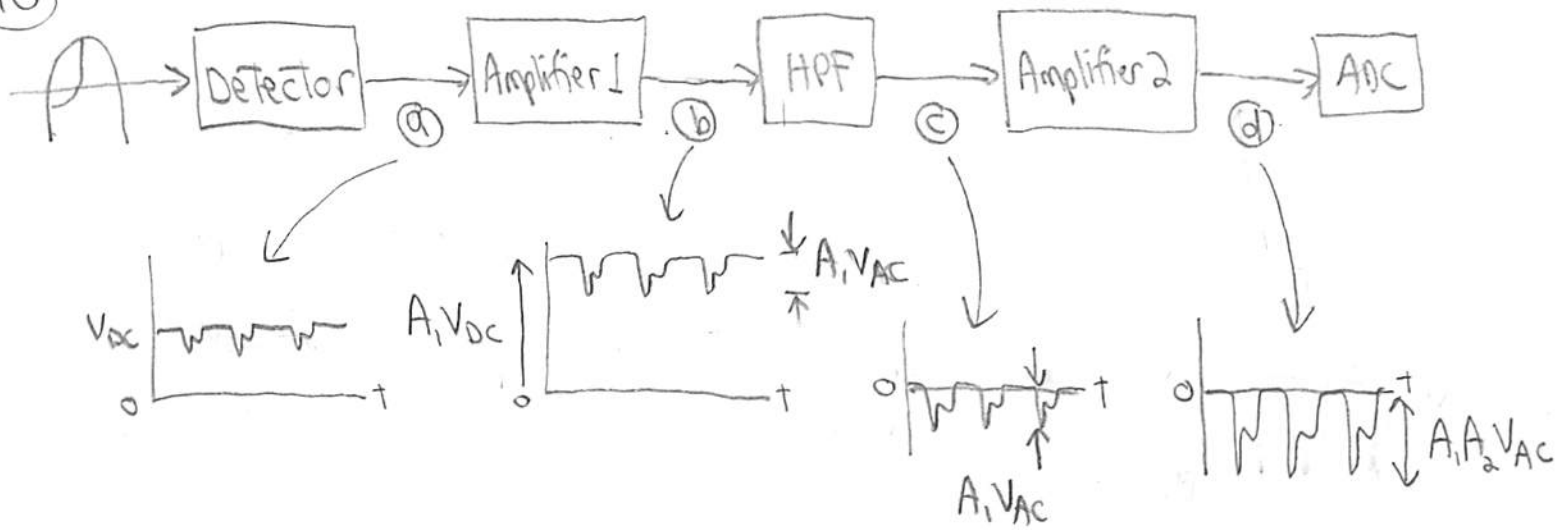
BME 386
HW5 Solns

Total = 100 pts

1) Helps to sketch the signal at different stages.

(+10)



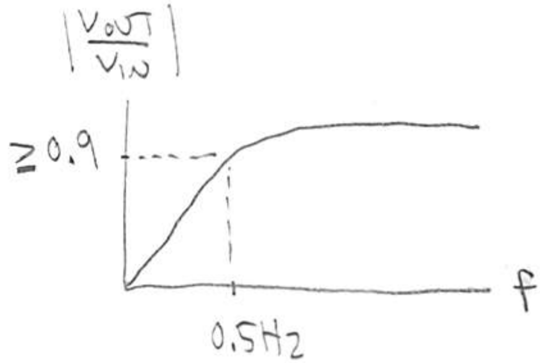
want $A_1 \times (\max V_{DC}) < 4V$

$$A_1 < \frac{4V}{0.3V} = 13.3 \qquad \text{Choose } \boxed{A_1 = 10}$$

2) Want $\left|\frac{V_{OUT}}{V_{IN}}\right| \geq 0.9$ @ $f = 0.5\,Hz$

(+10)

$$30\ \frac{\text{beats}}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{sec}} = 0.5\ Hz$$



$$\frac{0.5/f_H}{\sqrt{1+(0.5/f_H)^2}} \geq 0.9$$

$$(0.5/f_H)^2 \geq 0.81\left[1+(0.5/f_H)^2\right]$$

$$0.19\,(0.5/f_H)^2 \geq 0.81 \rightarrow \frac{0.5}{f_H} \geq 2.065$$

$$0.5 \cdot 2\pi RC \geq 2.065 \rightarrow C \geq \frac{2.065}{\pi \times 220\times10^{3}} = 2.99\times10^{-6}\,F$$

$C \geq 3\mu F$ Choose $\boxed{C = 3.3\mu F}$

3) want $A_1 A_2 \times (\max V_{AC}) < 4V$

+10

$$A_2' < \frac{4V}{10 \times (10^{-3} \times 0.3V)} = 1333$$

Choose $\boxed{A_2 = 1000}$

4) $V_{meas} = V_{ref} + A_d \Delta V$

+10

$= V_{ref} + A_d SP = 2 + A_d SP$

$$\uparrow \frac{9\,mV}{psi} \times \frac{14.7\,psi}{760\,mmHg} = 0.174\,\frac{mV}{mmHg}$$

want $V_{meas} < 9V$ when $P = 240$ mmHg

$$2 + A_d \cdot \left(.174\times10^{-3}\frac{V}{mmHg}\right)(240\,mmHg) < 9V$$

$$A_d < \frac{9-2}{(.174\times10^{-3})(240)} = 167.6$$

Choose $\boxed{A_d = 150}$

5) $P = \dfrac{V_{meas} - V_{ref}}{A_d S}$

+6

$$V_{meas} = 3V \rightarrow P = \frac{3-2}{150\,(.174\times10^{-3})} = \boxed{38.3\,mmHg}$$

$$V_{meas} = 7V \rightarrow P = \frac{7-2}{150\,(.174\times10^{-3})} = \boxed{191.6\,mmHg}$$

6) want $\Delta V_{ADC} < \frac{1}{2} V_N$

+6

$$\frac{10-0\,V}{2^n-1} < .0025\,V \Rightarrow 2^n-1 > \frac{10}{.0025} = 4000$$

$$2^n > 4001$$

$$n \log_{10} 2 > \log_{10} 4001$$

Choose $\boxed{n=12 \text{ bits}}$ $\qquad n > 11.97$

7) $$\Delta P_{min} = \frac{\Delta V_{min}}{\frac{\partial V_{meas}}{\partial P}} = \frac{V_N}{A_d S} = \frac{.005\,V}{150\left(.174\times10^{-3}\,\frac{V}{mmHg}\right)}$$

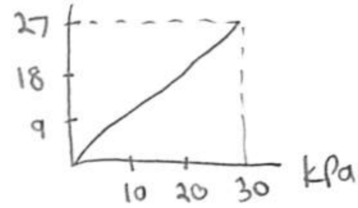
+6

$$= \boxed{0.19 \text{ mmHg}}$$

8) $V_{Meas} = A_d S P + V_{Ref}$

(+14)

$\uparrow$ From plot, $S = \dfrac{27\,mV}{30\,kPa}$



$$= 0.9\ \frac{mV}{kPa} \times \frac{101\ kPa}{760\ mmHg} = 0.12\ \frac{mV}{mmHg}$$

$\boxed{\text{Method 1}}$ Check max $V_{Meas} < 5V \leftarrow$ limited by ADC

$$200 \times \left(.12 \times 10^{-3} \frac{V}{mmHg}\right)(220\ mmHg) + 1 = \underline{\underline{6.28V}}\ \times \text{ Too High}$$

(above 5V)

$\boxed{\text{Method 2}}$ Find P_{Max}: $\quad 5V = A_d S P_{Max} + V_{ref}$

$$P_{Max} = \frac{5-1}{200(.00012)} = \underline{\underline{166.7\ mmHg}}\ \times \text{ Too low}$$

(below 220 mmHg)

Sensitivity? $\quad \Delta P_{MIN} = \dfrac{\Delta V_{MIN}}{\frac{\partial V_{Meas}}{\partial P}} = \dfrac{\Delta V_{MIN}}{A_d S} \leftarrow$ Noise or ΔV_{ADC}?

$$\Delta V_{ADC} = \frac{5-0}{2^{12}-1} = 1.22\,mV$$

$$V_N = \sqrt{(1.5)^2 + (3)^2} = \underline{\underline{3.35\,mV}}$$

$\uparrow$ amp noise $\quad \uparrow$ ADC noise $\quad \uparrow$ ΔV_{MIN}

$$\text{So, } \Delta P_{MIN} = \frac{3.35\,mV}{200\,(.12\ mV/mmHg)}$$

$$= \underline{\underline{.14\ mmHg}}\ \checkmark$$

$\boxed{\text{Old system \underline{does NOT satisfy} } P_{max} \quad \text{\underline{does satisfy} } \Delta P_{min}}$

9) Helpful to make a table to organize everything

+18

Component	Value	Noise
Amp	$A_d = 200$	1.5 mV
S_{old}	.12 $\frac{mV}{mmHg}$	
S_{new}	.18 $\frac{mV}{mmHg}$	
ADC_{old}	0-5V, 12 bits	3 mV
ADC_{new}	0-10V, 12 bits	5 mV

Compute P_{max} and ΔP_{MIN} for all 4 combinations.

Old Sensor + old ADC : $P_{Max} = 166.7$ mmHg X (want $P_{max} \geq 220$ mmHg)

$\Delta P_{MIN} = .14$ mmHg ✓

New Sensor + old ADC : $5 = 200(.00018)P_{max} + 1$

$\rightarrow P_{max} = 111.1$ mmHg X (Too low)

$$\Delta P_{MIN} = \frac{3.35 \text{ mV}}{200(.18 \text{ mV/mmHg})} = .093 \text{ mmHg} ✓$$

Old Sensor + New ADC : $9 = 200(.00012)P_{max} + 1 \rightarrow P_{max} = 333.3$ mmHg ✓

$\Delta V_{ADC} = \frac{10}{2^{12}-1} = 2.44$ mV , $V_N = \sqrt{(1.5)^2 + (5)^2} = 5.22$ mV ← ΔV_{MIN}

$$\Delta P_{MIN} = \frac{5.22 \text{ mV}}{200(.12 \text{ mV/mmHg})} = 0.22 \text{ mmHg X} \left(\begin{array}{c}\text{Too}\\\text{big}\end{array}\right)$$

★ New Sensor + New ADC : $9 = 200(.00018)P_{max} + 1 \Rightarrow P_{max} = 222.2$ mmHg ✓

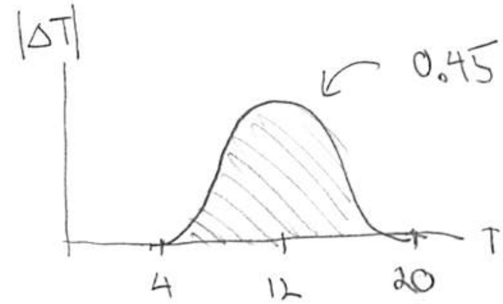
WINNER

$$\Delta P_{MIN} = \frac{5.22 \text{ mV}}{200(.18 \text{ mV/mmHg})} = 0.145 \text{ mmHg} ✓$$

10) +10

$$CO = \frac{\cancel{\rho_i c_i} V_i \Delta T_i}{\cancel{\rho_b c_b} \int \Delta T_b \, dt} = \frac{V_i \Delta T_i}{\int \Delta T_b \, dt}$$

Area under curve



$$0.45\left[\frac{1}{2} + \frac{1}{2}\cos 2\pi \frac{t-12}{16}\right]$$

$$\int \Delta T_b \, dt = \int_4^{20} 0.45\left[\frac{1}{2} + \frac{1}{2}\cos 2\pi \frac{t-12}{16}\right] dt$$

$$= \frac{0.45}{2} \int_4^{20} \left[1 + \cos 2\pi \frac{t-12}{16}\right] dt$$

$$= \frac{0.45}{2} \left[t + \frac{16}{2\pi} \sin 2\pi \frac{t-12}{16}\right] \Bigg|_4^{20}$$

$$= \frac{0.45}{2} \left[(20-4) + \frac{8}{\pi}\left(\underbrace{\sin \pi}_{0} - \underbrace{\sin(-\pi)}_{0}\right)\right] = 8 \times 0.45$$

$$\Rightarrow CO = \frac{(.0102) \times (37^\circ C - 4^\circ C)}{8 \times .45 \; {}^\circ C \times s} = 0.0917 \, \frac{L}{s} \times \frac{60 s}{1 \min} = \boxed{5.5 \, \frac{L}{\min}}$$