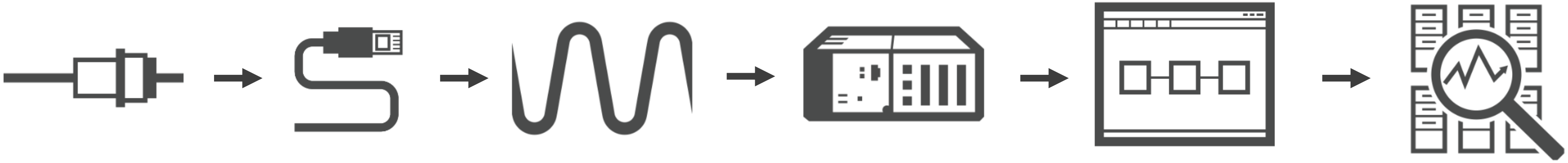
NIDays

ENGINEER NEXT

# Conseils pratiques pour monter un système d’acquisition de données



# 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!

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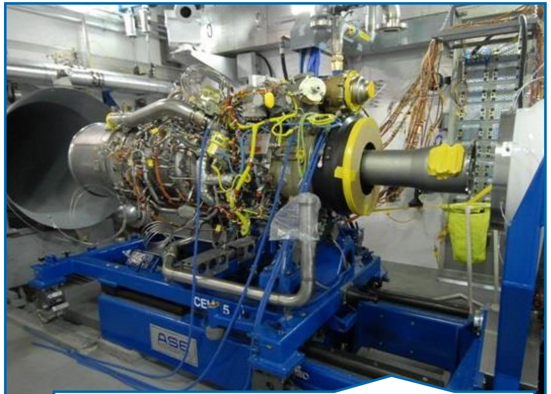
# What is a DAQ System?

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



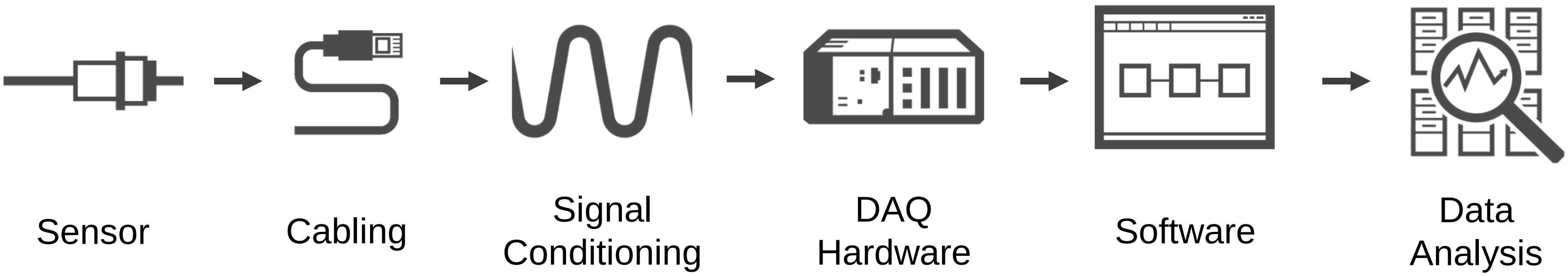
Test Cell

Structural

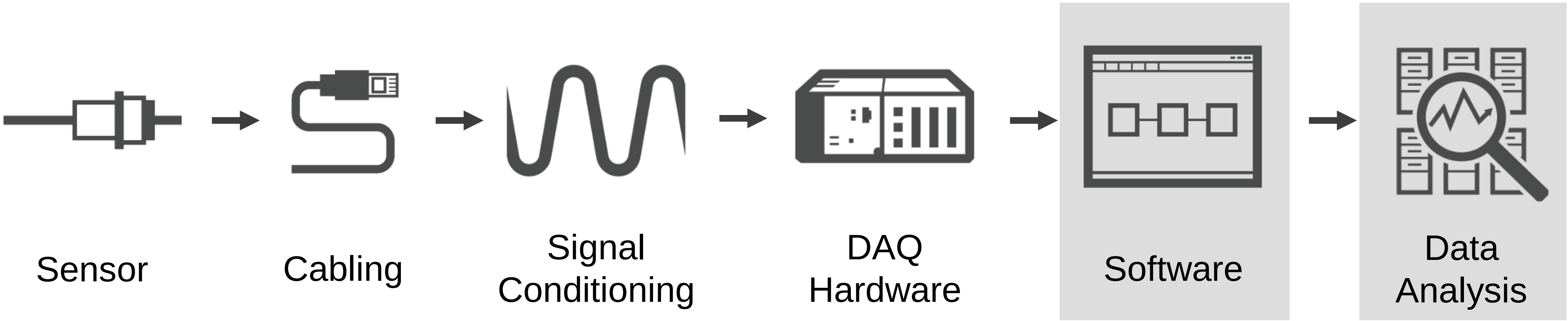
# What is the Purpose of DAQ System?

| | |
|---|---|
| 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 |

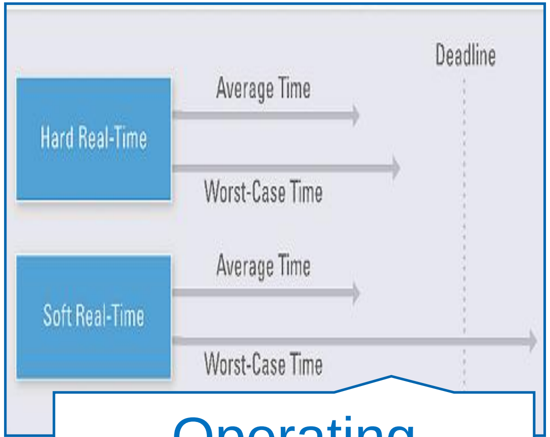
# Elements of a DAQ System



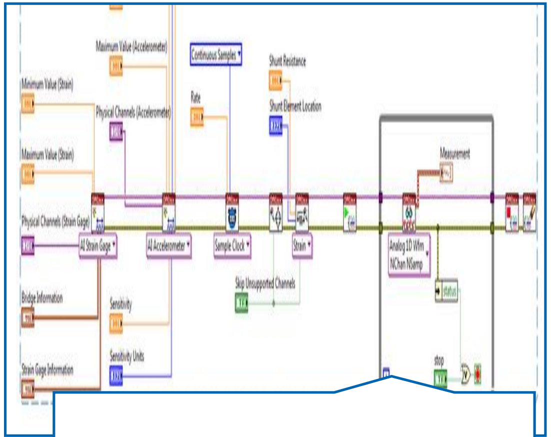
# Elements of a DAQ System



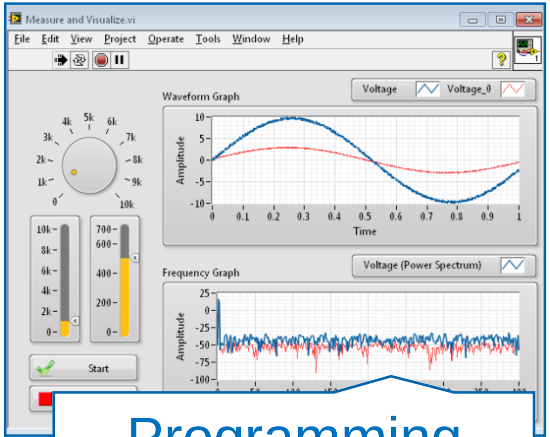
# What Software Do I Use?




Operating System

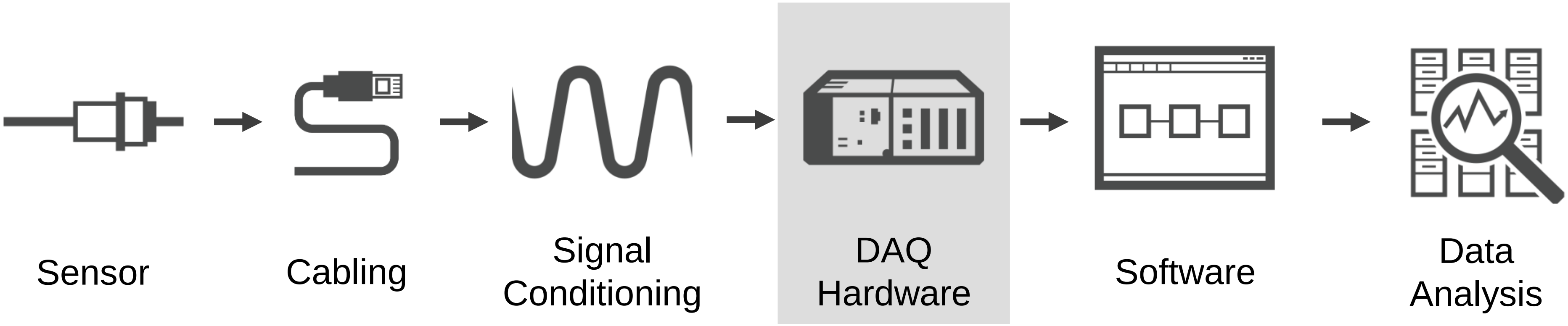



Hardware Driver



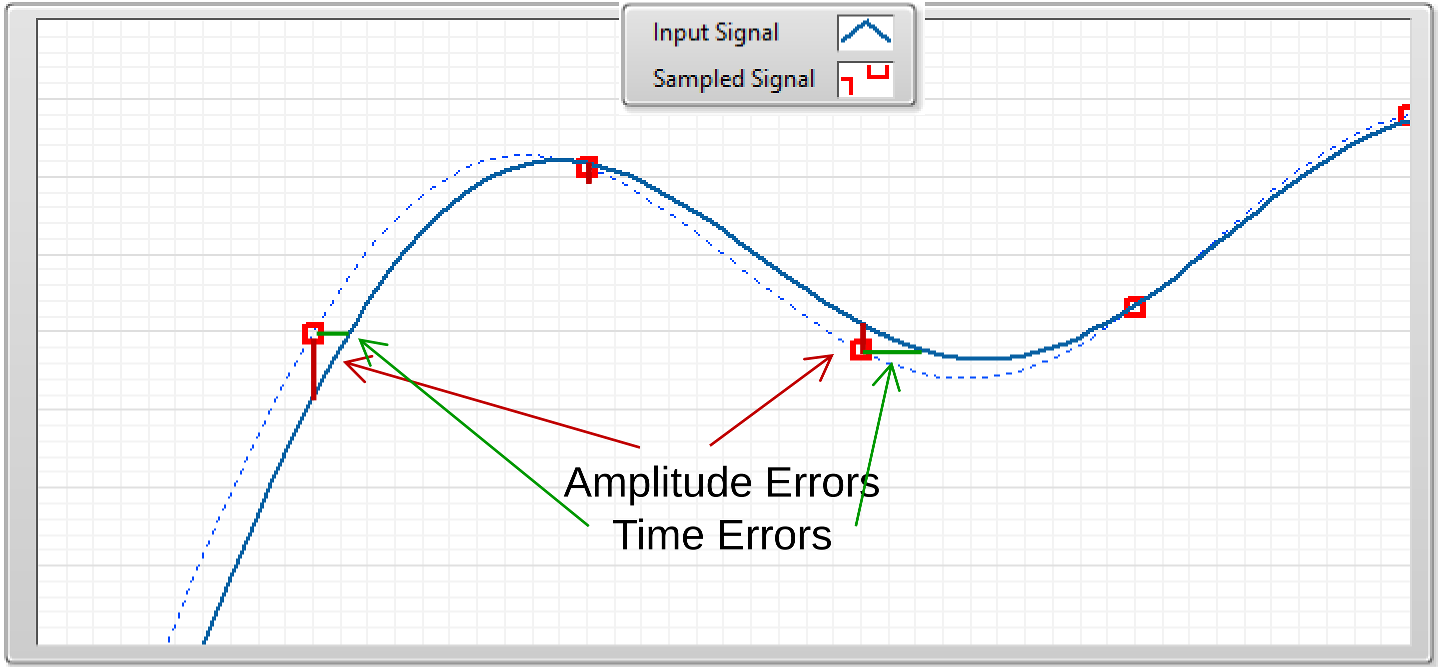

Programming Environment

# Elements of a DAQ System



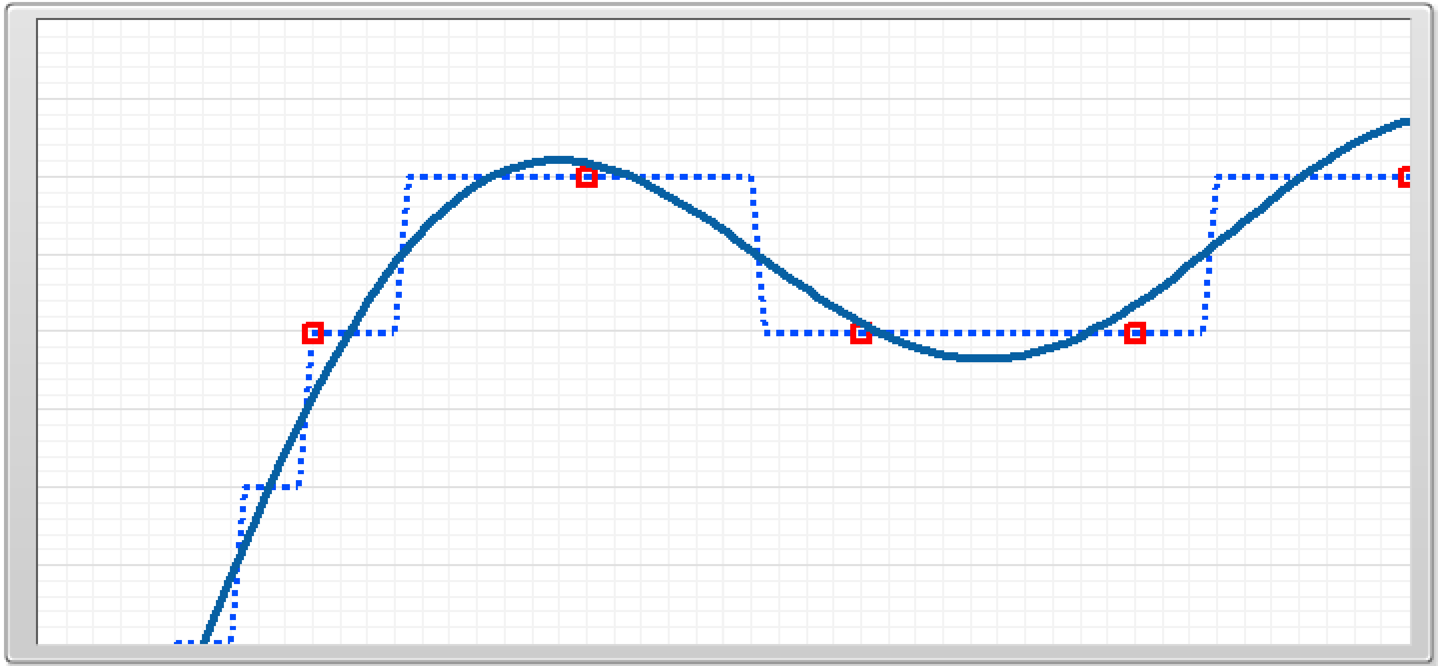
# Data Acquisition Hardware

## Acquiring one or more measurements in both amplitude and time



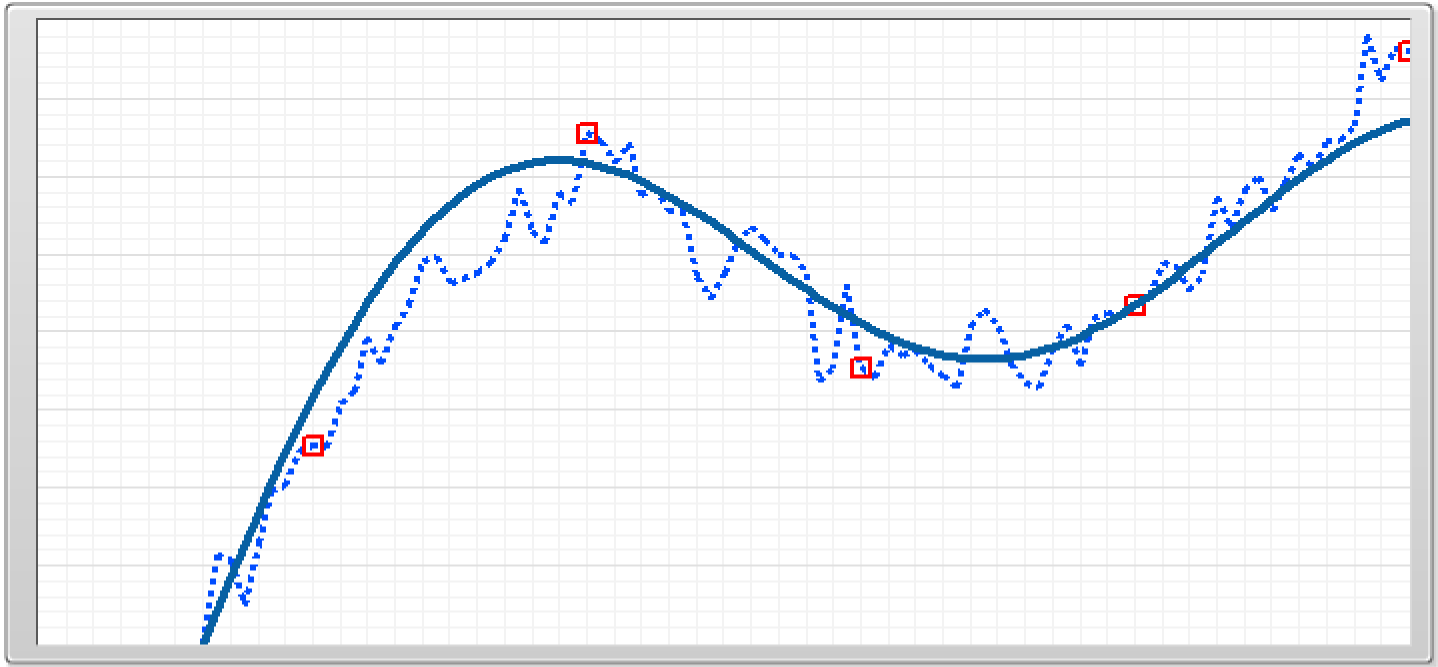
# Measurement Resolution

Limited by quantization error (number of bits)



# Measurement Resolution

## Also limited by noise



# 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 $\mu V_{rms}$ |
| 2 | ±5V | 150 µV | 157 $\mu V_{rms}$ |
| 5 | ±2V | 60 µV | 64 $\mu V_{rms}$ |
| 10 | ±1V | 30 µV | 38 $\mu V_{rms}$ |
| 20 | ±0.5V | 15 µV | 27 $\mu V_{rms}$ |
| 50 | ±0.2V | 6 µV | 21 $\mu V_{rms}$ |
| 100 | ±0.1V | 3 µV | 17 $\mu V_{rms}$ |

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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

- 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 $\mu V_{rms}$ |
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| 100 | ±0.1V | 3 µV | 17 $\mu V_{rms}$ |
| | | NI 9251 | |
| 1 | ±4.25V | 0.5 µV | 9 $\mu V_{rms}$ |

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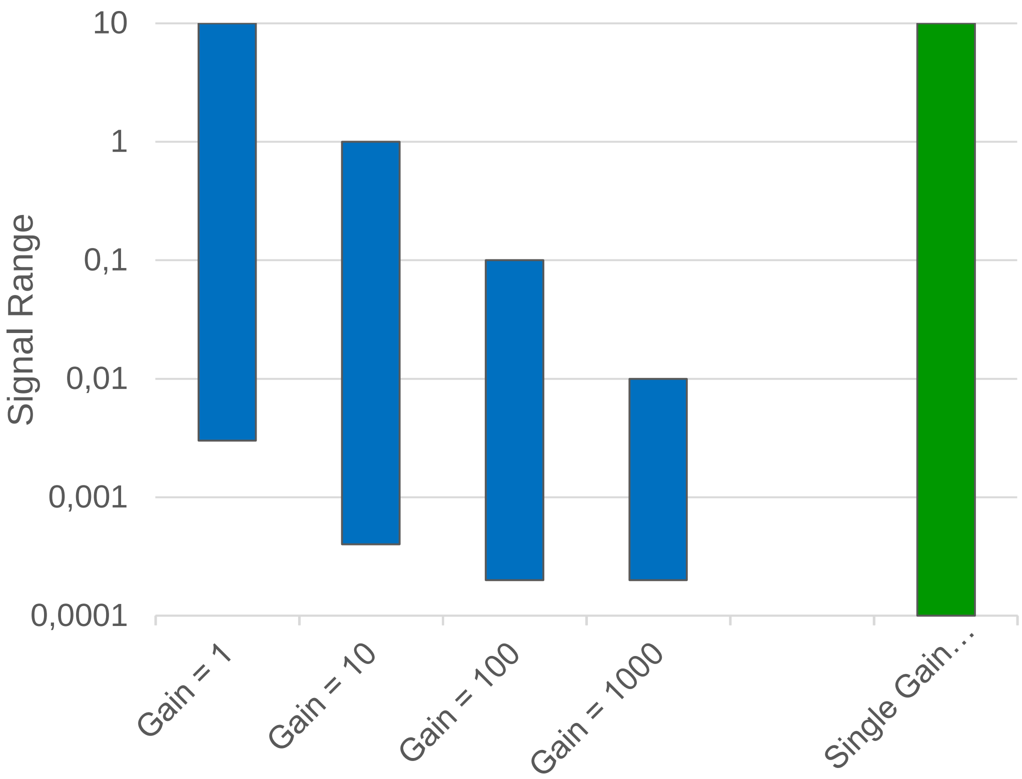
# Programmable gain is a crutch for limited resolution

MYTH

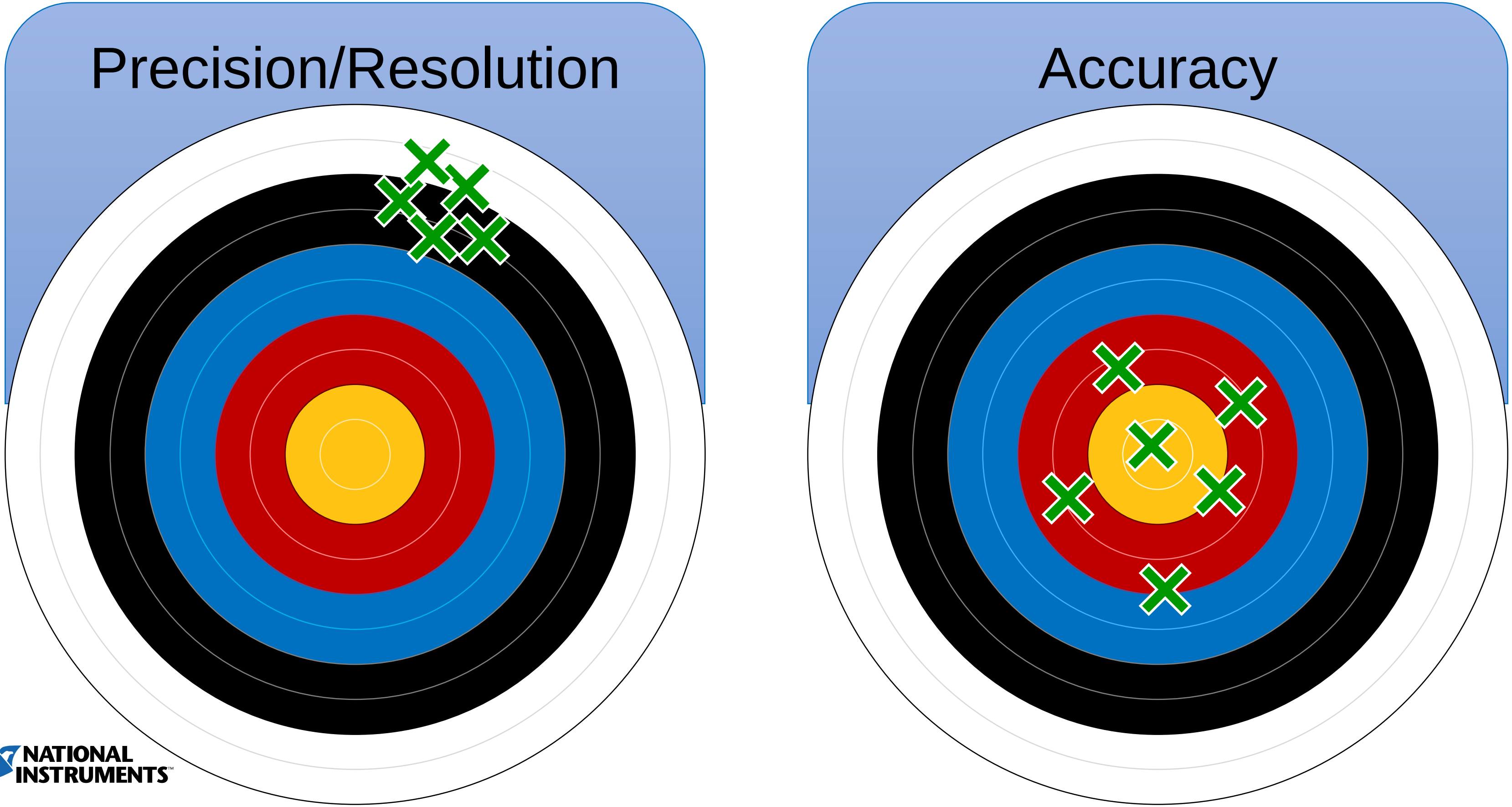
- "Use gain to match the input range to the signal range, or else you are throwing away resolution"

REALITY

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

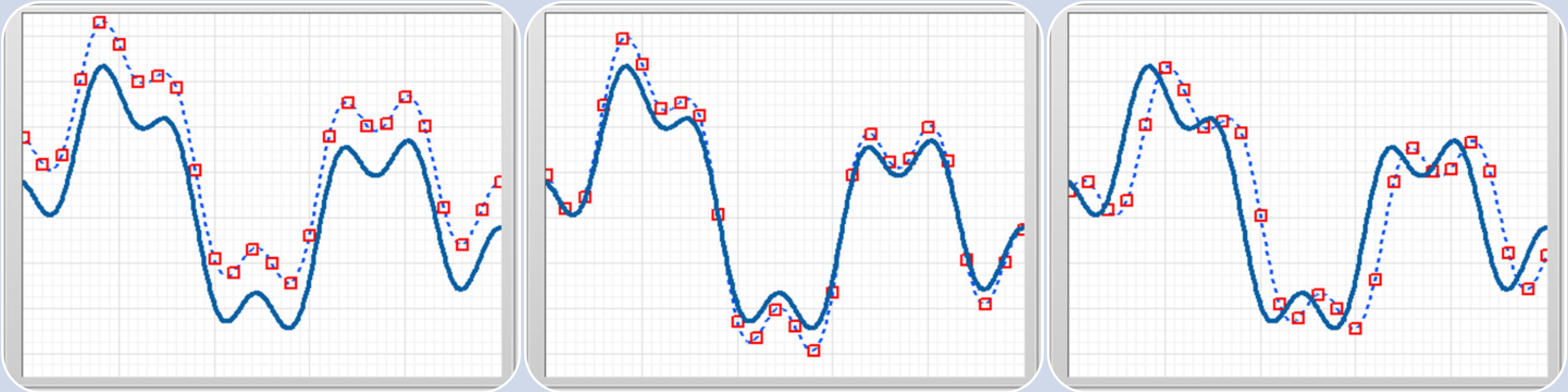


# Resolution vs Accuracy



# 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

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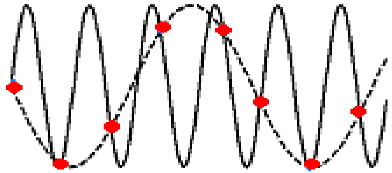
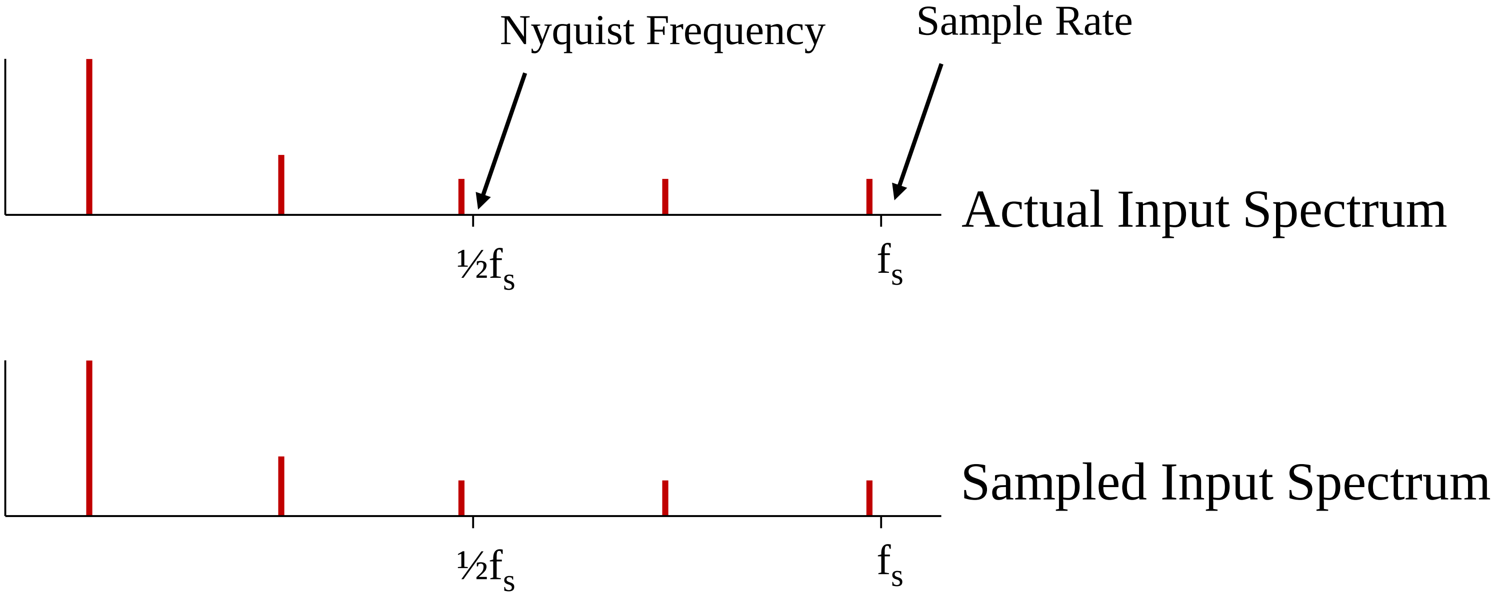
# Aliasing from Sampling



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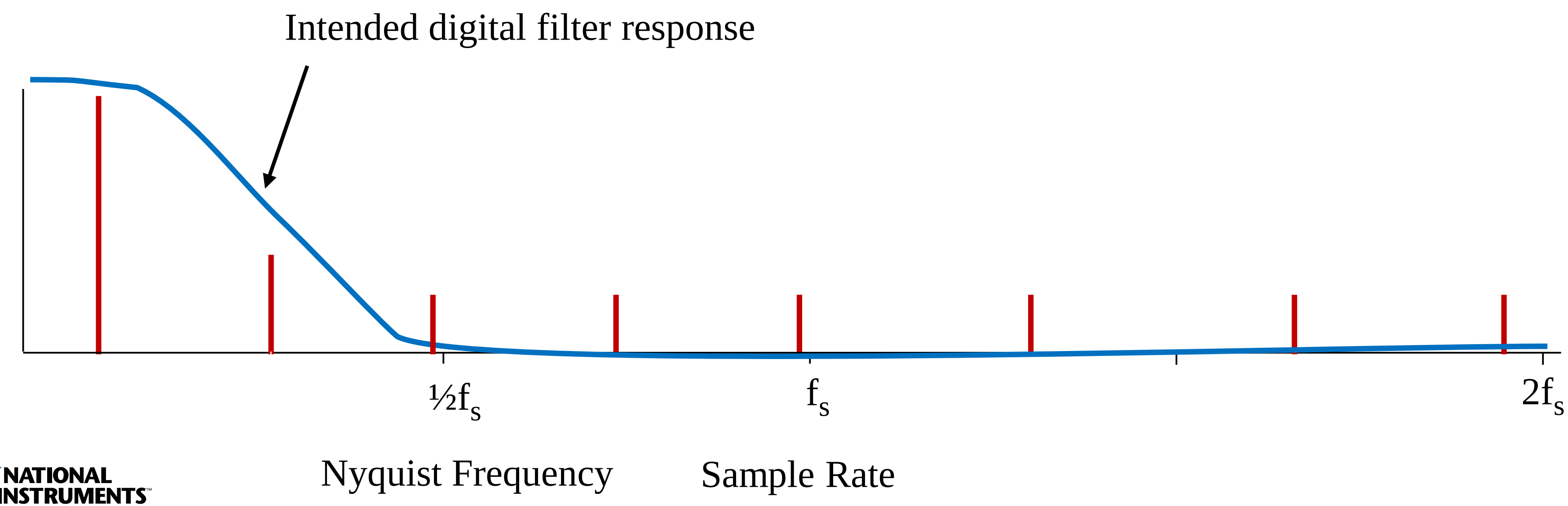
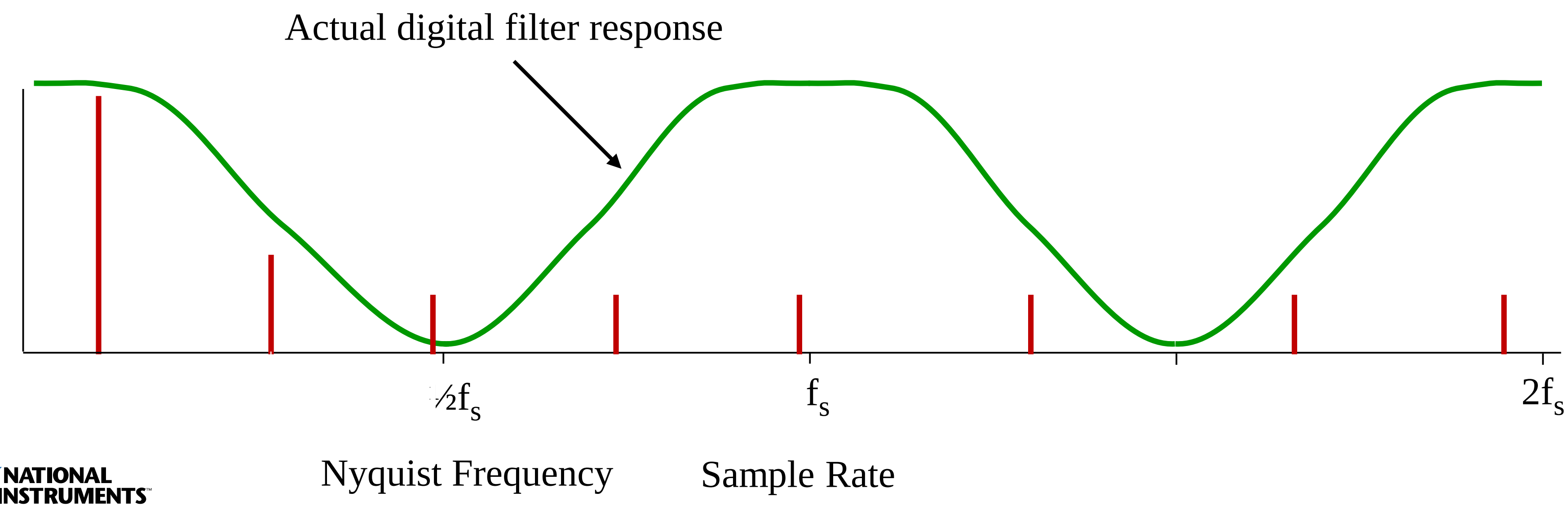
# Anti-Aliasing before Software Digital Filtering

- 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

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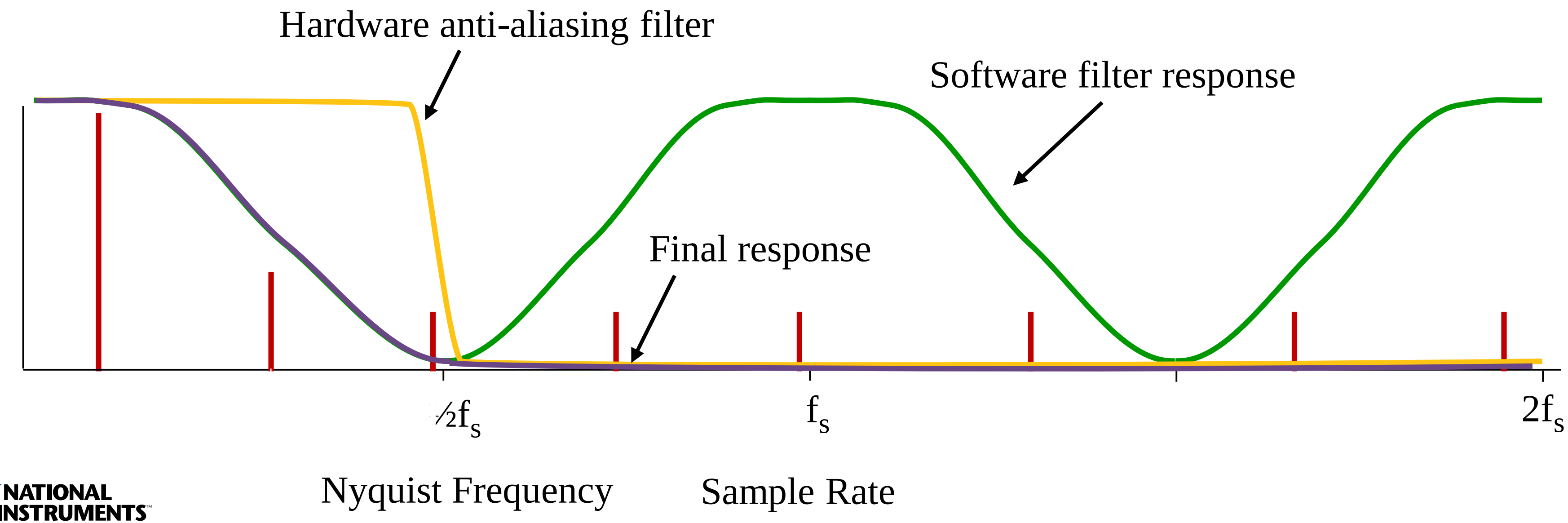
# Anti-Aliasing before Software Digital Filtering

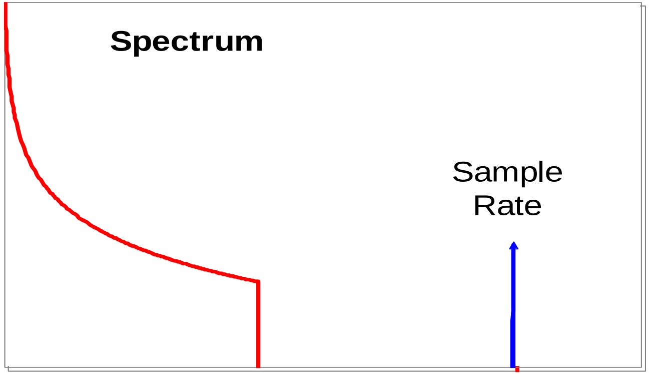
- Digital filtering of sampled data can have unexpected results
- Actual filter response is aliased as well
- Use hardware anti-aliasing filters to prevent aliasing of software filters

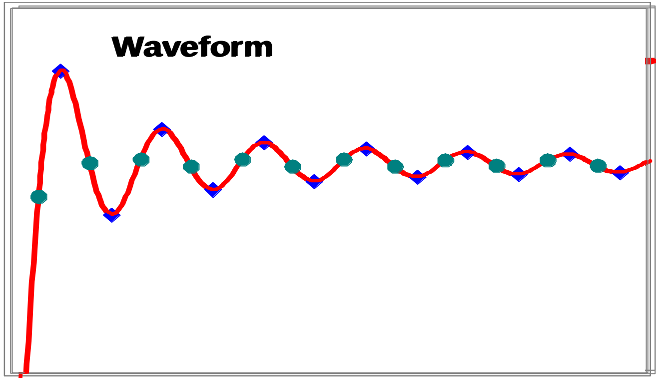


# Ideal Anti-Aliasing Filter Step Response

- Consider a step function
- Brick wall filter will ring
- Overshoot is always 9%
- Filtering at ½ Fs can catch the 9% …

  … or not, depending on the phase of sampling



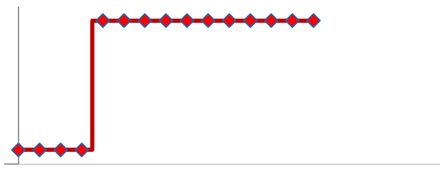
# The Myth of Anti-Alias Filtering: Lying vs Misleading

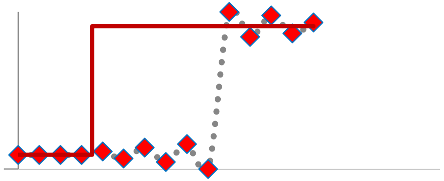
## MYTH

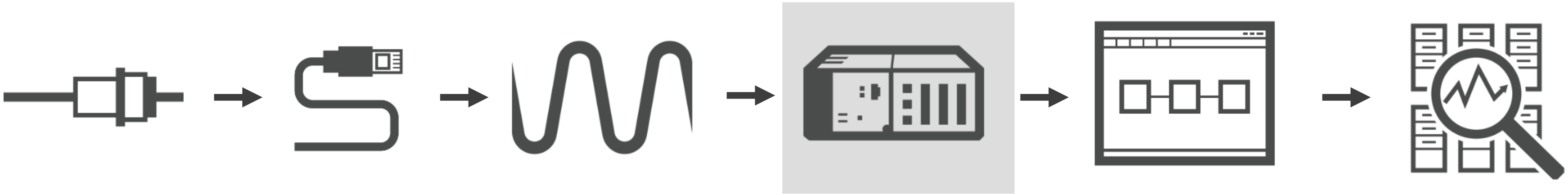
- “You must always use anti-alias filters or else your measurements will lie to you”

## REALITY

- Aliased data is still data
- You need to decide whether it will mislead you or not (a lie of omission?)



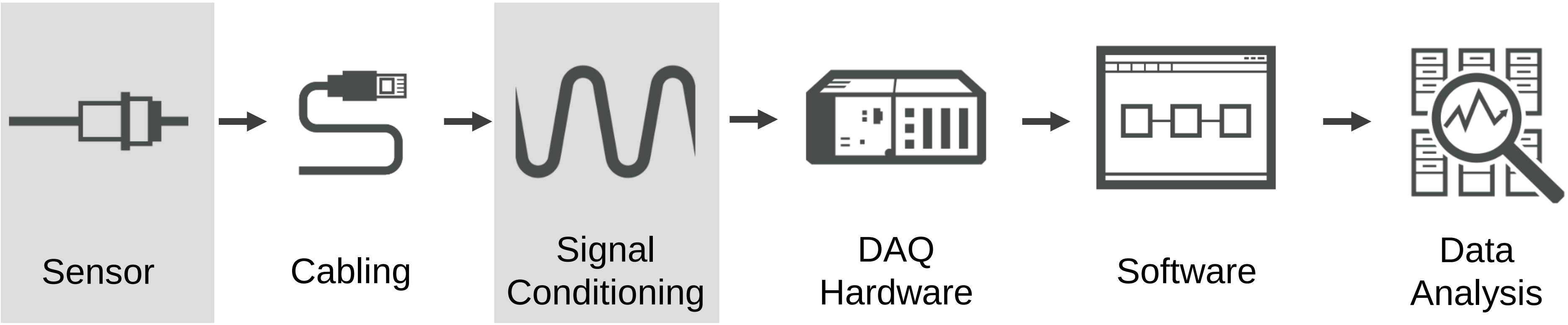




# Key Things to Remember

- Don’t make data analysis an afterthought- it can dictate DAQ Hardware needs
- You might not need as much accuracy as you think
- Gain is nice, but high resolution is better
- Aliasing can be bad- or not.
- Use sample rates and bandwidth appropriate for your analysis

# Elements of a DAQ System



# Data Acquisition Hardware and Signal Conditioning

Signal Conditioning

Integrated Hardware & Signal Conditioning

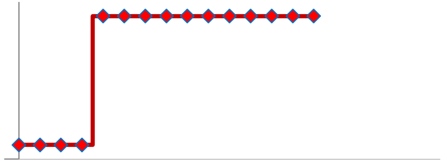
DAQ Hardware

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

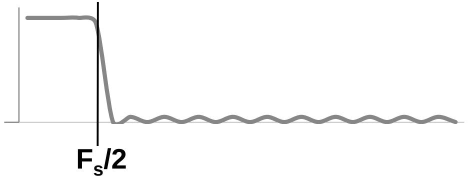
# Filter Responses of the Measurement Architectures

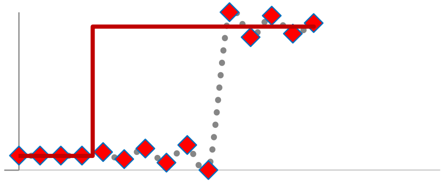
**Frequency Response** | **Step Response**

**Instant Response**

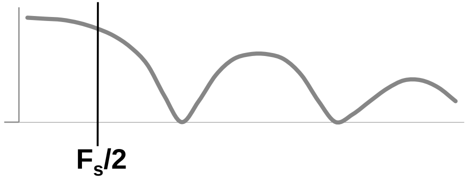



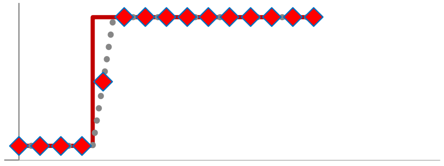
**Anti-Aliased**



**Low-speed filters**



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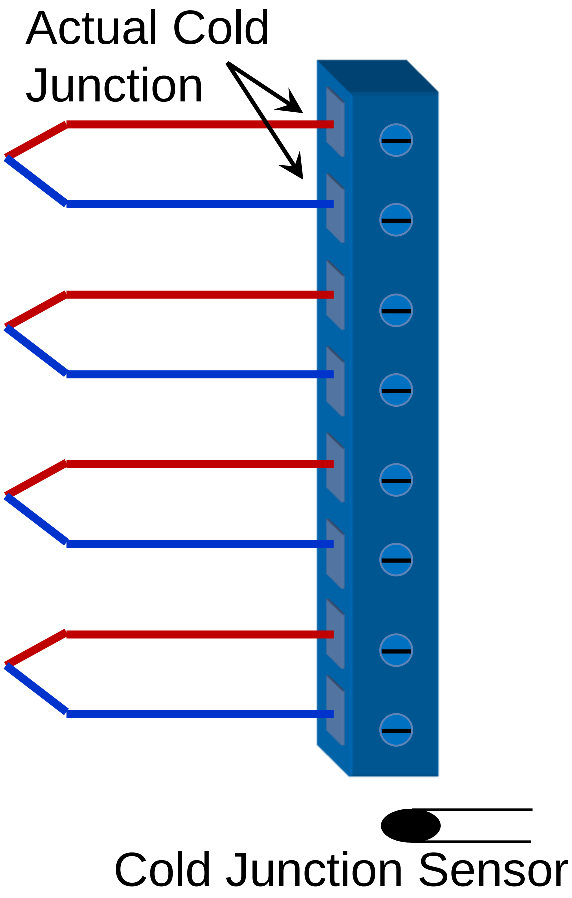
# Do You Need Signal Conditioning?

- 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

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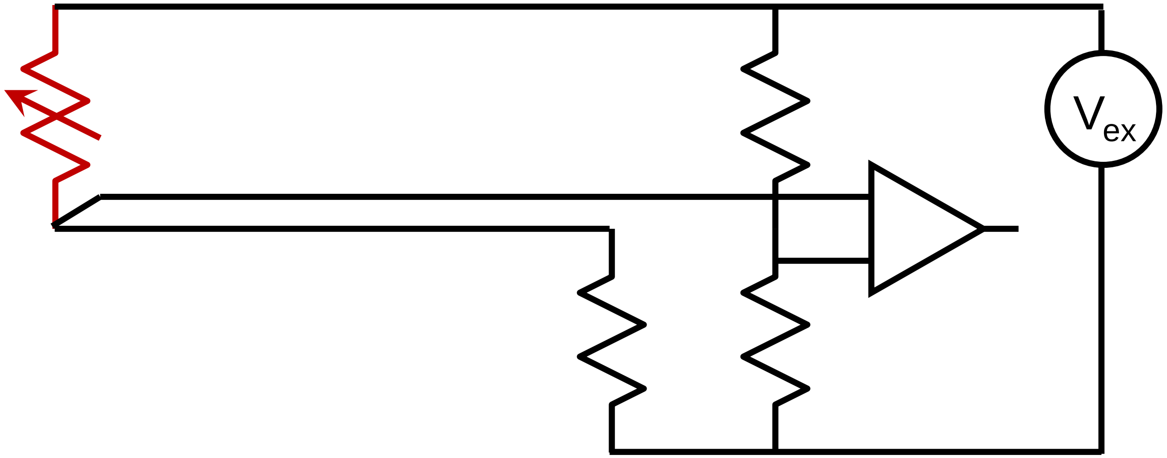
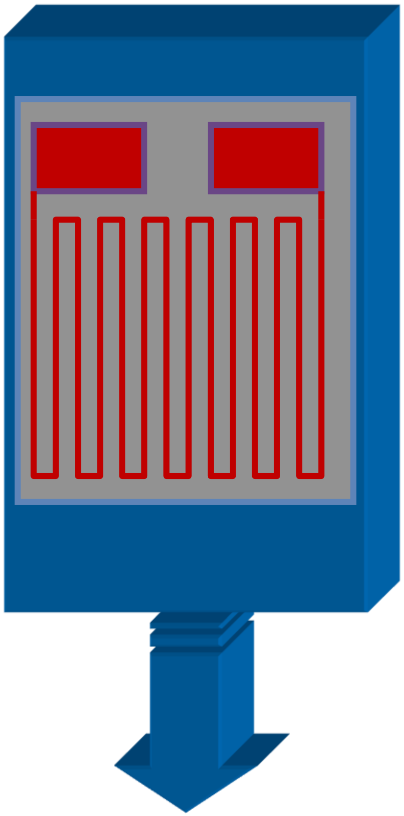
# Strain Gages

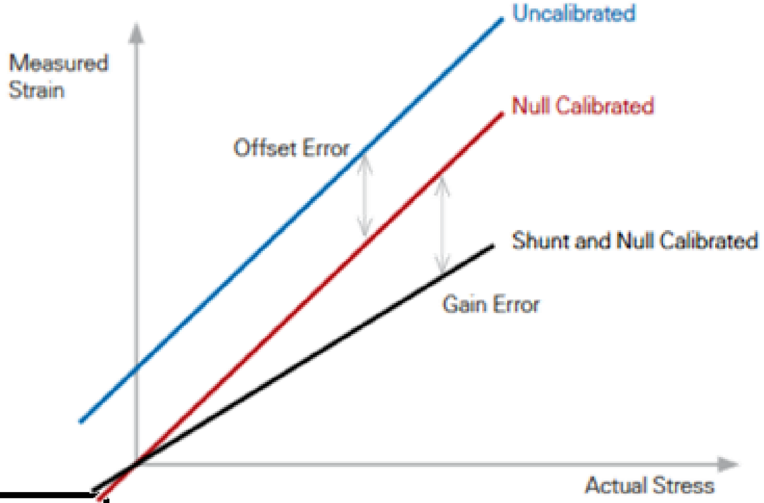
- Resistance changes with strain
- Sensitive to small (~0.1 milliohm) changes
- Measured with Whetstone Bridges

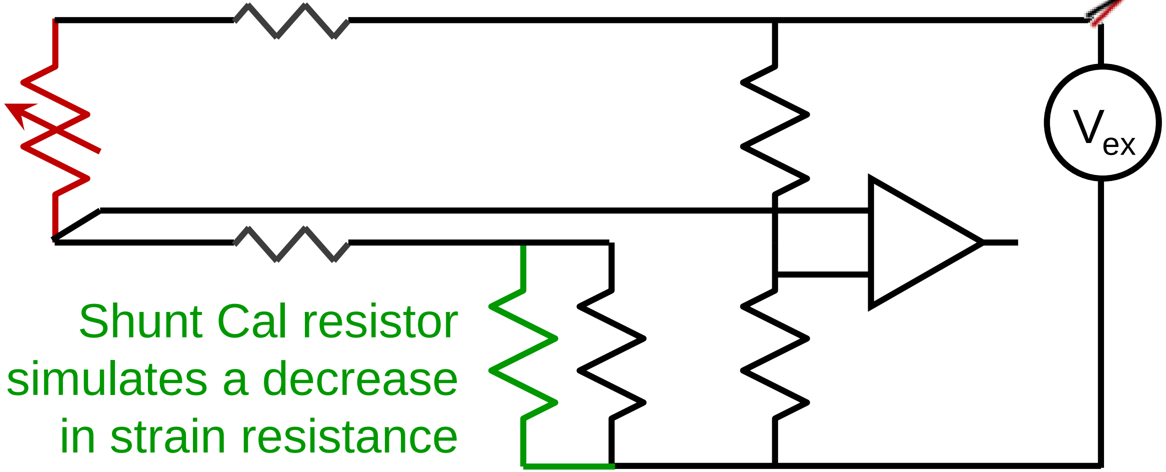


# Strain Gages

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

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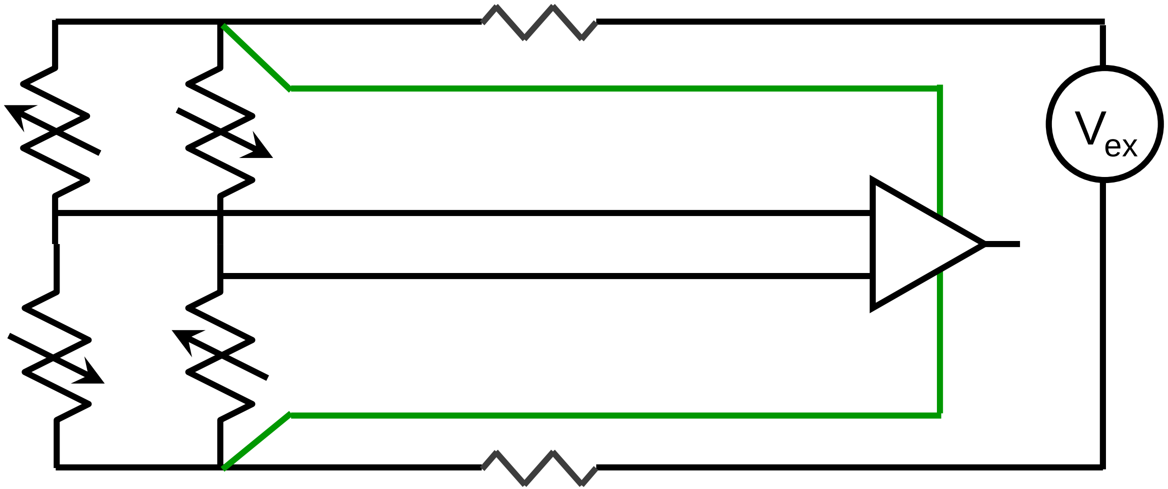
# Strain Gage based sensors

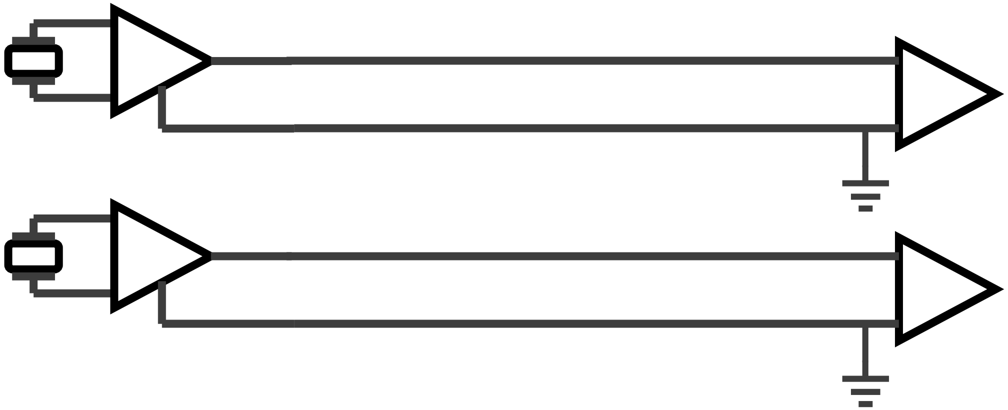
- Cable resistance creates gain errors
- **Remote Sense corrects for gain errors**
- Measure ratio of signal to excitation
- **National Instruments bridge modules directly measure ratiometrically**

Load, Pressure, Force, Torque



# Single Ended Inputs

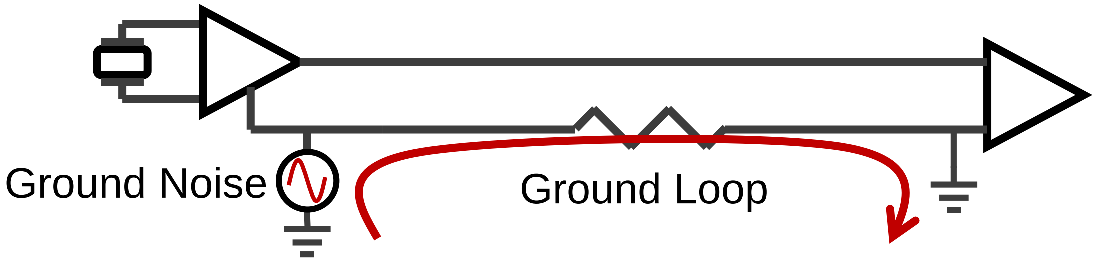
- Most suitable with floating Sensors
  - Provides a single connection to ground
  - Often provides lowest cost per channel



Floating (isolated) Sensors

# Single Ended Inputs and Ground Loops

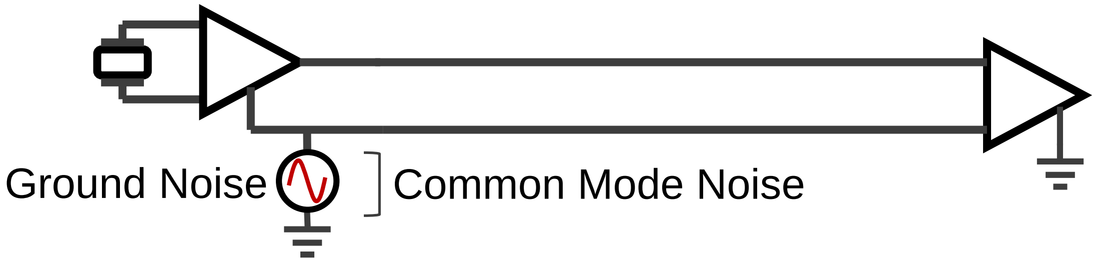
- Grounded Sensors with Single-ended Measurements
  - “Grounds” are never exactly the same
  - Create potential for Ground Loops
  - Create measurement errors in cabling
  - Better choice: use Differential Measurements




Grounded Sensor

# Differential Inputs to Break Ground Loops

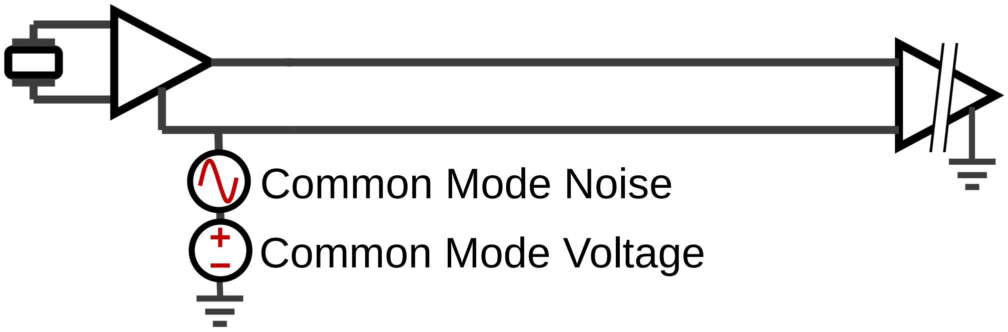
- High impedance of differential inputs break ground loops
  - Ground noise now becomes Common Mode noise
  - Rejected by Common Mode Rejection Ratio (CMRR) of measurement device
  - Limited to Common Mode Range of measurement device (e.g., 10 V)




Grounded Sensor

# Isolated Inputs

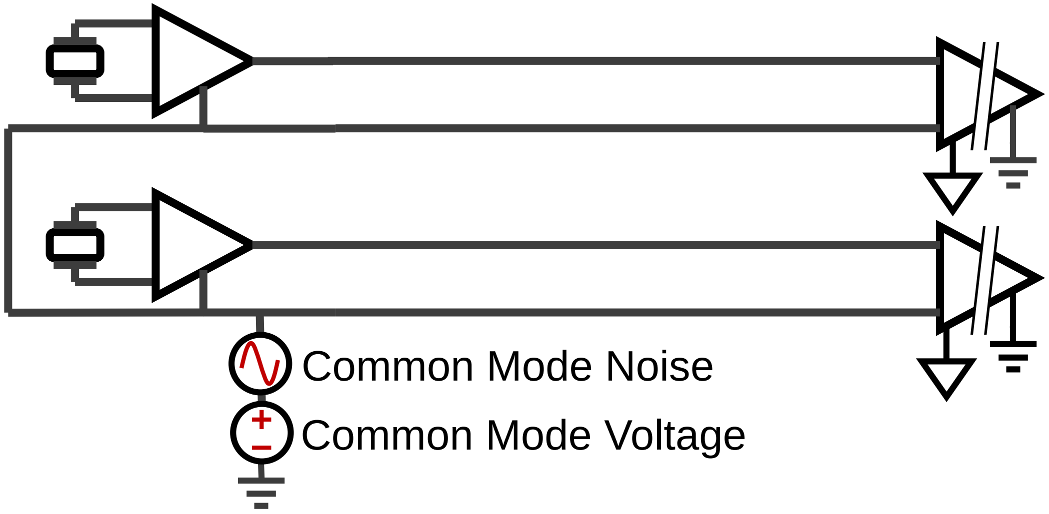
- Inputs isolated from ground provide higher common mode voltage range
  - Improved Common Mode Rejection Ratio (CMRR)
  - Typical common mode ranges are 60 Vdc or 250 Vac
  - Fault withstand levels can be thousands of volts
  - “Isolation” at National Instruments implies “Galvanic Isolation”- no conductive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



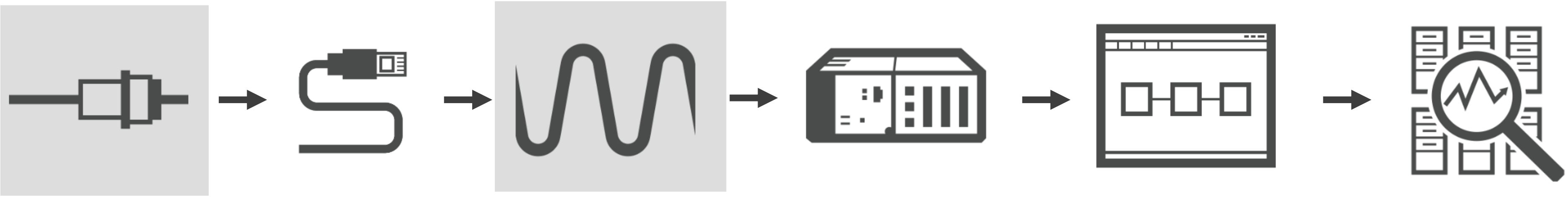

Ground Referenced Sensor

# 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



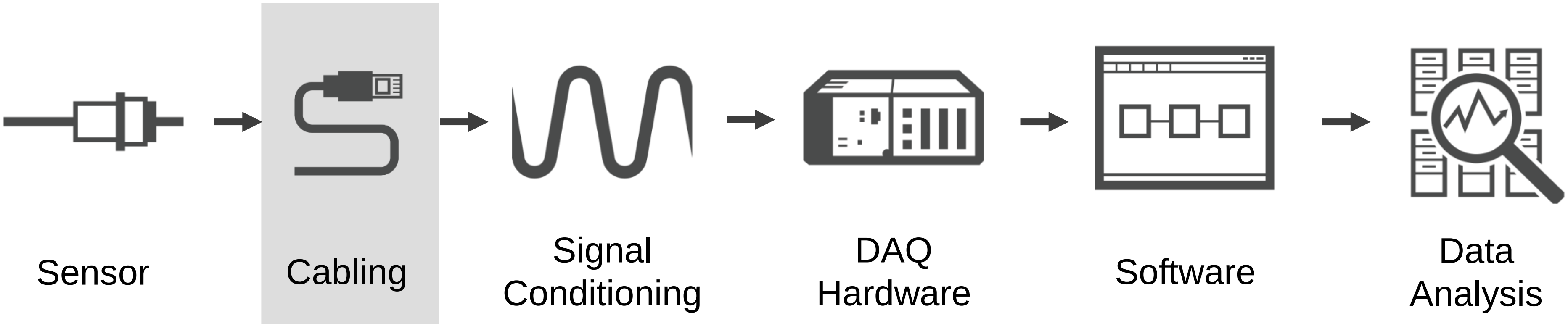

Ground Referenced Sensors



# Key Things to Remember

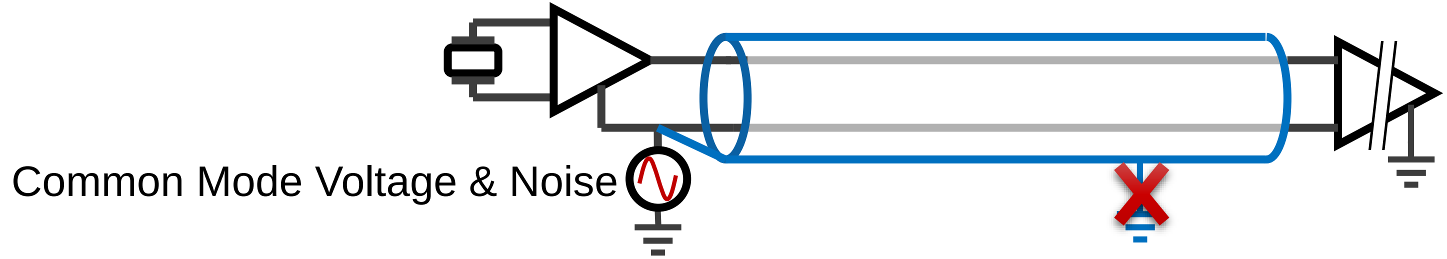
- Consider power line filtering for static (<10Hz), low-level signals
- Use terminal blocks designed for Thermocouples
- Use Bridge sensor conditioning for ratiometric, bridge-based sensors
  - Use Offset Nulling and Shunt Calibration for quarter-bridge strain gage
  - Use Remote Sense for full-bridge sensors
- Sensor grounding will dictate single-ended, differential, or isolated inputs

# Elements of a DAQ System



# Isolated Inputs

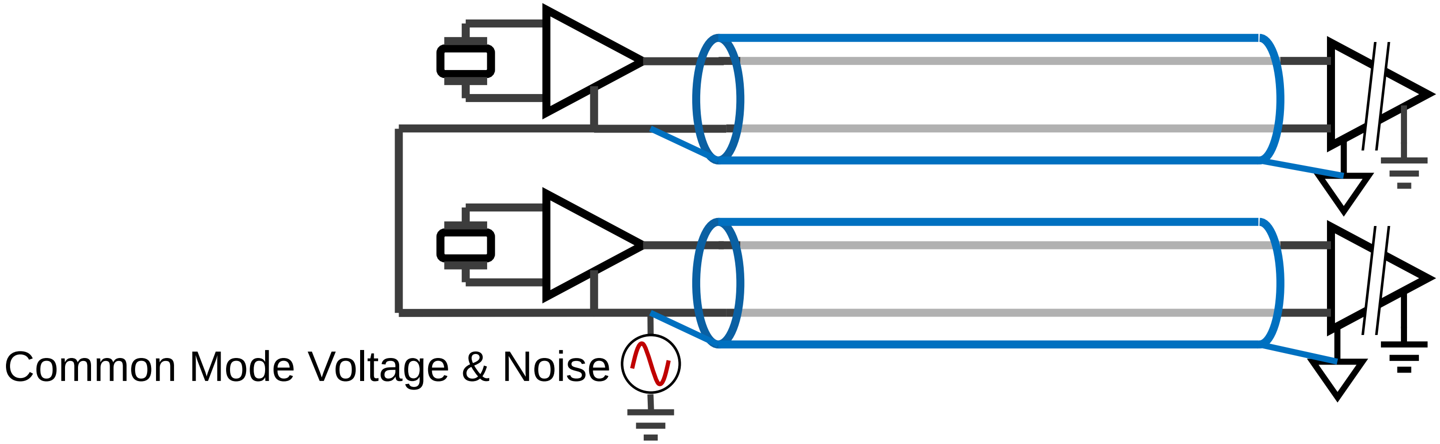
- When signal reference is noisy relative to Earth ground…
- Earth ground becomes a (relative) noise source!
- Connect shields to signal ground




Ground Referenced Sensor

# Bank Isolated Inputs

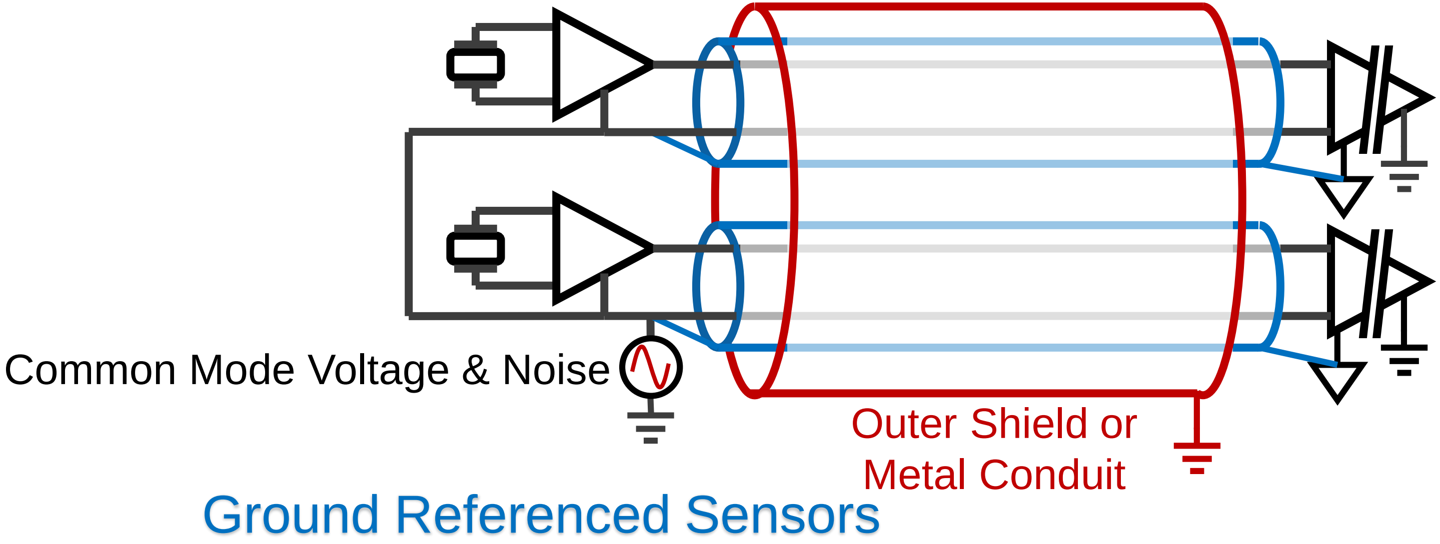
- Shields are still connected to the local signal reference
- Also connect Shield(s) to isolated measurement ground/common



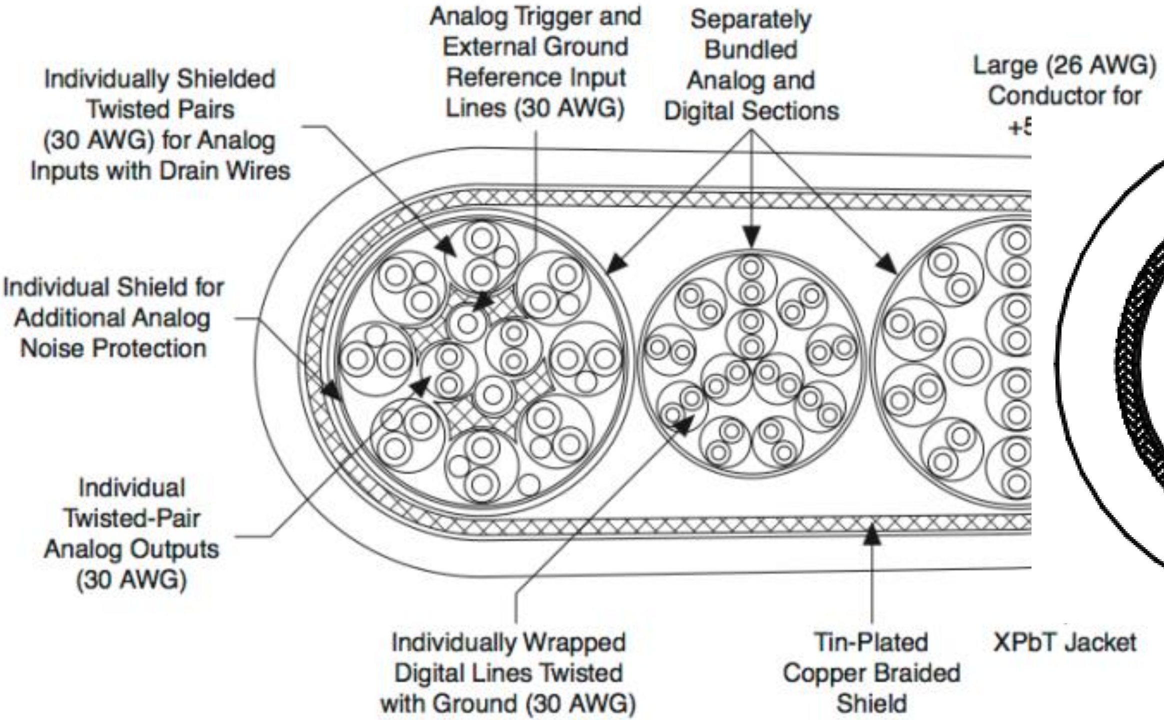

Ground Referenced Sensors

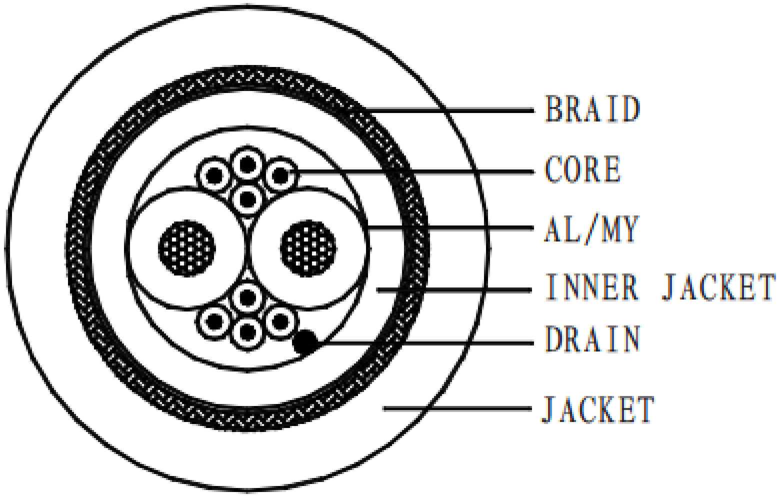
# Double-Shielded Cables

- 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



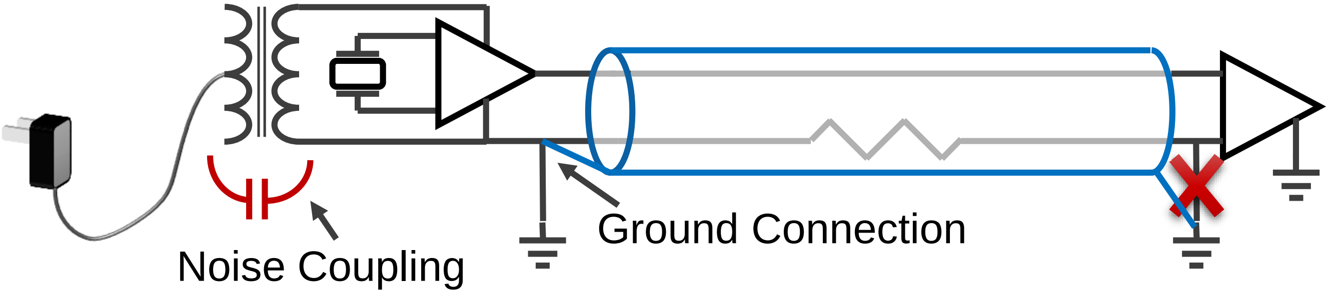
# Double-Shielded Cables



# Floating Sensors

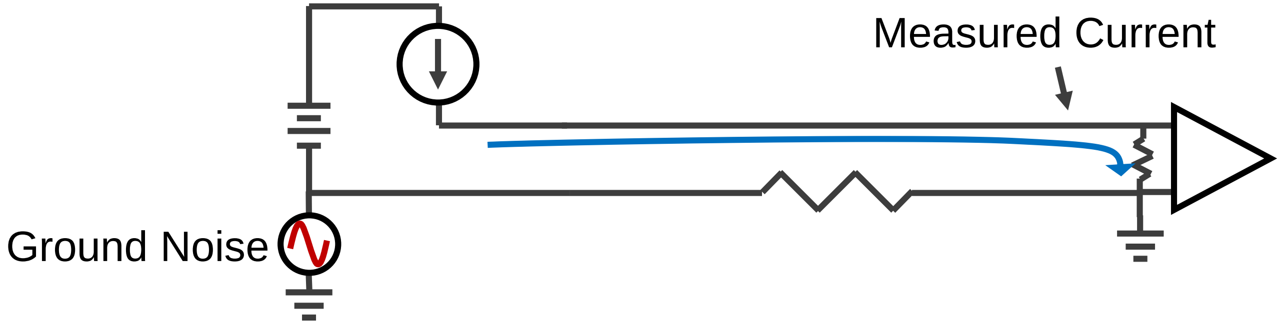
- Isolated signal sources with no direct connection to ground
  - Pick up common mode noise easily
  - Make ONE connection to ground
  - Ground near most likely noise source
  - Connect shields to ground
    - Shield connection point is less important
    - Ground loops in shields are less concerning




Floating Sensor

# Measuring Current Sources and 4-20 mA Sensors

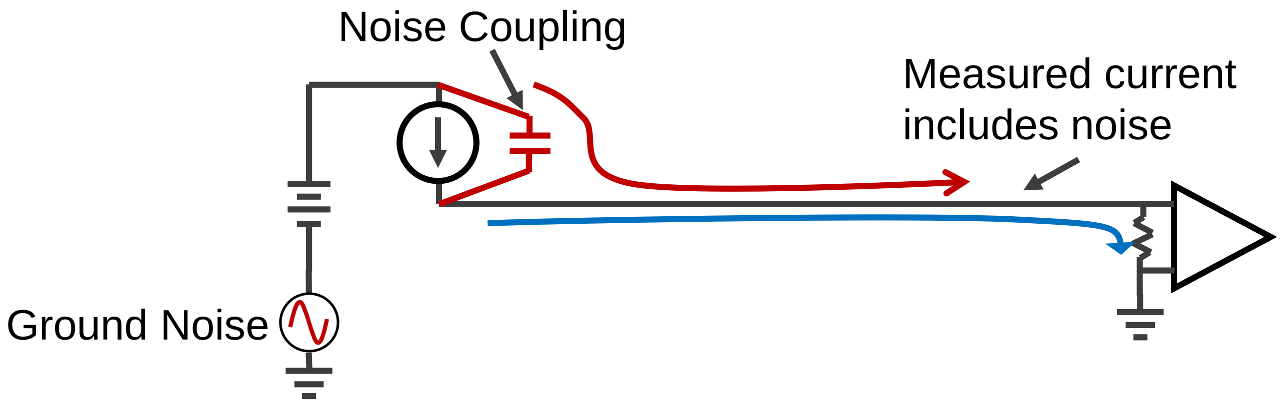
- "Ground Loops" don't have the same impact as with voltage sensors
  - Common mode noise doesn't impact measurement
  - Ground loops don't generate measurement errors
  - No need for differential inputs or isolation to break ground loops




Current Output Sensor

# Measuring Current Sources and 4-20 mA Sensors

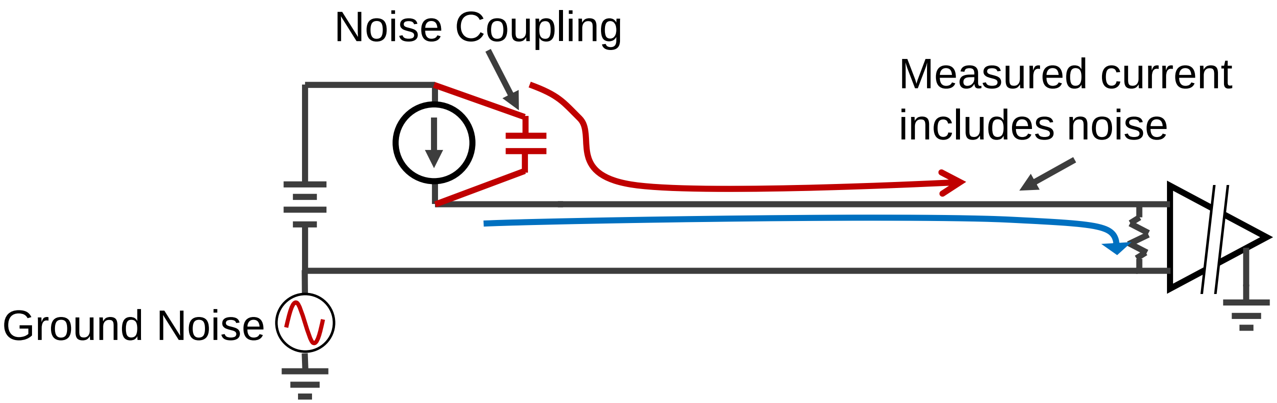
- Sensors have their own finite Common Mode Rejection
  - Sensor cable capacitance can couple AC power supply noise
  - Higher frequencies → more coupling
  - Use low-noise loop supplies
  - Use filtering on signal conditioning




Current Output Sensor

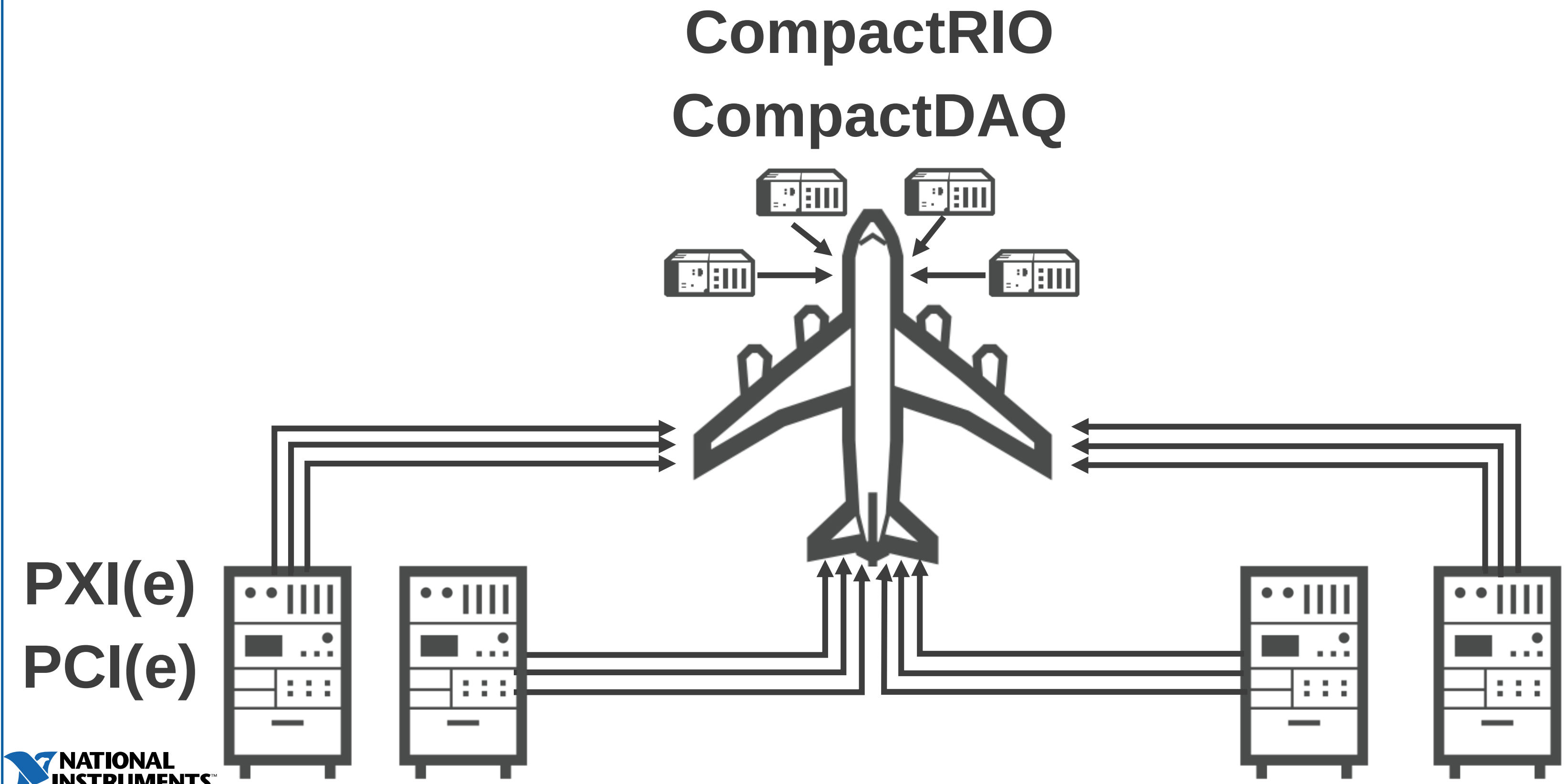
# Measuring Current Sources and 4-20 mA Sensors

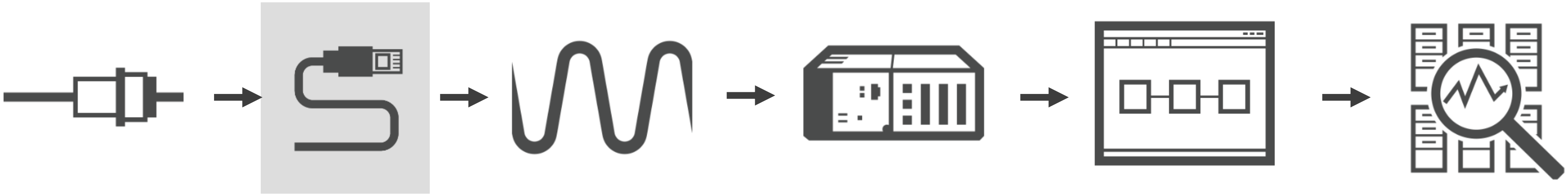
- Isolated inputs allow remote connection to power supply ground
  - Helps with ground noise
  - Doesn't help with fundamentally noisy power supplies




Current Output Sensor

# Minimizing Sensor Cable Lengths





# 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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