ST Sensor Solutions for Condition Monitoring and Predictive Maintenance

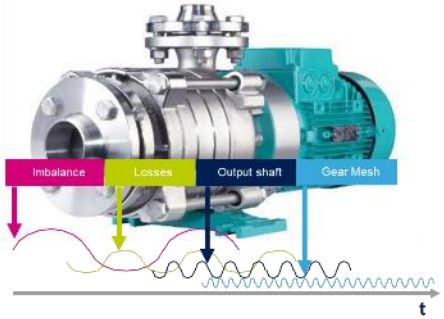
EMEA Marketing and Application

June 2020

Webinar with Rutronik

Agenda

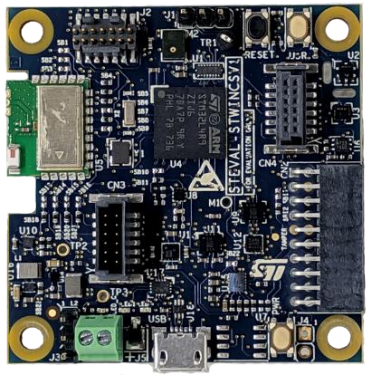
#1 Condition Monitoring and Predictive Maintenance Overview



#2 Typical Application Block Diagram

#3 Focus on IIS3DWB MEMS vibration sensor

#4 Tools Overview including STWIN details



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Condition Monitoring and Predictive Maintenance overview

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Predictive Maintenance
A smart industry hot topic

Preventive Maintenance (scheduled)

Predictive Maintenance (at the optimal moment)

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Predictive Maintenance Benefits

Reduced lost production time
Maintenance on the production line only when needed and at the optimal time

Longer machine lifetime/lower effective cost
Replacing the minimum amount of parts before failure causes damage to others

Faster and more efficient repair
Optimized worker interventions and minimum labor for parts replacement

Increased safety
Prevents failures that could be dangerous for workers before they happen

Aggregated figures from different sources

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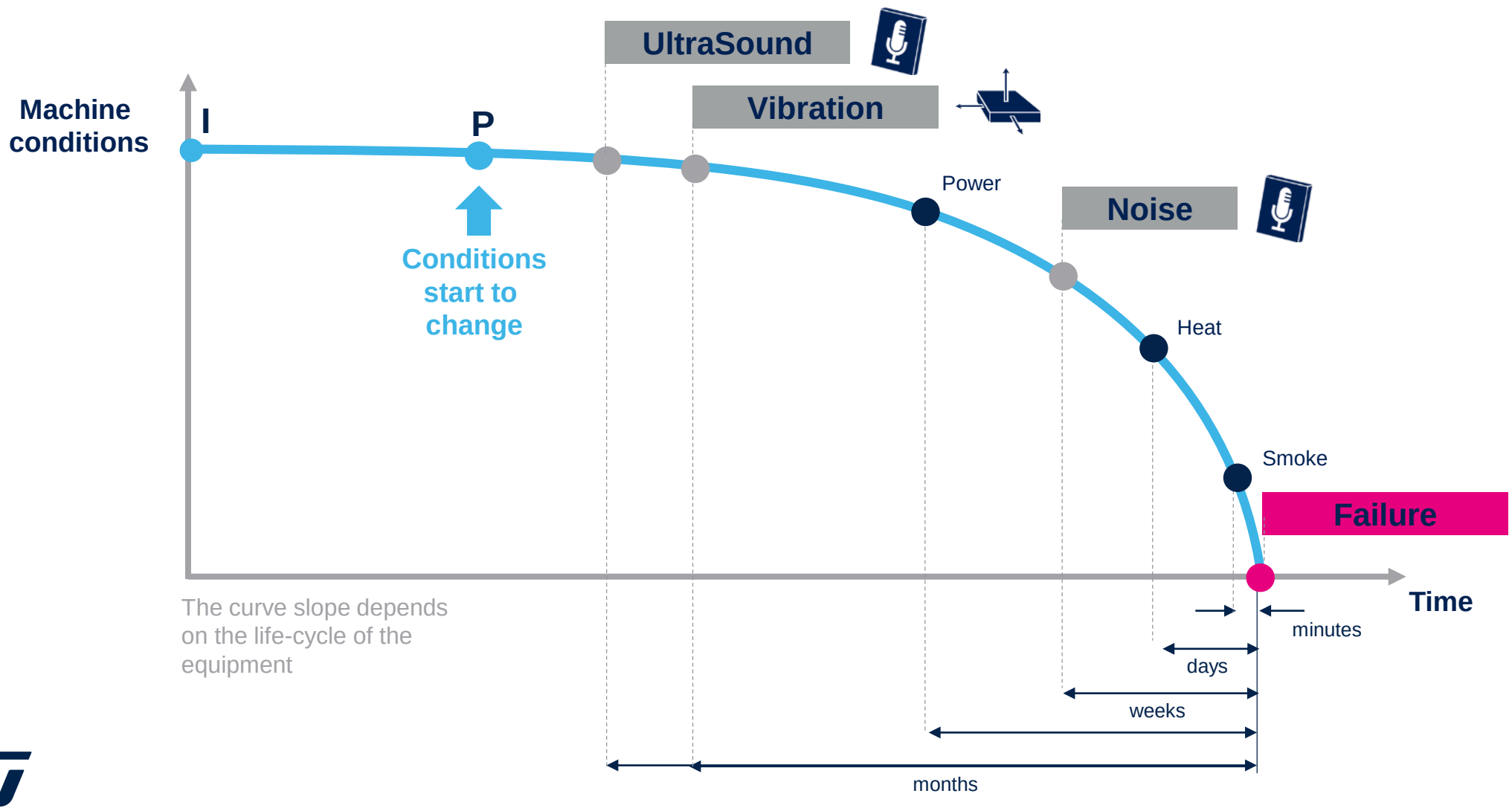
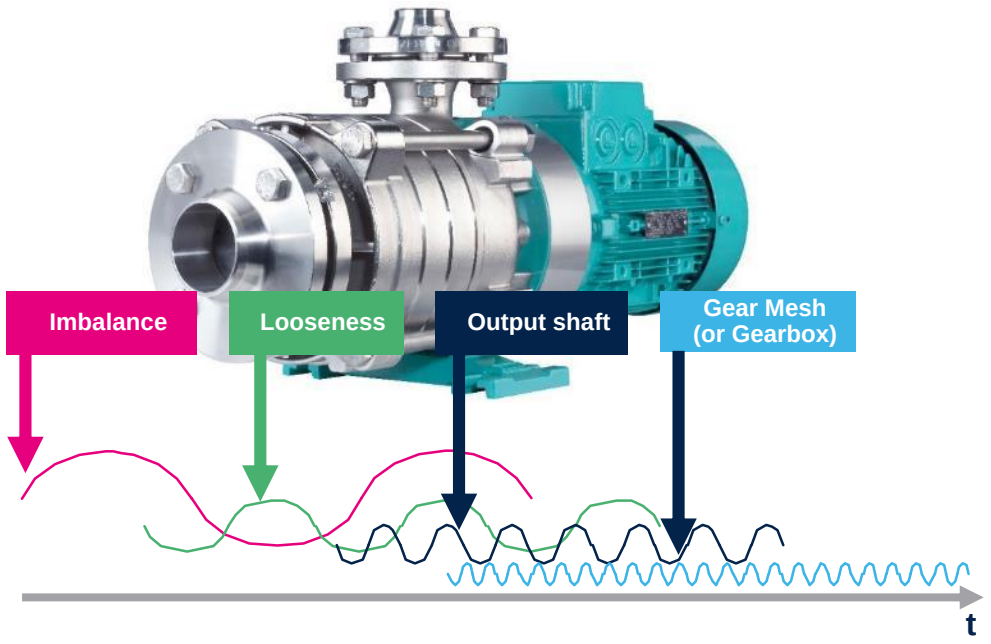
IPF installation point failure curve
Condition Monitoring



Typical use case
Industrial motor monitoring

Mechanical vibration

- Displacement
- Speed
- Acceleration
- Acoustic noise
- Angular speed
- Torque

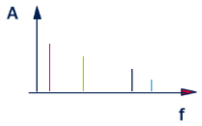


Functionality

Vibration Capture

Connectivity

Wireless Connectivity



Processing

Secure Connections

ISO 10816-3 standard
Vibration evaluation of various machine types

- Standard defines measurement method and limits for vibrations of motor installations, for pumps standard 10816-7
- 3 orientations specified, with piezos 3 separate measurements needed
- Limits specified in velocity i.e. integrating of acceleration signal
- Medium sized motors, in rigid support, with Zone B acceptable limit equals to (1.4-) 2.8 mm/s RMS velocity limit

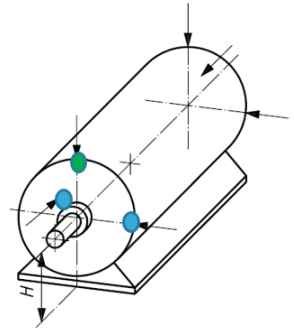


Table A.1 — Classification of vibration severity zones for machines of Group 1: Large machines with rated power above 300 kW and not more than 50 MW; electrical machines with shaft height $H \geqslant$ 315 mm

Support class	Zone boundary	r.m.s. displacement µm	r.m.s. velocity mm/s
Rigid	A/B	29	2,3
	B/C	57	4,5
	C/D	90	7,1
Flexible	A/B	45	3,5
	B/C	90	7,1
	C/D	140	11,0

Table A.2 — Classification of vibration severity zones for machines of Group 2: Medium-sized machines with rated power above 15 kW up to and including 300 kW; electrical machines with shaft height 160 mm $\leqslant H <$ 315 mm

Support class	Zone boundary	r.m.s. displacement µm	r.m.s. velocity mm/s
Rigid	A/B	22	1,4
	B/C	45	2,8
	C/D	71	4,5
Flexible	A/B	37	2,3
	B/C	71	4,5
	C/D	113	7,1

Zone A: The vibration of newly commissioned machines normally falls within this zone.

Zone B: Machines with vibration within this zone are normally considered acceptable for unrestricted long-term operation.

Zone C: Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.

Zone D: Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

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Predictive maintenance
Changing the paradigm: moving the intelligence to the node

Current Approach

Raw data collection by Technician

Huge amount of Data

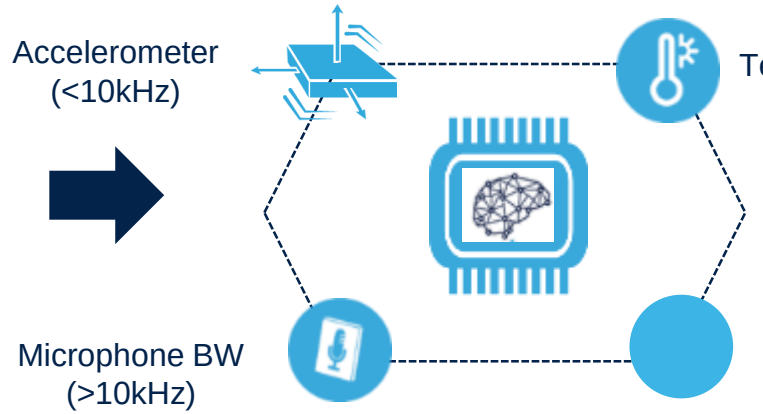
Large Storage and Data Processing

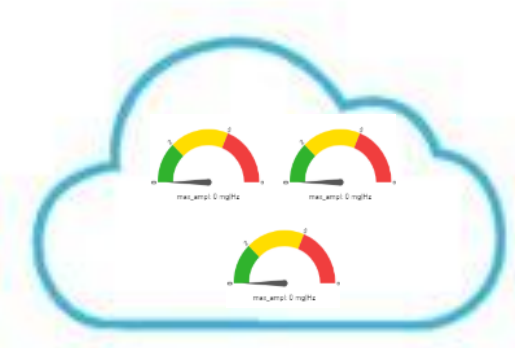
ST enables new approaches

Sensors fusion with AI capabilities

Pre-processed Data and Alarms

Smart and Light Cloud





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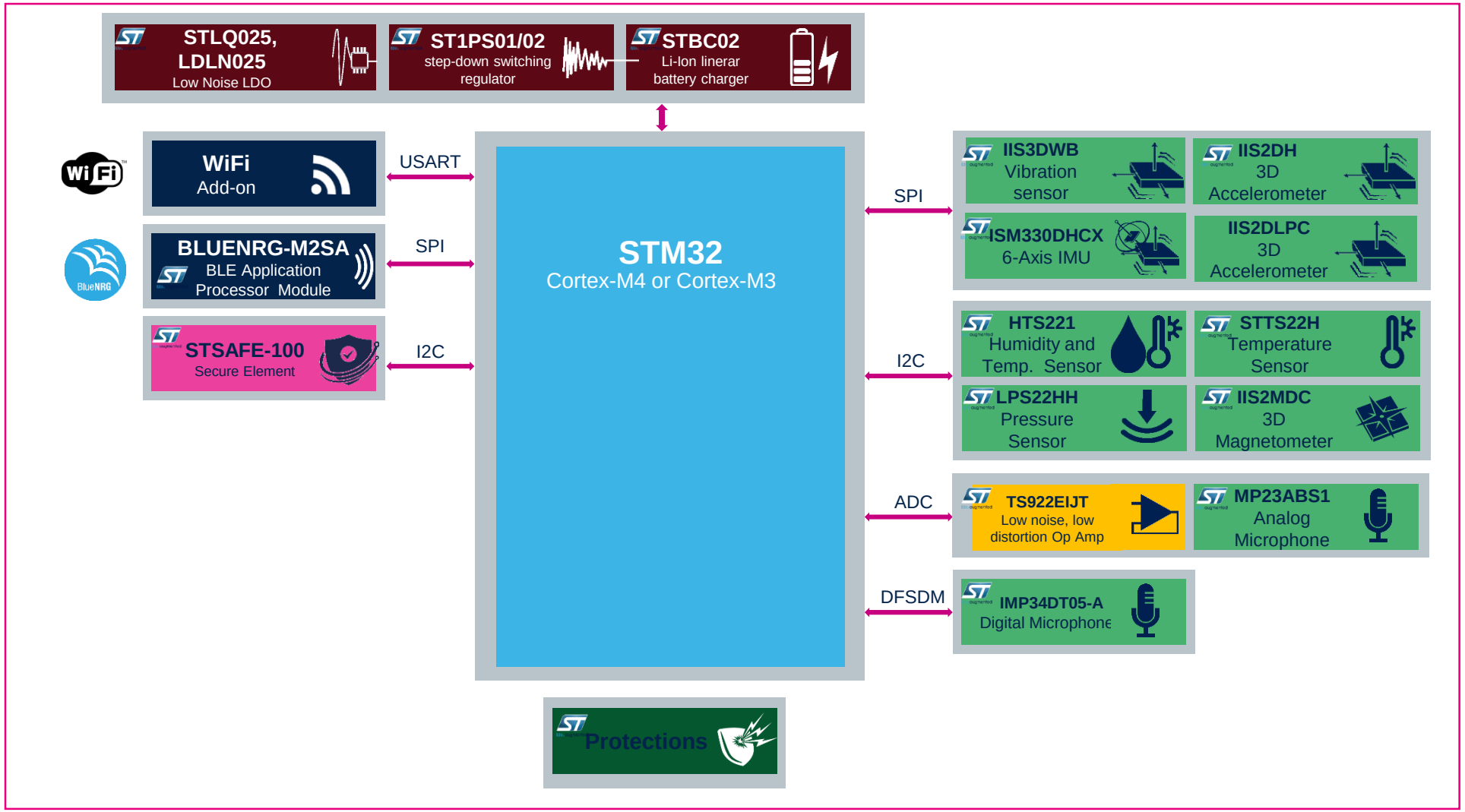
Typical block diagrams

Condition Monitoring block diagram
Battery-operated smart sensor node



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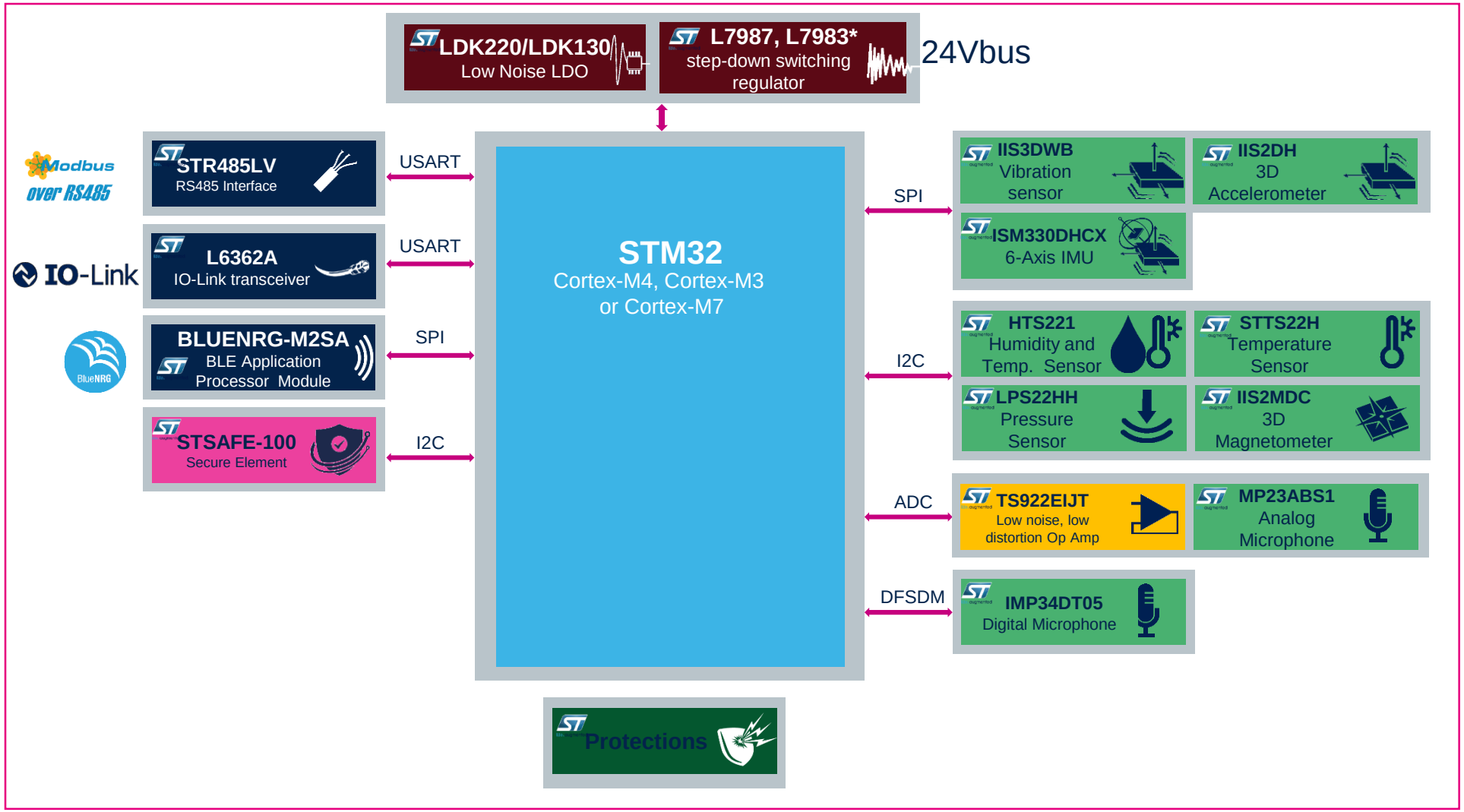
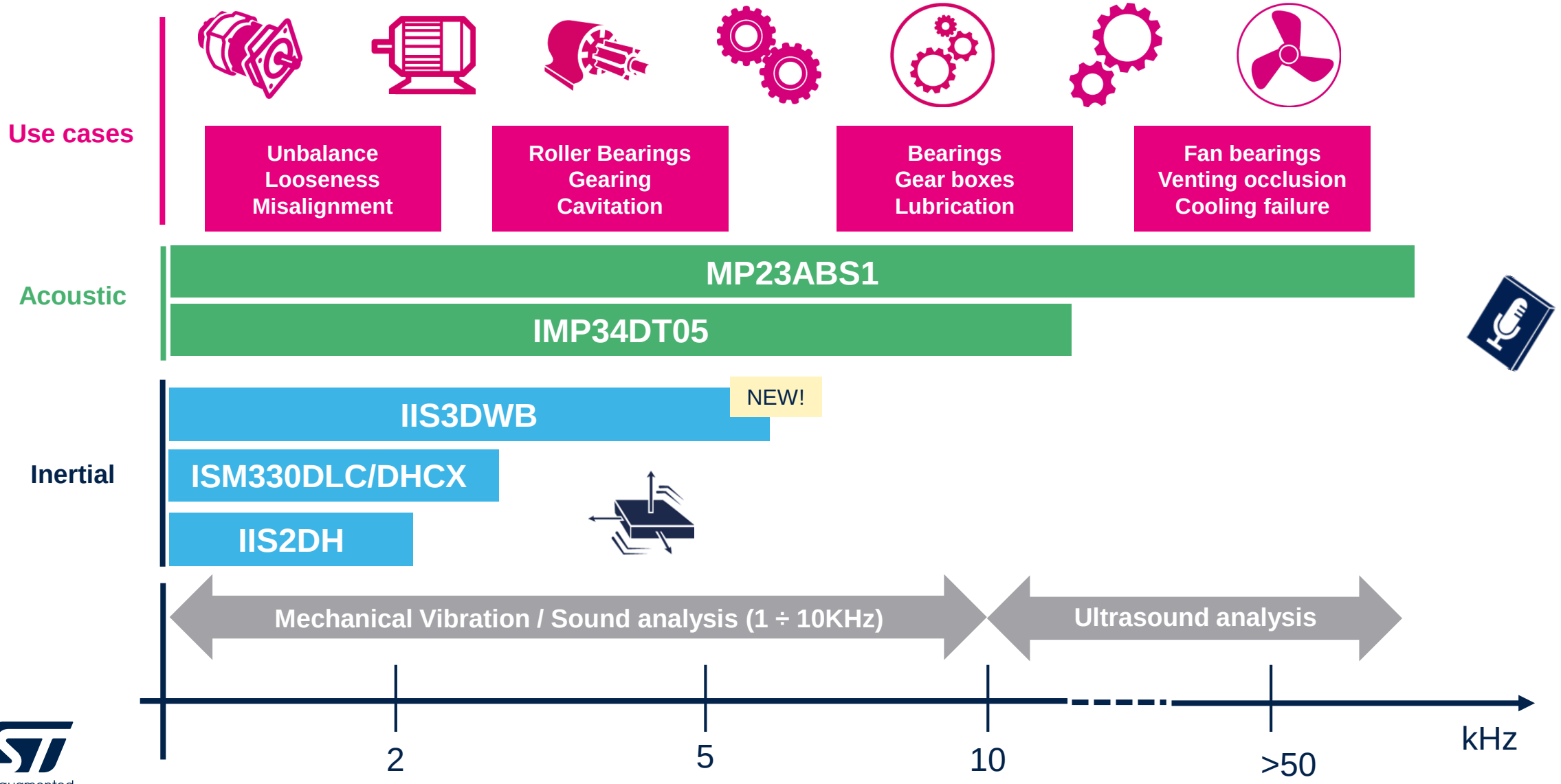
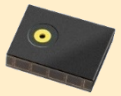
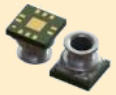
Condition Monitoring block diagram
Vbus-powered industrial smart sensor node



MEMS for vibration analysis
Sensors and defects over bandwidth



MEMS & Sensors for CbM and PdM

Function	IC	Description	Package	Features
Vibration	**IIS3DWB** NEW!	Ultra Wide Bandwidth **Accelerometer**	LGA-14, 2.5x3 mm 	• 3D Accelerometer – 16g Full Scale - Digital Output • **Ultra Wide Bandwidth (up to 6 kHz)** • Ultra Low Noise + up to 105°C operating Temp
	ISM330DLC **ISM330DHCX**	Wide Bandwidth **Accelerometer + Gyroscope**		• 3D Accelerometer + 3D Gyro - Digital Output • 3 kHz bandwidth accelerometer • Ultra Low Power + Smart Features
	IIS2DH	Wide Bandwidth, Ultra-low-power **Accelerometer**	LGA-12, 2x2 mm 	• 3D Accelerometer – Digital Output • Up to 2.3 kHz bandwidth • Ultra Low Power – Ultra Compact
	IIS2MDC	Low-Noise, Low Power **Magnetometer**		• 3D Magnetometer – Digital Output • AMR Technology - Up to 50 Gauss Full Scale • Ultra Low Noise, Low Power
Acoustic	**MP23ABS1TR**	Analog single ended **Microphone**	RHLGA metal cap 5-L, 3.5x2.65x0.98 mm	• Bottom port Microphone • **Wide Acoustic Bandwidth (up to 80 kHz)** • Wide Dynamic Range (AOP up to 130 dBSPL)
	IMP34DT05-A	Digital Top Port **Microphone**	3x4x1 mm 	• Top port Microphone with Digital Output • Wide dynamic range (AOP up to 122 dBSPL) • ESD up to ±15kVolt
Environ-mental	**LPS22HH**	High Accuracy – Compact Size Absolute **Pressure Sensor**	HLGA-10-L, 2x2x0.76 mm Ultra Compact full molded	• 260 to 1260 hPa Range - Digital Output • High Accuracy (±1 hPa) • Low noise (0.75 Pa RMS)
	LPS27HHW **LPS33W**	Water Resistant Absolute **Pressure Sensor**	2.7x2.7x1.7 mm 3.3x3.3x2.9 mm 	• 260 to 1260 hPa Range - Digital Output • High Accuracy (±2.5 hPa) + Low noise (0.8 Pa RMS) • Water resistant up to 10 atm
	STTS22H	Digital **Temperature Sensor**	2 x 2 x 0.50 mm 6-lead UDFN	• Operating temperature -40 °C to +125 °C • Accuracy: ±0.5 ºC max (-10 °C to +60 °C) • Programmable threshold, One-shot mode
	STLM20	Analog **Temperature Sensor**	SOT323-5L, UDFN-4L	• Accuracy ±0.5 °C (typ.) • Operating Temp –55 °C to +130 °C

Focus on IIS3DWB vibration sensor

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MEMS sensors vs. Piezoelectric

- MEMS Pros
  - Low power, small size, low weight
  - Cost effective
  - Digital output: easy wiring and no need for external ADC or other signal conditioning circuits
  - Fast recovery after high shock and in power up
  - Frequency response includes DC
  - Good stability over time and across temperatures
  - Integrated self-test
  - Embedded functionalities
- Cons
  - Lower achievable BW vs. Piezoelectric
  - Higher noise, lower resolution

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IIS3DWB ultra-wide bandwidth, low-noise 3-axis digital accelerometer for vibration monitoring

Parameter	Value
N. of axis	3-axis
Full Scale [g]	±2/±4/±8/±16
Bandwidth (-3dB) [kHz]	6.3
ODR [kHz]	26.7
Output i/f	Digital: SPI
Noise Density [µg/√Hz]	75 (60 in single axis)
Current Consumption [mA]	1.1
Features	FIFO (3kbyte) Programmable HP Filter Interrupts Temp. Sensor Embedded Self Test
Operating Temp [°C]	-40 ; +105
Operating Voltage [V]	2.1 ÷ 3.6
Package [mm3]	LGA 2.5x3x0.83 14Lead

Pin2pin compatible with ISM330x/LSM6DSx devices

Link to final datasheet/product page: https://www.st.com/en/mems-and-sensors/iis3dwb.html

IIS3DWB KPIs for condition monitoring

#1 Low noise levels

#2 Wide & Flat measurement bandwidth

#3 Flat frequency response, Sharp out of band roll-off, No aliasing

#4 Stable thermal behavior over extended temperature range

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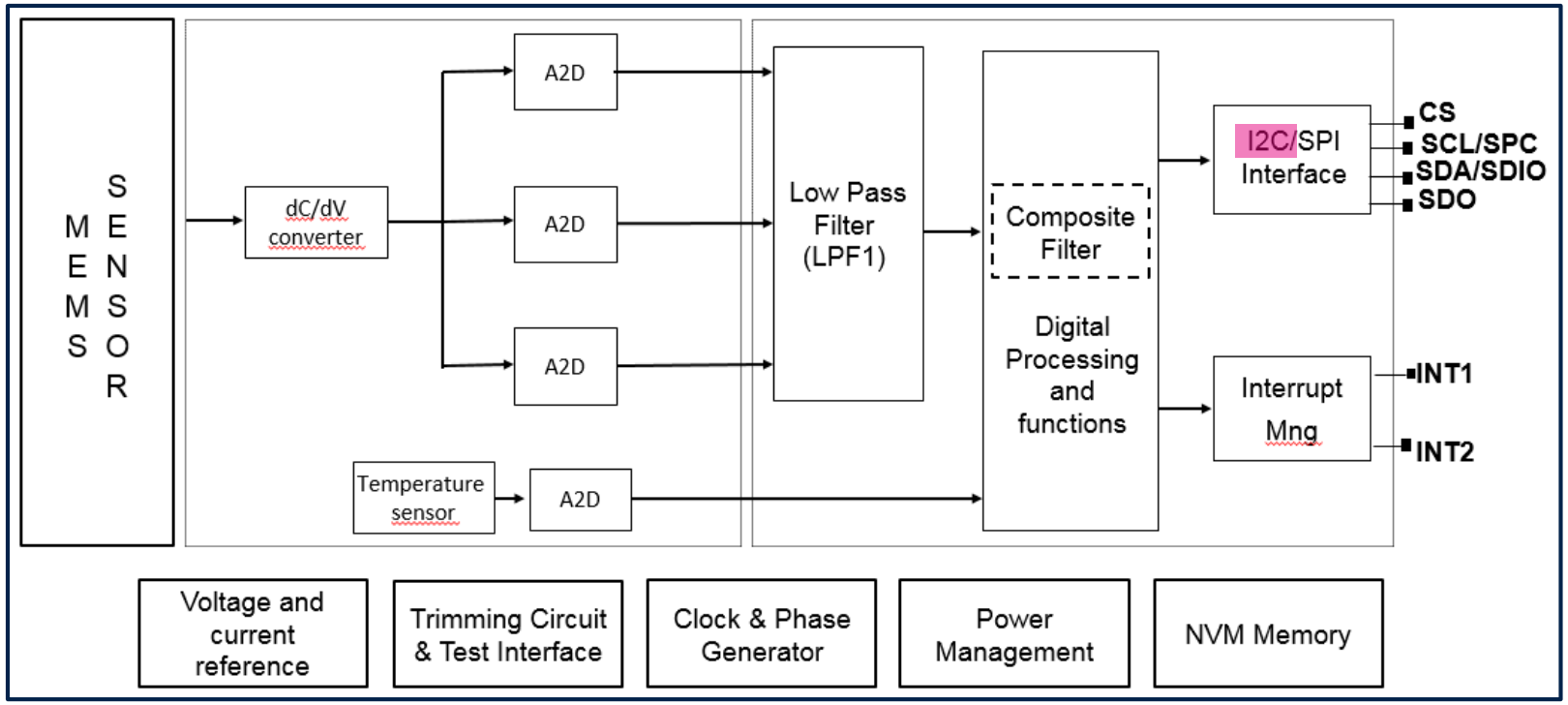
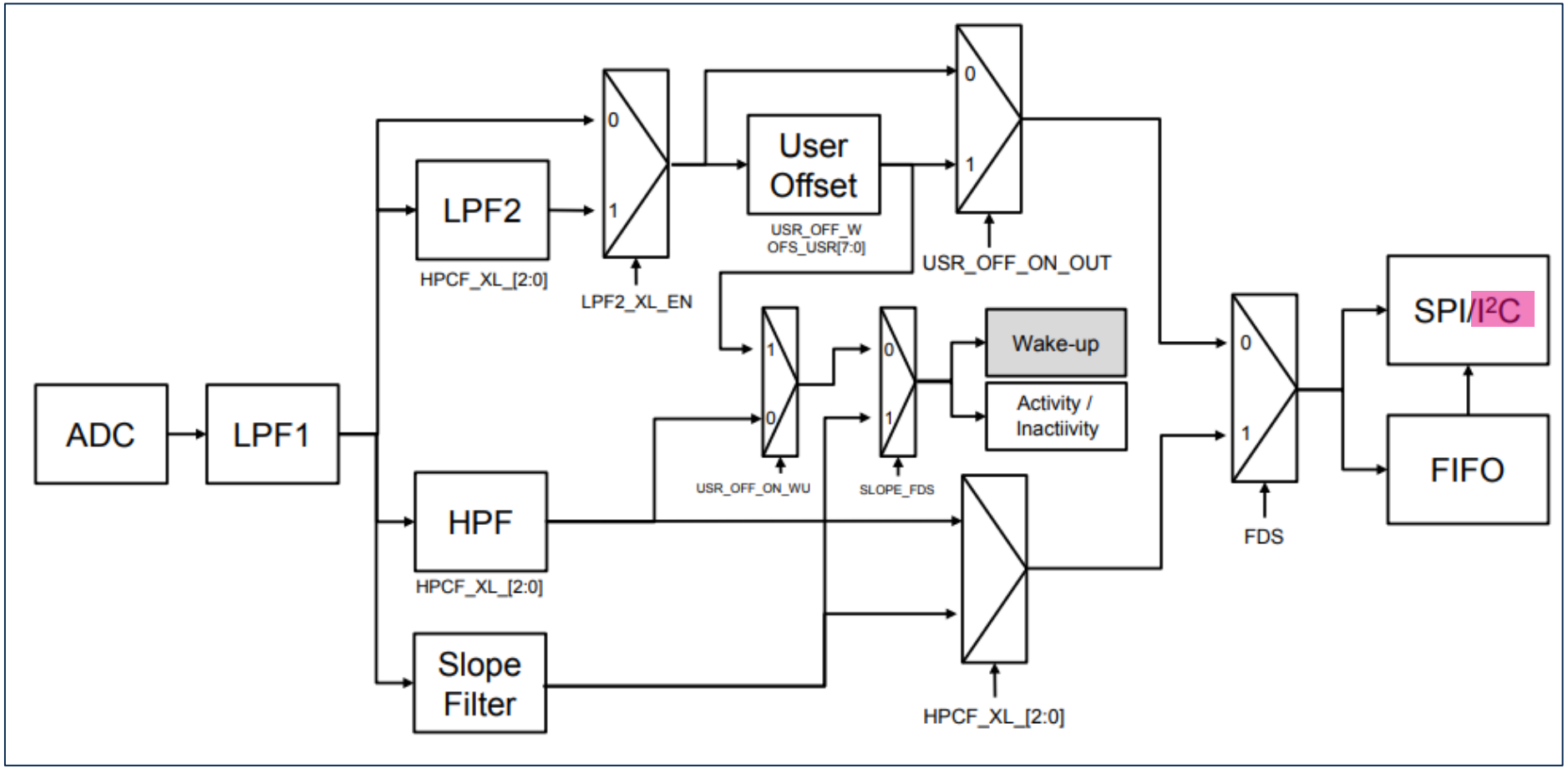
IIS3DWB architecture

- The IIS3DWB architecture is composed of the following functional blocks:
  - MEMS mechanical element
  - ADC
  - Low pass digital filter (LPF1)
  - Composite digital filter (LPF2, HPF)



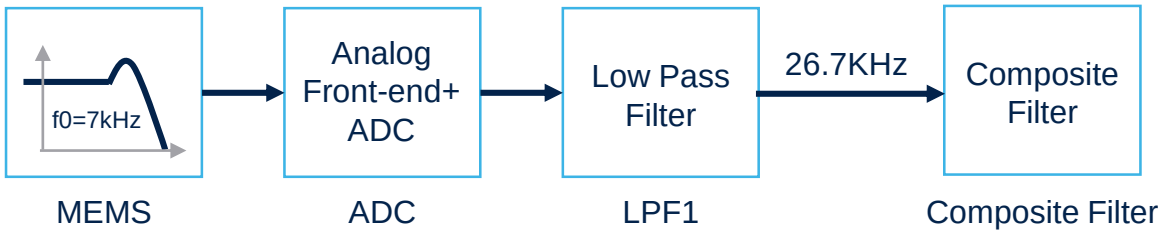
For full functionality SPI interface is recommended

IIS3DWB composite filter



IIS3DWB filtering chain

- The IIS3DWB is specifically designed to provide a wide bandwidth with very flat frequency response in the pass band and a high attenuation in the stop band to minimize any frequency aliasing
- The filtering chain is composed of:



#1 KPI Low noise level

An	Acceleration noise density 3 axes enabled[6]	X-axis		75	110	µg/√Hz
		Y-axis		75	110	
		Z-axis		110	190	
	Acceleration noise density only 1 axis enabled[6]	X-axis		60	90	
		Y-axis		60	90	
		Z-axis		80	130	

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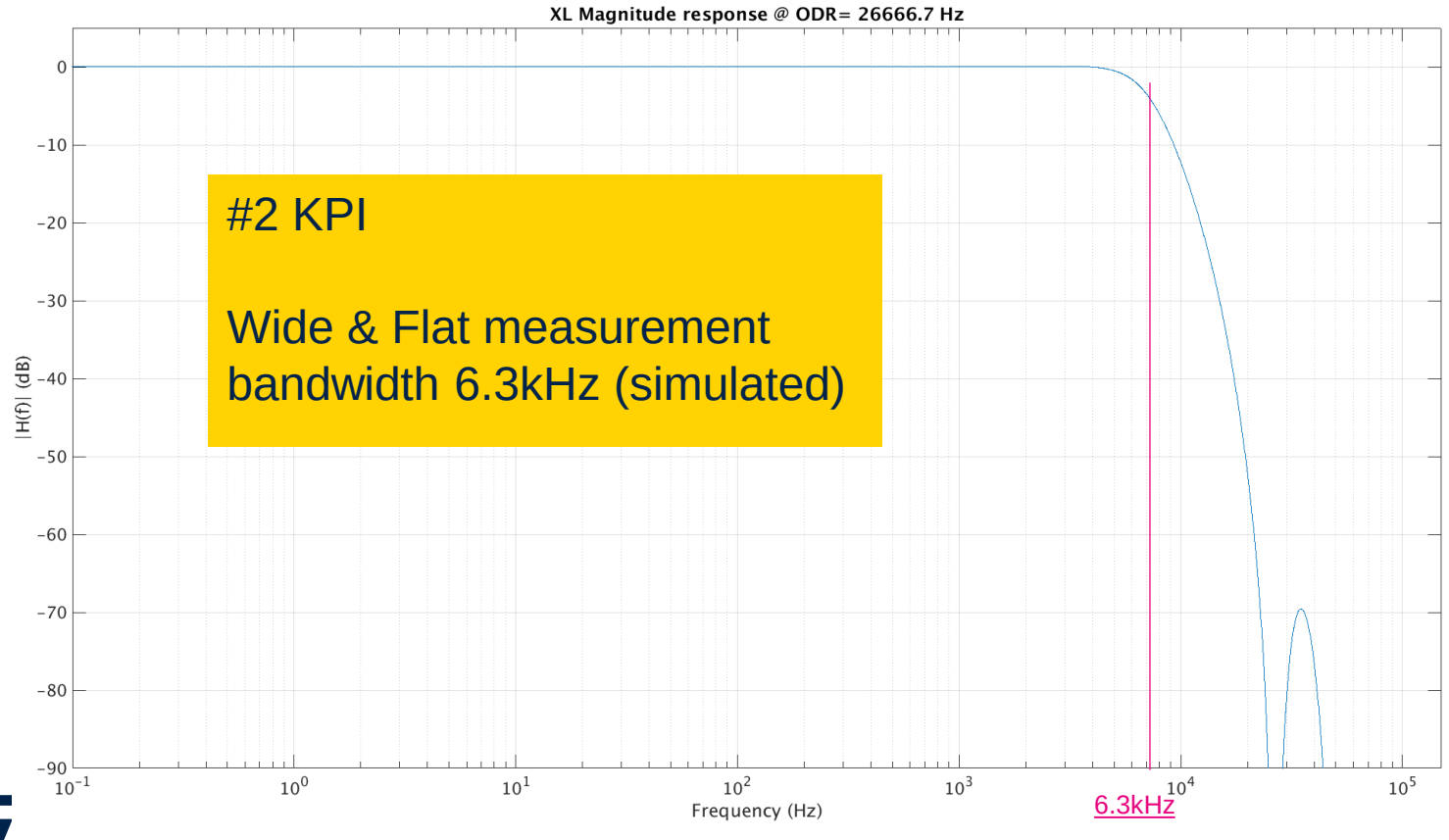
IIS3DWB filtering chain

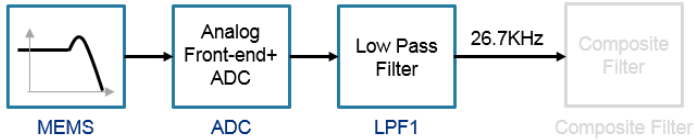
- The output of the ADC converter is filtered with a digital low pass filter LPF1 to ensure the intended sensor's frequency response:



#2 KPI

Wide & Flat measurement bandwidth 6.3kHz (simulated)

Frequency response at the output of LPF1

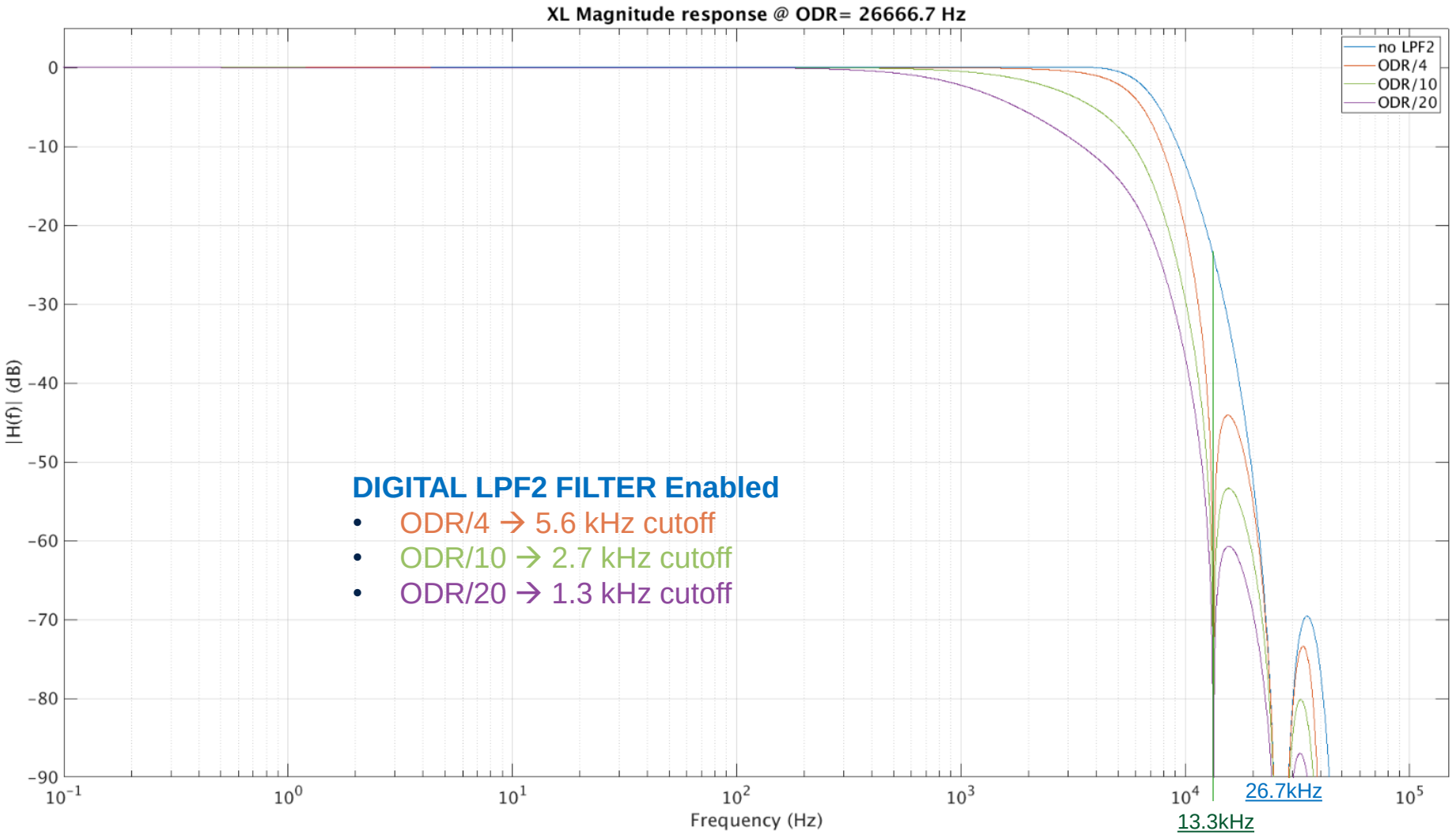


#3 KPI

Sharp out of band roll-off (>90 dB/dec).
Attenuation >70 dB at frequencies higher than ODR.
High attenuation (>50dB) and very low folding of spectrum inside signal bandwidth.

Frequency response determined by CAD simulation – at the output of LPF1

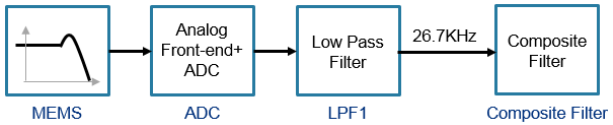
IIS3DWB frequency response with LPF2 enabled

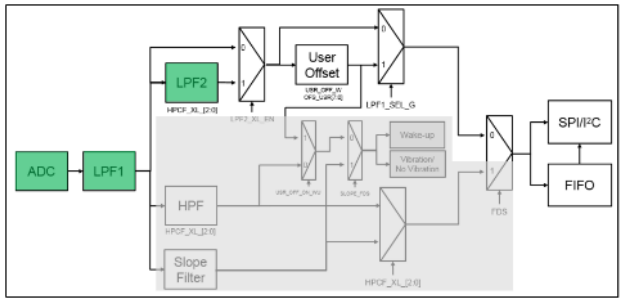


DIGITAL LPF2 FILTER Enabled

- ODR/4 → 5.6 kHz cutoff
- ODR/10 → 2.7 kHz cutoff
- ODR/20 → 1.3 kHz cutoff

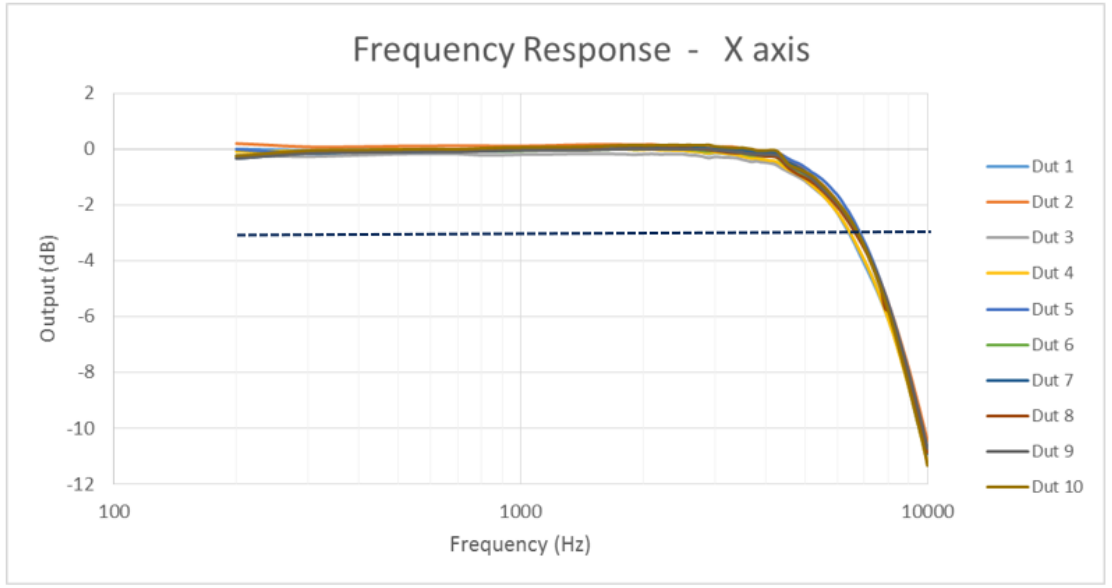
Frequency response at the output of Composite Filter when it is configured as Low Pass Filter (LPF2)



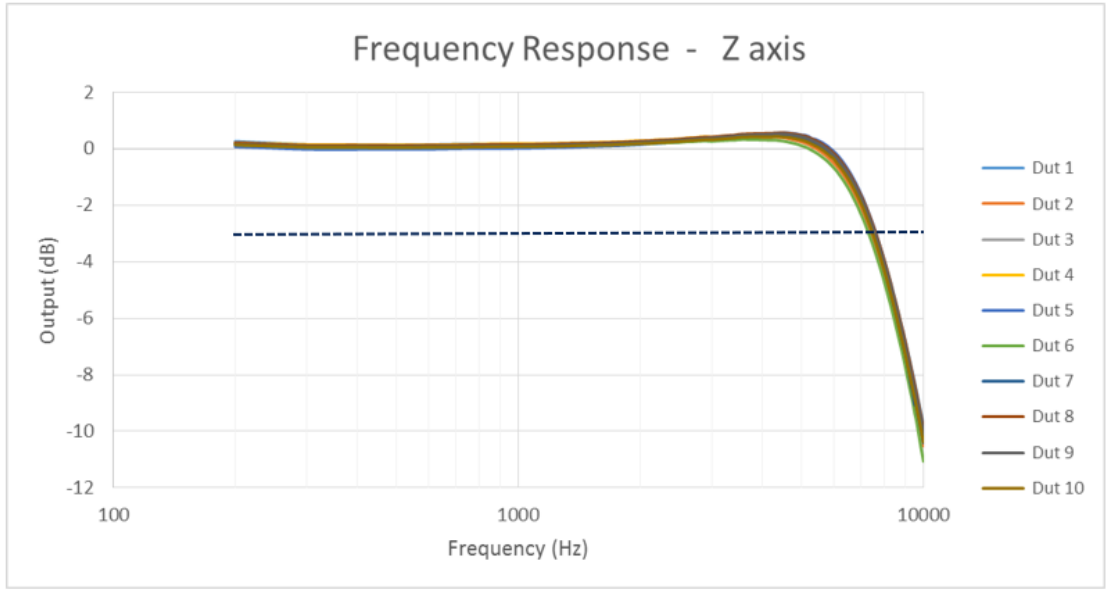


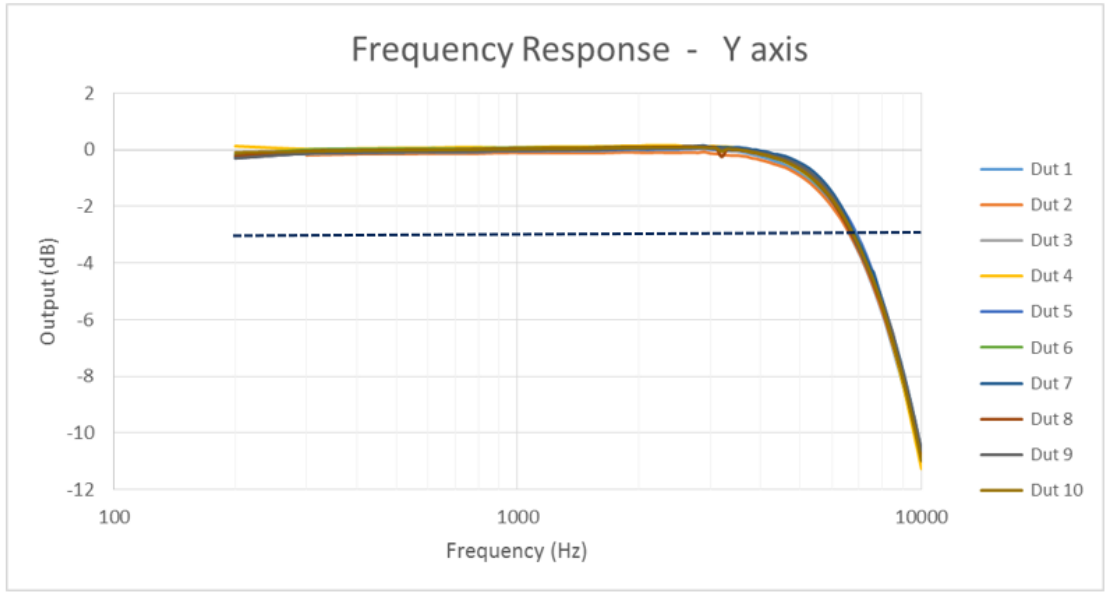
Frequency response determined by CAD simulation – at the output of LPF2 in different configurations

IIS3DWB



- **3-axis** Digital
- **6 kHz Bandwidth** (@–3dB)
- Frequency response with **Flat Pass Band, Steep roll-off (>90dB/dec)** & high **Stop Band attenuation (>70dB)**
- **Low Noise**





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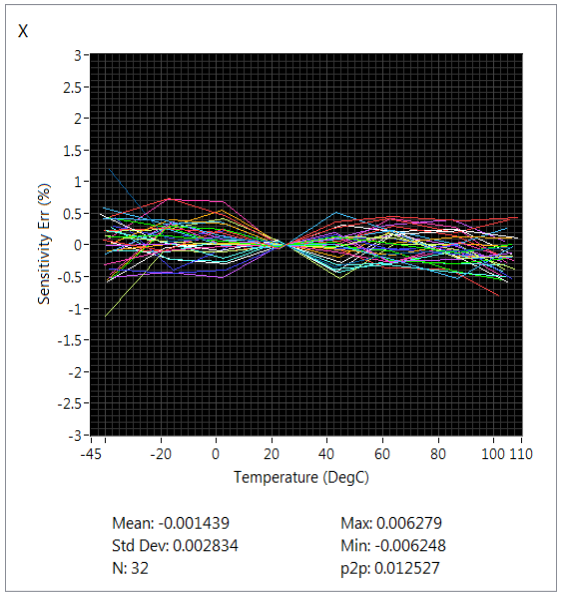
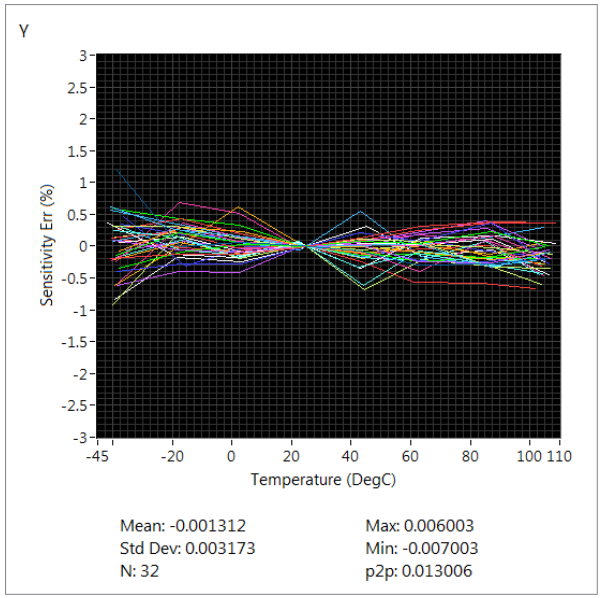
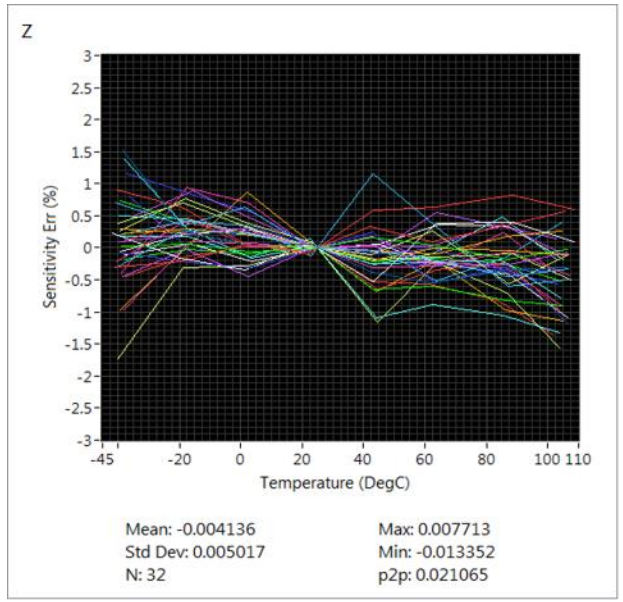
Sensitivity drift vs. temperature

#4 KPI

IIS3DWB sensitivity drift over temperature range is negligible. Zero g offset drift over temperature is not important for a vibration sensor (DC component is not interesting)







Sensitivity drift vs temperature < ± 2%

@ V_{DD} 3.0 Volt ; from -40°C to +105°C delta from T= +25°C

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Based on characterization results at 3σ on limited number of parts. Not guaranteed

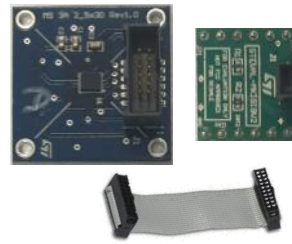
SW + HW tools overview

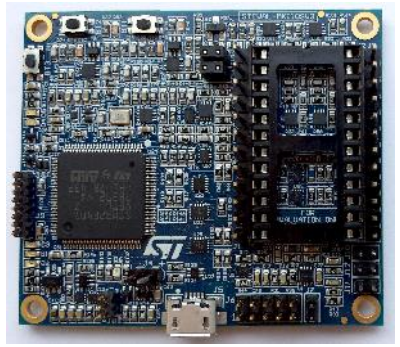
For detailed frequency measurements

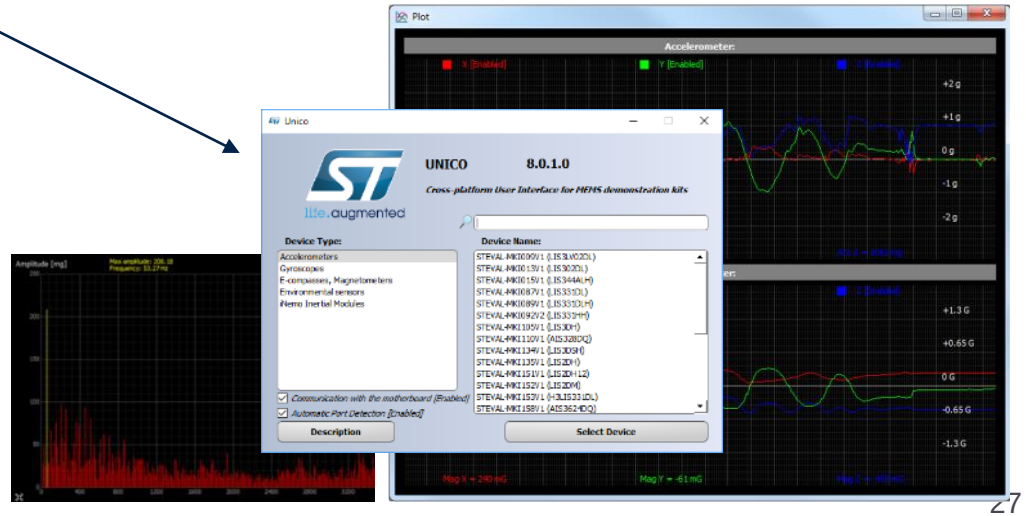
IIS3DWB evaluation tool

STEVAL-MKI109V3 + STEVAL-MKI208V1K

- ProfiMEMS Tool STEVAL-MKI109V3
- IIS3DWB square board connectable to DIL24 adapter / ribbon cable (STEVAL-MKI208V1K)
- STSW-MKI109W - Unico GUI - MEMS evaluation kit software package for Windows
- Raw data logging, real-time FFT, register access and control over Unico GUI







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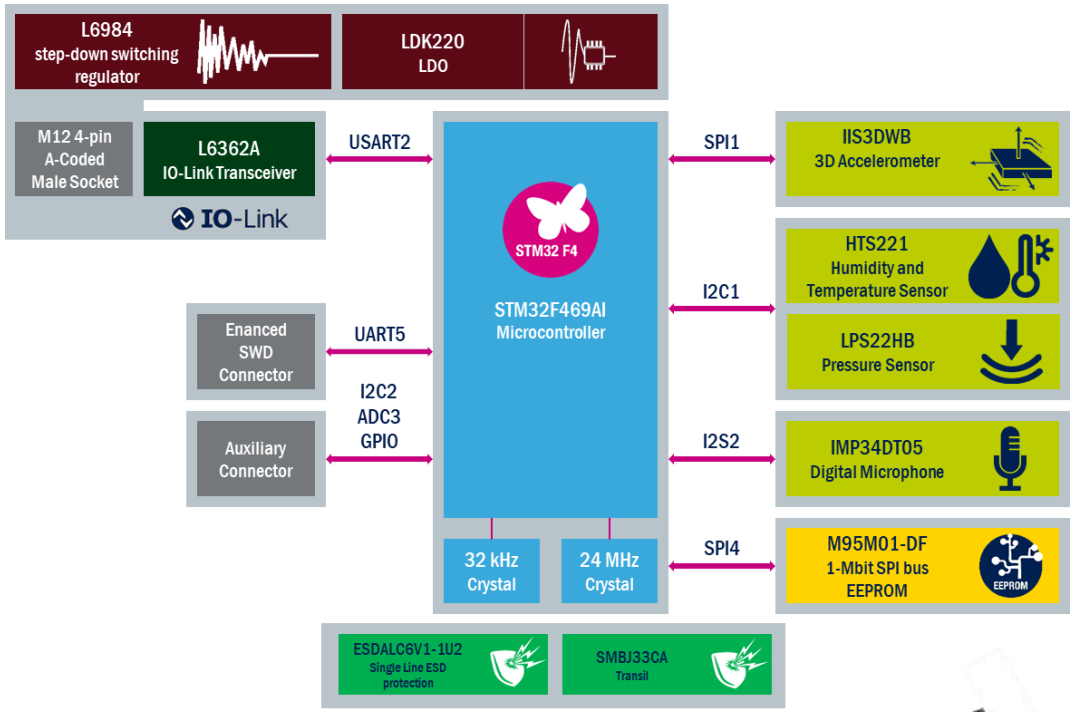
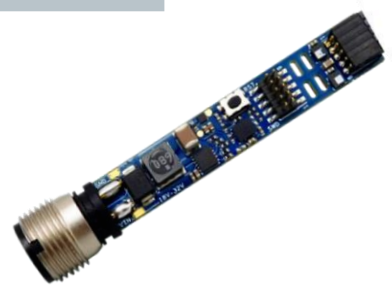
Especially for Industrial Vbus supply

STEVAL-BFA001V2B hardware overview

Multi-sensor predictive maintenance kit with IO-Link stack V1.1





- **MotionSP** Middleware
  - Programmable **FFT size** (256, 512, 1024, 2048 points)
  - **Windowing** (Flat Top, Hanning, Hamming, Rectangular)
  - **Overlapping** and acquisition time window
  - FFT **averaging** during acquisition time
  - **Speed RMS** moving average, **acceleration** max **peak**.
- Middleware integrating microphone algorithms also for **PDM to PCM** conversion, Sound Pressure Level (**SPL**), **Audio FFT**
- Third party middleware for **IO-Link device stack V1.1** (provided by **TEConcept GmbH**):
- Programmable **thresholds** for warning and alarm condition in spectral band and time domain
- Application examples with **dedicated PC GUI** to plot data with STEVAL-IDP004V2 IO-Link master multi-port evaluation board

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Wireless connectivity is a game changer? STWIN is the answer

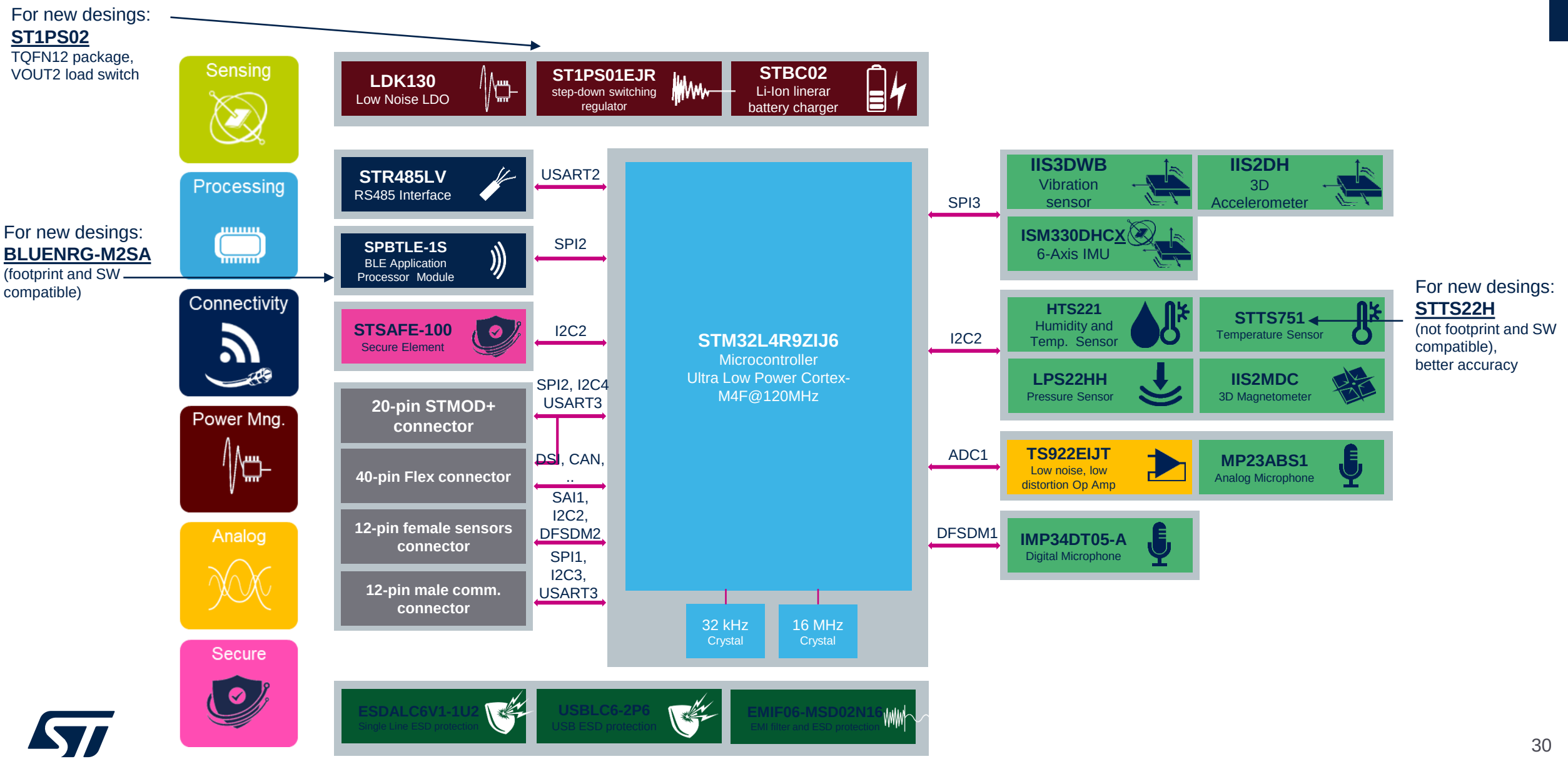
STWIN is the nickname for SensorTile Wireless Industrial node

STWIN is a kit made of:

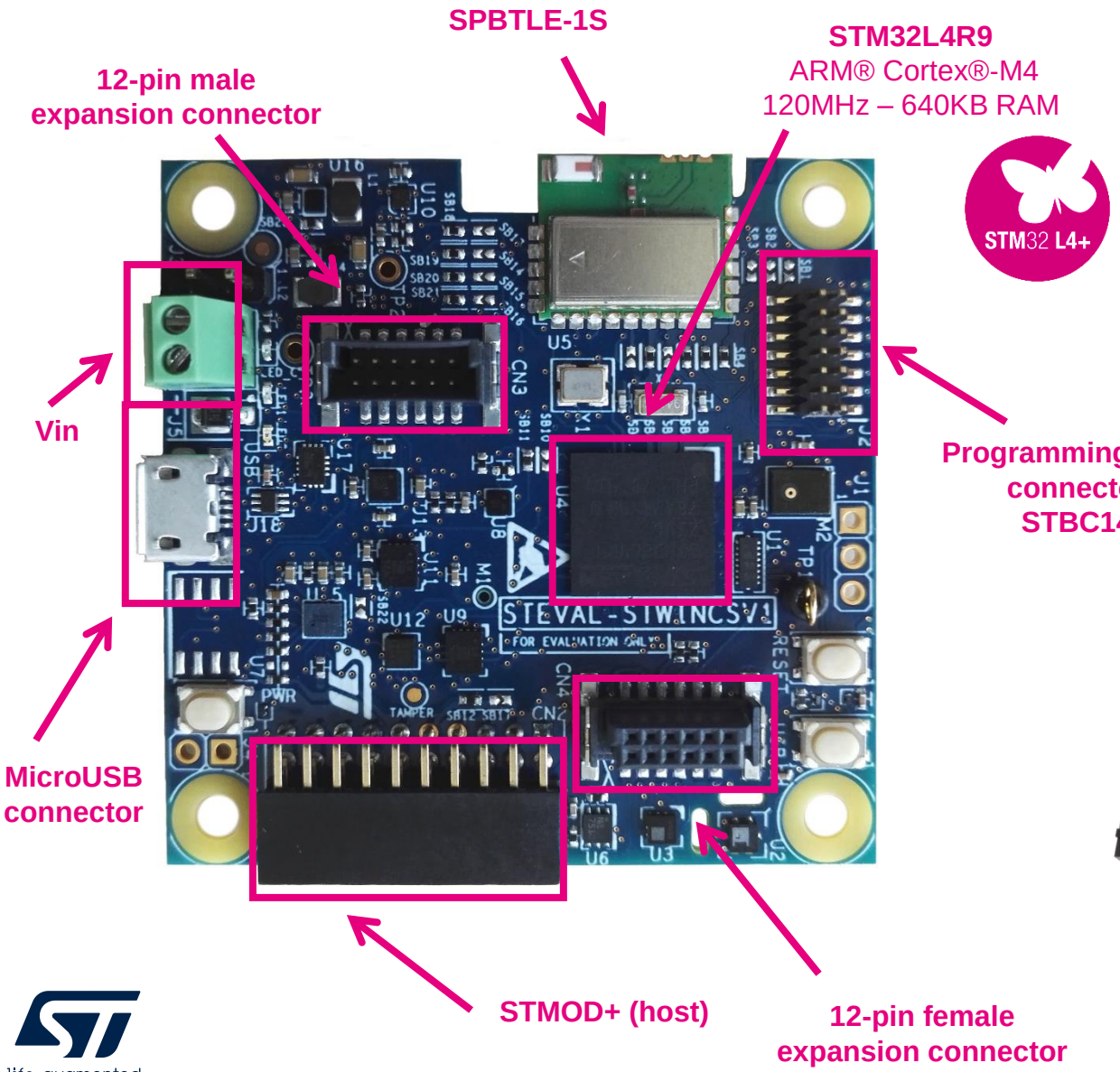
- Hardware Board
- Battery + plastic case for field testing
- STLink-V3MINI + cable for programming

STEVAL-STWINKT1

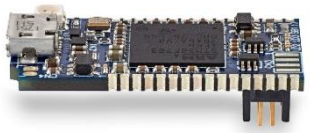
STWIN SensorTile kit



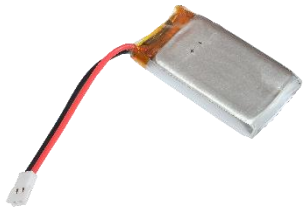
STWIN SensorTile kit



STLINK-V3MINI



480 mAh Li-Po battery



Programming cable

Plastic case

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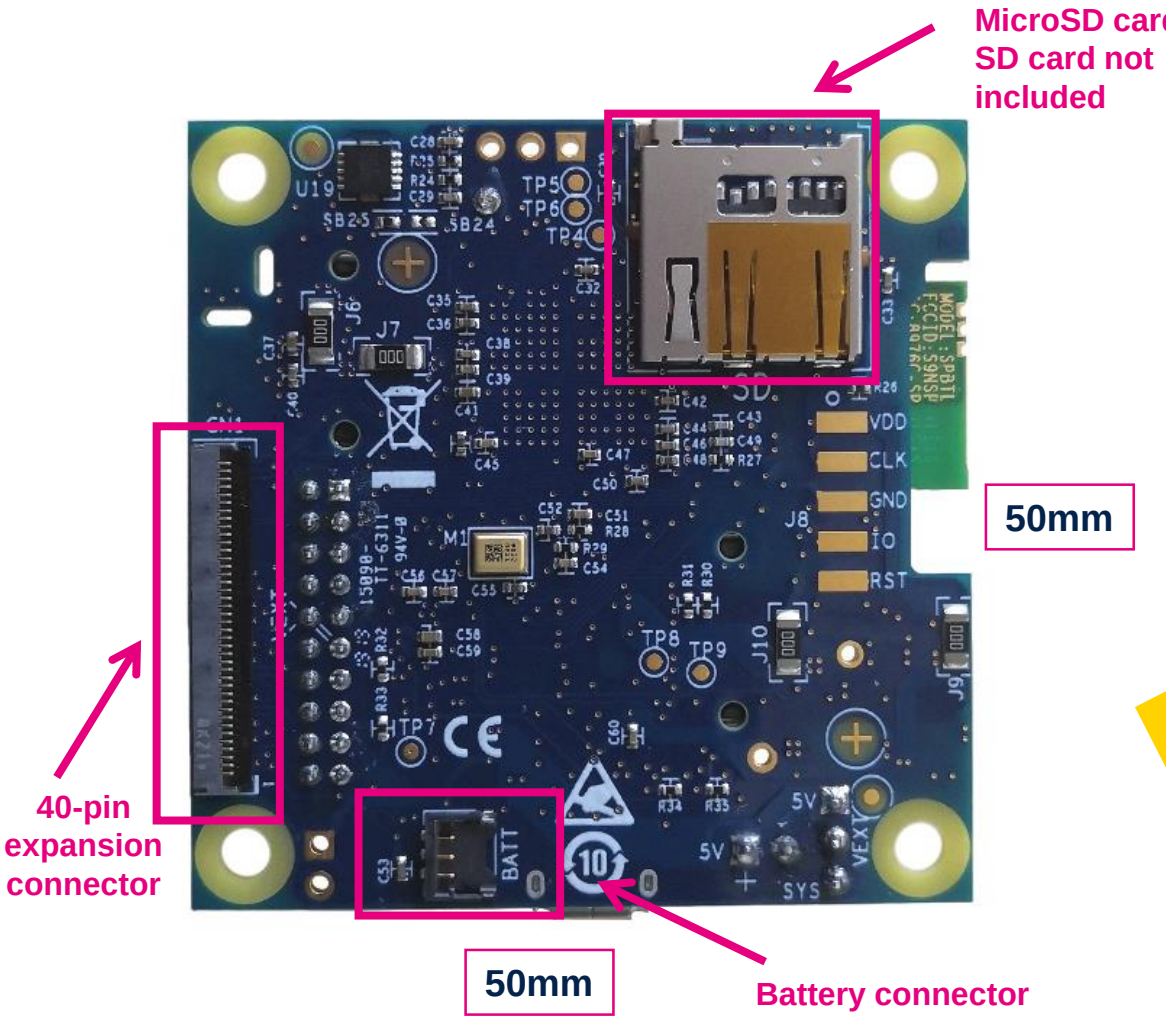
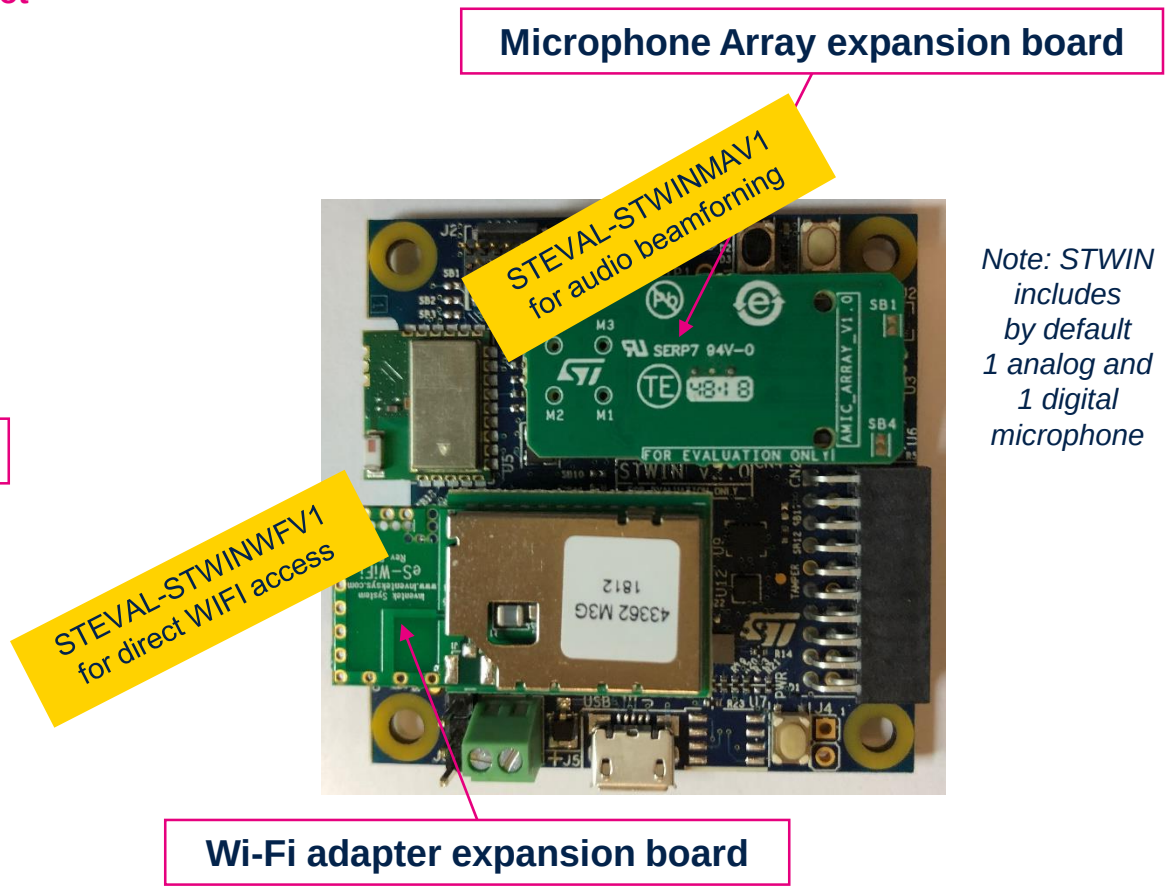
STWIN SensorTile kit & expansion boards





Note: STWIN includes by default 1 analog and 1 digital microphone

STWIN software in st.com
STSW-STWINKT01 and FP-IND-PREDMNT1

For development on PC and application demos in phone and cloud

EVALUATION TOOL SOFTWARE

For development (link)

Picture	Part number	Manufacturer	Description
	STSW-STWINKT01	ST	Firmware for STEVAL-STWINKT1 evaluation kit for predictive maintenance, smart industry, IoT and remote monitoring applications

MCU & MPU EMBEDDED SOFTWARE

For development & demos (link)

Picture	Part number	Manufacturer	Description
	FP-IND-PREDMNT1	ST	STM32Cube function pack for multi sensors node with signal processing to enable predictive maintenance

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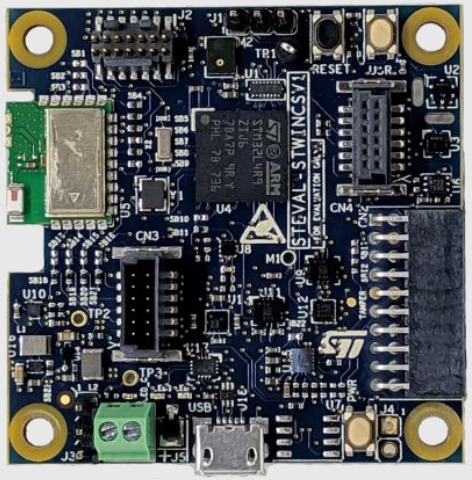
High-speed datalog STSW-STWINKT01

EVALUATION TOOL SOFTWARE

Picture	Part number	Manufacturer	Description
	STSW-STWINKT01	ST	Firmware for STEVAL-STWINKT1 evaluation kit for predictive maintenance, smart industry, IoT and remote monitoring applications



STWIN

- BLE_SampleApp
- HS_DataLog
- MicArrayCoupon
- OnboardMics
- Serial_DataLog
- UltrasoundFFT
- WiFi_Connectivity

MicroSD card or USB

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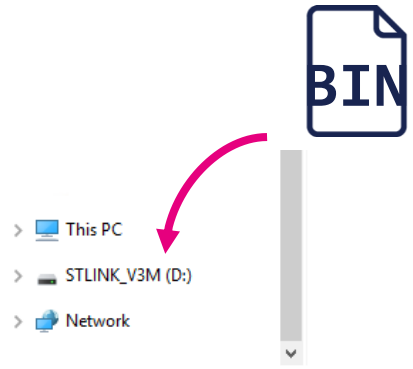
High-speed MicroSD logging run the demo

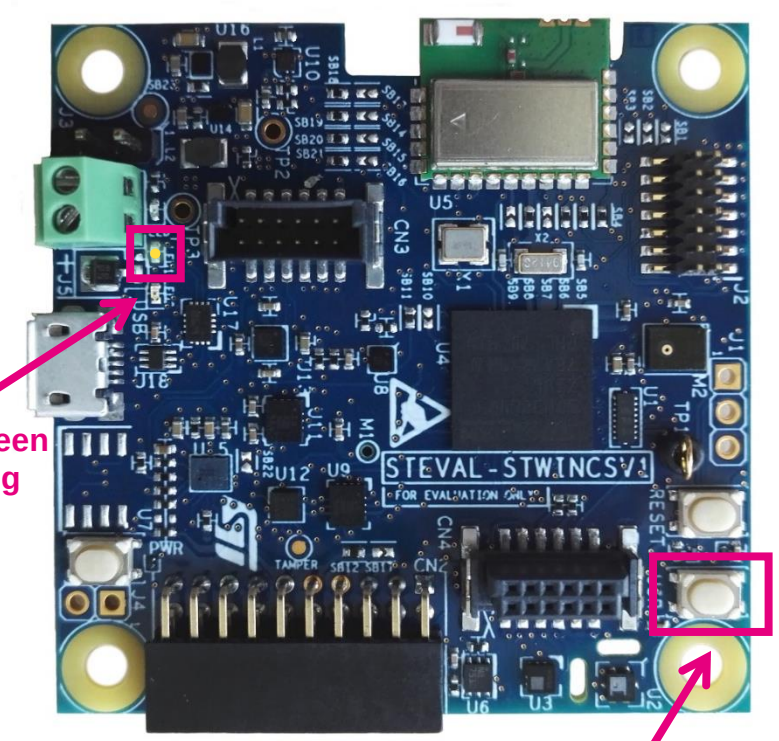
1. Program STWIN

with HS_DataLog.bin
from STSW-STWINKT01
be sure you have **SD card inserted**
Same BINARY file used for USB logging



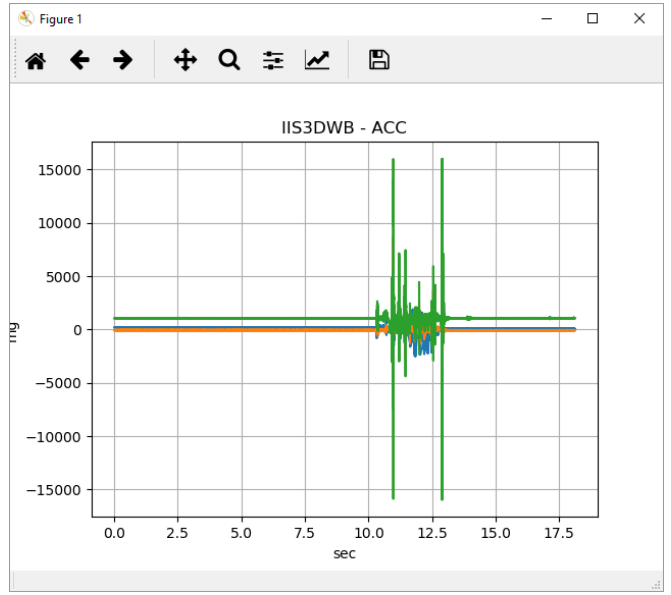
2. Log data

Press USR button to start and stop logging,
green LED blinks while logging



3. Enjoy demo

After finish of logging, data can be read/converted on PC from the microSD card by MATLAB script found in Utilities\HS_DataLog\ subdirectory or a Python script
Install first Anaconda Python environment:
https://www.anaconda.com/distribution/



Python script available in STSW-STWINKT01 v1.3.1

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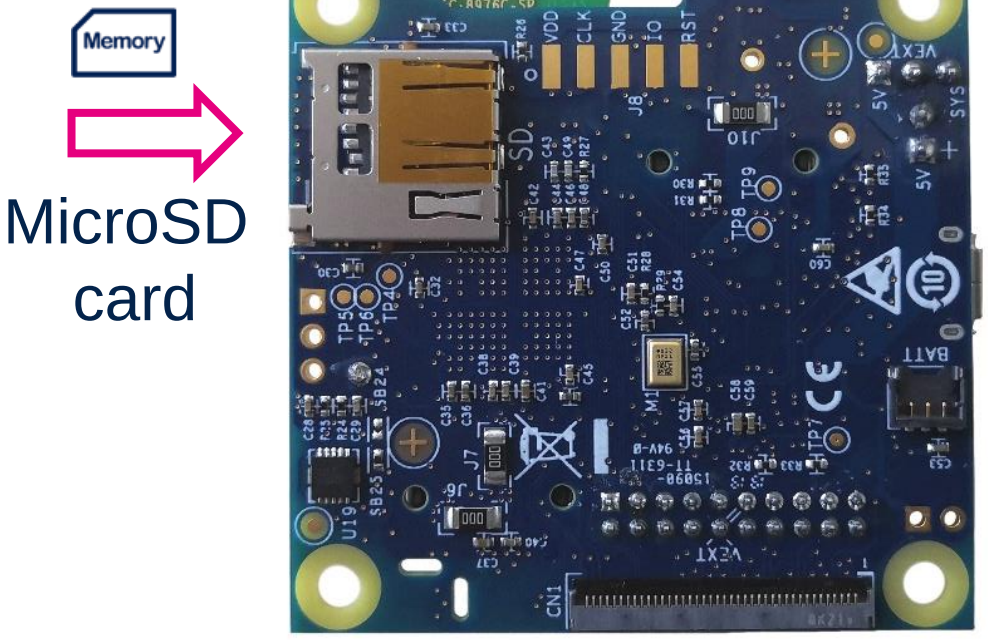
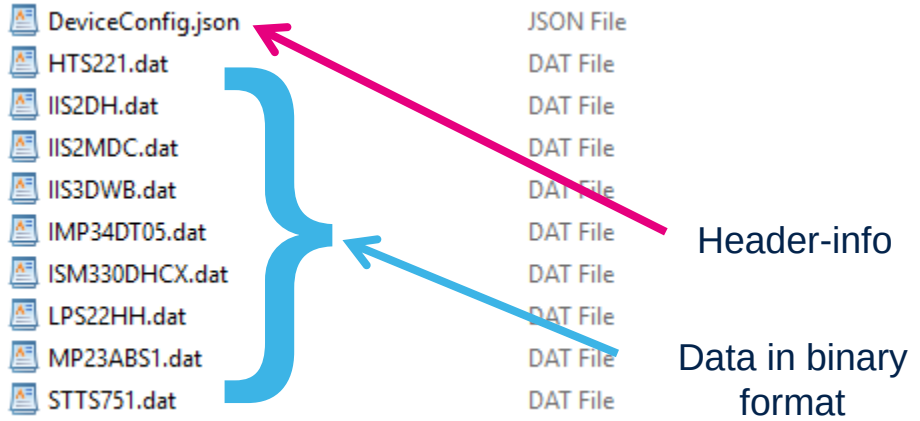
SD logging – STWIN MicroSD card directory tree



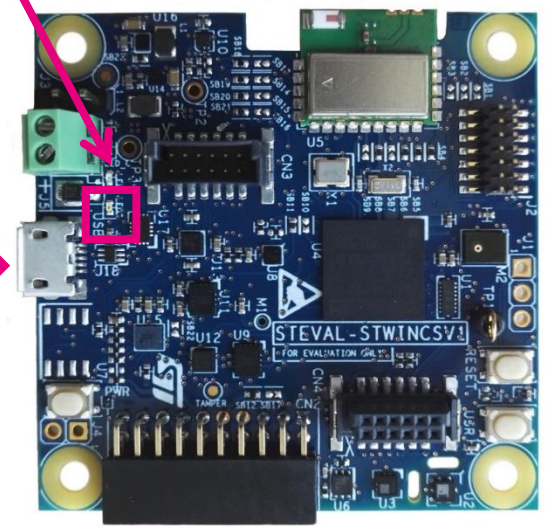


Data logs in binary format / must be converted in PC

High-speed USB logging
Run the demo

Orange LED blinks
during USB logging

USB



2. Log data

From STSW-STWINKT01_VX.X.X\
Utilities\HS_DataLog\cli_example\bin
run cli_example.exe and follow instructions

C:\Users\klara pacalova\Downloads\STSW-STWINKT01_V1.3.1\Utilities\HS_DataLog\cli_example\bin\cli_exan

```
STWIN Command Line Interface example
Version: 1.1.0
Based on : ST USB Data Log 1.1.0
Device information:
{
 "alias": "STWIN_001",
 "nSensor": 9,
 "serialNumber": "PN3K33 0190001800024"
}

Using default configuration

Press any key to start logging
```

C:\Users\klara pacalova\Downloads\STSW-STWINKT01_V1.3.1\Utilities\HS_DataLog\cli_example\bin\cli_example.exe

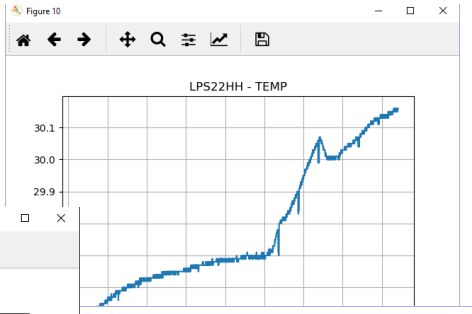
```
HS DataLog acquiring from the board named :"STWIN_001", seri

Received      3339000 total bytes from IIS3DWB
Received         2160 total bytes from HTS221
Received       177600 total bytes from IIS2DH
Received        12600 total bytes from IIS2MDC
Received      2007040 total bytes from IMP34DT05
Received      1671168 total bytes from ISM330DHCX
Received        30400 total bytes from LPS22HH
Received      8036352 total bytes from MP23ABS1
Received          352 total bytes from STTS751

Elapsed time:    21.955 seconds

press ESC to exit!
```

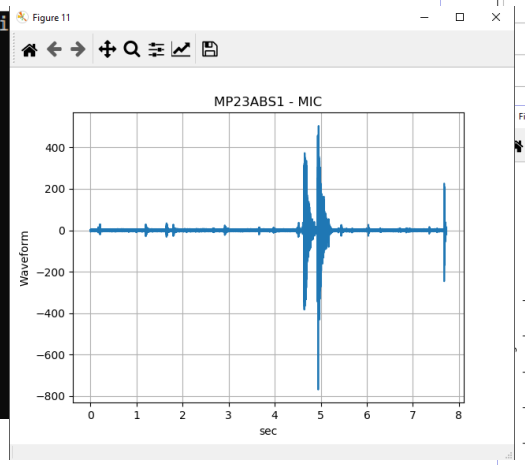
3. Enjoy demo

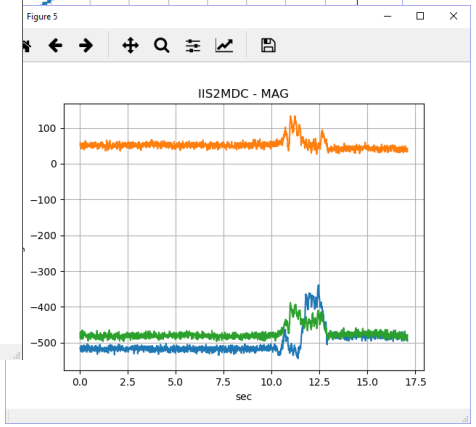
After finish of logging, copy folder with data to
Utilities\HS_DataLog\python and run
ReadSensorData.py to plot the data

This PC › Downloads › STSW-STWINKT01_V1.3.1 › Utilities › HS_DataLog › python ›

Name	Date modified	Type	Size
03032020_17_51_42	3/3/2020 5:55 PM	File folder	
03032020_17_52_15	3/3/2020 5:55 PM	File folder	
readme.txt	2/26/2020 12:02 PM	Text Document	3 KB
ReadSensorData.py	2/26/2020 3:36 PM	PY File	8 KB







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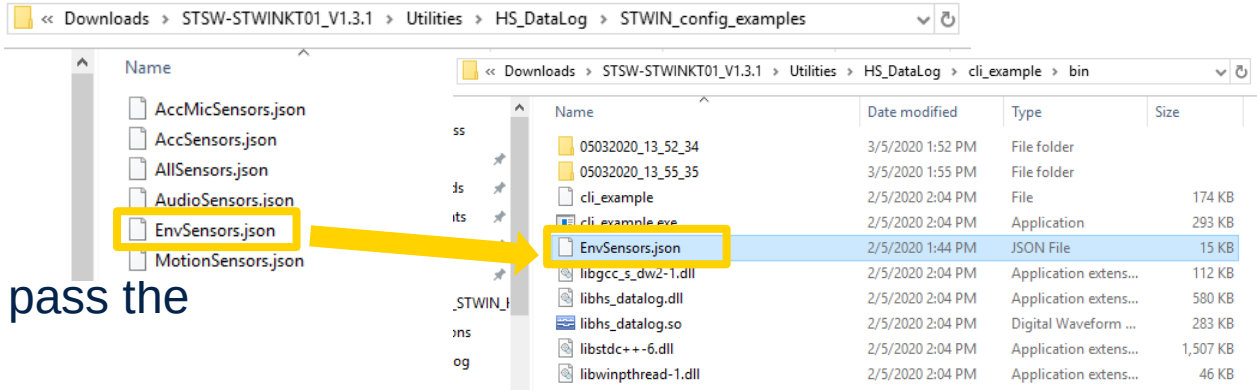
High-speed datalog Config examples

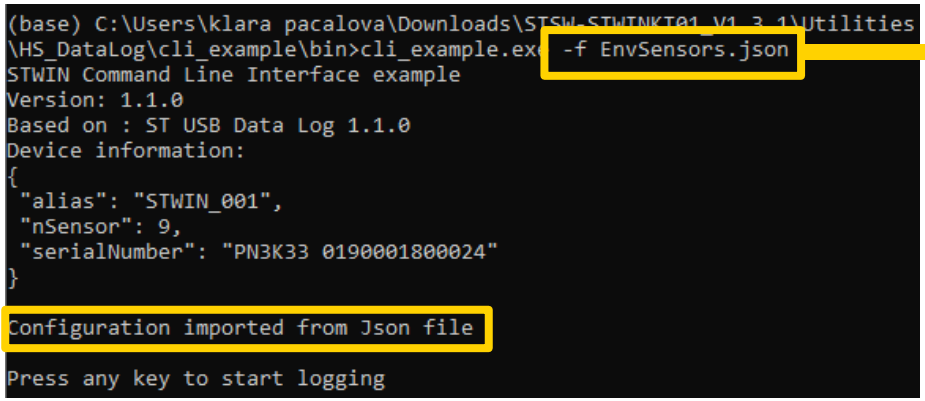
1. Copy desired config file

To STSW-STWINKT01_VX.X.X\ Utilities\HS_DataLog\cli_example\bin

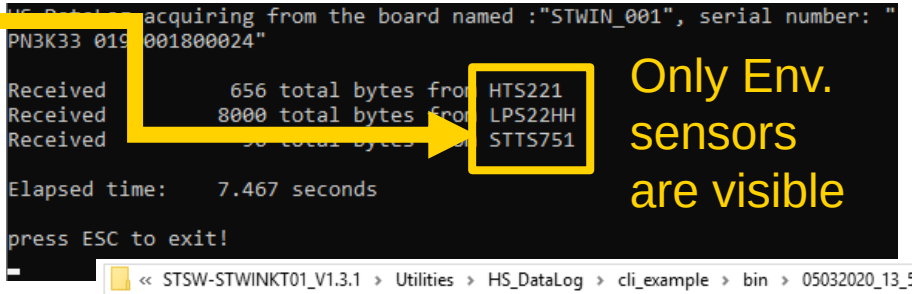


2. Log the data

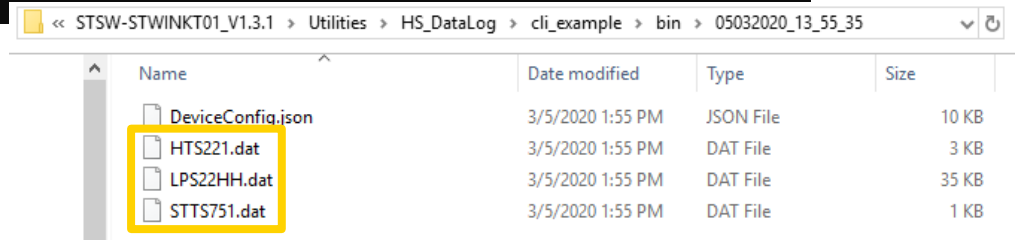
Run **cli_example.exe** and pass the configuration file with **–f filename.json**



3. Now you will log data only from desired sensors



Only Env. sensors are visible



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High-speed datalog Config examples

1. Log the data

Run **cli_example.exe** and pass the logging time with **–t [s]**

```
(base) C:\Users\klara pacalova\Downloads\STSW-STWINKT01_V1.3.1\Utilities\
HS_DataLog\cli_example\bin>cli_example.exe -t 10
STWIN Command Line Interface example
Version: 1.1.0
Based on : ST USB Data Log 1.1.0
Device information:
{
 "alias": "STWIN_001",
 "nSensor": 9,
 "serialNumber": "PN3K33 0190001800024"
}

Using default configuration

Press any key to start logging
```

2. Now you will log data for the programmed duration

```
HS DataLog acquiring from the board named :"STWIN_001", serial number: "P
N3K33 0190001800024"

Received       684000 total bytes from IIS3DWB
Received          432 total bytes from HTS221
Received        36000 total bytes from IIS2DH
Received         2400 total bytes from IIS2MDC
Received       413696 total bytes from IMP34DT05
Received       342016 total bytes from ISM330DHCX
Received         4800 total bytes from LPS22HH
Received      1658880 total bytes from MP23ABS1
Received           64 total bytes from STTS751

Elapsed time:    5.397 seconds
Remaining time:  4.603 seconds

press ESC to exit!
```

Elapsed+remaining time

```
HS DataLog acquiring from the board named :"STWIN_001", serial number: "P
N3K33 0190001800024"

Received      1548000 total bytes from IIS3DWB
Received          992 total bytes from HTS221
Received        81600 total bytes from IIS2DH
Received         5400 total bytes from IIS2MDC
Received       933888 total bytes from IMP34DT05
Received       776192 total bytes from ISM330DHCX
Received        12800 total bytes from LPS22HH
Received      3739648 total bytes from MP23ABS1
Received          144 total bytes from STTS751

Elapsed time:    10.797 seconds
Remaining time:  0 seconds

press ESC to exit!
```

Total time

Usage: cli_example.exe [-COMMAND [ARGS]]

-h: Show help
-f : Device Configuration file (JSON)
-t : Duration of the current acquisition (seconds)

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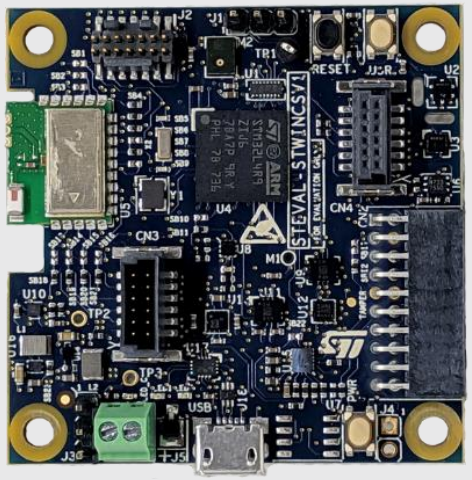
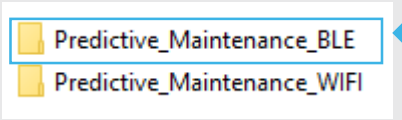
MCU & MPU EMBEDDED SOFTWARE

Picture	Part number	Manufacturer	Description
	FP-IND-PREDMNT1	ST	STM32Cube function pack for multi sensors node with signal processing to enable predictive maintenance



STWIN



DEFAULT STWIN SW

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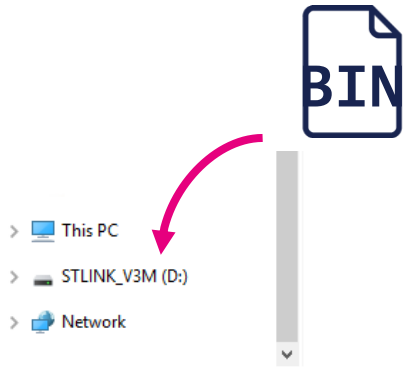
STWIN / ST BLE Sensor App FP-IND-PREDMNT1

Run the demo (1/3)

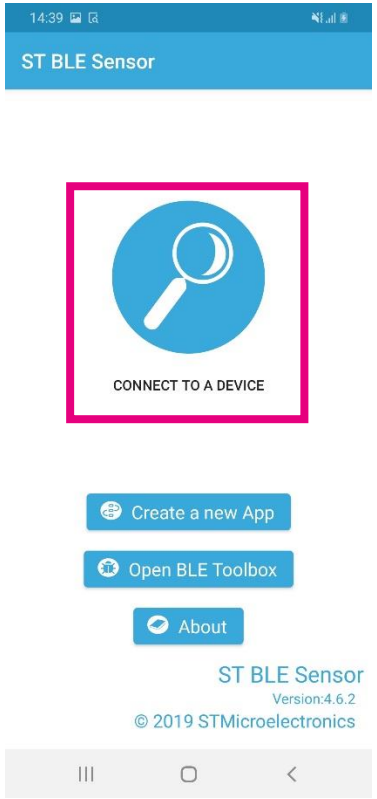
1. Program the STWIN

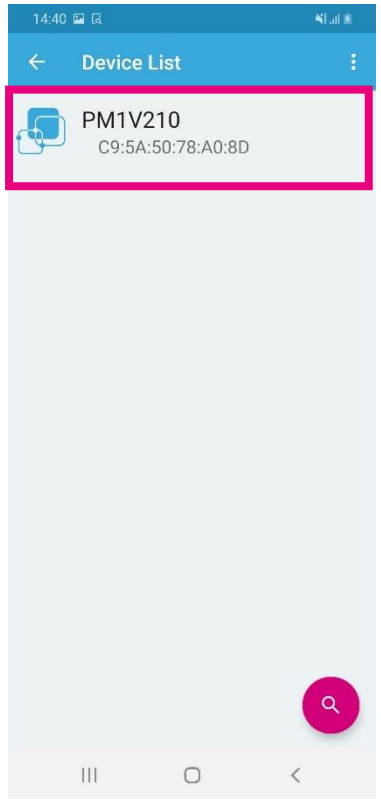
with STM32L4R9ZI-STWIN_PredictiveMaintenance_BL_v2.1.0.bin
from FP-IND-PREDMNT1



2. Open the ST BLE Sensor

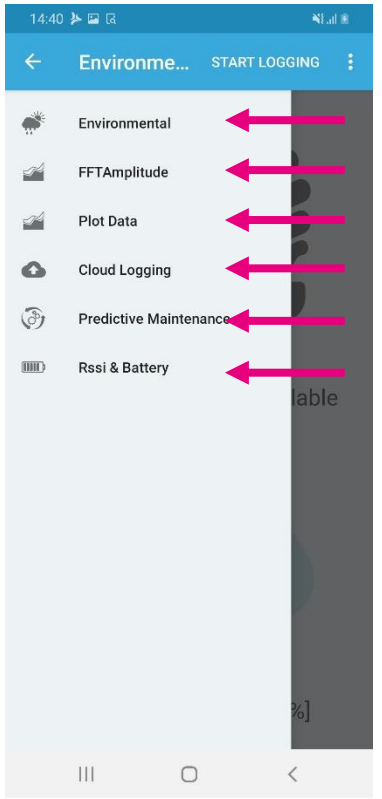
And connect to device





3. Enjoy the demo

Go through multiple functions

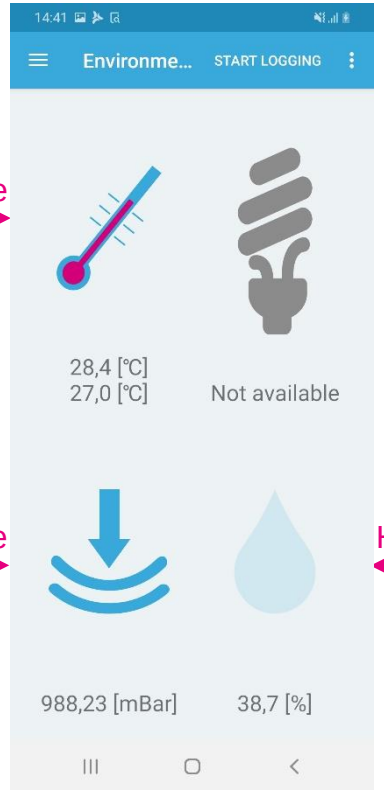


Note: Use above binary with Bootloader to copy-paste the image.
See Quick Start for details.

Run the demo (2/3)

1. Environmental

Environmental dashboard with temperature, humidity and pressure



Temperature

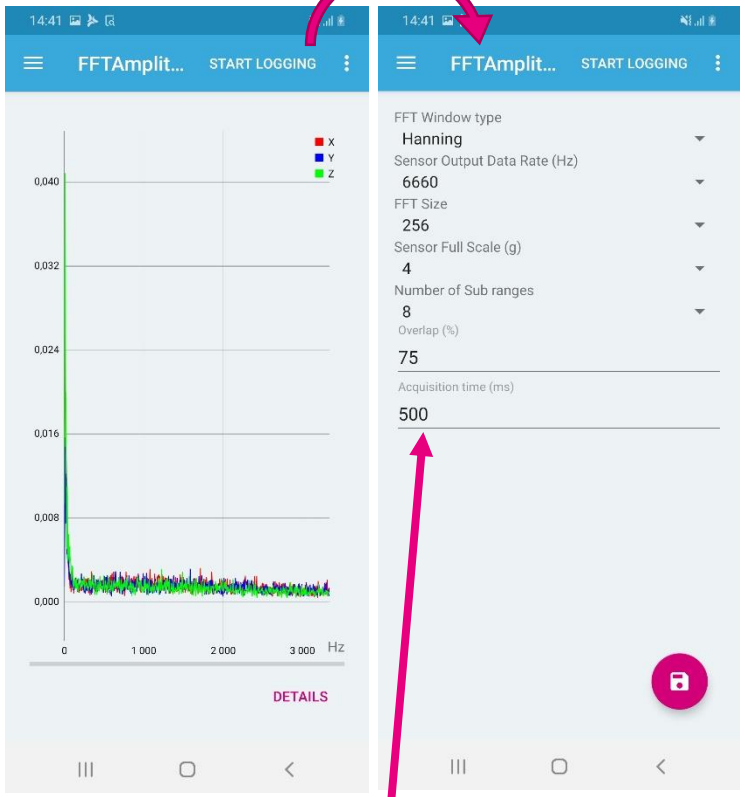
Pressure

Humidity

2. FFTAmplitude

FFT Amplitude visualization

FFT Settings



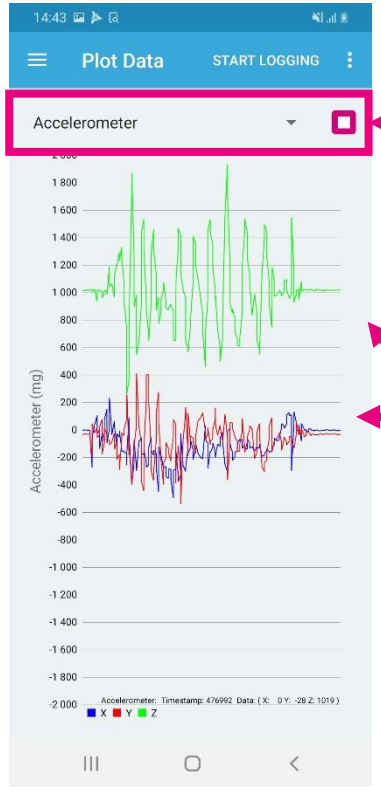
3. Plot data

Data visualization of various sensors

Sensor selection

Start/Stop

Raw data



Note: For faster response, recommendation to use 500ms acquisition time

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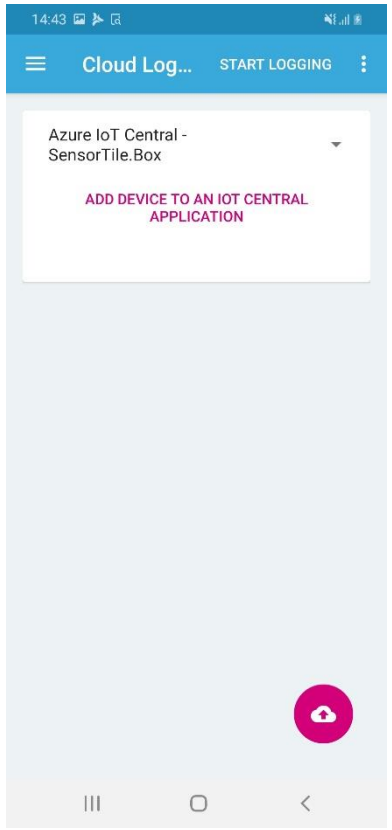
Run the demo (3/3)

4. Cloud logging

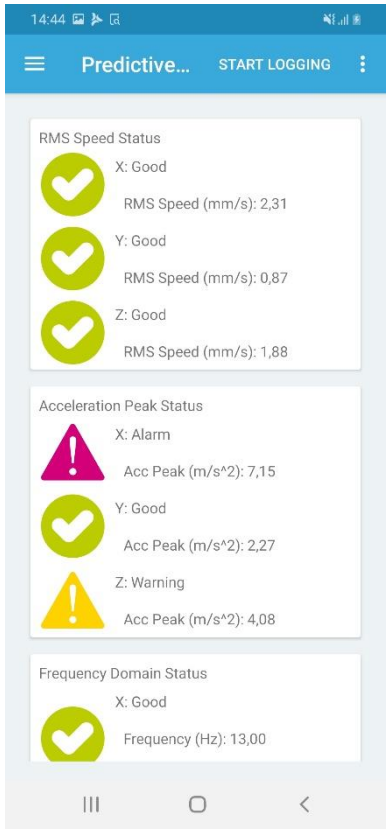
Cloud logging settings



5. Predictive maintenance

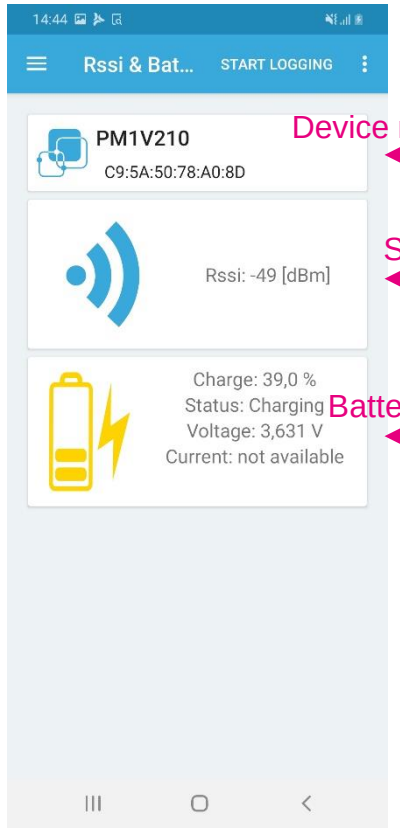
Interactive set of information for predictive maintenance

3 levels of classification – good, warning, alarm (*)



6. RSSI & Battery

Device, signal strength and battery information



Device name & address

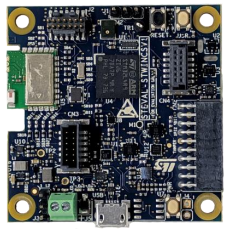
Signal strength

Battery information

Device name can be changed in  Settings

(*) 3 levels of classification – thresholds can be changed only by recompiling the project (MotionSP_Threshold.h)

Condition Monitoring using Wi-Fi with FP-IND-PREDMNT1 and DSH-PREDMNT

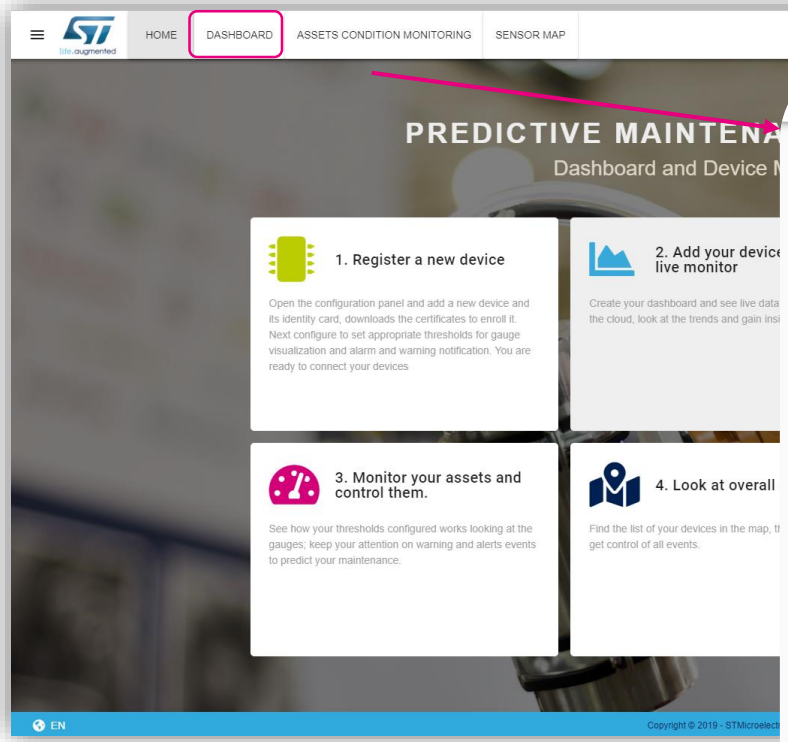


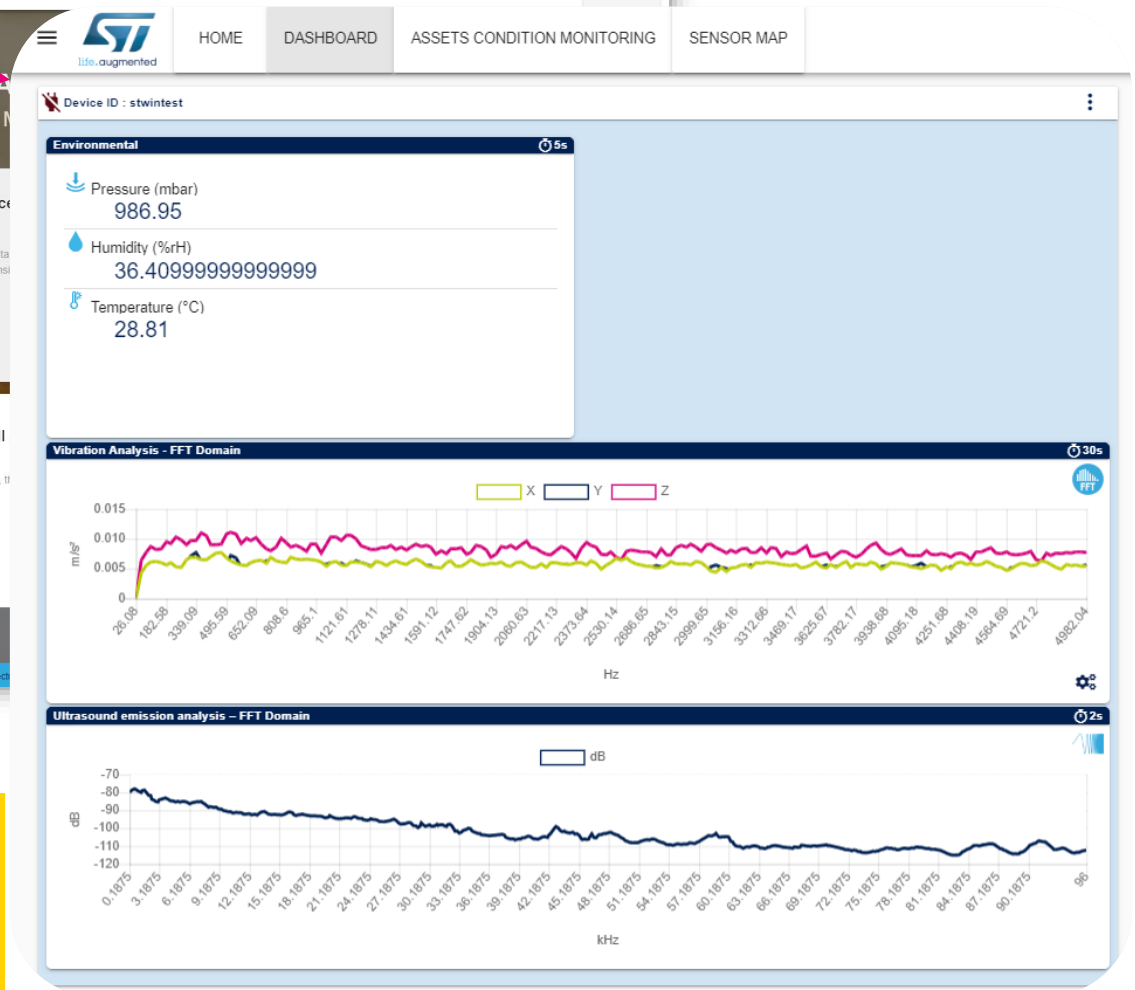
STWIN

STEVAL-STWINWFV1

NOTE:
Additional Wi-Fi extension required

Predictive_Maintenance_BLE
Predictive_Maintenance_WIFI





By connecting additional Wi-Fi extension,
Vibration and Ultrasound data
can be directly visualized in
AWS based Cloud Environment

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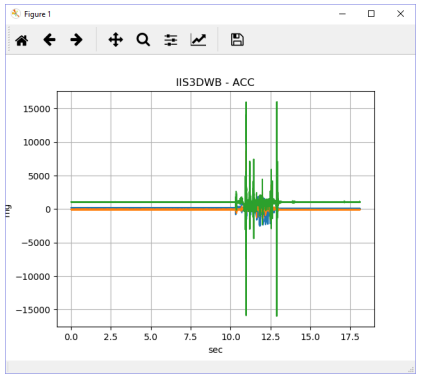
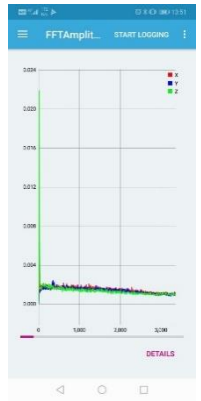
Condition Monitoring summary

- Condition Monitoring applications based on accelerometer vibration analysis with FFT and measuring ultrasound with microphones.
- New IIS3DWB sensor with 6 kHz of bandwidth now available
- New STWIN development kit with latest industrial sensors and SW examples available with BLE and Cloud connectivity
- STWIN includes also best components for power, connectivity and protection.

IIS3DWB

STWIN





Data logging and PREDMNT1 FFT DEMO

Thank you

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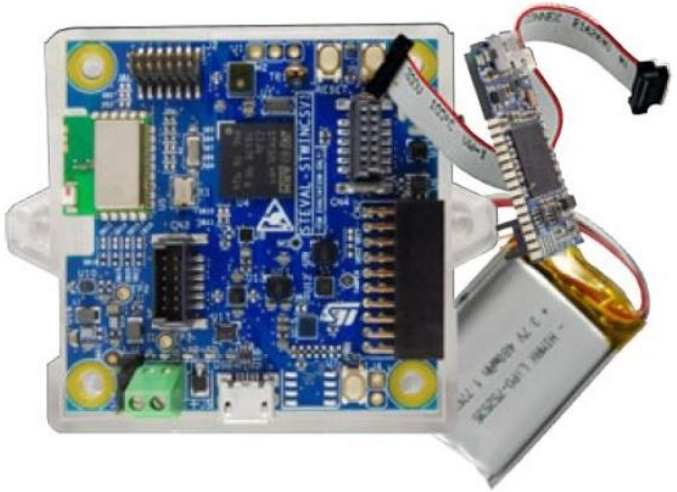
STWIN SensorTile Wireless Industrial Node development kit and reference design for industrial IoT applications



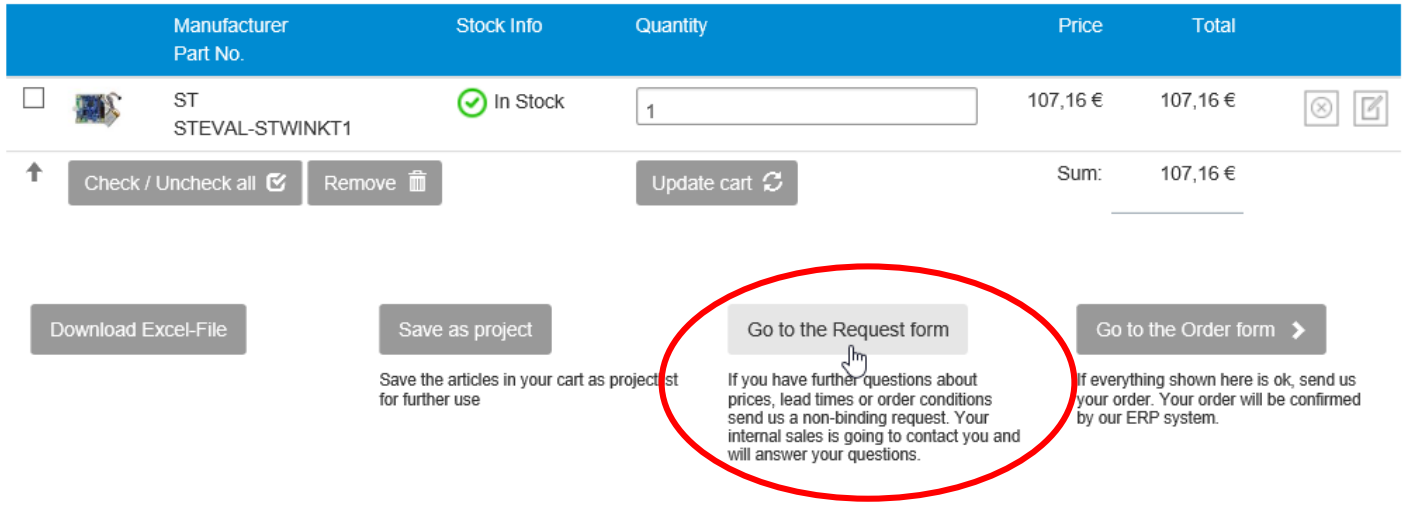
Get your STEVAL-STWINKT1 board free of charge in three steps and only today (limited to first 10 registrations)

STEVAL-STWINKT1

1. visit rutronik24.com

https://www.rutronik24.com/search-result/qs:STEVAL-STWINKT1/reset:0

2. add to cart



3. Fill in the request form