Raspberry PI Rotary Encoders

Tutorial

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Introduction

This tutorial has been designed to help students and constructors to understand how to use Rotary Encoders and to use them in their own Raspberry PI projects. The principle hardware required to build a project using Rotary Encoders consists of the following components:

- A Raspberry PI computer
- One or more rotary encoders with or without push button
- The rotary_class.py code and associated test programs.

Raspberry PI computer

The Raspberry Pi is a credit-card-sized single-board computer developed in the United Kingdom by the Raspberry Pi Foundation with the intention of promoting the teaching of basic computer science in schools.

Figure 1 Raspberry PI Computer

More information on the Raspberry PI computer may be found here: http://en.wikipedia.org/wiki/Raspberry_Pi

If you are new to the Raspberry PI try the following beginners guide. http://elinux.org/RPi_Beginners
**Rotary encoder**

A good place to start is by taking a look at the following Wikipedia article: [http://en.wikipedia.org/wiki/Rotary_encoder](http://en.wikipedia.org/wiki/Rotary_encoder)

There are several types of rotary encoder and encoding used. This tutorial is using the so called “Incremental Rotary Encoder”. An incremental rotary encoder provides cyclical outputs (only) when the encoder is rotated.

Rotary encoders have three inputs namely Ground, Pin A and B as shown in the diagram on the left. Wire the encoders according shown in Table 2 on page 10. If the encoder also has a push button knob then wire one side to ground and the other to the GPIO pin (Not shown in the diagram).

On the left is a typical hobbyist incremental rotary encoder. The one illustrated is the COM-09117 12-step rotary encoder from Sparkfun.com. It also has a select switch (Operated by pushing in on the knob in). This is the rotary encoder used in this tutorial.

The rotary encoder uses pins A and B as outputs. The A and B outputs to the GPIO inputs on the Raspberry PI will us the internal pull-up resistors, so that they read high when the contacts are open and low when closed. The inputs generate the sequence of values as shown on the left. As the inputs combined can have four states it is known as the quadrature sequence.

It is necessary to determine which direction the rotary encoder has been turned from these events.

---

**Figure 2 Rotary encoder wiring**

**Figure 3 Typical incremental rotary encoder**

**Quadrature Output Table**

<table>
<thead>
<tr>
<th>CW</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>A Signal</td>
<td>B Signal</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>CCW</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4 Quadrature output table**
The trick is to use the bitwise XOR value \( A^\wedge B \) to transform the input bits into an ordinal sequence number. There is no reason behind the XOR operation other than it to provide the bit sequence. For anti-clockwise the sequence is reversed.

The next task is to determine what direction the rotary encoder has been turned. This is first done by determining the delta (change) between the the previous state \((A + B + (A^\wedge))\) and the new state. The following code achieves this:

```python
delta = (new_state - last_state) % 4
```

The `%4` means give the remainder of a divide by 4 operation. The above code produces a value between 0 and 3 as shown in the following table:

<table>
<thead>
<tr>
<th>Delta</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No change</td>
</tr>
<tr>
<td>1</td>
<td>On step clockwise</td>
</tr>
<tr>
<td>2</td>
<td>Two steps clockwise or counter-clockwise</td>
</tr>
<tr>
<td>3</td>
<td>On step counter-clockwise</td>
</tr>
</tbody>
</table>

The whole sequence of code (Python) is shown below:

```python
# Get pin A state
if GPIO.input(pinA):
    rotary_a = 1
else:
    rotary_a = 0

# Get pin B state
if GPIO.input(pinB):
    self.rotary_b = 1
else:
    self.rotary_b = 0

# Create bit sequence
rotary_c = rotary_a ^ rotary_b

# Get the new rotary encoder state
new_state = rotary_a * 4 + rotary_b * 2 + rotary_c * 1

# Get the delta (difference) between the previous state and the new state
delta = (new_state - last_state) % 4

# Store the state for next time around
last_state = new_state
```

Why is `rotary_a` and `rotary_b` multiplied by 4 and 2 respectively? This is done to produce the value shown in the last column of Table 1 on page 5. The value of `rotary_c` will always be 0 or 1.
The Rotary Class

This tutorial uses the `rotary_class.py` Python class as shown in Appendix A The rotary encoder class. A class is like a blueprint for an object, in this case a rotary encoder. Why use a class? There are a lot of reasons but let's take a practical example. I wished to use rotary encoders in a project for building and Internet Radio using the Raspberry PI. For details of this project See: http://www.bobrathbone.com/raspberrypi_radio.htm

![Raspberry PI internet radio with Rotary Encoders](image)

Figure 5 Raspberry PI internet radio with Rotary Encoders

In this project I wish to use one rotary encoder for the volume control and mute functions and the other for the tuner and menu functions. The following table shows how the rotary encoders are wired. Of course other GPIO inputs may be used instead in your own project.

<table>
<thead>
<tr>
<th>GPIO Pin</th>
<th>Description</th>
<th>Function</th>
<th>Rotary Encoder 1 (Tuner)</th>
<th>Rotary Encoder 2 (Volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>GND</td>
<td>Zero volts</td>
<td>Common</td>
<td>Common</td>
</tr>
<tr>
<td>7</td>
<td>GPIO 4</td>
<td>Mute volume</td>
<td>Knob Switch</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>GPIO 14</td>
<td>Volume down</td>
<td></td>
<td>Output A</td>
</tr>
<tr>
<td>9</td>
<td>Reserved</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>GPIO 15</td>
<td>Volume up</td>
<td></td>
<td>Output B</td>
</tr>
<tr>
<td>11</td>
<td>GPIO 17</td>
<td>Channel Up</td>
<td>Output B</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>GPIO 18</td>
<td>Channel Down</td>
<td>Output A</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>GPIO 25</td>
<td>Menu Switch</td>
<td>Knob Switch</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Wiring list for Rotary Encoders used in the PI internet radio

To use the rotary class it must first be imported into the program that wishes to use it.

```python
from rotary_class import RotaryEncoder
```
The general call for the rotary_class is:

\[
\text{knob} = \text{RotaryEncoder}(	ext{PIN}_A, \text{PIN}_B, \text{BUTTON}, \text{event}\_\text{handler})
\]

Where PIN_A is the rotary encoder A output, PIN_B is the rotary encoder B output, BUTTON is the push button and event\_handler is the routine (callback) which will handle the events. The new switch object is called knob.

So to define a volume control this would become:

```python
VOLUME_UP = 15  # GPIO pin 10
VOLUME_DOWN = 14  # GPIO pin 8
MUTE_SWITCH = 4  # GPIO pin 7
volumeknob = RotaryEncoder(VOLUME_UP, VOLUME_DOWN, MUTE_SWITCH, volume_event)
```

We also need to define a routine called volume_event to handle the rotary encoder and push button events.

Events are defined in the rotary_class.py file.

```python
CLOCKWISE=1
ANTICLOCKWISE=2
BUTTONDOWN=3
BUTTONUP=4
```

The event handler looks something like below:

```python
# Call back routine for the volume control knob
def volume_event(event):
    global volumeknob
    if event == RotaryEncoder.CLOCKWISE:
        ... Code to handle volume increase
    elif event == RotaryEncoder.ANTICLOCKWISE:
        ... Code to handle volume decrease
    elif event == RotaryEncoder.BUTTONDOWN:
        ... Code to handle mute function
    return
```

In the same way we can define the tuner knob using a separate Rotary_Class definition.

```python
CHANNEL_UP = 18  # GPIO pin 12
CHANNEL_DOWN = 17  # GPIO pin 11
MENU_SWITCH = 25  # GPIO pin 25
tunerknob = RotaryEncoder(CHANNEL_UP, CHANNEL_DOWN, MENU_SWITCH, tuner_event)
```

Note that a different routine tuner_event is defined for the tuner event. Now it can be seen that a single class can be used to define more than one object. In this case the volume_knob and tuner_knob objects.

**Other rotary class calls**

The state of the rotary encoder push switch can be read with the getSwitchState function.

```python
MutePressed = tunerknob.getSwitchState(MENU_SWITCH)
```
GPIO Hardware Notes
The following shows the pin outs for the GPIO pins. For more information see: http://elinux.org/RPi_Low-level_peripherals

Raspberry PI GPIO numbering

<table>
<thead>
<tr>
<th>bottom left</th>
<th>top left</th>
</tr>
</thead>
<tbody>
<tr>
<td>3v3</td>
<td>5v</td>
</tr>
<tr>
<td>SDA0</td>
<td>--</td>
</tr>
<tr>
<td>SCL0</td>
<td>0v</td>
</tr>
<tr>
<td>GPIO 7</td>
<td>TX</td>
</tr>
<tr>
<td>--</td>
<td>RX</td>
</tr>
<tr>
<td>GPIO 0</td>
<td>GPIO 1</td>
</tr>
<tr>
<td>GPIO 2</td>
<td>--</td>
</tr>
<tr>
<td>GPIO 3</td>
<td>GPIO 4</td>
</tr>
<tr>
<td>--</td>
<td>GPIO 5</td>
</tr>
<tr>
<td>SPI MOSI</td>
<td>--</td>
</tr>
<tr>
<td>SPI MISO</td>
<td>GPIO 6</td>
</tr>
<tr>
<td>SPI SCLK</td>
<td>SPI CE0 N</td>
</tr>
<tr>
<td>--</td>
<td>SPI CE1 N</td>
</tr>
</tbody>
</table>

Raspberry GPIO Broadcom numbering

<table>
<thead>
<tr>
<th>bottom left</th>
<th>top left</th>
</tr>
</thead>
<tbody>
<tr>
<td>3v3 Power</td>
<td>5v Power</td>
</tr>
<tr>
<td>12C SDA</td>
<td>--</td>
</tr>
<tr>
<td>12C SCL</td>
<td>Ground</td>
</tr>
<tr>
<td>GPIO 4</td>
<td>UART TXD</td>
</tr>
<tr>
<td>--</td>
<td>UART RXD</td>
</tr>
<tr>
<td>GPIO 17</td>
<td>GPIO 18</td>
</tr>
<tr>
<td>GPIO 21</td>
<td>--</td>
</tr>
<tr>
<td>GPIO 22</td>
<td>GPIO 23</td>
</tr>
<tr>
<td>--</td>
<td>GPIO 24</td>
</tr>
<tr>
<td>SPI MOSI</td>
<td>--</td>
</tr>
<tr>
<td>SPI MISO</td>
<td>GPIO 25</td>
</tr>
<tr>
<td>SPI SCLK</td>
<td>SPI CE0 N</td>
</tr>
<tr>
<td>--</td>
<td>SPI CE1 N</td>
</tr>
</tbody>
</table>

Note: On rev 2 boards GPIO21 is now GPIO27
Appendix A The rotary encoder class

The source of these files is available on the Bob Rathbone website.

A.1 The rotary_class.py file

```python
#!/usr/bin/env python
#
# Raspberry Pi Rotary Encoder Class
# $Id: rotary_class.py,v 1.2 2014/01/14 07:30:07 bob Exp $
# Author : Bob Rathbone
# Site : http://www.bobrathbone.com
#
# This class uses standard rotary encoder with push switch
#
import RPi.GPIO as GPIO

class RotaryEncoder:
    CLOCKWISE=1
    ANTICLOCKWISE=2
    BUTTONDOWN=3
    BUTTONUP=4

    rotary_a = 0
    rotary_b = 0
    rotary_c = 0
    last_state = 0
    direction = 0

    # Initialise rotary encoder object
    def __init__(self,pinA,pinB,button,callback):
        self.pinA = pinA
        self.pinB = pinB
        self.button = button
        self.callback = callback

        GPIO.setmode(GPIO.BCM)

        # The following lines enable the internal pull-up resistors
        # on version 2 (latest) boards
        GPIO.setwarnings(False)
        GPIO.setup(self.pinA, GPIO.IN, pull_up_down=GPIO.PUD_UP)
        GPIO.setup(self.pinB, GPIO.IN, pull_up_down=GPIO.PUD_UP)
        GPIO.setup(self.button, GPIO.IN, pull_up_down=GPIO.PUD_UP)

        # For version 1 (old) boards comment out the above four lines
        # and un-comment the following 3 lines
        #GPIO.setup(self.pinA, GPIO.IN)
        #GPIO.setup(self.pinB, GPIO.IN)
        #GPIO.setup(self.button, GPIO.IN)

        # Add event detection to the GPIO inputs
        GPIO.add_event_detect(self.pinA, GPIO.FALLING,
                              callback=self.switch_event)
        GPIO.add_event_detect(self.pinB, GPIO.FALLING,
                              callback=self.switch_event)
        GPIO.add_event_detect(self.button, GPIO.BOTH,
                              callback=self.button_event, bouncetime=200)
        return

    # Call back routine called by switch events
    def switch_event(self,switch):
        if GPIO.input(self.pinA):
```

self.rotary_a = 1
else:
    self.rotary_a = 0

if GPIO.input(self.pinB):
    self.rotary_b = 1
else:
    self.rotary_b = 0

self.rotary_c = self.rotary_a ^ self.rotary_b
new_state = self.rotary_a * 4 + self.rotary_b * 2 + self.rotary_c * 1
delta = (new_state - self.last_state) % 4
self.last_state = new_state

if delta == 1:
    if self.direction == self.CLOCKWISE:
        event = self.direction
    else:
        self.direction = self.CLOCKWISE
elif delta == 3:
    if self.direction == self.ANTICLOCKWISE:
        event = self.direction
    else:
        self.direction = self.ANTICLOCKWISE
if event > 0:
    self.callback(event)
return

# Push button event
def button_event(self, button):
    if GPIO.input(button):
        event = self.BUTTONUP
    else:
        event = self.BUTTONDOWN
    self.callback(event)
return

# Get a switch state
def getSwitchState(self, switch):
    return GPIO.input(switch)

# End of RotaryEncoder class
A.2 The test_rotary_class.py file

This example uses GPIO pins 7, 8 and 10.

```python
#!/usr/bin/env python
#
# Raspberry Pi Rotary Test Encoder Class
#
# Author : Bob Rathbone
# Site   : http://www.bobrathbone.com
#
# This class uses a standard rotary encoder with push switch
#
import sys
import time
from rotary_class import RotaryEncoder

# Define GPIO inputs
PIN_A = 14      # Pin 8
PIN_B = 15      # Pin 10
BUTTON = 4      # Pi
    # This is the event callback routine to handle events
def switch_event(event):
    if event == RotaryEncoder.CLOCKWISE:
        print "Clockwise"
    elif event == RotaryEncoder.ANTICLOCKWISE:
        print "Anticlockwise"
    elif event == RotaryEncoder.BUTTONDOWN:
        print "Button down"
    elif event == RotaryEncoder.BUTTONUP:
        print "Button up"
    return

# Define the switch
rswitch = RotaryEncoder(PIN_A,PIN_B,BUTTON,switch_event)

while True:
    time.sleep(0.5)
```

A.3 Example using two switches
This example (test_rotary_switches.py) shows how to handle two or more switches.

```python
#!/usr/bin/env python
#
# Raspberry Pi Rotary Test Encoder Class
# $Id: test_rotary_switches.py,v 1.3 2014/01/31 13:57:28 bob Exp $
#
# Author : Bob Rathbone
# Site   : http://www.bobrathbone.com
#
# This class uses standard rotary encoder with push switch
#
import sys
import time
from rotary_class import RotaryEncoder

# Switch definitions
RIGHT_BUTTON = 25
LEFT_A = 14
LEFT_B = 15
RIGHT_A = 17
RIGHT_B = 18
LEFT_BUTTON = 4

# This is the event callback routine to handle left knob events
def left_knob_event(event):
    handle_event(event, "Left knob")
    return

# This is the event callback routine to handle right knob events
def right_knob_event(event):
    handle_event(event, "Right knob")
    return

# This is the event callback routine to handle events
def handle_event(event, name):
    if event == RotaryEncoder.CLOCKWISE:
        print name, "Clockwise event =", RotaryEncoder.CLOCKWISE
    elif event == RotaryEncoder.ANTICLOCKWISE:
        print name, "Anticlockwise event =", RotaryEncoder.ANTICLOCKWISE
    elif event == RotaryEncoder.BUTTONDOWN:
        print name, "Button down event =", RotaryEncoder.BUTTONDOWN
    elif event == RotaryEncoder.BUTTONUP:
        print name, "Button up event =", RotaryEncoder.BUTTONUP
    return

# Define the left and right knobs
leftknob = RotaryEncoder(LEFT_A, LEFT_B, LEFT_BUTTON, left_knob_event)
rightknob = RotaryEncoder(RIGHT_A, RIGHT_B, RIGHT_BUTTON, right_knob_event)

# Wait for events
while True:
    time.sleep(0.5)
```
Appendix B Licences

The software and documentation for this project is released under the GNU General Public Licence.

The GNU General Public License (GNU GPL or GPL) is the most widely used free software license, which guarantees end users (individuals, organizations, companies) the freedoms to use, study, share (copy), and modify the software. Software that ensures that these rights are retained is called free software. The license was originally written by Richard Stallman of the Free Software Foundation (FSF) for the GNU project.

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See http://www.gnu.org/licenses/#GPL for further information on the GNU General Public License.

Acknowledgements

Much of the information in this tutorial comes from an excellent article by Guy Carpenter. See:

http://guy.carpenter.id.au/gaugette/2013/01/14/rotary-encoder-library-for-the-raspberry-pi/
Glossary

GPIO  General Purpose IO (On the Raspberry PI)