

# DIY Earthquake Detector: The hardware side

## 自製地震探測器：硬件篇

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# Topics today.....

## 今天的主題.....

- A little bit of mechanics  
一點力學
- A bit of electronics  
一點電子學
- A bit of computer science  
一點電腦科學
- And a bit of your creativity!  
還有點你們的創意！

# Hardware 硬件

- hardware |'hɑːdweɪ|
  - ◆ tools, machinery, and other durable equipment.  
工具、機械和其他耐用設備。
  - ◆ the machines, wiring, and other physical components of a computer or other electronic system.  
機器、電線、電腦或其他電子系統的其他物理組件。

# When there is earthquake.....

## 當有地震時……

- Mercalli Intensity Scale - 1956 version  
修訂麥加利地震烈度表〔1956年版本〕
- IV: Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frames creak.

IV 度：懸掛的物件擺動。類似大型貨車駛過的振動，震盪感如大鐵球撞牆。停放著的汽車擺動。門、窗、碗碟發出響聲。緊靠的玻璃及陶瓷器皿叮噠作響。更甚時，木板牆和框架會發出吱吱聲。

A bit of mechanics first.....  
首先，來點力學……

# Recording effects of movement

## 記錄移動引致的後果

- Record the effect of movement.  
要能檢測物件的移動，我們要記錄移動引致的後果。
- To make slight movement detectable, we can amplify the effect of movement somehow.  
要能檢測物件的輕微移動，可設法放大其移動之後果。
- What effects? 甚麼後果？




# Effects of movement

## 移動的後果

- Vibrations 震動
  - ◆ Hanging objects swing. 懸掛的物件擺動
  - ◆ Vibration like passing of heavy trucks. 類似大型貨車駛過的振動
  - ◆ Sensation of a jolt like a heavy ball striking the walls. 震盪感如大鐵球撞牆
  - ◆ Standing motor cars rock. 停放著的汽車擺動
- Makes sound 產生聲響
  - ◆ Windows, dishes, doors rattle. 門、窗、碗碟發出響聲
  - ◆ Glasses clink. Crockery clashes. 緊靠的玻璃及陶瓷器皿叮噠作響
  - ◆ Wooden walls and frames creak. 木板牆和框架會發出吱吱聲。

# Effects of movement

## 移動的後果

- Vibration: oscillations around quiescent state  
震動：靜止狀態周圍振盪
  - ◆ Returns to normal after vibration. 震動後會回歸常態
- Makes sound 產生聲響 
  - ◆ Cannot hear except on real time. 過後便聽不到了 
- How to amplify their effects? 如何放大其後果？
  - ◆ Arrange to make the effects irreversible (or not easily reversible). 使後果不能（或很難）逆轉 



# Effects not easily reversible 很難逆轉的後果

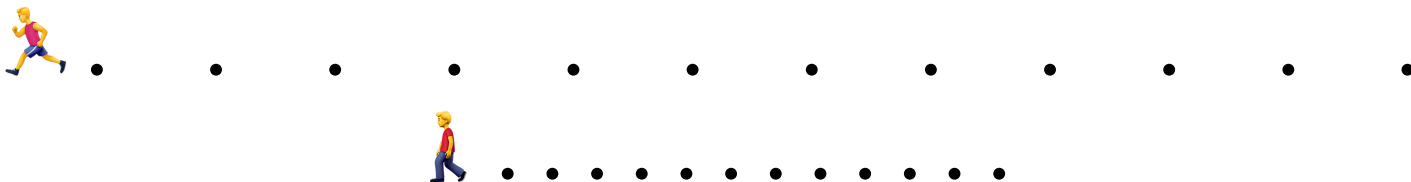
- If movements can..... 如果移動可以……
  - ◆ make a mark 製造標記
  - ◆ displace objects 使東西移位
    - ▶ lean on something 倚傍東西
    - ▶ topple 倒下

# Newton's First Law of motion

## 牛頓第一運動定律

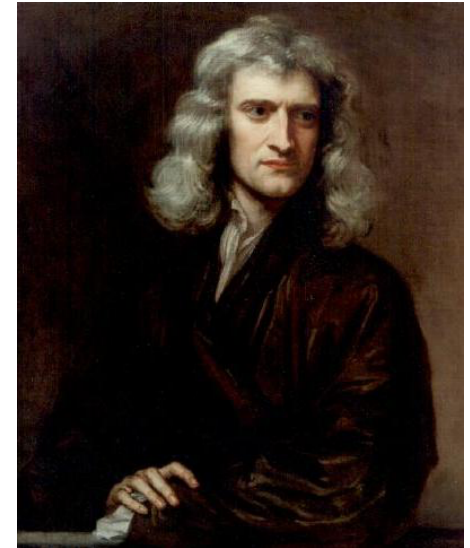
- Newton's First Law of motion: The velocity of an object remains the same unless acted upon by an unbalanced force.

牛頓第一運動定律：如無外力，物件移動速度及方向不變。



# In case you are curious.....

## 好奇的話.....



[https://commons.wikimedia.org/wiki/File:Sir\\_Isaac\\_Newton\\_\(1643-1727\).jpg](https://commons.wikimedia.org/wiki/File:Sir_Isaac_Newton_(1643-1727).jpg)

- Newton's three laws of motion:  
牛頓三條運動定律：

- ◆ 1st: velocity unchanged 動者常動 (靜者常靜)
- ◆ 2nd:  $F=ma$  剩外力 = 質量乘加速度
- ◆ 3rd: action=reaction 作用力 = 反作用力

# Mechanical equilibrium

## 力學平衡

- Equilibrium: net force on object is zero.  
平衡：施於物件上的淨力為零。
- (Stable, Unstable, Neutral) mechanical equilibrium: an object's potential energy (increases, decreases, unchanged) if it is slightly disturbed.  
(穩定, 不穩定, 中立 / 隨遇) 力學平衡：小量擾動使物件位能(增加, 減少, 不變)。
- Unstable mechanical equilibrium: the object goes away from its original state after a small perturbation.  
不穩定力學平衡：小量擾動後，物件遠離原來狀態。



# Bowl and bosu



- Stable or unstable equilibrium?  
力學平衡：穩定還是不穩定？
  - ◆ A ball in a bowl 碗內的球
  - ◆ A ball on a bosu Bosu 上的球
- Your earthquake detector: can this principle be applied?  
你的地震探測器：可以利用這原理嗎？

Image source: [https://commons.wikimedia.org/wiki/File:Iranian\\_-\\_Gombroon\\_Ware\\_Bowl\\_with\\_Diamond\\_Pattern\\_-\\_Walters\\_481730.jpg](https://commons.wikimedia.org/wiki/File:Iranian_-_Gombroon_Ware_Bowl_with_Diamond_Pattern_-_Walters_481730.jpg)

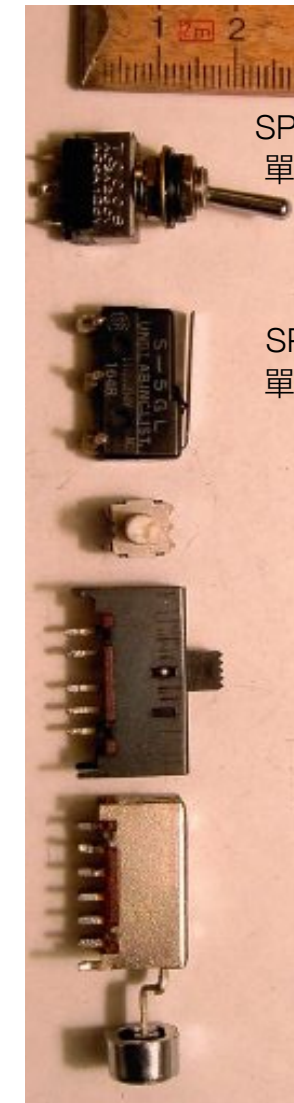
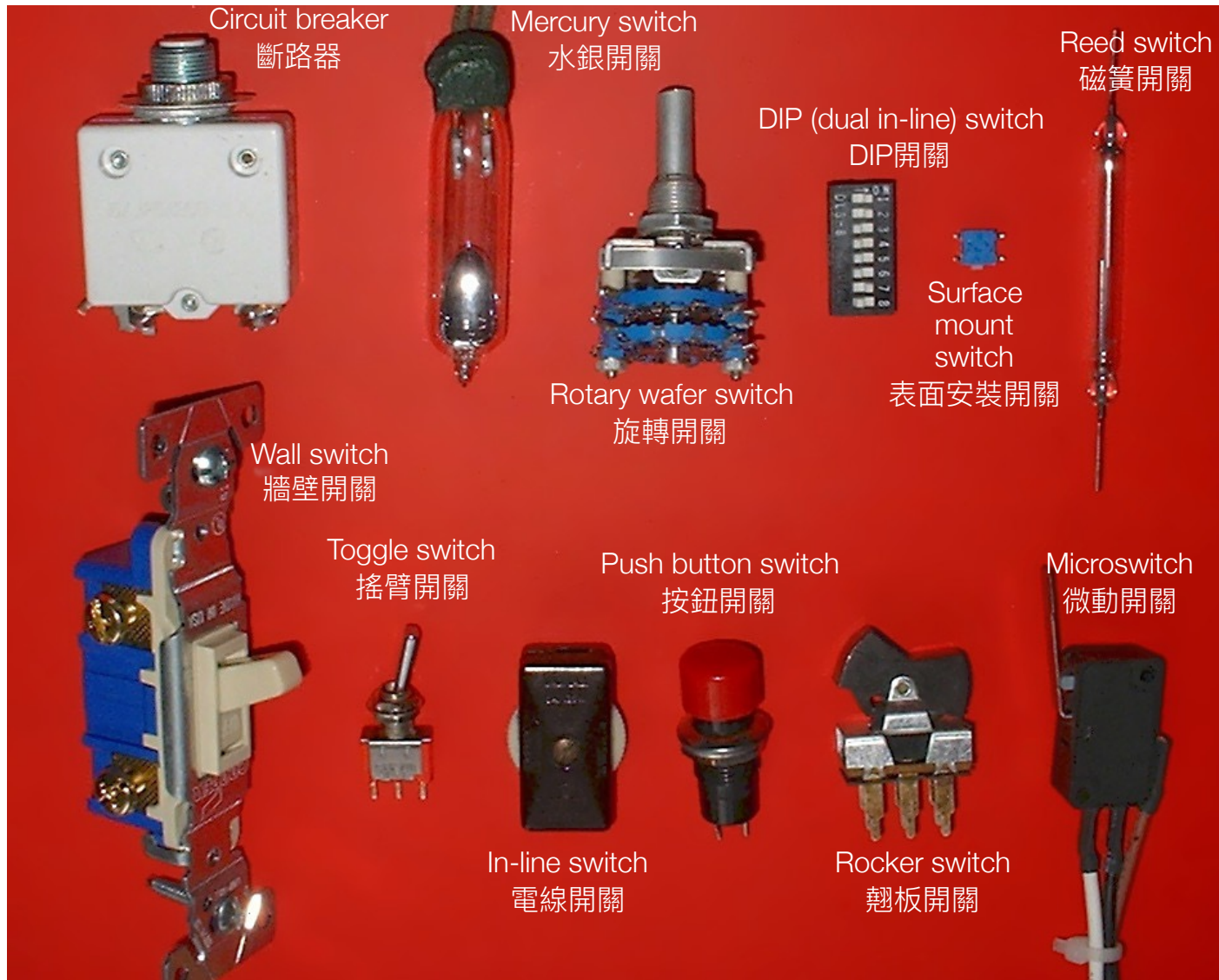
Next, a bit of electronics.....  
然後，來些電子學.....

# Record electronically

## 電子記錄

- Press a switch connected to a computer when there is vibration.  
有振動時按下連接電腦的開關。
- Switches lets current through under some conditions.  
開關在某些情況下允許電流通過。
- Two metal conductors that are in contact with each other under some conditions is a switch.  
在某些條件下會接觸的兩個金屬導體就是開關。

# Switches 開關



SPDT toggle switch  
單刀雙擲搖臂開關

SPDT microswitch  
單刀雙擲微動開關

SPDT switch  
單刀雙擲開關

1P4T switch  
單刀四擲開關

4P2T switch  
四刀雙擲開關

Image sources:

- Electrical switches. By ArnoldReinhold. CC-BY-SA-3.0, GFDL. <https://commons.wikimedia.org/wiki/File:Switches-electrical.agr.jpg>
- Image of electrical changeover switches. By Glenn. GFDL, CC-BY-SA-3.0 [https://commons.wikimedia.org/wiki/File:Changeover\\_switches.jpg](https://commons.wikimedia.org/wiki/File:Changeover_switches.jpg)

Earthquake detector design competition

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<http://www.cs.hku.hk/~quake/>



# About switches 關於開關

- 2P6T, etc. can be used for ganged rotary switches.  
2P6T 等等會用於旋轉開關。
- Some switches like push buttons has a normal state.  
有些開關有常態，例如按鈕開關。
- A Normally Open (NO) switch has a normal state that does not conduct electricity.  
常開 (NO) 開關常態為開路，即電流不能通過。
- A Normally Closed (NC) switch has a normal state that conducts electricity.  
常閉或常關 (NC) 開關常態為閉路，即電流可以通過。
- Relay contacts can also be designated by NO and NC.  
繼電器的接點亦能以 NO 和 NC 表示。

# Electricity-controlled switches: Relays

## 電控開關：繼電器



**TAKAMISAWA RY3W-K** Relay (2P2T, 3VDC, 18E [ ])

**TAKAMISAWA RY5W-K** Relay (2P2T, 5VDC, 167E [ ])

**TAKAMISAWA RY6W-K** Relay (2P2T, 6VDC, 240E [ ])

07-01-3003

07-01-3005

07-01-3006



**TAKAMISAWA RY12W-K** Relay (2P2T, 12VDC, 960E [ ])

**TAKAMISAWA RY24W-K** Relay (2P2T, 24VDC, 2880E [ ])

**TAKAMISAWA SY-3-K** Relay (1P2T, 3VDC, 15E [ ])



**OMRON H3Y-2** Timer Relay (24VDC, 3min)

**OMRON MK2P-I** Timer Relay (2P2T, 12VDC, 7A)

**OMRON MK2P-I** Timer Relay (2P2T, 24VDC, 7A)

07-20-2430

07-99-0012

07-99-0024



**OMRON MK2P-I** Timer Relay (2P2T, 110VAC, 7A)

**OMRON LY2J** Timer Relay (2P2T, 12VDC, 10A)

**OMRON LY2J** Timer Relay (2P2T, 24VDC, 10A)

Image source:

- [http://www.weclonline.com/eng/productlist.asp?page=1&display=photo&mc\\_code=08&sc\\_code=012&s2c\\_code=0001&s3c\\_code=0010](http://www.weclonline.com/eng/productlist.asp?page=1&display=photo&mc_code=08&sc_code=012&s2c_code=0001&s3c_code=0010)

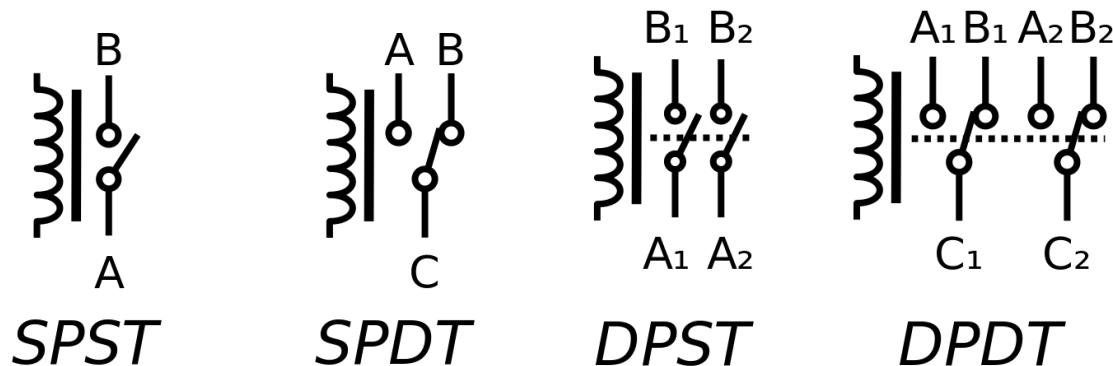
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# Relays 繼電器

- Relays are switches controlled by electromagnets.  
繼電器是用電磁鐵控制的開關。
- The controlling and controlled circuitries are isolated from each other.  
控制的與被控制的電路各自獨立，互不相干。



# Poles and throws

## 刀數和擲數

- Switches are categorised by the number of poles and throws.  
開關用刀數和擲數分類。
- Poles are the number of switches, and throws are the number of choices for each switch.  
刀數即開關數目，擲數即每個開關有多少選擇。
- They are abbreviated as xPyT where x and y are numbers, or S for Single, and D for Double. 分類用 xPyT 表示，x 和 y 為數字，或以 S 代表單，D 代表雙。
- Examples, used in both relays and switches 用於繼電器和開關的例子：
  - ◆ SPST = Single Pole Single Throw 單刀單擲
  - ◆ SPDT = Single Pole Double Throw 單刀雙擲
  - ◆ DPST = Single Pole Single Throw 雙刀單擲
  - ◆ DPDT = Single Pole Double Throw 雙刀雙擲

# Your design! 來設計吧！

- Linking the relay coil to power through a switch controls the relay by the switch; when switch is on, relay is on, when switch is off, relay is off.

將繼電器線圈經開關連接電源，繼電器會在開關開時開，關時關。

- How to make the relay stick at its on state once the switch is on?

如何使繼電器在開關關了後保持關的狀態而不回開的狀態？

- Let's try! 試試吧！

# Interfacing 介面

- What if..... 假如.....
  - ◆ There are many switches to read (why?)  
要讀很多開關的狀態（為何要如此？）
  - ◆ Need to process the states in a sophisticated way  
需要複雜地處理開關的狀態
  - ◆ Interface to computer is needed (e.g., for recording time accurately)  
需要有電腦介面（如需準確地記錄時間）

Computers are needed for more complex applications....  
複雜點就要電腦了……

# Reading switch states

## 讀取開關狀態

- For maximum flexibility, we can use credit card-sized computers such as Arduino or Raspberry Pi to read switch states electronically and program its reactions.

用如Arduino或樹莓派的卡片式電腦讀取開關狀態，編程控制反應，靈活方便。

Arduino: <https://www.arduino.cc/>

Raspberry Pi 樹莓派： <https://www.raspberrypi.org/>

- Please visit the home page for "Invention for Schools Contest" last year for lecture notes on introduction to credit card-sized computers.

<http://i.cs.hku.hk/~i4s/Download-English.php>

請往去年「校園發明大賽」網頁看卡片式電腦的簡介及講義。

<http://i.cs.hku.hk/~i4s/Download-Chinese.php>



# What is Arduino?

## 什麼是 Arduino ?

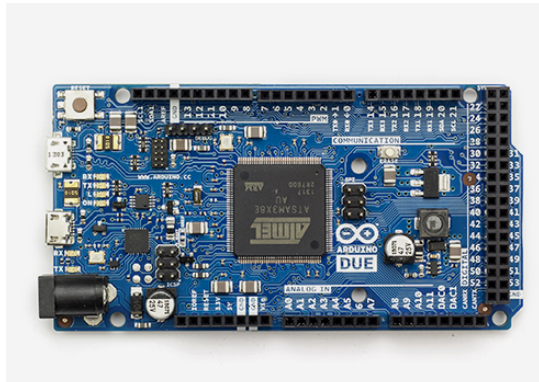
- An open-source prototype platform based on easy-to-use hardware and software.  
一套易用且建基於開放源碼平台的硬件和軟件。
- Can be connected to other electronics components to make different devices.  
可連接到其他電子零件去製作出不同的裝置。

# Some of the Arduino models

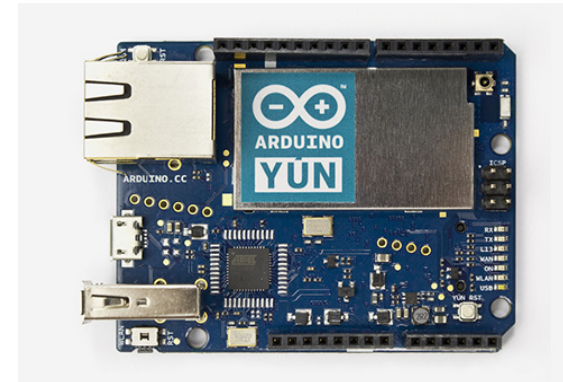
## 部分的 Arduino 類型



Arduino UNO / Genuino



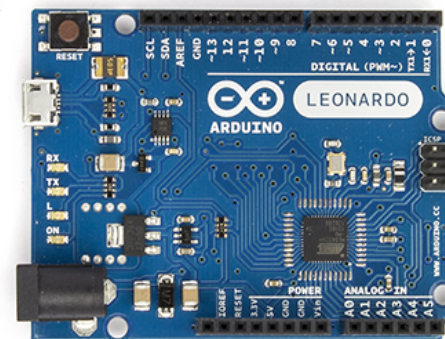
Arduino Due



Arduino Yun



Arduino Zero



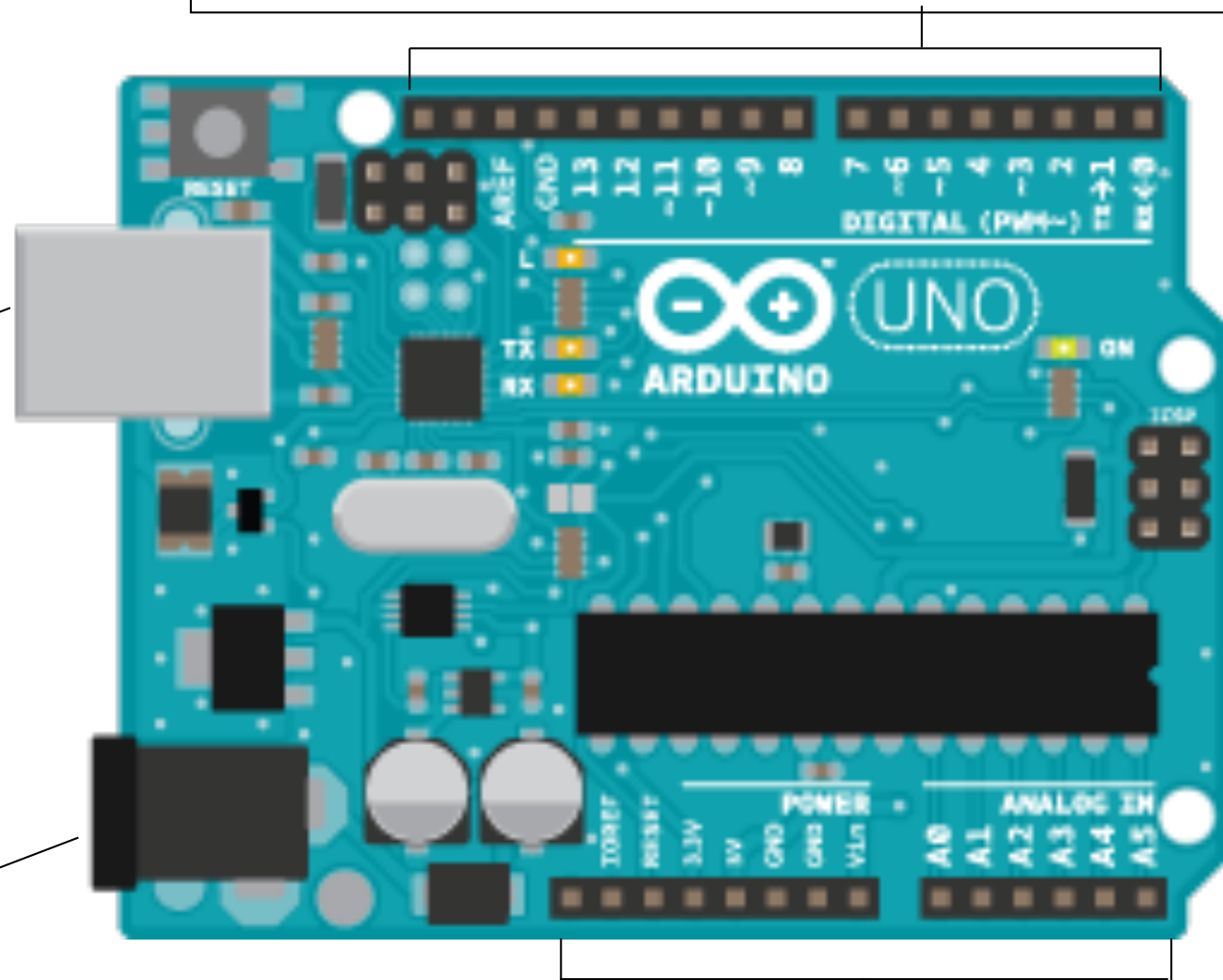
Arduino Leonardo

Comparison 比較 : <https://www.arduino.cc/en/Products/>

Sockets for connecting the Arduino to other electronics  
用以接駁電子零件

USB connector used to load programs on to Arduino from computer USB 插頭，用以上載程式到 Arduino

Power connector 接駁電源



Sockets for connecting the Arduino to other electronics  
用以接駁電子零件

Image source:

- <https://www.arduino.cc>

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<http://www.cs.hku.hk/~quake/>

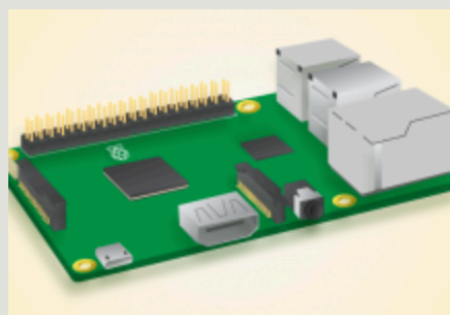
# What is Raspberry Pi?

## 什麼是樹莓派？

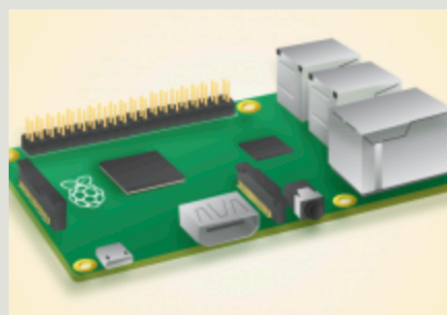
- Low cost, credit card-sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse.  
便宜的卡片式電腦，可接駁顯示屏、鍵盤及滑鼠使用。
- Capable of doing everything you'd expect a desktop computer to do, from browsing the Internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.  
可作桌面式電腦使用，能用以瀏覽網頁、播放影片、製作試算表、文字報告或玩電腦遊戲等。
- Can be connected to other electronic components to make different devices.  
可連接到其他電子零件去製作出不同的裝置。
- Can be used to learn how to program in languages like Scratch and Python.  
可用以學習程式編寫如 Scratch 及 Python。

# Some Raspberry Pi products

## 一些樹莓派產品



RASPBERRY PI 3 MODEL B



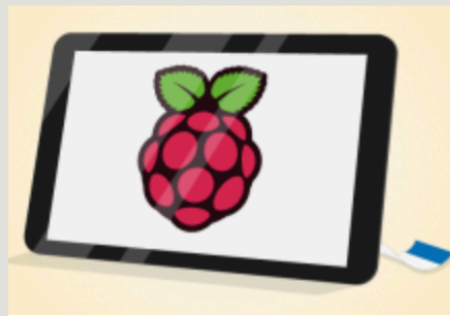
RASPBERRY PI 2 MODEL B



RASPBERRY PI 1 MODEL A+



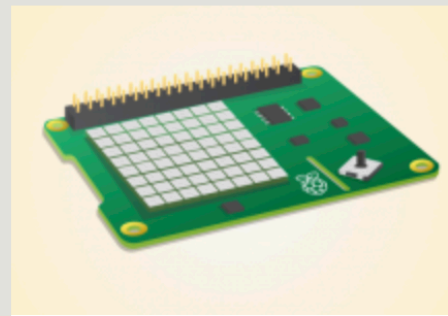
RASPBERRY PI ZERO



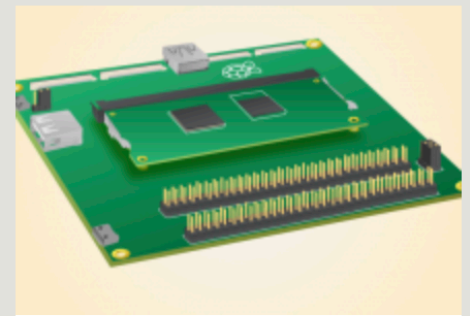
RASPBERRY PI TOUCH DISPLAY



RASPBERRY PI CASE



SENSE HAT



COMPUTE MODULE DEVELOPMENT KIT

Source 資料來源: <https://www.raspberrypi.org/products/>

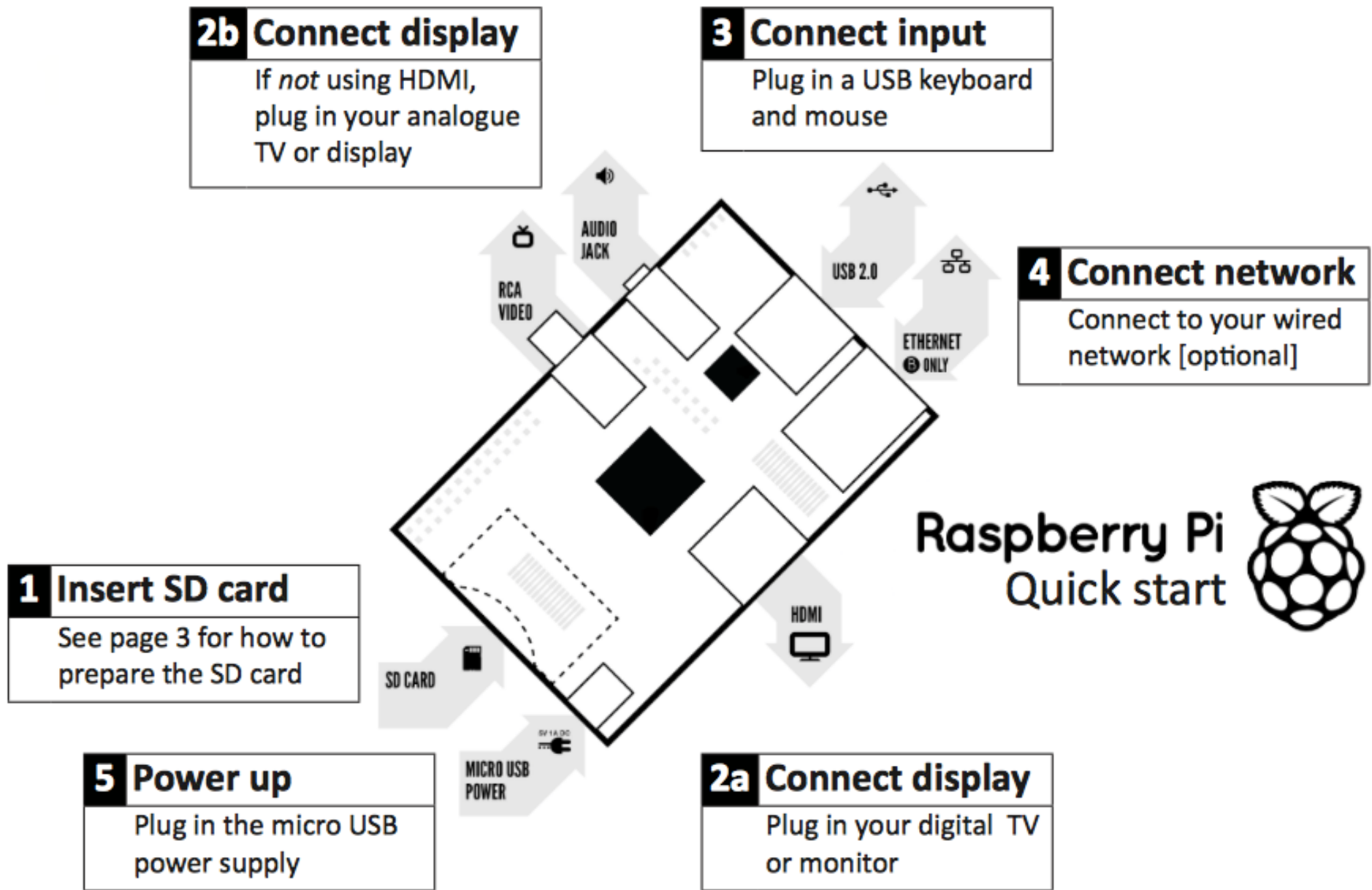


Image source:

- <https://www.raspberrypi.org/wp-content/uploads/2012/12/quick-start-guide-v1.1.pdf>

# Handling multiple switches

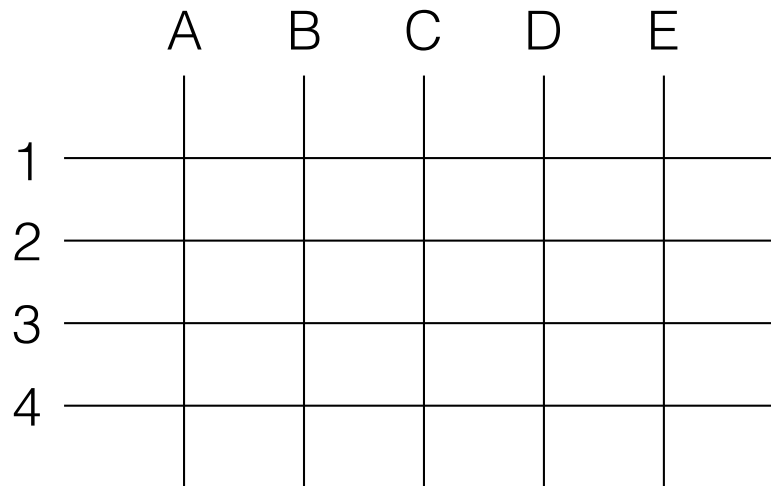
## 處理多個開關

- Raspberry Pi 3 has 26 GPIO pins which can be used for detecting switch states.  
樹莓派3 有 26 GPIO 輸入輸出腳，可用於檢測多個開關狀態。
- Number of pins for I/O for Arduino depends on the model.  
Arduino 不同型號有不同數量的輸入輸出腳。  
<https://www.arduino.cc/en/Products/Compare>

# I have hundreds of switches.....

## 我有上百個開關啊.....

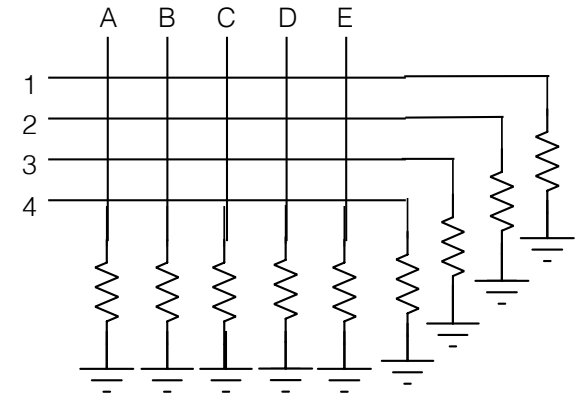
- Modify a keyboard to interface with a Raspberry Pi  
改裝鍵盤以連接樹莓派
- Use matrix scanning 使用矩陣掃描





# Matrix scanning

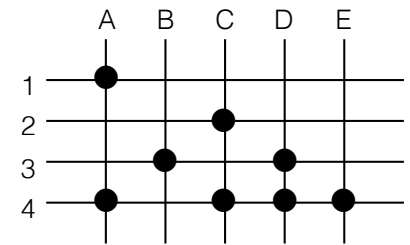
## 矩陣掃描 (1/2)



- The way computer keyboards work.  
電腦鍵盤常用此法。
- Column and row wires are arranged in a matrix and do not normally connect.  
行及列的電線安排成矩陣，平時互不相連。
- All wires pulled low internally or externally using resistors.  
所有行列電線內部或外部用電阻下拉往地。
- One of row/column wires are connected to programmable outputs, the other inputs, of the credit card-sized computer.  
行列之其中一組接往卡片式電腦之可編程輸出，另一組接往輸入。

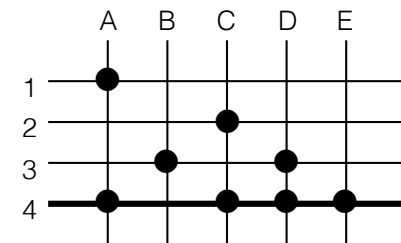
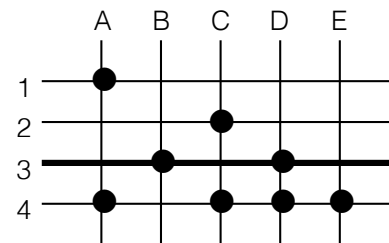
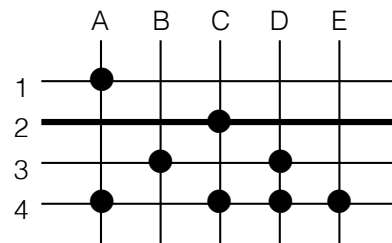
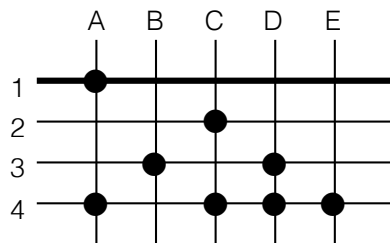
# Matrix scanning

## 矩陣掃描 (2/2)



- Program controls the output to be active (high) wire by wire, reading the inputs every time a wire is activated.

程式逐一控制輸出端高輸出，然後讀輸入端數據。



# Feedback in simple terms

## 反饋：簡單概念

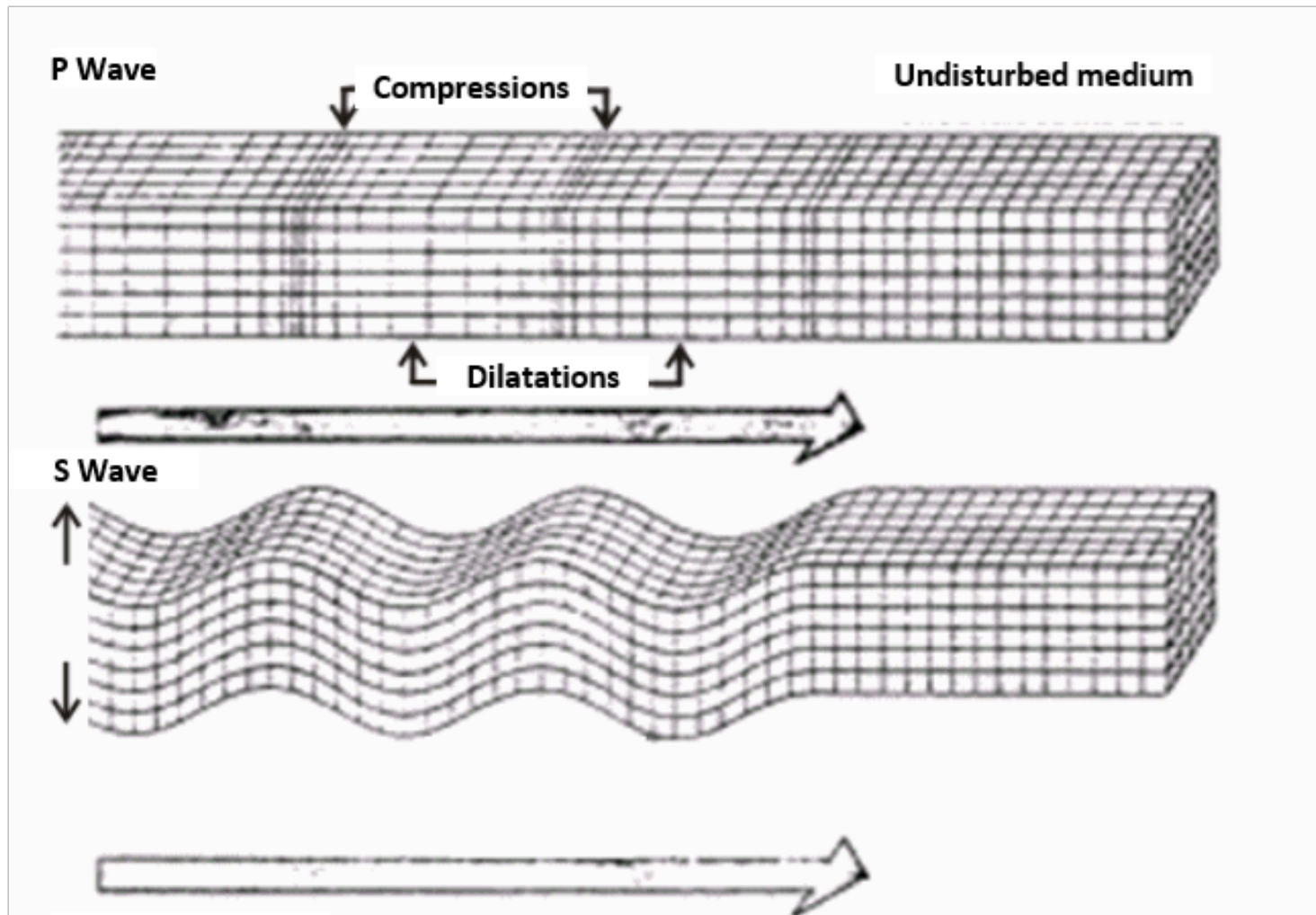
- When all or part of the output of a system goes to its input. 當一個系統的全部或部分輸出變成輸入時
- (Positive, Negative) feedback: the feedback (strengthens, weakens) the output  
(正, 負)反饋：反饋使輸出(加強, 減弱)
- Positive feedback examples: oscillators; amplified sound going back to microphone  
正反饋例子：振盪器；喇叭聲入咪
- Negative feedback examples: temperature controllers in air conditioners; human body thermoregulation  
負反饋例子：冷氣溫度控制；人體體溫調節

# Some issues to take note of

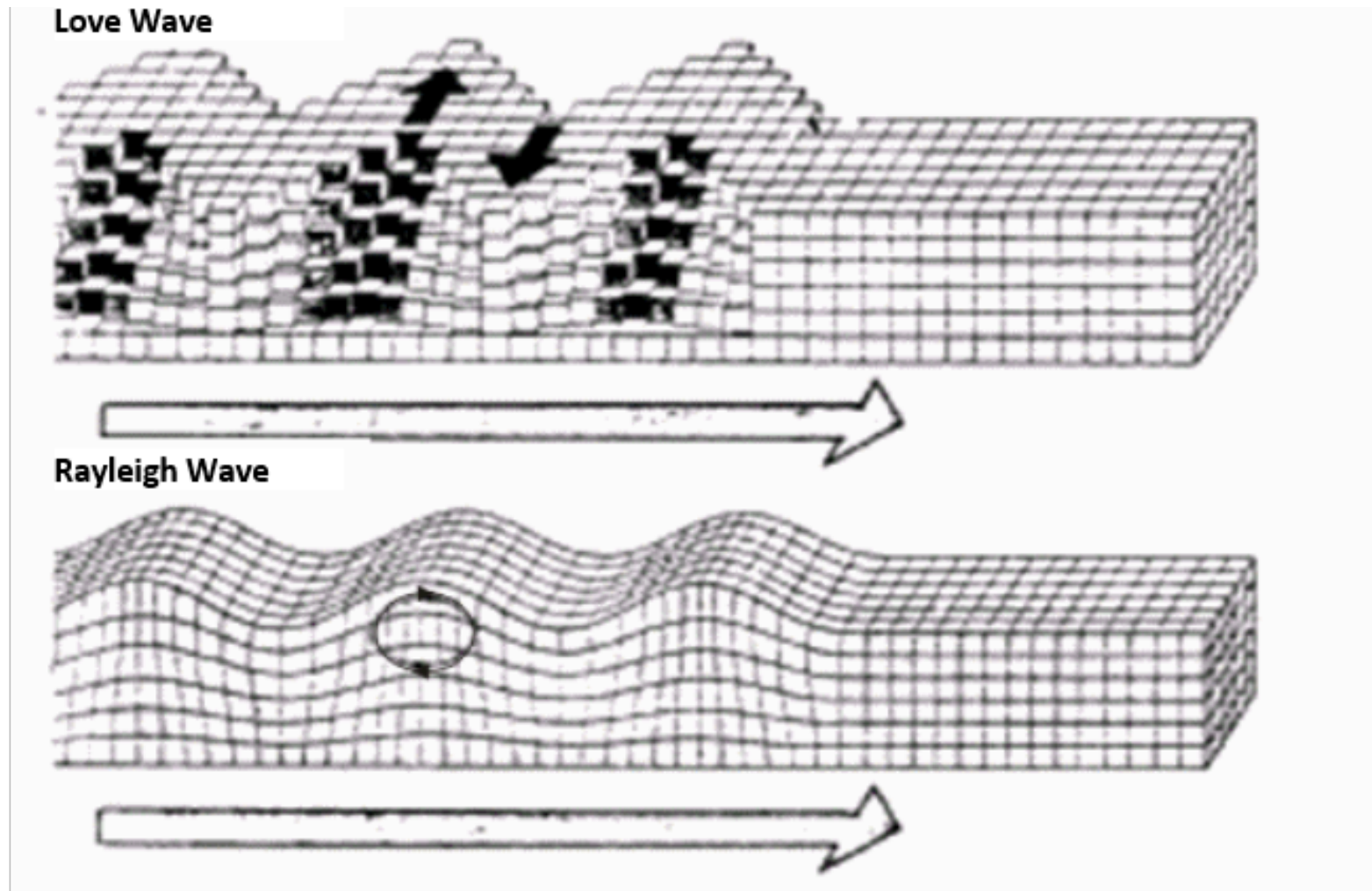
## 設計時要注意的事

- How fast can your detector be reset?  
重置探測器要多久？
- Can its sensitivity be adjusted?  
敏感度可以調校嗎？
- Which category of waves can it detect?  
它可以探測到哪種震波？

# How does an object on the surface move? 表面上的物體會如何移動？(1/2)



# How does an object on the surface move? 表面上的物體會如何移動？(2/2)



Good luck!  
大家好運！