# Introduction to Mechatronics (ME/AE 6705)
# Lab Assignment 7

## Stepper Motor Control using MSPM0 LaunchPad

## 7.1 Objective

The objective of this lab is to learn how to interface and control a unipolar stepper motor with MSPM0. You will control both the *speed* and *direction* of the stepper motor using the MSPM0 LaunchPad.

## 7.2 Deliverables and Grading

To get credit for this lab assignment you must:

1. Submit a typed report as a PDF file to Canvas, answering the questions at the end of the lab (2 pages max, can be shorter). This is due at the beginning of class on the due date specified on Canvas. (20 points)
2. Demonstrate proper operation of your code to TAs or instructor during office hours or demo hours. You must write your own code for this lab – no lab groups are allowed. (40 points)
3. Submit the commented final version of your code on Canvas (single .c file containing your main() function, do not submit header files, etc. You should only submit a single file.) (Pass/Fail)

## 7.3 Setup

This lab requires Code Composer Studio, MSPM0 LaunchPad, and a stepper motor driver circuit which you will build to control the unipolar stepper motor. The lab uses onboard features of the MSPM0 such as GPIO and the general purpose timer.

All components needed for this lab are available in the mechatronics lab. You can power your motor via 4 double A batteries. You can use disposable alkaline batteries or rechargeable NiMH 1.5V batteries.

## 7.4 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 MSPM0 program will be used to control the stepper motor. The program should start a timer that generates an interrupt at a rate of 20 Hz. Buttons S1 and S2 should be initiated as inputs. The code should turn the motor in one direction when S1 is held down and in the opposite direction if S2 is held down. The shaft should increment its rotational position at a rate of 20 Hz in the corresponding direction when a button is held down. When no buttons are pressed, the motor should not turn.

More details about hardware and software requirements will be discussed in the next sections.

## 7.5 Hardware

### 7.5.1 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 bipoloar, 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 (28BYJ-48 5V) in this lab. More details about the stepper are available at:

https://www.adafruit.com/product/858#technical-details

Figure 1: The 28BYJ-48 Unipolar Stepper Motor.

**Bipolar Stepper Motor.** Consider a two-phase bipolar stepper motor with coils A and B as shown in the Figure 2. 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 drive.

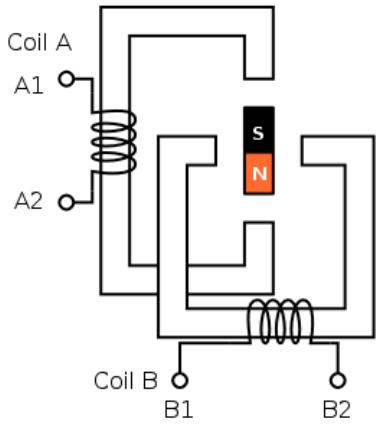



Figure 2: Bipolar Stepper Motor.

**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 3 shows a basic diagram of the coils in a unipolar stepper motor.

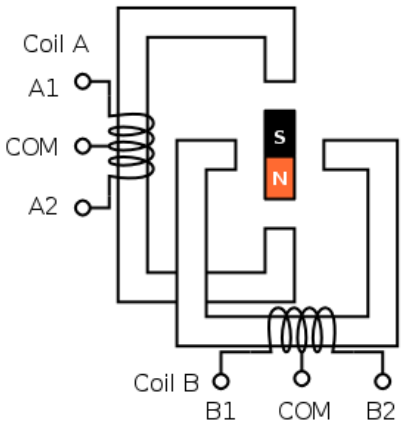



Figure 3: Unipolar Stepper Motor.

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 3 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. So a bipolar motor is used in applications where higher torque is required.

### 7.5.2 PN2222/2N2222 Transistor

PN2222 transistor is a NPN general-purpose amplifier. This device is for use as a medium power amplifier and switch requiring collector currents up to 500mA.

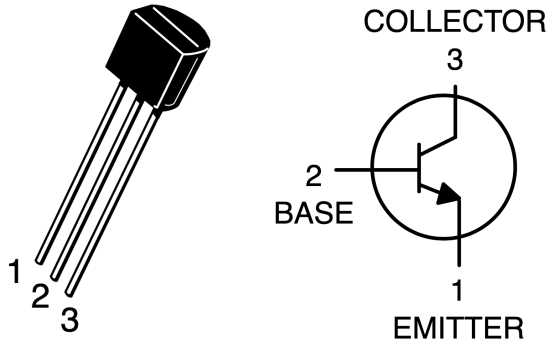



Figure 4: Pinout of the PN2222 transistor.

The datasheet for PN2222 can be downloaded from the below link:

https://www.onsemi.com/pub/Collateral/PN2222A-D.pdf

### 7.5.3 Diodes

Diodes are semiconductor devices used to control the direction of current flow. They are used often in mechatronic devices. In this lab, 1N5819 diodes will be used flyback diodes for the motor driver. Flyback diodes provide alternative path for current in motor coil and mitigates arcing/excessive current through transistors, to avoid damaging the transistors.

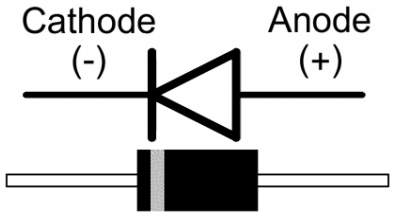



Figure 5: The diode circuit symbol, and the physical shape.

As shown in Figure 5, the silver line on 1N5819 diode indicates the cathode pin, which matches the vertical line in the diode circuit symbol.

## 7.6 Circuit Schematic

Figure 6 shows the circuit that will be used to interface the stepper motor with the MSPM0 LaunchPad. The stepper motor needs a voltage supply between 5V to 6V. 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 MSPM0. The MCU pins shown in Figure 6 are just for reference. You can use any output pins you prefer. **The diagram below shows the wiring for the MSP432 launchpad but it is the same for the MSPM0 - you just need to choose any output pins you want to use for each of the phases.**

The circuit consists of 4 diodes, 4 NPN transistors, and 4 resistors. All components needed to construct this circuit are provided in the Mechatronics kit. Implement the circuit on the solderless breadboard.

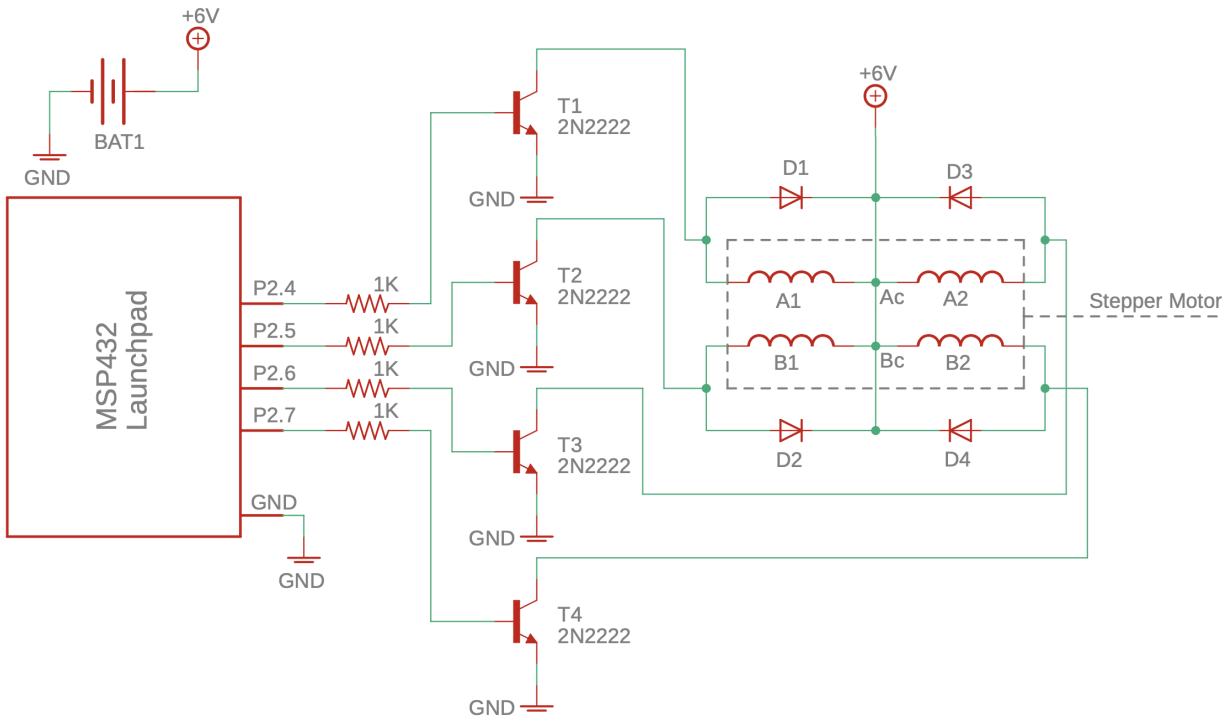


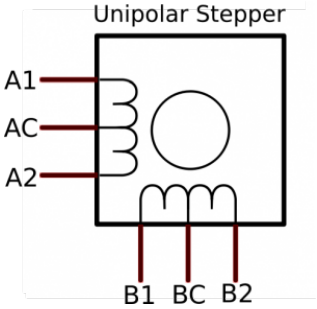

Figure 6: Circuit schematic for interfacing stepper motor to MSP LaunchPad.

**Note:** Remember to connect a common ground between the LaunchPad and the driver circuit.

### Identifying the wires of unipolar steppers

To identify the stepper motor wires, a multimeter is needed to measure the resistance.

Stepper motors with six wires are unipolar and have one winding per phase (like the bipolar steppers) but with a center tap. The internal wiring of these motors looks like this:



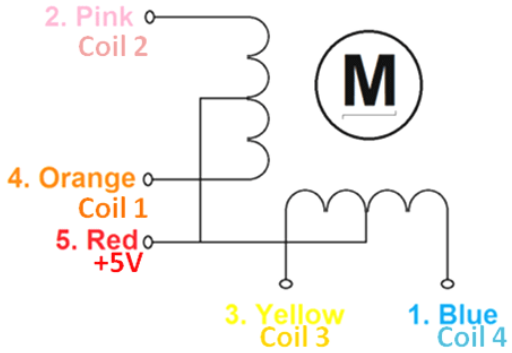

Looking at the diagram above, we can assume that the resistance between A1 and AC will be half of that between A1 and A2. This is because there is less wire between AC and A1 than between the two ends of the A coil, A1 and A2. The same applies to the resistance between BC and B1, or B2. There is no connection (infinite resistance) between any of the wires from coil B and coil A.

Now that we have determined which wires belong to each coil, we need to determine the proper stepper polarity. Connect the motor to your motor driver circuit. Connect power and run the code to spin the motor clockwise. If the motor spins in the expected direction, you have the correct polarity. If it spins in reverse, you need to switch the polarity of one of the two pairs (it does not matter which one).

The common stepper motor wire colors are as follows.

**Five wire motors:** Blue: A1, Pink: B1, Yellow: A2, Orange: B2, Red: Common

If the colors are different, you need to identify the wires of the stepper motor by the above instructions.




**Six wire motors:** Brown: A1, Yellow: B1, Orange: A2, Black: B2.

The other two red wires are common wires (AC and BC).

## 7.7 Software and Expected Performance

**Note:** To create a new CCS project for the MSPM0, please use the same steps as you did for Labs 3-6.

The program should energize coils in one sequence (direction) when switch S1 is pressed and held. Similarly, when S2 is pressed and held, coils are energized in the opposite sequence. The program should use TIMG to sequence through the phases at a rate of 20 Hz.

## 7.8 Requirements

1. Successfully demonstrate the outcome of the program and all the required functionalities to TAs or Instructor.
2. Submit the commented final version of the code on Canvas.
3. Answer the below questions and submit the PDF report to Canvas before the due date specified on Canvas.

## 7.9 Questions

1. At what frequency of excitation does the stepper motor fail to move anymore (in a predictable way)? (You can determine this by increasing the frequency of excitation from 20 Hz to something higher). 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?