UiO : University of Oslo

FYS3240- 4240
Data acquisition & control

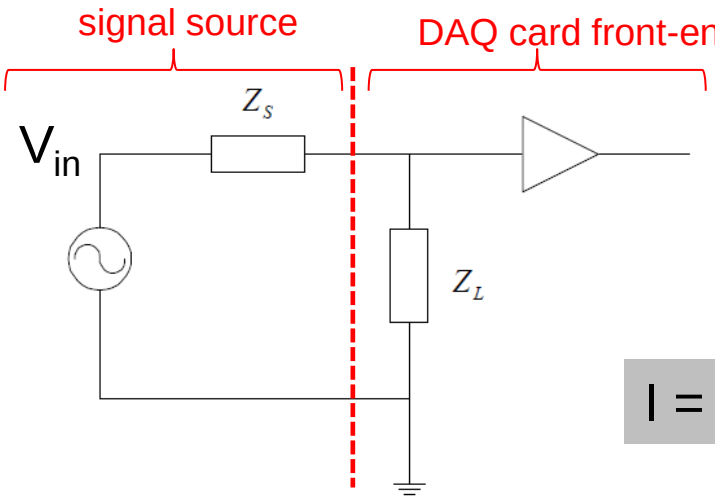
Analog front-end electronics

Spring 2019– Lecture #6

Bekkeng, 3.1.2018

Considerations for analog signals

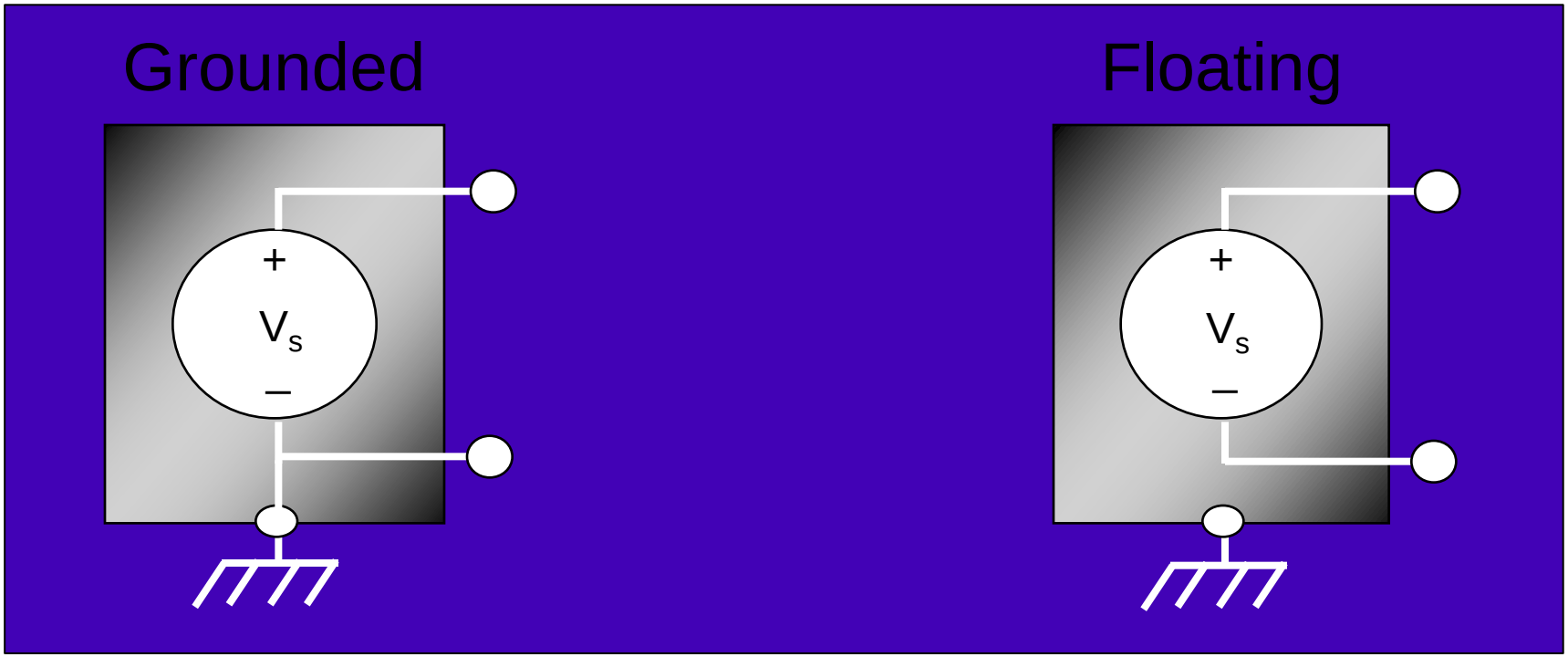
- Signal source - grounded or floating
- Source impedance
  - The DAQ device must have a much higher input impedance than the signal source
  - This is usually not a problem as the DAQ devices are designed to have a very high input impedance (MΩ – GΩ range)
- Single-ended & differential signals



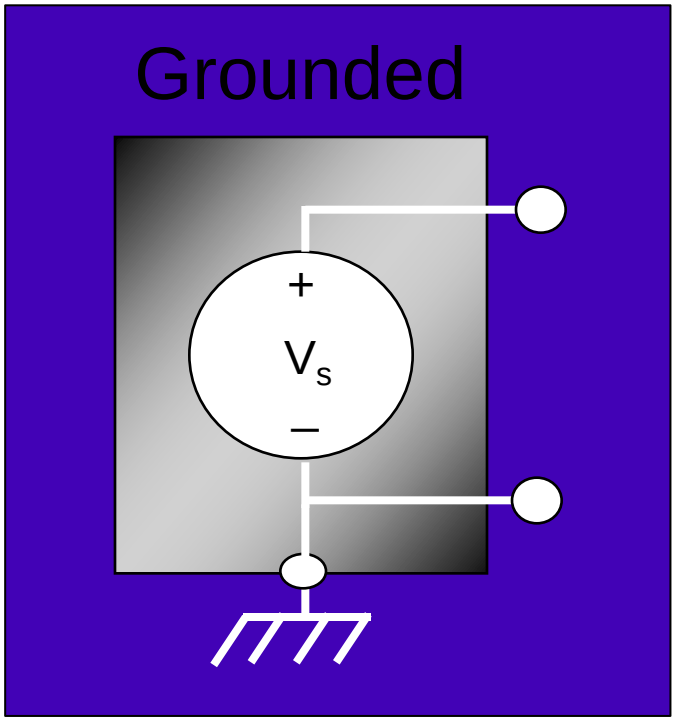
$$V_{out} = \frac{Z_L}{Z_s + Z_L} \cdot V_{in}$$ (voltage divider)

I = V / Z, where (Z is the impedance)

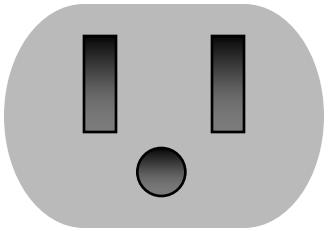
Signal Source Categories



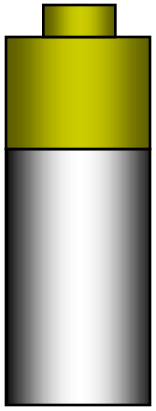
Grounded Signal Source



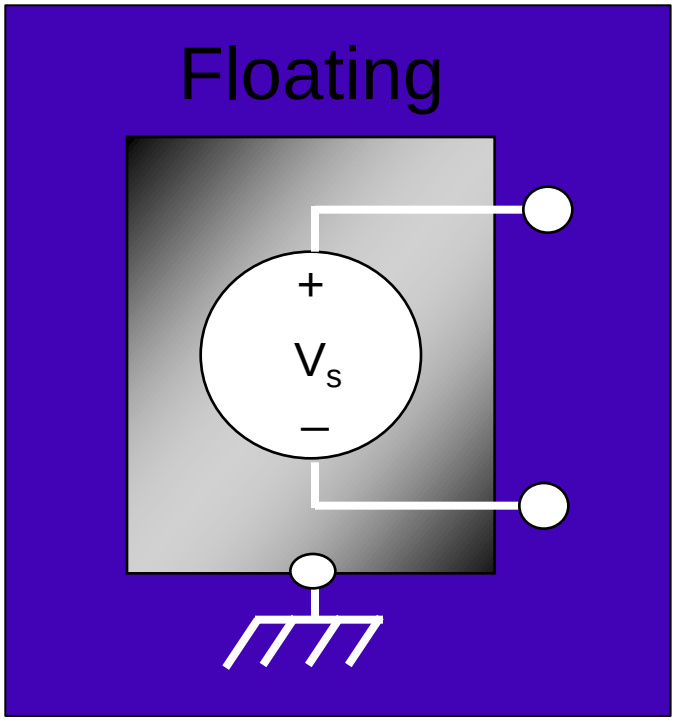
- Signal is referenced to a system ground
  - earth ground
  - building ground
- Examples:
  - Power supplies
  - Signal Generators
  - Anything that plugs into an outlet ground



Floating Signal Source



- Signal is NOT referenced to a system ground
  - earth ground
  - building ground
- Examples:
  - Batteries
  - Transformers
  - Isolation Amplifiers

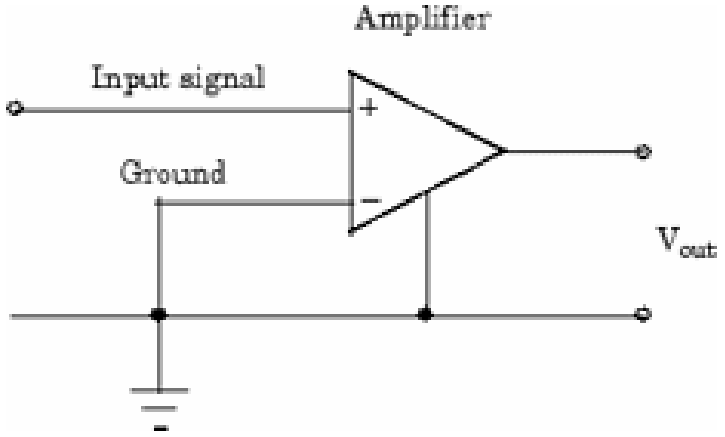


DAQ-card input signal configuration

- DAQ input channels can be configured in two ways:
  - Differential
  - Single-ended
    - Referenced Single-Ended (RSE)
    - Non-Referenced Single-Ended (NRSE)
- The optimal connection depends on how your signal is grounded

Single-ended (SE) signals

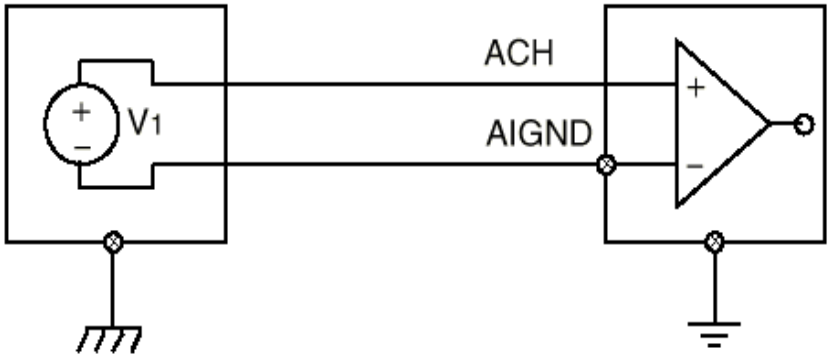
- One signal wire for each input signal
- Can be used for the following conditions:
  - High-level input signals (greater than 1 V)
  - Short cables
  - Properly-shielded cables or cables traveling through a noise-free environment
  - All input signals can share a common reference point (ground)
- To types of connections:
  - Referenced Single-Ended (RSE)
  - Non-Referenced Single-Ended (NRSE)



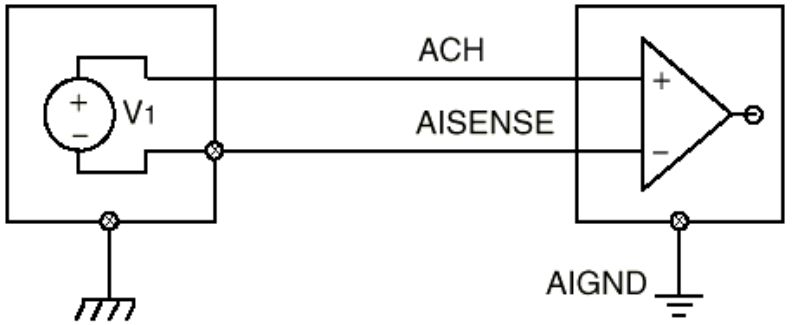
RSE vs. NRSE configuration

- The **RSE** configuration is used for floating signal sources. In this case, the DAQ hardware device itself provides the reference ground for the input signal.
- The **NRSE** input configuration is used for grounded signal sources. In this case, the input signal provides its own reference ground and the hardware device should not supply one.
  - Measurement made with respect to a common reference (AISENSE), not system ground (AIGND)
  - AISENSE is floating

RSE

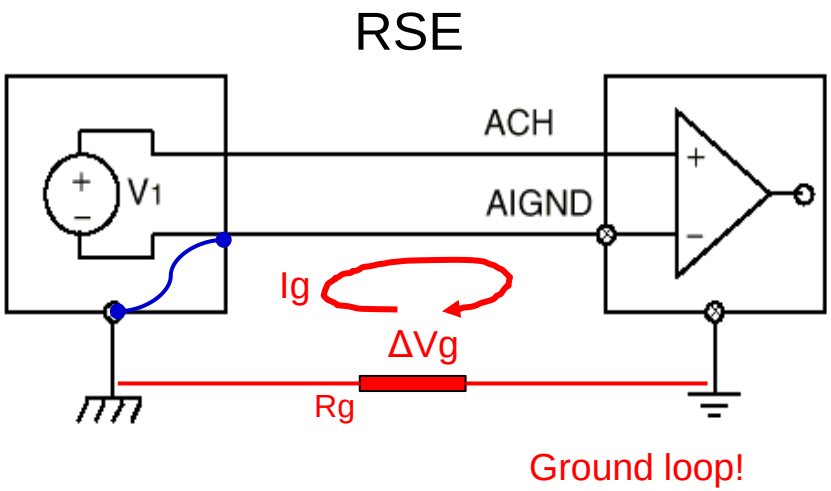


NRSE



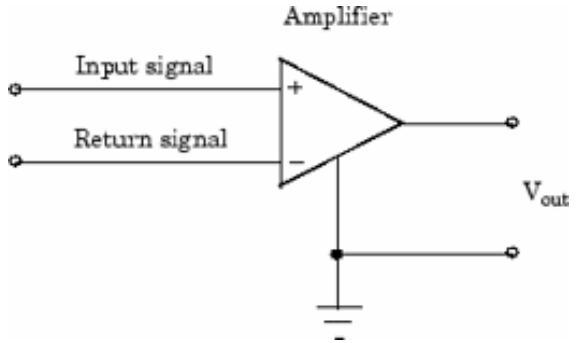
Ground loop illustration

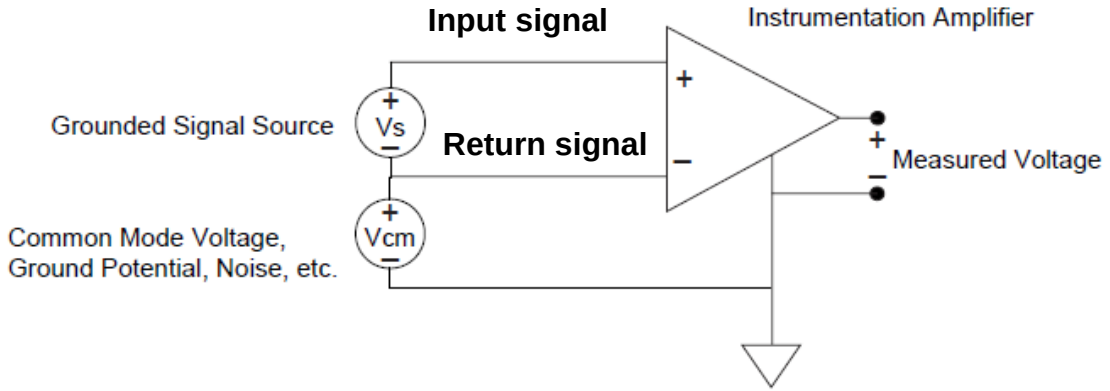
The blue connection to ground must not be added, since it creates a ground loop (red)



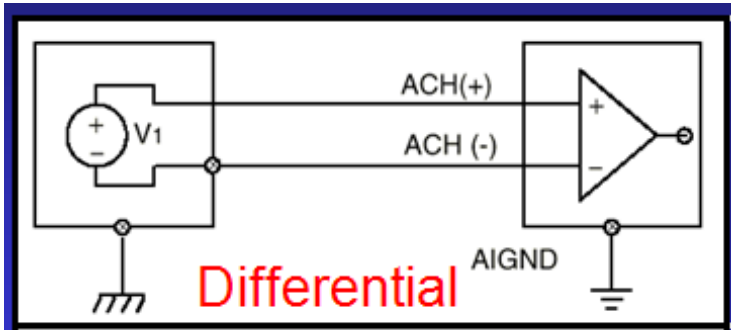
Differential signals

- Two signal wires for each input signal (input and return signals)
- The measurement is the voltage difference between the two wires
- Recommended for the following conditions:
  - Low-level signals (less than 1 V)
  - Long cables
  - The input signal requires a separate ground-reference point or return signal
  - The signal leads go through a noisy environment
- DAQ devices with instrumentation amplifiers can be configured as differential measurement systems
- Any voltage present at the instrumentation amplifier inputs with respect to the amplifier ground is called a common-mode voltage
- The instrumentation amplifier rejects common-mode voltage and common-mode noise





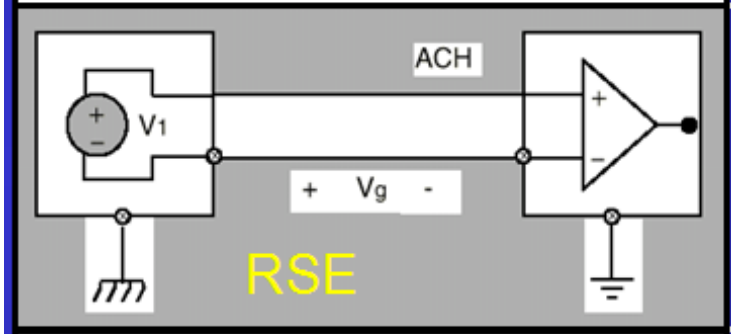
Options for Grounded Signal Sources



BETTER

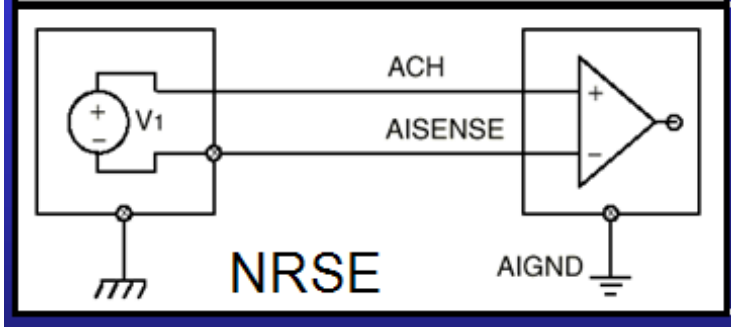
+ Rejects Common-Mode Voltage

- Cuts Channel Count in Half



NOT RECOMMENDED

- Voltage difference (Vg) between the two grounds makes a ground loop that could damage the device



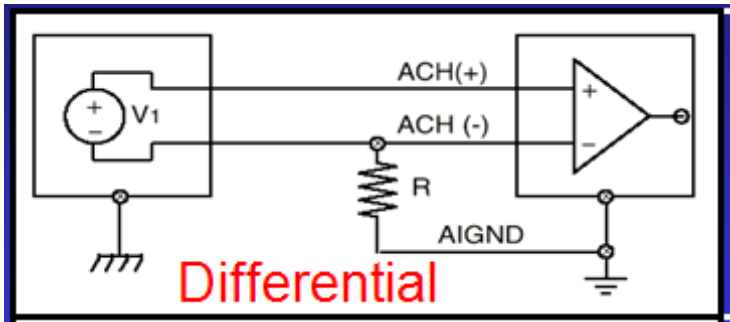
GOOD

+ Allows use of entire channel count

- Doesn't reject Common-Mode Voltage

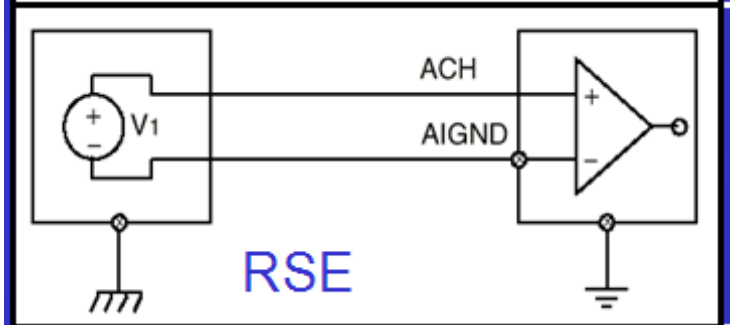
From NI manuals for DAQ devices

Options for Floating Signal Sources



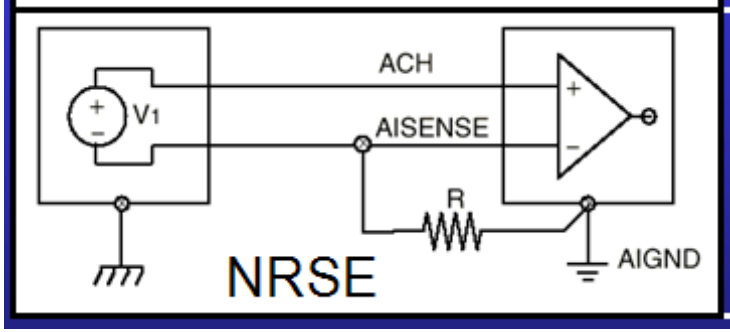
BEST

+ Rejects Common-Mode Voltage
- Cuts Channel Count in Half
- Need bias resistors



BETTER

+ Allows use of entire channel count
+ Don't need bias resistors
- Doesn't reject Common-Mode Voltage



GOOD

+ Allows use of entire channel count
- Need bias resistors
- Doesn't reject Common-Mode Voltage

From NI manuals for DAQ devices

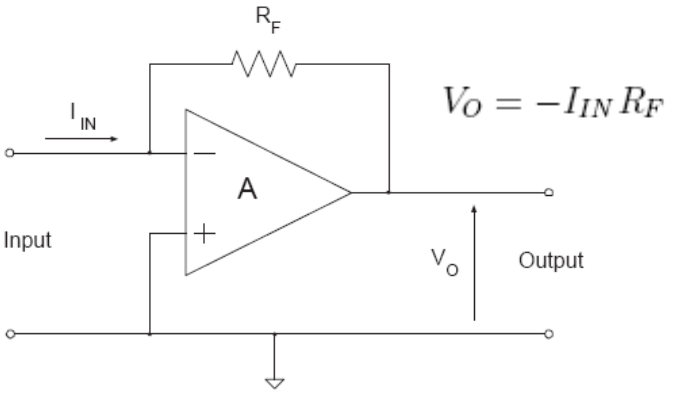
Questions: why is the bias resistor needed for differential and NRSE connection?

Signal conditioning

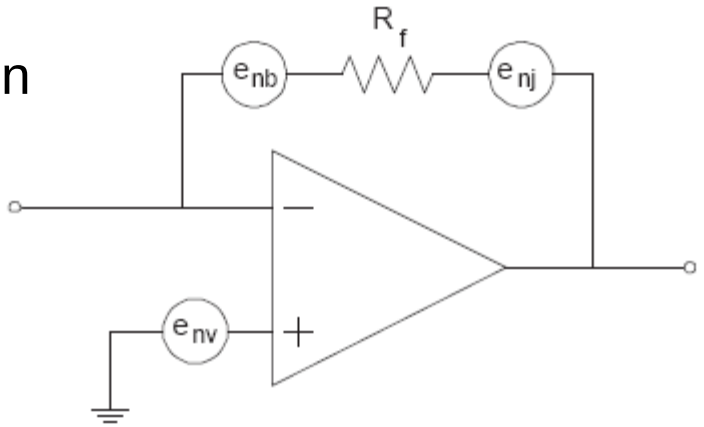
- Signal conversion
  - E.g. current-voltage converter
- Amplification
- Attenuation
  - Voltage divider
- Filtering
  - Anti-aliasing

Current-to-voltage converter

- Transimpedance amplifier (Feedback Ammeter)
- Recommended connection for small currents
- Sensitivity determined by Rf
- Add a capacitor Cf in parallel with Rf to avoid oscillations
- Rf usually large to achieve a large gain
- e_{nb} dominate for large Rf



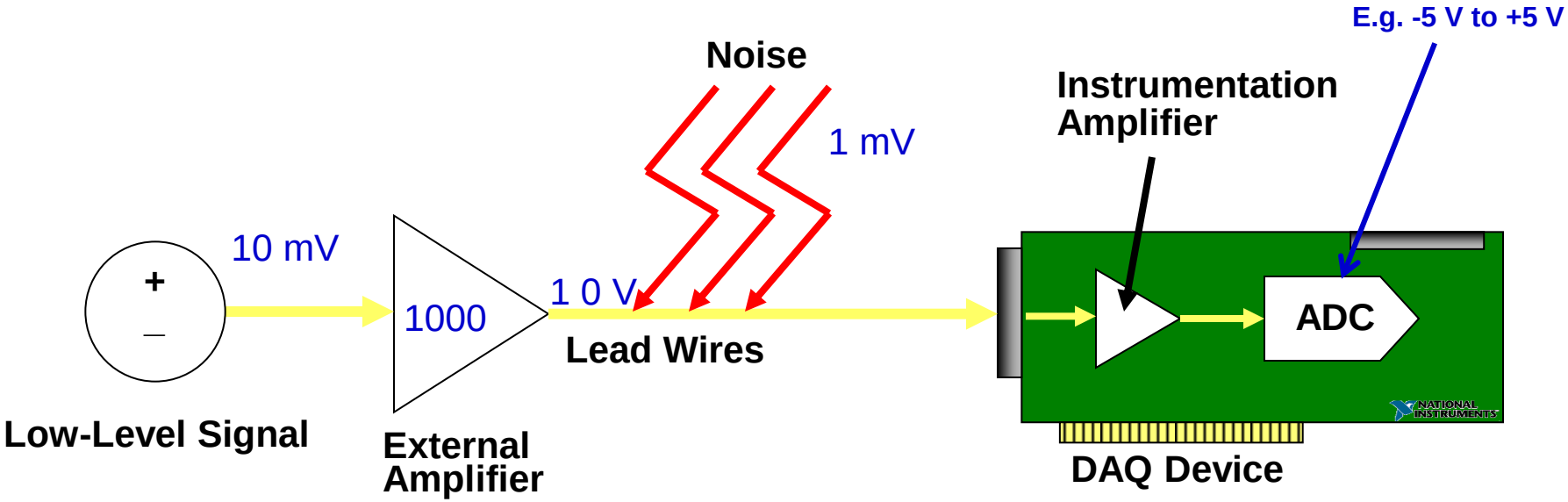
Noise equivalent circuit:



e_{nb} = input current noise * Rf
e_{nv} = input voltage noise
e_{nj} = thermal noise (voltage)

Amplification

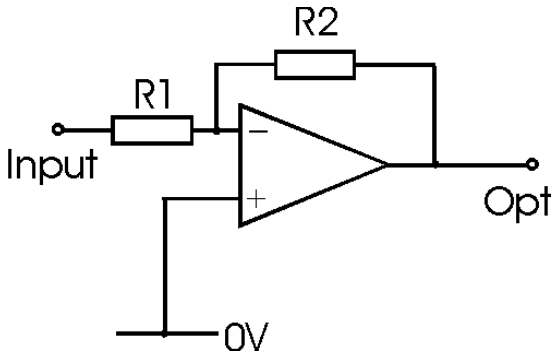
- Used on low-level signals (less than around 100 mV)
- Maximizes use of Analog-to-Digital Converter (ADC) range and increases accuracy
- Increases Signal to Noise Ratio (SNR)

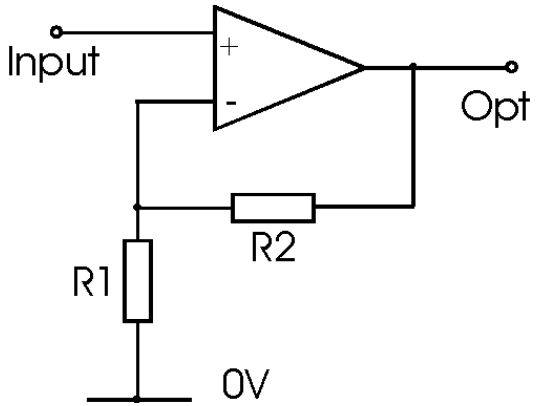


SNR = V_{signal}/V_{noise} = (10 mV * 1000) /1 mV = 10 000

$$SNR = 20 \log\left(\frac{V_{signal}}{V_{noise}}\right)$$

Operational amplifier (Op-amp)

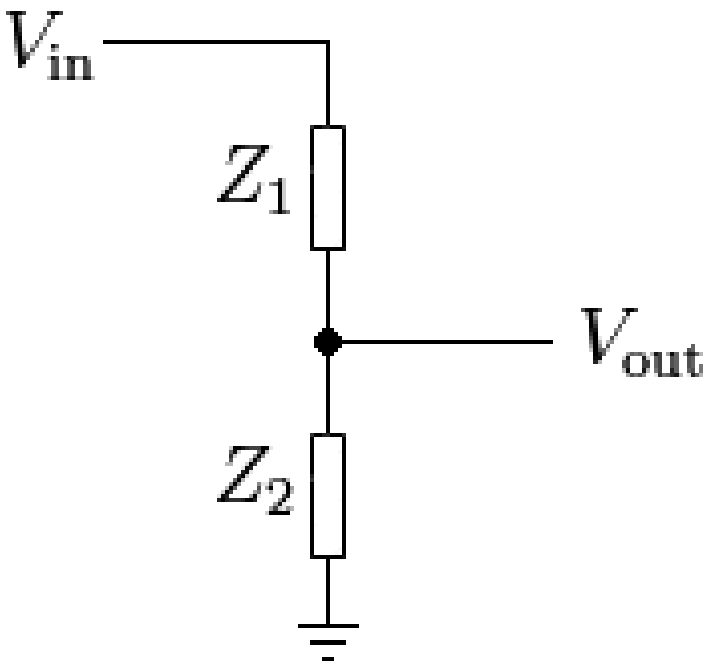




- Inverting op-amp amplifier
  - Vo = -R2/R1 * Vi
- Non-inverting op-amp amplifier
  - Vo = (1+R2/R1) * Vi
- Non-inverting op-amp amplifier useful when a **high impedance** input is needed
- Inverting op-amp amplifier useful when a **low impedance** input is needed

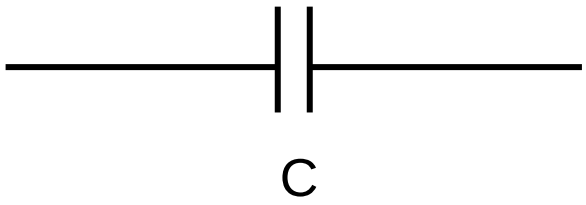
Attenuation

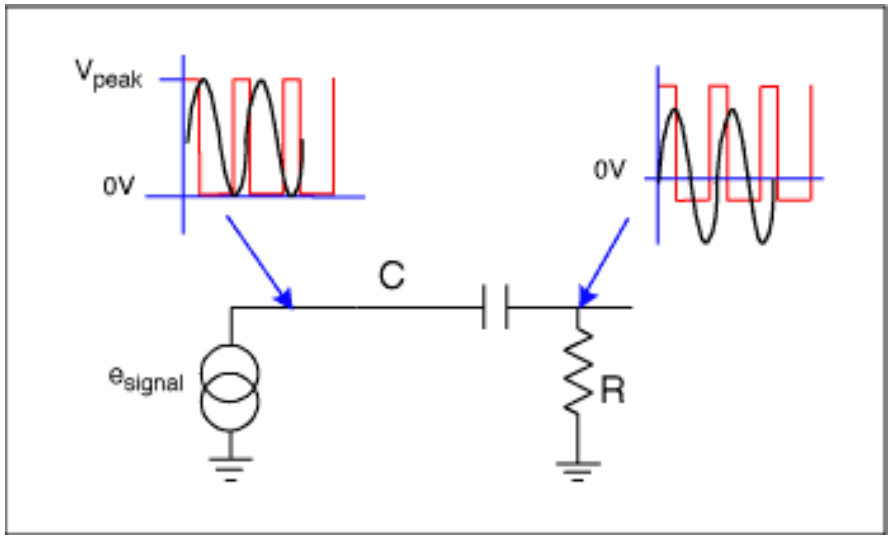
- Voltage divider
- A circuit that produces an output voltage (V_{out}) that is a fraction of its input voltage (V_{in})
- Can be needed to get a high-level signal down to the acceptable DAQ-card range



Input Coupling

- Use AC coupling when the signal contains a large DC component. If you enable AC coupling, you remove the large DC offset for the input amplifier and amplify only the AC component. This configuration makes effective use of the ADC dynamic range





Note: mid-scale level sin vs. pulses