

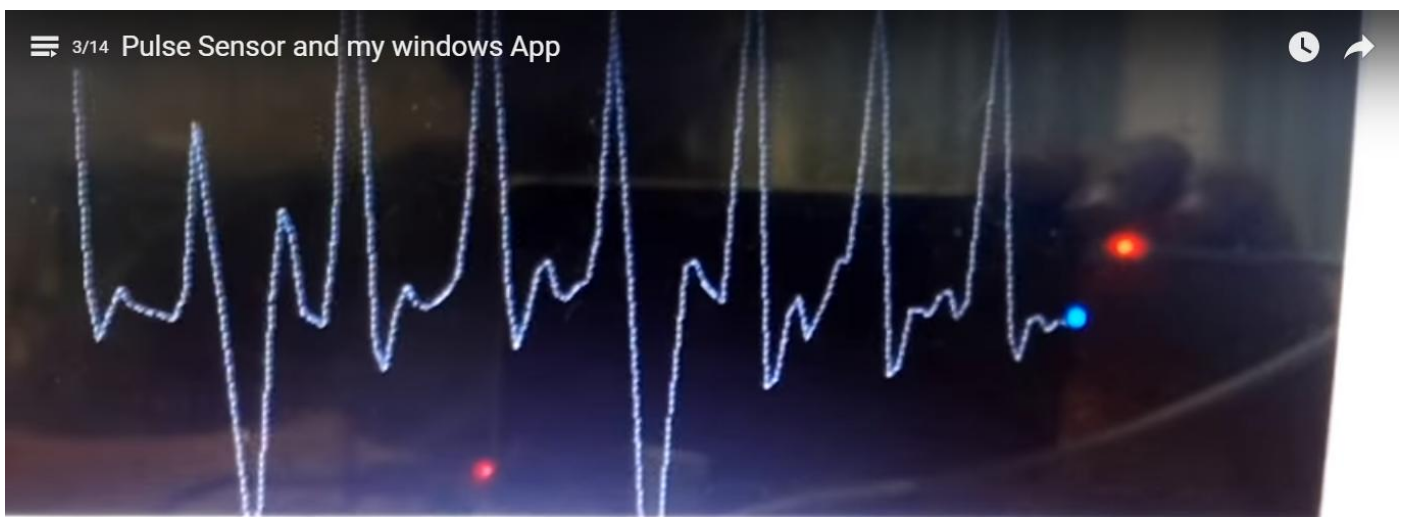
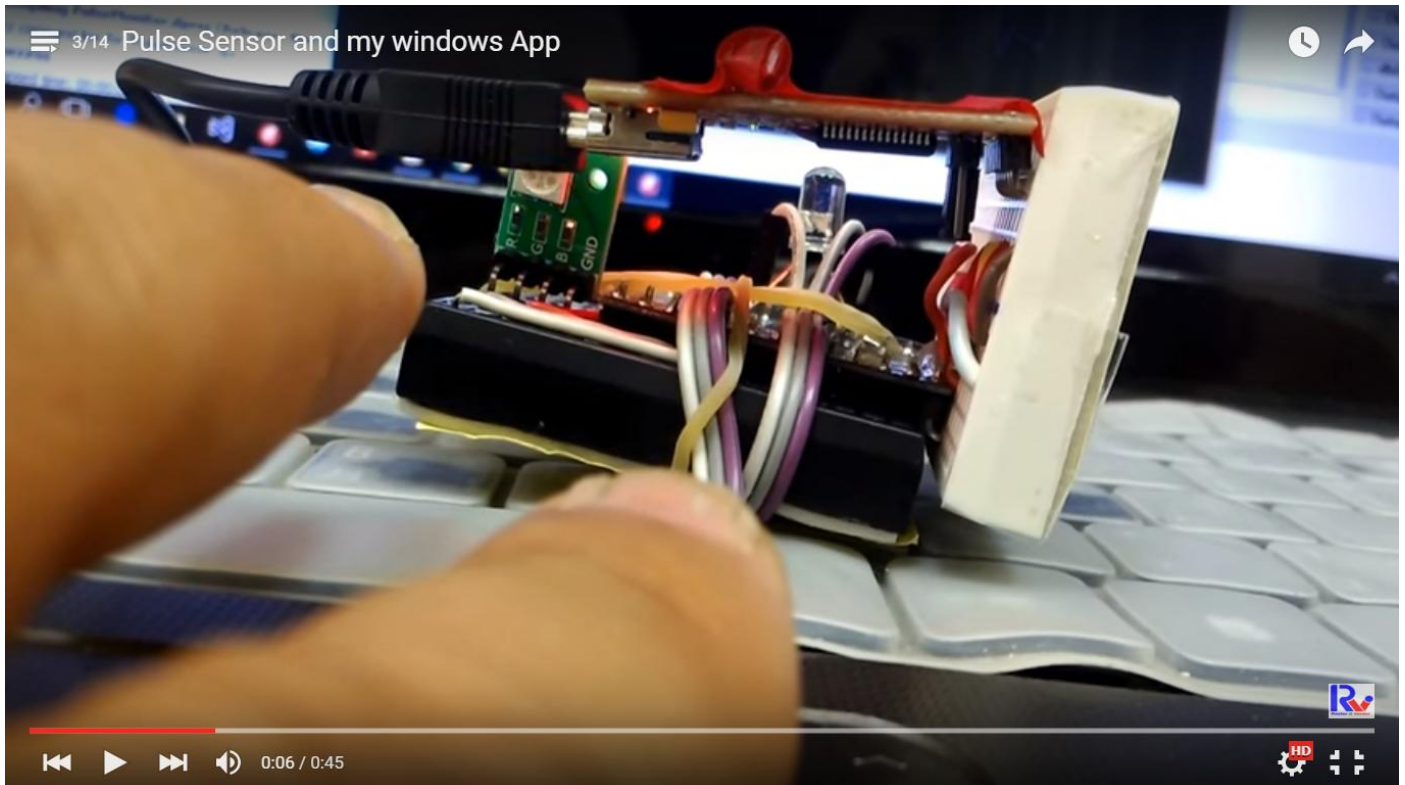
## Arduino Pulse Sensor

呂芳元 2015 /12/ 2

<http://www.rasvector.url.tw/>

說明：

使用 Arduino + Pulse Sensor 擷取心脈波訊號，以 RGB LED 顯示心跳快慢程度，並將心脈波、心跳數據傳送到 PC 端顯示波形。



影片：

[https://www.youtube.com/watch?v=oCKQ7as65yc&index=5&list=PLZG\\_AEGYW1gIMxUBlrYXnEpwFF9Llxn3T](https://www.youtube.com/watch?v=oCKQ7as65yc&index=5&list=PLZG_AEGYW1gIMxUBlrYXnEpwFF9Llxn3T)

[https://www.youtube.com/watch?v=p0KdO7rtU7o&list=PLZG\\_AEGYW1gIMxUBlrYXnEpwFF9Llxn3T](https://www.youtube.com/watch?v=p0KdO7rtU7o&list=PLZG_AEGYW1gIMxUBlrYXnEpwFF9Llxn3T)

Arduino 程式碼、線路圖、PC 端程式、說明 下載：

<https://www.dropbox.com/sh/iy5nacruhfk7c28/AADUfQWsaexbhZdodKG-M77Pa?dl=0>

材料：

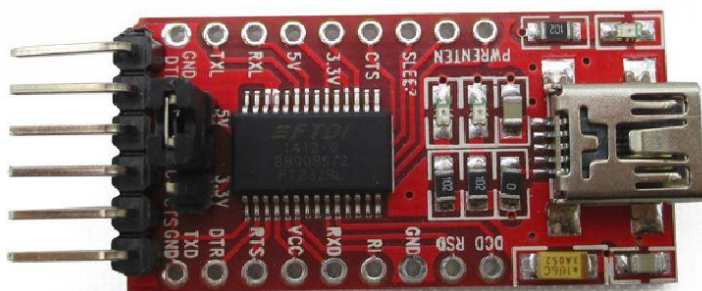
USB_To_TTL	x1	用來將 Arduino 程式碼燒錄到 Arduino，和將心跳數據傳回 PC。
Arduino ProMini	x1	用來控制 LED 閃爍和接收 Pulse Sensor 數據。
Pulse Sensor	x1	用來接收人體上的心跳、心脈波數據。
共陰極 RGB LED	x1	以 紅色(心跳快) -> 綠色 -> 藍色(心跳慢) 用來顯示心跳快慢程度。
單色 LED	x1	用來做心跳指示燈。

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線材：

杜邦線 ( 公/公、公/母、母/母 )各 10 條以上、麵包版。

USB to TTL 模組



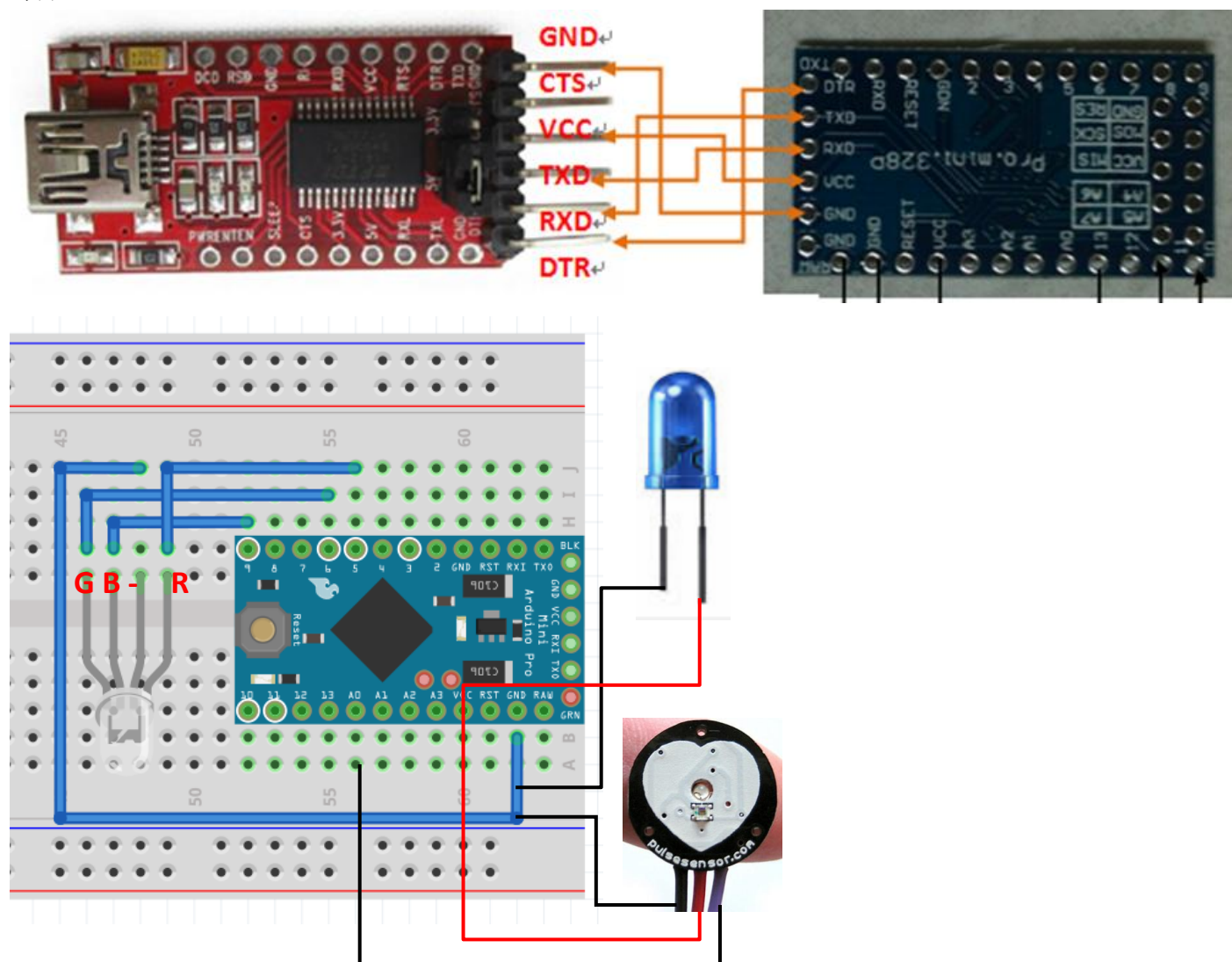
## Arduino ProMini



## Pulse Sensor



線路:



## Arduino 程式碼:

### 主程式 PulseSensor\_BlinkLed.ino

/\*

使用 Timer2 中斷服務，擷取 PulseSensor 的數值

Daniel Lu : dan59314@gmail.com

<http://www.rasvector.url.tw/>

<http://www.youtube.com/dan59314/playlist>

blinkPin : 當心跳訊號出現時，用來快閃

fadPin : 心跳訊號出現後，用來漸暗 LED

指令：

Serial.print(78, BIN) gives "1001110"

Serial.print(78, OCT) gives "116"

Serial.print(78, DEC) gives "78"

Serial.print(78, HEX) gives "4E"

Serial.println(1.23456, 0) gives "1"

Serial.println(1.23456, 2) gives "1.23"

Serial.println(1.23456, 4) gives "1.2346"

Serial.println("S," + String(pulseVal) + "," + String(gTotalTime, HEX));

\*/

#include <SoftwareSerial.h>

#define EnableReceiveCommand

#define AverageHeartBeat;

#define RGBColorFading

#define UseTimer2IRS

#define CommonAnode

#define debug

typedef struct TRGB {

byte R, G, B;

unsigned long DelayMSec;

};

```

#ifdef EnableReceiveCommand
const byte cMaxCommandCount = 5;
const int cMaxCommandStringLength = 10; // length("C,255,255,255,12345");
String inputBtString = "", inputPcString = "",
    sCommand[cMaxCommandCount] = { "D","13","0","0","0" }; //將 Digital Pin 13 設為 0;
bool stringBtComplete = false, stringPcComplete;
byte pinRx =10, pinTx =11;
unsigned long gLastListeningTime, gLastActionTime;

// BlueTooth in Pin10(RX) Pin11(TX)  PWM Pin -----
SoftwareSerial BlueToothSerial(pinRx, pinTx); //10, 11); // RX, TX
#endif

#ifdef AverageHeartBeat
const int cHeartBeatCount = 10;
#endif

#ifndef UseTimer2IRS
unsigned long gLastCheckMs;
#endif

const int cRamboCount = 20;
const int cHeartBeatMin = 40, cHeartBeatMax = 120;
const int cHeartBeatStep = (cHeartBeatMax - cHeartBeatMin) / cRamboCount;
const int cFadeStep = 10;
const int cTimer2IntervalMSec=2;           // 設定每 2 毫秒一次中斷
const byte cMinSampeDurationMsec = 250;    // 取樣最小間隔毫秒
const byte cSampleCount = 10;              // 取樣數
const byte cOutputIntervalMSec = 50;       // 每 50 毫秒輸出一一次

const byte funcOutputPulse=1;
const byte funcAveragePulse=2;
const byte funcOneColorFadding =4;

TRGB gRamboRGBs[cRamboCount];

// Timer2 掌管 PWM pin 3, 11, 因此不能使用這兩個 Pin -----
int pulsePin = 0;           // 連接到 Pulse Sensor 的 A 訊號
int blinkPin = 13;          // 用來快閃顯示心跳訊號
int fadePinR = 5, fadePinG = 6, fadePinB = 9;           // 用來漸暗心跳訊號出現後的

```

```
// 因為這些變數使用在 ISR (中斷 Routine 內)，因此須加 volatile -----
```

```
#ifndef AverageHeartBeat
```

```
volatile int gHeartBeats[cHeartBeatCount];
```

```
volatile int gCurHeartBeatId=0;
```

```
#endif
```

```
volatile int BPM; // 心跳，次/分
```

```
volatile int gPeakTime = 600; // 紀錄目前的心跳間隔時間
```

```
volatile boolean bInPeakPulse = false; // true when pulse wave is high, false when it's low
```

```
volatile boolean bOutputHeartBeat = false; // becomes true when Arduino finds a beat.
```

```
volatile int gMin_PeakTime = 60000 / 200; // 假設最大心跳 200 次/分，則最小間隔時間為 60000/200
```

```
volatile int gCurSampleID = 0; // 目前 Sample ID
```

```
volatile int PulseDurations[cSampleCount]; // 心跳間隔時間取樣陣列
```

```
volatile unsigned long gLastBeatTime = 0; // 上一次心跳波峰時間
```

```
volatile unsigned long gTotalTime = 0; // 總共經過時間
```

```
volatile int gCurMaxPulse = 512; // 最高 Pulse 波峰
```

```
volatile int gCurMinPulse = 512; // 最低 Pulse 波峰
```

```
volatile int gLastPulseThreshold = 512; // 紀錄最近的 Pulse Value 平均值
```

```
volatile byte decR = 255/cFadeStep, decG = decR, decB = decR;
```

```
volatile int gFadeValueR = 0, gFadeValueG = 0, gFadeValueB = 0; // 用來更新 FadePin 的 PWM 數值
```

```
volatile byte gFunctions = 0x00000000;
```

```
void buildRamboRGBs(bool ignoreBlueToRed=true)
```

```
{
```

```
    const byte cR = 0, cG = 1, cB = 2;
```

```
    byte aR, aG, aB;
```

```
    aR = 255;
```

```
    aG = 0;
```

```
    aB = 0;
```

```
    byte aRGB = 0;
```

```
    byte rangeN = 3;
```

```
    if (ignoreBlueToRed) rangeN = 2;
```

```
    else rangeN = 3;
```

```
    byte cRamboStep = (255 * rangeN / (cRamboCount)); // 限制在 R-G, G-B, 因此 rangeN=2
```

```

for (int i = cRamboCount - 1; i>=0; i--) //從 B 開始往前填入
{
gRamboRGBs[i].R = aR;
gRamboRGBs[i].G = aG;
gRamboRGBs[i].B = aB;
    gRamboRGBs[i].DelayMSec = 10000 / cRamboCount;

String s1 = "R" + String(aR) + ", G" + String(aG) + ", B" + String(aB);
Serial.println(s1);

if (aRGB == cR)
{
    aR -= cRamboStep;
    aG += cRamboStep;
    if (aR<cRamboStep)
    {
        aR = 0;
        aG = 255;
        aB = 0;
        aRGB = cG;
    }
}
else if (aRGB == cG)
{
    aG -= cRamboStep;
    aB += cRamboStep;
    if (aG<cRamboStep)
    {
        aG = 0;
        aB = 255;
        aR = 0;
        aRGB = cB;
    }
}
else //if (aRGB=cB)
{
    aB -= cRamboStep;
    aR += cRamboStep;
    if (aB<cRamboStep)
    {
        aB = 0;

```



```

        aR = 255;
        aG = 0;
        aRGB = cR;
    }
}
}
}
}

```

```

void initial_Variables()

```

```

{
#ifdef UseTimer2IRS
    gLastCheckMs = millis();
#endif

    // 給予取樣心跳陣列初值 -----
    for (int i = 0; i < cSampleCount; i++)
        PulseDurations[i] = 60000 / 72;

#ifdef AverageHeartBeat
    // 給予 gHeartBeats 初值 -----
    for (int i = 0; i < cHeartBeatCount; i++)
        gHeartBeats[i] = 72;
#endif
}

```

```

#ifdef EnableReceiveCommand

```

```

bool GetCompleteStringFromBlueTooth(String &str)

```

```

{
    while (BlueToothSerial.available()) {

        // 逐一加入字元直到遇到 \n-----
        char inChar = (char)BlueToothSerial.read();

        // 如果字元 = \n 則跳出 -----
        if ((inChar == '\r') || (inChar == '\n') || (str.length() > cMaxCommandStringLength))
        {
            return (str != "");
        }
    }
}

```

```

        else
        {
            str += inChar;
            return false;
        }
    }

    return false;
}

```

```

bool GetCompleteStringFromPC(String &str)

```

```

{
    while (Serial.available()) {
        // 逐一加入字元直到遇到 \n-----
        char inChar = (char)Serial.read();

        // 如果字元 = \n 則跳出 -----
        if ((inChar == '\r') || (inChar == '\n') || (str.length() > cMaxCommandStringLength))
        {
            return (str != "");
        }
        else
        {
            str += inChar;
            return false;
        }
    }

    return false;
}

```

```

bool GetCommand(String inStr, String sCmd[], int &cmdCnt) //    call by reference, 陣列不需加 &

```

```

{
    //int cmdCnt=0;
    char *p = &inStr[0];
    char *str;

    cmdCnt = 0;

```

```

// 以 "," 來拆解字串-----
while (cmdCnt<cMaxCommandCount && (str = strtok_r(p, ",", &p)) != NULL)
{
    sCommand[cmdCnt] = str;
    sCommand[cmdCnt].toUpperCase();
    cmdCnt++;
}

#ifdef debug
    //Serial.println(cmdCnt);
#endif

    return (cmdCnt>0);
}

void Process_Command(String sCmd[])
{
#ifdef debug
    /*Serial.println("Process_Command() ");
    Serial.println(sCmd[0]);
    Serial.println(sCmd[1]);
    Serial.println(sCmd[2]);
    Serial.println(sCmd[3]);*/
#endif

    // P,0/1 取消/啟動 輸出 Pulse -----
    if (sCmd[0].indexOf("FN") == 0 || sCmd[0].indexOf("fn") == 0) // Analog
    {
        gFunctions = sCmd[1].toInt();
#ifdef debug
        Serial.print("FN: "); Serial.println(gFunctions, BIN);
#endif
    }
    else if (sCmd[0].indexOf("T") == 0 || sCmd[0].indexOf("t") == 0) // TI, TD
    {
        if (sCmd[0].indexOf("D") == 1 || sCmd[0].indexOf("d") == 1) // TD,200 delay msec
        {
            //gDelayMsec = sCmd[1].toInt();
            //String s1 = "DelayMSec : " + sCmd[1];
            //Serial.println(s1);
        }
    }
}

```

```

    }
    else if (sCmd[0].indexOf("l") == 1 || sCmd[0].indexOf("i") == 1) // Tl, 2000 ldel time msec
    {
        //gIdleMsec = sCmd[1].toInt() % cMaxIdleMsec;

        //String s1 = "IdleMSec : " + sCmd[1];
        //Serial.println(s1);
    }
    else;
}
else
{
#ifdef debug
    BlueToothSerial.println("Command : " + sCmd[0] + "-" + sCmd[1] + "-" + sCmd[2] + "not processed");
#endif
}
}
#endif

```

```

void setup()
{
    pinMode(blinkPin, OUTPUT);    // 心跳時閃一下
    pinMode(fadePinR, OUTPUT);    // 心跳後漸暗
    pinMode(fadePinG, OUTPUT);    // 心跳後漸暗
    pinMode(fadePinB, OUTPUT);    // 心跳後漸暗
    Serial.begin(115200);          // Serial BaudRate

#ifdef UseTimer2IRS
    // 設定 Timer2 Interrupt，每 2 毫秒中斷一次 -----
    interruptTimer2Setup(cTimer2IntervalMsec);
#endif

    initial_Variables;

    buildRamboRGBs();
}

```

```

void loop()
{

```

```

#ifdef EnableReceiveCommand
    if (GetCompleteStringFromBlueTooth(inputBtString))
    {
        //PlayMode = cListening;
        gLastListeningTime = millis();
        stringBtComplete = true;
    }
    else if (GetCompleteStringFromPC(inputPcString))
    {
        //PlayMode = cListening;
        gLastListeningTime = millis();
        stringPcComplete = true;
#ifdef debug
        //Serial.println(inputPcString);
#endif
    }
    else
    {

```

```

int cmdCnt;
if (stringBtComplete)
{
    // 將字串拆成 Pin,Id,Value, Ex: D,13,0 就是將 Digital Pin 13 設為 0
    if (GetCommand(inputBtString, sCommand, cmdCnt))
    {
        Process_Command(sCommand);
    }

    // clear the string:
    inputBtString = "";
    stringBtComplete = false;
}
else if (stringPcComplete)
{
    // 將字串拆成 Pin,Id,Value, Ex: D,13,0 就是將 Digital Pin 13 設為 0
    if (GetCommand(inputPcString, sCommand, cmdCnt))
    {
        Process_Command(sCommand);

```

```

    }

    // clear the string:
    inputPcString = "";
    stringPcComplete = false;
}
#endif

// 漸減 fadPin 的 pwm 值，漸暗 -----
ledFadeToBeat();

#ifdef UseTimer2IRS
    delay(20);
#else
    unsigned long nowMs = millis();
    if (nowMs - gLastCheckMs >= cTimer2IntervalMSec)
    {
        OnTimer2Interrupt();
        gLastCheckMs = nowMs;
    }
#endif
}

void ledFadeToBeat()
{
    gFadeValueR -= decR;                // 遞減 PWM 值
    gFadeValueR = constrain(gFadeValueR, 0, 255);    // 將 PWM 值限制在 0~255
#ifdef CommonAnode
    analogWrite(fadePinR, 255-gFadeValueR);        // 送出 PWM 值
#else
    analogWrite(fadePinR, gFadeValueR);            // 送出 PWM 值
#endif

#ifdef RGBColorFadding
    if (gFunctions&funcOneColorFadding)
        ;
    else
    {
        gFadeValueG -= decG;
        gFadeValueG = constrain(gFadeValueG, 0, 255);    // 將 PWM 值限制在 0~255
    }
}

```

```

#ifdef CommonAnode
    analogWrite(fadePinG, 255-gFadeValueG);    // 送出 PWM 值
#else
    analogWrite(fadePinG, gFadeValueG);        // 送出 PWM 值
#endif

    gFadeValueB -= decB;
    gFadeValueB = constrain(gFadeValueB, 0, 255);    // 將 PWM 值限制在 0~255
#ifdef CommonAnode
    analogWrite(fadePinB, 255-gFadeValueB);    // 送出 PWM 值
#else
    analogWrite(fadePinB, gFadeValueB);        // 送出 PWM 值
#endif
}
#endif

}

void sendDataToProcessing(String sCmd, int data)
{
    Serial.print(sCmd+",");    // 開頭字元
    Serial.println(data);    // 數值
}

void OnTimer2Interrupt()
{
    int pulseVal = analogRead(pulsePin);    // 讀取 PulseSensor 數值

    gTotalTime += cTimer2IntervalMSec;    // 因為 Timer2 每次中斷間隔為 cTimer2IntervalMSec
    int dTime = gTotalTime - gLastBeatTime;    // 用來篩選過近時間內的雜訊

    bool bIsOverMinPeakTime = (dTime > gMin_PeakTime);

    // 更新 波峰和波谷的數值 -----
    if (pulseVal < gLastPulseThreshold &&    // 如果 pulse 小於上次的平均值
        bIsOverMinPeakTime)    // 且間隔時間也超過上次間隔時間的 3/5
    {
        if (pulseVal < gCurMinPulse) // 如果 pulse 比上次的波谷還小
            gCurMinPulse = pulseVal;    // 更新波谷數值
    }
}

```

```

if (pulseVal > gLastPulseThreshold) // &&    // 如果 pulse 大於上次的平均值，過濾掉雜訊
    // dTime > gMin_PeakTime)    不過濾時間，所有的波峰都取，以免漏掉真正的波峰
{
    if (pulseVal > gCurMaxPulse)    // 且比上次的波峰值還大
    {
        gCurMaxPulse = pulseVal;    // 更新波峰值
    }
}

// 開始計算心跳數值 -----
if (dTime > cMinSampeDurationMsec)    // 過濾掉太相近的雜訊
{

    if (gFunctions&funcOutputPulse) //送出 pulseSender 讀到的數值
    if (gTotalTime % cOuputIntervalMSec == 0)
    {
        Serial.println("S," + String(pulseVal) + "," + String(gTotalTime, HEX)+",");
    }

    if ((pulseVal > gLastPulseThreshold) &&    // 如果目前的 pulse 超過上次的平均值
        (bInPeakPulse == false) &&    // 且還沒找到新的 Pulse
        bIsOverMinPeakTime)    // 且間隔時間也超過上次間隔時間的 3/5
    {
        bInPeakPulse = true;    // 找到 Pulse
        digitalWrite(blinkPin, HIGH);    // 開啟閃爍的 Pin13 LED
        gPeakTime = dTime;    // 紀錄距離上次 Pulse 的時間間隔

#ifdef Debug
        //sendDataToProcessing("Q", gPeakTime);    // 送出波峰間的時間間隔 dT
#endif

        gMin_PeakTime = (gPeakTime / 5) * 3;    // 更新新的 時間間隔 Threshold
        gLastBeatTime = gTotalTime;    // 更新最後 Pulse 時間

        gCurSampleID %= cSampleCount;    // 目前填入的陣列位置
        PulseDurations[gCurSampleID] = gPeakTime;    // 填入目前的間隔時間
        gCurSampleID++;    // 到下一個陣列空間

        // 計算所有心跳間隔時間加起來的總數 -----
        word runningTotal = 0;
        for (int i = 0; i < cSampleCount; i++)

```



```

        runningTotal += PulseDurations[i];

    runningTotal /= cSampleCount;    // 平均每次心跳的間隔時間
    int heartBeat = 60000 / runningTotal;    // 將 60000 毫秒 / 每次間隔 -> 每分鐘心跳數

#ifdef AverageHeartBeat
    if (gFunctions&funcAveragePulse)
    {
        gCurHeartBeatId %= cHeartBeatCount;
        gHeartBeats[gCurHeartBeatId] = heartBeat;
        gCurHeartBeatId++;
        int allHb = 0;
        for (int i = 0; i < cHeartBeatCount; i++)
            allHb += gHeartBeats[i];
        BPM = allHb / cHeartBeatCount;
    }
    else
#endif

        BPM = heartBeat;

    //ifndef debug
    //sendDataToProcessing("B", BPM);    //送出心跳資料到 Serial
    Serial.println("B," + String(BPM) + "," + String(gTotalTime, HEX) + ",");
//endif

    int ald = (BPM - cHeartBeatMin) / cHeartBeatStep;
    //constrain(ald, 0, cRamboCount - 1); // 無效
    // BPM, cHeartBeatMin, cHeartBeatStep...必須 int, 否則 ald 會超出邊界
    if (ald < 0) ald = 0; else if (ald >= cRamboCount) ald = cRamboCount - 1;

    gFadeValueR = gRamboRGBs[ald].R;
    decR = gFadeValueR / cFadeStep;    //設定 PWM fadPin 從 255 開始遞減

#ifdef RGBColorFadding

    if (gFunctions&funcOneColorFadding)
        ;
    else
    {
        gFadeValueG = gRamboRGBs[ald].G;
        decG = gFadeValueG / cFadeStep;

```

```

        gFadeValueB = gRamboRGBs[ald].B;
        decB = gFadeValueB / cFadeStep;
    }

#endif

#ifdef debug
    /*
    sendDataToProcessing("i", ald);
    sendDataToProcessing("r", gFadeValueR);
    sendDataToProcessing("g", gFadeValueG);
    sendDataToProcessing("b", gFadeValueB);
    */
#endif

    }

}

if (pulseVal < gLastPulseThreshold &&    // Pulse 比上次平均值低
    bInPeakPulse == true)                // 且上一次是找到波峰，則表示目前由波峰往下走
{
    digitalWrite(blinkPin, LOW);          // 關閉 Pin13 LED
    bInPeakPulse = false;                  // 離開波峰
    int amp = gCurMaxPulse - gCurMinPulse; // 振幅
    gLastPulseThreshold = amp / 2 + gCurMinPulse; // 更新 Pulse 平均值
    gCurMaxPulse = gLastPulseThreshold;    // 更新波峰、波谷的數值
    gCurMinPulse = gLastPulseThreshold;
}

if (dTime > 2500)                        // 很久沒有發現 HeartBeat
{
    gFadeValueR = 0;
#ifdef RGBColoreFading
    gFadeValueG = 0;
    gFadeValueB = 0;
#endif

    gLastPulseThreshold = 512;            // 重設 Pulse 平均值
    gCurMaxPulse = 512;                   // 更新波峰、波谷的數值
    gCurMinPulse = 512;
    gLastBeatTime = gTotalTime;           // 更新上次心跳時間
}

```

```
}  
}
```

## 中斷服務 Interrupt.ino

```
/*
```

Timer0 - An 8 bit timer used by Arduino functions delay(), millis() and micros().

Timer1 - A 16 bit timer used by the Servo() library

Timer2 - An 8 bit timer used by the Tone() library

Timer_output	Arduino_output	Chip_pin	Pin_name
OC0A (Timer0)	6	12	PD6
OC0B (Timer0)	5	11	PD5
OC1A (Timer1)	9	15	PB1
OC1B (Timer1)	10	16	PB2
OC2A (Timer2)	11	17	PB3
OC2B (Timer2)	3	5	PD3

```
*/
```

```
void interruptTimer2Setup(int timer2IntervalMsec)
```

```
{
```

```
    TCCR2A = 0x02;    // DISABLE PWM ON DIGITAL PINS 3 AND 11, AND GO INTO CTC MODE
```

```
    TCCR2B = 0x06;    // DON'T FORCE COMPARE, 256 PRESCALER
```

```
    // SET THE TOP OF THE COUNT TO 124 (16MHz/256/500 = 125, because index start from 0, so count=124) FOR 500Hz
```

```
SAMPLE PulseDurations, 500 Hz/sec => 1000 msec/500 -> 2 MSec
```

```
    //OCR2A = 0X7C;
```

```
    float scaledFrequency = 16000000 / 256.0;
```

```
    float wantedFrequency = 1.0 / (timer2IntervalMsec / 1000.0); //timer2IntervalMsec
```

```
    int tickCount = scaledFrequency / wantedFrequency;
```

```
    OCR2A = tickCount - 1;
```

```
//#ifdef debug
```

```
    //Serial.print("Scaled Frequency: "); Serial.println(scaledFrequency);
```

```
    //Serial.print("Wanted Frequency: "); Serial.println(wantedFrequency);
```

```
    //Serial.print("TickCount: "); Serial.println(tickCount);
```

```
//#endif
```

```
    TIMSK2 = 0x02;    // ENABLE INTERRUPT ON MATCH BETWEEN TIMER2 AND OCR2A
```

```
    sei();            // MAKE SURE GLOBAL INTERRUPTS ARE ENABLED
```

```
}
```

```

// TIMER 2 INTERRUPT SERVICE ROUTINE -----
ISR(TIMER2_COMPA_vect)  // triggered when Timer2 counts to 124,  0~124 = 125
{
#ifdef debug
    //Serial.print('Tick: ');  Serial.println(millis());
#endif

    cli();                      // disable interrupts

    OnTimer2Interrupt();

    sei();                      // enable interrupts when youre done!

#ifdef debug
    //Serial.print('Finish OnTimer2Interrupt(): ');  Serial.println(millis());
#endif
}

```

監看程式: