University of Pennsylvania
Department of Electrical and System Engineering
Medical Devices Lab

ESE3400, Fall 2022 — Quiz 1: 60 minutes — Wednesday, October 12

- 4 Problems with equal weight. All 4 problems must be completed.
- Calculators allowed.
- Closed book = No text or notes allowed.

Name: **Answers**

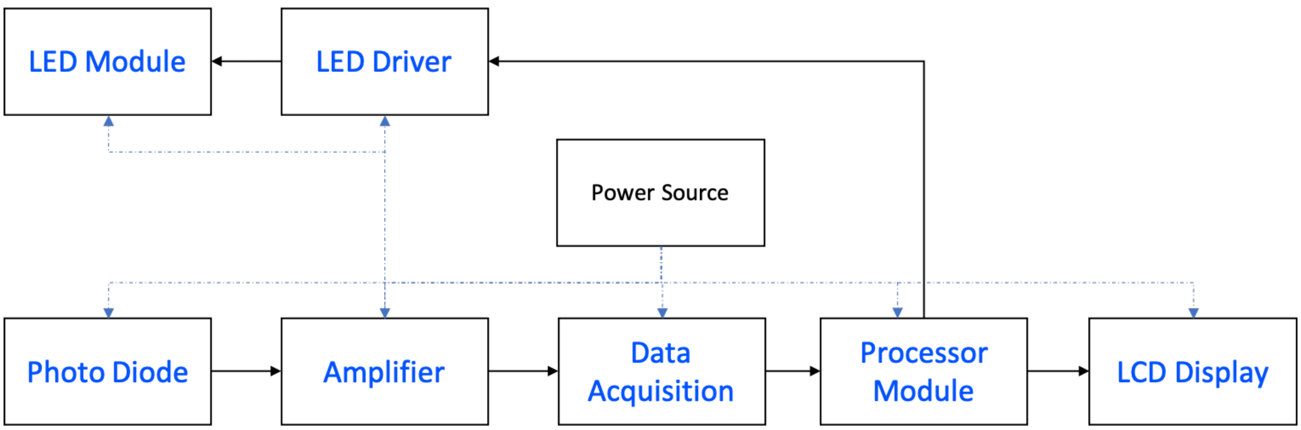
Grade:

Q1	
Q2	
Q3	
Q4	
Total	

1. Pulse Oximetry System. Below is a block system diagram for a pulse oximetry system, which measures the blood oxygen levels by using a photo diode detecting light from pulsed LEDs passed through a finger. There are seven unlabeled boxes along with a power source. The seven blocks are given in the following alphabetized list:

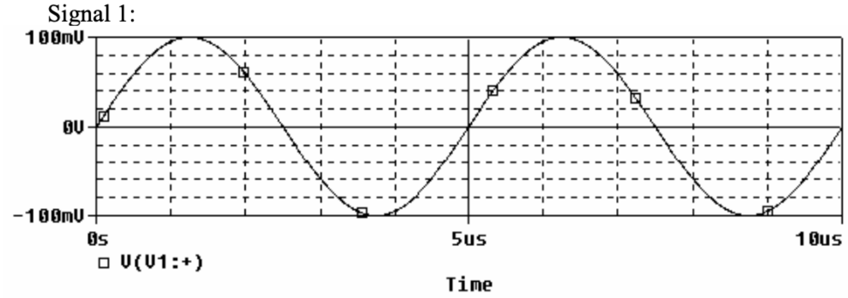
   - Amplifier
   - Data Acquisition
   - LCD Display
   - LED Driver
   - LED Module
   - Photo Diode
   - Processor Module

   Fill in the empty blocks with the appropriate label from the list above.

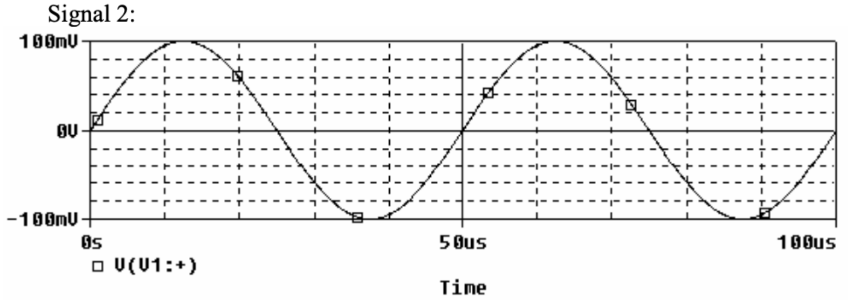


2. Filters. Consider the following three input signals:

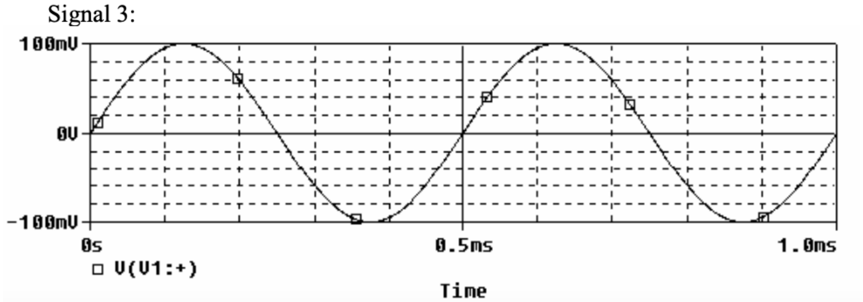
Signal 1:



Signal 2:



Signal 3:



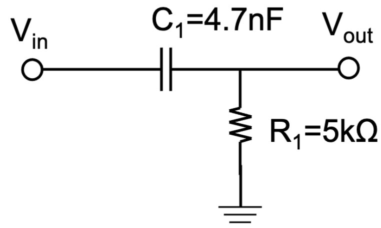
(a) What is the frequency of each of the signals above (in Hertz)?

i. Signal 1: 200kHz

ii. Signal 2: 20kHz

iii. Signal 3: 2kHz

(b) Below is a filter circuit. What kind of filter is it and what is the corner frequency?

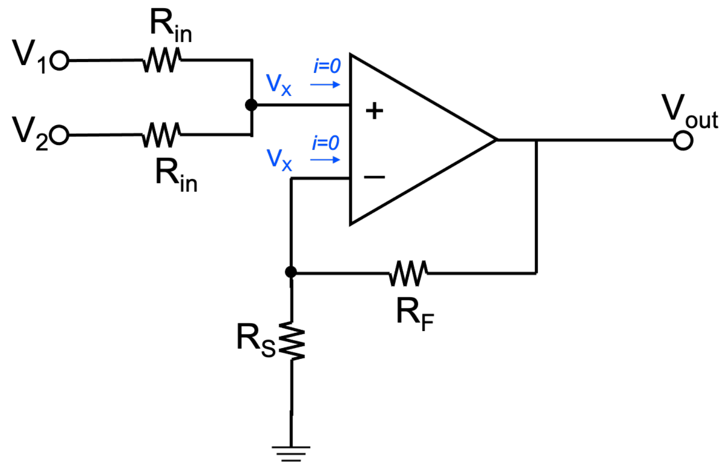


High pass filter.
$f_C = \frac{1}{2\pi RC} = \frac{1}{2\pi \cdot 5k\Omega \cdot 4.7nF} = 6.77kHz$

(c) Fill out the following chart. Enter lower if the amplitude of the output of the given circuit will be substantially lower than the input amplitude. Enter higher if the amplitude of the output of the given circuit will be substantially higher than the input amplitude. Enter same if the amplitude of the output of the given circuit will be about the same as the input amplitude. The signals are the same ones you looked at in part (a).

	Output Amplitude
Signal 1	Same
Signal 2	Same
Signal 3	Lower

3. Biopotential Amplifier. Below is a schematic of an amplifier using an ideal Opamp in a closed loop configuration. Use KCL and Ohms law to write an expression for the output voltage, V_{out}, as a function of the inputs, V_1 and V_2, and resistances, R_{in}, R_S and R_F. If you wanted to use this as a biopotential amplifier for an ECG electrode signal, how would you size the resistances? Give reasonable values for R_{in}, R_F, and R_S.



Both opamp inputs are at the same voltage, which is labeled V_X here, and the current into both inputs is 0. We can do KCL at both inputs:

$$\frac{V_1 - V_X}{R_{in}} = \frac{V_X - V_2}{R_{in}}$$
$$\frac{V_{out} - V_X}{R_F} = \frac{V_X}{R_S}$$

Solving the bottom equation for V_X:

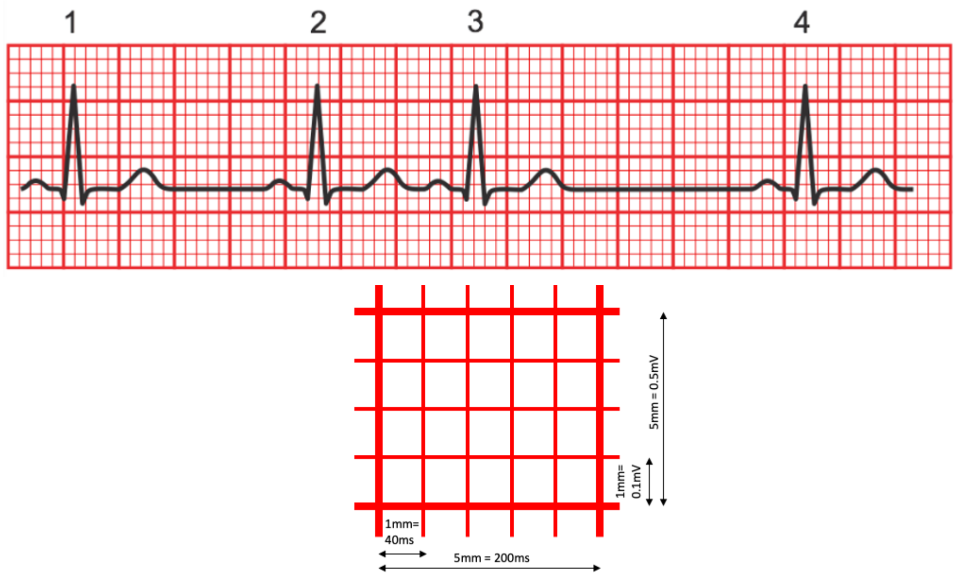
$$V_X = V_{out}\frac{R_S}{R_S + R_F}$$

Substituting in to the top equation and solving for V_{out}:

$$V_1 + V_2 = 2 \times V_{out}\frac{R_S}{R_S + R_F}$$
$$V_{out} = \frac{R_S + R_F}{2R_S}(V_1 + V_2)$$

While R_{in} doesn't impact the gain of the amplifier, we want a high input impedance. So we chose $R_{in} = 1M\Omega$. For large gain we need to make $R_F > R_S$. If we choose $R_F = 500k\Omega$ and $R_S = 5k\Omega$ we get a gain of 51.

4. ECG Heart Rate. Below is an image of an ECG with 4 distinct heart beats on the standard ECG grid. The units for the grid are also given. Calculate the 3 different heart rates in beats-per-minute (bpm) represented in the ECG.



There are three different beats between the adjacent PQRST waves:
Beat 1 = $\frac{60000}{22*40ms} = 68.2BPM$
Beat 2 = $\frac{60000}{14*40ms} = 107.1BPM$
Beat 3 = $\frac{60000}{30*40ms} = 50BPM$