

Using Vibration Monitoring, Edge AI and SPE/PoDL for Predictive Maintenance



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Factory production lines, manufacturing robots (see [Figure 1](#)) and wind turbines can unexpectedly break down due to hardware failures that are very expensive to repair. Some of these failures, such as worn-out gears, motors and mechanical interconnections, may already be visible long before a total breakdown event. [Figure 2](#) illustrates the steps of such degradation over time.



Figure 1. A Robotic Machinery Installation in a Factory Floor

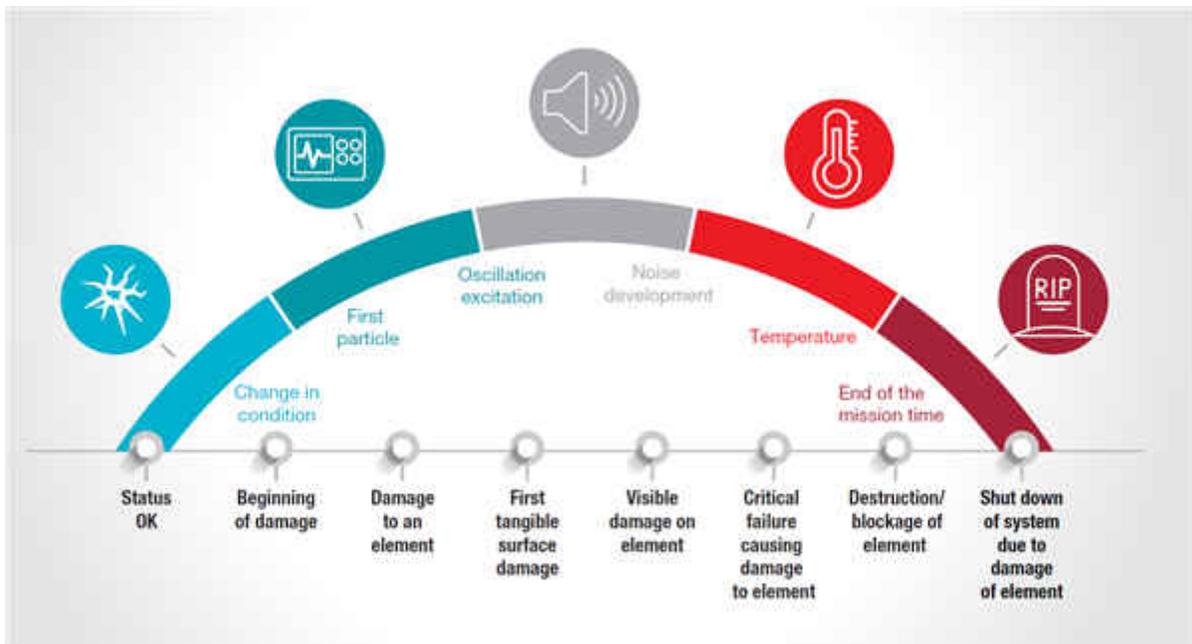


Figure 2. How Machinery Degrades, from Being Fully Operational to Shutting Down

Predictive maintenance is a proactive approach that can offer significant benefits in factory automation. By using technologies such as vibration sensing and edge artificial intelligence (AI), predictive maintenance can detect potential equipment failures before they occur, allowing maintenance teams to take corrective action before equipment failure occurs and thus reducing the risk of unplanned downtime, increasing equipment lifespans, and improving operational efficiency.

Vibration sensing technology plays a critical role in predictive maintenance, allowing the monitoring of equipment for signs of wear and tear or other anomalies, while edge AI enables the monitoring and analysis of equipment in real time.

Predictive Maintenance with Vibration Sensing and Edge AI

A predictive maintenance system with vibration sensing and edge AI contains the components shown in [Figure 3](#).

Attached to the motor or the turbine is an integrated electronics piezoelectric (IEPE) sensor, which measures the vibration in the machinery. The analog IEPE vibration sensor signal requires conditioning, so the data-acquisition block converts the signal from the analog to the digital domain. Data analysis, typically performed using time- and frequency-domain graphs, is calculated at the sensor board to match the data against the failure models. Fast Fourier transform (FFT) is one method of data analysis.

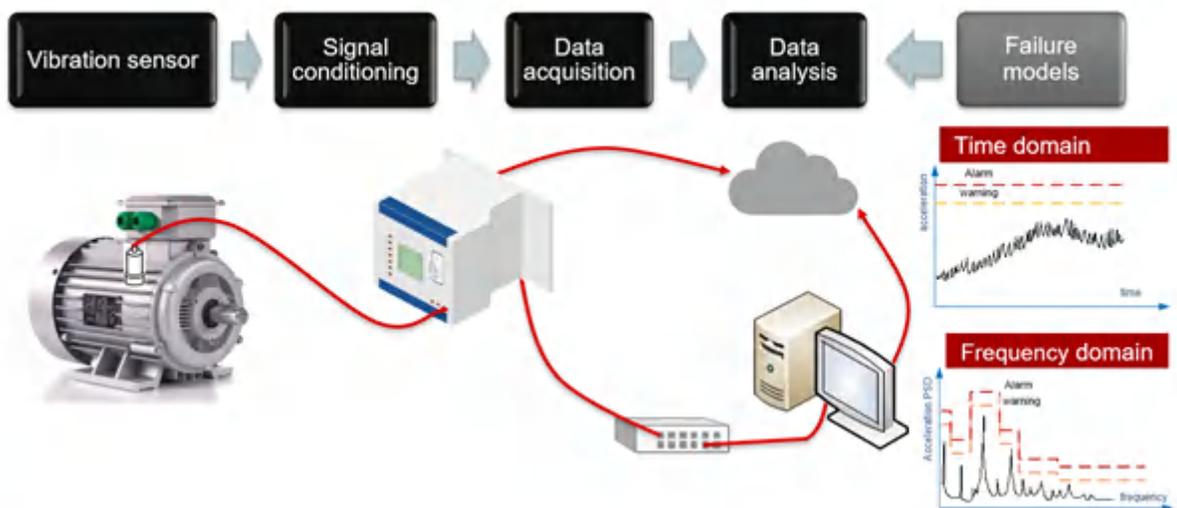


Figure 3. A Predictive Maintenance System with Vibration Sensing and Edge AI

A degrading motor or turbine will show higher amplitudes, as well as additional spikes in the frequency-domain graph. A data-collecting gateway sends the results of the data analysis to the cloud, where a plant operator uses operative technology to access it.

[Figure 4](#) shows a predictive maintenance system with TI hardware. The IEPE sensor board connects to as many as four IEPE vibration sensors. The IEPE sensor board also performs signal conditioning and data acquisition with the [ADS127L11](#) delta-sigma analog-to-digital converter (ADC). The edge processing board reads the ADC samples using the [AM2434](#) microcontroller (MCU) and performs FFT calculations and additional data analysis. The edge processing board is powered by power over data line (PoDL), which combines data and power using single-pair Ethernet (SPE).

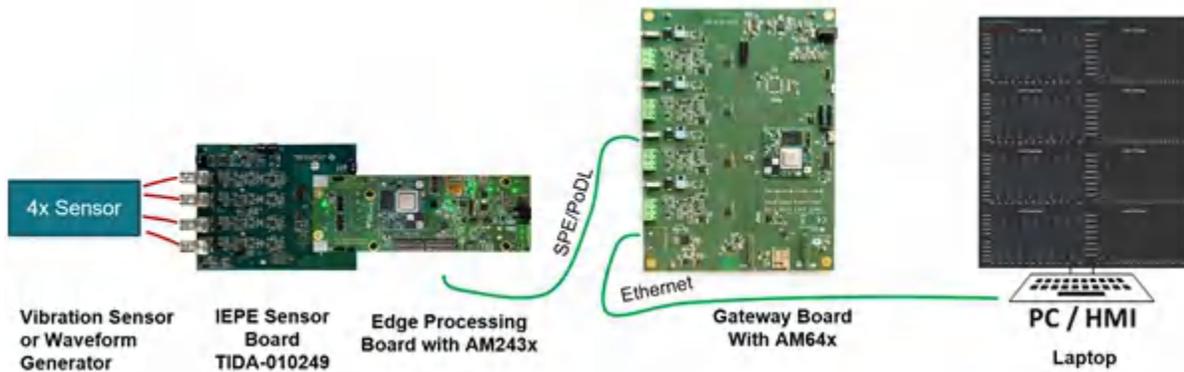


Figure 4. TI Evaluation Demonstrating a Predictive Maintenance System

The edge processing board sends data analysis (such as FFT results) over SPE to the gateway carrier board. The gateway carrier board collects data analysis from up to four edge processing boards, which are connected over the four SPE/PoDL ports. In total, this gateway carrier board can collect data analysis for as many as 16 IEPE vibration sensors.

The [Four-Channel Synchronous Vibration Sensor Interface Reference Design \(Figure 5\)](#) is a synchronous, wideband high-resolution interface. Its main target is vibration sensing applications, but it is also a good fit for any application that requires wideband front-end, such as three-phase voltage and current monitoring in power-factor correction. It contains four signal-chain front-ends and four ADS127L11 ADCs. The parallel interface of the ADC interfaces to the sensor gateway carrier board MCU and enables a high-speed data bus.



Figure 5. IEPE Vibration Sensor Board

The synchronous four-channel wideband integrated electronic piezoelectric (IEPE) sensor interface connects to four individual IEPE vibration sensors, which are placed directly at a vibration sources such as motor or gear box.

The edge processing board ([Figure 6](#)) contains four AM2434 Arm® Cortex®-R5F-based MCUs, programmable real-time cores to interface to the sensor board, and the DP83TD510E SPE physical layer (PHY). The edge processing board receives the ADC samples over the parallel interface from the sensor board. The Cortex-R5F MCU performs data analysis such as FFT and sends that analysis over the 10-Mbps T1L SPE interface to the gateway carrier board.

The edge processing board and IEPE sensor board receive the 24-V power supply over PoDL from the two-wire SPE connection. The edge processing board uses FreeRTOS on the Cortex-R5F MCU and [TQ-Group's TQMa243xL system on module \(SOM\)](#), which includes the AM2434 MCU, double-data-rate four random access memory, an embedded multimedia card and power-management integrated circuit. The SOM simplifies board layout and time to market when developing the gateway carrier board.



Figure 6. Edge Processing Board

The gateway carrier board ([Figure 7](#)) contains two Arm Cortex-A53 microprocessors and four Arm Cortex-R5F MCUs. The gateway carrier board has four SPE/PoDL power-sourcing equipment ports to provide data and 24 V to as many as four edge processing boards. The cable reach of the SPE interface is up to 2000 meters. The gateway carrier board provides a Gigabit Ethernet uplink port for cloud and operative technology connections. The gateway carrier board's operating system is Linux and uses [TQ-Group's TQMA64XXL system on module \(SOM\)](#).

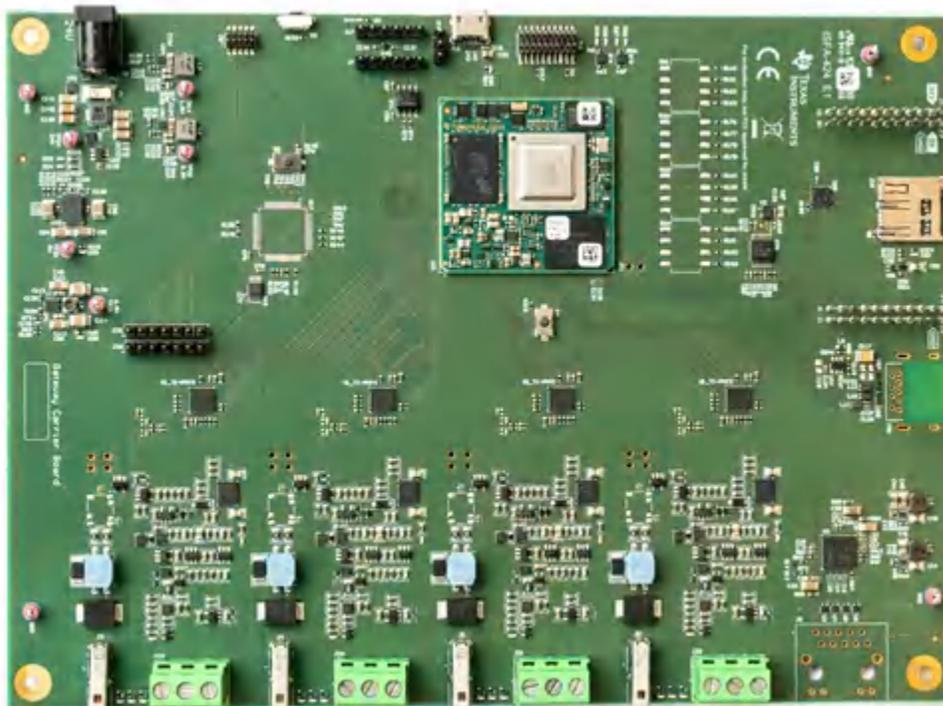


Figure 7. Gateway Carrier Board

Conclusion

To reduce downtime, costs and damages, factory plant operators need to invest in automation that supports predictive maintenance with vibration monitoring and edge AI. TI's analog and embedded products enable such predictive maintenance technology.

Additional Resources

- Watch the video, [“IEPE vibration monitoring front-end and high-speed data capturing with edge AI processing.”](#)
- Check out the [AM2434](#) microcontroller, [AM6442](#) microprocessor and [DP83TD510E](#) Ethernet PHY.

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