



# 嵌入式系統總整與實作

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# 嵌入式系統總整與實作



## 嵌入式應用與原理

電子學/電路學

電阻, 電壓, 電流

閱讀規格書

記憶體位置, 設定參數

物理, 地球科學

加速度, 角速度, 磁北極...

微積分, 濾波器

網路攝影機

影像傳輸, 影像辨識

訊號處理

語音識別

AI模型

姿態識別

雲端運算

嵌入式開發

Cross-compile

Build Kernel

(其他...)

provided by you

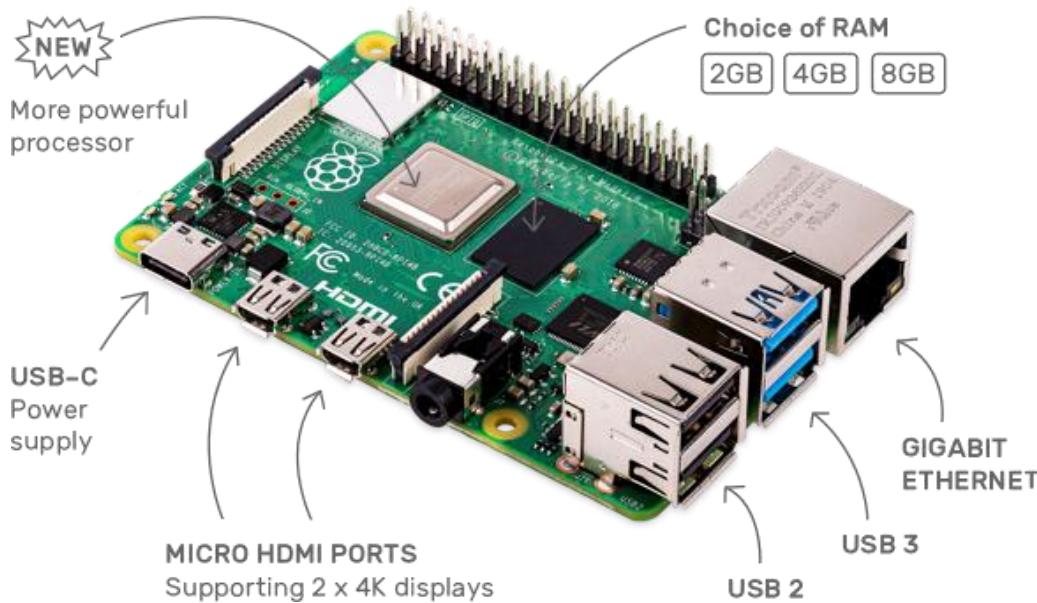


# Today summary

- Embedded development board
- Setup Raspberry PI by headless
- GPIO introduction & Python environment
- Understanding this course:
  - Discussion & quiz (no quiz this week)



# Raspberry Pi



工業用途例子

## Modular IPC/Soft-PLC

- Modular IPC/Soft-PLC by Revolution Pi by KUNBUS GmbH



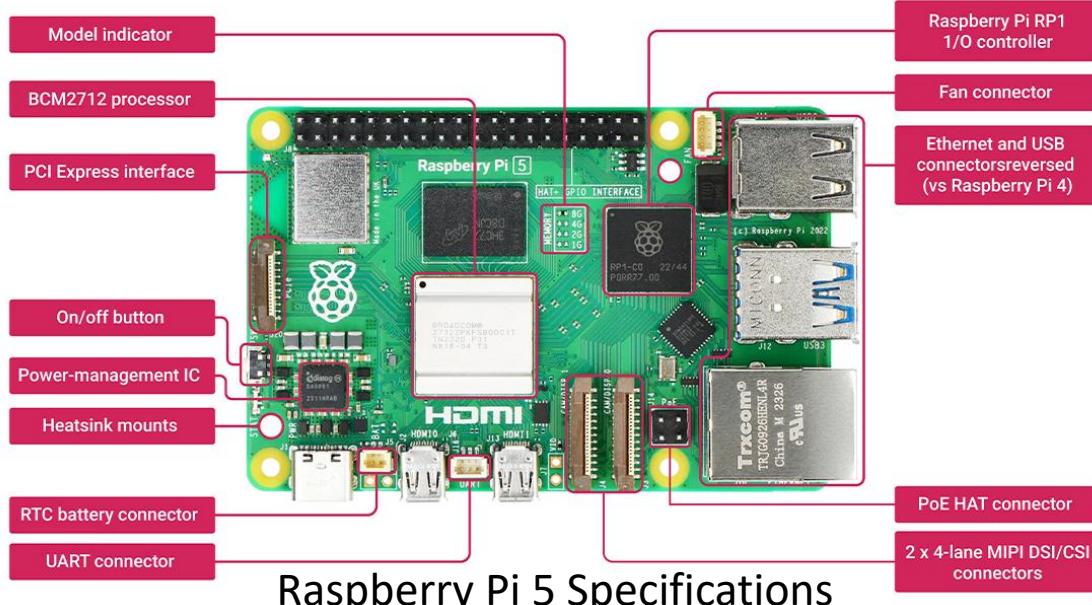
## SMEMA Hermes Adaptor

- retrieve the Hermes board data then convert into SMEMA signals for the legacy equipment

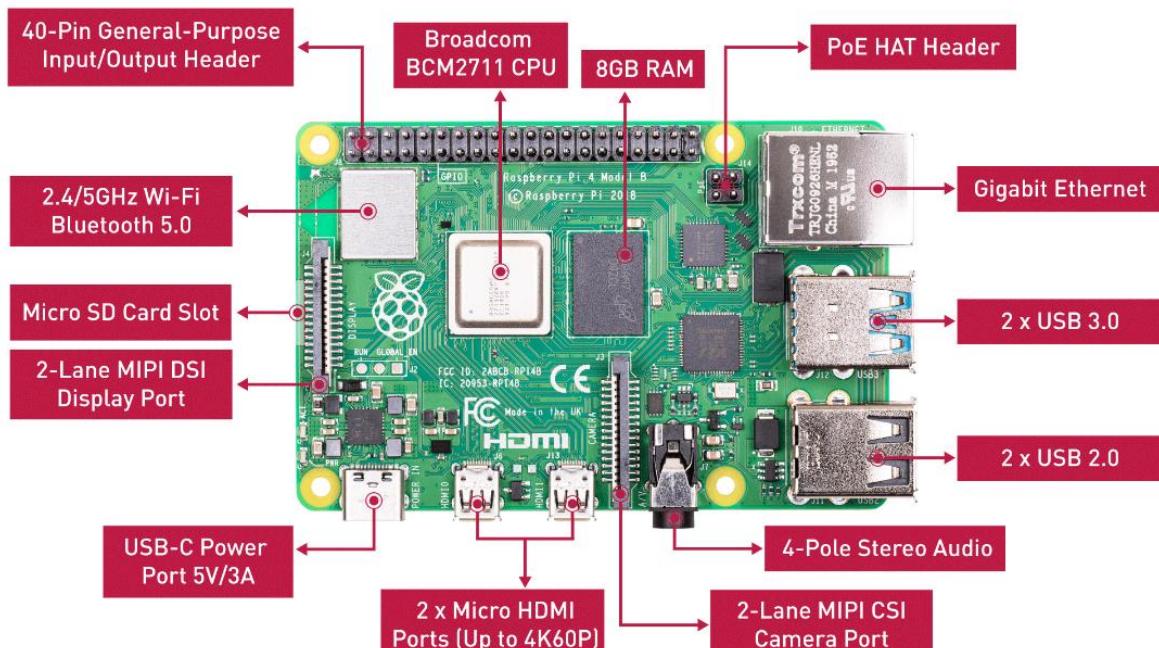


# PI4 vs PI5

- 全新 BCM2712 處理器
  - Pi 4: Broadcom BCM2711 quad-core CortexA72 (ARM v8), 64-bit SoC @ 1.8GHz (28nm)
  - Pi 5: Broadcom BCM2712 quad-core CortexA77 (ARM v8), 64-bit SoC @ 2.4GHz (16nm)
- 數字提昇約 33%
- 實際約提昇 2-3 倍



Raspberry Pi 5 Specifications

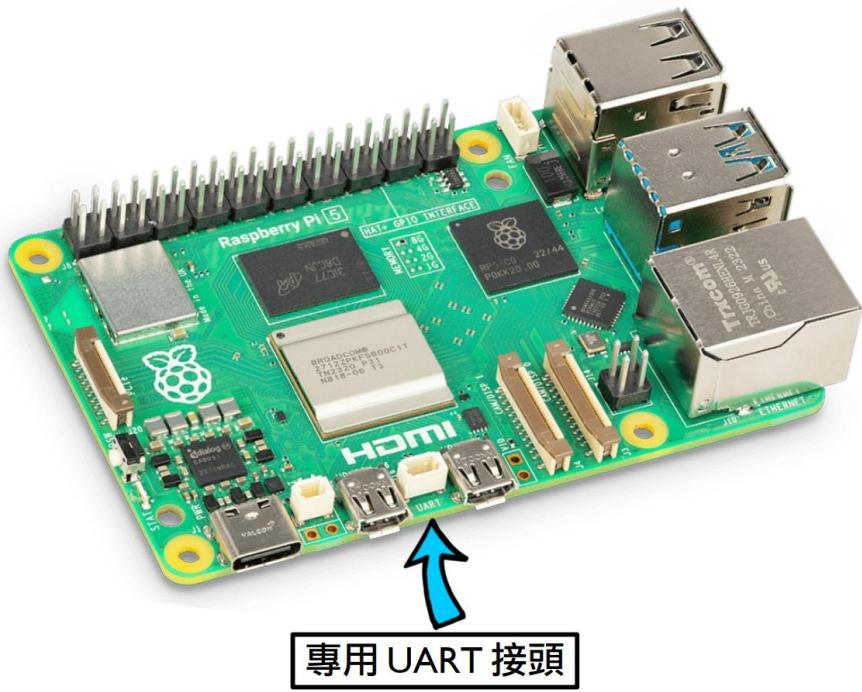


Raspberry Pi 4 Specifications



# Raspberry Pi Debug Probe

- Headless operation without modifying config



Connect Raspberry Pi Debug Probe to PI5



# PI4 materials in this course





# USB轉TTL序列傳輸線

- 此傳輸線可經由本機的USB介面，連至另一端的TTL信號規格的RS-232或UART介面。
- 傳輸線的一端為USB Type-A接頭，另一端為分離的杜邦母接頭，信號分別為：
  - TXD(綠)：TTL輸出，接MCU.RX
  - RXD(白)：TTL輸入，接MCU.TX
  - GND(黑)：0V
  - VCC(紅)：+5V
  - RTS(黃)：輸出訊號，接MCU.CTS
  - CTS(藍)：輸入訊號，接MCU.RTS
- USB轉TTL序列傳輸線的應用包括：
  - 主機板、單板電腦或嵌入式系統等具有UART接口時的開發偵錯





# Outline

- 1. 安裝OS (Raspbian)
- 2. PI的環境設定
  - raspi-config (環境設定, 開啟interface, Wi-Fi設定...等)
  - nmcli: 命令列的網路設定工具
- 3. 設定遠端桌面連線
  - 內建的realvnc
- 4. GPIO 介紹
- 5. 傳輸檔案

[wikipedia]

無頭系統(headless system)是指已組態為無須顯示器(即「頭」)、鍵盤和滑鼠操作的電腦系統或裝置。無頭系統通常通過網路連接控制，但也有部分無頭系統的裝置需要通過RS-232串行連接進行裝置的管理。伺服器通常採用無頭模式以降低運作成本。



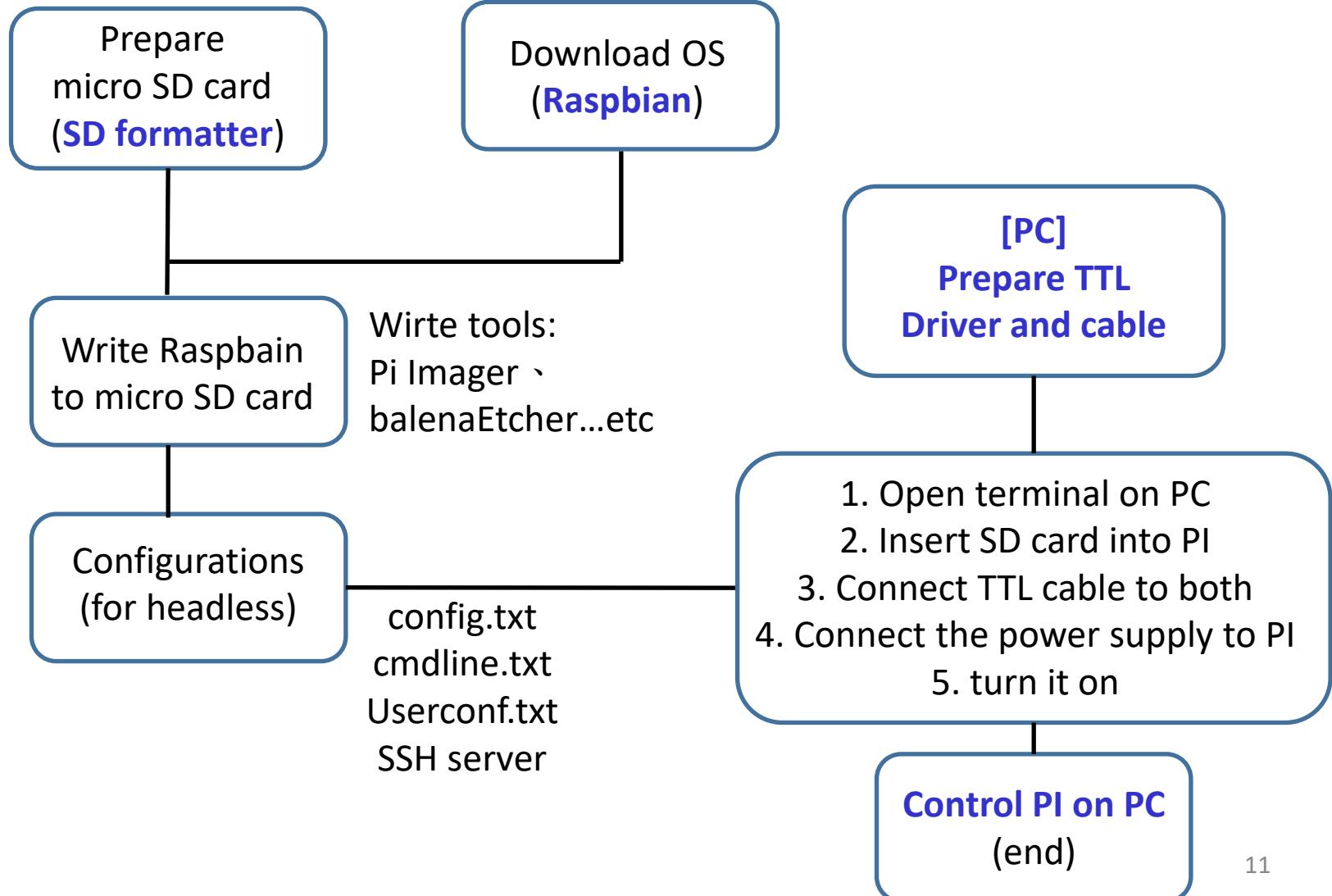


# Outline

- 1. 安裝OS (Raspbian)
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- 4. GPIO 介紹
- 5. 傳輸檔案



# Step by step installation





# Download OS

- 下載作業系統(Raspbian) (**可能很花時間, 建議先下載**)
  - 官方連結 (Raspberry Pi OS 64-bit (Legacy) with desktop)
    - [https://downloads.raspberrypi.com/raspios\\_oldstable\\_armhf/images/raspios\\_oldstable\\_armhf-2024-10-28/2024-10-22-raspios-bullseye-armhf.img.xz](https://downloads.raspberrypi.com/raspios_oldstable_armhf/images/raspios_oldstable_armhf-2024-10-28/2024-10-22-raspios-bullseye-armhf.img.xz)
  - 下載檔案後, 將系統寫入到SD卡 (balenaEtcher可直接載入壓縮檔)

## Raspberry Pi OS (Legacy, 64-bit)

Compatible with:

3B    3B+    3A+    4B  
400    CM3    CM3+  
CM4    CM4S    Zero 2 W

### Raspberry Pi OS (Legacy) with desktop

Release date: October 22nd 2024

System: 64-bit

Kernel version: 6.1

Debian version: 11 (bullseye)

Size: 868MB

[Show SHA256 file integrity hash](#)

[Release notes](#)

[Download](#)

[Download torrent](#)

[Archive](#)



# OS name? Legacy?

- Latest: bookworm
- Legacy: bullseye



Fig source: <https://pixar.fandom.com/wiki>

- Debian的版本使用Disney/Pixar的Toy Story角色來命名
- Bookworm取消Legacy camera的支援, 只支援 libcamera
- Bookworm桌面環境改用Wayland, 傳統的 X remote desktop不再支援, 連 VNC 與 AnyDesk 也不能用



# 準備工具

- **SD Formatter (清除SD卡舊有的檔案系統)**
  - <https://www.sdcard.org/downloads/formatter/sd-memory-card-formatter-for-windows-download/>
- **Etcher (寫入映像檔到SD卡)**
  - <https://etcher.balena.io/>
- **Raspberry Pi Imager (寫入映像檔到SD卡)**
  - <https://www.raspberrypi.com/software/>
- **MobaXterm Home Edition (終端機程式)**
  - <https://mobaxterm.mobatek.net/download-home-edition.html>
- **USB TTL driver (TTL控制線驅動程式, win11已內建)**
  - [https://www.prolific.com.tw/US>ShowProduct.aspx?p\\_id=225&pcid=41](https://www.prolific.com.tw/US>ShowProduct.aspx?p_id=225&pcid=41)



# 安裝Raspbian

- **步驟1：下載映像檔**
  - Raspbian
- **步驟2：將映像檔燒錄至SD卡**
  - (1)SD formatter(格式化); (2)Etcher or Raspberry Pi Imager (寫入OS)
- **步驟3：調整開機設定檔**
  - config.txt, cmdline.txt, 開啟SSH, 建立使用者
- **步驟4：電腦端準備 USB 轉 TTL 序列傳輸線 (or 網路線+SSH)**
  - 電腦端需要安裝Driver
- **步驟5：將SD卡插到Raspberry PI並開機**
  - 用終端機控制 (by Serial port), SSH連線, VNC遠端桌面



## 步驟1：下載映像檔

- 官方下載網頁

- 官方連結 (Raspberry Pi OS 64-bit (Legacy) with desktop)

- [https://downloads.raspberrypi.com/raspios\\_oldstable\\_armhf/images/raspios\\_oldstable\\_armhf-2024-10-28/2024-10-22-raspios-bullseye-armhf.img.xz](https://downloads.raspberrypi.com/raspios_oldstable_armhf/images/raspios_oldstable_armhf-2024-10-28/2024-10-22-raspios-bullseye-armhf.img.xz)

### Raspberry Pi OS (Legacy, 64-bit)

Compatible with:

[3B](#) [3B+](#) [3A+](#) [4B](#)  
[400](#) [CM3](#) [CM3+](#)  
[CM4](#) [CM4S](#) [Zero 2 W](#)

#### Raspberry Pi OS (Legacy) with desktop

Release date: October 22nd 2024

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Size: 868MB

[Show SHA256 file integrity hash](#):

[Release notes](#)

[Download](#)

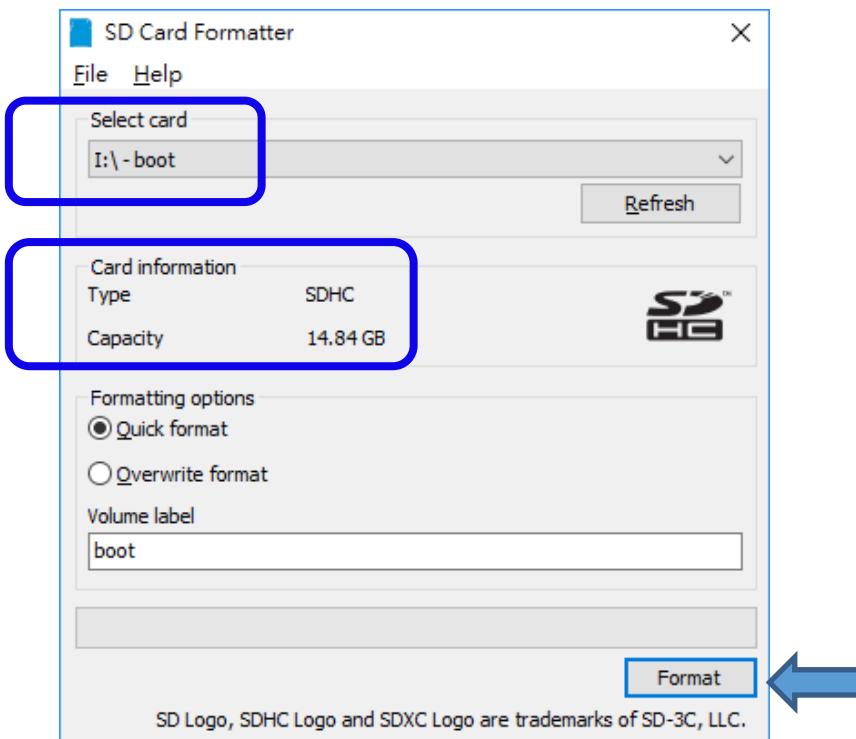
[Download torrent](#)

[Archive](#)



## 步驟2：將映像檔燒錄至SD卡之前

- 此步驟適用於“已寫入過資料的SD卡”
  - 因為Raspbian會將SD卡分成兩個磁區
  - 若要重新寫入OS, 需先re-format SD卡

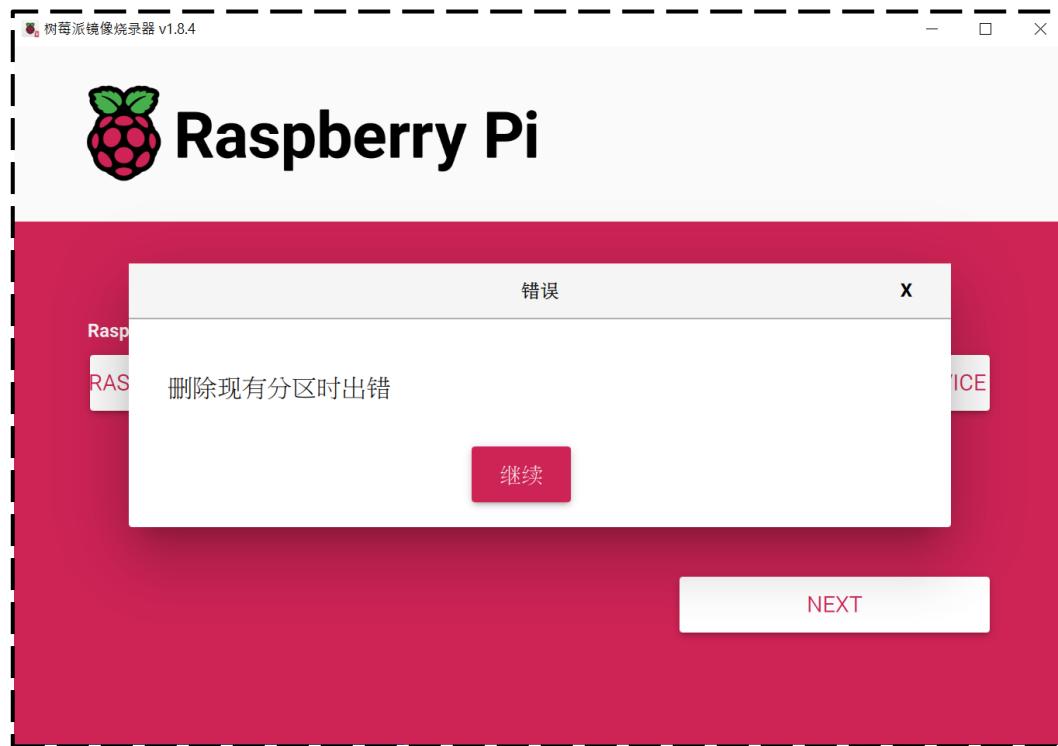


Check Device ID and capacity



## 沒有re-format會？

- 如果SD卡已經寫入過Raspbian (分割磁區), 直接燒錄會出現錯誤訊息
- Sol: 使用SD formatter重新格式化





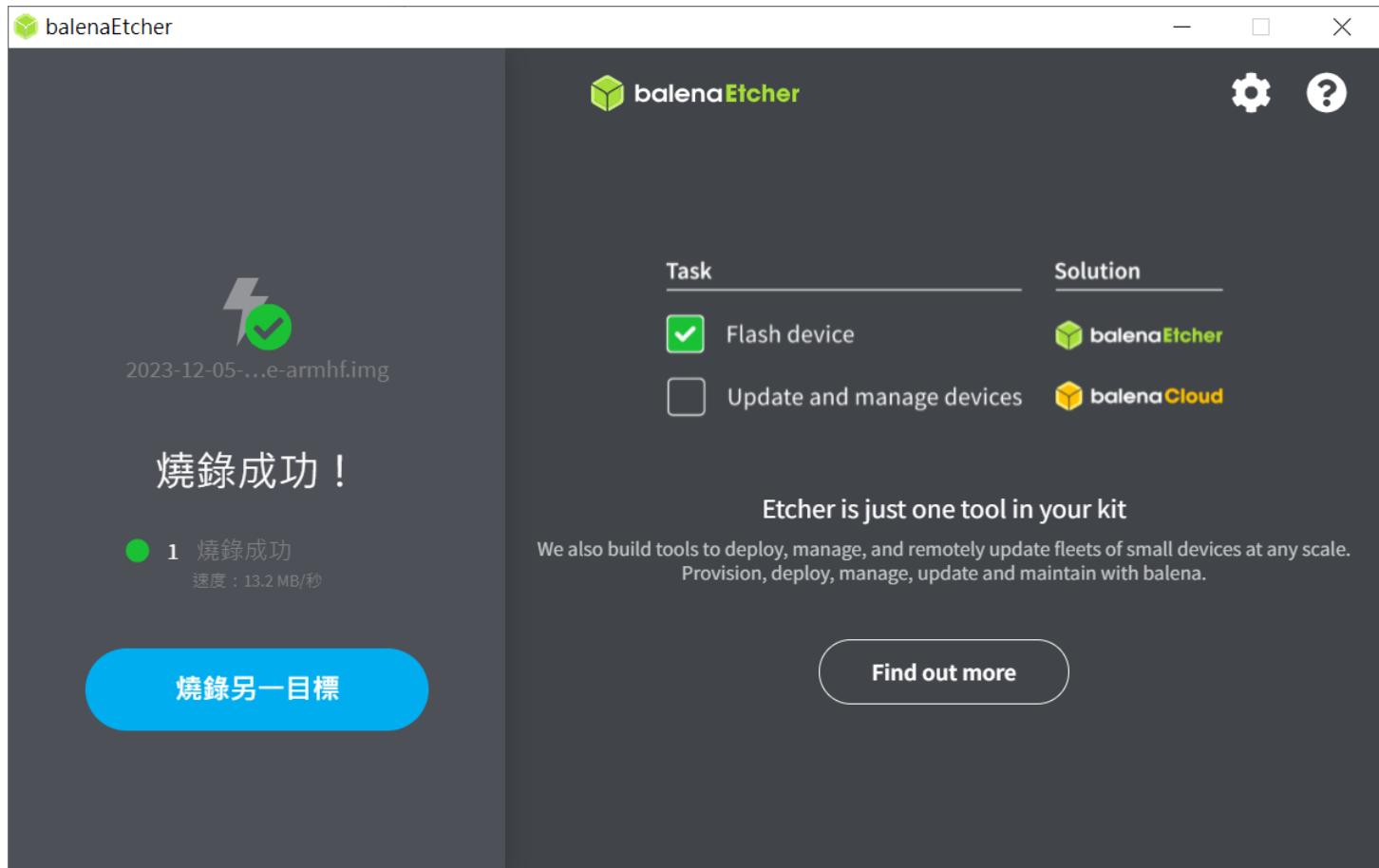
## 步驟2：將映像檔燒錄至SD卡

- 下載燒錄軟體: balenaEtcher
  - <https://etcher.balena.io/>
  - 寫入img至SD卡, 會自動排除USB外接硬碟
  - 可直接載入壓縮檔, 不須事先解壓縮





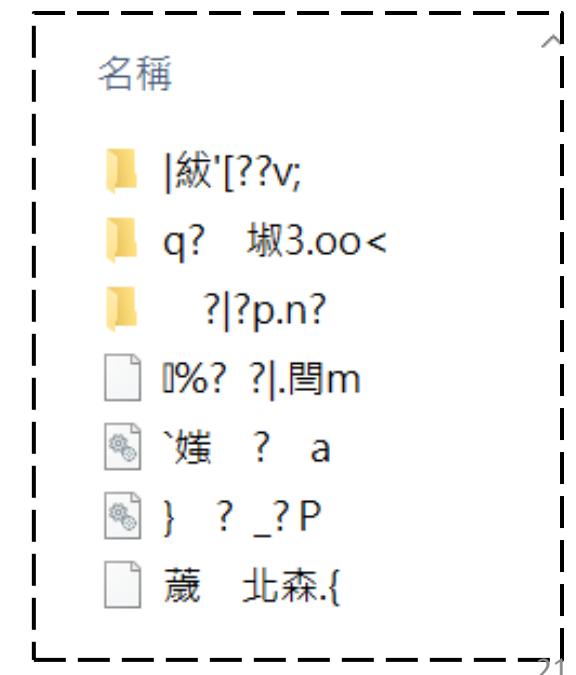
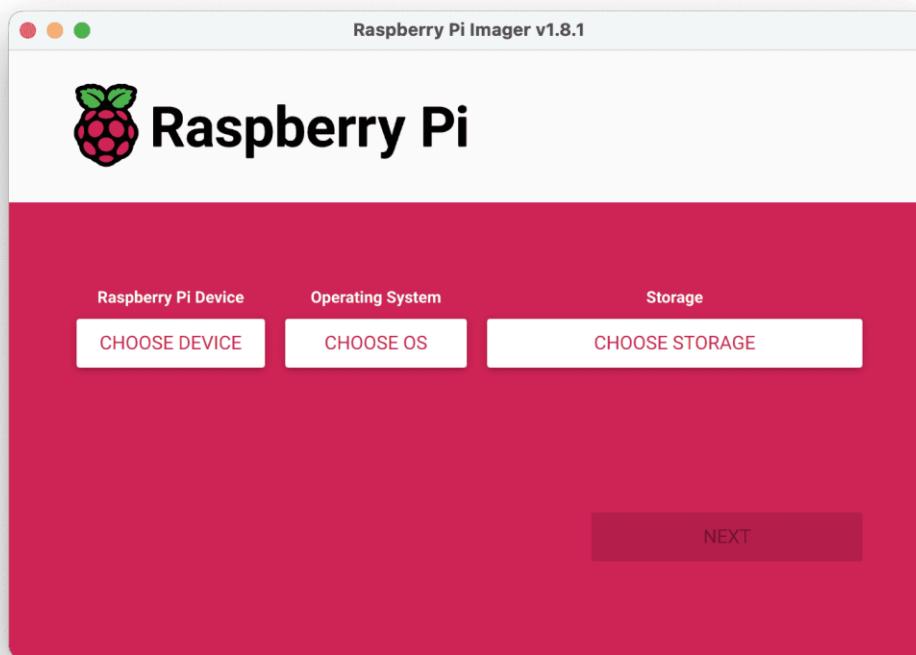
## 燒錄完畢後





## (選用) Pi Imager工具

- 下載寫入工具: Raspberry Pi Imager
  - <https://www.raspberrypi.com/software/>
  - 樹莓派官方釋出的img寫入工具
  - Ps. 個人使用時很常遇到磁區錯誤...





## 步驟2：將映像檔燒錄至SD卡

### ■ For MAC OS

- Use “`diskutil list`” to check the device number of your SD card
  - Ex: `/dev/disk2`
- After insert SD card, remember to unmount it
- `diskutil unmountDisk /dev/diskX` (change **diskX** to above ID)
- Write image to SD card
  - `sudo dd bs=1m if=2017-01-11-raspbian-jessie.img of=/dev/diskX`



Raspbian image path



Your SD card ID

- You can use **Ctrl+T** to check the progress (It would take a long time)



# 步驟3：調整開機設定檔 (PI4)

- 修改/**boot/config.txt**

- 刪除註解 `hdmi_force_hotplug`
- 新增 `enable_uart=1`

```
# uncomment if hdmi display is not
detected and composite is being output
hdmi_force_hotplug=1
```

[pi4]

```
# Enable DRM VC4 V3D driver on top of
the dispmanx display stack
dtoverlay=vc4-fkms-v3d
max_framebuffers=2
```

[all]

```
#dtoverlay=vc4-fkms-v3d
enable_uart=1
```

- 修改/**boot/cmdline.txt**, 將quiet splash的quiet移除

```
console=serial0,115200 console=tty1 root=PARTUUID=fba96bfa-02 rootfstype=ext4
elevator=deadline fsck.repair=yes rootwait quiet plymouth.ignore-serial-consoles
```

SD卡插入windows電腦後，會出現一個磁碟機(即 /boot)  
修改磁碟機裡面的檔案即可！



## 補充: 參數設定說明

- `hdmi_force_hotplug` (`config.txt`)
  - uncomment if hdmi display is not detected and composite is being output
  - 安裝攝影機後有可能vnc桌面顯示Cannot currently show the desktop, 強制開啟hdmi可修正此問題
- `enable_uart=1` (`config.txt`)
  - request the kernel creates a serial console, accessible using GPIOs 14 and 15
- 移除`quiet` (`cmdline.txt`)
  - enables boot messages from the kernel to also appear there



# config.txt 的用途？

- Instead of the BIOS found on a conventional PC, Raspberry Pi devices use a configuration file called config.txt.
- The GPU reads config.txt before the Arm CPU and Linux initialise.
- Raspberry Pi OS looks for this file in the boot partition, located at /boot/firmware/.
- Prior to Raspberry Pi OS Bookworm, Raspberry Pi OS stored the boot partition at /boot/.

- 修改 /boot/config.txt
  - 刪除註解 `hdmi_force_hotplug`
  - 新增 `enable_uart=1`

```
# uncomment if hdmi display is not detected and composite is being output
hdmi_force_hotplug=1

[pi4]
# Enable DRM VC4 V3D driver on top of the dispmanx display stack
dtoverlay=vc4-fkms-v3d
max_framebuffers=2

[all]
#dtoverlay=vc4-fkms-v3d
enable_uart=1
```



# 準備開機使用

- 參數設定完，可以開機使用了？

Originally, the default user on early versions of Raspberry Pi OS was **pi** with the password **raspberry**.

The default user is now set while **configuring the OS image** or **on first boot using a configuration wizard (with screen)**.

- Headless要怎麼設定new user?



# 設定SSH與使用者帳號

- Originally, the default user on early versions of Raspberry Pi OS was pi with the password raspberry. **The default user is now set while configuring the OS image or on first boot using a configuration wizard.**
- For headless setup, **SSH can be enabled by placing a file named ssh, without any extension**, onto the boot partition of the SD Card. When the Raspberry Pi boots, it looks for the ssh file. If it is found, SSH is enabled and the file is deleted. The content of the file does not matter; it could contain text, or nothing at all.
- **For headless setup** in addition to the ssh file you need a **userconf.txt** file, which contains a string **username:encryptedpassword**. Please refer to the section on configuring a user in the discussions around headless setup of a Raspberry Pi.



# 什麼是SSH?

- **SSH: Secure Shell Protocol**
  - 是一種加密的網路傳輸協定，可提供安全的傳輸環境。
- **SSH最常見的用途是遠端登入系統，通常利用SSH來傳輸命令列介面和遠端執行命令。**
- **功能: 遠端加密連線**
  - SSH 在使用者裝置和遠端電腦(通常是伺服器)之間建立連線。
  - 它使用加密來擾亂通過連線的資料。攔截者只能找到靜態的隨機資料，這些資料如果不解密，就毫無意義。

[https://zh.wikipedia.org/zh-tw/Secure\\_Shell](https://zh.wikipedia.org/zh-tw/Secure_Shell)

<https://www.cloudflare.com/zh-tw/learning/access-management/what-is-ssh/>



## 設定SSH與使用者帳號 (2)

- Step1: 在SD卡(/boot磁區)建立檔案, 檔名為ssh
- Step2: 在同位置建立userconf.txt, 輸入帳號與加密密碼
  - username:encryptedpassword

*<username> must only contain lower-case letters, digits and hyphens, and must start with a letter. It may not be longer than 31 characters.  
To generate the encrypted password, use OpenSSL on another computer.  
Open a terminal and enter: openssl passwd -6*

- Example: 建立帳號皆為pi的設定檔 (以下為一列內容)

pi:\$6\$1tbdThc.nwBoOE7R\$iV.05jvw31icLYXcXStuQOUt5SIyVjstochOnaqfvhKLxItuqcyhce  
ilxo5QVluJ7K0Pw79U4.YT9okW2g9jn1

<https://www.raspberrypi.com/documentation/computers/configuration.html#configuring-a-user>



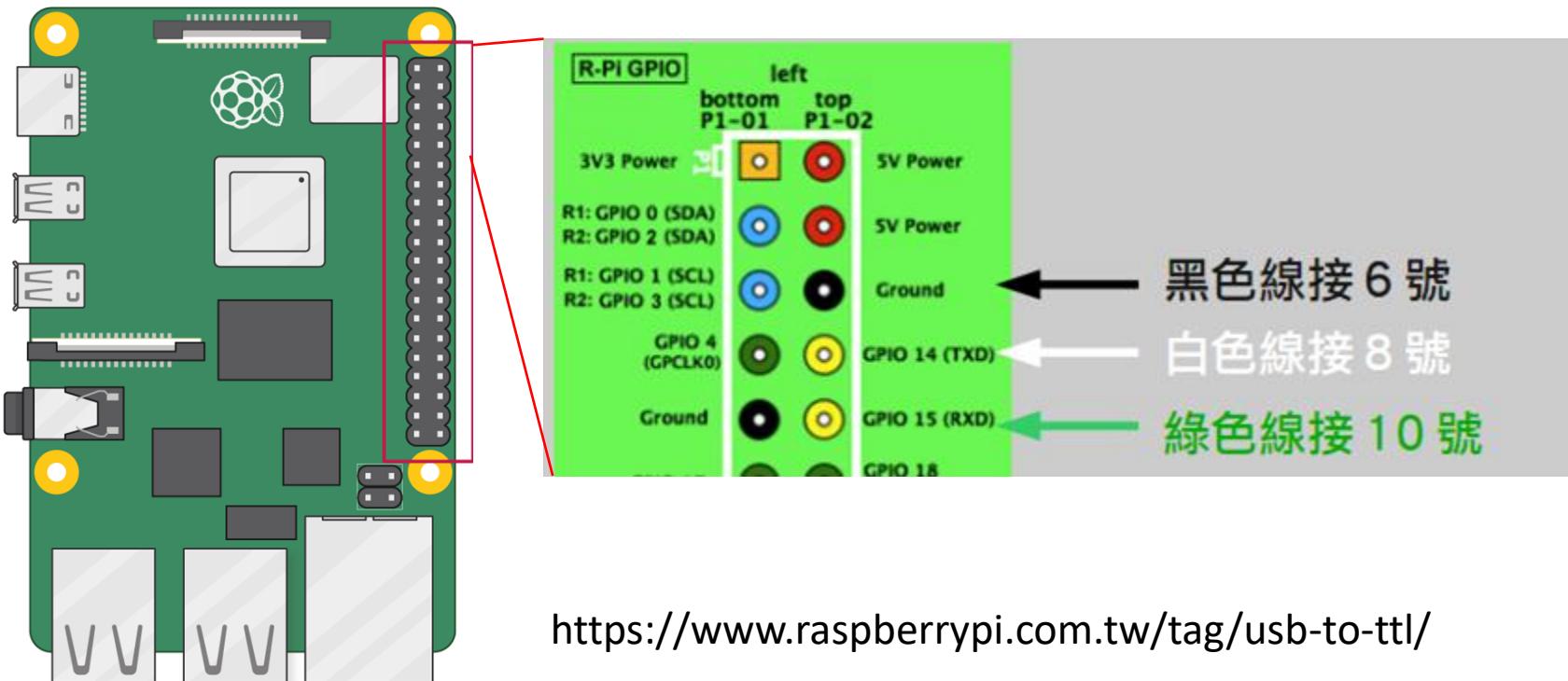
## 步驟4：USB 轉 TTL 序列傳輸線

- 透過USB 轉 TTL 序列傳輸線，從序列埠登入 Raspberry Pi
  - 不需要螢幕和鍵盤滑鼠的情況下登入
  - 設定SSH，使用網路線連線進去
- 傳輸線規格: 晶片組PL2303HXD
  - Windows Driver (win 11已內建):
  - [https://www.prolific.com.tw/US>ShowProduct.aspx?p\\_id=225&pcid=41](https://www.prolific.com.tw/US>ShowProduct.aspx?p_id=225&pcid=41)
- MAC driver:
  - [https://www.prolific.com.tw/US>ShowProduct.aspx?p\\_id=229&pcid=41](https://www.prolific.com.tw/US>ShowProduct.aspx?p_id=229&pcid=41)
  - <https://www.ftdichip.com/Drivers/VCP.htm>



# 步驟5：連接TTL, 放置SD卡並開機

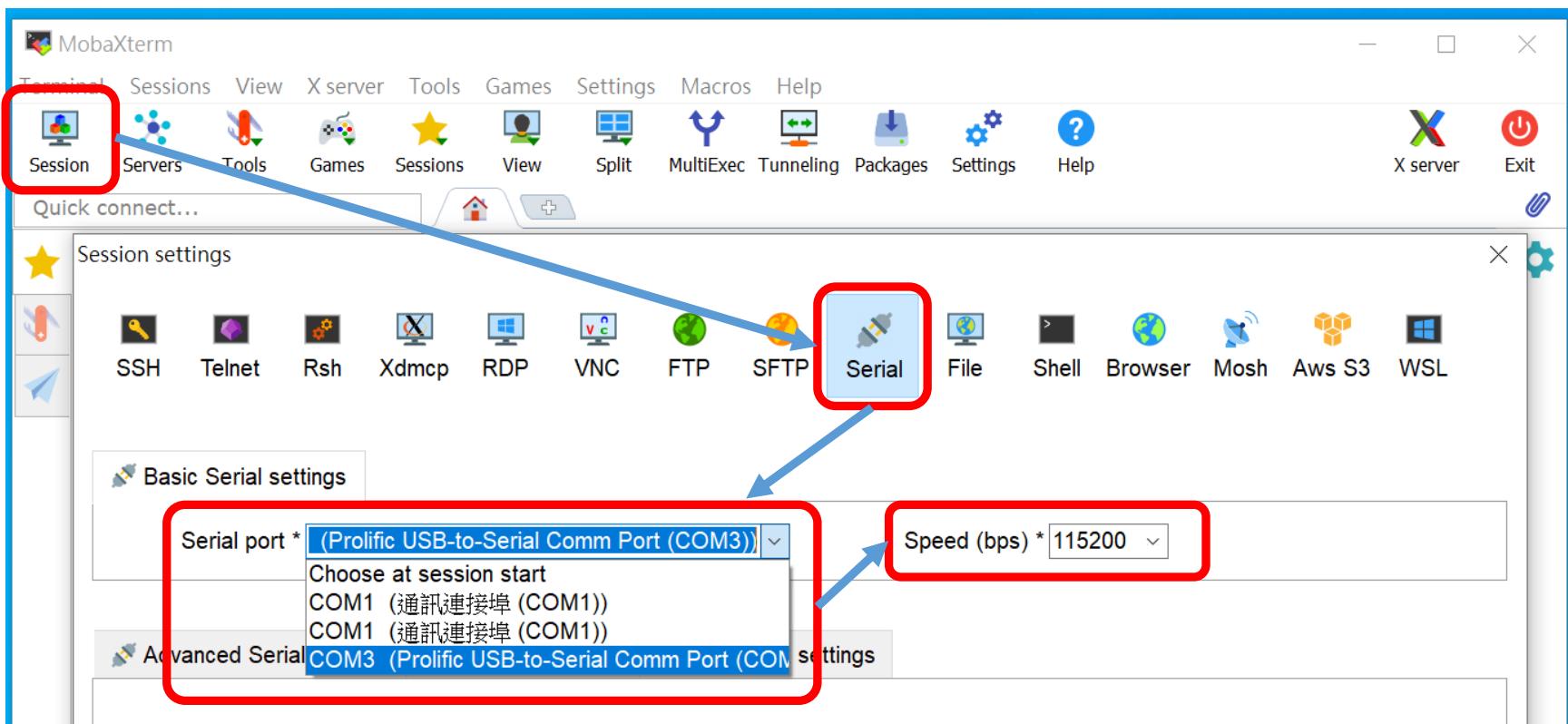
- 傳輸線使用方式
  - 依照下圖說明，將線材上相應顏色的腳位，連接到樹莓派上





# 步驟5：連接TTL, 放置SD卡並開機

- PC端準備終端機程式
  - 下圖範例為 Mobaxterm 的設定





# 終端機程式畫面

COM3 (Prolific USB-to-Serial Comm Port (COM3))

Terminal Sessions View X server Tools Games Settings Macros Help

Session Servers Tools Games Sessions View Split MultiExec Tunneling Packages Settings Help

X server Exit

Quick connect...

User sessions  
140.113.213.228 (hscc)  
COM3 (Prolific USB-to-Serial Com)

```
[ 4.828828] systemd[1]: Mounted Kernel Debug File System.  
[ 4.835747] systemd[1]: Mounted Kernel Trace File System.  
[ 4.843915] systemd[1]: Finished Restore / save the current clock.  
[ 4.853225] systemd[1]: Finished Create list of static device nodes for the current kernel.  
[ 4.864700] systemd[1]: modprobe@configfs.service: Succeeded.  
[ 4.865805] cryptd: max_cpu_qlen set to 1000  
[ 4.872114] systemd[1]: Finished Load Kernel Module configfs.  
[ 4.883534] systemd[1]: modprobe@drm.service: Succeeded.  
[ 4.890374] systemd[1]: Finished Load Kernel Module drm.  
[ 4.898239] systemd[1]: modprobe@fuse.service: Succeeded.  
[ 4.905601] systemd[1]: Finished Load Kernel Module fuse.  
[ 4.917420] systemd[1]: Mounting FUSE Control File System...  
[ 4.929575] systemd[1]: Mounting Kernel Configuration File System...  
[ 4.949534] systemd[1]: Started File System Check Daemon to report status.  
[ 4.981238] systemd[1]: Finished File System Check on Root Device.  
[ 4.996455] systemd[1]: Mounted FUSE Control File System.  
[ 5.007810] systemd[1]: Mounted Kernel Configuration File System.  
[ 5.018540] systemd[1]: Starting Remount Root and Kernel File Systems...  
[ 5.051385] systemd[1]: Started Journal Service.  
[ 5.056578] i2c /dev entries driver  
  
Debian GNU/Linux 11 raspberrypi ttyS0  
  
raspberrypi login: █
```

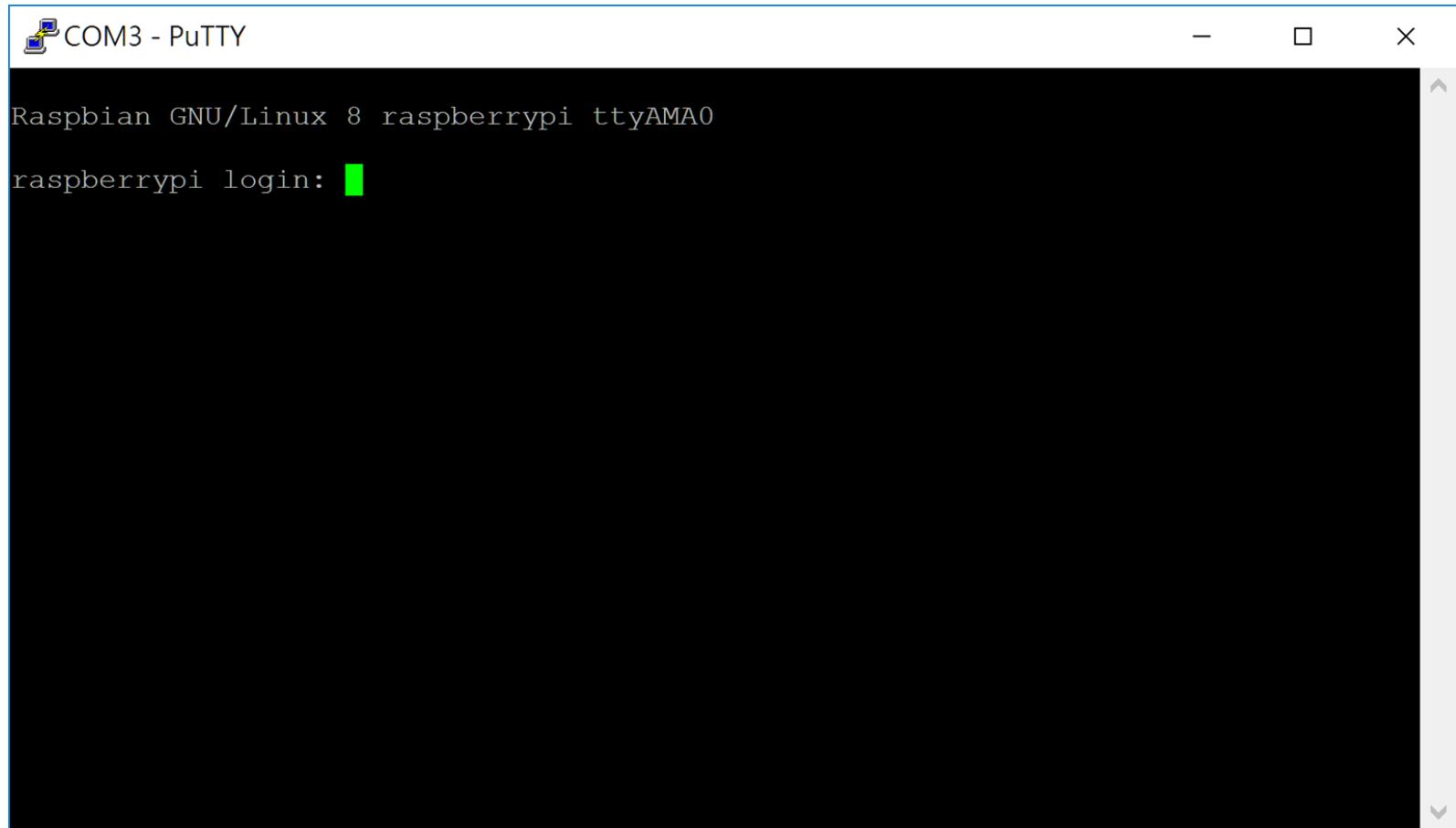
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33



## 終端機程式畫面



COM3 - PuTTY

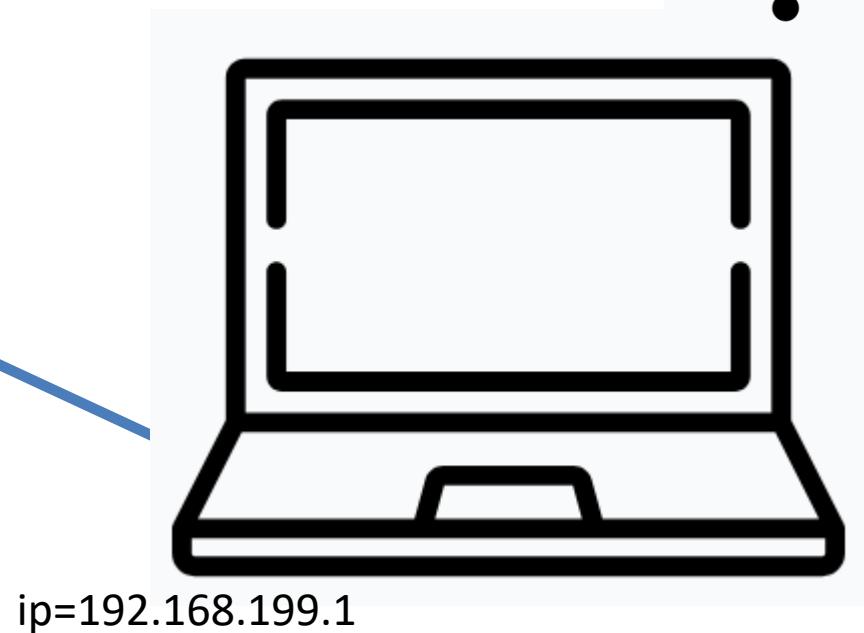
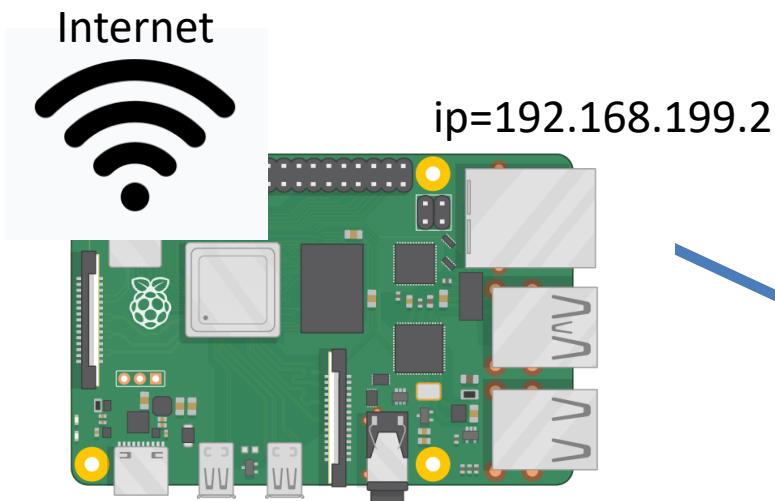
```
Raspbian GNU/Linux 8 raspberrypi ttyAMA0
raspberrypi login: █
```

終端機打開沒有畫面? -> 按一下Enter鍵試試



## (另) 網路線headless設定

- 使用網路線對接，利用SSH遠端進去
- 此處亦為headless (不接螢幕鍵盤滑鼠)
- 用設定檔指定**static IP address**





# (另) 網路線headless設定

- PI端:

- 編輯 /boot/cmdline.txt, 最後加上 ip=192.168.199.2

```
console=serial0,115200 console=tty1 root=PARTUUID=fba96bfa-02
rootfstype=ext4 elevator=deadline fsck.repair=yes rootwait
plymouth.ignore-serial-consoles ip=192.168.199.2
```

- 電腦端:

- 有線網路設定:

192.168.199.1/255.255.255.0



**注意: 在cmdline加入ip設定後, 每次開機都會檢查網路線!**

**若無連接網路線, 會反覆檢查 & 延遲兩分鐘才能開機**



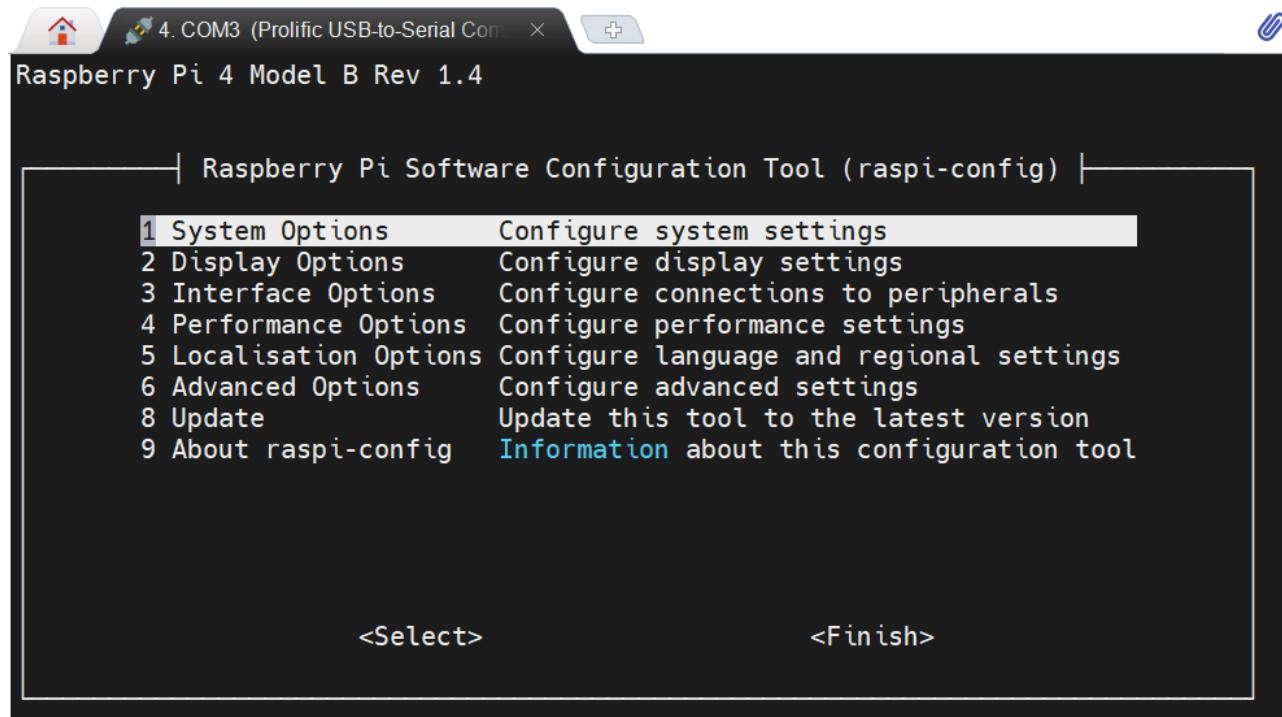
# Outline

- 1. 安裝OS (Raspbian)
- 2. PI的環境設定
  - raspi-config (環境設定, 開啟interface, Wi-Fi設定...等)
  - nmcli: 命令列的網路設定工具
- 3. 設定遠端桌面連線
  - 內建的realvnc
- 4. GPIO 介紹
- 5. 傳輸檔案



# PI的環境設定

- 指令: sudo raspi-config (進行系統設定)





# 環境設定: raspi-config

- 1 System Options
  - S1 Wireless LAN
    - Select the located country for PI

以前要修改系統設定檔, 現在  
可以直接輸入SSID與密碼了!

- 2 Display Options
  - D1 Resolution

設定螢幕解析度, VNC會用到

- 3 Interface Options
  - I1 Legacy Camera
  - I3 VNC
  - I5 I2C

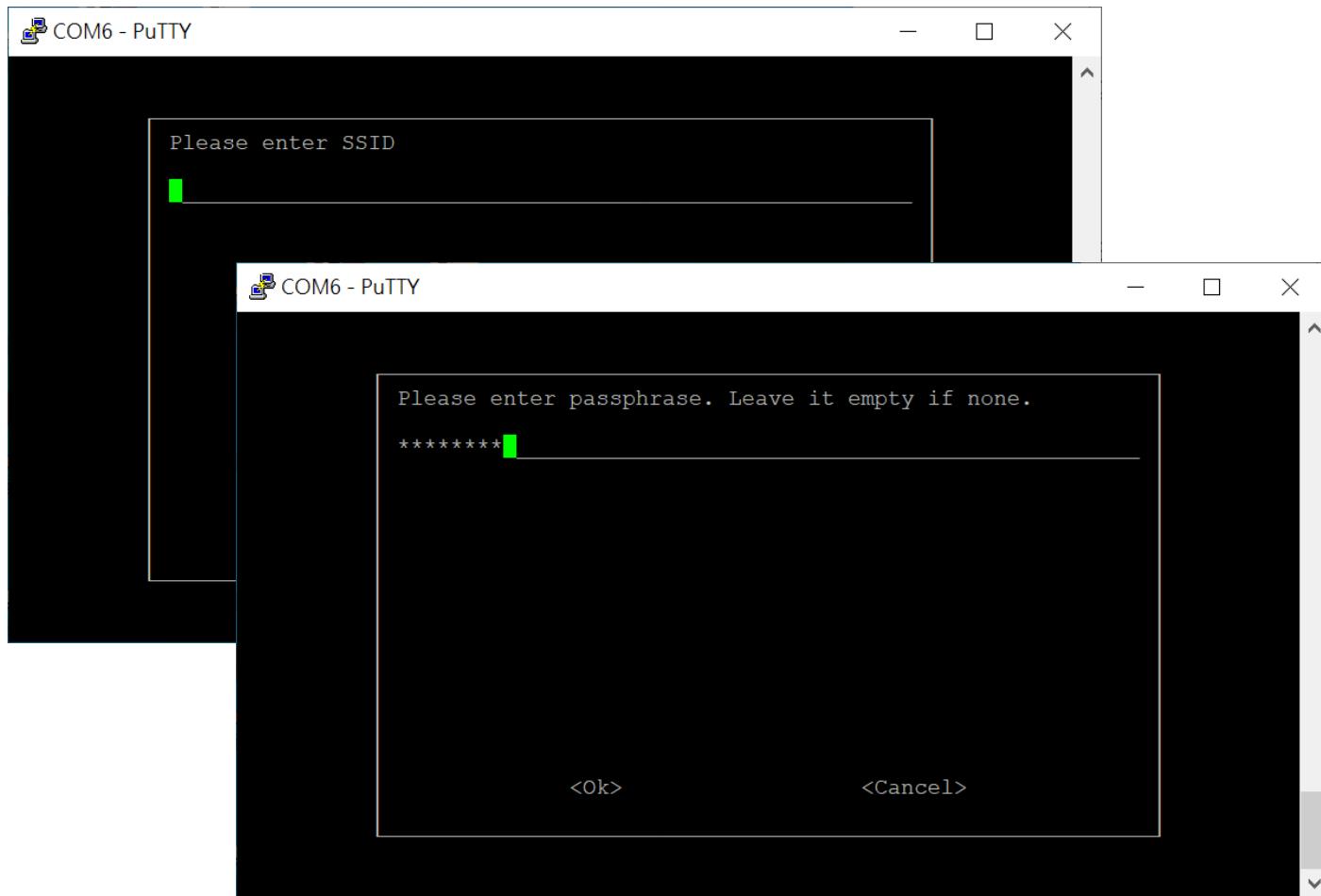
啟用camera interface

啟用vnc server, 可以透過網路遠端操控(圖形介面)

啟用I2C interface, 可以接I2C sensor



# S1 Wireless LAN



Wi-Fi is currently blocked by rfkill.

**Use raspi-config to set the country before use.**



# (補充) 設定網路指令 nmcli

- nmcli: command-line tool for controlling NetworkManager

```
pi@raspberrypi:~ $ nmcli
Error: NetworkManager is not running.
pi@raspberrypi:~ $ sudo systemctl start NetworkManager
pi@raspberrypi:~ $ nmcli
eth0: connecting (getting IP configuration) to Wired connection 1
    "eth0"
    ethernet (bcmgenet), E4:5F:01:C5:54:ED, hw, mtu 1500

wlan0: disconnected
    "Broadcom BCM43438 combo and Bluetooth Low Energy"
    wifi (brcmfmac), 82:DC:EE:B8:39:47, hw, mtu 1500

p2p-dev-wlan0: disconnected
    "p2p-dev-wlan0"
    wifi-p2p, hw

lo: unmanaged
    "lo"
    loopback (unknown), 00:00:00:00:00:00, sw, mtu 65536

Use "nmcli device show" to get complete information about known devices and
"nmcli connection show" to get an overview on active connection profiles.

Consult nmcli(1) and nmcli-examples(7) manual pages for complete usage details.
```



# (補充) 設定網路指令 nmcli

## Example 1. Listing available Wi-Fi APs

```
$ nmcli device wifi list
*   SSID             MODE   CHAN  RATE      SIGNAL  BARS  SECURITY
    netdatacomm_local  Infra   6     54 Mbit/s  37      2/5    WEP
*   F1               Infra   11    54 Mbit/s  98      4/5    WPA1
    LoremCorp         Infra   1     54 Mbit/s  62      2/5    WPA2
802.1X
    Internet          Infra   6     54 Mbit/s  29      2/5    WPA1
    HPB110a.F2672A    Ad-Hoc  6     54 Mbit/s  22      2/5    --
    Jozinet           Infra   1     54 Mbit/s  19      2/5    WEP
    VOIP              Infra   1     54 Mbit/s  20      2/5    WEP
    MARTINA          Infra   4     54 Mbit/s  32      2/5    WPA2
    N24PU1            Infra   7     11 Mbit/s  22      2/5    --
    alfa              Infra   1     54 Mbit/s  67      2/5    WPA2
    bertnet           Infra   5     54 Mbit/s  20      2/5    WPA1 WPA2
```

This command shows how to list available Wi-Fi networks (APs). You can also use `--fields` option for displaying different columns. `nmcli -f all dev wifi list` will show all of them.

## Example 2. Connect to a password-protected wifi network

→

```
$ nmcli device wifi connect "$SSID" password "$PASSWORD"
$ nmcli --ask device wifi connect "$SSID"
```



# D1 Resolution

Set a specific screen resolution

```
Choose screen resolution

Default      720x480
DMT Mode 4   640x480 60Hz 4:3
DMT Mode 9   800x600 60Hz 4:3
DMT Mode 16  1024x768 60Hz 4:3
DMT Mode 85  1280x720 60Hz 16:9
DMT Mode 35  1280x1024 60Hz 5:4
DMT Mode 51  1600x1200 60Hz 4:3
DMT Mode 82  1920x1080 60Hz 16:9

<Ok>           <Cancel>
```



# 3 Interface

Would you like the VNC Server to be **enabled**?

Would you like the ARM I2C interface to be **enabled**?

**<Yes>**      **<No>**

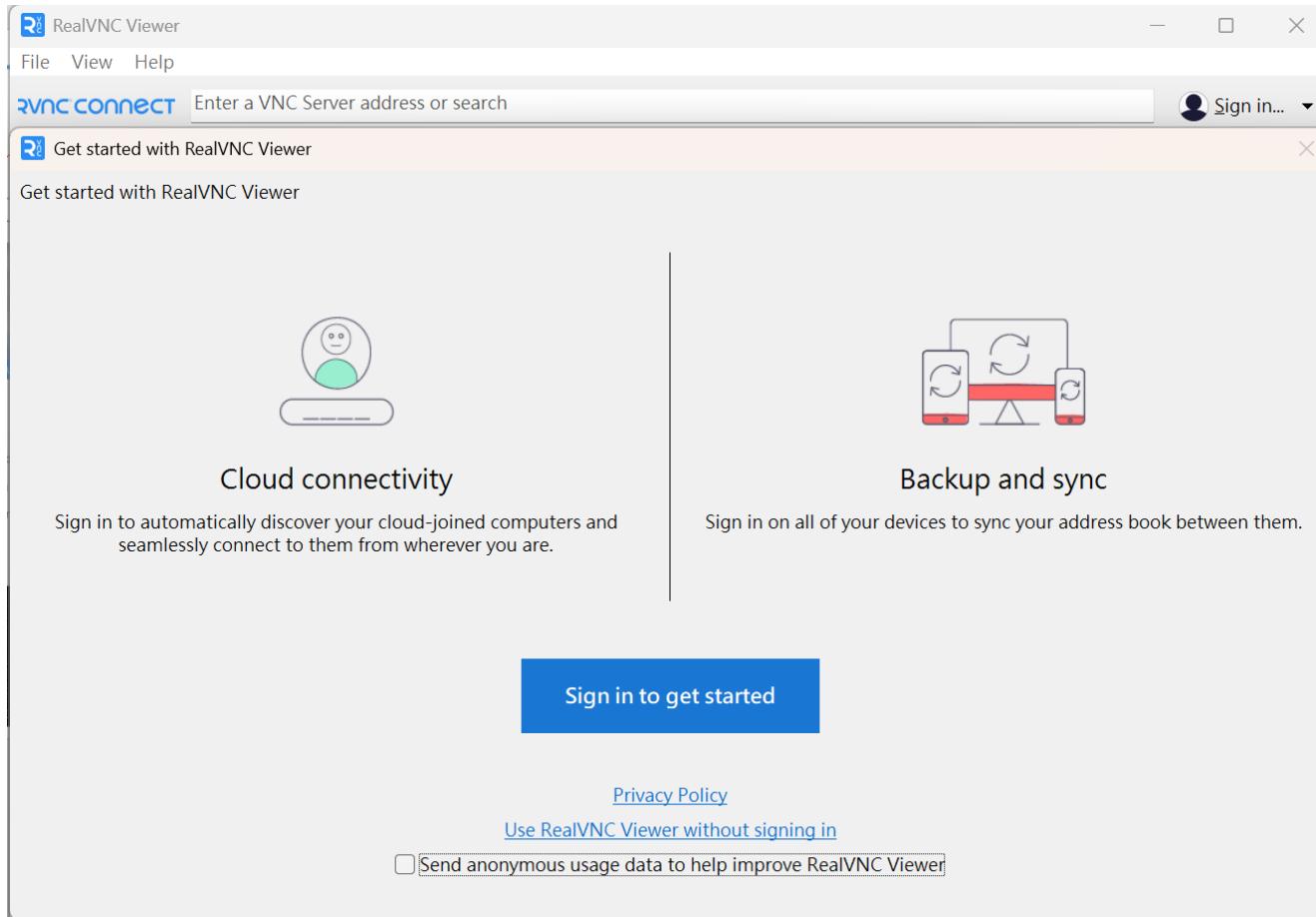


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# VNC viewer on PC



<https://www.realvnc.com/en/connect/download/viewer/>



# 內建的realvnc

- 電腦端執行vncviewer
  - 輸入樹莓派的IP (可在PI執行 ifconfig 查詢)
- 提醒: PC與PI必須在同一個網段!

VNC Viewer

File View Help

192.168.1.20

Sign in...

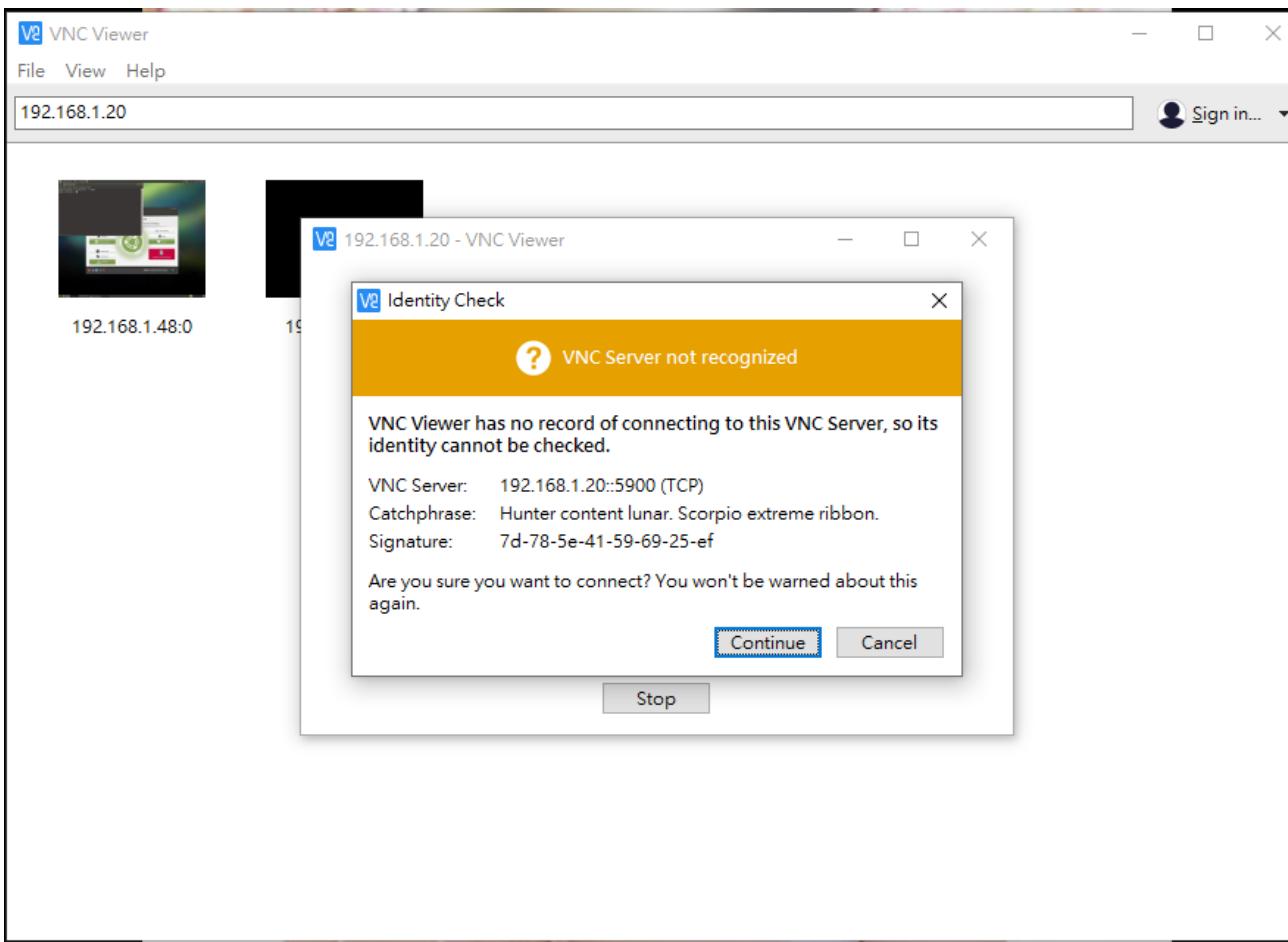
192.168.1.48:0      192.168.1.48:1

```
wlan0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 192.168.1.20 netmask 255.255.255.0 broadcast 192.168.1.255
        inet6 fe80::bdbe:cb97:93ed:4516 prefixlen 64 scopeid 0x20<link>
          ether b8:27:eb:ea:da:f8 txqueuelen 1000 (Ethernet)
            RX packets 10 bytes 1575 (1.5 KiB)
            RX errors 0 dropped 0 overruns 0 frame 0
            TX packets 34 bytes 5841 (5.7 KiB)
            TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```



## 內建的realvnc

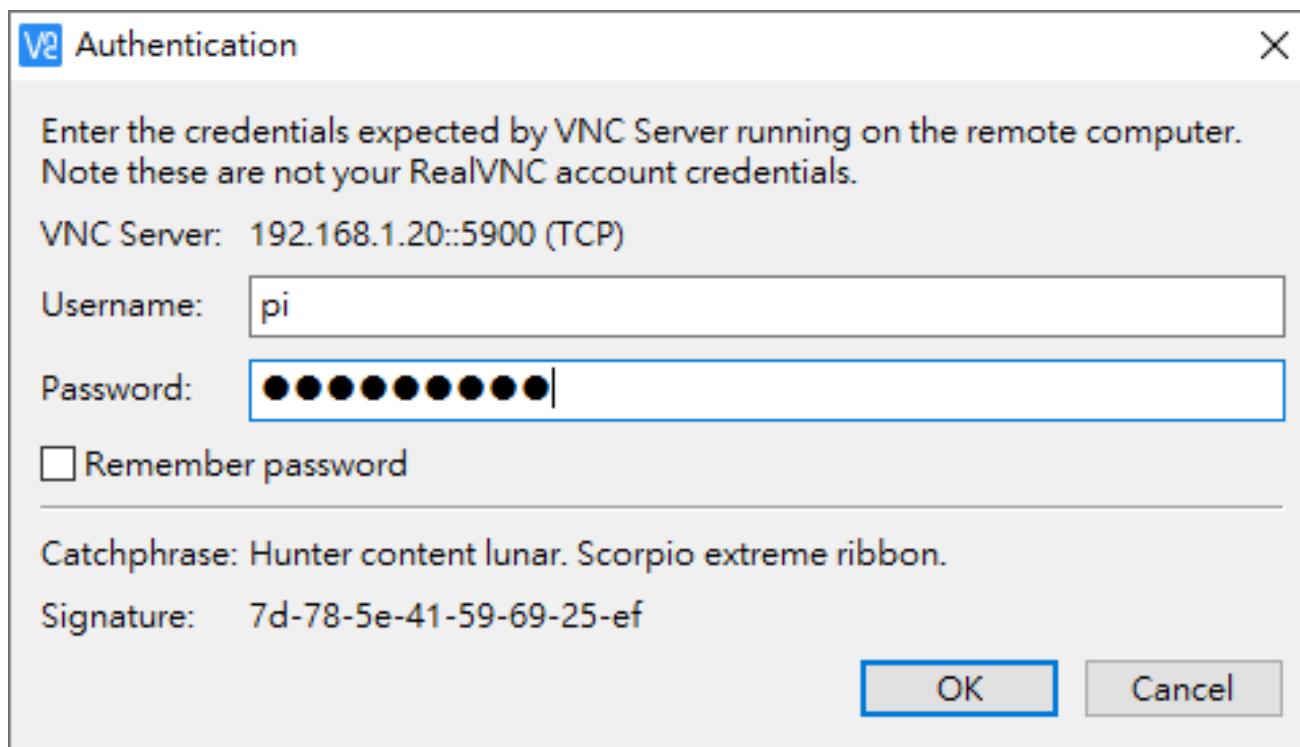
- 電腦端執行vncviewer





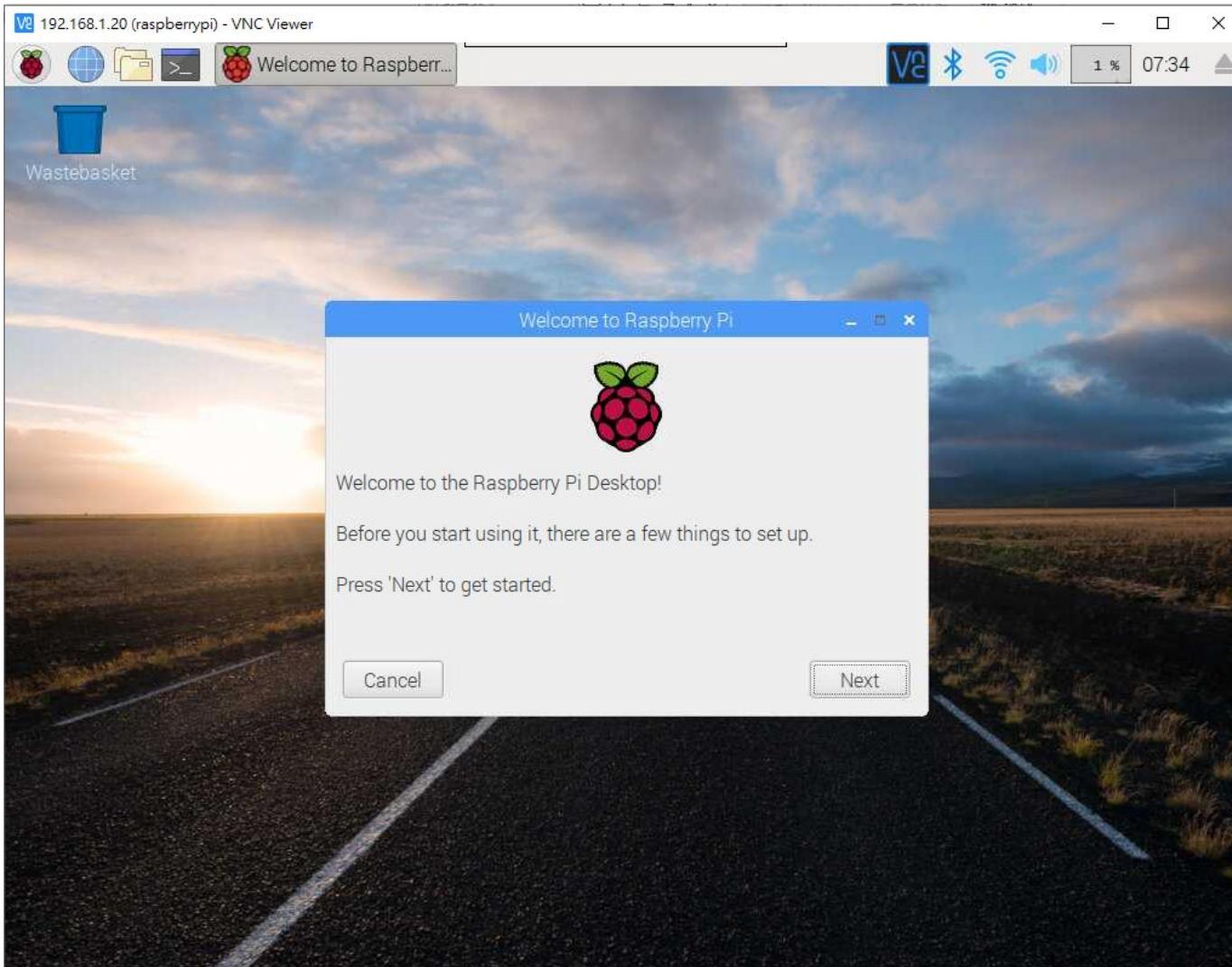
# 內建的realvnc

- 電腦端執行vncviewer



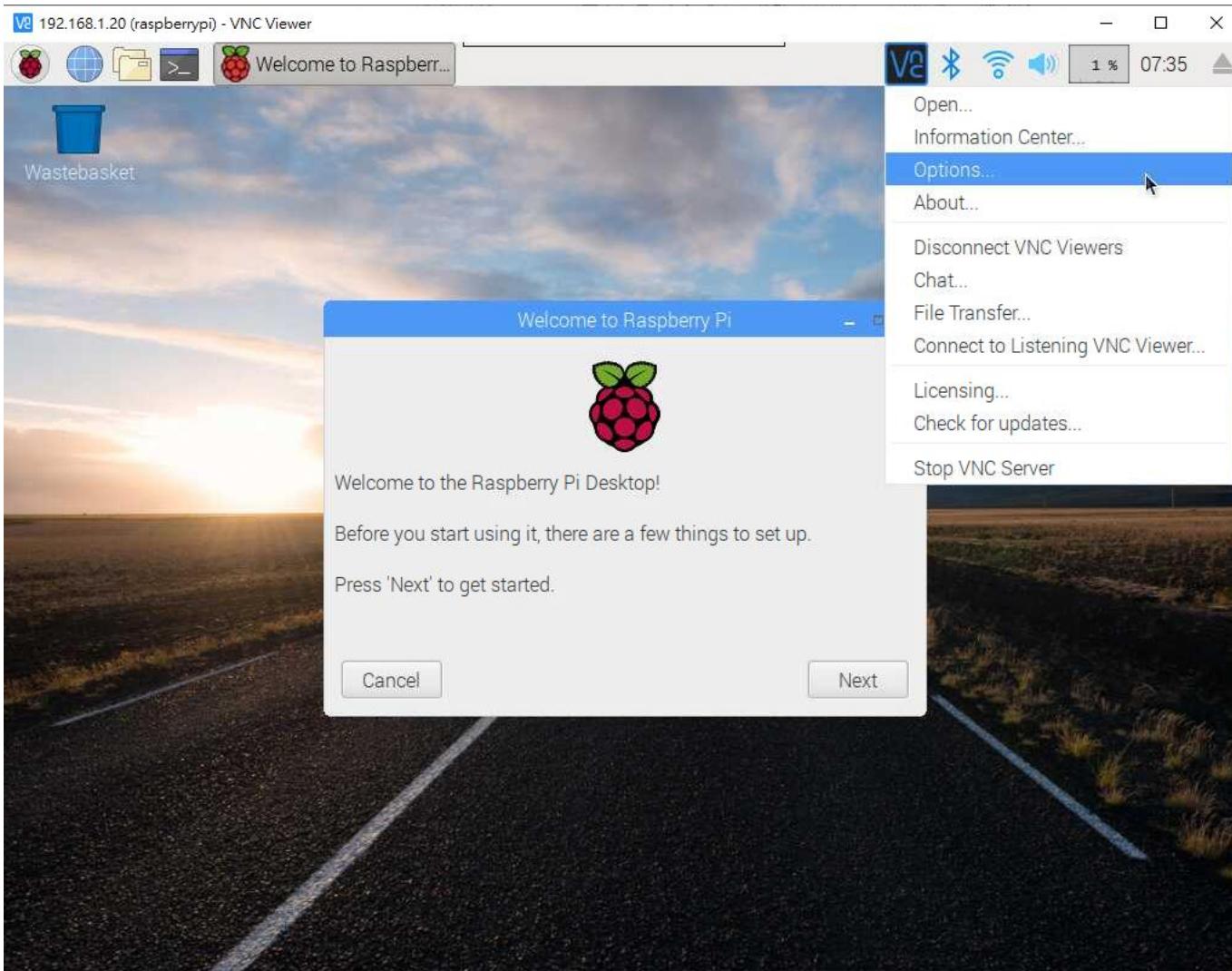


## 內建的realvnc



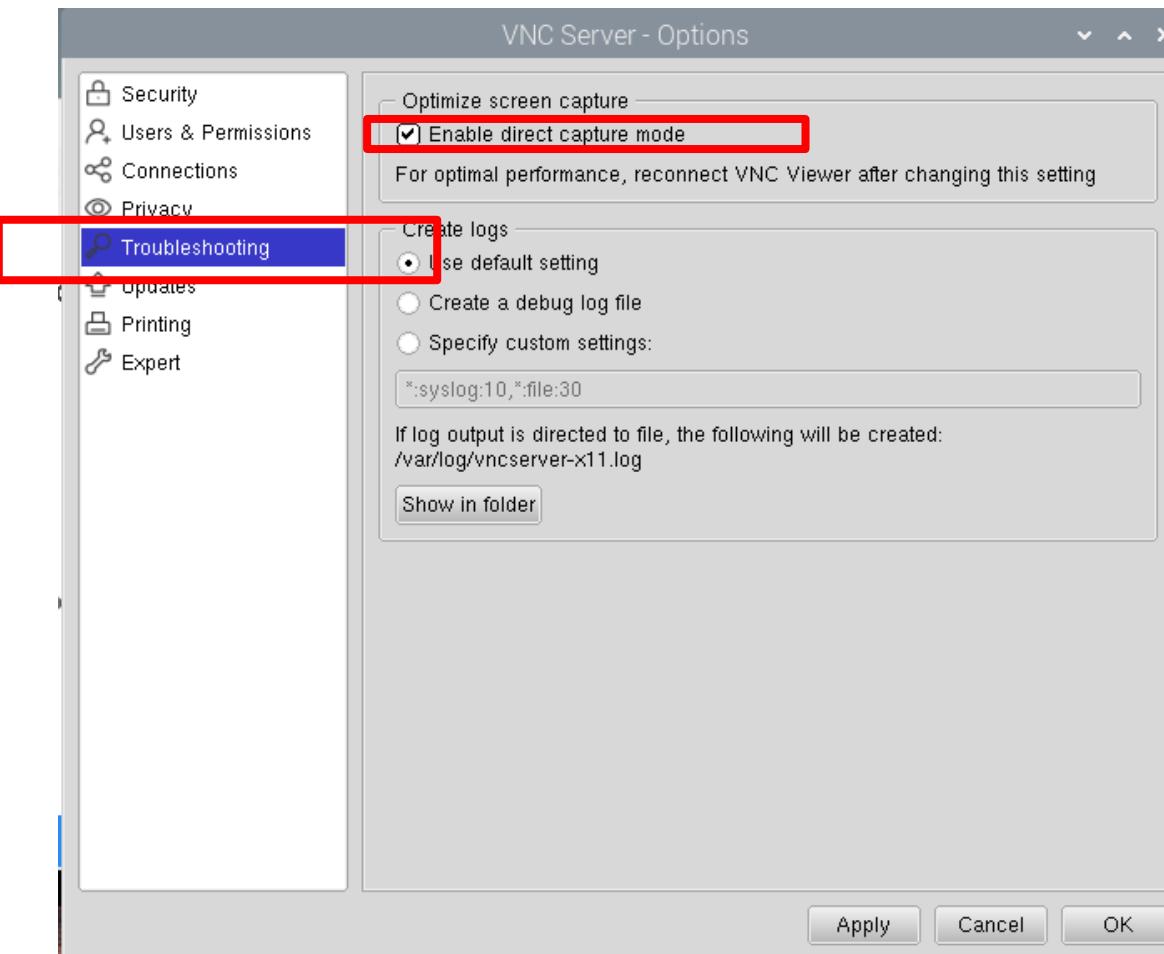


## VNC額外設定





# VNC額外設定: direct capture mode





# Connect: PI的專屬遠端桌面

- 如果想遠端存取 Raspberry Pi 的桌面，過去有許多技術可以實現，例如 VNC、X Protocol (X Window System)、Remote Desktop Protocol (RDP) 等，但如果還需要跨網段存取或是穿過防火牆的話就需要更多的設定才行了
- 隨著 Raspberry Pi OS 進版到 Bookworm 預設使用 Wayland，傳統的 X remote desktop 將不再支援了，連 AnyDesk 也不能使用了
- 因為目前 AnyDesk 只支援 Raspbian/Raspberry Pi OS (32 bit) 和 Raspberry Pi OS 11 “Bullseye” 以下的版本。
- Raspberry Pi 的OS必須使用Bookworm之後的版本才能使用Connect



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# 4. GPIO introduction

- General-purpose input/output (GPIO)
  - You can set PIN as **Input** or **Output** or **both**
    - Input: write a value on PIN
    - Output: Read the value on PIN



<https://www.raspberrypi.org/documentation/usage/gpio/README.md>



# 4. GPIO introduction

- Pin number != GPIO number
  - Physical numbering vs. GPIO numbering

## Raspberry Pi Pinout

3v3 Power	1	5v Power	2	5v Power
GPIO 2 (I2C1 SDA)	3	5v Power	4	5v Power
GPIO 3 (I2C1 SCL)	5	Ground	6	Ground
GPIO 4 (GPCLK0)	7	GPIO 14 (UART TX)	8	GPIO 15 (UART RX)
Ground	9	Ground	10	GPIO 18 (PCM CLK)
GPIO 17	11	GPIO 23	12	GPIO 24
GPIO 27	13	GPIO 24	14	Ground
GPIO 22	15	GPIO 25	16	GPIO 25
3v3 Power	17	GPIO 8 (SPI0 CE0)	18	GPIO 7 (SPI0 CE1)
GPIO 10 (SPI0 MOSI)	19	Ground	20	GPIO 1 (EEPROM SCL)
GPIO 9 (SPI0 MISO)	21	GPIO 7 (SPI0 CE1)	22	GPIO 12 (PWM0)
GPIO 11 (SPI0 SCLK)	23	GPIO 16	24	GPIO 16
Ground	25	GPIO 20 (PCM DIN)	26	GPIO 20 (PCM DOUT)
GPIO 0 (EEPROM SDA)	27	GPIO 21 (PCM DOUT)	28	GPIO 21 (PCM DOUT)
GPIO 5	29	Ground	30	Ground
GPIO 6	31	Ground	32	Ground
GPIO 13 (PWM1)	33	Ground	34	Ground
GPIO 19 (PCM FS)	35	Ground	36	Ground
GPIO 26	37	Ground	38	Ground
Ground	39	Ground	40	Ground

5v Power SDIO JTAG 3v3 Power UART DPI PCM 1-WIRE WiringPi  
GPCLK Ground I2C PWM SPI

Browse pinouts for HATs, pHATs and add-ons »

## GPIO 4

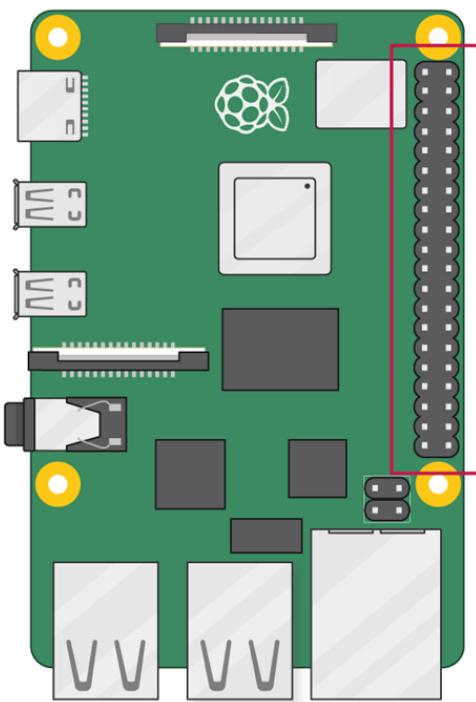
Alt0	Alt1	Alt2	Alt3	Alt4	Alt5
GPCLK0	SMI SA1	DPI D0	AVEOUT VID0	AVEIN VID0	JTAG TDI

• Physical/Board pin 7  
 • GPIO/BCM pin 4  
 • Wiring Pi pin 7



# 4. GPIO introduction

- The PIN (Physical) numbering is in Z-shape



3V3 power	1	2	5V power
GPIO 2 (SDA)	3	4	5V power
GPIO 3 (SCL)	5	6	Ground
GPIO 4 (GPCLK0)	7	8	GPIO 14 (TXD)
Ground	9	10	GPIO 15 (RXD)
GPIO 17	11	12	GPIO 18 (PCM_CLK)
GPIO 27	13	14	Ground
GPIO 22	15	16	GPIO 23
3V3 power	17	18	GPIO 24
GPIO 10 (MOSI)	19	20	Ground
GPIO 9 (MISO)	21	22	GPIO 25
GPIO 11 (SCLK)	23	24	GPIO 8 (CE0)
Ground	25	26	GPIO 7 (CE1)
GPIO 0 (ID_SD)	27	28	GPIO 1 (ID_SC)
GPIO 5	29	30	Ground
GPIO 6	31	32	GPIO 12 (PWM0)
GPIO 13 (PWM1)	33	34	Ground
GPIO 19 (PCM_FS)	35	36	GPIO 16
GPIO 26	37	38	GPIO 20 (PCM_DIN)
Ground	39	40	GPIO 21 (PCM_DOUT)



# 4. GPIO introduction

- Raspbian有內建gpio查詢指令: pinout
- 執行結果

```
pi@raspberrypi:~$ pinout
,-----+-----+-----+-----+-----+
| 000000000000000000000000 | J8   +-----+
| 100000000000000000000000 | PoE  +-----+
| Wi   Fi  Pi Model 4B V1.4 oo | 1o  +-----+
| [D]  [S]  [SoC]  [RAM] | C  |  Net
| [I]  [ ]  [ ]  [ ] | S  |  USB3
| pwr | hd | hd | I | A | V | USB2
|   | m0 | m1 |   |   |   |
Revision      : d03114
SoC          : BCM2711
RAM          : 8GB
Storage       : MicroSD
USB ports     : 4 (of which 2 USB3)
Ethernet ports: 1 (1000Mbps max. speed)
Wi-fi         : True
Bluetooth     : True
Camera ports (CSI): 1
Display ports (DSI): 1

J8:
  3V3  (1) (2)  5V
  GPIO2 (3) (4)  5V
  GPIO3 (5) (6) GND
  GPIO4 (7) (8) GPIO14
  GND  (9) (10) GPIO15
  GPIO17 (11) (12) GPIO18
  GPIO27 (13) (14) GND
  GPIO22 (15) (16) GPIO23
  3V3 (17) (18) GPIO24
  GPIO10 (19) (20) GND
  GPIO9  (21) (22) GPIO25
  GPIO11 (23) (24) GPIO8
  GND  (25) (26) GPIO7
  GPIO00 (27) (28) GPIO1
  GPIO5  (29) (30) GND
  GPIO6  (31) (32) GPIO12
  GPIO13 (33) (34) GND
  GPIO19 (35) (36) GPIO16
  GPIO26 (37) (38) GPIO20
  GND  (39) (40) GPIO21

POE:
TR01 (1) (2) TR00
TR03 (3) (4) TR02

For further information, please refer to https://pinout.xyz/
58
```



# PI4 datasheet

- Power Requirements

- USB-C power supply: 5V at 3A
- If attached devices consume less than 500mA, a 5V, 2.5A supply may be used.

<https://datasheets.raspberrypi.com/rpi4/raspberry-pi-4-datasheet.pdf>

- GPIO Limitations

- Do not poke at the GPIO connector with a screwdriver or any metal object when the PI is powered up.
- Do not power the PI with more than 5V.
- Do not put more than 3.3V on any GPIO pin being used as an input.

From: Raspberry Pi Cookbook: Software and Hardware Problems and Solutions  
<https://books.google.com.tw/books?id=0skvDAAAQBAJ&pg=PT270&lpg=PT270#v=onepage&q=&f=false>



# Pi4 datasheet

## • 4 Electrical Specification

**Caution!** Stresses above those listed in Table 2 may cause permanent damage to the device. This is a stress rating only; functional operation of the device under these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Symbol	Parameter	Minimum	Maximum	Unit
VIN	5V Input Voltage	-0.5	6.0	V

Table 2: Absolute Maximum Ratings

## • 5.6 Temperature Range and Thermals

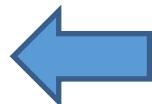
The Pi4B will operate perfectly well without any extra cooling and is designed for sprint performance - expecting a light use case on average and ramping up the CPU speed when needed (e.g. when loading a webpage). If a user wishes to load the system continually or operate it at a high temperature at full performance, further cooling may be needed.

<https://datasheets.raspberrypi.com/rpi4/raspberry-pi-4-datasheet.pdf>



# Programming language for GPIO

- C
- C + wiringPi
- C#
- Ruby
- Perl
- Python
- Scratch
- Java Pi4J Library
- Shell script



We use Python3



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  - MobaXterm
  - Winscp



# A. Mobaxterm + ssh

Linux raspberrypi 5.10.103-v7l+ #1529 SMP Tue Mar 8 12:24:00 GMT  
2022 armv7l

The programs included with the Debian GNU/Linux system are free software;  
the exact distribution terms for each program are described in the  
individual files in /usr/share/doc/\*copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent  
permitted by applicable law.

Last login: Tue Feb 28 15:50:26 2023 from 140.113.5.63

SSH is enabled and the default password for the 'pi' user has not  
been changed.  
This is a security risk - please login as the 'pi' user and type  
'passwd' to set a new password.

Wi-Fi is currently blocked by rfkill.  
Use raspi-config to set the country before use.

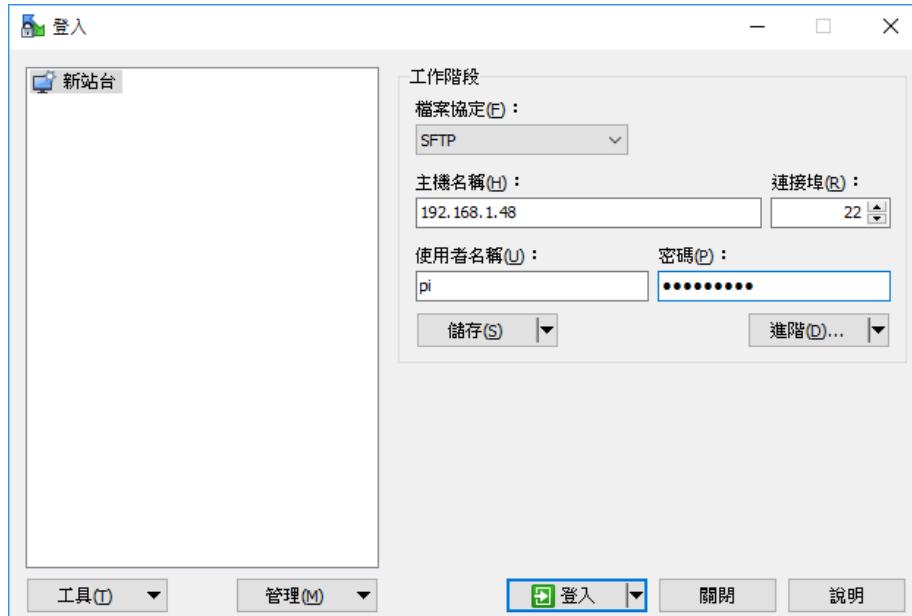
pi@raspberrypi:~ \$

遠端目的的資料夾



## B. WinSCP

- 在電腦上安裝winscp, 輸入IP的ip address與帳密, 即可連線傳輸資料(如同ftp介面)
- 需先啟用ssh login功能 (sudo raspi-config)





## B. WinSCP

- 使用畫面

The screenshot shows the WinSCP interface with two panes. The left pane shows the local directory structure under 'C:\Users\wufish\Documents\' on the left, and the right pane shows the remote directory structure under '/home/pi/' on the right. A file named 'master.zip' is selected in the right pane.

名稱	大小	最後修改時間	權限	擁有者
..		2018/11/13 下午 09:09...	rwxr-xr-x	root
Desktop		2018/11/13 下午 10:25...	rwxr-xr-x	pi
Documents		2018/11/13 下午 10:25...	rwxr-xr-x	pi
Downloads		2018/11/13 下午 10:25...	rwxr-xr-x	pi
MagPi		2018/11/13 下午 09:45...	rwxr-xr-x	pi
Music		2018/11/13 下午 10:25...	rwxr-xr-x	pi
Pictures		2018/11/13 下午 10:25...	rwxr-xr-x	pi
Public		2018/11/13 下午 10:25...	rwxr-xr-x	pi
Templates		2018/11/13 下午 10:25...	rwxr-xr-x	pi
thinclient_drives		2019/1/10 下午 07:00...	rwxr-xr-t	pi
Videos		2018/11/13 下午 10:25...	rwxr-xr-x	pi
master.zip	55 KB	2019/1/14 下午 03:57...	rw-r--r--	pi

Bottom status bar: 0 B / 0 B 在 0 / 9 個項目    54.3 KB / 54.3 KB 在 1 / 11 個項目    14 個隱藏項目

Bottom icons: Lock, SFTP-3, Progress Bar, 0:32:51



# Today summary

- Embedded development board
- Setup Raspberry PI, headless
- GPIO introduction & Python environment
- Understanding this course:
  - Discussion & quiz (no quiz this week)



# Summary

- Labs
  - 1. 根據安裝步驟, 使用TTL控制樹莓派, 完成環境設定
  - 2. 建立VNC遠端桌面, 需開啟 “direct capture mode”
  - 3. 練習傳輸檔案的方式
- Write down the answer for discussion, upload to e-campus.  
Deadline (before next class): 13:00, 3/15(Fri.)
  - Discussion 1: What is the advantage of headless operation?
- **No quiz this week.**  
When you finish all Labs, tell TAs to record your attendance.



# Next week

- How to access GPIO pins and read sensing data?

**LED**



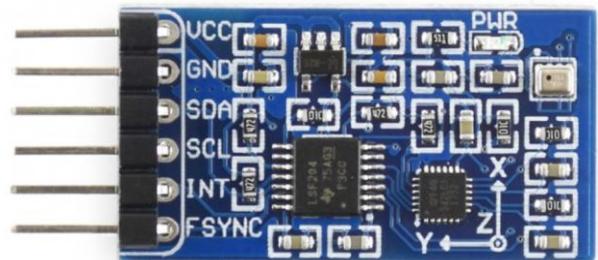
VCC      GND

**HC-SR04**



**Ultrasonic**

**ICM20948**



**IMU**  
(Inertial measurement unit)