ADI设备状态监测系统方案

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**ANALOG
DEVICES**

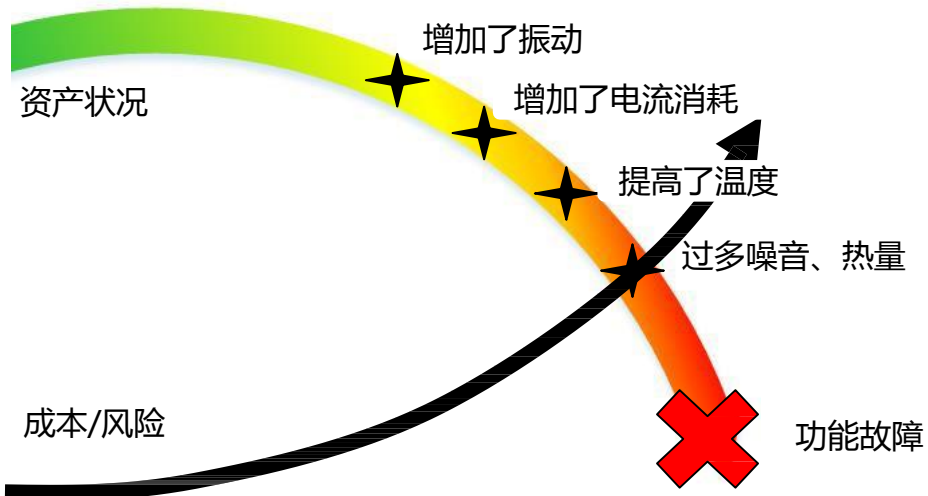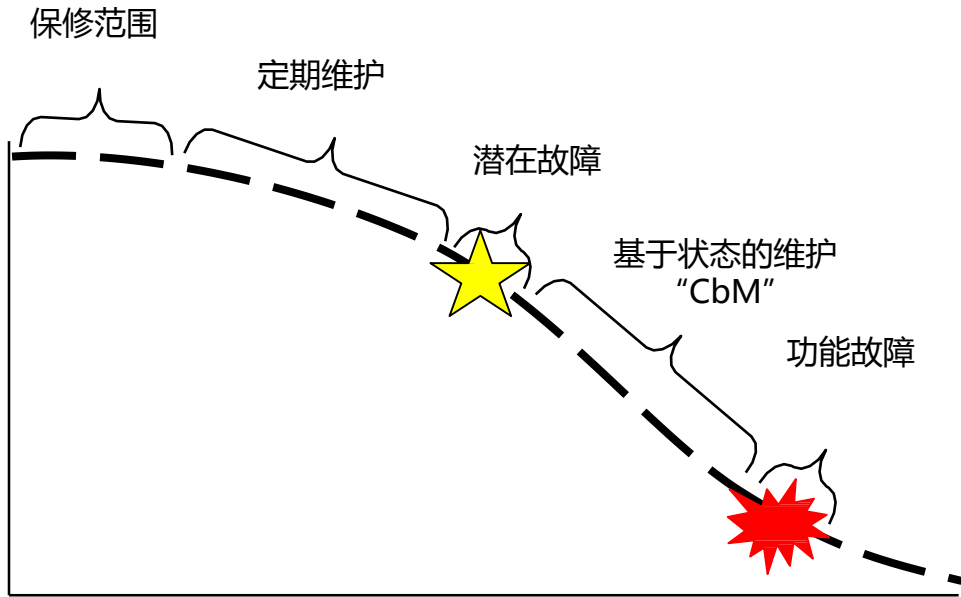AHEAD OF WHAT'S POSSIBLE™

目录

市场概况

保修范围

定期维护

潜在故障

基于状态的维护 "CbM"

功能故障

资产状况

增加了振动

增加了电流消耗

提高了温度

过多噪音、热量

成本/风险

功能故障

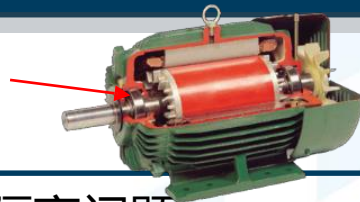| CbM**不是...**	CbM是...
不是一个市场	是一种应用
不是仅传感器解决方案	系统解决方案
不仅限于振动	完整的诊断解决方案

优化的CbM解决方案提供预测性和可行见解

检测

- 通过异常工作条件检测潜在问题

诊断

轴承故障

- 识别并隔离问题和损坏程度

预测

- 确定设备的剩余使用寿命

行动：

- 存在潜在问题
- 需要执行什么操作？
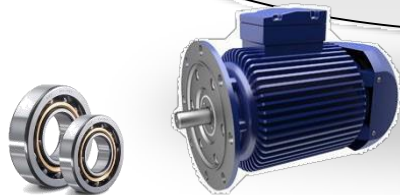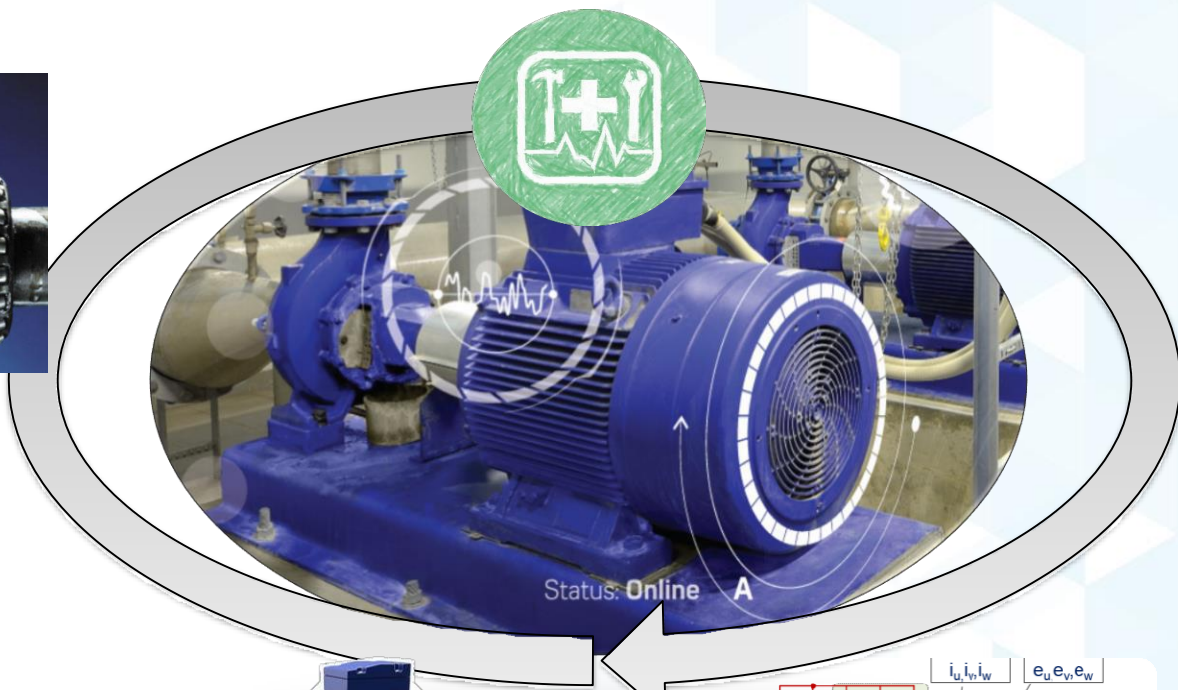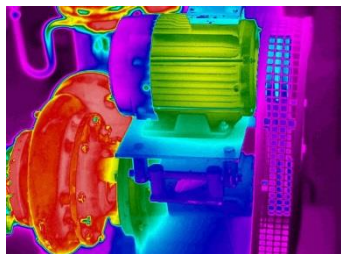- 故障检测的可靠程度如何？

- 存在问题
- 需要维护
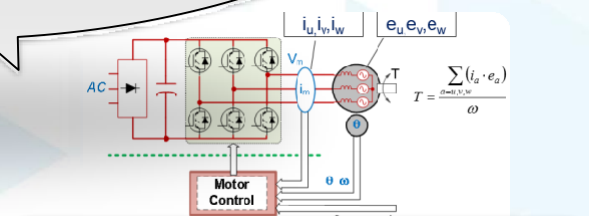- 还有多久出现故障？

- 识别了问题
- 安排了维护
- 订购了部件

嵌入式检测技术增强了诊断解决方案

油品分析
- 分析润滑油成分的变化来检测一场

振动和声学
- 早期机械故障检测/诊断/预测
- 异常检测/诊断
- 改进系统性能控制

温度
- 与振动故障的关联增强了诊断能力

电压和电流
- 机电故障诊断
- 增强了基于振动的诊断解决方案

磁场
- 非侵入性故障检测
- 通常需要了解机器、系统和环境

Status: Online A

$$T = \frac{\sum_{\theta=U,V,W}(i_a \cdot e_a)}{\omega}$$

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CBM 实例 --- 电机驱动系统

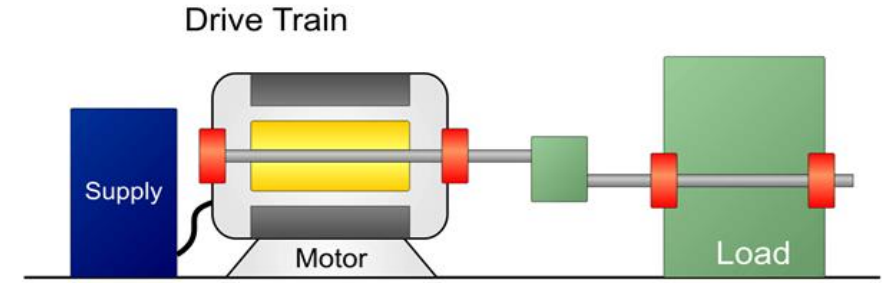- **Available approaches to Condition Monitoring-**
  - Generally understood to mean vibration or velocity
  - But other tools in the toolbox like Power Quality can be monitored with ADE9000

- **Node types**
  - Wireless – Easy deployment, Interval monitoring
    - Cons: Power sensitive, Radio Architecture Selection, Duty cycle
  - Wired – Continuous Monitoring
    - Cons: Facility costs, Routing wire harness on mechanical equipment

- **Diagnostic Levels / Prognostics**
  - Immediate: Failure imminent
  - Local modeling of machine (classic model, science is still developing today)
  - Machine Learning is emerging (manual and cloud based)

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Supply	Power Quality	EPVA (Voltage)	
Mec. Imbalance or Misalignment	MCSA	Vibration	EPVA
Insulation Faults	Partial Discharge	EPVA	
Stator Electrical Imbalance	EPVA	MCSA	Power Quality
Broken Bars	MCSA	EPVA and IPSA	
Bearing Faults	Vibration	Wavelet on Current	MCSA,EPVA and IPSA
Coupling and Load Mechanical Failures	Vibration	MCSA,EPVA and IPSA	

Significance: High / Medium / Low

- EPVA- Extended Parks Vector Approach
- MCSA- Motor Current Signature Analysis
- IPSA- Instantaneous Power Signature Analysis

CBM系统架构

SENSE

- Wide Bandwidth
- Wide Measurement Range
- Low Noise
- Stability over Temp & Life
- Multi-axis
- Small Form Factor

MEASURE

PROCESS

CONNECT

ANALYZE

CBM常见产品形态

Sensing   **Processing**   **Algorithm**

Wireless Sensor
- Lora
- Zigbee
- 2.4GHz Mesh

Wired Sensor
- IEPE(2/3 wire)
- Voltage
- 4~20mA
- RS485
- IND Ethernet

Hand-hold sensor
- Blue Tooth
- WIFI

Field Instru.
- 4~20mA
- RS485

Wireless Gateway

Data Collector
- GPRS/4G
- NB
- G Ethernet
- WIFI

Cloud

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ADI所提供方案概述

工业CBM客户群体

OEM/Machine Builders
Asset/equipment manufactures

Siemens, ABB, Rockwell, Danfoss, SKF

#1: Component
#2: Signal Chain
#3: AI & Algorithms
#4: Module

Asset Monitoring Suppliers
Asset/equipment condition monitoring manufactures

IFM, Hansford, Bentley Nevada

#1: Signal Chain
#2: Component
#3: Modules
#4: AI & Algorithms

ADI Domain Knowledge

System Integrators
One-stop, full install/service, supplying assets/equipment from many different suppliers
JR Automation, Leidos, SAGE Automation

#1: Module
#2: AI & Algorithms
#3: Signal Chain
#4: Components

Solution/Service Providers
Providing maintenance service for assets/equipment

GE Digital, Augury, Presenso, Software AG

#1: Module
#2: Signal Chain
#3: AI & Algorithms
#4: Component

ADI针对CBM的产品系列
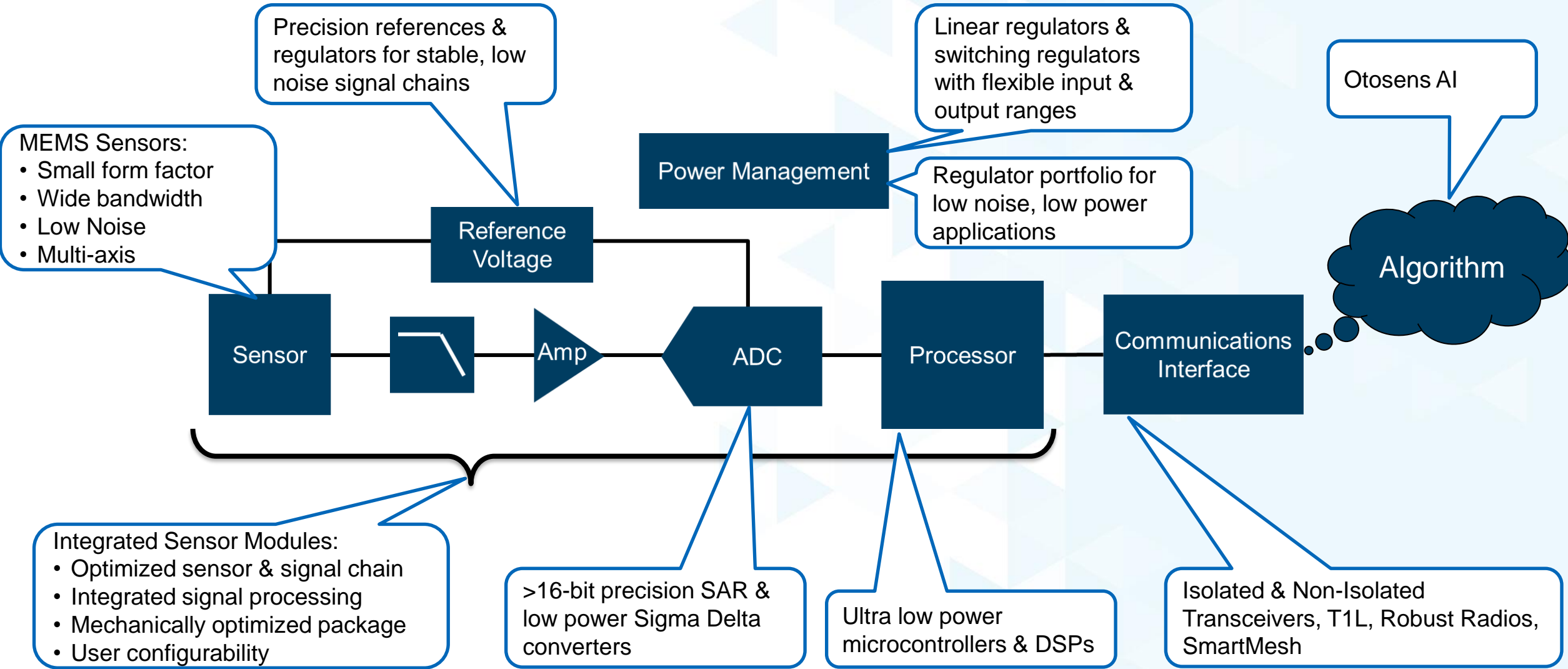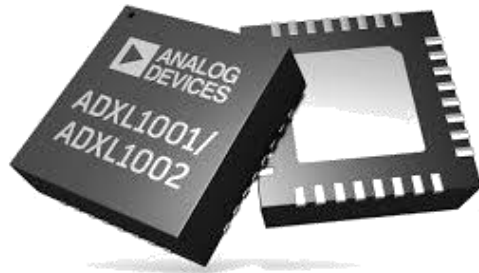
工业 CBM --- 器件

MEMS Sensors

Broad portfolio of high-performance MEMS sensors
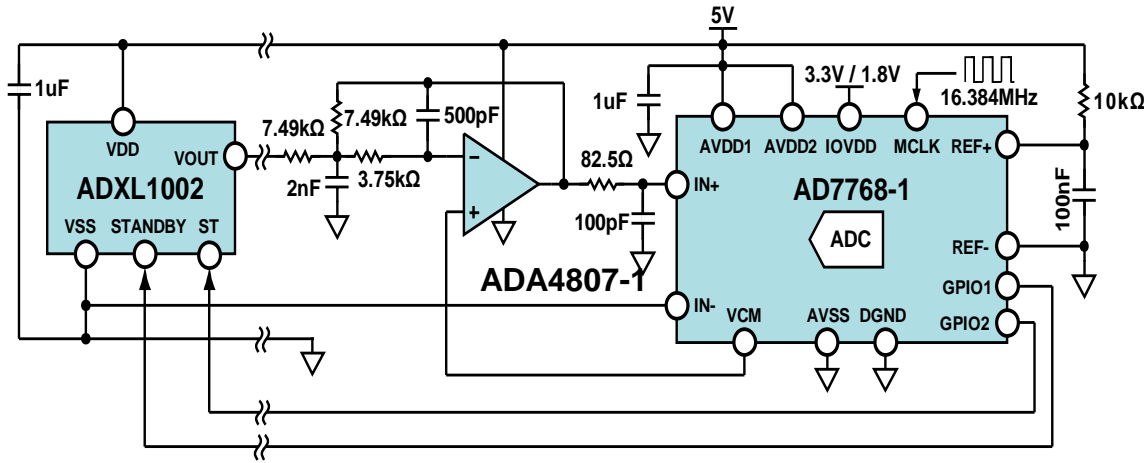
Data Acquisition

Full Data Acquisition Precision Offering

Wired/Wireless Connectivity
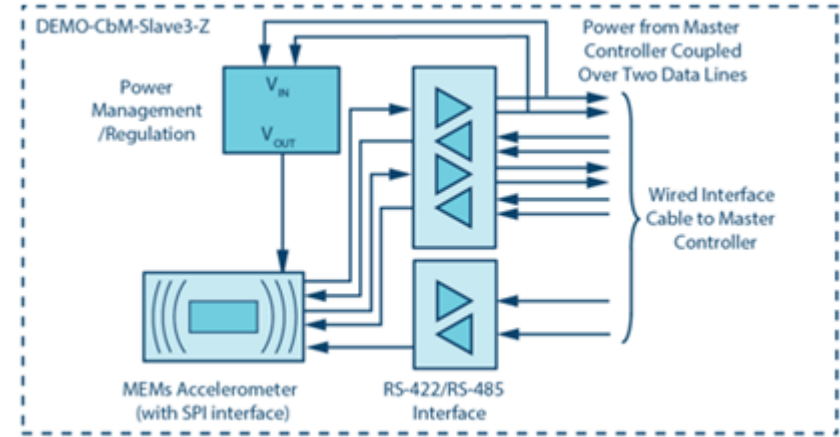
DUST Networks, RS-485, IEPE, Ethernet

MEMS Based Signal Chain

RS-485 Signal Chain/Pioneer1
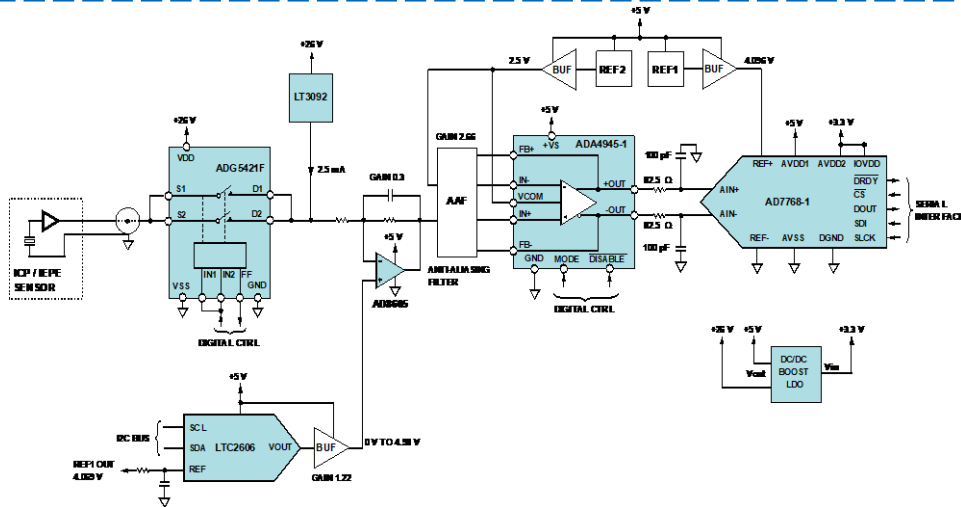
IEPE-Compliant Based Signal Chain
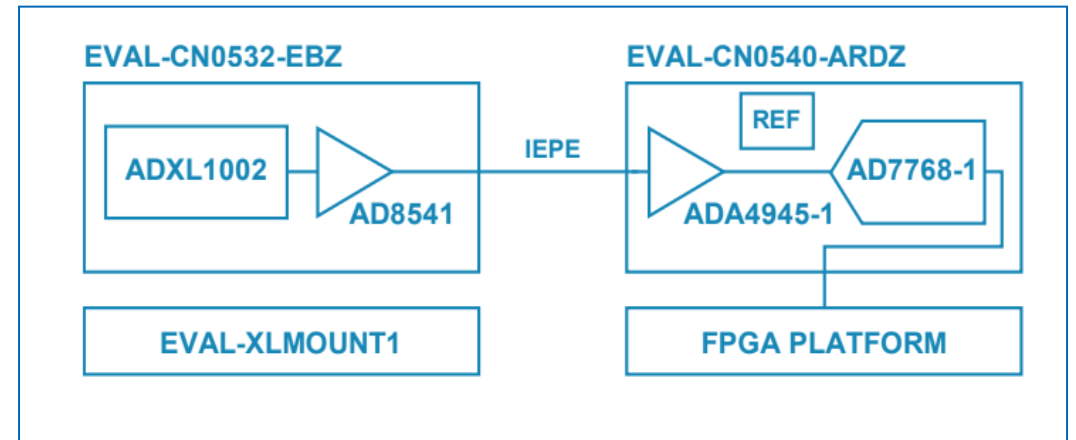
CbM Development Platform/CN0549

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ADcmXL3021

Voyager

AMC Vibro

OtoSense® PdM Predictive Maintenance

Real time recommendations based on LV /MV electric motors performance

- Processes incoming data continuously
- Provides expert feedback on specific assets
- Leverages existing domain knowledge

Increasing deployment readiness

OtoSense® PdM (SMS)

工业CBM -- AI & 算法
OtoSense - Hardware Agnostic

OtoSense® AI Quality Control	OtoSense® AI Field Diagnostics	OtoSense® AI EDGE Monitoring	OtoSense® PdM Predictive Maintenance
Enhance the quality control for 100% of the assets on production line	Portable maintenance solution to perform on-site inspection of assets	Real time condition monitoring of any assets	Real time recommendations based on LV /MV electric motors performance

OtoSense® AI Quality Control

- Identifies assets, integrates with industrial buses
- Outputs quality assessment score
- Stores structured and searchable data.

OtoSense® AI Field Diagnostics

- Use any OtoSense-enabled tablet to perform field diagnostics offline
- See the health score of the asset instantly
- Each diagnostic increases accuracy and knowledge

OtoSense® AI EDGE Monitoring

- Processes incoming data continuously
- Detects anomalies and recognizes events
- Enables control over the data sent by the edge device

OtoSense® PdM Predictive Maintenance

- Processes incoming data continuously
- Provides expert feedback on specific assets
- Leverages existing domain knowledge

传感器的考量

CBM 实例 --- e.g. Motor Drive System

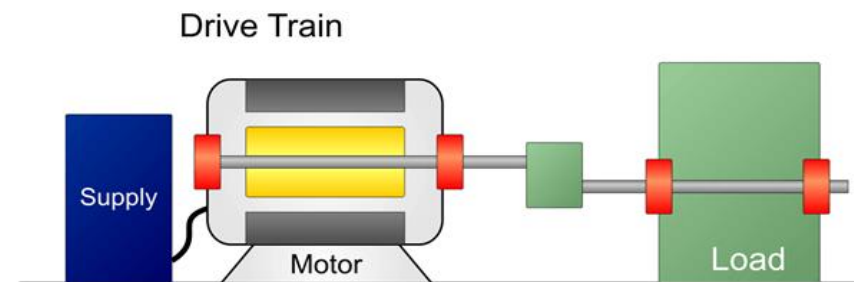- ► **Available approaches to Condition Monitoring-**
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- ► **Node types**
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- ► **Diagnostic Levels / Prognostics**
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  - Local modeling of machine (classic model, science is still developing today)
 - Machine Learning is emerging (manual and cloud based)

Drive Train

Supply	Power Quality	EPVA (Voltage)	
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Stator Electrical Imbalance	EPVA	MCSA	Power Quality
Broken Bars	MCSA	EPVA and IPSA	
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Coupling and Load Mechanical Failures	Vibration	MCSA, EPVA and IPSA	

Significance: High Medium Low

- EPVA- Extended Parks Vector Approach
- MCSA- Motor Current Signature Analysis
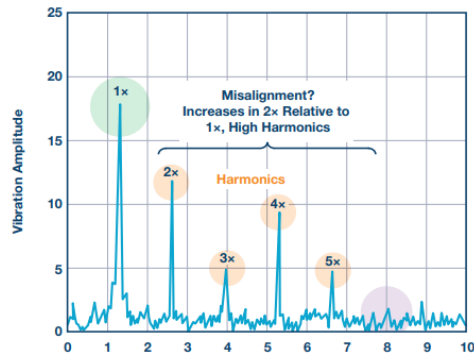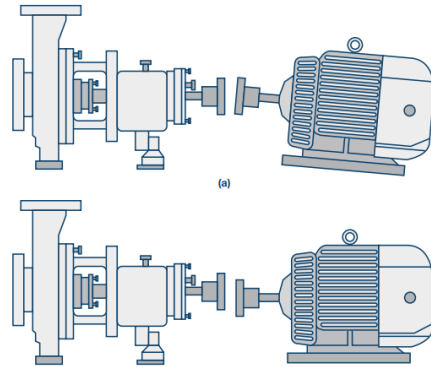- IPSA- Instantaneous Power Signature Analysis

常见故障类型与传感考量

Imbalance
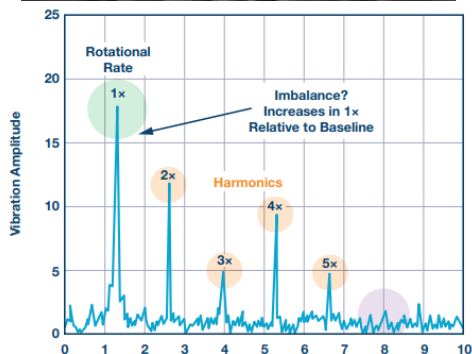
Sensor & System Considerations
- Low noise
- Sufficient resolution
- Bandwidth ~5x fundamental
- Multi-axis sensing
- Low frequency response for slow rotating machines

Misalignment

Sensor & System Considerations
- Low noise
- Bandwidth 10x fundamental
- Multi-axis sensing is important
- Phase matched simultaneous sampling

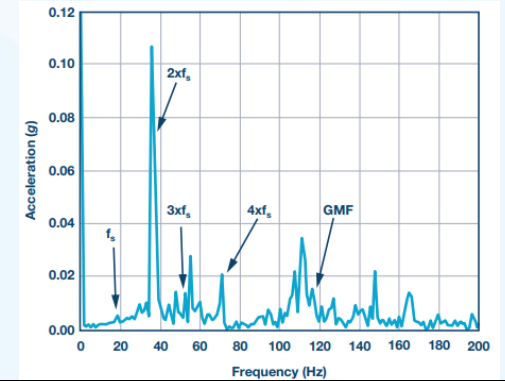## Bearing Defects
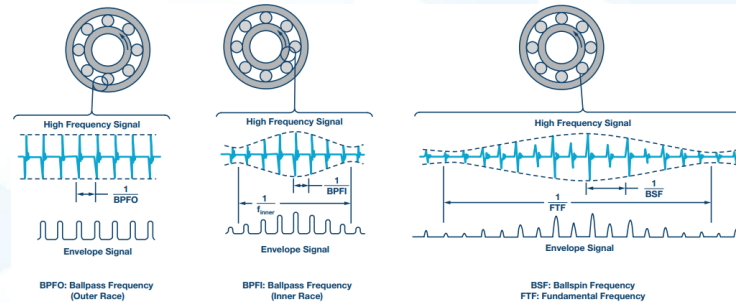
Sensor & System Considerations
- Low noise to detect early defects
- Wide bandwidth is critical
- High g range

Gear Defects

Sensor & System Considerations
- Wide bandwidth is critical.
- Low noise is critical due to limited sensor mounting location

故障类型与传感器需求对照表

Fault Type	Bandwidth	Noise Density	Dynamic Range
Imbalance	Low	Medium	High
Misalignment	Medium	Low/Medium	High
Bearings	High/Very high	Low	Medium
Gears	Very high	Low	Low

Guidelines

Bandwidth: Low<1kHz, Medium 1-5kHz, High>5kHz,

Noise Density: Low <100ug/(Hz)$^{0.5}$, Medium 100u-1mg/(Hz)$^{0.5}$, High >1mg/(Hz)$^{0.5}$,

Dynamic Range: Low <5g, Medium 5-20g, High >20g

Resolution: Low 12-14 bits, Medium 14-16 bits, High 16-20 bits

将系统需求转化为设计需求

System Requirements → Translation → Design Criteria

- level of detection
- Machine characteristics
- type of faults
- System architecture
- Sensor type

- Bandwidth
- Noise/Resolution
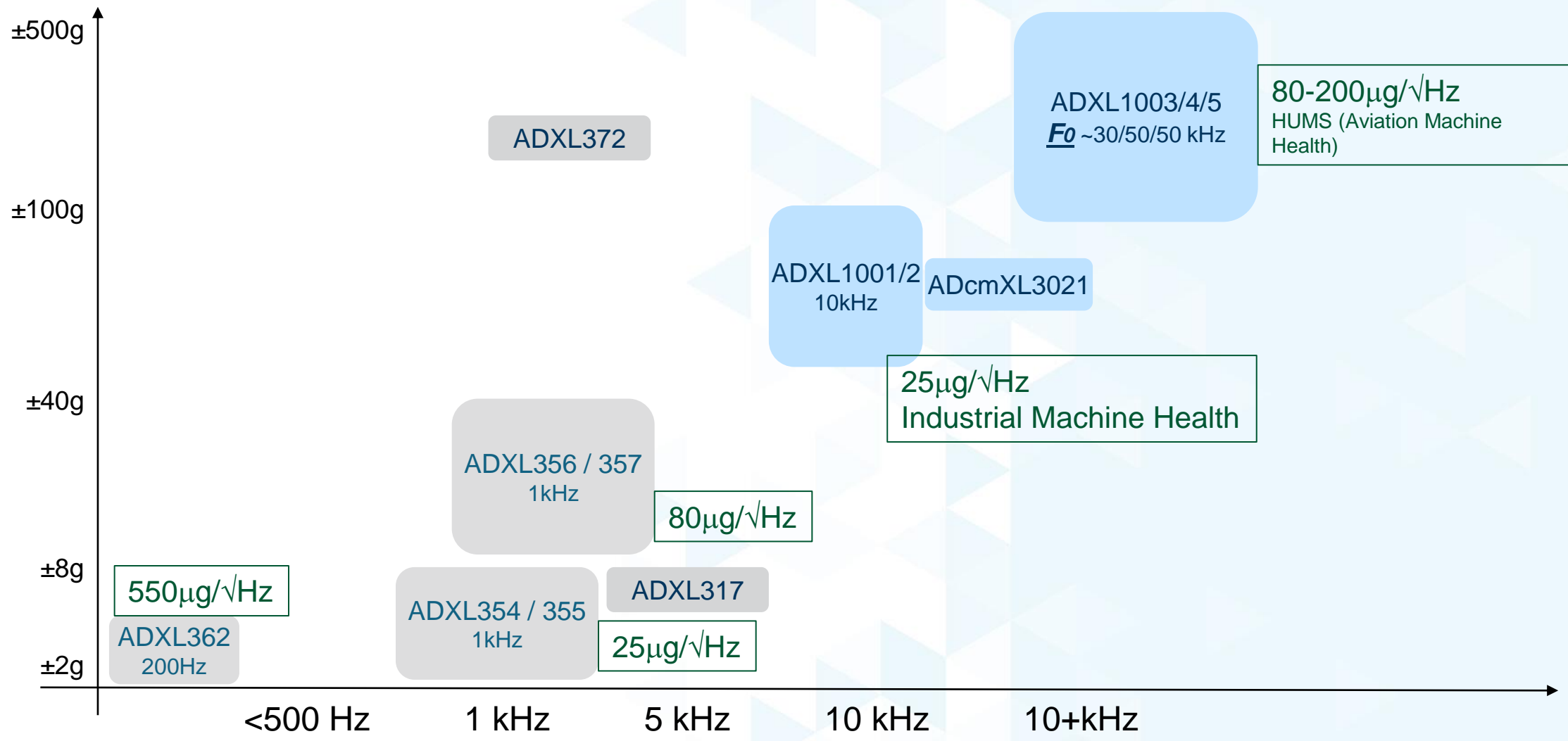- Range
- Axis/Channel
- Size
- Power

如何选择合适的传感器

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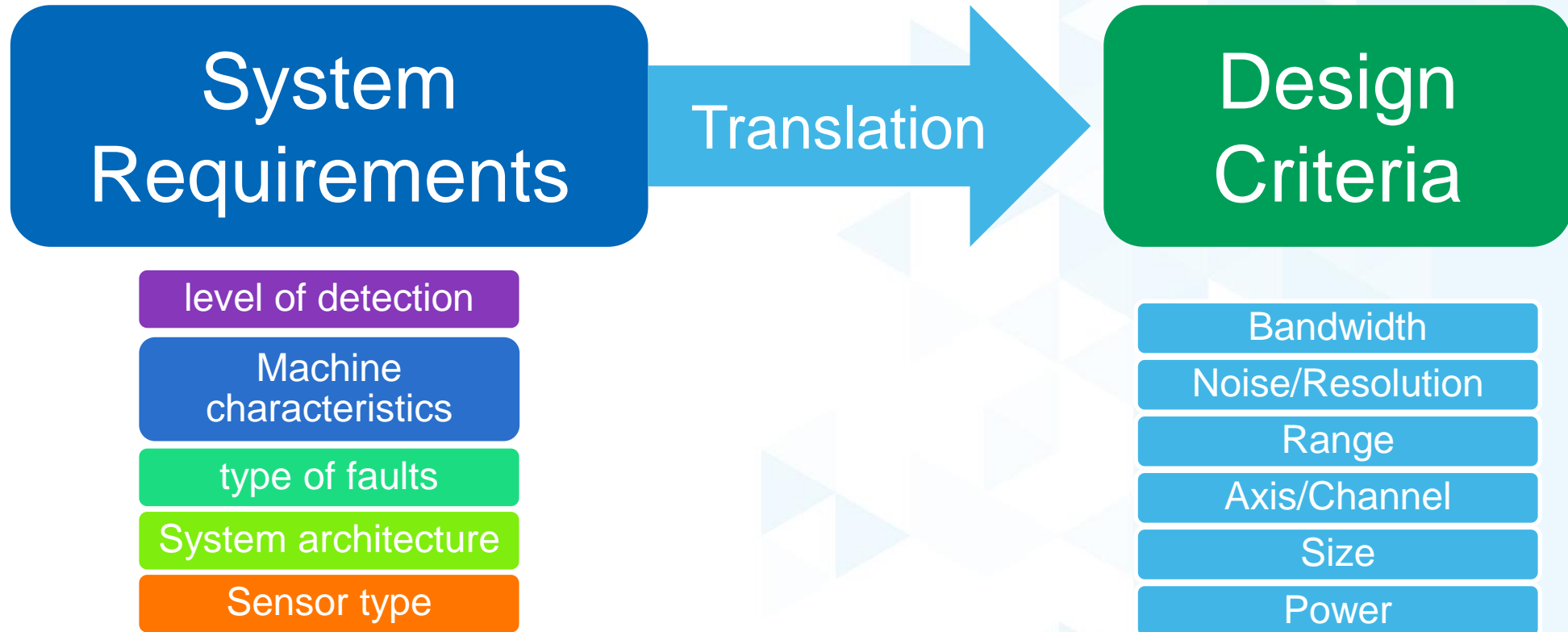
- 你想要测量什么?
  - 原始数据还是特征值
  - 加速度,速度还是位移
  - 是否振动加温度
  - 单轴,双轴还是三轴
- 振幅有多大?
- 被测振动频率范围是多少?
- 环境温度是多少?
- 是否会浸没在液体中?
- 是否会暴露在潜在有害的物质中?
- 你是否需要顶出,侧出,小巧的连接?
- 你是使用高精度的还是低成本的传感器?
- 需求特殊的认证吗?

振动测量一般意味着对频谱进行勘测,以确定机械或设备是否出现故障。

ADXL1001/ADXL1002

ADXL356/ADXL357

ADcmXL3021BLWZ

- 宽带宽
- 宽测量范围
- 低噪声
- 温度范围和生命周期内的
- 稳定性 多轴
- 小尺寸

ADI加计产品与故障类型对应表

System-Level Faults

Equipment/Machine-Level Faults

Fault Types:
- **Misalignments**
- **Imbalance**
- **Mechanical Looseness**
- **Others…**

Fault Types:
- **Bearings**
- **Gearboxes**
- **Cavitation (Pumps)**
- **Others…**

ADXL356/357 Accelerometers
- **ADXL356/7 offer low noise in 3-axis package**
- **ADXL356/7 offers flexible bandwidth > 2-3kHz**

ADXL100x Accelerometers
- **ADXL1001/2 preferred for lower noise & DC→10kHz BW**
- **Capable of measuring slow rotation machines because of operation down to DC**

VIBRATION

FREQUENCY (Hz)

1   10   100   1k   10k

信号处理链路的考量

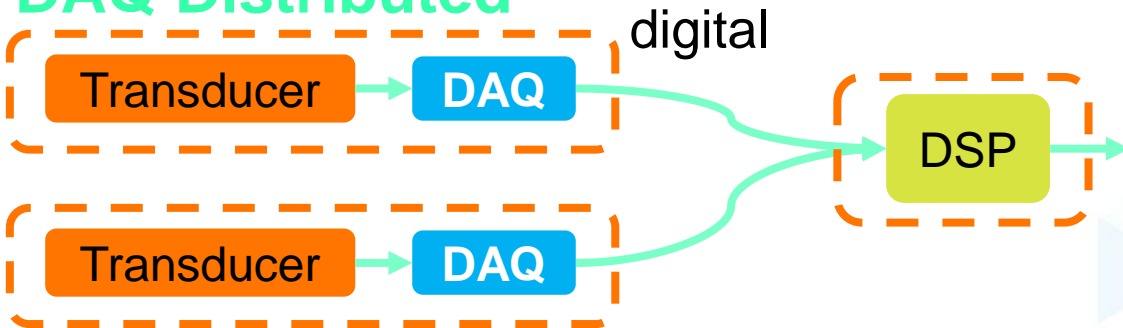# 数据采集系统架构

## DAQ Centralized

Transducer

Transducer

analog

DAQ → DSP
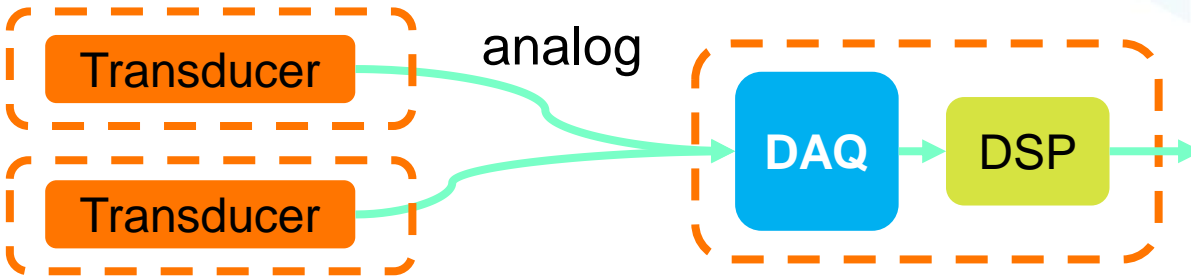
DAQ centralized system typically have a multi-channel DAQ unit connected with multiple sensors through analog communication link (voltage or current).

DAQ Distributed

Transducer → DAQ

Transducer → DAQ

digital

DSP

DAQ distributed system typically have DAQ by the sensor. Digital data is send back to the central processing unit though protocols such as SPI, RS485 or Ethernet

Edge Node

Transducer → DAQ → DSP

digital/wireless
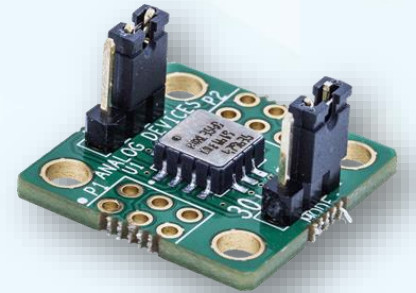
Edge node digitize and processes the sensor output data locally. Uplink can be done through wireless or wired communication.
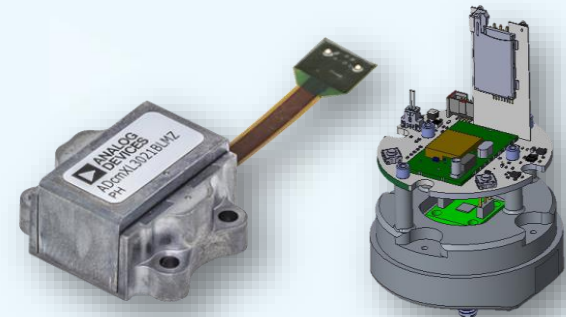
集中式数据采集架构

Common interface type:

- IEPE (Integrated Electronics Piezo-Electric)
- 4-20mA
- Voltage output

Pros:

- Robust connection
- Low cost 2-wire cable
- Not power constrained
- Wide bandwidth
- Multi-channel DAQ to save cost
- Very high temp tolerance (charge based)

Cons:

- Higher power consumption
- Wired based system

DAQ Centralized

Transducer

Transducer

analog

DAQ | DSP
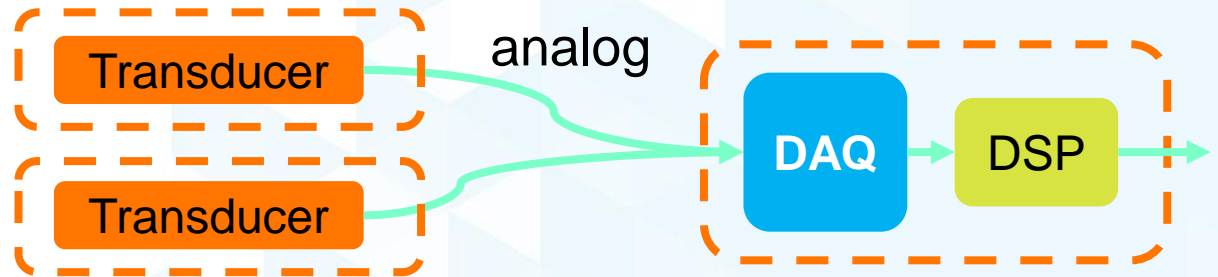
VCC

2~10mA Current Source

VCC-VEE>24V

±10V

VEE

2-wire coaxial

AC couple | Buffer | Filter+ Driver | ADC

DAQ

IEPE Accelerometer

AC102-1A
SN: 207421
CE

Example System Architecture with IEPE

配合集中式数据采集架构的传感器

DAQ
Current Source
24V or ±12V
supply
SE input

Piezo IEPE — 2-wire coaxial

MEMS — Buffer Amplification — 2-wire coaxial

DAQ
5V supply
Pseudo Diff

MEMS — 4-wire shielded

DAQ
Current input

Piezo — Voltage Current Conversion — 2-wire twisted pair

MEMS — Voltage Current Conversion — 2-wire twisted pair
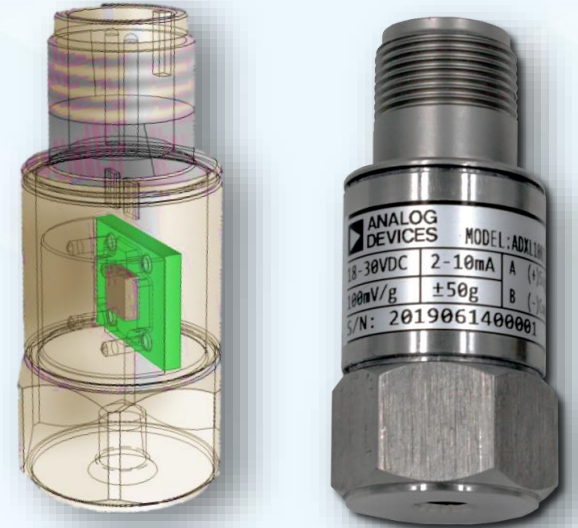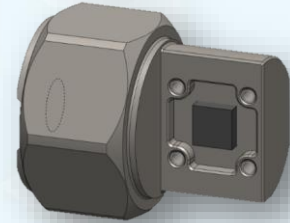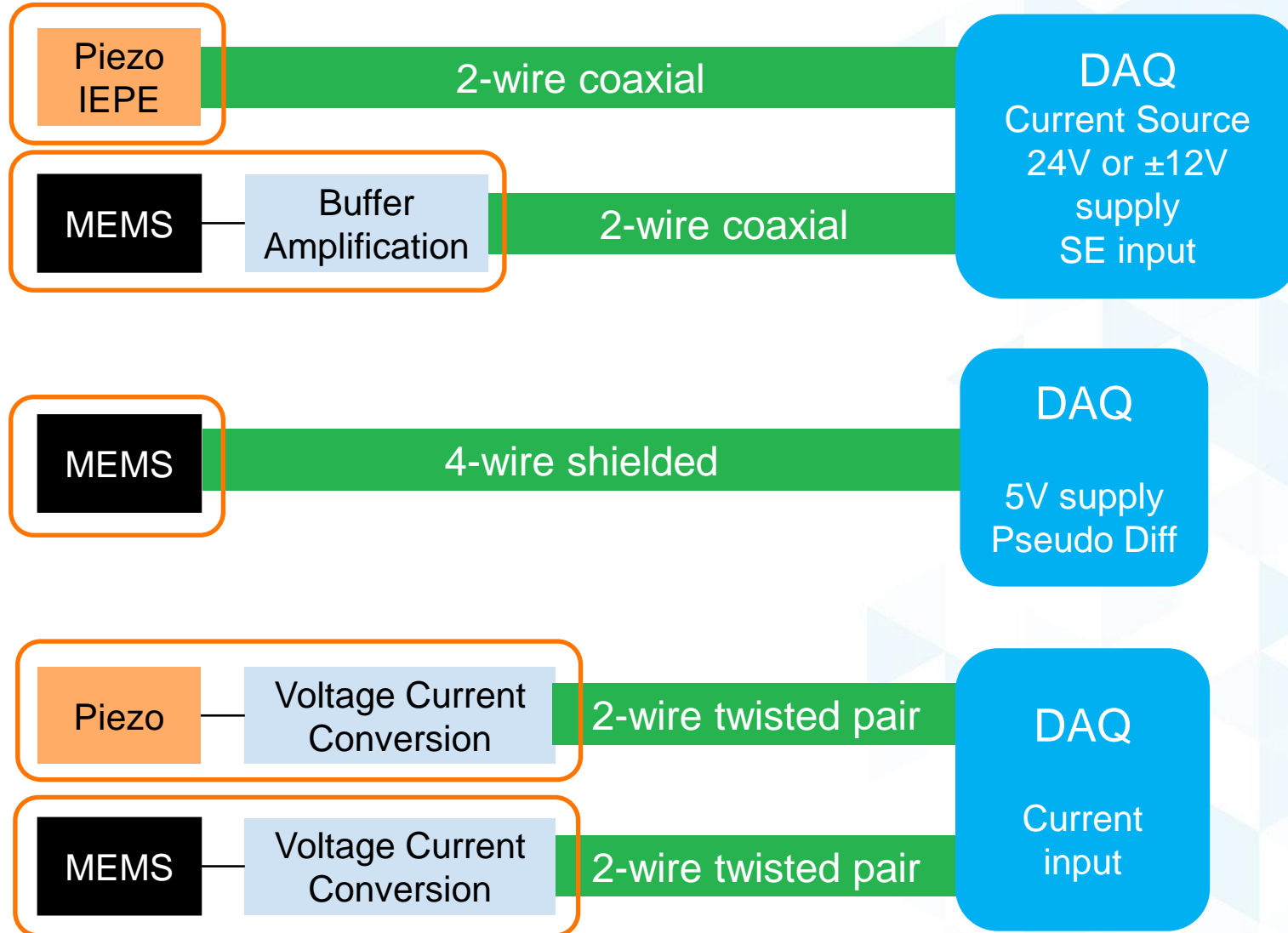
离散式数据采集架构

Common interface type:
- SPI
- RS485
- Ethernet

Pros:
- Robust connection
- Low cost cable
- Daisy chain (Ethernet)
- Phantom power (RS485 and Ethernet)
- Wide bandwidth

Cons:
- Short distance communication (SPI only)
- Higher design complexity (transceiver)
- Wired based system

digital
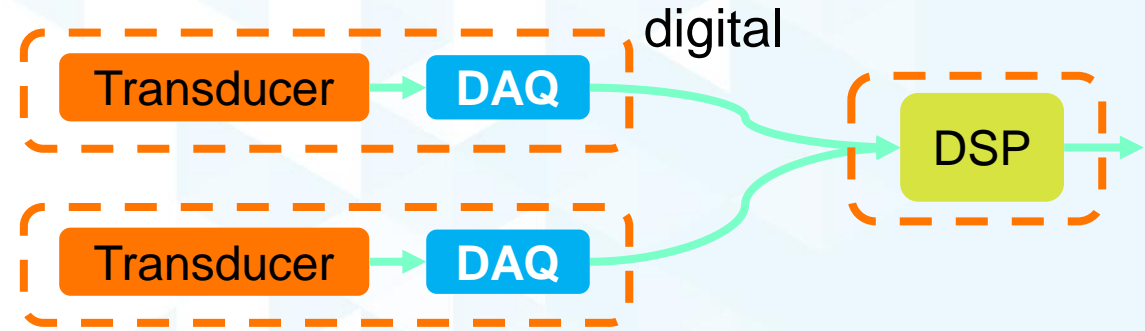
Example System Architecture with RS485

配合离散式数据采集架构的传感器
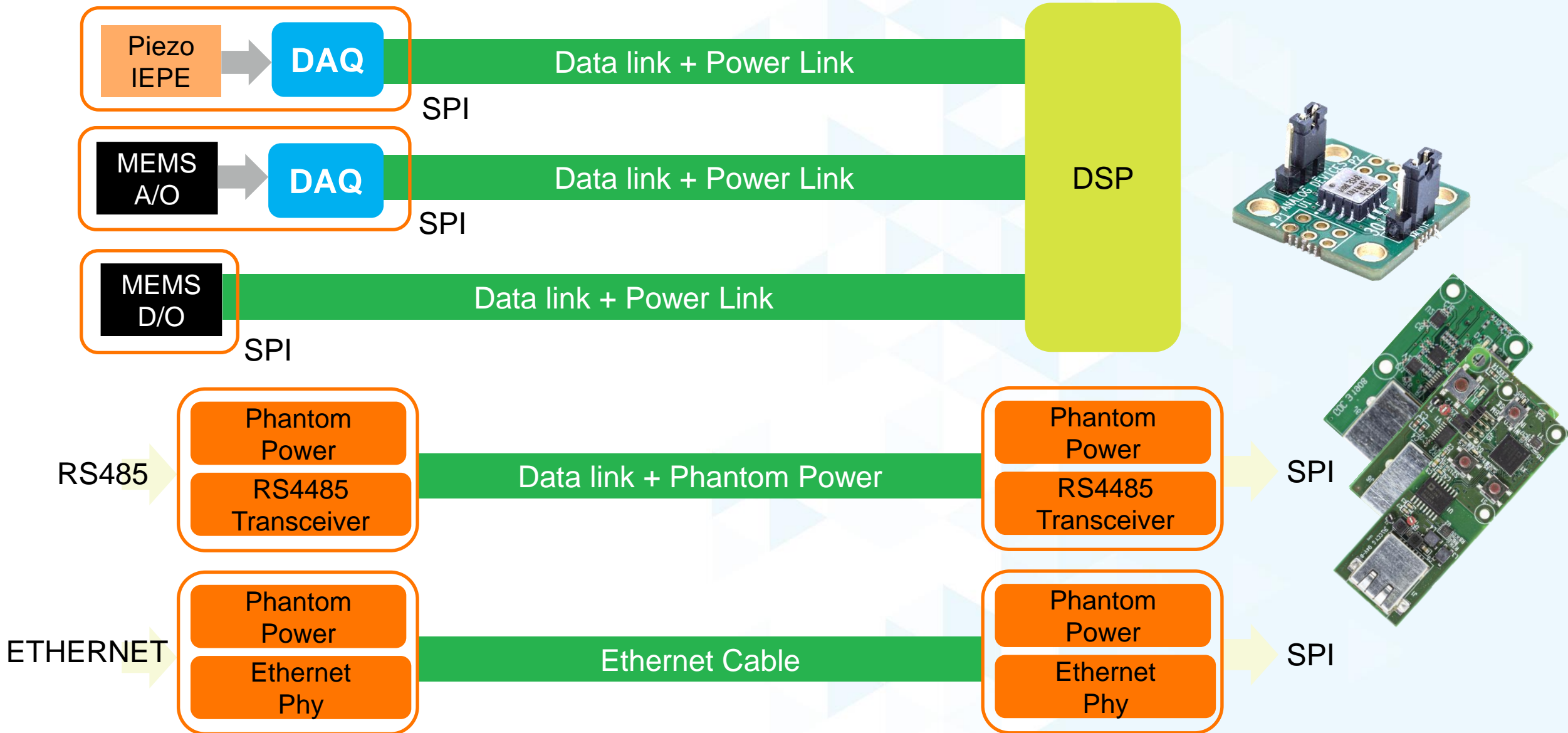
边缘节点架构

Common interface type:
- Wireless
  - Bluetooth/ Smart Mesh/ Cellular link
- Wired
  - SPI, RS485, Ethernet

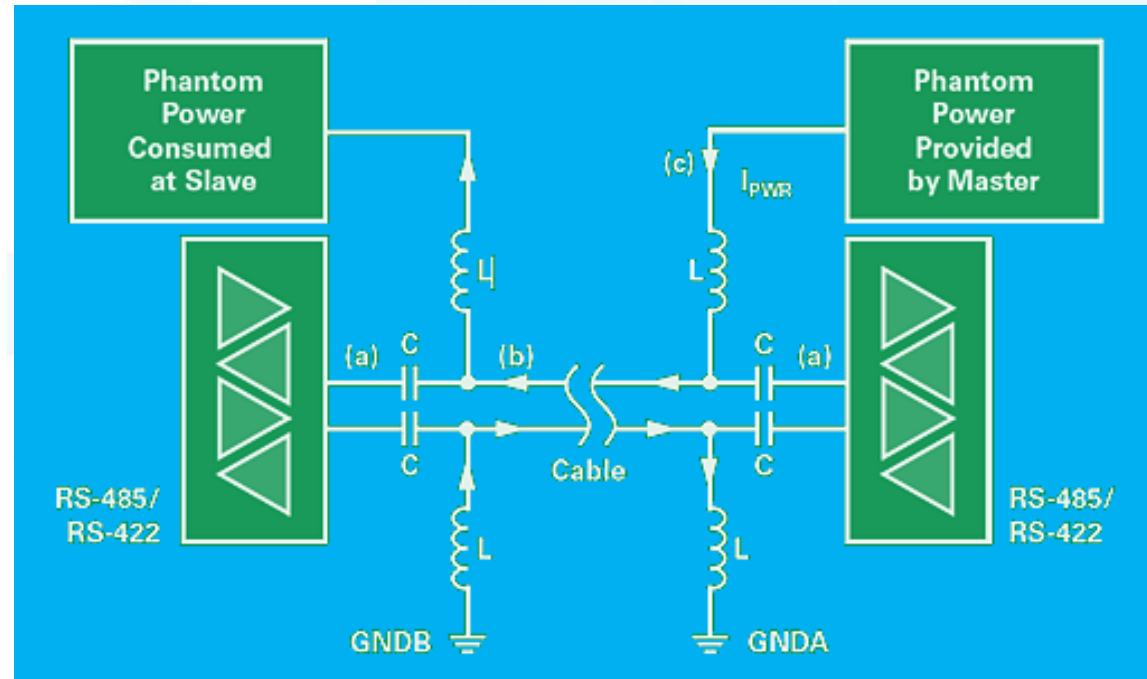Pros:
- Easy to install
- Can be low power
- Built-in intelligence
- Daisy chain (Ethernet)

Cons:
- Limited bandwidth and performance (wireless)
- No continuous monitoring (wireless)
- Process power constrained (wireless)

Edge Node   digital/wireless

Transducer → DAQ → DSP →

ADC 架构选择

1. Precision Medium BW sigma delta
- Characteristic:
  - **High dynamic range**
  - Wide bandwidth (160kHz flat BW)
  - **Cost competitive**
  - Flexible
  - **Include digital filter**
  - Single channel or multi-channel sim-sampling
- Example parts: AD7768 family (8/4/1 channel), AD7761
- Suitable for:
  - General purpose CbM
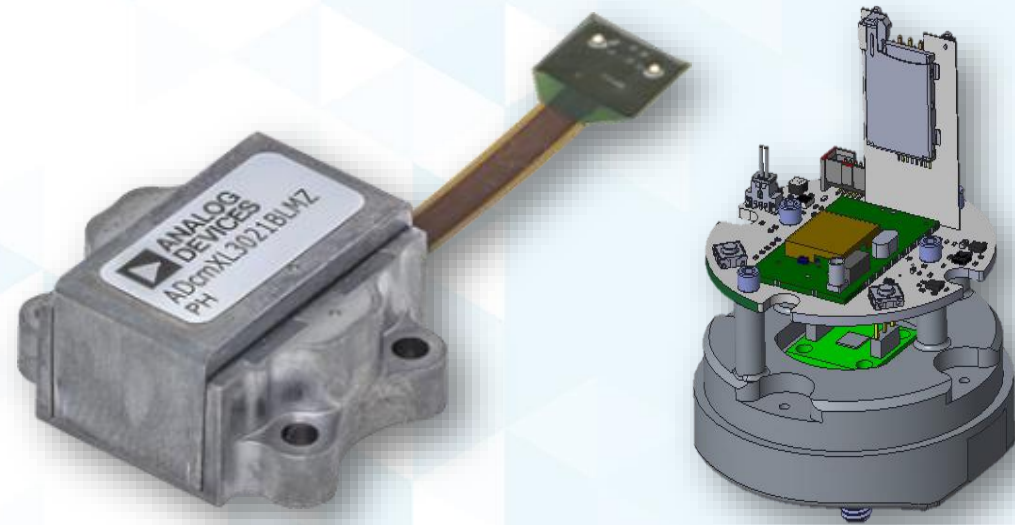 - Frequency domain and time domain analysis
  - High performance piezo system

2. Precision narrow BW, multiplexed sigma delta
- Characteristic:
  - **High dynamic range**
  - **Narrow bandwidth** (<5kHz)
  - **Low power**
  - Multi-channel
- Example parts: AD7124, AD7175
- Suitable for:
  - Low bandwidth sensors, tilt/inclination monitoring
  - Low power systems
  - Strain and temperature monitoring

3. Precision SAR
- Characteristic:
  - **Low power** (if not require digital filter)
  - **Small size**
  - Wide bandwidth (up to MHz)
  - Low latency
  - Single channel or multi-channel sim-sampling
- Example parts: AD7988-1, AD4008, AD7767
- Suitable for:
  - General purpose CbM
  - Time domain analysis
 - High frequency shock analysis

4. Precision Multiplexed SAR
- Characteristic:
  - **Very low power**
  - **Tiny size**
  - Multi-channel
- Example parts: AD4698
- Suitable for:
  - Low power multichannel vibration sensing
  - Small size, multichannel vibration sensing

数据通讯方式的考量

ADI SmartMesh IP Wireless Mesh Networking Protocol Solution

- ► 2.4 GHz multihop wireless mesh networking solution

- ► Established industrial grade solution
  - ▪ Robust 6LoWPAN, IEEE 802.15.4e standards based

- ► Complete wireless networking solution
  - ▪ LTC5800 SoC with embedded protocol software and reference design
  - ▪ Pre certified surface mount pcb (castellated) with embedded software
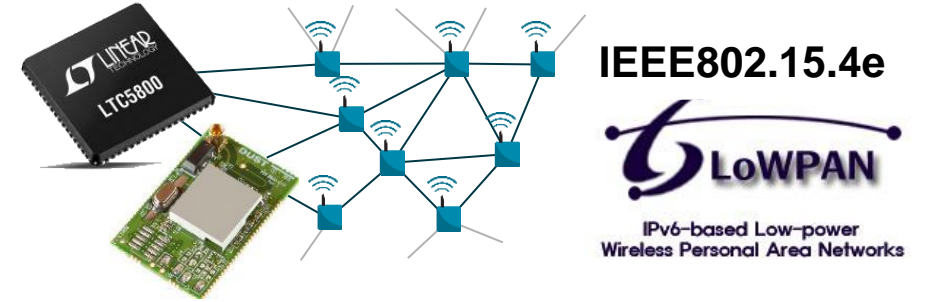
Key Benefits

- ► Ultralow power consumption delivering >10 year battery life

- ► High reliability, robustness, and immunity to interference
  - ▪ Maintains network integrity, avoiding data loss in industrial environments

- ► Scalability for networks to work in different configurations

- ► High data capacity with up to 7.2 kbps of payload data per node

IEEE802.15.4e

Industrial Process

Condition-Based Monitoring

Transportation

Data Center Monitoring

ADI SmartMesh IP—Features

Features and Specifications

▶ 2.4 GHz ISM global license-free multi-hop mesh network

▶ High reliability avoids node communication dropouts

▶ Self-optimizing algorithms maintain high QoS over network life

▶ Efficient power management
  - Network-wide low power consumption
    - Typical Routing Node: <50 µA at 3.6 V
  - Industry-leading low power radio technology
    - 4.5 mA to receive a packet
    - 9.7 mA to transmit at 8 dBm
  - Deterministic power management
    - Extends time to first battery failure

▶ Bidirectional communications

▶ On-demand bandwidth allocation

▶ High uplink bandwidth of 10 packets/sec per node (90 B payload)

▶ Built-in network health statistics and diagnostics

▶ Micro-second accurate timestamping

▶ OTA (over-the-air) updating

Target Application

▶ For use in medium to high density networks in harsh industrial environments, such as
  - Industrial processing
  - Condition-based monitoring
  - Transportation
  - Data center monitoring

## Value Proposition

▶ Robustly tested wireless protocol which avoids multiple hour communication dropouts due to changes in the environment

▶ Industrial-grade wireless protocol delivers high quality of service in commercial and industrial RF environments

▶ Position sensors to make the best measurement rather than to enable communications

SMARTMESH 模块

► With an onboard PA to increase Tx power from 8dbm to **14dbm**, and extend the hop-hop RF distance from 300m to **1200m**.

► Use the spare MCU bandwidth implement a **transparent data transmission** to ease the user application design.

► Keep **cost effective** while removing the customer design complexity of RF board.

► **Same package and pinout** as LTP5902 module to offer customer more flexibility to choose between non-PA/PA version.
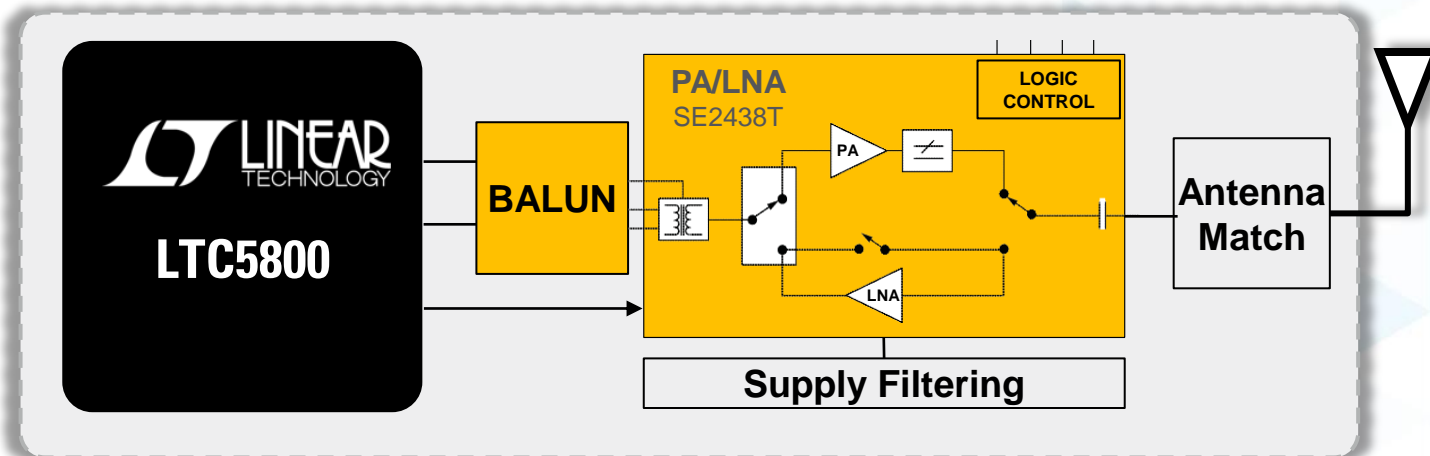
What is 10BASE-T1L (IEEE802.3cg)

► IEEE® 802.3cg™ Approved Standard Nov 7th 2019

► 10BASE-**T1L**
  - 10MBit/s
  - Power & Data over the cable
  - Single Twisted Pair
    - (Fieldbus Cable, NOT Standard CAT-x Cable)
  - Full duplex, Point to point
  - Distance up to **1km**
  - Suitable for intrinsic safe (explosive safe) applications

ADIN1100 - Low Power 10BASE-T1L PHY

Industrial CbM Asset Monitoring Connectivity
SPE/10BASE-T1L & MQTT

Condition monitoring applications

Field Asset 10BASE-T1L Connectivity

MEMS Vibration Sensor — Processor — MAC — ADIN1100 10BASE-T1L PHY — Single Twisted Pair Cable — Power & Data up to 1km
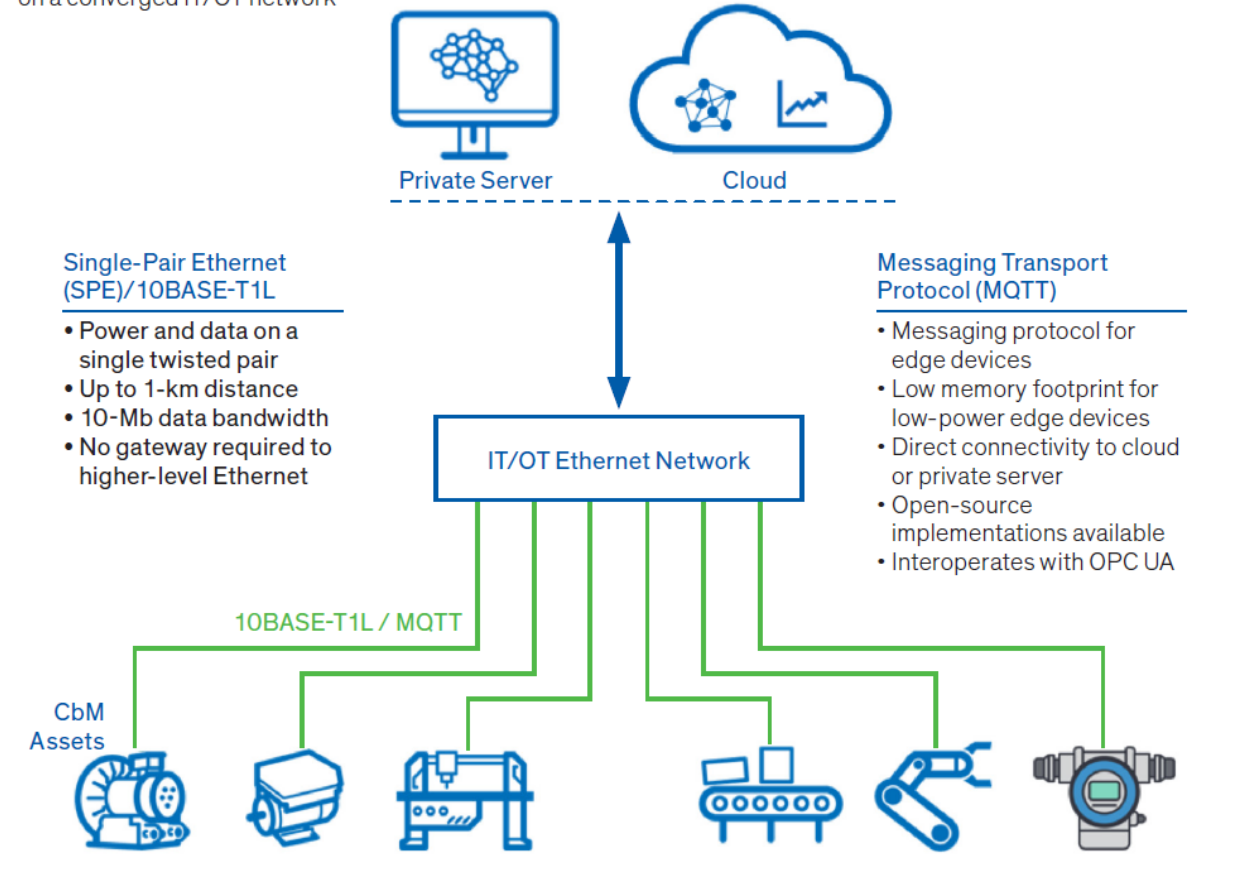
Low Noise High Bandwidth — Low Power Processor — Low Power PHY

Field asset, smart sensor connectivity with a 10BASE-T1L PHY
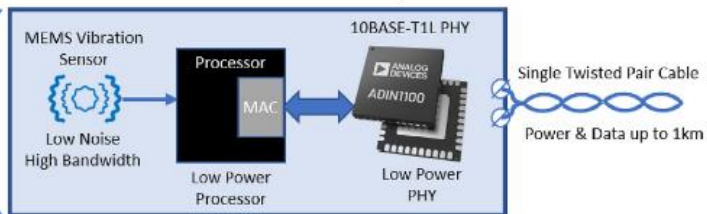
Asset health insights on a converged IT/OT network

Private Server — Cloud

Single-Pair Ethernet (SPE)/10BASE-T1L
- Power and data on a single twisted pair
- Up to 1-km distance
- 10-Mb data bandwidth
- No gateway required to higher-level Ethernet

Messaging Transport Protocol (MQTT)
- Messaging protocol for edge devices
- Low memory footprint for low-power edge devices
- Direct connectivity to cloud or private server
- Open-source implementations available
- Interoperates with OPC UA

IT/OT Ethernet Network

10BASE-T1L / MQTT

CbM Assets

ADIN1100 10BASE-T1L PHY

Sampling Now!

FEATURES

- **10BASE-T1L IEEE® Std 802.3cg™ -2019 compliant**

- **Supports Intrinsic Safe applications**
  - 1.0 V pk-pk & 2.4 V pk-pk transmit levels

- **Single supply 1.8 V or 3.3 V**
  - Mode dependent, multiple supplies also possible

- **Ultra-Low power consumption**
  - 1V pk-pk with Dual Supply – **39 mW**
  - 2.4V pk-pk Multiple Supplies – **75 mW**
    - Specification for all power options in datasheet

- **Small package** 40-lead LFCSP

- **Industrial temperature range** -40⁰C to 105⁰C

Ultra-Low Power 10BASE-T1L PHY

www.analog.com/ADIN1100

ADIN1100 10BASE-T1L PHY

► **Configurations**
  ▪ Unmanaged using hardware pin strapping
  ▪ Managed via management interface (MDIO)
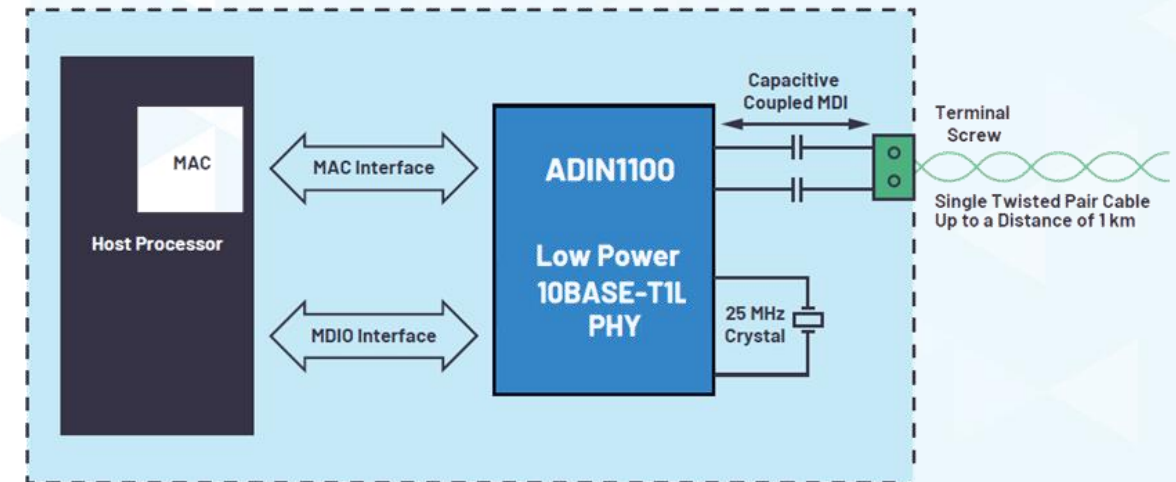
► **Standard PHY Data Interface**
  ▪ MII, RMII, RGMII Interface
  ▪ 25 MHz crystal oscillator/clock input frequency
  ▪ 50MHz clock input for RMII

► **10BASE-T1L Modes**
  ▪ 1.0 V pk-pk & 2.4 V pk-pk transmit levels
  ▪ Master / Slave
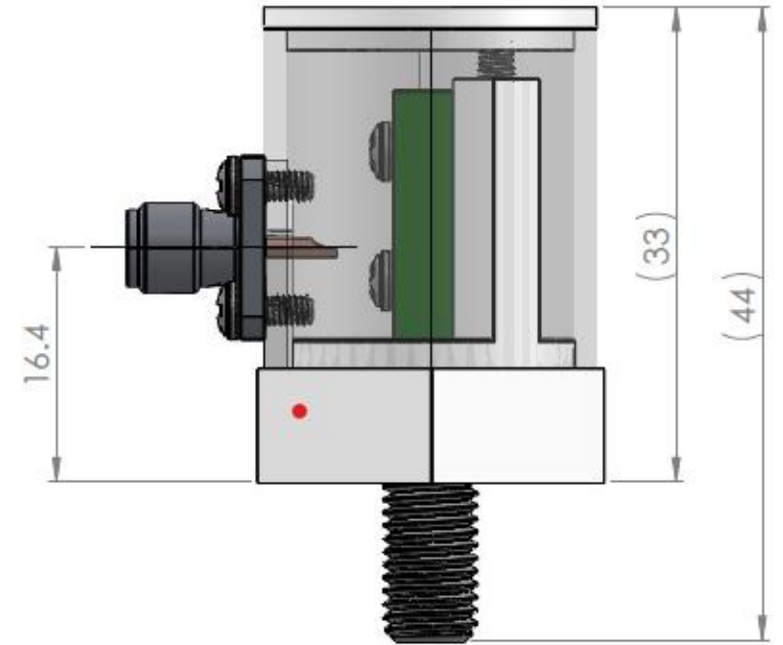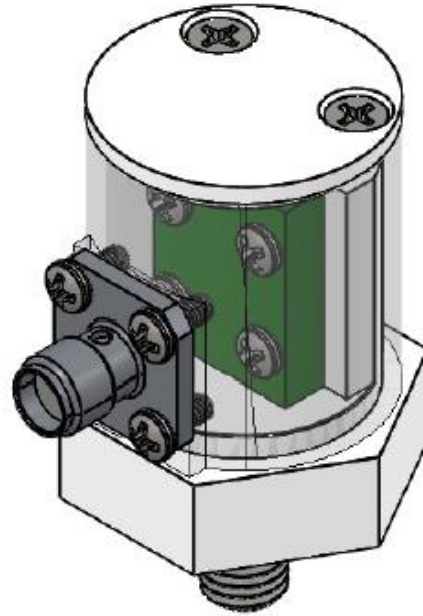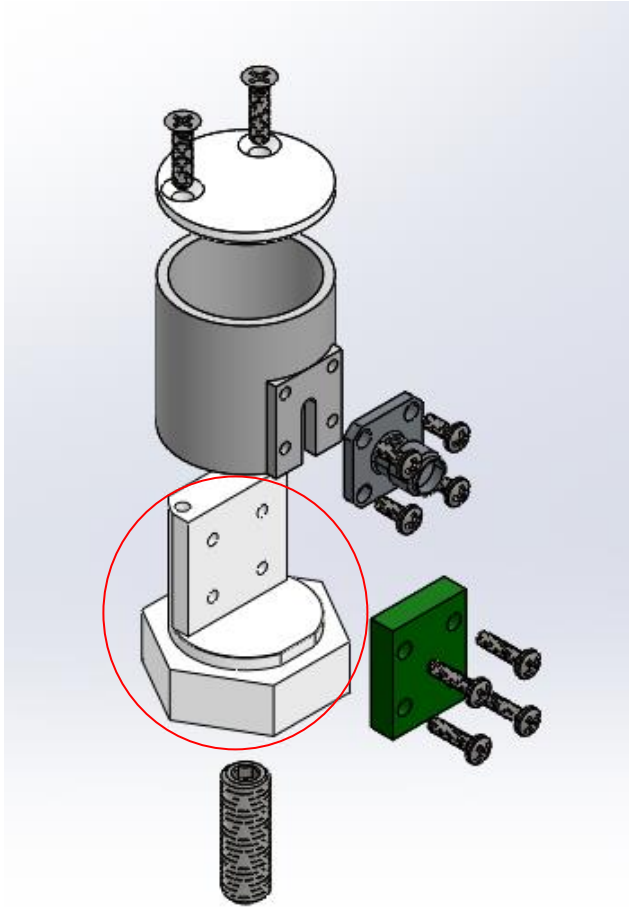 ▪ Auto-negotiation

► **Diagnostics**
  ▪ Frame Generator and Checker
  ▪ Multiple Loopback Modes
  ▪ IEEE Test Mode Support
  ▪ Cable Diagnostics

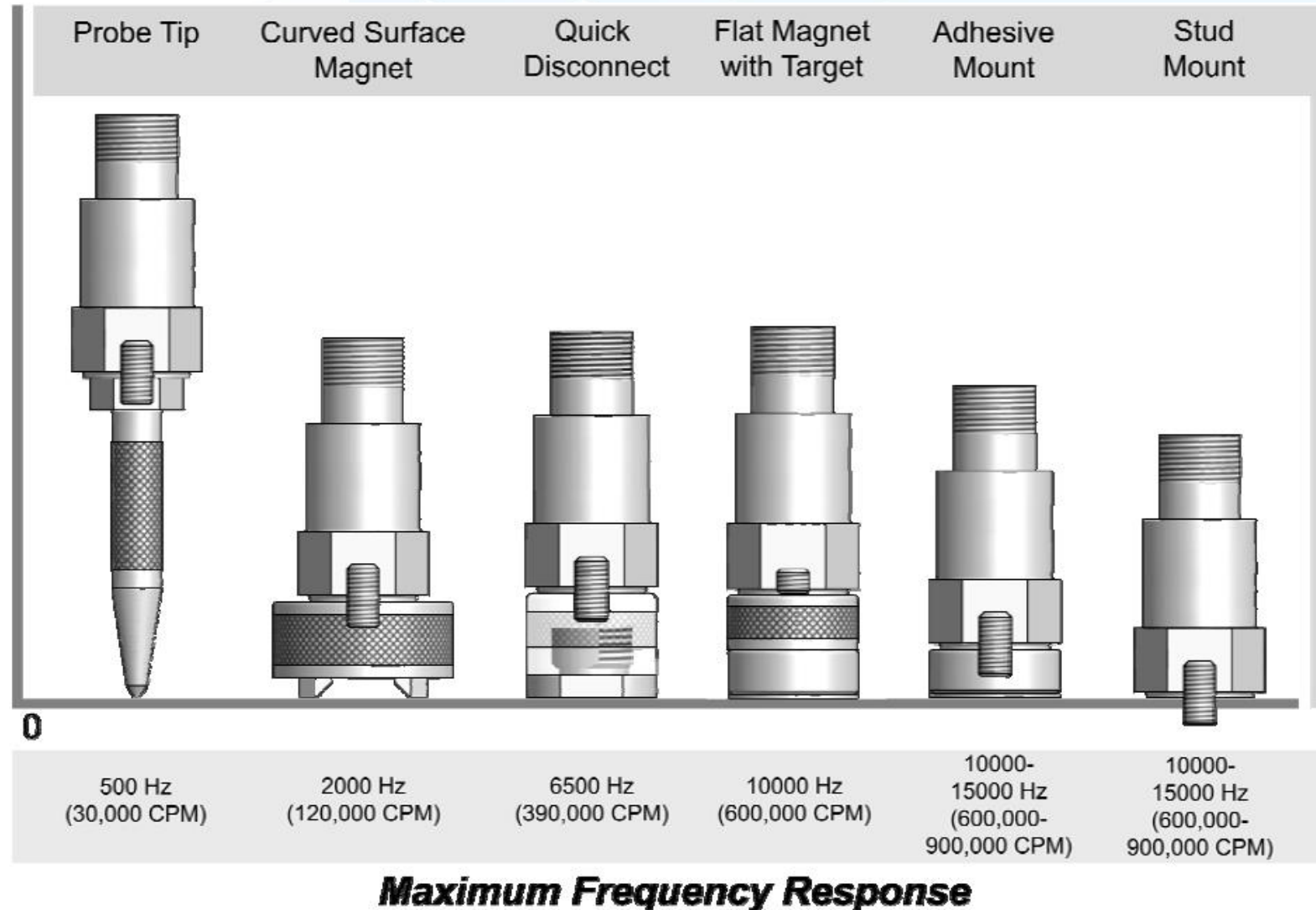Simplified 10BASE-T1L Connectivity Diagram

机械结构的考量

- **The housing design will affect the sensor noise as well as the measurement bandwidth**

- **Customers need to have the vibration tester to do their own sensor module testing**

- **Epoxy also play a key role for the sensor system resonant frequency**

- **Epoxy also will affect the MEMS sensor when it becomes to solid state**

安装方式

- First consideration must be capability of the Sensor

- Almost as critical is mounting strategy

- For MEMS, PCB thickness and mounting need consideration

- **Warning:** Magnetic mount can generate significant *g* force and care must be taken when placing on equipment.

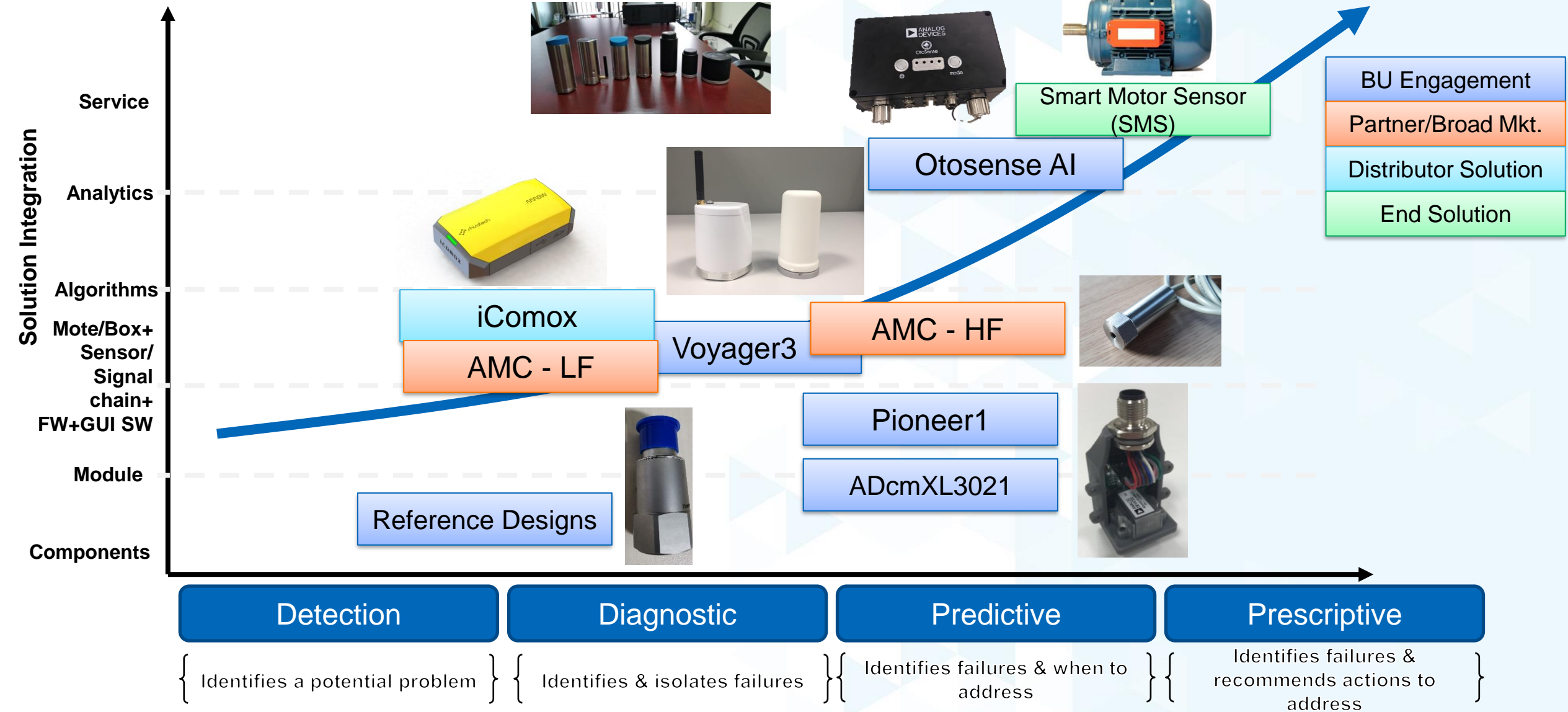| Probe Tip	Curved Surface Magnet	Quick Disconnect	Flat Magnet with Target	Adhesive Mount	Stud Mount
500 Hz (30,000 CPM)	2000 Hz (120,000 CPM)	6500 Hz (390,000 CPM)	10000 Hz (600,000 CPM)	10000-15000 Hz (600,000-900,000 CPM)	10000-15000 Hz (600,000-900,000 CPM)

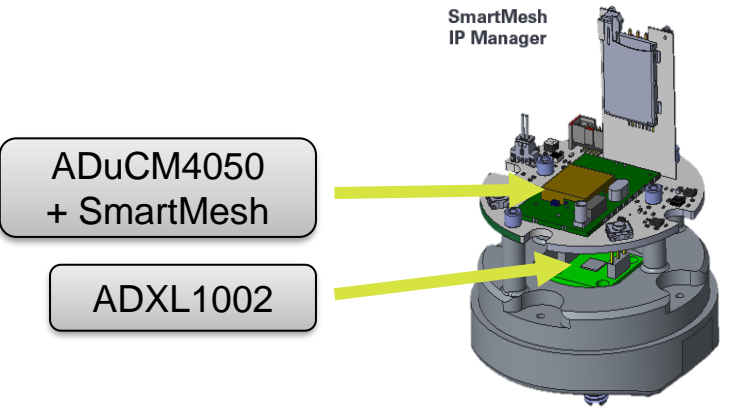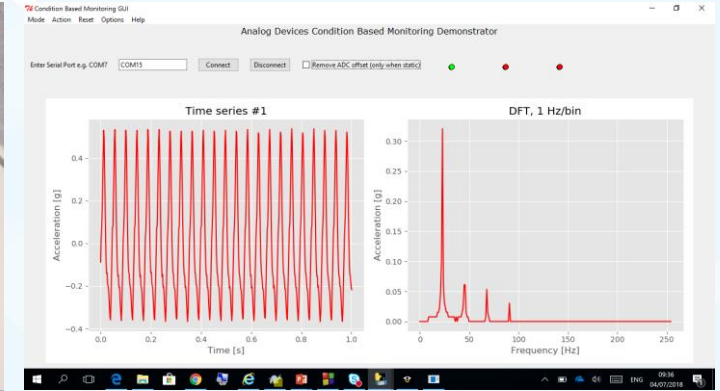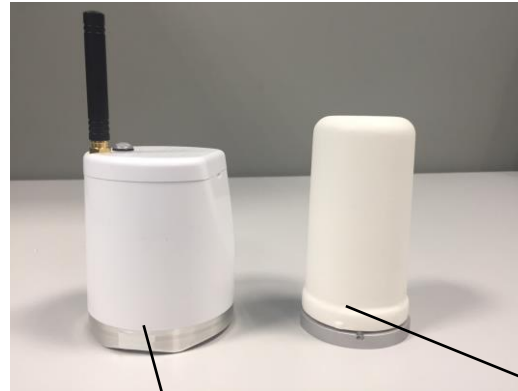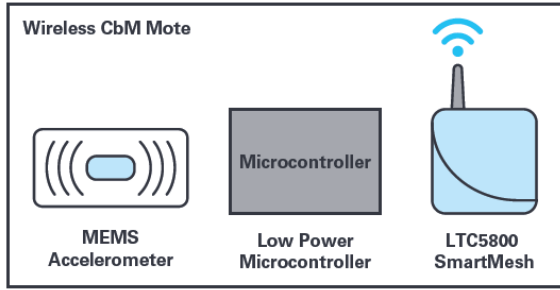**Maximum Frequency Response**

安装方式 Mounting Methods Session Summaries

➤ How an accelerometer is mounted can have significant impact on frequency performance.

➤ Stud mounting is best; but use grease or Bees Wax

➤ Adhesives work very well, so long as the bond line is thin (< 0.005"). Even double-sided tape is a great solution

完整解决方案的交付

ADI可以提供的支持方案汇总

Solution Integration (vertical axis):
- Service
- Analytics
- Algorithms
- Mote/Box+ Sensor/ Signal chain+ FW+GUI SW
- Module
- Components

Labels in chart:
- Smart Motor Sensor (SMS)
- Otosense AI
- iComox
- Voyager3
- AMC - HF
- AMC - LF
- Pioneer1
- ADcmXL3021
- Reference Designs

Legend:
- BU Engagement
- Partner/Broad Mkt.
- Distributor Solution
- End Solution

Horizontal axis:

Detection	Diagnostic	Predictive	Prescriptive
Identifies a potential problem	Identifies & isolates failures	Identifies failures & when to address	Identifies failures & recommends actions to address

无线方案

Wireless CbM Mote

MEMS Accelerometer

Microcontroller — Low Power Microcontroller

LTC5800 SmartMesh

SmartMesh IP Manager

ADuCM4050 + SmartMesh

ADXL1002

AD7685+ ADuCM4050 + SmartMesh

ADXL356

RS485通讯的有线方案

Productised Digital-out Sensors with ADI Signal Chain

ADXL1001

ADA4805

+

-

AD7768-1

ARM

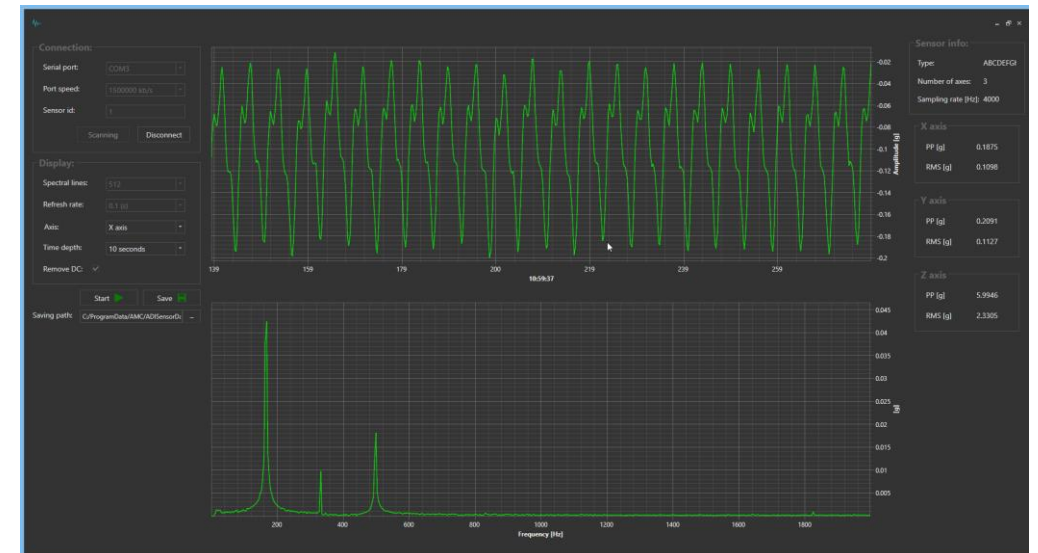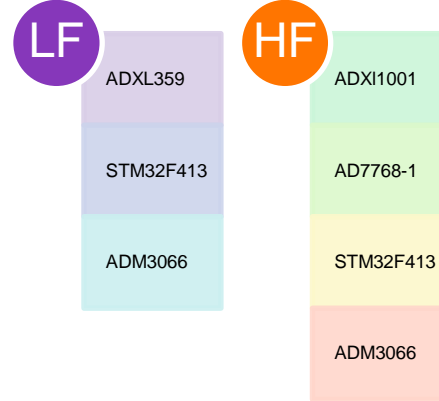ADM3066

ADM3066

ARM

ADXL359
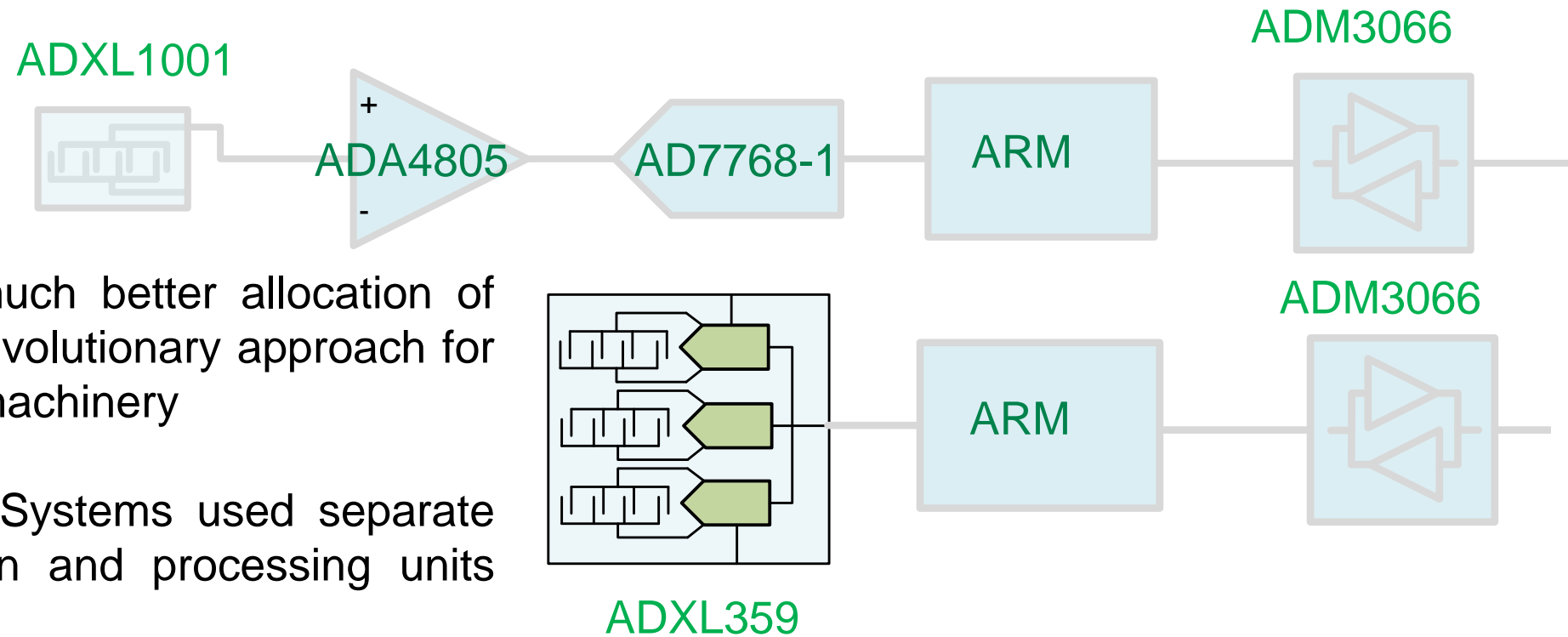
NMV Sensor enables much better allocation of resources and creates revolutionary approach for Condition Monitoring of machinery

Up to now, all the CM Systems used separate sensors, data acquisition and processing units and user interfaces.

NMV Sensor can be directly connected to a SCADA system or to a specialized diagnostic app.
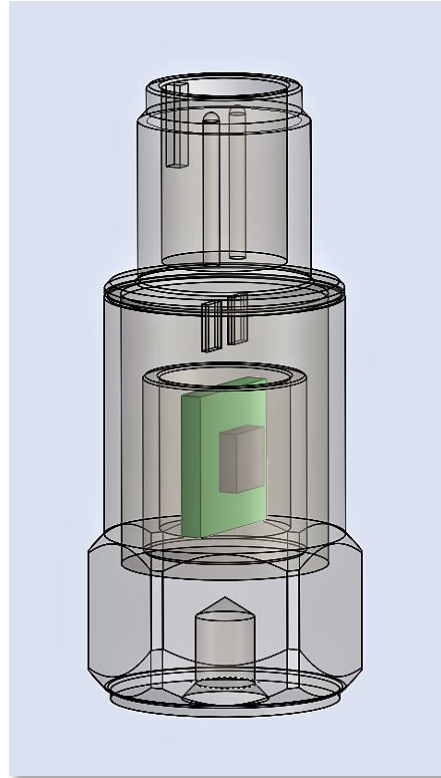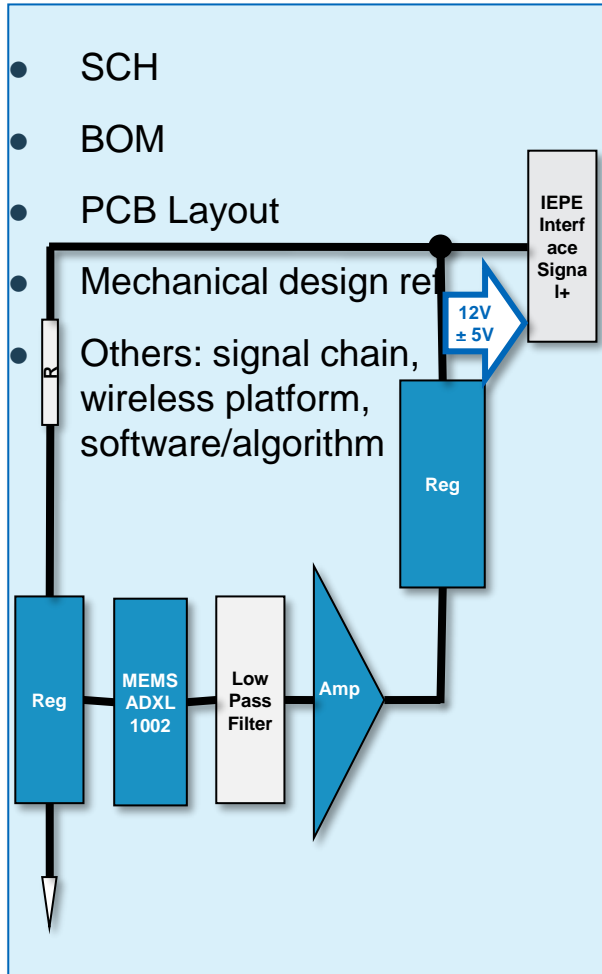
RS485通讯的有线方案

	LF	HF
generic state, according to ISO	√	√
unbalance	√	√
misalignment	√	√
motor broken bars	√	√
pedestal looseness	√	√
fan blade faults	√	√
gear faults		√
rolling element bearings faults		√
pump cavitation		√

LF
- ADXL359
- STM32F413
- ADM3066

HF
- ADXl1001
- AD7768-1
- STM32F413
- ADM3066

MEMS 1

IEPE接口方案

1. IEPE传感器

- SCH
- BOM
- PCB Layout
- Mechanical design re[...]
- Others: signal chain, wireless platform, software/algorithm

IEPE Interface Signal+

12V ± 5V

Reg

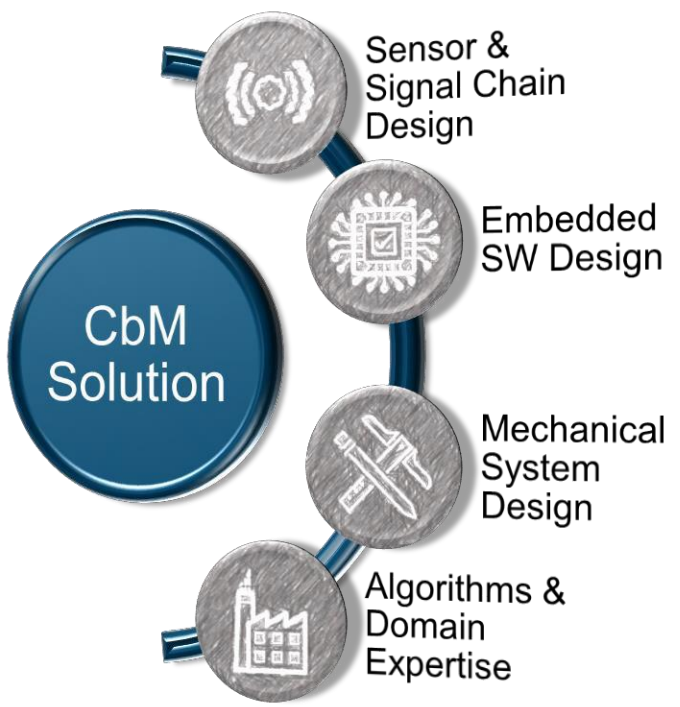Reg | MEMS ADXL 1002 | Low Pass Filter | Amp

Solution
Epoxy resin fixation

2. IEPE 采集卡

1. For ADXL100x connection directly (1 channel)
2. For IEPE interface (3 channels)
3. Mid noise + wide bandwidth(100kHz) for general (2 channels)
4. Low noise + narrow bandwidth(2.5kHz) for seismic detection (2 channels)
5. Use AD7768, 24-bit, 8-Channel, 256kSPS, Σ-Δ ADC

深厚的系统专业知识可打造具有洞察力、准确和可靠的CbM解决方案
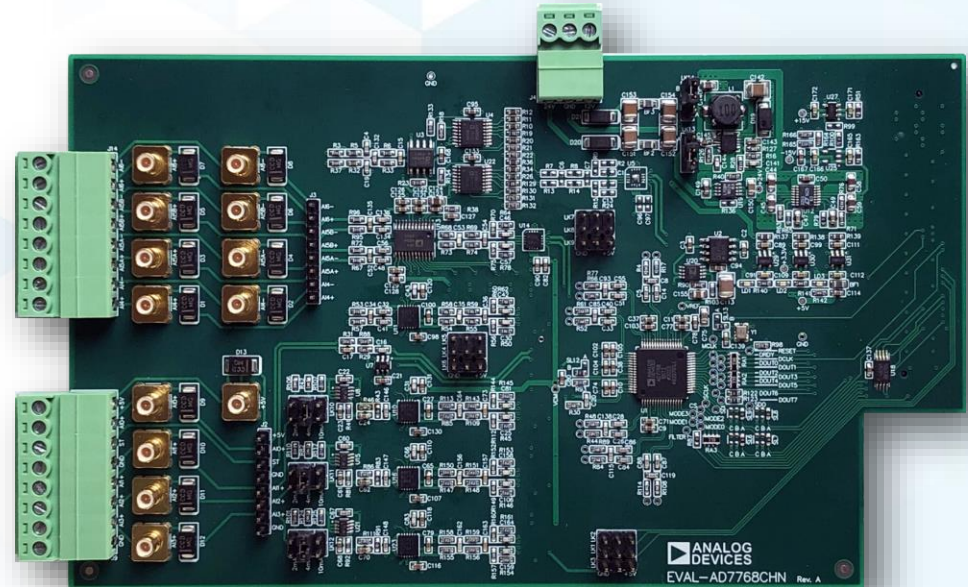
传感器和信号链

- 新一代高性能MEMS加速度计
- 温度传感器
- 磁场传感器
- 支持信号链

集成式解决方案

- 多轴传感器模块
- 可靠的工业设计
- 优化的封装

算法和见解

- 优质可靠的数据为算法提供机器洞察力铺平了道路
- 实时异常和事件检测增强了CbM解决方案。

答疑进行中.....

欢迎大家踊跃提问！！！