ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

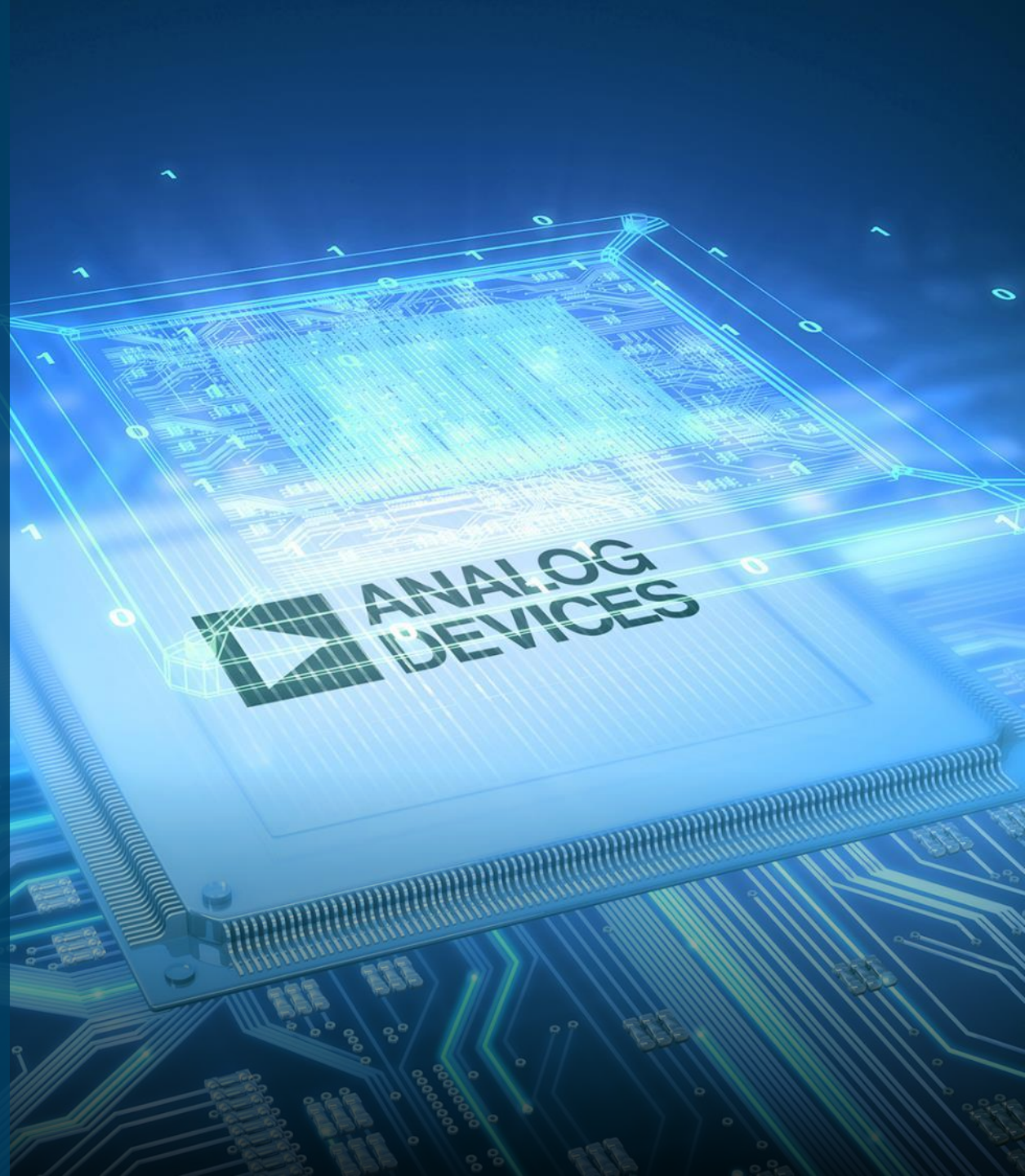
CBM China Strategy

ROGER YU

CHINA IAT MARKETING MANAGER

ROGER.YU@ANALOG.COM

MAY 2019



ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

CBM

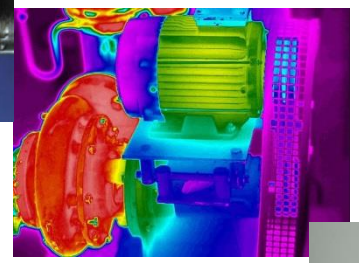
Extra value delivered to end customers

Common Condition Monitoring Techniques

- Vibration analysis and diagnostics

- Lubrication Analysis
  - WDA – Wear Debris Analysis 磨损颗粒分析

- Infrared thermography



- Ultrasonic testing (material thickness/flaw testing)

- MCSA – Motor Current Signature Analysis
  - Direct (invasive) or Eddy Current transducers (less invasive) 涡流传感器
  - MBVI/MCA – Model based Voltage and current/Motor Current Analysis

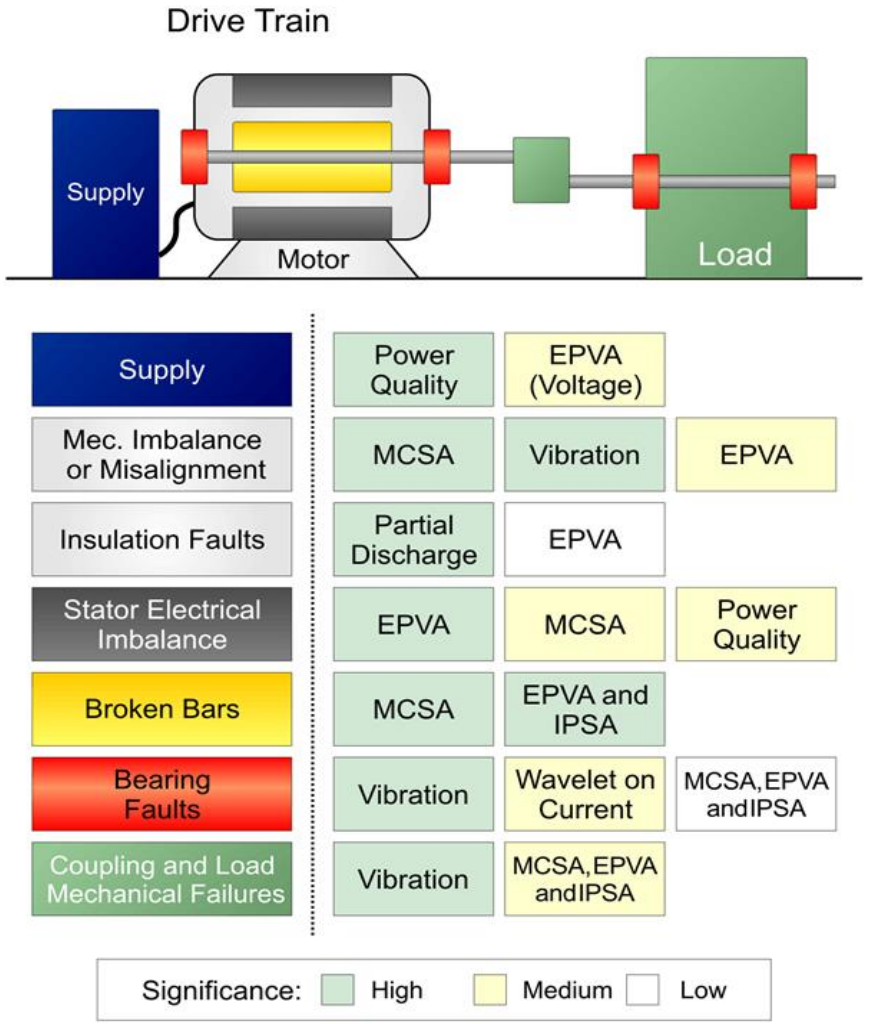
- Acoustic emission (Airborne ultrasound)声发射检测

CbM Methodologies --- e.g. Motor Drive System

- **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 (more on next slide)

- **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)



Machine Health – Problem Statements & Trends

Problem statements

- **Driving down the cost of plant operations in an age of over capacity…**
  - Expensive equipment, critical to maintain up-time
  - Expensive monitoring equipment / Diagnostic Technicians
  - Expensive repairs, cheaper if discovered early
- **Safety enhancement (SILs) also drives adoption, cost**

Emerging trends

- **Integrated ‘smart’ solutions reduce costs**
  - Reduces the need for highly skilled maintenance personnel
  - Reduces the cost of continuous monitoring systems
  - Economical Condition Monitoring for lower cost equipment
- **More investment in analytics**
  - Both local at the node and in the cloud
  - Avoid False Alerts while improving early detection
- **Smaller, lower cost, low power MEMS sensors enable highly integrated embedded solutions**

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

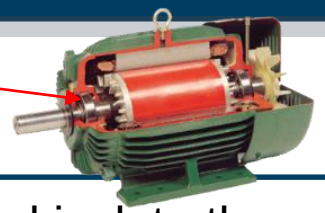
CbM Final Delivery

Detection

- Detect a potential problem through abnormal operating conditions

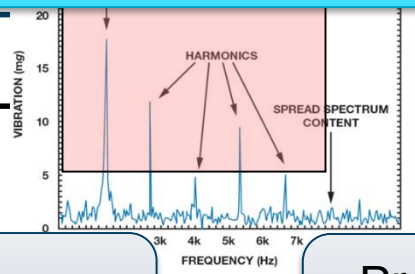
Lower cost, lower BW sensors

Diagnosis



ntify and isolate the
blem and the extent of
e damage

Performance Matters



Prognosis

- Determine the remaining useful life of the equipment

ACTION:

- Potential problem exists but what action is required?
- How reliable is the fault detection?

- Problem exists
- Maintenance required
- How long before failure?

- Problem identified
- 3 weeks left
- Part ordered and maintenance scheduled

ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

ADI Solution Offer

Kep Components:
MEMS Sensor

ADXL355/57

ADXL354

ADXL372, ADXL356, ADIS16228

ADXL100x, ADcmXL3021

1kHz	1kHz - 10kHz	10kHz+
~16%	~68%	~16%

Bandwidth (kHz)

- NXP – 2.7kHz
- Kionix – 6kHz?
- Bosch – 1.6kHz
- ST – 5kHz
- Colibrys – 7kHz

ADXL354/5

ADIS16228

ADXL356/7

ADXL37x, ADXL100x, ADcmXL3021

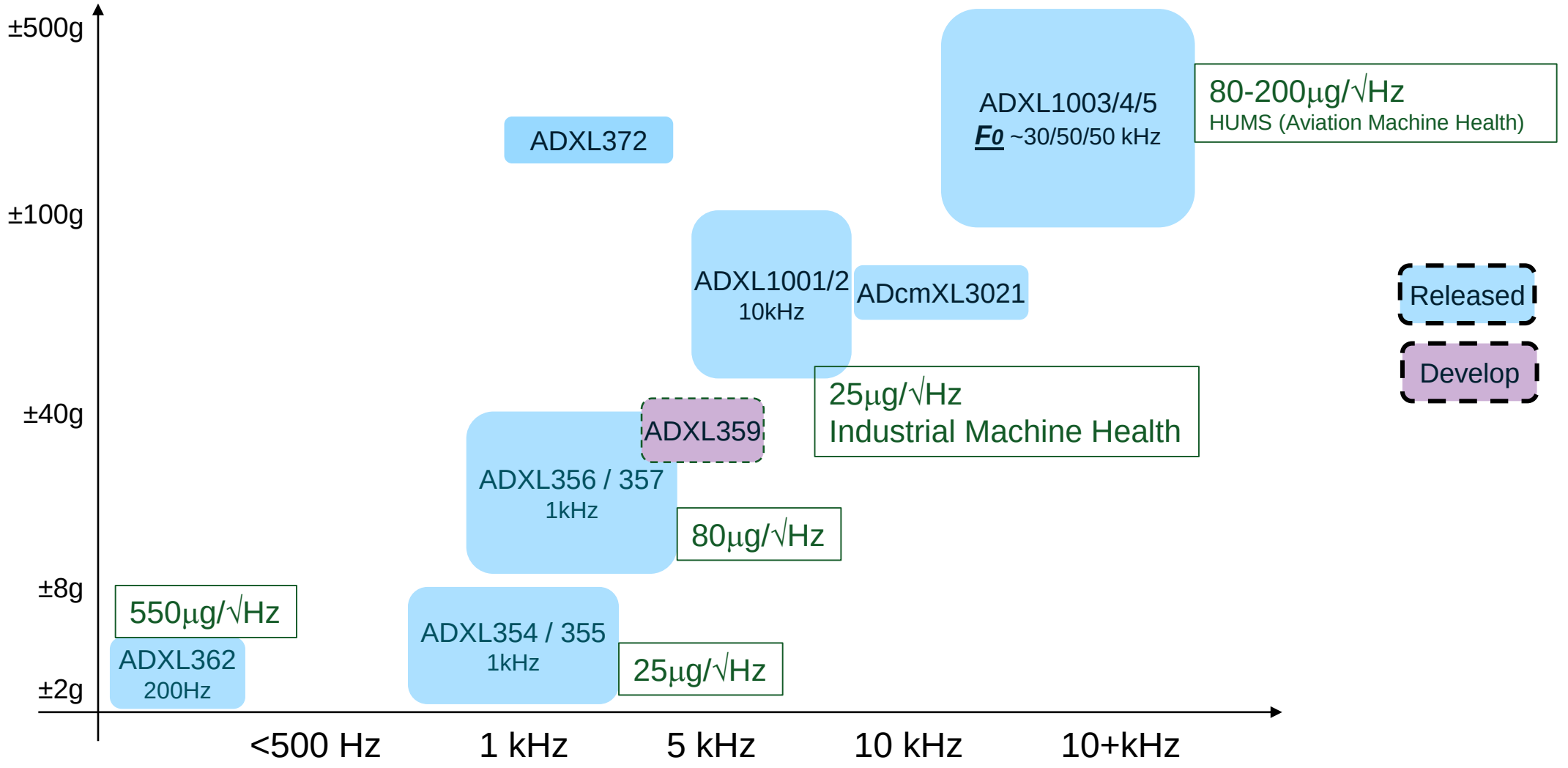
20g	20g - 50g	50g+
~13%	~59%	~28%

***g*-Range (*g*)**

- NXP – ±250g
- Kionix – ±64g
- Bosch – ±480g
- ST – ±400g
- Colibrys – ±30g

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

MEMS Accelerator Landscape



ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

ADXL354/ADXL355/ADXL356/ADXL357: High Performance 3-axis Accelerometers

Features and Specifications

- **ADXL354/5 ±2g/ ±4g/ ±8g**
  - 20/25µg/√Hz noise density
  - Guaranteed 0.15mg/C offset drift
  - 200µa power supply current (ADXL355)
  - -40C to +125C operation
  - Hermetic package
  - Both analog and digital interface models

- **ADXL356/7 ±10g/ ±20g/ ±40g**
  - 80µg/√Hz noise density
  - Guaranteed 0.75mg/C offset drift
  - 200µa power supply current (ADXL357)
  - -40C to +125C operation
  - Hermetic package
  - Both analog and digital interface models

Portolio Positioning	ADXL203	ADXL354	% Delta
Noise (µg/√Hz)	110	20	-77%
0-g Tempco (mg/C Max)	0.8	0.15	-81%
Power supply current (µa, per axis)	350	60	-83%
Orientation (DoF)	XY	XYZ	

Noise Density

- **ADXL356 is an upgrade to ADI's best selling ADXL22037 – with 30% less noise at 1/5th the power**
- .

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

ADXL100x High Performance Accelerometers

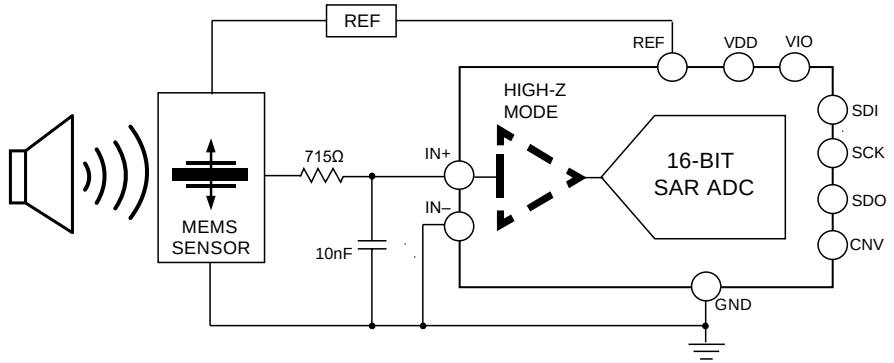
Higher resonant frequencies, pin compatible with ADXL1001 and ADXL1002

Features and Specifications

- ADXL1001/2/3/4/5
  - **High Full Scale Ranges (FSR) ±50g to ±500g**
  - Low noise density
    - **25 to 80µg/√Hz noise density**
  - Single, in-plane orientation
  - Analog output
  - Overrange indicator (OR)
  - Electro-static Self test (ST)
  - **21kHz to 45kHz resonant frequencies**
  - 1mA power supply current
  - -40C to +125C operation
  - **5x5mm LFCSP package**

Typical Interface

ADXL1002 **AD4000**



5 x 5 x 1.8mm LFCSP package
Single, in-plane axis

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Kep Components:
SAR ADC

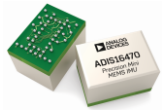
Specification		AD7768-1 Median WB 128 ksps Decimate x32	AD7768-1 Fast WB 128 ksps Decimate x64	Comparison Commentary
Input BW (kHz) ODR (kSPS)		55 kHz @ 128 kSPS	55 kHz @ 128 kSPS 110 kHz @ 256 kSPS	Up to ~2x Input Bandwidth
Dynamic Range (dB)		108 typ	111 typ	5 dB Extra Dynamic Range
THD (dB)		-120 typ	-120 typ	12dB THD Improvement
INL (ppm/FSR)		*2ppm typ, 7 max (Endpoint)*	*2ppm typ, 7 max (Endpoint)*	Improved INL
Offset Error		*50 uV typ, 150uV max*	*50 uV typ, 150uV max*	*6x reduction in max Offset*
Offset Drift Error (nV/degC)		140 typ	140 typ	12x Improvement in Offset Drift
Gain Error (ppm/FSR)		50	50	20x Improvement in Gain Error
Gain Drift (ppm/degC)		0.5 typ, 1 max	0.5 typ, 1 max	Improved Gain Drift
Current Consumption (mA)		1.4 (5V AVDD1) 2.7 (2V to 5V AVDD2) 5 (1.8V IOVDD)	2.3 (5V AVDD1) 4.5 (2V to 5V AVDD2) 7.8 (1.8V IOVDD)	4x Lower Power in Median >2x Lower Power in Fast
Input Current		Pre Charge on:~12uA Pre-charge off: ~125 uA	Pre Charge on:~25uA Pre-charge off: ~250 uA	12x lower with precharge on Lower with precharge off
Ref Input Current		150 uA (28 kOhm)	300 uA (14 kOhm)	~4x lower refin current in Median
Package		28ld LFCSP (4x5) = 20mm^2	28ld LFCSP (4x5) = 20mm^2	~40% Area Saving

Module Offer:

- **Module Rationale**
  - No time or resources to become a MEMS expert
  - Proven solution designed specifically for CbM
    - No need to do mechanical simulations and characterization
    - Designed & characterized for known performance
    - Embedded microcontroller provides software tailored for CbM usage
  - Decreased Time To Market gives customer advantage
  - ADI handles all procurement

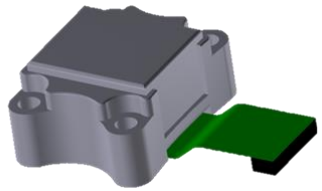
- **Why ADI for Modules**
  - 15+ years experience in module design and deployment with iSensor IMU
  - Over 40 products released and over one million units sold

***i*Sensor**



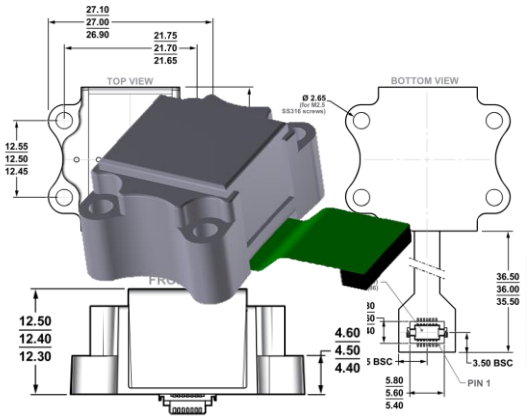
World's smallest, high performance SMT IMU

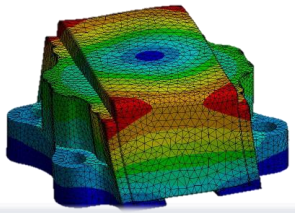
CbM



ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

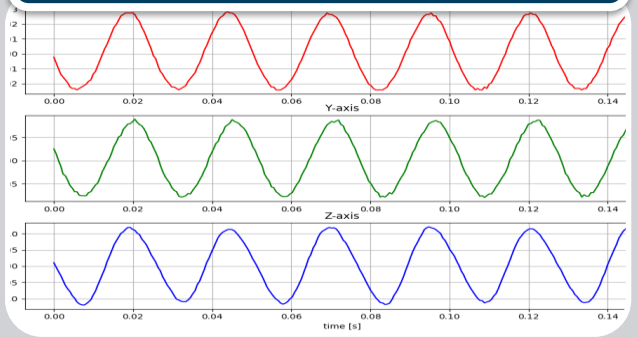
ADcmXL3021 Combines Embedded Processing into a Mechanically Optimized Package





Mechanically designed to ensure natural frequency >50kHz

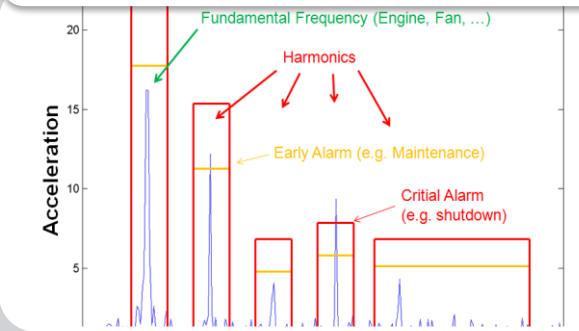
Time Domain Modes



Features

- Sampled at 220kSPS
- **Real-Time Streaming**
  - Raw, unfiltered data
  - Enables custom processing
- **Manual Time Capture**
  - User initiated
  - Filtered & decimated
  - Stores 4096 samples per axis
  - Calculated statistical metrics

Frequency Domain Modes



Features

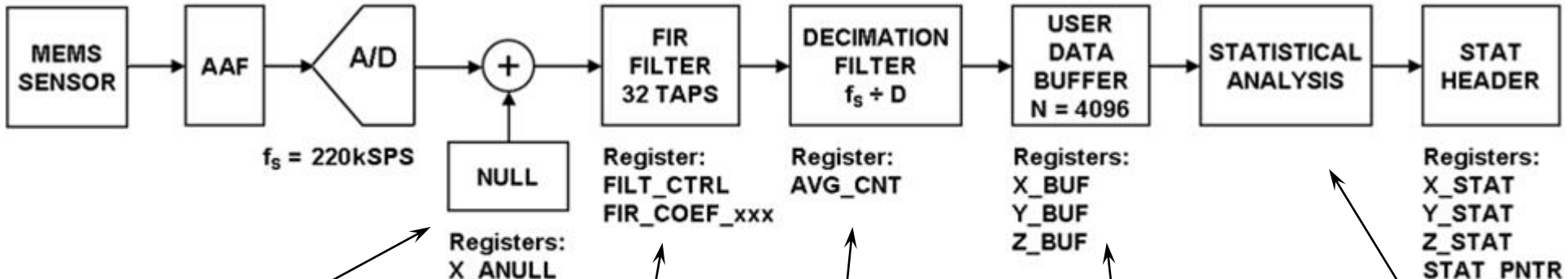
- Sampled at 220kSPS
- **Manual FFT**
- User initiated capture of 4096 samples
- Filtered & decimated
- Windowing & FFT Averaging
- Configurable spectral alarms & interrupts
- **Automatic FFT**
  - Same as Manual FFT
  - Periodically triggered

ADcmXL3021 Highlights

- Triaxial vibration sensing based on the ADXL100x
- ±50 g measurement range
- Wide bandwidth:
  - DC-10 kHz (within 5% flatness)
- Fast data sampling, up to 220 kSPS
- User configurable
- External Clock for synchronization
- Single supply operation 3.0-3.6V
- Operating temperature: -40°C to +105°C

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

ADcmXL3021
Manual Time Capture



Auto zero

FIR at 220kHz

6 coefficient banks:
- LP: 1, 5, 10 kHz
- HP: 1, 5, 10 kHz
User definable

Decimation

2, 4, 8, .. 128

Direct Access

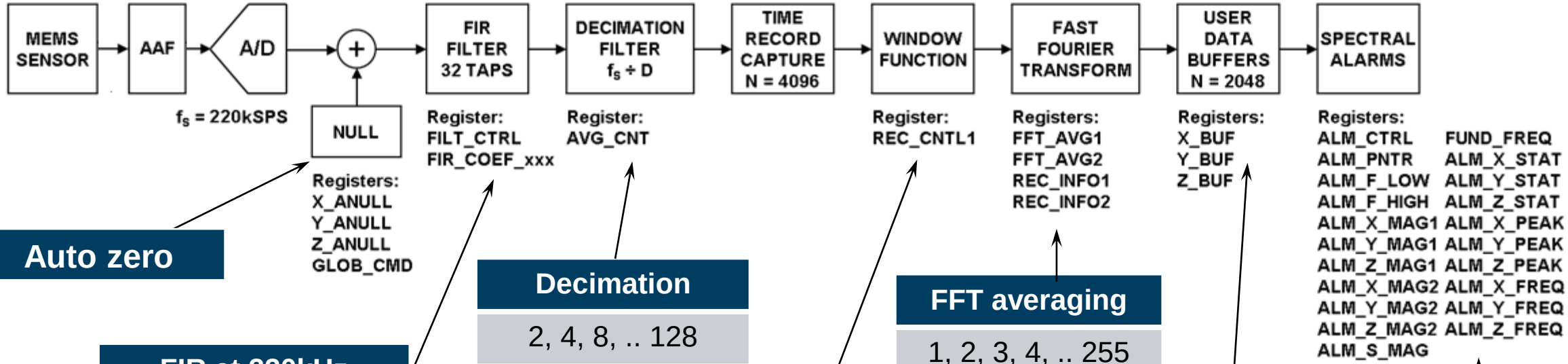
4096 samples
X, Y, Z

Statistical analysis

Peak
Mean
Standard deviation
Crest factor
Kurtosis
Skew factor
Peak to Peak

ADcmXL3021

FFT Capture



Auto zero

FIR at 220kHz

6 coefficient banks:
- LP: 1, 5, 10 kHz
- HP: 1, 5, 10 kHz
- User definable

Decimation

2, 4, 8, .. 128

Windowing

Rectangular
Hanning
Flat top

FFT averaging

1, 2, 3, 4, .. 255

FFT output

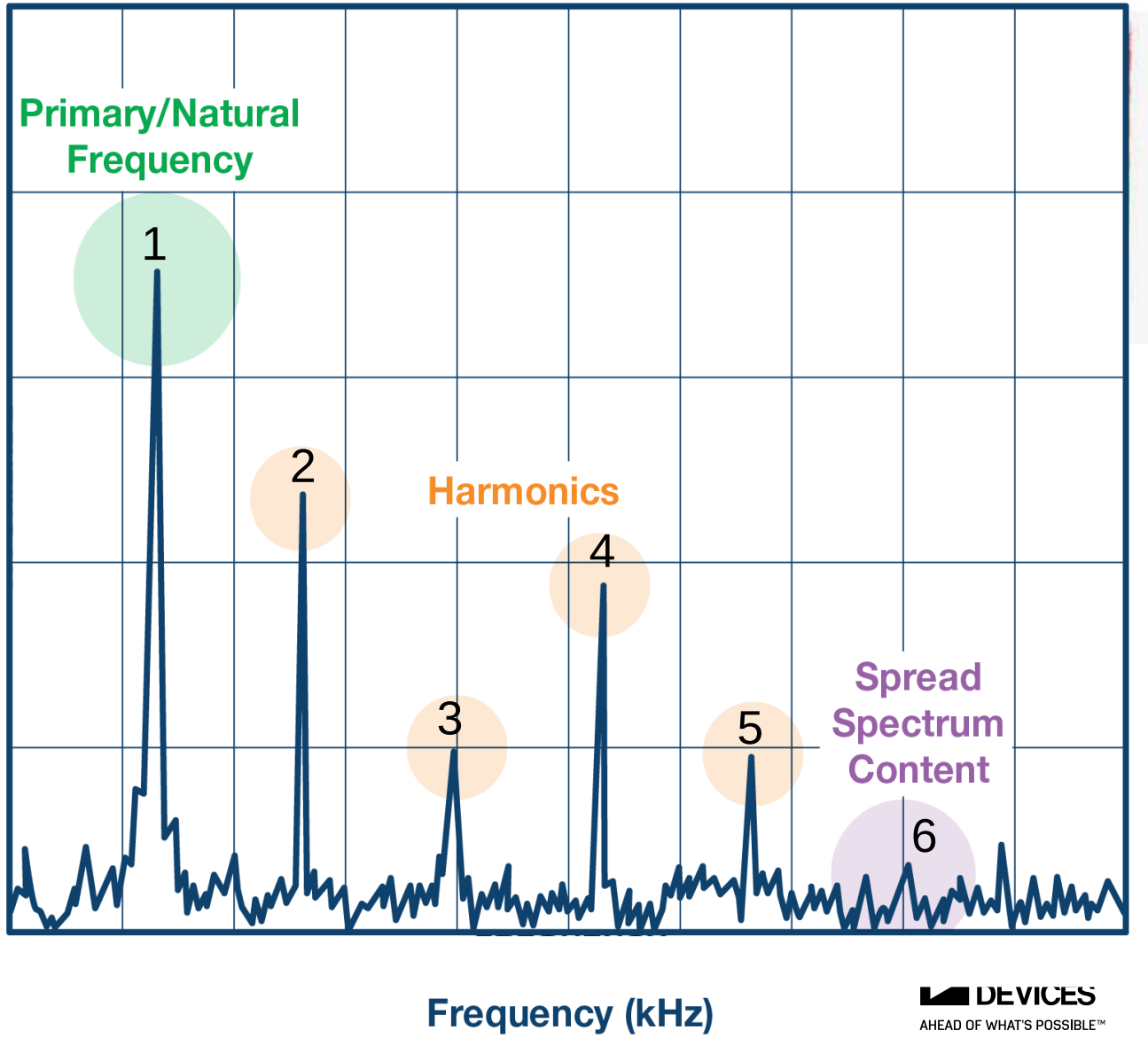
2048 points
X, Y, and Z

Spectral Alarm

Exceeding peak level
Deviation of magnitude
Deviation of frequency

ADcmXL3021
Alarm features

- 2 levels of alarm: alarm1 and alarm2
- Alarm delay
- Exceeding peak level
  - Alarm on peak going above set level
- Deviation of magnitude
  - Alarm on magnitude going above level
  - Alarm on magnitude going below level
- Deviation of frequency
  - 6 different bands
  - Alarm on vibration going out of band



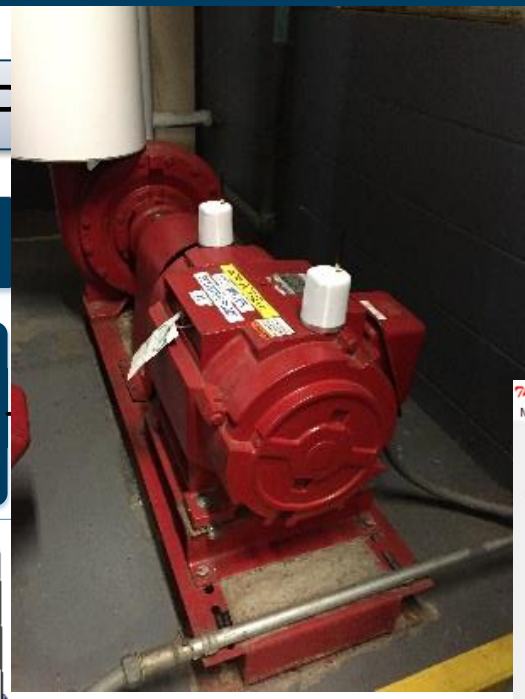
Platform Offer (Wireless):

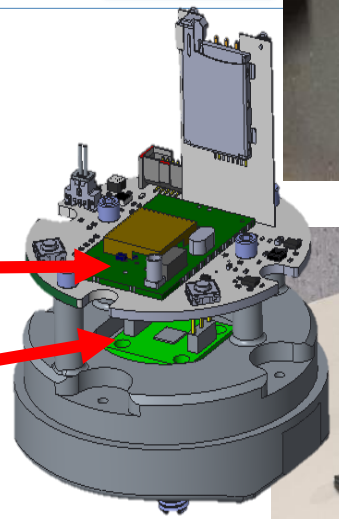
Wireless MVP

Power Supply (Battery)

Accelerometer

MCU





ADuCM4050 + SmartMesh

ADXL1002

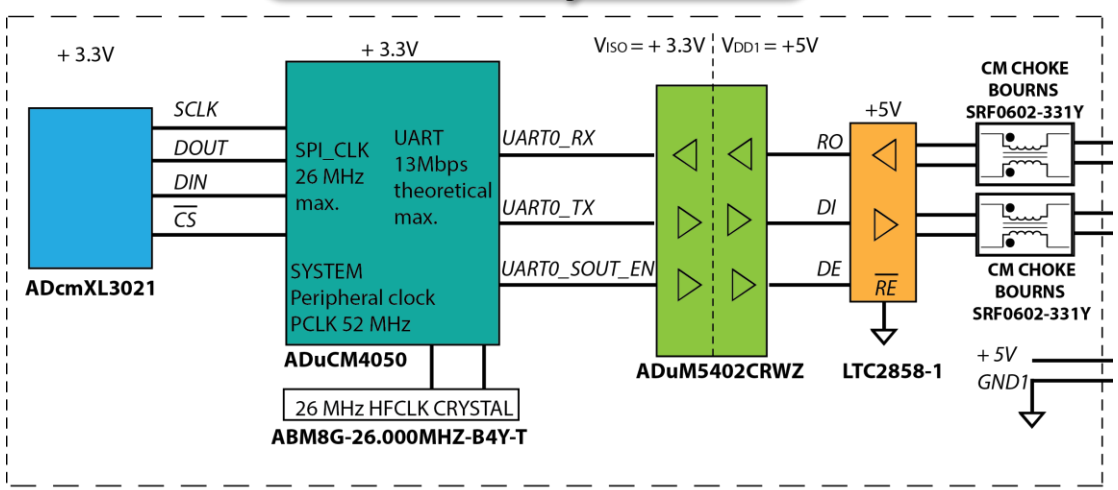
Wireless Reference Design

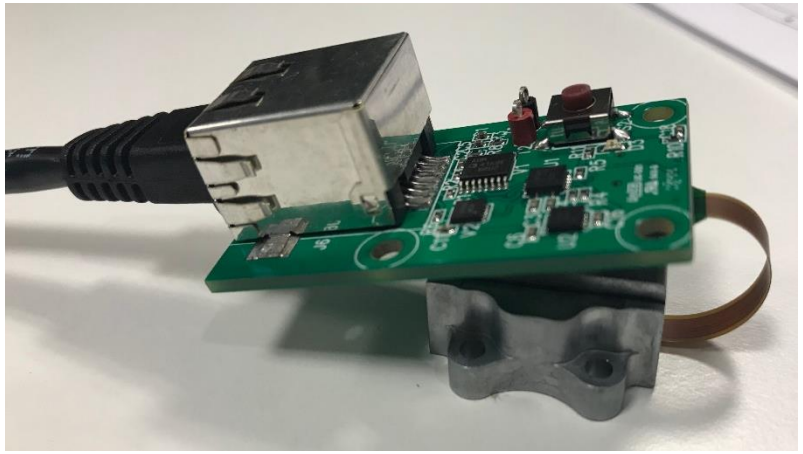
- Schematics & Design Files available for hardware design

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Platform Offer (wired):

Pioneer1
Wired System





ADcmXL3021 Module Based Design

- Simplifies sensor attachment & signal chain design

RS-485 Industrial Interface

- Robust interface for industrial environments
  - Offers noise immunity across long cables
- Several variations available based on system requirements & solution cost

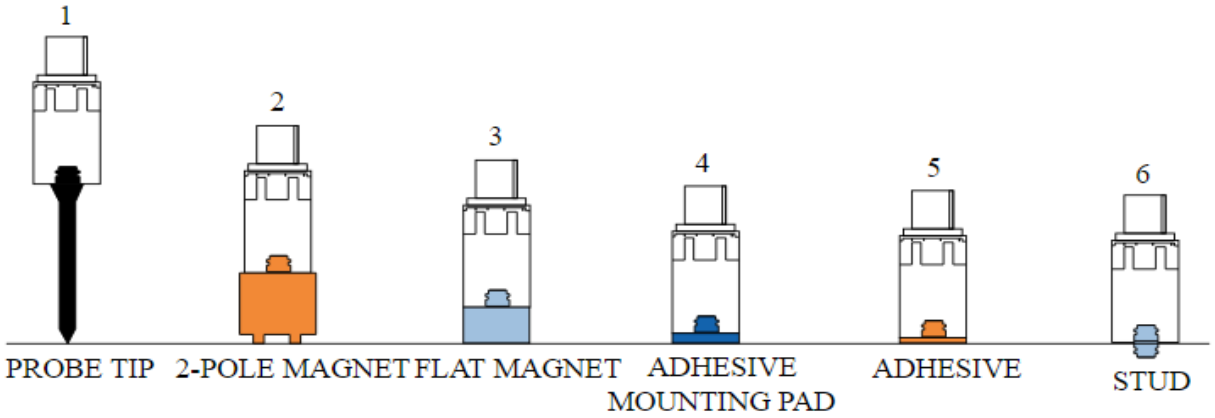
Software Available for Development

- Includes ADcmXL3021 interface drivers
- Access to off-board ADuCM4050 for custom protocol & application design

Mechanical Enclosure Design

- IP67 enclosure will integrate ADcmXL3021 & supporting circuitry

Mechanical Considerations Are Required for Optimized Vibration Monitoring Solutions



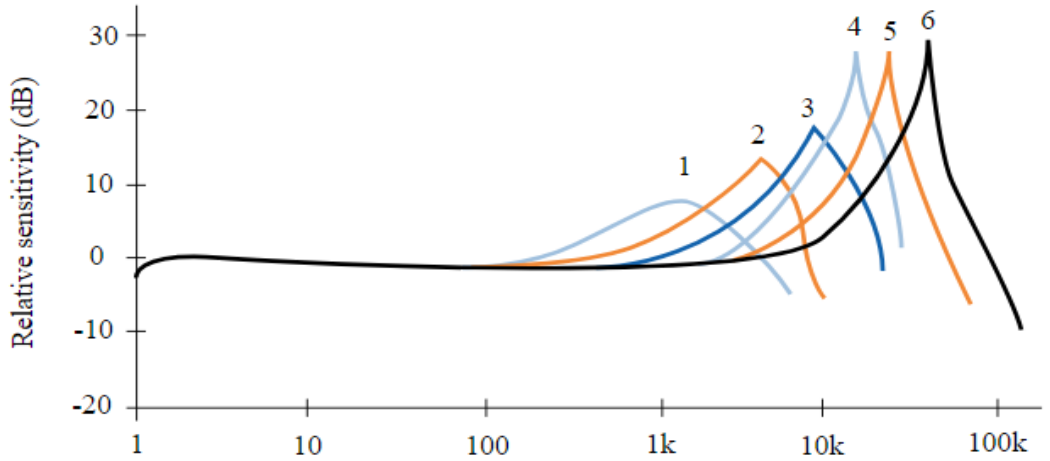
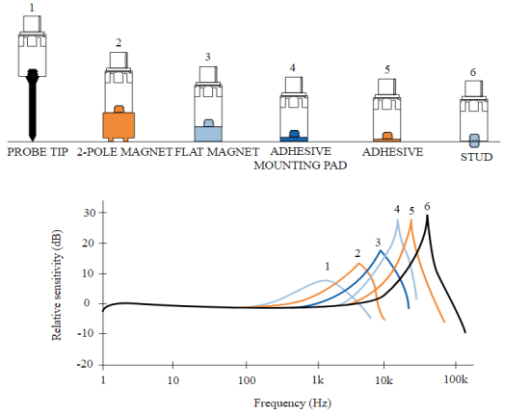


Figure courtesy of DEWESoft

Attachment is Critical

- Direct, rigid sensor attachment is required to maximize energy transfer across the desired bandwidth
- Stud or screw mounting in conjunction with adhesives maximizes the frequency response



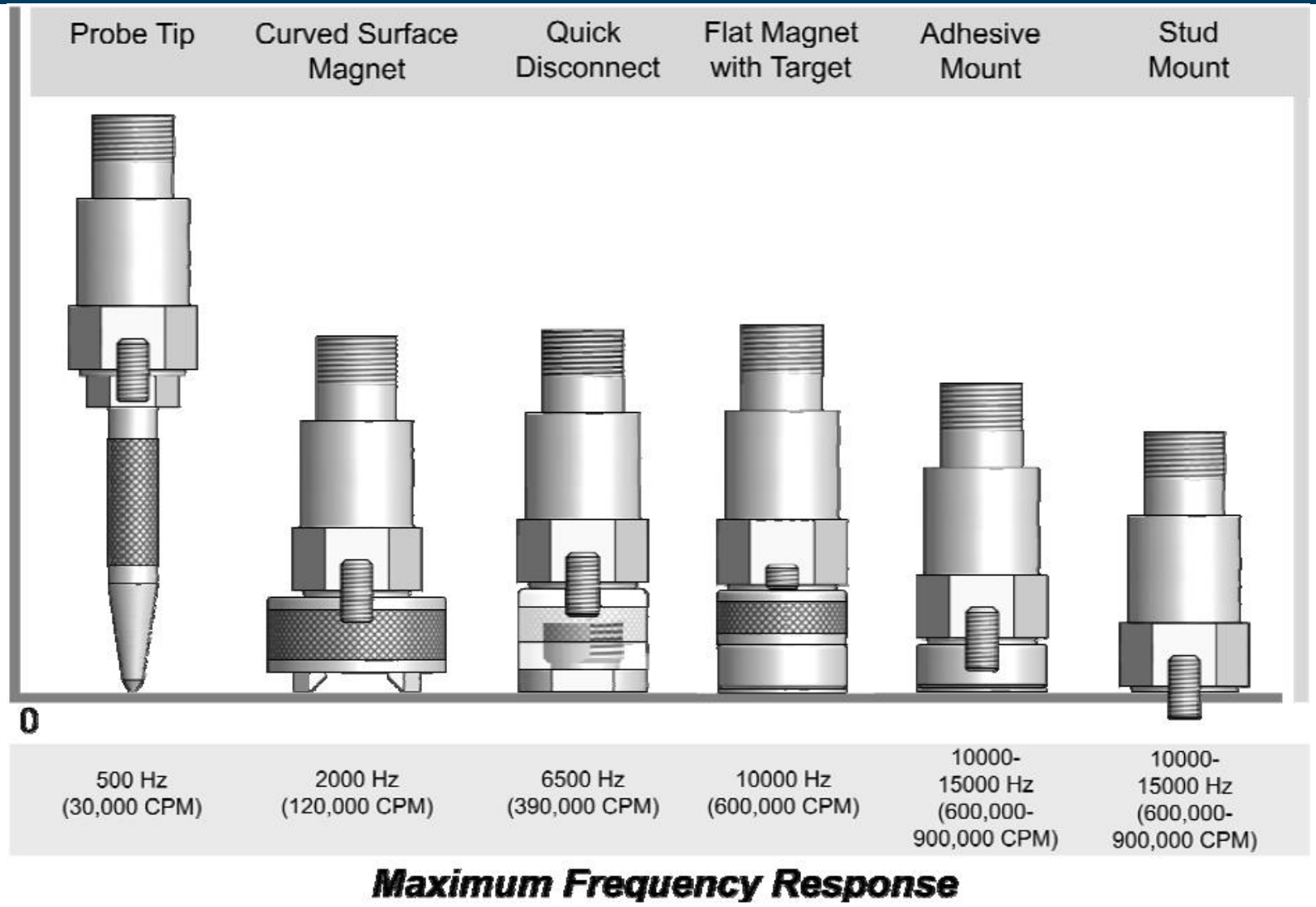
Size Matters

- Larger PCBs, packages, enclosures, batteries, etc. impact the sensor response
- Resonances introduced into the mechanical design degrade the quality of the data extracted from the sensor

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Condition Monitoring – Mounting strategies

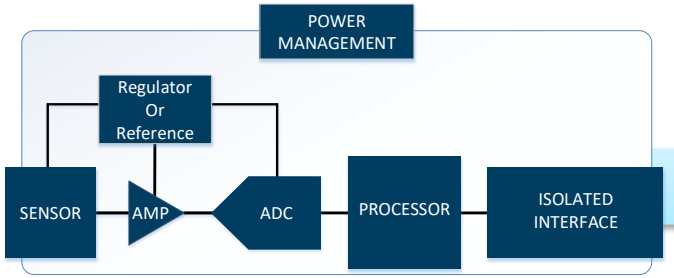
- First consideration must be capability of the Sensor
- Almost as critical is mounting strategy
- For MEMS, PCB thickness and mounting need consideration
- **Warning:** Magnetic mount can generate significant *g* force and care must be taken when placing on equipment.

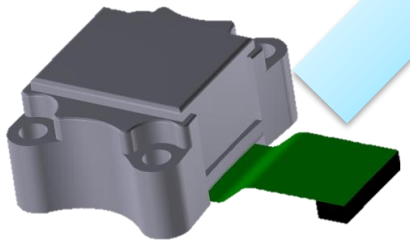


ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Future Offer:

Today's CbM Business:
Sensor + Signal Chain





Condition Monitoring Solutions

Expanding Opportunities:
Algorithms to augment HW

Otosense:
- Event detection algorithms & machine learning solutions to augment sensors/signal chain

Material Sensing:
- Lubrication monitoring to identify potential contamination and breakdown

Services & Analytics:
- Potential for service offerings that enable customers with analytic insights

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

Q&A