

A PharoThings Tutorial

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In this booklet we will show you how to develop a little application that collect weather information. We will start to show how we can play with leds and others.



Installations

The first step you need to do to get started with PharoThings is to install an Operating System in your Raspberry Pi. When you buy a Raspberry Pi, the OS is not factory installed.

1.1 Installing OS on RASPBERRY (RASPBIAN)

In this chapter, we will download and install NOOBS (New Out Of the Box Software). NOOBS is an easy operating system installer which contains Raspbian (<https://www.raspberrypi.org/downloads/raspbian/>) and LibreELEC (<https://libreelec.tv>).

Raspbian is the Foundation's official supported operating system, a Linux OS based on Debian Stretch to run in ARM processors.

Download

You can download an official image from the Raspberry Pi website Noobs downloads page (<https://www.raspberrypi.org/downloads/noobs/>). You will download a zip file and extract the files to your SD card.

Copying

You will need a computer with an SD card reader to install the image. This process basically extracts the files from the zip file downloaded into an SD card formatted and start the Raspberry Pi with this SD card.

You can go directly to your operating system by clicking on the links below:

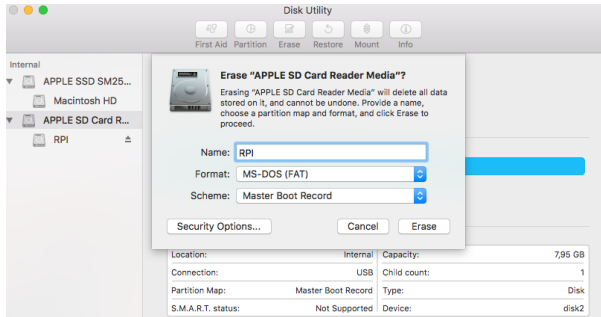


Figure 1-1 Preparing SD Card.

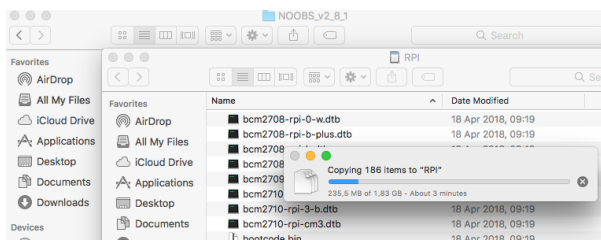


Figure 1-2 Copying NOOBS.

1.2 Copying Raspbian files on MAC OSX

- Open “disk utility”, select the SD Card and Erase (Format MS-DOS FAT) as shown in Figure 1-1.
- Copy the files from folder NOOBS_xxx to SD Card as shown in Figure 1-2.

1.3 Copying Raspbian files on Linux

1.4 Copying Raspbian files on Windows

1.5 Installing the Raspbian in Raspberry Pi

Insert the SD Card on Raspberry and turn it on. Select “Raspbian” and “Yes” as shown by Figure 1-3.

In a few minutes, you will have your Raspberry Pi running Raspbian OS. Now you can install PharoThings and control devices remotely.

1.6 Installing PharoThings on Raspberry Pi

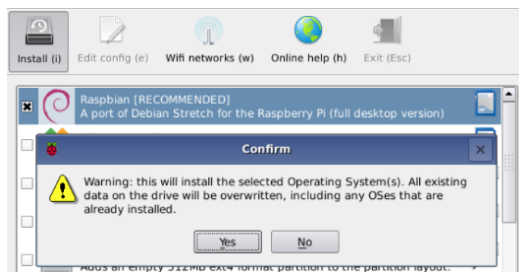


Figure 1-3 Installing Raspbian.

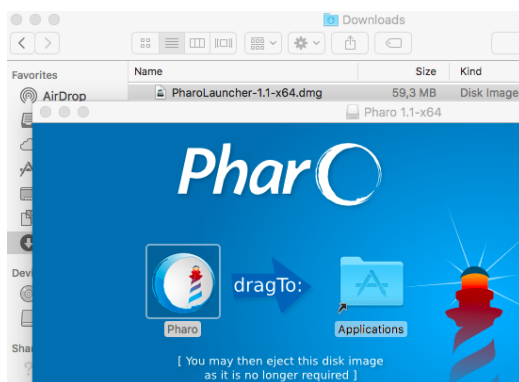


Figure 1-4 Installing PharoLauncher.

1.6 Installing PharoThings on Raspberry Pi

Install PharoThings requires to get Pharo, PharoThings and an ARM virtual machine. We will build the image on our local computer with the correct files and after we will copy to a Raspberry Pi and execute it there. In the third step, we will connect the Pharo from the local computer into Pharo of Raspberry Pi.

Download PharoLauncher

Use the PharoLauncher (an application to help you running multiple versions and images of Pharo) and install Pharo 6.1. You can get the launcher from <http://pharo.org/download>. You can also directly install a version of Pharo from the same place.

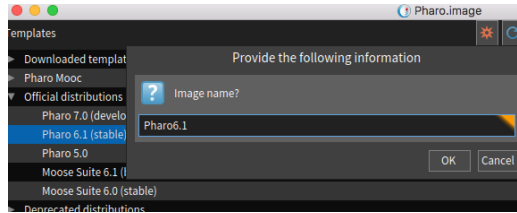


Figure 1-5 Download Pharo 61.

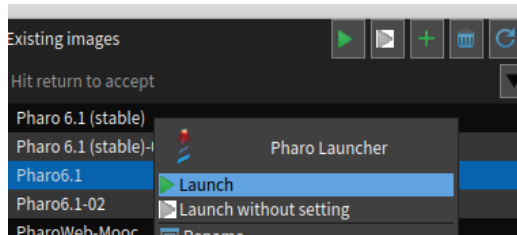


Figure 1-6 Open your Pharo image.

Download Pharo 61

Run the Pharo Launcher. Double click the distribution you want to create a image and give a name to image (see Figure 1-5). A short name and without spaces is recommended, because we will type this name and path in command line on Linux.

Execute your Pharo image

Launch the image as shown in Figure 1-6. A folder with the image name will be created inside the folder Pharo: `/Users/your_user_name/Documents/Pharo/`

In this example the folder is `/Users/my_user_name/Documents/Pharo/Pharo6.1`

Load PharoThings

Open Playground and execute this command to install the server part of PharoThings (as shown in Figure 1-7):

```
Metacello new
  baseline: 'PharoThings';
  repository: 'github://pharo-iot/PharoThings/src';
  load: #(RemoteDevServer Raspberry).
```

1.6 Installing PharoThings on Raspberry Pi

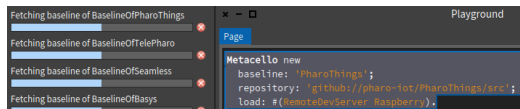


Figure 1-7 Loading PharoThings.

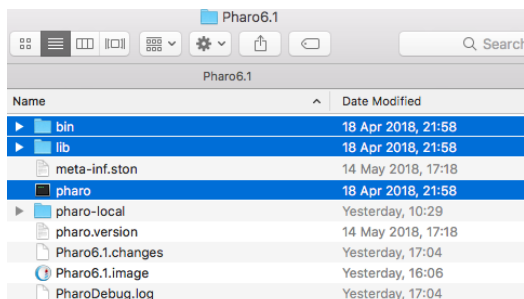


Figure 1-8 Copying PharoARM.

Then configure image to disable slow browser plugins (instead remote browser will be much slower):

```
[ClySystemEnvironmentPlugin disableSlowPlugins.
```

Snapshot your Image

In Pharo, click and “Save and Quit”. This way all your code and configurations are saved and ready to be reused.

Download the VM

- Download ArmVM from <http://files.pharo.org/vm/pharo-spur32/linux/armv6/latest.zip>.
- Unzip it
- Copy the files shown in Figure 1-8 to Pharo folder `/Users/your_user_name/Documents/Pharo/pharo_image_folder`

Copying Sources

Copy the file `PharoV60.sources` from the folder `/Applications/Pharo.app/Contents/MacOS` to folder `/Users/your_user_name/Documents/Pharo/images/pharo_image_folder/lib/pharo/5.0-201804182009/`

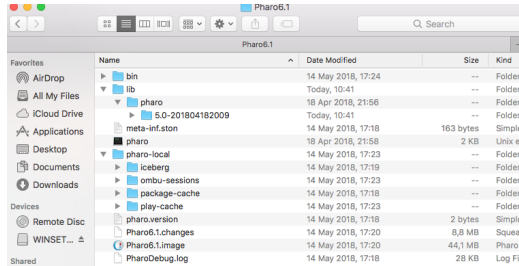


Figure 1-9 Copying the folder on your Raspberry.

Copy to the Raspberry

Copy this folder to your Raspberry Pi (via flashdrive, network etc). The folder must have the structure shown in Figure 1-9.

1.7 Execute PharoThings on Raspberry

Turn on your Raspberry and connect it to the network.

In this example, the folder Pharo6.1 was copied to folder /home/pi/.

Is necessary apply execute permissions on the Pharo files, using the command `chmod +x`

```
chmod +x /home/pi/Pharo6.1/pharo
chmod +x /home/pi/Pharo6.1/lib/pharo/5.0-201804182009/pharo
```

Start Server

Start the Pharo typing the following command in the Terminal on your Raspberry :

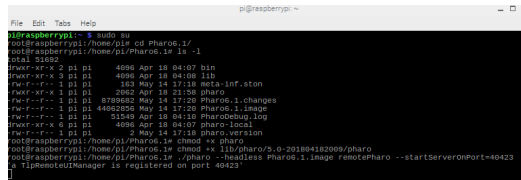
```
pharo --headless Server.image remotePharo --startServerOnPort=40423
```

If all is right, you will see the answer:

```
'a TlpRemoteUIManager is registered on port 40423'
```

So now we have the Raspberry running the TelePharo on TCP port 40423 (as shown in Figure 1-10) and we can connect into it from another computer.

1.8 Connecting Pharo client on remote Pharo



```
pi@raspberrypi:~$ sudo su
root@raspberrypi:/home/pi# cd Pharo.1/
root@raspberrypi:/home/pi/Pharo.1# ls -l
total 5180
drwxr-xr-x 2 pi pi 4096 Apr 18 04:07 bin
-rw-r--r-- 3 pi pi 4996 Apr 18 04:08 lib
-rw-r--r-- 1 pi pi 163 May 14 17:18 meta.inf.ston
-rw-r--r-- 1 pi pi 2082 Apr 18 21:28 pharo
-rw-r--r-- 1 pi pi 8789682 May 14 17:20 Pharo.1.changes
-rw-r--r-- 1 pi pi 4488205 May 14 17:20 Pharo.1.image
-rw-r--r-- 1 pi pi 51549 Apr 18 04:10 PharoDebug.log
-rw-r--r-- 4 pi pi 496 Apr 18 04:07 pharo-local
-rw-r--r-- 1 pi pi 2 May 14 17:18 pharo.version
root@raspberrypi:/home/pi/Pharo.1# chpwd & pharo
root@raspberrypi:/home/pi/Pharo.1# chpwd & lib/pharo/5.0-201804182009/pharo
root@raspberrypi:/home/pi/Pharo.1# pharo --headless pharo.1.image remotePharo --startServerOnPort=40423
^ TipRemoteUIManager is registered on port 40423
```

Figure 1-10 Server up and running.

1.8 Connecting Pharo client on remote Pharo

Open again the Pharo on your local computer and execute this command to install the PharoThings client:

```
Metacello new
baseline: 'PharoThings';
repository: 'github://pharo-iot/PharoThings/src';
load: 'RemoteDev'.
```

Type this command to connect to the remote TelePharo on Raspberry (change the IP to your Raspberry IP):

```
remotePharo := TlpRemoteIDE connectTo: (TCPAddress ip: #[193 51 236
167] port: 40423)
```

Here we are using specialized Raspberry tools. They require the auto-refresh feature of inspector which is not enabled by default in Pharo 6. To activate it evaluate:

```
GTInspector enableStepRefresh
```

So for your board model you need to choose an appropriate board class. For Raspberry, it will be one of the RpiBoard subclasses. Currently, you can use the following classes according to the models:

- RpiBoardBRev1: Raspberry Pi Model B Revision 1
- RpiBoardBRev2: Raspberry Pi Model B Revision 2
- RpiBoard3B: Raspberry Pi Model B+, Pi2 Model B, Pi3 Model B, Pi3 Model B+

With the chosen class evaluate the following code to open an inspector:

```
remoteBoard := remotePharo evaluate: [ RpiBoardBRev1 current].
remoteBoard inspect.
```

And will be open the inspector showing the PIN scheme (as shown in Figure 1-11)

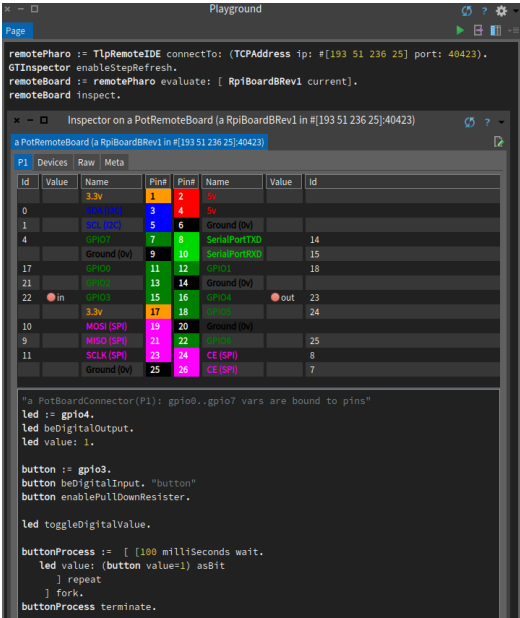


Figure 1-11 Remote GPIO inspector

GPIOS

The board inspector shows a layout of pins similar to Raspberry Pi docs. But here it is a live tool which represents the current pins state.

In the picture the board is shown with two configured pins: gpio3 and gpio4, which are connected to physical button and led accordingly.

Digital pins are shown with green/red icons which represent high/low (1/0) values. In case of output pins you are able to click on the icon to toggle the value. Icons are updated according to pin value changes. If you click on physical button on your board the inspector will show the updated pin state by changing its icon color.

The evaluation pane in the bottom of the inspector provides bindings to gpio pins which you can script by #doIt/printIt commands. The example shows expressions which were used to configure a button and led.

1.9 In the next chapter

Now that we have installed the Operation System and PharoThings in the Raspberry Pi, we can play with LEDs, sensors, LCD displays and more.

In the next chapter we will see how turing on/off a LED using PharoThings.

Lesson 1 – Turning LED on/off

One of the classic analogies in electronics to “Hello World” is turn on a led or lamp. In this first lesson, we will learn how to connect correctly an LED to your Raspberry Pi and how to use PharoThings to control this led by turning it on and off.

Coding in Pharo is very simple, but it is very powerful and you can control all the GPIOs of your Raspberry Pi remotely.

If you did not yet see how to install the PharoThings on your Raspberry Pi and how to control it remotely, you can find the instructions in Chapter 1.

2.1 What we need?

In this lesson we will use a very simple setup.

Components

- 1 Raspberry Pi connected to your network (wired or wireless)
- 1 Breadboard
- 1 LED
- 1 Resistor (330ohms)
- Jumper wires

2.2 Experimental theory

Before constructing any circuit, you must know the parameters of the components in the circuit, such as their operating voltage, operating current, etc.

The LED

To turn on the LED, we need to send the correct voltage and current to it. The voltage and current can't be too high, otherwise, the LED will burn, or in some cases, damage the Raspberry.

Typically, the forward voltage of an LED is between 1.8 and 3.3 volts. It varies by the color of the LED. A red LED typically drops 1.8 volts, but voltage drop normally rises as the light frequency increases, so a blue LED may drop from 3 to 3.3 volts[1].

Most 3mm and 5mm LEDs will operate close to their peak brightness at a drive current of 20 mA. This is a conservative current: it doesn't exceed most ratings (your specs may vary, or you may not have any specs—in this case, 20 mA is a good default guess [2])

In this experiment, the operating voltage of the LED is between 1.5V and 2.0V and the operating current is between 10mA and 20mA.

The Resistor

We must always use resistors to connect LEDs up to the GPIO pins of the Raspberry Pi to limit the voltage and current between the LED and the Raspberry to a safe value.

A small change in voltage can produce a huge change in current (see more: LED Current vs. Voltage [2])

In this experiment, we will use a 330ohm resistor. To identify the correct resistor, follow one of the following color sequences, depending on the number of bands [3]:

- If there are four colour bands, they will be Orange, Orange, Brown, and then Gold;
- If there are five bands, then the colours will be Orange, Orange, Black, Black, Brown.

It does not matter which way round you connect the resistors (in this experiment). Current flows in both ways through them. This means that you can connect the resistor at the positive pole or the negative pole of the LED, as well as starting with the first or last color, as shown in the Picture 2-1.

But the LEDs will only work if the power is supplied correctly (if the polarity is correct). You will not burn the LEDs if they connect the wrong way – they just will not turn on.

2.3 Experimental procedure

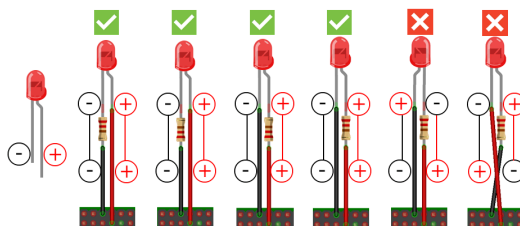


Figure 2-1 Led polarity and resistors.

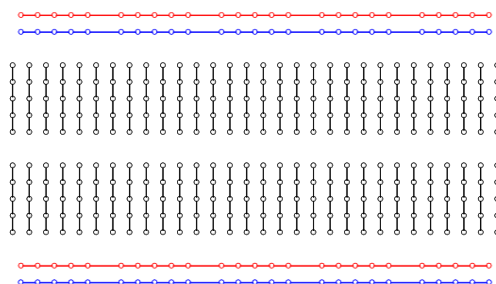


Figure 2-2 Breadboard scheme.

The Breadboard

A breadboard is used to build prototyping of electronics. With a breadboard, it is not necessary to use solder, this way you can reuse the board. This makes it easy to use to create temporary prototypes and experiment with circuit design.

The holes in the breadboard are connected following a pattern, as shown in the Picture 2-2.

- The red (+) and blue (-) rail are connected horizontally;
- The holes in the middle are connected vertically.

2.3 Experimental procedure

Now we will build the circuit. This circuit consists of an LED that lights up when power is applied, a resistor to limit current and a power supply (the Rasp).

- Connect the Ground PIN from Raspberry in the breadboard blue rail (-). Raspberry Pi models with 40 pins has 8 GPIO ground pins. You can connect with anyone. In this experiment we will use the PIN6 (Ground);

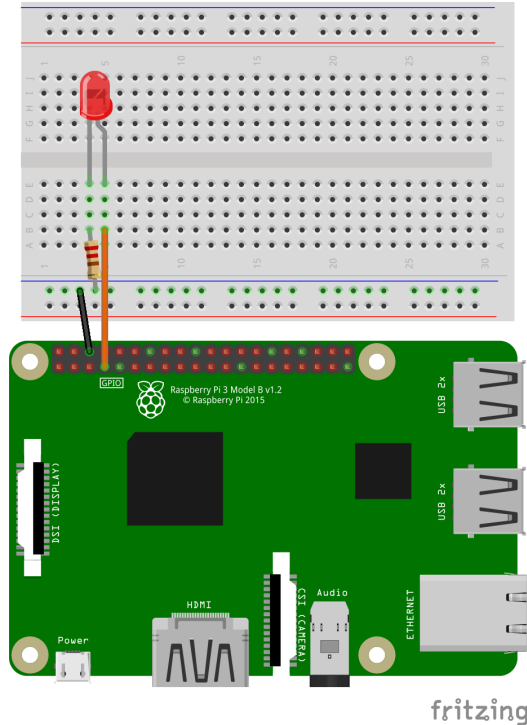


Figure 2-3 Physical connection LED.

- Then connect the resistor from the blue rail on the breadboard (-) to a column on the breadboard, as shown in the Picture 2-3;
- Now push the LED legs into the breadboard, with the long leg (with the kink) on the right;
- And insert a jumper wire connecting the right column and the PIN7 (GPIO7).

The Figure 2-3 shows how the electric connection is made:

2.4 Experimental code

Now, we can write some code in Pharo to control the GPIOs using PharoThings and turn the LED on. We have 2 options to do this:

- Write the code locally on the Raspberry;
- Use TelePharo to connect from your computer into the Raspberry and do all the work remotely.

2.4 Experimental code

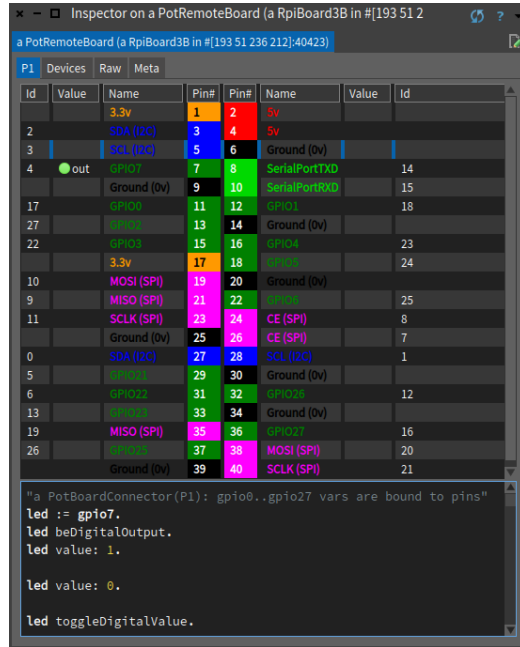


Figure 2-4 Remote Board Inspector.

In this experiment, we will use the second option: connect and do all the work remotely.

If you didn't see how to install the PharoThings on your Raspberry Pi and how to control it remotely, take a look in the Chapter 1: Installations.

Connecting remotely

Through your local Pharo image, let's connect in the Pharo image running on Raspberry, enable the auto-refresh feature of the inspector and open the inspector. Run this code in your local playground:

```
remotePharo := TlpRemoteIDE connectTo: (TCPAddress ip: #[193 51 236
167] port: 40423)
GTInspector enableStepRefresh
remoteBoard := remotePharo evaluate: [ RpiBoardBRev1 current].
remoteBoard inspect.
```

In your inspect window (Inspector on a PotRemoteBoard) you can see a scheme of pins similar to the Raspberry Pi docs. But here it is a live tool which represents the current pins state.

Digital pins are shown with green/red icons which represent high/low (1/0) values. In case of output pins you are able to click on the icon to toggle the

value.

To control the led we first introduce the named variable #led which we assigned to GPIO7 pin instance:

```
[ led := gpio7.
```

Then we configure the pin to be in digital output mode and set the value:

```
[ led beDigitalOutput.  
led value: 1.
```

It turns the led on.

You can notice that gpio variables are not just numbers/ids. PharoThings models boards with first class pins. They are real objects with behaviour. For example you can ask pin to toggle a value:

```
[ led toggleDigitalValue.
```

Or ask a pin for current value if you want to check it:

```
[ led value.
```

2.5 What did we learn?

With PharoThings you can remotely control all the GPIOs in your running board!

You can:

- Interact remotely with pins and boards;
- See the current pins state in real time;
- Run the code dynamically.
- Easy, powerful.

2.6 In the next lesson

Let's use what we learned in this lesson and write a simple code to blink the LED.



Lesson 2 – Blinking LED

Now we can play with the LEDs, turn them on and off. Let's use this basic setup to write some code on the inspector playground to blink the LED. Next, we will learn how to remotely create a very simple application using classes, methods, and instances to control the LED.

3.1 What do we need?

We are using the same setup as the last section: 1 Raspberry Pi, 1 Breadboard, 1 LED, 1 Resistor 330ohms. If you didn't do the last lesson to understand how to do the connections, go back to Chapter 2 and do it.

Connecting remotely

Through your local Pharo image, let's connect to the Pharo image by running on Raspberry, enable the auto-refresh feature of the inspector, and open the inspector.

Run this code in your local playground:

```
remotePharo := TlpRemoteIDE connectTo: (TCPAddress ip: #[193 51 236
212] port: 40423)
GTInspector enableStepRefresh.
remoteBoard := remotePharo evaluate: [ RpiBoardBRev1 current].
remoteBoard inspect.
```

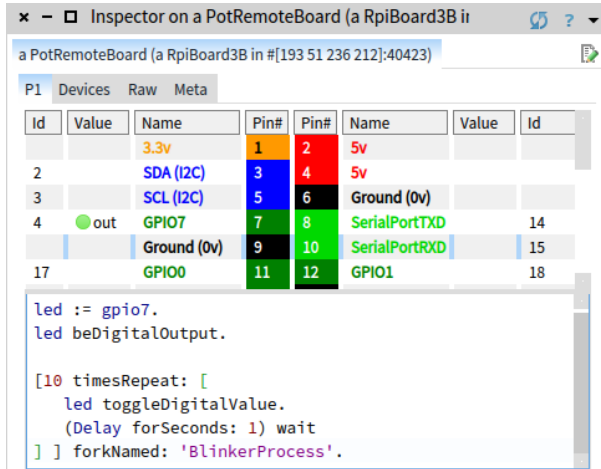


Figure 3-1 Remote playground.

3.2 Experimental code

In your inspect window (Inspector on a PotRemoteBoard), let's initialize the led and set the pin 7 to be in digital output mode as we did in the last lesson:

```
led := gpio7.
led beDigitalOutput.
```

To blink the LED let's create a simple loop to change the value of the LED every 1 second by 10 times. To change the value of the object (led value), let's call the method `toggleDigitalValue`, as we saw previously:

```
[ 10 timesRepeat: [
  led toggleDigitalValue.
  (Delay forSeconds: 1) wait
] ] forkNamed: 'BlinkerProcess'.
```

Run this code, as shown in Figure 4-5 and... cool! Now your LED is blinking!

Change the values to repeat more times and to wait less time between toggling. This will cause the LED to blink faster.

3.3 In the next lesson

In this tutorial, you learned how to blink a LED by typing some code in the remote inspector. But with Pharo we can do more! And in the next lesson, let's start to use OOP (object-oriented programming). Let's create a simple application, write classes and methods, all remotely.



Lesson 3 – A brief introduction to Pharo object-oriented language

Pharo is a new generation reflective language and programming environment. The last code was executed inside the remote inspector. To get started using OOP (Object-Oriented Programming) with classes, methods, and instances, I invite you to implement a simple application to blink the LEDs.

4.1 Developing a simple LED blinker

The following part of this chapter and application was based on the exercise Developing a Simple Counter, of Week 1 of Pharo MOOC (<https://mooc.pharo.org/>). I strongly recommend that you read and do the "counter exercise" to better understand the concepts explained here. And, of course, do the MOOC to learn how to develop using Pharo and the OOP concept.

4.2 Our use case

We want to create a blinker LED using a few parameters such as time to repeat the blinking LED and how many seconds to wait between blinks. The following code should run in the playground when we finish this lesson:

```
[|blinker|  
  blinker := Blinker new.  
  blinker timesRepeat: 10 waitForSeconds: 1.
```

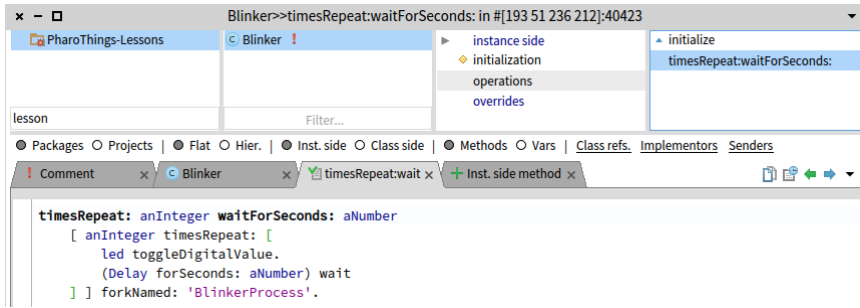


Figure 4-1 Remote System Browser.

Here is a short explanation of this code:

- In the first line, we declare the variable `blinker`. We can use any name. We will use this variable to create an object using the `Blinker` class;
- In the second line, we instantiate the `Blinker` class (with uppercase B) in the `blinker` variable, creating an object. In this lesson, we will create this class and methods to control the LED;
- In the third line, we send some messages to the `blinker` object, for how long and how many times per second. This will make the GPIO behave according to the parameters sent.

Now we will develop all the mandatory class and methods to support this scenario.

4.3 Create your own class remotely

Let's create our first class. To create a class in Pharo, we need first to create a package. Inside the package, you can create many classes and inside the classes, you can create many methods. The methods are organized in protocols, to become more easily navigate between them. Take a look in Figure 4-1 to better understanding. *edit image, put name in windows

In your local playground, call the Remote System Browser of your Raspberry Pi. If you are already connected to your Raspberry Pharo, you do not need to run the first line below again. This will open a window as shown in Figure 4-1

```
remotePharo := TlpRemoteIDE connectTo: (TCPAddress ip: #[193 51 236
    212] port: 40423).
remotePharo openBrowser.
```

4.4 Create a package

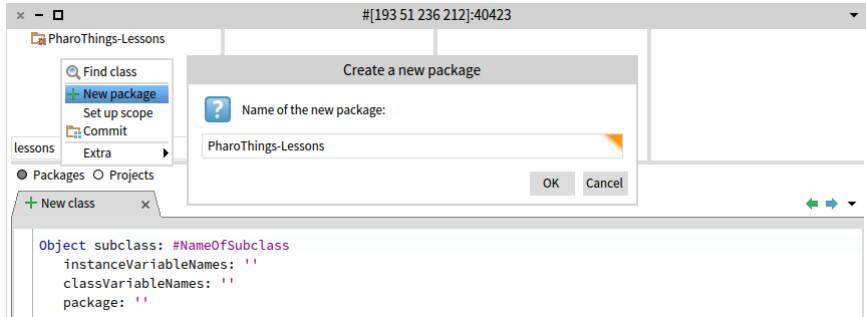


Figure 4-2 Creating a package remotely.

4.4 Create a package

Let's create a package using the Remote Browser. Right-click the package area and enter the package name, as shown in Figure 4-2. In this example, we will create a package named `PharoThings-Lessons`.

4.5 Create a class

To create a new class, edit the default class template by changing the `#NameOfSubclass` to the name of the new class. In this example let's create the class `#Blinker`. Take care that the class name begins with a capital letter and that you do not remove the hash symbol (`#`) in front of `NameOfSubclass`.

You must then fill in the names of the instance variables for this class. We need an instance variable called `led`. Be careful to leave the string quotes!

```
Object subclass: #Blinker
instanceVariableNames: 'led'
classVariableNames: ''
package: 'PharoThings-Lessons'
```

Now we need to compile it. Right click on the code area and select `Accept` option. The `Blinker` class is now compiled and added to the system, as shown in Figure 4-3.

4.6 Create a protocol

Let's create a new protocol to organize the methods. The first protocol we are going to create is `initialization`, as shown in Figure 4-4.

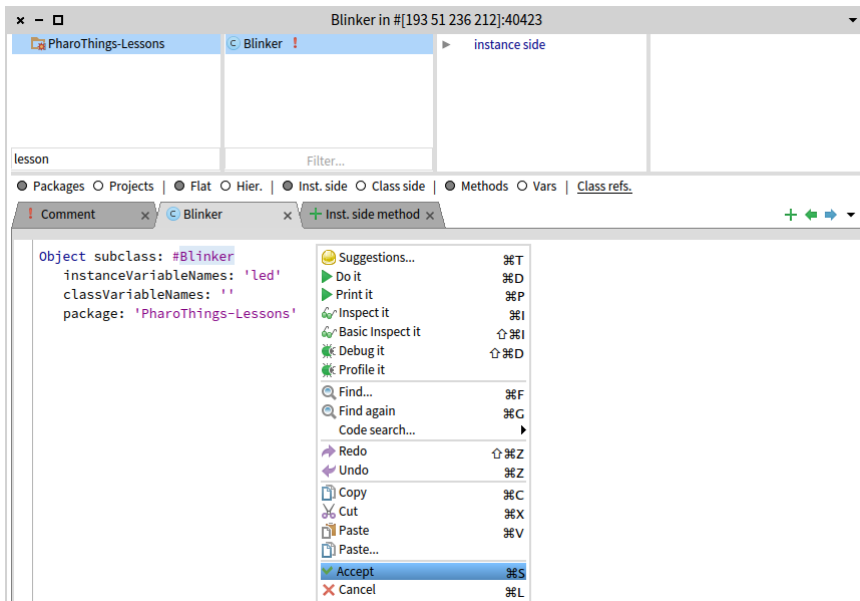


Figure 4-3 Creating a class remotely.

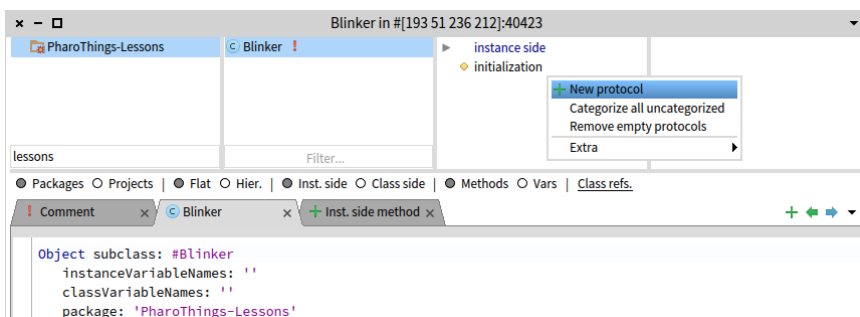
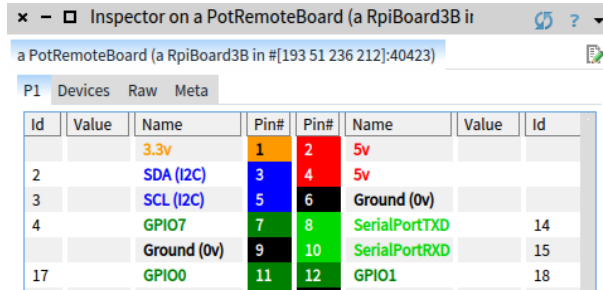


Figure 4-4 Creating a package remotely.



The screenshot shows a web-based inspector for a PotRemoteBoard (a RpiBoard3B in #[193 51 236 212]:40423). It displays a table of GPIO pins with their IDs, values, names, and pin numbers.

Id	Value	Name	Pin#	Pin#	Name	Value	Id
		3.3v	1	2	5v		
2		SDA (I2C)	3	4	5v		
3		SCL (I2C)	5	6	Ground (0v)		
4		GPIO7	7	8	SerialPortTXD		14
		Ground (0v)	9	10	SerialPortRXD		15
17		GPIO0	11	12	GPIO1		18

Figure 4-5 Looking for ID and GPIO number on Remote Inspector.

4.7 Creating an initialize method

Inside this protocol, we will create a `initialize` method. This means that every time we create a new object using this class, in this case, the `Blinker` class, this method will be executed to define some variable in the new object.

Let's use the instance variable `led`, which we defined when we created the class. The instance variable is private to the object and accessible by any methods inside this class. These methods can access this variable to get or set any value to it.

```
initialize
  led := PotClockGPIOPin id: 4 number: 7.
  led board: RpiBoard3B current; beDigitalOutput
```

Here is a short explanation of this code:

- The first line defines the name of the method;
- In the second line, we configure the GPIO that we wanna use. Note that we need the GPIO number and ID. The ID is required to communicate with Wiring Pi Library. You can see the ID and GPIO number in PotRemoteBoard inspector, as shown in Figure 4-5;
- In the third line, we define the model of the Raspberry board and configure this GPIO as `beDigitalOutput`. This means that when the GPIO change to value:1, the power will go out of the GPIO to power the LED.

Compile your code (`cmd + S`) and the method will be shown in the remote browser, as shown in Figure 4-6:

Creating a method to do actions

Now let's create a method to control the object `led` inside the class `Blinker`. Let's take the code that we used in PotRemoteBoard inspector to do the LED

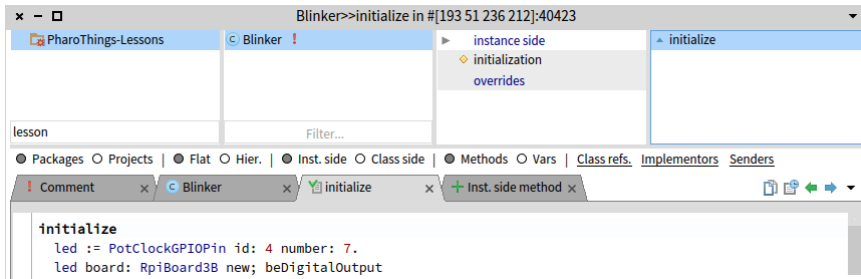


Figure 4-6 Creating the initialize method.

to blink and replace the numbers on code for two arguments. Create the protocol operations and inside this protocol, create the following method:

```
[ timesRepeat: anInteger waitforSeconds: aNumber
  [ anInteger timesRepeat: [
    led toggleDigitalValue.
    (Delay forSeconds: aNumber) wait
  ] ] forkNamed: 'BlinkerProcess'.
```

Here is a short explanation of this code:

- In the first line, we define the message with timesRepeat: and waitforSeconds:. We inform the kind of value will be received, creating 2 variables: aNumber and anInteger;
- We replace these variables in the code and now we have the control to say how many times repeat and for how many seconds;
- We finished the code by putting everything inside a fork to create a process in Pharo. While the process is running, you can open the Remote Process Browser (remotePharo openProcessBrowser) and see the process. This is useful when you wanna kill the remote process.

Compile your code (cmd + S) and the method will be shown in the remote browser, as shown in Figure 4-7:

4.8 Using your new class

Now we can use the class that we created, the Blinker class. To do this, let's open the Remote Playground:

```
[ remotePharo openPlayground.
```

and run the code that we saw in the begin of this lesson:

4.9 Save your work

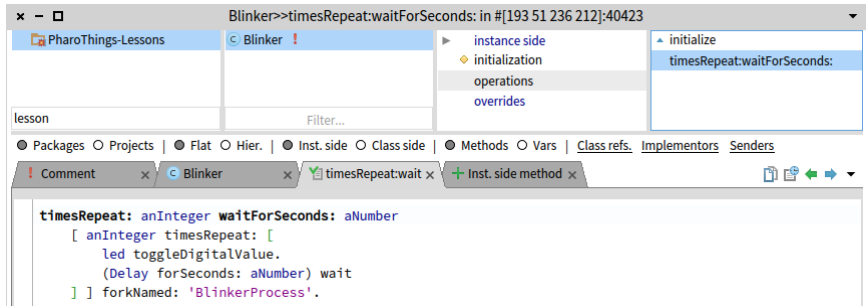


Figure 4-7 Creating an operation method.

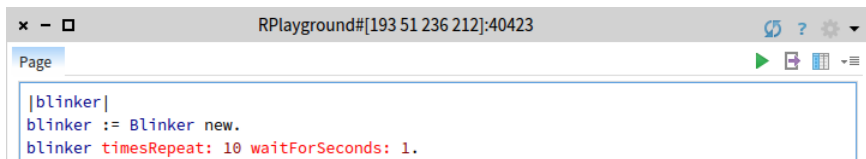


Figure 4-8 Remote playground.

```
[|blinker|
blinker := Blinker new.
blinker timesRepeat: 10 waitForSeconds: 1.
```

Run this code, as shown in Figure 4-8 and... cool! Now your LED is blinking! And the better, you did this using object-oriented programming!

You do not need to change your code every time you wanna change these parameters. Just change the messages you send to the object and it will behave as you want.

4.9 Save your work

Don't forget to save your work remotely. To do this, run this command on your local playground:

```
[remotePharo saveImage.
```

4.10 Conclusion

In this tutorial, you learned how to define packages, classes, and methods. The flow of programming that we chose for this first tutorial is similar to most of the programming languages.

With PharoThings you can remotely develop and manage your Raspberry GPIOs. Very easy and powerful.

In the next lesson, let's use what we learned in this lesson and write a simple code to flow lights using 8 LEDs.



Lesson 4 - LED Flowing Lights

Now we can play with the LEDs, turn them on, off, and blink. Let's put 8 LEDs on the breadboard and create a code to turn on/off one at a time. Let's use some methods to change the flow direction and control the flow time. As we did in the last lesson, let's write the first code in playground and then create a class with methods to better control the flow of LED lights.

5.1 What do we need?

We are using the set of the first lesson, but let's use 8 LEDs and 8 resistors and some more jumper wires.

Components

- 1 Raspberry Pi connected to your network (wired or wireless)
- 1 Breadboard
- 8 LEDs
- 8 Resistors 330ohms
- Jumper wires

5.2 Experimental procedure

We saw in lesson 1 how to connect the LED and resistors on the breadboard. Now let's do the same, but putting more 7 LEDs and resistors on the breadboard.

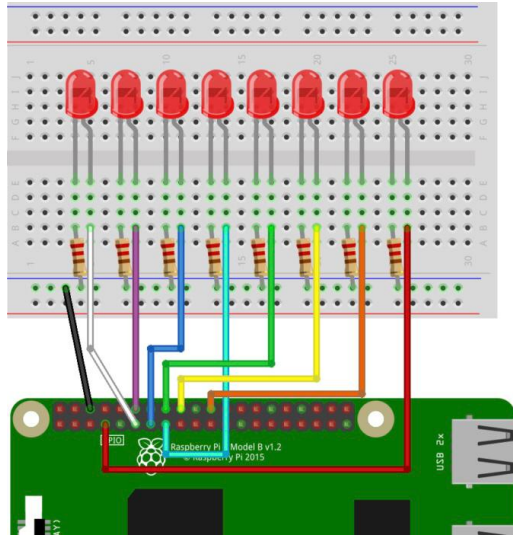


Figure 5-1 Schema connection 8 LEDs.

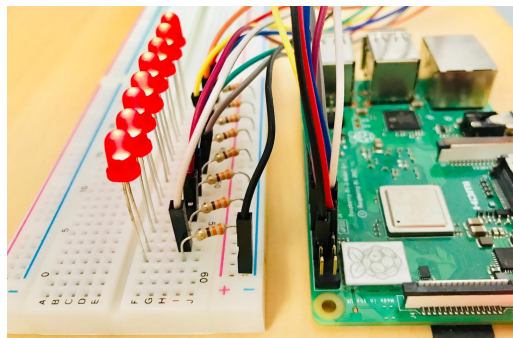


Figure 5-2 Physical connection 8 LEDs.

- Connect the Ground PIN from Raspberry in the breadboard blue rail (-).
- Then connect the 8 resistors from the blue rail (-) to a column on the breadboard, as shown below;
- Now push the LED legs into the breadboard, with the long leg (with the kink) on the right;
- And insert the jumper wires connecting the right column of each LED to GPIO from 0 to 7, as shown in the Picture 5-1.

The Figure 5-2 shows how the electric connection is made.

Connecting remotely

Through your local Pharo image, let's connect in the Pharo image by running on Raspberry, enable the auto-refresh feature of the inspector, and open the inspector.

Run this code in your local playground:

```
remotePharo := TlpRemoteIDE connectTo: (TCPAddress ip: #[193 51 236
    212] port: 40423)
GTInspector enableStepRefresh.
remoteBoard := remotePharo evaluate: [ RpiBoardBRev1 current].
remoteBoard inspect.
```

5.3 Experimental code

In your inspect window (Inspector on a PotRemoteBoard), let's create an array and initialize the 8 LEDs, putting each one in a position of the array. This way we can send messages more easily to all objects. Look at the second line, we set the GPIOs to beDigitalOutput only using the method do: to move through the entire array:

```
gpioArray := { gpio0. gpio1. gpio2. gpio3. gpio4. gpio5. gpio6.
    gpio7 }.
gpioArray do: [ :item | item beDigitalOutput ].
```

To change the value of the object (led value), let's call the method toggleDigitalValue, as we saw previously. You can also use the method value: and send 1 or 0, instead toggleDigitalValue, but let's use this last. To do this fast and simple, let's use again the method do: to send the parameters to all objects on the array. In this example, we turn On all the LEDs at the same time:

```
gpioArray do: [ :item | item toggleDigitalValue ].
```

Let's put a Delay after changing the led value, to wait a bit time before to change the next LED value. Let's also put this inside a process using the method forkNamed:

```
[
    gpioArray do: [ :item | item toggleDigitalValue. (Delay
        forSeconds: 0.3) wait ].
] forkNamed: 'FlowingProcess'.
```

Execute this code and... cool! Now your LEDs are on by flowing an ordering!

Change the value of the method forSeconds: to wait less time between toggling it. This will cause the line LEDs to turn on faster. The Figure 5-3 and 5-4 shows the code and the LEDs turn On.

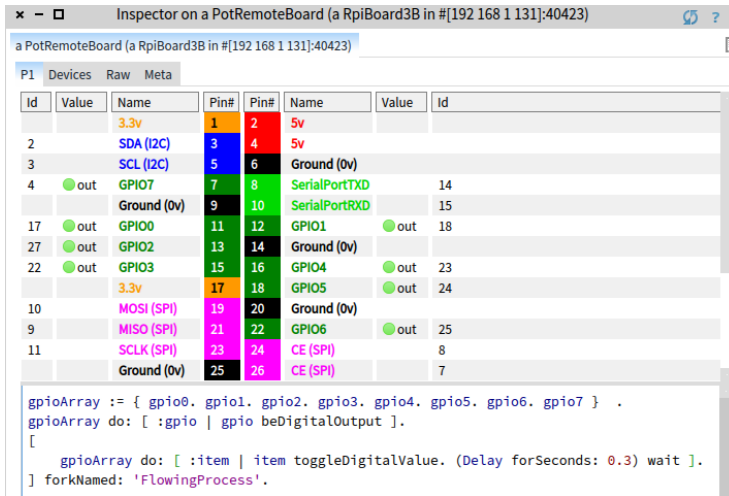


Figure 5-3 Code on Inspector

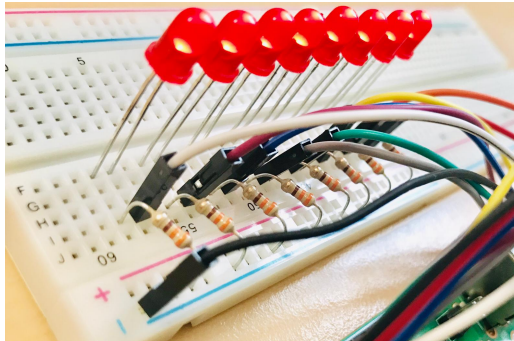


Figure 5-4 LEDs turn On.

5.4 Adding features

Every time you run this code, the LEDs toggles the state, from Off to On or vice versa. Let's reduce the delay time and add the `timesRepeat:` method, as we did in the last lesson, to repeat the alternation as many times as we want:

```

[ 2 timesRepeat: [
    gpioArray do: [ :item | item toggleDigitalValue. (Delay
forSeconds: 0.1) wait ].
] ] forkNamed: 'FlowingProcess'.

```

Execute this code and... cool! Now your LEDs are flowing On and Off!

5.5 Reversing the flow

We can have more fun with this experiment by changing the order of where to start changing the value of LEDs. To do this is very easy, just call the method `reverseDo:` and it will solve all for you:

```
[ 2 timesRepeat: [
  gpioArray reverseDo: [ :item | item toggleDigitalValue. (Delay
    forSeconds: 0.1) wait ].
] ] forkNamed: 'FlowingProcess'.
```

Execute this code and... cool! Now your LEDs are flowing on reverse order!

5.6 Going and backing the flow

To finish this experiment, let's combine the flowing On and Off with the Reverse!

```
[ 2 timesRepeat: [
  gpioArray do: [ :item | item toggleDigitalValue. (Delay
    forSeconds: 0.1) wait ].
  gpioArray reverseDo: [ :item | item toggleDigitalValue. (Delay
    forSeconds: 0.1) wait ].
] ] forkNamed: 'FlowingProcess'.
```

Execute this code and... cool! Now your LEDs are flowing On and Off and on normal and reverse order!

We can improve this code. Do you see this part where the code is repeating `"[:item | item toggleDigitalValue. (Delay forSeconds: 0.1) wait]"`? Let's put this inside a variable named `action`, so we can call it when we want:

```
action := [ :item | item toggleDigitalValue. (Delay forSeconds: 0.1)
  wait ].
[ 2 timesRepeat: [
  gpioArray do: action.
  gpioArray reverseDo: action.
] ] forkNamed: 'FlowingProcess'.
```

We can put the code inside the block closure `"[]"` in a variable also and call it in just one line. Let's put it inside the variable `flowing`:

```
action := [ :item | item toggleDigitalValue. (Delay forSeconds: 0.1)
  wait ].
flowing := [ 2 timesRepeat: [
  gpioArray do: action.
  gpioArray reverseDo: action.
] ].
```

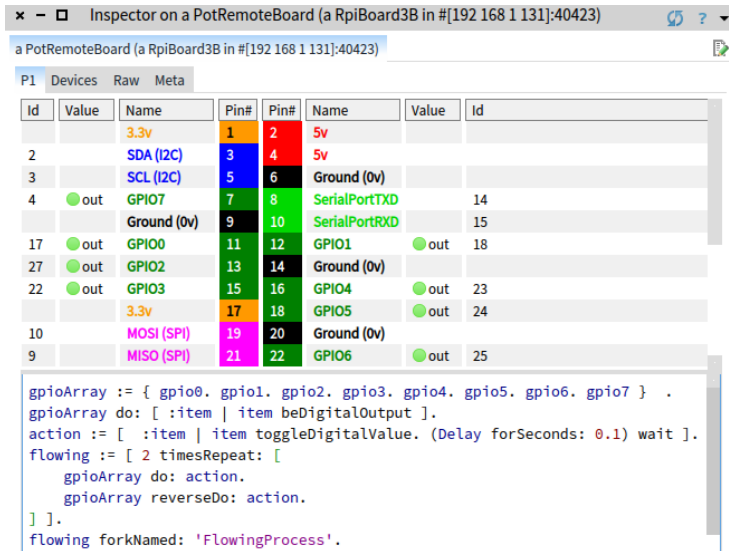


Figure 5-5 Process Browser terminate.

Now we can start the process just send the method `forkNamed:` to the object `flowing`, like in the following line:

```
[flowing forkNamed: 'FlowingProcess'.
```

Your final code will seem like the Picture 5-5. Run this code once and when you want to flow the LEDs again, just run the last line. But remember, to each change in the code, you need to run the part that you changed.

```

gpioArray := { gpio0. gpio1. gpio2. gpio3. gpio4. gpio5. gpio6.
    gpio7 }.
gpioArray do: [ :item | item beDigitalOutput ].
action := [ :item | item toggleDigitalValue. (Delay forSeconds: 0.1)
    wait ].
flowing := [ 2 timesRepeat: [
    gpioArray do: action.
    gpioArray reverseDo: action.
] ].

```

5.7 Terminating the process

As we saw in the Blinking LED lesson, you can finish this process remotely, case you don't want to wait it finish. To do this, call the Remote Process Browser:

```
[remotePharo openProcessBrowser.
```

5.8 In the next lesson

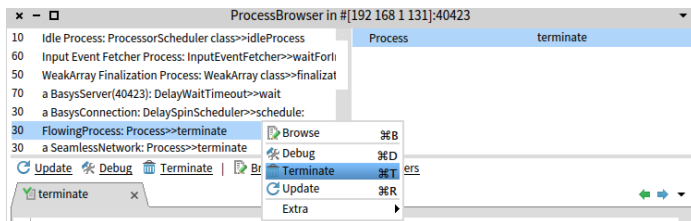


Figure 5-6 Process Browser terminate.

Search the `FlowingProcess` and terminate it, like in Picture 5-6, using one of these options:

- selecting the process and using the shortcut “Cmd + T”;
- selecting the process and using the button Terminate;
- or right-click and select Terminate.

5.8 In the next lesson

In this tutorial, you learned how to use an Array and control 8 objects at the same time by typing some code in the remote inspector. But with Pharo we can do more!

You can create your own program in classes and methods using the codes you learned in this lesson. Go ahead and try to do this yourself to test your knowledge.

And in the next lesson, let’s use object-oriented programming, OOP to create a simple program, using these codes, to control the flow like as we want.



Lesson 5 - LED Flowing Lights using OOP

Now we can play with the LEDs, turn them on, off, blink it and manipulate many at the same time. Let's use object-oriented programming, OOP to create methods and classes, to build a simple program, to control the LEDs flow like as we want.

```

leds := Flowing new.
leds times: 2 delay: 0.1 direction: 'lrl'.
leds flowStart.
leds flowStop.
leds turnOn.
leds turnOff.

```

```

Object subclass: #Flowing
  instanceVariableNames: 'ledArray flowProcess flowDirection
    toggleDelay timesRepeat'
  classVariableNames: ''
  package: 'PharoThings-Lessons'

```

```

initialize
  ledArray := {
    (PotGPIOPin id: 17 number: 0).
    (PotGPIOPin id: 18 number: 1).
    (PotGPIOPin id: 27 number: 2).
    (PotGPIOPin id: 22 number: 3).
    (PotGPIOPin id: 23 number: 4).
    (PotGPIOPin id: 24 number: 5).
    (PotGPIOPin id: 25 number: 6).
    (PotGPIOPin id: 4 number: 7)
  }.

```

```

[
    ledArray do: [ :item | item board: RpiBoardBRev2 current;
        beDigitalOutput; value:0 ].
    timesRepeat := 2.
    toggleDelay := 0.5.
    flowDirection := 'lr'.

[
    times: anInteger delay: aNumber direction: aString
    timesRepeat := anInteger.
    toggleDelay := aNumber.
    flowDirection := aString

[
    flowDirection
    ^flowDirection

[
    flowTimesRepeat
    ^timesRepeat

[
    toggleDelay
    ^toggleDelay

[
    flowStart
    flowProcess := [ (self flowTimesRepeat) timesRepeat: [
        self action
        ] ] forkNamed: 'FlowingProcess'.

[
    flowStop
    flowProcess terminate

[
    action
    flowDirection do: [ :character | character == $l ifTrue: [ ledArray
        do: self toggleLedArray ].
        character == $r ifTrue: [ ledArray
        reverseDdo: self toggleLedArray ] ]

[
    toggleLedArray
    ^[ :item | item toggleDigitalValue. (Delay forSeconds: self
        toggleDelay) wait ]

[
    turnOn
    ledArray do: [ :item | item value:1 ].

[
    turnOff
    ledArray do: [ :item | item value:0 ].

```



Lesson 6 - LED Breathing PWM



Lesson 7 - Controlling LED by Button

In the previous lessons, we learned how to control the GPIOs putting them in mode OUT. This means send power to wire connected in on specific GPIO. Now we will put the GPIO in mode IN, to read the pin state. This means that our application can know when a button is pressed. Let's create a shortcode on the remote inspector to turn On one LED each time we press the button.

8.1 What do we need?

We are using the set of the first lesson, but let's use 8 LEDs and 8 resistors and some more jumper wires.

Components

- 1 Raspberry Pi connected to your network (wired or wireless)
- 1 Breadboard
- 1 LED
- 1 Resistors 330ohms
- 1 Push button
- Jumper wires

8.2 Experimental theory

The Raspberry Pi GPIOs can be set OUT or IN mode. When we set them to IN, the selected pin can have change the state from 0 to 1 or vice-versa when we connect it in the 3.3V or ground PIN.

In this lesson, we will use the pull-up mode with an internal resistor. This means that we will use the 3.3V pin to change the GPIO value. If we used the pull-down mode, we would use the Ground Pin to change the GPIO value. To know more, you can access the Wiring Pi website, <http://wiringpi.com/reference/core-functions>.

In this scenario, we will put a push button between the 3.3V pin and GPIO pin, to control when to send energy to GPIO.

8.3 Experimental procedure

Now we will build the circuit. This circuit consists of an LED, a resistor to limit current and a push button, to control when to send power to GPIO IN.

- Connect the Ground PIN from Raspberry in the breadboard blue rail (-). In this experiment we will use the PIN6 (Ground);
- Then connect the resistor from the same row on the breadboard to a column on the breadboard, as shown below;
- Now push the LED legs into the breadboard, with the long leg (with the kink) on the right;
- And insert a jumper wire connecting the right column and the PIN7 (GPIO7);
- Connect the 3.3V PIN in the red rail (+);
- Then insert the push button on the breadboard and connect one leg on PIN11 (GPIO0);
- And another button leg on the red rail (+). Pay attention to the position of the button!

The figure below shows how the electric connection is made:

8.4 Connecting remotely

Through your local Pharo image, let's connect in the Pharo image by running on Raspberry, enable the auto-refresh feature of the inspector, and open the inspector. Run this code in your local playground:

```

remotePharo := TlpRemoteIDE connectTo: (TCPAddress ip: #[193 51 236
    212] port: 40423)
GTInspector enableStepRefresh.
remoteBoard := remotePharo evaluate: [ RpiBoardBRev1 current].
remoteBoard inspect.

```

8.5 Experimental code

In your inspect window (Inspector on a PotRemoteBoard), let's create the instances of the LED and button.

To instantiate the LED, let's do how we did previous, putting it in beDigitalOutput mode:

```

led := gpio7
led beDigitalOutput.

```

To instantiate the button let's do the same, but putting it in beDigitalInput and setting it to enablePullUpResister mode:

```

button := gpio0.
button beDigitalInput.
button enablePullUpResister.

```

This means each time that we connect the 3.3V on this GPIO (pushing the button), the state will be changed to 1, and back to 0 after release the button.

You ask the value of the button using the value method. Do this test running this line with the button pressed and after with the button released. This test is good for you to check if your button is working correctly:

```

[ button value.

```

Now let's create a process to check when the button is pressed and send this value to led object:

```

[ [100 milliSeconds wait.
  led value: (button value=1) asBit
  ] repeat
  ] forkNamed: 'button process'.

```

Your LED will turn On when the button is pressed!

8.6 Terminating the process

As we saw in the Blinking LED lesson, you can finish this process remotely, case you don't want to wait it finish. To do this, call the Remote Process Browser:

```

[ remotePharo openProcessBrowser.

```

Search the FlowingProcess and terminate it:

- selecting the process and using the shortcut “Cmd + T”;
- selecting the process and using the button Terminate;
- or right-click and select Terminate.

8.7 In the next lesson

In this lesson, you learned how to configure a push button, take the value of the button and send it to LED value, doing the LED turn On or Off using the button.

Next lesson we will start to use the sensors using I2C protocol. We will see the BME280 (temperature, humidity, and air pressure), ADXL (accelerometer X, Y, Z) and MCP9808 (temperature).



Lesson 8 - I2C Sensors (Temperature, Humidity, Pressure and Accelerometer)

In the previous lessons, we learned how to control LEDs and to use a button to interact with LEDs. Now let's start using some sensors to interact automatically with the real world, taking the temperature, air pressure and humidity. This kind of sensor use the I2C protocol to communicate.

9.1 What we need?

In this lesson we will use a very simple setup.

Components

- 1 Raspberry Pi connected to your network (wired or wireless)
- 1 Breadboard
- 1 ADXL345 accelerometer sensor
- 1 BME280 temperature, humidity and pressure sensor
- 1 MCP9808 temperature sensor
- Jumper wires

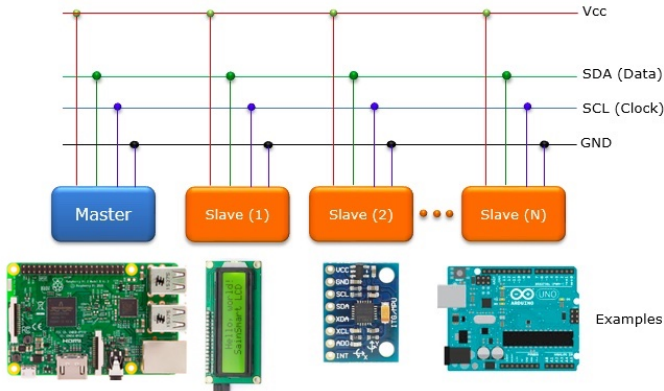


Figure 9-1 Devices connected using I2C bus.

9.2 Experimental theory

Before constructing any circuit, you must know the parameters of the components in the circuit, such as their operating voltage, operating circuit, etc.

The I2C protocol

The I2C communication protocol can be easily implemented in many electronic projects, being a very popular and widely used protocol. It is possible to perform communication between one or more master devices and several slave devices. It is an easy-to-implement protocol because it uses only 2 wires to communicate between up to 112 devices using 7-bit addressing and up to 1008 devices using 10-bit addressing.

The Figure 9-1 shows how you can connect the devices using the same I2C bus.

How I2C works?

How can we communicate with multiple devices using only two wires? For this to happen, each device has set an ID or an unique address. Then the master device can choose which device to communicate with.

The two wires are called Serial Clock (or SCL) and Serial Data (or SDA). The SCL wire is the clock signal that synchronizes the data transfer between devices on the I2C bus and is generated by the master device. The other wire is the SDA line that carries the date.

9.3 Experimental procedure

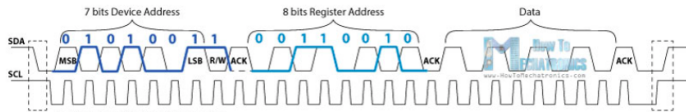


Figure 9-2 Bits sequence.

Protocol

The data is transferred in 8-bit sequences, like you can see in Figure 9-2. After a special starting condition occurs, comes the first 8-bit sequence that indicates the address of the slave to which the data is being sent. For example, for the ADXL345 accelerometer device, the default address is 16r53 (0X53) or 0101 0011 (the last bit activated means the device is on read mode).

After each 8 bit sequence follows a bit called Acknowledge. After the first Acknowledge bit, in most cases another addressing sequence comes, but this time to the internal registers of the slave device.

The internal registers are locations in the slave's memory containing various information or data. For example, the ADX345 accelerometer has a unique device address (16r53) and addition internal record addresses for the X, Y, and Z axes (16r32, 16r33, 16r34, etc.). Therefore, if we want to read the X-axis data, we first need to send the address of the device and then the internal register address specific to the X-axis.

After the addressing sequences, the data streams are as many as they are sent until the data is completely sent and ends with a special stop condition.

9.3 Experimental procedure

Now we will build the circuit. This circuit consists of an LED that lights up when power is applied, a resistor to limit current and a power supply (the Rasp).

- Connect the Ground PIN from Raspberry in the breadboard blue rail (-). Raspeberry Pi models with 40 pins has 8 GPIO ground pins. You can connect with anyone. In this experiment we will use the PIN6 (Ground);
- Then connect the 3.3V pin in the red rail (+).
- Now let's conect the SCL and SDA wires. Connect them like as shown in the Picture ;
- Now push the sensors in the breadboard;
- And insert the jumper wires connecting the sensor in the bus, like as shown in the Picture .

The Figure 2-3 shows how the electric connection is made:

9.4 Connecting remotely

Through your local Pharo image, let's connect in the Pharo image by running on Raspberry, enable the auto-refresh feature of the inspector, and open the inspector. Run this code in your local playground:

```
remotePharo := TlpRemoteIDE connectTo: (TCPAddress ip: #[193 51 236
    212] port: 40423)
GTInspector enableStepRefresh.
remoteBoard := remotePharo evaluate: [ RpiBoardBRev1 current].
remoteBoard inspect.
```

9.5 Experimental code

In your inspect window (Inspector on a PotRemoteBoard), let's create the instances of the first sensor, .



Lesson 9 - Ultrasonic Sensor (Distance)

In the previous lessons, we learned how to control LEDs and to use a button to interact with LEDs. Now let's start using some sensors to interact automatically with the real world, taking the temperature, air pressure and humidity. This kind of sensor using the I2C protocol to communicate.

10.1 Connecting remotely

Through your local Pharo image, let's connect in the Pharo image by running on Raspberry, enable the auto-refresh feature of the inspector, and open the inspector. Run this code in your local playground:

```
remotePharo := TlpRemoteIDE connectTo: (TCPAddress ip: #[193 51 236  
    212] port: 40423)  
GTInspector enableStepRefresh.  
remoteBoard := remotePharo evaluate: [ RpiBoardBRev1 current].  
remoteBoard inspect.
```

10.2 Experimental code

In your inspect window (Inspector on a PotRemoteBoard), let's create the instances of the LED and button.



Lesson 10 - LCD Display

In the previous lessons, we learned how to control LEDs and to use a button to interact with LEDs. Now let's start using some sensors to interact automatically with the real world, taking the temperature, air pressure and humidity. This kind of sensor using the I2C protocol to communicate.

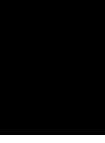
11.1 Connecting remotely

Through your local Pharo image, let's connect in the Pharo image by running on Raspberry, enable the auto-refresh feature of the inspector, and open the inspector. Run this code in your local playground:

```
remotePharo := TlpRemoteIDE connectTo: (TCPAddress ip: #[193 51 236
    212] port: 40423)
GTInspector enableStepRefresh.
remoteBoard := remotePharo evaluate: [ RpiBoardBRev1 current].
remoteBoard inspect.
```

11.2 Experimental code

In your inspect window (Inspector on a PotRemoteBoard), let's create the instances of the LED and button.



Lesson 11 - Building a Mini Weather Station

