RASPBERRY PI BASICS

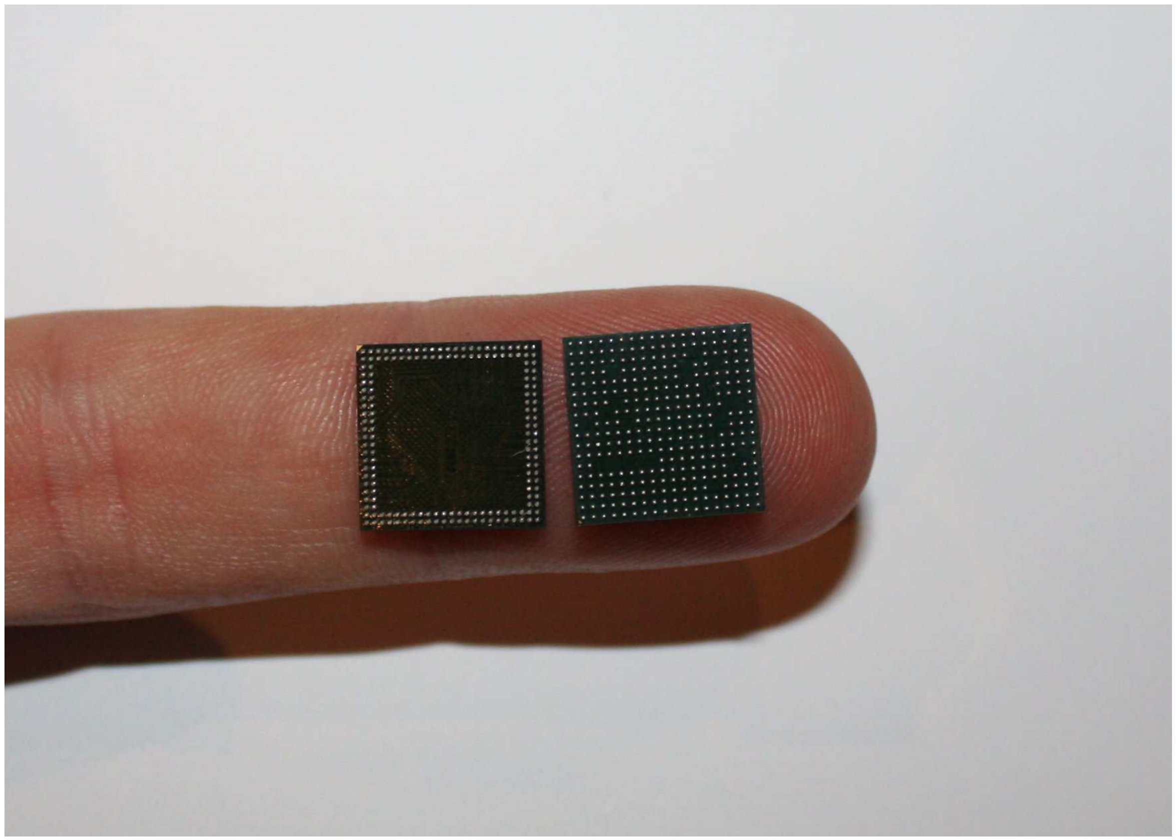
System on Chip (SoC)

- What is System on Chip?
  - A complex IC that integrates the major functional elements into a single chip or chipset.
    - programmable processor
    - on-chip memory
    - accelerating function hardware (e.g. GPU)
    - both hardware and software
    - analog components
- Benefits of SoC
  - Reduce overall system cost
  - Increase performance
  - Lower power consumption
  - Reduce size

SoC in Raspberry Pi: Broadcom BCM2835 SoC Multimedia processor

- CPU
  - ARM 1176JZF-S (armv6k) 700MHz
  - RISC Architecture and low power draw
  - Not compatible with traditional PC software
- GPU
  - Broadcom Video IV
  - Specialized graphical instruction sets
- RAM
  - 512MB (Model B rev.2)
  - 256 MB (Model A, Model B rev.1)

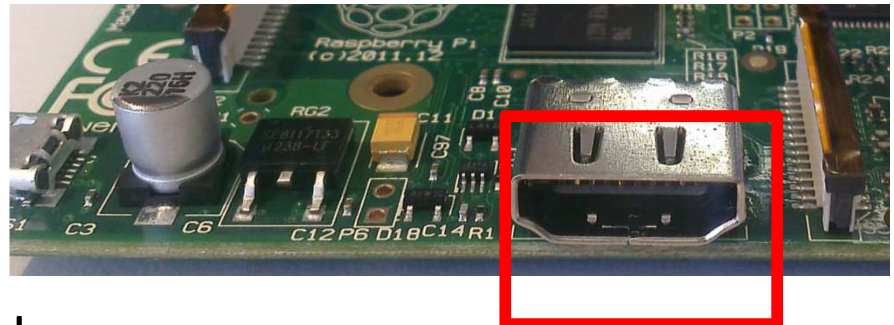
SoC in Raspberry Pi: Broadcom BCM2835 SoC

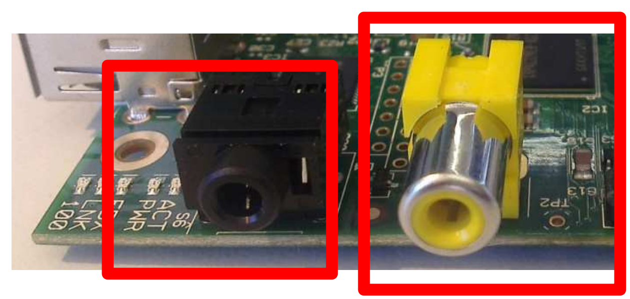


BCM2835 SoC (right) and Samsung K4P2G324ED Mobile DRAM (left)

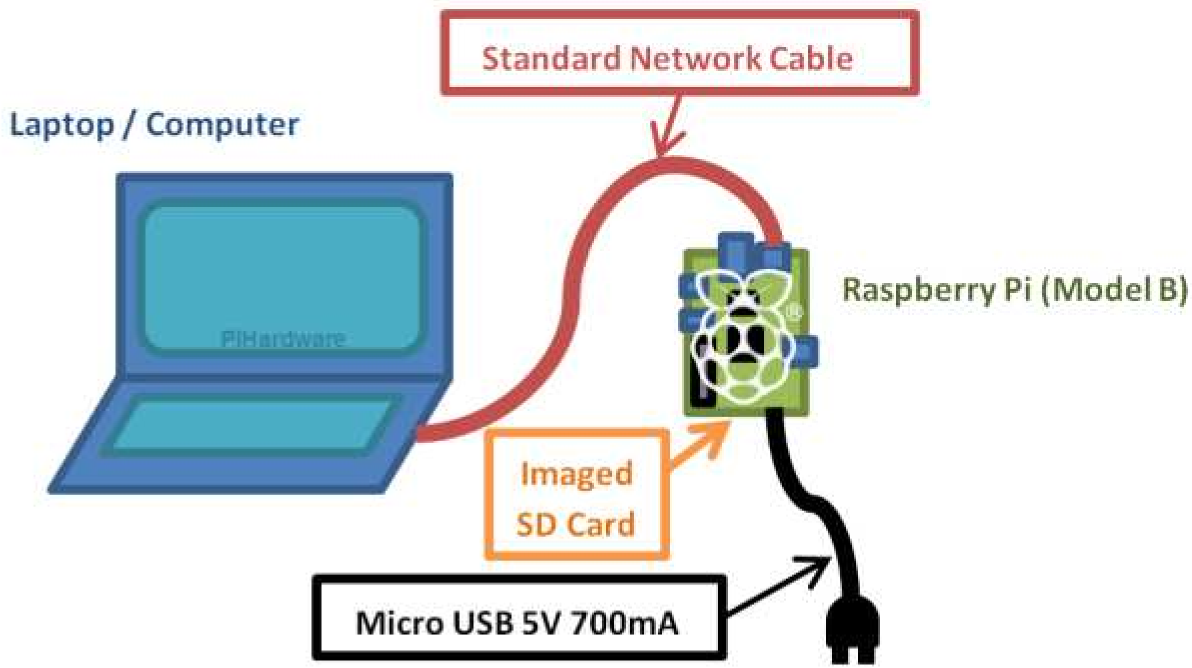
Connecting a Display and Audio

- HDMI
  - Digital signal
  - Video and audio signal
  - DVI cannot carry audio signal
  - Up to 1920x1200 resolution
- Composite RCA
  - Analog signal
  - 480i, 576i resolution
- 3.5mm jack





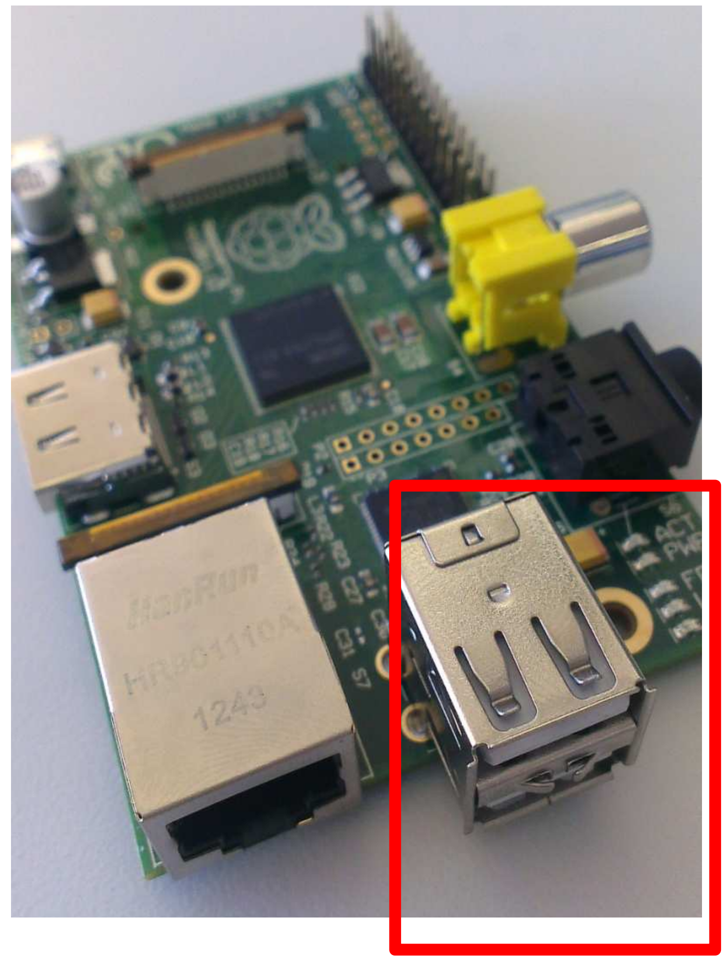
RPi Remote Connections



http://pihw.wordpress.com/guides/direct-network-connection/

Universal Serial Bus

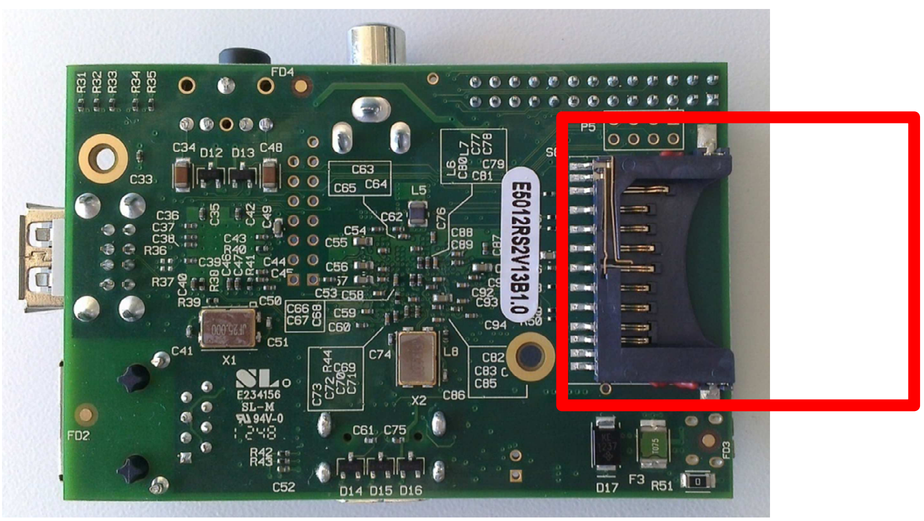
- Two USB 2.0 ports in RPi
- Buy a powered USB hub

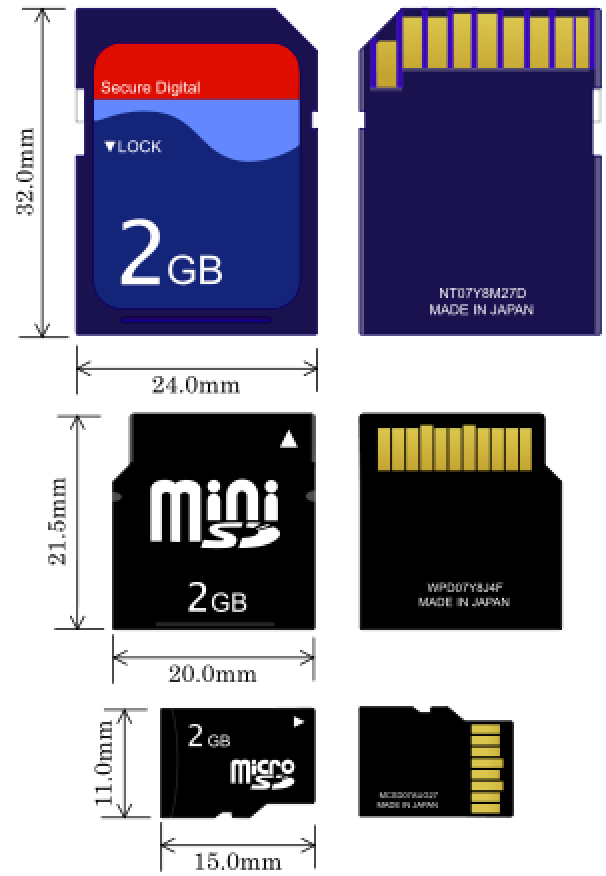


Passive models are cheaper and smaller, but lack the ability to run current-hungry devices like CD drives and external hard drives.

Storage: Secure Digital (SD)

- Form factor
  - SD, Mini SD, Micro SD
- Types of Card
  - SDSC (SD): 1MB to 2GB
  - SDHC: 4GB to 32 GB
  - SDXD up to 2TB





The card should be at least 2GB in capacity to store all the required files

Storage: Continue

SD Formatter:

https://www.sdcard.org/downloads/formatter_4/

How to mount USB flash drive from command line:

http://linuxcommando.blogspot.co.uk/2007/12/how-to-mount-usb-flash-drive-from.html

Networking

Ethernet (IEEE 802.3)

USB Ethernet Converter

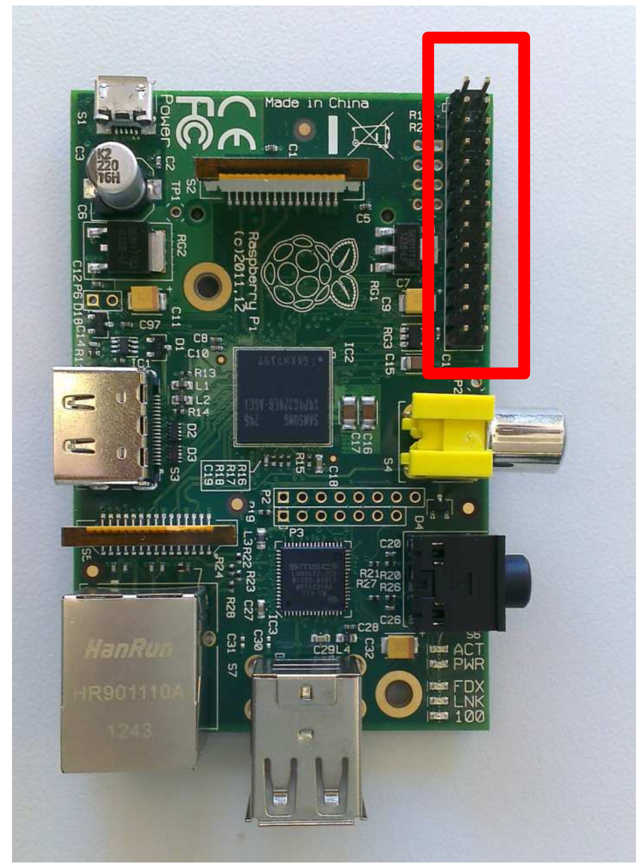
Wi-Fi Adapter

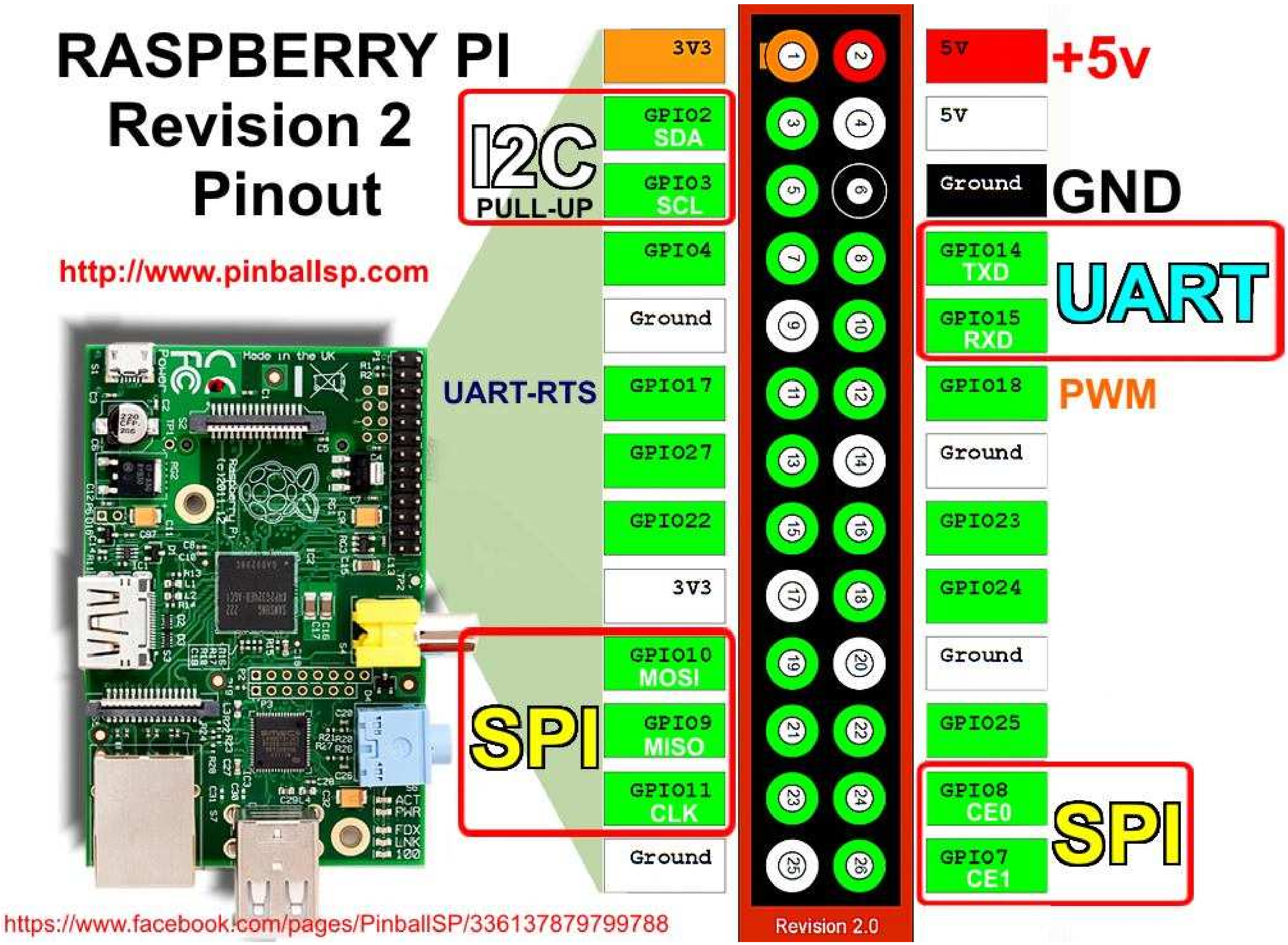
Networking - wireless

- IEEE 802.11 Wi-Fi
  - Protocols
    - 802.11 b, up to 11Mbps
    - 802.11 g, up to 54Mbps
    - 802.11 n, up to 300Mbps
    - 802.11 ac (draft), up to 1Gbps
  - Frequency band
    - 2.4GHz, 5GHz

Low Speed Peripherals

- General Purpose Input/Output (GPIO)
  - Pins can be configured to be input/output
  - Reading from various environmental sensors
    - Ex: IR, video, temperature, 3-axis orientation, acceleration
  - Writing output to dc motors, LEDs for status.





RASPBERRY PI
Revision 2
Pinout
http://www.pinballsp.com
I2C
PULL-UP
UART-RTS
SPI
3V3
GPIO2
SDA
GPIO3
SCL
GPIO4
Ground
GPIO17
GPIO27
GPIO22
3V3
GPIO10
MOSI
GPIO9
MISO
GPIO11
CLK
Ground
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
Revision 2.0
5V
+5v
5V
Ground
GND
GPIO14
TXD
GPIO15
RXD
UART
GPIO18
PWM
Ground
GPIO23
GPIO24
Ground
GPIO25
GPIO8
CE0
GPIO7
CE1
SPI
https://www.facebook.com/pages/PinballSP/336137879799788

Power Consumption

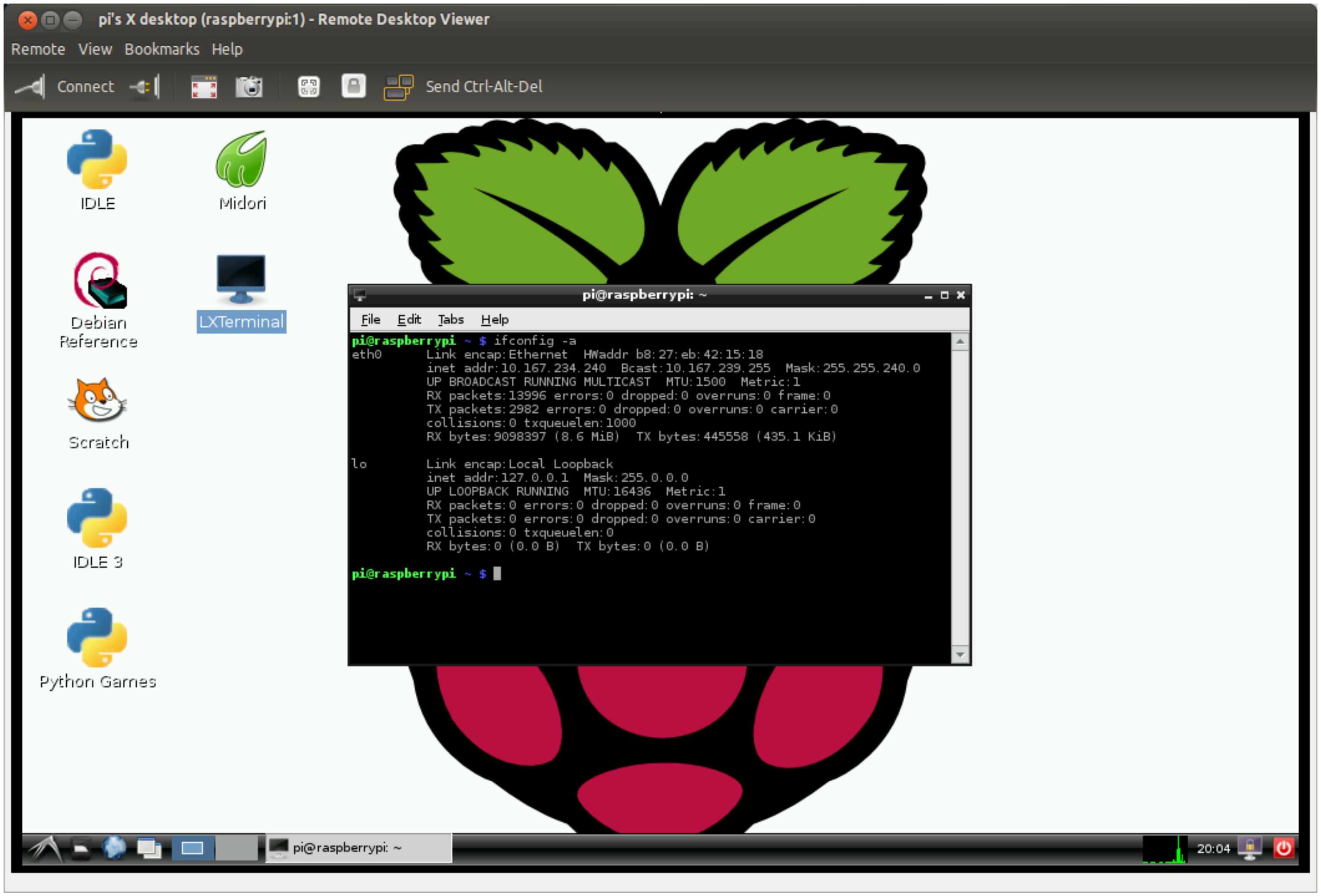
- microUSB power connector
  - 2.5W (model A)
  - 3.5W (model B)
- Powered USB hub
  - To provide more power for USB peripherals

Useful links

- Raspberry Pi official website
  - http://www.raspberrypi.org/
- Raspberry Pi wiki
  - http://elinux.org/RaspberryPiBoard
- Raspberry Pi verified peripherals
  - http://elinux.org/RPi_VerifiedPeripherals
- The MagPi
  - http://www.themagpi.com
- Raspberry Pi on Adafruit Learning System:
  - http://learn.adafruit.com/category/learn-raspberry-pi

Raspberry Pi Setup

- 1. Download the Raspberry Pi operating system
  - Linux releases compatible with the Pi: http://www.raspberrypi.org/downloads
  - The recommended OS is Raspbian: http://downloads.raspberrypi.org/raspbian_latest
- 2. Unzip the file that you just downloaded
  - Right click on the file and choose “Extract all”.
  - Follow the instructions—you will end up with a file ending in .img


pi's X desktop (raspberrypi:1) - Remote Desktop Viewer
Remote View Bookmarks Help
Connect
Send Ctrl-Alt-Del
IDLE
Midori
Debian Reference
LXTerminal
Scratch
IDLE 3
Python Games
pi@raspberrypi: ~
File Edit Tabs Help
pi@raspberrypi ~ $ ifconfig -a
eth0 Link encap:Ethernet HWaddr b8:27:eb:42:15:18
inet addr:10.167.234.240 Bcast:10.167.239.255 Mask:255.255.240.0
UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
RX packets:13996 errors:0 dropped:0 overruns:0 frame:0
TX packets:2982 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:1000
RX bytes:9098397 (8.6 MiB) TX bytes:445558 (435.1 KiB)
lo Link encap:Local Loopback
inet addr:127.0.0.1 Mask:255.0.0.0
UP LOOPBACK RUNNING MTU:16436 Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:0
RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)
pi@raspberrypi ~ $
pi@raspberrypi: ~
20:04

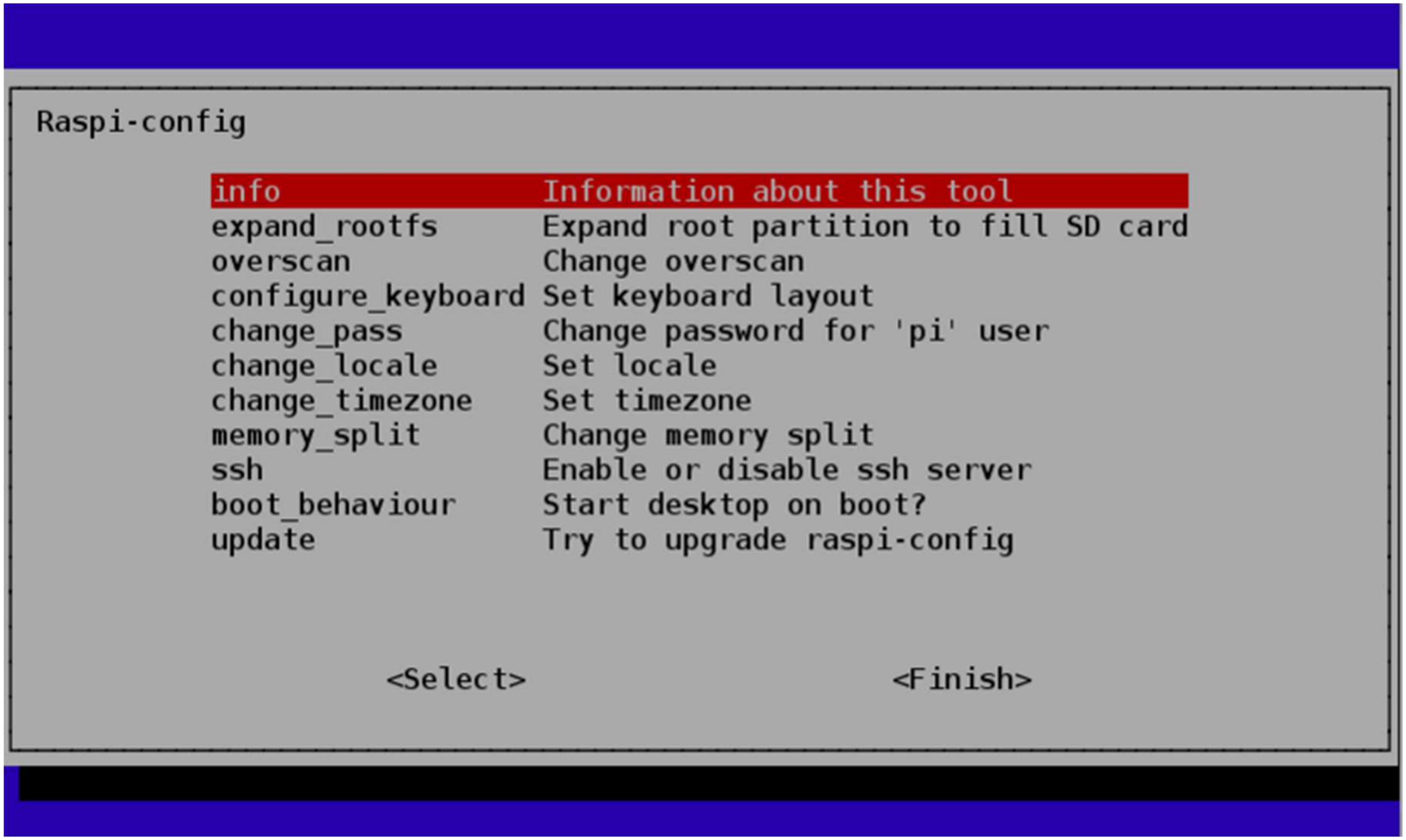

xbmc
1:42 PM
Sun, 29 Jul 2012
PICTURES
VIDEOS
MUSIC
Files
Add-ons
BenQ
TECHNIKA

- 3. Download the Win32DiskImager software
  - a) Download win32diskimager-binary.zip (currently version 0.6) from:

    https://launchpad.net/win32-image-writer/+download
  - b) Unzip it in the same way you did the Raspbian .zip file
  - c) You now have a new folder called win32diskimager-binary

- 4. Writing Raspbian to the SD card
  - a) Plug your SD card into your PC
  - b) In the folder you made in step 3(b), run the file named Win32DiskImager.exe
  - c) If the SD card (Device) you are using isn’t found automatically then click on the drop down box and select it
  - d) In the Image File box, choose the Raspbian .img file that you downloaded
  - e) Click Write
  - f) After a few minutes you will have an SD card that you can use in your Raspberry Pi

- 5. Booting your Raspberry Pi for the first time
  - On first boot you will come to the Raspi-config window
  - Change settings such as timezone and locale if you want
  - Finally, select the second choice: **expand_rootfs** and say ‘yes’ to a reboot
  - The Raspberry Pi will reboot and you will see raspberrypi login:
    - Username: pi, password: raspberry
  - Start the desktop by typing: **startx**
  - The desktop environment is known as the Lightweight X11 Desktop Environment (LXDE)


Raspi-config
info Information about this tool
expand_rootfs Expand root partition to fill SD card
overscan Change overscan
configure_keyboard Set keyboard layout
change_pass Change password for 'pi' user
change_locale Set locale
change_timezone Set timezone
memory_split Change memory split
ssh Enable or disable ssh server
boot_behaviour Start desktop on boot?
update Try to upgrade raspi-config
<Select>
<Finish>

Re-mapping Keyboard:

- sudo vi /etc/default/keyboard
  XKBLAYOUT=”gb”
  Change “gb” to “us”

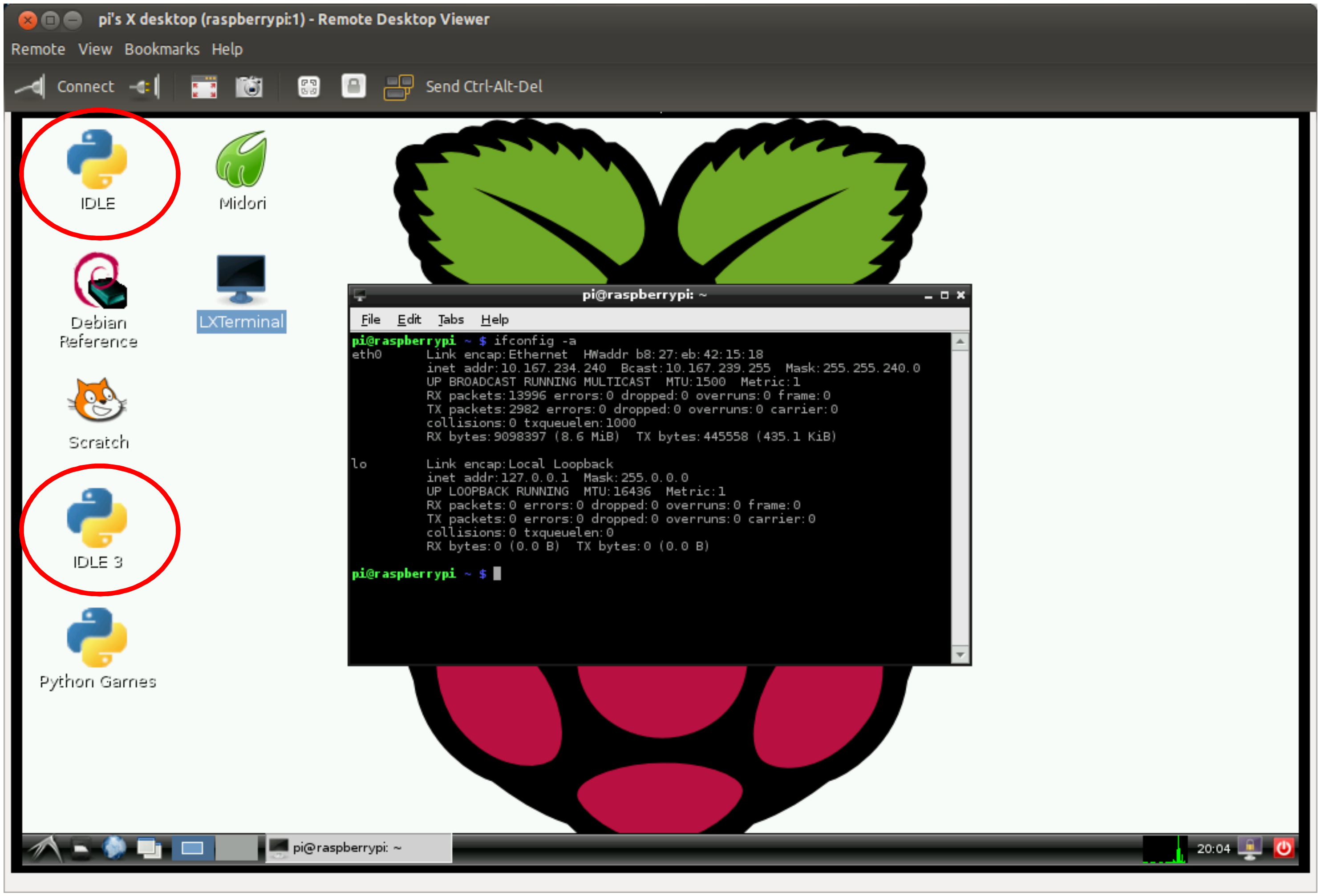
- (This assumes you want a us mapping, if not replace the gb with the two letter code for your country)

Install and Start SSH

- Update apt-get package index files:
  - sudo apt-get update
- Install SSH:
  - sudo apt-get install ssh
- Start SSH server:
  - sudo /etc/init.d/ssh start
- To start the SSH server every time the Pi boots up:
  - sudo update-rc.d ssh defaults

- SSH client for Windows:
  - PuTTY
  - http://www.putty.org/

- SSH Secure File Transfer
  - http://www.utexas.edu/learn/upload/ssh_client.html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collisions:0 txqueuelen:0
RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)
pi@raspberrypi ~ $
pi@raspberrypi: ~
20:04

Install Java

- 1. JDK 8 (with JavaFX) for ARM Early Access http://jdk8.java.net/fxarmpreview/
  - Download from Raspberry pi
  - Download from your own PC and copy it (scp) to Raspberry pi
- Extract the JDK tar.gz file
  - tar –zxvf fileToExtract.tar.gz
  - You will get a folder “jdk1.8.0”

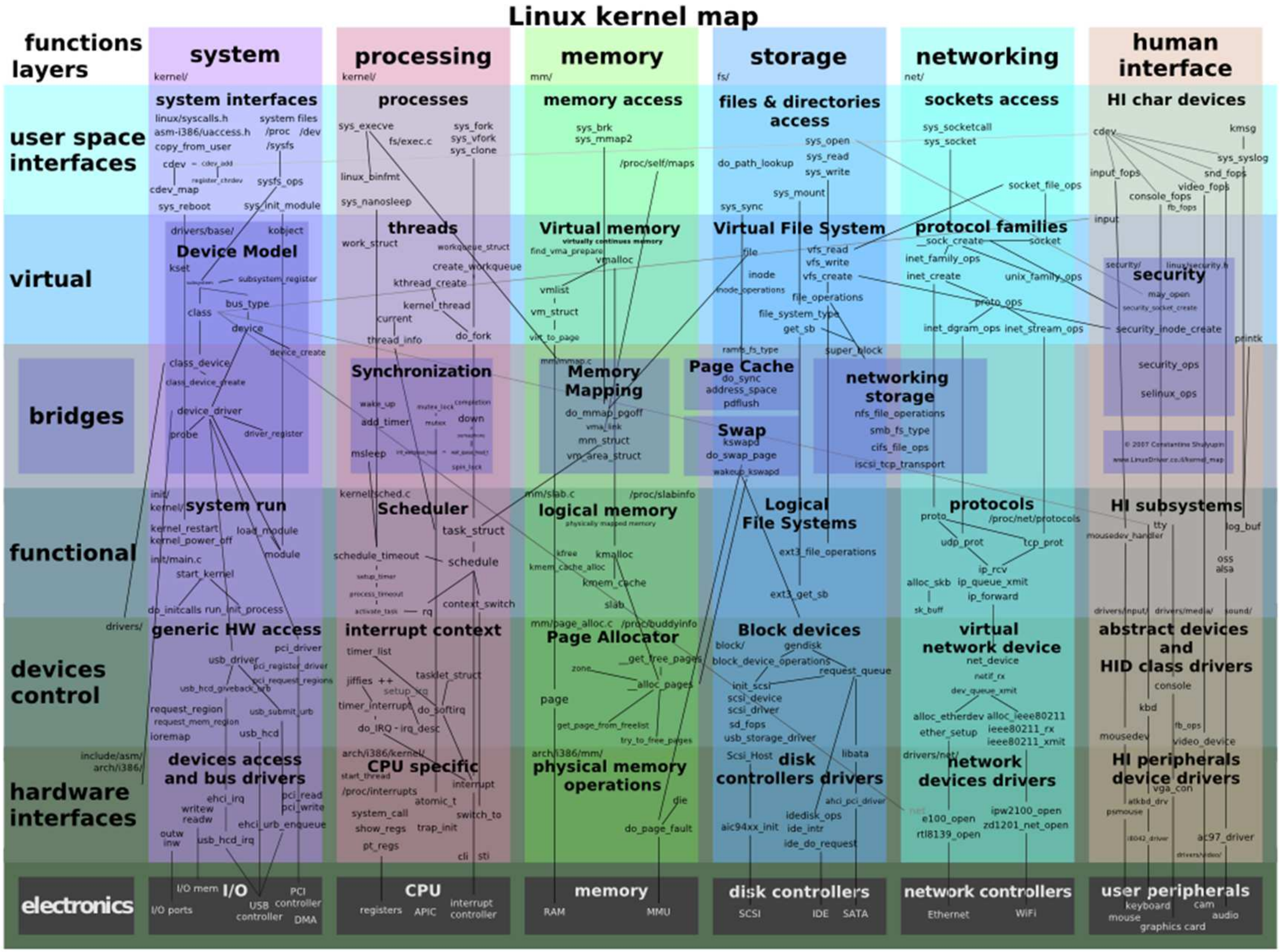
Set Java PATH

- If you put the folder “jdk1.8.0” in the home directory (i.e. /home/pi), you will see the java executables (e.g. javac, java, appletviewer) in the directory: /home/pi/jdk1.8.0/bin
- open /etc/profile
  add:
  ```
  PATH=$PATH:/home/pi/jdk1.8.0/bin
  export PATH
  ```
- Reboot:

  sudo reboot

Linux System Administration

Kernel and Distribution



Kernel and Distribution

Although only the kernel itself is rightly called Linux, the term is often used to refer to a collection of different open-source projects from a variety of companies. These collections come together to form different flavors of Linux, known as distributions.

File System Logical Layout

boot: This contains Linux kernel and other packages needed to start the Pi

bin: OS-related binary files, like those required to run the GUI, are stored here.

dev: Virtual directory, which doesn't actually exist on the SD card. All devices connected to the system can be accessed from here.

etc: This stores miscellaneous configuration files, including the list of users and their encrypted passwords

home: Each user gets a subdirectory beneath this directory to store all their personal files

lib: This is a storage space for libraries, which are shared bits of code required by different applications.

lost+found: A special directory where file fragments are stored if the system crashes.

media: A special directory for removable storage devices, like USB memory sticks or external CD drives.

File System Logical Layout

mnt: This folder is used to manually mount storage devices, such as external hard drives.

opt: This stores optional software that is not part of the OS itself. If you install new software to your Pi, it will usually go here.

proc: Another virtual directory, containing information about running programs which are known in Linux as processes.

selinux: Files related to Security Enhanced Linux, a suite of security utilites originally developed by the US National Security Agency.

sbin: Stores special binary files, primarily used by the root account for system maintenance.

sys: This directory is where special OS files are stored.

tmp: Temporary files are stored here automatically.

usr: This directory provides storage for user accessible programs.

var: This is virtual directory that programs use to store changing values or variables.

Software

LXTerminal and Root Terminal: use the Linux command line in a window without leaving the GUI.

Midori & NetSurf: Lightweight web browser

IDLE and IDLE 3: IDE for Python 2.7 and 3

Task Manager: Checks the available memory, processor workload, closes crashed or unresponsive programs

Music player at the console: moc

OpenOffice.org: sudo apt-get install openoffice.org

Image Editing: Gimp

LAMP (Linux, Apache, MySQL and PHP) stack
Sudo apt-get install apache2 php5 php5-mysql mysql-server

Installing, Uninstalling and Updating Software

- Package manager in Debian: apt
  - GUI for apt, Synaptic Package Manager doesn't work well on Pi due to the lack of memory
- Make sure that the apt cache is up to date:
  - apt-get update
- Finding software:
  - apt-cache search emacs
- Installing software and dependencies:
  - sudo apt-get install emacs
- Uninstalling software:
  - sudo apt-get remove emacs
  - sudo apt-get purge emacs (removes everything including configurations)
- Upgrading software:
  - Sudo apt-get upgrade
  - Sudo apt-get install emacs

Troubleshooting

Keyboard and Mouse Diagnostics

Power Diagnostics

Display Diagnostics

Network Diagnostics

Emergency Kernel

Wired Networking Configuration

```
sudo nano /etc/ntework/interfaces

iface eth0 inet static
[tab] address 192.168.0.10
[tab] netmask 255.255.255.0
[tab] gateway 192.168.0.254

sudo /etc/init.d/networking restart

sudo nano /etc/reslov.conf

nameserver 8.8.8.8
nameserver 8.8.4.4

sudo /etc/init.d/networking restart

ping –c 1 www.raspberrypi.org
```

Wireless Networking Configuration

- USB Wi-Fi adapters are very power-hungry. Connect a powered USB hub to the Pi, and then insert the Wi-Fi adapter into that.
- Print out the entire kernel ring buffer and find out the company that makes the actual chip: mesg | grep ^usb

Atmel-firmware
Firmware-atheros
Firmware-brcm80211
Firmeware-intelwimax
Firmware-ipw2x00
Firmware-iwlwifi
Firmware-ralink
Firmware-realteck
Zd1211-firmware

- Check the current status of the network: iwconfig

Configurating the Raspberry Pi

RPi doesn’t have a BIOS menu. It relies on text files containing configuration strings that are loaded by the chip when powers on.

- Hardware settings: config.txt
- Memory Partitioning: start.elf
- Software Settings: cmdline.txt

References for Python

Beginner's Guide to Python
http://wiki.python.org/moin/BeginnersGuide

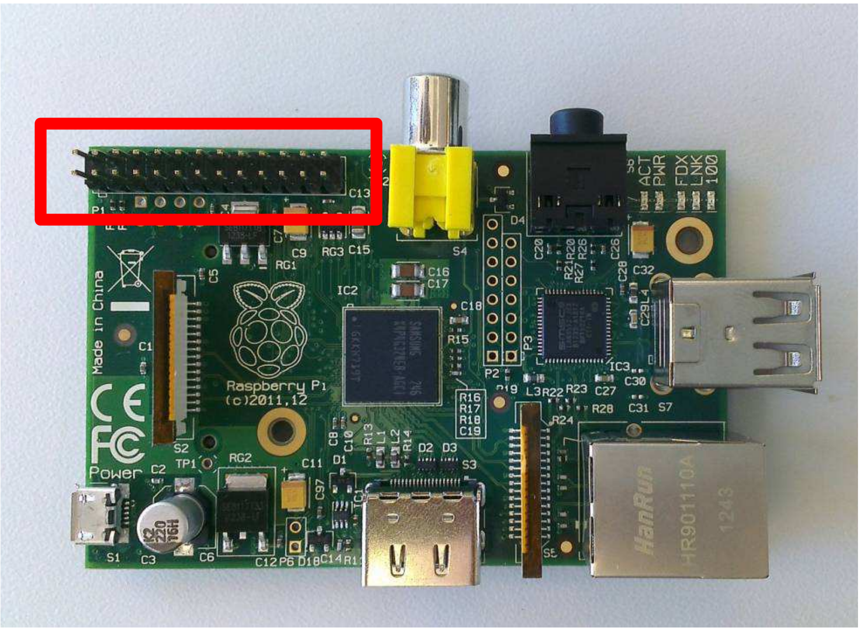
A free, interactive tutorial
http://www.learnpython.org

Learn Python the Hard Way (Shavian Publishing, 2012)

Dive Into Python 3 (APRESS, 2009)

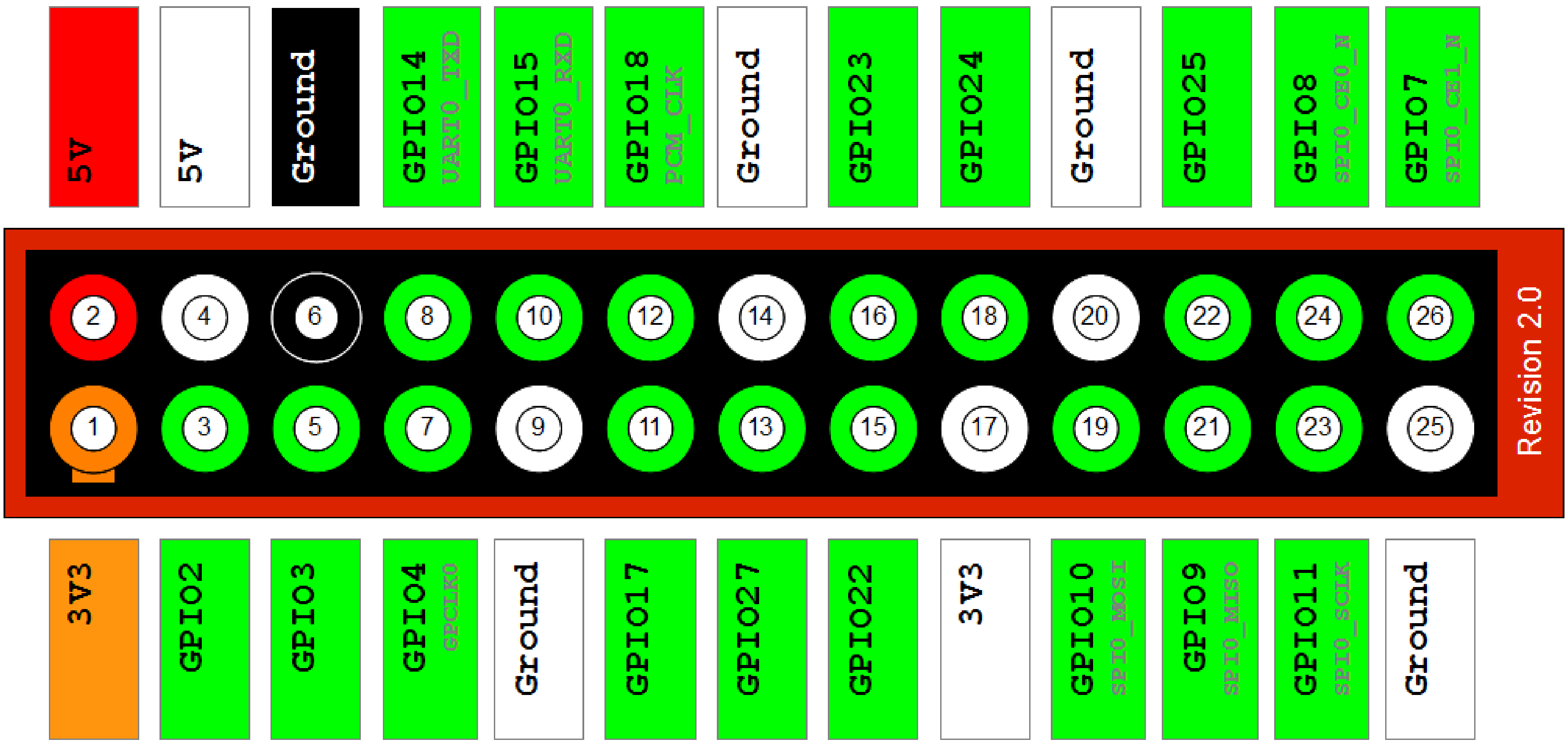
General Purpose Input/Output (GPIO)

- General Purpose Input/Output (GPIO) is a generic pin on a chip whose behavior can be controlled by the user at run time.



- The GPIO connector has a number of different types of connection:
  - True GPIO (General Purpose Input Output) pins that you can use to turn LEDs on and off etc.
  - I2C interface pins that allow you to connect hardware modules with just two control pins
  - SPI interface with SPI devices, a similar concept to I2C but uses a different standard
  - Serial Rx and Tx pins for communication with serial peripherals

- GPIO pins can be used as both digital outputs and digital inputs.
- Output: turn a particular pin HIGH or LOW.
  - Setting it HIGH sets it to 3.3V; setting it LOW sets it to 0V.
- Input: detect the pin being at HIGH or LOW
  - we can connect switches and simple sensors to a pin and check whether it is open or closed (that is, activated or not)



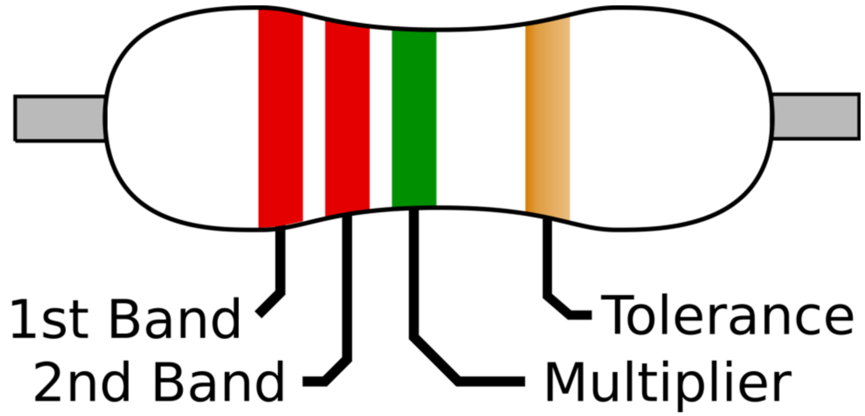
To use the pin numbers from the ribbon cable board:
GPIO.setmode(GPIO.BCM)

To use the pin numbers on raspberry pi board
GPIO.setmode(GPIO.BOARD)

All the pins have 3.3V logic levels and are not 5V-safe so the output levels are 0-3.3V and the inputs should not be higher than 3.3V.

Electronic Equipment

- Breadboard
  - Components in the same row are connected together without wires
- Jumper Wires
  - Try to use different colors to differentiate different purposes
- Resistors
- Push-Buttons
- LEDs



	1st/2nd Band	Multiplier	Tolerance
Black	0	0	-
Brown	1	$\times 10^1$	±1%
Red	2	$\times 10^2$	±2%
Orange	3	$\times 10^3$	-
Yellow	4	$\times 10^4$	-
Green	5	$\times 10^5$	±0.5%
Blue	6	$\times 10^6$	±0.25%
Violet	7	$\times 10^7$	±0.1%
Grey	8	$\times 10^8$	±0.05%
White	9	$\times 10^9$	-
Gold	-	$\times 10^{-1}$	±5%
Silver	-	$\times 10^{-2}$	±10%
None	-	-	±20%

GPIO setup on Raspberry Pi

- Install Python 2 library Rpi.GPIO.
  - A library that will let us control the GPIO pins.
- https://pypi.python.org/pypi/RPi.GPIO
- Install commands:

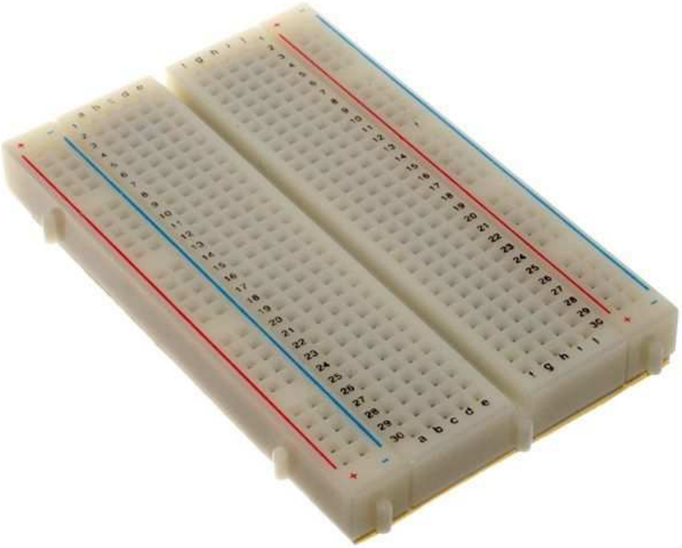
```
sudo apt-get update
sudo apt-get install python-dev
sudo apt-get install python-rpi.gpio
```

GPIO as Output

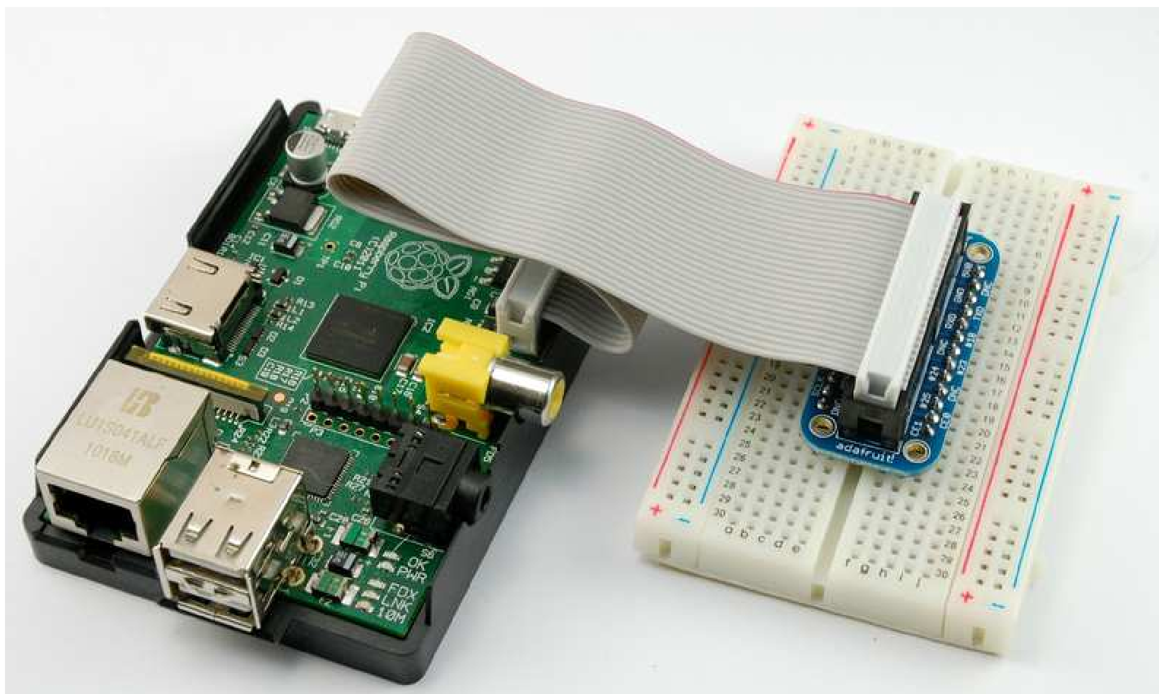
- Experiment 1: Controlling LED
  – LED
  – Breadboard
  – Jumper wire

Breadboard

- Build circuit easily without soldering

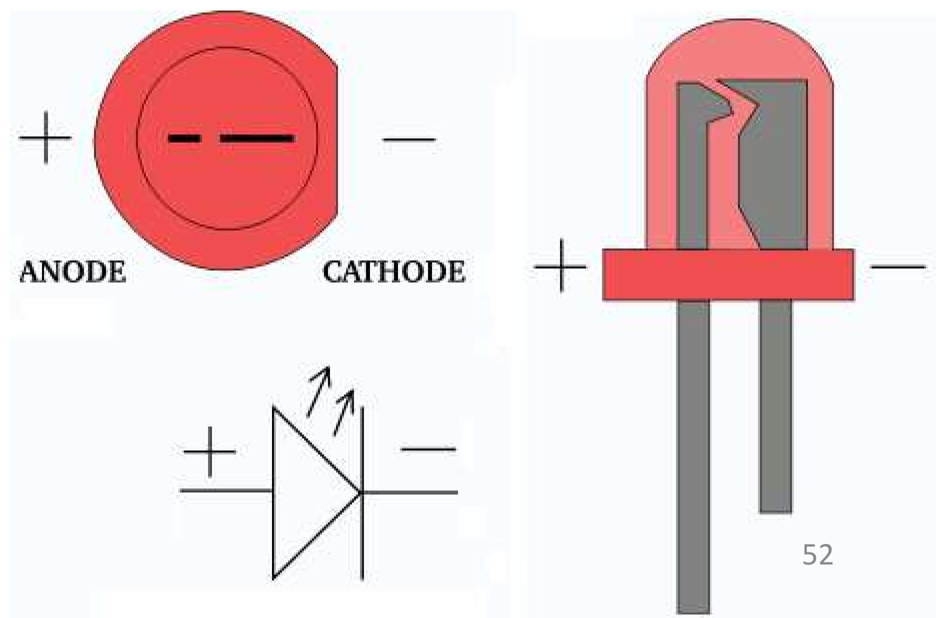


Use Cobbler kit to extend the GPIO to breadboard

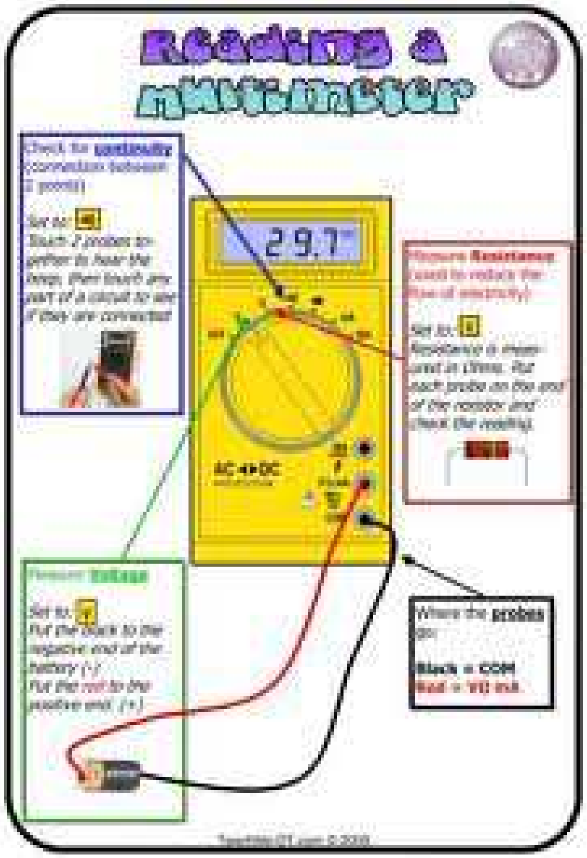


Light-emitting diode (LED)

- Current flows from the anode to cathode.
  - Anode: longer pin
  - Cathode: shorter pin
- Use a multimeter to test the polarity
  - Check resistance
  - In both directions.



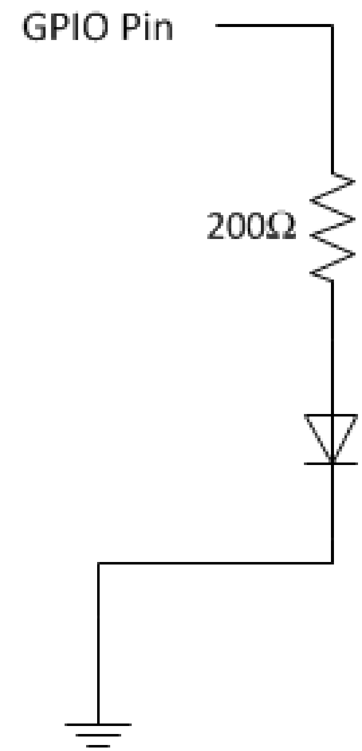
Multimeter



Check for continuity
Measure Resistance
Measure Voltage
Where the probes go:
Black = COM

Task 1: Turn LED on for 2 seconds and off for 1 second, loop forever

- In this example, we control the LED by controlling the voltage at the anode (+).

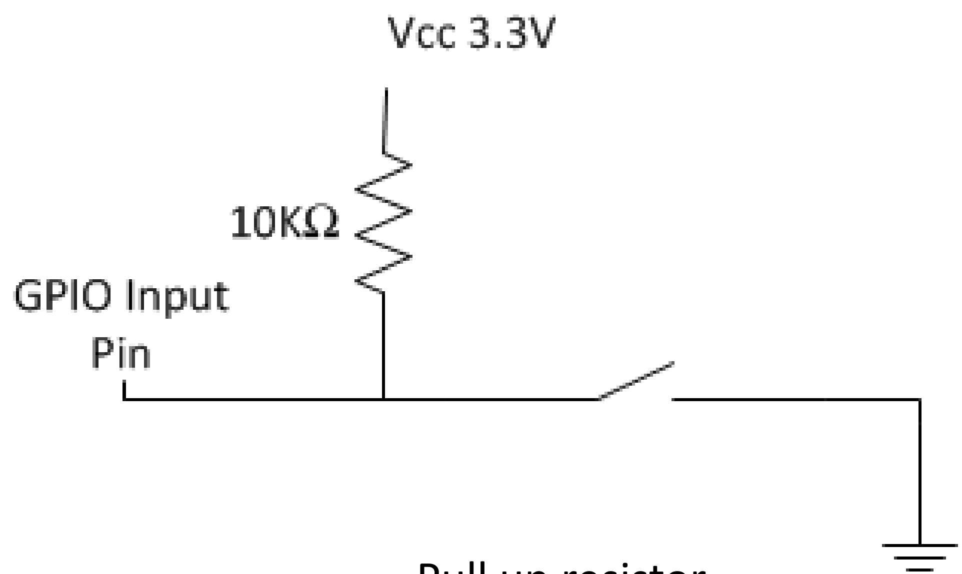


Code for task 1

```
import RPi.GPIO as GPIO
import time

def main():
    GPIO.cleanup()
    GPIO.setmode(GPIO.BOARD)    # to use Raspberry Pi board pin numbers
    GPIO.setup(11, GPIO.OUT)    # set up GPIO output channel

    while True:
        GPIO.output(11, GPIO.LOW) # set RPi board pin 11 low. Turn off LED.
        time.sleep(1)
        GPIO.output(11, GPIO.HIGH) # set RPi board pin 11 high. Turn on LED.
        time.sleep(2)

main()
```

GPIO as Input

- When the switch is not pushed: GPIO detects Vcc (HIGH)
- When the switch is pushed: GPIO detects GND (LOW)



Pull up resistor

GPIO Input Sample Code

- `import RPi.GPIO as GPIO`
- `# Use the pin numbers from the ribbon cable board`
  `GPIO.setmode(GPIO.BCM)`
- `# Set up this pin as input.`
  `GPIO.setup(17, GPIO.IN)`
- `# Check the value of the input pin`
  `GPIO.input(17)`
- `# Hold down the button, run the command again. The output should be "true".`
  `GPIO.input(17)`

Check input using polling

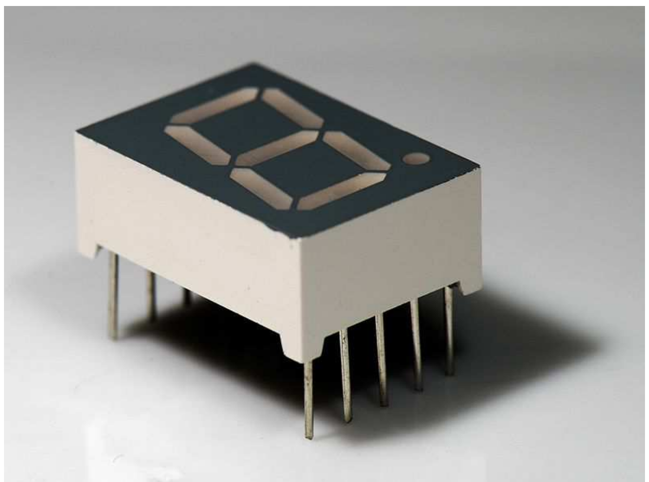
```
input =  True
prev_input = True

while True:
   input = GPIO.input(17)

   if (prev_input and (not input)):
       print("Button pressed")

   #update previous input
   prev_input = input

   #slight pause to debounce
   time.sleep(0.05)
```

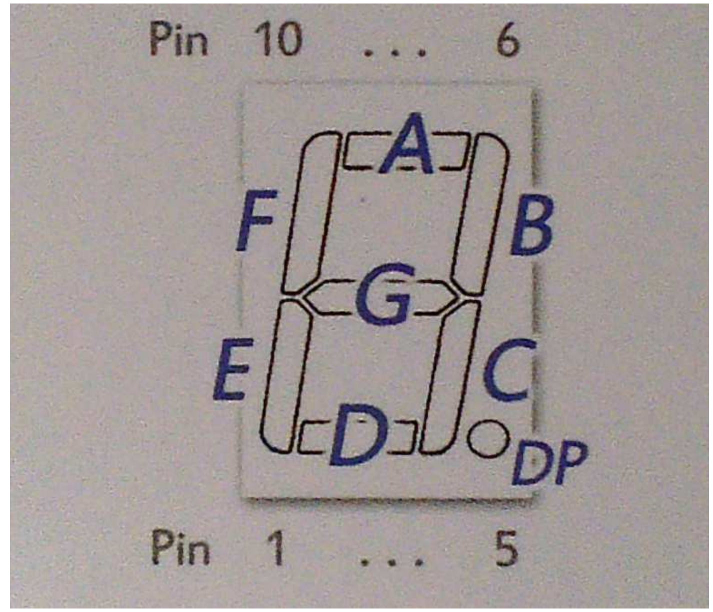
Check input using call back

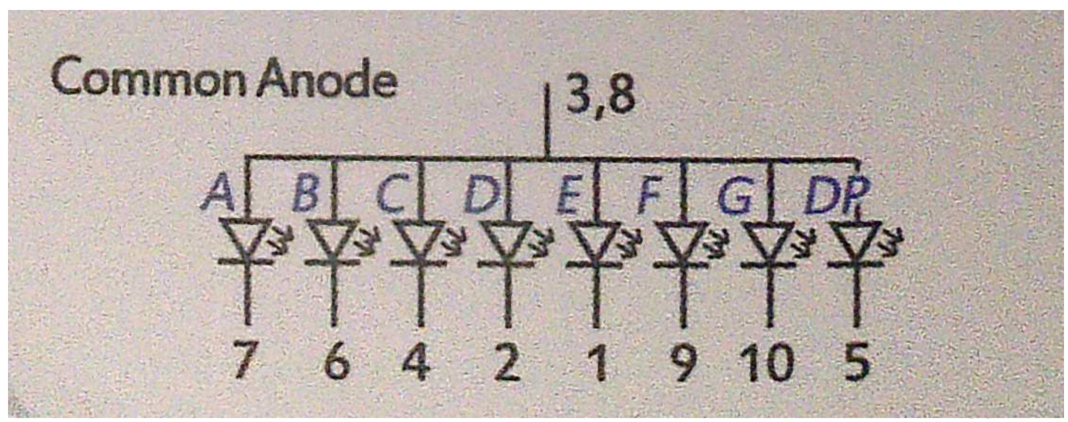
RPi.GPIO version 0.5.1a

```
GPIO.setup(17, GPIO.IN)

def my_callback():
    global time_stamp       # put in to debounce
    time_now = time.time()
    if (time_now - time_stamp) >= 0.05:
        print “Button Pressed"
    time_stamp = time_now

GPIO.add_event_detect(17, GPIO.FALLING, callback=my
_callback)
```

Experiment 2: Display digit on 7-segment LED







Experiment 2: Display digit on 7-segment LED

- Most direct way to control display:
  - Connect pin 3/8 of 7-seg-LED to Vcc
  - Connect the other 8 pins to 8 GPIO pins
  - Configure the 8 GPIO pins as output

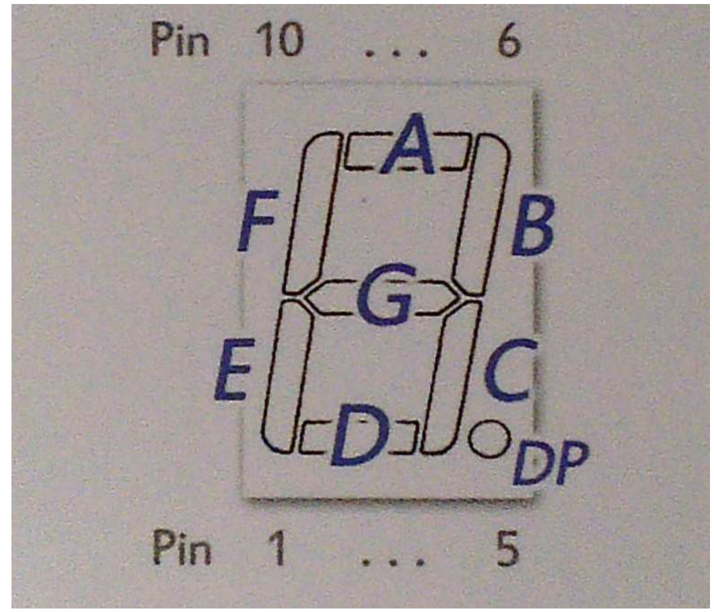
Experiment 2: Display digit on 7-segment LED

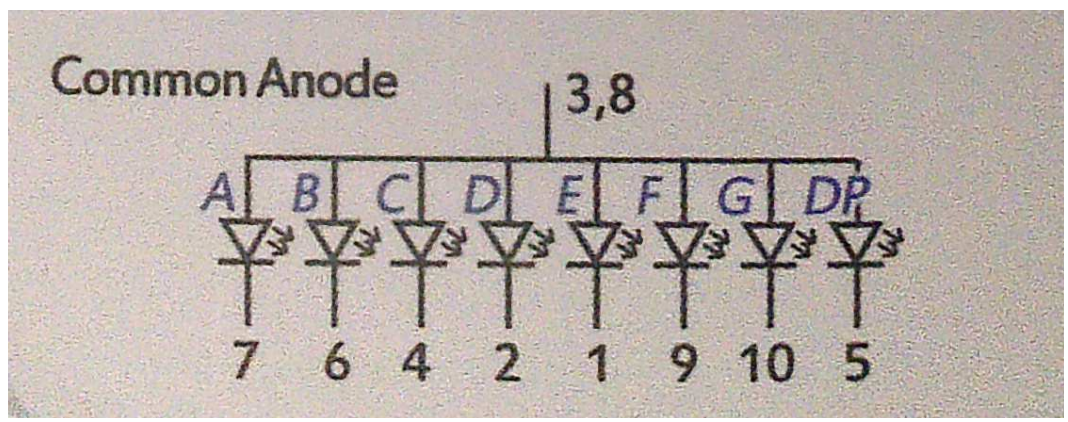
- For example: display "2"
  - Turn on segments A, B, D, E G.

    and turn off segments C, F, DP
  - Set A,B,D,E,G to LOW

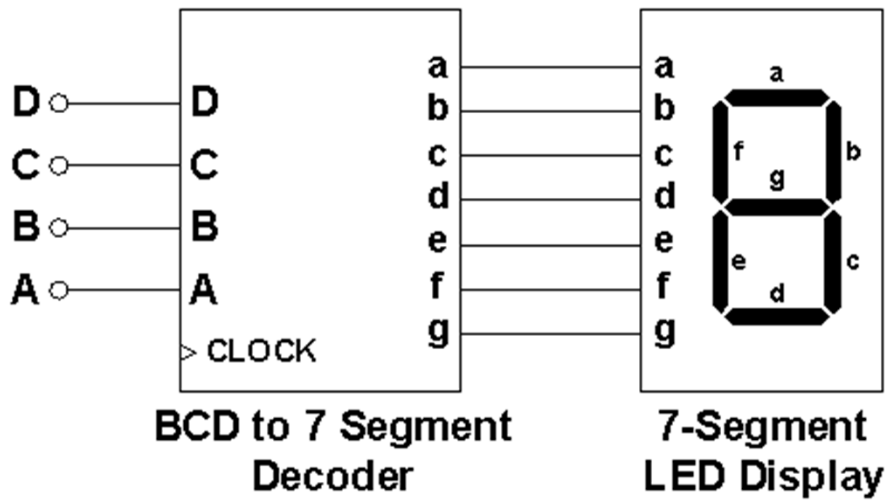
    and set C, F, DP to HIGH
  - Set Pin 7, 6, 2, 1, 10 LOW

    Set pin 4, 9, 5 HIGH





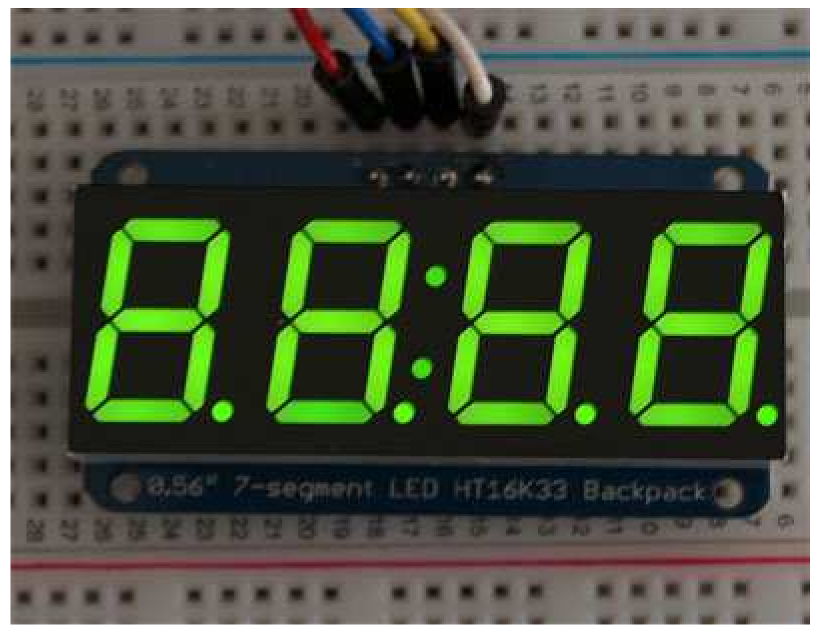
- The most direct way uses 8 GPIO pins.
- If we only display 0-9 digits, this is inefficient.
  - Use BCD to 7-segment decoder to display digit



- How to display multiple digits?

Using I2C: Control 4 digit 7-segment display

- How to do multiple 7-segment display?
  - Multiplexing
- The driver chip behind it will do this for us
- We can control it through I2C



Configure I2C

- Add modules
  - Add two modules to the end of file /etc/modules :

    i2c-bcm2708

    i2c-dev
- Install I2C tools utility

    sudo apt-get install python-smbus

    sudo apt-get install i2c-tools
  - If we have file: /etc/modprobe.d/raspi-blacklist.conf, comment the following two lines:

    blacklist spi-bcm2708

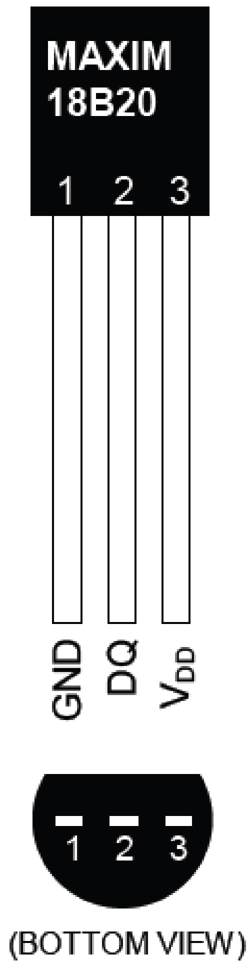
    blacklist i2c-bcm2708
- To see all the connected devices:
  - sudo i2cdetect -y 1

Control 4-digit 7-Segment Display

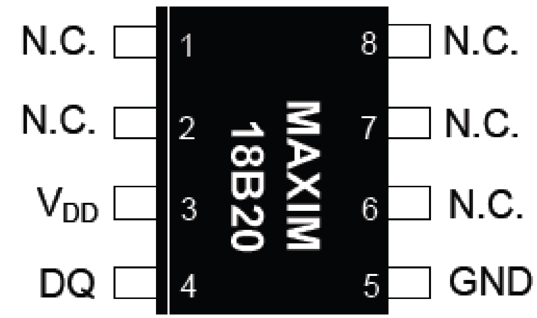
- Connect the 4 digit 7-segment display:
  - Four pins
  - Vcc, GND, SDA (Serial Data Line), SCL (Serial Clock)
- Use Adafruit's library to control the display:
  http://learn.adafruit.com/matrix-7-segment-led-backpack-with-the-raspberry-pi/using-the-adafruit-library
- All the low level I/O: Adafruit_LEDBackpack.py
- 7-Segment Library: Adafruit_7Segment.py
  - **writeDigit(charNumber, value, dot=False)**
  - **setColon(state)**

Experiment 3: Temperature Sensor

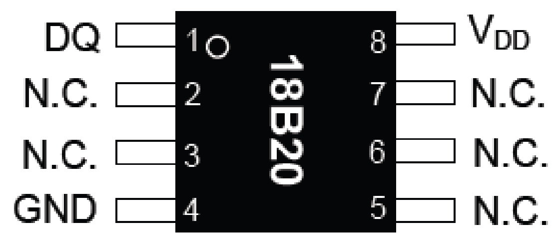
- Maxim: DS18B20+
- Operating temperature: -55 °C to +125 °C
- Accuracy: 0.5 °C (-10 °C to +80 °C)
- Datasheet: http://datasheets.maximintegrated.com/en/ds/DS18B20.pdf
- Request free sample at: http://www.maximintegrated.com/



TO-92
(DS18B20)



SO (150 mils)
(DS18B20Z)

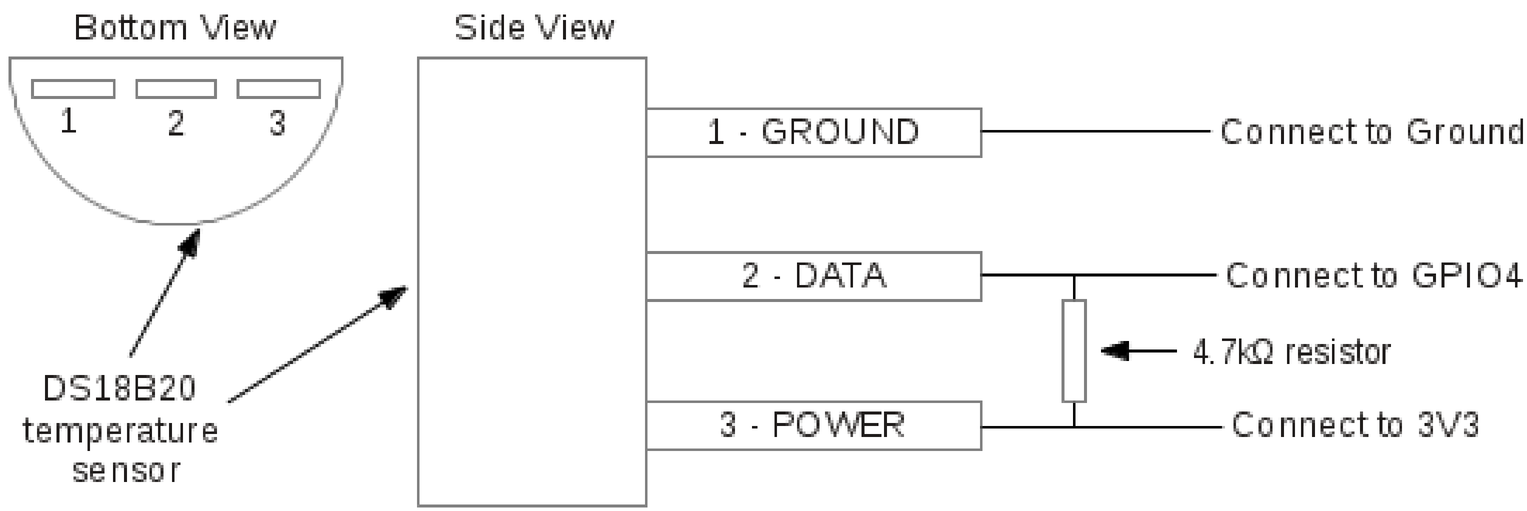


µSOP
(DS18B20U)

DS18B20+ Features

- Unique 1-Wire® Interface Requires Only One Port Pin for Communication
- Each Device has a Unique 64-Bit Serial Code Stored on an On-Board ROM
- Requires No External Components
- Thermometer Resolution is User Selectable from 9 to 12 Bits
- Convert temperature to 12-Bit Digital Word in 750ms (max)

DS18B20+ connection diagram



This is a BOTTOM view. Identify GND and POWER correctly before you connect.

!!! Wrong connection of GND and POWER will burn the chip instantly.

How to read data from DS18B20+?

- Look at DS18B20+. Follow the 1-wire protocol.
  - **1-Wire** is a device communications bus system designed by Dallas Semiconductor Corp. that provides low-speed data, signaling, and power over a single signal.
  - Multiple 1-wire sensors can share the same pin
  - See http://en.wikipedia.org/wiki/1-Wire for details
  - http://datasheets.maximintegrated.com/en/ds/DS18B20.pdf

Read temperature

- We do not need to implement the 1-wire protocol ourselves.
- We can read temperature from a file
  - sudo modprobe w1-gpio
  - sudo modprobe w1-therm
  - cd /sys/bus/w1/devices
  - ls
  - cd 28-xxxx (may need change to match serial no.)
  - cat w1_slave

Read temperature

- In Python, we can read the temperature by parsing that file:

```
import os
import glob
import time
os.system('modprobe w1-gpio')
os.system('modprobe w1-therm')
base_dir = '/sys/bus/w1/devices/'
device_folder = glob.glob(base_dir + '28*')[0]
device_file = device_folder + '/w1_slave'
```

Python Socket Programming

- Two types of sockets:
  - Stream & datagram
  - streamSock = **socket.socket**(socket.AF_INET, socket.SOCK_STREAM)
  - dgramSock = **socket.socket**(socket.AF_INET, socket.SOCK_DGRAM)

Sample Code: Stream Client

```
import socket

clientSocket = socket.socket(socket.AF_INET,
socket.SOCK_STREAM)
clientSocket.connect((‘192.168.2.10',23000))
clientSocket.send("Hello World\n")

# data receive from server and print
print clientSocket.recv(100)

clientSocket.close()
```

Sample Code: Stream Server

```
import socket

serverSocket = socket.socket(socket.AF_INET,
socket.SOCK_STREAM)
serverSocket.bind(('',23000))
serverSocket.listen( 5 )

while 1:
       # wait for client’s connection
       clientSocket, (remoteHost, remotePort) =
serverSocket.accept()
       # receive data from client
       s = clientSocket.recv(100)
       # send data back to server
       clientSocket.send(s)
       clientSocket.close()
```

Experiment: LED controlled by remote sensor

- 1st Raspberry Pi board houses temperature sensor
- 2nd Raspberry Pi board houses an LED.
- The sensor reports the temperature to the 2nd Raspberry Pi board. LED will be turned on when the temperature is higher than a threshold.

IP Camera Setup

- Turn a USB-based camera to an IP camera
- Install “motion” package
  - sudo apt-get install motion
- Start “motion” service
  - sudo services motion start
- Configure “motion” in /etc/motion/motion.conf

  Daemon = OFF to ON
  webcam_localhost = ON to OFF
  webcam_port = desired port number or 8088
  control_port = desired port number or 8089

IP Camera Setup

- Let the motion service start automatically:

  sudo vi /etc/default/motion:

  "start_motion_daemon=no" to "yes"

- sudo service motion restart
- View video from webcam
  - http://192.168.0.85:8088
- Remotely control the web cam settings:
  - http://192.168.0.85:8089

References

- http://en.wikipedia.org/wiki/Breadboard
- http://robig.net/blog/
- http://www.societyofrobots.com/electronics_led_tutorial.shtml
- http://macao.communications.museum/eng/exhibition/secondfloor/moreinfo/Displays.html
- See http://en.wikipedia.org/wiki/1-Wire for details
- http://datasheets.maximintegrated.com/en/ds/DS18B20.pdf
- http://learn.adafruit.com/category/raspberry-pi