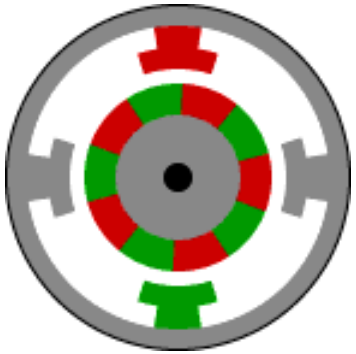
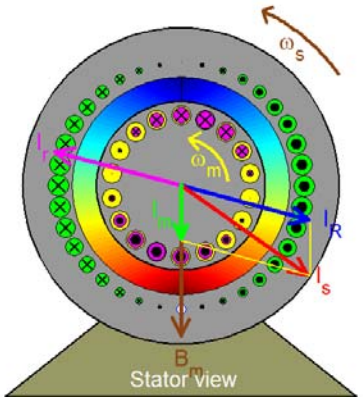
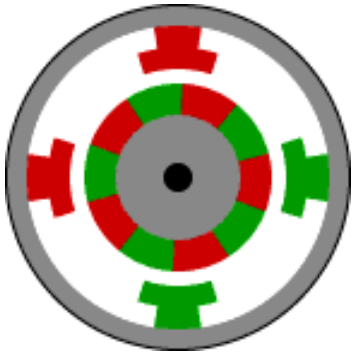
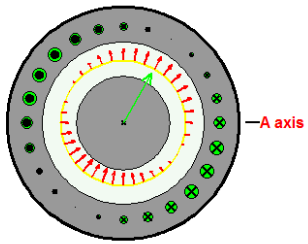
EE373-Electrical Machines

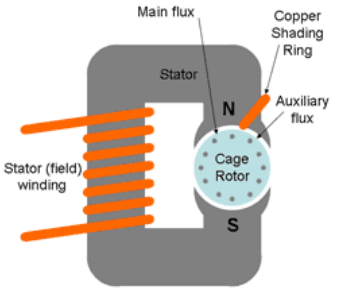
Topic 6: Special Motors







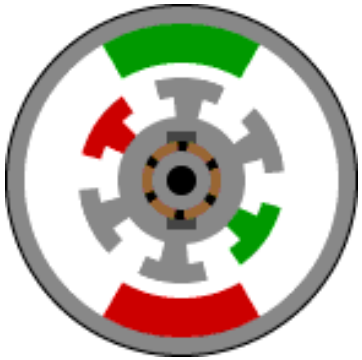




Shaded Pole Induction Motor

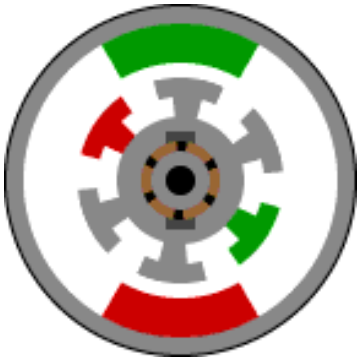
DC Motors

- The stator is the stationary outside part of a motor. The rotor is the inner part which rotates. In the motor animations, red represents a magnet or winding with a north polarization, while green represents a magnet or winding with a south polariztion. Opposite, red and green, polarities attract.



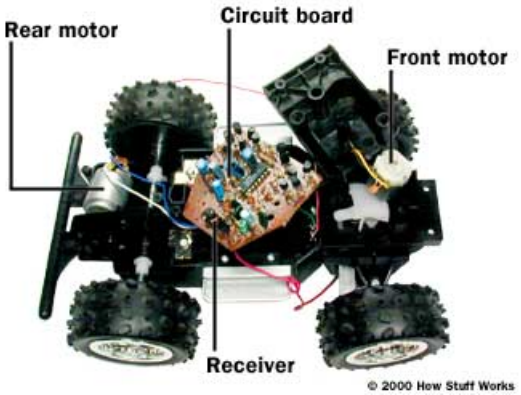
DC Motors

- Just as the rotor reaches alignment, the brushes move across the commutator contacts and energize the next winding. In the animation the commutator contacts are brown and the brushes are dark grey. A yellow spark shows when the brushes switch to the next winding.



DC Motor Applications

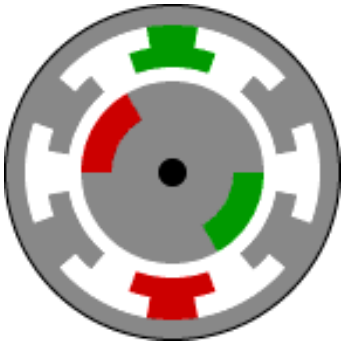
- Automobiles
  - Windshield Wipers
  - Door locks
  - Window lifts
  - Antenna retractor
  - Seat adjust
  - Mirror adjust
  - Anti-lock Braking System



- Cordless hand drill
- Electric lawnmower
- Fans
- Toys
- Electric toothbrush
- Servo Motor

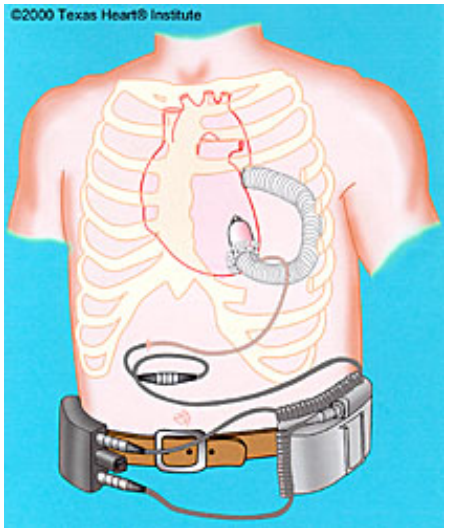
Brushless DC Motors

- A brushless dc motor has a rotor with permanent magnets and a stator with windings. It is essentially a dc motor turned inside out. The control electronics replace the function of the commutator and energize the proper winding.



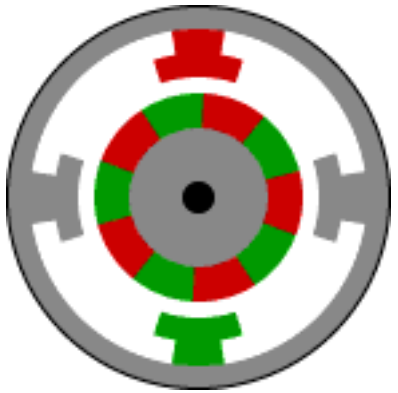
Brushless DC Motor Applictions

- Medical: centrifuges, orthoscopic surgical tools, respirators, dental surgical tools, and organ transport pump systems
- Model airplanes, cars, boats, helicopters
- Microscopes
- Tape drives and winders
- Artificial heart



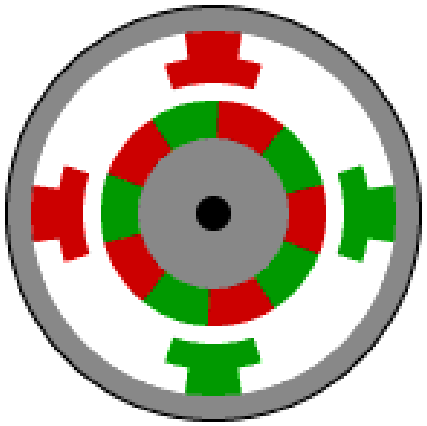
Full Stepper Motor

- 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°.



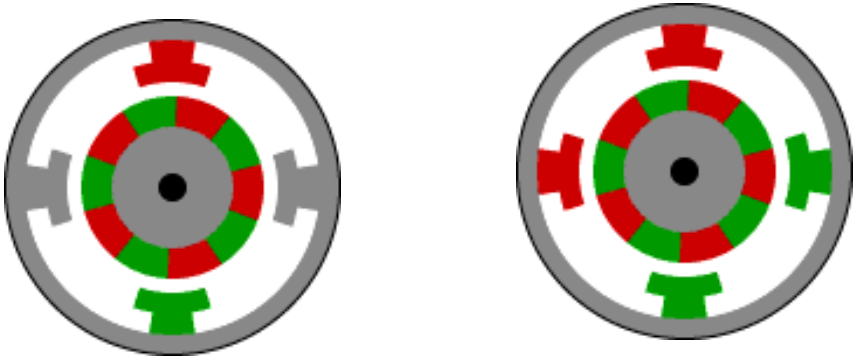
Half Stepper Motor

- 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.

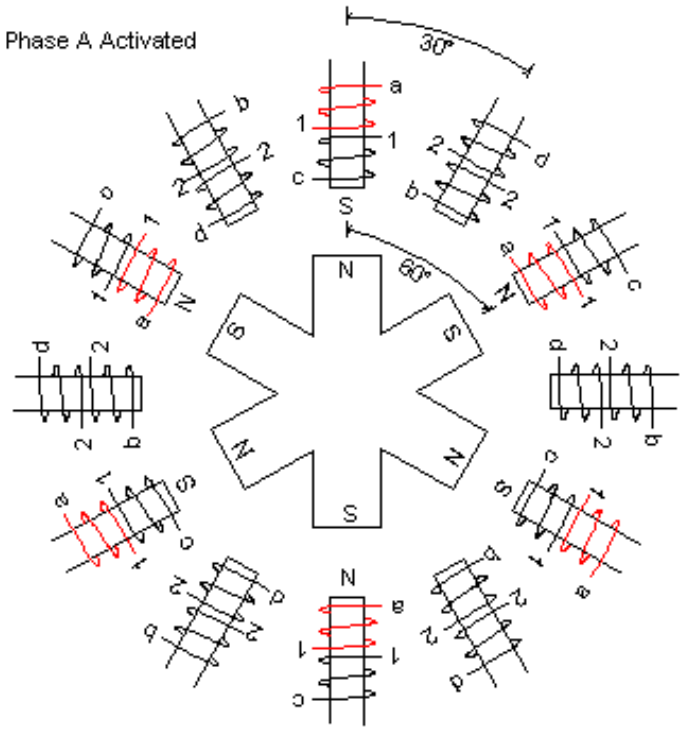


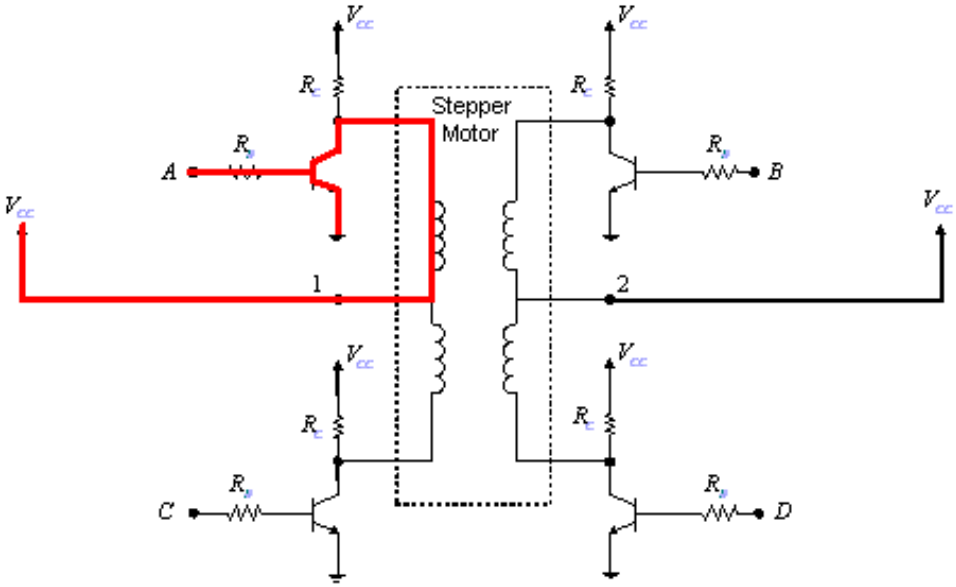
Stepper Motors

- This stepper motor is very simplified. The rotor of a real stepper motor usually has many poles. The animation has only ten poles, however a real stepper motor might have a hundred. These are formed using a single magnet mounted inline with the rotor axis and two pole pieces with many teeth. The teeth are staggered to produce many poles. The stator poles of a real stepper motor also has many teeth. The teeth are arranged so that the two phases are still 90° out of phase. This 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.



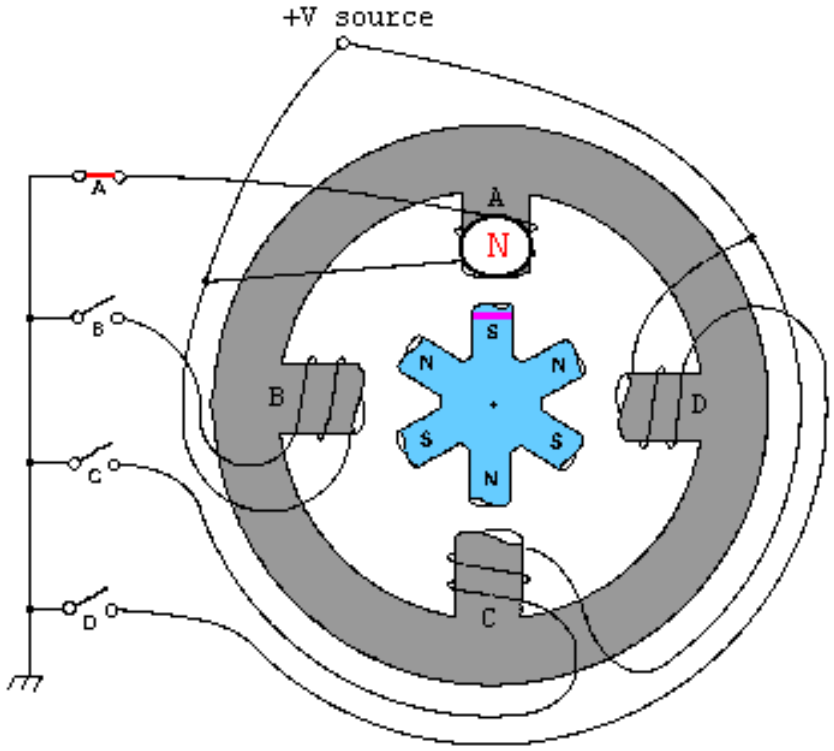
More on Stepper Motors





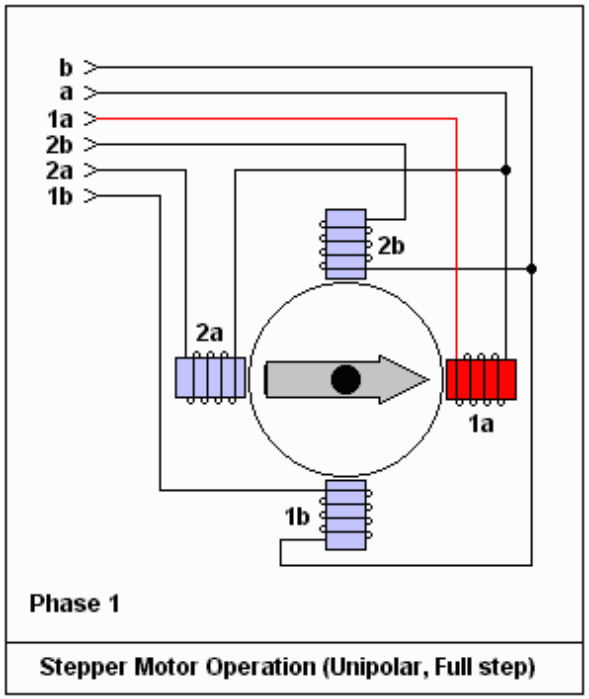
- **Note how the phases are driven so that the rotor takes half steps**

More on Stepper Motors



- Animation shows how coils are energized for full steps

More on Stepper Motors



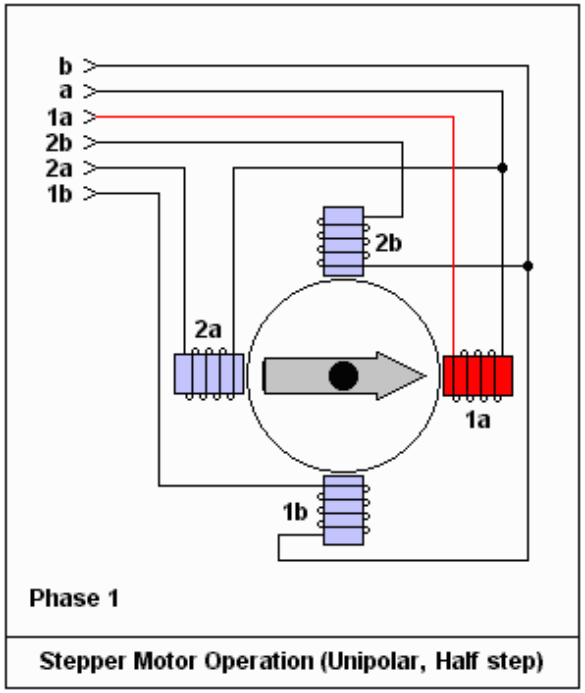
Stepper Motor Operation (Unipolar, Full step)

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

Clockwise Rotation ➡

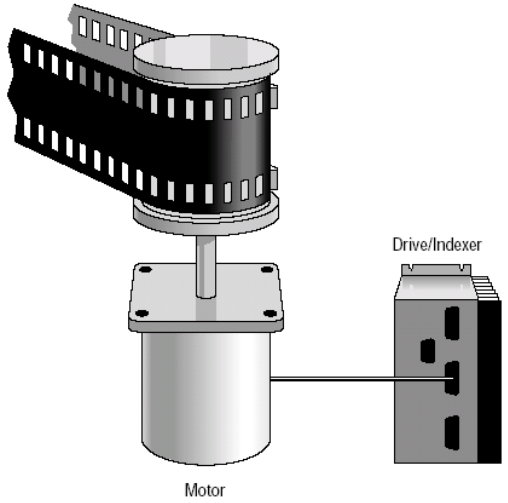
Index	1a	1b	2a	2b
1	1	0	0	0
2	1	1	0	0
3	0	1	0	0
4	0	1	1	0
5	0	0	1	0
6	0	0	1	1
7	0	0	0	1
8	1	0	0	1
9	1	0	0	0
10	1	1	0	0
11	0	1	0	0
12	0	1	1	0
13	0	0	1	0
14	0	0	1	1
15	0	0	0	1
16	1	0	0	1



Stepper Motor Operation (Unipolar, Half step)

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

Stepper Motor Applications

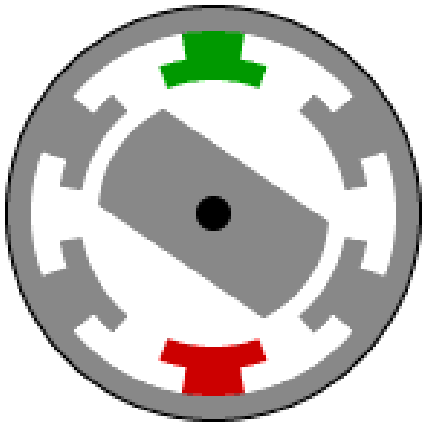


- Film Drive
- Optical Scanner
- Printers
- ATM Machines

- I. V. Pump
- Blood Analyzer
- FAX Machines
- Thermostats

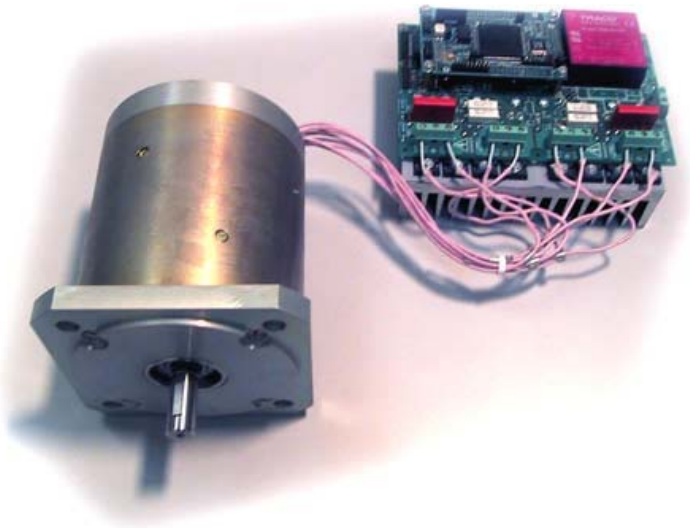
Switched Reluctance Motor

- A switched reluctance or variable reluctance motor does not contain any permanent magnets. The stator is similar to a brushless dc motor. However, the rotor consists only of iron laminates. The iron rotor is attracted to the energized stator pole. The polarity of the stator pole does not matter. Torque is produced as a result of the attraction between the electromagnet and the iron rotor in the same way a magnet is attracted to a refrigerator door. An electrically quiet motor since it has no brushes.



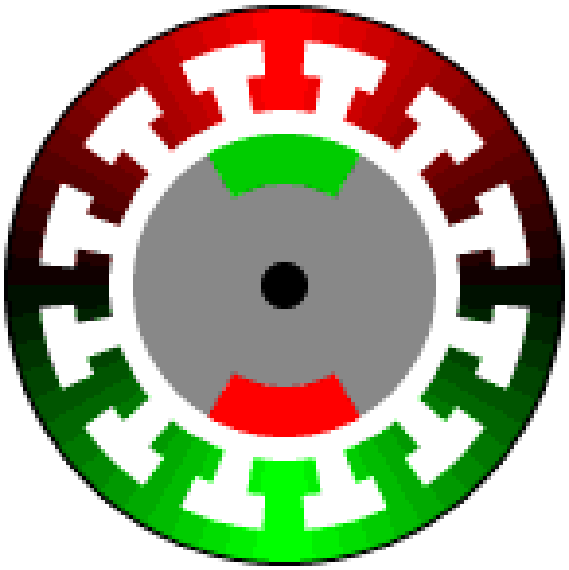
Switched Reluctance Motor Applications

- Motor scooters and other electric and hybrid vehicles
- Industrial fans, blowers, pumps, mixers, centrifuges, machine tools
- Domestic appliances



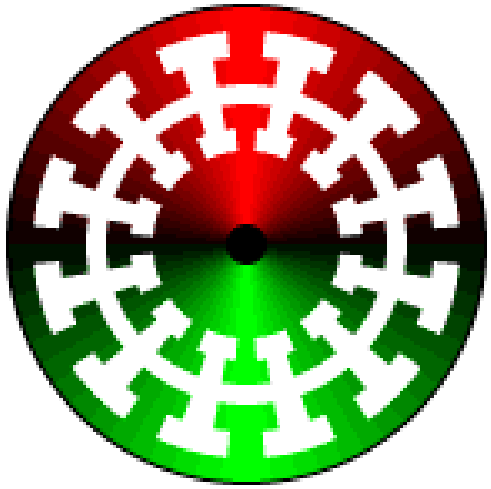
Brushless AC Motor

- A brushless ac motor is driven with ac sine wave voltages. The permanent magnet rotor rotates synchronous to the rotating magnetic field. The rotating magnetic field is illustrated using a red and green gradient. An actual simulation of the magnetic field would show a far more complex magnetic field.



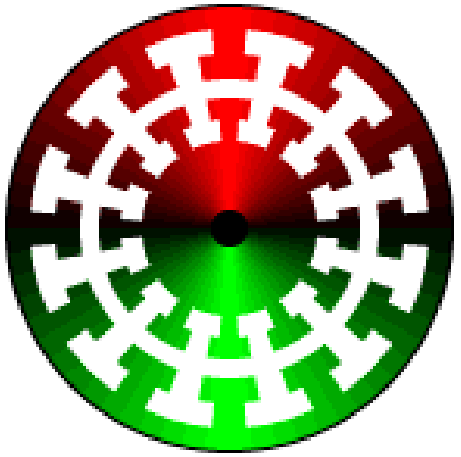
AC Induction Motor

- The stator windings of an ac induction motor are distributed around the stator to produce a roughly sinusoidal distribution. When three phase ac voltages are applied to the stator windings, a rotating magnetic field is produced. The rotor of an induction motor also consists of windings or more often a copper squirrel cage imbedded within iron laminates. Only the iron laminates are shown. An electric current is induced in the rotor bars which also produce a magnetic field.



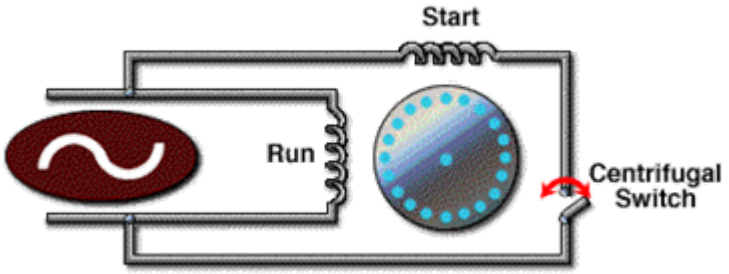
AC Induction Motor

- The rotating magnetic field of the stator drags the rotor around. The rotor does not quite keep up with the the rotating magnetic field of the stator. It falls behind or slips as the field rotates. In this animation, for every time the magnetic field rotates, the rotor only makes three fourths of a turn. If you follow one of the bright green or red rotor teeth with the mouse, you will notice it change color as it falls behind the rotating field. The slip has been greatly exaggerated to enable visualization of this concept. A real induction motor only slips a few percent.

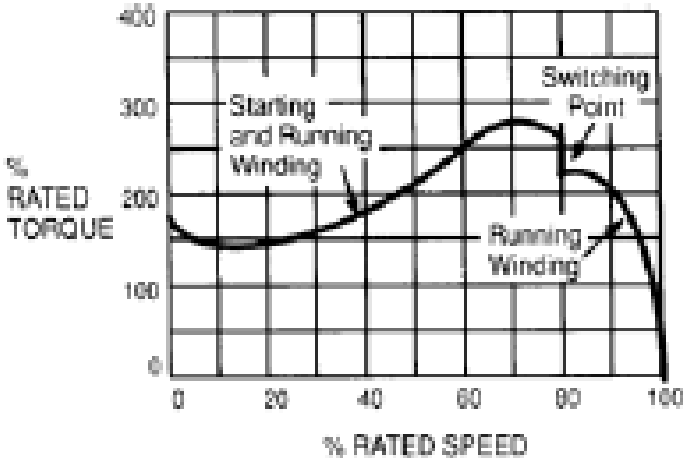


Split-Phase Induction Motor

- Common small single phase motor
  - Good Starting Torque
  - Moderate Efficiency
  - Moderate Cost
- Small conveyors, augers, pumps, and some compressors
- 1/20th to ¾ Hp, available to 1.5 Hp



- Starting winding in parallel with Running winding
- Switch operates at 70-80% of full speed.
- Centrifugal Switch
  - Sticks Open
  - Sticks Shut

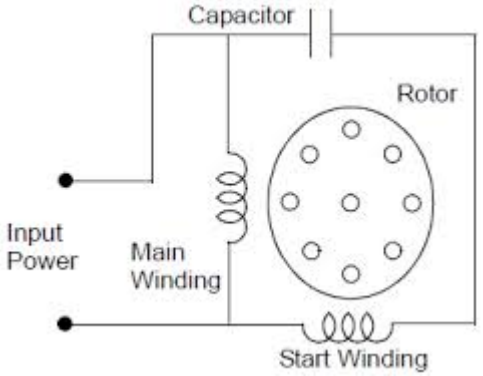


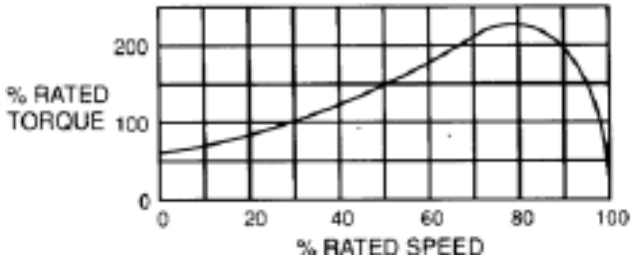
Capacitor Run Induction Motor

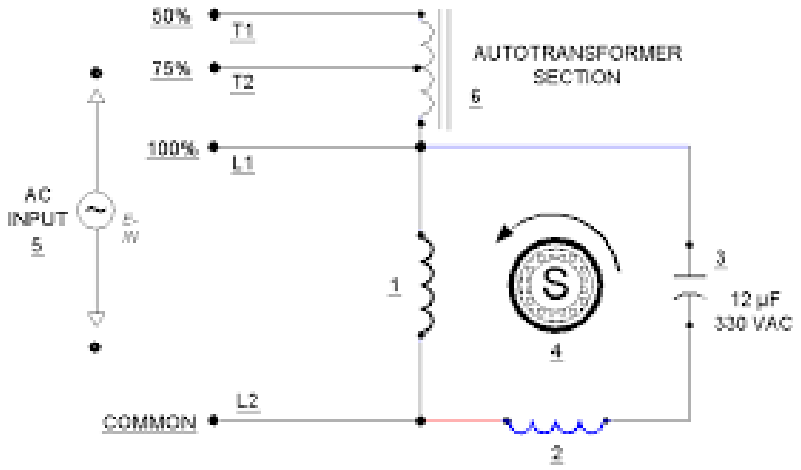
Permanent Split Capacitor

- Primarily a fan and blower motor.
- Poor starting torque
- Very low cost motor.

- Capacitor in "Capacitor Winding"
  - Provides a "phase shift" for starting.
  - Optimizes running characteristics.
- No centrifugal switch

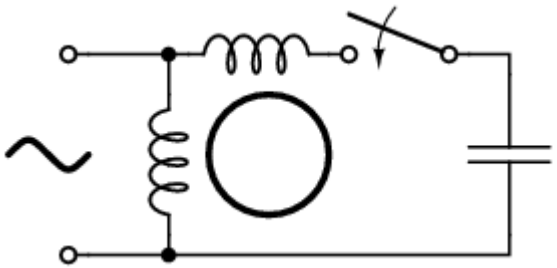


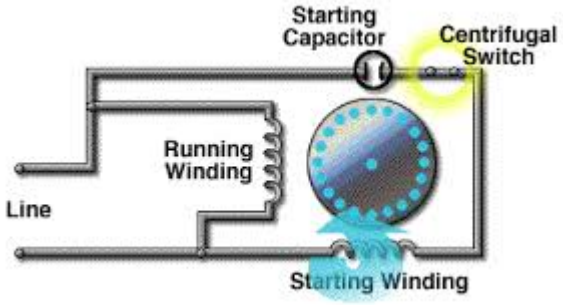


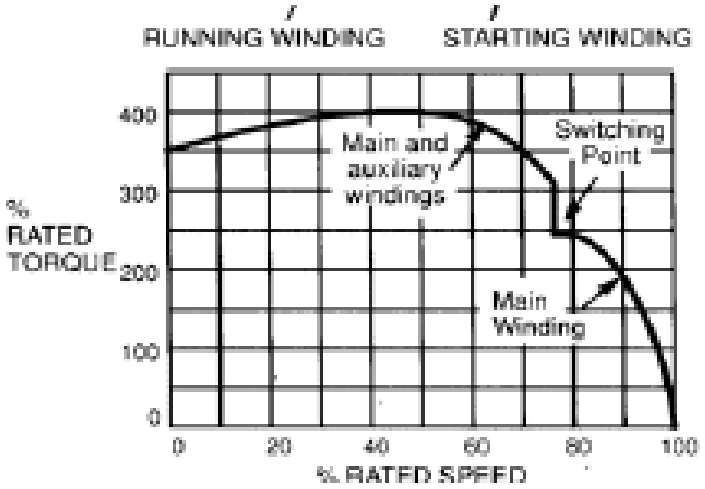


Capacitor Start Induction Motor

- Larger single phase motors up to about 10 Hp.
- A split phase motor with the addition of a capacitor in the starting winding.
- Capacitor sized for high starting torque.
- Very high starting torque.
- Very high starting current.
- Common on compressors and other hard starting equipment.

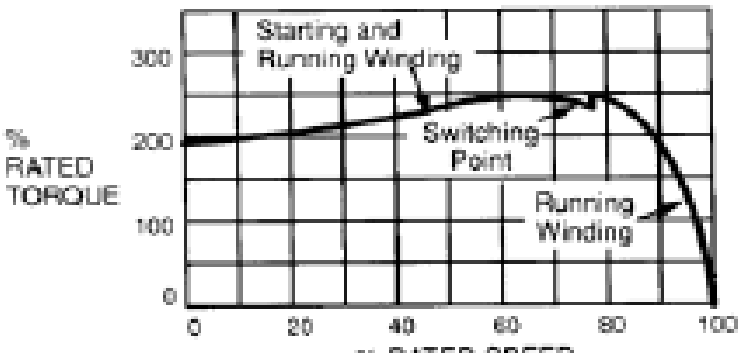


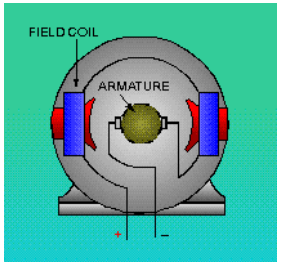




Capacitor Start-Capacitor Run Induction Motor

- Both starting and running characteristics are optimized.
  - High starting torque
  - Low starting current
  - Highest cost
- For hard starting loads like compressors and pumps.
- Up to 10 Hp or higher is some situations.
- Larger single phase motors up to 10 Hp.
- Good starting torque (less than cap start) with lower starting current.
- Higher cost than cap start.

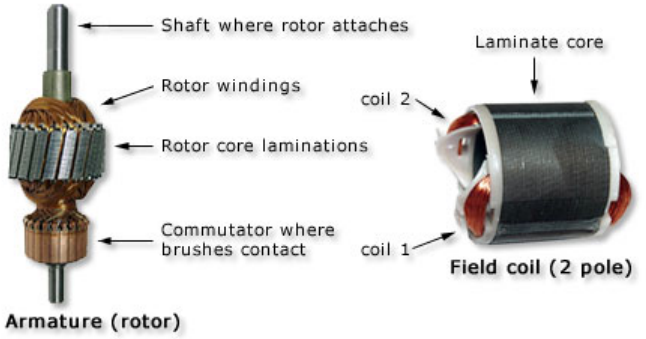




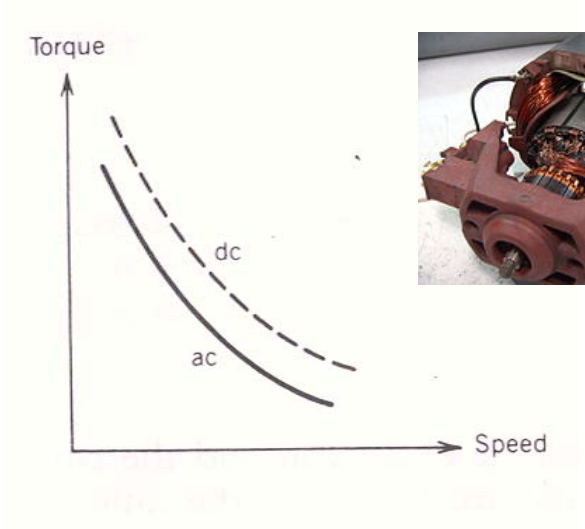
Universal Motor

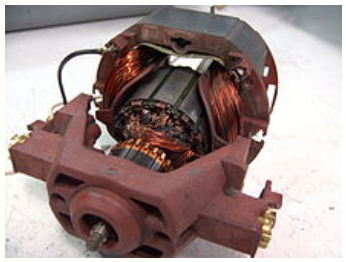
A universal motor is a series motor that may be operated either on d.c. or on single phase a.c . Its speed is usually high (1500-15000 rpm) and widely used in fractional horsepower ratings. It is identical to a series d.c. motor except that stator core and poles are laminated to limit the iron losses when operated from a.c. supply

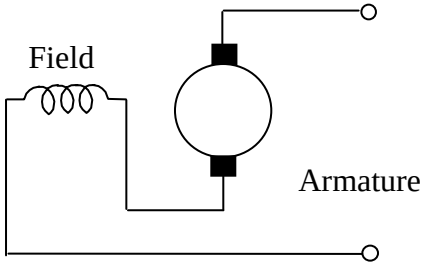
- Runs on AC or DC
- Commutator and brushes
- Generally found in portable power tools.
- Lower Hp sizes



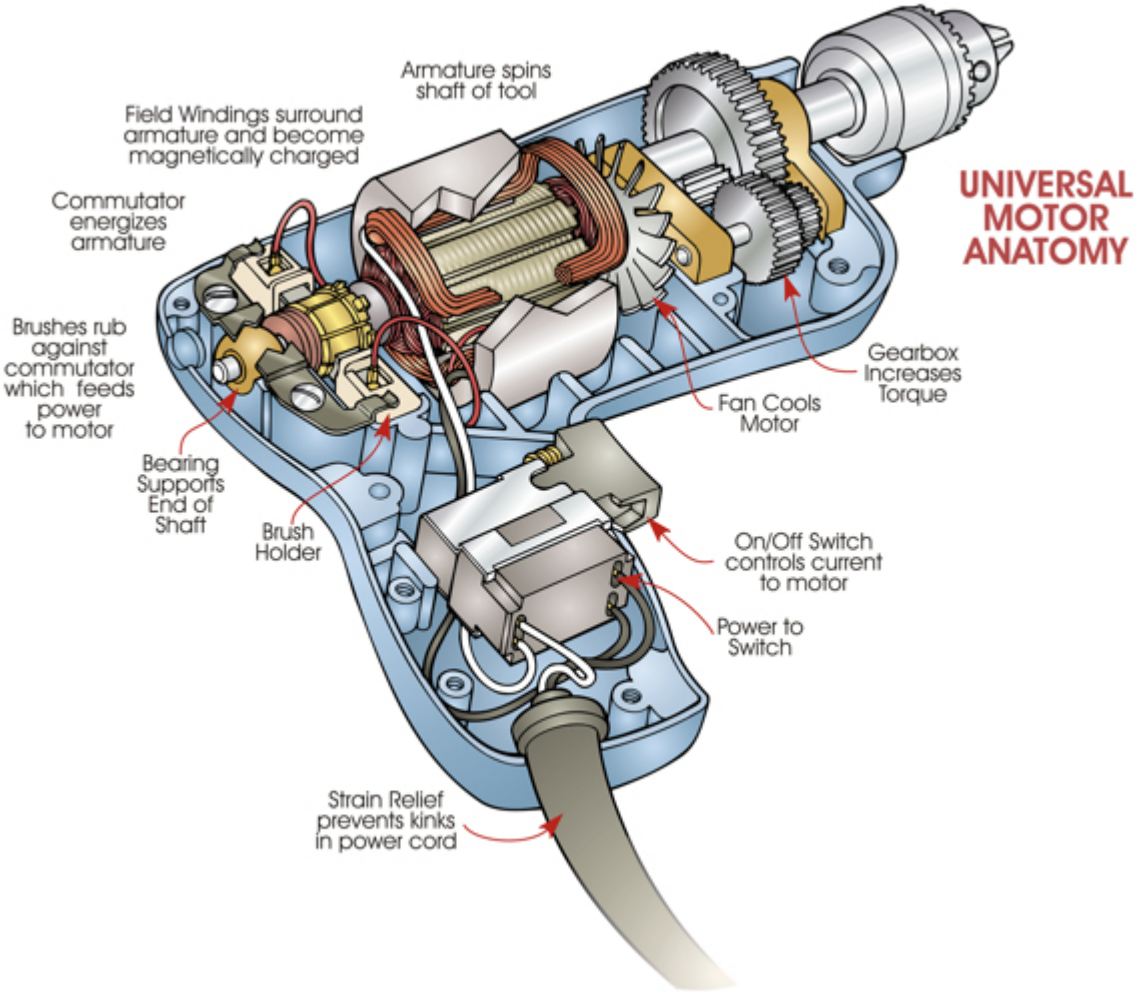
- Very high starting torque.
- Higher torque on DC than AC (battery operated tools)
- The higher the rpm, the lower the torque.





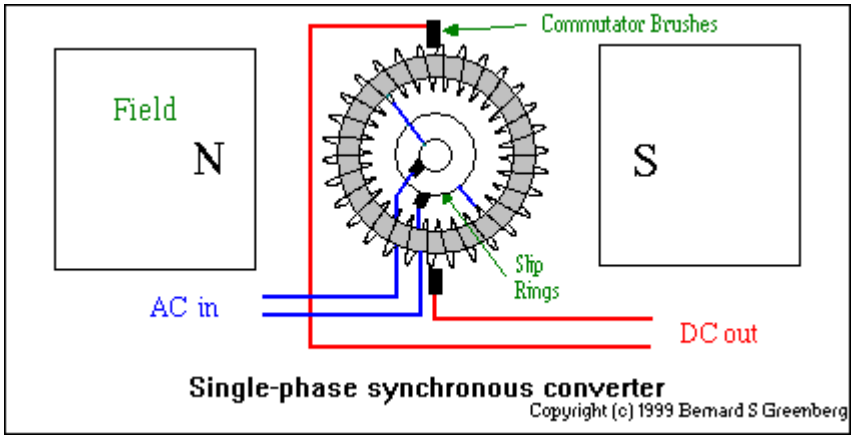


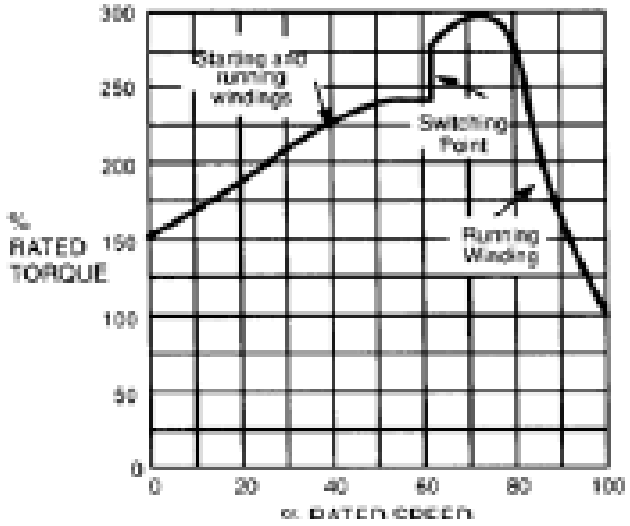
Universal Motor



Single-Phase Synchronous Motor

- Special design for "constant speed" at rated horsepower and below.
- Used where maintaining speed is critical when the load changes.





Huge List of Applications

- Aircraft Window Polarizing Drives
- Antenna Positioning and Tuning Devices
- Audio/Video Recording Instruments
- Automated Inspection Equipment
- Automated Photo Developing Equipment
- Automated Photo Slide Trimming & Mounting Equipment
- Automatic Carton Marking & Dating Machines
- Automatic Dying and Textile Coloring Equipment
- Automatic Food Processing Equipment
- Automatic I.V. Dispensing Equipment
- Automatic Radio Station Identification Equipment
- Automotive
- Automotive Engine Pollution Analyzers
- Baseball Pitching Machine
- Blood Agitators
- Blood Cell Analyzer
- ……..
- Warning Light Flashers
- Railroad Signal Equipment
- Remote Focusing Microscopes
- Resonator Drives for Vibraphones
- ……..
- Silicone Wafer Production Equipment
- Solar Collector Devices
- Sonar Range Recorders and Simulators
- Steel Mill Process Scanners
- Tape Cleaning Equipment
- Tape Input for Automatic Typewriters
- Telescope Drives
- Ultrasonic Commercial Fish Detectors
- Ultrasonic Medical Diagnostic Equipment
- Voltage Regulators
- Water and Sewage Treatment Controls
- Weather Data Collection Machines
- Welding Machines
- X-Ray Equipment
- XY Plotters