The Rotary Encoder

You may work in pairs for this lab, and you will need access to an *oscilloscope* (located at each lab bench).

One of the components in your kit that we have not used yet is the *rotary encoder*. This device is a combination "rotation sensor" and push-button component, and it can be useful on a wearable device that needs a range of inputs but needs to be compact.

Find the rotary decoder in your kit. The decoder has a cylindrical handle with one flat side, and five pins (and two tabs) facing downwards. When you turn the handle, you will feel a noticeable click, and when you push down on the handle, you can feel a button click. (*Note*: There is a similar-looking device called a *potentiometer*, which only has a total of three pins sticking out horizontally, and whose handle does not click as it rotates)

Part I: Components

For this lab, you will need the following components:

Component
Breadboard with power supply (3.3V)
Rotary Encoder
Light Blue Bean
Red LED
Eleven Female-Male wires
Three ~10KΩ resistors
One ~100Ω resistor
Two male-male wires.

Once you have your components, download the Fritzing Breadboard from the course web site:

http://www.cs.tufts.edu/comp/50WD/RotaryEncoder.fzz

You can also download the Arduino .ino file as well:
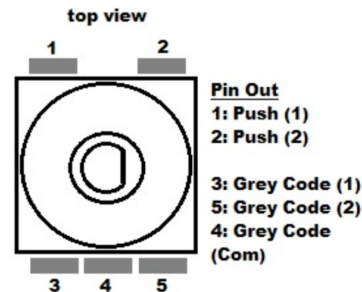
http://www.cs.tufts.edu/comp/50WD/RotaryEncoder.ino

Do not set up the part on your breadboard yet.

Part II: What do we expect?

The rotary encoder (30403 SW) part is a 20-position, continuous encoder with a push-button switch. There is a data sheet for the part, located here:

http://www.mpja.com/download/30403sw.pdf

This is the pin-out from the above page:

The push-button switch (pins 1 and 2 on the data sheet) is a simple closed-when-pushed switch, which you have seen before as a single button. When the button is pressed down, the connection between pins 1 and 2 is closed, when it is not pressed, the connection between pins 1 and 2 is open.

Pins 3, 4, and 5 are connected so that when the knob is turned, the output on pins 3 and 5 produce what is called a "Gray Code" (named after Frank Gray from Bell Labs in 1947) to designate which direction the switch has been turned, clockwise or counterclockwise.

A Gray Code is a binary numeral system where two successive values differ by a single bit, and is frequently used in error correction schemes for digital communications. In the rotary encoder, pins 3 and 5 produce a pattern of high/low pulses when the knob is turned:
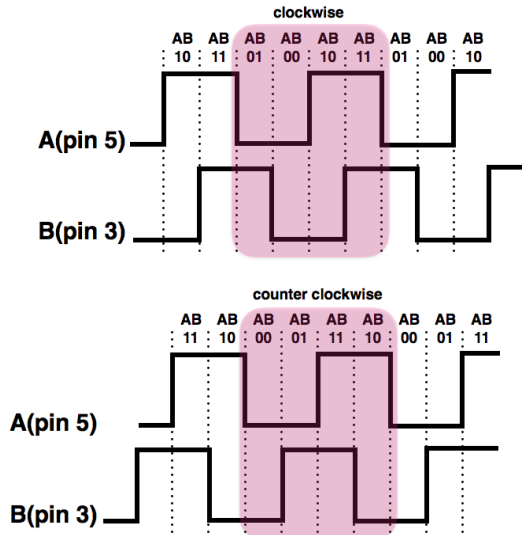
We can find out which direction the knob has been turned in the following way:

1. We determine when A (pin 5) has transitioned from High to Low.
2. If B (pin 3) is High, the knob was turned clockwise.
3. If B is low, the knob was turned counterclockwise.

You can see this in the beginning of the shaded area in the figure on the diagram above: when A transitions from High to Low, B is high if the knob was turned clockwise, and low if the knob was turned counterclockwise.

Part III: Using an Oscilloscope

The rotary encoder seems somewhat complicated, and many times when we want to observe complicated circuits, we use another lab tool called an *oscilloscope*. The oscilloscope is a powerful diagnostic tool that enables you to capture signals in real time and analyze them in great detail. We are going to use the oscilloscope to analyze the rotary encoder.
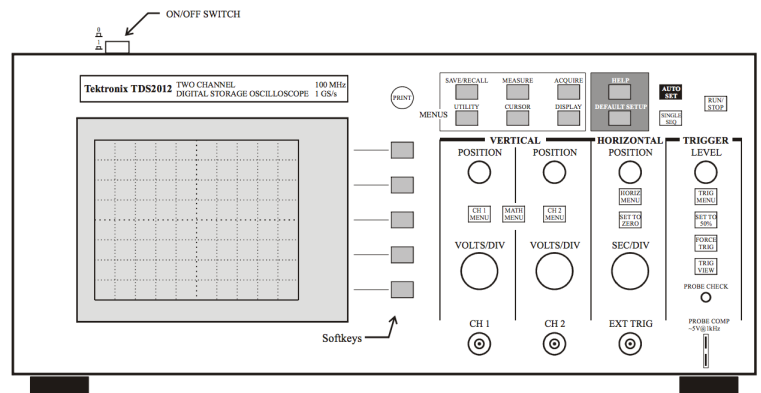
Steps:

1. Build the circuit shown in the Fritzing diagram, but do not connect the Bean to the breadboard yet.

2. The "dangling wires" in the diagram are going to be connected to the oscilloscope, which you can do with alligator clips (preferred), or with copper tape.

3. Locate the oscilloscope on your lab bench. It looks like this:


and here is a line-art diagram:

4. Turn on the oscilloscope.

5. There should be two cables coming out of connectors labeled "CH 1" and "CH 2". The alligator clips that are already on the cables should be connected to ground — the easiest place will be on the ground connector of the LED you put into the circuit. Connect the end of each cable to the dangling wires — CH 1 should be connected to Pin 5 on the Rotary Encoder, and CH 2 should be connected to Pin 3. Make sure the little switch on the connector cable is switched to "1X" (not 10X).

6. Make sure that the breadboard power supply is turned on.

7. Click the "CH 1 MENU" button, and then click the brown button next to "Probe" (it says "Probe 10X" on the screen) until it says "1X". Do the same with "CH 2 MENU".

8. Click the "AUTO SET" button on the oscilloscope — it is located on the top right in a group of three buttons, and is highlighted in black with white text.

9. You should see two lines, one yellow (CH 1) and the other blue (CH 2). If you disconnect the (not the ground cables), you should see these go up and down. These lines are measuring the voltage of pins 3 and 5, and based on the way we designed the circuit, they will both be 3.3V right now. The little 1> and 2> symbols on the left show the 0V mark for CH 1 and CH 2 respectively. It should say "CH1 2.00V   CH2 2.00V" at the bottom of the screen. This means that each large division (dotted lines) on the screen is 2V. Notice that both CH1 and CH2 are about 1.7 divisions from their 1> and 2> symbols, meaning that it is about 3.3V.

10. Turn the rotary encoder knob a few times clockwise and counter-clockwise. Your lab partner will probably have to hold the encoder so the wires don't slip out. Notice on the screen that you can see some square waves going across the screen really fast. We want to stop them to measure them.

11. The right-most knob on the oscilloscope is the "TRIGGER" knob (see the diagram above). Click "TRIG MENU" below that knob. Make the Trigger options read as follows:

Type: Edge
Source: CH1
Slope: Falling
Mode: Auto
Coupling: DC

12. Next, use the trigger knob to scroll the trigger arrow (on the right side of the screen) up to align with the yellow (CH 1) line.

13. Use the "SEC/DIV" knob (it is the big knob on the bottom right) to change the white text at the bottom of the screen to read "M 10.0ms" This

14. Click the "SINGLE SEQ" button underneath the "AUTO SET" button on the top right of the oscilloscope.

15. Now rotate the rotary encoder knob clockwise, and see that you get some square waves that have stopped on the screen. This is the signal we are looking for!

16. Note that when CH1 falls, CH2 is high — this designates that you turned the knob clockwise. If you can't tell, you can click the brown "CURSOR" button, change the "Type" to "Time," and you can use the VERTICAL Position knobs (above CH1 and CH2) to move two vertical lines on the screen to line up the falling edge of one square wave. It should look something like this:
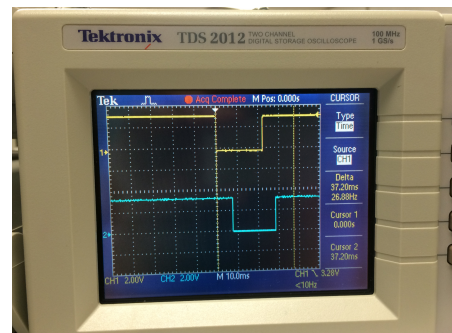
17. Click "SINGLE SEQ" again, and turn the knob counterclockwise. You should get a stopped set of square waves that look like this, with CH2 low when CH1 falls (because you turned the knob counterclockwise!)
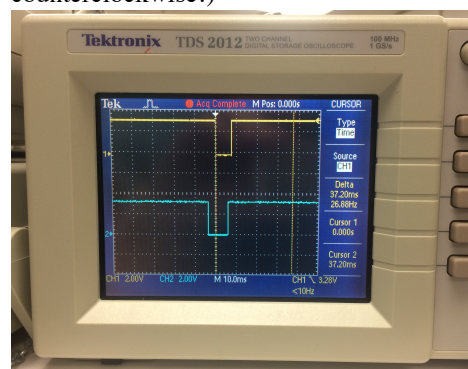
18. Now hook up your Light Blue Bean, and load the RotaryEncoder.ino sketch onto it. Take some time to look over the sketch to see that it uses the features of the rotary encoder to determine whether the direction of rotation of the knob, and whether the button was pushed or not.

19. Once you have that running, you should be able to use the serial terminal to see the output of the sketch when you turn the knob clockwise ("+"), counterclockwise ("-"), when you push the button ("d"), and when you release the button ("u").

20. You should also see that the LED gets brighter and dims when you turn the knob enough times in one direction (clockwise to get brighter, counterclockwise to get dimmer).

## Part IV: Rotary Encoder Takeaways

The rotary encoder is a nice little input device that can be used on a wearable. There are smaller versions you can purchase, too.

You only need three total pins on your Bean to get input from the rotary encoder (including the button), and it can be used to control any number of different types of user interfaces.

Part V: Extra Oscilloscope Practice

Your lab bench has another interesting piece of equipment on it called a *function generator*. The function generator is on the top left side of the bench, to the left of the oscilloscope and on top of the multimeter.

The function generator produces alternating waves that you can analyze with the oscilloscope (or use for projects that need waveform input).The generator will produce three types of waves, as shown below:

Square Wave

Triangle Wave

Sine Wave
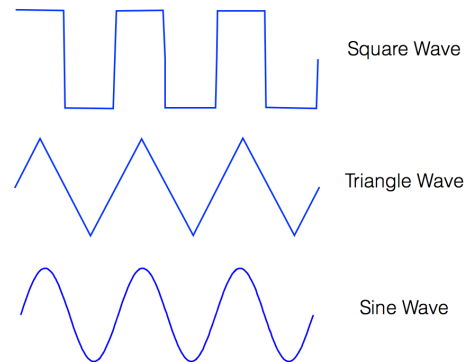
Let's produce a 1KHz triangle wave on the function generator:

1. Turn on the function generator (bottom left button).
2. Press the 1k button (for a 1KHz signal).
3. Press the "triangle wave" button (underneath the 100 button).
4. Slowly adjust the big button on the left until you get as close to 1.0000 as you can (you should be able to get 1.00xx).
5. Make sure the other four knobs all have their raised line pointing straight up.
6. Take the cable off the wall that has a male plug on one side and two alligator clips on the other side, and plug it into the function generator "OUTPUT" receptacle.
7. Take the oscilloscope CH 1 probe, and connect the two alligator clips to it (if there is a black alligator clip on the cable, connect it to the alligator clip on the probe).
8. Press the "AUTO SET" button on the oscilloscope. You should see a triangle wave.
9. Measure the "peak-to-peak" time by pressing the "CURSOR" button, setting "Type" to "Time," and putting the left cursor over a top peak of a triangle, and the right cursor over the next top peak. You should read a "Delta" of 1.000ms and 1.000kHz.

Play around with the knobs and buttons on both the oscilloscope and the function generator to see what other analysis the oscilloscope is capable of. A key knob on the oscilloscope is the "SEC/DIV" knob, which adjusts the amount of time that the oscilloscope displays.