

# Embedded Linux Systems Programming: Introduction

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# Outline

- Welcome!
- Concepts
- Case Studies

# References

- [https://en.wikipedia.org/wiki/Embedded\\_system](https://en.wikipedia.org/wiki/Embedded_system)
- [https://en.wikipedia.org/wiki/Linux\\_on\\_embedded\\_systems](https://en.wikipedia.org/wiki/Linux_on_embedded_systems)
- <https://www.raspberrypi.com/>

# What is an Embedded Linux System?

# What is an embedded system?

- An **Embedded Linux System** is a **computer system** build upon the Linux operating system that has a **dedicated function** within a larger system
  - Everyday Examples
    - Setup Boxes, Smart TVs, Personal Video Recorders, In-Vehicle Info Systems, Network Equipment (routers, etc), industrial equipment, medical equipment, etc. etc. etc
    - Embedded Linux Systems are everywhere!

# Example Embedded Linux System

Itron  
Electric  
Meter



# Example Embedded Linux System



# Key Parts of All Embedded Linux Systems

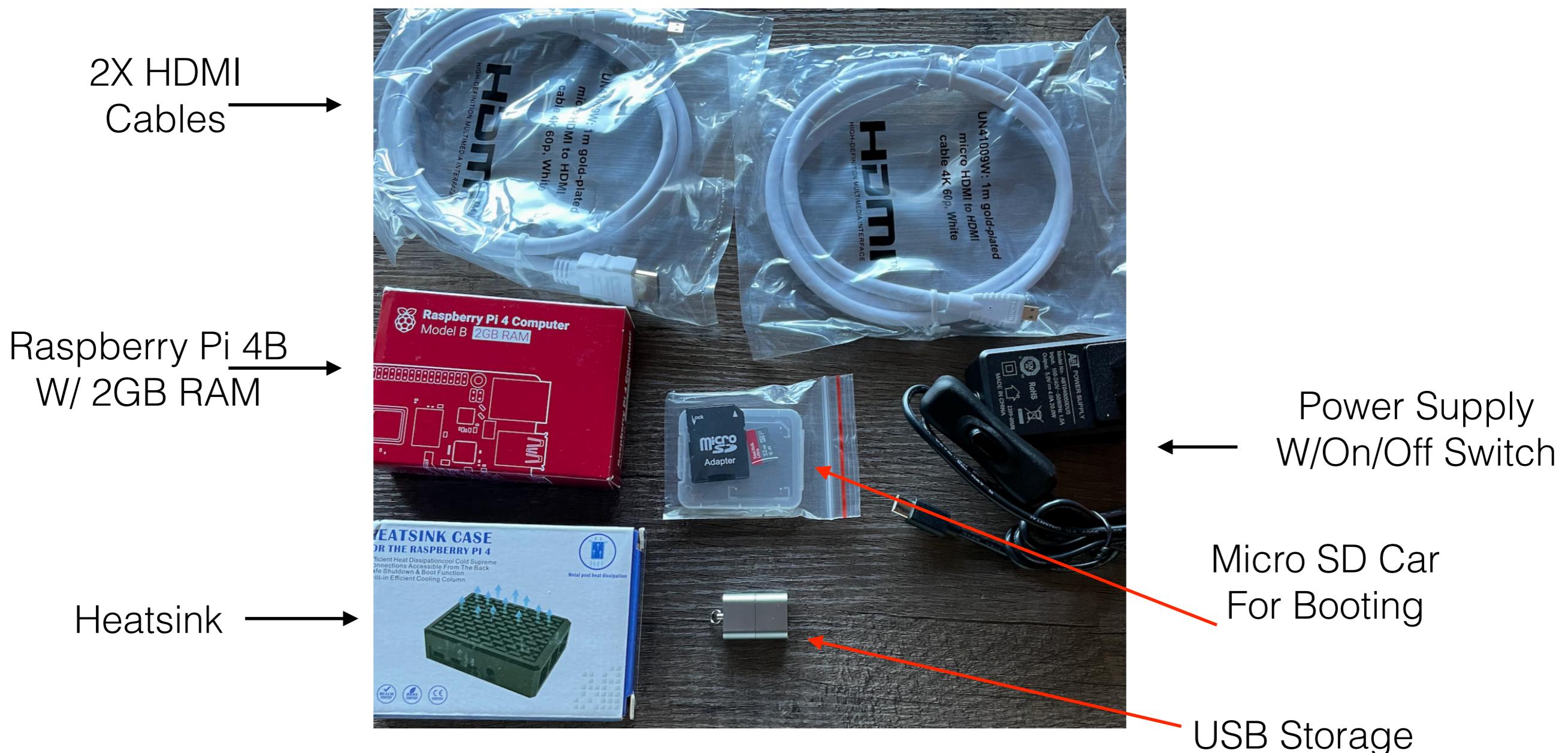
- Boot Loader
- Linux Kernel / Linux Kernel Modules
- Root Filesystem
- Busybox (Command-Line Interface)
- Systems Programs / Daemons

# Using Raspberry Pi To Explore an Embedded Linux System

# Raspberry Pi 4B Starter More Kit

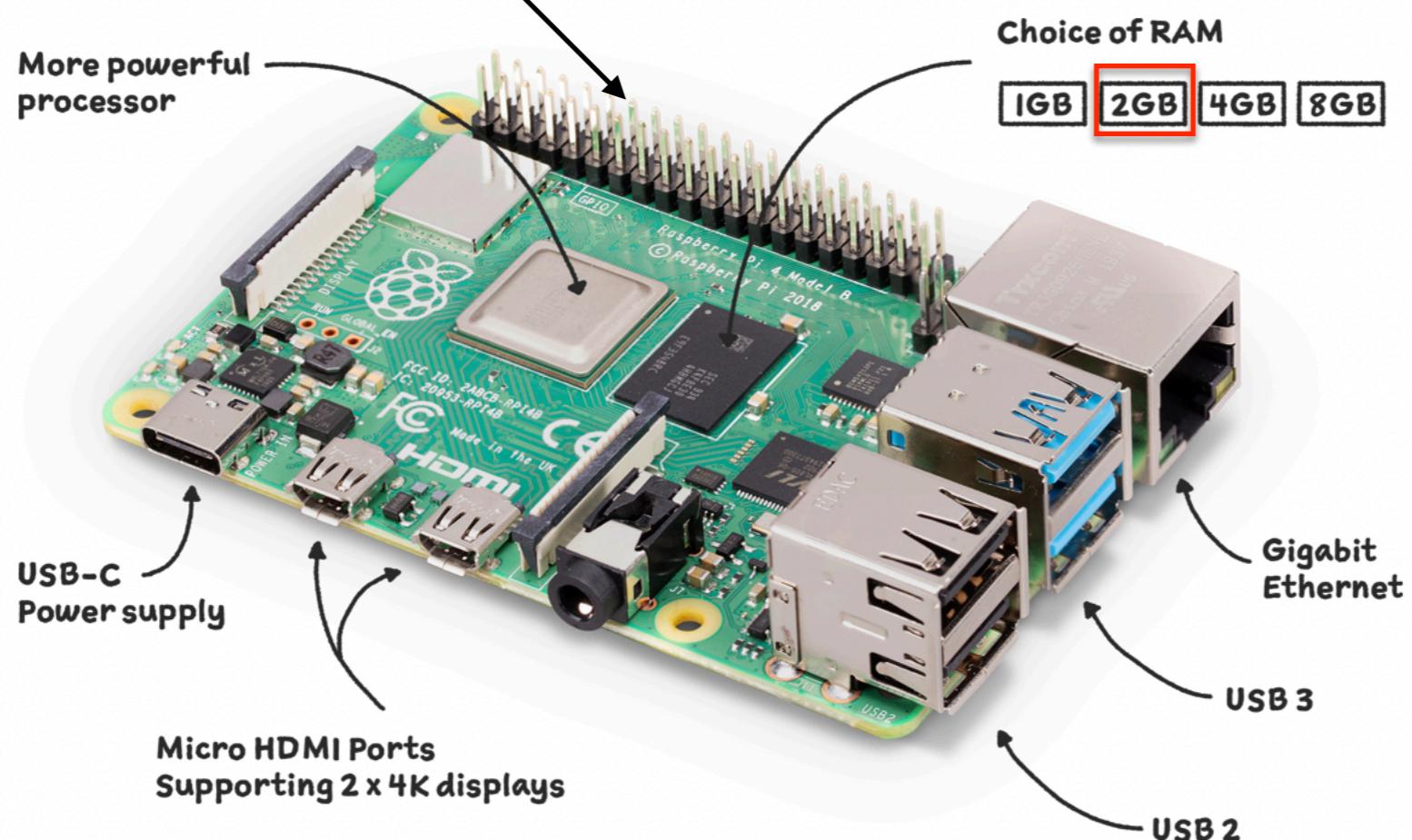


# Raspberry Pi 4B Starter More Kit - Items Inside Box

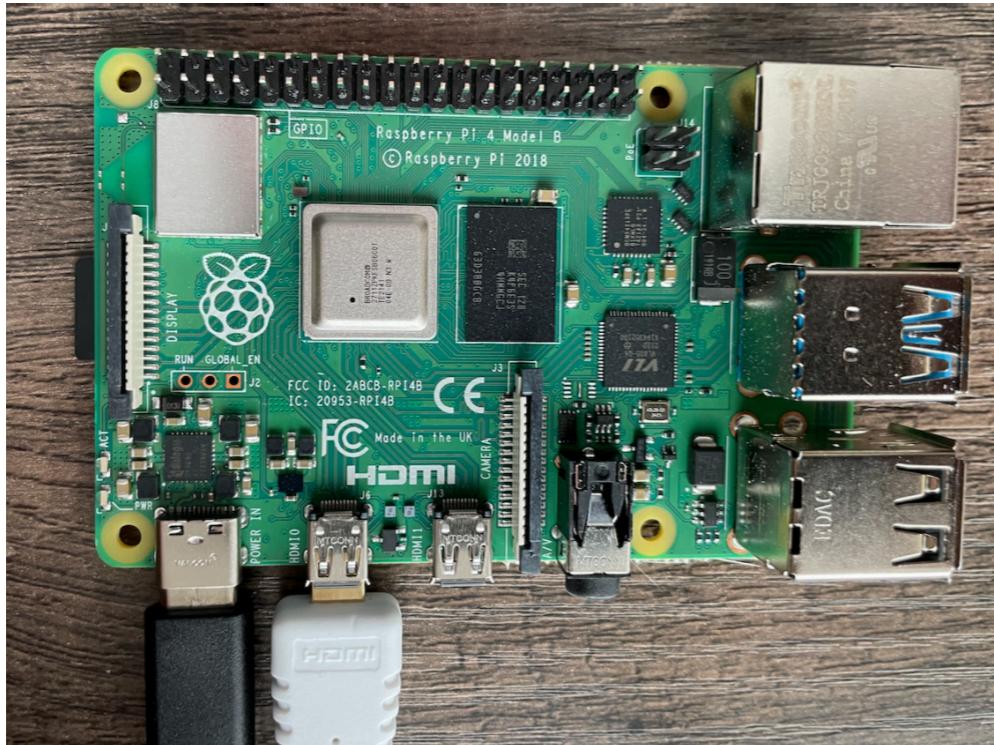


# Raspberry Pi 4B

## I/O Expansion

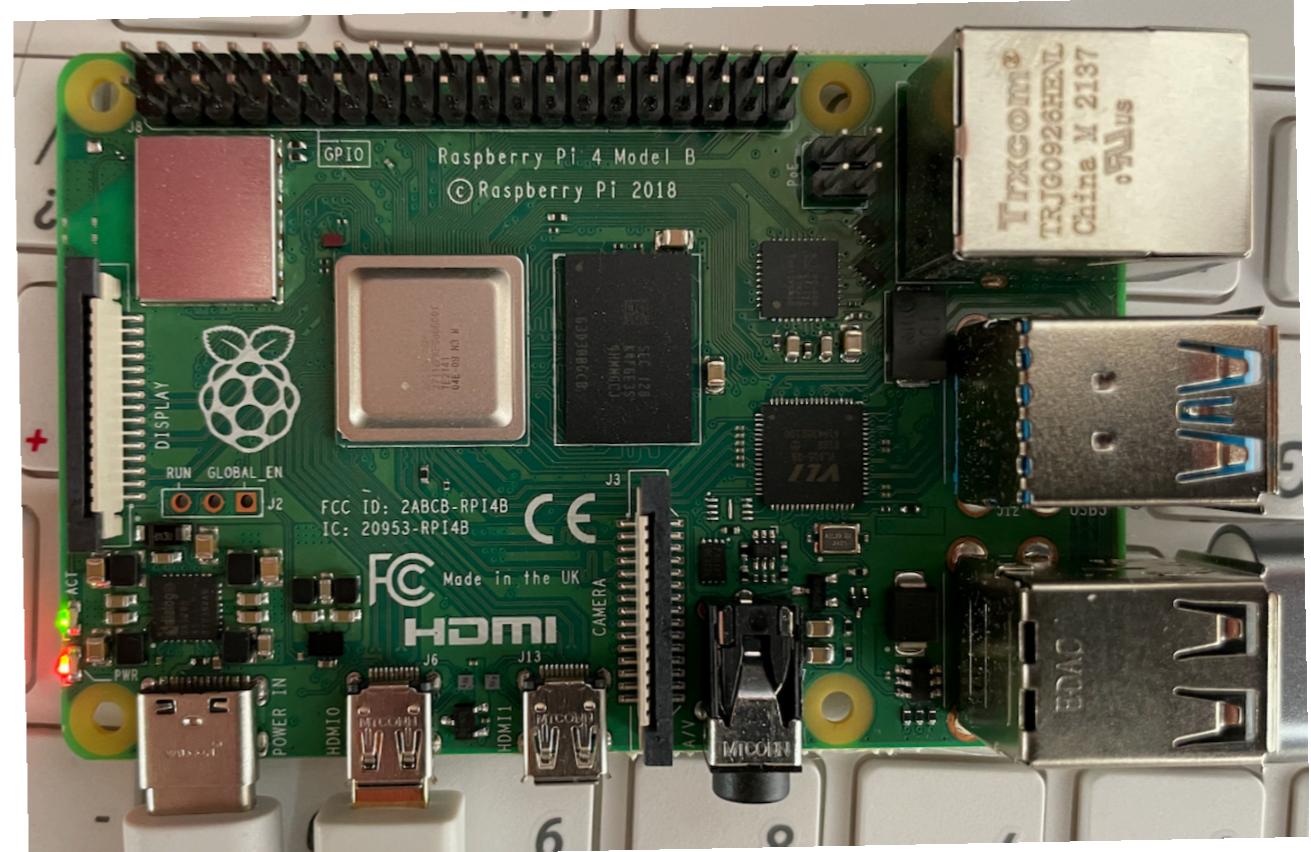


# Connect Video and Power Cables

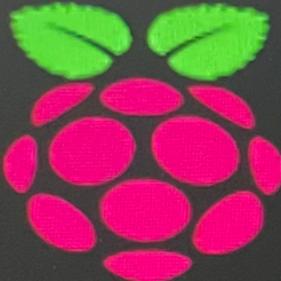


Power      Video

LEDs



# Initial Message After Power (No SD Card Inserted)



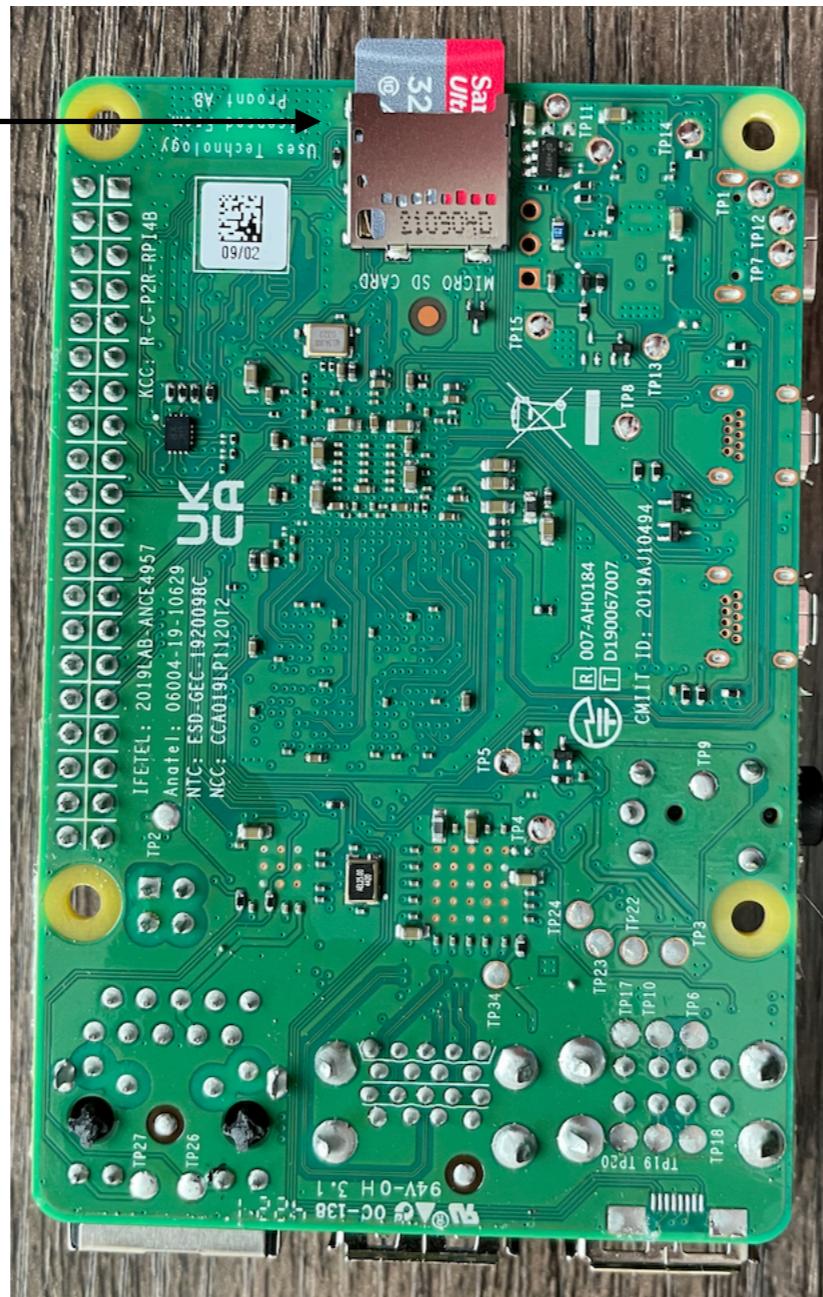
```
Raspberry Pi 4 Model B - 2GB
bootloader: c2f8c388 Apr 29 2021
update-ts: 1619712685

board: b03115 2d7fcfd61 e4:5f:01:98:ae:db
boot: mode USB-MSD 4 order f41 retry 0/128 restart 0/
SD: card not detected
part: 0 mbr [0x00:00000000 0x00:00000000 0x00:00000000
fw:
net: down ip: 0.0.0.0 sn: 0.0.0.0 gw: 0.0.0.0
tftp: 0.0.0.0 00:00:00:00:00:00
```

tftp : Trivial File Transfer Protocol

# Insert Micro SD Card (Although not yet formatted)

Micro SD Card



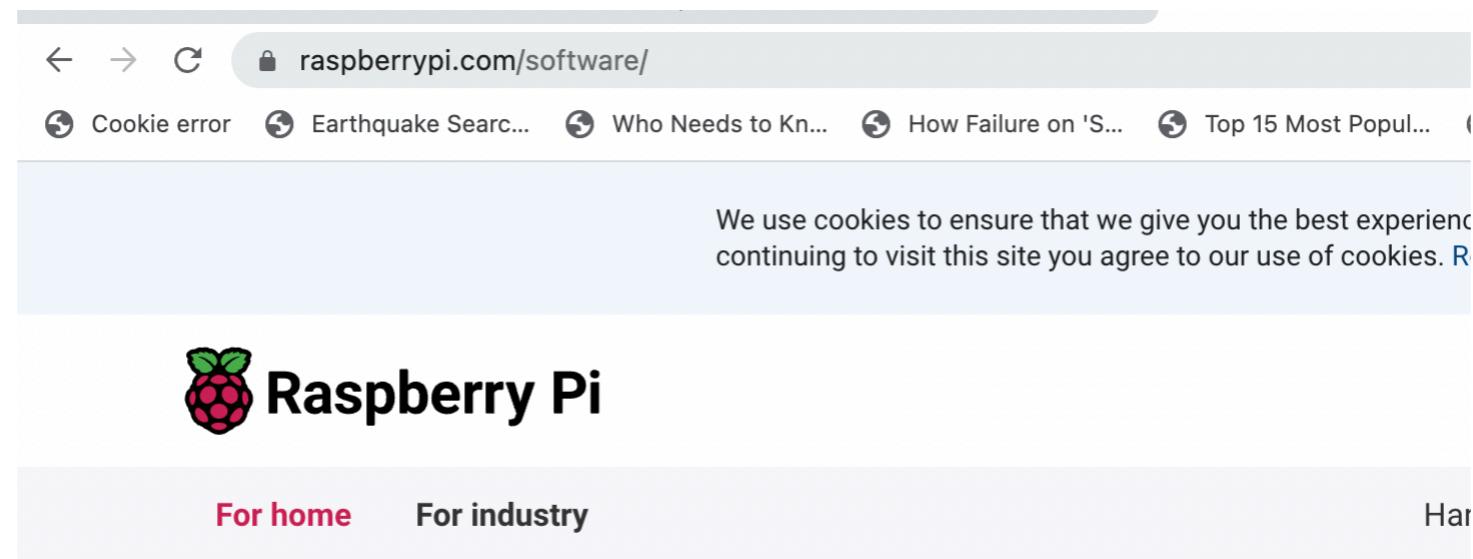
# Power (But SDCard Not Formatted)

```
board: dos110 zarraco1 e4.31.01.98.ae.ad
boot: mode SD 1 order f41 retry 1/1 restart 2/-1
      SD: card detected 00035344534433324785fcedb6ab016
part: 0 mbr lba:0x0c:00002000 0x00:00000000 0x00:000000
      fw: start.elf fixup.dat
net: down ip: 0.0.0.0 sn: 0.0.0.0 gw: 0.0.0.0
tftp: 0.0.0.0 00:00:00:00:00:00

rsc 1164 fat-sectors 7610 c-count 973952 c-size 64 r-dir
Trying partition: 0
lba: 8192 oem: '          ' volume: ' NO NAME '
rsc 1164 fat-sectors 7610 c-count 973952 c-size 64 r-dir
Firmware not found
trying partition: 0
lba: 8192 oem: '          ' volume: ' NO NAME '
rsc 1164 fat-sectors 7610 c-count 973952 c-size 64 r-dir
Trying partition: 0
lba: 8192 oem: '          ' volume: ' NO NAME '
rsc 1164 fat-sectors 7610 c-count 973952 c-size 64 r-dir
Firmware not found
```

# To Download Raspberry Pi Firmware

<https://www.raspberrypi.com/software/>



## Raspberry Pi OS

Your Raspberry Pi needs an operating system to work. This is it. Raspberry Pi OS (previously called Raspbian) is our official supported operating system.

# Raspberry Pi Imager

## **Install Raspberry Pi OS using Raspberry Pi Imager**

Raspberry Pi Imager is the quick and easy way to install Raspberry Pi OS and other operating systems to a microSD card, ready to use with your Raspberry Pi. [Watch our 45-second video](#) to learn how to install an operating system using Raspberry Pi Imager.

Download and install Raspberry Pi Imager to a computer with an SD card reader. Put the SD card you'll use with your Raspberry Pi into the reader and run Raspberry Pi Imager.

# Raspberry Pi Imager

## Step 1

Insert SD card

## Step 2

Choose Operating System



## Step 3

Choose SD card



## Step 4

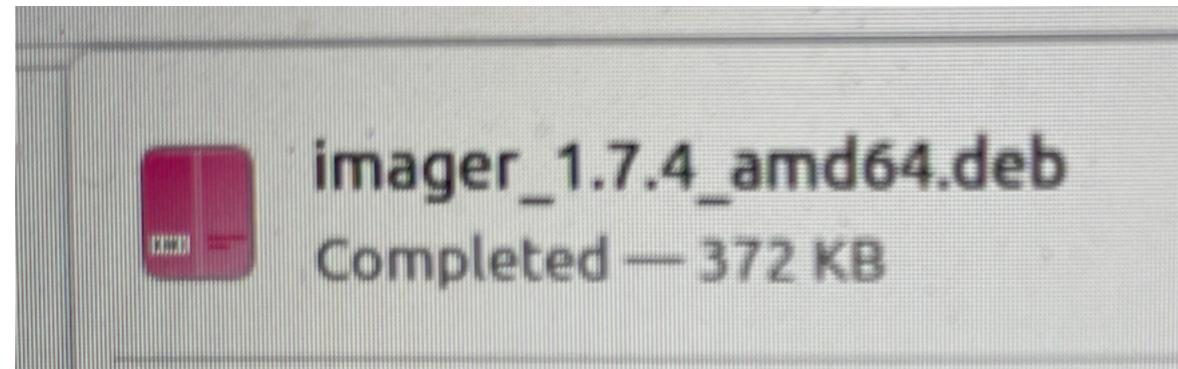
Write and verify SD card



# Preparing Micro SD Card



# Download Imager (On Ubuntu 22.04)



# First Install Attempt (Using dpkg)

```
© LIVE centre@system76-pc:~/Downloads $ sudo dpkg -i imager_1.7.4_amd64.deb
Selecting previously unselected package rpi-imager.
(Reading database ... 289734 files and directories currently installed.)
Preparing to unpack imager_1.7.4_amd64.deb ...
Unpacking rpi-imager (1.7.4) ...
dpkg: dependency problems prevent configuration of rpi-imager:
  rpi-imager depends on libqt5qml5 (>= 5.10.0); however:
    Package libqt5qml5 is not installed.
  rpi-imager depends on qml-module-qtquick2; however:
    Package qml-module-qtquick2 is not installed.
  rpi-imager depends on qml-module-qtquick-controls2; however:
    Package qml-module-qtquick-controls2 is not installed.
  rpi-imager depends on qml-module-qtquick-layouts; however:
    Package qml-module-qtquick-layouts is not installed.
  rpi-imager depends on qml-module-qtquick-templates2; however:
    Package qml-module-qtquick-templates2 is not installed.
  rpi-imager depends on qml-module-qtquick-window2; however:
    Package qml-module-qtquick-window2 is not installed.
  rpi-imager depends on qml-module-qtgraphicaleffects; however:
    Package qml-module-qtgraphicaleffects is not installed.
```

# Transition

- Embedded Linux often uses the dpkg (Debian Package) command to install .deb packages
- However, the dpkg command does NOT resolve dependencies
- To resolve dependences, use the apt command
  - However the .deb must be installed into a local repo (repository) to do that
    - Instead of doing that here, I decide to use the dd (disk direct) copy command

# First, notice how Micro SD Card appears on Linux

```
nmcentire@system76-pc:~/Downloads$ df /media/nmcentire/2EF2-BEFF/
Filesystem      1K-blocks  Used Available Use% Mounted on
/dev/nmcblk0p1   31166464     32  31166432    1% /media/nmcentire/2EF2-BEFF
nmcentire@system76-pc:~/Downloads$
```

df = Disk Filesystem Space

# Use lsblk to see your block devices

```
/home/nmcentire@system76-pc:~/Downloads: $ lsblk
NAME   MAJ:MIN RM  SIZE RO TYPE MOUNTPOINTS
loop0    7:0    0   4K  1 loop /snap/bare/5
loop1    7:1    0 63.3M  1 loop /snap/core20/1852
loop2    7:2    0 63.3M  1 loop
loop3    7:3    0 63.3M  1 loop /snap/core20/1828
loop4    7:4    0 239.1M  1 loop /snap/firefox/2311
loop5    7:5    0 346.3M  1 loop /snap/gnome-3-38-2004/115
loop6    7:6    0 346.3M  1 loop /snap/gnome-3-38-2004/119
loop7    7:7    0 81.3M  1 loop /snap/gtk-common-themes/1534
loop8    7:8    0 91.7M  1 loop /snap/gtk-common-themes/1535
loop9    7:9    0 49.8M  1 loop /snap/snapd/18596
loop10   7:10   0 142.4M  1 loop /snap/lxd/24483
loop11   7:11   0 45.9M  1 loop /snap/snap-store/599
loop12   7:12   0 45.9M  1 loop /snap/snap-store/638
loop13   7:13   0 73M  1 loop /snap/core22/583
loop14   7:14   0 49.8M  1 loop /snap/snapd/18357
loop16   7:16   0 304K  1 loop /snap/snapd-desktop-integration/49
loop17   7:17   0 239.8M  1 loop /snap/firefox/2391
loop18   7:18   0 72.9M  1 loop /snap/core22/547
loop19   7:19   0 163M  1 loop /snap/lxd/24643
loop20   7:20   0 428K  1 loop /snap/snapd-desktop-integration/57
loop21   7:21   0 160.3M  1 loop /snap/gnome-42-2204/65
mmcblk0  179:0  0 29.7G  0 disk
└─mmcblk0p1 179:1  0 29.7G  0 part /media/nmcentire/2EF2-BEFF
nvme0n1  259:0  0 465.8G  0 disk
└─nvme0n1p1 259:1  0 512M  0 part /boot/efi
└─nvme0n1p2 259:2  0 461.3G  0 part /var/snap/firefox/common/host-hunspell/
└─nvme0n1p3 259:3  0 4G  0 part [SWAP]
nmcentire@system76-pc:
```

# Size of Image - Before and After Decompression

```
system76-pc:~/Downloads$ ls -l 2023-02-21-raspios-bullseye-armhf.img.xz  
1 nmcentire nmcentire 968676228 Mar 26 18:40 2023-02-21-raspios-bullseye-armhf.img.xz  
system76-pc:~/Downloads$
```

About 1GB

```
mcentire@system76-pc:~/Downloads$ xz -d 2023-02-21-raspios-bullseye-armhf.img.xz  
mcentire@system76-pc:~/Downloads$ ls -l 2023-02-21-raspios-bullseye-armhf.img  
rw-rw-r-- 1 nmcentire nmcentire 4391436288 Mar 26 18:40 2023-02-21-raspios-bullseye-armhf.img  
mcentire@system76-pc:~/Downloads$
```

About 4GB

# Using dd to send image to Micro SD Card

```
$ sudo dd if=2023-02-21-raspios-bullseye-armhf.img of=/dev/mmcblk0 bs=4M conv=fsync status=progress
```

dd = disk direct

if = input file

of = output file

bs = block size

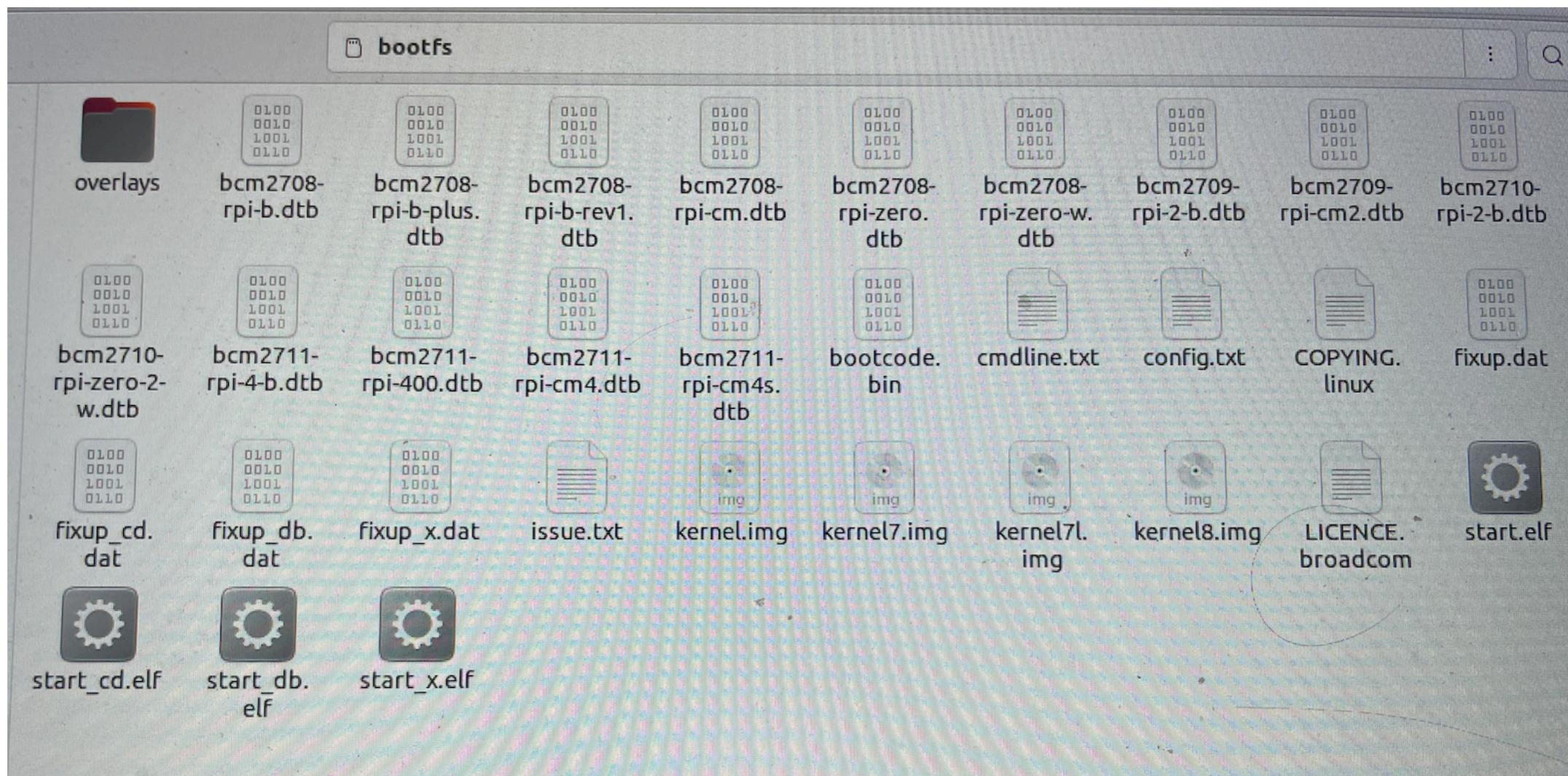
conv=convert (fsync says do not end command until all are copied)

status=progress (show progress)

# Showing Progress

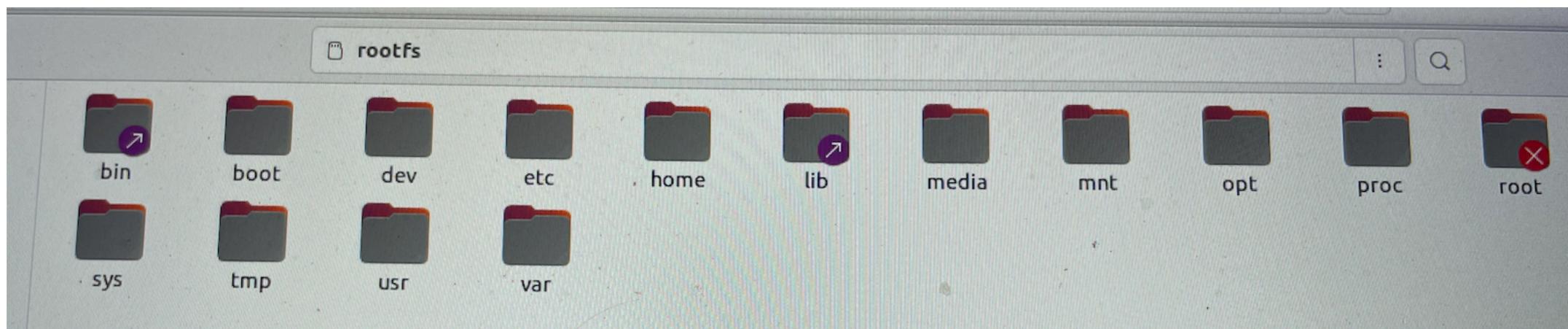
```
4378853376 bytes (4.4 GB, 4.1 GiB) copied, 95 s, 46.0 MB/s
1047+0 records in
1047+0 records out
4391436288 bytes (4.4 GB, 4.1 GiB) copied, 216.705 s, 20.3 MB/s
percent complete [6 88%] (Raw Data)
```

# Results - Partition 1 bootfs (Boot Filesystem)



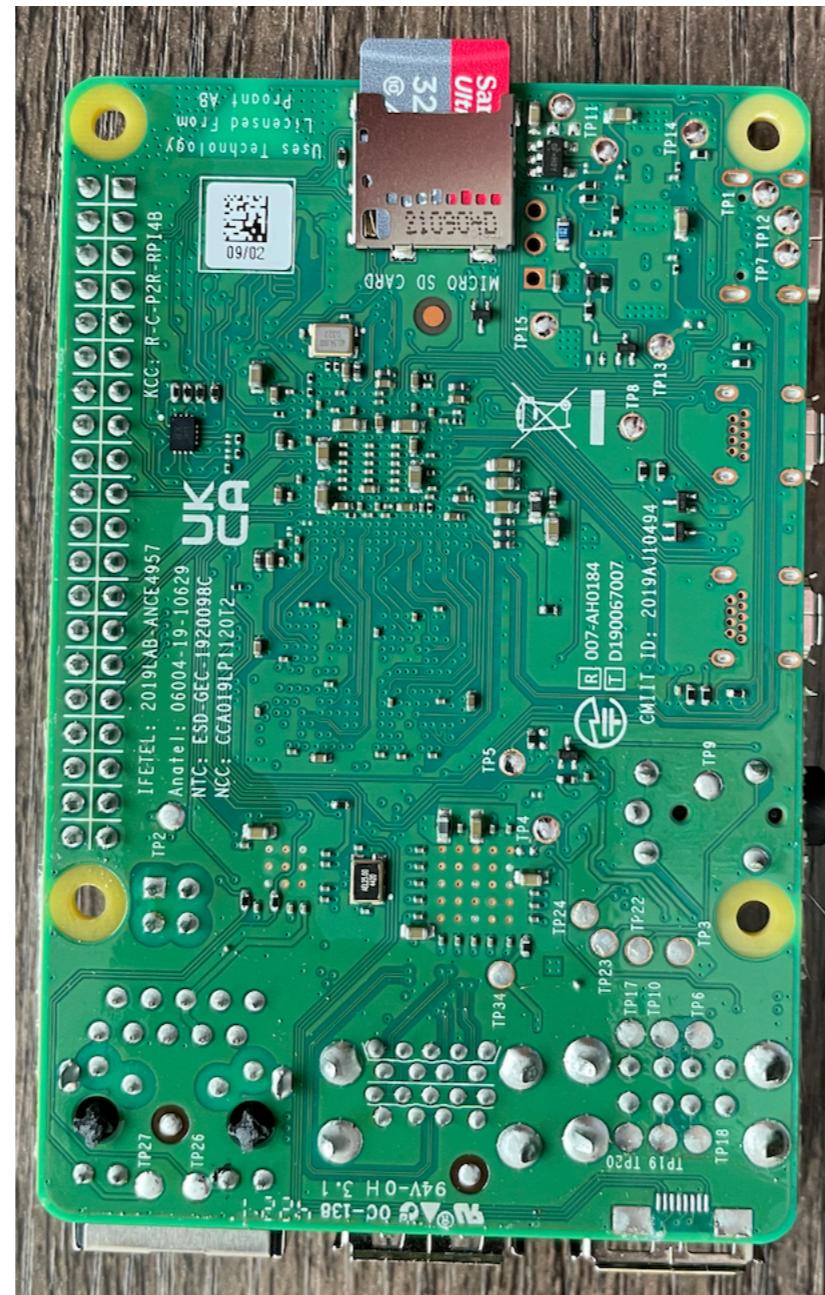
# Results - Partition 2

## rootfs (Root Filesystem)

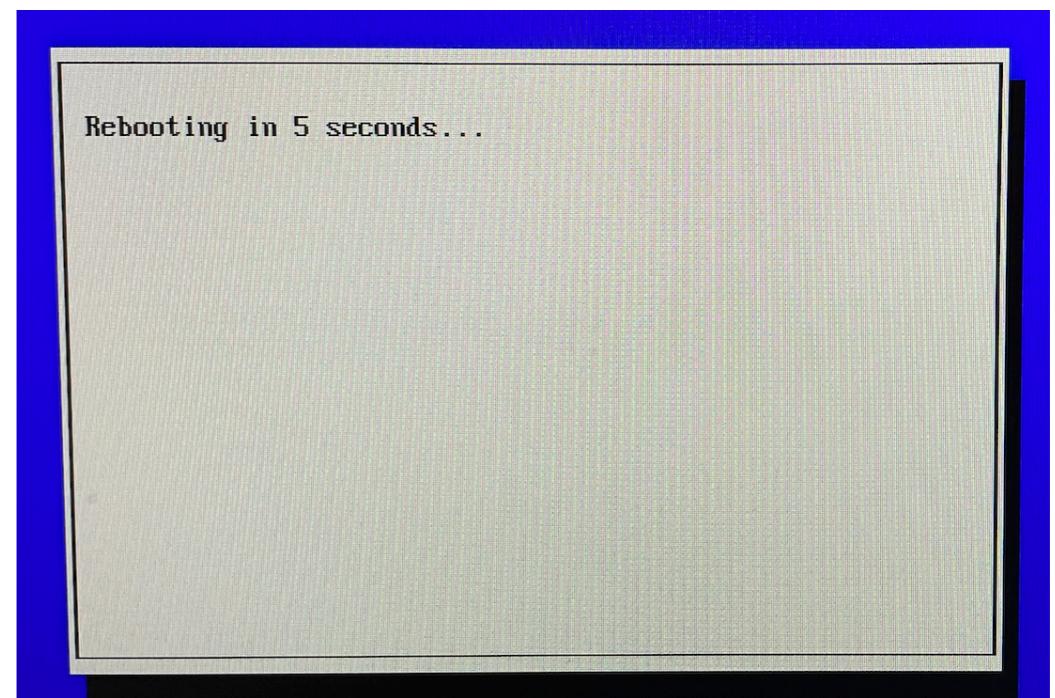
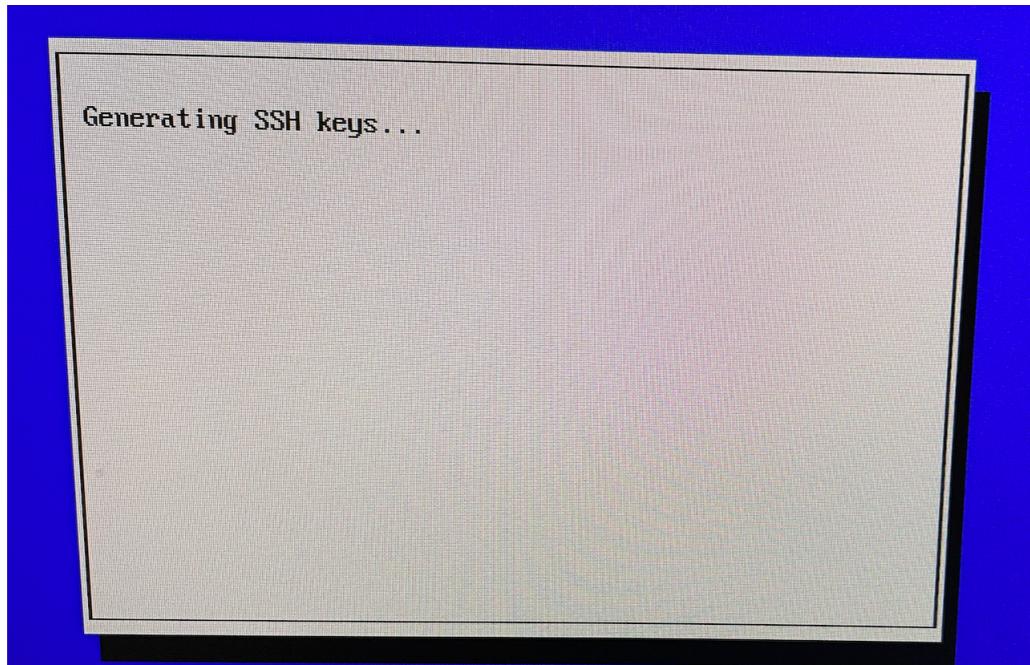


You can now remove the Micro SD Card from Ubuntu and Insert into the Raspberry Pi

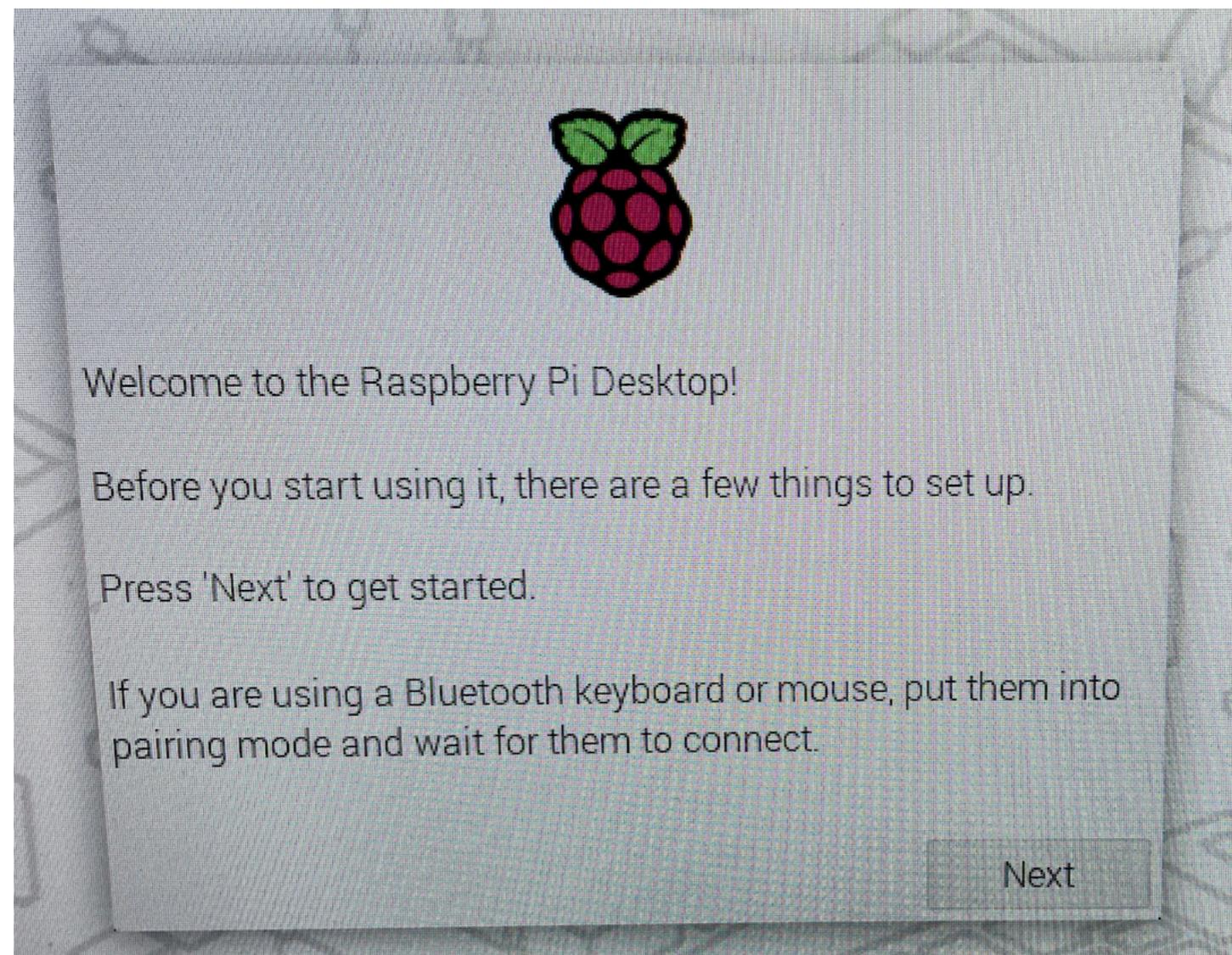
# Micro SD Card Inserted into Raspberry Pi



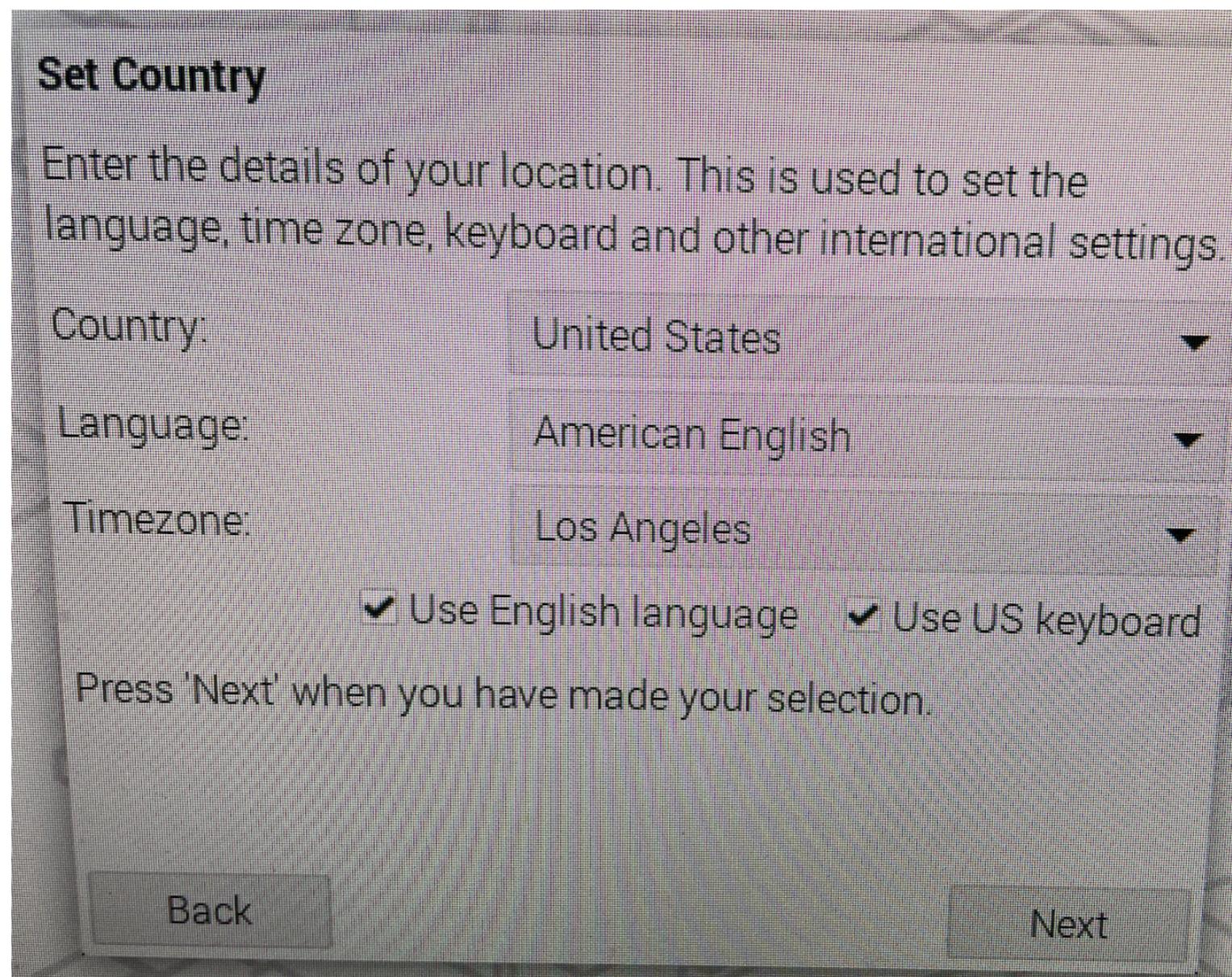
# Booting Up First Time



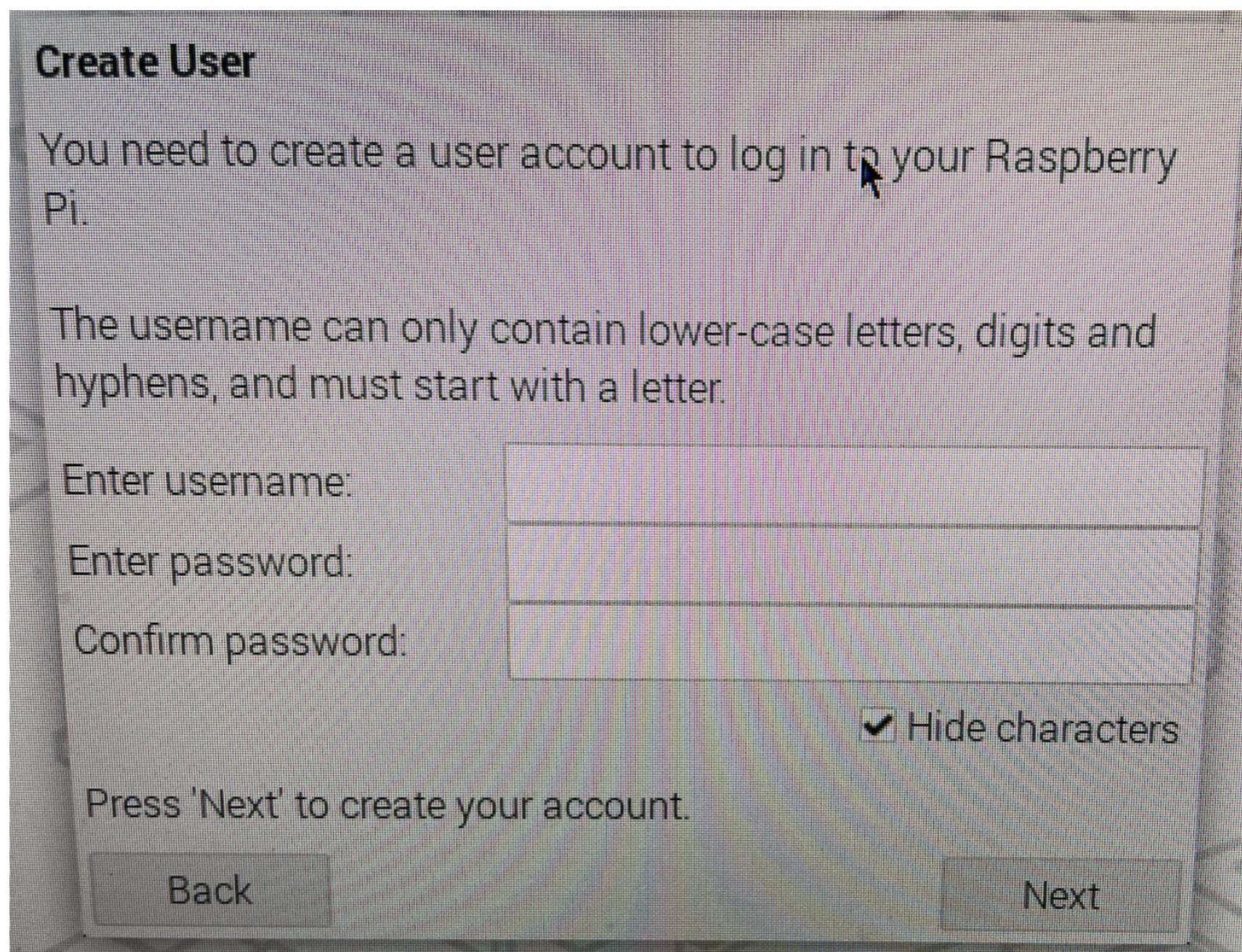
# Setup Screen - Intro



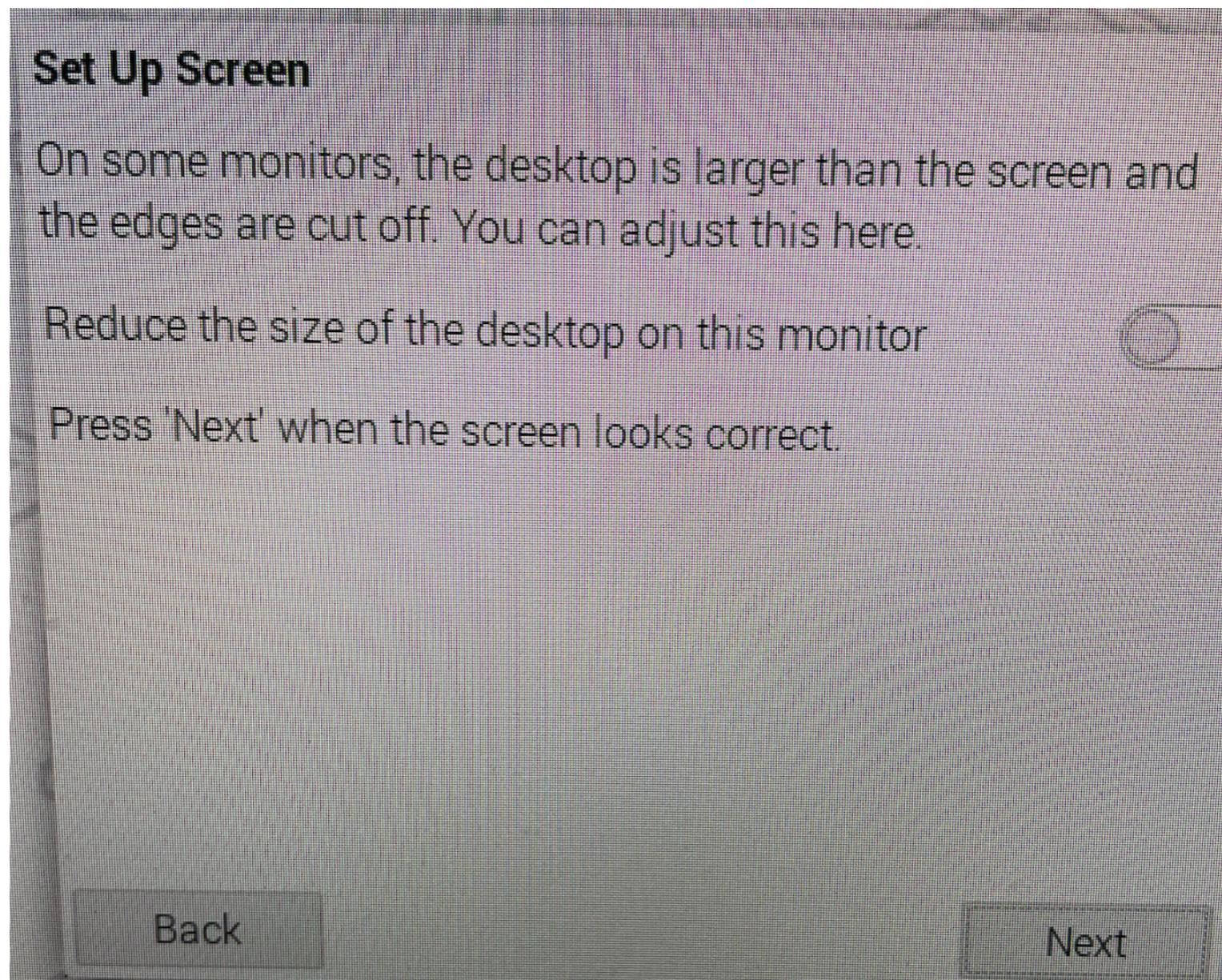
# Setup Screen - Country



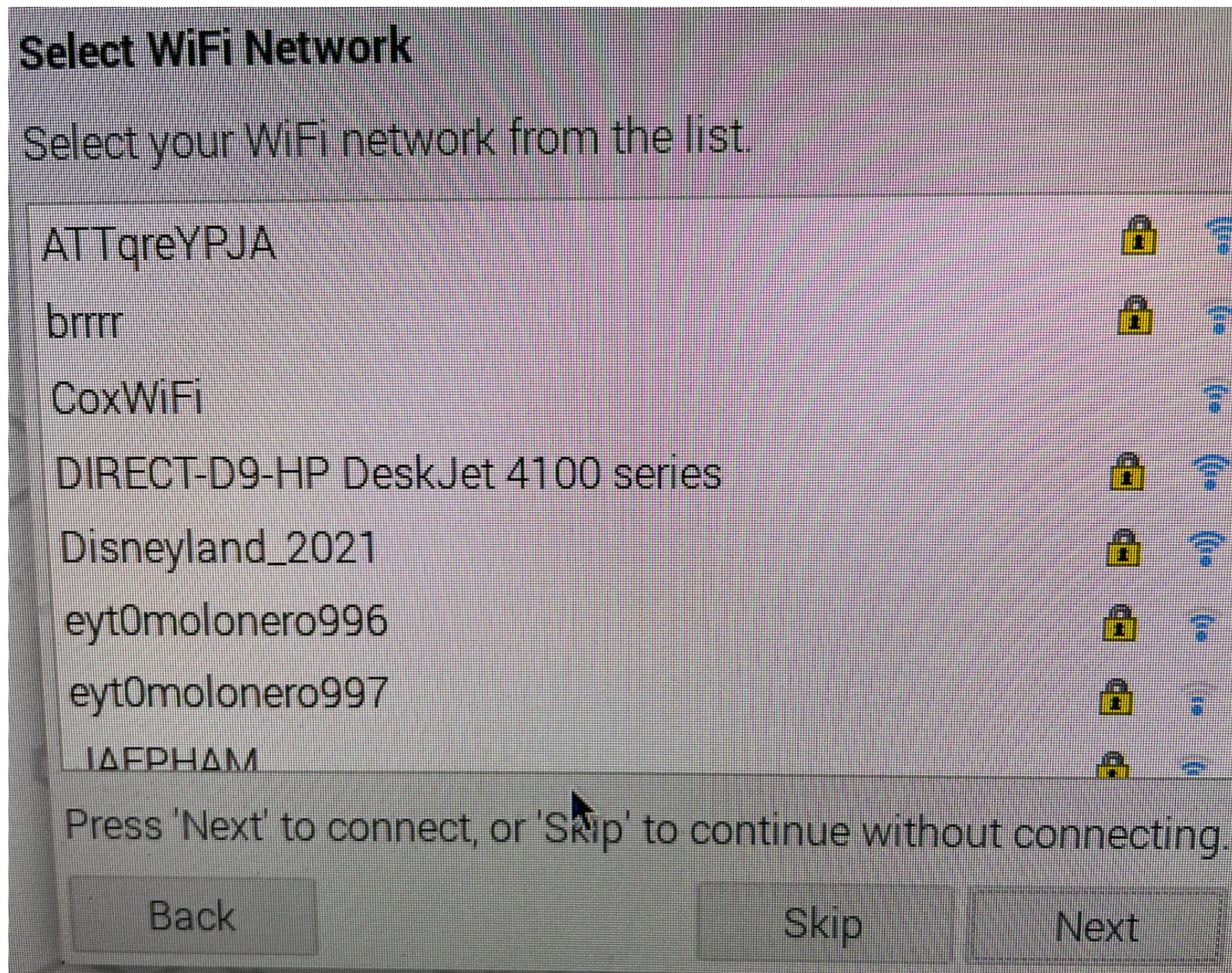
# Setup Screen - Create User



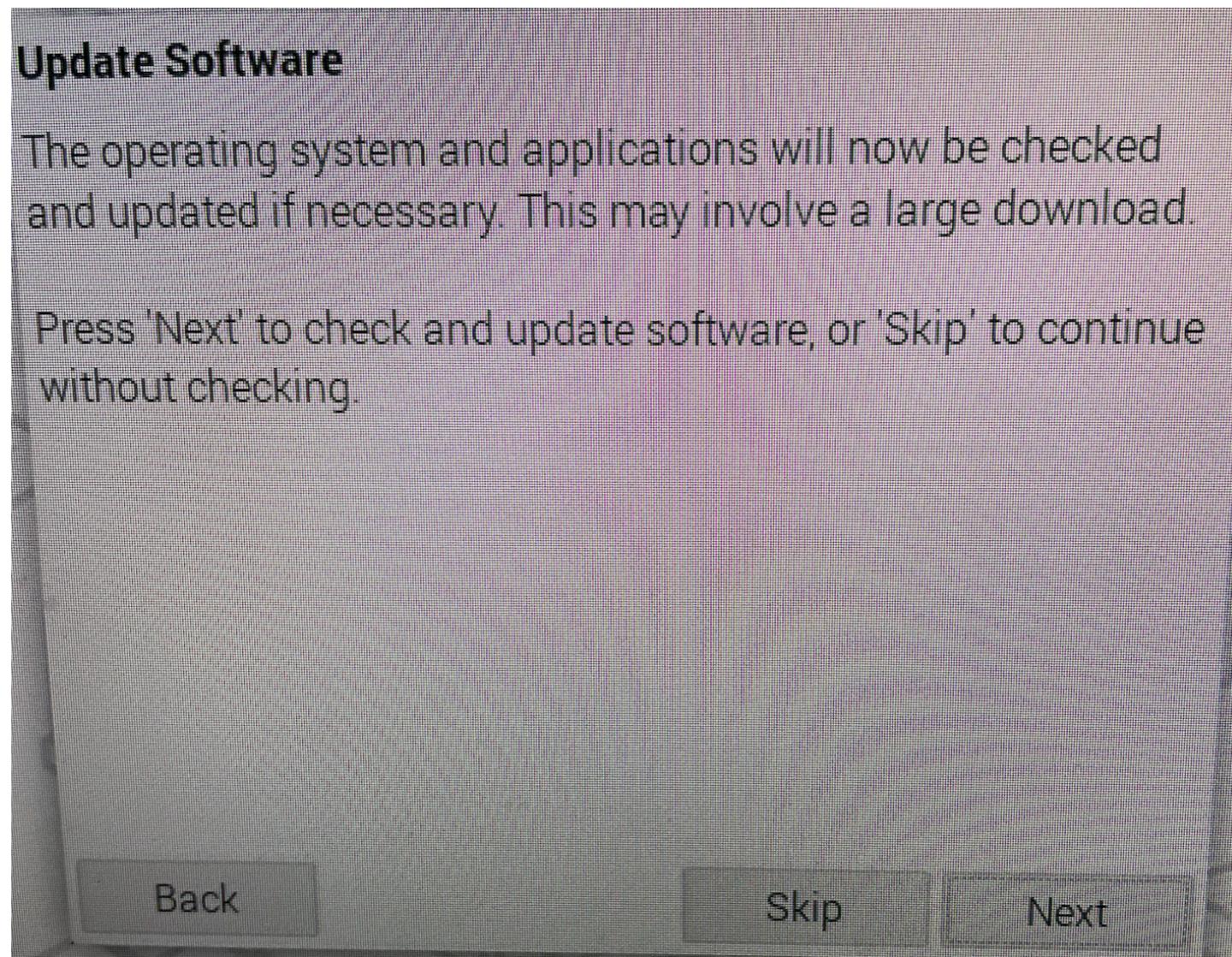
# Setup Screen - Setup Screen



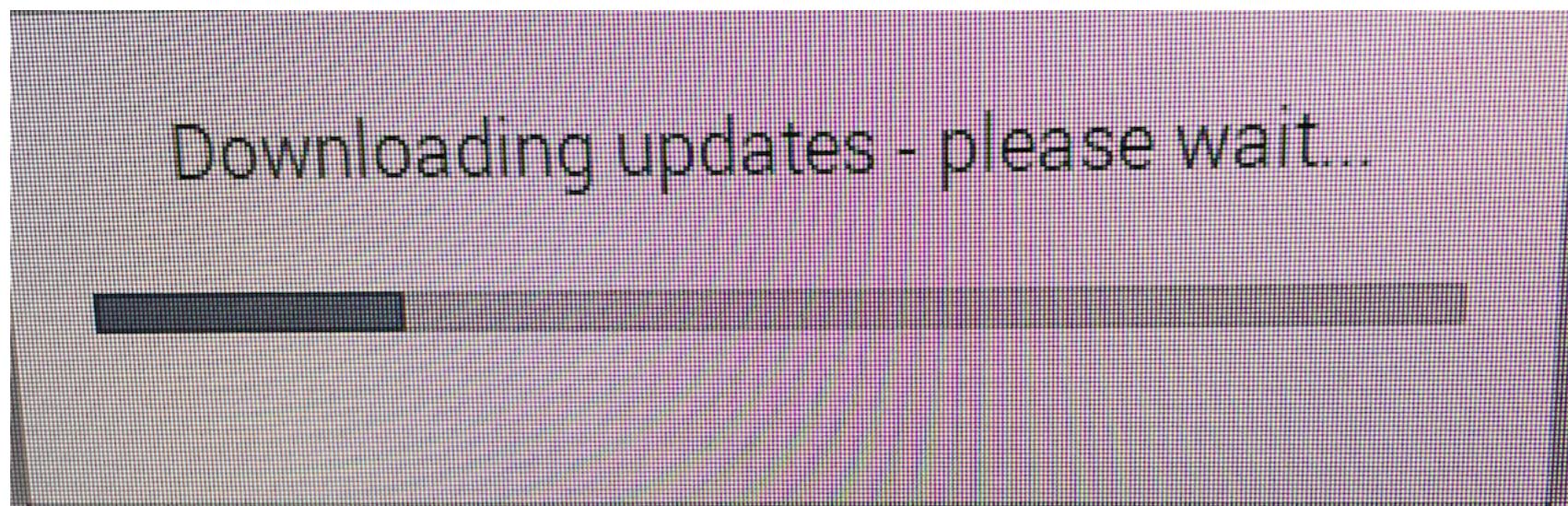
# Setup Screen - Select Wifi Network



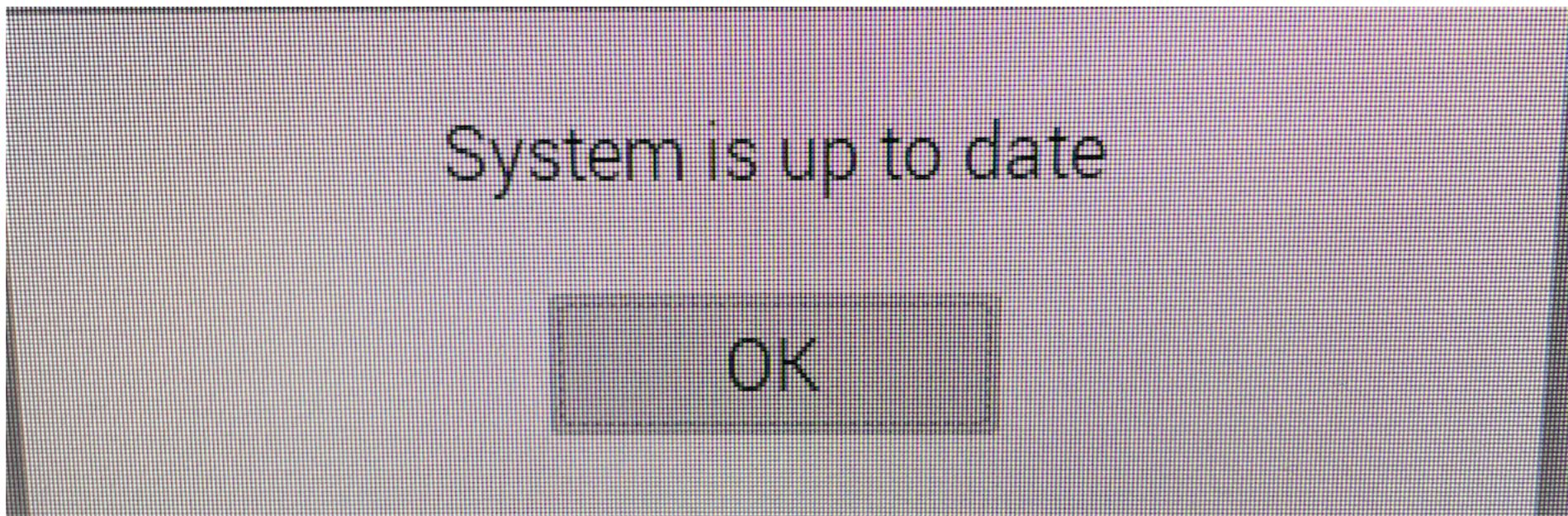
# Setup Screen - Update Software



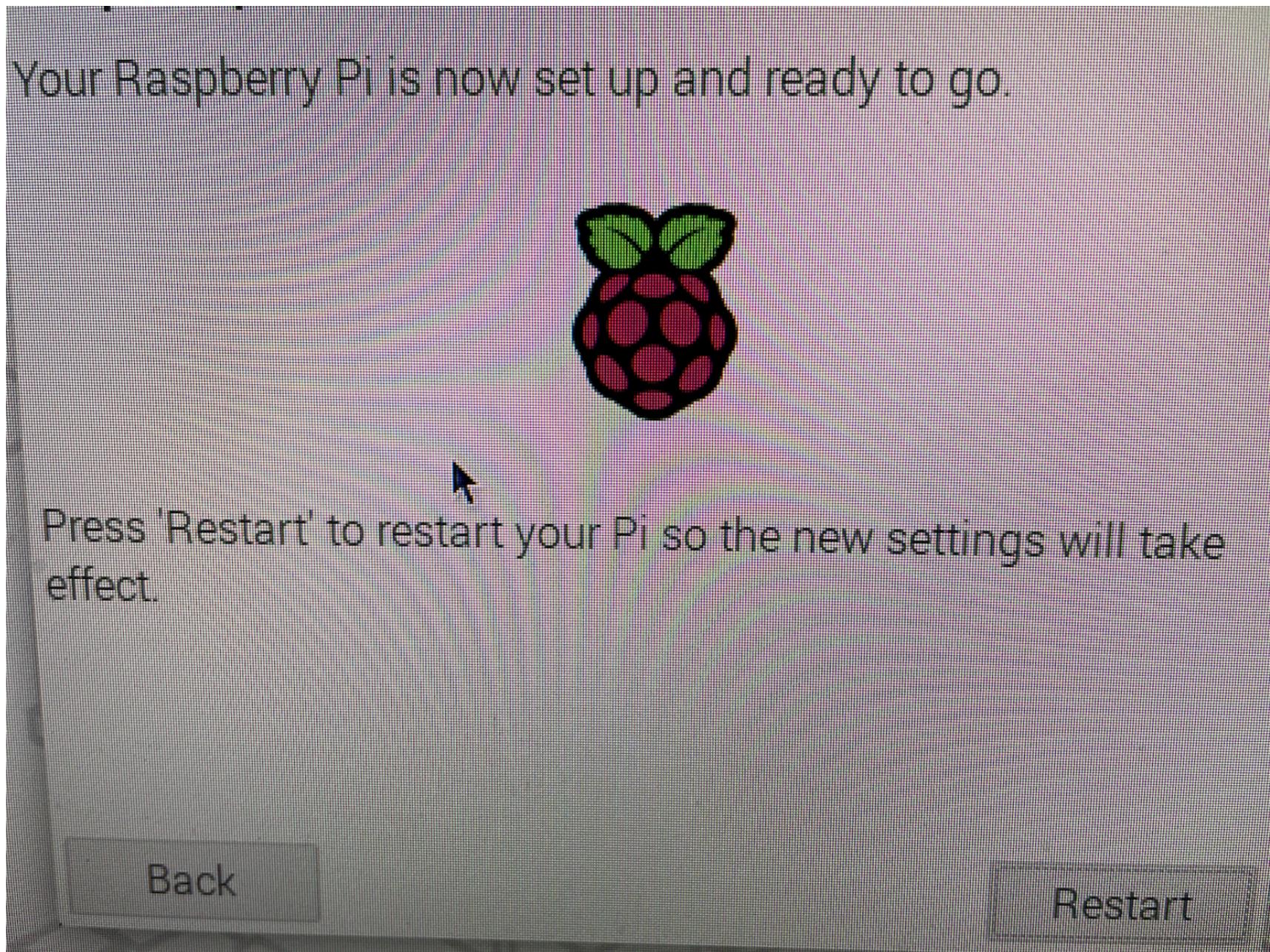
# Setup Screen - Downloading Updates



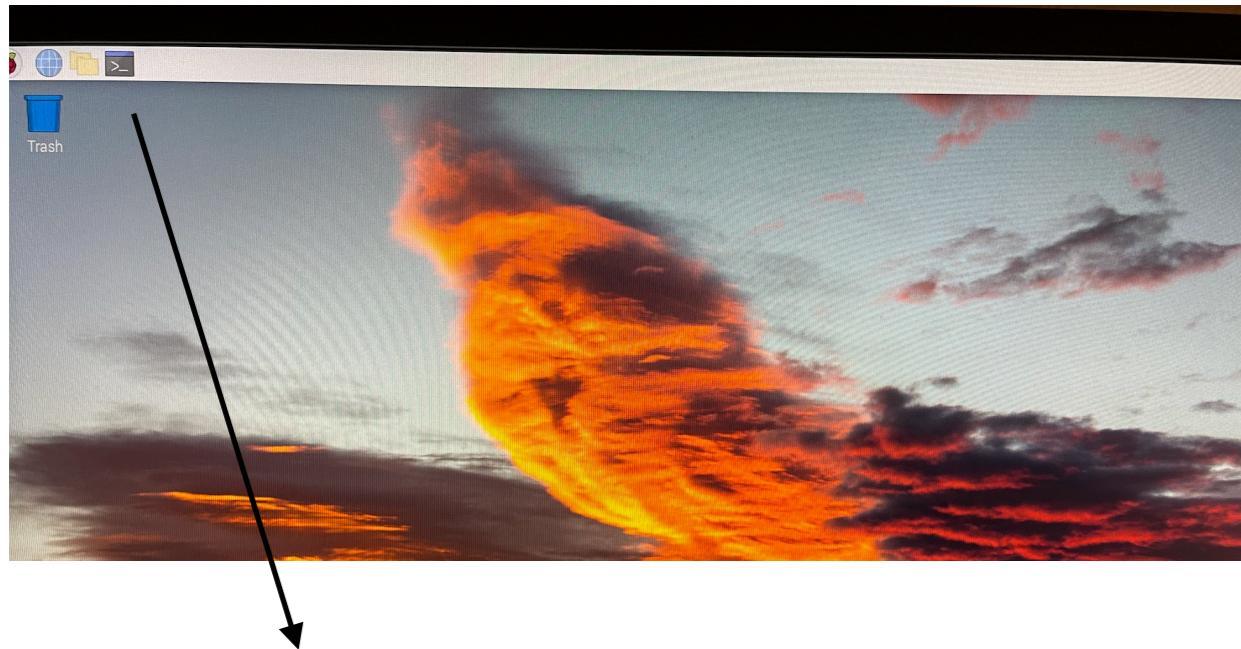
# Setup Screen - System Is Up To Date



# Setup Screen - Ready For Restart



# Desktop



```
nmcentire@raspberrypi: ~
File Edit Tabs Help
nmcentire@raspberrypi:~ $ arch
aarch64
nmcentire@raspberrypi:~ $ uname -a
Linux raspberrypi 6.1.19-v8+ #1637 SMP PREEMPT Tue Mar 14 11:11:47 GMT 2023 aarc
h64 GNU/Linux
nmcentire@raspberrypi:~ $ |
```

# Finding your RPI IP address (for remote ssh)

```
nmcentire@raspberrypi:~ $ hostname -I  
192.168.1.177 2600:1700:6cf8:1120::11 2600:1700:6cf8:1120:dff9:a001:acf1:e3b6  
nmcentire@raspberrypi:~ $ █
```

# Ping your remote RPi

```
[nmcentire@nmcentire-Galago-Pro:~$ ping -c3 192.168.1.177
PING 192.168.1.177 (192.168.1.177) 56(84) bytes of data.
64 bytes from 192.168.1.177: icmp_seq=1 ttl=64 time=100 ms
64 bytes from 192.168.1.177: icmp_seq=2 ttl=64 time=3.02 ms
64 bytes from 192.168.1.177: icmp_seq=3 ttl=64 time=142 ms
```

# Try to ssh into RPI

```
[nmcentire@nmcentire-Galago-Pro:~$ ssh nmcentire@192.168.1.177  
ssh: connect to host 192.168.1.177 port 22: Connection refused
```

Default has sshd (Secure Shell Daemon)  
not installed

# To install sshd on RPI

```
sudo apt install openssh-server
```

```
sudo systemctl enable ssh
```

```
sudo systemctl start ssh
```

# Logging onto RPi remotely via ssh

```
[nmcentire@nmcentire-Galago-Pro:~$ ssh nmcentire@192.168.1.177
The authenticity of host '192.168.1.177 (192.168.1.177)' can't be established.
ECDSA key fingerprint is SHA256:LkPSMjbzuiR5WImRor0jt6W7N5nFploB+lT0TyIpZ98.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '192.168.1.177' (ECDSA) to the list of known hosts.
[nmcentire@192.168.1.177's password:
Linux raspberrypi 6.1.19-v8+ #1637 SMP PREEMPT Tue Mar 14 11:11:47 GMT 2023 aarch64

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: Sun Mar 26 19:30:39 2023
[nmcentire@raspberrypi:~ $ ]
```

# Summary

- At this point your RPi is ready to explore how it can be used for Embedded Linux Development
  - As a development system
  - As a deployment system

# Questions?