

Lesson Plan 10-11: Stepper Motors

Unit: Arduino Motors Unit

Previous lesson: Servo Robot Project

Next lesson: Windmill Project

Main objectives: Students will be able to correctly wire a stepper motor using an external power supply and a stepper motor driver. SWBAT import and use the stepper library to control the stepper motor, including spinning specific angles and speeds clockwise and counterclockwise.

Standards:

- 9-12.IC.7 Career Paths: Investigate the use of computer science in multiple fields.
- 9-12.CT.4 Abstraction and Decomposition: Implement a program using a combination of student-defined and third-party functions to organize the computation.
- 9-12.CT.8 Abstraction and Decomposition: Develop a program that effectively uses control structures in order to create a computer program for practical intent, personal expression, or to address a societal issue.

Timing: This is a 2-period lesson.

In-class exercises: The students will complete the worksheet, below.

Notes: The wiring for the stepper motors is somewhat complex so make sure that students follow the directions in the student handout

Resources: Video on stepper motors: <https://www.youtube.com/watch?v=eyqwLiowZiU>

Materials: Elegoo uno circuits kits (including Arduino Uno, breadboard, stepper motor, stepper motor driver board, power supply module, battery wire, jumper wires, USB cable), 9V battery, student handouts, projector, teacher computer, Google slides presentation (the slide deck is in the lesson folder on Github)

Assignments: The class assignment for students is below. The answer key is on the next page.

Formative assessment: Student handout (see below)

Lesson:

10 min: Intro

- Use provided powerpoint
- Goals: To learn how to wire and program a stepper motor to spin specific angles and speeds clockwise and counterclockwise
- Recap from intro lesson:
- Precise: Can program to rotate to a specific angle or step
- Unlimited rotation in either direction
- High torque at low speeds

- What are some devices that could use stepper motors?
 - 3d printers, printing presses, analog clocks, feed mechanisms for ATMs and metrocard machines. Note that stepper motors have poor performance at high speeds.
- Other disadvantages is that they are often noisy and less energy efficient than servos.
- What's inside a stepper motor?
 - Stepper motor driver chip controls which of the 4 electromagnets is magnetized at any given moment. In the center is a permanent magnet which has gear teeth that align to one of the 4 electromagnets. As the electromagnets are magnetized, the rotor will spin to align its teeth with the magnet, spinning $\frac{1}{4}$ of one tooth. This allows for extremely accurate rotational angles.

25 min: Work time

- Students work on the attached assignment with their partners

10 min: Day 1 summary

- Answer the Qs in the “Experimentation” section of the handout as a class
- How can we make the stepper motor spin faster?
 - Change the speed inside of setup from *myStepper.setSpeed(5);* to *myStepper.setSpeed(10);* (or another number >5)
- What happens if you change the number of steps?
 - The stepper motor spins a smaller angle rather than a complete rotation (in this case about 1/10 of a circle)
- What does the negative sign inside of *myStepper.step(-stepsPerRevolution);* do?
 - Causes the stepper to spin counterclockwise instead of clockwise
- How can we make the stepper motor rotate 90°?
 - *myStepper.step(stepsPerRevolution/4);* OR *myStepper.step(512);*

Day 2:

40 min: Work time

- Students work on the attached assignment with their partners

5 min: Summary

- Students share one thing they accomplished, one bug they overcame, or one idea they have for how they could use stepper motors in the future

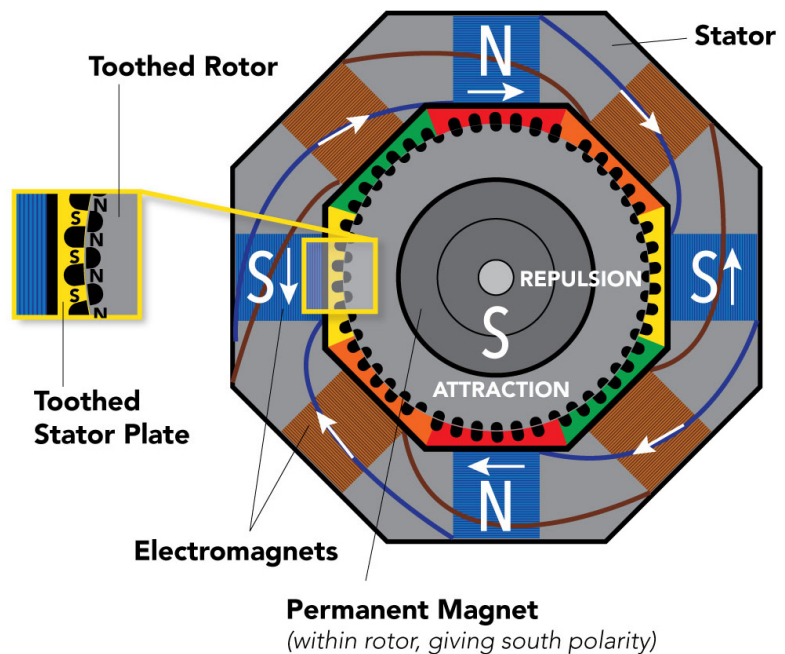
Names: _____

Arduino Stepper Motor

Background:

The stepper motor is a device that is capable of producing large torque with a high level of precision. Stepper motors contain a toothed rotor that spins based on its attraction and repulsion to 4 surrounding electromagnets. We can control the exact angle that the motor spins by turning on and off the four electromagnets. You can learn more about how a stepper motor works [here](#).

Due to their ability to rotate exact angles, stepper motors are used in a wide range of applications. For example, stepper motors drive the hands of analog clocks (rotating the second hand 6° every second) and in 3-D printers.



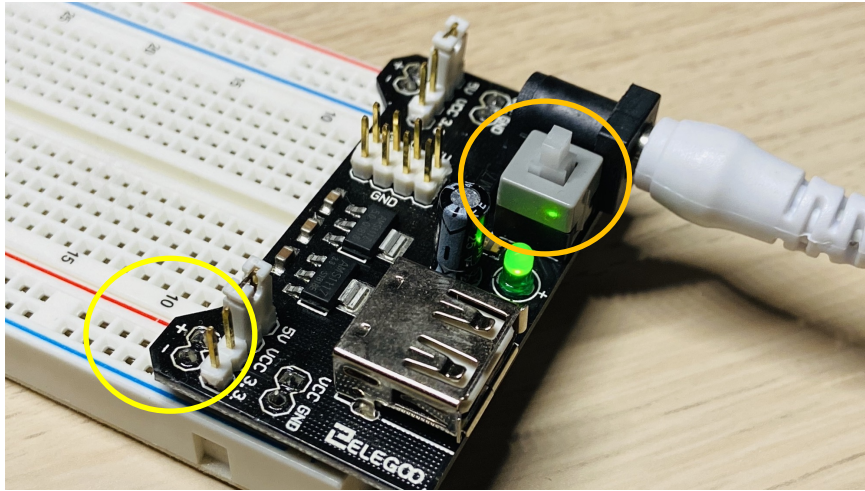
Question: What is another possible application for stepper motors?

Part 1: Hardware

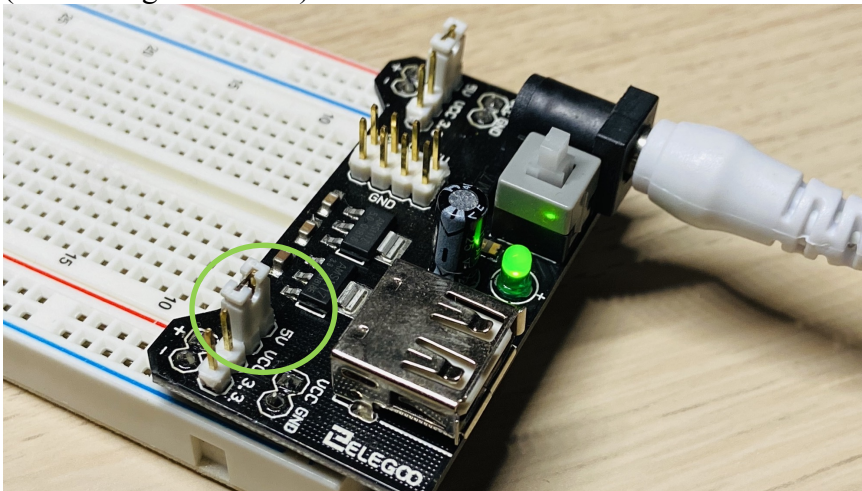
Materials: Arduino Uno, breadboard, stepper motor, stepper motor driver board, power supply module, 9V battery, battery wire, jumper wires, USB cable

The stepper motor is a device that needs a large amount of current to operate. This much current would fry the delicate circuitry of the Arduino, so the motor must be powered separately using a 9V battery and power supply module. The Arduino also does not produce the correct frequency signal in order to communicate directly with the stepper motor, so they must both communicate through the stepper motor driver board. The stepper motor driver board is connected to the 9V power supply *and* the Arduino. It contains an IC chip that translates the Arduino's signal into the correct pattern to rapidly turn the four electromagnets inside the motor on and off, connecting them in turn to the power from the battery in order to drive it.

1. Draw an arrow on a small piece of paper and attach it to the stepper motor axle. (This makes it easier to see exactly how far the motor has rotated)
2. Plug the power supply module into the breadboard, as shown below. Make sure to align the positive and negative markings with the correct rails of your breadboard (circled in yellow).



3. Connect a 9V battery to a battery wire and plug it into the power supply. When you press down the button (circled in orange) the green LED should light.
4. Verify that the white jumper is set to 5V rather than 3.3V for the power rail that you plan to use (circled in green below).



5. Connect the GND pin on the Arduino to the ground rail of the breadboard in order to ensure a common ground.
6. Plug the stepper motor into the stepper motor driver board.
7. Connect the 4 input pins on the stepper motor driver board to the Arduino as listed:

Driver pin	Arduino pin
IN1	8
IN2	9
IN3	10
IN4	11

8. Connect the bottom left pin (labeled “-”) to the ground rail and the bottom right pin (labeled “+”) to the power rail

Part 2: Software

Open a new program in the Arduino code editor. Copy the starter code below:

Starter code:

```

#include <Stepper.h>
const int stepsPerRevolution = 2048; //based on the physical hardware of the stepper motor

// initialize the stepper library on pins 8 through 11:
Stepper myStepper(stepsPerRevolution, 8, 10, 9, 11);

void setup() {
  // set the speed at 5 rpm:
  myStepper.setSpeed(5);
  // initialize the serial port:
  Serial.begin(9600);
}

void loop() {
  // step one revolution in one direction:
  Serial.println("clockwise");
  myStepper.step(stepsPerRevolution);
  delay(500);
  // step one revolution in the other direction:
  Serial.println("counterclockwise");
  myStepper.step(-stepsPerRevolution);
  delay(500);
}

```

Run the code and check that it works! The motor should rotate in one full circle, wait half a second, then rotate one full circle in the other direction.

Video: Take a video of your circuit. Include your names. Paste it here or upload it to this Google Classroom assignment.

Experiment: Play around with the code; try changing parameters in order to answer the questions below. Don't change the stepsPerRevolution variable (this is based on the physical number of teeth on the rotor inside the stepper motor).

Questions	Answers
1. How can we make the stepper motor spin faster?	
2. What happens if you change the number of steps: <i>myStepper.step(200);</i> <i>delay(500);</i> instead of <i>myStepper.step(stepsPerRevolution);</i> <i>delay(500);</i>	

3. What does the negative sign inside of <i>myStepper.step(-stepsPerRevolution)</i> ; do?	
4. How can we make the stepper motor rotate 90°?	

Part 3: Extras

Task 1: Modify the code so that motor spins 180° clockwise, then spins counterclockwise in three 60° increments, defining your own functions in order to simplify your code.

Paste your code here:

Take a video of your circuit. Include your name. Paste it here or upload it to this Google Classroom assignment.

Task 2: Add a slide switch to your circuit. Program the Arduino so that when the slide switch is up, the motor spins clockwise, and when the slide switch is down, the motor spins counterclockwise.

Paste your code here:

Take a video of your circuit. Include your name. Paste it here or upload it to this Google Classroom assignment.

Task 3: Add a button switch to your circuit. Program the Arduino so that when the button is pressed, the motor starts/stops spinning (if it was stopped, it starts, and if it was spinning, it stops). Challenge: Modify your code so that whether the user holds the button down for a long or short period of time doesn't matter

Paste your code here:

Take a video of your circuit. Include your name. Paste it here or upload it to this Google Classroom assignment.

Task 4: Modify the code so that when the button is pressed once, the motor spins slowly. When the button is pressed again it spins more quickly. When the button is pressed a third time, it turns off. (When the button is pressed again, it spins slowly again, etc.)

Paste your code here:

Take a video of your circuit. Include your name. Paste it here or upload it to this Google Classroom assignment.

Task 5: Watch the video about how stepper motors work [here](#) (make sure to wear headphones). Write a paragraph summarizing how a stepper motor is able to achieve such a high degree of precision.

Paragraph:

Extra Resources:

If you are stuck, check out [this YouTube tutorial](#).

Arduino Stepper Motor KEY

Question: What is another possible application for stepper motors?

Grocery store conveyor belt

Experiment: Play around with the code; try changing parameters in order to answer the questions below. Don't change the stepsPerRevolution variable (this is based on the physical number of teeth on the rotor inside the stepper motor).

Questions	Answers
1. How can we make the stepper motor spin faster?	Change the speed inside of setup from <i>myStepper.setSpeed(5);</i> to <i>myStepper.setSpeed(10);</i> (or another number >5)
2. What happens if you change the number of steps: <i>myStepper.step(200);</i> <i>delay(500);</i> instead of <i>myStepper.step(stepsPerRevolution);</i> <i>delay(500);</i>	The stepper motor spins a smaller angle rather than a complete rotation (in this case about 1/10 of a circle)
3. What does the negative sign inside of <i>myStepper.step(-stepsPerRevolution);</i> do?	Causes the stepper to spin counterclockwise instead of clockwise
4. How can we make the stepper motor rotate 90°?	<i>myStepper.step(stepsPerRevolution/4);</i> OR <i>myStepper.step(512);</i>