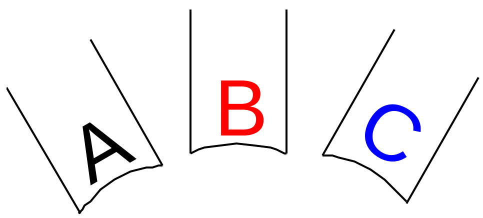
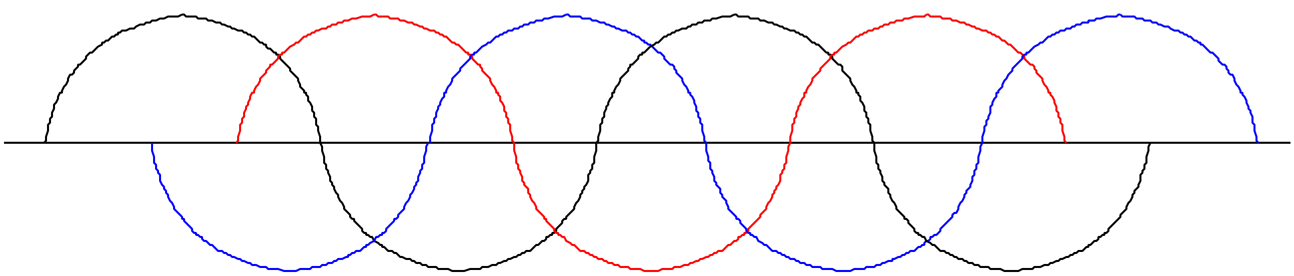
Single Phase AC Motors

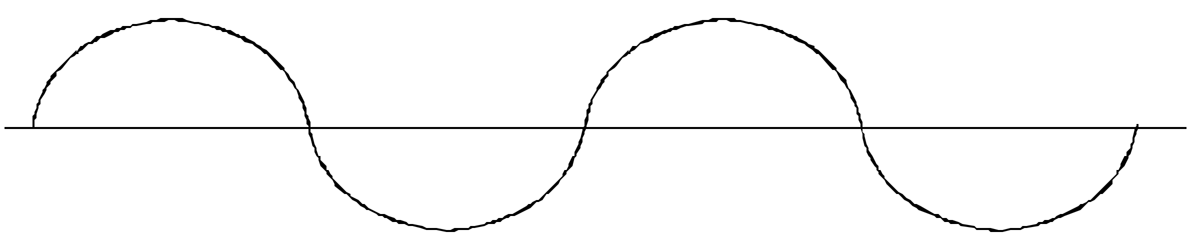
Some of the most inexpensive and simple motors are AC motors that utilize squirrel cage rotors. In contrast to a wound rotor, a squirrel cage rotor has no windings, no commutator, and no need for brushes. Therefore, the only parts needing maintenance attention are the bearings. Most single phase and poly phase AC motors operate on the principle of a rotating magnetic field in the stator. This rotating magnetic field cuts conductive bars on the rotor, inducing a voltage that causes current to flow through the rotor bars. This current flow produces magnetic fields on the rotor, and the rotor tries to keep up with the rotating magnetic field in the stator.



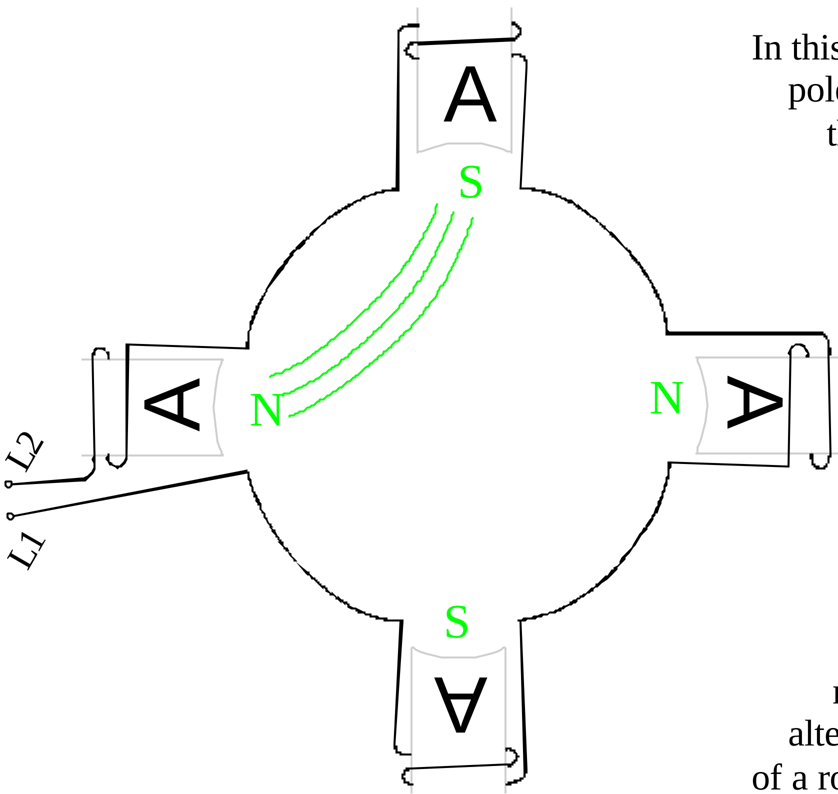
In the three phase motor, the effect of a rotating magnetic field is easily achieved because there are three current waveforms. The stator windings are arranged on pole pieces in such a way as to create the effect of a rotating magnetic field.



The challenge for single phase motors is this; How to produce a rotating magnetic field from a single phase voltage waveform.



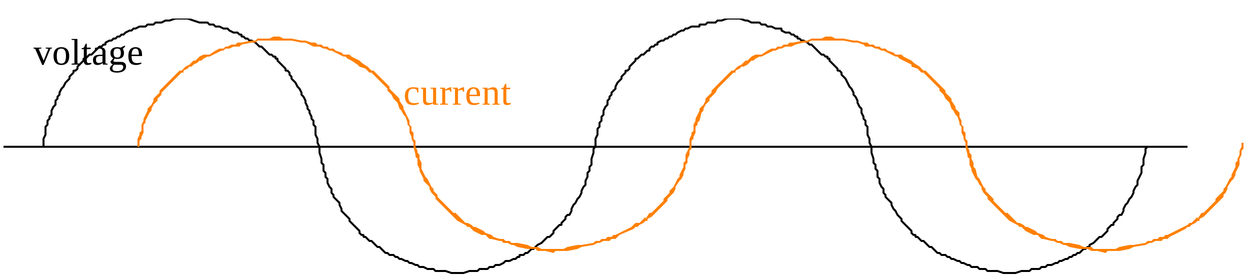
The answer lies in a method involving inductance and capacitance, called phase splitting.



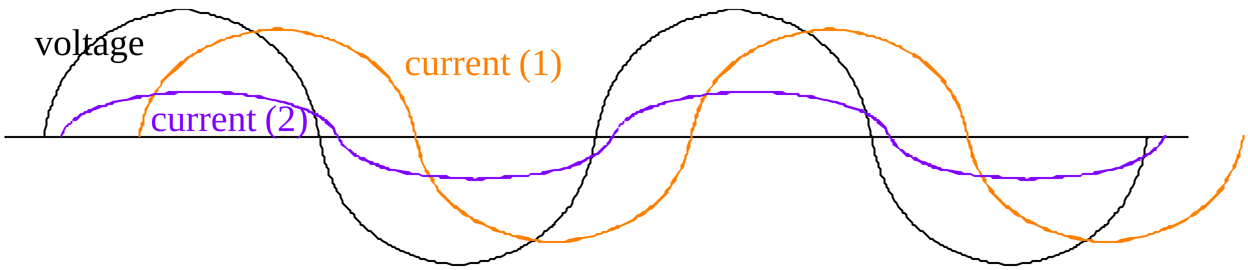
In this simplified illustration of a 4 pole, single phase motor, notice that the direction of the winding turns changes from one pole to the next. The horizontal pole of the left has clockwise windings, while the adjacent pole on the top is wound counter-clockwise. This arrangement produces opposite pole face polarities, and sets up the magnetic fields as shown. When the AC current changes direction in the second half of the AC cycle, the pole faces change polarity, and the result is the creation of an alternating magnetic field instead of a rotating magnetic field.

With 60hz AC, this polarity change happens in 1/120th of a second, and the rotor cannot move 90 mechanical degrees from a stop in such a short period of time. This would cause the rotor to just chatter back and forth between the alternating poles at a rate of 60 cycles per second. If the rotor was turned fast enough by some mechanical means for it's momentum to carry past the next pole face, it would run, but this motor would not start by itself.

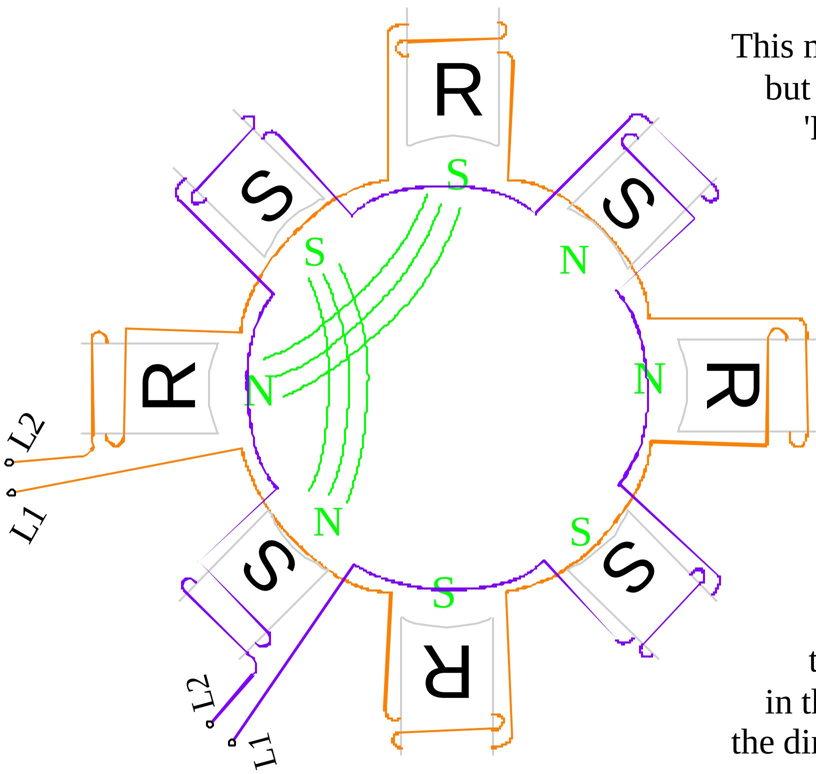
Now imagine that the circuit indicated above is made up of large gauge wire, wound 1000 times around each pole piece. This results in a circuit with low resistance and high inductive reactance, which causes current to lag voltage by about 75 electrical degrees.



Now imagine another arrangement of small gauge wire wound 100 times around the pole pieces. This would result in a circuit with high resistance and low inductive reactance. The current waveform in this circuit having less inductive reactance might only be 15 degrees out of phase with the voltage, and the amount of current, (or magnitude), would be considerably less.



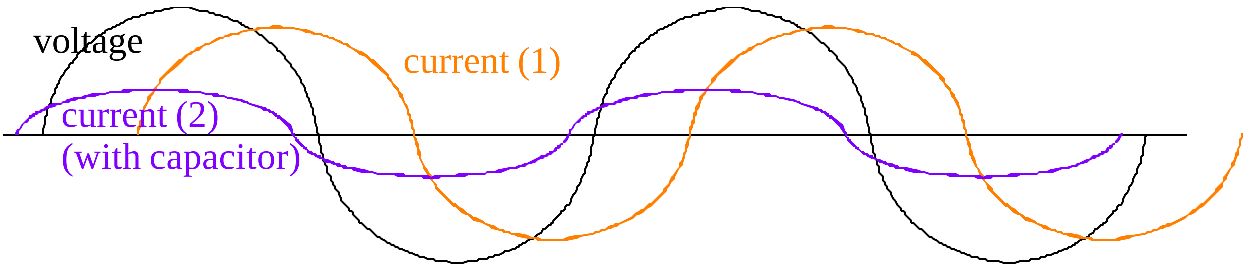
These 2 current waveforms, produced from a single-phase voltage, rise and fall approximately 60 electrical degrees apart, because inductance causes current to lag voltage. (See 'AC Theory').

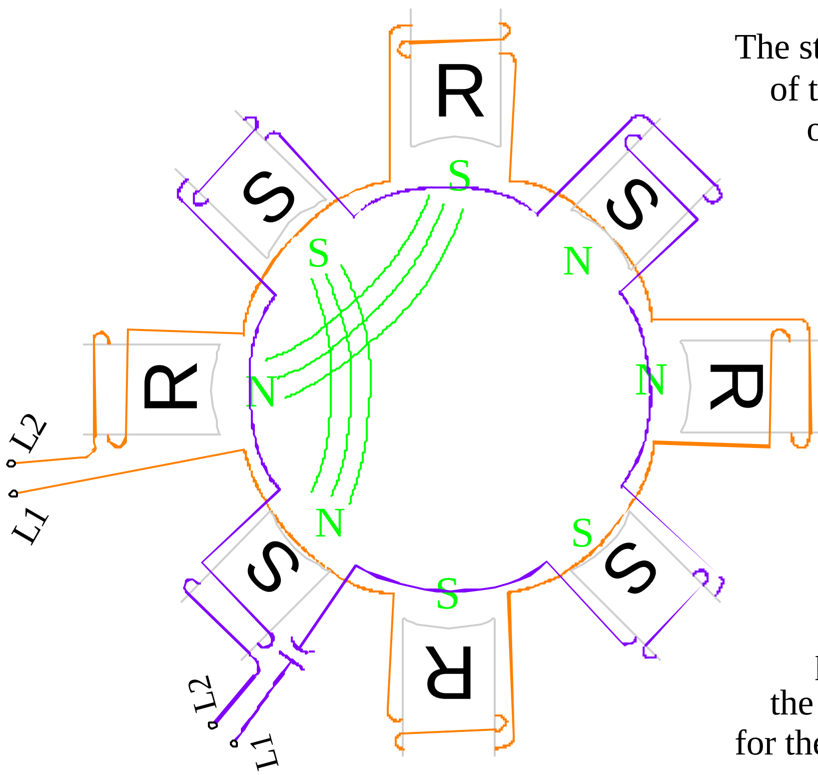


This may look like an eight pole motor, but notice the difference between the 'Run' and 'Start' windings. Both of these winding circuits connect to the same, single phase voltage source.The start poles will reach their peak magnetic strength 60 electrical degrees before the run poles. This is a simplified example of how phase-splitting is used to create the effect of a rotating magnetic field in the stator of of a motor, from a single phase, AC voltage waveform. From the pole face polarities shown in this example, can you determine the direction of rotation for this motor?

The direction of rotation for this arrangement is clockwise. Notice that if the supply voltage polarity were changed on either the 'Run' windings, or the 'Start' windings, the pole face polarity for that circuit would change, causing the motor to run in the opposite direction. Remember that the start windings are fewer turns of smaller wire, therefore the magnetic strength of these pole pieces is considerably less. Earlier split phase motors utilized a centrifugal switch to disconnect the start windings from the source voltage once the motor came up to speed.

Maximum starting torque for this motor will be achieved if the 2 current waveforms are 90 degrees apart, instead of 60 degrees. Capacitance in a circuit causes current to lead voltage, (see the article on AC Theory for further explanation of this AC circuit characteristic). By including a capacitor in the start winding, we can increase the phase angle between the 2 current waveforms.





The start capacitor inserted in Line 1 of the start winding causes the current of this circuit to lead the voltage. This arrangement causes the current waveforms of the run and start windings to be 90 degress out of phase with each other, and increases the starting torque of the motor. This configuration is common in today's single phase motors. This motor can be manufactured to be dual voltage, using the same techniques employed by three phase motors; dual windings on the pole pieces, connected in series for the high voltage, and parallel for low.

There are several ways that different motor manufacturers configure the line terminals on this type of motor, to achieve dual voltage and reverse rotation. The NEC requires all motors to be provided with connection diagrams.

Got Questions?

e-mail your questions to a.step@comcast.net