Motors and drivers

Electric motor types

1.Ac Motors

2.Dc Motors

3.Special motors

- ***Stepper motors***
- ***Servo motors***

AC Motors

AC motors are electrical motors that convert electrical energy into mechanical energy by using alternating current (AC). They are widely used in various applications, including industrial machinery, household appliances, and HVAC systems.

There are two main types of AC motors.

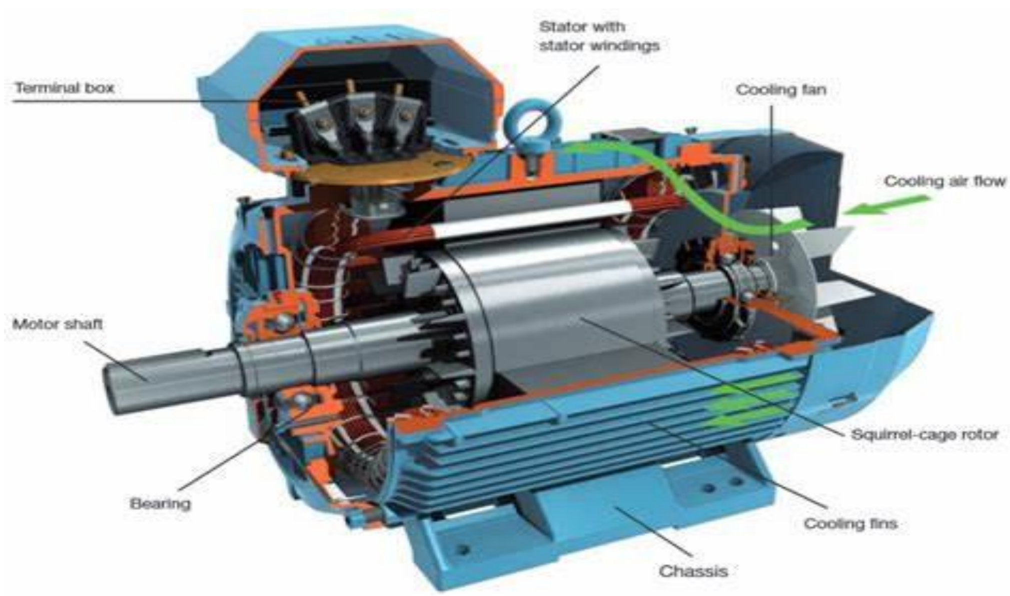
1. **Synchronous AC motors** operate at a fixed speed that is synchronized with the frequency of the AC power supply.
2. **Asynchronous AC motors**, on the other hand, operate at a slightly lower speed than the synchronous speed and are also known as induction motors.

Induction motors are the most common type of AC motor and are used in a wide variety of applications. They consist of a stator, which is a stationary part that contains the winding, and a rotor, which is a rotating part that is induced by the magnetic field created by the stator.

When an AC voltage is applied to the stator winding, it creates a rotating magnetic field.

This magnetic field induces a current in the rotor, which in turn creates a magnetic field that interacts with the stator magnetic field, causing the rotor to rotate.

There are two main types of induction motors: single-phase and three-phase. Single-phase induction motors are used in smaller applications such as household appliances, while three-phase induction motors are used in larger industrial applications.



DC motors

DC motors are electrical motors that convert electrical energy into mechanical energy. They are widely used in various applications, including electric vehicles, robotics, and industrial machinery. DC motors are classified into different types based on their construction and performance characteristics.

Some of the most common types of DC motors are:

1. **Permanent magnet DC motors:** These motors have a permanent magnet rotor and a wound stator. When current flows through the stator windings, a magnetic field is generated, which interacts with the magnetic field of the rotor, causing it to rotate.

2. **Series DC motors:** These motors have a wound rotor and a wound stator. The rotor and stator windings are connected in series, and the motor produces a high starting torque, making it suitable for applications such as electric vehicles and cranes.

3. **Shunt DC motors:** These motors have a wound rotor and a wound stator. The rotor and stator windings are connected in parallel, and the motor produces a constant speed, making it suitable for applications such as conveyor belts and fans.

4. **Compound DC motors**: These motors have both series and shunt winding, allowing them to have both high starting torque and constant speed characteristics.

5. **Brushless DC motors:** These motors have a permanent magnet rotor and a wound stator, but they use electronic commutation instead of mechanical brushes. This makes them more efficient and reliable than traditional brushed DC motors.

DC motors work by using the interaction between magnetic fields to produce mechanical motion. When a current flows through the stator windings, a magnetic field is generated, which interacts with the magnetic field of the rotor, causing it to rotate.

The direction of rotation can be reversed by changing the polarity of the current in the stator windings.

DC motors working principle.

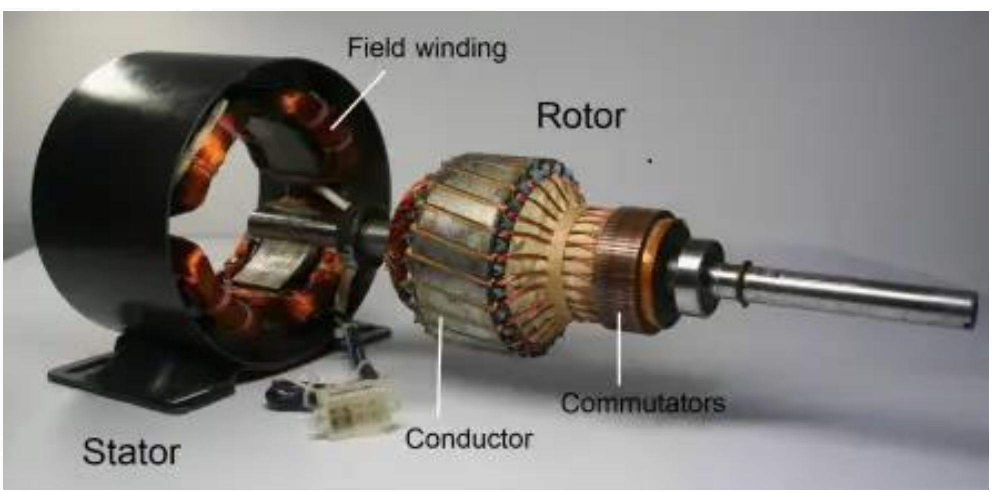
DC motors include two key components: a stator and an armature.

The stator is the stationary part of a motor, while the armature rotates.

In a DC motor, the stator provides a rotating magnetic field that drives the armature to rotate.

A simple DC motor uses a stationary set of magnets in the stator, and a coil of wire with a current running through it to generate an electromagnetic field aligned with the center of the coil.

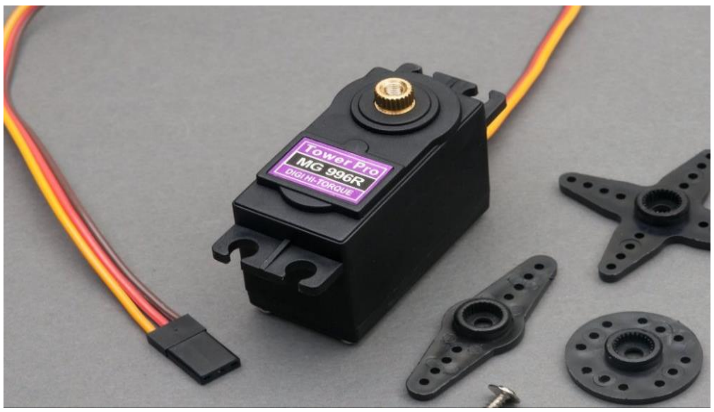
One or more windings of insulated wire are wrapped around the core of the motor to concentrate the magnetic field. The windings of insulated wire are connected to a commutator (a rotary electrical switch), that applies an electrical current to the windings. The commutator allows each armature coil to be energized in turn, creating a steady rotating force (known as torque). When the coils are turned on and off in sequence, a rotating magnetic field is created that interacts with the differing fields of the stationary magnets in the stator to create torque, which causes it to rotate. These key operating principles of DC motors allow them to convert the electrical energy from direct current into mechanical energy through rotating movement, which can then be used for the propulsion of objects.



servo motor

Servo motors are a type of DC motor that are commonly used in industrial and robotics applications.

They are designed to provide precise control over the rotation of a shaft as it consists of a control circuit that provides feedback on the current position of the motor shaft making them ideal for applications that require high accuracy and precision.



Construction:

The construction of a servo motor consists of a small DC motor, a gear train, a control circuit, and a feedback mechanism. The motor is connected to the gear train, which reduces the speed and increases the torque of the motor. The control circuit receives a signal from a controller that specifies the desired position or speed of the motor. The feedback mechanism, usually a potentiometer, provides information about the actual position or speed of the motor.

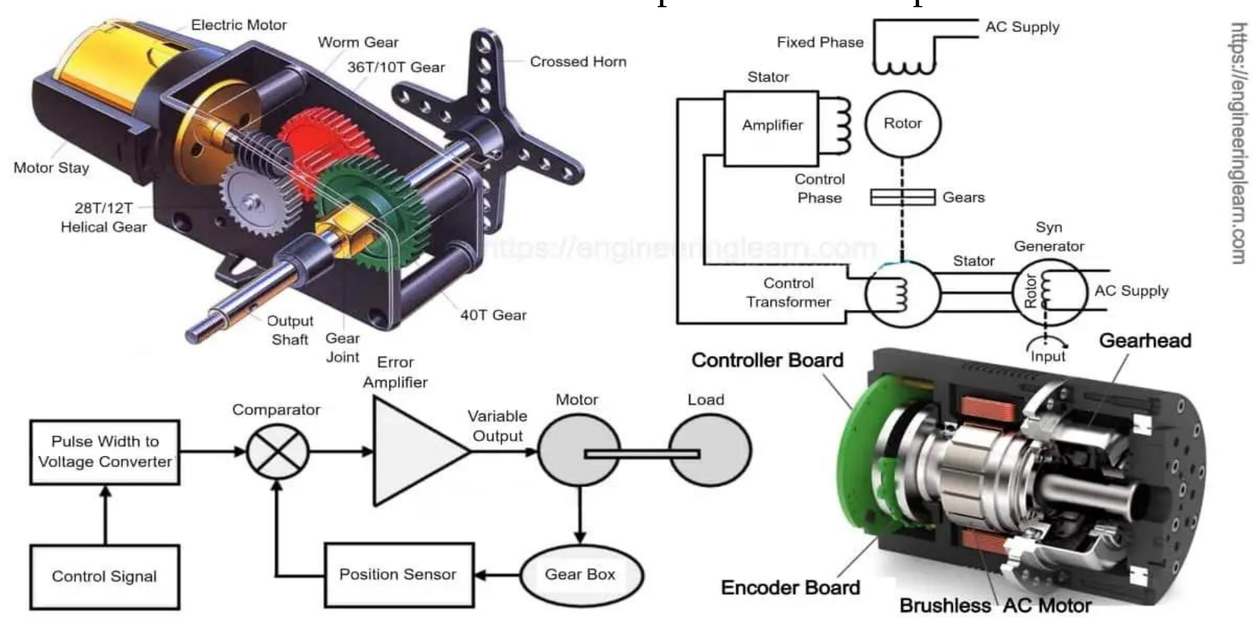
Due to these features, they are being used in many applications like toy cars, RC helicopters and planes, Robotics, etc.

Servo motors are rated in kg/cm (kilogram per centimeter) most hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm. This kg/cm tells you how much weight your servo motor can lift at a particular distance.

For example: A 6kg/cm Servo motor should be able to lift 6kg if the load is suspended 1cm (about 0.39 in) away from the motors shaft, the greater the distance the lesser the weight carrying capacity. The position of a servo motor is decided by electrical pulse and its circuitry is placed beside the motor.

Servo Motor Working Principle

The working principle of a servo motor is based on a closed-loop control system. The control circuit compares the desired position or speed of the motor with the actual position or speed provided by the feedback mechanism. If there is an error between the desired and actual values, the control circuit adjusts the voltage applied to the motor to correct the error. This continues until the desired position or speed is achieved.



Now the difference between these two signals, one comes from the potentiometer, and another comes from other sources, will be processed in a feedback mechanism and output will be provided in terms of error signal. This error signal acts as the input for the motor and motor starts rotating. Now the motor shaft is connected to the potentiometer and as the motor rotates so the potentiometer the potentiometer generates a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After some time, the position of potentiometer reaches a position where the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stops rotating.

Controlling Servo Motor

Servos have three wires coming out of them.

positive wire is red, and ground is brown, and one is orange will be used for the signal that is to be sent from the MCU.

Servo motors are controlled using a pulse width modulation (PWM) signal.

The PWM signal consists of a series of pulses with varying widths and frequencies.

The width of the pulse determines the desired position of the motor, while the frequency of the pulse determines the speed of the motor.

To control a servo motor, you need to connect it to a controller that generates the PWM signal.

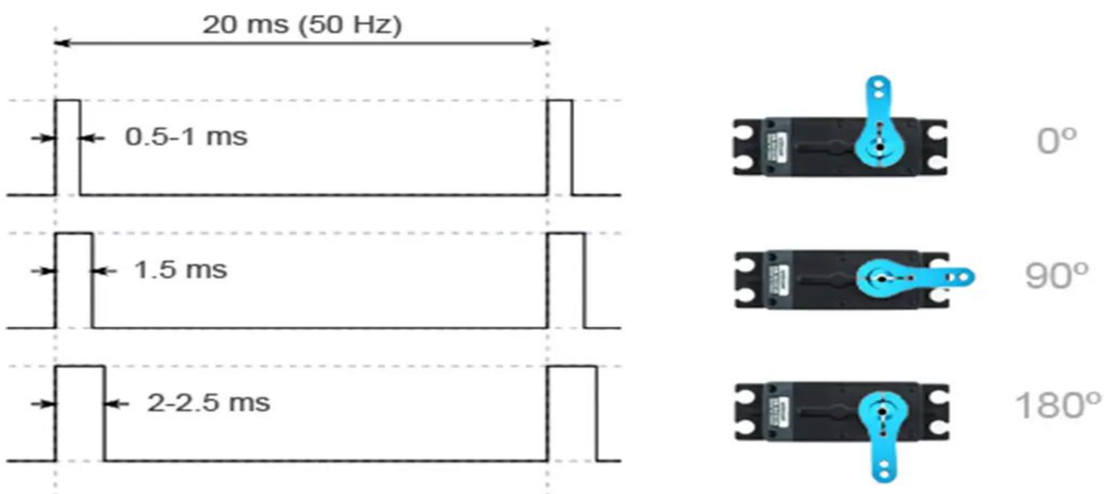
The controller can be a microcontroller or a dedicated servo controller. The controller generates the PWM signal based on the desired position or speed of the motor and sends it to the servo motor.

There is a minimum pulse, a maximum pulse and a repetition rate.

The servo motor expects to see a pulse every 20 milliseconds and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position, such as if pulse is shorter than 1.5ms shaft moves to 0° and if it is longer than 1.5ms than it will turn the servo to 180°.

Servo motor works on PWM (Pulse width modulation) principle, means its angle of rotation is controlled by the duration of applied pulse to its

Control PIN. Basically, servo motor is made up of DC motor which is controlled by a variable resistor (potentiometer) and some gears. High speed force of DC motor is converted into torque by Gears. We know that WORK= FORCE X DISTANCE, in DC motor Force is less and distance (speed) is high and in Servo, force is High, and distance is less. The potentiometer is connected to the output shaft of the Servo, to calculate the angle and stop the DC motor on the required angle.



Servo motor can be rotated from 0 to 180 degrees, but it can go up to 210 degrees, depending on the manufacturing. This degree of rotation can be controlled by applying the Electrical Pulse of proper width to its Control pin. Servo checks the pulse in every 20

milliseconds. The pulse of 1 ms (1 millisecond) width can rotate the servo to 0 degrees, 1.5ms can rotate to 90 degrees (neutral position) and 2 ms pulse can rotate it to 180 degree. All servo motors work directly with your +5V supply rails but we must be careful about the amount of current the motor would consume.

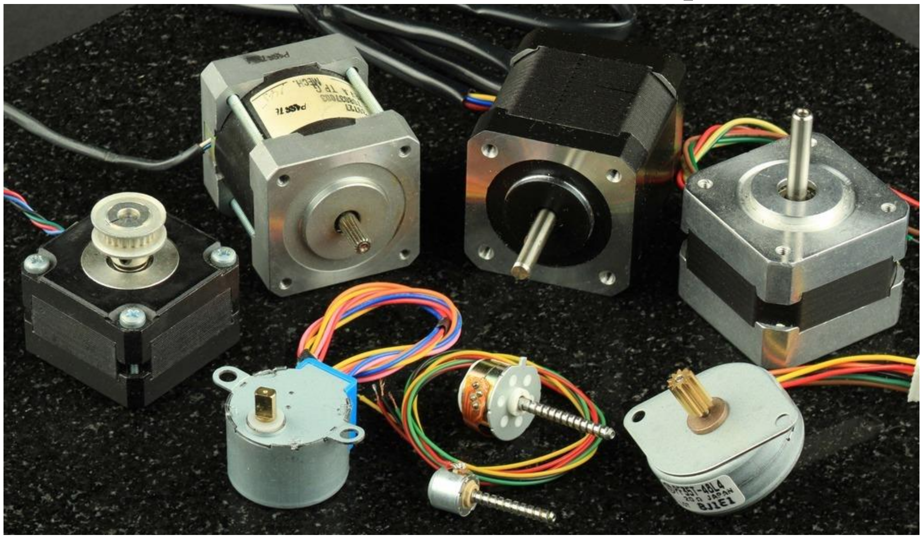
If you were planning to use more than two servo motors a proper servo shield should be designed.

Stepper motors

A stepper motor is an electromechanical device it converts electrical power into mechanical power. Also, it is a brushless, synchronous electric motor that can divide a full rotation into an expansive number of steps.

The motor's position can be controlled accurately without any feedback mechanism, as long as the motor is carefully sized to the application.

They are commonly used in applications that require precise control of movement, such as robotics, 3D printers, and CNC machines.



Types of Stepper Motor

- Permanent magnet stepper
- Hybrid synchronous stepper
- Variable reluctance stepper

Permanent Magnet Stepper Motor

Permanent magnet motors use a permanent magnet (PM) in the rotor and operate on the attraction or repulsion between the rotor PM and the stator electromagnets.

This is the most common type of stepper motor as compared with different types of stepper motors available in the market.

This motor includes permanent magnets in the construction of the motor. This kind of motor is also known as tin-can/can-stack motor.

The main benefit of this stepper motor is less manufacturing cost. For every revolution, it has 48-24 steps.

Variable Reluctance Stepper Motor

Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles.

The stepper motor like variable reluctance is the basic type of motor and it has been used for the past many years.

As the name suggests, the rotor's angular position mainly depends on the magnetic circuit's reluctance that can be formed among the teeth of the stator as well as a rotor.

Hybrid Synchronous Stepper Motor

Hybrid stepper motors are named because they use a combination of permanent magnet (PM) and variable reluctance (VR) techniques to achieve maximum power in small package sizes.

It is the most popular type of motor because it gives a good performance as compared with a permanent magnet rotor in terms of speed, step resolution, and holding torque. But this type of stepper motor is expensive as compared with permanent magnet stepper motors. This motor combines the features of both the permanent magnet and variable reluctance stepper motors. These motors are used where less stepping angle is required like 1.5, 1.8 & 2.5 degrees.

Stepper Motor Working Principles

Stepper motors have a stationary part (the stator) and a moving part (the rotor). On the stator, there are teeth on which coils are wired, while the rotor is either a pm or a variable reluctance iron core.

Figure 1 shows a drawing representing the section of the motor is shown, where the rotor is a variable-reluctance iron core.

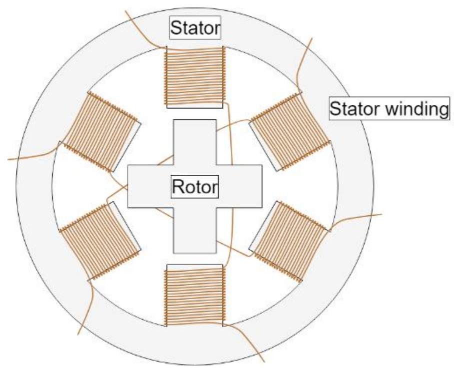


Figure 1: Cross-Section of a Stepper Motor

The basic working principle of the stepper motor is the following:

By energizing one or more of the stator phases, a magnetic field is generated by the current flowing in the coil and the rotor aligns with this field.

By supplying different phases in sequence, the rotor can be rotated by a specific amount to reach the desired final position.

Figure 2 shows a representation of the working principle.

At the beginning, coil A is energized, and the rotor is aligned with the magnetic field it produces. When coil B is energized, the rotor rotates clockwise by 60° to align with the new magnetic field. The same happens when coil C is energized. In the pictures, the colors of the stator teeth indicate the direction of the magnetic field generated by the stator winding.

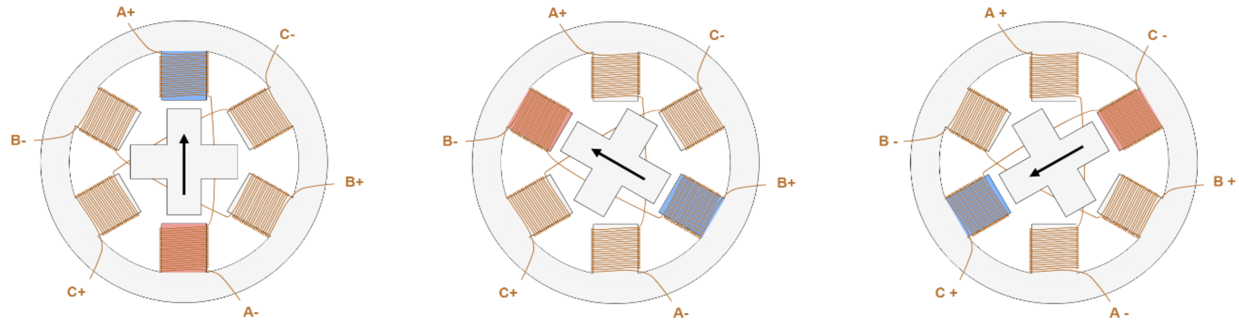


Figure 2: Stepper Motor Steps

Stepper Motor Control

We have seen previously that the motor coils need to be energized, in a specific sequence, to generate the magnetic field with which the rotor is going to align.

Several devices are used to supply the necessary voltage to the coils, and thus allow the motor to function properly.

- A transistor bridge is the device physically controlling the electrical connection of the motor coils. Transistors can be seen as electrically controlled interrupters, which, when closed allow the connection of a coil to the electrical supply and thus the flow of current in the coil. One transistor bridge is needed for each motor phase.
- A pre-driver is a device that controls the activation of the transistors, providing the required voltage and current, it is in turn controlled by an MCU.

- An MCU is a microcontroller unit, which is usually programmed by the motor user and generates specific signals for the pre-driver to obtain the desired motor behavior.

Figure 3 shows a simple representation of a stepper motor control scheme. The pre-driver and the transistor bridge may be contained in a single device, called a **driver**.

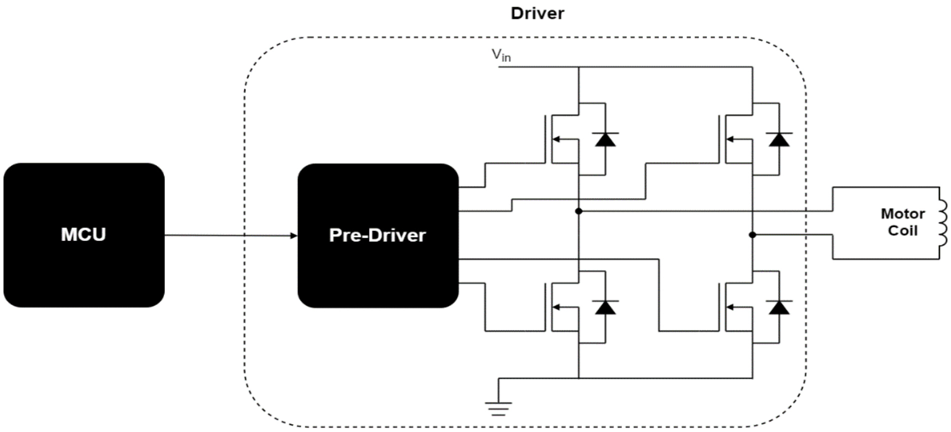


Figure 3: Motor Control Basic Scheme

Unipolar vs. Bipolar Motors

Polarity

When the current through a solenoid coil is reversed, the polarity of an electromagnet is also reversed. Due to their configuration, current can only be directed through the coils of a Unipolar Motor in one direction. This means that, as their name suggests, Unipolar Motors can only power individual phases at fixed polarities. Bipolar Stepper Motors, on the other hand, can reverse their phase polarity with the use of an H-bridge.

Wiring

Unipolar Stepper motors are very similar to Bipolar Stepper Motors but are manufactured with a central tap that connects back to the power source, essentially splitting each coil into two smaller coils that can be powered independently. If required, the central tap can also be left disconnected, allowing the Unipolar Stepper Motor to be converted into a Bipolar configuration.

Bipolar Stepper Motors do not feature a central tap for dividing their solenoid coils - this makes their internal wiring slightly less complex than that of a Unipolar Motor.

For this reason, smaller Motors such as NEMA 14 Stepper Motors are more commonly available in a Bipolar configuration due to their reduced size.

Unipolar Vs Bipolar Motors

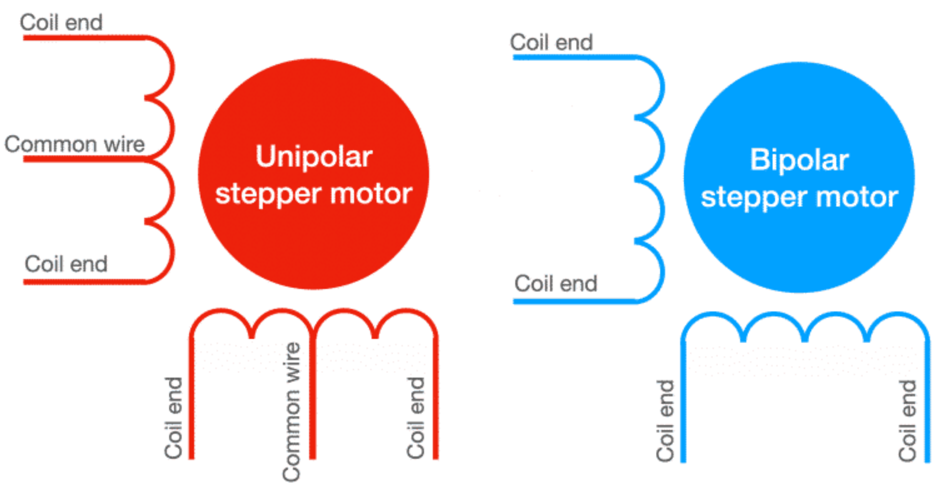
Unipolar and Bipolar Stepper motors both have their own distinct advantages and disadvantages, dependent on their application.

Bipolar Stepper Motors uses a single, larger coil per winding, this creates larger, more powerful magnetic fields than Unipolar alternatives, which allows for greater torque forces to be achieved. Because the coils of a Bipolar Stepper Motor can change polarity, this also means that all phases can be put to work at once, further increasing potential torque output. The main disadvantage of a Bipolar Stepper Motor is the requirement for H-bridge circuits to reverse the polarity of the circuit.

Unipolar Stepper Motors use tapped coils, of which each side can be independently magnetized. Because the current running through each coil will be running in a different direction depending on which side of the coil is magnetized, the polarity of each phase can be reversed without reversing the current of the entire circuit. However, because only half of each coil is magnetized, Unipolar Stepper Motors suffers from reduced magnetic force, and thus reduced torque.

Unipolar Motors are simpler to install and operate than Bipolar Stepper Motors, because their circuitry does not require the use of H-bridges.

Older and smaller electronic devices tend to use Unipolar Stepper Motors due to their simple, space-saving circuitry requirements, but with advancements in technology and reductions in the size of components, many modern electronic devices now favor Bipolar Stepper Motors.



Stepper Motor Driving Techniques

There are four different driving techniques for a stepper motor:

1. **wave mode**, only one phase at a time is energized (see **Figure 5**).

For simplicity, we will say that the current is flowing in a positive direction if it is going from the + lead to the - lead of a phase (e.g., from A+ to A-); otherwise, the direction is negative.

Starting from the left, the current is flowing only in phase A in the positive direction and the rotor, represented by a magnet, is aligned with the magnetic field generated by it. In the next step, it flows only in phase B in the positive direction, and the rotor spins 90° clockwise to align with the magnetic field generated by phase B. Later, phase A is energized again, but the current flows in the negative direction, and the rotor spins again by 90°. In the last step, the current flows negatively in phase B and the rotor spins again by 90°.

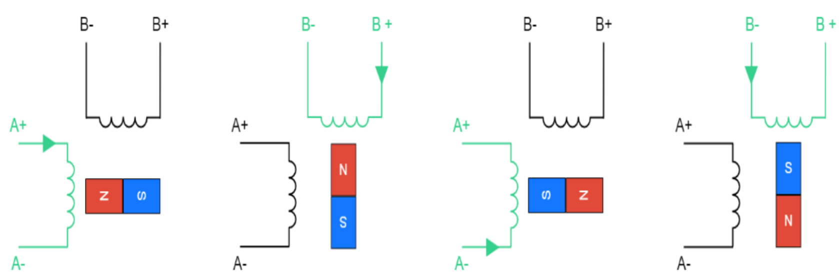


Figure 5: Wave Mode Steps

2. **full-step mode**, two phases are always energized at the same time.

The steps are similar to the wave mode ones, the most significant difference being that with this mode, the motor is able to produce a higher torque since more current is flowing in the motor and a stronger magnetic field is generated.

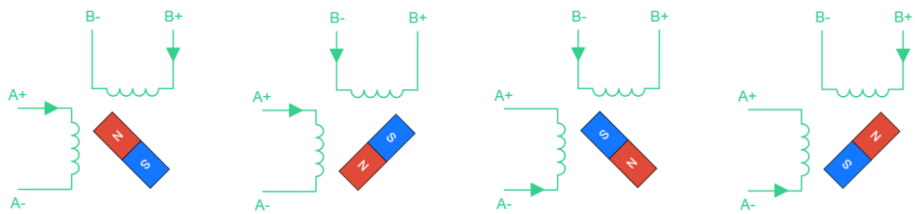


Figure 6: Full-Step Mode Steps

3. **Half-step mode** is a combination of wave and full-step modes (see **Figure 7**).

Using this combination allows for the step size to be reduced by half (in this case, 45° instead of 90°). The only drawback is that the torque produced by the motor is not constant, since it is higher when both phases are energized, and weaker when only one phase is energized.

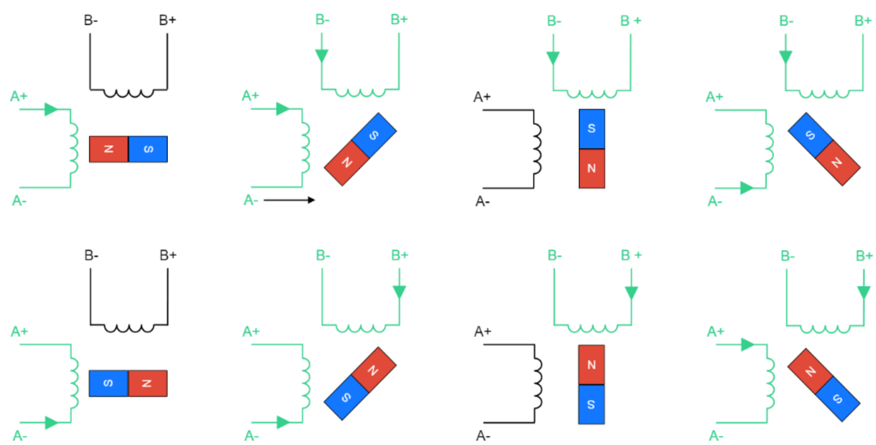


Figure 7: Half-Step Mode Steps

4. **Micro stepping** can be seen as a further enhancement of half-step mode

because it allows us to reduce even further the step size and to have a constant torque output. This is achieved by controlling the intensity of the current flowing in each phase. Using this mode requires a more complex motor driver compared to the previous solutions.

Figure 8 shows how micro stepping works.

If I_{MAX} is the maximum current that can flow in a phase, starting from the left, in the first figure $I_A = I_{MAX}$ and $I_B = 0$. In the next step, the currents are controlled to achieve $I_A = 0.92 \times I_{MAX}$ and $I_B = 0.38 \times I_{MAX}$, which generates a magnetic field that is rotated by 22.5° clockwise compared to the previous one. This step is repeated with different current values to reach the 45°, 67.5°, and 90° positions. This provides the ability to reduce by half the size of the step, compared to the half-step mode; but it is possible to go even further. Using micro stepping helps reach very high position resolution, but this advantage comes at the cost of a more complex device to control the motor, and a smaller torque generated with each step. Indeed, the torque is proportional to the sine of the angle between the stator magnetic field and the rotor magnetic field; therefore, when the steps are smaller, the torque is smaller. This may lead to missing some steps, meaning the rotor position does not change even if the current in the stator winding has.

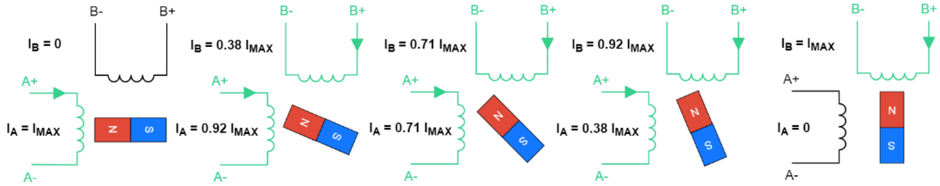


Figure 8: Micro stepping

Parameters of Stepper Motor

The stepper motor parameters mainly include step angle, steps for each revolution, steps for each second, and RPM.

Step Angle

The step angle of the stepper motor can be defined as the angle at which the motor's rotor turns once a single pulse is given to the stator's input. The resolution of the motor can be defined as the number of steps of the motor and the number of revolutions of the rotor.

Resolution = Number of Steps/Number of Revolution of the Rotor

The motor's arrangement can be decided through the step-angle & it is expressed within degrees. The resolution of a motor (the step number) is the no. of steps which make within a single revolution of the rotor. When the step-angle of the motor is small then the resolution is high for the arrangement of this motor.

The exactness of the arrangements of the objects through this motor mainly depends on the resolution. Once the resolution is high then the accuracy will be low.

Some accuracy motors can create 1000 steps within a single revolution including 0.36 degrees of step-angle. A typical motor includes 1.8 degrees of step angle with 200 steps for each revolution. The different step angles such as 15 degrees, 45 degrees, and 90 degrees are very common in normal motors. The number of angles can change from two to six and a small step angle can be attained through slotted pole parts.

Steps for Each Revolution

The steps for each resolution can be defined as the number of step angles necessary for a total revolution.

The formula for this is 360°/Step Angle.

Steps for Each Second

This kind of parameter is mainly used for measuring the number of steps covered within each second.

Revolution per Minute

The RPM is the revolution per minute. It is used to measure the frequency of revolution. So, by using this parameter, we can calculate the number of revolutions in a single minute. The main relation between the parameters of the stepper motor is as follows.

Steps for Each Second = Revolution per Minute x Steps per Revolution / 60

Stepper Motors Advantages and Disadvantages

Advantages

- Due to their internal structure, stepper motors do not require a sensor to detect the motor position. Since the motor moves by performing “steps,” by simply counting these steps, you can obtain the motor position at a given time.

- In addition, stepper motor control is pretty simple. The motor does need a driver but does not need complex calculations or tuning to work properly. In general, the control effort is lower compared to other motors. With micro stepping, you can reach high position accuracy, up to approximately 0.007°.

- Stepper motors offer good torque at low speeds, are great for holding positions, and also tend to have a long lifespan.

Disadvantages

- They can miss a step if the torque load is too high. This negatively impacts the control, since there is no way to know the real position of the motor. Using micro stepping makes stepper motors even more likely to experience this issue.

- These motors always drain maximum current even when still, which makes efficiency worse and can cause overheating.

- Stepper motors have low torque and become pretty noisy at high speeds.

- Finally, stepper motors have low power density and a low torque-to-inertia ratio.

Drivers

Electric motor drivers are electronic devices that control the speed, torque, and direction of an electric motor. They are essential components of modern motor control systems, providing precise and efficient control over the motor's operation.

There are various types of electric motor drivers, including DC motor drivers, stepper motor drivers, and servo motor drivers. Each type has its own unique features and advantages.

One example of a DC motor driver is the L298N dual H-bridge module. This driver is capable of controlling two DC motors simultaneously, with a maximum current rating of 2A per channel.

It can also handle a wide range of input voltages and has built-in protection features against overvoltage, overtemperature, and short circuits.

For stepper motors, the A4988 driver is a popular choice. This driver can control a single bipolar stepper motor, with a maximum current rating of 2A per phase.

It supports micro stepping resolutions up to 1/16th of a step, providing smooth and precise control over the motor's movement.

Servo motor drivers, such as the PCA9685 PWM module, offer even more precise control over motor position and speed. This driver can control up to 16 servo motors simultaneously, each with a resolution of 12 bits (4096 steps). It also supports a variety of PWM frequencies and has built-in features for controlling motor acceleration and deceleration.

A4988 motor drive

The A4988 is a complete micro stepping motor drive with built-in translator for easy operation.

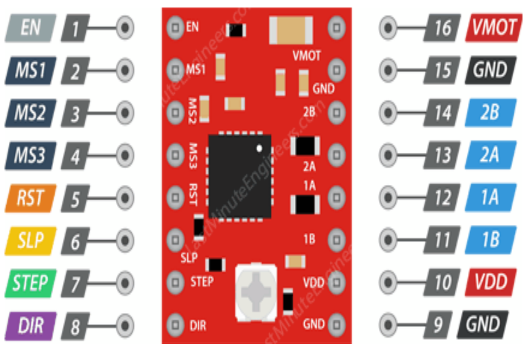
It is designed to operate bipolar stepper motors in full, half, and micro stepping 3modes, with an output drive capacity of up to 35 V and ±2 A. The A4988 includes a fixed off-time current regulator which can operate in slow or mixed decay modes.

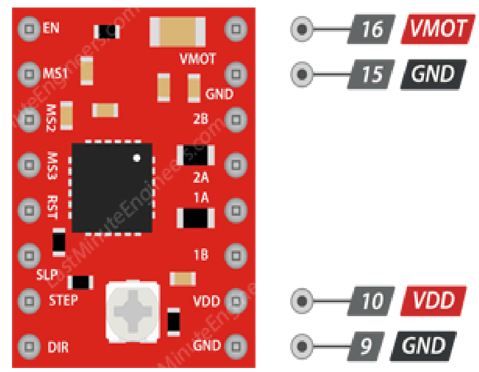
Technical Specifications

Motor output voltage	8V – 35V
Logic input voltage	3V – 5.5V
Continuous current per phase	1A
Maximum current per phase	2A
Micro step resolution	full, 1/2, 1/4, 1/8 and 1/16

A4988 Motor Driver Pinout

The A4988 driver has a total of 16 pins that connect it to the outside world. The pinout is as follows:





Power Pins

The A4988 requires two power supply connections.

VDD and GND are used to power the internal logic circuitry, which can range from 3V to 5.5V.

Whereas,

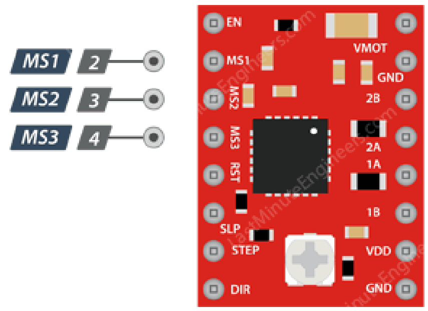
VMOT and GND supply power to the motor, which can range from 8V to 35V.

Micro step Selection Pins

The A4988 driver supports micro stepping by dividing a single step into smaller steps.

This is achieved by energizing the coils with intermediate current levels.

For example, if you choose to drive the NEMA 17 (with 1.8° step angle or 200 steps/revolution) in quarter-step mode, the motor will produce 800 micro steps per revolution.



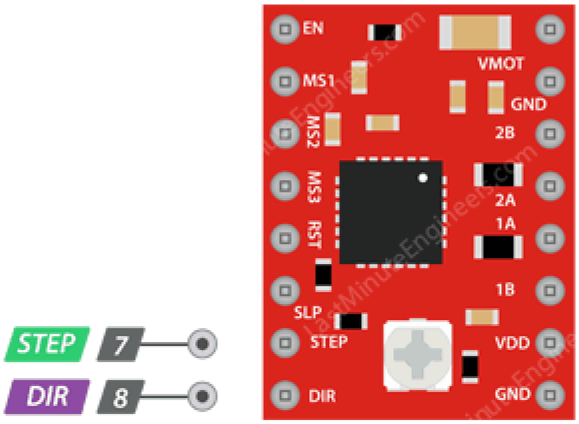
The A4988 driver has three resolutions selector inputs: MS1, MS2 & MS3.

MS1	MS2	MS3	Micro step Resolution
Low	Low	Low	Full step
High	Low	Low	Half step
Low	High	Low	Quarter step
High	High	Low	Eighth step
High	High	High	Sixteenth step

These three micro step selection pins are pulled LOW by internal pull-down resistors, so if you leave them unconnected, the motor will operate in full step mode.

Control Input Pins

The A4988 has two control inputs: STEP and DIR.



STEP input controls the micro steps of the motor.

Each HIGH pulse sent to this pin drives the motor according to the number of micro steps determined by the micro step selection pins. The higher the pulse frequency, the faster the motor will spin.

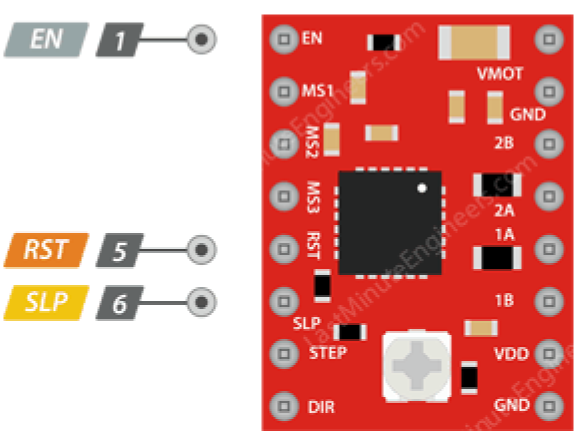
DIR input controls the spinning direction of the motor. Pulling it HIGH turns the motor clockwise, while pulling it LOW turns it counterclockwise.

If you want the motor to only turn in one direction, you can connect the DIR directly to VCC or GND.

The STEP and DIR pins are not pulled to any specific voltage, so you should not leave them floating in your application.

Pins For Controlling Power States

The A4988 has three separate inputs for controlling its power states: EN, RST, and SLP.



EN is an active low input pin.

When this pin is pulled LOW, the A4988 driver is enabled.

By default, this pin is pulled low, so unless you pull it high, the driver is always enabled. This pin is particularly useful when implementing an emergency stop or shutdown system.

SLP is an active low input pin.

Pulling this pin LOW puts the driver into sleep mode, reducing power consumption to a minimum.

You can use this to save power, especially when the motor is not in use.

RST is an active low input as well.

When this pin is pulled LOW, all STEP inputs are ignored.

It also resets the driver by setting the internal translator to a predefined “home” state.

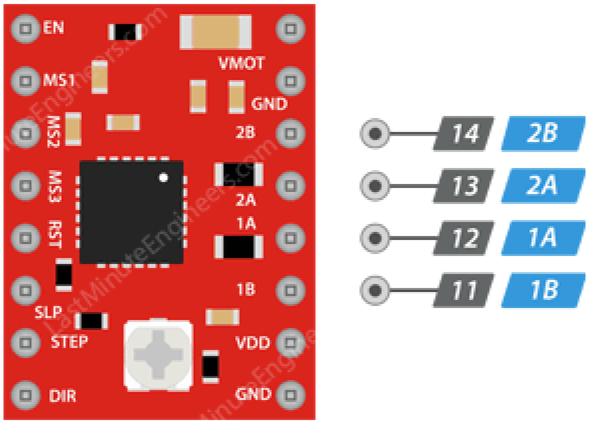
Home state is basically the initial position from which the motor starts, and it varies based on micro step resolution.

RST is a floating pin. If you’re not using this pin, connect it to an adjacent SLP/SLEEP pin to make it high and enable the driver.

After the wake-up event (logic HIGH on the SLEEP pin), wait 1 millisecond before issuing a Step command to allow the charge pump to stabilize.

Output Pins

The output channels of the A4988 motor driver are broken out to the side of the module with pins 1B, 1A, 2A & 2B.



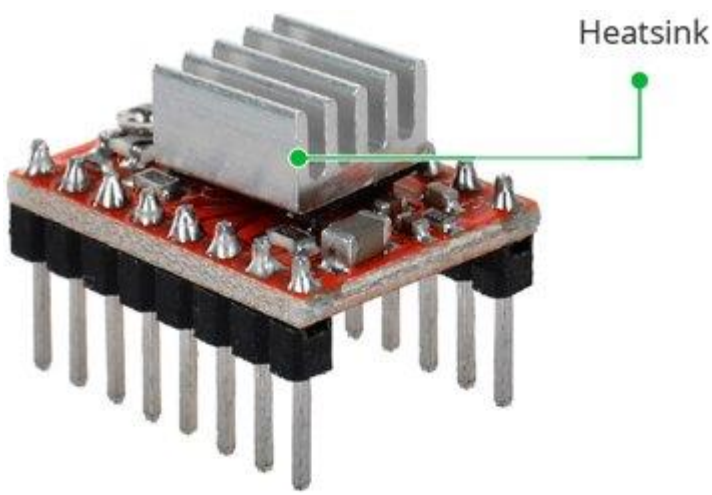
You can connect any small to medium-sized bipolar stepper motor, such as NEMA 17, to these pins.

Each output pin can supply up to 2A to the motor. However, the amount of current supplied to the motor is determined by the power supply, cooling system, and current limiting setting of the system.

Cooling System – Heatsink

Excessive power dissipation of the A4988 driver IC causes a temperature rise, which could potentially damage the IC if it exceeds its capacity.

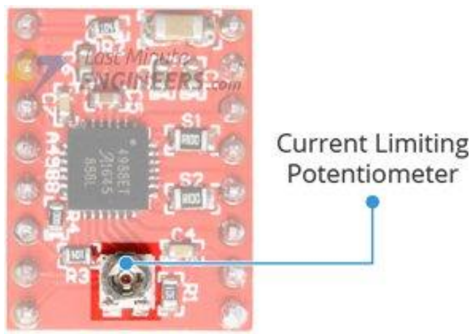
Despite having a maximum current rating of 2A per coil, the A4988 driver IC can only supply about 1A per coil without overheating. To achieve more than 1A per coil, a heat sink or other cooling method is required.



Usually, the A4988 driver comes with the heatsink. It is recommended that you install the heatsink before using the driver.

Current limiting

Before running the motor, you must limit the maximum current flowing through the stepper coils so that it does not exceed the motor's rated current.

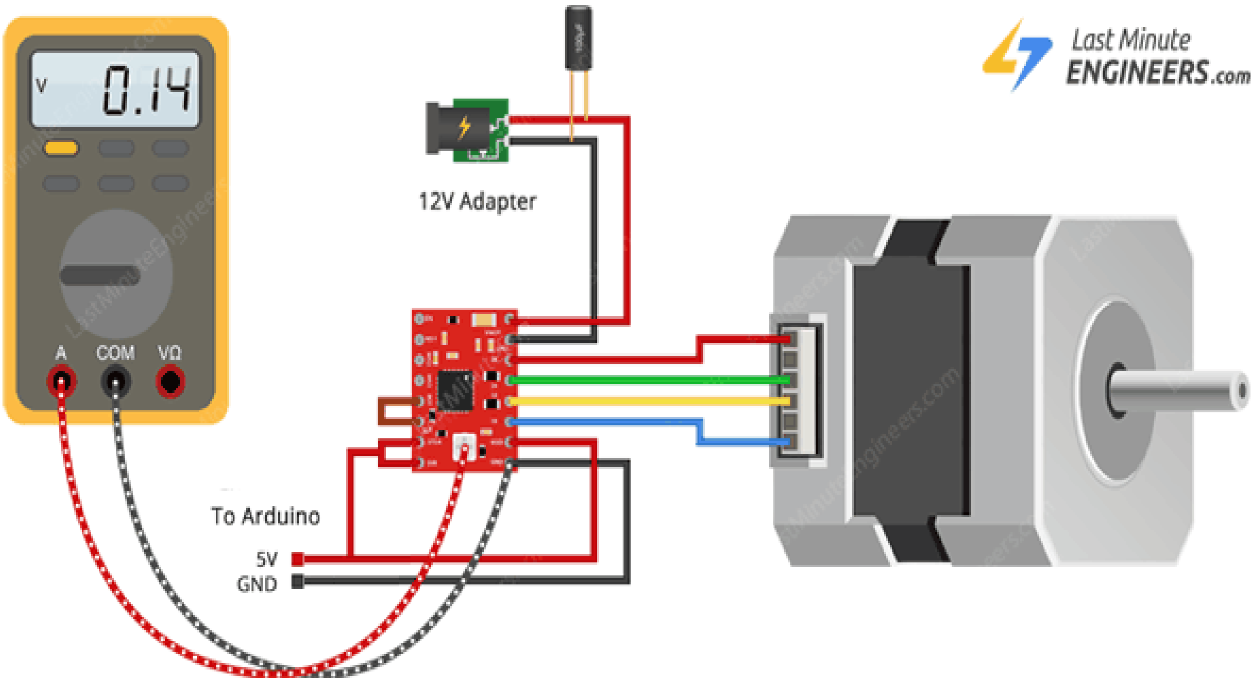


The A4988 driver includes a small trimmer potentiometer for setting the current limit.

The current limit could be determined by measuring the voltage (Vref) at the "ref" pin.

3. Take a look at the datasheet for your stepper motor. Make a note of the rated current. In our case, NEMA 17 200steps/rev, 12V 350mA is used.
4. Disconnect the three micro step selection pins to put the driver in full-step mode.
5. Hold the motor in a fixed position without clocking the STEP input.
6. Measure the voltage (Vref) on the metal trimmer pot as you adjust it.
7. Adjust the Vref voltage by using the formula
8. Vref = Current Limit / 2.5

9. For example, if your motor is rated at 350mA, you would set the reference voltage to 0.14V.



Electronic devices

Ir sensor

What is IR Sensor?

The IR sensor or infrared sensor is one kind of electronic component, used to detect specific characteristics in its surroundings through emitting or detecting IR radiation. These sensors can also be used to detect or measure the heat of a target and its motion. In many electronic devices, the IR sensor circuit is a very essential module. This kind of sensor is like human’s visionary senses to detect obstacles.

IR Sensor

The sensor which simply measures IR radiation instead of emitting is called PIR or passive infrared. Generally, in the IR spectrum, the radiation of all the targets radiation and some kind of thermal radiation are not visible to the eyes but can be sensed through IR sensors.

In this sensor, an IR LED is used as an emitter whereas the photodiode is used as a detector. Once an infrared light drops on the photodiode, the output voltage & resistance will be changed in proportion to the received IR light magnitude.

IR Sensor Working Principle

An infrared sensor includes two parts namely the emitter & the receiver (transmitter & receiver), so this is jointly called an optocoupler or a photo-coupler.

Here, IR LED is used as an emitter whereas the IR photodiode is used as a receiver.

The photodiode used in this is very sensitive to the infrared light generated through an infrared LED.

The resistance of photodiode & output voltage can be changed in proportion to the infrared light obtained.

The type of incident that occurred is the direct otherwise indirect type where indirect type, the arrangement of an infrared LED can be done ahead of a photodiode without obstacle.

In indirect type, both the diodes are arranged side by side through a solid object ahead of the sensor. The generated light from the infrared LED strikes the solid surface and returns back toward the photodiode.

IR sensors use three basic Physics laws like Planck's Radiation, Stephan Boltzmann & Wein's Displacement.

- Planck's Radiation law defines that the temperature of any object is not equivalent to Zero
- Stephan Boltzmann Law defines that the whole energy which is generated at all wavelengths through a black body is associated with the total temperature.
- Wein's Displacement Law defines that the temperature of different objects emits spectra that are maximum at various wavelengths and inversely proportional with temperature.

IR Sensor Module

The IR sensor module includes five essential parts like IR Tx, Rx, Operational amplifier, trimmer pot (variable resistor) & output LED. The pin configuration of the IR sensor module is discussed below.

IR Sensor Module

- VCC Pin is power supply input
- GND Pin is power supply ground
- OUT is an active-high o/p

The main **specifications and features of the IR sensor** module include the following.

- The operating voltage is 5VDC
- I/O pins – 3.3V & 5V
- Mounting hole
- The range is up to 20 centimeters (about 7.87 in)
- The supply current is 20mA
- The range of sensing is adjustable
- Fixed ambient light sensor

Types of IR Sensor

The classification of IR sensors can be done based on the application which includes the following.

- Active Infrared Sensors
- Passive Infrared Sensors

Active IR Sensor

This type of sensor includes both the emitter & the receiver which are also known as transmitter & receiver. In most situations, a laser diode or LED is used as a source.

For non-imaging infrared sensors, LED is used whereas laser diode is used for imaging infrared sensors.

The working of an infrared sensor can be done through radiating energy, detected and received through the detector. Further, it is processed through a signal processor to fetch the required data. The best examples of active infrared sensors are reflectance & break beam sensors.

Passive Infrared Sensor

Passive Infrared Sensor (PIR) includes detectors only and this kind of sensor uses targets like infrared transmitters or sources. Here, the object will radiate energy & detect it through infrared receivers. After that, a signal processor is used to understand the signal to obtain the required data.

The best examples of PIR sensors are bolometer, Pyro-Electric Detector, Thermocouple-Thermopile, etc. PIR sensors are available in two types, like thermal IR sensor and quantum IR sensor.

Thermal Infrared Sensor

These types of sensors are independent of wavelength, and they utilize heat-like energy sources. These are slow along with the response time as well as detection time.

Quantum Infrared Sensor

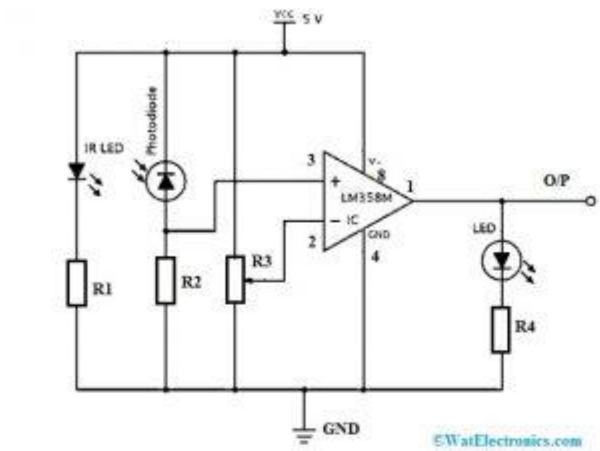
These types of sensors depend on wavelengths and the response time and detection time they have are high. These kinds of infrared sensors need repeated cooling for exact measurement.

IR Sensor Circuit

The application circuit of the IR sensor is an obstacle detecting circuit that is shown below. This circuit can be built with a photodiode, IR LED, an op-amp LED & a potentiometer.

The main function of an infrared LED is to emit IR light and the photodiode is used to sense the IR light. In this circuit, an operational amplifier is used as a voltage comparator and the output of the sensor can be adjusted by the potentiometer based on the requirement.

Once the light generated from the infrared LED can be dropped on the photodiode once striking an object, then the photodiode’s resistance will be dropped.



IR Sensor Circuit Diagram

Here, op-amp’s one of the inputs at threshold value can be set through the potentiometer whereas other inputs can be set by using the series resistor of the photodiode. Once the radiation on the photodiode is more, then the voltage drop will be more across the series resistor. In the operational amplifier, both the voltages are evaluated.

If the series resistor’s voltage is higher than the threshold voltage, then the IC output is high. When the IC output is given to an LED then it will blink.

So, using a potentiometer, the threshold voltage can be adjusted based on the conditions of surroundings.

In this circuit, the arrangement of the IR receiver and the IR LED is a very essential factor. Once the infrared LED is placed directly ahead of the infrared receiver, then this arrangement can be known as Direct Incidence.

So, in this case, nearly all the radiation from the infrared LED will drop on the infrared receiver. Therefore, there is a row of view contact among the IR Tx & Rx.

If a target drops in this row, it blocks the emission while approaching the receiver by reproducing or absorbing the radiation.

Advantages

- Low power consumption
- Noise immunity is strong
- Detects motion when the light is present or absent
- These sensors are not affected by rust
- They do not need to get in touch with objects for detection.
- No data leakage
- These are more modest in size and are more moderate.
- It responds very quickly as compared to thermocouples.
- It provides high reliability

Disadvantages

- Line of sight is necessary
- It can be affected based on the conditions of the environment like fog, rain, pollution, dust, etc.
- These sensors can be blocked with common objects.
- The data rate transmission is not fast
- Range is limited
- High force IR signals can harm human eyes

Applications

- Rail Safety
- IR Imaging Devices
- Infrared Astronomy
- Optical Power Meters
- Night Vision Devices

- Sorting Devices
- Moisture Analyzers
- Missile Guidance
- Flame Monitors
- Remote Sensing
- Climatology
- Gas Analyzers
- Meteorology
- Rail safety
- Exploration of Petroleum
- Flame Monitors
- Gas detectors
- Water analysis

Camera

Cameras are an essential component of image processing and computer vision systems.

Choosing the camera

When it comes to choosing a camera for these applications, there are several factors to consider.

First and foremost, **the resolution** of the camera is critical.

The higher the resolution, the more detail the camera can capture.

This is especially important in computer vision applications, where high-resolution images are necessary for accurate object recognition and tracking.

Another factor to consider is the **frame rate of the camera**.

In applications that involve moving objects, a high frame rate is crucial to capture accurate and smooth motion.

The frame rate also affects the amount of data that the camera produces, so it is essential to choose a camera with a frame rate that meets your application's requirements.

The sensitivity of the camera is also important.

In low-light applications, a camera with high sensitivity can capture clear images even in dark environments. On the other hand, in applications with high levels of ambient light, a camera with low sensitivity may be preferable to prevent overexposure.

Finally, **the interface of the camera** is also a consideration.

Many cameras come with a USB or Ethernet interface, making them easy to integrate into existing systems.

Other cameras may require special interfaces or software to use.

When choosing a camera for image processing and computer vision applications, it is important to consider all these factors and choose a camera that meets your specific requirements.

Some popular camera brands for these applications include Basler, FLIR, and Allied Vision.

one camera that can be used for capturing images and sending them to MATLAB for processing and comparison is the Basler acA2000-165uc. This camera has a resolution of 2 megapixels and can capture up to 165 frames per second, making it ideal for capturing fast-moving objects. It also has a high sensitivity, allowing it to capture clear images in low-light environments.

To use this camera with MATLAB, you would need to connect it to a computer using a USB 3.0 interface. You can then use MATLAB's Image Acquisition Toolbox to capture images from the camera and process them using MATLAB's image processing functions.

To detect if a can is valid or not, you would first need to capture images of both valid and invalid cans as reference images. You can then use MATLAB's image processing functions to compare each captured image with the reference images and determine if it matches a valid or invalid can. This can be done by analyzing features such as the shape, color, and texture of the can.

Overall, the Basler acA2000-165uc is a high-performance camera that can be used in combination with MATLAB for image processing and analysis applications such as can validation.

I2C LCD

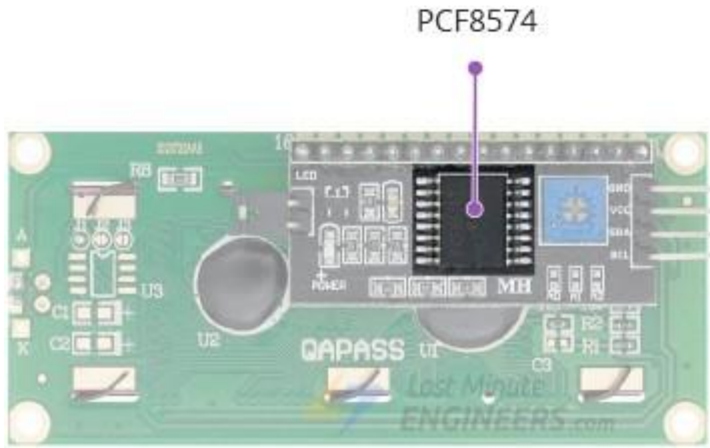
is a type of LCD display that can be connected to a microcontroller using the I2C communication protocol. I2C (Inter-Integrated Circuit) is a synchronous serial communication protocol that allows multiple devices to be connected to a microcontroller using only two wires, making it a popular choice for connecting peripherals to microcontrollers.

If you’ve ever attempted to connect an LCD display to an Arduino, you’ve probably noticed that it uses a lot of Arduino pins. Even in 4-bit mode, the Arduino requires seven connections – half of the Arduino’s available digital I/O pins.

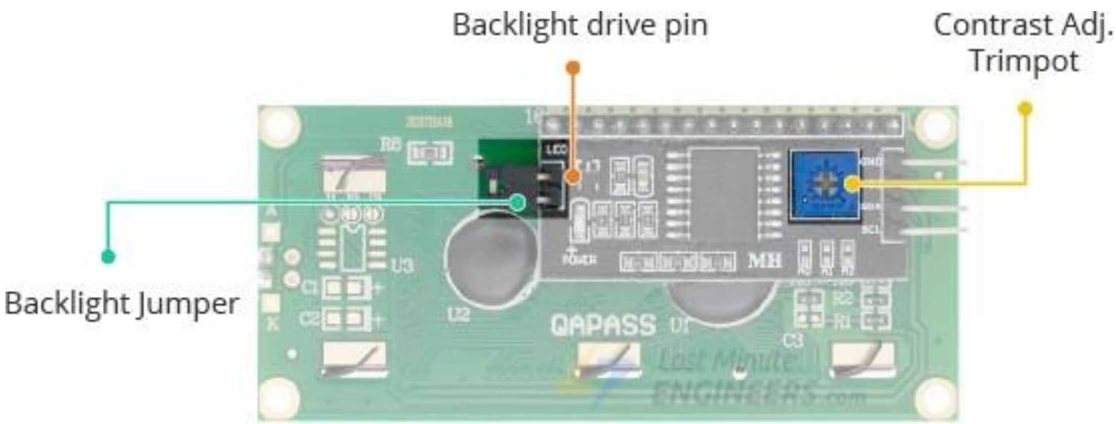
The solution is to use an I2C LCD display. It only uses two I/O pins that are not even part of the digital I/O pin set and can be shared with other I2C devices.

I2C LCD Adapter

At the heart of the adapter is an 8-bit I/O expander chip – PCF8574. This chip converts the I2C data from an Arduino into the parallel data required for an LCD display.



The board also includes a tiny trim pot for making precise adjustments to the display's contrast.



There is a jumper on the board that provides power to the backlight. To control the intensity of the backlight, you can remove the jumper and apply external voltage to the header pin labeled 'LED'.

I2C Address of LCD

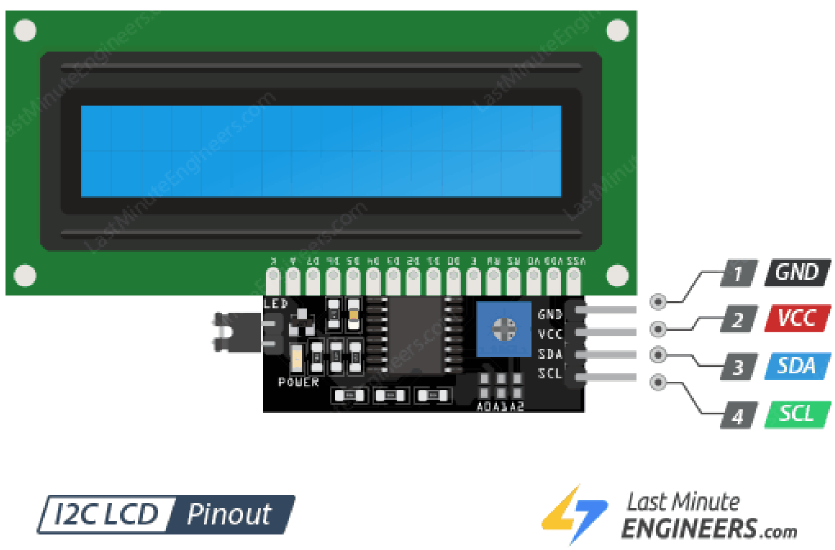
If you have multiple devices on the same I2C bus, you may need to set a different I2C address for the LCD adapter to avoid conflicting with another I2C device.

For this purpose, the adapter comes with three solder jumpers/pads (A0, A1, and A2). The address is set when a jumper is shorted with a blob of solder.

An important point to note here is that several companies, including Texas Instruments and NXP Semiconductors, manufacture the same PCF8574 chip. And the I2C address of your LCD depends on the chip manufacturer.

I2C LCD Display Pinout

The I2C LCD Display has only four pins. The following is the pinout:



GND is a ground pin.

VCC is the power supply pin. Connect it to the 5V output of the Arduino or an external 5V power supply.

SDA is the I2C data pin.

SCL is the I2C clock pin.

Wiring an I2C LCD Display to an Arduino

Connecting an I2C LCD is much simpler than connecting a standard LCD.

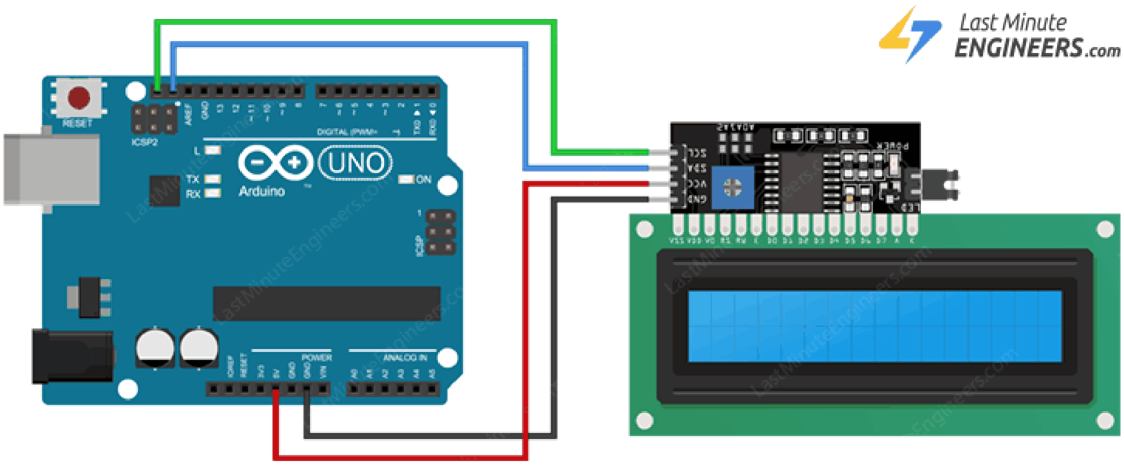
You only need to connect four pins.

Begin by connecting the VCC pin to the Arduino's 5V output and the GND pin to ground.

Now we are left with the pins that are used for I2C communication. Note that each Arduino board has different I2C pins that must be connected correctly. On Arduino boards with the R3 layout, the SDA (data line) and SCL (clock line) are on the pin headers close to the AREF pin.

They are also referred to as A5 (SCL) and A4 (SDA).

	SCL	SDA
Arduino Uno	A5	A4
Arduino Nano	A5	A4
Arduino Mega	21	20
Leonardo/Micro	3	2



Notes

1.After wiring the LCD, you will need to adjust the contrast of the LCD. On the I2C module, there is a potentiometer that can be rotated with a small screwdriver.

2.Before you can proceed, you must install the LiquidCrystal_I2C library. This library allows you to control I2C displays using functions that are very similar to the Liquid Crystal library.

Bill of used materials

Quantity	Component Name	n
2	Arduino uno	1
1	Portable conveyor belt	2
6	Mg 966r servo motor	3
1	12-volt-2A- power supply	4
1	A4988 stepper driver	5
2	IR sensor (Trct5000)	6
1	Nema-17 stepper bracket	7
1	IR camera-(0v7970) camera module	8

---	3d printed parts of arm robot	9
1	Robot Gripper parts	10
----	Resistance & wires	11
2	Power cables	12
1	12v-6A-power supply	13
2	Bread board	14
1	12c lcd	15

Software tools

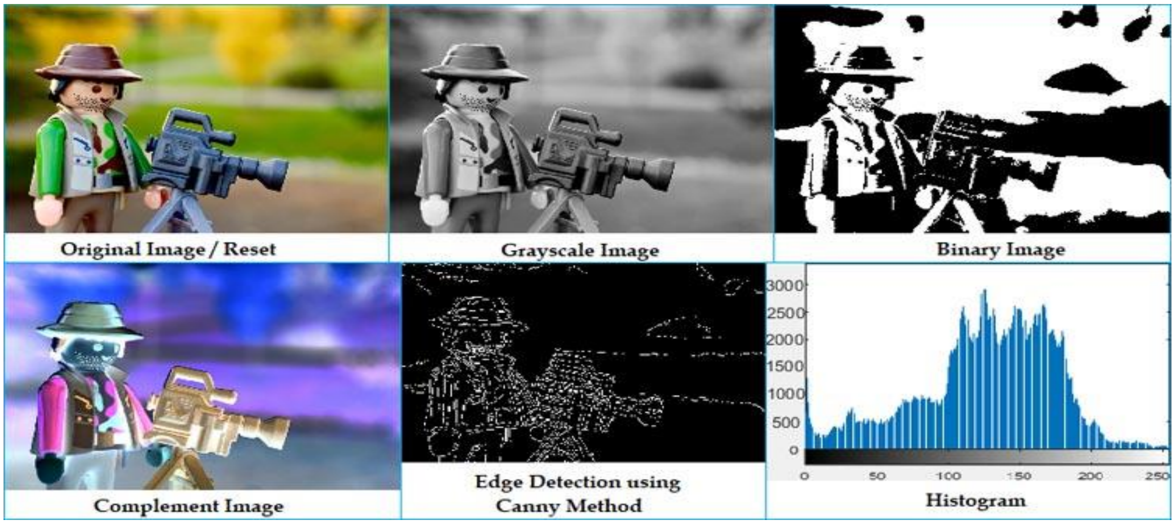
Matlab:

is well-known for its powerful mathematical capabilities, making it an ideal tool for data analysis, simulation, and modeling.

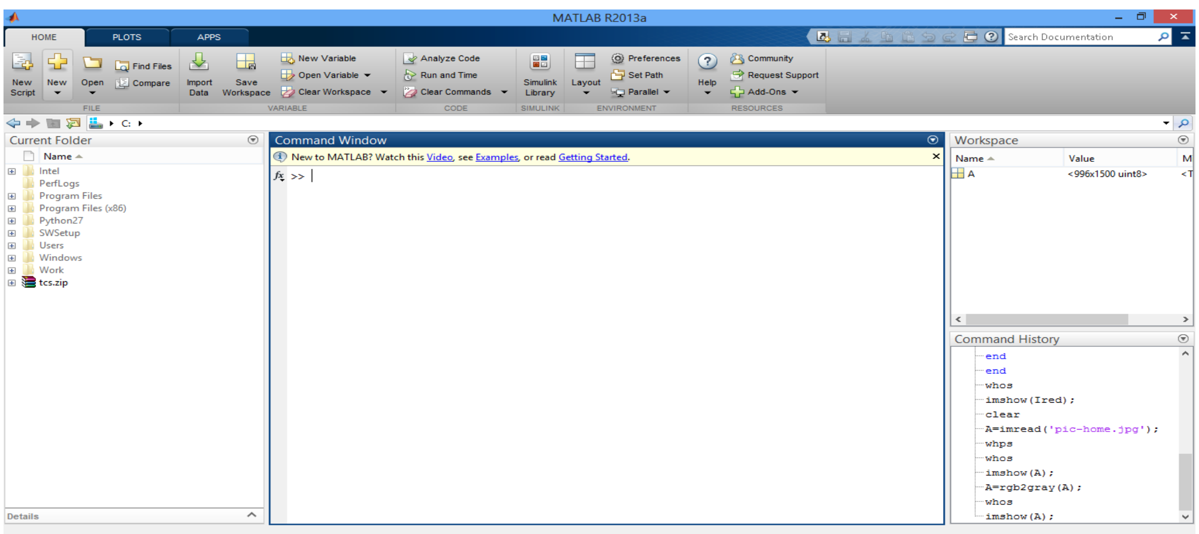
Its user-friendly interface and comprehensive documentation make it easy for beginners to learn and use.

Matlab also has a vast library of functions and toolboxes that cover various areas of engineering and science.

For instance, the Image Processing and computer vision Toolbox can be used for image processing and analysis, while the Control System Toolbox can be used for designing and analyzing control systems.



Matlab IDE



Arduino ide

Arduino IDE is an open-source software development environment used for programming Arduino boards. It is a user-friendly platform that allows beginners and experts to develop and upload code to their Arduino boards.

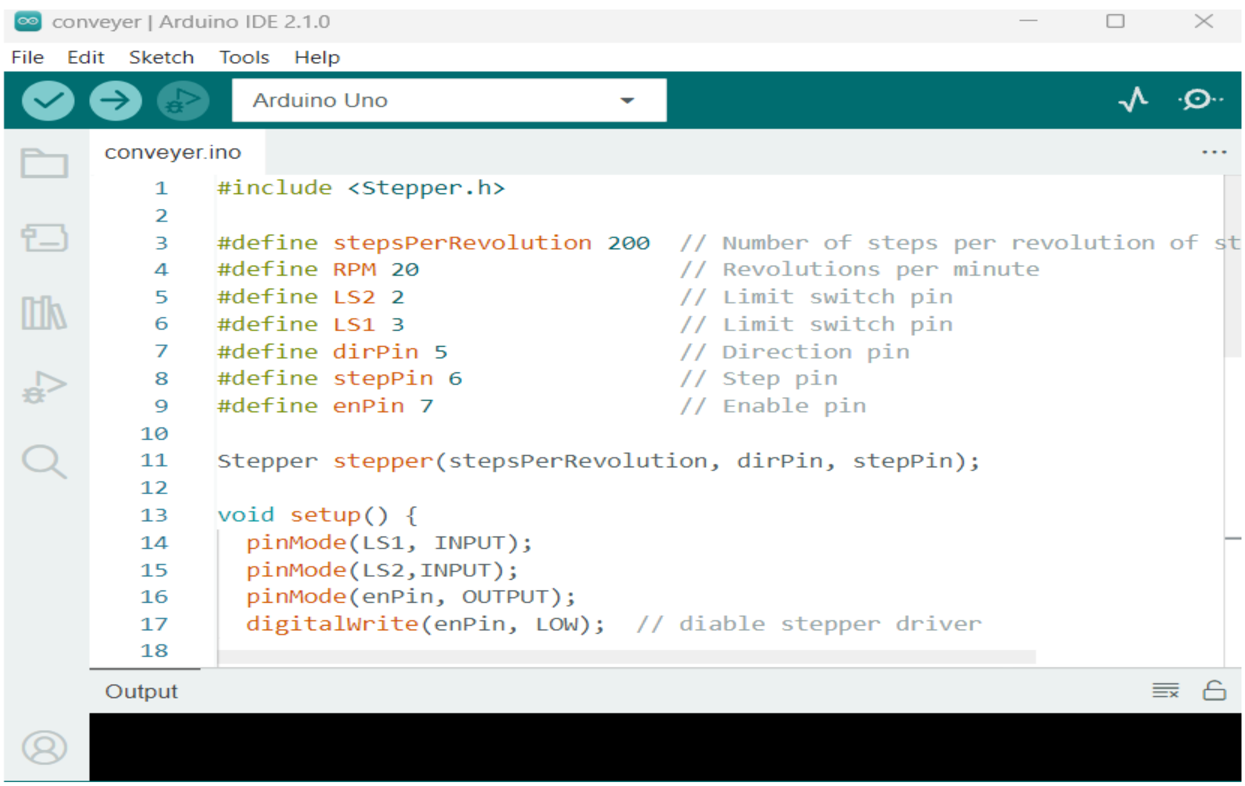
The Arduino IDE supports popular programming languages such as C and C++ and comes with a range of libraries that make it easy to program different sensors, actuators, and other components.

The IDE also has a built-in serial monitor that allows users to communicate with their Arduino board and view data output from sensors or other components.

The Arduino IDE features a simple and intuitive interface, making it easy to write, compile, and upload code to the Arduino board.

In addition to the standard text editor, the IDE provides a range of helpful features such as syntax highlighting, auto-completion, and error detection.

The IDE also includes a range of example sketches that can be used as templates for different projects.



Proteus

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation.

The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing PCBs.

Schematic Capture

Schematic capture in the Proteus Design Suite is used for both the simulation of designs and as the design phase of a PCB layout project.

It is therefore a core component and is included with all product configurations.

Microcontroller Simulation

The microcontroller simulation in Proteus works by applying either a hex file or a debug file to the microcontroller part on the schematic.

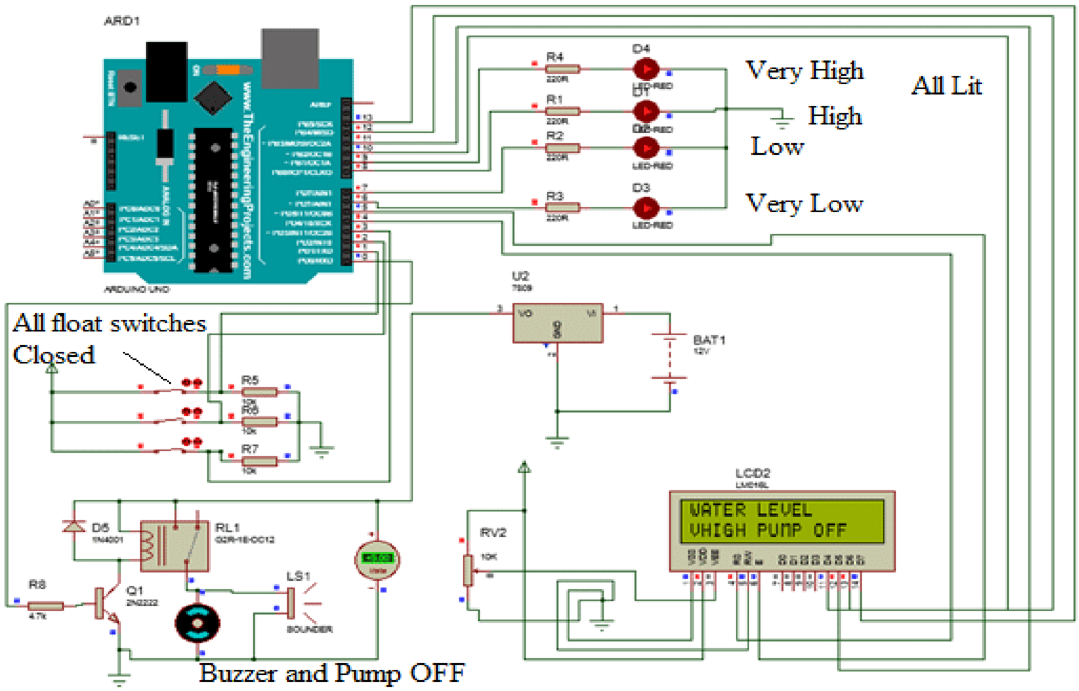
It is then co-simulated along with any analog and digital electronics connected to it.

This enables its use in a broad spectrum of project prototyping in areas such as motor control, temperature control and user interface design.

It also finds use in the general hobbyist community and, since no hardware is required, is convenient to use as a training or teaching tool.

Support is available for co-simulation of:

- Microchip technologies PIC10, PIC12, PIC16, PIC18, PIC24, dsPIC33 microcontrollers
- Atmel AVR and Arduino, 8051 and ARM Cortex microcontrollers
- Texas instruments MSP430, PICCOLO DSP and ARM Cortex-M3 microcontrollers


ARD1
ARDUINO UNO
www.TheEngineeringProjects.com
R4
D4
R1
D1
R2
D2
R3
D3
LED-RED
Very High
High
Low
Very Low
All Lit
U2
BAT1
12V
All float switches
Closed
R5
R6
R7
D5
RL1
R8
Q1
LS1
SOUNDER
RV2
LCD2
WATER LEVEL
VHIGH PUMP OFF
Buzzer and Pump OFF