SENSORS #2: ANALOG INTERFACE CIRCUITS

READ: CH 5 (FRADEN)

OBJ: ① MOTIVATION FOR INTERFACE CIRCUITS ② DESCRIBE COMMON INTERFACE CIRCUITS

① HOW SENSORS INTERFACE TO DATA ACQUISITION SYSTEMS:
- OFTEN YOU CAN'T JUST ATTACH A SENSOR TO A DATA ACQUISITION SYSTEM
- "RAW" SENSOR OUTPUTS
  - NOISY CORRUPTION
  - WEAK SIGNAL
  - UNDESIRABLE COMPONENTS
  - INCOMPATIBLE WITH DATA ACQ. REQUIREMENTS

③ IMPEDANCE:
- INPUT IMPEDANCE → HOW MUCH DOES INTERFACE CIRCUIT LOAD THE SENSOR

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- A lot of times, interface circuit has resistance & capacitance

\[ Z_{\text{in}} = \frac{R}{1 + j\omega RC} \]

- If \( \omega \) is small, then \( Z_{\text{in}} \approx R \) \( (RC \ll \frac{1}{\omega}) \)

- Also need to consider sensor output impedance

\[ V_{\text{in}} = V_{\text{out}} = V_s \frac{Z_{\text{in}}}{Z_{\text{in}} + Z_{\text{out}}} \]

3. Amplifiers

- Used to "amplify" sensors with weak outputs (\( V_{\text{in}} \leq I \))

- Scale sensor output to data acquisition system

- Built from op-amps (could be made from discrete elements (transistors, diodes, \( R, C, L \)))

\[ V_{\text{out}} = A_{\text{OL}} V_{\text{in}} \]

- \( A_{\text{OL}} \) - dependent on frequency, temperature, load resistance, etc.
A) Non-Inverting Amplifier

\[ V_{out} = \left(1 + \frac{R_2}{R_1}\right) V_{in} \]

- Limited by Gain-Bandwidth, \( f_1 \) (Freq above which Op-Amp can not amplify)
- Open Loop Gain (A_{OL}) should be \( > 100 \times \text{Gain at } f_1 \) (Accurate)
  \( > 1000 \times \text{Gain at } f_1 \) (High Accuracy)
- Consider Bias & Offset Voltages (These will get Amp'ed)

B) Voltage Follower

- Gain \( = 1 \)
- High Current Gain

- Used for “Impedance” Conversion from High to Low (Low Resist)
  Impedance
- Current Converter (Boosts Current)
- Widely Used as Buffer to Data Acquisition System

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C) INSTRUMENTATION AMPLIFIER:

- Some sensors output a differential voltage (ΔV)
  e.g. strain gage bridge
  - Stand-alone or assembled from 3 op-amps

\[
V_0 = \Delta V \left(1 + \frac{2R}{R_a}\right) \frac{R_3}{R_2}
\]

From 3rd op-amp

D) BRIDGE CIRCUIT:

- Wheatstone bridge: used to convert ΔR to ΔV
  - Resistive sensors require

\[
V_{\text{out}} = \left(\frac{R_2}{R_1+R_2} - \frac{R_4}{R_3+R_4}\right)V_{\text{ref}}
\]
E) Filters:

- Selectively alter signal in frequency domain
  - Let some frequencies through & not others

- Based on Fourier Analysis

- 4 Major Filters:
  A) Low Pass
  B) High Pass
  C) Band Pass
  D) Notch

- Can be built from
  A) Passive (R, L, C)
  B) Active (op-amps)
**Passive Filters**

Low Pass:

\[ V_{in} \quad R \quad C \quad V_{out} \quad f_c = \frac{1}{2\pi RC} \]

High Pass:

\[ V_{in} \quad C \quad R \quad V_{out} \quad f_c = \frac{1}{2\pi RC} \]

**Active Filters**

Commonly used for Low Pass: Butterworth, Bessel, Chebyshev

Butterworth ("4-Pole"):

\[ C_1 = 2.613 \text{F} \]
\[ C_2 = 0.924 \text{F} \]
\[ c_2 = 0.8825 \text{ F} \]

\[ V_{in} \quad 1\Omega \quad 1\Omega \quad V_{out} \]

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