A Photoplethysmography Based Heart-rate Monitoring System

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Abstract-

The plan for the project was to detect heart-rate through sensors and present the data as an electrocardiogram. Photoplethysmographic sensors were used to detect the heart-rate and transmit this information onto a waveform graph. Photoplethysmography is low-cost method used to detect blood volume changes in the microvascular bed of tissue. Using software called Eagle, a printed circuit board was designed and ordered that was used to operate a LabView program. The LabView program creates a waveform graph of each heartbeat and series of heartbeats overtime. This new heart-rate monitoring system is very cost effective and provides an accessible record of instantaneous and long-term heart-rate changes.

INTRODUCTION

MONITORING AND ANALYZING HEART FUNCTIONS ARE KEY ASPECTS FOR MAINTAINING A HEALTHY BODY. TYPICAL HEART MONITORS HAVE BEEN SUCCESSFUL IN HOSPITAL SETTINGS; HOWEVER, THE EXPENSE AND SIZE MAKES THEM INCONVENIENT TO USE AT HOME. OUR DEVICE, PHOTOPLETHYSMOGRAPHIC HEART-RATE MONITORS, ARE SMALL HEART-RATE MONITORS THAT COST ABOUT TEN DOLLARS. IN ADDITION TO THE SIZE AND COST, WHEN HOOKED UP TO A COMPUTER, A SINUSOIDAL GRAPH OF THE HEART'S RHYTHMIC FUNCTIONS WILL APPEAR. THESE NEW HEART-RATE MONITORS WILL PROVIDE DOCTORS AND SCIENTISTS WITH A CHEAP AND EFFECTIVE WAY TO TEST HEART-RATE. THE SOFTWARE PROGRAM PROVIDES A SIMPLE WAY TO MONITOR HEART-RATE INSTANTANEOUSLY AND OVERTIME. THIS NEW HEART-RATE MONITOR WILL ALSO ALLOW PROFESSIONALS TO DETECT CHANGES IN HEART RHYTHM AND ABNORMALITIES, SUCH AS ARRHYTHMIA.

CONVENTIONAL HEART RATE VARIES FROM PERSON TO PERSON, BUT ANY PULSE IS A MEASUREMENT OF THE NUMBER OF BEATS PER MINUTE YIELDED BY THE HEART. A SINUSOIDAL GRAPH IS CREATED FROM THE RHYTHMIC FUNCTIONS OF THE HEART. A SINUSOIDAL PATTERN IS DEFINED AS A PATTERN OF FIXED, UNIFORM FLUCTUATIONS THAT CREATES A PATTERN RESEMBLING SUCCESSIVE GEOMETRIC SINE WAVES.

THIS NEW METHOD OF HEART-RATE MONITORING IS REVOLUTIONARY IN THE MEDICAL FIELD. IT IS AN INNOVATIVE WAY TO MEASURE PULSE AND

EXAMINE A SINUSOIDAL GRAPH WITH THE SAME PRECISION USED IN A HOSPITAL.

Literature Review

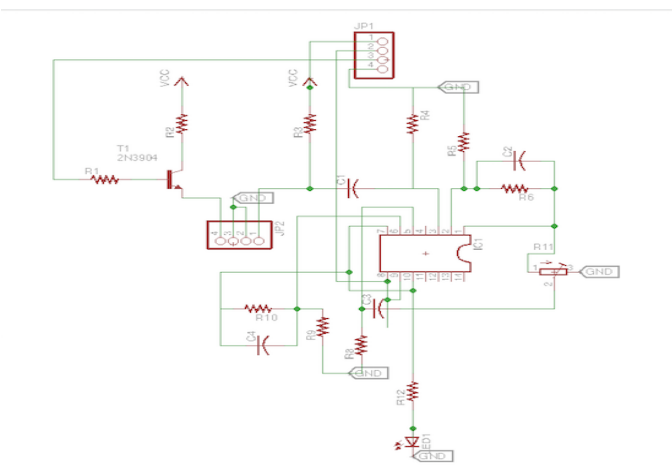
An electrocardiogram , or EKG, is a test that checks for problems with the electrical activity of a person's heart. An EKG shows the heart's electrical activity as line tracings on paper. The spikes and dips in the tracings are called waves. Most professional healthcare establishments use typical electrocardiogram instruments. However, they are very inconvenient and expensive for patients to use at home. A cardiac monitor's cost ranges from five hundred dollars to one thousand seven hundred dollars. The new photoplethysmographic heart-rate monitors will only cost approximately ten dollars. The photoplethysmographic sensors only require holding on to the sensor so that optical lens can detect the blood volume changes in the bed of micro-vascular tissue. Theses sensors are less invasive than traditional EKGs which use electrodes that can be very harmful and irritating to the skin.

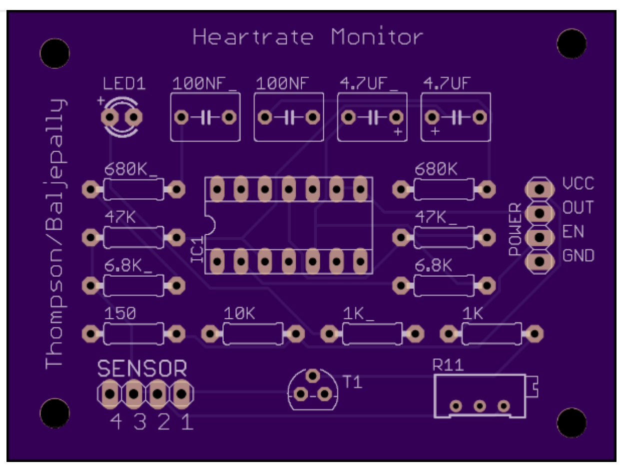
The skin is so elaborately permeated, and therefore, it is fairly easy to detect the pulsatile element of the cardiac cycle. The direct current component of the signal, which circuit boards are based on, is attributable to the mass absorption of the skin tissue, while the alternating current component, which is the current used for signal generation, is directly attributable to the variation in blood volume in the skin.

The photoplethysmographic sensors can detect premature ventricular contractions (PVC) more easily compared to regular EKGs. A premature ventricular contraction (PVC) is an extra, unusual heartbeat that starts in one of the heart's two lower pumping chambers. Ventricular tachycardia and ventricular fibrillation can also be detected with this photoplethysmographic sensors. Typical electrocardiogram monitors, do not use an exchange of alternating and direct current, whereas photoplethysmographic sensors do. This exchange of current gives an accurate signal of PVC, which, if not detected and resolved, could lead to serious health issues, such as tachycardia. PVC is a common heart health issue; unfortunately, the majority of the medical community does not know of the advantages photoplesmography has on detecting heart problems.

Method

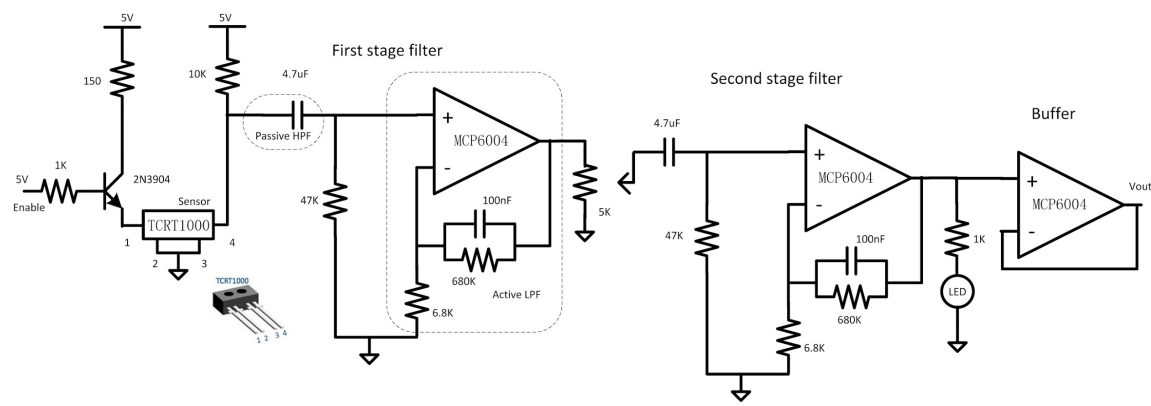
Using the photoplethysmographic sensors, the monitor will determine a person's heart-rate and display this information on a computer in the form of a sinusoidal graph. In order to create this display, a printed circuit board had to be designed and ordered to operate the sensors. A software program called Eagle was used to design the circuit board. After importing a virtual library of all the separate components onto the Eagle software interface, each component was added to the schematic and placed in the layout shown in the picture below.





Using the rotation tool, each component was turned in the direction that was requested. In order to connect each of the components, the green wiring tool was used that represents actual wiring on the circuit board. This tool is used to connect the separate ports of each component to the desired port of another component. For example, the third connection port of the JP2 sensor was connected to the R1 resistor. The mentor for this project, Mr. Habib, created a basic layout that was used as a reference to create the schematic.

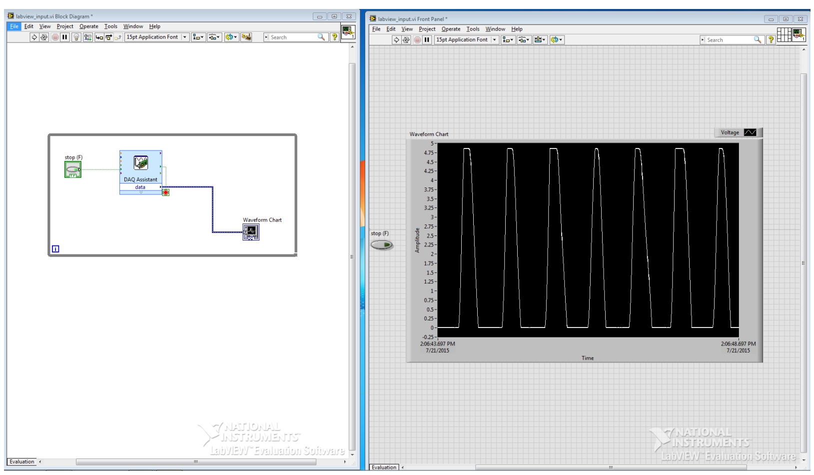
Eagle has a board function that automatically transfers a schematic design into a board design. Once it is transferred into a board design, the dragging tool is used to move the components onto



the rectangular section that represents the board. A function called “Ratsnest” automatically rewires the design in order to clean up the look and make the board more efficient. Every time a piece was moved “ratsnest” enabled easy wire transfers. Luckily, Eagle has a automatic routing function that saves valuable time so that manual routing is not necessary. After automatically routing the board design, the board was ready for production. Mr. Habib sent the design to a production company and it was manufactured and sent back in approximately one week.

While the printed circuit board was being manufactured, a LabView program was created in order to view heart-rate on a computer and see a sinusoidal graph of the data. The program was fairly simple and only require minimal research. A waveform graph was inserted onto the Front Panel of LabView and consequentially appeared on the Block Diagram. A DAQ Assistant was then inserted onto the Block Diagram as a representation of the MyDAQ that was connected to the USB port on the computer. A stop button was added in order to stop and start running the program. The entire LabView Block Diagram was then enclosed in a While Loop function so that the program will continually collect data until it is stopped. Below is a picture of the final LabView program.

Once the circuit board arrived from the production company, the separate components had to be soldered onto each specifically labeled spot. Each of the different resistors and capacitors were in different labeled bags, but they were also labeled with different colors. The colors are standardized so that, if they are misplaced, they can be easily recognized. The following materials were needed to solder on the parts: soldering iron, solder, a sponge, pliers,



and cutters. Each of the components had two long wires coming from each side. So, the pliers were used to bend down the wires so that they were parallel. The two wires were then slid through the appropriate holes in the circuit board. Once the wires were set in the holes, solder had to be placed around the wire connecting it to the board. Only a tiny amount of solder was necessary and it normally just formed a small blob around the wire. The difficult part of soldering on the components was that, once the board was turned over to solder on the wires, the component began to fall through the other side. One person would hold down the component with their fingers while another person soldered. However, this method did not work because the component got very hot from the soldering iron. So to fix this problem, pliers were utilized to hold on the component instead of fingers. The wires were very good conductors of heat and thus became very hot and burnt skin.

After the circuit board was completed and all the components were soldered on, it was tested on an instrument called an oscilloscope. An oscilloscope is a testing device used to determine varying voltages on a two-dimensional plot as a function of time. The graph for this project that displayed on the oscilloscope was set for a sinusoidal wave. After connecting the sensor to the board and connecting the board to the oscilloscope, the board was then attached to a waveform or function generator. The waveform or function generator provides a power supply or voltage to the printed circuit board. The waveform generator was set to output from zero to five volts because that range contains typical digital output values. With the waveform generator, oscilloscope, and photoplethysmographic sensor wired to the circuit board, the program was tested for any faulty parts on the board. Unfortunately the first test was unsuccessful, and thus additional research had to be performed to determine which component of the board was not working properly. Using a multimeter set to pick up voltage frequencies, the board was attached to the waveform generator but disconnected to the oscilloscope. By placing the wires from the multimeter onto each of the separate capacitors, resistors, and LED on the circuit board, a change in voltage from the wires connecting a capacitor to the LED proved that the LED was not functioning properly. After removing the solder and the LED, a brand new LED was soldered onto the board. The board was then reconnected to the oscilloscope, sensor, and waveform generator in order to test the new LED. After the second test run, the circuit board was working correctly and a sinusoidal graph appeared on the oscilloscope.

The next step was to test out the circuit board using the LabView program. However, a MyDAQ was needed so that the circuit board could link to the computer. National Instruments' MyDAQ is a low-cost data acquisition(DAQ) that has eight different input, output, and ground ports for inserting wires that allows the computer to become an engineering instrument itself. The MyDAQ connects the wires from the circuit board to the USB on a computer. The MyDAQ has different screws that hold the wires in place. Once the wires from the circuit board were linked to the MyDAQ, which was connected to the computer, and the waveform generator, the LabView program could finally start running. By placing the sensor between the index finger and thumb, the photoplethysmographic sensor can detect changes in blood volume and thus can send this information to the LabView program to produce a graph. The LED on the circuit board lights up each time that it detects a heartbeat. The LabView program displays a waveform graph that varies depending on different heart rhythms. The program successfully projected the the heart-rate in the form of a sinusoidal graph. The LabView program can record the data for long-term monitoring, but can also just be used as an instantaneous monitor. Long-term storage could be very beneficial for those who want to monitor their heart-rate overnight or want to send recorded data to their physician.

Results

Since this was just a manufacturing project rather than a data acquiring project, the only data that we actually received is that the system works and is successfully producing a graph of a person's heart-rate. After testing it on three different people, the changes became clear when one person's heart-rate was higher than the other person's heart-rate.

Discussion

Fortunately this project has several benefits including low cost and accessibility. It can monitor long term as well as short term changes in heart-beat, rhythm, pattern and pulse. Current EKGs can cost hundreds of dollars whereas the photoplethysmographic based heart-rate monitoring systems only cost around ten dollars. This will be beneficial for doctors to help save the hospital and patients money rather than getting a full EKG. Since it is so cheap and easy to operate, it could be accessible to all. Although as of right now either LabView and a MyDAQ or an oscilloscope are required to operate the circuit board, hopefully in the future and with further research the monitor can become sleeker and more compact to where these items are not necessary for operation.

Conclusion

In 2010, Qualcomm Inc. established the first patent on a very basic form of a photoplethysmogram. However, there is still plenty of reach that is still needed to be done in order to improve design and applications. The need for a DAQ, for example, is not readily available to most people. Hopefully with time, the photoplethysmographic based heart-rate systems will become more portable and convenient for at home use. Our device has many advantages over an EKG which will make it more suitable for certain situations. With the growing support from the medical community, photoplethysmography based heart-rate sensors will have a higher acceptance once it is developed to accommodate to residential settings.

Acknowledgements

This work made use of Engineering Research Center shared facilities supported by the Engineering Research Center Program of the National Science Foundation and the Department of Energy under NSF Award Number EEC-1041877 and the CURENT Industry Partnership Program. This project would not have been possible if it was not for the mentor, Mr. Habib,

Dr. McFarlane, Mr. Erin Wills, and Dr. Chien Fei Chen. Thank you for the support and teaching.

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