# Data Acquistion Technologies and Applications

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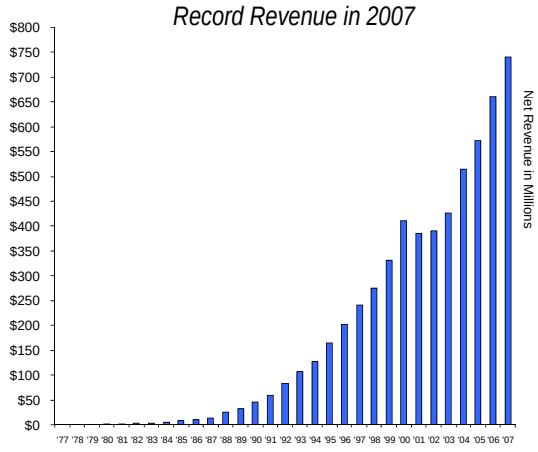
ni.com

NATIONAL INSTRUMENTS

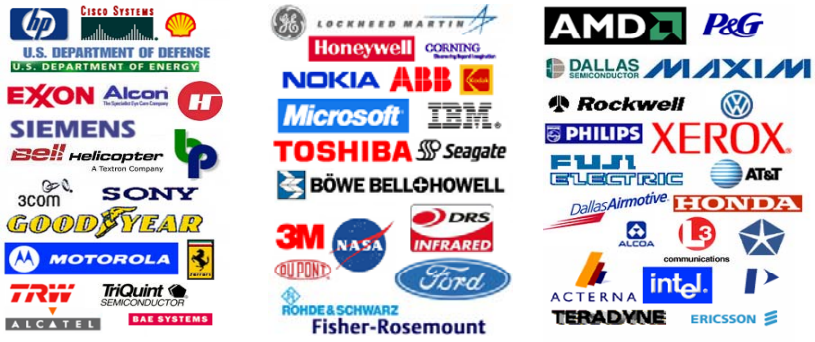
# National Instruments Overview

- *Leaders in Computer-Based Measurement and Automation*
- Long-term Track Record of Growth and Profitability
- $740M Revenue in 2007
- $205M Revenue in Q4 2007
- More than 4,600 employees; operations in 40+ countries
- *Fortune's* 100 Best Companies to Work For Nine Consecutive Year



# Diversity of NI Customers

- More than 25,000 Customers in more than 90 countries
- 95% of Fortune 500 in manufacturing

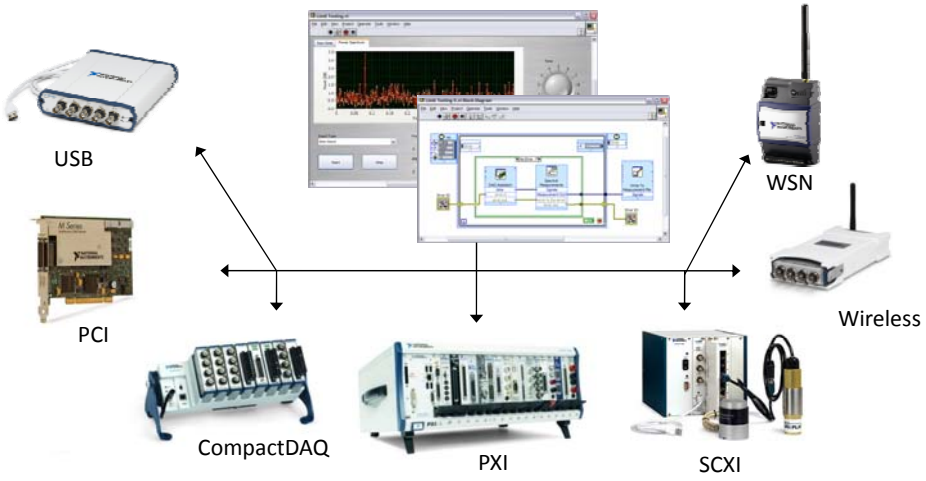



# ALL NEED DAQ …

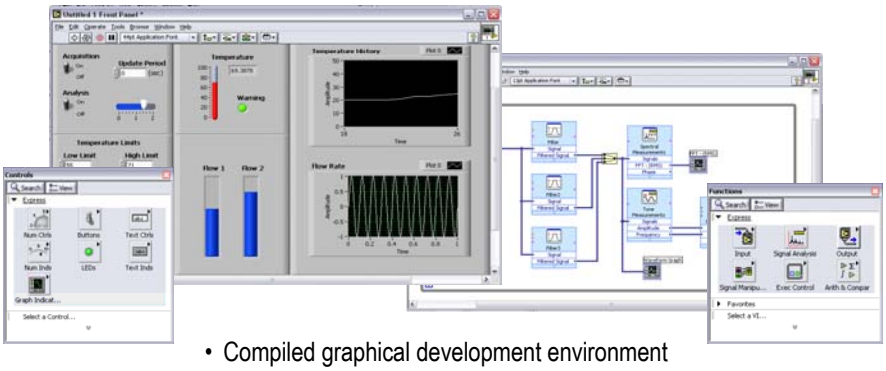


# NI DAQ Platforms

One application, multiple targets



# LabVIEW Graphical Development Environment



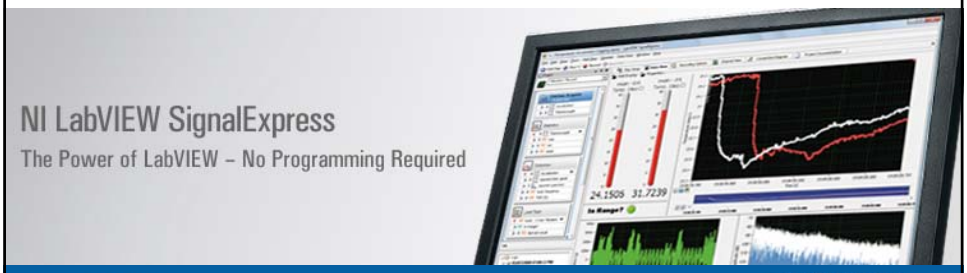
- Compiled graphical development environment
- Development time reduction of four to ten times
- Tools to acquire, analyze, and present your data



# LabVIEW Signal Express

Interactive, measurement software for quickly acquiring, analyzing and presenting data from hundreds of data acquisition devices and instruments, with no programming required.

Part of the LabVIEW Full and Professional Development Systems

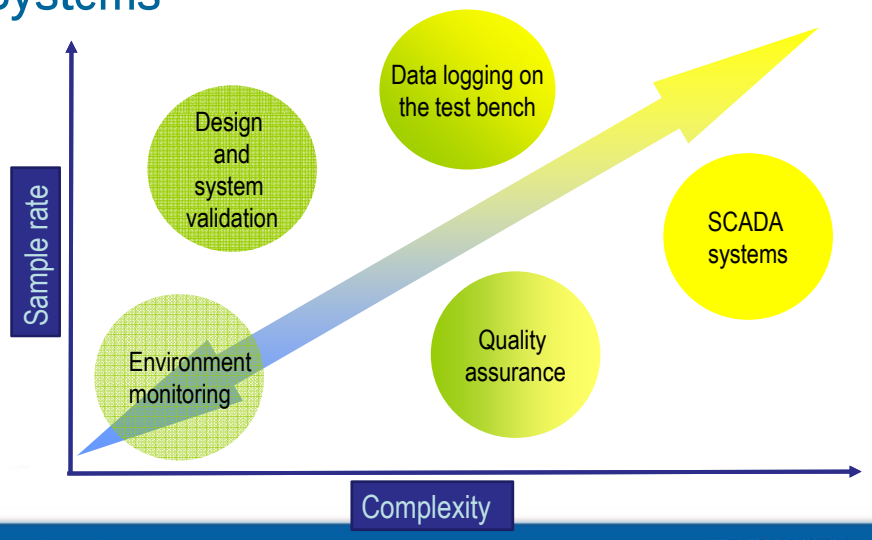


# Outline

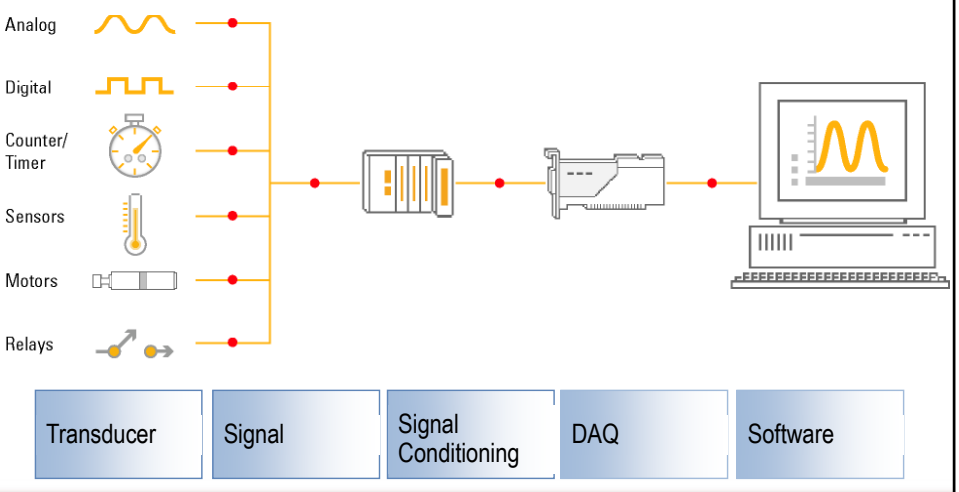
- Intro – PC Based Data Acqusition
- Part 1: Sensors & Signal Conditioning
- Part 2: DAQ Hardware
- Part 3: Timing & Synchronization
- Summary



# Application Area of Data Logging Systems



# PC-Based Data Acquisition (DAQ)




Transducer | Signal | Signal Conditioning | DAQ | Software



# Advantages of PC-Based Data Logging

- Integrate traditional logging tasks:
  - Acquisition
  - Logging
  - Display
- Provides new capabilities:
  - Multiple measurement types and locations
  - Custom analysis
  - Reporting
  - Network integration

## Data Logger Hardware Considerations

- What types of sensors do you have?
- How many channels do you need?
- What accuracy and resolution are required?
- How fast do you need to log?
- Do you need synchronization or trigger?
- Would you like to control any outputs?
- Do you need end-to-end calibration?
- Will you need to expand in the future?



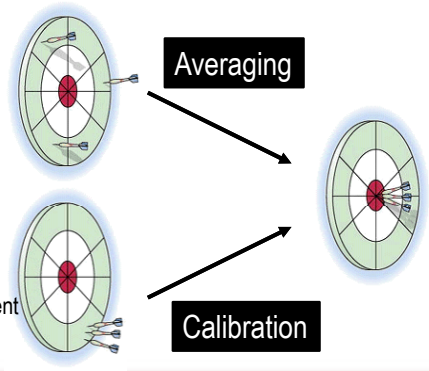
## Measurement Accuracy and Inaccuracy

- Measurement accuracy or measurement uncertainty or fault defines the range by which an experimental value can deviate from the real value

  Accuracy = Measurement value +/- gain error +/- offset error +/- noise

- Measurement inaccuracies result from measuring physical values. Measurements scatter around the real value.

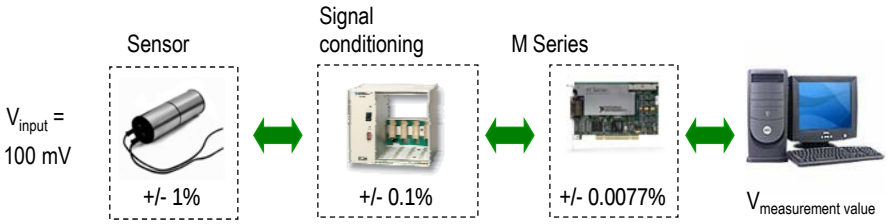
Statistical error
caused by noise




Systematic error
caused by deviation of an instrument

## Measurement Chain – Measurement Inaccuracy

- Inaccuracy results from the inaccuracies in single steps according to the rules of error propagation
- Precise hardware for signal conditioning and DAQ can reduce the measurement inaccuracy significantly



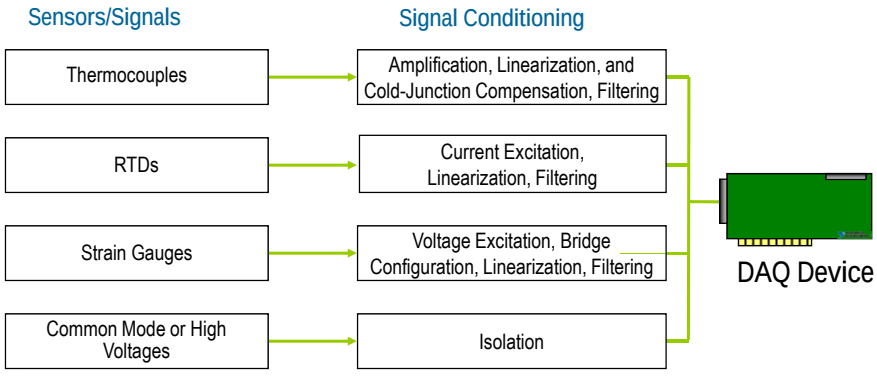

Systematic error

M Series = 100 ± 1.101 mV



## Signal Conditioning Hardware

**High voltage signals and most sensors require signal conditioning to properly read the signal**

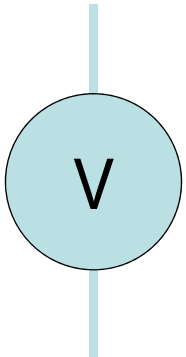


## Input/output signals

- Voltage
- Current
- Thermocouple
- RTD
- Strain Gage
- Pressure / Load
- Microphone
- Accelerometer
- LVDT / RVDT
- Light
- Encoder
- Others ...

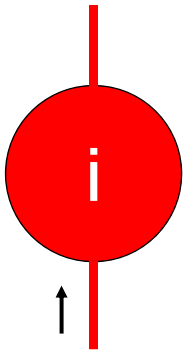


## Voltage Measurement




- Straight in
- Isolation
- Attenuation
- Amplification

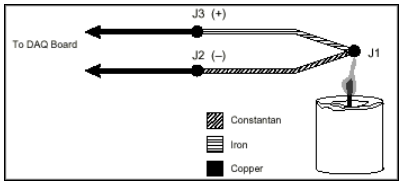
## Current Measurement



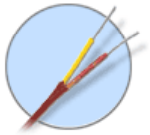

- Known resistor
- Measure voltage drop

# Thermocouple

- Junction of two dissimilar metals
  - Small Voltages (mV)
  - Voltage non-linear with temp
- Cold-Junction Compensation
- Connection Problems
- Noise Problem




Metal Sheathed Thermocouple Wire



Duplex Insulated Thermocouple Wire

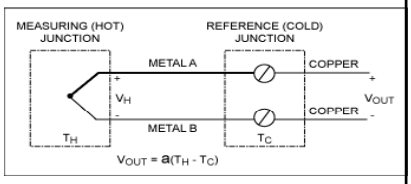


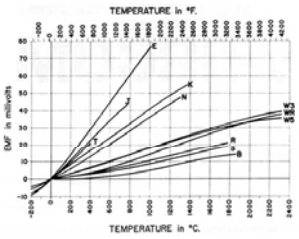
# Type of Thermocouples

| Thermocouple Type | Overall Range | Typical Accuracy* | Comments |
|---|---|---|---|
| Type B (Platinum / Rhodium) | 100 to 1800 | 5 °C (at 1000°C) | Suited for high temperature measurements. Unusually, type B thermocouples give the same output at 0 °C and 42 °C. This makes them useless below 50 °C. |
| Type E (Chromel / Constantan) | -200 to 900 | 1.7 °C | Type E has a high output (68 µV/°C) which makes it well suited to low temperature (cryogenic) use. Another property is that it is non-magnetic. |
| Type J (Iron / Constantan) | -40 to 760 | 2.2 °C | Limited range makes type J less popular than type K. J types should not be used above 760°C as an abrupt magnetic transformation will cause permanent decalibration. |
| Type K (Chromel / Alumel) | -200 to 1300 | 2.2 °C | Type K is the 'general purpose' thermocouple. It is low cost and popular. Sensitivity is approx 41 µV/°C. Use type K unless you have a good reason not to. |
| Type N (Nicrosil / Nisil) | -200 to 1300 | 2.2 °C | High stability and resistance to high temperature oxidation makes type N suitable for high temperature measurements without the cost of platinum (B,R,S) types. Designed to be an 'improved' type K, it is becoming increasingly popular. |
| Type R (Platinum / Rhodium) | -50 to 1760 | 1.5 °C | Suited for high temperature measurements up to 1600 °C. Low sensitivity (10 µV/°C) and high cost makes them unsuitable for general purpose use. |
| Type S (Platinum / Rhodium) | -50 to 1760 | 1.5 °C | Suited for high temperature measurements up to 1600 °C. Low sensitivity (10 µV/°C) and high cost makes them unsuitable for general purpose use. Due to its high stability type S is used as the standard of calibration for the melting point of gold (1064.43 °C). |
| Type T (Copper / Constantan) | -200 to 400 | 1 °C | Best accuracy of common thermocouples, often used for food monitoring and environmental applications. |

# Signal Conditioning - Thermocouple

- Cold-Junction Compensation
  - Precision RTD/thermistor in good thermal contact with the input connectors of the measuring instrument
  - Type of CJC Source: Constant, Built-In, Channel
- Linearization
  - The relationship between temperature and output voltage is a complex polynomial equation (5th to 9th order depending on thermocouple)
- Auto Zero Channel
  - Measuring offset eror

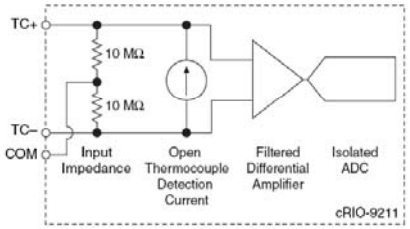


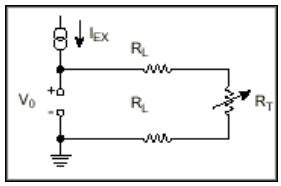



# Signal Conditioning - Thermocouple

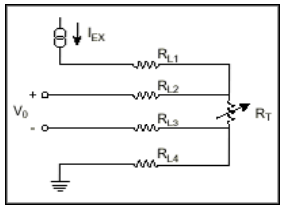
- Amplification
  - Signals usually between -80mV – 80mV
- Filtering
  - Lowpass filter
- High Input Imedance
  - To eliminate lead resistance (20 MOhm)
- Open-Thermocouple Detection



# RTDs




- Resistance Temperature Detector
- Most Common: Pt100
  - Low sensitivity (0.385 Ω/°C)
  - 1 Ω resistance in each lead connecting the Pt100 to the meter will cause an error of more than 5 °C.
- Positives
  - From -250 Up to 850 °C
  - Very Accurate and Stable
- Negatives
  - Expensive
  - Slow response time
  - Self-heating

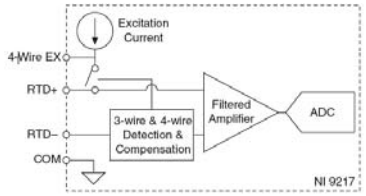


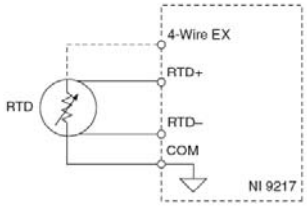

1 mA drive into 100 Ohm dissipates 1mW that cause 0.1 °C error



# Signal Conditioning - RTD

- Current Excitation
- Linearization
  - The relationship between temperature and output voltage is a complex polynomial equation
- Amplification
  - Signals usually between -80mV – 80mV
- 2-Wire,3-Wire,4-Wire Measurements
  - To Eliminate Lead Resistance



# Thermocouple vs RTD vs Thermistor

| | Thermocouple | RTD | Thermistor |
|---|---|---|---|
| Operating Range | -200 °C to 2000 °C | -250 to 850 °C | -100 to 300 °C |
| Accuracy | Low | Very High | High |
| | 1 °C common | 0.03 °C common | 0.1°C common |
| Linearity* | Medium | High | Low |
| Thermal Response** | Fast | Slow | Medium |
| Cost | Low | High | Low to moderate |
| Noise Problems | High | Medium | Low |
| Long term stability | Low | High | Medium |
| Cost of measuring instrument | Medium | High | Low |



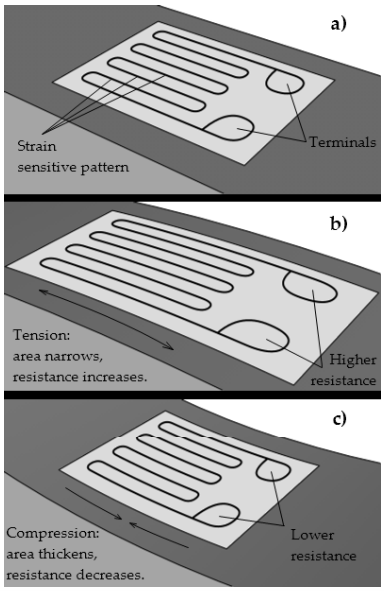
# Strain Gauge

The gauge factor GF is defined as:

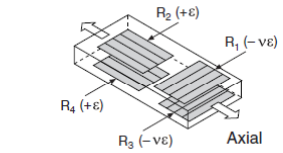
$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

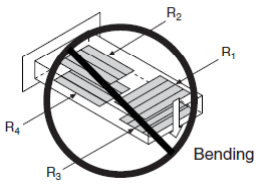
where:

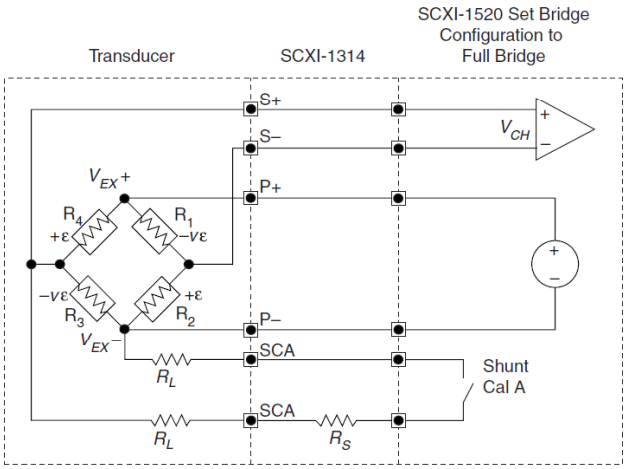
- R is the resistance of the undeformed gauge,
- ΔR is the change in resistance caused by strain, and
- ε is strain



# Signal Conditioning – Strain



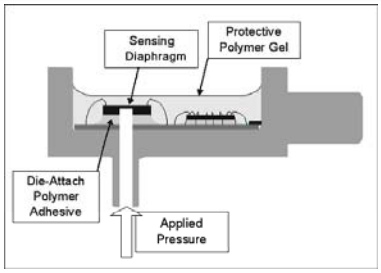


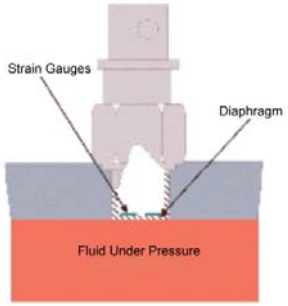

# Signal Conditioning - Strain

- Bridge Completation: Complet the bridge with reference resistor
  - Full, Half, Quarter
- Excitation: Constant Voltage Source to Power the Bridge
- Remote Sensing: Eliminate the Lead Resistance
- Amplification
  - Output less than 10mV/V
- Filtering
  - Lowpass filters
- Offset Nulling
  - Software Compensation: Initial Voltage
  - Offset-Nulling Circuit
- Shunt Calibration

# Pressure Sensor

- Works like a Strain Gauge
  - Mounted on a Diaphragm
  - Diaphragm deforms due to pressure
- Meas. Unit: Pascal (N/m2)
- Types:
  - Bonded Foil Strain Gage : Fast reponse time (1000Hz)
  - Silicon Strain Gage: more sensitive, large overload capability (400%)
- Reference: Absolute, Gauge, Difference

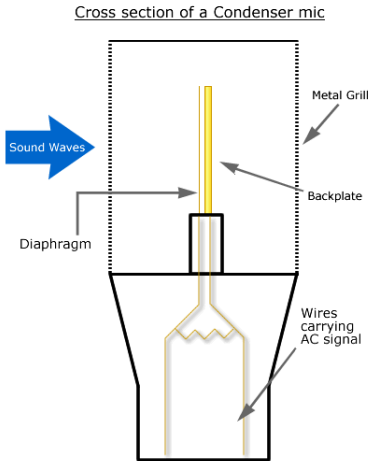




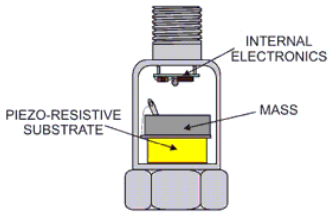

# Microphone

- Most widely used type: condenser (capacitor)
- Charge generated by an external polarizing voltage, or
- Generated by the properties of the material itself (prepolarized)



# Accelerometer

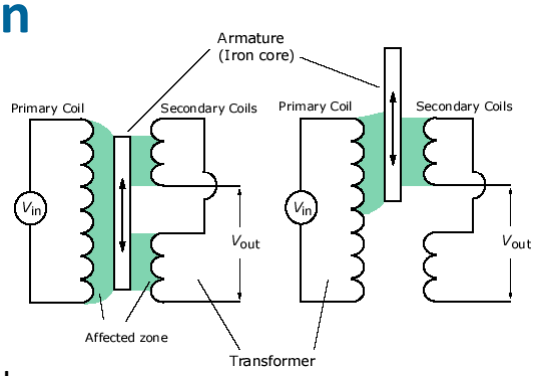
- Relies on the piezoelectric effect
- Other design: shear mode (less temperature sensitive)
- Conditioning: built-in microelectronics (ICP®) or external (charge mode)





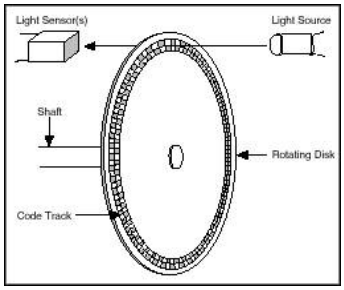

# LVDT Operation

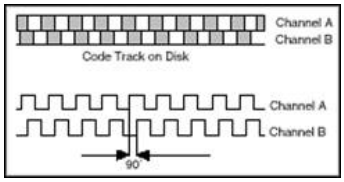
- **Linear Variable Differential Transformer**
- Iron core slides through the transformer
- Certain number of coil windings are affected by the proximity of the sliding core
- Voltage output is generated



# Incremental Encoder

- Measure
  - Motion, Direction, Position
- Output
  - Pulse train
  - Channel: A, B, Z
- Counter needed
- Types of Encoding: X1, X2, X4

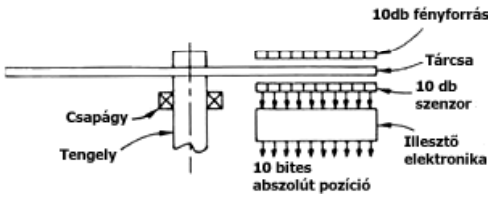


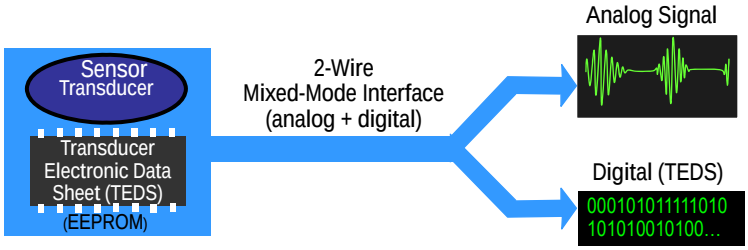



# Absolute Encoder

- Measure
  - Motion, Direction, Position
- Output
  - Binary Coded Decimal (BCD) or Grey Code
- Counter Not Needed



# IEEE 1451.4 TEDS
## TEDS = Transducer Electronic Data Sheet




IEEE P1451.4 TEDS:

- Automates system setup
- Eliminate cable connection errors
- Improves sensor data management and bookeeping
- Contains user info (i.e. sensor location)

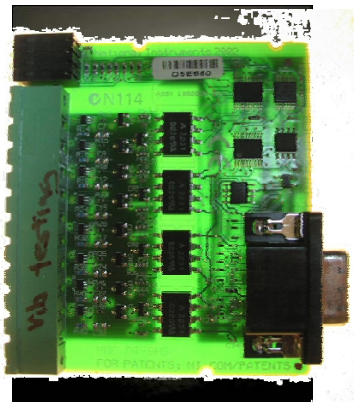
- Sensor manufacturer
- Model & serial number
- Calibrated sensitivity
- Transfer function
- Calibration information
- User Info
- And more …



# Signal Conditioning

# Isolation

- No direct electrical connection between two or more circuits
- Floating from any other reference potential
- Separated from undesired influence of another circuit
- Optical, Capacitive, Inductive

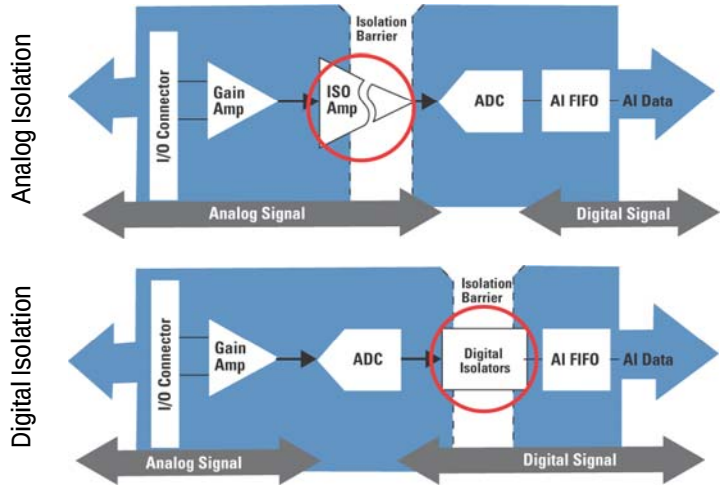




# Benefits of Isolation

- Accuracy
  - Eliminates ground loops
  - Rejects common mode voltage
- Safety
  - Protection from voltage spikes
  - Tested and certified
- Simplicity
  - 0 to 20 mA I/O, 24 V DIO
  - No need for external conditioning

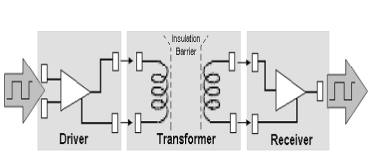

# Types of Isolation






# Digital Isolation Lowers Cost, Improved Performance

- New digital isolators replace analog optocouplers with chip-scale transformers:
  - Increased data rates and bandwidth
  - Smaller size
  - Lower power consumption
  - Lower cost

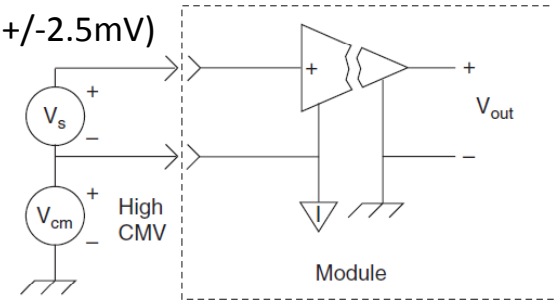




2300 Vrms Transient

# Signal Conditioning – SCXI-1125

- CMRR = 160dB
- Gain = 2000 (+/-2.5mV)
- CMV = 300V




**Extra voltage = 300V/10^8 = 3µV**

**INPUT RANGE = +/- 2.5mV !!!**



# PC Based Signal Conditioning Hardware Options

High Channel Count System

SCXI

Portable, Low Cost System

SCC

Simple Complete USB System

NI CompactDAQ

Built –In Signal Conditioning

PXI & PCI Instruments

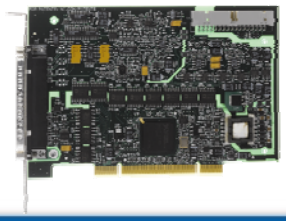
# Isolated M and S Series

## M Series

| Product | AI | Max AI Rate | AO | Max AO Rate | Digital Level | Sourcing/ Sinking | |
|---|---|---|---|---|---|---|---|
| NI 6230 | 8 | 250 KS/s | 4 | 500 kS/s | TTL | NA | Voltage I/O |
| NI 6232 | 16 | 250 KS/s | 2 | 500 kS/s | 24V | Sourcing | |
| NI 6233 | 16 | 250 KS/s | 2 | 500 kS/s | 24V | Sinking | |
| NI 6236 | 8 | 250 KS/s | 4 | 500 kS/s | TTL | NA | Current I/O |
| NI 6238 | 16 | 250 KS/s | 2 | 500 kS/s | 24V | Sourcing | |
| NI 6239 | 16 | 250 KS/s | 2 | 500 kS/s | 24V | Sinking | |
| NI 6515 | 16 | 250 kS/s | 2 | 250 kS/s | TTL | Sourcing | USB |
| 6518 | 32 | 250 kS/s | 2 | 250 kS/s | TTL | Sourcing | |

## S Series

| | | | | | | |
|---|---|---|---|---|---|---|
| NI 6154 | 4 | 250 KS/s Simultaneous | 4 | 250 KS/s | TTL | NA |



5 V TTL/CMOS digital I/O with a single isolation plane
24 V digital I/O with different analog and digital isolation planes
5 V TTL digital I/O with channel-to-channel isolation
Current input and output channels



# Signal Conditioning - SCXI Product Overview

- Modular signal conditioning platform for M Series, S Series, and E Series DAQ devices
- Multiplexer, matrix, and general-purpose switching
- Several chassis options; ideal for high-channel-count systems

NI SCXI: High-Performance Signal Conditioning

# Signal Conditioning – SCXI-1125

- Programmable gain and filter settings
- Programmable offset calibration
- 333 kS/s maximum sampling rate
- Each channel has independent input range from ±2.5 mV to ±5 V.
- 300 Vrms working isolation per channel
- Terminal blocks for thermocouple and current measurements
- Signal inputs from ±2.5 mV to 300 V

NI SCXI-1520: 8-Channel Isolation Amplifier

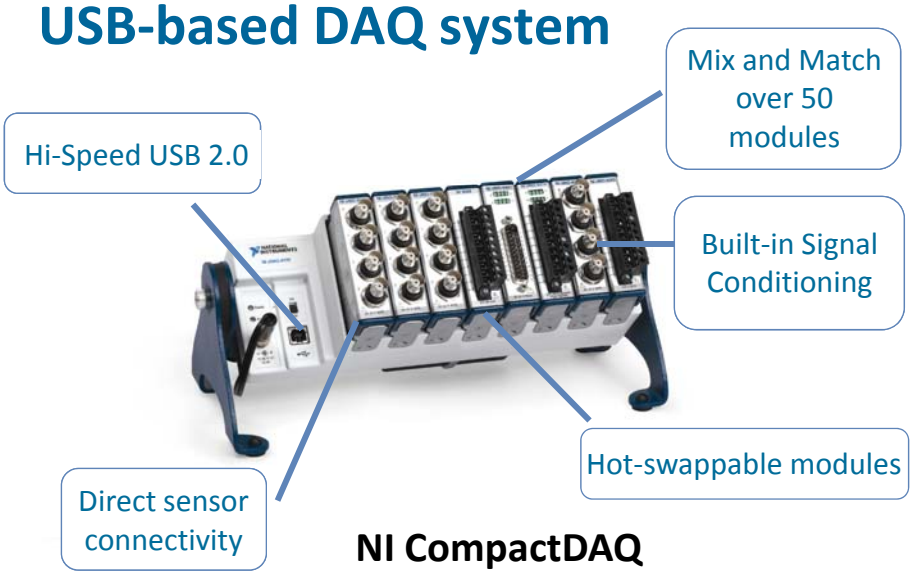


# Signal Conditioning – SCXI-1520

- 8-channel simultaneous sampling (SSH)
- 0-10 V programmable voltage excitation per channel
- Programmable lowpass filters per channel
- Programmable offset nulling and shunt calibration per channel
- Remote sense feature that ensures accurate voltage excitation to sensor
- Compatibility with SCXI-1600 USB DAQ module and IEEE 1451.4 smart TEDS sensors

NI SCXI-1520: Pressure, Force, Load, and Torque Sensor Input Module

# USB-based DAQ system




**NI CompactDAQ**



# C Series for USB compactDAQ
# In-Builted Signal Conditioning

- ✓ Accelerometer
- ✓ Strain Gauge
- ✓ Load Cells
- ✓ Digital I/O
- ✓ Thermocouples
- ✓ 4 to 20mA
- ✓ High Voltage (60V)
- ✓ RTD

# C Series Modular I/O Platform

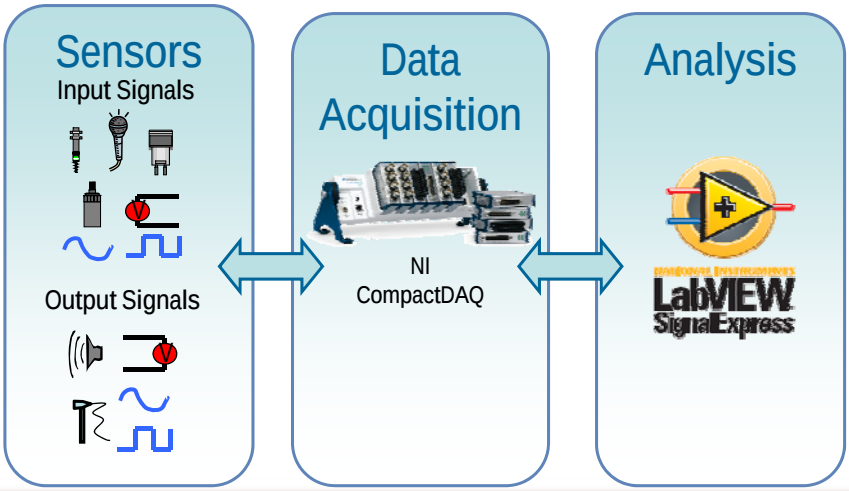
NATIONAL INSTRUMENTS LabVIEW

USB NI CompactDAQ | USB Carrier | Wi-Fi/ENET Carrier | NI PXI | NI CompactRIO

More Than 60 Measurement Modules

ni.com 47 NATIONAL INSTRUMENTS

# compactDAQ Demo
# Signal Conditioning & Measurement

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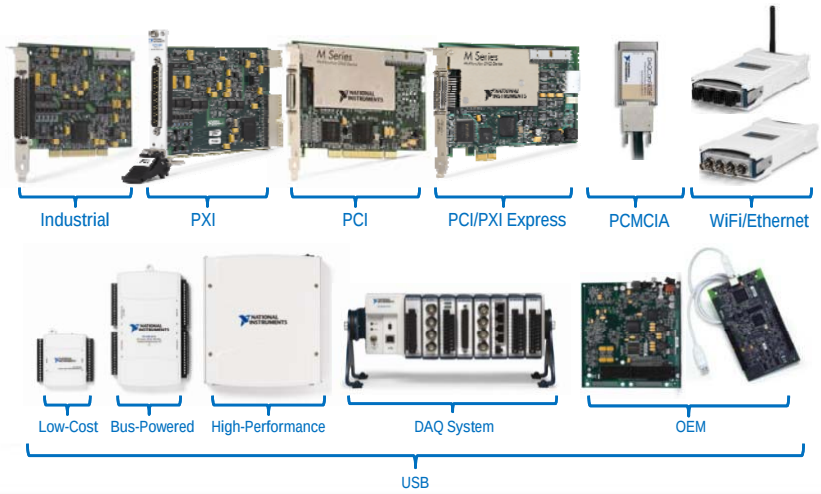
# Data Acquisition Hardware



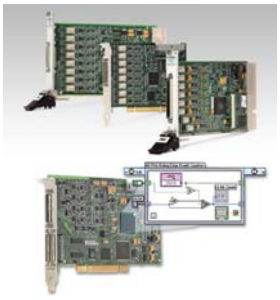
# Multifunction DAQ



# Multifunction DAQ

**M Series – Multifunction**

- Configurable triggering, timing, and onboard decision making
- Up to 18-bit resolution and 1.25 MS/s



**S Series Simultaneous-Sampling**

- Simultaneous sampling with dedicated A/D converter per channel
- Up to 16-bit resolution and 60 MS/s

**R Series Intelligent DAQ Devices**

- Analog I/O with onboard digital signal processing for filter design and high-speed control
- User-configurable with the LabVIEW FPGA Module

**NEW X Series DAQ**

- Multiplexed and Simultaneous
- Advanced timing/synchronisation/bandwith



# M Series Multifuntion DAO

- •Buses: USB, PCI, PXI
- •Up to 80 Channels Analog Input
- •Up to 18-bit Resolution
- • Up to 1,25 MS/s Analog Input (single channel)
- •Up to 4 analog outputs at 16 bits, up to 2.8 MS/s (2 µs full-scale settling)
- •Up to 48 digital I/O lines, with 32 hardware-timed up to 10 MHz;
- • Two 32-bit, 80 MHz counter/timers
- •NI-DAQmx driver software and NI LabVIEW SignalExpressLight

# Bundle kit

- NI USB 6221

- LabVIEW Base

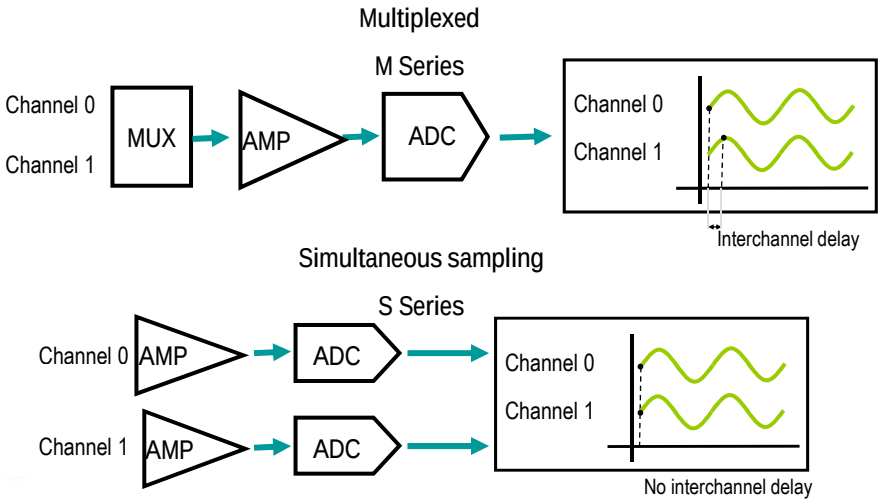
- LabVIEW Course – Basic I-II



# USB M Series – NI USB 6221

- Analog Input - 16 SE/8 DI , 250 kS/s, 16 bits, +-10V..+-200mV
- Analog Output - 2 ch, 833kS/s, 16 bits, +-10V
- Digital IO - 24 DIO , 1 MHz, TTL
- Number of Counter/Timers 2
- Resolution 32 bits
- Maximum Source Frequency 80 MHz

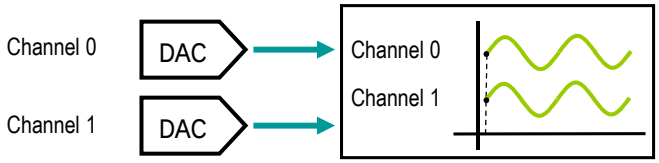
# Analog Input - Architectures






# Analog Output – Considerations

- Accuracy: digital-to-analog converter (DAC) resolution
- Update Rate: settling time and waveform frequency
- Range: fixed or adjustable output voltage/current



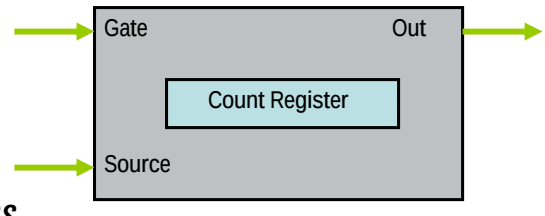

16-bit
2,8 MS/sec
±10 VDC

# Digital I/O – Terminology

- General Terminology
  - Bit – The smallest unit of data. Each bit is either a 1 or a 0.
  - Line – One individual signal in a port. *Bit* refers to the data transferred. *Line* refers to the hardware.
  - Port – A collection of digital lines.
- M Series digital I/O
  - 10 MHz digital pattern I/O
  - Synchronization with AI and AO
  - Up to 48 digital I/O lines



# Counter/Timers – Parts and Functions




- *Two basic functions*
  - *To "count" based on the comparison of input signals (Gate, Source…)*
  - *To generate pulses based upon inputs and register value*

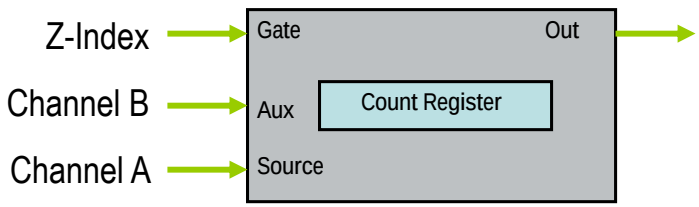
## Counter/Timers – Applications

- Edge Counting
  - Simple Edge Counting
  - Time Measurement
- Pulse Generation
  - Single Pulse Generation
  - Pulse Train Generation
- Pulse Measurement
  - Period Measurement
  - Pulse Width Measurement
- Frequency Measurement
- Position Measurement
- Quadrature Encoder Measurement



## DEMO

Encoder Measurement with M Series on NI USB 6221 (from Bundle Kit)



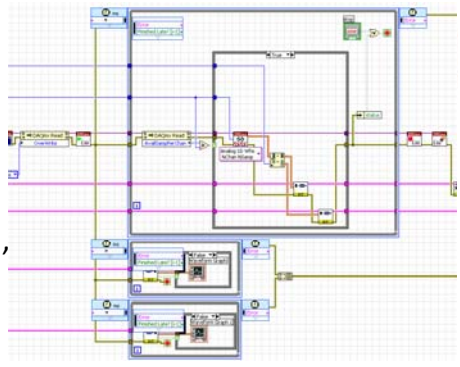
## Synchronization - What Is Synchronization?

- Intra-board
  - Synchronization among multiple operations on the same device
- Inter-board
  - Synchronization among multiple operations on multiple devices
- Types
  - Shared trigger
  - Shared clock
  - Shared clock and trigger

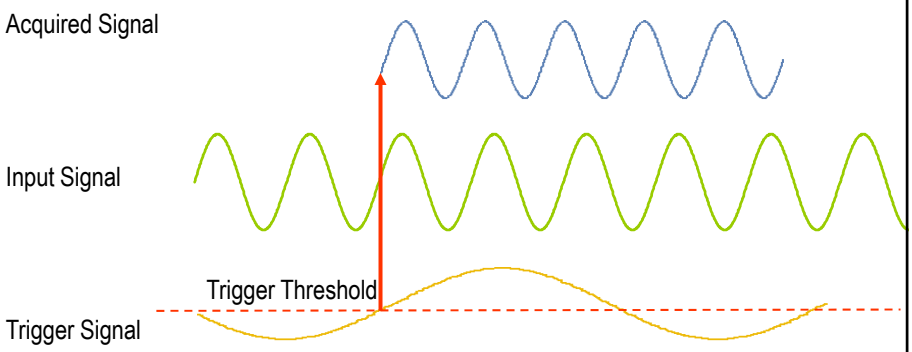


## When sync is needed

- Any mixed sensor input (AI, DI, Pulse, Encoder, ...)
- Multiple instruments phase-locked (i.e. arb+scope)
- Multi-loop, multi-periferial, prioritized applications

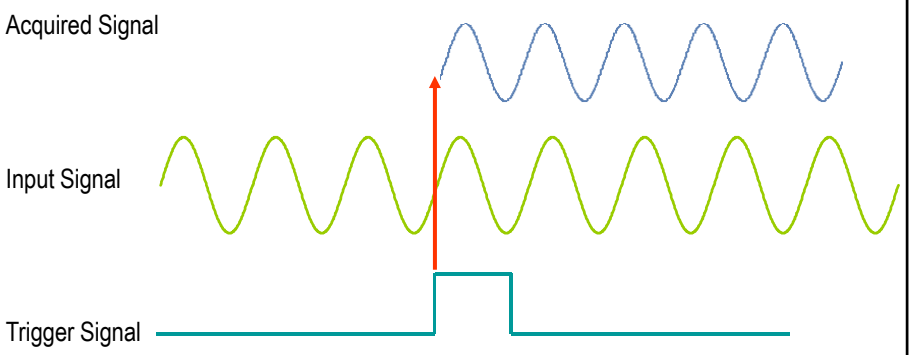


## Triggering – Analog Triggering





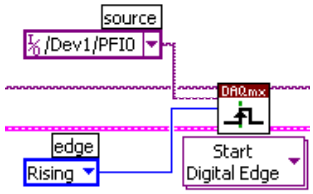

## Triggering – Digital Triggering

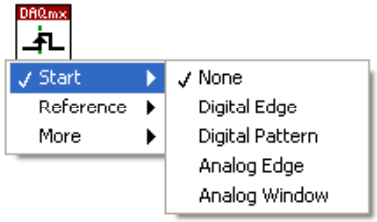


# Multi-Function Synchronization

Shared Start Trigger

- Operations start simultaneously but are not synchronized
- Operations can be simultaneously started and set to run at the same rate






# Multi-Function Synchronization

Shared Start Trigger

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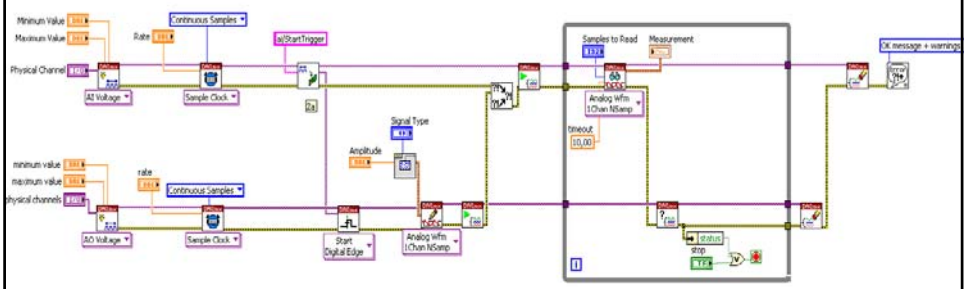
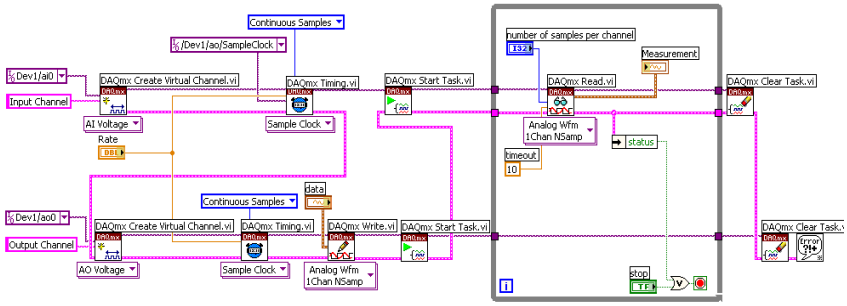


# Multi-Function Synchronization

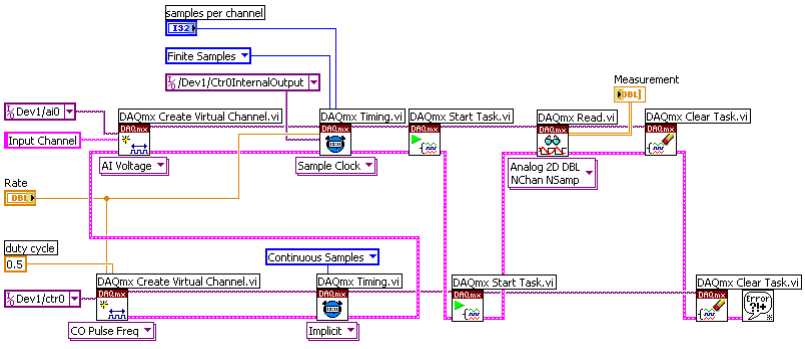
- Shared Sample Clock
  - Operations start at the same time and proceed at the same rate






# Multi-Function Synchronization

- Synchronized Analog and Counter Operations
- Counter creates pulse train as clock for analog operation



# Multi-Function Synchronization DEMO

## PWM Signal Generation

- Synchronized Counter Operations and DO
- Counter creates pulse train as clock for DO operation



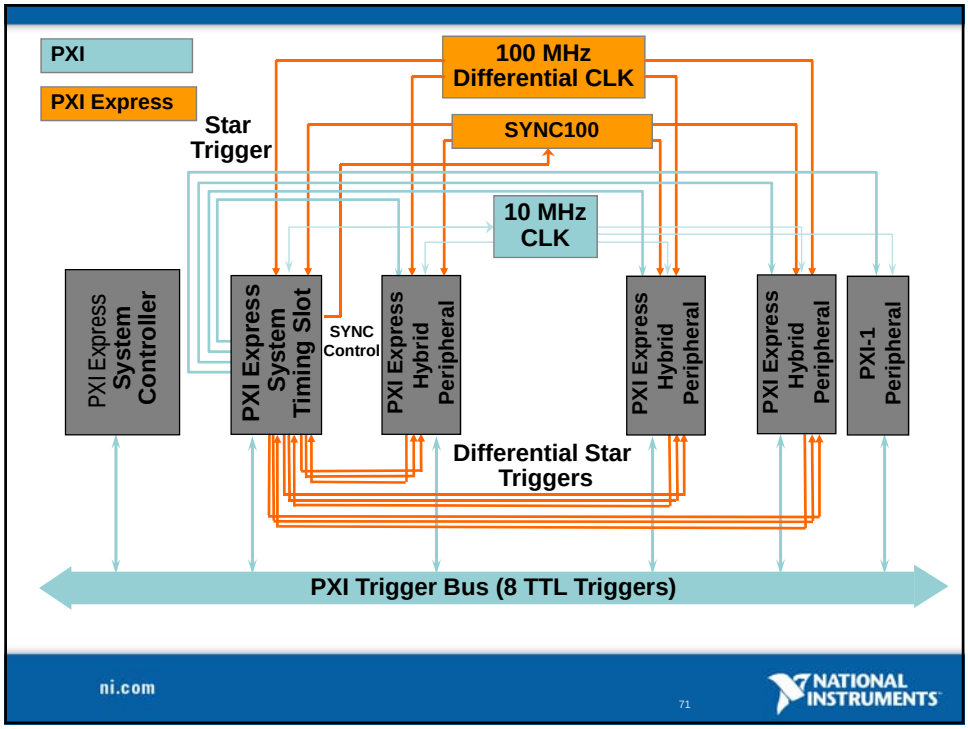
# Multi-Device Synchronization

## PCI Synchronization Using the Reference Clock

- The RTSI bus offers the ability to share signals between independent devices in the system
- Typically, 10MHz is a more stable clock frequency to route between devices
- The master device can set the source of its 10MHz reference clock to "Onboard Clock„

## PXI Synchronization Using the Reference Clock

- 10MHz reference clock for synchronization of multiple devices is already built into the backplane with the PXI_CLK10 signal


PXI
PXI Express
Star Trigger
100 MHz Differential CLK
SYNC100
10 MHz CLK
PXI Express System Controller
PXI Express System Timing Slot
SYNC Control
PXI Express Hybrid Peripheral
PXI Express Hybrid Peripheral
PXI Express Hybrid Peripheral
PXI-1 Peripheral
Differential Star Triggers
PXI Trigger Bus (8 TTL Triggers)
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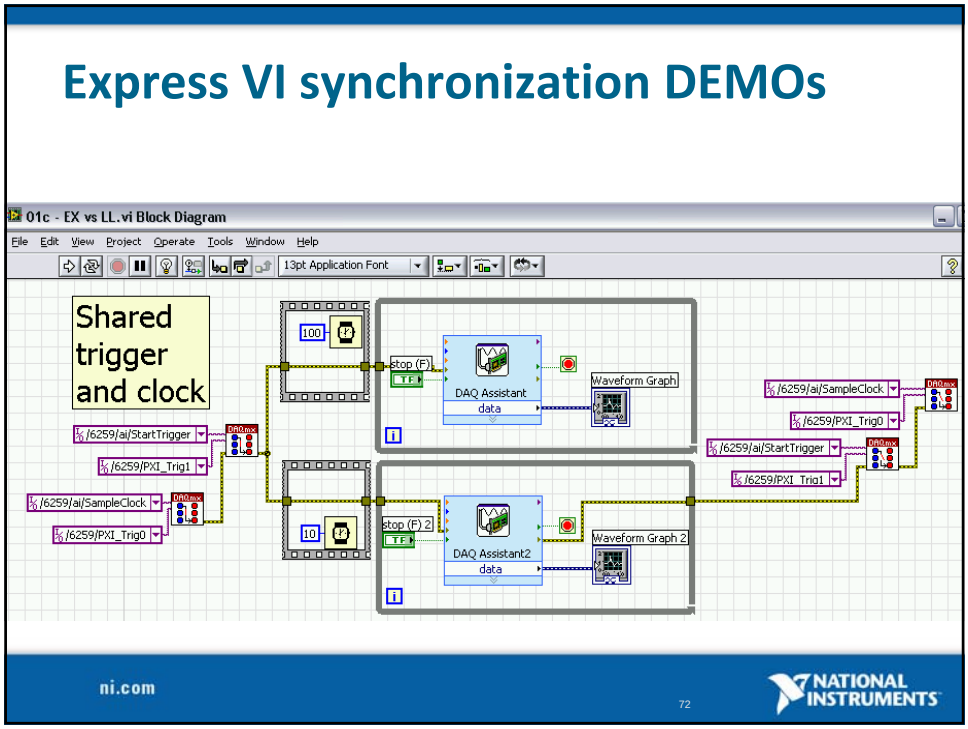
Express VI synchronization DEMOs
01c - EX vs LL.vi Block Diagram
File Edit View Project Operate Tools Window Help
13pt Application Font
Shared trigger and clock
100
stop (F)
DAQ Assistant
data
Waveform Graph
/6259/ai/StartTrigger
/6259/PXI_Trig1
/6259/ai/SampleClock
/6259/PXI_Trig0
10
stop (F) 2
DAQ Assistant2
data
Waveform Graph 2
/6259/ai/SampleClock
/6259/PXI_Trig0
/6259/ai/StartTrigger
/6259/PXI_Trig1
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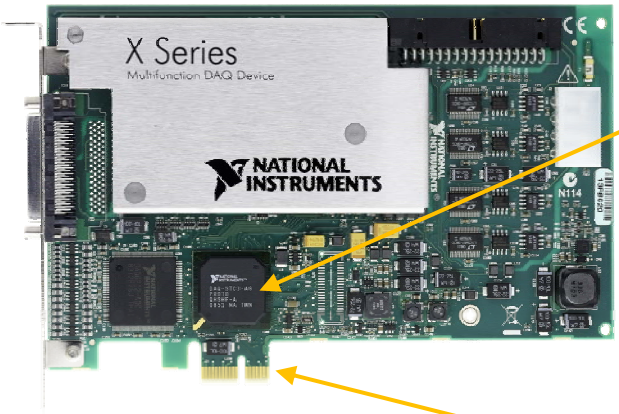
# X Series



# X Series Key Features




NI-STC3 timing and synchronization technology

Parallel software execution with NI-DAQmx and NI LabVIEW

High-throughput, native PCI Express interface

## High Throughput, Low Latency

- Native PCI Express interface with dedicated bandwidth of up to 250 MB/s in each direction
- 8 DMA channels for parallel data streaming directly to PC memory
- Optimizations for low-latency, single-point control and HW-timed single point I/O




## NI-STC3 Timing and Synchronization Technology

- Independent timing engines and advanced triggering
- 100 MHz timebase
- Four enhanced counters for the following:
  - PWM
  - Frequency
  - Encoders
  - Event counting

# Upgrading to X Series

## Hardware

- VHDCI connector lets you reuse existing cabling and accessories
- Same device pinouts as NI M Series devices

## Software

- Same NI-DAQmx driver as other NI data acquisition hardware



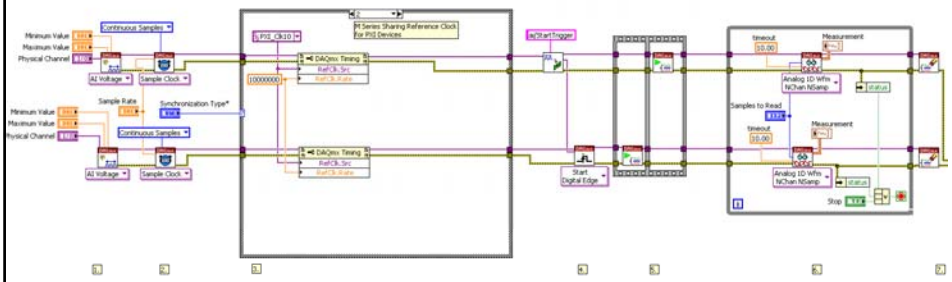

# X Series Specifications

| | Model # | AI Samp Rate | AI Throughput | AI/AO/DIO | HW Timed DIO |
|---|---|---|---|---|---|
| **Multiplexed** | PCIe-6320 | 250 kS/s | 250 kS/s | 16/0/24 | 1 MHz |
| | PCIe-6321 | 250 kS/s | 250 kS/s | 16/2/24 | 1 MHz |
| | PCIe-6323 | 250 kS/s | 250 kS/s | 32/4/48 | 1 MHz |
| | PCIe-6341 | 500 kS/s | 500 kS/s | 16/2/24 | 1 MHz |
| | PCIe-6343 | 500 kS/s | 500 kS/s | 32/4/48 | 1 MHz |
| | PCIe-6351 | 1.25 MS/s | 1 MS/s | 16/2/24 | **10 MHz** |
| | PCIe-6353 | 1.25 MS/s | 1 MS/s | 32/4/48 | 10 MHz |
| | PCIe-6361 | **2 MS/s** | 1 MS/s | 16/2/24 | 10 MHz |
| | PCIe-6363 | 2 MS/s | 1 MS/s | 32/4/48 | 10 MHz |
| | PXIe-6341 | 500 kS/s | 500 kS/s | 16/2/24 | 1 MHz |
| | PXIe-6361 | 2 MS/s | 1 MS/s | 16/2/24 | 10 MHz |
| | PXIe-6363 | 2 MS/s | 1 MS/s | **32/4/48** | 10 MHz |
| **Simultaneous** | PXIe-6356 | 1.25 MS/s/ch | 8 MS/s | 8/2/24 | 10 MHz |
| | PXIe-6358 | 1.25 MS/s/ch | 16 MS/s | 16/4/48 | 10 MHz |
| | PXIe-6366 | 2 MS/s/ch | 16 MS/s | 8/2/24 | 10 MHz |
| | PXIe-6368 | 2 MS/s/ch | **32 MS/s** | 16/4/48 | 10 MHz |

All devices have 16 bits of AI resolution and have 4 counters

# Synchronizing Multiple X Series

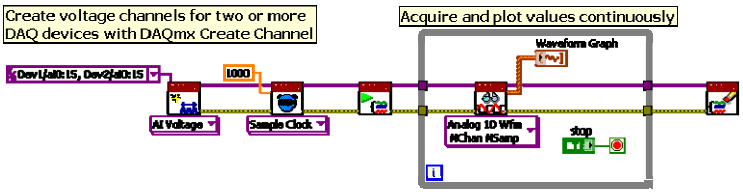
Old way: synchronizing two devices is nontrivial, and it gets more complicated with each additional device.





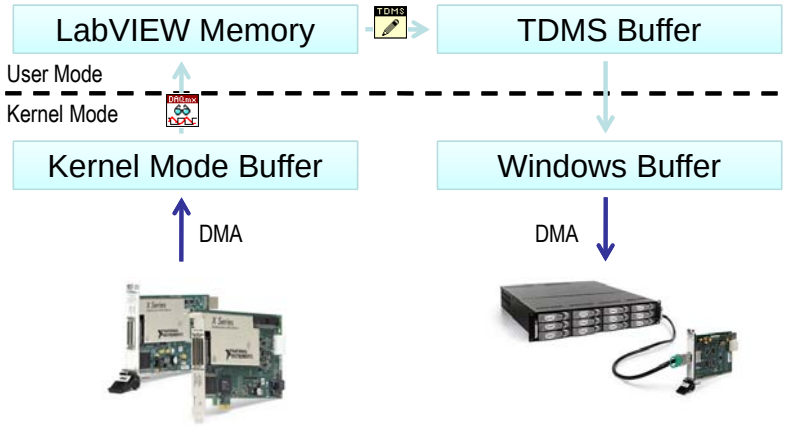
# Synchronizing Multiple X Series

New way: with multidevice tasks (channel expansion), synchronizing 2 or more devices is no more complicated than acquiring from 1 device. Multiplexed and simultaneous.



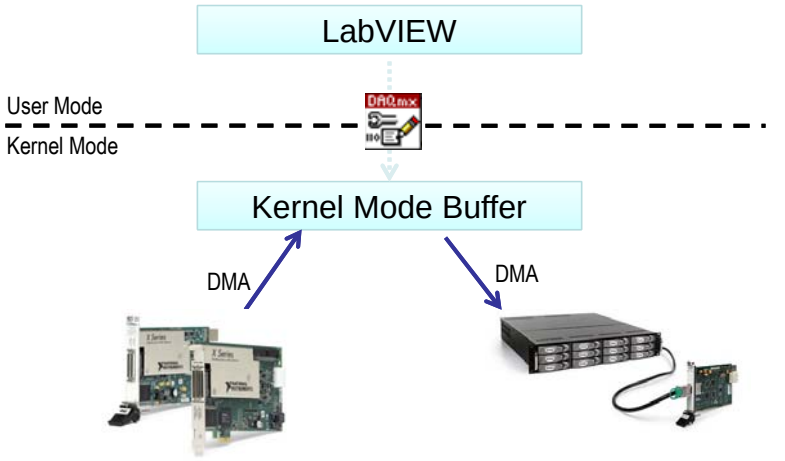

Now, what if we want to log this to disk?

# The Old "Typical" Way to Stream

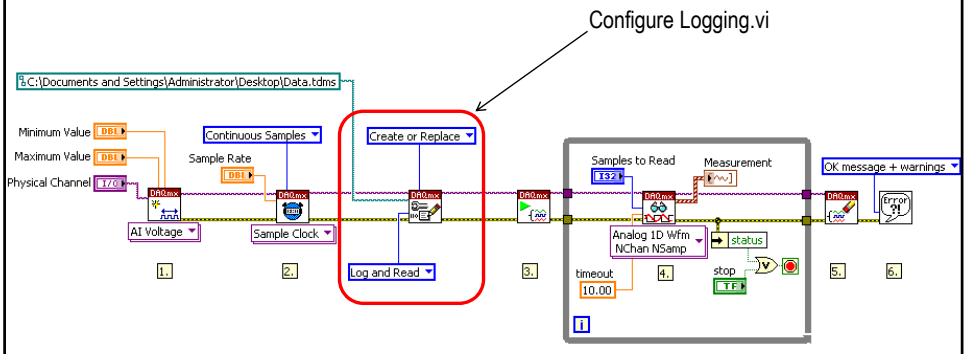





# The New, Fast and Easy Way to Stream



# Multidevice acquisition AND logging

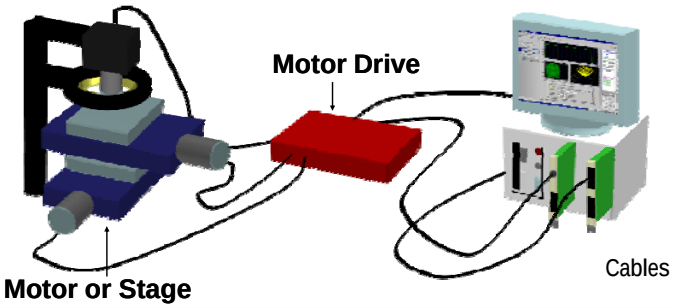





# Hybrid usage

# Motion and DAQ

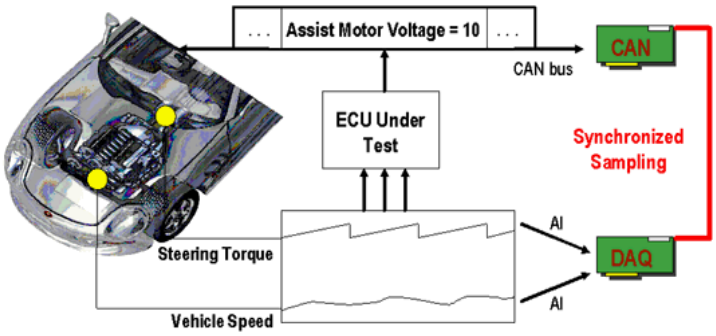
- Trigger from specific position
- Position synced sample clock (no stopping)
- Capture position / halt from measurement event



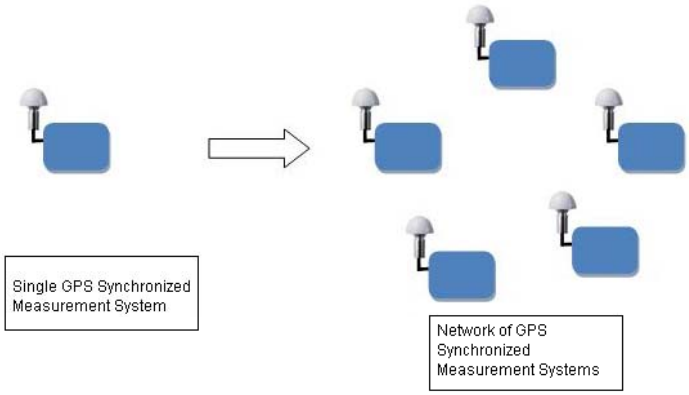



# CAN and DAQ

- Drive CAN frames with measurement events
- Trigger/clock measurements from frame arrival

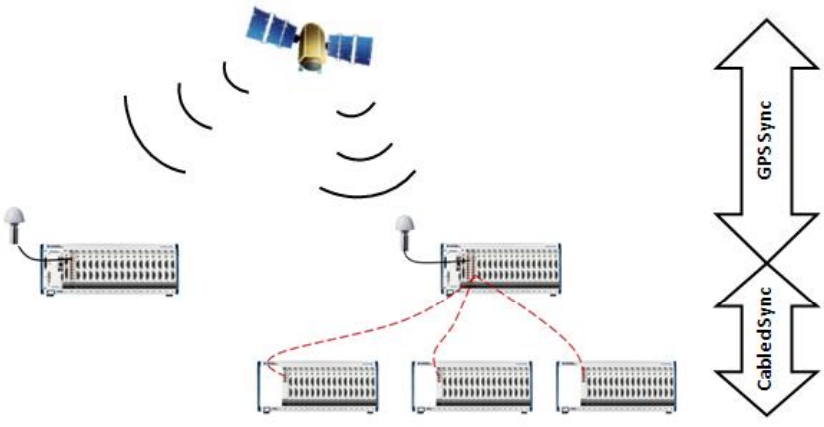


# Distributed Synchronized System



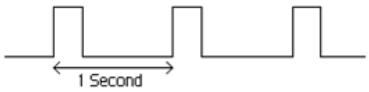



# Distributed Synchronized System



# GPS – PPS (Pulse Per Second )

- Does not contain information about the specific time of day or year
- Outputs a pulse once a second
- The pulse width is generally 100 ms
- 10M PPS - 10M pulses per second. This signal is usually used as the sample base frequency.

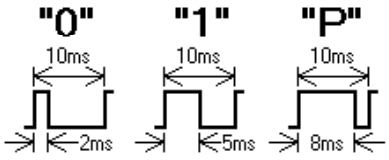


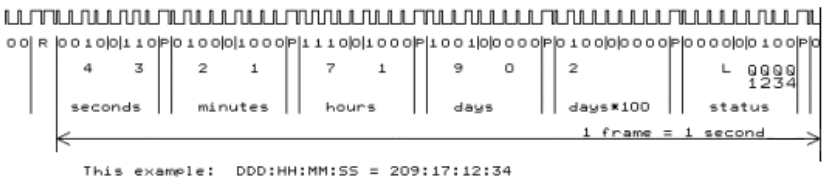

PPS signal



# GPS - IRIG-B Signal

- encoded TTL signal carrying the absolute time
- repeats or re-synchronizes every second

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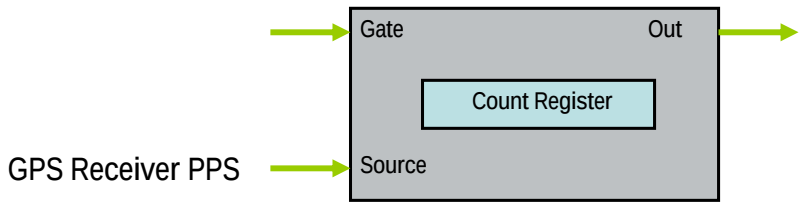
# GPS synchronization between Chassis

Generating a Trigger at a User-Specified Time & Synchronizing Chassis





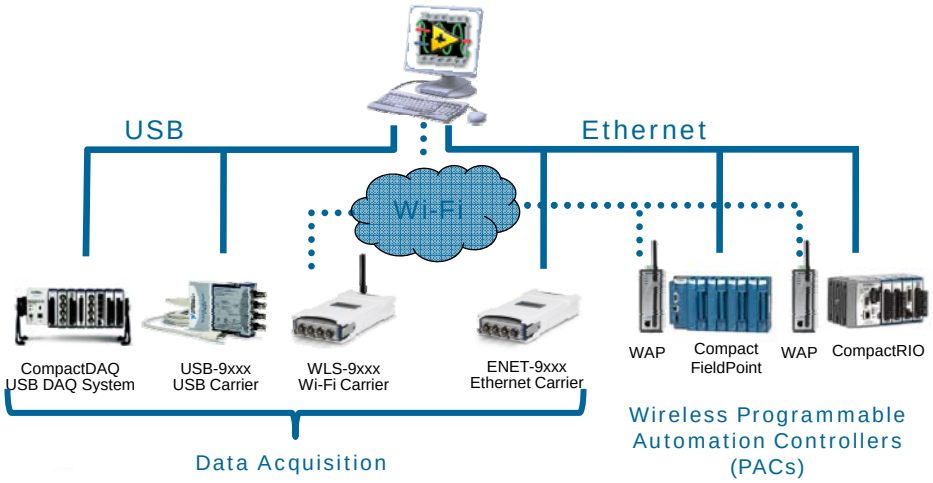

# NI Solution: Performing Structural Health Monitoring

Application:
Structural health monitoring systems with GPS Timing and Synchronization based on LabVIEW and CompactRIO monitor the Beijing National Stadium, the main venue for the 2008 Summer Olympics for stability, reliability, and livability.

Products:
CompactRIO, Real-Time Module, LabVIEW, FPGA Module

"We deployed an embedded monitoring system with unmatched competitive accuracy, price, and flexibility by using LabVIEW and CompactRIO as the computing platform. "

## Wireless: The Next Bus for Data Acquisition






## NI Wi-Fi Data Acquisition

- NI-DAQmx driver software
- 10/100 Base-T/X Ethernet
- IEEE 802.11b/g radio
  - Easy to use
  - Secure (IEEE 802.11i)
  - High bandwidth
  - Established infrastructure

## Researchers Use NI LabVIEW and NI CompactRIO to Perform Environmental Monitoring in the Costa Rican Rain Forest

The Challenge:
Supporting a wide range of wireless environmental measurements using a single device that provides robotic control, remote configuration, and data sharing over the Web for a measurement system that researchers use to characterize the forest understory microclimate and fluxes of carbon between the rain forest floor and the atmosphere.

The Solution:
Using NI LabVIEW software and NI CompactRIO hardware, we developed a wireless sensor system that collects a variety of environmental measurements, offers remote configuration capabilities, permits future expansion, and gives researchers around the world access to the measurements over the Internet.

"Because of the flexibility of LabVIEW, we can configure measurement types, select channels, and even add scaling from a laptop connected to the system. "

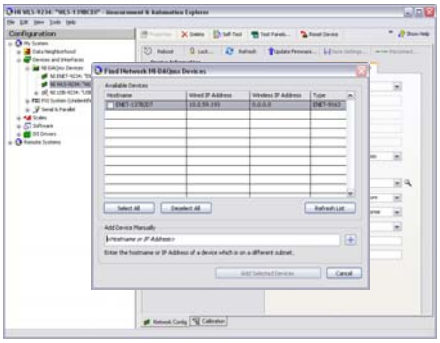


# Introducing Simple. Secure. Wi-Fi DAQ

- IEEE 802.11b/g radio (NI WLS-9163)
- 10/100 Base-T/X Ethernet (NI WLS/ENET-9163)
- NI-DAQmx driver
- DC powered (9-30 VDC)
- C Series module support
  - NI 9211 (4-ch thermocouple)
  - NI 9215 (4-ch SSH ±10V inputs )
  - NI 9234 (4-ch IEPE accelerometers)
  - NI 9237 (4-ch strain gauges)
  - NI 9219 (4-ch universal inputs)

## How does it work?

- Each carrier has two IP addresses (Ethernet & Wi-Fi)
- Configure first with Ethernet, then Go Wireless!
- MAX Setup
  - Device discovery
  - Network configuration
  - Test panels





## Wi-Fi: The Basics

| Version | Released | Frequency | Max Rate | Range |
|---|---|---|---|---|
| 802.11 | 1997 | 2.4 GHz | 2 Mb/s | ~30 m |
| 802.11b | 1999 | 2.4 GHz | 11 Mb/s | 30 m |
| 802.11a | 1999 | 5 GHz | 54 Mb/s | 10 m |
| 802.11g | 2003 | 2.4 GHz | 54 Mb/s | 30 m |
| 802.11n | 2009? | 2.4 GHz | ~540 Mb/s | ~50 m |

- 2.4GHz is an unlicensed band
  - You're competing with cordless phones, Wi-Fi hotspots, and microwaves

# Wireless Bandwidth

- IEEE 802.11g theoretical bandwidth: 54 Mbps
- IEEE 802.11g practical bandwidth: 20 Mbps*
- Ethernet theoretical bandwidth: 100 Mbps

**Single Module Bandwidth**

| Model | Max Rate Per Channel | # Channels | Resolution | Max Bandwidth Consumption |
|---|---|---|---|---|
| WLS/ENET-9211 | 3 S/s[1] | 4 | 24 bit | .000448 Mbps |
| WLS/ENET-9215 | 100 kS/s | 4 | 16 bit | 6.4 Mbps |
| WLS/ENET-9219 | 100 S/s | 4 | 24 bit | .0128 Mbps |
| WLS/ENET-9234 | 51.2 kS/s | 4 | 24 bit | 6.5536 Mbps |
| WLS/ENET-9237 | 50 kS/s | 4 | 24 bit | 6.4 Mbps |

[1]14 S/s max aggregate sample rate

*Dependent upon RF environment



# Accessories: Batteries

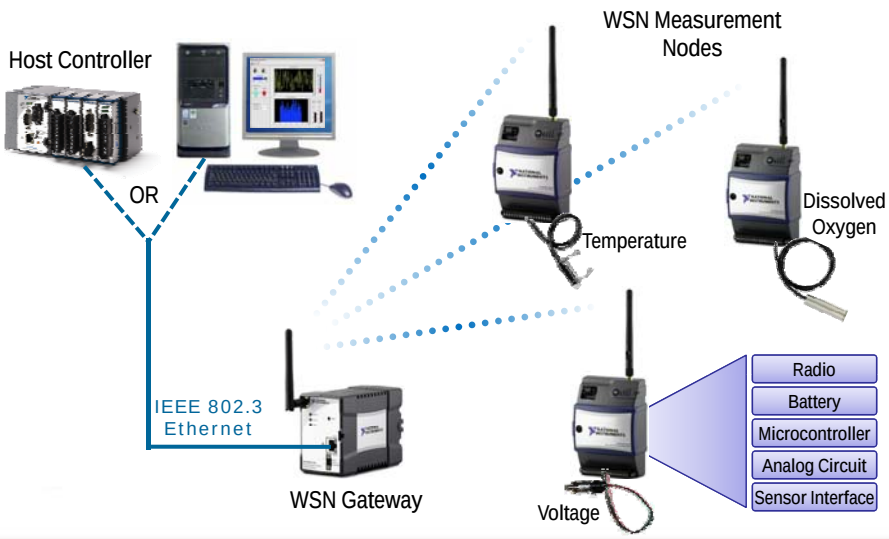
- Wi-Fi and Ethernet sleeves are DC powered
- You can use almost any battery
- Example battery configurations:

| Device | 8 AA Alkaline | 8 AA NiMH | NiMH 4/3 A Pack | Li-Ion 18650 Pack |
|---|---|---|---|---|
| NI WLS-9234 | 5.5 h | 6.9 h | 13.8 h | 15.3 h |
| NI WLS-9219 | 6.9 h | 8.6 h | 17.2 h | 19.1 h |
| NI WLS-9237 | 5.6 h | 7.0 h | 14.0 h | 15.6 h |
| NI WLS-9215 | 5.8 h | 7.3 h | 14.6 h | 16.2 h |
| NI WLS-9211 | 7.7 h | 9.7 h | 19.3 h | 21.4 h |

# Wireless Sensor Network



# WSN System Architecture



## Wireless Terminology

- IEEE 802.11, WiFi
  - Access Point
  - Repeater
  - Client
- IEEE 802.15.4, NI-WSN
  - Gateway
  - Router
  - End Node




## NI-WSN, Based IEEE 802.15.4

- Frequency: 2.4 GHz
- RF Channels: 14 Channels (11-24)
- Data Rate: 250 kbits/s
- Provides:
  - Mesh Routing - Ability for network to detect alternative paths
  - Sleep Mode – Ability end node conserve power and maintain reliable communication

# NI WSN-9791

## Wireless Sensor Network Ethernet Gateway

Features
- 2.4 GHz, IEEE 802.15.4 radio
- 10/100 Ethernet
- Outdoor range up to 300 m
- 9-30 VDC power input

Specifications
- 2U Compact Form Factor
- Panel or DIN rail mounting
- Industrial ratings
  - Operating temperature -30 to 70 °C
  - Industrial shock and vibration, 50 $g_{rms}$
- Status LEDs



# NI WSN-3202 and NI WSN-3212

## Wireless Sensor Network Measurement Nodes

Common Features
- 2.4 GHz IEEE 802.15.4 radio
- Outdoor range up to 300 m
- Multi-year battery life
  - Optional 9-30 VDC power input
- Configurable as a mesh router
- Four bi-directional DIO lines
- Industrial ratings
  - Operating temperature -40 to 70 °C
  - Industrial shock and vibration, 50 $g_{rms}$

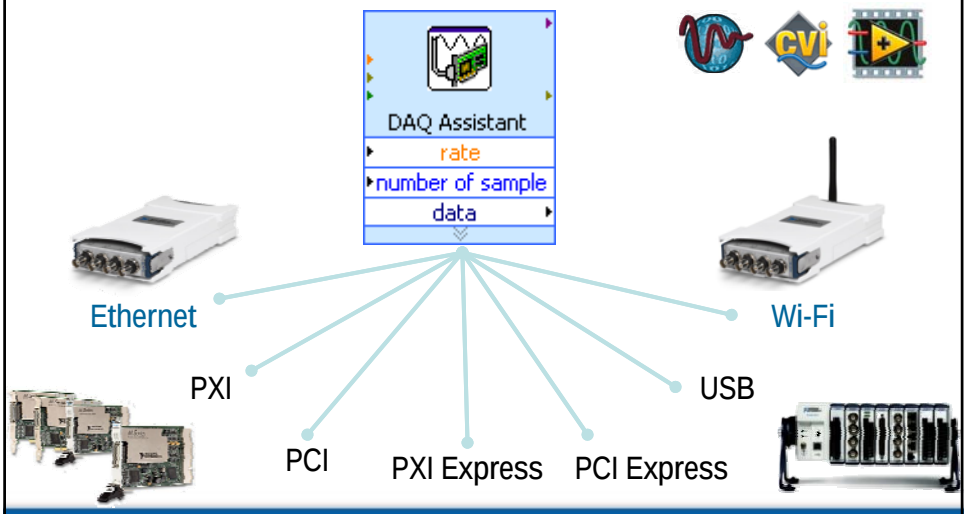
| Node | AI Channels | DIO Channels | Sample Rates | Resolution (bits) | Features |
|---|---|---|---|---|---|
| NI WSN-3202 Analog Input Node | 4 | 4 | 60 samples/min. | 16 | Sensor power: 20 mA @ 12V Input Ranges: ±10 V, ±5 V, ±2 V, ±0.5 V |
| NI WSN-3212 Thermocouple Input Node | 4 | 4 | 30 samples/min. | 24 | Supports types J, K, R, S, T, N, B, E |

## LabVIEW Wireless Sensor Network (WSN) Module *Pioneer*

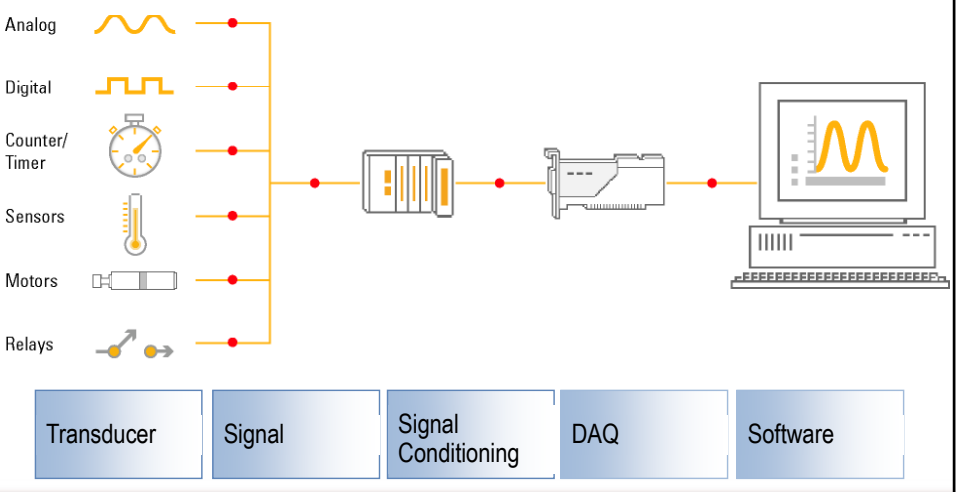
- Extend battery life
  - Transmit only meaningful data (threshold, averaging, dead-band)
  - Adapt sample and transmission rates to operating conditions
- Perform custom analysis
  - Convert raw data into meaningful information
  - Interface to sensors
- Reduce response time with embedded decision making
  - Control actuators without host interaction



## Multiple Bus Technologies With Same API



# PC-Based Data Acquisition (DAQ)




Transducer | Signal | Signal Conditioning | DAQ | Software



# Questions ?

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