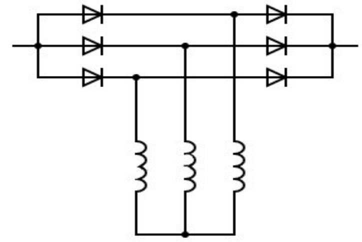
Generator Project

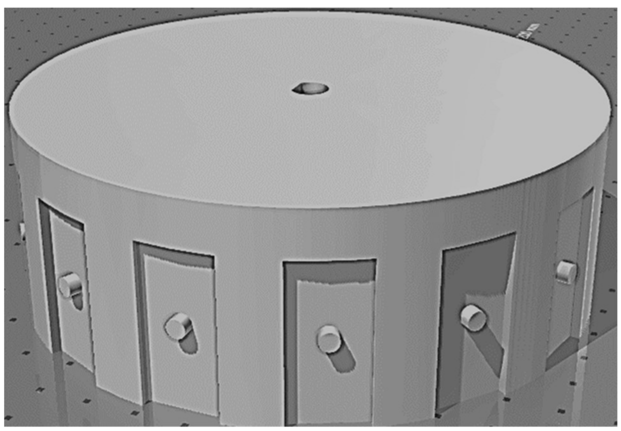
This project is to fulfill the honors contract with ECEN 2714. I was tasked with making a functional generator based on the brushless motor design that is powered by manually spinning a rotor. This is done using the theory that change in flux through a coil of wire will induce a current in that wire. This document contains the building process and outcome of the project.

Build

This project consists of three parts: the rotor, the stator and the rectifier circuit. The generator itself is the rotor and the stator, while the rectifier circuit converts the 3-Phase AC to DC. The generator and the rectifier circuit are connected together as in the schematic to the right.



1. **Rotor:**



The rotor (picture to the left) was designed as an encasement that would rotate freely around the stator on a shaft that is inserted into two bearings. I designed the rotor and had my mechanical engineering friend, Josh Anderson, CAD it for me in Solid Works. We finished the original design fall semester 2018. On the first design the slots were located on the inside of the rotor. However, due to the chance that the neodymium magnets could pull off the slots and attach themselves to the metal rotor, the slots were moved to the outside. So this year we had to change the magnet location. After we finished CADing, Josh sent me the STL file. I then transferred the STL file to Cookware, where I made G-Code and then printed the part in Endeavor.

While researching the optimal number of magnets for a 12 branch stator, I found:

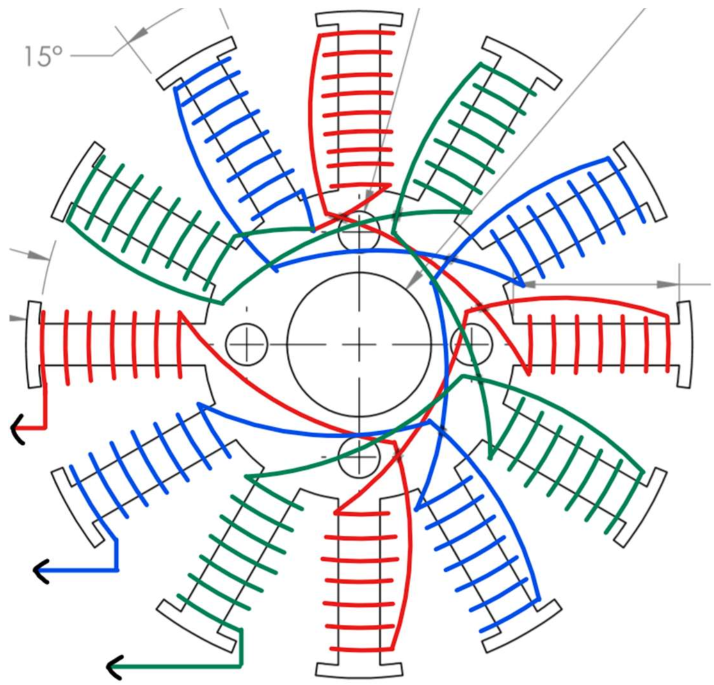
1. The standard ratio that most people use is 4 magnets to 3 coils, but this is usually for smaller configurations such as 12:9 or 8:6. Once more coils are added, the ratio does not need to be as close to 4:3.
2. The number of magnets should not equal the number of coils. This is due to the difficulty of spinning the rotor when in a 1:1 configuration. Each magnet wants to be in-line with a coil and will heavily resist rotation. Because of this, there need to be a couple more or a couple less magnets so that the generator is easier to spin.
3. The number of magnets needs to be even so that they can be alternating positive and negative poles around the rotor and so there will be a magnet of opposite pole directly across from any given magnet.

My stator has 12 coils so, using the ratio, I would need to have 16 magnets. When CADing the slots for these magnets, I realized that we would need a larger rotor than we already had to fit all the magnets. Therefore, I decided to reduce the number of magnets to 14.

While searching last year, I found the magnets that I wanted in a 16 pack. When I went to buy them this year, they apparently halved the amount and so I only bought 8. I bought these very early on and, for some reason, I did not double check the number. Therefore, I have 14 slots and only 8 magnets to test with. All 14 magnets will be included on the final product.

2. Stator Assembly:

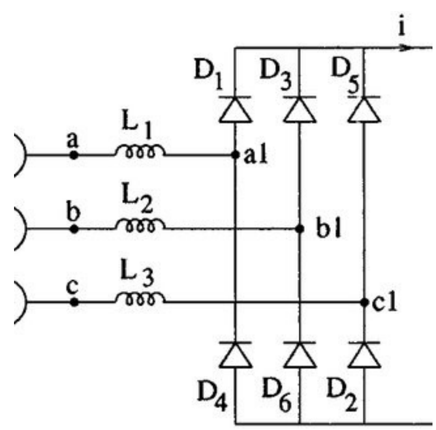
The stator is of a 3 phase 12 branch design. I designed the stator last year and had my older brother, Brad Thompson, laser cut it out at his place of employment, Port City Metal Services in Tulsa. Due to having to cut the stator from 30mm thick plates of A36 steel, we decided to cut three of them and stack them on top of each other to get the thickness I desired.



I researched the metal used in normal stators and discovered that thin sheets of a special silicon steel are used. Stators are made of these thin sheets to prevent the induction of eddy currents. Induced eddy currents cause loss of energy in the mechanical to electrical transformation. I originally believed the reason for the separated sheets was to dissipate the heat produced by the flow of current through the wires. Because of this belief, I decided the thin sheets were not needed because there should not be a large buildup of heat due to the generator being power by hand. This was an error in design.

For wrapping the stator, I used 24AWG magnetic wire provided to me by Dr. O'Hara. To the right is the wiring diagram. Each color is a different phase. Each phase is connected together to form a common neutral. This is considered a Wye configuration. Originally, I planned on wrapping each branch as many times as I could without overlapping. This came out to be about 37 loops of coil.

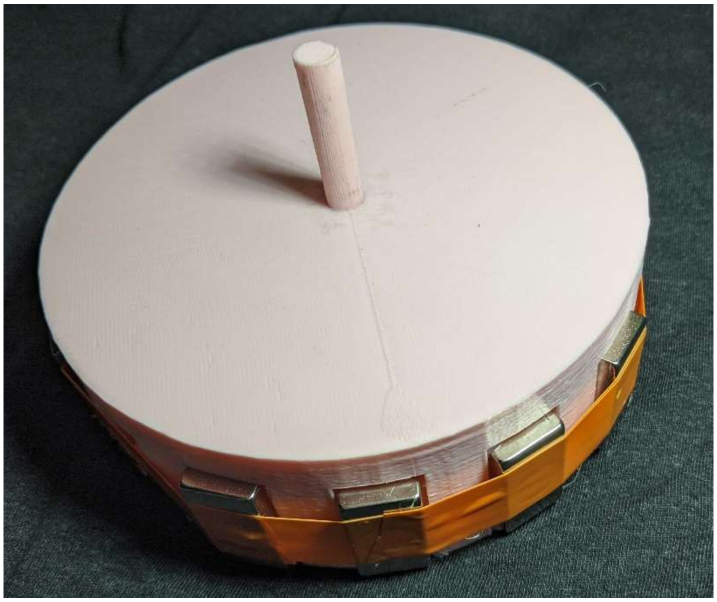
3. Rectifier Circuit:

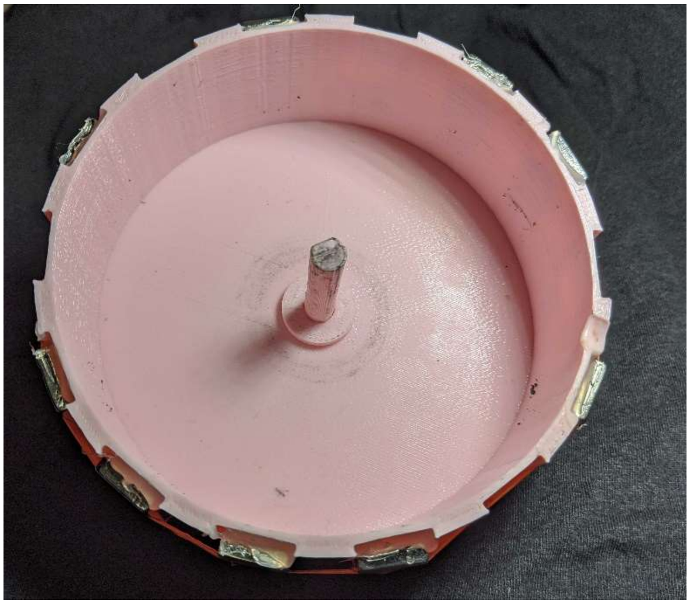


The rectifier circuit I constructed is based on the schematic to the right. I used 6 diodes rated for 15amps (15SQ045) and soldered them together. Because the generator produced such a low current, there was no measurable current flowing when measured from the ends of the circuit. As a result, I decided to remove the rectifier circuit and instead hook it up to an Oscilloscope to show the sinusoids produced by each phase.

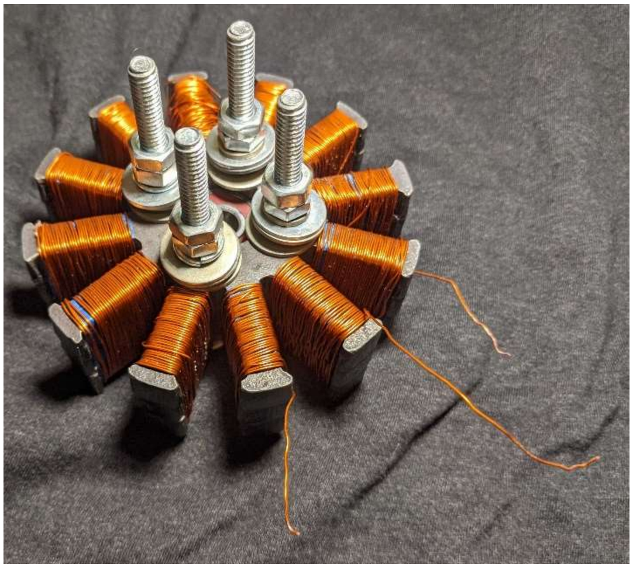
Finished components

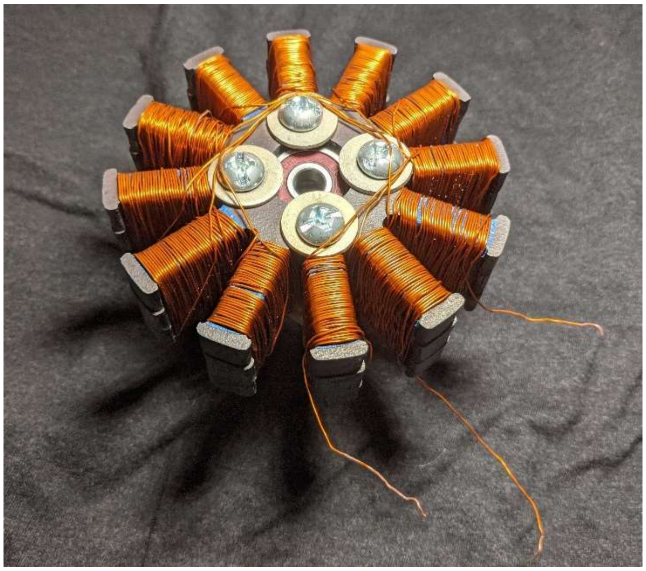
Rotor:





Stator:



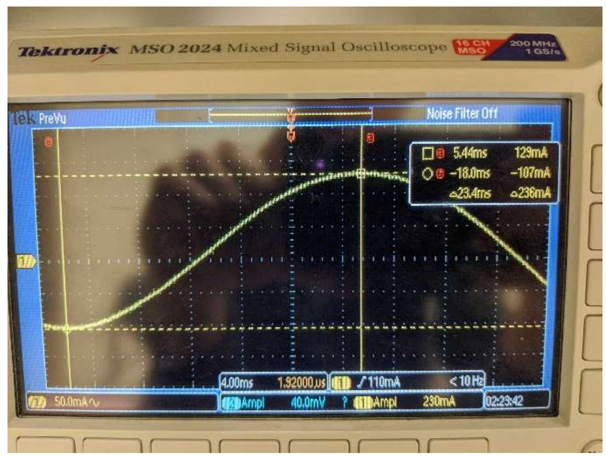


Rectifier Circuit:

Testing and Analysis

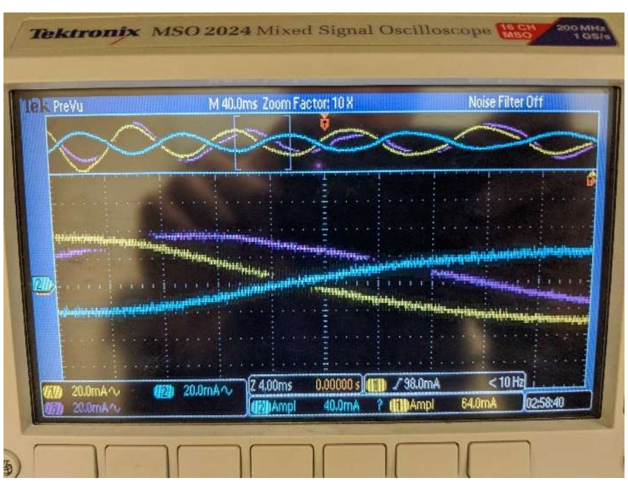
After the wrapping was completed I tested the current output from each phase using a multimeter. I was only able to get max reading of 9 microamps. I measured this by connecting the positive probe to the output of a phase and the other at the common ground. I made sure the probe was in the correct slot for reading current. I knew 9 microamps would not be sufficient, so I decided to add more loops to each coil. However, I later determined the original coils were sufficient. Instead, the multimeter I used to test the current was faulty.

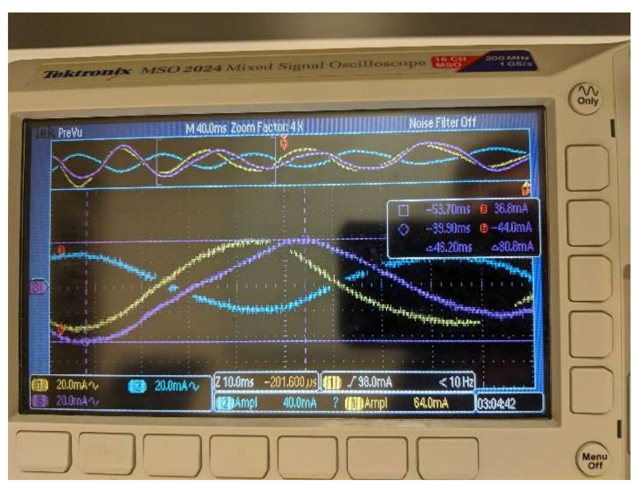
For the second round I got 7 strands of wire and twisted them together to allow easier wrapping. I wrapped each branch 9 times on-top of the original 37 wraps. I misjudged the length required and for two of the phases I had to solder more wire together to complete the phase. I made sure to only solder one strand to another strand in order to avoid connecting all the strands together. I wrapped each solder with electrical tape. Once this was complete I connected one end of each phase together as the common neutral. When I tested it this time I got no current at all. I thoroughly went over every part of the generator and could not determine the reason I was measuring 0A for the current.



Dr. O'Hara examined the generator and advised me to make sure there was an induced current in at least one of the coils. To do this, I removed the twisted wire and wrapped a single with as many loops as I could. I then hooked the coil up to an Oscilloscope. I set the input as AC and adjusted the sensitivity until I could see a current. The picture to the right is the result of that test.

After determining that a current could be induced I decided to hook up the original 37 loop phases to see if they produced anything. Each phase produced a fairly consistent sinusoid with about -+40mA and the expected errors due to the lack of all 14 magnets. The strange part occurred when each phase was layered on top of each other. In normal 3-phase AC, each phase is offset by 120 degrees from the last phase. The reading I got was not consistent with this because of an unknown reason.





For Generator Demonstration

At this point, the generator needs a few adjustments to be ready to be used as a demonstration tool. The first thing is to create a stand to hold the generator. The second is to determine an alternate way to spin the generator that is not manual.

For the stand not much is needed. The stator has very long bolts that hold the three layers together. Those bolts protrude about two inches from the stator and can easily be used to mount the generator to a solid object like piece of plywood or a 2x4. The bolts already hold two nuts, two washers and two lock washers. The generator operates most optimally when on its side where nothing impedes the rotation of the rotor. Because of this the best way to mount it would be to drill holes in the side of a vertical piece of wood and attach that piece of wood to a large base, then insert the bolts into the holes and tighten the nuts until the lock washers are tight enough.

There are many alternate ways of spinning the rotor. I originally printed a handle to spin the shaft but I found it was more effective to just spin the shaft itself. For non-manual spinning, the easiest way is to attach the shaft of the rotor to a drill. A more elegant way is to set up a belt system. Because the rotor shaft is notched, a pulley wheel can be 3D printed that would attach to the shaft. Then another wheel of a desired size can be printed and a belt run from the generator to the other wheel and that wheel spun by hand or by drill.

To display the sinusoids produced by the generator, it must first be hooked up to an Oscilloscope. There are a couple of steps required to set up the scope before it will show the sinusoid.

1. Hook up the generator by using three sets of probes connected to the oscilloscope. Connect each red probe to a different phase wire and the black probe to the common neutral. (Only one of the black probes needs to be connected to the common neutral)
2. Next, set each probe to AC mode by pressing the probe number and pressing the button under the far left side of the screen until the box above the button displays AC.
3. After changing to AC, the next step is to set the probe to read current. Do this by pressing the button on the right side of the display that is next to Voltage/Current until current is selected.
4. For each probe, adjust the range to 50mA by turning the nob over the probe.
5. Make sure all three probes are on and are being displayed.

Once those steps are complete, spin the rotor and 3 sinusoids should be displayed by the Oscilloscope.