ME4405 - Fundamentals of Mechatronics (Spring 2020)

Lab Assignment Seven

Stepper Motor Control with the MSP432

Due Thursday, March 12th, 2020

Objective: This objective of this lab is to learn how to interface and control a unipolar stepper motor with the MSP432.

Deliverables and Grading:

To get credit for this lab assignment you must:

1. Turn in a typed report answering the questions at the end of the lab. This is due **by 5pm** on the above due date. You must submit the typed report electronically on Canvas. **(15 points)**
2. Demonstrate proper operation of your code to the TA or instructor during lab or by the end of Wednesday office hours. **(35 points)**
3. Submit the commented final version of your code on Canvas. **(Pass/Fail)**
4. Lab quiz will be held Friday, March 13th. **(10 pts)**

Setup:

This lab requires Code Composer Studio, MSP432, and a stepper motor driver circuit which you will build to control the unipolar stepper motor. The lab uses onboard features of the MSP432 such as GPIO and Timer A.

Problem Statement:

Build a driver circuit for a unipolar stepper motor. This circuit will be used to control the motor via the MCU. The direction and speed of the motor will be controlled by the MCU software.

An MSP432 program will be used to make the stepper motor act like an egg timer. One full rotation of the motor will correspond to 60 seconds. The program will prompt for an integer number of seconds in a PuTTY terminal. When a number between 0 and 60 is entered and the "Enter" key is pressed, the motor should quickly rotate the corresponding number of degrees in a counter-clockwise direction. Once the motor is in position, the program should prompt with "Start?" When the "Enter" key is pressed again, the motor should spin clockwise to reach the home position. Upon reaching the home position, the program should prompt for time to be entered again.

Background:

Stepper Motor:

Stepper motors, as their name suggests, operate in steps. A step is the distance/angle by which the rotor advances when the next consecutive coil is energized. They are divided into two categories, unipolar and bipolar, based on construction and excitation method. Current flows a single direction through the coils of a unipolar motor. Current flows in both directions though coils of a bipolar stepper motor. We are using a unipolar motor in this lab.

Bipolar Stepper Motor:

Consider a two-phase bipolar stepper motor with coils A and B as shown in the Figure 1. These coils are arranged in the stator (stationary part of the motor) in opposite orientations with respect to the rotor. As discussed in class, to execute a full rotation with a bipolar motor both positive and negative voltages must be generated across the coils. This usually requires use of an H-bridge.

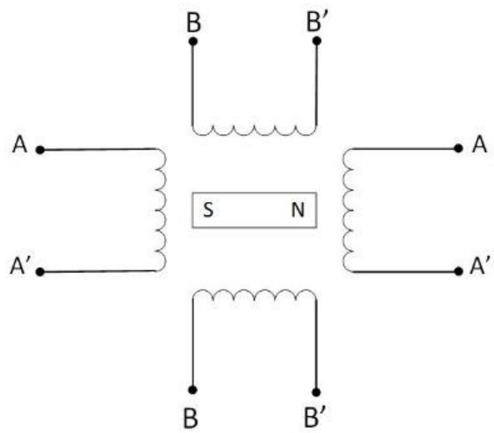

Figure 1. Bipolar Stepper Motor.

Unipolar Stepper Motor:

A coil in a unipolar motor is split in half, and three leads are exposed for each phase. One lead is used as the voltage input, and the other two leads are connected to ground (at different times) to complete the coil circuit. Hence, for a unipolar motor with two phases, six leads come out of the motor as opposed to four in a bipolar motor. Figure 2 shows a basic diagram of the coils in a unipolar stepper motor.

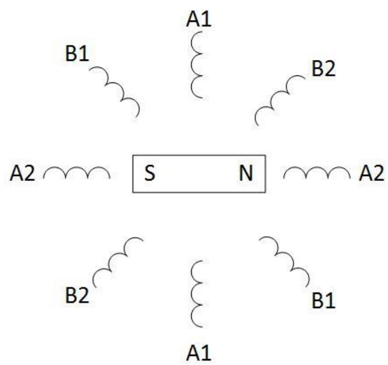

Figure 2. Possible Arrangement of Coils in a Unipolar Stepper Motor.

When a coil is energized the rotor aligns itself with the coil based on the magnetic field produced. For example, consider coil A2 as shown in Figure 2 energized first. Then, if B2 is energized next, the rotor shifts and aligns itself with coil B2. Energizing coils in the order A1-B1-A2-B2-A1 and so on will cause the rotor to turn counterclockwise in this case. For clockwise rotation the sequence would be the opposite.

Since only half a coil is energized in a unipolar motor compared to the bipolar one, the torque generated by the unipolar motor is less than that of a bipolar motor. Therefore, a bipolar motor is used in applications where higher torque is required.

Hardware:

Figure 4 shows the circuit that will be used to interface the stepper motor with the MSP432. The stepper motor needs a +5V supply (+12 for the old motors). Voltage is applied to the coils through the use of transistors. The transistors are operated in the saturation and off states and are controlled by the MSP432. The MCU pins shown in Figure 4 are just for reference. You can use any output pins you prefer.

The circuit consists of 4 diodes, 4 MOSFETs, and 4 resistors. All components needed to construct this circuit are provided in the Mechatronics lab. Construct the circuit using the breadboards provided. You can take the breadboard and other components out of the lab, **but please do not remove the stepper motors**. **The stepper motors should remain in the Mechatronics lab at all times so students can share them as needed.** The breadboards should be returned after check-off, as they will be needed again for future labs.

There are two kinds of stepper motors available for this lab. The older ones are 6-lead and newer ones are 5-lead. For the older 6-lead steppers, generally the middle lead is the power lead for each phase. However, this is not always the case. This must be verified by using a multimeter to measure the resistance between the leads of each phase. For the same phase, the resistance between one phase lead and the power lead should be equal to the resistance between the other phase lead and the power lead. Once the power leads have been identified, the individual coils A1, A2, B1 and B2 should be identified by powering each coil independently and observing the movement of the shaft. For the newer 5-lead steppers, please refer to the datasheet uploaded in the resources tab on Canvas.

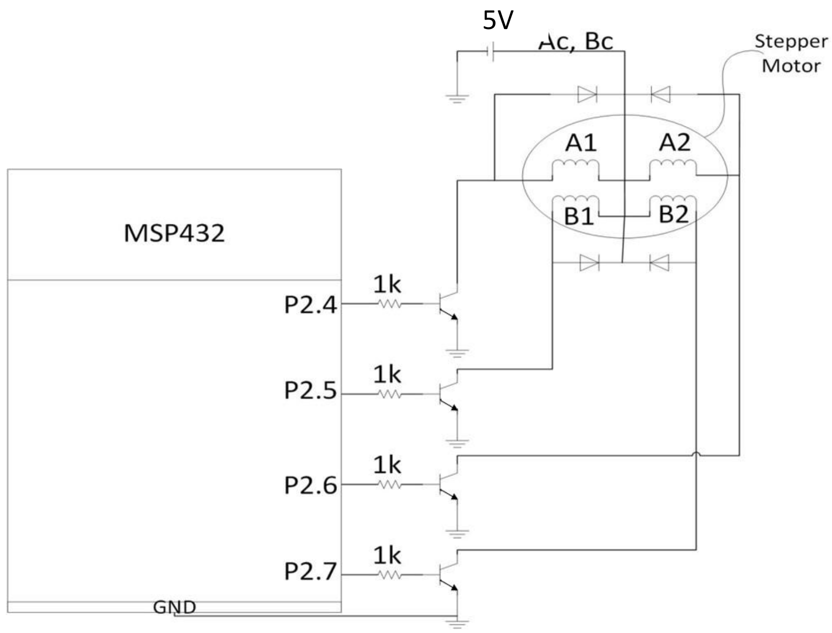

Figure 4. Circuit for interfacing stepper motor to MSP

Software:

The program should energize coils in one sequence (direction) when setting the starting position, and in the opposite sequence when counting down. When moving to the starting position (obtained from PuTTY), the shaft should move as quickly as possible. Once in position, the frequency of actuation should be changed so that the time taken by the stepper to return to home position is equal to the input value from PuTTY (in seconds). For example, if the start position entered in PuTTY is 15, the stepper should quickly rotate the shaft by 90 degrees in one direction. When prompted to begin counting down, the stepper should move in the opposite direction and the time taken to finish counting down and reach the home position should be 15 seconds. The rate at which you need to activate the coils in order to move the timer at 1 degree/second may be a factor of 2 off of what the datasheet and its stated gear ratio implies (this mistake in the datasheet was noted by previous semesters' students).

Requirements:

1. At what frequency of excitation does the stepper motor fail to move anymore (in a predictable way)? Explain why this occurs.
2. What happens if two consecutive coils are energized simultaneously, i.e. if A1:B1 are energized, then B1:A2 are energized and then A2:B2 and so on (A1B1-B1A2-A2B2-B2A1-A1B1). What happens to the torque as compared to A1-B1-A2-B2-A1? What is this method of excitation called?
3. Consider the use of half-stepping excitation. What happens to the torque in each step when using half-stepping operation with a unipolar motor?
4. What excitation method would you use to achieve greater motion resolution than possible with half-stepping? How would you implement this method using the MSP432?