A Dive into the Latest MEMS Pressure Sensors

for Wearable and IoT Applications

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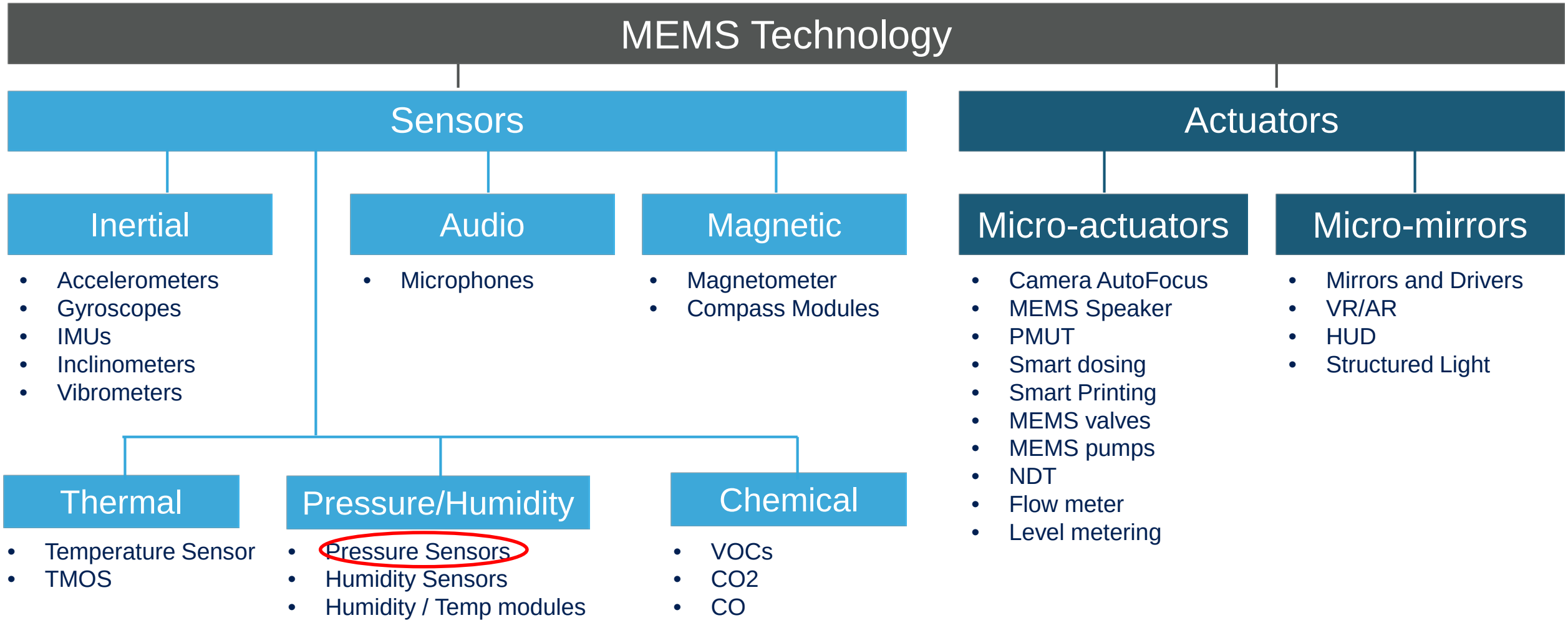
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Agenda

- MEMS Technology and Products
- Pressure Sensor Technology
  - Process
  - Principle of Design
  - Packaging
- Pressure Sensor Applications

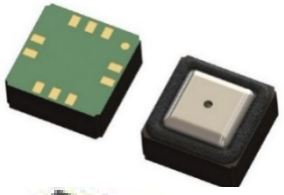
MEMS Technology and Products



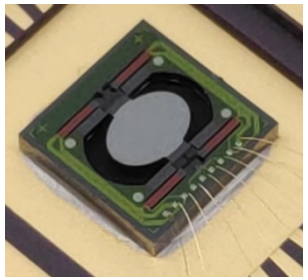
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MEMS Processes and Products









Next Generation ThELMA*

- Higher accuracy
- Ultra-low power
- Embedded Machine Learning Core

→ Motion sensors for Personal Electronics, Automotive & Industrial

Next Generation BASTILLE*

- Higher accuracy
- Size reduction
- Waterproofing

→ Environmental sensors for Personal Electronics & Industrial

Thin Film Piezoelectric PεTRA*

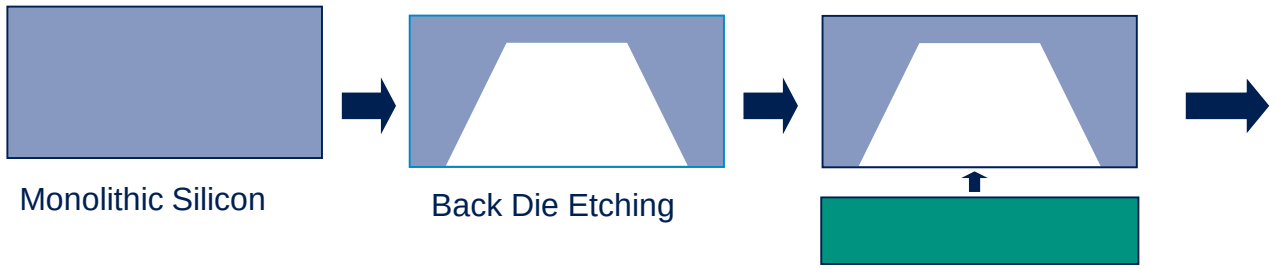
- Innovative piezoelectric materials
- Higher efficiency
- Lower cost

→ Microactuators for Ink Jet printing, Speakers & Infrared Scanners

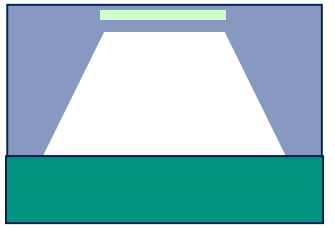
*ST proprietary MEMS technologies

Pressure Sensor Technology

Typical Conventional technology



Air cavity ~100um
Membrane 1mm thick



Piezoresistive Resistor diffusion

Full Silicon Pressure Sensor technology



Air cavity ~1um
Membrane 300um thick



Piezoresistive Resistor diffusion

Full Silicon Technology Advantages

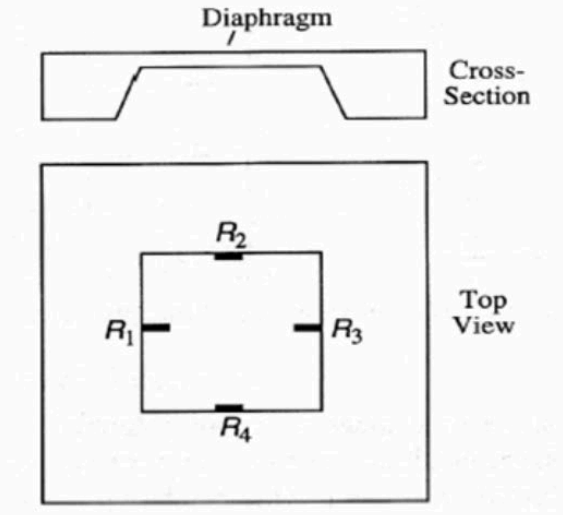
- Monolithic sensor: no need for wafer to wafer bonding to create the cavity
- High burst pressure - Intrinsic mechanical stopper
- High shock survivability
- Good temperature behavior – one temperature coefficient (only silicon)
- More robust and thinner sensor

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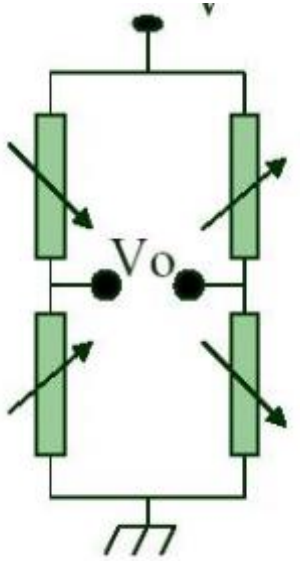
Piezo-resistive Technology

Principle of Design

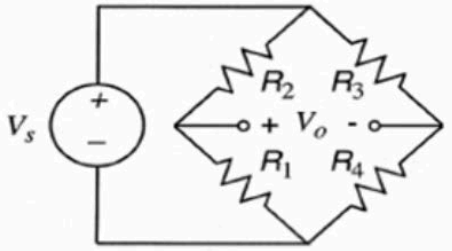
- Piezoresistivity: a change in the electrical resistivity of a metal or semiconductor due to an applied stress (force, pressure, flow, acceleration)
- All the materials show a piezoresistivity effect but semiconductors possess stronger piezoresistivity property: Si is the best one (Smith, 1953).
- Four 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:



$$R_1 = R_3 = (1+\alpha_1)R_0$$
$$R_2 = R_4 = (1-\alpha_2)R_0$$
$$\frac{V_o}{V_s} = \frac{R_1R_3 - R_2R_4}{(R_1+R_2)(R_3+R_4)} \approx \frac{2(\alpha_1+\alpha_2)}{1+\alpha_1-\alpha_2}$$

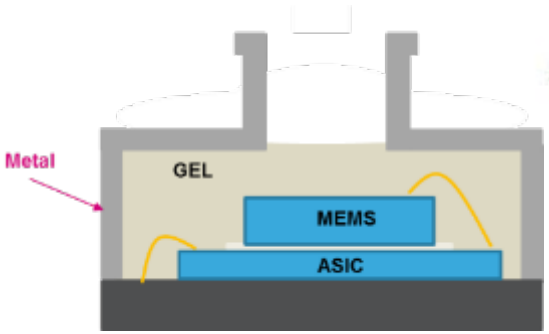
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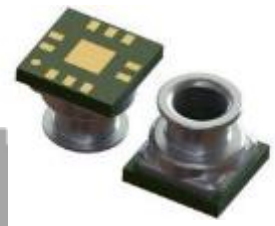
Pressure Sensor
with Sensing Element & ASIC



2.0 x 2.0 x 0.76 mm

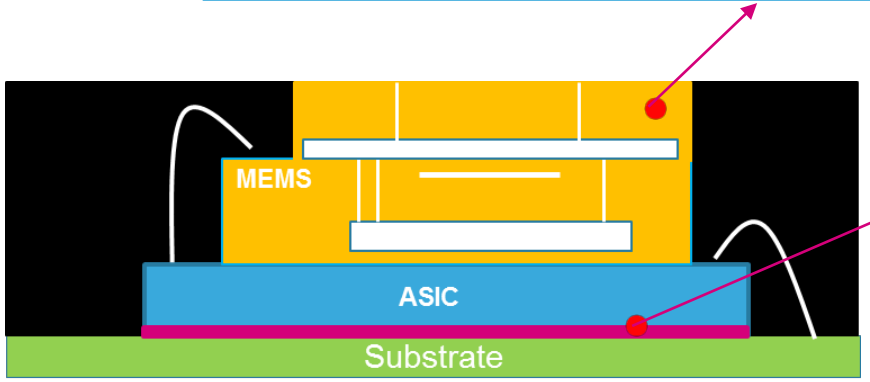
Ultra high-performance pressure sensor in small fully molded PKG for vertical position (i.e indoor navigation / E911 application / dusty environment)





CCLGA-10L, 3.3 x 3.3 x 2.9mm

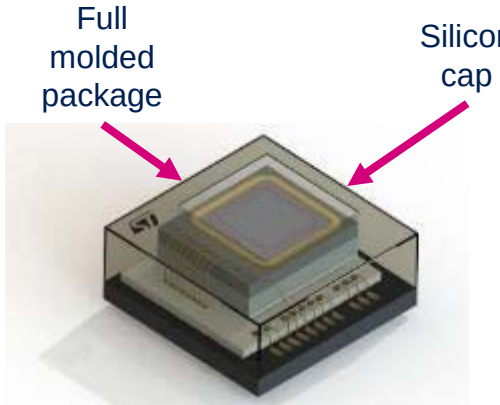
New Sensor
- Better Pressure accuracy & faster response
- Better mechanical robustness

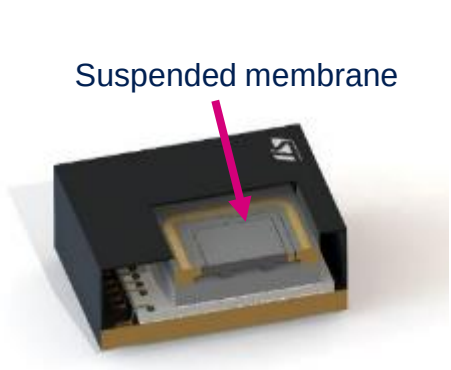


New ASIC
- Better Pressure accuracy , Less RMS noise
- RF immunity

ST Unique package advantage

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



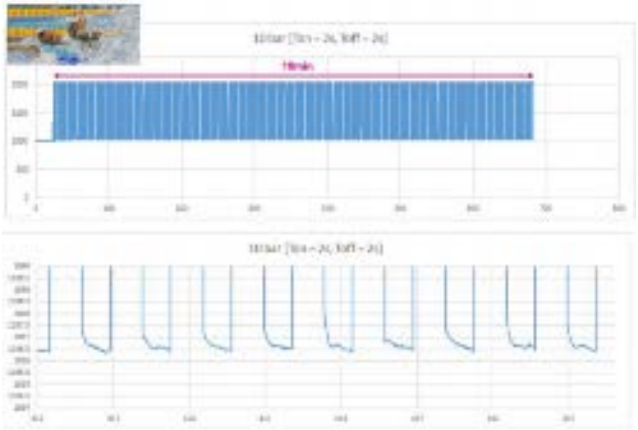


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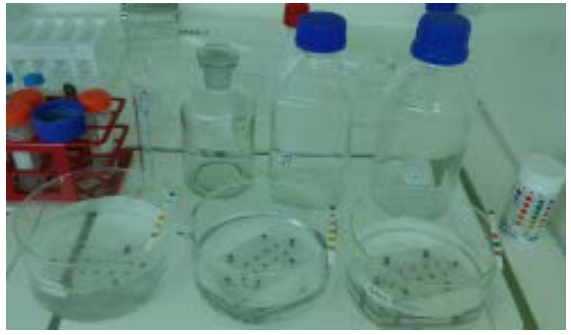
Water-Resistant Package

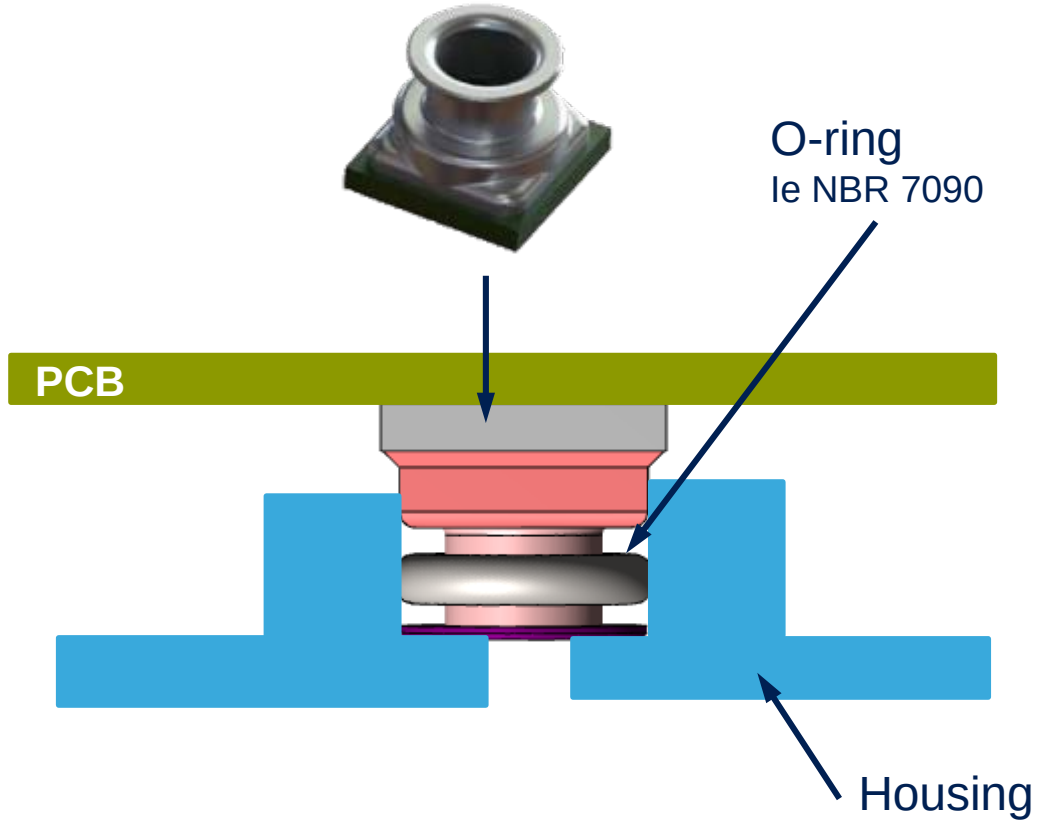
Tests and Sealing

- 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

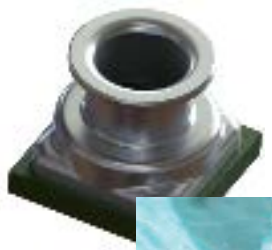




Sealing is guaranteed by rubber o-ring and housing design

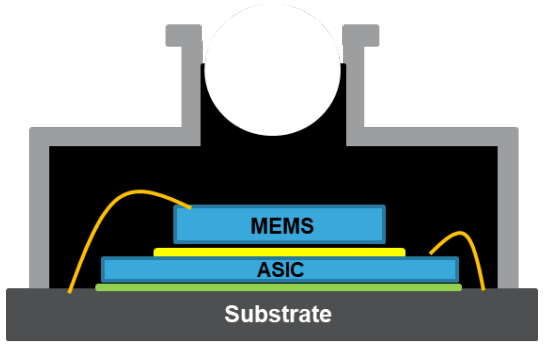
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Water Resistant Pressure Sensor
for Harsh Environment





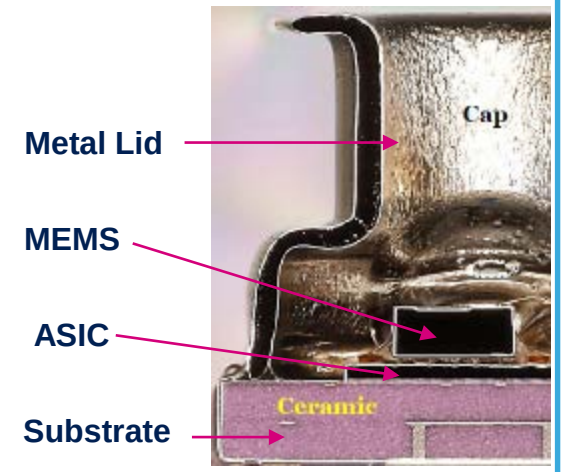
A look inside

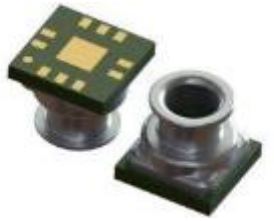


Features

- 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





3.3 x 3.3 x 2.9mm

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

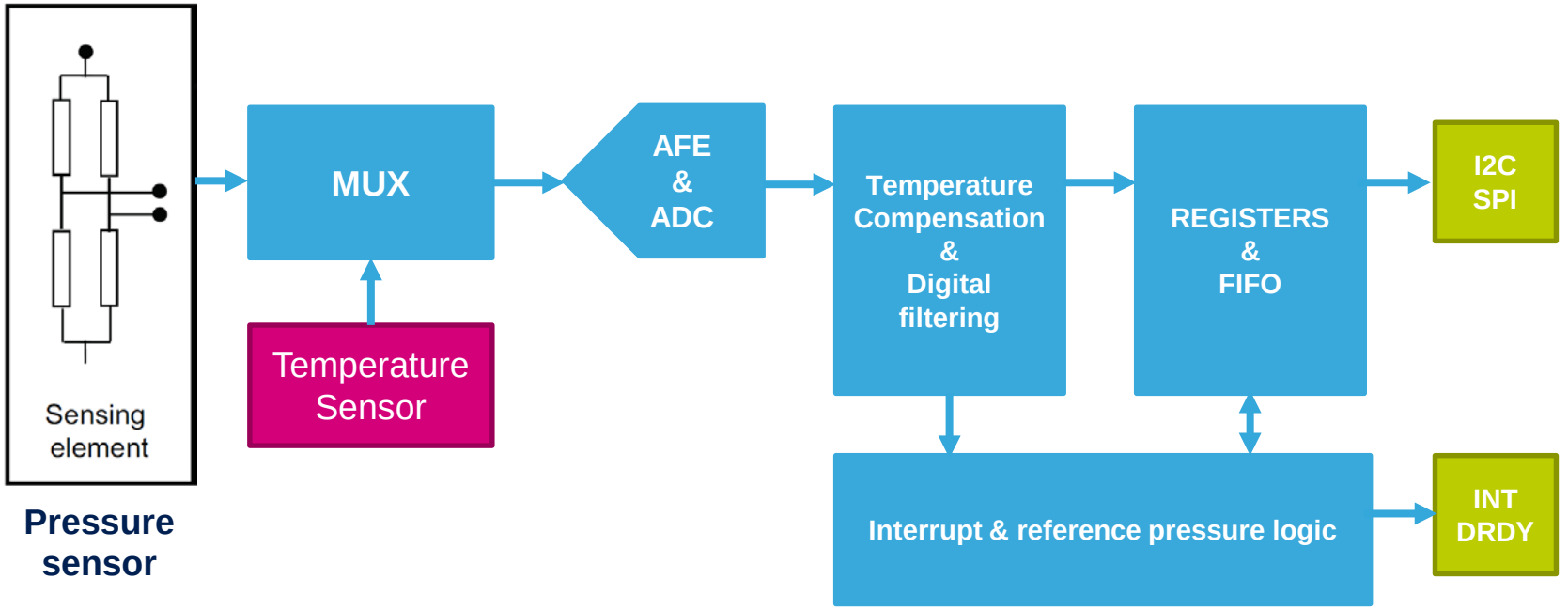
❖ **For Swim user case in swimming pool & Sea**

❖ **Compatible with human body**

❖ **Corrosion Test for industrial**

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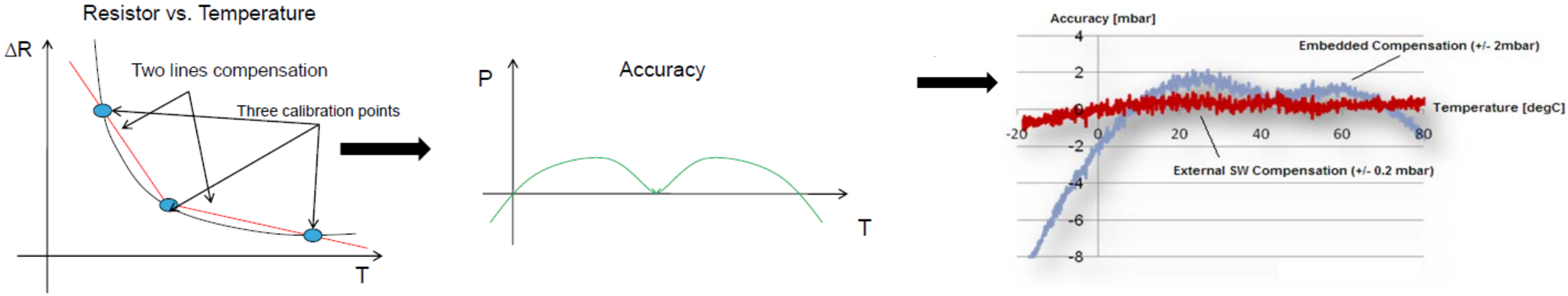
Internal Block Diagram of a Pressure Sensor



- 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.

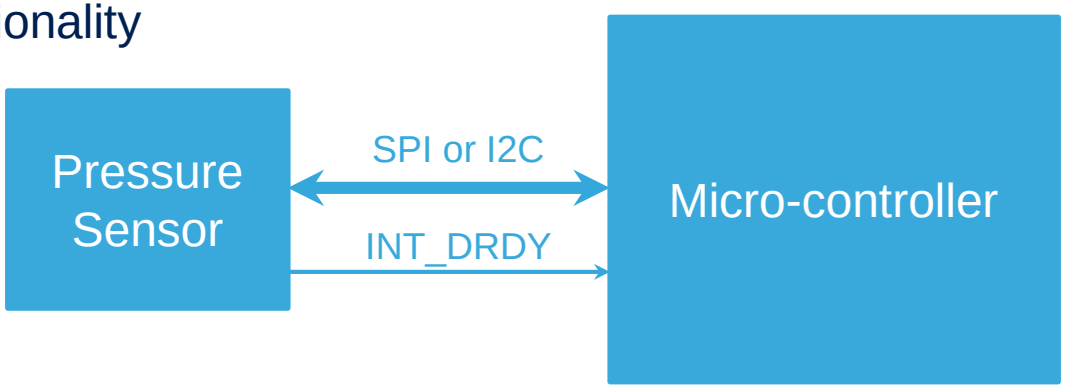
Embedded Linear Compensation

- Latest pressure sensors are factory calibrated
- Compensation uses the embedded temperature sensor
- Result is a good linear accuracy which is specified in the datasheet
- SW compensation can be used for even better temperature and noise accuracy



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)



Pressure Sensor Applications

in Wearables and IoT devices



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Pressure Sensor Applications



Altimeter and Barometer



Asset tracking
Takeoff/ landing pressure



Gas meter
Leakage detection



E-cigarette
Detect inhalation



Indoor & outdoor Navigation
Floor level detection



GPS Applications



Smart Glasses



Smart Watch



Drone
Pressure measurement



Weather station /
Air quality monitoring



Vaccum cleaner
Floor type, dust bag content level



Smart AC



Man Down Detection



Performance Measurement
Measure pressure variation



Water L. management



Blood pressure sensors



Balloons

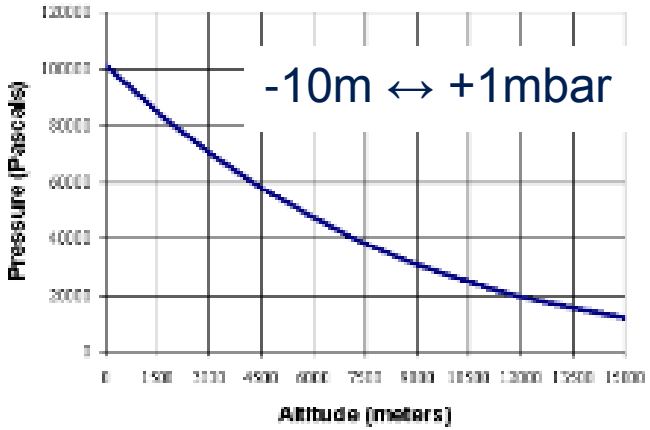
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And many others….

Pressure Sensor as an Altimeter



1800m ⟶ 815mbar



1000m ⟶ 899mbar

pressure range from **260** to **1260 mbar** ⟶ Maximum altitude range **11800 m**

RMS Noise Level **7µbar** ⟶ Minimum altitude difference **~6 cm**

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Pressure Sensor in Drone Application

- The barometric pressure sensor is needed in drone application in order to give an accurate position of the UAV height (Altitude Hold).



LPS22HH



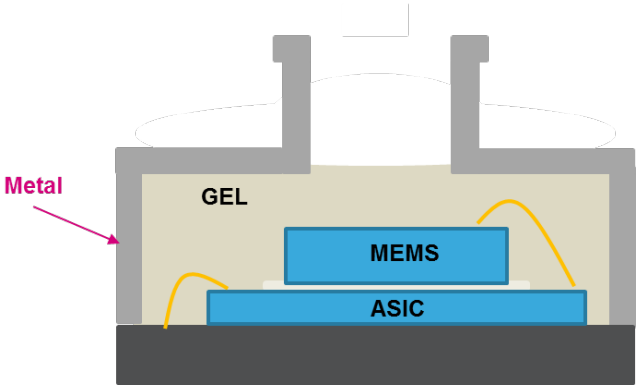
5cm * With sampling rate of 100Hz, ascent/descent @10ms*5m/s=5cm

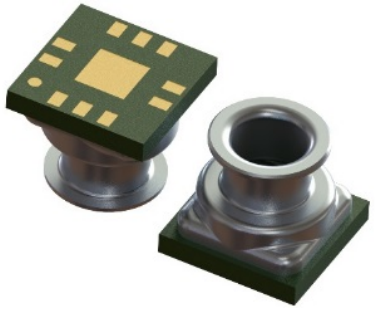
Sampling rate up to 200Hz

Waterproof PS in a Wash Machine

Water/Laundry Detergent Level/Temp Control

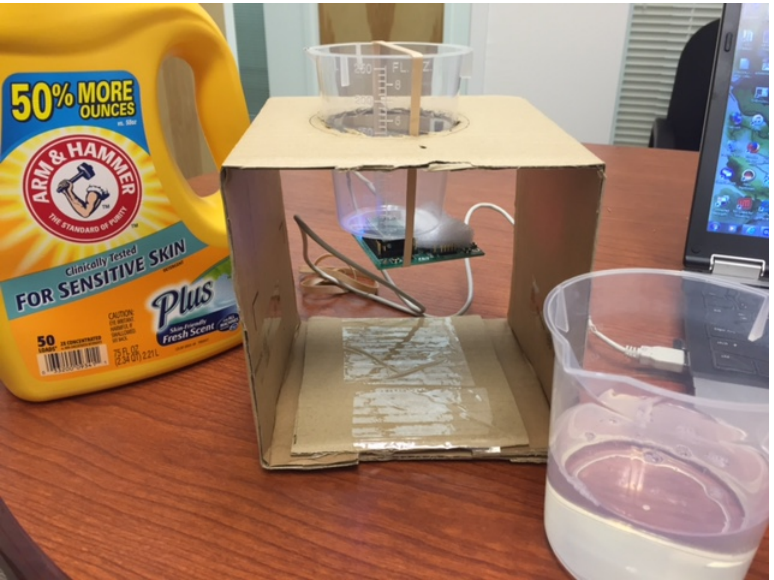
Pressure Sensor in Washing Machines

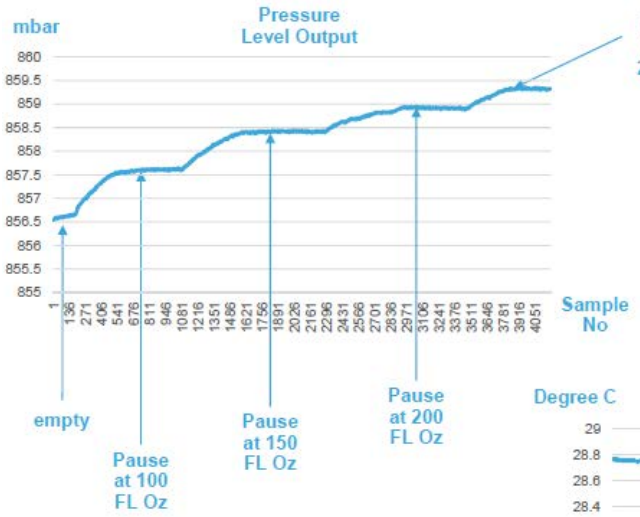


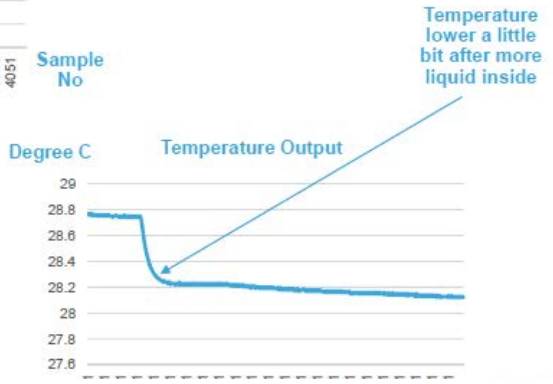


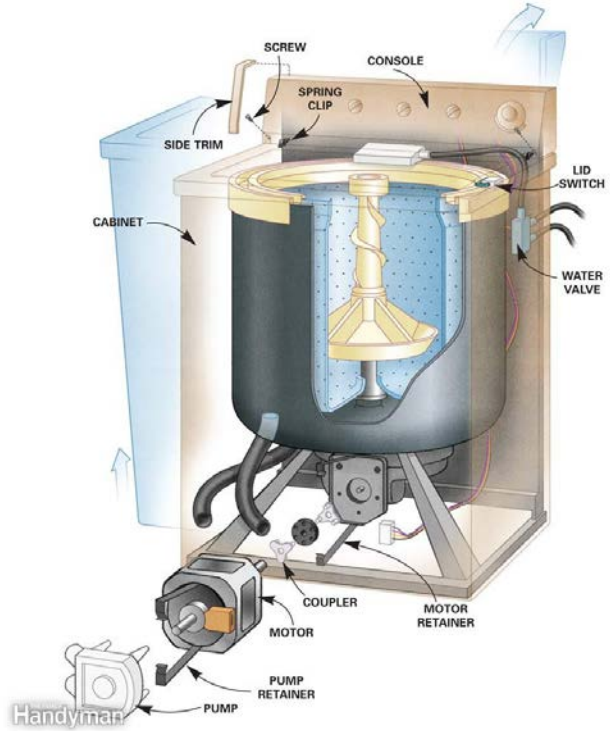
In the stream water level and temperature control

- Remove pressure hose
- Precise water level detection
- Sensing/control water temperature for different type of clothing
- Any liquid









Water Level Monitoring / Alarm
with Pressure Sensor

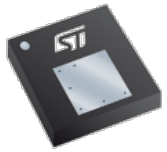
Pressure Sensors in Water Level Monitoring / Alarms





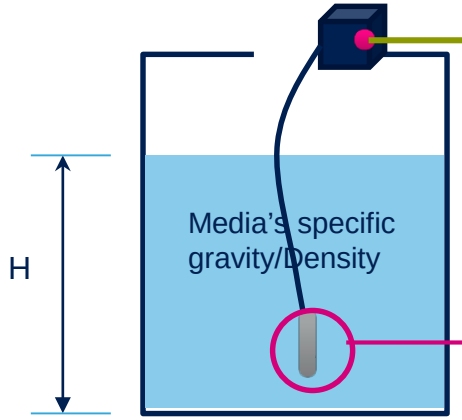
- Pressure sensor used to measure Water Level in SMART Water Level monitoring / Alarm
- Usage of two pressure sensors one on the top of the tank (LPS22HB) measuring the ambient temperature and one on the waterproof device (LPS33HW) as a probe within the water.





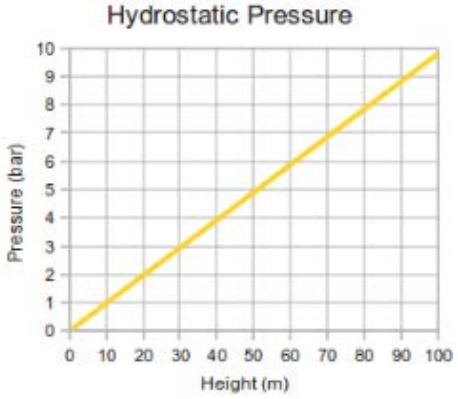
LPS22HB Pressure Sensor

P1 : Ambient Pressure



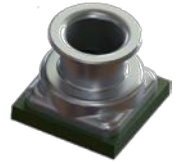


- ✓ **P2-P1: Calculate to Water Depth in below.**
  - ✓ **P2 – P1 : 100hPa (0.1Bar) = 1 meter (3.3feet)**
  - ✓ **P2 – P1 : 1000hPa (1Bar) = 10 meter (33 feet)**



LPS33HW **Water Proof** Pressure Sensor

P2 : Pressure in Water & Need Water Proof



Fall Detection

- 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**

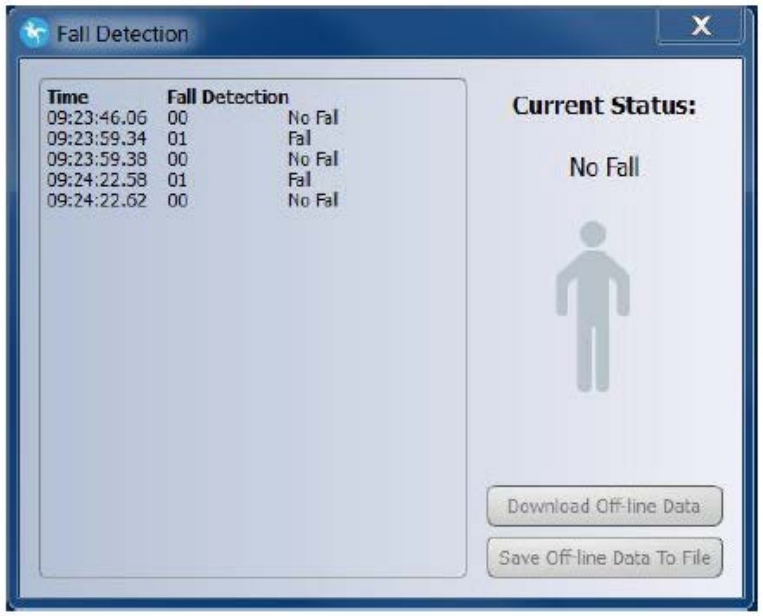
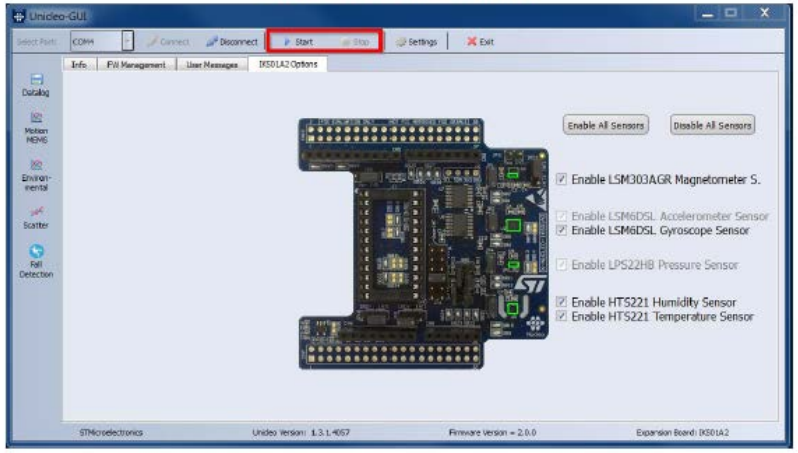


Figure 3. **Unicleo main window**





Water Resistant Pressure Sensor enables the monitor used in bath/shower

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Take off & Landing Detection

Pressure Sensors use case

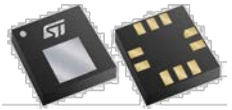


Absolute Pressure Sensors

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

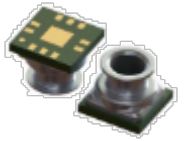
LPS22HH



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

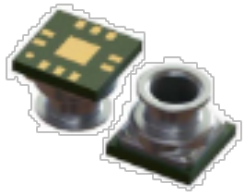
LPS33HW



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Pressure Sensor for Flow Metering in Industrial Market

Pressure sensor used for flow metering in **Industrial market**



LPS33HW

- Robustness to harsh environment (chemical compounds)
- Accuracy for precise measurement

Final Application





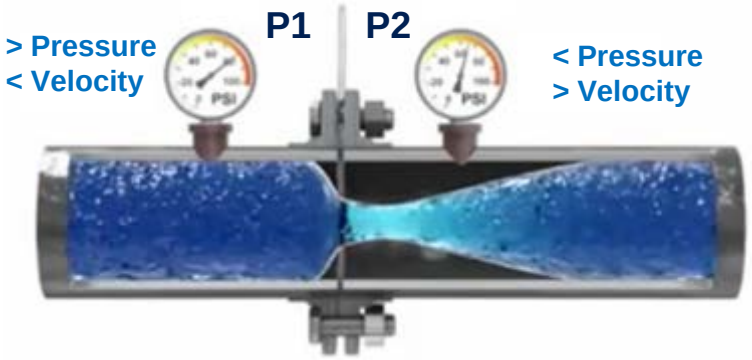


Flow meters are based on different 3 kinds of **Orifice**, **Venturi** and **Ultrasonic** methodology

How it works

Orifice / Venturi Metering

Flow monitoring with differential or two pressure sensors.

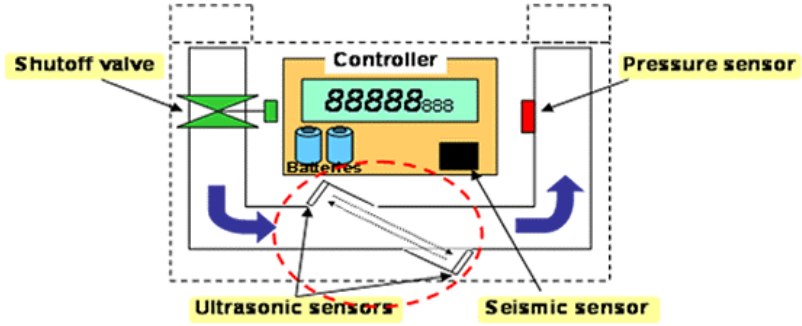


$$Q = K\sqrt{\Delta P}$$

Q = Flow Rate
K = A constant determined by orifice size type of liquid
P = Differential Pressure

Ultrasonic Metering

One pressure sensor needed for compensation of flow meter.



Takeaways

- Dedicated MEMS Process for Pressure sensors.
- New advances in MEMS technology and ASIC has lead to higher accuracy, better resolution, lower current consumption, and smaller size.
- These improvement have enabled a wider range of applications in addition to conventional altimeter application.
- Advancements in packaging for high volume manufacturing.
- Full-scale range and packaging technology are the primary determining factors for pressure sensor applications.



Thank You!

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