Pre-Lab Assignment 4

BioE 101 Spring 2017

Answer the following questions.

1. **EKG Basics**
   a) In this lab you will be building a circuit/VI to measure an electrocardiogram (EKG or ECG) signal and compute heart rate. Please familiarize yourself with the basics of an EKG here:

      http://en.wikibooks.org/wiki/Biomedical_Engineering:_A_Roadmap/Biomedical_Instrumentation/Electrocardiography

   b) Note that, for most modern EKGs, there are twelve or more electrodes (called leads), each placed at a different anatomical location for different measurements. However, we will only use three leads total: one lead each on the left/right wrist, as well as a reference lead on the lower back.

Question 1.1: What kind of signal (resistance, current, voltage) is an EKG measuring? What is a typical signal amplitude and frequency range?

Question 1.2: If we want to amplify our EKG signal to around 500mV, what gain range would we need?

Question 1.3: List 3 types of interference that are usually present as artifacts in an EKG.

Question 1.4: What do you think is the point of having a reference electrode? What voltage would you connect to that electrode?

2. **Instrumentation Amplifier AD620 and Operational Amplifier LM324**
   a) An EKG represents the heart's electrical activity as measured from two different points, so it is a *differential measurement*. We will use an instrumentation amplifier to make the differential measurement as well as to amplify the signal. The instrumentation amplifier we'll use is the AD620.

   a) We will also be using op-amp LM324 for filters. Read both datasheets of AD620 and LM324, especially the pin configurations and specifications. The datasheets for each can be found here:

http://www.analog.com/static/imported-files/data_sheets/AD620.pdf
http://www.national.com/ds/LM/LM124.pdf

Make sure you read the entire AD620 data sheet.

Question 2.1: What is the typical CMRR of the AD620 at a gain of 50 for 60 Hz interference (use Fig. 14 from datasheet)? If we were to build an instrumentation amplifier from op-amps, such as LM324, what is the CMRR of the LM324? Which one would you prefer using for getting rid of 60 Hz common-mode interference?

Question 2.2: Explain one need for the 0.03 Hz High-pass filter in Fig 41 of the AD 620 data sheet. Hint: it may have something to do with Figs. 10 and 11.

Question 2.3: Even if you can perfectly attenuate the common mode 60 Hz signal, you might not get rid of all 60 Hz interference. Differential mode interference can still creep into your signal and degrade SNR. What are two ways you can attenuate differential mode 60 Hz interference from your EKG signal? State your assumptions.

3. **<u>Measuring EKG</u>**
   a) We would ideally want our AD620 instrumentation amplifier to be noise matched to the sensor impedance (assume that this sensor impedance is the impedance of your skin). Attached is a plot of skin impedance vs. frequency.

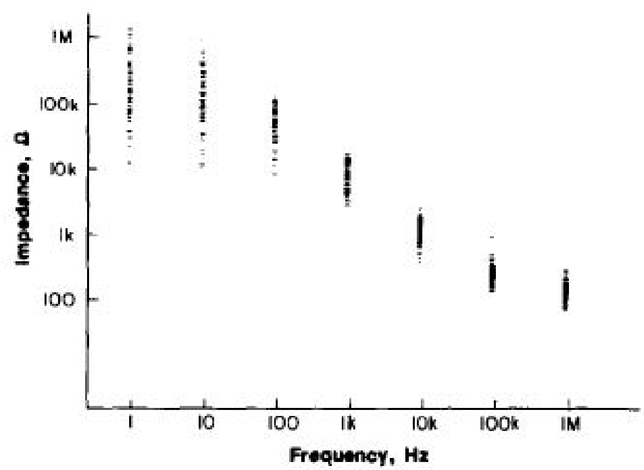
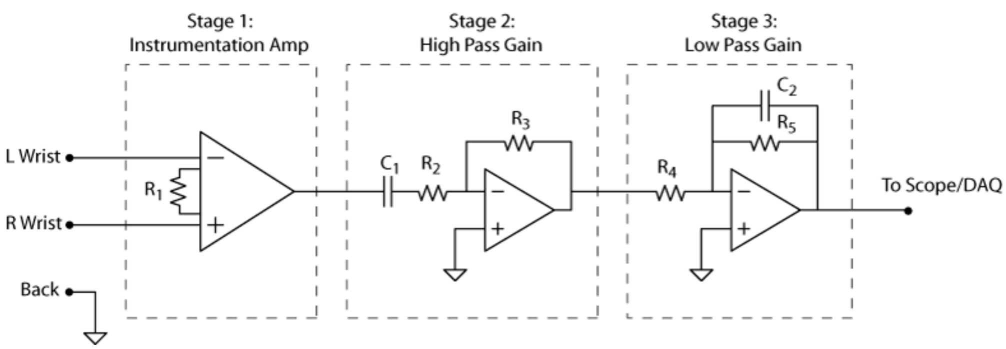


Fig. 4. Impedance versus frequency for all data. High-frequency impedance is about 100 Ω, whereas low-frequency impedance varies from 10 kΩ to 1 MΩ.

Question 3.1: Calculate the Noise Factor for your sensor-amplifier system at EKG-relevant frequencies. What frequency bandwidth did you use? Why? You may need to review the voltage and current noise specs from the AD620 datasheet.

b) Below is a circuit diagram of the EKG amplification and signal conditioning circuit you will build for this lab. Note that Stage 1 will use the AD620 instrumentation amp, while Stages 2 and 3 will use the LM324 op-amp. All amplifiers will be powered from +9V to -9V with a common GND reference.



R1	1 kΩ
R2	300 kΩ
R3	620 kΩ
R4	3.9 kΩ
R5	39 kΩ
C1	1 μF
C2	0.1 μF

Question 3.2: Calculate the analytic transfer function $H(\omega) = V_{out}(\omega)/V_{in}(\omega)$ as a function of the input signal frequency (V_{out} is the voltage seen at the input to the scope/DAQ, and V_{in} is the difference in signal amplitude between the L and R wrist electrodes). You can start off with getting the transfer function for each stage and then putting them all together. What does each stage do and what is the transfer function associated with each stage? What is the total transfer function of the system? Now plug in the component values listed in the box and plot in MATLAB the transfer function $H(\omega)$.

c) You will be using 9V batteries to power your circuit.

Question 3.3: How can you create a ±9V power supply using two 9V batteries?