Experiment-9: Interfacing Stepper Motor

- Stepper Motor – Introduction, working and types
- Types of Winding and Lead-out
- A simple 5-Lead Stepper Motor
- Working of Stepper Motor
- Stepping Modes
- Working of Full Step and Half Step Sequences
- Stepping sequence for 2-wire unipolar stepper
- Stepping sequence for bipolar stepper
- Calculation of Step Angle
- Stepper Motor Connections
- AT89C51ED2 on board stepper motor interface
- Pseudocode
- Hands on:
    - Interfacing stepper motor to the kit
    - Rotate the stepper motor clockwise and anti-clockwise
        - Wind Drive
        - Full Drive or Full Step Sequence
        - Half Drive or Half Step Sequence
    - Change the direction of the stepper motor based on user input from port

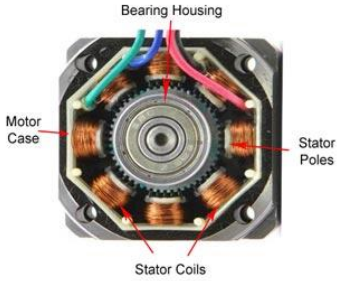
Introduction

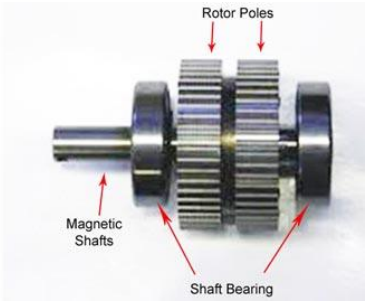
- A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements.
    - The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence.
- A **Stepper Motor** or a step motor is a brushless, synchronous motor which divides a full rotation into a number of steps.
- Unlike a brushless DC motor which rotates continuously when a fixed DC voltage is applied to it, a step motor rotates in discrete step angles.
- The **Stepper Motors** therefore are manufactured with steps per revolution of 12, 24, 72, 144, 180, and 200, resulting in stepping angles of 30, 15, 5, 2.5, 2, and 1.8 degrees per step.
- The stepper motor can be controlled with or without feedback.

- The motors rotation has several direct relationships to the applied digital input pulses.
    - The sequence of the applied pulses is directly related to the direction of motor shafts rotation.
    - The speed of the motor shafts rotation is directly related to the frequency of the input pulses and
    - The length of rotation is directly related to the number of input pulses applied.
- Stepper motors can be used in various areas of microcontroller projects such as making robots, robotic arm, automatic door lock system etc.

How a stepper motor works?

- Stepper motors work on the principle of electromagnetism.
- There is a soft iron or magnetic rotor shaft surrounded by the electromagnetic stators.
- The rotor and stator have poles which may be teethed or not depending upon the type of stepper.
- When the stators are energized the rotor moves to align itself along with the stator (in case of a permanent magnet type stepper) or moves to have a minimum gap with the stator (in case of a variable reluctance stepper).
- This way the stators are energized in a sequence to rotate the stepper motor.





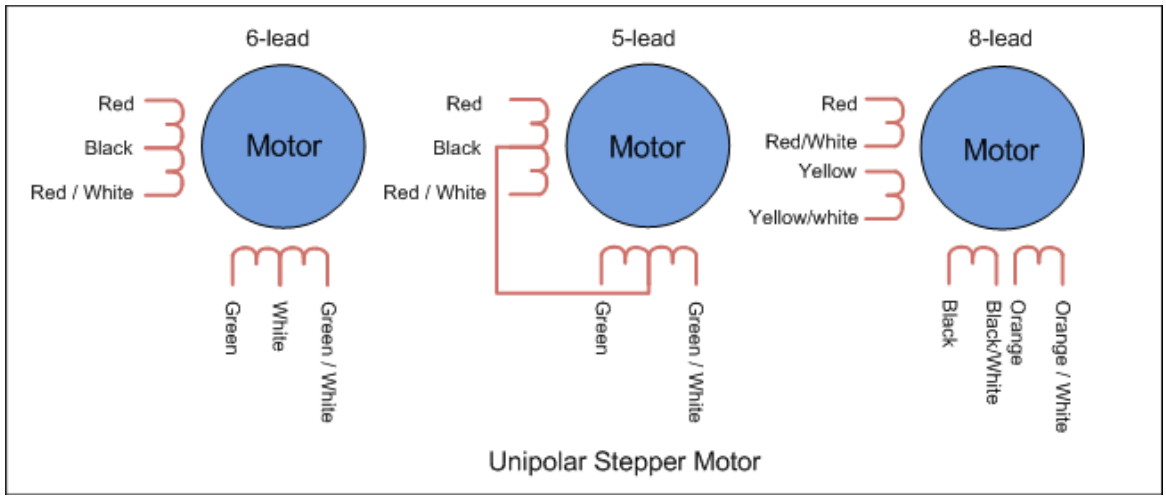
Types of Stepper Motor

By construction the step motors come into three broad classes:

- Permanent Magnet Stepper
- Variable Reluctance Stepper
- Hybrid Stepper

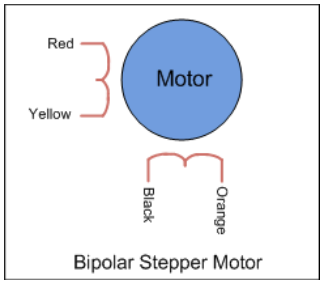
Types of Winding and Lead-out

- The step motors are mostly two phase motors.
- These can be unipolar or bipolar.
- **In unipolar step motor** there are two winding per phase.
- The two winding to a pole may have one lead common i.e. centre tapped.
- The unipolar motor so, have five, six or eight leads.
- In the designs where the common of two poles are separate but centre tapped, motor have six leads.
- If the centre taps of the two poles are internally short, the motor has five leads.
- Eight lead unipolar facilitates both series and parallel connection whereas five lead and six lead motors have series connection of stator coils.
- The unipolar motor simplifies the operation because in operating them there is no need to reverse the current in the driving circuit. These are also called bifilar motors.



Unipolar Stepper Motor

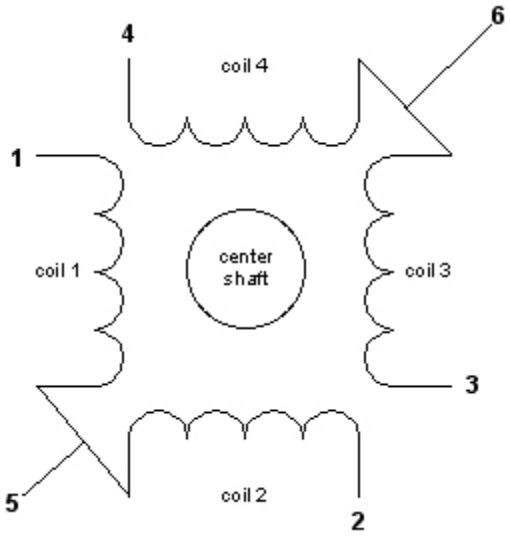
- **In bipolar stepper** there is single winding per pole.
- The direction of current need to be changed by the driving circuit so the driving circuit of the bipolar stepper becomes complex.
- These are also called unifilar motors.



Bipolar Stepper Motor

A simple 5-lead stepper motor

- A simple example of 6 lead step motor is given below and in 5 lead step motor wire 5 and 6 are joined together to make 1 wire as common.

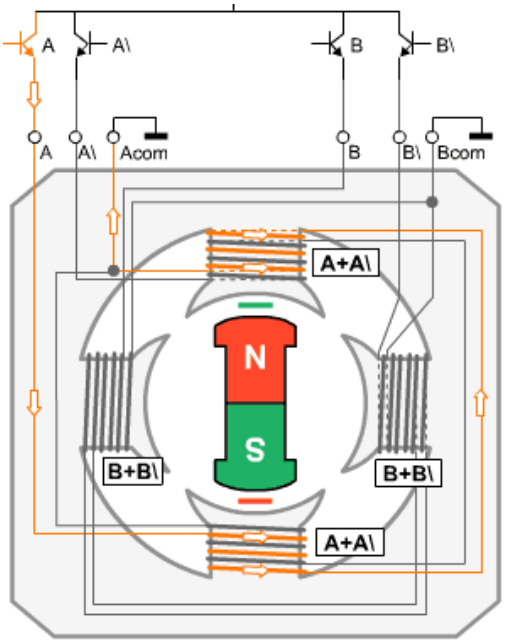


Working of Stepper Motor

- When we energize a coil of stepper motor, the shaft of stepper motor (which is actually a permanent magnet) align itself according to poles of energized coil.

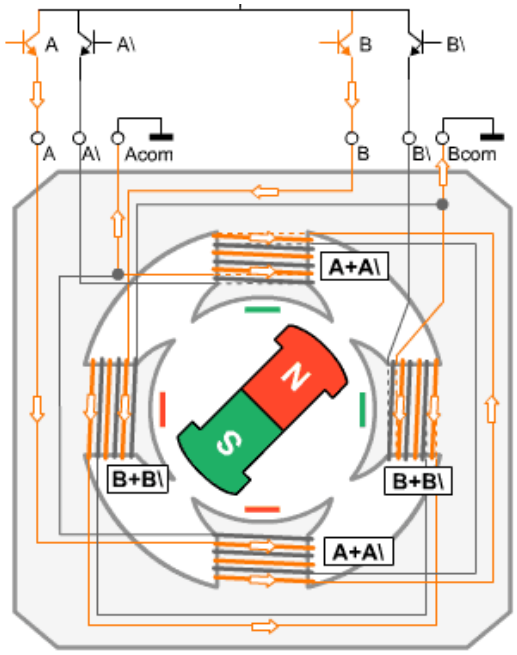
- So when motor coils are energized in a particular sequence, motor shaft tend to align itself according to pole of coils and hence rotates.

- A small example of energizing operation is given below.



- You can see in the example, when coil "A" is energized, A north-south polarity is generated at "A+A\" as shown in the figure above and magnetic shaft automatically align itself according to the poles generated.

- When the next coil is energized the shaft again aligns itself and takes a step. Hence the working principle.

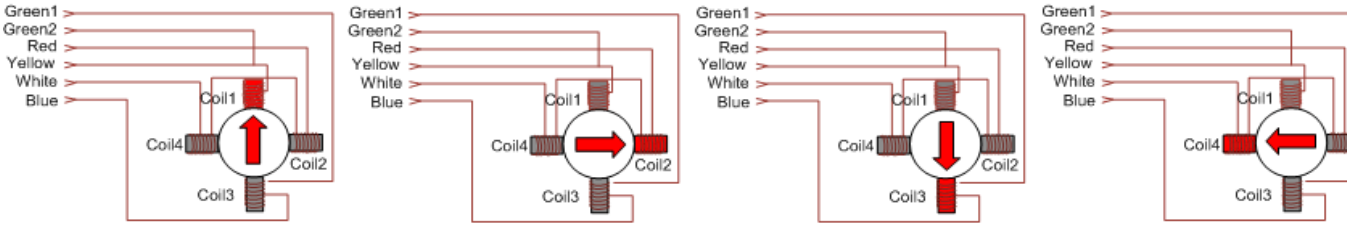


Stepping Modes

- There are three stepping modes of a stepper motor. The stepping mode refers to the pattern of sequence in which stator coils are energized.
  - Wave drive (One phase ON at a time)
  - Full drive (Two phase ON at a time)
  - Half drive (One and two phase ON at a time)

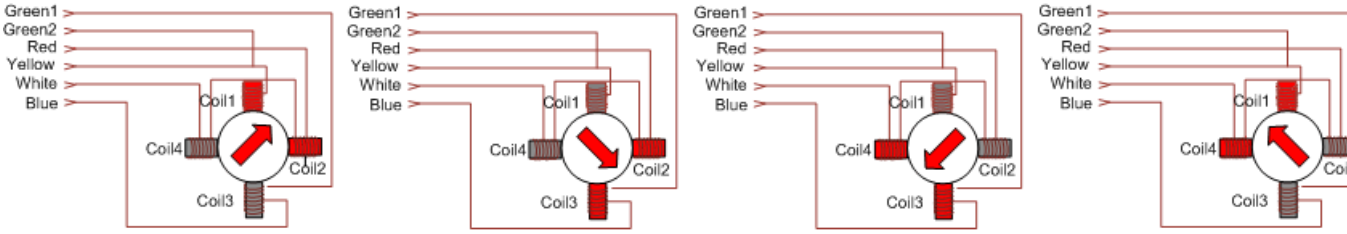
1. Wave drive :

In wave drive stepping mode only one phase is energized at a time.



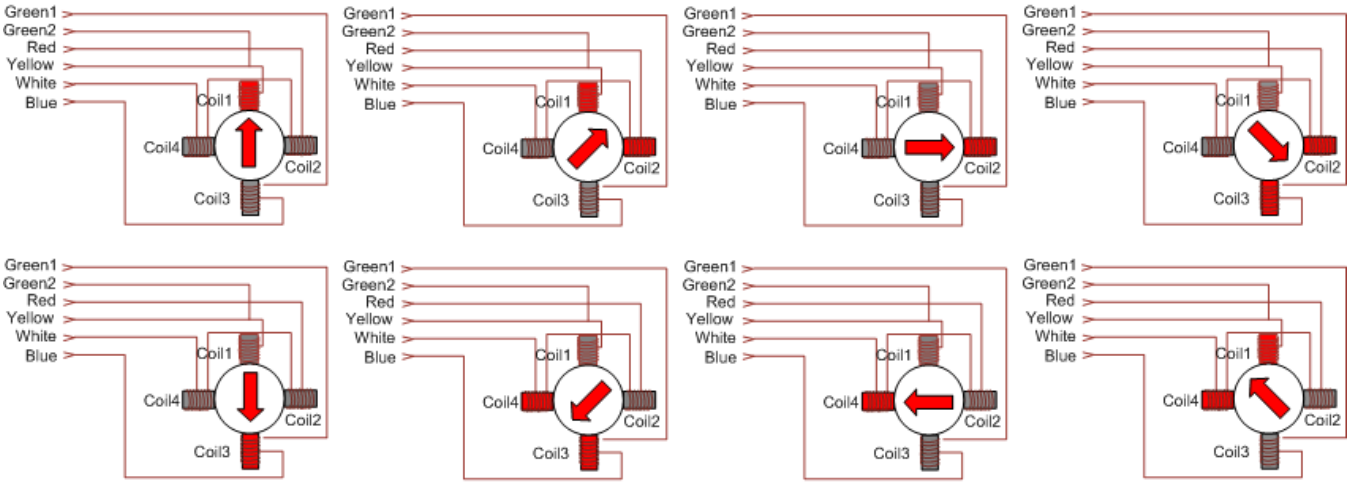
2. Full Drive :

In full drive, two phases are energized at a time.



3. Half Drive :

In half drive, alternately one and two phases are energized. This increases the resolution of the motor.



- Stepper motors can be driven in two different patterns or sequences. Namely,

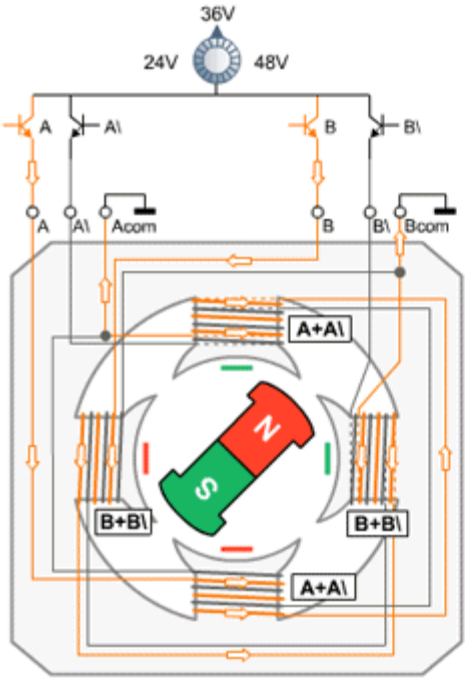
  - Full Step Sequence
  - Half Step Sequence

- **Full Step Sequence**

  In the full step sequence, two coils is energized at the same time and motor shaft rotates. The order in which coils has to be energized is given in the table below.

Full Mode Sequence				
Step	A	B	A\	B\
0	1	1	0	0
1	0	1	1	0
2	0	0	1	1
3	1	0	0	1

- The working of the full mode sequence is given in the animated figure below.



6 Lead Unipolar Driver

Unipolar control is the most simple and cost-effective way to drive a stepper motor, but results in approximately 30% less torque in comparison to the nowadays widely used bipolar drivers. Since the cost advantage is very small today due to cheap integrated circuits, bipolar drivers are now used in most new applications.

Stepmode								
F	0		1		2		3	
H	0	1	2	3	4	5	6	7
A	1	0	0	0	0	0	1	1
B	1	1	1	0	0	0	0	0
A\	0	0	1	1	1	0	0	0
B\	0	0	0	0	1	1	1	0
dez	12	4	6	2	3	1	9	8

- **Half Step Sequence**

  In Half mode step sequence, motor step angle reduces to half the angle in full mode.

- So the angualar resolution is also increased i.e. it becomes double the angular resolution in full mode.

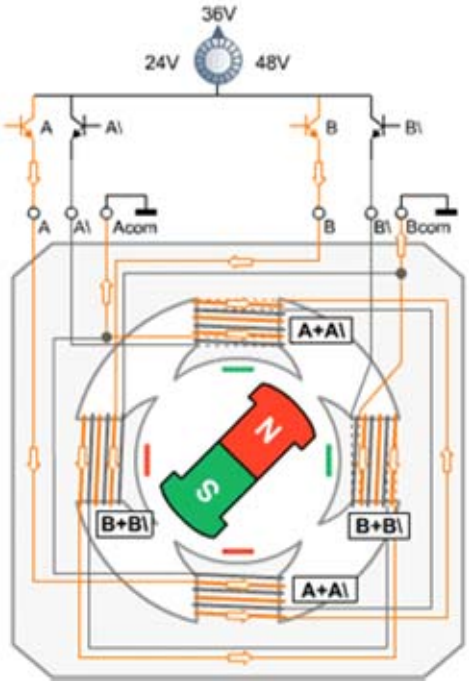
- Also in half mode sequence the number of steps gets doubled as that of full mode.

- Half mode is usually proffered over full mode.

- Table below shows the pattern of energizing the coils.

Half Mode Sequence				
Step	A	B	A\	B\
0	1	1	0	0
1	0	1	0	0
2	0	1	1	0
3	0	0	1	0
4	0	0	1	1
5	0	0	0	1
6	1	0	0	1
7	1	0	0	0

- The working of the half mode sequence is given in the animated figure below.



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Stepmode								
F	0		1		2		3	
H	0	1	2	3	4	5	6	7
A	1	0	0	0	0	0	1	1
B	1	1	1	0	0	0	0	0
A\	0	0	1	1	1	0	0	0
B\	0	0	0	0	1	1	1	0
dez	12	4	6	2	3	1	9	8

Step Sequence for 2-wire control of Unipolar stepper motor

- As seen in above explanation, In every step of the sequence, two wires are always set to opposite polarities.
- Because of this, it's possible to control steppers with only two wires instead of four, with a slightly more complex circuit.
- The stepping sequence is the same as it is for the two coils A and B, and the opposite polarity value is given to A\ and B\.
- The sequence is given in the table below:

2-wire Mode Sequence		
Step	A	B
0	0	1
1	1	1
2	1	0
3	0	0

Step Sequence for Bipolar stepper motor

Bipolar motor has simpler construction.

- It has two windings with no center taps and a permanent magnet at the center just like unipolar stepper motors.
- Being simpler in contruction, the stepping sequence is a little complex, as the power for both the coils has to be controlled in such a way that the polarity of the poles get reversed.
- This polarity sequence is shown in the table below.

Polarity Sequence				
Step	A	A\	B	B\
0	+ve	-ve	-ve	-ve
1	-ve	-ve	+ve	-ve
2	-ve	+ve	-ve	-ve
3	-ve	-ve	-ve	+ve

- The above polarity sequence can be interpreted in terms of logic levels for microcontroller by activating one coil at a time as shown in the table below.

Step Sequence				
Step	A	A\	B	B\
0	1	0	0	0
1	0	0	1	0
2	0	1	0	0
3	0	0	0	1

- **Step Angle**

  Step angle of the stepper motor is defined as the angle traversed by the motor in one step.

- To calculate step angle, simply divide 360 by number of steps a motor takes to complete one revolution.

- As we have seen that in half mode, the number of steps taken by the motor to complete one revolution gets doubled, so step angle reduces to half.

  As in above examples, Stepper Motor rotating in full mode takes 4 steps to complete a revolution,

- So step angle can be calculated as...

  Step Angle ø = 360° / 4 = 90°

  and **in case of half mode step angle gets half so 45°.**

  So this way we can calculate step angle for any stepper motor.

- Usually step angle is given in the spec sheet of the stepper motor you are using.

- Knowing stepper motor's step angle helps you calibrate the rotation of motor also to helps you move the motor to correct angular position.

Stepper Motor Connections

Connecting Unipolar Stepper Motor

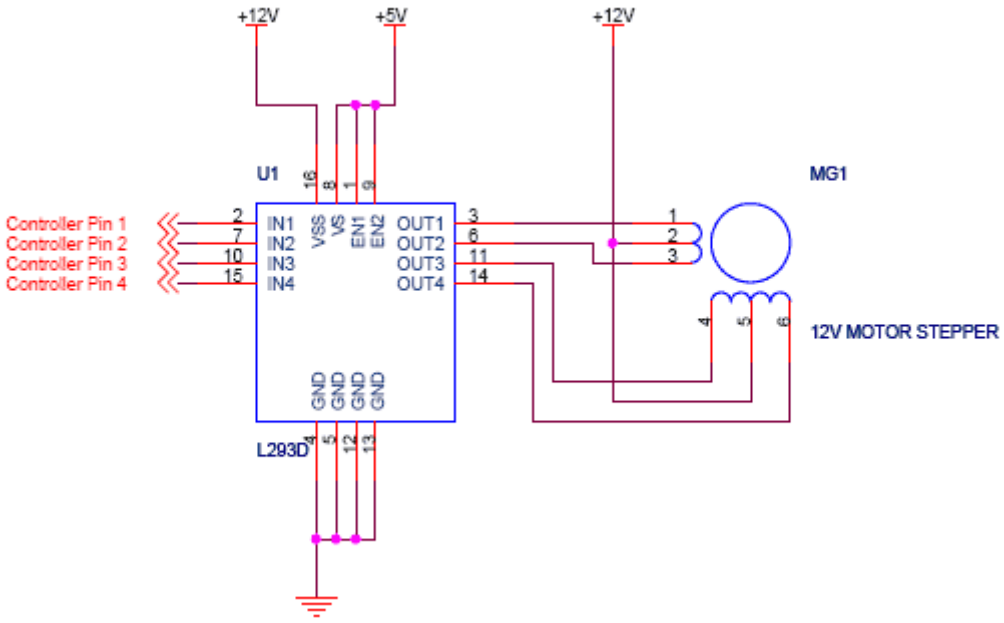
There are actually many ways you can interface a stepper motor to your controller, out of them the most used interfaces are:

Interface using L293D - H-Bridge Motor Driver

Interface using ULN2003/2004 - Darlington Arrays

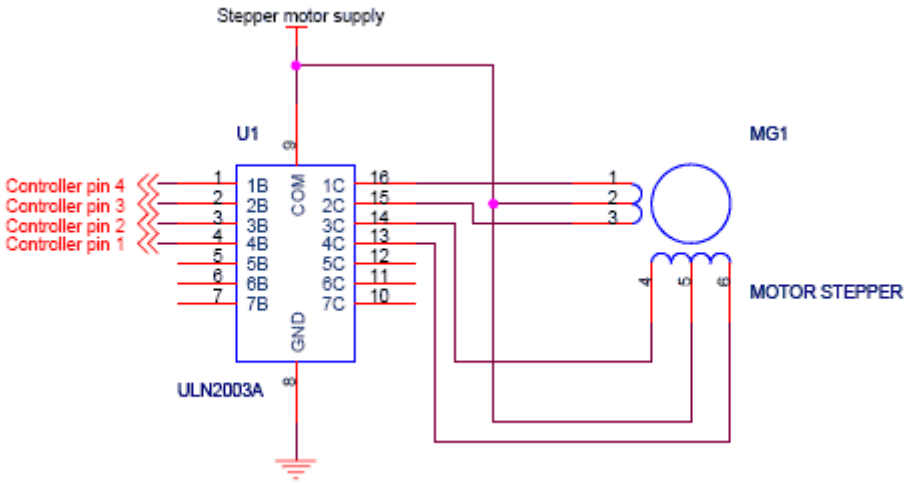
The above mentioned methods need 4 controller pins for interface.

►Connecting Unipolar stepper using L293D



As you see in the circuit above the four pins "Controller pin 1",2,3 and 4 will control the motion and direction of the stepper motor according to the step sequence programmed in the controller.

►Connecting Unipolar stepper using ULN2003/2004

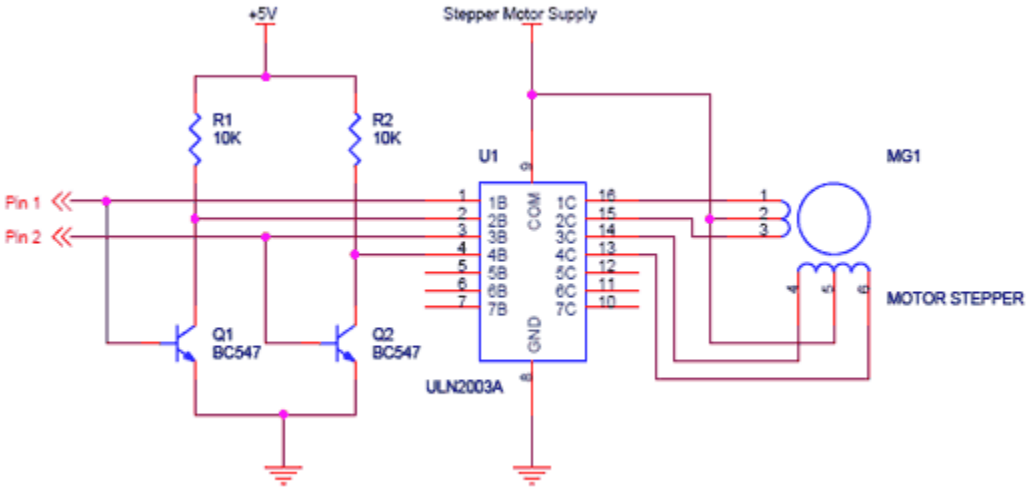


As already discussed in case of L293D, Here in this circuit too the four pins "Controller pin 1",2,3 and 4 will control the motion and direction of the stepper motor according to the step sequence sent by the controller.

►2-wire connection for Unipolar Stepper Motor

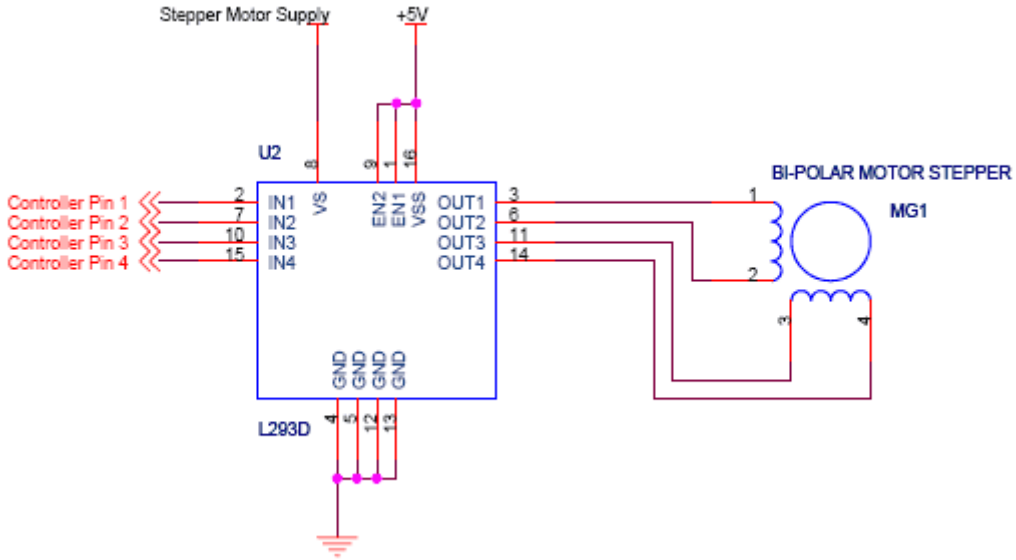
We have seen the generally used 4-wire connection method for interfacing unipolar stepper motor, but we can simplify the design to make controller use less pins with the help of 2-wire connection method.

The circuit for 2-wire connection is shown below.



►Connecting Bipolar Stepper Motor

As we have studied that, Bi-polar stepper motors has 2 different coils. The step sequence for Bipolar stepper motor is same as that of unipolar stepper motors. The driving circuit for this require an H-Bridge as it allows the polarity of the power applied to be controlled independently. This can be done as shown in the figure below:

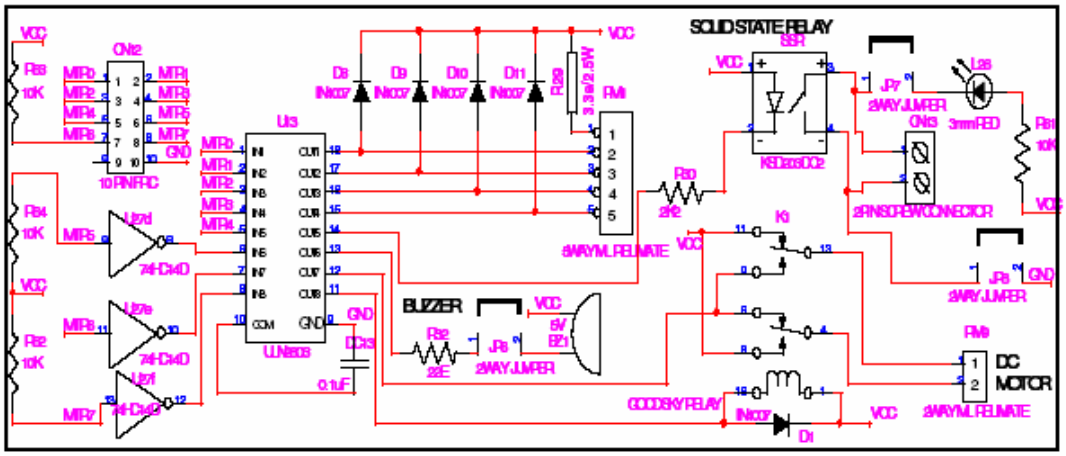


AT89C51ED2 Kit

On-board stepper motor and DC motor control interface.

- High Current Output Lines and Relay Interface:
- Any of the 4 ports can be used for High Current applications where a stepper motor, a Dc motor, a solid state relay & a buzzer are interfaced through the high current driver ULN2803.
- These lines will have high current (max 300 mA) with low voltage level of 0.7V.
- The Stepper motor can be interfaced to the board by connecting it to the Power mate PM1.
- The rotating direction of the stepper motor can be changed.

Interface Diagram:



Stepper Motor, DC Motor, Solid State Relay & Buzzer

POWER MATE DETAILS:

PM1: 5 Pin Power mate (High Current Output Lines for Stepper Motor)

Pin No.	Description
1	OUT1
2	OUT2
3	OUT3
4	OUT4
5	VCC

Pseudocode

<do infinitely>
<read the port input pin>
<if value is non-zero>
Val = 0x08
Right shift the value 4 times to the port for clock wise direction with a delay
<if value is zero>
Val = 0x08
Left shift the value 4 times to the port for anti-clock wise direction with a delay

Samples:

Assuming that **stepper motor** is connected at Port 1.0 to Port 1.3
Adjusting the delay will increase or decrease the speed of the **motor**

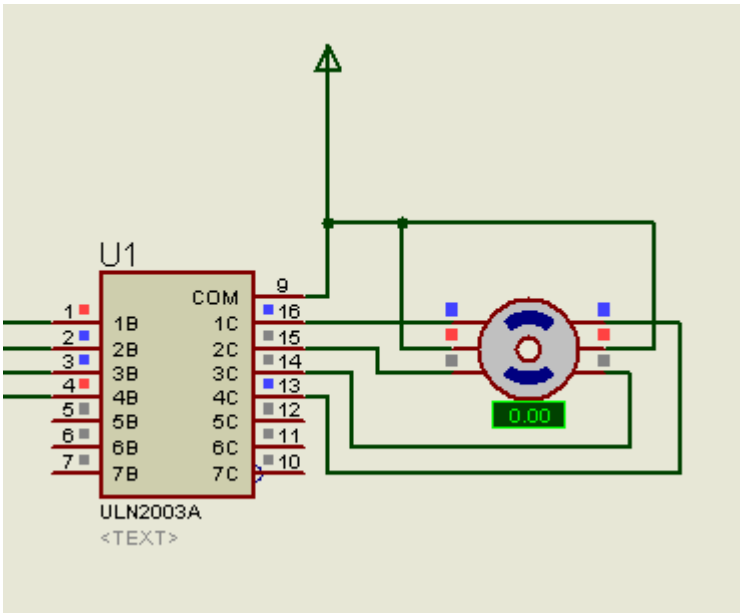
Programming Full step Sequence or Full Drive (1100 – 0110 – 0011 – 1001) (Two Phase ON at a time)

```
#include <REG2051.H>.
#define stepper P1
void delay();

void main(){
	while(1){
		stepper = 0x0C;
		delay();
		stepper = 0x06;
		delay();
		stepper = 0x03;
		delay();
		stepper = 0x09;
		delay();
	}
}

void delay(){
	unsigned char i,j,k;
	for(i=0;i<6;i++)
		for(j=0;j<255;j++)
			for(k=0;k<255;k++);
}
```

```
org 0H

stepper equ P1

main:
	mov stepper, #0CH
	acall delay
	mov stepper, #06H
	acall delay
	mov stepper, #03H
	acall delay
	mov stepper, #09H
	acall delay
	sjmp main

delay:
	mov r7,#4
wait2:
	mov r6,#0FFH
wait1:
	mov r5,#0FFH
wait:
	djnz r5,wait
	djnz r6,wait1
	djnz r7,wait2
```

```
    ret
    end
```

The working of the above code can be seen in the demo animation below.



►Programming Half step Sequence or Half Drive (One and Two Phases ON at a time)

(1000 – 1100 – 0100 – 0110 – 0010 – 0011 – 0001 – 1001)

►C Programming

Just the main routine changes rest everything remains same (same delay routine)

CODE:

```
void main(){
    while(1){
        stepper = 0x08;
        delay();
        stepper = 0x0C;
        delay();
        stepper = 0x04;
        delay();
        stepper = 0x06;
        delay();
        stepper = 0x02;
        delay();
        stepper = 0x03;
        delay();
        stepper = 0x01;
        delay();
        stepper = 0x09;
        delay();
    }
}
```

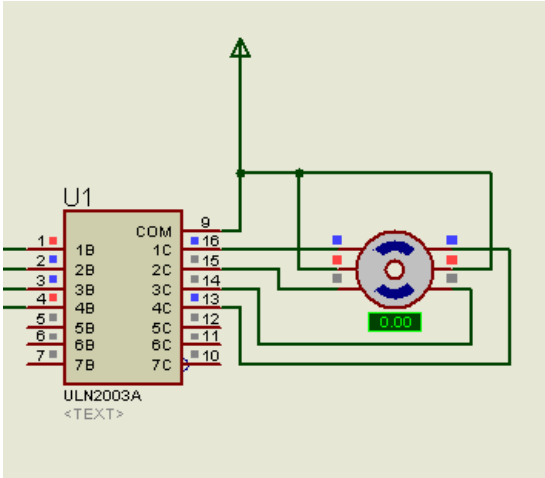
►Assembly Programming

Here also the main routine changes rest everything remains same.

CODE:

```
main:
    mov stepper, #08H
    acall delay
    mov stepper, #0CH
    acall delay
    mov stepper, #04H
    acall delay
    mov stepper, #06H
    acall delay
    mov stepper, #02H
    acall delay
    mov stepper, #03H
    acall delay
    mov stepper, #01H
    acall delay
    mov stepper, #09H
    acall delay
    sjmp main
```

The working of the above code can be seen in the demo animation below.



►Programming for 2-wire connection of Unipolar Stepper Motor

►C Programming

CODE:

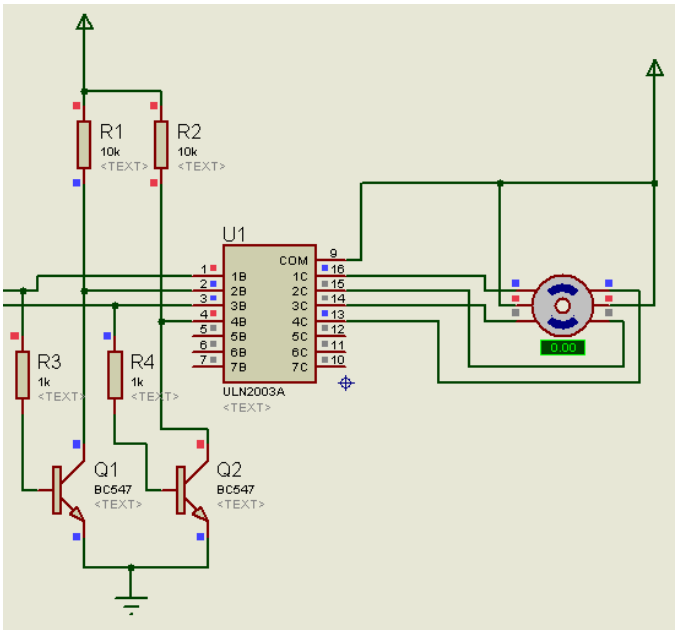
```
void main(){
	while(1){
		stepper = 0x03;
		delay();
		stepper = 0x01;
		delay();
		stepper = 0x00;
		delay();
		stepper = 0x02;
		delay();
	}
}
```

►Assembly Programming

CODE:

```
main:
	mov stepper, #03H
	acall delay
	mov stepper, #01H
	acall delay
	mov stepper, #00H
	acall delay
	mov stepper, #02H
	acall delay
	sjmp main
```

The working of the above code can be seen in the demo animation below.



►Programming for Bipolar Stepper Motor

►C Programming

CODE:

```
void main(){
	while(1){
		stepper = 0x08;
		delay();
		stepper = 0x02;
		delay();
		stepper = 0x04;
		delay();
		stepper = 0x01;
		delay();
	}
}
```

►Assembly Programming

CODE:

```
main:
	mov stepper, #08H
	acall delay
	mov stepper, #02H
	acall delay
	mov stepper, #04H
	acall delay
	mov stepper, #01H
	acall delay
	sjmp main
```