WIRELESS HEART RATE MONITOR

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BY

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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Date:

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To my parents and my friends

ABSTRACT

This work derives the heart pulse rate outputs by the principle of PhotoPlethysmography. Arduino Uno microprocessor used in calculation of the output pulse rate of the user. Results shows that the system build by Pulse Plugin v.1 sensor gives good BPM measurement. The practical analysis is done by a prototype of the system with Simple pulse sensor.

Key words: pulse rate output, Arduino Uno, Pulse Plugin v.1, Simple Pulse sensor.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

Through the past years, huge improvements were noticed in the world of technology and computerized systems. The medical industry had remarkable advances at the level of smaller packaging, multi functionality and lower cost. In the biomedical world, the most important specifications include ease of operation, portability, safety, and lower audible noise levels at an inexpensive cost.

Monitoring of the heart rate has been an integral part of medicine to both doctors and researchers since it forms useful indicator of physiological adaptation and intensity of effort.

Nowadays, hospitals, health centers and private clinics are in challenge to be equipped with the most improved technologies in the world of medical industries. They are looking forward to getting the best results with the least cost.

Since the use of needles in the usual process of measuring the pulses or the heart rate may be annoying to the patient, a need exists for a device that is mainly non-invasive and measures pulses in a much easier and at the same time accurate way. This device must be accurate, user friendly, safe, and easy to maintain.

1.2 Literature review

We researched similar projects and approaches to our design then summarized and evaluated the main points in this approaches .

Design and development of heart rate measuring device using fingertip :

In this project the author designed and developed a low powered HRM device that provides an accurate reading of the heart rate using optical technology.The device is ergonomic, portable, durable, and cost effective. He incorporated the optical technology using standard Light Emitting Diode (LED) and photo-sensor to measure the heart rate within seconds using index finger with a microcontroller that is programmed to count the pulse and then The heart rate is digitally displayed on an LCD controlled by the same microcontroller that counts the pulse.

(M.M.A. Hashem1 , Rushdi Shams2 , Md. Abdul Kader3 , and Md. Abu Sayed4 Department of Computer Science and Engineering Khulna University of Engineering & Technology (KUET) Khulna 9203, Bangladesh)

A Wearable pulse oximeter :

In this project the author implemented a design of a low-cost, portable and wearable pulse oximeter , The system consists of three main parts ,the optical sensor: consisting of the optical transmitter and receiver for emitting the light and receiving it and filter, the microcontroller: which receives and processes the signal to display the heart rate and blood’s oxygen saturation on an LCD display in real time; and mobile phone app which is designed to receive data wirelessly through Bluetooth.

(Fanpeng Kong , Yubo Qin , Zhengyu Yang , Zhongtian Lin . Captson Design – Rutgers university)

Polar s-720 heart rate monitor:

The author used a functional modern design, The Polar S720 includes a speed sensor, bike mount, built-in altimeter and thermometer. It measures heart rate at different exercises levels, and the average heart rate of total training.[1]

1.3 Aims of project

In the previous years , many people has been suffering from chronic heart complications that may affect their daily life routines and put them in a need for a 24/7 heart monitoring .that’s indicates our main aim which is to provide a portable device so the patient can continue his or her daily activities without worrying about the monitoring process . Now days there is a lot of portable heart monitoring devices but some of these devices are complicated and requires someone with a background to use it , so one of our project aims is to make the device as easy and simple for the patient to use without any complications . We also aim to provide a small and a very lite device so the patient can carry it without worrying him/her.So basically our main aims is to provide a portable , small , lit , and accurate heart rate monitor to help the patients with chronic cardiac diseases monitoring their heart rate in an easy , simple and quick way .

1.4 Thesis overview

In this report , The first chapter generally talks about the design and the aims of it, its main components, production share among the world .The second chapter will discuss the physiology of the heart and the heart rate , its importance , effects and its problems .In the third chapter we will go to the structure of the design , its components , methods and its methodologies .The fourth chapter will include the result of the project , the limitations we faced and our future aspects to improve the design .

CHAPTER 2

HEART RATE

2.1 Heart rate

Heart rate is the speed of the heartbeat measured by the number of contractions of the heart per minute (bpm). The heart rate can vary according to the body's physical needs, including the need to absorb oxygen and excrete carbon dioxide. It is usually equal or close to the pulse measured at any peripheral point.

The normal resting adult human heart rate ranges from 60–100 bpm. Tachycardia is a fast heart rate, defined as above 100 bpm at rest. Bradycardia is a slow heart rate, defined as below 60 bpm at rest. During sleep a slow heartbeat with rates around 40–50 bpm is common and is considered normal. When the heart is not beating in a regular pattern, this is referred to as an arrhythmia. Abnormalities of heart rate sometimes indicate disease.

2.2 Physiology of the heart

While heart rhythm is regulated entirely by the sinoatrial node under normal conditions, heart rate is regulated bysympathetic and parasympathetic input to the sinoatrial node. The accelerans nerve provides sympathetic input to the heart by releasing norepinephrine onto the cells of the sinoatrial node (SA node), and the vagus nerve provides parasympathetic input to the heart by releasing acetylcholine onto sinoatrial node cells. Therefore, stimulation of the accelerans nerve increases heart rate, while stimulation of the vagus nerve decreases it.

Due to individuals having a constant blood volume, one of the physiological ways to deliver more oxygen to an organ is to increase heart rate to permit blood to pass by the organ more often. Normal resting heart rates range from 60–100 bpm. Bradycardia is defined as a resting heart rate below 60 bpm. However, heart rates from 50 to 60 bpm are common among healthy people and do not necessarily require special attention. Tachycardia is defined as a resting heart rate above 100 bpm, though persistent rest rates between 80–100 bpm, mainly if they are present during sleep, may be signs of hyperthyroidism or anemia .

The heart rate is rhythmically generated by the sinoatrial node. It is also influenced by central factors through sympathetic and parasympathetic nerves. Nervous influence over the heartrate is centralized within the two paired cardiovascular centres of the medulla oblongata. The cardioaccelerator regions stimulate activity via sympathetic stimulation of the cardioaccelerator nerves, and the cardioinhibitory centers decrease heart activity via parasympathetic stimulation as one component of the vagus nerve. During rest, both centers provide slight stimulation to the heart, contributing to autonomic tone. This is a similar concept to tone in skeletal muscles. Normally, vagal stimulation predominates as, left unregulated, the SA node would initiate a sinus rhythm of approximately 100 bpm.

The cardiovascular centres receive input from a series of visceral receptors with impulses traveling through visceral sensory fibers within the vagus and sympathetic nerves via the cardiac plexus. Among these receptors are various proprioreceptors, baroreceptors, and chemoreceptors, plus stimuli from the limbic system which normally enable the precise regulation of heart function, via cardiac reflexes. Increased physical activity results in increased rates of firing by various proprioreceptors located in muscles, joint capsules, and tendons. The cardiovascular centres monitor these increased rates of firing, suppressing parasympathetic stimulation or increasing sympathetic stimulation as needed in order to increase blood flow.

Factors influencing heart rate

Table 1: Major factors increasing heart rate and force of contraction

Factor	Effect
Cardioaccelerator nerves	Release of norepinephrine
Proprioreceptors	Increased rates of firing during exercise
Chemoreceptors	Decreased levels of O_2; increased levels of H^+, CO_2, and lactic acid
Baroreceptors	Decreased rates of firing, indicating falling blood volume/pressure
Limbic system	Anticipation of physical exercise or strong emotions
Catecholamines	Increased epinephrine and norepinephrine
Thyroid hormones	Increased T3 and T4
Calcium	Increased Ca^{2+}
Potassium	Decreased K^+

Table 2: Factors decreasing heart rate and force of contraction	
Factor	**Effect**
Cardioinhibitor nerves (vagus)	Release of acetylcholine
Proprioreceptors	Decreased rates of firing following exercise
Chemoreceptors	Increased levels of O_2; decreased levels of H^+ and CO_2
Baroreceptors	Increased rates of firing, indicating higher blood volume/pressure
Limbic system	Anticipation of relaxation
Catecholamines	Decreased epinephrine and norepinephrine
Thyroid hormones	Decreased T3 and T4
Calcium	Decreased Ca^{2+}
Potassium	Increased K^+
Sodium	Decreased Na^+
Body temperature	Decrease in body temperature

2.3 Heart rate in different circumstances

Heart rate is not a stable value and it increases or decreases in response to the body's need in a way to maintain an equilibrium (basal metabolic rate) between requirement and delivery of oxygen and nutrients. The normal SA node firing rate is affected by autonomic nervous system activity: sympathetic stimulation increases and parasympathetic stimulation decreases the firing rate. A number of different metrics are used to describe heart rate.

The basal or resting heart rate (HR_{rest}) is defined as the heart rate when a person is awake, in a neutrally temperate environment, and has not been subject to any recent exertion or stimulation, such as stress or surprise. The typical resting heart rate in adults is 60–100 beats per minute (bpm). This is the firing rate of the heart's sinoatrial node, where the faster pacemaker cells driving the self-generated rhythmic firing and responsible for the heart's autorhythmicity are located. For endurance athletes at the elite level, it is not unusual to have a resting heart rate between 33 and 50 bpm.

For healthy people, the *Target Heart Rate* or *Training Heart Rate* (THR) is a desired range of heart rate reached during aerobic exercise which enables one's heart and lungs to receive the most benefit from a workout. This theoretical range varies based mostly on age; however, a person's physical condition, sex, and previous training also are used in the calculation. Below are two ways to calculate one's THR. In each of these methods, there is an element called "intensity" which is expressed as a percentage. The THR can be calculated as a range of 65–85% intensity. The *maximum heart rate* (HR_{max}) is the highest heart rate an individual can achieve without severe problems through exercise stress, and generally decreases with age. Since HR_{max} varies by individual, the most accurate way of measuring any single person's HR_{max} is via a cardiac stress test.

CHAPTER 3

PROPOSED SYSTEM

3.1 Microprocessor

The Microprocessor is the main piece in our design that controls the other parts and do all of the necessary calculations in the measurement .Here we used Arduino Uno microprocessor with a 9v battery as a power supply , so will be no need for further wire connections with the PC .The Arduino is connected with the Pulse sensor , when the sensor detect the user's live heart beat , it will be transmitted to the Arduino to calculate the BPM. The codes used to compute the heart rate and connect the Arduino board with the display is shown below :

3.2 Pulse sensor

Easy Pulse Plugin is an open-source pulse sensor based on the principle of photoplethysmography (PPG), which is a non-invasive technique of measuring the cardiovascular pulse wave by detecting blood volume changes in the blood vessels close to the skin. This sensor applies the principle of PPG to the tip of a finger using an infrared light emitting diode (IR-LED) and a photodetector. Easy Pulse Plugin provides all necessary instrumentation and amplification on board to retrive a filtered cardiovascular pulse signal from the photodetector output. The power supply and output pins of Easy Pulse Plugin are accessed through standard 0.1" male header pins. They are arranged in an Arduino-friendly fashion so that it can be directly plugged into the left female headers of Arduino Uno (or any other compatible) board for easy interfacing. It operates at both 5.0V and 3.3V, and is also breadboard-friendly to work with other platforms.

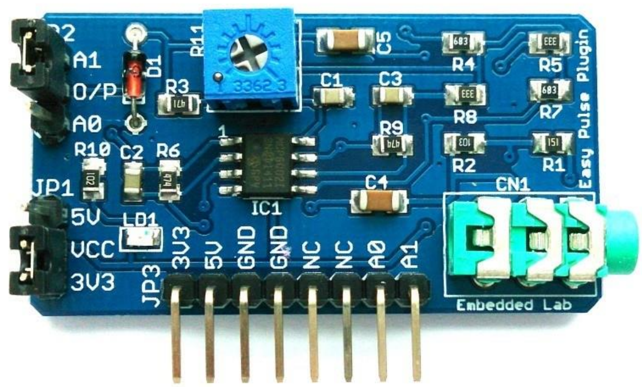
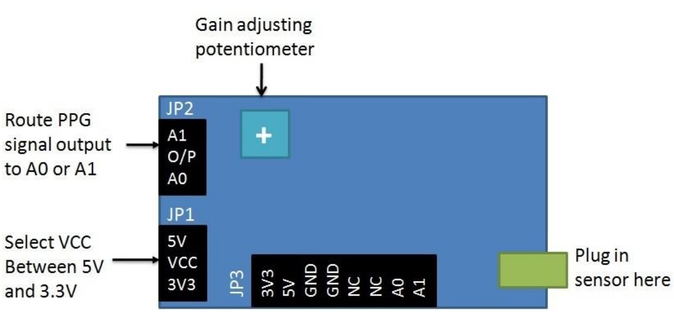


Figure 1: Easy Pulse Plugin V.1

The details of the headers and their functions are described below.



JP3 headers pin name	Function
3V3	3.3V input power supply
5V	5.0V input power supply
GND	Power supply ground
GND	Power supply ground
NC	Connected to nothing
NC	Connected to nothing
A0	PPG output appears at this pin if JP2 is at A0 position
A1	PPG output appears at this pin if JP2 is at A1 position

Figure 2: Pulse Plugin Ports

When the heart pumps blood through the body, with every beat there is a pulse wave that travels along all arteries to the very extremities of capillary tissue where the

Pulse Sensor is attached. Actual blood circulates in the body much slower than the pulse wave travels. A rapid upward rise in signal value occurs as the pulse wave passes under the sensor, then the signal falls back down toward the normal point. the dicroic notch (downward spike) is more pronounced than others, but generally the signal settles down to background noise before the next pulse wave washes through. Since the wave is repeating and predictable, we could choose almost any recognizable feature as a reference point, say the peak, and measure the heart rate by doing math on the time between each peak. This can run into false readings from the dicroic notch, if present, and may be susceptible to inaccuracy from baseline noise as well .

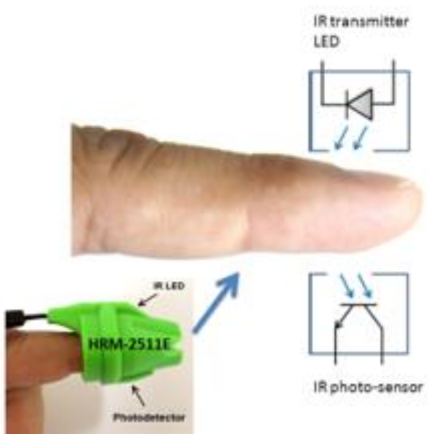


Figure 3: Internal Components of The Sensor

The pulse detector is consist of a photo-detector to measure once heart rate through the change of the blood reflectivity on the index finger .When the heart beat occurs the blood vessels will undergo a volume change because of the increased blood flow inside of the vessels , The first photo-detector will transmit a light signal with a fixed angle and frequency. it will collide with the vessels and because of the volume change in the blood vessels the light signal will be reflected in a different angle and frequency to be detected by a second photo-detector to transmit it to the microprocessor.

3.3 Bluetooth hc-05 module

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup.Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Bluecore 04-External single chip Bluetooth system with CMOS technology and with AFH(Adaptive Frequency Hopping Feature). It has the footprint as small as 12.7mmx27mm. Hope it will simplify your overall design/development cycle.In our design the Bluetooth HC-05 is an interface between the microprocessor and the PC , it allows the Arduino to be connected to the PC via Bluetooth signals . So after the measurement is done the result will be transmitted to the PC without any wire connections .

Connections between the Arduino and the HC-05 Module :

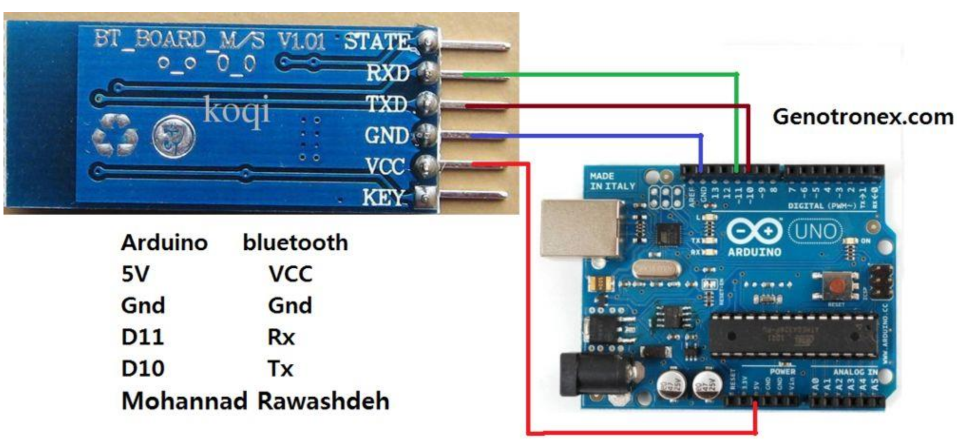


Figure 4: Connections between Arduino and Bluetooth

3.4 Display system

In our design we're using a PC to show the result of the measurement , but in fact any electronic device with a Bluetooth terminal Software can be used as a display device. The Bluetooth terminal software is a program that uses serial connection between the PC and any external device via Bluetooth to sends and receives data . in our design we used "Tera Term" software for serial connection .

Figure 5: Tera Term Software

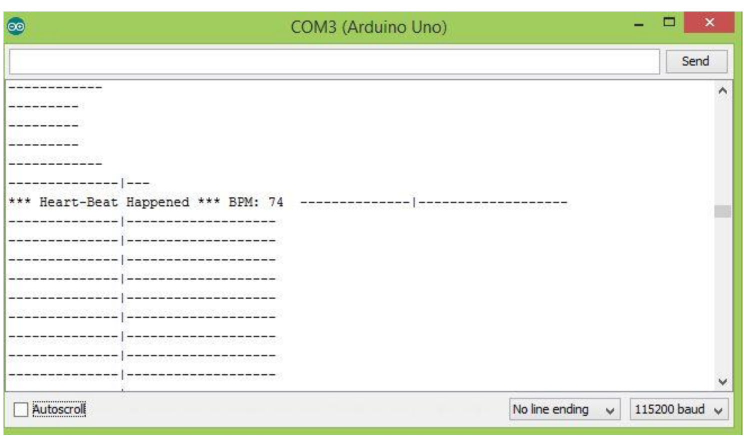


Figure 6: Measured result shown on a pc screeen

CHAPTER 4

SYSTEM PERFORMANCE

4.1 Evaluation and Limitations

- The first Design included a simple pulse sensor that caused the inaccuracy in the measurement
- Only random bpm values appeared on the display device
- In the second device we replaced the sensor with the Easy Pulse Plugin module.
- The final result was a continuous series of digital BPM values that appears on the PC screen with a good accuracy

4.2 Future aspects

The high standards of modern technology, especially in the biomedical field, made the different producers in a continuous race to provide the best. These high international standards include the use of minor devices, portable, and at a competing price. From here, though we are glad to perform our simple device, we look forward to enhance its specifications including:

- Adding additional parameters to the design , like measuring the O2 saturation level in the blood .
- The ability to detect any kind of abnormalities in the heart rate and the use of modern software to give possible diagnosis.
- Adding alarms for indications at abnormal recordings.
- Use of a software that can be easily modified in order to display all signals and with capabilities to extract more features from the signals.

CONCLUSION

We were able to Modify the device by replacing the pulse sensor with the Easy Pulse Plugin module and improving the codes to result in a better measurement accuracy and an overall device performance. The device is completely portable with an acceptable size. The device is user friendly , could be used without any complexity.

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APPENDIX

```
#include <SoftwareSerial.h>// import the serial library

SoftwareSerial Genotronex(10, 11); // RX, TX

int ledpin=12; // led on D13 will show blink on / off

int BluetoothData; // the data given from Computer

#define Sampling_Time 5

#define Num_Samples 600

#define Peak_Threshold_Factor 85

#define Minimum_Range 500

#define Minimum_Peak_Separation 75  // 75*5=375 ms

#define DC_Added 10;

#define Moving_Average_Num 5




int ADC_Samples[Num_Samples], Index1, Index2, Index3, Peak1, Peak2, Peak3;

long Pulse_Rate, Temp1=1L, Pulse_Time1, Pulse_Time2;

int Peak_Magnitude, Peak_Threshold, Minima, Range;

void setup(){

Genotronex.begin(9600);
```

```
 }
void loop() {
 Read_ADC_Samples();
  Genotronex.println("Sample Read Finished ");
  Remove_DC();
  Genotronex.println("DC component subtracted ");
  Scale_Data();
  Genotronex.println("Data scaled ");
  if (Range > Minimum_Range){  // ADC range is > 70, otherwise increase gain
    Filter_Data();
    Genotronex.println("Data Filtered ");
    Compute_Pulse_Rate();
    Genotronex.println("Pulse rate computed ");
  }
  else{
    Genotronex.println ("Error No Pulse Found") ;
  }
}  // Main Loop
    // Read ADC samples at a predefined interval
 void Read_ADC_Samples(){
   for (int i = 0; i < Num_Samples; i++){
     ADC_Samples[i] = analogRead(A0);
     delay(Sampling_Time);
```

```
  }
 }


 void Remove_DC(){
   Find_Minima(0);
   Genotronex.println("Minima = ");
   Genotronex.println(Minima);
   // Subtract DC (minima)
   for (int i = 0; i < Num_Samples; i++){
     ADC_Samples[i] = ADC_Samples[i] - Minima;
   }
   Minima = 0;  // New minima is zero
 }  // Remove_DC
void Find_Minima(int Num){
  Minima = 1024;
  for (int m = Num; m < Num_Samples-Num; m++){
      if(Minima > ADC_Samples[m]){
         Minima = ADC_Samples[m];
      }
  }
}  // Find_Minima
void Scale_Data(){
```

```
  // Find peak value
  Find_Peak(0);
  Genotronex.println("Peak = ");
  Genotronex.println(Peak_Magnitude);
  Genotronex.println("Minima = ");
  Genotronex.println(Minima);
  Range = Peak_Magnitude - Minima;
  Genotronex.println("Range = ");



  Genotronex.println(Range);
  // Sclae from 1 to 1023
  for (int i = 0; i < Num_Samples; i++){
    ADC_Samples[i] = map(ADC_Samples[i], 0, Range, 1, 1023);

  }
  Find_Peak(0);
  Find_Minima(0);
  Genotronex.println("Scaled Peak = ");
  Genotronex.println(Peak_Magnitude);
  Genotronex.println("Scaled Minima = ");
  Genotronex.println(Minima);
} // Scale_Data
```

```
void Find_Peak(int Num){
 Peak_Magnitude = 0;
 for (int m = Num; m < Num_Samples-Num; m++){
   if(Peak_Magnitude < ADC_Samples[m]){
     Peak_Magnitude = ADC_Samples[m];
   }
 }
} // Find_Peak
void Filter_Data(){
 int Num_Points = 2*Moving_Average_Num+1;
 for (int i = Moving_Average_Num; i < Num_Samples-Moving_Average_Num; i++){
  int Sum_Points = 0;



  for(int k =0; k < Num_Points; k++){
   Sum_Points = Sum_Points + ADC_Samples[i-Moving_Average_Num+k];
  }
  ADC_Samples[i] = Sum_Points/Num_Points;
 }
}  // Filter_Date
void Compute_Pulse_Rate(){
 // Detect Peak magnitude and minima
 Find_Peak(Moving_Average_Num);
```

```
Find_Minima(Moving_Average_Num);

Range = Peak_Magnitude - Minima;

Peak_Threshold = Peak_Magnitude*Peak_Threshold_Factor;

Peak_Threshold = Peak_Threshold/100;

// Now detect three peaks

Peak1 = 0;

Peak2 = 0;

Peak3 = 0;

Index1 = 0;

Index2 = 0;

Index3 = 0;

// Find first peak

for (int j = Moving_Average_Num; j < Num_Samples-Moving_Average_Num; j++){

  if(ADC_Samples[j] >= ADC_Samples[j-1] && ADC_Samples[j] > ADC_Samples[j+1] &&

    ADC_Samples[j] > Peak_Threshold && Peak1 == 0){

   Peak1 = ADC_Samples[j];

   Index1 = j;

  }

// Search for second peak which is at least 10 sample time far

  if(Peak1 > 0 && j > (Index1+Minimum_Peak_Separation) && Peak2 == 0){
```

```
    if(ADC_Samples[j] >= ADC_Samples[j-1] && ADC_Samples[j] > ADC_Samples[j+1] &&
    ADC_Samples[j] > Peak_Threshold){
    Peak2 = ADC_Samples[j];
    Index2 = j;
    }
  } // Peak1 > 0

  // Search for the third peak which is at least 10 sample time far
  if(Peak2 > 0 && j > (Index2+Minimum_Peak_Separation) && Peak3 == 0){
    if(ADC_Samples[j] >= ADC_Samples[j-1] && ADC_Samples[j] > ADC_Samples[j+1] &&
    ADC_Samples[j] > Peak_Threshold){
      Peak3 = ADC_Samples[j];
      Index3 = j;
    }
  } // Peak2 > 0

}
Genotronex.println("Index1 = ");
Genotronex.println(Index1);
Genotronex.println("Index2 = ");
Genotronex.println(Index2);
Genotronex.println("Index3 = ");
Genotronex.println(Index3);
```

```
 Pulse_Time1 = (Index2-Index1)*Sampling_Time; // In milliseconds

Pulse_Time2 = (Index3-Index2)*Sampling_Time;


if(Pulse_Time1 > 0 && Pulse_Time1 > 0){

  Pulse_Rate = 2*60000/(Pulse_Time1+Pulse_Time2); // In BPM

}

Genotronex.println("Pulse Rate (BPM) = ");

Genotronex.println(Pulse_Rate);

if (Genotronex.available()){

BluetoothData=Genotronex.read();

 if(BluetoothData=='1'){   // if number 1 pressed ....

 digitalWrite(ledpin,1);

 Genotronex.println("LED  On D12 ON ! ");

 }

if (BluetoothData=='0'){// if number 0 pressed ....

digitalWrite(ledpin,0);

 Genotronex.println("LED  On D12 Off ! ");

}

}

delay(20000);                          //  take a break

}


// Compute_Pulse_Rate
```