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Research Paper

Design and construction of a microcontroller-based heartbeat monitoring device with display

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Abstract

Strong indications have emerged the world over that a large proportion of people in developing countries are now at great risk of developing cardiovascular (heart) diseases which currently accounts for one-third of all deaths worldwide. The need for an accurate, yet affordable ECG (Electrocardiogram) machine is necessary to ensure the quality of cardiovascular health of the average citizen. This research entails the design and implementation a portable, easy-to-use ECG machine. The heartbeat rhythm was obtained using 12-lead ECG electrodes and displayed in a waveform using a GLCD (Graphic Liquid Crystal Display) screen. Interpretation of the heartbeat rhythm was done by the use of red and blue LEDs (Light Emitting Diodes) indicating normal and abnormal heartbeat rhythms which are stored on an SD card for easy retrieval, thereby ensuring a user-friendly design. The significance of this design lies in its potential to empower patients with heart conditions by providing a means of monitoring progress in the areas of drugs being administered, effects of surgical repairs and general well-being of the patient.

Keywords: *Heart Monitor, Electrocardiogram, Heartbeat, Heart Rate, Cardiovascular Diseases, Heart.*

1. Introduction

The human heart pumps blood by the contraction and relaxation of the heart. Specifically, a small group of specialized muscle cells located in the upper right-hand corner of the right atrium (upper part of the heart) called sinoatrial (SA) node. Cells in the SA node generate their electrical signals more frequently than cells elsewhere in the heart. On the other hand, the ventricle which is the lower part of the heart pumps blood with much more force because of the thick muscle which it's walls are composed of. Both the atrium and the ventricle perform their operations with the help of cells. These atrium cells in the cause of discharging their duties generate electrical signals which is passed through the help of some connected tissues partitioned by a small bridge of muscle called the atrio-ventricular conduction system down to the ventricle. The delay (lag time) between the signals reaching the ventricle is about two-tenth of a second. This delay allows time for the blood in the artria to empty into the ventricle before the ventricle begins contracting [1].
It is therefore paramount to note that the atrium and the ventricle do not pump blood simultaneously but take turns to do so. The activities of cells in the heart can be monitored by a heartbeat monitor called an Electrocardiogram (ECG or EKG). Electrocardiogram is derived from the Greek word "electro" for "electric"; "kardio" for "heart" and "graph" for "to write") and the German word "electrocardiogram". An ECG machine is used to detect and record electrical activity for diagnostic purposes [2]. An ECG records the heart's own electrical impulses to create an electrocardiograph, a reading that helps physicians learn more about the heart. It is important to note that the ECG is not a form of treatment but allows physicians diagnose heart diseases by taking a close look at the heart and its activities.
An electrocardiogram can:

i) Evaluate damaged and diseased tissue or other physical irregularities.
ii) Monitor any surgical repairs, pacemakers, or effects of drugs used to treat existing heart conditions.
iii) Determine whether the heart is performing normally or suffering from abnormalities (extra or skipped heartbeats - cardiac arrhythmia).
iv) Indicate acute or previous damage to heart muscle (heart attack).

v) Be used for detecting potassium, calcium, magnesium and other electrolyte disturbances.
vi) Allow the detection of conduction abnormalities (heart block).
vii) Suggest non-cardiac disease (pulmonary embolism) [2] [3].

The ECG records electrical activity by the aid of electrodes that are connected at strategic points on the body of the patient. These strategic placements which give the readings are recorded in pairs and these pairs are called leads. There are 3 types of leads which are 3-lead, 6-lead and 12-lead.

Each lead views the heart from a different angle. 3 and 6-lead ECGs, record limited heart activity, and are primarily used to monitor a patient's heart during surgery, and can be used to diagnose early heart conditions. 12-lead machines look at the heart from twelve different angles and provide the type of readings necessary to diagnose and monitor patients with advanced heart conditions [4].

In a 12-lead ECG, six electrodes are attached to the skin on the chest around the heart. Four more electrodes are added, one on each arm and leg. The ten electrodes combine in twelve different ways to read twelve different angles on the heart [5] [6].

When the heart depolarizes which occurs when the heart muscle which is negative at rest moves closer to a neutral charge with each heartbeat, the electrodes sense the tiny electrical impulses on the skin that are created as a result. The impulses travel back to the machine where they are interpreted and printed on a graph.

A healthy heart will print out an orderly wave of progression with each heartbeat, while a heart with diseased or damaged tissue will show certain irregularities in the heart's rhythm, size, or position [2].

1.1. The normal ECG

A typical ECG tracing of a normal heartbeat consists of a P wave, a QRS complex and a T wave.

Axis: The axis is the general direction of the electrical impulse through the heart. It is usually directed to the bottom left.

P wave: The P wave is the electrical signature of the current that causes atrial (top chamber of the heart) contraction. Both the left and right atria contract simultaneously.

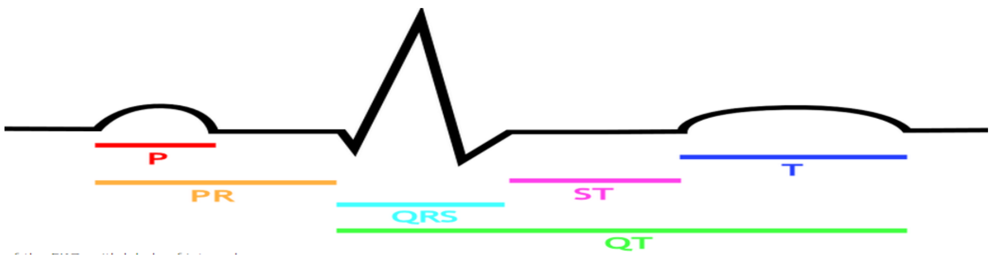

Fig. 1: Drawing of the EKG, with Labels of Intervals; P=P Wave, PR=PR Segment, QRS=QRS Complex, QT=QT Interval, ST=ST Segment, T=T Wave [5].

QRS: The QRS complex corresponds to the current that causes contraction of the left and right ventricles, causing a greater ECG deflection due to more muscle mass.

The Q wave, when present, represents the small horizontal (left to right) current as the action potential travels through the inter-ventricular (lower chamber of the heart) septum.

The R and S waves indicate contraction of the myocardium (the thickest muscular wall of the heart around the ventricle where the pressure is greatest).

T wave: The T wave represents the repolarization of the ventricles, which is when the heart muscles go back to their negative state at rest after a heartbeat. The QRS complex usually obscures the atrial repolarization wave so that it is not usually seen. In most leads, the T wave is positive. Negative T waves can be signs of diseases; however an inverted T wave is common amongst black people.

The ST segment connects the QRS complex and the T wave.

An ECG is not usually performed as a preventative measure that is prior to any symptoms of possible heart conditions, it is only utilized to diagnose or rule out the presence of diseases, disorders, and other irregularities. ECG machines are often found in general practice clinics, as well as in ambulances, emergency rooms, hospitals, and cardiology centers [5]. Strong indications have emerged that people in under-developed countries are now at great risk of developing cardiovascular (heart) diseases which currently accounts for one-third of all deaths worldwide. Cardiovascular disease (CVD) is an umbrella term that refers to any of a number of diseases affecting the heart and blood vessels [7]. Electrocardiographs (results of ECG analysis) are usually complex and can only be interpreted by medical practitioners. This leaves the patients in the dark regarding the meaning of their ECG results. Also, most ECG machines print out the result in a sinusoidal wave form on a special tracing paper which makes subsequent accessibility rather tedious and traditional [8][9].

Consequently, the need for a device that addresses this issue is needed hence the birth of this project. The aim of this project is to provide the average person suffering from a heart condition with a portable device that can be used to monitor the heart, with results that are easily understandable to the patient and a form of storage for perusal later and analysis by medical personnel. Objectives of this project are to reduce the size of the heartbeat monitoring device currently available and making it more portable, furthermore, interpreting results to an extent and making it easily understood by non-medical personnel (layman), also to provide storage for heartbeat readings on the device which when connected to a computer system, can be analyzed by a doctor or printed for documentation.

2. Review of closely related works

Some of the notable achievements in relation to ECG analysis in terms of algorithms, software and hardware implementations are discussed below. In analyzing these we took into consideration the similarities and short-coming of these project.

2.1. An implementation of a real-time and parallel processing ECG features extraction algorithm in a field programmable gate array (FPGA)

This project analyzed the component of the ECG signals and information in real time for identifying the abnormal rhythm and heartbeat. A programmed System on Chip (SOC) (an Integrated Circuit that contains all components of a computer or electronic system into a single chip) was used to control the detection and digitizing of the ECG, analyze and extract features of ECG, monitor the information update to the LCD and interface with USB and Flash Memory. In this way, both the ECG signal in real time and the analyzed information could be displayed on the LCD panel [10].

2.2. Study on AFE (analog front end) chip based ECG data acquisition

This project illustrates the use of Analog Front End (AFE) chip for the construction of ECG rather than the traditional circuitry. The chip based circuitry suggested here is programmable and whose parameter values are not vulnerable to change of temperature or other environmental conditions on account of being packaged inside the chip, hence giving us accurate results. This project drew the flaws of the traditional ECG which included restriction of ECG machine to hospitals, power consumption and prevented real time analysis. This research proposed the model that a signal ECG has been suggested using the AFE chip and MSP430 microcontroller performing signal processing to see a noise free signal on the on the display unit. The integrated AFE comes inbuilt with multiple components including programmable gain amplifiers, filters, Analogue to Digital Converter (ADC) to sample and digitize the signal [11].

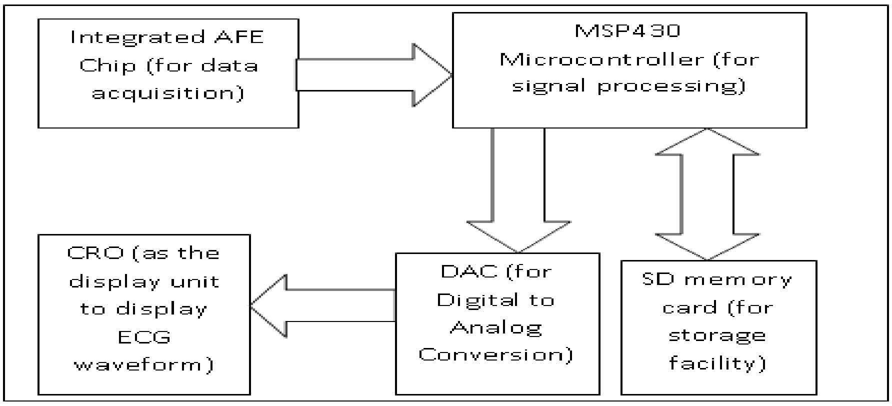

Fig. 2: AFE Chip Based ECG Data Acquisition. Source: [11].

2.3. Microcontroller-based heart rate monitors using fingerprint sensors

This design presents the development of a microcontroller based heart rate monitor using finger sensor. The device uses the optical technology to detect flow of blood through the finger and offers the advantage of portability over tape-based recording system. It incorporated the optical technology using standard infrared Light Emitting Diode (LED) and photo sensor to measure the heart rate using the index finger.

A microcontroller is programmed to acquire the signal using its embedded analogue to digital converter, ADC, and use the readings to compute the heart rate; eventually, the reading is digitally displayed on an LCD. This project makes use of optical mechanism to detect modulations caused by the electrical or physical changes, the keypad is to allow users to enter information about them, device connected to an SMS modem for transmission of alert messages to medical professional, an LCD screen to output heartbeat rate, audible tone to indicate any abnormalities in the patient's heartbeat reading.

The sensor consists of an Infrared (IR) LED transmitter and also an IR photo detector acting as the receiver. The IR light passes through the tissues. Vibration in the volume of blood within the finger modulates the amount of light incident on the IR detector [12].

2.4. Heart rate monitor

This project implements an ECG and digital heart rate counter. The main challenges included amplifying the desired weak signal in the presence of noise from other muscles and electrical sources. A display of the heart rate was obtained by measuring the time between signal peaks and then calculating the frequency of the peaks in units of beats per minute. The implementation of the heart monitor involved low cost amplifier and filter components coupled with a sophisticated microcontroller and LCD screen.

An 8-bit microcontroller was chosen to process the output signal produced by the amplification stage. The Microchip PIC16F877A was selected due to its additional output and processing power, and also its onboard 10-bit analogue to digital converter and in-circuit debugging features. Using this highly integrated microcontroller allowed for a simpler design and the troubleshooting debugging process. This project successfully implemented an ECG while the Digital Heart Rate counter was only partially successful [13] [14].

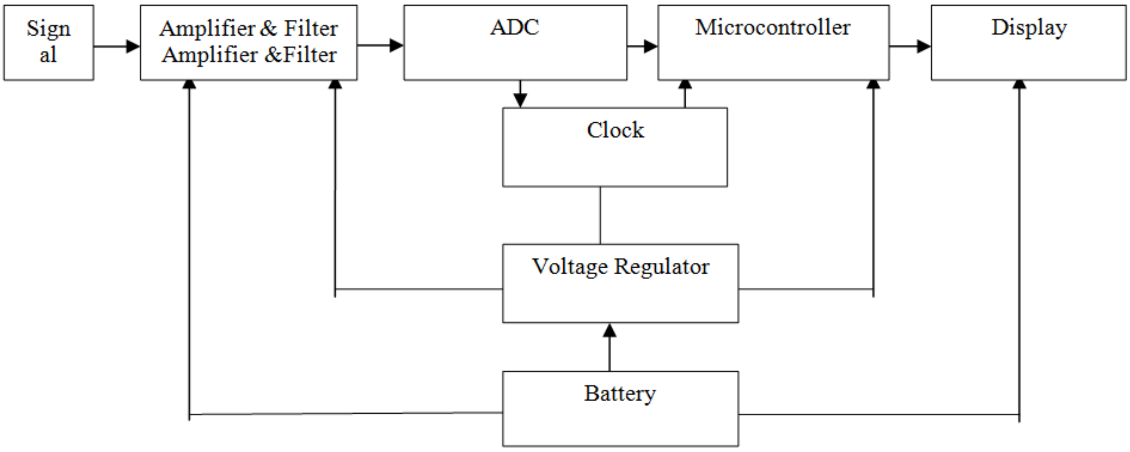

Fig. 3: Heart Rate Monitor System Design. Source: [13].

3. System analysis and design

The proposed Heartbeat Monitor was divided into different units in order to make the analysis and design of the system easier, and also to ensure that all the components required by each unit is properly outlined. The various units of the proposed system include:

i) Heartbeat Monitor Unit
ii) System Storage Unit
iii) System Display Unit
iv) Power Supply
v) System Function Code Unit

The system will be able to obtain the patient's heartbeat reading, interpret and display it on a graphic liquid crystal display (GLCD). Also, the system will contain a detection algorithm that will indicate abnormal and normal heartbeat reading with the aid of LEDs. The system is designed to be portable so it can be used at home, easily understood by the patient and the reading can also be stored on an SD card for proper interpretation by a medical practitioner subsequently.

3.1. Design tools/modeling of proposed system

The ECG system is designed using the following: a ten-lead electrode for obtaining heartbeat readings from patients, operational amplifier as a differentiator, Integrated circuit (IC) (CD10164) for getting the optimal signal, microcontroller (PIC18F258) for processing of the signal, QRS Complex Feature Identification for detection algorithm, Scan disk module for storage and GLCD for display of the signal. The circuit design of the proposed system was simulated using livewire. The Desktop application for accessing the readings on the SD card was implemented with MATLAB and Heart Logger.

3.1.1. Analysis of proposed system

To obtain accurate readings from the patient, the system will require the 12-lead method of electrodes placement (actually 10 electrodes giving 10 leads, the remaining 2 leads are differences between the electrodes placed on the arms and legs). Each of the ten electrodes will be connected as an input to ten operational amplifiers. An operational amplifier has two inputs; the second input of each operational amplifier will be connected to the power source. The operational amplifier acts as a differentiator that is the output of the Op-amp is the difference between its two inputs. Consequently, the outputs from the ten op-amps are sent to the IC (CD10164). The IC is configured in such a way that all the signals received from the operational amplifiers are compared with each other and the best input is passed to the microcontroller.

The microcontroller (PIC18F258) is connected to the GLCD, the SD storage medium, and detection LEDs (Light Emitting Diode) for indication of normal and abnormal heartbeat readings. Also, the detection algorithm will be implemented on this same microcontroller which works with the LEDs to indicate red for abnormal heart reading and blue for normal heart reading. The GLCD will display the human heart reading in continuous form i.e. analogue form.

3.1.2. Features of proposed system

The features of the proposed system include:

i) 10 electrodes used to obtain the ECG signals from the Patients body.
ii) A GLCD screen used to display the output of the heartbeat readings in a graphical format.
iii) LEDs used to indicate normal and abnormal heart rhythms.
iv) SD card used to store the heartbeat readings for retrieval later.
v) A desktop application for viewing the electrocardiographs (ECG results) stored on the SD card.

3.1.3. Functional/non-functional requirements

Functional Requirements: The functional requirements for the proposed system are as follows:

i) The system would be able to obtain heartbeat readings accurately through the use of the electrodes.
ii) The system would be able to adequately convert the analogue signal to digital signal.
iii) The system would be able to filter out noise or interferences from the signal and produce an almost perfect signal.
iv) The system would be able to compare and get the right signal amongst others to serve as input to the microcontroller.
v) The system would be able to detect if the heart reading is a normal or abnormal reading.
vi) The system would be able display the heartbeat readings on the GLCD screen.
vii) Non-Functional Requirements: The non-functional requirements of the system include:
viii) The system would be able to store the Electrocardiographs on a storage media for retrieval later.
ix) The system would be able to interpret the Electrocardiographs to an extent using LEDs.
x) The system would come with a desktop application that would enable the results on the storage media to be viewed for analysis by medical personnel.

3.1.4. Block diagram of proposed system

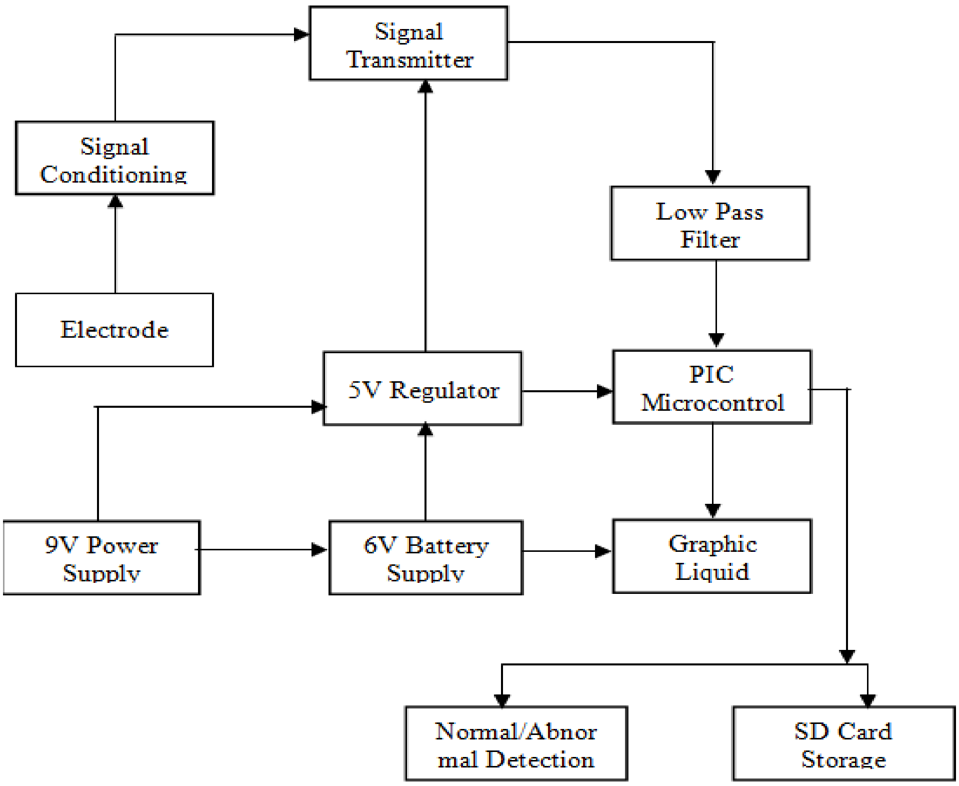

Fig. 4: Block Diagram of the Proposed System

3.2. Hardware requirements

Electrodes: The electrodes are used to obtain the heartbeat signals by converting the pulse to electrical voltage. These electrodes are made of Ag/AgCl- Silver/Silver Chloride. They are placed at strategic locations on the body of the patient [15].
Operational Amplifier: These are voltage amplifiers with the provision of accommodating two signal sources connected such that the amplifier amplifies only the difference between these two signal sources [16].
Capacitors: Capacitor, or electrical condenser, is a device for storing an electrical charge. In its simplest form a capacitor consists of two metal plates separated by a non-conducting layer called the dielectric. . The forms of practical capacitors vary widely, but all contain at least two electrical conductors separated by a dielectric (insulator) [17].
Resistors: Resistor is a component of an electric circuit that resists the flow of direct or alternating electric current. Resistors can limit or divide the current, reduce the voltage, protect an electric circuit, or provide large amounts of heat or light [18].
LEDs: Light-Emitting Diode (LED) is a device that emits visible light or infrared radiation when an electric current passes through it. When electrical current passes through the diode the semiconductor emits infrared radiation, which the phosphors in the diode absorb and reemit as visible light. The visible emission is useful for indicator lamps and alphanumeric displays in various electronic devices and appliances [19].
Microcontroller: A microcontroller can be considered a self-contained system with a processor, memory and peripherals and can be used as an embedded system. The Microcontroller is a chip that works exactly like a computer but on a much smaller scale. All PIC microcontrollers are made in 8, 16, 18, 28 and 40 pins devices [20].
Storage Unit: Secure Digital (SD) is non-volatile memory card format for use in portable devices. The storage unit consists of a one Gigabyte SD card which would be used to store the electrocardiographs (heartbeat readings) to be available for perusal later [20].
Power Supply Unit: The power for this system will be supplied by a 12V AC to DC conversion. A 12V step down transformer is connected to main supply to reduce the voltage from 220V ac to 12V ac. The voltage is converted from A.C to D.C with the use of a bridge rectifier which consists of four diodes wired in a bridge form. A 5V IC regulator will be used to step down the 12v to 5V [20].

3.3. Software requirements

Microcontroller System Code Unit: The microcontroller would be programmed to carry out the operation of displaying the result to the LCD and storing the results on the SD card. An algorithm for detection of abnormalities in the ECG signal was also incorporated into the program. The code for the microcontroller was written in Assembly language, as it is efficient for programming devices and is also fast.
Personal Computer Application: This application would be used to enable the personal computer recognize the heartbeat readings stored on the SD card and enabled it to be displayed in a manner that is easy for perusal. The application would be designed using MATLAB and Heart Logger.

4. Construction and testing

This section gives an in-depth explanation of the peculiarities as well as the practical implementation of the microcontroller-based heartbeat monitoring device with display. It explains in details the mode of operation of the device and the implementation of the principles of signal processing and display. It also describes the testing formats that were employed to ensure the accuracy and proper functioning of the device.

4.1. Circuit design and operation

The circuit diagram gives a graphical display of all the components in the device and how they have been integrated to carry- out the overall function of a heart-beat monitoring device with display.

4.1.1. Circuit diagrams

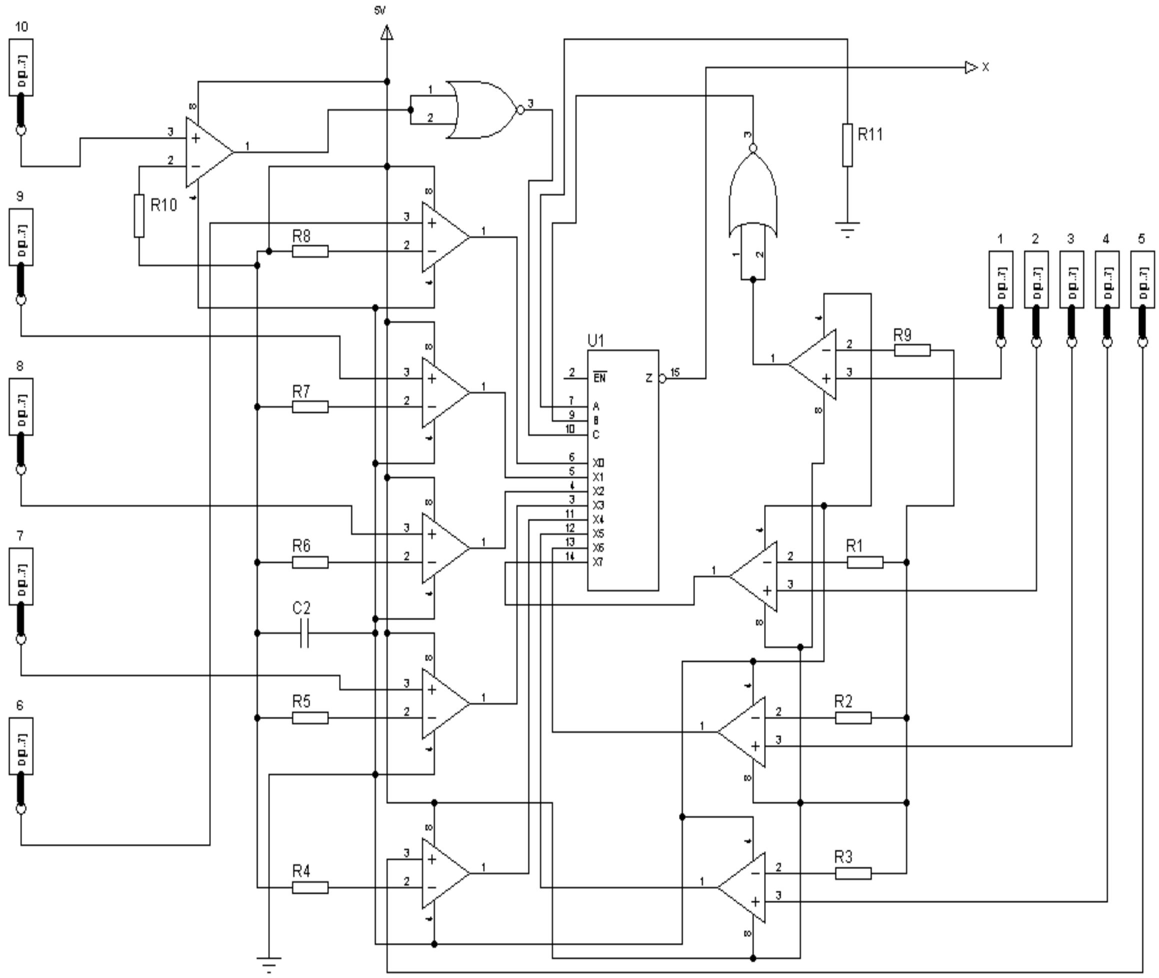

Fig. 5: Signal Acquisition and Selection

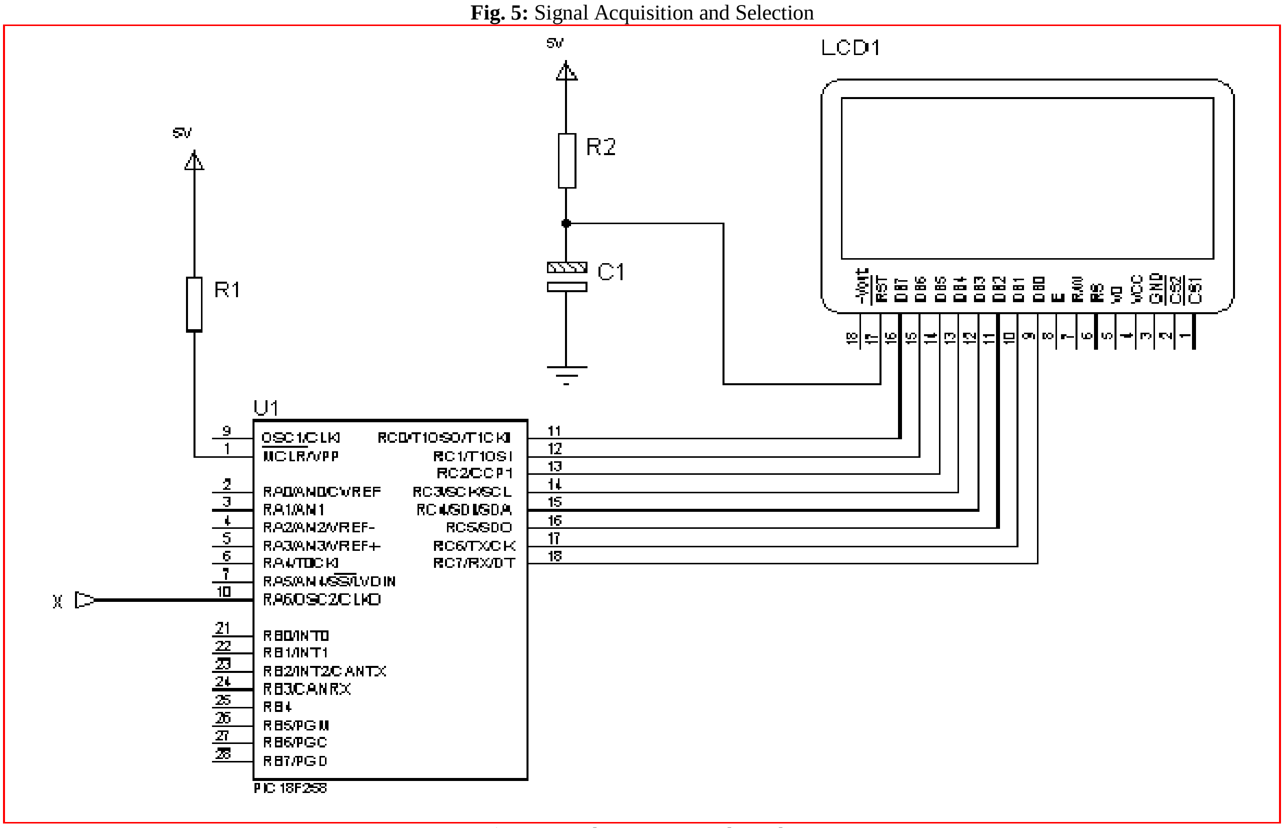

Fig. 6: Signal Processing and Display

4.1.2. Circuit operations

The circuit operation of this project can be divided into various functions and is indicated as follows: Signal Acquisition, Signal Selection, Signal Processing, and Signal Display.
Signal in this case refers to the heart beat reading. The signal is obtained in the acquisition stage then fine-tuned in the processing stage and the output is seen in the display stage.

4.1.2.1. Signal acquisition

Electrodes are the main components in this part of the circuit and the electrodes used in this project are made of silver chloride components that are attached to the main unit of the machine. 10 electrodes were used to obtain the heartbeat readings. Each ECG electrode is attached to the arms, legs and chest of the patients.
The power for this system will be supplied by a 12V AC. A 12V, 1Amp step-down transformer is connected to the main supply to reduce the voltage from 220V AC to 12V AC. The voltage is converted from AC to DC with the use of D15XB80 1.5Amp bridge rectifiers which consists of four diodes wired in a bridge form. In addition, there is need to reduce the voltage to about 5V for the components on the circuit board (especially, the microcontrollers) to function because a higher supply will damage these components. A 5V regulator IC-LM7805 was introduced, which takes in the 12V DC at its input pin and gives 5V at its output pin.
The signal from the heart and that of the power supply is channeled through the operational amplifier. The electrodes are connected to the positive terminal while the power supply is connected to the negative terminal of the operational amplifier. The operational amplifier finds the difference between the two signals hence, acting as a differentiator in this circuit.

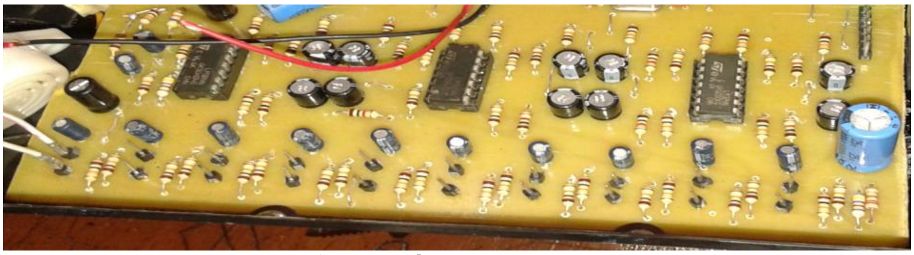

Fig. 7: Signal Acquisition Circuitry

Fig. 8: Signal Acquisition (Power Unit)

4.1.2.2. Signal selection

The operational amplifiers receive the electrical signals from the electrodes and convert the information. The operational amplifier acts as a differential amplifier by finding the difference between the input signal and the electric current. The positive input pin on the operational amplifier gets the signal from the patient while the negative pin gets the electrical signal from the power source. The difference between these signals is passed to the IC and the best is chosen as input to the microcontroller. [21]
The Pin connections X1 through X7 represent the input pins on the IC and signals from Lead 2 through Lead 9 are fed into these ports. The signals from electrode 1 and 10 are passed through a NOR gate to the IC in pin B and C. This is because these pins are used for outputs from the IC therefore; in order for them to be utilized as input pins, signals into them have to be inverted, hence the NOR gates.

4.1.2.3. Signal processing

The foundation for signal processing can be seen in the microcontroller system code that is embedded in the microcontroller. The system code was written in Assembly language and compiled using the A51 Compiler. This compiler converts the code to machine language making it easy to be embedded in the microcontroller. The embedding

process was made possible by the Mikroelektronika programmer. This programmer is a software that can be installed on a PC and it also has a slot for the microcontroller which is connected to the PC (Personal Computer) using a USB (Universal Serial Bus) cable. The system code to be embedded is selected from the programmer interface and launched to begin the process of installing the code on the microcontroller. The 64-bit microcontroller-PIC18F258 is responsible for all signals processing to be channeled to the GLCD, LED and SD card slot.
The best signal is received from the IC to the microcontroller. A detection algorithm is the basis for the interpretation of results and the algorithm involves the identification of the QRS complex feature of a heart beat pulse. QRS has the highest deflection and an aberration in the display of this wave is an indication of a heart condition. The presence of the QRS complex feature is converted to the heart rate which is between 50-80 bps (beats per second) for a healthy heart. Therefore, any signal that produces readings above or below this range is indicates an abnormal heart rhythm. A good heart rhythm is indicated by LED with a blue light and red light indicates an abnormal heart rhythm.
Signals in the 64-bit microcontroller are interpreted in such a way that they will be used as inputs into the 8-bit PIC microcontroller that will be responsible for processing the signals for display on the GLCD. The processed signal from the 64-bit microcontroller is also fed as input to the 8-bit PIC microcontroller responsible for storage of the heartbeat readings on an SD card for further reference.

Fig. 9: Signal Processing (Microcontroller)

4.1.2.4. Signal display

This section of the system involves a graphical output of the signal that has been previously acquired. The display device used is a GLCD screen. The LCD screen has 18 pins for connection to the microcontroller. The order in which these were connected was based on the information contained in the datasheets of the GLCD and Microcontroller.
Pin 1 and 2 of the GLCD are used for contrast adjustment. Pin 3 represents the ground connection; pin 4 and 5 represents the connection to the supply voltage, pin 6 represents Reset and enables the data displayed by pin 8 to be erased. Pin 7 is utilized when information displayed on the GLCD is in a form that requires measurement details on different positions on the waveform. Pin 8 stands for Error data and is used when information about errors in results of processes being carried out by the system is to be displayed. Pins DB0 through DB7 are used as input pins to the GLCD. Pin RST stands for reset and is used to clear information displayed on the screen. Pin 18 stands for negative voltage is used as a negative terminal for power supply. The pins on the GLCD which have no connections to the microcontroller are not required to obtain the maximum output of our signal on the screen. The pin connected to the resistor and capacitor is used as a reset mechanism in order to clear the data that has been displayed on the GLCD. [4][16].The expected output of the GLCD is the Heartbeat pulse displayed in a sinusoidal wave format.

Fig. 10: Signal Display (GLCD)

4.2. Testing

The Testing format for our device was designed to ensure that the aims of the project have been achieved. This means that testing of the device can only be done as a whole hence the System testing foundation of our testing format. The format is divided into various sections which are: interpretation, storage, display. Ten people were used to determine the

accuracy of our device in displaying results. This was done to ensure that our aim of interpreting the result by the use of LEDs –Green for Good and Red for Bad is achieved.
The ability to access heartbeat readings of patients stored on the SD (Secure Digital) card via the PC application indicates the achievement of the storage aim. A perfect display of the heartbeat pulse (one in which all the features of a normal heartbeat is present) on the GLCD without abnormalities generated as a result of voltage bias or interference indicates the achievement of the display section of the testing format.

4.2.1. Discussion of results

One of the challenges that was faced in the construction of this project was the issue of interference from the environment that was distorting the signals from the heart, these interferences were of three categories: Magnetic interference from devices in the environment, noise from the AC power supply, and contact source impedance (interference from the friction between the skin and electrodes). This issue was partially resolved by twisting the electrode wires along their length, using a differential amplifier to remove the Common Mode Ratio (CMMR) of the AC signal, and the use of electrodes with a large surface area to shield the conductors from interference respectively.
The signals obtained when the ten volunteers were tested were not perfect as there was still a little bit of interference which produced a wandering baseline for the signals, however the main features of a proper heartbeat signal were present, the heart rate was within the range of 50-80 bps and the blue indicator light was lit. Also, when the electrodes were not connected to any volunteer, the signals obtain as a result of interference, the heart rate was not within the accepted range and the red indicator light came up, acknowledging an abnormal signal.

Fig. 11: Normal Heart Rhythm from A Volunteer with the Blue Indicator Light

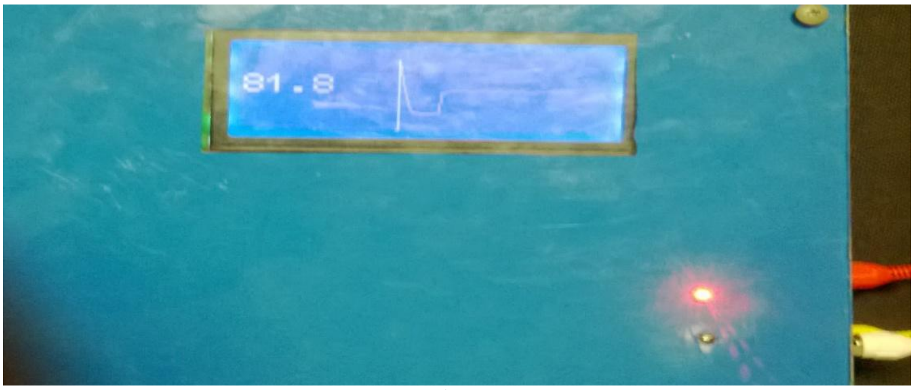

Fig. 12: Signals Due to Interference with Red Indicator Light

5. Summary

The design and implementation of a heart beat monitor involves attention to detail and all the processes that have been mentioned in the previous sections. The purpose of this work is to provide a device that can be used by Nigerians to promote the culture of monitoring and maintaining quality cardiovascular health. In summary, the project, involved a review of other systems, design and construction of a heart beat monitor with display and proper testing of the device to ensure accurate results.

5.1. Conclusion

The successful completion of this project has led to a deep understanding of how the human heart works, various abnormalities that might exist and how they might be detected in the graphical display of the pulse reading. Also, a practical understanding of the characteristics of signals and how they can be manipulated was gained.

These wealth of knowledge were incorporated into the design of the device, enhancing the features of already existing ECG machines to empower patients with heart conditions.

Hence this project can be described as a journey that brought about the fusion of two fields-medicines (cardiology) and computer technology, once again exhibiting the core attribute of Computer Science, which is problem solving.

As Computer Scientists, we saw the need in our environment and this gave birth to the microcontroller based heartbeat monitoring device with display.

5.2. Recommendations/future works

After successfully acquiring signals from a patient and displaying the heart rhythm on the GLCD, interpreting the result with the help of LED and storing the results on an SD card, further research can be carried out on this subject matter. Pointers to research areas include:

i) The device can be modified to include a wireless medium that transmits patient result via the internet in real time to a cardiologist for review.

ii) Detection Algorithms with a more precise indication level can be implemented on this device to give a prognostic result on the state of the patient's heart.

iii) The GLCD can be modified to display percentage progress of surgical repairs and drugs administered to patients.

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