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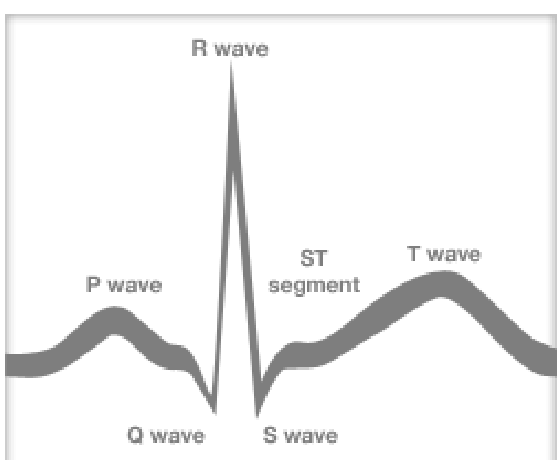
University Physics II Honors Project
Lab Section H2

Electrocardiograph

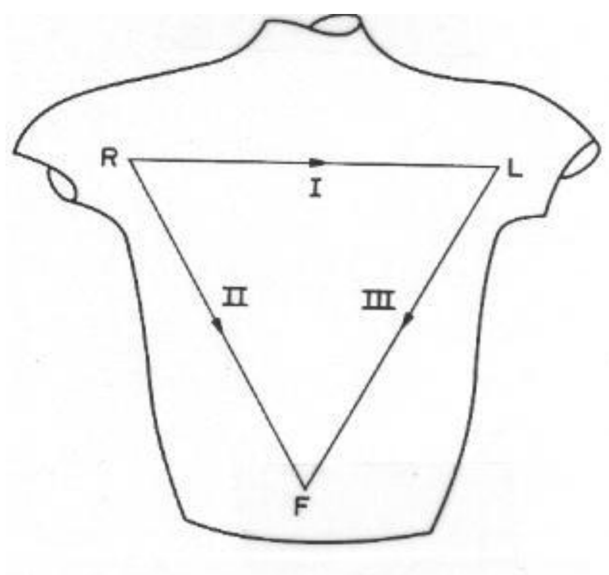
For our Honors project, we built and successfully tested an electrocardiograph machine. Electrocardiographs are medical devices that measure the electric impulse that passes through the heart. This is important to measure because the contraction of the heart muscles occurs as a direct result of the electric signals sent through it. Anatomically, the heart has many nerve pathways in it that allow for it to contract properly when an electrical signal is sent through it. These electrical impulses can be detected through the skin using electrodes and an amplifier circuit. Electrocardiographs also known as ECG or EKG show how fast the heart is beating in real time and the strength and timing of electrical signals through the heart in order to determine whether the heartbeat is steady or irregular.

The electrocardiograph picks up the electrical impulses sent from the heart, amplifies, and records them to produce an electrocardiogram. An electrocardiogram waveform shows a typical cycle of heart rhythm with the following timing pattern: the P wave is seen first, corresponding to both the atrium contracting and priming the ventricle with blood; this is followed by the QRS complex where the ventricles fire and push blood through both the pulmonary artery to the lungs and through the aorta to the body; the final part of the wave is the T wave which is the time at which the ventricles repolarize themselves for the next cycle.

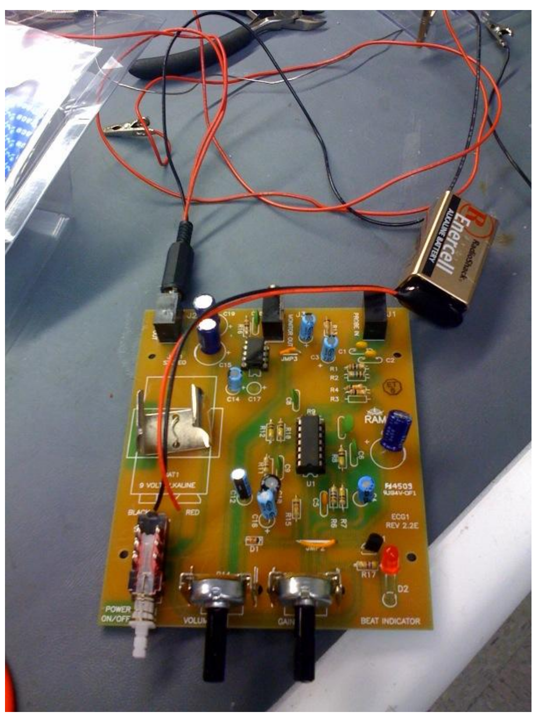


The electrical events that precede the mechanical contraction and relaxation of the atrial and ventricular muscles, that are shown in the electrocardiogram above, are generated by action potentials in specialized conduction cells in the heart (Ritter 167). The action potential is initiated by the firing of the vagus nerve at the sinoatrial node, it is then spread radially outward in the specific pattern described above (Ritter 169). The way the action potential is spread through the heart creates momentary minute electromotive force or potential of both negative and positive polarity across the chest; these change from moment to moment causing a change in electric field (Webster 290).

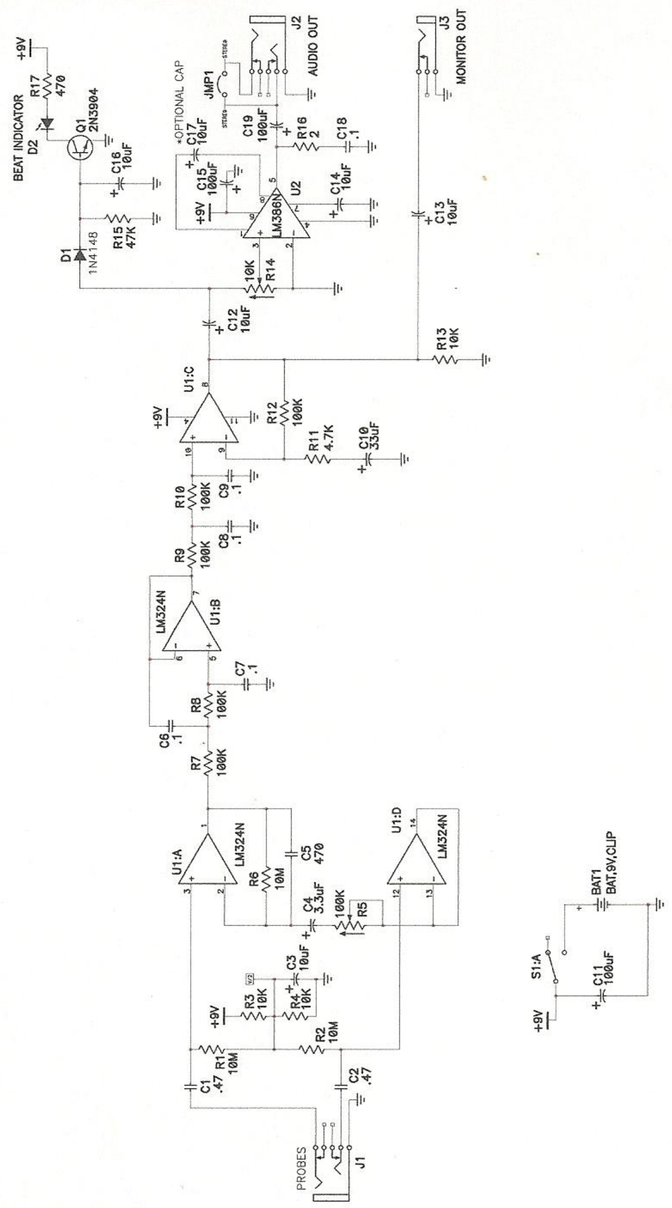
With correct placement of up to five electrodes on the body (placed typically on the patient’s right arm, left arm, chest, right leg, and left leg) the EKG records the electric signals. At least three electrode leads must be placed on the body to correctly record the waveform (Ritter 170). These leads are electrical conductors that measure the electrical activity of the heart in the frontal plane with the heart positioned at the center of an equilateral triangle, called Eindhoven’s Triangle, so that the changing electric field can be recorded (Webster 292). This EKG electrode system set up establishes a ground between the instrument and the patient so the instrument can pick up and record voltage waves in relation to some neutral point.



Because the voltages received from the electrodes on the patient’s body range from 1 millivolt to 5 millivolts and they are often swamped out by other noise and static in our body at any time, the EKG circuit must eliminate common noise present in the inputs and amplify the difference between the voltages (Smith 105). The circuitry used in our EKG is common for operational amplifiers and achieves these goals. Using a kit from Ramsey Electronics, we used two inputs to the circuit, and the circuit mirrored itself with respect to the two inputs. The differential circuit we used is also used extensively in modern electronic circuits. Our differential amplifier recovered the original signal from the heart, which required filtering of the signals picked up by the leads. This was achieved through some resistor capacitor combinations that filtered off high frequency noises leaving the heartbeat signal intact for analysis. In order to avoid causing bodily harm due to external power supplies, our circuit ran directly off of a 9 volt alkaline battery.

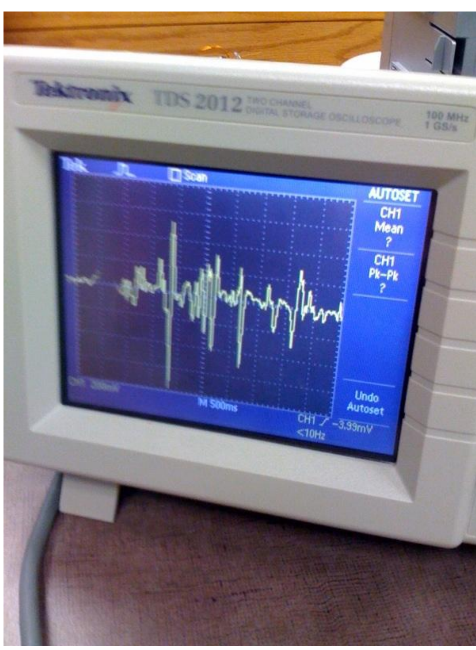


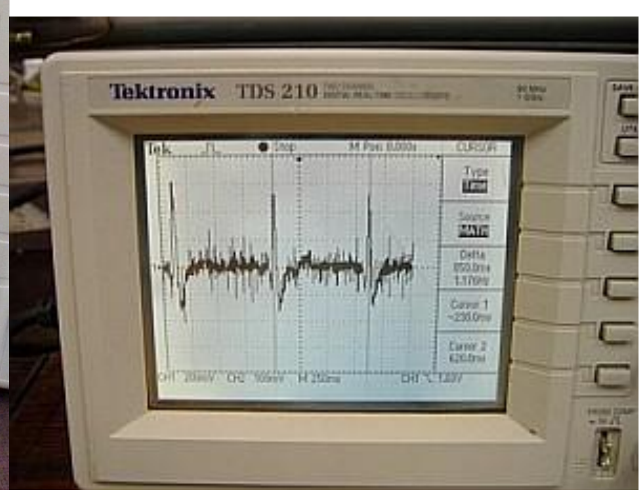
ECG1 SCHEMATIC DIAGRAM



After the signal is detected, filtered, and amplified, the heartbeat can be heard and viewed in close to real time using a speaker and an oscilloscope. This is because our EKG circuit had an audio amplifier so the heartbeat could be heard using a headset. Furthermore, the circuit also had a monitor output for a connection to an oscilloscope to view the EKG pattern directly.

When testing the EKG we monitored the heartbeat at resting conditions and also under conditions of high stress—after exercise. Our EKG worked in that the indicator light that was coupled to our output signal was triggered whenever the transistor was triggered by a positive peak from the heart flashed in time with the heart’s rhythm. Also, the heartbeat was clearly audible through the audio output and when attached to an oscilloscope the waveform was seen. Under resting conditions the heart beat more slowly than when under exercise conditions. Below are pictures of the trial runs—the first shows the oscilloscope recording a heartbeat under normal conditions, and the second shows the heart under exercise conditions—it is clear by the spacing that the heart was beating faster to pump more blood to the muscles. Overall the project was successful in that we assembled a working electrocardiograph machine.





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