

# DC Motor Theory

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Industrial Electronics, Second Edition, Prentice Hall PTR

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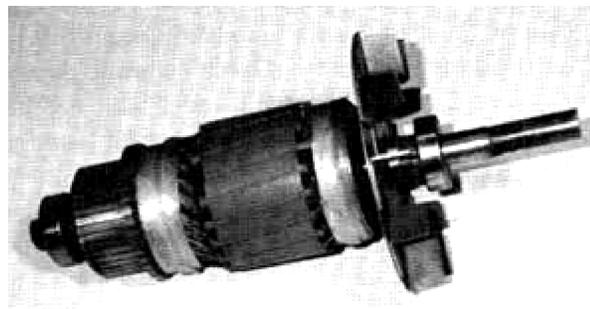
## DC Motor Overview

The DC motor has two basic parts: the rotating part that is called the *armature*, and the stationary part that includes coils of wire called the *field coils*. The stationary part is also called the *stator*. Figure 12-1 shows a picture of a typical DC motor, Fig. 12-2 shows a picture of a DC armature, and Fig. 12-3 shows a picture of a typical stator. From the picture in Fig. 12-2 you can see the armature is made of coils of wire wrapped around the core, and the core has an extended shaft that rotates on bearings. You should also notice that the ends of each coil of wire on the armature are terminated at one end of the armature. The termination points are called the *commutator*, and this is where the brushes make electrical contact to bring electrical current from the stationary part to the rotating part of the machine.

The picture in Fig. 12-3 shows the location of the coils that are mounted inside the stator. These coils will be referred to as field coils in future discussions and they may be connected in series or parallel with each other to create changes of torque in the motor. You will find the size of wire in these coils and the number of turns of wire in the coil will depend on the effect that is trying to be achieved.



**FIGURE 12-1** A typical DC motor.



**FIGURE 12-2** The armature (rotor) of a DC motor has coils of wire wrapped around its core. The ends of each coil are terminated at commutator segments located on the left end of the shaft. The brushes make contact on the commutator to provide current for the armature.

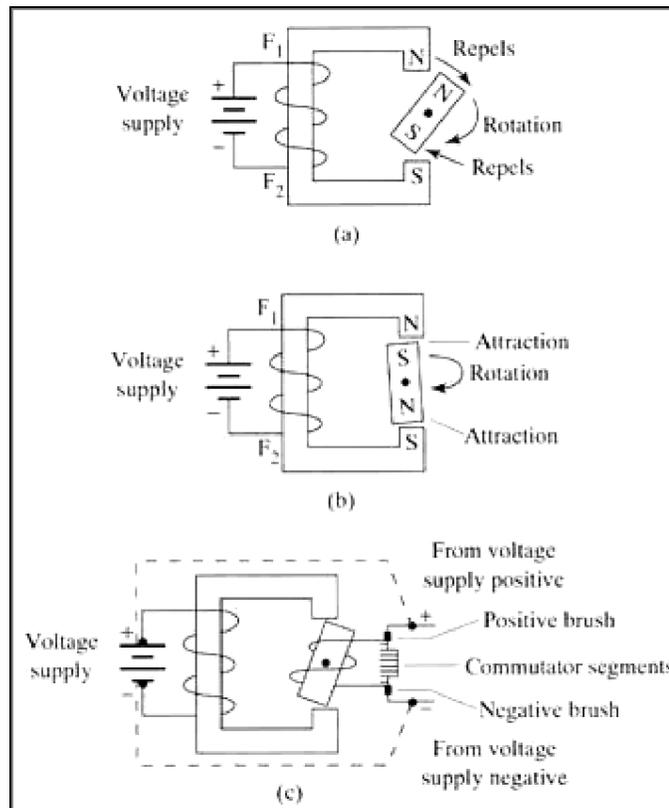


**FIGURE 12-3** The stationary part of a DC motor has the field coils mounted in it.

### Magnetic Diagram of a DC Motor

It will be easier to understand the operation of the DC motor from a basic diagram that shows the magnetic interaction between the rotating armature and the stationary field's coils. Figure 12-4 shows three diagrams that explain the DC motor's operation in terms of the magnetic interaction. In Fig. 12-4a you can see that a bar magnet has been mounted on a shaft so that it can spin. The field winding is one long coil of wire that has been separated into two sections. The top section is connected to the positive pole of the battery and the bottom section is connected to the negative pole of the battery. It is important to understand that the battery represents a source of voltage for this winding. In the actual industrial-type motor this voltage will come from the DC voltage source for the motor. The current flow in this direction makes the top coil the north pole of the magnet and the bottom coil the south pole of the magnet.

The bar magnet represents the *armature* and the coil of wire represents *the field*. The arrow shows the direction of the armature's rotation. Notice that the arrow shows the armature starting to rotate in the clockwise direction. The north pole of the field coil is repelling the north pole of the armature, and the south pole of the field coil is repelling the south pole of the armature.



**FIGURE 12-4** (a) Magnetic diagram that explains the operation of a DC motor. The rotating magnet moves clockwise because like poles repel. (b) The rotating magnet is being attracted because the poles are unlike. (c) The rotating magnet is now shown as the armature coil, and its polarity is determined by the brushes and commutator segments.

As the armature begins to move, the north pole of the armature comes closer to the south pole of the field, and the south pole of the armature is coming closer to the north pole of the field. As the two unlike poles near each other, they begin to attract. This attraction becomes stronger until the armature's north pole moves directly in line with the field's south pole, and

its south pole moves directly in line with the field's north pole (Fig. 12-4b).

When the opposite poles are at their strongest attraction, the armature will be "locked up" and will resist further attempts to continue spinning. For the armature to continue its rotation, the armature's polarity must be switched. Since the armature in this diagram is a permanent magnet, you can see that it would lock up during the first rotation and not work. If the armature is an electromagnet, its polarity can be changed by changing the direction of current flow through it. For this reason the armature must be changed to a coil (electromagnet) and a set of commutator segments must be added to provide a means of making contact between the rotating member and the stationary member. One commutator segment is provided for each terminal of the magnetic coil. Since this armature has only one coil, it will have only two terminals, so the commutator has two segments.

Since the armature is now a coil of wire, it will need DC current flowing through it to become magnetized. This presents another problem; since the armature will be rotating, the DC voltage wires cannot be connected directly to the armature coil. A stationary set of carbon brushes is used to make contact to the rotating armature. The brushes ride on the commutator segments to make contact so that current will flow through the armature coil.

In Fig. 12-4c you can see that the DC voltage is applied to the field and to the brushes. Since negative DC voltage is connected to one of the brushes, the commutator segment the negative brush rides on will also be negative. The armature's magnetic field causes the armature to begin to rotate. This time when the armature gets to the point where it becomes locked up with the magnetic field, the negative brush begins to touch the end of the armature coil that was previously positive and the positive brush begins to touch the end of the armature coil that was negative. This action switches the direction of current flow through the armature, which also switches the polarity of the armature coil's magnetic field at just the right time so that the repelling and attracting continues. The armature continues to switch its magnetic polarity twice during each rotation, which causes it to continually be attracted and repelled with the field poles.

This is a simple two-pole motor that is used primarily for instructional purposes. Since the motor has only two poles, the motor will operate rather roughly and not provide too much torque. Additional field poles and armature poles must be added to the motor for it to become useful for industry.

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