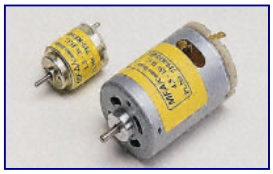


DC Motors

General

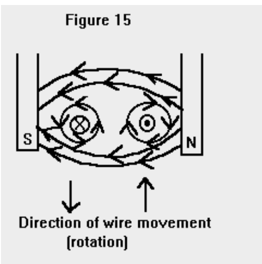
DC motors are widely used in robotics for their small size and high energy output. They are inexpensive, small, and powerful.

Typical DC motors operate on as few as 1.5 volts on up to 100 volts. Roboticists often use motors that operate on 6, 12, or 24 volts. DC motors run at speeds from several thousand to ten thousand RPM. A low voltage (e.g., 12 volt or less) DC motor may draw from 100 milliamps to several amps at stall, depending on its design.

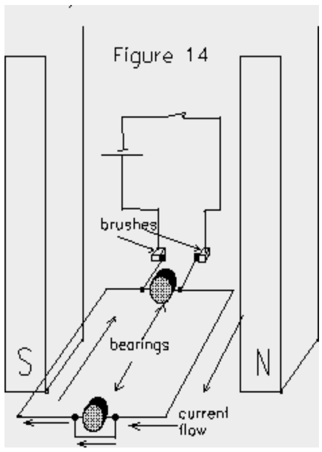
Main Characteristics of DC Motors include: High Speed, Low Torque, Reversibility and Continuous Motion.

Theory

If you were to place a loop of wire within the magnetic field of a horseshoe magnet in the manner shown (Fig14) and apply current to it you would experience a motor action such that the loop of wire would try to turn.



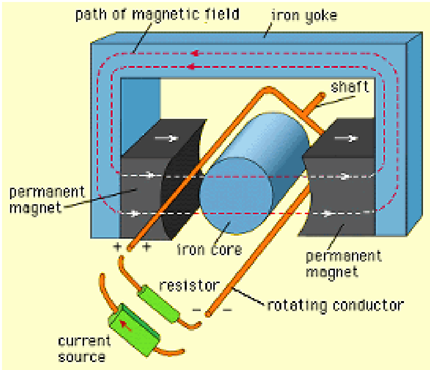
This effect will only occur when the wire lays adjacent or in line with the magnetic field (Fig15).



As you can see the right hand piece of wire in our example has a concentration of the magnetic lines of force at the bottom or underneath and a cancellation of the magnetic field at the top. This will cause the wire to rise up. However the piece of wire on the left hand side has the opposite situation (strong field on the top and a weak field on the bottom). As a consequence of this the loop of wire will rotate so that it lies at right angles.

Let' s say the loop of wire was arranged on a bearing so that it could freely rotate. What we need is some way of switching the current through the wire on each 180 degrees of rotation. We do this with a simple brush mechanism (Fig 14).

In this case as the loop rotates to a vertical position you notice that the end of the wire leaves the switch contact. Under inertia, the loop continues to rotate until the other side of the loop strikes the right hand side contact and the original loop contact makes contact with the left hand side brush. If you examine this concept carefully you can see that while current is applied to the brush contacts the loop of wire will rotate through 180 degrees where contact will be made again and the rotor (the revolving thing) will continue rotation.



The direction of rotation depends on:

- the polarity of the battery (Power Source)

The *stator* is the stationary outside part of a motor.

The *rotor* is the inner part which rotates.

The ends of each wire set for a connecting set is called a *commutator.*

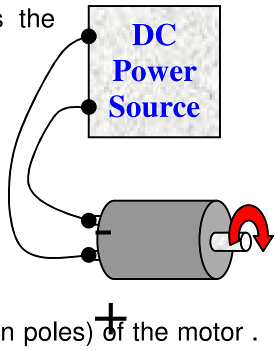
The torque of a motor is the rotary force produced on its output shaft. When a motor is stalled it is producing the maximum amount of torque that it can produce. Hence the torque rating is usually taken when the motor has stalled and is called the stall torque.

The power of a motor is the product of its speed and torque. The power output is greatest somewhere between the unloaded speed (maximum speed, no torque) and the stalled state (maximum torque, no speed).

Motors that draw more current will deliver more power. Also, a given motor draws more current as it delivers more output torque. Thus current ratings are often given when the motor is stalled. At this point it is drawing the maximal amount of current.

Practical motors rotors are made up of multiple sets of wire each set being comprised of a single piece of wire wrapped may times around the loop. The many sets enable a much smoother power train much like the difference between a single cylinder engine and an engine with many cylinders like a V8 or a V12.

Practice



Application of voltage difference on the two poles of a motor creates the rotation of the output shaft.

Direction of rotation depends on the polarity of the potential applied. Change the polarity in order to reverse direction.

In order to achieve quick stop connect the poles (create a shortcut between poles) of the motor . Note that, if you preserve this state you will harm the motor. So, use this method for instantenous applications.

The speed of the output shaft is directly proportional with the applied voltage. Increase (decrease) voltage for higher (lower) speeds.

Torque is related with the current drawn. With a constant voltage applied, current drawn increases (decreases) as the force on the output shaft increases (decreases).

DC motors run at high speeds, as high as 8000 - 10000 revolutions per minute (rpm). Also, the torque they provide is quite low to do work. Thus, they are not useful for applications requiring high torque and low speed. Note that you cannot directly connect a DC motor to a drive wheel of your robot. If you do so, what you will be observing will be a motor not able to move your robots` wheel and it will in the end heat up with time.

A typical DC motor operates at speeds that are far too high to be useful, and torques that are far too low. In order to make DC motors capable of doing work requires the increase of Torque and decrease of Speed. The most extensively used method is the introduction of a Reduction unit. The reduction unit may either be a Gear Box or a simple Belt (Pulley) Assembly. A Gearbox or any other reduction unit will simply be used to achieve the very problem of increasing the Torque and decreasing the Speed of the output shaft of the DC motor.

Using gear reduction, the motor shaft is fitted with a gear of small radius that meshes with a gear of large radius. The motor' s gear must revolve several times in order to cause the large gear to revolve once. It is evident that the speed of rotation is decreased, but, overall power is preserved (excepting losses due to friction) and therefore the torque must increase. By ganging together several stages of this gear reduction, an immensely strong torque can be produced at the final stage. GearTrains are excellent for powering the drive wheels of a mobile robot as well as powering other mechanical assemblies.

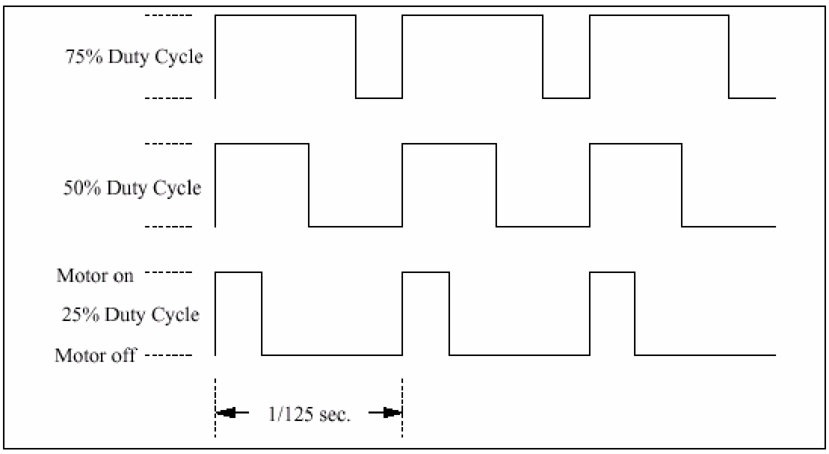
Pulse Width Modulation (PWM)

Pulse width modulation is a technique for reducing the amount of power delivered to a DC motor. This is typically used in mechanical systems that will not need to be operated at full power all of the time.

Instead of reducing the voltage operating the motor (which would reduce its power), the motor's power supply is rapidly switched on and off. The percentage of time that the power is on determines the percentage of full operating power that is accomplished.

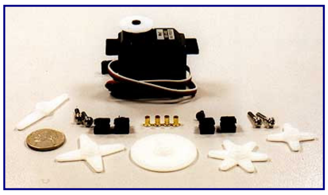
Figure 2.3 illustrates this concept, showing pulse width modulation signals to operate a motor at 75%, 50%, and 25% of the full power potential.

A wide range of frequencies can be used for the pulse width modulation signal.
A PWM waveform consisting of eight bits, each of which maybe on or off, is repetitiously used to control the motor. Every 1/1000 of a second, a control bit determines whether the motor is enabled or disabled. Every 1/125 of second the waveform is repeated.
Because one to eight bits may be set in the PMW waveform, the motors may be adjusted to eight power levels between off and full on.



METU ROBOT SOCIETY

R/C Servomotors



General

R/C Servomotors are used in model radio control cars, airplanes and helicopters to control the position of wing flaps and other light control mechanisms within similar devices. A servo motor includes a built-in geartrain and is capable of delivering high torques directly. The output shaft of a servo *does not rotate freely* as do the shafts of DC motors and stepper motors, but rather is made to seek a particular angular position under electronic control.
Main characteristics include: Restricted Motion, High Speed, High Torque, Controlled Position.
Advantages: Extremely Powerful for its size, High Accuracy and Repeatability, Low Power Consumption, Fast Response (Actuation)

Theory

Servo motors incorporate several components into one device package:

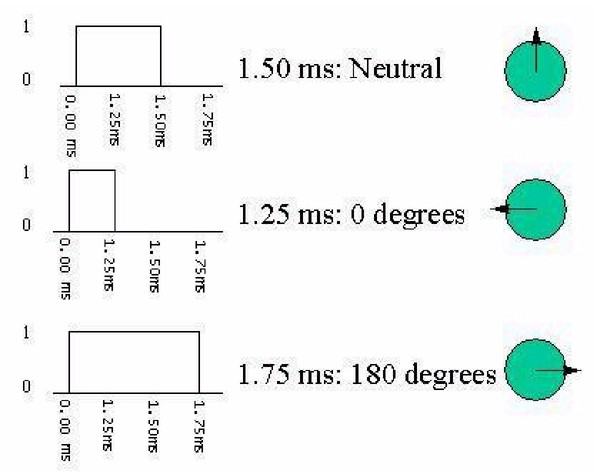
- a small DC motor;
- a gear reduction unit for torque increase;
- an electronic shaft position sensing and control circuit (control circuitry).

The output shaft of a servo motor does not rotate freely, but rather is commanded to move to a particular angular position. The electronic sensing and control circuitry - the servo feedback control loop - drives the motor to move the shaft to the commanded position. If the position is outside the range of movement of the shaft, or if the resisting torque on the shaft is too great, the motor will continue trying to attain the commanded position.

A servo is a classic example of a closed-loop feedback system. The potentiometer is coupled to the output gear. It's resistance is proportional to the position of the servo's output shaft (0° to 180°). This resistance is used by the control electronics to generate an error signal when the desired position isn't the same as the current position. If you send a servo a command to place itself at 90° and the head is actually at 45°, an error signal will cause the motor to move the head (via the gears) until the error signal is 0 (when the head has reached 90°). If the head had been at 180°, an error signal of opposite polarity would have been generated and the motor would have turned in the oposite direction to bring the head 'back' to 90°. As you can see, the current position is 'fed-back' to the control system in a loop to maintain a zero error signal. The farther the actual position from the desired position, the faster the motor turns to bring the error back to zero.

A servo motor has three wires: Power, Ground, and Control. The power and ground wires are simply connected to a power supply (As with a DC Motor). Most servo motors operate from five volts (4.8V -7.2V). Servos are controlled using a system called Pulse Code Modulation (PCM). The Control lead is used to send the positioning signal. The control signal consists of a series of pulses that indicate the desired position of the shaft. Each pulse represents one position command. The length of a pulse in time corresponds to the angular position. Typical pulse times range from 0.7 to 2.0 milliseconds for the full range of travel of a servo shaft. Most servo shafts have a 180 degree range of rotation. The control pulse must repeat every 20 milliseconds. In order to understand this, you need to understand the terms &"miliseconds"(ms) and &"microseconds"(µs). 1 ms is 1/1000th of a second; or put another way, there are 1000 ms in every second. 1 µs is 1/1,000,000th (one -one millionth) of a second, or, there are 1 million µs in each second. Servo manufacturers usually specify pulse-widths in µs, so it's hands to be able to convert between µs and ms. The servo's electronics work in 20 ms blocks (50 of them every second). For each 20 ms block, the servo needs to see a positive-going pulse who' s period (width in ms) tells it where to position the head (output shaft).
The period of the pulse that is sent determines where (0° to 180°) to place the head. Different servo manufacturers require different pulse-widths, so you have to experiment a little to find the pulse-widths that correspond to each position. For example, the Futaba servo has a 90° position (middle) pulse-width of about 1.5 ms. This means that if you send a 1.5 ms pulse to the servo at least once every 20 ms, the servo will move to, and hold at, it's 90° position. If you try to turn the head with your hand you will feel the servo forcing against you, trying to keep the 90° position.

In practice, you can send pulses more often that once every 20 ms; you can send them less often as well, but if you don't send any pulses for about 50 ms or so, the control electronics in the servo will "go to sleep" (enter a power-saving mode). Don't forget, servos were designed for R/C airplanes and cars, where battery life is important. When a servo powers-down, it no longer works against an applied force to maintain it' s position. You will find that even then the head is fairly difficult to turn.


1
0
0.00 ms
1.25ms
1.50ms
1.75ms
1.50 ms: Neutral
1.25 ms: 0 degrees
1.75 ms: 180 degrees