

Sensor Principle & ST Sensors

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Agenda

- Sensor Principle
- ST MEMS Sensors Products
 - Market trend
 - Motion sensors
 - Consumer
 - Industrial
 - Automotive
 - Pressure sensors
- Applications with ST sensors



What is Sensor?

 A sensor is a device, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor.





What is MEMS?

- MEMS stands for Micro Electro-Mechanical Systems
- Three key elements
 - Micron sized Transducer realized through a specific process Micro Machining
 - A Mixed Signal Analog/Digital ASIC with embedded smart functionalities
 - Dedicated package and calibration features







ThELMA MEMS





MEMS Accelerometer

- Device for measuring accelerations
 - Static: acceleration of gravity
 - Dynamic: caused by moving or vibrating the accelerometer

• Multi-axis devices are available to achieve multi degree of freedom.





Linear 1-Axis Accelerometer





MEMS Gyroscope

• Sensor designed to measure angular velocity

• A differential mechanical structure to avoid linear acceleration

Oscillating structure for Coriolis effect



MEMS Gyroscopes: Working Principle



- Based on Coriolis effect
- Continuous movement of a mass by a driving circuitry (V direction)
- Angular rate is applied (red arrow)
- The physical displacement (yellow arrow) → sensing capacitive interface



MEMS Gyroscope

- It needs continuous movement to detect rotational movement.
 - Vibration is a method to generate continuous movement in limited space.





Pressure Sensor Type

Pressure p1





https://www.first-sensor.com/en/products/pressure-sensors/pressure-sensors-and-transmitters/pressure-types.html

Absolute pressure sensor

• Need to measure absolute pressure through vacuum sealed area.

- Gauge pressure sensor
 - Need to measure pressure based on atmospheric pressure.
- Differential pressure sensor

GAUGE PRESSURE

• Need to measure differential pressure between 2 pressures.

ABSOLUTE

DIFFERENTIAL PRESSURE

Barometric Absolute Pressure Sensors

- Are sensors used to measures the absolute pressure in the atmosphere
- The atmospheric pressure range varies between 20kPa-130kPa



$$P = Po \cdot \left(1 - \frac{Altitude}{44330}\right)^{5.255}$$

For small altitudes could be linearly approximated to $P=P_0 - 0.119 h$



What is the MEMS based Pressure Sensor?

Pressure Sensor structure & technology





Wheatstone Bridge





ST MEMS Sensors Products



Market Trend



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ST MEMS Market Leader

#1 Motion MEMS

Motion Sensor: ST #1 – 39% MS

- ST: + 5.3% YoY with overall 39% Market Share
- ST Qty ~ Bosch + Invensense Qty

Supplier	V2013	V201/	V2015	V2016	V2017	V2018	Market Share
Supplier	12013	12014	12013	12010	12017	12010	2018
STMicroelectronics	1,153	918.6	897.3	1072.3	1179.1	1242.0	39%
Bosch *	626	813.9	828.3	733.9	756.2	871.1	27%
InvenSense	237	415.7	588.5	462.2	376.0	412.4	13%
MEMSIC	51	136.4	165.2	178.7	221.0	210.7	7%
Rohm (Kionix)	230	234.1	225.5	213.7	211.9	181.7	6%
mCube	30	37.0	81.5	116.0	148.3	127.5	4%
Sensortek (Sitronix)	3	10.0	29.0	31.0	30.8	29.5	1%
Freescale	86	36.3	30.5	9.5	17.1	28.6	1%
MiraMEMS	3	20.0	15.0	22.0	22.7	21.0	1%
Epson	45	33.9	30.8	25.0	22.7	20.7	1%
Analog Devices	18	12.8	17.3	17.9	17.6	18.1	1%
Grand Total	2528.4	2713.1	2941.9	2903.2	3020.3	3180.2	100%

* 2018 Bosch Qty w/o iOS – Motion Sensor: 550Mu

#2 Pressure Sensor

• Pressure Sensor: ST #2 – 30% MS

- ST and Bosch lead the pressure sensor market.
- Dominant M/S for non-iOS market.

Supplier	Y2013	Y2014	Y2015	Y2016	Y2017	Y2018	Market Share 2018
Bosch **	121	207.2	304.2	270.2	295	321.2	64%
STMicroelectronics	50.5	65.0	88.0	83.2	152.0	151.5	30%
InvenSense						12.0	2%
MEAS	6.6	8.1	6.5	9.0	9.2	10.1	2%
Freescale	2.2	3.8	2.0	2.0	2.0	2.0	0%
TDK	1.5	1.5	1.5	1.5	1.5	1.5	0%
Murata	0.0	0.0	3.0				0%
Grand Total	181.8	285.6	405.2	365.9	459.7	498.3	100%



** 2018 Bosch Qty w/o iOS – Pressure Sensor: **100Mu**

Consumer Accelerometers



3 x 3 package

2.5 x 2.5 package

2 x 2 package

Consumer Accelerometers Portfolio







LIS2DW12

- Product specifications
 - Fs: ±2g, ±4g, ±8g, ±16g
 - Post solder offset: ±20mg (typ)
 - Post solder offset drift vs temperature: ±0.2mg/°C
 - Output formatting: 16 bit
 - Up to 10 operating modes delivering the maximum flexibility
 - ODR: from 1.6Hz to 800Hz
 - Noise / supply current:
 - 120μg/√Hz, 120μA @ HPM, all ODR, ±8g Fs, 1.8V
 - 1900µg/√Hz, 700nA @ LPM4, 1.6Hz, ±8g Fs, 1.8V
 - Current consumption in sleep mode: 50nA @ 1.8V
 - Supply voltage from 1.62V to 3.6V
 - Operating temperature: from -40°C to +85°C
 - Package: 2.0x2.0x0.7 mm max LGA12
 - Android stationary/motion-detection

- Target applications
 - Gesture recognition and gaming
 - · Handheld devices
 - Motion-activated functions and user interfaces
 - Wearable
 - Wireless sensor nodes

ULTRA LOW NOISE

10 OPERATING MODES

ANDROID FRIENDLY



LIS25BA

Product specifications

- Supply voltage: 1.71V 1.99V
- Current consumption: 5mA (max in NM)
- ODR: 8Hz, 16Hz, 24Hz
- Output interface: TDM
- Full scale: 3.85g 7.7g
- Zero-g level offset: ±300mg (max)
- Zero-g level drift vs temperature: ±500mg (max)
- Acceleration electrical noise @ BW = 2.4kHz: $30\mu g/\sqrt{Hz}$
- Bandwidth: 2.4kHz
- Latency: 80µs
- LGA 14L 2.5 x 2.5 x 0.86mm

- Target applications
 - Headset/Headphones
 - Smart speaker
 - Voice activated devices
 - Bone conduction
 - Beam forming
 - Speech enhancement



ULTRA LOW NOISE

WIDE BANDWIDTH

LOW LATENCY



LIS25BA Application Use Cases

The LIS25BA is a unique accelerometer in the market delivering a flat frequency response up to 2.4kHz together with • an TDM output interface. The combination of these features make the LIS25BA the perfect fit for audio enhanced applications (like headphones, smart speakers or conferencing systems) that combine audio with vibration detection.

Headphones

THE CASE

noise.

THE NEED

the audio captured by the microphone.

THE PERFECT FIT LIS25BA



Conferencing systems

THE CASE

Laptop based conferencing systems exploit expensive microphones arrays to perform beam forming and noise reduction.

THE NEED

Improve the overall user experience by detecting the vibrations of the keyboard and cooling fan to suppress them from the captured voice.





Consumer IMU Sensors



LSM6DSL/M

- Market Proven solution
- 10Y longevity version available (IIS330DLC)

2.5 x 3 x 0.86 mm

Cur. Cons: 0.65 mA combo

Smartphone / Wearable

- High stability + SW compensation
- Pedometer 2.x (WeChat compliant)
- Finite State Machine

2.5 x 3 x 0.86 mm

LSM6DSO/OW

- FS: up to 2000 dps; up to16 g
- Cur. Cons: 0.45 mA gyro; 0.55 mA combo

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- ULP: 15uA AXL only (100Hz)
- OIS: Aux SPI
- UI: I3C / I2C / SPI
- FIFO: 3kB, compressed FIFO

Virtual / Augmented Reality

- LSM6DSR
- High stability Robot / Dead Reckoning



High precision 6X IMU

6x Roadmap

Accelerometer 32g FS



2.5 x 3 x 0.86 mm

Consumer Motion MEMS

- · Dual core XL for simultaneous processing
- FIFO store and retrieve fall data
- Dedicated interrupt for fall detection
- Ultra low power consumption

life.auamente



- FS: up to 4000 dps; up to16 g
- Cur Cons: 0.90 mA gyro; 1.2 mA combo
- UI: I3C / S4S / I2C / SPI
- FIFO: 3kB, compressed FIFO

LSM6DSO Family Consumer and Mobile Market

Wearable – Mid-End & Mobile High End

LSM6DSO

Cur Cons:0.55 mA combo

 $\ensuremath{\textbf{FS:}}$ up to 2000 dps; up to 16 g

INTERFACE:

- UI: I2C, I3C, SPI
- OIS: Auxiliary SPI





KEY ADVANTAGES

- 3 Power Modes: High Performance / Low Power / Ultra Low Power
- Self Test XL and Gyro
- Pedometer 2.0
 with Embedded False Rejection Block
- Finite State Machine on XL and Gyro (Run up to 16 program simultaneously)
- Flexibility on U/I using OIS Aux SPI
 - Gyro U/I independent FS
 - XL independent up to ±8g
- Dedicated signal chain for OIS

Mobile – High End & Personal Electronics

LSM6DSOX

Supporting all features LSM6DSO INTERFACE (extra):

• UI: Additional S4S

KEY ADVANTAGES

- Including all features of LSM6DSO
- OIS and U/I data streaming by I3C
- S4S Protocol compliant
- A.I. Machine Learning Core





LSM6DSR Family VR/AR Market

Also selected by Google for the new Pixel phone

LSM6DSR

- Cur Cons: 1.2 mA combo FS: up to 4000 dps; up to 16 g INTERFACE:
- UI: I2C, I3C (+S4S), SPI
- OIS: <u>SPI_{AUX}</u>

KEY ADVANTAGES

- U/I OIS full scale
 - Gyro U/I OIS independent FS
 - XL independent up to ±8g
- Self Test XL and Gyro from OIS chain
- Finite State Machine
- I3C interface
- S4S Protocol compliant
- Dedicated OIS <u>SPI_{AUX}</u>interface



LSM6DSRX

Supporting all features LSM6DSR



KEY ADVANTAGES



LSM6DSR + A.I. Machine Learning Core





Industrial Accelerometer





5 x 5 package 2.5 x 3 package

2 x 2 package



Industrial Accelerometer

 IIS2DH Low Power Wide BW (2 kHz) IIS3DWB 3-axis Digital axel Ultra Wide and Flat Bandy I ow Naise (75 ws//lla) 	•
 Subscription Subsc	ıdwidth (>5Khz) 105°C itoring







Inclinometers



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Industrial IMU Sensors





4 x 4 package

2.5 x 3 package



Industrial IMU





Automotive Accelerometers



4 x 4 package 2.5 x 3 package 2.5 x 2.5 package 2 x 2 package

Automotive Axel for Smart Driving







New ST Automotive Axel

Sensor



AEC-Q100 Ultra low power 3-axis digital axel AIS2DW12

Main Application



Passive Key entry (Key Fob)

Pruduct Strength

- Ultra low power (0.67uA @3V @1.6Hz)
- Superioir robustness to mechanical shock and drops
- Package with wettable flanks
- Multiple Resolution / Power configurations for high flexibility
- Package with wettable flanks
- Extended Top: -40°C +105°C



AEC-Q100 High Performance 3-axis digital axel AIS2IH

Under development





Anti-theft, Tbox, Navigation





Key Fob for Automotive

MEMS Accelerometer



Automotive IMU Sensors



4 x 4 package

2.5 x 3 package

2 x 2 package

Portfolio and Short-Term Roadmap





ASM330LHH for Accurate Navigation



Pressure Sensors





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Pressure Sensors Roadmap Main Products



(*) Com

(*) Compatible with MS5837, CCLGA – 4PIN

10Bar WaterIPx8 Waterresistantresistant

ST Pressure Sensor Working Principle – Piezo Resistive Solution

- ST Pressure sensor is based on piezo-resistivity technology in Wheatstone Bridge to measure the pressure applied on the membrane.
- Piezo-resistors are under membrane above an hermetic air cavity



ST Unique Pressure Sensor Package Patented Technology



life.gugmented

Value of Pressure Sensor PKG LPS33HW / LPS27HHW



Potting GEL

 Proven in automotive application with heat / oil / chemical resistance, low moisture permeability and hardness (penetration)

Ceramic Substrate

- Resist water/humidity permeability
- Robust assy of Metal LID on substrate
- ✓ **Strength** to **resist high air pressure** (i.e 10ATM)

Metal LID

- High rejection to oxidation & corrosion (as same substance of medical knives)
- Cylindrical design for easy assemble with O-Ring in application

MEMS & ASIC

 Best performance of MEMS & ASIC designed for high accuracy & less drift by thermal.

Applications with ST sensors



Addressing Market





TWS Earphone



- LIS25BATR for bone vibration detection and noise cancelling
- AXL/IMU for motion detection to replace button
- MEMs Microphone for noise cancellation, up to 6Mics/set

MEMs inside		
LIS25BATR	Bone detect sensor for noise cancellation	
LIS2DW12TR	Ultra low-power 3-axes accelerometer	
LIS2DH12TR	3-axes accelerometer	
LSM6DSLTR	Low power 6-axis IMU	
LSM6DSOWTR	6-axis IMU with state machine	
MP23ABS1TR	Analog MEMs Microphone	



Smart Watch/Bracelet



- LIS2DS12TR for H/W pedometer
- LIS2DW12 for activity monitor
- Pressure sensor for elevation measurement
- Water resistant barometer for waterproof scenarios.
- 6-axis IMU for motion detection

MEMs inside		
LIS2DS12TR	3-axes accelerometer with pedometer	
LIS2DW12TR	Ultra low-power 3-axes accelerometer	
LIS2DH12TR	3-axes accelerometer	
LPS27HHW	Water resistant barometer	
LPS22HH/HBTR	Pressure sensor	
LSM6DSOW/XTR	6-axis IMU with state machine	
LSM6DSO32TR	6-axis IMU for high scale	



Smart Pen









- Heating tobacco product.
- Motion MEMs for motion detection to replace button
- Pressure sensor to detect inhale level

MEMs inside		
LIS2DH12TR	3-axes accelerometer	
LPS22HH/HBTR	MEMS pressure sensor	
LPS27HHW	Waterproof pressure sensor	
LPS33WTR	Waterproof pressure sensor	



Toy Drone





• Pressure sensor used for the height fix function

MEMs inside		
LPS22HH/HBTR	MEMS pressure sensor	
LSM6DSRTR	6-axis IMU	
LSM6DS3TR-C	6-axis IMU	



Robot



- Robot for hobby and programing education.
- LSM6DSL detect posture of the robot and detect movement

MEMs inside		
LSM6DSLTR	Low power 6-axis IMU	
LSM6DSRTR	6-axis IMU	
LSM6DS3TR-C	6-axis IMU	



Hair Dryer

Hair Dryer

 Pressure sensor is used to determine the sensor is usensor is used to determine the sensor is used to determine t	ect the airflow of the fan.
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MEMs inside		
LPS22HH/HBTR	MEMS pressure sensor	
LPS27HHW	Waterproof pressure sensor	



Smart Cooker



• LPS22HBTR used to detect the environment pressure info, calculate water boiling point, optimize the rice cooker efficiency.

MEMs inside		
LPS22HH/HBTR	MEMS pressure sensor	



Vacuum Cleaner



• Pressure sensor used for the dust bag status detect

MEMs inside		
LPS22HH/HBTR	MEMS pressure sensor	
LPS33HWTR	Waterproof pressure sensor	



Smart Toothbrush





Sharing Bike



- LIS3DHTR used for fall down/ movement detection on smart lock for sharing bikes.
- LSM6DSLTR for more movement monitoring
- LSM6DS3TR-C for wheel rotation speed detection, for attracting visual advertisement display during biking.

MEMs inside		
LIS3DHTR	Ultra low-power 3-axes accelerometer	
LSM6DSLTR	Low power 6-axis IMU	
LSM6DS3TR-C	6-axis IMU	



Asset Tracker



• Motion sensor for movement detection and positioning

MEMs inside		
LIS2DH12TR	3-axes accelerometer	
LIS2DW12TR	Ultra low-power 3-axes accelerometer	
LSM6DS3TR-C	6-axis IMU	
HTS221TR	Humidity and temperature sensor	



Safety Helmet



• Motion sensors for movement detection and height detection.

MEMs inside	
LIS2DW12TR	Ultra low-power 3-axes accelerometer
LPS22HBTR	MEMS pressure sensor
LSM6DS3TR-C	6-axis IMU



Balance Scooter



• Motion MEMS are widely used in scooters for balance monitoring and motion detection

MEMs inside	
LSM6DSDTR	6-axis IMU
LSM6DSLTR	Low power 6-axis IMU



Speaker



- MEMs Microphone array for voice detection and beam forming.
- Motion sensor for gesture detection and tilt detection.

MEMs inside	
MP34DT05TR-A	Digital MEMS Microphone
MP34DT06JTR	Digital MEMS Microphone
LIS2DW12TR	Ultra low-power 3-axes accelerometer



Smart Car Key



• AXL detect steady state condition and turn off RF signal in order to extend battery life and increase security.

MEMs	inside

AIS2DW12TR Ultra

Ultra low-power 3-axes accelerometer for automotive



E-motorbike



• Motion MEMs used for movement/ vibration/ collision detection.

MEMs inside	
AIS328DQTR	Automotive 3-axis accelerometer
LSM6DSDTR	6-axis IMU



Notebook



- IMU supports notebook movement detection.
- MEMs Microphone integrated.

MEMs inside		
LSM6DSLTR	Low power 6-axis IMU	
LIS2DH12TR	3-axes accelerometer	
MP34DT05TR-A	Digital MEMS Microphone	
MP34DT06JTR	Digital MEMS Microphone	
MP23DB02MMTR	Bottom-port digital MEMS Microphone	

