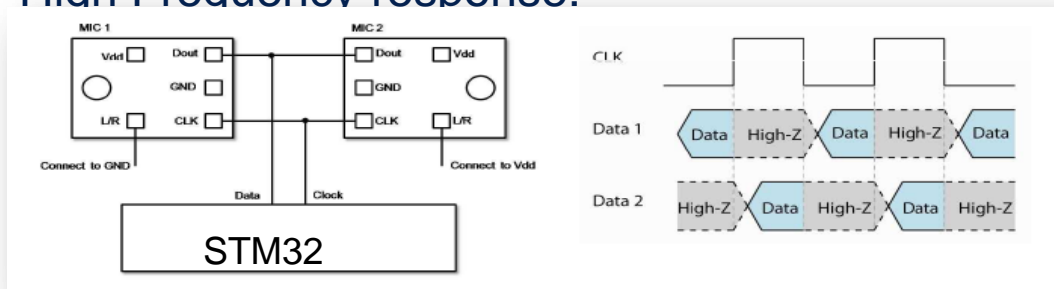
- Digital Bottom Port
- Analog Bottom Port
- Digital Top Port

# MEMS Microphone – MP34DB01

33

- **Bottom-port** Digital microphone, Pulse Density Modulation single bit output with stereo support
- Omni-directional sensitivity
- High level performance for:
  - Signal to noise ratio: **62.6dB** (@1KHz)
  - Acoustic overload point: 120 dB SPL
  - Sensitivity of -26dBFS
  - Power supply rejection: -70 dBFS
  - 10ms wake-up time

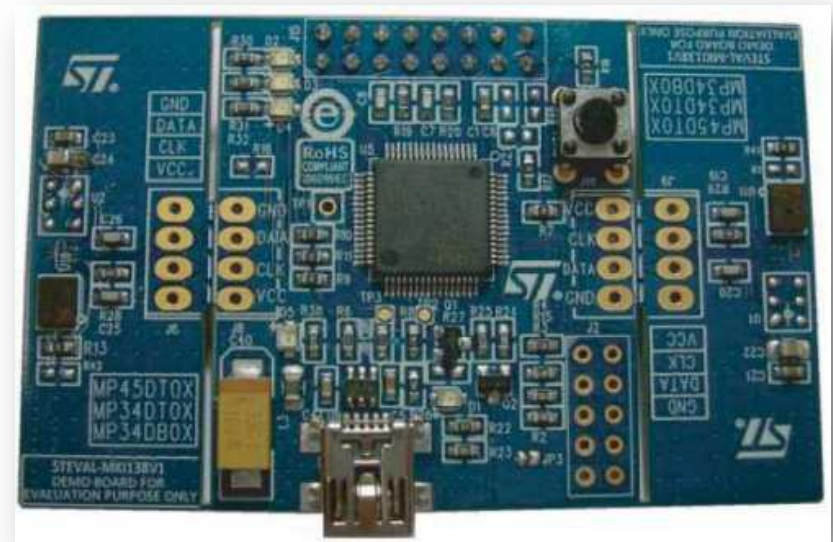
- High Frequency response:



- Low power consumption (normal / low power): 600µA / 20µA
- Small Package, **3x4x1** HPGA package
- Single supply voltage from 1.64 to 3.6V
- Temp. range: -40 to +85°C

- PC sound recording device via USB
- Compatible with audio recording/analysis tools (Audacity, Microsoft Sound Recorder, Adobe Audition, etc..)
- Microcontroller decodes the digital microphone PDM output, producing a 48KHz PCM audio stream
- Possibility to use it in conjunction with **STEVALMKI126Vx** (**STSmartVoice**) and **APWorkbench software suite**

ORDER CODE	MICROPHONE
STEVAL-MKI138V1	MP45DT02







ORDER CODE	MICROPHONE	TYPE
STEVAL-MKI129V1	MP45DT02	Digital
STEVAL-MKI129V2	MP34DB01	Digital
STEVAL-MKI129V3	MP34DT01	Digital
STEVAL-MKI139V1	MP33AB01	Analog
STEVAL-MKI139V2	MP33AB01H	Analog

ORDER CODE	MICROPHONE
STEVAL-MKI126V1	MP45DT02
STEVAL-MKI126V2	MP34DB01
STEVAL-MKI126V3	MP34DT01



I2C



USB

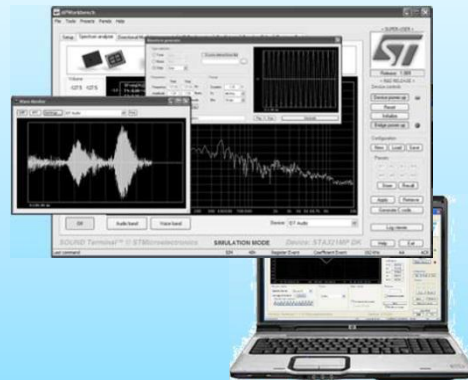


+



## APWorkbench

- Test signal generator
- Freq response acquisition
- Automatic equalization
- Custom filter design
- Device configuration
- C code generation



For more info contact:  
[enrico.marinoni@silica.com](mailto:enrico.marinoni@silica.com) FAE  
[roberto.rossetti@silica.com](mailto:roberto.rossetti@silica.com) BDM