Stepper Motor Lab

Rules:
This lab includes 4 sub-labs and composes 16.6% of your final grade. You are to form a team of 3 people; together you will work through all the lab challenges. Time management and strategy are particularly important. The challenges will start today and end at **11:59pm on Oct 17**. The lab location is room 314, where the lab instructor will be to provide support if needed. When you have completed a challenge, you must demonstrate your results to the instructor during a lab session and answer the instructor's questions. **Ask the instructor for help if you are unsure!**

Report:
Please compile a report of evidence to demonstrate your group's completion of each task, including your answers (and figures if required) for each lab question. Please email your report with the email subject "CSE4320 Lab Report" to ziontse@uga.edu no later than **11:59pm on Oct 17**. Only one copy of the report per group is necessary. On the cover page of the report, please include the names of all team members. Work will be evaluated from the report, but instructors will be available during lab time for assistance as usual. NOTE: Report submission status will ONLY be evaluated from emails, since the email timestamp is definitive; any report with a late submission will not be graded.

Academic Honesty:
All students are responsible for maintaining the highest standards of honesty and integrity in every phase of their academic careers. The penalties for academic dishonesty are severe and ignorance is not an acceptable defense. The document for academic honesty may be found at the website for The University of Georgia Office of Senior Vice President for Academic Affairs and Provost.

Labs:
Lab 1: Stator & Rotor (25%)
Lab 2: Circuit (25%)
Lab 3: Programming (25%)
Lab 4: Control (25%)

Acknowledgements:
Special thanks to Proto G for developing the lab materials.
https://makezine.com/2015/08/18/3d-print-stepper-motor/

Thoroughly read each challenge before beginning!

LAB 1: STATOR & ROTOR

Objective

1. Practice 3D printing, electromagnetic control, Arduino programming.
2. Become familiar with implementing state machines in software for stepper motor control.

Prelab Assignment

1. Review the lecture handouts about stepper motor principles and control
2. Review “How does a Stepper Motor work?” in the YouTube link below:
   https://www.youtube.com/watch?v=eyqwLiowZiU
3. Register and have safety training in order to access to the Design Workspace at Driftmier Rm 230. Please contact Dr. Roger Hilton rog@uga.edu or Mr. Terrance Walsh for the training schedule tlwalsh@uga.edu
4. Review the Arduino documentation for if/else and switch/case statements.
   http://arduino.cc/en/Reference/If
   http://arduino.cc/en/Reference/Else
   http://arduino.cc/en/Reference/SwitchCase

3D Printed Stepper Motor

In this lab, we will design a stepper motor with eight electromagnets and six neodymium magnets with a 3D-printed rotor and stator housing. This is specifically a permanent magnet stepper motor capable of 15-degree full steps and 7.5-degree half steps. It will run on a 5-12VDC power supply for compatibility with most USB power supplies. Courtesy to Proto G for designing the materials in this lab.

Step 1: Parts

1. Six 1/4" neodymium magnets (Fig. 1)
2. 608ZZ Bearing (Fig. 1) – The outer and inner diameters of the 608ZZ bearing are approximately 22mm and 8mm. Please google the datasheet to verify this information.
3. Eight 8d 2-3/8" nails - Not critical what nails you use as long as they fit. (Fig. 1)
4. Magnet Wire - 0.315mm magnet wire is used but this is not critical.
5. Arduino Uno
6. Four Transistors - PNP transistors are selected, but you can use whatever transistors you want or MOSFETS as long as you make sure they can handle the current your motor will draw. Read the datasheet carefully for specific recommendations. On 5v, the motor draws about ~1 amp and on 12v it demands about 3 amps.
7. 3D Printed Rotor and Stator
8. Hot glue
9. Electrical Tape
10. A compass (Fig. 2) to determine the magnet polarity – Each smartphone has a magnetometer. Google an app to enable your smartphone to be a compass.
11. On/off switch
12. Potentiometer

Step 2: 3D Print the Dodecagon Rotor and Octagon Stator

Design a stator and rotor based on the design in Figure 4. The stator should be able to hold 8 set of solenoids and support the rotor via a bearing. You will need to consider the size of parts provided in Step 1 during your design process. <u>Please also refer to a design provided by the instructor for your reference.</u> Print your stator and rotor design with Makerbot! Each student should have access to Makerbot 3D printers in the Collaborative Design and Integration Studio in 329 Driftmier (Fig. 3).

Fig. 1. Key stepper motor components: Six 1/4" neodymium magnets, 608ZZ Bearing, and Eight 8d 2-3/8" nails.

Fig. 2 A compass (Fig. 2) to determine the magnet polarity

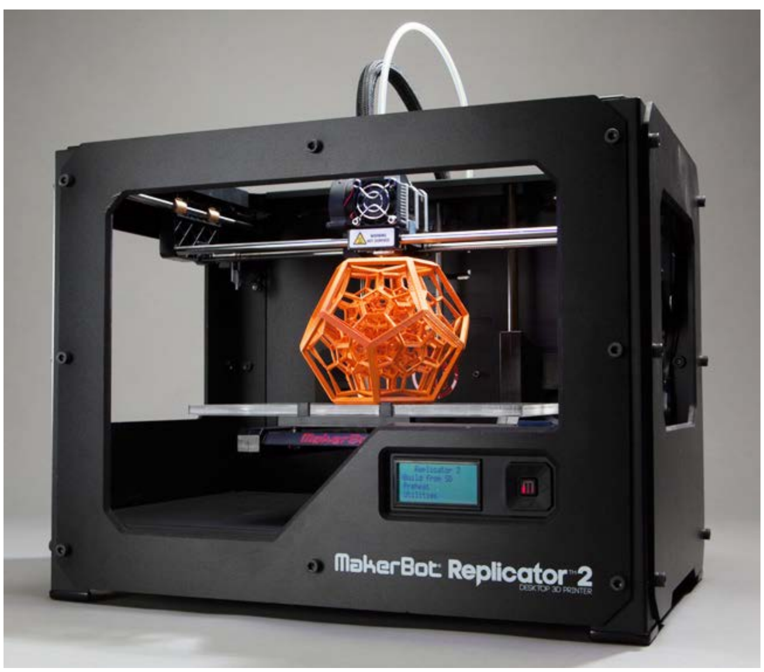

Fig. 3. Makerbot 3D printers in the Collaborative Design and Integration Studio in 329 Driftmier

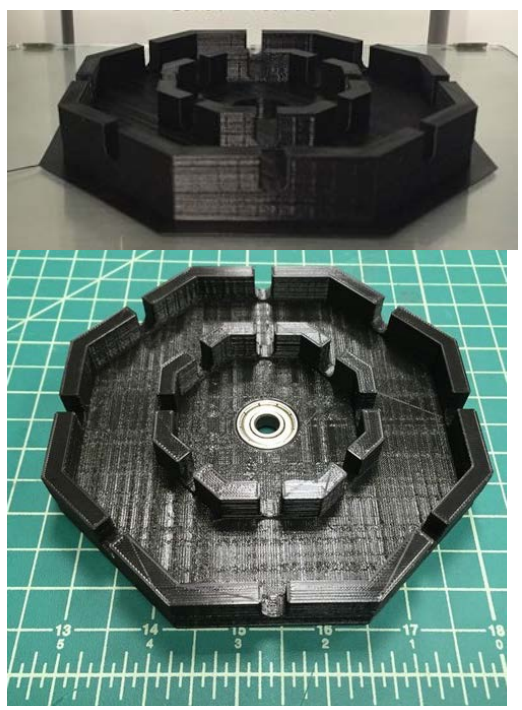

Fig. 4. fitting the bearing into the stator and then press the rotor into the bearing

Step 3: Determine the magnet polarity

Use a compass to determine the poles of your magnets and glue the magnets with the north poles facing outward. If your magnets are strong enough, the compass on some smartphones will show you the polarity of the magnets. Each smartphone has a magnetometer. You could google and install an app to enable your smartphone as a compass.

Step 4: Stator-bearing Fitting

Press fit the bearing into the stator and then press the rotor into the bearing (Fig. 4). When 3D printing, holes tend to want to shrink inward and end up smaller than expected, thus it is recommended to oversize them slightly

Step 5: Solenoid Fabrication

Cut 9 pieces of wire to 25 feet each and wind them with a drill available in the Design workspace (Fig. 5). Use a compass and a battery to determine the configuration required to give you the south pole at the head of the nail. Use a marker or heat shrink tubing to mark the negative lead of your electromagnets. Wrap the sections of the electromagnets with electrical tape where they will come in contact with the stator housing. This serves two purposes. It firmly secures the electromagnets in place and also insulates the housing from any heat the coil may produce. The coil pairs draw about 1 amp with a 5V power supply. The transistors can handle using a 12V power supply from which the coils draw about 3 amps. With the higher voltage supply, leaving it running will cause the coils to get warm.

Warning:

We will design the solenoids to run on a 5-12VDC power supply. You can use Ohm's Law to determine what size coils you want. V = I*R

Remember, the fewer windings on your coil, the lower the resistance is going to be. If you are not careful, your coils will pull more current than your power supply or transistors can handle and overheating or damages to your electronics will occur.

Step 6: Stepper Motor Assembly

Push the electromagnets into the stator until they are about 1/4" from the neodymium magnets. You can slide the electromagnets in and out as you wish, but making them too close will cause the nails to become magnetized much faster. The motor will still work once they become magnetized, but it will be less efficient.

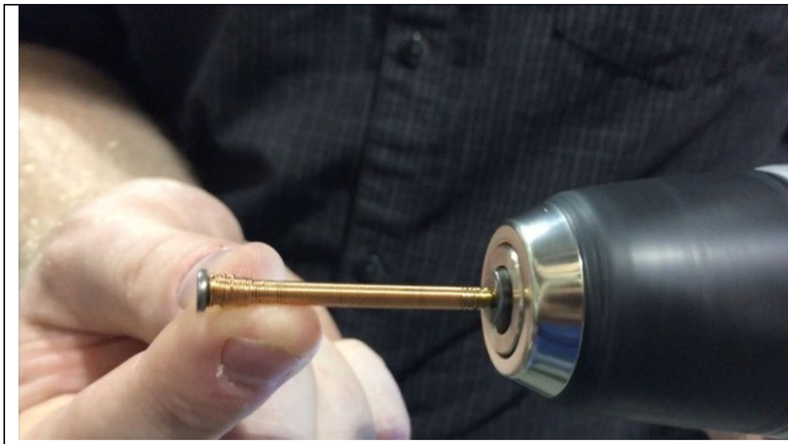
Fig. 5 Solenoid fabrication

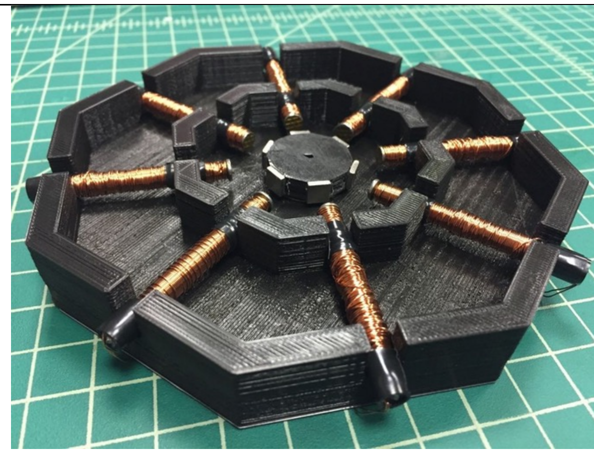
Fig. 6 Stepper motor assembly

LAB 2: CIRCUIT

Step 7: Solder Everything Together

Wire your coil pairs in series and connect them so that all the south poles of the electromagnets face inwards (Fig. 7). The resistor used in the schematic is a 1k resistor. The purpose of this is to prevent the digital pin from "floating" high when in the off position. Again, make sure to use a transistor capable of holding up to the current that your coils will be demanding. Load the source code to you Arduino and you are ready to go!

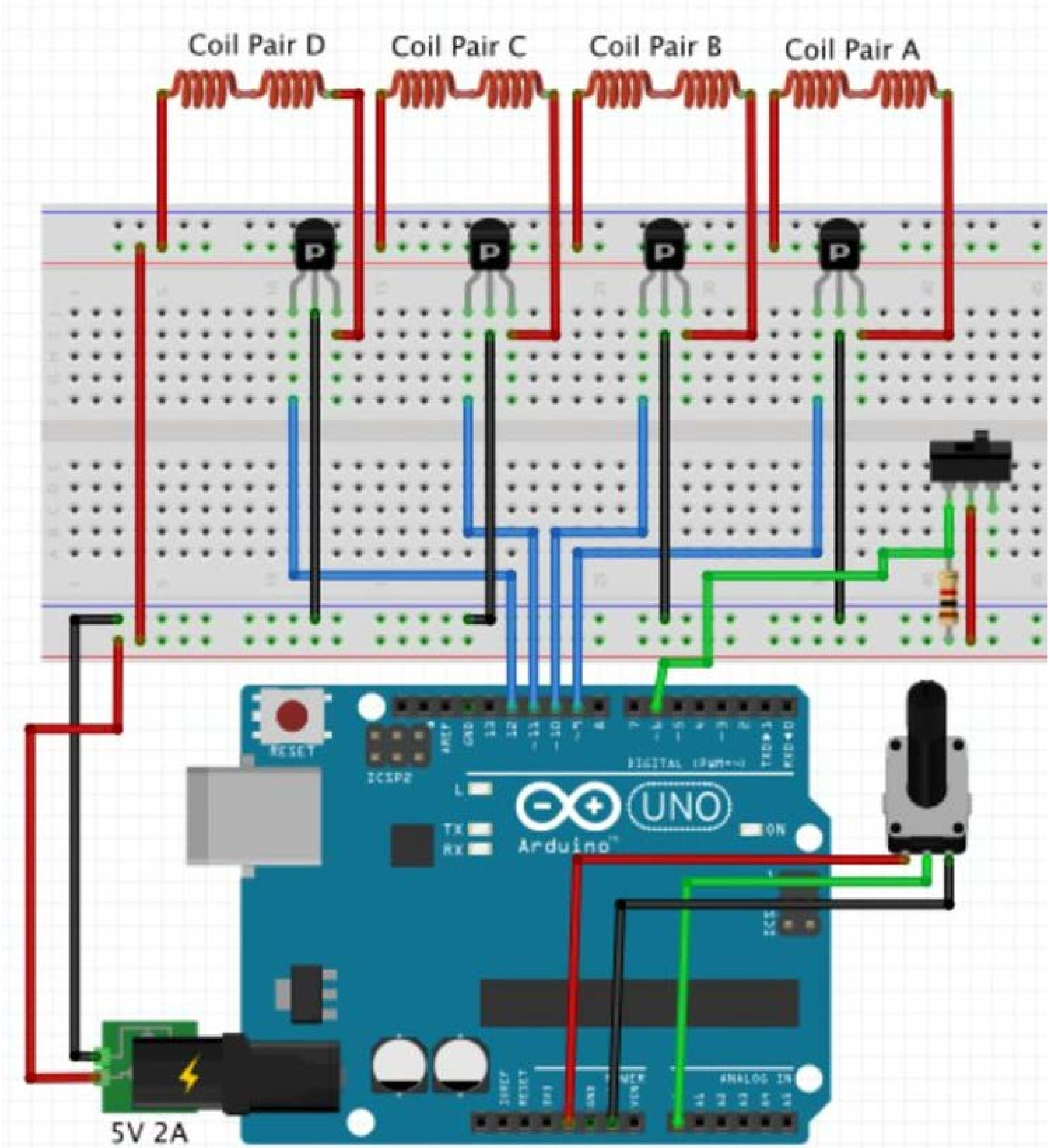

Fig. 7 Circuit diagram for the stepper motor control. A color version is available in the lab source code folder.

Lab 3: PROGRAMMING (25%)

Step 8: Arduino Programming

Please develop a program in Arduino to control (1) direction and (2) speed control of your stepper motor using an on/off switch and a potentiometer. The switch should control the clockwise and anticlockwise directions, and the potentiometer should control the speed from 0 to 100%.

Lab 4: CONTROL (25%)

Step 9: Final Test

Please demonstrate to the lab instructors the direction and speed control of your stepper motor.

In your report, please

(1) Include a video of the motor running from 0 to 100% of no load speed;

(2) Document each fabrication step;

(3) Plot out the relationship between the output voltage of the potentiometer and the rotational speed of your stepper motor. The rotational speed (rpm) can be estimated using the step rate [step per second].

(4) Discuss what angular resolution, maximum rotational speed your motor can achieve, and what signal control scheme is used;

(5) Attach the Arduino code you used to control the stepper motor;

(6) Include a group photo with your stepper motor.

(7) Limit your report to be within 8 pages. Please develop your report using the IEEE template as below.

https://www.ieee.org/content/dam/ieee-org/ieee/web/org/conferences/Conference-template-A4.doc