Raspberry Pi GPIO for Dummies

Part 2: Python

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1) INTRODUCTION

In part 1 of this series, we discussed the GPIO ports on the Raspberry Pi. We accessed the ports from the command line, lighting up LEDs on the "Push your Pi" kit from MyPiShop.com. In this part we will develop a more robust interface using Python.

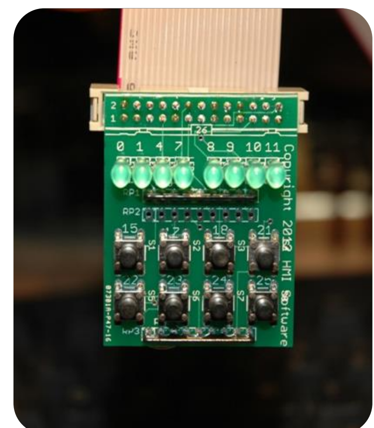
2) PUSH YOUR PI

The "Push your Pi" kit is a small add-on board that mounts on the GPIO connector. It contains 8 super-bright LEDs and 8 switches. I think of the 8 LEDs as a string of binary bits in a byte and number them accordingly, left to right: LED7 through LED0. The LEDs and switches are connected to the GPIO ports as follows:

You might notice that each device has a silkscreened number on the PCB. These numbers are the GPIO port numbers (very nice!). My kit uses version 1 numbers, which are slightly different than my version 2 Pi. The table shows the version 2 numbers. Do you know which Pi hardware version you have? Version 2 Pi's have two mounting holes, but version 1 boards do not have any mounting holes.

LED#	GPIO	SWITCH#	GPIO
7	2*	1	15
6	3*	2	17
5	4	3	18
4	7	4	27*
3	8	5	22
2	9	6	23
1	10	7	24
0	11	8	25

*Changed in version 2



3) PYTHON

Why Python? Other languages, like C, will work equally well. But Python seems to be a preferred language on the Raspberry Pi and this project a good excuse to learn something about it. I prefer starting simple, getting small stuff to work, then adding to it. If you like this method too then read on.

There are two popular Python modules for GPIO programming: RPi.GPIO and WiringPi. I downloaded and installed both. WiringPi is currently the most feature-complete, and also has a familiar feel to anyone used to Arduino coding. But I am going to skip over it, and write about RPi.GPIO instead. Try both and see which one you prefer.

If you are using a recent version of Raspian on your Pi, then you already have RPi.GPIO installed. If not, visit the project home page at http://code.google.com/p/raspberry-gpiopython/ to get the latest version.

Let's start with the interactive-mode python interpreter. RPi.GPIO must run from root, so please login as root and start python. You will see the triple-chevron (>>>) prompt:

```
$ sudo su
# python
>>>
```

Import the RPi.GPIO module. The first thing we'll do is configure it to use the Broadcom port-numbering scheme. And we'll turn off warnings about port usage:

```
>>> import RPi.GPIO as GPIO
>>> GPIO.setmode(GPIO.BCM)
>>> GPIO.setwarnings(False)
```

If python complains at the first statement, make sure that: 1) you have already installed RPi.GPIO; 2) you spelled it correctly, with a lower-case 'i'; and 3) you started python from root.

Now we are ready to specify which I/O pins we are going to use, and how we are going to use them. Let's try GPIO4, like in part 1, which is attached to the third LED.
We must declare it as an output.

```
>>> GPIO.setup (4, GPIO.OUT)
```

Assuming that you got no feedback from the four python statements above, output on GPIO4 is ready. Let's try lighting the LED

```
>>> GPIO.output(4,1)
```

Is the LED on?. Use the output function again to turn it off:

```
>>> GPIO.output(4,0)
```

If your LED turned on & off, everything is working fine. Type exit() to leave python. It's time to write a real program.

4) A SIMPLE PYTHON SCRIPT

Let's put these statements in the form of a python script. You can use IDLE, Geany, or even a simple text editor like Nano to enter your code. The first line in your script should be a command that points to the proper interpreter of your code. In this case, we need to point to the python interpreter, which is located at /usr/bin/python. We point to python using an interpreter directive, the special character combination known as the shebang (#!).

```
#!/usr/bin/python
```

We need to import the time module, in addition to RPi.GPIO. Now we have enough to create an honest-to-goodness python script. Copy the following into your editor of choice, and save it as blink.py:

```
#!/usr/bin/python

import RPi.GPIO as GPIO
import time

GPIO.setmode(GPIO.BCM)
GPIO.setup(4,GPIO.OUT)

while True:
        GPIO.output(4, 1)
        time.sleep(1)
        GPIO.output(4, 0)
        time.sleep(1)
```

Change the file permissions, and you can run it from the shell:

```
$ sudo su
# chmod +x blink.py
# ./blink.py
```

If all goes well, the third LED (on GPIO4) should be blinking away. Hit Ctrl-C to stop the fun. We have the same result as we had in part1, but programmed from python instead of bash. It is time to expand our code, and tackle multiple inputs & outputs.

5) A BIGGER PYTHON SCRIPT

First, for convenience & readability, declare each LED and switch in terms of its GPIO port number.

```
LED7   = 2    #GPIO2; use 0 on rev1 boards
LED6   = 3    #GPIO3; use 1 on rev1 boards
```

```
LED5   = 4     #GPIO4
LED4   = 7     #GPIO7
LED3   = 8     #GPIO8
LED2   = 9     #GPIO9
LED1   = 10    #GPIO10
LED0   = 11    #GPIO11
LEDS   = [LED0,LED1,LED2,LED3,LED4,LED5,LED6,LED7]

SW1    = 15    #GPIO15
SW2    = 17    #GPIO17
SW3    = 18    #GPIO18
SW4    = 27    #GPIO27; use 21 on rev1 boards
SW5    = 22    #GPIO22
SW6    = 23    #GPIO23
SW7    = 24    #GPIO24
SW8    = 25    #GPIO25
SWITCHES = [SW1,SW2,SW3,SW4,SW5,SW6,SW7,SW8]
```

Combine all of the I/O setup commands into a function called InitIO. We can set all of the LEDs as outputs using a for loop and the LED list. Similarly, we can set all of the switches as inputs. We add an extra parameter to the input setup, enabling pull-up resistors. These internal pull-ups keep the input at logic ‘1’ until the switch is pressed. Without the pull-ups enabled, the port input is ‘floating’ and at an unpredictable logic state.

```
def InitIO():
    GPIO.setmode(GPIO.BCM)
    GPIO.setwarnings(False)
    for led in LEDS:
        GPIO.setup(led,GPIO.OUT)
    for switch in SWITCHES:
        GPIO.setup(switch,GPIO.IN, pull_up_down=GPIO.PUD_UP)
```

Next, create some small, helper functions that encapsulate direct calls to GPIO. These simple routines let us set individual LEDs and read individual switches. Notice the ‘not’ operator in the GetSwitch routine. Our switches are pulling the input port down to logic 0, and will result in a 0 result when the switch is pressed. The ‘not’ converts the 0 to 1, and vice versa. Also, the last four functions could be rewritten in terms of SetLed, if desired. You choose!

```
def GetSwitch(index):
    #returns value of selected switch.  Expects value 0-7
    return not GPIO.input(SWITCHES[index])

def SetLed(num,value):
    #sets the led to desired value (1=on,0=off)
    GPIO.output(LEDS[num],value)

def AllLedsOn():
    for led in LEDS:
        GPIO.output(led, GPIO.HIGH)

def AllLedsOff():
    for led in LEDS:
        GPIO.output(led, GPIO.LOW)
```

```
def TurnOnLed(num):
    #turn on the indicated led.  Expects num 0-7
    GPIO.output(LEDS[num], GPIO.HIGH)

def TurnOffLed(num):
    #turn off the indicated led.  Expects num 0-7
    GPIO.output(LEDS[num], GPIO.LOW)
```

You should try them as you go. Start your main program block with InitIO(), then call whichever of them you want to try. For instance, what would the following do?

```
InitIO()
AllLedsOn()
time.delay(2)
AllLedsOff()
```

I like to build simple functions first and then call them, testing as I go. This 'bottom-up' programming style works well for me, especially when I am learning how to do something new. It is a good confidence-builder. Try some of your own simple functions. Perhaps you can take the test code above and put it into its own 'FlashLed' function.

Here is a more complex function: DisplayBinary. I want to be able to use the 8 LEDs to display an 8 bit binary number. For example, the number 101 in decimal is 0x65 in hexadecimal or 01100101 in binary. We'll use the 8 LEDs to display these 8 bits:

Led7	**Led6**	**Led5**	**Led4**	**Led3**	**Led2**	**Led1**	**Led0**
0	1	1	0	0	1	0	1

Every other LED should be on. To display any binary pattern, we look at each bit: if it's a one, then turn the led on; otherwise turn it off. We can use the left shift '<<' operator to select each bit. For 0x65, the value of bit2 (the third bit from the right) is 1. To isolate this bit, we can use a 'mask' that is all zeros except for bit2. Then, went we logically AND the value with this mask, the result will be greater than zero if bit2 was 1, and zero if bit2 was zero:

bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	
0	1	1	0	0	1	0	1	Value = 0x65
0	0	0	0	0	1	0	0	Mask = 1<<2
0	0	0	0	0	1	0	0	Result = Value & Mask

Using this mask & value approach, it is easy to turn on the correct LEDs. Select each bit, and set the LED according to the result. Any nonzero result from (value & mask) will result in the LED turning on.

```
def DisplayBinary(value):
    #displays value on LEDS in binary format
    for bit in range(8):
        mask = 1<<bit
        SetLed(bit,value & mask)
```

Nice and neat. We can use the left shift operator for another trick: bar graphs. If we want to light up any number of sequential LEDs, the corresponding binary value is (2^n) -1. For instance, 4 LEDs would be a value of 2^4 -1 = 16-1 = 15 (binary 00001111). Performing the 2^n is just the left shift operator: 2^n = (1<<n). If you don't believe me, type python on the command line to get into immediate-mode, then type '1<<4'. You'll get 16 (2^4) as your answer.

```
$ python
>>>  1<<4
16
>>> exit()
$
```

Let's see why that works. Start with 1 (binary 00000001) and shift it to the left. Every time you do, the value of the byte doubles.

bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	
0	0	0	0	0	0	0	1	Starting value = 1 (2^0)
0	0	0	0	0	0	1	0	1st shift: value = 2 (2^1)
0	0	0	0	0	1	0	0	2nd shift: value = 4 (2^2)
0	0	0	0	1	0	0	0	3rd shift: value = 8 (2^3)
0	0	0	1	0	0	0	0	4th shift: value = 16 (2^4)

A bar graph function might come in handy, so let's make one:

```
def BarGraph (value):
    #light up same # of LEDs as value.  Expects values 0-8
    temp = 1<<value
    DisplayBinary(temp-1)
```

That's all for part 2. The script that follows includes a few additional display routines. There is also a routine for getting switch input. Try them out, and then add your own!

6) PYTHON SCRIPT for GPIO, PART 2:

```
#!/usr/bin/python

########################################################################
#
#    GPIO2  :  Python control of the Raspberry Pi GPIO ports
#
#    Author :  Bruce E. Hall  <bhall66@gmail.com>
#    Date   :  25 Mar 2013
#
#    Use this script with the “Push your Pi” kit from MyPiShop.com
#    See w8bh.net for more information.
#
########################################################################

import RPi.GPIO as GPIO
import time

LED7  = 2    #GPIO2; use 0 on rev1 boards
LED6  = 3    #GPIO3; use 1 on rev1 boards
LED5  = 4    #GPIO4
LED4  = 7    #GPIO7
LED3  = 8    #GPIO8
LED2  = 9    #GPIO9
LED1  = 10   #GPIO10
LED0  = 11   #GPIO11
LEDS  = [LED0,LED1,LED2,LED3,LED4,LED5,LED6,LED7]

SW1   = 15   #GPIO15
SW2   = 17   #GPIO17
SW3   = 18   #GPIO18
SW4   = 27   #GPIO27; use 21 on rev1 boards
SW5   = 22   #GPIO22
SW6   = 23   #GPIO23
SW7   = 24   #GPIO24
SW8   = 25   #GPIO25
SWITCHES = [SW1,SW2,SW3,SW4,SW5,SW6,SW7,SW8]


########################################################################
#
#   Bit-manipulation routines
#   Nothing here relates to GPIO or the 'Push your Pi' kit.
#

def ReverseBits (byte):
    #reverse the bit order in the byte: bit0 <->bit 7, bit1 <-> bit6, etc.
    value = 0
    currentBit = 7
    for i in range(0,8):
        if byte & (1<<i):
            value |= (0x80>>i)
            currentBit -= 1
    return value

def ROR (byte):
    #perform a 'rotate right' command on byte
    #bit 1 is rotated into bit 7; everything else shifted right
    bit1 = byte & 0x01          #get right-most bit
    byte >>= 1                  #shift right 1 bit
    if bit1:                    #was right-most bit a 1?
        byte |= 0x80            #if so, rotate it into bit 7
```

```
    return byte

def ROL (byte):
    #perform a 'rotate left' command on byte
    #bit 7 is rotated into bit 1; everything else shifted left
    bit7 = byte & 0x080        #get bit7
    byte <<= 1                 #shift left 1 bit
    byte &= 0xFF               #only keep 8 bits
    if bit7:                   #was bit7 a 1?
        byte |= 0x01           #if so, rotate it into bit 1
    return byte


########################################################################
#
#   Low-level routines
#   These routines access GPIO directly
#

def InitIO():
    GPIO.setmode(GPIO.BCM)
    GPIO.setwarnings(False)
    for led in LEDS:
        GPIO.setup(led,GPIO.OUT)
    for switch in SWITCHES:
        GPIO.setup(switch,GPIO.IN, pull_up_down=GPIO.PUD_UP)

def GetSwitch(index):
    #returns value of selected switch.  Expects value 0-7
    return not GPIO.input(SWITCHES[index])

def SetLed(num,value):
    #sets the led to desired value (1=on,0=off)
    GPIO.output(LEDS[num],value)


########################################################################
#
#   Intermediate-level routines
#   These routines perform simple tasks with the I/O devices,
#

def TurnOnLed(num):
    #turn on the indicated led.  Expects num 0-7
    SetLed(num,1)

def TurnOffLed(num):
    #turn off the indicated led.  Expects num 0-7
    SetLed(num,0)

def FlashLED(num, delay=0.08):
    #turn on specified LED for given amount of time
    TurnOnLed(num)
    time.sleep(delay)
    TurnOffLed(num)

def AllLedsOn():
    for i in range(8):
        TurnOnLed(i)

def AllLedsOff():
    for i in range(8):
       TurnOffLed(i)
```

```
def DisplayBinary(value):
    #displays value on LEDS in binary format
    for bit in range(8):
        mask = 1<<bit
        SetLed(bit,value & mask)

def BarGraph (value):
    #light up same # of LEDs as value.  Expects values 0-8
    temp = 1<<value
    DisplayBinary(temp-1)


########################################################################
#
#   Test routines:
#   These routines perform more complex tasks with the I/O devices,
#   calling on the low and intermediate level routines

def BlinkAll(numCycles=4, delay=0.5):
    for count in range(numCycles):
        AllLedsOn()
        time.sleep(delay)
        AllLedsOff()
        time.sleep(delay)

def Count(upTo=0xFF, delay=0.1):
    #count in binary to the value 'upTo'
    for count in range(upTo):
        DisplayBinary(count)
        time.sleep(delay)

def Cylon (numCycles=8, delay=0.08):
    #creates a cyclon animation on the LEDs
    for count in range(numCycles):
        for i in range(7):
            FlashLED(i,delay)
        for i in range(7,0,-1):
            FlashLED(i,delay)

def SwitchTest():
    #lights up LED associated with pressed switch
	print "Press some switches.  This test lasts about 15 seconds."
	for count in range(150):
		for i in range(8):
			SetLed(i,GetSwitch(i))
		time.sleep(0.1)

def BarGraphTest(delay=0.4):
	#display 0 through 8 as a bar of lighted LEDs
	for value in range(9):			#count up
		BarGraph(value)
		time.sleep(delay)
	for value in range(7,-1,-1):		#count back down
		BarGraph(value)
		time.sleep(delay)

def RotateTest (numCycles=32, delay=0.05):
	#rotates a binary pattern on the LEDs
	for i in range(1,8):
		pattern = (1<<i) - 1
		for count in range(numCycles):
			DisplayBinary(pattern)
```

```
                time.sleep(delay)
                pattern = ROR(pattern)
        for i in range(7,0,-1):
            pattern = (1<<i) - 1
            for count in range(numCycles):
                DisplayBinary(pattern)
                time.sleep(delay)
                pattern = ROL(pattern)



########################################################################
#
#   Main Program
#

InitIO()
AllLedsOff()
SwitchTest()
Cylon()
BarGraphTest()
RotateTest()
Count()
BlinkAll()

#   END  ###############################################################
```