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物聯網裝置與平台
IoT Devices and Platforms

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National Yang Ming Chiao Tung University

	日期	主題
1	9/17	(加退選9/13-27) 課程介紹, arduino簡介
2	9/24	物聯網裝置: Arduino basic introduction
3	10/1	物聯網裝置: Arduino Digital Interface
4	10/8	物聯網裝置: Arduino Analog Interface
5	10/15	sensor介紹 part 1
6	10/22	sensor介紹 part 2
7	10/29	sensor介紹 part 3
8	11/5	(期中考周11/1-5) sensor介紹 part 4
9	11/12	期中考
10	11/19	通訊模組 Bluetooth, Lora
11	11/26	通訊模組-wifi
12	12/3	Proposal
13	12/10	物聯網平台 - IoT Cloud Platform
14	12/17	AI應用 (SVM)
15	12/24	(期末考周 12/24-30) Project 準備周
16	12/31	(國定假日)
17	1/7	(彈性補充教學) Final demo
18	1/14	(彈性補充教學) Final demo part 2 (如果需要兩周進行)

Important date

- **Find your team member (each group: 2~4 persons)**
  - Total: 15 groups
- (12/3) Project proposal
  - Prepare slide (2 pages are enough) with 5 min introduction
    - P0. Project title
    - P1. Your idea/motivation
    - P2. What do you need (ex: sensors)
  - We will discuss and provide suggestions to each team
- (1/7, 1/14) Final project demo (via Teams)
  - Prepare both slide and live demo
  - Upload slide and demo video to e3
  - **Each team has 10 minute, so we might only need one week.**

Ch 5, Sensors (3) - Summary

- Arduino IDE and how it interacts with the external world
  - Sensors
- Understanding this course:
  - Discussion: upload to e3
  - Quiz: show your code to TA
    - For remote-access, use discord to interact with TA

Last week

1. **DHT-11 (thermometer + hygrometer)**: read the values for the temperature and humidity
2. **ASCIITable**: Demonstrates the advanced serial printing functions

DHT-11

Thermometer + Hygrometer

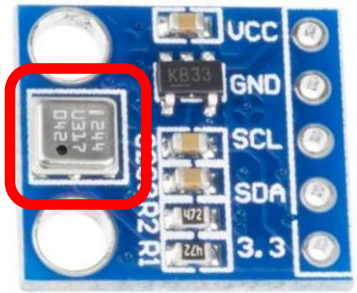
HC-SR04

Ultrasonic

This week

1. **Sweep:** Sweeps the shaft of a RC servo motor (Radio Control or Remote control) back and forth across 180 degrees.
2. **Knob:** Control the position of a RC servo motor with Arduino and a potentiometer.
3. **Altimeter:** Use BMP180 to read the pressure and temperature, and then calculate the altitude.
4. **Pulse sensor:** Optical Sensors for Heart Rate Monitor

SG-90
servo motor



Pressure (altimeter)


Pulse Sensor

https://www.youtube.com/watch?v=BoJ3QUGUA6w

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Automatic Soap Dispenser

https://www.youtube.com/watch?v=8HEfIJlcFbs

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World Record Domino Robot (100k dominoes in 24hrs)

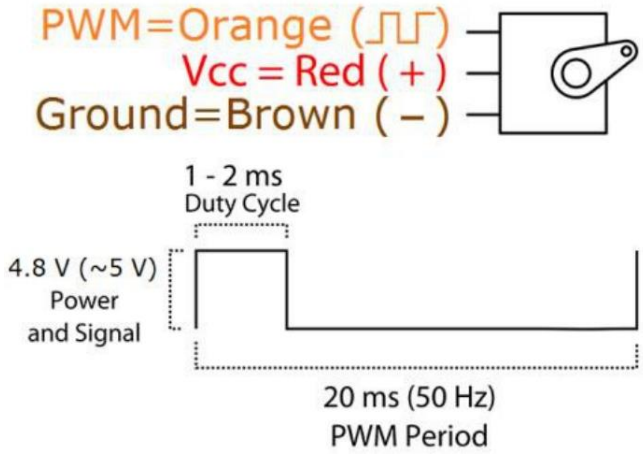
Lab1. Sweep

Sweeps the shaft of a RC servo motor

Servo motor

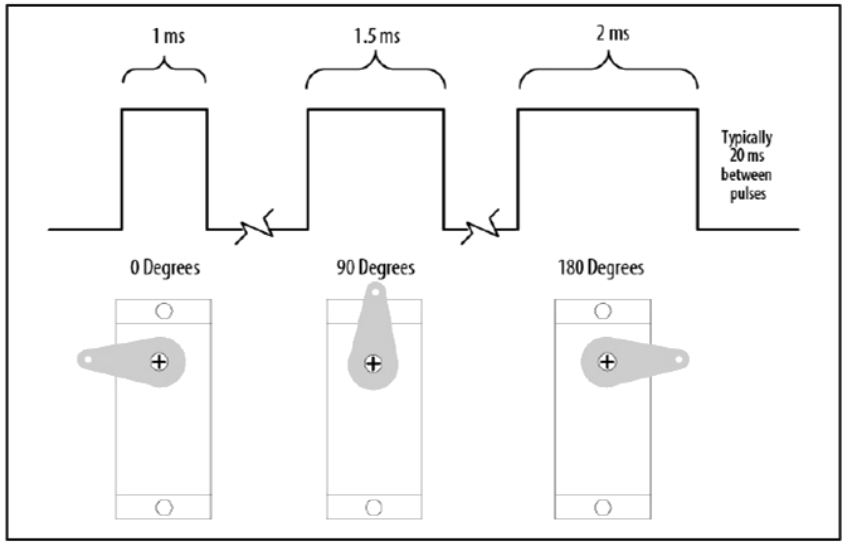
- Servos are small, cheap, mass-produced actuators used for radio **control** and small-scale robotics.
- Servo motors have three wires: power, ground, and signal.
  - Power: typically red, connect to the 5V pin.
  - Ground: typically black or brown, connect to a ground pin.
  - Signal: the remaining pin, maybe yellow, orange or white, connect to digital pin.

Cable: power, ground, and signal



Servo motor

- The signal pin accepts the **control signal** which is a **pulse-width modulation (PWM) signal**.
- (Example) The pulse width sent to servo ranges as follows:
  - Minimum: 1 ms ---> Corresponds to 0 rotation angle.
  - Maximum: 2 ms ---> Corresponds to 180 rotation angle.
  - Please refer to its spec.



Servo motor

可控角度伺服馬達
(SG-90)

360度連續旋轉伺服馬達
(MG996R)

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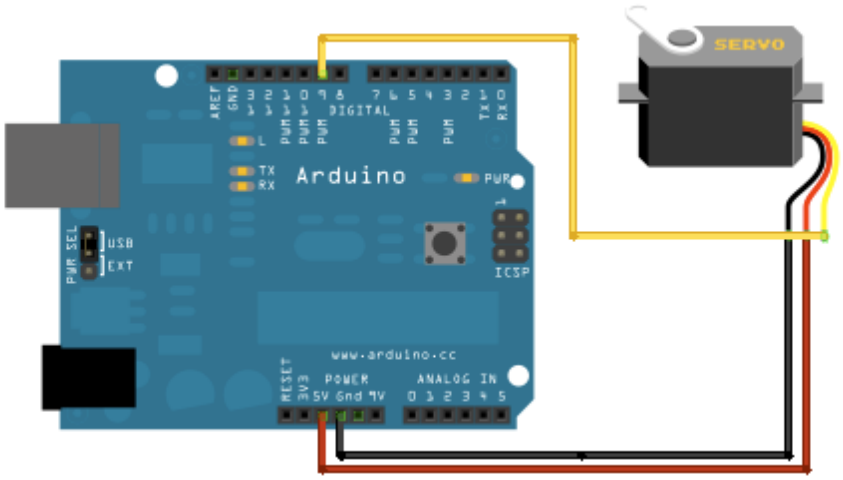
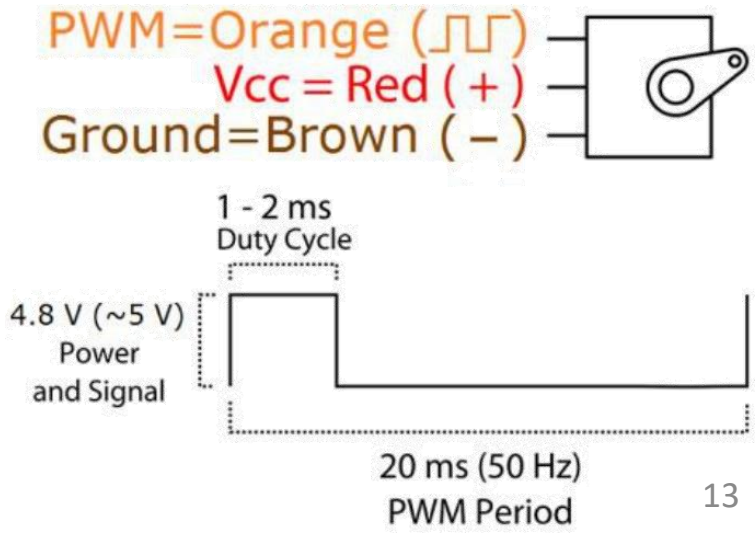
Lab1. Sweep

- Goal: Sweeps the shaft of a servo motor back and forth across 180 degrees.
- Hardware Required
  - Arduino
  - Servo Motor
  - Hook-up wire

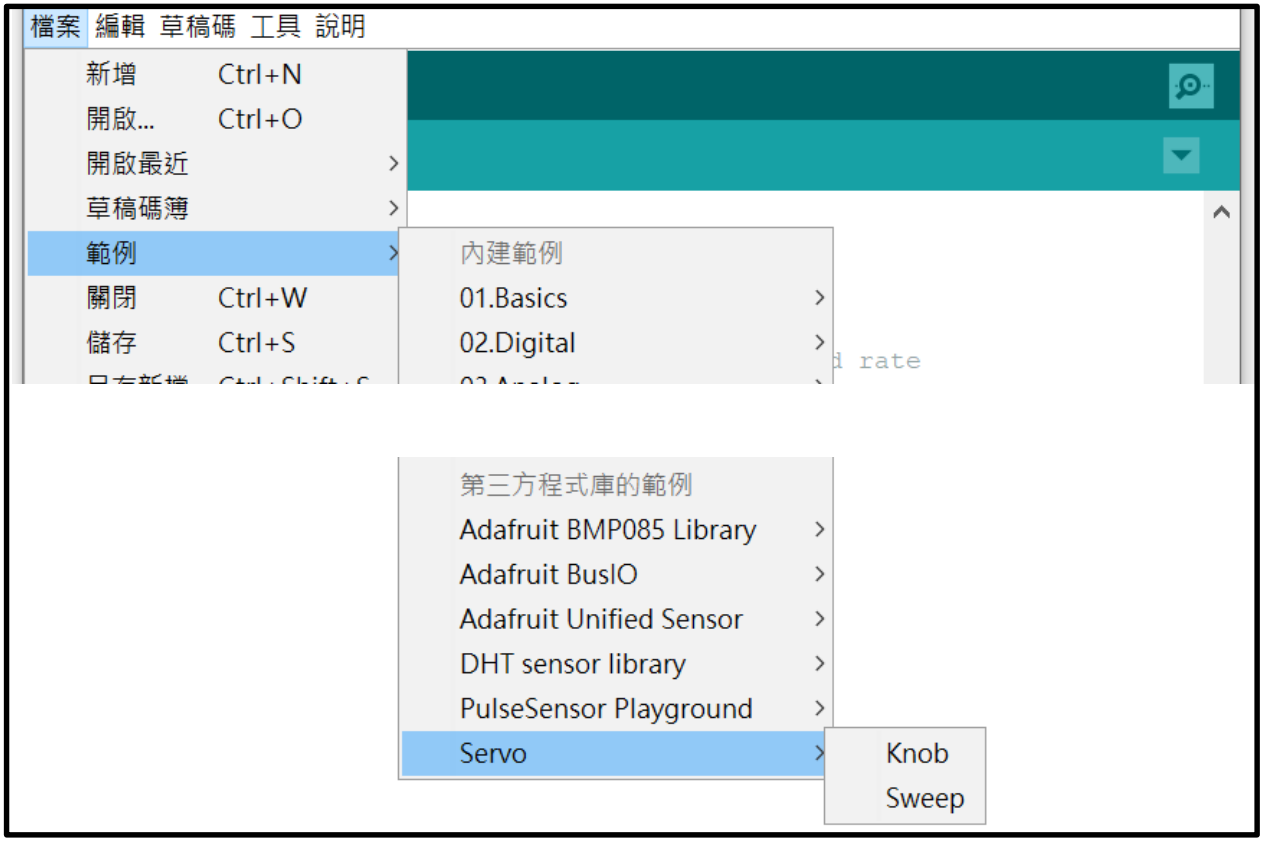




Lab1. Sweep

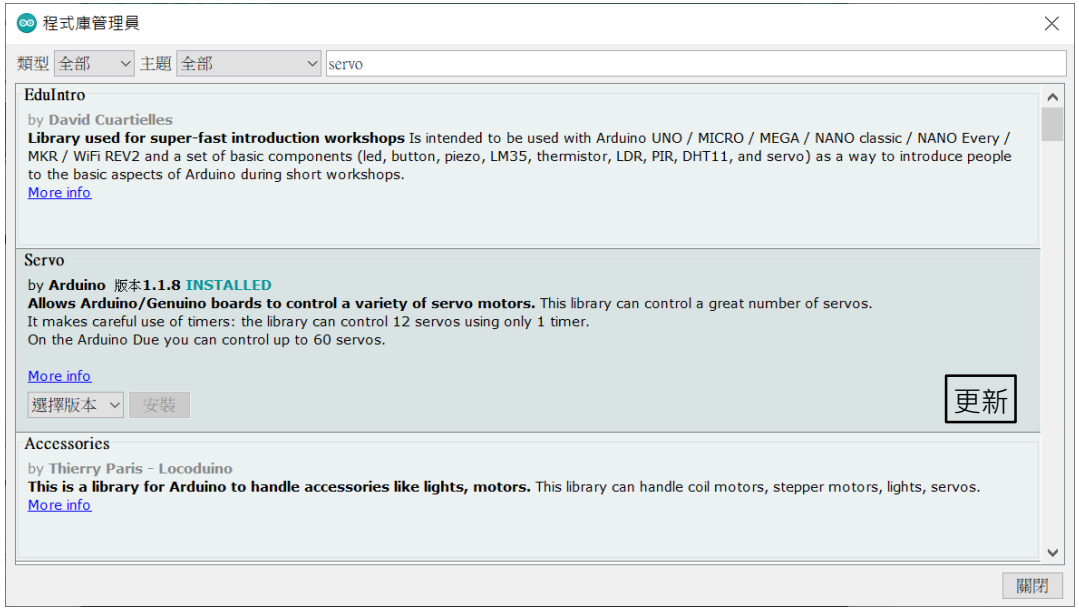
Arduino IDE

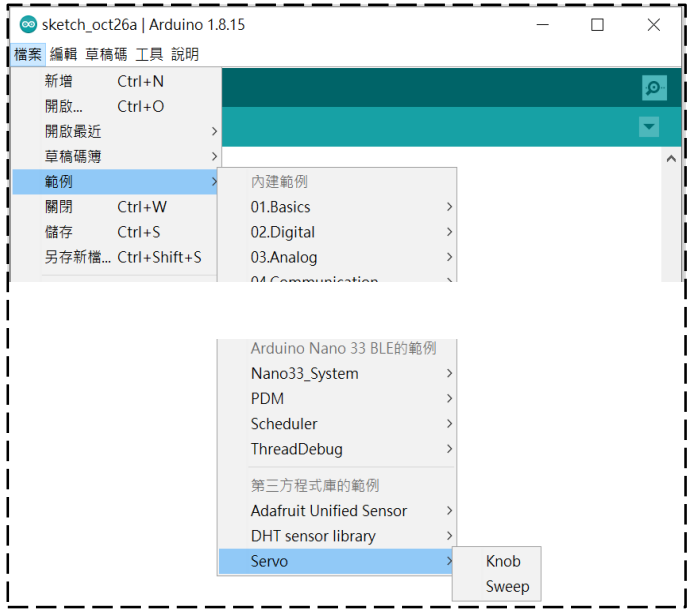
Open--->File--->Examples---> 第三方程式庫 --> Servo



Servo is not found?

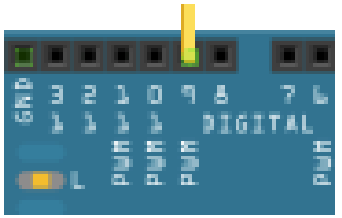
- 程式庫管理員 -> Servo -> 更新





Sample code

```
#include <Servo.h>

Servo myservo;              // create servo object to control a servo
// twelve servo objects can be created on most boards

int pos = 0;                // variable to store the servo position

void setup() {
  myservo.attach(9);        // attaches the servo on pin 9 to the servo object
}

void loop() {
  for (pos = 0; pos <= 180; pos += 1) {   // goes from 0 degrees to 180 degrees, in steps of 1 degree
    myservo.write(pos);                   // tell servo to go to position in variable 'pos'
    delay(15);                            // waits 15ms for the servo to reach the position
  }
  for (pos = 180; pos >= 0; pos -= 1) {   // goes from 180 degrees to 0 degrees
    myservo.write(pos);                   // tell servo to go to position in variable 'pos'
    delay(15);                            // waits 15ms for the servo to reach the position
  }
}
```



myservo.write(0) -> myservo.write(1) -> … -> myservo.write(179) -> myservo.write(180)
-> myservo.write(179) -> myservo.write(178) -> … -> myservo.write(0)

Syntax

- Syntax
  - servo.attach(pin)
  - servo.attach(pin, min, max)

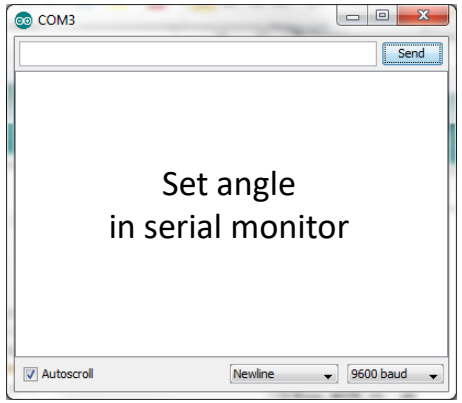
- Parameters
  - pin: the pin number that the servo is attached to (usually, Pin 9 or 10)
  - min (optional): the pulse width, in microseconds, corresponding to the minimum (0-degree) angle on the servo (defaults to 544)
  - max (optional): the pulse width, in microseconds, corresponding to the maximum (180-degree) angle on the servo (defaults to 2400)

Syntax

- Syntax
  - servo.write(angle)
- Description
  - Writes a value to the servo, controlling the shaft accordingly.
  - On a **standard servo**, this will set the angle of the shaft (in degrees), moving the shaft to that orientation.
  - On a **continuous rotation servo**, this will set the speed of the servo (with 0 being full-speed in one direction, 180 being full speed in the other, and a value near 90 being no movement).
- Parameters
  - angle: the value to write to the servo, from 0 to 180 (in degree)
- Example
  - myservo.write(90); // set servo to mid-point

Quiz 1

- In lab 1, the servo motor sweeps continuously.
- How do we **set a specific angle** for RC motor **in serial monitor**?
  - The servo motor does not sweep continuously
  - Hint: we can refer to the “guess what” in last week



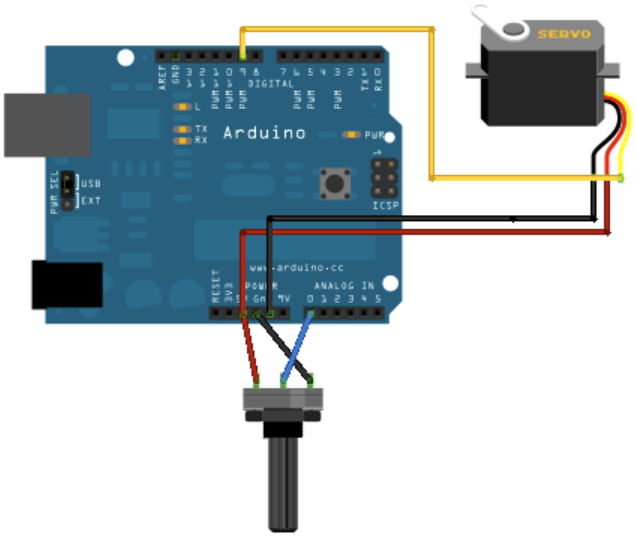
Control the angle of the shaft

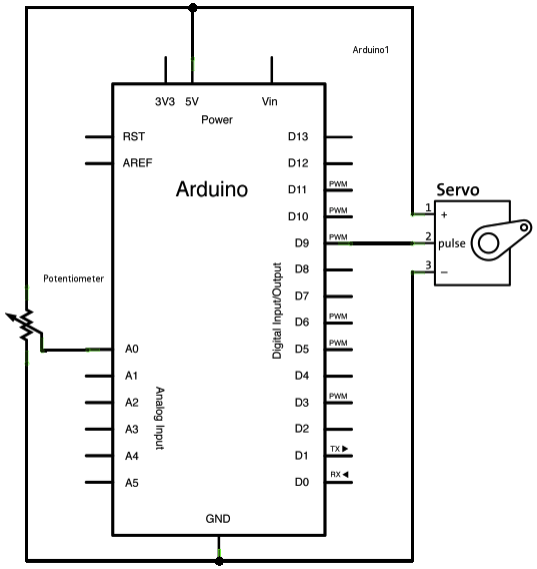
Lab2. Knob

Control the position of a servo motor

Lab2. Knob

- Goal: **Control the position** of a servo motor with your Arduino and a **potentiometer**.
- Hardware Required
  - Arduino
  - Servo Motor
  - Potentiometer
  - Hook-up wire

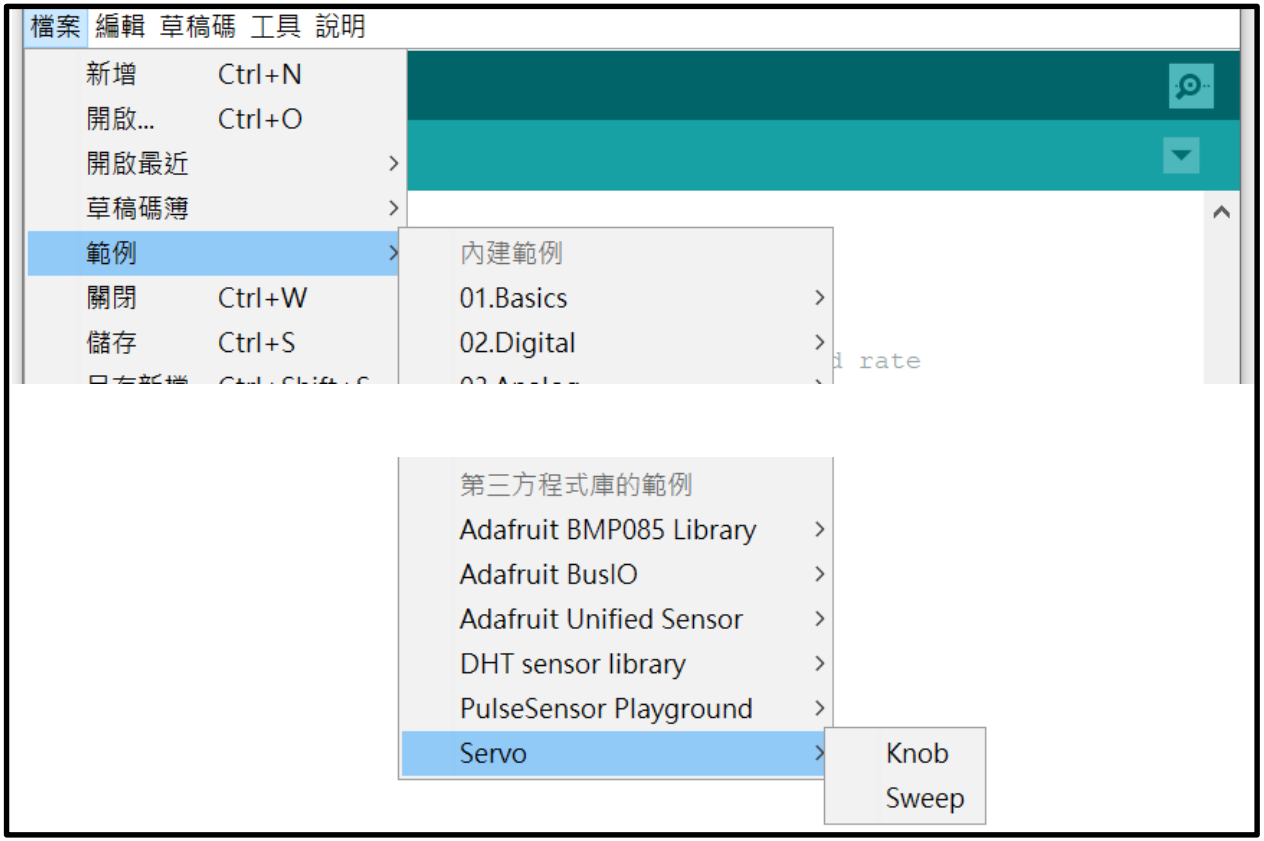




Lab2. Knob

Arduino IDE

Open--->File--->Examples---> 第三方程式庫 --> Servo



Sample code

```
#include <Servo.h>

Servo myservo;          // create servo object to control a servo

int potpin = A0;        // analog pin used to connect the potentiometer
int val;                // variable to read the value from the analog pin

void setup() {
  myservo.attach(9);    // attaches the servo on pin 9 to the servo object
}

void loop() {
  val = analogRead(potpin);          // reads the value of the potentiometer (value between 0 and 1023)
  val = map(val, 0, 1023, 0, 180);   // scale it for use with the servo (value between 0 and 180)
  myservo.write(val);                // sets the servo position according to the scaled value
  delay(15);                         // waits for the servo to get there
}
```

Syntax

- analogRead
  - 10-bit analog to digital converter
  - https://www.arduino.cc/reference/en/language/functions/analog-io/analogread/
- map
  - Re-maps a number from one range to another.
  - https://www.arduino.cc/reference/en/language/functions/math/map/
- servo write
  - Writes a value to the servo, controlling the shaft accordingly.
  - https://www.arduino.cc/en/Reference/ServoWrite

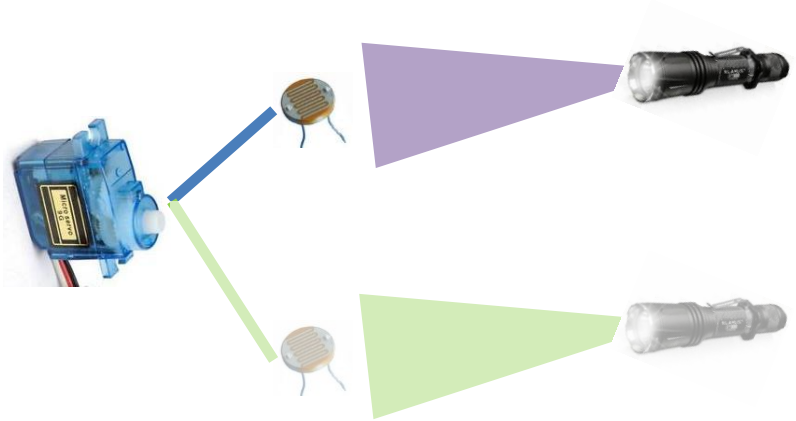
Discussion 1

- After myservo.write(val), why do we need delay(15)? What will happen if we don't use delay?

```
void loop() {
  val = analogRead(potpin);
  val = map(val, 0, 1023, 0, 180);
  myservo.write(val);
  delay(15);
}
```

Quiz 2

- Design a sunflower by one photocell and one servo motor
  - Attach photocell to servo
  - When one moves the light source (e.g., torch from smartphone), the servo moves the photocells till the photocells face the light source.
  - **Sweep the photocell to find the position with maximum illumination**

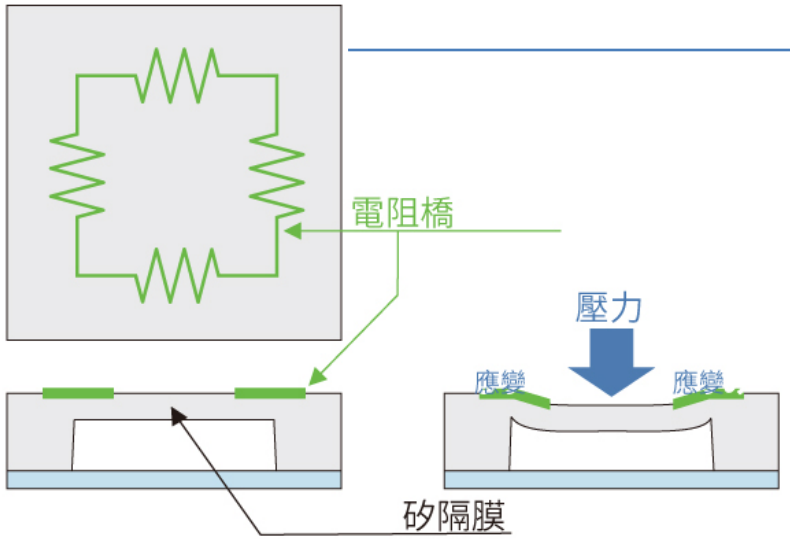


Lab3. Altimeter (Pressure Sensor)

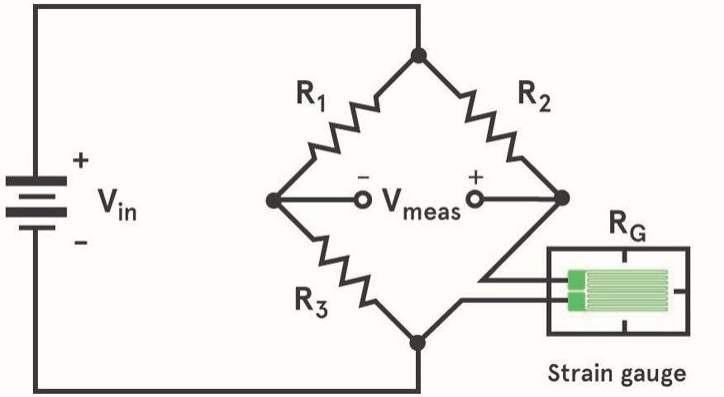
measure barometric pressure and temperature,
and then calculate the altitude

壓阻式氣壓感測器
https://www.rohm.com.tw/electronics-basics/sensors/sensor_what4

Pressure Sensor



當R3/R1 = RG/R2時，電橋平衡，檢流計無電流通過。
對於電流是否經過非常敏感，可以獲取頗精確的測量。



Wheatstone bridge

表面擴散雜質形成電阻橋電路(Wheatstone bridge)，
施加壓力產生的變形會影響電阻值，進而來計算壓力（氣壓）。

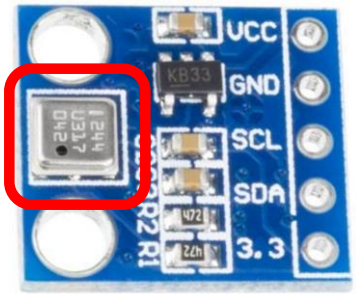
Piezo-Resistive 壓阻式感測器

The BMP085 is based on piezo-resistive technology for EMC robustness, high accuracy and linearity as well as long term stability.

Lab3. Altimeter

- BMP180: measure barometric pressure and temperature.
  - The pressure changes with altitude, we can also use it as an altimeter.
  - Use I2C-bus to read the sensor values.
- Altimeter, Barometer, barometric pressure sensor

Technical Details
- VCC: 3 to 5V
- Pressure sensing range: 300-1100hPa
- 9000m to -500m above sea level
- Up to 0.03hPa / 0.25m resolution
- Temperature sensing range: -40 to 85˚C
- +-2˚C temperature accuracy
- Use I2C address 0x77

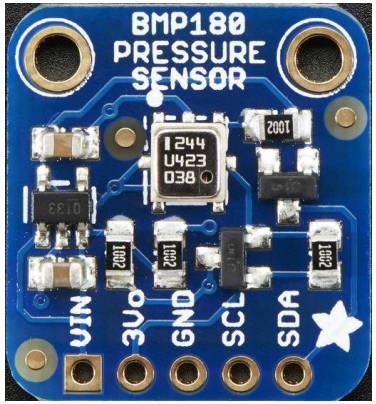


https://static.sparkfun.com/datasheets/Sensors/Pressure/BMP180.pdf
https://learn.sparkfun.com/tutorials/bmp180-barometric-pressure-sensor-hookup-

BMP085? BMP180?

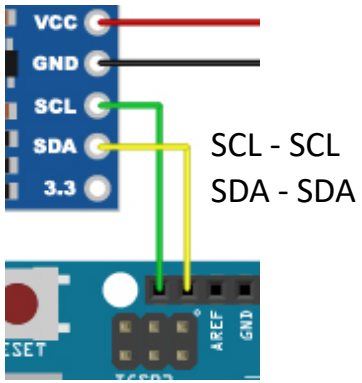
- Two common model: BMP085 and BMP180

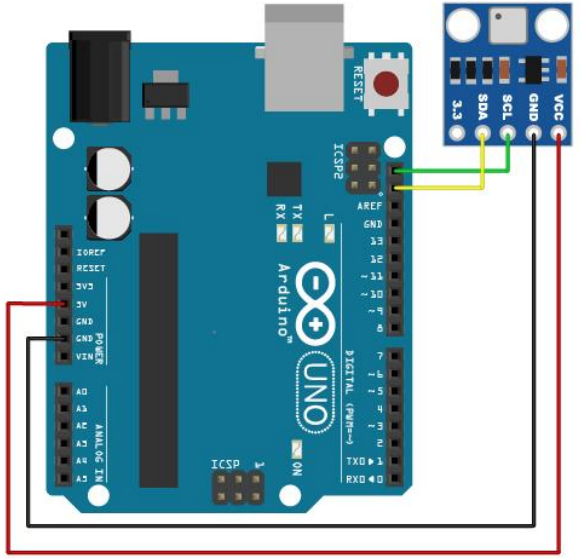
- What is the difference?
  - The BMP180 is the next-generation of sensors from Bosch, and replaces the BMP085.
  - BMP180 is **completely identical** to the BMP085 in terms of **firmware/software**



Lab3. Altimeter

- Goal: Use BMP180 to read the pressure and temperature, and then calculate the altitude and floor number.
- Hardware Required
  - Arduino
  - BMP180



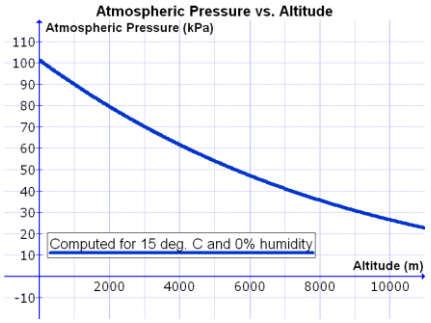


Pressure and altitude

- Barometric formula (valid within troposphere/對流層) :

$$p = p_0 \cdot \left(1 - \frac{L \cdot h}{T_0}\right)^{\frac{g \cdot M}{R_0 \cdot L}} \approx p_0 \cdot \left(1 - \frac{g \cdot h}{c_p \cdot T_0}\right)^{\frac{c_p \cdot M}{R_0}},$$

$$p \approx p_0 \cdot \exp\left(-\frac{g \cdot M \cdot h}{R_0 \cdot T_0}\right)$$



Parameter	Description	Value
p_0	sea level standard atmospheric pressure	101325 Pa
L	temperature lapse rate, = g/c_p for dry air	0.0065 K/m
c_p	constant pressure specific heat	~ 1007 J/(kg•K)
T_0	sea level standard temperature	288.15 K
g	Earth-surface gravitational acceleration	9.80665 m/s^2
M	molar mass of dry air	0.0289644 kg/mol
R_0	universal gas constant	8.31447 J/(mol•K)

Pressure and altitude

- How to calculate altitude?
  1. Start temperature measurement
  2. Start pressure measurement
  3. Based on sea-level and measured pressure, calculate the altitude

$$p = p_0 \cdot \left(1 - \frac{L \cdot h}{T_0}\right)^{\frac{g \cdot M}{R_0 \cdot L}} \approx p_0 \cdot \left(1 - \frac{g \cdot h}{c_p \cdot T_0}\right)^{\frac{c_p \cdot M}{R_0}}$$

$$p \approx p_0 \cdot \exp\left(-\frac{g \cdot M \cdot h}{R_0 \cdot T_0}\right)$$

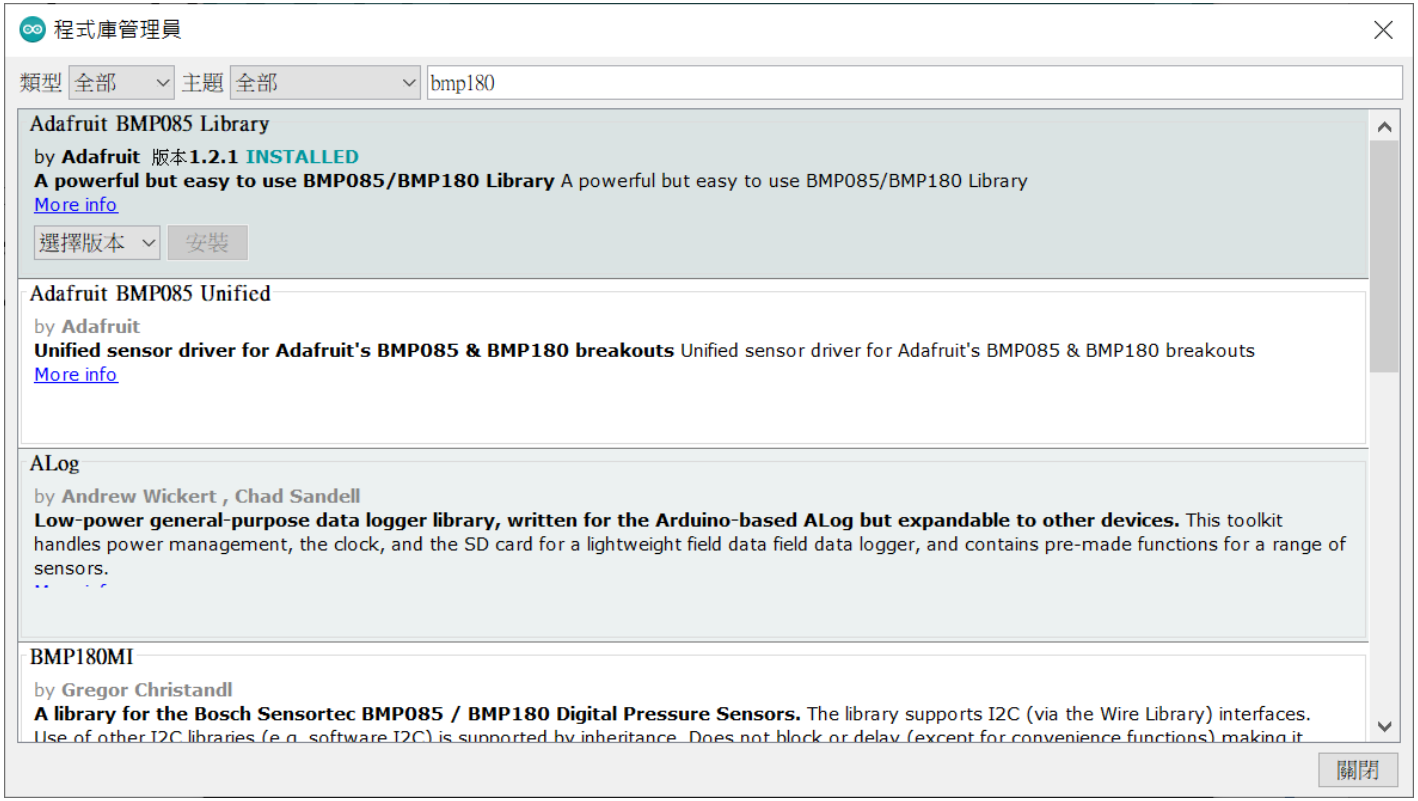
$$\text{altitude} = 44330 * \left(1 - \left(\frac{p}{p_0}\right)^{\frac{1}{5.255}}\right)$$

BMP085.cpp

```
float BMP085::getAltitude(float pressure, float seaLevelPressure) {
  return 44330 * (1.0 - pow(pressure / seaLevelPressure, 0.1903));
}
```

Lab3. Library

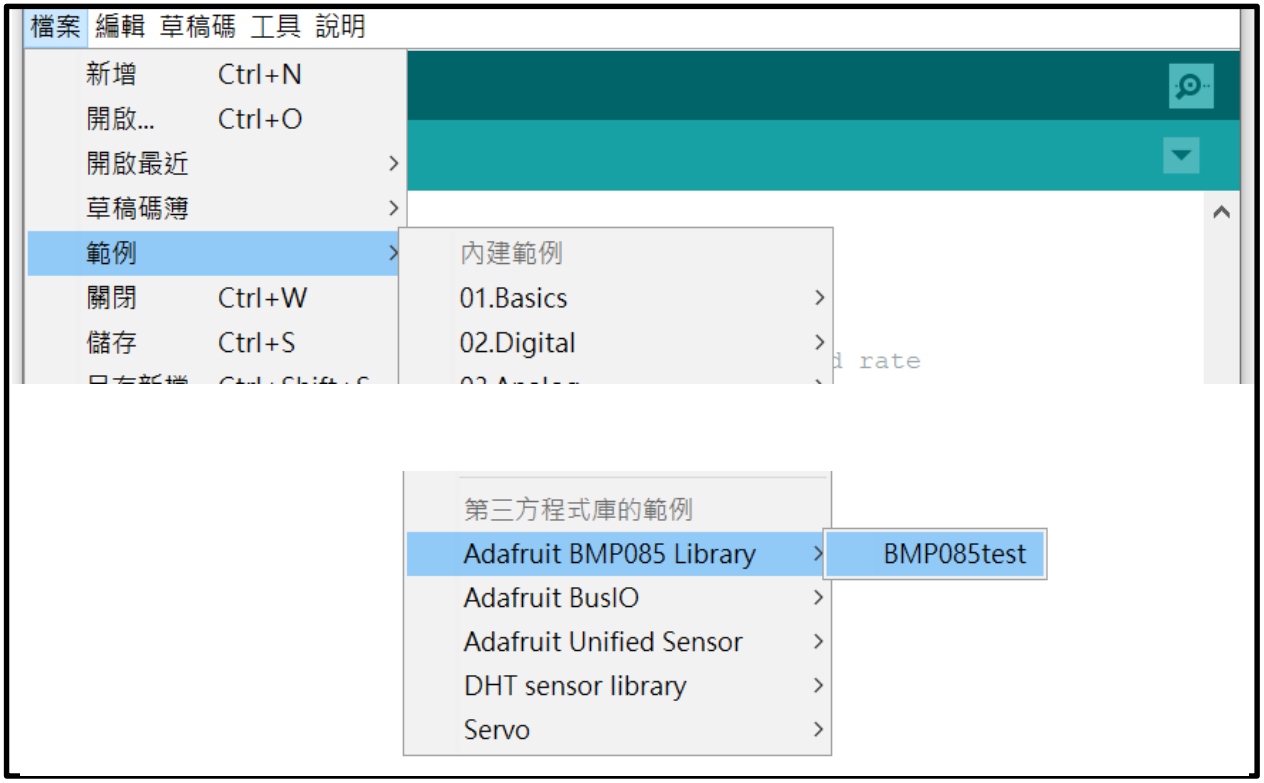
- Download and install (BMP085)



Lab3. Altimeter

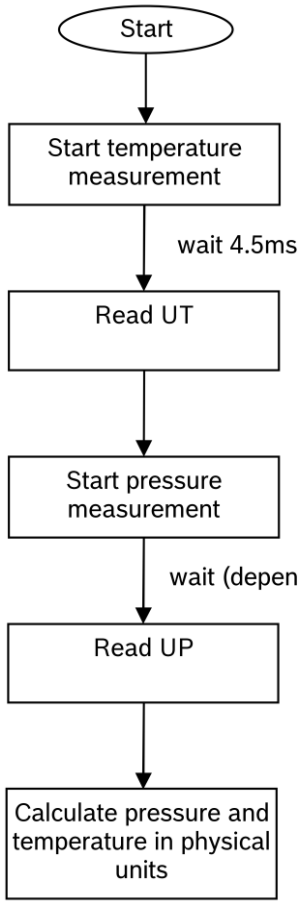
Arduino IDE

Open--->File--->Examples---> 第三方程式庫 --> BMP085



Sample code

```
Adafruit_BMP085 bmp;

void setup() {
  Serial.begin(9600);
  if (!bmp.begin()) {
            Serial.println("Could not find a valid BMP085 sensor,
check wiring!");
            while (1) {}
  }
}

void loop() {
    Serial.print("Temperature = ");
    Serial.print(bmp.readTemperature());
    Serial.println(" *C");

    Serial.print("Pressure = ");
    Serial.print(bmp.readPressure());
    Serial.println(" Pa");
```



- **The standard atmosphere (1 atm) is a unit of pressure defined as 101325 Pa.**
- **Average sea-level pressure is 1013.25 mbar (101.325 kPa; 29.921 inHg; 760.00 mmHg).**

```
  // Calculate altitude assuming 'standard' barometric
  // pressure of 1013.25 millibar = 101325 Pascal
  Serial.print("Altitude = ");
  Serial.print(bmp.readAltitude());
  Serial.println(" meters");

  Serial.print("Pressure at sealevel (calculated) = ");      // if altitude_meters is given
  Serial.print(bmp.readSealevelPressure());
  Serial.println(" Pa");

 // you can get a more precise measurement of altitude
 // if you know the current sea level pressure which will
 // vary with weather and such. If it is 1015 millibars
 // that is equal to 101500 Pascals.
  Serial.print("Real altitude = ");
  Serial.print(bmp.readAltitude(101500));
  Serial.println(" meters");

  Serial.println();
  delay(500);
}
```

中央氣象局

測站名稱	觀測時間 10/29	溫度 ˚C	天氣	相對濕度 (%)	海平面氣壓(百帕)
新竹	11:00	25.0		58	1019.4

Discussion 2

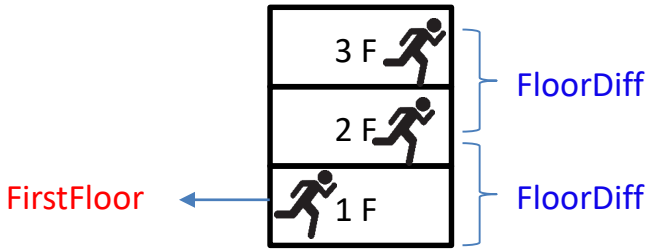
1. **Study the code in BMP085.cpp**. How does the altitude is calculated by using pressure? (paste the code)
2. What is **the unit** of the altitude formula? (as follows)
3. Try to lift your BMP180 sensor, and **write down the value** change between put it on the table and lift it up.

$$\text{altitude} = 44330 * \left(1 - \left(\frac{p}{p_0}\right)^{\frac{1}{5.255}}\right) \quad \text{(unit ???)}$$

Quiz 3

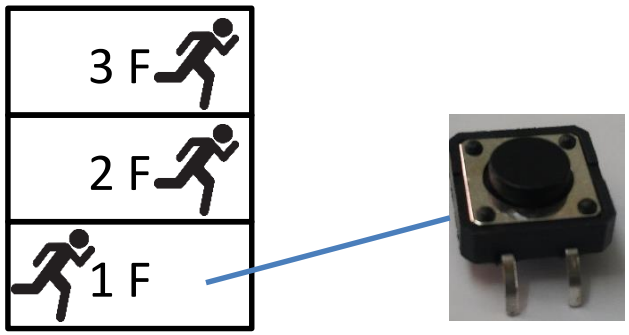
- Use the following formula to design a machine to detect the floor number of Engineer Building 3
  - Use one button and three LED (or one RGB LED)

- $Floor = \frac{Current\_Altitude - FirstFloor}{FloorDiff} + 1$
  - FirstFloor: the altitude of the first floor
  - FloorDiff: the altitude difference between floors

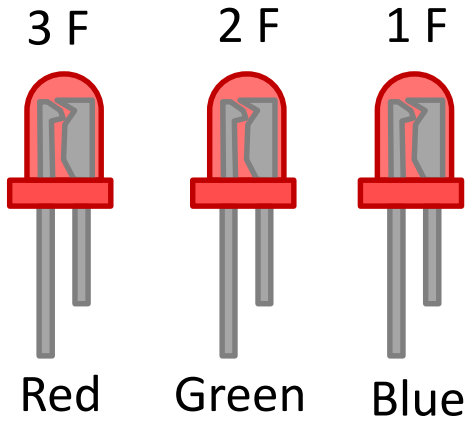


Quiz 3 (cont.)

- Steps:
  1. Press a button to measure the altitude of first floor
  2. Press a button to measure the altitude of second floor and calculate the altitude difference between the two floors
  3. Press button again and use 3 LEDs (or color) to present the floor number



Move with your laptop or power bank

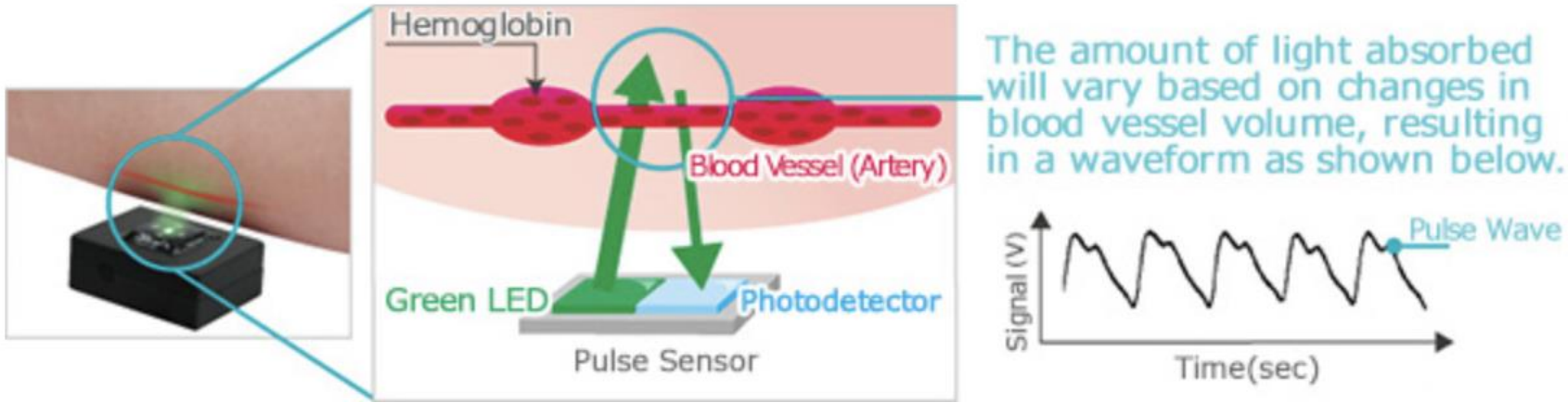


Lab4. Pulse sensor

Optical Sensors for Heart Rate Monitor

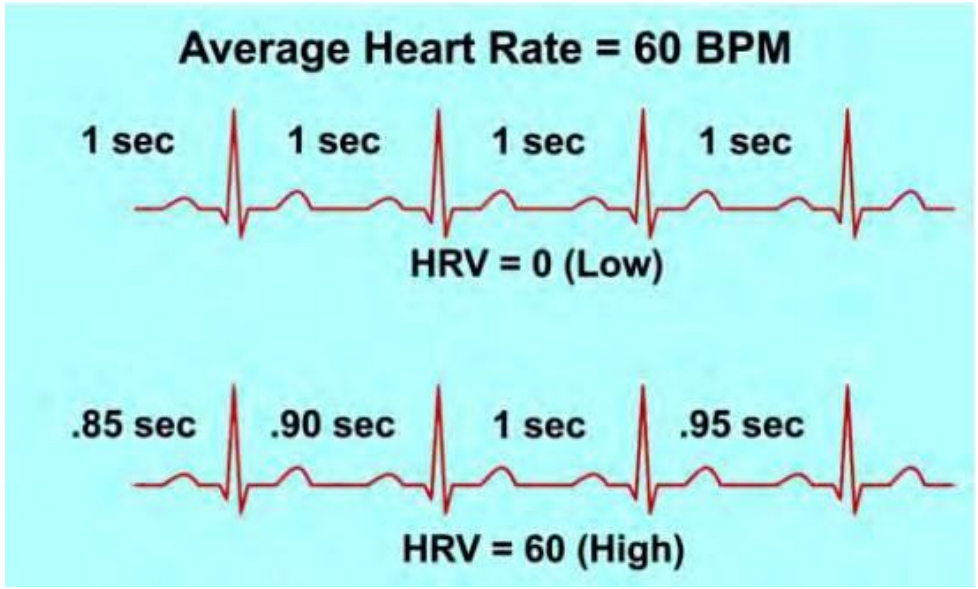
xd-58c pulse Sensor

- **Reflection-type** pulse sensors (Optical Sensors for Heart Rate Monitor) emit infrared, red, or green light (~550nm) towards the body and **measure the amount of light reflected** using a photodiode or phototransistor. Oxygenated hemoglobin present in the blood of the arteries has the characteristic of absorbing incident light, so by **sensing the blood flow rate (change in blood vessel volume) that changes following heart contractions over time we are able to measure the pulse wave signal**.

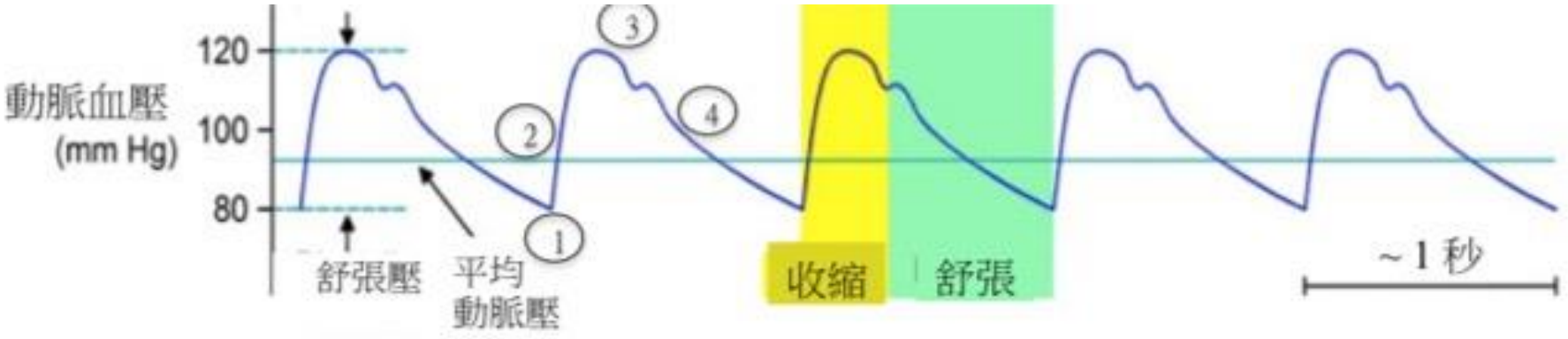


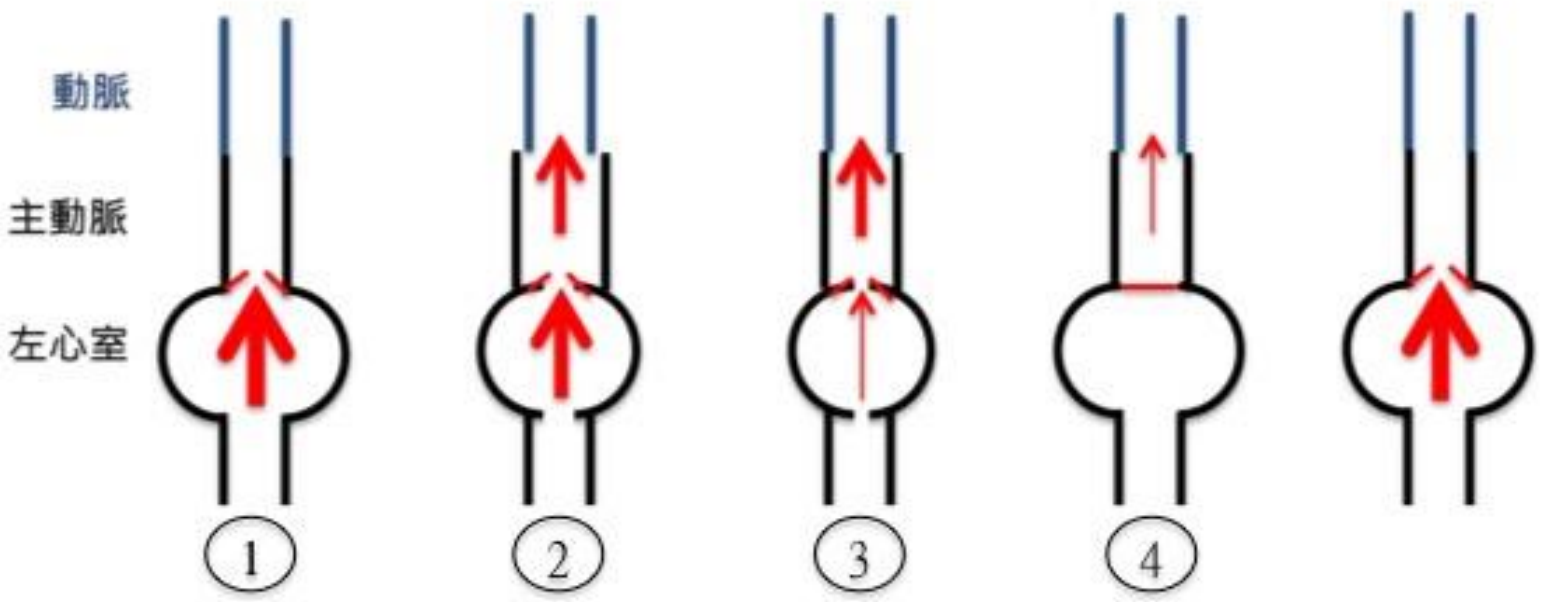
生理訊號名詞

- 心律 (HR, Heart Rate)
- 每分鐘心跳數 (BPM, Beats Per Minutes)
- 心律變異性 (HRV, Heart Rate Variability)
- 心跳間隔 (IBI, Inter-beat Interval)
  - BPM(beats per minute) = 60(sec) / IBI



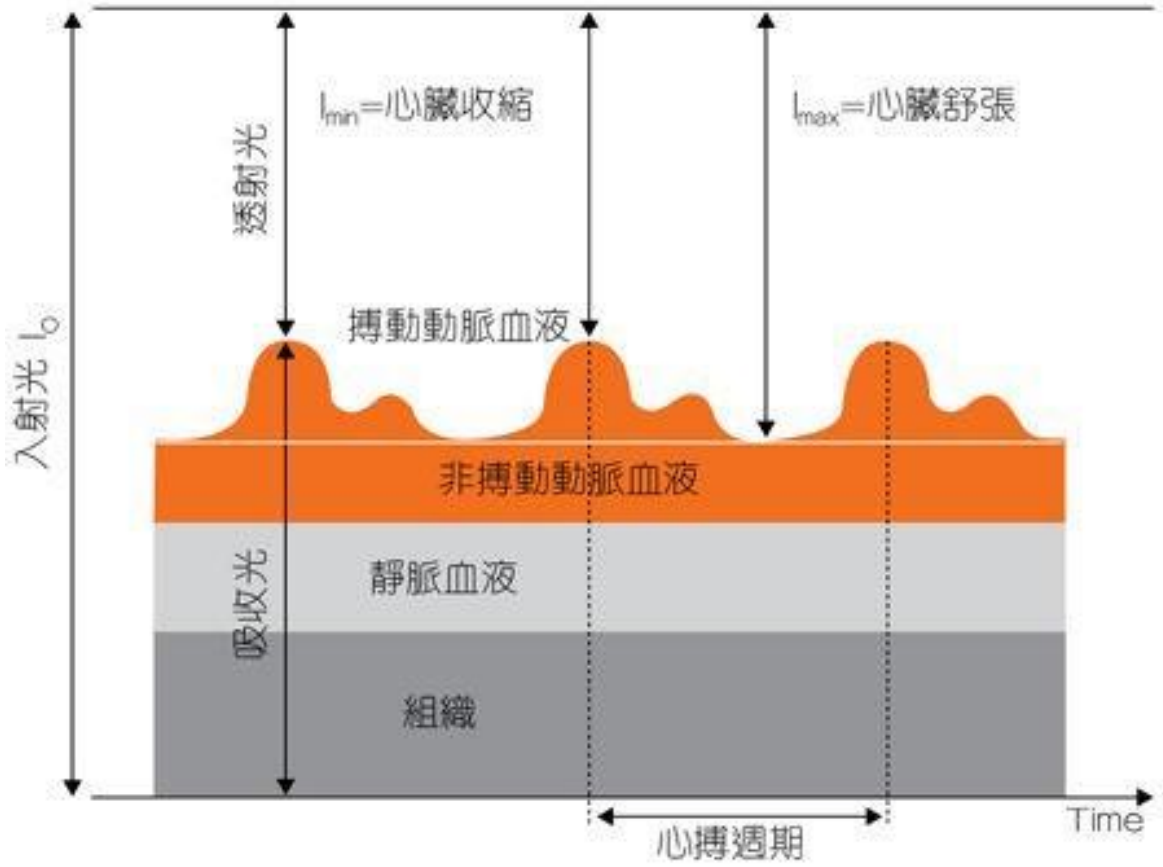
心律和脈博





PPG 測量中檢測器訊號的產生

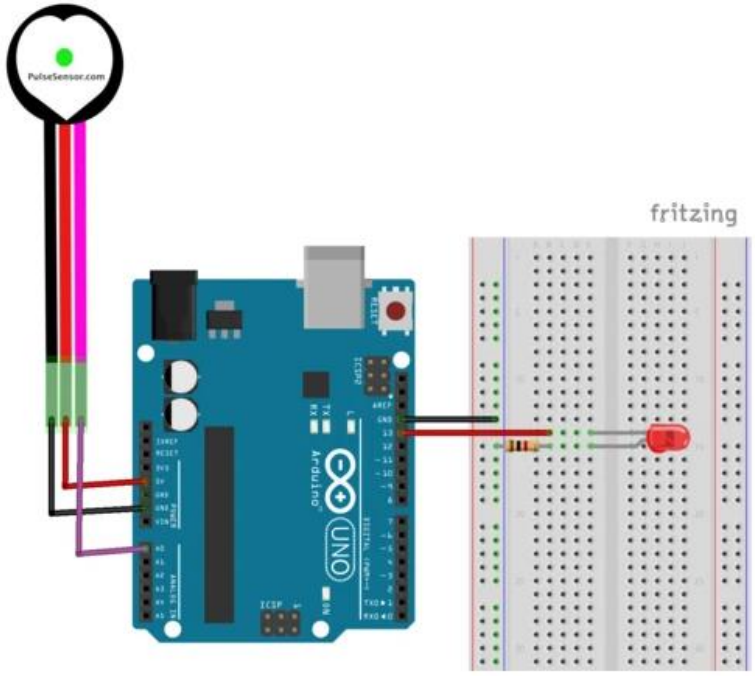
- 光反射的強度 = 血流量的變化 = 心臟律動的結果



GettingStartedProject

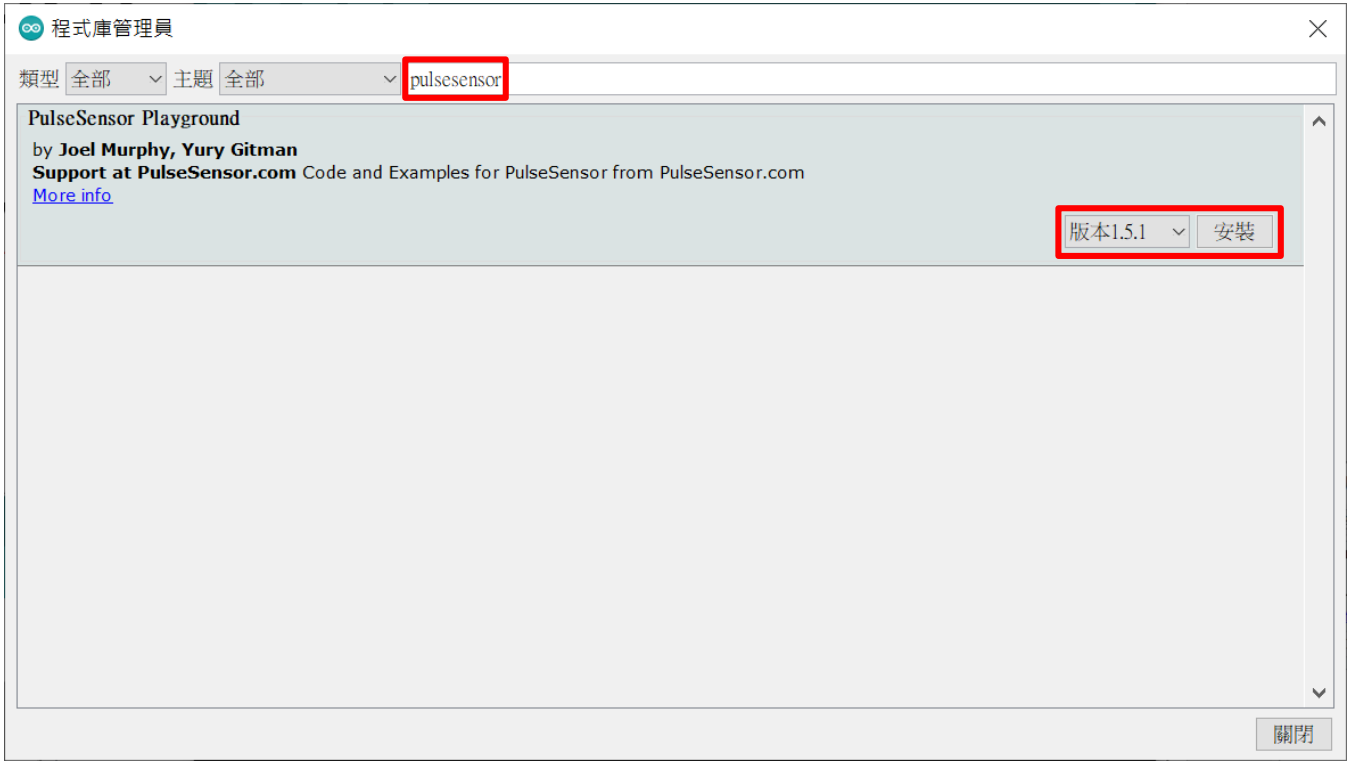
- Goal: Live visualization of Pulse Signal on Arduino Serial Plotter and blink led with your heart rate

- Hardware Required
  - XD-58C pulse sensor
  - Arduino
  - 220 ohm resistor
  - Led
- How to connect?
  - Vcc connects to 5V
  - Gnd connects to Gnd
  - The other connects to analog input



Lab4. Library

- Download and install libarary (pulsesensor)

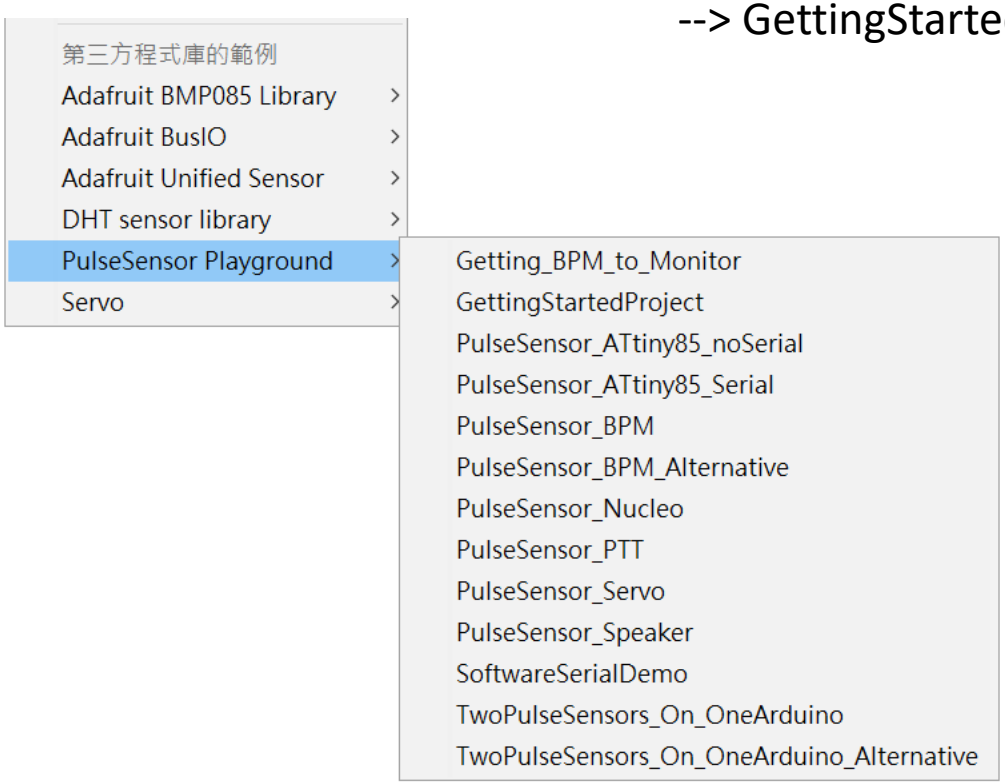


Lab4. pulse sensor

Arduino IDE

Open--->File--->Examples---> 第三方程式庫 --> PulseSensor

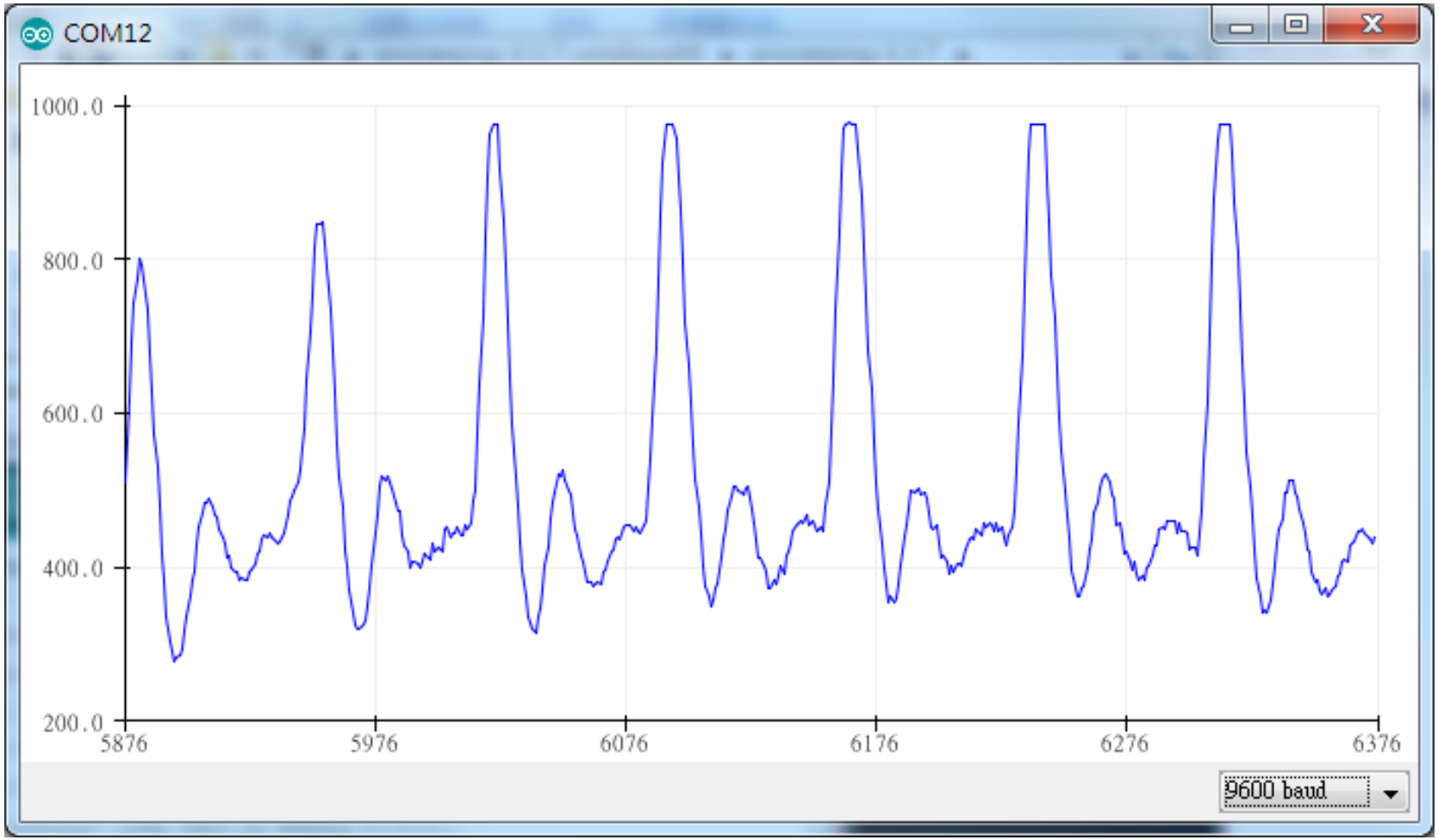
--> GettingStartedProject



Sample code

```
int PulseSensorPurplePin = 0; // Pulse Sensor PURPLE WIRE connected to ANALOG PIN 0
int LED13 = 13;               // The on-board Arduion LED
int Signal;                   // holds the incoming raw data. Signal value can range from 0-1024
int Threshold = 550;          // Determine which Signal to "count as a beat", and which to ingore.

// The SetUp Function:
void setup() {
  pinMode(LED13,OUTPUT);   // pin that will blink to your heartbeat!
   Serial.begin(9600);           // Set's up Serial Communication at certain speed.

}

// The Main Loop Function
void loop() {

  Signal = analogRead(PulseSensorPurplePin); // Read the PulseSensor's value.
                                             // Assign this value to the "Signal" variable.

   Serial.println(Signal);                   // Send the Signal value to Serial Plotter.

   if(Signal > Threshold){                   // If the signal is above "550", then "turn-on" Arduino's on-Board LED.
     digitalWrite(LED13,HIGH);
   } else {
     digitalWrite(LED13,LOW);                //  Else, the sigal must be below "550", so "turn-off" this LED.
   }

delay(10);
}
```

Lab4. pulse results



Summary

Summary

- **教室座位實聯制**
  - https://docs.google.com/spreadsheets/d/1k4q-JP9Pk9cLGY70V04Nbc6XbUbBdYu_TXqJtHF6rGk
- **Practice Labs by yourself**
- **Write Answers for Discussion**
  - Upload to e3 before next class
- **Quiz: Write code for quiz, then demonstrate to TAs**
  - Quiz 1: set a specific angle for RC motor in serial monitor
  - Quiz 2: photocell + servo motor = sunflower
  - **Quiz 3: detect the floor number**