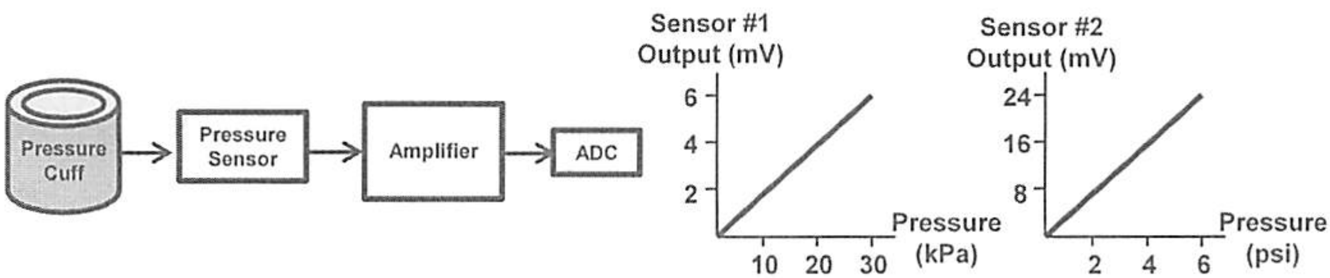
BME/ECE 386 QUIZ (W20) NAME: Solutions

1 problem for 20 pts

Blood Pressure

You are asked to design a blood pressure measurement system that measures up to 240 mmHg with a sensitivity of 0.5 mmHg. The electronic hardware consists of a piezoresistive pressure sensor, instrumentation amplifier, and analog-to-digital converter (ADC).



- There are two available amplifiers: (A_{d1} = 150, V_{N1} = 1 mV) and (A_{d2} = 600, V_{N2} = 6 mV).
- Both amplifiers have V_{REF} = 1.5V and are powered by +10V and GND. Therefore, assume the output is limited to +9V (max) and 1V (min).
- The ADC operates from 0 to 5V (12 bits) with V_N = 3 mV.

NOTE:

- Recall that 1 atm = 760 mmHg = 101 kPa = 14.7 psi (this will NOT be provided on the exam).
- The total noise from two components is computed by: $V_{N,TOTAL} = \sqrt{V_{N1}^2 + V_{N2}^2}$

Problem: Which combination of sensor and amplifier best satisfies the desired system specs? You must show why each combination is OK or not OK. Show all work!

$$V_{Meas} = V_{Ref} + A_d \underbrace{\Delta V}_{S \times P}$$

$$S_1 = \frac{.006V}{30kPa} \times \frac{101\ kPa}{760\ mmHg} = 2.66\times10^{-5}\ \frac{V}{mmHg}$$

$$S_2 = \frac{.024V}{6\ psi} \times \frac{14.7\ psi}{760\ mmHg} = 7.74\times10^{-5}\ \frac{V}{mmHg}$$

$\boxed{\text{Method 1}}$ For P = 240 mmHg, check $V_{Meas} < 5V$ ← limited by ADC for all cases

- S_1, A_1: $V_{Meas} = 1.5 + 150 \times 2.66\times10^{-5} \times 240 = 2.46V$ ✓ ← Need To check ΔP_{min}!
- S_1, A_2: $V_{Meas} = 1.5 + 600 \times 2.66\times10^{-5} \times 240 = 5.33V$ X

- S_2, A_1: $V_{Meas} = 1.5 + 150 \times 7.74\times10^{-5} \times 240 = 4.29V$ ✓
- S_2, A_2: $V_{Meas} = 1.5 + 600 \times 7.74\times10^{-5} \times 240 = 12.6V$ X

$\boxed{\text{Method 2}}$ Find P that produces $V_{meas} = 5V$ ← limited by ADC for all cases

(extra sheet for work)

- S_1, A_1: $P_{max} = \dfrac{5 - 1.5}{150 \times 2.66 \times 10^{-5}} = 877.2$ mmHg ✓
- S_1, A_2: $P_{max} = \dfrac{5 - 1.5}{600 \times 2.66 \times 10^{-5}} = 219.3$ mmHg X (Too low)
- S_2, A_1: $P_{max} = \dfrac{5 - 1.5}{150 \times 7.74 \times 10^{-5}} = 301.5$ mmHg ✓
- S_2, A_2: $P_{max} = \dfrac{5 - 1.5}{600 \times 7.74 \times 10^{-5}} = 75.4$ mmHg X (Too low) ← Cannot measure 240 mmHg

Need to check ΔP_{min}!

☆ Check sensitivity!

- S_1, A_1: $V_N = \sqrt{1^2 + 3^2} = \overbrace{3.2\,mV}^{\Delta V_{MIN}!}$ $\qquad \Delta V_{ADC} = \dfrac{5 - 0}{2^{12} - 1} = 1.22\,mV$

$$\Delta P_{min} = \frac{\Delta V_{min}}{\frac{\partial V_{meas}}{\partial P}} = \frac{.0032V}{150 \times 2.66 \times 10^{-5}\ \frac{V}{mmHg}} = 0.8 \text{ mmHg X}$$

(Too big)

- S_2, A_1: $V_N = \sqrt{1^2 + 3^2} = 3.2\,mV > \Delta V_{ADC} = 1.22\,mV$

$$\Delta P_{min} = \frac{.0032V}{150 \times 7.74 \times 10^{-5}\ \frac{V}{mmHg}} = \boxed{0.28 \text{ mmHg}} ✓$$

$\boxed{\text{Winner is } S_2, A_1}$