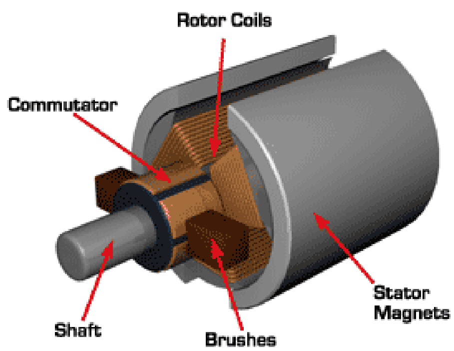
Computer Interfacing

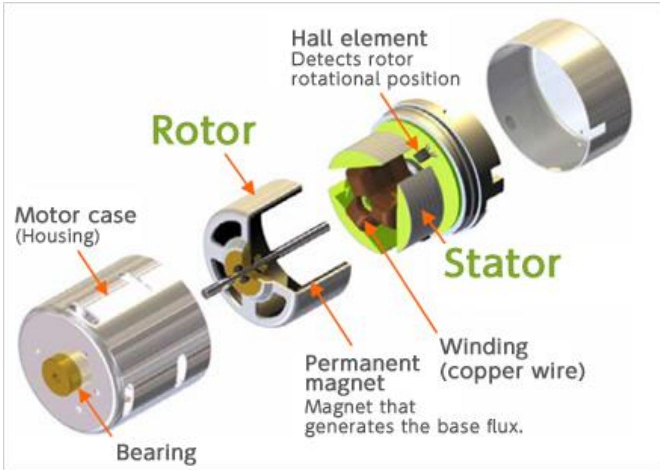
Chapter-5: DC Motor

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.



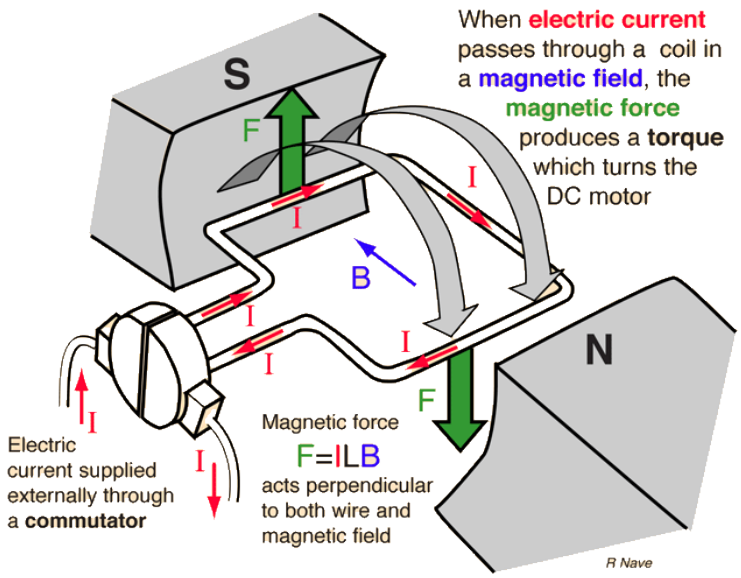


- **Rotor**
    - The rotor is the inner part which rotates.
    - The rotor is composed of windings (called armature windings) which are connected to the external circuit through a mechanical commutator.
    - Both stator and rotor are made of ferromagnetic materials. The two are separated by air-gap.

- **Winding**
    - A winding is made up of series or parallel connection of coils.
    - Armature winding - The winding 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 $N_{no\ load}$ is the speed at no load and $N_{full\ load}$ 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.

No Load RPM

- This is how fast (angular velocity) the final output shaft will rotate assuming nothing is connected to it.
- The motor's RPM is proportional to the voltage input. "No Load" means the motor encounters no resistance whatsoever (no hub or wheel mounted to the end). Usually the No Load RPM provided is associated with the nominal voltage.

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.
- When choosing a motor, you should consider subjecting it to no more than ~1/4 to 1/3 the stall torque.

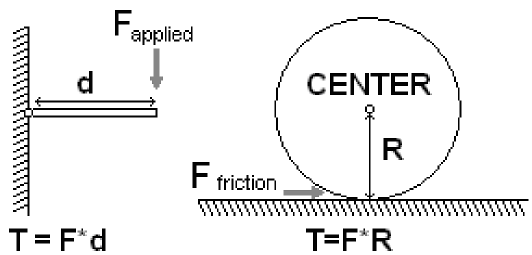
Stall Current:

- 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.
- If neither the stall nor the nominal current are provided, try to use the motor's power rating (in Watts) and the nominal voltage to estimate the current: Power [Watts] = Voltage [Volts] x Current [Amps]

Power rating:

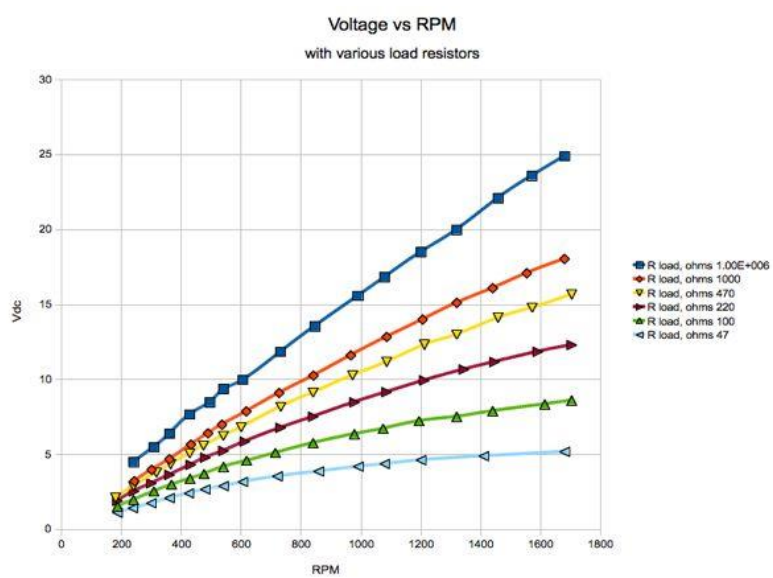
- If a motor's power is not listed, it can be approximated.
- Power is related to current (I) and voltage (V) by the equation P = I×V. Use the no load current and nominal voltage to approximate the motor's power output.
- The motor's maximum power (which should only be used for a short time) can be approximated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

Torque



- Torque is calculated by multiplying a force (acting at a distance away from a pivot) by the distance.
- A motor rated at a stall torque of 10Nm can hold 10N at the end of 1m. Similarly, it could also hold 20N at the end of 0.5m (20 x 0.50 = 10) and so on.

Voltage VS RPM

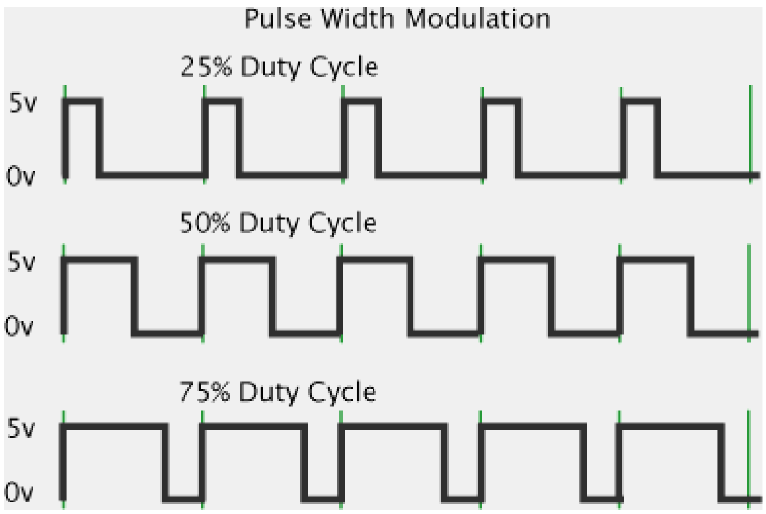


- Ideally, the manufacturer would list the graph of a motor's voltage vs. rpm. For a quick approximate, consider using the no-load rpm and nominal voltage: (nominal voltage, rpm) and the point (0, 0).

Torque vs. Current

- Current is a value that cannot be easily controlled. **DC motors use only as much current as they need**. Ideal specifications include this curve, and approximations are not easily reproduced.
- The stall torque is related to the stall current. A motor that is prevented from turning will consume maximum ("stall") current and produce the maximum torque possible.
- The current required to provide a given torque is based on many factors including the thickness, type and configuration of the wires used to make the motor, the magnets and other mechanical factors.

Pulse Width Modulation



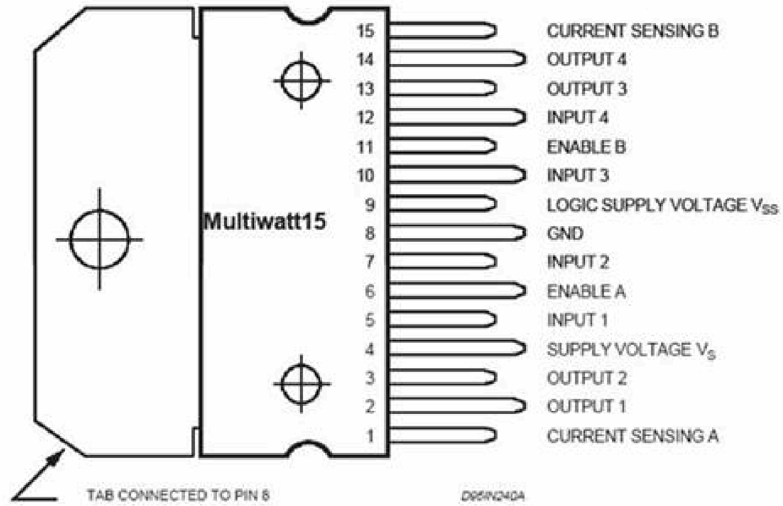
Pulse Width Modulation is a means in controlling the duration of an electronic pulse. In motors, try to imagine the brush as a water wheel and electrons as the flowing droplets of water. The voltage would be the water flowing over the wheel at a constant rate, the more water flowing the higher the voltage. Motors are rated at certain voltages and can be damaged if the voltage is applied to heavily or if it is dropped quickly to slow the motor down. Thus PWM. Take the water wheel analogy and think of the water hitting it in pulses but at a constant flow. The longer the pulses the faster the wheel will turn, the shorter the pulses, the slower the water wheel will turn. Motors will last much longer and be more reliable if controlled through PWM.

Common Useful Systems

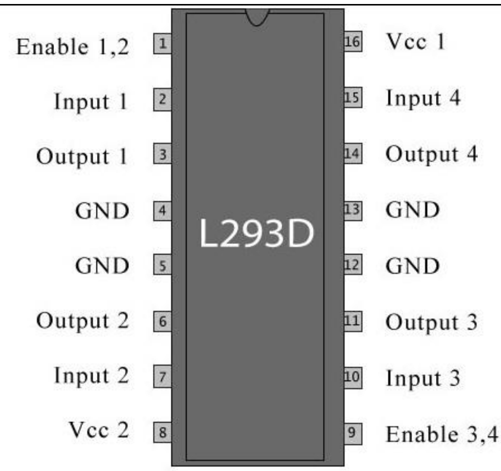
Motor Driver

A motor driver is a little current amplifier; the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor.

L298 (Max O/P 2A)

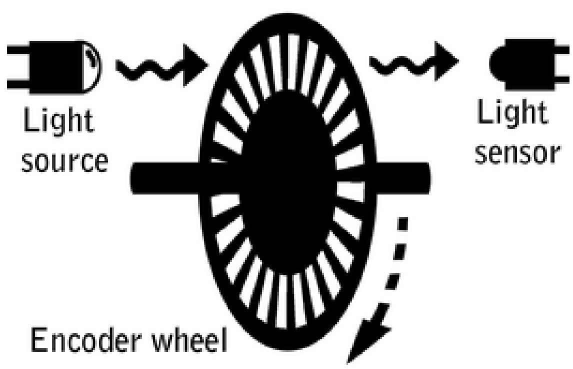


L293D (Max O/P 1A)



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.

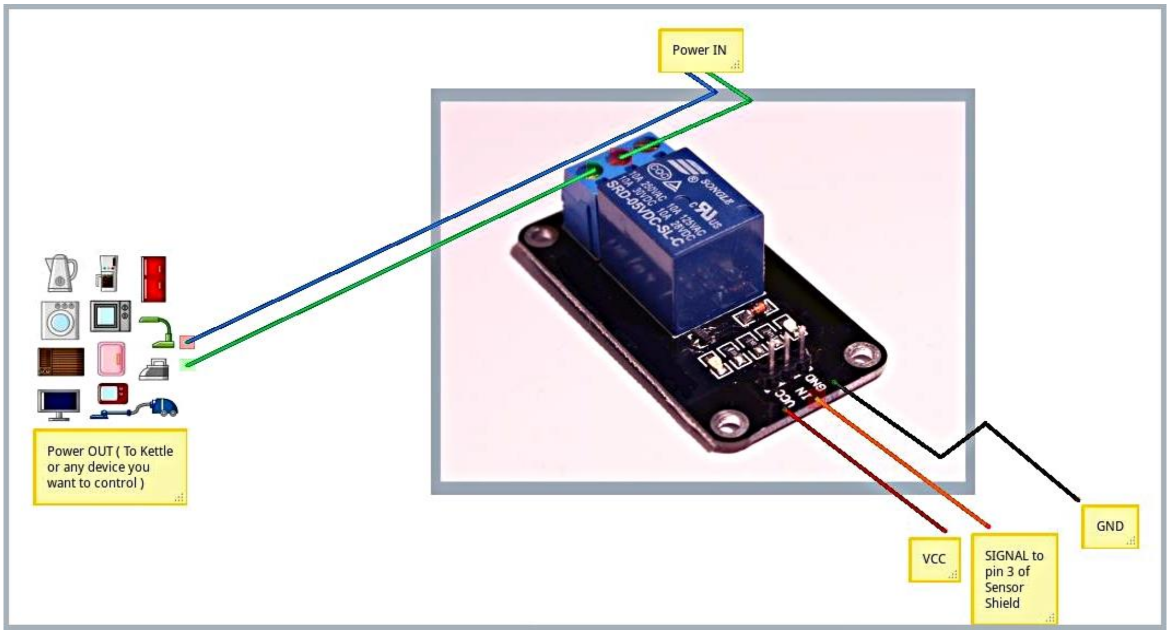


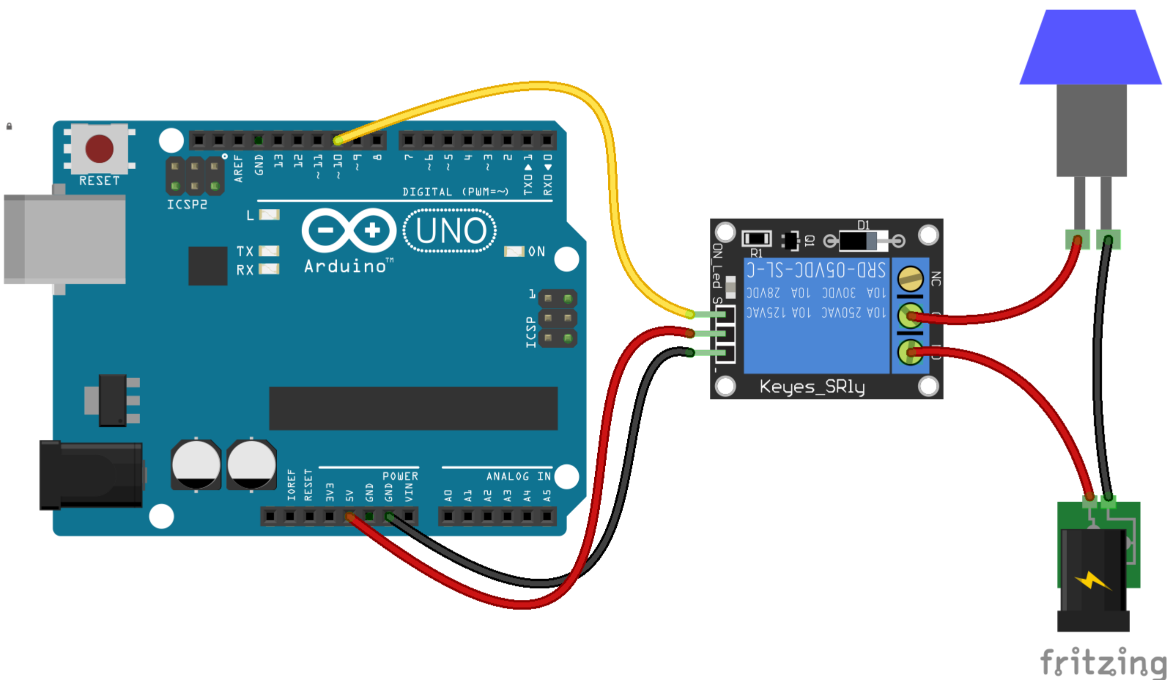
$$d = \frac{2\pi r \times n}{total\ number\ of\ slots}$$

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 a simple electromechanical switch made up of an electromagnet and a set of contacts. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal.


Power IN
Power OUT (To Kettle or any device you want to control)
VCC
SIGNAL to pin 3 of Sensor Shield
GND


RESET
ICSP2
AREF
GND
13
12
~11
~10
~9
8
7
~6
~5
4
~3
2
TX▶1
RX◀0
DIGITAL (PWM=~)
L
TX
RX
UNO
Arduino™
ON
ICSP
IOREF
RESET
3V3
5V
GND
GND
VIN
POWER
ANALOG IN
A0
A1
A2
A3
A4
A5
Keyes_SRly
fritzing