Affordable high-performance vibration monitoring

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Overview

Introduction to Vibration Monitoring

- Why predicative maintenance?
- Condition monitoring
- Vibration sensors
- Inside IEPE sensor
- Vibration monitoring system
- Existing commercial IEPE interface products
- Vibration monitoring challenges for Industry 4.0

Solution Toolbox

– Wafer Fab monitoring example
– High-performance IEPE sensor front-end
– Very compact design with IO-Link interface
– Wireless condition monitor using a MEMS sensor
– Vibration monitor with energy harvesting
– What's next after getting the data?

Predictive maintenance

Unpredicted failure
- Costly (tools, material)
- Safety Concerns
- Affects Production

Why predictive maintenance?

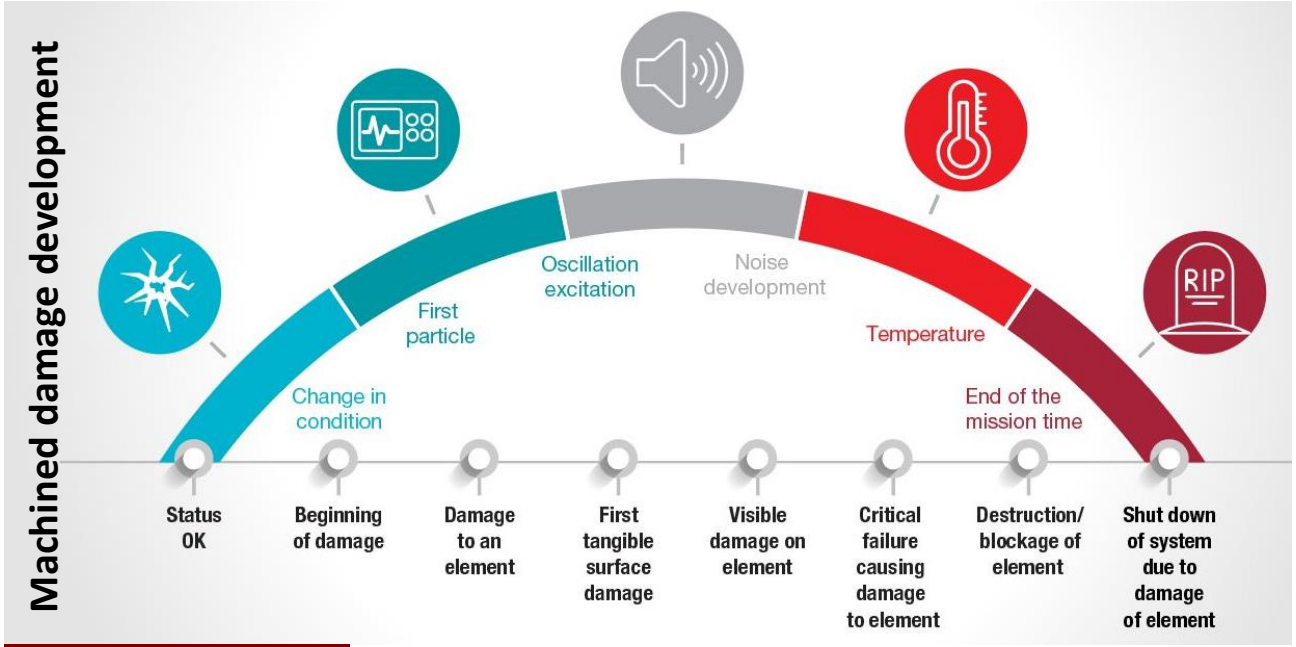
"It costs approximately 50% more to repair a failed asset than if the problem had been addressed prior to failure"

Machine breakdown can be unsafe leading to manpower loss, fines, audit, production stop…

Non-invasive, retrofitting techniques reduces down time, increases availability and productivity

Maintenance	Corrective	Preventive	Predictive
	•Replace when breaks	•Replace upon schedule	•Replace when required

Condition monitoring



Condition monitoring

- **Current**
- **Temperature**
- **Vibration**

Misalignment
Mechanical defects
Unbalance
Loose fixtures

Condition Monitoring

Vibration sensors

Vibration sensor technology

	IEPE Piezoelectric	Charge Piezoelectric	Piezoresistive	Capacitive MEMS	Servo Accelerometer
					
Freq. range	0.5 to 50 kHz	0.5 to 50 kHz	1- 10 kHz	0- 1 kHz	0-100 Hz
Sensiti-vity	5E-5 to 10 V/g	.01 to 100 pC/g	1E-7 to 1E-2 V/g	10m to 1 V/g	1 to 10 V/g
Measure. Range	1E-6 to 1E5 g	1E-5 to 1E5 g	1E-3 to 1E5 g	1E-5 to 1E3 g	1E-6 to 1E3 g
Dynamic Range	~120 dB	~110 dB	~80 dB	~90 dB	> 120 dB
Applicat-ion	Industrial	High Temp	Crash test	Airbag	Space Navigation

***This table features typical ranges of such devices, but not necessarily the actual ranges/specs of the these products shown.**

Table source : Sensor Technology Handbook, Wilson, Jon. Elsevier 2005

Inside IEPE sensor

IEPE sensor structure

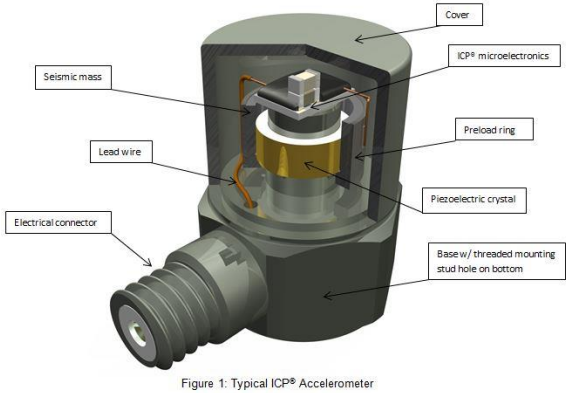
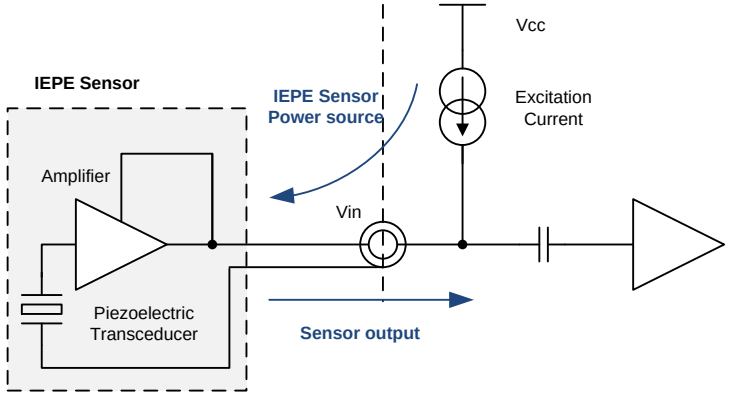


Figure 1: Typical ICP® Accelerometer

Image source: http://www.pcb.com

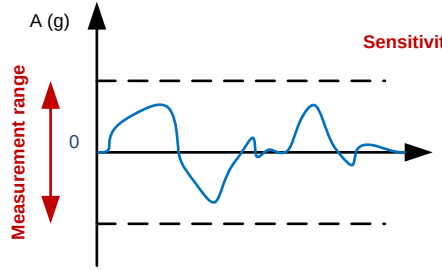
Simplified sensor interface



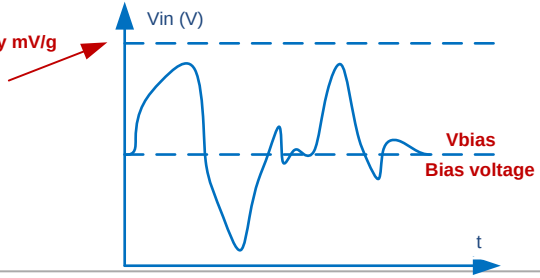
Sensor specs

Measurement range
Sensitivity
Bias voltage
Frequency range

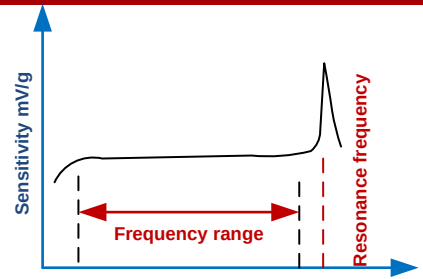
Acceleration input



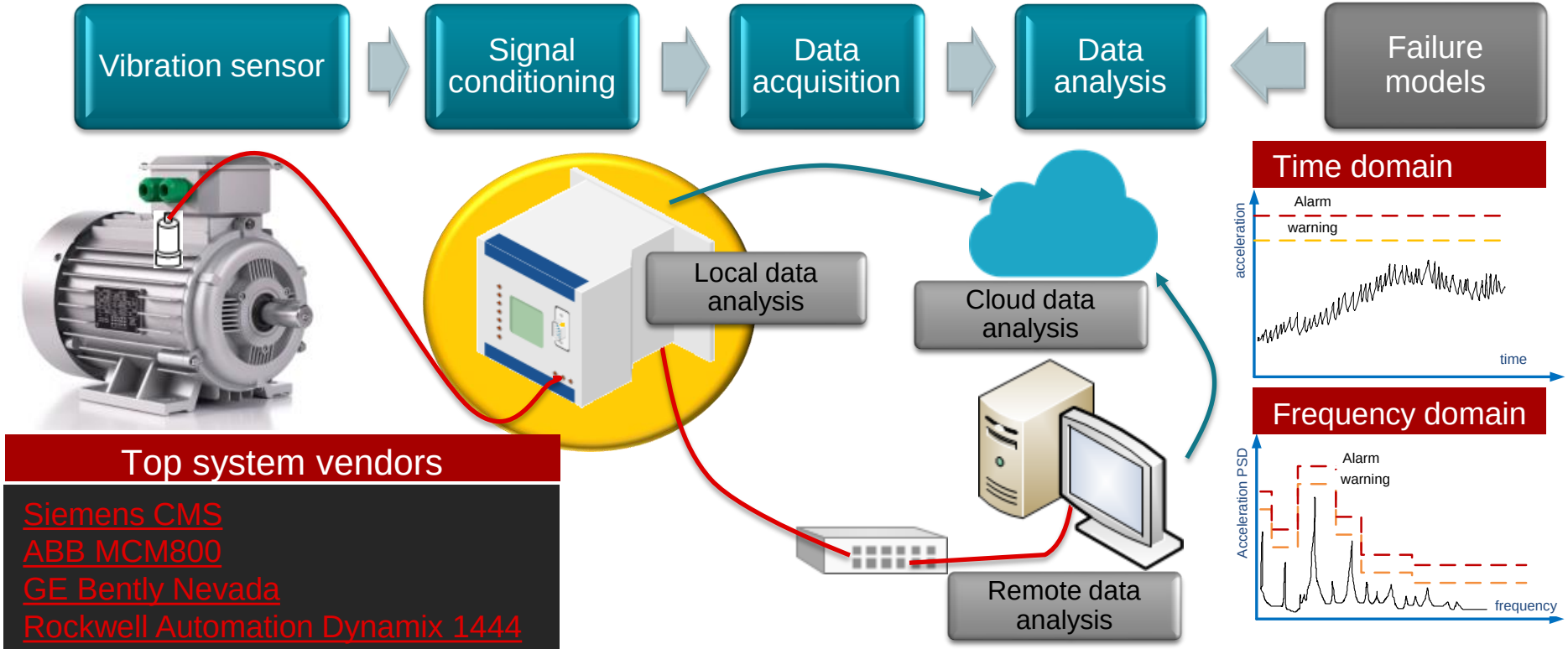
Sensor output



Sensor frequency response



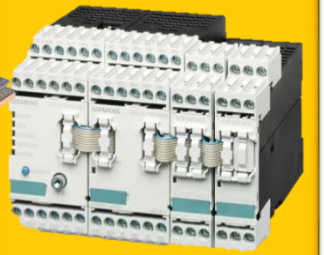
Vibration monitoring system



Existing commercial IEPE interface products

IEPE interface products

Analog signal conditioner	Analog signal transmitter	Vibration switch	Data acquisition	PLC analog input	Measurement systems
Filter, gain, isolation	Filter, gain, RMS or peak detection	Includes DQ	High speed, Highly flexible	Ready for control loop	High end/High capacity, accuracy



17 ENOBs, 20kHz BW, 50 kSPS, average web price $500/Ch.

Vibration Input Module

Vibration monitoring challenges for Industry 4.0

Connectivity and bandwidth

How to transfer this amount of data from distributed nodes?

Data processing and power

Where to do data processing? How to do that efficiently.

Space and cost

How to build a small-footprint affordable solution that can scale.

Split processing
- Local processing (Low-power processing)
- Sending health indicators infrequently, cloud.

Efficient acquisition
- Interleaved monitoring (reduce hardware)
- Scheduled monitoring. (reduce power and BW requirements)

Efficient BW usage
- Send indicators, data frame only when requested.

Powering
- Use available 24-V power, or battery, or energy harvesting.
- Power through data link (Ethercat-P, IO-Link).

Failure models availability

How to recognize failures from vibration spectrum?

Employ machine learning techniques to build failure models based on big data obtained in the cloud.

Solution toolbox

For Industry 4.0 large-scale vibration monitoring

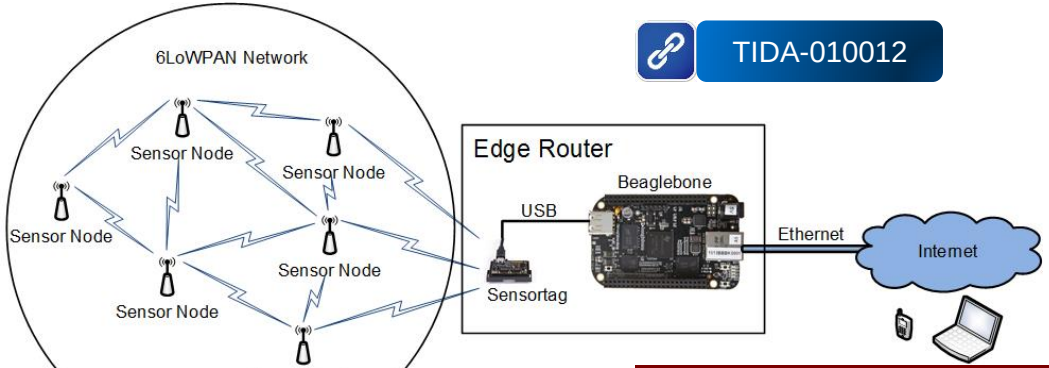
Wafer Fab monitoring example

5000 m^2 fab with 100's of Pumps with RS422 ports

Data available per pump

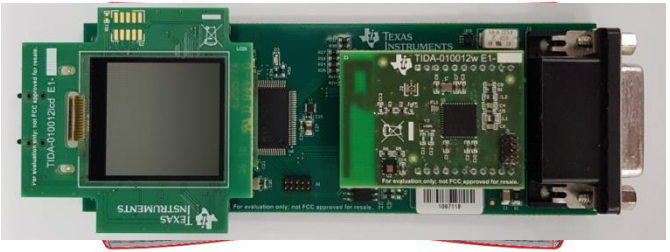
- Oil level
- H2O flow
- N2 flow
- Temp.
- Current consumption
- Operating hours
- Faults
- Leaks
- Exhaust pressure

Different pumps
Large area
Uncontrolled use of H2O, N2, I
High Cost of unplanned maint.



TIDA-010012

Industrial wireless condition monitoring reference design (TIDA-010012)

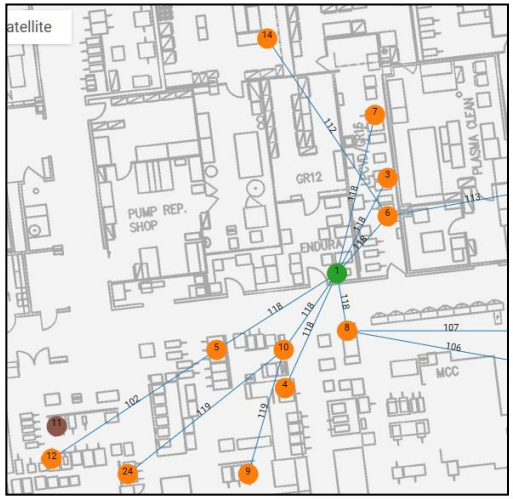


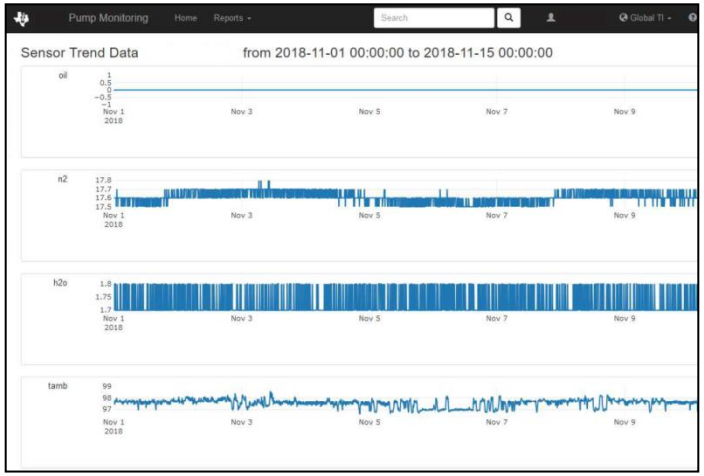
Benefits of the design

- Multi-protocol support: 6LoWPAN + BLE, …
- RS232/RS422/485 if
- 3-wire RTD sensor input
- 4-20 mA interface
- Isolated 24-V to 60-V DIN
- IO-Link support for COM3
- Onboard humidity sensor
- Powered by 24 from pump

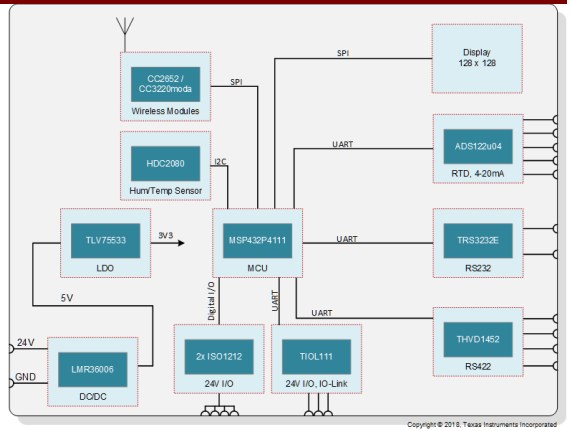
Solution in action

Nodes on Google Maps



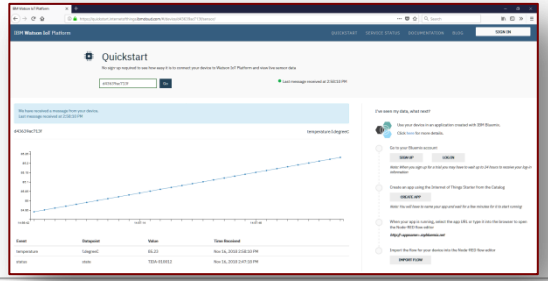


Industrial wireless condition monitoring reference design block diagram (TIDA-010012)



Vacuum pump status: N2 flow, H2O flow, and temperature

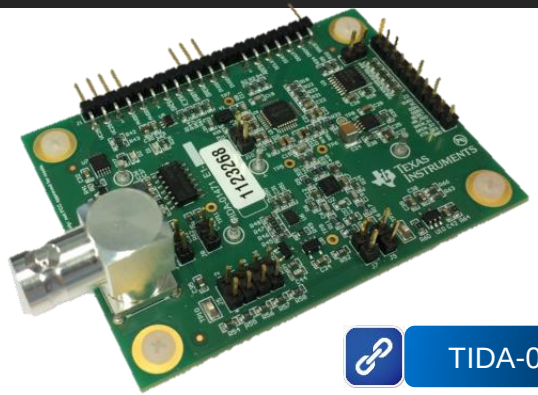
Connected to IBM Watson IoT service using MQTT Lib API avail for SimpleLink



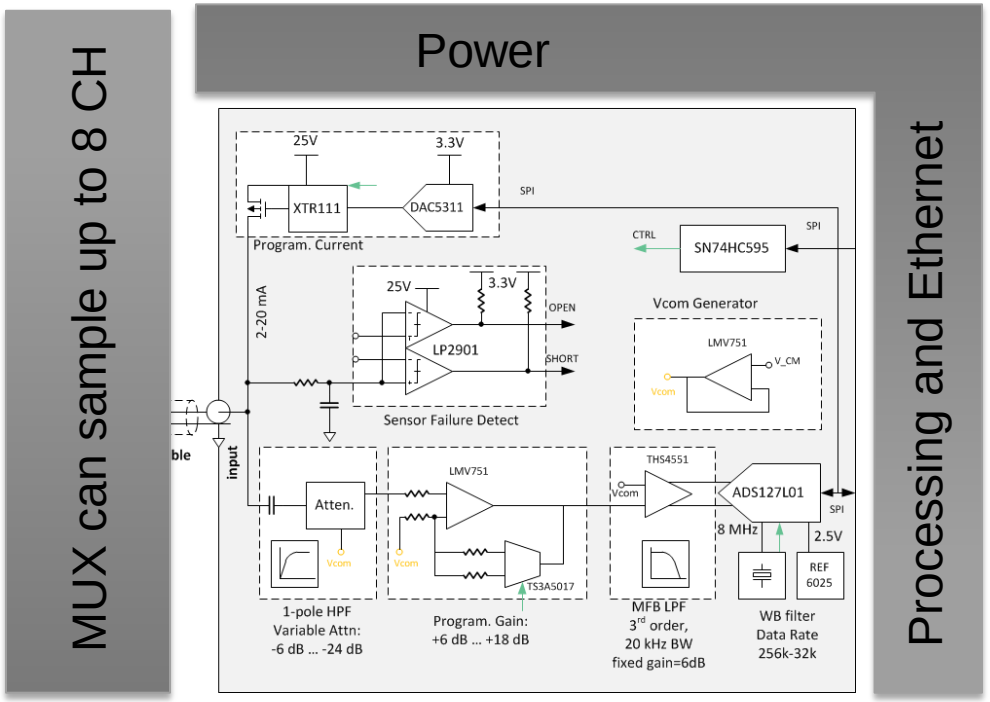
High-performance IEPE sensor front-end

IEPE vibration sensor interface for PLC analog input reference design (TIDA-01471)

- High-resolution ADC (24b) with integrated filter
- Very high sampling rate of 64 kSPS
- Wide bandwidth: 20 kHz
- Measurement grade performance SNR=107dB
- Signal chain BOM<$15
- With simple additions we can reach $5/channel



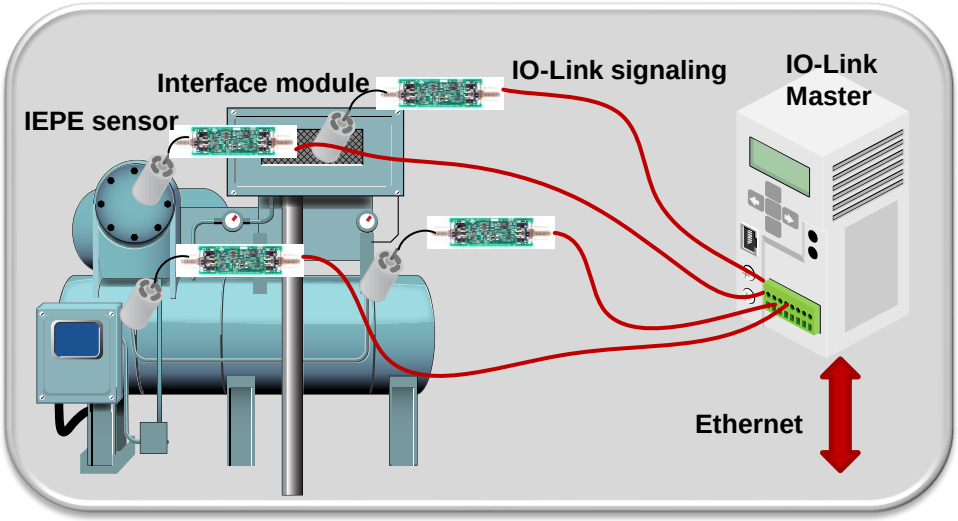
TIDA-01471

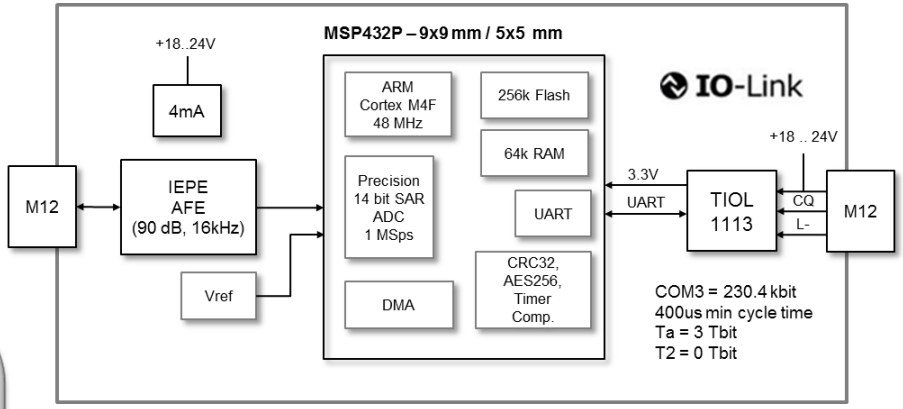


Compact design with IO-Link interface

IEPE Sensor analog front-end with digital interface reference design benefits

- Integrated MCU+ADC (14b)
- Local FFT processing (1kS)
- IO-Link interface running full speed
- Powered through IO-Link
- Robust digital signaling



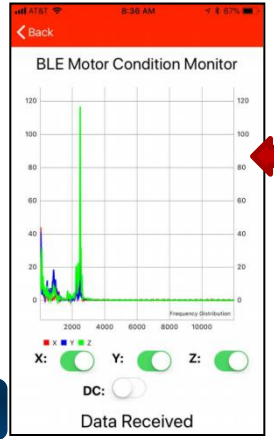


TIDA-010045

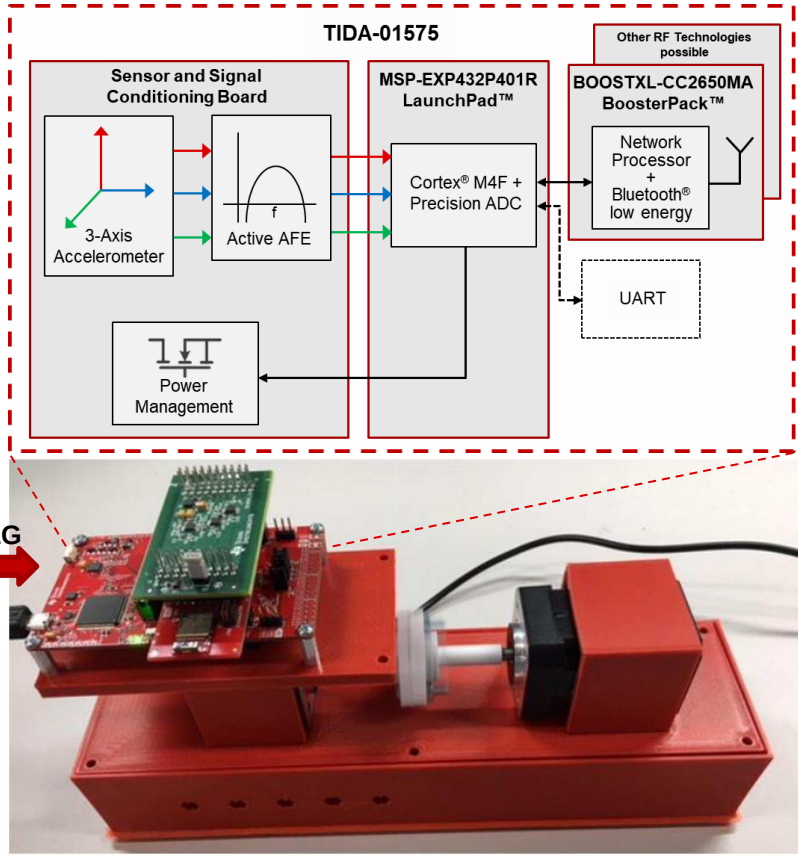
Wireless condition monitor using a MEMS sensor

Benefits of the reference design for wireless condition monitor for motors and pumps using multi-axis vibration (TIDA-01575)

- Integrated MCU+SAR ADC (14b)
- Local FFT Processing
- Easy switch: BLE, WiFi, Sub 1GHz
- Ultra low power: sparse measurement
- Battery life up to 15 years, meas./4h



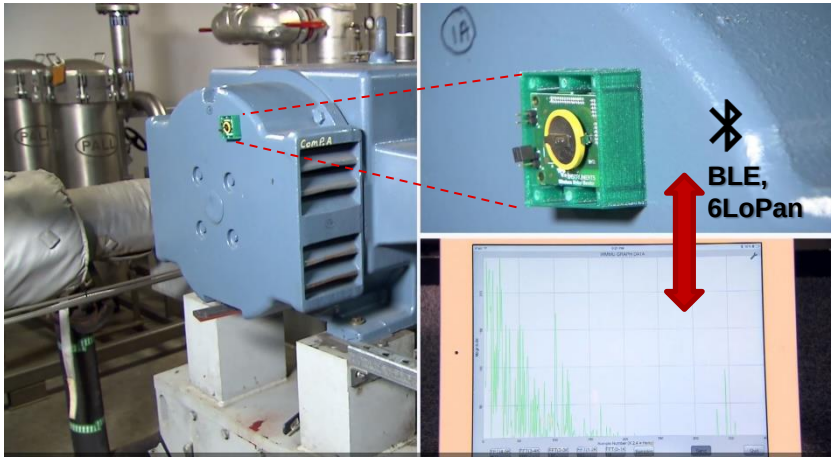
BLE, WiFi Sub 1G

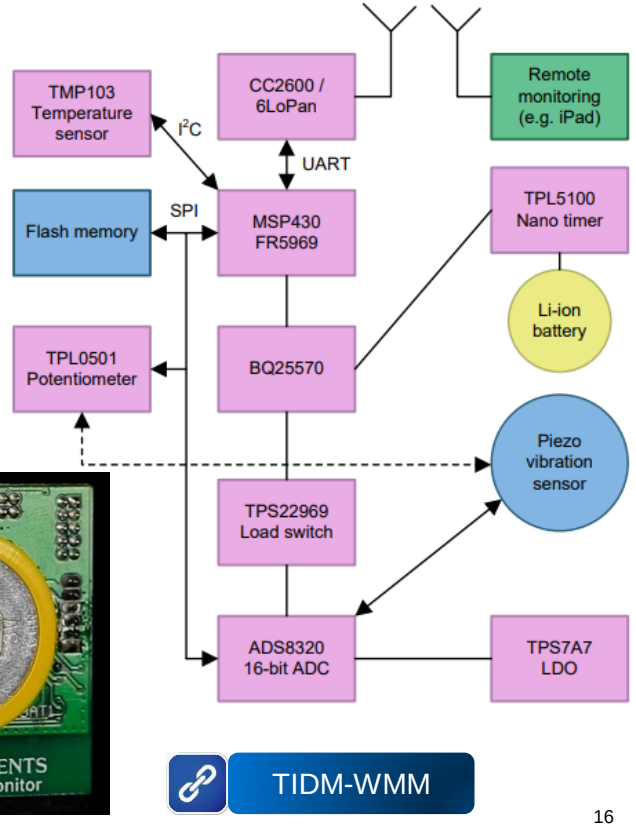


Vibration monitor with energy harvesting

Wireless motor monitor reference design benefits

- Piezoelectric capacitive sensor
- Integrated MCU+ ADC
- Local FFT Processing, and Temp sensing.
- Connectivity: 6 LoWPan, BLE
- Ultra Low Power : sparse measurement
- High Efficiency energy harvesting



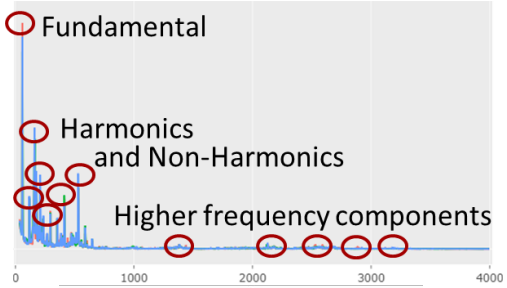


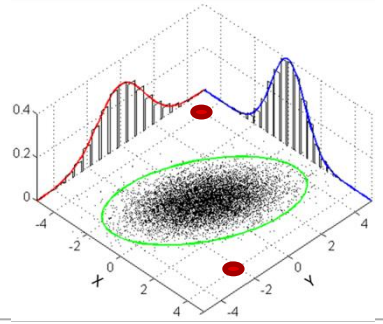
TIDM-WMM

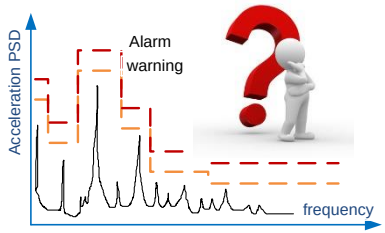
What's next after getting the data?

Anomaly detection by multivariate distribution

- Many dimensions
- What are the relevant frequencies?







Analytical models

Depends on Load Mounting, …

Empirical models

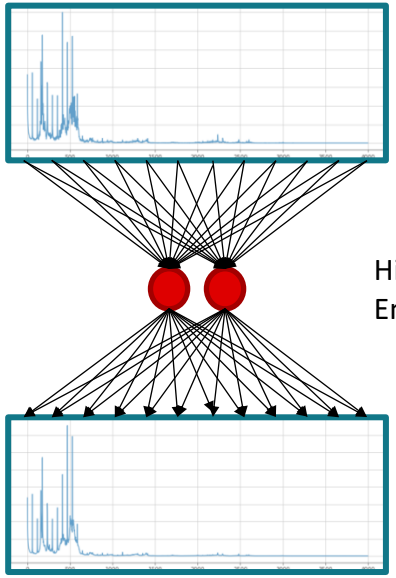
Very specific needs previous data to build

Machine learning

If no training data? Anomaly detection can be used

Anomaly detection by Autoencoders

- Compare simplified spectrum
- Use Neural processing for simplification



Input Layer
Original Spectrum

Hidden Layer(s)
Encoded Spectrum

Output Layer
Reconstructed
Spectrum