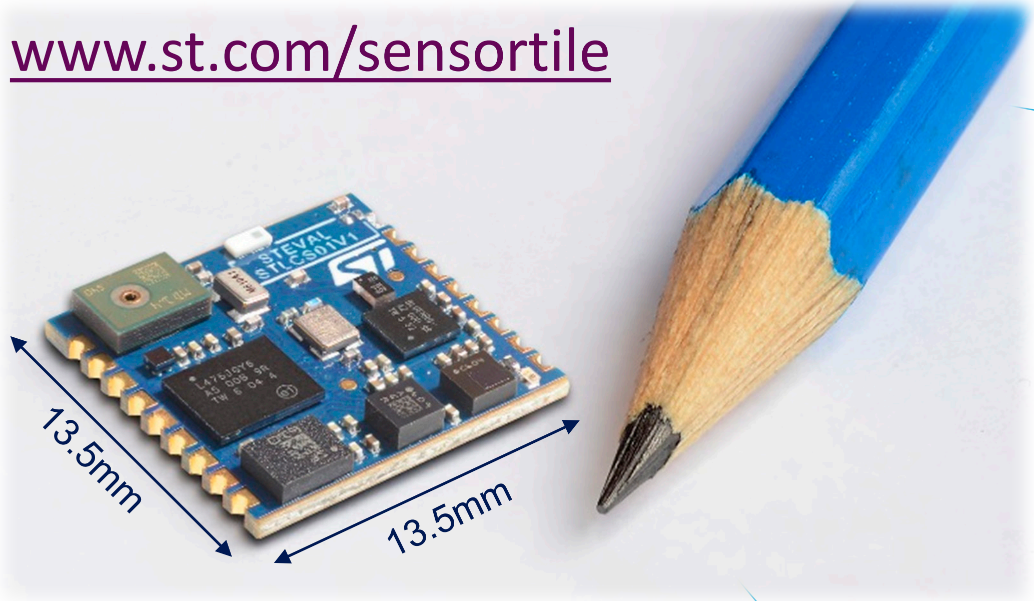
2017 SensorExpo
SensorTile Hands-on Workshop

IoT Systems Development

STMIcroelectronics

www.st.com/sensortile



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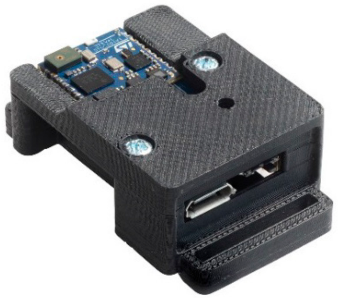
LABs Preparation

At the end of the workshop you will receive a **free Sensortile kit**

For the workshop ST will provide

ST USB Key
with relevant material for the workshop (software, documents, presentation)



Preprogramed and pre-assembled SensorTile

They need to be **returned to ST** at the end of the workshop

LABs Preparation

ON YOUR LAPTOP

- Have a google account (creation of Google Speech API)

ON YOUR PHONE

- Install **ST BlueMS app** on your smartphone (available for iOS and android)

Agenda

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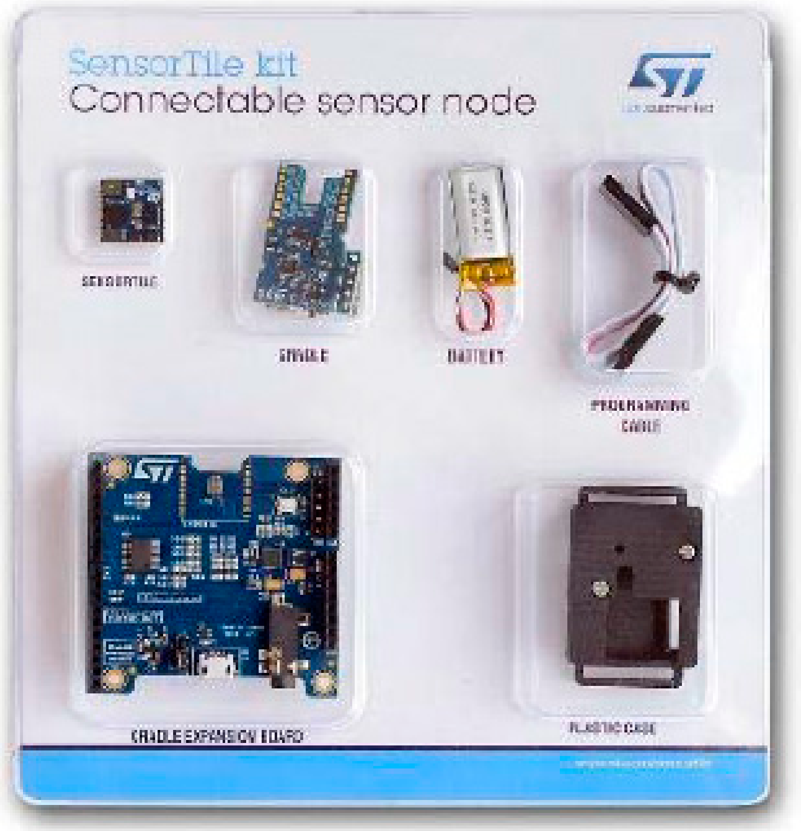

- SensorTile Overview
- SensorTile Hardware Architecture
- *S*ensorTile Firmware and Software packages
  - Software and Application packages
  - Customization example
- Hands-on **SensorTile** using the **ST BlueMS app**
  - **Open.MEMS** Software Expansion
  - **Voice over BLE** and **Automatic Speech Recognition** (ASR)
  - **Cloud connectivity** using the IBM Watson cloud
  - **Firmware Over-The-Air updates**

Hands-on **SensorTile**

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- LAB1: Install the BlueMS app
- LAB2: Real-Time Data Plot and Log
- LAB3: Sensor Fusion
- LAB4: Magnetometer Calibration
- LAB5: Context Awareness
- LAB6: Event Detection
- LAB7: Voice over Bluetooth LE
- LAB8: Google Speech Recognition
- LAB9: Current Consumption
- LAB10: IBM Watson IoT
- LAB11: Debug Console
- Firmware Over The Air Update

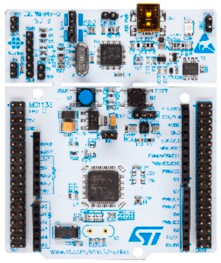
SensorTile Overview

ST ecosystem: STM32 **ODE**

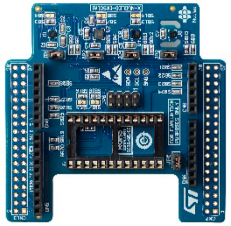
HARDWARE

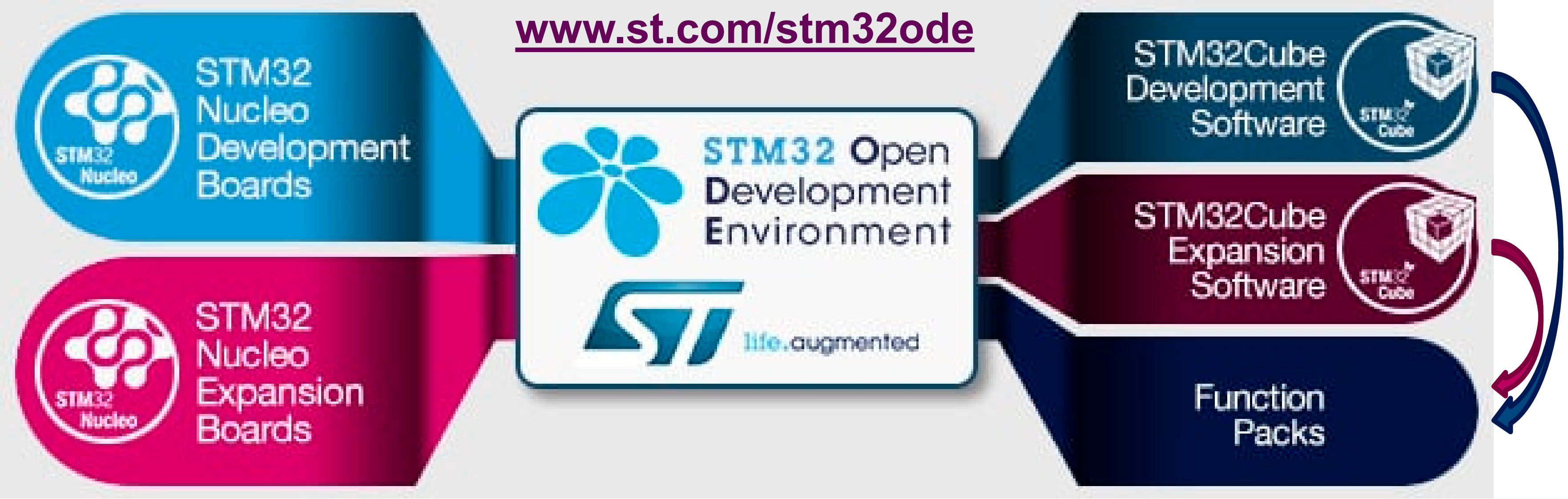
SOFTWARE

16
NUCLEO
L0 to L4
F0 to F7



33
X-NUCLEO





www.st.com/stm32ode

STM32 Nucleo Development Boards

STM32 Nucleo Expansion Boards

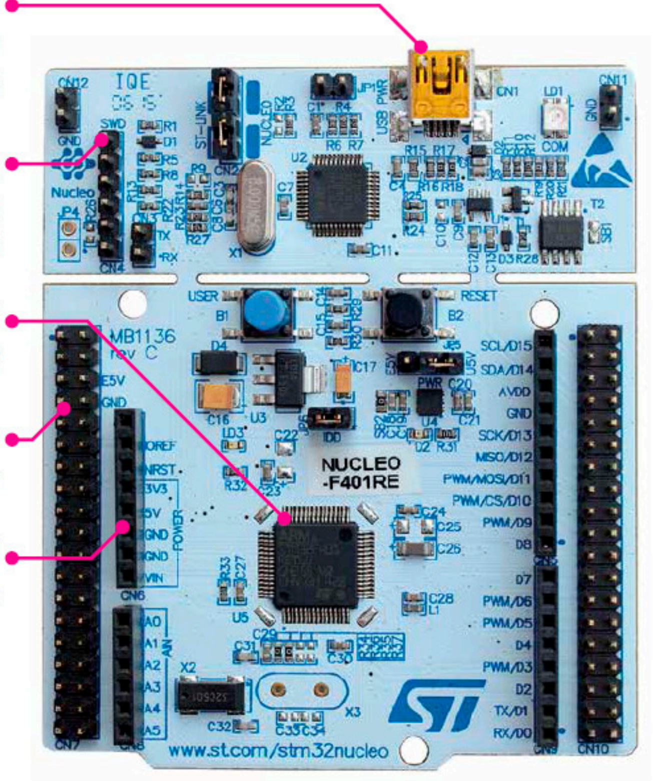
STM32 Open Development Environment

STM32Cube Development Software

STM32Cube Expansion Software

Function Packs

Nucleo / X-Nucleo



Board power supply through USB or external source

Integrated debugging and programming ST-LINK probe

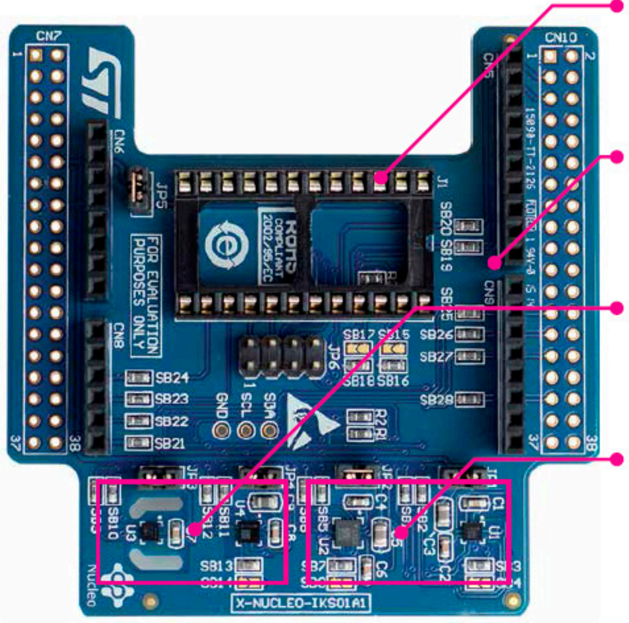
STM32 microcontroller

ST morpho extension header

Arduino™ extension headers

STM32 Nucleo

Development board



DIL24 support for new devices

Arduino extension headers

Environmental sensors

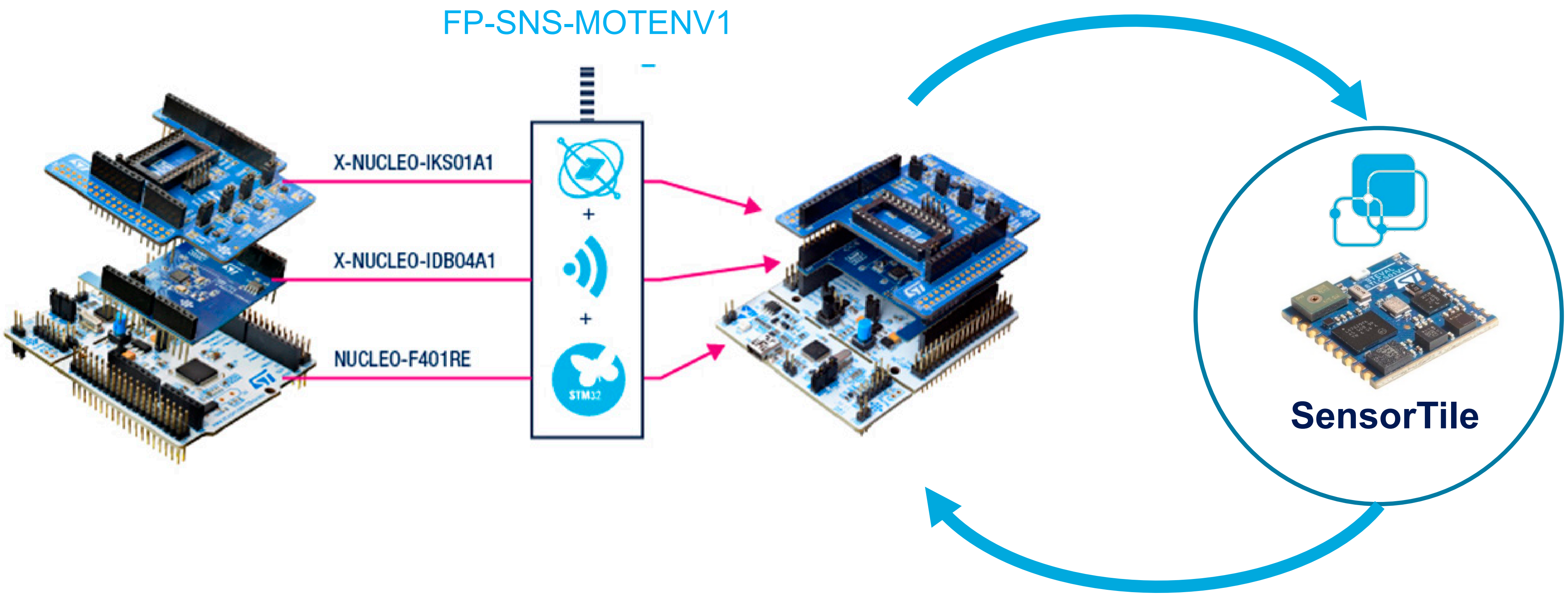
Motion sensors

Expansion board (X-NUCLEO)

Nucleo / X-Nucleo and SensorTile

- Modular development system
- Rich set of **firmware packages**

- Form-factor development system
- Same set of firmware packages & **more**



FP-SNS-MOTENV1

X-NUCLEO-IKS01A1

X-NUCLEO-IDB04A1

NUCLEO-F401RE

SensorTile

SensorTile

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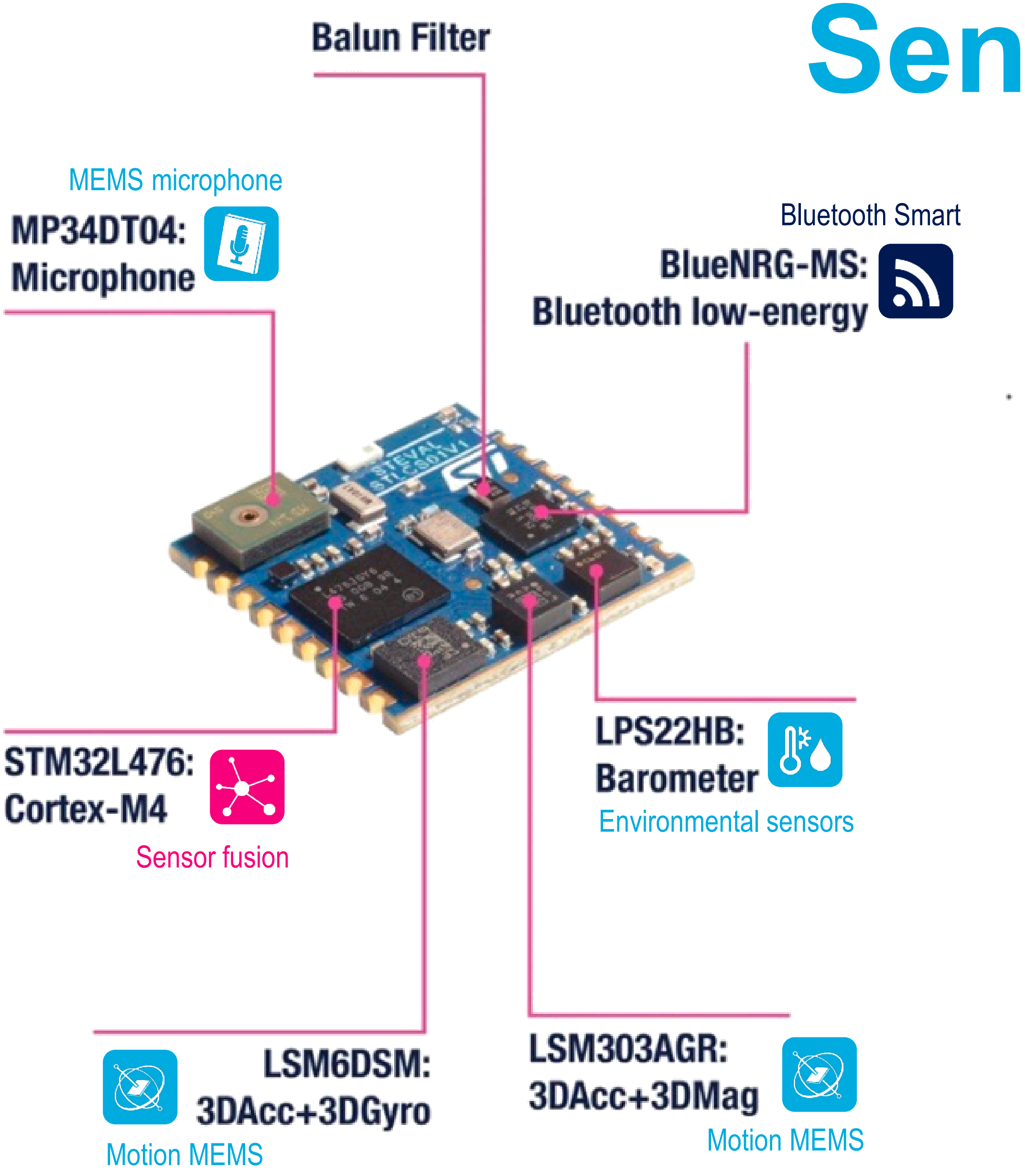


Balun Filter

MEMS microphone

MP34DT04:
Microphone

Bluetooth Smart

BlueNRG-MS:
Bluetooth low-energy

STM32L476:
Cortex-M4

Sensor fusion

LPS22HB:
Barometer

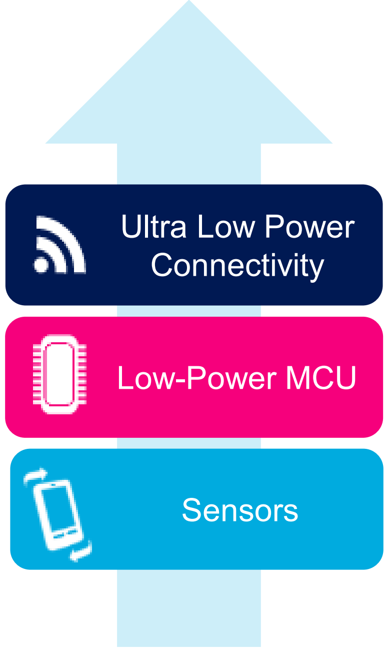
Environmental sensors

LSM6DSM:
3DAcc+3DGyro

Motion MEMS

LSM303AGR:
3DAcc+3DMag

Motion MEMS



Ultra Low Power Connectivity

Low-Power MCU

Sensors

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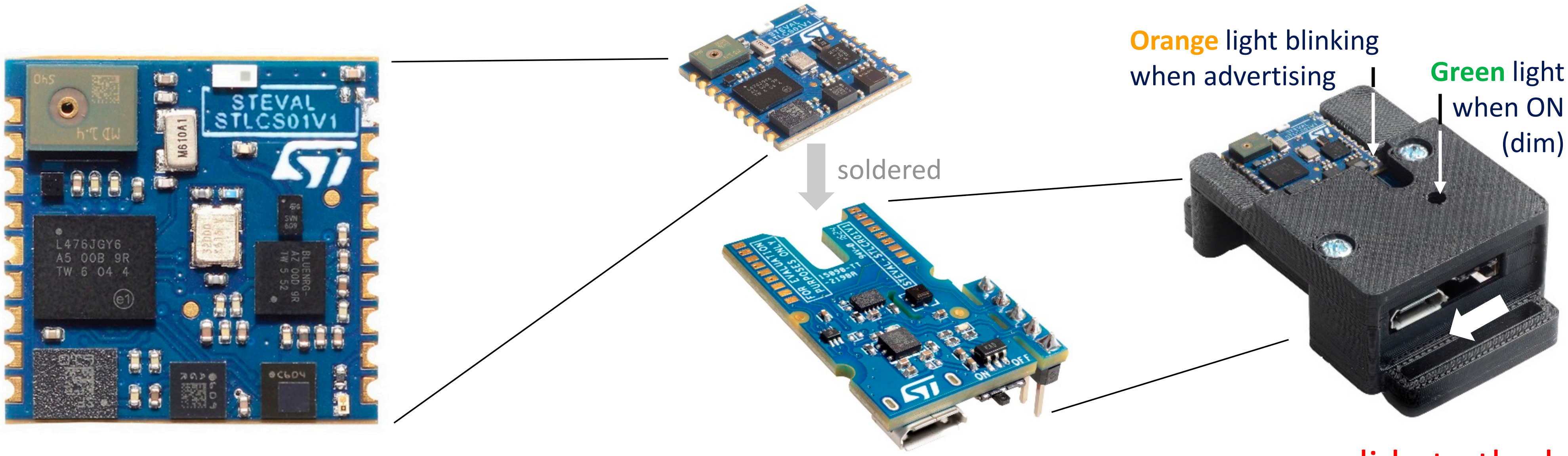
SensorTile



soldered

Orange light blinking when advertising

Green light when ON (dim)

slide to the left to turn it ON

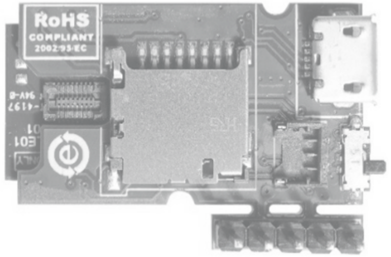
SensorTile Core System STLCS01V1

- STM32L476 Microcontroller
- BlueNRG-MS Bluetooth low-energy
- BALF-NRG-01D3 Balun filter
- MP34DT04 digital microphone
- LSM6DSM digital acc + gyro
- LSM303AGR digital acc + mag
- LPS22HB digital barometer
- LD39115J18 voltage regulator

SensorTile **Cradle** STLCR01V1

- HTS221 digital temp/RH
- STC3115 battery gas gauge
- STBC08 battery charger
- USBLC6-2P6 USB ESD protection
- USB micro connector
- Battery connector
- SWD connector (detachable)
- SD card slot
- On/Off switch

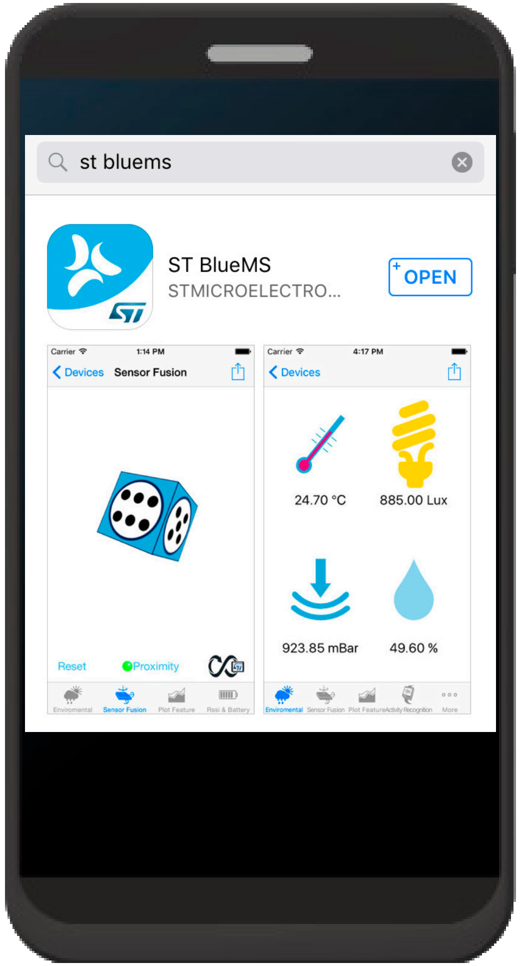
bottom view



SensorTile & ST BlueMS app

SensorTile
assembled and
pre-programmed

Please download and install
ST BlueMS from the app store



LAB1: the BlueMS app

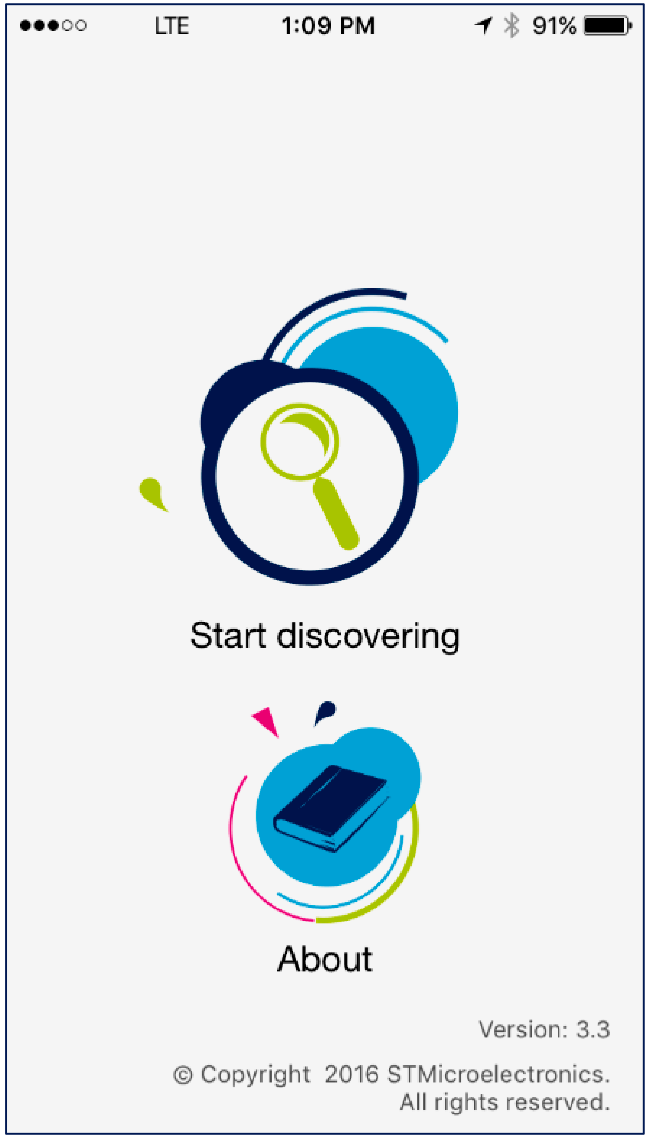
- Goal:
  - Familiarize with the app
  - See raw data from environmental sensors

LAB1: the BlueMS app

On iOS / Android store

BlueMS

Search and Install the BlueMS app



Version: 3.3

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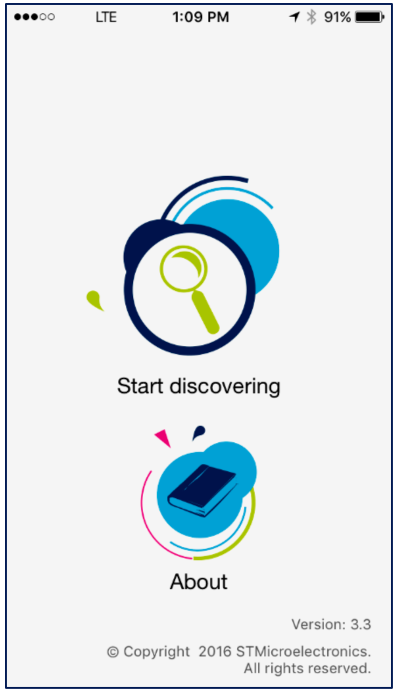
LAB1: the BlueMS app

Turn on the SensorTile and wait for the **orange** blinking light

Touch “Start discovering”



●●●○○ LTE 1:09 PM 91%

Start discovering

About

Version: 3.3

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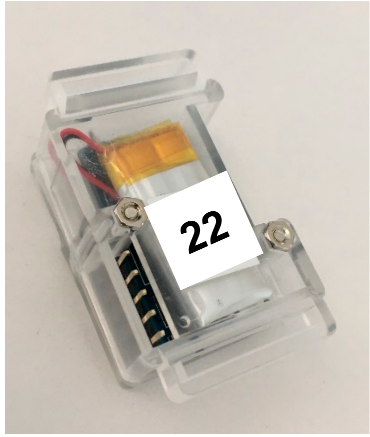
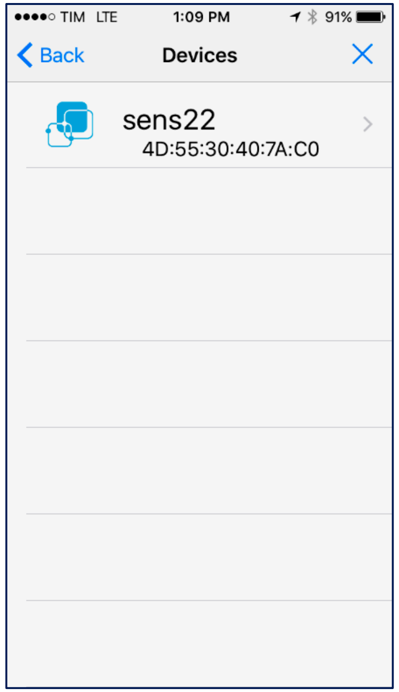
The name is “sensNN”

(look at the label on the bottom)



Select your SensorTile

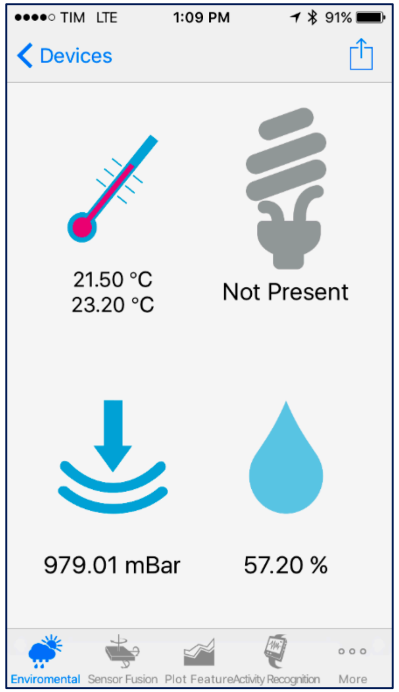


●●●●○ TIM LTE 1:09 PM 91%

< Back Devices ✕

sens22
4D:55:30:40:7A:C0

You are connected



●●●●○ TIM LTE 1:09 PM 91%

< Devices

21.50 °C
23.20 °C

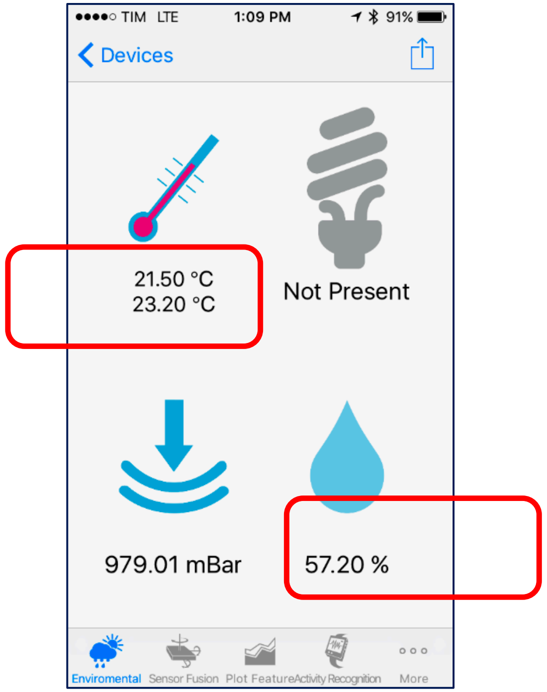
Not Present

979.01 mBar

57.20 %

LAB1: the BlueMS app

View the SensorTile
Environmental sensor real-time data



●●●●○ TIM LTE 1:09 PM 91%

Devices

21.50 °C
23.20 °C

Not Present

979.01 mBar

57.20 %

Swipe left
for more

LAB: temperature and humidity sensor

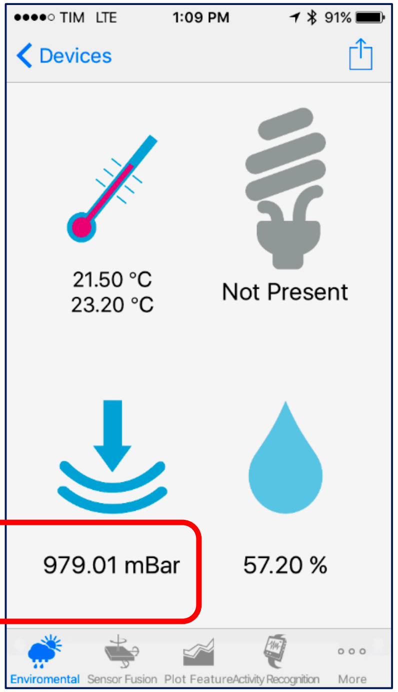
Try to blow some hot air on the SensorTile to see temperature and humidity changes

- Temperature measured using:
  - HTS221 Temperature and humidity sensor (±0.5C deg accuracy)
  - Internal Temperature sensor of pressure sensor (±1.5C deg accuracy)

LAB1: the BlueMS app

View the SensorTile Environmental sensor real-time data

979.01



●●●●○ TIM LTE 1:09 PM 91%

Devices

21.50 °C
23.20 °C

Not Present

979.01 mBar

57.20 %

Swipe left for more

LAB: pressure sensor

Try to move the SensorTile up/down by 20-30cm (7-12in),

wait a few seconds and observe the change in the barometer reading (mbar).

SensorTile Fits All **IoT** Design Needs

www.st.com/sensortile

EVALUATION TOOL

- **Evaluate** the most advanced ST sensors in an all-ST optimized **system architecture**
- **Field-test** Data-Fusion and Embedded Signal Processing **Algorithms**
- Use it for **Data collection** campaigns, to develop new customized algorithms

FAST PROTOTYPING

- **Plug** the SensorTile on your **prototype** board to instantly add its embedded sensing and communication functionalities to your design
- Use the provided **3D CAD** files to integrate it in your mechanical prototype

REFERENCE DESIGN

- A **form-factor Reference Design** for sensing, processing and streaming
- A complete **Hardware and Software example**, the starting point for your design
- **Freely download** all design information:
  - HW: Schematics, Gerber, BoM, 3D CAD
  - FW: from basic examples to the complete application

SOFTWARE DEVELOPMENT TOOL

- **Firmware** examples based on **STM32Cube**
- Supported by the **STM32 Open Development Environment**
- Host board supports A**rduino expansion connector** to bridge into other ecosystems from Arduino itself to the STM32ODE, and other developer communities

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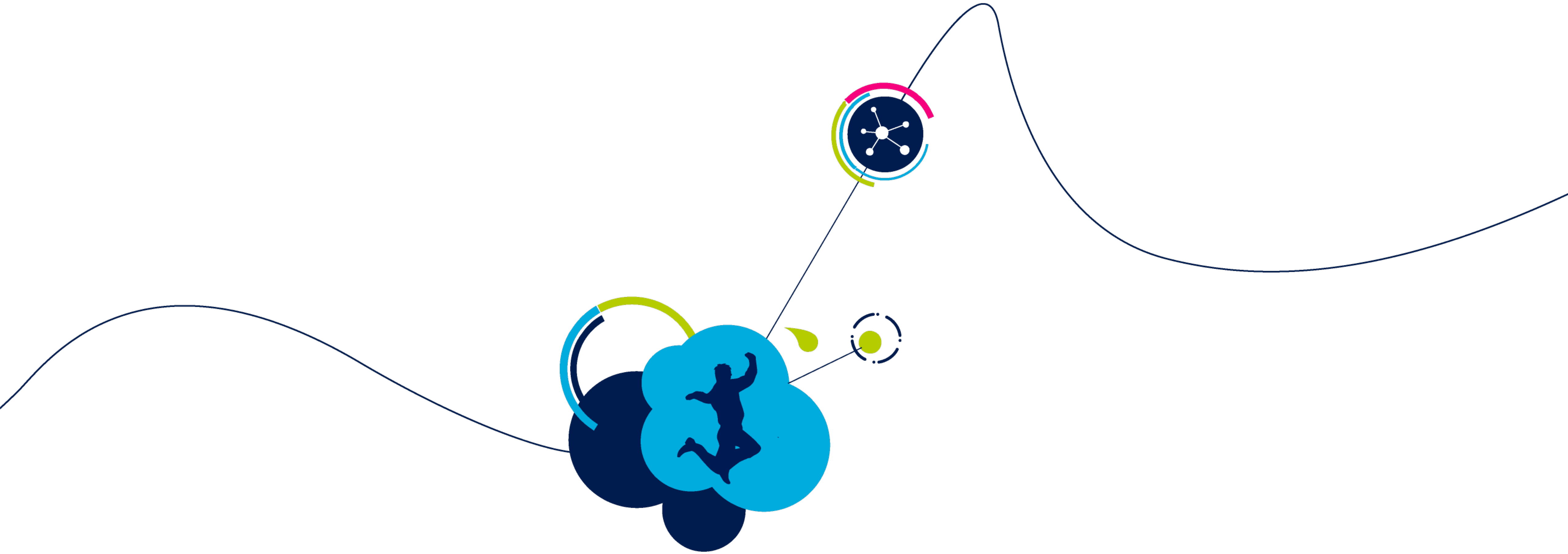
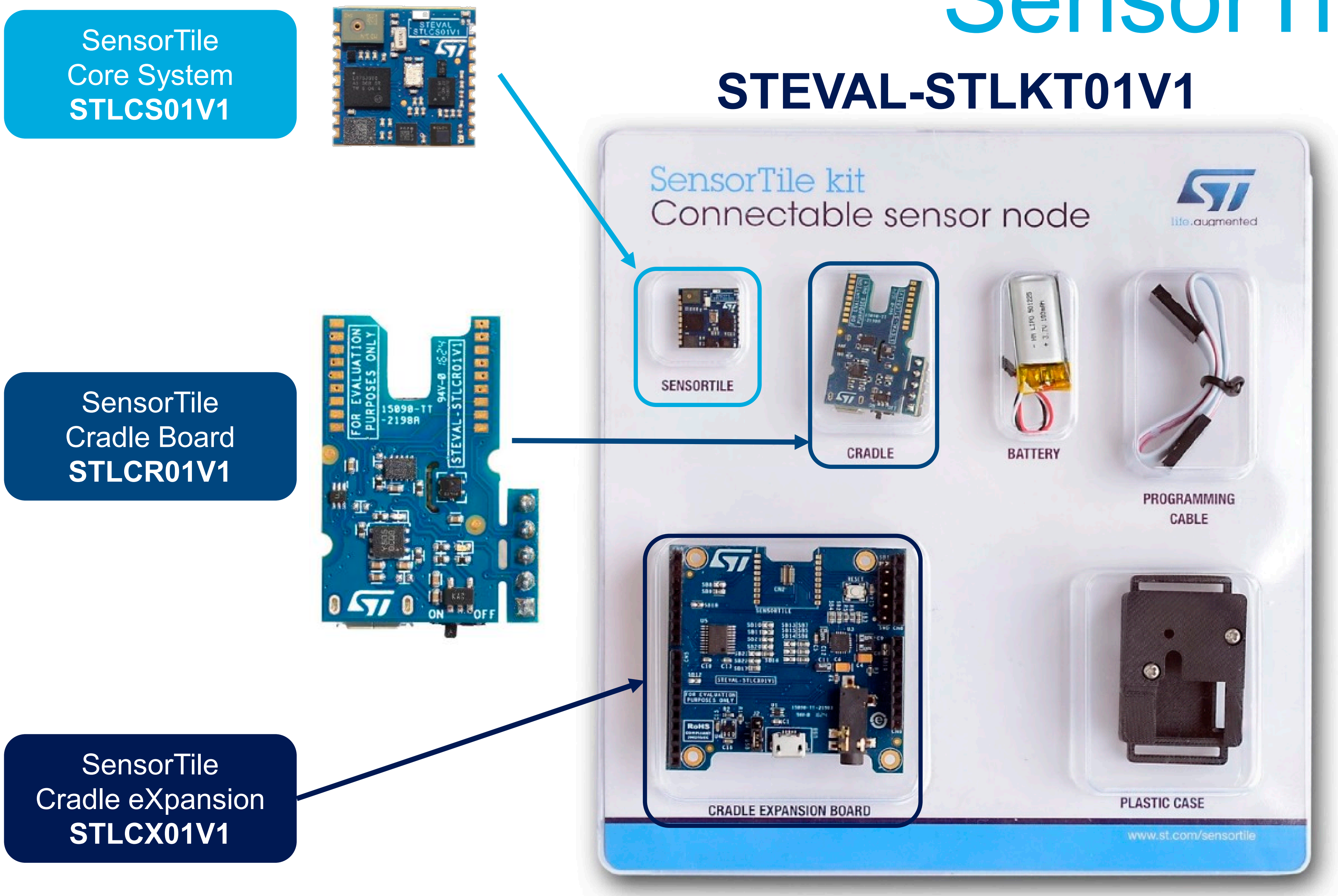


SensorTile Hardware Architecture Overview

SensorTile Kit

STEVAL-STLKT01V1



SensorTile
Core System
STLCS01V1

SensorTile
Cradle Board
STLCR01V1

SensorTile
Cradle eXpansion
STLCX01V1

SensorTile Kit

STEVAL-STLKT01V1

SensorTile
Core System
STLCS01V1

bottom view

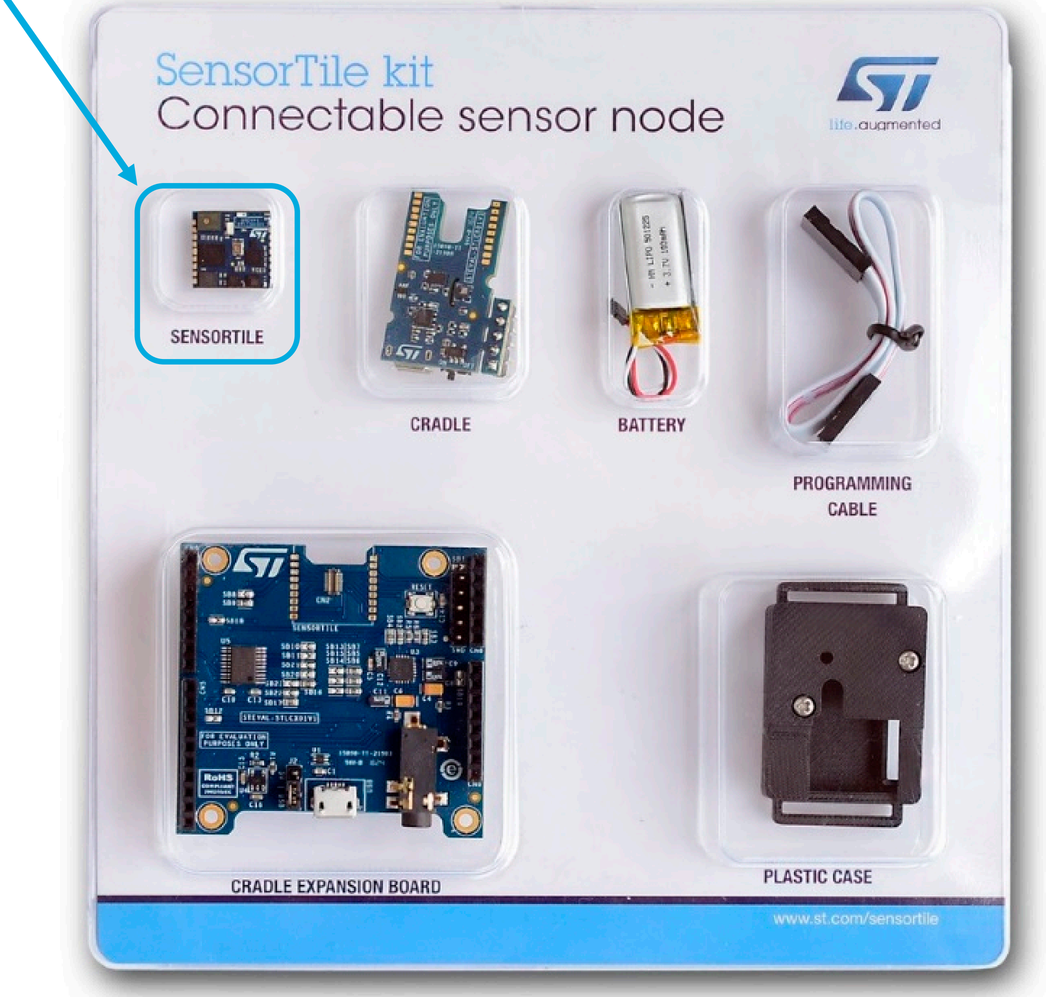
FC ID: S9NSTILE01

IC IC: 8976C-STILE01

100mAh LiPo battery
UN38.3 certified

ST-Link SWD
programming cable

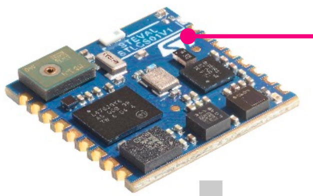
Protective plastic enclosure to house the SensorTile, cradle and battery



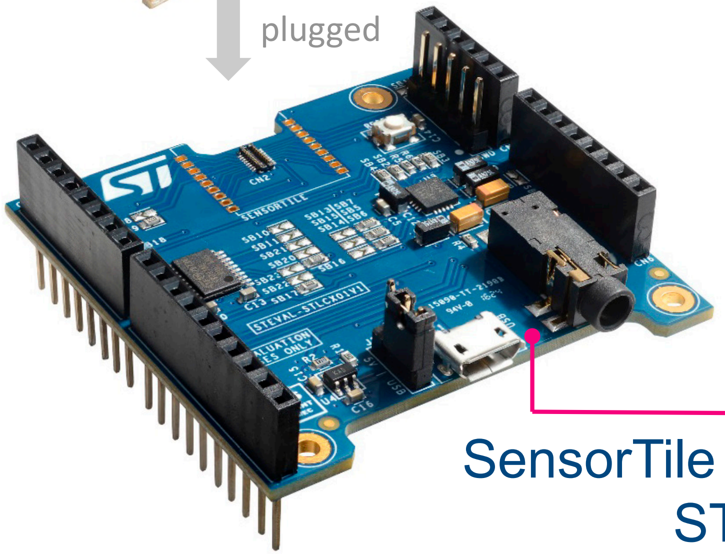
SensorTile Kit

SensorTile Core System STLCS01V1

- STM32L476 Microcontroller
- BlueNRG-MS Bluetooth low-energy
- BALF-NRG-01D3 Balun filter
- MP34DT04 digital microphone
- LSM6DSM digital acc + gyro
- LSM303AGR digital acc + mag
- LPS22HB digital barometer
- LD39115J18 voltage regulator

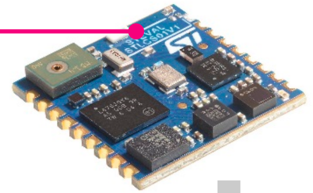


plugged

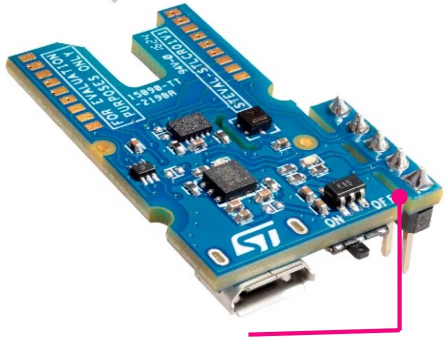


SensorTile **Cradle eXpansion** STLCX01V1

- Level translator (8bit, 1.7 to 5.5V)
- Arduino connectors
- Audio DAC (16bit, stereo)
- Audio jack connector
- USBLC6-2P6 USB ESD protection
- USB micro connector
- SWD connector
- Reset button



soldered



SensorTile **Cradle** STLCR01V1

- HTS221 digital temp/RH
- STC3115 battery gas gauge
- STBC08 battery charger
- USBLC6-2P6 USB ESD protection
- USB micro connector
- Battery connector
- SWD connector (detachable)
- SD card slot
- On/Off switch

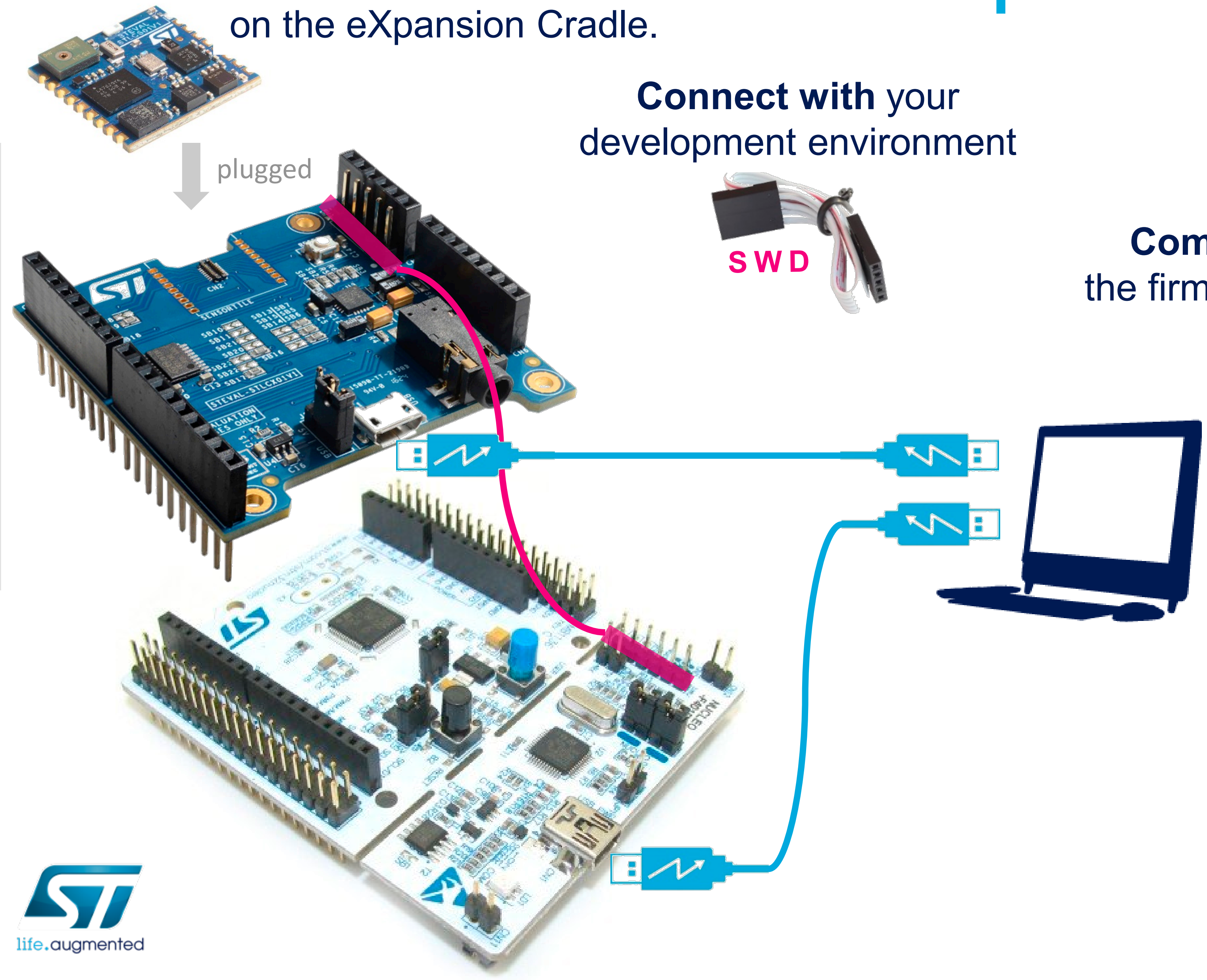
Jump start your project

Plug the SensorTile
on the eXpansion Cradle.

Connect with your
development environment

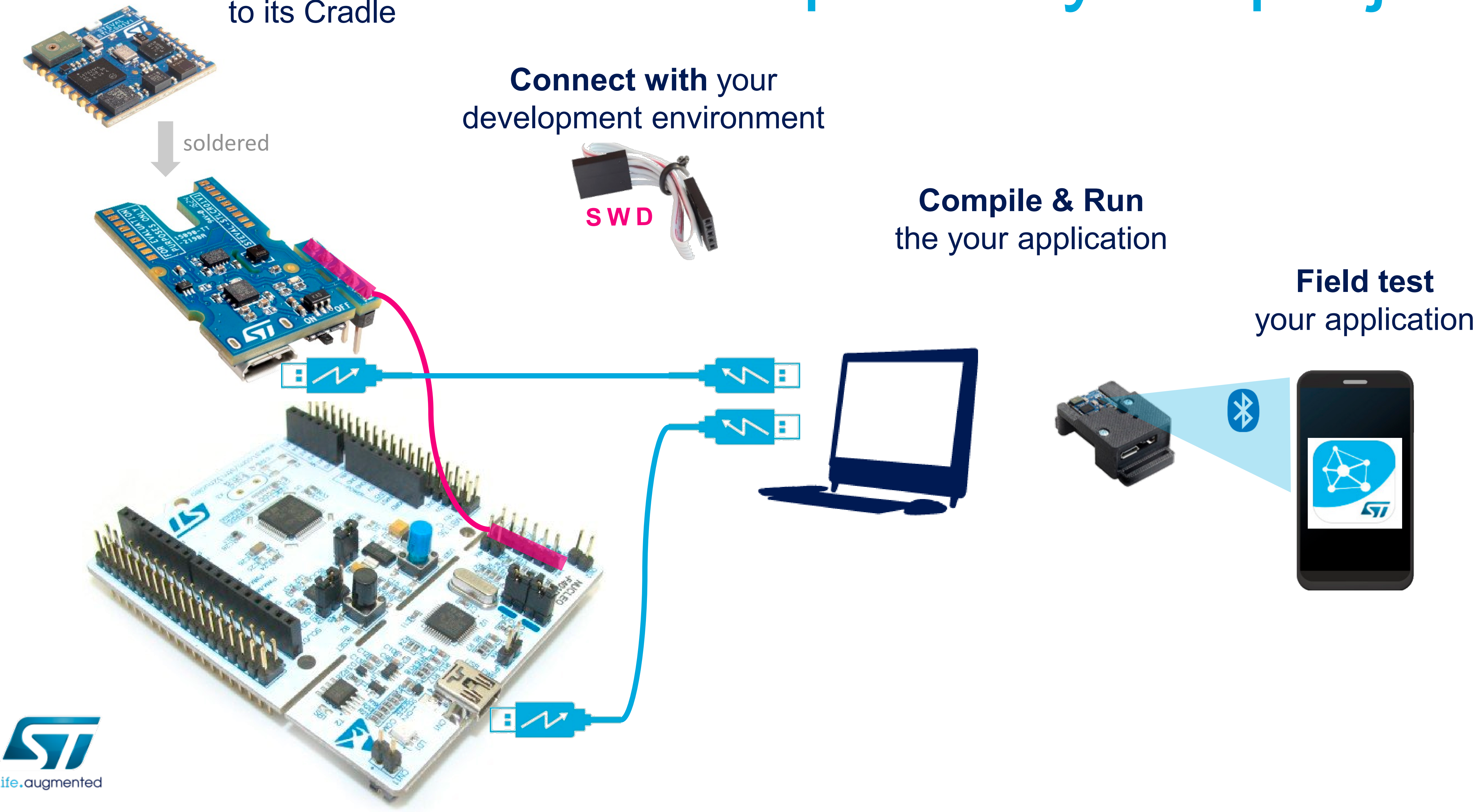
Compile & Run
the firmware package

Design your
custom application



Jump start your project

Solder the SensorTile to its Cradle



soldered

Connect with your development environment

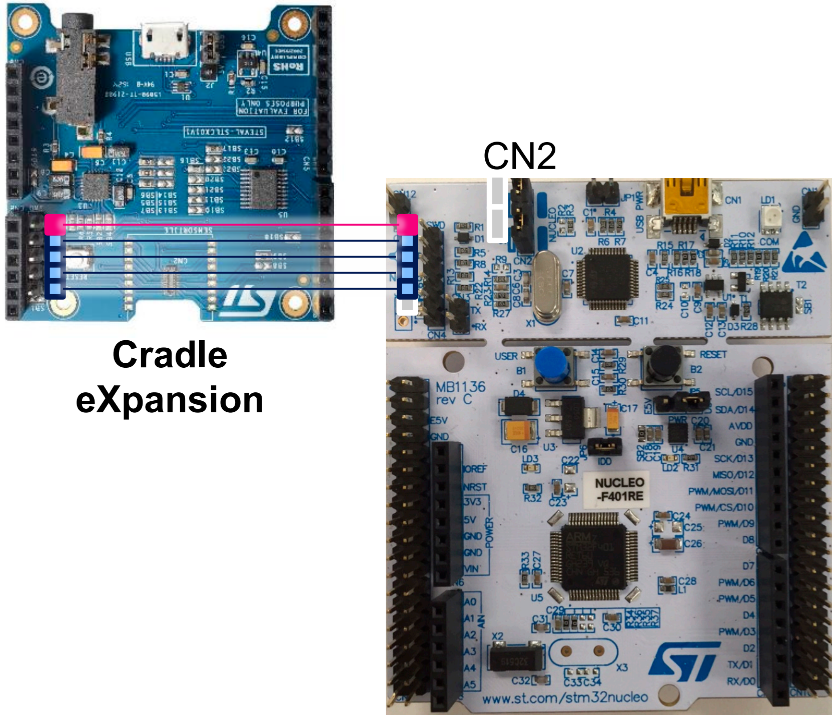
Compile & Run the your application

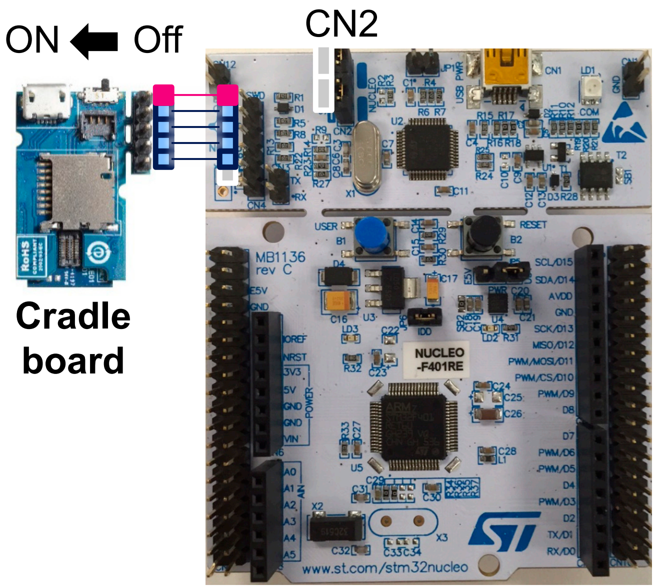
Field test your application

How to Flash

1. Remove two jumpers on CN2 of the Nucleo board
2. Plug the 5-pin cable to the SWD connectors (pin1 is square, highlight in red below)
3. Plug the USB cable of the cradle (if there is a switch: turn it ON) to power the target STM32L4
4. Plug the USB cable of the Nucleo board to power the ST-Link/V2
5. Drag and drop the .bin on the virtual device (or flash the .bin / .hex using the ST-Link Utility)

STM32 ST-LINK Utility





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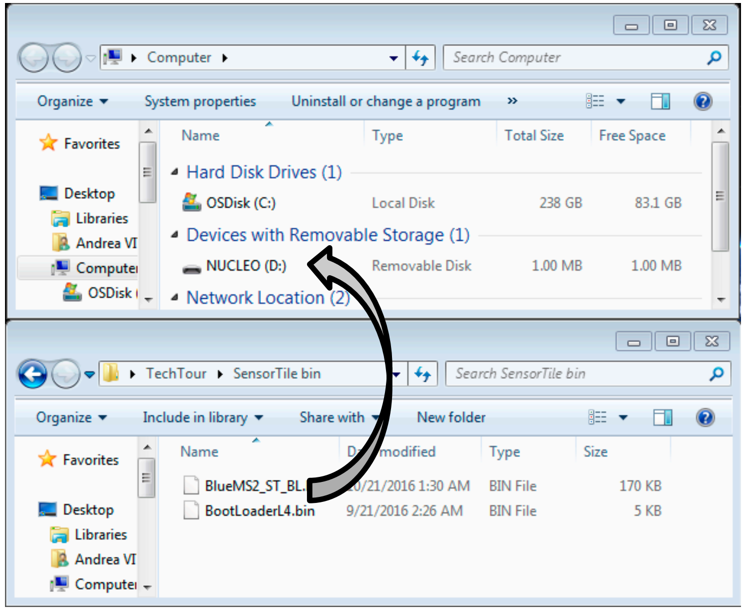
STM32 ST-LINK Utility

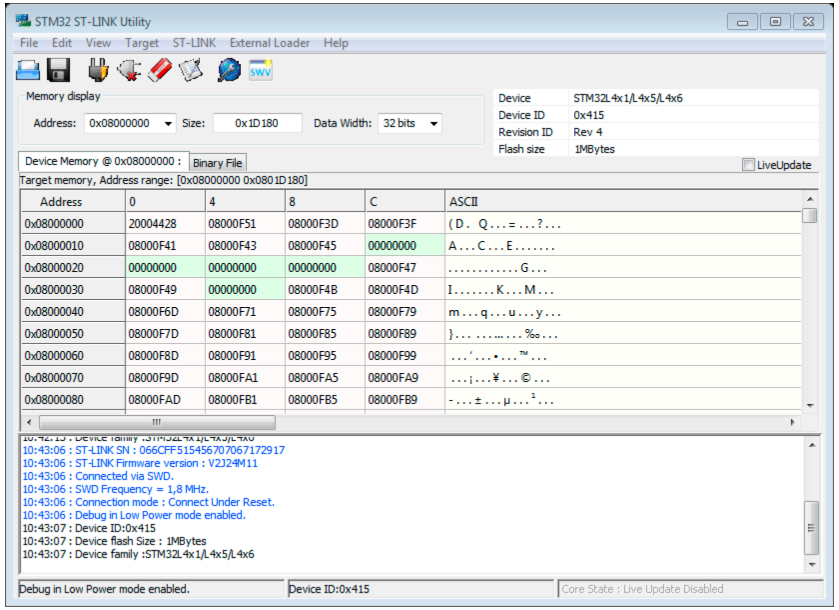
Drag and drop on virtual device



Name	Type	Total Size	Free Space
Hard Disk Drives (1)			
OSDisk (C:)	Local Disk	238 GB	83.1 GB
Devices with Removable Storage (1)			
NUCLEO (D:)	Removable Disk	1.00 MB	1.00 MB
Network Location (2)			

Name	Date modified	Type	Size
BlueMS2_ST_BL.	0/21/2016 1:30 AM	BIN File	170 KB
BootLoaderL4.bin	9/21/2016 2:26 AM	BIN File	5 KB

ST-Link Utility



Address: 0x08000000 Size: 0x1D180 Data Width: 32 bits

Device	STM32L4x1/L4x5/L4x6
Device ID	0x415
Revision ID	Rev 4
Flash size	1MBytes

Target memory, Address range: [0x08000000 0x0801D180]

```
Address     0         4         8         C         ASCII
0x08000000  20004428  08000F51  08000F3D  08000F3F  (D. Q...=...?...
0x08000010  08000F41  08000F43  08000F45  00000000  A...C...E.......
0x08000020  00000000  00000000  00000000  08000F47  ............G...
0x08000030  08000F49  00000000  08000F4B  08000F4D  I.......K...M...
0x08000040  08000F6D  08000F71  08000F75  08000F79  m...q...u...y...
0x08000050  08000F7D  08000F81  08000F85  08000F89  }... ...…...‰...
0x08000060  08000F8D  08000F91  08000F95  08000F99  ...'...•...™...
0x08000070  08000F9D  08000FA1  08000FA5  08000FA9  ...¡...¥...©...
0x08000080  08000FAD  08000FB1  08000FB5  08000FB9  -...±...µ...¹...
```

```
10:42:15 : Device family :STM32L4x1/L4x5/L4x6
10:43:06 : ST-LINK SN : 066CFF515456707067172917
10:43:06 : ST-LINK Firmware version : V2J24M11
10:43:06 : Connected via SWD.
10:43:06 : SWD Frequency = 1,8 MHz.
10:43:06 : Connection mode : Connect Under Reset.
10:43:06 : Debug in Low Power mode enabled.
10:43:07 : Device ID:0x415
10:43:07 : Device flash Size : 1MBytes
10:43:07 : Device family :STM32L4x1/L4x5/L4x6
```

Debug in Low Power mode enabled. | Device ID:0x415 | Core State : Live Update Disabled

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SensorTile Components

MP34DT04

Microphone

64dB SNR, 120dBSPL

Alt: dual high-dynamic-range

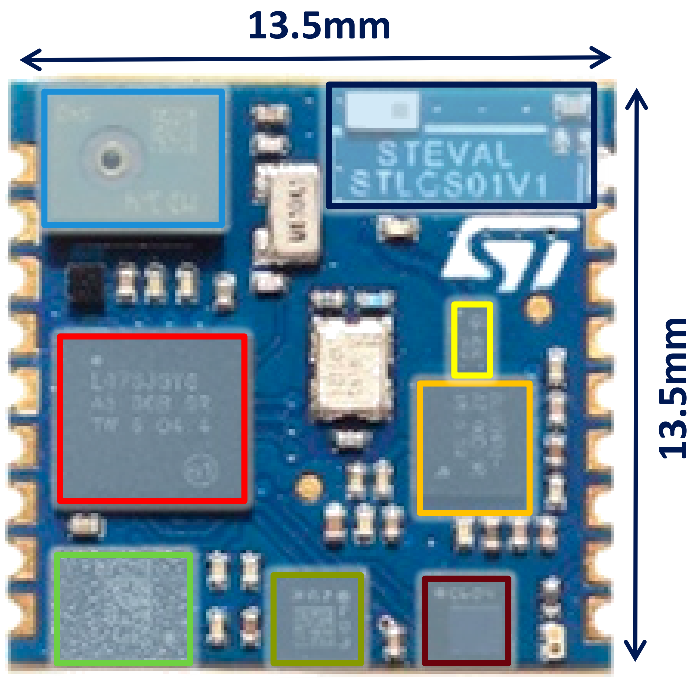
STM32L476

Cortex-M4F

Up to 100DMIPS 80MHz

100uA/MHz at 24MHz

35uA/MHz at 2MHz



Antenna Clearence Area

Balun Filter

BlueNRG-MS

Bluetooth low-energy

Concurrent master/slave

BT4.1

LSM6DSM

3DAcc+3DGyro

0.65mA at 6.6kHz, 9uA at 12.5Hz

6.6kHz acc, 90ug/sqrtHz

6.6kHz gyro, 6mdps

LSM303AGR

3DAcc+3DMag

± 50Ga mag,

6uA at 50Hz acc,

25uA at 10Hz mag

LPS22HB

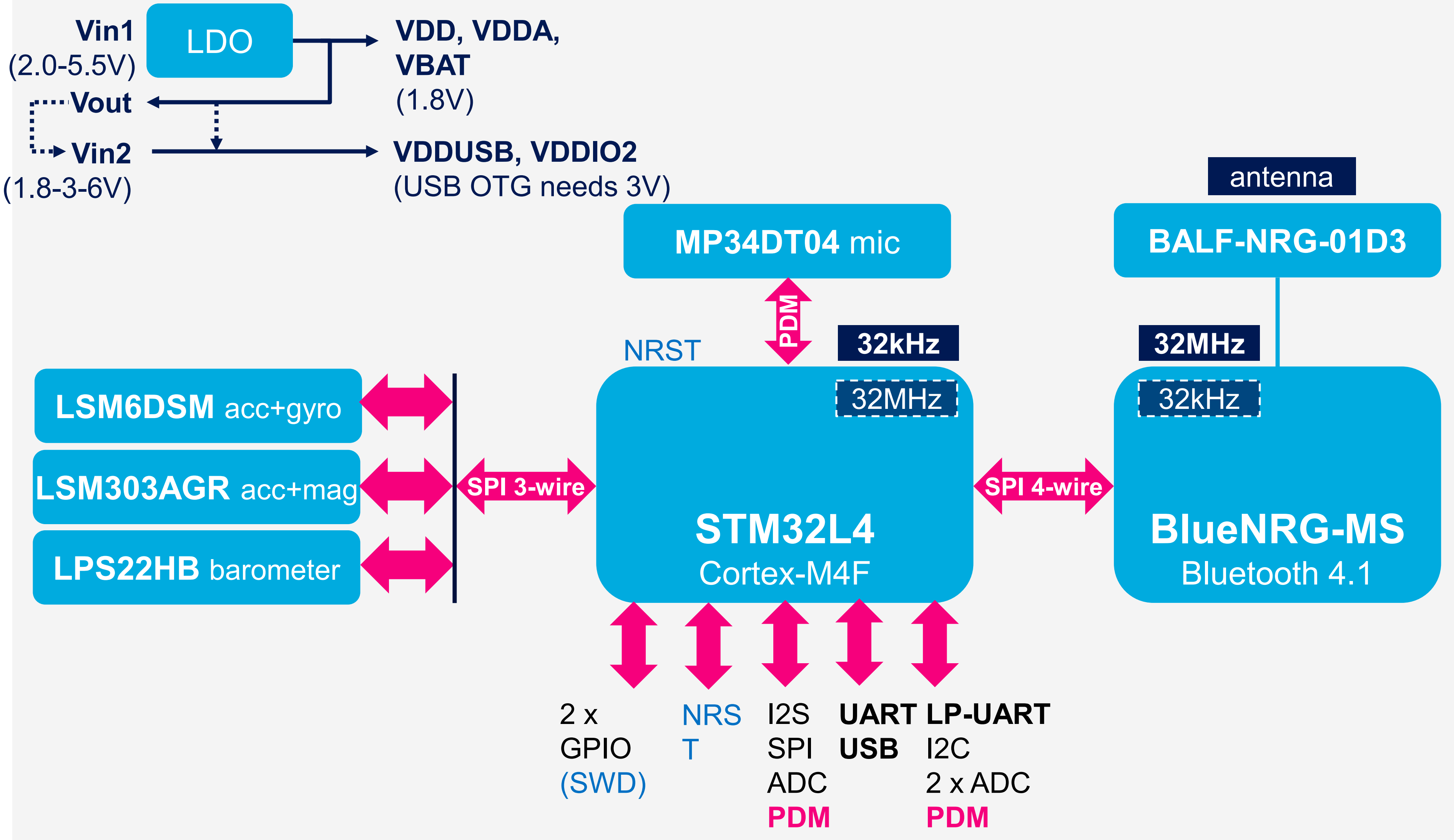
Barometer

0.1hPa accuracy

0.01hPa RMS noise

1-75Hz, 4-15uA at 1Hz

SensorTile Block Diagram



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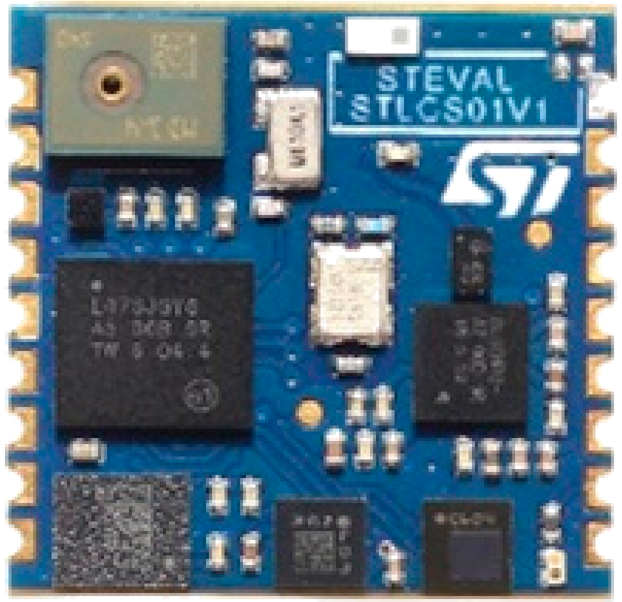
SensorTile Pinout



(ADC / **PDM out**) GPIO 1

(SWD VDD, VDD 1.8V) VOUT 2

(2.0-5.5V) VIN1 3

(VOUT or VUSB 3-3.6V) VIN2 4

GND 5

USART RX / USB DP 6

USART TX / USB DM 7

SAI SCLK / SPI SCK 8

SAI FS / SPI MISO 9

18 GND

17 GND (SWD GND)

16 GPIO (SWD IO)

15 GPIO (SWD CLK)

14 NRST (SWD RST)

13 GPIO (**LP UART RX / I2C SCL** / ADC / **PDM in**)

12 GPIO (**LP UART TX / I2C SDA** / ADC / **PDM clk in**)

11 SAI SD / SPI NSS

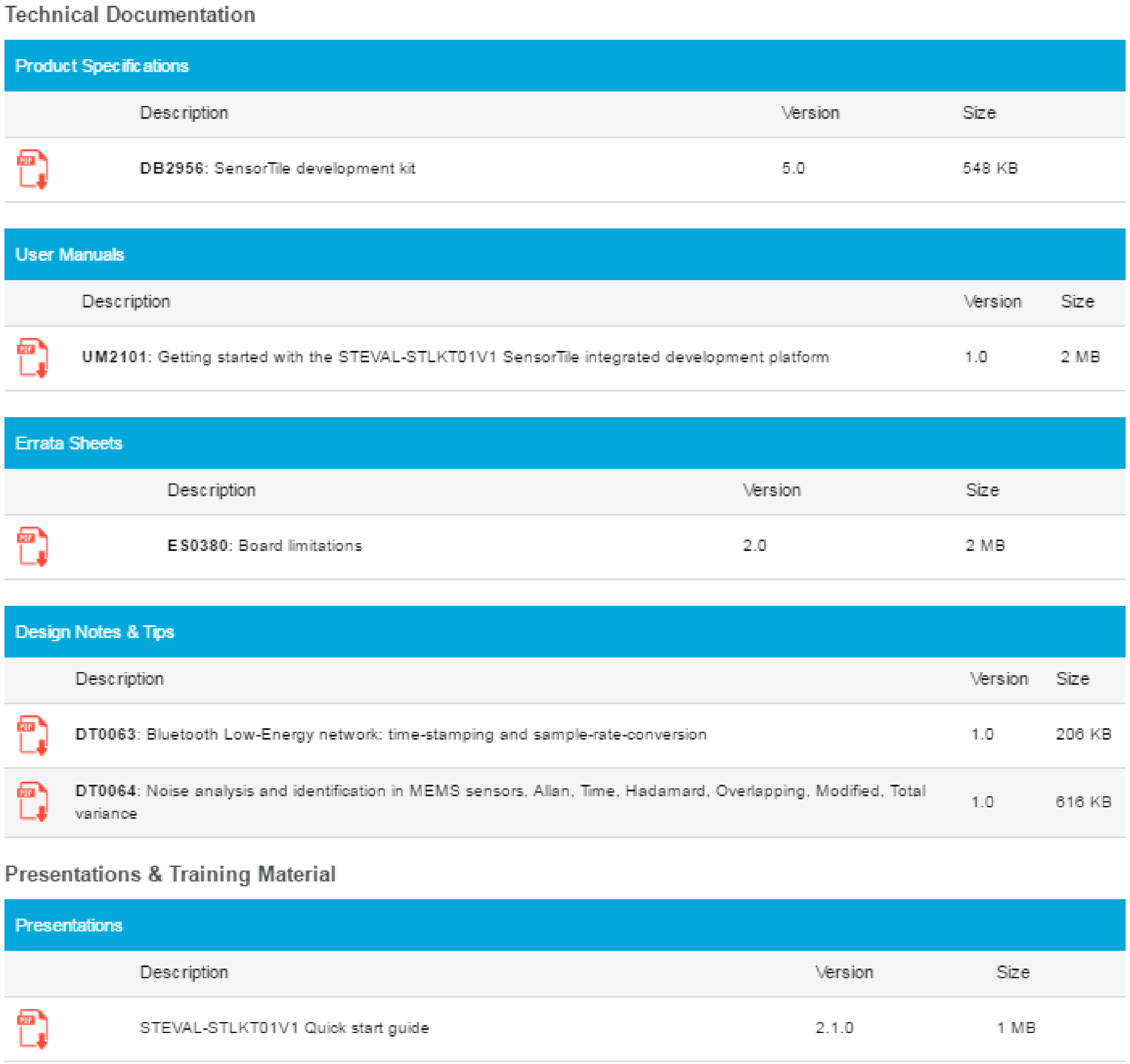
10 SAI MCLK / SPI MOSI

2 x GPIO (SWD)	NRST	I2S SPI ADC **PDM**	**UART** **USB**	**LP-UART** I2C 2 x ADC **PDM**

SensorTile Firmware and Software Overview

www.st.com/sensortile

Technical Documentation



Technical Documentation

Product Specifications

Description	Version	Size
DB2956: SensorTile development kit	5.0	548 KB

User Manuals

Description	Version	Size
UM2101: Getting started with the STEVAL-STLKT01V1 SensorTile integrated development platform	1.0	2 MB

Errata Sheets

Description	Version	Size
ES0380: Board limitations	2.0	2 MB

Design Notes & Tips

Description	Version	Size
DT0063: Bluetooth Low-Energy network: time-stamping and sample-rate-conversion	1.0	206 KB
DT0064: Noise analysis and identification in MEMS sensors, Allan, Time, Hadamard, Overlapping, Modified, Total variance	1.0	616 KB

Presentations & Training Material

Presentations

Description	Version	Size
STEVAL-STLKT01V1 Quick start guide	2.1.0	1 MB

Datasheet

User Manual

Design Tips and Application Notes

Presentations (**Quick guides!**)

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www.st.com/sensortile

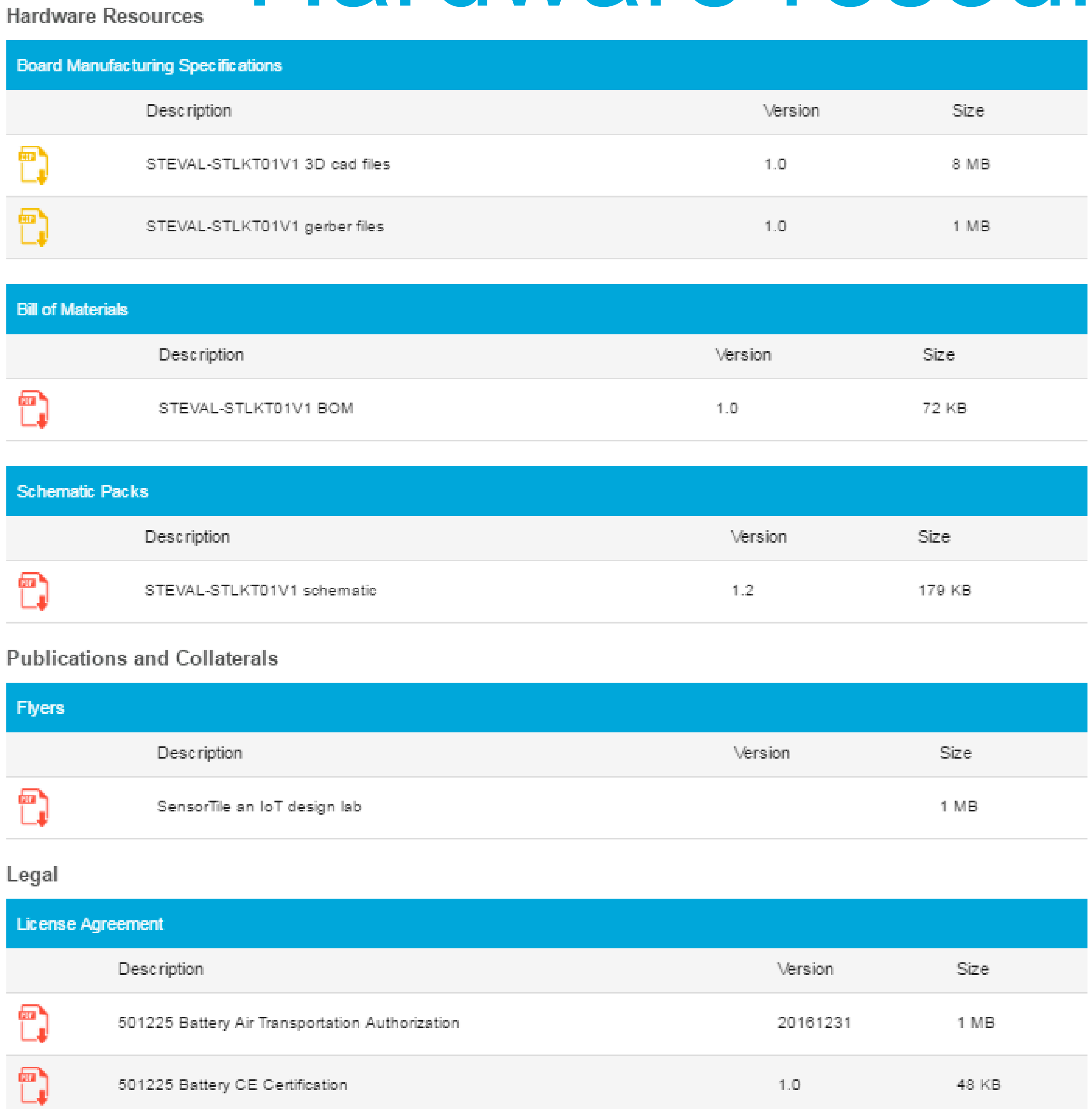
Hardware resources

3D CAD and Gerbers

BOM

Flyers

License agreements and certifications



Hardware Resources

Board Manufacturing Specifications

	Description	Version	Size
	STEVAL-STLKT01V1 3D cad files	1.0	8 MB
	STEVAL-STLKT01V1 gerber files	1.0	1 MB

Bill of Materials

	Description	Version	Size
	STEVAL-STLKT01V1 BOM	1.0	72 KB

Schematic Packs

	Description	Version	Size
	STEVAL-STLKT01V1 schematic	1.2	179 KB

Publications and Collaterals

Flyers

	Description	Version	Size
	SensorTile an IoT design lab		1 MB

Legal

License Agreement

	Description	Version	Size
	501225 Battery Air Transportation Authorization	20161231	1 MB
	501225 Battery CE Certification	1.0	48 KB

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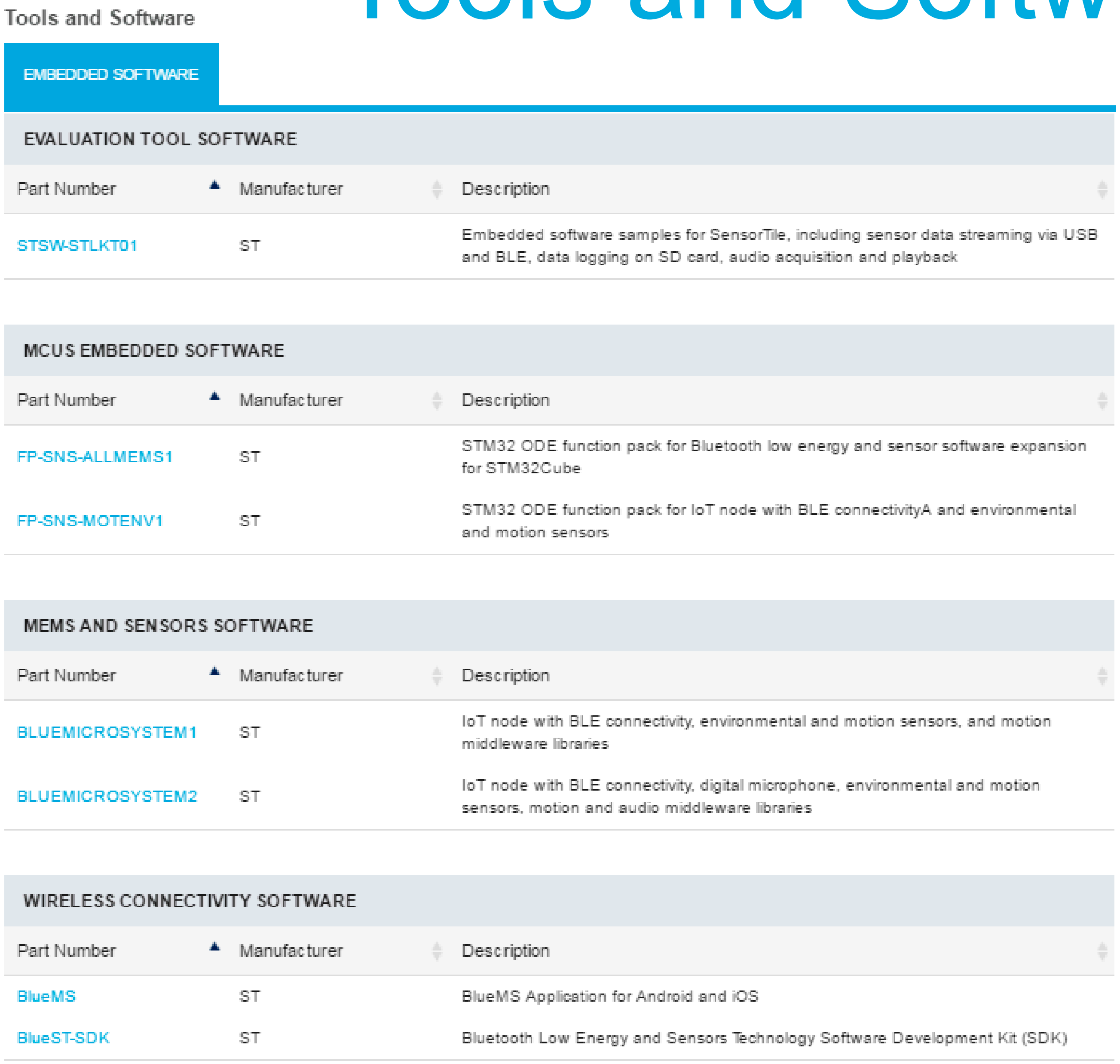
Tools and Software



Tools and Software

EMBEDDED SOFTWARE

EVALUATION TOOL SOFTWARE

Part Number ▲	Manufacturer	Description
STSW-STLKT01	ST	Embedded software samples for SensorTile, including sensor data streaming via USB and BLE, data logging on SD card, audio acquisition and playback

MCUS EMBEDDED SOFTWARE

Part Number ▲	Manufacturer	Description
FP-SNS-ALLMEMS1	ST	STM32 ODE function pack for Bluetooth low energy and sensor software expansion for STM32Cube
FP-SNS-MOTENV1	ST	STM32 ODE function pack for IoT node with BLE connectivityA and environmental and motion sensors

MEMS AND SENSORS SOFTWARE

Part Number ▲	Manufacturer	Description
BLUEMICROSYSTEM1	ST	IoT node with BLE connectivity, environmental and motion sensors, and motion middleware libraries
BLUEMICROSYSTEM2	ST	IoT node with BLE connectivity, digital microphone, environmental and motion sensors, motion and audio middleware libraries

WIRELESS CONNECTIVITY SOFTWARE

Part Number ▲	Manufacturer	Description
BlueMS	ST	BlueMS Application for Android and iOS
BlueST-SDK	ST	Bluetooth Low Energy and Sensors Technology Software Development Kit (SDK)

Firmware packages

App and corresponding SDK

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Hardware, Software and Documentation

HARDWARE

- **STEVAL-STLKT01V1** SensorTile kit

FIRMWARE

- **STSW-STLKT01** fw for beginners (bin + src code)
  - Runs specifically on Sensortile
- **FP-SNS-ALLMEMS1** default fw (bin + src code)
  - Runs on **Sensortle** as well as on system made of Nucleo + Nucleo expansions for Bluetooth LE, MEMS inertial and environmental sensors and MEMS microphones

APPS

- **ST BlueMS** iOS/Android app (bin)
- **BlueST-SDK** iOS/Android app dev kit (src code)

DOCUMENTATION

- **UM2101** getting started with SensorTile kit
- **UM2090** getting started with STSW-STLKT01
- **UM2059** getting started with FP-SNS-ALLMEMS1
- **UM1997** getting started with ST BlueMS app

Function Packages

ODE software package

(Open Development Environment – src code)

With fusion libraries

(Open Sw eXpansion – bin libraries)

- **X-CUBE-MEMS1** MEMS sensors: motion + environ
- **X-CUBE-BLE1** BLE: Bluetooth Low Energy

These software packages can be used with **SensorTile**

FP-SNS-MOTENV1	BLE + MEMS	FX, AR, CP, GR, PM
FP-SNS-ALLMEMS1	BLE + MEMS + digital microphone	FX, AR, CP, GR, BlueVoice
FP-SNS-FLIGHT1	BLE + MEMS + Time of Flight + NFC	FX, AR, CP, GR, GR-ToF
FP-AUD-BVLINK1	BLE + digital microphone	BlueVoice
FP-NET-BLESTAR1	BLE + MEMS + WiFi	

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Function Packages

ODE software package

(Open Development Environment – src code)

- **X-CUBE-MEMS1** MEMS sensors: motion + environ
- **X-CUBE-BLE1** BLE: Bluetooth Low Energy

peripherals

- **FP-SNS-MOTENV1** BLE + MEMS
- **FP-SNS-ALLMEMS1** BLE + MEMS + digital microphone
- **FP-SNS-FLIGHT1** BLE + MEMS + Time of Flight + NFC

- **FP-AUD-BVLINK1** BLE + digital microphone

central

- **FP-NET-BLESTAR1** BLE + MEMS + WiFi

The BLE STAR topology package enables
cloud gateway functionality

With fusion libraries

(Open Sw eXpansion – bin libraries)

- FX, AR, CP, GR, PM
- FX, AR, CP, GR, BlueVoice
- FX, AR, CP, GR, GR-ToF

- BlueVoice

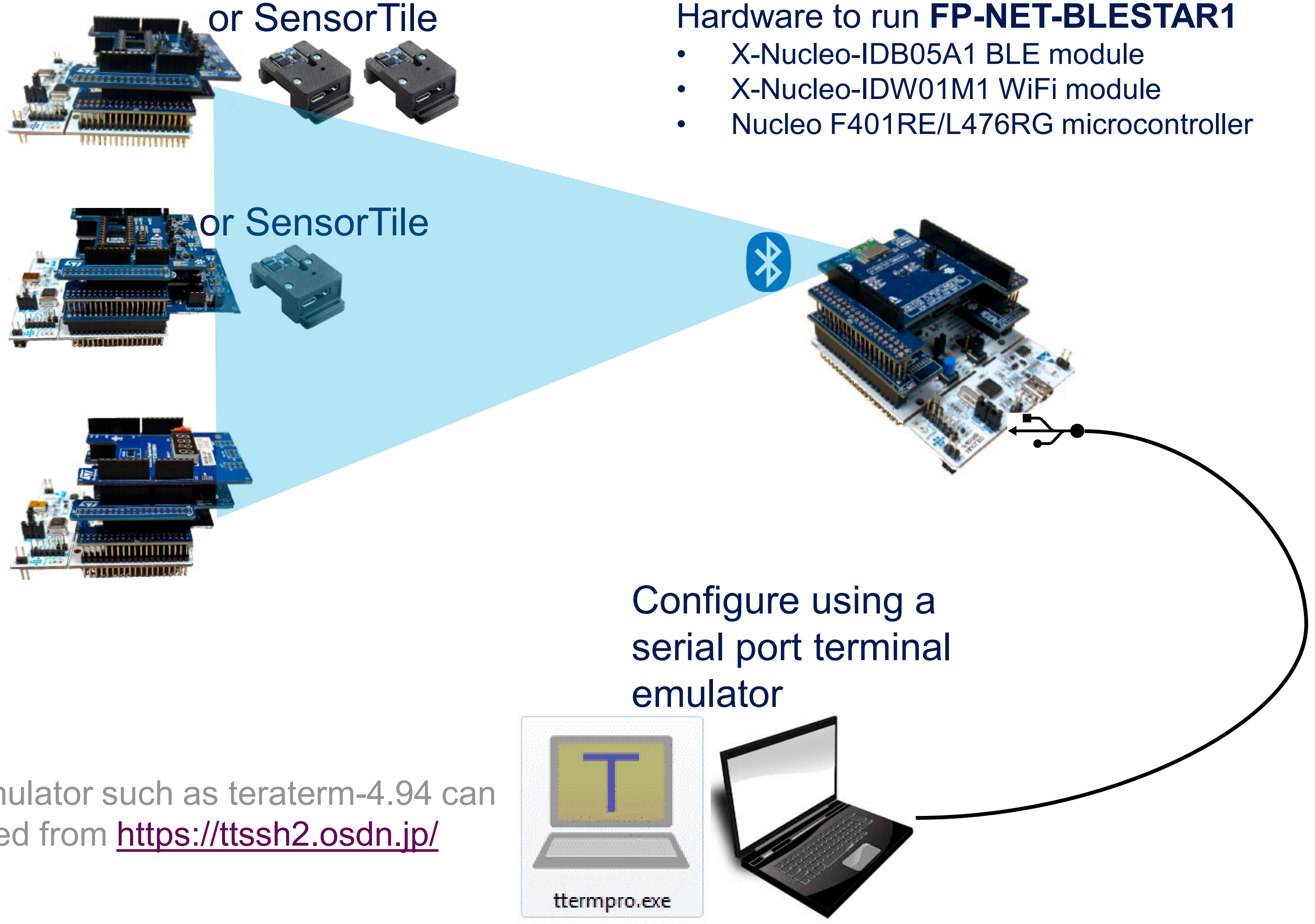
A Network Connected to the Cloud

up to 6 peripherals

Hardware to run **FP-SNS-MOTENV1**
- X-Nucleo-ISK01A1/A2 MEMS sensors
- X-Nucleo-IDB05A1 BLE module
- Nucleo F401RE/L476RG microcontroller

Hardware to run **FP-SNS-ALLMEMS1**
- X-Nucleo-ISK01A1/A2 MEMS sensors
- X-Nucleo-CCA02M1 digital mic sensors
- X-Nucleo-IDB05A1 BLE module
- Nucleo F401RE/L476RG microcontroller

Hardware to run **FP-SNS-FLIGHT1**
- X-Nucleo-6180XA1 time-of-flight
- X-Nucleo-ISK01A1 MEMS sensors
- X-Nucleo-IDB05A1 BLE module
- Nucleo F401RE/L476RG microcontroller



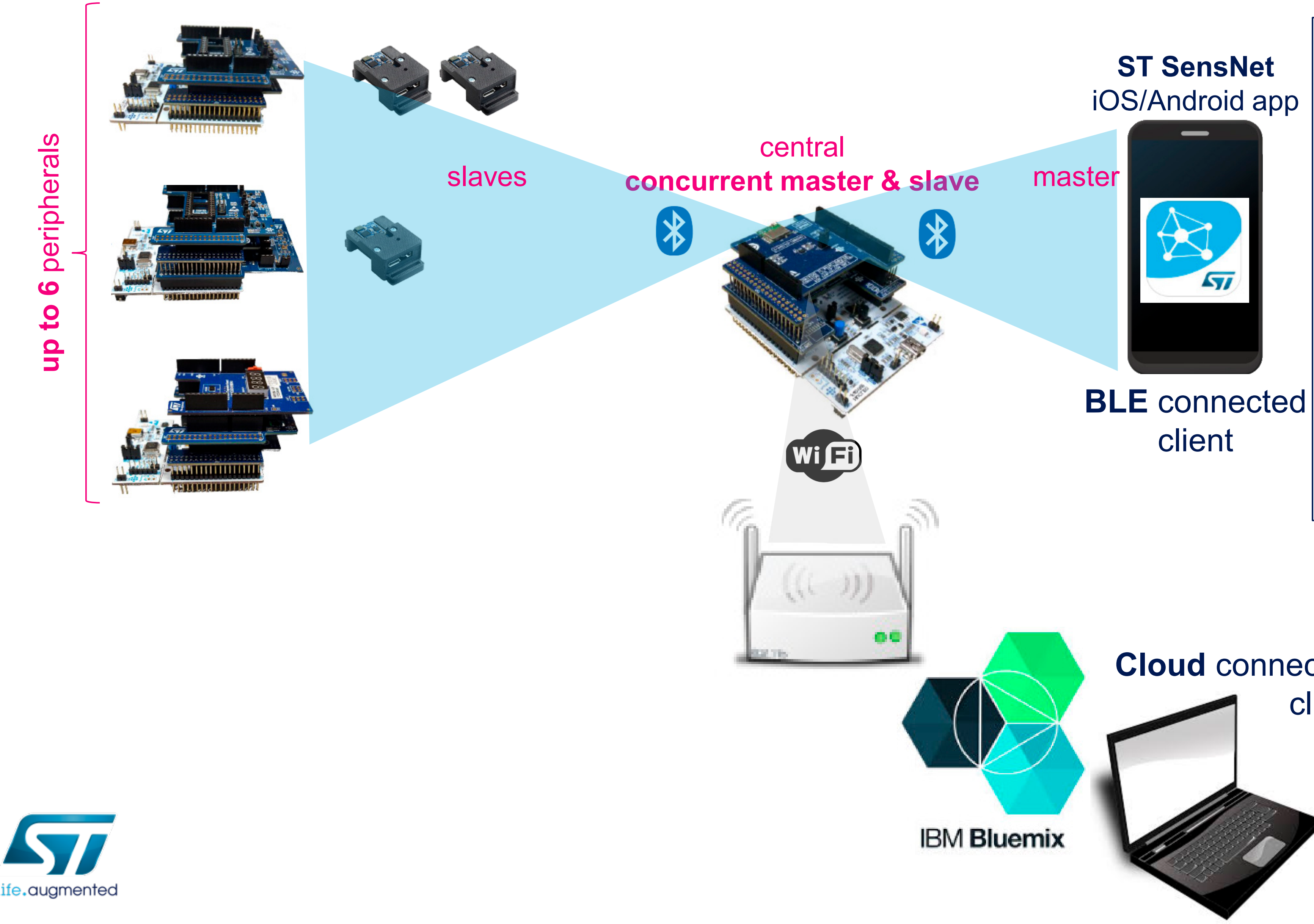
central, **concurrent master & slave**

Hardware to run **FP-NET-BLESTAR1**
- X-Nucleo-IDB05A1 BLE module
- X-Nucleo-IDW01M1 WiFi module
- Nucleo F401RE/L476RG microcontroller

Configure using a serial port terminal emulator

A terminal emulator such as teraterm-4.94 can be downloaded from https://ttssh2.osdn.jp/

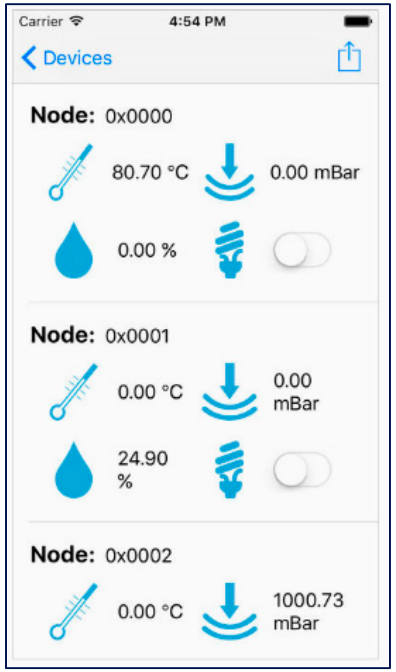
A Network Connected to the Cloud



ST SensNet
iOS/Android app

BLE connected
client

Cloud connected
client



Node: 0x0000

80.70 °C 0.00 mBar

0.00 %

Node: 0x0001

0.00 °C 0.00 mBar

24.90 %

Node: 0x0002

0.00 °C 1000.73 mBar

Function Packages

ODE software package (Open Development Environment – src code)		With fusion libraries (bin libraries)
X-CUBE-MEMS1	MEMS sensors: motion + environ	All libraries
X-CUBE-BLE1	BLE: Bluetooth Low Energy	
FP-SNS-MOTENV1	BLE + MEMS	FX, AR, CP, GR, PM
FP-SNS-ALLMEMS1	BLE + MEMS + digital microphone	FX, AR, CP, GR, BlueVoice
FP-SNS-FLIGHT1	BLE + MEMS + Time of Flight + NFC	FX, AR, CP, GR, GR-ToF
FP-AUD-BVLINK1	BLE + digital microphone	BlueVoice
FP-NET-BLESTAR1	BLE + MEMS + WiFi	

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X-CUBE-MEMS1

- Fusion libraries are distributed as binaries, with example source code on how to use them.

- A free license is granted.

- They can run on every STM32 microcontroller.

open.MEMS

X-CUBE-MEMS1

Fusion libraries are distributed as binaries, with example source code on how to use them.

A free license is granted. They can run on every STM32 microcontroller.

X-CUBE-MEMS1 real-time context awareness:

Low-rate data
from the accelerometer to keep power low

X-CUBE-MEMS1 real-time sensor fusion

High-rate data
from all the motion sensors to keep accuracy high

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X-CUBE-MEMS1

Fusion libraries are distributed as binaries, with example source code on how to use them.

A free license is granted. They can run on every STM32 microcontroller.

X-CUBE-MEMS1 real-time context awareness:

Low-rate data
from the accelerometer to keep power low

• **MotionID** intensity detection (scale 0 to 10, from doing nothing to sprinting)	based on acc data at **16Hz**
• **MotionPE** pose estimation (standing, sitting, lying down)	based on acc data at **16Hz**
• **MotionAW** user activity recognition (stationary, walking, jogging, biking…)	based on **wrist** acc data at **16Hz**
• **MotionAR** user activity recognition (stationary, walking, jogging, biking…)	based on acc data at **16Hz**
• **MotionCP** carry position detection (on desk, in hand…)	based on acc data at **50Hz**
• **MotionPM** pedometer (step count)	based on acc data at **50Hz**
• **MotionGR** gesture recognition (tilt to glance, shake to wake up, pick up)	based on acc data at **100Hz**

X-CUBE-MEMS1 real-time sensor fusion:

- MotionFX orientation estimation based on acc+gyro data (6X) or acc+gyro+mag data (9X) typically at **100Hz**, it does include gyro calibration, and mag calibration (to compensate only offset)
- MotionGC gyroscope calibration (to compensate zero-rate offset)
- MotionMC magnetometer calibration (to compensate offset and scale)
- MotionAC accelerometer calibration (to compensate offset and scale)

X-CUBE-MEMS1

Fusion libraries are distributed as binaries, with example source code on how to use them.

A free license is granted. They can run on every STM32 microcontroller.

X-CUBE-MEMS1 real-time context awareness:

- MotionID intensity detection (scale 0 to 10, from doing nothing to sprinting) based on acc data at 16Hz
- MotionPE pose estimation (standing, sitting, lying down) based on acc data at 16Hz
- MotionAW user activity recognition (stationary, walking, jogging, biking…) based on wrist acc data at 16Hz
- MotionAR user activity recognition (stationary, walking, jogging, biking…) based on acc data at 16Hz
- MotionCP carry position detection (on desk, in hand…) based on acc data at 50Hz
- MotionPM pedometer (step count) based on acc data at 50Hz
- MotionGR gesture recognition (tilt to glance, shake to wake up, pick up) based on acc data at 100Hz

X-CUBE-MEMS1 real-time sensor fusion:

- **MotionFX** orientation estimation based on acc+gyro data (6X) or acc+gyro+mag data (9X) typically at **100Hz**,
  it does include gyro calibration, and mag calibration (to compensate only offset)
- **MotionGC** gyroscope calibration (to compensate zero-rate offset)
- **MotionMC** magnetometer calibration (to compensate offset and scale)
- **MotionAC** accelerometer calibration (to compensate offset and scale)

High-rate data

from the motion sensors to keep accuracy high

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X-CUBE-MEMS1

Fusion libraries are distributed as binaries, with example source code on how to use them.

A free license is granted. They can run on every STM32 microcontroller.

X-CUBE-MEMS1 real-time context awareness:

MotionID intensity detection (scale 0 to 10, from doing nothing to sprinting)	based on acc data at 16Hz
MotionPE pose estimation (standing, sitting, lying down)	based on acc data at 16Hz
MotionAW user activity recognition (stationary, walking, jogging, biking…)	based on wrist acc data at 16Hz
MotionAR user activity recognition (stationary, walking, jogging, biking…)	based on acc data at **16Hz**
MotionCP carry position detection (on desk, in hand…)	based on acc data at **50Hz**
MotionPM pedometer (step count)	based on acc data at **50Hz**
MotionGR gesture recognition (tilt to glance, shake to wake up, pick up)	based on acc data at **100Hz**

These libraries are included in the **FP-SNS-MOTENV1** & **FP-SNS-ALLMEMS1** function packages.

X-CUBE-MEMS1 real-time sensor fusion:

- **MotionFX** orientation estimation based on acc+gyro data (6X) or acc+gyro+mag data (9X) typically at **100Hz**, it does include gyro calibration, and mag calibration (to compensate only offset)
- MotionGC gyroscope calibration (to compensate zero-rate offset)
- MotionMC magnetometer calibration (to compensate offset and scale)
- MotionAC accelerometer calibration (to compensate offset and scale)

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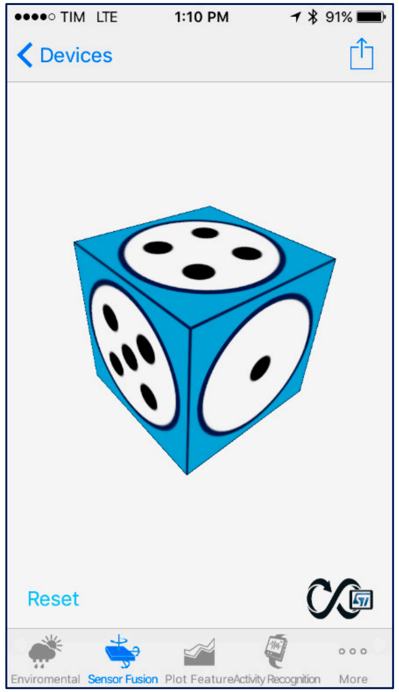
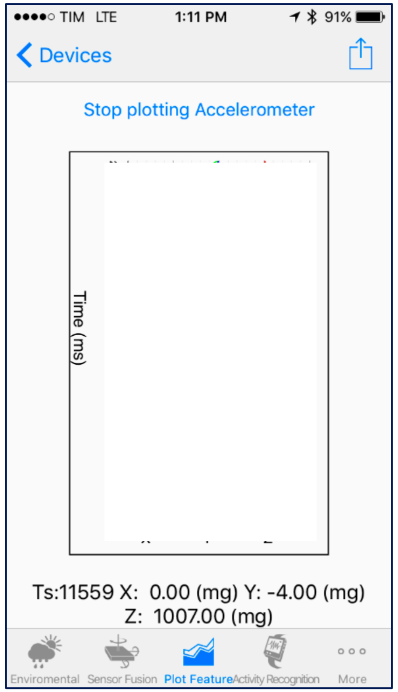
LAB2: Real Time Data Plot

Swipe left to view the real-time data plot

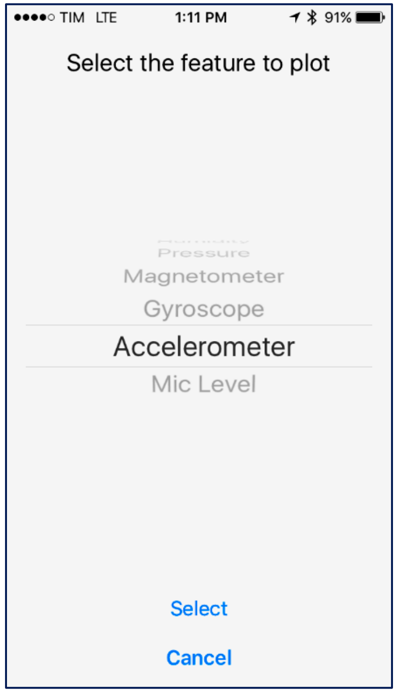


“Plot Feature” tab



Ts:11559 X: 0.00 (mg) Y: -4.00 (mg) Z: 1007.00 (mg)

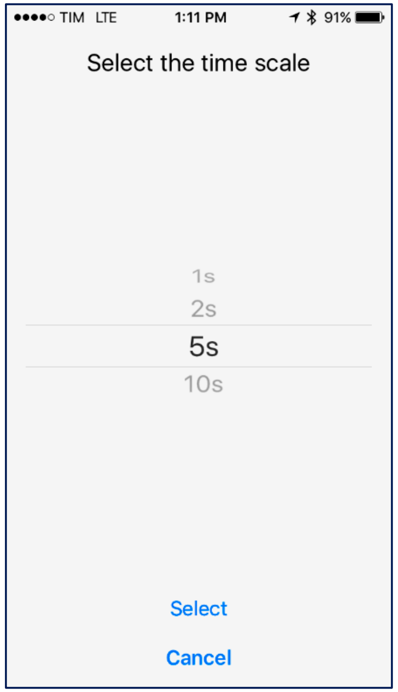
Select the sensor device



Select the feature to plot

Accelerometer

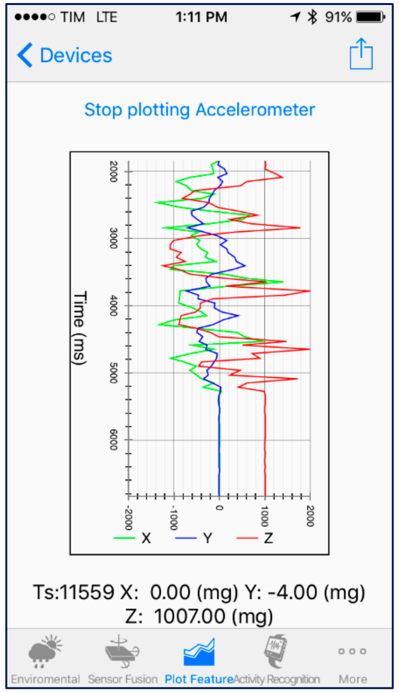
Select the time frame



Select the time scale

5s

View the real-time data plot



Ts:11559 X: 0.00 (mg) Y: -4.00 (mg) Z: 1007.00 (mg)

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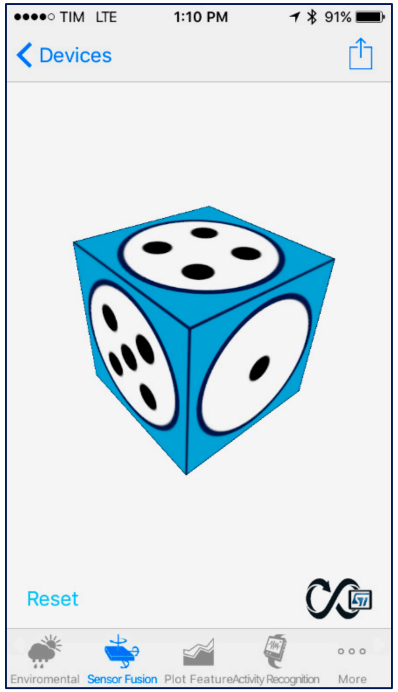
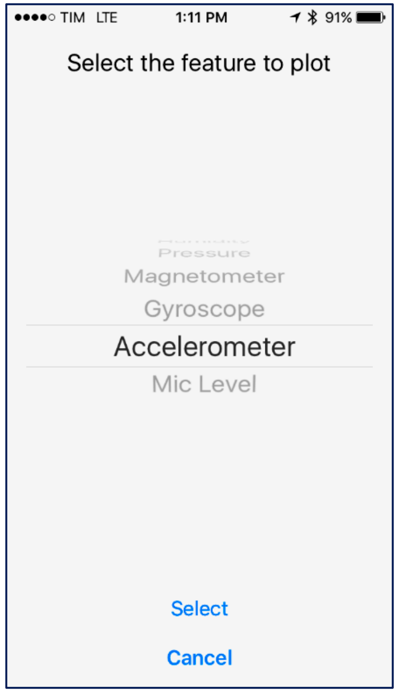
LAB2: Real Time Data Plot

Swipe left to view the real-time data plot



Select the sensor device

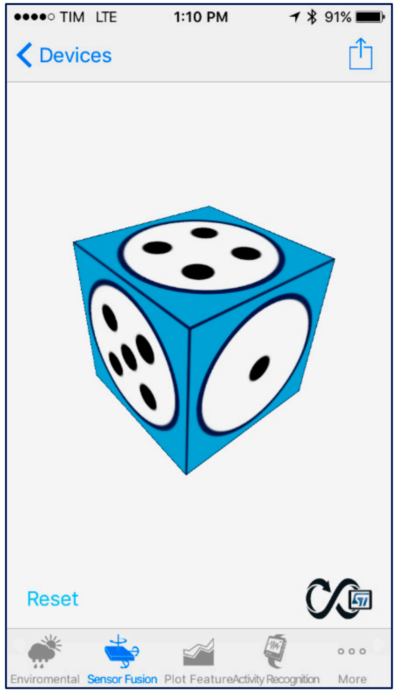

Select the feature to plot

LAB

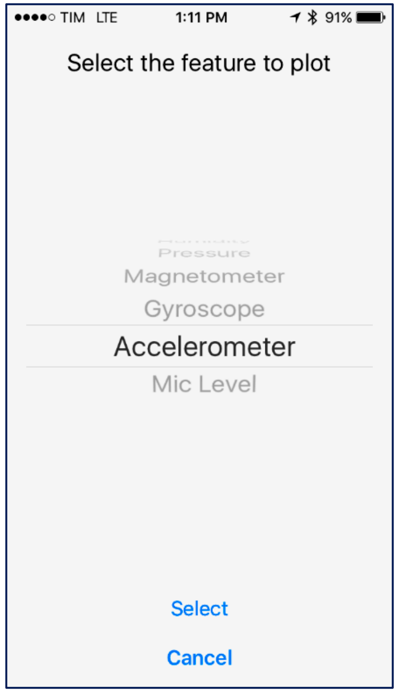
Check the accelerometer output when the device is standing still with module facing up, left, right, etc…

LAB2: Real Time Data Plot

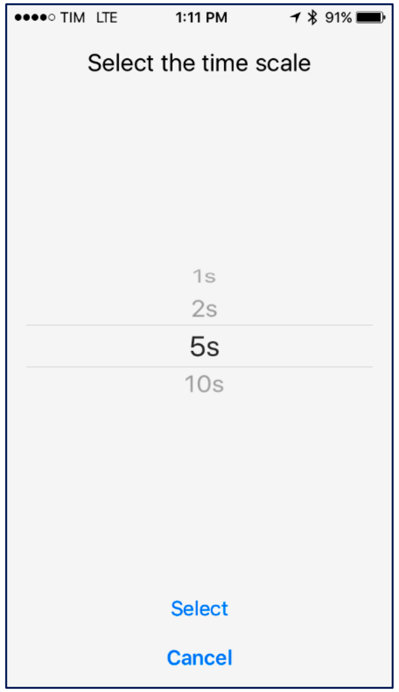
Swipe left to view the real-time data plot



Select the sensor device



Select the time frame



LAB

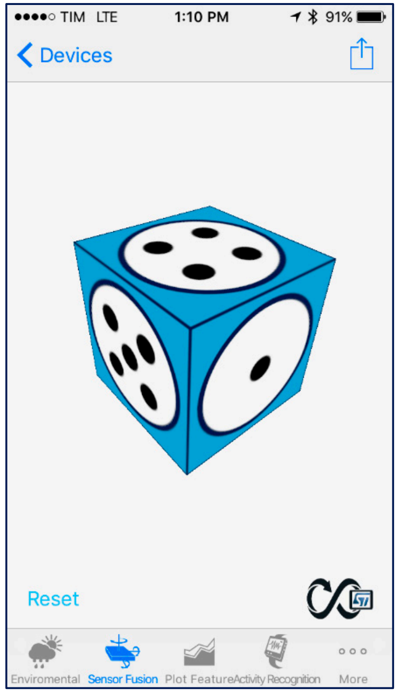
Try 1s time scale (fast moving plot)

Try 10s time scale (slow moving plot)

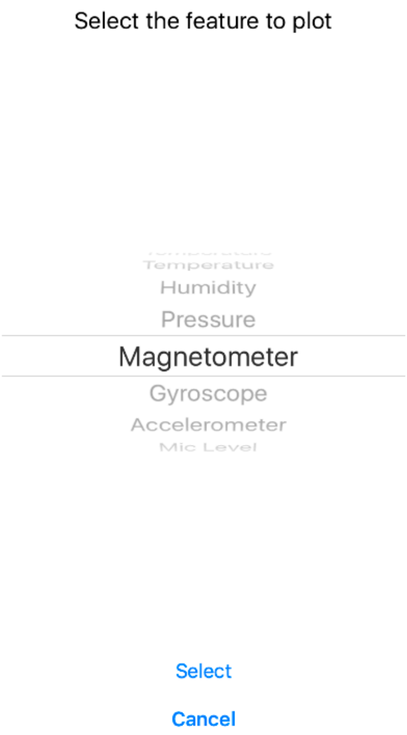
LAB2: Real Time Data Plot

effects of a magnetic interference

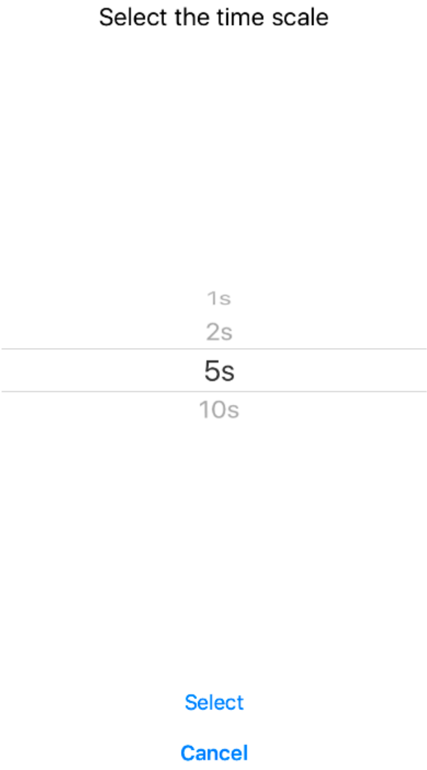
Swipe left to view the real-time data plot



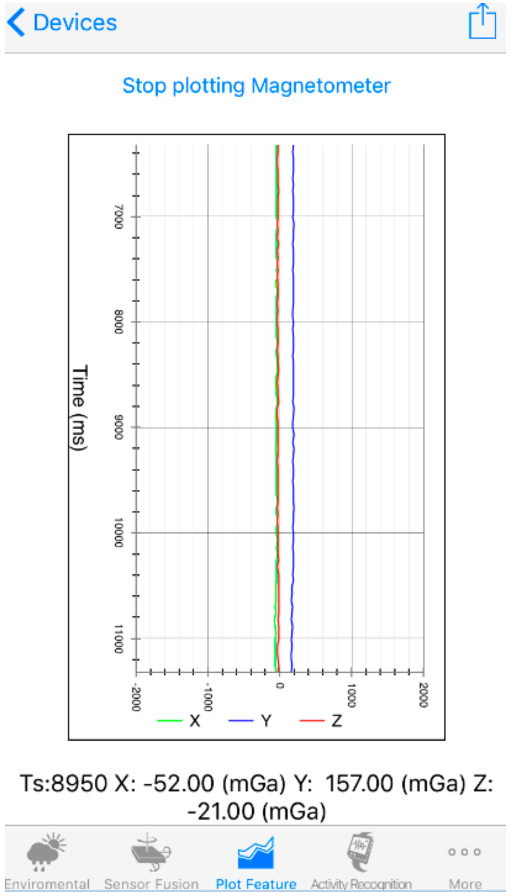
Select the magnetometer


Select the feature to plot

Select the time frame


Select the time scale

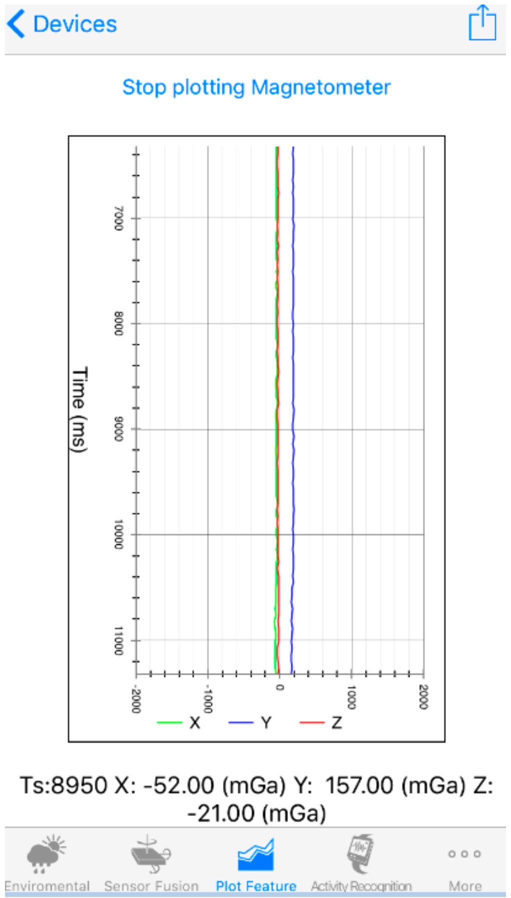
Magnetic field plot



Ts:8950 X: -52.00 (mGa) Y: 157.00 (mGa) Z: -21.00 (mGa)

LAB2: Real Time Data Plot

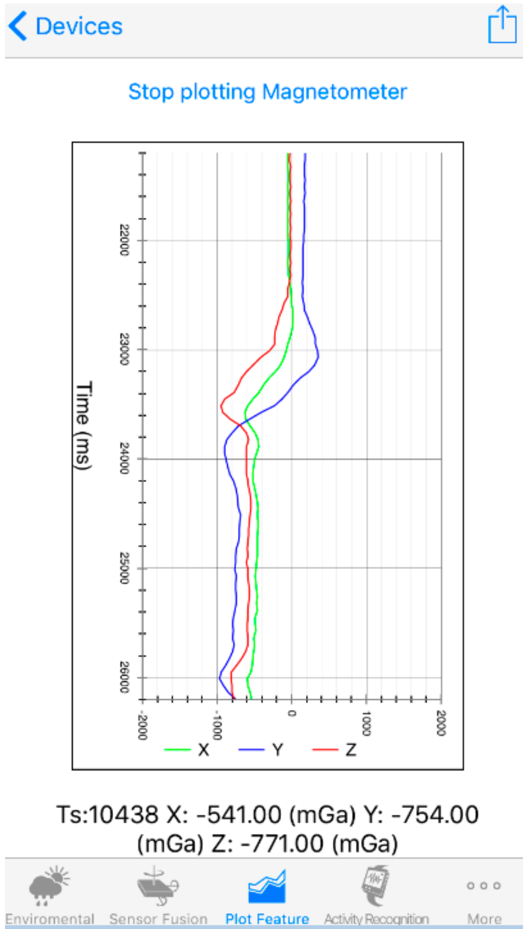
effects of a magnetic interference



Ts:8950 X: -52.00 (mGa) Y: 157.00 (mGa) Z: -21.00 (mGa)

LAB

Move the smartphone over the sensortile

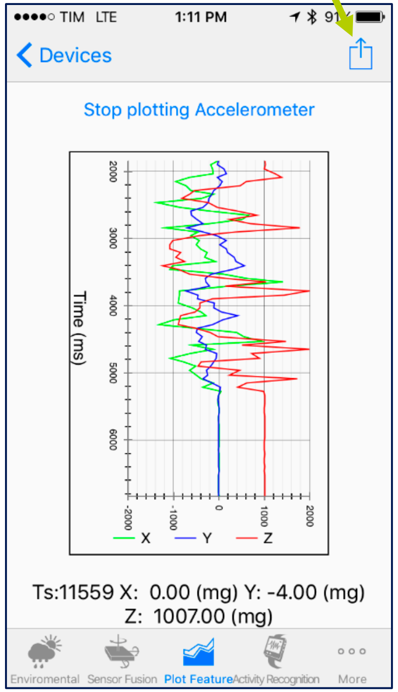


Ts:10438 X: -541.00 (mGa) Y: -754.00 (mGa) Z: -771.00 (mGa)

The magnetic field measured by the sensor has changed because of the magnetic field induced by the smartphone (speakers, antennas, battery, currents)

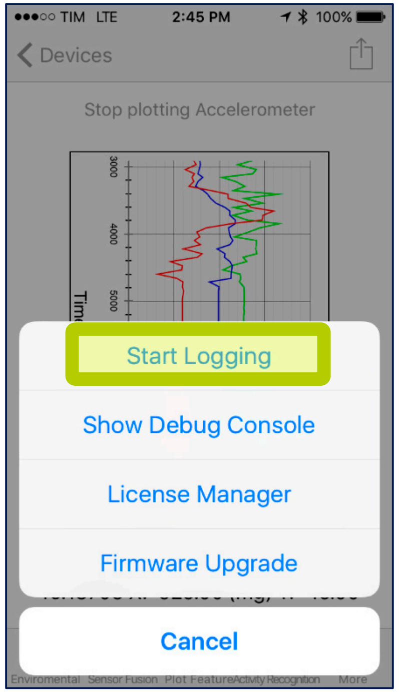
LAB2: Real-Time Data Log

Touch

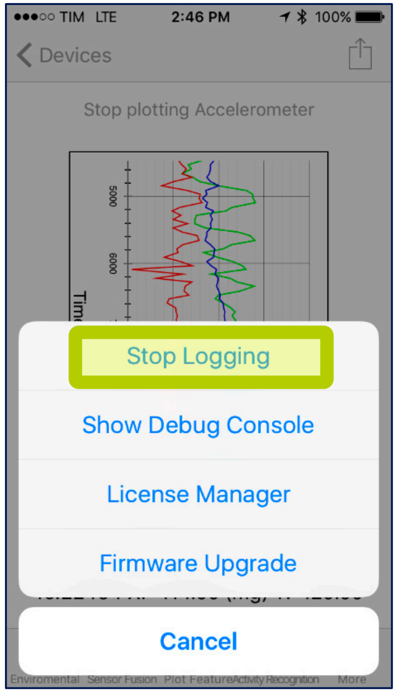


Ts:11559 X: 0.00 (mg) Y: -4.00 (mg)
Z: 1007.00 (mg)

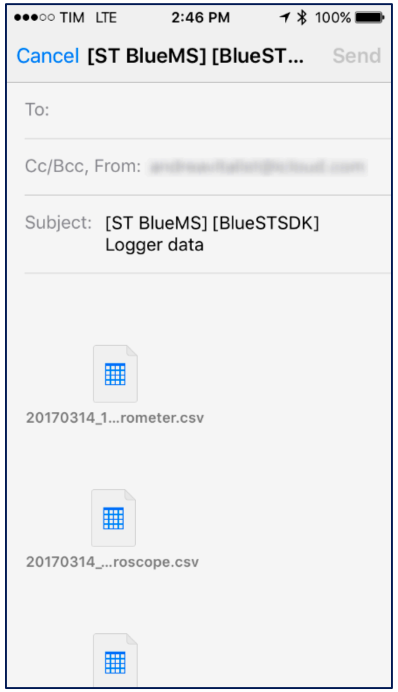
Start logging



Stop logging



Send log data using email



[ST BlueMS] [BlueST...

To:

Cc/Bcc, From: [redacted]

Subject: [ST BlueMS] [BlueSTSDK] Logger data

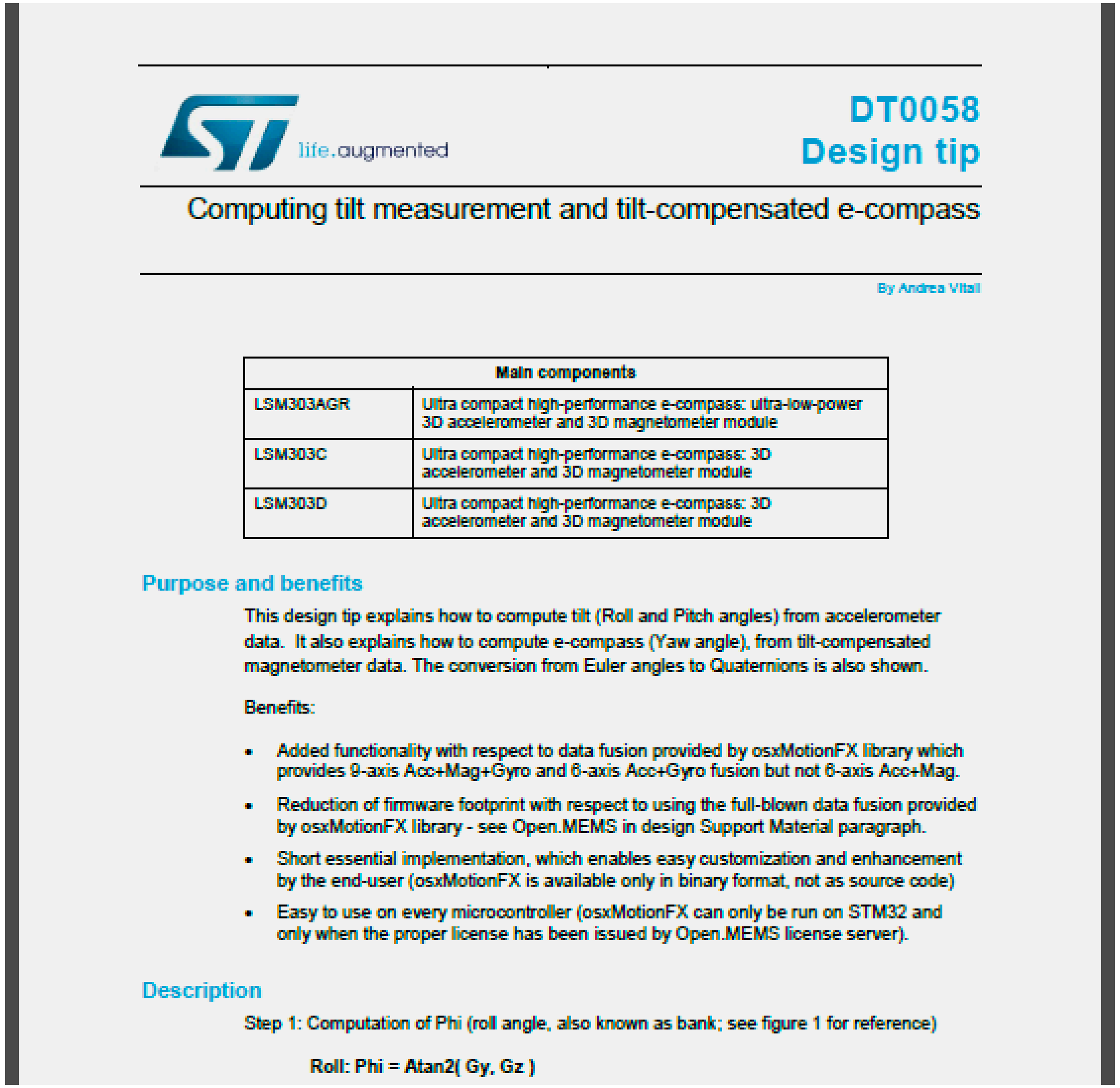
20170314_1...rometer.csv

20170314_...roscope.csv

Process log data

Log accelerometer data.

Process it as described in **DT0058** to compute roll & pitch angle and tilt angle.



DT0058
Design tip

Computing tilt measurement and tilt-compensated e-compass

By Andrea Vitali

Main components	
LSM303AGR	Ultra compact high-performance e-compass: ultra-low-power 3D accelerometer and 3D magnetometer module
LSM303C	Ultra compact high-performance e-compass: 3D accelerometer and 3D magnetometer module
LSM303D	Ultra compact high-performance e-compass: 3D accelerometer and 3D magnetometer module

Purpose and benefits

This design tip explains how to compute tilt (Roll and Pitch angles) from accelerometer data. It also explains how to compute e-compass (Yaw angle), from tilt-compensated magnetometer data. The conversion from Euler angles to Quaternions is also shown.

Benefits:

- Added functionality with respect to data fusion provided by osxMotionFX library which provides 9-axis Acc+Mag+Gyro and 6-axis Acc+Gyro fusion but not 6-axis Acc+Mag.
- Reduction of firmware footprint with respect to using the full-blown data fusion provided by osxMotionFX library - see Open.MEMS in design Support Material paragraph.
- Short essential implementation, which enables easy customization and enhancement by the end-user (osxMotionFX is available only in binary format, not as source code)
- Easy to use on every microcontroller (osxMotionFX can only be run on STM32 and only when the proper license has been issued by Open.MEMS license server).

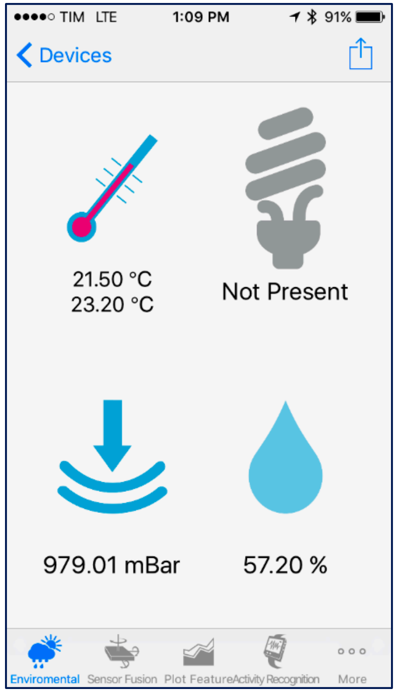
Description

Step 1: Computation of Phi (roll angle, also known as bank; see figure 1 for reference)

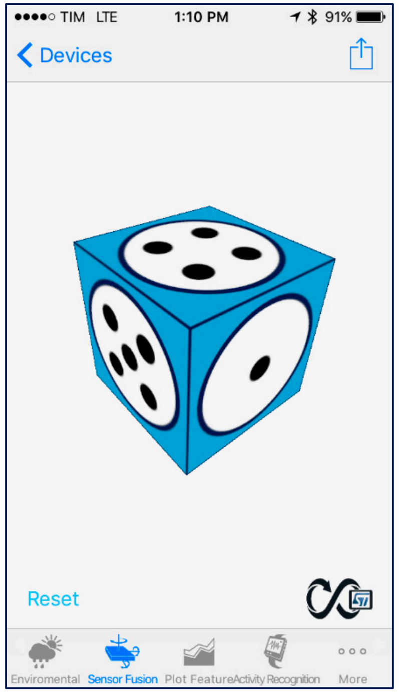
Roll: Phi = Atan2(Gy, Gz)

LAB2: Sensor Fusion

Swipe left to view SensorTile orientation



Move the SensorTile



LAB

Try highly dynamic motion: when the motion ends how quickly the steady position is reached?

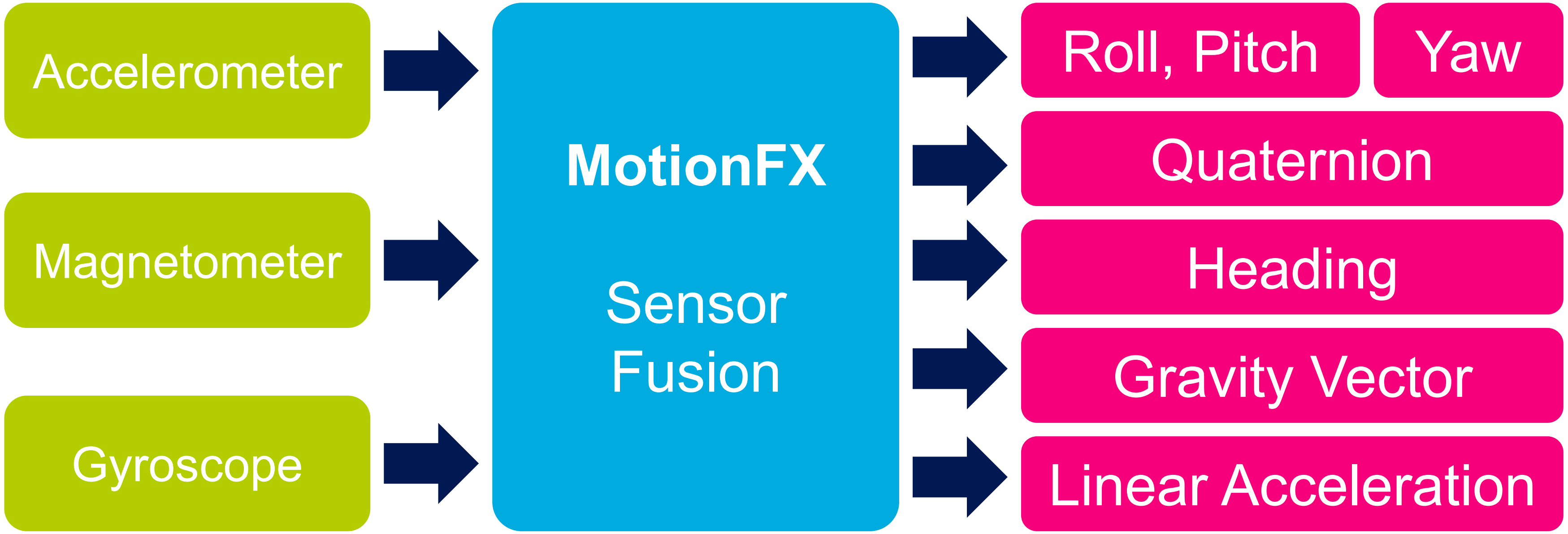
- In high dynamic motion gyro updates the orientation and produce a visible integration error
- When the sensortile is in steady position again then acc and mag correct the error

Try static position: there should be no drift, should be perfectly still.

- sensors drift and magnetic interferences are compensated by the motionFX library

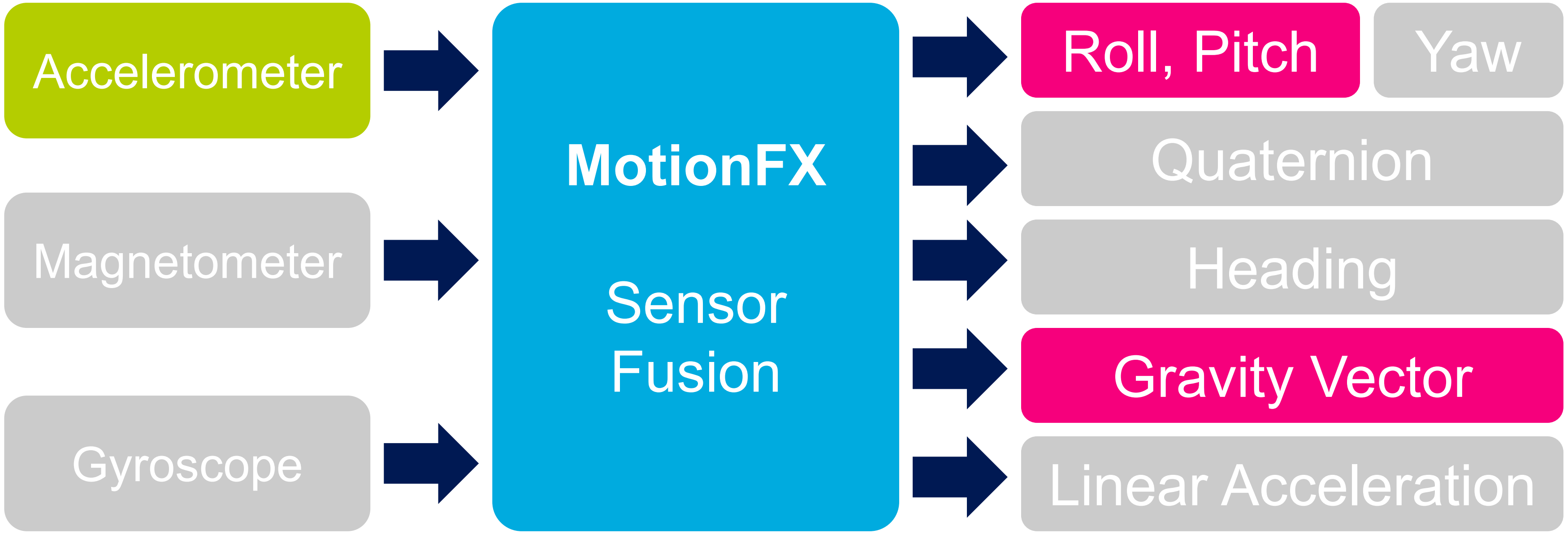
LAB3: Sensor Fusion

MotionFX library



LAB3: Sensor Fusion

MotionFX library

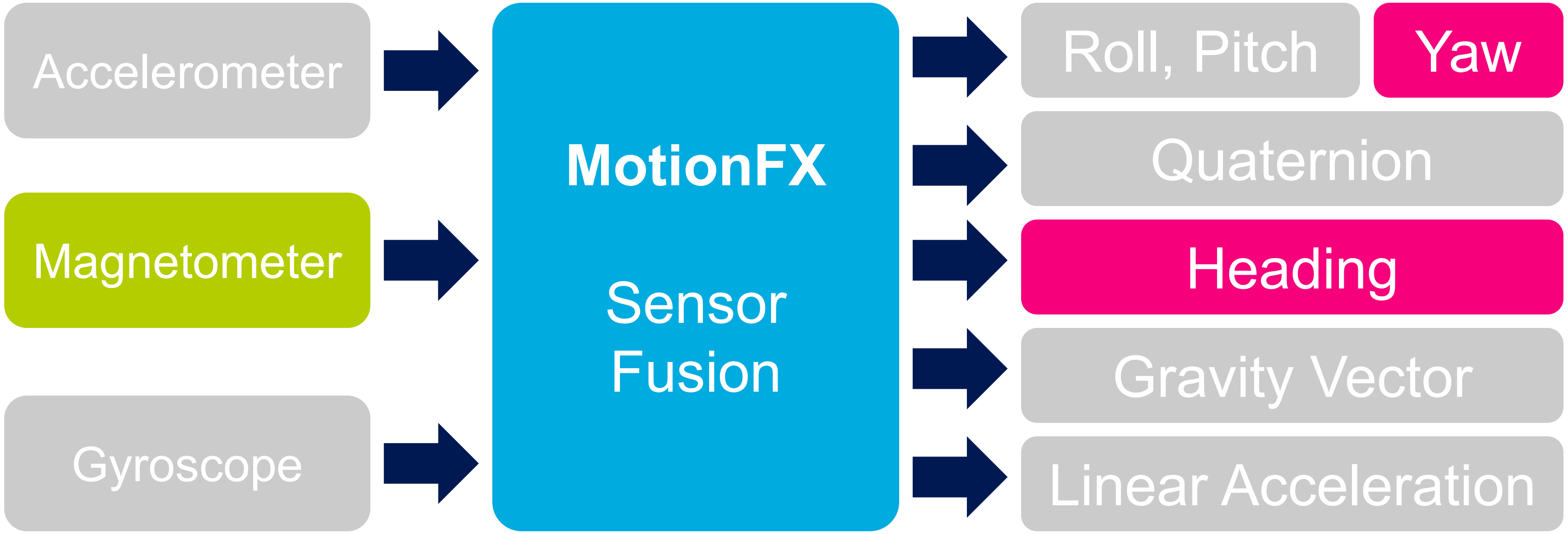


- **Accelerometer** gives roll and pitch angles and the gravity vector

…but **only in static conditions**!

LAB3: Sensor Fusion

MotionFX library

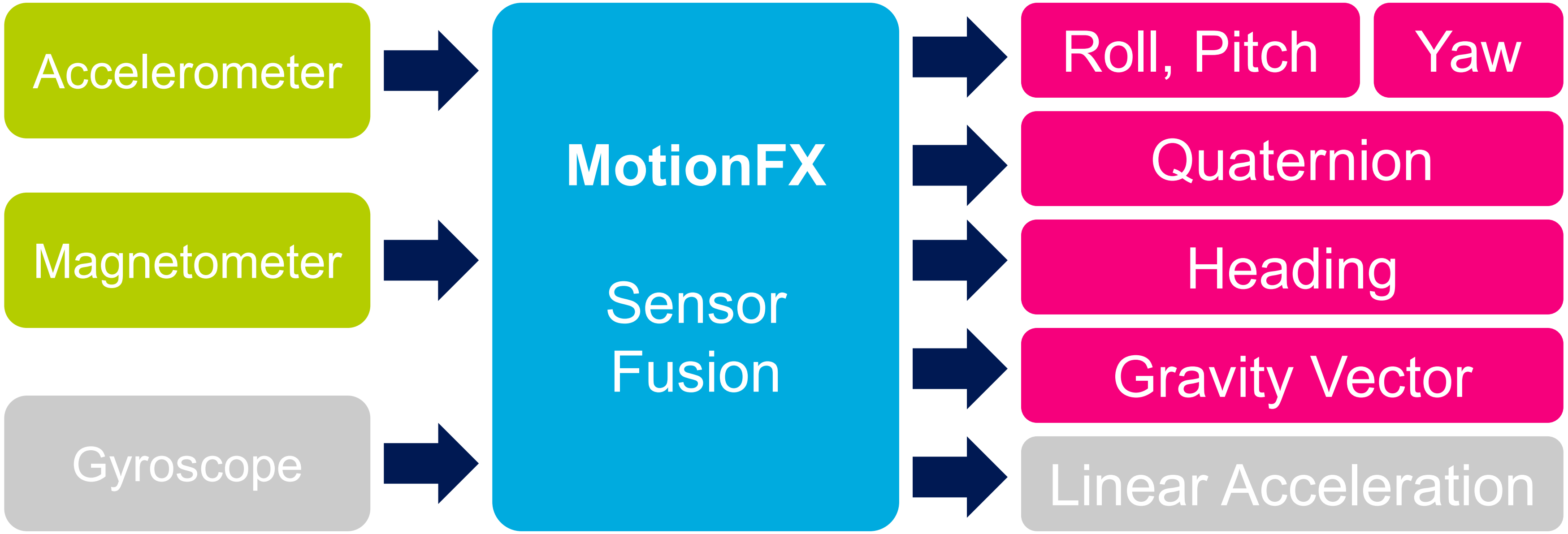


- **Magnetometer** gives yaw angle and heading

…but **only if hard-iron offset is compensated**!

LAB3: Sensor Fusion

MotionFX library

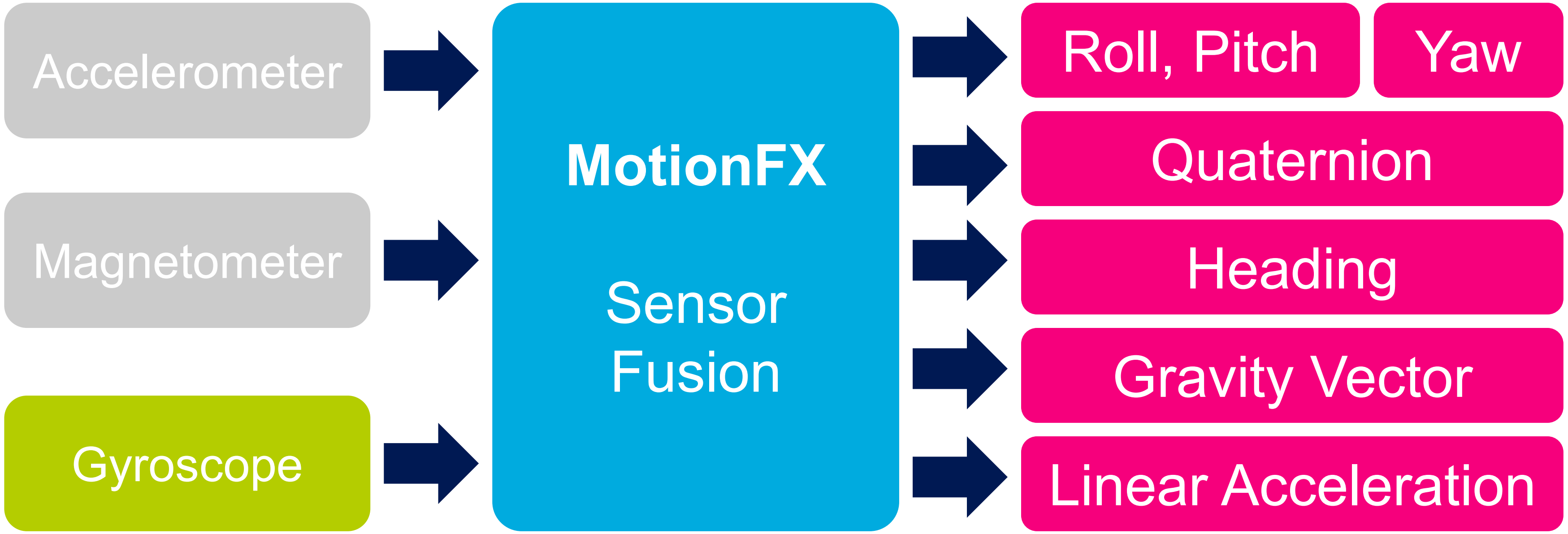


- **Magnetometer** gives yaw angle and heading

…and **only if tilt is compensated**: the accelerometer is needed!

LAB3: Sensor Fusion

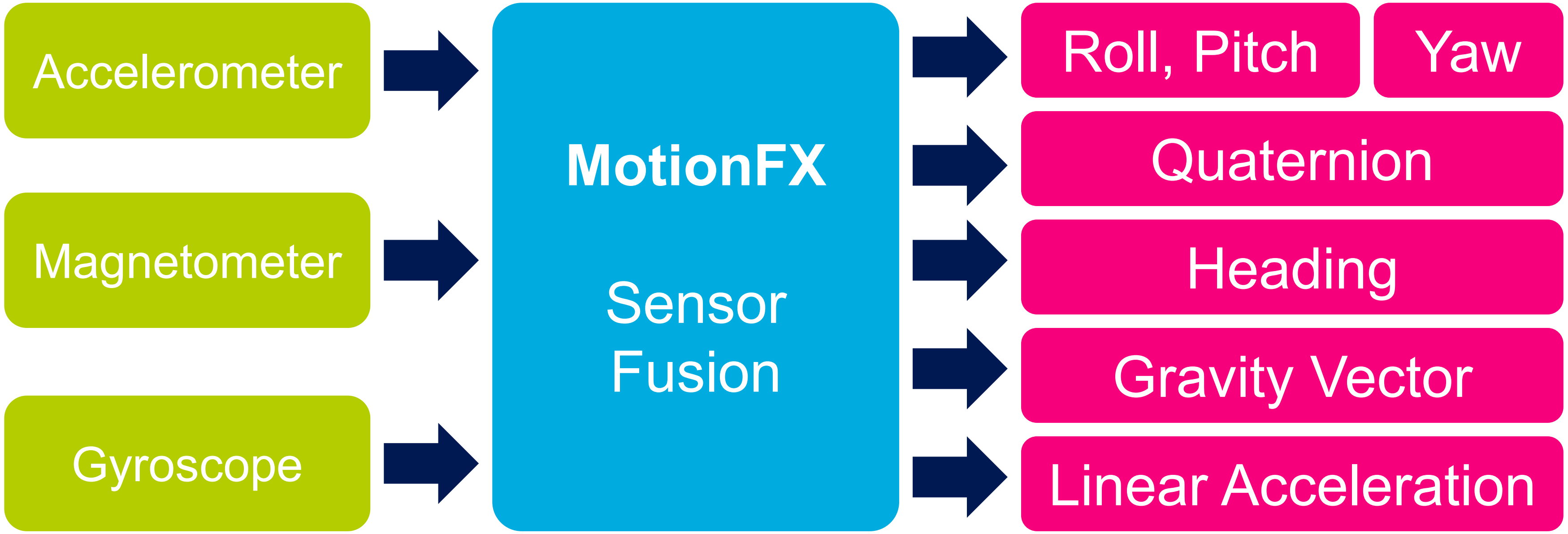
MotionFX library



- **Gyroscope** gives the new orientation based on previous orientation …but **only if bias offset is compensated**!

LAB3: Sensor Fusion

MotionFX library

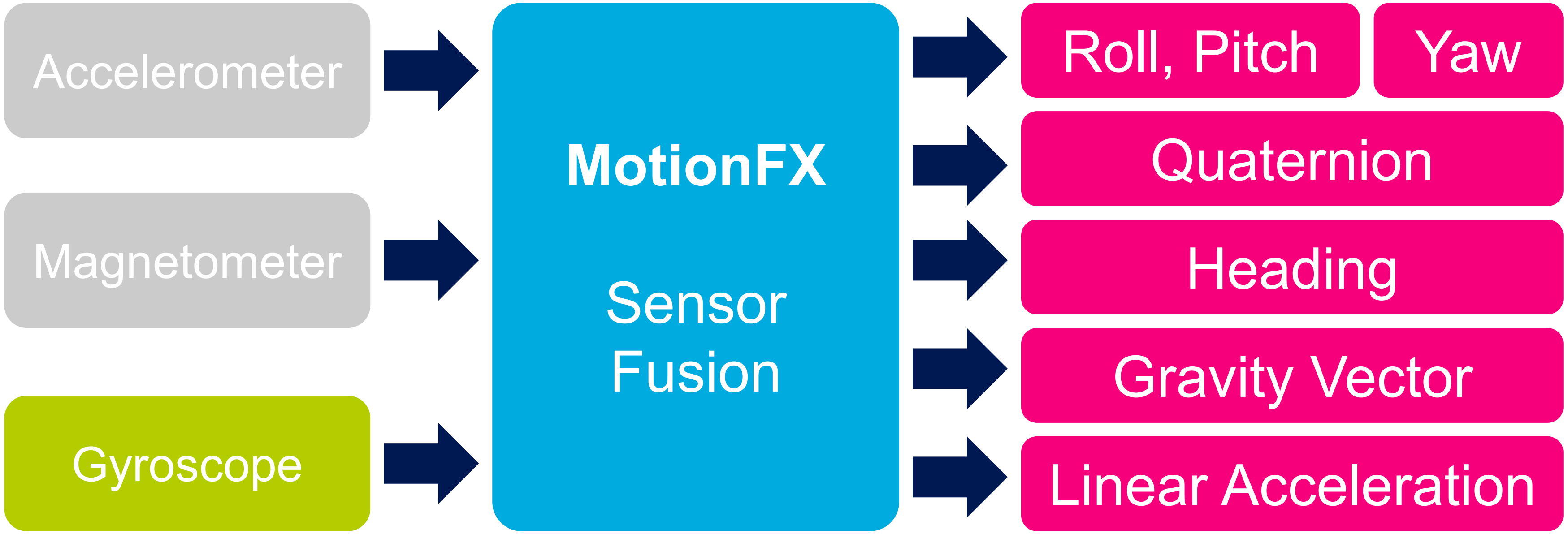


Motion FX library provides orientation estimation plus:

- Magnetometer hard-iron offset compensation.
- Accelerometer vibrations rejection.
- Gyroscope bias offset compensation.

LAB3: Sensor Fusion

MotionFX library



- **Gyroscope is the most important sensor in the system**

…works in highly dynamic conditions when the Acc cannot be used
…works with magnetic anomalies when the Mag cannot be used

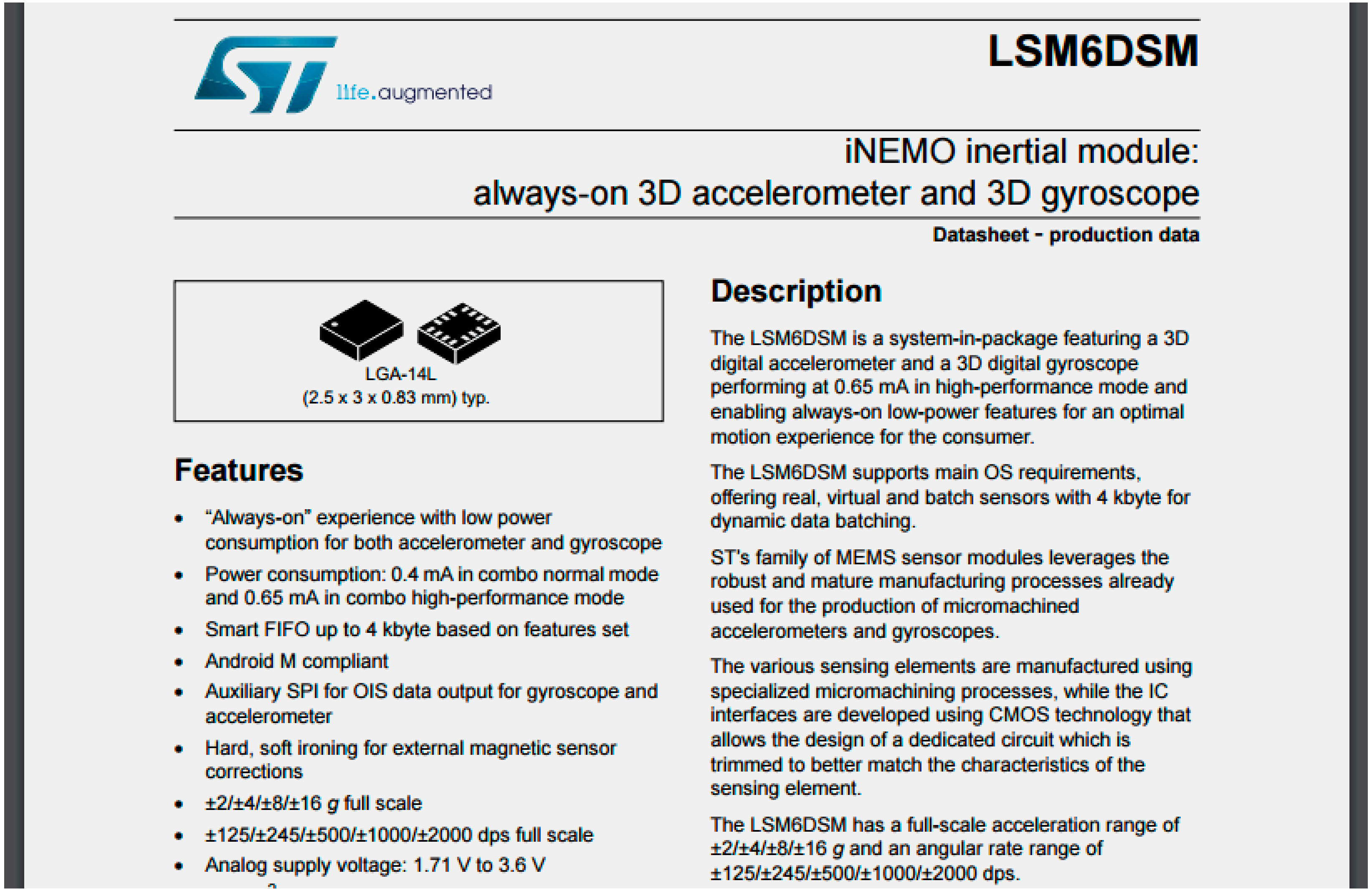
Gyroscope

LSM6DSM:

Acc + Gyro in high-performance mode (low noise)

GyroRMS 3.8mdps
AccRMS 90ug
(per sqrtHz)

0.65mA peak power at 6.66kS/s



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LSM6DSM

iNEMO inertial module:
always-on 3D accelerometer and 3D gyroscope

Datasheet - production data

LGA-14L
(2.5 x 3 x 0.83 mm) typ.

Features

- “Always-on” experience with low power consumption for both accelerometer and gyroscope
- Power consumption: 0.4 mA in combo normal mode and 0.65 mA in combo high-performance mode
- Smart FIFO up to 4 kbyte based on features set
- Android M compliant
- Auxiliary SPI for OIS data output for gyroscope and accelerometer
- Hard, soft ironing for external magnetic sensor corrections
- ±2/±4/±8/±16 *g* full scale
- ±125/±245/±500/±1000/±2000 dps full scale
- Analog supply voltage: 1.71 V to 3.6 V

Description

The LSM6DSM is a system-in-package featuring a 3D digital accelerometer and a 3D digital gyroscope performing at 0.65 mA in high-performance mode and enabling always-on low-power features for an optimal motion experience for the consumer.

The LSM6DSM supports main OS requirements, offering real, virtual and batch sensors with 4 kbyte for dynamic data batching.

ST's family of MEMS sensor modules leverages the robust and mature manufacturing processes already used for the production of micromachined accelerometers and gyroscopes.

The various sensing elements are manufactured using specialized micromachining processes, while the IC interfaces are developed using CMOS technology that allows the design of a dedicated circuit which is trimmed to better match the characteristics of the sensing element.

The LSM6DSM has a full-scale acceleration range of ±2/±4/±8/±16 *g* and an angular rate range of ±125/±245/±500/±1000/±2000 dps.

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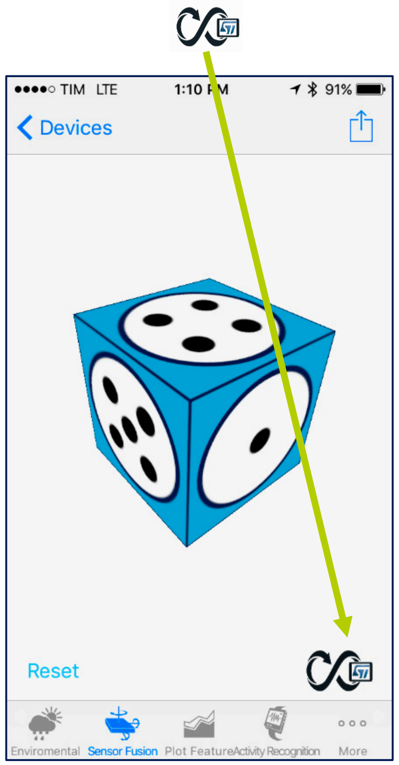
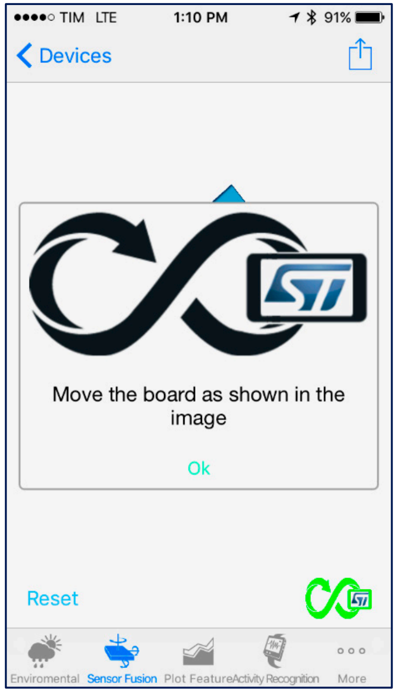
LAB4: Magnetometer

Calibration

Touch



Move the sensortile with the 8 pattern shown in the figure to calibrate the magnetometer



Move the board as shown in the image

Ok

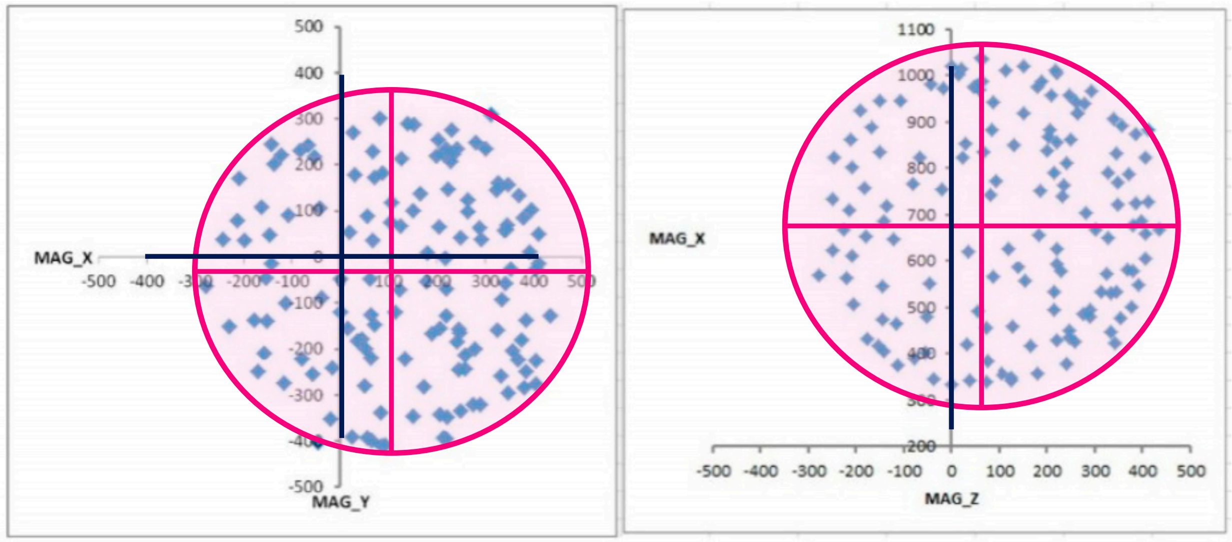
Calibration is completed when the icon becomes green.

- Calibration and compensation are performed by the STM32L4
- compensation can alternatively be done within the sensor
  - Hard-iron data are stored inside 3 dedicated register of LSM303AGR
  - The hard-iron values are automatically subtracted from the output data within the LSM303AGR

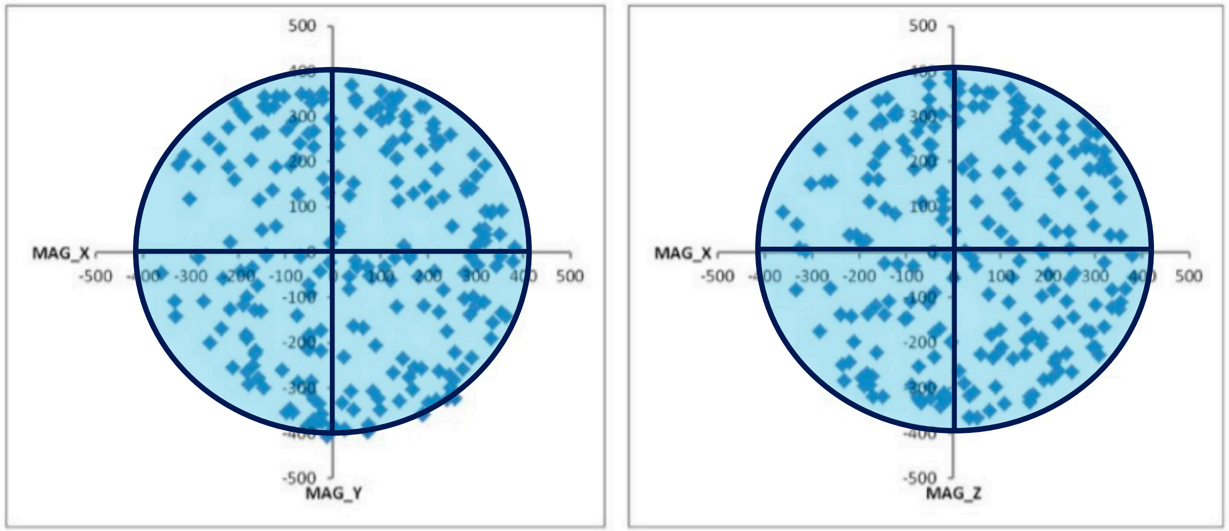
LAB4: Magnetometer

Calibration

Before calibration, data points are not centered as they should be.



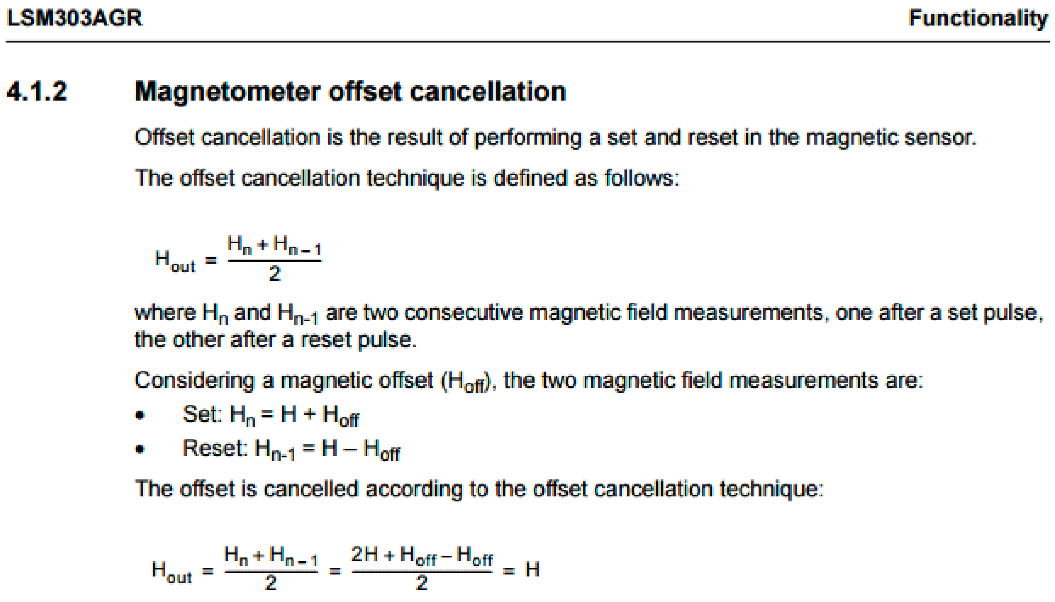
After calibration, data points are centered, **hard-iron offset** has been subtracted.



LAB4: Magnetometer Calibration

LSM303AGR:

Magnetometer **intrinsic offset** is compensated internally



LSM303AGR — Functionality

4.1.2 Magnetometer offset cancellation

Offset cancellation is the result of performing a set and reset in the magnetic sensor.

The offset cancellation technique is defined as follows:

$$H_{out} = \frac{H_n + H_{n-1}}{2}$$

where H_n and H_{n-1} are two consecutive magnetic field measurements, one after a set pulse, the other after a reset pulse.

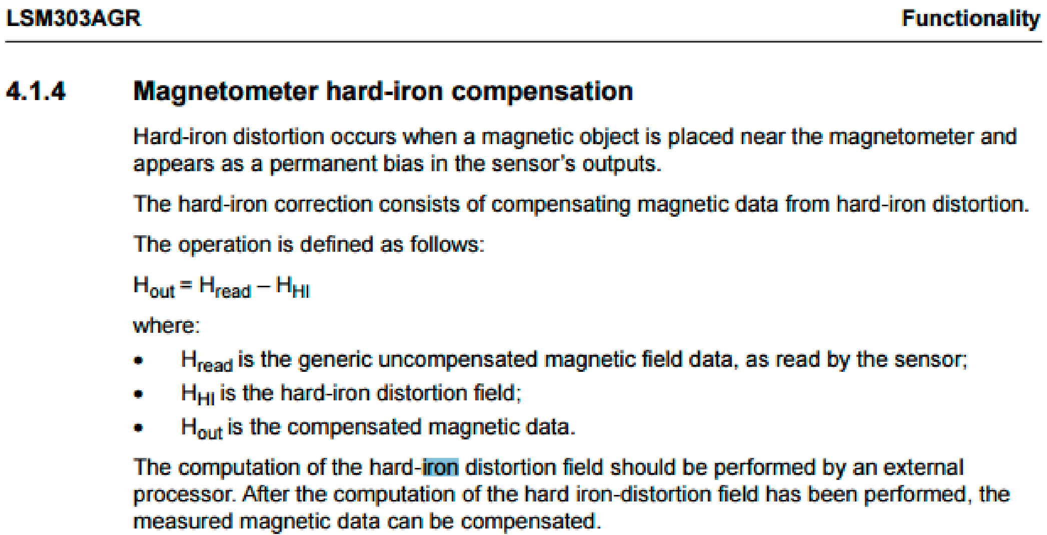
Considering a magnetic offset (H_{off}), the two magnetic field measurements are:

- Set: $H_n = H + H_{off}$
- Reset: $H_{n-1} = H - H_{off}$

The offset is cancelled according to the offset cancellation technique:

$$H_{out} = \frac{H_n + H_{n-1}}{2} = \frac{2H + H_{off} - H_{off}}{2} = H$$

Magnetometer **hard-iron distortion** is compensated internally



LSM303AGR — Functionality

4.1.4 Magnetometer hard-iron compensation

Hard-iron distortion occurs when a magnetic object is placed near the magnetometer and appears as a permanent bias in the sensor's outputs.

The hard-iron correction consists of compensating magnetic data from hard-iron distortion.

The operation is defined as follows:

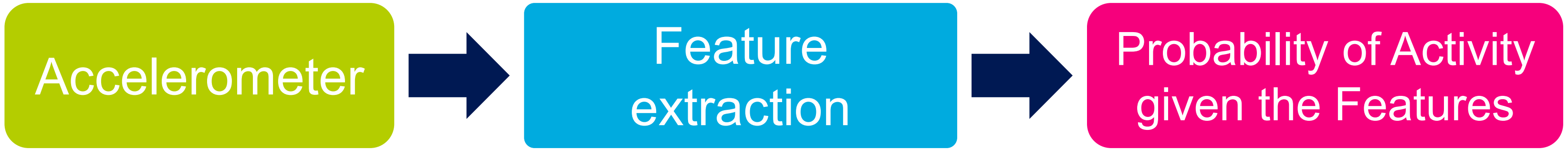
$H_{out} = H_{read} - H_{HI}$

where:

- H_{read} is the generic uncompensated magnetic field data, as read by the sensor;
- H_{HI} is the hard-iron distortion field;
- H_{out} is the compensated magnetic data.

The computation of the hard-iron distortion field should be performed by an external processor. After the computation of the hard iron-distortion field has been performed, the measured magnetic data can be compensated.

LAB5: Context Awareness

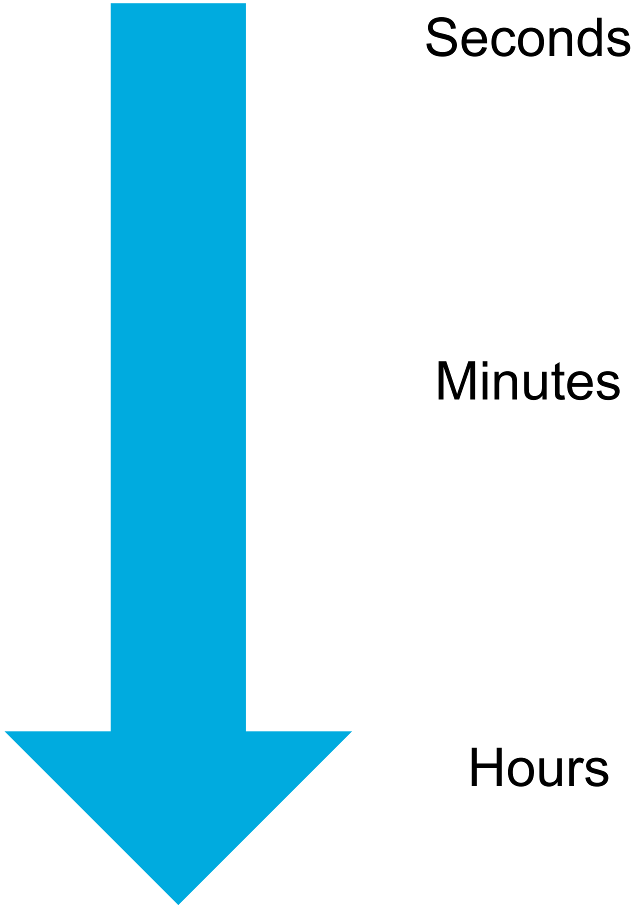


Accelerometer → Feature extraction → Probability of Activity given the Features

- 16Hz osxMotionAR library (activity recognition)
- 50Hz osxMotionCP library (carry position detection)
- 100Hz osxMotionGR library (gesture recognition)

Categorizing physical activity

- Gestures/ Movements/ Motifs
  - Brief and distinct body movements,
    - e.g. taking a step, bending the arm
- (Low-Level) Activities
  - Sequence of movements/ a distinct posture,
  - e.g. walking, sitting, cleaning windows
- High-Level Activities/ Scenes/ Routines
  - Collection of activities,
  - e.g. office work, lunch, shopping at mall



Seconds

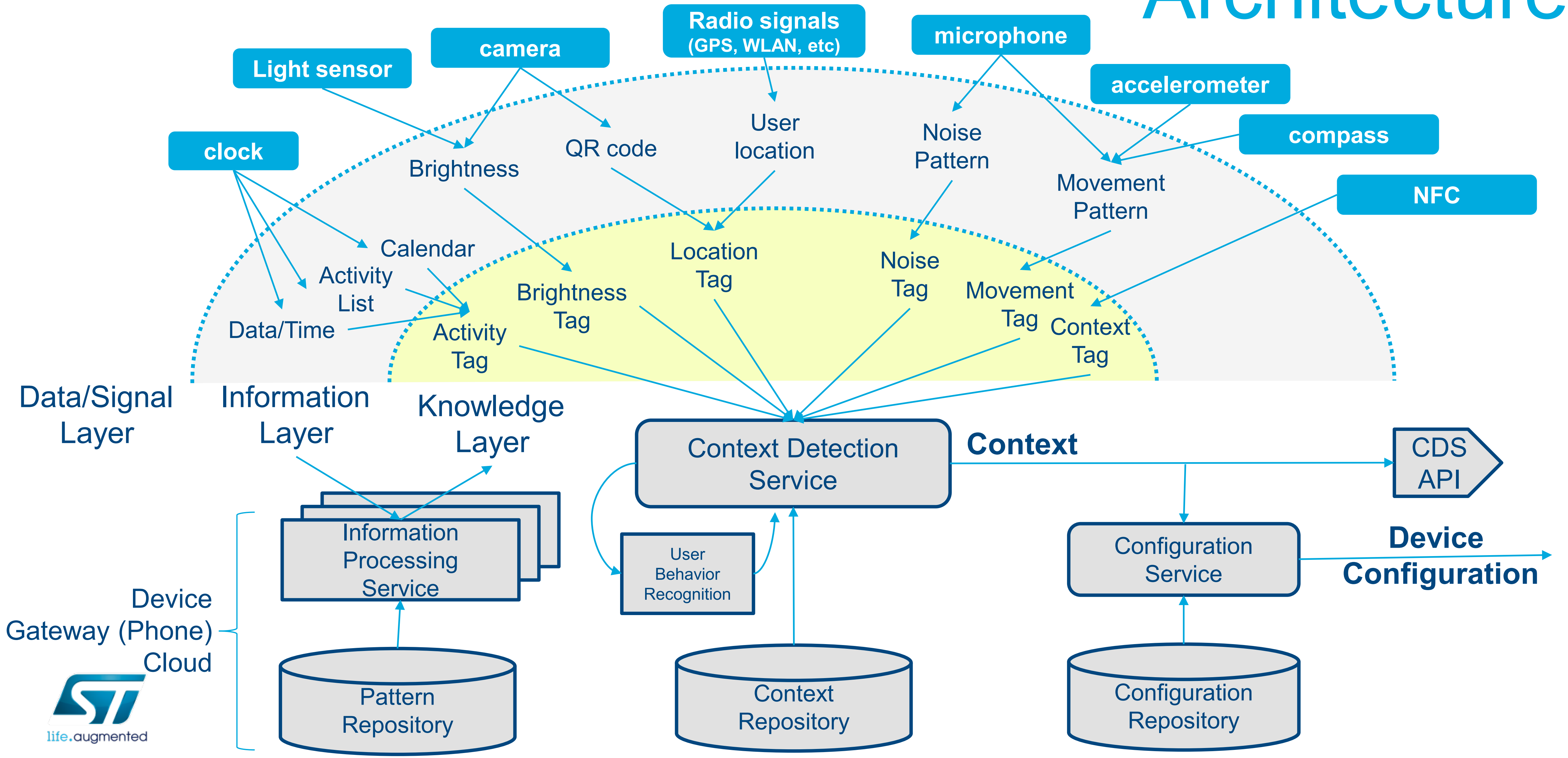
Minutes

Hours

Applications enabled by MEMS sensors

- User activity recognition
  - Travel mode: pedestrian, bicycle, vehicle
  - Pedestrian mode: stationary, walking, fast walking, running, stairs (up/down), elevator, escalator
  - Sports / fitness: Swimming, jumping rope, court games (tennis, basket ball, ..), ..
- Gesture recognition
  - Glance, pick-up, User definable, look-at, shake, tap, swipe, CW/CCW rotation, symbols
- Fusion of Audio and Motion sensors for situational awareness
- Carry position (device placement on body) determination
  - Shirt pocket, holster, trouser pocket, backpack, handbag, near the head, ..
- Pedestrian Dead-Reckoning (PDR) for indoor location

Generic Context Awareness Architecture



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Activities and Environments

Motion Activity Vector

Stationary	86%
Walking	1%
Jogging	0%
Escalator	0%
Elevator	1%
Bicycling	1%
Driving	0%
None of these	0%

MAP

Motion Activity Posteriogram

Voice Activity Vector

Silence	0%
Face to face talk	2%
Phone conversation	88%
None of these	0%

VAP

Voice Activity Posteriogram

Spatial Activity Vector

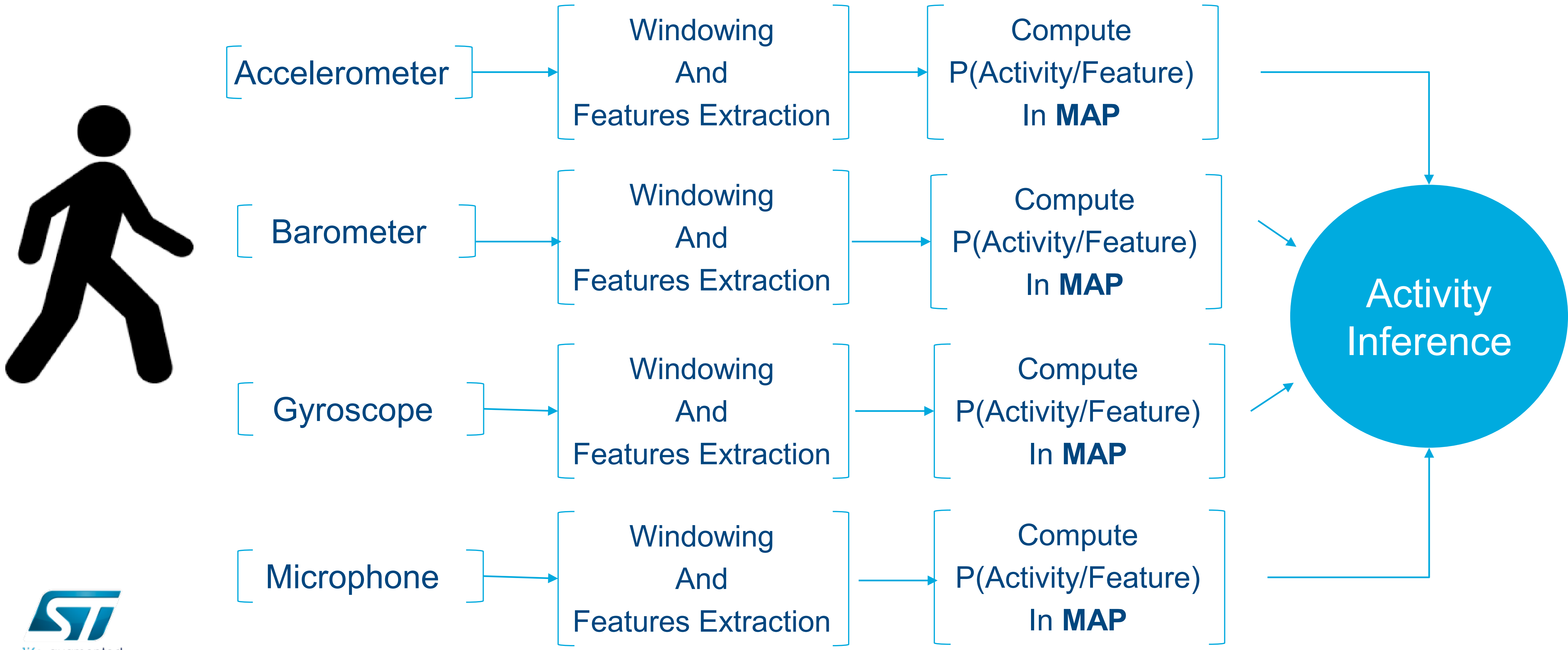
Street	0%
Nature	1%
Garden/Park	0%
Beach	0%
Stadium	1%
Office	70%
Mall/Restaurant	2%
Home	1%
Conference room	25%
None of these	0%

SAP

Spatial Activity Posteriogram

Human Motion Activity Detection

Architecture



Accelerometer

Barometer

Gyroscope

Microphone

Windowing And Features Extraction

Compute P(Activity/Feature) In **MAP**

Activity Inference

Activity Recognition Test results

- 682 data sets - 71 unique individuals, 48 hours of activity data
- Activities included (stationary, walking, fast walking, jogging, vehicle, bicycle) for different carry positions (body placement)
    - Pedestrian: Trouser pocket, in-hand, shirt pocket, in back pocket, near-the-head, ..
    - Vehicle: in cup-holder, in-shirt pocket, in-trouser pocket, ..
    - Bicycle: in-shirt pocket, in-trouser pocket

Actual Activity	Classified As						Detection Probability
	Stationary	Walking	Fast Walking	Jogging	Biking	Driving	
Stationary	16279	1	0	0	98	1431	91.41%
Walking	3	49030	51	9	483	25	98.85%
Fast Walking	0	116	3143	6	10	3	95.88%
Jogging	0	14	11	2781	8	2	98.76%
Biking	63	132	4	0	5292	633	86.41%
Driving	1113	6	1	0	436	7912	83.57%

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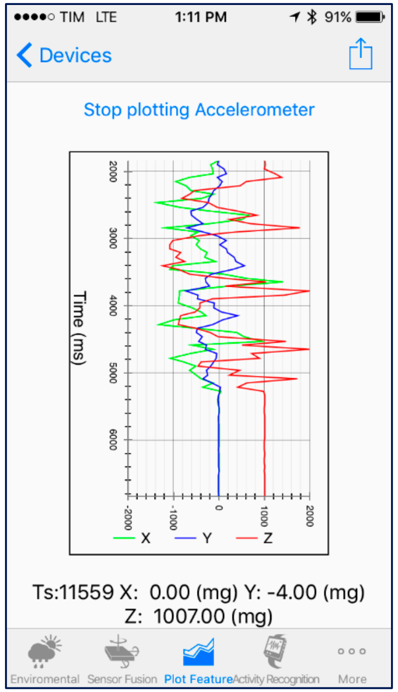
LAB5: Context Awareness

MotionAR library (activity recognition)
MotionCP library (carry position detection)
MotionGR library (gesture recognition)

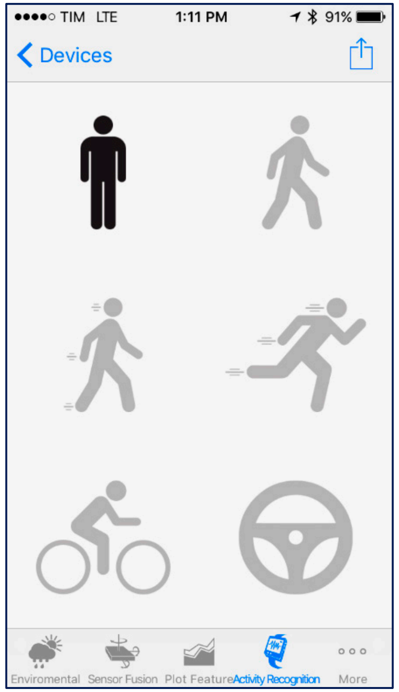
Swipe left to move from one screen to the next

Swipe left to view the SensorTile activity recognition options

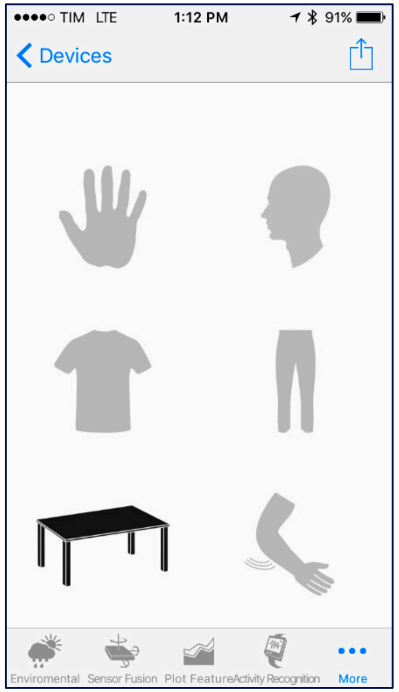


Ts:11559 X: 0.00 (mg) Y: -4.00 (mg)
Z: 1007.00 (mg)

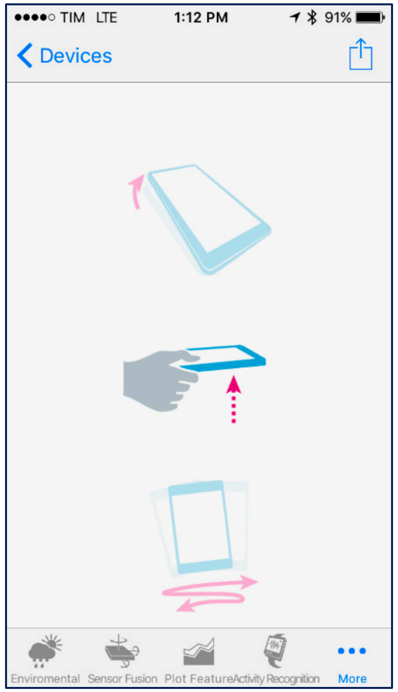
Activity recognition



Carry position detection



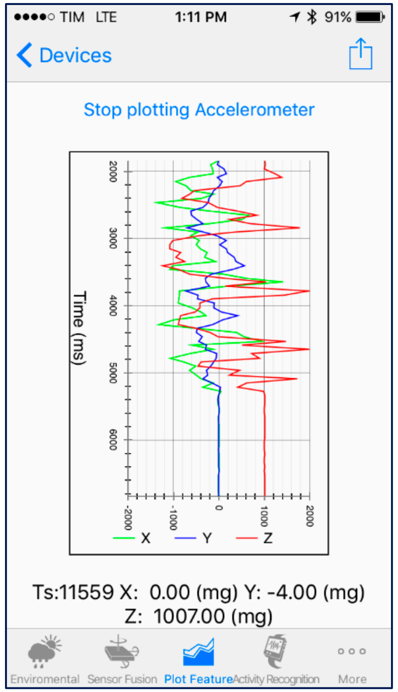
Gesture recognition



MotionAR library (activity recognition)
MotionCP library (carry position detection)
MotionGR library (gesture recognition)

LAB5: Context Awareness

Swipe left to view the SensorTile activity recognition options



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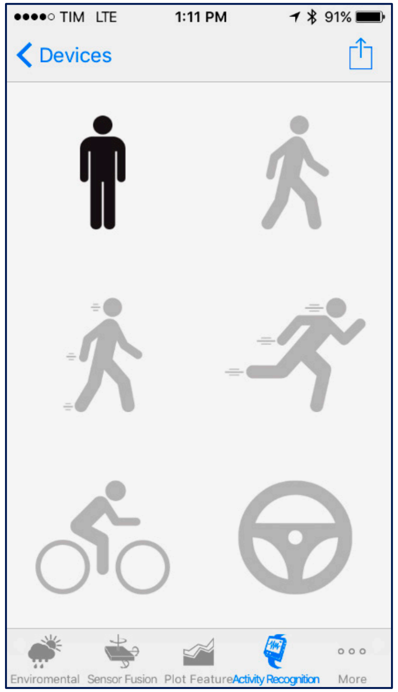
Z: 1007.00 (mg)

Activity recognition



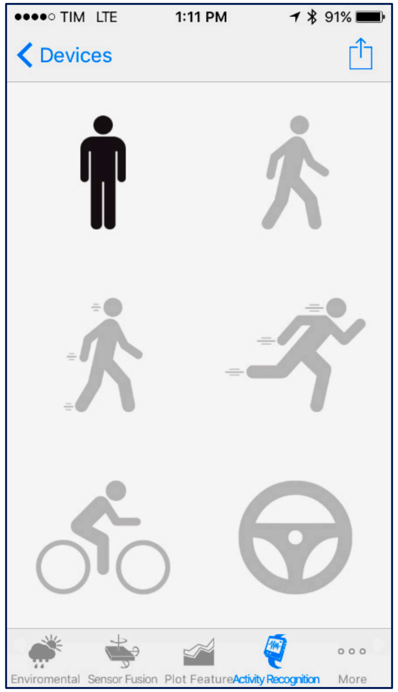
LAB

Try to walk around
(for at least 10 seconds)

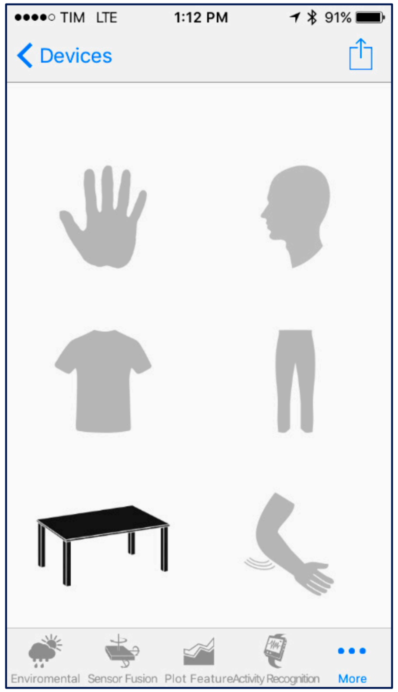
MotionAR library (activity recognition)
MotionCP library (carry position detection)
MotionGR library (gesture recognition)

LAB5: Context Awareness

Swipe left



Carry position detection



LAB

Pretend it is a phone.

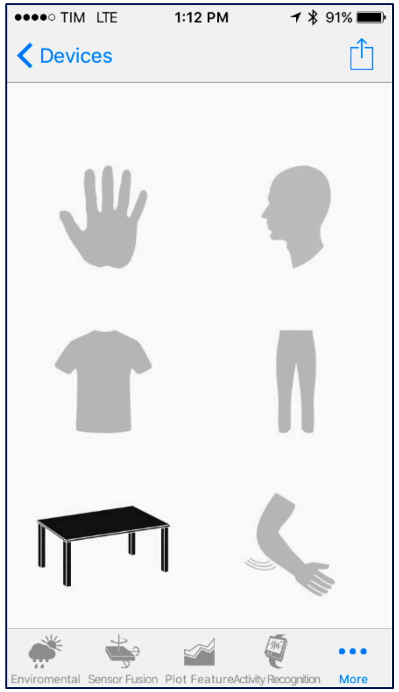
- Hold it in your hand and look at it
- Hold it in your hand and walk around
- Hold it near your ear
- Put it in the table

(for at least 10 seconds)

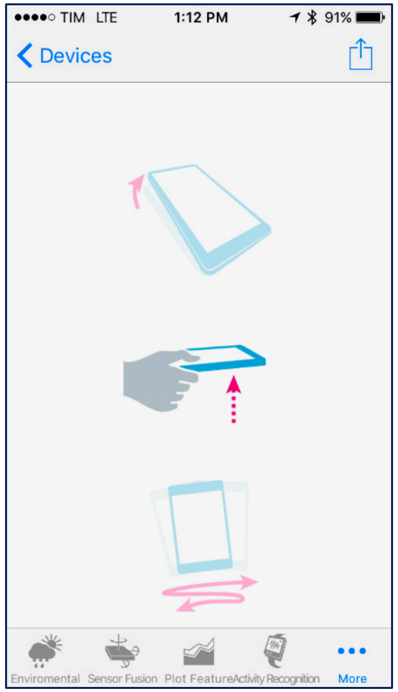
MotionAR library (activity recognition)
MotionCP library (carry position detection)
MotionGR library (gesture recognition)

LAB5: Context Awareness

Swipe left



Gesture recognition

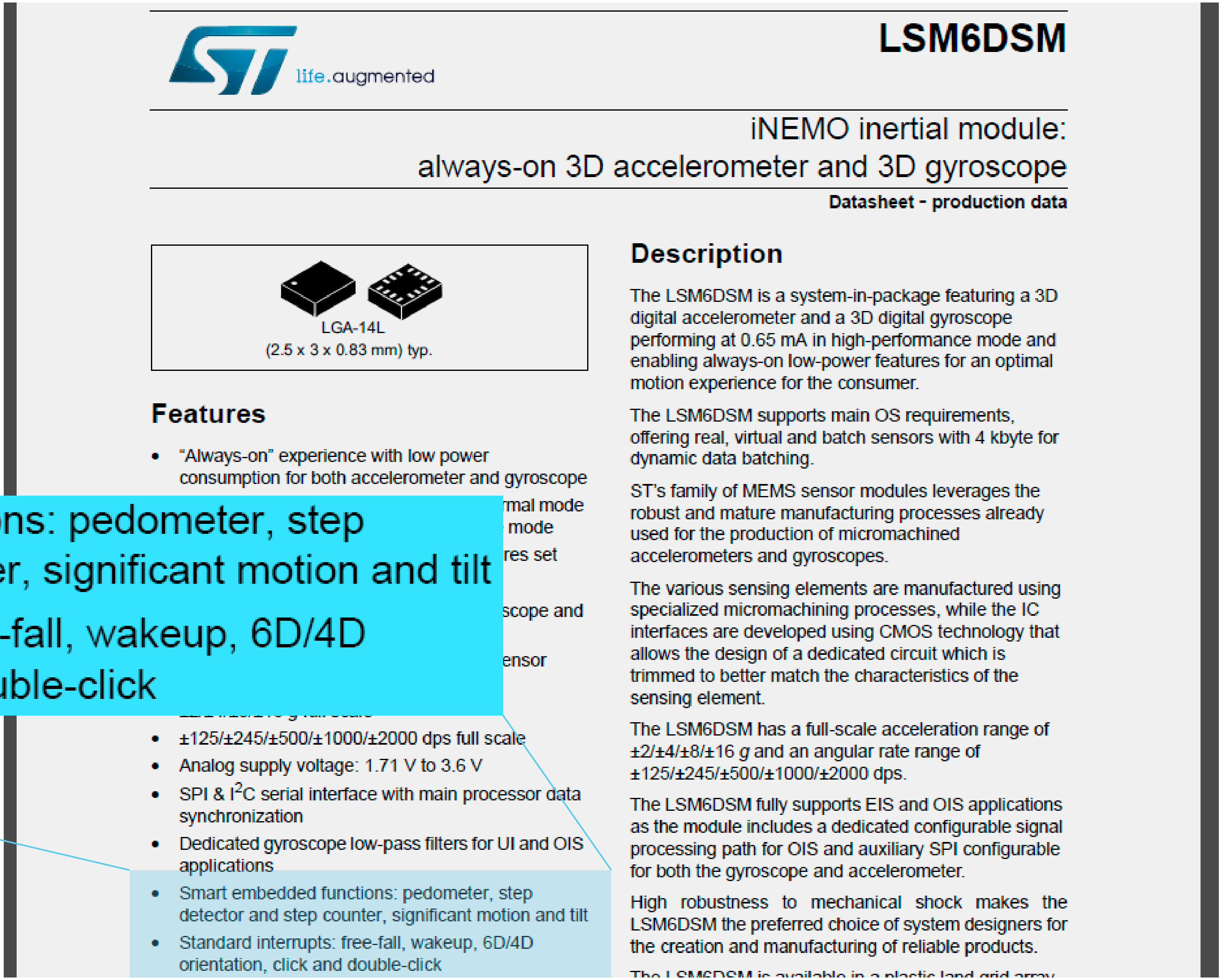


LAB

- Tilt it to look at it.
- Pick it up from the table
- Shake it

LAB6: Event Detection

- Smart embedded functions: pedometer, step detector and step counter, significant motion and tilt
- Standard interrupts: free-fall, wakeup, 6D/4D orientation, click and double-click



LSM6DSM

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iNEMO inertial module: always-on 3D accelerometer and 3D gyroscope

Datasheet - production data

LGA-14L
(2.5 x 3 x 0.83 mm) typ.

Features

- “Always-on” experience with low power consumption for both accelerometer and gyroscope

rmal mode
mode
res set

scope and

ensor

- ±125/±245/±500/±1000/±2000 dps full scale
- Analog supply voltage: 1.71 V to 3.6 V
- SPI & I^2C serial interface with main processor data synchronization
- Dedicated gyroscope low-pass filters for UI and OIS applications

- Smart embedded functions: pedometer, step detector and step counter, significant motion and tilt
- Standard interrupts: free-fall, wakeup, 6D/4D orientation, click and double-click

Description

The LSM6DSM is a system-in-package featuring a 3D digital accelerometer and a 3D digital gyroscope performing at 0.65 mA in high-performance mode and enabling always-on low-power features for an optimal motion experience for the consumer.

The LSM6DSM supports main OS requirements, offering real, virtual and batch sensors with 4 kbyte for dynamic data batching.

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The various sensing elements are manufactured using specialized micromachining processes, while the IC interfaces are developed using CMOS technology that allows the design of a dedicated circuit which is trimmed to better match the characteristics of the sensing element.

The LSM6DSM has a full-scale acceleration range of ±2/±4/±8/±16 *g* and an angular rate range of ±125/±245/±500/±1000/±2000 dps.

The LSM6DSM fully supports EIS and OIS applications as the module includes a dedicated configurable signal processing path for OIS and auxiliary SPI configurable for both the gyroscope and accelerometer.

High robustness to mechanical shock makes the LSM6DSM the preferred choice of system designers for the creation and manufacturing of reliable products.

The LSM6DSM is available in a plastic land grid array

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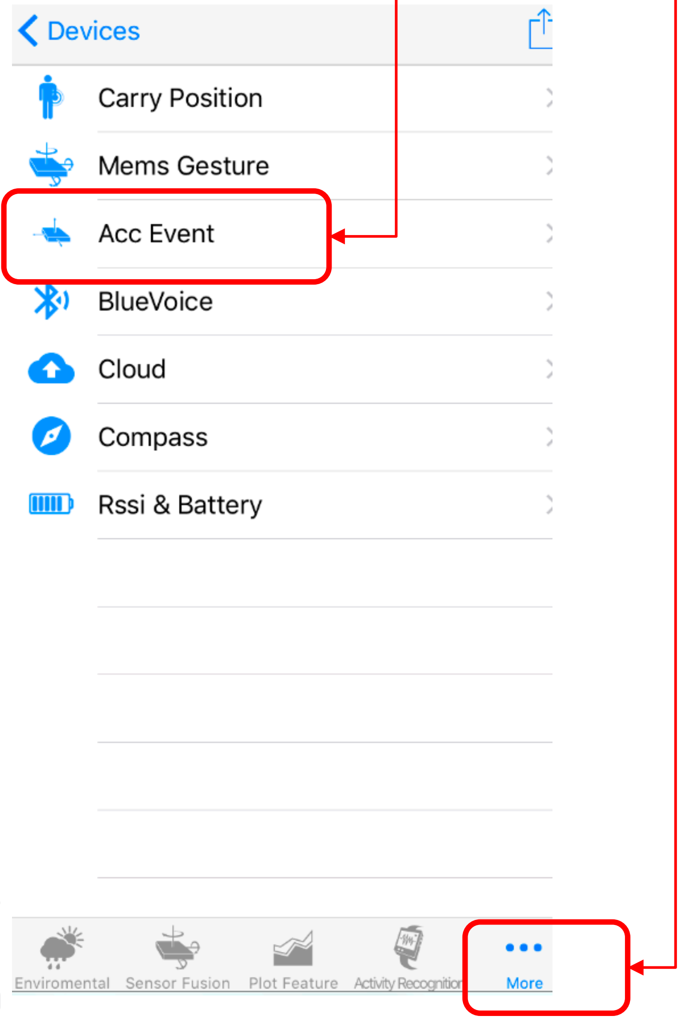
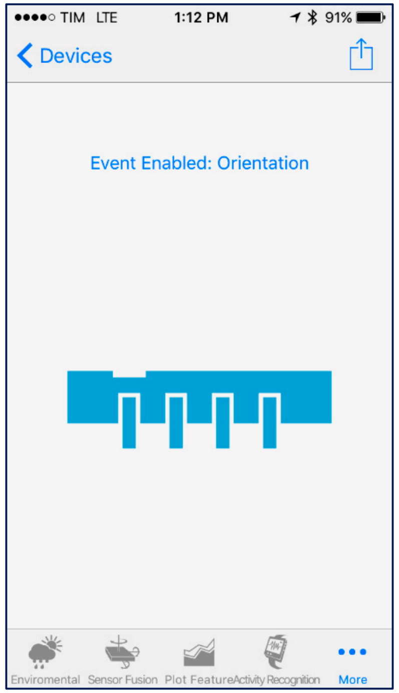
LAB6: Event Detection

Select “more”

Select “Acc Event”

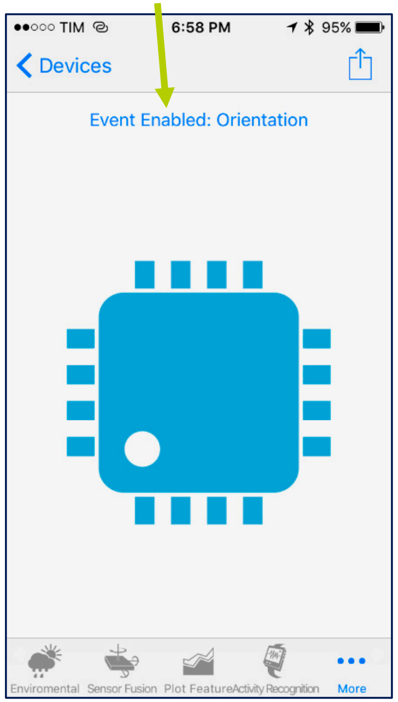


Change orientation



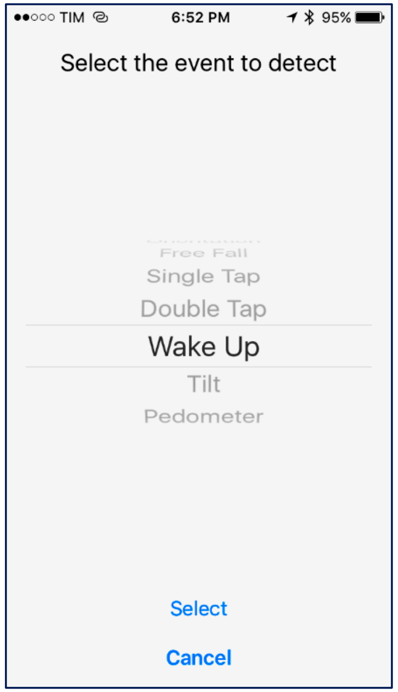
Event Enabled: Orientation

Touch ‘event enabled’



Event Enabled: Orientation

Select another event

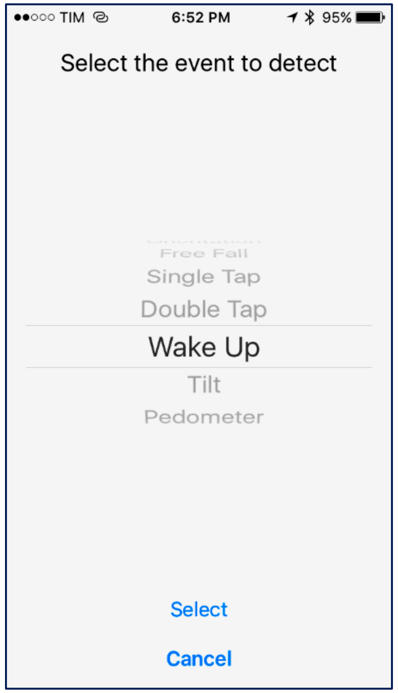


Select the event to detect

LAB6: Event Detection

The MEMS sensor hardware performs event detection recognition using a programmable interrupt logic block

Select another event



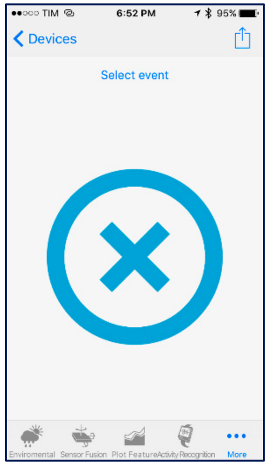
Select the event to detect

Orientation
Free Fall
Single Tap
Double Tap
Wake Up
Tilt
Pedometer

Select

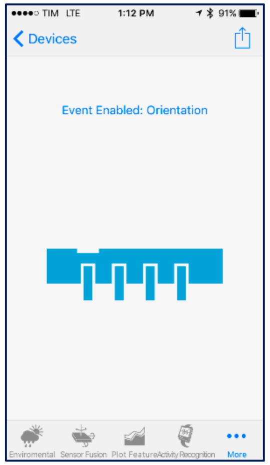
Cancel

No event



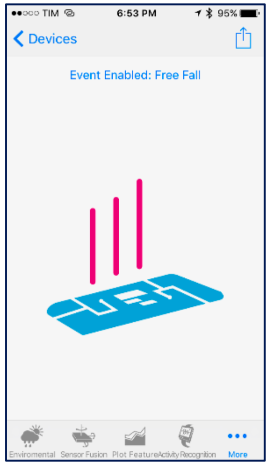
Select event

Orientation



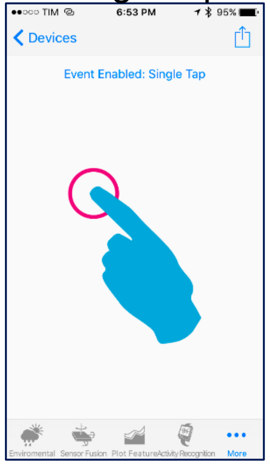
Event Enabled: Orientation

Free fall



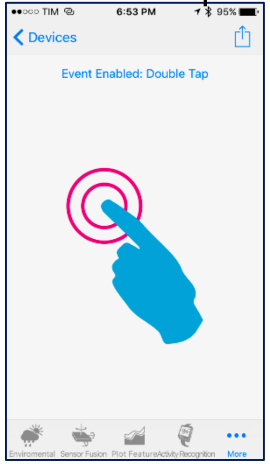
Event Enabled: Free Fall

Single tap



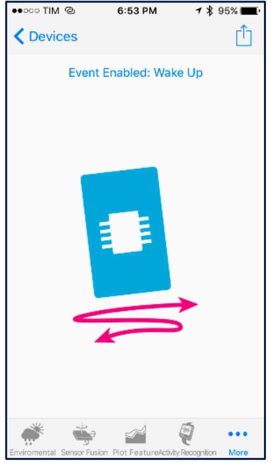
Event Enabled: Single Tap

Double tap



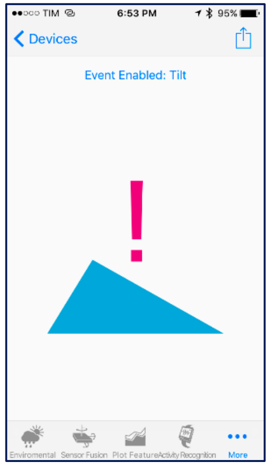
Event Enabled: Double Tap

Wake up



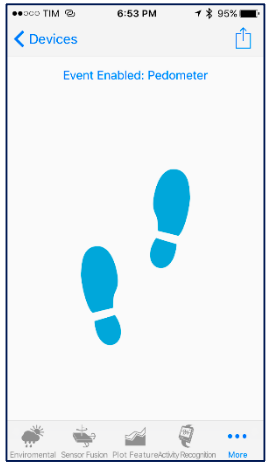
Event Enabled: Wake Up

Tilt



Event Enabled: Tilt

Pedometer

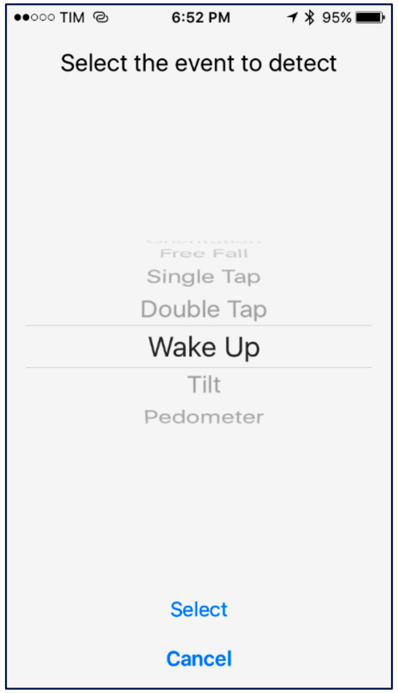


Event Enabled: Pedometer

LAB6: Event Detection

The MEMS sensor hardware performs event detection recognition using a programmable interrupt logic block

Select another event



●●○○○ TIM 6:52 PM 95%

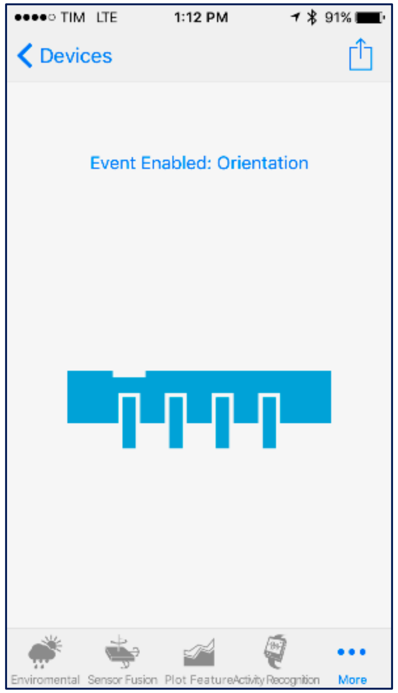
Select the event to detect

Free Fall
Single Tap
Double Tap
Wake Up
Tilt
Pedometer

Select

Cancel

Orientation



●●●●○ TIM LTE 1:12 PM 91%

Event Enabled: Orientation

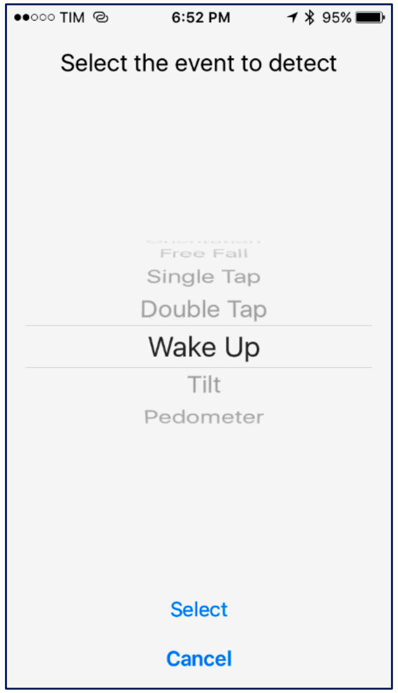
LAB

Change orientation: an interrupt is sent to the microcontroller and a notification is sent through BLE

LAB6: Event Detection

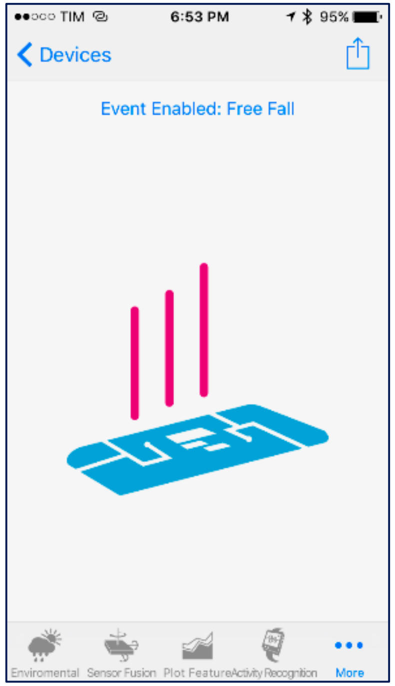
The MEMS sensor hardware performs event detection recognition using a programmable interrupt logic block

Select another event



Select the event to detect

Free Fall



Event Enabled: Free Fall

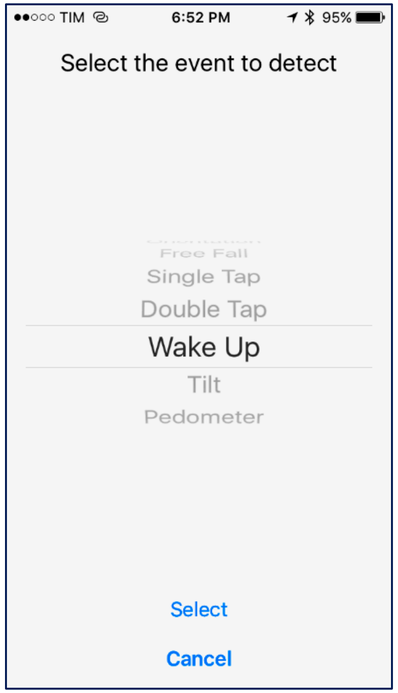
LAB

Drop it and catch it on the fly, the acceleration will drop to zero during the free fall and an interrupt will be generated.

LAB6: Event Detection

The MEMS sensor hardware performs event detection recognition using a programmable interrupt logic block

Select another event



●●○○○ TIM 6:52 PM 95%

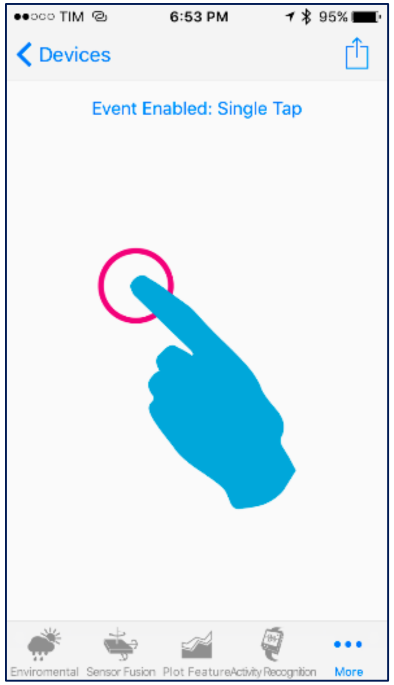
Select the event to detect

Free Fall
Single Tap
Double Tap
Wake Up
Tilt
Pedometer

Select

Cancel

Single Tap



●●○○○ TIM 6:53 PM 95%

Devices

Event Enabled: Single Tap

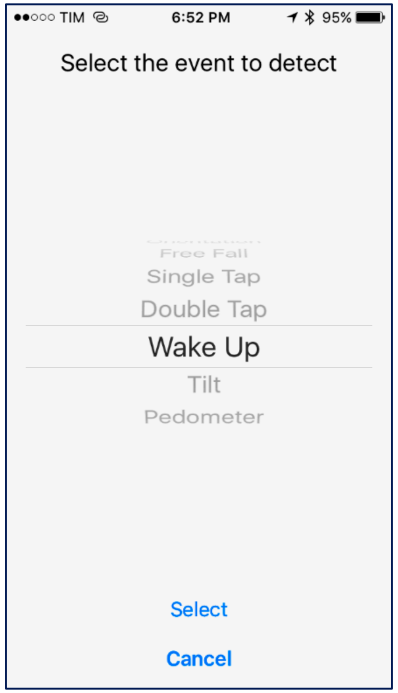
LAB

Tap the device. What happens for the double tap?

LAB6: Event Detection

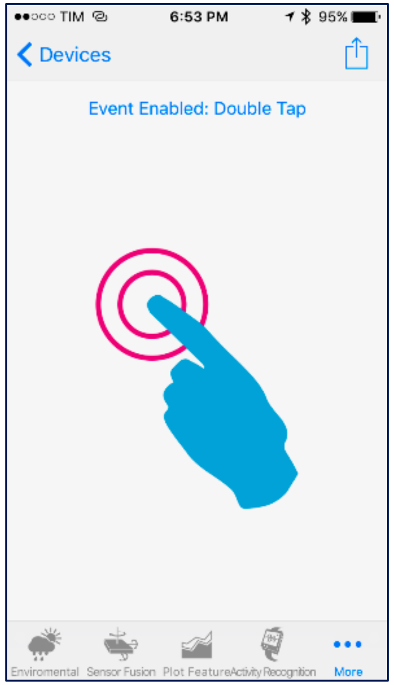
The MEMS sensor hardware performs event detection recognition using a programmable interrupt logic block

Select another event



Select the event to detect

Double Tap



Event Enabled: Double Tap

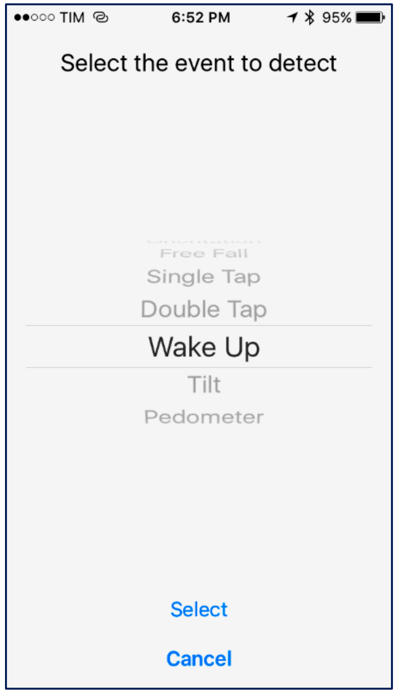
LAB

Double tap the device. What happens now for the single tap?

LAB6: Event Detection

The MEMS sensor hardware performs event detection recognition using a programmable interrupt logic block

Select another event



●●○○○ TIM 6:52 PM 95%

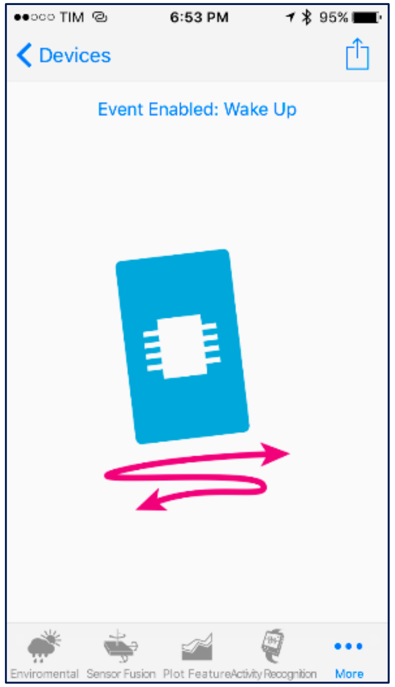
Select the event to detect

Free Fall
Single Tap
Double Tap
Wake Up
Tilt
Pedometer

Select

Cancel

Wake Up



●●○○○ TIM 6:53 PM 95%

Devices

Event Enabled: Wake Up

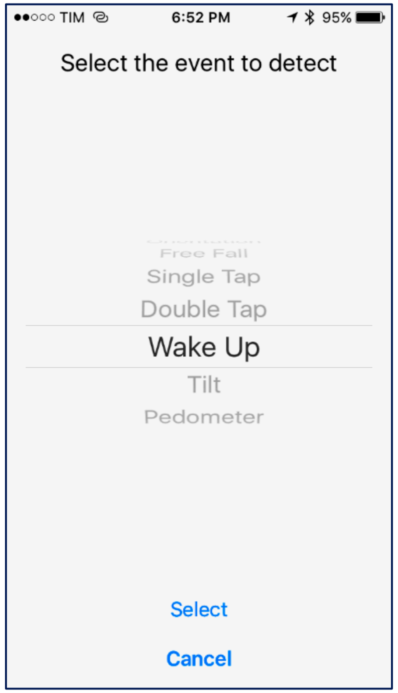
LAB

Shake the device, the acceleration will trigger an interrupt to wake up the MCU (in the meanwhile captured data can be saved to internal FIFO)

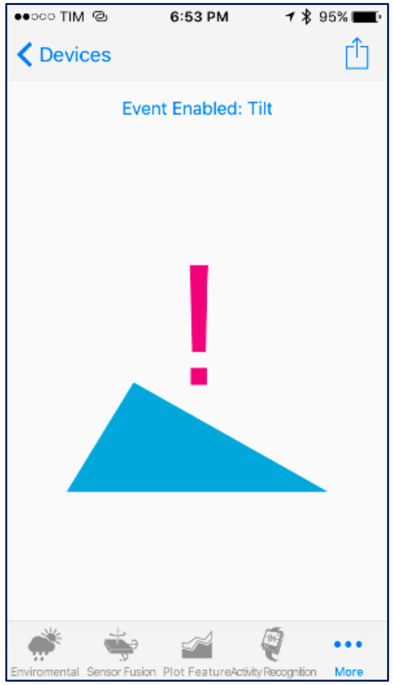
LAB6: Event Detection

The MEMS sensor hardware performs event detection recognition using a programmable interrupt logic block

Select another event


Select the event to detect

Orientation


Event Enabled: Tilt

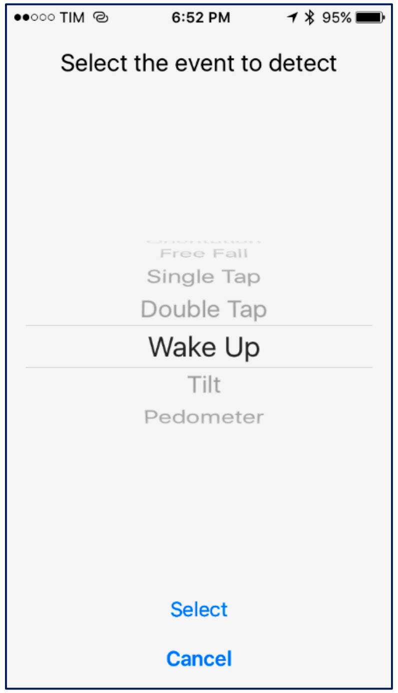
LAB

With the tile facing up, slowly tilt the device to see when the interrupt is generated.

LAB6: Event Detection

The MEMS sensor hardware performs event detection recognition using a programmable interrupt logic block

Select another event



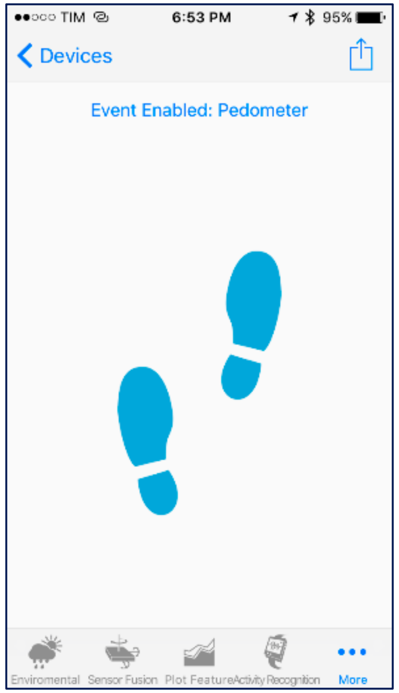
Select the event to detect

Free Fall
Single Tap
Double Tap
Wake Up
Tilt
Pedometer

Select

Cancel

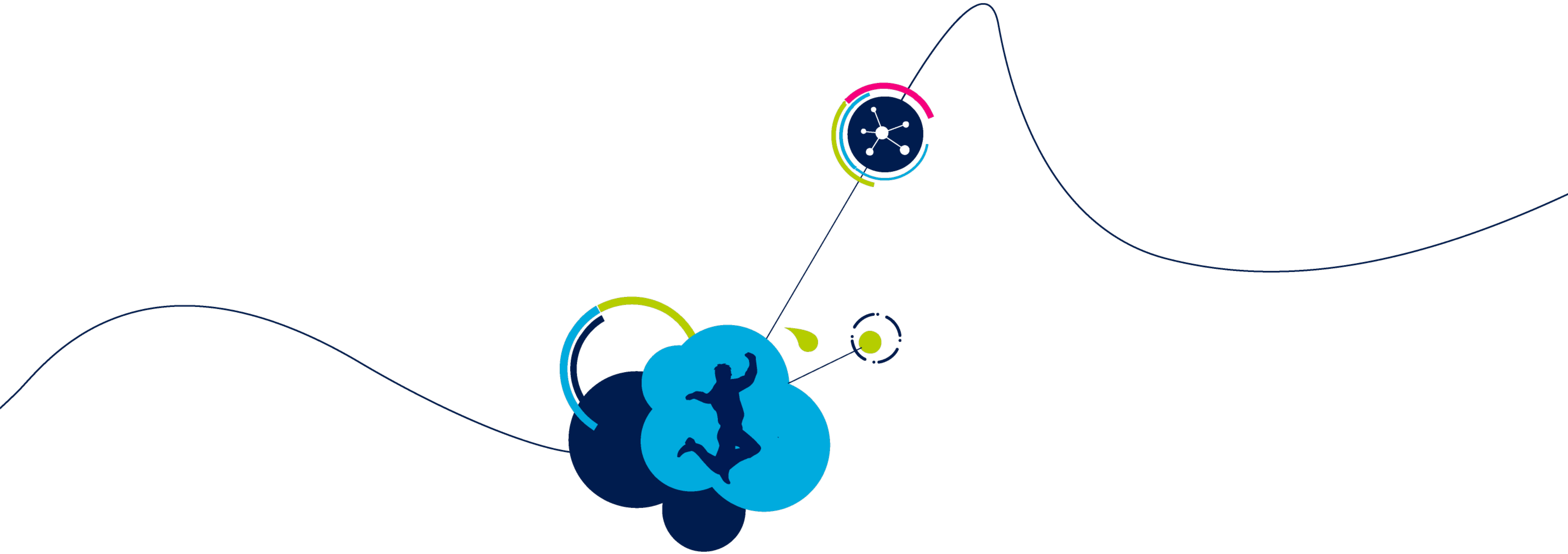
Pedometer



Event Enabled: Pedometer

LAB

Keep the device in your hand and swing your arm. After at least 7 ‘steps’ the counter is updated (these initial steps are also counted).



Firmware packages structure

Function Packages

ODE software package

(Open Development Environment – src code)

With fusion libraries

(bin libraries)

X-CUBE-MEMS1	MEMS sensors: motion + environ	All libraries
X-CUBE-BLE1	BLE: Bluetooth Low Energy	
FP-SNS-MOTENV1	BLE + MEMS	FX, AR, CP, GR, PM
FP-SNS-ALLMEMS1	BLE + MEMS + digital microphone	FX, AR, CP, GR, BlueVoice
FP-SNS-FLIGHT1	BLE + MEMS + Time of Flight + NFC	FX, AR, CP, GR, GR-ToF
FP-AUD-BVLINK1	BLE + digital microphone	BlueVoice
FP-NET-BLESTAR1	BLE + MEMS + WiFi	

open.MEMS
open.AUDIO

Function Packages

ODE software package

(Open Development Environment – src code)

- **FP-SNS-ALLMEMS1** BLE + MEMS + digital microphone
- **STSW-STLKT01** runs on SensorTile

With fusion libraries

(bin libraries)

- FX, AR, CP, GR, BlueVoice (was BLUEMICROSYSTEM2)

STSW-STLKT01 runs on SensorTile. It includes 3 samples applications (AudioLoop, BLE_SampleApp, DataLog).

FP-SNS-ALLMEMS1 runs on SensorTile, as well as on the system made of Nucleo + Nucleo expansions for BLE, MEMS inertial and environmental sensors and MEMS microphones. It includes 1 sample application.

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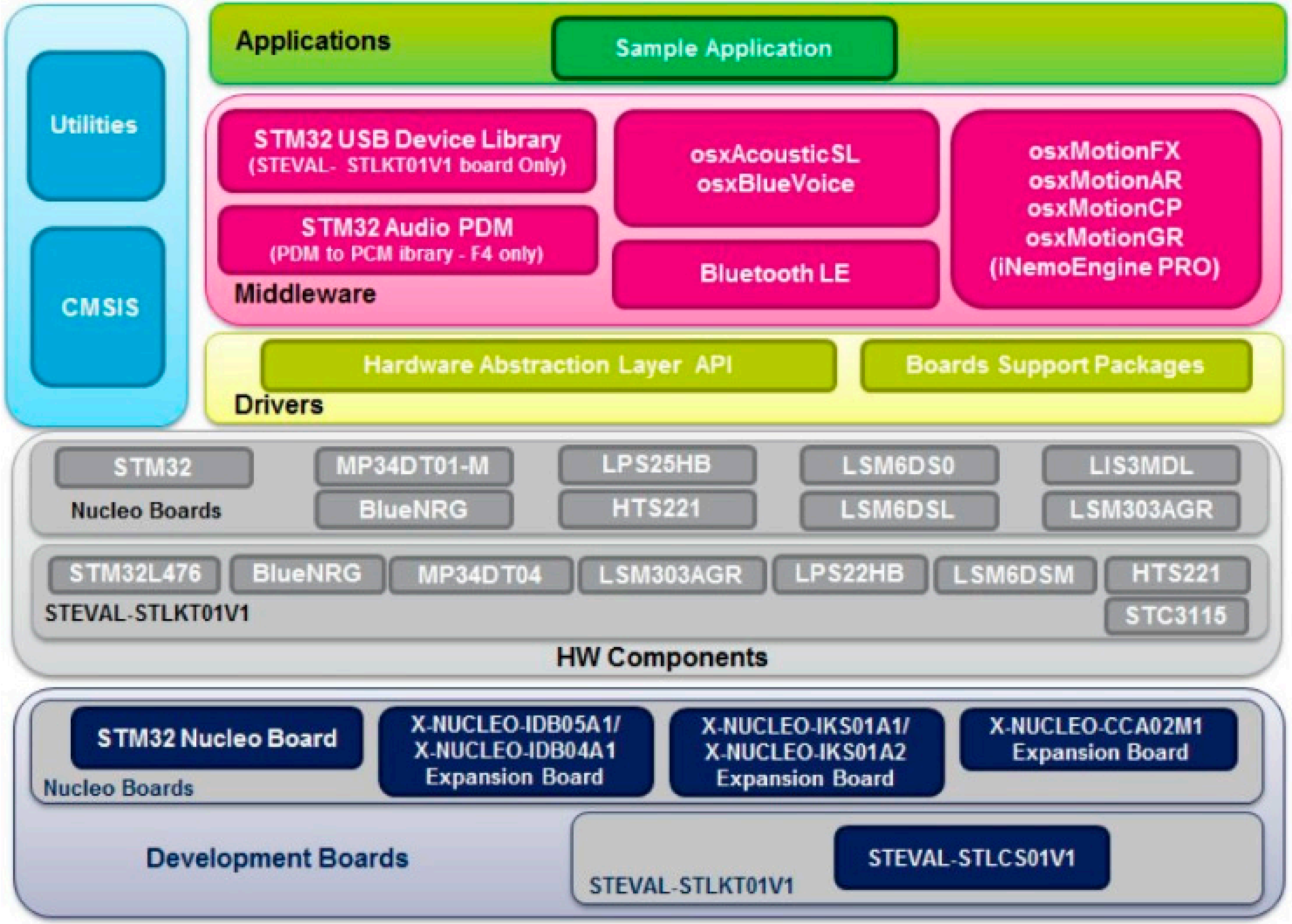
Hardware and Software Block Diagram



Utilities

CMSIS

Applications

Sample Application

STM32 USB Device Library
(STEVAL- STLKT01V1 board Only)

STM32 Audio PDM
(PDM to PCM ibrary - F4 only)

Middleware

osxAcousticSL
osxBlueVoice

Bluetooth LE

osxMotionFX
osxMotionAR
osxMotionCP
osxMotionGR
(iNemoEngine PRO)

Hardware Abstraction Layer API

Boards Support Packages

Drivers

STM32

Nucleo Boards

MP34DT01-M

BlueNRG

LPS25HB

HTS221

LSM6DS0

LSM6DSL

LIS3MDL

LSM303AGR

STM32L476

BlueNRG

MP34DT04

LSM303AGR

LPS22HB

LSM6DSM

HTS221

STC3115

STEVAL-STLKT01V1

HW Components

STM32 Nucleo Board

X-NUCLEO-IDB05A1/
X-NUCLEO-IDB04A1
Expansion Board

X-NUCLEO-IKS01A1/
X-NUCLEO-IKS01A2
Expansion Board

X-NUCLEO-CCA02M1
Expansion Board

Nucleo Boards

Development Boards

STEVAL-STLCS01V1

STEVAL-STLKT01V1

Application (e.g. BMS2)

ST and 3rd party libraries

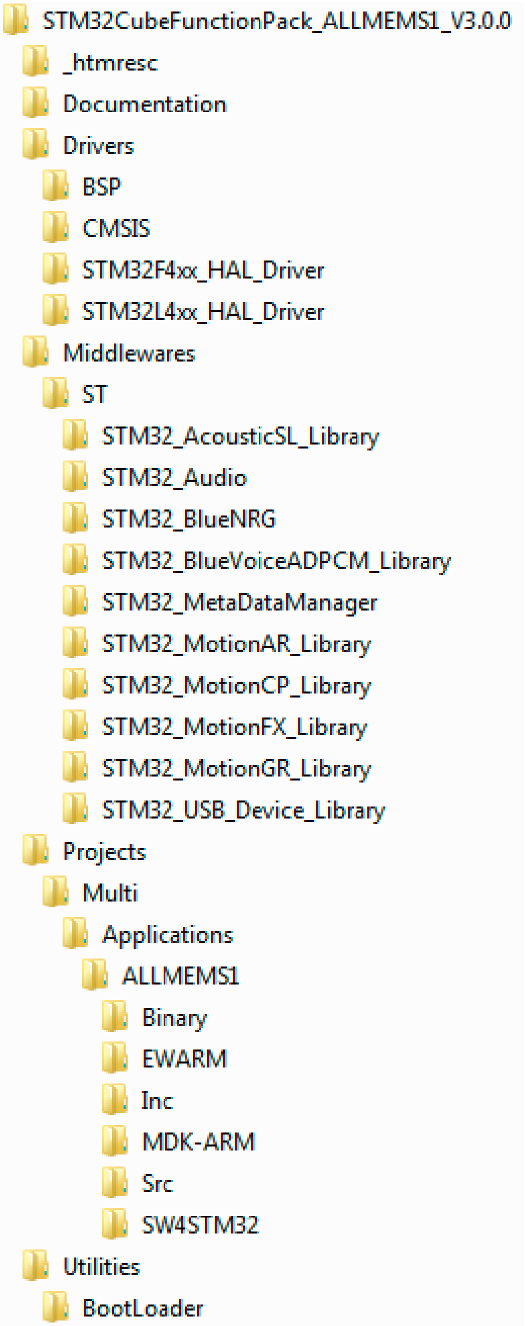
HAL and BSP

Components

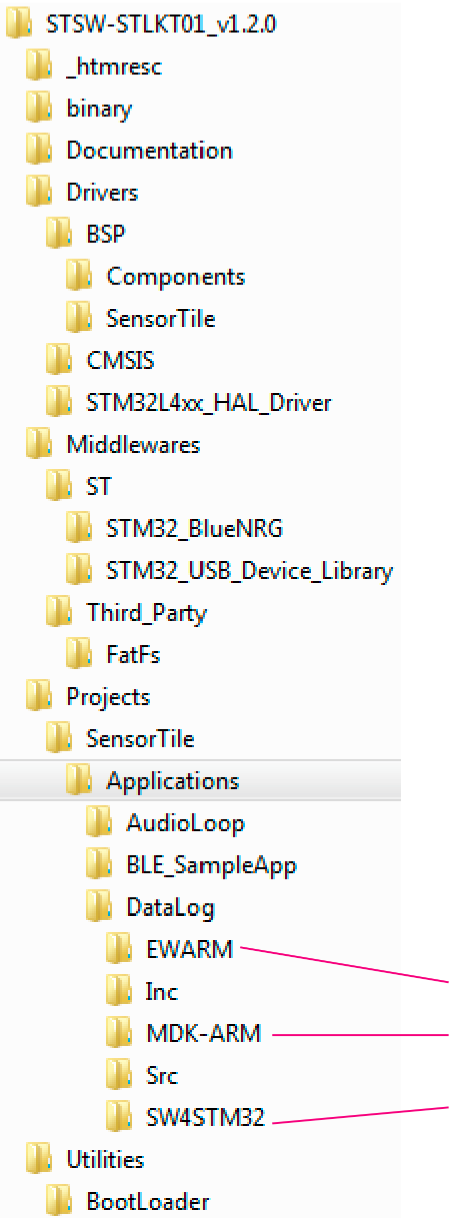
Boards

Folder Structure

C:\ Program Files (x86) \STMicroelectronics \



- STM32CubeFunctionPack_ALLMEMS1_V3.0.0
  - _htmresc
  - Documentation
  - Drivers
    - BSP
    - CMSIS
    - STM32F4xx_HAL_Driver
    - STM32L4xx_HAL_Driver
  - Middlewares
    - ST
      - STM32_AcousticSL_Library
      - STM32_Audio
      - STM32_BlueNRG
      - STM32_BlueVoiceADPCM_Library
      - STM32_MetaDataManager
      - STM32_MotionAR_Library
      - STM32_MotionCP_Library
      - STM32_MotionFX_Library
      - STM32_MotionGR_Library
      - STM32_USB_Device_Library
  - Projects
    - Multi
      - Applications
        - ALLMEMS1
          - Binary
          - EWARM
          - Inc
          - MDK-ARM
          - Src
          - SW4STM32
  - Utilities
    - BootLoader



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    - Third_Party
      - FatFs
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        - BLE_SampleApp
        - DataLog
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          - SW4STM32
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BSP = Board Support Package

- Components (typ. MEMS sensors)
- Boards (SensorTile, Nucleo, Nucleo-expansion)

CMSIS = Cortex Microcontroller Software Interface Standard

- DSP library collection (fixed / float)

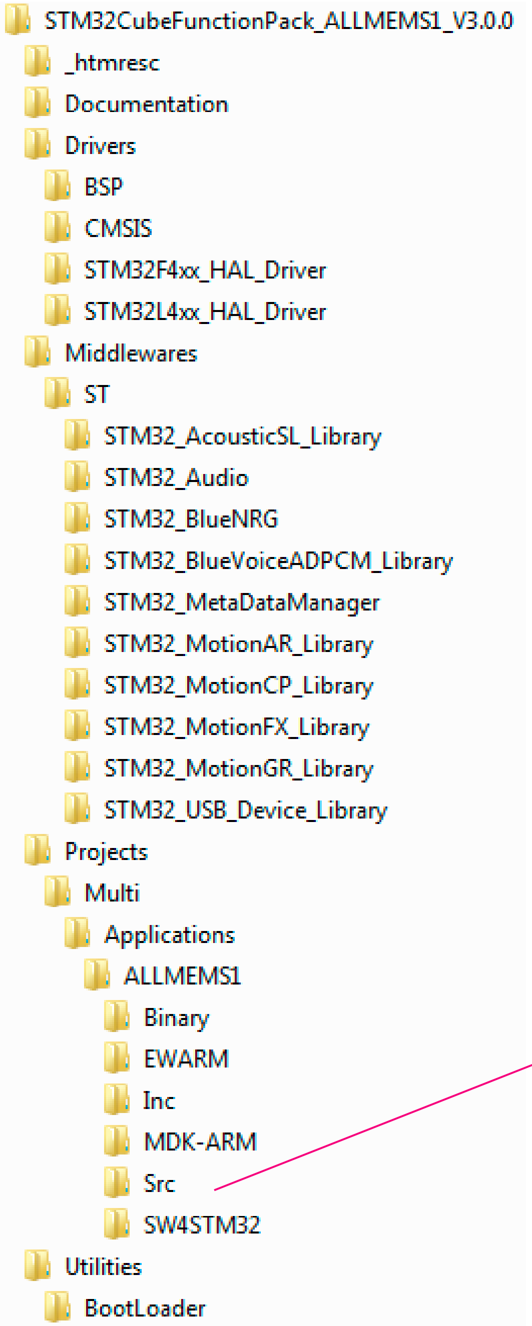
HAL = Hardware Abstraction Layer

- STM32 specific hardware drivers

Main.c is in Applications\...\Src\

EWARM = IAR project files
MDK-ARM = Keil project files
SW4STM32 = SystemWorkbench

C:\ Program Files (x86) \STMicroelectronics \



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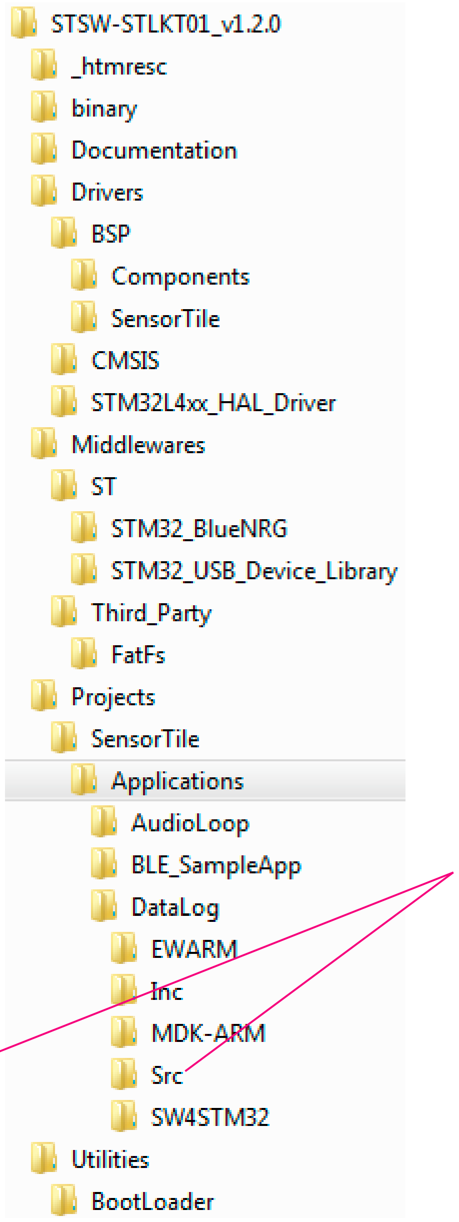

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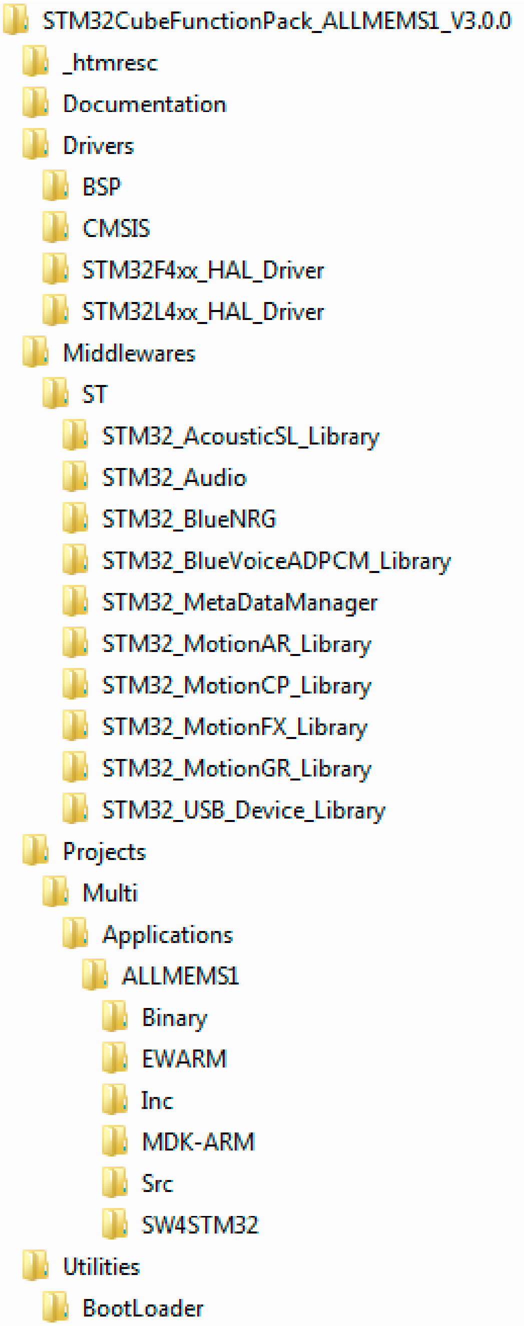

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          Src
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  Utilities
    BootLoader
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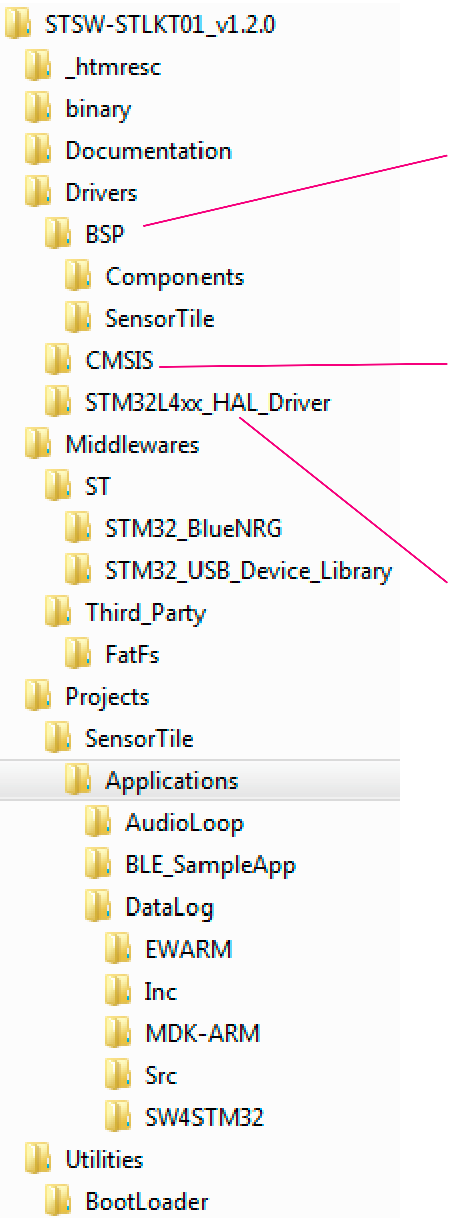

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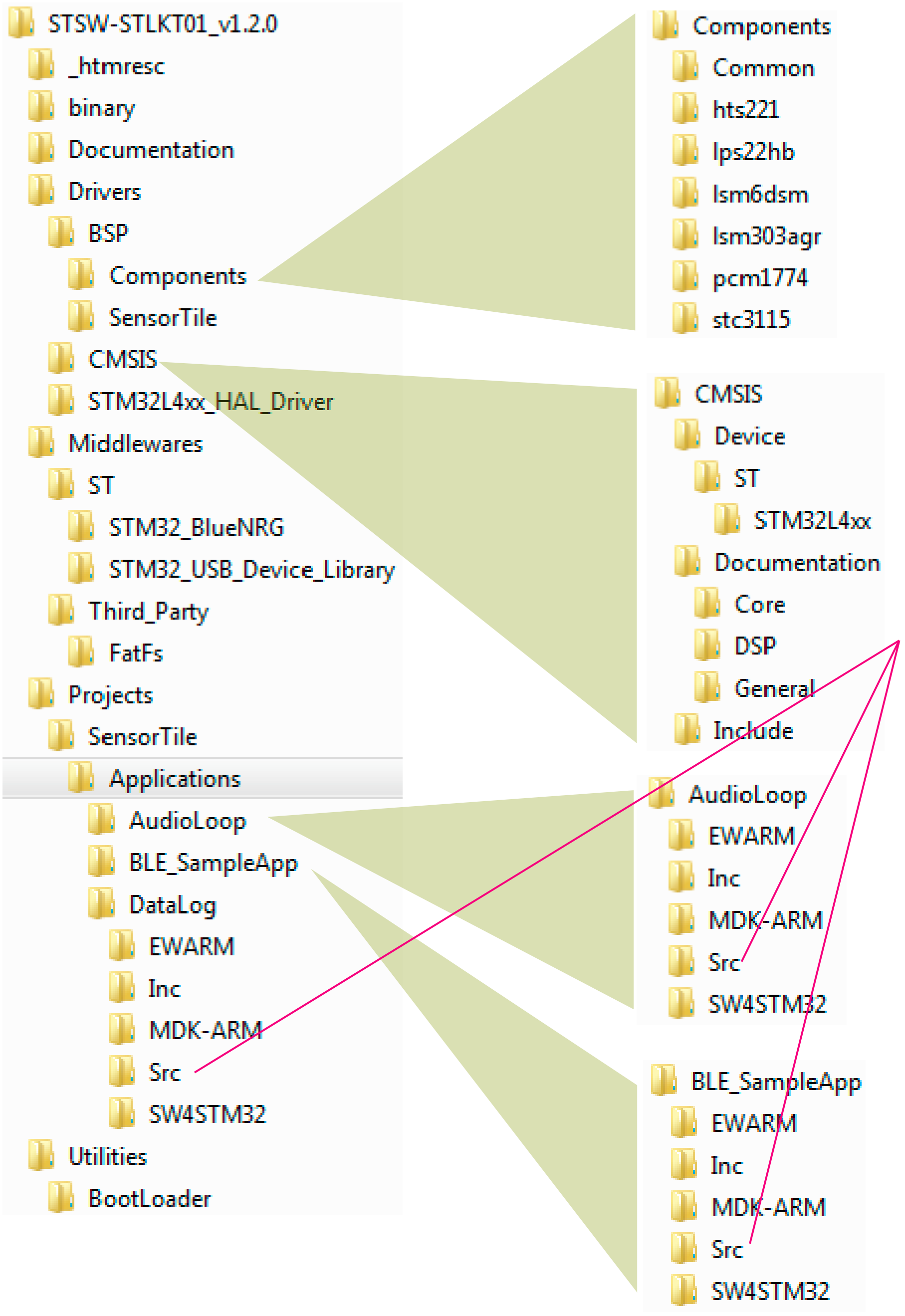
C:\ Program Files (x86) \STMicroelectronics \ STSW-STLKT01



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        - DataLog
          - EWARM
          - Inc
          - MDK-ARM
          - Src
          - SW4STM32
  - Utilities
    - BootLoader

- Components
  - Common
  - hts221
  - lps22hb
  - lsm6dsm
  - lsm303agr
  - pcm1774
  - stc3115

- CMSIS
  - Device
    - ST
      - STM32L4xx
  - Documentation
    - Core
    - DSP
    - General
  - Include

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  - EWARM
  - Inc
  - MDK-ARM
  - Src
  - SW4STM32

Main.c is in Applications\...\Src\

AudioLoop

Read input from the digital microphone, process it (PDM to PCM conversion) and send to external DAC via I2S

BLE_SampleApp

Read MEMS sensors and send data over BLE (Bluetooth low-energy).

DataLog

Read MEMS sensors and save data on the SD card or send data over USB port.

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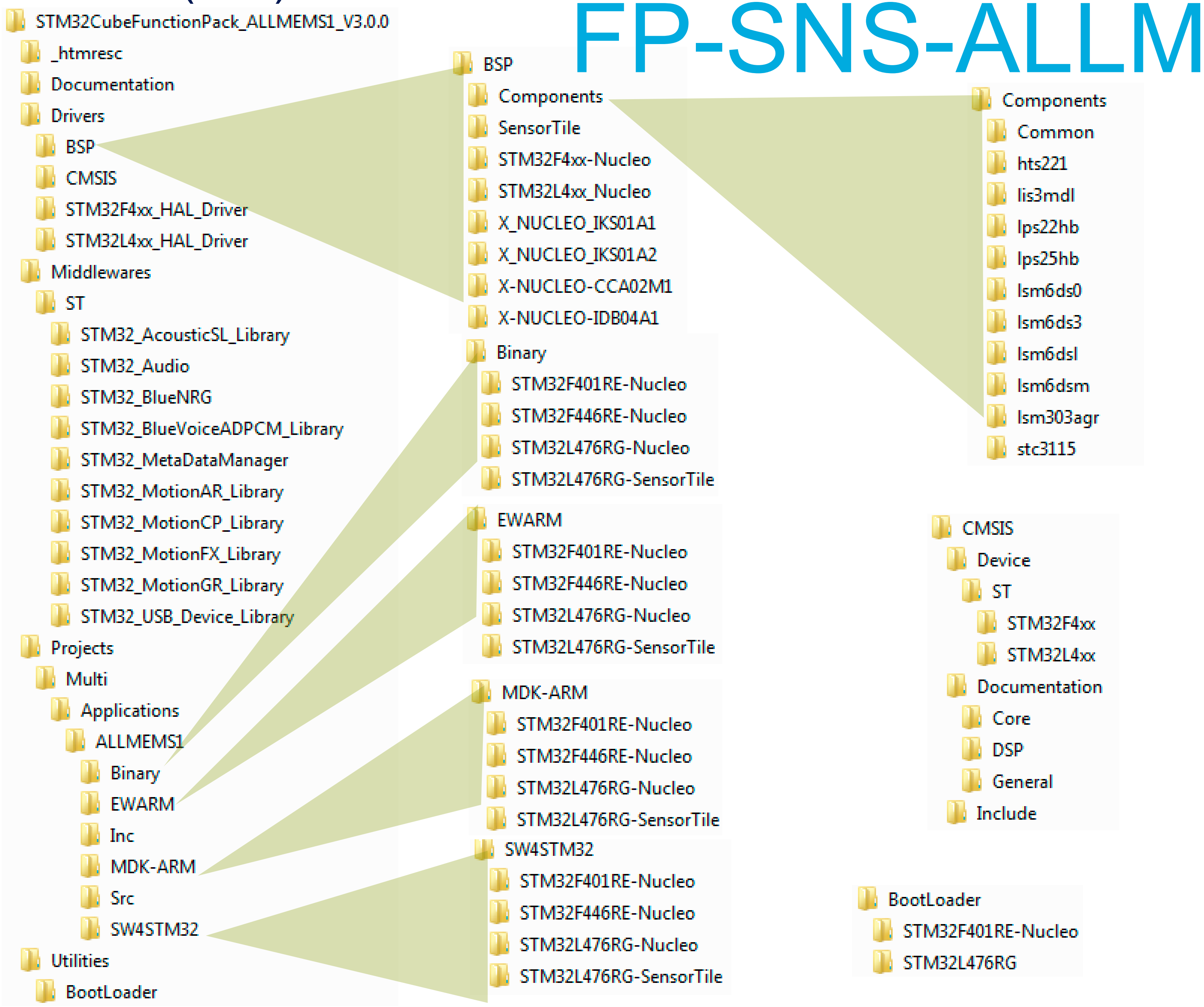
FP-SNS-ALLMEMS1



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STM32CubeFunctionPack_ALLMEMS1_V3.0.0
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          Src
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  X-NUCLEO-IDB04A1
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```
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  Common
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  lps25hb
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  lsm6ds3
  lsm6dsl
  lsm6dsm
  lsm303agr
  stc3115
```

```
Binary
  STM32F401RE-Nucleo
  STM32F446RE-Nucleo
  STM32L476RG-Nucleo
  STM32L476RG-SensorTile
```

```
EWARM
  STM32F401RE-Nucleo
  STM32F446RE-Nucleo
  STM32L476RG-Nucleo
  STM32L476RG-SensorTile
```

```
MDK-ARM
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  STM32F446RE-Nucleo
  STM32L476RG-Nucleo
  STM32L476RG-SensorTile
```

```
SW4STM32
  STM32F401RE-Nucleo
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  STM32L476RG-Nucleo
  STM32L476RG-SensorTile
```

```
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      STM32L4xx
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    DSP
    General
  Include
```
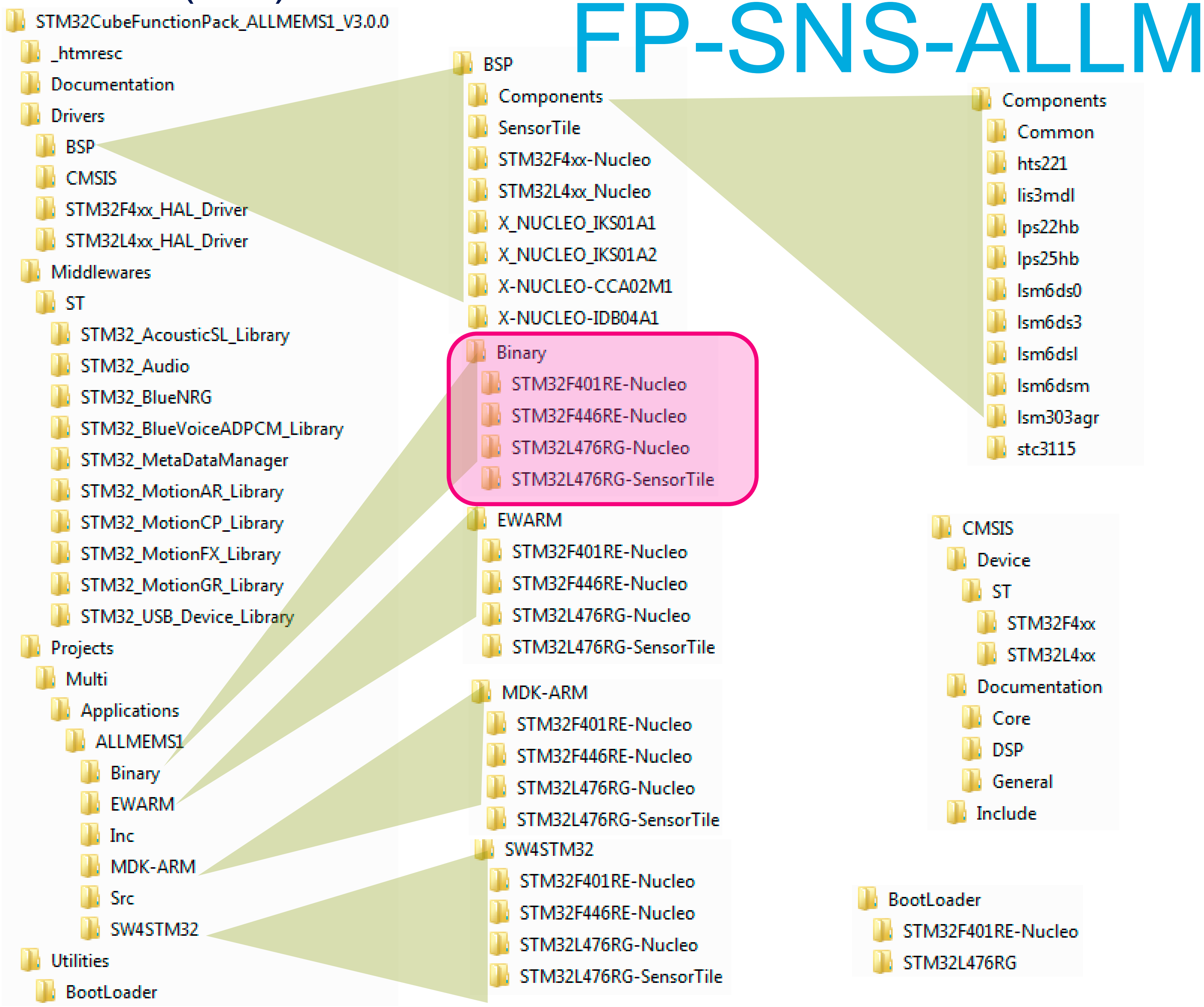

```
BootLoader
  STM32F401RE-Nucleo
  STM32L476RG
```

C:\ Program Files (x86) \STMicroelectronics \

FP-SNS-ALLMEMS1



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```

```
Components
  Common
  hts221
  lis3mdl
  lps22hb
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  lsm6ds3
  lsm6dsl
  lsm6dsm
  lsm303agr
  stc3115
```

```
Binary
  STM32F401RE-Nucleo
  STM32F446RE-Nucleo
  STM32L476RG-Nucleo
  STM32L476RG-SensorTile
```

```
EWARM
  STM32F401RE-Nucleo
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```
MDK-ARM
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  STM32L476RG-SensorTile
```

```
SW4STM32
  STM32F401RE-Nucleo
  STM32F446RE-Nucleo
  STM32L476RG-Nucleo
  STM32L476RG-SensorTile
```

```
CMSIS
  Device
    ST
      STM32F4xx
      STM32L4xx
  Documentation
    Core
    DSP
    General
  Include
```

```
BootLoader
  STM32F401RE-Nucleo
  STM32L476RG
```

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Pre-compiled Binaries

FP-SNS-ALLMEMS1

Application, flash at 0x0800 4000

- **BlueMS2_ST.bin**
- **BlueMS2_ST.hex**

Bootloader + App, flash at 0x0800 0000

- **BlueMS2_ST_BL.bin**
- **BlueMS2_ST_BL.hex**

STSW-STLKT01

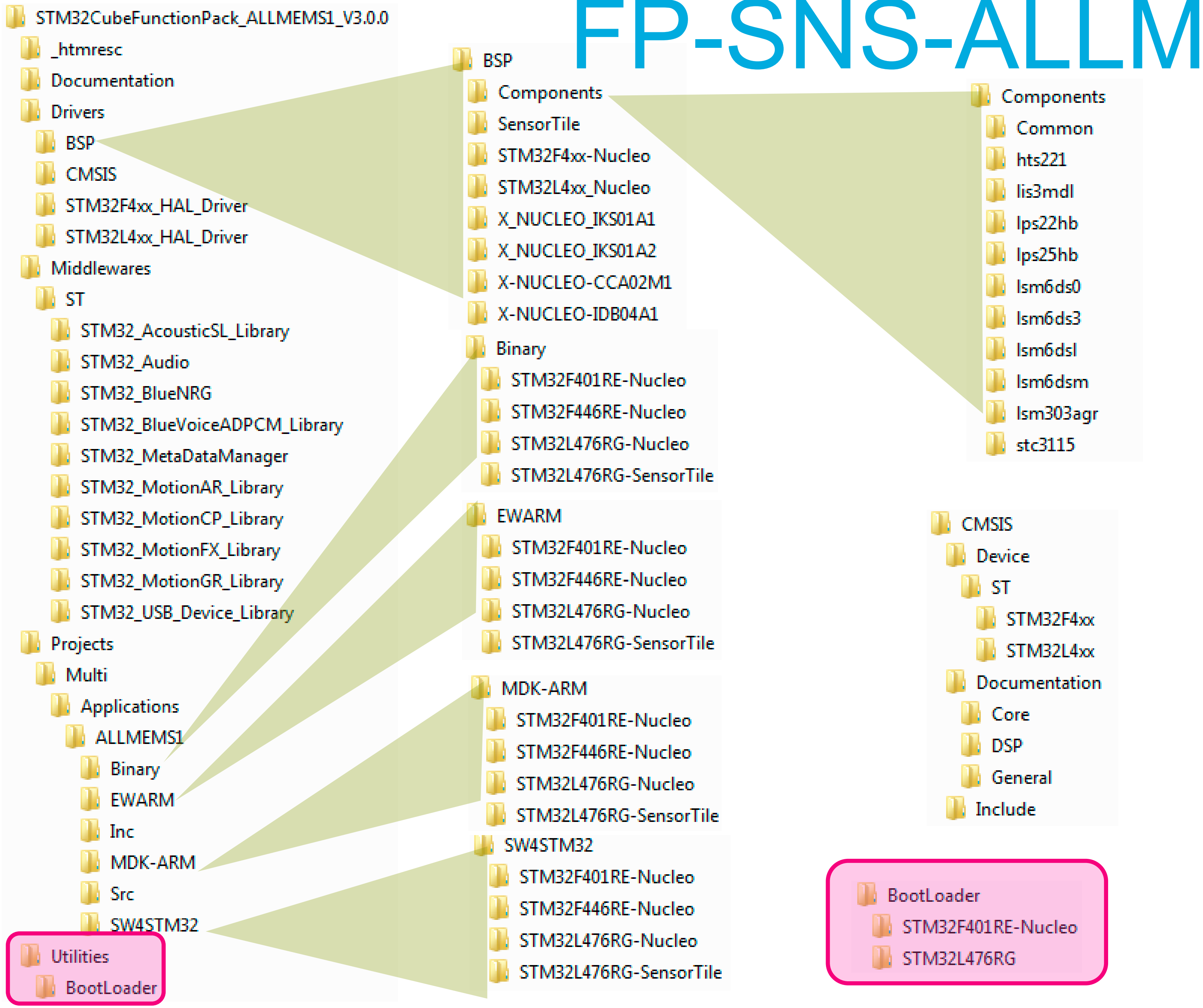
Application, flash at 0x0800 4000

- **AudioLoop.hex**
- **BLE_SampleApp.hex**
- **DataLog_SDCard.hex**
- **DataLog_USB.hex**

hex Intel format already includes the correct address
bin format requires the correct address to be specified

C:\ Program Files (x86) \STMicroelectronics \

FP-SNS-ALLMEMS1



- STM32CubeFunctionPack_ALLMEMS1_V3.0.0
  - _htmresc
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      - STM32_MotionFX_Library
      - STM32_MotionGR_Library
      - STM32_USB_Device_Library
  - Projects
    - Multi
      - Applications
        - ALLMEMS1
          - Binary
          - EWARM
          - Inc
          - MDK-ARM
          - Src
          - SW4STM32
  - Utilities
    - BootLoader

- BSP
  - Components
  - SensorTile
  - STM32F4xx-Nucleo
  - STM32L4xx_Nucleo
  - X_NUCLEO_IKS01A1
  - X_NUCLEO_IKS01A2
  - X-NUCLEO-CCA02M1
  - X-NUCLEO-IDB04A1

- Components
  - Common
  - hts221
  - lis3mdl
  - lps22hb
  - lps25hb
  - lsm6ds0
  - lsm6ds3
  - lsm6dsl
  - lsm6dsm
  - lsm303agr
  - stc3115

- Binary
  - STM32F401RE-Nucleo
  - STM32F446RE-Nucleo
  - STM32L476RG-Nucleo
  - STM32L476RG-SensorTile

- EWARM
  - STM32F401RE-Nucleo
  - STM32F446RE-Nucleo
  - STM32L476RG-Nucleo
  - STM32L476RG-SensorTile

- MDK-ARM
  - STM32F401RE-Nucleo
  - STM32F446RE-Nucleo
  - STM32L476RG-Nucleo
  - STM32L476RG-SensorTile

- SW4STM32
  - STM32F401RE-Nucleo
  - STM32F446RE-Nucleo
  - STM32L476RG-Nucleo
  - STM32L476RG-SensorTile

- CMSIS
  - Device
    - ST
      - STM32F4xx
      - STM32L4xx
  - Documentation
    - Core
    - DSP
    - General
  - Include

- BootLoader
  - STM32F401RE-Nucleo
  - STM32L476RG

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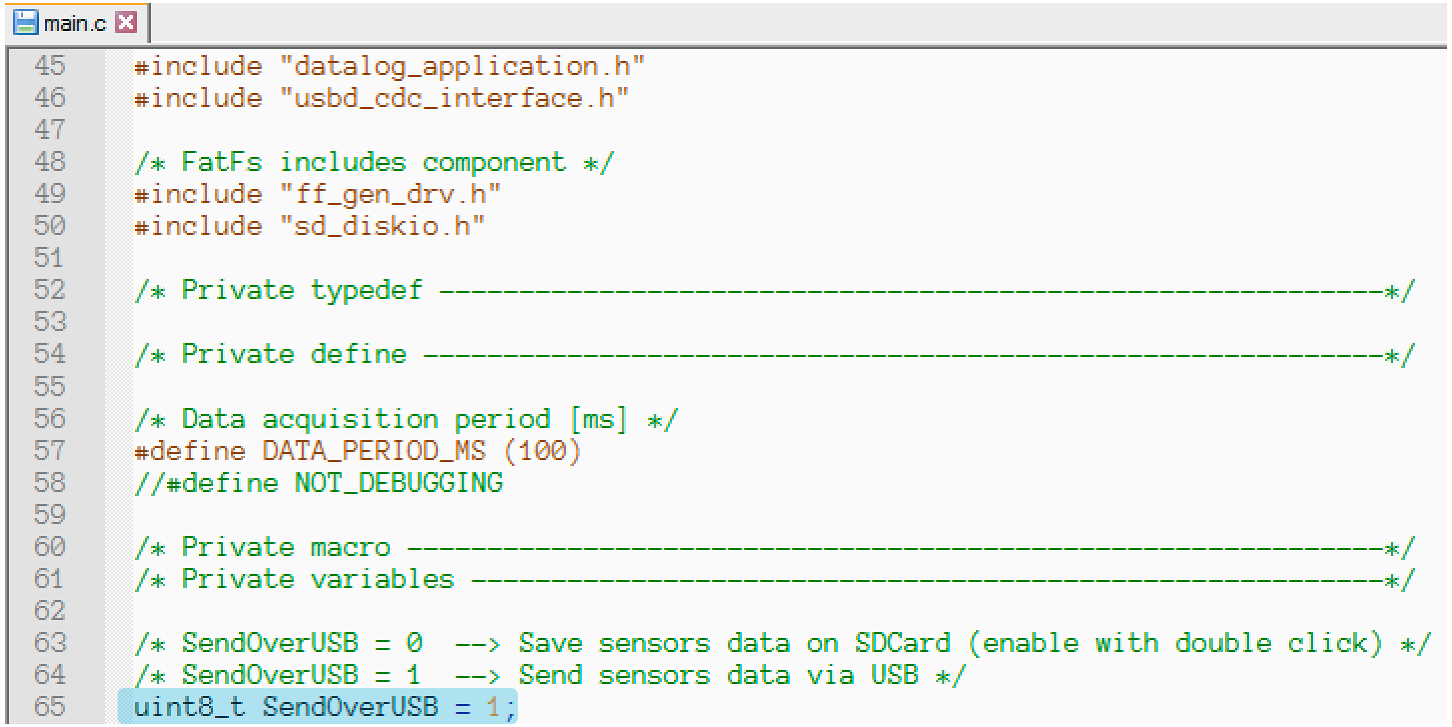
STSW-STLKT01, DataLog



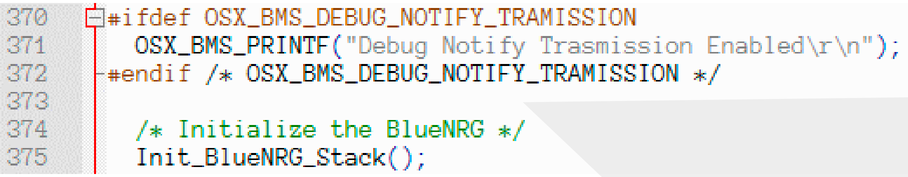
```c
#include "datalog_application.h"
#include "usbd_cdc_interface.h"

/* FatFs includes component */
#include "ff_gen_drv.h"
#include "sd_diskio.h"

/* Private typedef -----------------------------------------------------------*/

/* Private define ------------------------------------------------------------*/

/* Data acquisition period [ms] */
#define DATA_PERIOD_MS (100)
//#define NOT_DEBUGGING

/* Private macro -------------------------------------------------------------*/
/* Private variables ---------------------------------------------------------*/

/* SendOverUSB = 0  --> Save sensors data on SDCard (enable with double click) */
/* SendOverUSB = 1  --> Send sensors data via USB */
uint8_t SendOverUSB = 1;
```

In **main.c** you can choose where the log is sent: to SD card or USB port

FP-SNS-ALLMEMS1

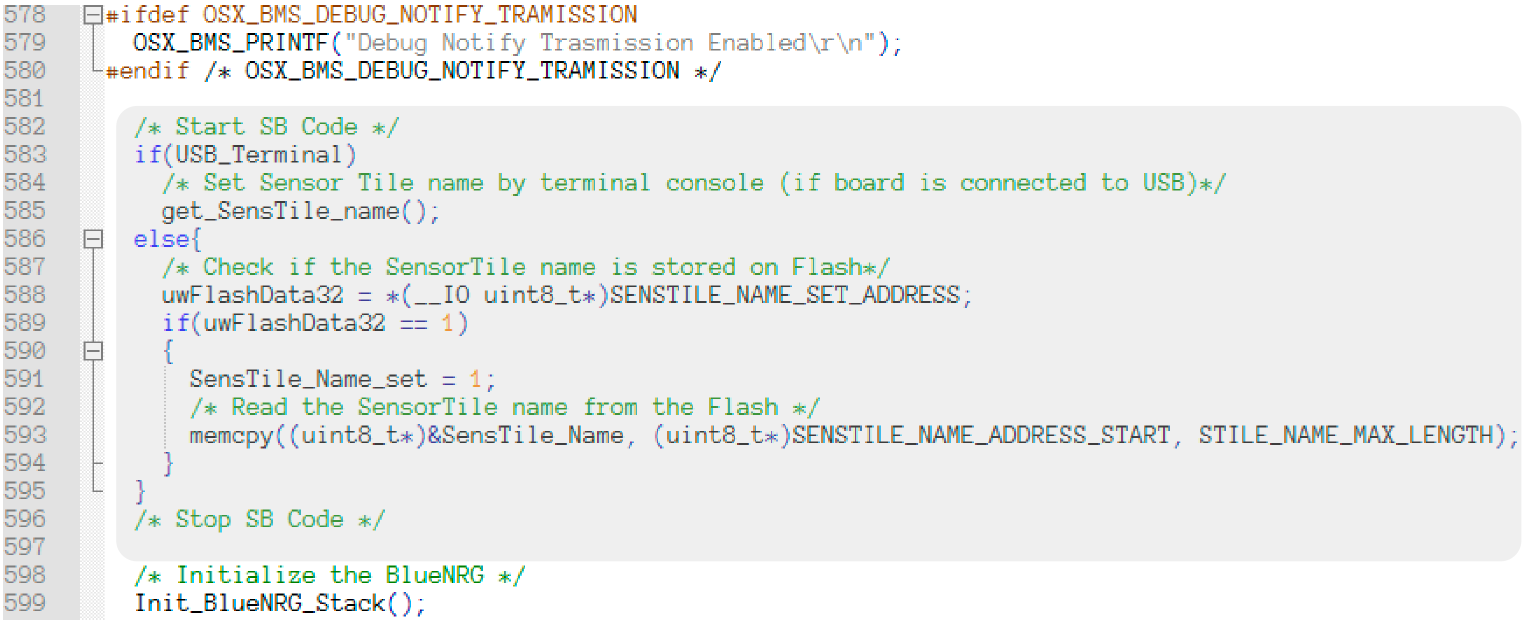
If USB is connected, the firmware asks the user if the device name is to be set (y/n?).
If no answer is given, at the timeout (15 sec), the existing name is kept.

BLUEMICROSYSTEM2



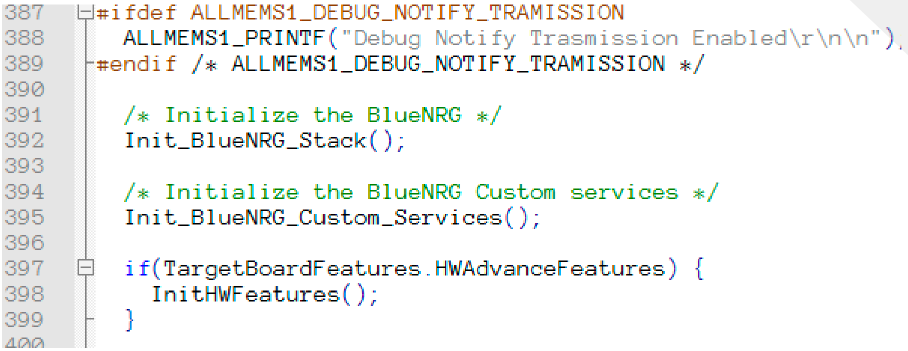
```
#ifdef OSX_BMS_DEBUG_NOTIFY_TRAMISSION
  OSX_BMS_PRINTF("Debug Notify Trasmission Enabled\r\n");
#endif /* OSX_BMS_DEBUG_NOTIFY_TRAMISSION */

  /* Initialize the BlueNRG */
  Init_BlueNRG_Stack();
```

BLUEMICROSYSTEM2 modified



```
#ifdef OSX_BMS_DEBUG_NOTIFY_TRAMISSION
  OSX_BMS_PRINTF("Debug Notify Trasmission Enabled\r\n");
#endif /* OSX_BMS_DEBUG_NOTIFY_TRAMISSION */

  /* Start SB Code */
  if(USB_Terminal)
    /* Set Sensor Tile name by terminal console (if board is connected to USB)*/
    get_SensTile_name();
  else{
    /* Check if the SensorTile name is stored on Flash*/
    uwFlashData32 = *(__IO uint8_t*)SENSTILE_NAME_SET_ADDRESS;
    if(uwFlashData32 == 1)
    {
      SensTile_Name_set = 1;
      /* Read the SensorTile name from the Flash */
      memcpy((uint8_t*)&SensTile_Name, (uint8_t*)SENSTILE_NAME_ADDRESS_START, STILE_NAME_MAX_LENGTH);
    }
  }
  /* Stop SB Code */

  /* Initialize the BlueNRG */
  Init_BlueNRG_Stack();
```

FP-SNS-ALLMEMS1



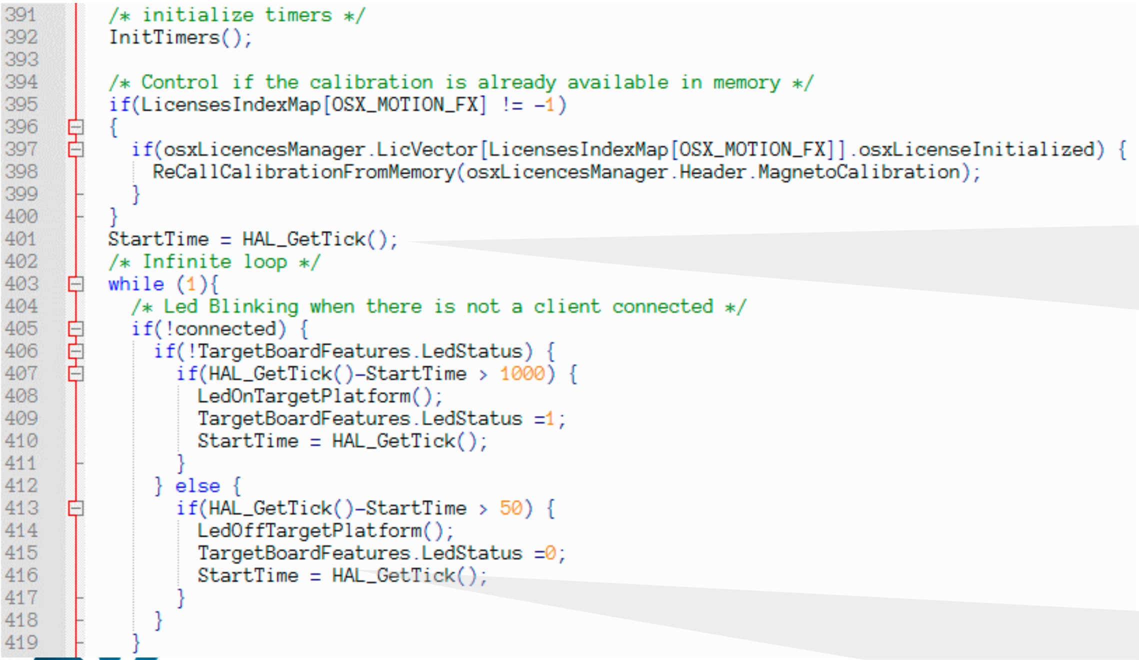
```
#ifdef ALLMEMS1_DEBUG_NOTIFY_TRAMISSION
  ALLMEMS1_PRINTF("Debug Notify Trasmission Enabled\r\n\n");
#endif /* ALLMEMS1_DEBUG_NOTIFY_TRAMISSION */

  /* Initialize the BlueNRG */
  Init_BlueNRG_Stack();

  /* Initialize the BlueNRG Custom services */
  Init_BlueNRG_Custom_Services();

  if(TargetBoardFeatures.HWAdvanceFeatures) {
    InitHWFeatures();
  }
```

life.augmented

FP-SNS-ALLMEMS1

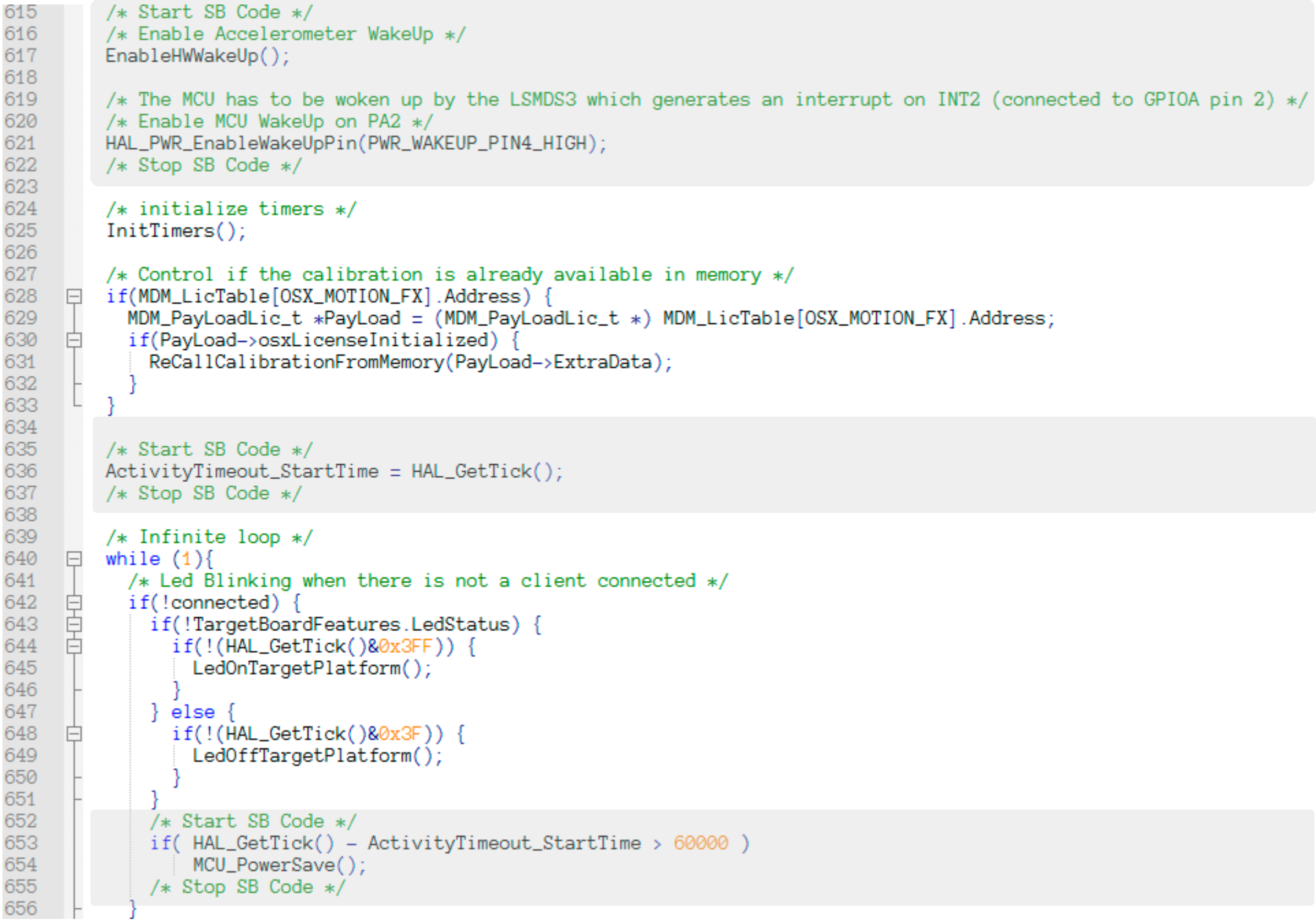
After 1 minute of inertial inactivity, the system goes into power save mode.
Any inertial activity will wake-up the system again (all other wake-up pins are disabled).

FP-SNS-ALLMEMS1



```
/* initialize timers */
InitTimers();

/* Control if the calibration is already available in memory */
if(LicensesIndexMap[OSX_MOTION_FX] != -1)
{
  if(osxLicencesManager.LicVector[LicensesIndexMap[OSX_MOTION_FX]].osxLicenseInitialized) {
    ReCallCalibrationFromMemory(osxLicencesManager.Header.MagnetoCalibration);
  }
}
StartTime = HAL_GetTick();
/* Infinite loop */
while (1){
  /* Led Blinking when there is not a client connected */
  if(!connected) {
    if(!TargetBoardFeatures.LedStatus) {
      if(HAL_GetTick()-StartTime > 1000) {
        LedOnTargetPlatform();
        TargetBoardFeatures.LedStatus =1;
        StartTime = HAL_GetTick();
      }
    } else {
      if(HAL_GetTick()-StartTime > 50) {
        LedOffTargetPlatform();
        TargetBoardFeatures.LedStatus =0;
        StartTime = HAL_GetTick();
      }
    }
  }
```

FP-SNS-ALLMEMS1 modified



```
/* Start SB Code */
/* Enable Accelerometer WakeUp */
EnableHWWakeUp();

/* The MCU has to be woken up by the LSMDS3 which generates an interrupt on INT2 (connected to GPIOA pin 2) */
/* Enable MCU WakeUp on PA2 */
HAL_PWR_EnableWakeUpPin(PWR_WAKEUP_PIN4_HIGH);
/* Stop SB Code */

/* initialize timers */
InitTimers();

/* Control if the calibration is already available in memory */
if(MDM_LicTable[OSX_MOTION_FX].Address) {
  MDM_PayLoadLic_t *PayLoad = (MDM_PayLoadLic_t *) MDM_LicTable[OSX_MOTION_FX].Address;
  if(PayLoad->osxLicenseInitialized) {
    ReCallCalibrationFromMemory(PayLoad->ExtraData);
  }
}

/* Start SB Code */
ActivityTimeout_StartTime = HAL_GetTick();
/* Stop SB Code */

/* Infinite loop */
while (1){
  /* Led Blinking when there is not a client connected */
  if(!connected) {
    if(!TargetBoardFeatures.LedStatus) {
      if(!(HAL_GetTick()&0x3FF)) {
        LedOnTargetPlatform();
      }
    } else {
      if(!(HAL_GetTick()&0x3F)) {
        LedOffTargetPlatform();
      }
    }
    /* Start SB Code */
    if( HAL_GetTick() - ActivityTimeout_StartTime > 60000 )
      MCU_PowerSave();
    /* Stop SB Code */
  }
```

X-CUBE-MEMSMIC1 / FP-AUD-…

- Fusion libraries are distributed as binaries, with example source code on how to use them.
- A free license is granted.
- They can run on every STM32 microcontroller.

open.AUDIO

X-CUBE-MEMSMIC1 / FP-AUD-…

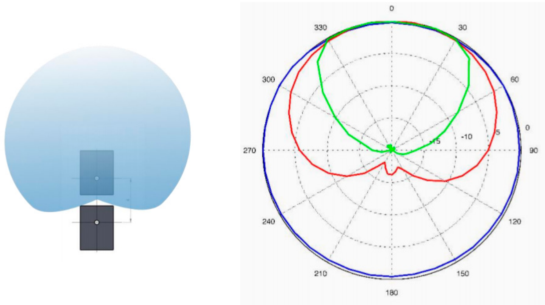
Fusion libraries are distributed as binaries, with example source code on how to use them.

A free license is granted. They can run on every STM32 microcontroller.

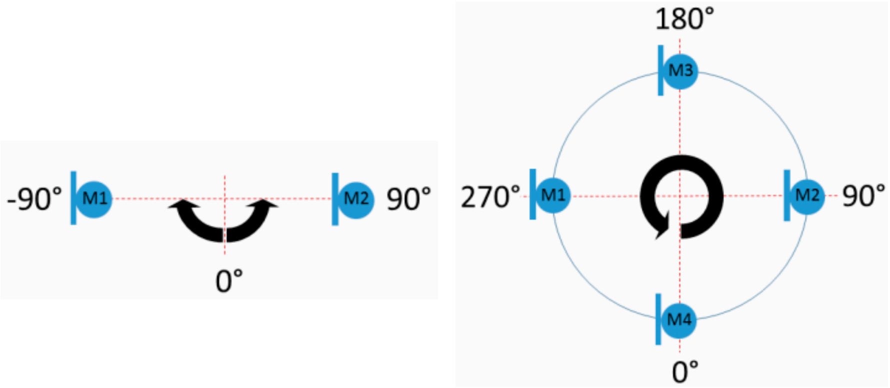
- **BlueVoice** (in FP-AUD-BVLINK1) voice streaming over BLE (needs 1 digital microphone, 8kHz PCM, ADPCM compression)

- **AcousticBF** (in X-CUBE-MEMSMIC1) beam-forming (needs 2 digital mic, cardiod or narrow cardiod, denoise optional filter)
- **AcousticSL** (in X-CUBE-MEMSMIC1) sound source localization (needs 2/4 mic for 180/360 deg range, three DOA algo)
- **AcousticEC** (in FP-AUD-SMARTMIC1) echo cancellation (adaptive filter to subtract noise-ref signal, SPEEX MDF algo)

BEAMFORMING
omnidir, cardiod, narrow cardiod



SOURCE LOCALIZATION
2 mic 180deg, 4 mic 360 deg



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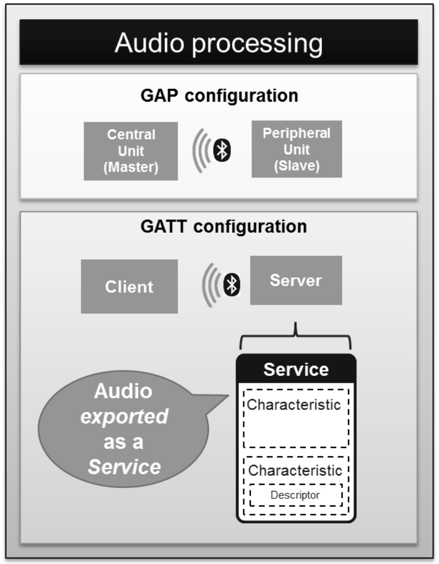
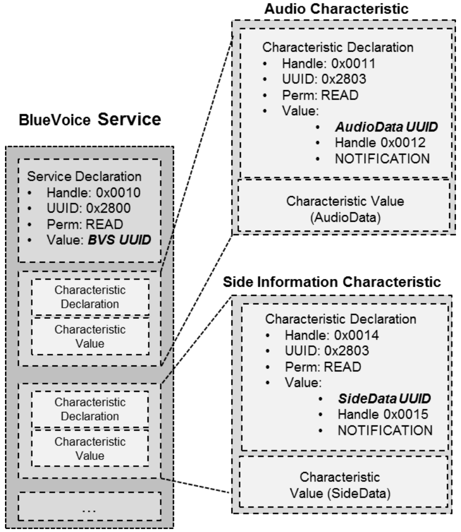
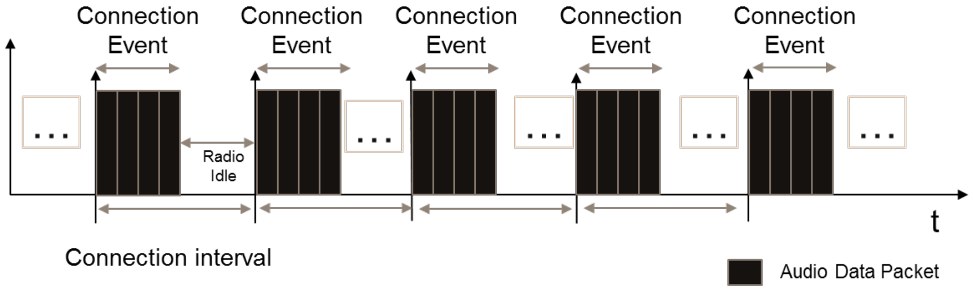




(details on BlueVoice
in the next few slides)



X-CUBE-MEMSMIC1 / FP-AUD-…

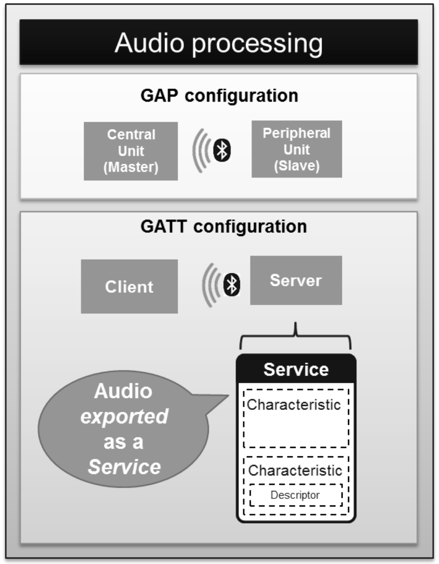
Fusion libraries are distributed as binaries, with example source code on how to use them.

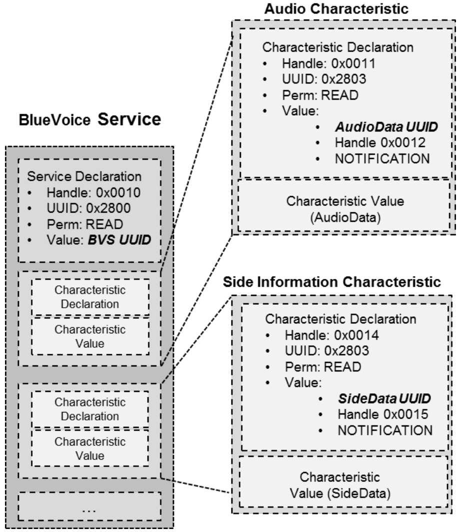
A free license is granted. They can run on every STM32 microcontroller.

This library is included in the **FP-AUD-BVLINK1** and in the **FP-SNS-ALLMEMS1** software package.

- **BlueVoice** (in FP-AUD-BVLINK1) voice streaming over BLE (needs 1 digital microphone, 8kHz PCM, ADPCM compression)

- AcousticBF (in X-CUBE-MEMSMIC1) beam-forming (needs 2 digital mic, cardiod or narrow cardiod, denoise optional filter)
- AcousticSL (in X-CUBE-MEMSMIC1) sound source localization (needs 2/4 mic for 180/360 deg range, three DOA algo)
- AcousticEC (in FP-AUD-SMARTMIC1) echo cancellation (adaptive filter to subtract noise-ref signal, SPEEX MDF algo)





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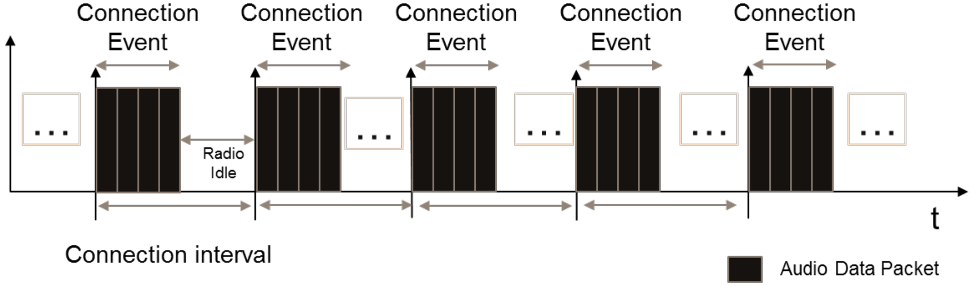

Function Packages

ODE software package (Open Development Environment – src code)		With fusion libraries (bin libraries)
X-CUBE-MEMS1	MEMS sensors: motion + environ	All libraries
X-CUBE-BLE1	BLE: Bluetooth Low Energy	
FP-SNS-MOTENV1	BLE + MEMS	FX, AR, CP, GR, PM
FP-SNS-ALLMEMS1	BLE + MEMS + digital microphone	FX, AR, CP, GR, BlueVoice
FP-SNS-FLIGHT1	BLE + MEMS + Time of Flight + NFC	FX, AR, CP, GR, GR-ToF
FP-AUD-BVLINK1	BLE + digital microphone	BlueVoice
FP-NET-BLESTAR1	BLE + MEMS + WiFi	

open.MEMS
open.AUDIO

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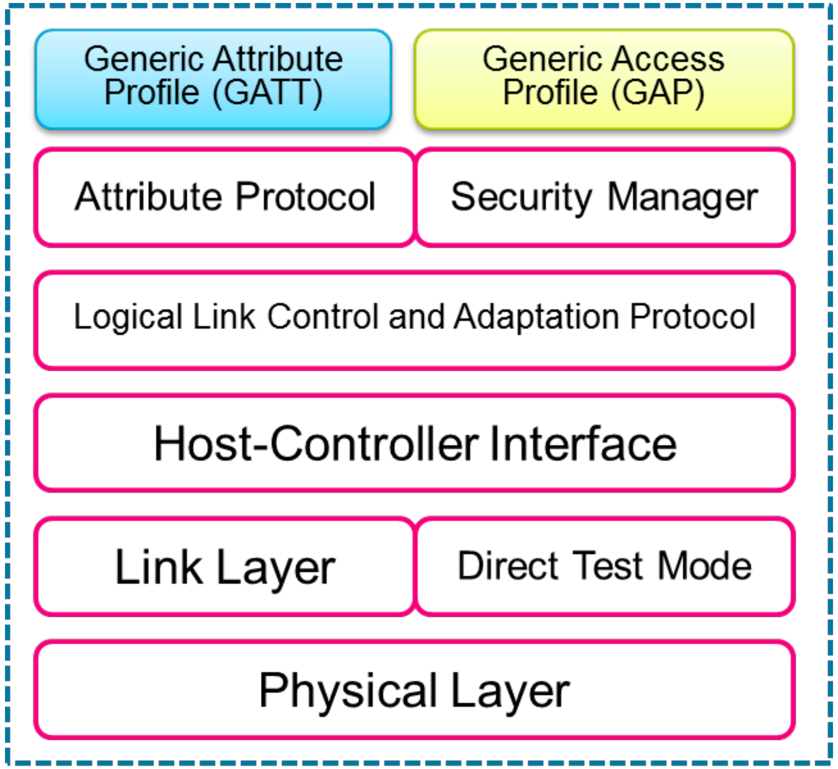
BlueVoice: voice over Bluetooth LE


Generic Attribute Profile (GATT)
Generic Access Profile (GAP)
Attribute Protocol
Security Manager
Logical Link Control and Adaptation Protocol
Host-Controller Interface
Link Layer
Direct Test Mode
Physical Layer

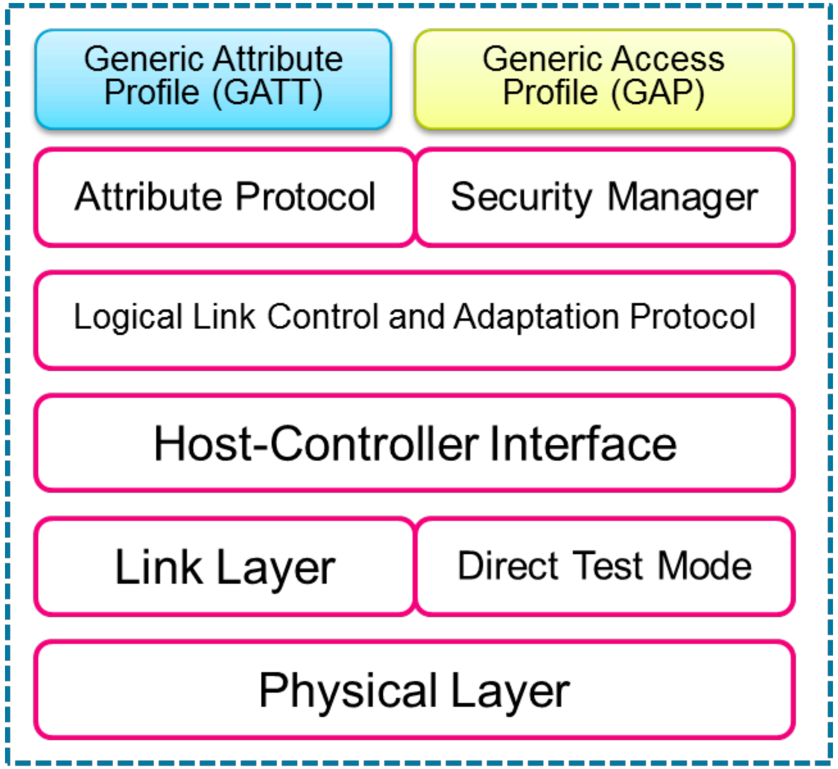
Bluetooth Low Energy Stack

GAP: who controls the connection

GATT: who generates the data

GAP and GATT roles are independent.

BlueVoice: voice over Bluetooth LE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Attribute Protocol
Security Manager
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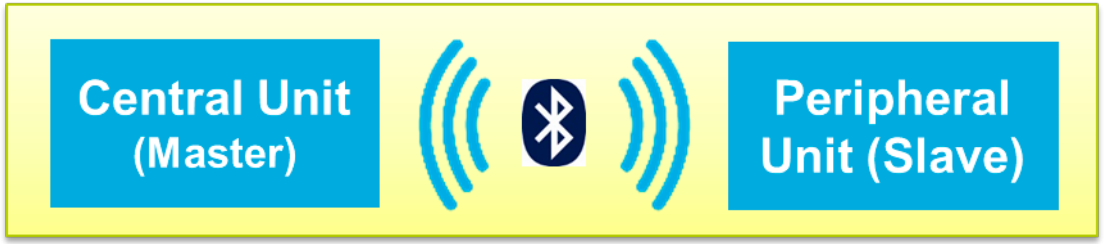
Host-Controller Interface
Link Layer
Direct Test Mode
Physical Layer

Bluetooth Low Energy Stack

GAP: who controls the connection

GATT: who generates the data



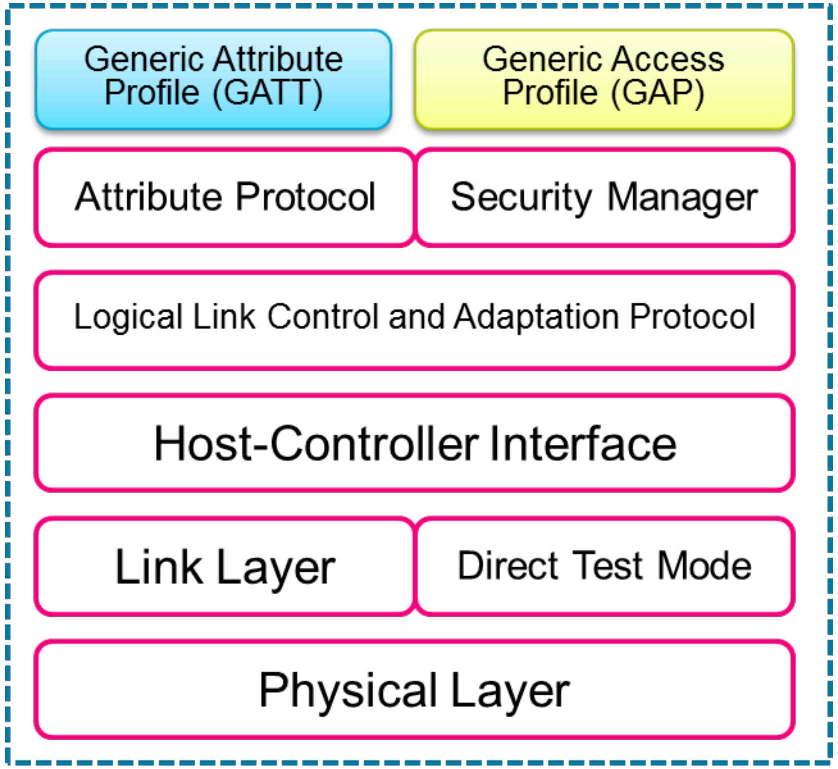
Master/Central

- Scan for advertise packets
- Initiate connection, set conn. parameters and impose timing

Slave/Peripheral

- Broadcast advertise packets
- Follow master timing

BlueVoice: voice over Bluetooth LE


Generic Attribute Profile (GATT)

Generic Access Profile (GAP)

Attribute Protocol

Security Manager

Logical Link Control and Adaptation Protocol

Host-Controller Interface

Link Layer

Direct Test Mode

Physical Layer

Bluetooth Low Energy Stack

GAP: who controls the connection

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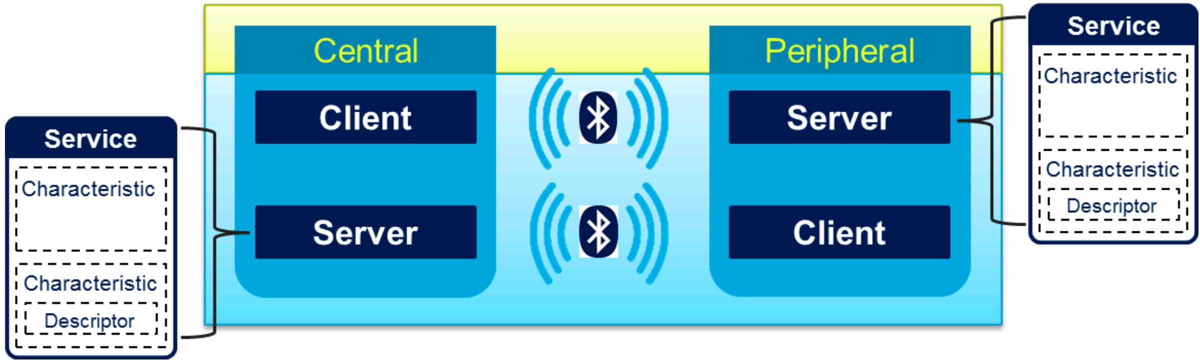
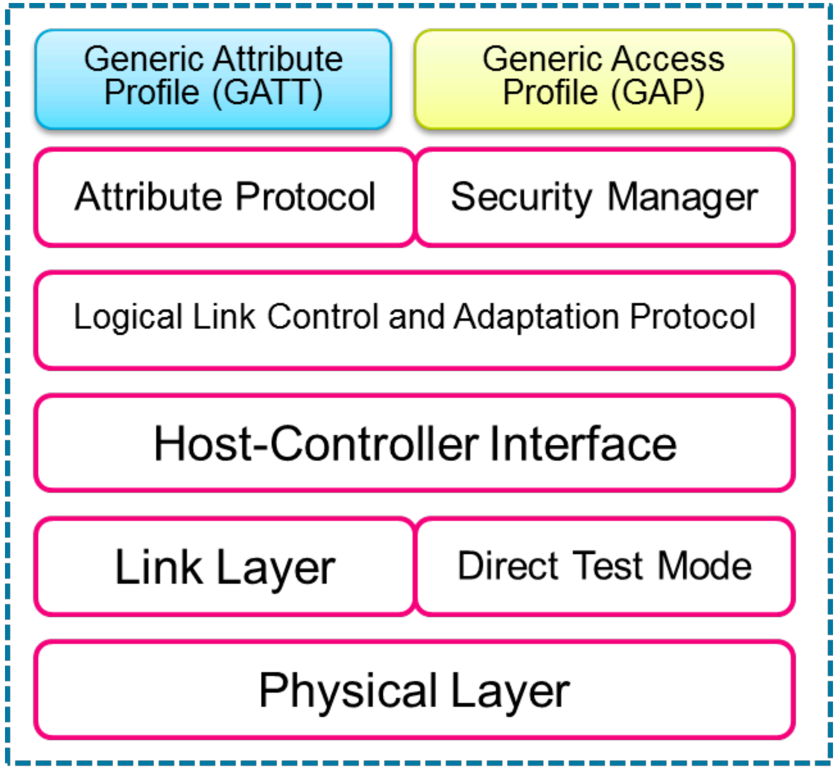


Master/Central
- Can be client
- Can be server
- Can be both

Slave/Peripheral
- Can be client
- Can be server
- Can be both

BlueVoice: voice over Bluetooth LE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Bluetooth Low Energy Stack

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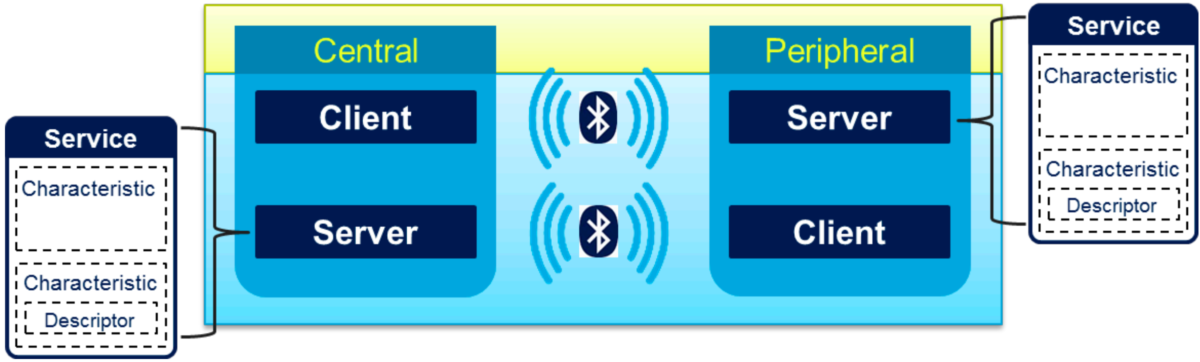

Client

- Browse remote data, “attributes”
- Send requests to pull data from the server
- May receive “notifications”

Server

- Has data organized as “attributes”
- Respond to client requests
- May send automatic updates “notifications”

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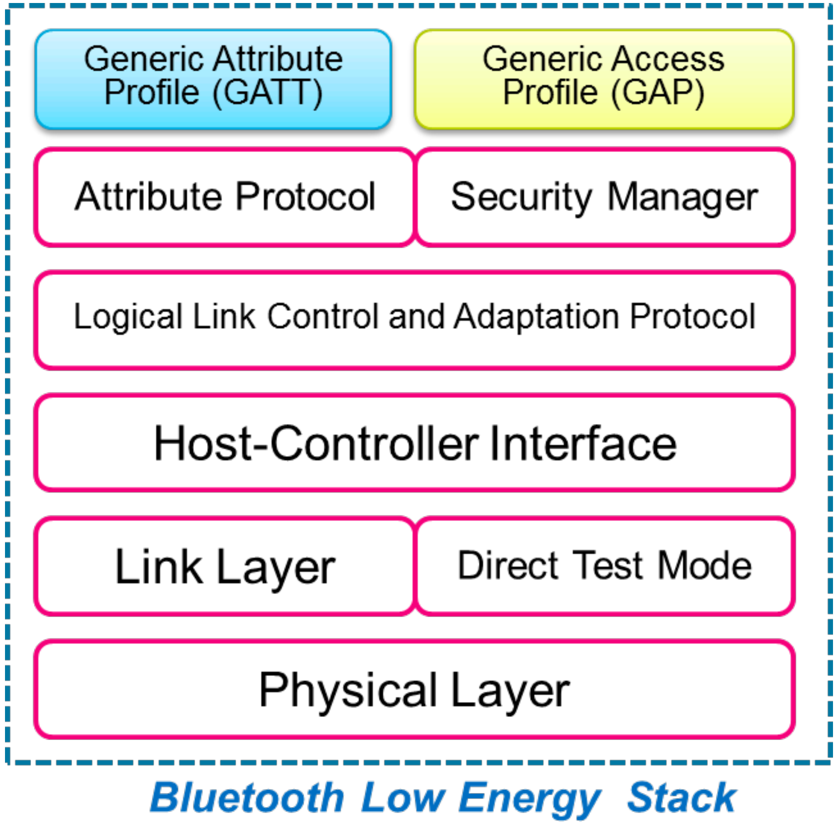
BlueVoice: voice over Bluetooth LE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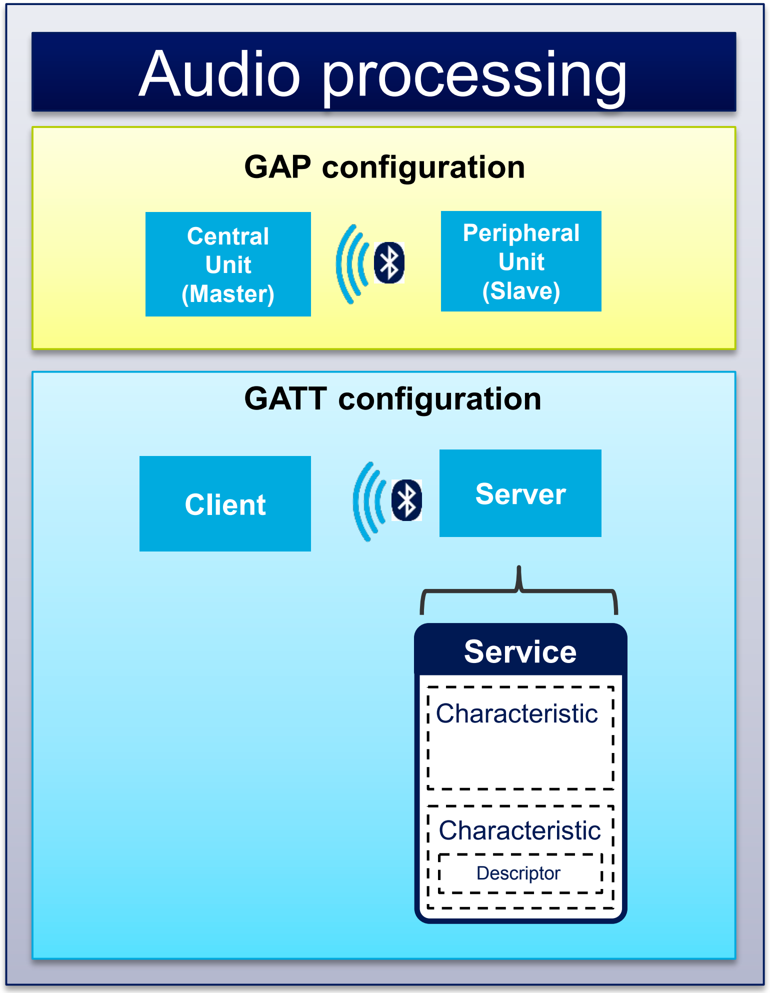
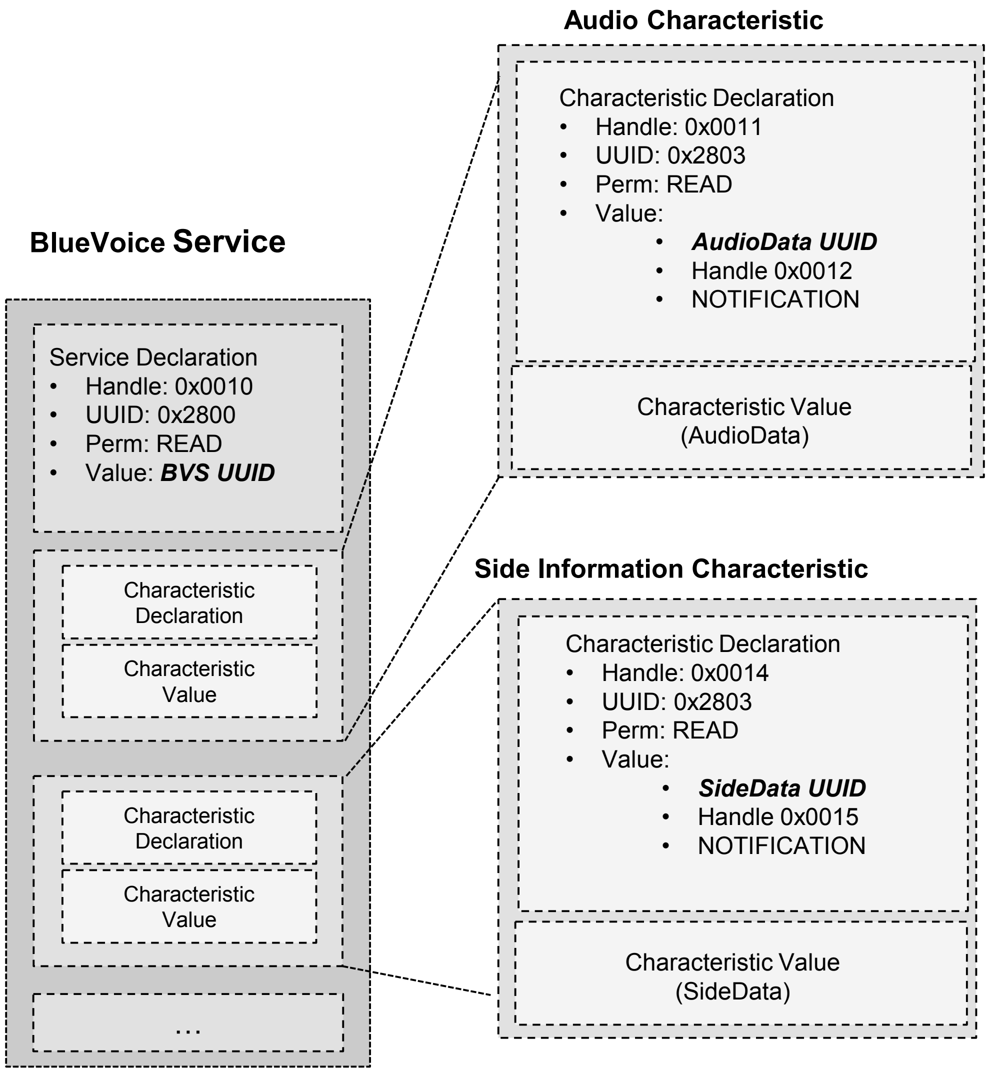


Audio is exported by the Server as a “service”

BlueVoice: voice over Bluetooth LE



BlueVoice Service

Service Declaration
- Handle: 0x0010
- UUID: 0x2800
- Perm: READ
- Value: ***BVS UUID***

Characteristic Declaration

Characteristic Value

Characteristic Declaration

Characteristic Value

…

Audio Characteristic

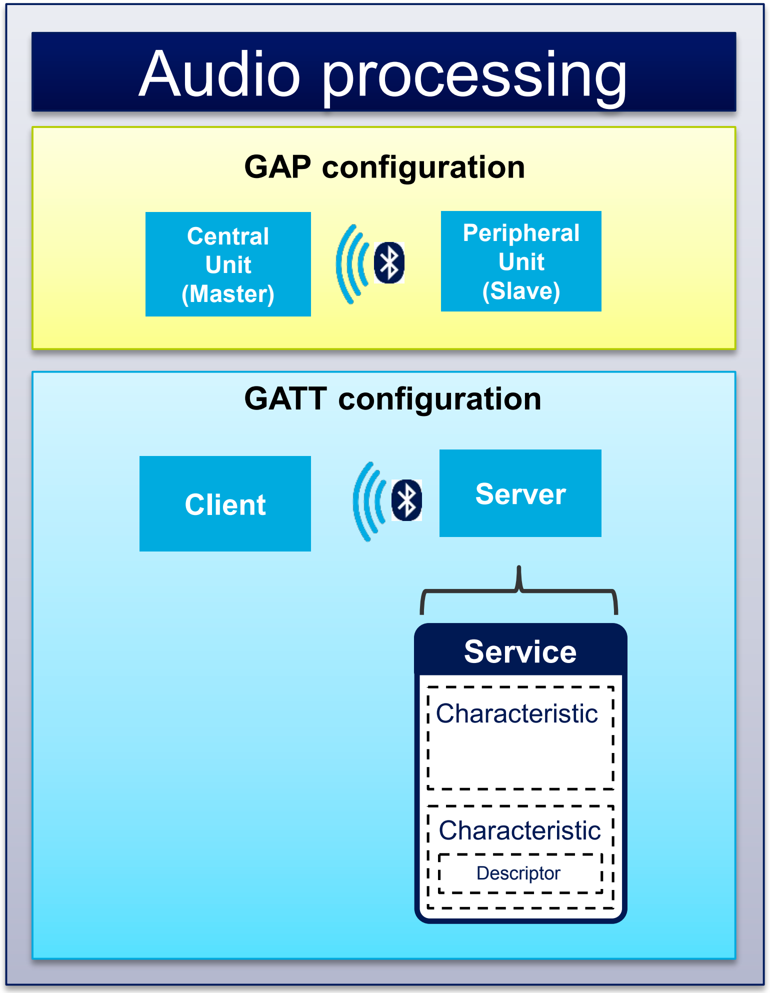
Characteristic Declaration
- Handle: 0x0011
- UUID: 0x2803
- Perm: READ
- Value:
  - ***AudioData UUID***
  - Handle 0x0012
  - NOTIFICATION

Characteristic Value (AudioData)

Side Information Characteristic

Characteristic Declaration
- Handle: 0x0014
- UUID: 0x2803
- Perm: READ
- Value:
  - ***SideData UUID***
  - Handle 0x0015
  - NOTIFICATION

Characteristic Value (SideData)



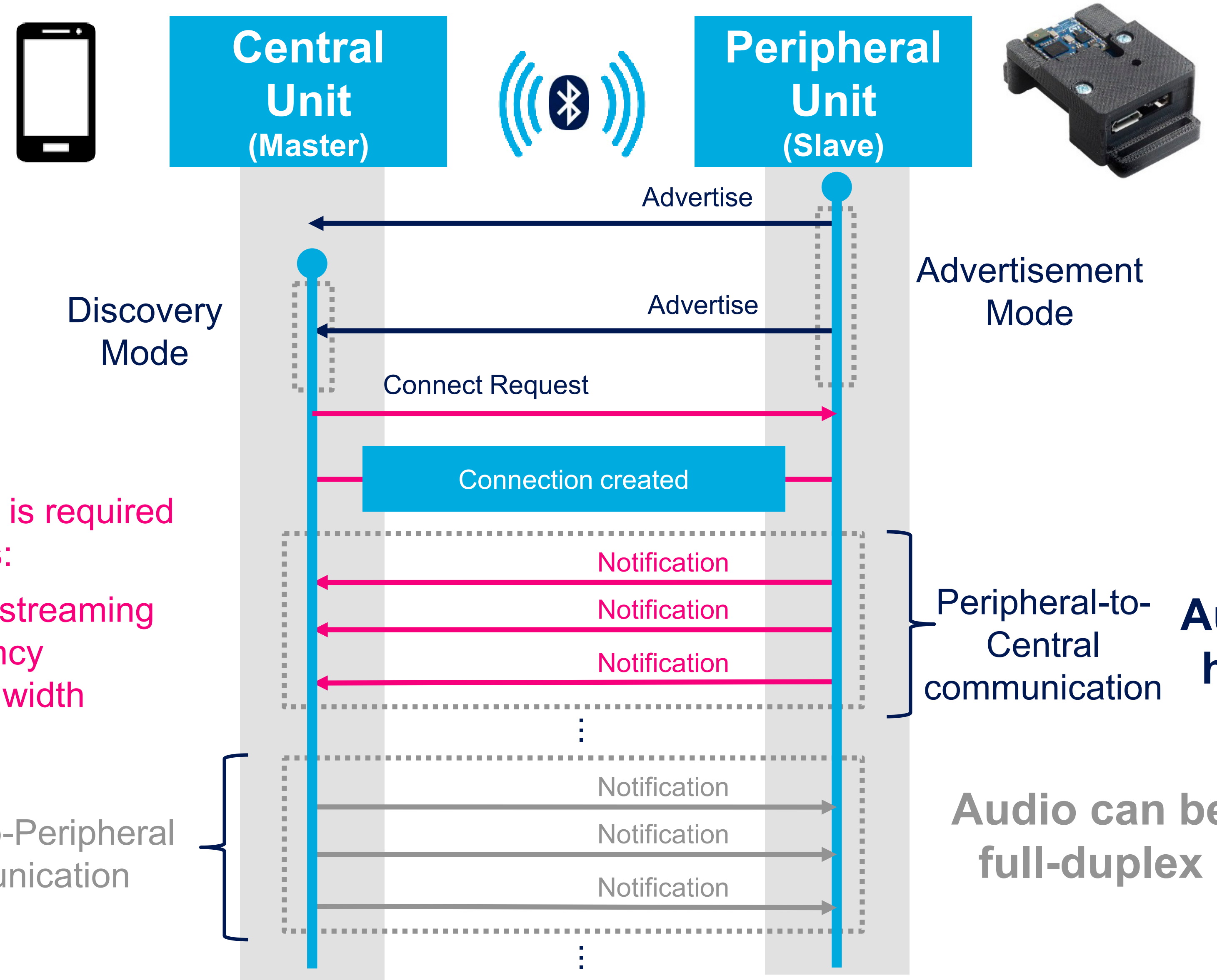
Audio processing

GAP configuration

GATT configuration

Audio is exported by the Server as a “service”

BlueVoice: voice over Bluetooth LE



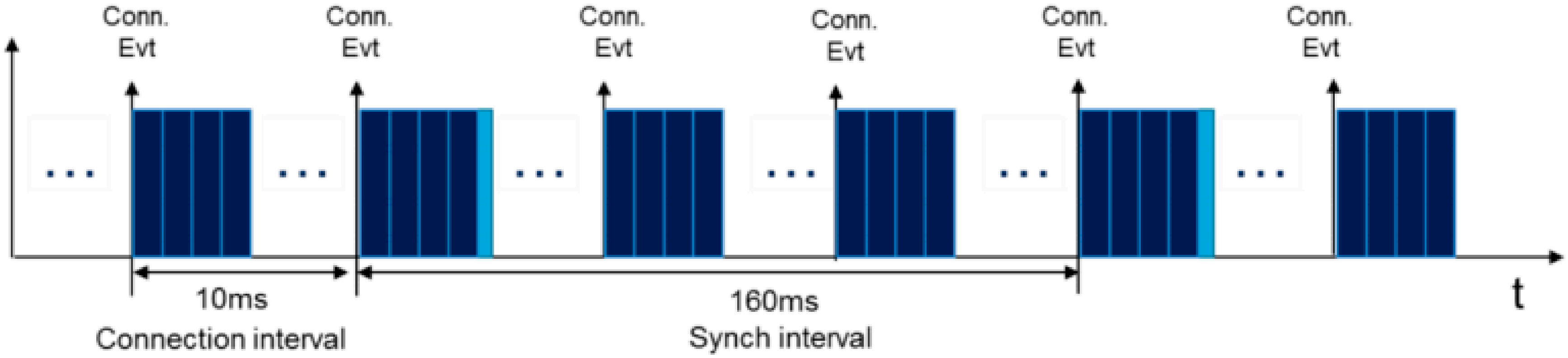
No acknowledge is required for **Notifications**:

- OK for Audio streaming
- Minimal Latency
- Optimal Bandwidth

Audio can be half-duplex

Audio can be full-duplex

BlueVoice: voice over Bluetooth LE

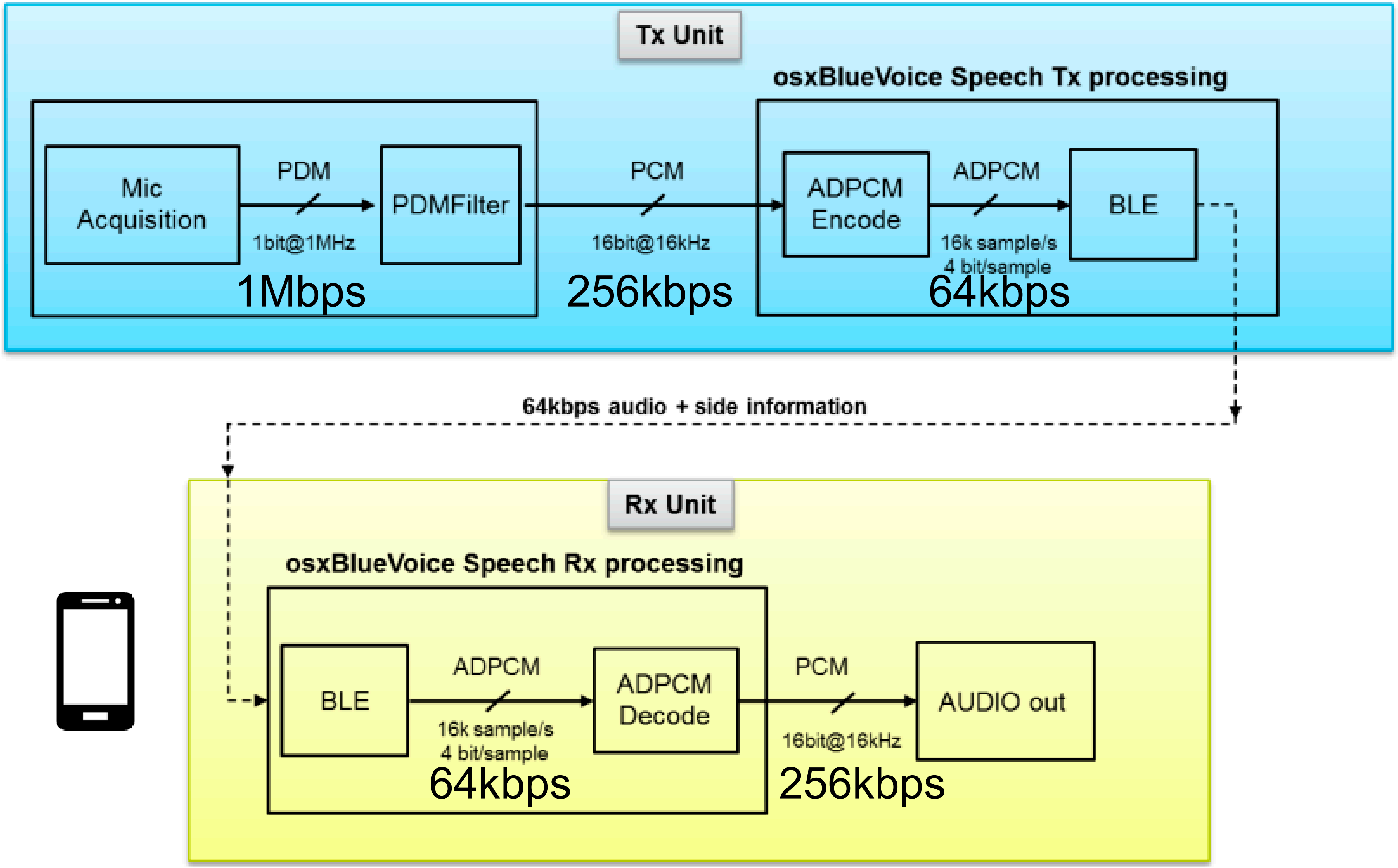


■ Audio Data Packet
- Len: 20 Bytes
- Handle: Audio Data Handle

■ Sync Data Packet
- Len: 6 Bytes
- Handle: SyncData Handle

4 packets/event
20 bytes/packets
100 events/sec
=
64kbps

BlueVoice: voice over Bluetooth LE



PDM to PCM library
+
ADPCM library
(encode)

ADPCM library
(decode)

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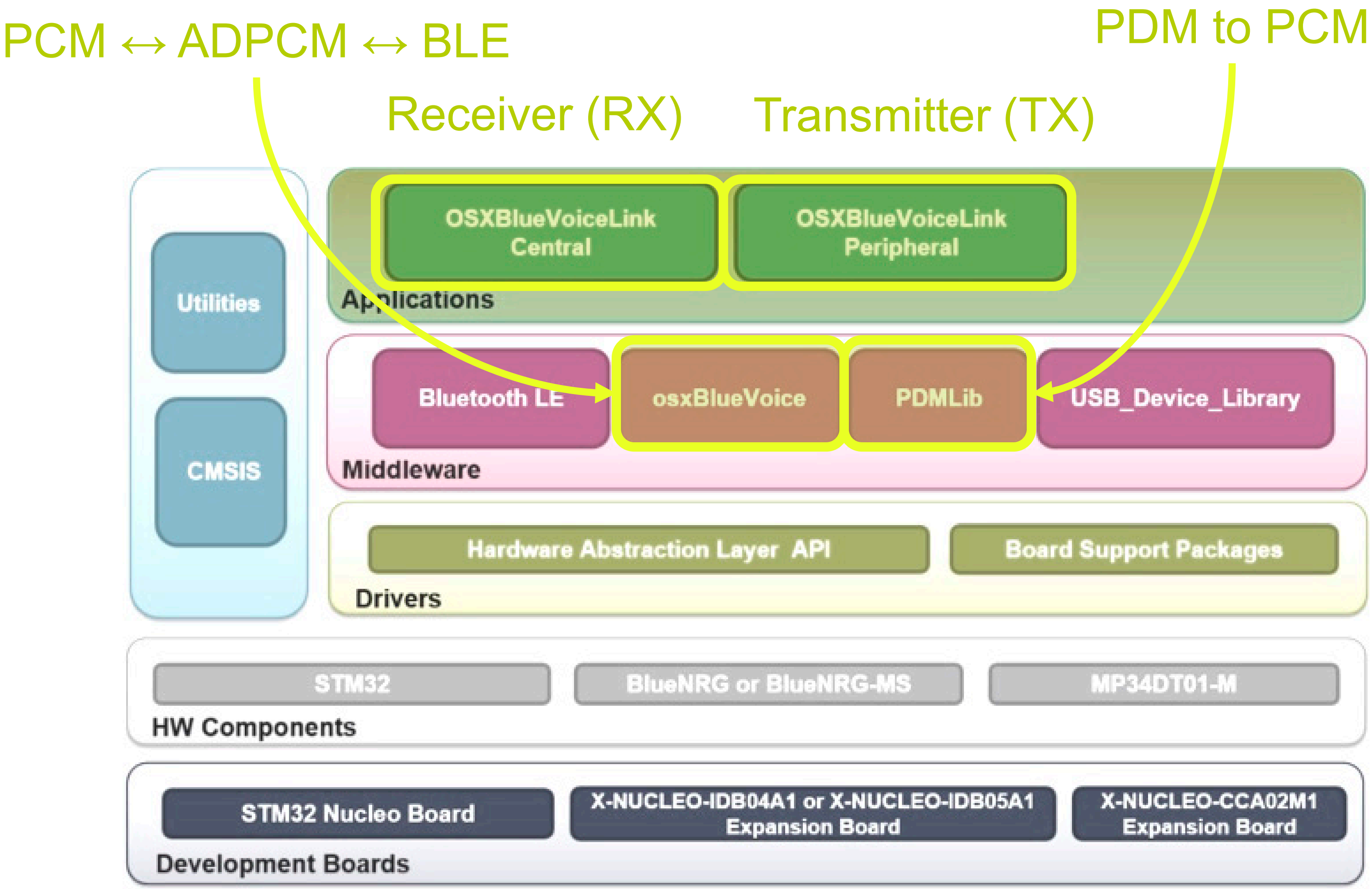
BlueVoice: voice over Bluetooth LE



Application

ST and 3rd party libraries

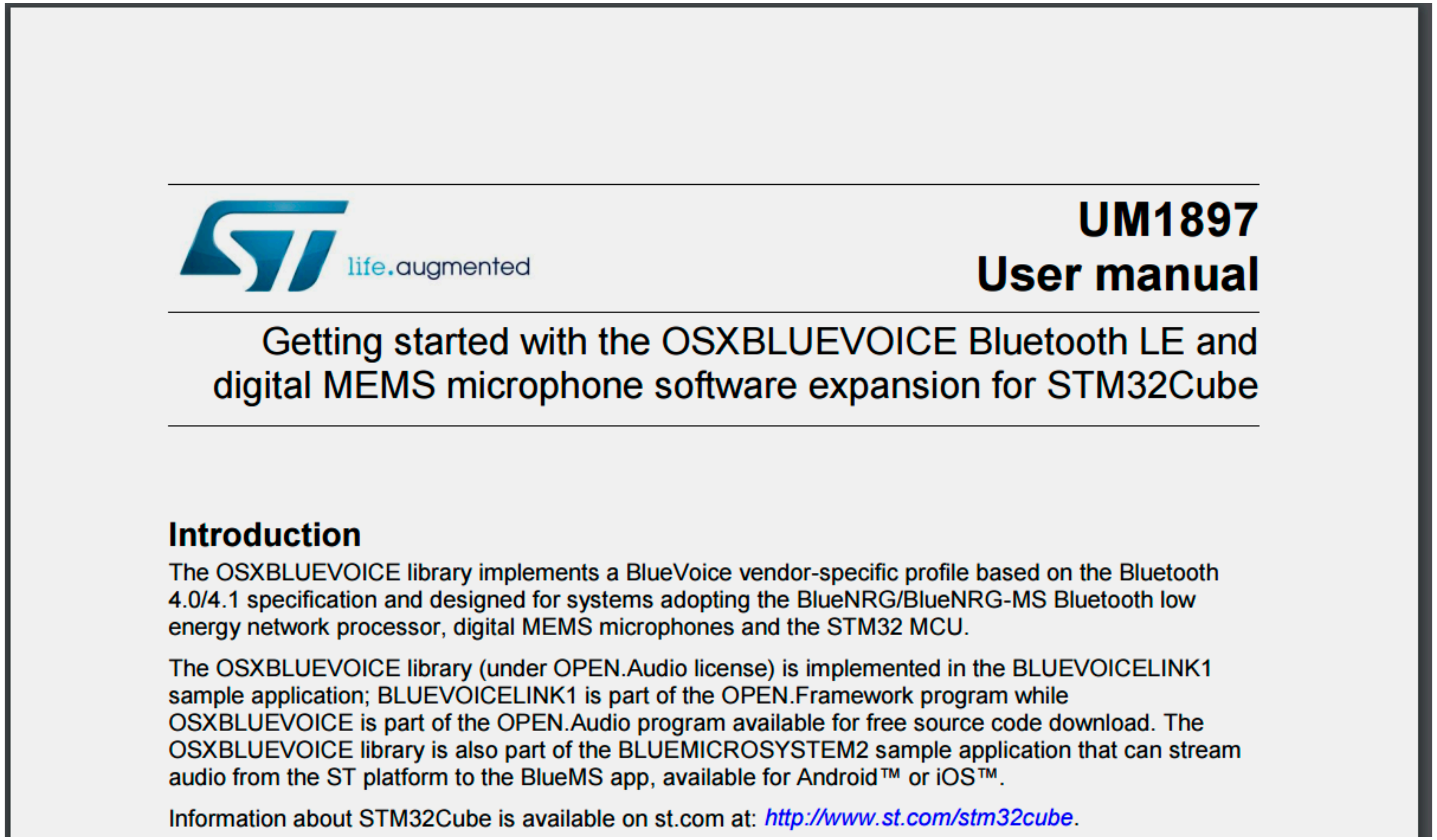
HAL and BSP

Components

Boards

BlueVoice: voice over Bluetooth LE

www.st.com/bluevoice



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UM1897
User manual

Getting started with the OSXBLUEVOICE Bluetooth LE and digital MEMS microphone software expansion for STM32Cube

Introduction

The OSXBLUEVOICE library implements a BlueVoice vendor-specific profile based on the Bluetooth 4.0/4.1 specification and designed for systems adopting the BlueNRG/BlueNRG-MS Bluetooth low energy network processor, digital MEMS microphones and the STM32 MCU.

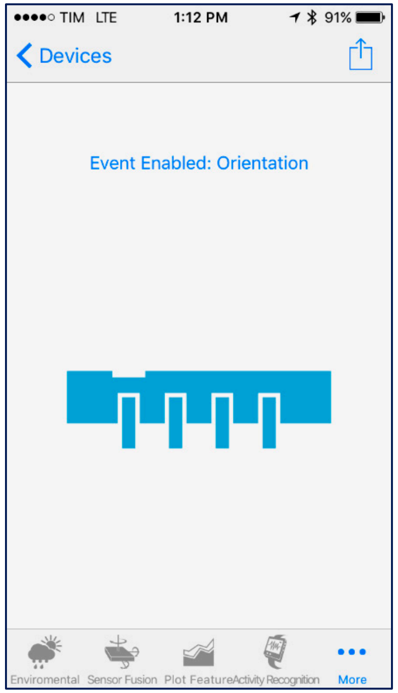
The OSXBLUEVOICE library (under OPEN.Audio license) is implemented in the BLUEVOICELINK1 sample application; BLUEVOICELINK1 is part of the OPEN.Framework program while OSXBLUEVOICE is part of the OPEN.Audio program available for free source code download. The OSXBLUEVOICE library is also part of the BLUEMICROSYSTEM2 sample application that can stream audio from the ST platform to the BlueMS app, available for Android™ or iOS™.

Information about STM32Cube is available on st.com at: *http://www.st.com/stm32cube*.

LAB7: Voice over Bluetooth LE

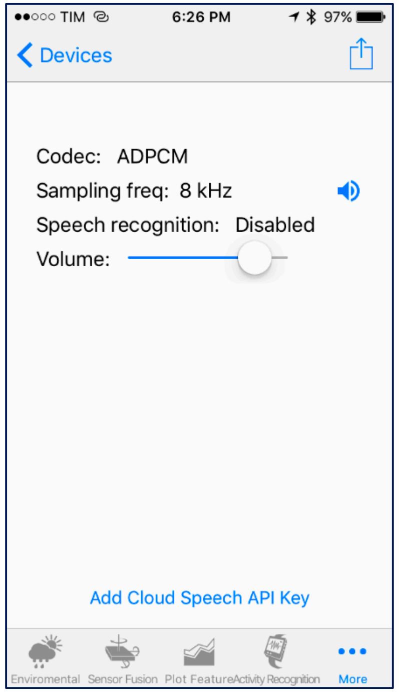
Do not silence your phone,
must not be vibration only!

Swipe left view the SensorTile Voice over BLE feature



Event Enabled: Orientation

Speak to device, hear on phone



Codec: ADPCM

Sampling freq: 8 kHz

Speech recognition: Disabled

Volume:

LAB

Speak into the SensorTile mic and listen to your phone
(if the mic captures the audio from the phone speaker, a very high pitch sound can happen!)

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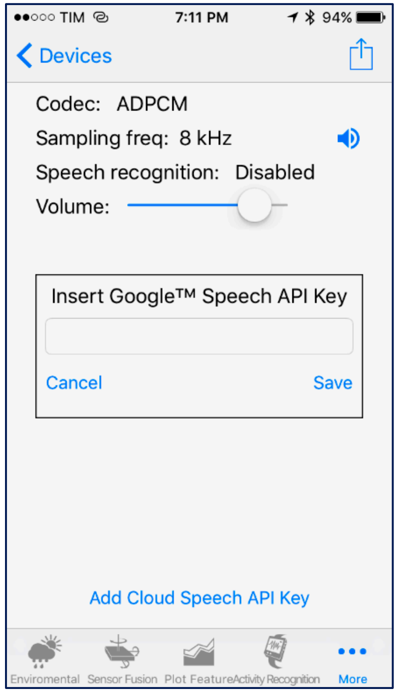
LAB8: Cloud Base ASR with Sensortile

Cloud Based Automatic Speech Recognition

- Goal:
    - Install Google Speech API credential in the sensortile
    - Use Google Speech with sensortile



Codec: ADPCM

Sampling freq: 8 kHz

Speech recognition: Disabled

Volume:

1. Login with your Gmail account
2. Join **Chromium-Dev** in https://groups.google.com
3. Go to https://console.developers.google.com
4. Create a project and open it
5. From the dashboard select “Speech” API
6. Create API key credential

To delete the API key,
delete and reinstall the app

LAB8: Cloud Base ASR with Sensortile

Google speech ASR Key generation

- The Google Speech APIs require a key to access the web-based service. You need a Google account to complete the procedure and access the service.

- Pre-requisite:
  - □ Have a google account

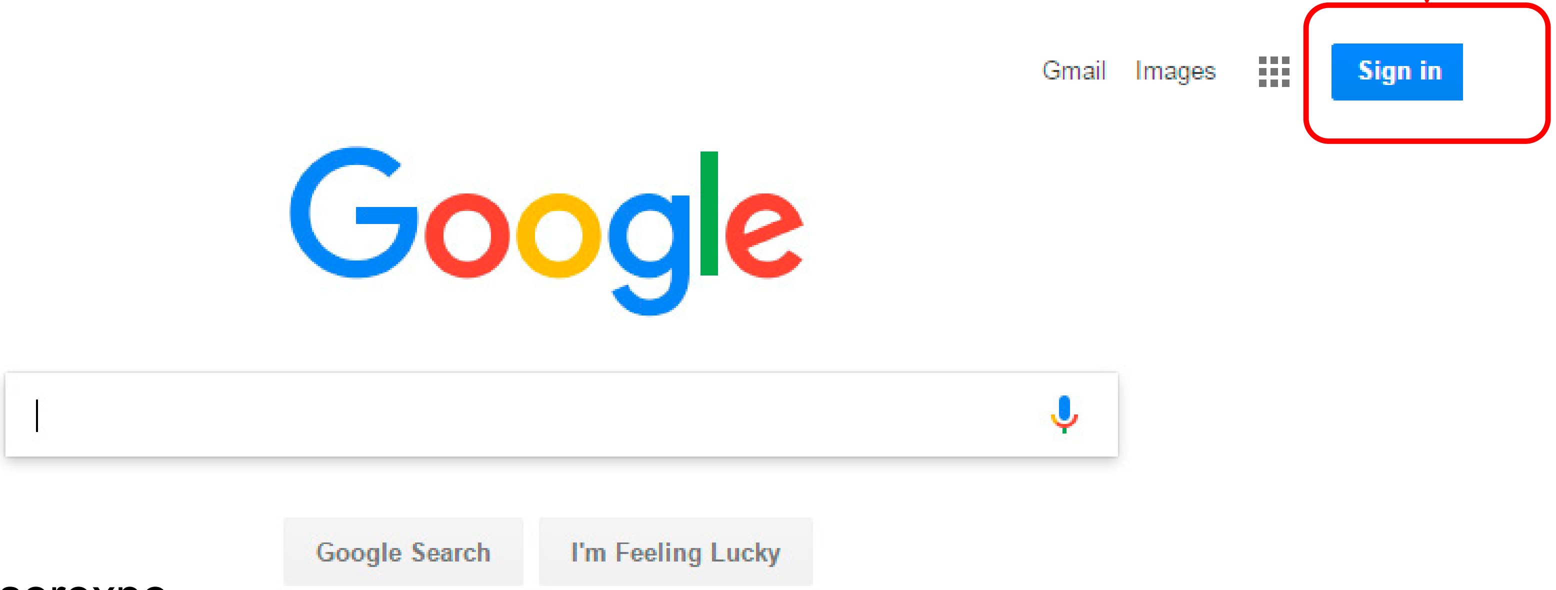
ON YOUR LAPTOP

LAB8:

Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Login with your own Google account.



Username: STMsensorexpo
Password: STMsensorexpo2017

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ON YOUR LAPTOP

LAB8:

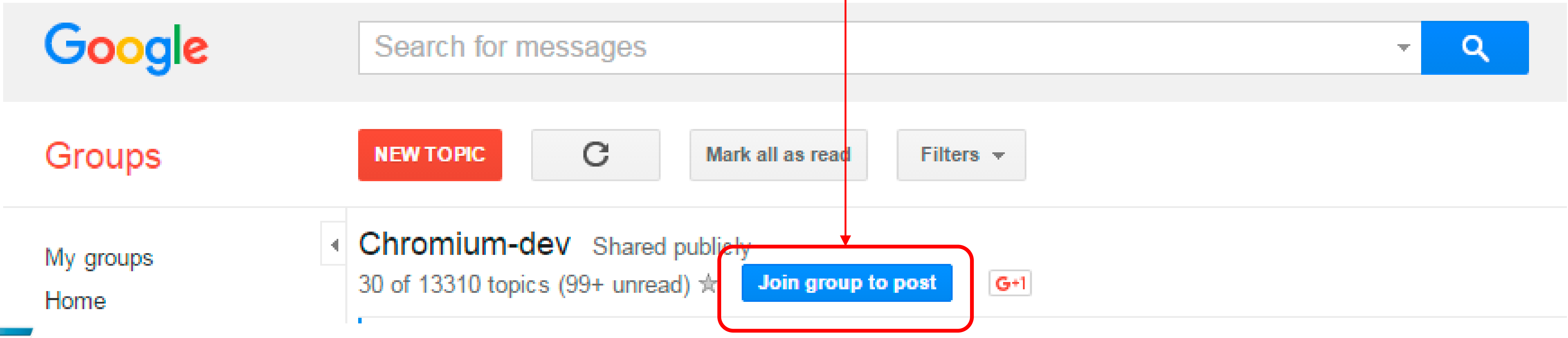
Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Go To Chromium-dev
  - https://groups.google.com/a/chromium.org/forum/?fromgroups#!forum/chromium-dev

- Subscribe to Chromium-dev:

Click on “Join group to post” button



ON YOUR LAPTOP

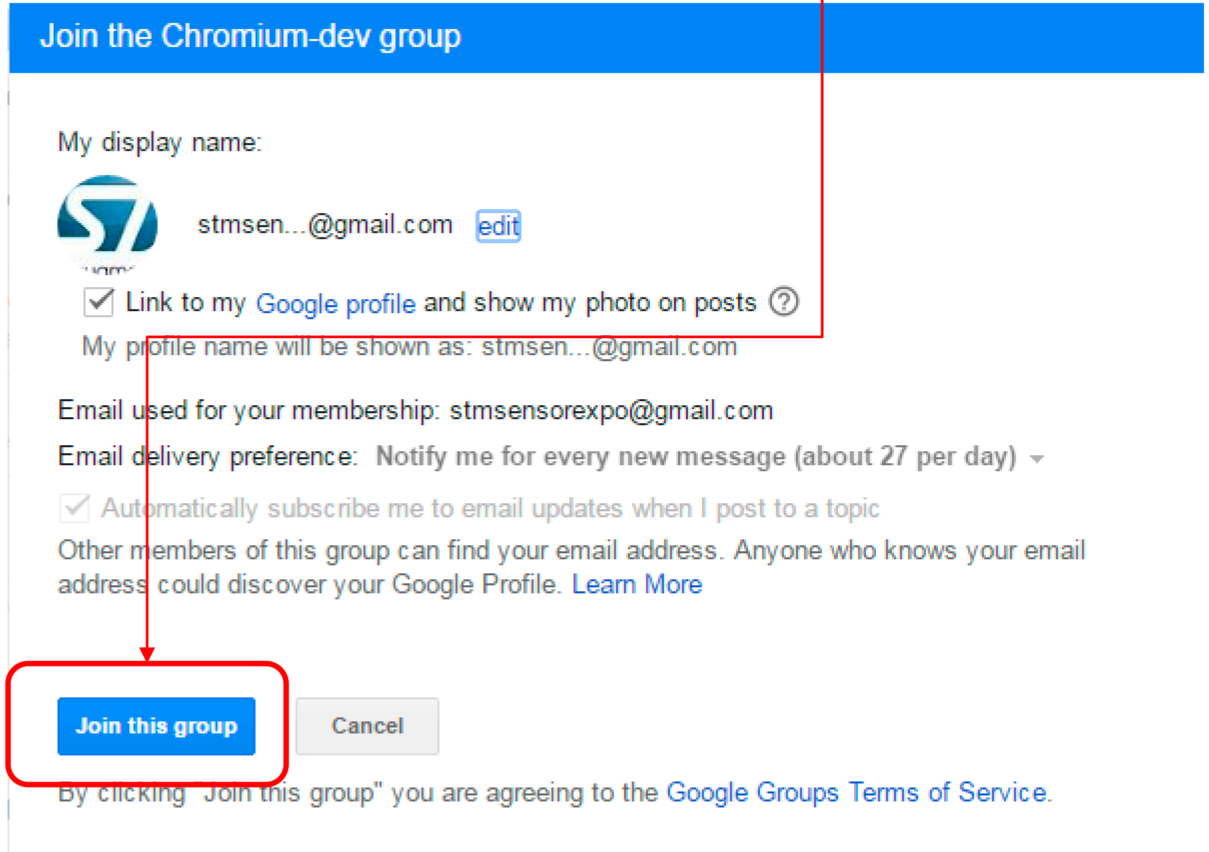
LAB8:

Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Subscribe to Chromium-dev

Click on “Join this group” button to join the Chromium-dev group



Join the Chromium-dev group

My display name:

stmsen...@gmail.com edit

☑ Link to my Google profile and show my photo on posts ?

My profile name will be shown as: stmsen...@gmail.com

Email used for your membership: stmsensorexpo@gmail.com

Email delivery preference: Notify me for every new message (about 27 per day)

☑ Automatically subscribe me to email updates when I post to a topic

Other members of this group can find your email address. Anyone who knows your email address could discover your Google Profile. Learn More

By clicking "Join this group" you are agreeing to the Google Groups Terms of Service.

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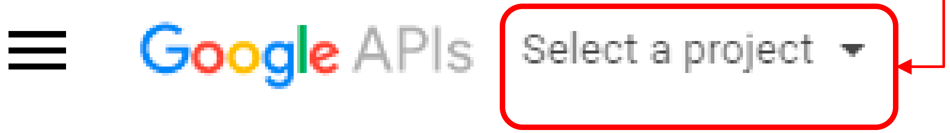
LAB8:

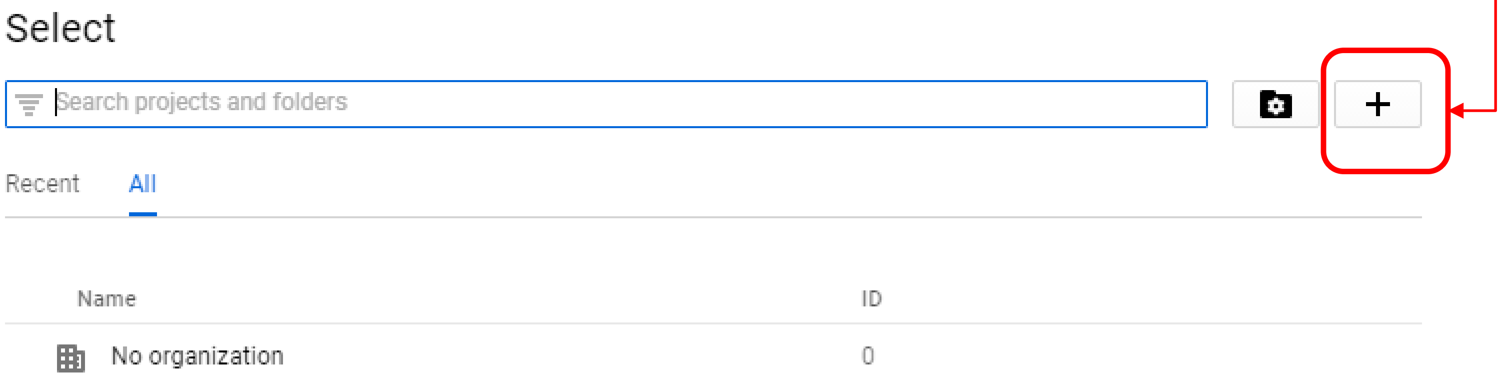
Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Go to https://console.developers.google.com/project
- Click on “Select a Project”



- Click the “+” icon



Name	ID
No organization	0

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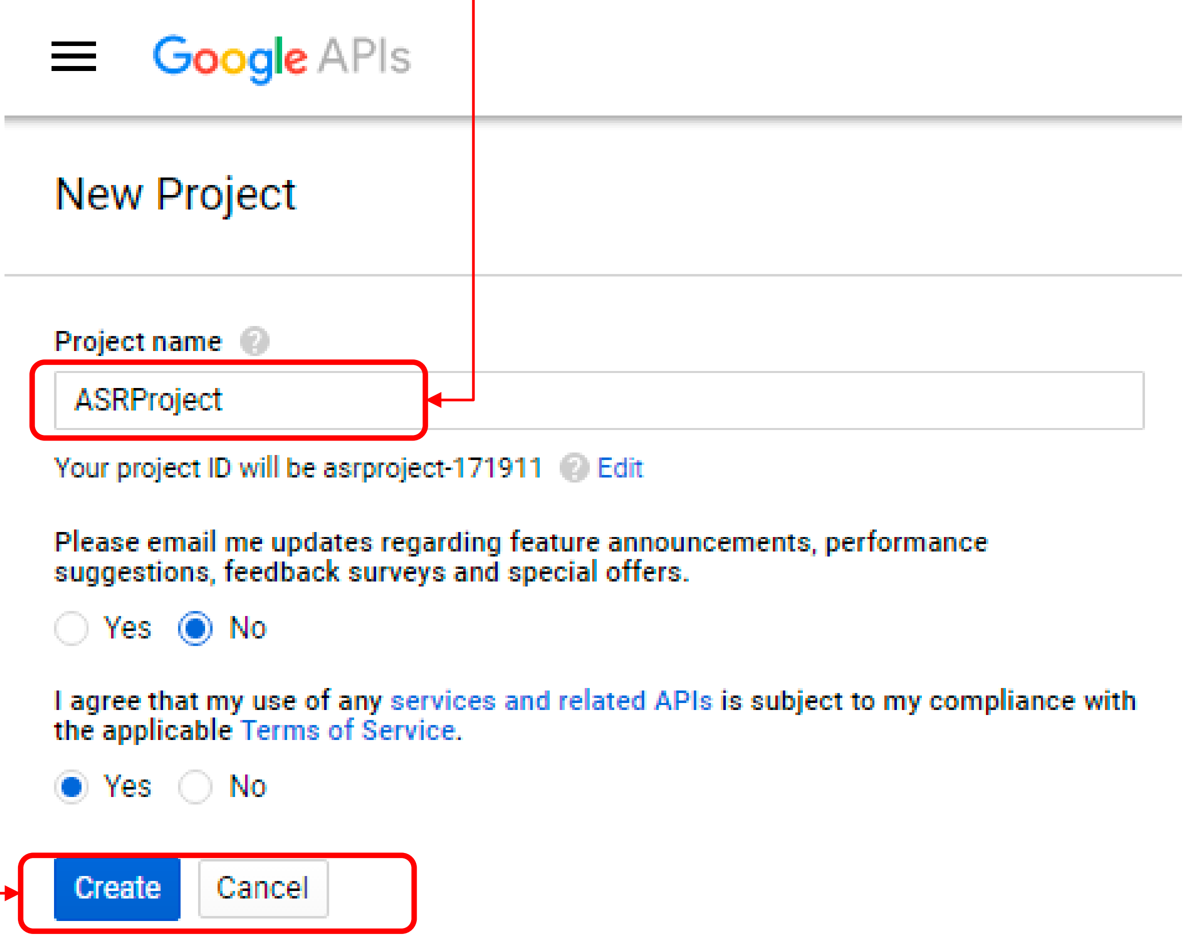
ON YOUR LAPTOP

LAB8: Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Choose a Project name: “ASRProject”.

- Click on “Create” button



New Project

Project name

ASRProject

Your project ID will be asrproject-171911 Edit

Please email me updates regarding feature announcements, performance suggestions, feedback surveys and special offers.

○ Yes ● No

I agree that my use of any services and related APIs is subject to my compliance with the applicable Terms of Service.

● Yes ○ No

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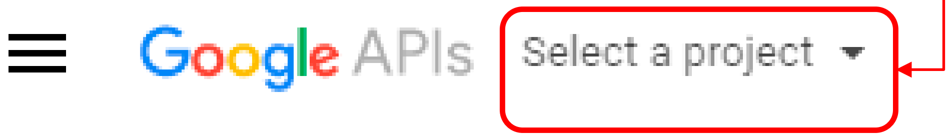
ON YOUR LAPTOP

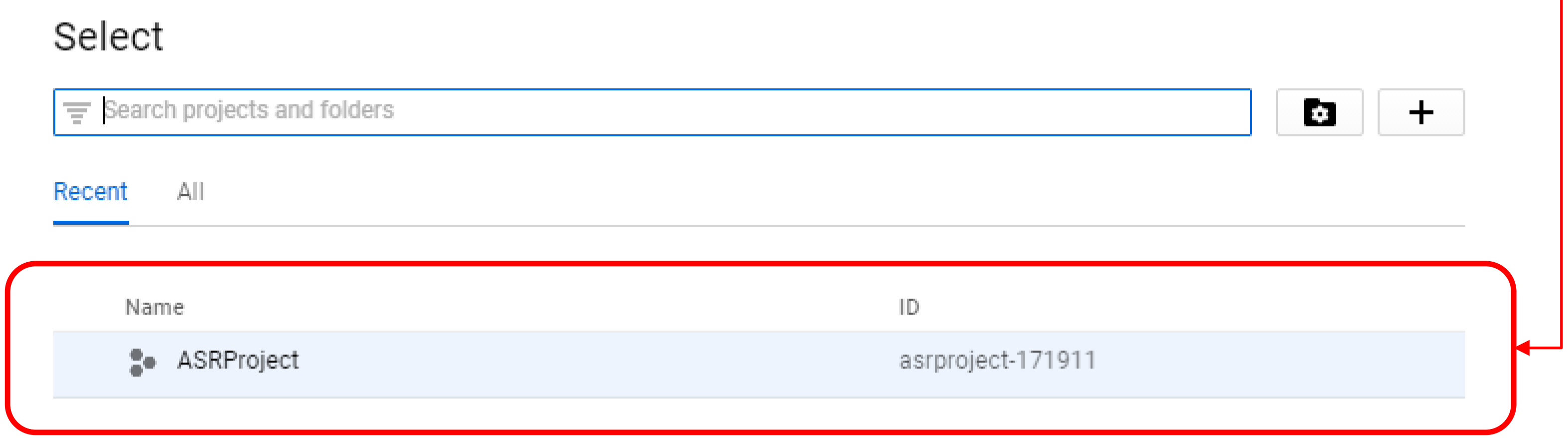
LAB8:
Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Click on “Select a Project”



- Click on “ASRProject”



Name	ID
ASRProject	asrproject-171911

ON YOUR LAPTOP

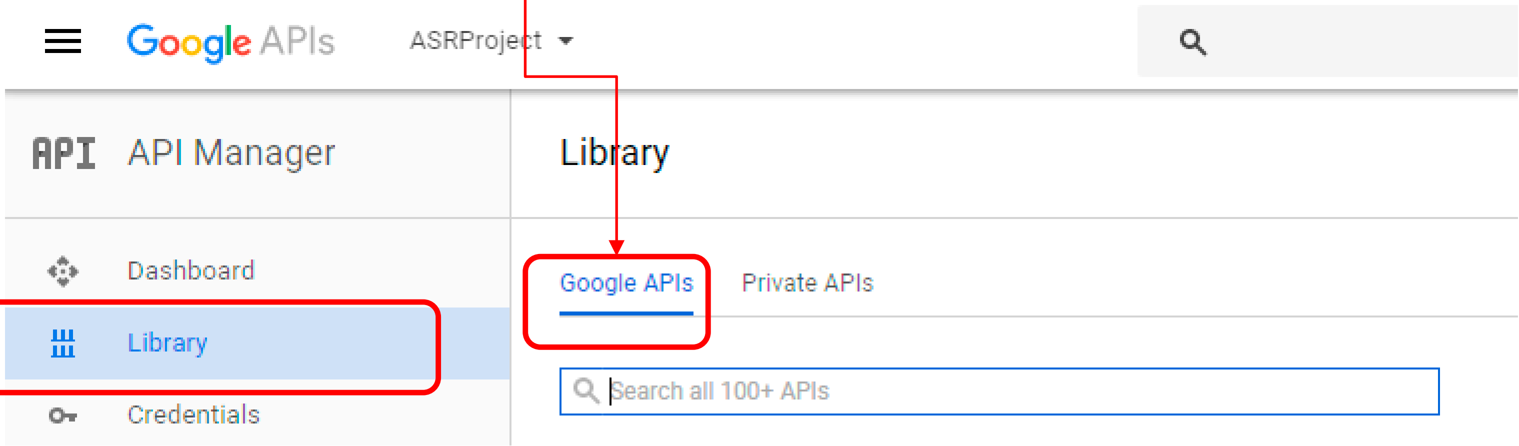
LAB8:

Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Select “Library” in the left menu list

- Select “Google APIs” in the Library tabs



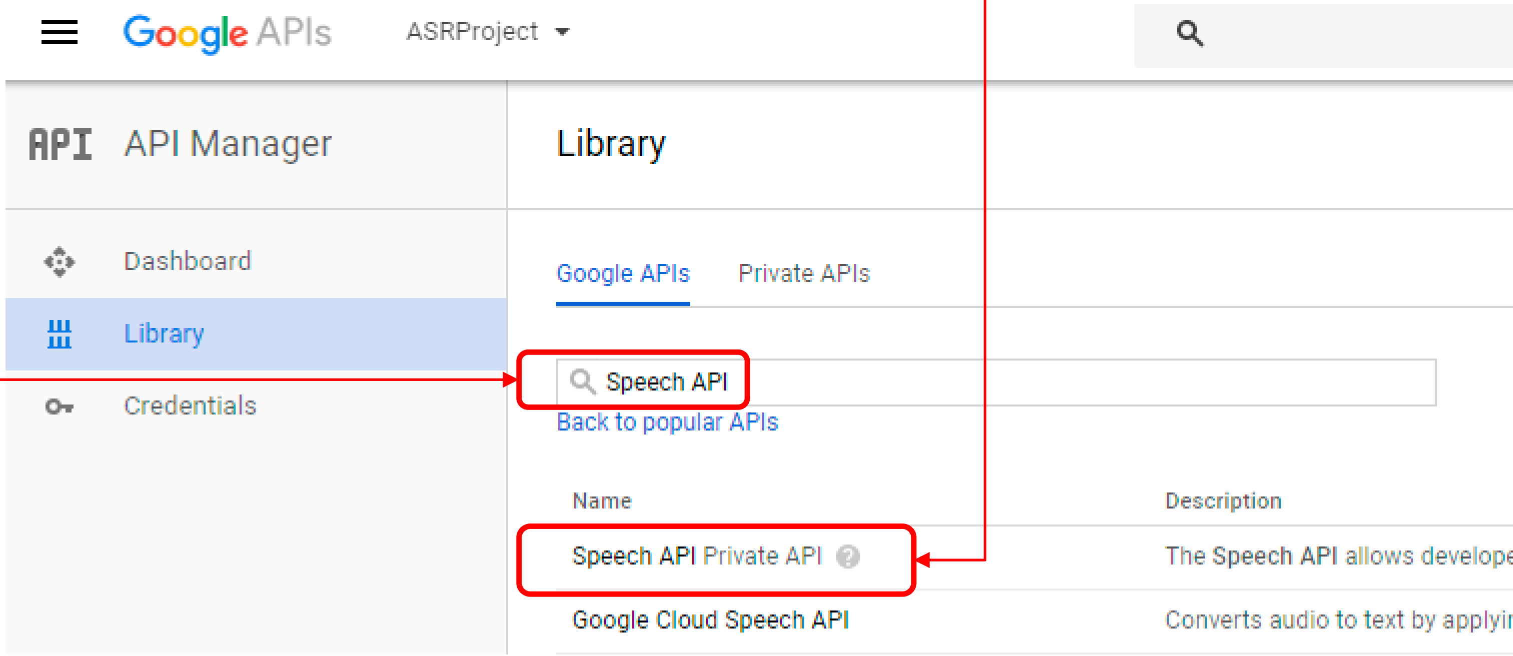
ON YOUR LAPTOP

LAB8:
Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Write "Speech API" in the search box

- Select “Speech API Private API”



Name	Description
Speech API Private API	The Speech API allows develope
Google Cloud Speech API	Converts audio to text by applyi

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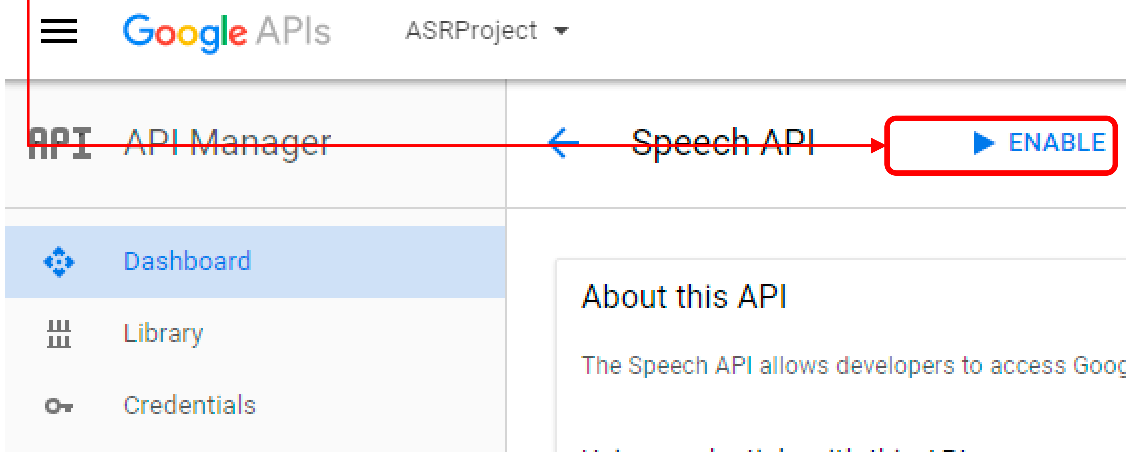
LAB8: Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Enable the Speech API clicking on the blue button “ENABLE”



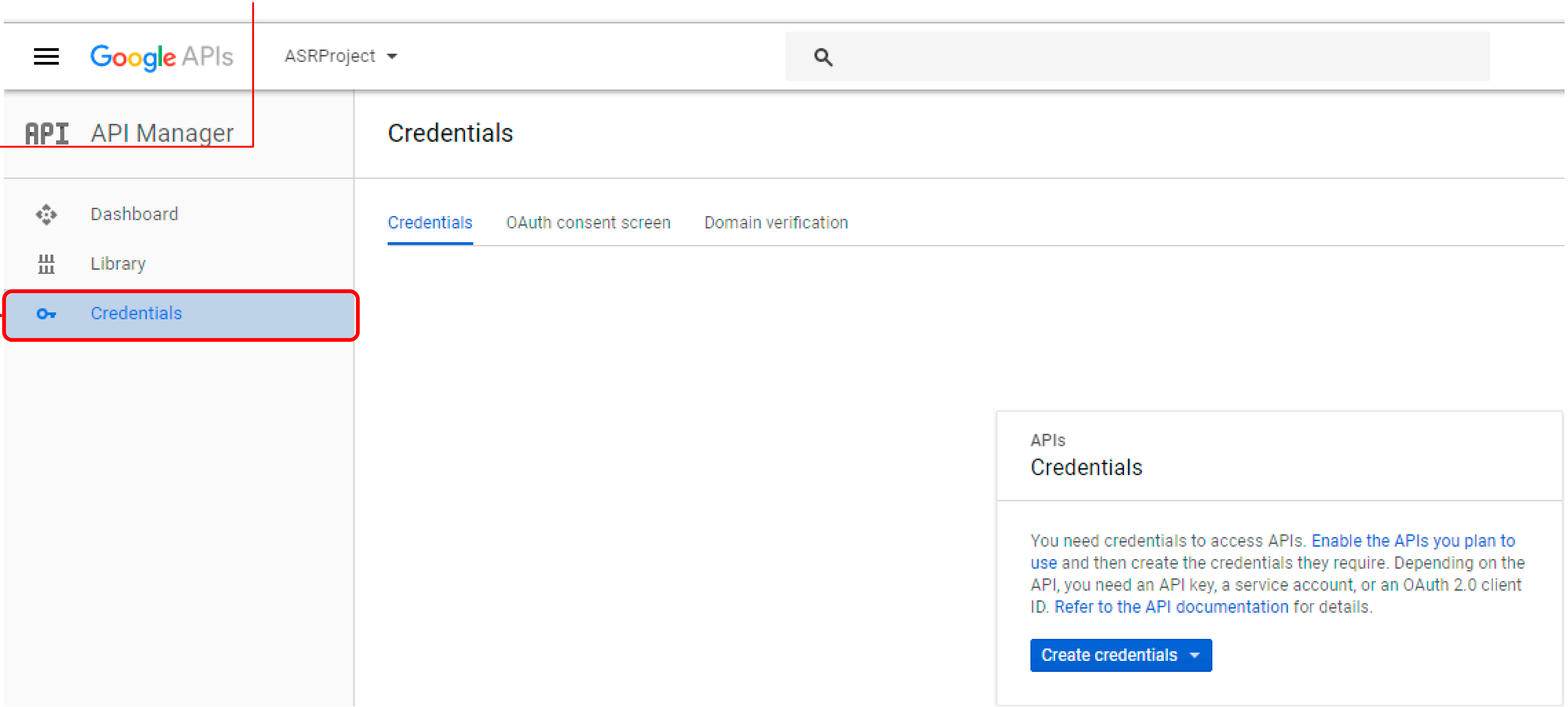
The Speech API allows developers to access Goog

ON YOUR LAPTOP

LAB8: Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Click on the tab “Credentials”



You need credentials to access APIs. Enable the APIs you plan to use and then create the credentials they require. Depending on the API, you need an API key, a service account, or an OAuth 2.0 client ID. Refer to the API documentation for details.

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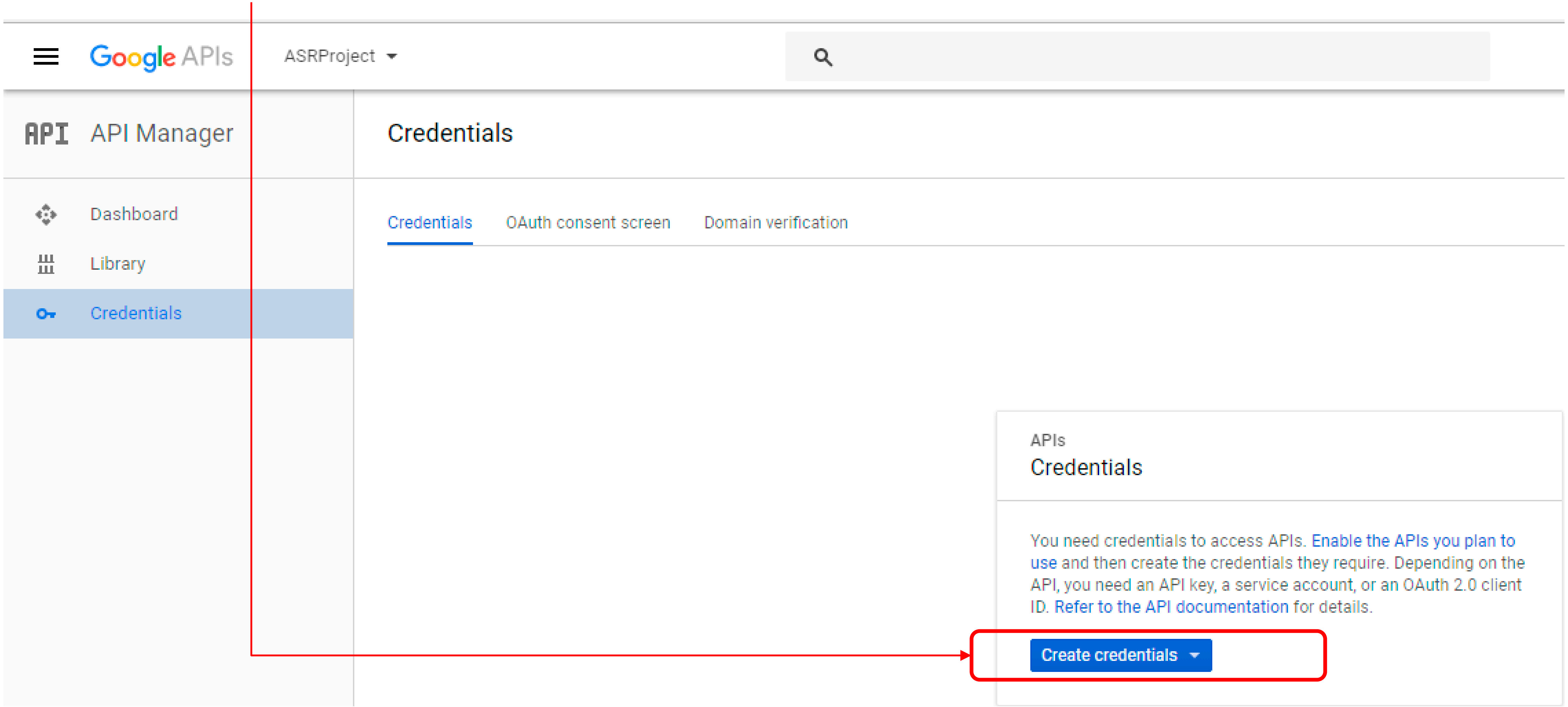
ON YOUR LAPTOP

LAB8: Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Click on “Create Credentials”



You need credentials to access APIs. Enable the APIs you plan to use and then create the credentials they require. Depending on the API, you need an API key, a service account, or an OAuth 2.0 client ID. Refer to the API documentation for details.

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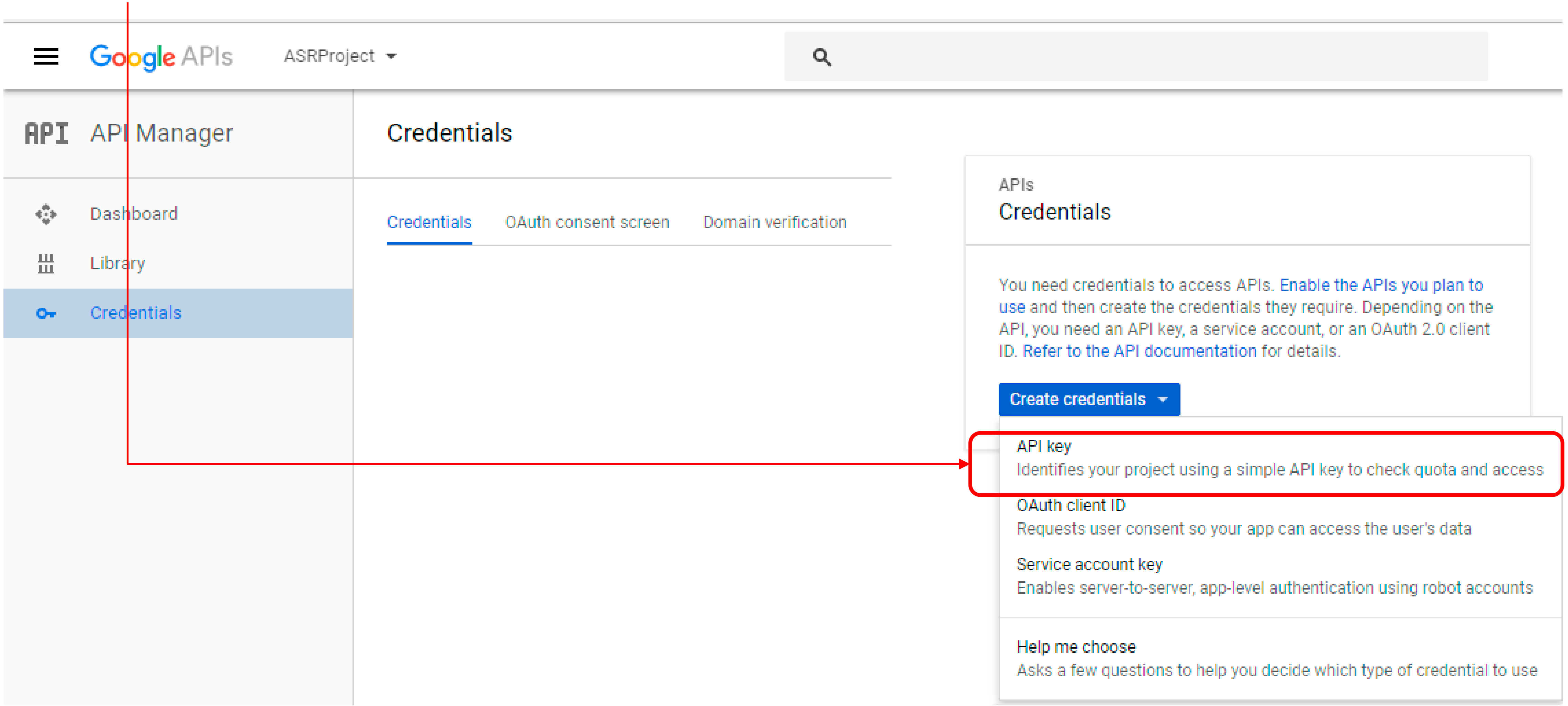
ON YOUR LAPTOP

LAB8: Cloud Base ASR with Sensortile

Google speech ASR Key generation

- select “API key”



You need credentials to access APIs. Enable the APIs you plan to use and then create the credentials they require. Depending on the API, you need an API key, a service account, or an OAuth 2.0 client ID. Refer to the API documentation for details.

Create credentials

API key
Identifies your project using a simple API key to check quota and access

OAuth client ID
Requests user consent so your app can access the user's data

Service account key
Enables server-to-server, app-level authentication using robot accounts

Help me choose
Asks a few questions to help you decide which type of credential to use

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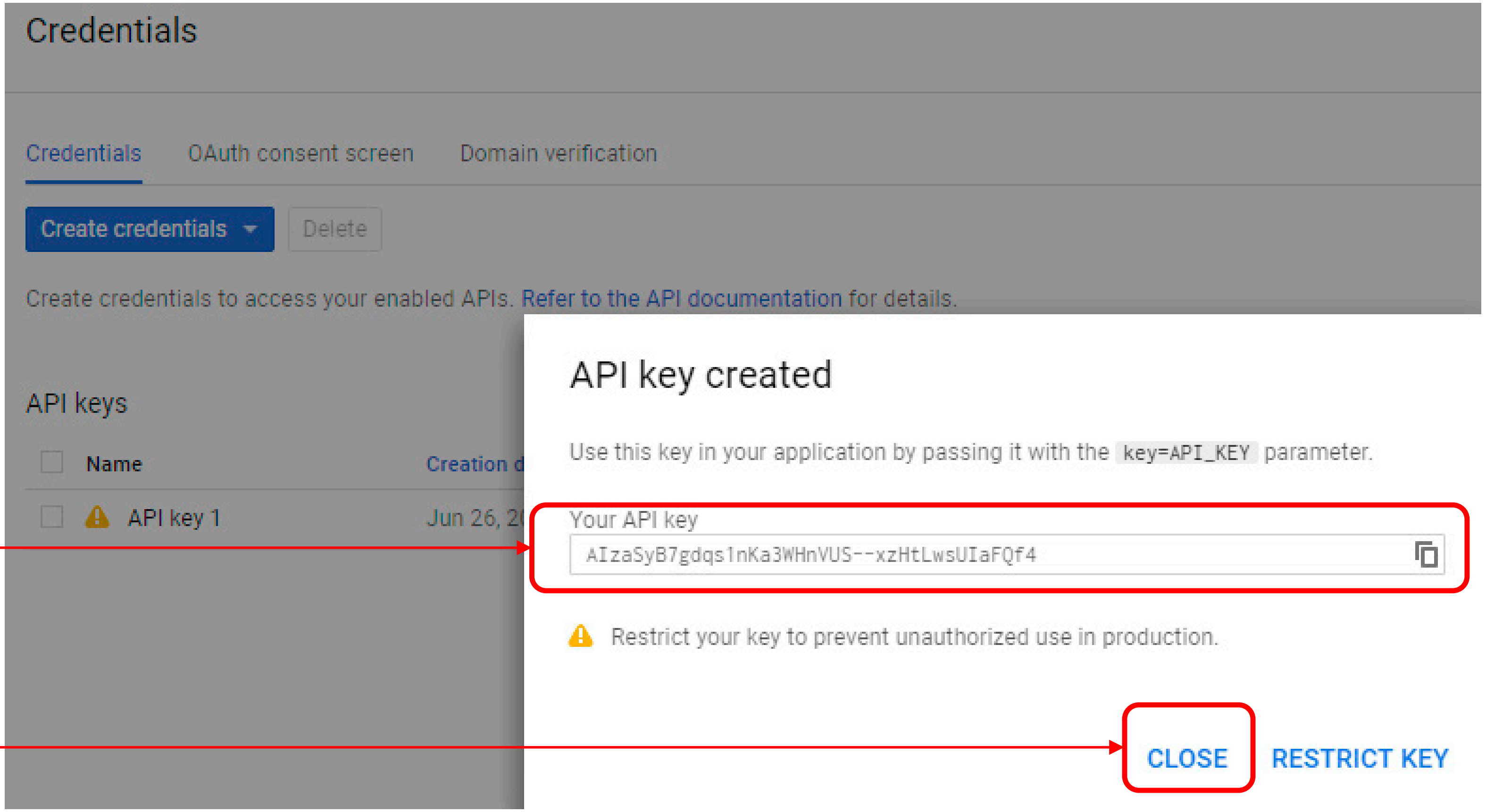
LAB8:
Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Your API key is created.
- Click “CLOSE”



Credentials

Create credentials to access your enabled APIs. Refer to the API documentation for details.

API keys

□	Name	Creation d
□	⚠ API key 1	Jun 26, 2

API key created

Use this key in your application by passing it with the `key=API_KEY` parameter.

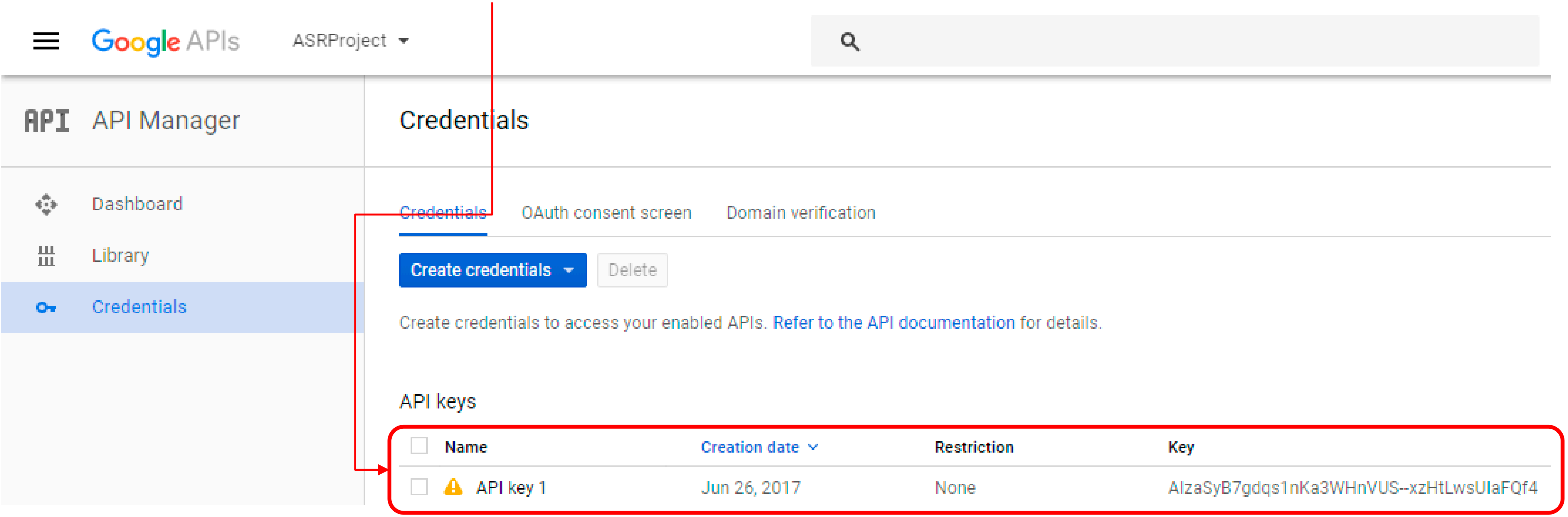
Your API key: `AIzaSyB7gdqs1nKa3WHnVUS--xzHtLwsUIaFQf4`

⚠ Restrict your key to prevent unauthorized use in production.

LAB8: Cloud Base ASR with Sensortile

Google speech ASR Key generation

- in the the Credentials section you can see your API Key



Credentials

Create credentials to access your enabled APIs. Refer to the API documentation for details.

API keys

□	Name	Creation date	Restriction	Key
□	⚠ API key 1	Jun 26, 2017	None	AIzaSyB7gdqs1nKa3WHnVUS--xzHtLwsUlaFQf4

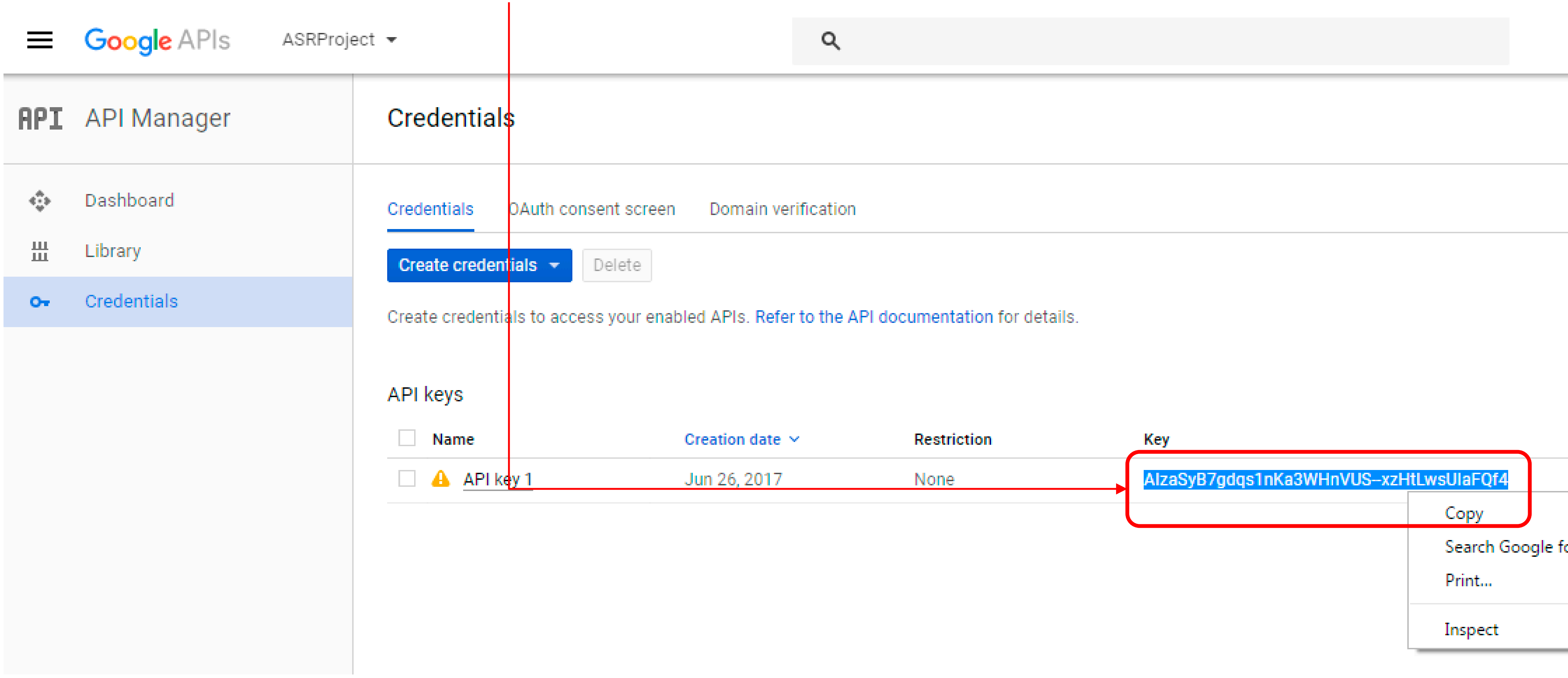
ON YOUR LAPTOP

LAB8:

Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Select the key, right click with your mouse and press copy



Credentials

Credentials | OAuth consent screen | Domain verification

Create credentials | Delete

Create credentials to access your enabled APIs. Refer to the API documentation for details.

API keys

	Name	Creation date	Restriction	Key
□	API key 1	Jun 26, 2017	None	AIzaSyB7gdqs1nKa3WHnVUS–xzHtLwsUIaFQf4

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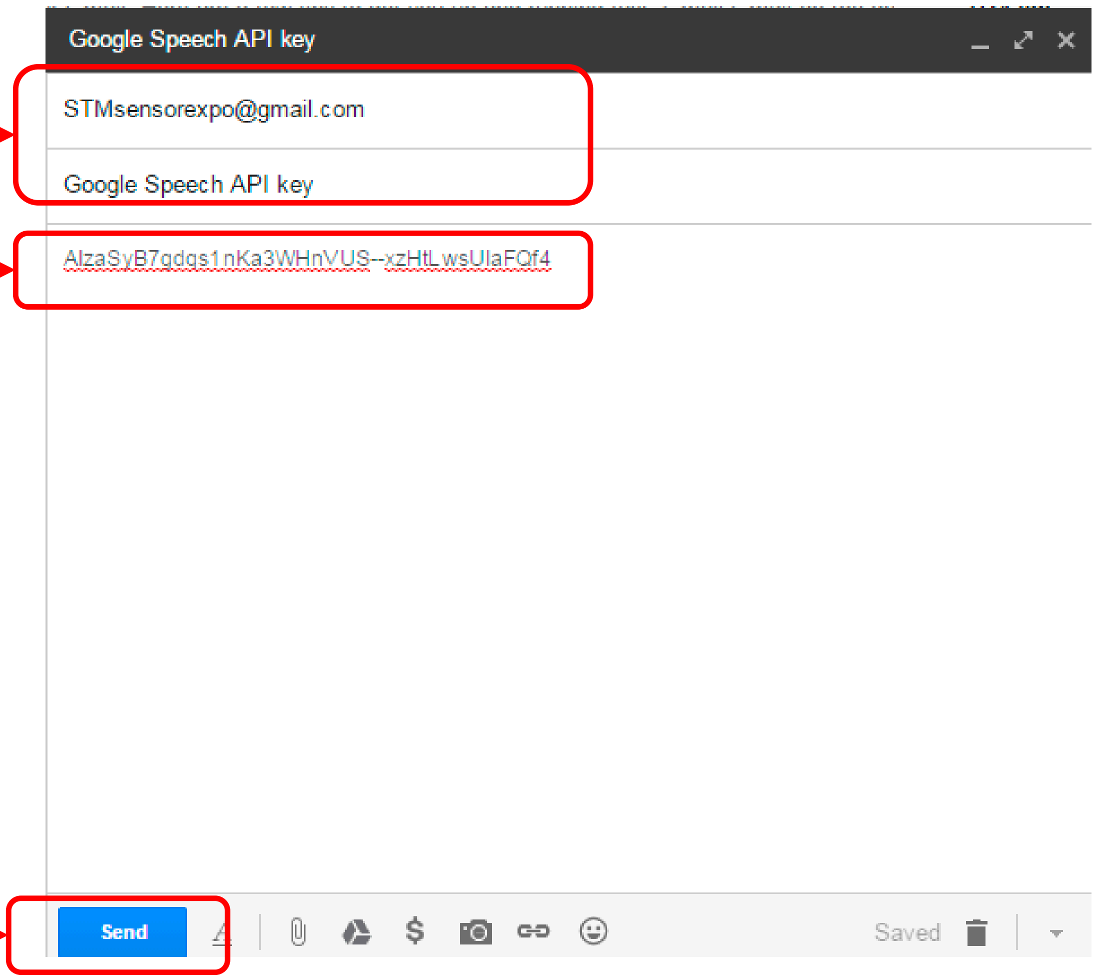
ON YOUR LAPTOP

LAB8:
Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Open your e-mail client
  - **To**: your e-mail address
  - **Subject**: you can pick one
    - (i.e. “Google Speech API Key”)
- Paste the Google API key in the body
- Send the e-mail



Google Speech API key

STMsensorexpo@gmail.com

Google Speech API key

AIzaSyB7gdqs1nKa3WHnVUS--xzHtLwsUIaFQf4

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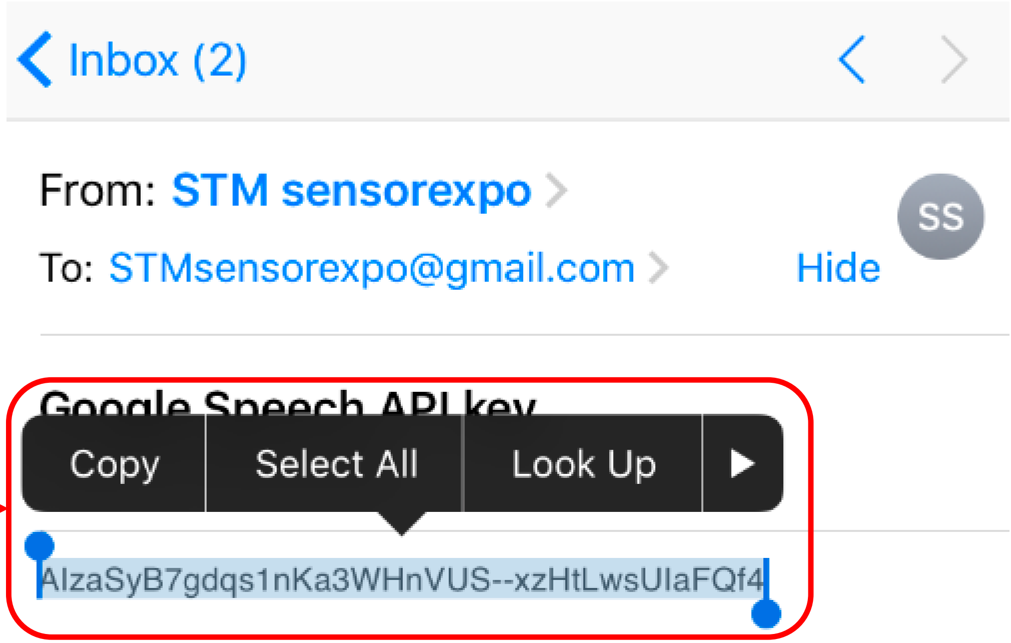
ON YOUR PHONE

LAB8:
Cloud Base ASR with Sensortile
Google speech ASR Key generation

- Open the e-mail client
- Open the e-mail with the Google Speech API key
- Select and copy the key



From: STM sensorexpo

To: STMsensorexpo@gmail.com

Google Speech API key

AIzaSyB7gdqs1nKa3WHnVUS--xzHtLwsUIaFQf4

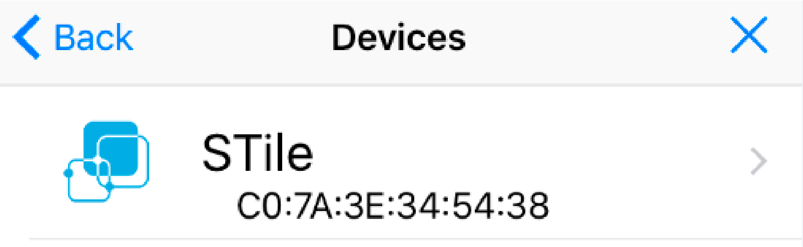
ON YOUR PHONE

LAB8:

Cloud Base ASR with Sensortile

Google speech ASR Key generation

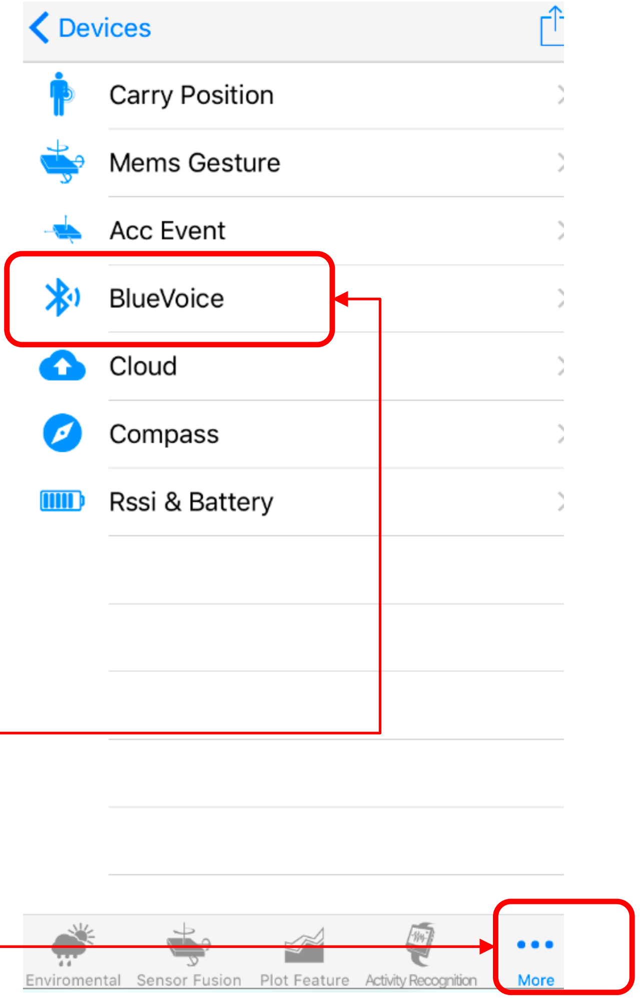
- Open the ST BlueMS app
- Connect to the Sensortile



Back Devices

STile
C0:7A:3E:34:54:38

- Select “More” and then “Bluevoice”



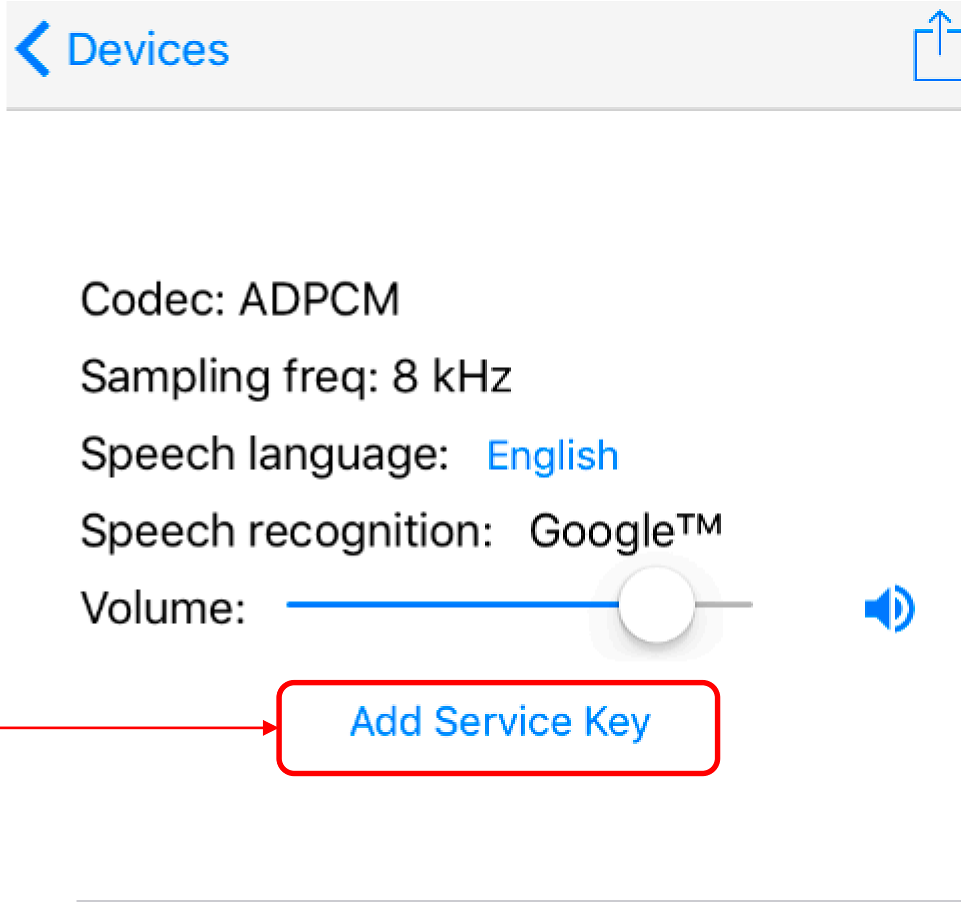
ON YOUR PHONE

LAB8:

Cloud Base ASR with Sensortile

Google speech ASR Key generation

- Click on “Add Service Key”



Codec: ADPCM

Sampling freq: 8 kHz

Speech language: English

Speech recognition: Google™

Volume:

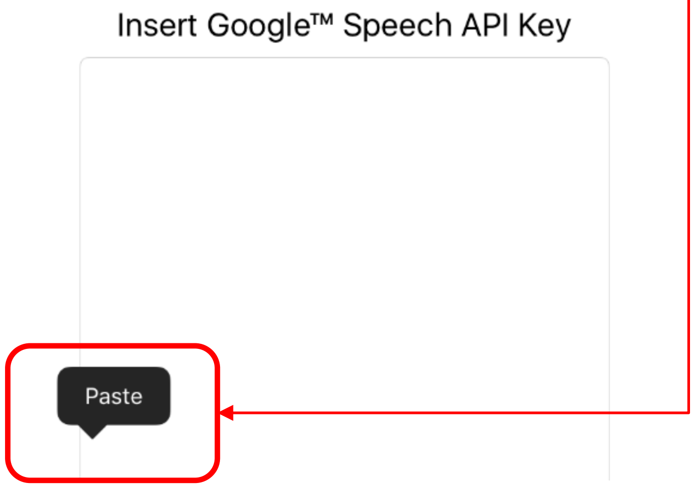
ON YOUR PHONE

LAB8:

Cloud Base ASR with Sensortile

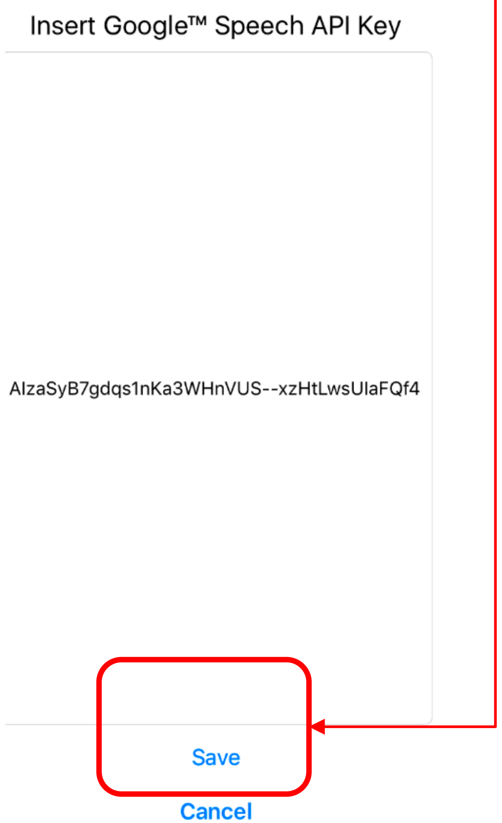
Google speech ASR Key generation

- Paste the key



Insert Google™ Speech API Key

- Press Save



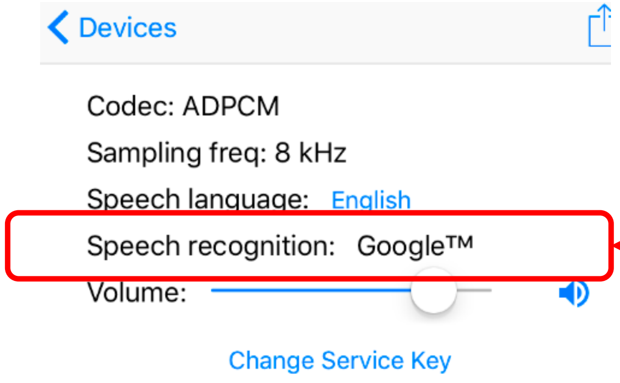
Insert Google™ Speech API Key

AIzaSyB7gdqs1nKa3WHnVUS--xzHtLwsUIaFQf4

Congratulations!!!

Google Speech API key Installed

Let's now use it!



Codec: ADPCM

Sampling freq: 8 kHz

Speech language: English

Speech recognition: Google™

Volume:

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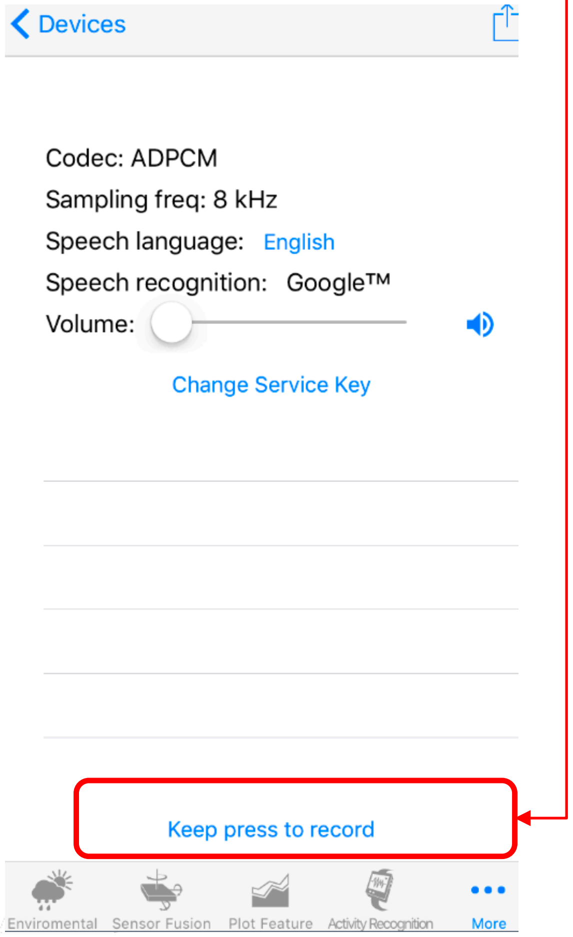
ON YOUR PHONE

LAB8:
Cloud Base ASR with Sensortile

Keep pressed the button below



Codec: ADPCM

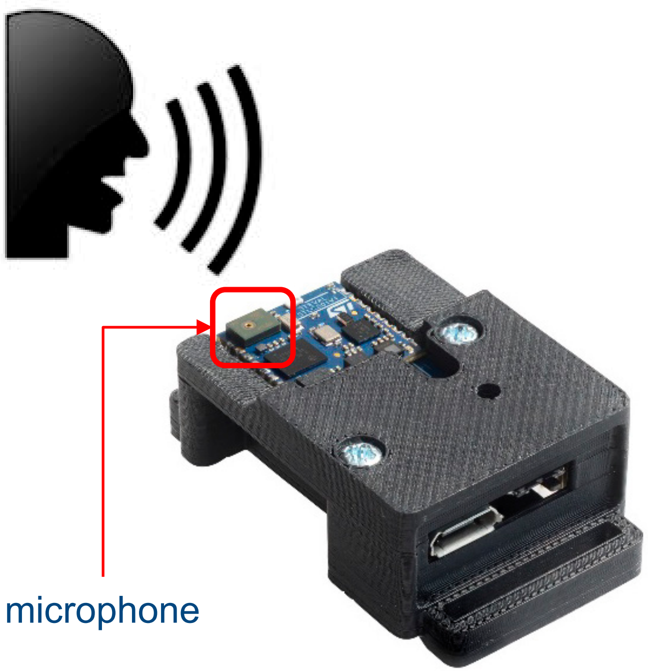
Sampling freq: 8 kHz

Speech language: English

Speech recognition: Google™

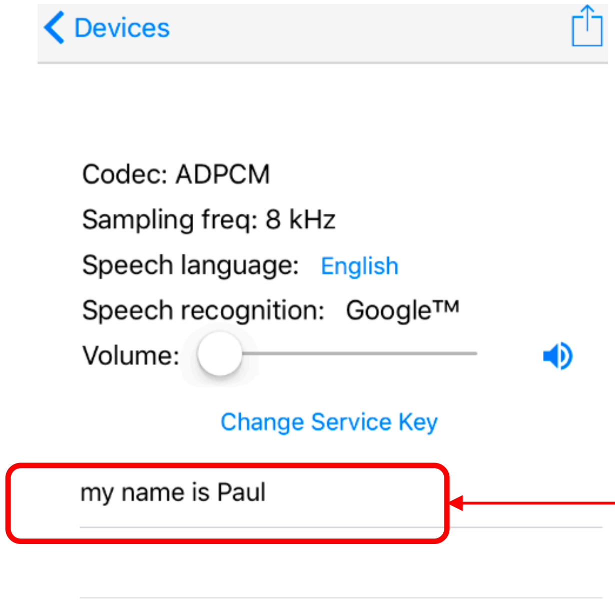
Volume:

Facing the sensortile
Say something like:
“My name is …”



microphone

Release the button and wait
You should see something like:



Codec: ADPCM

Sampling freq: 8 kHz

Speech language: English

Speech recognition: Google™

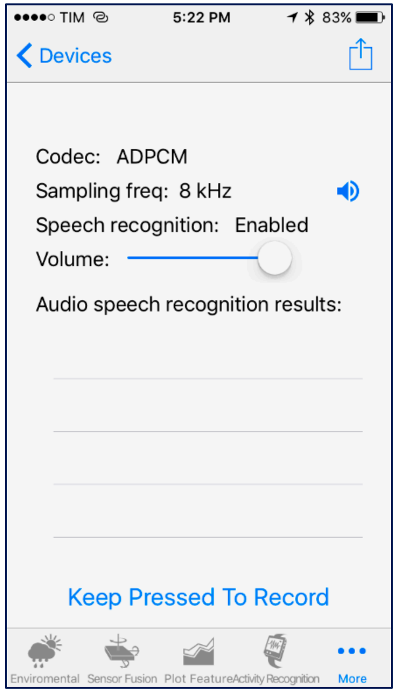
Volume:

my name is Paul

Additional Options and Settings

Swipe left and right to go from one screen to the other

Swipe left to view additional SensorTile options & settings



Codec: ADPCM

Sampling freq: 8 kHz

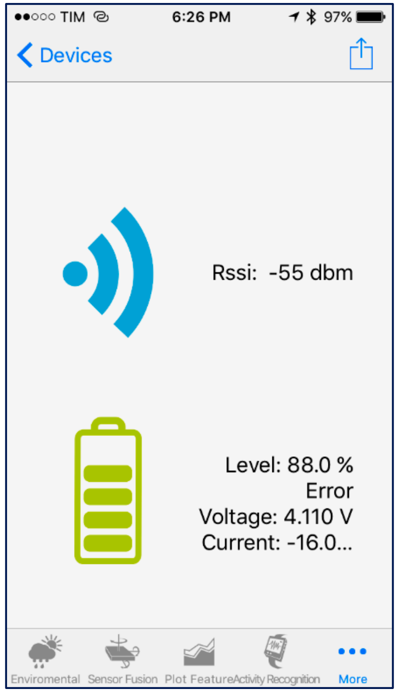
Speech recognition: Enabled

Volume:

Audio speech recognition results:

Keep Pressed To Record

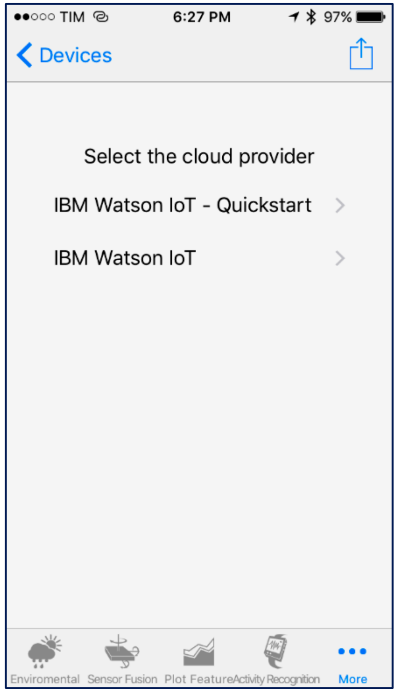
RSSI and battery



Rssi: -55 dbm

Level: 88.0 %
Error
Voltage: 4.110 V
Current: -16.0...

Cloud storage

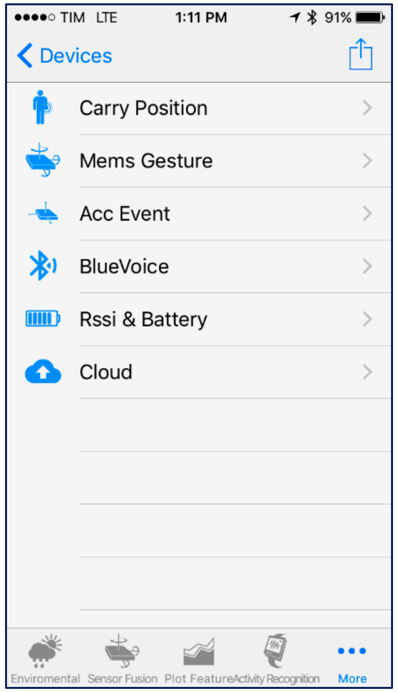


Select the cloud provider

IBM Watson IoT - Quickstart

IBM Watson IoT

Quick menu

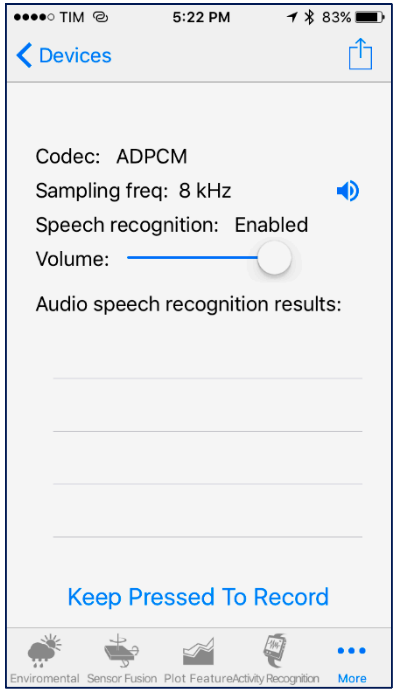


LAB9: Current Consumption

Battery status, sensortile current consumption and RSSI level

Swipe left and right to go from one screen to the other

Swipe left to view additional SensorTile options & settings



Codec: ADPCM

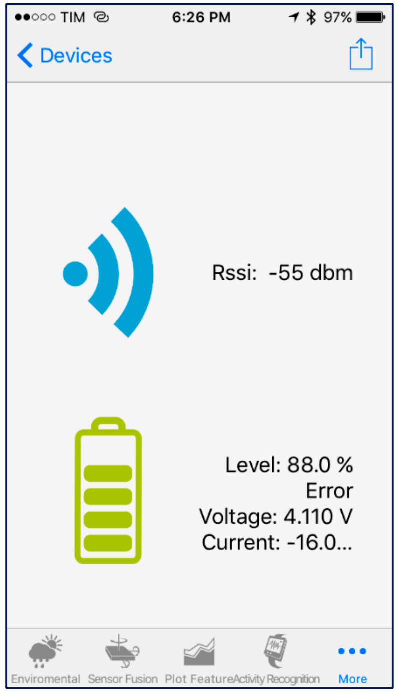
Sampling freq: 8 kHz

Speech recognition: Enabled

Volume:

Audio speech recognition results:

RSSI and battery



Rssi: -55 dbm

Level: 88.0 %
Error
Voltage: 4.110 V
Current: -16.0...

LAB

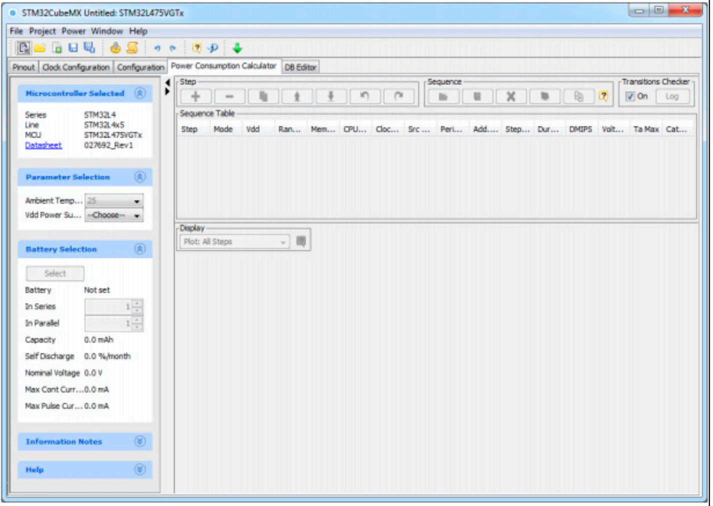
read the current consumption (-14mA).

LAB9: Current Consumption

- **STM32CubeMX** power consumption calculator (power sequence can be specified)

- **STSW-BNRG001** current consumption estimation tool (connection interval and amount of data can be specified)

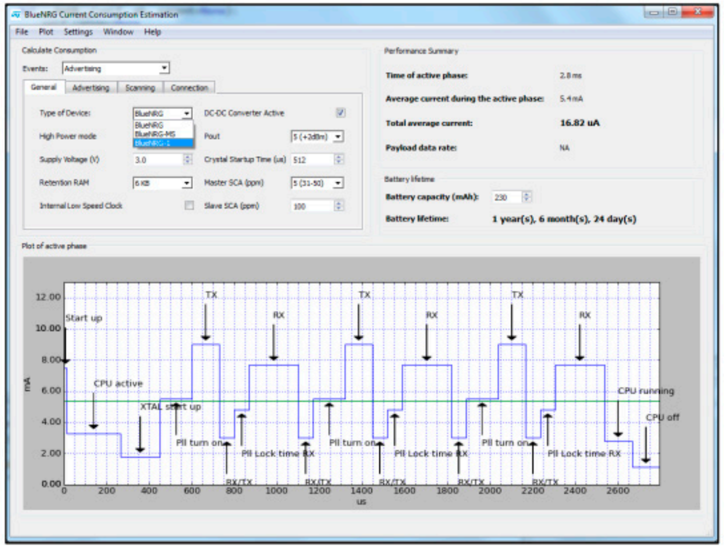
- Check datasheets and application notes for microcontroller, network processor and MEMS sensors.



Series STM32L4
Line STM32L4x5
MCU STM32L475VGTx
Datasheet 027692_Rev1

Ambient Temp... 25
Vdd Power Su... --Choose--

Battery Not set
In Series 1
In Parallel 1
Capacity 0.0 mAh
Self Discharge 0.0 %/month
Nominal Voltage 0.0 V
Max Cont Curr... 0.0 mA
Max Pulse Cur... 0.0 mA



Events: Advertising

Type of Device: BlueNRG
DC-DC Converter Active ☑
High Power mode
Pout 5 (+2dBm)
Supply Voltage (V) 3.0
Crystal Startup Time (us) 512
Retention RAM 6 KB
Master SCA (ppm) 5 (31-50)
Internal Low Speed Clock □
Slave SCA (ppm) 100

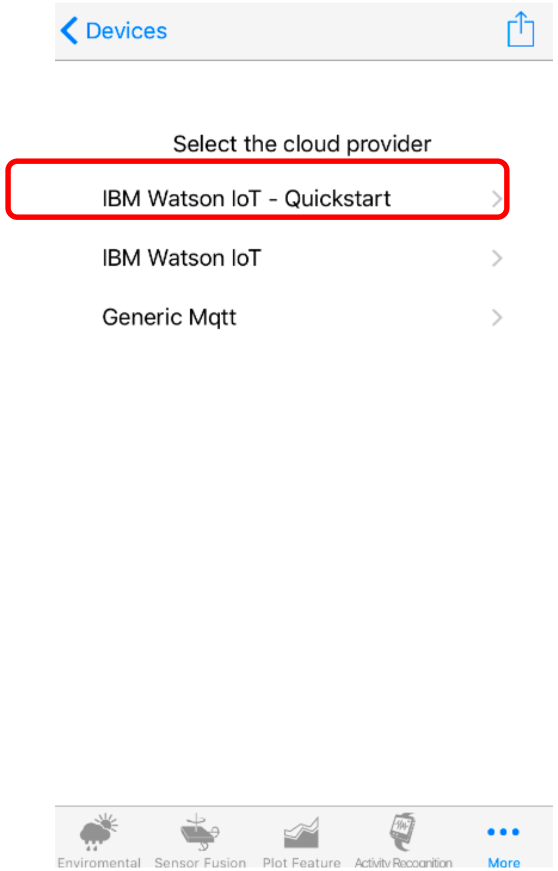
Time of active phase: 2.8 ms
Average current during the active phase: 5.4 mA
Total average current: 16.82 uA
Payload data rate: NA

Battery capacity (mAh): 230
Battery lifetime: 1 year(s), 6 month(s), 24 day(s)

LAB10: IBM Watson IoT

Post Sensortile sensor data on IBM Watson

Select “IBMQuickstart”



‹ Devices

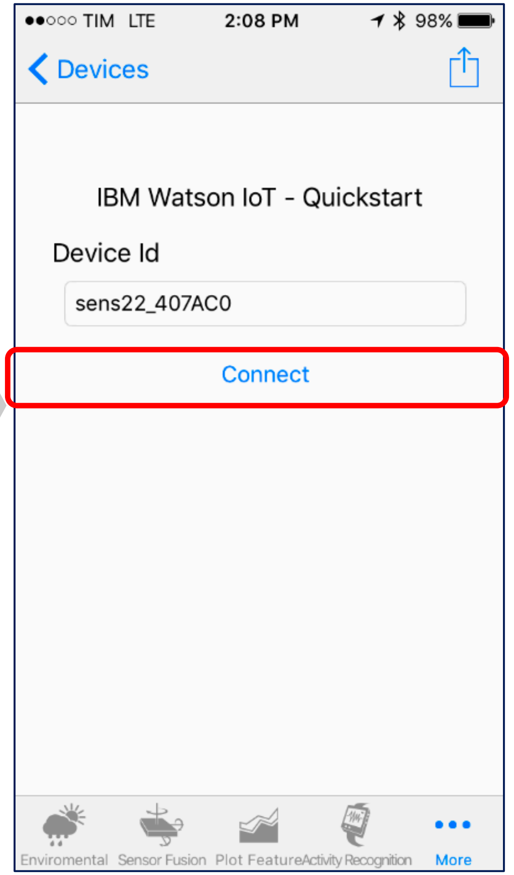
Select the cloud provider

IBM Watson IoT - Quickstart ›

IBM Watson IoT ›

Generic Mqtt ›

Click “Connect”



●●○○○ TIM LTE 2:08 PM 98%

‹ Devices

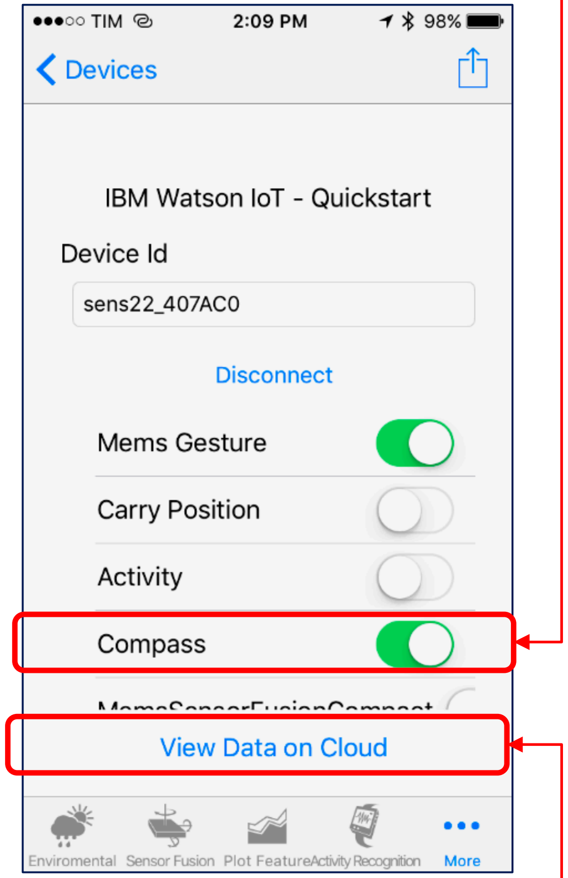
IBM Watson IoT - Quickstart

Device Id

sens22_407AC0

Connect

1. Select a feature



●●●○○ TIM 2:09 PM 98%

‹ Devices

IBM Watson IoT - Quickstart

Device Id

sens22_407AC0

Disconnect

Mems Gesture ●

Carry Position ○

Activity ○

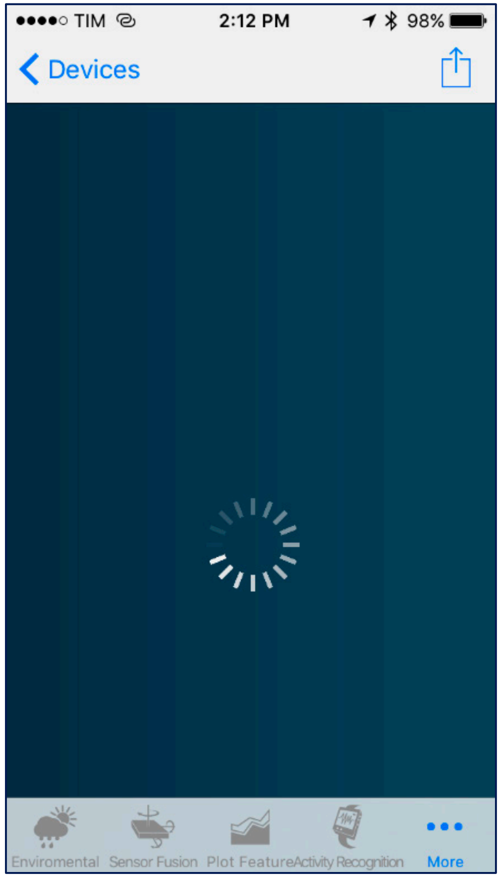
Compass ●

MemsSensorFusionCompact

View Data on Cloud

2. Click “Wiew Data in the Cloud”

Wait a few seconds



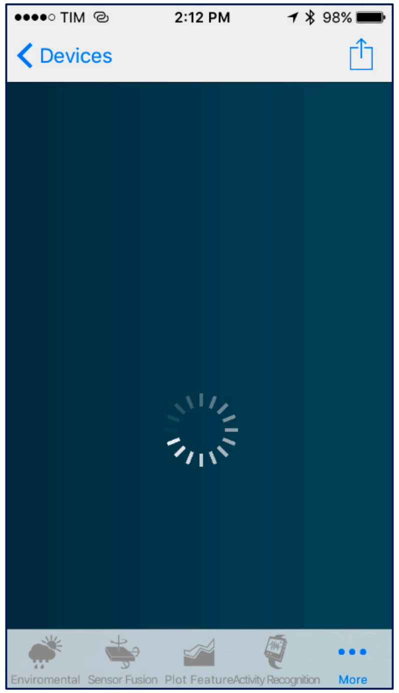
●●●●○ TIM 2:12 PM 98%

‹ Devices

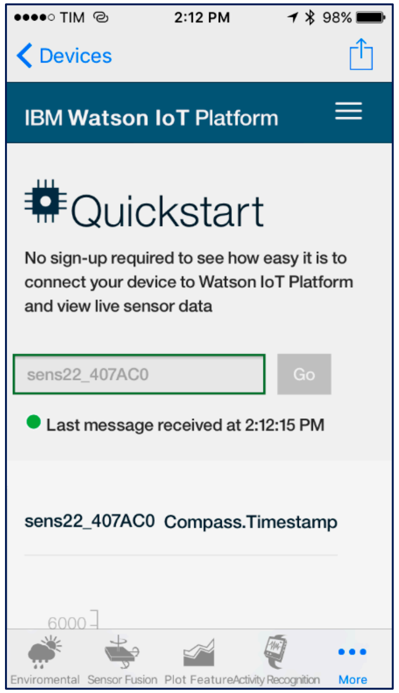
LAB10: IBM Watson IoT

Post Sensortile sensor data on IBM Watson

Wait a few seconds



Quickstart will appear



Quickstart

No sign-up required to see how easy it is to connect your device to Watson IoT Platform and view live sensor data

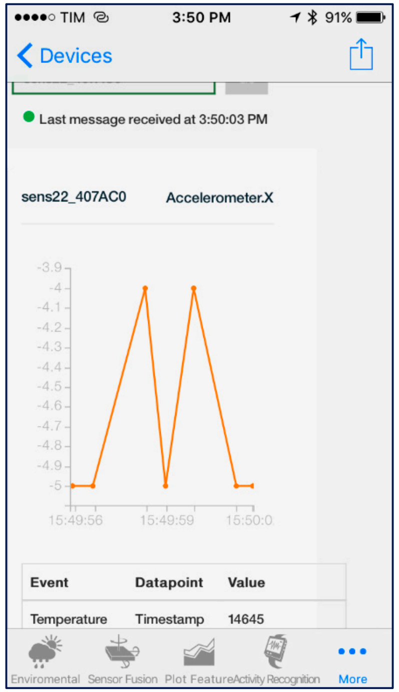
sens22_407AC0

● Last message received at 2:12:15 PM

sens22_407AC0 Compass.Timestamp

Scroll down to see your selected sensor plot and event data.

You will see the Plot of selected feature



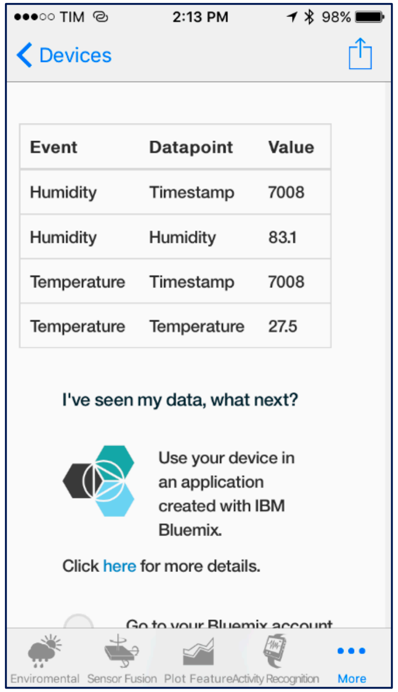
● Last message received at 3:50:03 PM

sens22_407AC0 Accelerometer.X

Event	Datapoint	Value
Temperature	Timestamp	14645

Scroll down again to change sensor data or axes

Table of available features



Event	Datapoint	Value
Humidity	Timestamp	7008
Humidity	Humidity	83.1
Temperature	Timestamp	7008
Temperature	Temperature	27.5

I've seen my data, what next?

Use your device in an application created with IBM Bluemix.

Click here for more details.

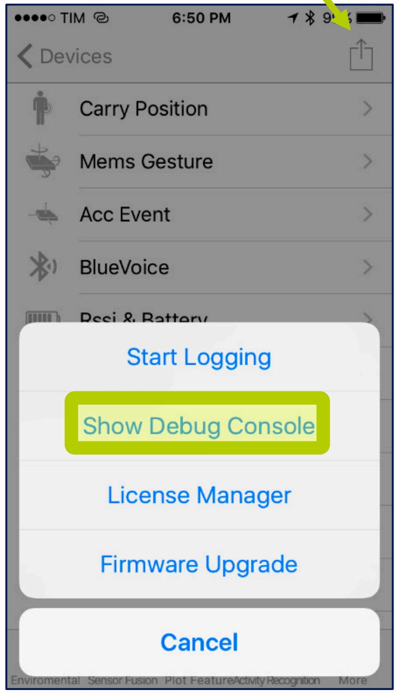
Go to your Bluemix account

life.augmented

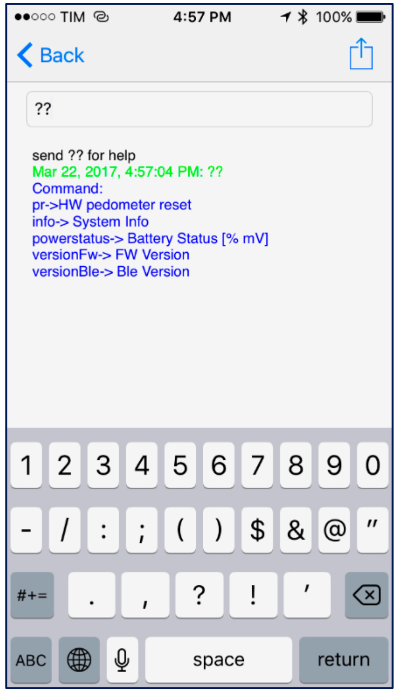
LAB11: Debug Console

A stream of bytes is exchanged in both directions between the SensorTile and the smartphone.
You can type commands on the smartphone and the SensorTile will reply.
This feature is similar to the well known Serial Port Profile (SPP) of Bluetooth classic.

Touch



Type “??”

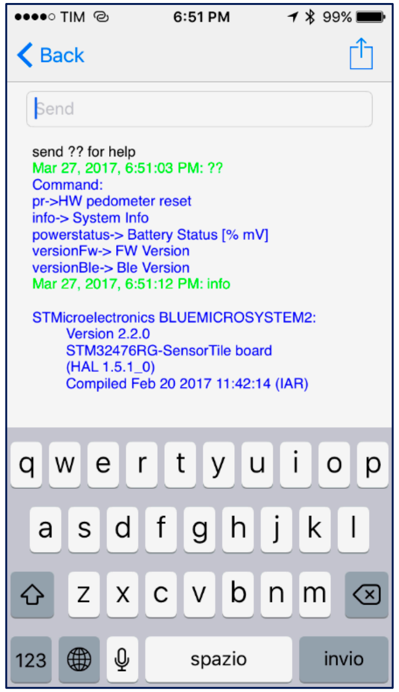


```
??

send ?? for help
Mar 22, 2017, 4:57:04 PM: ??
Command:
pr->HW pedometer reset
info-> System Info
powerstatus-> Battery Status [% mV]
versionFw-> FW Version
versionBle-> Ble Version
```

CASE sensitive

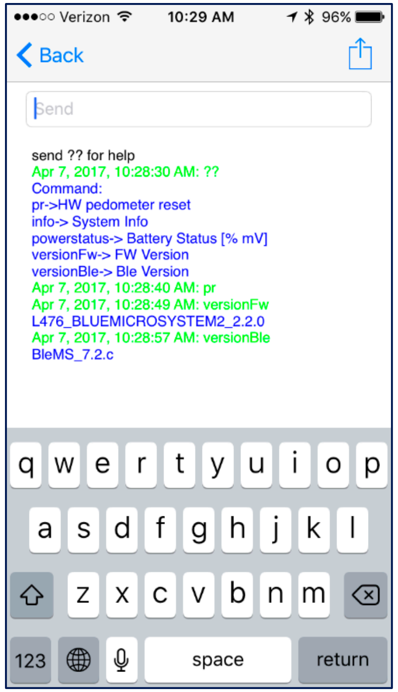
Type “info”



```
send ?? for help
Mar 27, 2017, 6:51:03 PM: ??
Command:
pr->HW pedometer reset
info-> System Info
powerstatus-> Battery Status [% mV]
versionFw-> FW Version
versionBle-> Ble Version
Mar 27, 2017, 6:51:12 PM: info

STMicroelectronics BLUEMICROSYSTEM2:
        Version 2.2.0
        STM32476RG-SensorTile board
        (HAL 1.5.1_0)
        Compiled Feb 20 2017 11:42:14 (IAR)
```

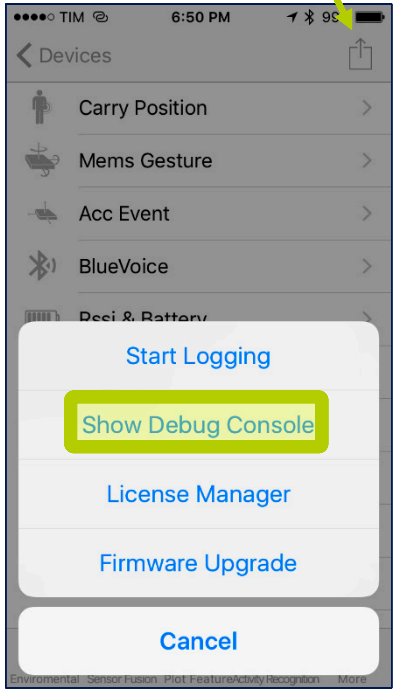
Type “versionFw”
or “versionBle”



```
send ?? for help
Apr 7, 2017, 10:28:30 AM: ??
Command:
pr->HW pedometer reset
info-> System Info
powerstatus-> Battery Status [% mV]
versionFw-> FW Version
versionBle-> Ble Version
Apr 7, 2017, 10:28:40 AM: pr
Apr 7, 2017, 10:28:49 AM: versionFw
L476_BLUEMICROSYSTEM2_2.2.0
Apr 7, 2017, 10:28:57 AM: versionBle
BleMS_7.2.c
```

LAB11: Debug Console

Touch



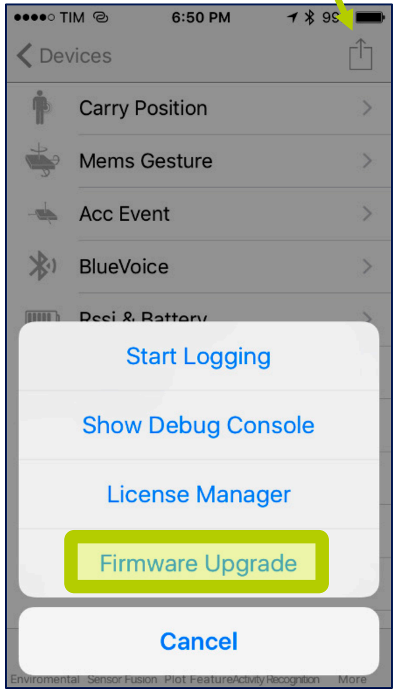
Temperature/humidity/pressure streaming rate:
@TM: environmental data every 5 s
@TH: environmental data every 1 s
@TL: environmental data every 100 ms
@TD: environmental data at the default rate (500 ms)

3D accelerometer, 3D gyroscope and 3D magnetometer rate:
@AM: inertial data every 5 s
@AH: inertial data every 1 s
@AL: inertial data every 100 ms
@AD: inertial data at the default rate (50 ms)

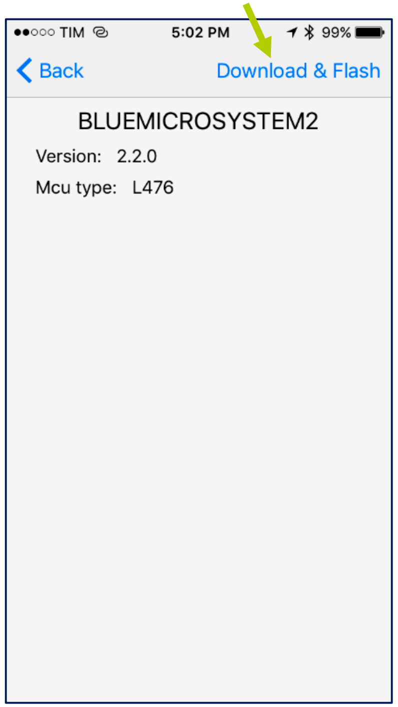
Sound Level from microphone, streaming rate:
@MM: sound level data every 5 s
@MH: sound level data every 1 s
@ML: sound level data every 100 ms
@MD: sound level data at the default rate (50 ms)

Firmware Update Over-The-Air (OTA)

Touch 📤



Select
“Download & Flash”

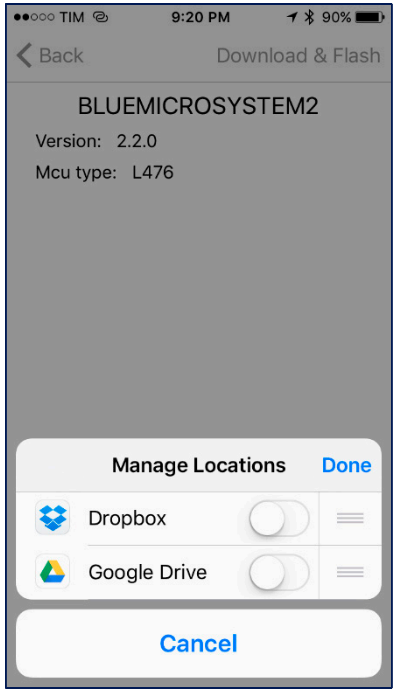


BLUEMICROSYSTEM2

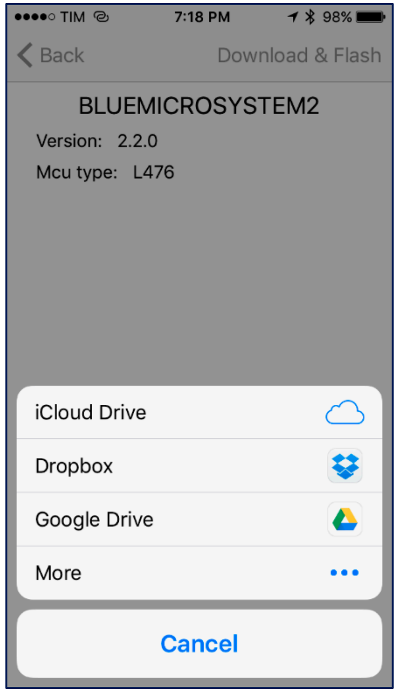
Version: 2.2.0

Mcu type: L476

Enable the
appropriate repository



Select the
repository

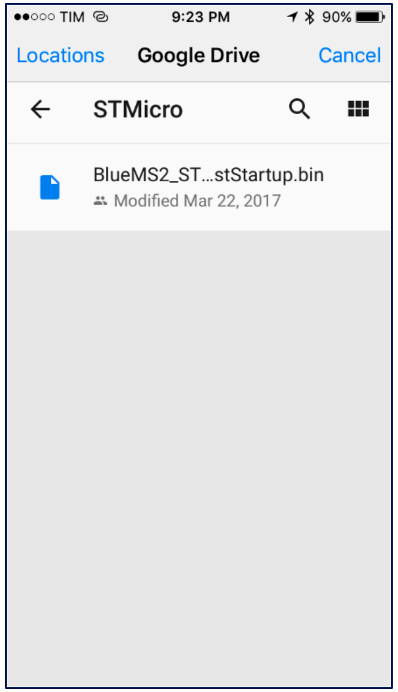


Firmware Update Over-The-Air (OTA)

SensorTile will confirm the integrity of the selected firmware binary before overwriting the current Flash memory image.

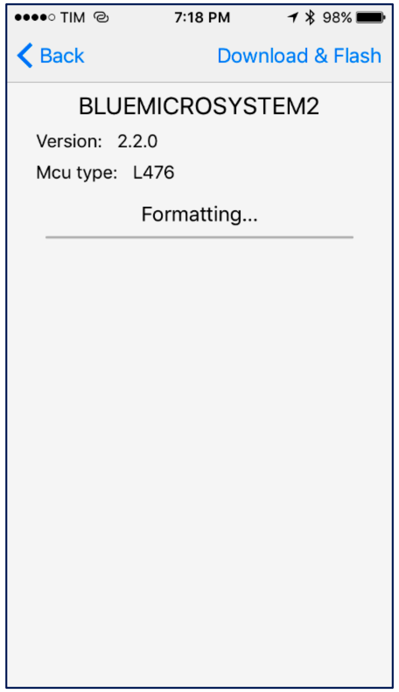
• Bootloader at	0x 0800 0000
• Current application at	0x 0800 **4**000
• New application at	0x 080**4** 0000

Select the firmware binary image



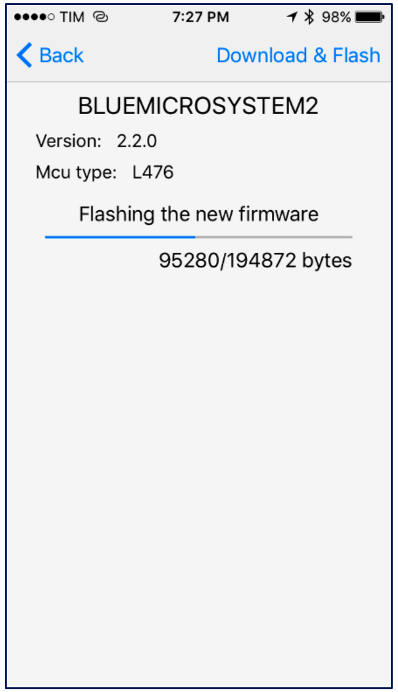
BlueMS2_ST...stStartup.bin
Modified Mar 22, 2017

Formatting…



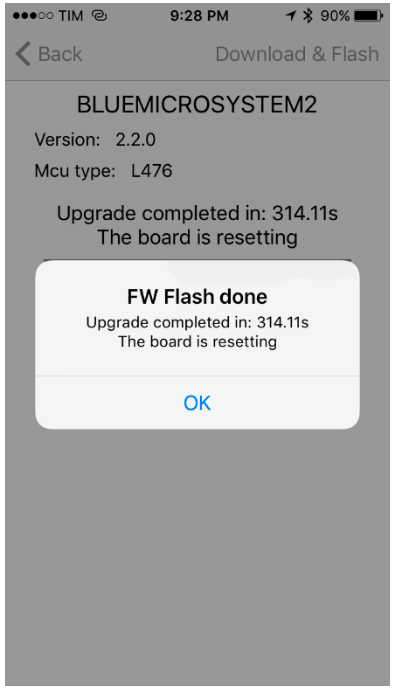
BLUEMICROSYSTEM2
Version: 2.2.0
Mcu type: L476
Formatting...

Flashing…



BLUEMICROSYSTEM2
Version: 2.2.0
Mcu type: L476
Flashing the new firmware
95280/194872 bytes

Confirmation!



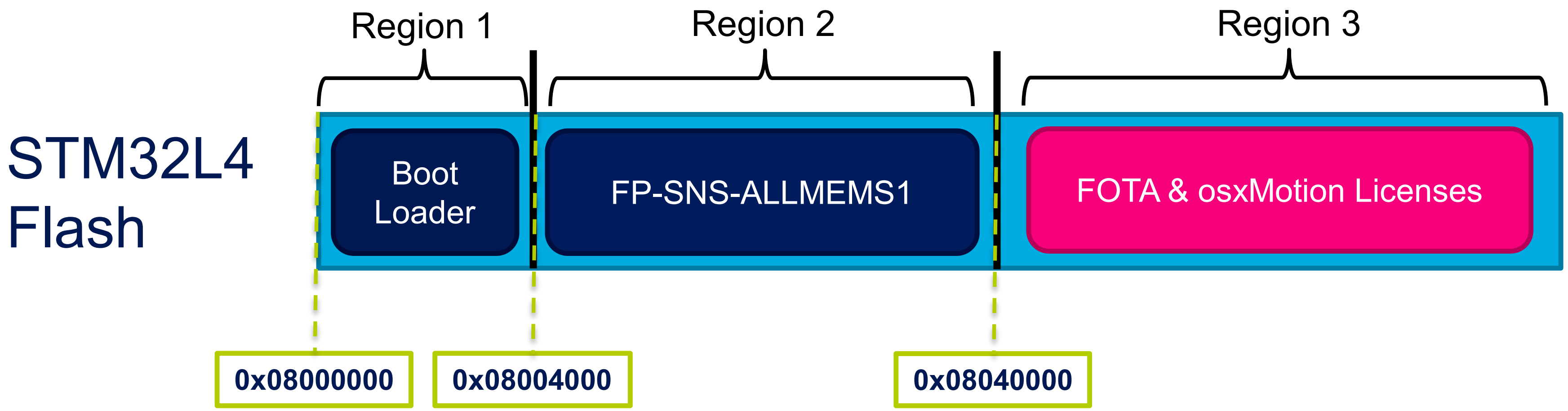
BLUEMICROSYSTEM2
Version: 2.2.0
Mcu type: L476
Upgrade completed in: 314.11s
The board is resetting

FW Flash done
Upgrade completed in: 314.11s
The board is resetting

Firmware Update Over-The-Air (OTA)

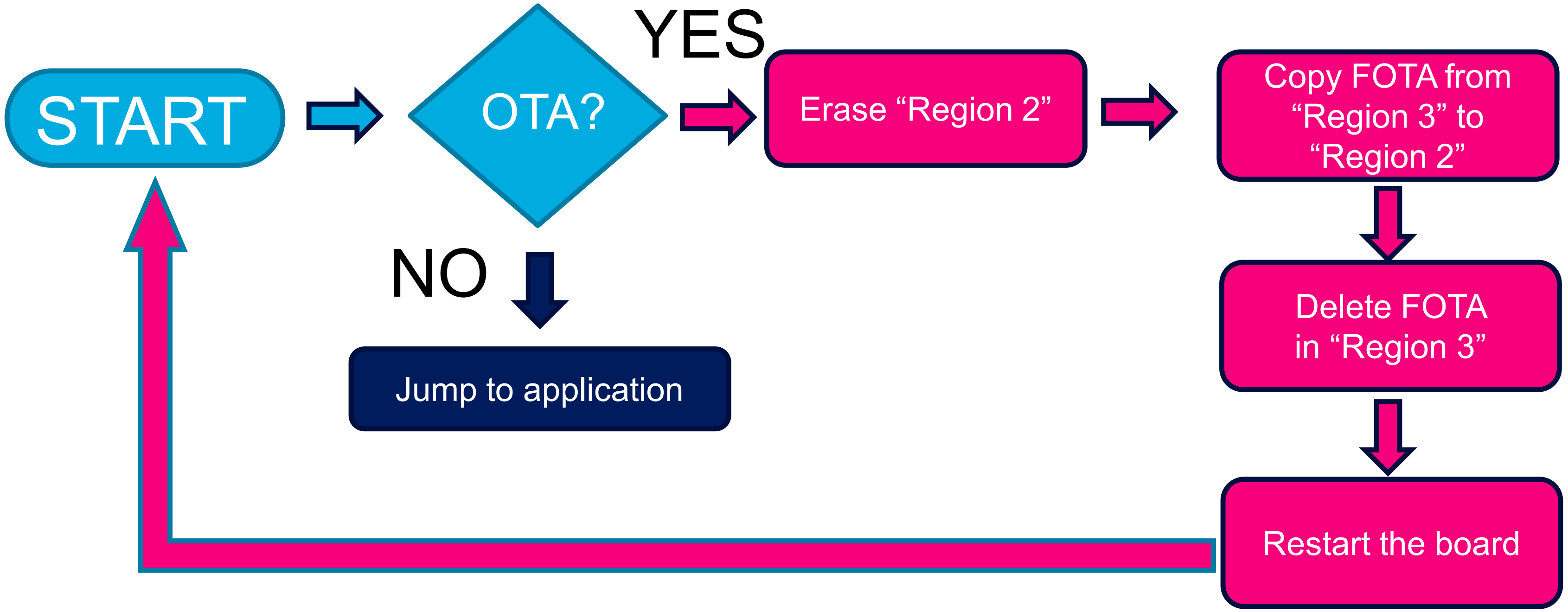
MEMORY ORGANIZATION

- By default, all SensorTile FW applications use a bootloader that resides in the first part of the flash memory of the STM32.
- For this reason the memory is organized into 3 different regions:



Firmware Update Over-The-Air (OTA)

- The bootloader manages the installation of On-The-Air upgrades, if any.
- Otherwise it jumps to the application

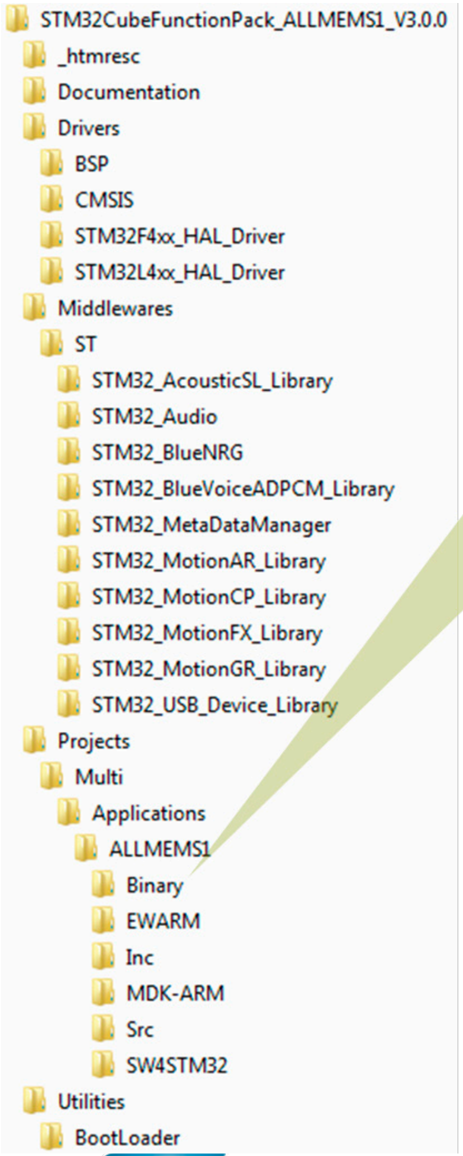


C:\ Program Files (x86) \STMicroelectronics \

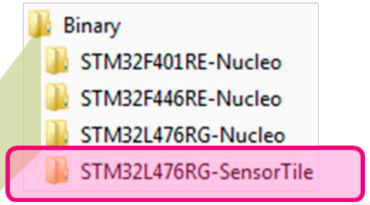
Firmware Update Over-The-Air (OTA)

FP-SNS-ALLMEMS1

The Binary Folder contains two binaries



- STM32CubeFunctionPack_ALLMEMS1_V3.0.0
  - _htmresc
  - Documentation
  - Drivers
    - BSP
    - CMSIS
    - STM32F4xx_HAL_Driver
    - STM32L4xx_HAL_Driver
  - Middlewares
    - ST
      - STM32_AcousticSL_Library
      - STM32_Audio
      - STM32_BlueNRG
      - STM32_BlueVoiceADPCM_Library
      - STM32_MetaDataManager
      - STM32_MotionAR_Library
      - STM32_MotionCP_Library
      - STM32_MotionFX_Library
      - STM32_MotionGR_Library
      - STM32_USB_Device_Library
  - Projects
    - Multi
      - Applications
        - ALLMEMS1
          - Binary
          - EWARM
          - Inc
          - MDK-ARM
          - Src
          - SW4STM32
  - Utilities
    - BootLoader



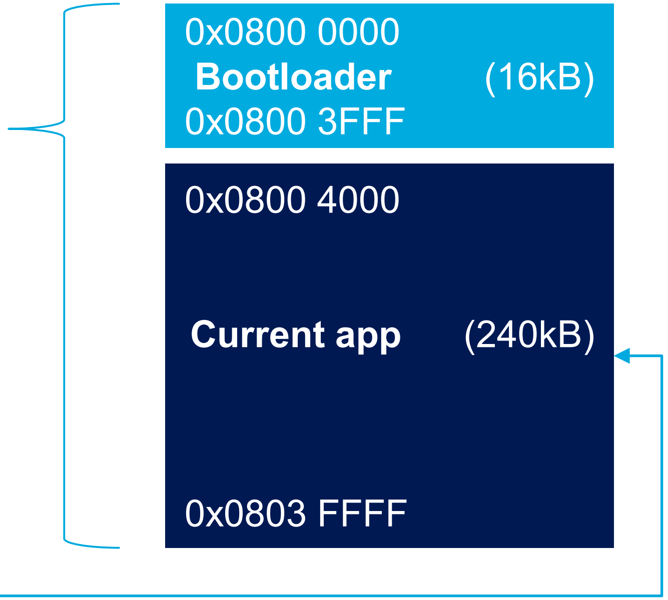
- Binary
  - STM32F401RE-Nucleo
  - STM32F446RE-Nucleo
  - STM32L476RG-Nucleo
  - STM32L476RG-SensorTile

Bootloader + App, flash at 0x0800 0000

- **BlueMS2_ST_BL.bin**
- **BlueMS2_ST_BL.hex**

Application, flash at 0x0800 4000

- **BlueMS2_ST.bin**
- **BlueMS2_ST.hex**



Question and Answers