STEPPER MOTORS

Electrical Machines – Elective Course for ELC

Stepper Motors

- Basic Principle of Operation
- Applications
- Types: - Variable Reluctance Stepper Motor
  - Permanent Magnet Stepper Motor
- Driving Circuits

Stepper Motors

- Video

Stepper Motors Basic Principle

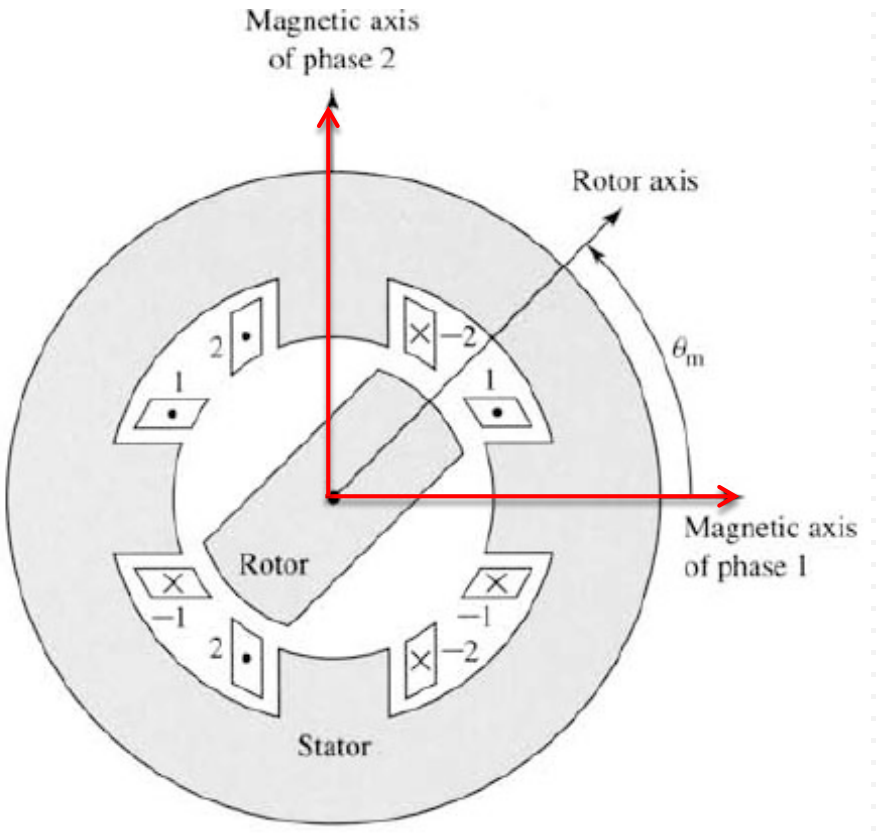
The simplest electrical machines. They consist of a stator with excitation windings and a magnetic rotor with saliency.

Torque is produced by the tendency of the rotor to align with the stator-produced flux.

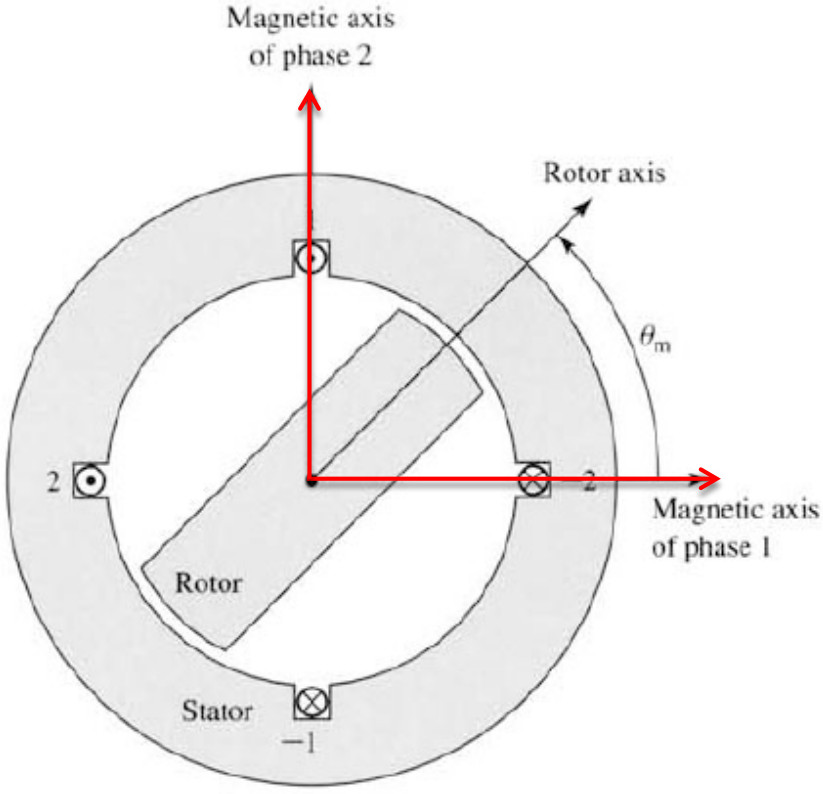
By sequentially exciting the phases of the machine, the rotor will rotate in a step-wise fashion, rotating through a specific angle per step.

Stepper motors are designed to take advantage of this characteristics.

Stepper Motors Basic Principle

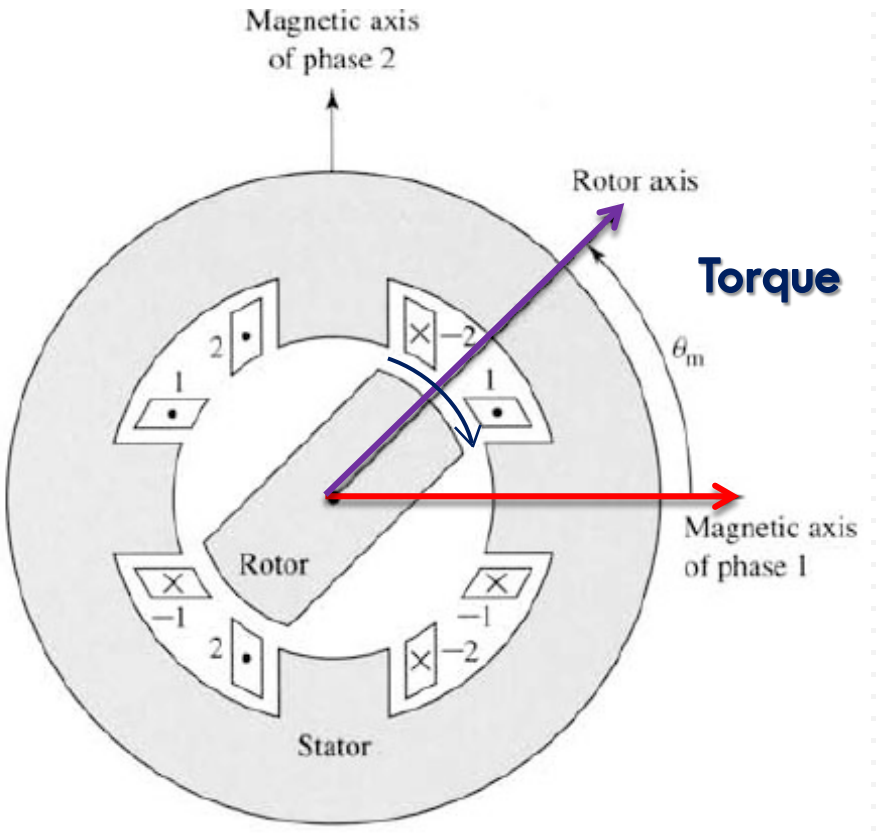


Doubly Salient

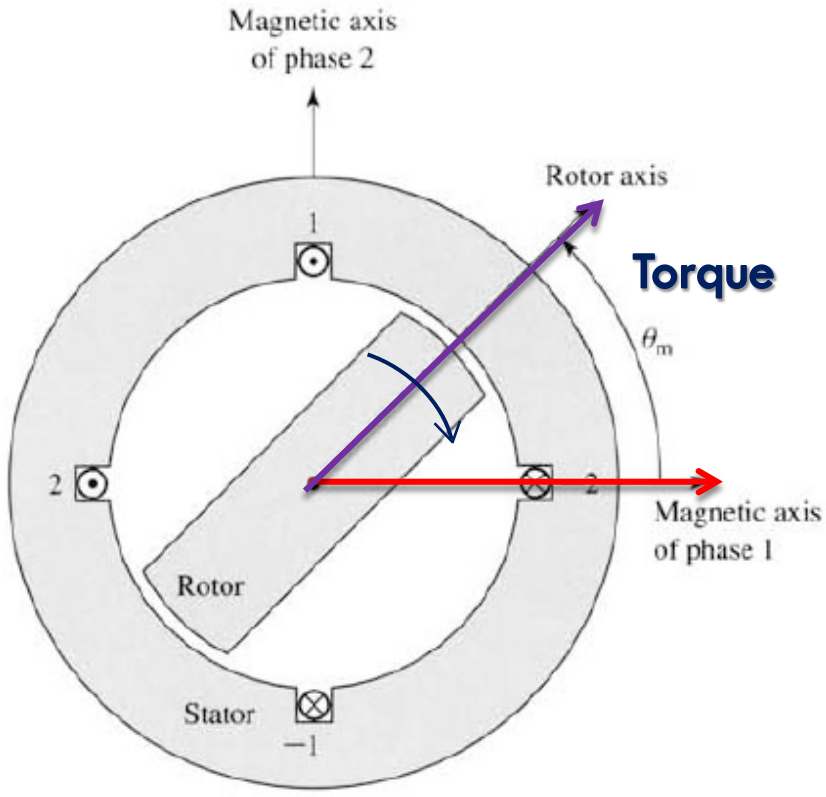


Singly Salient

Stepper Motors Basic Principle

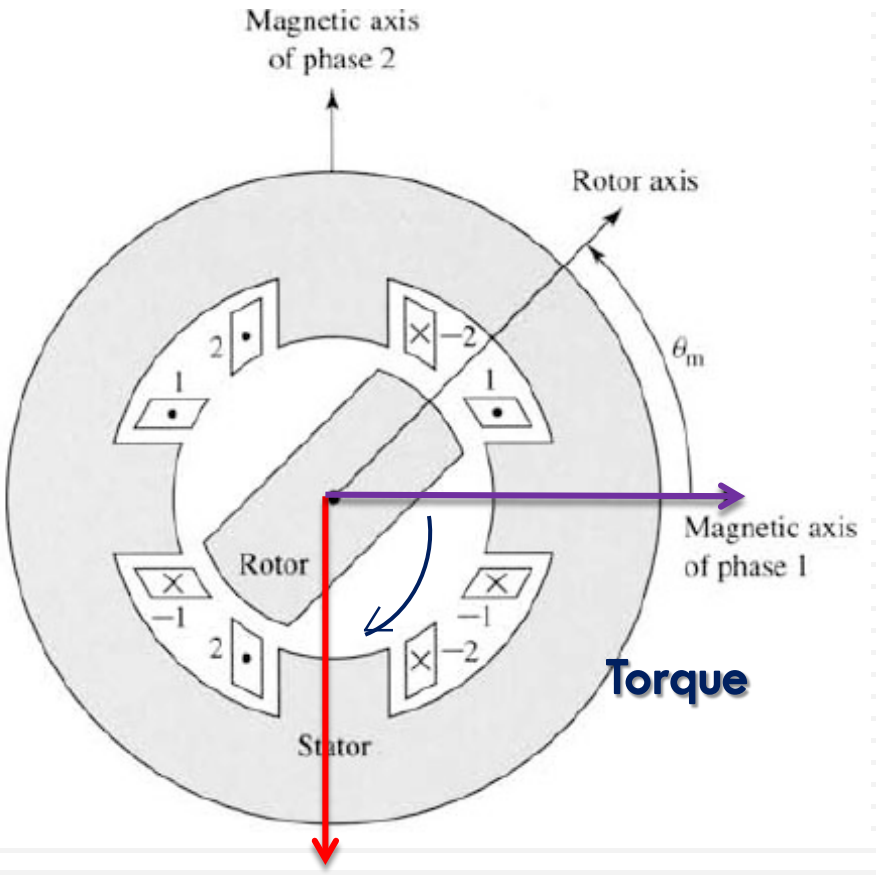


Doubly Salient

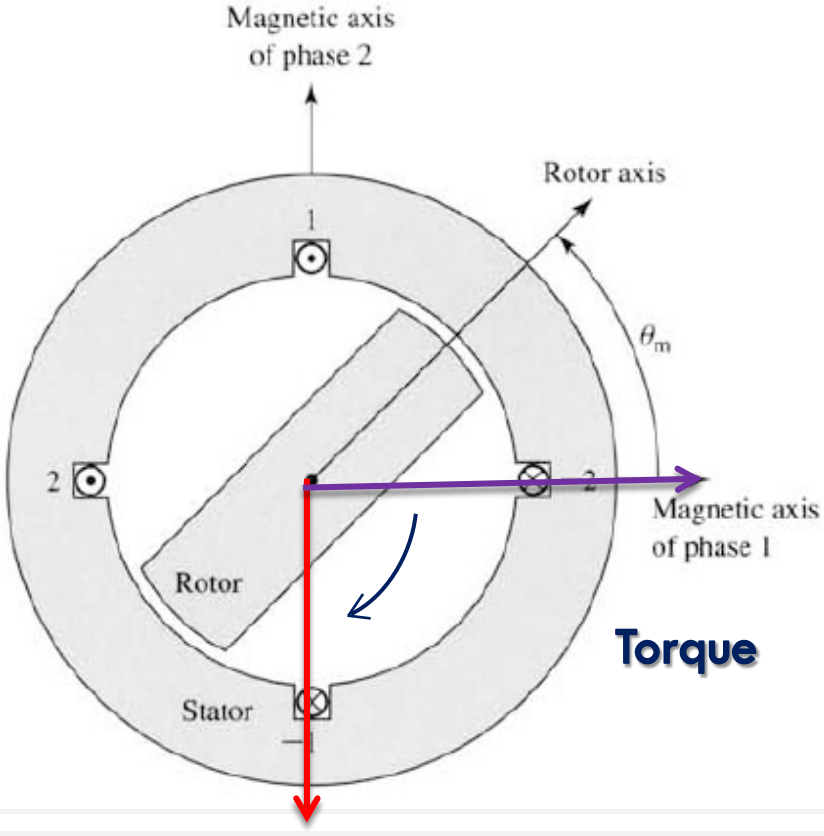


Singly Salient

Stepper Motors Basic Principle



Doubly Salient



Singly Salient

Stepper Motors Applications

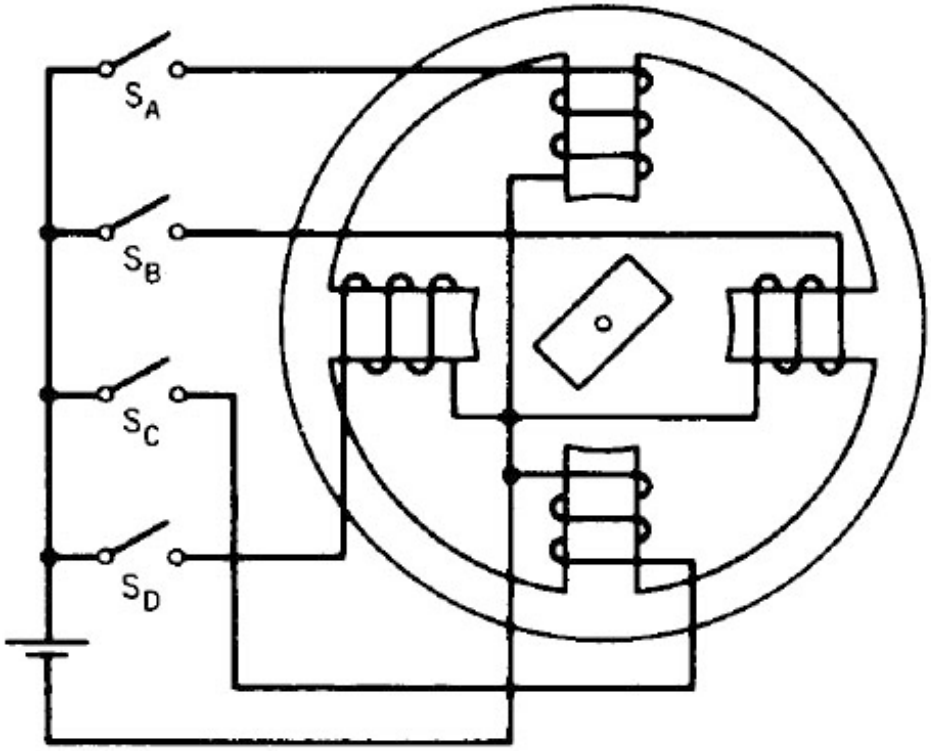
1. Hard Disk Drives: write and read magnetic heads are controlled by a stepper motor, while the discs it self is rotated using a brushless DC motor (BLDC)
2. Dot-Matrix printers: stepper motors are used for paper feed, ribbon feed, driving character wheel and for cartage transport.
3. Copying Machines: for paper feed and lens positioning.
4. Quartz Watches: used to drive the watch arms.

Stepper Motors Variable Reluctance Motor

Single Stack Variable Reluctance Stepper Motor

Modes of operation:

- 90° operation
- 45° operation

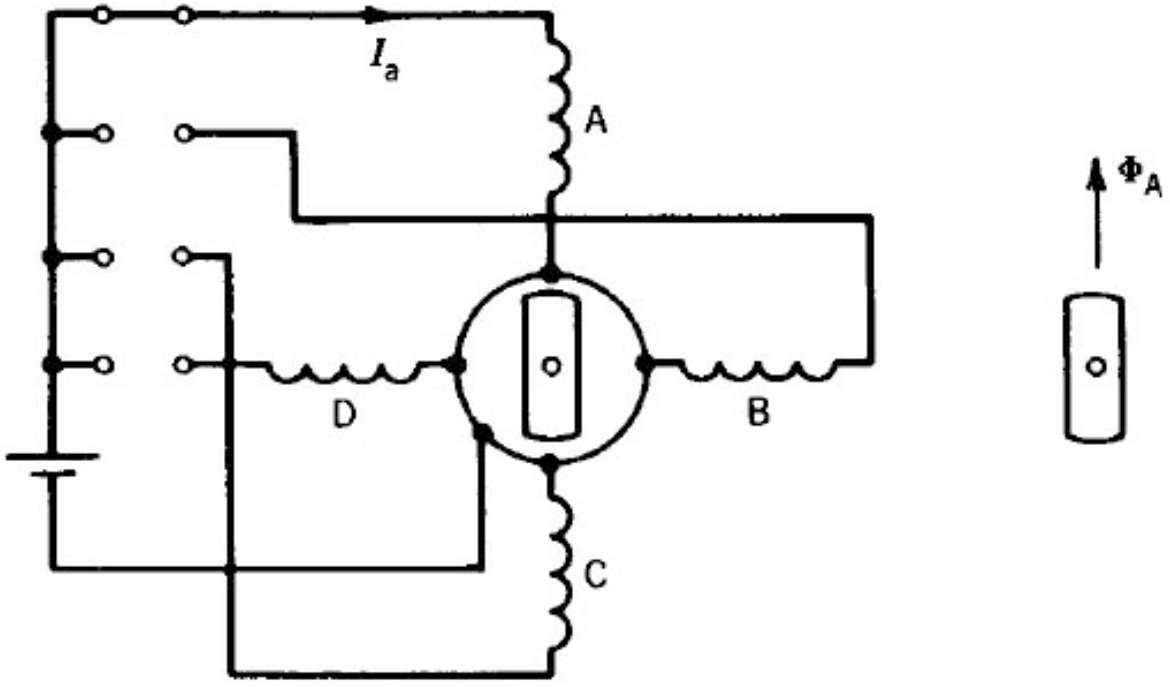


4 phases – 2 poles

Stepper Motors Variable Reluctance Motor

Single Stack Variable Reluctance Stepper Motor

90° operation

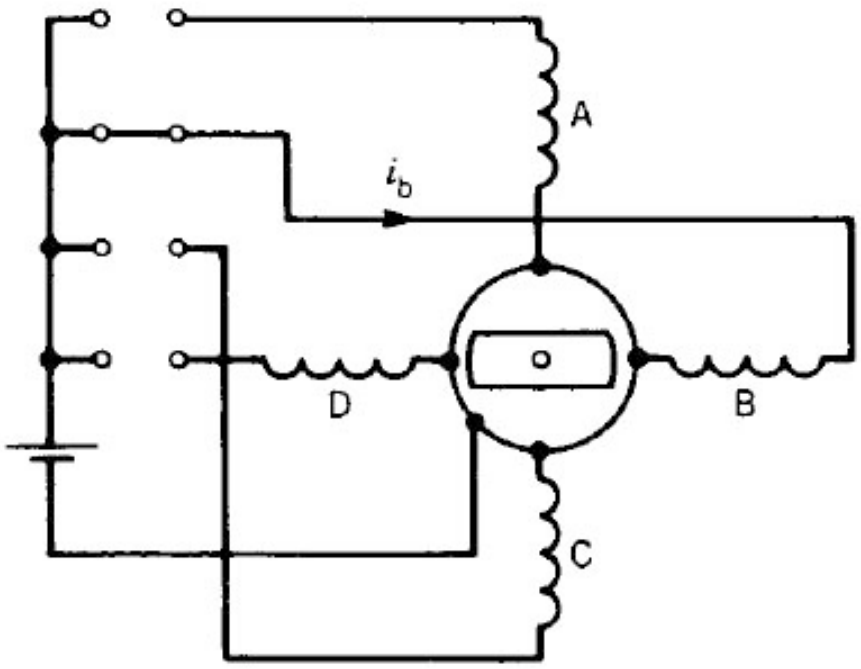


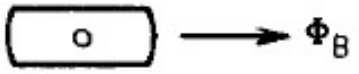
Phase A Energized

Stepper Motors Variable Reluctance Motor

Single Stack Variable Reluctance Stepper Motor

90° operation





Step Size

$$\alpha = \frac{360}{\frac{poles}{2} \times phases}$$

Number of Steps/rev.

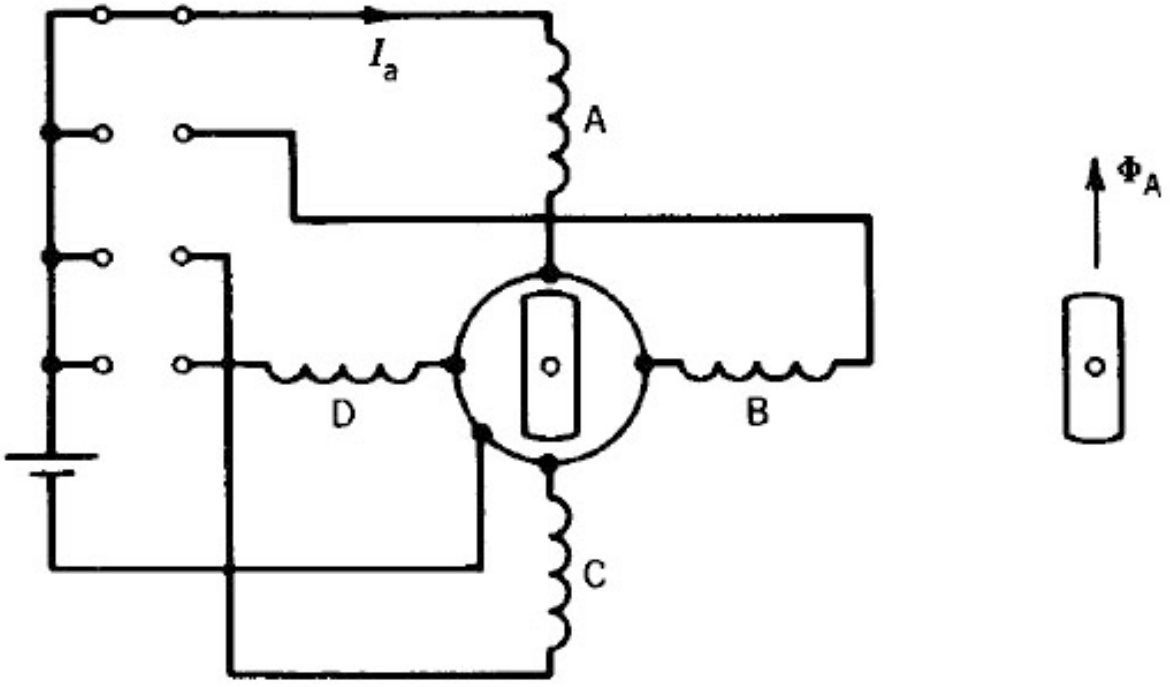
$$n = \frac{poles}{2} \times phases$$

Phase B Energized

Stepper Motors Variable Reluctance Motor

Single Stack Variable Reluctance Stepper Motor

45° operation

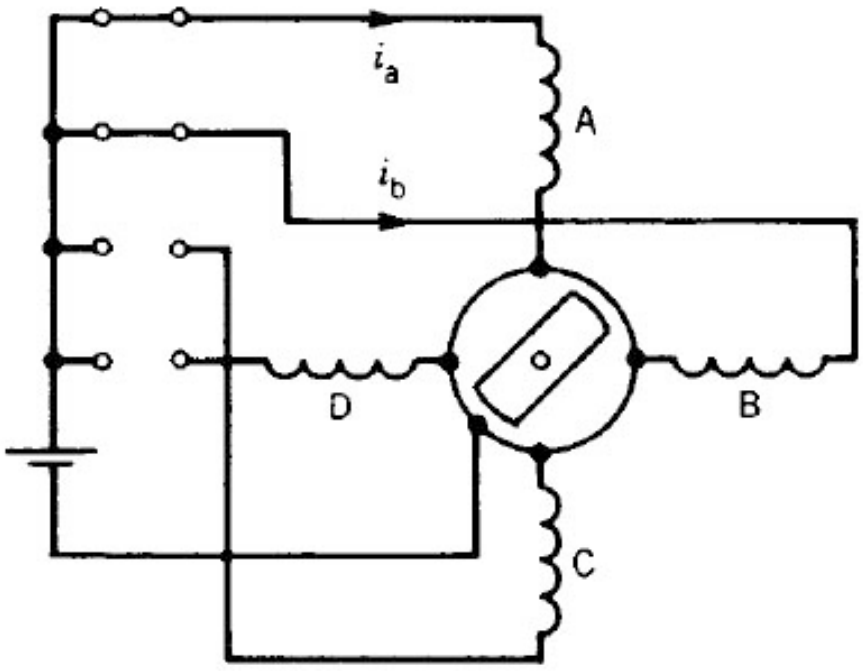


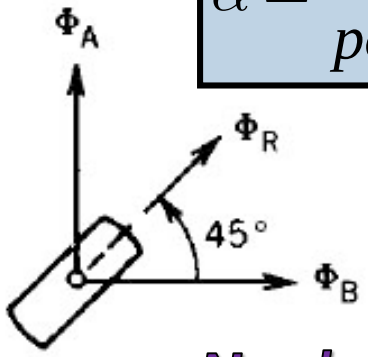
Phase A Energized

Stepper Motors Variable Reluctance Motor

Single Stack Variable Reluctance Stepper Motor

45° operation





Step Size

$$\alpha = \frac{360}{poles \times phases}$$

Number of Steps/rev.

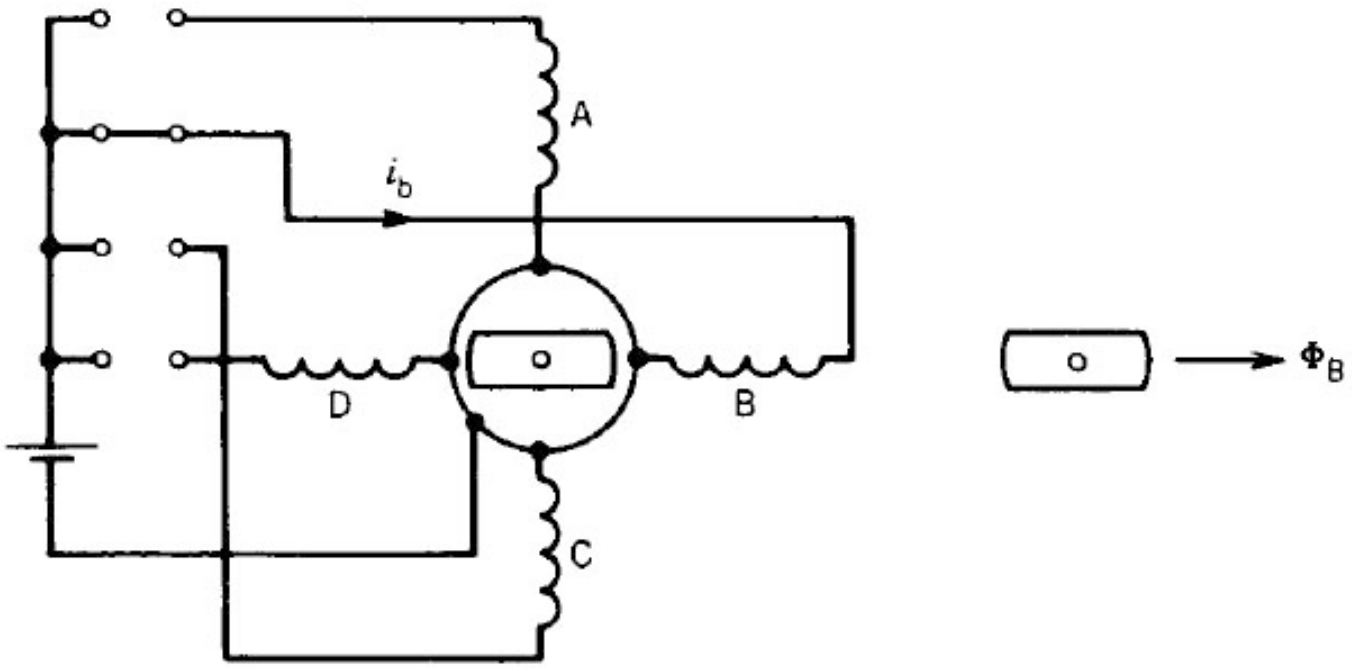
$$n = poles \times phases$$

Phases A & B Energized

Stepper Motors Variable Reluctance Motor

Single Stack Variable Reluctance Stepper Motor

45° operation

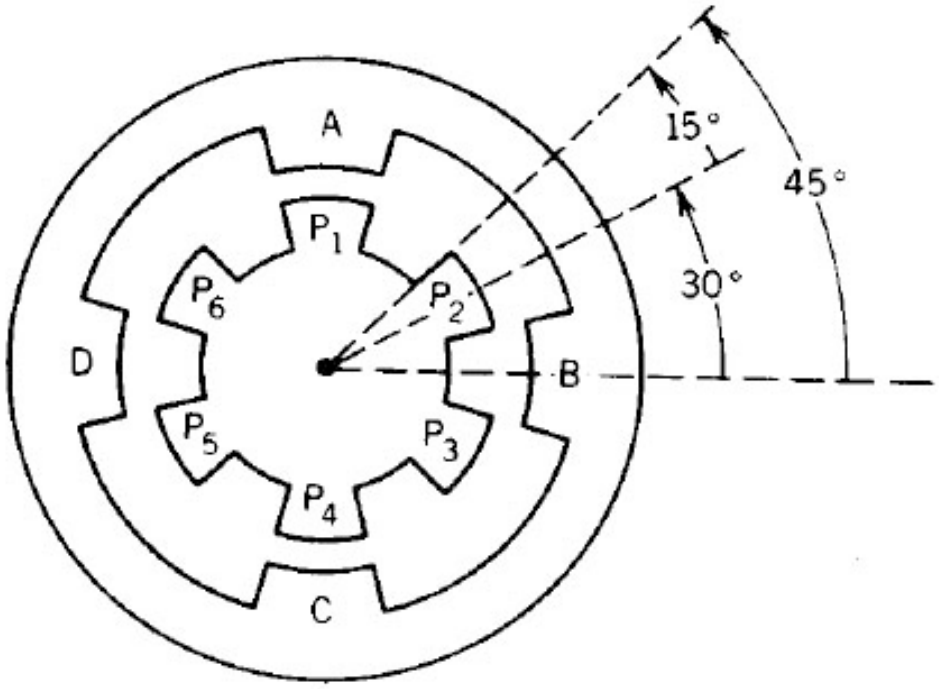


Phase B Energized

Stepper Motors Variable Reluctance Motor

Single Stack Variable Reluctance Stepper Motor

- 15° operation



4 phases – 6 poles

Step Size

$$\alpha = \frac{360}{poles \times phases}$$

Number of Steps/rev.

$$n = poles \times phases$$

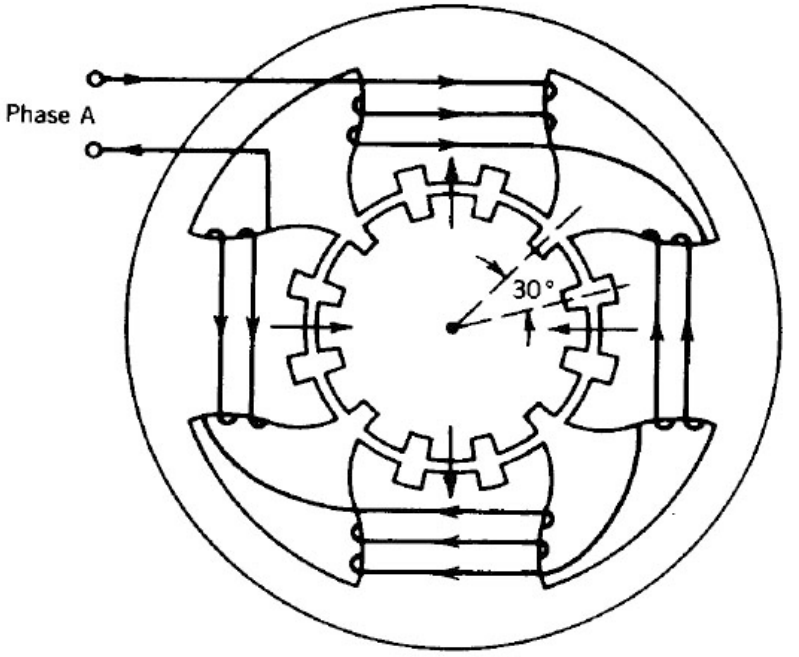
Stepper Motors Variable Reluctance Motor

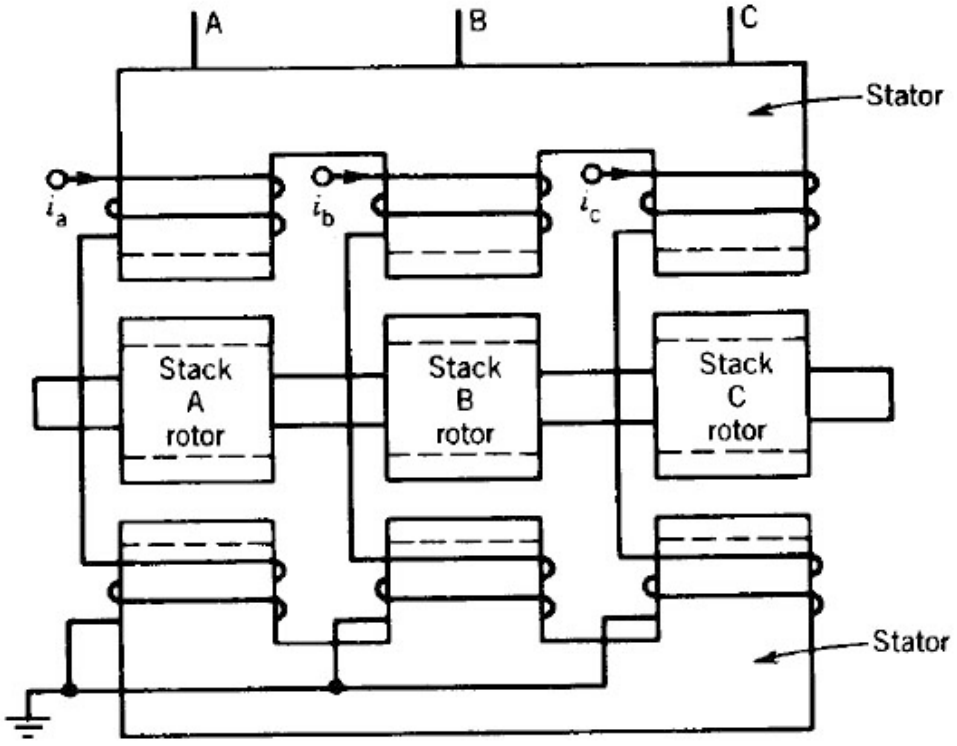
Multi Stack Variable Reluctance Stepper Motor

Multi stack motors are widely used to achieve smaller step sizes. The motor is divided along its axial length into magnetically isolated sections (stacks), and each of these sections can be excited by a separate winding (phase). Three phase arrangements are the most common.

Stepper Motors Variable Reluctance Motor

Multi Stack Variable Reluctance Stepper Motor





Stepper Motors Variable Reluctance Motor

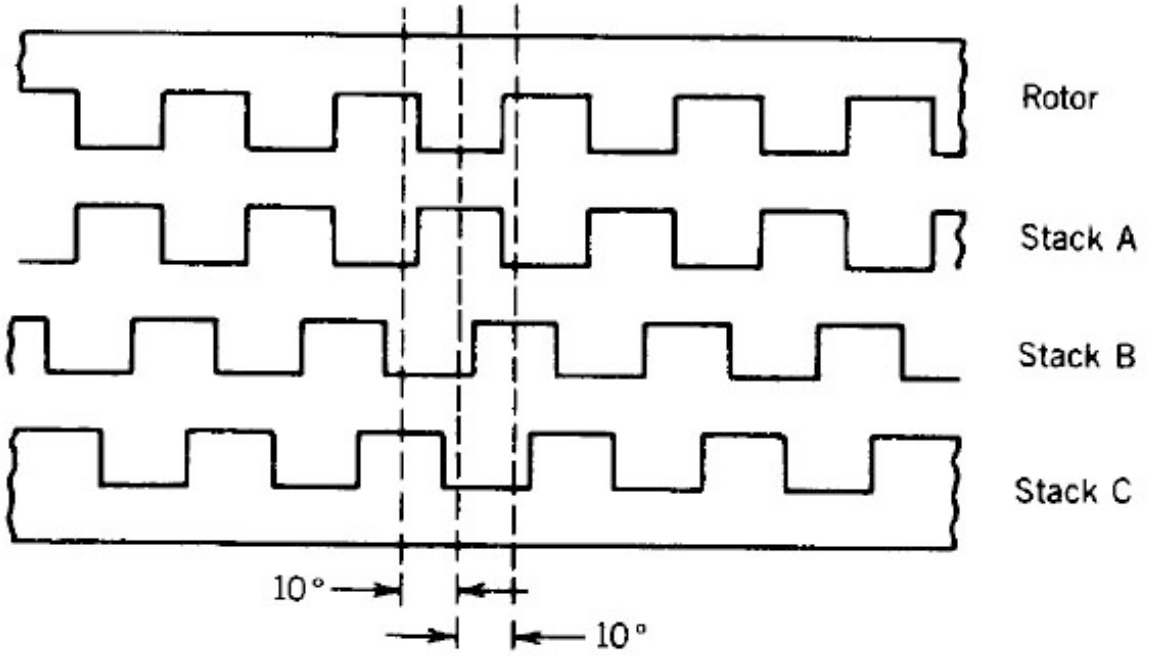
Multi Stack Variable Reluctance Stepper Motor

Step Size

$$\alpha = \frac{360}{stacks \times rotor\ teeth}$$

Number of Steps/rev.

$$n = stacks \times rotor\ teeth$$



Stepper Motors Variable Reluctance Motor

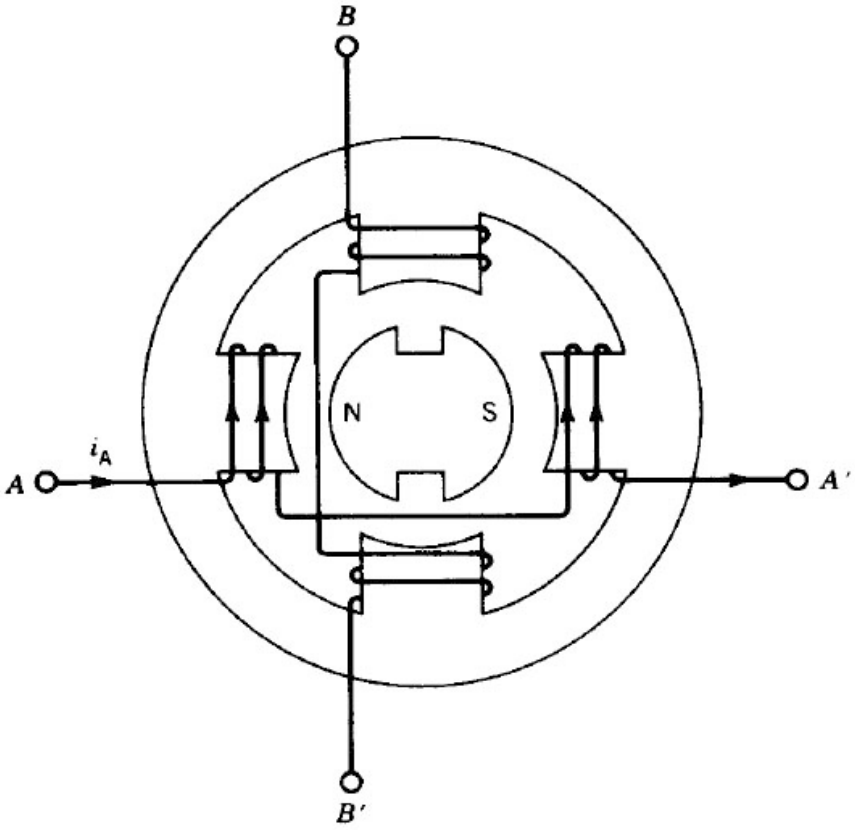
Permanent Magnet Stepper Motor

The permanent magnet stepper motor has a stator construction similar to that of the single-stack variable-reluctance type, but the rotor is made of a permanent magnet material.

Since it's difficult to make a small permanent magnet rotor with large number of teeth, this type is restricted to large step sizes (30-90°).

Stepper Motors Variable Reluctance Motor

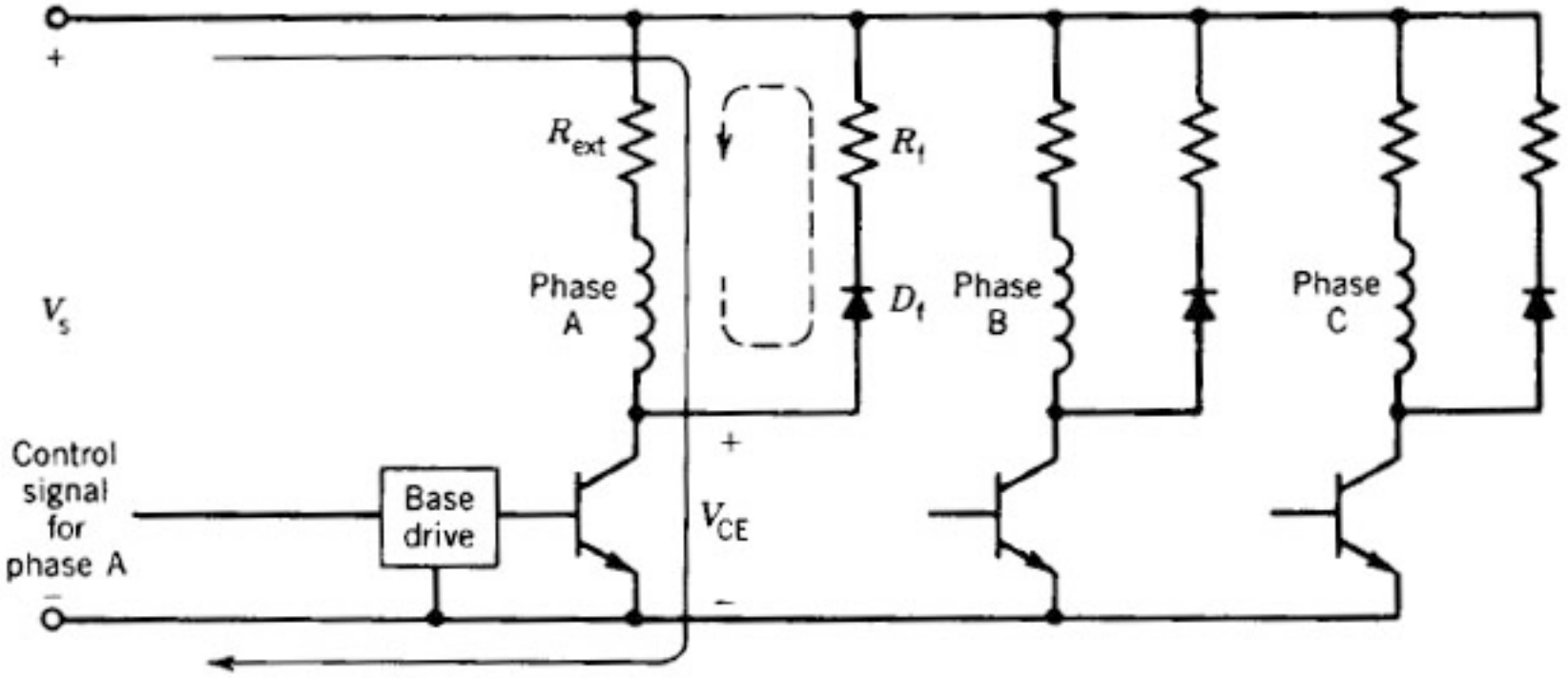
Permanent Magnet Stepper Motor



Stepper Motors Variable Reluctance Motor

Driving Circuits

Unipolar Drive Circuit for 3-phase VR Stepper Motor



Stepper Motors Variable Reluctance Motor

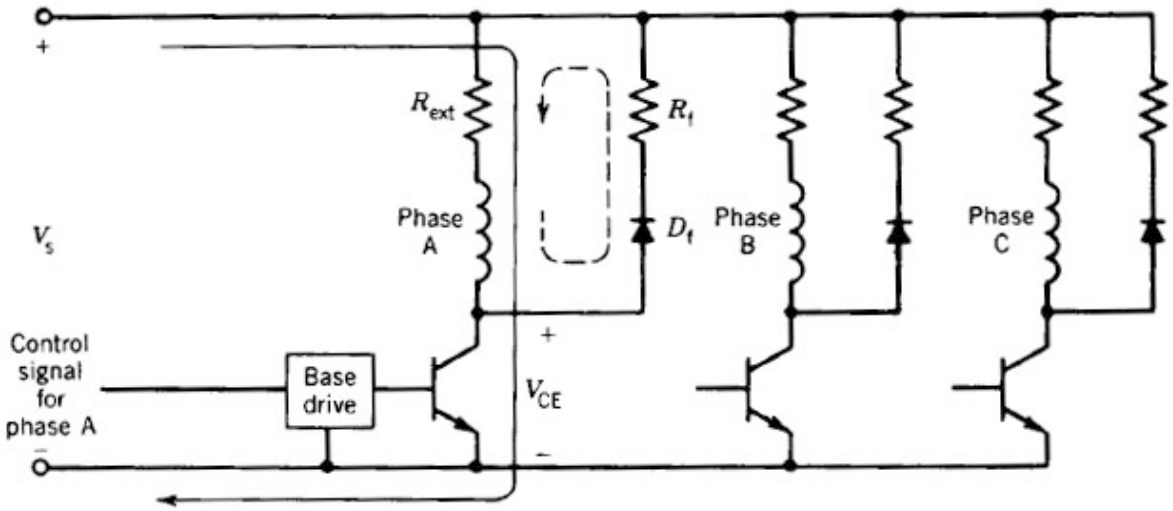
Driving Circuits

Unipolar Drive Circuit for 3-phase VR Stepper Motor

Chosen to produce I_{rated}

$$V_s = I_{rated}(R_w + R_{ext})$$

To decrease the circuit time constants



$$\tau_{on} = \frac{L_w}{R_w + R_{ext}}$$

$$\tau_{off} = \frac{L_w}{R_w + R_{ext} + R_f}$$

Stepper Motors Variable Reluctance Motor

Driving Circuits

Bipolar Drive Circuit for PM Stepper Motor