

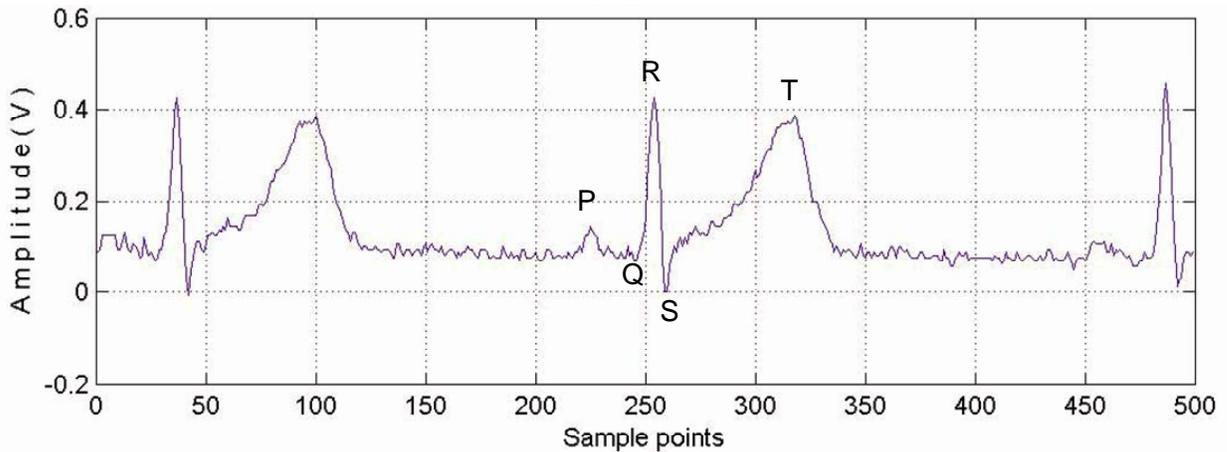
**Introduction:**

This lab familiarizes you with some of the electrical circuitry, such as resistors and basic operational amplifier (op-amp) circuits, involved in medical instrumentation, specifically the ECG. You will have an opportunity to build and test electronic circuits and in the process get acquainted with the different laboratory equipment such as breadboards, oscilloscopes, and multimeters.

Resistors are circuit elements that impede current flow. Ohm's law is  $v = iR$ , and says that the voltage across something is equal to the current through that thing times its resistance (or impedance). Current can be direct current (dc), which has a frequency of 0 Hz, or it can be alternating current (ac) with a frequency of  $>0$  to  $\infty$  Hz. Resistors impede current flow the same amount for any frequency. Their value of impedance is always  $R \Omega$  (ohms).

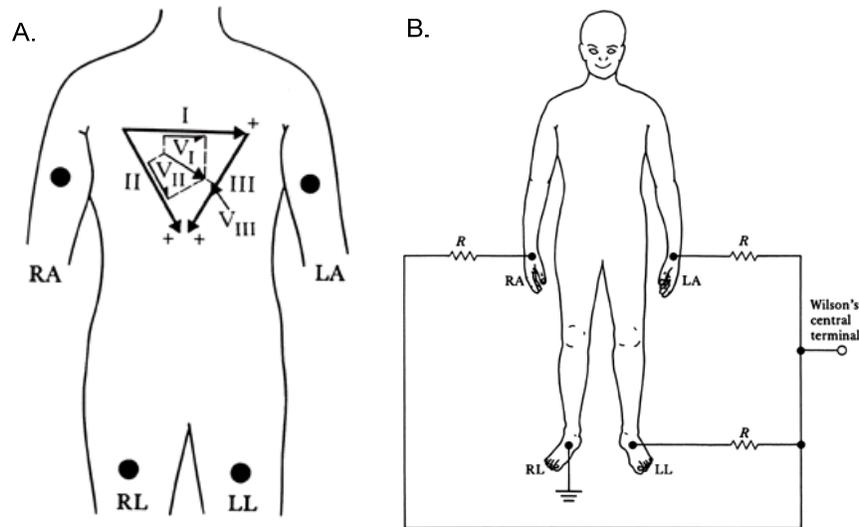
The op amp is an integrated circuit consisting of many transistors, resistors, and capacitors and is used to amplify signals. It is drawn as a triangle with + (noninverting) and - (inverting) terminals on it. Op amps are useful because they have gain—they can take an input and amplify it by some amount controlled by the person building the circuit. We use them in biomedical instrumentation to measure small signals from the body (ECG is ~1-5 millivolts) and amplify them to the 1 to 2 V range, so that they can be more easily observed.

Each time the heart beats, the contracting muscle generates potentials. The 1 mV resulting signal can be picked up on the skin on the chest or limbs, using electrodes. The signal is known as the electrocardiogram (ECG). Fig. 1 shows the ECG of an individual with the characteristic P, Q, R, S and T feature points.



**Fig. 1** The Electrocardiogram of an individual with the characteristic points (P, Q, R, S and T)

Continuously monitoring a single lead II, the physician can assess the rhythm and condition of the heart. Fig. 2 shows the standard notation for the different leads and the connections of the electrodes to the body.



**Fig. 2** A. The standard notation used for cardiologists to represent the different leads and B. Connection of electrodes to the body [1].

Bradycardia is slow heart rate. Tachycardia is fast heart rate. Ventricular fibrillation indicates that the heart has stopped pumping and defibrillation is required to restart the heart. S–T segment depression indicates that the heart muscle is damaged (recent heart attack) or lacks oxygen (during a treadmill stress test). Using a few seconds of twelve different scalar views of the electrical activity of the heart muscle, the cardiologist obtains a diagnostic ECG to more specifically diagnose heart disease.

**Overview:**

In this lab, we will explore the circuit elements involved in ECGs and the cardiac physiology that allows us to record these electrical signals. First, we will begin by understanding the circuit: namely, the power sources, resistors, and operational amplifiers. We will then look at a circuit that amplifies the 1mV ECG signal and look at the electrical conduction patterns of the heart, followed by a medical ECG device to compare the quality and discuss electrical sensitivity. After seeing the electrical conduction of the heart on an ECG output, we will discuss cardiac physiology to understand the origin of the signals and cardiac pathologies, to discuss the importance of medical instrumentation.

**References:**

[1] J. G. Webster (ed.), "Medical Instrumentation: Application and Design," 3<sup>rd</sup> ed., John Wiley & Sons, , 1998.  
[2] Amit Nimunkar, BME 310 Labs 1 and 4

## Laboratory Equipment

1. Resistors, op amps, LEDs
2. Bread board
3. HP 33120A signal generator
4. HP 54600B oscilloscope
5. HP 34401A digital multimeter
6. HP E3630A dc power supply

## Procedure

### *(LECTURE INTERLUDE: CIRCUITRY)*

#### A. Lab Equipment

1. Turn on dc power supply and digital multimeter (DMM).
2. Adjust the power supply to 15 V using the knob labeled 20 V.
3. Press the DC V button on the DMM. Plug one end of one cable into the COM port on the power supply and the other end into the GND port on the DMM. Plug one end of the other cable into the +20 V port on the power supply and the other end into the top right port of the DMM. Record the voltage and verify that the voltage displayed is close to +15 V.
4. Remove the cable from the +20 V port on the power supply and plug it into the –20 V port. Record the voltage and verify that the voltage displayed on the DMM is close to –15 V.
5. Turn dc power supply off.
6. Unplug both cables from the dc power supply.
7. Press the  $2\Omega$  button on the DMM. This will allow us to measure resistance.
8. Measure the resistances of the resistors in front of you and record their values.
9. Turn on the oscilloscope and waveform generator.
10. Connect probe 1 to the waveform generator. Make sure channel 1 is selected on the oscilloscope. Press the AUTO-SCALE button.
11. Press the VOLTAGE button on the oscilloscope and then press the button at the bottom of the display under V P-P. Record the peak-to-peak voltage of the waveform on the screen.
12. Press the TIME button on the oscilloscope and then press the button at the bottom of the display under FREQ. Record the frequency of the waveform on the display.
13. Verify that the voltage and frequency shown on the oscilloscope are the same as shown by the waveform generator.
14. Change the frequency and voltage of the waveform generator by pressing the FREQUENCY and AMPLITUDE buttons, respectively, and adjusting the knob accordingly. The values can also be changed by keying in the actual numerical values desired. Record the effects of changing the frequency and amplitude of the waveform.

## B. Operational Amplifier

1. Figure three shows the pin layout for a 741 Operational Amplifier (Op-amp)

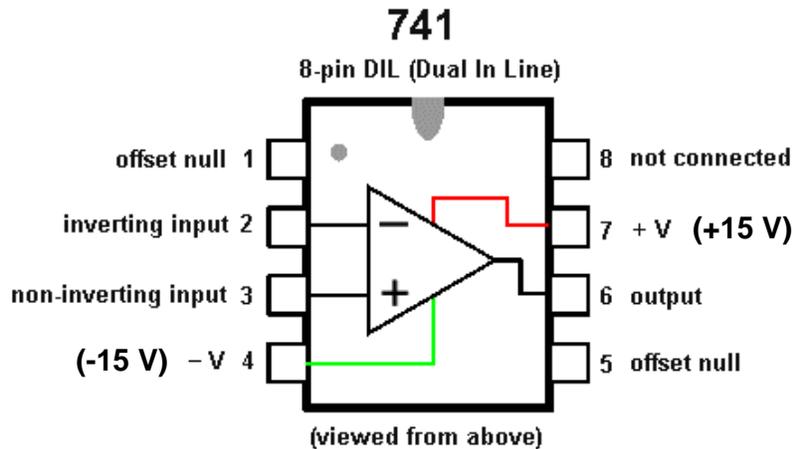


Fig3. Pin layout for 741 Op-amp

2. Construct the circuit shown below in figure four using 741 Op-amp pin layout in figure three.

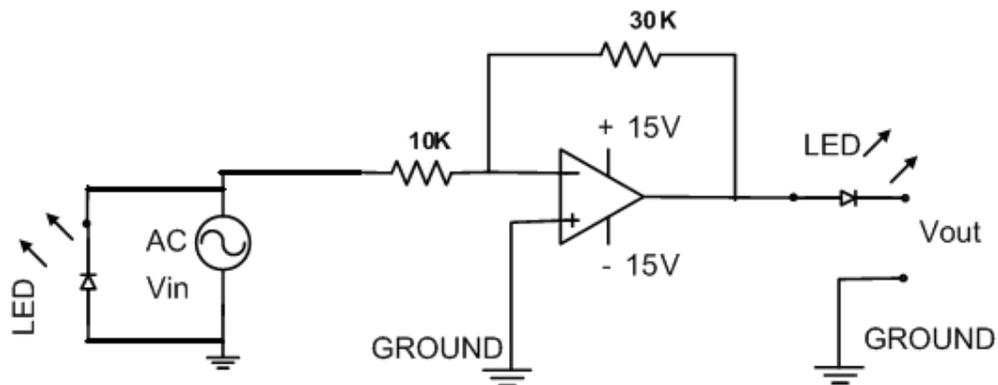


Fig4. LED/Inverting Operational Amplifier Circuit

3. Put the LED leads positive to negative in the circuit: Lg. Lead is (+); Sm. Lead is (-)
4. Set the AC source from the waveform generator to 1.5 V Peak to Peak and 5 Hz.
5. Don't forget to power the op amp with +15V, -15V, and the COM ground.
6. What is the voltage you expect at the output?
7. Observe two outputs on the oscilloscope: (1) Connect BNC/alligator clip ended wire from the oscilloscope in parallel with the first LED, which is in parallel with the source. (2) Connect a BNC/alligator clip ended wire in parallel with the output of the op amp.

8. What are the physical differences of the two readings (1 and 2 in question 6) with respect to the LED outputs (i.e. before and after the op amp)?
9. What are the physical differences of the two readings (1 and 2 in question 6) with respect to the waveforms depicted on the oscilloscope?
10. What is the voltage before and after the op amp?
11. Why/how do you think this circuit might be useful/implemented in an instrumentation system?

**C. Integration of Operational Amplifiers into the ECG.**

1. Hook up the ECG amplifier leads (4) to 10kOhm resistors (4) and connect those resistors to the electrodes placed on the Right Arm, Left Arm, Right Leg, and Left Leg.
2. Connect the out puts of the ECG to the oscilloscope.
3. What kind of signal do you see on the oscilloscope?

***(LECTURE INTERLUDE: CARDIAC PHYSIOLOGY)***

4. What is the signal mean/ where is the origin of its generation?
5. What are the different parts of the signal, and what does it mean?
6. What happens to the signal if you hold your breath? Why?
7. What happens to the signal if you exercise? Why?
8. Now, use a medical grade electrocardiogram and observe your ECG using that medical device. How does the medical grade ECG compare to the electrodes + amplification circuit, displayed on the oscilloscope?
9. What is “interference” and how might that affect the results seen on the oscilloscope?

**D. Integration of Circuitry and Other Medical Devices**

1. In this section of the workshop we will explore other vital signs using other electronic medical equipment such as the ultrasonic flow meter and the blood pressure monitor.