Signal Conditioning
Common Signal Conditioning Functions

- Amplification
- Attenuation
- Filtering
- Conversion (among voltage, current, and/or resistance)
- Differentiation
- Integration
- Linearization
- Frequency Analysis
Gain

- Gain is an expression of voltage amplification:

\[ G = \frac{V_o}{V_i} \]

- Gain is often expressed in decibels:

\[ G_{dB} = 20 \log_{10} \frac{V_o}{V_i} \]

- For example, \( G = 1000 \) corresponds to \( G_{dB} = \) ____ ?
Bandwidth

- Amplifiers do not provide constant gain throughout all operating frequencies.
- The **bandwidth** is frequency range in which gain is relatively constant.
- Beyond cut-off frequencies, amplified signals are likely to suffer from distortion.
Common-Mode Rejection

- Ideally, amplifiers should not produce any output if identical “common-mode” voltages are applied to both input terminals, and instead should amplify only inputs that are distinctly different (“differential-mode”).

- However, real amplifiers exhibit non-zero output even for common-mode voltages.

- A high-quality amplifier should have a large common-mode rejection ratio:

  \[ \text{CMRR} = 20 \log_{10} \frac{G_{\text{diff}}}{G_{\text{cm}}} \]

- Commercial amplifiers can readily have CMRR > 100 dB, so \( \frac{G_{\text{diff}}}{G_{\text{cm}}} = \ldots \)?
Connecting an amplifier to a sensor can change what would otherwise have been the original signal $V_s$, because a new circuit loop is made. Likewise a problem at the output. Circuit analysis shows:

$$V_i = \frac{R_i}{R_s + R_i} V_s$$

$$V_L = \frac{R_L}{R_o + R_L} GV_i$$

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Examples of Operational Amplifiers

- Commercial op-amps readily can have gain > $10^5$, CMRR near 100 dB, input impedance > $10^5 \, \Omega$, and output impedance < 100 $\Omega$. Why are these good?

\[ G = 1 + \frac{R_2}{R_1} \quad \quad \quad G = -\frac{R_2}{R_1} \]
Signal Attenuation

- The most straightforward way to attenuate (reduce) a voltage that is higher than desirable for measurement electronics is to use a voltage divider:

\[ V_o = \frac{R_2}{R_1 + R_2} V_i \]

- A drawback is that the resistors of the voltage divider cause loading effects.
Signal Filtering

- Filtering is often needed to remove selected ranges of frequencies in time-varying voltage signals.

- The most intuitive and common scenario that demands filtering is the rejection of high-frequency noise.

- A low-pass filter attenuates high frequencies, a high-pass filter attenuates low frequencies, and a band-pass filter attenuates both low and high frequencies.