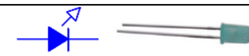
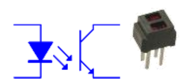
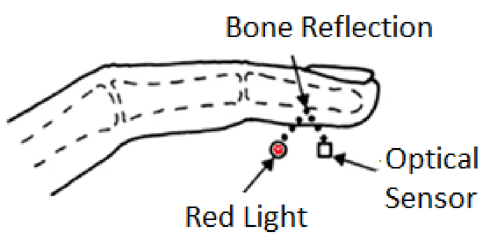
Activity: Heart Rate Monitor

Introduction

Materials			
• 6 resistors		• 1 green light (LED)	
• 2 capacitors		• 1 LED + photodetector	
• 1 amplifier			

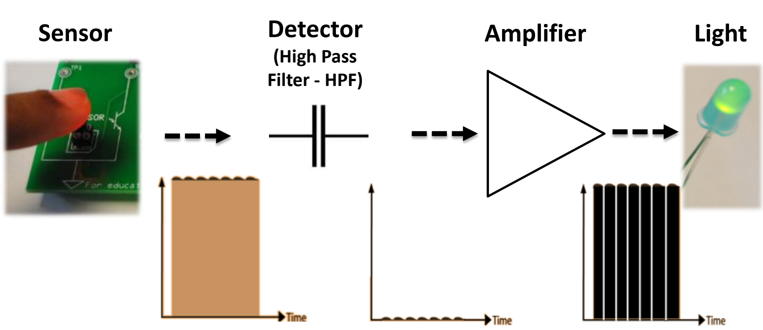
Heart rate is an important physiological data value for the diagnosis and treatment of many diseases. It is typically expressed as beats per minute (bpm) and ranges from 60 to 100 bpm in healthy adults. Heart rate can be measured by monitoring changes in volume within a certain organ, in the case of this activity, the blood vessels. This process is called plethysmography.

Did you know? Bradycardia is a slow heart rate, defined as below 60 bpm. Tachycardia is a fast heart rate, defined as above 100 bpm at rest. When the heart is not beating in a regular pattern, this is referred to as an arrhythmia.



Today, you will assemble and test an Optical Heart Rate Monitor! The monitor creates a circuit that generates a red ray which penetrates the finger and reflects off the bone to create a returning signal that is measured by an optical (photo) sensor. Whenever the heart beats, the diameter of small arteries (arterioles) increases a little bit, which causes very small changes in the circuit reading. The most common sites to measure light reflecting off the skin are either the fingers or earlobes. We will use the finger.

The optical sensor gathers information from many tissues, such as skin and muscle, but only the volume change in the small arteries is important for our measurement. To get a better measurement, we need to separate (filter) the small waves through the detector and increase the pulse level with an amplifier. The resulting signal is strong enough to make a green light blink every time the heart beats.



Since our board measures the heart rate optically, by detecting small changes in the arterioles volume, this device can also be called a photoplethysmograph!

Part 1: Find your resting heart rate

Before assembling the monitor, let's measure our heart rate with our fingers.

1. Place your index and middle finger on either your radial or carotid artery to locate your pulse (as in the picture below).

Radial artery (wrist)

Carotid artery (neck)

2. When your instructor tells you to, begin counting your pulse. After 10 seconds you will be asked to stop.
3. Record this number below and multiply it by six. This is your resting beats per minute (BPM).

Resting Pulse: ______________ X 6 = ______________

Resting Beats (10s) *Resting Beats (1 min)*

4. Now stand up and get your heart beating fast! Do jumping jacks for 15-20 seconds. Be careful not to hurt yourself or anyone around you.
5. Sit down and measure your pulse again for 10 seconds. Multiply this number by six and record below. This is your active BPM.

Active Pulse: ______________ X 6 = ______________

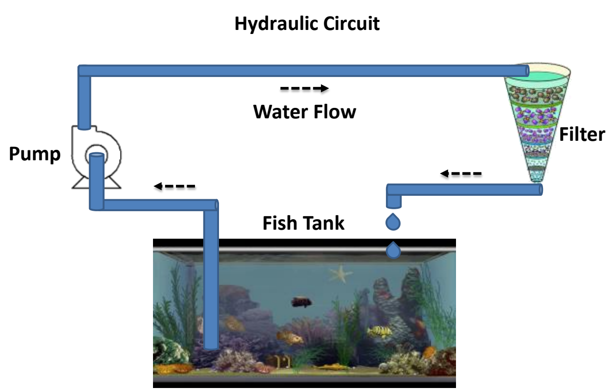
Active Beats (10s) *Active Beats (1 min)*

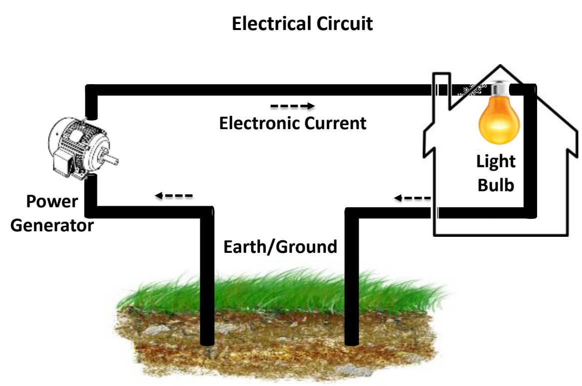
Compare your results with other members of your group. Did everyone have the same BPMs? Probably not! This is because our hearts are all different, and BPMs are influenced by factors like the ones listed below. Put an up arrow ⬆ next to the factors which cause you to have a higher heartbeat, and draw a down arrow ⬇ next to the ones that cause you to have a lower heartbeat.

Factor	⬆ or ⬇
Exercising	
Stress	
Sleeping	
Being overweight	
Being healthy	

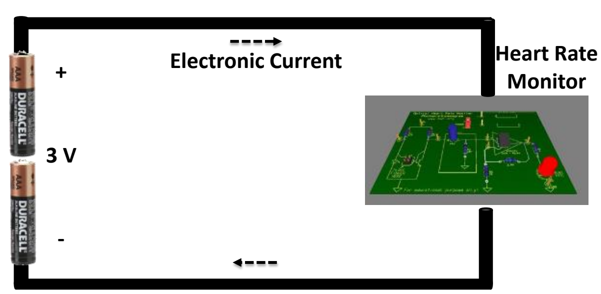
Part 2: Assemble an Optical Heart Rate Monitor

Besides understanding how the human body works, biomedical engineers also need to know principles of electronics. The figures bellow show how electrical and hydraulic circuits are similar:



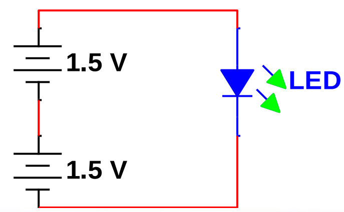
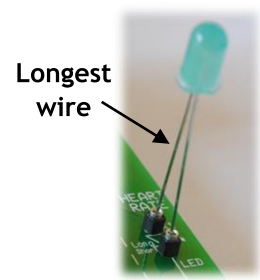
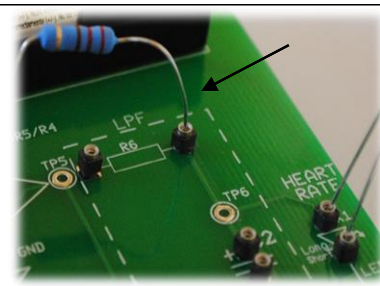


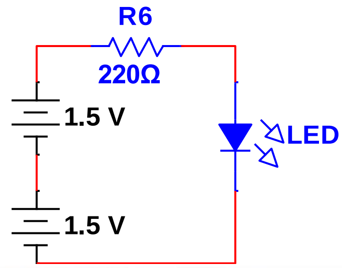
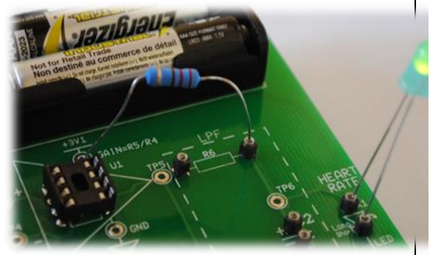
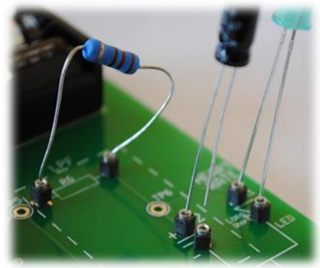
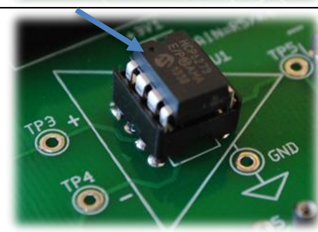
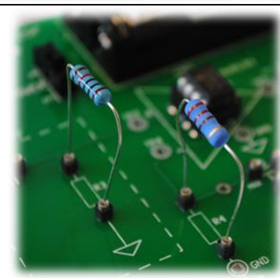
Just as the pump in a fish tank pulls water into the filter through tubes, power generators create electronic current that flows from the earth to our houses through metal cables. In the case of our OHRM circuit, the batteries replace the earth as well as the generator.

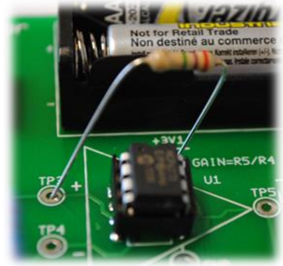
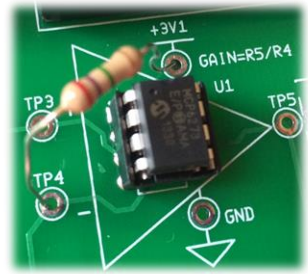
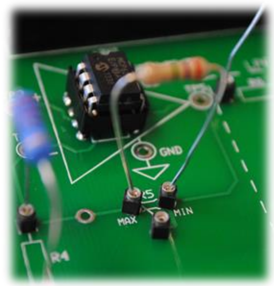
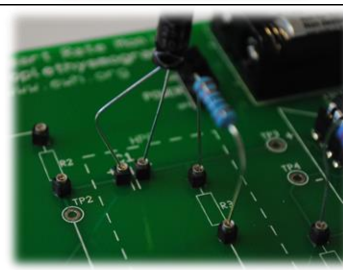
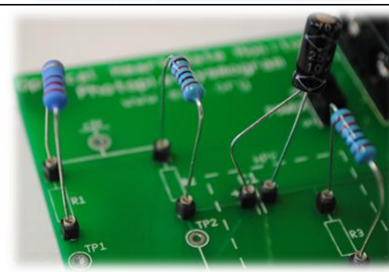
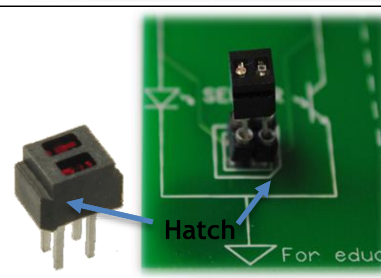


The Optical Heart Rate Monitor circuit will use the current from the batteries to measure the red light that reflects in the finger.

Let’s start assembling the OHRM board:

1	First, test the light emission diode (LED) to be sure it works. With both AAA batteries installed in the board, connect the long end of the LED wire to the positive contact and the short end to the negative contact from the battery holder. What happens? ____	
2	All electronic components that have uneven legs, like the LED, have polarity, which means they must be connected in the correct direction to work properly. Try to connect the longest wire to the negative contact and the shortest to the positive. What happens now? ____	
3	Place the LED X1 on the board; pay special attention so the longest wire is connected to the top contact (also called socket). Although the light works fine if connected directly to the battery, we do not need such a strong intensity, nor do we want to drain a high current in the circuit. Can you think of reasons why you should limit the current? ____	
4	Electrical engineers use components called resistors to decrease the system power consumption of electronic circuits. Place one leg from the R6 resistor on the contact (marked R6 above the LED) next to TP6. Notice that the resistor does not have polarity, so it does not matter which wire you connect.	

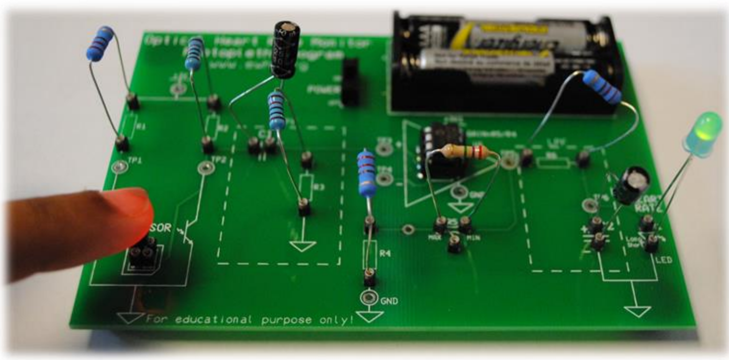
5	Turn the power switch **ON**. Connect the left resistor leg to the +3V contact. Do you notice any difference between the light intensity with the resistor between the battery and the LED and without any resistance (item 1)? ____	 
6	Place the other resistor leg in the remaining contact.	
7	Add the capacitor C2 next to the LED. Make sure the longest wire is in the (+) socket. It is VERY important to add the capacitor in the correct orientation.	
8	Let's connect the amplifier in the board. Like LEDs and some capacitors, amplifiers require the right polarity to work. Make sure the power switch is **OFF**. Place the amplifier chip on the socket. Check that pin 1, marked with a small hole on the chip, is placed in the appropriate connector (top left connector).	
9	Place the resistors R3 and R4 on the board.	

10	It is important to test if the amplifier is working properly. Turn **ON** the power switch and use the resistor R5 to connect the test point TP3 with the +3 V contact. Does the LED turn ON or OFF? ____	
11	Now use the same resistor, R5, to connect the test point TP4 with the +3 V contact. Does the LED turn ON or OFF? ____	
12	If +3V in TP3 (positive amplifier input) turns ON the light and +3V in TP4 (negative input) turns it off, then your amplifier is working. Place the resistor R5 in the correct place on the board.	
13	Switch **OFF** the circuit. Assemble the capacitor C1 in the board. Notice that its legs have different sizes, which means that it also requires a special polarity. Place the longest wire in the left contact (+) and the shortest in the right (-).	
14	It is time to assemble the sensor block. Place the resistors R1 and R2.	
15	The sensor has two windows. The left part generates a red light that will penetrate the skin in the finger and reflect off the bone. The right window is an optical sensor that measures the returning light from the bone. Connect the sensor in the circuit making sure that the small hatch in the right-lower corner corresponds to the drawing on the circuit board.	

Congratulations! You just assembled a very important clinical monitoring device. Let's test our Optical Heart Rate Monitor!

Connect the two AAA batteries in the holder and turn ON the board. Gently, place the ring finger of your right hand on the sensor. You do not need to press down; keep a light touch. The circuit works better if your elbow and all fingers lay on the table. Use your left hand index finger to feel your heart pulse in your neck.

Wait 15 seconds. Does the green light flash at the same time you feel your heart beat in your neck? This means the monitor is working!



Fill in the blanks with following words: fingers, arrhythmia, heart or plethysmography.

1. The monitoring of changes in volume within a certain organ is also called __________________.

2. ________________ happens when the heart is not beating in a regular pattern.

3. The most common sites of light measurements are either the _________________ or earlobes.

4. Whenever the ___________ beats, the diameters of small arteries (arterioles) increases a little bit.

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