BME/ECE 386 QUIZ (W20) NAME: Solutions

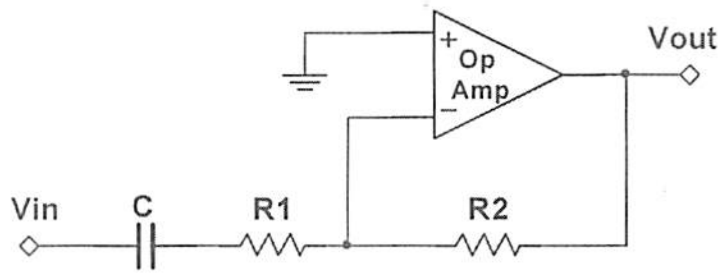
1 problem for 20 pts

ECG Amplifier

You are asked to design an ECG system to monitor a patient in a helicopter (i.e. being flown to a hospital). Suppose the ECG input is a PQRST waveform with a 1 mV amplitude R-wave. The patient's heart rate is 100 beats per minute. This desired signal is superimposed with a constant 25 mV differential offset voltage (e.g. due to skin-electrode impedance mismatch). The helicopter vibration produces a 30 Hz common mode voltage with a peak amplitude of 2.5 V. The instrumentation amplifier has a differential gain A_d = 30, CMRR = 75 dB, and V_{REF} = 0.5V.

a) Compute and sketch the instrumentation amplifier output over a 3 second interval. Label important features.

b) After the instrumentation amplifier we want a circuit that blocks DC. The op amp circuit shown below combines a high pass filter with an inverting amplifier. Use the Golden Rules to show that:



$$\frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}\frac{jf/fc}{1+jf/fc}$$

NOTE: Make sure to clearly define f_C (i.e. in terms of R_1, R_2, and/or C)!

$CMRR = 20\log_{10}\left(\frac{A_d}{A_{CM}}\right)$

$\frac{A_d}{A_{CM}} = 10^{CMRR/20}$

$\rightarrow A_{CM} = \frac{30}{10^{75/20}} = .0053$

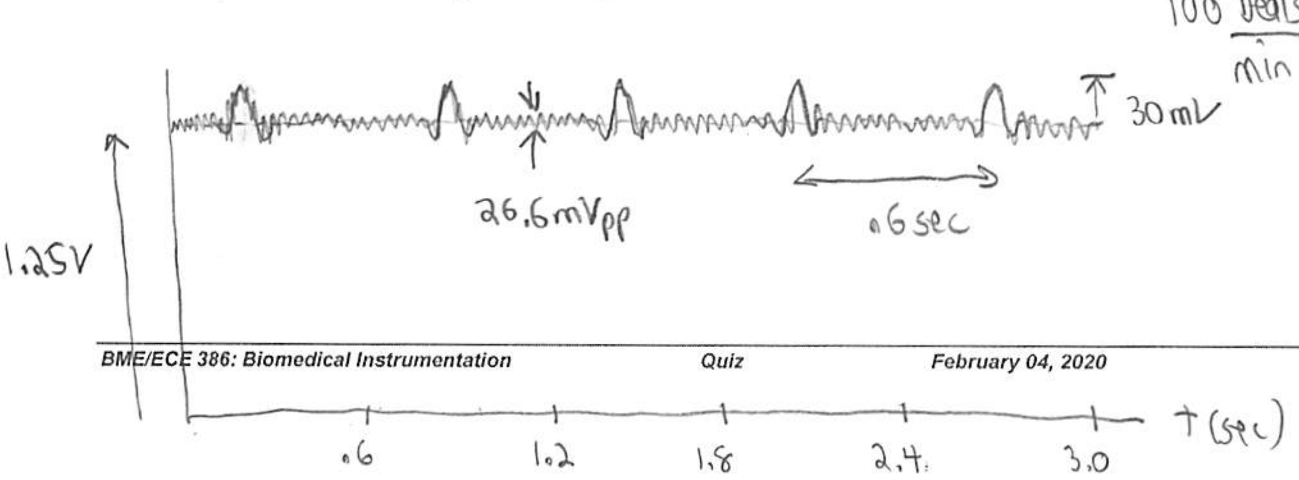
(a) $V_{Meas} = V_{Ref} + A_d \Delta V + A_{CM} V_{CM}$

+10

V_{Ref}: 0.5V; A_d: 30; ΔV: 25mV + [1mV PQRST]; V_{CM}: $2.5 \sin 2\pi f_o t$ (30Hz)

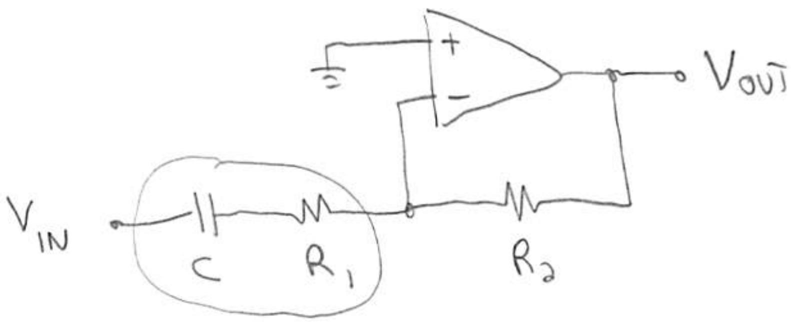
$\rightarrow V_{Meas} = .5 + .75 + [30mV\ PQRST] + [13.3mV] \sin 2\pi f_o t$

$\frac{100\ beats}{min} \times \frac{1 min}{60 sec} \times 3sec = 5\ beats$

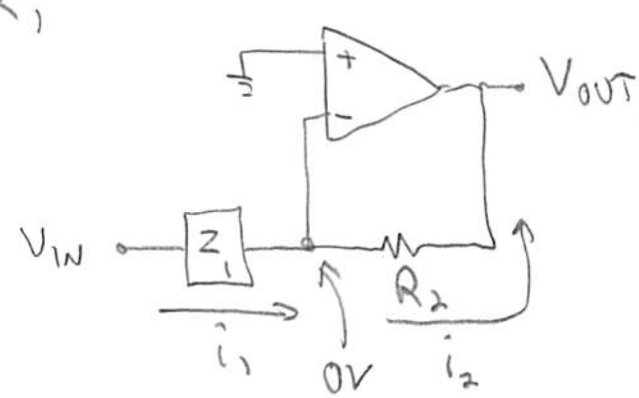


(b)

(+10)



$$Z_1 = \frac{1}{j\omega C} + R_1$$



KCL at node V_-:

$$i_1 = i_2$$

$$\frac{V_{IN} - 0}{Z_1} = \frac{0 - V_{OUT}}{R_2}$$

$$\frac{V_{OUT}}{V_{IN}} = -\frac{R_2}{Z_1} = -\frac{R_2}{\frac{1}{j\omega C} + R_1} = -\frac{R_2 j\omega C}{1 + j\omega R_1 C} = \frac{-R_2}{R_1}\frac{j\omega R_1 C}{1 + j\omega R_1 C}$$

$\omega = 2\pi f$

$$\rightarrow \frac{V_{OUT}}{V_{IN}} = -\frac{R_2}{R_1} \cdot \frac{jf \cdot 2\pi R_1 C}{1 + jf \cdot 2\pi R_1 C} \leftarrow \text{Let } \frac{1}{f_c} = 2\pi R_1 C$$

$$\boxed{f_c = \frac{1}{2\pi R_1 C}}$$

$$\boxed{\frac{V_{OUT}}{V_{IN}} = -\frac{R_2}{R_1}\frac{jf/f_c}{1 + jf/f_c}}$$