8051 interfacing with stepper Motor

Stepper motor

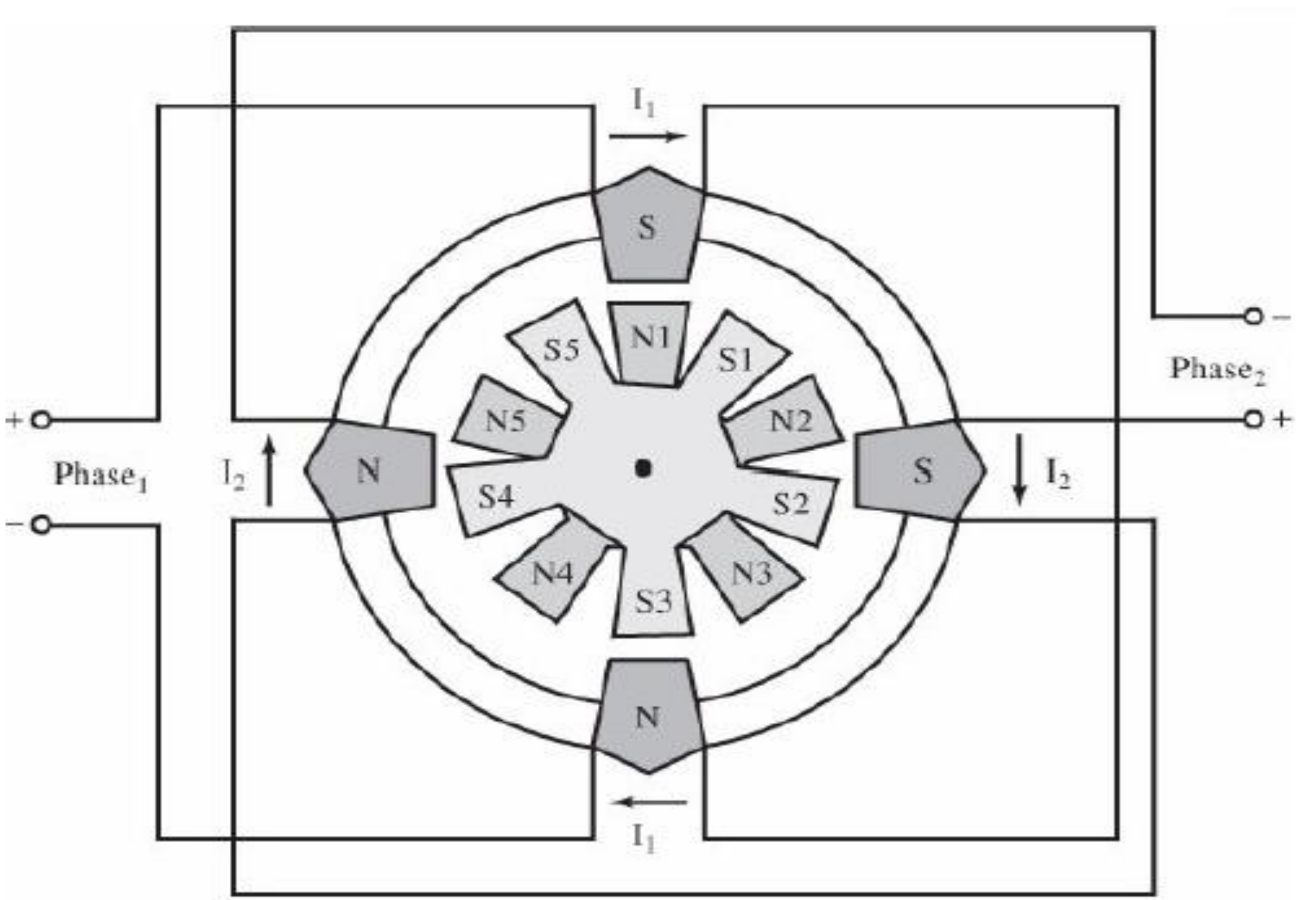
A ***motor*** is one which translates electrical pulses into mechanical motion.

Types of motor are:

1. Stepper Motor
2. DC Motor
3. AC Motor

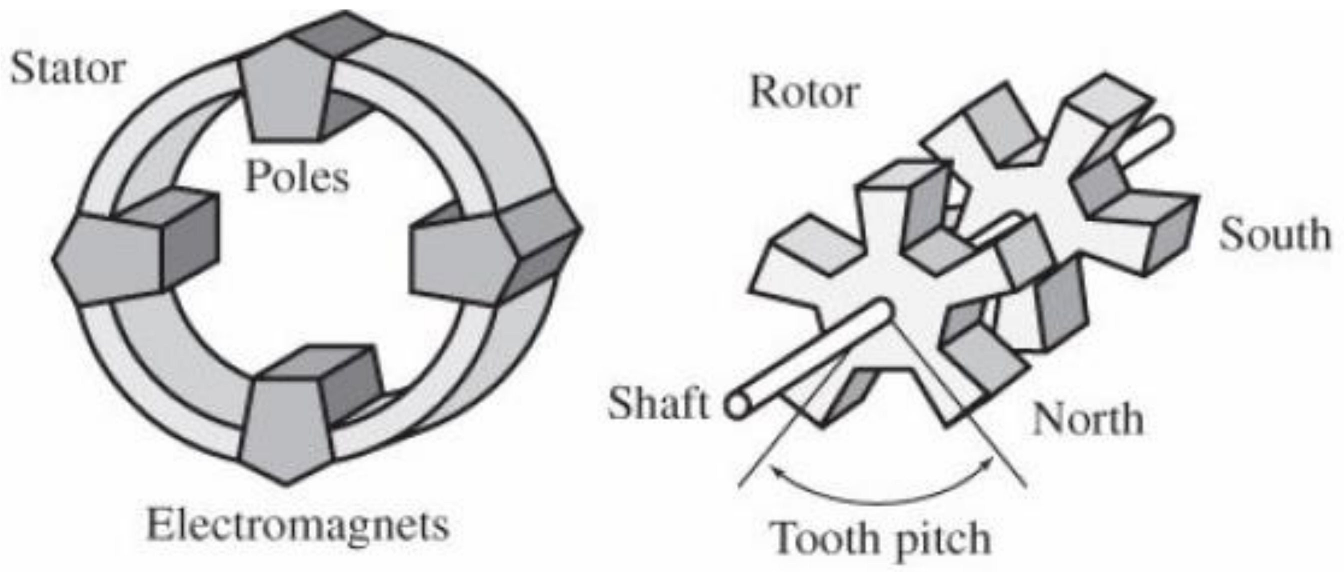
- A ***stepper motor*** is a special type of electric motor that moves in increments, or steps, rather than turning smoothly as a conventional motor does.
- Typical increments are 0.9 or 1.8 degrees, with 400 or 200 increments thus representing a full circle.
- The speed of the motor is determined by the time delay between each incremental movement.

- Motor Moves Each Time a Pulse is Received
- Can Control Movement (Direction and Amount) Easily
- Can Force Motor to Hold Position Against an Opposing Force



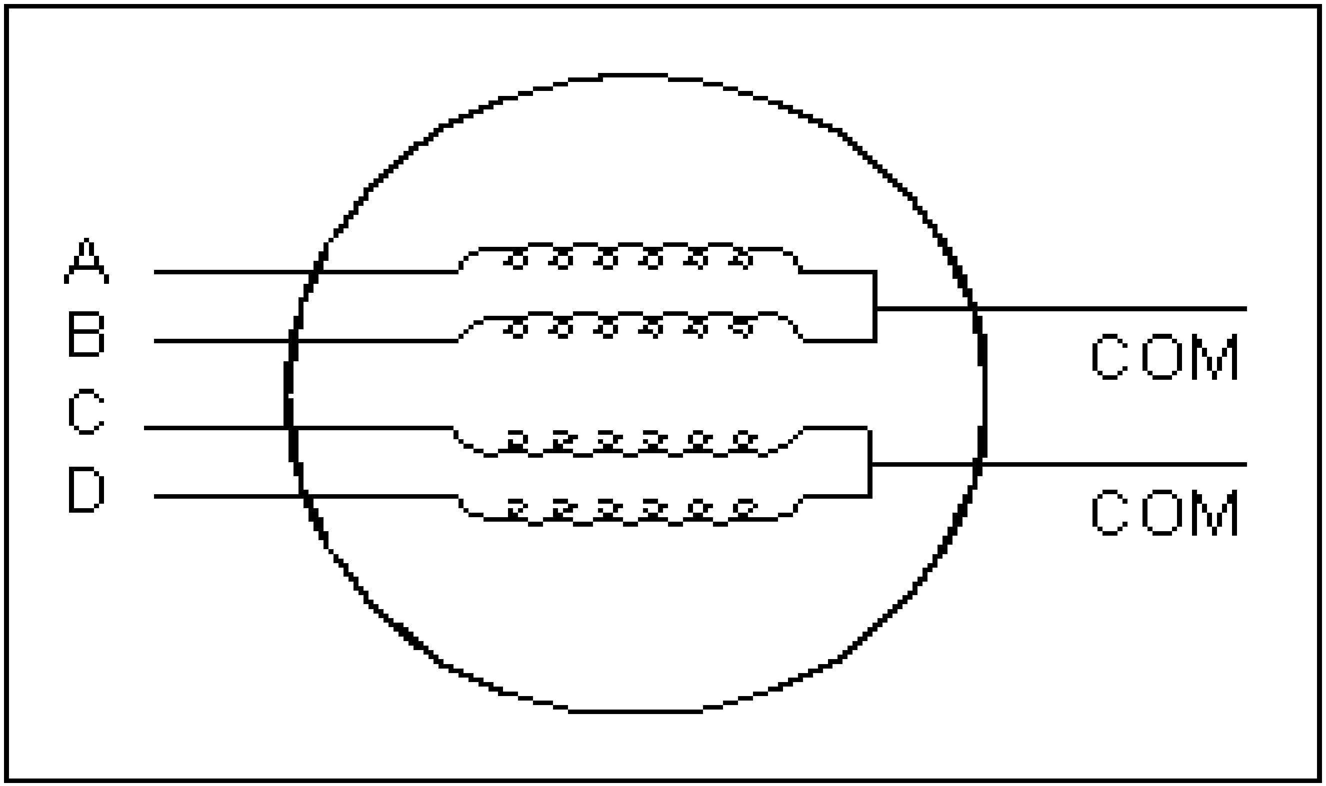
Construction

- Permanent Magnet Rotor
  - Also Called the *Shaft*
- Stator
  - Surrounds the Shaft
  - Usually Four Stator Windings Paired with Center-Tapped Common
    - Known as Four-Phase or Unipolar Stepper Motor



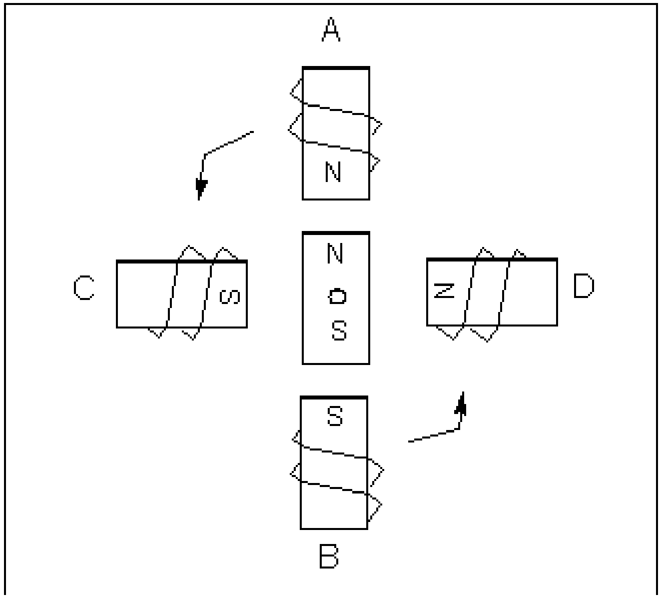
Construction (con't)

- Center Tapped Common

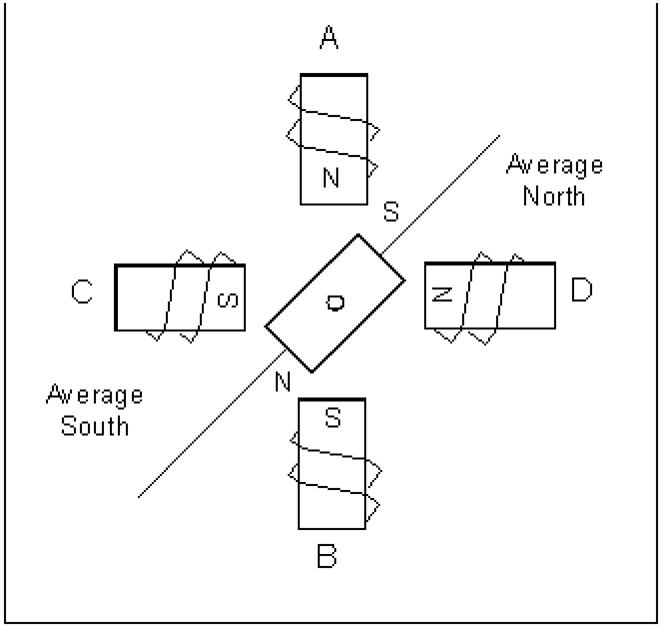


Moving the Rotor

Unstable

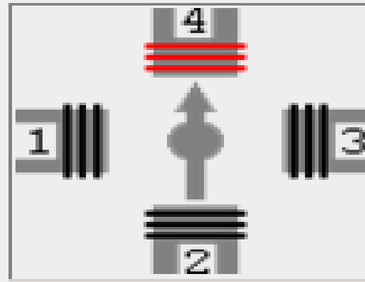
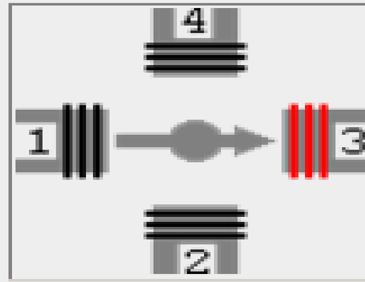
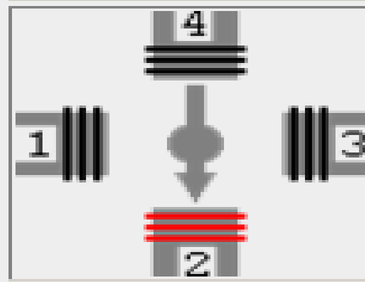
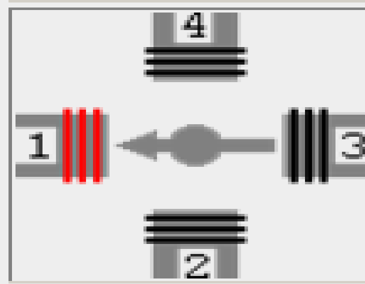


Stable

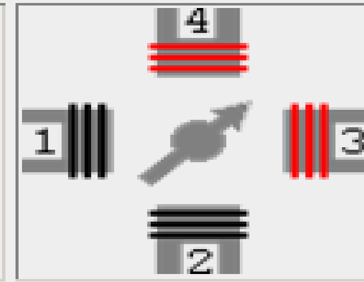
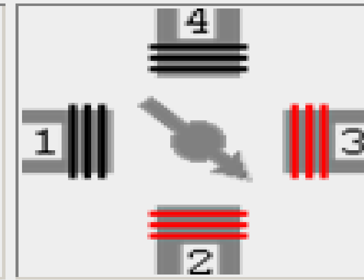
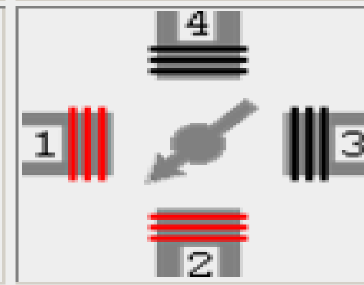
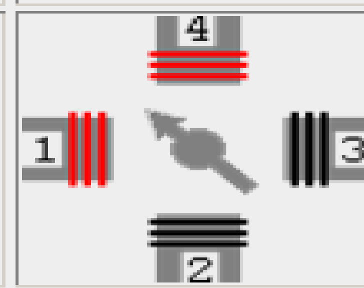


Rotor will ALWAYS seek a *stable* position.

Single-Coil Excitation - Each successive coil is energised in turn.

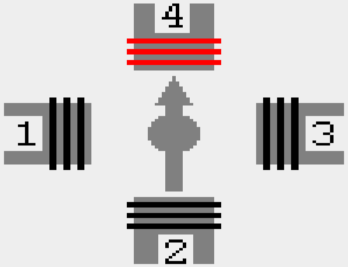
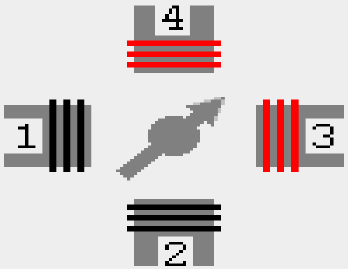
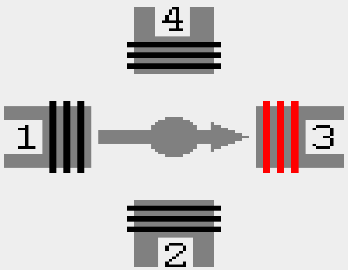
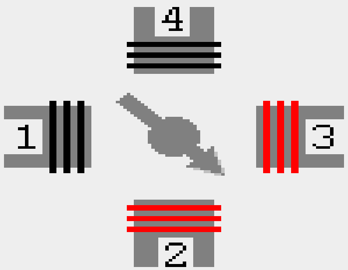
Step	Coil 4	Coil 3	Coil 2	Coil 1	
a.1	on	off	off	off	
a.2	off	on	off	off	
a.3	off	off	on	off	
a.4	off	off	off	on	

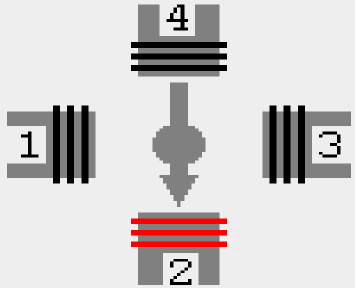
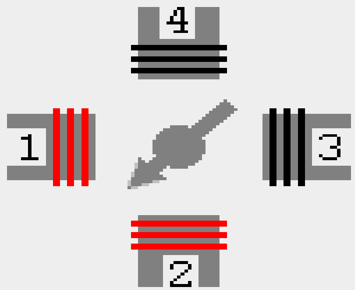
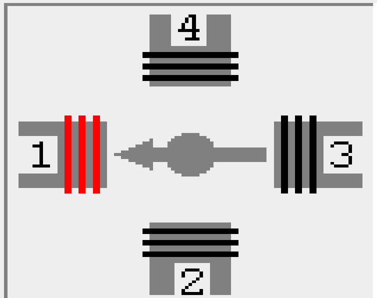
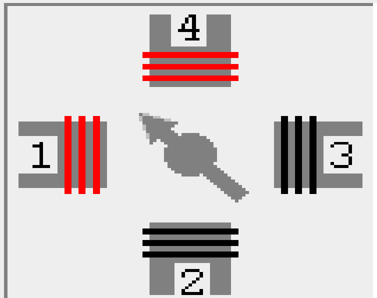
Two-Coil Excitation - Each successive pair of adjacent coils is energised in turn.

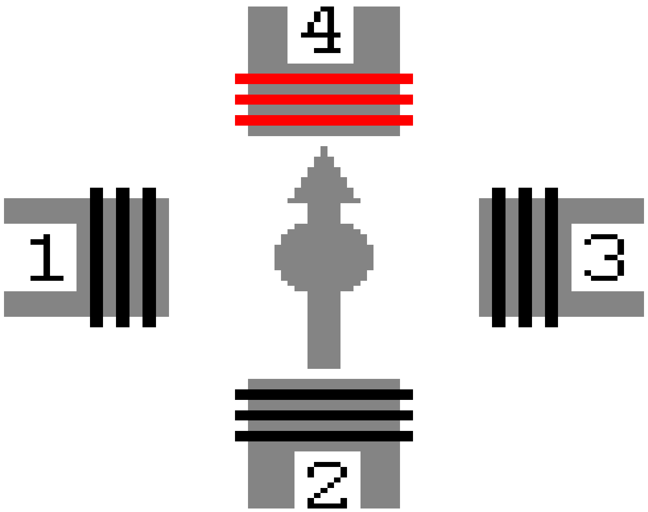
Step	Coil 4	Coil 3	Coil 2	Coil 1	
b.1	on	on	off	off	
b.2	off	on	on	off	
b.3	off	off	on	on	
b.4	on	off	off	on	

Interleaving the two sequences will cause the motor to half-step

8 step sequence = normal 4 step + wave drive 4 step.

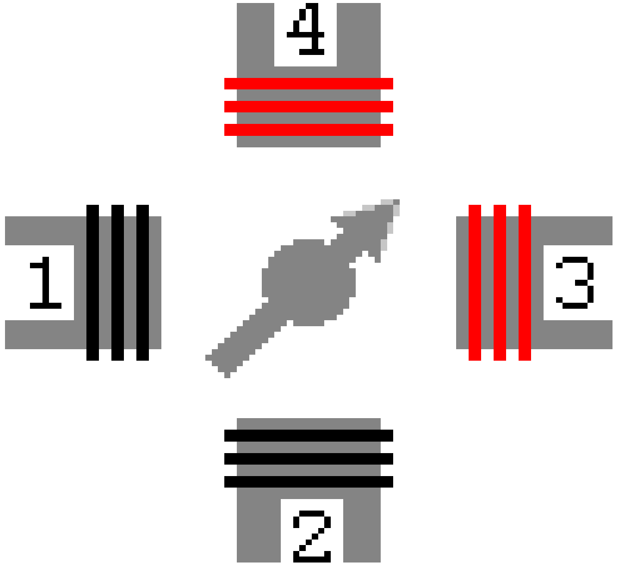
Step	Coil 4	Coil 3	Coil 2	Coil 1	
a.1	on	off	off	off	
b.1	on	on	off	off	
a.2	off	on	off	off	
b.2	off	on	on	off	

Step	Coil 4	Coil 3	Coil 2	Coil 1	
a.3	off	off	**on**	off	
b.3	off	off	**on**	**on**	
a.4	off	off	off	**on**	
b.4	**on**	off	off	**on**	

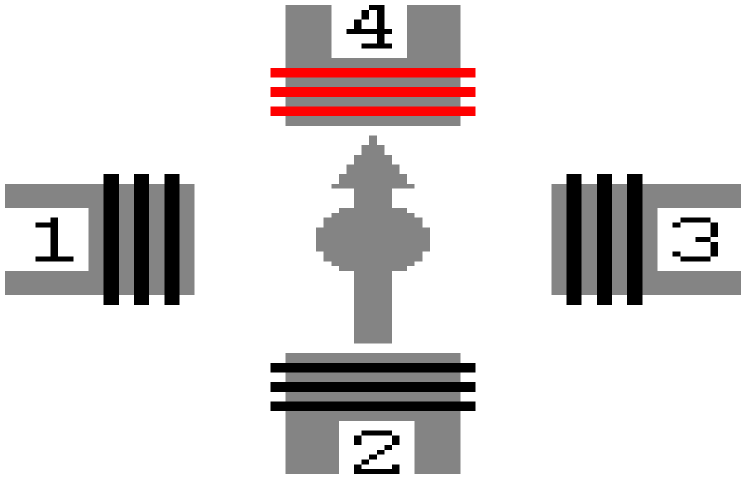


Single-Coil Excitation

Two-Coil Excitation



Interleaved Single- and Two-Coil Excitation



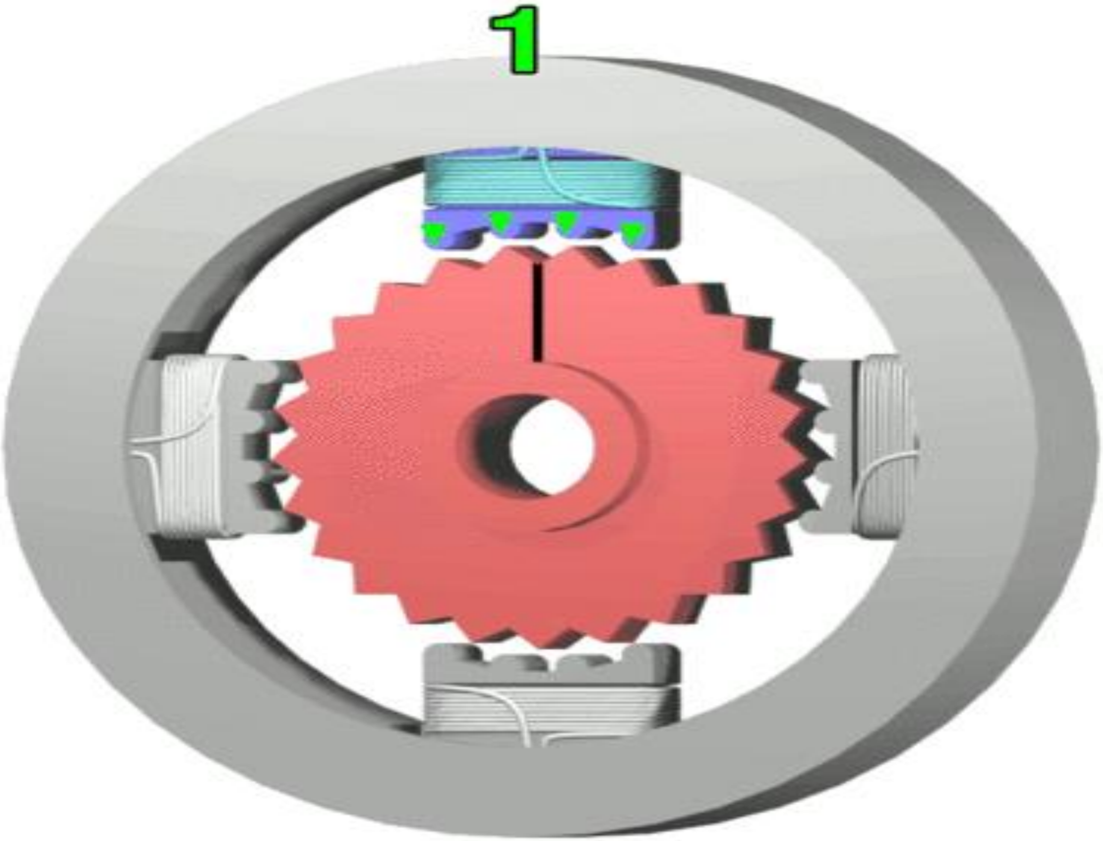
Half-Stepping

Sequence	Name	Description
0001 0010 0100 1000	Wave Drive, One-Phase	Consumes the least power. Only one phase is energized at a time. Assures positional accuracy regardless of any winding imbalance in the motor.
0011 0110 1100 1001	Hi-Torque, Two-Phase	Hi Torque - This sequence energizes two adjacent phases, which offers an improved torque-speed product and greater holding torque.
0001 0011 0010 0110 0100 1100 1000 1001	Half-Step	Half Step - Effectively doubles the stepping resolution of the motor, but the torque is not uniform for each step. (Since we are effectively switching between Wave Drive and Hi-Torque with each step, torque alternates each step.) This sequence reduces motor resonance which can sometimes cause a motor to stall at a particular resonant frequency. Note that this sequence is 8 steps.

How Far Does It Move?

- Step Angle
  - Arc Through Which Motor Turns With ONE Step Change of the Windings
  - Varies With Model of Stepper Motor

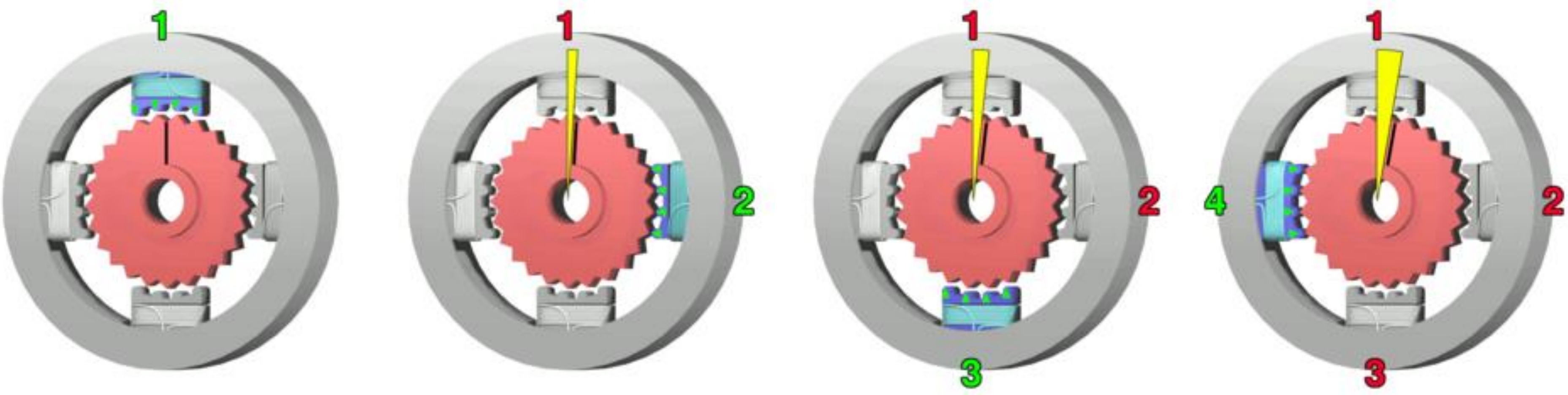
  (Depending on the number of teeth on stator and rotor)
  - Normally in Degrees
  - Step angle = 360/No. of Steps per Revolution
  - Commonly available no. of steps per revolution are 500, **<u>200</u>**, 180, 144, 72, 48, 24


1

How Fast?

Revolutions per Minute (RPM)

$$rpm = \frac{60 \times Steps\ per\ Second}{Steps\ per\ \mathrm{Re}volution}$$



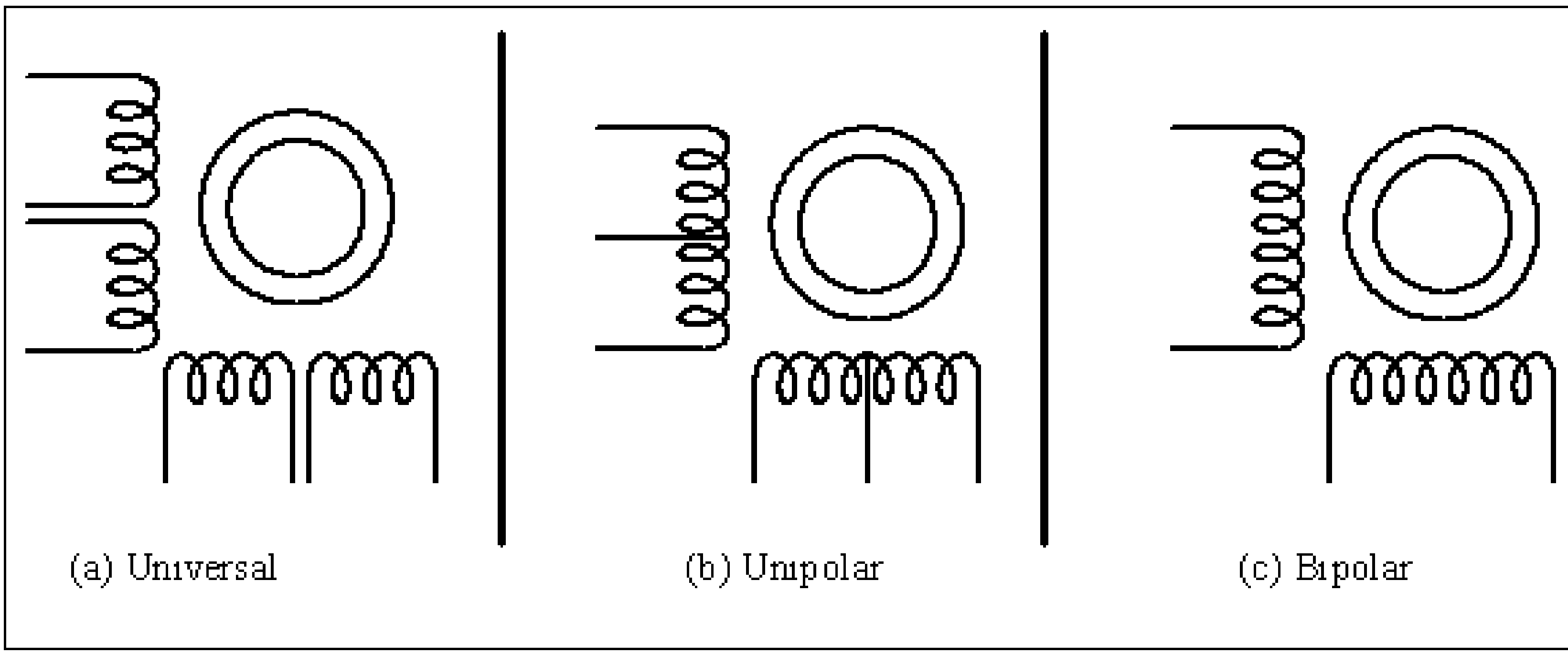
The top electromagnet (1) is turned on, attracting the nearest teeth of a gear-shaped iron rotor. With the teeth aligned to electromagnet 1, they will be slightly offset from electromagnet 2.

The top electromagnet (1) is turned off, and the right electromagnet (2) is energized, pulling the nearest teeth slightly to the right. This results in a rotation of 3.6° *(1.8°)* in this example.

The bottom Electromagnet (3) is energized; another 3.6° *(1.8°)* rotation occurs.

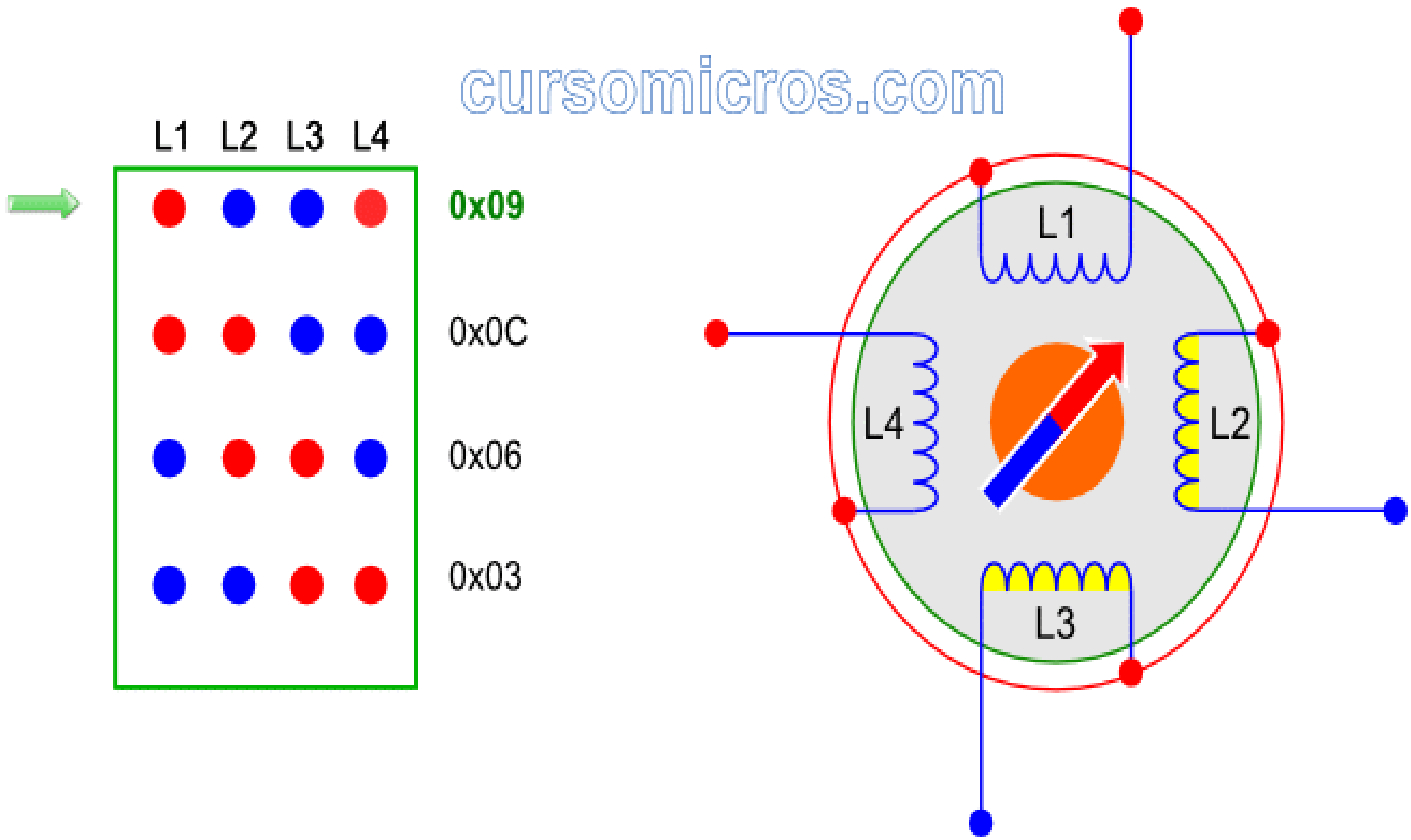
The left electromagnet (4) is enabled, rotating again by 3.6° *(1.8°)*. When the top electromagnet (1) is again enabled, the teeth in the sprocket will have rotated by one tooth position; since there are 25 *(50)* teeth, it will take 100 *(200)* steps to make a full rotation in this example.

Common Stepper Motor Types



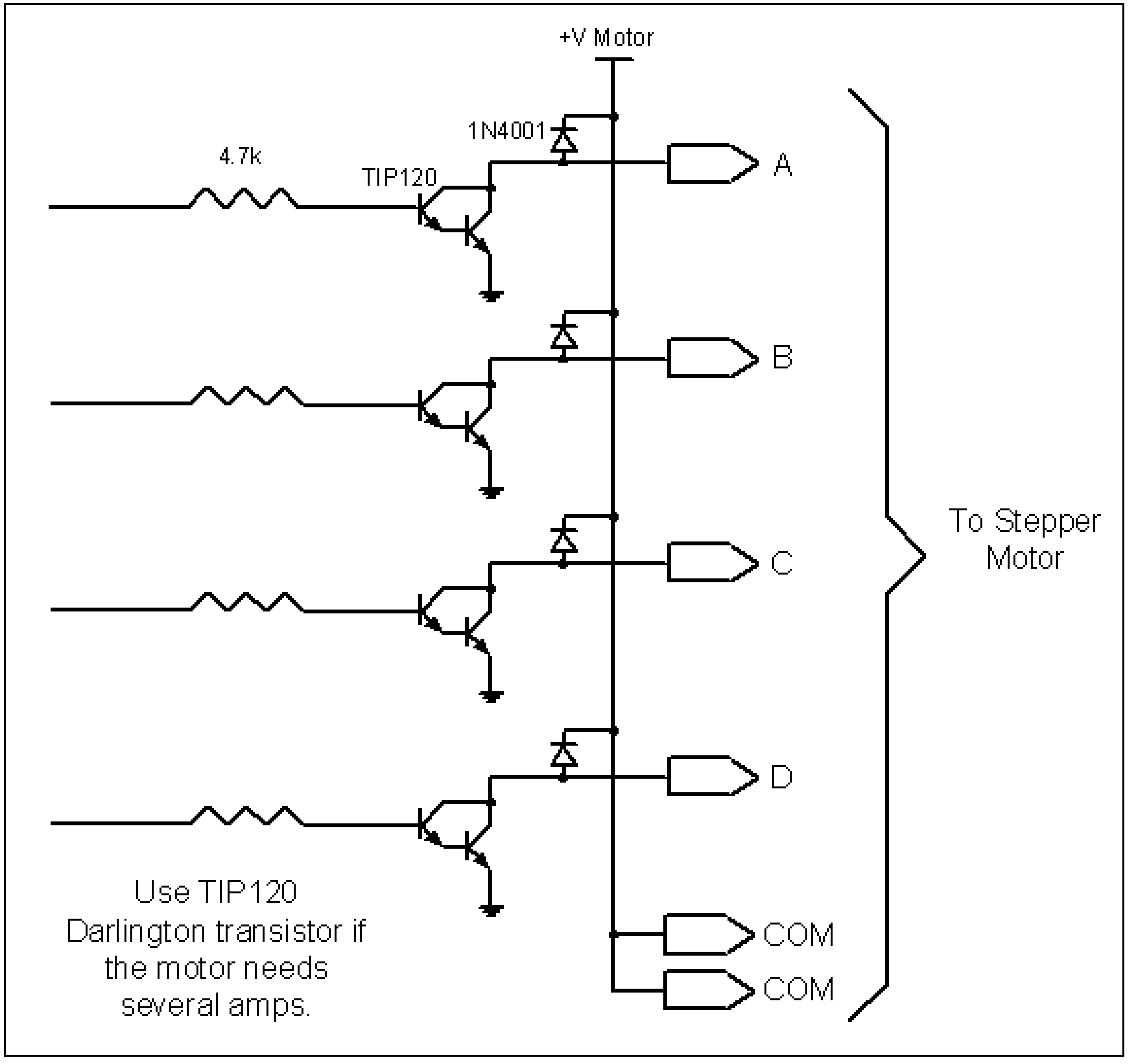
Drivers

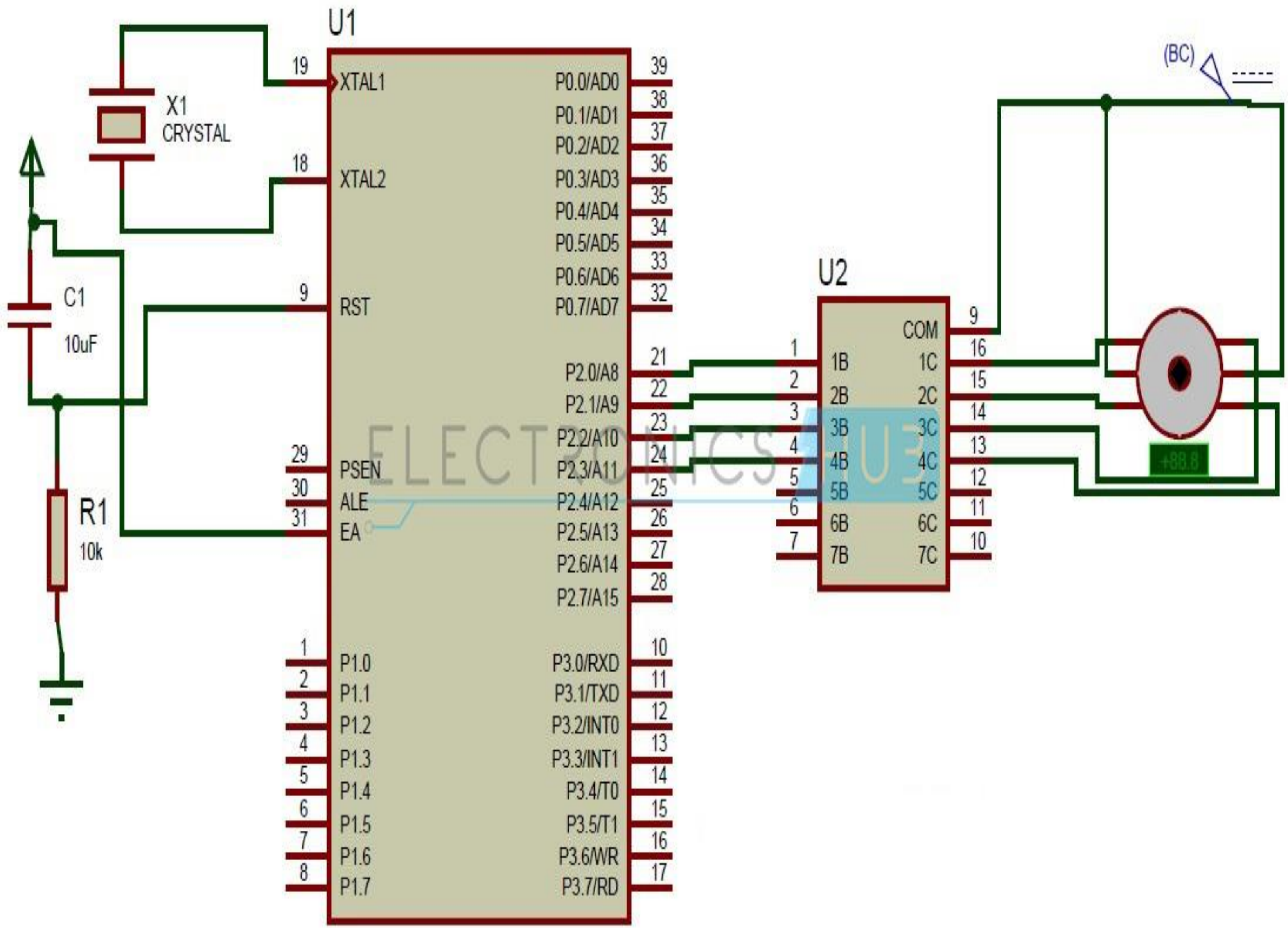
- May Need a Driver Circuit
  - Same Problem as Relays – May Draw Too Much Current
- Types
  - Transistor Drivers
    - Usually a Darlington Pair
  - Darlington Arrays
  - *Can* Build It Yourself

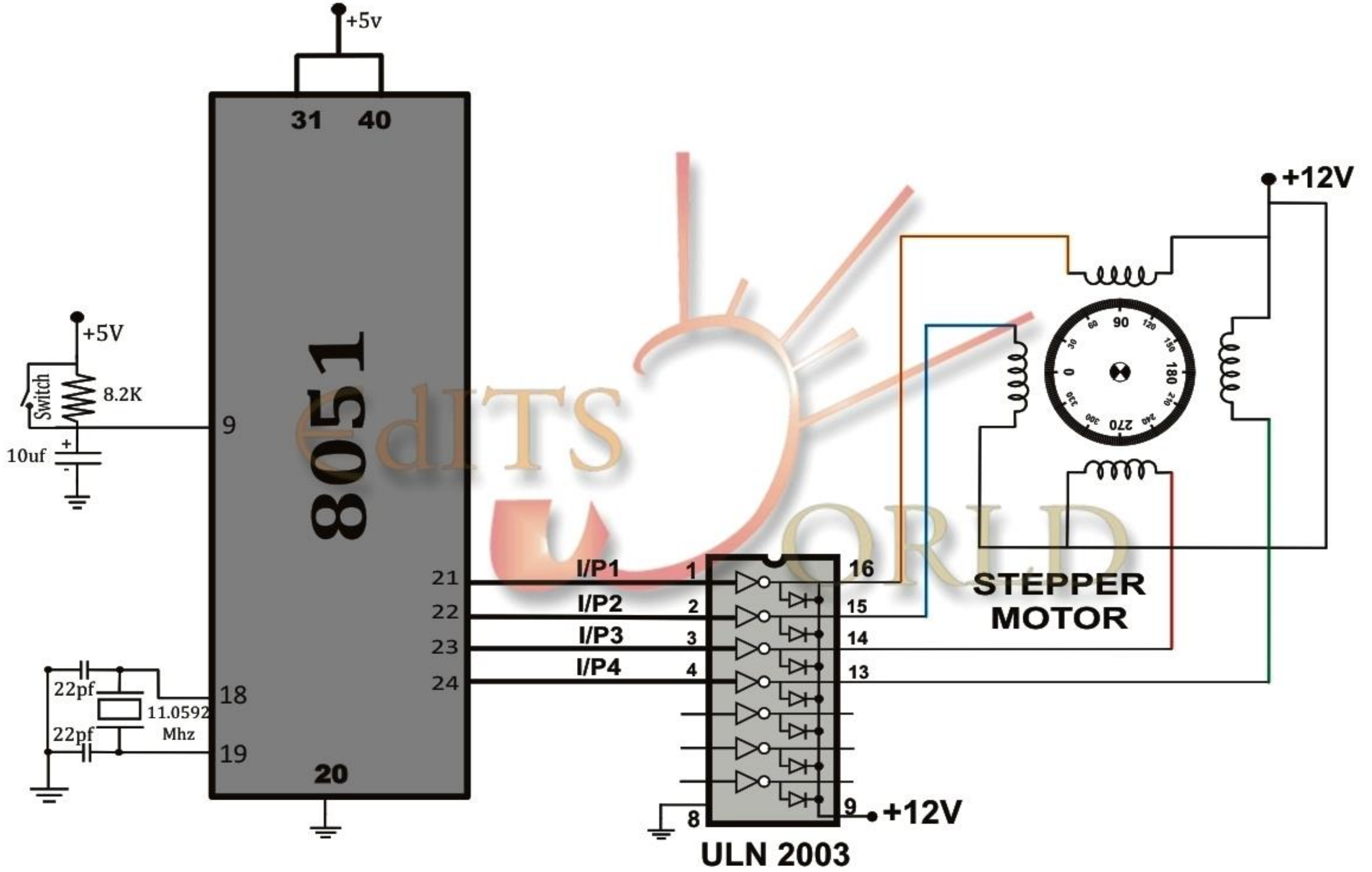


cursomicros.com
L1 L2 L3 L4
0x09
0x0C
0x06
0x03
L1
L4
L2
L3

Using Transistors for Stepper Motor Driver

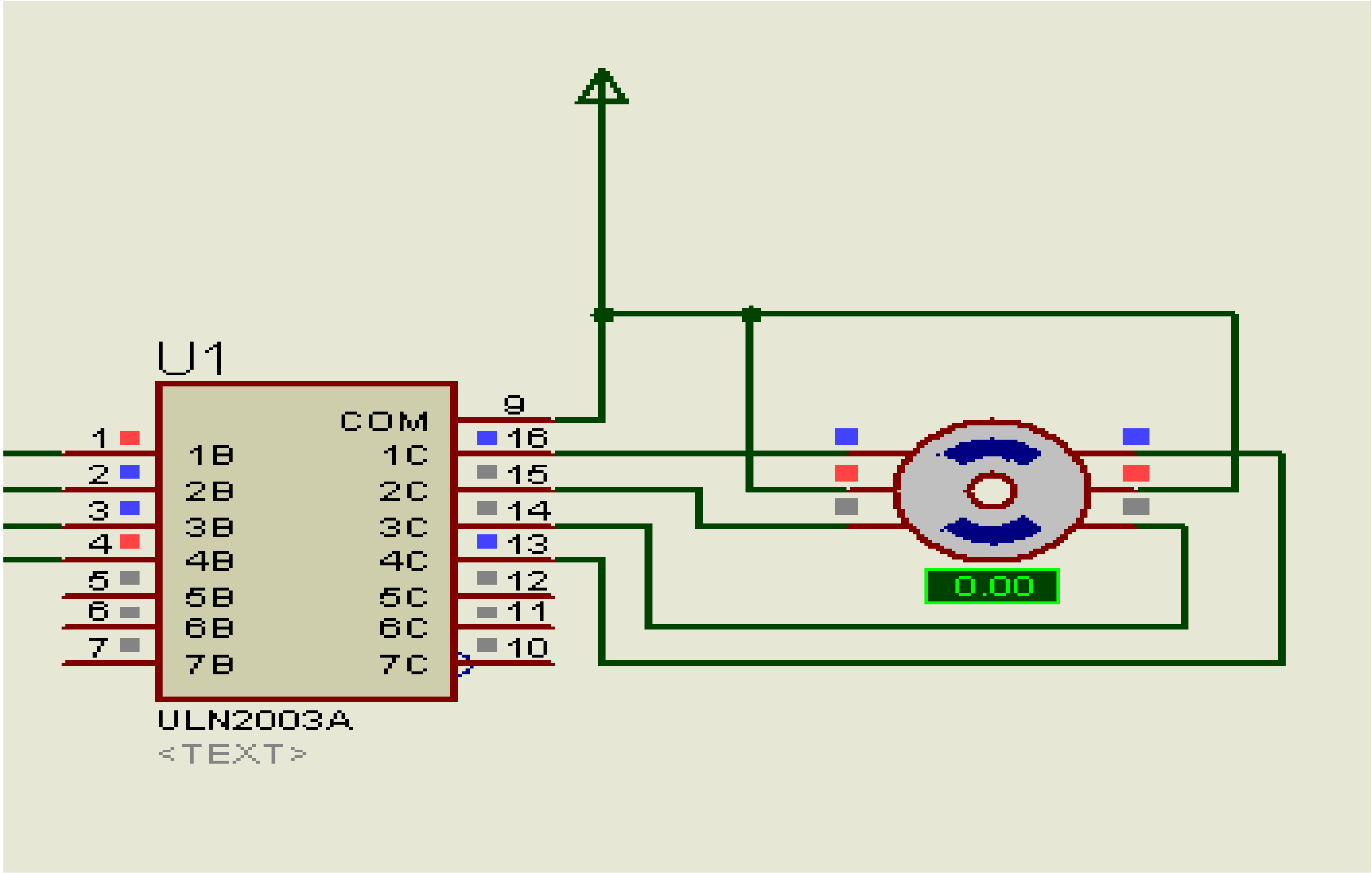



U1
X1
CRYSTAL
C1
10uF
R1
10k
XTAL1
XTAL2
RST
PSEN
ALE
EA
P1.0
P1.1
P1.2
P1.3
P1.4
P1.5
P1.6
P1.7
P0.0/AD0
P0.1/AD1
P0.2/AD2
P0.3/AD3
P0.4/AD4
P0.5/AD5
P0.6/AD6
P0.7/AD7
P2.0/A8
P2.1/A9
P2.2/A10
P2.3/A11
P2.4/A12
P2.5/A13
P2.6/A14
P2.7/A15
P3.0/RXD
P3.1/TXD
P3.2/INT0
P3.3/INT1
P3.4/T0
P3.5/T1
P3.6/WR
P3.7/RD
U2
COM
1B
2B
3B
4B
5B
6B
7B
1C
2C
3C
4C
5C
6C
7C
(BC)
+88.8
ELECTRONICS HUB



INTERFACING OF STEPPER MOTOR WITH 8051

Half Step Sequence Simulation



Applications:

Used in

- In instrumentation such as watches, clocks, etc.
- Computer peripherals such as card readers, teleprinters, teletypes, dot matrix printers, etc.
- Robotics

Stepper Motor Position Control

Normal 4-Step Sequence

Clockwise

Step #	Winding A	Winding B	Winding $\overline{A}$	Winding $\overline{B}$
1	1	0	0	1
2	1	1	0	0
3	0	1	1	0
4	0	0	1	1

Counter-clockwise

4 step seq

10011001
11001100
01100110
00110011
10011001

```
        ORG     0000H
        MOV     A, #10011001B   ; load step sequence
BACK:   MOV     P1, A           ; issue sequence to motor
        RR      A               ; rotate right clock
        ACALL   DELAY           ; wait
        SJMP    BACK            ; repeat the rotation sequence
        ;
DELAY:  ……..                    ; time delay subroutine
        RET
        END
```

Stepper Motor Position Control

8-Step Sequence (Half Step)

1001
1100
0110
0011

1000
0100
0010
0001

Clockwise

Step #	Winding A	Winding B	Winding $\overline{A}$	Winding $\overline{B}$
1	1	0	0	1
2	1	0	0	0
3	1	1	0	0
4	0	1	0	0
5	0	1	1	0
6	0	0	1	0
7	0	0	1	1
8	0	0	0	1

Counter-clockwise

Stepper Motor Position Control

Program of 8-Step Sequence (Half Step)

```
        ORG     0000H
        MOV     R0, #10011001B      ; load normal step sequence
        MOV     R1, #10001000B      ; load half step sequence
BACK:   MOV     A, R0               ; load normal sequence value
        MOV     P1, A               ; issue sequence to motor
        RR      A                   ; rotate right - clockwise
        MOV     R0, A               ; store normal sequence value
        ACALL   DELAY               ; wait
        MOV     A, R1               ; load half step sequence value
        MOV     P1, A               ; issue sequence to motor
        RR      A                   ; rotate right - clockwise
        MOV     R1, A               ; store half step sequence value
        ACALL   DELAY               ; wait
        SJMP    BACK                ; repeat the rotation sequence
        ;
DELAY:  ……..                        ; time delay subroutine
        RET
        END
```

P1.x : 0=on, 1=off

Further example on Stepper Motor Position Control

Controlling stepper motor via optoisolator

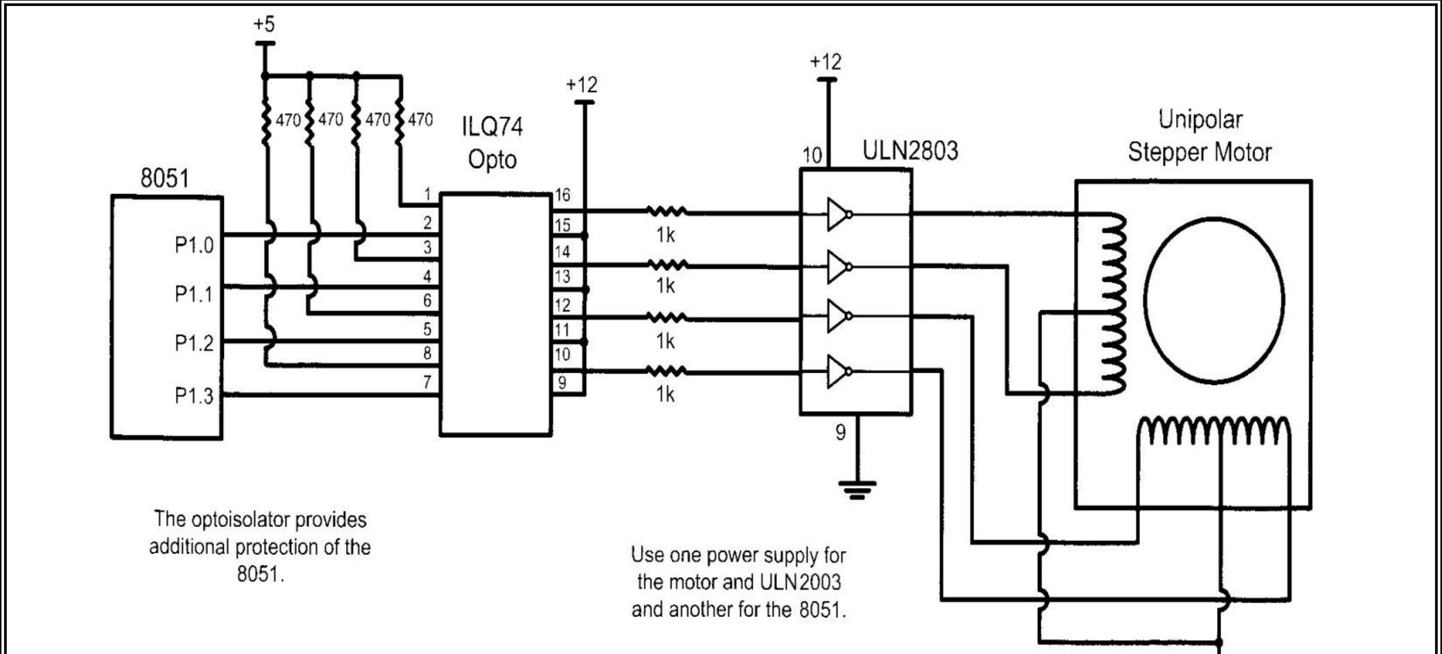


Figure 6. 8051 connection to Stepper motor

Example 1

If a switch is connected to port P2.7. Write a program to monitor the status of SW and perform the following:

(a) If SW=0, the stepper motor moves clockwise.

(b) If SW=1, the stepper motor moves counter-clockwise.

Further example on Stepper Motor Position Control

Example 1 Program listing

```
          ORG     0000H
MAIN:     SETB    P2.7          ; make P2.7 as an input
          MOV     A, #99H       ; starting phase value, 10011001B
          MOV     P1, A         ; send value to port 1
TURN:     JNB     P2.7, CW      ; check switch
          RL      A             ; rotate right – counter clockwise
          ACALL   DELAY         ; wait
          MOV     P1, A         ; send value to port 1
          SJMP    TURN          ; repeat
CW:       RR      A             ; rotate left – clockwise
          ACALL   DELAY         ; wait
          MOV     P1, A         ; send value to port 1
          SJMP    TURN          ; repeat
          ;
DELAY:    MOV     R2, #100      ; time delay subroutine
H1:       MOV     R3, #255
H2:       DJNZ    R3, H2
          DJNZ    R2, H1
          RET
          END
```

Normal 4-Step Sequence

Clockwise ↓

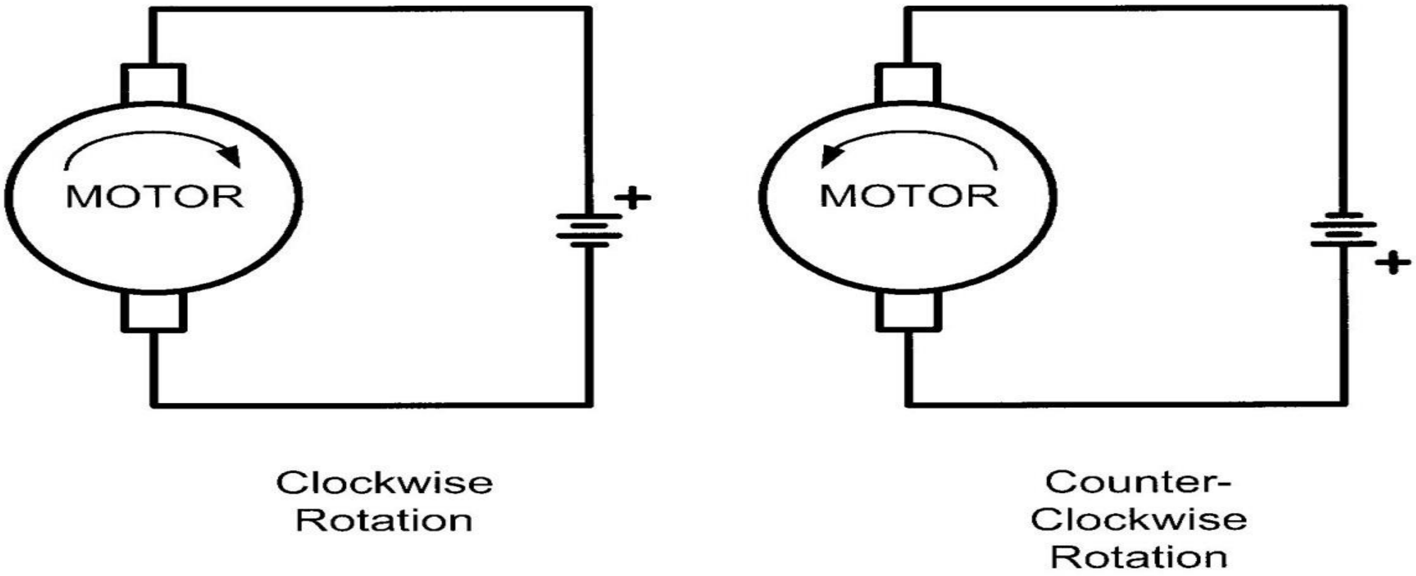
Step #	Winding A	Winding B	Winding $\overline{A}$	Winding $\overline{B}$
1	1	0	0	1
2	1	1	0	0
3	0	1	1	0
4	0	0	1	1

Counter-clockwise ↑

DC MOTOR Interfacing with Microcontroller

DC Motors

- DC motor: has only a pair of + and – leads.
- Connecting to a DC voltage source, DC motors move in one direction. By reversing the voltage polarity, they will move in the opposite direction.



DC motor rotation

DC Motors - Bidirectional control

- With the help of relays or some specially designed chips, the rotational directions (forward and backward) of DC motors can be control.
- The basic concept is the H-Bridge control of DC motors

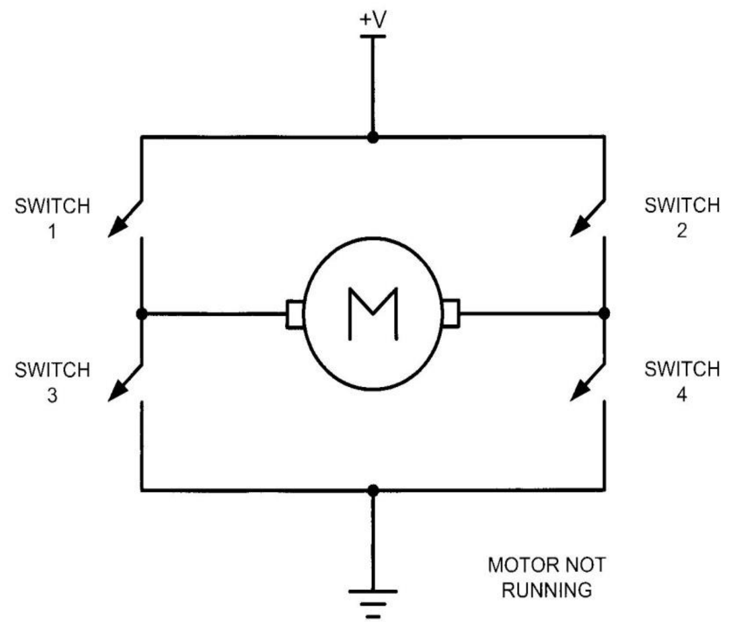


Figure 11.8 H-Bridge Motor Configuration

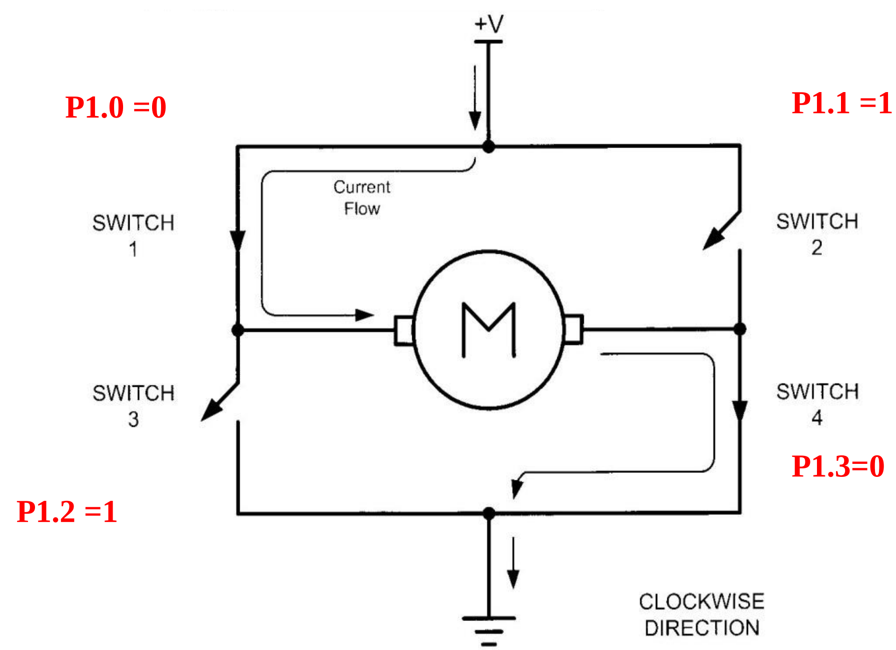


Figure 11.9 H-Bridge Motor Clockwise Configuration

P1.x : 0=on, 1=off

DC Motors - Bidirectional control

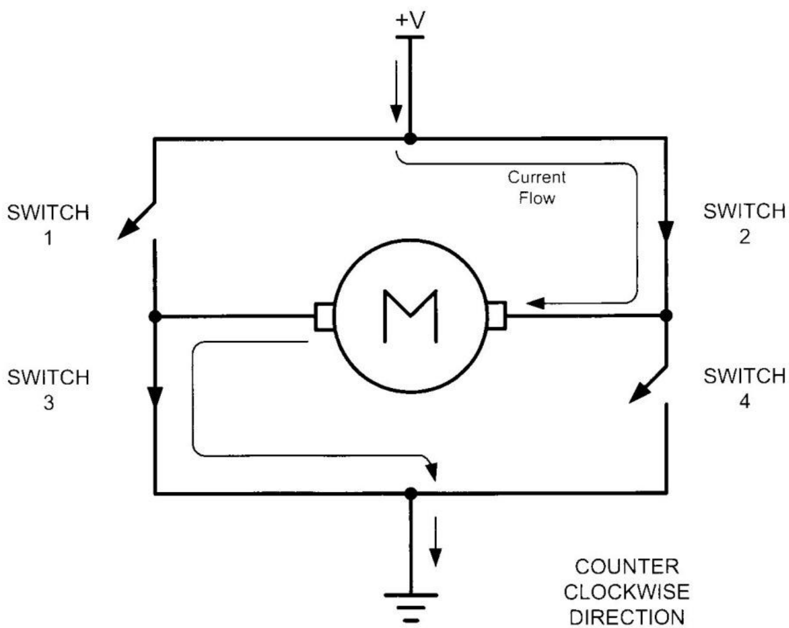


Figure 10 H-Bridge Motor Counter-Clockwise Configuration

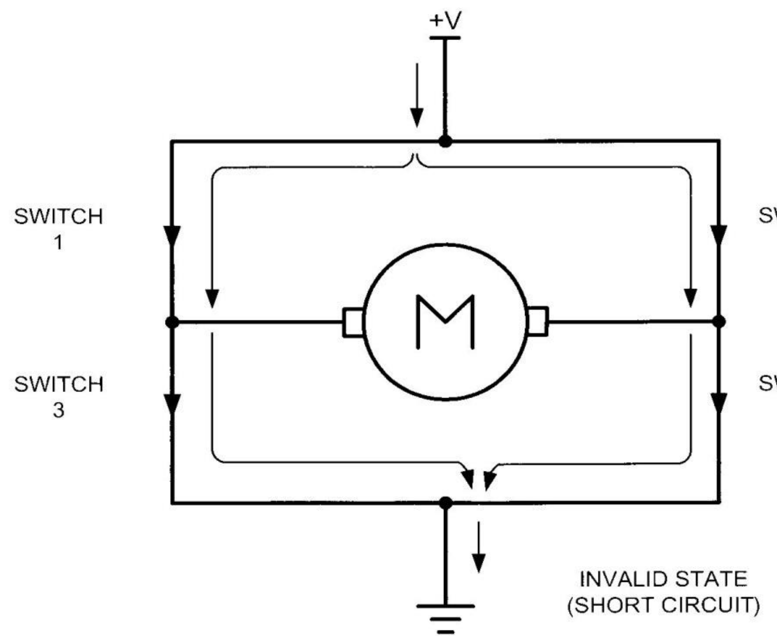


Figure 11 H-Bridge in an Invalid Configuration

- **H-Bridge control can be created using relays, transistors, or a single IC solution.**
- **When using relays and transistors, make sure that invalid configuration do not occur.**

Example 11.2 :

If a switch is connected to port P2.7. Write a program to monitor the status of SW and perform the H-Bridge direction control of DC motor as follow:

(a) If SW=0, the DC motor moves clockwise.

(b) If SW=1, the DC motor moves counter-clockwise.

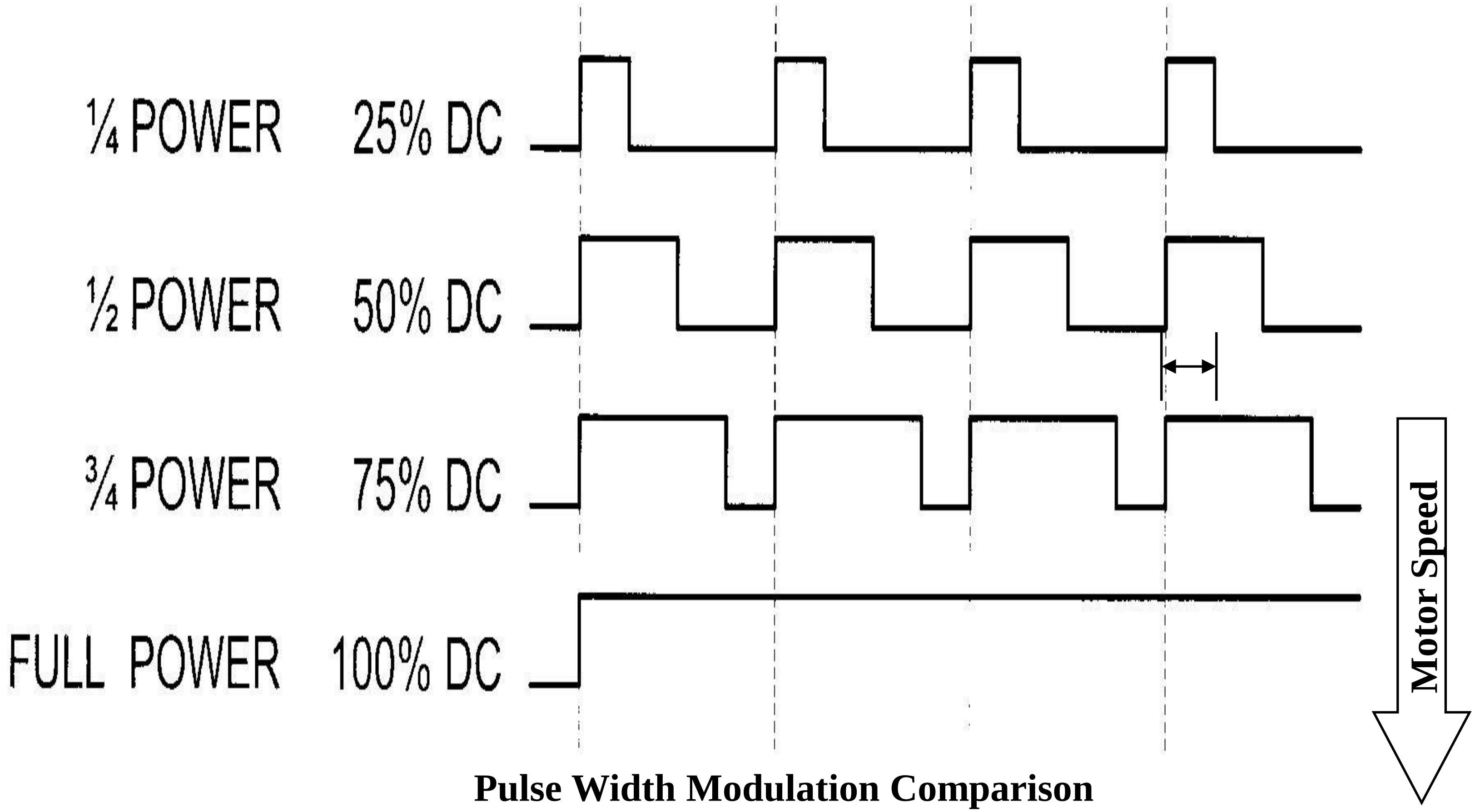
Solution:

```
            ORG      0000H
MAIN:       CLR      P1.0              ; H-Bridge switch 1
            CLR      P1.1              ; H-Bridge switch 2
            CLR      P1.2              ; H-Bridge switch 3
            CLR      P1.3              ; H-bridge switch 4
            SETB     P2.7       ; config P2.7 as input port
MONITOR:    JB       P2.7, CW          ; check switch
            SETB     P1.0              ; H-Bridge switch 1 (Counter-Clookwise)
            CLR      P1.1              ; H-Bridge switch 2
            CLR      P1.2              ; H-Bridge switch 3
            SETB     P1.3              ; H-Bridge switch 4
            SJMP     MONITOR
CW:         CLR      P1.0              ; H-Bridge switch 1  (Clockwise)
            SETB     P1.1              ; H-Bridge switch 2
            SETB     P1.2              ; H-Bridge switch 3
            CLR      P1.3              ; H-Bridge switch 4
            SJMP     MONITOR
            END
```

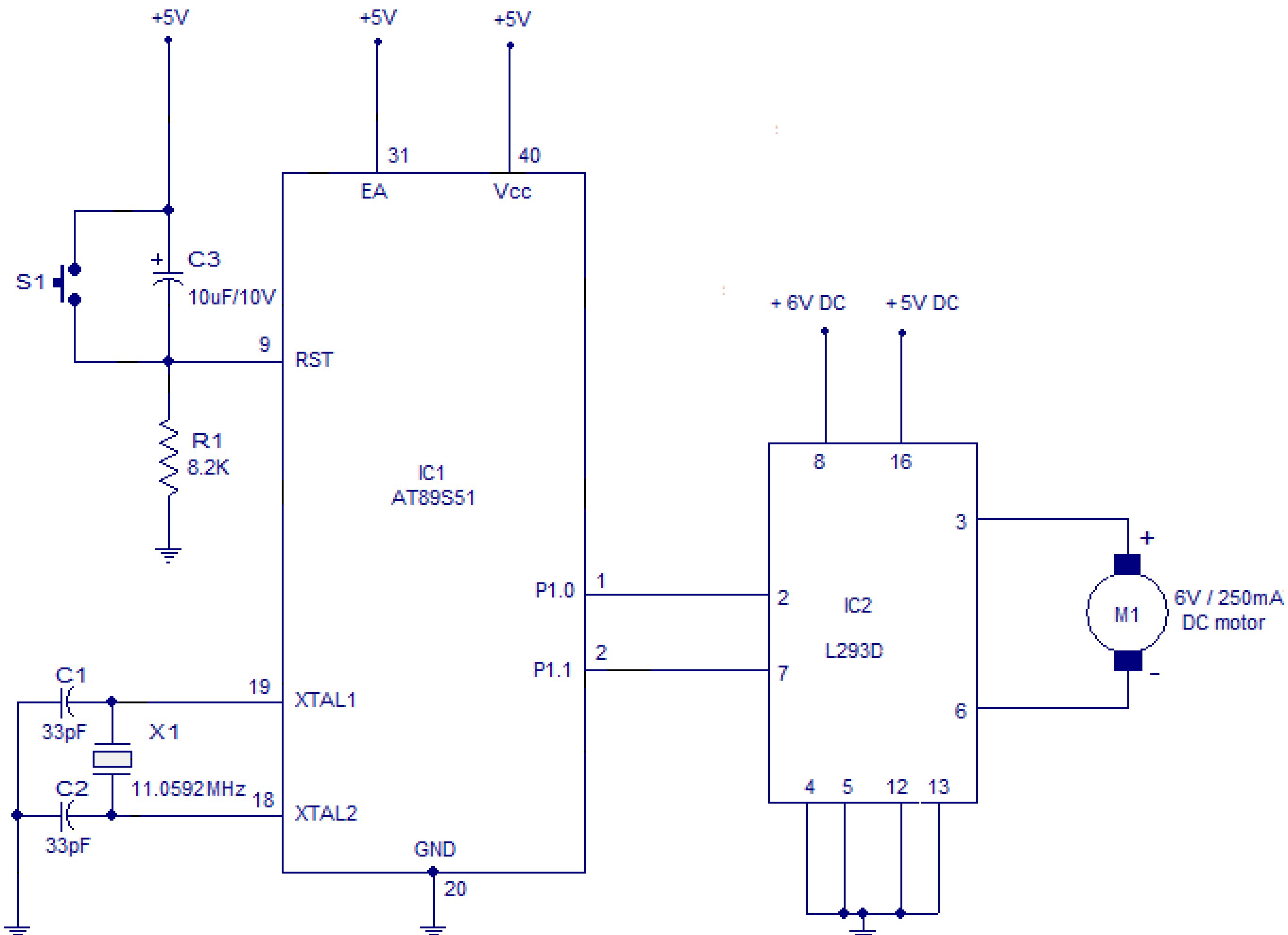
DC Motors - Speed control by PWM

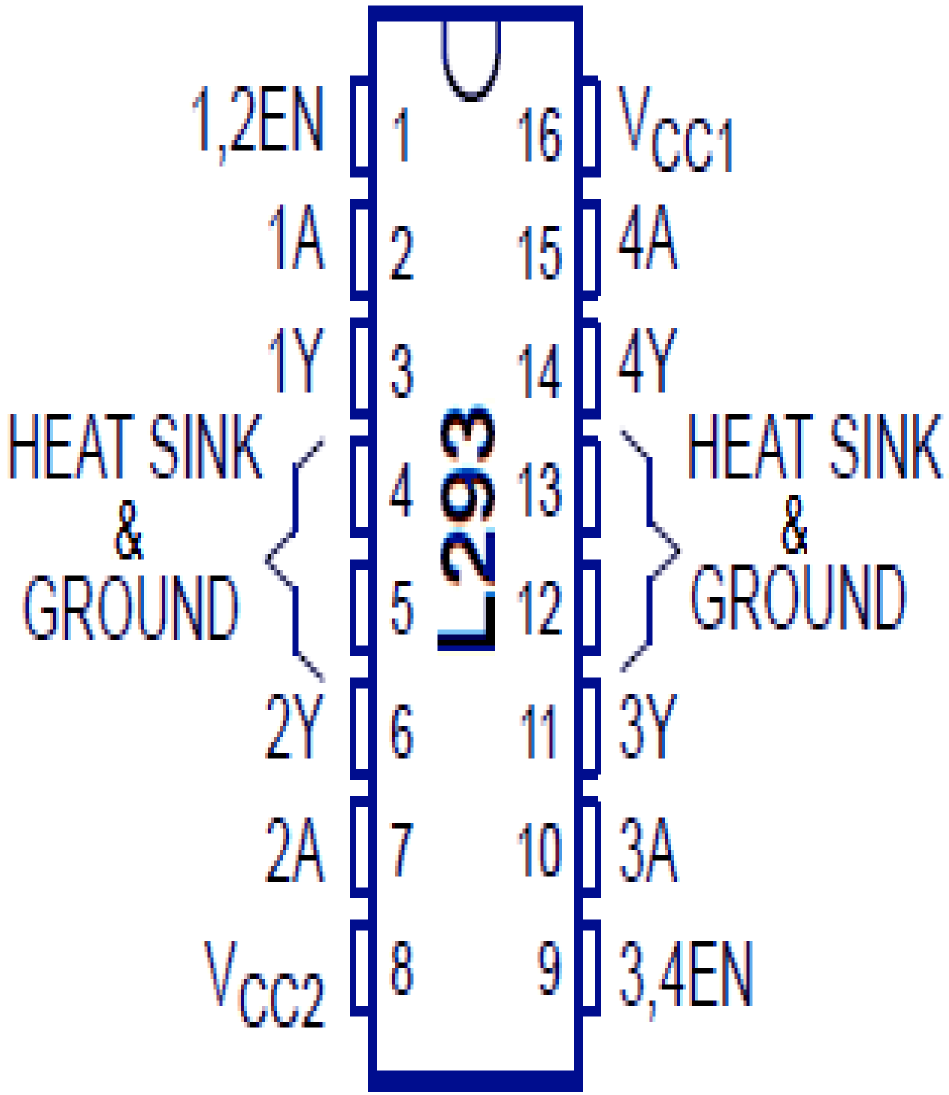
- **The speed of DC motor depends on three factors; (a) load, (b) voltage and (c) current**
- **For a fixed load, speed of DC motor can be changed by *pulse width modulation* (PWM)**
- **PWM is to change the width of the pulse applied to DC motor which lead to an increase or decrease the amount of power supplied to the motor.**
- **As a result, the motor speed increases or decreases respective to the power supplied.**
- **Although the amplitude of the pulse is fixed at a voltage level, but its duty is varied.**
- **The wider the pulse, the higher speed of motor.**

DC Motors - Speed control by PWM



Pulse Width Modulation Comparison


+5V
+5V
+5V
31
40
EA
Vcc
S1
C3
10uF/10V
9
RST
R1
8.2K
IC1
AT89S51
+ 6V DC
+ 5V DC
8
16
3
+
6V / 250mA
DC motor
M1
P1.0
1
2
IC2
L293D
P1.1
2
7
6
C1
19
XTAL1
33pF
X1
C2
11.0592MHz
18
XTAL2
33pF
GND
20
4
5
12
13



FUNCTION TABLE

(each driver)

INPUTS		OUTPUT
A	**EN**	**Y**
H	H	H
L	H	L
X	L	Z

H = high level, L = low level,

X = irrelevant,

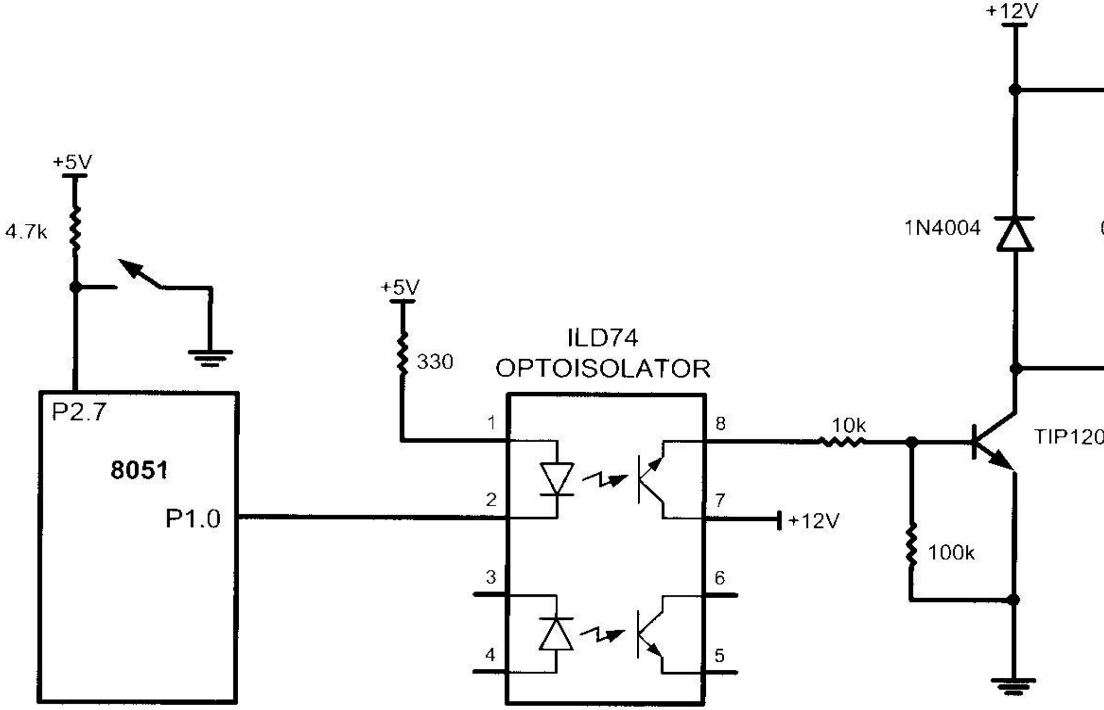
Z = high impedance (off)

Example 3 :

Refer to figure 9, write a program to monitor the status of SW and perform the following:

(a) If P2.7 =1 , the DC motor moves with 25% duty cycle pulse.

(b) If P2.7 =0 , the DC motor moves with 50% duty cycle pulse.



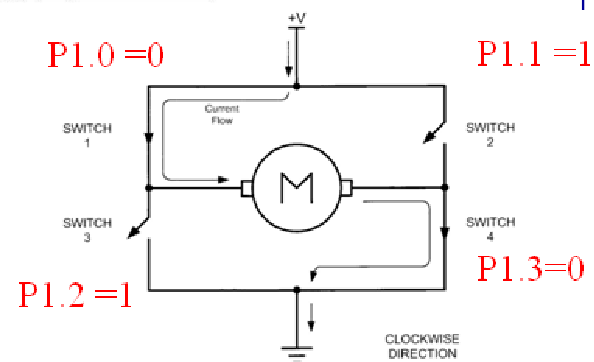


Figure 11.9 H-Bridge Motor Clockwise Configuration

Figure 13 Connection of DC Motor speed Control by PW

P1.x : 0=on, 1=off

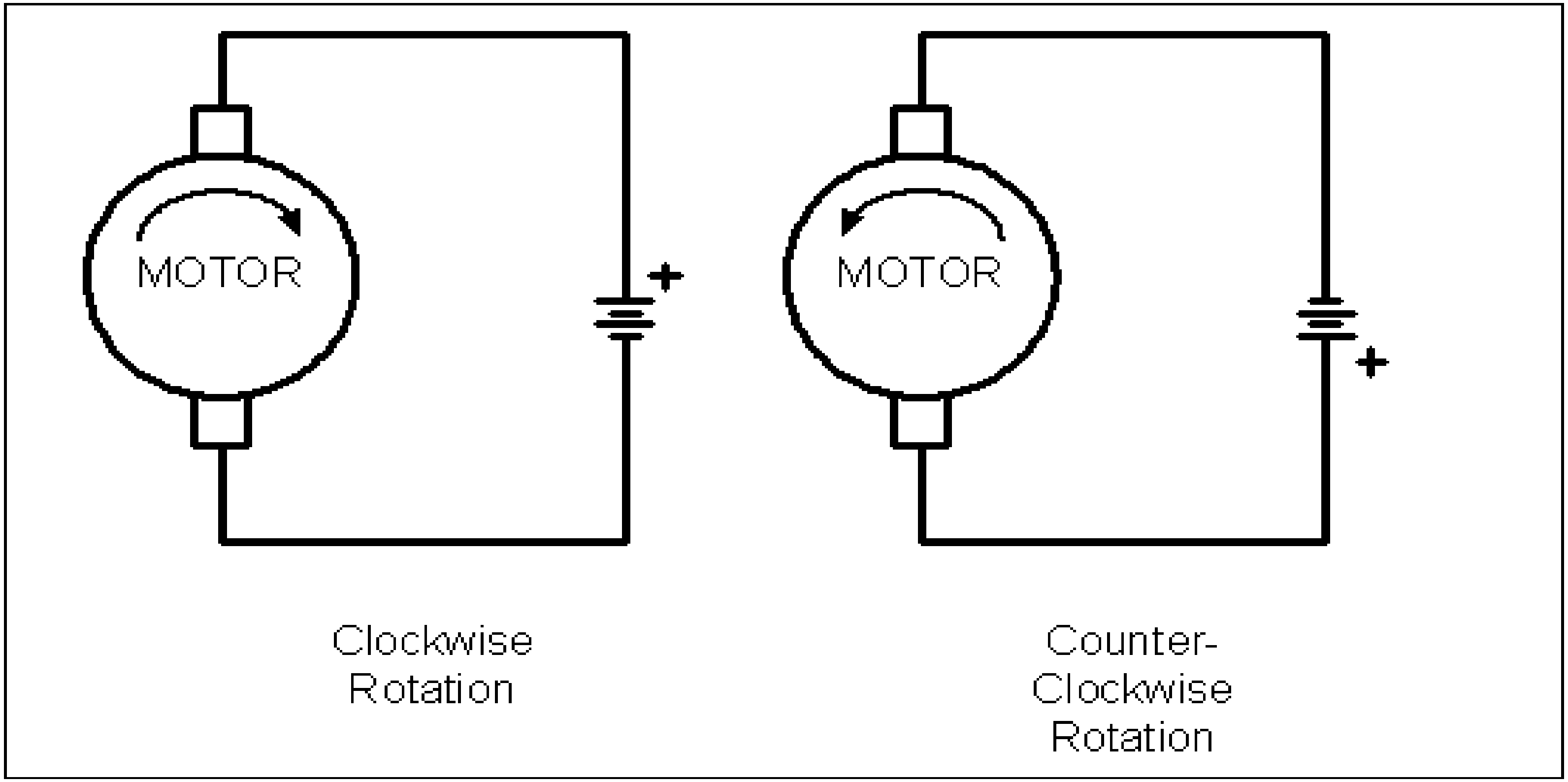
DC Motors

- Only One Winding
- Two Connections: + and –
- Reversing Polarity Reverses Motor
- Move Continuously
- Cannot Determine Position

Characteristics:

- RPM
  - No Load: Maximum RPM With No Load on Shaft
    - Given in Data Sheets
  - Loaded: Actual Maximum When Loaded
    - Not in Most Data Sheets
- Voltage Range
  - Speed Increases With Voltage on a Given Motor
- Current Draw
  - Data Sheet Rating Is With Nominal Voltage and No Load
  - Increases With Load
- Speed Decreases With Load

DC Motor Rotation (Permanent Magnet Field)



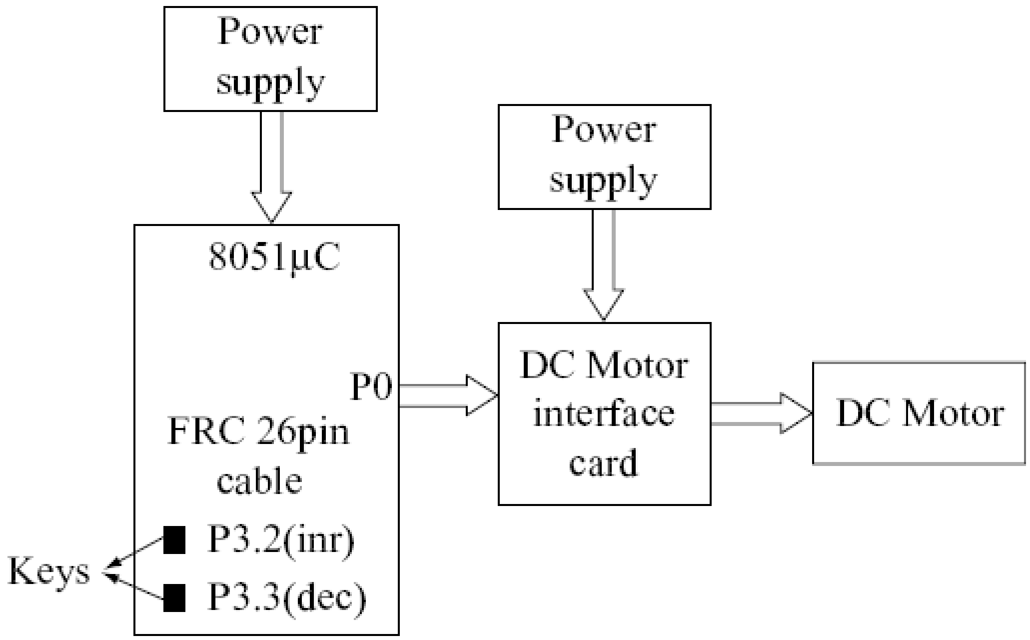
Bi-Directional Control

- Can Change Polarity With a Little Work
- H-Bridge Is Simplest Method
  - Uses Switches (Relays Will do)

Controlling Speed

- Speed Depends On
  - Load
  - Voltage
  - Current
- Can Control Power By Changing (Modulating) Width of Pulse to Motor
  - Wider Pulse → Faster Speed
  - Narrower Pulse → Slower Speed
- Note: Doesn’t Work With AC Motors
  - AC Motor Speed Depends on AC Frequency (CPS)

DC| Motor	Stepper Motor
- It has a frame that remains motionless and an armature that moves (like EM relay and solenoids) - Armature moves in a circular manner (shaft rotation). -Brushes positioned between the frame and armature are used to alternate the current direction through the coil so that a DC current generates a continuous rotation of the shaft. - When the current is removed, the magnetic force stops and the shaft is free to rotate. - In a PWM DC motor, the computer activates the coil with a current of fixed magnitude but varies the duty cycle to control the motor speed.	- Both the position and velocity of a stepper motor can be controlled using a microcontroller in open-loop fashion. - Stepper motors may not require feedback sensor, so cost is less as compared to a DC motor. - Used in hard disk drives, floppy disk drives, printers and can also be used as shaft encoders for measuring both position and speed.



DC motor connection