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

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Objective:

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

1. 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: bi-polar and uni-polar. Current flows only one direction through coils of an uni-polar motor. Current needs to flow in two directions though coils of a bi-polar stepper motor.

Motors need controllers to adjust position and speed. A driver is needed to amplifiy a controller's low output current to a larger current requried 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

An uni-polar stepper motor will be used in this exercise. A simplified diagram of an uni-polar stepper motor is shown in Fig. 1.

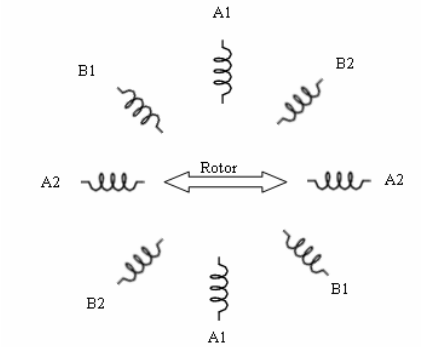

Fig.1 Diagram of Uni-polar Stepper Motor

The uni-polar stepper motor shown in Fig. 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 an uni-polar stepper motor regardless of degree per step is given in Fig. 2.

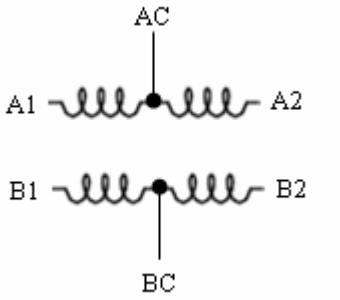

Fig.2 Schematic Symbol for Uni-polar Stepper Motor

There are a many ways of energizing stepper motor coils in the proper sequence. A microcontroller may be used as an 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 an uni-polar stepper motor controller circuit. Inputs into an uni-polar stepper motor controller circuit should be when to step and which direction to turn. This can be accomplished using an universal shift register as a controller.

2. Universial 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 pin out is shown in Fig. 3.

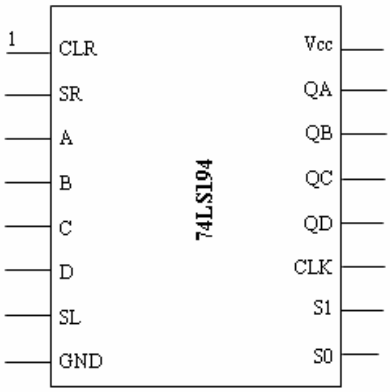

Fig.3 Universal Shift Register (74LS194) Pin Out

Pins of the universal shift register are as follows:

- Gnd 0V Ground connection for chip
- Vcc 5V Power supply for chip
- CLR Clear Output Pin

- SR Serial Shift Right Input Pin
- A,B,C,D Parallel Shift Input Pins
- SL Serial Shift Left Input Pin
- QA, QB, QC, QD Output Pins
- S0, S1 Mode Select Pins
- CLK Clock Input Pin

The operation of the chip is summarized in Table 2.

Table 2: Operation of Universal Shift Register
(L – 0V, H – 5V, X – does not matter, ↑ - transition from 0V to 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	QA	QB	QC	QD	Outputs Stay the Same
3	H	↑	L	H	QB	QC	QD	SL	Outputs Shift Left. Input SL before clock transition is copied to Output QD
4	H	↑	H	L	SR	QA	QB	QC	Outputs Shift Right. Input SR before clock transition is copied to Output QA
5	H	↑	H	H	A	B	C	D	Output Parallel Shift. Inputs A,B,C,D copied to Outputs QA, QB, QC, QD

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

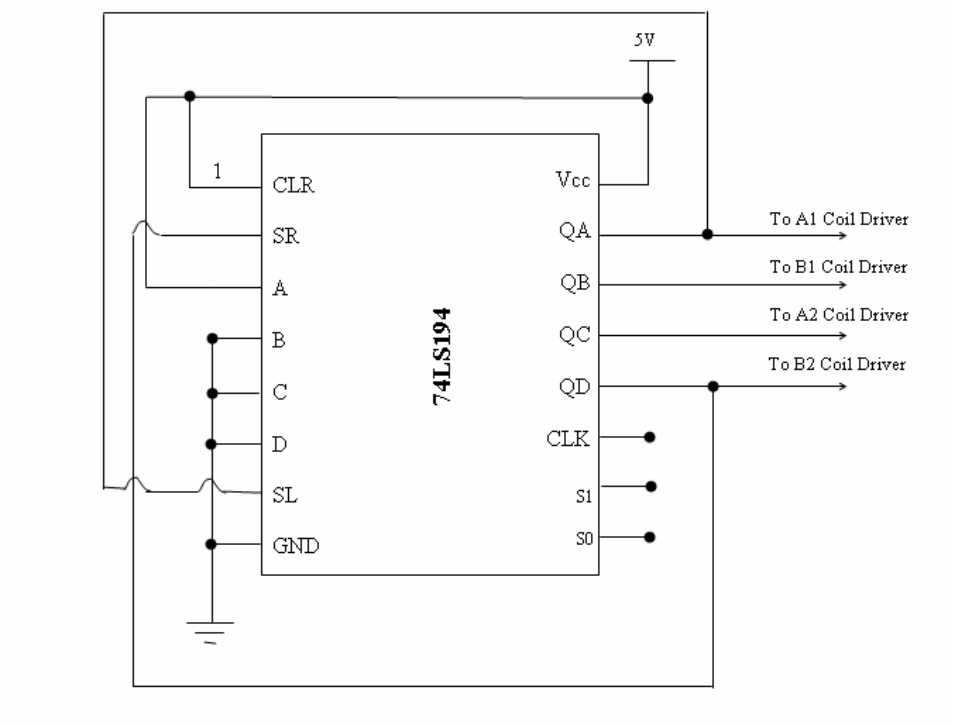

Fig.4 Universal Shift Register used as Uni-polar Stepper Motor Controller

Only CLK, S0, and S1 inputs need to be manipulated in order to control a uni-polar stepper motor using the circuit in Fig. 4. Setting rotation direction and initialization of the circuit is done using inputs S0 and S1. 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 3: Example of stepping uni-polar stepper motor using circuit shown in Fig. 4
(L – 0V, H – 5V, X – does not matter, ↑ - transition from 0V to 5V)

CLK	S0	S1	QA (A1 Coil)	QB (B1 Coil)	QC (A2 Coil)	QD (B2 Coil)	Operation from Table 2	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

3. 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 an 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 Fig 5.

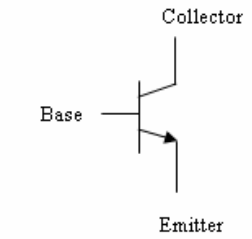

Fig. 5 Schematic Symbol for NPN Transistor

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 an 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.)

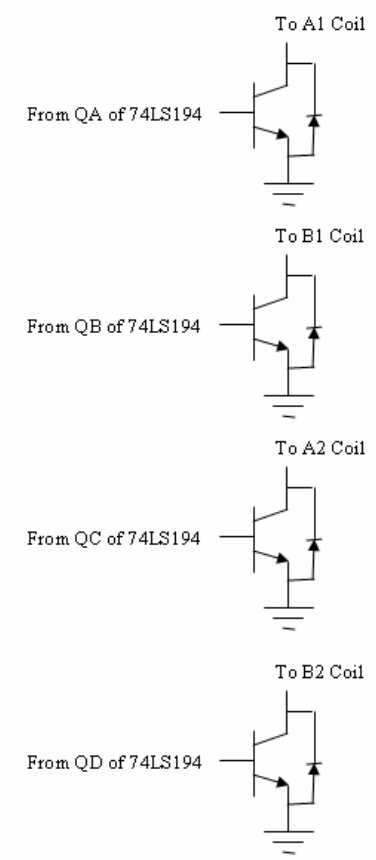

Fig. 6 Driver for Uni-polar Stepper Motor

4. Create an uni-polar stepper motor controller /driver

Students should solder the circuit shown in Fig. 7 on a protoboard. An uni-polar stepper motor will be given to the students to test the circuit. Show the working controller/driver to the TA.

Questions:

1. 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?

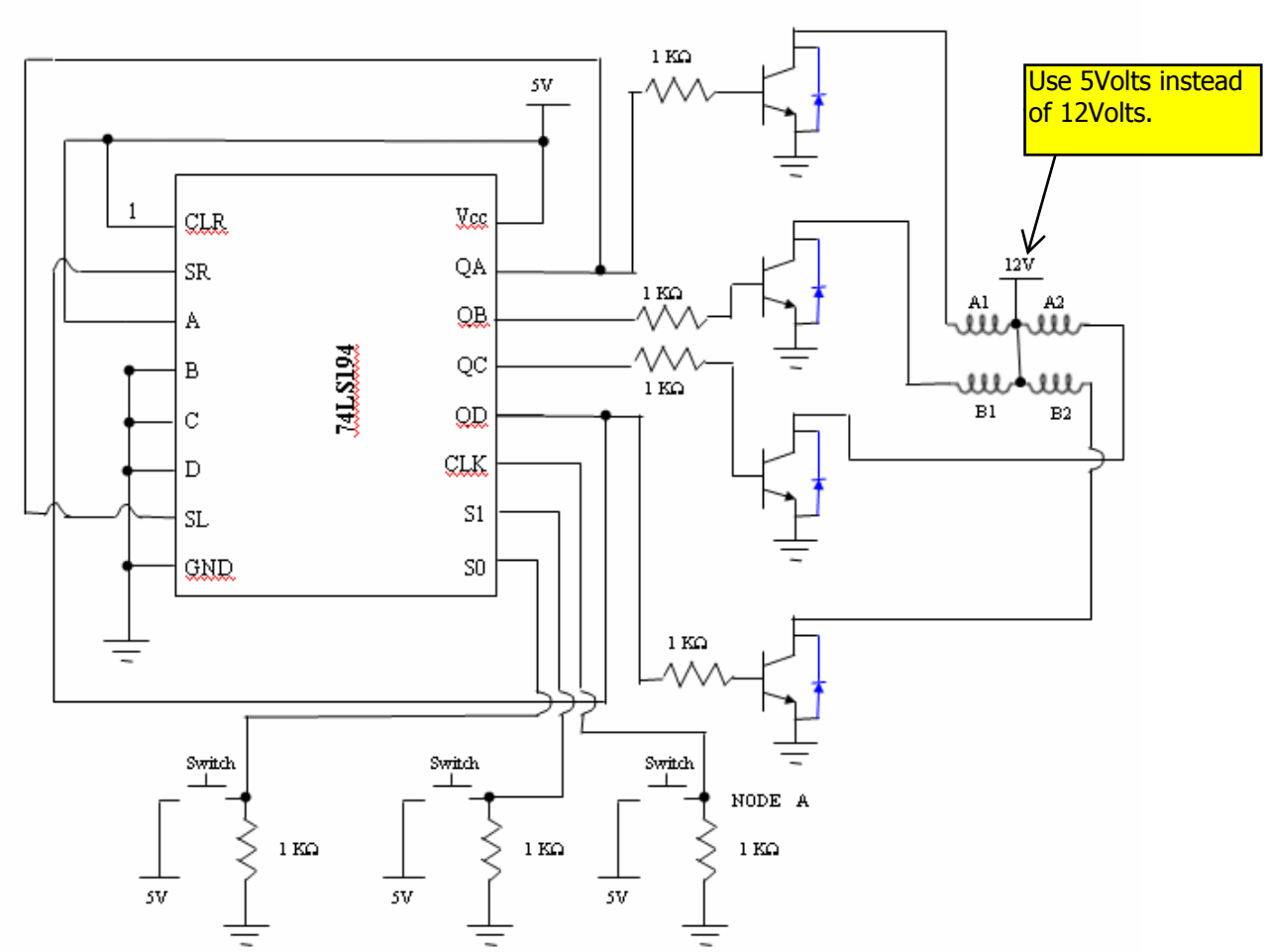

Fig.7 Schematic of Uni-polar Stepper Motor Controller/Driver (Note: Diodes are built into transistors provided for this exercise. There is no need for a separate diode.)