NIDays09

WORLDWIDE GRAPHICAL SYSTEM DESIGN

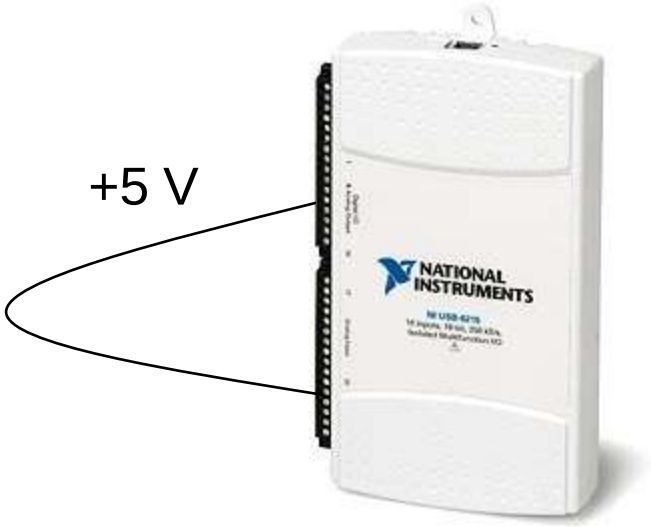
CONFERENCE

NATIONAL INSTRUMENTS

Tips and Tricks to Improve Signal Quality in Data Acquisition Systems

Presenter name

Demo 1

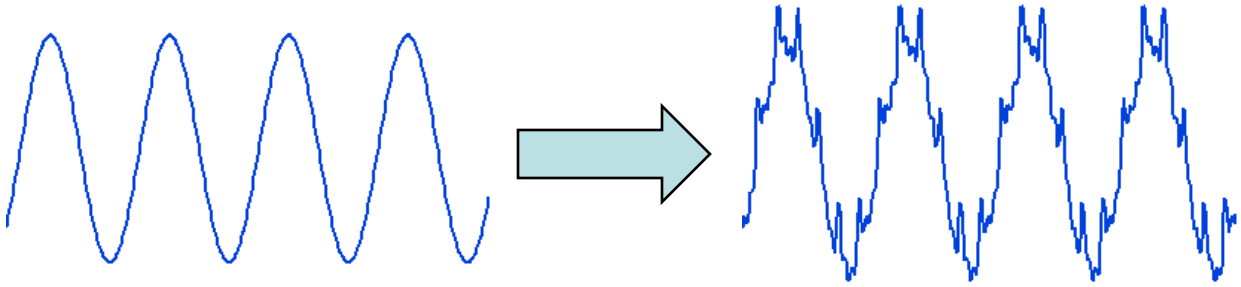


Topics

- Noise and its sources
- Five tips to reduce noise
  - Positioning and shielding
  - Rejecting common-mode noise
  - Breaking ground loops
  - Filtering
  - Alternative technologies

Electronic Noise Basics

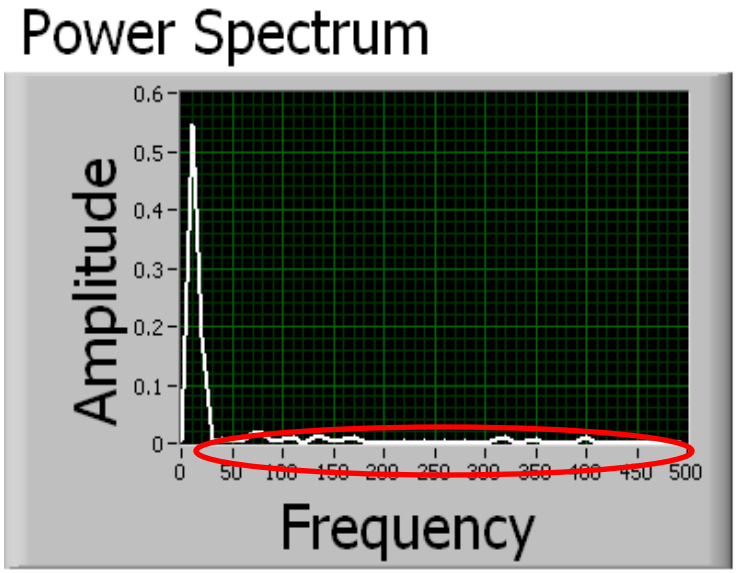
- Any unwanted signal added to your sensor signal



- Electromagnetic interference
  - Electric fields, magnetic fields, radio waves
- Common sources: motors, lighting, CRTs, cell phones

Characterizing Noise

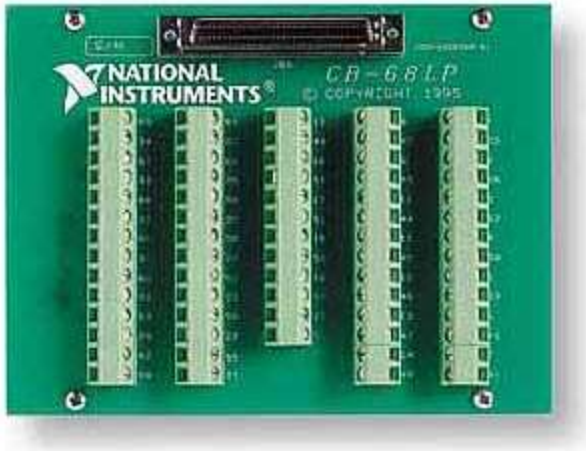
- Signal-to-noise ratio (SNR) describes total power ratio of signal and noise components
- Typically has DC and AC components

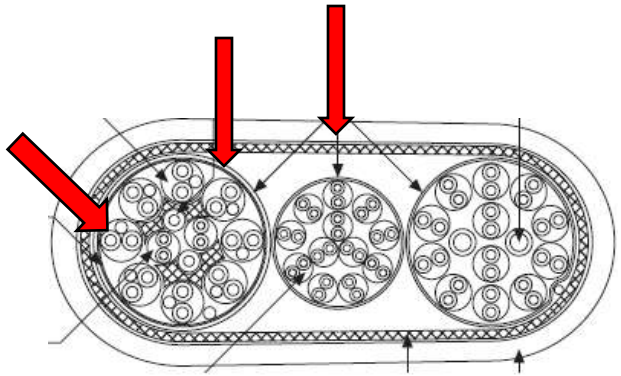


1 Proper positioning

- Position monitor, motors, and power lines away from data acquisition device, cable, and sensor if possible
- Place data acquisition device as close to sensor as possible to prevent noise from entering

1 Proper Shielding



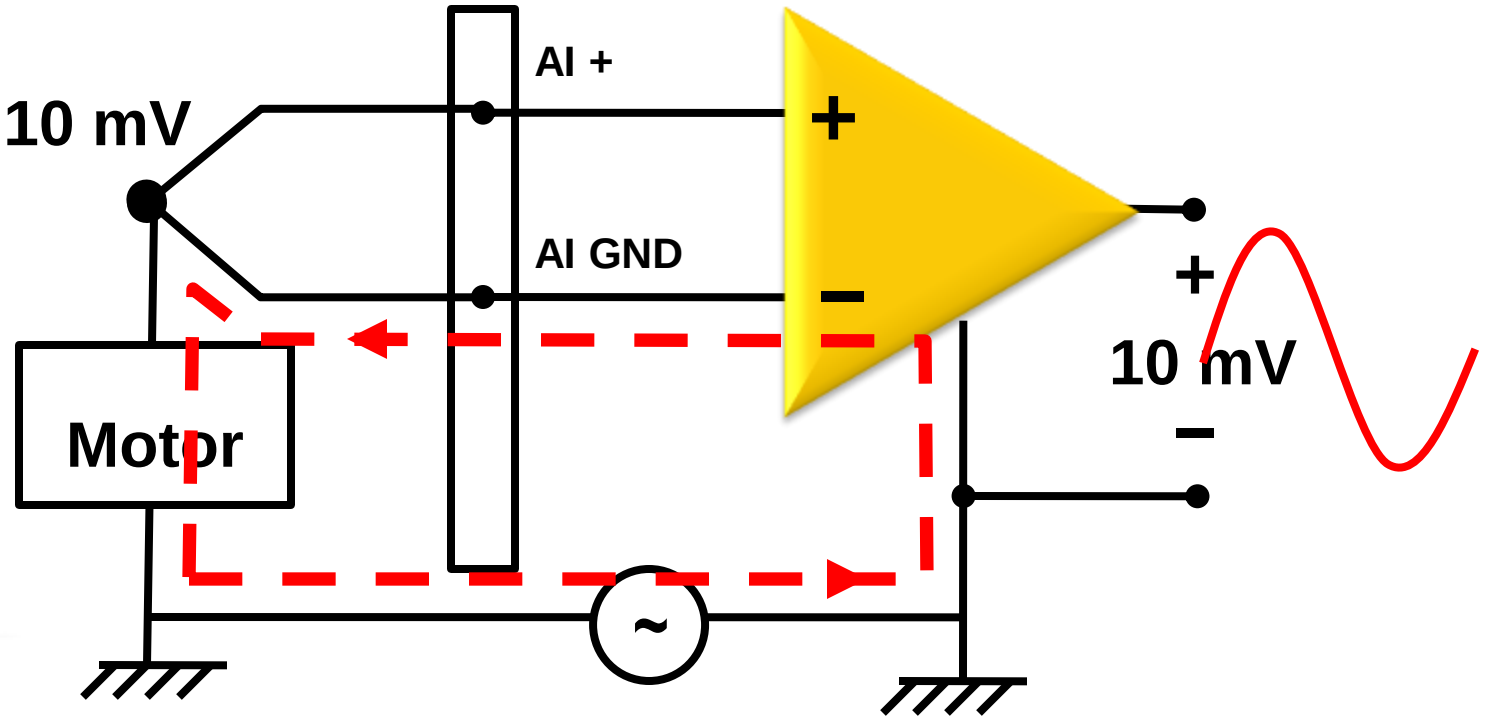


2 Break Ground Loops

- There is no such thing as absolute ground

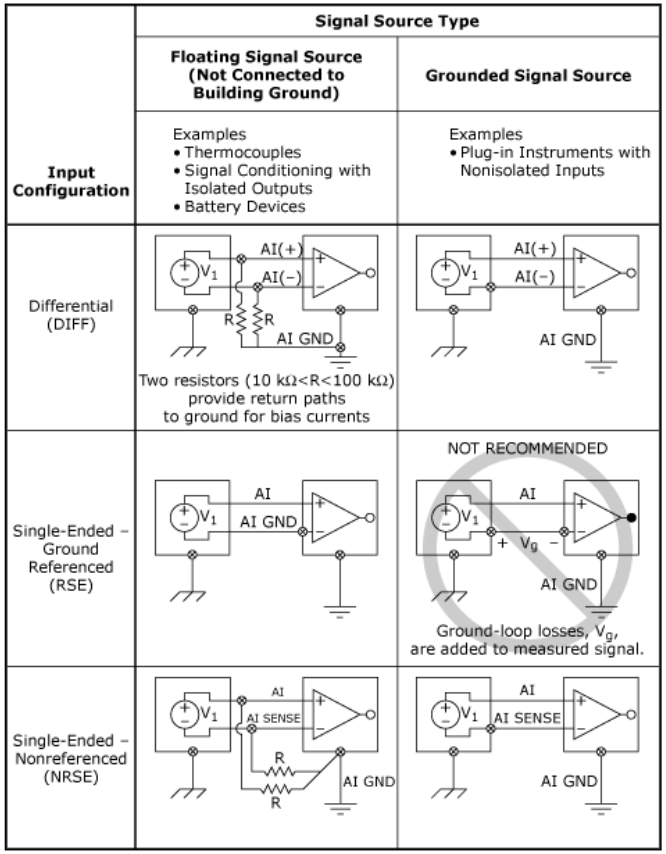
2 Break Ground Loops

When two so-called “grounds” are connected in your circuit, current flows and your measurement suffers



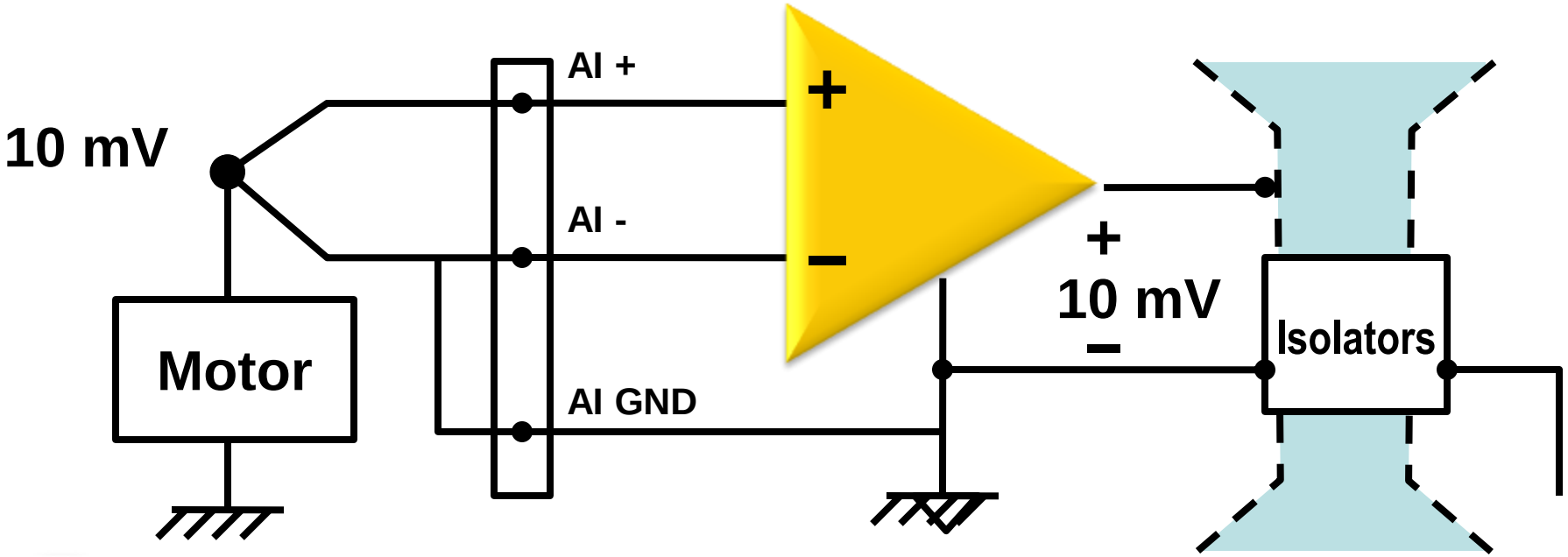
Proper Measurement Mode

- Field Wiring and Noise Considerations for Analog Signals
  (NI Developer Zone)



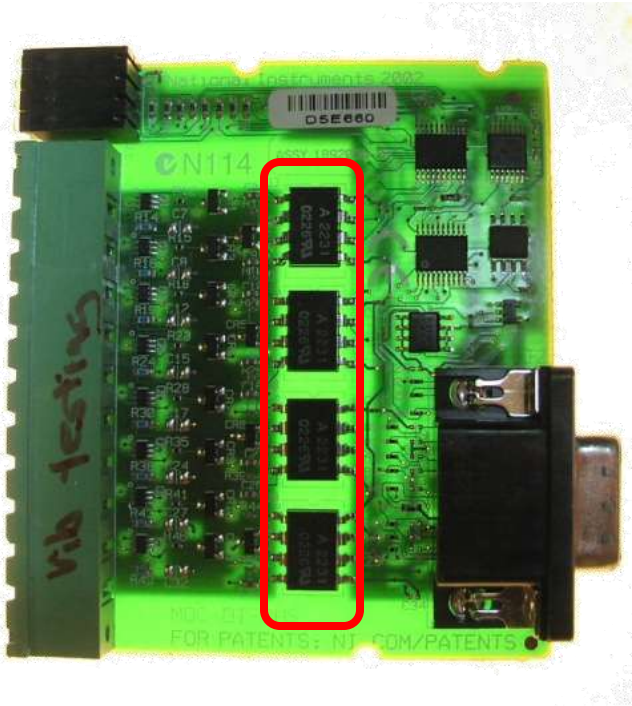
The Most Effective Method

- Use **isolation** to separate ground planes of data acquisition device and sensor

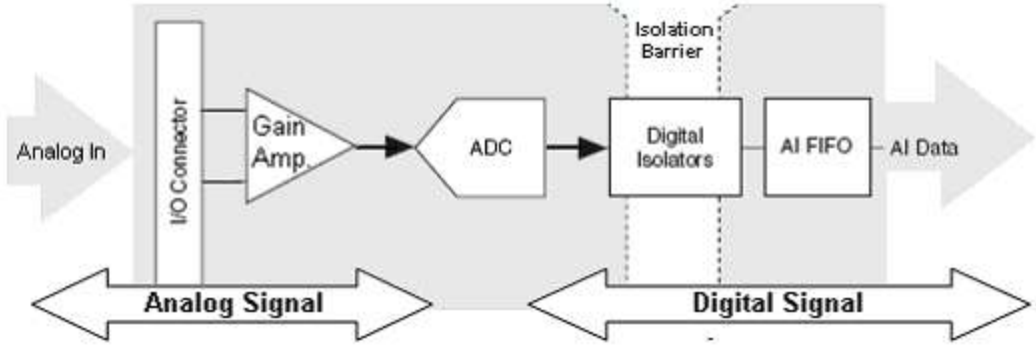


What Is Isolation?

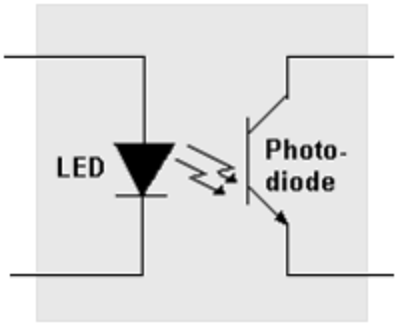
- Physical and electrical separation of two parts of a measurement device
- Terminals are floating (not tied to system ground)
- Protects device from high voltages and prevents ground loops
  - Electrons cannot flow across gap



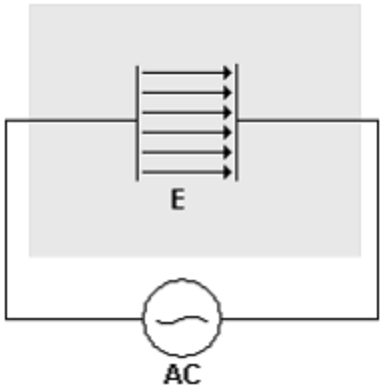
Isolation Technologies



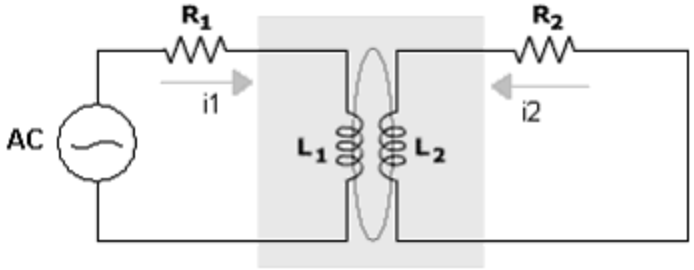
Optical



Capacitive

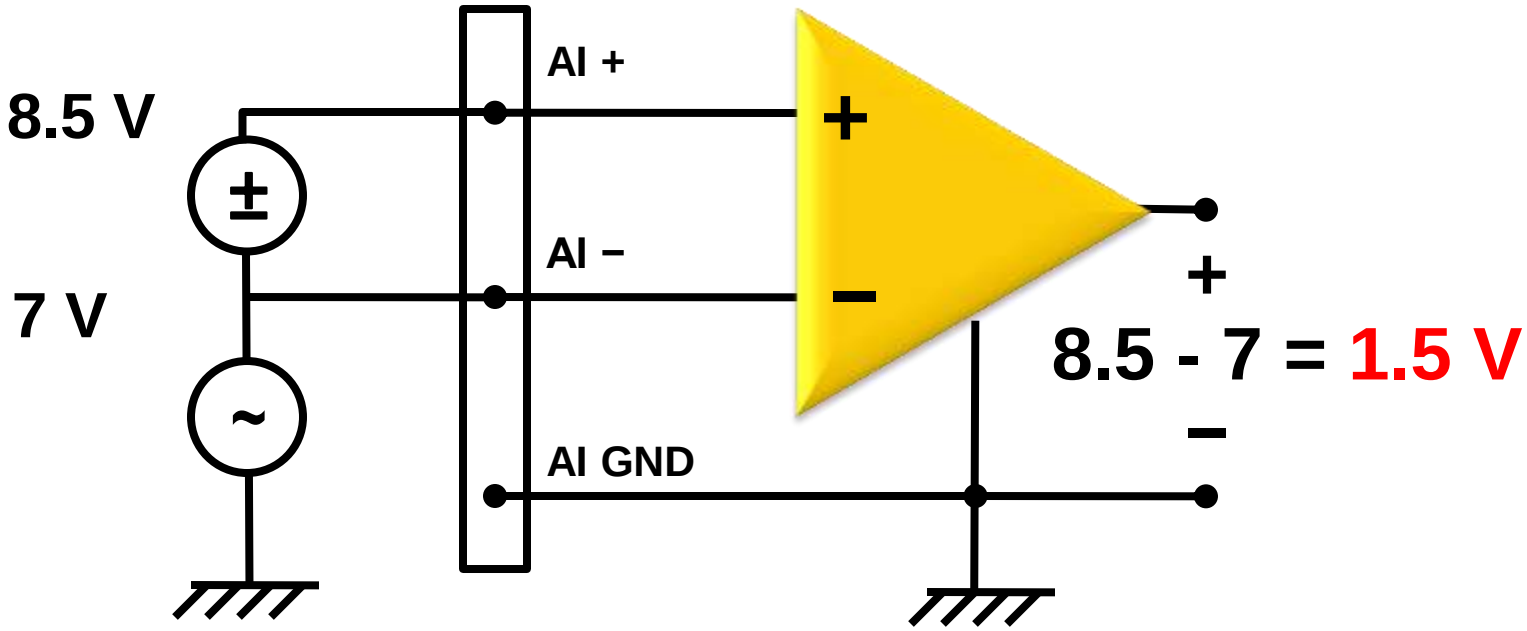


Inductive Coupling



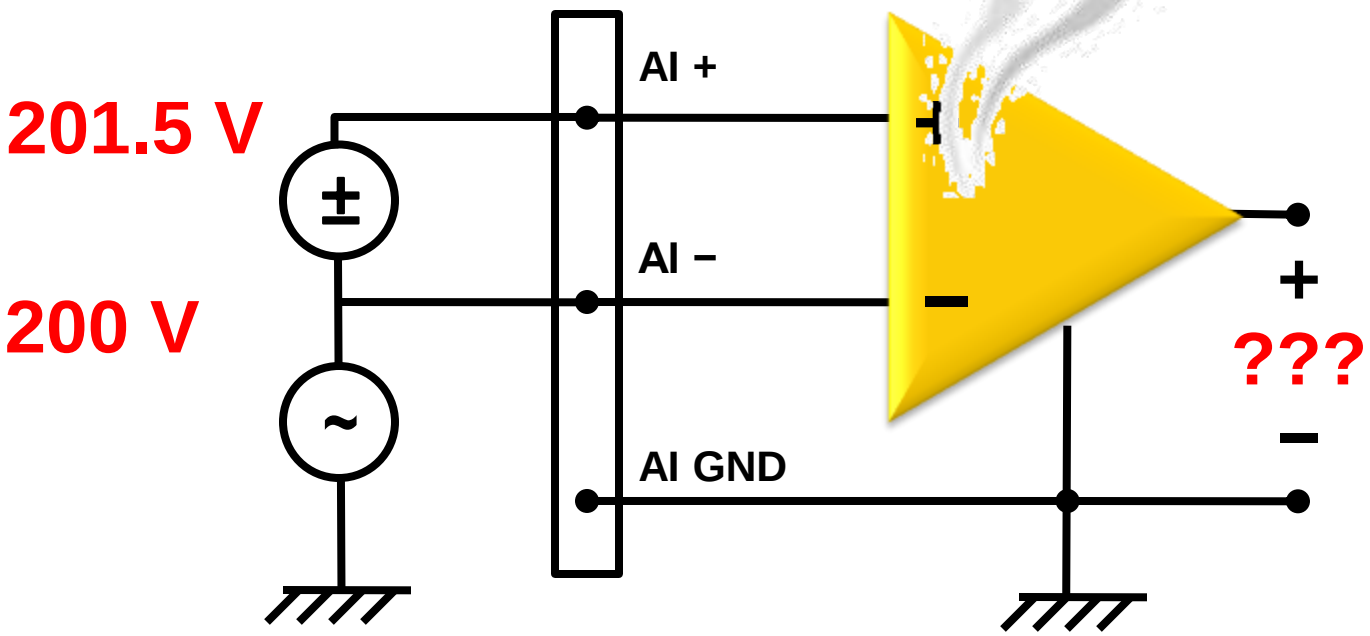
3 Reject Common-Mode Noise

- What does a normal data acquisition device read?




TEST
Industrial DAQ Battery
Stack Tester

- What does a norm[illegible]ata a[illegible]isition device read now?



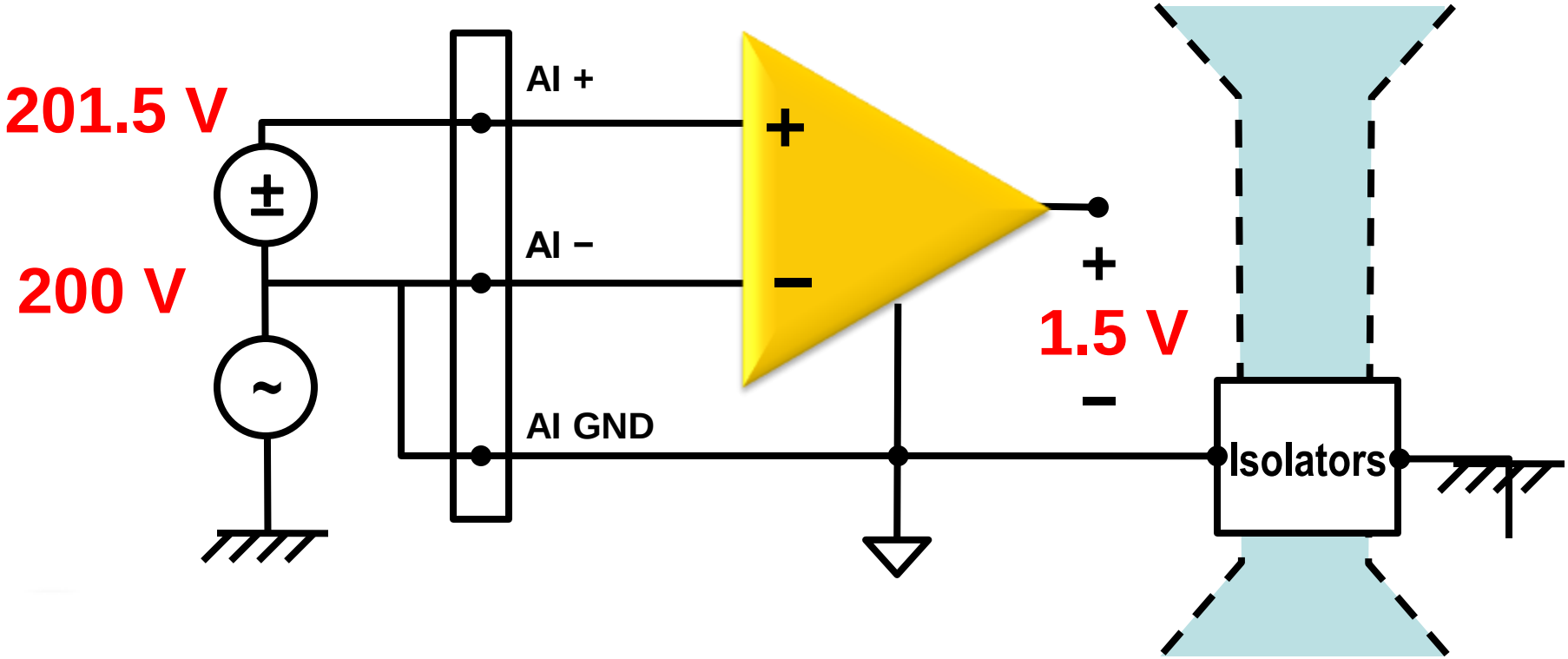
- Amplifiers have limited common-mode rejection

Common-Mode Voltage Rejection

Device	Max Signal Voltage
NI USB-621x 	10.4 V from AI GND
NI 9206 	600 V DC isolation from system ground, plus 10 V (measurement range)

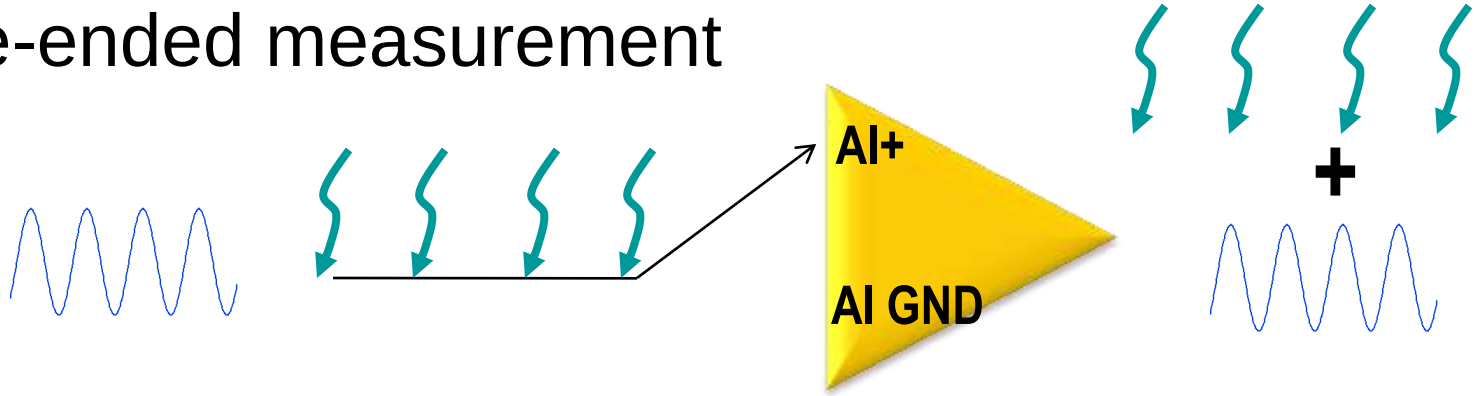
Isolated Data Acquisition Device

- NI 9206

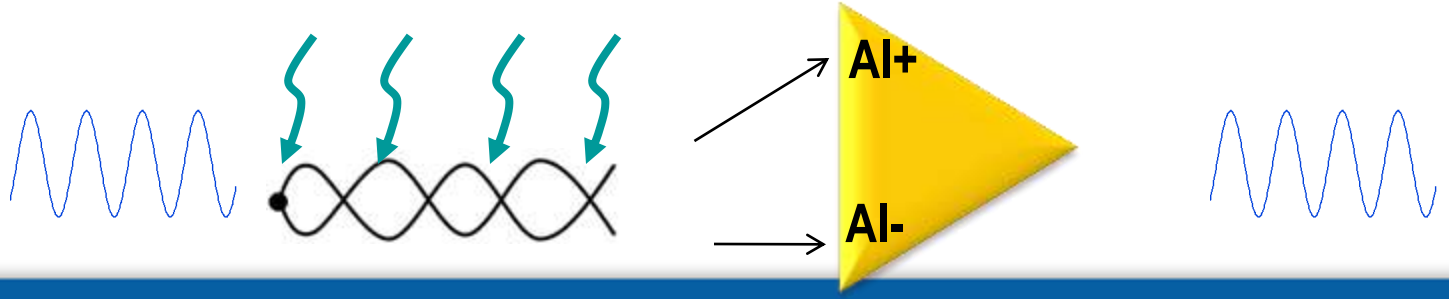


3 Reject Common-Mode Noise

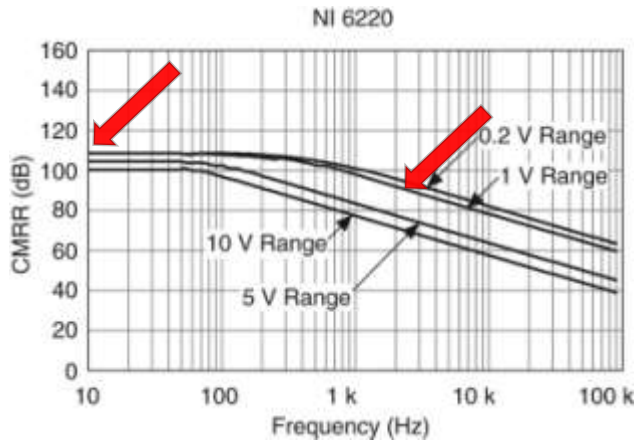
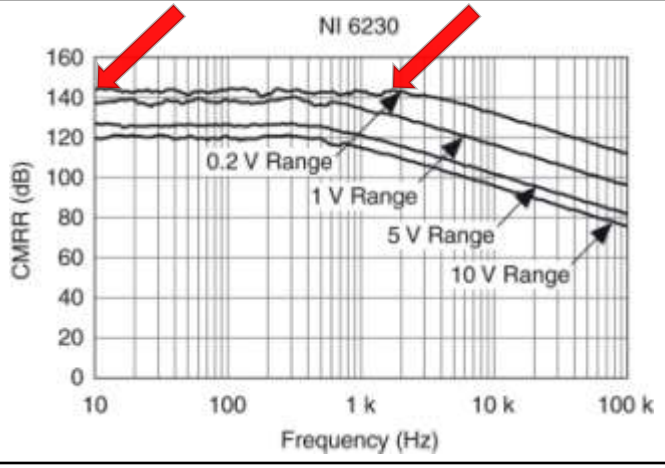
- Noise enters on a single wire with a single-ended measurement



- Noise enters on **+** and **–** wires and is rejected with differential measurements

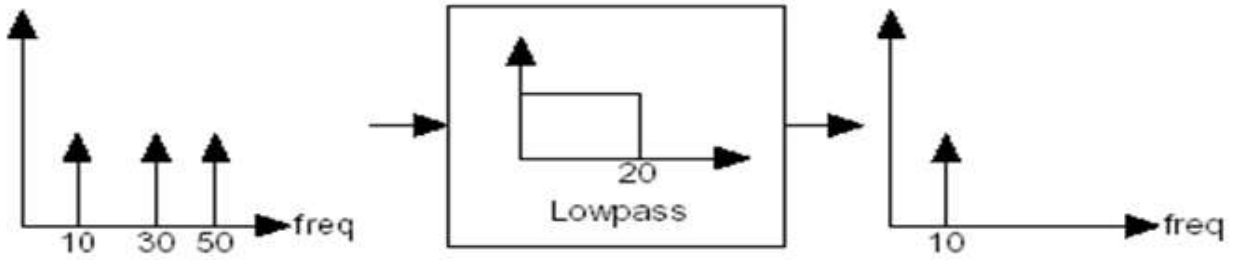


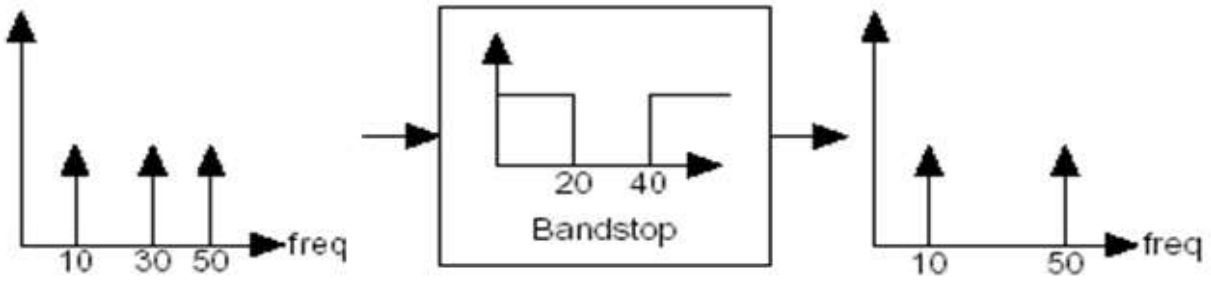
CMRR Graphs – Rejection versus Frequency

NI 6220 – Low-Cost DAQ		
NI 6230 – Industrial NI M Series (Isolated)		

Demo 2

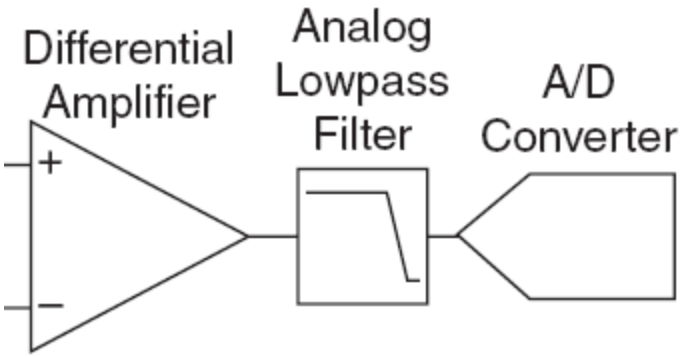
4 Filtering


10
30
50
freq
20
Lowpass
10
freq


10
30
50
freq
20
40
Bandstop
10
50
freq

4 Hardware Filtering

- Antialias filters
  - Based on sampling rate

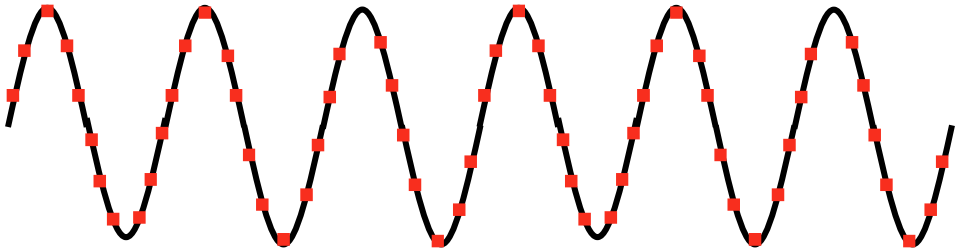


NI USB-9234

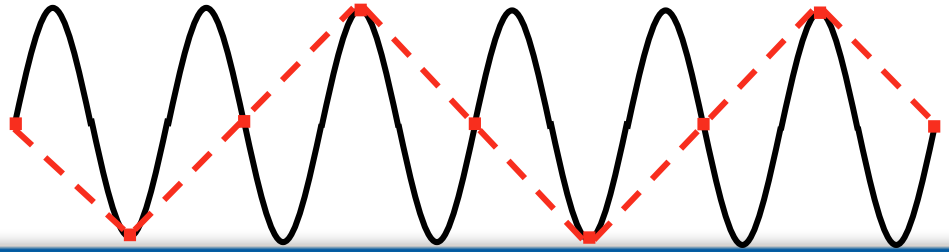
Nyquist Theorem

You must sample **at least twice as fast** as the maximum frequency component of your signal in order to accurately represent the **frequency** of your signal.

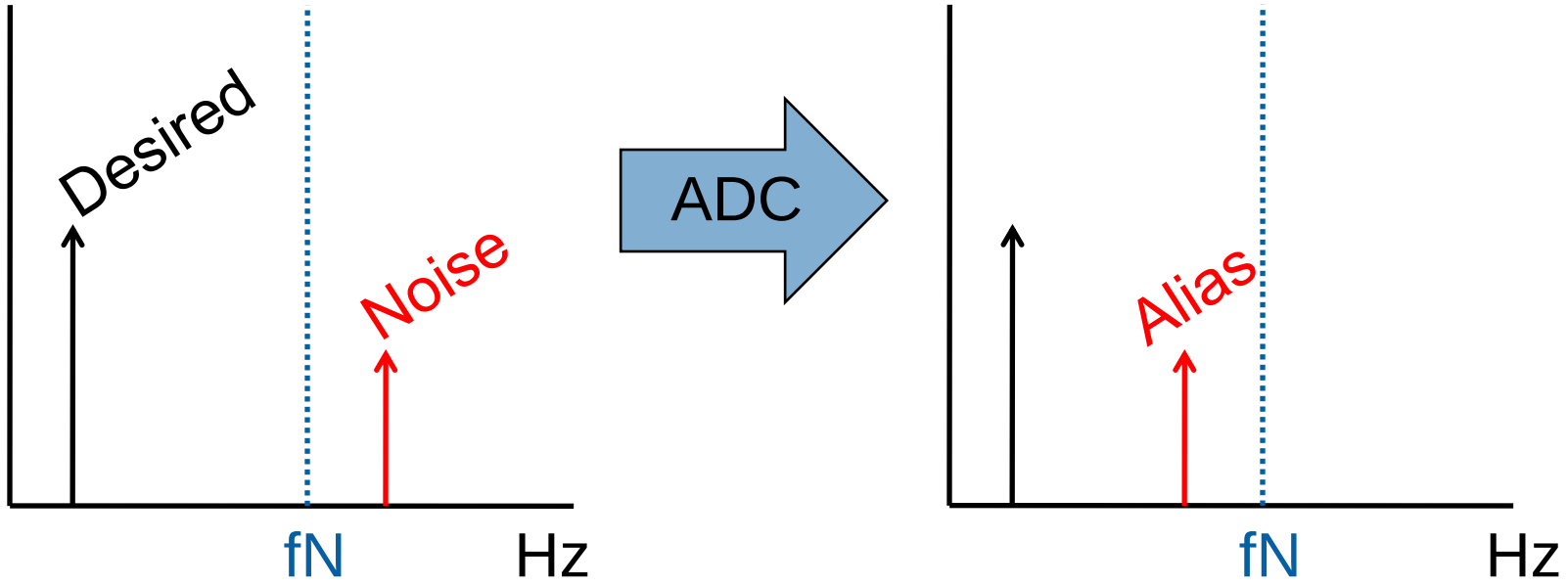
Adequately sampled:



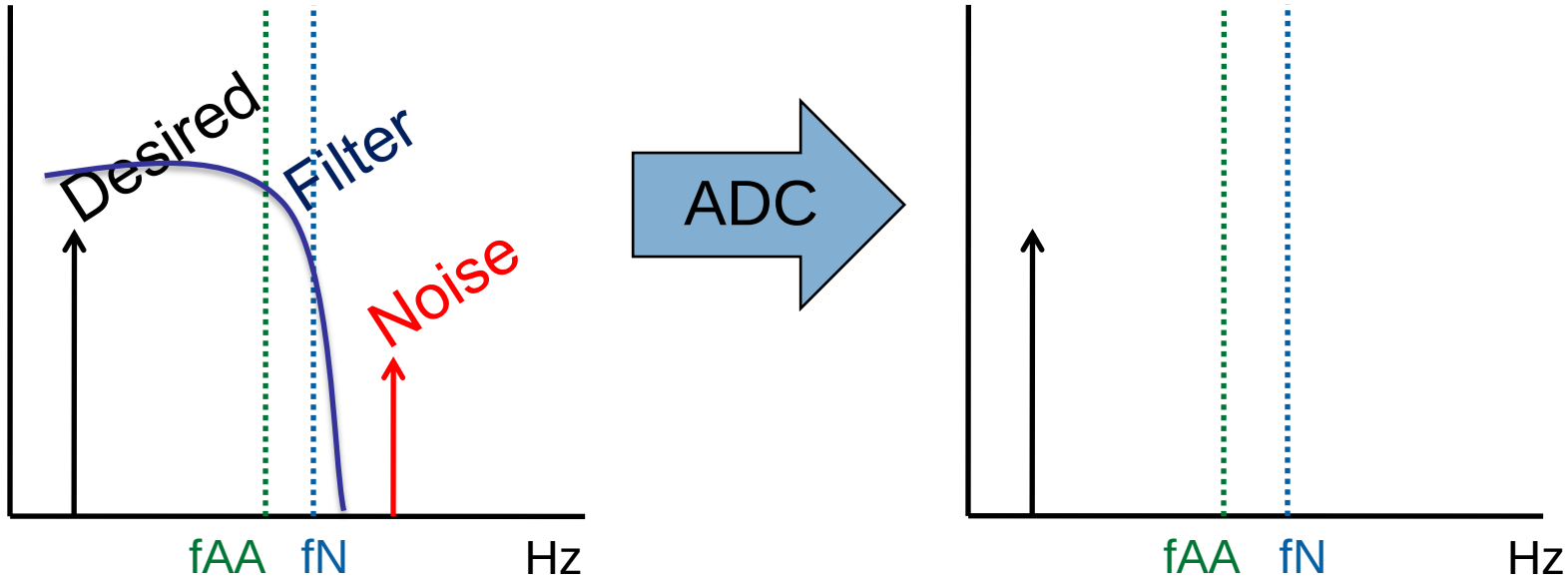
Aliased due to undersampling:



Aliasing Example – Frequency Domain

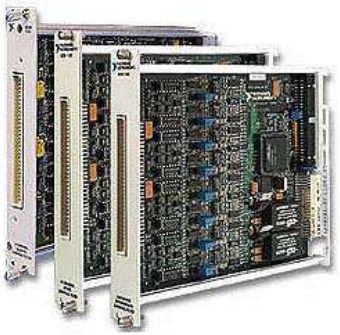


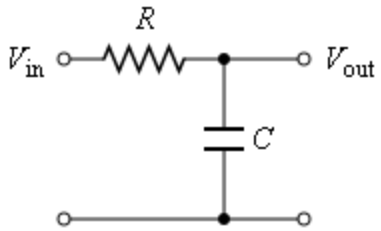
Antialias Filters



4 Hardware Filtering

- Noise removal filters: off-the-shelf or custom
- Varying frequency levels and topologies

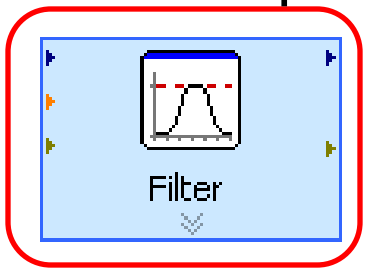




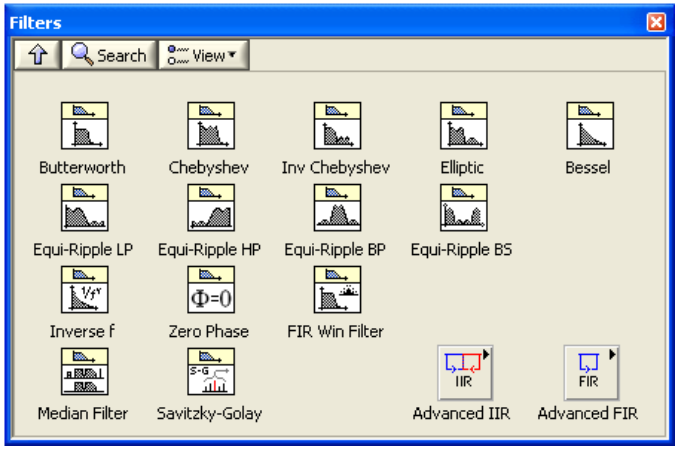
4 Software Filtering

- Easy, flexible, predictable, inexpensive
- Unable to distinguish aliased signals from true ones
- High performance: implement in FPGA

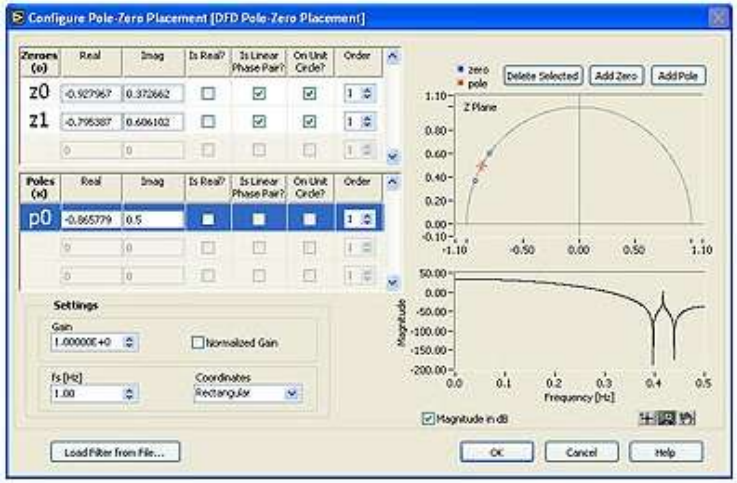
Filter Express VI



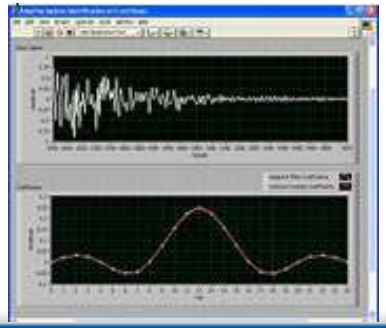
Lower-Level Filter VIs



Digital Filter Design Toolkit

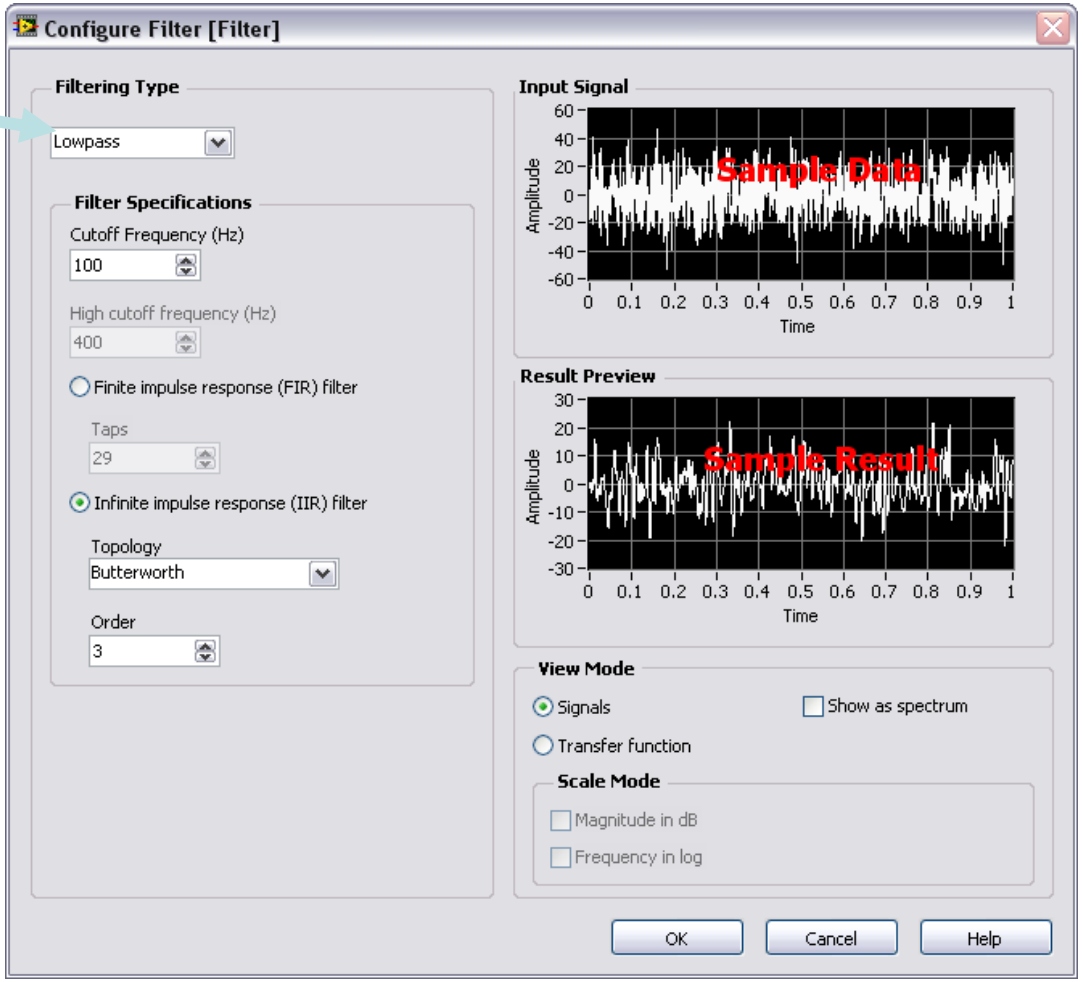


Adaptive Filter Toolkit

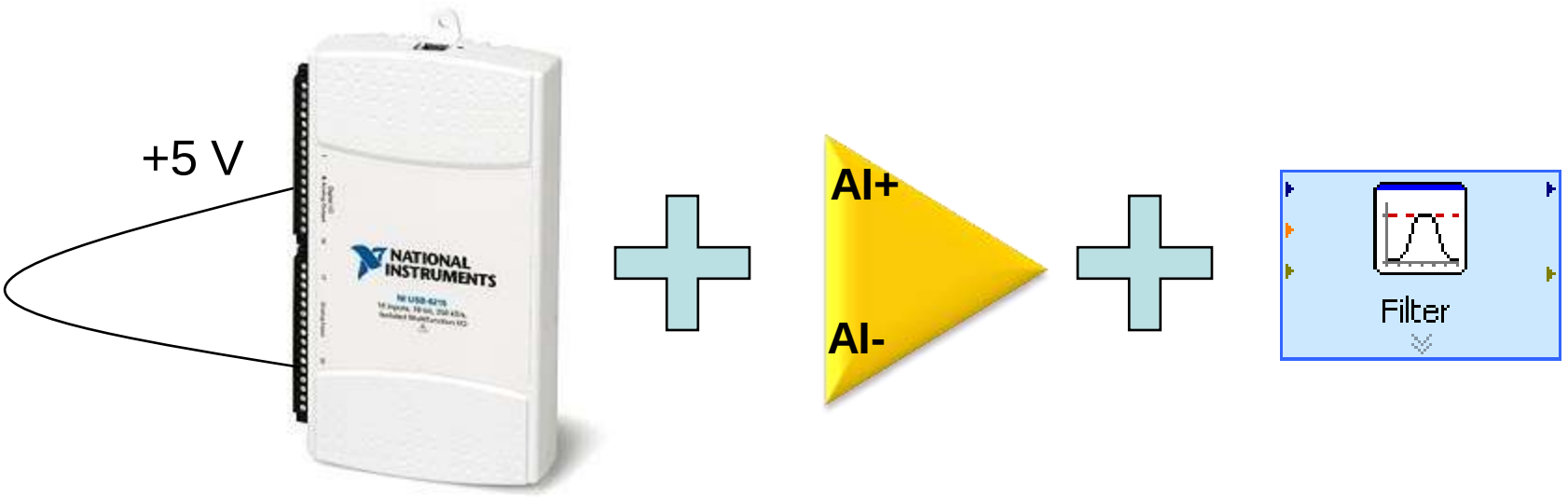


Filter Express VI

- Select filter type
  - Lowpass
  - Highpass
  - Bandpass
  - Bandstop
  - Smoothing
- Select filter specs
  - Cutoff frequency
  - FIR or IIR

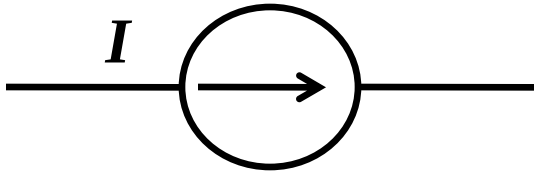


Demo 3

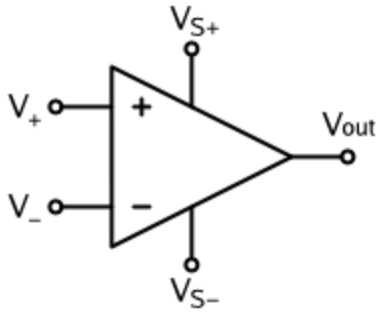


5 Alternative Measurement Technologies

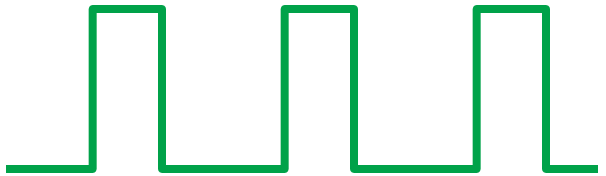
- Current loops



- Conditioned sensors

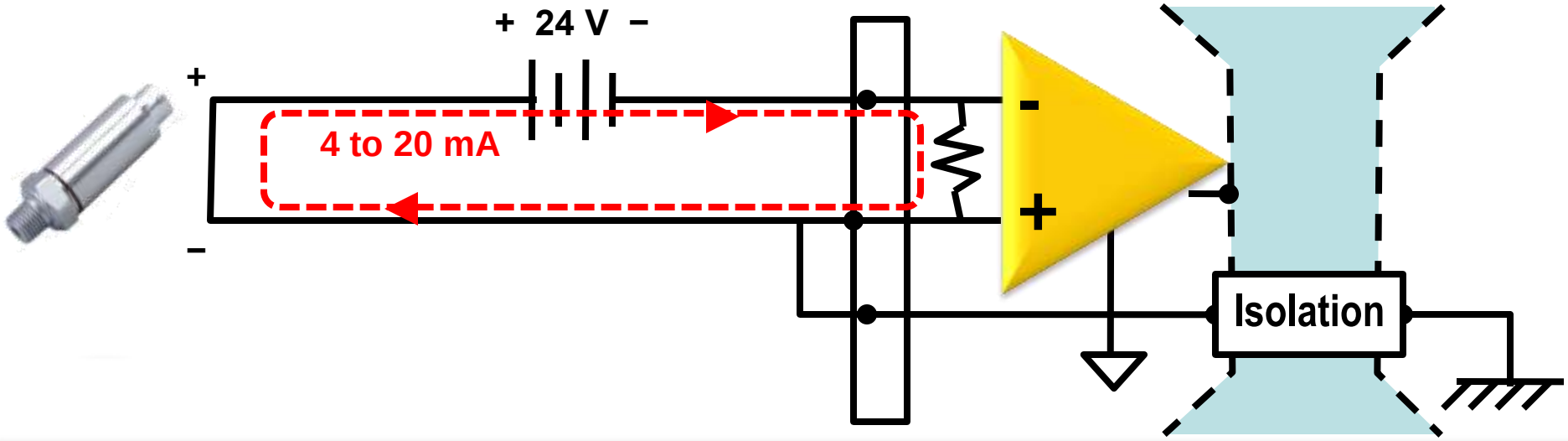


- Digital sensors



Current Loops

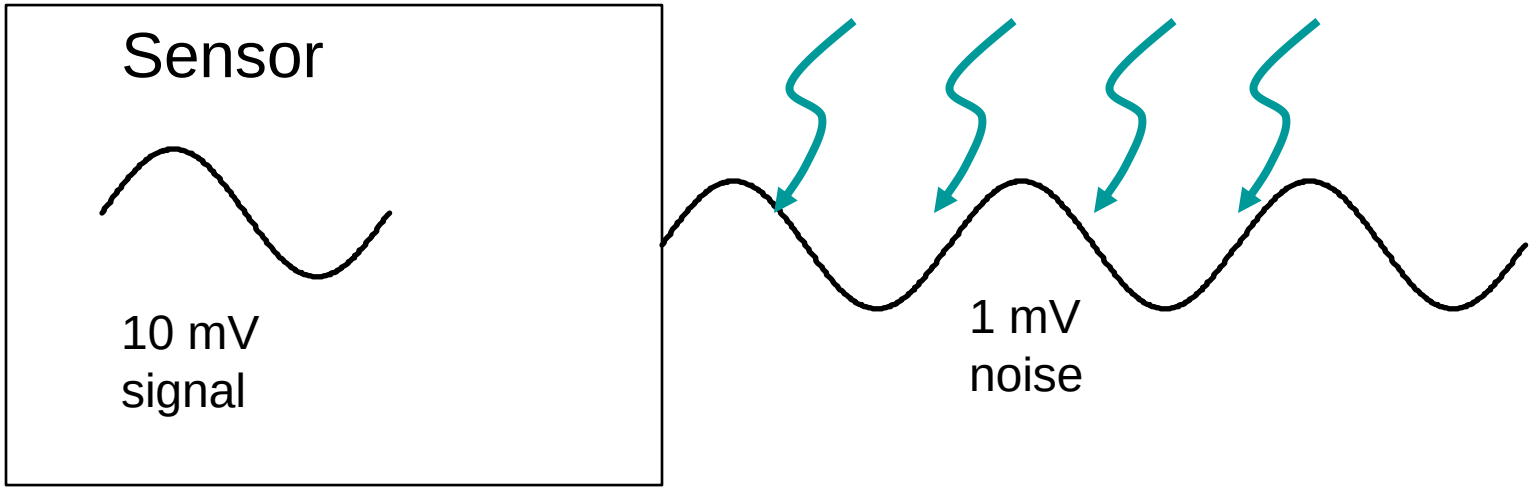
- Long cabling is susceptible to noise and voltage drops in sensor signal
- Many industrial sensors use current for better noise immunity



Conditioned Sensors

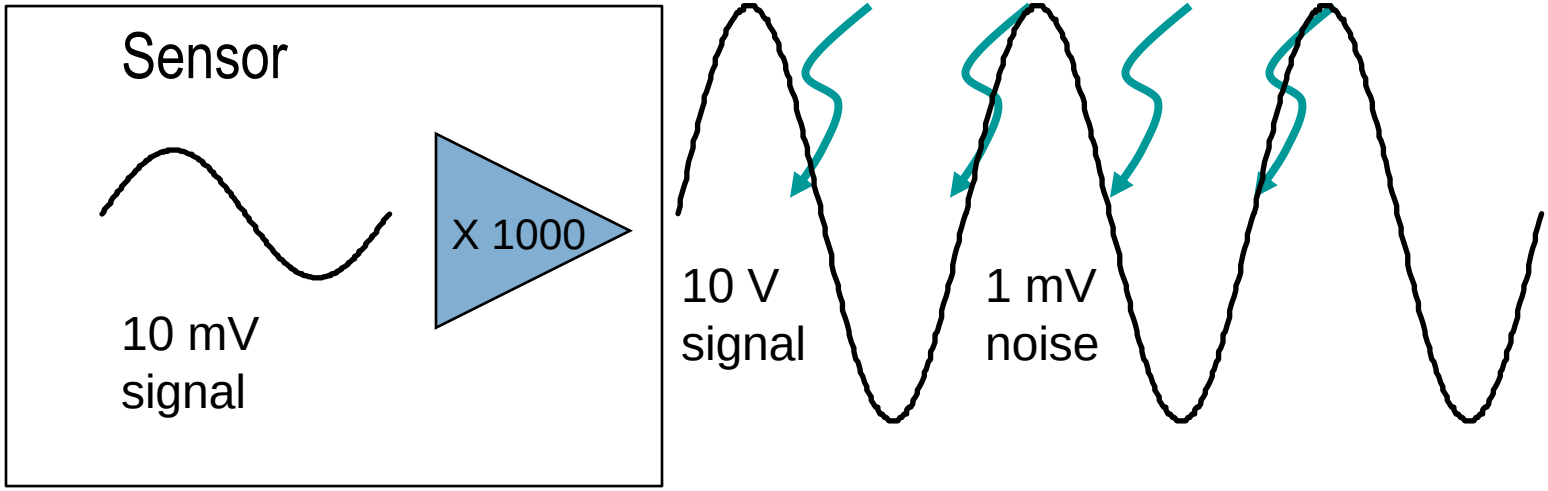
- Some sensors integrate filtering and amplification
- They then output in voltage range rather than mV range (for example, 0 to 10 V)
- This provides a higher SNR

Conditioned Sensors and Amplification



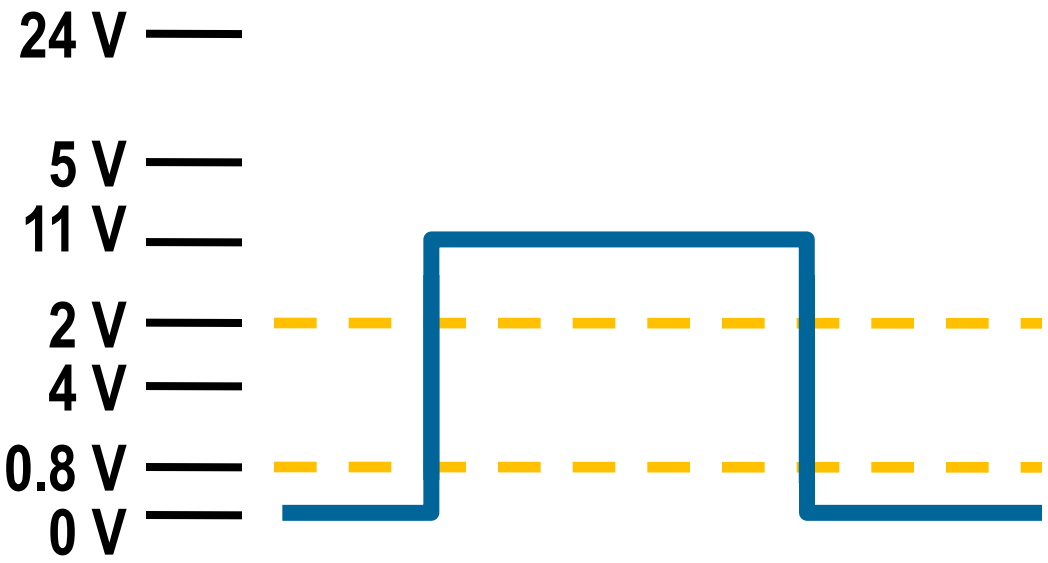
SNR = 10 mV/1 mV = **10**

Conditioned Sensors and Amplification



SNR = 10 V/1 mV = **10,000**

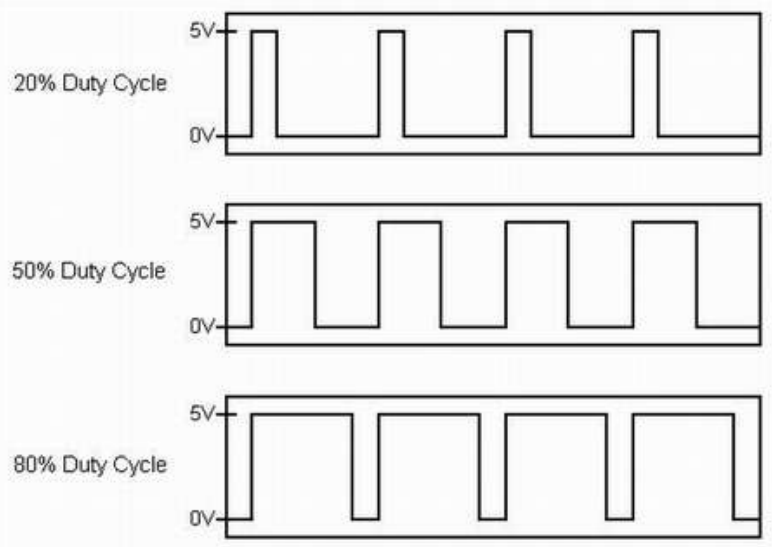
Digital Sensors



- 5 V TTL usually effective
- But 24 V logic is often used in very noisy environments

Digital Sensors

- Certain temperature, pressure load sensors use digital pulses or PWM
- Some sensors even integrate the ADC
  - RS232, RS485, USB



Summary

- Prevent noise from entering system with **positioning** and **shielding**
- Reject common-mode noise and ground loops with **differential measurements** and **isolation**
- Use hardware and software **filtering**
- Use **alternative technologies**
  - 4 to 20 mA current loops, conditioned, and digital sensors