SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE NAME : 19EE407 ELECTRICAL MACHINES AND DRIVES

II YEAR / 04 SEMESTER MECH

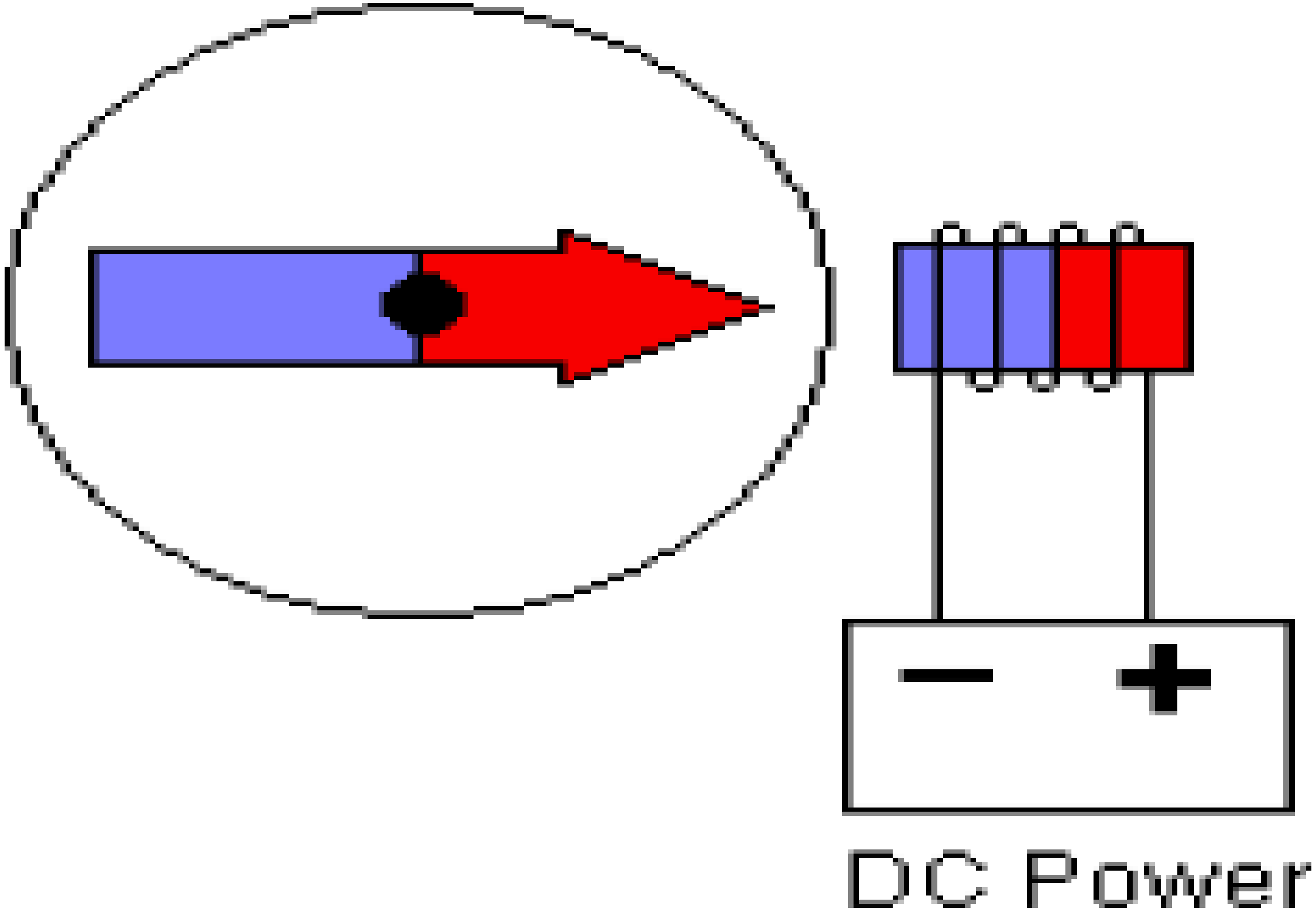
Unit 2 – ELECTRICAL MOTORS

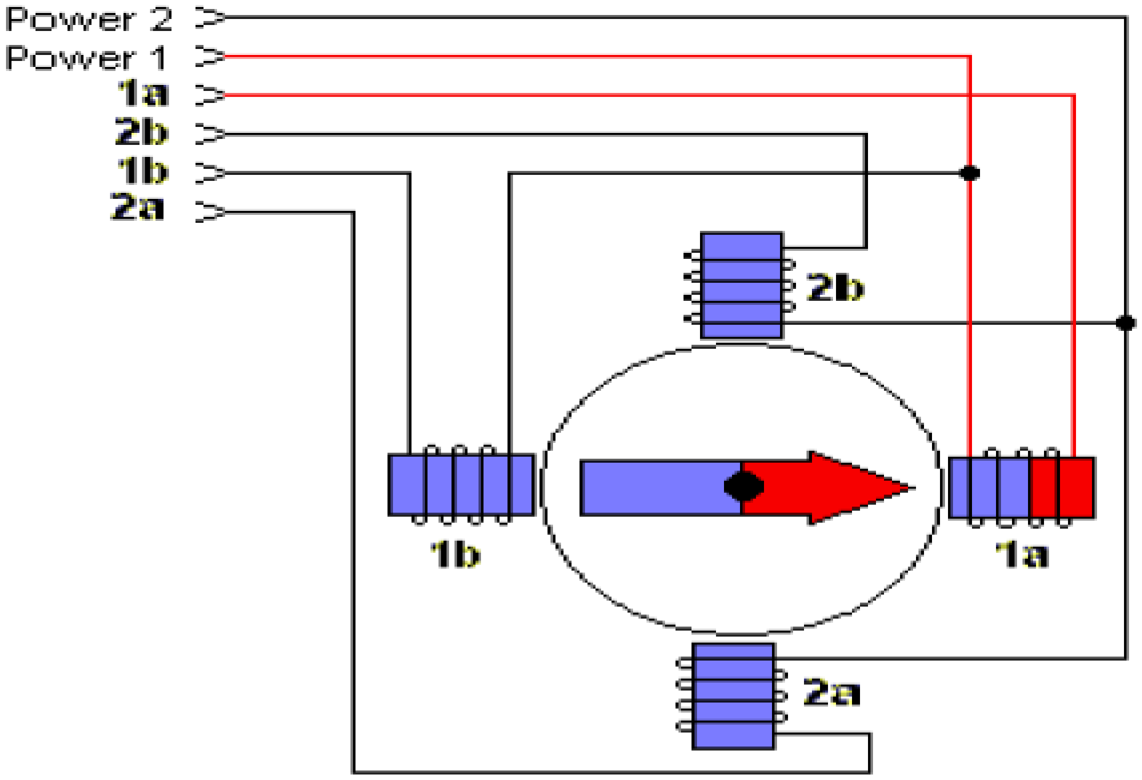
Stepper Motors

Stepper Motor

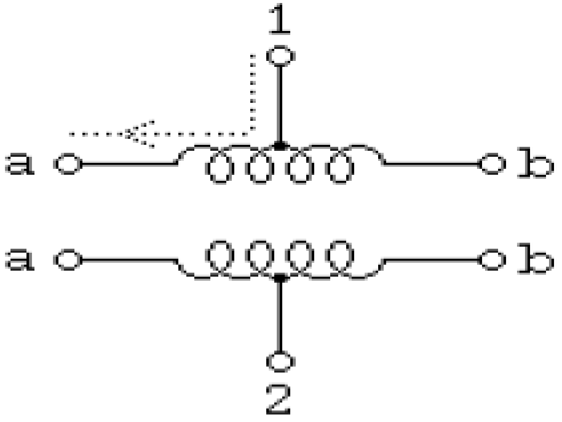
Stator

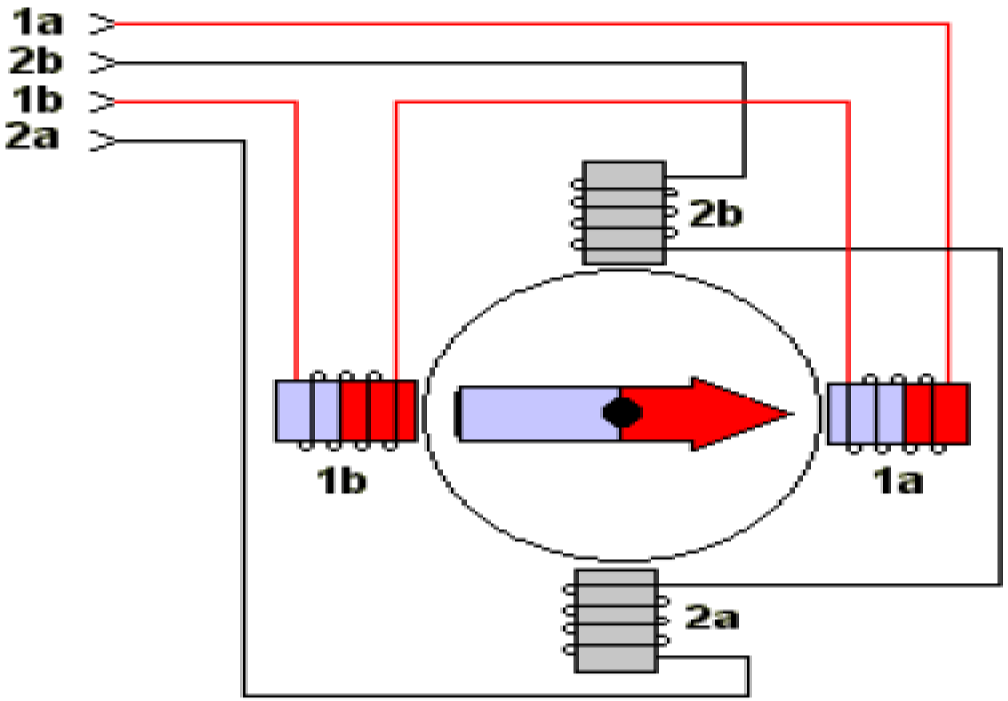
Rotor


DC Power



Conceptual Model of Unipolar Stepper Motor

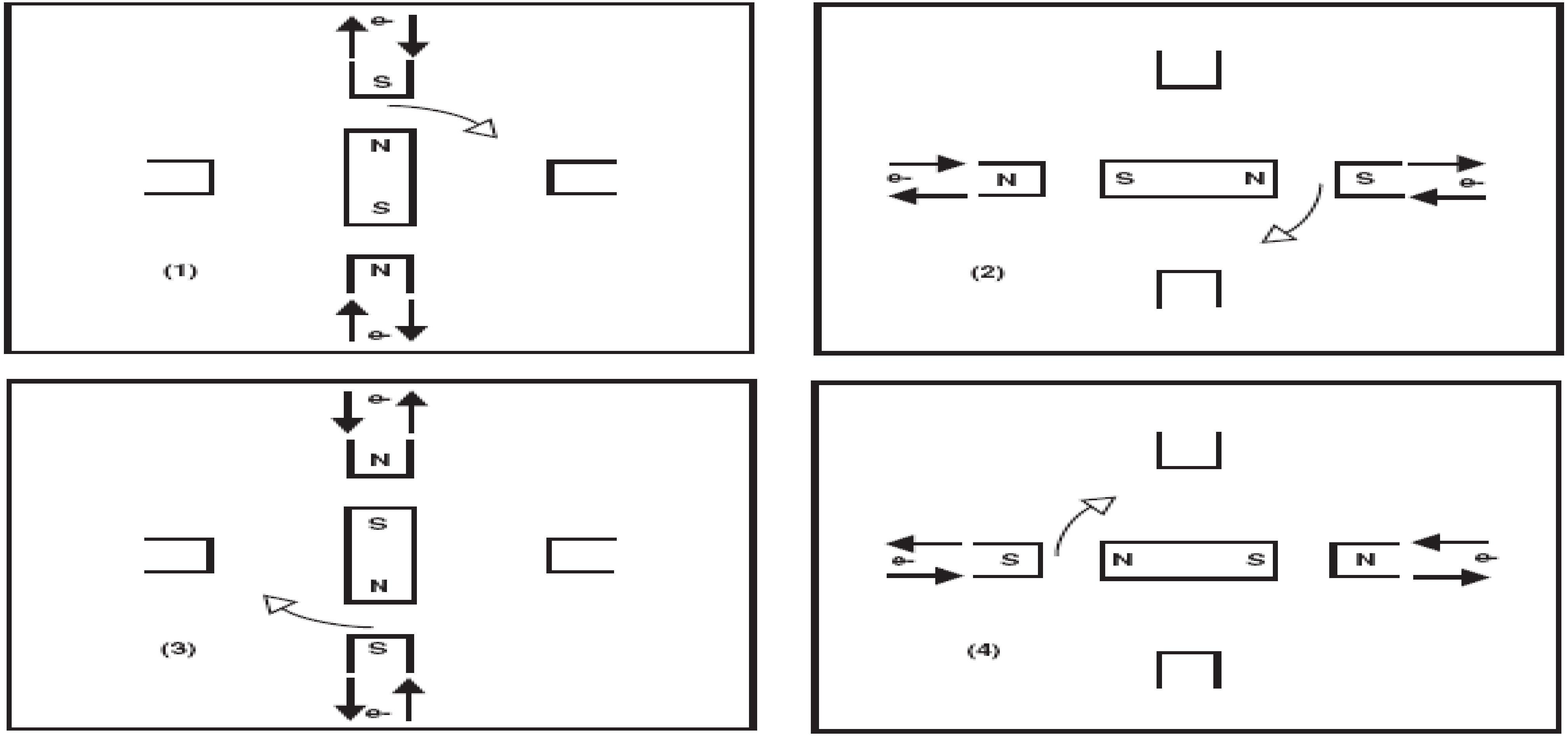




Conceptual Model of Bipolar Stepper Motor

Full Stepping

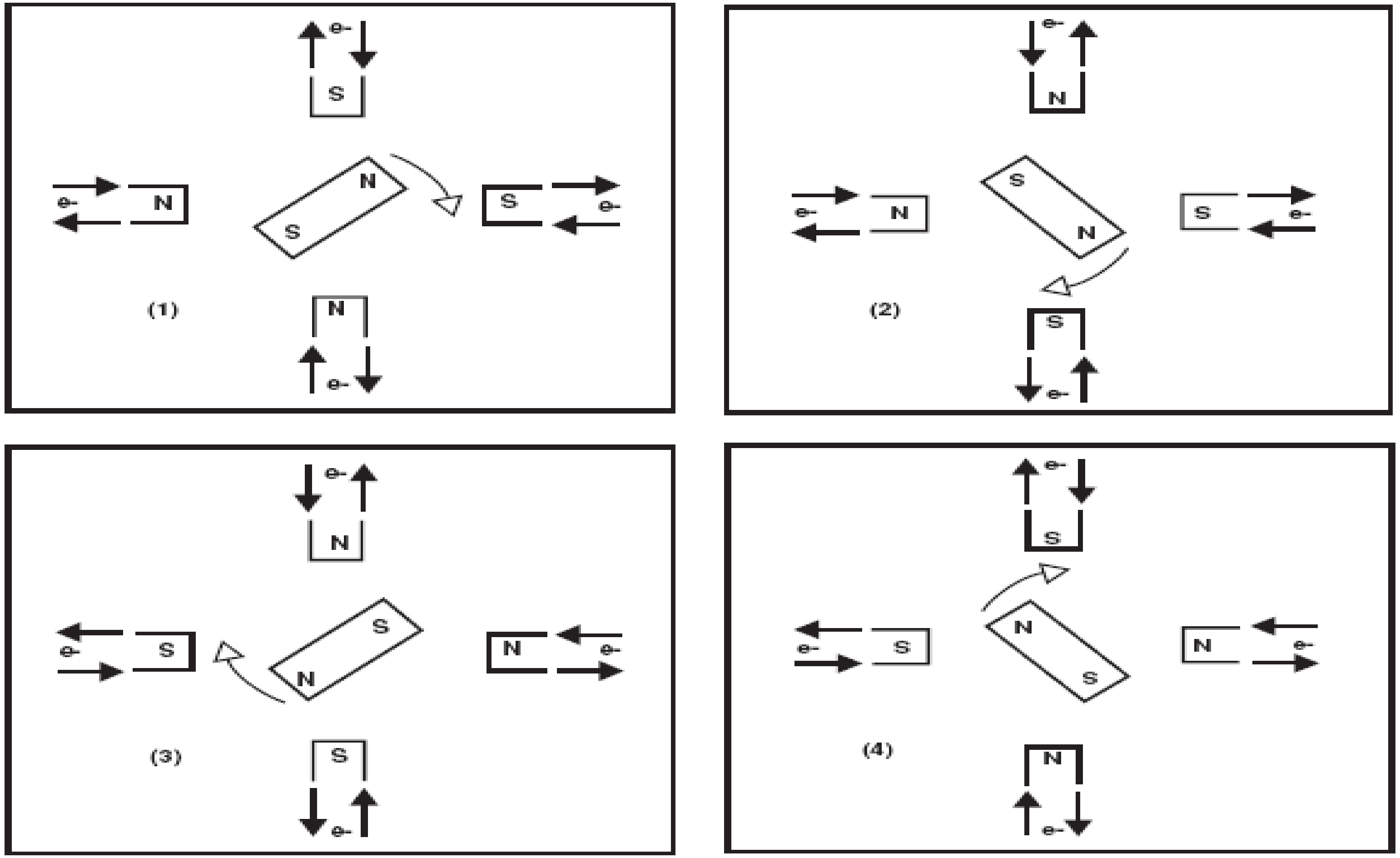
- Energizing one coil at a time is known as running the motor in 'full steps'. In a 200 step motor, this means the resolution of the motor is 200 positions for a single revolution; 200 separate rotational positions that can be achieved. **Half Stepping**
- There is a trick you can do to double the resolution of the motor; instead of just energizing one coil at a time in order, you can create positions *inbetween* by energizing the next coil in the sequence, before de-energizing the current coil. This also makes for smoother motion at slower speeds.
- Stepper motors can be controlled with bipolar techniques, to strengthen the motor's ability to turn, and to lock. Rather than energizing single coils, one is energized with a positive voltage, while the opposite coil is given a negative voltage. Running a motor using bipolar techniques does NOT affect the resolution of the motor, only power and maximum running speed.
- Here's an animated diagram showing a bi-polar half-step sequencing technique. Note that there are 8 half steps to this sequence. The rotor shaft is in the center, and is a fixed magnet. The four coils around it are energized in the order shown to achieve shaft rotation



	PHASE			
	A	B	$\overline{A}$	$\overline{B}$
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1

One-Phase On, Full Step

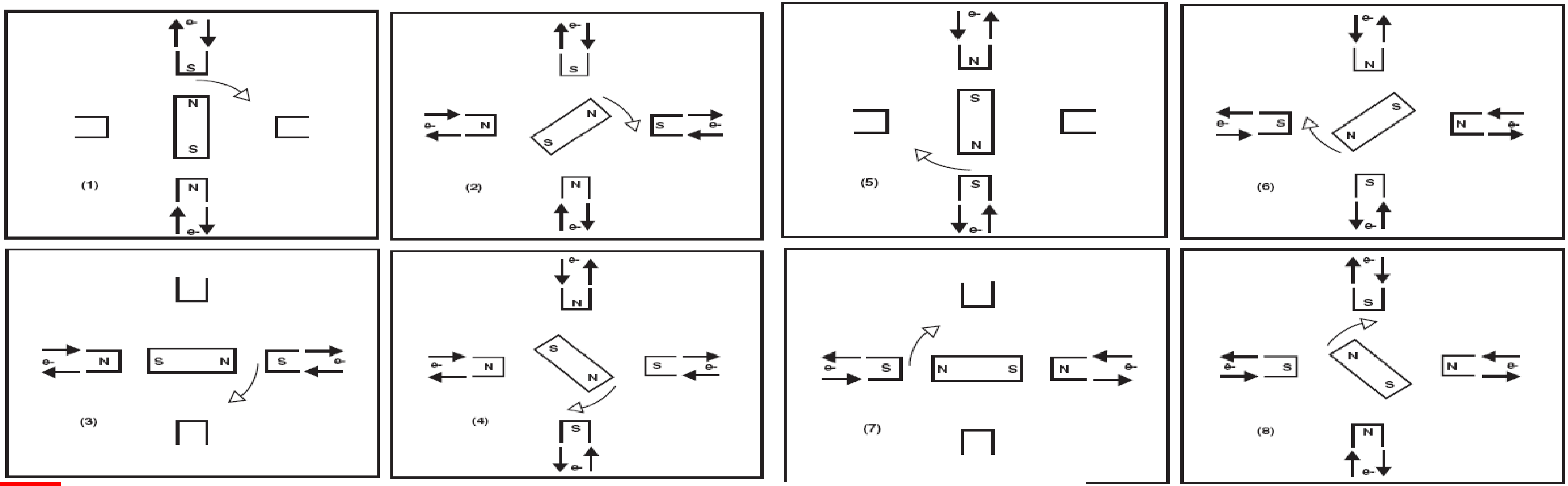
Figure 5a.



Two-Phase On, Full Step

Figure 5b.

	PHASE			
	A	B	$\bar{A}$	$\bar{B}$
1	1	1	0	0
2	0	1	1	0
3	0	0	1	1
4	1	0	0	1

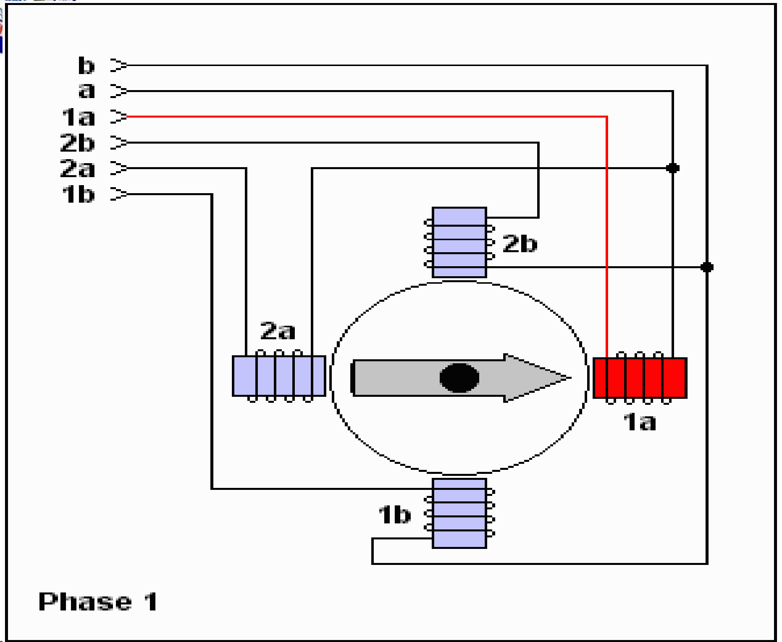


	PHASE			
	A	B	$\overline{A}$	$\overline{B}$
1	1	0	0	0
2	1	1	0	0
3	0	1	0	0
4	0	1	1	0
5	0	0	1	0
6	0	0	1	1
7	0	0	0	1
8	1	0	0	1

Half Step

Figure 6.

Stepping Sequence



Stepper Motor Operation (Unipolar, Full step)

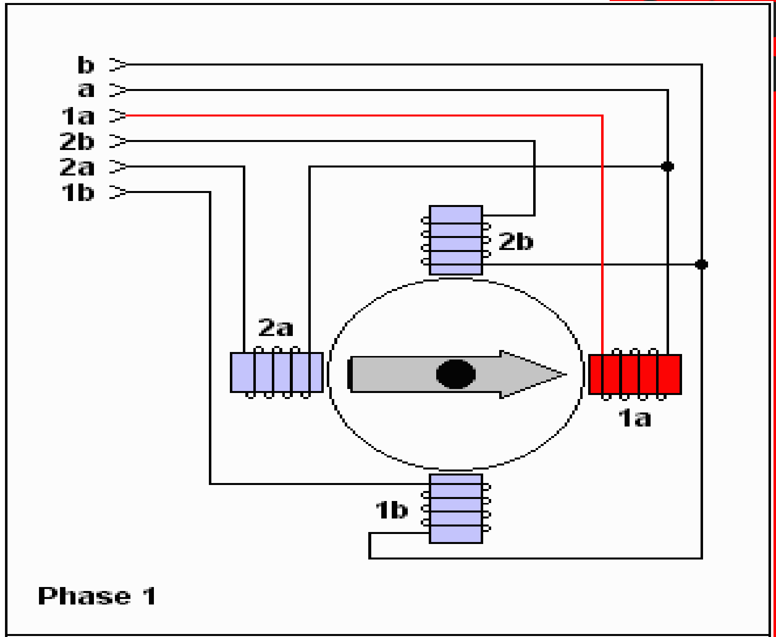
Clockwise Rotation

Index	1a	1b	2a	2b
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1
5	1	0	0	0
6	0	1	0	0
7	0	0	1	0
8	0	0	0	1

- Full step sequence showing how binary numbers can control the motor

Clockwise Rotation

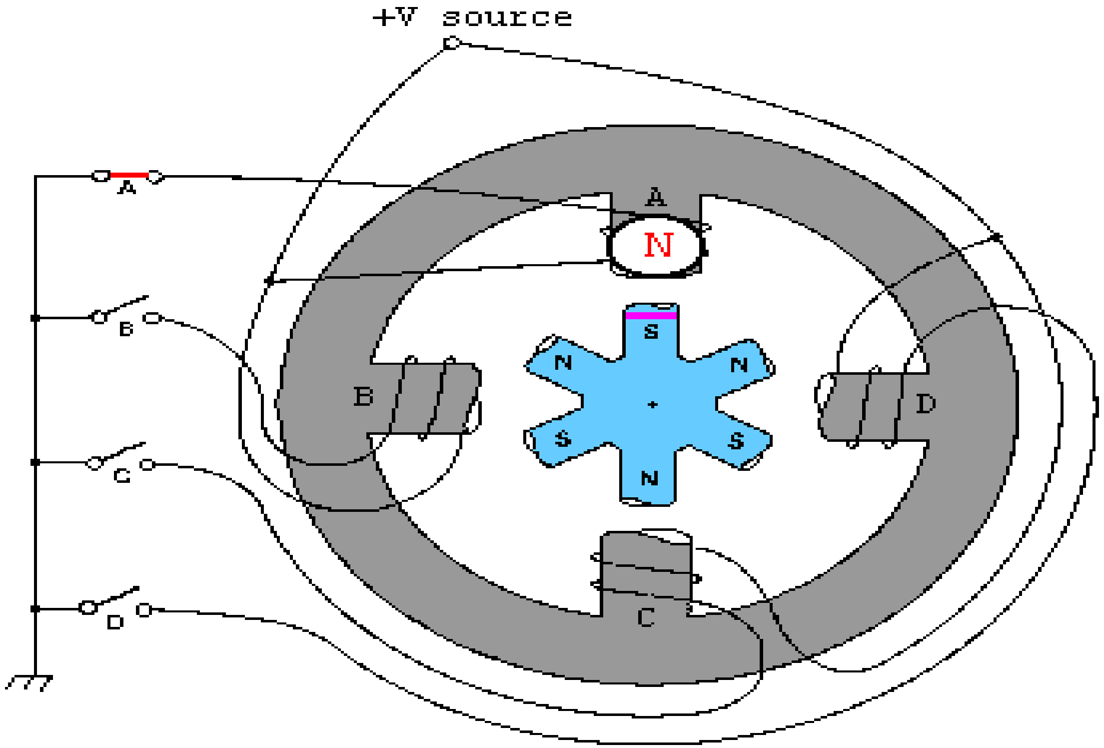
Index	1a	1b	2a	2b
1	1	0	0	0
2	1	1	0	0
3	0	1	0	0
4	0	1	1	0
5	0	0	1	0
6	0	0	1	1
7	0	0	0	1
8	1	0	0	1
9	1	0	0	0
10	1	1	0	0
11	0	1	0	0
12	0	1	1	0
13	0	0	1	0
14	0	0	1	1
15	0	0	0	1
16	1	0	0	1



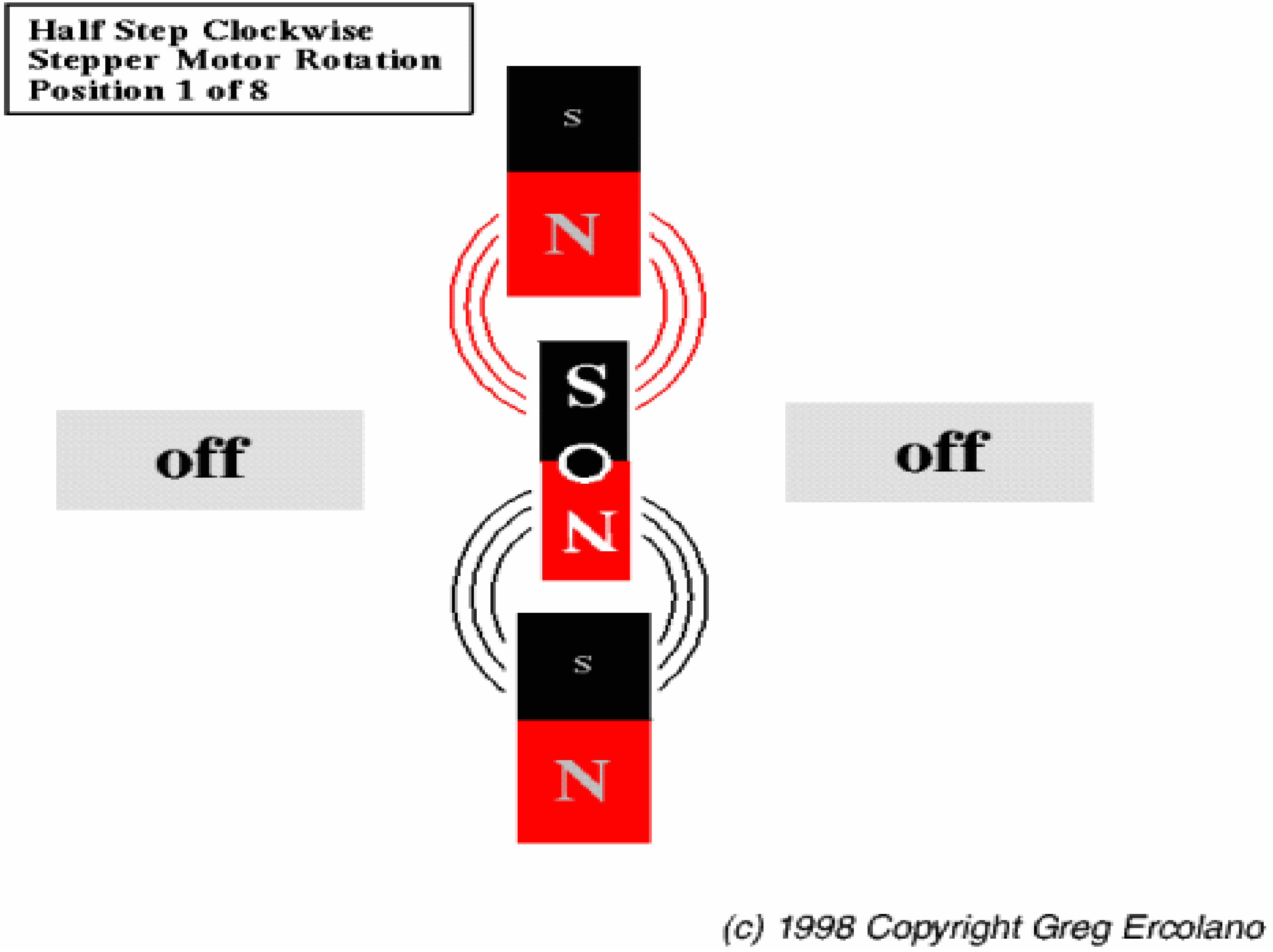
Stepper Motor Operation (Unipolar, Half step)

- Half step sequence of binary control numbers

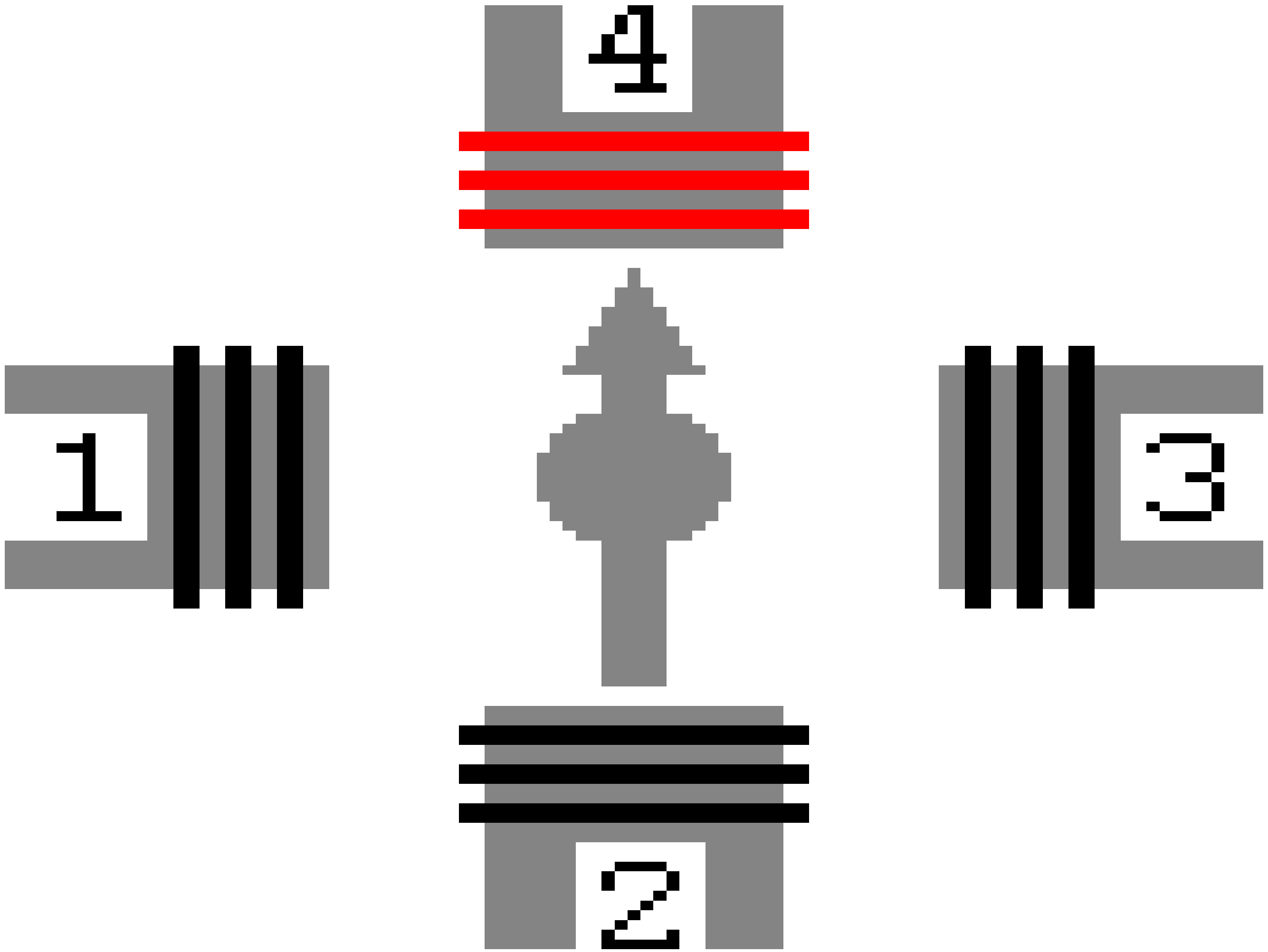
Full Stepping



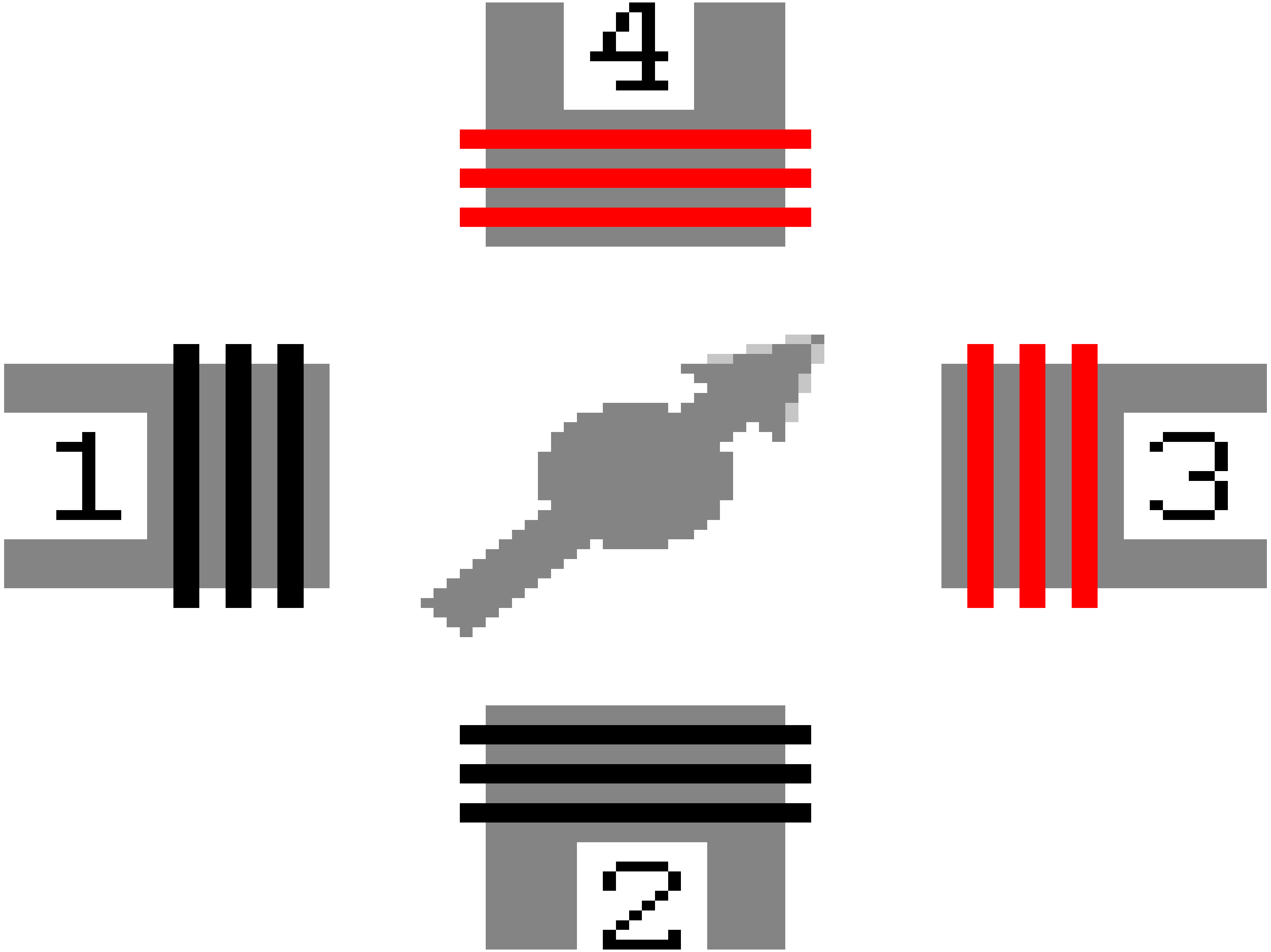
- Animation shows how coils are energized for full steps


Half Step Clockwise
Stepper Motor Rotation
Position 1 of 8
S
N
S
N
S
N
off
off
(c) 1998 Copyright Greg Ercolano

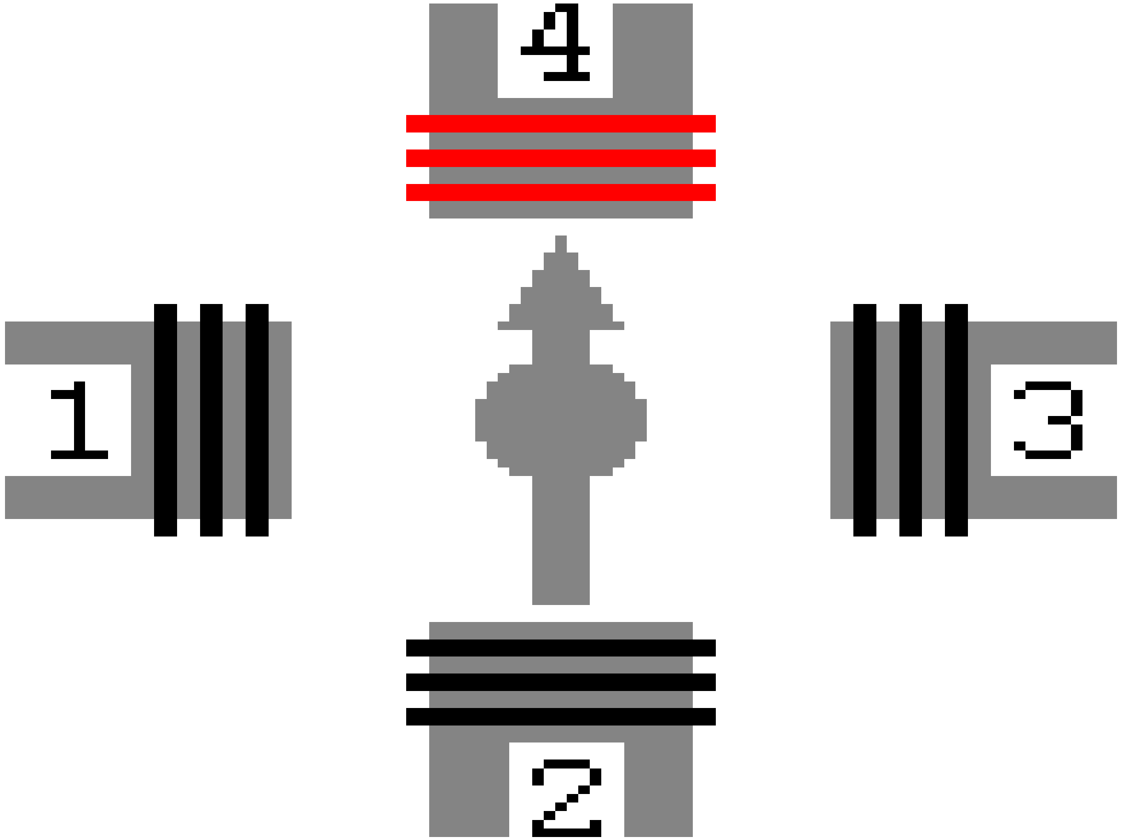
Single

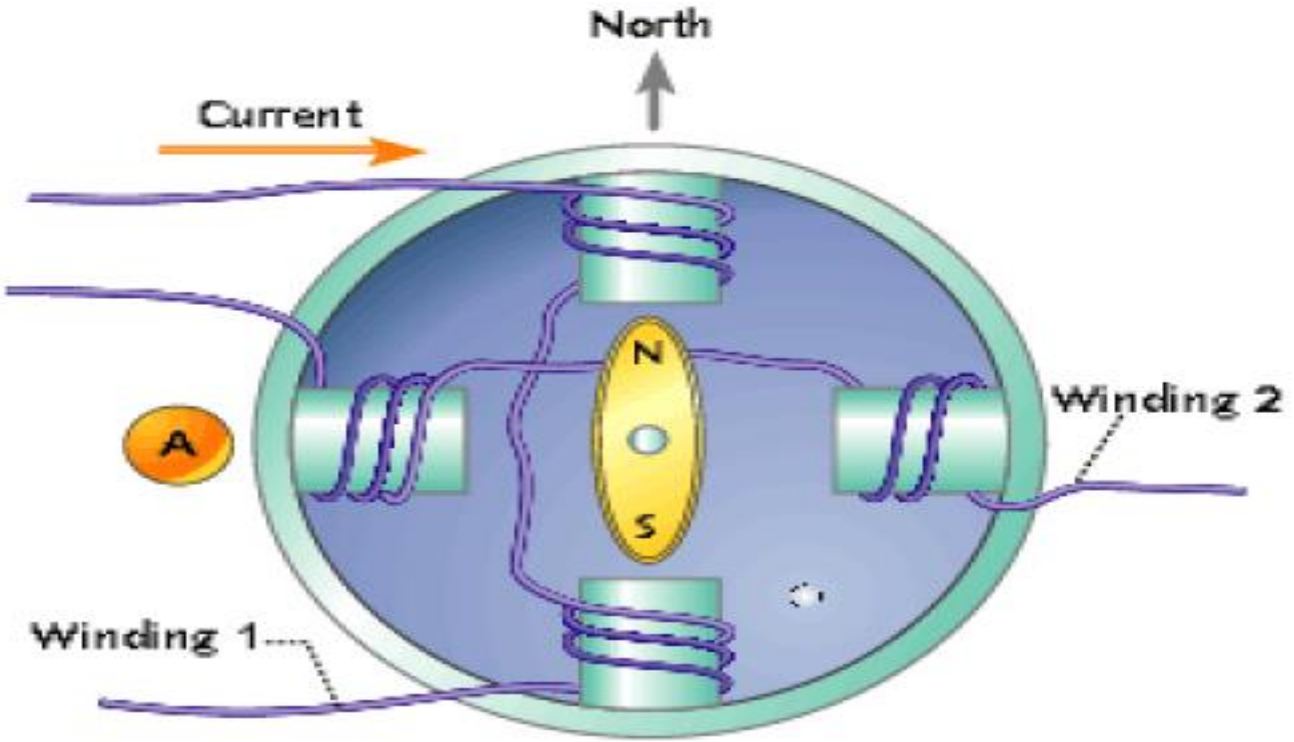


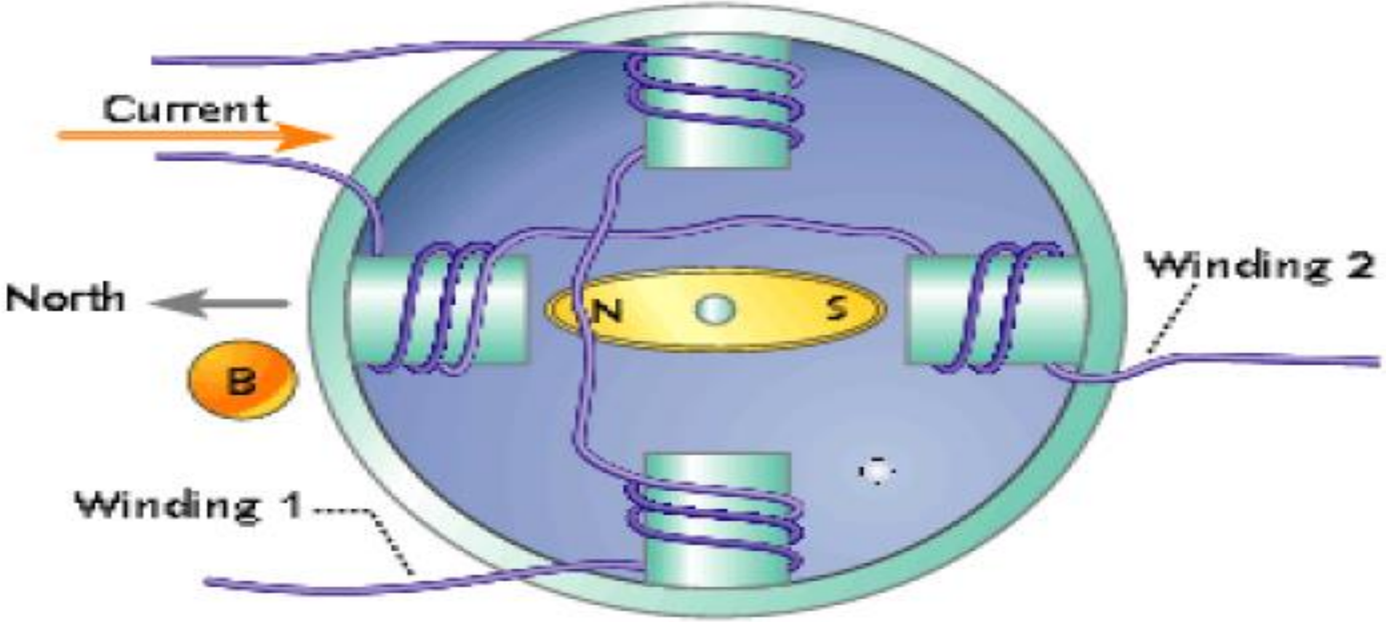
Dual

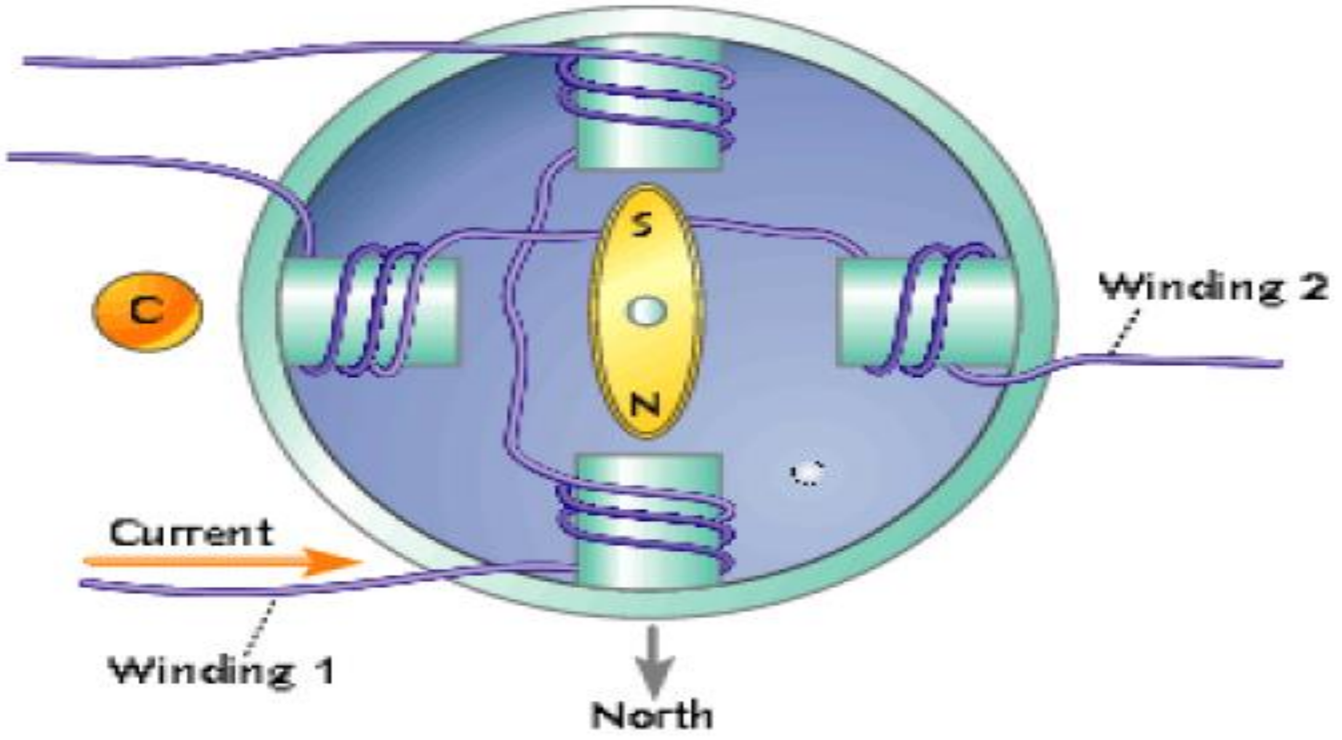


Both

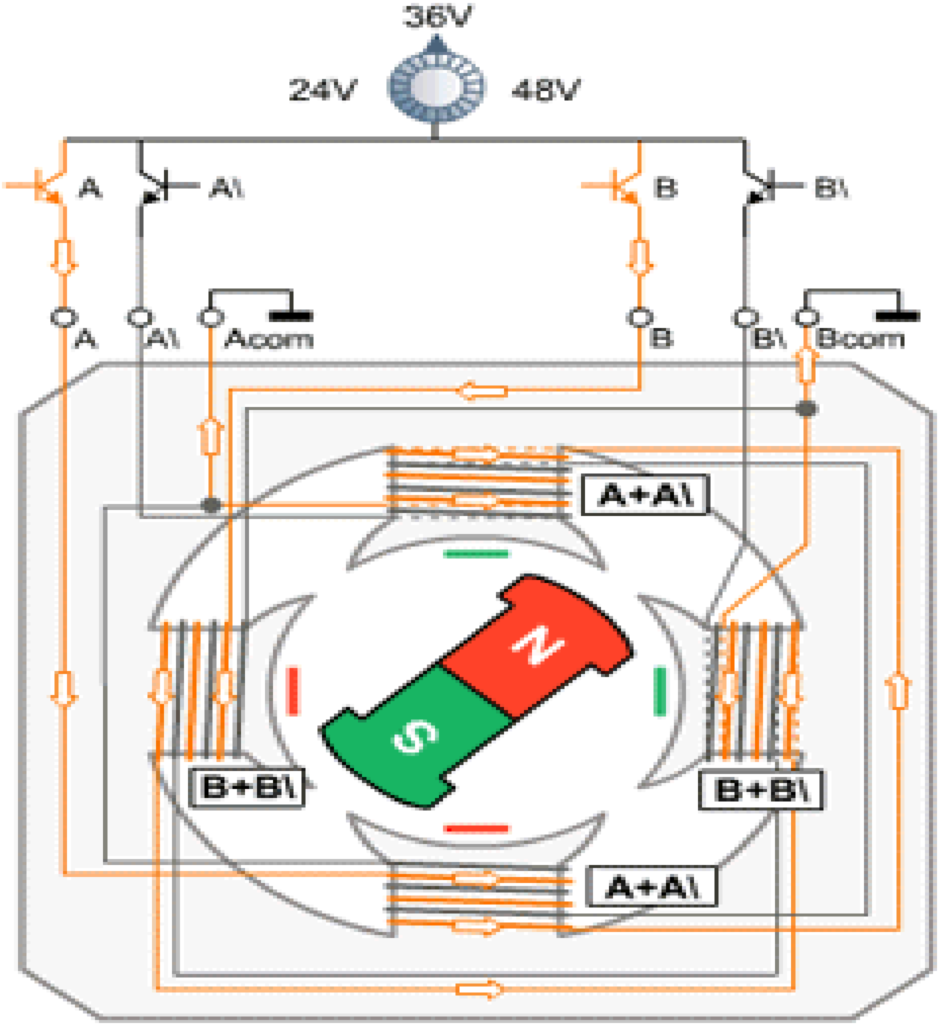



North
Current
N
S
A
Winding 2
Winding 1


Current
North
B
N
S
Winding 2
Winding 1



S
N
C
Winding 2
Current
Winding 1
North



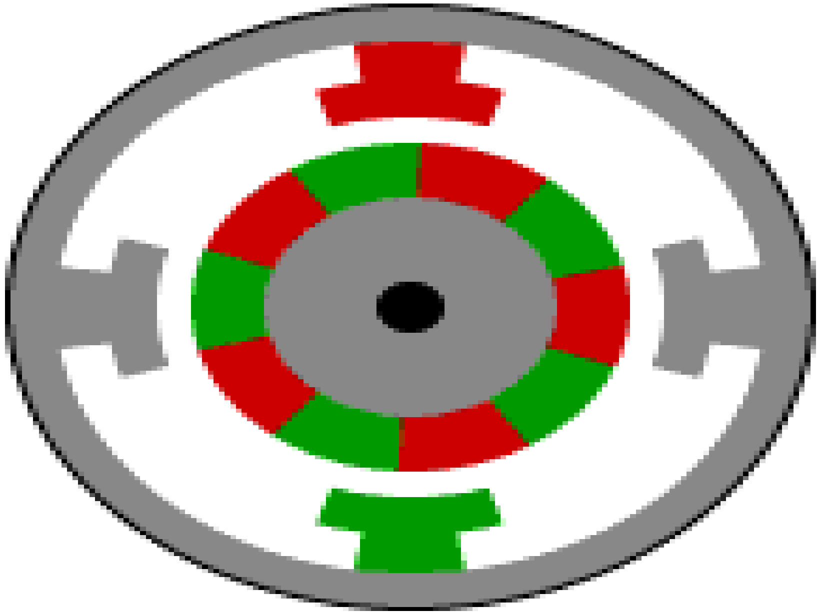
6 Lead Unipolar Driver

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

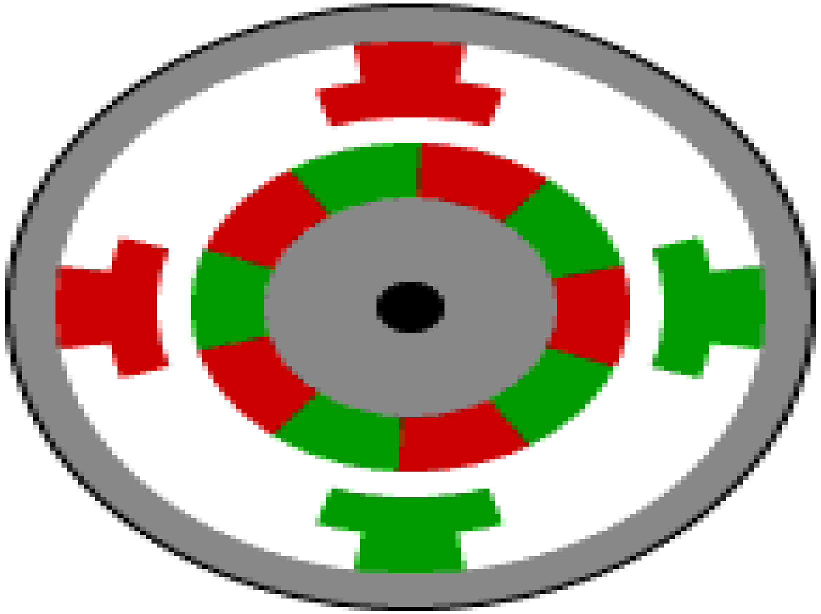
F	0		1		2		3	
H	0	1	2	3	4	5	6	7
A	1	0	0	0	0	0	1	1
B	1	1	1	0	0	0	0	0
A\	0	0	1	1	1	0	0	0
B\	0	0	0	0	1	1	1	0
dez	12	4	6	2	3	1	9	8

Full Stepper Motor



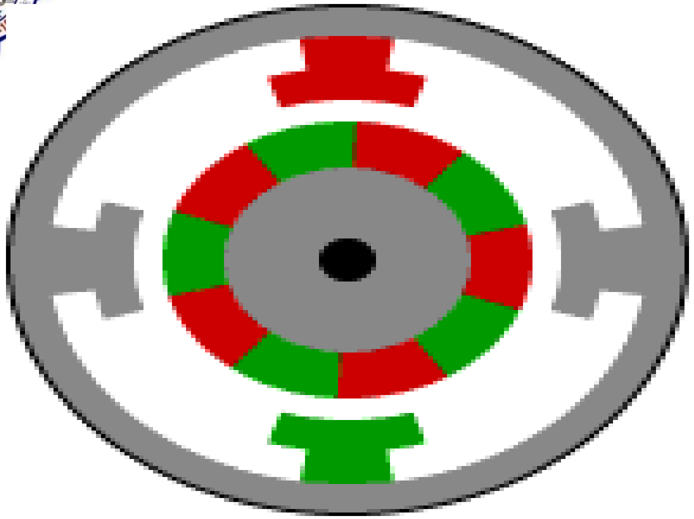
- This animation demonstrates the principle for a stepper motor using full step commutation. The rotor of a permanent magnet stepper motor consists of permanent magnets and the stator has two pairs of windings. Just as the rotor aligns with one of the stator poles, the second phase is energized. The two phases alternate on and off and also reverse polarity. There are four steps. One phase lags the other phase by one step. This is equivalent to one forth of an electrical cycle or 90° .

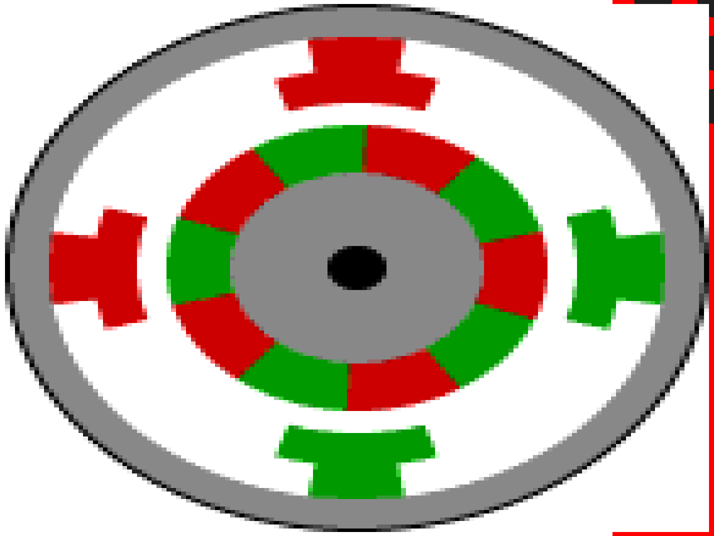
Half Stepper Motor



- This animation shows the stepping pattern for a half-step stepper motor. The commutation sequence for a half-step stepper motor has eight steps instead of four. The main difference is that the second phase is turned on before the first phase is turned off. Thus, sometimes both phases are energized at the same time. During the half-steps the rotor is held in between the two full-step positions. A half-step motor has twice the resolution of a full step motor. It is very popular for this reason.

Stepper Motors

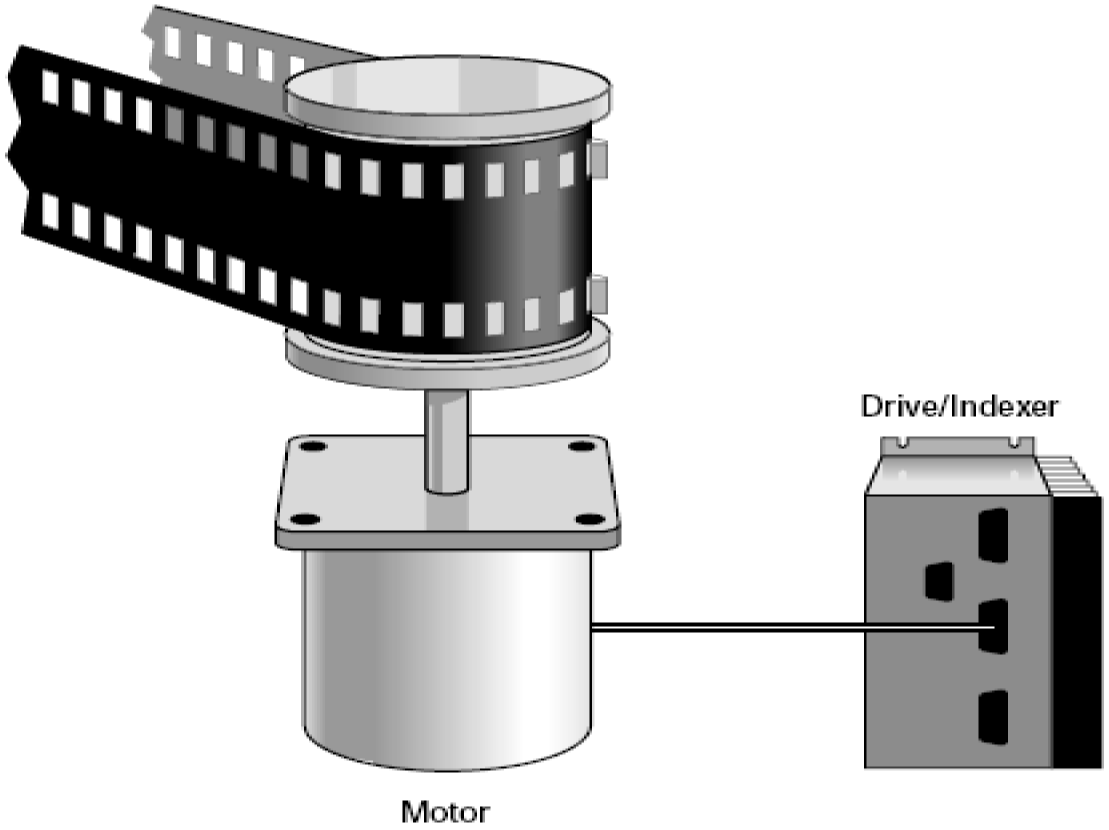




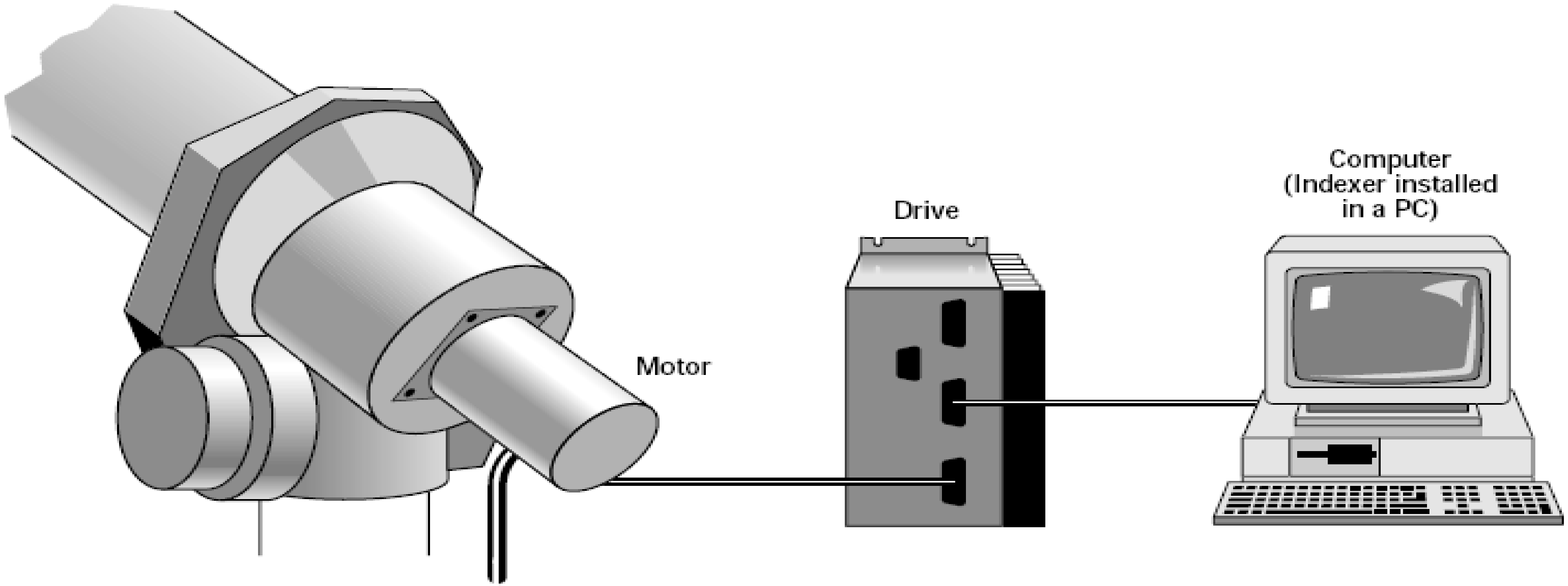
- Some stepper motor uses permanent magnets. Some stepper motors do not have magnets and instead use the basic principles of a switched reluctance motor. The stator is similar but the rotor is composed of a iron laminates.

Application Examples

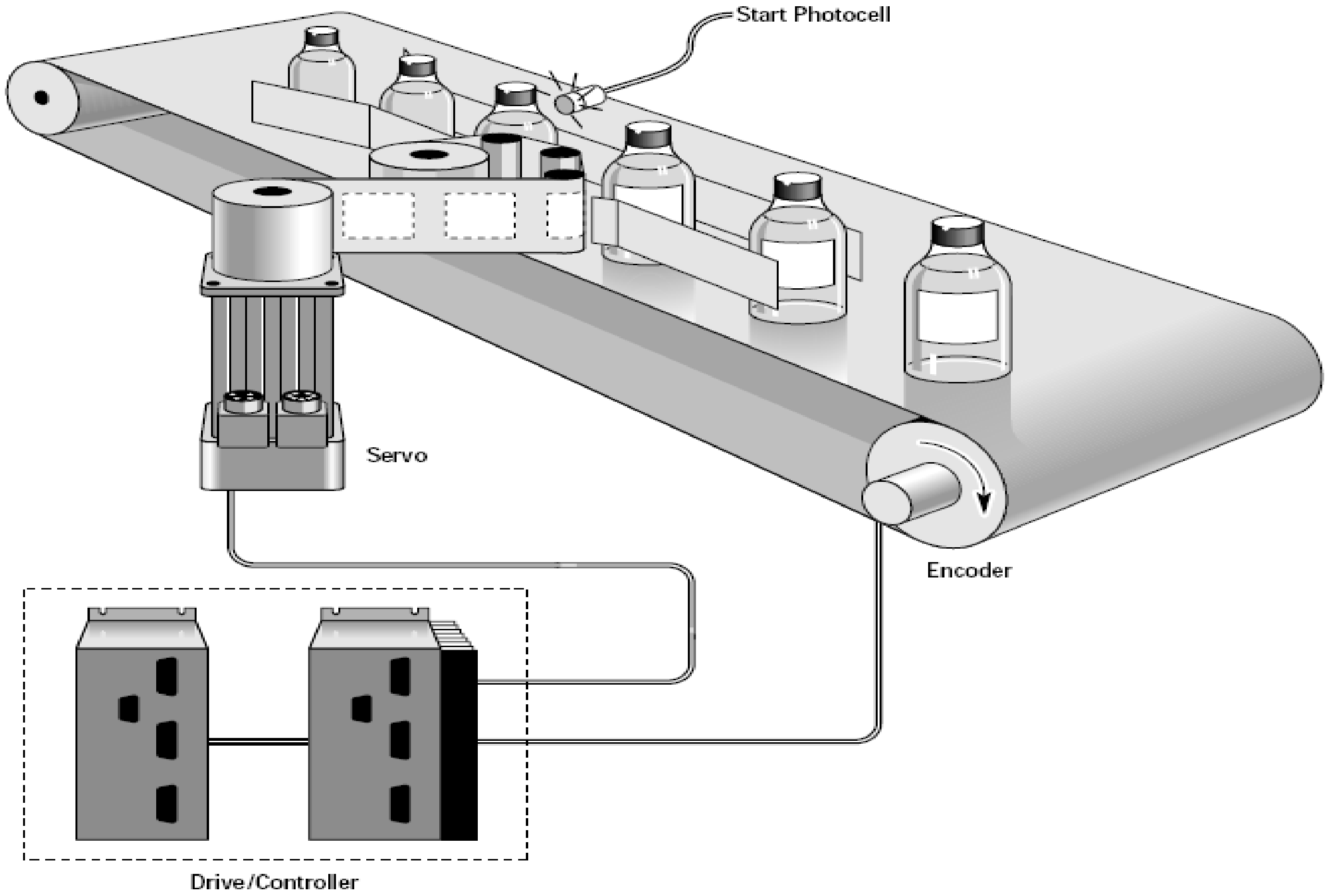
Film Advance



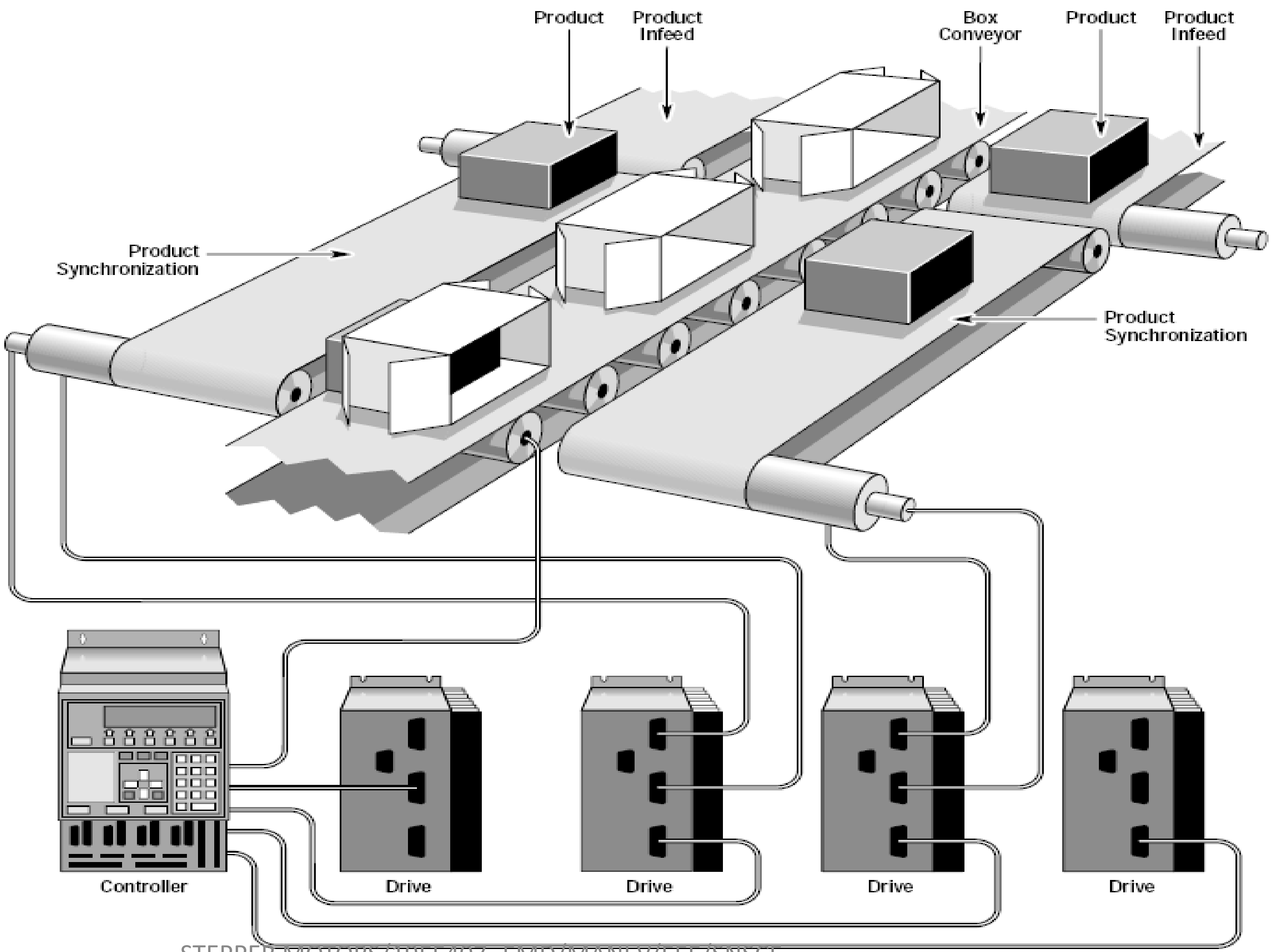
Telescope Drive



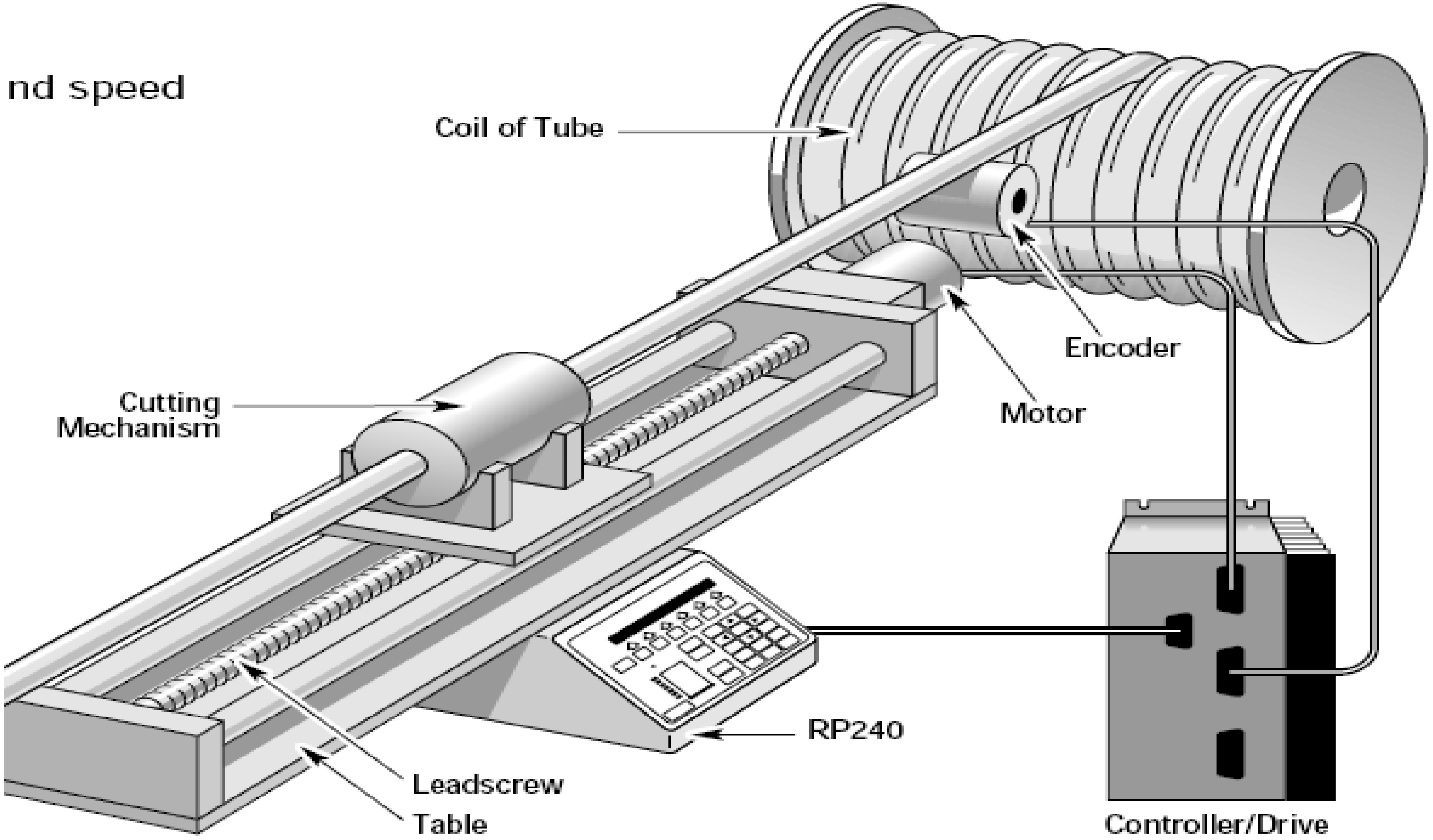
Labeling Machine

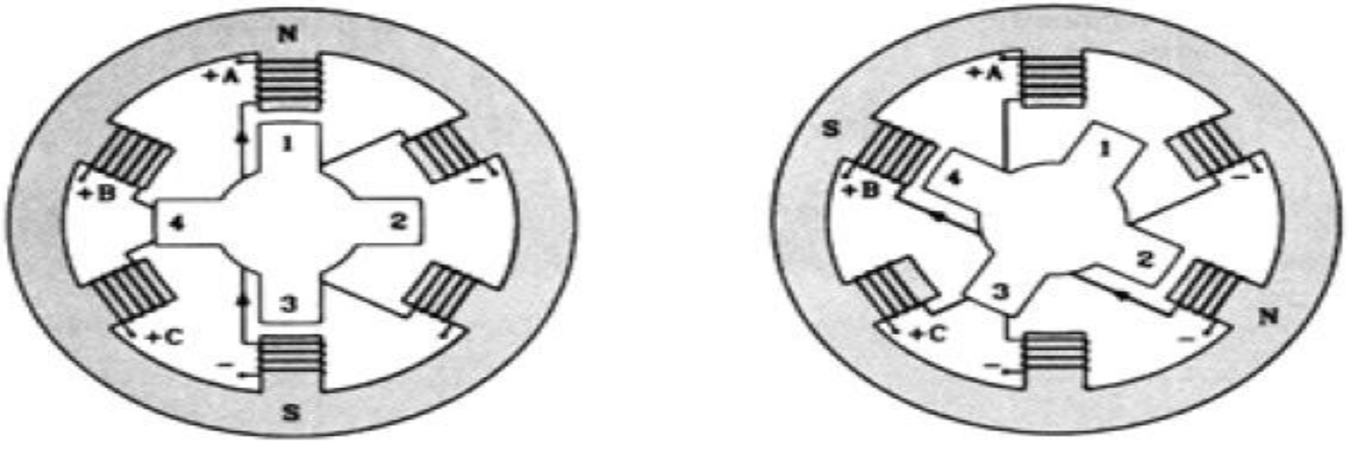


Moving Positioning System

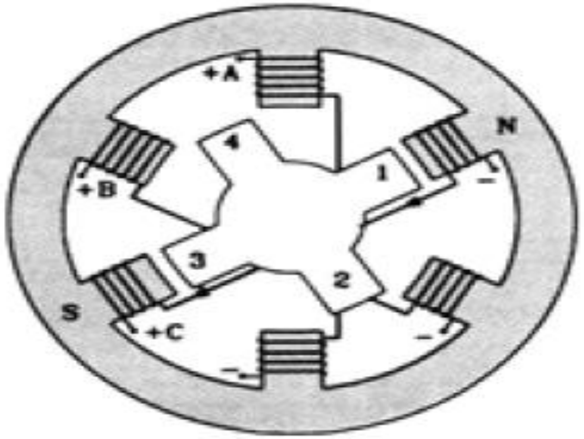


Rotating Tube Cutter





(a) (b)



(c)

Cycle	Phase A	Phase B	Phase C	Position
1	ON	OFF	OFF	0°
	OFF	ON	OFF	30°
	OFF	OFF	ON	60°
2	ON	OFF	OFF	90°
	OFF	ON	OFF	120°
	OFF	OFF	ON	150°
3	ON	OFF	OFF	180°
	OFF	ON	OFF	210°
	OFF	OFF	ON	240°
4	ON	OFF	OFF	270°
	OFF	ON	OFF	300°
	OFF	OFF	ON	330°
5	ON	OFF	OFF	360°

(d)

Figure 6-21 Variable-reluctance stepper motor and switching sequence.

$$N = \frac{\Psi(s/s)}{6}$$

where N = motor speed, in RPM
Ψ = step angle, in mechanical degrees
s/s = number of steps per second

A stepper motor with a step angle of 15° has a maximum rating of 300 s/s. What is the motor speed?

$$N = \frac{\Psi(s/s)}{6}$$

$$= \frac{(15°)(300)}{6}$$

$$= 750 \text{ RPM}$$

$$\text{Step Angle}\,(\Theta_S) = \frac{360^\circ}{S}$$

$$S = mN_r$$

$$m = number\ of\ phases$$

$$N_r = number\ of\ rotor\ teeth$$

For this motor:

$$m = 3$$

$$N_r = 4$$

$$S = mN_r = 3 \bullet 4 = 12$$

$$\Theta_S = \frac{360^\circ}{12} = 30^\circ\ per\ step$$