

ECG Monitoring System

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ABSTRACT

Considering that your heart is one of the most, if not the most, important muscle in your body, it is imperative that it remains strong and healthy. That said, having a good heart rate is an essential way to know how the heart is currently doing, as well as know when to take measures to fix it. In addition, it helps to know your resting heart rate. In other words, it is the rate at which your heart beats when your body is at rest, is ideal to monitor from time to time, so as to make sure that you remain alive and well. Heart rate is a useful indicator of the intensity of effort and body's physiological adaptation. When it comes to your heart rate, it's a bit like the speed of your car. What you want is not too fast, not too slow, and not too erratic. In fact, most of the time, heart rhythm and pace are not things you need to think about. And unless something unusual is going on, you're likely completely unaware of what your heart is doing. Heart rate is important because the heart's function is so important. The heart circulates oxygen and nutrient-rich blood throughout the body. When it's not working properly, just about everything is affected. Heart rate is central to this process because the function of the heart (called "cardiac output") is directly related to heart rate and stroke volume (the amount of blood pumped out with each beat).

KEYWORDS

Heartrate, IoT application, Raspberrypi, ECG, EKG

1. Introduction

Electrocardiography is the process of producing an electrocardiogram (ECG or EKG[a]). It is a graph of voltage versus time of the electrical activity of the heart[4] using electrodes placed on the skin. These electrodes detect the small electrical changes that are a consequence of cardiac muscle depolarization followed by re-polarization during each cardiac cycle (heartbeat). Changes in the normal ECG pattern occur in numerous cardiac abnormalities, including cardiac rhythm disturbances (such as atrial fibrillation and ventricular tachycardia), inadequate coronary artery blood flow (such as myocardial ischemia and myocardial infarction), and electrolyte disturbances (such as hypoglycemia and hyperglycemia). In a conventional 12-lead ECG, ten electrodes are placed on the patient's limbs and on the surface of the chest.

The overall magnitude of the heart's electrical potential is then measured from twelve different angles ("leads") and is recorded over a period of time (usually ten seconds). In this way, the overall magnitude and direction of the heart's electrical depolarization is captured at each moment throughout the cardiac cycle.[5] There are three main components to an ECG: the P wave, which represents the depolarization of the atria; the QRS complex, which represents the depolarization of the ventricles; and the T wave, which represents the re-polarization of the ventricles.[6] During each heartbeat, a healthy heart has an orderly progression of depolarization that starts with pacemaker cells in the sinoatrial node, spreads throughout the atrium, and passes through the atrioventricular node down into the bundle of His and into the Purkinje fibers, spreading down and to the left throughout the ventricles.[6] This orderly pattern of depolarization gives rise to the characteristic ECG tracing. To the trained clinician, an ECG conveys a large amount of information about the structure of the heart and the function of its electrical conduction system.[7] Among other things, an ECG can be used to measure the rate and rhythm of heartbeats, the size and position of the heart chambers, the presence of any damage to the heart's muscle cells or conduction system, the effects of heart drugs, and the function of implanted pacemakers.[8]

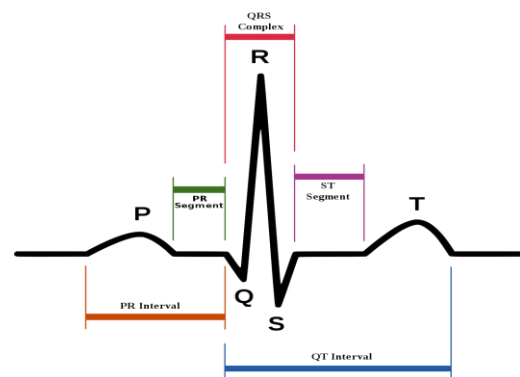


Figure 1: ECG of heart in normal sinus rhythm

2. Design

2.1 Raspberry Pi 3 B+

The Raspberry Pi is a portable minicomputer. The Raspberry Pi model B+ has inbuilt wireless LAN 802.11n and Bluetooth 4.1. It has a RAM of 1GB which makes it ideal for faster calculations and real time implementation. The RasPi model B+ has 40 GPIO pins at its disposal, which allows for greater flexibility to extend the device for more sensors. The RasPi was booted with Raspbian OS operating system, which is stable open source. Scripting can be carried out using Python 3 supported by the Raspbian platform. ECG monitoring system is hardware dependent work, hence Serial Peripheral Interface bus and GPIO pins in RasPi are very useful. The RasPi is powered by 5V micro USB supply, to make the device portable we have used a standard power bank.

2.2 AD8232

AD8232 is a dedicated IC for signal conditioning of ECG signal. In order to achieve the best possible output we are using the AD8232 SparkFun Single Lead Heart Rate Monitor [10]. The evaluation board is mounted with AD8232 and resistors and capacitor. It is designed to filter, amplify ECG signals in the presence of noisy conditions, created by movement or electrode positioning. The board has 3.5mm jack for connecting sensor pad connection as shown in Fig1(C). The usage of 3.5mm jack reduces the interference of noise. The power supply to the evaluation board is 3.3V which is provided from the RasPi pin out. The output of the AD8232 is analog, whereas the RasPi reads only digital signal. Hence we use MCP3008 for analog to digital conversion.

2.3 MCP3008

MCP3008 is capable of taking 8 channels of input and converts it to 10-bit digital value. MCP3008 uses serial peripheral interface (SPI) bus to establish a synchronous serial communication between the master and slave. Here the RasPi is the master and MCP3008 is slave as the clock is being generated by the RasPi. The ADC/MCP3008 is capable of sending 75Ksps to 200Ksps based on the supply voltage. The rate at which these samples are read decides the sampling rate. The sampling rate is software programmed by reading after every sampling interval. The ADC is single supply operated and the voltage can be between 2.7V to 5.5V. The RasPi has a standard 3.3V supply, hence we use it to power the MCP3008 which is also used for AD8232 and Vref.

2.4 Interface of Components

In order to get a clear ECG signal, 3-electrode method is followed. The sensor pads were placed close to heart forming a right triangle [Fig. 2]. The sensor pads were connected to the tri-conductor sensor cable with the 3.5mm jack output connected to AD8232. We have developed our device with a three electrode system to have the optimum accuracy as well

as make it more user friendly compared to the 12-lead ECG. The analog output of the AD8232 is given to input of the Analog to Digital Converter (MCP3008). The SPI bus was used for serial communication between the MCP3008 and RasPi. The output of the AD8232 varies between 0-3.3V as per the data sheet, hence the reference voltage of ADC is set as 3.3V. The ECG output plotted on the RasPi after digitalisation using MCP3008 is shown in Fig 2(a)

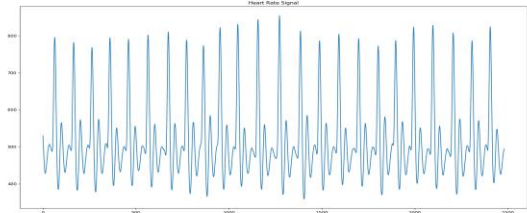


Figure 2(a): ECG signals as observed on RasPi

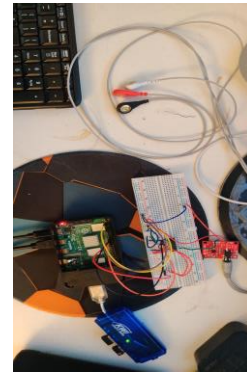


Figure 2(b): Portable ECG device



Figure 1: AD8232 with probes and MCP3008



Figure 2(d): Placement of three electrodes in a right angled triangle

3. Implementation

The electrodes are connected to patient and the AD8232 heart rate sensor senses the electrical activity of the heart and gives out analog readings at the output port of the sensor. The output port is then connected to channel 0 of MCP3008 ADC which gives this information to RaspPi. We have a python code which reads this signals and converts it to the corresponding heart rate. The signals given by AD8232 are processed every 5 sec and can be changed to the desired frequency.

Printing the ECG:

We have a separate script to read the readings of the mcp3008 and convert it to the ECG. These readings are stored in a separate array and the graph is plotted using pandas library

4. Evaluation

4.1 Detecting the first peaks

The first step is to find the position of all the R-peaks. To do this we need to determine Regions of Interest (ROI's), namely for each R-peak in the signal. After we have these, we need to determine their maxima.

4.2 Calculating heart rate

We know the position of each peak in time, so calculating the average 'beats per minute' (BPM) measure over this signal is straightforward. Just calculate the distance between the peaks, take the average and convert to a per minute value

5. Conclusion

In this work, we presented simple way to detect the heart rate using cost effective instruments. There were a lot of challenges faced by the team in order to make it work properly. The noise in the surrounding caused a lot of disturbances to the analog sensor and hence had to be taken in a closed room. There was also a instance where we had to replace the whole sensor as it had absorbed the moisture and the ground terminal did not work. In the future the peaks detected by this devices can be given as input

to the peak detection algorithms to detect different heart diseases like arrhythmia.

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