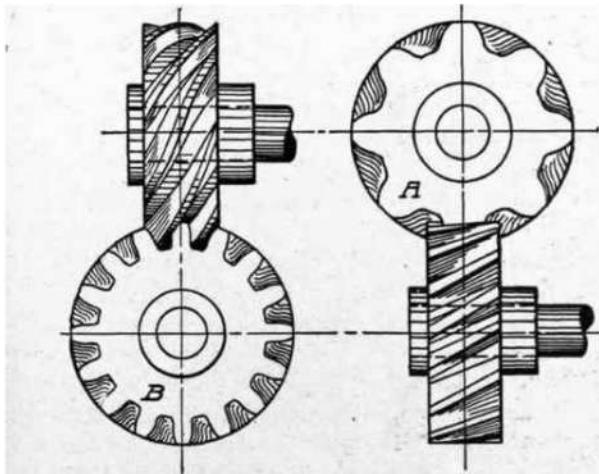


NIDays

WORLDWIDE GRAPHICAL SYSTEM DESIGN
CONFERENCE



Test System Setups for NVH and MCM applications



Ingo Schumacher
Systems Engineer, Sound and Vibration
National Instruments
Ingo.Schumacher@ni.com

Outline

- Introduction
- Sensors, Signal Conditioning & A/Ds
- Part 1: Noise Vibration Harshness (NVH)
 - Analysis & Signal Processing
 - Real Life Application Examples
- Part 2: Machine Condition Monitoring (MCM)
 - Analysis & Signal Processing
 - Real Life Application Examples

Why Measure Sound & Vibration?

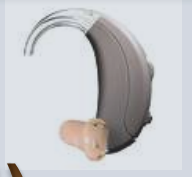
Audio Performance

Quality of speakers, cell phone, distortion, freq. response, etc.



R&D

Reduce vibration, improve acoustics



Control

Active car suspension, cabin noise suppression, ...



Noise Vibration Harshness (NVH)

Structural Testing

Determine integrity of structure by measuring vibrations



Predictive Maintenance

Trend and analyze machine performance to prevent damages

(Machine) Condition Monitoring

Machinery Protection

Monitor vibration and shutdown at critical level



Sensors for Dynamic Data Acquisition

- Accelerometers
- Velocity sensors
- Proximity Probes
- Microphones
- Strain gauges
- Dynamic pressure probes
- Current probes
- Laser vibrometers



Transducer Selection Considerations

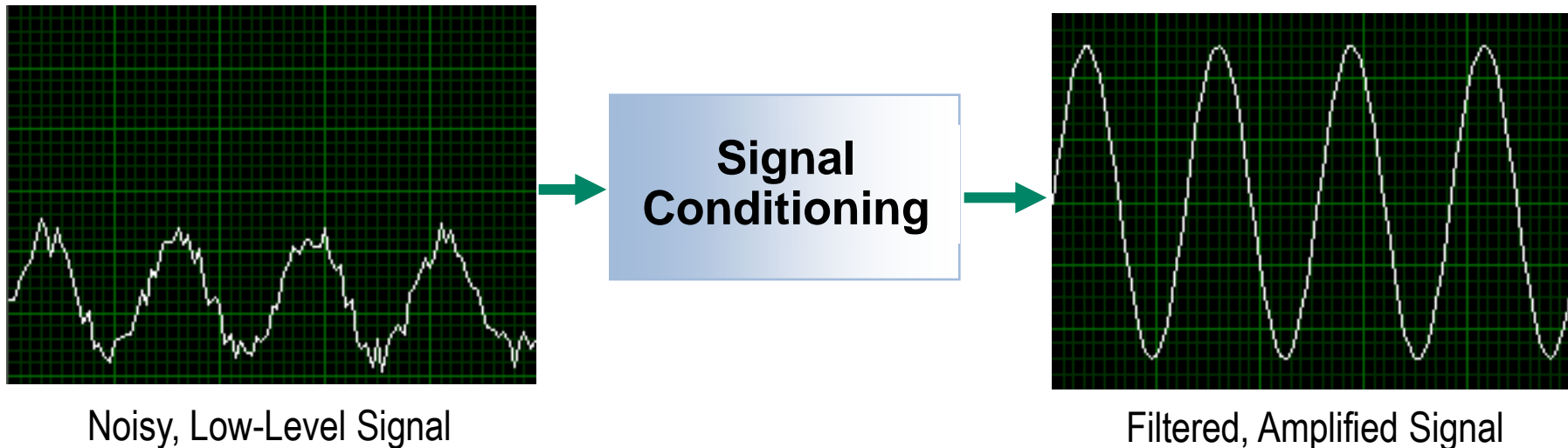
- What is the vibration or sound level?
- What are the frequencies of interest (max and min)?
- What is the temperature range required?
- What cable length will be required?



Other Sensors - Temperature and Process

- RTDs
- Thermocouples
- Infrared Sensors (non-Contact)
- 4-20ma process variables
- Proximity Probes
- Tachometers
- Standard NI Thermocouple / RTD / voltage / 0-20 mA input modules

Data Acquisition Considerations



- Improve signals for better measurement quality
- Power or excite sensors
- Read sensor information – TEDS

Data Acquisition Considerations

- ADC with high dynamic range
- Anti-Aliasing Filters
- Integrated Electronics Piezo Electric (IEPE)* signal conditioning
- Simultaneous Sampling
- AC/DC Coupling – high pass filter
- Input Voltage Range



*IEPE is also referred to as ICP®, CCLD, Isotron®, Deltatron®, Piezotron®

Noise Vibration Harshness (NVH)

Analysis & Signal Processing
Real Life Application Examples

What is NVH actually?

Wikipedia:

Noise, vibration, and harshness (NVH) is the study and modification of the noise and vibration characteristics of vehicles, particularly cars and trucks.

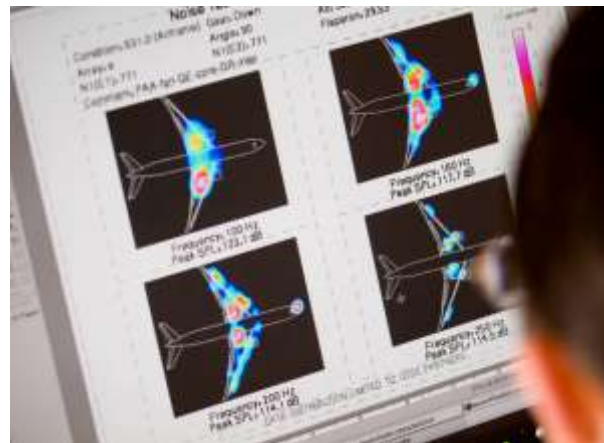
Can also apply to other objects, such as cooling fans, power tools, dishwashers, etc.

More about NVH

- Noise
 - Unwanted sounds
 - Broadband (road noise, wind noise)
 - Tonal (engine noise)
- Vibration
 - Mechanical oscillations, resonances
- Harshness
 - Discomfort of a noise or vibration
 - Subjective

Applications withing NVH testing

- Buzz, Squeak and Rattle
- Passby Noise
- Modal Analysis



Operational Modal Analysis: Vibration Monitoring of Meazza Stadium in Milan

Requirements

- High-channel, distributed network monitoring system
- Structural evaluations, modal analysis, static and dynamic measurements, and corrosion testing



Solution

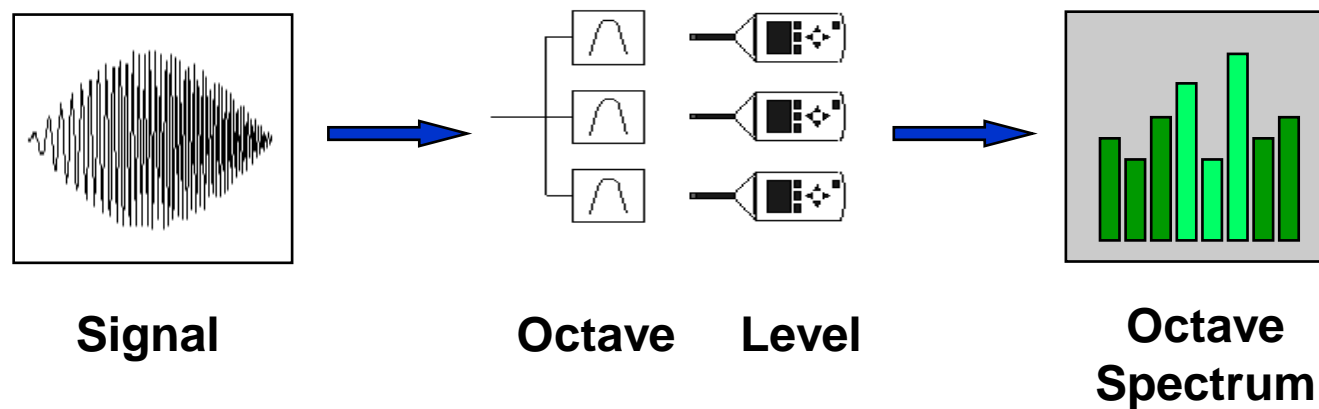
- 14 CompactRIO chassis with mixed sensor connectivity
- LabVIEW for flexibility and advanced analysis



POLITECNICO
DI MILANO

Example - Fractional Octave Analysis

- Used when final customer is the human ear
 - amplitude scale in dB
 - logarithmic frequency scale
- Implementation: Bank of bandpass filters followed by level measurements



- Compliance with ANSI and IEC standards

DEMO 1

Quickly setup an test application using
Sound & Vibration Assistant

NVH Application:

Acoustic Beamforming in Vehicle Pass-By Noise Tests

Portable acoustic beamformer for noise source identification in pass-by noise measurements from moving vehicles

Tools used:

- spiral array of 32 microphones
- NI LabVIEW software
- NI Sound and Vibration Measurement Suite
- NI CompactDAQ
- eight NI 9234 4-channel dynamic signal acquisition modules



"We chose NI hardware because it is compact and DC-powered, and provides power to the microphones used in the array." - UFSC

NVH Application:

Wireless Environmental Noise Monitoring in Mexico City

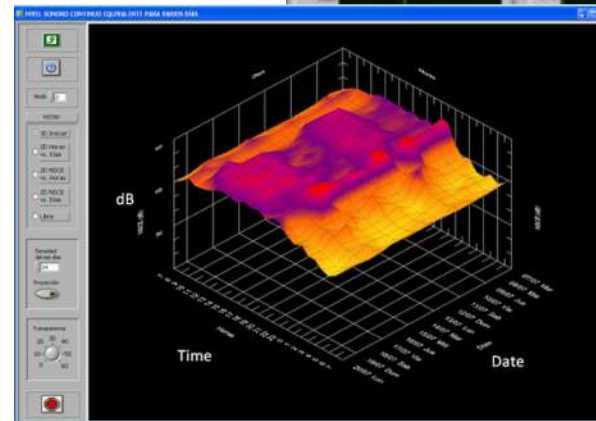
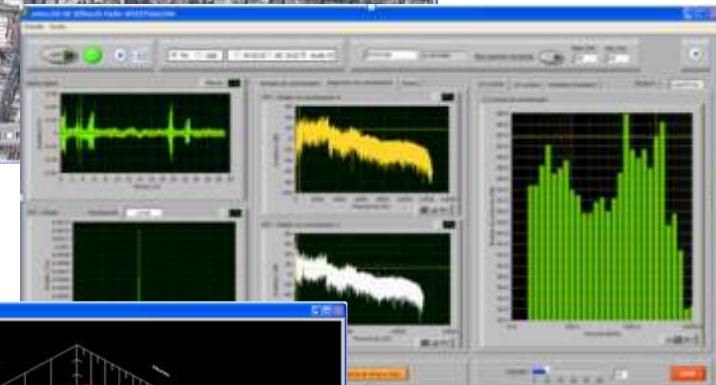


Instituto Politécnico Nacional
"La Técnica al Servicio de la Patria"

Monitor and record noise levels in different parts of the central historical district in Mexico City so the government can develop and implement regulatory action to control or prevent the noise.

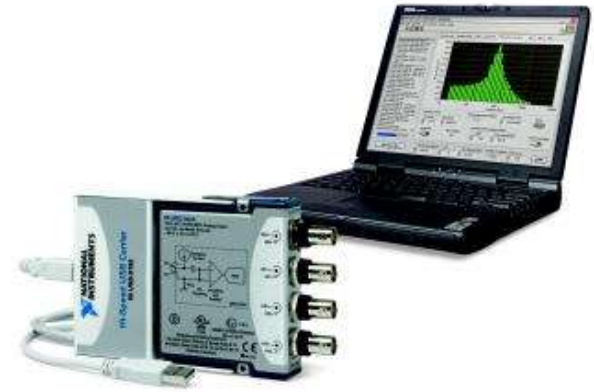
Tools used:

- Sound and Vibration Measurement Suite
- USB-9234
- LabVIEW



USB Dynamic Acquisition Systems

- Lightweight and portable
- Easy to Setup
- Full Featured Measurement
 - 24-bit simultaneous ADCs
 - 101 dB dynamic range
 - 102,4 kS/s/ch sample rate
 - Signal conditioning included
- Highly flexible
 - Up to 24 synchronous DSA channels
 - Choose from 50 different modules



Part 2: Machine Condition Monitoring (MCM)

Analysis & Signal Processing
Real Life Application Examples

Why monitor machinery?

- Prevent failure, damage, risk
- Stop unscheduled outages
- Optimize machine performance
- Lengthen maintenance cycle
- Reduce repair time and spare parts inventory
- Increase product quality

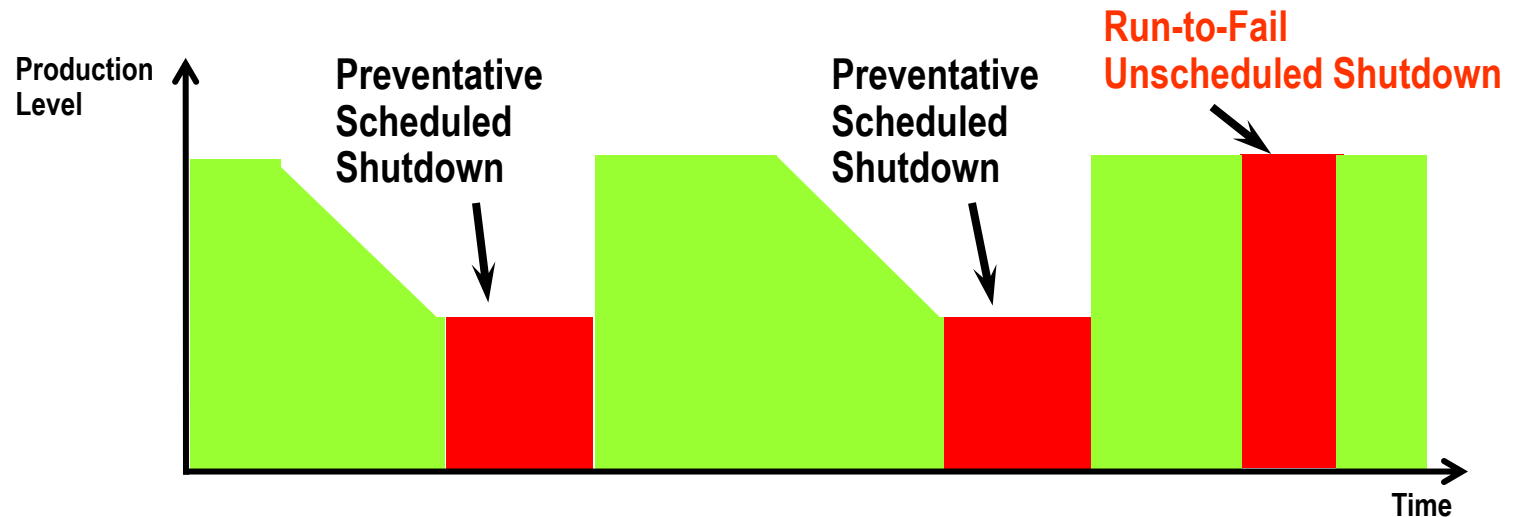
Maintenance Strategies

- Reactive
- Preventive
- Predictive

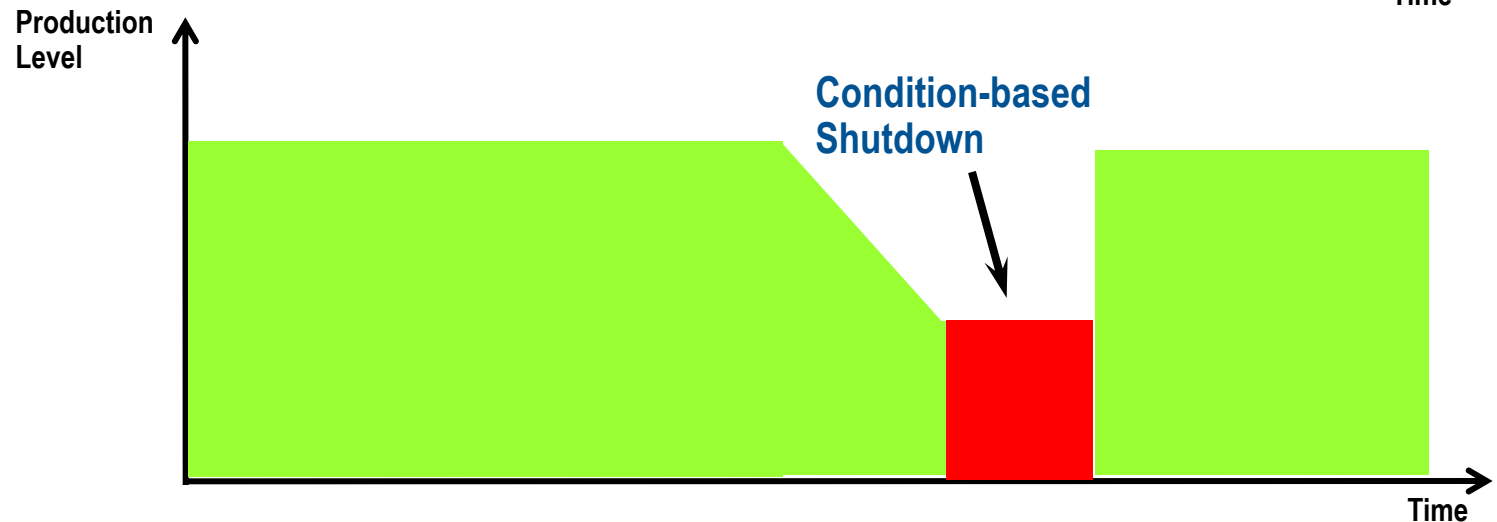


Economics of Planned Outages

Traditional Approach



Predictive Maintenance Approach



Designing a condition Monitoring System

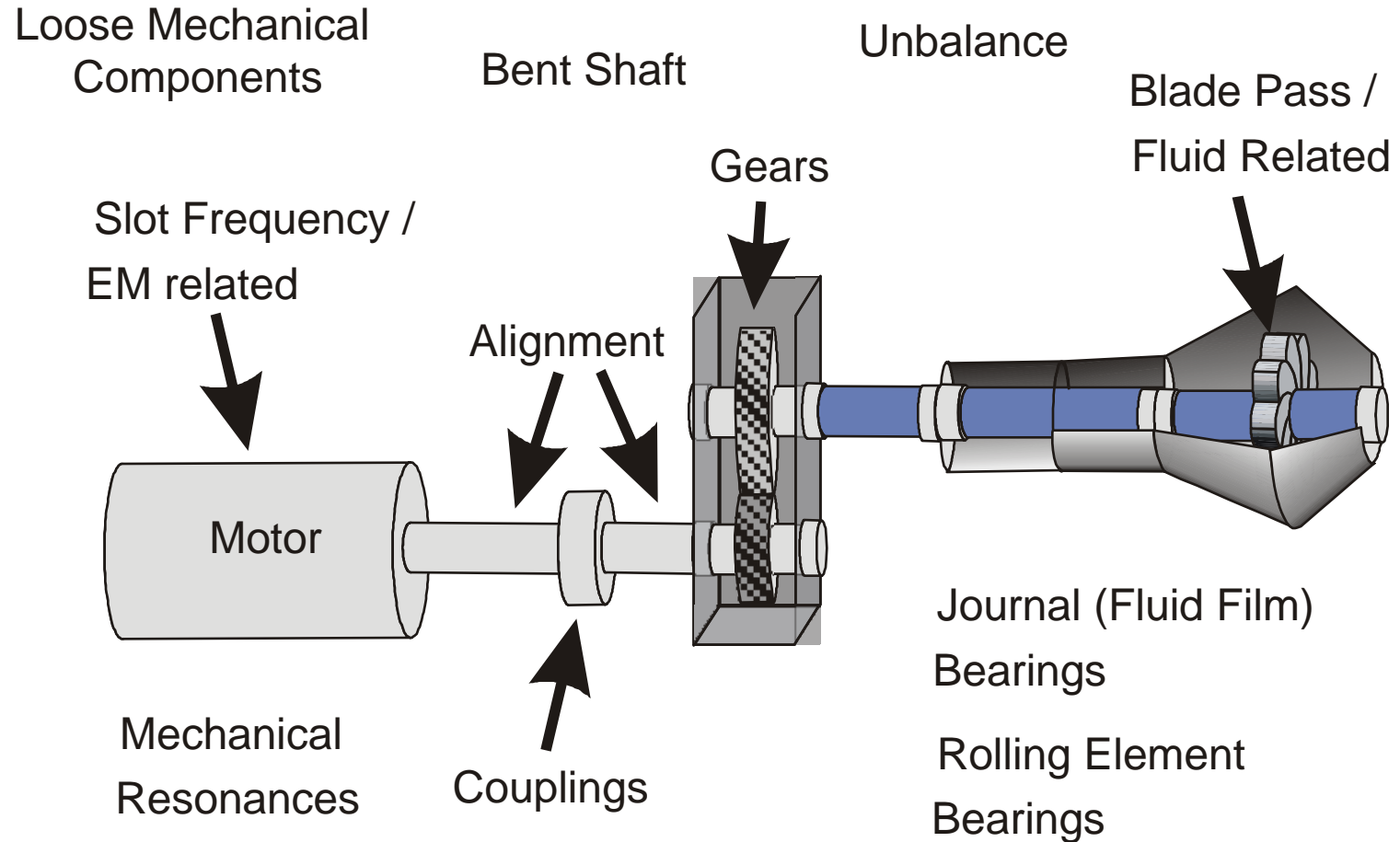
- Define monitored parameters
- Find suitable sensors and sensor locations
- Integrate data acquisition system
- Collect data and process data
- Interpret data analysis results
- Define suitable warning and alarm limits
- Deploy system

Monitoring parameters



- Machine wear is based on internal forces
- Effects of forces can be measured
 - Vibration (acceleration, velocity, distance)
 - Heat
 - Pressure
 - Strain
- Monitor changes of measured parameters (trends)
- Monitor relevant process parameters

Sources of Vibration



Signal Processing

- Trend Analysis
 - RMS, Peak, Peak to Peak, Crest Factor
- Spectral Analysis
 - Baseband FTT, Zoom FFT
 - Joint Time Frequency Analysis
 - Envelope Analysis, Cepstrum Analysis, Wavelet Analysis
- Order Analysis
 - Order Spectrum, Order Tracking
 - Orbit Plots, Shaft Centerline Plots

Interpretation of results

- Industrial Standards
 - ISO 7919
 - ISO 10816
- Comparison with reference measurements
- Experience

Software Architecture

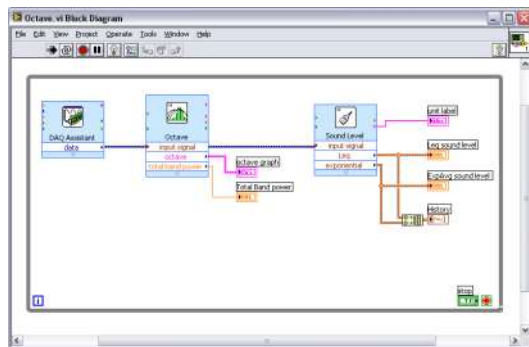
- In the on-line unit
 - Data acquisition from sensors
 - Computation and analysis
 - Communication
 - Visualization
- Optional Operator and Engineering Workstation
 - Data management
 - Alarm and trending
 - Diagnostic with history data

Sound & Vibration Measurement Suite



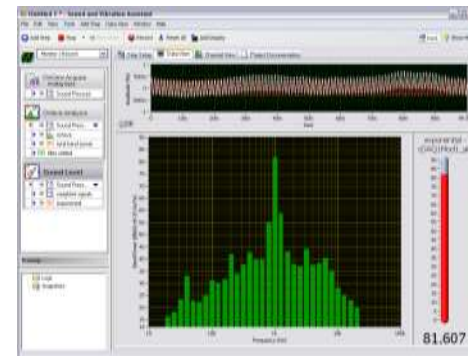
LabVIEW Analysis VI Library

- Spectral Analysis, Zoom FFT, Frequency Response
- Sound Level & Vibration Level
- ANSI & IEC Octave Analysis
- Order Tracking and Analysis
- Human Vibration Weighting



NI Sound & Vibration Assistant

- Drag-and-drop data acquisition & logging
- Interactive, reconfigurable acoustic & vibration analysis
- No programming required – ready-to-run software



NI CompactRIO Architecture



- **Reconfigurable FPGA** for high-speed and custom I/O timing, triggering, and control
- **I/O modules** with built-in signal conditioning for connection to sensors/actuators
- **Real-time processor** for reliable measurement, analysis, connectivity, and control

DEMO 2

Machine Condition Monitoring with CompactRIO

Nexjen VTS



- TurboCharger Field Test
- Field Technician safe
- NI LabVIEW
- NI Sound & Vibration Measurement Suite
- NI USB- 9233



<http://www.nexjen.com>

VBOX3, portable vibration analyzer



- NI USB- 9234
- 4 ch, 24 bit ADC, 51.2kHz sample rate
- Vibration Signal Processing based on NI LabVIEW
- Turn-key application



www.vbox3.com

Embedded Control/Monitoring Systems

- High Reliability
 - Stand alone operation,
 - Realtime OS
 - harsh environment ready
- Online Signal processing
- Local data storage
- Connectivity
 - Network, GSM/3G
 - Industrial Networks
- Flexibility
 - Great selection of modules



F'IS ProCheck



- Intelligent online monitoring system
- Data collection, filtering and analysis
- Characteristic values and alarms can be passed on to external systems
- Serial, modem and TCP/IP communication.
- Store the data locally and transfer the data later



<http://www.fis-services.de>

Summary

- Sound and Vibration applications requires engineers with domain expertise
- NI provides hardware tools for
 - Portable test setups (USB & Wireless)
 - Embedded, Stationary or Large networked setups (CompactRIO, PXI)
- NI also provides analysis software tools for
 - Interactive, configuration based rapid measurement setups (S&V assistant)
 - Extensive, fully customizable, programming environment (LabVIEW with S&V Measurement Suite)



Questions?