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Real time ECG monitoring circuit and discharging circuit.

Shalaka Bose
Electronics and telecommunication Engineering
MET's Institute Of Engineering Nashik, India
shalakabose2001@gmail.com

Payal Pagere
Electronics and telecommunication Engineering
MET's Institute Of Engineering Nashik, India
payalpagere123@gmail.com

Omkar Sangpal
Electronics and telecommunication Engineering
MET's Institute Of Engineering Nashik, India
sangpal.omkar2811@gmail.com

Shridhar Subramaniam
Electronics and telecommunication Engineering
MET's Institute Of Engineering Nashik, India
shridharsubramaniam663@gmail.com

Abstract:

Real-time electrocardiogram (ECG) monitoring plays a vital role in the diagnosis and management of cardiovascular diseases. This abstract presents a novel design for an ECG monitoring and discharging circuit that enables continuous monitoring of a patient's heart activity and provides a safe and efficient mechanism for electrical discharge, if necessary.

The proposed circuit consists of three main components: ECG sensing, signal processing, and discharge control. The ECG sensing module incorporates high-precision electrodes to capture the electrical signals generated by the heart. These signals are then amplified, filtered, and digitized by the signal processing module to extract relevant information and eliminate noise interference.

The discharge control module is designed to assess the patient's condition based on the ECG data and trigger an electrical discharge, if required. This module includes a comprehensive algorithm that analyses the ECG waveform and detects critical events, such as arrhythmias or abnormal heart rhythms. Upon detection, the circuit initiates a controlled discharge process to restore normal cardiac function.

The proposed ECG monitoring and discharging circuit offers several advantages over traditional

systems. Its real-time capabilities provide continuous monitoring, enabling healthcare professionals to promptly identify and address cardiac abnormalities. The discharge control functionality enhances patient care by offering a reliable and efficient method for intervention in critical situations.

.***Keywords: ECG monitoring, Sudden Cardiac Arrest, Discharging Circuit, Pan-Tompkins***

I. INTRODUCTION

Amongst the most impending health challenges of modern society, the Sudden Cardiac Arrest (SCA) is probably one of the most deadly. SCA alone is responsible every year for over 300'000 deaths in the United States. As a mean of comparison, this number is greater than the combined number of those who die from Alzheimer's disease, assault with firearms, breast cancer, cervical cancer, colorectal cancer, diabetes, HIV, house fires, motor vehicle accidents, prostate cancer, and suicides. SCA is a condition in which the heart suddenly and unexpectedly stops beating in an ordered fash ion way, and instead start exhibiting a chaotic behaviour. When this happens, blood stops flowing to the brain and other vital organs. In these conditions the patient may be considered to all effects dead, and will remain so unless someone help him/her immediately. The most effective way to treat a SCA is with defibrillation, namely a therapeutic dose of electrical energy. The necessity of performing defibrillation as soon as possible -in order to significantly raise the chance of resuscitation has led to the development of Automated External Defibrillators (AED).

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LITERATURE SURVEY

In [1] Paulo Barbosa and Yang Medeiros describes Due to complex safety requirements, medical devices must obey rigorous standards. In the development of these devices, modeling techniques must be used to analyze the design decisions in agreement with such standards. In this paper, we present a Matlab/Simulink specification as an analytical model for Automated External Defibrillators (AEDs) and its integration with a Model Based Systems Engineering (MBSE) approach through descriptive models. The proposed model allows us to analyze algorithms for decision of shock application, performance of circuits when obtaining the required voltage, safety of the produced energy for shock delivery and characteristics of signals produced at the output of the AED. The model is composed of modules with interfaces specification, allowing safe module replacement and the assessment of the module influence over the system at a technical level

In [2] Karim Meddah , Malika Kedir Talha , Mohammed Bahoura , HadjerZairi describes The continuous monitoring of cardiac patients requires an ambulatory system that can automatically detect heart diseases. This study presents a new field programmable gate array (FPGA)-based hardware implementation of the QRS complex detection. The proposed detection system is mainly based on the Pan and Tompkins algorithm, but applying a new, simple, and efficient technique in the detection stage. The new method is based on the centered derivative and the intermediate value theorem, to locate the QRS peaks. The proposed architecture has been implemented on FPGA using the Xilinx System.

In [3] Liang-Hung Wang, Member, IEEE, Yi-Mao Hsiao, Member, IEEE, Xue-Qin Xie, and Shuenn-Yuh Lee The current paper presents an outdoor monitoring system for elderly people, which can transmit information on physiological signals and falling events to a healthcare center at any time and from any place. To detect simultaneously the occurrence of any falling event, as well as the relative electrocardiogram (ECG) signal of the user, a multithread method is proposed with the objective of enhancing the response time and the accuracy of detection. A healthcare box is used to determine the relative position of the patient through a global positioning system for fall detection; moreover, an ECG signal acquisition thread is adopted to increase the precision of the fall detection system. Integrating a precise map into the monitoring system facilitates understanding of a client user of the correct location and surrounding environment using the portable display. According to experimental results based on 4,000 samples, successful detection time with the multi-thread method was reduced by 38%, thereby increasing rescue opportunities for elderly patients who are at risk.

In [4] Dr. Ganesh V Bhat and Bhimasen G Tasaganva This paper describes Biosignals are recorded as potentials, voltages, and electrical field strengths generated by nerves and muscles. The measurements involve voltages at very low levels, typically ranging between and , with high source impedances. Bio signals need to be amplified to make them compatible with devices such as displays, recorders, or A/D converters for computerized equipment. Amplifiers adequate to measure these signals have to satisfy very specific requirements. They have to provide amplification selective to the physiological signal, reject noise and interference signals. This paper, deals with some of the prominent aspects involved in the design of Electrocardiogram (ECG) acquisition system has been discussed with furthermore design and implementation of instrumentation amplifier with appropriate filtering circuits are discussed. The design circuit is tested in real time and results obtained from the test and analysis of result are presented. The main challenge in ECG acquisition system is to detect the desired potential and attenuation of the amidst undesired biopotentials, noise and 50Hz electrical interference. The ECG acquisition system consisting of instrumentation amplifier amplifies the potentials and which is used to reject the common mode signals collected from electrodes with the gain of 364. This is followed by a Low pass filter (LPF), High pass filter (HPF) with the cut-off frequency of 220Hz and 0.16Hz respectively to attenuate the noise amidst from electrodes. Followed by the notch filter is used for attenuation of 50Hz line interference.

In[5]Avishek Paul and Jahnavi Jha describe An ECG is a measurement of the electrical activity of the heart muscle as obtained from the surface of the skin. The aim of this project is to sense the ECG voltage from an individual, using a three lead ECG system, and process the signal to extract necessary information. The purpose is to approach close to a medical opinion by measuring abnormalities in the ECG parameters. The system consists of two main modules; the hardware module containing the data acquisition card and the software module containing a graphical user interface which processes the ECG signal and displays the necessary information.

In [6] Jacopo Ferretti a , Licia Di Pietro a , Carmelo De Maria describes The Automated External Defibrillator (AED) is a medical device that analyzes a patient’s electrocardiogram in order to establish whether he/she is suffering from the fatal condition of Sudden Cardiac Arrest (SCA), and subsequently allows the release of a therapeutic dose of electrical energy (i.e. defibrillation). SCA is responsible for over 300,000 deaths per year both in Europe and in USA, and immediate clinical assistance through defibrillation is fundamental for recovery. In this context, an open-source approach can easily lead in improvements to the distribution and efficiency of AEDs. The proposed Open-Source AED (OAED) is composed of two separate electric boards: a high voltage board (HV-B), which contains the circuitry required to perform defibrillation and a control board (C-B), which detects SCA in the patient and controls the HVB. Computer simulations and preliminary tests show that the OAED can release a 200 J biphasic defibrillation in about 12 s and detects SCA with sensitivity higher than 90% and specificity of about 99%. The OAED was also conceived as a template and teaching tool in the framework of UBORA, a platform for design and sharing medical devices compliant to international standards.

In [7] Sunil Kumar, Gurmohan Singh, Manjit Kaur This paper describes the design and implementation of ECG signal processing on FPGA. Lot of research work has been carried out for implementation of ECG signal processing circuitry on FPGA. In this research work all the work is carried out using Xilinx Spartan-3E FPGA starter kit which is taken as a central processing unit. On board Programmable preamplifier, ADC and quad DAC on Spartan-3E FPGA kit have been employed for amplification, A/D conversion and D/A conversion respectively. To generate the necessary control signals for on board Pre-amplifier, A/D converter and D/A Converter, we have designed different HDL modules. The digital output of A/D converter is applied to the low pass FIR digital filter for processing the ECG signals. All the designed modules are integrated in a single TOP level entity.

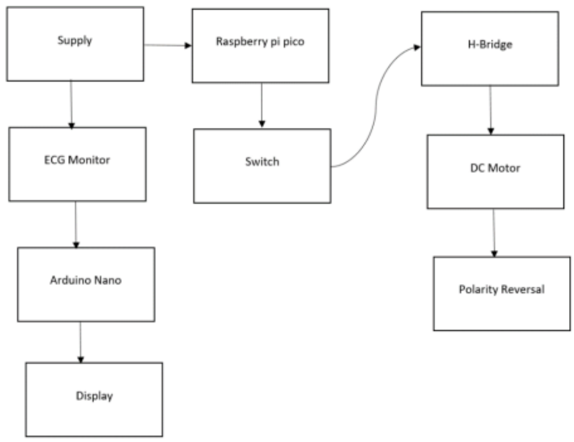
All modules are designed, functionally verified, synthesized, placed & routed using Xilinx 14.3i ISE tool.

In [8] Tomoya Shirane Bristol-Myers Squibb This paper describes According to the 2019 annual report by Fire and Disaster Management Agency (FDMA) in Japan, the survival rate of patients with Out-of-Hospital cardiac arrest (OHCA) who were rescued by Automated External Defibrillators (AED) was 6.2 times higher than those who were not treated appropriately. Unmanned Aerial Vehicles (UAV) have been evaluated as the means of delivering medical equipment and goods. This study was therefore designed to evaluate the effectiveness of UAV technology applied to AED delivery through a systematic review methodology. METHODS: Preferred Reporting Items for Systematic Reviews and Meta- Analyses (PRISMA) statement was utilized to guide the review.

In [9] Peter Magnusson, Joseph V. Pergolizzi and Jo Ann LeQuang This paper describes The wearable cardioverter-defibrillator (WCD) is a rechargeable external device that can be worn under the clothing all day long and protects the wearer from potentially life-threatening ventricular tachyarrhythmias. When a dangerous arrhythmia is detected, the WCD can deliver high-energy shocks. The WCD has been shown to be effective in accurately detecting and appropriately treating ventricular tachycardia (VT) and ventricular fibrillation (VF). It is intended for temporary use as a bridge to an implantable cardioverter-defibrillator (ICD), heart transplantation, or left ventricular assist device; patients with heart failure with reduced ejection fraction may benefit from the WCD while their condition improves. It can be used temporarily after explant of an ICD until reimplantation is deemed possible. In select patients with myocardial infarction, a WCD may be useful during the immediate period after infarction. It is indicated for use when a permanently implanted ICD must be explanted because of infection; the patient can use the WCD until the infection resolves, and a new ICD can be implanted. The role of the WCD is emerging as an important therapeutic option to protect patients at elevated risk of sudden cardiac death (SCD)

II. PROPOSED SYSTEM

The system consists a 2 controller setup where the first controller is used to acquire ECG signal form ECG module AD8232 while the other is used to drive the H-Bridge circuit. The Ad8232 is interfaced with Arduino NANO controller and then the data from the AD8232 is sent serially over computers display while when the patient experiences arrhythmia the secondary controllers activates the H-bridge circuit necessary for defibrillation.



3.1 Proposed System Diagram

METHODOLOGY

1. Real time ECG acquisition
2. Serial plotting of ECG data
3. SCA detection using Pan Tompkins

4. Biphasic Discharging using H-bridge.

Real time ECG acquisition

The AD8232 is an integrated signal conditioning block for ECG and other biopotential measurement applications. It is designed to extract, amplify, and filter small biopotential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement. This design allows for an ultralow power analog-to-digital converter (ADC) or an embedded microcontroller to acquire the output signal easily. The AD8232 can implement a two-pole high-pass filter for eliminating motion artifacts and the electrode half-cell potential. This filter is tightly coupled with the instrumentation architecture of the amplifier to allow both large gain and high-pass filtering in a single stage, thereby saving space and cost. An uncommitted operational amplifier enables the AD8232 to create a three-pole low-pass filter to remove additional noise. The user can select the frequency cutoff of all filters to suit different types of applications.

To improve common-mode rejection of the line frequencies in the system and other undesired interferences, the AD8232 includes an amplifier for driven lead applications, such as right leg drive (RLD). The AD8232 includes a fast restore function that reduces the duration of otherwise long settling tails of the high-pass filters. After an abrupt signal change that rails the amplifier (such as a leads off condition), the AD8232 automatically adjusts to a higher filter cutoff. This feature allows the AD8232 to recover quickly, and therefore, to take valid measurements soon after connecting the electrodes to the subject

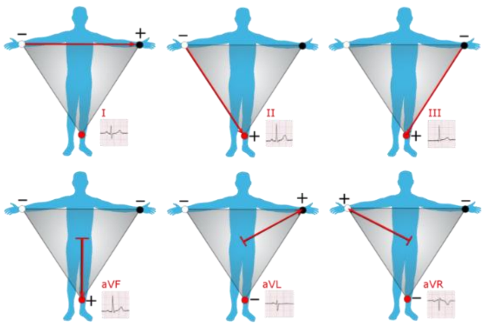
Three Lead Setup

Einthoven's triangle is an imaginary formation of three limb leads in a triangle used in electrocardiography, formed by the two shoulders and the pubis.[1] The shape forms an inverted equilateral triangle with the heart at the centre. It is named after Willem Einthoven, who theorized its existence.

- **Lead I** — this axis goes from shoulder to shoulder, with the negative electrode placed on the right shoulder and the positive electrode placed on the left shoulder. This results in a 0 degree angle of orientation.[4]

- **Lead II** — This axis goes from the right arm to the left leg, with the negative electrode on the shoulder and the positive one on the leg. This results in a +60 degree angle of orientation.[4]

- **Lead III** — This axis goes from the left shoulder (negative electrode) to the right or left leg (positive electrode). This results in a +120 degree angle of orientation.[4]



Serial Plotting of ECG data

The Arduino Nano and the ECG AD8232 module have distinct functions and work together to measure and interpret the electrocardiogram (ECG) signals.

The Arduino Nano:

The Arduino Nano is a microcontroller board based on the ATmega328P chip. It provides the processing power and I/O capabilities necessary to interface with external devices and perform tasks based on programmed instructions.

The Arduino Nano reads the analog voltage values from the AD8232 module and can perform various operations on them, such as filtering, analyzing heart rate, detecting abnormalities, or transmitting the data to other devices.

ECG AD8232 Module:

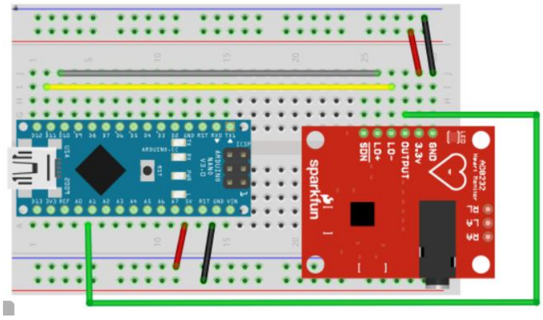
The ECG AD8232 module is specifically designed to measure and amplify the electrical signals generated by the heart. It is equipped with integrated amplifiers, filters, and other components necessary to capture and condition the ECG signals. The module takes the weak electrical signals from the body and amplifies them to a measurable level.

The AD8232 module provides an analog voltage output that represents the ECG waveform. This analog signal is then connected to an analog input pin on the Arduino Nano, which can read and process the voltage values.

By connecting the Arduino Nano and the AD8232 module, you enable the Arduino to receive and interpret the ECG signals. The Arduino can then perform further processing, analysis, or transmission of the ECG data based on the program you have written.

The output you will get from the provided Arduino code is a stream of numbers representing the ECG signal. The code reads the analog value from the ECG pin (connected to A0 in this example) using the analogRead() function and prints it to the serial monitor using the Serial.println() function.

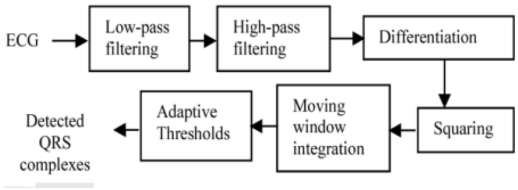
Each number represents the voltage value of the ECG signal at a particular moment in time. The range of the values depends on the resolution of the analog-to-digital converter (ADC) of the Arduino Nano. The ADC on most Arduinos has a 10-bit resolution, meaning it can represent values from 0 to 1023.



SCA detection using Pan-Tompkins Algorithm

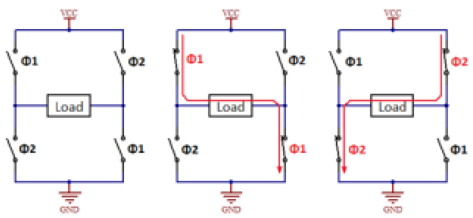
The Pan-Tompkins algorithm is generally used for pre-processing and as a QRS detection algorithm in real-time approaches. This algorithm utilises the amplitude, slope, and width of an integrated window to identify the Rpeaks in QRS complexes. The algorithm consists of two stages, which are pre-processing and decision. In pre-processing, the raw ECG signal is prepared as input to the detection process. Pre-processing includes noise removal, signal smoothing, and width and QRS slope increasing. Then, the thresholds are used to only consider the signal peaks and eliminate the noise peaks in the decision stage. The algorithm consists of a band-pass filter (Low Pass and High Pass Filters), derivatives, a squaring function, a moving window integration (WMI), threshold, and decision, as shown in the diagram in Figure. In this algorithm, the false detection produced by the noise and artefact

Present in the ECG signal was reduced using a digital band-pass filter. To adapt to the changes in QRS morphology and heart rate, the thresholds were automatically adjusted with the parameter in the decision stages. The detailed algorithm process flow is presented in the flowchart of Figure



Biphasic discharging using H-bridge

An H-Bridge is a circuit commonly used in robotic and power electronics applications -as an inverter- to control DC motors. In Figure there are the schematics that describe the operation of a generic H-Bridge. From those is also evident the name origin, in fact the circuit representation resemble an"H".



An H-Bridge is built with four switches. As we can see in Figure by opening and closing them in a controlled manner, it is possible to revert the current flowing through the load. Thus, closing Φ1 switches while Φ2 are still open, a positive voltage will be appied across the load. By opening Φ1 switches and closing the Φ2 ones instead, a negative voltage will be applied, reverting the current. As a last observation, it is extremely important to notice that closing both Φ1 and Φ2 switches in the same branch will cause a short circuit with devastating effects. To ensure that this would never happen I used redundant controls on Φ1 and Φ2 piloting signals, and a short pause between voltage reversions – Negligible for the purpose of defibrillation, but vital to ensure a time margin on Relay switching.

4 CONCLUSION

In the present study, it was also aimed to use the defibrillator remotely by the expert in addition to sending the data of the patient who are at risk of heart attack to the specialist. However, automatic control of the defibrillator from a remote unit appears as a limitation at the time of heart attack. Incase data packets are transferred incorrectly or a failure occurs in this transfer, repetition of transfer request causes instant delays in communication. For this reason, a delay occurs for the computer-controlled remote control of the defibrillator. The timing errors at the time of defibrillation give rise to different arrhythmias instead of placing the heart into normal rhythm. In such a situation, it is impossible for the patient to survive. It is impossible for semi-automatic defibrillator devices to work independently from an expert or a healthcare team. In critical situations, the specialist intervenes in the patient on telephone communication with the medical team waiting by the patient. Despite this limitation, Automatic External Defibrillators (AEDs) are capable of automatic or semi-automatic decision-making and improving arrhythmia rapidly. It is not necessary for the user to be trained in manual defibrillators as well as in ECG and arrhythmias. The user attaches the electrodes to the body, turns on the AED, and signal-processing circuits decide whether or not it is necessary to perform a defibrillation. The user follows the ECG signal on the monitor and watches the process. It is not possible to use automatic AEDs manually. In semi-automatic models; however, the confirmation of the specialist is required for the process. Another limitation is that the connections of the defibrillator are carried out by the patient or by his/her relatives. People like relatives of patients, firefighters, policemen, hostesses, and airport employees must be trained for using such devices. It is recommended that Automatic External Defibrillators are commonly available in places where people exist in crowds like airports, airplanes, shopping centres, stadiums, entertainment areas etc

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