ST SENSOR overview

March 2016
ST SENSOR categories overview

**ENVIRONMENTAL**
- Temperature
- Humidity
- Light
- Proximity
- Pressure
- Audio (MEMS mic.)

**MOTION**
- Accelerometer
- Gyroscope
- Magnetometer

**HMI**
- Touch sense I/F
- Image
- 3D sensing
- Biosensing
FlightSense™
Ranging sensors
Distance measurement sensor

- How many ways there are to measure a distance?
- How to select the right technology by application?

<table>
<thead>
<tr>
<th>Measurement type</th>
<th>Target objects</th>
<th>Minimum distance</th>
<th>Maximum distance</th>
<th>Resolution range</th>
<th>Linearity range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitive sensor</td>
<td>potentially any</td>
<td>&lt; 0.05 mm</td>
<td>~ 10 mm</td>
<td>&lt; 1 nm</td>
<td>&lt; 10 nm</td>
</tr>
<tr>
<td>Inductive sensor (eddy current)</td>
<td>Ferromagnetic material</td>
<td>&lt; 0.5 mm</td>
<td>~ 80 mm</td>
<td>&lt; 1 µm</td>
<td>&lt; 10 µm</td>
</tr>
<tr>
<td>IR/Laser triangulation sensor</td>
<td>light reflective materials</td>
<td>&lt; 2 mm</td>
<td>~1000 mm</td>
<td>&lt; 10 µm</td>
<td>&lt; 100 µm</td>
</tr>
<tr>
<td><strong>Laser &quot;Time-of-Flight&quot; sensors</strong></td>
<td>light reflective materials</td>
<td>&lt; 2 mm</td>
<td>~ 100 m</td>
<td>&lt; 1 mm</td>
<td>&lt; 5 mm</td>
</tr>
<tr>
<td>Ultrasound &quot;sonar&quot; sensors</td>
<td>sound reflective materials</td>
<td>&lt; 20 mm</td>
<td>~ 5 m</td>
<td>&lt; 5 mm</td>
<td>&lt; 5 mm</td>
</tr>
<tr>
<td>IR - reflected light intensity</td>
<td>light reflective materials</td>
<td>&lt; 10 mm</td>
<td>~ 500 mm</td>
<td>&lt; 10 mm</td>
<td>&lt; 50 mm</td>
</tr>
<tr>
<td>Camera stereovision (passive triangulation)</td>
<td>light reflective materials</td>
<td>&lt; 100 mm</td>
<td>∞</td>
<td>&lt; 20 mm</td>
<td>~ 0.1%</td>
</tr>
<tr>
<td>structured light camera (active triangulation)</td>
<td>light reflective materials</td>
<td>&lt; 20 mm</td>
<td>~ 30 m</td>
<td>&lt; 20 mm</td>
<td>~ 0.1%</td>
</tr>
<tr>
<td>3D camera &quot;Time-of-flight&quot;</td>
<td>light reflective materials</td>
<td>&lt; 30 mm</td>
<td>~ 10 m</td>
<td>&lt; 1 mm</td>
<td>&lt; 5 mm</td>
</tr>
<tr>
<td>RADAR (24Ghz industrial/automotive)</td>
<td>radio-waves reflective materials</td>
<td>&lt; 1 m</td>
<td>~ 30 m</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

- Ranges and resolutions are very dependant from the product configuration and the specific target type.
FlightSense™
ToF principle explanation

Measurement at the speed of light! 1cm round-trip at 67ps

3.3ps / mm !!

FlightSense™ Principle

Emitter    Photon    Target
Sensor

Measured distance = Photon travel time /2 × Speed of light

Fully Integrated Time of Flight Module
ST #1 World Wide Supplier

True distance measurement
Independent of target size, color & reflectance

Very fast (few ms)
Low power
FlightSense™ by ST is the only technology on the market today offering accurate measurements with tiny and low power modules.

<table>
<thead>
<tr>
<th>Signal Amplitude</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real distance output</td>
<td>No (computed)</td>
<td>Real distance in mm (readable thru i²C register)</td>
</tr>
<tr>
<td>Maximum distance</td>
<td>20cm</td>
<td>up to 2 meters (1)</td>
</tr>
<tr>
<td>Works with all objects color and reflectance</td>
<td>No</td>
<td>Yes even black (3%), gloves, …</td>
</tr>
<tr>
<td>Gesture control Tap vs Swipe</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
**FlightSense™ available products**

**VL6180X**
- Proximity, Gesture & ALS sensor
- Up to 40cm Ranging

In Mass production

- Proximity & Ambient Light Sensing
  - Small 3-in-1 module, 4.8 x 2.8 x 1.0 mm
- 850nm IR emission (Vcsel)
- Advanced microcontroller and light rejection
- Gesture control capability
- Proximity detection and ranging, Smart lighting

**VL53L0X**
- Ranging sensor
- Up to 200cm ranging

Mass Market availability: May 2016

- Smallest ToF sensor in the market
  - Miniature 4.4 x 2.4 x 1.0 mm
- 940nm IR emission (Vcsel)
- Advanced microcontroller and light rejection
- User detection, long ranging
**FlightSense™**

... for higher distances... **VL53L0**

---

Fully integrated miniature module
- 940nm Laser VCSEL
- Ranging sensor with advanced embedded microcontroller
- 4.4 x 2.4 x 1.0mm

**Fast, accurate distance ranging**
- Measures absolute range beyond **2m**
- Reported range is independent of the target reflectance
- Operates in high IR ambient light levels
  - Advanced embedded optical cross-talk compensation to simplify cover glass selection

**Eye safe**

**Easy integration**
- Single reflowable component
- No additional optics
- Single power supply
- I2C interface for device control and data transfer
- Xshutdown (Reset) and interrupt GPIO

**1D gesture recognition**
FlightSense™
VL6180X Nucleo pack

VL6180X
3-in-one sensor

Selection switch:
- Ranging mode
- Ambient Light mode

Push button
Mode selection
(Scaler, interrupt etc...) 

4-digit display
- Distance (mm)
- Ambient light (Lux)
- Gesture

Graphical User Interface

Order code (available May 2015):
P-NUCLEO-6180X1 (with stm32F401)
P-NUCLEO-6180X2 (with stm32L053)
X-NUCLEO-6180XA1 (expansion board)
Environmental sensors
### MEMS vs. ECM microphones

<table>
<thead>
<tr>
<th></th>
<th>MEMS Microphones</th>
<th>ECM: Electret Condenser Microphones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soldering</td>
<td>Easy Reflow</td>
<td>Temperature stability issue: requires additional controls</td>
</tr>
<tr>
<td>Form Factor</td>
<td>Convenient for ultra thin or multiple Mics designs</td>
<td>Usually bigger</td>
</tr>
<tr>
<td>Vibrations Robustness</td>
<td>More robust</td>
<td>requires rubber gasket</td>
</tr>
<tr>
<td>Temperature</td>
<td>Immune to variation</td>
<td>Impacted</td>
</tr>
<tr>
<td>Electromagnetic Interferences</td>
<td>Immune (package is a Faraday cage)</td>
<td>More impacted</td>
</tr>
<tr>
<td>Part-to-part Sensitivity Matching</td>
<td>Excellent (+/- 0.2dBFS standard deviation)</td>
<td>Difficult</td>
</tr>
</tbody>
</table>
MEMS microphones ev boards

X-NUCLEO-CCA02M1

- **MEMS microphone** evaluation board
  - STM32Nucleo Expansion, compatible with STM32 ODE
- 2X **MP34DT01–M** microphones
- 1x miniUSB FS connector:
  - USB audio data streaming
- Up to 4 microphone **synchronized acquisition and streaming**
- 6X ST MEMS Microphone coupons housing:
  - STEVAL-MKI129V1
  - STEVAL-MKI129V2
  - STEVAL-MKI129V3
MEMS mic.ev boards sw libraries

- **PDM filter library**
  - It converts from PDM to PCM

- **Acoustic echo cancellation**

- **Beamforming**
  - It creates a virtual directional microphone using 2 or 4 microphones

- **Audio source localization**
  - Localize the sound source over the 360° space using 4 microphones
BLUEVOICE DEMO

Central Unit

SetTopBox
(USB Microphone @16kHz)

Peripheral Unit

Audio In Expansion *
STM32-Nucleo
BLE Expansion
BLE @64kbps

STM32-Nucleo
Audio In Expansion
BLE Expansion

Voice commands over Bluetooth LE

- Audio entertainment and gaming
- Smart home
- Voice controlled TV remote
- Wearables
LPS22HB
High Accuracy Barometric Sensor / altimeter

Optimizing the main blocks, we enhanced the performances: better noise, improved accuracy and reduced current consumption

• Key parameters
  • 260 to 1260 mbar absolute pressure (10,000 mt altitude)
  • Pressure noise: down to 20µbar & 7.5µbar (LPF)
    • Less than 10cm noise up to 4000 mt
  • ODR from 1 to 75Hz, one shot
  • Low power consumption: 15µA (low noise) to 3µA (low power) @1Hz
  • 32 samples Embedded FIFO for Pressure and Temperature
  • SPI and I²C interfaces
  • Smallest and thinnest form factor: 2x2x0.76 mm package
HTS221 humidity + temp. sensor

- Features:
  - Humidity (0 to 100% RH) and temperature (-40 to 120 °C) sensor
  - Humidity Accuracy ±3.5%RH (20%RH to 80%RH)
  - Low Power Consumption: 2 µA @ 1Hz ODR
  - SPI and I²C interfaces
  - Self-Test
  - Supply voltage: 1.7 to 3.6 V

Key Features
±3.5%RH Accuracy
2x2 Package
Low Power

$C_{sense} = C_o + S \cdot r_H$
UVIS25M
UV Index Sensor

Features

- 0 - 15 UV index output range
- Threshold interrupt management
- No factory calibration needed
- UVI available with no need for computation
- Interruption on UV value threshold
- Digital output
- Active and power down modes
- Wide field of view measurement

Key Features
Digital, no calibration needed
UVI with UV-A & UV-B computation
MEMS Motion sensors
MEMS Motion sensors

- MEMS is **Micro Electro-Mechanical Systems**
- MEMS contain movable 3D structure
- Structure move accordingly to external displacement
- **In MEMS not only electrons are moving!**
MEMS Motion sensors

Accelerometer
- Measures acceleration
- Unity measured: g (1g is gravity – 9.8m/sec²)
- Can measure up to 400g!

Gyroscope
- Measures angular rate
- Unity measured: DPS (Degree Per Second)
- It’s power hungry!

Magnetometer
- Measures earth magnetic field
- Unity measured: Gauss
- Measured magnetic field is 1000 times lower than conventional magnetic sensors!

IMU (Inertial Measurement Unit)
LIS2DS12
14bit, 3-axis, low power digital accelerometer

- 3-Axis Digital SPI/I2C Accelerometer from ±2 to ±16 g Full Scale
- Up to 14 bit resolution
- Operating voltage: 1.62 – 1.98V

**Accuracy**
- Sensitivity: 0.244 mg
- 0g offset: ±30mg
- Noise density: 140µg/√Hz
- Temperature drift: ±0.3 mg/°C

**Very low power**
- 2.5µA in **Low Power Mode** (1Hz)
- 150µA in **High Resolution Mode** (6.4KHz)
- 12.5µA/150µA in **LPM/HRM** (100Hz)
- 0.5µA in Power down mode

**2x2mm LGA12 package**

**Key Features**
- Big FIFO: allow data storage with no MCU access
- Pedometer and motion detection algorithms
- Sensor HUB allows acquiring data from 1 external sensor
## ST MEMS accelerometer table

### Applications

<table>
<thead>
<tr>
<th>Package size (mm)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x 2 x 1 mm</td>
<td></td>
</tr>
<tr>
<td>3 x 3 x 1 mm</td>
<td></td>
</tr>
<tr>
<td>&gt; 4 x 4 x 1 mm</td>
<td></td>
</tr>
</tbody>
</table>

### Consumer & Industrial

<table>
<thead>
<tr>
<th>Applications</th>
<th>Package size (mm)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-bit HLIS331DL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-bit H3LIS100DL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H3LIS200DL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-bit LIS331HH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-bit LIS2HH12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIS3DSH</td>
<td></td>
<td>High-g</td>
</tr>
<tr>
<td>(smart AXL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-bit LIS2DS12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-bit LIS2DH</td>
<td></td>
<td>Low-g</td>
</tr>
<tr>
<td>LIS2DH12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-bit LIS2DE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIS2DE12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LI344ALH</td>
<td></td>
<td>Analog</td>
</tr>
</tbody>
</table>

### Long-life applications

<table>
<thead>
<tr>
<th>Applications</th>
<th>Package size (mm)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIS2DH</td>
<td></td>
<td>IIS328DQ</td>
</tr>
</tbody>
</table>

### Automotive non-safety

<table>
<thead>
<tr>
<th>Applications</th>
<th>Package size (mm)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS328DQ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AES3624DQ</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Automotive safety (central & peripheral airbags)

<table>
<thead>
<tr>
<th>Applications</th>
<th>Package size (mm)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS1120SX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIS2120SX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIS1200PS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Medical

<table>
<thead>
<tr>
<th>Applications</th>
<th>Package size (mm)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIS2DH</td>
<td></td>
<td>For implantable devices</td>
</tr>
</tbody>
</table>
LSM303AGR
high performance e-compass module

- 3-axis accelerometer: up to ± 16g full-scale, LIS2DH12 based
- 3-axis magnetic sensor: ± 50Ga FS
  - Resolution down to 2.5 mGa RMS
  - 10, 20, 50, 100,-OneShot ODR
- Embedded temperature sensor
- Embedded **Self test** for both sensors
- Embedded magnetic Offset compensation
  - No offset thermal drift
- LGA-12, 2x2, P2P compatible with LSM303C, LIS2DH12, LIS2HH12, LIS2DS12

**Key Features**

- High Full Scale Magnetometer
- Flexibility resolution vs. power consumption
- Magnetic offset compensation embedded
LSM6DS3

iNEMO 6 axis Inertial Measurement Unit

**Ultra low power**
- 0.9mA in combo Normal Mode
- 420µA in combo Low Power Mode

**Ultra small size**
- Tiny size to fit in the smallest, wearable and Internet of Things devices
- 2.5mm x 3.0mm x 0.8mm

**Ultra performing**
- Intrinsic Performances for both gyroscope and accelerometer
- Gyroscope rate noise down to 7mdps/√Hz (typ.)
- Accelerometer rate noise down to 90µg/√Hz (typ.)

**Ultra capable**
- Embedded Features 8kbytes “smart” FIFO
- Limit MCU access

**Ultra smart**
- Algorithms embedded
- Motion tracking, Pedometer and context awareness
- Less SW and less access on MCU, faster system reaction time

**Ultra scalable**
- External Sensors synchronization
- HUB Capability
- Easier to Use

0.9mA in combo Normal Mode
420µA in combo Low Power Mode
20% better than the best alternative solution
LSM6DS3

iNEMO 6 axis Inertial Measurement Unit

- **Low Power**
  - 420µA for Accelerometer and Gyro running in Low Power Mode
  - 0.9mA in Normal Mode and 1.25 mA in high performance mode (up to 1.6 KHz)
  - 24µA for the accelerometer in Low Power Mode at ODR <52 Hz
  - 6µA in Power Down mode

- **Low noise level**
  - Gyro noise 7 mdps/√Hz
  - Accel noise 90 µg/√Hz

- **Extended digital features**
  - Smart FIFO up to 8 Kbytes with dynamic allocation of significant data
    - external sensors, time stamp
  - Sensor Hub:
    - Up to 4 external sensors with configurable data acquisition (synchro., data rate, Nb of data)
    - I2C Master / Aux SPI to collect data from external sensors
    - Hard-Iron/Soft-Iron correction for external magnetic sensor corrections
  - Event detection interrupts, fully configurable
    - Tap/double tap, Free-fall, activity-inactivity recognition, Wake-up, 6D-4D orientation
  - Advanced algorithm embedded
    - Significant motion, tilt, pedometer functions (Step detector and step counters)
LSM9DS1
high performance 9-axis Inertial Measurement Unit

Main Features
• 3-axis accelerometer: up to ±16g
• 3-axis gyroscope: up to ±2000 dps
• 3-axis magnetic sensor: up to ±16Gs
• FIFO, Temperature sensor
• Package: LGA-24, 3.5 x 3 x 1 mm
• Power Supply range: 1.9V to 3.6V

Key Features
• Package: 3.5x3x1 mm
• “Always-on” eco power mode: 1.9 mA
• Mag pwr consumption: 15 μA @ 1 Hz

Advanced Features
• “Always-on” eco power mode down to 1.9 mA
• Low power magnetometer
• Position and motion detection functions
• Click/double-click recognition
• Intelligent power saving for handheld devices
Hardware description

• The X-NUCLEO-IKS01A1 is a motion MEMS and environmental sensor evaluation board system.
• It is compatible with the Arduino UNO R3 connector layout, and is designed around ST's latest sensors.

Products on board

6-AXIS IMU: MEMS 3D accelerometer (±2/±4/±8 g) + 3D gyroscope (±245/±500/±2000 dps)

3-Axis Magnetometer: MEMS 3D magnetometer (±4/ ±8/ ±12/ 16 gauss)

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

HUMIDITY SENSOR: Capacitive digital relative humidity and temperature

DIL 24-pin: Socket available for additional MEMS adapters and other sensors (UV index)
X-NUCLEO-IKS01A1 & Open.MEMS
Software libraries

- **X-CUBE-MEMS1** (v1.4.0)
  - Complete middleware to build applications using 6-axis IMU (LSM6DS0 / LSM6DS3), Magnetometer (LIS3MDL), Pressure sensor (LPS25HB) and Humidity/Temperature sensor (HTS221) raw data
  - Sample application to transmit real-time sensor data to a PC
  - Available for STM32F401, STM32L053, STM32L152 and STM32L476RG

- **OsxMotionFX** (v1.3) (X-CUBE-MEMS1 Add-on)
  - iNEMOEnginePRO real-time motion sensor fusion (under OPEN.MEMS license)
  - 6 & 9-axis sensor fusion available thru compilation option
  - Available for STM32F401, STM32F411 and STM32L476RG

- **OsxMotionAR** (v1.1) (X-CUBE-MEMS1 Add-on)
  - Real-time activity tracking using accelerometer
  - Detects: rest; walking; fast walking; jogging; biking; driving
  - Available for STM32F401

- **OsxMotionCP** (v1.0) (X-CUBE-MEMS1 Add-on)
  - Real-time carried position using accelerometer
  - Detects: on desk; in hand; near head; shirt pocket; trouser pocket; arm swing;
  - Available for STM32F401

All libraries share one GUI

**Development Toolchains and Compilers**
- IAR Embedded Workbench for ARM (EWARM) toolchain V7.40
- RealView Microcontroller Development Kit (MDK-ARM) toolchain V5.16
- System Workbench for STM32 V1.3.0.20150724
Thank you.