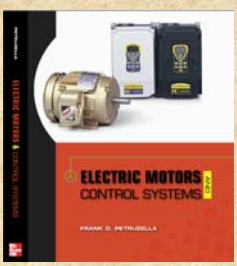


Chapter 5

Electric Motors

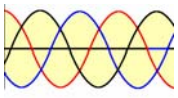
PART 4 Single-Phase Alternating Current Motors

Most home and business appliances operate on single-phase AC power. For this reason, *single-phase AC motors* are in widespread use.

- **A single-phase induction motor is larger in size, for the same horsepower, than a three-phase motor.**

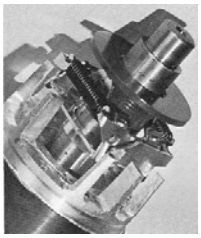
Single-Phase

Three-Phase



- **When running, the torque produced by a single-phase motor is pulsating and irregular, contributing to a lower power factor and efficiency.**
- **They are generally available in the fractional to 10-HP range.**

Whereas a three-phase induction motor sets up a rotating field that can start the motor, a single-phase motor needs an auxiliary means of starting.

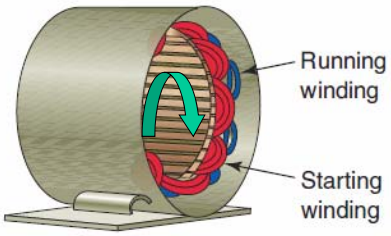


- Once a single-phase induction motor is running, it develops a rotating magnetic field. However, before the rotor begins to turn, the stator produces only a pulsating, stationary field.
- A single-phase motor could be started by mechanically spinning the rotor, and then quickly applying power. However, normally these motorsuse some sort of automatic starting.
- Single-phase induction motors are classified by their start and run characteristics.

SPLIT-PHASE MOTOR

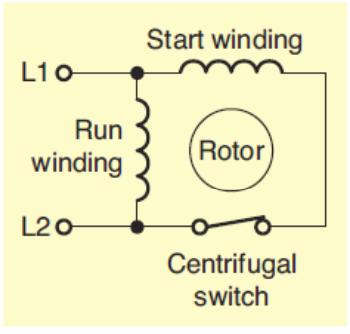
The split-phase motor uses a squirrel-cage rotor which is identical to that used in a three-phase motor.

To produce a rotating magnetic field, the single-phase current is split by two windings, the main *running* winding and an auxiliary *starting* winding, which is displaced in the stator 90 electrical degrees from the running winding.



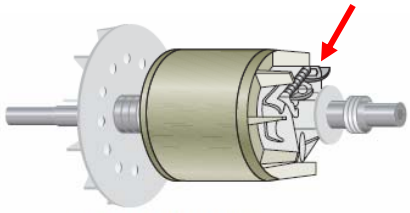
Motor stator windings

The starting winding is connected in series with a switch, centrifugally or electrically operated, to disconnect it when the starting speed reaches about 75% of full-load speed.

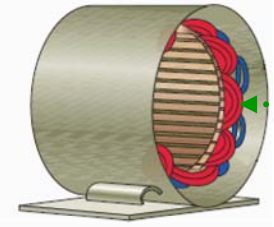


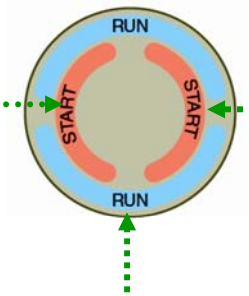
Motor circuit schematic

Centrifugally operated switch mechanism


Squirrel-cage rotor

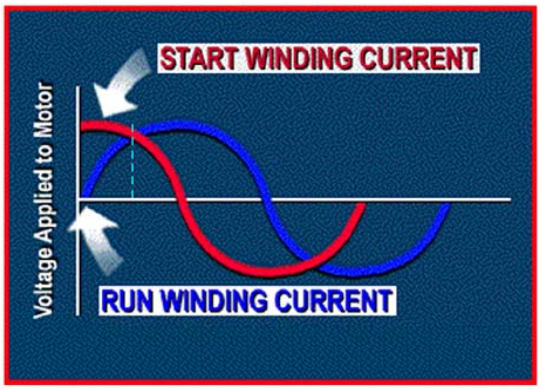
Phase displacement **is accomplished by the difference in inductive reactance of the two windings and the physical displacement of the windings in the stator.**





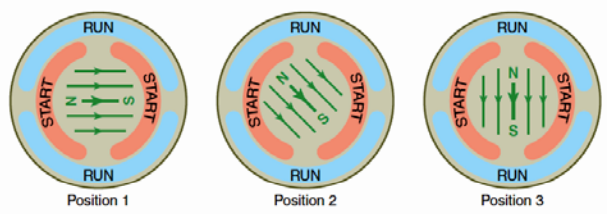
➢**The starting winding is wound on the top of the stator slots with fewer turns of smaller diameter wire.**

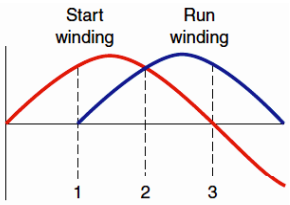
➢**The running winding has many turns of large diameter wire wound in the bottom of the stator slots that gives it a higher inductive reactance than that of the starting winding.**



➢**When AC line voltage is applied the current in the starting winding leads the current in the running winding by approximately 45 electrical degrees.**

➢**The two sine waves can be though of as the waveforms of the electromagnetism produced by the two windings.**



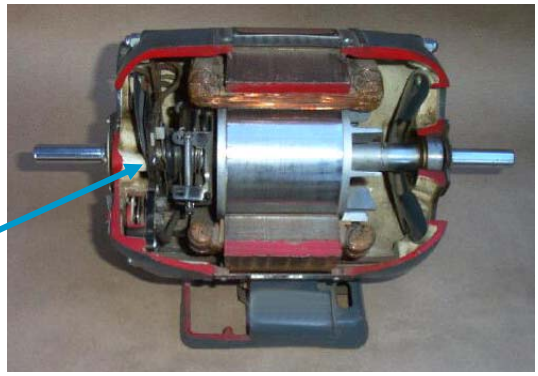


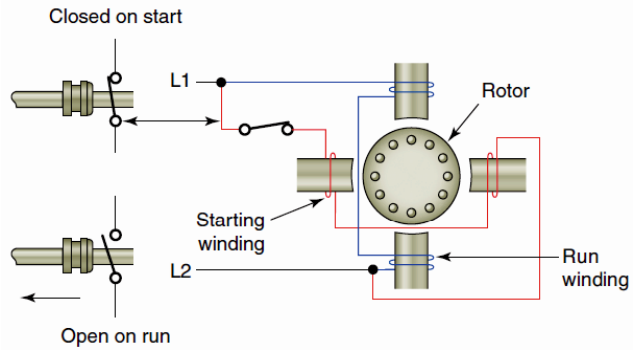
- As the alternations in current (and magnetism) continue the position of the north and south poles changes in what appears to be a **clockwise rotation.**

- At the same time the rotating field cuts the squirrel cage conductors of the rotor and induces a current in them.
- This current creates magnetic poles in the rotor, which interact with the poles of the stator rotating magnetic field to produce motor torque

Once the motor is running, the starting winding must be *removed from the circuit*. Since the starting winding is of a smaller gauge size, continuous current through it would cause the winding to burn out.

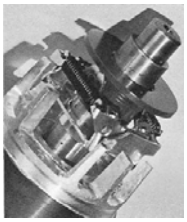
Centrifugally operated switch mechanism for removing the starting winding from the circuit.



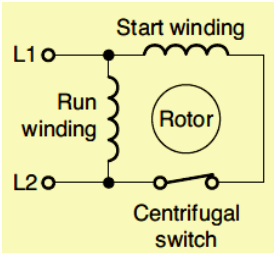


➢The centrifugal mechanism rotates on the motor shaft and interacts with a fixed stationary switch the contacts of which are connected in series with the start winding.

➢When the motor approaches its normal operating speed, centrifugal force overcomes the spring force allowing the contacts to open and disconnects the starting winding from the power source; the motor then continues operating solely using its running winding.



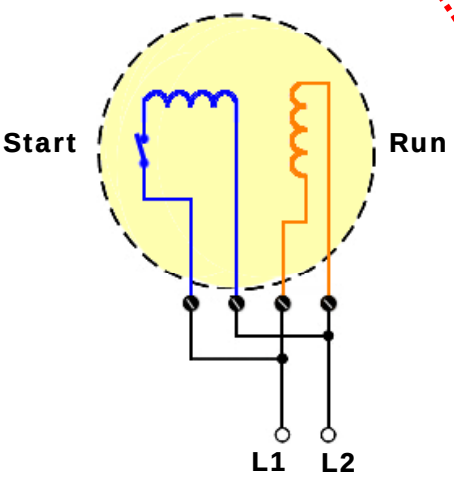
The centrifugal switch can be a source of trouble if it fails to operate properly.



➢Should the switch fail to close when the motor stops, the starting winding circuit will be open. As a result when the motor circuit is again energized, the motor will not turn but simply produce a humming sound.

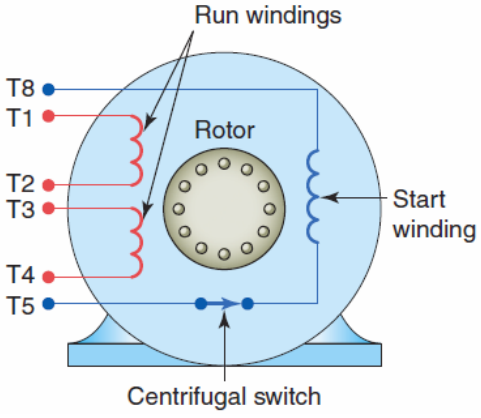
➢Normally the starting winding is designed for operation across line voltage for only a short interval during starting. Should the switch fail to open within a few seconds of starting may cause the starting winding to char or burn out.

Reversing the leads to either the start or run windings, but not to both (line leads) changes the direction of rotation of a split-phase motor.

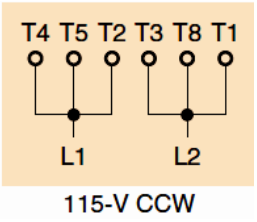


Dual-voltage split-phase motors have a set of two run windings that are connected for different line voltages.

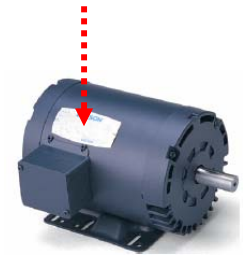
115/230 Volt Motor

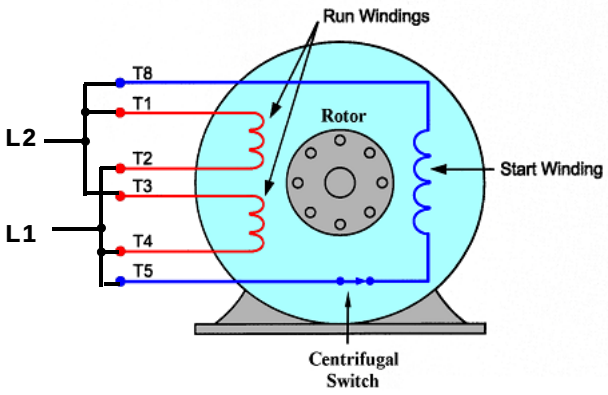


For low voltage, the two run windings and the start winding are all connected in parallel.

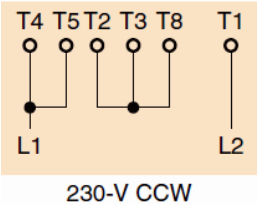


115-V CCW

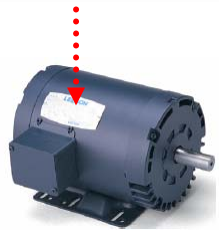


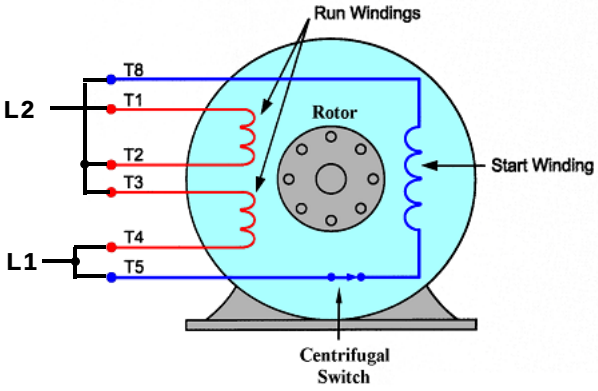


For high voltage, the two run windings connect in series and the start winding is connected in parallel with one of the run windings.



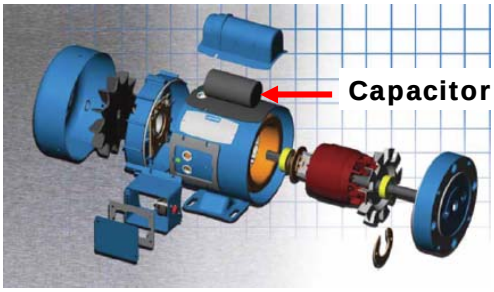
230-V CCW





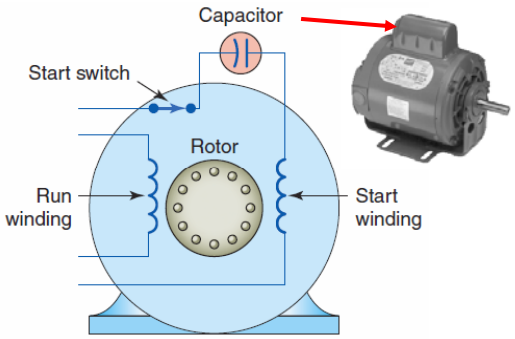
SPLIT-PHASE CAPACITOR MOTOR

The *capacitor-start motor* is a modified split-phase motor.



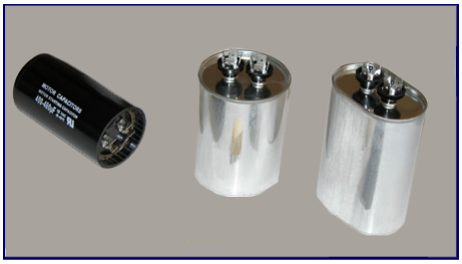
- A capacitor connected in series with the starting winding creates a phase shift of approximately 80 degrees between the starting and running winding.
- This is substantially higher than the 45 degrees of a split phase motor and results in a higher starting torque.
- Capacitor-start motors provide more than double the starting torque with one third less starting current than the split-phase motor.

- The motor also uses a start switch to disconnect the capacitor and start winding when the motor approaches full speed.



- The start switch may be either a mechanical centrifugal switch or solid state electronic switch.

- Solid- state potential relays are used for some applications. The coil of this potential relay is energized by the potential of the start winding. When this voltage is raised to the pick up value the contact will open and disconnect the start capacitor.



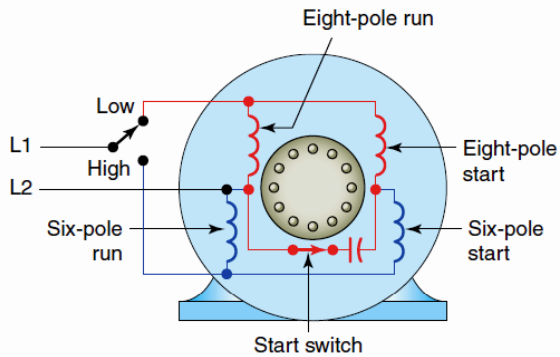
- The job of the capacitor is to improve the starting torque and not the power factor as it is only in the circuit for a few seconds at the instant of starting.

- The capacitor can be a source of trouble if it becomes shorted or open circuited.

- A shorted capacitor will cause an excessive amount of current to flow through the staring winding.

- An open capacitor will cause the motor not to start.

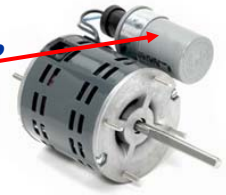
Dual-speed capacitor-start motors have leads that allow external connection for low and high speeds.



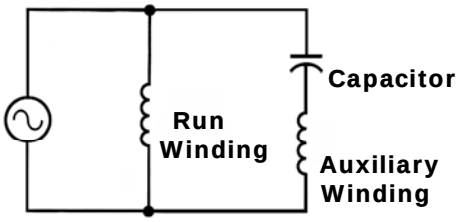
➢It uses **two sets** of start and run windings.

➢For **low speed** 900-rpm operation the **6-pole** set of start and run windings connect to the source and for **high speed** 1200-rpm the **8-pole** set is used.

The *permanent-capacitor* motor has neither a centrifugal switch, nor a capacitor strictly for starting. Instead, it has a run-type capacitor permanently connected in series with the start winding.

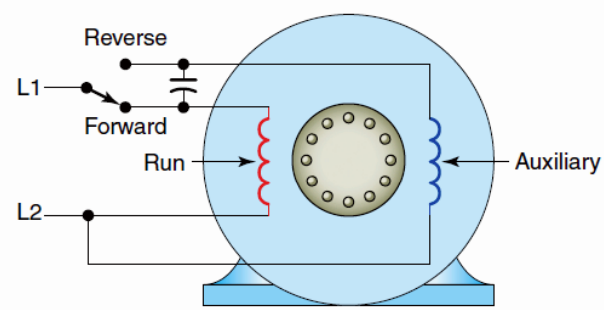


➢Because the run capacitor must be designed for continuous use, it cannot provide the starting boost of the capacitor-start motor.



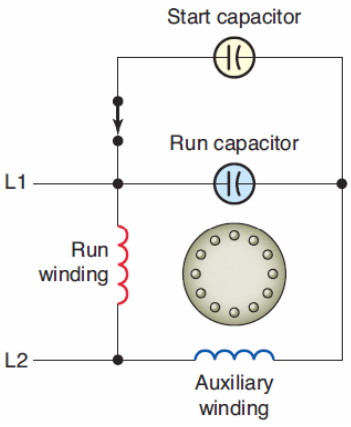
➢Typical starting torques for permanent-capacitor motors are low so these motors are not suited for hard-to-start applications.

The run and auxiliary windings of a permanent capacitor motor are identical allowing for the motor to be *reversed* by switching the capacitor from one winding to the other,



One common application is the garage door opener motor.

The *capacitor-start/ capacitor-run* motor uses both a start and run capacitor.



- When the motor is started the two capacitors connect in parallel to produce a large amount of capacitance and starting torque.
- Once the motor is up to speed, the start switch disconnects the start capacitor from the circuit.
- Capacitor start /capacitor run motors operate at lower full-load currents and higher efficiency.

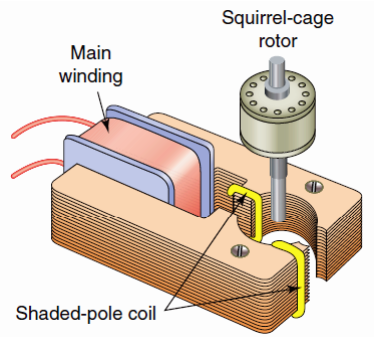
Electrolytic
Start Capacitor

Oil-Filed
Run Capacitor

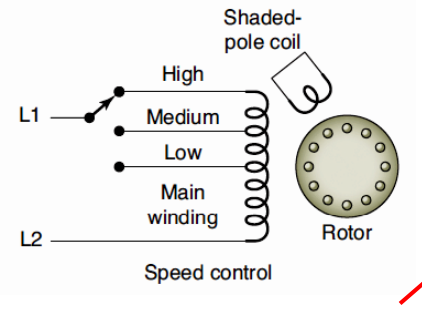
- The motor **start** capacitor is typically an **electrolytic** type while the **run** capacitor is an **oil-filed** type.
- The electrolytic type offers a large amount of capacitance when compared to its oil-filled counterpart.
- It is important to note that these two capacitors **are not interchangeable**, as an electrolytic capacitor used in an AC circuit for more than a few seconds will overheat.

SHADED-POLE MOTOR

Unlike other types of single-phase motors, *shaded-pole motors* have only one main winding and no start winding or switch.



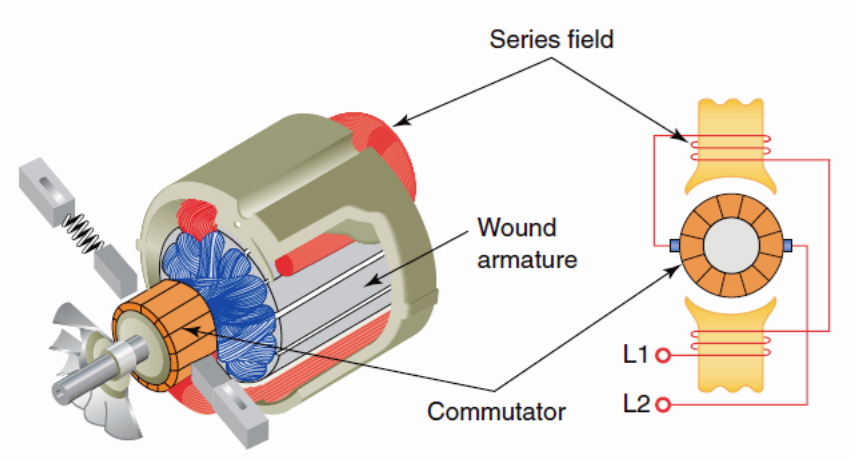
- As in other induction motors the rotating part is a squirrel-cage rotor.
- Shaded pole motors have low starting torque and efficiency ratings. They are made only in small sizes ranging from 1/20 to 1/6 HP.
- Applications for this type of motor include fans, can openers, blowers, and electric razors.

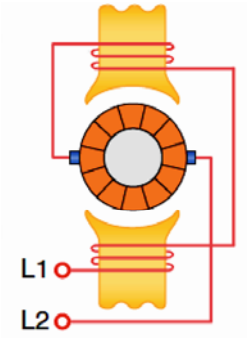


- Starting is by means of a design that uses a continuous copper loop around a small portion of each motor pole.
- Currents in this copper loop delay the phase of magnetic flux in that part of the pole enough to provide a rotating field with very low starting torque.
- Speed can be controlled by varying the applied line voltage, or through a multi-tap winding.

UNIVERSAL MOTOR

The *universal motor* is constructed similar to that of a series-type DC motor with a wound series field and a wound armature.





- Like the DC-series motor, its armature and field coils are connected in series.

- Although universal motors can be operated with either direct current or single-phase alternating current most are used for household appliances and portable hand tools that operate on single-phase AC power.

- Universal motors can easily exceed one revolution per cycle of the mains current. This makes them useful for appliances such as blenders, vacuum cleaners, and hair dryers where high-speed operation is desired.

- The speed of the universal motor like that of DC series motor varies considerably from no-load to full-load.

- Reversing is accomplished by reversing the current flow through the armature with respect to the series field.

- Varying the voltage that is applied to the motor controls the speed.