Mathematical Statistician and Engineering Applications
ISSN: 2094-0343
2326-9865

Designing of Portable Long Duration HRV Recorder

R. Krishna kumar[1], Dr. A. Kingsly Jabakumar[2], S. Syed Althaf[3], J. Saranraj[4], T. Arun[5], U.Rujeyanthi[6]

[1]AssistantProfessor, Department of Biomedical Engineering, KPR Institute of Engineering and Technology, Coimbatore,

[2]Assistant Professor, Electronics and Communication Engineering, Christ the King Engineering College, Coimbatore.

[3]Assistant Professor, Biomedical Engineering, Dhaanish Ahmed Institute of Technology, Coimbatore

[4]Assistant Professor, Electronics and Communication Engineering, Christ the King Engineering College, Coimbatore

[5]Assistant Professor, Electronics and Communication Engineering, Christ the King Engineering College, Coimbatore

[6]Assistant Professor, Biomedical Engineering, P.S.R.Engineering College, Sivakasi.

krishravi1994@gmail.com, kingslyjkumar@gmail.com, syedalthaf10495@gmail.com, er.saranraj89@gmail.com, arunmails@ymail.com, rujeyanthi@psr.edu.in

Article Info

Page Number: 8208 - 8219

Publication Issue:

Vol 71 No. 4 (2022)

Abstract

In the modern health scenario, prevention of disease is emphasized much rather than post-treatments. Certain life-threatening diseases like Cardiovascular disorders can be avoided, if found earlier. ECG is used to assess the heart rhythm, through which abnormalities such as poor electrical conduction and chest enlargement can be detected. The ECG waveform provides information about the heart rhythm and blood flow throughout the body. The electrodes used in ECG device can produce normal or abnormal waveform pattern. From the abnormal patterns, various heart diseases such asbachycardia, tachycardia, stroke syncope, premature contractions etc. can be diagnosed. The long duration ECG records the ECG signal of the patient continuously throughout the day, which can be stored and examined laterby the physician. In this work, recording of ECG was carried out using surface electrodes, which were connected with the instrumentation amplifier AD624, followed by the filter circuit. The obtained ECG signal is then given to ATMEGA 328p

Article History
***Article Received**: 15 September 2022*
***Revised**: 25 October 2022*
***Accepted**: 14 November 2022*
***Publication**: 21 December 2022*

Arduino, which can be used to measure heart rate. The storage of the heart rate data can be done with the help of an SD card by interfacing Arduino board with SD card module.

Keywords: ECG, Arduino, ATMEGA 328p, Heart rhythm

1. Introduction:

1.1 Action Potential:

Human body is composed of living tissue generating various electrical signals with two internal sources such as nerves and muscles. Bioelectric potentials are generated at the cellular level and the source of these potential are ionic in nature. The cell consists of three ions, Sodium, Potassium and chlorine, which can move inside and outside of the cell creates potential. The chlorine and potassium ions can easily penetrate the cell, whereas the sodium ions are blocked by the cell. Both the sodium and potassium ions are positive ions. The number of sodium ions inside the cell is lower than outside the cell. Hence, charge imbalance at the intercellular fluid occurs, To balance the equilibrium, the potassium ions mobilize through the cell, which creates more positive charge inside the cell rather than outside, whereas the equilibrium is reached casing a potential difference across the membrane leaving, negative charge at inside the cell and positive at outside. This state is called as Resting membrane potential. The cell in such a condition is said to be polarized. When the cell is excited, the outer side of the cell membrane becomes momentarily negative with respect to the interior. This process is called depolarization. Repolarization then takes place a short time later when the cell regains its normal state. The various stages of depolarization and repolarization is shown in figure1.1

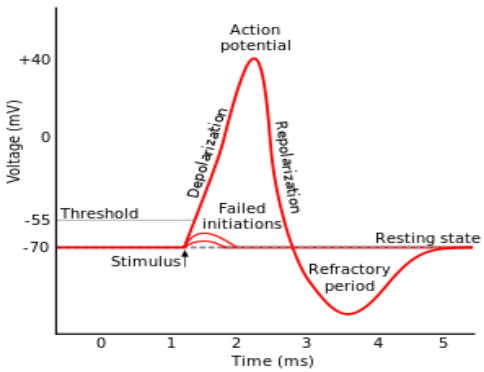


Fig 1.1 Bio-electric potential of a cell[11]

Initially, the cell is in relaxed and polarized state. Due to a stimulus, it is then depolarized. After sometime, cell again attains relaxed state. Hence, this is the potential of the cell, with the help of which all the bio-signals including cardiac signal is obtained.

1.2 Introduction to ECG:

The ECG or EKG is Electrocardiograph is a device, which displays electrical activity of the human body and produces waveform corresponds to the changes in electrical activity of the heart. The graph or output waveform obtained from ECG is Electrocardiogram. The Electrocardiogram consists of P, Q, R, S and T waves. The P wave, which denotes the contraction of atria is the first wave, associated with the ECG. The atrial contraction is reflected in the P wave and any abnormality in P wave indicated the issues in atrial contraction. The voltage of P wave is about 0.1mV. The P wave is followed by QRS complex. The atrial relaxation and ventricular contraction is associated with QRS complex. The QRS complex reaches to maximum of 1.6mV. The heart rate can be detected by measuring the potential between R-R intervals of two ECG waves. The T wave is characterized by ventricular relaxation.

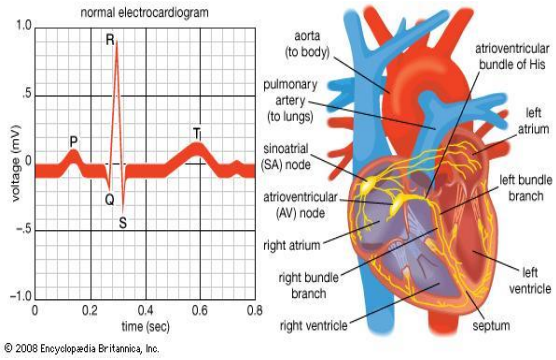


Fig 1.2 Electrocardiograph[12]

The conventional ECG machine has the capacity to store ECG to store the data for a maximum of 10 to 15 minutes. Also, continuous monitoring of ECG needs the patient to get admitted in Hospital. With the scarcity of beds and number of ECG devices in the hospitals, it would be better, if continuous monitoring of ECG signal can be transferred to home-care.This can be achieved by using a recorder for long duration storage of ECG signal and the data may be retrieved at any time by the physician or care-taker. Ttheproposed ECG recorder should be a portable one for ease of use. the simple portable ECG machine is demonstrated in figure 1.3

Fig 1.3 Portable ECG Recorder[13]

2. PROPOSED METHODOLOGY

Block diagram of ECG signal Acquisition was presented, which consists of a Pre-amplifier, a filter, an amplifier. The electrode, through which ECG is acquired are connected to pre-amplifier circuit. The output can be seen in DSO

2.1 Block diagram:

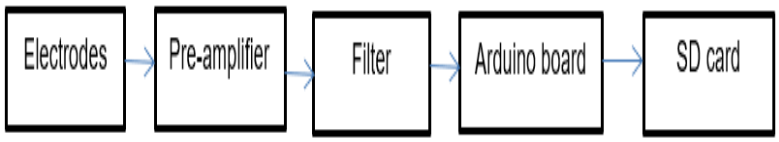


Fig 3.1 Block diagram of the proposed ECG acquisition system

The block diagram of the proposed device consists of a pre-amplifier circuit, where the ECG signal obtained by the clip electrodes are fed into. the ECG signal has low potential to process it in the device, hence a pre-amplifier circuit is necessary, where the obtained low potential ECG signal will be amplified and used for further processing and display. the noise in the raw ECG signal will get amplified along with ECG signal, which must be filtered for better diagnosis.

2.2 QRS complex detection Algorithm

After acquiring ECG signal and detecting QRS peaks with clinical accuracy, the signal will be given as input to a microcontroller (Arduino). Using the microcontroller, HRV will be recorded and stored in SD card for future application. The whole system will be then converted into a portable standalone HRV recording system.

Low frequency noise suppression

$h(t)= x(t) - [max*(t) + min*(t)]/ 2\ldots$ (1)

Where, $max*(t) = x(t)$ if $t= 0$

$= max*(t- 1) +s*d$ if $x(t) > max*(t - 1)$

$= max*(t- 1) - d$ if $x(t) \leq max*(t - 1)$

$min*(t) =x(t)$ if $t= 0$

$= min*(t- 1) - s*d$ if $x(t) < min*(t - 1)$

$= min*(t- 1) +d$ if $x(t) \geq min*(t - 1)$[1], s=sigma, d=delta,

x(t) be the discrete time function of thedigitized ECG input signal,

h(t) be the filter output.

High frequency noise suppression

$a(t)=max*(t)-min*(t)$ …….. (2)

Moving window integration

$y(n)= (1/N) [(x(n) – (N-1)T) + (x(n) – (N-2)T) +\ldots+x(n)]\ldots\ldots\ldots\ldots\ldots\ldots$ (3)

Thresholding

$T=\alpha\times\gamma\times PEAK+(1-\alpha)\times T\ldots\ldots\ldots\ldots$ (4)

whereα is forgetting factor, $0 <\alpha< 1$

γ is weighing factor and it can be between 0.15 to 0.2

3. HARDWARE DESCRIPTION

3.1.1Electrode placement:

By convention, lead I has the positive electrode on the left arm, and the negative electrode on the right arm, and therefore measures the potential difference between the two arms. An electrode on the right leg serves as a reference electrode for recording purposes. In the lead II configuration, the positive electrode is on the left leg and negative on the right arm. Lead III has the positive electrode on the left leg and the negative on the left arm. These three bipolar limbslead roughly form an equilateral triangle. We have used lead-I configuration.

3.1.2 ECG acquisition circuit:

A preamplifier (preamp) is an electronic amplifier that prepares a small electrical signal for further amplification or processing. A preamplifier is often placed close to the sensor to reduce the effects of noise and interference. It is used to boost the signal strength to drive the cable to the main instrument without significantly degrading the signal-to-noise ratio (SNR). The noise performance

of a preamplifier is critical. According to Friis's formula, when the gain of the preamplifier is high, the SNR of the final signal is determined by the SNR of the input signal and the noise figure of the preamplifier.

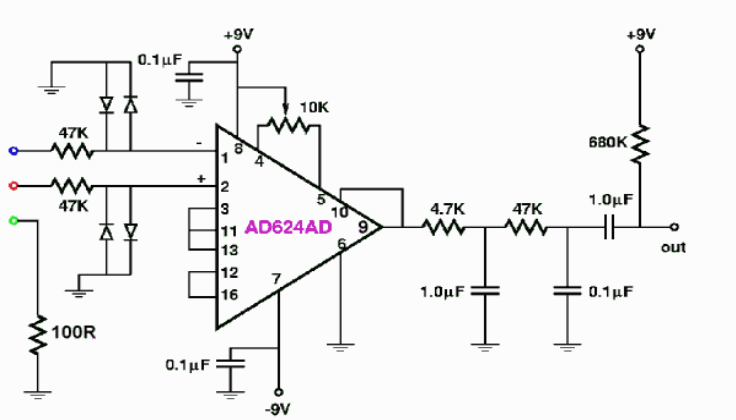


Fig 4.1 ECG Acquisition Circuit

3.1.2 AD624 Instrumentation amplifier:

The AD624 is a high precision, low noise, instrumentation amplifier designed primarily for use with low level transducers, including load cells, strain gauges and pressure transducers. A combination of low noise, high gain accuracy, low gain temperature coefficient and high linearity make the AD624 ideal for use in high resolution data acquisition systems. The pin diagram of IC AD624 is shown in figure 4.2

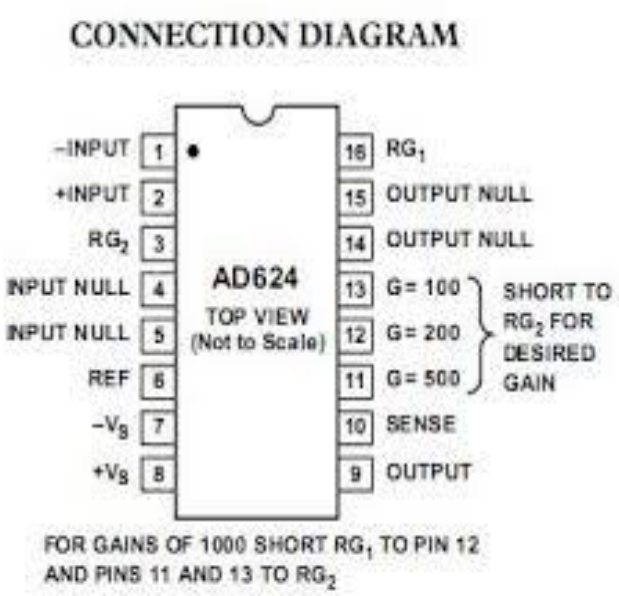


Fig 4.2 pin diagram of AD624[14]

3.2 Arduino board:

Arduino is a software company, project, and user community that designs and manufactures computer open-source hardware, open-source software, and microcontroller-based kits for building digital devices and interactive objects that can sense and control physical devices.[1]

These systems provide sets of digital and analog I/O pins that can interface to various expansion boards (termed shields) and other circuits. The boards feature serial communication interfaces, including Universal Serial Bus (USB) on some models, for loading programs from personal computers. For programming the microcontrollers, the Arduino project provides an integrated development environment(IDE) based on a programming language named Processing, which also supports the languages C and C++. The commercial arduino board is shown in figure 4.3

Fig 4.3 Arduino board[15]

3.2.1. ATMEGA 328p Arduino:

The Atmel 8-bit AVR RISC-based microcontrollercombines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channelsin TQFP & QFN/MLF packages),programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts. The device achieves throughputs approaching 1 MIPS per Mhz[1]. Today the ATmega328 is commonly used in many projects and autonomous systems where a simple, low-powered, low-cost micro-controller is needed.

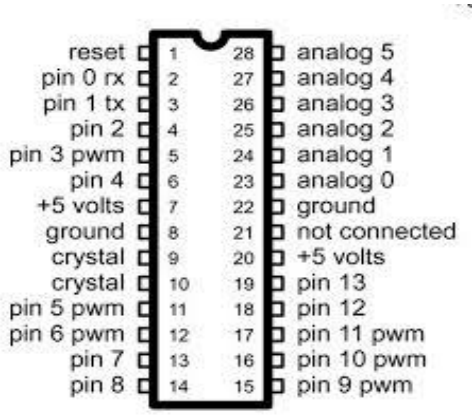


Fig 4.4 ATMEGA 328p Pin Configuration

3.3 SD CARD MODULE:

The Arduino SD Card Shield is a simple solution for transferring data to and from a standard SD card. The pinout is directly compatible with Arduino, but can also be used with other microcontrollers. It allows you to add mass storage and data logging to your project. Its features are:

1. Break out board for standard SD card.
2. Contains a switch to select the flash card slot
3. Sits directly on a Arduino
4. Also be used with other microcontrollers

Secure Digital (SD) is a non-volatile memory card format developed by the SD Card Association (SDA) for use in portable devices. The second-generation Secure Digital (SDSC or Secure Digital Standard Capacity) card was developed to improve on the Multi Media Card (MMC) standard, which continued to evolve, but in a different direction. Mini- and micro-card. The figure 4.6 shown below presents the SD card module used for SD card storage of data which is to be interfaced with Arduino board.

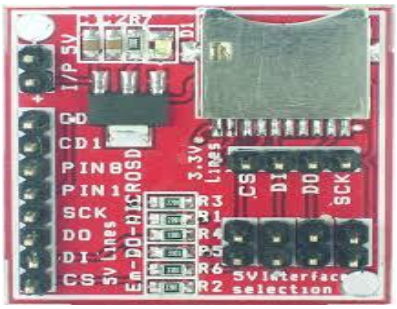


Fig 4.6 SD card module[16]

4. SOFTWARE DEVELOPMENT

A precise method of determining heart rate involves the use of an electrocardiograph, or ECG (also abbreviated EKG). An ECG generates a pattern based on electrical activity of the heart, which closely follows heart function. Continuous ECG monitoring is routinely done in many clinical settings, especially in critical care medicine. On the ECG, instantaneous heart rate is calculated using the R wave-to-R wave (RR) interval and multiplying/dividing in order to derive heart rate in heartbeats/min.

Five_pusle_time=time2-time1

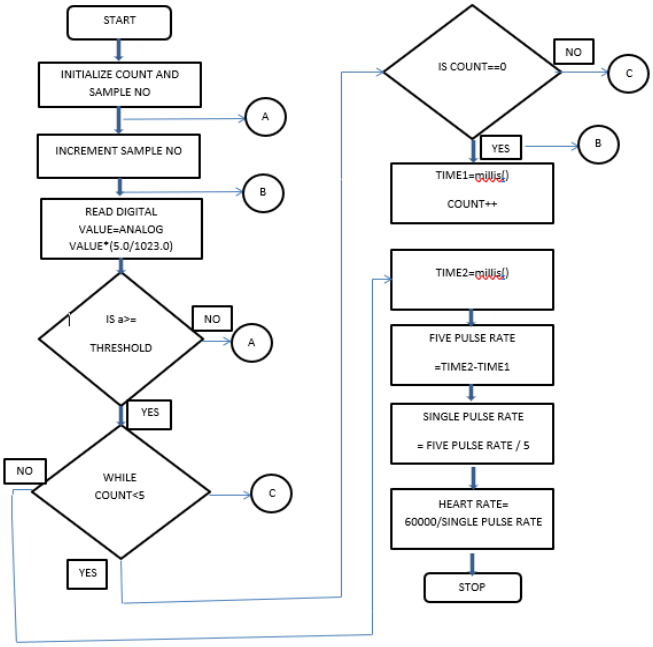
Single_pulse_time= Five_pusle_time /5;

rate=60000/ Single_pulse_time;

where, time1 is first pulse counter value

time2 is list pulse counter value

rate is final heart rate.



5. RESULTS AND DISCUSSION

The output ECG signal from the ECG acquisition circuit using an Instrumentation amplifier-AD 624 was viewed through DSO. This chapter presents the results of the proposed work.

Initially, the electrodes are connected to the pre-amplifier circuit as per the norms. After, preprocessing by the instrumentation amplifier-AD624, the signal was then filtered and the noiseless ECG signal was seen in DSO as shown in the figure 5.1

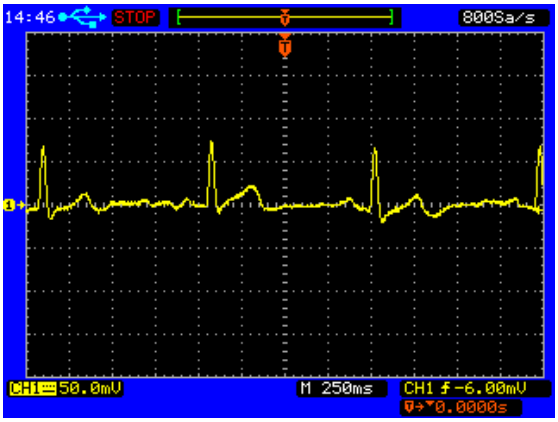


Fig 5.1 ECG waveform seen in DSO

5.2 Heart rate measured using Arduino:

The heart rate is measured from the ECG signal using the algorithm, presented in chapter 5. The obtained output is shown in figure 5.2

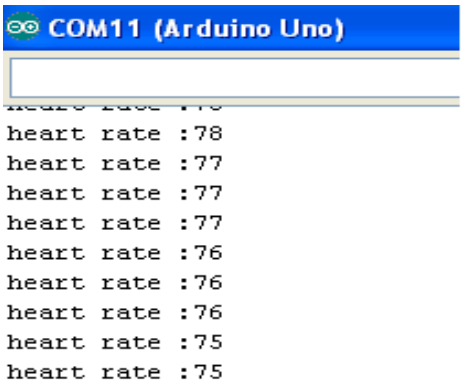


Fig 5.2 Heart rate obtained using Arduino

5.3 Heart rate recorded in SD card using Arduino:

The heart rate is measured from the ECG signal, is recorded in SD card for future reference. The output stored in SD card will be in the format (.CSV), when it is connected to a system, it can be viewed in excel sheet. The recorded or stored output is shown below.

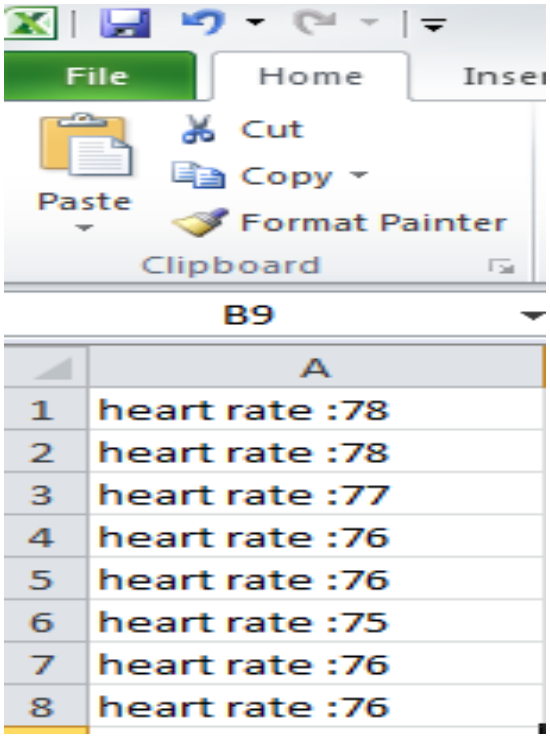


Fig 5.3 Heart rate recorded in SD card.

6. CONCLUSION AND FUTURE WORK

In this project work, an attempt was made to design a portable long duration HRV recorder. During phase I, the product and patent search was done. The literature survey was done to find research papers and articles relative to designing of ECG recorder and algorithm to extract QRS complex by various methods. The circuit for ECG acquisition was designed. The circuit is connected and the output is obtained project.

In phase II, the algorithm was developed to detect peak to peak interval so as to detect Heart Rate (HR) using Arduino-UNO. SD card module was interfaced with Arduino. The circuit was converted into a dot board and after burning the code in Arduino board and make it a Compatible, Portable device by connecting the circuit to a battery.

In future, this ECG recorder can be developed to Bio-signal recorder, which includes EMG, EEG signals etc.

Reference:

1. [David Castells-Rufas, Jordi Carrabina], [26 June 2015], "[Simple real-time QRS detector with the MaMeMi filter]," [Elsevier]

2. [Shreya Das, Dr. Monisha Chakraborty], [2012], "[QRS Detection Algorithm Using Savitzky-GolayFilter]," [ACEEE], Vol. [03], No.[01, Jan/ 2012]
3. [Manuel Merino∗, Isabel María Gómez, Alberto J. Molina], [23 March 2015], "[Envelopment filter and K-means for the detection of QRS waveforms in electrocardiogram]," [Elsevier]
4. [CHI Jian Nan, YAN Yan Tao, LIU Meng Chen, YANG Li],[10 OCT 2012], "[The Development of a Portable ECG Monitor Based on DSP]",[Elsevier]
5. [João Martinho, Luís Prates, João Costa] ,[10 OCT 2015], "[Design and Implementation of a Wireless Multiparameter Patient Monitoring System]", [Elsevier]
6. http://www.jatit.org/volumes/Vol62No3/4Vol62No3.pdf.
7. http://link.springer.com/chapter/10.1007%2F978-3-540-70994-7_22.
8. http://dl.acm.org/citation.cfm?id=1371604.1372238.
9. Khandpur R S., 1987, "Handbook of Biomedical Engineering," TataMcGraw-Hill., pp. 32-160"home is where ECG is" by Shawn Carlson
10. http://circuitdigest.com/microcontroller-projects/heartbeat-monitor-project-using-arduino.
11. https://en.wikibooks.org/wiki/File:Action_potential.svg
12. http://www.britannica.com/science/electrocardiography
13. https://www.dicardiology.com/content/blogs/real-time-vs-post-monitoring-review-approaches-holter-event-recording
14. http://www.ifuturetech.org/forums/topic/circuit-diagram-to-5v-dc-power-supply-to-microcontroller
15. http://www.embeddedmarket.com/products/Micro-SD-card-Interface-Breakout-5V-Logic-Level