EOH Hand Generator Upgrade

ECE 445 Design Document
Team 25
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1. Introduction

1.1 Objective

Currently, Engineering Open House has a hand crank generator that it uses to demonstrate how a winding rotating through a static magnetic field induces a voltage at the winding's terminals.

The existing generator system has a hand crank that the student rotates producing a pair of voltage waveforms (the shaft has 2 mechanically orthogonal windings). The induced voltages are displayed on the oscilloscope -- showing periodic voltage waveform with frequency and amplitude dependent upon the crank's rotational speed.

The existing system falls short because it does not display phase relationships -- specifically between shaft position, the physical position/orientation of the orthogonal windings, and the voltages induced at the winding terminals. The requirement is to sense the rotor's mechanical position and display it as a voltage on the oscilloscope alongside the induced voltages from the two windings. Additionally, the device is to display the shaft's rotational velocity in RPM and RAD/s as numbers.

1.2 Background

The product we envision is a stand alone device that receives data from an encoder attached to the generator shaft. We will use the microprocessor to produce two things:

1) An analog voltage waveform (to be determined -- must make intuitive sense to the audience) representing the shaft's mechanical phase that will be displayed on the oscilloscope.

2) Digital rotational speed data to be presented on the LCD digital display

1.3 High-Level Requirements

- The circuit must be able to output the correct velocity of the crank in both RPMs and rads/sec.
- The circuit must attach onto the current generator setup without blocking the internals of the generator.
- The circuit must output the location of the crank to the oscilloscope in a manner that is understandable to children.

2. Design

From an architectural standpoint, demonstrator system is composed of the generator, oscilloscope, and the position detector. The generator and oscilloscope are "black boxes" from and to which signals flow.   Our design effort is on the "position detector". This will be made of up four submodules: microprocessor, encoder, an LCD display (rotational speed data), and power supplies (microprocessor, LCD display, voltage waveform generation, with voltage regulation)

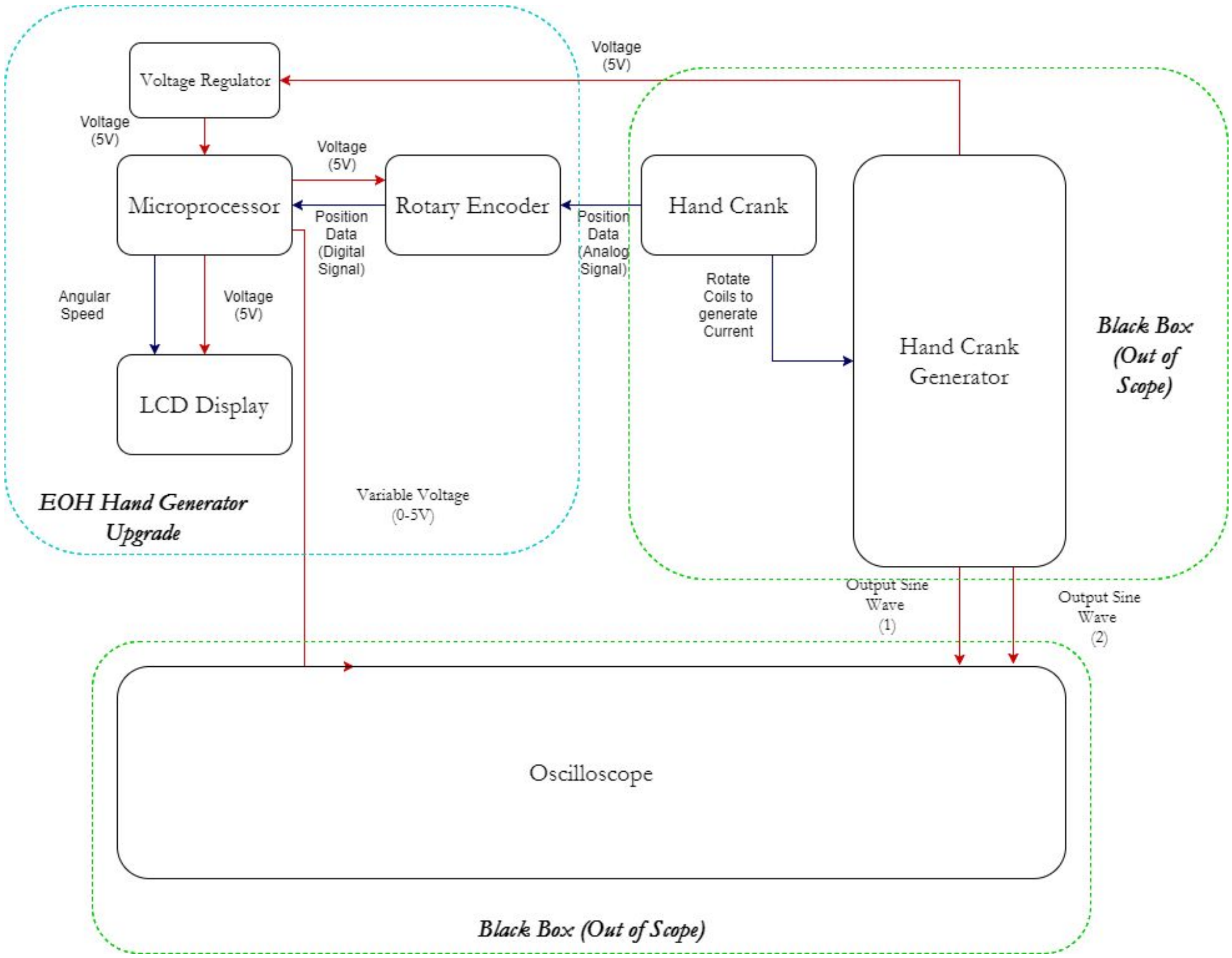

Figure 1: Block Diagram

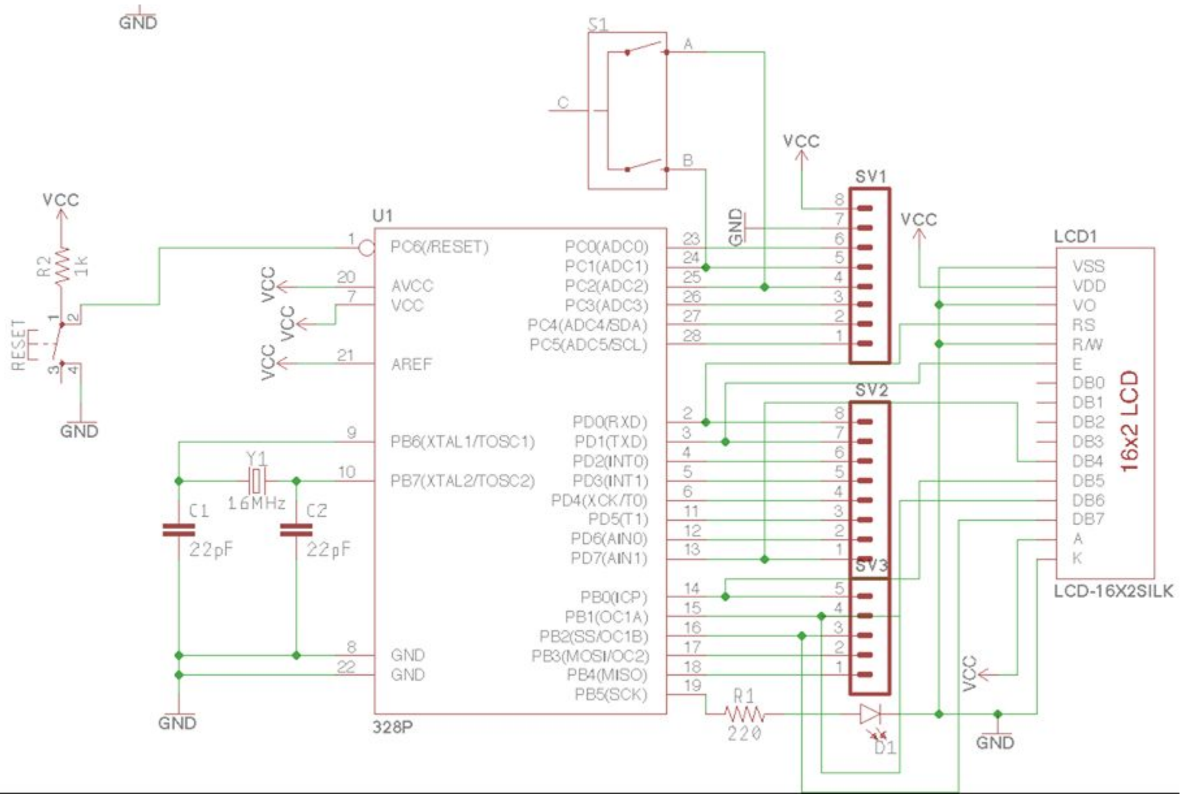

Figure 2: Complete Schematic

2.1 EOH Hand Generator Upgrade Module

The most challenging part of our project will be implementing a way to accurately track the position and the speed of the crank while displaying these values in an intuitive manner. The EOH Hand Generator Upgrade Module will consist of four different parts which will work together to display the position and speed of the crank instantaneously. These components are a rotary encoder, a microprocessor, a LCD display, and a voltage regulator. The EOH Hand Generator Upgrade Module will be powered by the crank generator, allowing it to be reused often with very little upkeep. Additionally, the microcontroller, and the rotary encoder together will consume approximately 50mA.

2.1.1 Rotary Encoder

We will be using a rotary encoder, part number COM-11102, to translate the mechanical position (an analog signal) to a PWW cycle (a digital signal). This device will be at the end of the generator, on the other end of the crank so we can still see the coils rotating. It will send the PWW cycle, also referred to as grey code, to the microprocessor using the black and white wires (in design specs), which corresponds to the A and B signals (see figure 2).

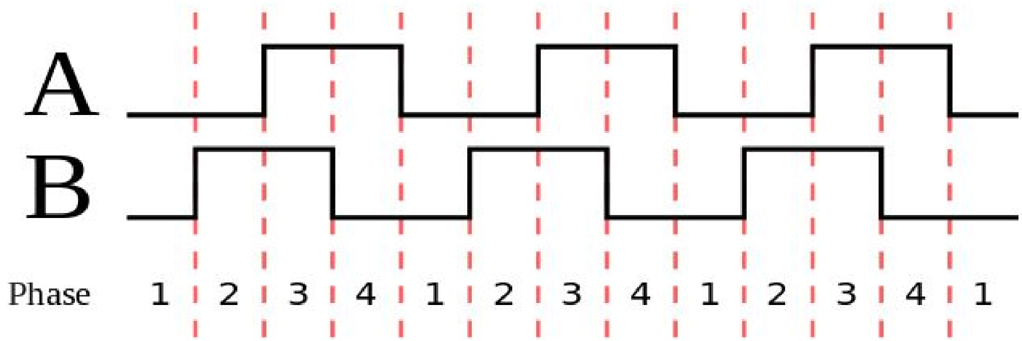

Figure 3: PWW Cycle generated by the Encoder

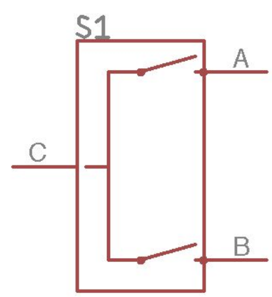

Figure 4: Rotary Encoder in Eagle

Since we are purchasing this part as is, our requirements and verifications will be to ensure that the correct data is coming out of the part.

Requirements	Verification
1. Be able to tell the direction (counterclockwise or. clockwise) the crank is moving. 2. Be able to judge when the crank is moving at different angular velocities.	1. A. Connect the rotary encoder to the crank as well connecting signals A and B to the oscilloscope. B. Rotate the crank counterclockwise. C. Check if signal B is leading signal A by

	90° D. Rotate the crank clockwise. E. Check if signal A is leading signal B by 90° 2. A. Connect the rotary encoder to the crank as well connecting signals A and B to the oscilloscope. B. Rotate the crank once, completing a full rotation in one second C. Record the produced waveform D. Rotate the crank twice within a timeframe of one second E. Record the produced waveform F. Measure the width of both waveforms and check if the second waveform 50% the width of the first waveform

2.1.2 Microcontroller

The microcontroller, an ATmega328 AVR, will translate the gray code output from the Rotation Encoder to interpret which direction the shaft of the encoder is turning and by how much. The microprocessor will output a variable voltage ranging from 0-5V, based off of the position of the crank (see Fig. 2), and will send this voltage to the LED display to show the position of the crank. Additionally, the RPM (which can also be interpreted from the grey code) will be output to the LED display. This microcontroller was chosen based off of its affordability, its robustness, and speed. This allows us to ensure that the LED display is getting all the information it needs in a timely manner, and that the project will last a long time despite its heavy use during Engineering Open House. Additionally, the rotation encoder manufacturer suggested that we use this microcontroller.

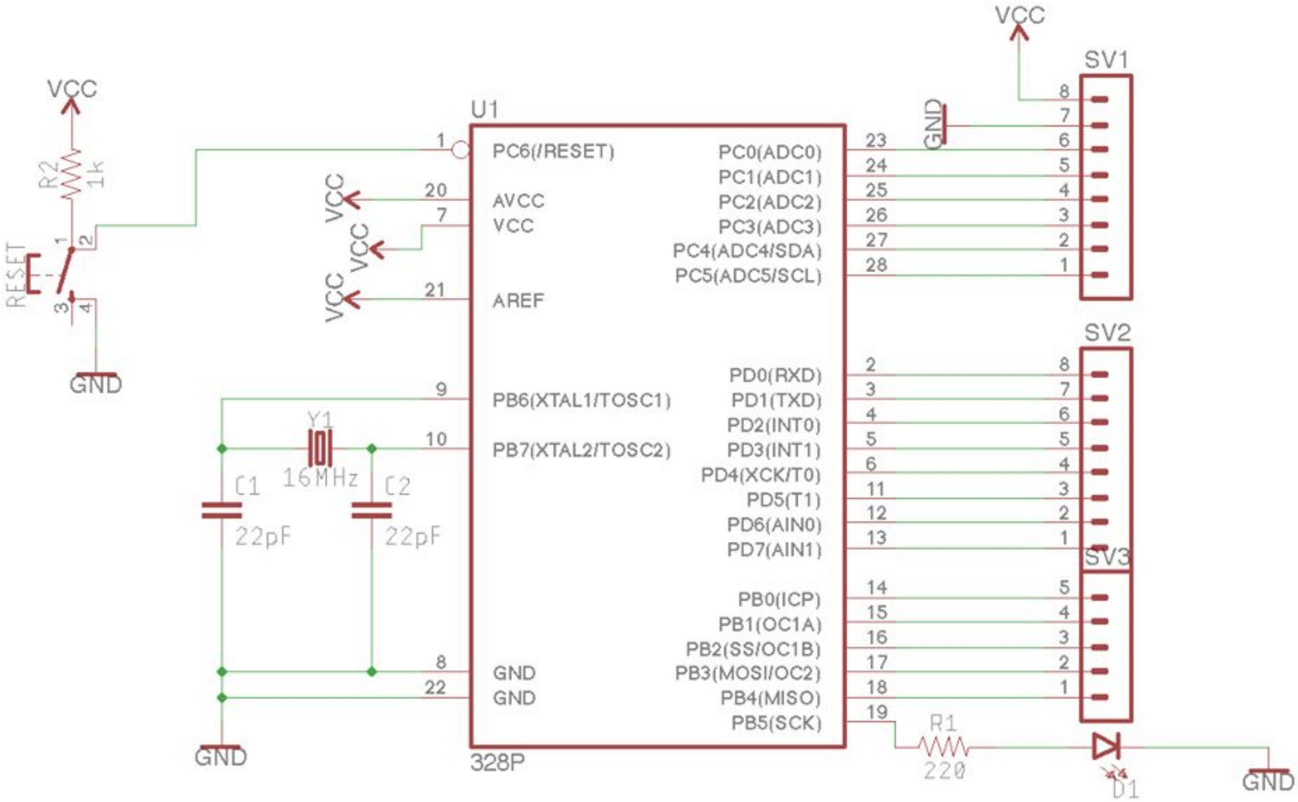

Figure 4: Microcontroller Schematic in Eagle

$$v(k) \approx \frac{x(k) - x(k-1)}{T} = \frac{\Delta X}{T}$$

$$v(k) \approx \frac{X}{t(k) - t(k-1)} = \frac{X}{\Delta T}$$

Figure 5: Equations to find angular velocity

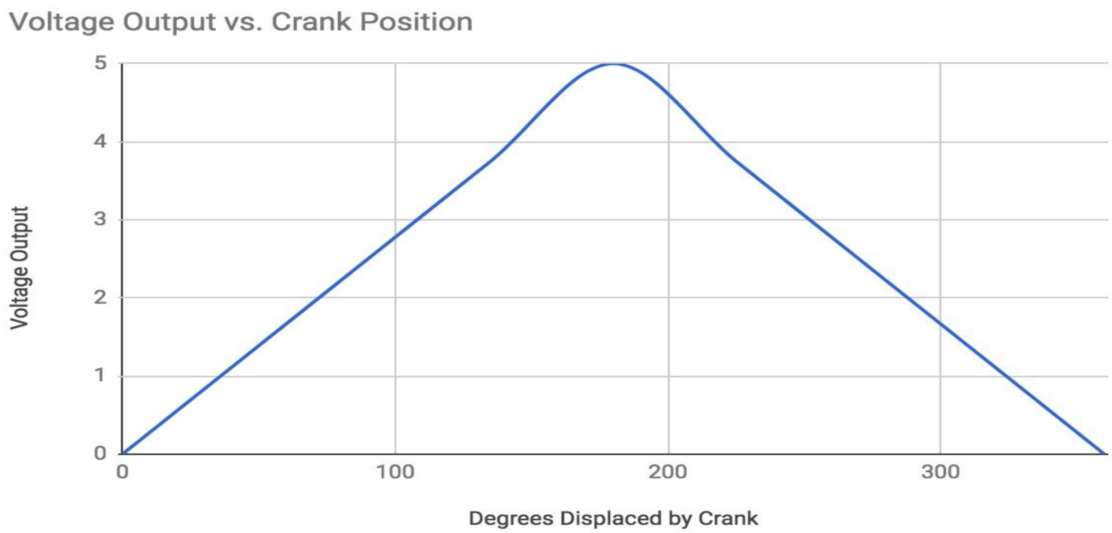

Figure 6. Voltage Output vs. Crank Position from Microcontroller

Requirements	Verification
1. Can receive grey code and successfully translate to position of encoder. 2.Can transmit encoder position via Voltage which corresponds to Figure 2.	1. A. Connect microcontroller to PC via USB-UART TTL converter. B. Slowly rotate encoder and read output of position. C. Stop in 90° increments and read calculated output on PC. D. Compare these two values and calculate the percent difference between them. E. Confirm that the position calculated by the microcontroller and the position of the physical crank have a percent difference of 5%. 2. A. Connect output of microcontroller to voltmeter B. Slowly move encoder and confirm that voltage reading is oscillating between 0V and 5V. C. Confirm peak voltage output is achieved within 5% of 180°. D. Confirm minimum output is achieved within 5% of 0° and 360°

	E. Confirm average output is achieved within 5% of 90° and 270°.

2.1.3 LCD Display

The LCD Display (LCD-00255) will take inputs from the microprocessor and display the speed of the crank in both RPMs and Rads/sec. The display will also be powered by the microprocessor.

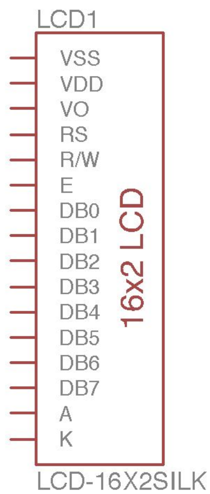

Figure 7: LCD Display in Eagle

Since we are purchasing this part as is, our requirements and verifications will be to ensure that the correct data is coming out of the part.

Requirements	Verification
1. Can display speed in both RPMs and Rads/sec	1. A. Make sure 5.0V are supplied to the display B. Using set print statements, print out statements to the screen C. Check speed displayed by counting how many cycles are done in 5 seconds

2.1.4 Voltage Regulator

We will be building the voltage regulator for the microprocessor to ensure that the chip gets the 5 volts that it needs. This is also make sure, since people are rotating the hand crank, it is possible that they could generate more than 5V. For this reason, we want to make sure that only 5V is being pushed into the system [4].

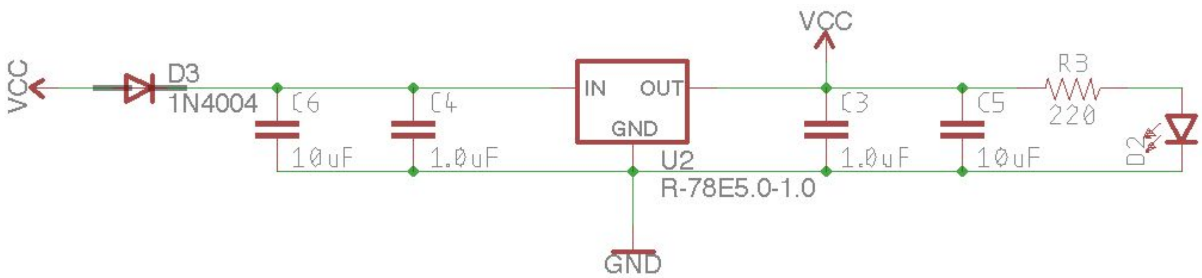

Figure 8: Voltage Regulator Schematic in Eagle

Requirements	Verification
1. The regulator does not allow more than 5V through the system	1. A. Once constructed, connect the voltage regulator to a variable power source as well as an oscilloscope B. Begin by putting 4V through the regulator and seeing if there is a 4V output C. Perform a second test by putting 6V through the system and seeing if the output is 5V

2.2 Algorithm

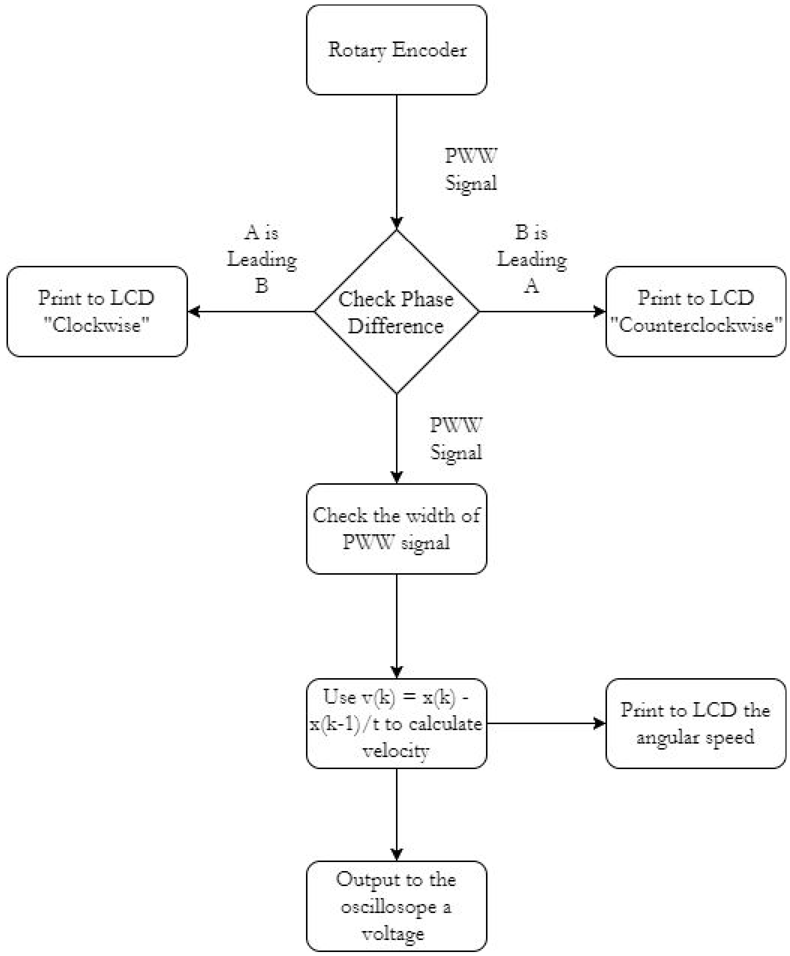

Figure 5: Algorithm flowchart

The main algorithm we need to run for this system is a way to get angular speed and position given the grey code from the rotary encoder. As seen in the figure below, a three bit rotary encoder (like the one we are using) will have several grey areas [5]. When the encoder is in one of these positions, it will return to the microprocessor the correct bit sequence. We can get the position of the crank from that. As for the finding the speed, we will be analyzing the square waves outputted from the encoder. There, we will be looking at the width of each wave and how that translates to angular speed.

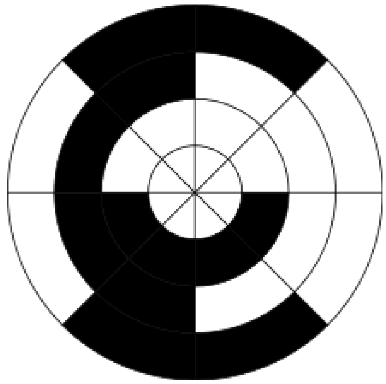

Figure 9: Rotary Encoder grey code generator

2.3 Tolerance Analysis

In our system, we want to ensure that students are able to see the relationships between position, angular speed, and the voltage generated. The rotary encoder will provide us the signals of how the crank is operating. From there it is up for the microcontroller to analyze the waves and extrapolate the information that we need.

However, we can only confirm that this association will be made if our system will provide these values in real time and on an appropriate scale for the students. The value of the position needs to align with the voltage on the oscilloscope as well as display the speed on the LCD Display as the crank is moving at the speed. For our tolerance analysis, we will be analyzing the amplitude change between a change in the speed of the cranks turns and its effects being represented on the oscilloscope and LCD and we will test to make sure these changes are being represented in a linear way. The correlation coefficient *M*, will represent change in voltage output per change in speed of the crank turn. It can be calculated as:

$$M = \frac{Voltage_f - Voltage_i}{Speed_f - Speed_i}$$

Voltage will represent the voltage generated as described on the oscillator, and *Speed* will represent the speed by which the crank is turning (which will be calculated via the rotary encoder). Ideally, the correlation coefficient will be constant regardless of any two values generated, meaning that the microprocessor is running correctly and is outputting speed in a timely manner. Additionally, this will ensure that the information which we are outputting for the students is accurately reflecting how the relation between crank speed and voltage occurs. We expect to keep the value of *M* constant within a range of 5% error throughout the different speeds that are being tested. We will test this by plotting different speeds with their correlating voltages on a graph and calculating the line of best fit for all of these points. If the slope of this best fit line is within 5% of each of the standard M, our project will pass the tolerance tests. If not, the project will fail.

3. Costs

Since we have our customer for our project, we have to work within their budget to ensure they will buy it. For this project, we used the average salary of a computer engineering in 2014-2015 as reported by the university. As listed on the ECE website, the average salary was $84,000. This equates to a hourly salary of $41/hr. We will be working on this project for about 10 hours a week for about 10 weeks this semester on this project. This would lead the labor costs to be:

$$2 \times 10\ \text{hr/wk} \times \$41/\text{hr} \times 10\ \text{wk} = \$8{,}200$$

The costs for the parts and manufacturing are listed below.

Part	**Cost (Dollars)**
Rotary Encoder (COM-11102)	$39.95
Microprocessor (ATmega328 AVR)	$1.83
LCD Display	$13.95
Miscellaneous (wires, resistors, etc) **(aggressive estimate)**	$10.00
Total	**$65.73**

Since there is only a need for one of these boards, we cannot look at the cost of the board in bulk. Because of this, the total cost of this board will be $8,265.73.

4. Schedule

Week	**Ayush**	**Serena**
10/9/17	Order rotary encoder and ensure the part is working correctly	Confirm pcb design based on the parts available
10/16/17	Begin wiring and soldering the parts for the microprocessor and voltage generator	Begin writing code to interpret the PWW signals
10/23/17	Continue building the microprocessor and voltage regulator voltage	Begin writing code to transmit angular speed to the LCD Display

10/30/17	Begin setting up the generator to provide voltage for the microprocessor	Begin code for outputting position to oscilloscope
11/6/17	Begin wiring for the variable voltage output to oscilloscope	Begin debugging code
11/13/17	Begin debugging circuit	Continue debugging code
11/20/17	Analyze if chosen way of displaying position is intuitive to children	Analyze if chosen way of displaying position is intuitive to children
11/27/17	Test circuit to make sure all components can handle stress	Test circuit to make sure all components can handle stress
12/4/17 (Demo Week)	Prepare documentation for the EOH volunteers	Prepare documentation for the EOH volunteers
12/11/17 (Demo Week)	Prepare documentation for the EOH volunteers	Prepare documentation for the EOH volunteers

5. Safety and Ethics

The biggest safety problem we see ourselves running into is with accidentally shocking a child. We all know that children find a way to break everything. Since children will be the ones cranking this device we need to ensure that our device is well built and will not expose anything during high stress situations. If something was to get expose, we could hurt a small child and perhaps scare him away from pursuing a career in engineering, which is the opposite of what we want to accomplish.

It also needs to be well built in order to last a long time in the shelves of the Electrical and Computer Engineering Building, being reused for every Engineering Open House for years to come.

In terms of ethics, we are responsible for the information that is sent through our technology. This spread of valuable knowledge is an implementation of the IEEE Code of Ethics, #5: “To improve the understanding of technology; its appropriate application, and potential consequences” [3].

Our system will be letting people who do not know how things like electricity work. We will be also using this to spark their curiosity to pursue a career in STEM fields. It is our duty to make sure that we portray the right information and do not mislead the public on how basic concepts like this work.

References

[1] How to Estimate Encoder Velocity Without Making Stupid Mistakes: Part I. (n.d.). Retrieved October 03, 2017, from https://www.embeddedrelated.com/showarticle/158.php

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[5] (n.d.). Wikipedia, the free encyclopedia. Gray code - Wikipedia. Retrieved from http://en.wikipedia.org/wiki/Gray_code