STEPPER MOTOR

Topics Covered

- Stepper motors.
- Stepper motor control and excitation modes.

Prerequisites

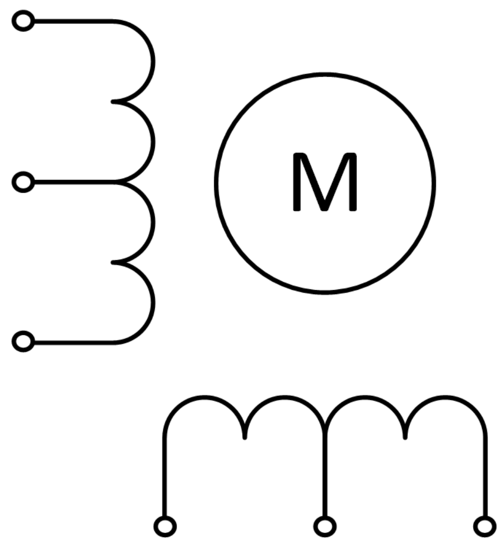
- The QNET Mechatronic Actuators has been setup and tested. See the QNET Mechatronic Actuators Quick Start Guide for details.
- You have access to the QNET Mechatronic Actuators User Manual.
- You are familiar with the basics of LabVIEW™.

1 Background

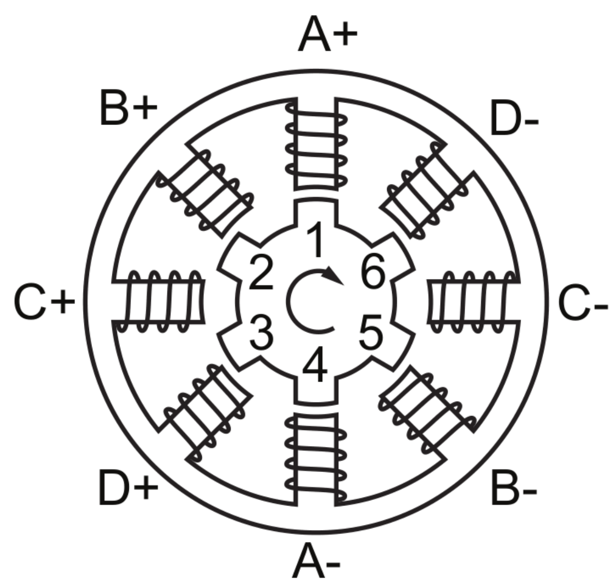
In contrast to the continuous rotation of a brushed or brushless DC motor, a stepper motor rotates the armature in discrete steps. The amount of steps it takes to complete a full revolution determines the stepper motor's step size. As the motor is only stepping between known distinct positions, it is possible to command it to hold a certain position without requiring any feedback sensors. This kind of control is called open-loop control and is easily implemented. To perform the same position control task with brushed or brushless DC motors requires sensor data feedback and is called closed-loop control.

The two basic winding configurations for stepper motors are unipolar and bipolar windings. A unipolar configuration has one winding with a center tap per face. Therefore, changing the polarity only requires choosing the other section of the winding, see Figure 1.1a. This commutation can be achieved by a single transistor for each winding, and a typical configuration is shown in Figure 1.1b.

In a bipolar configuration, there is a single winding per phase. Therefore, the current has to be reversed to change the polarity of the magnetic pole. This configuration requires a driving circuit that is more complex than that required for a unipolar configuration.



(a) Unipolar stepper motor coils



(b) Typical unipolar stepper configuration

Figure 1.1: Unipolar stepper motor

For the unipolar configuration used by the QNET Mechatronic Actuators and shown in Figure 1.1b, the armature has six teeth that are driven in four phases, resulting in a total of 6×4 steps per revolution, or a step size of 15°. There are several excitation modes for stepper motors of this configuration that are explained below, and summarized in Figure 1.2.

The most basic excitation mode is called *wave drive*. In this mode, one phase is on and three phases are off at any given time. At each step, the teeth of the rotor are aligned with the active phase pair, for example $A+$ and $A-$ in Figure 1.1b. Once the next step is commanded, the currently active phase pair, A, deactivates and the next phase pair, B, activates, resulting in a 15° step and a total of 24 steps per revolution. This excitation mode is easy to implement, but the holding torque is significantly less than the rated torque of the motor.

To achieve the rated torque, a *full step* drive is used. In this excitation mode, two neighboring phases are active at any given time, resulting in the maximum rated torque. Starting, for example, from phase A and B being active, a step command deactivates phase A and activates phase C. This approach results in a 15° step and a total of 24 steps per revolution.

Another excitation mode is the *half-step drive*. Here, the motor alternates between one and two active phases, resulting in double the angular resolution of wave or full step drives. Starting from phase A being active, the next step would activate phase A and B, rotating the armature by 7.5°. The next step would deactivate phase A and phase B remains active, moving the armature another 7.5°, resulting in a total of 48 steps for a complete revolution. This also implies that the maximum holding torque is only present when two phases are active, or only for every other step command.

Lastly, a stepper motor can be excited using *micro-stepping*. In this excitation mode, the current in each of the phases approximate sinusoids, allowing for very smooth motor operation. It is often referred to as *sine cosine micro-stepping* and is depicted in Figure 1.2. In contrast to the other excitation modes described above, micro-stepping requires a more complex amplifier circuitry. Furthermore, as the micro-stepping divisor grows, the step size repeatability degrades.

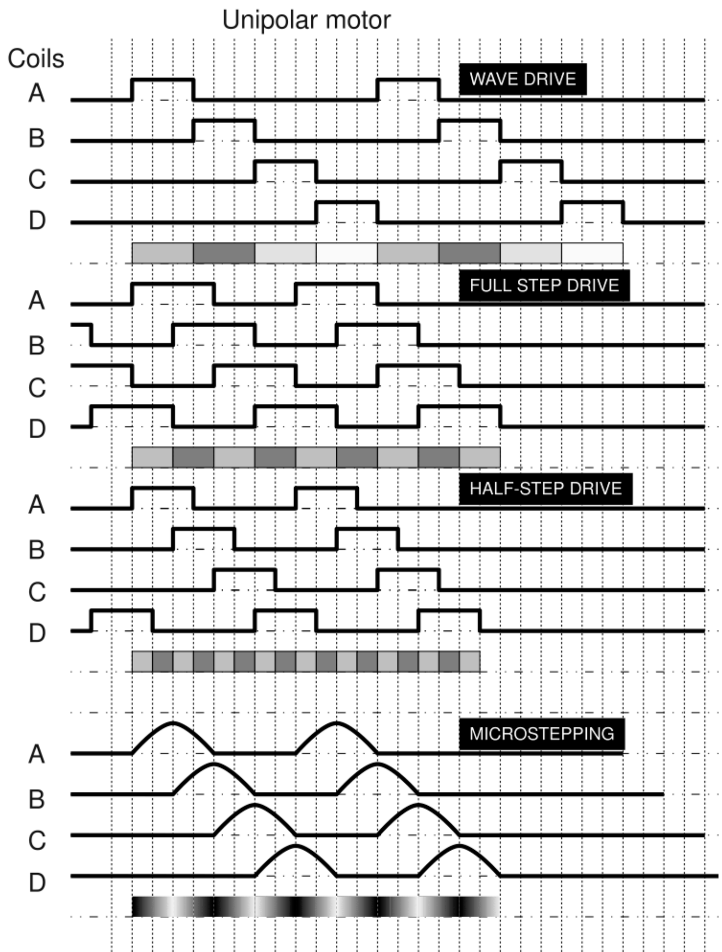


Figure 1.2: Drive modes of a 4 phase unipolar stepper motor [1]

Stepper motors are designed to run at high temperatures. The stepper motor on the QNET Mechatronic Actuators is rated at 130 °C, or 266 °F. To protect users from potential burns, the stepper motor on the QNET Mechatronic Actuators is not energized continuously, and instead uses a pulsed voltage. The coils are energized enough to move the motor one step position, and then de-energized until it's time to move to the next step position. Although this method isn't standard, it keeps the stepper motor cool while the VI is running. This method of excitation does, however, limit the stepper motor to full-stepping as outlined above. The stepper motor performs half-stepping with a pulsed half-step, but is not capable of micro-stepping.

[1] Misan2010

2 In-Lab Exercise

1. With power to the QNET Mechatronic Actuators turned off, rotate the cog wheel of the stepper motor and count the number of steps in one revolution.
2. What is the step angle for wave, full, and half-stepping drives of the QNET Mechatronic Actuators stepper motor?
3. Complete the logic table for full stepping below where phase B follows phase A.

A	B	C	D
1			
0			
0			
1			

Table 2.1: Full stepping

4. Open `QNET Actuators - Stepper Motor.vi`. Enter your result from the previous question in the first four lines of the table. Repeat the sequence for the last four lines of the table, and make sure that the toggle switch is set to User Table. Run the VI, and enable the stepper motor. Verify that the stepper motor rotates as expected, noting the direction of rotation.
5. Disable the stepper motor.
6. Complete the logic table below to configure full stepping in the opposite direction.

A	B	C	D
1			
0			
0			
1			

Table 2.2: Full stepping - change of direction

7. Update the table in your VI, and enable the stepper motor. Verify that you have indeed changed the direction of operation of the stepper motor. Note the time required to complete a full rotation.
8. Disable the stepper motor.
9. Complete the logic table for a half-stepping drive below where phase B follows phase A.

A	B	C	D
1			
1			
0			
0			
0			
0			
0			
1			

Table 2.3: Half-stepping

10. Update the table in your VI, and enable the stepper motor. Describe the motion of the stepper motor. Why is it not performing half-stepping as outlined in the background section?
11. How long does it take to complete one revolution compared to the full stepping drive used previously?
12. Record the Motor Current plot, and comment on the current commands observed when half-stepping is implemented.
13. Based on your observations of the performance and characteristics of the stepper motor, brainstorm potential applications for a stepper motor.
14. Click on the Stop button to stop the VI.

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