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UP II Honors Project
Lab: H3
Building an Electrocardiograph
April 25, 2011

Constructing an electrocardiograph was a challenging process, full of troubleshooting and reexamining, but after much struggle and sweat, it was effectively built and successfully tested. An electrocardiograph, referred to as an ECG or EKG generally, is a medical device used as a common diagnostic tool to monitor heart activity. To do so, the machine evaluates the electric activity of the heart, measuring the electrical impulses as they leave the heart and travel through the surrounding tissue during the contractions of the heart muscles. The electrical impulses are detected by the electrodes attached to the epidermis, which are then amplified by the circuit of the EKG. The EKG displays the heart rate in actual time, while also illustrating the electrical signal's strength and timing. The device is useful in detecting irregular heartbeats due to a cardiac infarction or any other source of disturbance.

The heart is made up of muscles, blood vessels, and nerves that all function together to supply the rest of the body with the blood gases, nutrients, waste products and immune cells the body requires at a constant rate. The heart consists of several bundles of nerves, which originate in nodes, and are capable of generating and transmitting an electrical impulse from one part of the organ to the other. The sinoatrial (SA) node, referred to as the heart's pacemaker and located in the superior and posterior wall of the right atrium, and the atrioventricular (AV) node, located in the upper AV septum, are key components to understanding the cardiac cycle. The electrocardiograph first identifies the aforementioned electrical impulses the heart transmits, and after amplification, it records them and generates an electrocardiogram. The electrocardiogram waveform demonstrates the heart's standard cardiac cycle, which is then divided into smaller waves, each depicting an activity in a particular area of the heart, shown in Figure A. ("Biomedical

Physics") The first activity is atrial depolarization, where the main electrical vector is directed from the SA node towards the AV node, and spreads from the right atrium to the left atrium, causing atrial contraction. This wave has a positive charge and is referred to as the P wave. The next division of the wave, the QRS complex, represents ventricular depolarization and causes a ventricular contraction. This contraction sends blood through the aorta to the body and through pulmonary artery to the lungs. The last wave, the T wave, represents the ventricular repolarization, which occurs as the ventricles ready themselves for the next cycle. (Conover 16) The intervals in between each of these waves are referred as refractory periods.

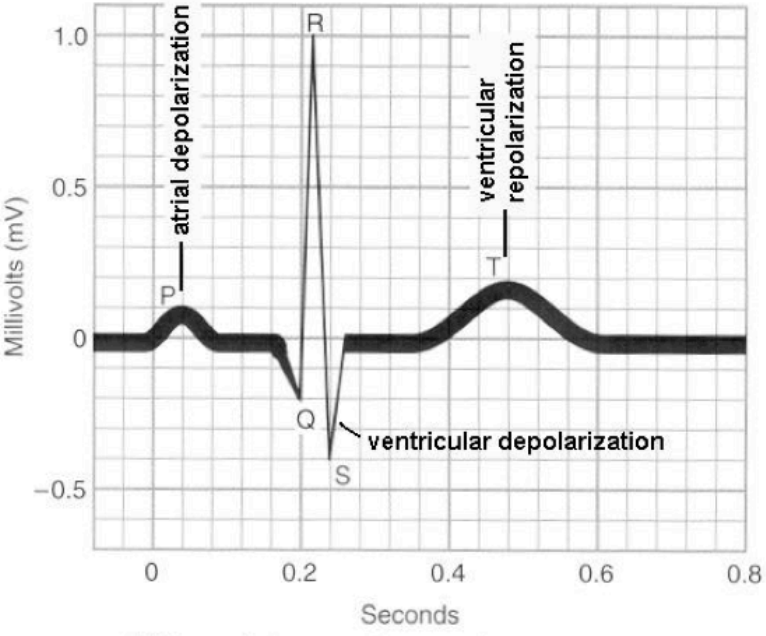


Figure A. An Electrocardiogram Waveform

The causation of the contraction and relaxation of the heart in the blood-pumping process is triggered by action potentials sweeping across the muscle cell membranes. (Sherwood 309) The heart possesses the property of autorhythmicity, meaning it contracts rhythmically due to the action potentials it produces itself. The action potentials in the heart go through five specific phases, causing changes in the electric field. To record these electric signals, the electrodes must be appropriately placed on the body. Typically, electrodes are twelve in number, with three “leads”, which measure the electrical activity of the heart. The inventor of the electrocardiograph, Dutch scientist Willem Einthoven, named the leads between the three limbs electrodes (right arm, left arm, and left leg) “standard I, II, and III”. This is now commonly referred to as “Einthoven’s triangle”, shown in Figure B. With the use of at least three leads, a ground is created, which allows the EKG to have a neutral point to better read the voltage waves. (“The Electrocardiogram”) The leads used in this experiment are presented in Figure C.

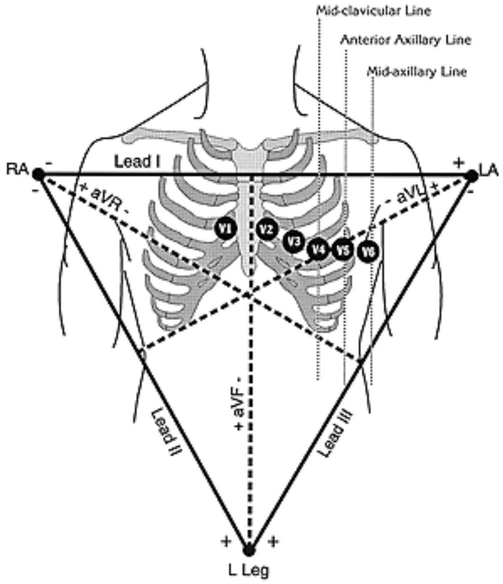


Figure B. Einthoven’s Triangle for Leads

Figure C. One Electrode Lead Used in this Experiment

The EKG in this experiment was constructed by meticulously soldering a combination of two 9V batteries, several resistors, two capacitors, three dual-operational amplifiers, six silicon diodes, and various wires to a proto-type board, constructed according to the circuit diagram shown in Figure D. The electrodes that attached to this EKG picked up a great deal of noise from the body and environment. The connected wire (shown on the circuit in Figure E and in Figure F) acted as an antenna, picking up 60 Hz interference from the lights and other electrical equipment present in the room. Foil was placed on the wire to act as an inexpensive shield, while the dual-op amps both amplified and cleaned up the signal. The first amplifier, the input amplifier, amplified the two signals from leads I and II by a gain of ten. The second pulse shaped and amplified the signals by a gain of ten once more. The third “output” amplifier amplified the signals by a gain of two, summed the two signals together, then inverted that one signal to give the output signal. For safety measures, the blocking diodes were placed on the circuit to keep the battery from shorting and sending electric current into the heart. Two wires that extended from the circuitry board which were connected to the phone plug were hooked up to the Mic In-put on the computer. The sound from the board was converted into a signal on the computer program designed to read EKG's.

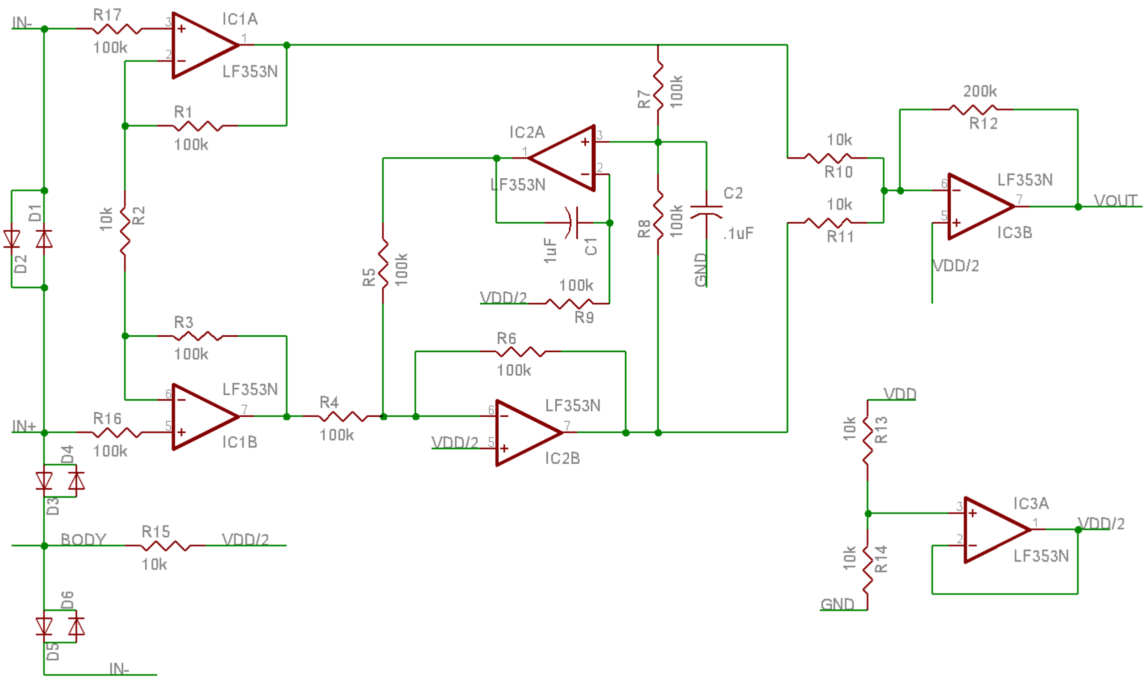


Figure D. Diagram of Circuit Schematic

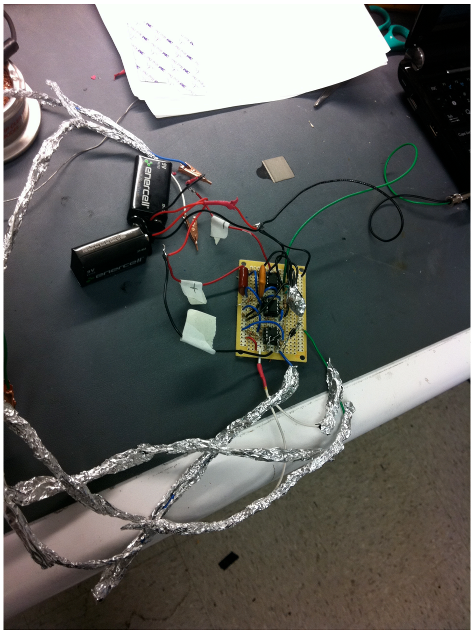


Figure E. Picture of fully functioning EKG hooked into computer for reading

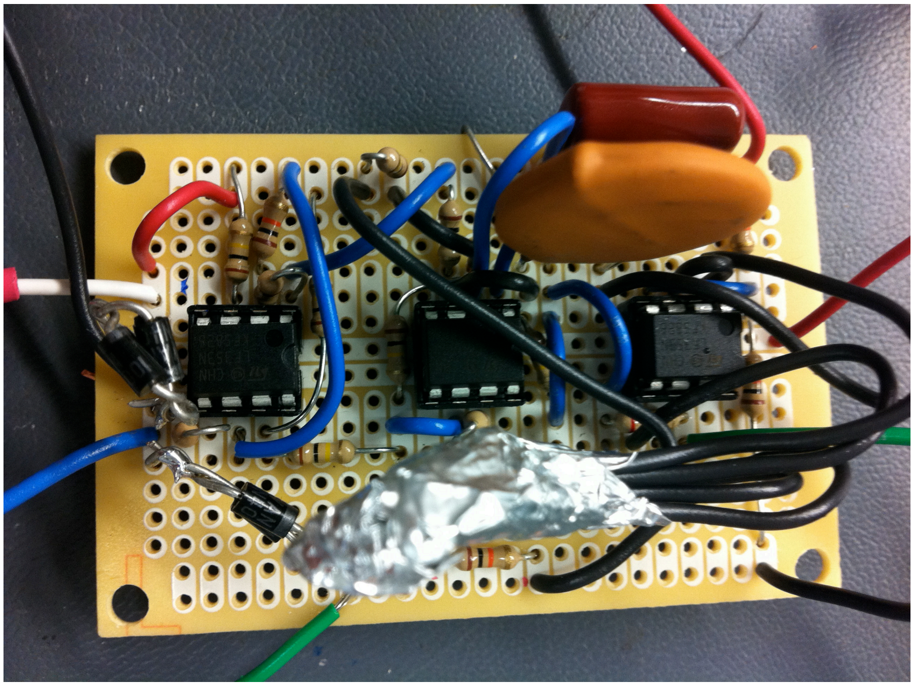
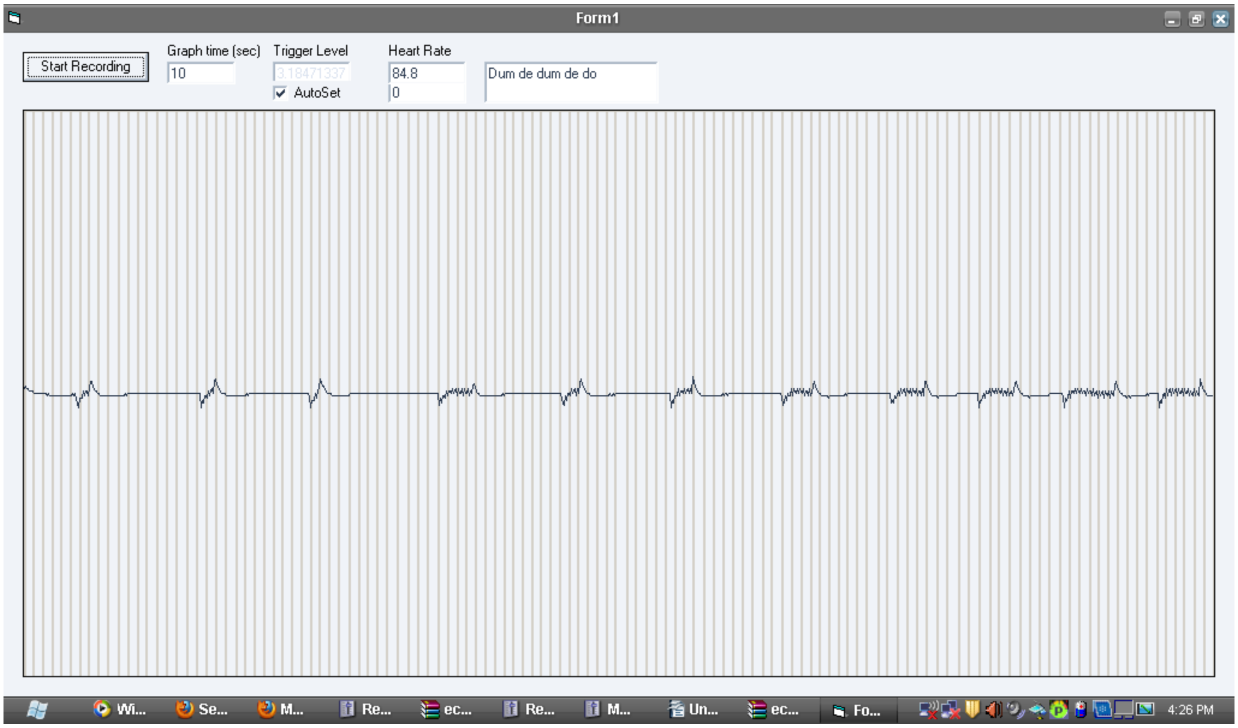


Figure F. Closer view of the circuitry board

To test the efficiency of the handcrafted EKG, we ran several experiments. In one experiment, the person attached to the EKG was under no-stress “resting” conditions, in which we recorded a steady, normal heartbeat. In the second experiment, the person had to undergo extensive activity, including jumping jacks and jogging. After this, she was once again hooked up to the EKG, where a higher heartbeat was measured. The heart had to pump more blood to the body’s muscles to perform this activity, which correlated to the results obtained. There is a distinct difference demonstrated in the two readings, shown in figures G and H, respectively. Ultimately, because a functioning EKG was built and a better understanding of the physics behind the heart was gained, the project was undoubtedly a success.



Graph time (sec): 10

Trigger Level: 3.18471337

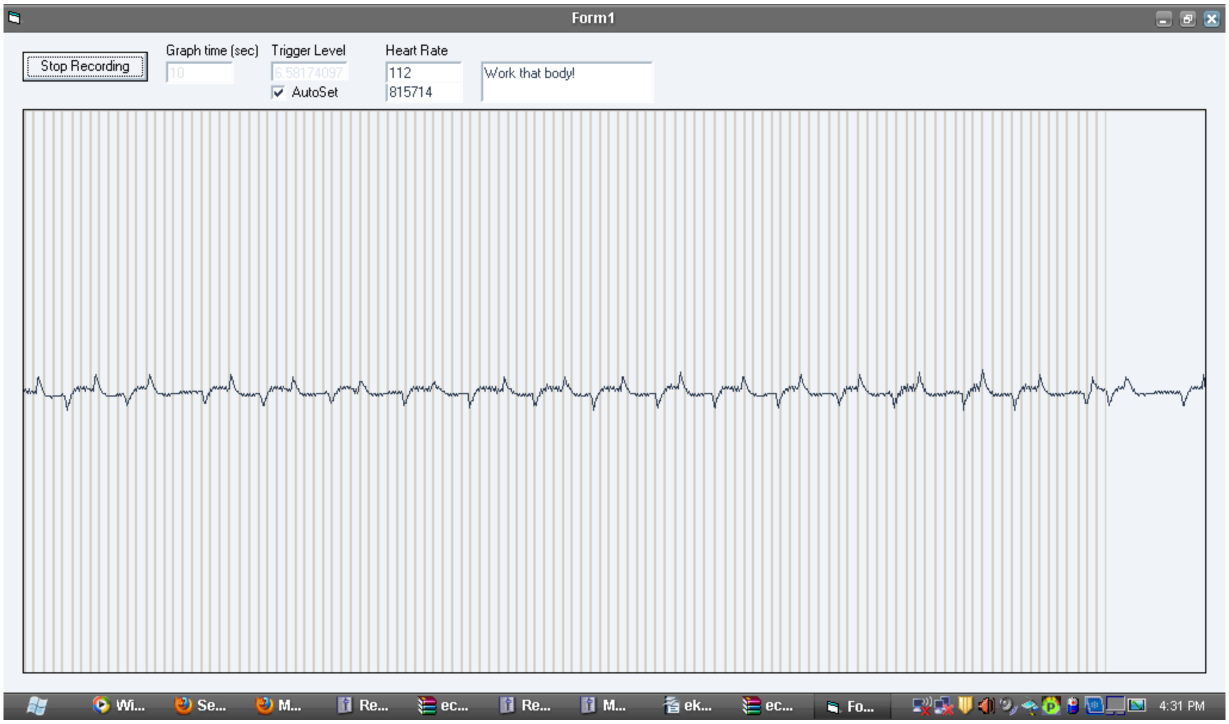
☑ AutoSet

Heart Rate: 84.8

0

Dum de dum de do

Figure G. Heart rate at "Resting" Condition



Graph time (sec): 10

Trigger Level: 6.58174097

☑ AutoSet

Heart Rate: 112

815714

Work that body!

Figure H. Heart rate after Extensive Activity

Works Cited

Conover, Mary. Understanding Electrocardiography. Seventh ed. St. Louis: Mosby-Year Book, Inc., 1995.

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