

# My first Raspberry Pi hands-on session

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**UNIMORE**  
UNIVERSITÀ DEGLI STUDI DI  
MODENA E REGGIO EMILIA

High Performance  
Real Time **Lab**

“

Programming is a skill  
best acquired by practice  
and example rather than  
from books.

ALAN TURING



# Our guy (Pi4)

General Purpose  
I/O ports (GPIO)

Eth

Pi3

Broadcom BCM2837 SoC

- 64-bit ARM Cortex-A53
- @1.2 GHz
- 512 KiB shared L2 \$

Pi4

Broadcom BCM2837 SoC

- 64-bit ARM Cortex-A72
- @1.5 GHz
- 1MiB shared L2 \$

USB

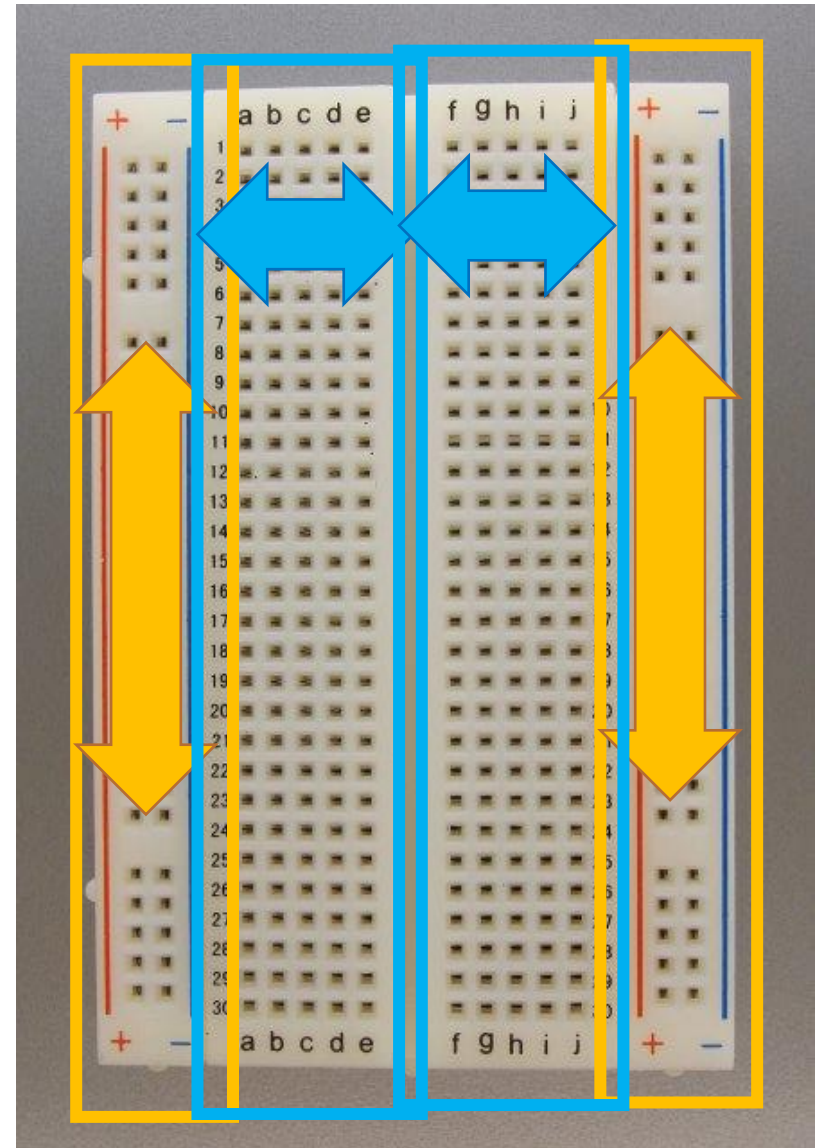
HDMI/s  
creen



# Breadboard

Provides electrical connectivity

- › Vertical vs. horizontal rails
- › (Typically, power vs other)
- › Can use jumper wires







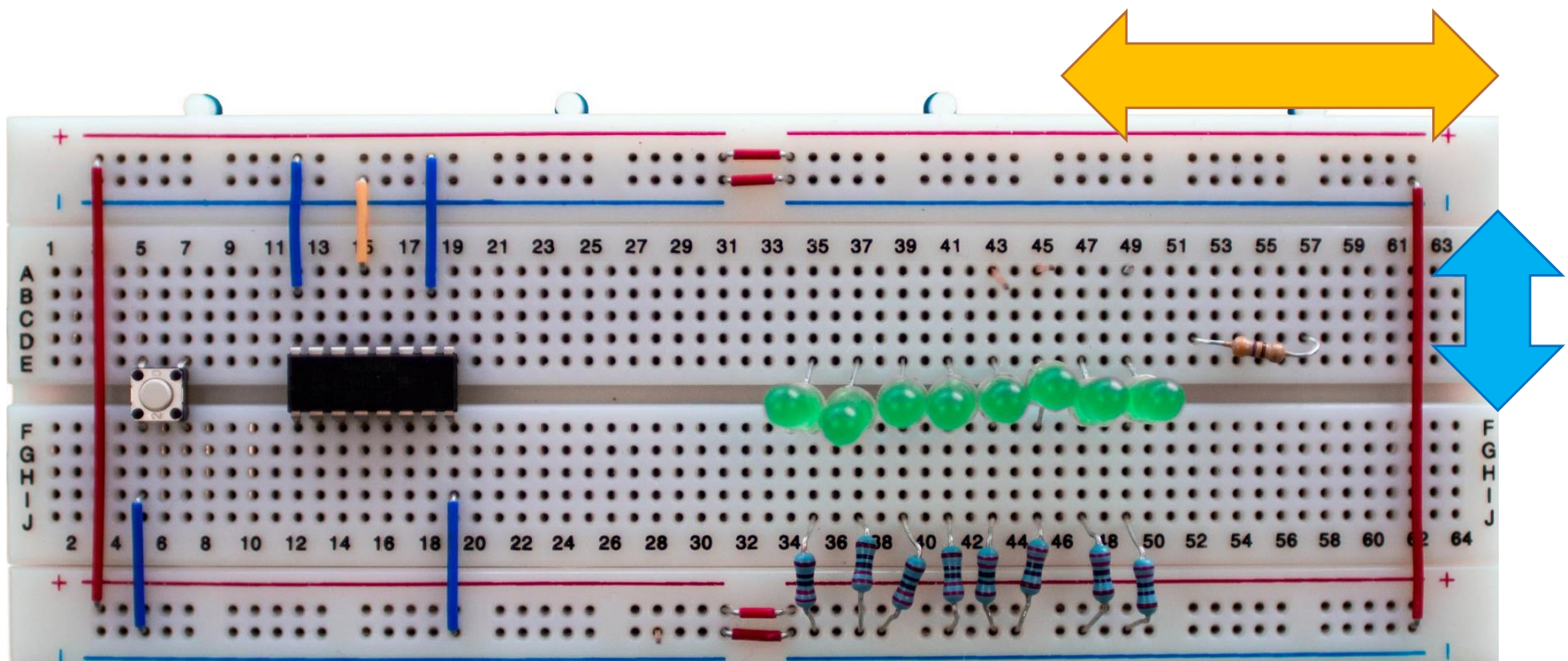
# Breadboard

The two sides of the  $+$  and  $-$  rails are wired together

- › Typically, used for power/GND

Brought to the internal rails with jumper wires

- › Where core/chip and other stuff reside



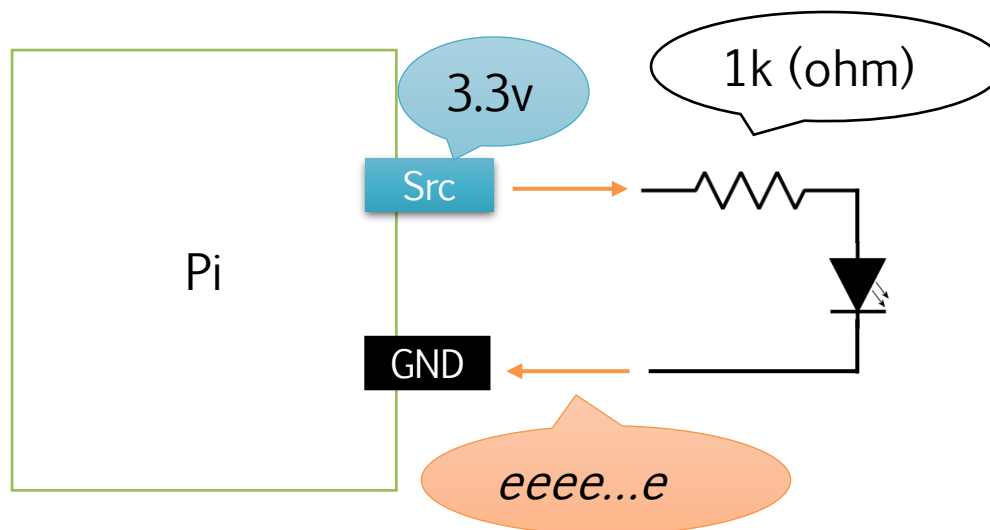


# Finally...LEDs

## Light Emitting Diodes

- › You feed with electrons; they light up
- › They have a side!!!!
- › They need a resistance to lower the charge

Wrong wiring => you burn them...





# General Purpose I/O Ports

Our interface towards the external world

- › <https://pinout.xyz/pinout/#>
- › BCM vs. Standard Wiring



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



# Software

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## Operating system

- › Debian-based GNU/Linux Distro called **Raspberry Pi OS**
  - Aka *Raspbian*
- › Also Ubuntu and Win10 IoT are supported
- › (and many more...)

## (A number of) dev environments

- › **Standard GCC toolchain**
- › Arduino IDE (micro-kernel)
- › Google's TensorFlow for AI ;)
- › ....





# Pi/ssh setup

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- › The easiest way is to compile our code directly on Pi
  - Cross-compilation requires to install the custom toolchain
- › We might connect Pi to HDMI, USB keyboard + mouse...  
...or...
- › Setup a ssh daemon, and access it via ssh

## HOWTO

- › Connect to eth, and log in (just one first time), to identify your IP address
  - Should set static IP? It typically never changes anyhow, if you do point-to-point
- › Create `/boot/ssh` empty file to enable ssh daemon at boot
  - Manual start: `$ sudo service ssh start`
- › Username: **pi** - Password: **raspberry**



# WiringPi

- › Library to interact with I/O
- › Uses “progressive” wiring

Let's see  
this in  
action



Raspberry Pi GPIO Header

BCM	WiringPi	Name	Physical	Name	WiringPi	BCM
		3.3v	1	2	5v	
2	8	SDA.1	3	4	5V	
3	9	SCL.1	5	6	0v	
4	7	1-Wire	7	8	TxD	15
		0v	9	10	RxD	16
17	0	GPIO. 0	11	12	GPIO. 1	1
27	2	GPIO. 2	13	14	0v	
22	3	GPIO. 3	15	16	GPIO. 4	4
		3.3v	17	18	GPIO. 5	5
10	12	MOSI	19	20	0v	
9	13	MISO	21	22	GPIO. 6	6
11	14	SCLK	23	24	CE0	10
		0v	25	26	CE1	11
0	30	SDA.0	27	28	SCL.0	31
5	21	GPIO.21	29	30	0v	
6	22	GPIO.22	31	32	GPIO.26	26
13	23	GPIO.23	33	34	0v	
19	24	GPIO.24	35	36	GPIO.27	27
26	25	GPIO.25	37	38	GPIO.28	28
		0v	39	40	GPIO.29	29
BCM	WiringPi	Name	Physical	Name	WiringPi	BCM



# WiringPi API

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Include library header

```
#include <wiringPi.h>
```

(In desktop environments doesn't exist, so you shall use macro to remove this code, e.g., NO\_PI)

Init library, and every GPIO port

```
wiringPiSetup(); // Init lib  
pinMode(0, OUTPUT); // GPIO 0 is output port
```

Write to port

```
digitalWrite(0, true); // Set port 0
```

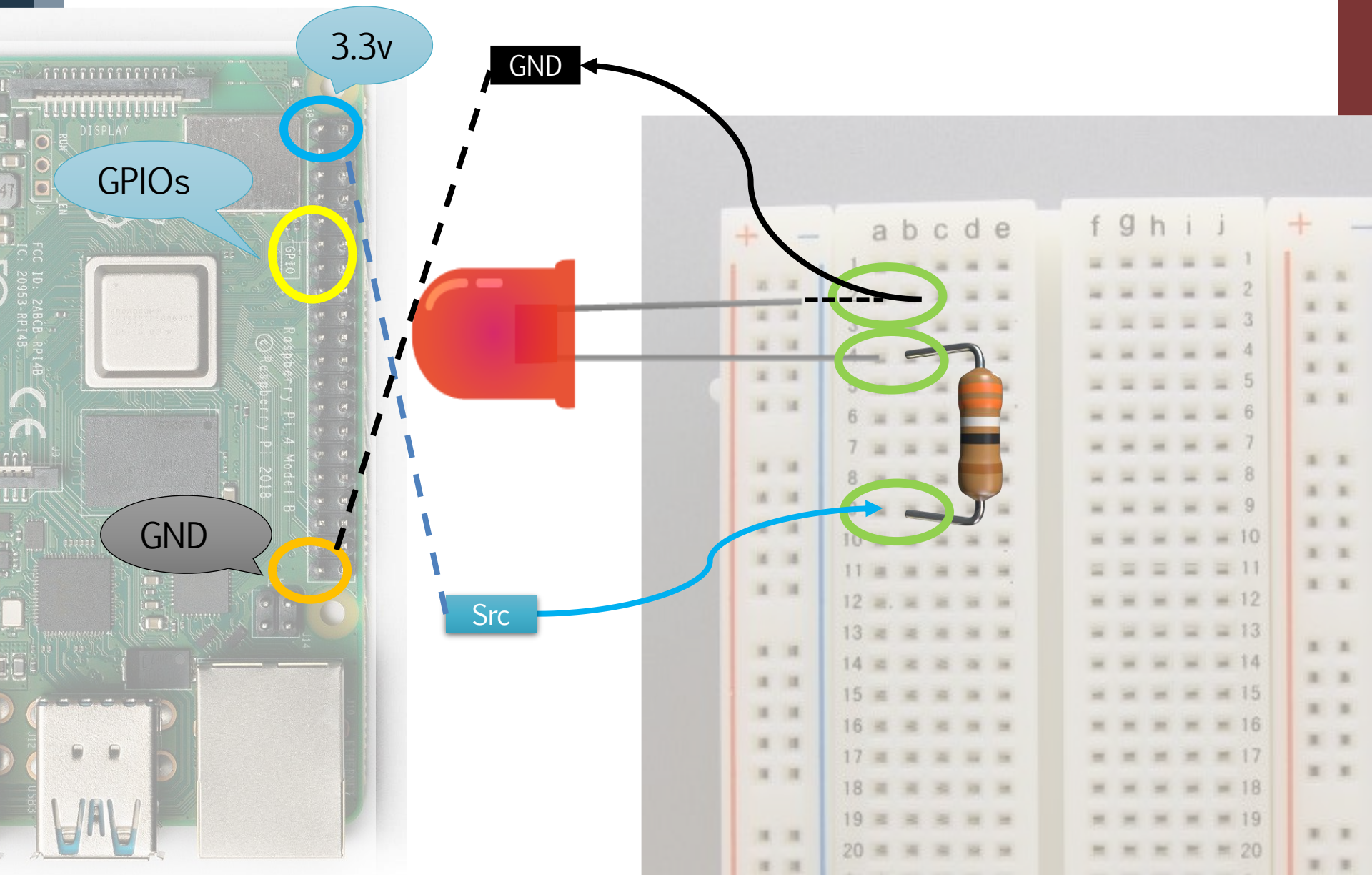
Link library

```
$ gcc ..... -l wiringPi
```





# E/E system





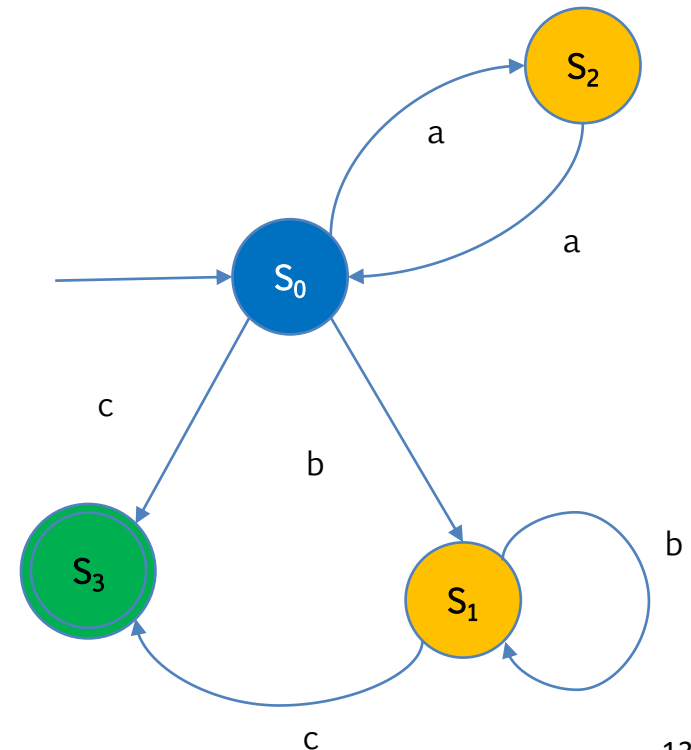
# Exercise

Let's  
code!

- › Implement the Moore machine of the FSM that understands whether a word is from L

*"Identify even sequences of a (even empty),  
followed by one, or more, or no, b, ended by c"*

- › ..and turns on the corresponding led color
  - Blue => GPIO 0
  - Red (error state) => GPIO 1
  - Yellow => GPIO 2
  - Green => GPIO 3





# Java on RPi





# Set-up

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See also "IoT" course from Prof. Picone

Install java using apt tool

```
$ sudo apt update && sudo apt install default-jdk
```

Set up JAVA\_HOME env var

```
$ export JAVA_HOME="/usr/lib/jvm/default-java"
```

```
$ export PATH=$PATH:$JAVA_HOME/bin
```

› (tip: set it in ~/.bashrc )



Install Maven

› Download, and follow instructions, from <http://maven.apache.org/install.html>

› (don't forget to set M2\_HOME and PATH vars in ~/.bashrc )



# Recap: eclipse Paho

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Eclipse Paho Java client

- › MQTT client lib

Download and install

- › <https://www.eclipse.org/paho/index.php?page=clients/java/index.php>

Dependencies

- › SLF4J



# PI4J: GPIO with Java



**The Pi4J Project**

*Java I/O library for the Raspberry Pi*

What it is

- › A library to control GP I/O on a Raspberry Pi

How to install the lib

```
$ curl -sSL https://pi4j.com/install | sudo bash
```

- › Target path /opt/pi4j/lib

Examples and code snippets

```
$ git clone https://github.com/Pi4J/pi4j.git
```

- › Compile with Maven

```
$ mvn package
```

- › Run (Beware: default example uses GPIO #1)

```
$ java -cp /opt/pi4j/lib/\*:target/??.jar ControlGpioExample
```



# Exercise

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Let's  
code!

## Traffic light

- › (Re)implement the traffic light FSMs so that we can dynamically switch among them using a MQTT topic sent by an external entity
  - I use MQTT Explorer, under Win, you can also use `AuthProducer.java`
  - `AuthConsumer.java`
- › TLs also publish their status on a MQTT topic, together with their time-to-change
  - In JSON (`JsonProducer.java`)
- › You will have to implement your JSON model `TrafficLightDescriptor.java`
  - Can get inspiration by [https://github.com/HiPeRT/MASA\\_protocol/blob/master/include/objects.hpp](https://github.com/HiPeRT/MASA_protocol/blob/master/include/objects.hpp)

## Some hints/design rules

- › Every TL has a unique ID, and sub-id ("orientation")
- › They are paired two-by-two, to implement 4-way crossroads
- › You will also need to create a protocol





# How to run the examples

Let's  
code!

Find them in Code/ folder from the course website

Use when compiling  
with desktop/laptop

For C++: compile

```
$ gcc code.cpp [-D NO_PI] -o code -Wall -l stdc++ [-l wiringPi]
```

Run (bash/cygwin)

```
$ ./code[.exe]
```

Use when compiling  
on Raspberry Pi

For Java/Maven: compile

```
$ mvn package
```

Run (command line)

```
$ java -cp /path/to/libs/\*:target/?????.tar <main-class>
```

Add folders separated  
by ':' or ';' on Win

Your tar, and the full  
name of your class



# References

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## Course website

- › [http://hipert.unimore.it/people/paolob/pub/Industrial\\_Informatics/index.html](http://hipert.unimore.it/people/paolob/pub/Industrial_Informatics/index.html)

## My contacts

- › [paolo.burgio@unimore.it](mailto:paolo.burgio@unimore.it)
- › <http://hipert.mat.unimore.it/people/paolob/>

## Resources

- › <https://www.digikey.com/en/maker/blogs/2019/how-to-use-gpio-on-the-raspberry-pi-with-c>
- › <http://maxembedded.com/2014/07/using-raspberry-pi-gpio-using-python/>
- › <https://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-resistor-color-code>
- › Pi wires -> [https://pinout.xyz/pinout/pin11\\_gpio17#](https://pinout.xyz/pinout/pin11_gpio17#) | <http://wiringpi.com/>
- › Pi4J -> <https://pi4j.com/1.2/install.html> | <https://pi4j.com/1.2/example/control.html> | <https://github.com/Pi4J/pi4j>
- › A "small blog -> <http://www.google.com>