Stepper Motors

ECE230 Introduction to Embedded Systems

Motors

Learning objectives

Following this lesson and related activities, students will be able to

- Distinguish between unipolar and bipolar stepper motors
- Describe the tradeoffs between wave drive, two-phase, and half-step methods of driving a stepper motor
- Calculate the number of steps needed to rotate a stepper motor a specified angle
- Calculate the number of steps per second needed to rotate a stepper motor at a specified rate

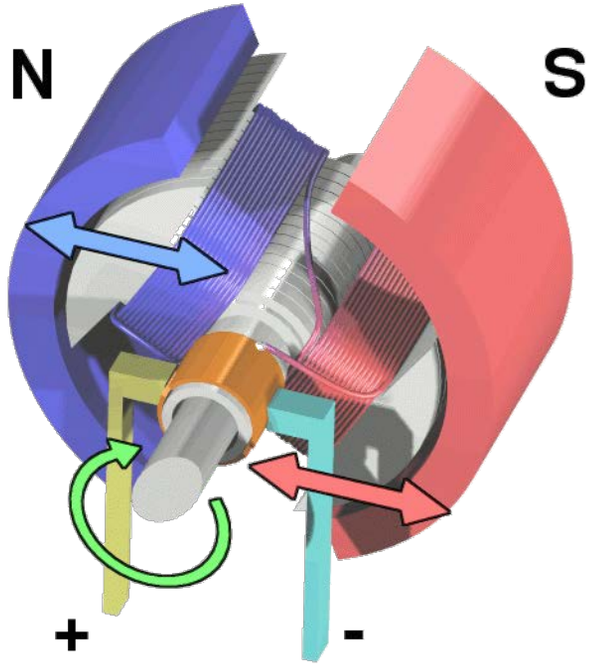
Motors

Convert electrical energy into linear or rotary force (torque)

- Electrical current passed through windings produce magnetic field
  - Causes motor shaft to rotate to align with magnetic field of magnets
  - Continuously altering current causes continuous change in magnetic field and continuous rotation

Types of motors

- **DC motor** – continuous angular motion (ON/OFF)
- **Stepper motor** – rotation specified in steps (steps per rotation dependent on resolution and gearing)
  - Requires continuous signaling for rotation
  - Inherent knowledge of position
    - May be limited due to external forces restricting movement
- **Servo motor** – specify angular position
  - Generally limited angular range

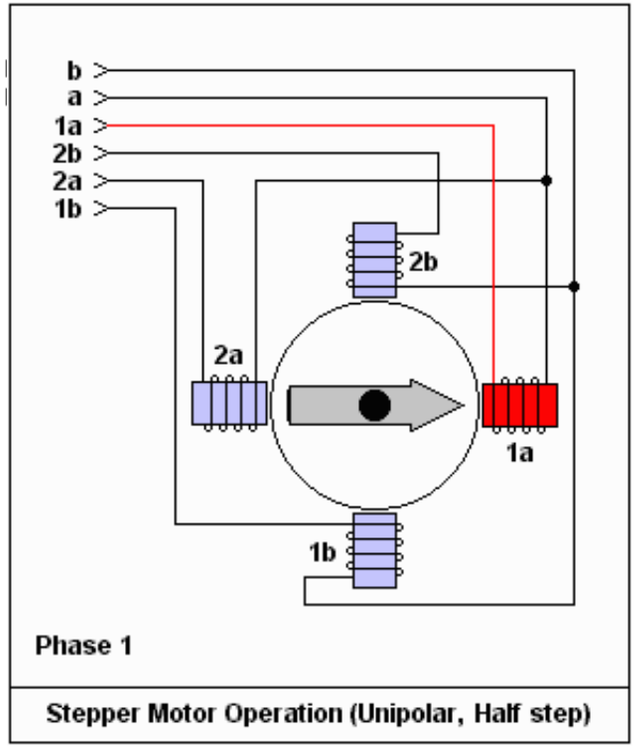


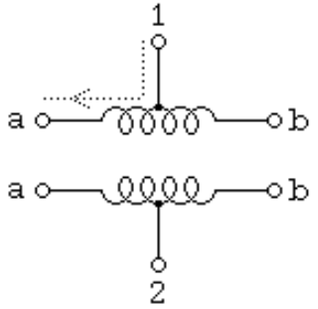
Unipolar Stepper Motor

Center-tap in each coil

Unidirectional current flow through half of winding

Commons (center-taps) may be tied together

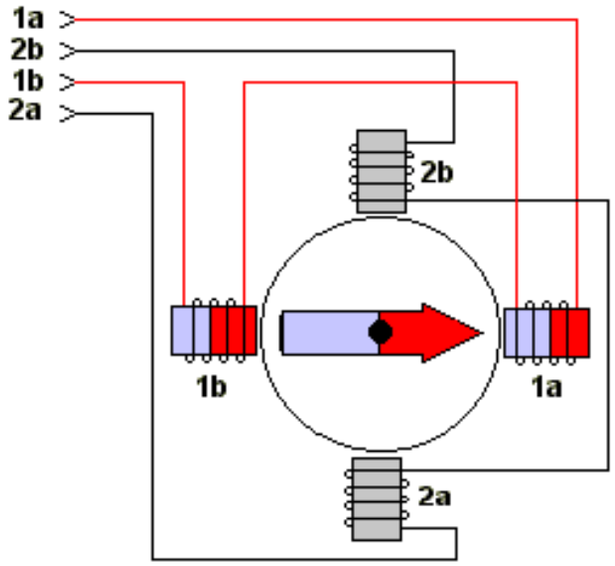




Bipolar Stepper Motor

Bi-directional current flow through entire winding

Potentially increased torque

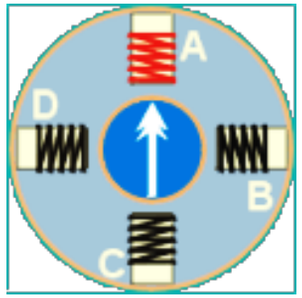


Conceptual Model of Bipolar Stepper Motor

Wave Drive Sequence

Wave Drive (One-Phase)

- Only one phase is energized at a time
- Consumes the least power
- Assures positional accuracy regardless of any winding imbalance in the motor



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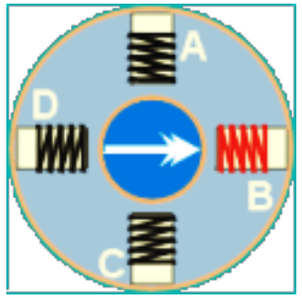

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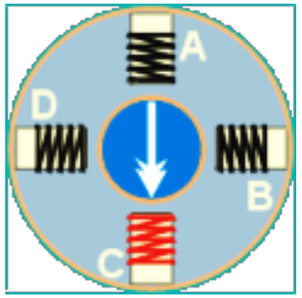

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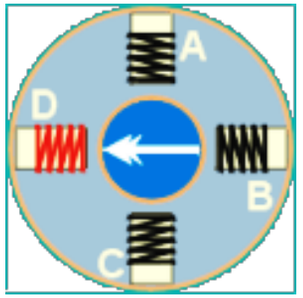

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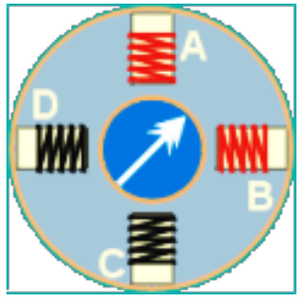
Two-phase Sequence

Hi-Torque (Two-Phase)

- Energizes two adjacent phases
- Improved torque-speed product
- Greater holding torque



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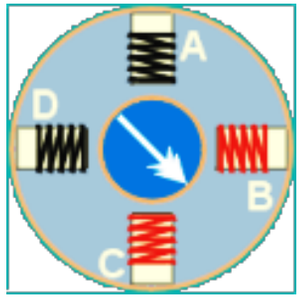

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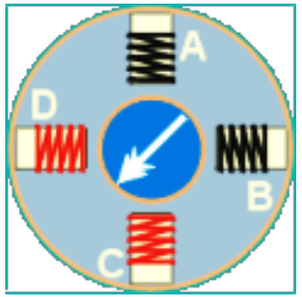

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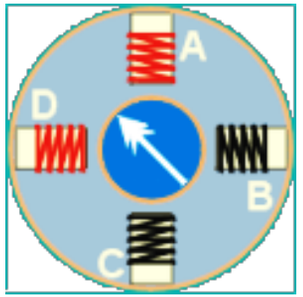

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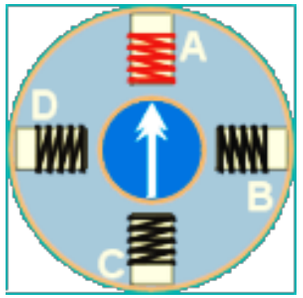
Half-step Sequence

Effectively doubles the stepping resolution of the motor, but the torque is not uniform for each step



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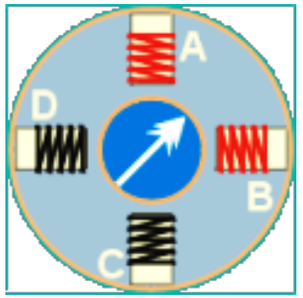

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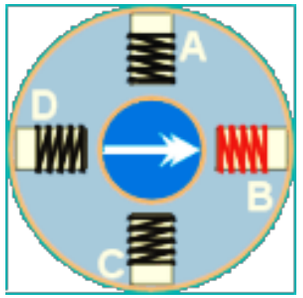

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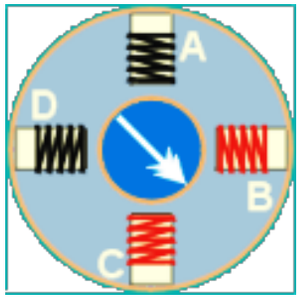

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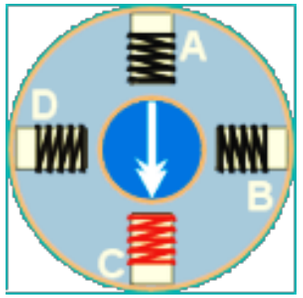

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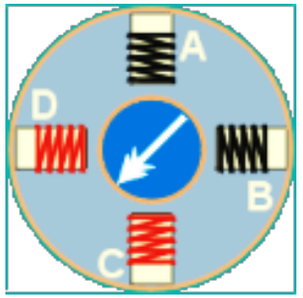

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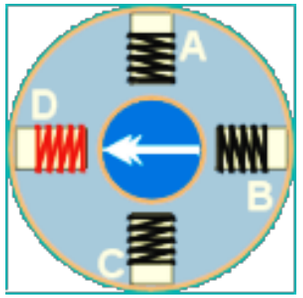

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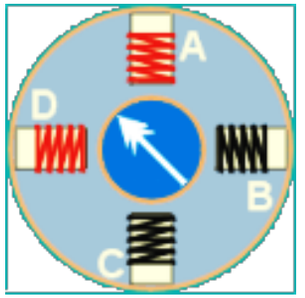

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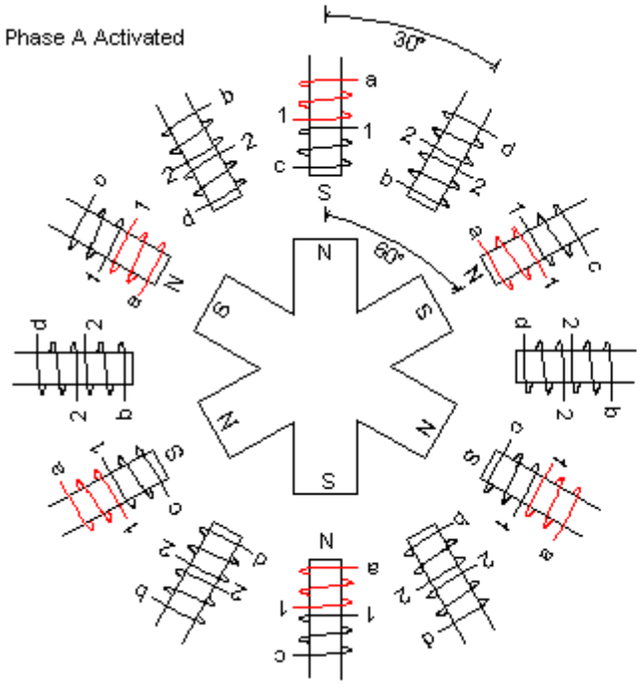
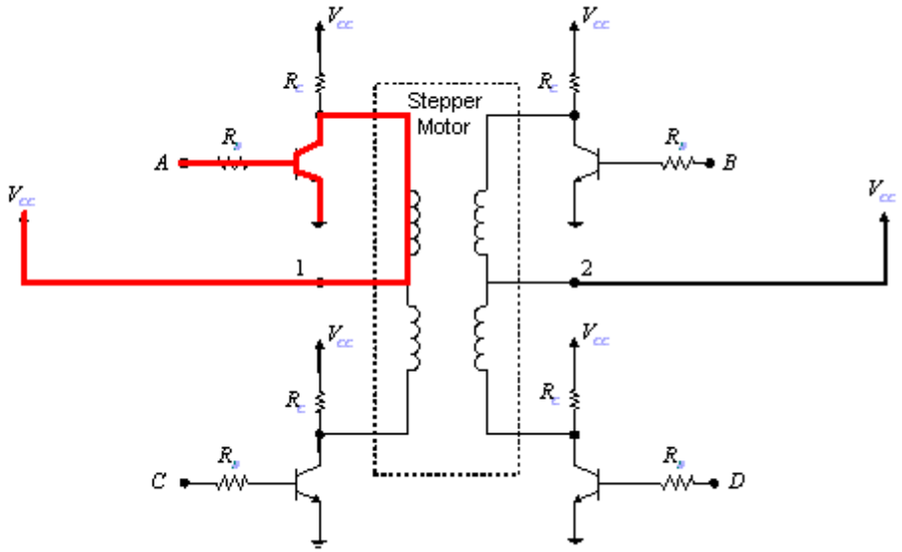
Step angle

Resolution (step angle) depends on:

- Number of permanent magnet pole pairs
- Number of phases (windings)

Gearing may further increase resolution (reduce step angle)





Step calculations

Steps needed to rotate a desired angle – *A (in degrees)*

$$Steps = \frac{A}{step\_angle} = \frac{A * steps\_per\_revolution}{360°}$$

Step rate to RPM conversion

$$\frac{revolutions}{minute} \; x \; \frac{1\ minute}{60\ seconds} \; x \; \frac{steps}{revolution} = \frac{steps}{second}$$

The inverse of this value will give you the period between steps for the desired RPM

$$\frac{1}{(\text{steps/second})} \Rightarrow seconds\ per\ step$$

Summary

Motors convert electrical energy into linear or rotary force (torque)

- Stepper motor specifies rotation in steps

Unipolar Stepper Motor – center tap windings, creating four zones

- Unidirectional current flow through half of winding
- 5 or 6-pin interface

Bipolar Stepper Motor – bi-directional current flow through entire winding

- 4-pin interface

Drive sequences

- **Wave Drive (One-Phase)** – only one phase is energized at a time
- **Hi-Torque (Two-Phase)** – energizes two adjacent phases
- **Half-step** – hybrid of one- and two-phase

Resolution (step angle) varies based on number of phases, permanent magnet pole pairs

References

Images

- Title
  - Adobe stock
- Motors
  - https://en.wikipedia.org/wiki/Electric_motor#/media/File:Electric_motor.gif