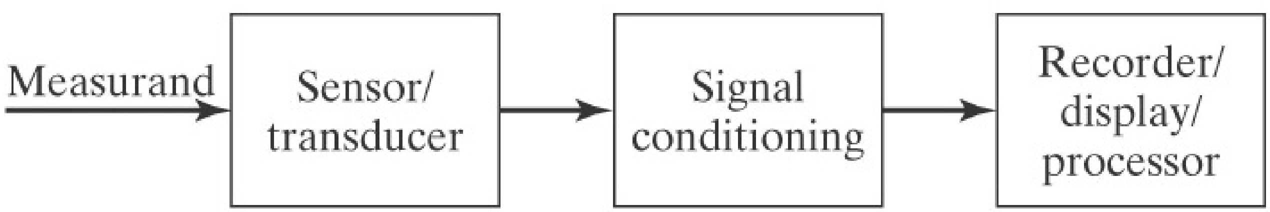
Signal Conditioning

Common Signal Conditioning Functions

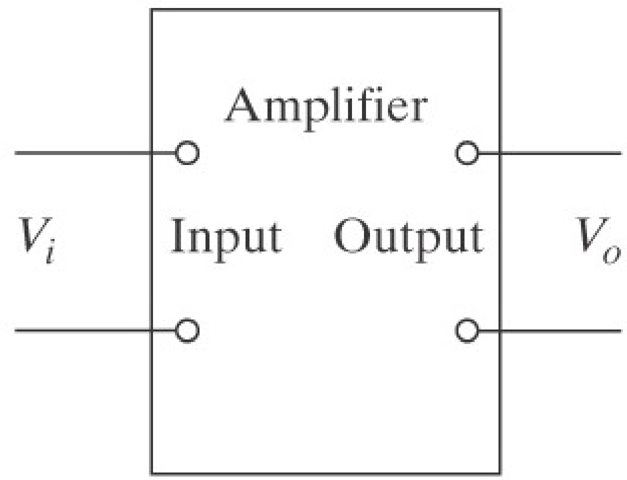
- Amplification
- Attenuation
- Filtering
- Conversion (among voltage, current, and/or resistance)
- Differentiation
- Integration
- Linearization
- Frequency Analysis



Gain

- Gain is an expression of voltage amplification:

$$G = \frac{V_o}{V_i}$$

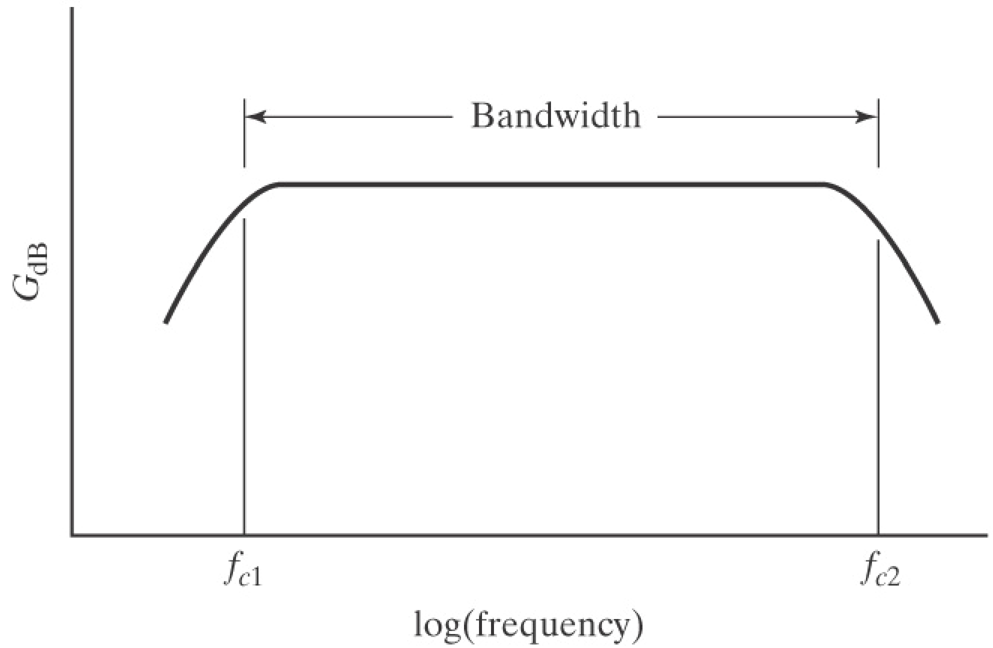


- Gain is often expressed in decibels:

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

  - For example, $G = 1000$ corresponds to G_{dB} = ___ ?

Bandwidth



- Amplifiers do not to 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.

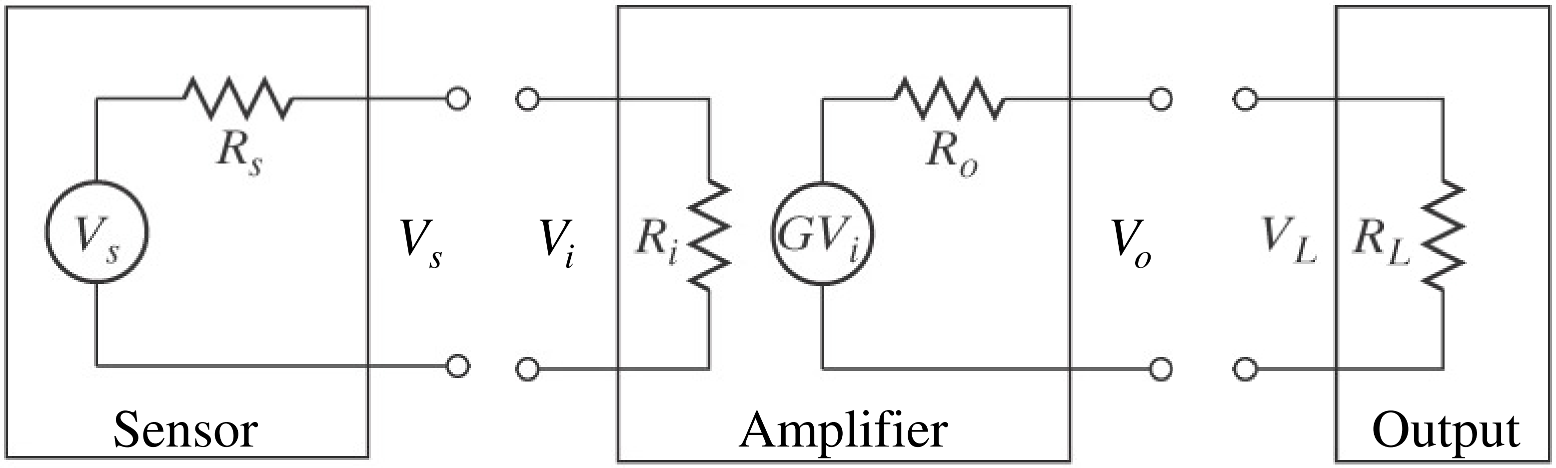
Common-Mode Rejection

- 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:

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

- Commercial amplifiers can readily have CMRR > 100 dB, so $G_{\text{diff}}/G_{\text{cm}}$ = _____ ?

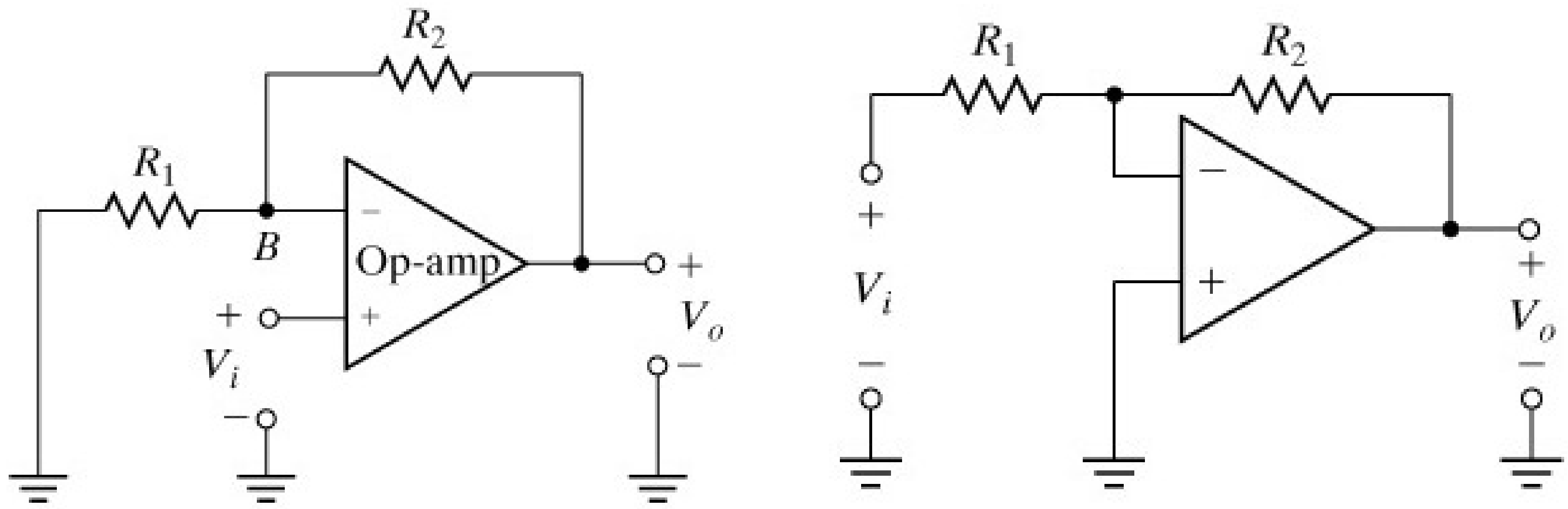
Loading Problems



- 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:

$$V_i = \frac{R_i}{R_s + R_i} V_s \qquad V_L = \frac{R_L}{R_o + R_L} GV_i$$

Examples of Operational Amplifiers



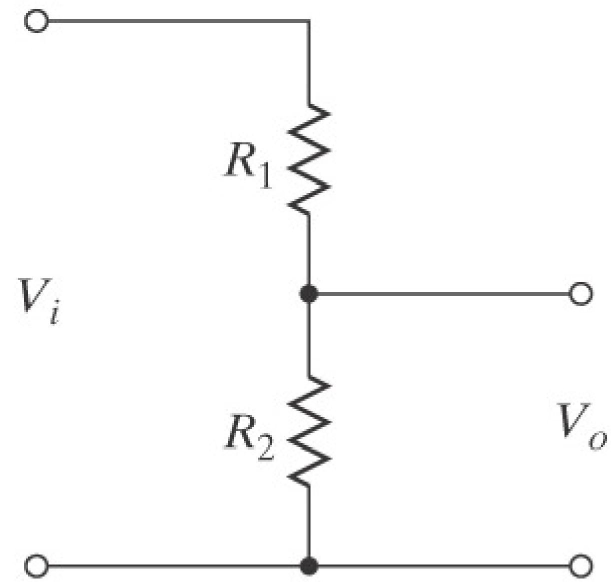
$$G = 1 + \frac{R_2}{R_1} \qquad\qquad G = -\frac{R_2}{R_1}$$

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

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:

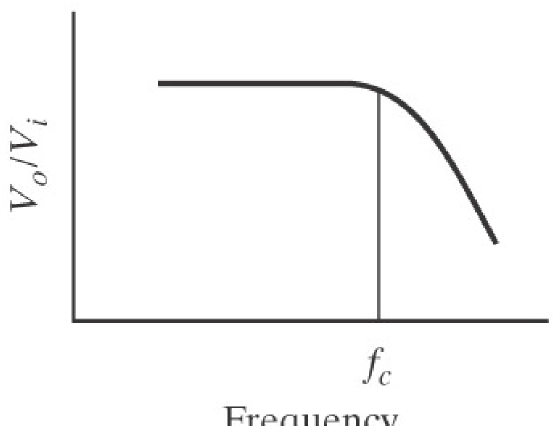
$$V_o = \frac{R_2}{R_1 + R_2} V_i$$



- 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.



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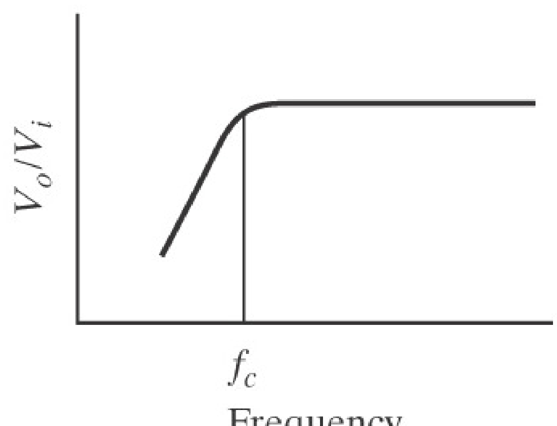

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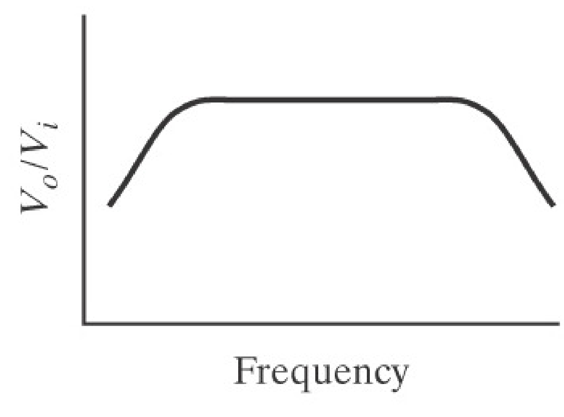

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