Intelligent Condition Monitoring Box

Smart Maintenance Made Easy

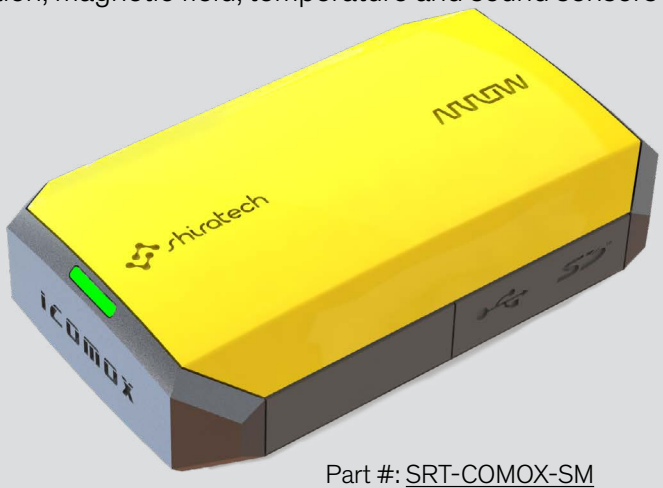
Unplanned equipment downtime causes significant disruption to operations and productivity which directly impacts a company's bottom line. This problem is further compounded with legacy equipment that is prone to frequent failures. Current inspection methods mainly involve maintenance personnel physically checking equipment on a periodic basis. This approach is resource intensive and cannot be scaled easily. Further, complexity and cost of repairs increase after equipment failures occur, compared to preventive measures.

iCOMOX (Intelligent Condition Monitoring Box) – is an open development platform for Condition Based Monitoring (CBM) of industrial equipment, assets, and structures. iCOMOX monitors operating conditions from the surface of the equipment to identify potential faults and reduce risks associated with equipment operation and maintenance. This extends the lifetime of the equipment, reduces unplanned downtime, cuts maintenance costs and unlocks potential for energy savings.

Benefits of the iCOMOX Platform

- **Rapid prototyping and product development** – Quick prototyping, rapid development and testing for condition-based monitoring designs
- **Fast time to market for customer products** – Out-of-the-box use case with software and application support for quick deployment with minimal changes. CE and FCC certified
- **Reliable and accommodates a wide range of monitored equipment -** Small form-factor and options for mounting adapters
- **Quick customization services** – Add new functionality, lower BOM cost, or have the complete product designed

Multi-sensing condition monitoring solution:
Vibration, magnetic field, temperature and sound sensors



Part #: SRT-COMOX-SM

Features

Measured Parameters

- Vibrations
  - Range: ±10 g and ±20 g
  - Bandwidth: 1.5 kHz
- Magnetic Field
  - Range: ±1300 µT (x/y-axis), ±2500 µT (z-axis)
  - Resolution: ~0.3 µT
- Temperature
  - Range: -55 °C to +150 °C
  - Accuracy: ±0.5 °C (-55 °C to +125 °C)
- Sound
  - Dynamic Range: 105 dB
  - Sensitivity: -36 dBFS

Other Features

- Wake-up and auto-sleep function with adjustable thresholds
- Built-In Self-Test (BIST)
- Raw data access (wirelessly or via USB)
- Programmable warning/alarm levels and pattern events for each sensor
- Compact design in IP66 enclosure
- Support of various mounting adapters
- CE and FCC certified
- 2× coin batteries CR3032
- Operating temperature -40 °C to 85 °C

Processor

- Ultra-low power Arm® Cortex®-M4F MCU with integrated power management
- SensorStrobe™ technology with 10× system-level power savings

Connectivity

- SmartMesh IP™ 2.4 GHz IEEE 802.15.4e SoC offering >99.999% network reliability
- Auxiliary ports for additional sensors
- USB 2.0
- Micro-SD

Software and Analytics

- Sensor data acquisition on schedule
- Embedded fundamental time-domain and frequency-domain analysis
- Advanced analytics on demand
- Cloud connectivity (optional)

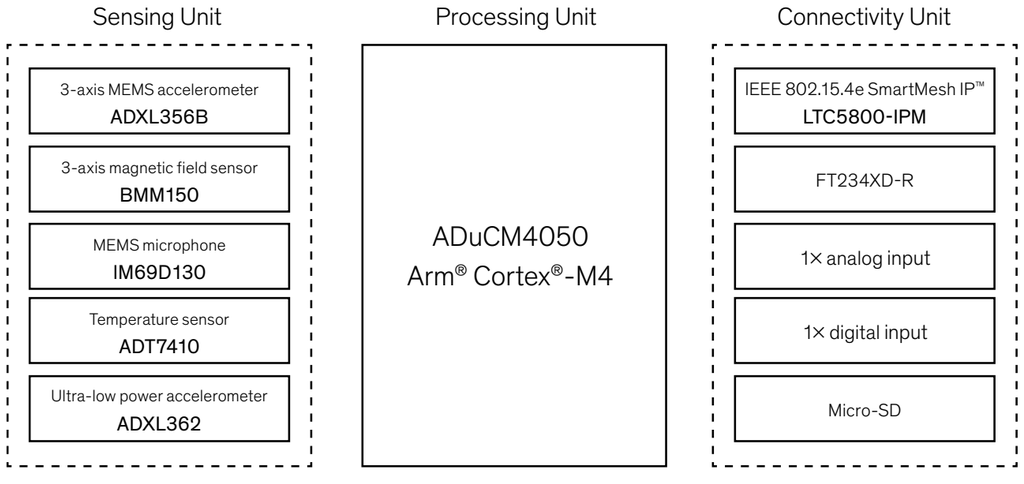


Figure 1: Functional block diagram of iCOMOX

iCOMOX system architecture, schematically shown in Figure 1, utilizes a modular concept that combines multiple functional blocks unfolding sensing, connectivity, and processing capabilities of the platform.

Sensing Unit

The Sensing Unit captures CBM data using sensors of four different types to cover a wide range of physical aspects of the monitored equipment an accelerometer ADXL356B, a geomagnetic sensor BMM150, a temperature sensor ADT7410 , and a MEMS microphone IM69D130. These sensors perform real-time acquisition of vibrations, magnetic field, temperature, and acoustic parameters collected from a surface of the monitored equipment either on-schedule or on-demand. The data acquisition process can also be triggered with an embedded wake-up/auto-sleep function realized in iCOMOX using an ultra-low power accelerometer ADXL362 to extend the battery life by disabling the sensors if there is no motion detected.

The acquired raw sensor data are routed to the Processing Unit for a full-scale multiparameter assessment of the current physical condition of the equipment and its subsequent analysis.

Processing Unit

The iCOMOX Processing Unit is an ultra-low-power microcontroller ADuCM4050 based on Arm® Cortex®-M4 processor with integrated power management. This functional part is the core element underlying the open platform concept of iCOMOX which gives a user full flexibility for system configuration to meet the most demanding requirements of a wide range of applications. The Processing Unit fulfills three main functions that can be programmed according to the specific user needs – control, processing, and connectivity.

The control function ensures overall system management of iCOMOX components according to required settings and operational modes. The processing function allows for embedded sensor data processing such as fundamental time-domain and frequency-domain analysis implemented in standard configuration. The connectivity function provides the data and control interface and defines the Connectivity Unit of the iCOMOX system architecture.

Connectivity Unit

The Connectivity Unit offers various interfaces that can be used to configure the system, readout raw data, access CBM parameters, view analysis results or transfer the data into the cloud for advanced analytics.

To access processed CBM data or for optional cloud connectivity, iCOMOX features IEEE 802.15.4e System on Chip transceiver LTC5800-IPM with an embedded Arm® Cortex®-M3 microprocessor and SmartMesh IP™ networking software offering low-power performance and 99.999% network reliability in the most challenging RF environments.

For raw data access and for system control and configuration, iCOMOX features full speed compatible USB 2.0 interface based on the FTDI chip FT234XD enabling USB to serial UART communication with the Processing Unit ADcUM4050. iCOMOX offers a Micro-SD card interface for onboard data storage and supports additionally two external sensors that can be connected to the system via a digital and an analog port for an extended CBM analysis.

Applications

- Manufacturing facilities: Motors, pumps, gearboxes, etc
- Construction facilities: Drills, motors, and heavy equipment
- Buildings: Elevators, moving walkways, escalators, refrigeration, and HVAC systems
- Healthcare: Medical imaging equipment and large systems with motors
- Oil & gas: Pumps, drills
- Transportation: Fleet management
- Structures: Bridges, towers, and pipelines

The iCOMOX comprised of all its functional units is powered with 2× CR3032 coin batteries allowing for long-term operation in the field that can last from several months to several years depending on the operational mode of the system.

Measurements

The multi-sensing capability of the iCOMOX platform offers a multifaceted measurement approach allowing to capture a broad range of CBM parameters and create a high-quality full-scale condition profile of the monitored equipment to meet strict requirements of the most demanding CBM applications.

Vibrations Measurements

Vibration analysis is one of the most widely used techniques for machine health monitoring. Changes in the vibration frequency spectrum can often be the earliest indicator of a potential machine failure. iCOMOX captures vibration data from a surface of the monitored equipment using a 3-axis MEMS accelerometer ADXL356B. It offers ultra-low noise density, minimal offset drift over temperature, excellent long-term stability and a broad analog output bandwidth performance for high precision condition monitoring applications. ADXL356B measures axial, radial and tangential vibrations up to 1.5 kHz in a user-selectable full-scale range ±10 g or ±20 g. The acquired vibration raw data are routed to the GPIO inputs of the ADuCM4050 and then digitized using an integrated 12-bit SAR ADC offering a programmable update rate ranging from 10 kSPS to 1.8 MSPS. Depending on the application requirements a user can optimize the sensitivity and noise performance of the system by selecting an appropriate measurement range of the accelerometer and a sampling rate of the ADC. The obtained digital sensor data are used for embedded fundamental time-domain and frequency-domain signal analysis implemented in the Processing Unit in standard configuration. If needed, the raw data can also be directly readout via a USB port for off-board post-processing.

Acoustic Measurements

Acoustic emission is another type of operational condition parameter that can be an early indicator of machine failure. Potential fault sources originating inside a machine may often result in a deviation of its actual acoustic spectrum from the reference signature of its normal operation. To capture acoustic data iCOMOX uses a high-performance digital MEMS microphone IM69D130 which is designed for wide dynamic range applications requiring low-distortion and high acoustic overload performance. IM69D130 offers highly linear output signal within a dynamic range of 105 dB, supports high acoustic overload of up to 130 dBSPL and exhibits low total harmonic distortion which does not exceed 1 percent even at sound pressure levels of 128 dBSPL. IM69D130 includes a digital ASIC that contains an extremely low-noise preamplifier and a high-performance sigma-delta ADC supporting very fast conversion speeds with 6µs latency @1kHz. Acoustic measurements enabled by the IM69D130 provide not only an additional CBM parameter but can in some cases also help to overcome bandwidth limitations of the vibration analysis which might be needed for certain CBM applications.

Magnetic Field Measurements

Magnetic flux detection is another condition monitoring approach implemented in iCOMOX that can be very useful for early detection of potential machine faults in specific application scenarios. For instance, when a rotor bar or end ring is broken it prevents normal current flow which causes an unbalance in the rotor magnetic flux. As a non-intrusive and easily deployable method, the magnetic flux measurement can complement the fundamental vibration and acoustic analysis to create a full-scale condition profile of the monitored equipment and improve CBM data quality for early fault detection and predictive maintenance. iCOMOX uses a standalone geomagnetic sensor BMM150 that allows measurements of the magnetic field in three perpendicular axes. BMM150 can capture magnetic field in the range ±1300 µT in x- axis and y-axis and ±2500 µT in z-axis with a resolution of ~0.3 µT and supports output data rates above 300 Hz in forced mode with low power preset. The sensor offers ultra-low voltage operation and can be programmed to optimize functionality, performance and power consumption in user-specific applications.

Temperature Measurements

Temperature monitoring is the classical approach supported by iCOMOX for machine health assessment implemented using a high accuracy digital temperature sensor ADT7410. This sensor contains a band gap temperature reference and an ADC to monitor the temperature with an accuracy of ±0.5 °C and digitize it to a resolution of 0.0078 °C. The ADT7410 is rated for operation over the temperature range from −55 °C to +150 °C which enables its use for a forced system shut-down should the iCOMOX be exposed to temperatures beyond the specified operating range.

Wake-Up/Auto-Sleep

iCOMOX features a wake-up and auto-sleep function, that reduces power consumption, improves battery life and extends its operational time in the field. This function is realized using an ultra-low power accelerometer ADXL362 that triggers operational states of onboard sensors depending on the current presence of motion. ADXL362 offers unpresented current consumption of 270 nA in wake-up and 10 nA in standby mode and supports adjustable thresholds for sleep and wake-up operation. The sensor has an output resolution of 12-bit and allows a user to select between three measurement ranges of ±2 g, ±4 g or ±8 g offering the best sensitivity of 1 mg/LSB for the narrowest range.

Operational Principles

iCOMOX captures CBM parameters from the surface of the monitored equipment to create its condition profile. The condition profile of the equipment is a set of data that represents its physical condition and include a motion fingerprint captured with the accelerometer ADXL356B, an acoustic fingerprint obtained using the MEMS microphone IM69D130, a magnetic flux profile measured with the geomagnetic sensor BMM150 and a pre-defined operating temperature window monitored using ADT7410.

In the initial “learning” phase, iCOMOX creates a reference condition profile for the monitored equipment by capturing its CBM data while the equipment runs through all possible stages of its normal operation. The obtained data are processed in the onboard microcontroller to extract all relevant time and frequency-domain CBM parameters forming a full-scale condition profile for this equipment.

When the reference profile is created, the iCOMOX continues its operation collecting the CBM data on demand or on schedule and compares it to the reference data searching for possible changes. In a basic use case, the iCOMOX triggers a specific action as soon as these changes are detected. In a more general case, iCOMOX gives a user full flexibility to implement smart analysis techniques and deep learning algorithms for an autonomous self-learning CBM system to meet specific requirements of a target application. This can be done in various ways by using a broad set of connectivity options provided by the iCOMOX. For instance, advanced CBM analysis can be implemented in the cloud by sending the data wirelessly using SmartMesh IP™. Alternatively, this can be done offline by storing data on a Micro-SD card or reading it out directly via a USB interface for further processing on a PC. It is a versatile platform that offers both standard operating modes and a possibility to program custom modes to meet the most demanding application requirements.

Firmware/Software

The iCOMOX is an open platform that allows users to develop and implement their own firmware and software (FW/SW) algorithms and analytics tailored to the needs of a target application.

Standard firmware provided with iCOMOX in its default configuration supports two operating modes: a data acquisition mode and a fault detection mode. In the data acquisition mode, the platform captures CBM data and pushes it at pre-defined time steps (on schedule) to an external host unit via the USB cable or wirelessly through SmartMesh IP™. In the fault detection mode, the iCOMOX pushes the CBM data to the host unit only if changes between the actual data and the reference condition profile of the monitored equipment are detected.

The multi-sensing iCOMOX platform based on an open concept provides the highest level of functionality and reconfigurability and offers a wide spectrum of connectivity options that gives a user a ready to use tool for implementation of a broad range of CBM applications and a full-scale realization of advanced condition-based monitoring techniques for early fault detection and predictive maintenance.

iCOMOX Specifications

System Parameters	
Physical	
Dimensions	83.9 × 52.0 × 27.0 mm
Weight	112 g
Enclosure	Material ABS, IP Class – IP66
Mounting	Various mounting adapters to accommodate a wide range of monitored equipment
Power	
Current	see Appendix 1
Batteries	2× CR3032
Battery lifetime	8 years (active operational time - 1 min/day), 50 days (active operational time - 1 h/day)
Start-up time	< 3 Sec
Connectivity	
Interfaces	Auxiliary ports for external sensors (1× analog, 1× digital), USB 2.0, Micro-SD
Wireless	SmartMesh IP™ 2.4 GHz IEEE 802.15.4e
Operating/Storage Conditions	
Temperature range	-40 °C to 85 °C / -40 °C to +85 °C (storage)
Absolute maximum ratings	-55 °C to 125 °C
Other	
Certifications	CE, FCC

Application Processor: ADuCM4050 – ultra-low-power Arm® Cortex®-M4F MCU with integrated power management featuring SensorStrobe™ technology enables 10× system-level power savings.	
Memory	512 kB - Embedded flash memory with ECC 4 kB - Cache memory to reduce active power 128 kB - Configurable system SRAM with parity
Safety	Watchdog with dedicated on-chip oscillator Hardware CRC with programmable polynomial Multiparity bit protected SRAM ECC protected embedded flash
Security	Hardware cryptographic accelerator supporting AES-128, AES-256, and SHA-256 Protected key storage in flash, SHA-256-based keyed HMAC and key wrap and unwrap User code protection TRNG
Digital peripherals	SPI, I2C, UART, SPORT, GPIO, and more
Analog peripherals	12-Bit SAR ADC, 1.8 MSPS, 8 channels, and digital comparator
Current	41 µA/MHz - active mode dynamic current 400 µA - flexi mode 0.65 µA - hibernate mode 50 nA - shutdown mode 0.20 µA - Shutdown mode (fast wake-up)
Vibration Measurements: ADXL356 - Low power, 3-axis accelerometers with industry leading noise, minimal offset drift over temperature, and long-term stability performance enabling precision applications with minimal calibration.	
Measurement range	±10 g, ±20 g, user selectable
Bandwidth	1500 Hz
Resonant frequency	5500 Hz
Sensitivity	80 mV/g (±10 g), 40 mV/g (±20 g)
Noise density	80 µg/√Hz for ±10 g range
0g offset vs temperature	±0.5 mg/°C
Current	150 µA (measurement mode), 21 µA (standby mode)
Temperature range	-40 °C to +125 °C (operating), -55 °C to +150 °C (storage)
Wake-Up Function: ADXL362 - an ultralow power, 3-axis MEMS accelerometer with adjustable threshold sleep and wake-up operation.	
Measurement range	±2 g, ±4 g, ±8 g (user selectable)
Output resolution	12-Bit
Sensitivity	1 mg/LSB for 2 g range
Current	270 nA (wake-up mode), 10 nA (standby mode)
Temperature range	-40 °C to +85 °C (operating), -50 °C to +150 °C (storage)

Temperature Measurements: ADT7410 - a high accuracy digital temperature sensor with programmable over and under temperature interrupts.	
Measurement range	-55 °C to +150 °C
Accuracy	±0.5 °C (-55 °C to +125 °C)
Resolution	16-Bit (0.0078 °C)
Conversion time	240 ms (continuous/one-shot conversion modes), 6 ms (first conversion on power-up only)
Current	46 µA (1 SPS mode), 2 µA (shutdown mode)
Acoustic Measurements: IM69D130 - High performance microphone with dual backplane MEMS technology.	
Sensitivity	-36 dBFS
Acoustic overload point	130 dBSPL
SNR	69 dB(A)
Dynamic range	105 dB
Total harmonic distortion	≤1% up to 128dBSPL
Low frequency cutoff point	28 Hz (-3dB point relative to 1 kHz)
Current	300-980 µA (standard/low power modes), 25 µA (standby mode), 1 µA (clock-off mode)
Temperature range	-40 °C to +100 °C (operating), -40 °C to +125 °C (storage)
Magnetic Field Measurements: BMM150 - a triaxial low-power and low-noise magnetic field sensor.	
Magnetic field range	±1300 µT (x-, y-axis), ±2500 µT (z-axis)
Heading accuracy	±2.5 deg (30 µT horizontal geomagnetic field component, T_A=25°C)
Start-up time	3.0 ms (from suspend to sleep)
Resolution	~0.3 µT (T_A=25°C)
Output Data Rate (ODR)	>300 Hz (adjustable)
Output noise	0.3 µT to 1.0 µT (adjustable)
Current	170 µA (low power preset mode), 500 µA (normal mode)
Temperature range	-40 °C to +85 °C (operating), -50 °C to +150 °C (storage)
Connectivity: LTC5800-IPM - IEEE 802.15.4e SoC Transceiver with an Embedded Arm® Cortex®-M3 32-bit microprocessor running SmartMesh IP™ networking software and offering >99.999% network reliability in the most challenging RF environments.	
Wireless	
Frequency	2.4 to 2.4835 GHz
Number of channels	15
Channel separation	5 MHz
Raw data rate	250 kbps
Range	Up to 50 m
Antenna	Internal
Temperature range	-40 °C to +85 °C (operating), -55 °C to +125 °C (storage)
Interfaces	
1× Digital Input	SPI/I2C, SPI1_ or SPI_2 (ADUCM4050) – for external sensors
1× Analog Input	ADC0_VIN (ADUCM4050) – for external sensors
USB 2.0	system setup and control, raw data readout
Micro-SD	external data storage

Appendix 1

Table 1 Current consumption of iCOMOX functional elements.

Component	CBM Mode	Standby Mode
ADXL356B	150 µA (measurement mode)	21 µA in standby mode
ADXL362	270 nA (wake-up mode)	10 nA
BMM150	170µA (low preset mode for high ODR)	1µA (suspend mode)
ADT7410	46µA (1SPS mode)	2µA (shutdown mode)
IM69D130	300 µA	25 µA (standby mode)
ADuCM4050	400 µA in Flexi Mode	0.65 µA (hibernate mode)
LTC5800-IPM	5.4 to 30 mA	0.8µA (deep sleep mode)

Ordering information

> iCOMOX Part #: SRT-COMOX-SM
> iCOMOX Evaluation Kit: SRT-ICOMOX-KIT

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