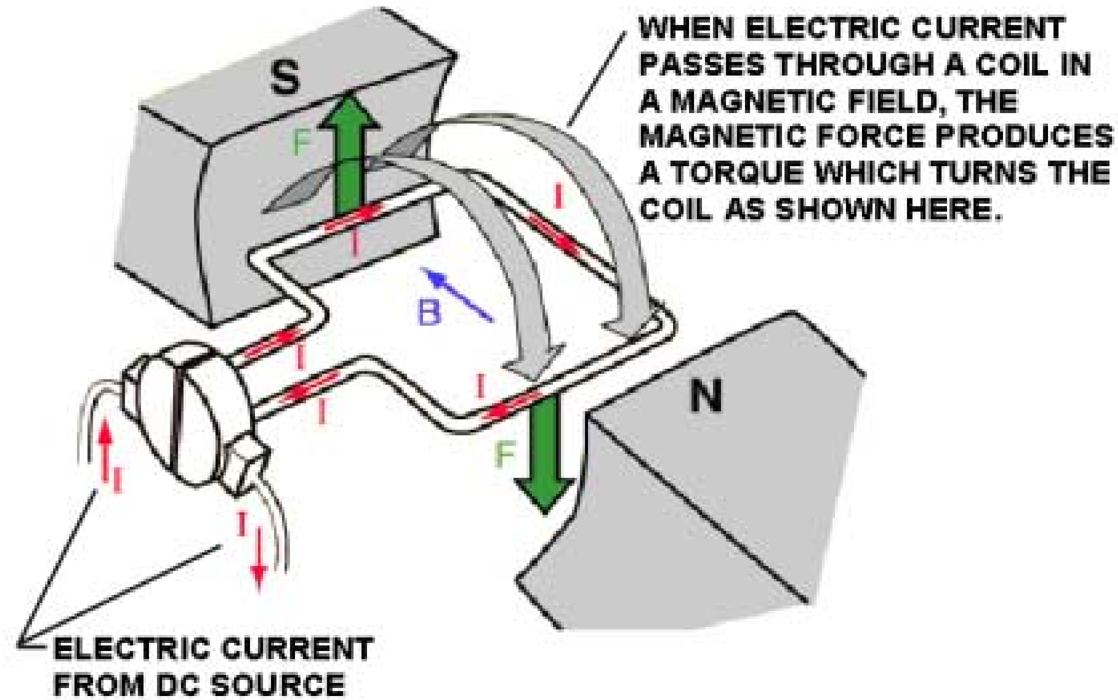
DC MOTORS & GENERATORS

The DC Motor

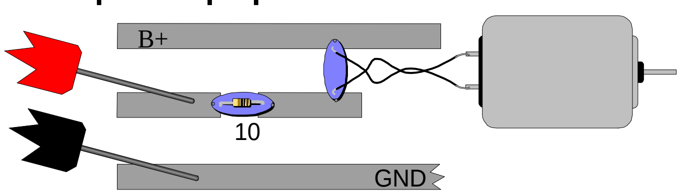
In general, DC motors are similar to DC generators in construction. They may, in fact, be described as generators "running backwards". When current is passed through the armature of a DC motor, a torque is generated by magnetic reaction, and the armature revolves.

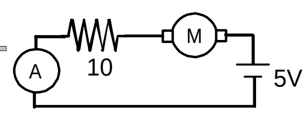


The action of the commutator and the connections of the field magnets of motors are precisely the same as those used for generators. The turning of the armature induces a voltage in the armature windings. This induced voltage is opposite in direction to the outside voltage applied to the armature, and hence is called back voltage or counter electromotive force (emf). As the motor rotates more rapidly, the back voltage rises until it is almost equal to the applied voltage. The current is then small, and the speed of the motor will remain constant as long as the motor is not under load and is performing no mechanical work except that required to turn the armature. Under load the armature turns more slowly, reducing the back voltage and permitting a larger current to flow in the armature. The motor is thus able to receive more electric power from the source supplying it and to do more mechanical work.

Water Pipe Analogy of the Motor

To see a motor analogy using water pipes run the automated file called Motor.gif on the free courses page. This file is located on the emailschool free courses page under DC Motors and Generators. Notice how the current has to reverse direction when the brush contacts switch paths. Also take note that the armature is really an inductor creating a magnetic field that is used to rotate the shaft. As the speed of the rotation increases the frequency of switching increases. This means the inductive armature starts to block the flow of current by the build up of a voltage (sometimes called back emf) and the current is reduced. To understand inductors better please review the lesson on Coils and Inductors.
Because the speed of rotation controls the flow of current in the armature, special devices must be used for starting DC motors. When the armature is at rest, it has virtually no resistance, and if the normal working voltage is applied, a large current will flow, which may damage the commutator or the armature windings. The usual means of preventing such damage is the use of a starting resistance in series with the armature to lower the current until the motor begins to develop an adequate back voltage. As the motor picks up speed, the resistance is gradually reduced, either manually or automatically. In the circuit shown here current is being measured as the motor picks up speed.





Schematic to run DC Motor

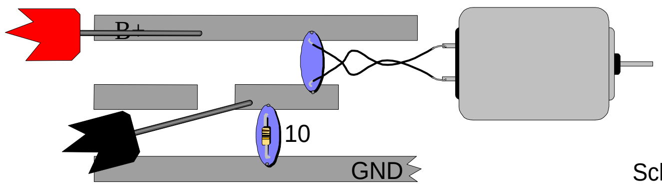
As the motor picks up speed the current drops until the no load current is reached and the motor runs as fast as it can.

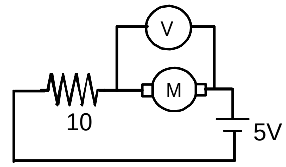
Direction of Rotation for DC Motor

The motor in the circuit above was used and a piece of tape was attached to the motor shaft. The power was turn “ON then OFF" and the direction of rotation clockwise or counter-clockwise was recorded. The leads of the motor were then reversed. The power was turned “ON then OFF" and the direction of rotation was recorded. It was found to be opposite to the first test. The direction of rotation depends on the direction of the current through the armature of the motor.

Measuring Back EMF

The circuit shown here was used to measure the back emf of the motor.





Schematic to measure back EMF

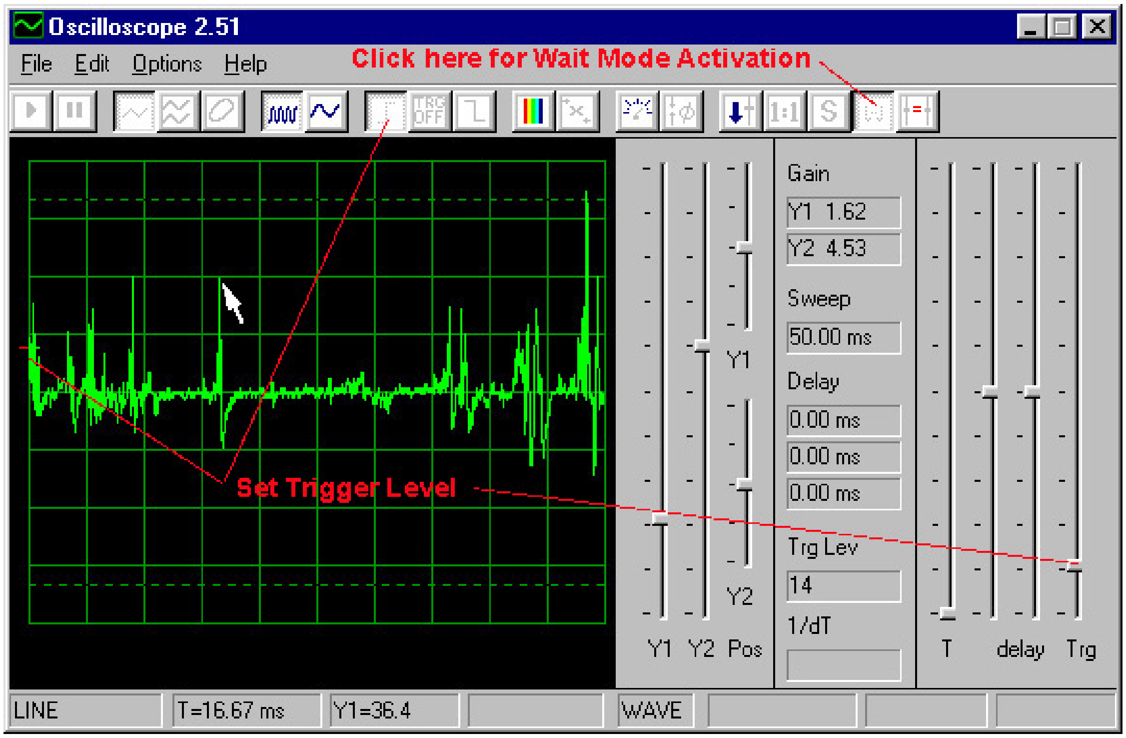
A multimeter in the DC voltage Mode and on 2 volt scale was placed in the circuit as shown above. When the motor was running at full speed the voltage across the motor was recorded. While holding the voltage probes on the foils the motor was stopped by squeezing the shaft. The voltage dropped due to the back EMF being removed when the motor is stopped. NEVER LET A MOTOR STAY STALLED FOR LONG OR IT MAY CAUSE DAMAGE. As soon as the motor was allowed to spin again the voltage returned to its original reading.

Polarity of back EMF

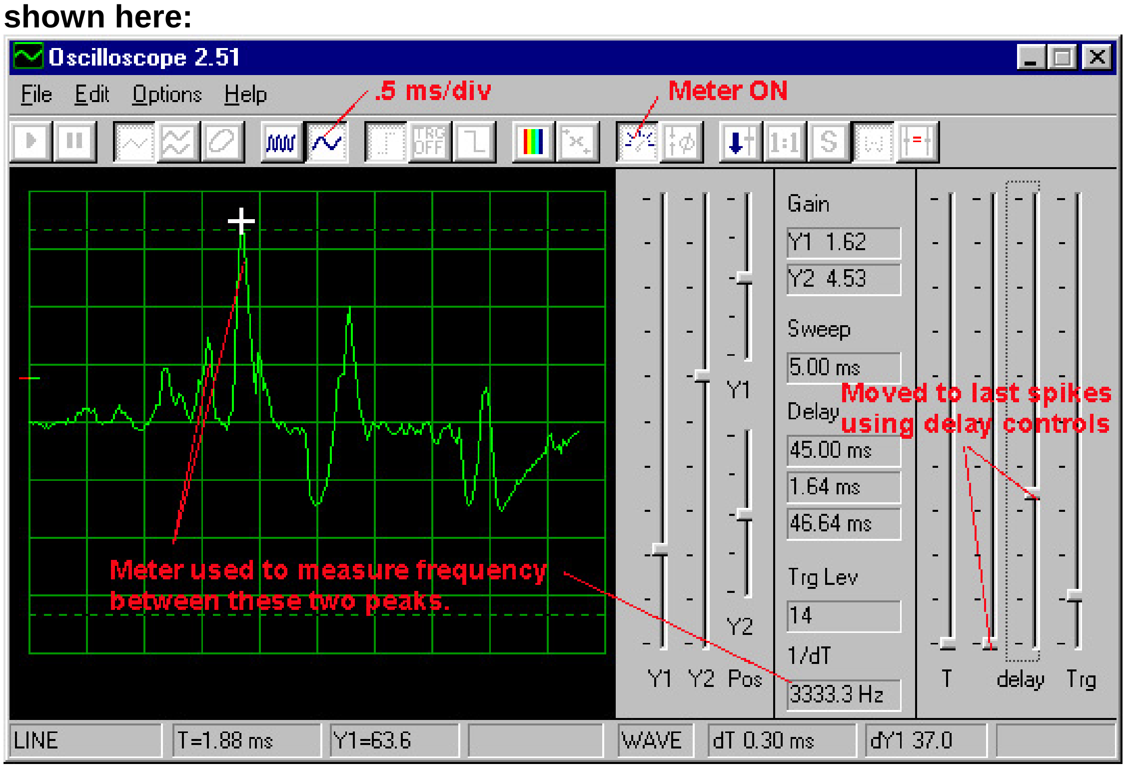
In the above experiment the leads were reversed and the measurement repeated. The direction of the motor reversed but the voltage polarity stayed in the same direction to reduce the current. Back EMF (Electro Motive Force or Voltage) will always have a polarity that reduces the current flow produced when the motor is stalled (not spinning).
The DC Motor is also a generator. Spinning in one direction should produce a momentary positive voltage, and spinning in the other direction should produce a momentary negative voltage.

Viewing Current with an Oscilloscope

An oscilloscope is a device that allows a visual display of voltages. In other words it allows you to see the changes in electrical pressure that occur very quickly. When current passes through a resistor it produces a voltage. The only way to see these currents on an oscilloscope is to look at the voltage they produce as they pass through resistive components. As stated earlier, the voltage across a 1K Ω resistor is equal to the current in ma (milliamps) passing through that resistor. In similar fashion the voltage across a 10Ω resistor is equal to the current in amperes divided by 10. If this voltage is used to represent the current, then the oscilloscope can also view currents.
A computer oscilloscope was used to view the voltage across the 10 ohm resistor in the previous circuit and the battery was replaced with a short to complete the circuit path. This voltage is also equal to the current in amperes divided by 10 coming from the motor. The oscilloscope was placed in the wait mode so rotating the shaft of the motor triggered the trace that produced the display shown here.



After capturing the current spikes shown above, the delay controls were adjusted to inspect each spike in greater detail. The horizontal display was changed to .5 ms/div. Then the delay sliders were used to move the captured wave to the different spikes for a closer look at their shapes as shown here:



The frequency between peaks was measured by turning the oscilloscope meter on and placing the plus cursor over the first peak. The left mouse button was then pressed. Then the plus cursor was moved over the second peak and the right mouse button was pressed. The frequency appears in the 1/Dt window. In this case the frequency was 3333.3 Hz.
The 10Ω load was removed and the generator shaft was turned again. It was obvious that it was easier to turn the shaft with no load. Replacing the 10Ω load with a short or jumper wire makes it even harder to turn the shaft of the generator. The more current in the load the harder it is to turn the generator shaft. The mechanical force is generating the electrical current that is sent to the load.

Quick Review:

Current & Magnetism: **An electric current flowing through a wire produces a magnetic field around that wire.**
EMF: **Electro Motive Force or Voltage**
Back emf: **The induced voltage that is opposite in direction to the outside voltage applied to the armature of a motor. As the motor rotates more rapidly, the back voltage rises until it is almost equal to the applied voltage.**
Motor Rotation: **The direction of rotation depends on the direction of the current through the armature of the motor**
Electric Motors and Generators: **A group of devices used to convert mechanical energy into electrical energy, or electrical energy into mechanical energy, by electromagnetic means.**

Something to Think About:

If passing electrical current through materials can create heat, is there a device that will create electrical current when heat is applied?

Answer: **A thermocouple will generate an electric voltage when placed in a heat source.**