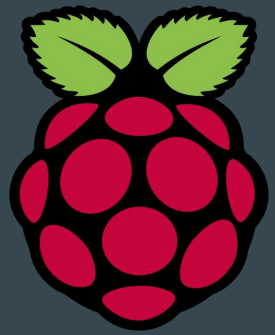




# Working with a Raspberry Pi

...

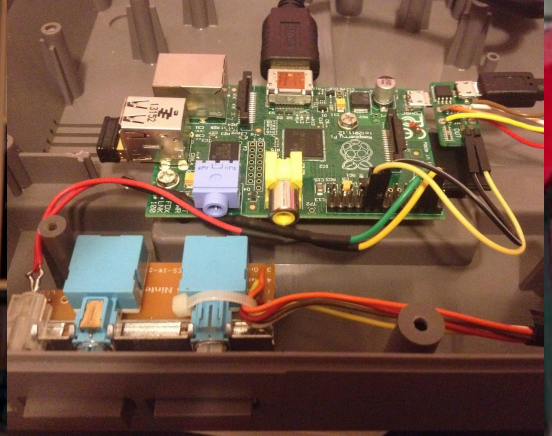
The RPi is based on Linux. You can communicate to the world using GPIO pins as well as Ethernet, USB, Audio, and Video. The RPi stands out from a regular computer because of its GPIO pins which can be controlled a variety of ways. This talk will discuss basic RPi uses and how to use the Java PI4j Library to work with hardware devices.

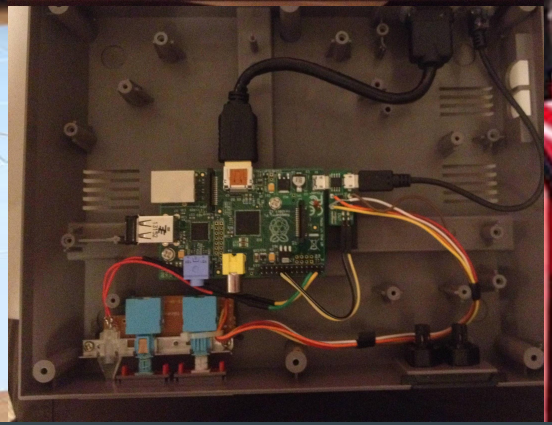
# What is a Raspberry Pi?


https://s3.amazonaws.com/gmi-digital-library/3878228e-c2ee-4267-a93e-f930ff89f9a7.jpg


This is a
Raspberry Pi!
Raspberry Pi
Power
http://arstechnica.com/information-technology/2012/12/10-raspberry-pi-creations-that-show-how-amazing-the-tiny-pc-can-be/

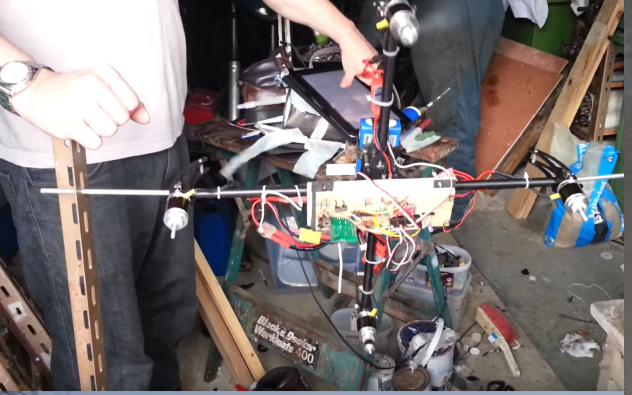
# What can it do?

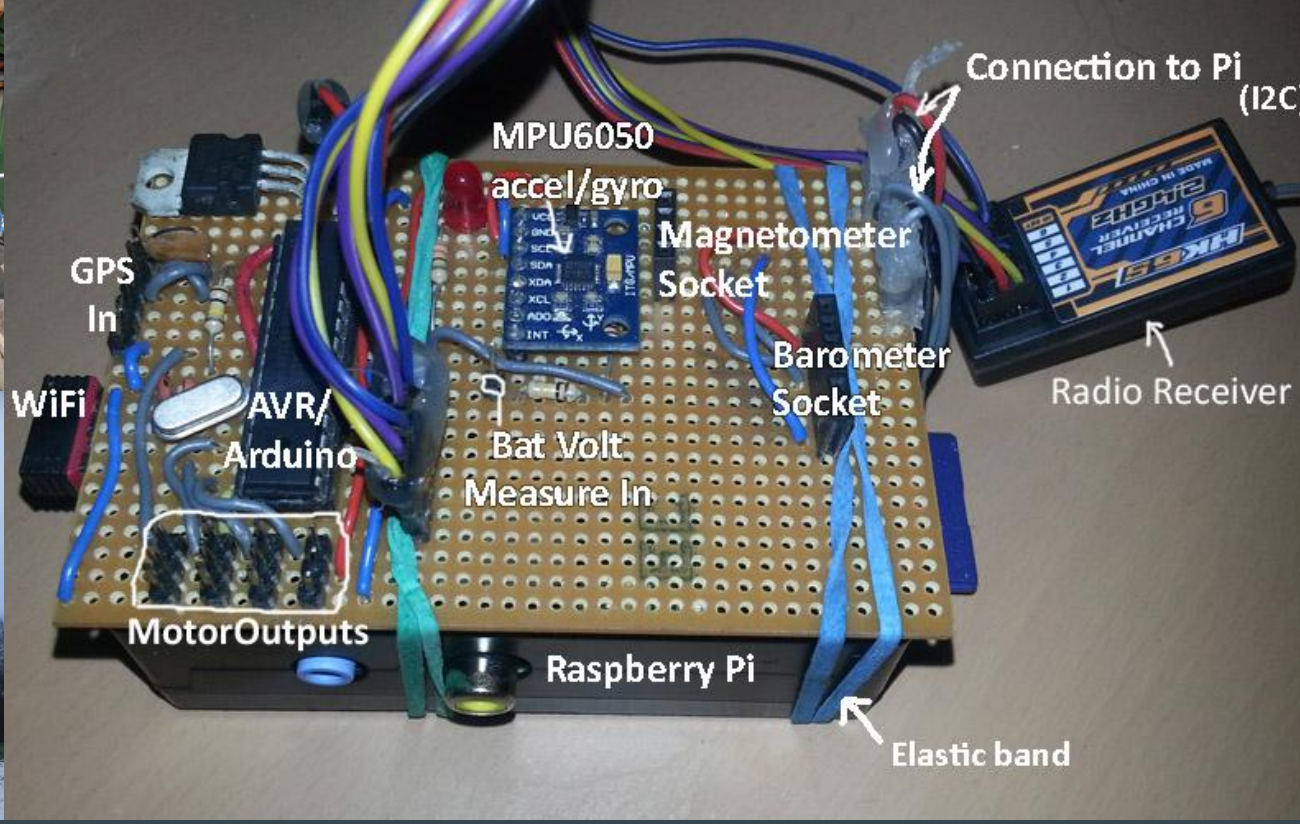






# Retro Gaming with Raspberry Pi

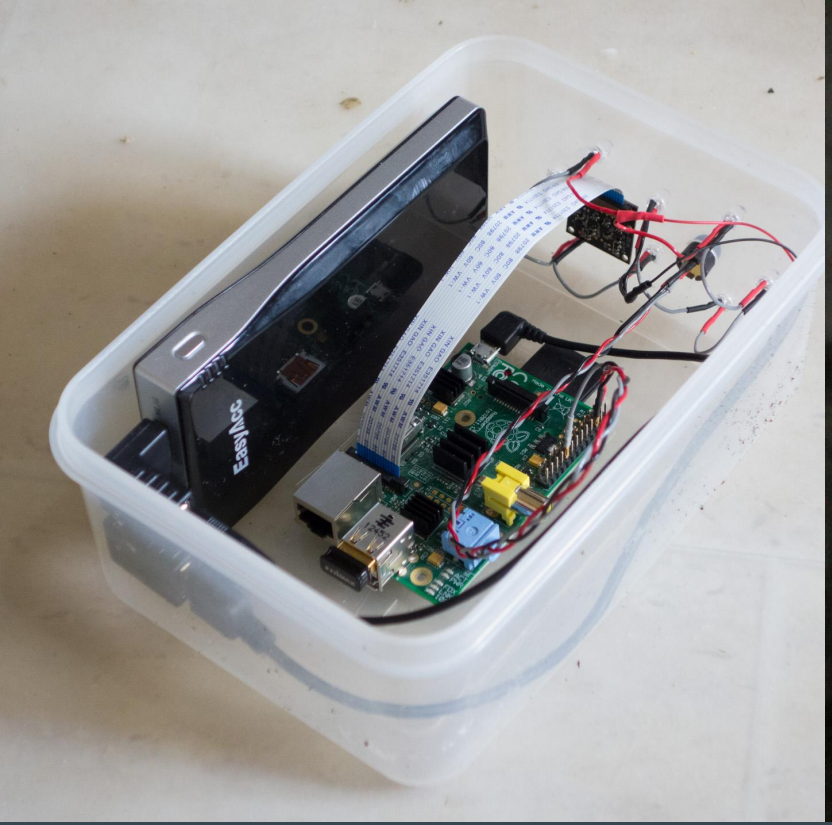
https://learn.adafruit.com/retro-gaming-with-raspberry-pi/overview
https://imgur.com/gallery/o5vjL





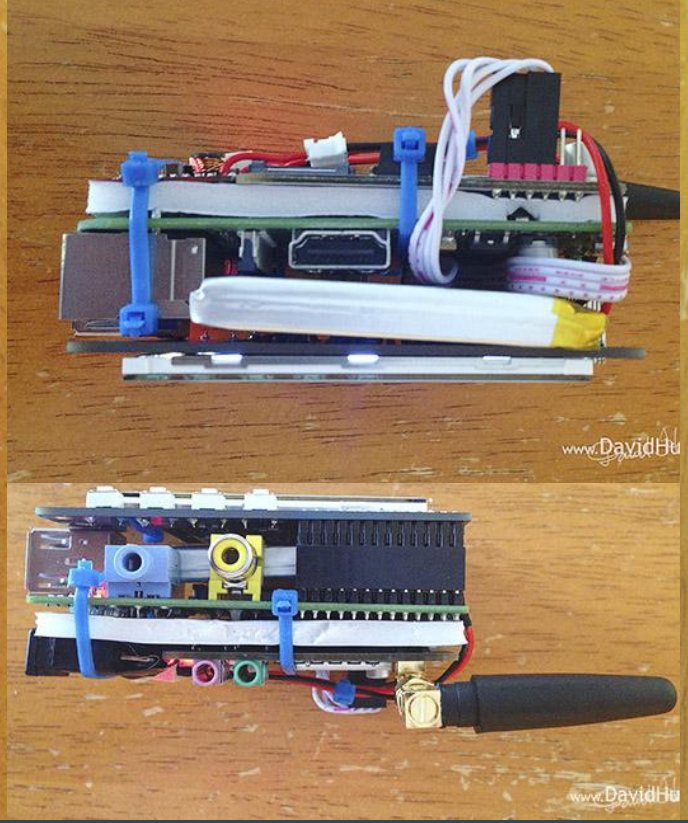

# Raspberry Pi based quadcopter

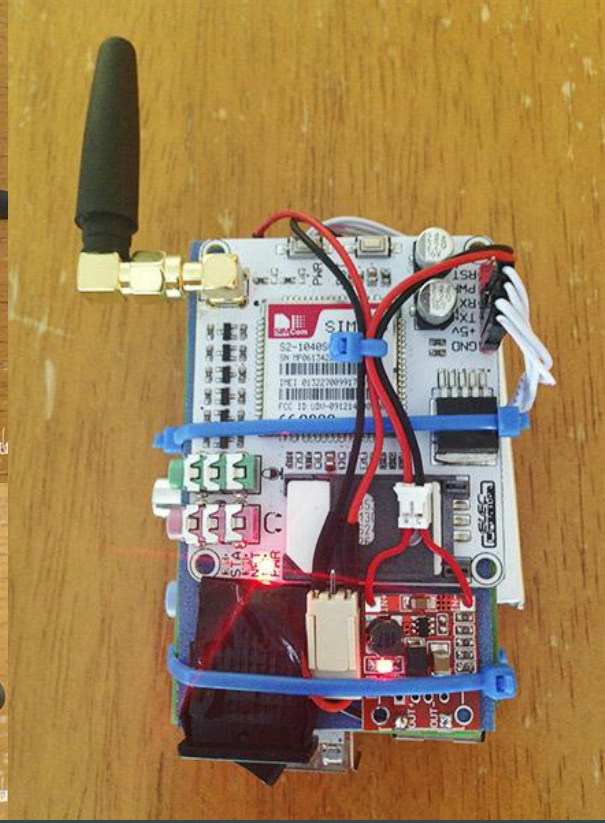
https://code.google.com/p/owenquad/




# Hedgehog Pi Recipe

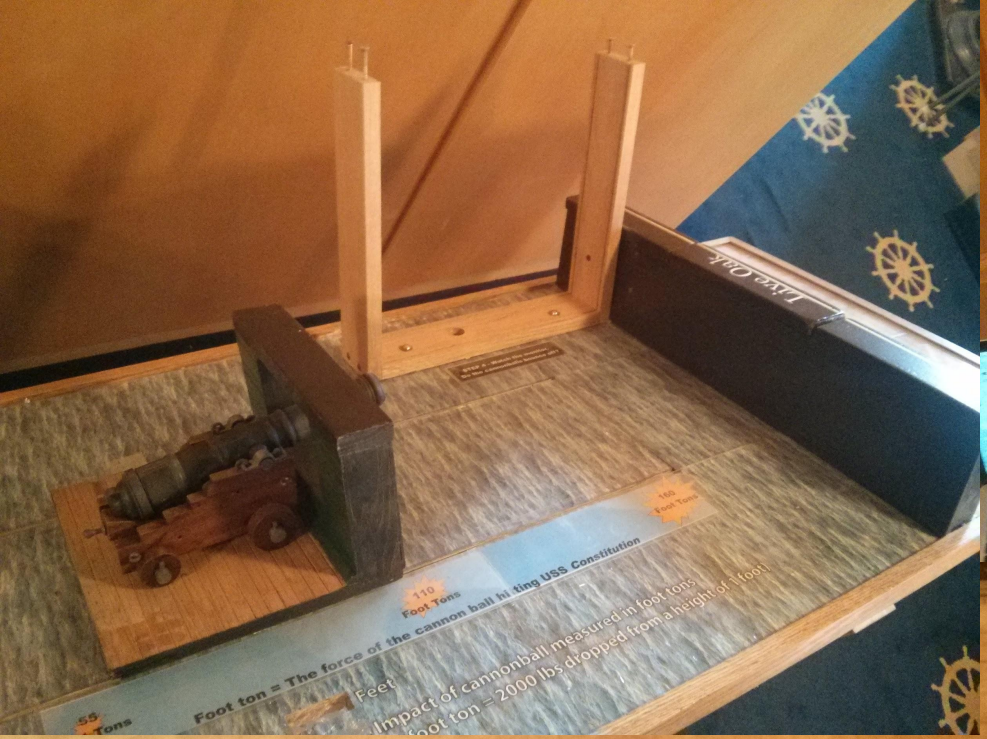
http://blog.pistuffing.co.uk/category/hedgehogpi/

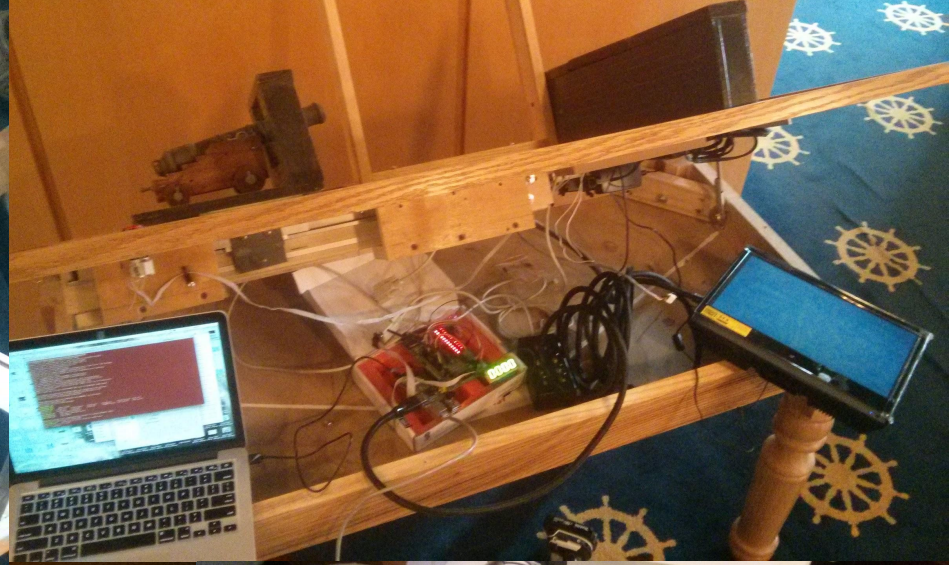



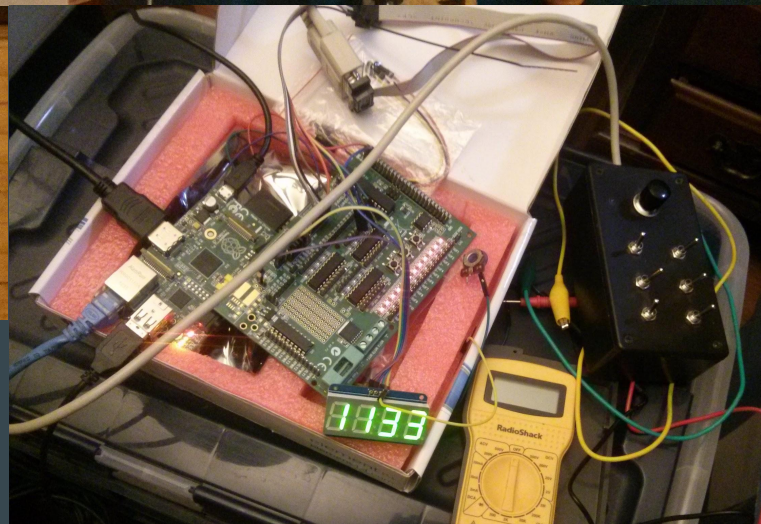



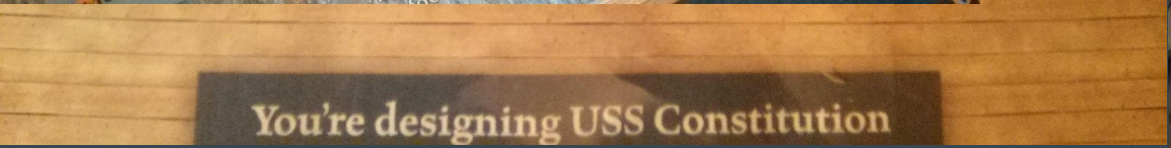
# PiPhone - A Raspberry Pi based Smartphone

http://www.davidhunt.ie/piphone-a-raspberry-pi-based-smartphone/



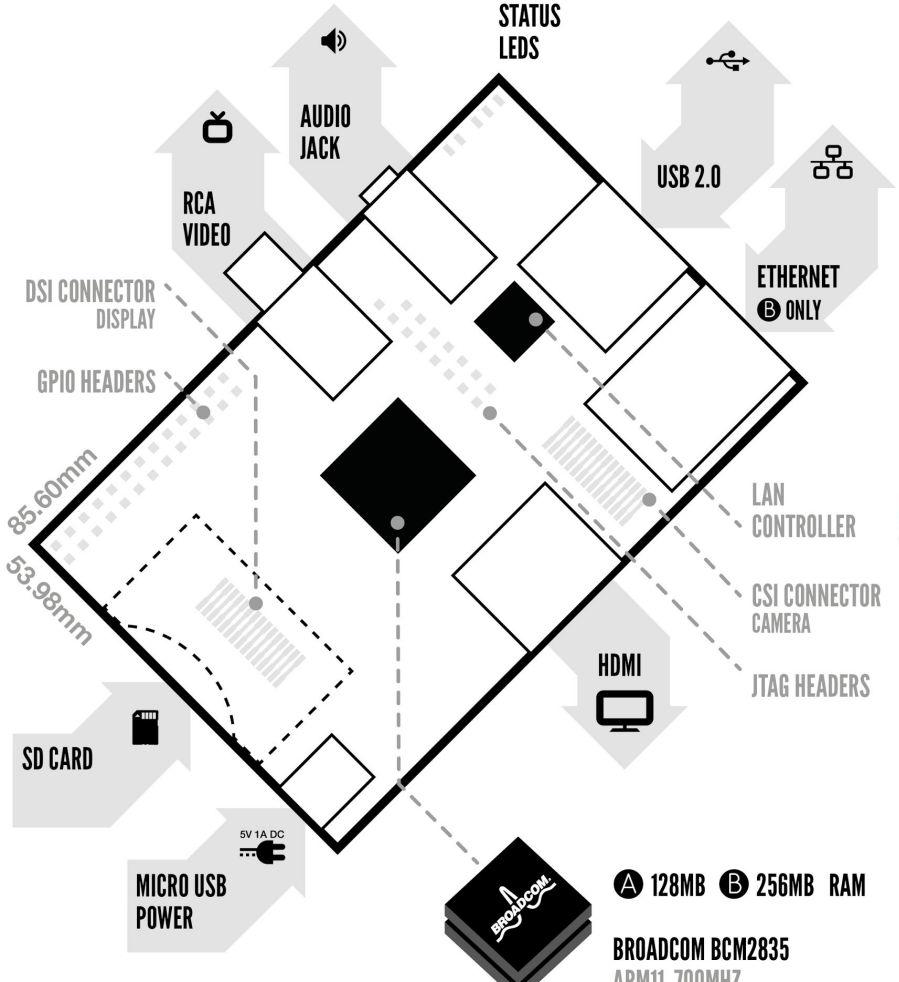


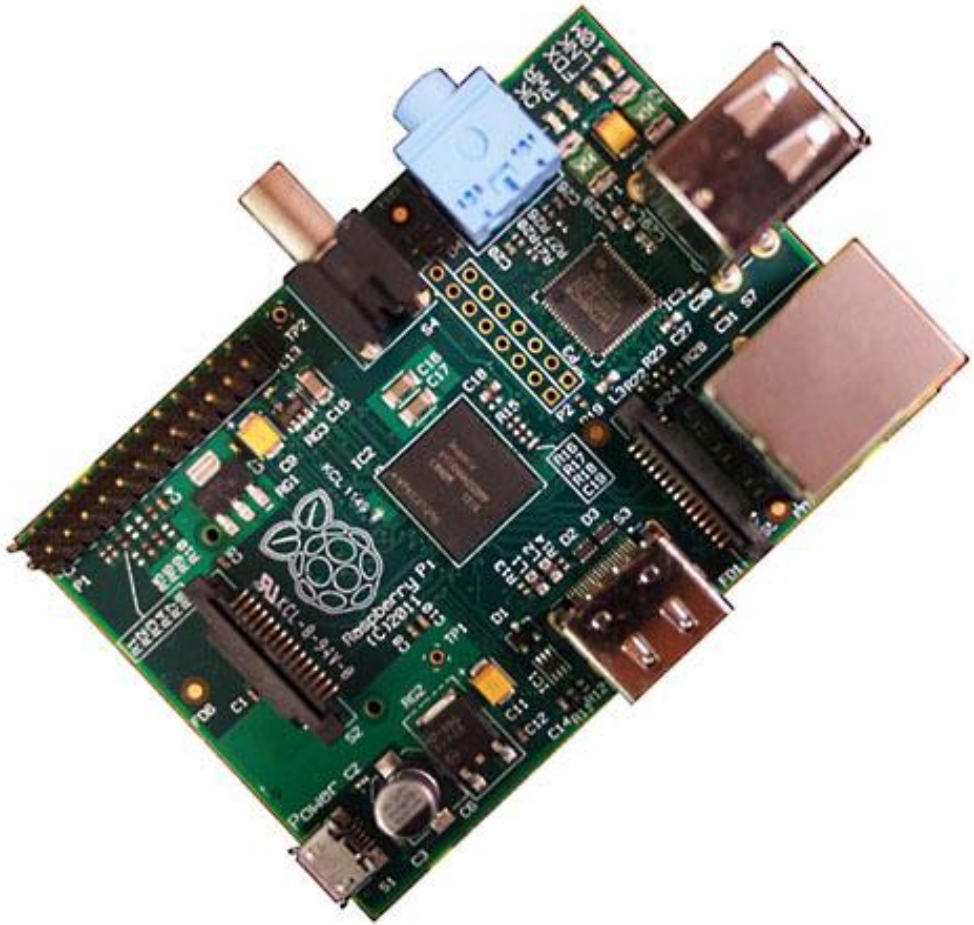




# USS Constitution Museum Cannon Force Exhibit

http://josephpcohen.com/w/uss-constitution-museum-cannon-force-exhibit/

# How do you make things with them?


STATUS LEDS
AUDIO JACK
USB 2.0
RCA VIDEO
ETHERNET
Ⓑ ONLY
DSI CONNECTOR
DISPLAY
GPIO HEADERS
85.60mm
53.98mm
LAN CONTROLLER
CSI CONNECTOR
CAMERA
HDMI
JTAG HEADERS
SD CARD
5V 1A DC
MICRO USB
POWER
Ⓐ 128MB Ⓑ 256MB RAM
BROADCOM BCM2835
ARM11 700MHZ



# It's just a regular computer! ...But it's a bit different

- For the OS it runs Raspbian Linux instead of Debian Linux
- It runs an ARM processor instead of a x86 or x64
  - Raspberry Pi 2 runs a 900 MHz quad-core ARM Cortex A7 with 1GB RAM!
  - Special package repository that has ARM compatible packages
  - Comes with **gcc** so you can compile anything you want to run!
  - Runs Java and Python
- Uses ~100mA to ~600mA from a Micro-USB cable.
  - 10000mAh battery = 16~100 hours!
- GPIO Pins! (General-purpose input/output)

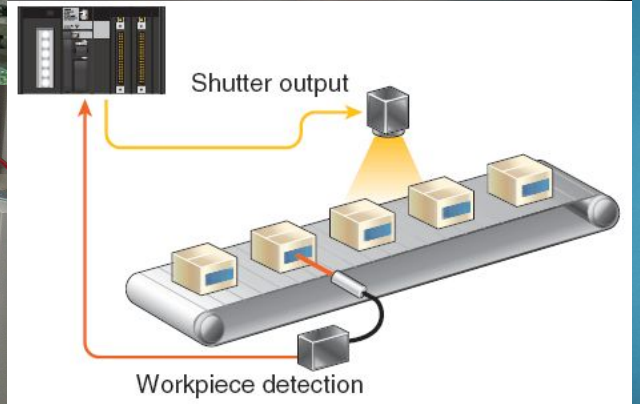
# Outline

1. What is a GPIO?
2. GPIO command line interface
    a. SysFS
    b. wiringPi
3. Pi4J Java Interface
    a. GPIOReadExample.java
    b. GPIOWriteExample.java
    c. WalkTurtleDemo.java
    d. WalkTurtleGame.java (You finish the code!)

# GPIOs are huge in industry!

Programmable Logic Controllers (PLCs) use GPIOs to power power plants, airplanes, ships, water filtration plants, bottling plants, and almost everything you have see on How it's Made!

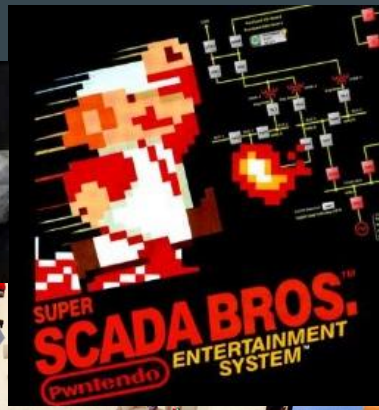





# SCADA (supervisory control and data acquisition)

These systems are full of PLCs which recently have become a target of war. It's important to understand them in order to build secure systems!





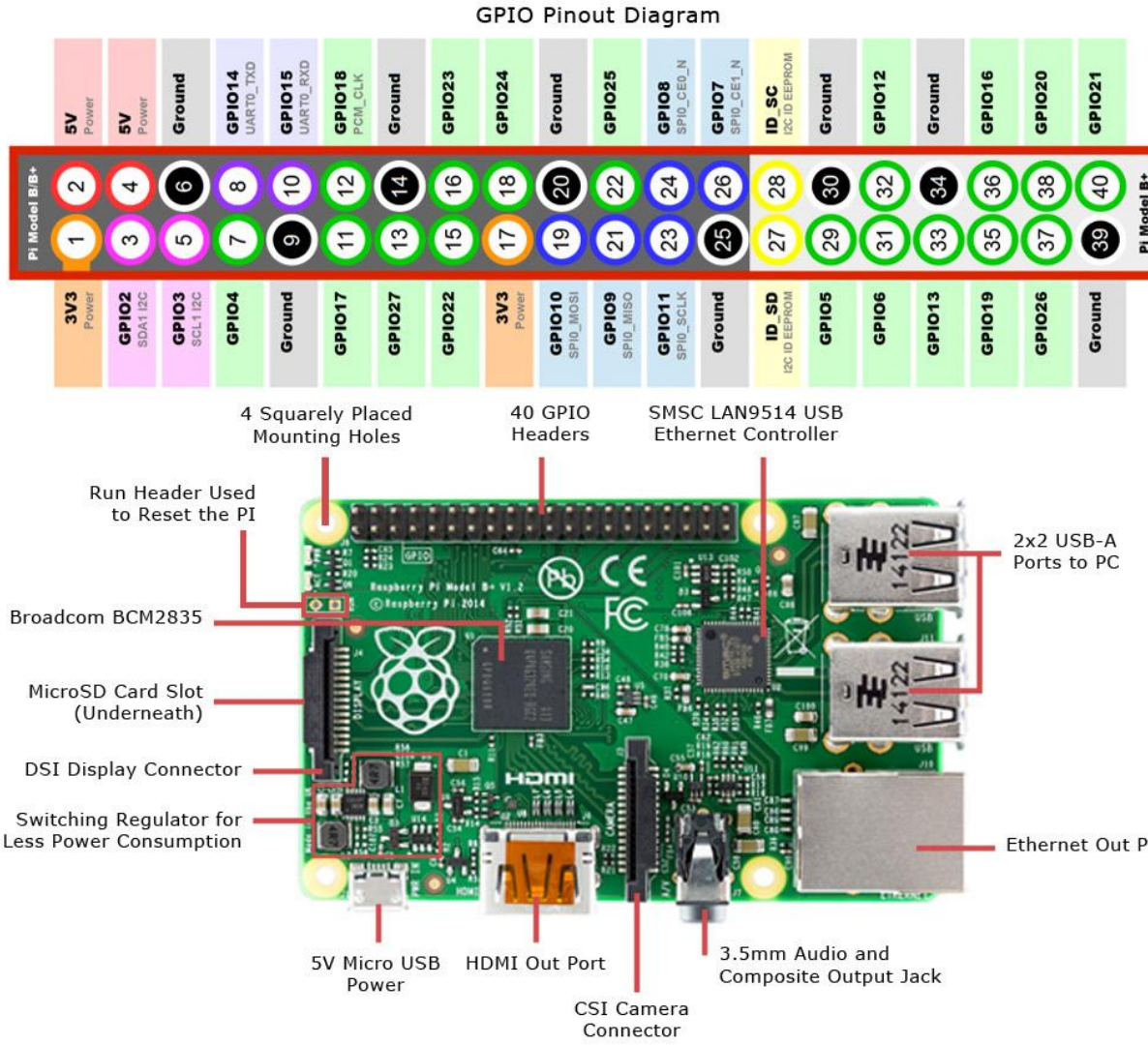

SCADA Village at Defcon 23

# GPIO Pins!

This pins allow you to read and write 3.3 volt values with the world.

When you write a value of 1 or 0 the pin will then have a 0 or 3.3 volt potential

Before you can read a value you must configure the pin to be a pullup or pulldown input. A pullup input will have a default potential of 3.3 volts (value 1) and will have the value 0 once the pin is grounded. A pulldown is the opposite.

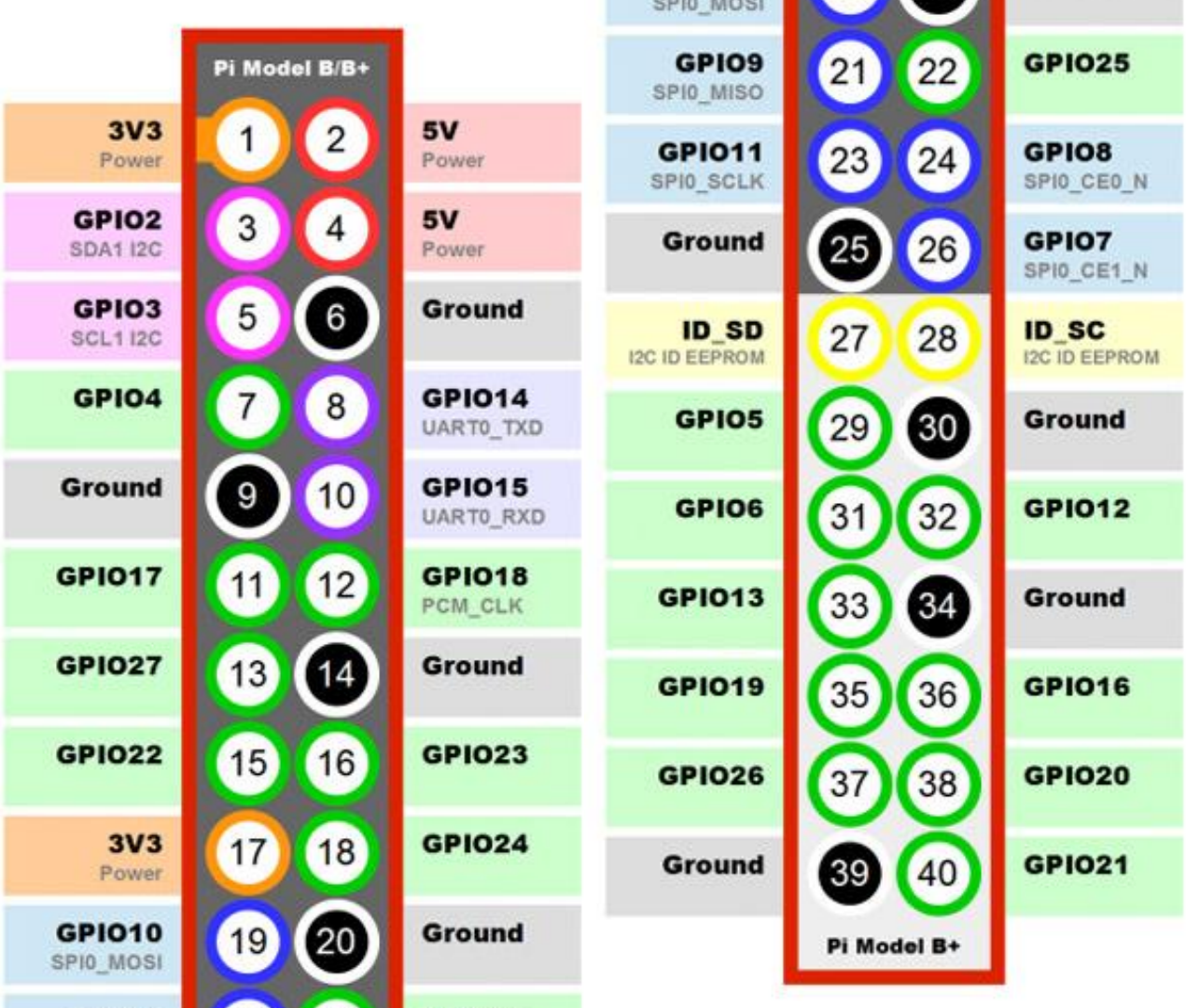


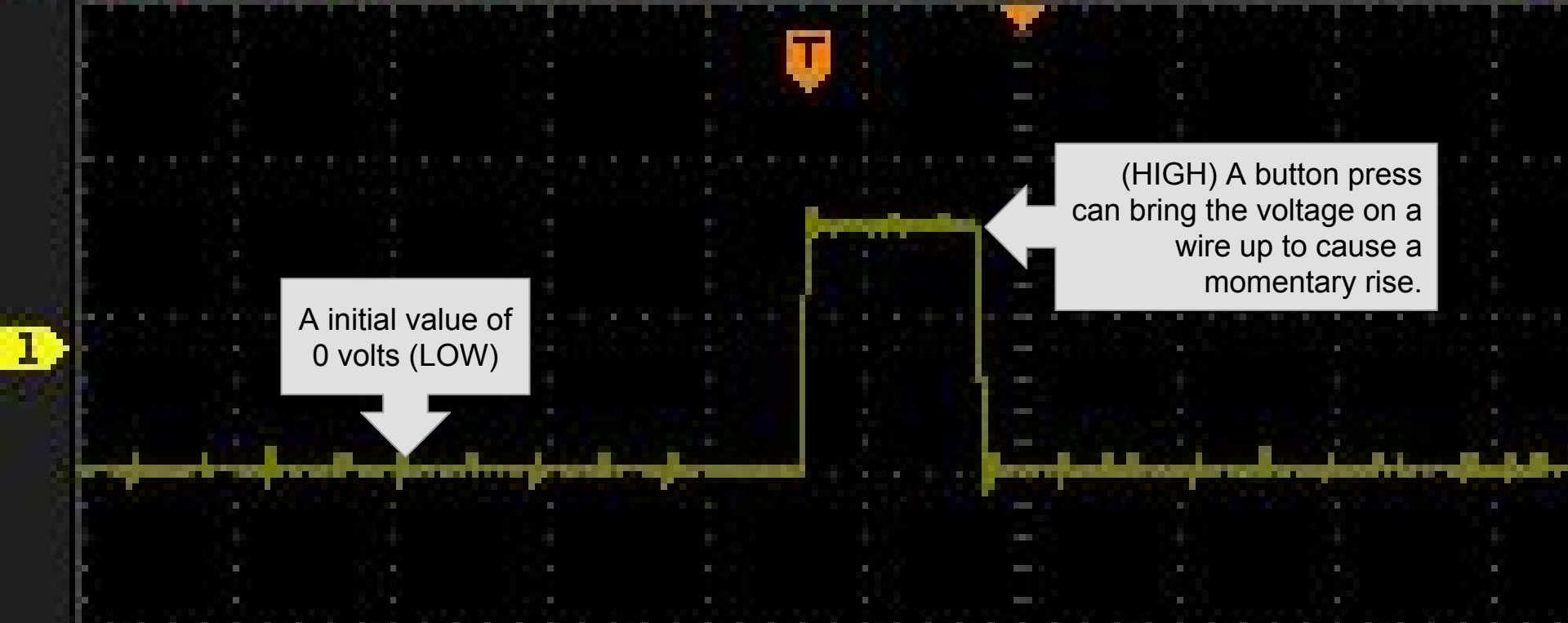
# GPIO Pins!

Some pins on the Raspberry Pi header allow access to other inputs such as the SPI and I2C busses as well as a UART.

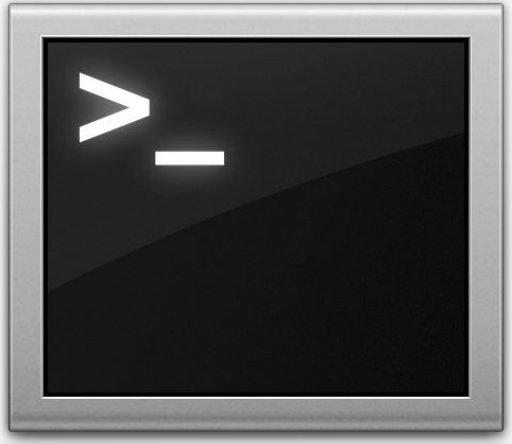
UART: A serial controller that allows buffered and timed serial communication

SPI/I2C: Busses similar to USB that connect to LCD Panels, LED arrays, Analog to Digital converters (A2D), etc






Each GPIO is a digital input from an analog signal.
When the signal is around 3.3 volts the device will read in a 1.



# GPIO command line interface

# GPIO SysFS Interface

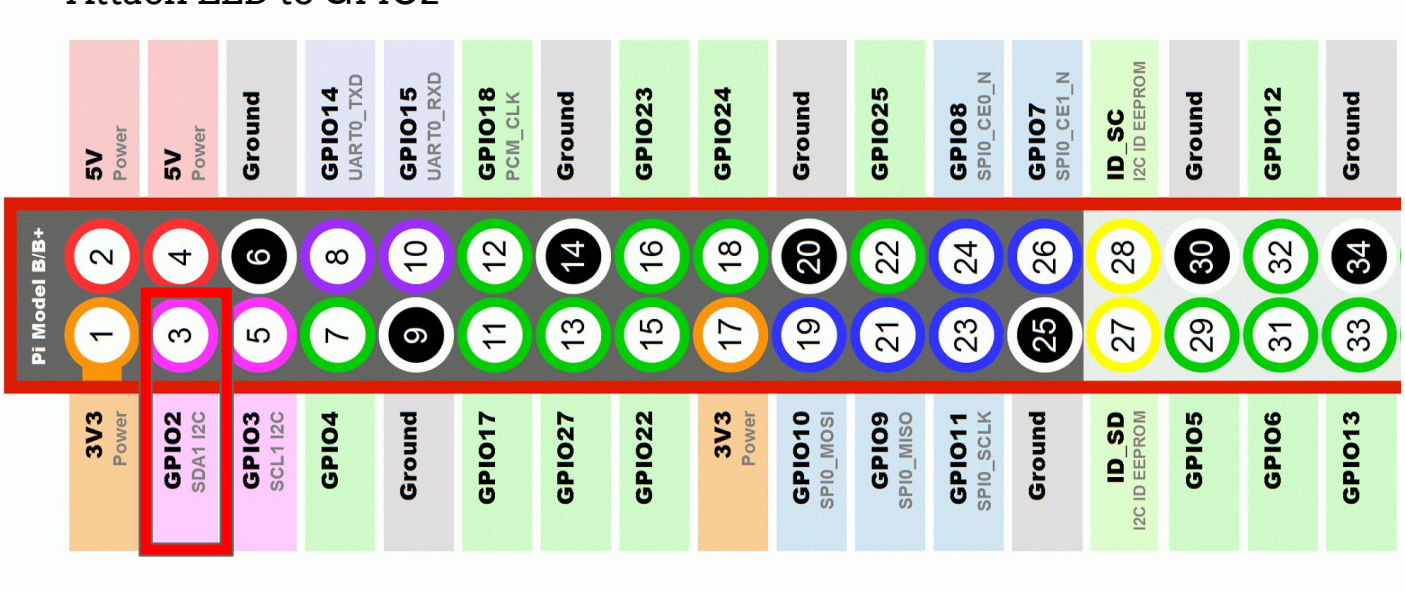
```
pi@raspberrypi /sys/class/gpio $ ls
export  gpio2  gpio3  gpiochip0  unexport
pi@raspberrypi /sys/class/gpio $
pi@raspberrypi /sys/class/gpio $
pi@raspberrypi /sys/class/gpio $
pi@raspberrypi /sys/class/gpio $
pi@raspberrypi /sys/class/gpio $
pi@raspberrypi /sys/class/gpio $
pi@raspberrypi /sys/class/gpio $
pi@raspberrypi /sys/class/gpio $
pi@raspberrypi /sys/class/gpio $
pi@raspberrypi /sys/class/gpio $ find .
.
./unexport
./gpio2
./gpio3
./export
./gpiochip0
```

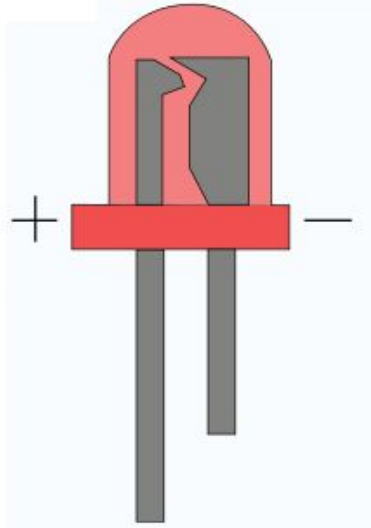
Part of the Linux kernel!

- Filesystem abstraction to GPIOs
- Not just for Raspberry Pi
- Works on desktop Linux
  - where are the pins?!
- Debug projects in the field

https://www.kernel.org/doc/Documentation/gpio/sysfs.txt

# Attach LED to GPIO2





Connect LED

Plug in + to GPIO2

Plug in - to Ground

# Echo and cat to read pin state

We must be root to work with GPIO pins

This folder gpio is a fake folder that provides access to the gpio driver

If we pipe into export it creates a new folder with new fake files. If there are errors, unexport and try again.

direction will specify "in" or "out" communication

What changes the state: "none", "rising", "falling"

Setting value to 1 or 0 will set the pins voltage to 0 or 3.3 volts.

```
$ sudo su
#

# ls /sys/class/gpio
export gpiochip0 unexport

# echo 2 > /sys/class/gpio/export


# ls /sys/class/gpio
export gpio2 gpiochip0 unexport


# ls /sys/class/gpio/gpio2
direction    edge         uevent    value    ...
```

# Echo and cat to read pin state

Set the direction of GPIO2 to "out"

Set the value of GPIO2 to HIGH

Reset the pin and change direction to in

read the current value at GPIO2. Connect GPIO2 to ground or 3.3 volts to change the value.

```
# echo out > /sys/class/gpio/gpio2/direction

# echo 1 > /sys/class/gpio/gpio2/value



# echo 2 > /sys/class/gpio/unexport
# echo 2 > /sys/class/gpio/export
# echo in > /sys/class/gpio/gpio2/direction


# cat /sys/class/gpio/gpio2/value
0
```

# WiringPi

```
pi@raspberrypi ~ $ gpio readall
 +-----+-----+---------+------+---+---Pi
 | BCM | wPi |   Name  | Mode | V | Phys
 +-----+-----+---------+------+---+----+
 |     |     |    3.3v |      |   |  1 |
 |   2 |   8 |   SDA.1 |  OUT | 1 |  3 |
 |   3 |   9 |   SCL.1 |  OUT | 1 |  5 |
 |   4 |   7 | GPIO. 7 |  OUT | 0 |  7 |
 |     |     |      0v |      |   |  9 |
 |  17 |   0 | GPIO. 0 |   IN | 0 | 11 |
 |  27 |   2 | GPIO. 2 |   IN | 1 | 13 |
 |  22 |   3 | GPIO. 3 |   IN | 1 | 15 |
 |     |     |    3.3v |      |   | 17 |
 |  10 |  12 |    MOSI |   IN | 0 | 19 |
 |   9 |  13 |    MISO |  OUT | 0 | 21 |
 |  11 |  14 |    SCLK |   IN | 0 | 23 |
 |     |     |      0v |      |   | 25 |
 |   0 |  30 |   SDA.0 |   IN | 1 | 27 |
 |   5 |  21 | GPIO.21 |   IN | 1 | 29 |
 |   6 |  22 | GPIO.22 |   IN | 1 | 31 |
 |  13 |  23 | GPIO.23 |   IN | 0 | 33 |
 |  19 |  24 | GPIO.24 |   IN | 0 | 35 |
 |  26 |  25 | GPIO.25 |   IN | 0 | 37 |
 |     |     |      0v |      |   | 39 |
 +-----+-----+---------+------+---+----+
 | BCM | wPi |   Name  | Mode | V | Phys
 +-----+-----+---------+------+---+---Pi
```

Author: Gordon Henderson
Licensed under the GNU LGPLv3

C library, GPIO utility, Easy access to:

- Read/write GPIO pin values
- Read/write gertboard a2d converters
- Debug i2c bus devices
- and more!

http://wiringpi.com/
git://git.drogon.net/wiringPi

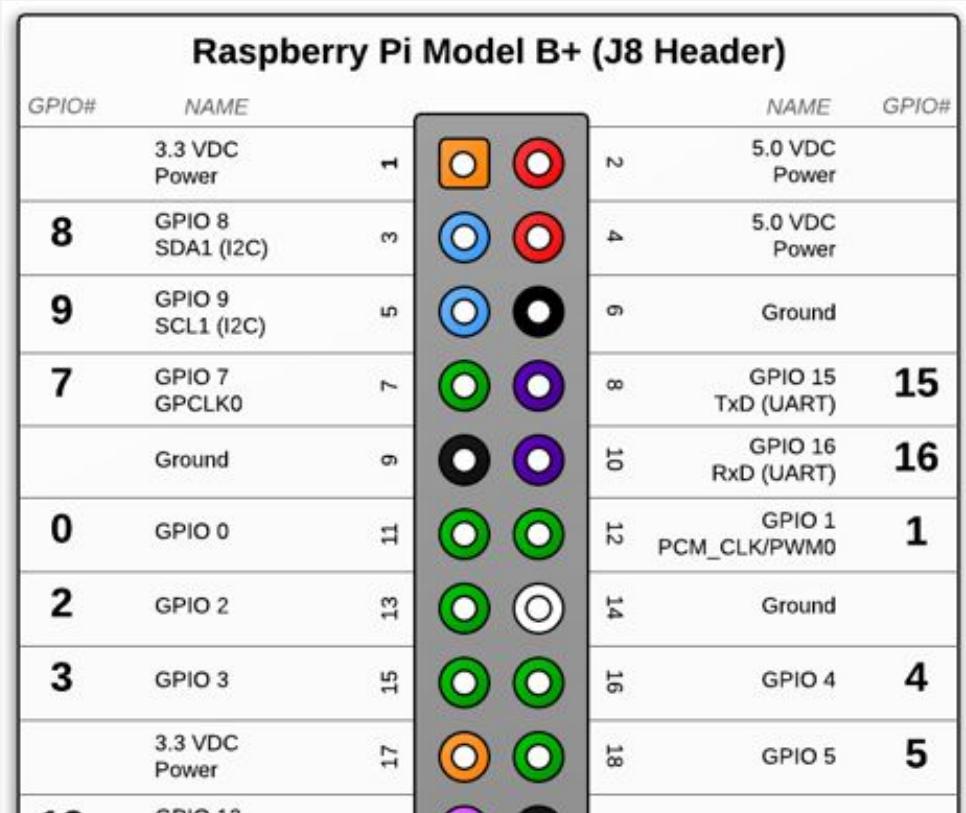
# Install WiringPi for gpio utility

```
# git clone git://git.drogon.net/wiringPi
# ./build
wiringPi Build script
=====================
WiringPi Library
[UnInstall]
[Compile] wiringPi.c
[Compile] wiringSerial.c
[Compile] wiringShift.c
...
All Done.
# gpio
Usage: gpio -v
       gpio -h
       gpio <read/write/aread/awritewb/pwm/clock/mode> ...
       gpio readall/reset
       ...
```

Different Pin Numbering Schemes!

Broadcom BCM GPIO numbers


WiringPi/Pi4J (Historic GPIO Numbers)



## Echo and cat to read pin state

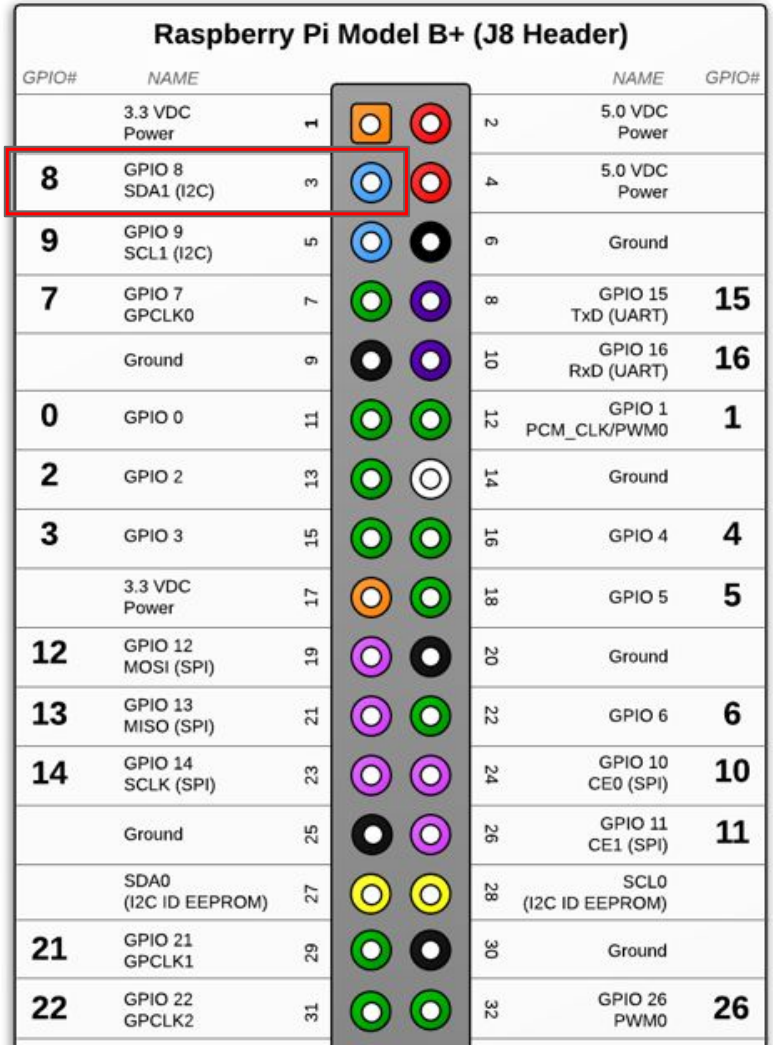
Set direction for pin number. Pin exported as needed.

Pin numbers are different than standard numbers

```
# gpio mode 8 in
# gpio read 8
0

# gpio mode 8 out

# gpio write 8 1
# gpio write 8 0
```

Read and write pins easily!

Find your pin layout: http://pi4j.com/pins/model-2b-rev1.html



# Echo and cat to read pin state

Use a while loop to repeat the reading forever

```
# while [ true ]; do gpio read 8; done
0
0
0
0
0
1
1
...
```

Press Ctrl-C to stop the loop

# The Pi4J Project

## *Connecting Java to the Raspberry Pi*


```
Author: Robert Savage
Licensed under the GNU LGPLv3

Included as a jar, able to build closed
source project around them!

http://pi4j.com/
https://github.com/pi4j
```

## Get the code and run it!

```
$ git clone https://github.com/ieee8023/RaspberryPi-ExampleGPIO
Cloning into 'RaspberryPi-ExampleGPIO'...
remote: Counting objects: 33, done.
remote: Compressing objects: 100% (30/30), done.
remote: Total 33 (delta 2), reused 28 (delta 1), pack-reused 0
Unpacking objects: 100% (33/33), done.
Checking connectivity... done.

$ cd RaspberryPi-ExampleGPIO/

$ sh compile.sh

$ sh run.sh WalkTurtleDemo

...
```

# How the scripts make our code work

The classpath is set using backticks which execute the script getclasspath.sh

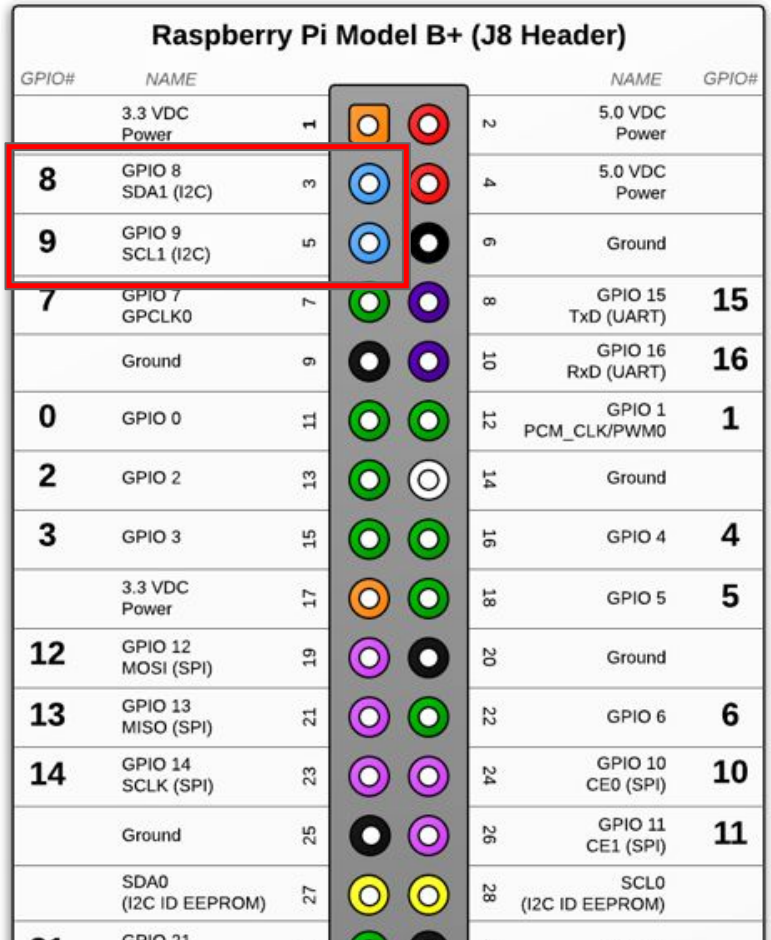
All java files are found using find which recursively searches the folder src

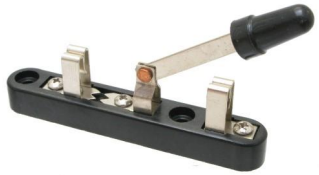
```
$ cat compile.sh
mkdir -p classes
javac -cp `sh getclasspath.sh` -d classes `find src -type f -name "*.java"`

$ cat getclasspath.sh
echo `find lib-pi4j | tr '\n' ':'`

$ cat runWalkTurtleDemo.sh
sudo java -Xmx128m -cp `sh getclasspath.sh`:classes WalkTurtleDemo
```

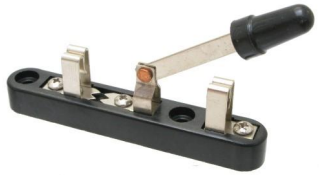
sudo is needed in run.sh in order for Pi4J access GPIO pins

This script runs the WalkTurtleDemo class.

# Attach switches to GPIO8 and GPIO9 for wiringPi



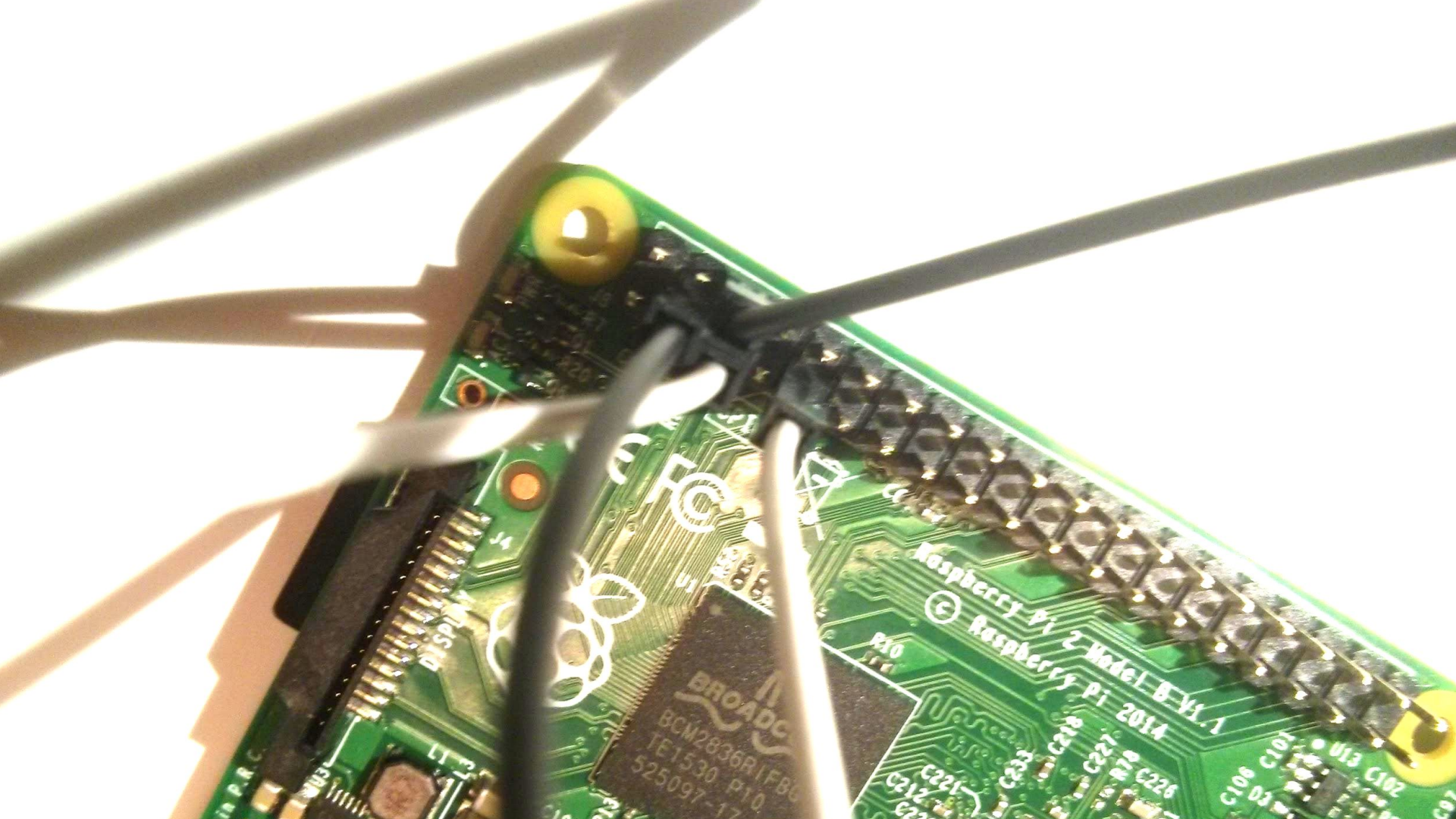





Connect Switches

Ground<->GPIO8

Ground<->GPIO9


Raspberry Pi 2 Model B v1.1
© Raspberry Pi 2014
BROADCOM
BCM2836BIFB0
TE1530 P10
525097-17

# GPIOReadExample.java

```
final GpioController gpio = GpioFactory.getInstance();
final GpioPinDigitalInput trigger = gpio.provisionDigitalInputPin(RaspiPin.GPIO_08, PinPullResistance.PULL_UP);
final GpioPinDigitalInput input = gpio.provisionDigitalInputPin(RaspiPin.GPIO_09, PinPullResistance.PULL_UP);
...
```

A singleton GPIO Controller is required to create input objects

Pi4j addresses GPIOs from 0 to 29

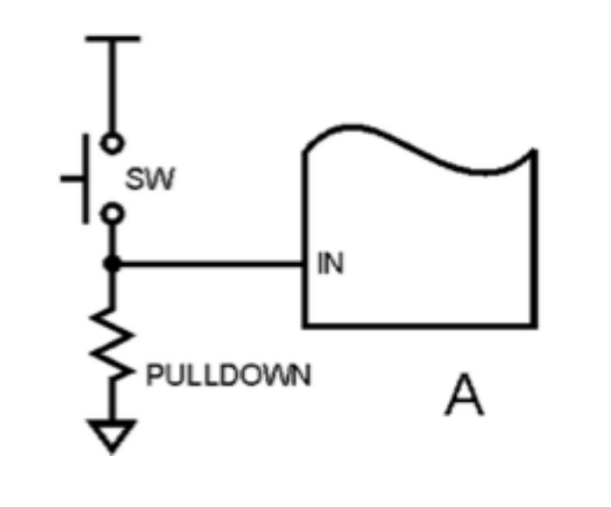
Without pull-up and pull-down resistors the GPIO may float between values or 0 or 1.

To deal with the Raspberry Pi has built in resistors that you can configure with code!

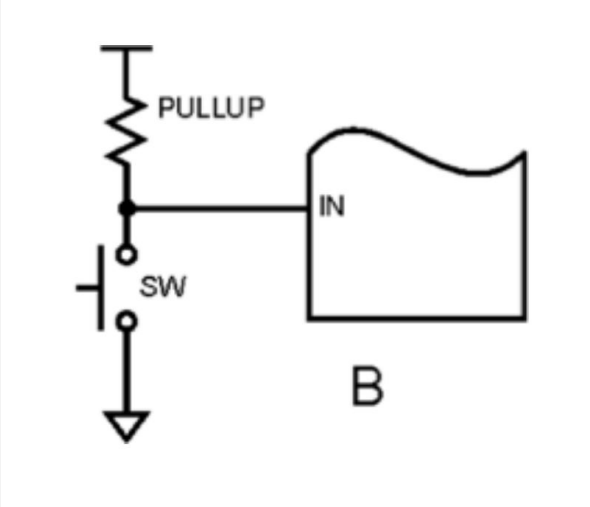
http://www.roguescience.org/wordpress/building-a-midi-out-controller/part-3-add-a-switch/exercise-6/

# GPIOReadExample.java

```
final GpioController gpio = GpioFactory.getInstance();
final GpioPinDigitalInput trigger = gpio.provisionDigitalInputPin(RaspiPin.GPIO_08, PinPullResistance.PULL_UP);
final GpioPinDigitalInput input = gpio.provisionDigitalInputPin(RaspiPin.GPIO_09, PinPullResistance.PULL_UP);
...
```




Pull-down: Input starts as 0 and 3.3 volts is needed to become 1




Pull-up: Input starts as 1 and connecting ground results in a 0

# GPIOReadExample.java

We set a debounce time of 100ms to avoid false changes

We had a listener in typical Java fashion

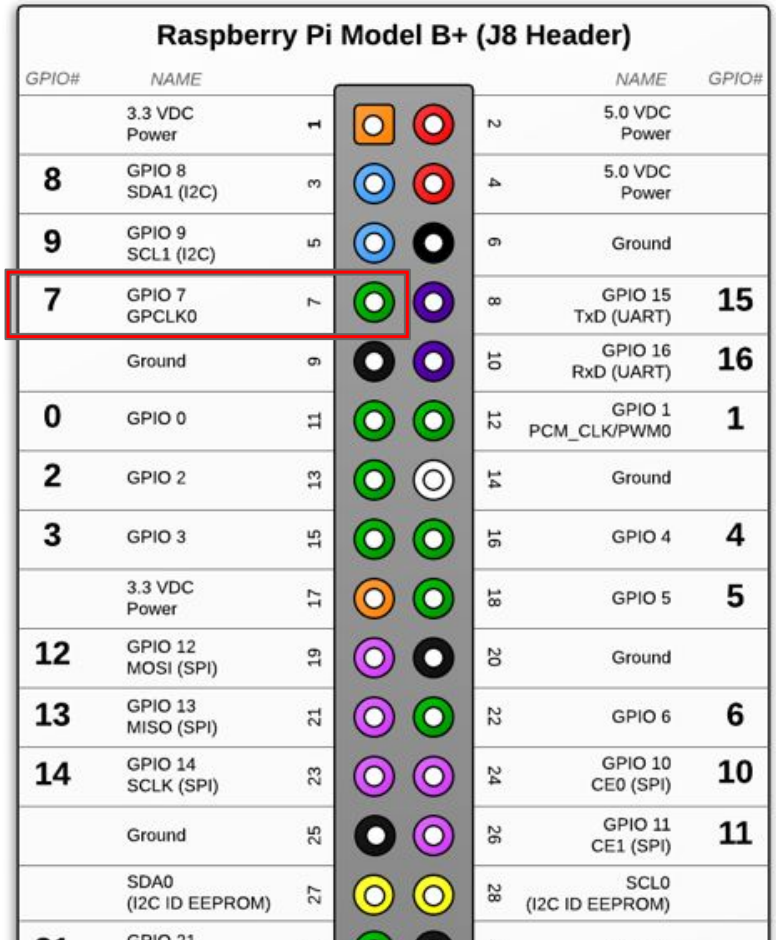
Inside the listener we can access the trigger and input variables

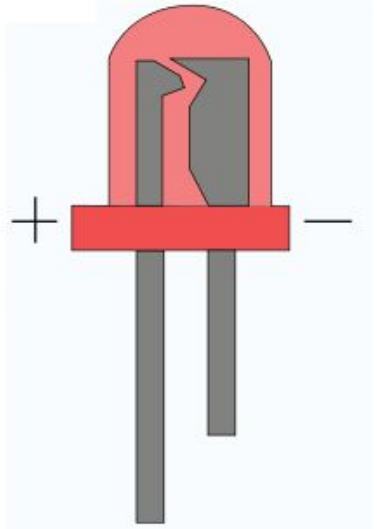
PinState is an enum with values HIGH and LOW

Continue running and wait for the pin to change state

```
final GpioPinDigitalInput trigger = ...
final GpioPinDigitalInput input =  ...
trigger.setDebounce(100);
trigger.addListener(new GpioPinListenerDigital(){
  public void handleGpioPinDigitalStateChangeEvent(...) {

    System.out.println(trigger.getPin() + " triggered!");
    PinState state = input.getState();
    if (state == PinState.HIGH)
      System.out.println(input.getPin() + " is high");
    else
      System.out.println(input.getPin() + " is low");
  }
});

while (true){ Thread.sleep(500);}
```

# Attach LED to GPIO7

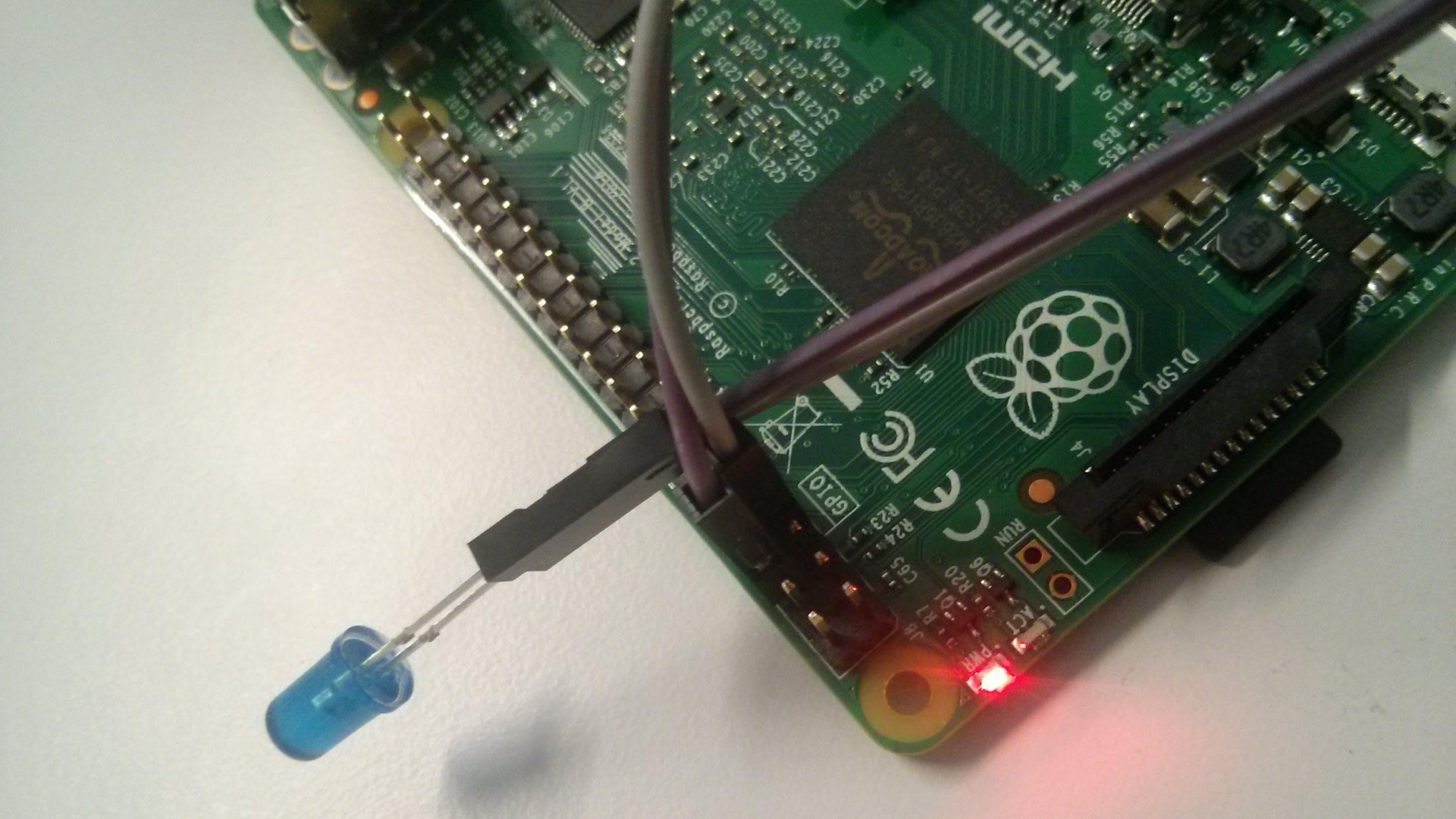


Connect LED

\+ <-> GPIO7

\- <-> Ground


HDMI
DISPLAY
GPIO
RUN
ACT
PWR

# GPIOWriteExample.java

Configure GPIO7 as output

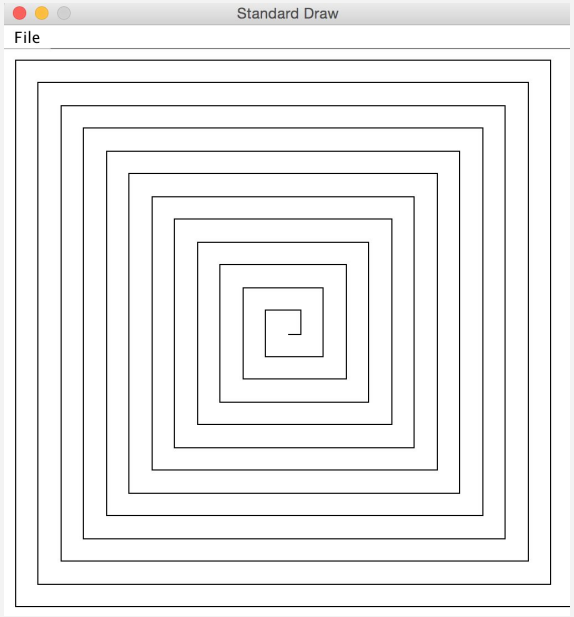
Use scheduled executor to execute Runnable object at an interval

Check and set to opposite

```
final GpioPinDigitalOutput output =
          gpio.provisionDigitalOutputPin(RaspiPin.GPIO_07);
ScheduledExecutorService exec =
               Executors.newSingleThreadScheduledExecutor();



exec.scheduleAtFixedRate(new Runnable() {

    public void run() {

        if (output.getState() != PinState.LOW)
            output.setState(PinState.LOW);
        else
            output.setState(PinState.HIGH);
    }
}, 0, 100, TimeUnit.MILLISECONDS);
```

# WalkTurtleDemo.java

The turtle can go forward and turn left. Every second the turtle turns 90 degrees and steps forward more and more




```
double x0 = 0.5, y0 = 0.5, a0 = 0.0;
final Turtle turtle = new Turtle(x0, y0, a0);

ScheduledExecutorService exec = ...
       exec.scheduleAtFixedRate(new Runnable() {

    double step = 0.002;

    public void run() {
        turtle.goForward(step += 0.02);
        turtle.turnLeft(90);
    }
}, 0, 1, TimeUnit.SECONDS);
```

# WalkTurtleGame.java

A scheduled task checks the GPIOs and updates the game

Read GPIO pins and set new rotation and speed here

The turtle turns left when the GPIO is 1 otherwise continues

Speed increases as long as GPIO is 1 otherwise we stop moving

```
ScheduledExecutorService exec = ...
exec.scheduleAtFixedRate(new Runnable() {

    double rot = 0, spd = 0;
    public void run() {

        if (true /*check if GPIO is 1*/)
            rot = (rot + turn)%360;
        else rot = 0;

        if (true /*check if GPIO is 1*/)
            spd += step;
        else spd = 0;

        turtle.goForward(spd);
        turtle.turnLeft(rot);
    }
}, 0, 500, TimeUnit.MILLISECONDS);
```

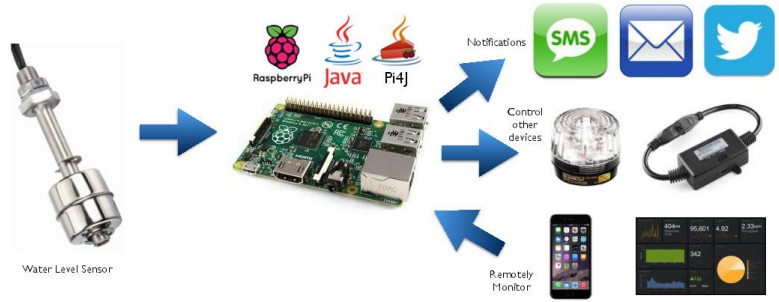
# Ideas to improve WalkTurtleGame.java

1. Use a listener to speed up feedback
2. Instead of stopping, just reduce speed
3. Change to left and right control
4. Make a goal space that gives you points
5. Paint a car that drives around
6. Add an a2d converter as accelerator

Project ideas by Robert Savage

# Basement Flood Alarm:

- Take a water level sensor and instrument it to add intelligent monitoring and notification capability



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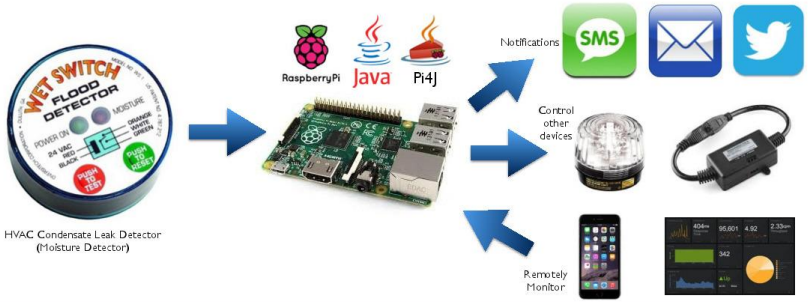
# HVAC Alarm:

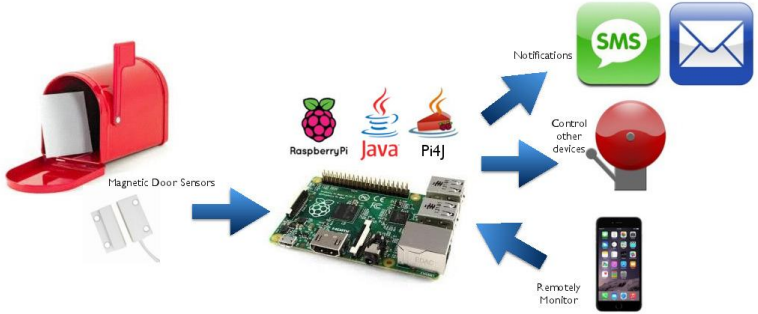
- Take a HVAC moisture sensor and extend it to add intelligent monitoring and notification capability






# Mail Notification:

- Instrument a mailbox to get notified when mail arrives.



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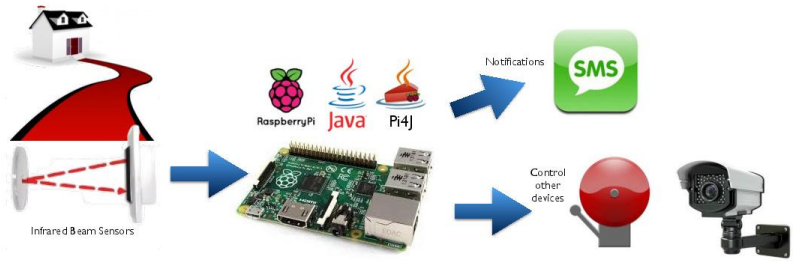
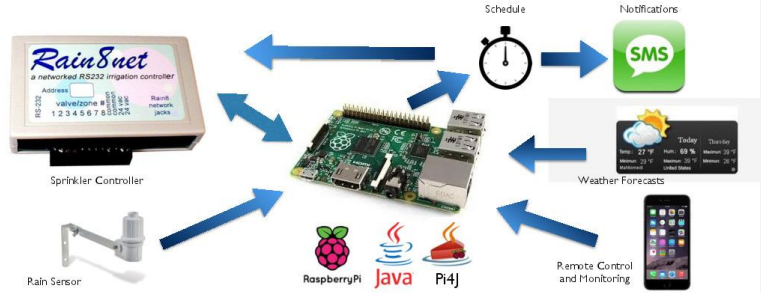
# Driveway Alarm:

- Add a sensor to driveway to get notified when someone approaches the house.



# Sprinkler System

- Remotely control, configure and schedule the system.
- Skip watering schedules if raining or if rain is forecasted



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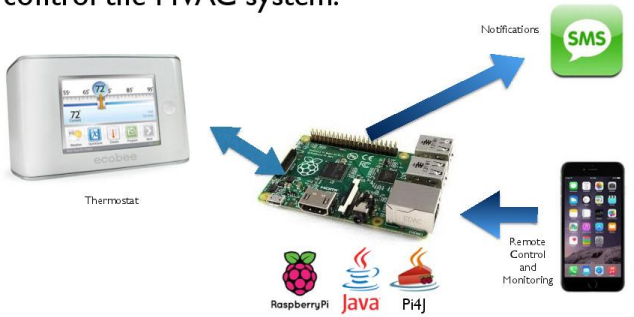
# HVAC System

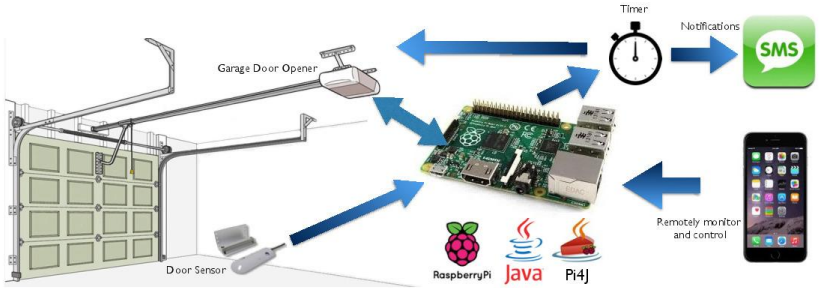
- Interface with HVAC thermostat to remotely monitor and control the HVAC system.






# Garage Door Opener:

- Remote control and monitoring of garage door
- Auto-close if left open



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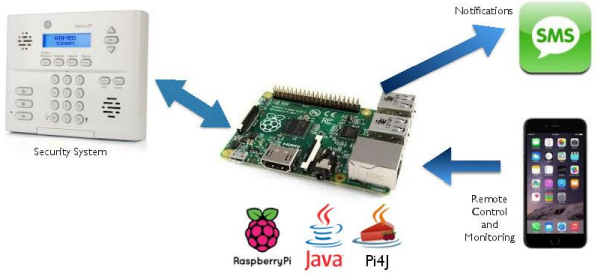
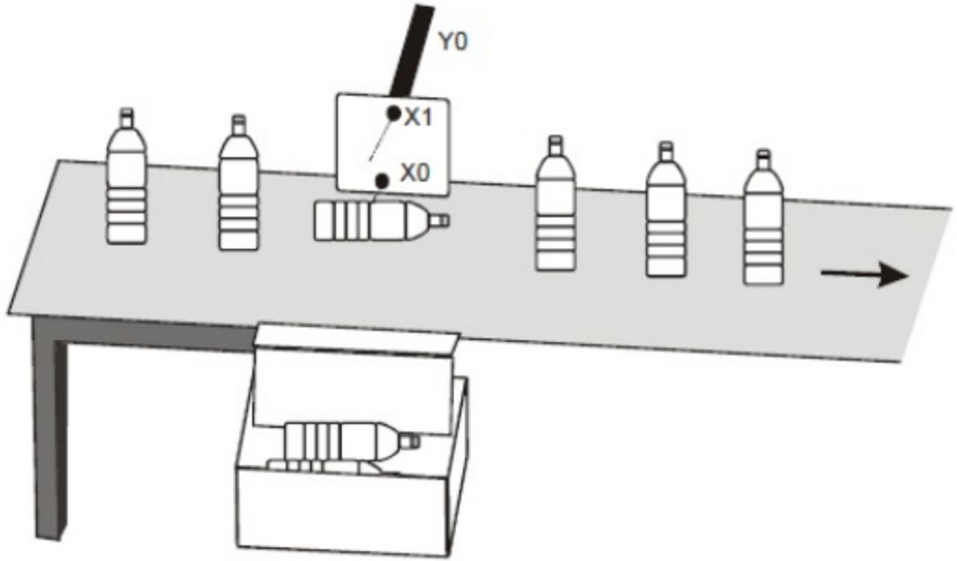
# Security System

- Remote control and monitoring of the system
- Activate other devices based on the state of the system



## 1.1 Normally Closed Contact in Series Connection



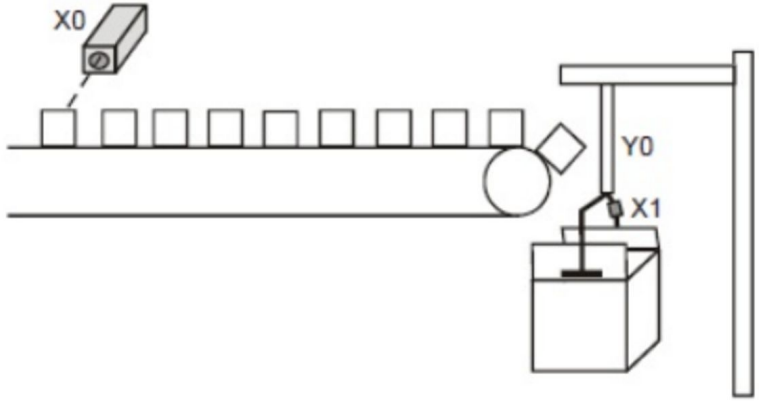

**Control Purpose:**

- Detecting the standing bottles on the conveyor and pushing the fallen bottles out

**Devices:**

| Device | Function |
|---|---|
| X0 | X0 = ON when the detected input signal from the bottle-bottom is sheltered. |
| X1 | X1 = ON when the detected input signal from the bottle-neck is sheltered. |
| Y0 | Pneumatic pushing pole |

## 2.1 Product Mass Packaging




**Control Purpose:**

- Once the photoelectric sensor detects 10 products, the robotic arm will begin to pack up. When the action is completed, the robotic arm and the counter will be reset.

**Devices:**

| Device | Function |
|---|---|
| X0 | Photoelectric sensor for counting products. X0 = ON when products are detected. |
| X1 | Robotic arm action completed sensor. X1 = ON when packing is completed. |
| C0 | Counter: 16-bit counting up (general purpose) |
| Y0 | Robotic arm for packing |

# This talk was organized and created by Joseph Paul Cohen

# Raspberry Pi Giveaway sponsored by BATEC

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