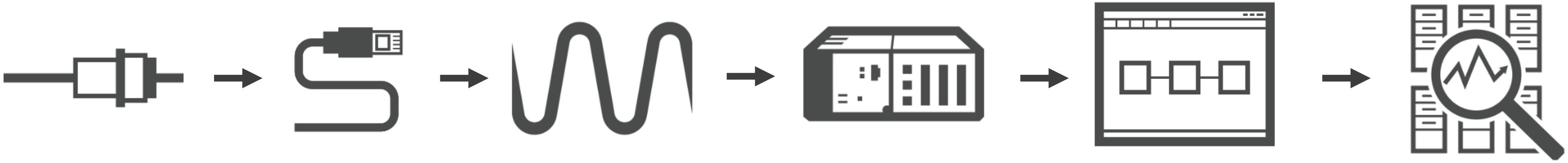
NIDays

ENGINEER NEXT

Practical Advice for Building a DAQ System

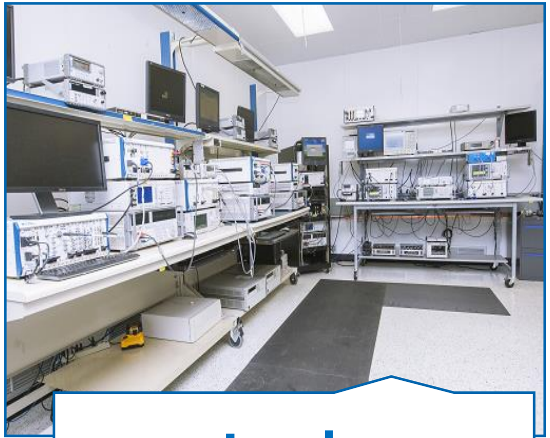


Topics to Cover

- What is a DAQ System?
- What is the Purpose of a DAQ System?
- Elements of a DAQ System
- Now You’re Ready!

What is a DAQ System?

Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound with an acquisition device. A DAQ system consists of many elements from the sensor to the data analysis


Lab

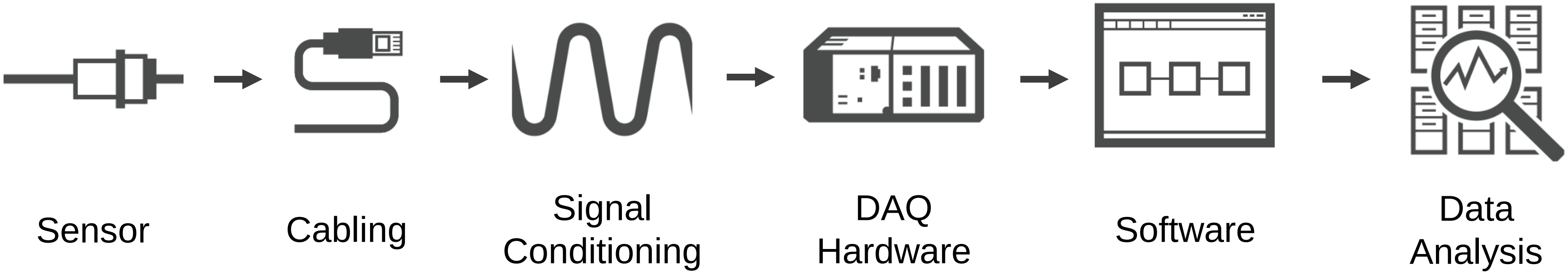

Test Cell


Structural

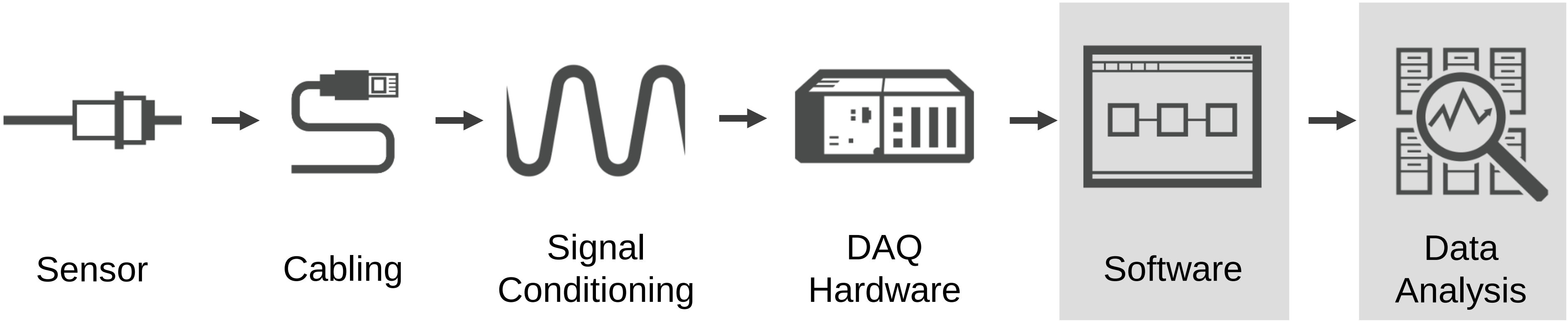
What is the Purpose of DAQ System?

Research & Analysis	Characterizing and logging behaviors or properties
Design Validation & Verification	Testing adherence to an industry standard
Manufacturing & Quality Test	Performing functional and system-level product test
Diagnostics and Repair	Manual and ad-hoc troubleshooting
Asset Condition Monitoring	Long-term, continuous monitoring of equipment
PC-based Control & Automation	Performing open-loop and closed-loop control, such as PID

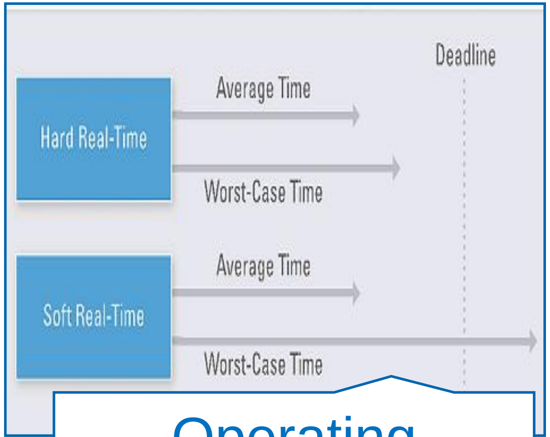
Elements of a DAQ System



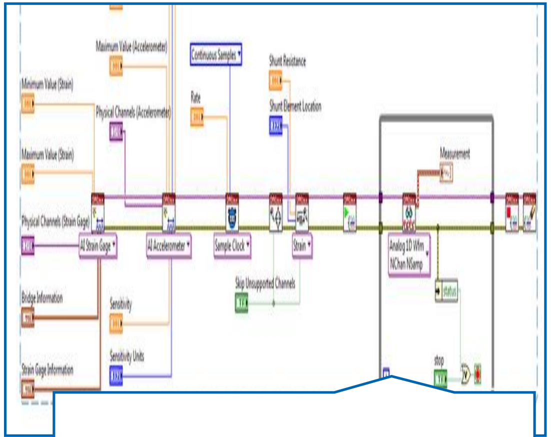
Elements of a DAQ System



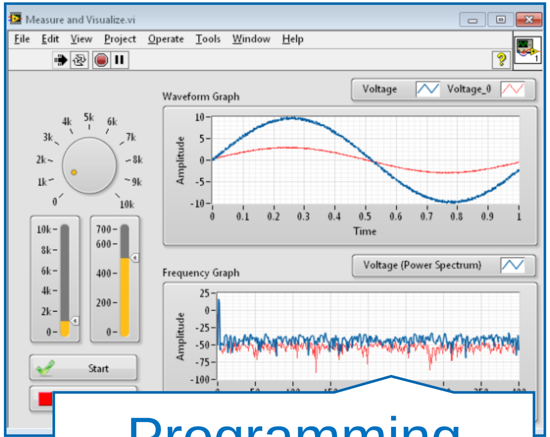
What Software Do I Use?



Operating System

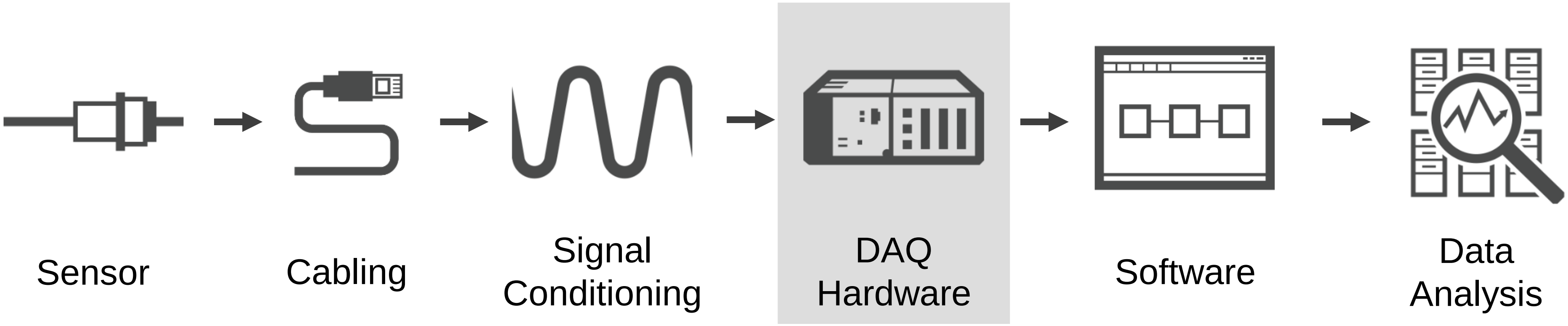


Hardware Driver



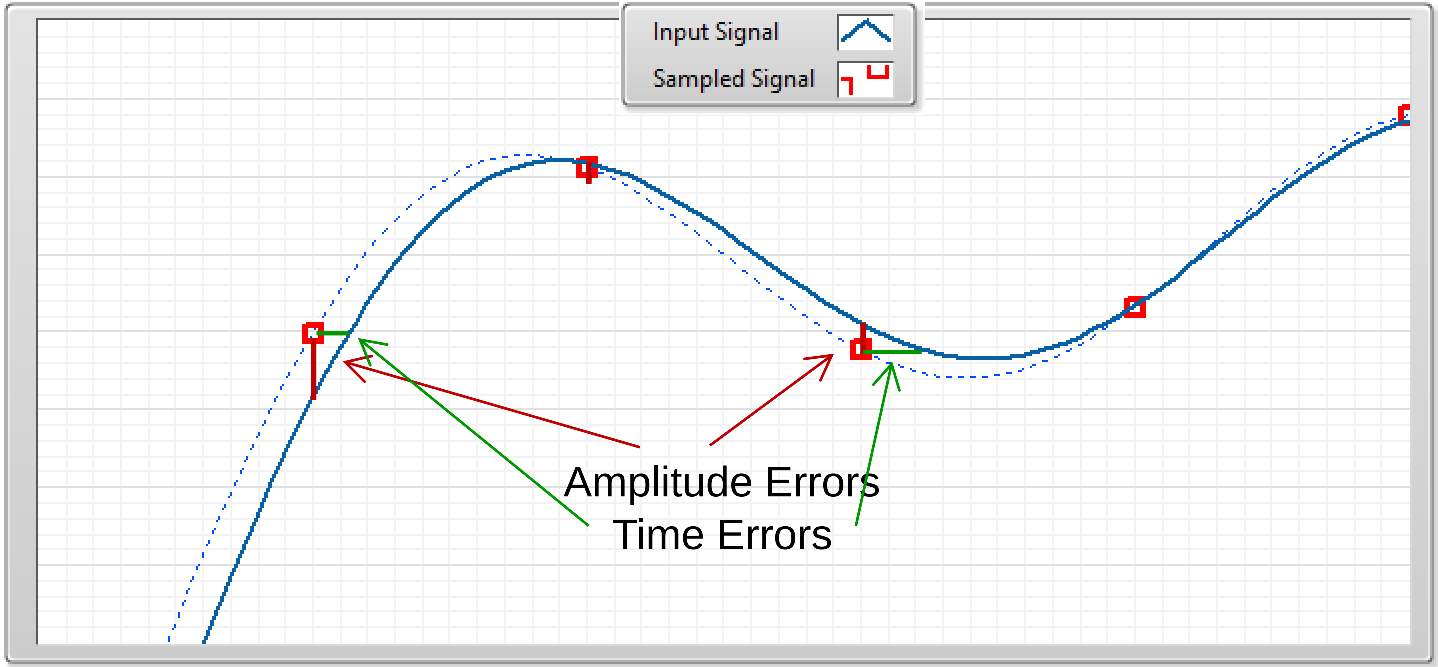
Programming Environment

Elements of a DAQ System



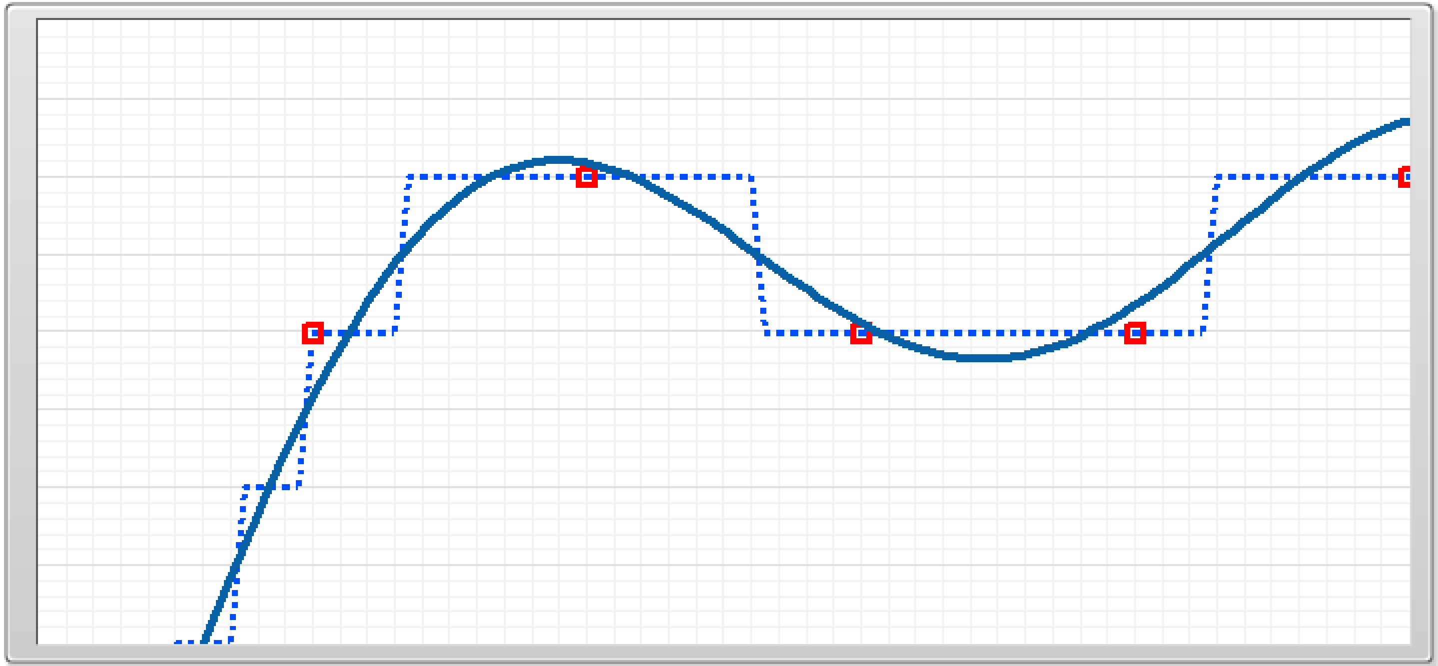
Data Acquisition Hardware

Acquiring one or more measurements in both amplitude and time



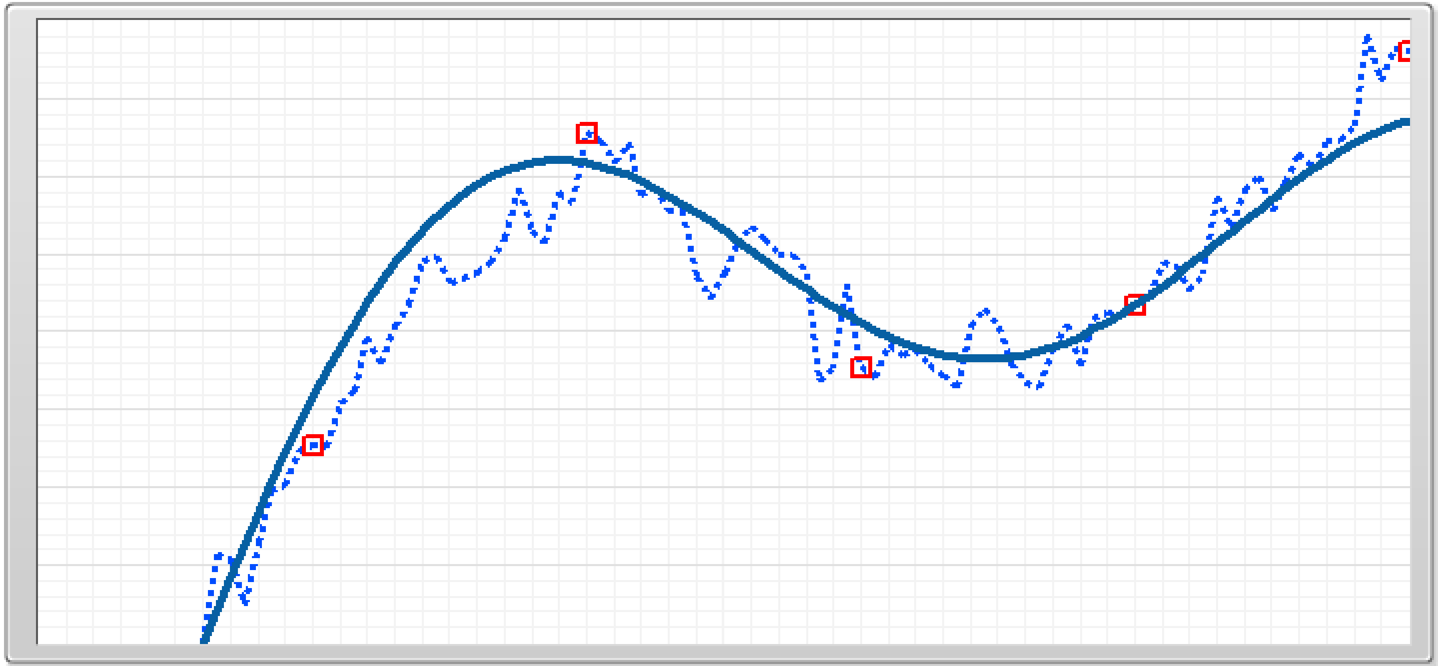
Measurement Resolution

Limited by quantization error (number of bits)



Measurement Resolution

Also limited by noise



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Resolution and Gain

- RESOLUTION limits your measurements' PRECISION
- Both quantization error ("bits") and noise impact resolution

- Example: 16-bit PXI-6361
  - Noise dictates resolution at high gains

Gain	Input Range	Bit Size	Random Noise
1	±10V	300 µV	315 μV_{rms}
2	±5V	150 µV	157 μV_{rms}
5	±2V	60 µV	64 μV_{rms}
10	±1V	30 µV	38 μV_{rms}
20	±0.5V	15 µV	27 μV_{rms}
50	±0.2V	6 µV	21 μV_{rms}
100	±0.1V	3 µV	17 μV_{rms}

Resolution and Gain

- RESOLUTION limits your measurements' PRECISION
- Both quantization error ("bits") and noise impact resolution

- Example: 16-bit PXI-6361
  - Noise dictates resolution at high gains

- Another Example: 24-bit NI 9251
  - Only has a single gain-
  - Only needs a single gain!

Gain	Input Range	Bit Size	Random Noise
1	±10V	300 µV	315 μV_{rms}
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50	±0.2V	6 µV	21 μV_{rms}
100	±0.1V	3 µV	17 μV_{rms}
		NI 9251	
1	±4.25V	0.5 µV	9 μV_{rms}

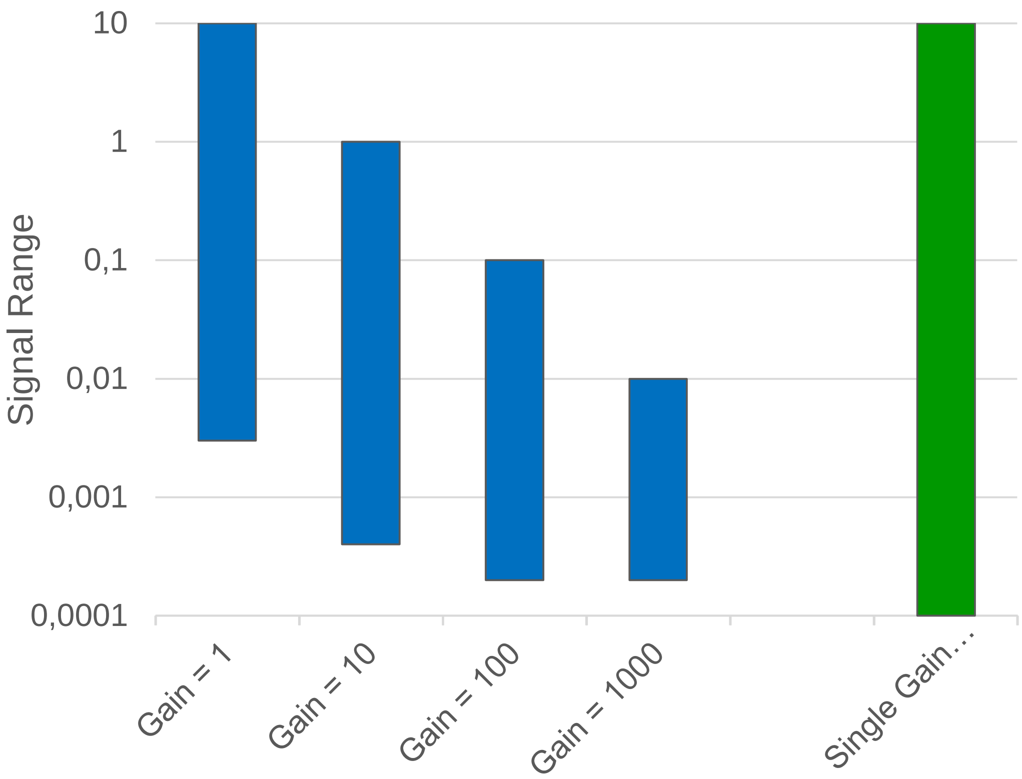
Programmable gain is a crutch for limited resolution

MYTH

- “Use gain to match the input range to the signal range, or else you are throwing away resolution”

REALITY

- Choose your DAQ Hardware to have enough resolution for your application, resorting to gain that limits your range only if necessary



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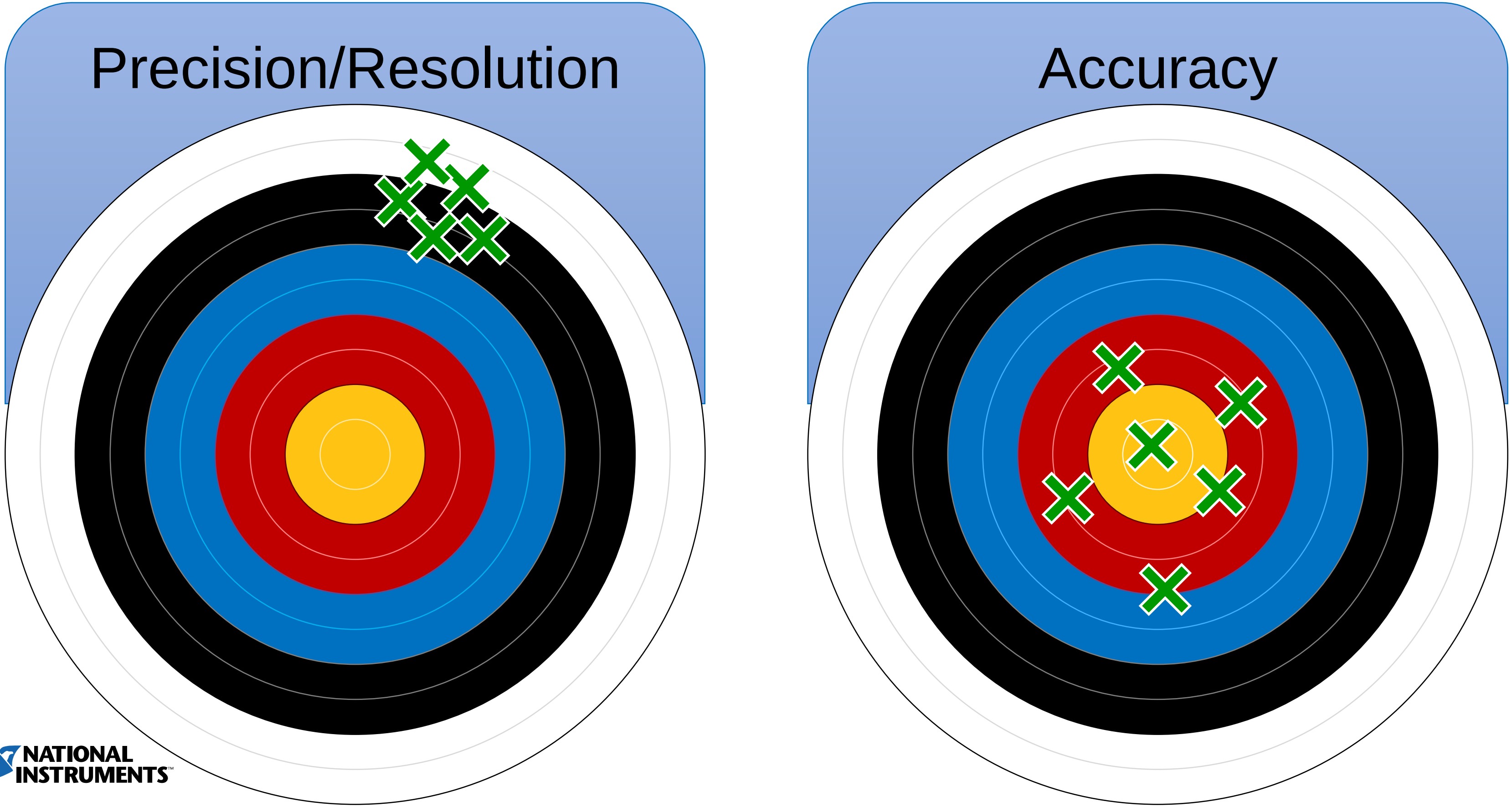
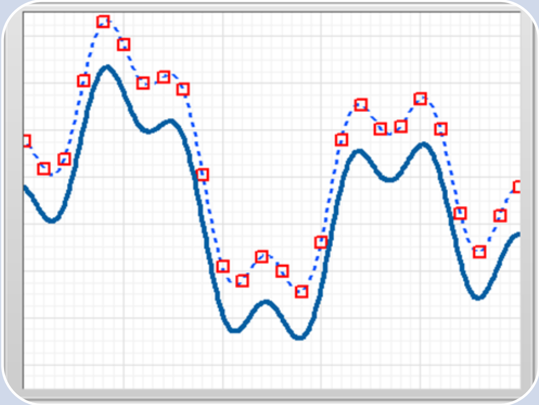
Resolution vs Accuracy



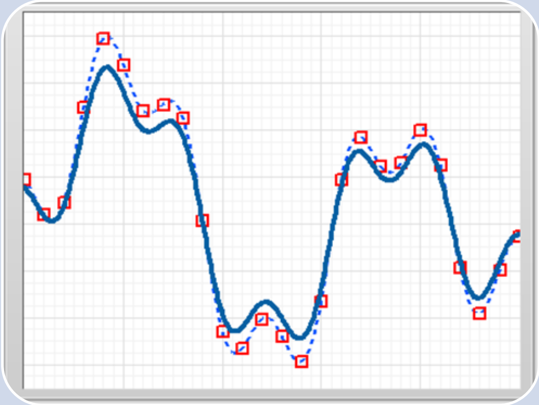
Different Types of Error Combine to Limit Accuracy

Your application may be more sensitive to one form of error than to others



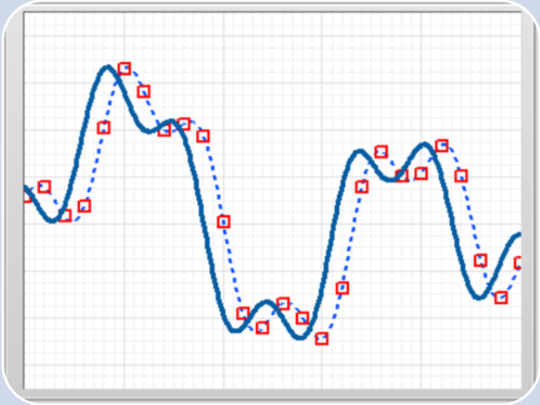
Offset Error

- Shifts readings by constant value



Gain Error

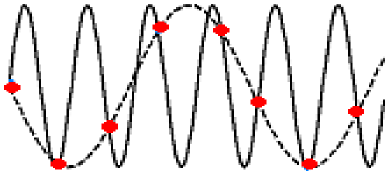
- Scales readings proportionally

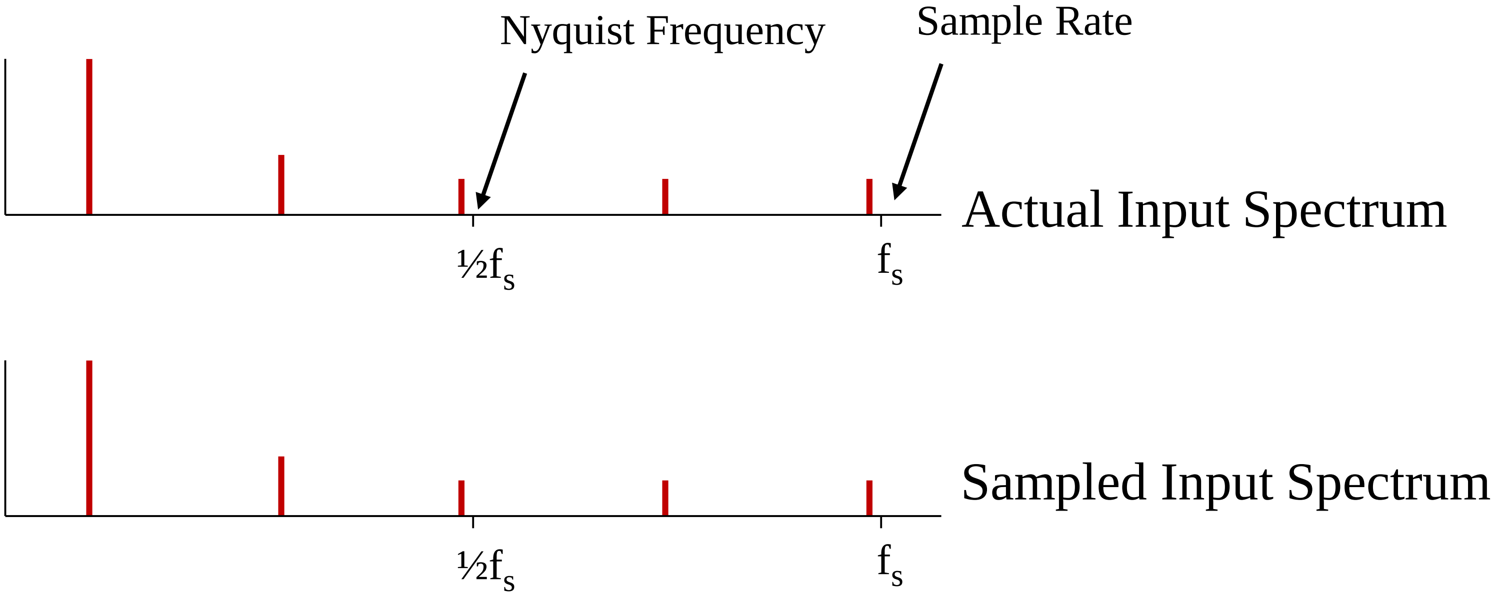


Delay (Latency)

- Shifts readings in time

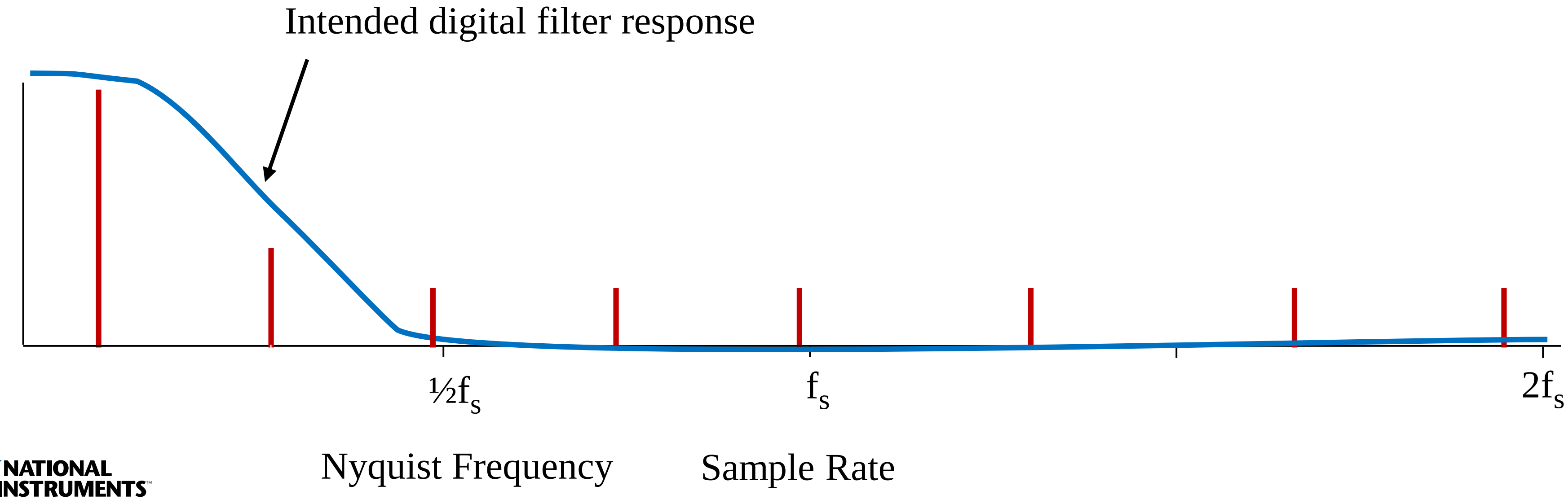
Aliasing from Sampling





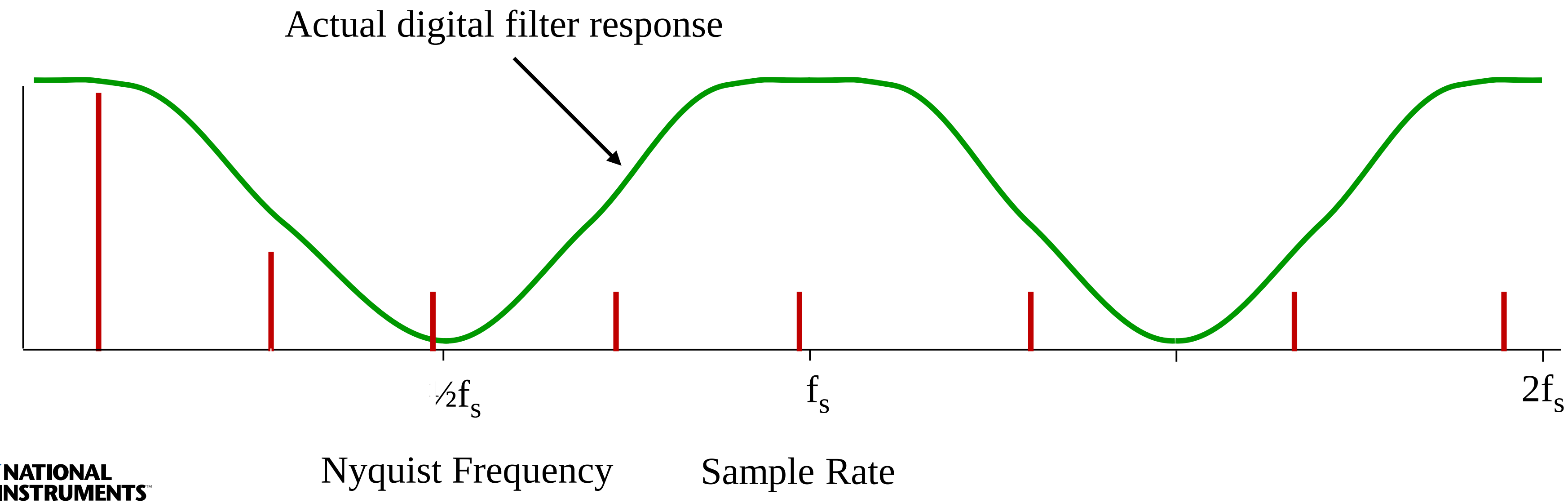
Anti-Aliasing before Software Digital Filtering

- Digital filtering of sampled data can have unexpected results



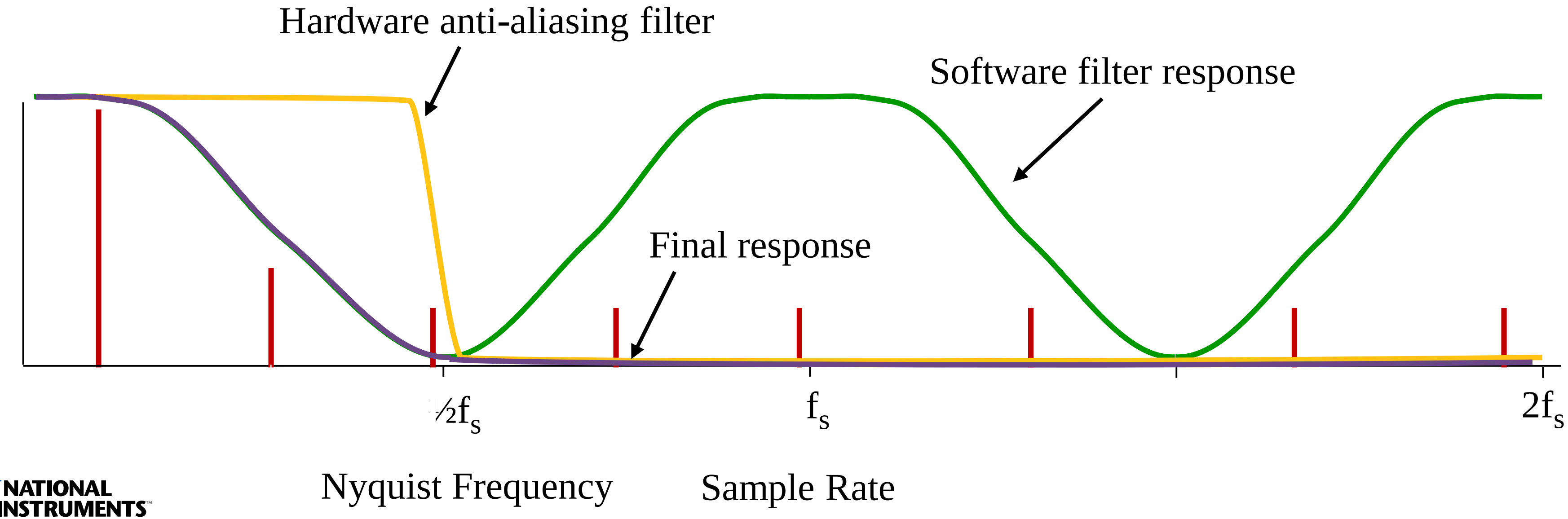
Anti-Aliasing before Software Digital Filtering

- Digital filtering of sampled data can have unexpected results
- Actual filter response is aliased as well

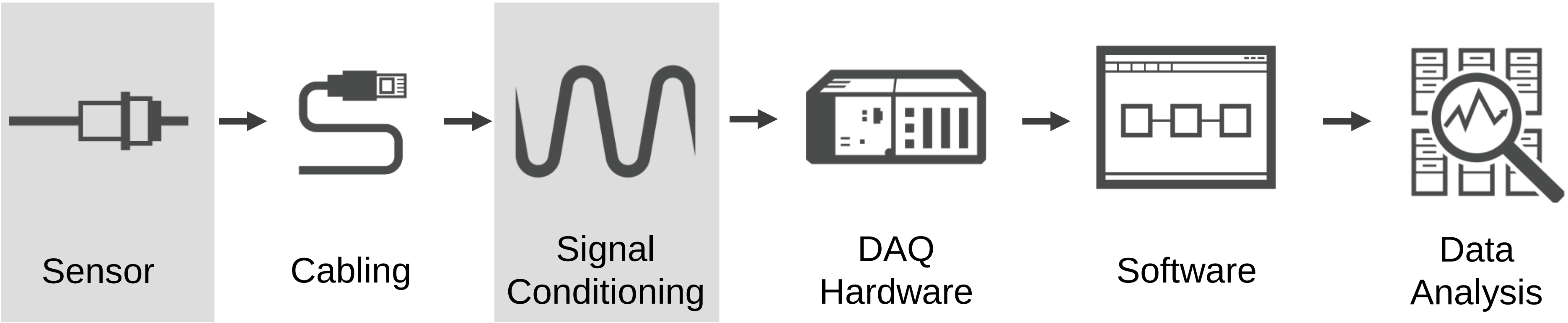


Anti-Aliasing before Software Digital Filtering

- Digital filtering of sampled data can have unexpected results
- Actual filter response is aliased as well
- Use hardware anti-aliasing filters to prevent aliasing of software filters



Elements of a DAQ System



Data Acquisition Hardware and Signal Conditioning

Signal Conditioning

Integrated Hardware & Signal Conditioning

DAQ Hardware

- Designed for specific measurement types
- Improved accuracy of measurement
- Integrate newer technologies
- Fewer system components

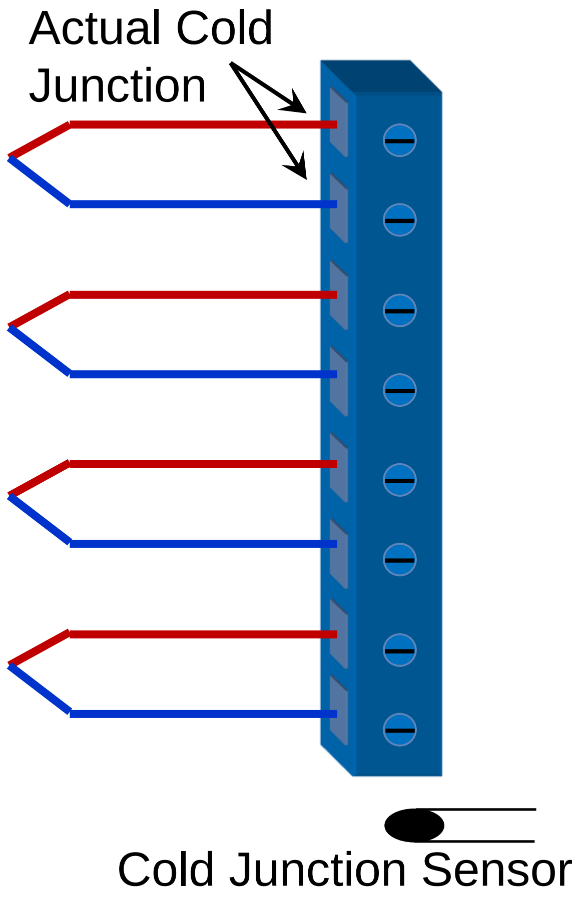
Do You Need Signal Conditioning?

- There are many different types of signal conditioning
- You will need conditioning for certain sensor types
  - RTD
  - Thermocouple
  - Strain gage
  - Bridge sensors
  - Accelerometers
- You may need conditioning based on what you're measuring and the environment you are in
  - Amplification
  - Attenuation
  - Isolation
  - Filtering

Thermocouple Measurements

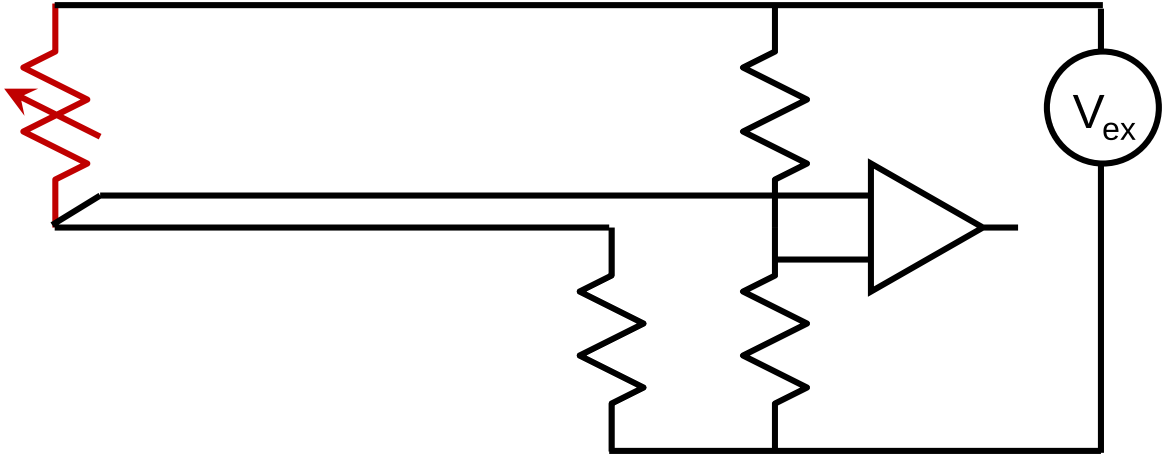
- Adjust for cold junction temperature
- Isothermal error:
  - Temperature difference between actual cold junction and cold junction sensor
- **Isothermal terminal blocks** designed to minimize temperature gradients

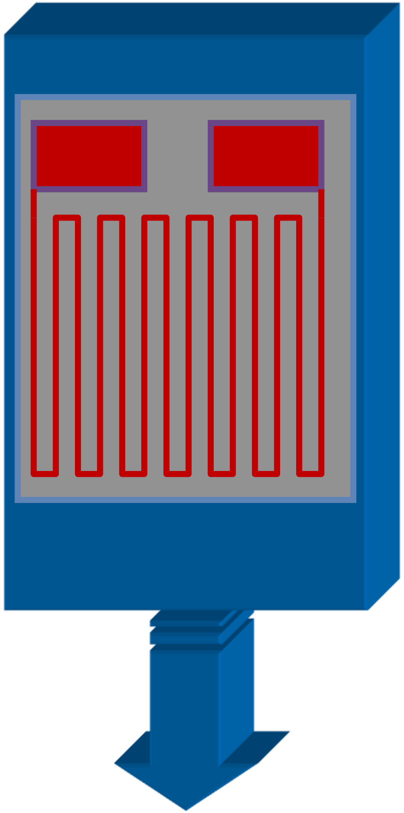
- Millivolt level signals- 10 to 60 µV per °C
- Sensitive to noise pickup
- **50/60Hz comb filters** to reject powerline noise



Strain Gages

- Resistance changes with strain
- Sensitive to small (~0.1 milliohm) changes
- Measured with Whetstone Bridges





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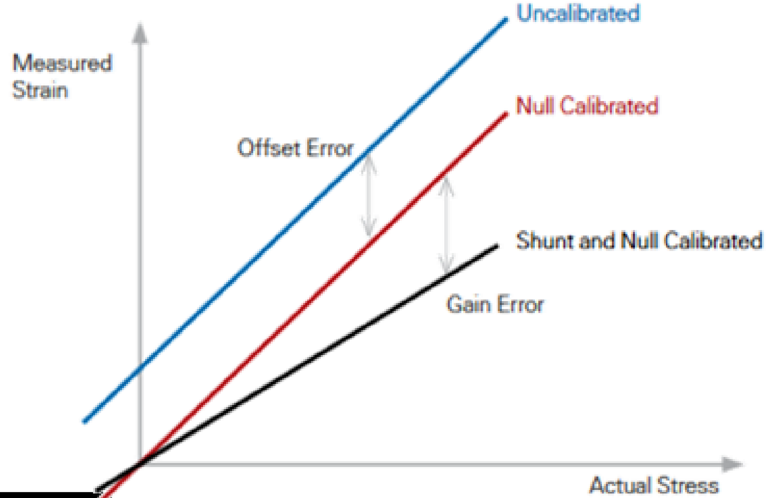
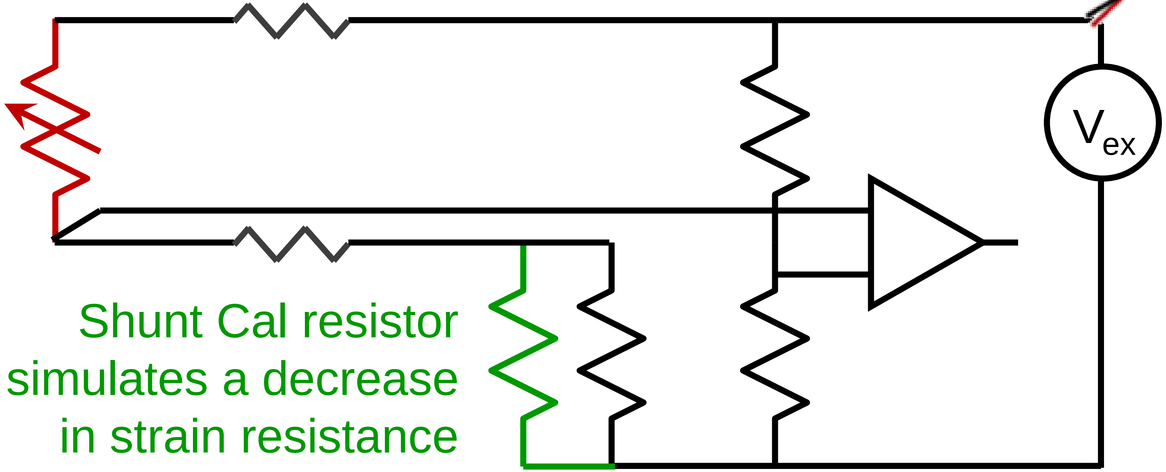
Strain Gages

- Cable resistance creates offset and gain errors
- **Offset nulling (Tare) adjusts offset error**
- **Shunt Calibration corrects for gain errors**

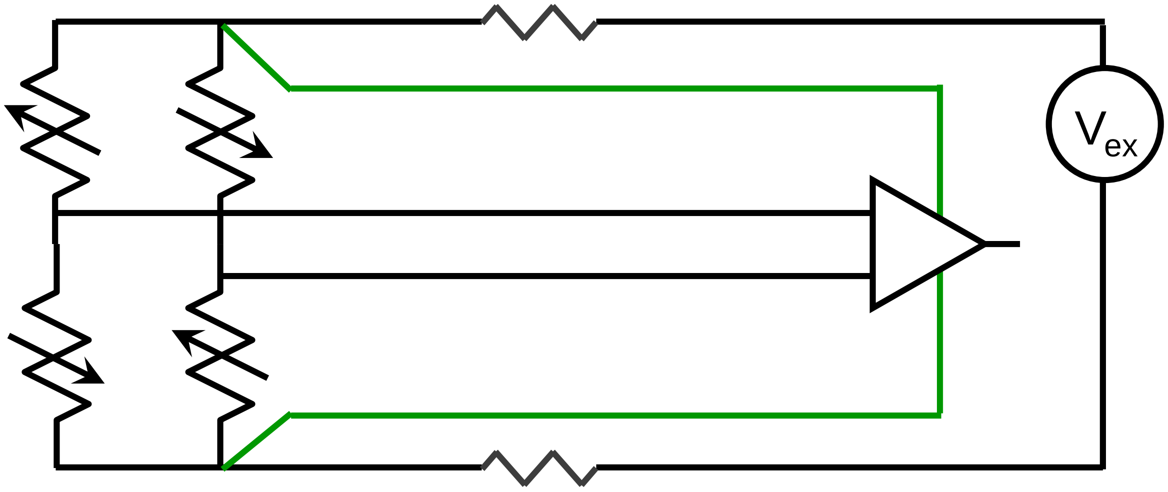




Strain Gage based sensors

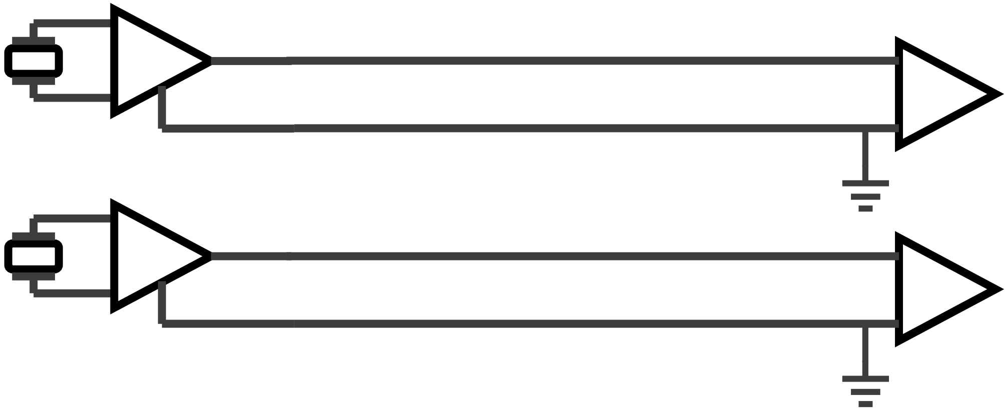
- Cable resistance creates gain errors
- **Remote Sense corrects for gain errors**
- Measure ratio of signal to excitation
- **National Instruments bridge modules directly measure ratiometrically**

Load, Pressure, Force, Torque



Single Ended Inputs

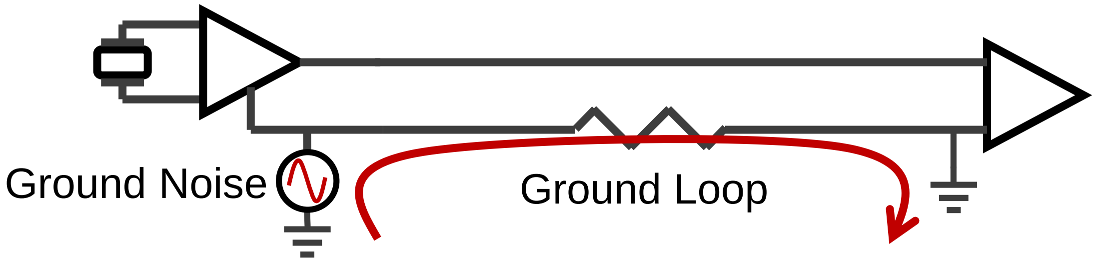
- Most suitable with floating Sensors
  - Provides a single connection to ground
  - Often provides lowest cost per channel



Floating (isolated) Sensors

Single Ended Inputs and Ground Loops

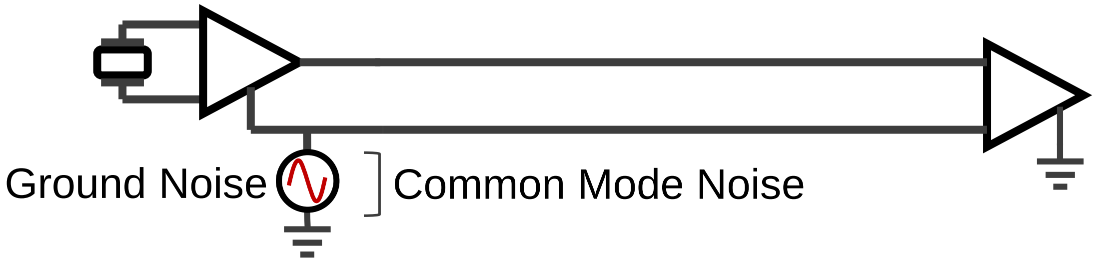
- Grounded Sensors with Single-ended Measurements
  - “Grounds” are never exactly the same
  - Create potential for Ground Loops
  - Create measurement errors in cabling
  - Better choice: use Differential Measurements



Grounded Sensor

Differential Inputs to Break Ground Loops

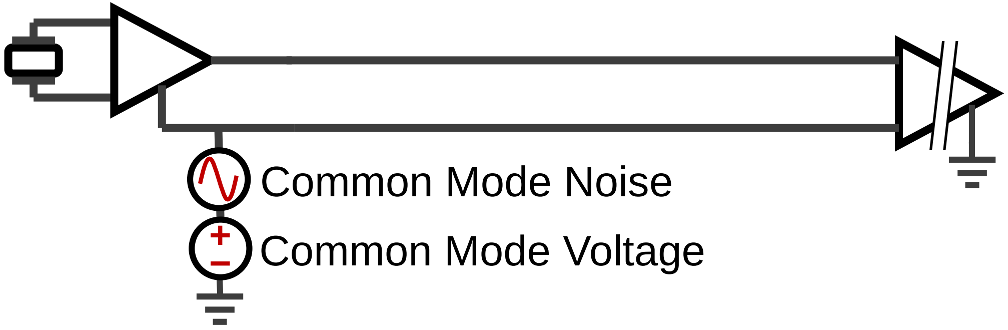
- High impedance of differential inputs break ground loops
  - Ground noise now becomes Common Mode noise
  - Rejected by Common Mode Rejection Ratio (CMRR) of measurement device
  - Limited to Common Mode Range of measurement device (e.g., 10 V)



Grounded Sensor

Isolated Inputs

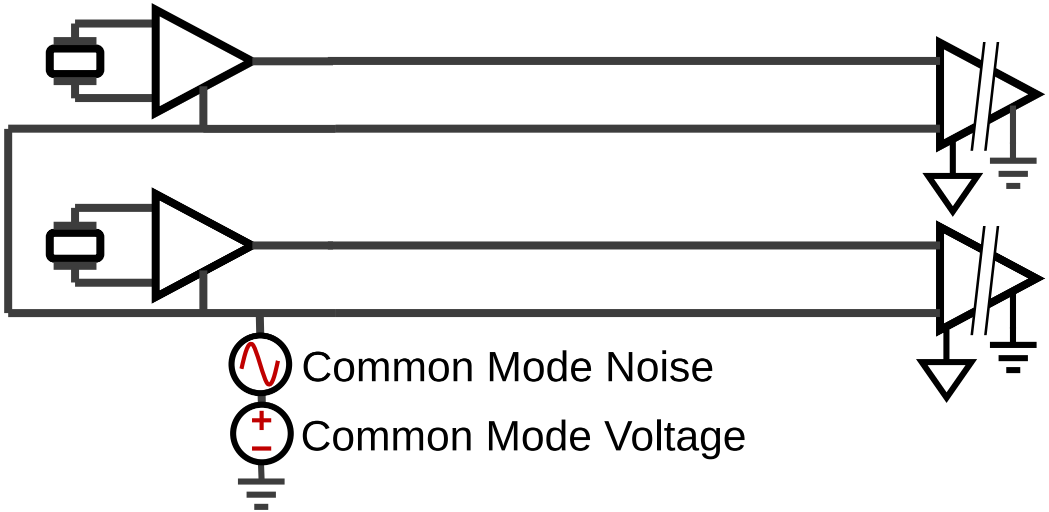
- Inputs isolated from ground provide higher common mode voltage range
  - Improved Common Mode Rejection Ratio (CMRR)
  - Typical common mode ranges are 60 Vdc or 250 Vac
  - Fault withstand levels can be thousands of volts
  - “Isolation” at National Instruments implies “Galvanic Isolation”- no conductive path



Ground Referenced Sensor

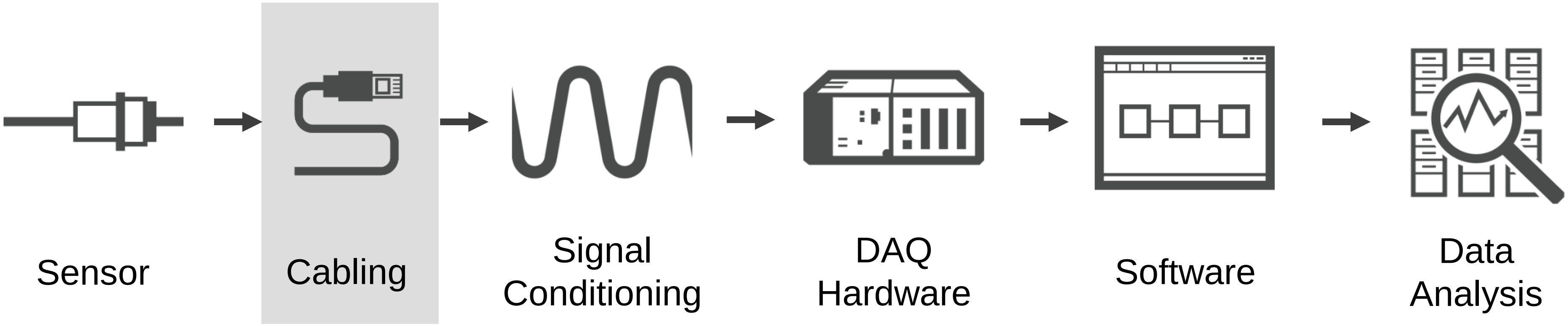
Bank Isolated Inputs

- Multiple input channels, isolated from ground, but not each other
  - High common mode voltage and CMRR to Earth
  - Lower common mode voltage and CMRR to Isolated Ground



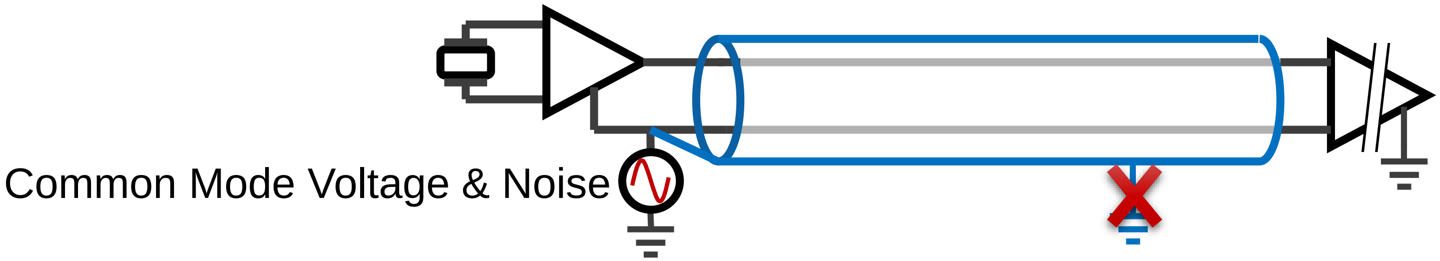
Ground Referenced Sensors

Elements of a DAQ System



Isolated Inputs

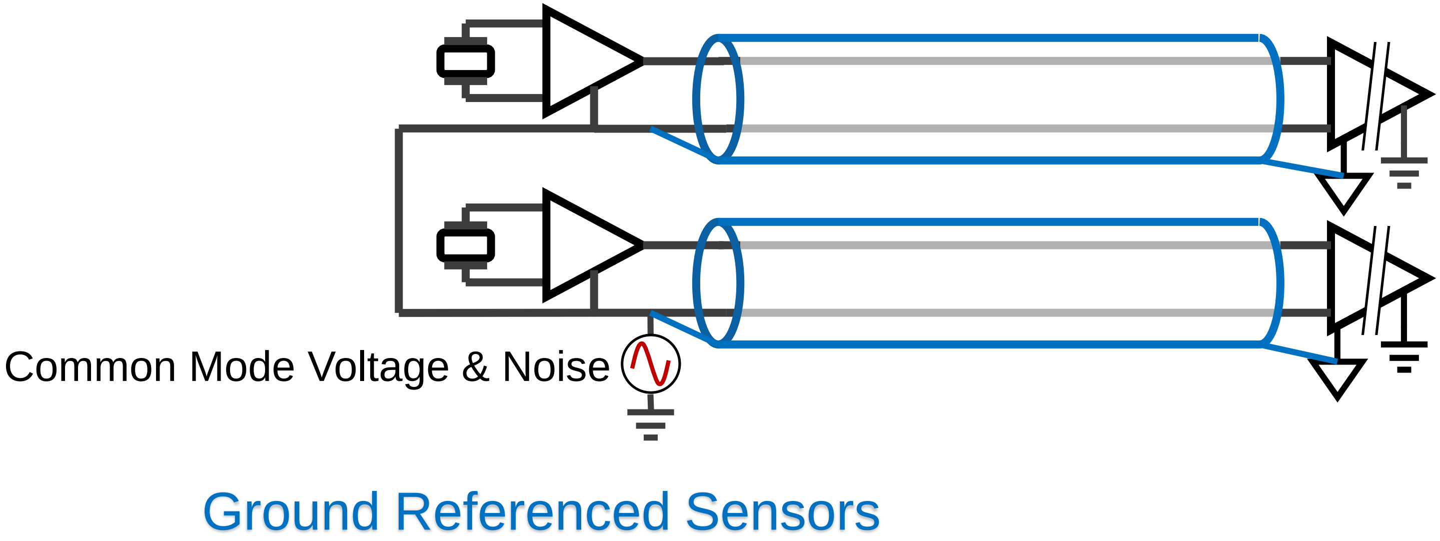
- When signal reference is noisy relative to Earth ground…
- Earth ground becomes a (relative) noise source!
- Connect shields to signal ground



Ground Referenced Sensor

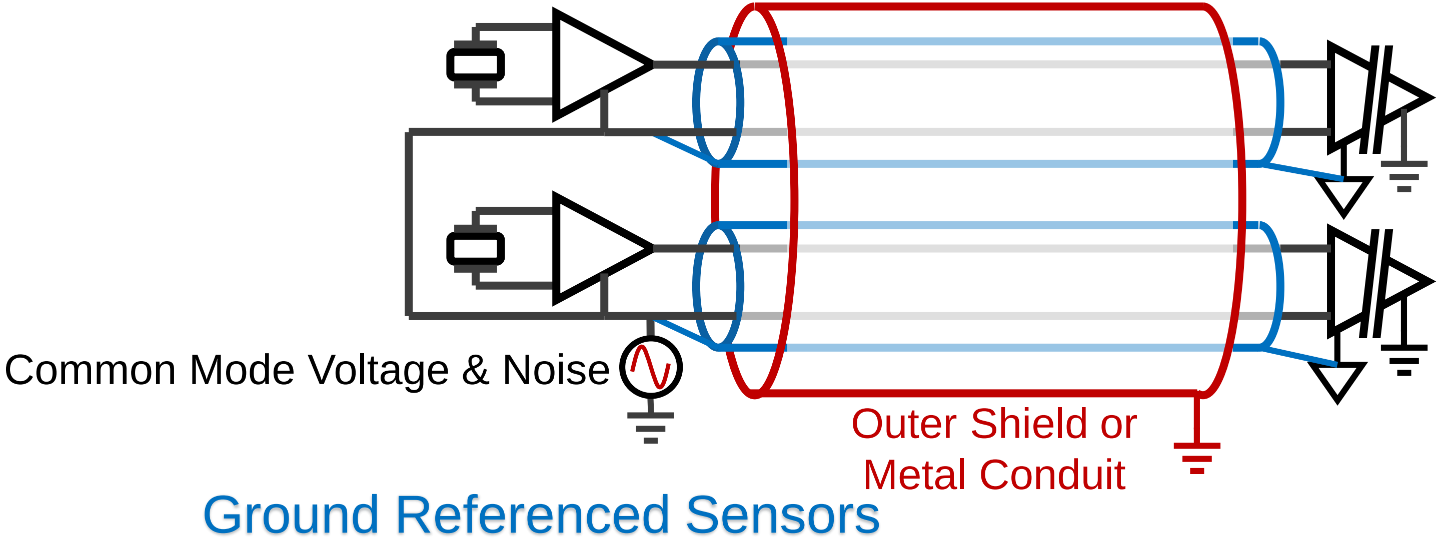
Bank Isolated Inputs

- Shields are still connected to the local signal reference
- Also connect Shield(s) to isolated measurement ground/common

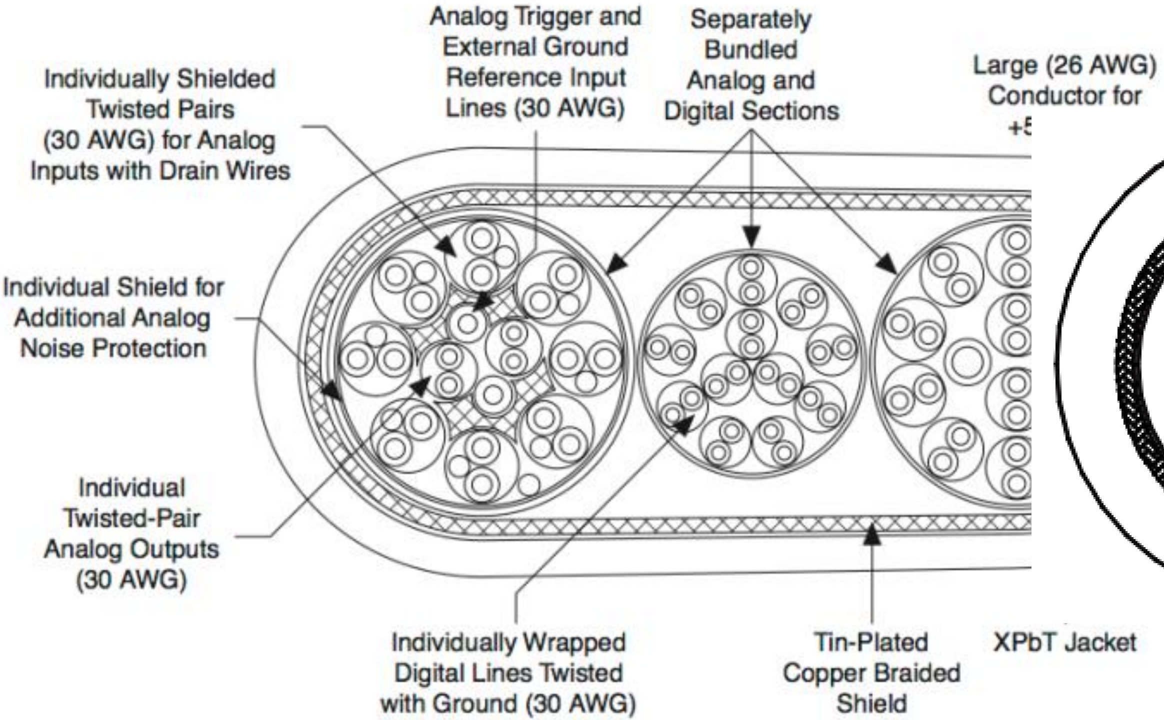


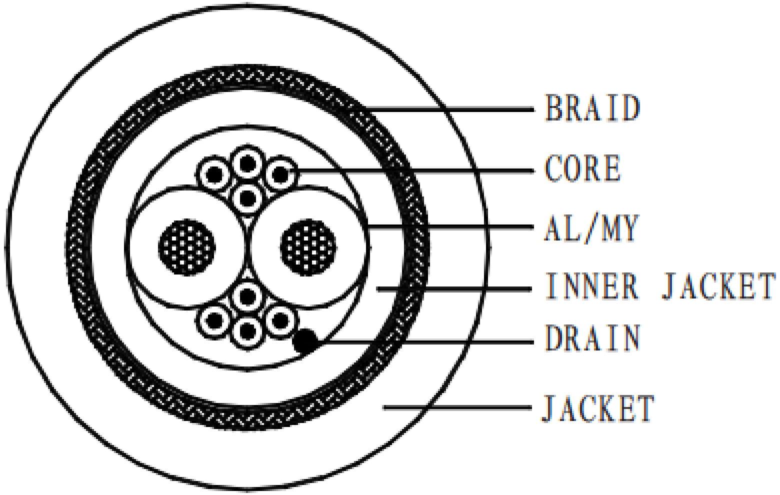
Double-Shielded Cables

- Inner shield tied to measurement ground, outer shield tied to Earth ground
  - Inner shield protects signal pair(s)
  - Outer shield reduces common mode noise pickup
  - Outer shield blocks common mode noise emissions



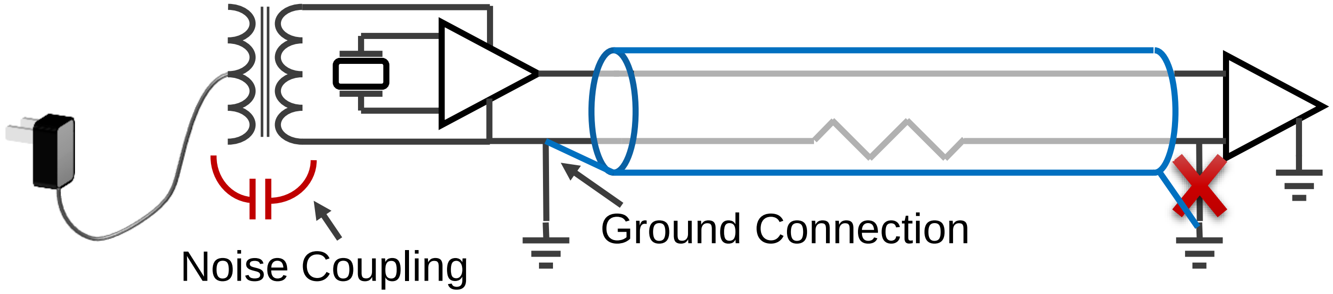
Double-Shielded Cables





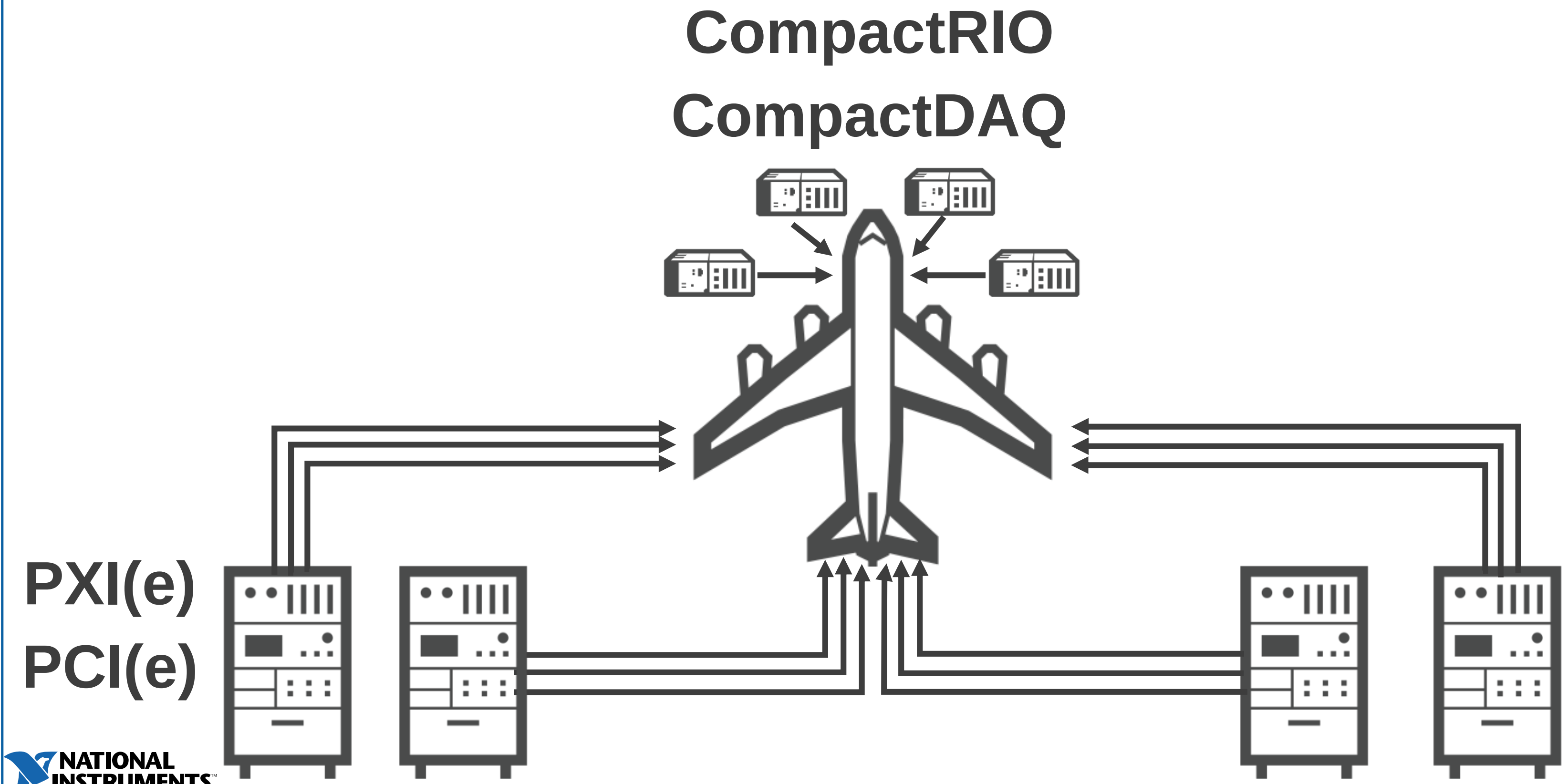
Floating Sensors

- Isolated signal sources with no direct connection to ground
  - Pick up common mode noise easily
  - Make ONE connection to ground
  - Ground near most likely noise source
  - Connect shields to ground
    - Shield connection point is less important
    - Ground loops in shields are less concerning



Floating Sensor

Minimizing Sensor Cable Lengths



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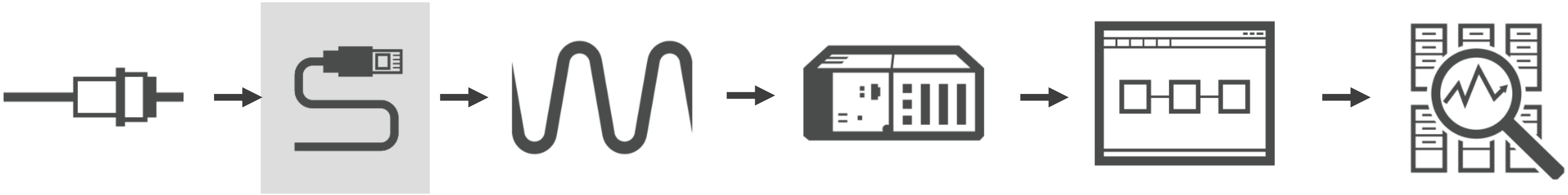

Key Things to Remember

- Signals should have one, and only one, reference connection to Earth ground
- Connect inner shields to this reference connection (the signal ground)
- Connect outer shields or conduit to Earth ground
- Place measurement devices closer to sensors to limit cable noise pickup

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