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Design and Production of Heartbeat Counter for Medical Application

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.**ABSTRACT:** Heartbeat pulse measurement is an important medical practice used to determine the health status of an individual. This research was concerned on the design and production of heartbeat pulse counter for medical applications with specific features. The device senses and monitors the heartbeat rate whenever a fingertip is placed on the pulse sensor, the pulse sensor is a plug and play device which is detachable from the Arduino Uno board, the Arduino Uno receives and calculates this data and the result displayed on the 16X2 LCD display based on the written codes. It has the features for initial display, showing system on and when a finger is placed, it readily displays heartbeat rate detected and presents the pulse rate of the individual. Its design and production was achieved and used to test the heartbeat of many persons. Further work is required to incorporate GSM module with the capability of sending text message and cloud hosting of the medical data of an individual.

KEYWORDS: Heartbeat, pulse counter, medical application, GSM module, cloud computing

1.0 INTRODUCTION

In recognition of the past 62 years, various heart rate monitoring devices have been invented with different degrees of accuracy and technological application [1]. Before we review various constructions done on this project topic in recent times, we must look at the evolution of these monitoring devices over the years and the various improvements that have been made, to make them what they are today.

The first heart rate monitor came into existence in the 1950s and was then called the “Cardiotachoscope”. It was only during this era that its name was ever used and it was never even found to enter into production, thus, its exclusion from many historical documents.

Monitors of this era were often referred to as electrocardioscopes or cardioscopes. Sometimes they were simply referred to as an oscilloscope. Unlike modern monitors, devices of this era had monochrome displays and the persistence of the wave was generally not sufficient to cover the screen. There were no numeric parameters or annotations on the screen [2].The advantage of the monitor was the immediacy of the information and the ability to generate alarms. Most devices had an output connector to allow direct printing on a standard electrocardiograph.

However, a challenge with monitors of this era was the presentation of heart rate information. Many early units did not provide a cardio-tachometer or rate-meter to provide a heart rate.

The decade of the 1970s saw some significant improvements in the presentation of the displayed waveforms and information. This was a result of the incorporation of digital electronics and, eventually, microprocessors. Real-time (centrally controlled and processed) arrhythmia analysis appeared at the beginning of the decade and evolved over the duration of the 1970s. Standards documents that established minimum performance criteria for physiologic monitors began appearing from several bodies such as the "Specification for Biomedical Monitoring Systems" X-1414 of 1970 from the Veterans Administration [4].

The appearance of the so-called “Memory Monitor” occurred at the beginning of the decade. These monitors incorporated analogue to digital converters and small memories to briefly store several seconds of incoming data. The stored data was then used to define the display on the CRT. The advantage of this scheme was that the stored data could be written to the screen quickly and repeatedly at the same location well before it would fade out resulting in a “non-fade” persistent display, waveform that is overwritten by the trailing left edge of a narrow "eraser bar" which travels from left to right. Modern monitors use one display method or they permit the selection of either of these modes of display. Some memory monitors also allowed data to be cascaded [5]. This meant that an ECG trace would continue on the line below thereby providing more visible information over a greater time period. The display of most memory monitors could also be stopped or “frozen” for review of the appearance of a particular waveform. Also, printing or viewing of several seconds preceding an alarm condition was possible with some systems.

The middle of the decade saw the introduction of microprocessors and thus the beginning of modern monitoring systems. Spacelab claims to have launched the first (bedside) monitoring system which incorporated microprocessor technology in 1974. Among other things, microprocessors enabled further exploitation of the CRT as a means to display information. By 1978 some vendors such as Hewlett Packard and Phillips began integrating the heart rate information on the CRT display as a numeric value (in models HP78341A and HP78342A and Philips model CM-120). In summary, heart rate presentation evolved over the course of the decade from a bar-graph display to a numeric LED display located next to the CRT on the front panel and then to a numeric integrated with the CRTs' display [6].

Appearing at the end of the 20th century and into the new century was a new generation of monitors which were designed to be flexible enough to remain with the patient through various stages of acuity and during transport. These monitors support the continuum-of-care approach to patient care. These monitors leveraged the increased miniaturization of parameter modules and the lighter flat-screen technology. Transport monitors with their more limited subset of parameters are replaced by the more capable continuum of care monitors. An example is the Siemens Infinity SC 9000XL monitor [7]

Summarily, the evolution of the monitors is as shown below;

(1) 1950: First 'modern' monitor reported in use.
(2) 1954: First appearance of production monitors (Cambridge cardioscope).
(3) 1956: Production monitors enter clinical use (Electro dyne PM-65).
(4) 1966: Non-circular displays and Nixie numeric indicators are employed.
(5) 1968: Heart rate included on CRT as a progress bar indicator.
(6) 1970: The memory monitor appears which allows for a non-fade display. Isolated inputs appear for added patient safety.
(7) 1975: LEDs employed as numeric indicators on physiologic monitors.
(8) 1978: Monitor displays include heart rate as a numeric on the CRT.
(9) 1980: Modern modular parameter modules appear.
(10) 1983: Arrhythmia analysis available at the bedside. The first colour physiologic monitors appear.
(11) 1990: Transport monitors appear which could transfer the same patients' module and cabling to a compatible bedside monitor. Flat-screen (non-CRT) monitors appear on physiologic monitors.
(12) 1995: Some monitors can run Windows applications.
(13) 1996: Continuum of care monitors appears and parameter modules begin to be replaced by configured acquisition panels on the side of monitors.
(14) 2000: Internet connectivity at the bedside becomes available.

Among various methods employed in the construction of heartbeat counters are simple, reliable, microcontroller-based devices that demonstrate a technique to measure the alteration in blood volume at fingertip with each heartbeat. The sensor unit consists of an infrared light-emitting-diode (IR LED) and a photodiode, placed side by side as shown below. The IR diode transmits an infrared light into the fingertip (placed over the sensor unit), and the photodiode senses the portion of the light that is reflected back. The intensity of reflected light depends upon the blood volume inside the fingertip. So, each heartbeat slightly alters the amount of reflected infrared light that can be detected by the photodiode. With proper signal conditioning, this little change in the amplitude of the reflected light can be converted into a pulse. The pulses can be later counted by the microcontroller to determine the heart rate which is displayed on a 3-digit, CA (Common Anode) display. This design is shown in Figure 1 below;

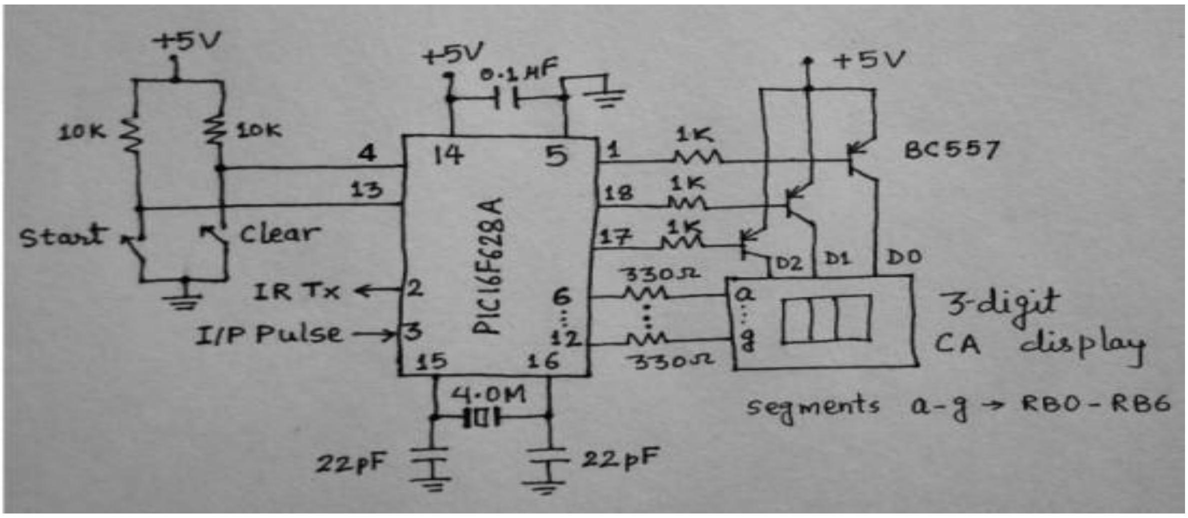

Figure 1. Heart Rate Measuring Device using PIC16F628A[8]

Once the start button is pressed, the microcontroller activates the IR transmission in the sensor unit for 15 seconds. During this interval, the numbers of pulses are counted and the number of heartbeats would be calculated by the microcontroller to be four times the counted value [9].

This device is not free from errors and several modifications can be made to improve its accuracy, sophistication and convenience. The work described above does not implement any form of alarm system either by use of a speaker, light indicator, etc. to indicate and alert the user when the heartbeat count rises or falls off a certain threshold. Also, the alteration in the blood volume is too little to be measured directly by a microcontroller as is done above. It is, therefore, necessary to use a high gain amplifier to increase the signal significantly before it is applied to the microcontroller. All these modifications have been implemented in this project.

For the sake of convenience and mobility, many heart rate monitoring devices were incorporated into wristbands and wristwatches but heart rate measurement through the wrist, by transmission and reflection of light rays, and the consequent measurement of blood volume changes, comes at an unnecessary price.

One principal and mitigating issue to wrist-based monitors is skin pigmentation (skin colour) because the light has to penetrate through several layers of the skin. The higher the position of the person on the Fitzpatrick scale (a measure of skin tone), the greater the difficulty associated with the reflection of light [10]. Therefore, “...the heart rate monitor will not work if the user is very dark in complexion,” [11]. From research carried out, it has been shown that light will reflect more easily on smooth brighter skin than on dark thick scruffy skin. The heartbeat counter will therefore give different readings for the same patient when the heartbeat is counted from the wrist and from the fingertips. The palm of the hand is one of the lightest parts of the human body in terms of complexion; hence its result will be much more accurate than that of the wrist. Also, unlike the narrow, slow-pumping capillaries in the wrists, there is an arterial vessel at the tip of the forefinger which keeps up with even the fastest pulsations of the heart. Thanks to the translucency of the fingertip’s skin, the heart rate is easy to read. It was therefore decided that measurement through the fingertip is the best and cheapest technique for a heartbeat count.

In terms of sensitivity, a very reliable heart rate monitor was proposed a few years ago. Instead of the principle of photoplethysmography (measurement of blood volume through the use of light), pressure-sensing was introduced. Unlike other conventional methods, a flexible pressure sensor was designed with the capability of measuring the heart rate, by sensing the pulsations of the arteries in the wrists [11]. This design also incorporated an ASP (Analogue Signal Processor) to extract the required signal in the midst of several noise inputs. It also had a counter, an indicator and a timing circuit to stop the measurement.

Roughly two years ago, a heartbeat counter capable of maintaining the heart rate and making an alarm at heightened levels of the heart pulse was introduced. It was constructed using a 4026 IC and had an in-built counter and seven-segment drivers embedded in a single IC. It also employed the use of two mono-stable multi-vibrators, one for enabling the counter for one minute, and the other for feeding pulses from the heartbeat sensor circuitry. With the aid of a buzzer, a sound is produced when the heart rate goes above 80 BPM.

The incorporated alarm, the cost and ease of construction were only part of its advantages [12]. See the circuit shown in Figure 2.

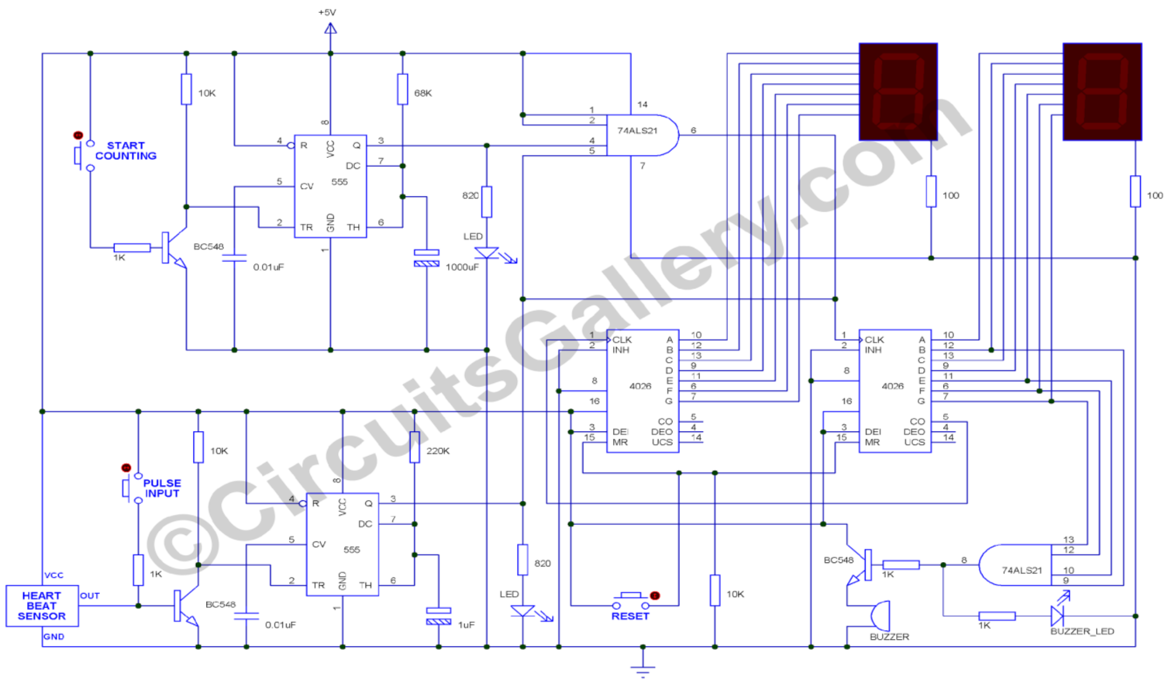

Figure 2. Heart rate monitors using 4026 IC[13]

However, the count was represented by two 7-segment displays multiplexed together meaning the device could not give a reading above 99 BPM. Besides that, each of the displays was associated with one of the 4026 IC's and an extra IC would be required for an extra display. Generally speaking, there are a lot of advantages of using the LCD

(Liquid Crystal Display) over the 7-segment LED (Light Emitting Diode) some of which includes a built-in processing power, character generators, fewer I/O lines required and the ability to easily represent complex/special characters. This is why an LCD was implemented in this project. Further details about this display will be discussed as we progress in this chapter.

Further research on various heart rate monitors showed many more methods of counting the heartbeat, one of which is achieved using the Pulse Oximeter[14]. This device uses optical sensors and LEDs emit light at different wavelengths. The LED will emit light through the finger and then the transmitted light is detected using an optical sensor. The heart pulse can be obtained from the value of oxygen saturation level which can be obtained based on the principle of oxygenated haemoglobin which has a higher absorption coefficient for infrared light than deoxygenated haemoglobin, which will observe more red light.

It was also discovered that the wireless pressure pulse system consists of a transmitter, a receiver, and a PC capable of recording online data. The device measured and displayed a pulse rate and the saturation of haemoglobin in the arterial blood. A LED was also used to emit light so that it is transmitted through an artery, and the resistance of the photo-resistor is determined by the amount of light reaching it. With each contraction of the heart, blood is forced to extremities and the amount of blood in the finger increases which is why the finger is suitable for the measurement of the pulse rate [15].

Summary of all past works on this topic and possible improvement we will incorporate into the proposed device will be shown in Table 1.

Table 1. Literature Review Summary

S/N	PREVIOUS DESIGNS	LIMITATIONS ON PREVIOUS DESIGNS	DESIGN IMPROVEMENT ON PROPOSED DESIGN
1	1950's: Early warning systems for cordials accident	ECG waveforms only show a second or two of new data. They did not provide a rate meter to display heart rate. Monitors were limited to 1 or two waveforms.	The proposed design stores data permanently through a wireless connection. An LCD display is used to display the heart rate.
2	1970's: Impact of Digital Electronics	Lack of mobility. These devices were large and could not be carried around.	The proposed design enhances mobility as the device is lightweight and can be carried around.
3	Simple reliable Microcontroller based pulse counter device	Prone to errors No form of alert by light indicator speaker when the heartbeat falls below or above a threshold value	Increased accuracy Alert system through text message indicating the current state of the patient
4	Wristband design	Skin colour and size matter. "The darker the skin, the more difficult it is for the PPG to shine a light through bodily tissues to record HR (Christina, 2018).	In the design, a fingerprint sensor will be utilized which is not limited by skin colour.
5	Yush 2015 Wrist heartbeat counter design	Noise can be easily introduced to the system by the muscle movement of the user. Inability to detect the difference between muscle movement and the actual pulse	The proposed device does not depend on muscle movement in the wrist as it is attached to the fingertips
6	40261C and seven-segment display heart rate sensor	It cannot display reading above 99 BPM	An LCD is utilised and not a seven-segment display unit thus higher rates will be displayed.

The research is significant because:

(a) This device uses an open-source programming software (Arduino Uno) which can be easily reprogrammed by connecting to a computer to make modifications and improvements.

(b) This research has enabled us to come up with a design in which operation will be simple and easy to handle, thus, people can monitor their heart rate and consequently, observe their health conditions without the intervention of skilled medical personnel.

(c) Since the device is cheap and portable compared to most smartwatches present today in the market, it is affordable to both sides of the financial class and can be easily carried around to conveniently meet the users' needs anywhere.

The major objective of this research is to design and produce a heartbeat pulse counter for medical applications. With this device, the heartbeat of patients is measured using sensors as analogue data, later it is converted into digital data using analogue to digital converter (ADC) which is suitable for wireless transmission using a GSM module.

2.0 MATERIALS AND METHODS

2.1 Design Concept of the Heartbeat Pulse Counter

This Project work presents a lot of considerations and improvements that were incorporated into the functionality of the device so as to reflect desired features such as cost, design complexity, size, software development, weight etc.

This design uses a miniaturized pulse sensor (IR sensor) which has been optimized for very accurate sensing and measurement of changes in the heartbeat rate. The system calculates the heartbeat rate in beat per minute (BPM) with the help of the microcontroller and displays the measured heart rate on a 16X2 character LCD. With small size and portability in mind, the choice of the LCD display and miniaturized sensor eliminates the need for a PC display, while making it easier to carry the system about, for continuous monitoring.

Another interesting feature of this particular design is the reprogrammable and open-source nature of the product, which makes it easier to re-specify the particular heart rate to watch out for, as well as play with the system parameters, to suit the users needs better. The introduction of the open-source Arduino board in this project makes it exceptionally unique and thus opens the door for greater exploration and maximization of its great flexibility features and the extent to which it can be implemented for a variety of functions.

The interaction between components is shown in Figure 3.

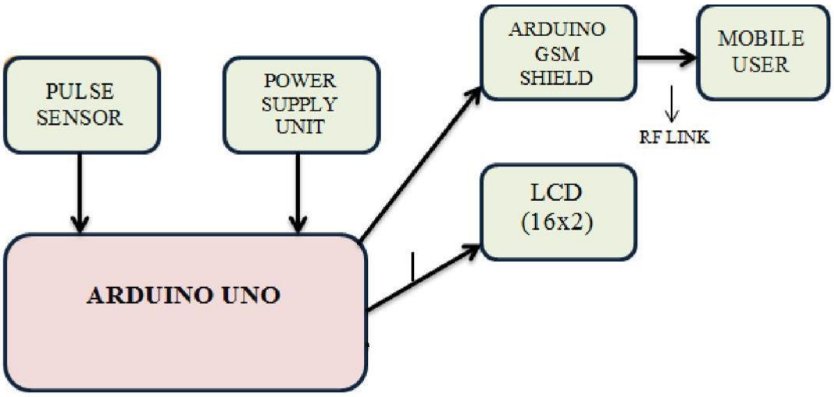

Figure 3. Interaction between input devices, output devices and microcontroller

2.2 Theory of Operation

In the operation of this device, the sensor is attached to the index finger of the right hand as positioning matters, make sure the hand is warm by rubbing against your palm or fabric and making sure the patient remains in a seated position.

The sensor is powered using the Vcc and the GND. A sensing probe will be attached to the patient’s finger with a spring-loaded clip or an adhesive band. On the front side of the probe is a pair of Light- Emitting Diodes (LEDs) and a photodiode and on the other side, there is a circuit responsible for signal amplification noise cancellation. The front side of the sensor is placed over a vane in our body (finger). This light will fall on the vein directly which will monitor the flow of blood and the heartbeat as well because if we can monitor the flow of blood we can monitor the heartbeat.

If the flow of blood is detected more light will be reflected by the blood, Received lights are analysed over time to determine our heartbeat. It is pertinent to note that a heartbeat range between 60 to 90 bpm is considered normal. Heartbeat rate outside this range indicated an abnormality.

2.3 Design Criteria

The Device produced met the following criteria both in aesthetics and functionality:

(1) The end-user
(2) The cost of production
(3) The economy of repair and maintenance/improvements
(4) Availability of energy source
(5) Ease of operation
(6) Durability and operation safety
(7) Efficiency and response

2.4 Design Analysis (Material Selection and Components Description)

The following components and units were utilized in the design of the Heartbeat pulse counter;

(1) Power Supply Unit
(2) Arduino UNO board
(3) The pulse sensor Unit
(4) LCD Display Unit
(5) LCM 1602 IIC
(6) Product case or compartment
(7) Soldering/Joining

In this device, the Arduino UNO serves as the microcontroller which is the brain of the device responsible for receiving data from required units and sending out information through another unit. All other units were connected to the Arduino UNO board by interfacing which will be discussed below. These components were connected to the Arduino UNO board by soldering and the aid of jumper cables and glues where necessary. This process of interfacing different components is shown in Figure 3.

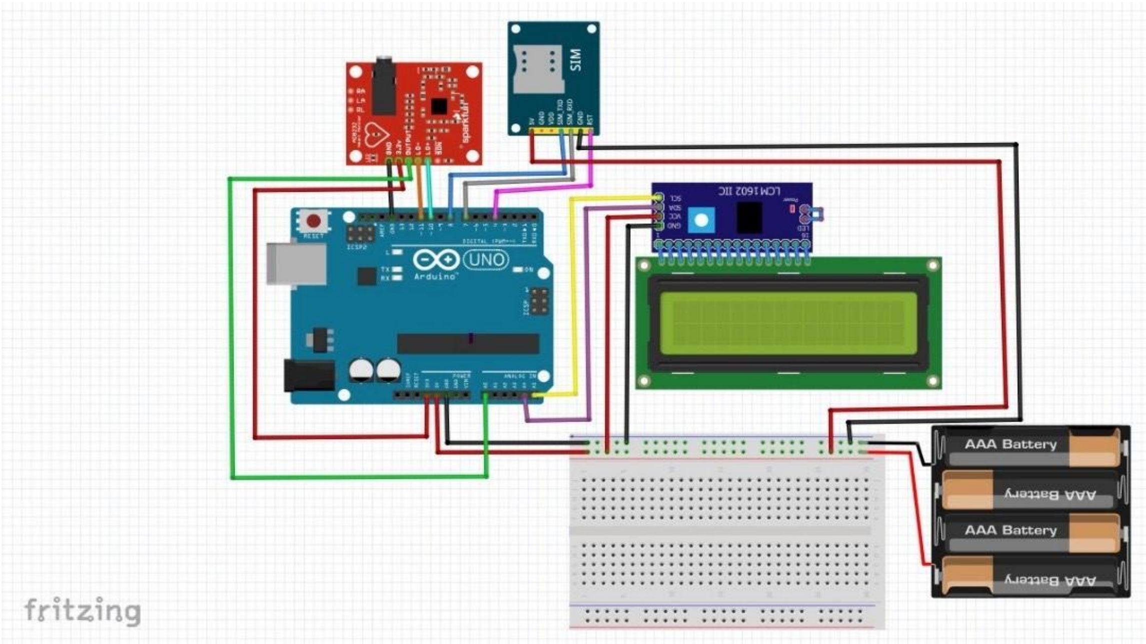

Figure 4. Interfacing All Components To The Microcontroller

The schematics of the designed system is shown in Figure 5

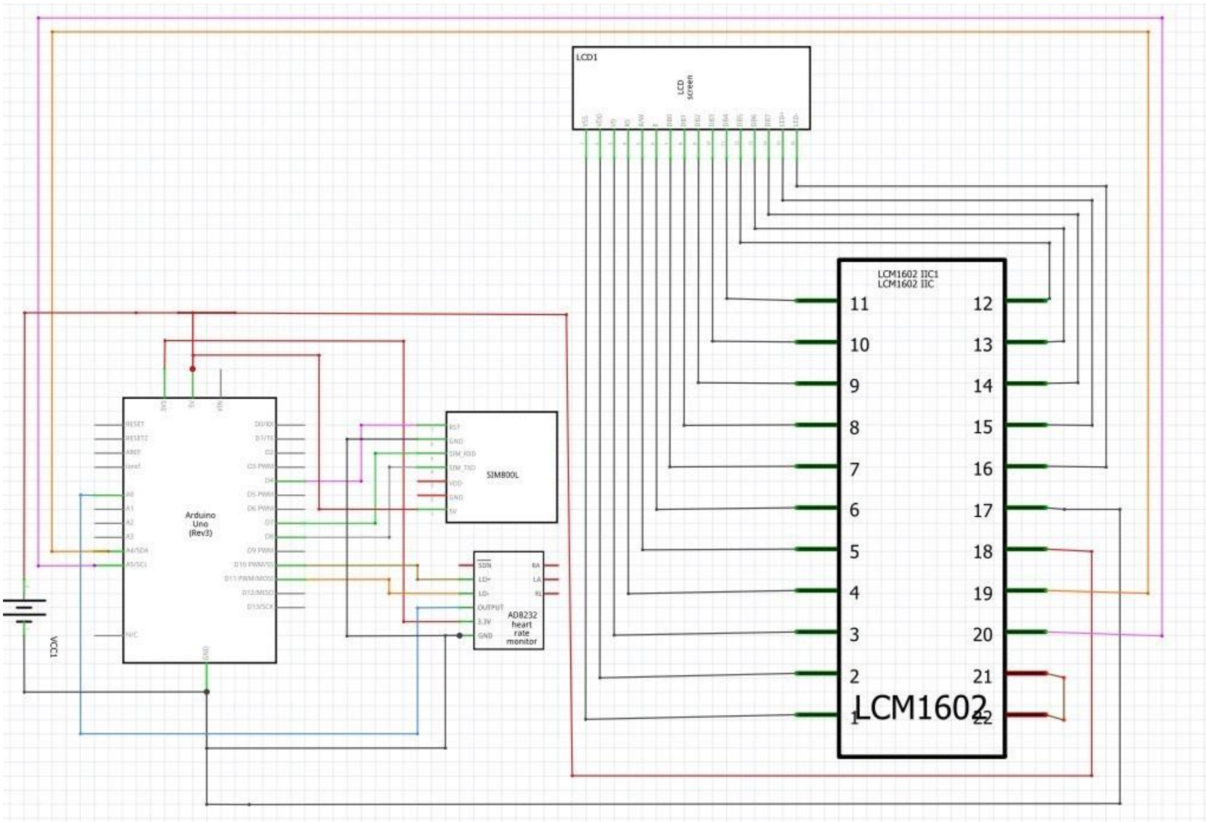

Figure 5. Schematics of Designed System

All individual components are described below as well as how they were interfaced with the microcontroller;

2.4.1 Power Supply Unit

The power supply source for this Device is a DC jack which supplies 4.2 Volts when fully charged. This powers the Arduino UNO board. Table 2 shows how the 5 Volts barrel jack was interfaced with the Arduino UNO;

Table 2. Interfacing The DC Barrel Jack With The Arduino UNO And GSM Module

BARREL JACK PINS	ARDUINO PINS
GND	GND
5V	Vin

2.4.2 Arduino UNO Board

Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. An ArduinoUNO board is shown in Figure 6

.

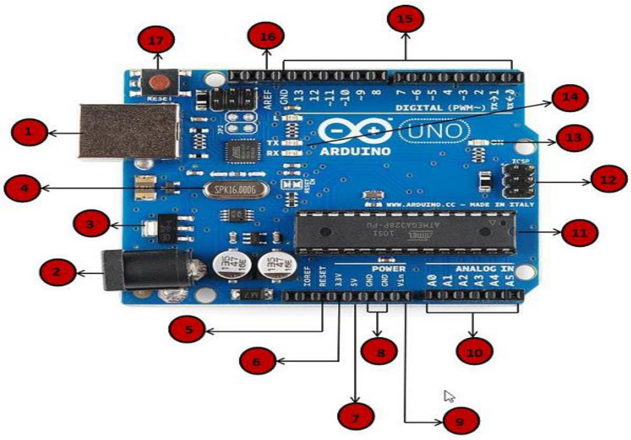

Figure 6. Arduino Uno Board[16]

2.4.3 The Pulse/Sensor Unit

A Heartbeat sensor is a monitoring device that allows one to measure his or her heart rate in real-time or record the heart rate for later study. It provides a simple way to study heart function. This sensor monitors the flow of blood through the finger and is designed to give a digital output of the heartbeat when a finger is placed on it. When the sensor is working, the beat LED flashes in unison with each heartbeat. This digital output can be connected to the microcontroller directly to measure the Beats per Minute (BPM) rate. It works on the principle of light modulation by blood flow through the finger at each pulse. The Pulse Sensor is a well-designed plug-and-play heart-rate sensor for Arduino. The front and back part of fingerprint sensor is shown in Figure 7a and Figure 7b.

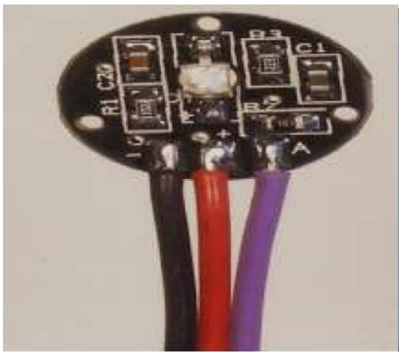

Figure 7a. Front Part Finger Pulse Sensor[17Figure 7b: Back Part of the Fingerprint[17] Sensor

This version incorporates amplification and noise cancellation circuitry into the hardware, making it much more reliable. Arduino watches the analogue signal from the pulse sensor, and a pulse is found when the signal rises above the midpoint, that's the moment when the capillary tissue gets slammed with a surge of fresh blood. When the signal drops below the midpoint, Arduino sees this and gets ready to find the next pulse. The finger sensor is interfaced with the ArduinoUNO as shown in Table 3.

Table 3. Interfacing The Finger Sensor and The Arduino Uno

FINGER SENSOR PINS	ARDUINO PINS
GND	GND
3.3V	3.3V
OUTPUT	A0
LC-	DIGITAL -11
LC+	DIGITAL -10

2.4.4 LCD Display Unit

Liquid Crystal Display (LCD) modules that display characters such as text and numbers are the cheapest and simplest to use of all LCDs. They can be purchased in various sizes, which are measured by the number of rows and columns of characters they can display. Any LCD with an HD44780- or KS0066-compatible interface is compatible with Arduino. A 16x2 LCD will be used, this means it can display 16 characters per line and there are 2 such lines. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. A typical 16X2 LCD display is shown in Figure 3.6 below and the pin configuration is shown in Table 4.

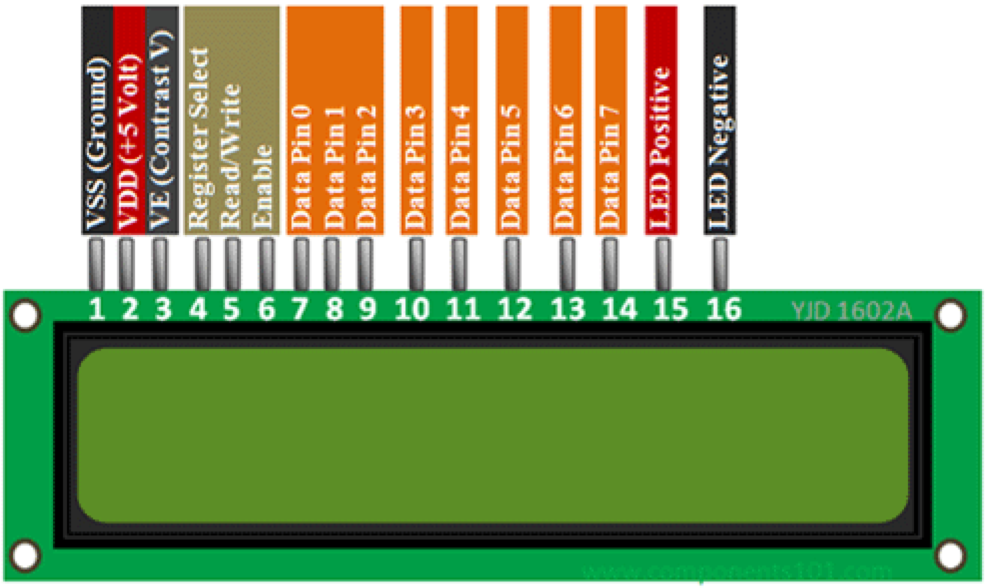

Figure 8. Lcd Display Unit [18]

The pin configuration is listed below:

Pin Configuration ForLcd Display Unit

Pin No:	Pin Name:	Description
(1)	Vss (Ground)	Ground pin connected to system ground
(2)	Vdd (+5 Volt)	Powers the LCD with +5V (4.7V – 5.3V)
(3)	VE (Contrast V)	Decide the contrast level of display. Grounded to get maximum contrast.
(4)	Register Select	Connected to Microcontroller to shift between command/data register

(5)	Read/Write	Used to read or write data. Normally grounded to write data to LCD
(6)	Enable	Connected to Microcontroller Pin and toggled between 1 and 0 for data acknowledgement
(7)	Data Pin 0	Data pins 0 to 7 form an 8-bit data line. They can be connected to Microcontroller to send 8-bit data. These LCD’s can also operate on the 4-bit mode in such cases Data pins 4,5,6 and 7 will be left free.
(8)	Data Pin 1	
(9)	Data Pin 2	
(10)	Data Pin 3	
(11)	Data Pin 4	
(12)	Data Pin 5	
(13)	Data Pin 6	
(14)	Data Pin 7	
(15)	LED Positive	Backlight LED pin positive terminal
(16)	LED Negative	Backlight LED pin negative terminal

2.4.5 LCM 1602 IIC

Arduino - LCD - I2C - LM1602 module, based on PCF8574 chip, allows to connect a popular 2x16, 4x20 or 2x8 LCD display to any microcontroller via the I2C bus. Thanks to such a connection, instead of 6 lines (D4, D5, D6, D7, E, RS), we will use only two. This will save valuable Arduino Uno outputs. We also don't have to connect a contrast adjustment potentiometer, because it is already on the board which will help in adjusting the backlight of the LCD. Figure 3.7 shows an LCM 1602 IIC;

Figure 9. LCM 1602 IIC[19]

All pins in the module will be connected to the LCD and the Module can easily be interfaced with arduino as shown in Table 4.

Table 4. Interfacing LCM 1602 IIC WithArduino

LCM 1602 IIC PINS	ARDUINO PINS
GND	GND
VCC	5V
SDA	A4
SCL	45

2.4.6 Producing The Compartment (Packaging)

The packaging was produced using a plastic material called PLA (Polylactic acid) which is a great material to use for 3D printing because it is easy to print and very inexpensive. Several factors led to the type of packaging adopted, which includes mechanical damage protection, moisture protection, portability, cost, convenience, etc. The compartment was produced using 3D printing following the steps below;

(1) Creating the design(blueprint of the compartment) using inventor professional: Figure 10, Figure 11 and Figure 12 show the isometric view of the compartment lid, isometric view of the compartment base, and the exploded view of the compartment respectively.

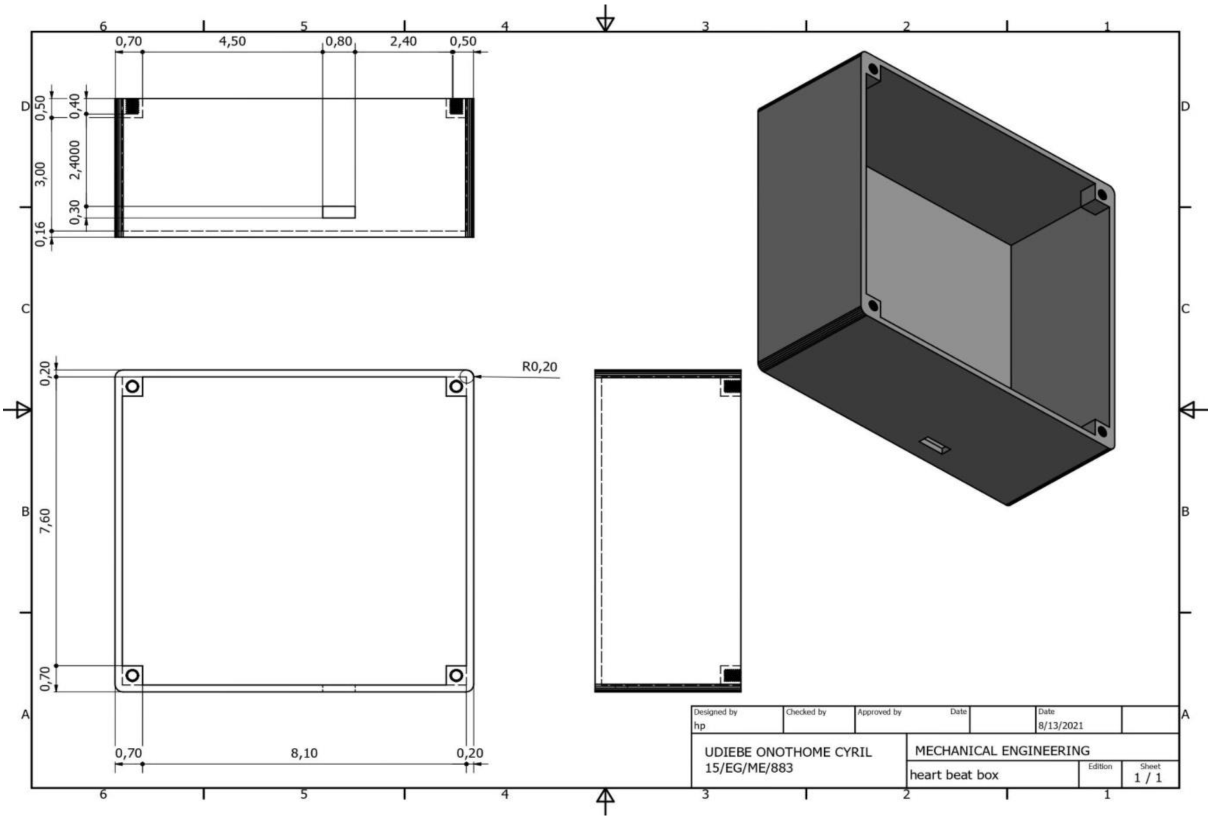

Figure 10. Isometric View of the Compartment Base

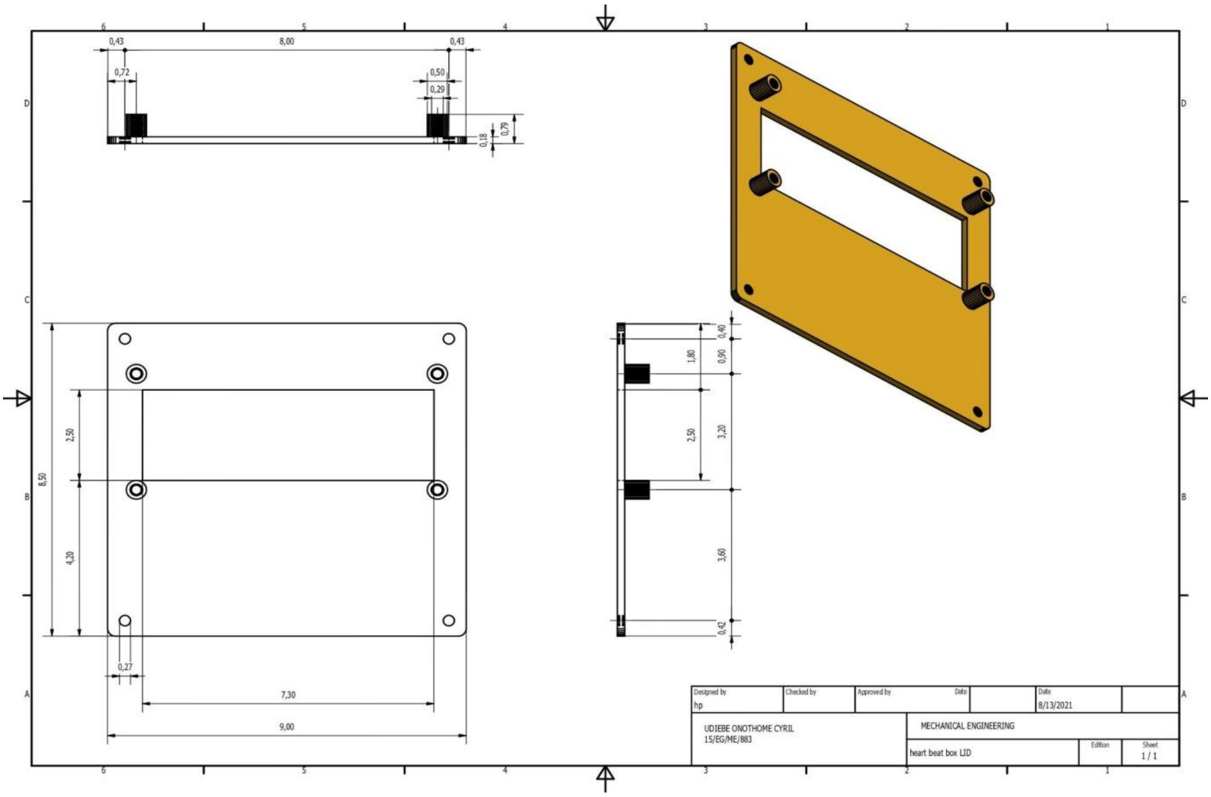

Figure 11. Isometric View of the Compartment Lid

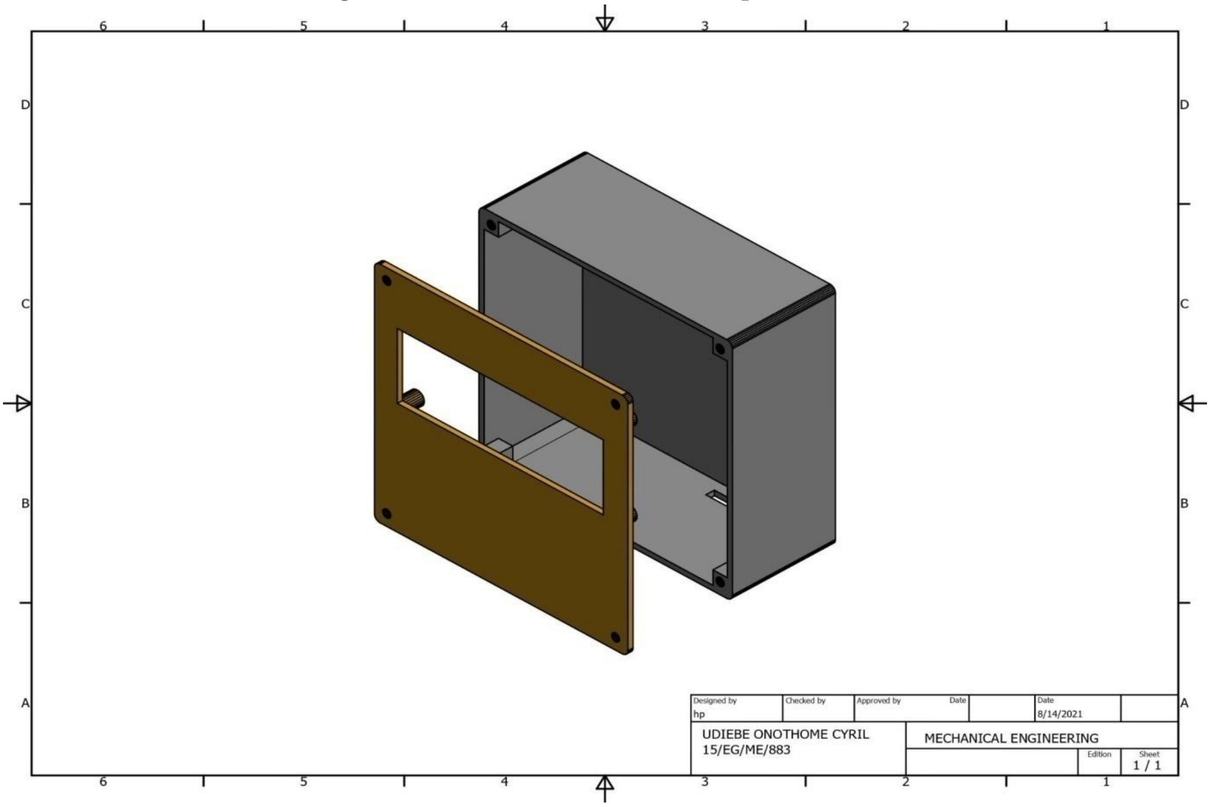

Figure 12. Exploded View of Compartment

(2) Sending the 3D design of the compartment to the printer

(3) collection of the 3D printed compartment.

2.4.7 Connection (Joining) Process

The components of the proposed system will be connected by soldering and using jumper wires where necessary.

2.5 Basic Principles, Mathematical Equations and Code Development

2.5.1 Mathematical Operation of the Pulse Sensor

The sensor system consists of a pair of light-emitting diodes which omit monochromatic red light at a wavelength of 660 nm and monochromatic infrared light which we cannot see because it is outside the visible spectrum of the wavelength of 940 nm.

Then there is a pair of photodiodesthat detect how much light of each wavelength was reflected back and convert this to an electrical signal. These senses are surrounded by an opaque case to minimise the ambient light signal as shown in Figure 13.

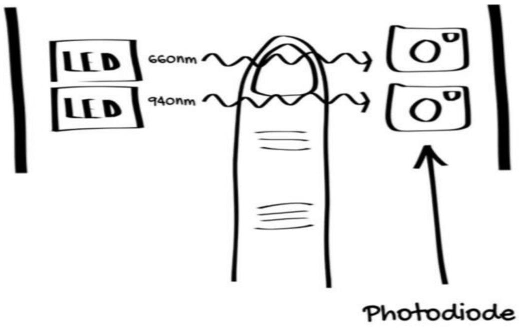

Figure 13. Diagrammatic Representation OfLed’s And Opaque Case

Periodic fluctuations in the received DC light on the receiver can be used very easily to estimate the heartbeat. Each heartbeat corresponds to an increase in brightness (red DC level) following a period of reduced brightness. If the number of peaks of DC light in a specific period of sampling is known, we can use this formula to get the heart rate, H_R;

$$H_R = N_{DC} x60 / S_p \qquad \text{Equation 1}$$

where N_{DC} is the Number of peaks in DC red level sampling in a sampling period

S_p is the sampling period

2.5.2 Arduino IDE (Heartbeat Pulse Counter Code Development)

The Arduino IDE was used to write the code which calculates the pulses received from the pulse sensor over a period of time and also sends commands to the 16X2 LCD display to display the result. The code below was used to activate these commands;

```
#define USE_ARDUINO_INTERRUPTS true    // Set-up low-level interrupts for most accurate BPM math
#include <PulseSensorPlayground.h>     // Includes the PulseSensorPlayground Library
#include <LiquidCrystal_I2C.h>

constintPulseWire = 0;       // 'S' Signal pin connected to A0
constint LED13 = 13;          // The on-board Arduino LED
int Threshold = 550;          // Determine which Signal to "count as a beat" and which to ignore

// Set the LCD address to 0x27 for a 16 chars and 2 line display
LiquidCrystal_I2C lcd(0x27, 16, 2);

PulseSensorPlaygroundpulseSensor;  // Creates an object

byte customChar1[8] = {0b00000, 0b00000, 0b00011, 0b00111, 0b01111, 0b01111, 0b01111, 0b01111};
byte customChar2[8] = {0b00000, 0b11000, 0b11100, 0b11110, 0b11111, 0b11111, 0b11111, 0b11111};
byte customChar3[8] = {0b00000, 0b00011, 0b00111, 0b01111, 0b11111, 0b11111, 0b11111, 0b11111};
byte customChar4[8] = {0b00000, 0b10000, 0b11000, 0b11100, 0b11110, 0b11110, 0b11110, 0b11110};
byte customChar5[8] = {0b00111, 0b00011, 0b00001, 0b00000, 0b00000, 0b00000, 0b00000, 0b00000};
byte customChar6[8] = {0b11111, 0b11111, 0b11111, 0b11111, 0b01111, 0b00111, 0b00011, 0b00001};
byte customChar7[8] = {0b11111, 0b11111, 0b11111, 0b11111, 0b11110, 0b11100, 0b11000, 0b10000};
byte customChar8[8] = {0b11100, 0b11000, 0b10000, 0b00000, 0b00000, 0b00000, 0b00000, 0b00000};
```

```
void setup() {
Serial.begin(9600);

// initialize the LCD
lcd.begin();

// Turn on the blacklight and print a message.
lcd.backlight();

lcd.createChar(1, customChar1);
lcd.createChar(2, customChar2);
lcd.createChar(3, customChar3);
lcd.createChar(4, customChar4);
lcd.createChar(5, customChar5);
lcd.createChar(6, customChar6);
lcd.createChar(7, customChar7);
lcd.createChar(8, customChar8);

// Configure the PulseSensor object, by assigning our variables to it
pulseSensor.analogInput(PulseWire);
pulseSensor.blinkOnPulse(LED13);       // Blink on-board LED with heartbeat
pulseSensor.setThreshold(Threshold);

// Double-check the "pulseSensor" object was created and began seeing a signal
if (pulseSensor.begin()) {
Serial.println("PulseSensor object created!");
}
}

void loop() {
intmyBPM = pulseSensor.getBeatsPerMinute();      // Calculates BPM

if (pulseSensor.sawStartOfBeat()) {              // Constantly test to see if a beat happened
Serial.println("♥  A HeartBeat Happened ! "); // If true, print a message
Serial.print("BPM: ");
Serial.println(myBPM);

// Print the BPM value
lcd.clear();
lcd.home();
lcd.setCursor(2, 0);
lcd.write(byte(1));
lcd.setCursor(3, 0);
lcd.write(byte(2));
lcd.setCursor(4, 0);
lcd.write(byte(3));
lcd.setCursor(5, 0);
lcd.write(byte(4));

lcd.setCursor(2, 1);
lcd.write(byte(5));
lcd.setCursor(3, 1);
lcd.write(byte(6));
lcd.setCursor(4, 1);
```

```
lcd.write(byte(7));
lcd.setCursor(5, 1);
lcd.write(byte(8));
lcd.setCursor(7, 1);
lcd.print(myBPM);
lcd.print(" BPM");
}
else
{
lcd.clear();
lcd.home();
lcd.print("No pulse is");
lcd.setCursor(2, 1);
lcd.print("detected");
}
delay(2000);
}
```

3.0 RESULTS AND DISCUSSION

3.1 Testing and Evaluation

The Device (Heartbeat Pulse Counter) senses and monitors the heartbeat rate whenever a fingertip is placed on the pulse sensor,the pulse sensor is a plug and play device which is detachable from the Arduino Uno board, the Arduino Uno receives and calculates this data and the result is displayed on the 16X2 LCD display based on the written codes. The Table 5shows the summary of the system.

Table 5. System Performances And Evaluation

S/N	TEST	OBSERVATION	RESULT
(1)	INITIAL DISPLAY	DISPLAY ‘ HEART BEST COUNTER ’	SYSTEM ON
(2)	FINGER PLACED ON THE SENSOR	DISPLAY A VALUE	HEARTBEAT RATE DETECTED
(4)	NORMAL PULSE RATE	DISPLAY A VALUE	NORMAL HEARTBEAT

4.0 CONCLUSION

A Heartbeat Pulse Counter for medical application was designed, produced and evaluated.

The device is simple to operate and thus can be used by both professionals and non-professionals. A simple pulse sensor was used which has good accuracy.Arduino Uno Board was used which served as the microcontroller/brain of the device. This makes the device easy to re-design and reprogram through the Arduino IDE. A 16X2 LCD Display Unit was used to display the pulse resultLCM 1602 IIC was utilised in interfacing the Arduino Uno and the 16X2 LCD display to eliminate the complexity in the connection.The following recommendations are hereby made for further studies for a better, improved and more efficient machine:

(i)An improved system can be made using a GSM module that sends text messages containing the heart rate of each individual.

(ii)A GSM module can be utilised but this time Cloud Hosting can be done with a one-time payment to eliminate the expense of text messages for better record purposes.

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