THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
ECE 2110: CIRCUIT THEORY LABORATORY

Experiment #7:

Introduction to Soldering Principles and Biomedical Engineering

EQUIPMENT

Lab Equipment	*Equipment Description*
(1) Digital Oscilloscope	Keysight DSOX1024G Digital Oscilloscope
(1) BioAmplifier Kit	UFI Model 2122 BioAmplifier
(1) Breadboard	Prototype Breadboard
(1) Test Leads	BNC to Mini-Grabber Lead Set
(1) BNC Cables	BNC to BNC Cable
(3) Disposable Electrodes	BIOPAC Disposable Monitoring Electrodes
(1) Electrode Gel	BIOPAC Signa Gel Electrode Gel

Table 1 – Equipment List

COMPONENTS

Type	*Value*	*Symbol Name*	*Multisim Part*	*Description*
Resistor	--- Ω	R_{LIMIT}	Basic/Resistor	---
LED	Red	LED1	Diodes/LED/LED_red	Red LED

Table 2 – Component List

OBJECTIVES

- Learn how an ECG works
- Learn how to use an ECG amplifier
- Learn how to set up a 3-lead ECG
- Use the digital oscilloscope to observe an ECG waveform
- Construct a simple LED circuit to monitor your heart rate

INTRODUCTION

In this lab, you will be recording ECG signals from your heart. In order to do this safely, you will be using an **isolated bioamplifier** to prevent possible electrical shock. A bioamplifier takes electrical signals from the human body, generally on the order of µV or mV, and amplifies them to produce a signal in the V range. One prominent aspect of biomedical engineering is designing and building bioamplifiers because almost all signals from the body must be amplified before they are usable. This is a common component of any BME based senior design project.

Additionally, you will be learning proper **soldering** technique and its importance for your future senior design project. Being comfortable using the soldering iron for small or large-scale projects will prove important in any electronics-related field. While the simple experiments performed in lab are done only on the breadboard, permanent projects can be soldered in place on a perf board or printed circuit board.

Electrocardiography

Electrocardiography (**ECG** or **EKG** from Greek: *kardia*, meaning heart) is the recording of the electrical activity of the heart [1]. Traditionally this is in the form of a transthoracic (across the thorax or chest) interpretation of the **electrical activity** of the heart over a period of time, as detected by electrodes attached to the surface of the skin and recorded or displayed by a device external to the body. The recording produced by this noninvasive procedure is termed an **electrocardiogram** (also **ECG** or **EKG**). It is possible to record ECGs invasively using an implantable loop recorder.

An ECG is used to measure the heart's electrical conduction system. It picks up **electrical impulses** generated by the **polarization** and **depolarization** of cardiac tissue and translates into a waveform. The waveform is then used to measure the rate and regularity of heartbeats, as well as the size and position of the chambers, the presence of any damage to the heart, and the effects of drugs or devices used to regulate the heart, such as a pacemaker. Most ECGs are performed for diagnostic or research purposes on human hearts, but may also be performed on animals, usually for diagnosis of heart abnormalities or research.

The ECG device detects and amplifies the **tiny electrical changes** on the skin that are caused when the heart muscle depolarizes during each heartbeat. At rest, each heart muscle cell has a negative charge, called the **membrane potential**, across its cell membrane. Decreasing this negative charge toward zero, via the influx of the positive cations, Na^+ and Ca^{++}, is called **depolarization**, which activates the mechanisms in the cell that cause it to contract. During each heartbeat, a healthy heart will have an orderly progression of a wave of depolarization that is triggered by the cells in the sinoatrial node, spreads out through the atrium, passes through the atrioventricular node, and then spreads all over the ventricles. This is detected as tiny rises and falls in the voltage between two electrodes placed on either side of the heart, which is displayed as a wavy line either on a screen or on paper as shown below in **Figure 1**. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle.

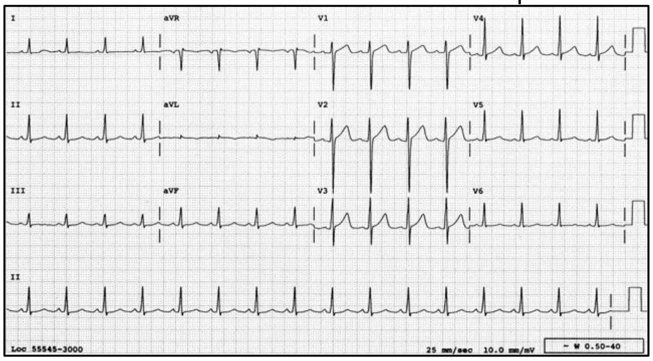

Figure 1 – Sample ECG Readout

QRS Complex

The **QRS complex** is a name for the combination of three of the graphical deflections seen on a typical electrocardiogram (ECG). It is usually the central and most visually obvious part of the tracing. It corresponds to the depolarization of the right and left ventricles of the human heart. In adults, it normally lasts 0.06-0.10s; in children and during physical activity, it may be shorter.

Typically, an ECG has **five deflections**, arbitrarily named "P" to "T" waves. The Q, R, and S waves occur in rapid succession, do not all appear in all leads, and reflect a single event, and thus are usually considered together. A **Q wave** is any downward deflection after the **P wave**. An **R wave** follows as an upward deflection, and the **S wave** is any downward deflection after the R wave. The **T wave** follows the S wave, and in some cases an additional **U wave** follows the T wave. **Figure 2** below shows a single PQRST pulse for a normal ECG. **Figure 3** shows possible configurations for connecting the ECG leads to the body.

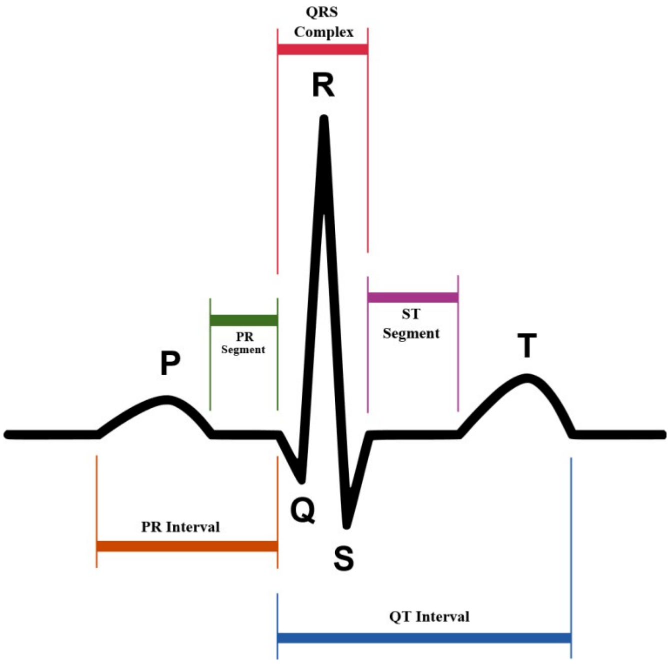

Figure 2 – Enlargement of One “PQRST” Wave

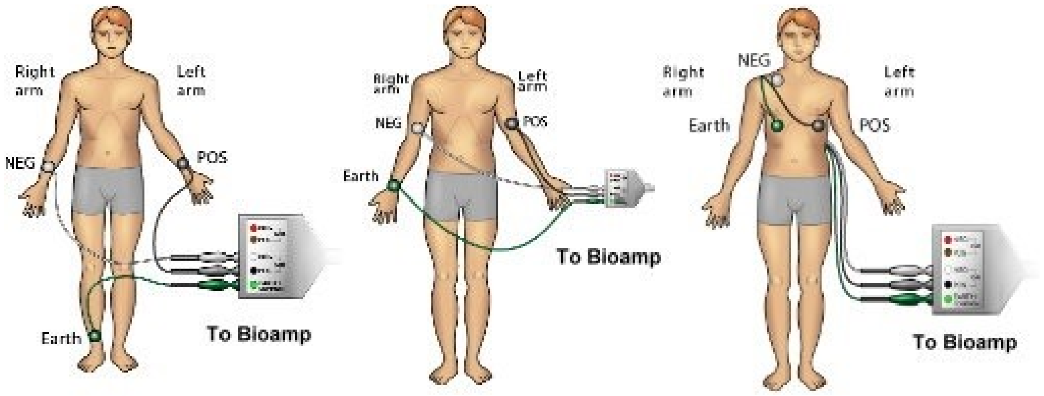

Figure 3 – Possible Three-lead ECG Configurations (Earth is Ground)

PRELAB

Figure P.1 shows the basic illustration of the circuit you will be building in lab. This figure does not show the bioamplifier, and instead shows your heart as the voltage source for the circuit. This will be replaced with the bioamplifier when you actually construct the circuit. The purpose of the circuit is for the LED to light up when it receives a positive voltage from your heart. For the prelab, you will use the circuit in **Figure P.2**.

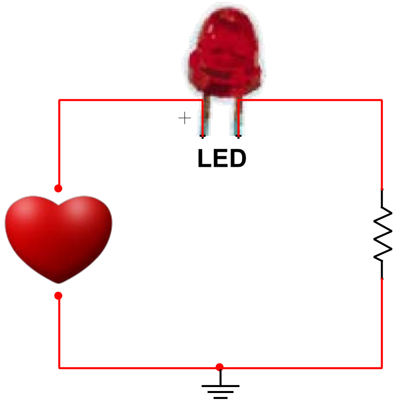

Figure P.1 – Bioamplifier Circuit Schematic

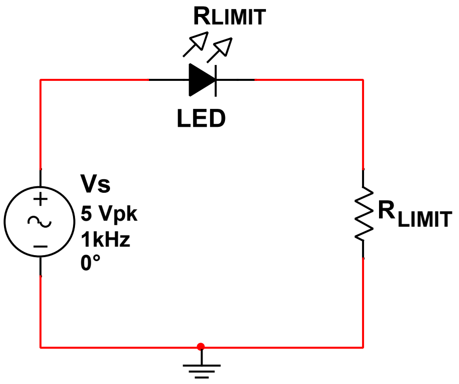

Figure P.2 – LED Circuit Schematic

1. **Simulate** the circuit in **Figure P.2** in Multisim.
    a. **Use** the **AC_Voltage** component as your voltage source (**5V$_{pk}$, 1kHz, no offset**).
    b. **Use** the **LED_red** component under Diodes/LED as the red LED.
    c. **Double-click** the red wire and rename the nets to **Vs** and **Rlimit**, respectively.
2. **Calculate R$_{LIMIT}$** so that it only allows **20mA** to flow through the circuit **assuming** the voltage drop across the LED is **1.75V**.
3. **Run** the simulation by pressing the green run button. **What** happens to the LED?
4. **Run** a **Transient Analysis** that shows both the source voltage **Vs** and the voltage across R$_{LIMIT}$ **V$_{RLIMIT}$** showing exactly **five** cycles of Vs.

Questions:

- **What** happened to the LED when you ran the simulation in Step 3?
- **What** do you notice about the output voltage in your Transient Analysis?
- **Describe** the behavior of the LED in terms of open-circuit or short-circuit for the positive and negative portions of the signal.

Turn In:

- Your Multisim circuit schematic
- Your simulation output
- Answer to the questions above, refer to your simulation data to justify your answers

LAB

Part I – Setting Up the ECG Bioamplifier

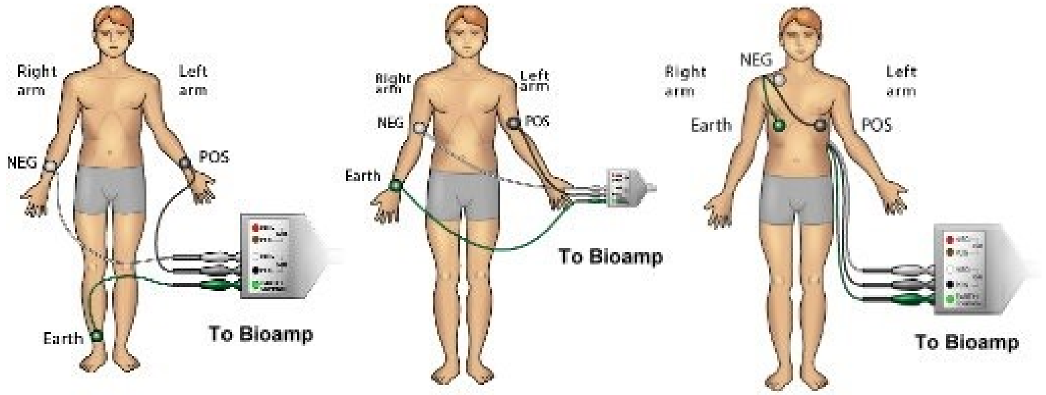

Figure 1.1 – Possible Three-lead ECG Configurations (Earth is Ground)

1. **Read** the user manual and familiarize yourself with the controls and method of operation.
2. **Connect** the amplifier to an AC outlet and flip the “**ON**” switch.
3. **Turn** the “**Balance**” dial until the front panel meter needle is **centered**.
4. **Set** the “**amplification**” to max on both dials.
5. **Set** the “high” frequency roll-off to **50Hz** and the “low” frequency roll-off to **0.1Hz**.
6. **Connect** the lead box to the 6-pin socket in the back of the amplifier.
7. **Connect** the three leads to the lead by matching their respective colors.
8. **Pick** a configuration from **Figure 1.1** and place electrodes at the designated locations on the subject’s body using the gel.
9. **Connect** the leads to their respective electrodes based on their respective colors (positive, negative, ground).
10. **Turn on** the digital oscilloscope.
11. **Connect** a **BNC to BNC cable** from the AC socket located in the back of the amplifier to the digital oscilloscope.
12. **Adjust** the Volts/div and sec/div until you see a signal that resembles the sample ECG readout from **Figure 1**. You may need to reduce the amplification if the signal is clipping.
13. **Show** the signal to the GTA **before** moving on.
14. **Record** the peak voltage $\mathbf{V_{pk}}$ of the ECG waveform.
15. **Save** the waveform as a **PNG** image on a **USB flash drive**.

Part II – Building the LED Circuit

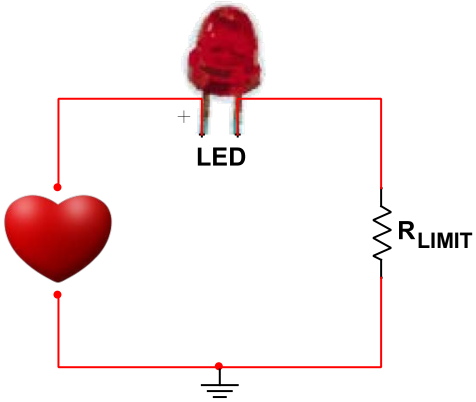

Figure 2.1 – LED Circuit Schematic

1. **Assuming** a **1.4V** drop across the LED and the peak voltage recorded from **Part I**, **calculate** the value of **R_{LIMIT}** required to obtain **20mA** through the circuit. This will be **different** from the R_{LIMIT} used in the prelab.
2. **Build** the circuit in **Figure 2.1** on a breadboard using the value you calculated for R_{LIMIT}. ***Note:*** *The longer pin of the diode is the positive end (anode).*
3. **Disconnect** the BNC to BNC cable from the back of the bioamplifier and replace it with a BNC to mini-grabber test lead.
4. **Connect** the mini-grabber ends to the positive and negative terminals of your circuit, denoted by the heart symbol in **Figure 2.1**.

   Note: *The LED should now blink at the same rate as your heart.*
5. **Show** this to the GTA before moving on.
6. **Disconnect** the mini-grabber ends.

POST-LAB ANALYSIS

1. **Calculate** your heart rate in beats-per-minute (bpm) from the ECG waveform.
2. **What** is the peak voltage of the raw signal voltage prior to amplification based on your peak output voltage?
3. Compared to the P and T waves, is the **QRS complex** a high or low frequency signal? **Explain**.
4. If you only wanted to view the QRS complex, how would you adjust the frequency roll-off values to **attenuate** the P and T waves?
5. **What** is the purpose of $\mathbf{R_{LIMIT}}$ in the LED circuit?

REFERENCES

[1] "Electrocardiography," *Wikipedia: The Free Encyclopedia*, https://secure.wikimedia.org/wikipedia/en/wiki/Electrocardiography