Electronics Exercise 3: Uni-Polar Stepper Motor Controller / Driver

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1. Objectives

1. Learn how uni-polar stepper motors work
2. Learn how to use a universal shift register (74LS194) as a uni-polar stepper motor controller
3. Create an uni-polar stepper motor controller /driver

2. Uni-Polar Stepper Motor

A stepper motor is used when open loop control of position is needed. Unlike a typical DC motor, the output shaft of a typical stepper motor can be rotated ("stepped") anywhere between 1.8 degrees per step to 15 degrees per step depending on the particular stepper motor. There are two types of stepper motors: bipolar and uni-polar. Current flows only in one direction through the coils of a uni-polar motor. Current needs to flow in two directions though coils of a bi-polar stepper motor. Motors need controllers to adjust their position and speed.

A driver is needed to amplify a controller's low output current to a larger current required by a motor. The advantages and disadvantages between bi-polar stepper motor, uni-polar stepper motor, and DC motors are given in Table 1.

Table 1 Comparison of DC, Uni-Polar and Bi-polar Stepper Motors

Motor Type	Complexity of Controller and Driver Electronics	Torque	Position Control
DC	Medium Complexity for Forward and Reverse operation. Simple for Single Direction	High Torque	No Open Loop Position Control (Note: A DC motor can be made into a servo motor by using an encoder for closed loop control).
Uni-Polar Stepper	Medium Complexity	Low Torque	Easy Open Loop Position Control
Bi-Polar Stepper	High Complexity	Medium Torque	Easy Open Loop Position Control

A uni-polar stepper motor will be used in this exercise. A simplified diagram of a uni-polar stepper motor is shown in ***Figure 1***.

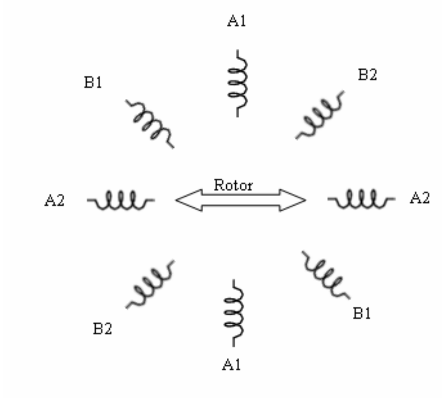


Figure 1 Diagram of Uni-Polar Stepper Motor

The uni-polar stepper motor shown in ***Figure 1*** has a 45 degree per step configuration. The rotor will point to the closest coil with power applied to it. The rotor will rotate counter clockwise if coils A1, B1, A2, B2, A1, B1, etc. are energized in sequence. The rotor will rotate clockwise if coils A1, B2, A2, B1, A1, B2,etc.. are energized in sequence. Another set of A1,B1,A2, and B2 coils will produce a 30 degree per step configuration. Two additional sets of A1,B1,A2, and B2 coils will produce a 22.5 degree per step configuration. More sets of A1, B1, A2, and B2 coils will produce even finer degrees per step configurations. The schematic symbol for a uni-polar stepper motor regardless of degree per step is given in ***Figure 2***

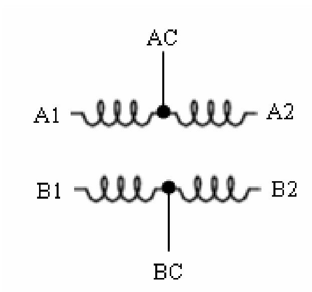


Figure 2 Schematic Symbol for Uni-polar Stepper Motor

There are a many ways of energizing stepper motor coils in the proper sequence. A microcontroller may be used as a uni-polar stepper motor controller but this will take memory and processing time. This is especially true in final projects where three or more stepper motors are used. It would be advantageous to make a uni-polar stepper motor controller circuit. Inputs into a uni-polar stepper motor controller circuit should be when to step and which direction to turn. This can be accomplished using a universal shift register as a controller.

3. Universal Shift Register (74LS194) as a Uni-polar Stepper Motor Controller

The universal shift register is a standardized logic chip (74LS194) manufactured by various companies. The universal shift register pinout is shown in ***Figure 3***.

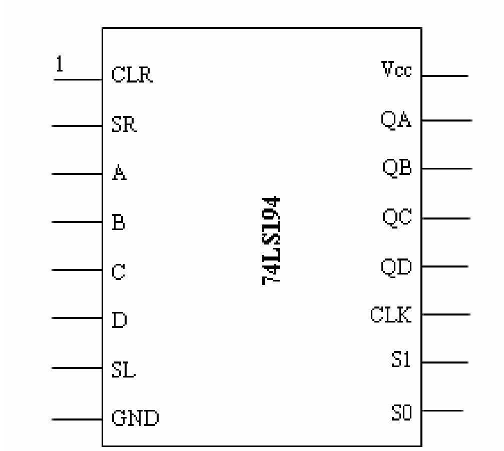


Figure 3 Universal Shift Register (74LS194) Pin out

Table 2 74LS194 Pinout

Pin	Name	Description
1	**CLR**	Clear Output Pin
2	**SR**	Serial Shift Right Input Pin
3	**A**	Parallel Shift Input Pins
4	**B**	
5	**C**	
6	**D**	
7	**SL**	Serial Shift Left Input Pin
8	**GND**	Logic Ground
9	**S_0**	Model Select Pins
10	**S_1**	
11	**CLK**	Clock Input Pin
12	**Q_D**	Output Pins
13	**Q_C**	
14	**Q_B**	
15	**Q_A**	
16	**V_{cc}**	5V Logic Power Supply

The operation of the chip is summarized in ***Table 3***

Table 3: Operation of Universal Shift Register
(L – 0V, H-5V, X-does not matter, ↑ - transition from 0V – 5V)

	CLR	CLK	S0	S1	QA	QB	QC	QD	Description
1	L	X	X	X	L	L	L	L	Outputs Cleared
2	H	X	L	L	Q_A	Q_B	Q_C	Q_D	Outputs Stay the same
3	H	↑	L	H	Q_B	Q_C	Q_D	SL	Output Shift Left. Input SL before clock transition is copied to Output Q_D
4	H	↑	H	L	SR	Q_A	Q_B	Q_C	Output Shift Right. Input SR before clock transition is copied to Output Q_A
5	H	↑	H	H	A	B	C	D	Output Parallel Shift. Inputs A, B, C, D copied to Outputs Q_A, Q_B, Q_C, Q_D

The following ***Figure 4***, shows a universal shift register used as an uni-polar stepper motor controller.

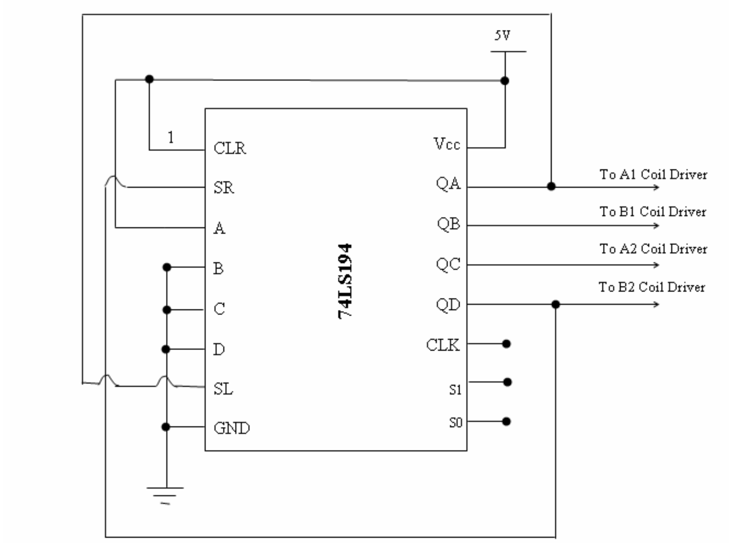


Figure 4 Universal Shift Register as a Uni-Polar Stepper Motor Controller

Only CLK, S_0, and S_1 inputs need to be manipulated in order to control a uni-polar stepper motor using the circuit in ***Figure 4***. Setting rotation direction and initialization of the circuit is done using inputs S_0 and S_1. The stepper motor steps when there is a transition from 0V to 5V on the clock pin. Therefore, the speed of rotation can be controlled by controlling the number of transitions on the clock pin per second. An example of how to step an uni-polar stepper motor 6 steps clockwise then 6 steps counter clockwise using the above circuit is shown below in table 3.

Table 4 Example of stepping uni-polar stepper motor using circuit show in Figure 4
(L – 0V, H – 5V, X – does not matter, ↑ - transition from 0V to 5V)

CLK	S_0	S_1	Q_A (A_1 Coil)	Q_B (B_1 Coil)	Q_C (A_2 Coil)	Q_D (B_2 Coil)	Operation (***Table 3***)	Description
X	X	X	X	X	X	X		Circuit Power On
↑	H	H	**H**	L	L	L	5	Initialize Controller
↑	L	H	L	L	L	**H**	3	Clockwise Step 1
↑	L	H	L	L	**H**	L	3	Clockwise Step 2
↑	L	H	L	**H**	L	L	3	Clockwise Step 3
↑	L	H	**H**	L	L	L	3	Clockwise Step 4
↑	L	H	L	L	L	**H**	3	Clockwise Step 5
↑	L	H	L	L	**H**	L	3	Clockwise Step 6
↑	H	L	L	L	L	**H**	4	Counter Clockwise Step 1
↑	H	L	**H**	L	L	L	4	Counter Clockwise Step 2
↑	H	L	L	**H**	L	L	4	Counter Clockwise Step 3
↑	H	L	L	L	**H**	L	4	Counter Clockwise Step 4
↑	H	L	L	L	L	**H**	4	Counter Clockwise Step 5
↑	H	L	**H**	L	L	L	4	Counter Clockwise Step 6

4. Uni-Polar Stepper Motor Driver

The power output from a universal shift register is inadequate for energizing coils in a stepper motor. Four NPN transistors and diodes are needed to create a uni-polar stepper motor driver. An NPN transistor has three pins: collector, base, and emitter. The circuit symbol for an NPN transistor is shown in ***Figure 5***

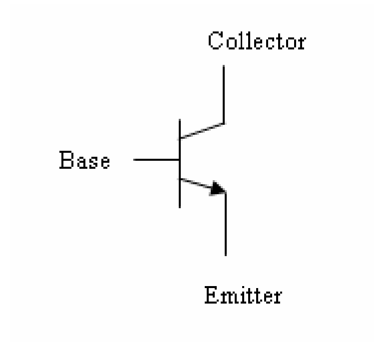


Figure 5 Schematic Symbol for NPN Transistor

The NPN Transistor will allow a large current to flow from collector to emitter when there is a smaller current from base to emitter. The schematic for a uni-polar stepper motor driver using four NPN transistors and diodes is given in Fig. 6. Diodes are used to protect the transistor from reverse currents generated by the motor. (Note: Transistors will be covered in greater detail during class lectures.)

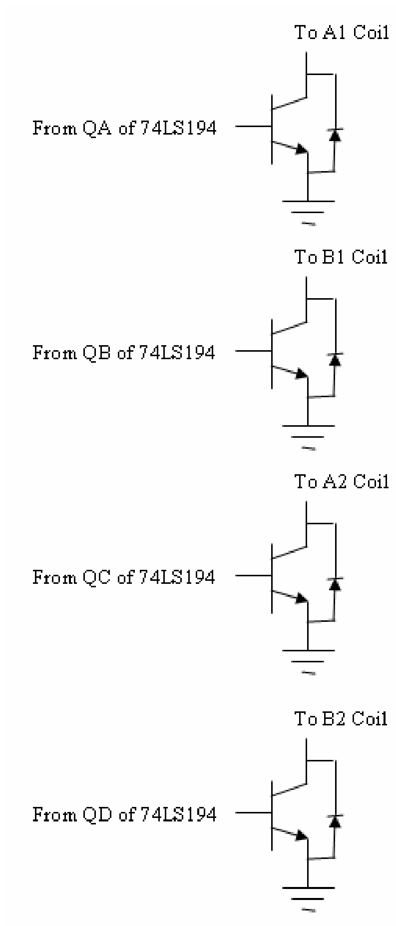


Figure 6 Driver for Uni-Polar Stepper Motor

5. Lab Task

Your task is to assemble the circuit shown in ***Figure 7*** on a perforated protoboard. You will also have a uni-polar stepper motor to test your circuit with. The Bill of Materials is given in 7. The pinouts are given in 8.

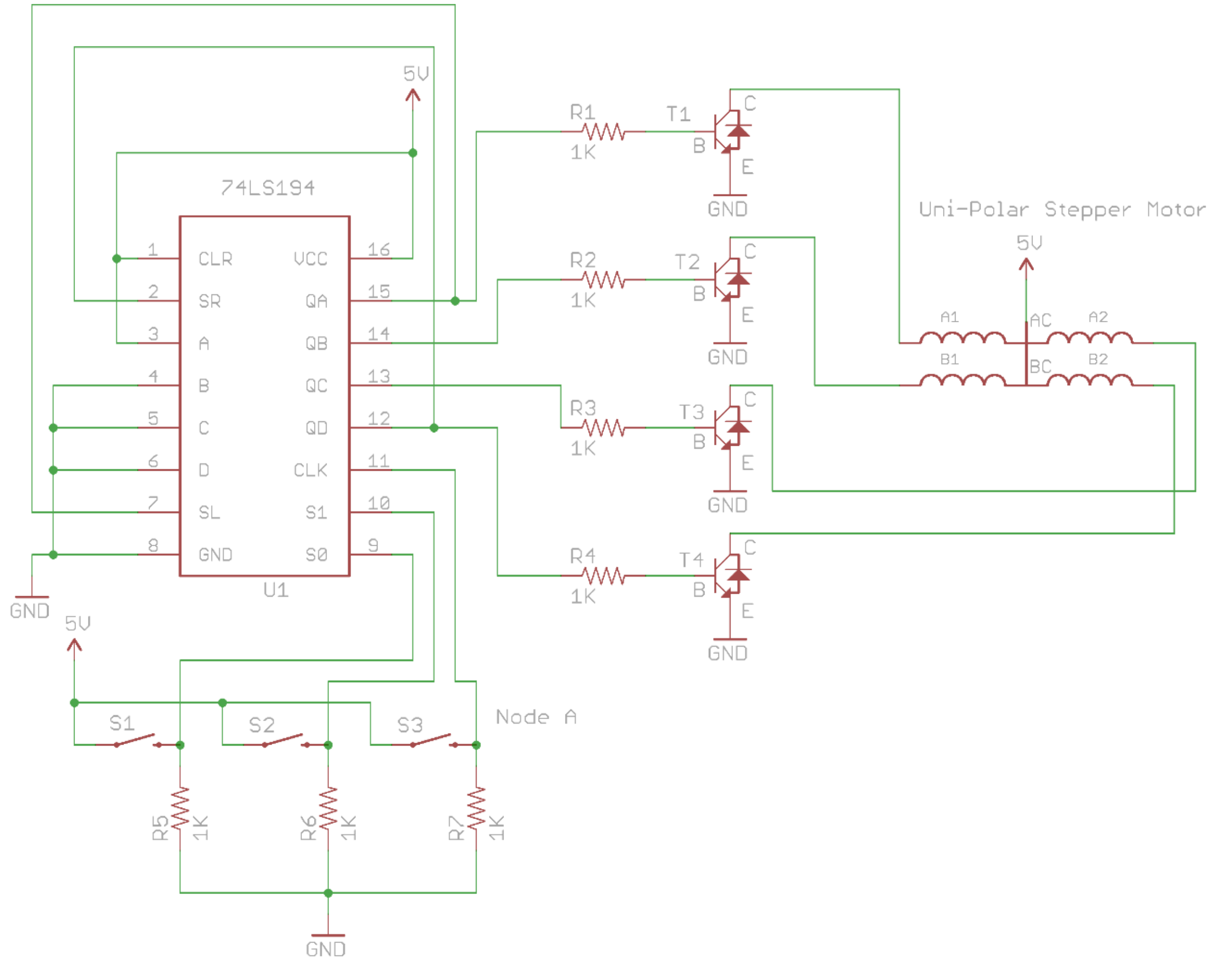


Figure 7 Schematic of Uni-polar Stepper Motor Controller/Driver *(Transistors have diodes already incorporated)*

Questions:

a) Connect the TTL output pulse of the function generator to Node A in Fig. 7. Connect the ground of the function generator to ground in Fig. 7. The function generator is now acting as the clock input into the controller. Vary the rotational speed by varying the frequency of the function generator. Slowly increase the rotational speed. At what frequency does the stepper motor stop rotating? Why?

6. Lab Deliverables

Demonstrate a working circuit setup to your lab instructor in person. And submit your answers to the above questions by the due date.

7. Bill of Materials

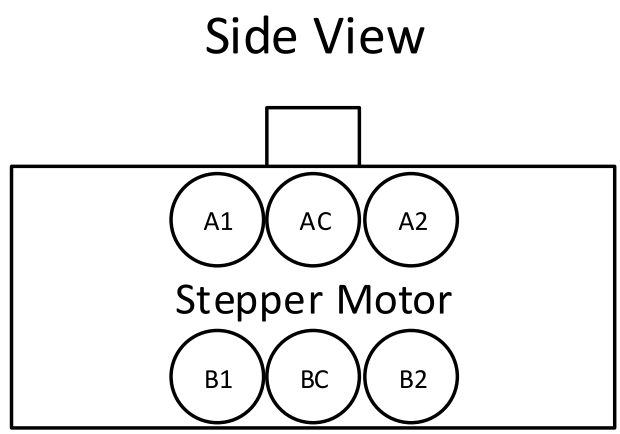
Note that designations are specific to ***Figure 7***

Designation	Description	Part No.
R1, R2, R3, R4, R5, R6, R7	1kΩ Resistor	
S1, S2, S3	Push Button (Momentary Switch)	
T1, T2, T3, T4	NPN transistor - Diode Incorporated	ZTX653
U1	74LS194 Counter Shift Registers	SN74LS194AN

8. Pinouts and Wirings

Stepper Motor Wiring – Example Only. Motors differ in configuration.

The stepper motor wiring is not consistent across all motors. To check the correct wiring configuration, read the resistance across the coils. The resistance between two coil ends should be double the resistance between one end and the center. For example, in the diagram below, the resistance across A1-AC is XΩ, across AC-A2 is also XΩ but is 2XΩ across A1-A2. Coil A and B are not connected, thus no resistance value to be expected.



NPN Transistor