Lab 4: Stepper Motor Control
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Fall 2018

Goals

1. Understand the limitation of GPIO output current.
2. Learn to use Darlington transistor arrays to perform high-current driving with extremely low input current.
3. Understand the usage of full stepping and half stepping to control the speed and position of a stepper motor.
4. Gain experience of generating pulse waveforms to control a stepper motor.

Grading Rubrics (Total = 100 points)

1. Pre-lab assignment (10 points).
2. Lab demonstration (75 points).
3. Something cool (15 points).

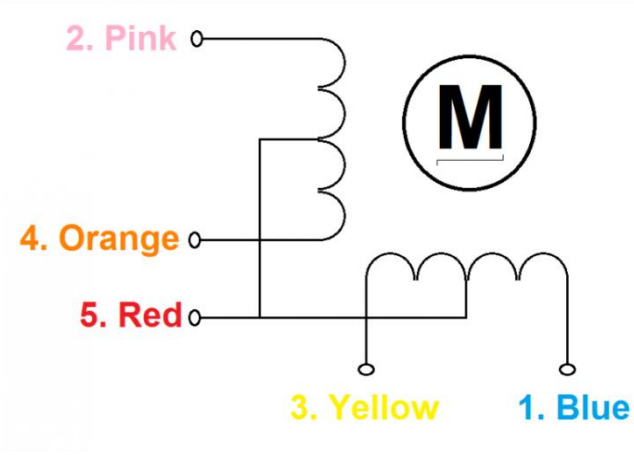
NOTE: Completing the basic lab requirement will only get you up to 75 points. If you want to get 100 points in this lab, **you will have to complete the pre-lab assignment, the basic lab requirement, and do something cool.**

Pre-Lab Assignment

1. Read the textbook Chapter 16 Stepper Motor.
2. Watch this video tutorial (8 minutes): How brushed DC motors are made and how they operate (Credit goes to *http://www.pcbheaven.com/*):
    a. https://youtu.be/RAc1RYilugI
3. Watch video tutorial: How the Stepper motors are made and how they operate (Credit goes to *http://www.pcbheaven.com/*):
    a. Part 1 (5 minutes): http://www.youtube.com/watch?v=MHdz3c6KLrg
    b. Part 2 (8 minutes): http://www.youtube.com/watch?v=t-3VnLadIbc
4. **Answer the pre-lab questions (10 points).**

Lab Requirements

1. **Basic requirement (75 points):** Turn the stepper motor exactly 360 degrees clockwise by using **half-stepping** or **full-stepping.**
2. **Something cool (15 points).** The following provide some examples.
    a. Use the keypad to set a specific degree to which the motor should rotate.
    b. The motor should smartly choose either clockwise or counter-clockwise to make a minimum amount of rotation.
    c. Display the degree and turning direction of the motor in real time.
    d. Perform micro-stepping to rotate the motor smoothly.



Stepper Motors

The motor has a ULN2003 Darlington Array.

Motor model	**28BYJ-48**	Number of phases	2
Rated voltage	5V DC	Geared reduction ratio	1/64
DC resistance per phase	50Ω±7%(25℃)	Pull in torque	>300gf.cm / 5VDC 100pp

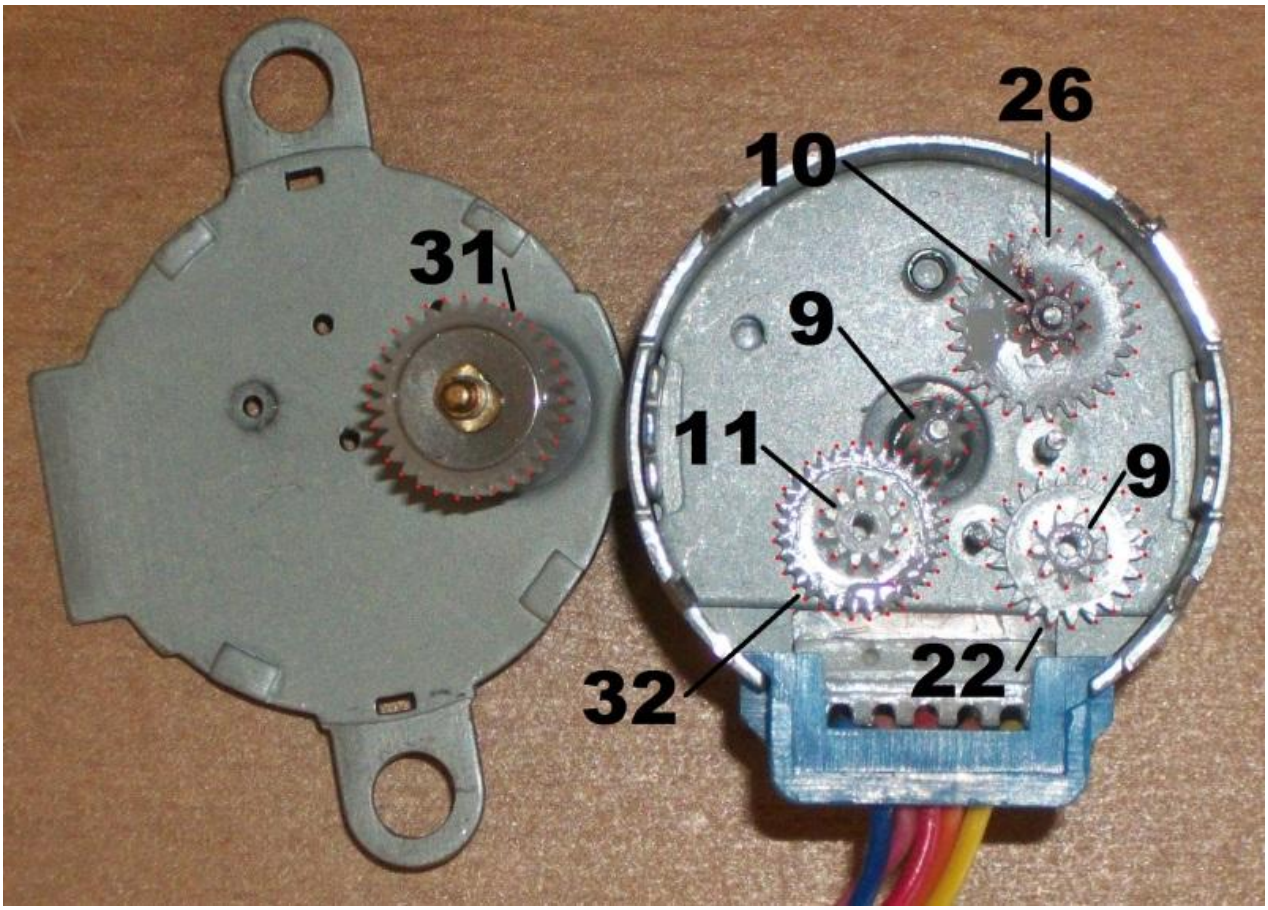


image from *forum.arduino.cc*

The gear ratio is:

$$\frac{31 \times 32 \times 26 \times 22}{11 \times 10 \times 9 \times 9} = 63.68395$$

If the output shaft rotates 1 resolution (gear with 31 teeth in the figure), the internal shaft (gear with 9 teeth in the middle) must rotate approximately 64 resolutions.

Full-stepping

- Internal motor: 32 steps per revolution
- Great reduction ratio: 1/63.68395, approximately 1/64
- Thus, it takes $32 \times 64 = 2048$ steps per revolution for the output shaft

Half-stepping

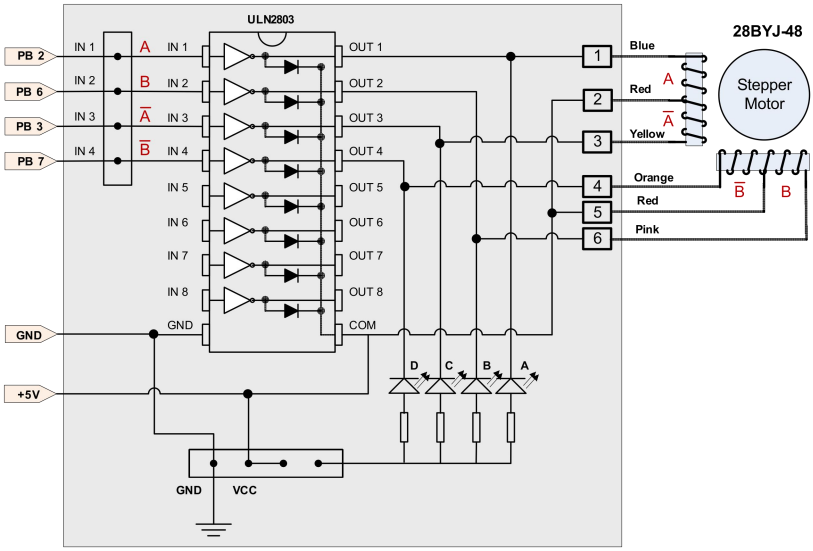
- Internal motor: 64 steps per revolution
- Great reduction ratio: 1/63.68395 ≈ 1/64
- Thus, it takes $64 \times 64 = 4096$ steps per revolution for the output shaft

Pre-lab Assignment (10 points)
Lab 4: Stepper Motor Control
Due on November 05, 2018 at the beginning of class
Print, answer and hand it back to T.A.
NO Dropbox Submission!

Student name: _____

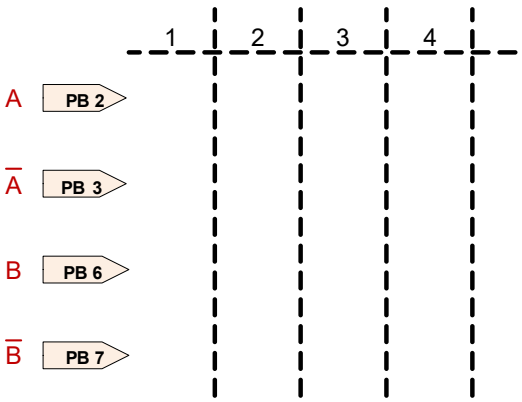
Date: _____

Interfacing the stepper motor requires four pins. We select the following four pins to control the stepper motor: **PB 2**, **PB 3**, **PB 6**, and **PB 7**. The textbook provides a connection diagram for stepper motor *Mabuchi #PF35T*, which is very similar to the diagram below.

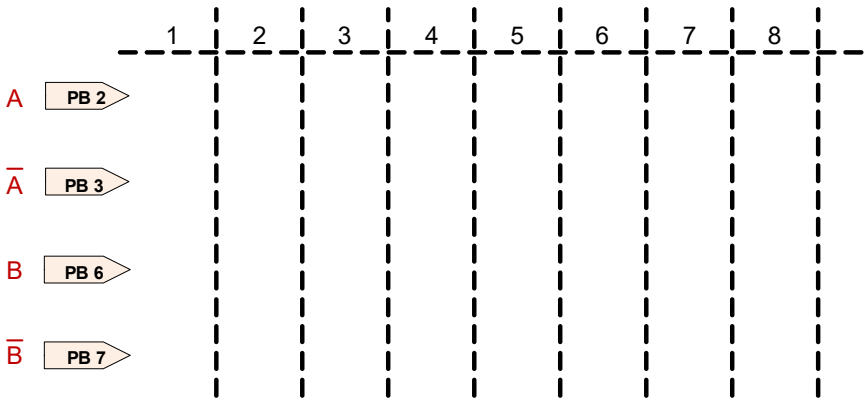


1. Complete the diagram below for one sequence using full stepping half stepping. Refer to Figure 16-10 and 16-12 of textbook to complete the following two diagrams.

Full stepping sequence



Half stepping sequence



2. How to change the rotation speed of a stepper motor?

3. How to reverse the rotation direction?

In-Lab Assignment
Lab 4: Stepper Motor Control

Grading: Up to 90 points (75 points (basic requirement) + 15 points (something cool))
Classes for this lab will be on Nov. 05, Nov. 12, and Nov. 19, 2018 (three weeks)

The basic requirement for this lab is to rotate your stepper motor exactly 360 degree either clockwise or counter-clockwise.

NOTE: Completing the basic lab requirement will only get you up to 75 points. If you want to get 100 points in this lab, **you will have to complete the pre-lab assignment, the basic lab requirement, and do something cool.**

- A startup Keil uVision project compressed in a zip-file (filename: *Lab 4 – Startup Keil Project.zip*) is available online. It contains the following files: **main.c**, **LED.c** and **SysClock.c**.
- Extract the zip-file and open the file **Lab04.uvprojx** (the file with a green icon) to start working on your lab. There is no need to set up anything in the project if you open **Lab04.uvprojx** file.
- In order to complete the basic lab requirement, you only need to write code in the **main.c** file.
- More specifically, you should complete two functions: ***GPIO_Init()*** and ***Full_Stepping_Clockwise()***.
    - **GPIO_Init():**
        - Set up the GPIO port B to be used to control the stepper motor.
    - Full_Stepping_Clockwise():
        - You should complete this function by following the textbook's section 16.4.
        - This function will start completely empty. Every week, more information will be given to help you complete the basic lab requirement.
- **Academic Integrity Notice:**
    - Students are supposed to work individually! Copied code will incur in reduced grade!

Warning: Motor Overheating

The motor constantly draws electrical currents. The motor will be overheated if you leave the power on for an extended period. **Make sure to disconnect the power (Vcc) to the Darlington array if you are not debugging/testing it.**

There will be no post-lab!