

Internet of Things Programming

Anas Dawod

adawod@swin.edu.au

Swinburne University of Technology

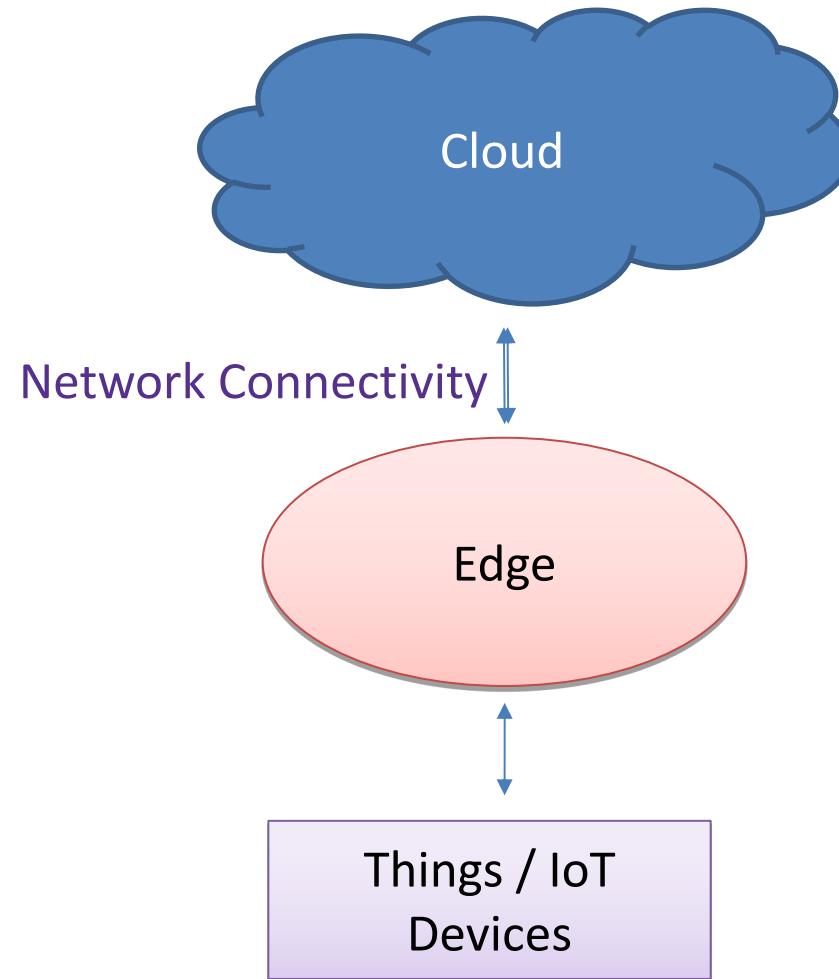
March 2023



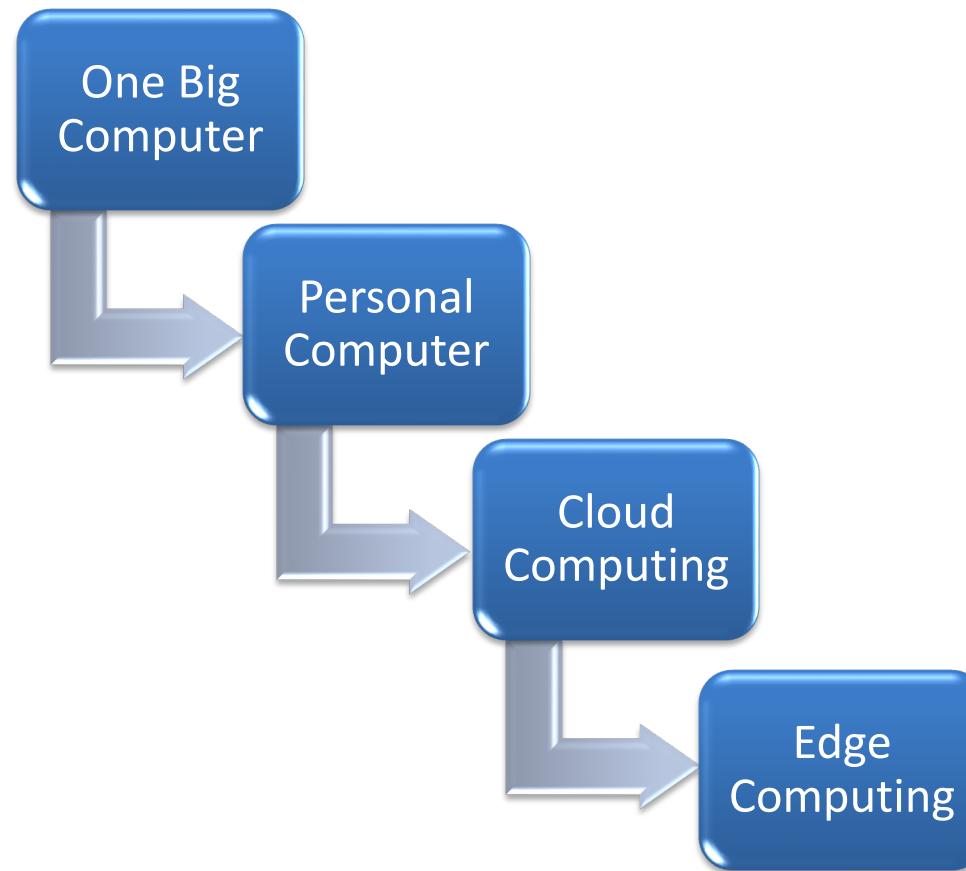
Before we start

- Check-in survey
- Week 3 Tutorials and quiz
- Discussion Board
- Assignment 1 – Questions???

Edge Computing



Edge Computing



Edge Computing

Edge Devices

- An edge device is a device that controls data flow at the interface between two networks.
 - In this case – Between the IoT device and cloud.
- Functions:
 - Network entry/exit points
 - Transmit, route, process, filter, monitor etc.
- Types:
 - Routers, switches, servers, firewalls,
 - LAN/WAN based network devices etc.



Edge Computing

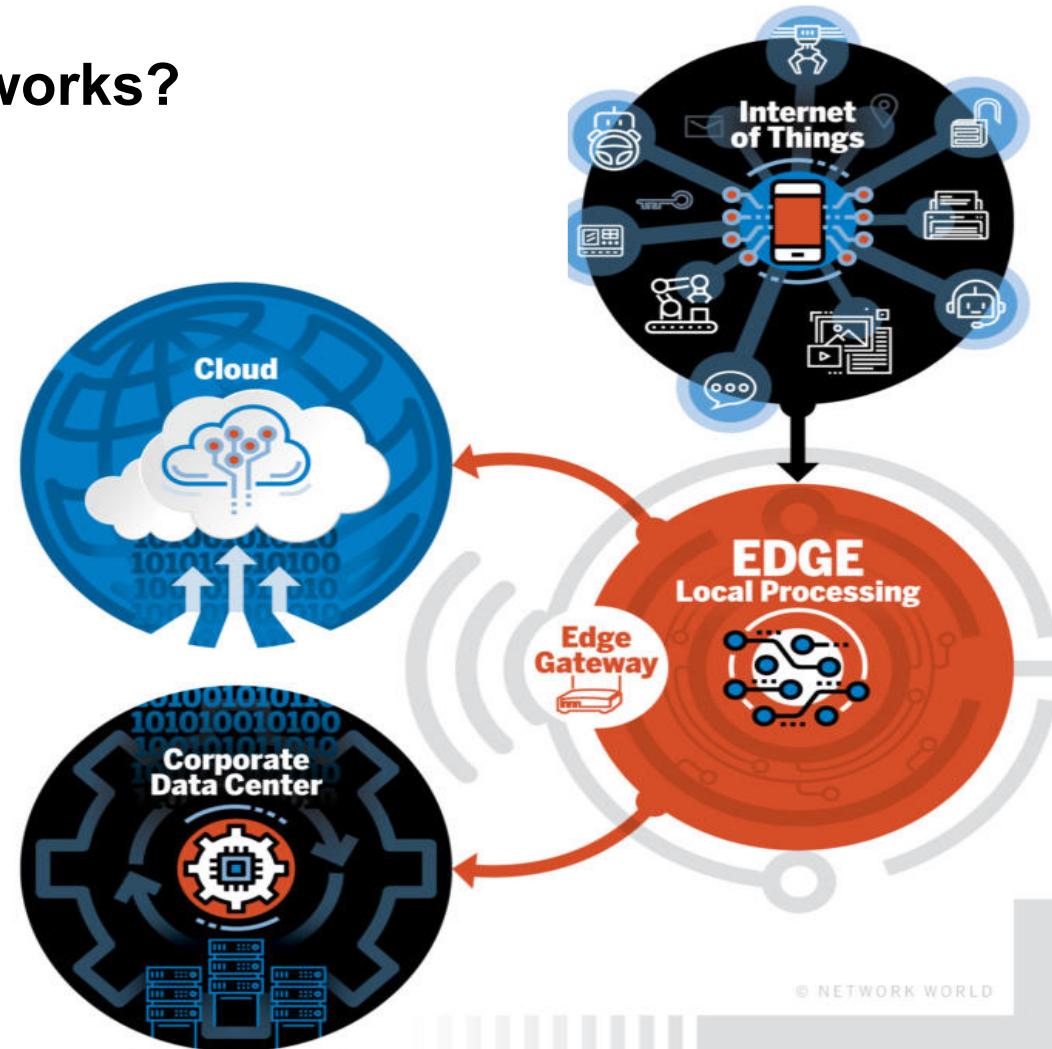
- Edge computing is a distributed computing paradigm
- Brings computing, processing, and storage closer to the source of data = “Edge”
- In other words – It’s the computing that happens at edge device level.



Edge Computing

How Edge Computing works?

- Collect
- Analyse
- Transmit



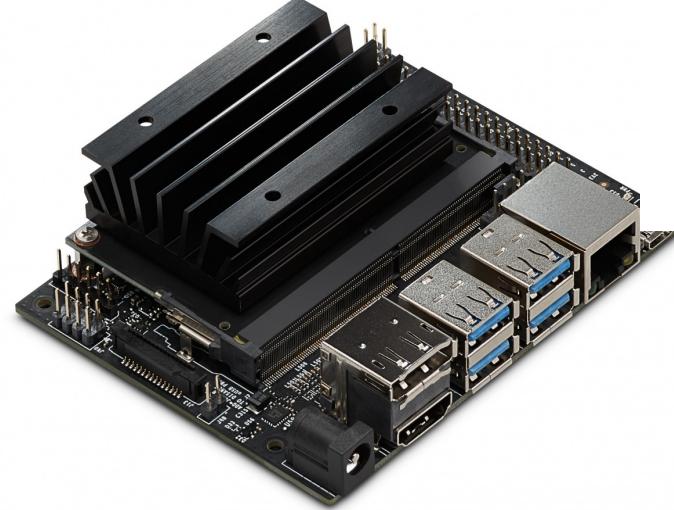
<https://www.networkworld.com/article/3224893/what-is-edge-computing-and-how-it-s-changing-the-network.html>

Edge Computing

Some different edge devices



Raspberry Pi



NVIDIA Jetson NANO



NVIDIA Jetson Xavier

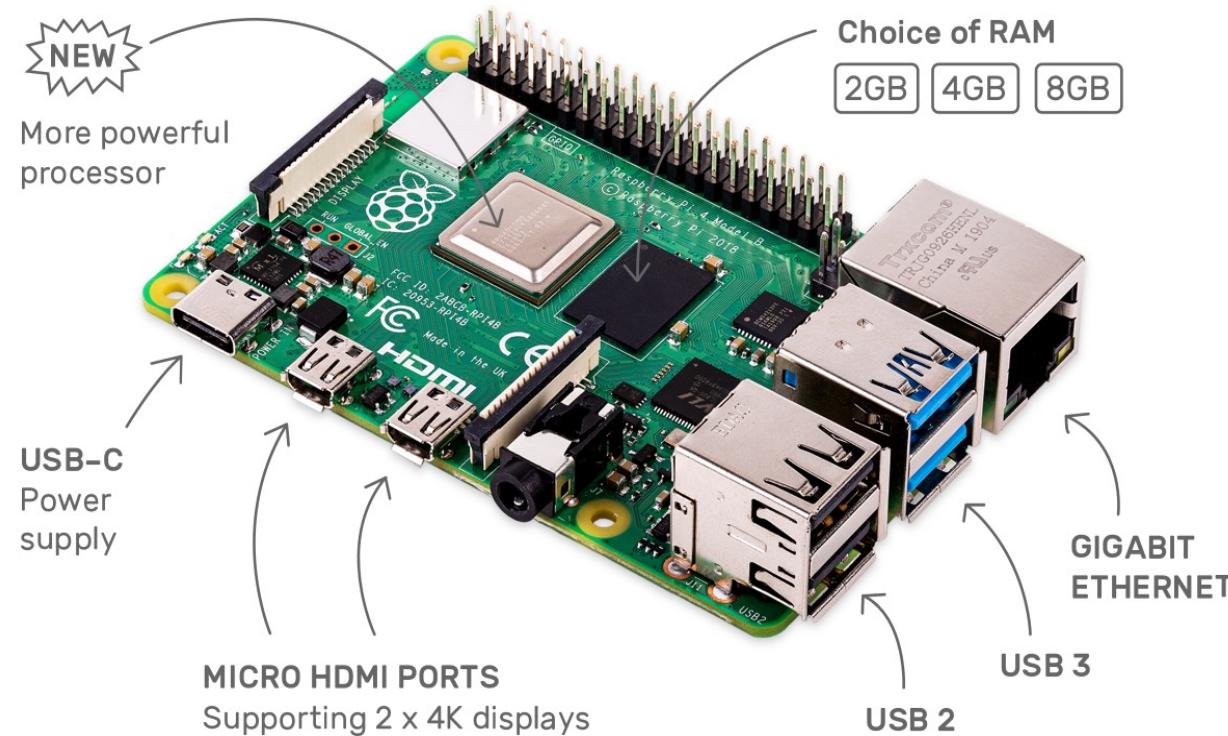
Edge Computing

Raspberry Pi

- The Raspberry Pi is a series of small single-board computers
- More than 5 million Raspberry PIs were sold by February 2015, making it the best-selling British computer. (theguardian.com)
- It has built in WiFi and Bluetooth
- The boards were developed by the Raspberry Pi Foundation to encourage basic computer science learning in schools, along with developing countries.

Edge Computing

Raspberry Pi 4



Edge Computing

Raspberry Pi 4 VS Arduino Uno

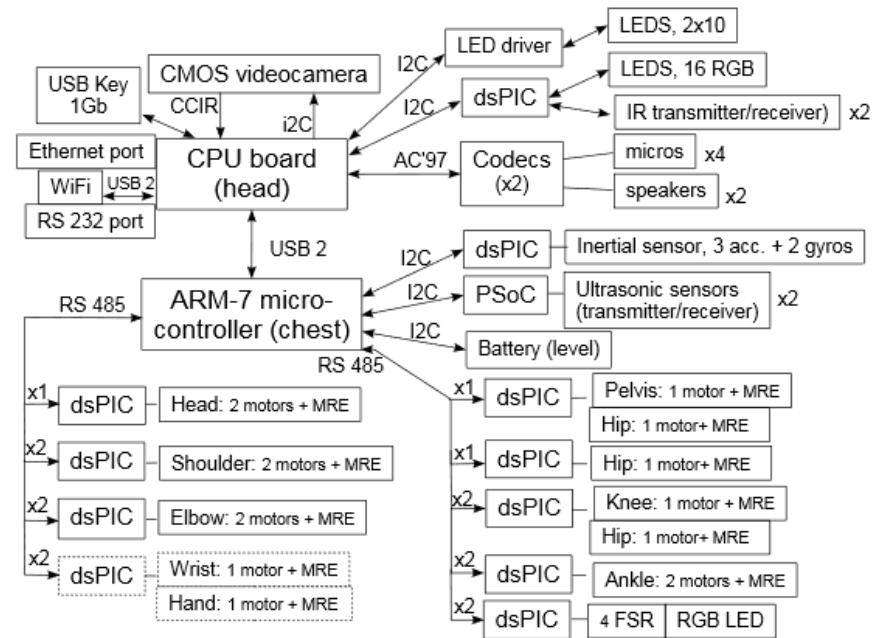
Arduino Uno	Raspberry Pi 4
Microcontroller	Microcomputer
No Operating System	Can run an Operating System
No multitasking	Multitasking
Cheap	Expensive
Low system resources: -Clock Speed 16MHz -RAM 2KB	More system resources: -Clock Speed 1.5 GHz -RAM 2, 4, or 8 GiB
Good for real-time applications	Not the best for real-time applications
Does not have Network Connectivity	Does not have AD Converter

Edge Computing

Microcontroller vs Microcomputer



Microcomputer running GNU/Linux distribution based on Gentoo
Microcontroller controlling motors and sensors



Edge Computing

Raspberry pi Operation System

- Raspberry Pi OS (previously called Raspbian) is the official operating system
- Raspberry Pi OS is a free operating system based on Debian optimized for the Raspberry Pi hardware.
- Raspbian was created by a small, dedicated team of developers that are fans of the Raspberry Pi

Edge Computing

Alternative Operation Systems

- Ubuntu for IoT
 - <https://ubuntu.com/download/iot>
 - Ubuntu for embedded and Internet-Of-Things devices.
 - Desktop and Server edition
- Ubuntu MATE (Desktop)
 - <https://ubuntu-mate.org/raspberry-pi/>
- OpenSUSE (Desktop)
 - https://en.opensuse.org/HCL:Raspberry_Pi4
- And much more...

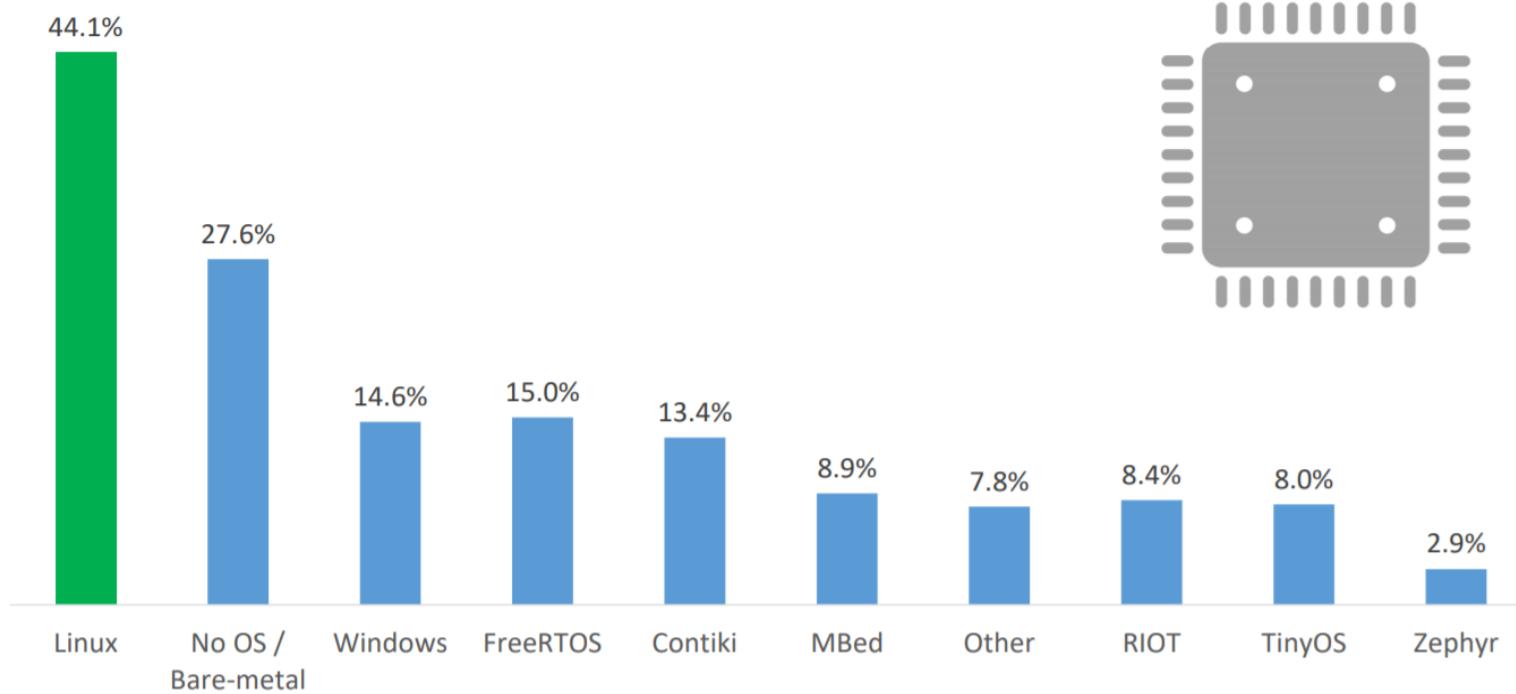
Edge Computing

Operating System

- Embedded Linux
 - Operating systems based on the Linux kernel are used in embedded systems such as consumer electronics
 - Smart TV
 - Routers and Switches
 - Car Audio Entertainment
 - Specific to each device/build
 - No GUI, why?

IoT OPERATING SYSTEMS – CONSTRAINED DEVICES

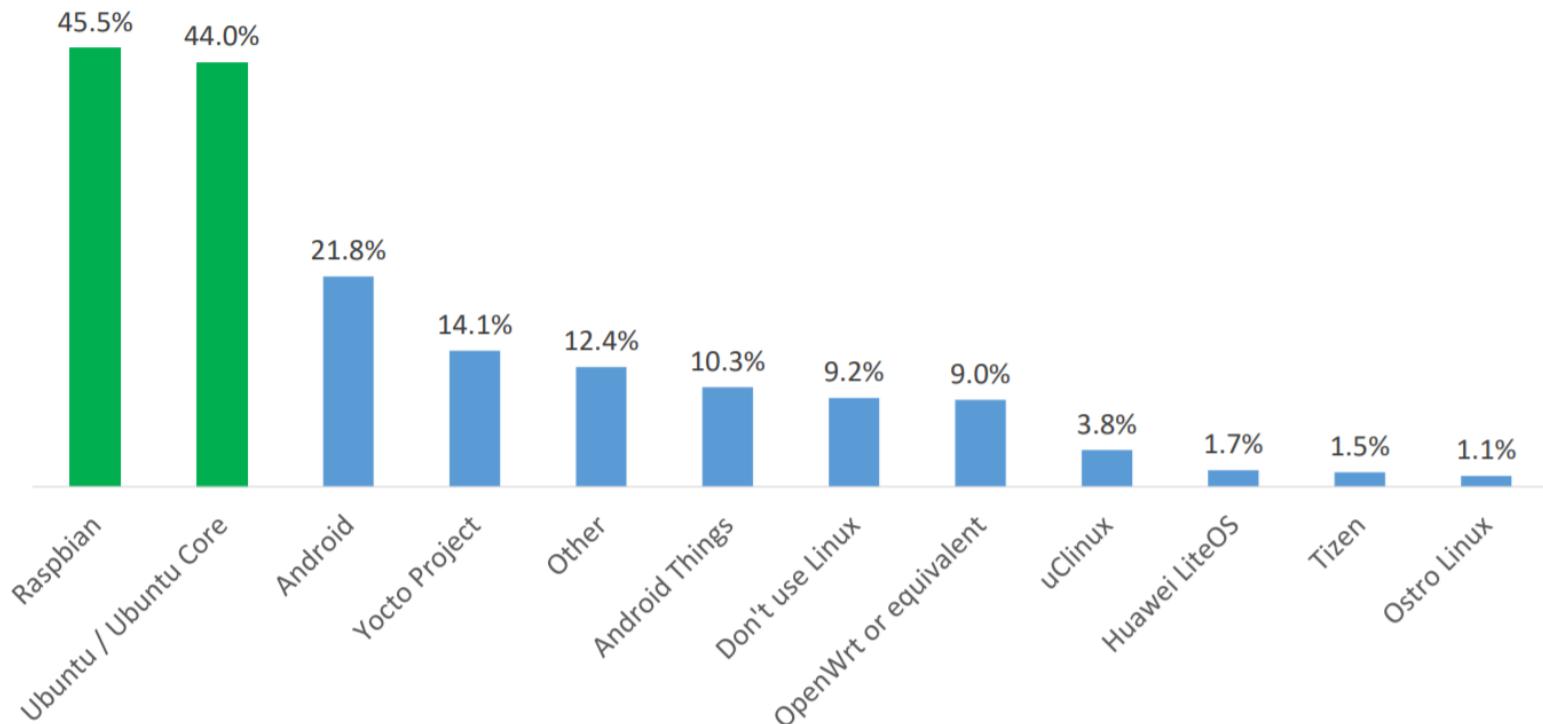
Which operating system(s) do you use for your IoT devices? (Devices)



IoT Developer Survey 2017 - Copyright Eclipse Foundation

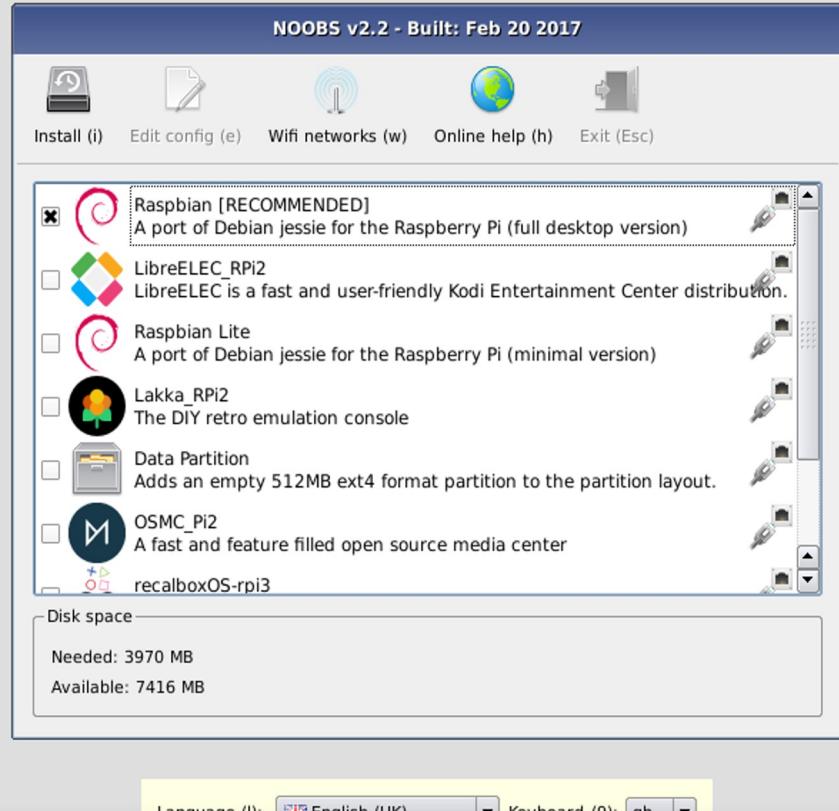
IoT OPERATING SYSTEMS / LINUX DISTROS FOR IoT

If you are using Linux, what distribution do you typically use for your IoT solution?

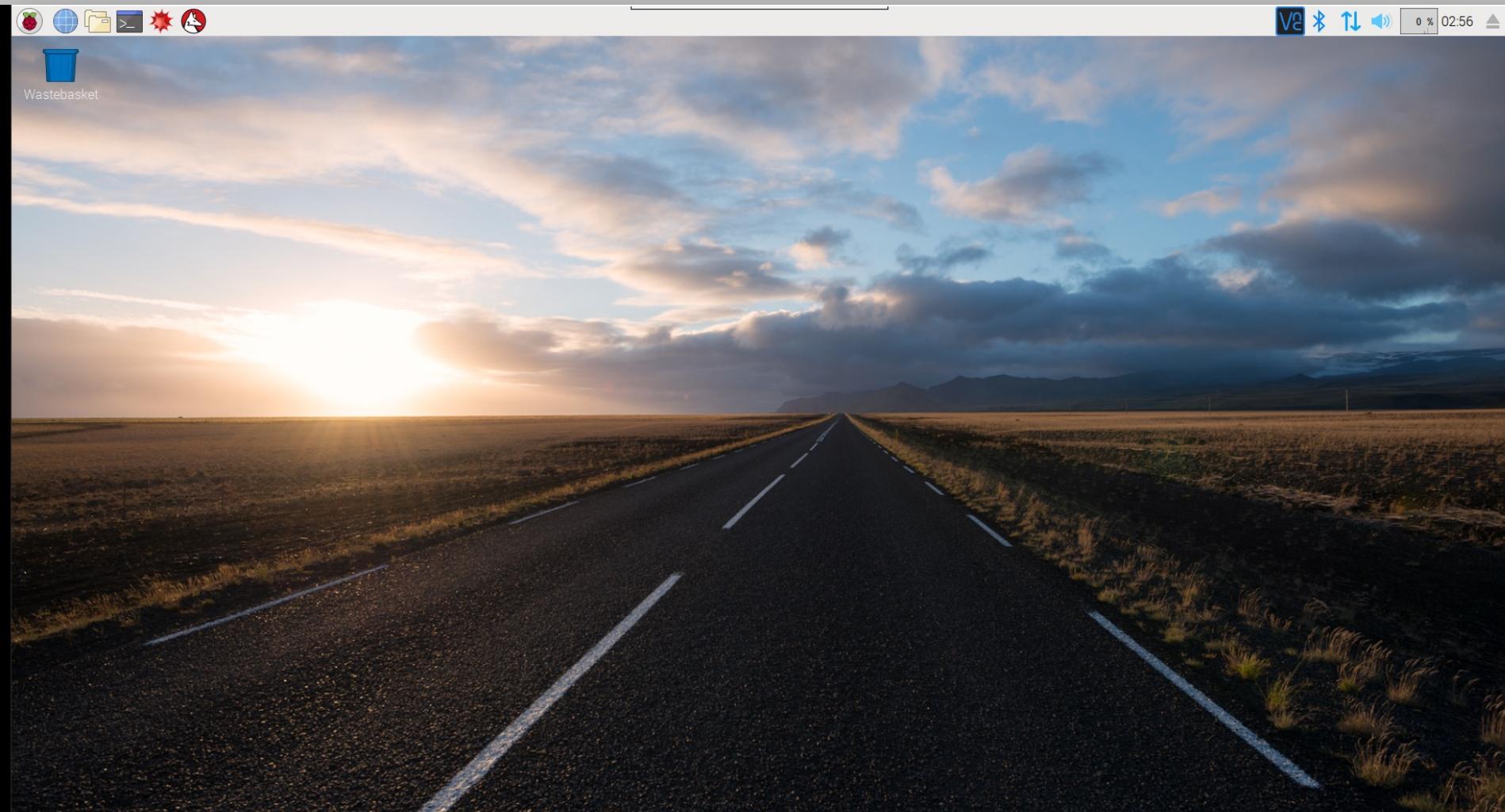


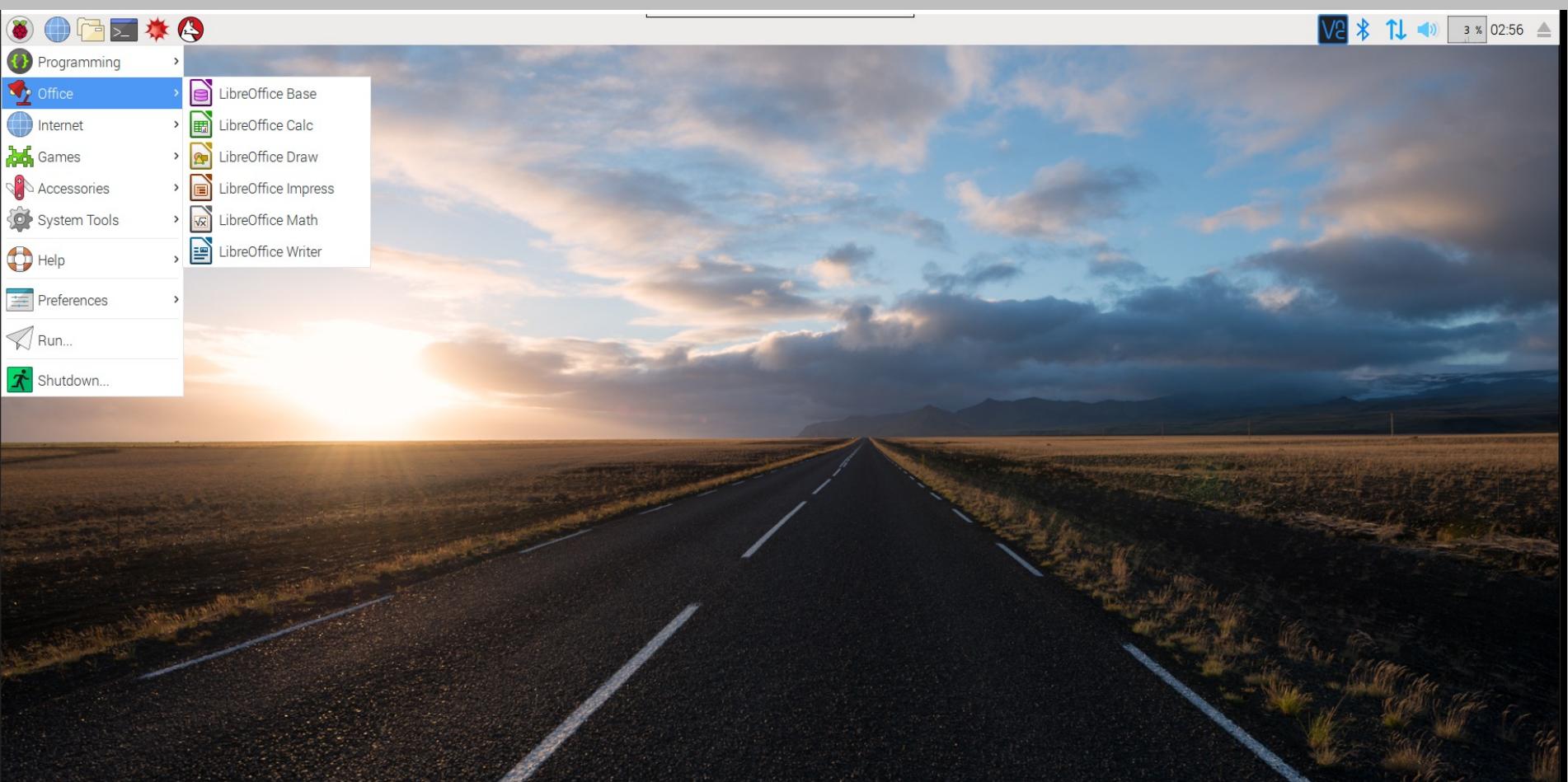
NOOBS

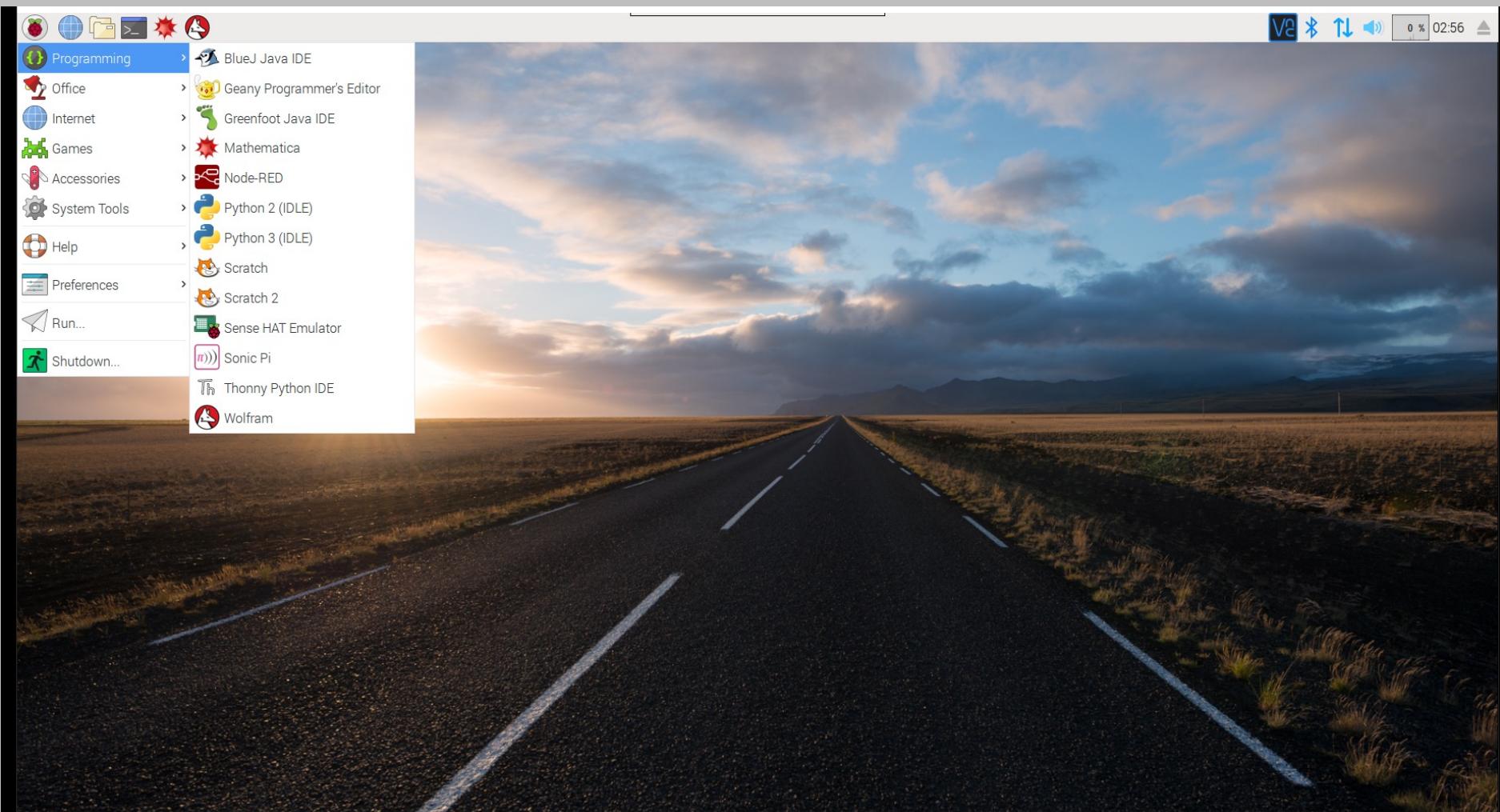
- ▶ New Out Of the Box Software
- ▶ NOOBS is an easy operating system installer which contains Raspbian
- ▶ Format an SD card which is 8GB or larger as FAT

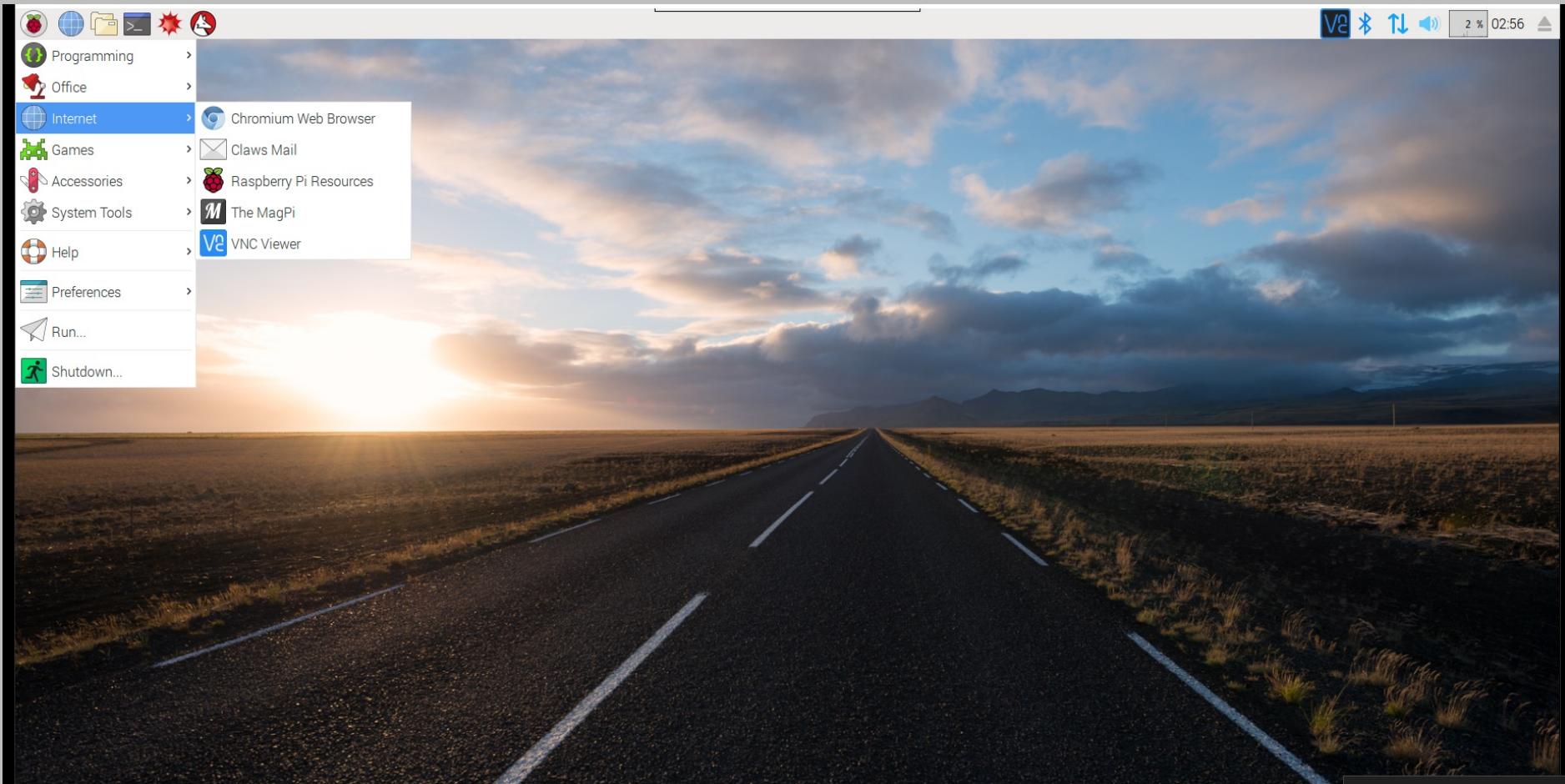


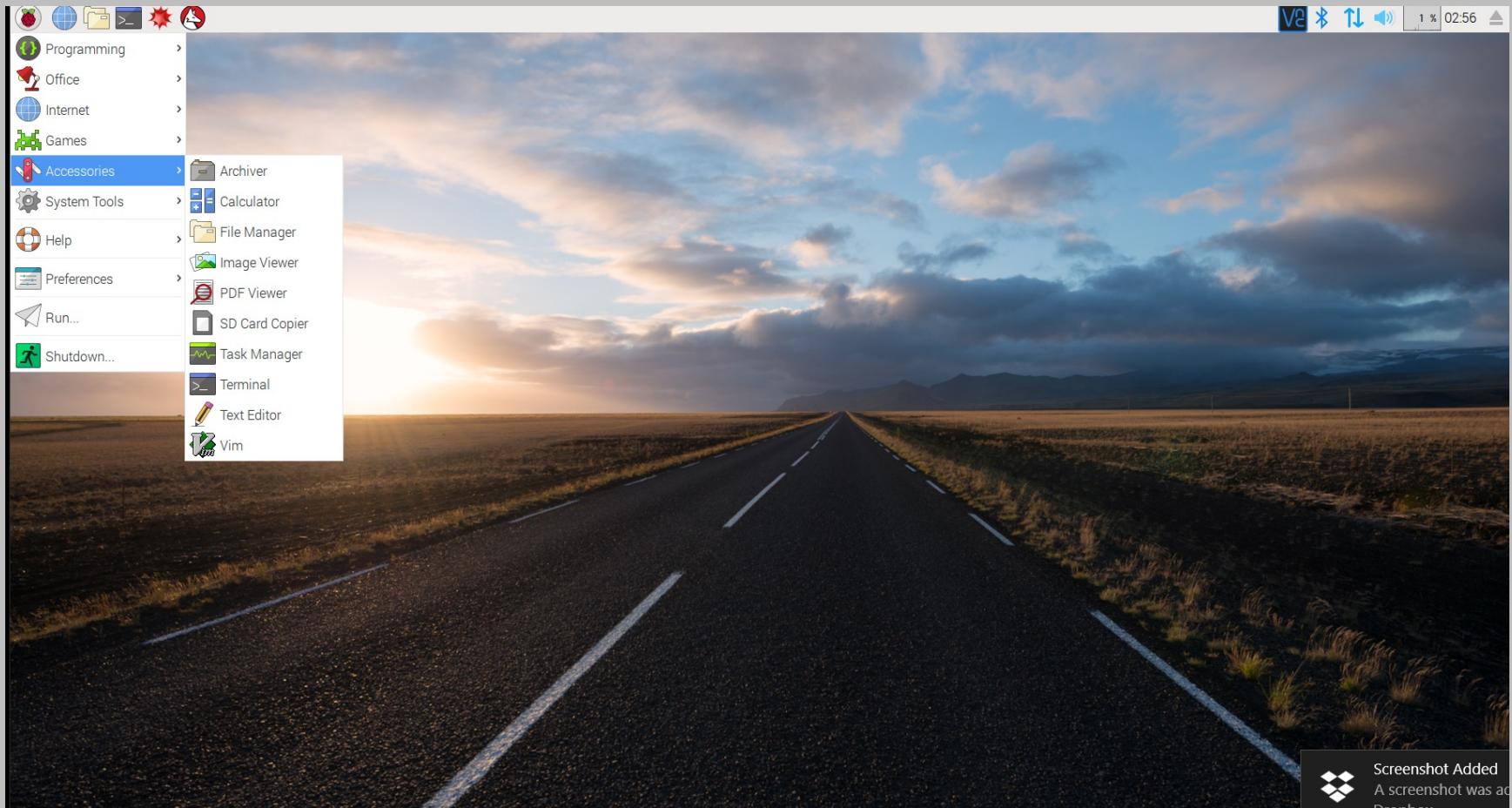
Download NOOBS: raspberrypi.org/downloads

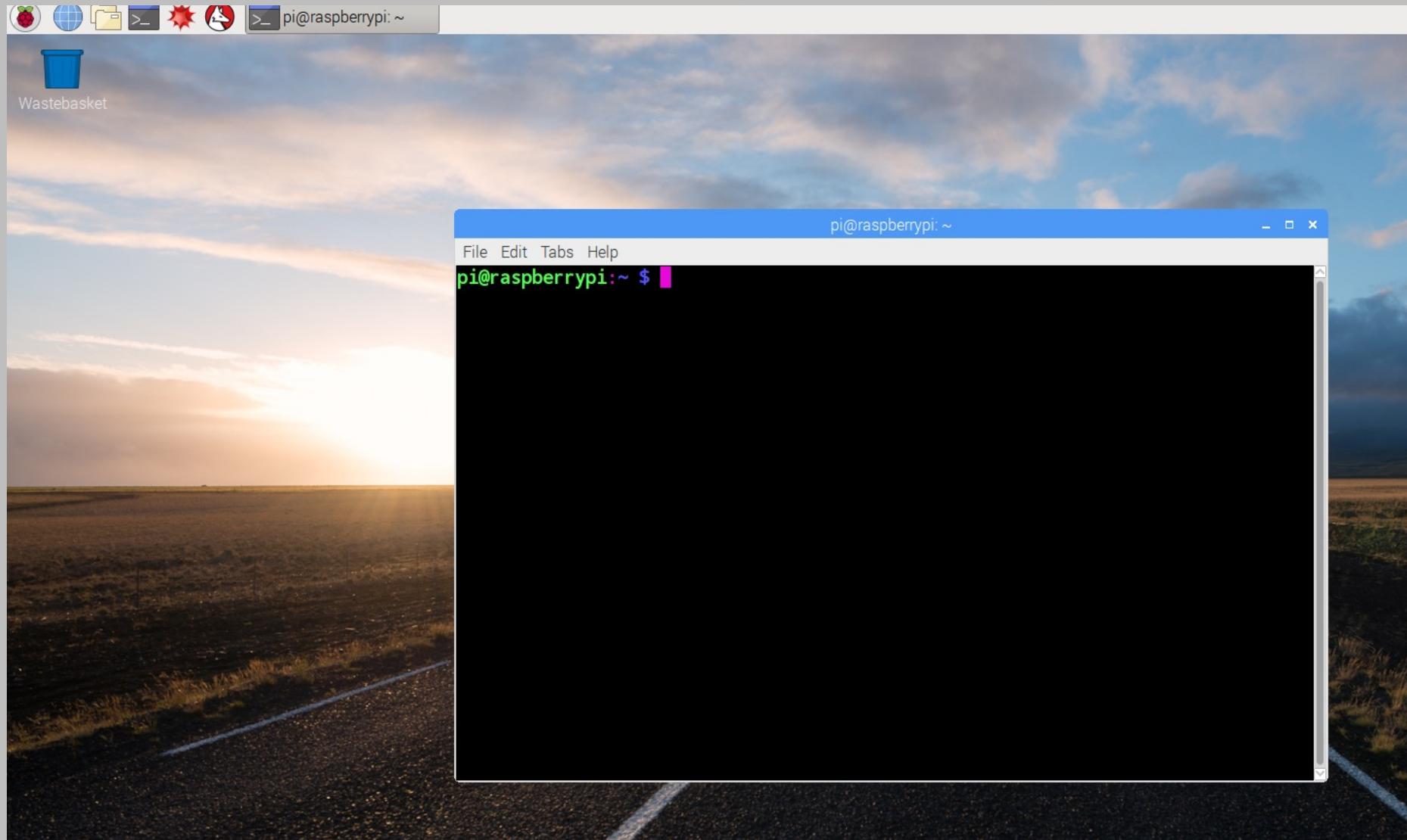












HOW TO INTERACT WITH RASPBERRY PI

Physical Monitor or TV, and Keyboard + Mouse

SSH

VNC

Default Username: pi

Default Password: raspberry

SSH

Secure Shell / An SSH client is a software program which uses the secure shell protocol to connect to a remote computer.

Secure remote login protocol

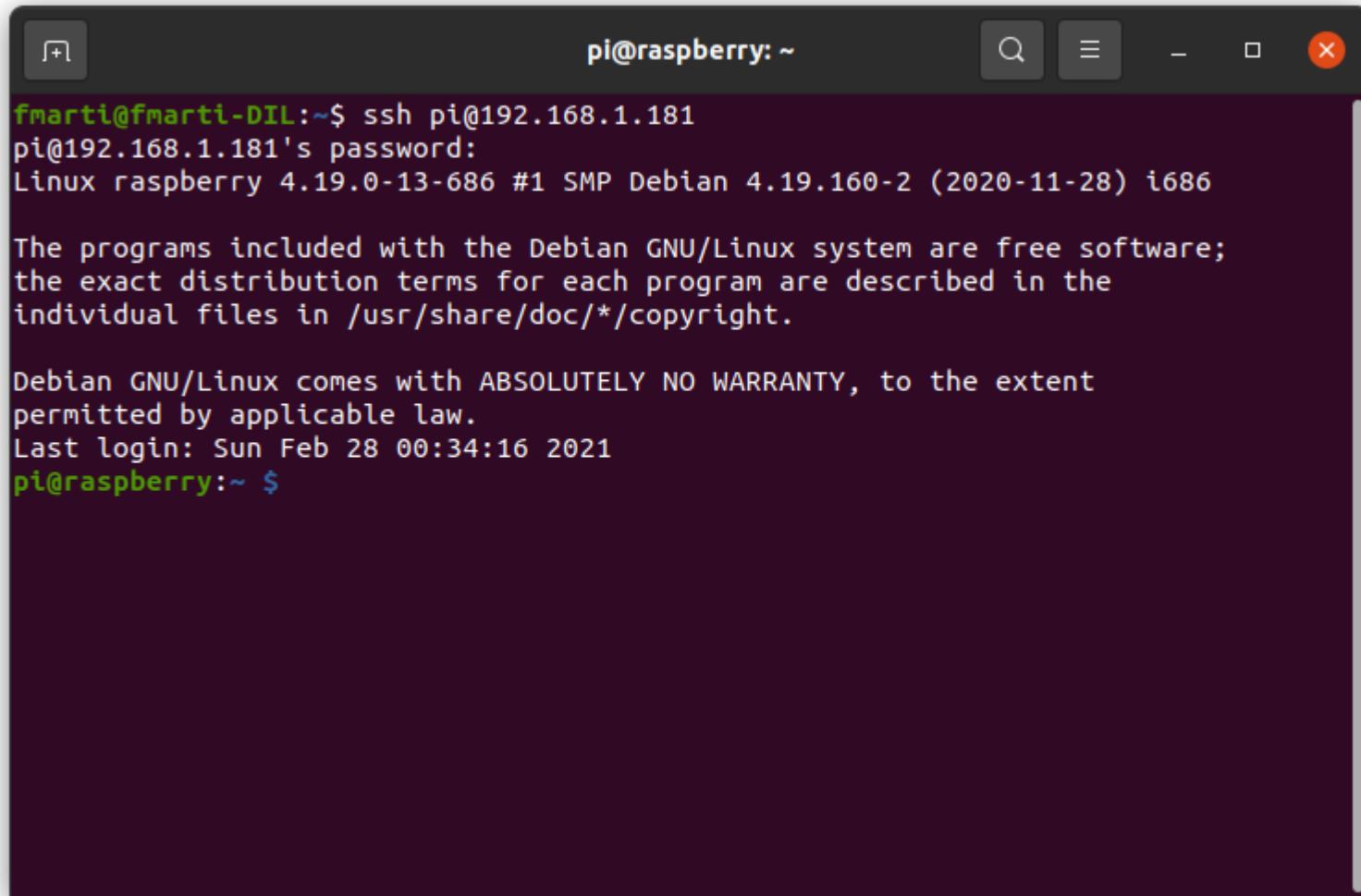
You can run commands on the remote server (or raspberry pi)

SSH USERNAME@IP_ADDRESS

In Windows you can use PuTTY <https://www.putty.org/>

PuTTY is a free and open-source terminal emulator, serial console and network file transfer application for Windows.

SSH in GNU/Linux



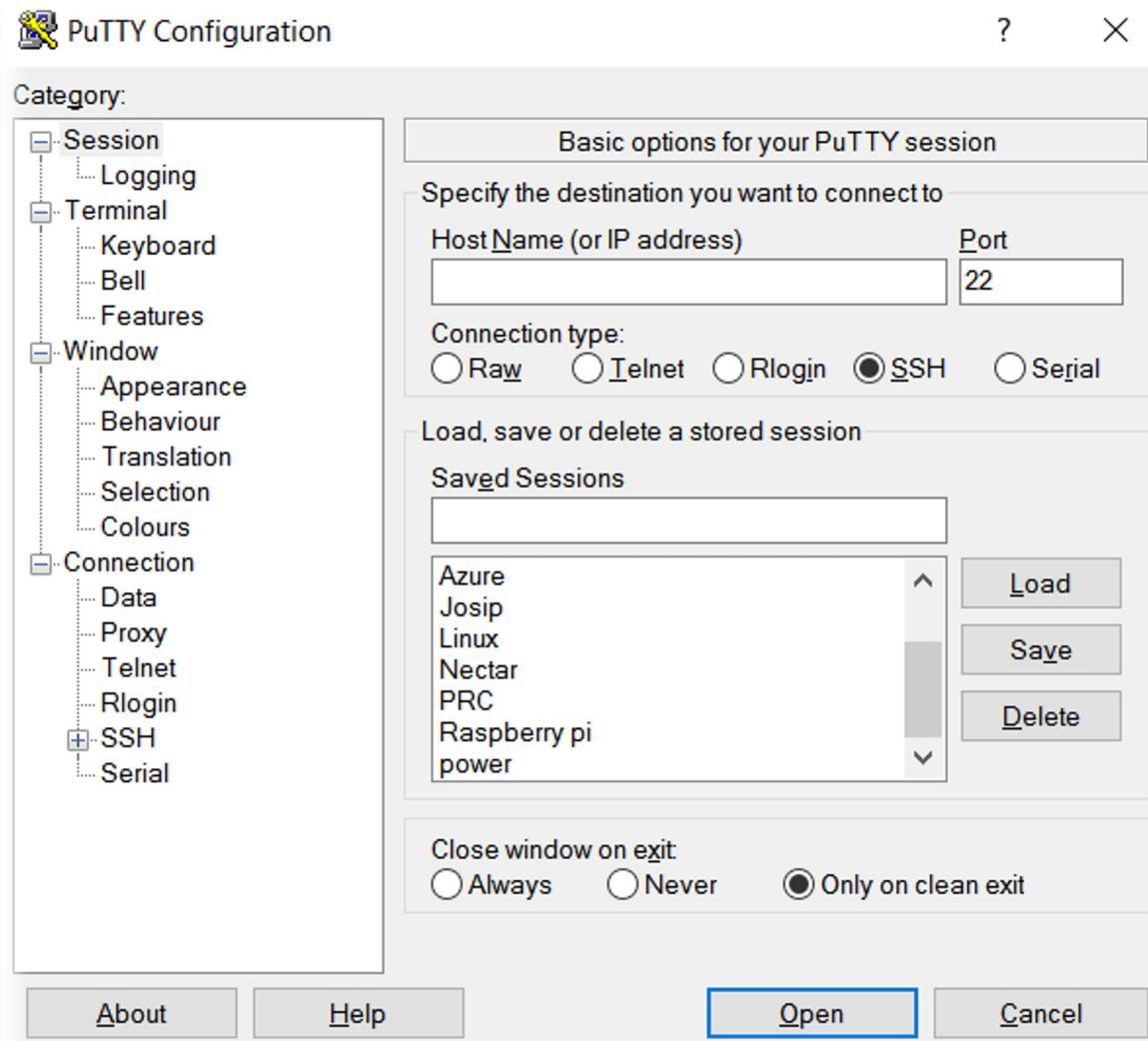
A screenshot of a terminal window titled "pi@raspberry: ~". The window shows an SSH session from a local machine ("fmarti@fmarti-DIL") to a Raspberry Pi ("pi@raspberry"). The session starts with a password prompt, followed by the standard Debian 4.19.0 kernel information. It then displays the standard Debian free software copyright notice. Finally, it shows the standard Debian warranty notice and the last login timestamp. The prompt "pi@raspberry:~ \$" is visible at the end.

```
fmarti@fmarti-DIL:~$ ssh pi@192.168.1.181
pi@192.168.1.181's password:
Linux raspberry 4.19.0-13-686 #1 SMP Debian 4.19.160-2 (2020-11-28) i686

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 Feb 28 00:34:16 2021
pi@raspberry:~ $
```

PuTTY



Rasbian Desktop Edge [Running] - Oracle VM VirtualBox

File Machine View Input Devices Help



pi@raspberry: ~



00:42

eth0: Configured 192.168.1.181/24

Tras

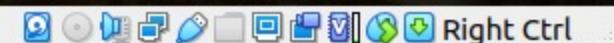
pi@raspberry: ~

File Edit Tabs Help

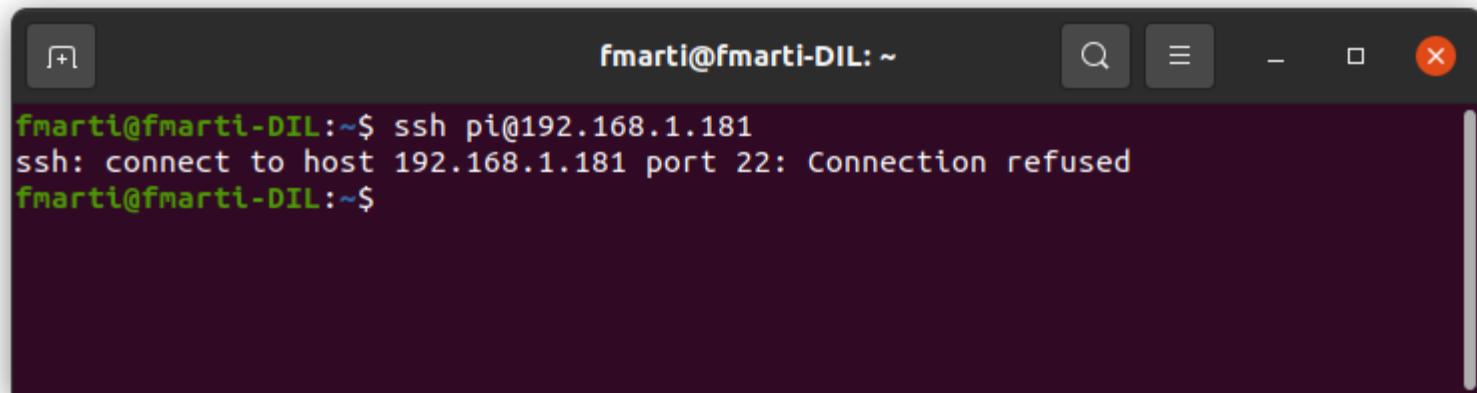
```
pi@raspberry:~ $ ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.1.181  netmask 255.255.255.0  broadcast 192.168.1.255
              inet6 fe80::e6b8:b9ed:db46:98ef  prefixlen 64  scopeid 0x20<link>
                ether 08:00:27:a7:6d:11  txqueuelen 1000  (Ethernet)
                  RX packets 510  bytes 52650 (51.4 KiB)
                  RX errors 0  dropped 0  overruns 0  frame 0
                  TX packets 362  bytes 41425 (40.4 KiB)
                  TX errors 0  dropped 0  overruns 0  carrier 0  collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        inet 127.0.0.1  netmask 255.0.0.0
              inet6 ::1  prefixlen 128  scopeid 0x10<host>
                loop  txqueuelen 1000  (Local Loopback)
                  RX packets 0  bytes 0 (0.0 B)
                  RX errors 0  dropped 0  overruns 0  frame 0
                  TX packets 0  bytes 0 (0.0 B)
                  TX errors 0  dropped 0  overruns 0  carrier 0  collisions 0

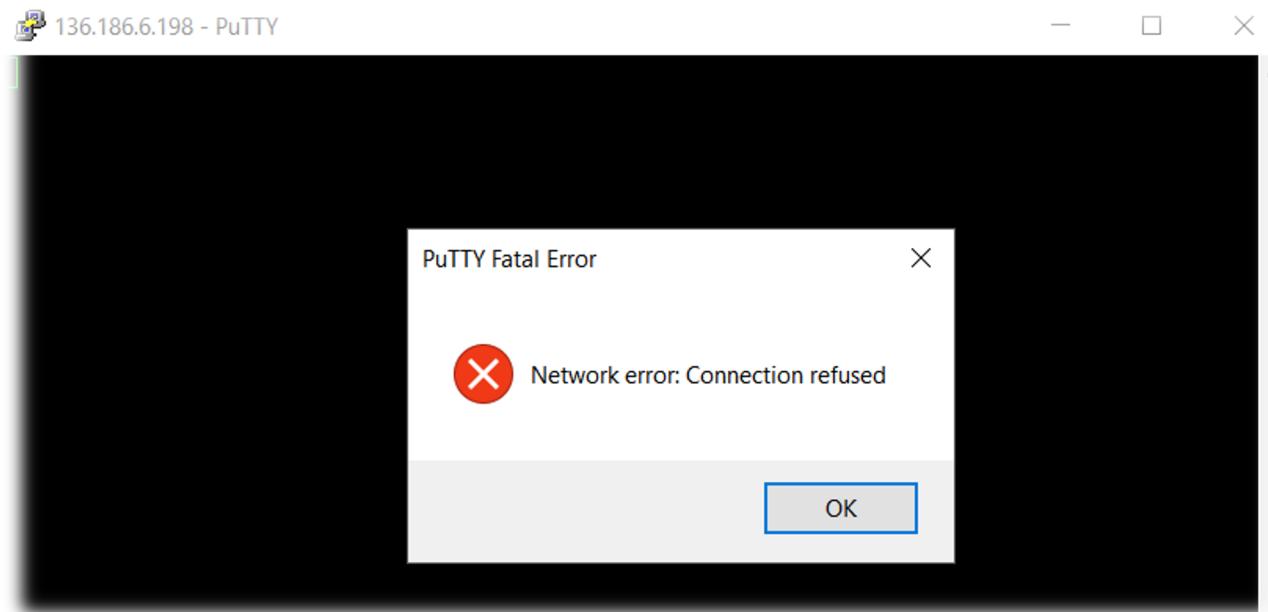
pi@raspberry:~ $
```



SSH Server



```
fmarti@fmarti-DIL:~$ ssh pi@192.168.1.181
ssh: connect to host 192.168.1.181 port 22: Connection refused
fmarti@fmarti-DIL:~$
```



Rasbian Desktop Edge [Running] - Oracle VM VirtualBox



File Machine View Input Devices Help



pi@raspberry: ~



00:45



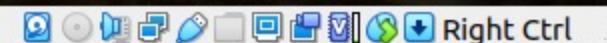
Tras

pi@raspberry: ~



File Edit Tabs Help

```
pi@raspberry:~ $ sudo systemctl enable ssh.service
Synchronizing state of ssh.service with SysV service script with /lib/systemd/systemd-sysv-install.
Executing: /lib/systemd/systemd-sysv-install enable ssh
pi@raspberry:~ $ sudo systemctl start ssh.service
pi@raspberry:~ $
```



```
fmarti@fmarti-DIL:~$ ssh pi@192.168.1.181
pi@192.168.1.181's password:
Linux raspberry 4.19.0-13-686 #1 SMP Debian 4.19.160-2 (2020-11-28) i686

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 Feb 28 00:34:16 2021
pi@raspberry:~ $
```

```
pi@raspberrypi: ~
login as: pi
pi@136.186.6.198's password:

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: Wed Aug 16 07:18:12 2017

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.

pi@raspberrypi:~ $
```

SENSE HAT

Fundamental part of the Astro Pi



SENSE HAT

The Sense HAT is an add-on board for Raspberry Pi, made especially for the Astro Pi mission

Astro Pi is a European Space Agency (ESA) Education project run in collaboration with the Raspberry Pi Foundation.

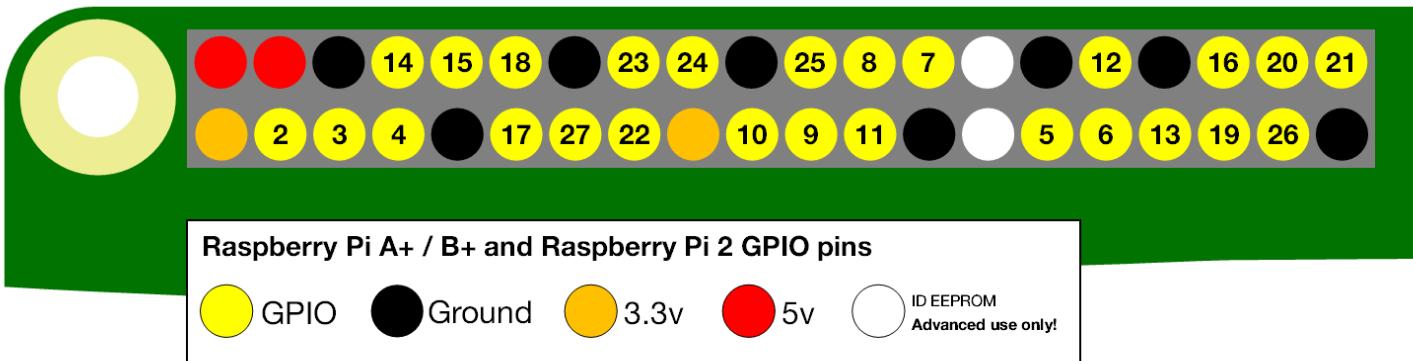
It is now available on the Internet to buy.

The Sense HAT has an 8×8 RGB LED matrix, a five-button joystick and includes the following sensors:

- Gyroscope
- Accelerometer
- Magnetometer
- Temperature
- Barometric pressure
- Humidity

- sudo apt-get update
- sudo apt-get install sense-hat
- sudo reboot

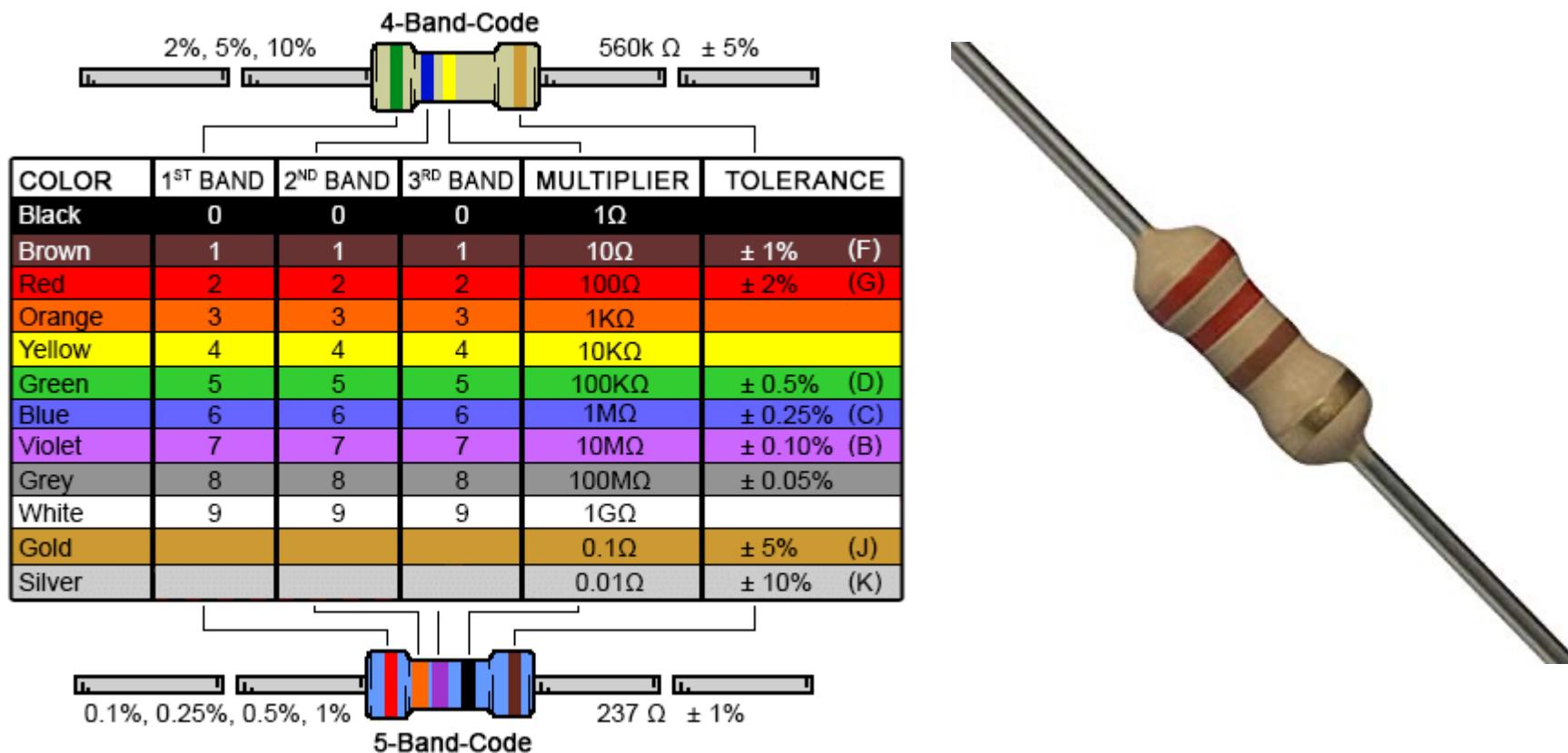
GENERAL-PURPOSE INPUT/OUTPUT (GPIO)



OHM LAW

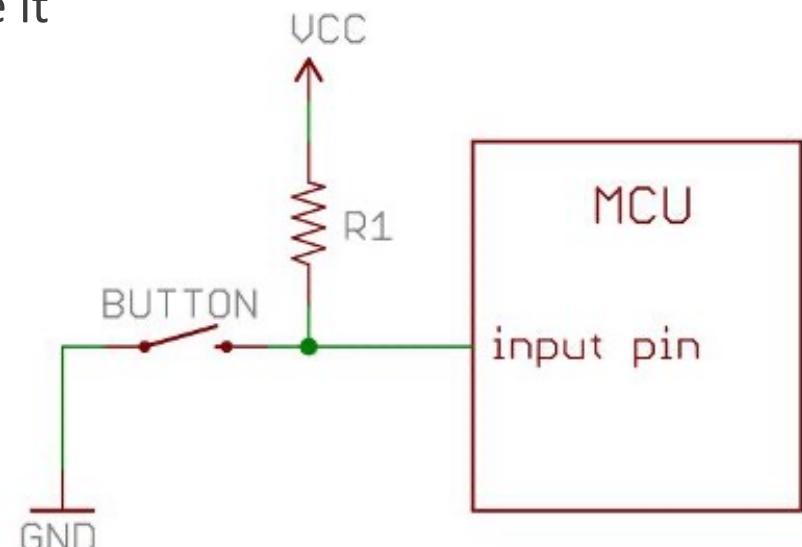
- $R=V/I$
- LED requires 5~20mA
- $R = V / I, \quad R = 3.3V / (5\text{~}20\text{mA}) = 3.3V / (0.005A \text{~} 0.020A) = 165\Omega \text{~} 660\Omega$
- That is why we use 220ohm resistor

RESISTORS



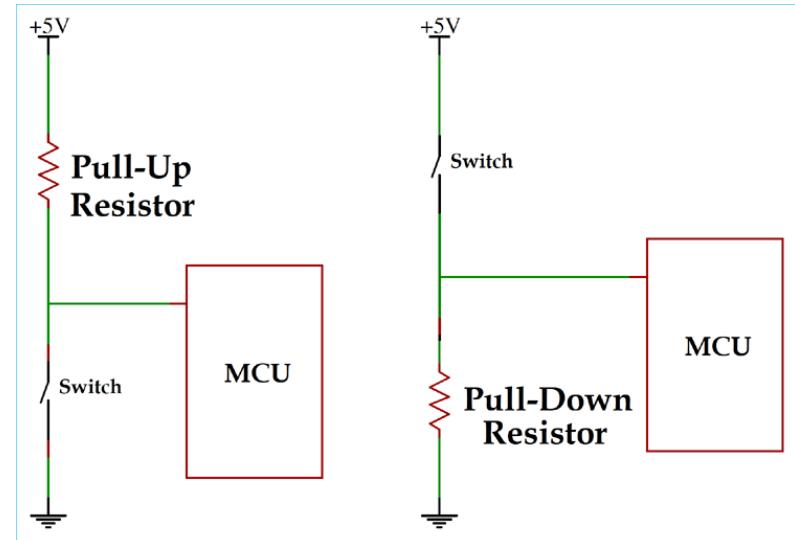
PULL-UP RESISTOR

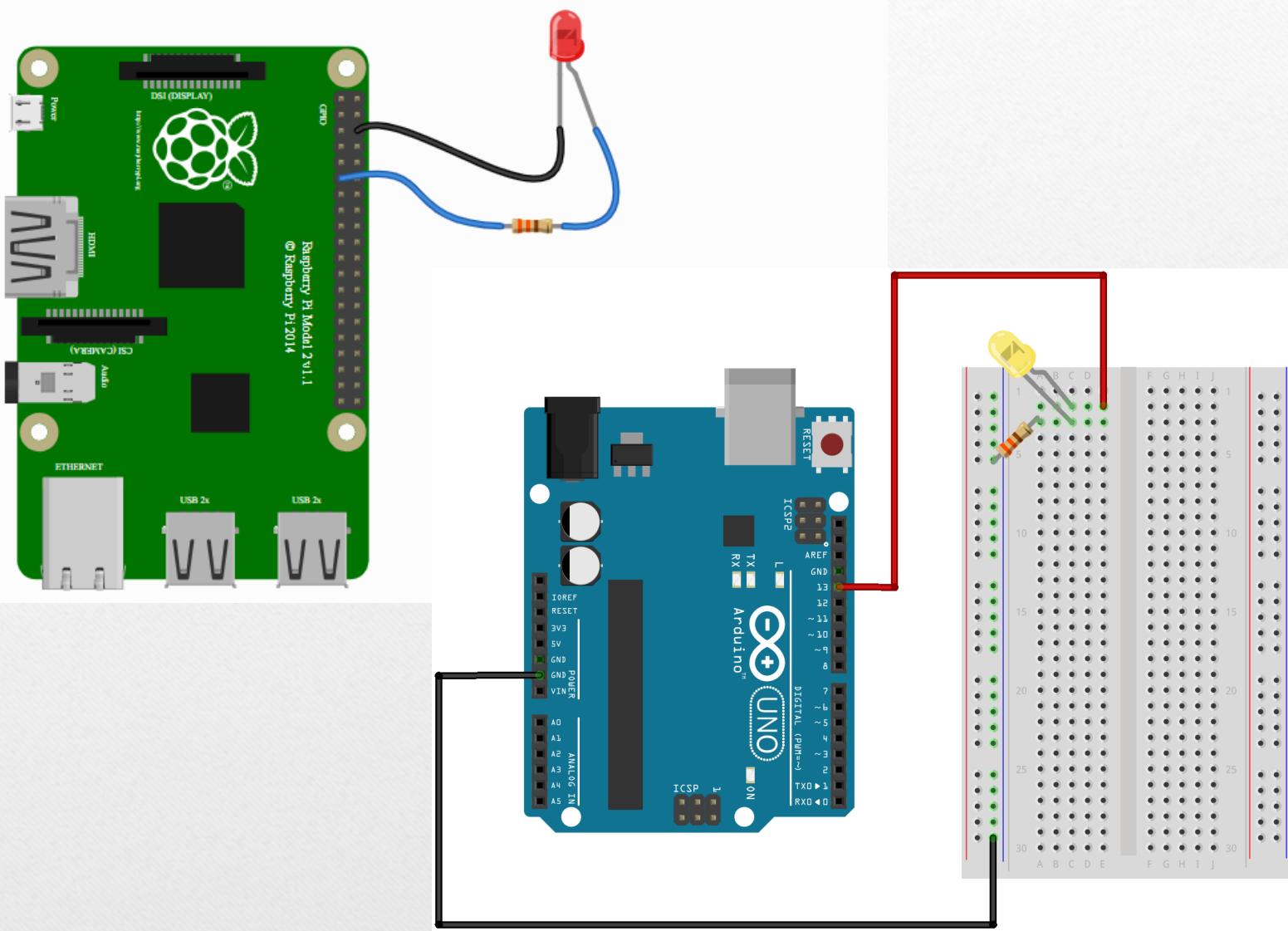
- Input pin connected to nothing is HIGH or LOW?
- Pull-up resistor connects input to HIGH
- Microcontrollers might have internal pull-up/down resistors
- We can use the following to activate it
- `pinMode(pin, INPUT_PULLUP)`



PULL-DOWN RESISTOR

- Similar to pull-up resistors
- Pull-down resistor connects input to LOW
- You can wire your own





fritzing

LED Blink

Arduino

```
void setup() {  
    pinMode(LED_BUILTIN, OUTPUT);  
}  
  
void loop() {  
    digitalWrite(LED_BUILTIN, HIGH);  
    delay(1000);  
  
    digitalWrite(LED_BUILTIN, LOW);  
    delay(1000);  
}
```

Raspberry Pi

```
from gpiozero import LED  
from time import sleep  
  
led = LED(17)  
  
while True:  
    led.on()  
    sleep(1)  
    led.off()  
    sleep(1)
```

GPIO Zero

- A simple interface to GPIO devices with Raspberry Pi in Python
- GPIO Zero is installed by default in the Raspbian image
- Comprehensive documentation is available at
<https://gpiozero.readthedocs.io>



Sensors



GPIO Zero - Button

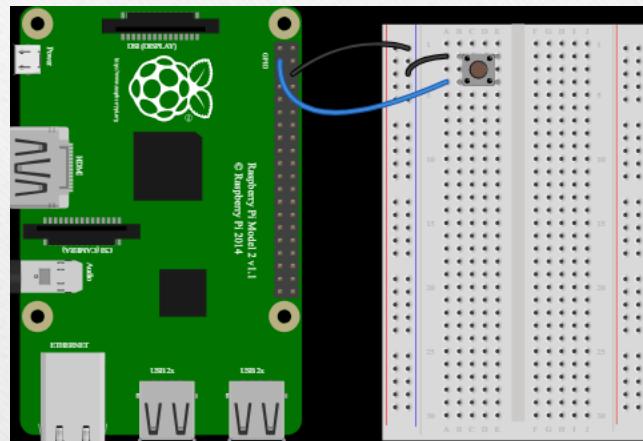
```
from gpiozero import Button
```

```
button = Button(2)
```

```
while True:
```

```
    if button.is_pressed:
```

```
        print("IoT Programming is fun!")
```



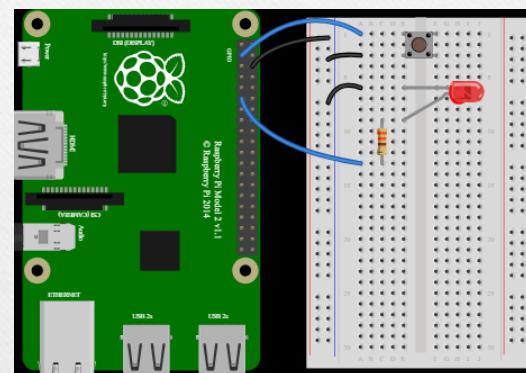
<https://gpiozero.readthedocs.io>

GPIO Zero - Button and LED

```
from gpiozero import LED, Button  
from signal import pause
```

```
led = LED(17)  
button = Button(2)
```

```
button.when_pressed = led.on  
button.when_released = led.off
```



<https://gpiozero.readthedocs.io>

GPIO Zero - Button and LED

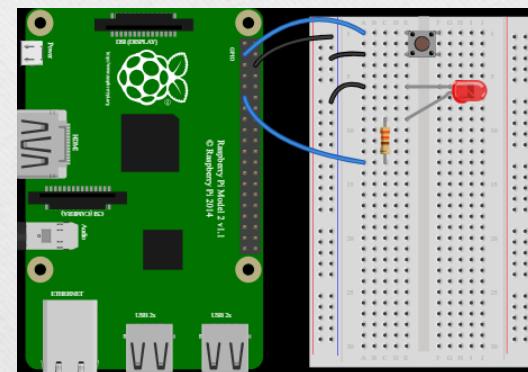
```
from gpiozero import LED, Button
```

```
from signal import pause
```

```
led = LED(17)
```

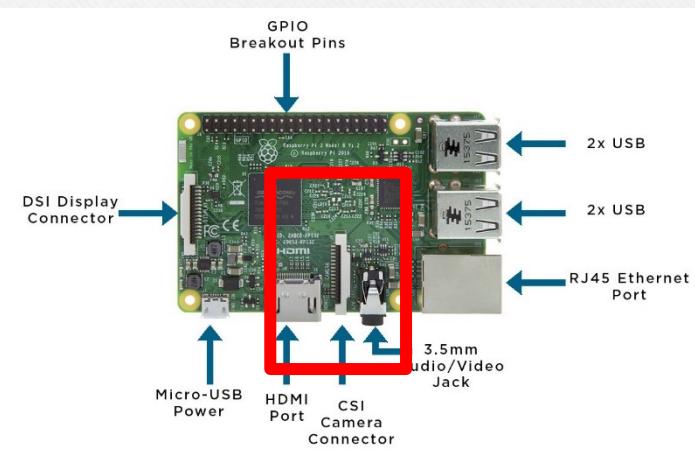
```
button = Button(2)
```

```
led.source = button
```



<https://gpiozero.readthedocs.io>

Camera Connector



RPi Camera (Python):

Capture picture when pressing push button

```
from gpiozero import Button  
from picamera import PiCamera  
from datetime import datetime  
  
button = Button(2)  
camera = PiCamera()  
def capture():  
    timestamp = datetime.now().isoformat()  
    camera.capture('/home/pi/%s.jpg' % timestamp)  
button.when_pressed = capture
```

RPi Camera (BASH):

Record 10s video every minute and upload it to OneDrive

- 1) Install rclone or a similar program to upload files to the cloud via command line

<https://rclone.org/>

<https://github.com/rclone/rclone>



- 2) Write a script to record 10s video
- 3) Upload file to cloud with rclone
- 4) Schedule a time-based job with cron (aka crontab)

<https://man7.org/linux/man-pages/man5/crontab.5.html>

<https://crontab.guru/>

RPi Camera (BASH):

Record 10s video every minute and upload it to OneDrive

- 1) Install rclone or a similar program to upload files to the cloud via command line



- 2) It is better to not install rclone from the repository (it is an old version). Install it from the binary (official website) or from the source code (github)

<https://rclone.org/downloads/>

<https://github.com/rclone/rclone>

Configure your Swinburne OneDrive following the configuration steps

<https://rclone.org/onedrive/>

Alternatives:

<https://rclone.org/#providers>

RPi Camera (BASH):

Record 10s video every minute and upload it to OneDrive

2 and 3) Script (BASH) to capture 10s video and upload to OneDrive

```
1 #! /bin/bash
2
3 ## Parameters
4 HOSTNAME=$(hostname)
5 DIR_OUTPUT=/home/pi/Videos/
6 FILENAME=$(date "+%Y-%m-%d_%H%M")_video.h264
7 TIME_RECORDING=10000
8 CAMERA_ROTATION=180
9
10 ## Code
11 raspivid -o $DIR_OUTPUT$FILENAME -t $TIME_RECORDING -rot $CAMERA_ROTATION
12 rclone copy $DIR_OUTPUT$FILENAME Felips_OneDrive:CoB_Boroondara/Video/$HOSTNAME/
```

RPi Camera (BASH):

Record 10s video every minute and upload it to OneDrive

4) Schedule the job to be executed every minute with crontab:

crontab -e

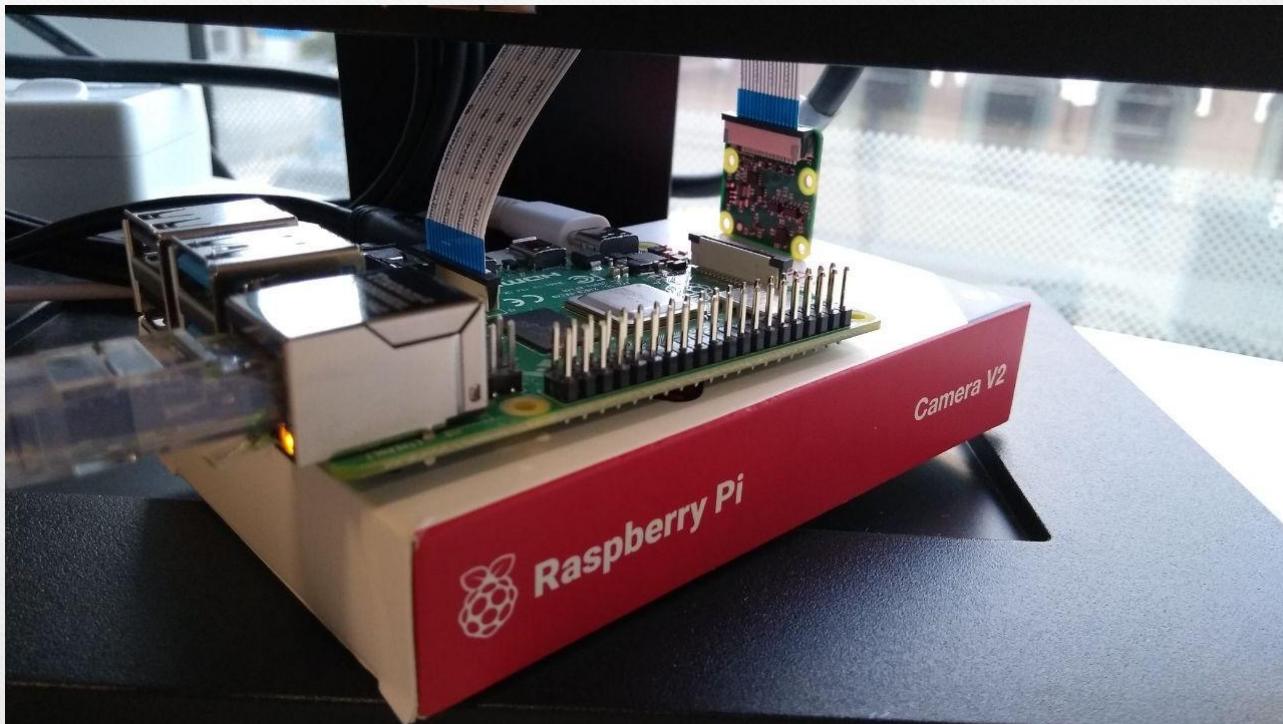
<https://crontab.guru/>

```
# Edit this file to introduce tasks to be run by cron.  
#  
# Each task to run has to be defined through a single line  
# indicating with different fields when the task will be run  
# and what command to run for the task  
#  
# To define the time you can provide concrete values for  
# minute (m), hour (h), day of month (dom), month (mon),  
# and day of week (dow) or use '*' in these fields (for 'any').  
#  
# Notice that tasks will be started based on the cron's system  
# daemon's notion of time and timezones.  
#  
# Output of the crontab jobs (including errors) is sent through  
# email to the user the crontab file belongs to (unless redirected).  
#  
# For example, you can run a backup of all your user accounts  
# at 5 a.m every week with:  
# 0 5 * * 1 tar -zcf /var/backups/home.tgz /home/  
#  
# For more information see the manual pages of crontab(5) and cron(8)  
#  
# m h dom mon dow   command  
* * * * * /bin/bash /home/pi/camera.sh
```



RPi Camera (BASH):

Record 10s video every minute and upload it to OneDrive



RPi Camera (BASH):

Record 10s video every minute and upload it to OneDrive



RPi Camera (BASH):

Record 10s video every minute and upload it to OneDrive

Name	Modified	Modified By	File size	Sharing
2021-03-13_1957_video.h264	A few seconds ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1956_video.h264	About a minute ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1955_video.h264	2 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1954_video.h264	3 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1953_video.h264	4 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1952_video.h264	5 minutes ago	Felip Marti Carrillo	19.8 MB	Shared
2021-03-13_1951_video.h264	6 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1950_video.h264	7 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1949_video.h264	8 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1948_video.h264	9 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1947_video.h264	10 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1946_video.h264	11 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1945_video.h264	12 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1944_video.h264	13 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1943_video.h264	14 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1942_video.h264	15 minutes ago	Felip Marti Carrillo	19.7 MB	Shared
2021-03-13_1941_video.h264	16 minutes ago	Felip Marti Carrillo	19.7 MB	Shared

RPi Camera (BASH):

Record 10s video every minute and upload it to OneDrive

- Demonstration of the recorded videos
- Other Ideas:
 - Start recording every time the RPi turns on:
systemctl
<https://www.commandlinux.com/man-page/man1/systemctl.1.html>
<https://www.linode.com/docs/guides/start-service-at-boot/>
 - Start recording every time a button is pressed
Interruptions via GPIO
 - Etc.

Week 4 and 5 Labs – Edge server and virtual RPi

Questions ...?