

Heart Irregularities Detection Based ECG Signals

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Abstract

ECG waveform plays vital role in providing the most information of the heart activity. This paper presents the design and implementation of an expert system for diagnosis of the heart abnormal activity. The proposed system consists of three parts; the first part includes the ECG waveform picking up and conditioning circuit. The second part performs waveform configuration, while the third part represents the core of the proposed diagnosis system which contains the algorithm that compares the acquired waveform with standard one. Any deviation in duration or amplitude from the standard will be detected by this algorithm and indicate heart abnormality. Experimental test has been performed for different waveforms and show promising results toward precise diagnosis of heart irregular activities.

Keywords: ECG Circuit; Arduino Uno; MATLAB.

Introduction

The heart function can be recorded as an electrical waveform which is called Electrocardiogram (ECG). ECG is a semi periodic repeating waveform that represent the heart function which acts as a source of bio events⁽¹⁾. The main feature of the recorded waveform is the amplitude-phase relationship therefore, any deviation from the standard amplitude-phase relationship can be indicated as a presence of an abnormality⁽¹⁾.

The primary pacemaker of the heart is cells group called “Sino-Atrial (SA node)”⁽¹⁾. SA is laying at the top of right atrium near the entry of the Vena Cava. The function of the SA node is to initiate the heart activity by generating impulses at the normal rate of the heart which is about 60-100 beat per minute for adult at rest. The impulses generated by SA contracts the atrial muscle and this impulse propagates through the atrial wall to the Atria-Ventricular (AV) node which is located at the lower part between the two atria. AV node ensures that

the ventricles contracted after the completion of the atria contraction. The standard ECG waveform is shown in Fig. 1.

The tie taken for an impulse to leave the SA node and reach ventricles is marked from the initial of the P wave to the beginning of the R or Q wave respectively. QRS is indicated by the pulse that transferred from the interventricular system to the Ventricles by passing through the free walls of Ventricles.

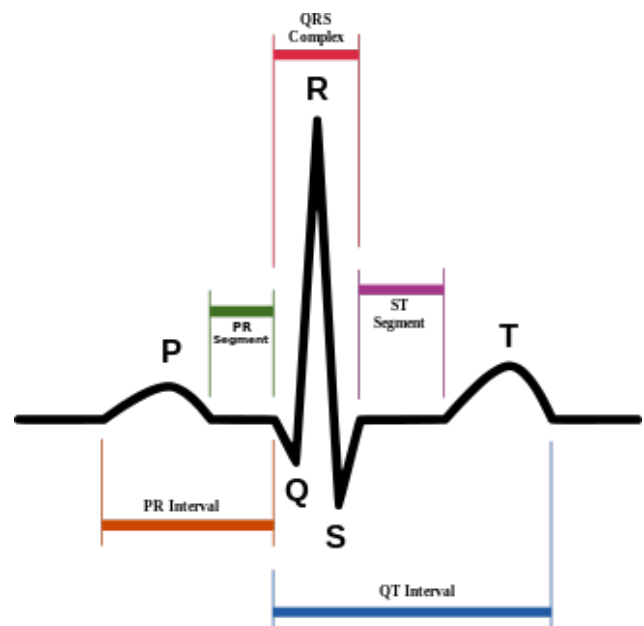


Fig. 1: A Typical ECG Signal

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Therefore, Ventricular contraction (systole) period is represented by one complete cycle and called QT wave. The time taken by the Ventricular diastole is represented by the period from the completed of T wave to the initial of the next Q wave⁽¹⁾. Table 1 shows the normal duration and amplitude for each part of ECG waveform.

Table 1: Normal ECG Parameters

Phase	Duration (Sec)	Amplitude (Volt)
Plus Wave	0.06-0.11	<0.25
PR Interval	0.12-0.20	-
PR Segment	0.08	-
QRS Complex	<0.12	0.8-1.2
ST Segment	0.12	-
QT Interval	0.36-0.44	-
T Wave	0.16	<0.5

Many researchers have been explored and propose different method for recording and analyzing ECG waveform⁽²⁾. Naazneen M. G, et. al.⁽²⁾ presents a simple 3-leads (ECG) monitoring and heart rate measurement system with LCD output. U. Pradhan and Naveen Kumar S.K⁽³⁾, suggest a circuit of a three leads ECG amplifier system which can achieve, amplifying and filtering the low amplitude, desired ECG signals. D. K. Ojha and M. Subashini⁽⁴⁾, propose a method of converting (ECG) information from paper charts into digital ECG signals using MATLAB. P. R. K. Shrivastava et. al.⁽⁵⁾ present an analysis of (ECG) waveform to detect abnormalities present regarding P and QRS complex peaks. M. K. Islam et. al.⁽⁶⁾ propose a study and analysis of ECG based on signal processing by means of MATLAB tools.

H.Gholam-Hosseini and H.Nazeran⁽⁷⁾ show a set of techniques that efficiently extract important features from the ECG data which used in automatic cardiac arrhythmia.

A. T. Rao et. al.⁽⁸⁾, suggest remote monitoring of the patients’ ECG signal and heart beat anywhere and anytime using wireless sensor network based on ZigBee modules and Arduino Uno board to process the data information.

In this paper, the circuit which is measures the ECG signal has been designed. The resulted analog ECG signal is configured and transformed to digital form via Arduino the fed to the pc through USB port. Analysis and detection of the heart irregularities is accomplished by a MATLAB program based on the data received from Arduino to detect the heart irregularities. This paper is organized as follows:

Section II presents the proposed system structure, details design of the pick-up and conditioning stage has been explained in section III. Section IV explain how to use the Arduino – uno to configure the preprocessed ECG waveform before transmit it to the diagnosis stage. An algorithm of diagnosis process is illustrated in section V, simulation results was presented in the conclusion.

Proposed Diagnosis System: Fig. 2 shows the structure of the block diagram of system which consist of three main stages, these are;

- Pick up and conditioning stage.
- Configuration stage.
- Diagnosis stage.

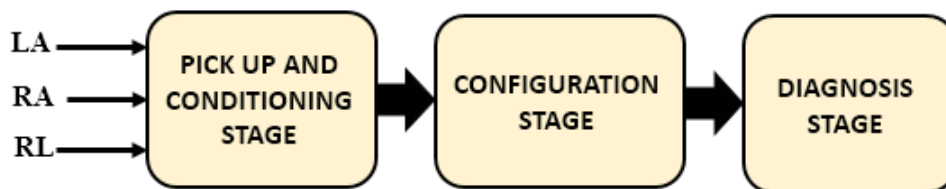


Fig. 2: Basic Block diagram of diagnosis system.

Pick Up and Conditioning Stage: As its name, the job of this stage is firstly picking up the ECG waveform by using 3-leads which are fixed on the left arm (LA), right arm (RA) and right leg (RL)

Since the picked waveform is very small in its amplitude, therefore, the main challenge of this stage includes amplifying the desired weak signal in the presence of noise from other muscles and electrical source.

The constraint in designing this stage is to satisfy the following requirements:

- The ECG waveform should not be influenced in any way by this stage.
- The measured ECG waveform should not be distorted.
- This stage should provide a separation of ECG and interference as best as possible.
- The stage protection of patient and device from electrical shock.

According to the above requirements, the design of this stage concerned with filtering and amplifying.

The required bandwidth for ECG signal(0.5Hz-30Hz) for normal heart human, so the bandwidth of the circuit has been chosen to be within this rang. Also, the gain should be enough to make the signal observable however, it should not be large enough to saturate the devices, so that no false peak should occur. Fig. 3 shows diagram of ECG circuit which is implemented using multisim 10.1 with ECG electrode to simulates the real-time ECG waveform.

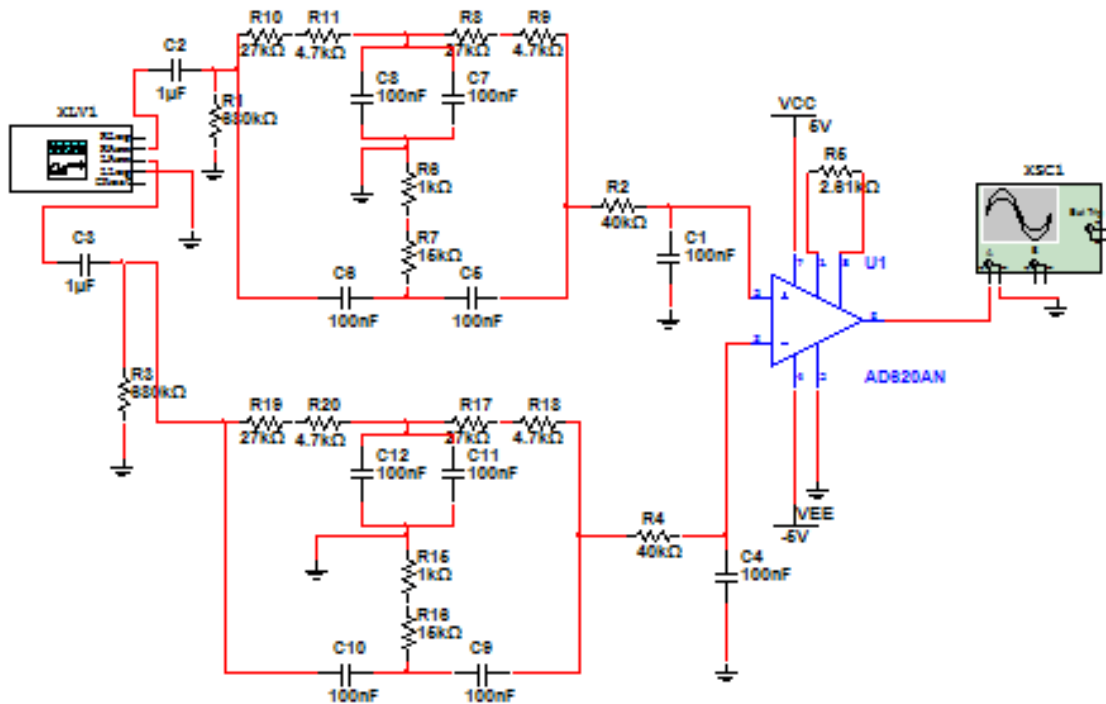


Fig. 3: Schematic of ECG Circuit

The ECG circuit consists of:

High Pass Filter: This filter used to eliminate an effect of the dc-offset caused by the dc bias on the surface of the patient’s body. The value of the cutoff frequency The RC passive filter was used. The value of the cutoff frequency (f_c) is 0.23Hz, where $f_c = 1/2\pi RC$.

Notch Filter: This block is used to eliminate an effect of power line interference which operates at 50Hz. we use proposed adaptive filtered algorithm to remove the power line noise⁽⁹⁾. Therefore, the cutoff frequency (f_c) is 50 Hz for notch filter.

Low Pass Filter: This filter used to eliminate an effect of EMG noise and frequencies higher than 40 Hz with any interference caused by sources. For this purpose, the RC passive filter was used. The value of the cutoff frequency (f_c) is 40Hz. Where

$$f_c = 1/2\pi RC.$$

Instrumentation Amplifier AD620: AD620 is a specific instrumentation amplifier used specially in bio-medical application because it has high CMRR (Common Mode Rejection Ratio) and low input noise amplifier. It well suited for medical applications, such as ECG and non-invasive blood pressure monitors.

Rg can be calculated by using the formula:

$$R_g = \frac{49.4k\Omega}{G-1}$$

Choose Rg is 2.61KΩ then the calculated gain is 19.93. Table 2 shows required values of Rg for different gains.

Table 2: values of Rg for various of AD620

1% std Table Value of R _g	Calculated Gain	0.1% std table value of R _g	Calculated gain
49.9 k	1.990	49.3 k	2.002
12.4 k	4.984	12.4 k	4.984
5.49 k	9.998	5.49 k	9.998
2.61 k	19.93	2.61 k	19.93
1.00 k	50.40	1.01 k	49.91
499	100.0	499	100.0
249	199.4	249	199.4
100	495.0	98.8	501.0
49.9	991.0	49.3	1003.0

Configuration Stage: The second stage of the proposed system is Arduino. The Arduino is described as “some open-source electronics prototyping platform based on flexible, easy to use of the hardware and software” (10). It can read analog input voltage (at input A0) and converts it to serial data, which is sent via the USB cable to display on the computer. The Code that used to communicate the USB/serial port the PC. The **Arduino Uno ADC** is of 10-bit resolution (so the integer values from (0-(2¹⁰ 1023)). This means that it will map input voltages between 0 and 5 volts into integer values between 0 and 1023. Therefore, for every (5/1024= 4.9mV) per unit. The Arduino would then calculate the patient’s heart rate by connected the output ECG circuit to analog input (pin A0) of Arduino board with baud rate 115200 bps, then Arduino device is connected to the USB port that continuously reads ADC data and sends it via the USB to MATLAB.

Diagnosis Stage: The main purpose of this stage is to extract the needed features from the acquired and pre-processed ECG signal. The extracted features which include amplitudes and intervals of QRS complex, PR intervals and ST intervals, will compared with the normal analogues features firstly, signal will have received from the configuration stage via USB port, the following codes is used for this purpose

```
Board=serial ('COM6', 'Baud Rate', 115200);
fopen (board);
v(x)=fscan(board,'%d');
```

The received signal will be processed using MATLAB software package which implements an algorithm that performs the extraction and diagnosis tasks per abnormal state illustrated in fig.4 .

- Sinus Tachycardia: if heart rate more than 100bpm.



Sinus Tachycardia

- Sinus Bradycardia: if heart rate less than 60bpm.

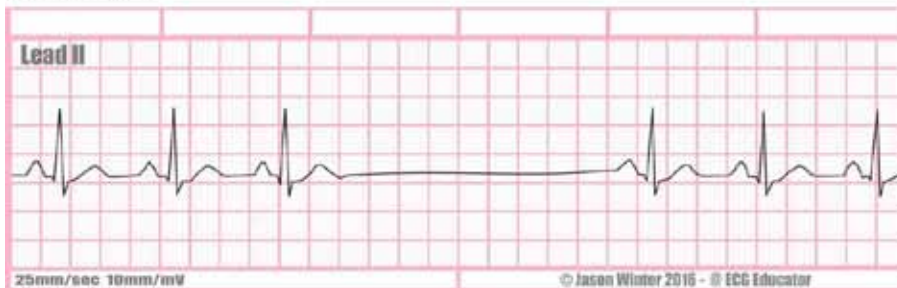
Sinus Bradycardia



Sinus Bradycardia

- Sinus Arrest: occurs when there is a sudden absence of electrical activity initiated by the SA node.

Sinus Arrest



Sinus Arrest

- Bundle Branch Block: can be diagnosed when the duration of the QRS complex on the ECG exceeds 0.12sec.



Bundle Branch Block

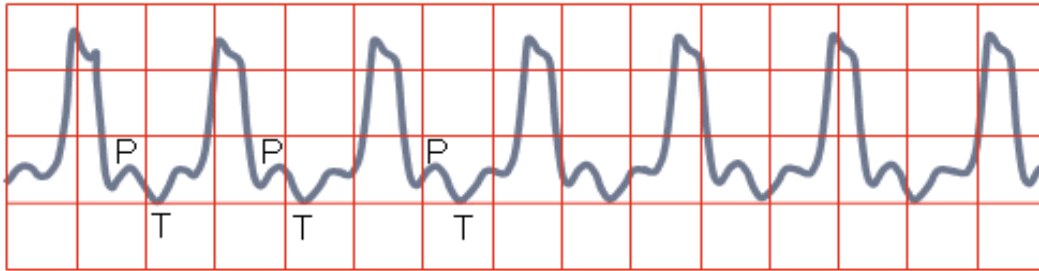
- Sinus Arrhythmia: occurring variation in heart rate that occurs during a cardiac cycle by measuring difference distance between R-R interval.

Sinus Arrhythmia



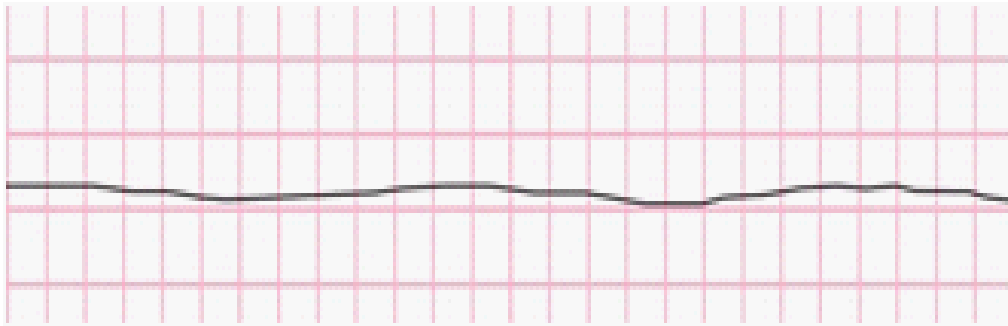
Sinus Arrhythmia

- Ventricular Tachycardia: causing rapid with heart rate >120 bpm and wide Ventricular QRS-complexes more than 0.12 sec.



Ventricular Tachycardia

- Asystole: no electrical activity from the heart and therefore no blood flow.



Asystole

Fig. 4: Abnormal state of ECG signal

The algorithm implemented in this paper focusses on the measurements of the time period between two successive R wave in order to extract the heart rate (normally 60 to 100 bpm for an adult), also it's calculates the QRS duration and amplitudes. The following procedure is considered to perform the diagnosis task:

1. Remove low frequency components as follow:

- Transform the signal to frequency domain using fft.
- Remove low frequency components.
- Back to time domain using ifft.

2. Find local maxima using windowed filter.

3. Remove small values, store significant ones.

Results

The ECG signal send to MATLAB via USB cable associated with the Arduino Uno where MATLAB in the reception of data on digital format in real time,

MATLAB starts to Remove low frequency components and detection of R- peaks then diagnosis some of heart disaes for ECG signal. In MATLAB code was taken waves of 2 or above in order to avoid the person movement at the beginning of measurement signal.

MATLAB show the results to diagnosis of heart irregular activities.

Conclusion

A diagnosis system has been designed and implemented to acquire the ECG signal. Preprocessing of ECG is performed in the designed analog circuit which consists of instrument amplifier and filters for amplifying ECG and removing different types of noise from it. Arduino has been used as a mediator which converts the analog signal into a digital form and then sent to the computer via USB port. An algorithm for R Peak and QRS complex detection using MATLAB software package has been proposed. Extraction of the R Peak and QRS complex obtained and used to compare

with the normal waves. Four types of heart abnormality are detected by using this proposed system.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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References

1. R. S. Khandpur, "Handbook of Biomedical Instrumentation", Tata McGraw-Hill publishing Company Limited, New Delhi 2005.
2. Naazneen M. G., S. Fathima, S. H. Mohammadi, Sarah Iram L. Indikar, A. Saleem, M. Jebran "Design and Implementation of ECG Monitoring and Heart Rate Measurement System," International Journal of Engineering Science and Innovative Technology (IJESIT), ISSN: 2319-5967, ISO 9001:2008 Certified, Volume 2, Issue 3, May 2013.
3. U. Pradhan, Naveen Kumar S.K, "Design of a Three Lead ECG Amplifier System," International Journal of Advanced Research in Computer Science and Software Engineering, 2015; 5, 12, 77-80.
4. D. K. Ojha, M. Subashini, "Analysis of Electrocardiograph (ECG) Signal for the Detection of Abnormalities Using MATLAB," International Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering 2014;8, 120-123
5. Ravichandran L, Harless C, Shah AJ, Wick CA, McClellan JH, Tridandapani S. Novel Tool for Complete Digitization of Paper Electrocardiography Data. *IEEE J TranslEng Health Med.* 2013;1:1800107. doi:10.1109/JTEHM.2013.2262024
6. M. K. Islam, A. N. M. M. Haque, G. Tangim, T. Ahammad and M. R. H. Khondokar "Study and Analysis of ECG Signal Using MATLAB & LABVIEW as Effective Tools," International Journal of Computer and Electrical Engineering, 2012: 4: (3), 404-408
7. H.Gholam-Hosseini and H.Nazeran "Detection and Extraction of the ECG Signal Parameters," Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Vol. 20, No 1,1998.
8. T. Rao, M.Gopi, M.VS.Prasad "Real Time ECG Signal Transmission for Remote Monitoring," International journal of engineering development and research (IJEDR), 2014: 2: 348-354
9. Levkov, C., Mihov, G., Ivanov, R. et al. Removal of power-line interference from the ECG: a review of the subtraction procedure. *BioMedEngOnLine* (2005). 4, 50 <https://doi.org/10.1186/1475-925X-4-50>
10. Massimo Banzi, David Cuartielles, Tom Igoe and GianlucaMartinoand David Mellis. *The Arduino.* <http://www.arduino.cc/>, February 2011.