

## Topic 04: Measuring Biomedical Signal

### A. Measuring Heart Rate by Finger

Sensor: Grove - Finger-clip Heart Rate Sensor with shell

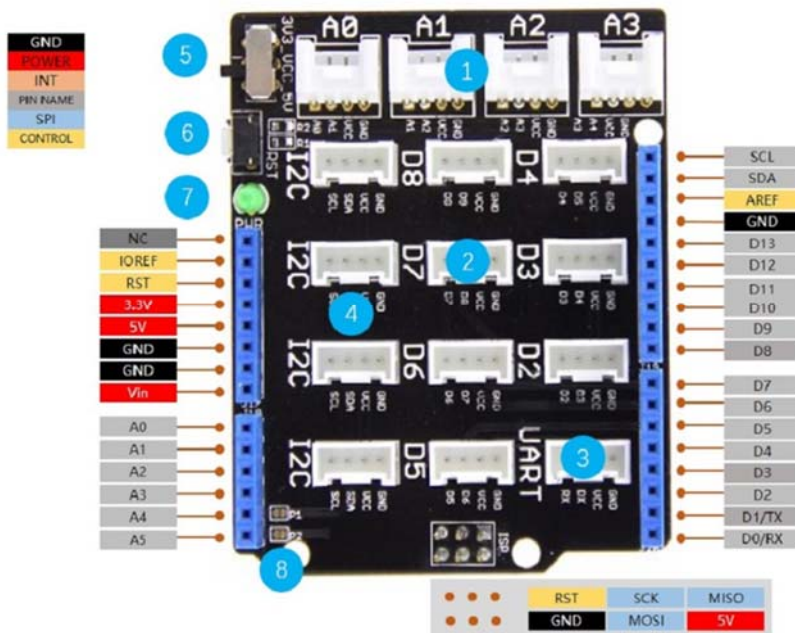
Grove – 帶有外殼的指夾式心率傳感器基於 PAH8001EI-2G，這是一款高性能低功耗 CMOS 工藝光學傳感器，集成了綠色LED 和 DSP，可用作心律檢測（HRD）傳感器。該模組基於光學技術，用於測量血管中人體血液運動的變化。低功耗和靈活的省電模式使其適用於可穿戴設備。

#### Specification

- Working Voltage: 5V
- SWD Interface
- Control Mode: IIC (I<sup>2</sup>C)
- Operating Temperature: -20 ~ +60°C

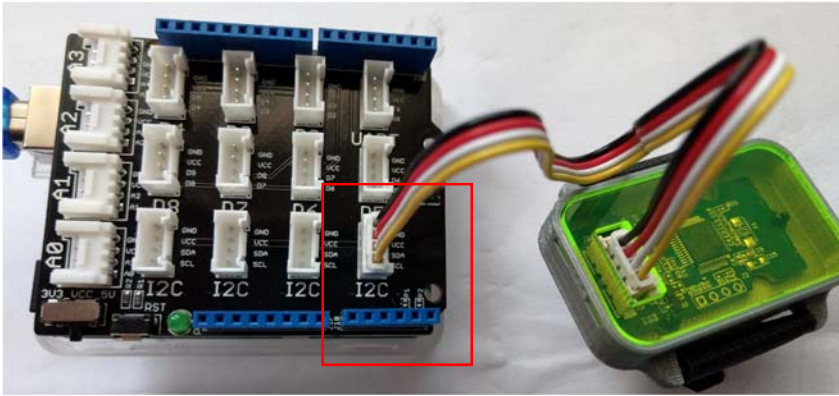


Base Shield V2([http://wiki.seeedstudio.com/Base\\_Shield\\_V2/](http://wiki.seeedstudio.com/Base_Shield_V2/))



- 1-Analog Ports: include 4 analog ports, A0, A1, A2 and A3.
- 2-Digital Ports: include 7 digital ports, D2, D3, D4, D5, D6, D7 and D8.
- 3-UART Port: 1 UART port.
- 4-I2C Ports: 4 I2C ports.
- 5-Power Switch: when using Arduino UNO with Base Shield v2, please turn the switch to 5v position; While using Seeeduino Arch with Base Shield v2, please turn the switch to 3.3v.
- 6-Reset Buton: reset the arduino board.
- 7-PWR LED : The Green LED turns on when power on.
- 8-P1, P2 : please solder the pads P1 and P2 • if use Base Shield v2 with Seeeduino V3.
- Dimension: 2.1 \* 2.7 inch

請準備好程式碼，先編譯好，再接上 **Arduino** 與 **sensor** 後上傳程式，若有錯誤，請先拔除 **PC** 上 **USB** 接 **Arduino** 與 **sensor**，再檢查程式碼！



Ex4\_1 FingerHR ([http://wiki.seeedstudio.com/Grove-Finger-clip\\_Heart\\_Rate\\_Sensor\\_with\\_shell/](http://wiki.seeedstudio.com/Grove-Finger-clip_Heart_Rate_Sensor_with_shell/))

// It may take about a minute to get valid heart rate after you touch your finger with sensor.

```
#include <Wire.h>
```

```
byte hr;
```

```
void setup() {
```

```
    Serial.begin(9600);
```

```
    Serial.println("heart rate sensor:");
```

```
    Wire.begin();
```

```
}
```

```
void loop() {
```

```
    Wire.requestFrom(0xA0 >> 1, 1);
```

```
// request 1 bytes from slave device
```

```
    if(Wire.available()) {
```

```
// slave may send less than requested
```

```
        hr = Wire.read();
```

```
// receive heart rate value (a byte)
```

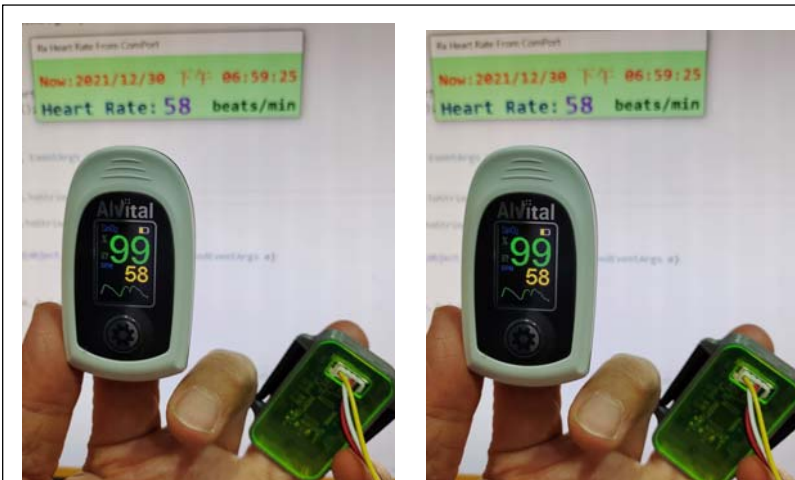
```
        Serial.println(hr);
```

```
// print heart rate value
```

```
    }
```

```
    delay(1000);
```

```
}
```



Rx Heart Rate From ComPort

2021/12/30 下午 07:12:44

Heart Rate: 56 beats/min

- Assign COM Port
- Configure COM Port
- Start Rx
- Stop Rx
- Exit

COMPortForm

Get Ports

COM3

OK

Serial Port Configuration

Baud Rate : 9600

Data Bit: 8

Parity: None

Stop Bit: One

DTR : ☒ On ☐ Off

RTS : ☒ On ☐ Off

Receive/Send Buffer Size : 8192

Update Com Port

- Assign COM Port
- Configure COM Port
- Start Rx
- Stop Rx
- Exit

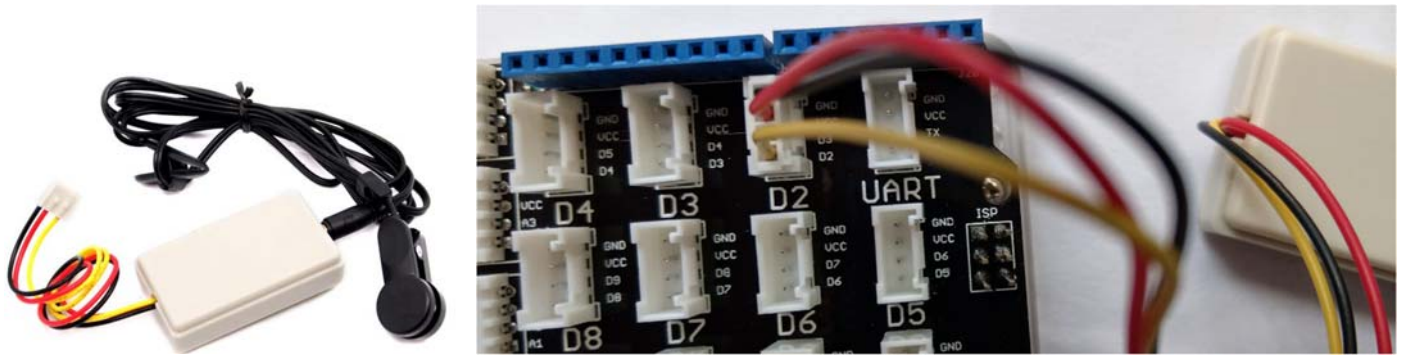
Rx Heart Rate From ComPort

Now: 2021/12/30 下午 07:12:44

Heart Rate: 56 beats/min

## B. Measuring Heart Rate by Ear

Sensor: Grove - Ear-clip Heart Rate Sensor with shell



Grove – Ear-clip Heart Rate Sensor 耳夾式心率感測套件包含一個耳夾和一個接收器模組。心率測量套件可用於監測患者和運動員的心率

Ex4\_2 EarHR([http://wiki.seeedstudio.com/Grove-Ear-clip\\_Heart\\_Rate\\_Sensor/](http://wiki.seeedstudio.com/Grove-Ear-clip_Heart_Rate_Sensor/))

```
/*Function: This program can be used to measure heart rate, the lowest pulse in the program be set to
30. Use an external interrupt to measure it.*/
#define LED 13//indicator
boolean led_state = LOW;//state of LED, each time an external interrupt will change the state of LED
unsigned char counter;
unsigned long temp[21];
unsigned long sub;
bool data_effect=true;
unsigned int heart_rate;//the measurement result of heart rate
const int max_heartpluse_duty = 2000;
//you can change it follow your system's request.
//2000 means 2 seconds. System return error if the duty overtrip 2-sec.
void setup()
{
    pinMode(LED, OUTPUT);
    Serial.begin(9600);
    Serial.println("Please ready your device.");
    delay(5000);
    arrayInit();
    Serial.println("Heart rate test begin.");
    attachInterrupt(0, interrupt, RISING);//set interrupt 0,digital port 2
}
void loop()
{
    digitalWrite(LED, led_state);//Update the state of the indicator
}
```

```

void sum()
{
  // calculate the heart rate
  if(data_effect)
  {
    heart_rate=1200000/(temp[20]-temp[0]); //60*20*1000/20_total_time
    Serial.print("Heart_rate_is:\t");
    Serial.println(heart_rate);
  }
  data_effect=1; //sign bit
}

void interrupt()
{
  // Interrupt service routine. Get the signal from the external interrupt
  temp[counter]=millis();
  //Serial.println(counter,DEC);
  //Serial.println(temp[counter]);
  switch(counter)
  {
    case 0:
      sub=temp[counter]-temp[20];
      //Serial.println(sub);
      break;
    default:
      sub=temp[counter]-temp[counter-1];
      //Serial.println(sub);
      break;
  }
  if(sub>max_heartpluse_duty) //set 2 seconds as max heart plus duty
  {
    data_effect=0; //sign bit
    counter=0;
    Serial.println("Heart rate measure error, test will restart!");
    arrayInit();
  }
  if (counter==20 && data_effect)
  {
    counter=0;
    sum();
  }
  else if(counter!=20 && data_effect)
    counter++;
  else
  {
    counter=0;
    data_effect=1;
  }
}

void arrayInit()
{
  // Initialization for the array(temp)
  for(unsigned char i=0; i<20; i++)
    temp[i]=0;
  temp[20]=millis();
}

```

Rx Heart Rate From ComPort

Now: 2021/12/30 下午 06:52:27  
Heart Rate: 54 beats/min

```

COM4
Please ready your device.
Heart rate test begin.
Heart rate measure error, test will restart!
Heart rate measure error, test will restart!
Heart_rate_is: 62
Heart_rate_is: 62
Heart_rate_is: 63
Heart_rate_is: 65
Heart_rate_is: 63
Heart_rate_is: 63
Heart_rate_is: 67
Heart_rate_is: 64

```



## C. Measuring Heart Rate & SpO2

Sensor: MAX30100

MAX30100 脈搏血氧儀 是一款集成脈搏血氧儀和心率監測傳感器解決方案。它結合了兩個LED，一個光電探測器，優化的光學系統和低噪聲模擬信號處理，以檢測脈搏血氧飽和度和心率信號。MAX30100採用1.8V和3.3V電源供電。

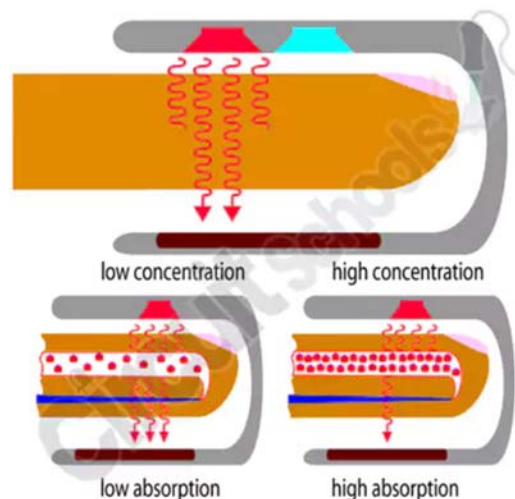
The MAX30100 is a **Pulse Oximetry** and heart rate monitor sensor solution. It combines two **LEDs**, a **photodetector**, **optimized optics**, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals. You can use this sensor with any microcontroller like Arduino, **ESP8266**, or **ESP32** and easily measure the patient's health parameters.

### What is Pulse Oximeter and how do they work?

Pulse Oximeter is a device used to measure the amount of oxygen present in the blood.


### Principle of Pulse Oximeters

According to biology oxygenated blood **absorbs more infrared light** and **passes red light** through it than deoxygenated blood. So by using these principle Pulse oximeters are equipped with **one Infrared** and **red light** LEDs together which **emit them** to know the passage of infrared and red lights.

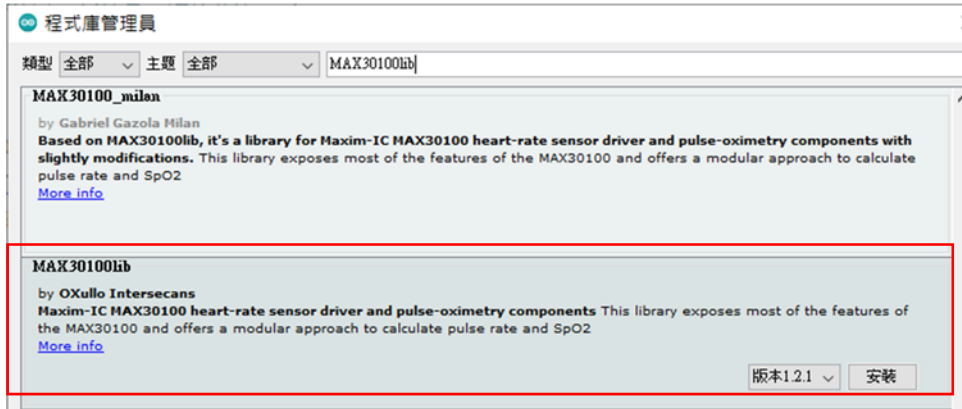


When the heart **pumps** blood the oxygenated blood in the body **increases** and when the heart **relaxes** the oxygenated blood **decreases**, with the help of sensors the time difference between the increase and decrease in the volume of oxygen in blood is calculated, which is nothing but **Pulse rate**.

## Ex.4\_3 Heart Rate & SpO2 by MAX30100

	Arduino的	模塊引腳
	5V	VIN
	GND	GND
	SDA A4	SDA
	SCL A5	SCL

Installing Library (<https://github.com/oxullo/Arduino-MAX30100>)



```
#include <Wire.h>
#include "MAX30100_PulseOximeter.h"
/* MAX30100_PulseOximeter.h"找到多個程式庫
已使用: F:\MCU_Demos\MCU_HealthSignal\111\libraries\MAX30100_milan
未使用: F:\MCU_Demos\MCU_HealthSignal\111\libraries\Arduino-MAX30100*/
#define REPORTING_PERIOD_MS      1000
```

```
PulseOximeter pox;
uint32_t tsLastReport = 0;
```

```
void onBeatDetected()
{
    Serial.println("Beat!");
}
```

```
void setup()
{
    Serial.begin(115200);
    Serial.print("Initializing pulse oximeter...");
```

```
// Initialize the PulseOximeter instance
//Failures are generally due to an improper I2C wiring, missing power
//supply or wrong target chip
if (!pox.begin()) {
    Serial.println("FAILED");
```

```
Initializing pulse oximeter..SUCCESS
HR: 0 bpm, SpO2: 0 %
HR: 0 bpm, SpO2: 0 %
Beat!
HR: 37 bpm, SpO2: 0 %
Beat!
HR: 47 bpm, SpO2: 0 %
Beat!
HR: 53 bpm, SpO2: 100 %
Beat!
HR: 55 bpm, SpO2: 100 %
Beat!
HR: 57 bpm, SpO2: 100 %
Beat!
HR: 55 bpm, SpO2: 97 %
Beat!
HR: 56 bpm, SpO2: 97 %
Beat!
HR: 56 bpm, SpO2: 97 %
```

```

        for(;;);
    } else {
        Serial.println("SUCCESS");
    }
    pox.setIRLedCurrent(MAX30100_LED_CURR_7_6MA);

    // Register a callback for the beat detection
    pox.setOnBeatDetectedCallback(onBeatDetected);
}
char bufHR[30],bufSpO2[20];
int hr,spo2;
void loop()
{
    // Make sure to call update as fast as possible
    pox.update();
    if (millis() - tsLastReport > REPORTING_PERIOD_MS) {
        hr=(int)pox.getHeartRate();
        spo2=pox.getSpO2();
        if (spo2 >100)
            spo2=100;
        sprintf(bufHR,"HR: %d bpm",hr);
        Serial.print(bufHR);
        Serial.print(", ");
        sprintf(bufSpO2,"SpO2: %d %%",spo2);
        Serial.print(bufSpO2);
        Serial.print("\n");
        tsLastReport = millis();
    }
}

```



## Ex.4\_3R Display SpO2 & Heart Rate on OLED (testMAX30100\_OLED2)

```
#include <Wire.h>
#include "MAX30100_PulseOximeter.h"
#include <Arduino.h>
#include <U8x8lib.h> // Comes from U8g2
#ifdef U8X8_HAVE_HW_SPI
#include <SPI.h>
#else
#include <SoftwareSerial.h>
#endif

#define REPORTING_PERIOD_MS 1000
U8X8_SH1106_128X64_NONAME_HW_I2C u8x8(/* reset= */ U8X8_PIN_NONE);

PulseOximeter pox;

uint32_t tsLastReport = 0;

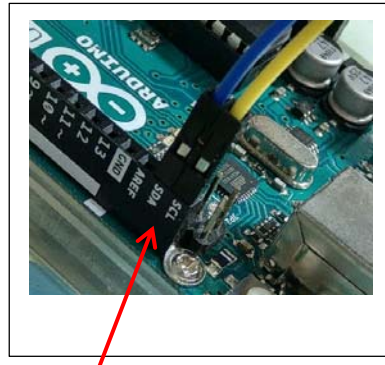
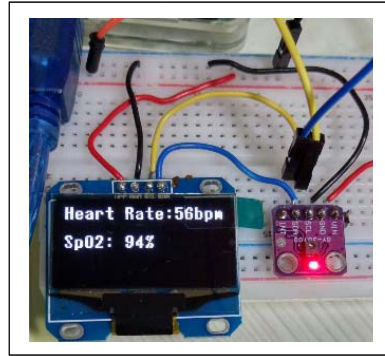
// Callback (registered below) fired when a pulse is detected
void onBeatDetected()
{
    Serial.println("Beat!");
}

void setup()
{
    Serial.begin(115200);
    u8x8.begin();
    u8x8.setPowerSave(0);
    u8x8.clearDisplay();
    //u8x8.setFont(u8x8_font_chroma48medium8_r); // small font
    u8x8.setFont(u8x8_font_7x14B_1x2_f);
    //u8x8.setFont(u8x8_font_courB18_2x3_f); // disturbs SPO2 calculating
    Serial.print("Initializing pulse oximeter..");

    if (!pox.begin()) {
        Serial.println("FAILED");
        u8x8.drawString(0,0,"SPO2 ");
        u8x8.drawString(1,1,"Sensor Fail!");
        delay(2000);
        for(;;);
    }
    else {
        Serial.println("SUCCESS");
    }

    pox.setIRLedCurrent(MAX30100_LED_CURR_7_6MA); // Must have this statement
    // Register a callback for the beat detection
    pox.setOnBeatDetectedCallback(onBeatDetected);
}

int hr, spo2, i=0;
void loop()
{
    // Make sure to call update as fast as possible
    pox.update();
    // Asynchronously dump heart rate and oxidation levels to the serial
```



```

// For both, a value of 0 means "invalid"
if (millis() - tsLastReport > REPORTING_PERIOD_MS) {
    hr=(int)(pox.getHeartRate()+0.5);
    spo2=pox.getSpO2();
    if ((spo2 <=100 && spo2 >= 90) || i<10)
    {
        Serial.print("Heart rate:");
        Serial.print(hr);
        Serial.print("bpm / SpO2:");
        Serial.print(spo2);
        Serial.println("%");

        u8x8.clearDisplay();
        u8x8.drawString(0,0,"Heart Rate:");
        u8x8.setCursor(11,0);
        u8x8.print(hr);
        u8x8.drawString(13,0,"bpm");
        u8x8.drawString(0,3,"SpO2: ");
        u8x8.setCursor(6,3);
        u8x8.print(spo2);
        u8x8.drawString(8,3,"%");
    }
    i++;
    tsLastReport = millis();
}
}

```

## Ex.4\_3I2C\_Scanning Scanning address of I2C device

//Step.1 先接Sensor: Grove - Finger-clip Heart Rate Sensor with shell

```
// Arduino I2C Scanner Re-written by Arbi Abdul Jabbaar
// Using Arduino IDE 1.8.7. Using GY-87 module for the target
// Tested on 10 September 2019
// This sketch tests the standard 7-bit addresses
// Devices with higher bit address might not be seen properly.
#include <Wire.h>
void setup()
{
  Wire.begin(); // Wire communication begin
  Serial.begin(9600); // The baudrate of Serial monitor is set in 9600
  while (!Serial); // Waiting for Serial Monitor
  Serial.println("\nI2C Scanner");
}
void loop()
{
  byte error, address; //variable for error and I2C address
  int nDevices;
  Serial.println("Scanning...");
  nDevices = 0;
  for (address = 1; address < 127; address++ )
  {
    // The i2c_scanner uses the return value of the Write.endTransmission to
    see if
    // a device did acknowledge to the address.
    Wire.beginTransmission(address);
    error = Wire.endTransmission();
    if (error == 0)
    {
      Serial.print("I2C device found at address 0x");
      if (address < 16)
        Serial.print("0");
      Serial.print(address, HEX);
      Serial.println(" !");
      nDevices++;
    }
    else if (error == 4)
    {
      Serial.print("Unknown error at address 0x");
      if (address < 16)
        Serial.print("0");
      Serial.println(address, HEX);
    }
  }
  if (nDevices == 0)
    Serial.println("No I2C devices found\n");
  else
    Serial.println("done\n");

  delay(5000); // wait 5 seconds for the next I2C scan
}
```

```
//接Sensor: Grove - Finger-clip
Heart //Rate Sensor with shell
I2C Scanner
Scanning...
I2C device found at address
0x50 !
done

Step.2 再接上 OLED (1.3")
I2C Scanner
Scanning...
I2C device found at address
0x3C !
I2C device found at address
0x50 ! (Max30100:0x57)
done
```

## D. Measuring ECG (可參考: <https://www.youtube.com/watch?v=rF0FB5S7Jhw>)

Sensor: AD8232 心律監測感測器模組測量脈搏 ECG Kit 心跳心電感測器

AD8232是一款用於ECG及其他生物電測量應用的集成信號調理模組。該器件設計用於在具有運動或遠端電極放置產生的雜訊的情況下提取、放大及過濾微弱的生物電信號。

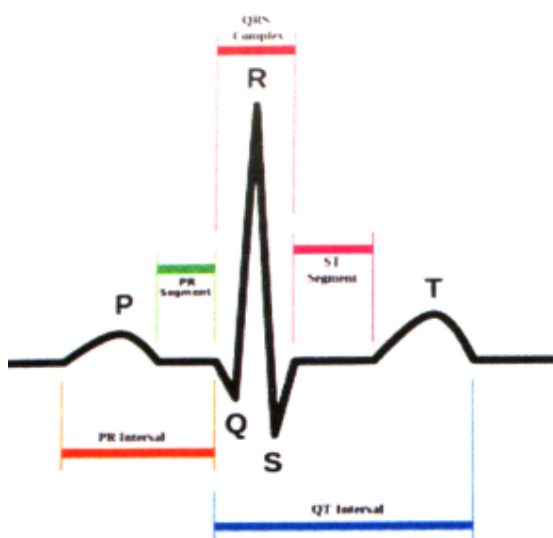
(下列文字參考來源: 飆機器人教材)

### 心電圖\_心電圖工作原理

ECG的工作原理為，當每次心跳心肌細胞去極化的時候會在皮膚表面引起很小的電學改變，這個小變化被心電圖記錄裝置捕捉並放大即可描繪心電圖。在心肌細胞處於靜息狀態時，心肌細胞膜兩側存在由正負離子濃度差形成的電勢差，去極化即是心肌細胞電勢差迅速向0變化，並引起心肌細胞收縮的過程。在健康心臟的一個心動周期中，由竇房結細胞產生的去極化波有序的依次在心臟中傳播，先傳播到整個心房，經過「內在傳到通路」傳播至心室。如果在心臟的任意兩面放置2個電極，那麼在這個過程中就可以記錄到兩個電極間微小的電壓變化，並可以在心電圖紙或者監視器上顯示出來。



### 心電圖與其波形的意義



P波:心房去極化，正常小於 0.12 秒

QRS波:心室去極化，正常不超過 0.11 秒

T波:心室再極化

U波:心室內 Purkinje fiber 的再極化

PR interval:

A.評估心房至心室間的傳導速度

B.正常值約 0.12 - 0.20 秒

ST segment:

A.心臟早期的再極化

B.ST segment 位置(高低)較長短來得重要

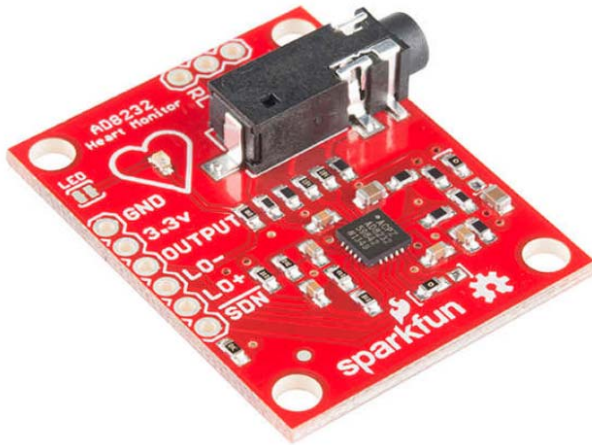
C.正常在  $\pm 1$  mm 之間

QT interval:

A.代表整個心縮期的電位變化

B.與心跳速率有關

Sensor: AD8232 Heart Rate (<https://learn.sparkfun.com/>)



Break Away Headers - Straight  
PRT-00116

A row of headers - break to fit. 40 pins that can be cut to any size.



Sensor Cable - Electrode Pads (3 connector)  
CAB-12970

This is your simple three conductor sensor cable with electrode pad



Biomedical Sensor Pad (10 pack)  
SEN-12969

This is a 10 pack of Biomedical Sensor Pads,

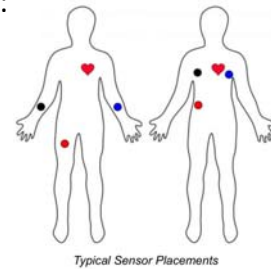
接線:

We'll connect five of the nine pins on the board to your Arduino. The five pins you need are labeled **GND**, **3.3v**, **OUTPUT**, **LO-**, and **LO+**.

Board Label	Pin Function	Arduino Connection
<b>GND</b>	Ground	<b>GND</b>
<b>3.3v</b>	3.3v Power Supply	<b>3.3v</b>
<b>OUTPUT</b>	Output Signal	<b>A0</b>
<b>LO-</b>	Leads-off Detect -	<b>11</b>
<b>LO+</b>	Leads-off Detect +	<b>10</b>
<b>SDN</b>	Shutdown	<b>Not used</b>



貼片位置:



Ex4\_4 ECG (ASCII)

/\*Demo Program for AD8232 Heart Rate sensor. [https://github.com/sparkfun/AD8232\\_Heart\\_Rate\\_Monitor](https://github.com/sparkfun/AD8232_Heart_Rate_Monitor)

The AD8232 Heart Rate sensor is a low cost EKG/ECG sensor.

This example shows how to create an ECG with real time display. \*/

void setup() { // initialize the serial communication:

Serial.begin(9600);

pinMode(10, INPUT); // Setup for leads off detection LO + 10

pinMode(11, INPUT); // Setup for leads off detection LO - 11

}

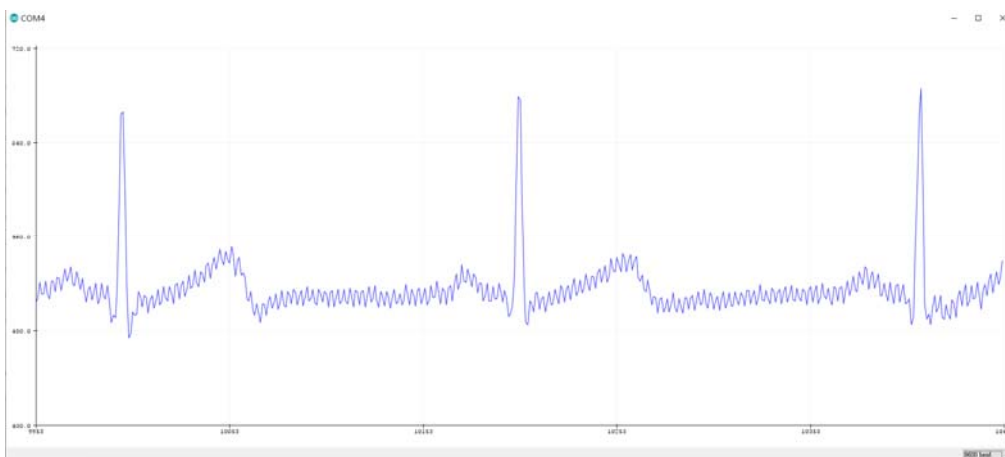
void loop() {

if((digitalRead(10) != 1)&&(digitalRead(11) != 1))

Serial.println(analogRead(A0));

delay(4); //Wait for a bit to keep serial data from saturating

}



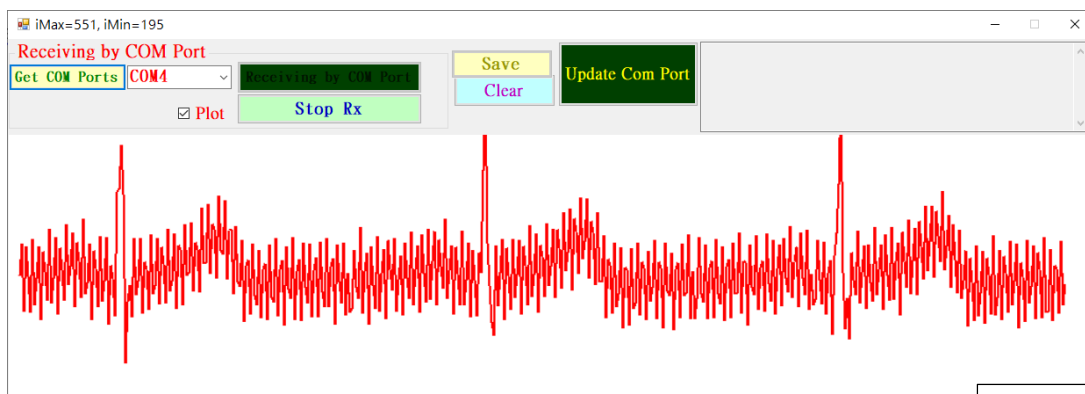


Ex4\_4A\_PackedECG

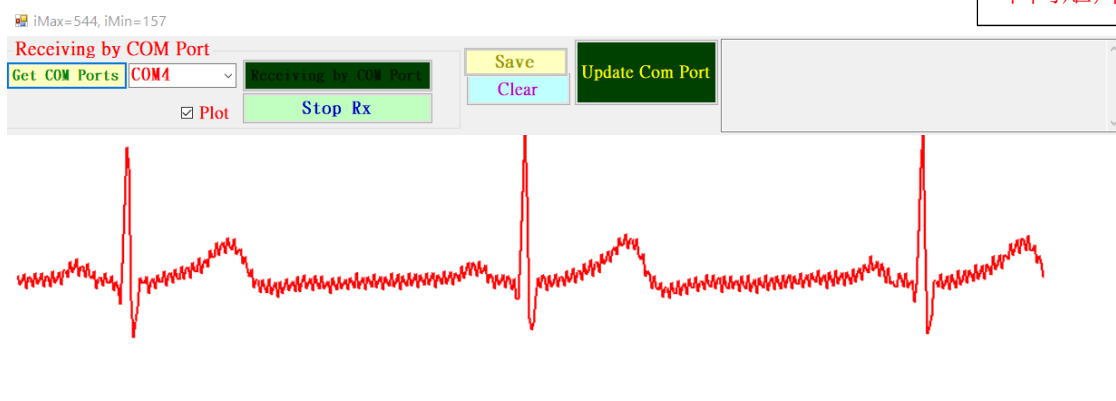
```
byte data[]={0xFF, 0xFF, 0, 0, 0xFE, 0xFE};
int iECG;

void setup() { // initialize the serial communication:
  Serial.begin(9600);
  pinMode(10, INPUT); // Setup for leads off detection LO + 10
  pinMode(11, INPUT); // Setup for leads off detection LO - 11
}

void loop() {
  if((digitalRead(10) != 1)&&(digitalRead(11) != 1))
  {
    //Serial.println(analogRead(A0));
    iECG = analogRead(A0);
    data[2]=(byte)( iECG &0xFF);          //Low byte
    data[3]=(byte)(( iECG &0x0300)>>8);    //Hight byte
    Serial.write(255);
    Serial.write(255);
    Serial.write(data[2]);
    Serial.write(data[3]);
    Serial.write(254);
    Serial.write(254);
  }
  delay(4); //Wait for a bit to keep serial data from saturating
}
```



不同贴片





## Ex.4\_4 PC\_RxPackedData6Plot



```
10 using System.IO.Ports;
11 using System.IO;
12 using mySerialPort;
13 using myTools;
14 namespace PC_RxPackedData6Plot
15 {
16     3 個參考
17     public partial class RxForm1 : Form
18     {
19         delegate void dispG();
20         dispG DispG;
21         int iStart, iEnd, len;
22         byte[] buf;
23         List<byte> raw;
24         int i;
25         PortConfigForm setupComPort;
26         int val;
27         myWaveBMP myWave;
28         Image img;
29         1 個參考
30         private void serialPortR_DataReceived(object sender, SerialDataReceivedEventArgs e) ...
31         1 個參考
32         /* private void displayG() ...
33         1 個參考
34         private void displayG() ...
35         2 個參考
36         private void getAllPorts() ...
37         1 個參考
38         public RxForm1() ...
39         1 個參考
40         private void btnUpdateComR_Click(object sender, EventArgs e) ...
41         1 個參考
42         private void RxForm1_Load(object sender, EventArgs e) ...
43         1 個參考
44         private void timer1_Tick(object sender, EventArgs e) ...
45         1 個參考
46         private void btnGetPorts_Click(object sender, EventArgs e) ...
47         1 個參考
48         private void btnStart_Click(object sender, EventArgs e) ...
49         1 個參考
50         private void btnStop_Click(object sender, EventArgs e) ...
51         1 個參考
52         private void btnSave_Click(object sender, EventArgs e) ...
53         1 個參考
54     }
55 }
```

```

28 private void serialPortR_DataReceived(object sender, SerialDataReceivedEventArgs e)
29 {
30     if (!btnStart.Enabled && serialPortR.BytesToRead > 0)
31     {
32         len = serialPortR.Read(buf, 0, buf.Length);
33         for (i = 0; i < len; i++)
34             raw.Add(buf[i]);
35         BeginInvoke(DispG, new Object[] { });
36     }
37 }
38 /*private void displayG()
39 { //for sine-wave with 1-byte
40     iEnd = raw.Count - 1;
41     while (iStart <= iEnd)
42     {
43         val = raw[iStart++];
44         myWave.update(val);
45     }
46     if (img != null)
47     {
48         img.Dispose();
49         img = null;
50     }
51     img = myWave.getBMP();
52     pictureBox1.Image = img;
53     //pictureBox1.Update();
54 }*/

55 private void displayG()
56 { //for ECG with 6-byte, test by Ex3_6Wave_byteTimer_6Bytes
57     iEnd = raw.Count - 1;
58     while (iStart <= iEnd-5)
59     {
60         if (raw[iStart]==255 && raw[iStart+1] == 255 && raw[iStart+4] == 254 && raw[iStart+5] == 254)
61         {
62             val = raw[iStart+3]*256+ raw[iStart + 2];
63             myWave.update(val);
64             iStart += 5;
65         }
66         iStart++;
67     }
68     if (img != null)
69     {
70         img.Dispose();
71         img = null;
72     }
73     img = myWave.getBMP();
74     pictureBox1.Image = img;
75     //pictureBox1.Update();
76 }

77 private void getAllPorts()
78 {
79     cmbBxPortR.Items.Clear();
80     string[] ports = SerialPort.GetPortNames();
81     Array.Sort(ports);
82     foreach (string port in ports)
83         cmbBxPortR.Items.Add(port);
84     cmbBxPortR.SelectedIndex = cmbBxPortR.Items.Count - 1;
85     btnStart.Enabled = true;
86     serialPortR.PortName = cmbBxPortR.SelectedItem.ToString();
87 }

88 public RxForm1()
89 {
90     InitializeComponent();
91 }

```

```

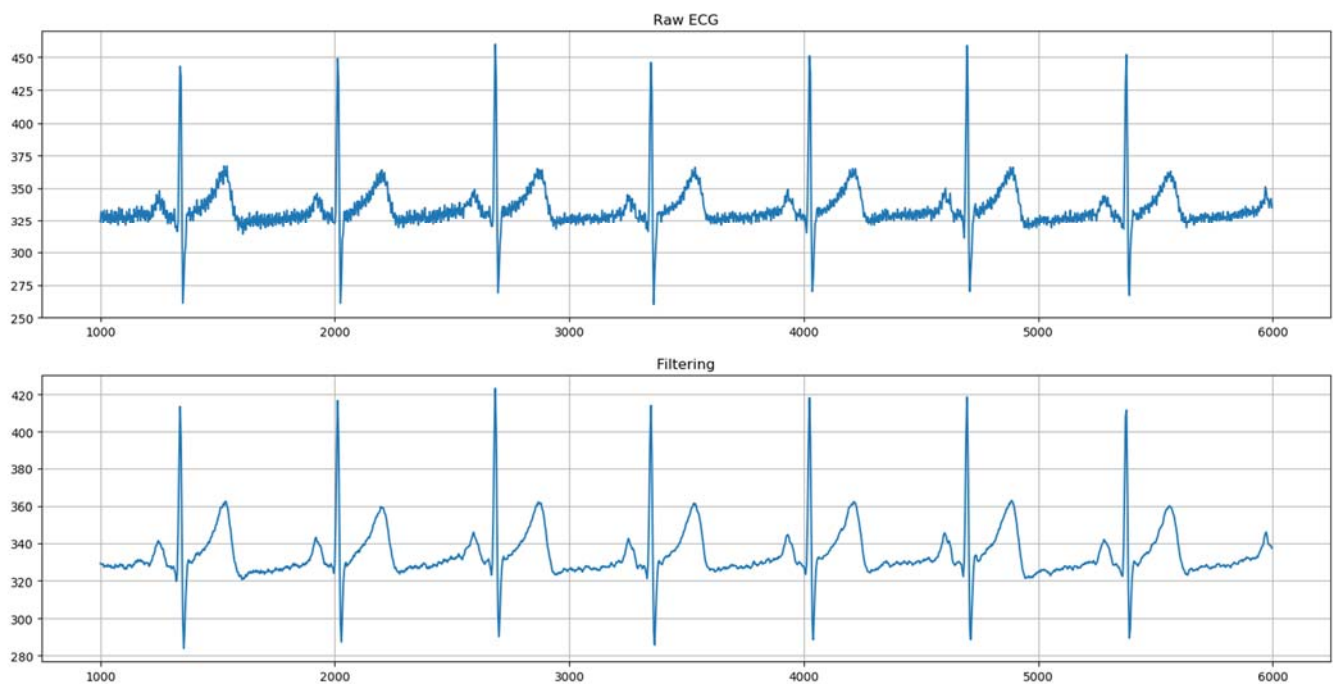
92 private void btnUpdateComR_Click(object sender, EventArgs e)
93 {
94     setupComPort.ComPortConfig(ref serialPortR);
95     setupComPort.ShowDialog();
96 }
97 1 图参考
98 private void RxForm1_Load(object sender, EventArgs e)
99 {
100     getAllPorts();
101     setupComPort = new PortConfigForm(ref serialPortR);
102     //setupComPort.ShowDialog();
103     raw = new List<byte>();
104     buf = new byte[serialPortR.ReadBufferSize];
105     DispG = new dispG(displayG);
106 }
107 1 图参考
108 private void timer1_Tick(object sender, EventArgs e)
109 {
110     Text = DateTime.Now.ToString();
111     Application.DoEvents();
112 }
113 1 图参考
114 private void btnGetPorts_Click(object sender, EventArgs e)
115 {
116     getAllPorts();
117 }
118
119 private void btnStart_Click(object sender, EventArgs e)
120 {
121     iStart = 0;
122     iEnd = -1;
123     btnStop.Enabled = true;
124     btnSave.Enabled = false;
125     raw.Clear();
126     myWave = new myWaveBMP(750);
127     if (img != null)
128     {
129         img.Dispose();
130         img = null;
131     }
132     img = myWave.getBMP();
133     pictureBox1.Image = img;
134     if (serialPortR.IsOpen)
135         serialPortR.Close();
136     serialPortR.PortName = cmbBxPortR.SelectedItem.ToString();
137     serialPortR.Open();
138     btnStart.Enabled = false;
139     timer1.Start();
140 }
141 1 图参考
142 private void btnStop_Click(object sender, EventArgs e)
143 {
144     btnStart.Enabled = true;
145     btnStop.Enabled = false;
146     btnSave.Enabled = true;
147     serialPortR.Close();
148     timer1.Stop();
149 }
150
151 private void btnSave_Click(object sender, EventArgs e)
152 {
153     serialPortR.Close();
154     saveFileDialog1.FileName = string.Format("ECG_{0:D4}{1:D2}{2:D2}_{3:D2}{4:D2}{5:D2}.txt",
155         DateTime.Now.Year, DateTime.Now.Month, DateTime.Now.Day,
156         DateTime.Now.Hour, DateTime.Now.Minute, DateTime.Now.Second);
157     if (saveFileDialog1.ShowDialog() != System.Windows.Forms.DialogResult.OK)
158         return;
159     StringBuilder sb = new StringBuilder();
160     for (int i = 0; i < raw.Count; i++)
161         sb.AppendLine(raw[i].ToString());
162     File.AppendAllText(saveFileDialog1.FileName, sb.ToString());
163 }
164 }
165 }

```

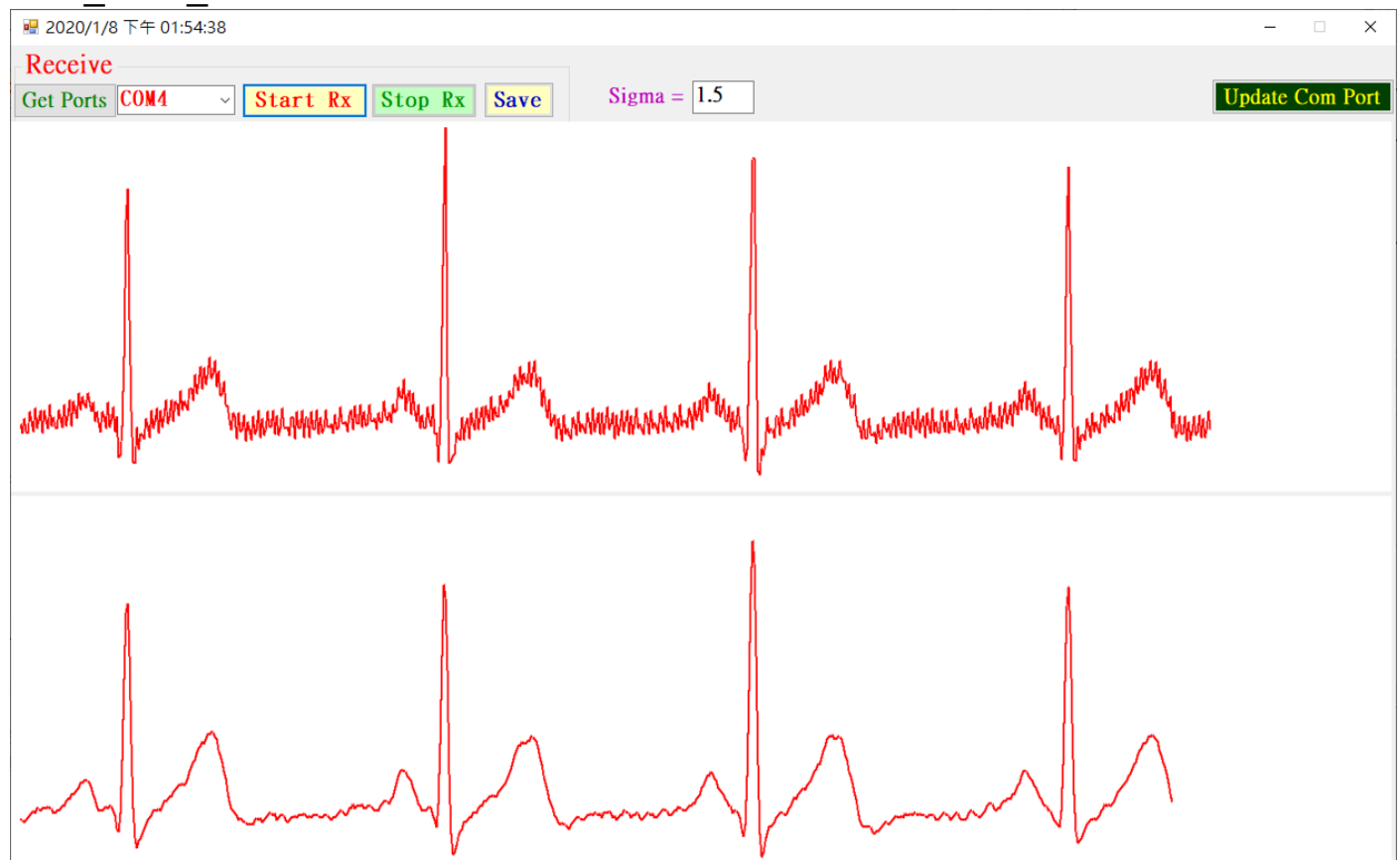
Q: How to filter the noise in the ECG?

Ans. In the previous study, I always use MATLAB to develop algorithm.

Now, I utilize **Python** to study **filtering noise** since my graduate students.



#### Ex.4\_5 PC\_RxPackedData6PlotDLL





```

9  using System.Windows.Forms;
10 using System.IO.Ports;
11 using System.IO;
12 using mySerialPort;
13 using myTools;
14 namespace PC_RxPackedData6PlotDLL
15 {
16     - 参考
17     public partial class RxForm1 : Form
18     {
19         delegate void dispG();
20         dispG DispG;
21         int iStart, iEnd, len, i, len2, iR0, iR1;
22         byte[] buf;
23         List<byte> raw;
24         List<int> iRaw;
25         PortConfigForm setupComPort;
26         int val, val2;
27         double sigma = 1.0;
28         myWaveBMP myWave, myWave2;
29         Image img, img2;
30
31         private void serialPortR_DataReceived(object sender, SerialDataReceivedEventArgs e) ...
32         /* private void displayG() ...
33         - 参考
34         private void displayG() ...
35         - 参考
36         private void showFiltering() ...
37         - 参考
38         private void getAllPorts() ...
39         - 参考
40         public RxForm1() ...
41         - 参考
42         private void btnUpdateComR_Click(object sender, EventArgs e) ...
43         - 参考
44         private void RxForm1_Load(object sender, EventArgs e) ...
45         - 参考
46         private void timer1_Tick(object sender, EventArgs e) ...
47         - 参考
48         private void btnGetPorts_Click(object sender, EventArgs e) ...
49         - 参考
50         private void btnStart_Click(object sender, EventArgs e) ...
51         - 参考
52         private void btnStop_Click(object sender, EventArgs e) ...
53         - 参考
54         private void btnSave_Click(object sender, EventArgs e) ...
55     }
56 }
57
58 - 参考
59 private void serialPortR_DataReceived(object sender, SerialDataReceivedEventArgs e)
60 {
61     if (!btnStart.Enabled && serialPortR.BytesToRead > 0)
62     {
63         len = serialPortR.Read(buf, 0, buf.Length);
64         for (i = 0; i < len; i++)
65             raw.Add(buf[i]);
66         //BeginInvoke(DispG, new Object[] { });
67     }
68 }
69
70 /* private void displayG() ...

```

```

56 private void displayG()
57 { //for ECG with 6-byte, test by Ex3_6Wave_byteTimer_6Bytes
58     iEnd = raw.Count - 1;
59     while (iStart <= iEnd-5)
60     {
61         if (raw[iStart]==255 && raw[iStart+1] == 255 && raw[iStart+4] == 254 && raw[iStart+5] == 254)
62         {
63             val = raw[iStart+3]*256+ raw[iStart + 2];
64             iRaw.Add(val);
65             myWave.update(val);
66             iStart += 5;
67         }
68         iStart++;
69     }
70     if (img != null)
71     {
72         img.Dispose();
73         img = null;
74     }
75     img = myWave.getBMP();
76     pictureBox1.Image = img;
77     //pictureBox1.Update();
78 }

```

```

79 private void showFiltering()
80 {
81     if (iRaw.Count < 1)
82         return;
83     iR1 = iRaw.Count - 1;
84     if (iR0 < len2+1)
85     {
86         while (iR0 < len2 + 1)
87         {
88             myWave2.update(iRaw[iR0]);
89             iR0++;
90         }
91     }
92     else
93     {
94         while (iR0 > len2 && iR1 - iR0 > 2 * len2)
95         {
96             val2 = (int)Filtering.doGaussian(iRaw, iR0);
97             myWave2.update(val2);
98             iR0++;
99         }
100     }
101     if (img2 != null)
102     {
103         img2.Dispose();
104         img2 = null;
105     }
106     img2 = myWave2.getBMP();
107     pictureBox2.Image = img2;
108     Application.DoEvents();
109 }

```



```

110 private void getAllPorts()
111 {
112     cmbBxPortR.Items.Clear();
113     string[] ports = SerialPort.GetPortNames();
114     Array.Sort(ports);
115     foreach (string port in ports)
116         cmbBxPortR.Items.Add(port);
117     cmbBxPortR.SelectedIndex = cmbBxPortR.Items.Count - 1;
118     btnStart.Enabled = true;
119     serialPortR.PortName = cmbBxPortR.SelectedItem.ToString();
120 }
121 - 参考
122 public RxForm1()
123 {
124     InitializeComponent();
125 }
126 - 参考
127 private void btnUpdateComR_Click(object sender, EventArgs e)
128 {
129     setupComPort.ComPortConfig(ref serialPortR);
130     setupComPort.ShowDialog();
131 }
132 - 参考
133 private void RxForm1_Load(object sender, EventArgs e)
134 {
135     getAllPorts();
136     setupComPort = new PortConfigForm(ref serialPortR);
137     //setupComPort.ShowDialog();
138     raw = new List<byte>();
139     iRaw = new List<int>();
140     buf = new byte[serialPortR.ReadBufferSize];
141     DispG = new dispG(displayG);
142 }
143 - 参考
144 private void timer1_Tick(object sender, EventArgs e)
145 {
146     Text = DateTime.Now.ToString();
147     displayG();
148     Application.DoEvents();
149     showFiltering();
150     Application.DoEvents();
151 }
152 - 参考
153 private void btnGetPorts_Click(object sender, EventArgs e)
154 {
155     getAllPorts();
156 }

```

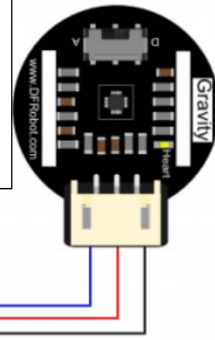
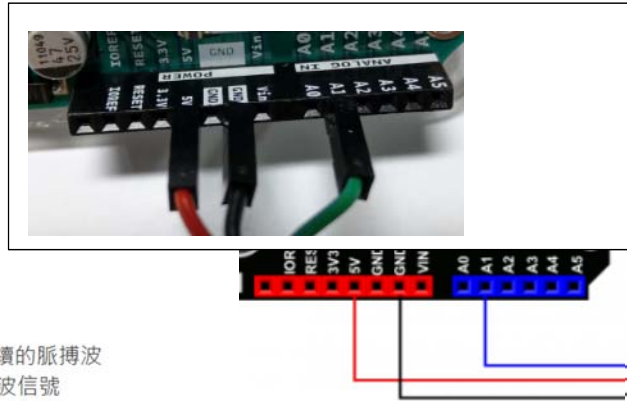
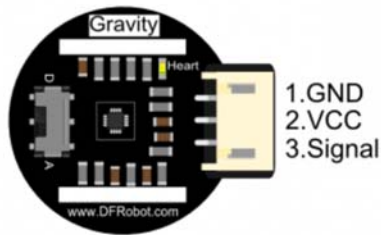
```

152 private void btnStart_Click(object sender, EventArgs e)
153 {
154     iStart = 0;
155     iEnd = -1;
156     sigma = double.Parse(txtBxSigma.Text);
157     myTools.Filtering.initGaussian(sigma);
158     len2 = Filtering.GaussianFilter.Length / 2;
159     iR0 = 0;
160     iR1 = -1;
161     btnStop.Enabled = true;
162     btnSave.Enabled = false;
163     raw.Clear();
164     myWave = new myTools.myWaveBMP(750);
165     myWave2 = new myTools.myWaveBMP(750);
166     if (img != null)
167     {
168         img.Dispose();
169         img = null;
170     }
171     //img = myWave.getBMP();
172     //pictureBox1.Image = img;
173     if (serialPortR.IsOpen)
174         serialPortR.Close();
175     serialPortR.PortName = cmbBxPortR.SelectedItem.ToString();
176     serialPortR.Open();
177     btnStart.Enabled = false;
178     timer1.Start();
179 }
180
181 private void btnStop_Click(object sender, EventArgs e)
182 {
183     btnStart.Enabled = true;
184     btnStop.Enabled = false;
185     btnSave.Enabled = true;
186     serialPortR.Close();
187     timer1.Stop();
188 }
189
190 private void btnSave_Click(object sender, EventArgs e)
191 {
192     serialPortR.Close();
193     saveFileDialog1.FileName = string.Format("ECG_{0:D4}{1:D2}{2:D2}_{3:D2}{4:D2}{5:D2}.txt",
194         DateTime.Now.Year, DateTime.Now.Month, DateTime.Now.Day,
195         DateTime.Now.Hour, DateTime.Now.Minute, DateTime.Now.Second);
196     if (saveFileDialog1.ShowDialog() != System.Windows.Forms.DialogResult.OK)
197         return;
198     StringBuilder sb = new StringBuilder();
199     for (int i = 0; i < raw.Count; i++)
200         sb.AppendLine(raw[i].ToString());
201     File.AppendAllText(saveFileDialog1.FileName, sb.ToString());
202 }

```

## E. Measuring Heart Rate by DFRPBOT's SEN0203 Heart Rate Sensor

Sensor:



模式開關：

“A”：脈搏波：模塊將根據心率變化輸出連續的脈搏波

“D”：方波：根據心率的變化輸出對應的方波信號

接線：綠線-> A1, 紅線:5V, 黑線: GND

### Ex4\_5 Pulse

```
/* AnalogReadSerial
```

```
Reads an analog input on pin A1, prints the result to the serial monitor.
```

```
Graphical representation is available using serial plotter (Tools > Serial Plotter menu)*/
```

```
void setup()
```

```
{ // initialize serial communication at 9600 bits per second:
```

```
  Serial.begin(9600);
```

```
}
```

```
// the loop routine runs over and over again forever:
```

```
void loop() {
```

```
  // read the input on analog pin A1:
```

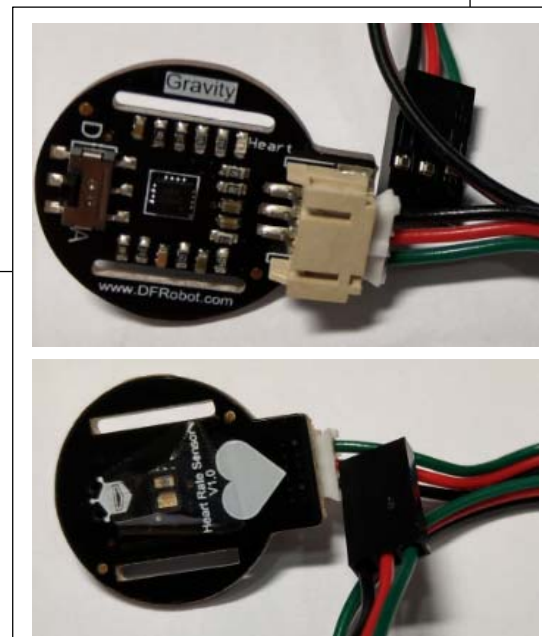
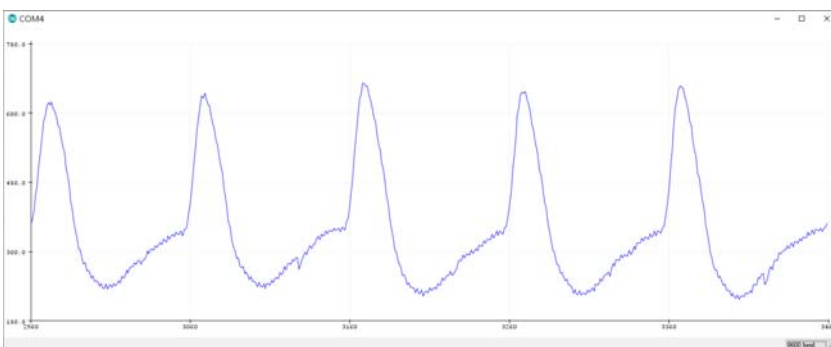
```
  int sensorValue = analogRead(A1);
```

```
  // print out the value you read:
```

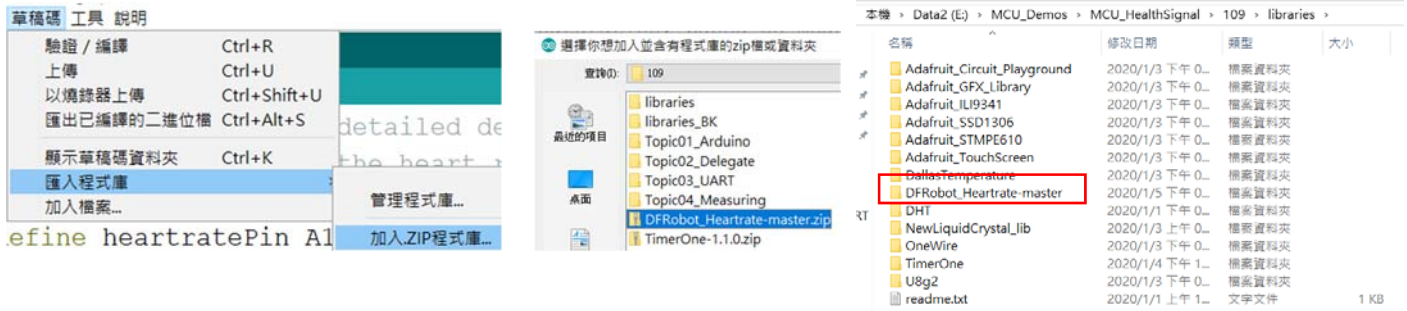
```
  Serial.println(sensorValue);
```

```
  delay(10); // delay 10ms in between reads for stability
```

```
}
```



## Ex4\_5A HeartRate by Library ([https://github.com/DFRobot/DFRobot\\_HeartRate](https://github.com/DFRobot/DFRobot_HeartRate))



```
/* DFRobot_HeartRate.h detailed description for HeartRate.cpp
 * This is written for the heart rate sensor the company library. Mainly used for real
 * time measurement of blood oxygen saturation, based on measured values calculate heart rate values.*/
#define heartratePin A1
#include "DFRobot_HeartRate.h"

DFRobot_HeartRate heartrate(DIGITAL_MODE); ///< ANALOG_MODE or DIGITAL_MODE

void setup() {
  Serial.begin(115200);
}

void loop() {
  uint8_t rateValue;
  heartrate.getValue(heartratePin); ///< A1 foot sampled values
  rateValue = heartrate.getRate(); ///< Get heart rate value
  if(rateValue) {
    Serial.println(rateValue);
  }
  delay(20);
}
```





#### Ex4\_5B Packed Pulse

```
byte data[]={0xFF, 0xFF, 0, 0, 0xFE, 0xFE};
int sensorValue;
void setup()
{
    Serial.begin(9600);
}
void loop()
{
    sensorValue = analogRead(A1);
    data[2]=(byte)( sensorValue &0xFF);           //Low byte
    data[3]=(byte)(( sensorValue &0x0300)>>8);    //Hight byte
    Serial.write(data,6);
    delay(10);           // delay 10ms in between reads for stability
}
```