Lab 3: Stepper Motor Control
Instructor: Prof. Yifeng Zhu
Spring 2017

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

Pre-Lab Assignment
1. Read the textbook Chapter 16 Stepper Motor
2. Watch video tutorial: How the Stepper motors are made and how they operate (Credit goes to pcbheaven)
   b. Part 2 (8 minutes): http://www.youtube.com/watch?v=t-3VnLadIbc
3. Answer the pre-lab questions

Lab Requirements
1. Basic requirement: Turn the stepper motor exactly 360 degrees clockwise by using half-stepping and full-stepping
2. Something cool. 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.

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

The gear ratio is:

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

Full-stepping

- Internal motor: 32 steps per revolution
- Great reduction ratio: 1/63.68395, approximately 1/64
- So 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 \(\approx\) 1/64
- So it takes \(64 \times 64 = 4096\) steps per revolution for the output shaft
Lab 3: Stepper Motor Control

Name: ________________________________

Pre-Lab Question
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.

Refer to Figure 16-10 and 16-12 of textbook to complete the following two diagrams.

Full stepping sequence

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<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tbody>
<tr>
<td>A</td>
<td>PB 2</td>
<td></td>
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</tr>
<tr>
<td>A</td>
<td>PB 3</td>
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<td></td>
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<tr>
<td>B</td>
<td>PB 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>PB 7</td>
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</table>

Half stepping sequence

<table>
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<th>3</th>
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<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>PB 2</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>PB 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>PB 6</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>PB 7</td>
<td></td>
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</tbody>
</table>
You must write your answer in *Readme.md* file and submit it to the gitlab server.

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

2. How to reverse the rotation direction?
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.**

Lab Demo Requirements

1. Rotate your stepper motor exactly 360 degrees either clockwise or counter-clockwise.

2. What is the highest update frequency of the full-stepping control signals while the motor does not drop any steps? Use an oscilloscope to find out your update frequency.

3. What is the highest update frequency of the half-stepping control signals while the motor does not drop any steps? Use an oscilloscope to find out your update frequency.

4. Is the highest update frequency of the half-stepping higher than full-stepping? Why?

Post-lab Assignments

1. The Darlington array has only 500-mA rated collector current. If you need a larger current, what option you can have to replace the Darlington array.

2. The full-stepping control sequence rotates a stepper motor a full step for each input pulse. The half-stepping rotates the motor 1/2 step for each input pulse. Is it possible to rotate the motor 1/4 or 1/8 step for each input pulse? (Hints: micro-stepping)