ST Sensor Solutions for Condition Monitoring and Predictive Maintenance

EMEA Marketing and Application
June 2020
Webinar with Rutronik
#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
Condition Monitoring and Predictive Maintenance overview
Predictive Maintenance
A smart industry hot topic

Preventive Maintenance (scheduled)

Predictive Maintenance (at the optimal moment)

Continuous condition monitoring (sensing)
Predictive Maintenance

Benefits

70% Fewer breakdowns

50% Reduction of machine downtime

50% Reduction of machine downtime

30% Savings thanks to earlier failure detection

12% Savings on scheduled repair costs

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
IPF installation point failure curve
Condition Monitoring

The curve slope depends on the life-cycle of the equipment.

- Machine conditions
  - I (Initial)
  - P (Point of Concern)
  - Conditions start to change

- Time
  - Days
  - Minutes
  - Weeks
  - Months

- Failure

- UltraSound
- Vibration
- Noise
- Power
- Heat
- Smoke
Typical use case
Industrial motor monitoring

Mechanical vibration

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

Functionality

Vibration Capture

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
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

Accelerometer (<10kHz)

Microphone BW (>10kHz)

Temperature

Wired Connectivity

Wireless Connectivity
Condition Monitoring block diagram
Battery-operated smart sensor node
Condition Monitoring block diagram
Vbus-powered industrial smart sensor node
MEMS for vibration analysis
Sensors and defects over bandwidth

Use cases
- Unbalance
- Loose ness
- Misalignment
- Roller Bearings
- Gearing
- Cavitation
- Bearings
- Gear boxes
- Lubrication
- Fan bearings
- Venting occlusion
- Cooling failure

Acoustic
- MP23ABS1
- IMP34DT05

Inertial
- IIS3DWB
- ISM330DLC/DHCX
- IIS2DH

Mechanical Vibration / Sound analysis (1 ÷ 10KHz)
Ultrasound analysis

kHz
- 2
- 5
- 10
- >50
# MEMS & Sensors for CbM and PdM

<table>
<thead>
<tr>
<th>Function</th>
<th>IC</th>
<th>Description</th>
<th>Package</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vibration</strong></td>
<td>IIS3DWB</td>
<td>Ultra Wide Bandwidth Accelerometer</td>
<td>LGA-14, 2.5x3 mm</td>
<td>• 3D Accelerometer – 16g Full Scale - Digital Output</td>
</tr>
<tr>
<td></td>
<td>ISM330DLC</td>
<td>Wide Bandwidth Accelerometer + Gyroscope</td>
<td></td>
<td>• Ultra Wide Bandwidth (up to 6 kHz)</td>
</tr>
<tr>
<td></td>
<td>ISM330DHCX</td>
<td></td>
<td></td>
<td>• Ultra Low Noise + up to 105°C operating Temp</td>
</tr>
<tr>
<td></td>
<td>IIS2DH</td>
<td>Wide Bandwidth, Ultra-low-power Accelerometer</td>
<td>LGA-12, 2x2 mm</td>
<td>• 3D Accelerometer – Digital Output</td>
</tr>
<tr>
<td></td>
<td>IIS2MDC</td>
<td>Low-Noise, Low Power Magnetometer</td>
<td></td>
<td>• Up to 2.3 kHz bandwidth</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Ultra Low Power – Ultra Compact</td>
</tr>
<tr>
<td><strong>Acoustic</strong></td>
<td>MP23ABS1TR</td>
<td>Analog single ended Microphone</td>
<td>RHLGA metal cap 5-L, 3.5x2.65x0.98 mm</td>
<td>• Bottom port Microphone</td>
</tr>
<tr>
<td></td>
<td>IMP34DT05-A</td>
<td>Digital Top Port Microphone</td>
<td>3x4x1 mm</td>
<td>• Wide Acoustic Bandwidth (up to 80 kHz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Wide Dynamic Range (AOP up to 130 dB SPL)</td>
</tr>
<tr>
<td></td>
<td>LPS22HH</td>
<td>High Accuracy – Compact Size Absolute Pressure Sensor</td>
<td>HLGA-10-L, 2x2x0.76 mm Ultra Compact full molded</td>
<td>• 260 to 1260 hPa Range - Digital Output</td>
</tr>
<tr>
<td></td>
<td>LPS27HHW</td>
<td>Water Resistant Absolute Pressure Sensor</td>
<td>2.7x2.7x1.7 mm 3.3x3.3x2.9 mm</td>
<td>• High Accuracy (±1 hPa)</td>
</tr>
<tr>
<td></td>
<td>LPS33W</td>
<td></td>
<td></td>
<td>• Low noise (0.75 Pa RMS)</td>
</tr>
<tr>
<td></td>
<td>STTS22H</td>
<td>Digital Temperature Sensor</td>
<td>2 x 2 x 0.50 mm 6-lead UDFN</td>
<td>• Water resistant up to 10 atm</td>
</tr>
<tr>
<td></td>
<td>STLM20</td>
<td>Analog Temperature Sensor</td>
<td>SOT323-5L, UDFN-4L</td>
<td>• Operating temperature -40 °C to +125 °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Accuracy: ±0.5 °C max (-10 °C to +60 °C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Programmable threshold, One-shot mode</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td></td>
<td></td>
<td></td>
<td>• Operating Temp –55 °C to +130 °C</td>
</tr>
</tbody>
</table>
Focus on IIS3DWB vibration sensor
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
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

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
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
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:

- MEMS
- ADC
- Low Pass Filter
- Composite Filter

![Filtering Chain Diagram]

#1 KPI Low noise level

<table>
<thead>
<tr>
<th>An</th>
<th>µg/√Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration noise density 3 axes enabled</td>
<td></td>
</tr>
<tr>
<td>X-axis</td>
<td>75</td>
</tr>
<tr>
<td>Y-axis</td>
<td>75</td>
</tr>
<tr>
<td>Z-axis</td>
<td>110</td>
</tr>
<tr>
<td>Acceleration noise density only 1 axis enabled</td>
<td></td>
</tr>
<tr>
<td>X-axis</td>
<td>60</td>
</tr>
<tr>
<td>Y-axis</td>
<td>60</td>
</tr>
<tr>
<td>Z-axis</td>
<td>80</td>
</tr>
</tbody>
</table>
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)

- **#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 $\rightarrow$ 5.6 kHz cutoff
- ODR/10 $\rightarrow$ 2.7 kHz cutoff
- ODR/20 $\rightarrow$ 1.3 kHz cutoff

Frequency response determined by CAD simulation – at the output of LPF2 in different configurations
• **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**
#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: $\pm 2\%$

@ $V_{DD}$ 3.0 Volt; from $-40^\circ C$ to $+105^\circ C$ delta from $T= +25^\circ C$

Based on characterization results at 3σ on limited number of parts. Not guaranteed
SW + HW tools overview
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
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
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

STM32L4R9
ARM® Cortex®-M4
120MHz – 640KB RAM

Programming cable connector
STBC14

Vin

MicroUSB connector

12-pin male expansion connector

12-pin female expansion connector

STMOD+ (host)

480 mAh Li-Po battery

Programming cable

Plastic case

STLINK-V3MINI
STWIN SensorTile kit & expansion boards

MicroSD card slot
SD card not included

Microphone Array expansion board

STEVAL-STWINMAY1
for audio beamforming

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

40-pin expansion connector

Battery connector

50mm

Wi-Fi adapter expansion board

STEVAL-STWINWFV1
for direct WiFi access
For development on PC and application demos in phone and cloud

**EVALUATION TOOL SOFTWARE**

<table>
<thead>
<tr>
<th>Picture</th>
<th>Part number</th>
<th>Manufacturer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td>STSW-STWINKT01</td>
<td>ST</td>
<td>Firmware for STEVAL-STWINKT1 evaluation kit for predictive maintenance,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>smart industry, IoT and remote monitoring applications</td>
</tr>
</tbody>
</table>

**MCU & MPU EMBEDDED SOFTWARE**

<table>
<thead>
<tr>
<th>Picture</th>
<th>Part number</th>
<th>Manufacturer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image2.png" alt="Image" /></td>
<td>FP-IND-PREDMNT1</td>
<td>ST</td>
<td>STM32Cube function pack for multi sensors node with signal processing to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>enable predictive maintenance</td>
</tr>
</tbody>
</table>
High-speed datalog
STSW-STWINKT01

STWIN

MicroSD card or USB
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\(\text{HS\_DataLog}\) subdirectory or a Python script. Install first Anaconda Python environment: https://www.anaconda.com/distribution/
SD logging – STWIN MicroSD card directory tree

- MicroSD card
- STWIN Data logs
- Header-info
- Data in binary format

Data logs in binary format / must be converted in PC
2. Log data
From STSW-STWINKT01_VX.X.X\Utilities\HS_DataLog\cli_example\bin
run cli_example.exe and follow instructions

3. Enjoy demo
After finish of logging, copy folder with data to
Utilities\HS_DataLog\python and run
ReadSensorData.py to plot the data
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
1. Log the data
Run `cli_example.exe` and pass the logging time with `-t [s]`

2. Now you will log data for the programmed duration

Usage: `cli_example.exe [-COMMAND [ARGS]]`
- `-h`: Show help
- `-f`: Device Configuration file (JSON)
- `-t`: Duration of the current acquisition (seconds)
<table>
<thead>
<tr>
<th>Picture</th>
<th>Part number</th>
<th>Manufacturer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="FP-IND-PREDMNT1" /></td>
<td>FP-IND-PREDMNT1</td>
<td>ST</td>
<td>STM32Cube function pack for multi-sensors node with signal processing to enable predictive maintenance</td>
</tr>
</tbody>
</table>

STWIN / ST BLE Sensor
App FP-IND-PREDMNT1

STWIN

DEFAULT
STWIN SW

Predictive_Maintenance_BLE
Predictive_Maintenance_WIFI
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.
1. Environmental
Environmental dashboard with temperature, humidity and pressure

2. FFTAmplitude
FFT Amplitude visualization

3. Plot data
Data visualization of various sensors

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

(*) 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

NOTE:
Additional Wi-Fi extension required

By connecting additional Wi-Fi extension, Vibration and Ultrasound data can be directly visualized in AWS based Cloud Environment.
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
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)
1. visit rutronik24.com


2. add to cart

3. Fill in the request form