

Florida Atlantic University – Biomedical Signal Processing Lab

Experiment 2 – Signal Transduction: Building an analog Electrocardiogram (ECG)

1. Introduction:

The Electrocardiogram (ECG) is a technique of recording bioelectric currents generated by the heart. From a recorded ECG waveform, clinicians can evaluate the conditions of the patient’s heart and perform further diagnostics. ECG records are obtained by the sensing of several electrodes, also known as leads.

The output of an ECG recorder is a graph with time represented on the x-axis and voltage represented on the y-axis. The amplitude of a measured ECG signal varies between 1 mV and 5 mV. Hence, there is a need to amplify the recorded signal.

The objective of this lab is to build a 3-lead ECG amplifier analog circuit using the ua741 operational amplifiers (op-amps) included in your lab kit. After the design and assembly of your circuit, you will be required to and record your ECG signal using inexpensive electrodes.

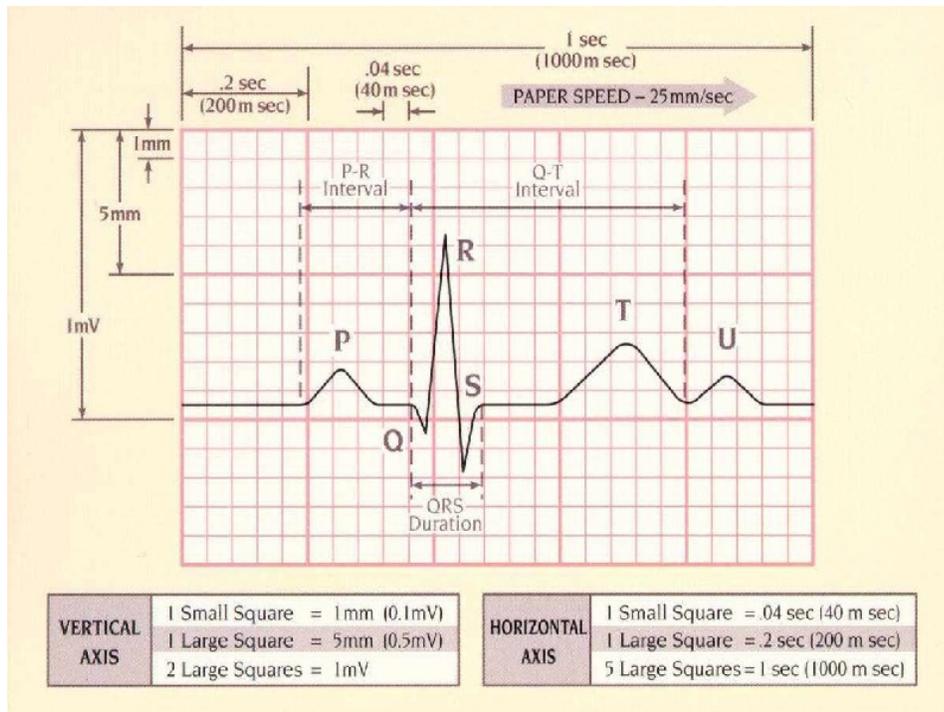


Figure 1: ECG waveform

2. Pre-lab:

Refresh your memory on op-amp circuits, and complete the table below. The pre-lab is worth 15% of your final Report 2 grade and should be completed prior to the in-class meeting.

	Schematic	Gain formula (V_{out}/V_{in})
Non-inverting amplifier		
Inverting amplifier		
Difference amplifier		

3. Circuit Design:

Our goal is to design a circuit that only amplifies the differential voltage, meaning that the common-mode voltage level remains unchanged. To achieve this goal, our method will consist of building an instrumentation amplifier structured in two main stages, as described below:

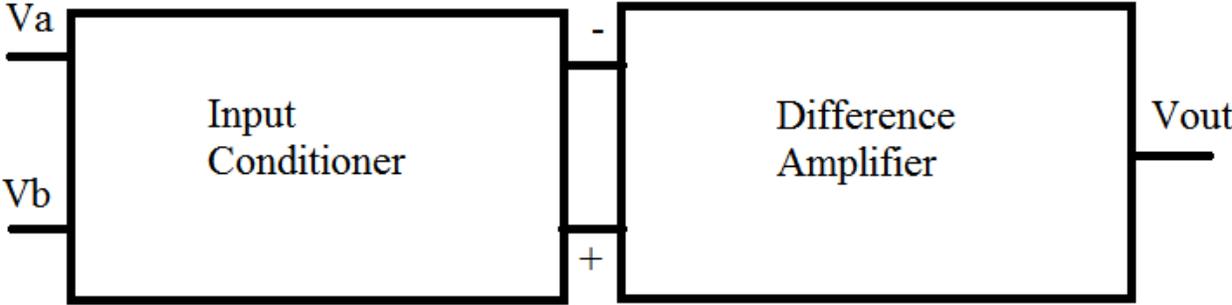


Figure 2: Block Diagram of ECG amplifier

The input conditioner's role is to ensure a very large input impedance (ideally, it approaches infinite), and to apply a gain. In the Difference Amplifier stage, the difference of the conditioned input signal will be amplified.

The main consideration of our analog design are as follows:

- I. Amplifier Gain: how much amplification is needed given that raw ECG signal is between 0.1 to 5 mV?
- II. Circuit noise level: how can we reduce power-line interference?
- III. Power consumption: can we save power and extend the battery life?

Below is the schematic of the circuit you will be designing and assembling in this lab:

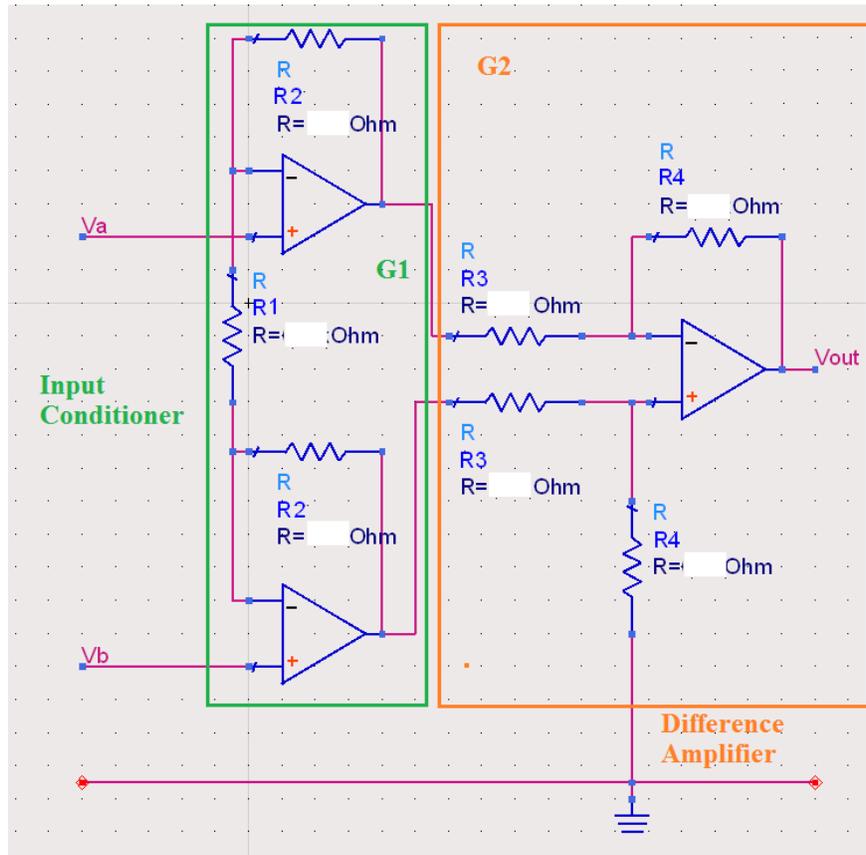


Figure 3: 3-lead ECG Amplifier schematic

Note that the Input Conditioner gain G1 is:

$$G1 = 1 + \frac{2R_2}{R_1}$$

The Difference Amplifier gain G2 is:

$$G2 = \frac{R_4}{R_3}$$

And therefore, the total Gain of the amplifier is $G_T = G1G2$

$$G_T = \left(1 + \frac{2R_2}{R_1}\right) \left(\frac{R_4}{R_3}\right)$$

4. Procedures

- I. Design an ECG Amplifier with a total Gain of $G_T=1000$.
 - a. Provide all the Resistors Values:

	Resistance Value (Ω)
R1	
R2	
R3	
R4	

- II. Simulate the circuit in Figure 2 on ADS and make sure that your values calculated above generate indeed a gain of 1000.
- III. Wire the circuit of Figure 2. To test your circuit, hook the positive pin of your function generator in Va and the negative pin of the function generator in Vb. Your input signal should be a 60 Hz sine wave of 5 mV peak-to-peak.
- IV. Observe the Output waveform and save a picture of the oscilloscope image.

Now that you have calculated the values of the electronic components and tested your circuit, go ahead and put three electrodes as your circuit input. Va should be connected to your left wrist, Vb to your right wrist and the ground should be connected to your left leg.

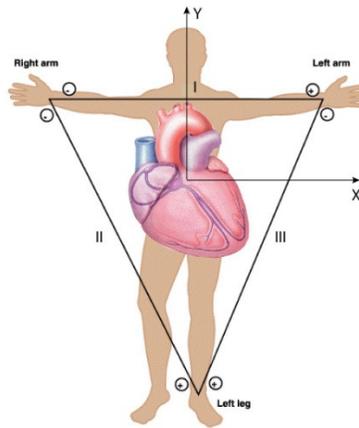


Figure 4: 3-lead ECG electrode placement

- V. With the electrodes connected to your wrists and leg, hookup the oscilloscope to your circuit output and observe your ECG signal being recorded.
- VI. Press Run/Stop in the oscilloscope, and make sure to register the oscilloscope image of your ECG waveform.
- VII. You might want to compare your waveform with Figure 1.

5. Simulation waveform:

