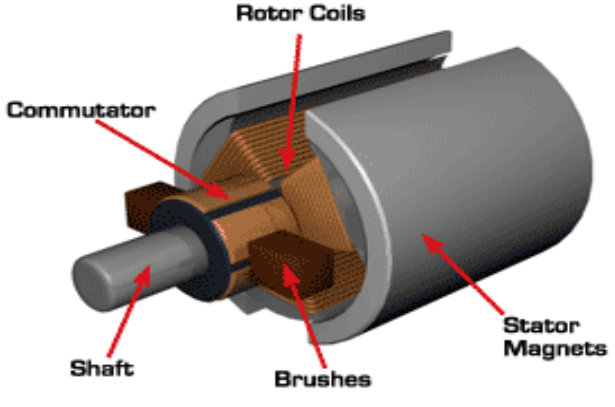
Introduction to DC Motors

In Electric Motors, the input is electrical energy and the output in mechanical energy.

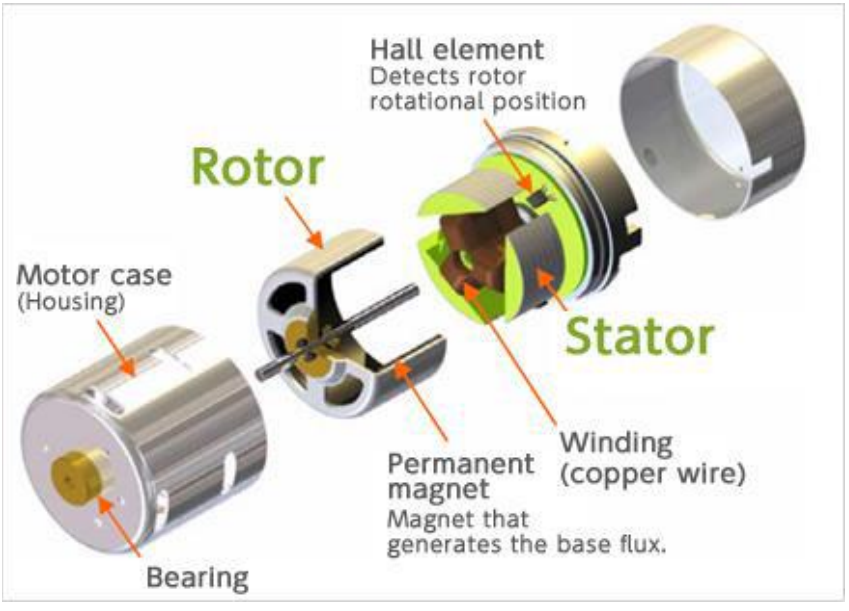
Stator

- The stator is the stationary outside part of a motor.
- The stator of a permanent magnet dc motor is composed of two or more permanent magnet pole pieces.
- The magnetic field can alternatively be created by an electromagnet. In this case, a DC coil (field winding) is wound around a magnetic material that forms part of the stator.



Rotor

- The rotor is the inner part which rotates.
- The rotor is composed of windings (called armature windings) which are connected to the external circuit through a mechanical commutator.
- Both stator and rotor are made of ferromagnetic materials. The two are separated by air-gap.



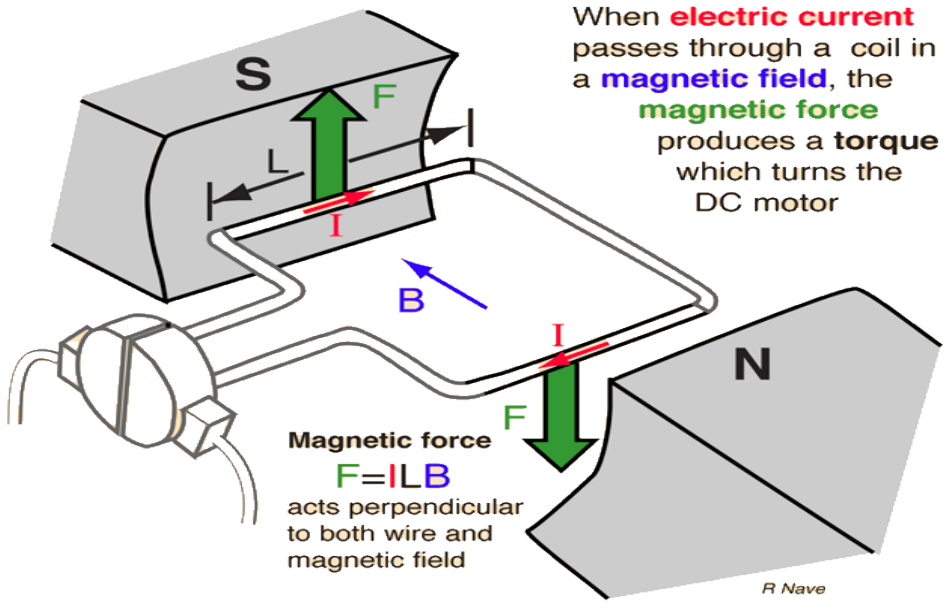
Winding

- A winding is made up of series or parallel connection of coils.
- Armature windings – The windings through which the voltage is applied or induced.
- Field winding - The winding through which a current is passed to produce flux (for the electromagnet)
- Windings are usually made of copper.

Basic Principles

- If electrical energy is supplied to a conductor lying perpendicular to a magnetic field, the interaction of current flowing in the conductor and the magnetic field will produce mechanical force (and therefore, mechanical energy).
- There are two conditions necessary to produce a force on the conductor.
- The conductor must be carrying current.

- It must be within a magnetic field.
- When these two conditions exist, a force will be applied to the conductor, which will attempt to move the conductor in a direction perpendicular to the magnetic field.



- Consider a coil in a magnetic field of flux density B. When the two ends of the coil are connected across a DC voltage source, current I, flows through it. A force is exerted on the coil as a result of the interaction of magnetic field and electric current. The force on the two sides of the coil is such that the coil starts to move in the direction of force.
- In an actual DC motor, several such coils are wound on the rotor, all of which experience force, resulting in rotation. The greater the current in the wire, or the greater the magnetic field, the faster the wire moves because of the greater force created.

Performance Calculation

Speed Regulation (SR): The performance measure of interest is the speed regulation, defined as the change in speed as full load is applied to the motor. It can be expressed as:

$$SR = \frac{N_{no\ load} - N_{full\ load}}{N_{full\ load}} \times 100\%$$

Where Nno_load is the speed at no load and Nfull_load is the speed when full load is applied.

Motor Specifications

Nominal voltage

- The voltage that corresponds to the highest motor efficiency.
- Try to choose a main battery pack which most closely matches the nominal voltage of the drive motors.
- For example, if the motor's nominal voltage is 6V, use a 5x 1.2V NiMh pack to get 6V. If your motor operates at 3.5V nominal, you can use either a 3xAA or 3xAAA NiMh pack or a 3.7V LiPo or LiIon pack.
- Operating a motor outside of its nominal voltage, the efficiency of the motor goes down.

  Often creating the following problems:
  - Additional current
  - Generating more heat
  - Decreasing the lifespan of the motor
- Aside from a "nominal voltage" DC motors also have an operating voltage range outside of which the manufacturer does not suggest operating the motor. For example, a 6V DC

Gear motor may have an operating range of 3-9V; it will not operate as efficiently as compared to 6V, but it will still run well.

Stall Torque

- This is the maximum torque a motor can provide with the shaft no longer rotating.
- It is important to note that most motors will sustain irreparable damage if subjected to stall conditions for more than a few seconds.

Stall Current

- This is the current the motor will draw under maximum torque conditions.
- This value can be very high and should you not have a motor controller capable of providing this current, there is a good chance your electronics will fry as well.

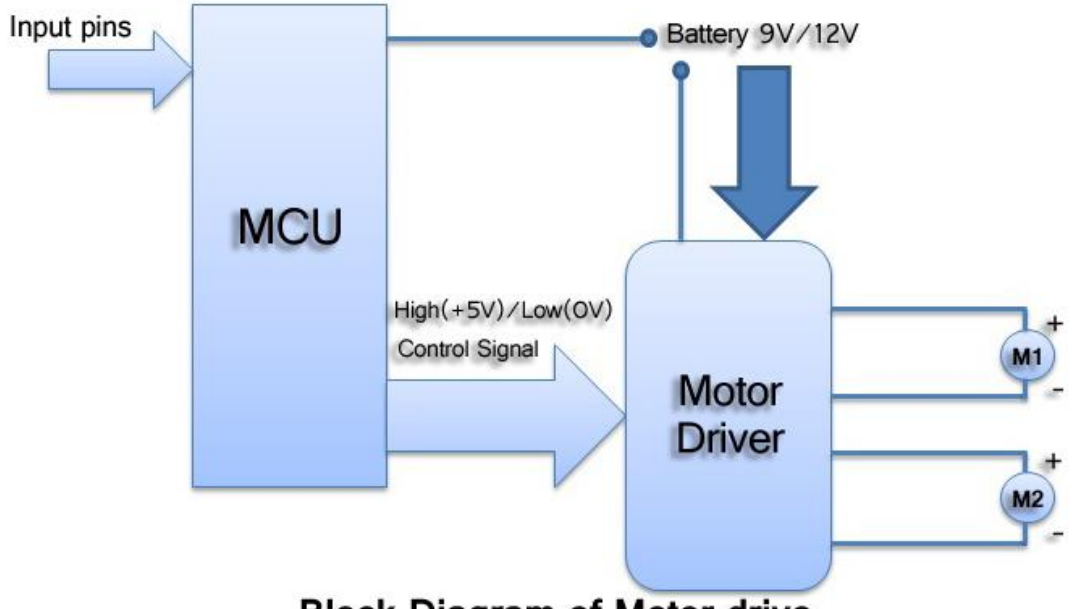
Power Rating

- If a motor's power is not listed, it can be approximated.
- Power is related to current (I) and voltage (V) by the equation $P = I \times V$. Use the no load current and nominal voltage to approximate the motor's power output.
- The motor's maximum power (which should only be used for a short time) can be approximated using the stall current and nominal voltage (rather than maximum voltage).

Common Useful Systems

Motor Driver

Motor drives are circuits used to run a motor. In other words, they are commonly used for motor interfacing. These drive circuits can be easily interfaced with the motor and their selection depends upon the type of motor being used and their ratings (current, voltage).



Block Diagram of Motor drive

DC Motor Driver Circuits

- Motor Driver circuits are current amplifiers. They act as a bridge between the controller and the motor in a motor drive.
- Motor drivers are made from discrete components which are integrated inside an IC.
- The input to the motor driver IC or motor driver circuit is a low current signal.
- The function of the circuit is to convert the low current signal to a high current signal. This high current signal is then given to the motor.

- The motor can be a brushless DC motor, brushed DC motor, stepper motor, other DC motors etc.

Need for Motor Driver Circuits/ICs

In motor interfacing with controllers, primary requirement for the operation of the controller is low voltage and small amount of current. But the motors require a high voltage and current for its operation. In other words we can say the output of the controller or processor is not enough to drive a motor. In such a case direct interfacing of controllers to the motor is not possible. So we use a Motor Driver Circuit or Motor Driver IC.

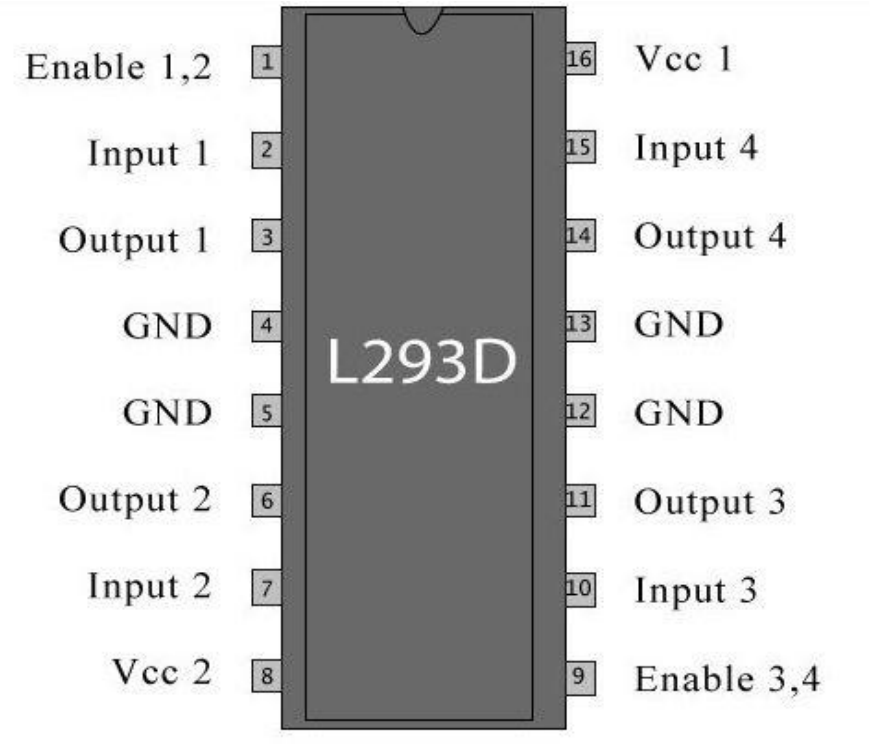
L293D Motor Driver

The most commonly used motor driver IC's are from the L293 series such as L293D, L293NE, etc. These ICs are designed to control 2 DC motors simultaneously.

The L293D is a 16 pin IC, with eight pins, on each side, dedicated to the controlling of a motor. There are 2 INPUT pins, 2 OUTPUT pins and 1 ENABLE pin for each motor. L293D consist of two H-bridge. H-bridge is the simplest circuit for controlling a low current rated motor.

Pin No. - Pin Characteristics

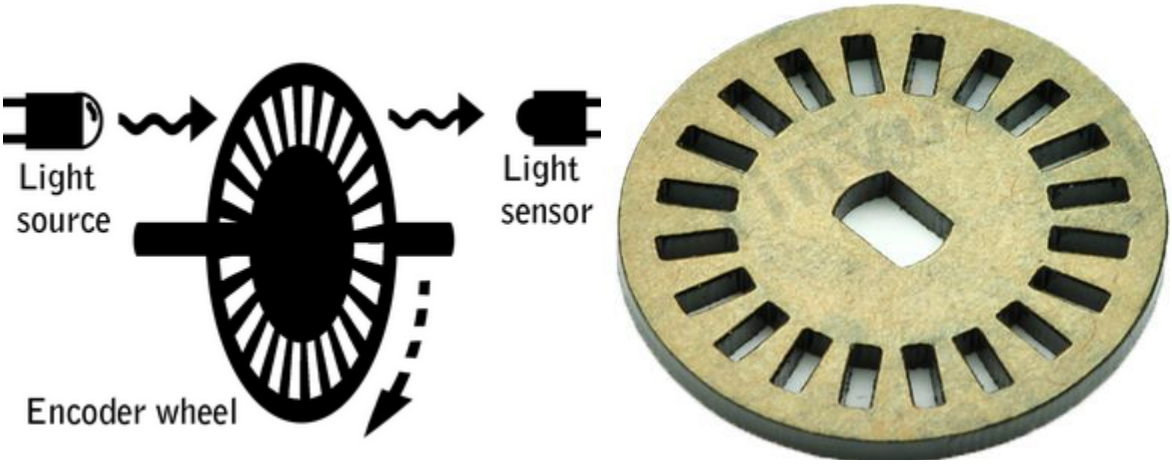
- 1 - Enable 1-2, when this is HIGH the left part of the IC will work and when it is low the left part won't work.
- 2 - INPUT 1, when this pin is HIGH the current will flow though output 1
- 3 - OUTPUT 1, this pin should be connected to one of the terminal of motor



- 4,5 - GND, ground pins
- 6 - OUTPUT 2, this pin should be connected to one of the terminal of motor
- 7 - INPUT 2, when this pin is HIGH the current will flow though output 2
- 8 - VCC2, this is the voltage which will be supplied to the motor.
- 16 - VCC1, this is the power source to the IC. So, this pin should be supplied with 5 V
- 15 - INPUT 4, when this pin is HIGH the current will flow though output 4
- 14 - OUTPUT 4, this pin should be connected to one of the terminal of motor
- 13,12 - GND, ground pins
- 11 - OUTPUT 3, this pin should be connected to one of the terminal of motor
- 10 - INPUT 3, when this pin is HIGH the current will flow though output 3
- 9 - Enable 3-4, when this is HIGH the right part of the IC will work and when it is low the right part won't work

Wheel Encoder

A wheel encoder is an electro-mechanical device that converts the angular position or motion of a shaft or axle to an analog or digital code.



Wheel Encoder allows you to track the number of revolutions each wheel has made. This sensor works by detecting the movement of small teeth connected to a motor through the reflection of infrared light. By measuring the amount of reflected infrared light you can tell not only how far each wheel has traveled but how fast the wheels are turning.

Relay

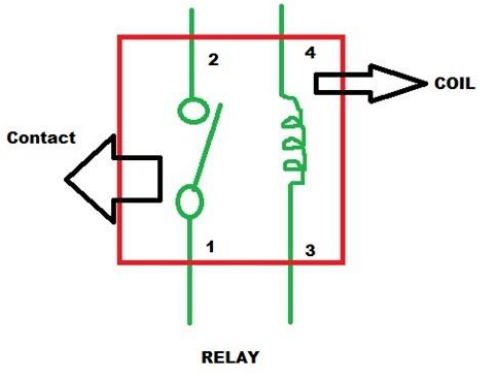
A relay is an electrical switch that turns on or off, based on an external electrical signal. It is just like a normal switch that we see in our homes. The only difference is that instead of a human being switching it on or off, the switching is controlled via an external electrical signal. When the external signal is applied, the relay energizes and the switch is on, and when, the external electrical signal is removed, the relay is de-energized and the switch is off.

Applications of relays

In many industrial applications and in control rooms where we have to control several circuits with one signal for this purpose relay is the best device to be used, because of its switching capability it can be used in different circuits. It is basically an electrical operating switch. Most of the times, they are used to switch the state of the circuit. It is also used as protection or isolation. Sometimes it is also used for time delay.

Operation of Relay

Relay switching circuit (coil) based upon the DC or AC voltage. For example when 6v given across the coil, current start flowing through it, energized and switched from NC path to NO path. Before energizing NC path followed but after switching NO path will be followed.



In above figure 1 and 2 shows contacts which are open while 3 and 4 shows coil. When coil become energized it become closed and change its state.

MultiCopter

A multicopter is a mechanically simple aerial vehicle whose motion is controlled by speeding or slowing multiple downward thrusting motor/propeller units.

QUADCOPTER

As the name suggests, it is basically a flying vehicle with four electric motors and four propellers. Unlike the traditional helicopter, quad relies on its four rotors to generate uplifting thrust by working together. Every single rotor lifts around a quarter of the overall

weight, which allows to use smaller and less expensive motors. The movement of the quad is basically controlled by changing the amount of power each motor delivers to propellers.

They are positioned in every corner of an imaginary square. On one diagonal, two motors that rotate in a clockwise direction, while the remaining two, on the opposite diagonal, rotate counterclockwise.

In order for the balance to be maintained, the quad relies on the data it gathers from internal sensors, and adjust the power it sends to each motor so that the entire drone is leveled. To keep the balance all the time, the quad uses an advanced control system, which usually makes the adjustments autonomously, and this is where Arduino board and the programming come into play.

Usually, each quad comes capable of performing four types of movement: Altitude, Roll, Yaw, and Pitch. Each of these movements is controlled by the amount of thrust each rotor produces.

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Components of Quadcopter

Every quad will have to include the elements listed below in order to fly:

- **Frame**– The "backbone" of the quadcopter. The frame is what keeps all the parts of the quadcopter together. It has to be sturdy, but on the other hand, it also has to be light so that the motors and the batteries don't struggle to keep it in the air.
- **Motors**– The thrust that allows the Quadcopter to get airborne is provided by Brushless DC motors and each of them is separately controlled by an electronic speed controller or ESC.
- **ESCs** – Electronic Speed Controller is like a nerve that delivers the movement information from the brain (flight controller) to the arm or leg muscles (motors). It regulates how much power the motors get, which determines the speed and direction changes of the quad.

- **PROPELLERS** - Propellers generate thrust, and each motor needs one in order for the quad to fly. Make sure that you buy the proper rotating pairs of propellers for clockwise and counterclockwise rotation.
- **BATTERY** - The most recommendable power source for quadcopter is the LiPo. It's not heavy, and the current levels are ideal. NiMH is cheaper but heavier and it is also an option.
- **FLIGHT CONTROLLER**-You can either choose to use a controller board that has only one purpose and that is to control a quadcopter, or you can choose an Arduino UNO. This is a general purpose microcontroller that allows you to build your own flight controller by buying the parts you want to install, and assembling the controller on your own.
- **IMU** – Inertial Measurement Unit is a board that is basically a sum of various sensors that help to know where the quad is and how to level itself. This unit is in charge of measuring the quad's orientation, velocity, and the force of gravity.
- **RC Controller** – The choice of the transmitter depends on the choice of the protocol you are going to use and the signal receiver that is onboard the drone.