INTERFACING

KEYPAD & STEPPER MOTOR

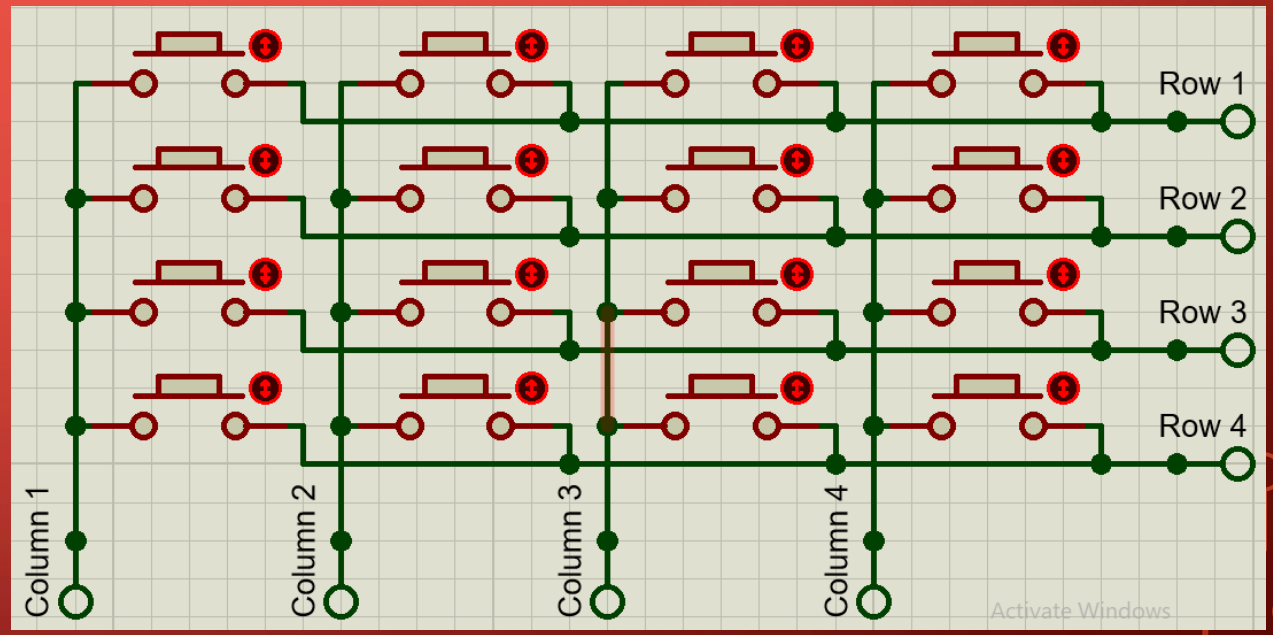
AMIT

KEYPAD CONCEPT:

- The keypad is a set of mechanical switches which are arranged into a matrix.

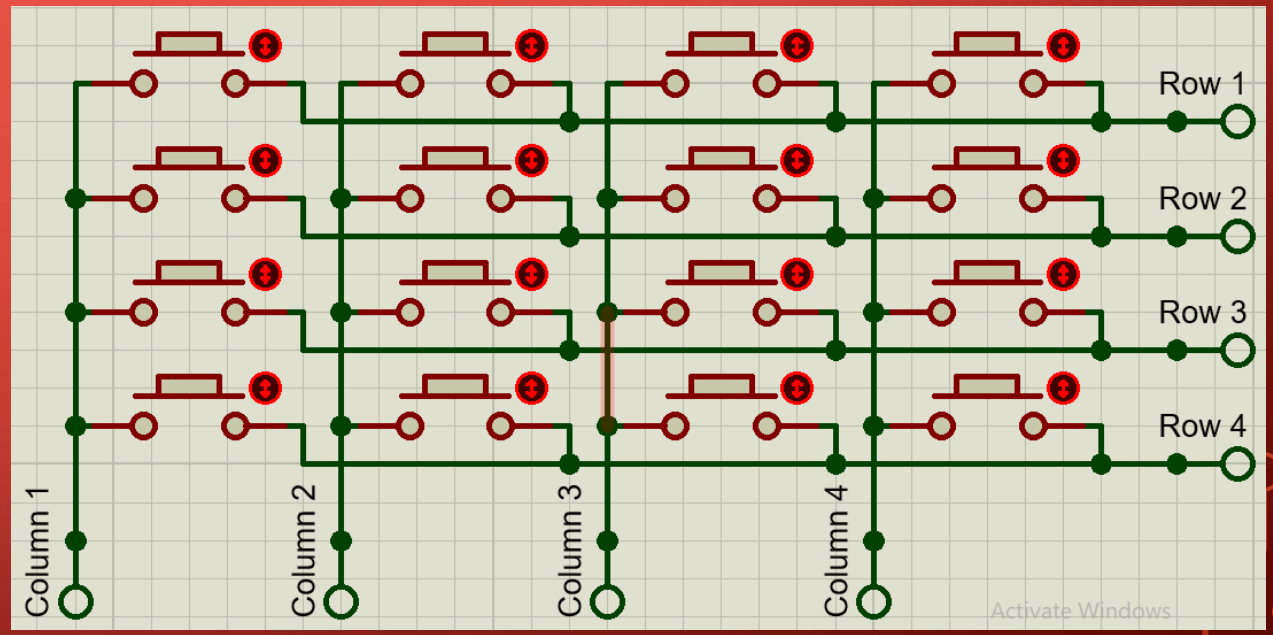
WHY KEYPAD?

- If we want to use about 16 switches into our project, we will need about 16 input pin from our microcontroller, about half of GPIO pins, but if we need about 49 switches, what shall we do?
- In this case, we need about 49 input pin for our switches, so if they are arranged into a matrix 7x7 we only need 14 pins only.



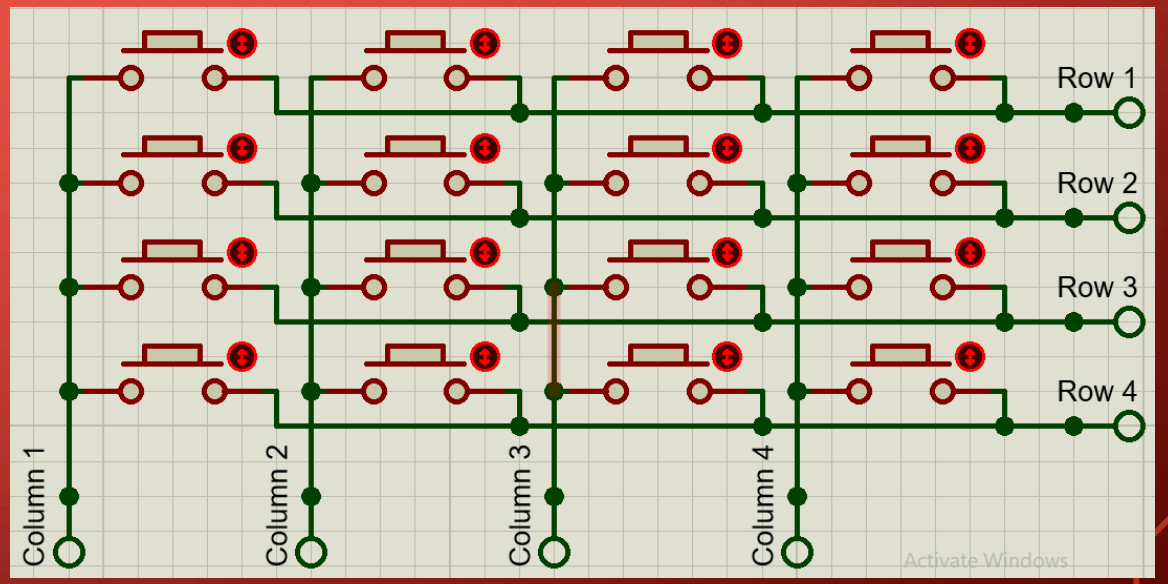
WHY KEYPAD?

- In the figure besides, keypad 4x4, so we only need about 8 pins to connect these switches into our system.
- **So**, the keypad concept is used to reduce the number of microcontroller pins.
- But in this case, how does the keypad work?



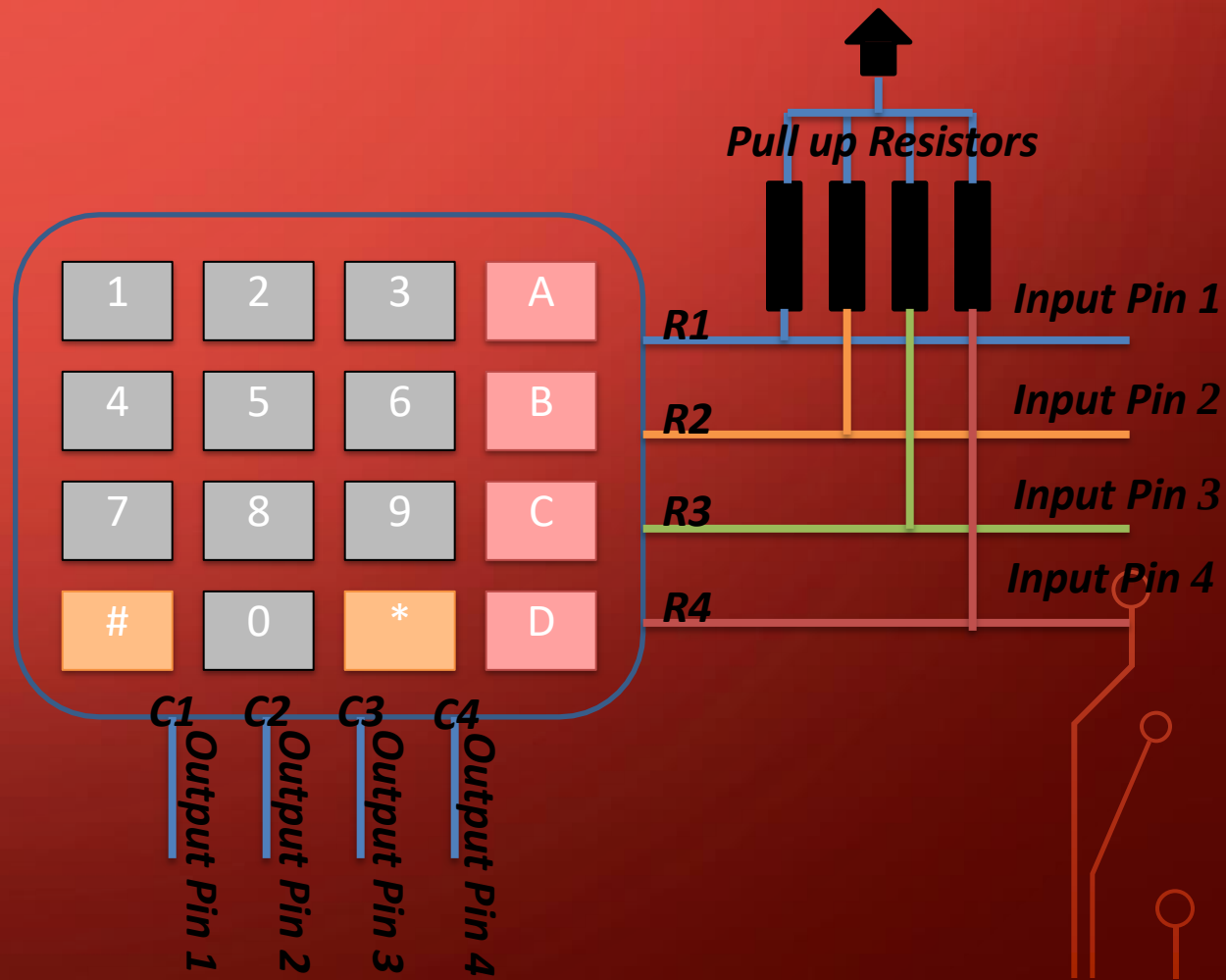
HOW KEYPAD WORKS?

- After arranging the switches into a matrix, we will have four columns and for rows, So, we can set any set of them as an output and the other as an input.
- Assume that the columns set is output, and the rows set is input, what is the kind of the signals must be written on these columns to easily indicate the pressed button?



HOW KEYPAD WORKS?

- The best sequence is to set all the columns by HIGH at first.
- Then, change C1 signal to LOW then check if any row read Zero or not.
- Assume that R3 reads Zero signal, so the pressed button is C1R3.
- If not, turn C1 to HIGH again and set C2 to LOW and check if any Row reads Zero or not.
- Repeat this sequence until you find zero on any row then return the pressed key, or until columns are finished and return keypad not pressed.



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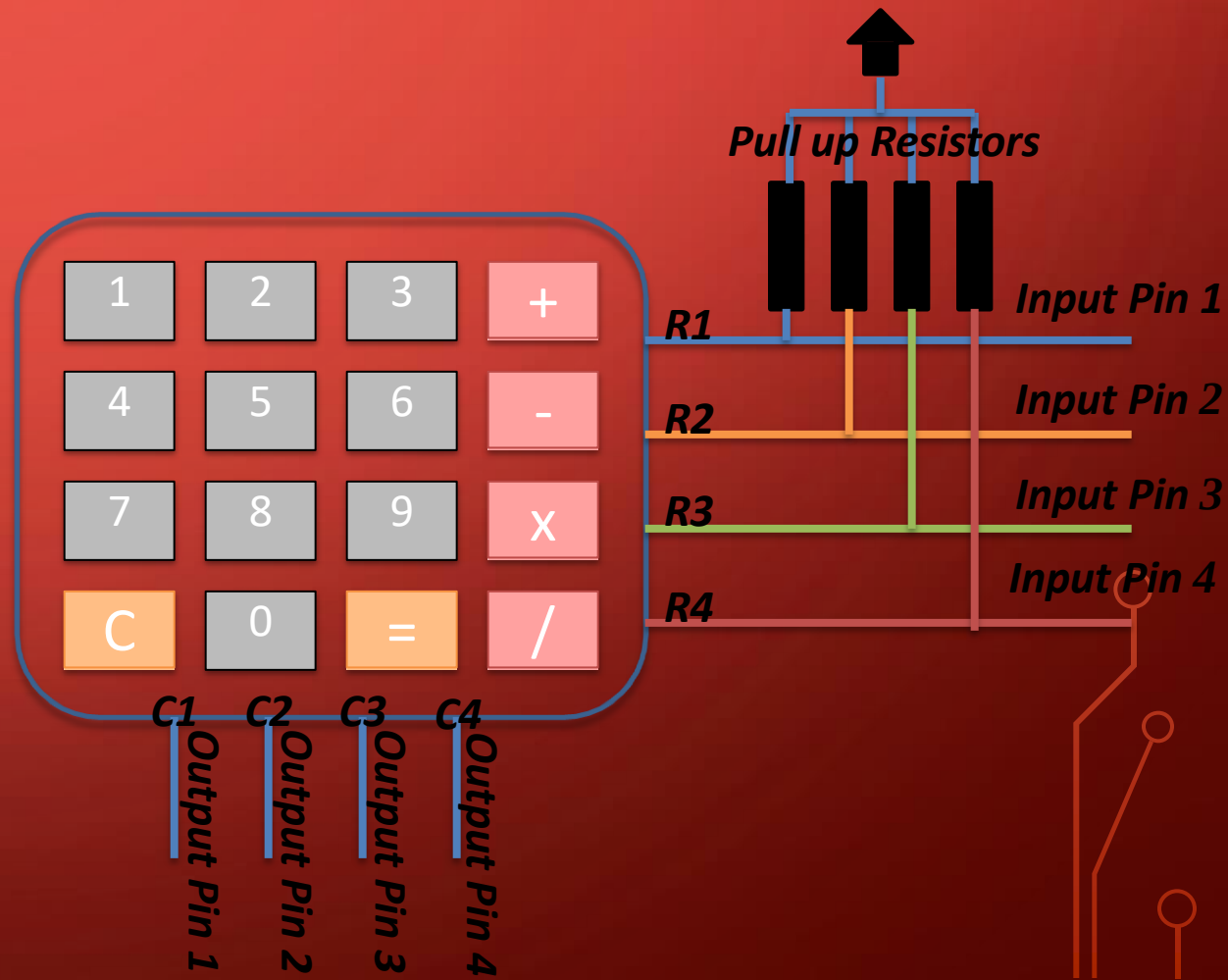
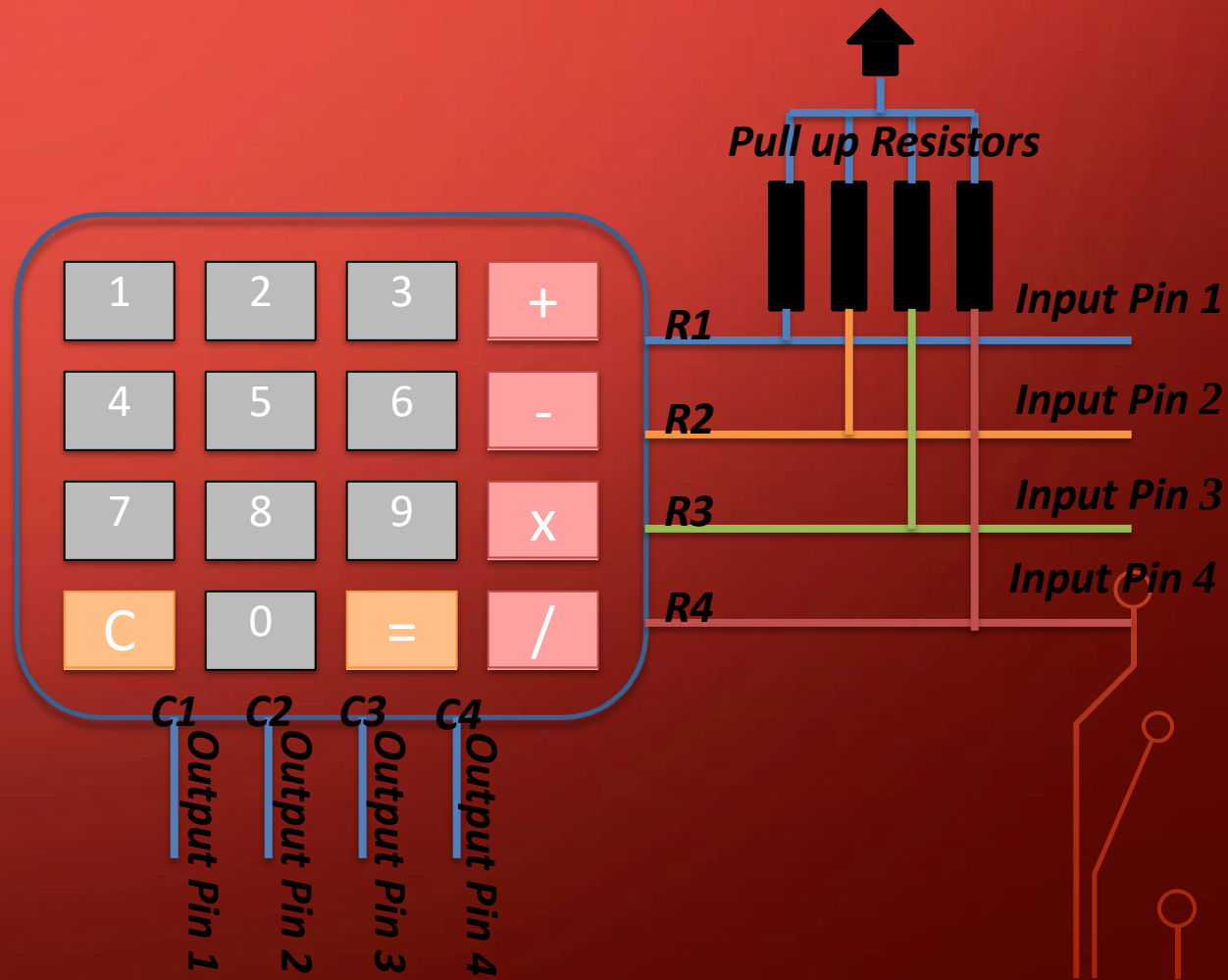


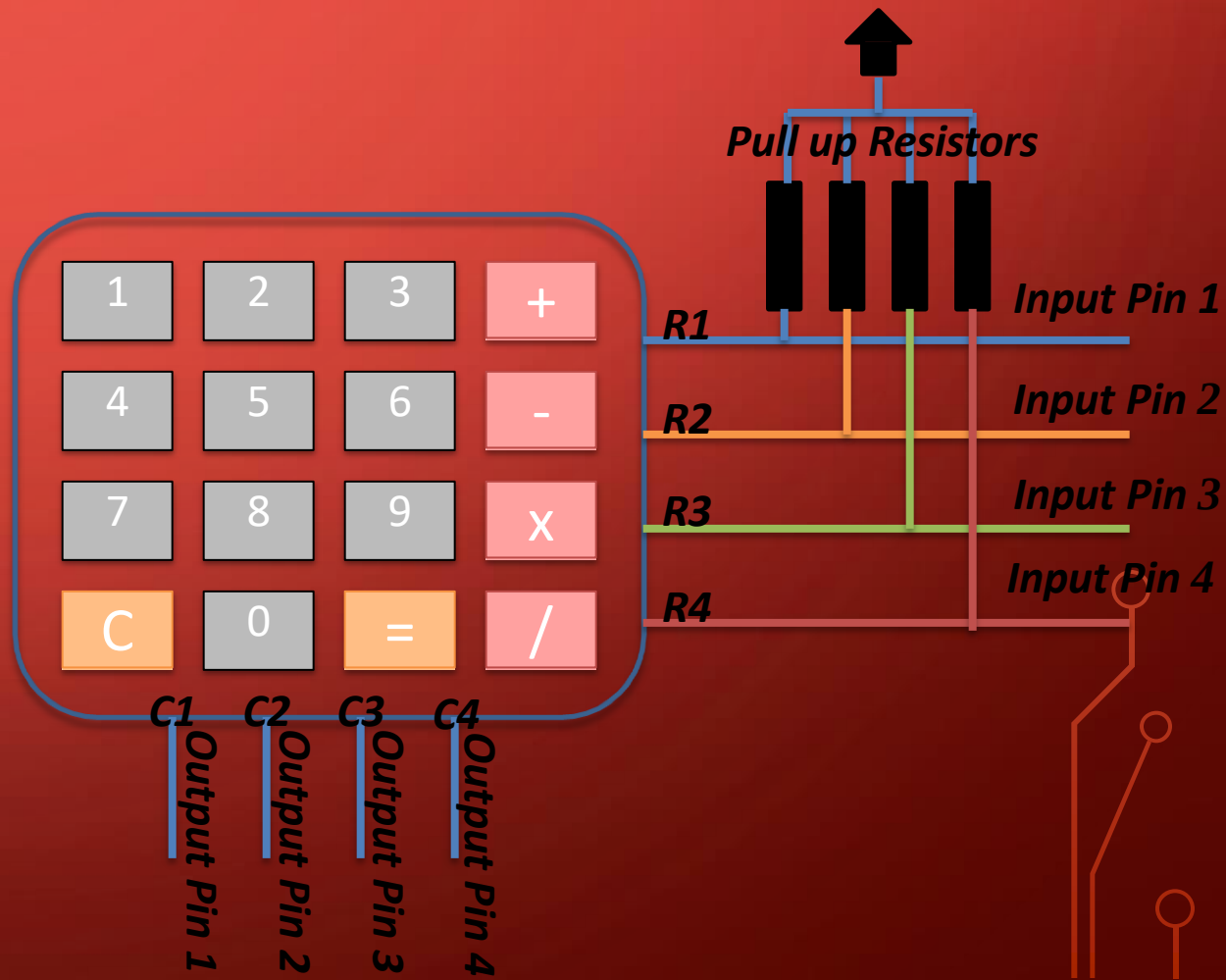
KEYPAD ALGORITHM:

- ***Write on C1 To C4 "0111":***
  - This means that C1 is activated, and we are going to check the buttons in C1, If any row of the rows R1 to R4 is set to 0, then the corresponding button in C1 is pressed.
- ***Write on C1 To C4 "1011":***
  - This means that C2 is activated, and we are going to check the buttons in C2, If any row of the rows R1 to R4 is set to 0, then the corresponding button in C1 is pressed.



KEYPAD ALGORITHM:

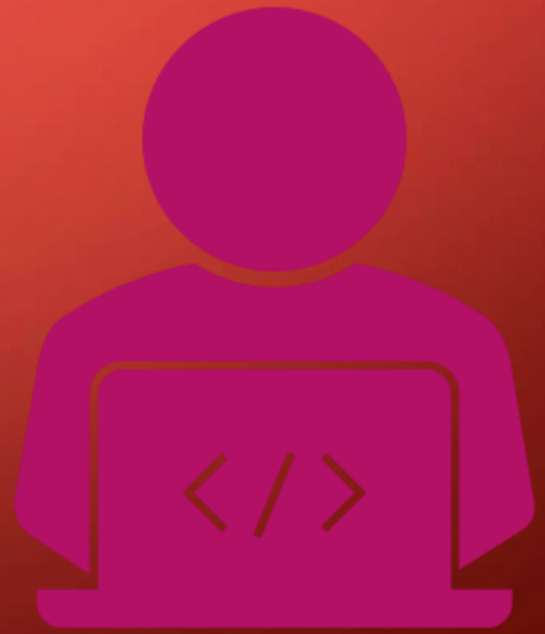
- ***Write on C1 To C4 "1101":***
  - This means that C4 is activated, and we are going to check the buttons in C3, If any row of the rows R1 to R4 is set to 0, then the corresponding button in C1 is pressed.
- ***Write on C1 To C4 "1110":***
  - This means that C4 is activated, and we are going to check the buttons in C4, If any row of the rows R1 to R4 is set to 0, then the corresponding button in C1 is pressed.



KEYPAD DRIVER:

- ***Now,*** *After understanding how to implement the Keypad matrix and the Algorithm of it,*

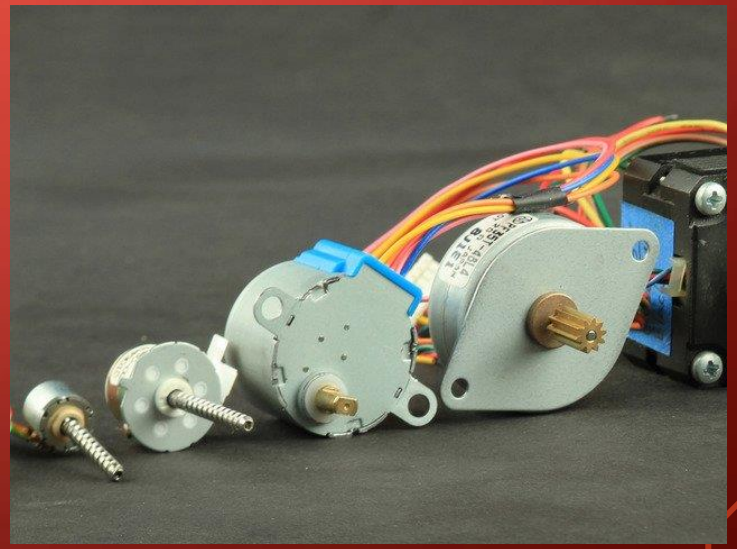
Try writing its software module



STEPPER MOTORS

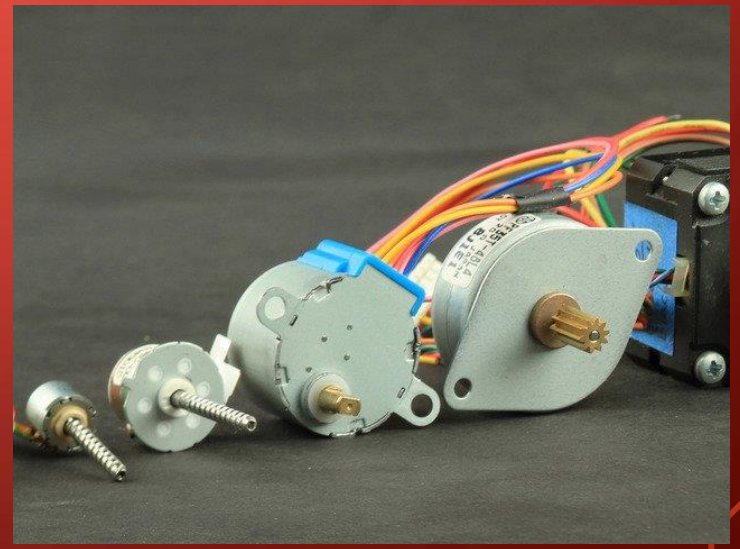
STEPPER MOTORS:

- **<u>What is the Stepper Motor?:</u>**
  - A stepper motor, also known as step motor or stepping motor, is a brushless DC electric motor that divides a full rotation into several equal steps. The motor's position can be commanded to move and hold at one of these steps without any position sensor for feedback (an open-loop controller in contrast to Servo which is a closed Loop system), if the motor is correctly sized to the application in respect to torque and speed.



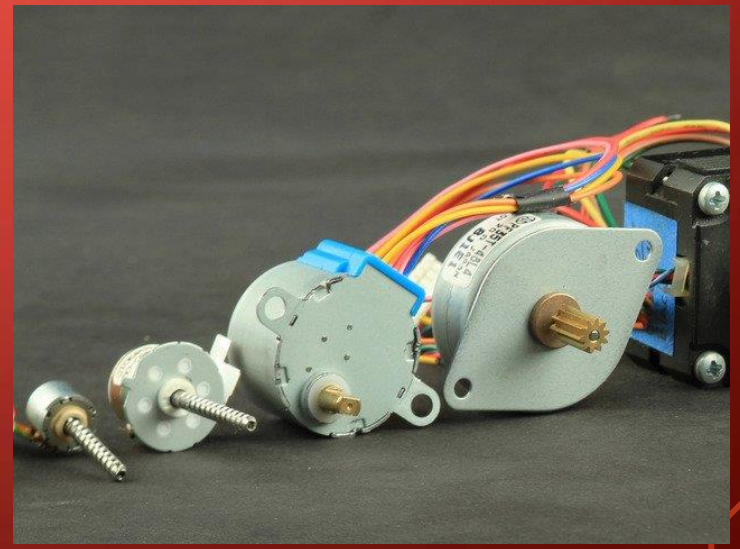
STEPPER MOTORS:

- **<u>Why the Stepper Motor:</u>**
  - Stepper motors are often an extremely important component in a motion control system.
  - Stepper motors can produce full, instantaneous torque - even from a standstill. This makes them very useful for motion control applications, where accuracy, repeatability, and power are paramount.



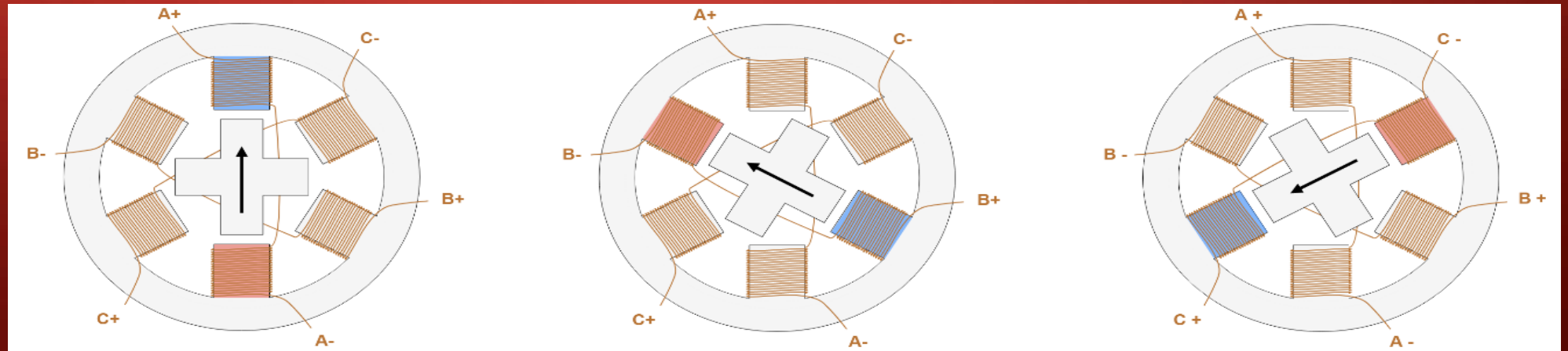
STEPPER MOTORS:

- **Types of Stepper Motors:**
  - Permanent magnet stepper
  - Variable reluctance stepper
  - Hybrid synchronous stepper
- **Types of Phases of Stepper Motors:**
  - **Unipolar.**
  - **Bipolar.**



THEORY OF STEPPER MOTORS:

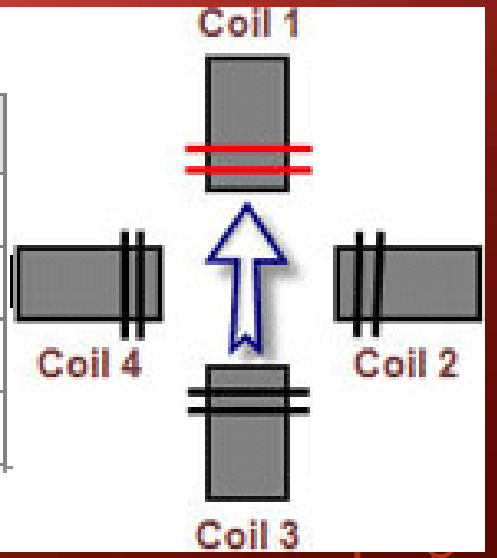
- **<u>Types of Stepper Motors:</u>**
  - The basic working principle of the stepper motor is the following: By energizing one or more of the stator phases, a magnetic field is generated by the current flowing in the coil and the rotor aligns with this field. By supplying different phases in sequence, the rotor can be rotated by a specific amount to reach the desired final position. Figure 2 shows a representation of the working principle. At the beginning, coil A is energized, and the rotor is aligned with the magnetic field it produces. When coil B is energized, the rotor rotates clockwise by 60° to align with the new magnetic field. The same happens when coil C is energized. In the pictures, the colors of the stator teeth indicate the direction of the magnetic field generated by the stator winding.



THEORY OF STEPPER MOTORS:

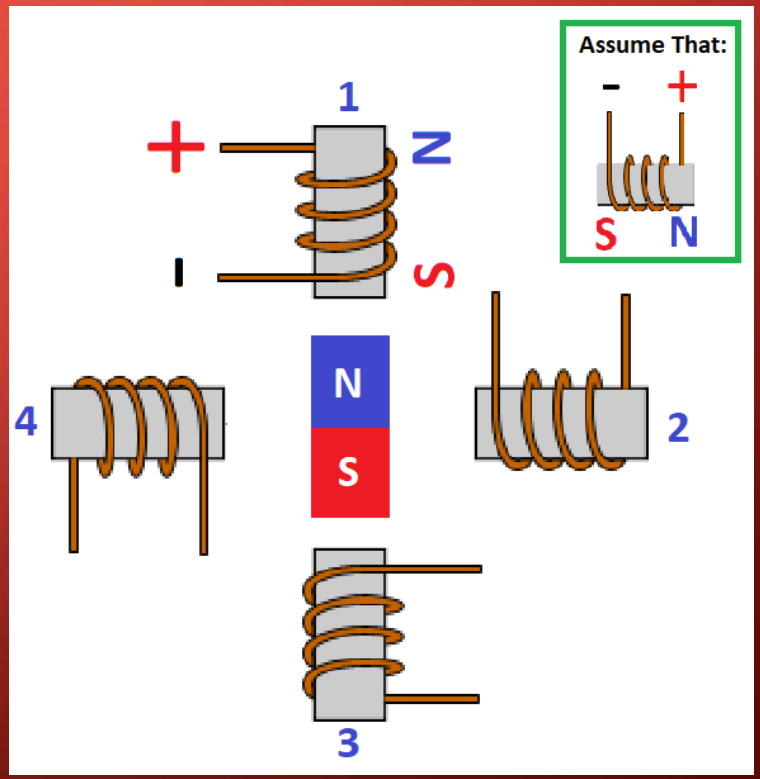
- **<u>Four Coils Full Step Activation:</u>**
  - In this type of stepper motors, the coils must be activated sequentially, as the following figure, the activated coils are 1 → 2 → 3 → 4 to generate Clockwise rotation.
  - To reverse the rotation, the sequence of activation will be 1→4→3→2.

Pulse	Coil 1	Coil 2	Coil 3	Coil 4
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1

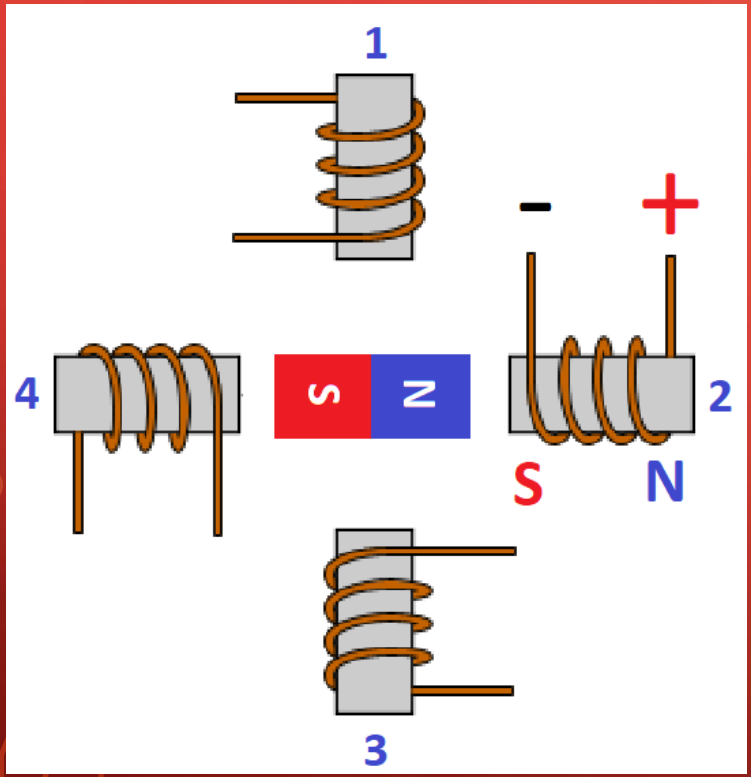


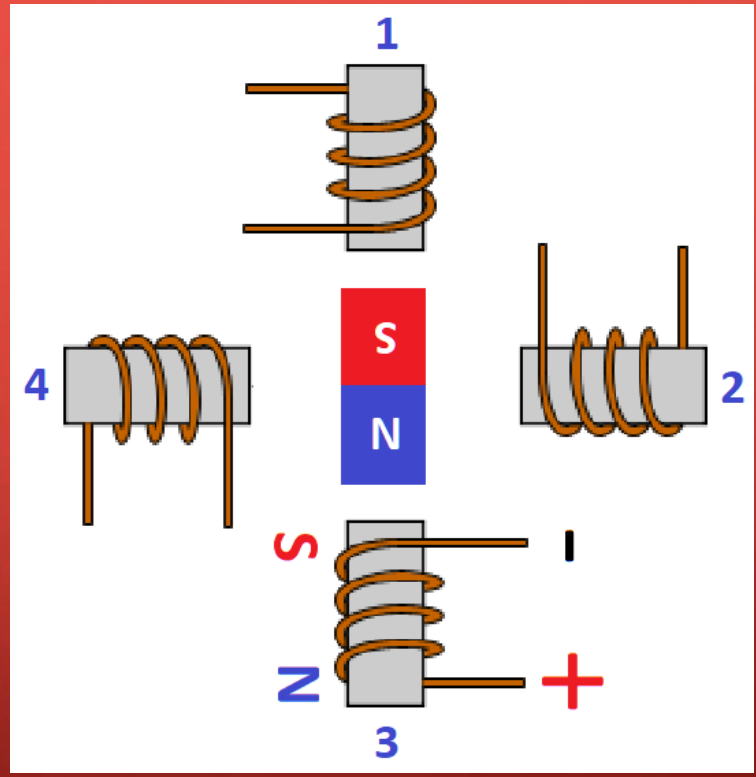
THEORY OF STEPPER MOTORS:

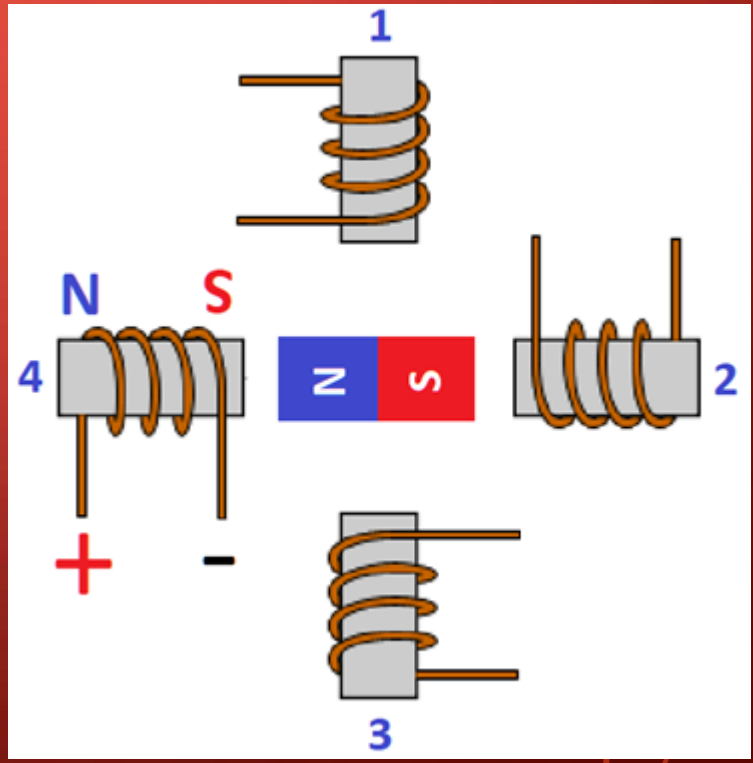
- **<u>Four Coils Full Step Activation:</u>**
  - Assume that if the current flows into the coil in clockwise direction, the North will be generated at left, South at right.
  - So, the south pole of electrical magnetic field will attract the North pole of permanent magnet.
  - After that, Deactivate Coil **1**, then activate the next coil.
  - Apply this sequence, Deactivate the current coil, then activate the next.
  - This type is called **Bipolar activation**.



THEORY OF STEPPER MOTORS:





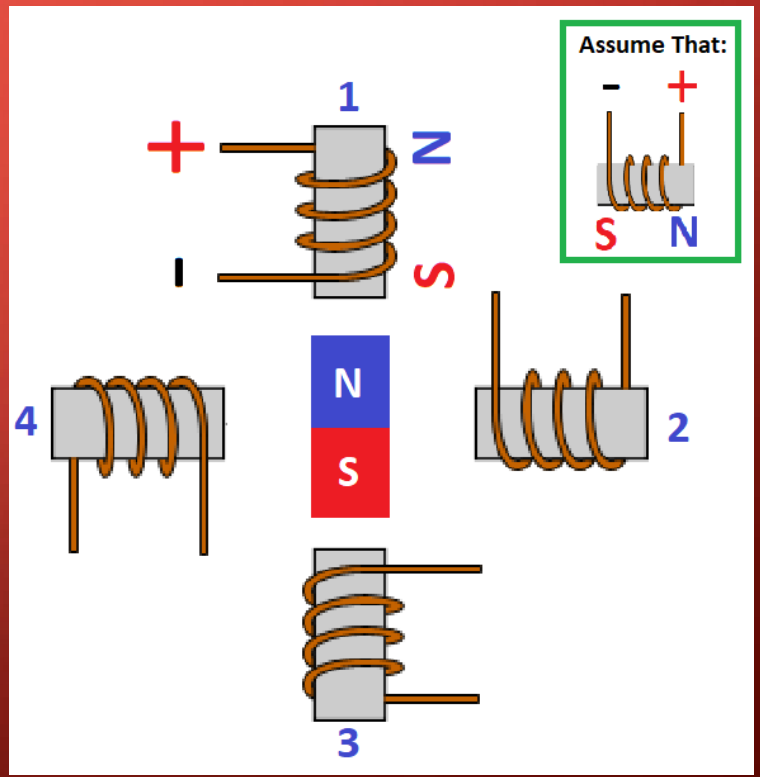


After applying this sequence, the rotor rotates at clockwise direction

THEORY OF STEPPER MOTORS:

- **<u>Four Coils Full Step Activation:</u>**
  - To change the direction of rotation, there are two methods:
    - Changing the activation sequence:

      1 → → 4 → 3 → 2



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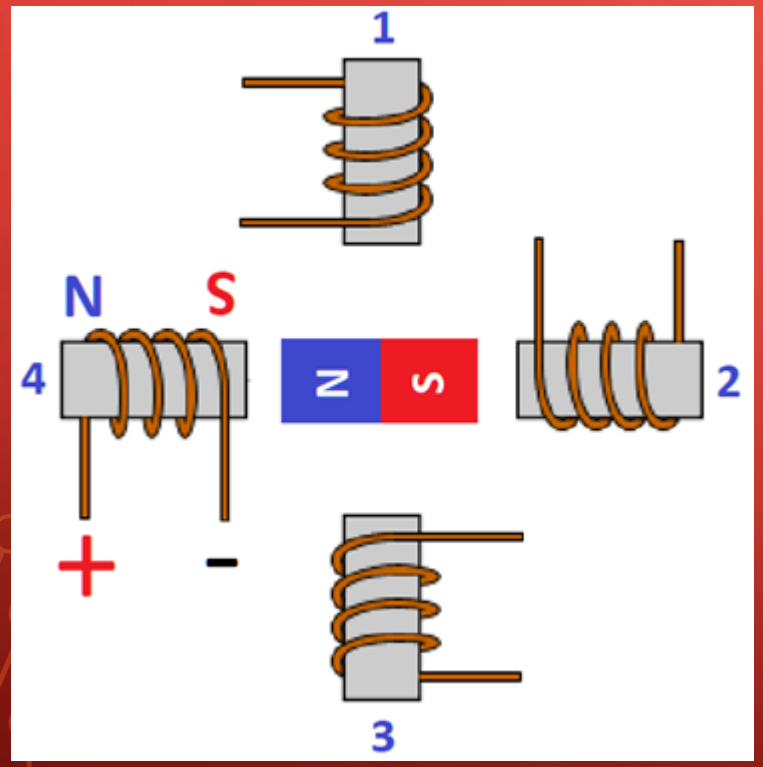
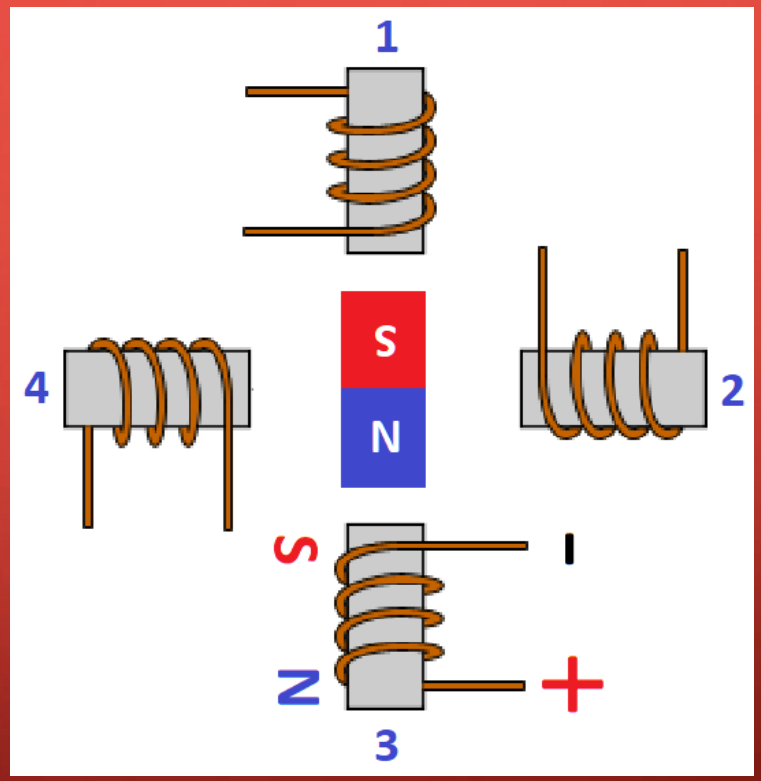
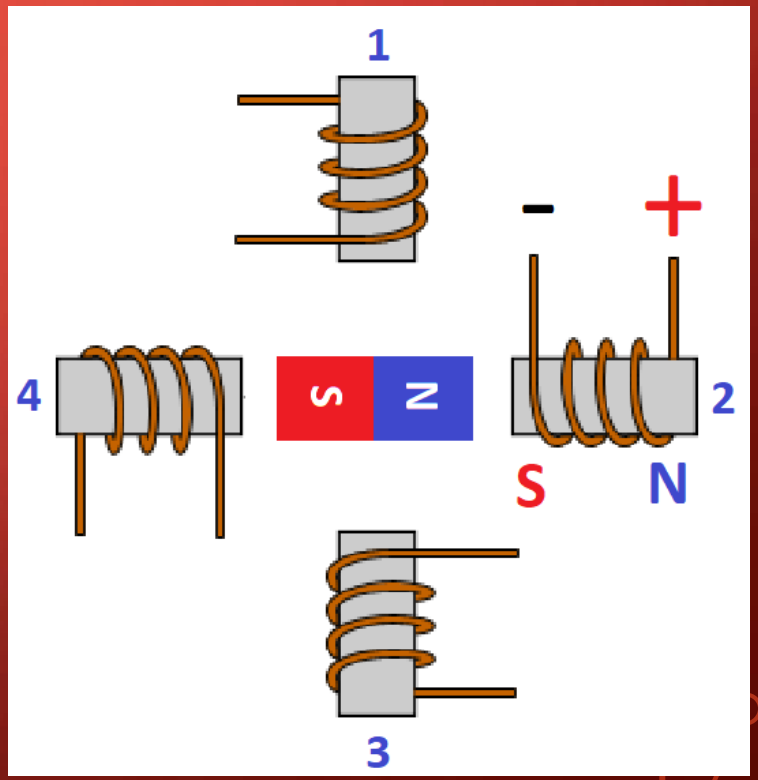


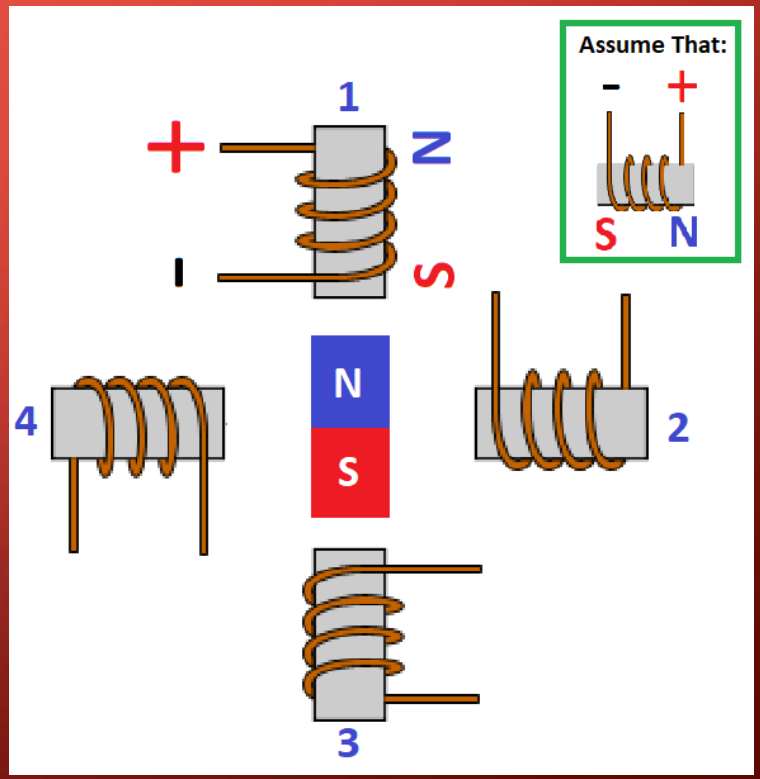




After applying this sequence, the rotor rotates at counter-clockwise direction

THEORY OF STEPPER MOTORS:

- **<u>Four Coils Full Step Activation:</u>**
  - To change the direction of rotation, there are two methods:
    - Changing the polarity of some coils.



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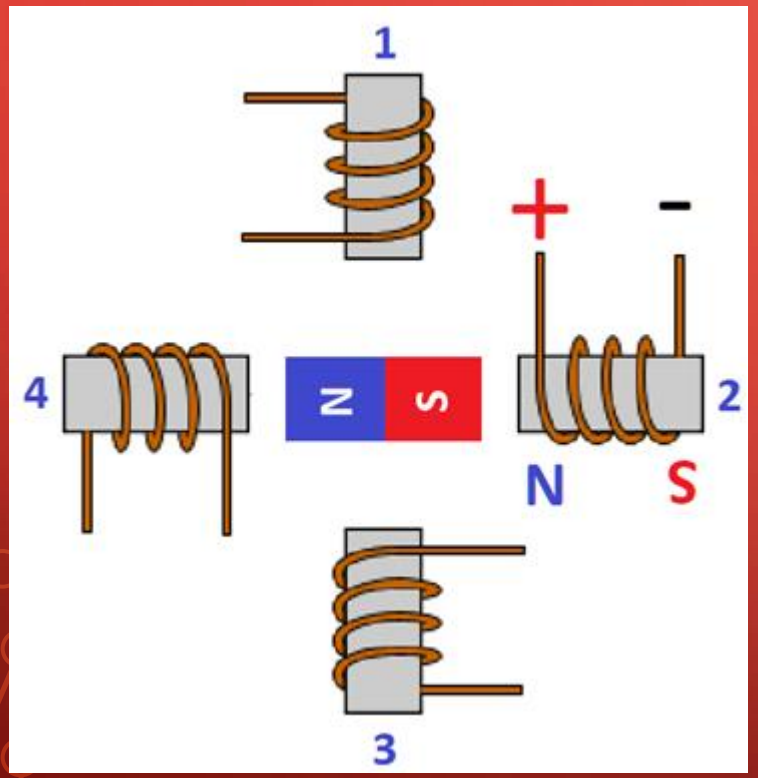
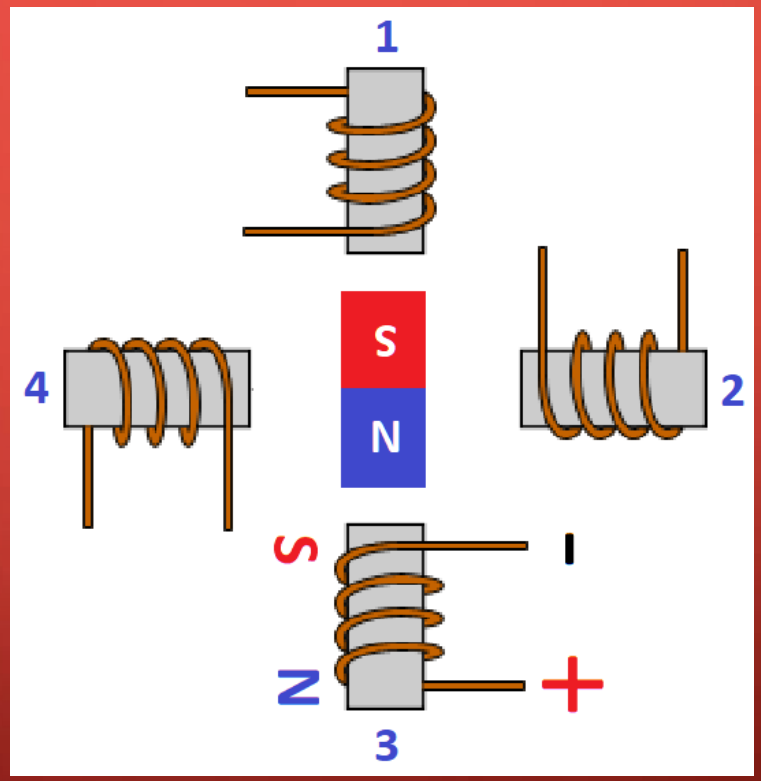
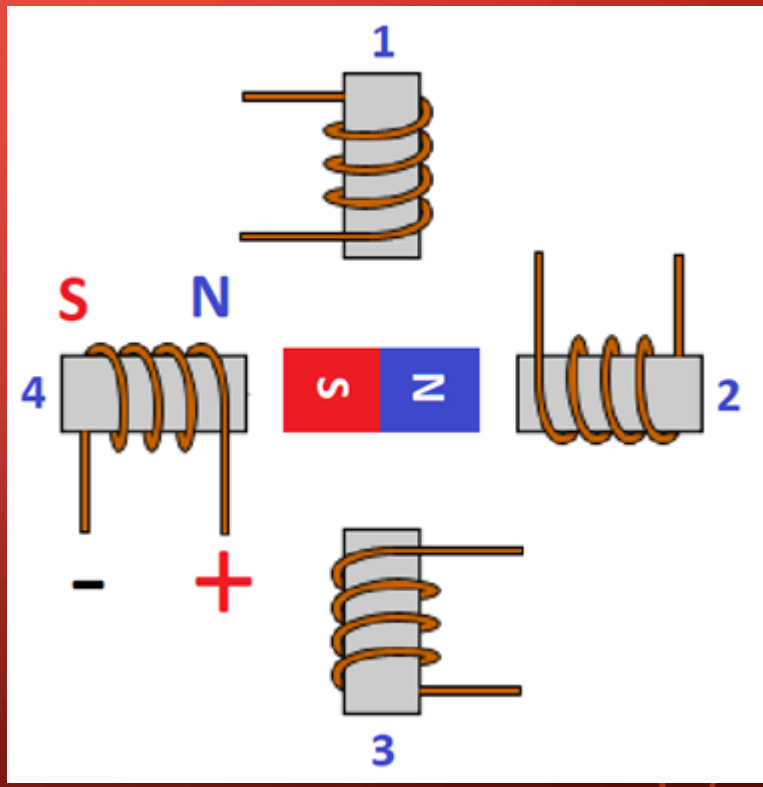


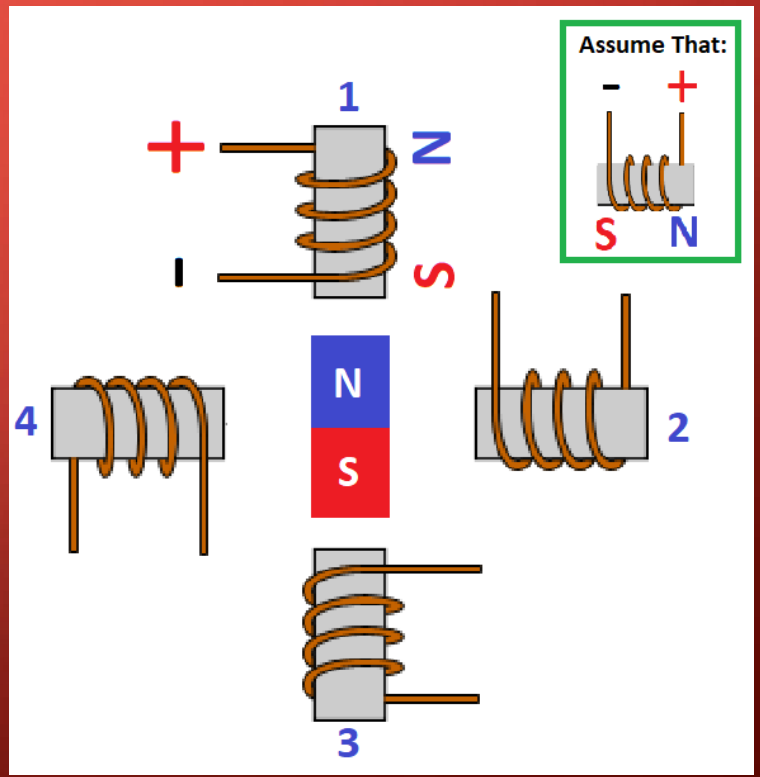




After applying this sequence, the rotor rotates at counter-clockwise direction

THEORY OF STEPPER MOTORS:

- **<u>Four Coils Half Step Activation:</u>**
  - Assume that if the current flows into the coil in clockwise direction, the North will be generated at left, South at right.
  - So, the south pole of electrical magnetic field will attract the North pole of permanent magnet.
  - After that, activate Coil **1** and the next coil to generate half step.
  - Apply this sequence.
  - This type is called **Bipolar activation**.



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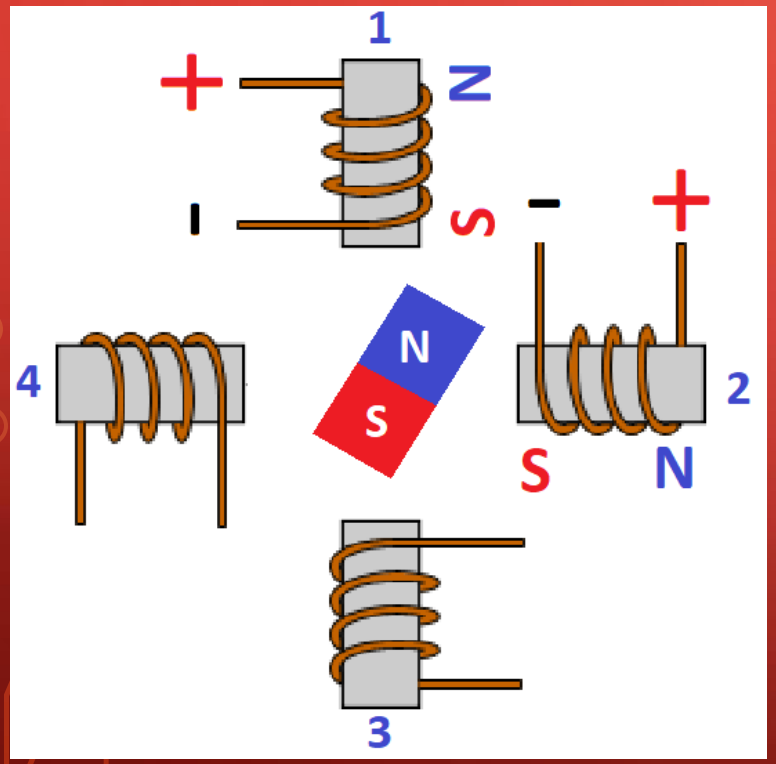

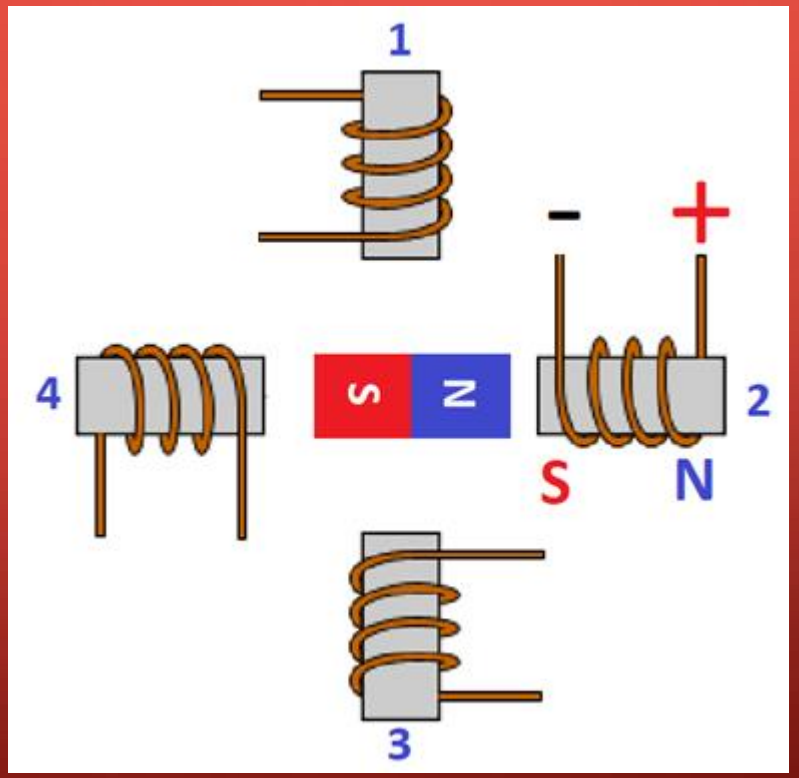

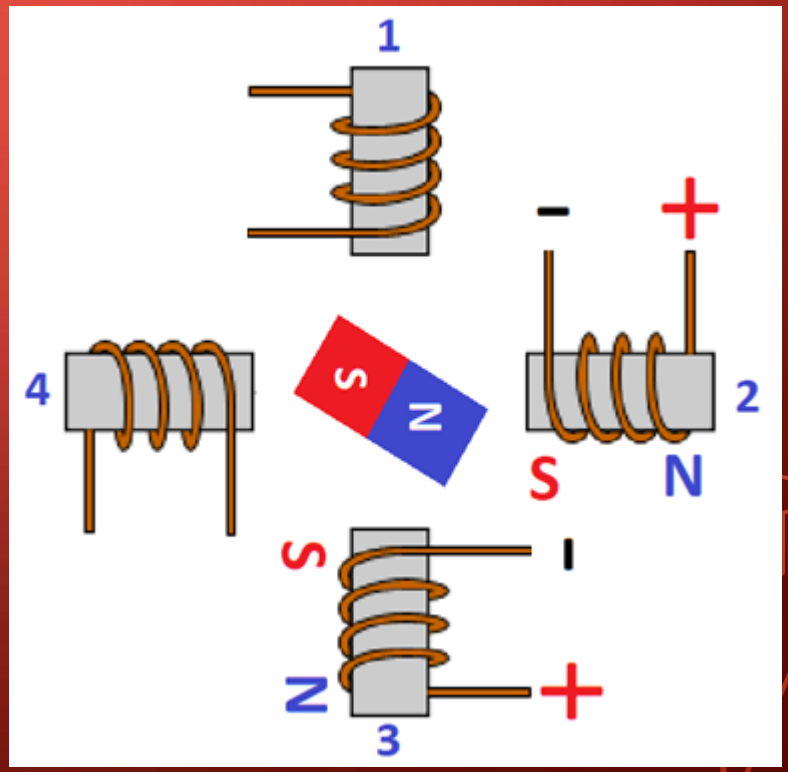

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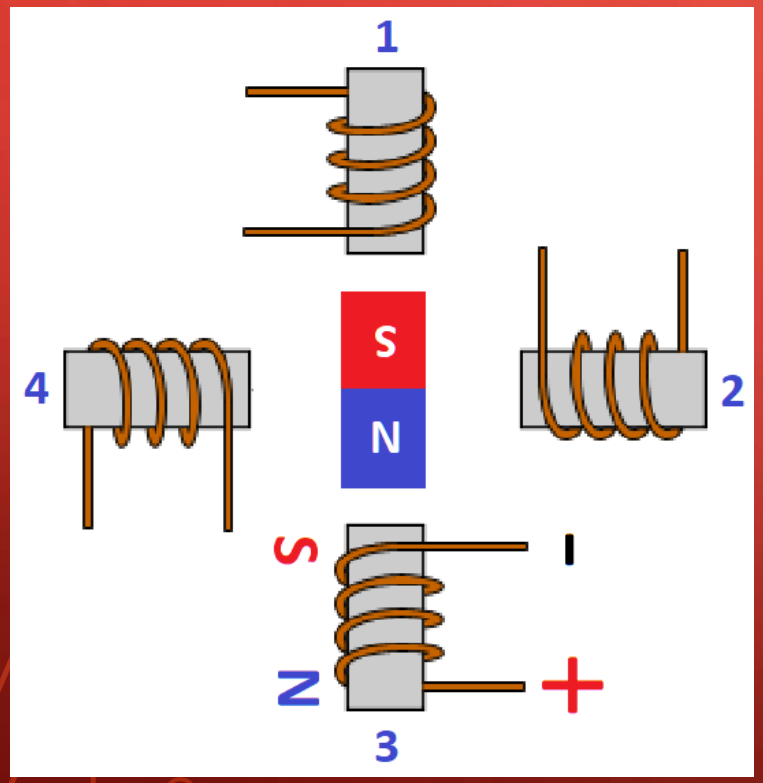
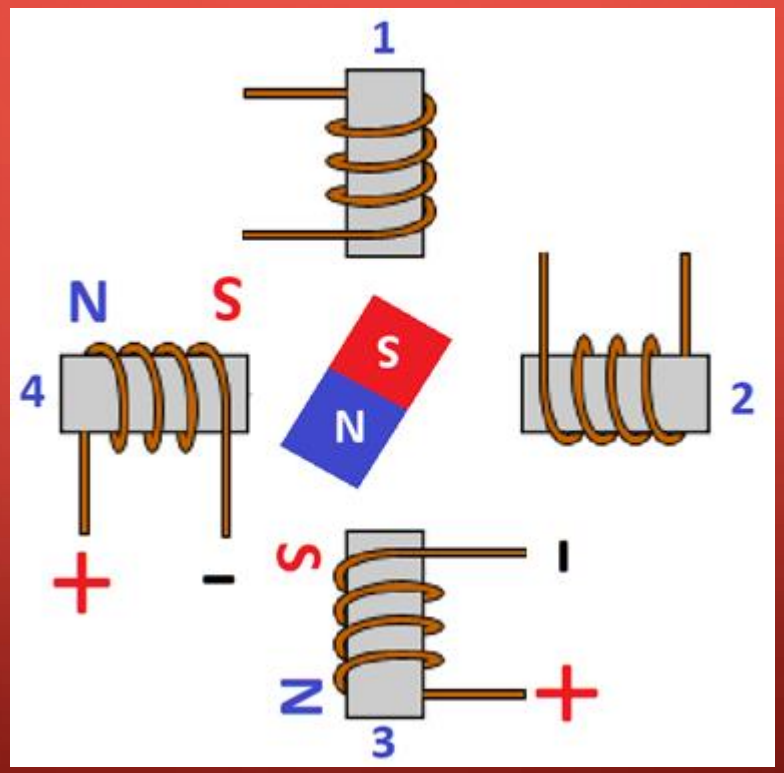
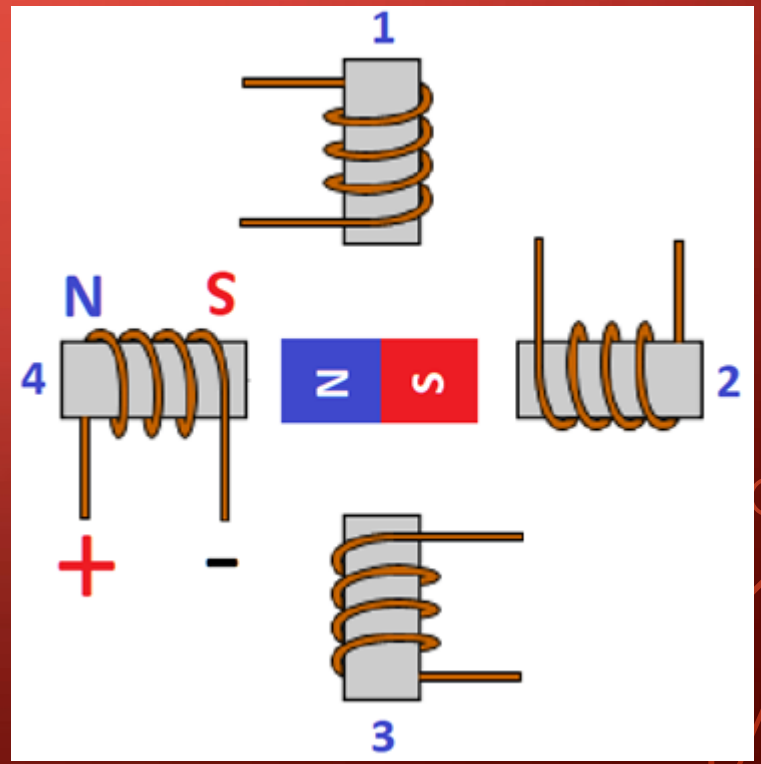
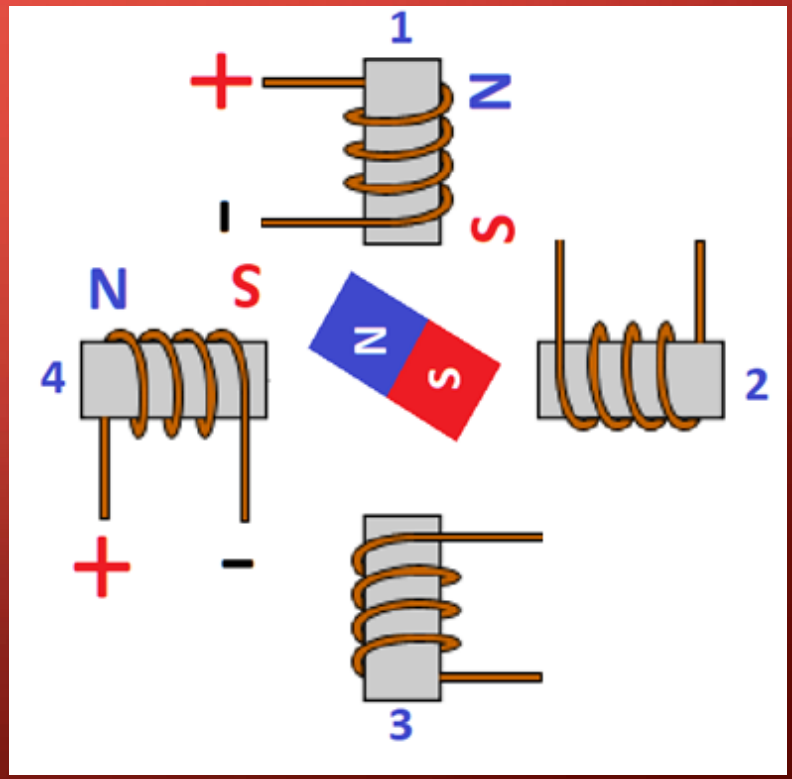






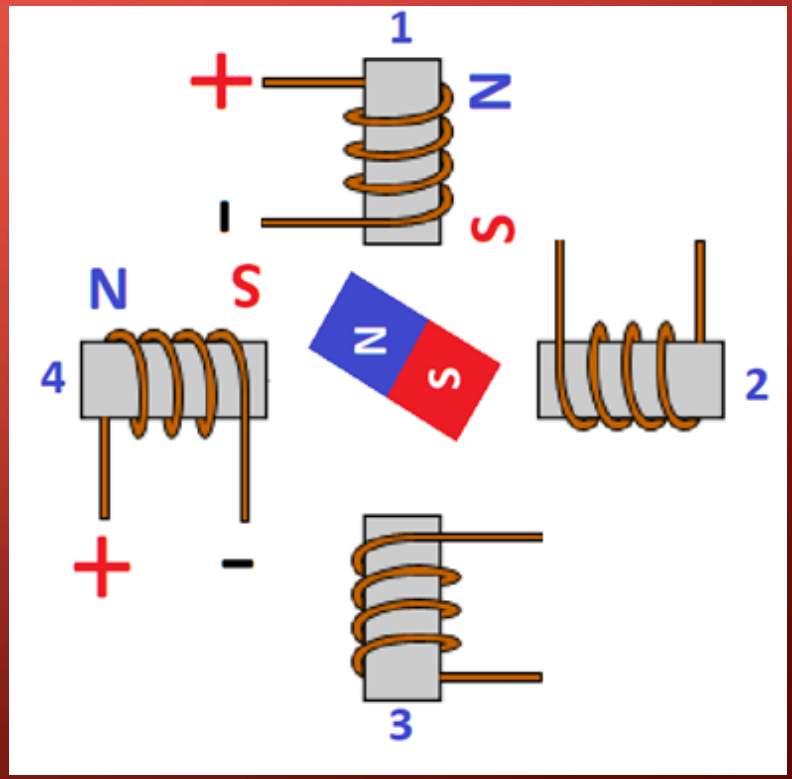
THEORY OF STEPPER MOTORS:

- **<u>Four Coils Half Step Activation:</u>**
  - It takes Eight steps for a completely cycle.
  - The stride angle become half of the full-step angle.
  - It can be reversed by the same way into full step by changing the activation sequence or by changing the polarity of some of coils.



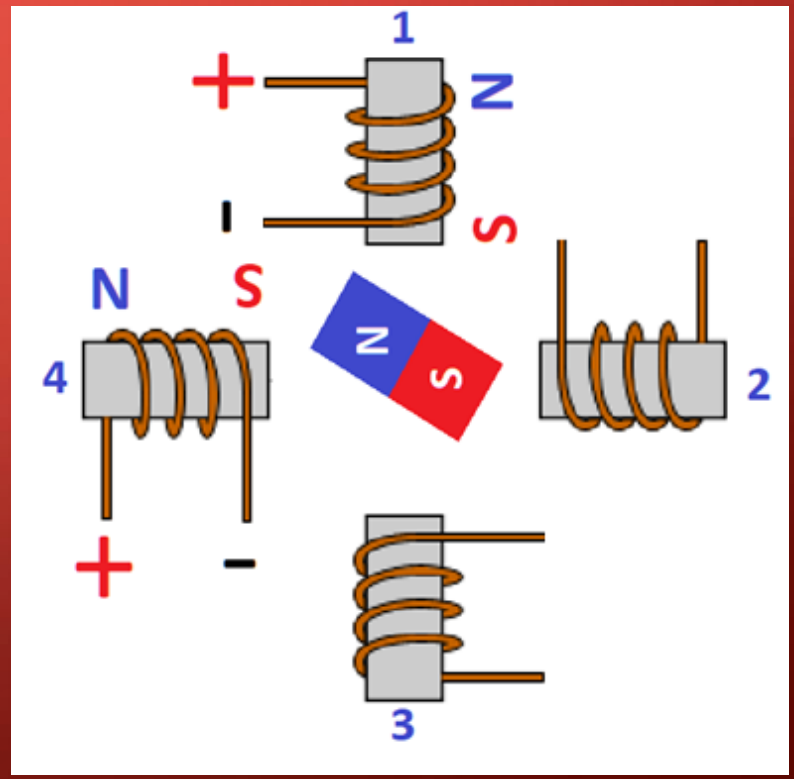
THEORY OF STEPPER MOTORS:

- **<u>Four Coils Half Step Activation:</u>**
  - Micro stepping:
    - It can be seen as a further enhancement of half-step mode, because it allows to reduce even further the step size and to have a constant torque output. This is achieved by controlling the intensity of the current flowing in each phase. Using this mode requires a more complex motor driver compared to the previous solutions.



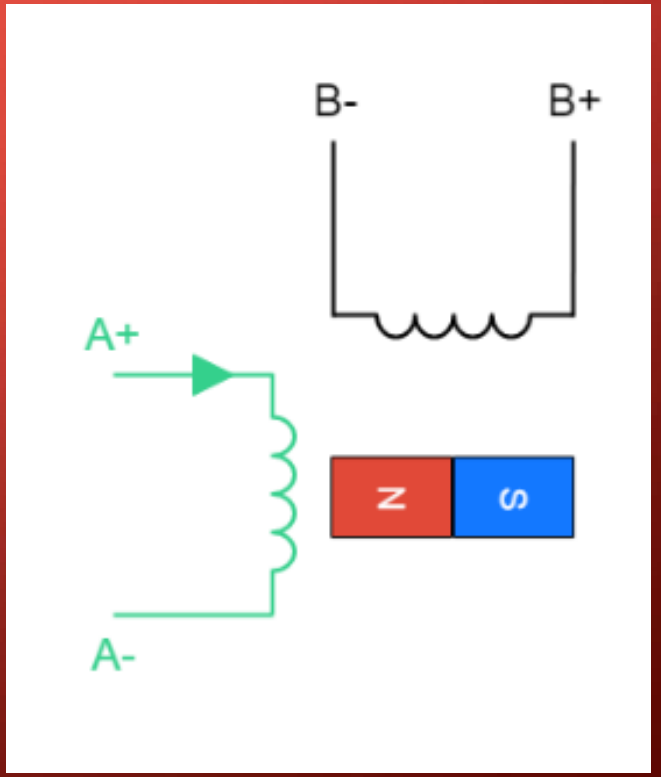
THEORY OF STEPPER MOTORS:

- **<u>Four Coils Half Step Activation:</u>**
  - Micro stepping:
    - Brief of micro stepping is to activate the different coils by different voltage, I meant that as example, at 1,2 activation, the voltage on coil 2 is reduced to generate several step angles.



THEORY OF STEPPER MOTORS:

- **<u>Two Coils Full Step Activation:</u>**
  - Assume that if the current flows into the coil in clockwise direction, the North will be generated at left, South at right.
  - So, the south pole of electrical magnetic field will attract the North pole of permanent magnet.
  - After that, Deactivate Coil 1, then activate the next coil.



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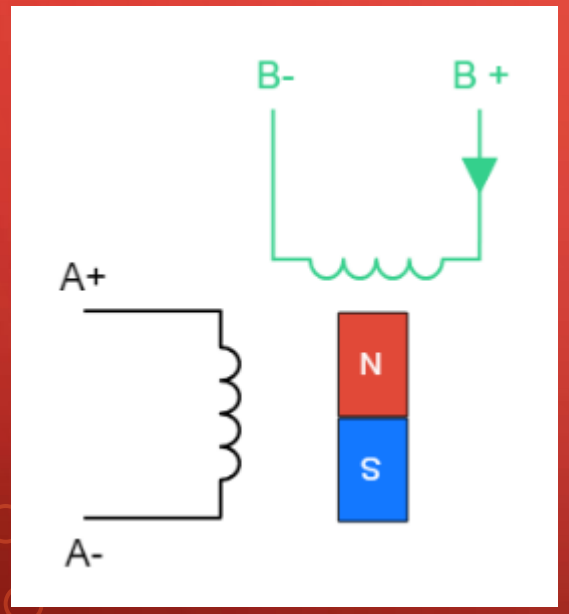
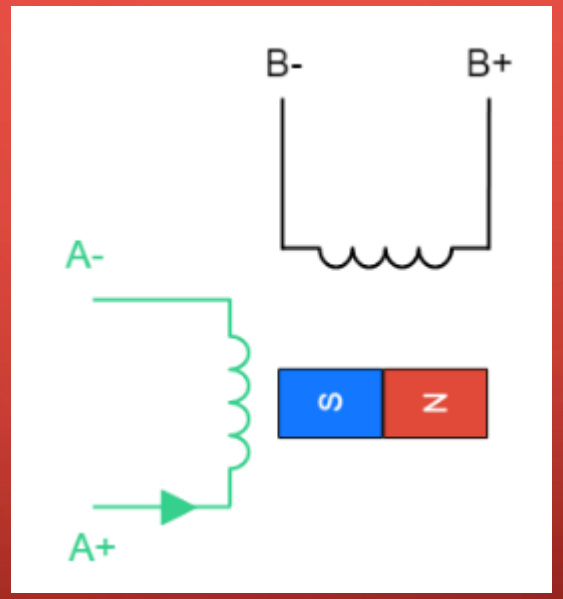
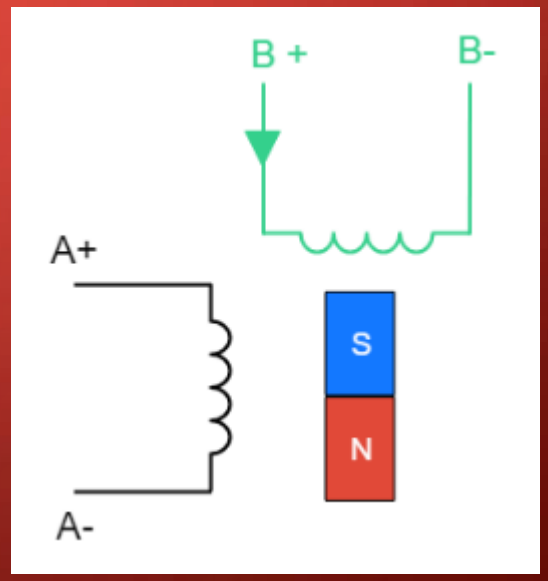




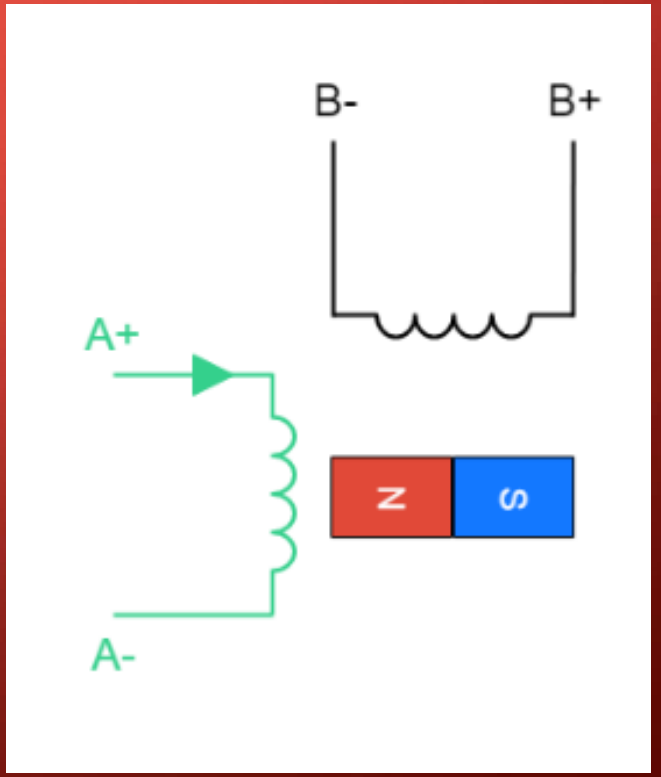


After deactivation of the coil 2, the first coil will be activated in inverse polarity.

Final step, coil 2 also will be activated in inverse polarity.

THEORY OF STEPPER MOTORS:

- **<u>Two Coils Half Step Activation:</u>**
  - Assume that if the current flows into the coil in clockwise direction, the North will be generated at left, South at right.
  - So, the south pole of electrical magnetic field will attract the North pole of permanent magnet.
  - After that, activate Coil 1 and activate the next coil.



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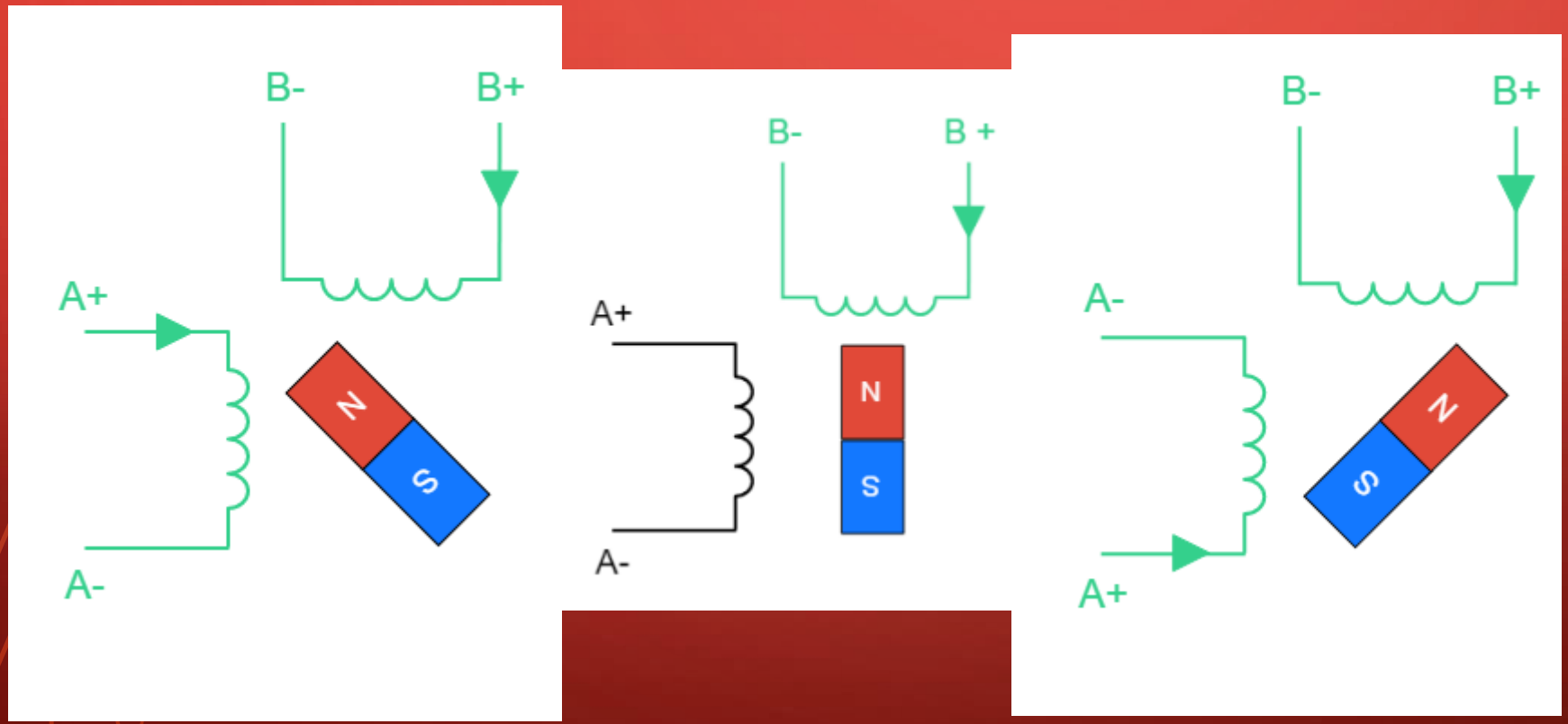

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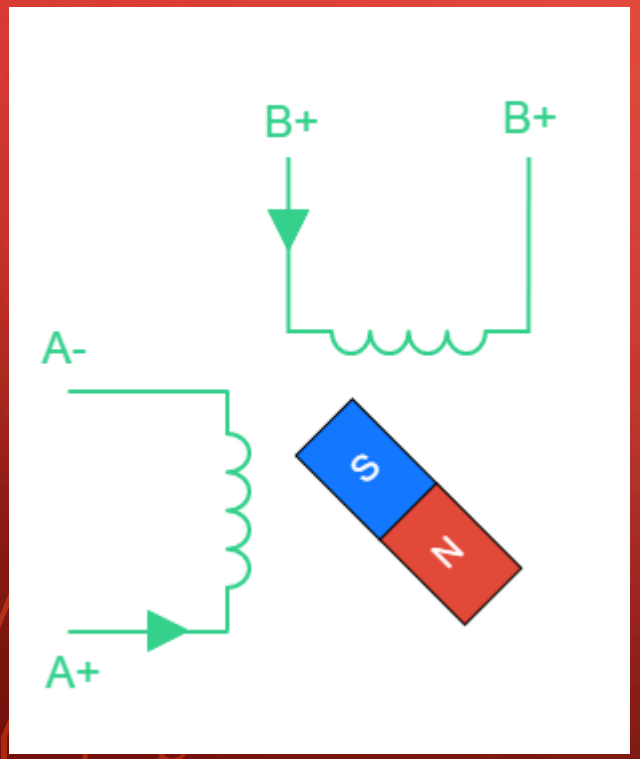
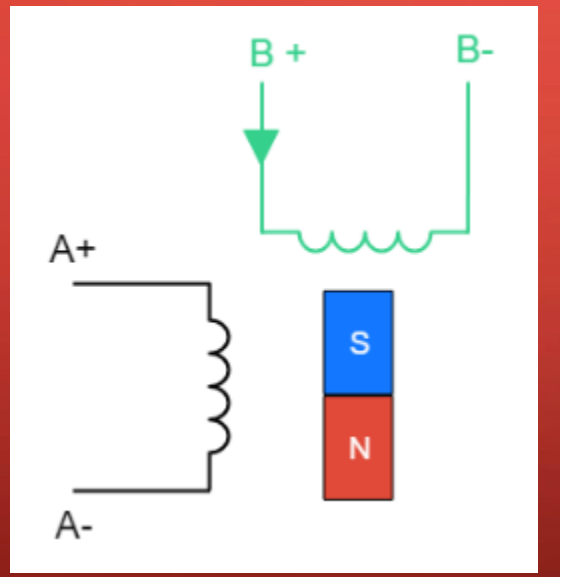
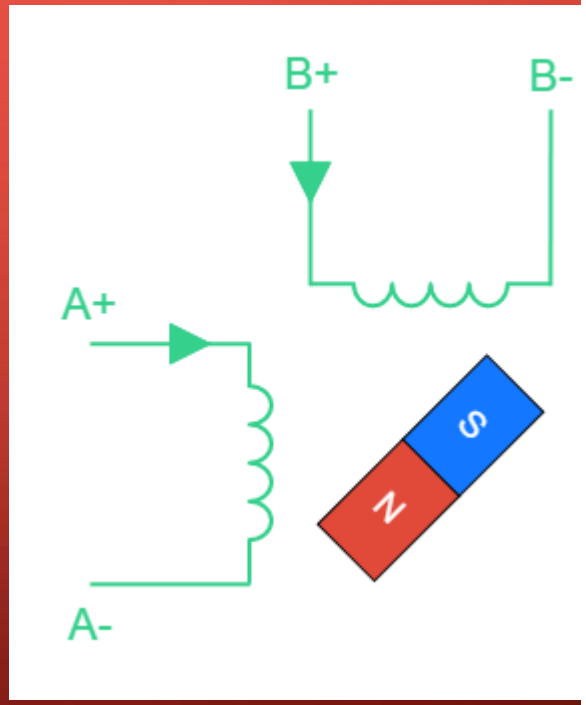
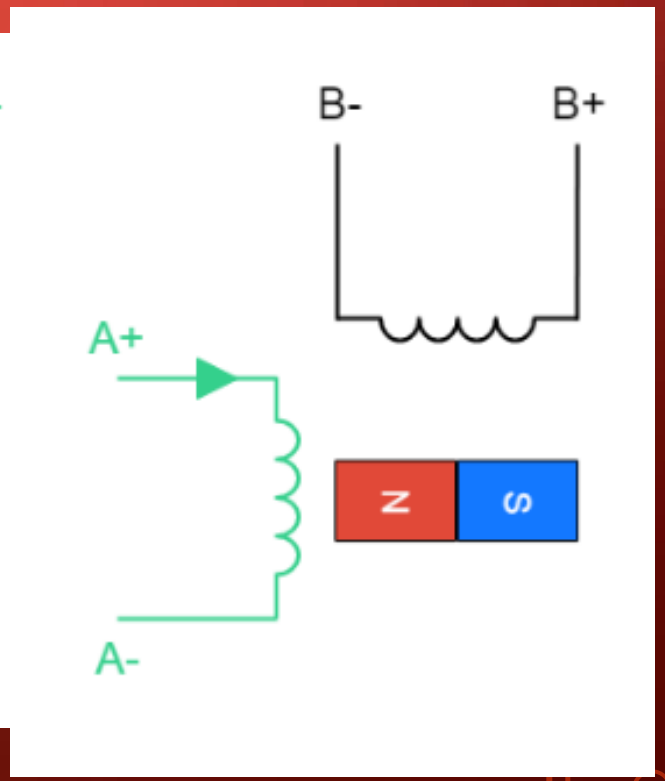


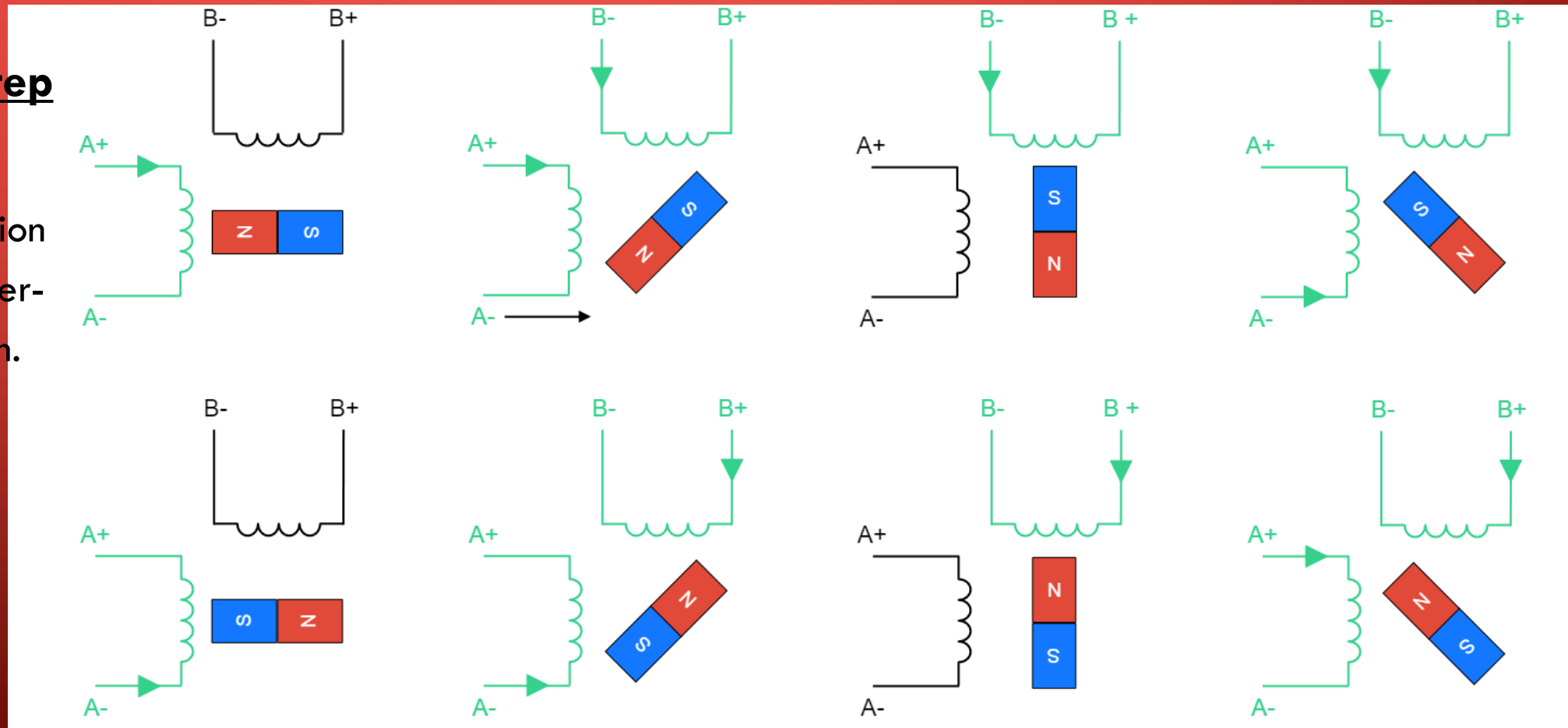






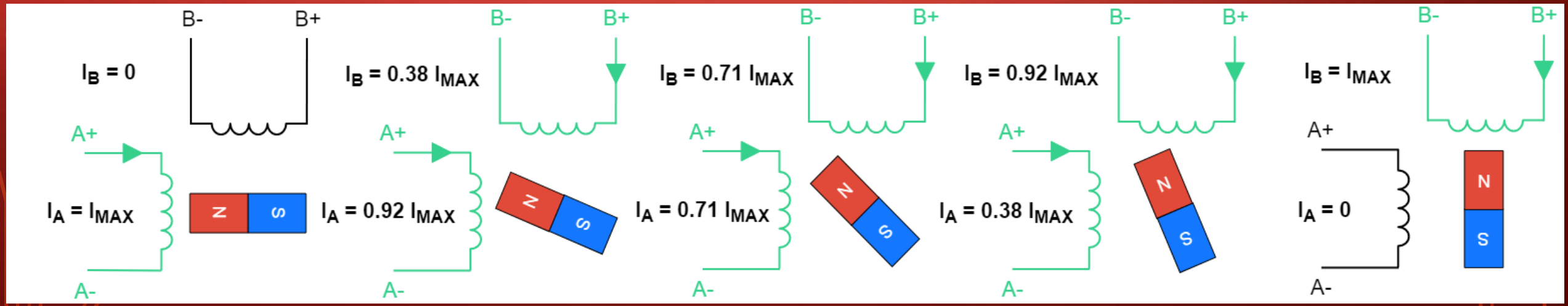
THEORY OF STEPPER MOTORS:

- **Two Coils Half Step Activation:**
  - This is the activation method for counter-clockwise rotation.



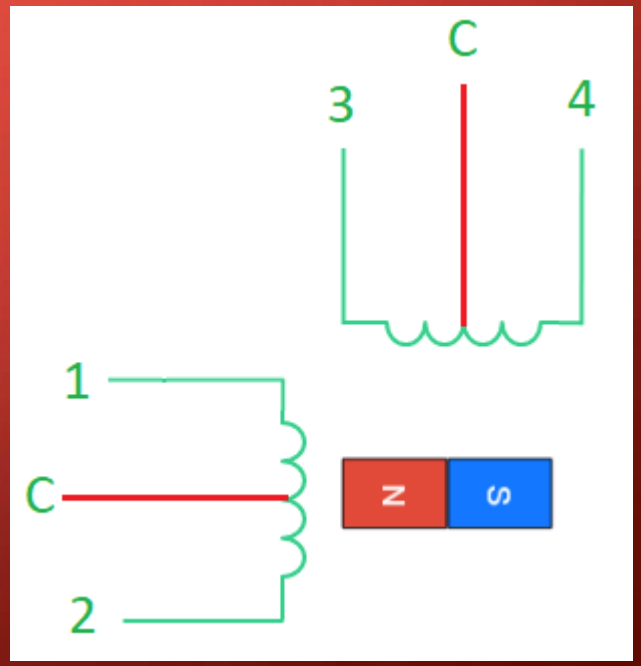
THEORY OF STEPPER MOTORS:

- **<u>Two Coils, Micro Stepping:</u>**
  - This is the activation method for counter-clockwise rotation.

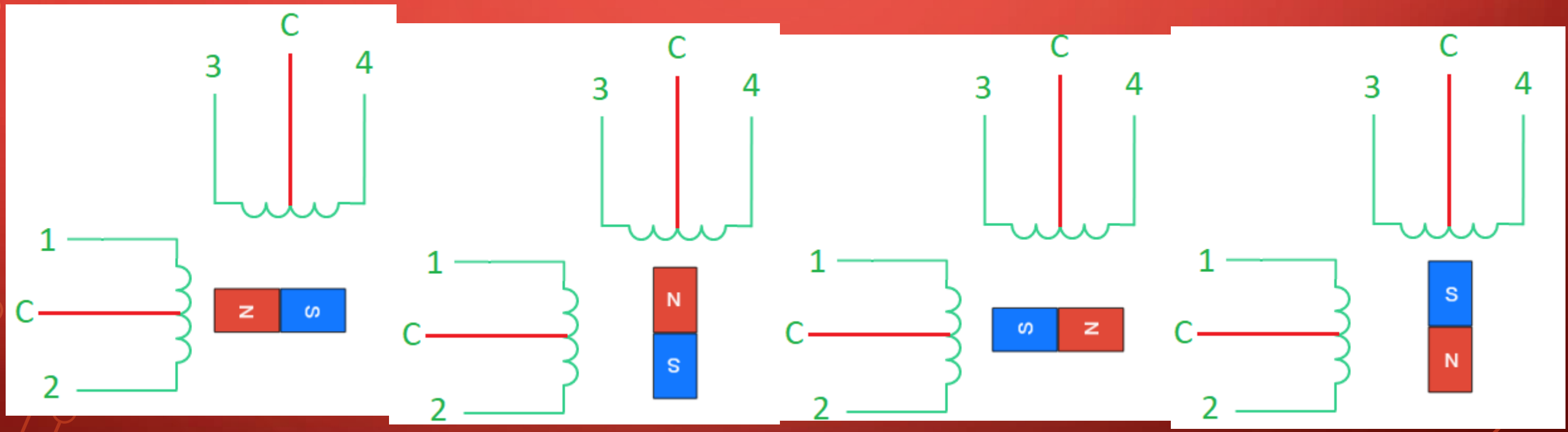


THEORY OF STEPPER MOTORS:

- **<u>Two Coils, Common Polar, Full Step Activation:</u>**
  - There are only two coil in this type of stepper motor, but each coil is divided from its middle point.
  - Because of division, Common pin polar exists, so the coil activation needs only one polar activation.
  - Now, we will apply clockwise rotation sequence on the coils as the following:



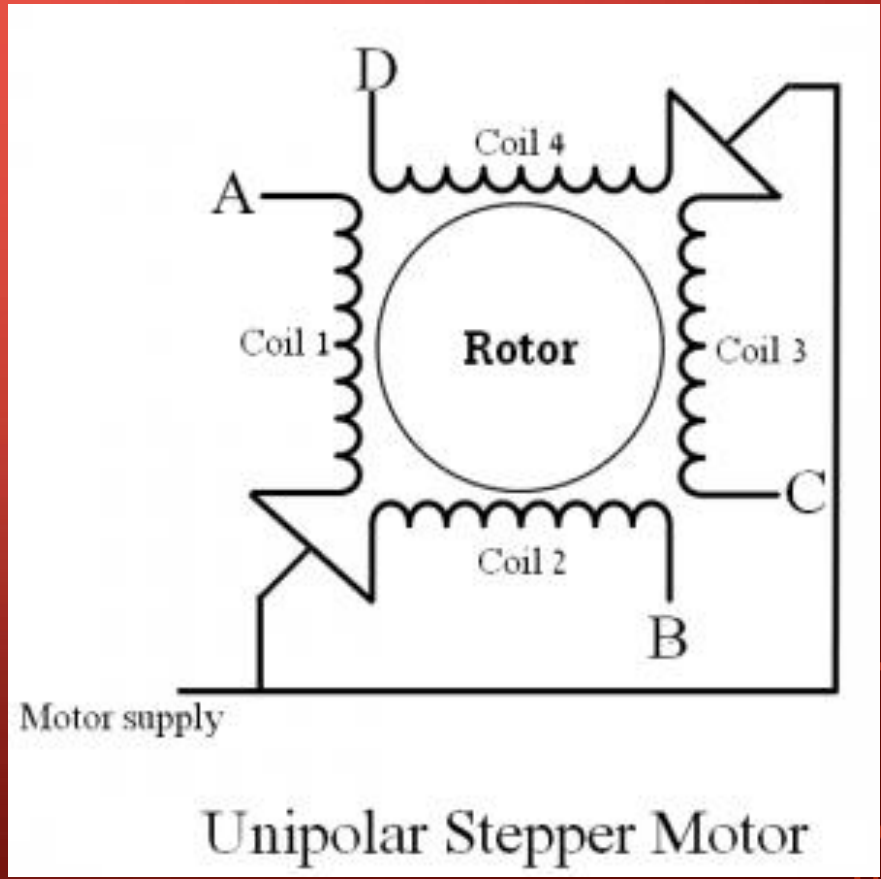
THEORY OF STEPPER MOTORS:



Applying High on **1,** Low on **Common.**
Applying High on **3,** Low on **Common.**
Applying High on **2,** Low on **Common.**
Applying High on **4,** Low on **Common.**

THEORY OF STEPPER MOTORS:

- **<u>Two Coils, Common Polar, Full Step Activation:</u>**
  - According the last activation method, you can notice that the common pin was activated every time by the same signal, So, this type of this motor is called **Unipolar activation.**
  - This motor type we will work on.



Unipolar Stepper Motor

THEORY OF STEPPER MOTORS:

- **<u>Different between Unipolar and Bipolar:</u>**
  - Assume that we has two identical motors with two coils, but one of them is unipolar and the other is bipolar

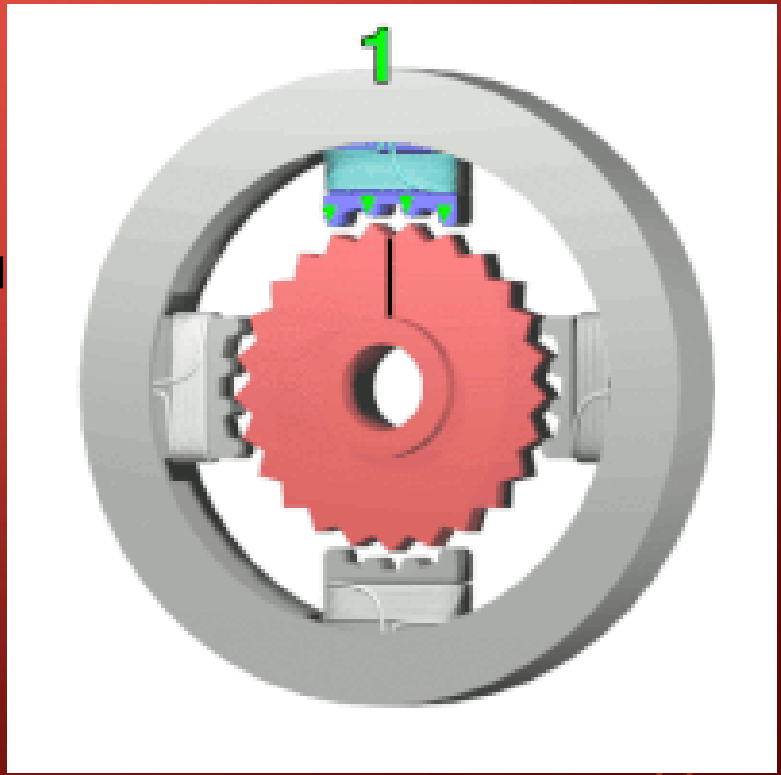
Criteria	Unipolar	Bipolar
Coil implementation	There are two coils with common pole	There are two coils without additional pole
Num of Control transistors	4	8
Torque	Weak	Double of unipolar
Configurability	Can be run as a Bipolar, also	Only runs as Bipolar

THEORY OF STEPPER MOTORS:

- **Internal Modification:**
  - As we mentioned before, we can decrease the angle of step by activation double coils or
    micro stepping, but now we will decrease the step by increasing the number of internal coils.
  - Unfortunately, increasing the number of coils will increase the number of wires outside the motor.
  - It will be difficult to control this motor because of huge quantity of wires.

THEORY OF STEPPER MOTORS:

- **Internal Modification:**
  - The last problem has been solved by that: the coils has 90 degrees between of them will have common wires outside the motor, like the following figure, all blue coils have the same wire outside the motor, and pink coil also and yellow and orange and so on.
  - So, after this modification, there are only four wires are outside of the motor.
  - If the blue coil is activated, all coils will generate electrical-magnetic field, and the nearest coil to the permanent magnet will attract the permanent magnet.



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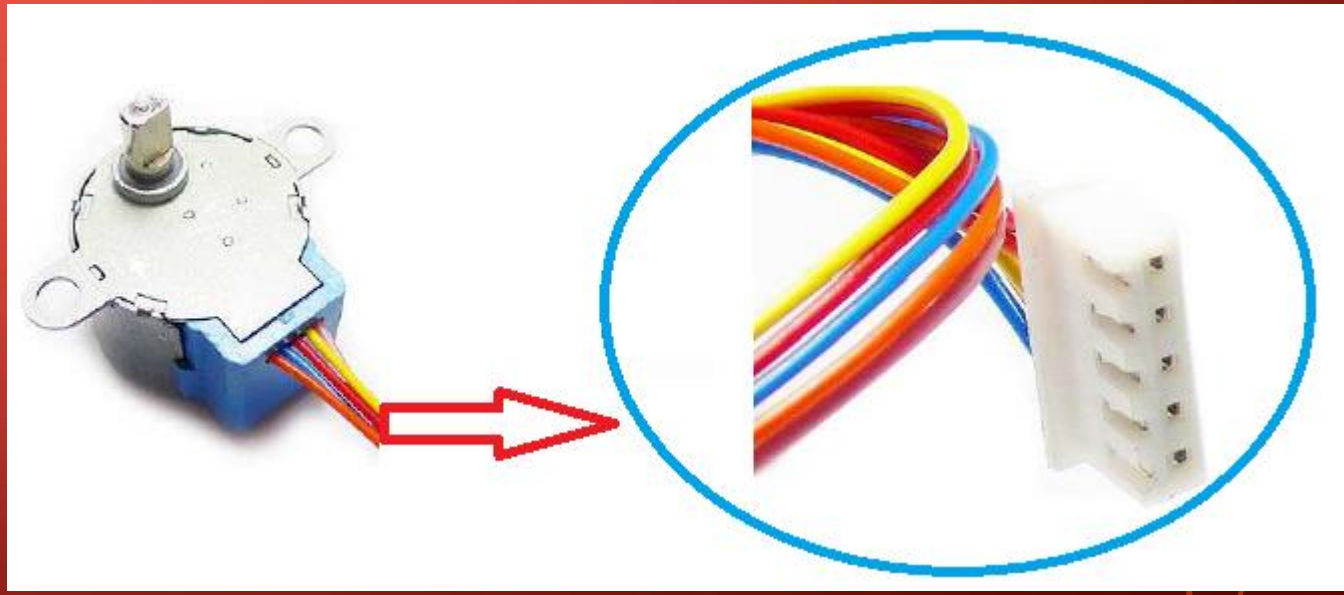
OUR STEPPER MOTOR:

- We will use a small stepper motor that works at 5-Volt power, it is Two-coil-common-wire motor.
- This Stepper can be run as:
  - Unipolar.
  - Bipolar.
- Its name is 28BYJ-48.
- It has five wires outside the motor:
  - Blue.
  - Pink.
  - Yellow.
  - Orange.
  - Red.



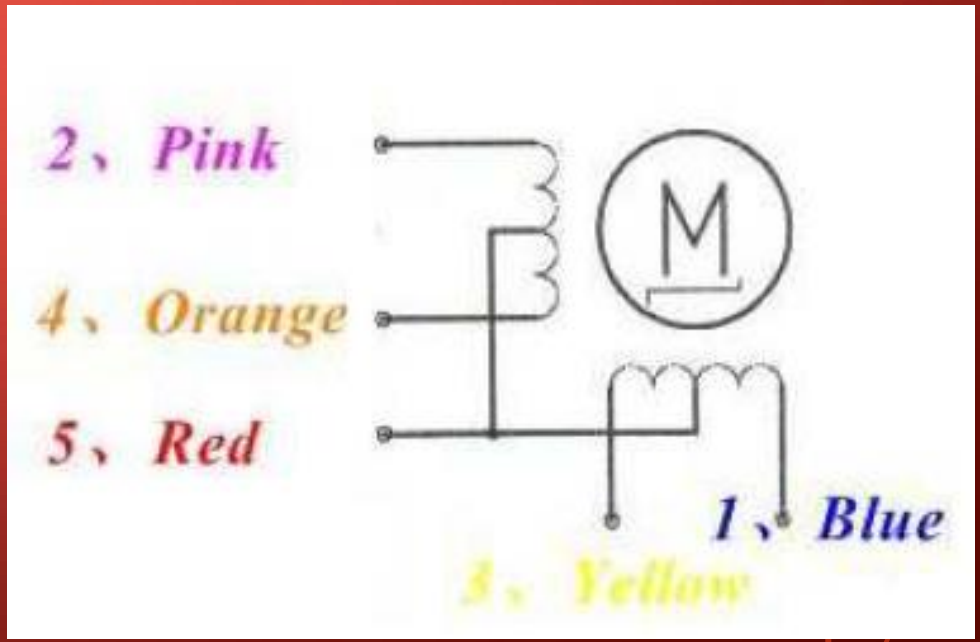
OUR STEPPER MOTOR:

- Into the following figure, there is the datasheet of 28BYJ-48.
- Stride angle means the minimum angle per step(half step).
- Variation ratio means that there is a gearbox that has been implemented on the rotor shaft of motor, it is used to increase the torque and decrease the rotational speed.
- We can get the full step by multiplying the stride angle by Two (11.25/64).

Rated voltage :	5VDC
Number of Phase	4
Speed Variation Ratio	1/64
Stride Angle	5.625°/64
Frequency	100Hz
DC resistance	50Ω±7%(25℃)
Idle In-traction Frequency	> 600Hz
Idle Out-traction Frequency	> 1000Hz
In-traction Torque	>34.3mN.m(120Hz)
Self-positioning Torque	>34.3mN.m
Friction torque	600-1200 gf.cm
Pull in torque	300 gf.cm
Insulated resistance	>10MΩ(500V)
Insulated electricity power	600VAC/1mA/1s
Insulation grade	A
Rise in Temperature	<40K(120Hz)
Noise	<35dB(120Hz,No load,10cm)
Model	28BYJ-48 – 5V

OUR STEPPER MOTOR:

- It can be used as a bipolar (blue, yellow), (pink, orange).
- It can be used as a unipolar by this sequence activation. (blue), (pink), (yellow), (orange).



FULL STEP SEQUENCE:

- These are the activation signals if the common wire is connected to ground(0 v).
- To rotate counterclockwise, start from last to beginning.

Full Step Mode Clockwise			
4 Orange	3 Yellow	2 Pink	1 Blue
0	0	0	1
0	0	1	0
0	1	0	0
1	0	0	0

HALF STEP SEQUENCE:

- These are the activation signals if the common wire is connected to ground(0 v).
- To rotate counterclockwise, start from last to beginning.

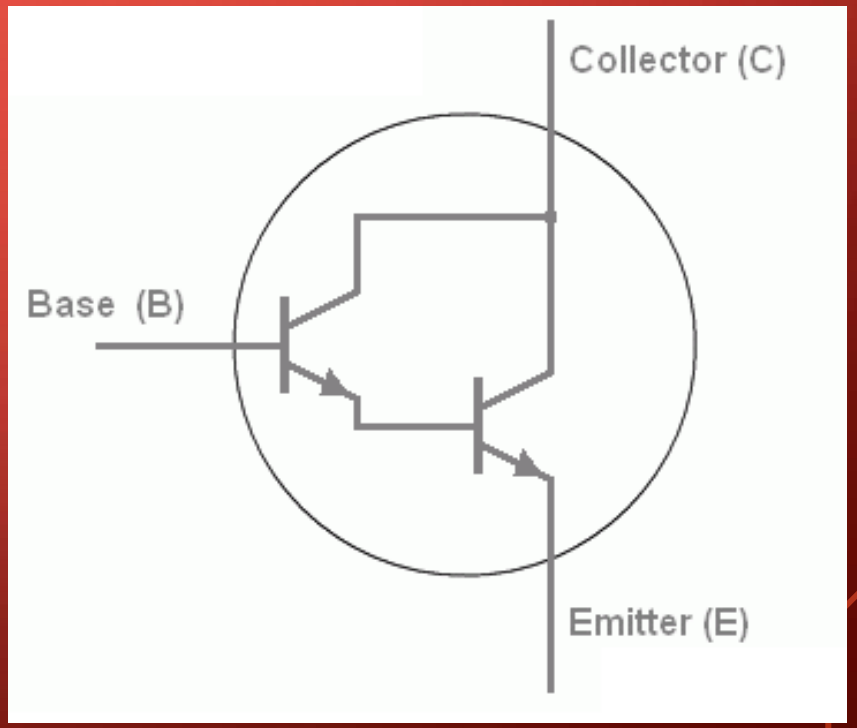
Half Step Mode Clockwise			
4 Orange	3 Yellow	2 Pink	1 Blue
1	0	0	1
0	0	0	1
0	0	1	1
0	0	1	0
0	1	1	0
0	1	0	0
1	1	0	0
1	0	0	0

ELECTRICAL SWITCH THAT WILL BE USED:

- Because the stepper is a coil-based component, so it will consume a huge power, that our micro can not be able to provide, and all coils generate a high Back EMF.
- Those problems can damage the micro controller, so we must use any electrical switch, the most common and widely used is transistors.
- The main component we will use is a Darlington Pair.

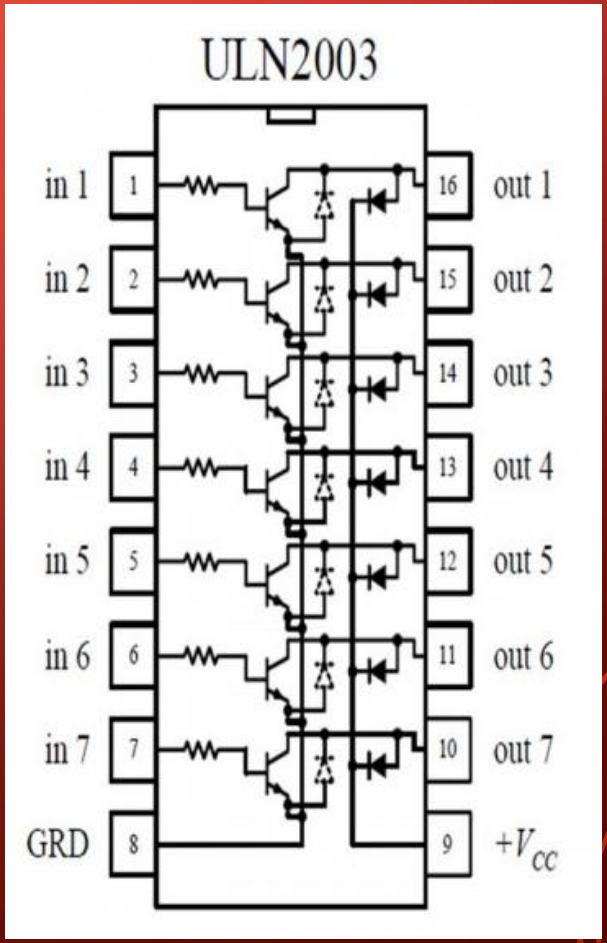
DARLINGTON PAIR:

- It is a multi-transistor configuration called the Darlington configuration (commonly called a Darlington pair) is a circuit consisting of two bipolar transistors with the emitter of one transistor connected to the base of the other, such that the current amplified by the first transistor is amplified further by the second one.[1] The collectors of both transistors are together connected. This configuration has a much higher current gain than each transistor taken separately. It acts like and is often packaged as a single transistor. It was invented in 1953 by Sidney Darlington.



ULN2003 IC WHICH IS BASED ON DARLINGTON PAIR:

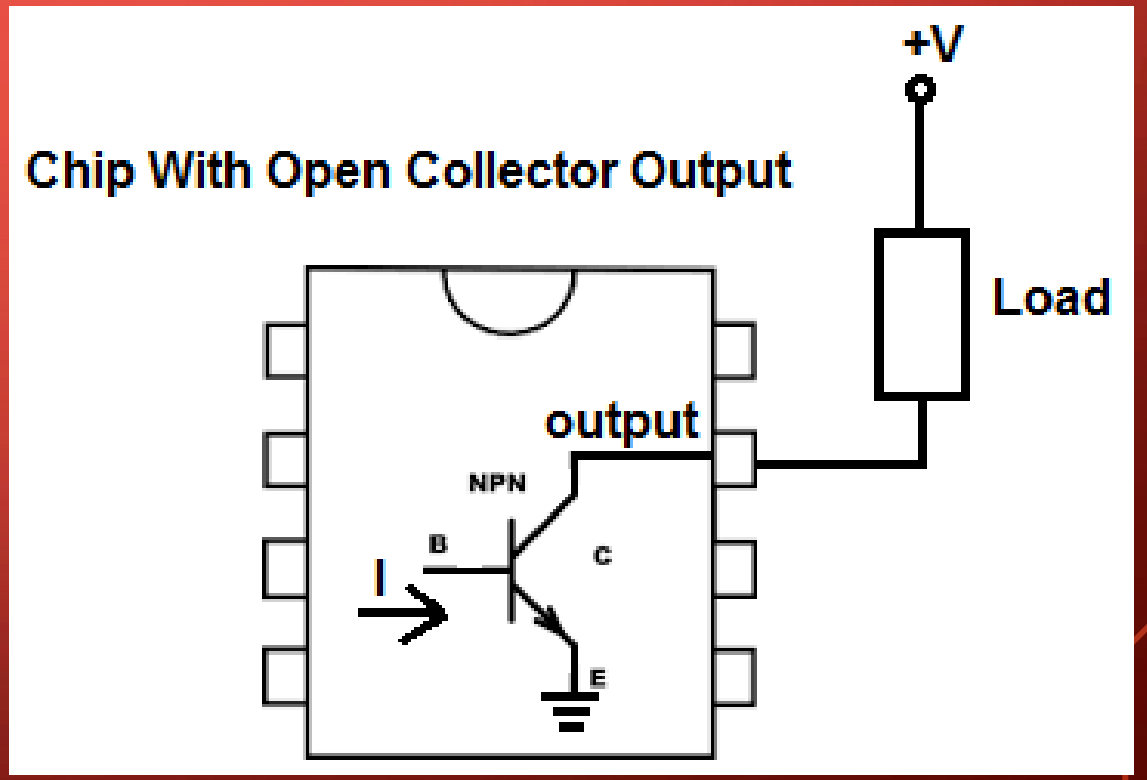
- It is an IC that has seven Darlington pair, every base pin of them is connected to in pins from In1 to in7.
- Every collector of Darlington pair is connected to out pins from out1 to out7.
- +Vcc pin16 is called free-wheeling diode which is connected to Vcc from sinking the current generated from Back EMF.
- GND pin8 is called common Emitter pin, all Emitter pins of Darlington Pair are assembled and connected to this pin.
- The last pin must be connected to GND because of the connection of this circuit is Open-Collector Circuit.



OPEN COLLECTOR CIRCUIT:

- The following figure shows that the load will be connected to the collector and the other side must be connected to Vcc.
- The common pin of our motor must be connected to Vcc.
- The

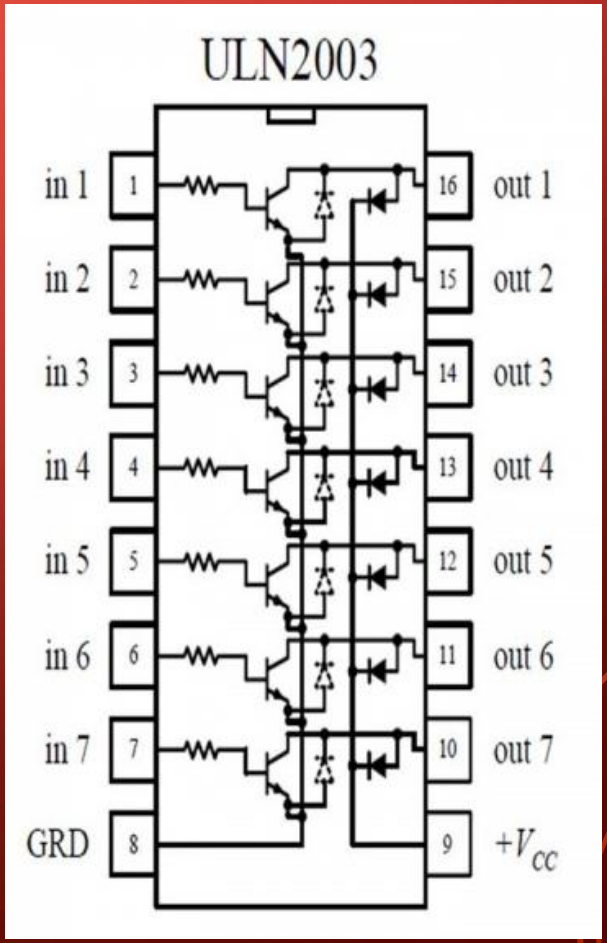
B	C
0	float
1	0



ULN2003 IC WHICH IS BASED ON DARLINGTON PAIR:

- To be the signals more logic, the ULN2003 added a NOT-Gate before the base of Darlington Pair, So the new truth table will be:

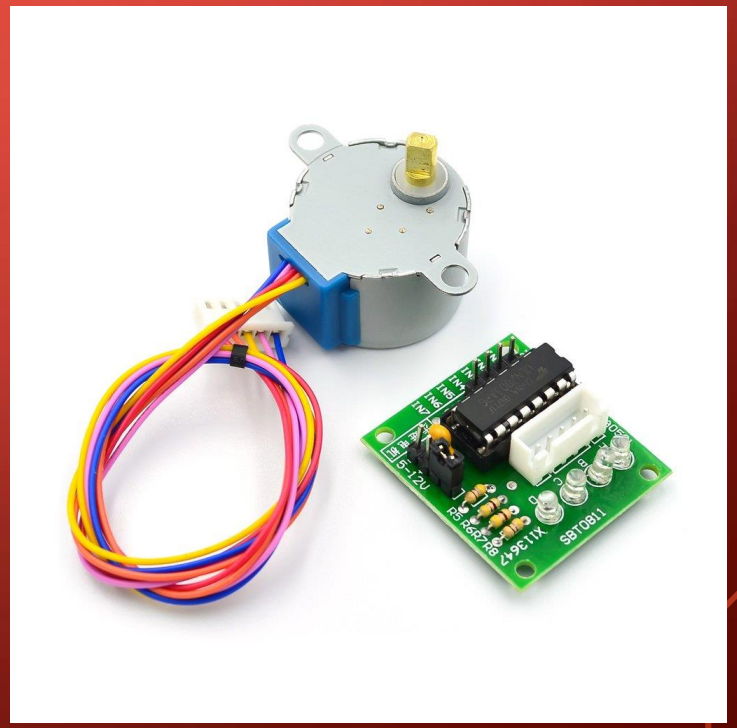
B	C
0	0
1	float



OUR STEPPER MOTOR:

- In the following figure, there are a PCB circuit which has been prepared for control our stepper motor.
- Now, the kind of activation signal is LOW because of UNL2003 Circuit as we mentioned before.
- Th

Blue	Pink	Yellow	Orange
0	1	1	1
1	0	1	1
1	1	0	1
1	1	1	0



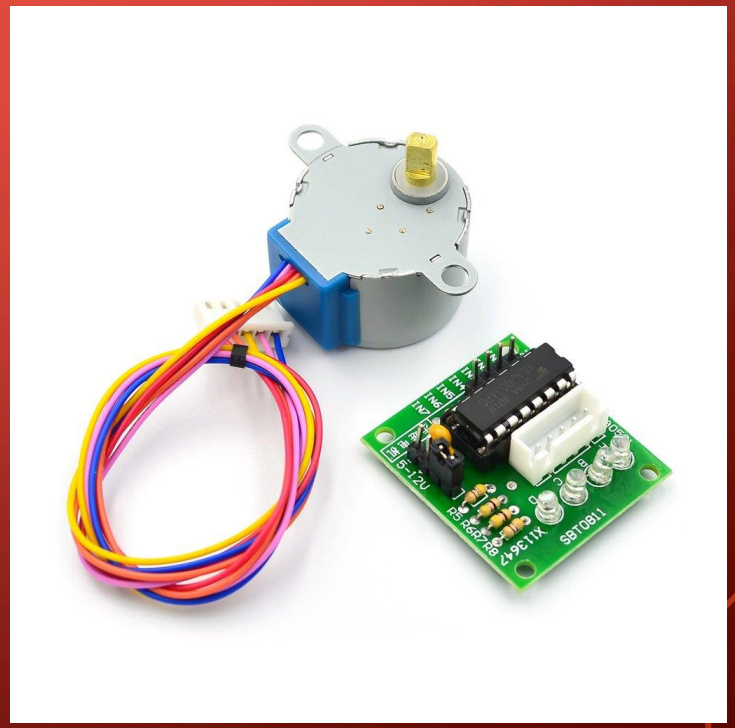
OUR STEPPER MOTOR:

- As we mentioned before, the full step of our motor is (**11.25/64**), so we will calculate how many steps our motor must move to complete one cycle?
  - Steps in a completed Cycle $= \frac{full\ rotation\ angle}{one\ step\ angle}$

$$= \frac{360}{(\frac{11.25}{64})} = 2048\ steps.$$

  - Steps in a specific angle $= \frac{Angle\ X\ steps\ into\ a\ completed\ cycle}{full\ rotation\ angle}$

$$= \frac{Angle\ X\ 2048}{360}$$



THANK YOU!