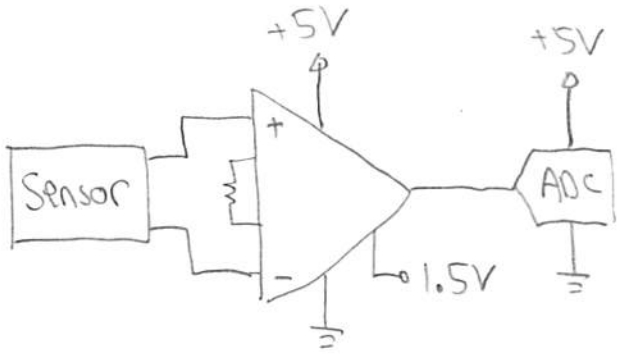
BME 386
HW6 Solns

Total = 100 pts




1) $V_{Meas} = A_d \Delta V + V_{ref}$

(+10) $= A_d S R F + V_{ref}$

$$S = \frac{.025V}{psi} \times \frac{14.7\,psi}{101kPa} = .00364\,\frac{V}{kPa}$$

For $F_{max} = 16\,L/s$,

want $V_{Meas} < 4V$ ← limited by amplifier

$$A_d S R F_{max} + 1.5 < 4 \rightarrow A_d < \frac{4 - 1.5V}{\left(.00364\,\frac{V}{kPa}\right)\left(.020\,\frac{kPa \cdot s}{L}\right)(16\,L/s)}$$

$$< \underline{2146} \Rightarrow \text{Choose } \boxed{A_d = 2000}$$

2) $\Delta V_{ADC} < \frac{1}{2} V_{noise} \Rightarrow \frac{5-0}{2^n - 1} < \frac{1}{2}(.015)$

(+7)

$$2^n - 1 > 666.7 \rightarrow n > \frac{\log 667.7}{\log 2} = 9.38$$

Choose $\boxed{n = 10 \text{ bits}}$

3) $\Delta F_{min} = \frac{\Delta V_{min}}{\frac{\partial V_{Meas}}{\partial F}} = \frac{.015V}{2000\left(.00364\,\frac{V}{kPa}\right)\left(.020\,\frac{kPa \cdot s}{L}\right)}$

(+7)

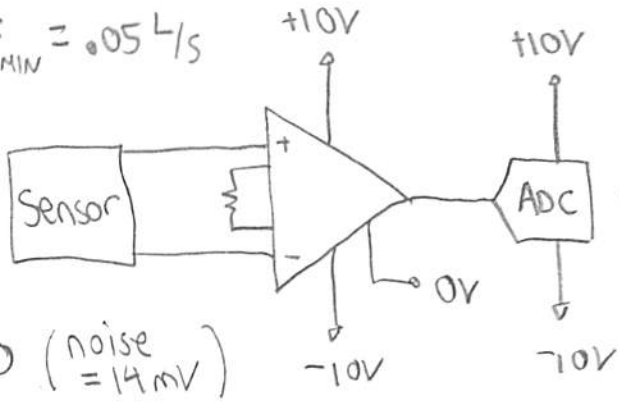
$= \boxed{0.1\,L/s}$

4) ✱ Want $|F_{max}| \geq 15$ L/s, $\Delta F_{MIN} = .05$ L/s

$V_{meas} = A_1 S R F + V_{ref}$

$V_{ref} = 0V$

(+16)




$S_1 = .008 \frac{V}{kPa}$, $A_1 = 1500$ (noise = 14 mV)

$S_2 = .030 \frac{V}{kPa}$, $A_2 = 2500$ (noise = 20 mV)

$\Delta V_{ADC} = \frac{20V}{2^{12}-1} = 4.9mV$

✱ Due to amplifier, $|V_{meas}| < 9V$!

⇒ Compute $F_{Max}$ and $\Delta F_{MIN}$ for each combo

- $S_1, A_1$: $9 = 1500\left(.008 \frac{V}{kPa}\right)(.025\ kPa \cdot \frac{s}{L}) F_{Max} \rightarrow F_{max} = 30$ L/s ✓

$$\Delta V_{MIN} = \begin{cases} \Delta V_{ADC} = 4.9mV \\ V_{N1} = \sqrt{(14)^2 + (10)^2} = 17.2mV \leftarrow \Delta V_{MIN} \end{cases}$$

$\rightarrow \Delta F_{MIN} = \frac{.0172V}{1500(.008)(.025)} = .057$ L/s X (Too big)

⇒ Rule out $S_1, A_1$

WINNER!

- $S_1, A_2$: $9 = 2500(.008)(.025) F_{max} \rightarrow F_{max} = 18$ L/s ✓

$V_{N2} = \sqrt{(20)^2 + (10)^2} = 22.4mV > 4.9mV$ ✓

$\rightarrow \Delta F_{MIN} = \frac{.0224V}{2500(.008)(.025)} = .045$ L/s ✓

Works!

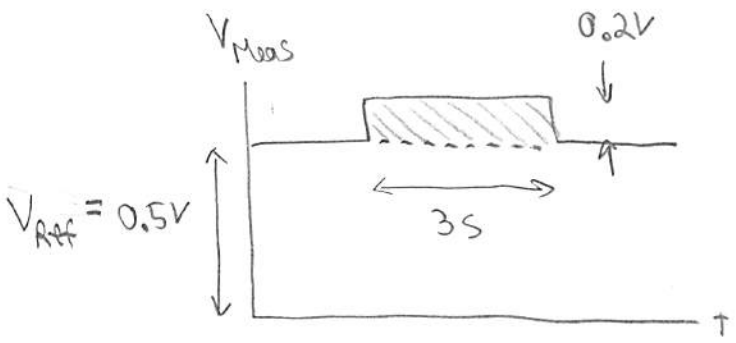
- $S_2, A_1$: $9 = 1500(.030)(.025) F_{max} \rightarrow F_{max} = 8$ L/s X (Too low) ⇒ Rule out $S_2, A_1$

- $S_2, A_2$: $9 = 2500(.030)(.025) F_{max} \rightarrow F_{max} = 4.8$ L/s X (Too low) ⇒ Rule out $S_2, A_2$

5) Want $F_{max} \geq 20$ L/s

$\Delta F_{MIN} = 0.05$ L/s

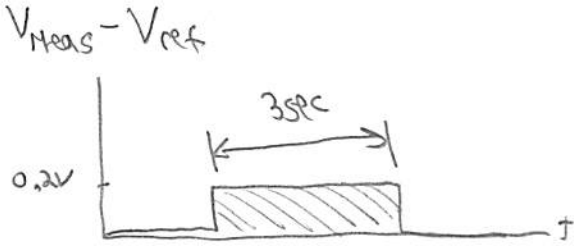
+12




$$V_{meas} = A_d S R F + V_{ref}$$

$$V_{meas} - V_{ref} = A_d S R F$$

$$F = \frac{1}{A_d S R}(V_{meas} - V_{ref})$$




$$\text{Total Volume} = \int F\,dt = \frac{1}{A_d S R}\underbrace{\int (V_{meas} - V_{ref})\,dt}_{\text{Area within rectangle}}$$

$$S = 24\frac{mV}{psi} \times \frac{14.7 psi}{\underbrace{101 kPa}_{1\ atm}}$$

$$= 3.5\ mV/kPa$$

$$\text{Total Volume} = 3L = \frac{1}{A_d S R}(0.2V \times 3sec)$$

$$R = \frac{0.6\ V \cdot s}{3L\,(1500)(.0035\ V/kPa)} = 0.038\ kPa \cdot s/L = \boxed{38\ Pa \cdot s/L}$$

6) +12

$$\Delta V_{ADC} = \frac{10V}{2^{10}-1} = 9.8mV \qquad V_N = \sqrt{(8)^2 + (15)^2} = \underbrace{17mV}_{\Delta V_{MIN}}$$

$$\rightarrow \Delta F_{MIN} = \frac{.017V}{1500\left(.0035\frac{V}{kPa}\right)(.038\ kPa \cdot s/L)}$$

$$= \boxed{0.085\ L/s} \times \text{(too big)}$$

$$4 = A_d SR F_{max} + 0.5 \Rightarrow F_{max} = \frac{4 - 0.5V}{1500\left(.0035 \frac{V}{kPa}\right)(.038\ kPa \cdot s/L)}$$

$$= \boxed{17.54\ L/s}\ X \text{ (too small)}$$

(want $\geq 20\ L/s$)

Does not satisfy $F_{max}$ nor $\Delta F_{MIN}$! ☹

7) For any combo, require $|V_{meas}| < 4V$

Amp 2, ADC1: $4 = 1000 \cdot (.0035)(.038) F_{max} + 0.5 \Rightarrow F_{max} = \underline{26.3\ L/s}$ ✓

(+12) $\Delta V_{ADC} = 9.8\ mV$ $\quad V_N = \sqrt{(5)^2 + (15)^2} = \underline{15.8\ mV}$ $\Delta V_{MIN}$

$$\Rightarrow \Delta F_{MIN} = \frac{.0158V}{1000(.0035)(.038)} = \boxed{0.12\ L/s}\ X \text{ (too big)}$$

Amp2, ADC2: $4 = 1000(.0035)(.038) F_{max} + 0.5 \Rightarrow F_{max} = \underline{26.3\ L/s}$ ✓

WINNER!

$\Delta V_{ADC} = \frac{10V}{2^{12}-1} = \underline{2.44\ mV}$ $\quad V_N = \sqrt{(5)^2 + (4)^2} = \underline{6.4\ mV}$ $\Delta V_{MIN}$

$$\Rightarrow \Delta F_{MIN} = \frac{.0064V}{1000(.0035)(.038)} = \boxed{.048\ L/s}$$ ✓

Amp1, ADC2: $4 = 1500(.0035)(.038) F_{max} + 0.5 \Rightarrow F_{max} = 17.5\ L/s$ X (too low)

Rule out this combo.

☆ Must replace both amplifier and ADC!

8) When patient tries to inhale, lungs expand → $P_{Mouth}$ goes down.

+8

$$FRC = \frac{101\,kPa - 1.5\,kPa}{1.5\,kPa} \times \underbrace{\Delta V_{Box}}_{\frac{.030L}{1.5Pa} \times 2Pa = .04L} = \boxed{2.65L}$$

9) Helium dilution: $C_s V_s = C_{LS}(V_L + V_s)$

+8

$$(C_s - C_{LS})V_s = C_{LS} \times FRC$$

$$\rightarrow FRC = \frac{C_s - C_{LS}}{C_{LS}} V_s = \frac{7.5\% - 5.8\%}{5.8\%} \cdot 8L$$

$$= \boxed{2.345L}$$

10) $N_2$ Washout: +8

$$C_L V_L = \sum_b C_b \Delta V_b \rightarrow FRC = \frac{\sum_b C_b \Delta V_b}{C_L}$$

$$FRC = \frac{\left[8.5 \times .4 + 7.7 \times .35 + 6.9 \times 0.4 + 6 \times 0.4 + 5.2 \times .35 + 4.4 \times .35 + 3.6 \times .45 + \right.}{\left. + 2.8 \times .45 + 2 \times .4 + 1.2 \times .35 + .6 \times .35 + 0 \right]}$$

$$9$$

$$= \boxed{2.1\,L}$$