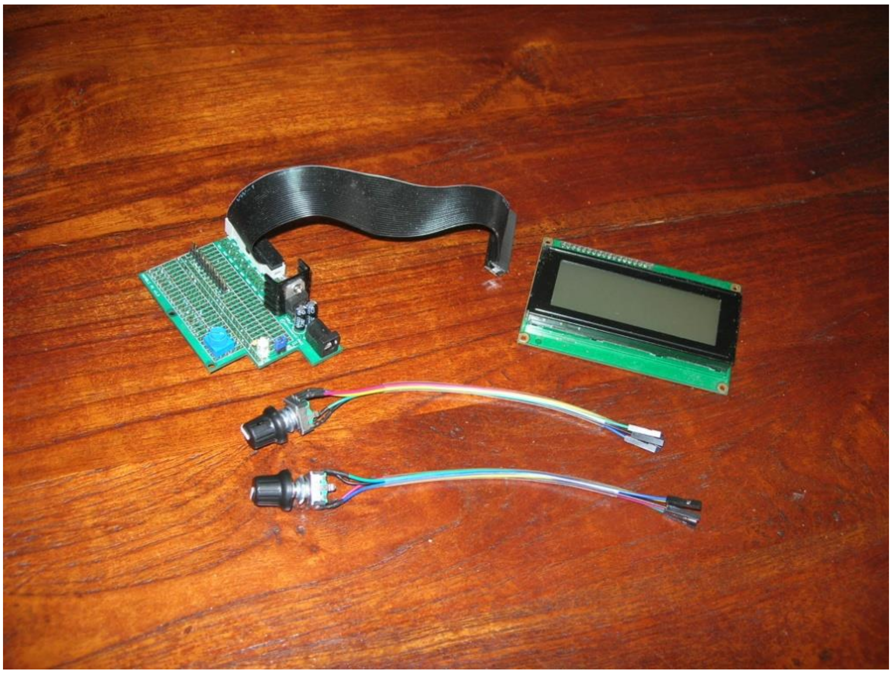
Raspberry PI Rotary Encoders

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 Model 3B 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 at
http://elinux.org/RPi_Beginners

Rotary encoders

A good place to start is by taking a look at the following Wikipedia article:
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.

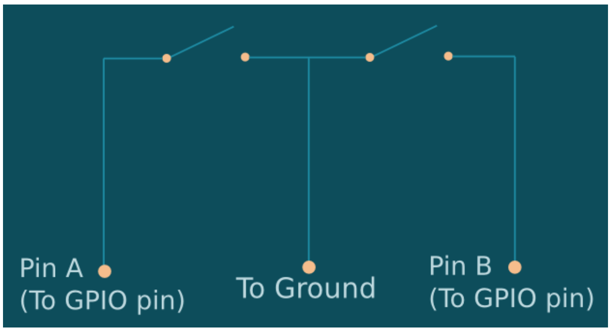


Figure 2 Rotary encoder wiring

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).


Figure 3 Typical incremental rotary encoder

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.

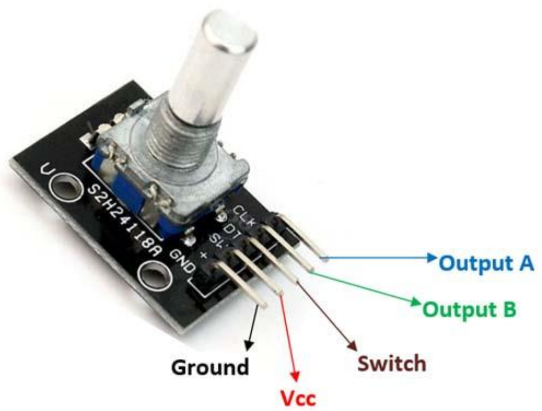
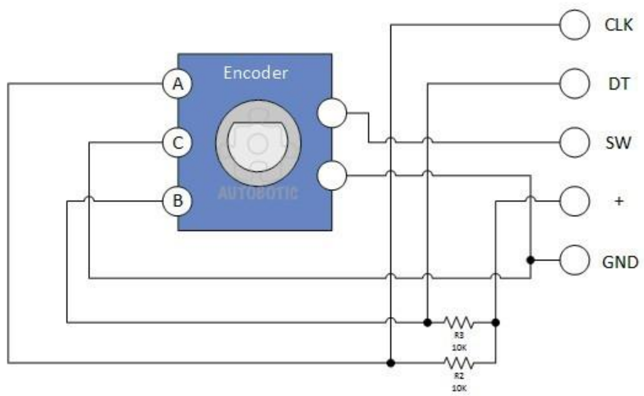


Figure 4 KY-040 Rotary Encoder

These cost-effective Rotary Encoders from Handson Technology are now being used more and more by constructors. The KY-040 Rotary Encoder specification shows that these are powered by +5V to the VCC pin.

However, the Raspberry Pi uses a +3.3V supply and cannot tolerate +5V on the GPIO's so the advice is to connect VCC to +3.3V. These encoders work fine with VCC as +3.3V with this project.



The specification shows the KY-040 rotary encoders are labelled CLK(Clock), DT(Data) and + (VCC) however it is more usual to label these A, B and C

The SW(Switch) connection is safe as it will pull the GPIO down to 0V.

Theory of incremental rotary encoders

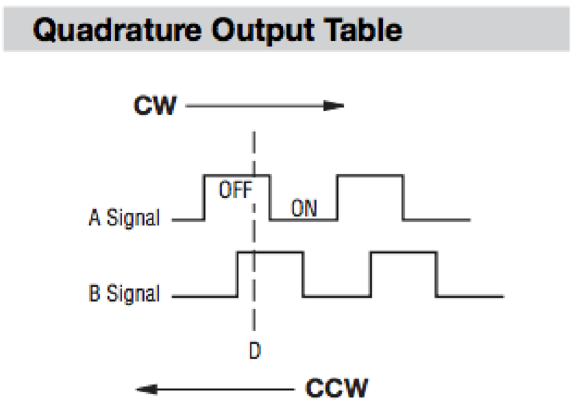


Figure 5 Quadrature output table

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.

Table 1 Rotary encoder sequence (Clockwise)

Sequence	A	B	A^B (C)	Value
0	0	0	0	0
1	1	0	1	5
2	1	1	0	6
3	0	1	1	3

The trick is to use the bitwise XOR value `A^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^)) and the new state. The following code achieves this:

```
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 2 Event interpretation using the delta between events

Delta	Meaning
0	No change (Ignored)
1	One step clockwise
2	Two steps clockwise or counter-clockwise (Ignored)
3	One step counter-clockwise

The delta is used to generate either the CLOCKWISE or ANTICLOCKWISE event which is then passed to the call-back event in the user's program. Delta 0 and 2 are ignored.

```
delta = (new_state - self.last_state) % 4
self.last_state = new_state
event = 0

if delta == 1:
        if self.direction == self.CLOCKWISE:
                # print "Clockwise"
                event = self.direction
        else:
                self.direction = self.CLOCKWISE
elif delta == 3:
        if self.direction == self.ANTICLOCKWISE:
                # print "Anticlockwise"
                event = self.direction
        else:
                self.direction = self.ANTICLOCKWISE
if event > 0:
        self.callback(event)
```

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.

Optical Rotary encoders

Optical rotary encoders are by nature of their manufacture are much more expensive than the mechanical (conductive) rotary encoders previously shown. These encoders offer the higher resolution compared to mechanical ones. They are usually used for scientific and industrial applications with very demanding output performance. They are overkill for this project but may be used.

This software has been tested with an HRPG-ASCA #16F optical encoder from Avago.
See https://media.digikey.com/pdf/Data%20Sheets/Avago%20PDFs/HRPG_Series.pdf

The Rotary Class

This tutorial uses the **rotary_class.py** Python class as shown in *Appendix A* - . 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. I want to define two rotary encoders. Using a rotary class, I can instantiate two or more rotary encoder definitions, for example: **leftknob** and **rightknob**, using the same rotary class code.

For details of this project See:
https://bobrathbone.com/raspberrypi/pi_internet_radio.html

Figure 6 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 3 Wiring list for Rotary Encoders used in the PI internet radio

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

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

```
from rotary_class import RotaryEncoder
```

The general call for the rotary_class is:

knob = RotaryEncoder(PIN_A, PIN_B, BUTTON, event_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:

```
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.

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

The event handler looks something like below:

```
# 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 definitiion

```
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.

```
MutePressed = tunerknob.getSwitchState(MENU_SWITCH)
```

GPIO Hardware Notes

The following shows the pin outs for the GPIO pins on revision 1 and 2 boards. For more information see: http://elinux.org/RPi_Low-level_peripherals.

GPIO Numbers

Raspberry Pi B
Rev 1 P1 GPIO Header

	Pin No.		
3.3V	1	2	5V
GPIO0	3	4	5V
GPIO1	5	6	GND
GPIO4	7	8	GPIO14
GND	9	10	GPIO15
GPIO17	11	12	GPIO18
GPIO21	13	14	GND
GPIO22	15	16	GPIO23
3.3V	17	18	GPIO24
GPIO10	19	20	GND
GPIO9	21	22	GPIO25
GPIO11	23	24	GPIO8
GND	25	26	GPIO7

Raspberry Pi A/B
Rev 2 P1 GPIO Header

	Pin No.		
3.3V	1	2	5V
GPIO2	3	4	5V
GPIO3	5	6	GND
GPIO4	7	8	GPIO14
GND	9	10	GPIO15
GPIO17	11	12	GPIO18
GPIO27	13	14	GND
GPIO22	15	16	GPIO23
3.3V	17	18	GPIO24
GPIO10	19	20	GND
GPIO9	21	22	GPIO25
GPIO11	23	24	GPIO8
GND	25	26	GPIO7

Raspberry Pi B+
B+ J8 GPIO Header

	Pin No.		
3.3V	1	2	5V
GPIO2	3	4	5V
GPIO3	5	6	GND
GPIO4	7	8	GPIO14
GND	9	10	GPIO15
GPIO17	11	12	GPIO18
GPIO27	13	14	GND
GPIO22	15	16	GPIO23
3.3V	17	18	GPIO24
GPIO10	19	20	GND
GPIO9	21	22	GPIO25
GPIO11	23	24	GPIO8
GND	25	26	GPIO7
DNC	27	28	DNC
GPIO5	29	30	GND
GPIO6	31	32	GPIO12
GPIO13	33	34	GND
GPIO19	35	36	GPIO16
GPIO26	37	38	GPIO20
GND	39	40	GPIO21

Key

Power +	UART
GND	SPI
I²C	GPIO

Figure 7 GPIO Numbers

Note: The B+, 2B, 3B and 4B have the same pin-outs.

Appendix A - Source files

The software is stored on GitHub at https://github.com/bobrathbone/pirotary

The convention for the following instructions is to show them preceded by a $ sign. This represents the pi user command line prompt as shown below.

```
pi@raspberrypi:~ $
```

This is represented by a $ sign followed by the instruction. Only copy the instruction and not the $ sign.

```
$ <instruction>
```

Install **Git** on the Raspberry Pi first

```
$ sudo apt-get install git
```

Clone the **pirotary** project in the user pi home directory

```
$ cd
$ git clone https://github.com/bobrathbone/pirotary
```

Make the software executable.

```
$ cd pirotary/
$ chmod +x *.py
```

Test the rotary class with the test program.

```
$ ./test_rotary_class.py
Clockwise
Clockwise
Clockwise
Anticlockwise
Anticlockwise
Anticlockwise
Button down
Button up
```

A.1 The rotary_class.py file

```
#!/usr/bin/env python
#
# Raspberry Pi Rotary Encoder Class
# $Id: rotary_class.py,v 1.3 2021/04/20 12:23:04 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.BOTH, 
callback=self.switch_event)
		GPIO.add_event_detect(self.pinB, GPIO.BOTH, 
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
                event = 0

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


        # Push button up 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.

```
#!/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      # Pin 7

# 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 encoders

This example (test_rotary_switches.py) shows how to handle two or more switches.

```
#!/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.BUTTONDOWN
        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.

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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/

My thanks to **Jim Smith** from Shropshire for his work on optical rotary encoder.

Glossary

GND	Ground, 0 Volts
GPIO	General Purpose IO (On the Raspberry PI)
VCC	Voltage Common Collector but now means the voltage supply to any electronic circuit