Water and Dust Resistant Pressure Sensors

Jay Esfandyari, Ph.D.

ST MEMS shipped **15 BILLION**

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Technology Tour 2019

Dallas-Richardson, TX | March 7

- ST Product Offerings

- MEMS Technology For Pressure Sensors

  - Bulk Micromachining

  - Surface Micromachining

- Water Resistant / Waterproof Pressure Sensors

- PCB Design Rules

- Pressure Sensors: Applications

Available in 2018	Applications

CONSUMER

AXL 6-axis IMU Mag, E-compass

Microphone Pressure, Humidity, Temperature

**IOT
Wearable
Alarm
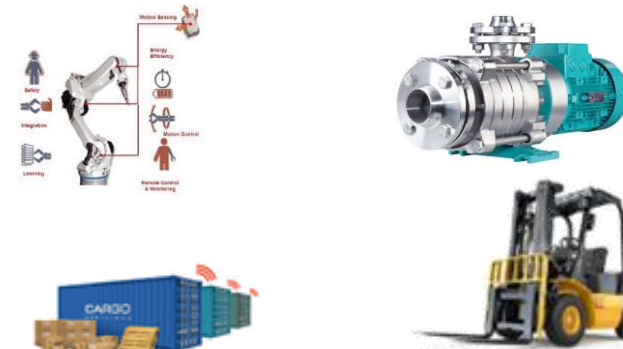Smart Home
Remote Control
Voice Assistant**

INDUSTRIAL

LONGEVITY 10 YEARS COMMITMENT

AXL 6-axis IMU Mag, E-compass

Microphone Dedicated AXL

**Indus Robot
Positioning
Tracking
Tilt
Vibration**

AUTOMOTIVE

AEC-Q100 COMPLIANT
PPAP LEVEL-3 AVAILABLE

AXL Gyro 6-axis IMU

**Alarm
E-call
Telematic
Vehicle tracking**

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Available in 2018	New products for H2 2018 / H1 2019

CONSUMER

AXL | 6-axis IMU | Mag, E-compass

Microphone | Pressure, Humidity, Temperature

LPS22HH | LPS33W | LPS27HHW

LSM6DSO | LSM6DSR | LSM6DSRX

LIS2DTW12 | LSM6DSOX | HTS2

STTS22H | MP23DB01HP

MP34DT06J | MP23DB02MM

**IOT
Wearable
Alarm
Smart Home
Remote Control
Voice Assistant**

INDUSTRIAL

AXL | 6-axis IMU | Mag, E-compass

Microphone | Dedicated AXL

IIS2DLPC | IIS2ICLH

IIS3DHHC | ISM330DHC | IIS3DWB

ISM330DLC

IMP34DT05

**Indus Robot
Positioning
Tracking
Tilt
Vibration**

AUTOMOTIVE

AXL | Gyro | 6-axis IMU

AIS2IH

ASM330LHH | AIS2DW12

**Alarm
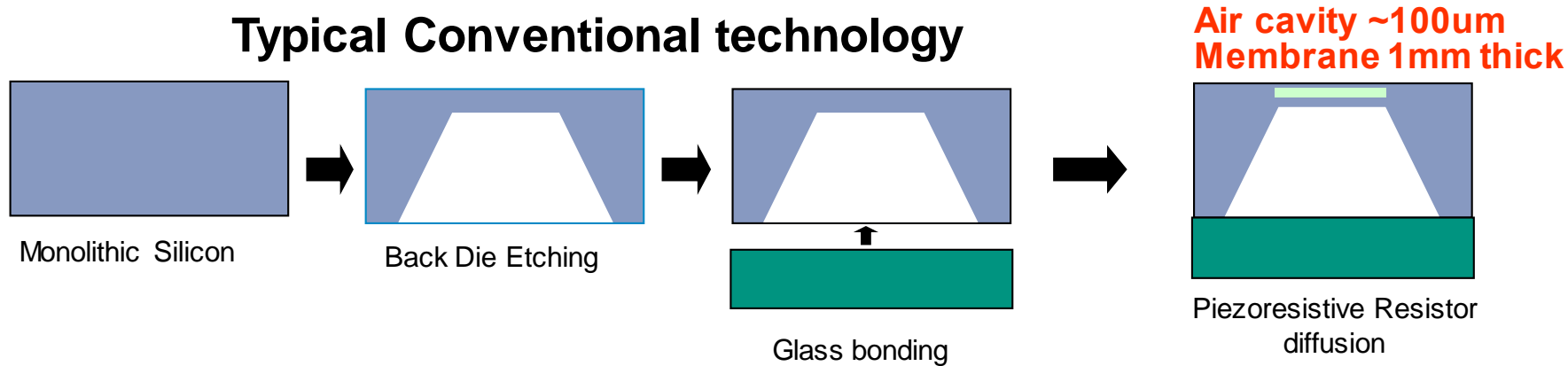E-call
Telematic
Vehicle tracking**

MP in 18H2	MP in 19H1

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MEMS Technology
For Pressure Sensors

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Pressure Sensor Technology

Typical Conventional technology

Air cavity ~100um
Membrane 1mm thick

Monolithic Silicon → Back Die Etching → Glass bonding → Piezoresistive Resistor diffusion

Full Silicon Pressure Sensor technology

Air cavity ~1um
Membrane 300um thick

Monolithic Silicon → Cavity creation → Cavity completed → Piezoresistive Resistor diffusion
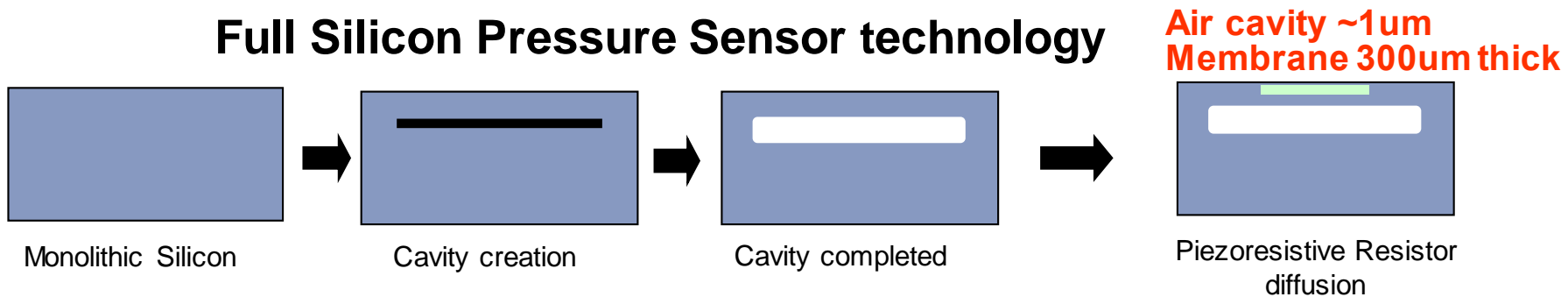
Full Silicon Technology Advantages

➢ Monolithic sensor: no need for wafer to wafer bonding to create the cavity
➢ High burst pressure - Intrinsic mechanical stopper
➢ High shock survivability
➢ Good temperature behavior – one temperature coefficient (only silicon)
➢ More robust and thinner sensor

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Principle of Design

➢ Piezoresistivity: a change in the electrical resistivity of a metal or semiconductor due to an applied stress (force, pressure, flow, acceleration)

➢ All the materials show a piezoresistivity effect but semiconductors possess stronger piezoresistivity property: Si is the best one (Smith, 1953).

➢ Four resistors are connected in a Wheatstone bridge configuration.
➢ Pressure variations change the bridge balance.

$$\alpha_1 = (\pi_l + \nu\pi_t)\sigma_l = (67.7\times10^{-11})\sigma_l$$

$$\alpha_2 = (\pi_t + \nu\pi_l)\sigma_l = (61.7\times10^{-11})\sigma_l$$
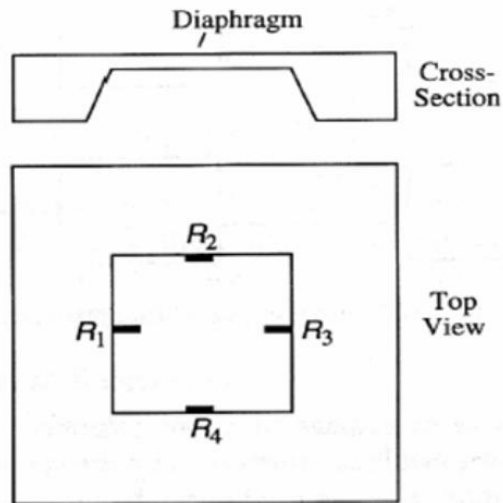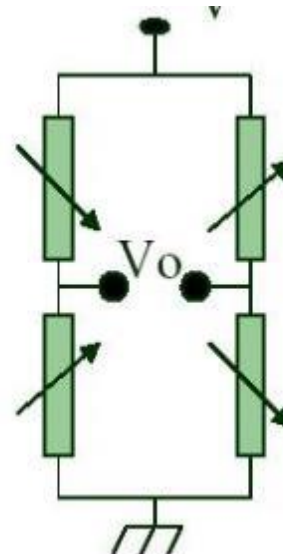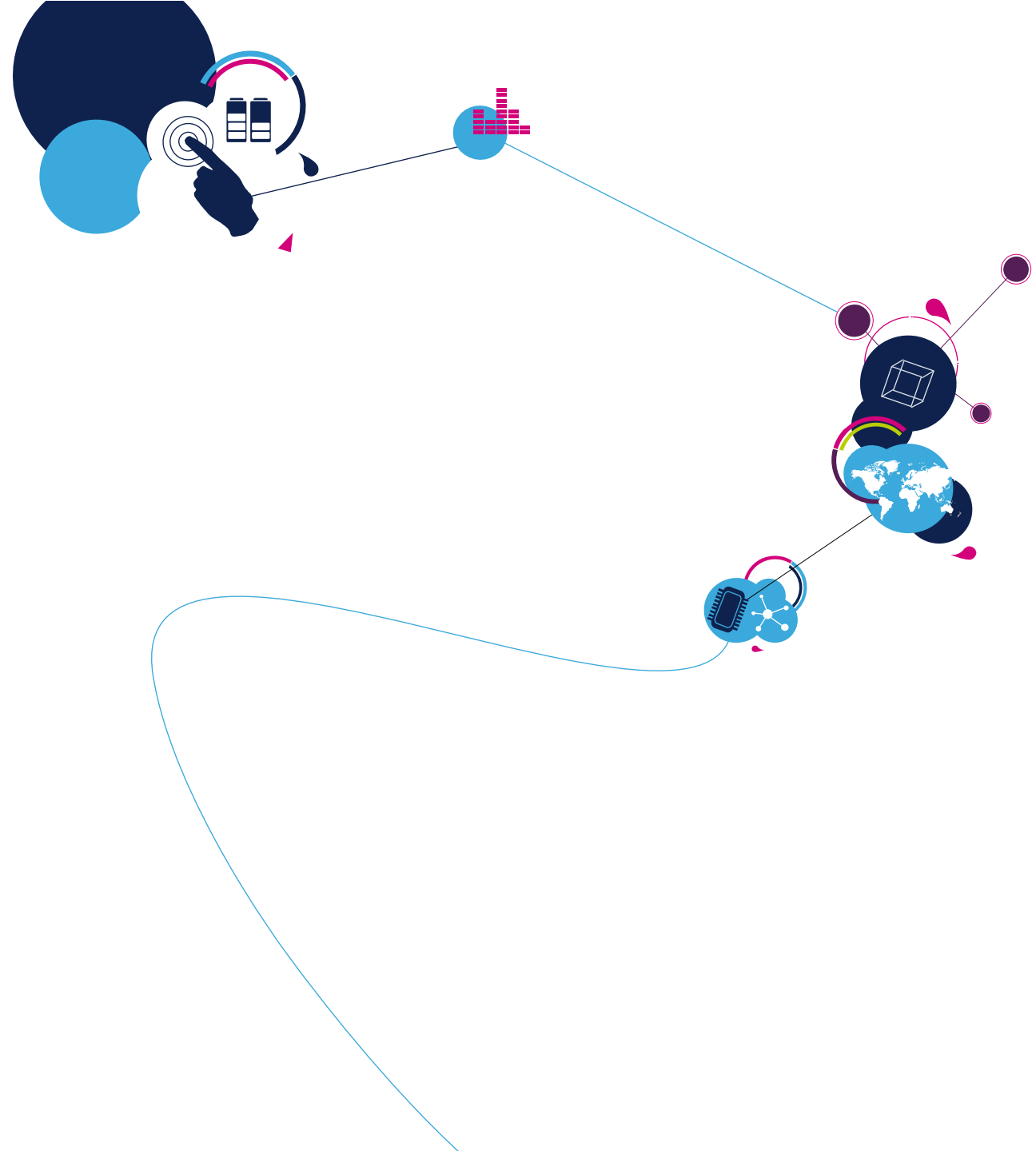
Wheatstone-bridge detection circuit:
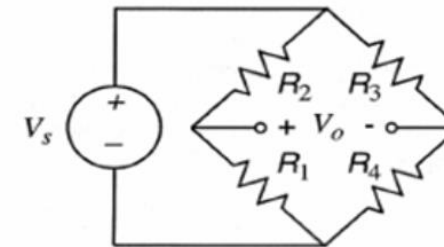
$$R_1 = R_3 = (1+\alpha_1)R_0$$

$$R_2 = R_4 = (1-\alpha_2)R_0$$

$$\frac{V_o}{V_s} = \frac{R_1R_3 - R_2R_4}{(R_1 + R_2)(R_3 + R_4)} \approx \frac{2(\alpha_1 + \alpha_2)}{1+\alpha_1 - \alpha_2}$$
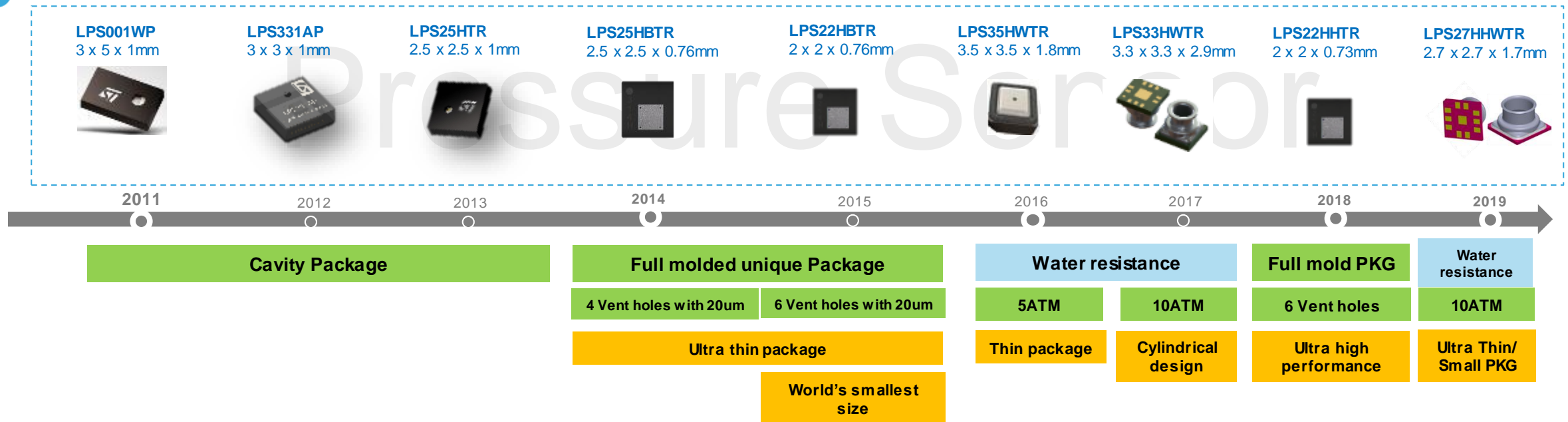
Pressure Sensors

Overview

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ST Pressure Sensor Evolution

LPS001WP	LPS331AP	LPS25HTR	LPS25HBTR	LPS22HBTR	LPS35HWTR	LPS33HWTR	LPS22HHTR	LPS27HHWTR
3 x 5 x 1mm	3 x 3 x 1mm	2.5 x 2.5 x 1mm	2.5 x 2.5 x 0.76mm	2 x 2 x 0.76mm	3.5 x 3.5 x 1.8mm	3.3 x 3.3 x 2.9mm	2 x 2 x 0.73mm	2.7 x 2.7 x 1.7mm

Timeline: 2011 — 2012 — 2013 — 2014 — 2015 — 2016 — 2017 — 2018 — 2019

Cavity Package

Full molded unique Package
- 4 Vent holes with 20um
- 6 Vent holes with 20um
- Ultra thin package
- World's smallest size

Water resistance
- 5ATM
- 10ATM
- Thin package
- Cylindrical design

Full mold PKG
- 6 Vent holes
- Ultra high performance

Water resistance
- 10ATM
- Ultra Thin/ Small PKG

>500 Million pressure sensors shipped

> 300Mpcs shipped with full-molded package technology

ST leads the Pressure Sensor market in Consumer segment
- Market share : 62% in Y2017 consumer
- Selected in various applications with superior performance & unique robustness of full molded package in consumer markets.

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LPS22HB & LPS22HH

High Accuracy Atmospheric Pressure sensor

General Features

- Absolute accuracy ±1hPa, Noise RMS 0.75Pa
- 260 to 1260 mbar absolute pressure (2bar Max)
- ODR from 1 to 75Hz, one shot
- Embedded Temperature compensation
- 32 samples Embedded FIFO for Pressure and Temperature
- SPI and I²C interfaces

LPS22HB

LPS22HB – Water Resistant

- 2x2x0.76 mm package, 6 holes with 20µm diameter to avoid contamination
- 12µA (HPM) to 3µA (LPM) @1Hz, 1µA in PDM

P2P solution

General Features

- Absolute accuracy **±0.5hPa**, Noise RMS **0.65Pa**
- 260 to 1260 mbar absolute pressure (1.6bar Max)
- ODR from 1 to **200Hz**, one shot
- Embedded Temperature compensation
- 32 samples Embedded FIFO for Pressure and Temperature
- **Temperature sensor calibrated**
- SPI and I²C interfaces

LPS22HH

LPS22HH – Water Resistant

- 2x2x0.76 mm package, 6 holes
- Improved accuracy
- 12µA (HPM) to 4µA (LPM) @1Hz, 0.9µA in PDM

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LPS22HH

New Sensing Element & ASIC

LPS22HH

Ultra high-performance pressure sensor on small full molded PKG for vertical position (i.e indoor navigation / E911 application / dusty environment)
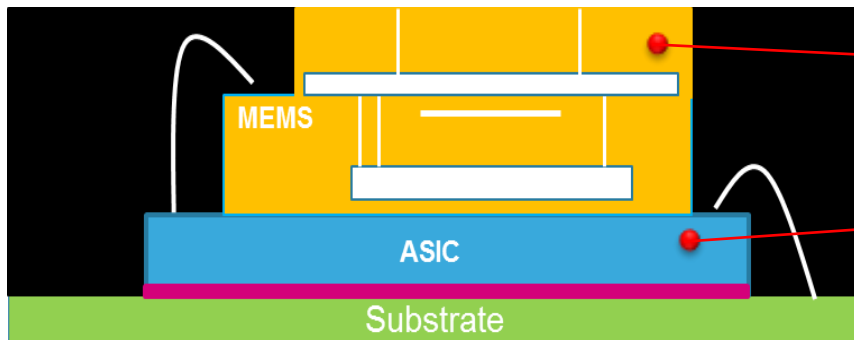
ES Sample	ST Qualification	Mass Production
Q1'18	Q2'18	Q318

MEMS

ASIC

Substrate

- **New Sensor**
    - Better Pressure accuracy & faster response
    - Better mechanical robustness

- **New ASIC**
    - Better Pressure accuracy , Less RMS noise
    - RF immunity

- **Full molded PKG**
    - Pin to Pin compatibility with LPS22HB (2x2mm)
    - 6 vent holes for redundancy

ST Unique Pressure Sensor Package(1)

Patented Technology

Conventional PKG – Pressure Sensor

ST Full molded PKG
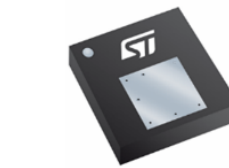
ST Pressure Sensor
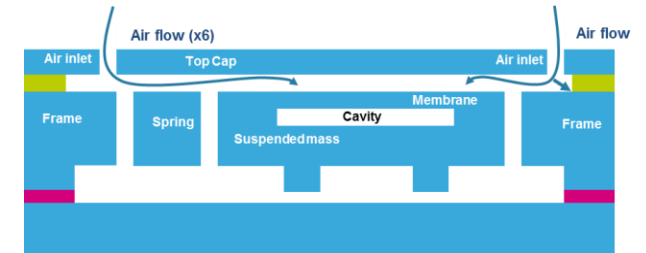
ST Unique package advantage

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

Full molded package

Silicon cap

Suspended membrane
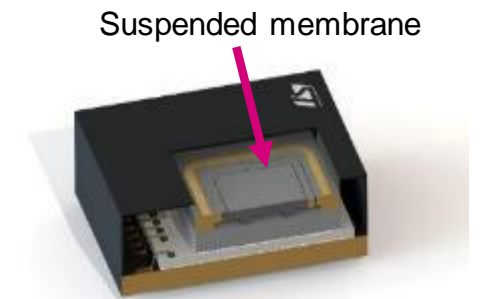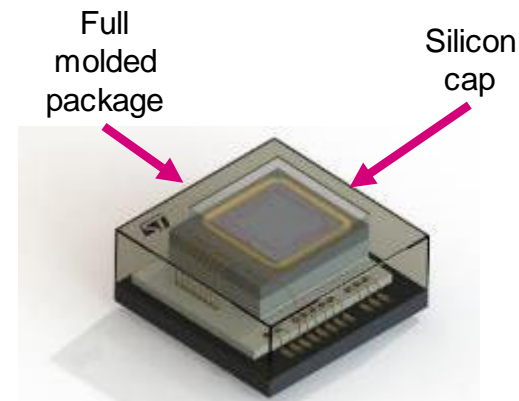
>500 Million pressure sensors shipped

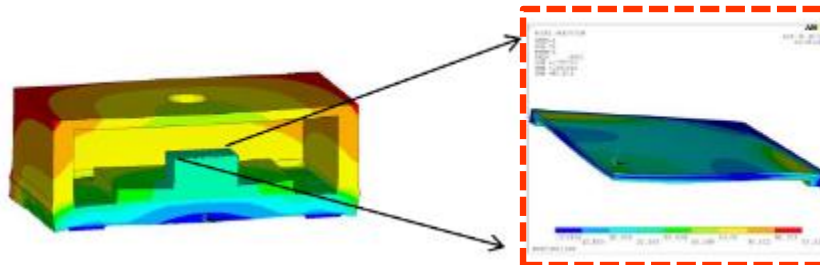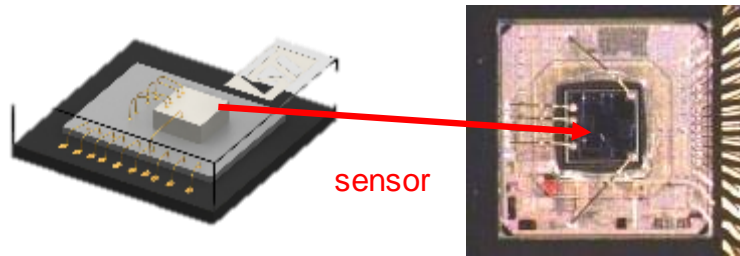More than 300Mpcs shipped with full-molded package technology

ST Unique Pressure Sensor Package(2)

Patented Technology

- Unique spring structure in fully molded PKG to isolate membrane from thermal stress.
    - **Lower stress on Membrane** by spring structure from thermal stress.
    - **Better accuracy stability** over temperature and after soldering.
    - Proven the performance with over than 300Mpcs shipment of full molded package.

Cavity Package	Full molded with Spring Structure
LPS25H Cavity Structure like conventional pressure sensor	**LPS22HB** World's Smallest pressure sensor in 2x2 package

sensor

Spring structure

Spring

❖ Simulation of deformation by soldering stress
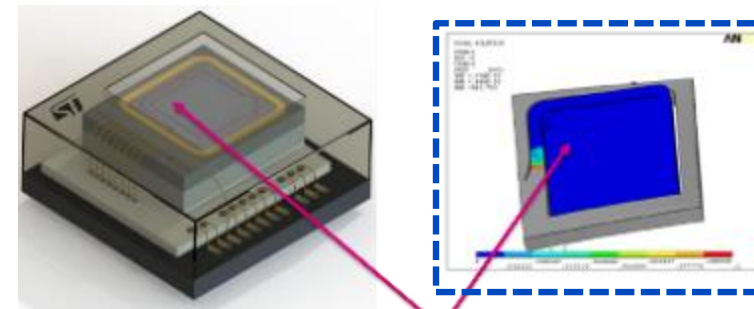
❖ Simulation of deformation by soldering stress

Water Resistant / Waterproof Pressure Sensors

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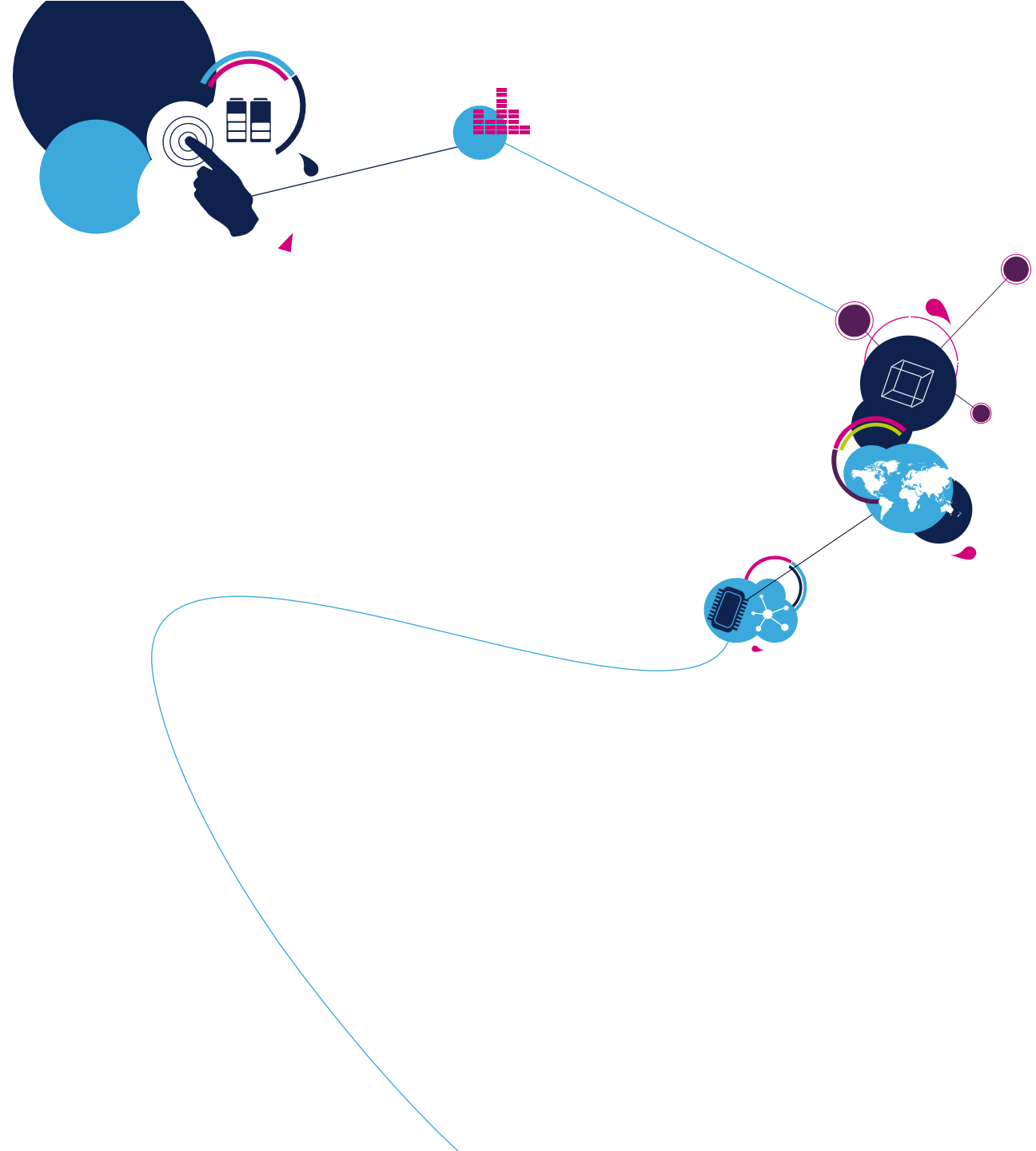
LPS33W & LPS33HW & LPS27HW*

Atmospheric Waterproof Pressure sensor

General Features – LPS33W, LPS33HW

- High Accuracy Waterproof Barometric Sensors
- 260 to 1260 mbar absolute pressure (2bar Max)
- ODR from 1 to 75Hz, one shot
- Embedded Temperature compensation
- 32 samples Embedded FIFO for Pressure and Temperature
- SPI and I²C interfaces

Wearable

- Chlorine, Bromine mixed, Salt water test
- Over Pressure Test (up to 10Bar / up to 24hr) (swimming pool, sea use case)

Industrial

- n-Pentane Chemical liquid (corrosion test for industry)

Specific Features to LPS27HHW*

- ODR up to 200Hz
- Higher accuracy embedded Temperature sensor
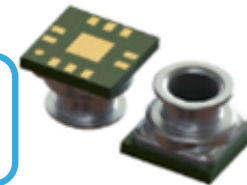- Improved power consumption
- 128 samples FIFO

*Available in Q3 2019

LPS33W

LPS33HW

MEMS
ASIC
Substrate
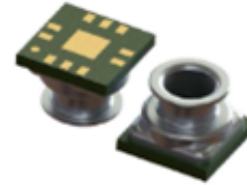
LPS27HW*

LPS33W – Water Proof
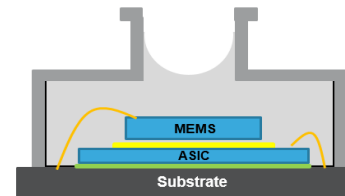
- 3.3x3.3x2.9 mm, CCLGA - 10L
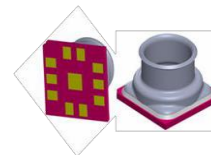- O-ring shaped PKG with full metal lid
- 15µA (HPM), 4µA (LPM) @1Hz

LPS33HW – Water Proof

- 3.3x3.3x2.9 mm, CCLGA - 10L
- O-ring shaped PKG with full metal lid
- **10bar resistant (100m)**
- 15µA (HPM), 4µA (LPM) @1Hz

LPS27HHW* – Water Proof

- 2.7x2.7x1.7mm
- O-ring shaped PKG with full metal lid
- **10bar resistant (100m)**
- Absolute accuracy ±1hPa
- Noise RMS [HP] - 0.7Pa
- 12µA (HPM), 4µA (LPM) @1Hz, 0.9µA PDM

Water Proof Pressure Sensor

LPS33HW

ST Harsh Environment and High Pressure Resistant - Up to 10 ATM

- Absolute Accuracy : ± 2.5hPa
- Relative Accuracy : ± 0.1hPa
- RMS noise : ± 0.8Pa (0.008hPa)
- **Water Resistant up to 10 ATM**
- High robustness with full Metal LID and Automotive gel
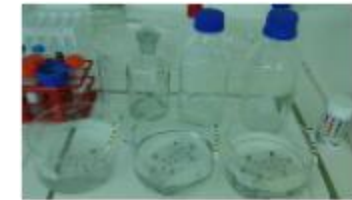- Easier assembly in application with O-ring shape of package.

Metal → GEL / MEMS / ASIC
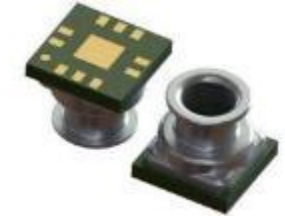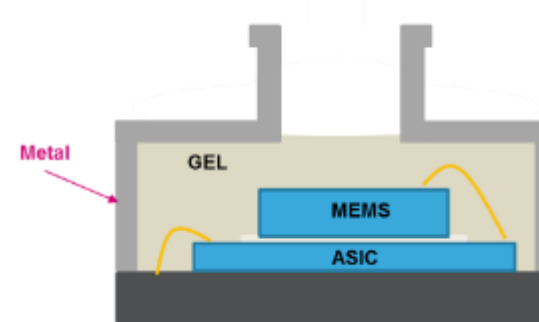
CCLGA-10L, 3.3 x 3.3 x 2.9mm

❖ For Swim user case in swimming pool & Sea

Wearable

- Chlorine, Bromine mixed water test
- Salt water test
- Over Pressure Test (up to 10Bar / up to 24hr)

❖ Compatible with human body

E-cigarette

- Robust to nicotine and high temperature

❖ Corrosion Test for industrial
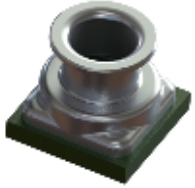
Gas Meter

- n-Pentane Chemical liquid

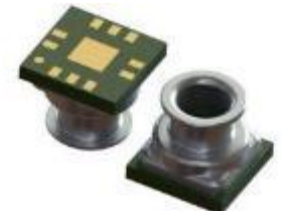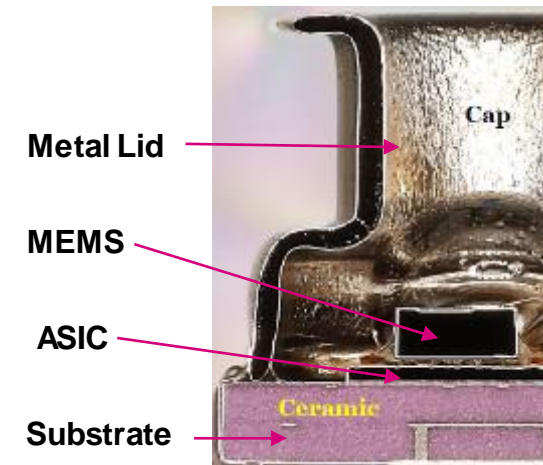life.augmented

Waterproof Pressure Sensor
For Harsh Environment

LPS27HHW

Features
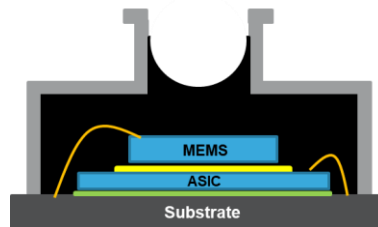
- 260 to 1260 mbar absolute pressure (18-3PSI)
- RMS noise 0.007 hPa with embedded filter
- Absolute accuracy ±1 hPa @ 0 ~ 65'C
- Relative Pressure accuracy ± 0.1hPa
- ODR from 1 Hz to 200 Hz
- Low power consumption: 4 µA
- Embedded FIFO (128 slots/40 bits)
    - Pressure and Temperature data
- Water resistant up to 10Bar
- Cylindrical Water proof package 3.3x3.3x2.9mm
- Potting GEL protects electrical components.
- 24 bit pressure resolution (0.0002 hPa/bit), 16 bit temperature
- SPI, I2C, I3C interface (I2C/I3C can be disabled)

PKG Structure

Metal Lid — Cap

MEMS

ASIC

Substrate — Ceramic

3.3 x 3.3 x 2.9mm

A look inside

MEMS
ASIC
Substrate

| Altimeter | E-Cigarette | Drone | GPS and Indoor navigation | Weather station |

Other Major Improvements in LPS27HHW
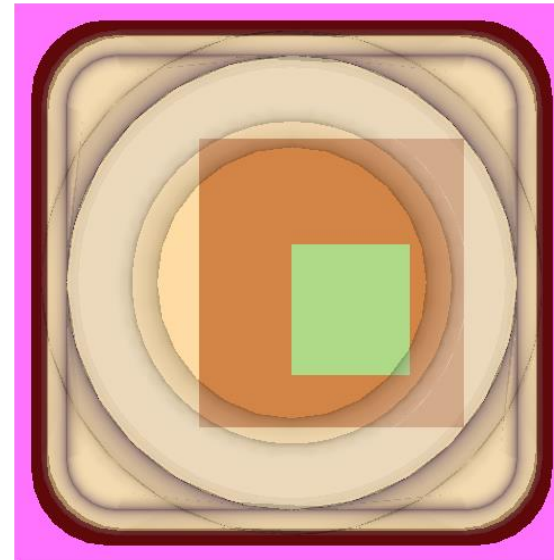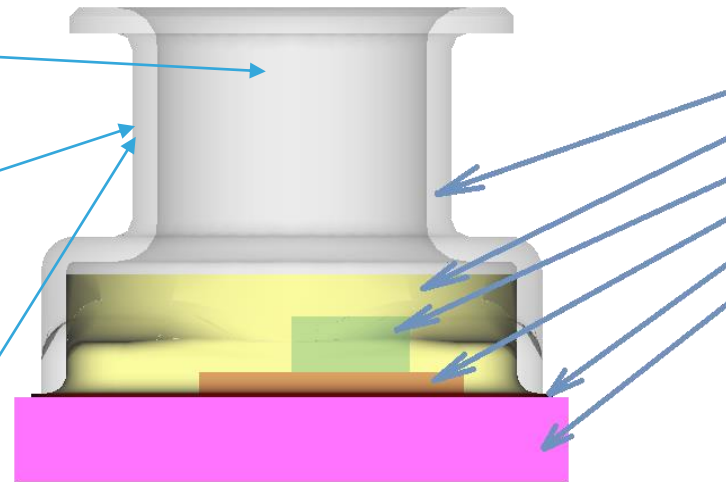
Large Opening
  prevent water/debris trapping
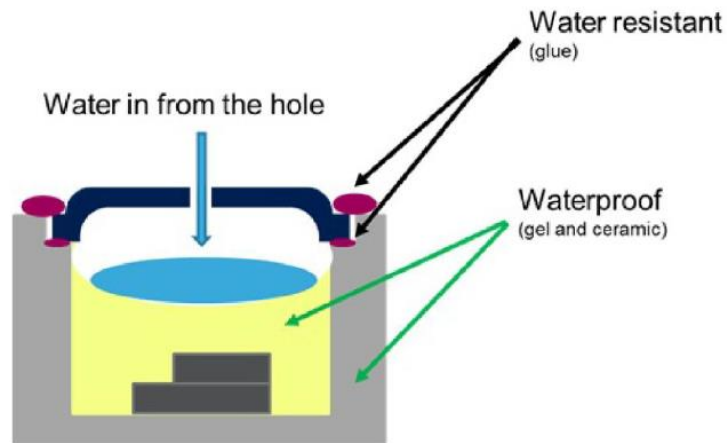
Cap Grounded
  Sustain higher ESD shock

Cylindrical Cap
  More secure seal against the device housing
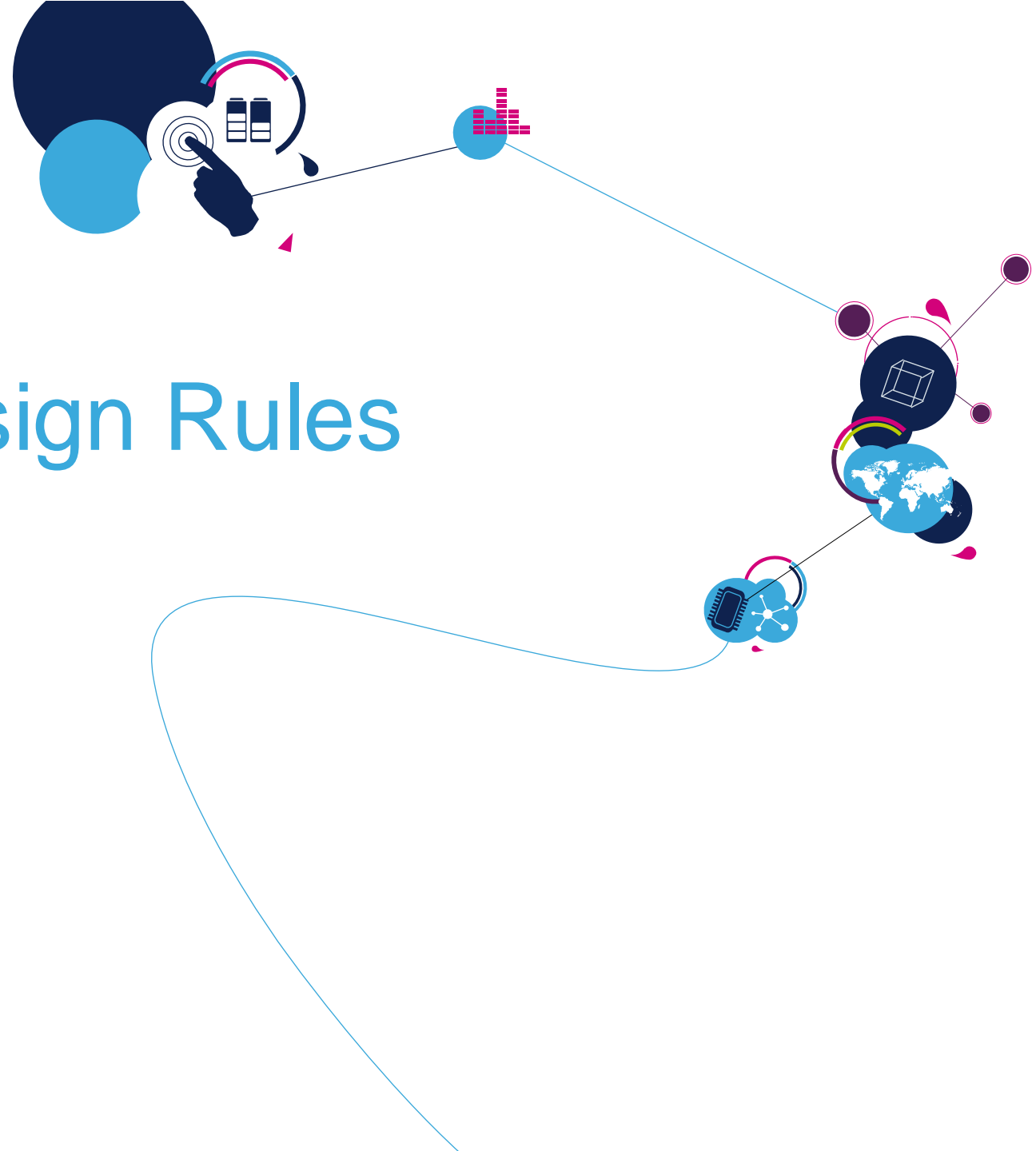

Stainless steel can
Potting gel for water-proof design
Pressure sensor membrane
Controller ASIC
Ceramic substrate

Water in from the hole

Water resistant (glue)

Waterproof (gel and ceramic)
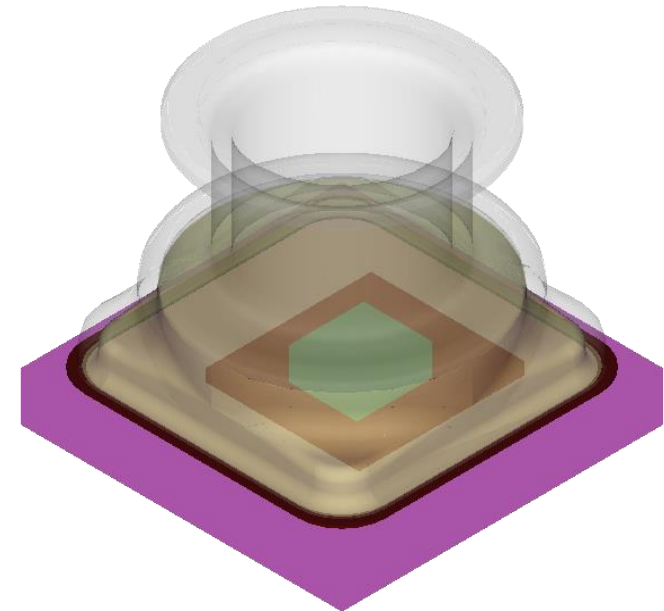
Cylindrical Cap: port opening, shear test data is available

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System and PCB Design Rules

For Pressure Sensors

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PCB Design Rules

- **PCB design rules**
  - ➢ The area below the sensor must be defined as "keep-out" area.
  - ➢ Mechanical stress coming from PCB board should be avoided
  - ➢ The whole package surface should have minimum temperature gradient

- **Soldering**
  - ➢ LGA packages for pressure sensor are qualified for soldering heat resistance according to JEDEC J-STD-020, in MSL3 condition.
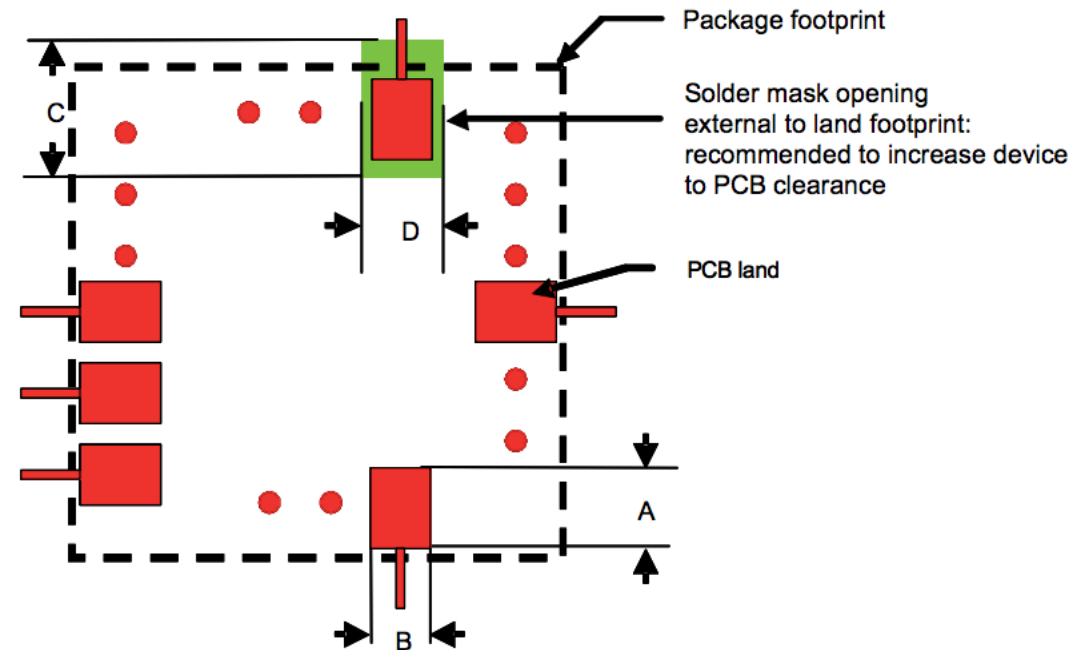
- **Surface mounting guidelines for MEMS sensors in LGA package**
  - ➢ Any cleaning process has to avoid foreign materials inside the sensing element holes
  - ➢ Kapton sticker can be applied after the soldering profile and before cleaning

of a Pressure Sensor
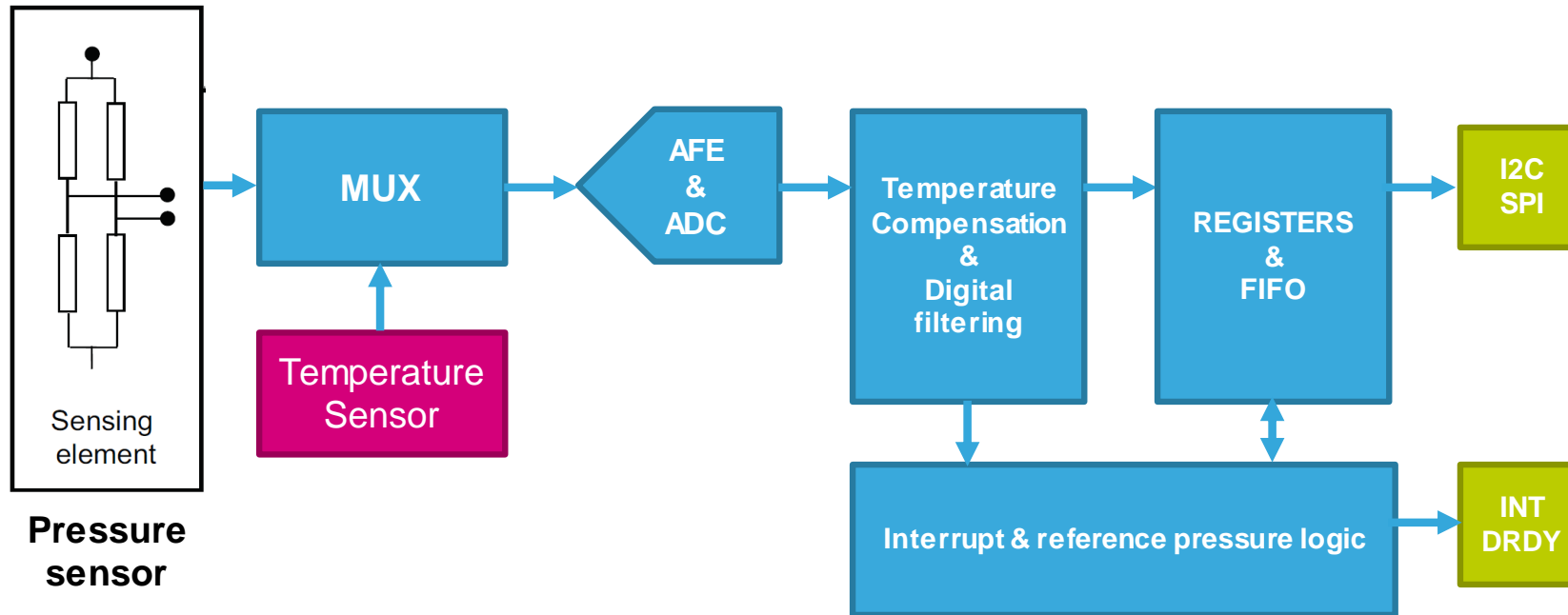
- The sensor is calibrated at 3 temperatures and 2 pressures for better accuracy
  - Trimming parameters are loaded at each start-up.
  - No need for re-calibration in application.

How to Interface with the Device

➢ **Power supply**

- ➢ Separated Vdd and Vdd_IO lines (ultra low drop, low noise LDO)
- ➢ Supply voltage range: 1.71 to 3.6V for both, VDD_IO <= VDD

➢ **The device is capable of communicating over 2 digital serial interfaces**

- ➢ SPI 3-wire(CS, SPC, SDI/O) or 4-wire (CS, SPC, SDI, SDO)
- ➢ I²C (SCL, SDA) with slave address selectable by SA0 pin
- ➢ CS pin is used to select between SPI and I²C
- ➢ I²C interface can be disabled using I2C_EN bit of CTRL_REG2 (21h)

➢ Device setup and data acquisition is done by accessing registers of the sensor

➢ INT_DRDY interrupt push-pull pin has programmable functionality (pressure high, pressure low, data ready, FIFO interrupts)
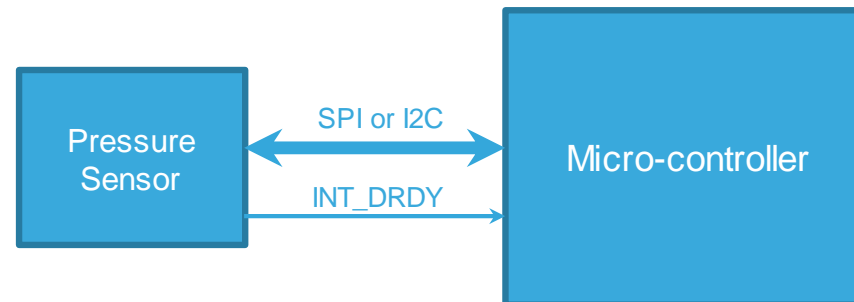
- Over pressure test
    - Test condition : 1.5 / 3 / 5 / 10 bar over pressure for 10sec & 60sec
    - no impact in accuracy nor other performance
- Hot Chlorine, Bromine and Salt water test
    - Potting GEL not affected to cause any accuracy error
- Detergent water (commercial shampoo, hand soap and water mixed in)
- Aging & corrosion test in n-Pentane liquid for 72hr
    - No physical damage by n-Pentane after 72hr with performance in SPEC

LPS33HW

O-ring

PCB
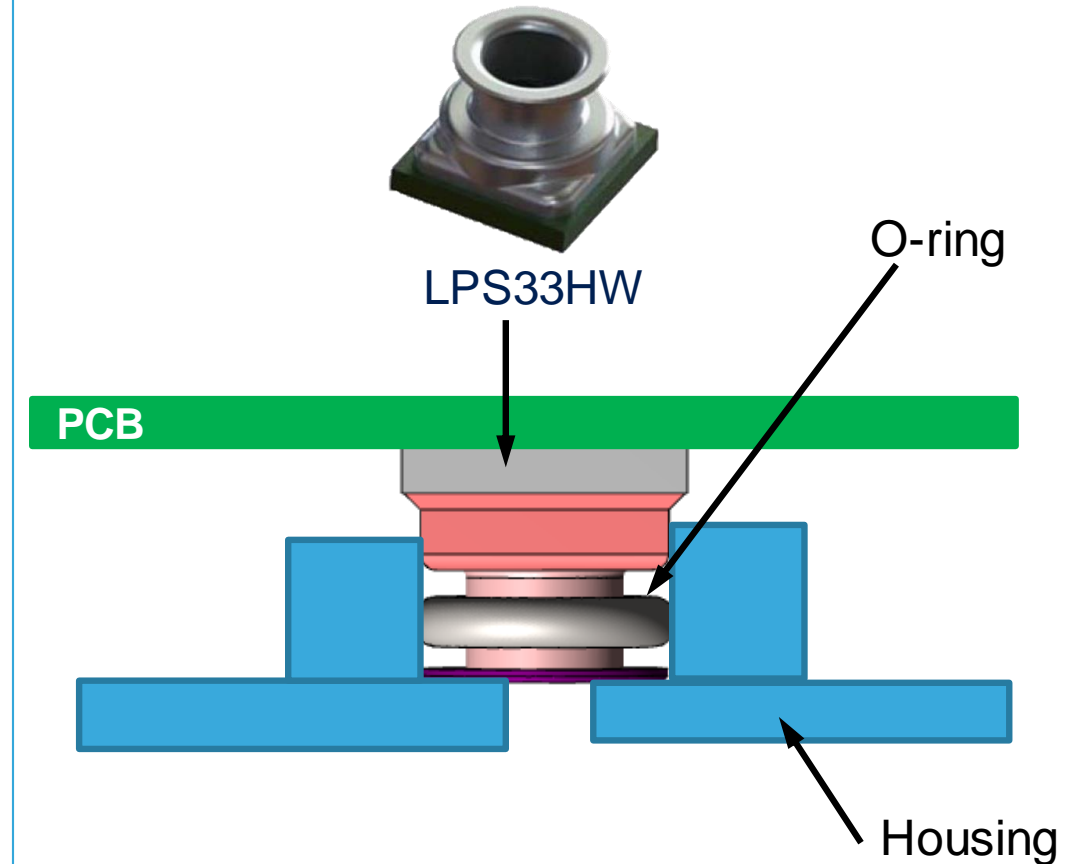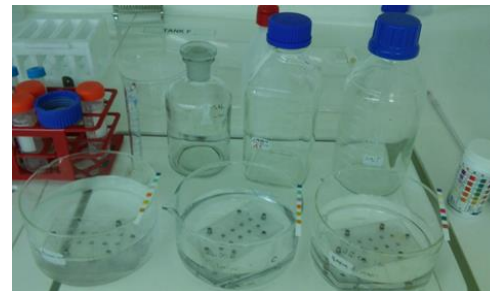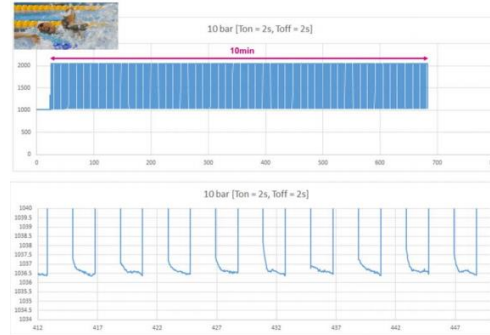
Housing

Sealing is guaranteed by rubber o-ring and housing design – guidelines provided in a dedicated AN (AN5063)

LPS35/33HW Recovery Time After Reflow

post soldering accuracy drift

- Average value on ~50 samples per device
- Multi-layer PCB with 1mm thickness
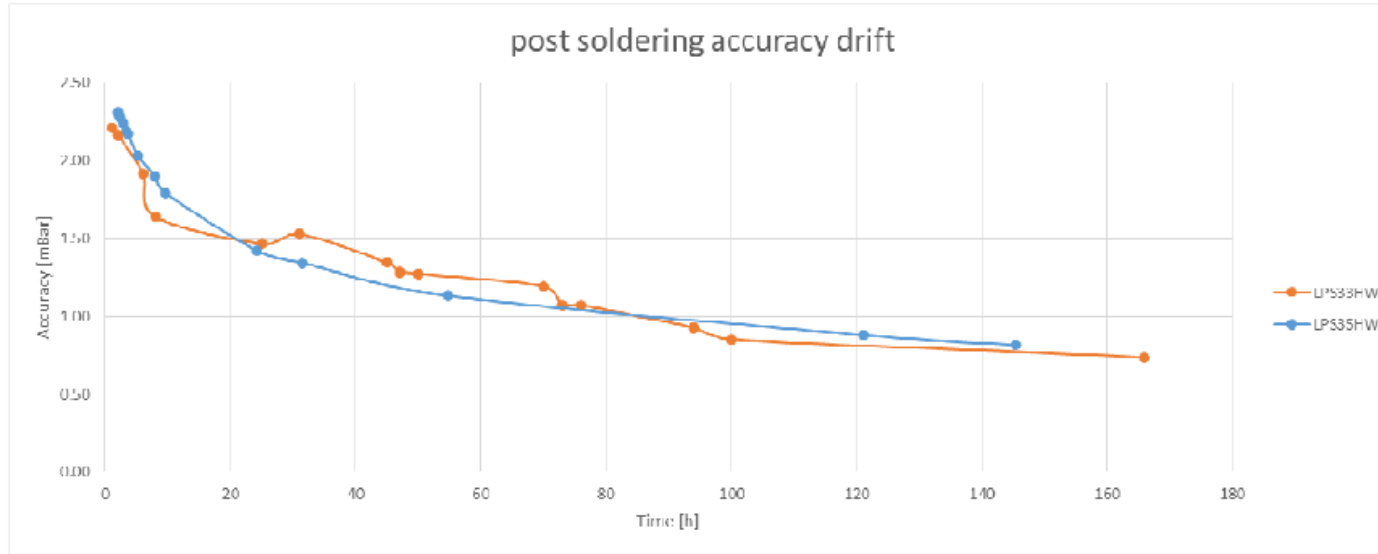
- It's normal for water resistant pressure output drift after SMD reflow. High temperature affects the gel, then causes the output shift.
- ST parts recover faster than most of the competitors' parts.
- Faster recovery time helps manufacturing process flow.

- All 100pcs LPS33HHW engineering samples have <3 days settle time

Pressure Sensors:
Applications

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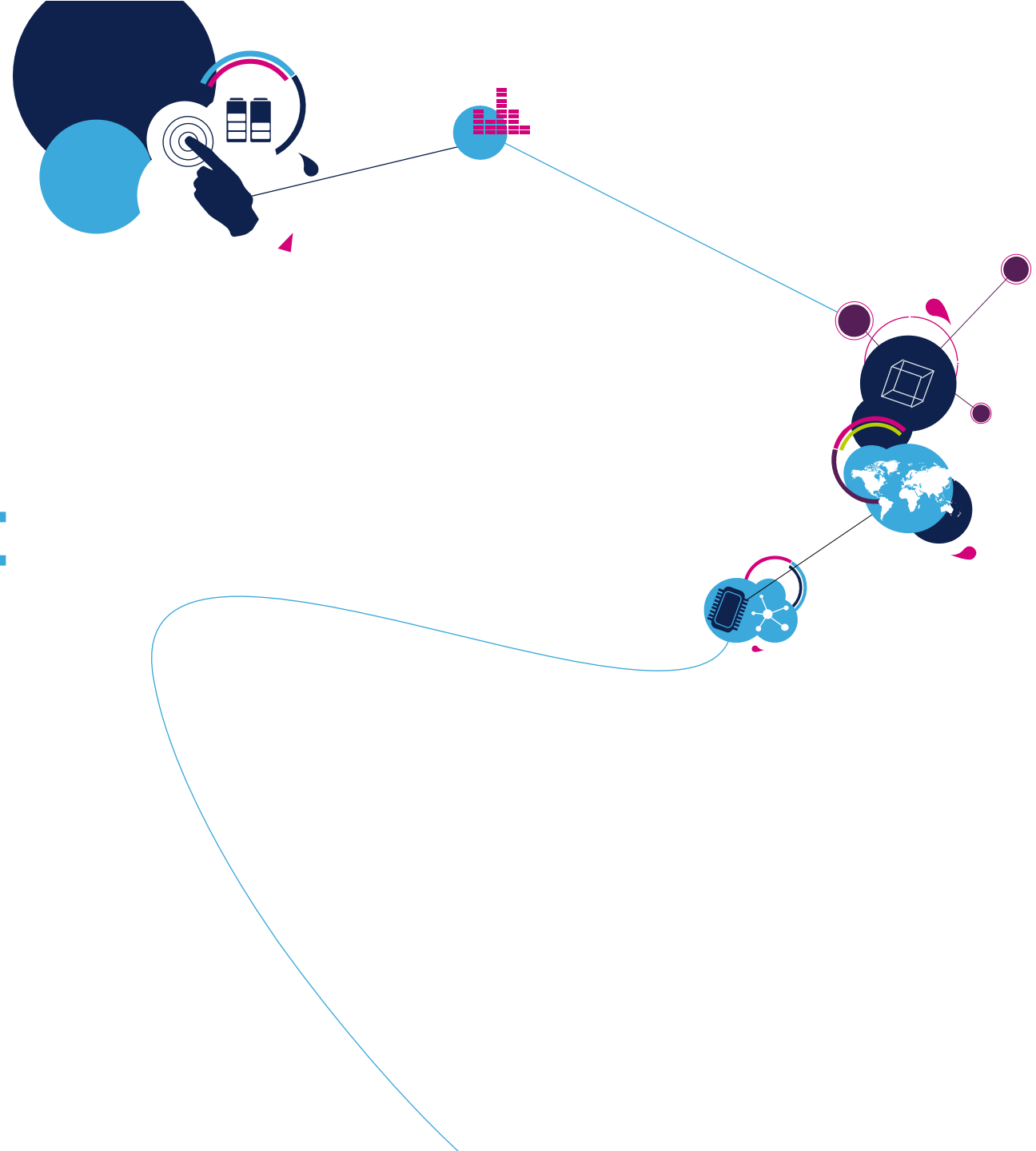
Key Roles of a Pressure Sensor
in Applications

- Ambient Pressure measurement – mbar/hPa (atmospheric pressure sensor – 260-1260mbar)
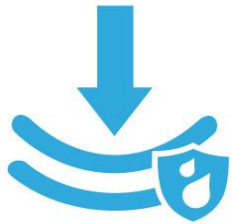
For weather forecasting

- Altimeter for navigation and tracking

Altitude (m)
10000
8000
6000
4000
2000
Sea level 0
-2000

Average Sea level pressure = 1013.25 mbar (varies with weather)
Pressure decrease when altitude increases

- For application where water-resistant or water-proof is needed

e.g. sport watches

- Monitoring under / over pressure

e.g. bag / water container content

Pressure Sensor Applications

Weather Station

Altimeter and Barometer

Smart Watch

Smart Glasses

GPS Applications

Indoor Navigation

Vacuum Cleaner

Man Down Detection

Drones

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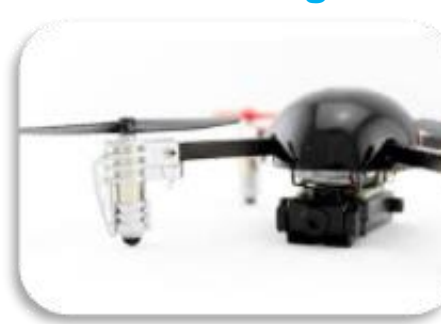
Pressure Sensor Applications
with water proof capability

Vaccum cleaner
Floor type, dust bag content level

Asset tracking
Takeoff/ landing pressure

Gas meter
Leakage detection
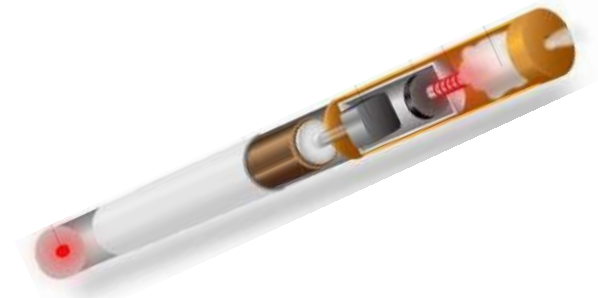
E-cigarette
Detect inhalation

Altimeter control
Pressure measurement

Weather station /
Air quality monitoring

Performance Measurement
Measure pressure variation

Indoor & outdoor Navigation
Floor level detection

And many others….

Water/Laundry Detergent Level/Temp Control

Pressure Sensor in Wash Machines

In the stream water level and temperature control
- Remove pressure hose
- Precise water level detection
- Sensing/control water temperature for different type of clothing
- Any liquid
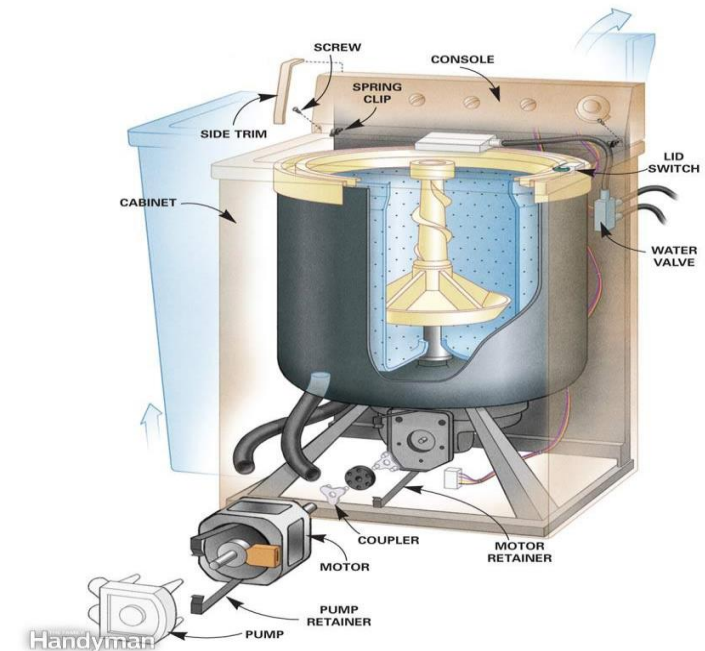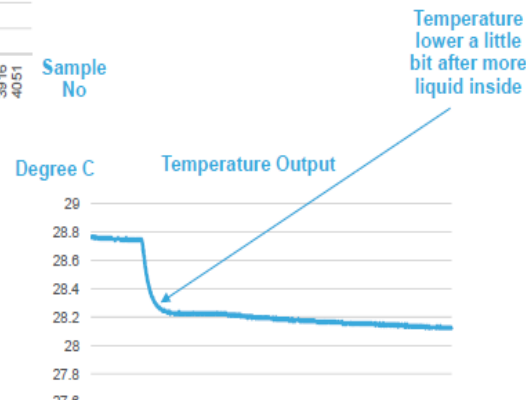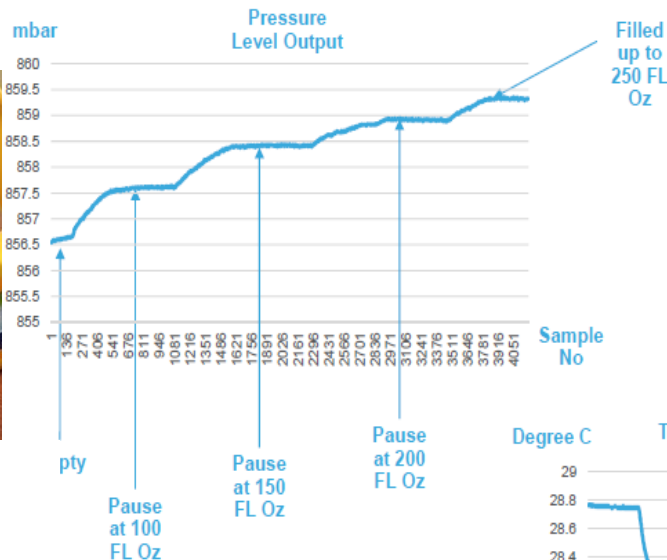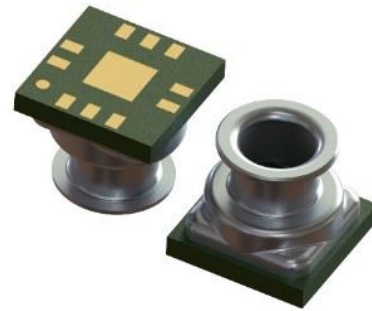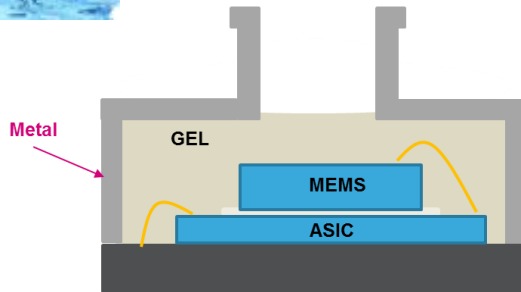
Pressure Sensors (LPS22HB and LPS33HW) in Water Level Monitoring / Alarms

- Pressure sensor used for measure Water Level in SMART Water Level monitoring / Alarm
- Usage of two pressure sensors one on the top of the tank (LPS22HB) measuring the ambient temperature and one on the waterproof device (LPS33HW) as a probe within the water.

LPS22HB Pressure Sensor

P1 : Ambient Pressure

Media's specific gravity/Density

H

✓ **P2-P1: Calculate to Water Depth in below.**
  ✓ **P2 – P1 : 100hPa (0.1Bar) = 1 meter (3.3feet)**
  ✓ **P2 – P1 : 1000hPa (1Bar) = 10 meter (33 feet)**

LPS33HW Water Proof Pressure Sensor

P2 : Pressure in Water & Need Water Proof

Hydrostatic Pressure

Pressure (bar) vs Height (m)

life.augmented
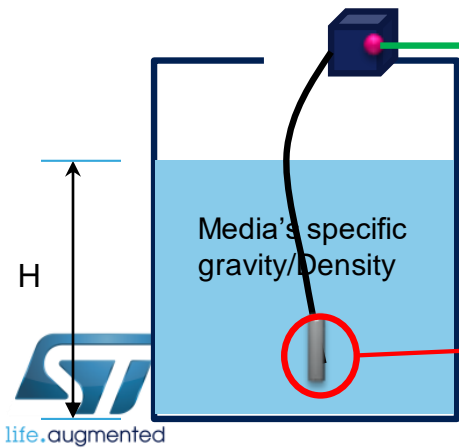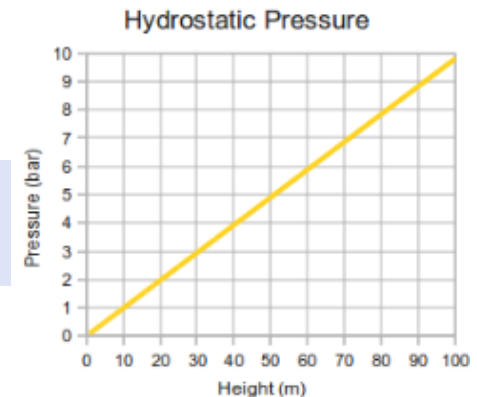
Fall Detection

- **ST SW Algorithm can detect fall of users**
  - Uses Accelerometer and Pressure sensor combination to minimize false alarm.
  - Uses change in acceleration + change in height from pressure sensor to detect fall.
  - Combining sensors allows fast detection and better rejection of false positives.
  - 36/36 falls classified correctly (forward, backward, left, right) with no false positive (sit down, lie down, stairs down, elevator).
  - Tested for belt position

Figure 5. Fall Detection window
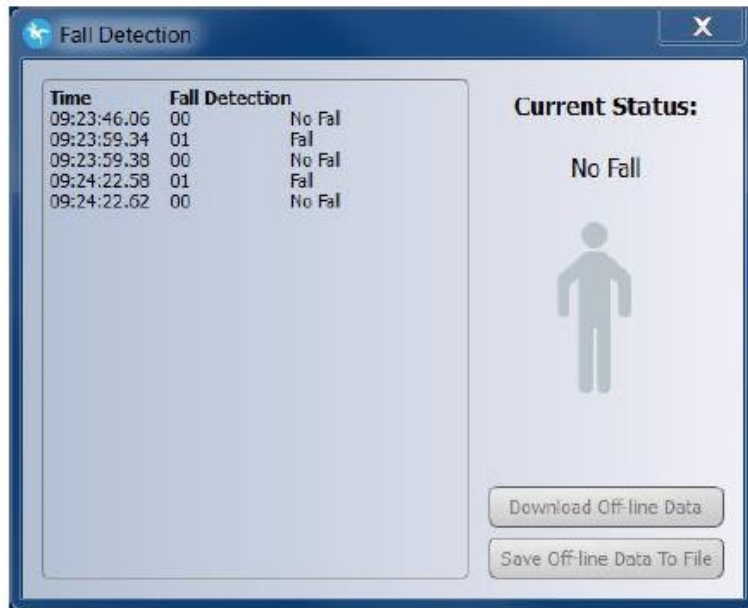
Figure 3. Unicleo main window
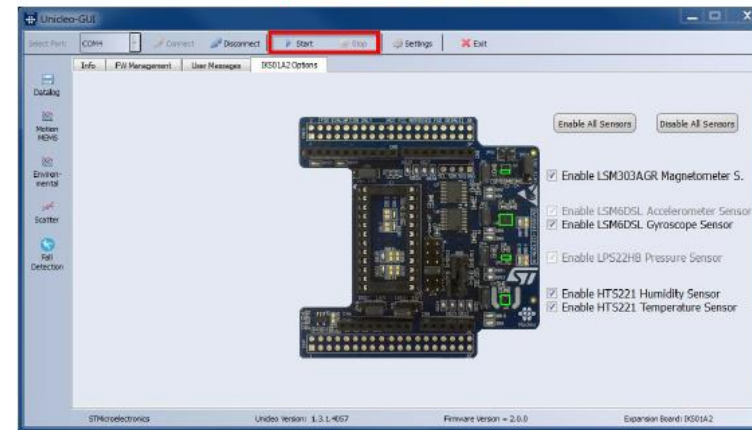
Water Resistant Pressure Sensor
enables the monitor used in bath/shower

Pressure Sensors
for Takeoff and Landing

Pressure Sensors In SCM

TAKE OFF DETECTION
TRACKER RADIO OFF

Take off and landing detection

LANDING DETECTION
TRACKER RADIO ON

Absolute Pressure Sensors

Nano digital absolute pressure sensor

- Embedded temperature compensation
- Pressure range 260 to 1260 hpa
- Over pressure capability: 20xFs
- Embedded FIFO
- HLGA 10L 2.0 x 2.0 x 0.73mm

ES AVAILABLE

LPS22HH
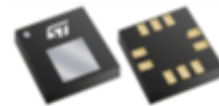
Water resistant absolute pressure sensor

- Absolute pressure range 260 to 1260 hpa
- Embedded temperature compensation
- Water resistant package
- Embedded FIFO
- CCLGA 10L 3.3 x 3.3 x 2.9mm

AVAILABLE

LPS33HW

Tools, SW & Evaluation Kits

life.augmented

Description

- Access to device registers and features in an easy to use GUI

- Useful as a comparison for debugging your system

- For feasibility / use case analysis

- eMotion Mainboard supports most MEMS devices via 24-pin socket

Pressure Sensor Adapters

LPS22HH
LPS22HB: STEVAL-MET001V1
LPS33HW: STEVAL-MKI183V1
LPS35HW: STEVAL-MKI177V1

ST MEMS adapters motherboard

STEVAL-MKI109V3

* New MKI109V3 board natively supports 1.8v adapters (e.g. MKI174V1) and is also backward compatible with 3.3v adapters
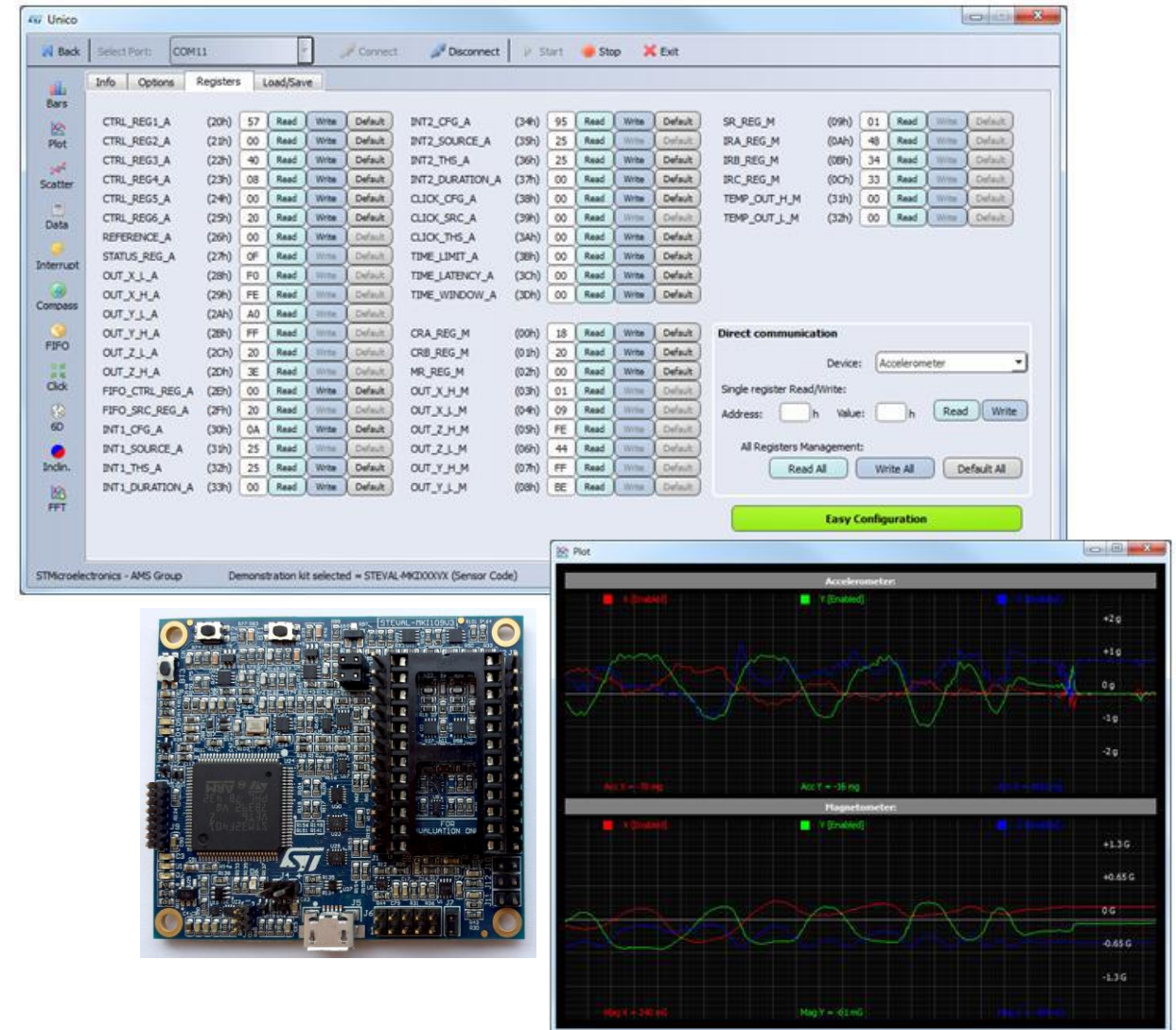
Unico.exe GUI for PC

Sensors+BLE+MCU Eval Kit!

13.5mm
13.5mm

MP34DT04
Microphone
3x4x1mm
64dB SNR, 120dBSPL

STM32L476
Cortex-M4
Up to 100DMIPS 80MHz
100uA/MHz@24MHz in run mode

LSM6DSM
3DAcc+3DGyro
0.65mA @ 1.6kHz - 9µA @ 12.5Hz
6.6kHz Max ODR for Gyro & Acc.

LSM303AGR
3DAcc+3DMag
200µA @ 20 Hz (HR mode)
Accel/Mag independent power down mode

LPS22HB
Barometer
Water & Dust resistant
1-75Hz, 3-12µA @ 1Hz

Balun Filter

BlueNRG-MS
BLE
Concurrent master/slave
BT4.1

Vin (1.9 – 5.5V) → LDO → VDD (1.8V)

MP34DT04 mic

LSM6DSM acc+gyro

LSM303AGR mag+acc

LPS22HB barometer

SPI-3w

STM32L4

NRST

PDM 32KHz

GPIO (SWD) PDM ADC UART USB LP-UART I2C

SPI

antenna

balun

BlueNRG-MS 32kHz

32MHz

DIME SIZED evaluation / development kit.

SensorTile + Eval kit

Sense

STEVAL-STLCS02V1

13.5 x 13.5 mm

Miniaturized Tile that can be **soldered** or **plugged** on a host board

Key products on board

LSM6DSM: MEMS 3D accelerometer (±2/±4/±8/±16 g) + 3D gyroscope (±245/±500/±2000 dps) with OIS

LSM303AGR: MEMS 3D magnetometer (±50 gauss) + 3D accelerometer (±2/±4/±8 g /±16 g)

LPS22HB: MEMS pressure sensor, 260-1260 hPa absolute digital output barometer

BLUENRG-MS: BLE Network processor

BALF-NRG-01D3 : 50 Ohm / Conjugate match to BlueNRG Balun

MP34DT04 : Digital MEMS microphone

STM32L4 : Microcontroller
100 mAh Li-Ion battery included

Info available at
STEVAL-STLKT01V1

OSX
OpenSoftwareX

open.AUDIO

open.MEMS

open.RF

Order code: STEVAL-STLKT01V1
Module only: STEVAL-STLCS02V1 (available NOW)

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Sense

LSM6DSM
6-axis inertial module

LSM303AGR
eCompass

LPS22HB
Barometer

4x MP34DT04-C1
MEMS Microphone

Expansion connectors
2x buttons

STM32F446
MCU

STM32 F4

STBC03J
Power management

BlueNRG-MS
Bluetooth Low Energy

BlueNRG

SMD Antenna

BALF-NRG-01D3
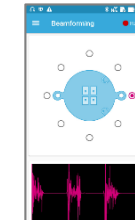Balun Filter

8 LEDs

25 mm

STSW-BCNKT01

Software examples for BlueCoin firmware package, including sensor data streaming via USB and BLE, data logging on SD card, gesture recognition, audio acquisition and playback. Support for custom App. development

Available now:
STEVAL-BCNKT01V1

Order code: STEVAL-BCNKT01V1
www.st.com/bluecoin

- STEVAL-SMARTAG1

  - **LIS2DW12** ultra-low-power high-performance three-axis linear accelerometer

  - **LPS22HB** Absolute pressure sensor which functions as a digital output barometer: 260-1260 hPa

  - **HTS221** humidity and temperature sensor

  - **ST25DV64K** dynamic NFC tag solution based on 64K-bit (8K-Byte) EEPROM and with I²C interface, Fast Transfer Mode and Energy Harvesting features

  - **STM32L031K6** ultra-low-power ARM Cortex-M0+ MCU running at 32 MHz with 32-Kbytes Flash and 8-Kbytes RAM

  - **STLQ015** low drop linear regulator power management

Available on:
STEVAL-SMARTAG1

Order code: STEVAL-SMARTAG1
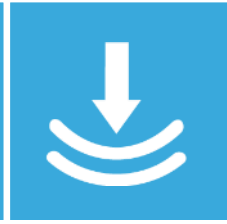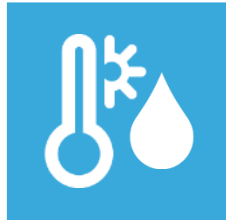
Nucleo / X-Nucleo: Stackable solution
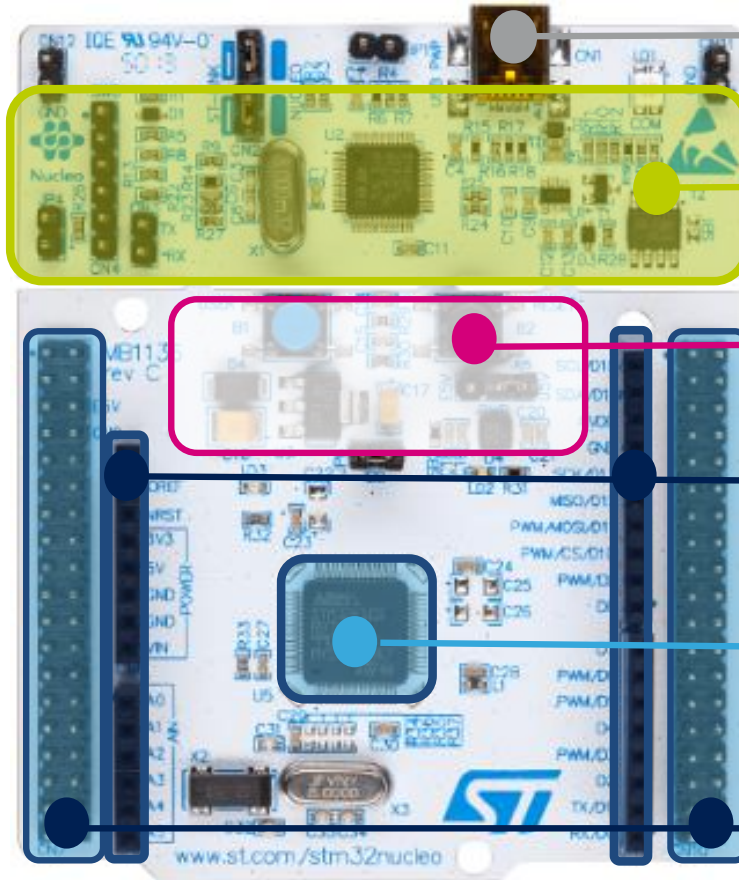
Flexible board power supply : through USB or external source

Integrated ST-Link/V2-1: mass storage device flash programming

2 push buttons, 2 color Leds

Arduino extension connectors : easy access to add-ons

One STM32 MCU flavor with 64 pins

Morpho extension headers : direct access to all MCU I/Os

STM32 Nucleo features

MEMS sensors in just 5 steps

1 www.st.com/X-NUCLEO

www.st.com

2 Select
X-NUCLEO-IKS01A1

3 Download & unpack
X-CUBE-MEMS1

X-CUBE-MEMS1 package structure

📁 [_htmresc]	→ Docs
📁 [Documentation]	→ Sensors Low Level drivers
📁 [Drivers]	→ Serial utility
📁 [Middlewares]	→ Firmware source code + binary
📁 [Projects]	→ PC GUI
📁 [Utilities]	
📄 package	xml
📄 Release_Notes	html

Graph Plots

Sensors Data Log - STMicroelectronics
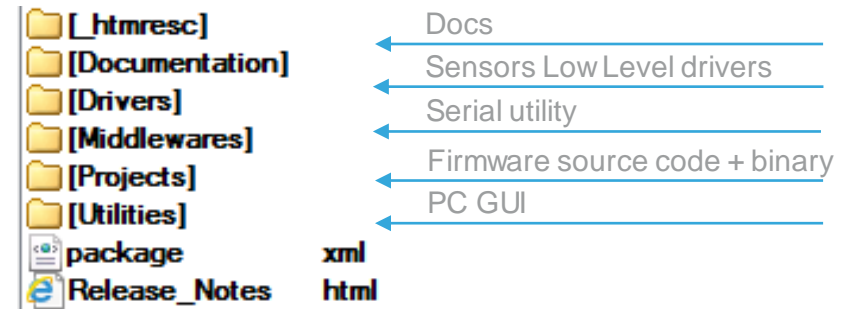
4 drag and drop
DataLog.bin
on Nucleo drive

5 ...and Run PC GUI

Computer
OSDisk (C:)
NUCLEO (F:)

Data Log Area

IAR SYSTEMS

KEIL Tools by ARM

ac6 Assistance Conseil Systemes
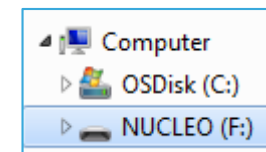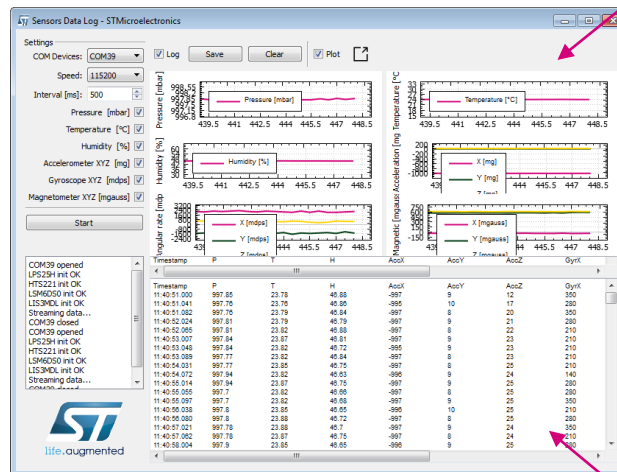
Sense

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The Right SW for Your Sensor
Middleware Libraries

Accuracy/Calibration	Position tracking	Activity/Sport tracking	Health care
Magnetometer Calibration / Sensor Fusion / Gyroscope Calibration / Accelerometer Calibration	Vertical Context / Sensor Fusion / eCompass / Tilt Sensing	Motion Intensity Detection / Activity Recognition for Wrist / Fitness Activities / Active Time / Activity Recognition / Pedometer / Gesture Recognition	Sleep Monitoring / Standing vs Sitting Desk Detection / Pedometer / Carry Position / Fall Detection / Pose Estimation
Accelerometer	**Accelerometer**	**Accelerometer**	**Accelerometer**
Gyroscope / IMU	**Gyroscope / IMU**	**Gyroscope / IMU**	
Magnetometer eCompass	**Magnetometer eCompass**		
	Pressure Sensor	**Pressure Sensor**	**Pressure Sensor**

All libraries are available in X-CUBE-MEMS1, X-CUBE-MEMS-XT1 package

Thank You!

jalinous.esfandyari @st.com