BABU BANARASI DAS UNIVERSITY, LUCKNOW

A PROJECT REPORT ON

4-STROKE SOLENOID ENGINE

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(Asst. Proof).

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Abstract:

In present investigation we have designed a solenoid coil engine based on Induction principle which is alternate option of electric Engine in future due to it high load carrying capacity and low cost as compared to electric engine. Through this work new advanced automobile cum electrical technology is implemented to regenerate a new advance electric engine without using a motor and it is possible to totally remove the motor from car which we name as high torque coil engine. It works like a normal fuel engine but now power source is battery with is totally pollution free and eco-friendly.

Introduction:

By Literature survey of [1, 2, 3&4] we develop the idea of an engine in which the reciprocating motion of the armature of the solenoid is transmitted to the crankshaft which converts into rotary motion of it, through a metal strip which acts as a connecting rod. When the power is turn ON, the coil is energized and hence pulls the armature in the middle of the coil and as the coil gets un-energized the armature returns back to its position with a hammering stroke. A single solenoid is responsible for 90 degree rotation of the crankshaft, hence to complete the cycle of 360 degree four solenoids are being used and actuator of this solenoid at different time is done using electronic equipments like Relay, switching mechanism, 555 timer, decoder counter 4017, nano Arduino(Atmega 328p), proximity IR sensor & LCD. The 555 timer get power from step down transformer 12v/2A, further it send pulse signal to the decoder counter 4017 which is connected to the relay mechanism, which is connected to the piston of the Electromagnetic coil hence energising each electromagnetic coil in specific time interval. The power obtained at the crankshaft is transmitted to a wheel. The RPM can be read through the LCD placed on the board which is connected to the Nano Arduino and proximity IR sensor. This proximity IR sensor is placed near the wheel with white strip on the wheel, this white strip reflection is counted by the IR sensor hence providing us the RPM of the solenoid engine.

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What is Solenoid ?

A solenoid is a coil of wire that acts as a magnet while carrying an electric current. It is a cylindrical coil wound into a tightly packed helix. **Solen** means *"***pipe, channel***'* and **eidos** means *"***form, shape***"* in Greek. Andre-Marie Ampere, French physicist invented the term solenoid. The core material that is used in the solenoid is ferromagnetic in nature ie; magnetic lines of flux are concentrated which increases the inductance of the coil. The magnetic flux can be seen outside the coil near the end of the core material but most of the flux is present within the core material.

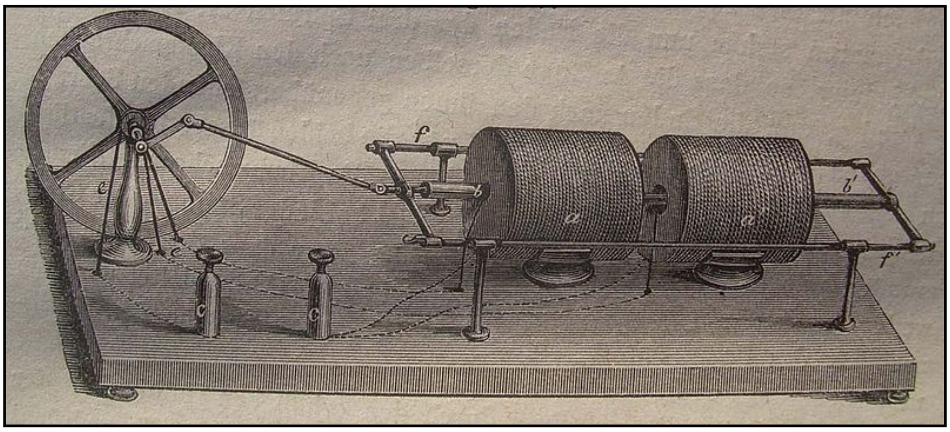
What is a Solenoid Engine ?

A solenoid engine is defined as the engine that works by passing electricity through the coils which makes the pistons to move back and forth due to electromagnetism. Also known as Reciprocating electric motor. A **reciprocating electric motor** is a motor in which the armature moves back and forth rather than circularly. Early electric motors were sometimes of the reciprocating type, such as those made by **Daniel Davis** in the 1840s.Today, reciprocating electric motors are rare but they do have some niche applications, e.g. in linear compressors for cryogenics and as educational toys.

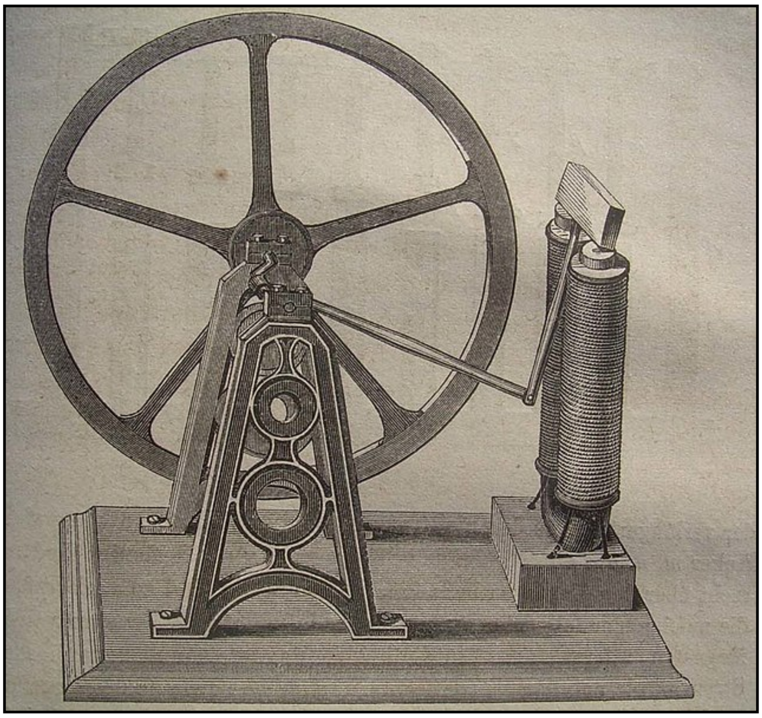
History

Daniel Davis was an early maker of reciprocating electric motors. As can be seen in these examples, early motors of this type often followed the general layout of the steam engines of the day, simply replacing the piston-and-cylinder with an electromagnetic solenoid.

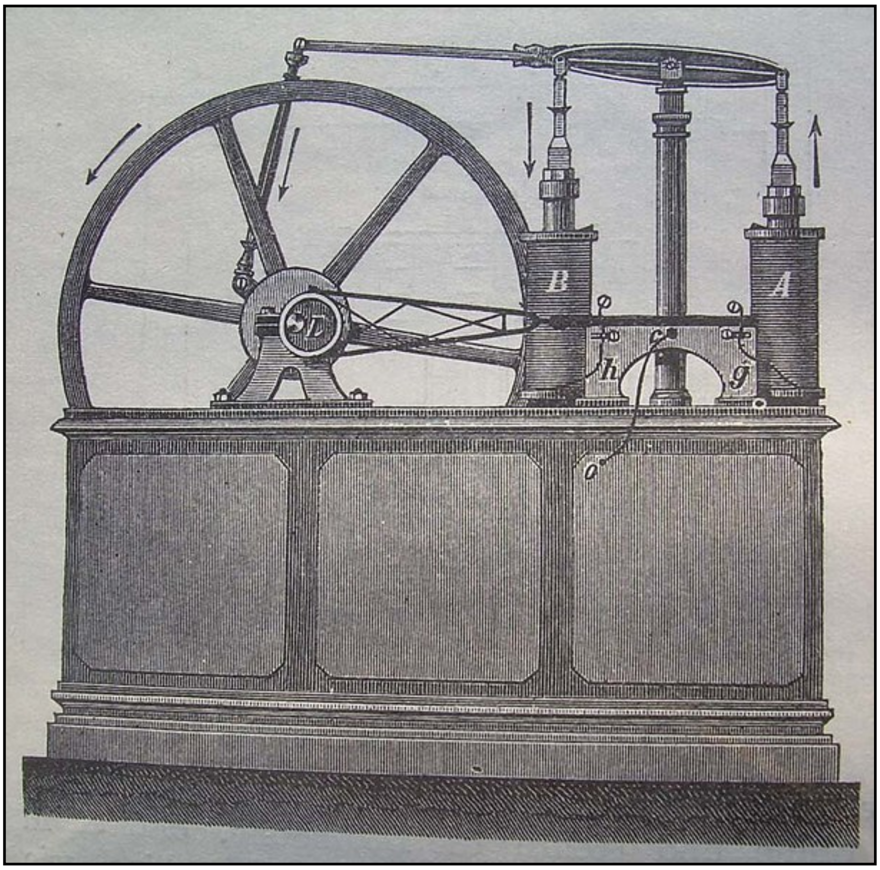
Page's reciprocating electric engine 1844



Gruel elektromotor, 1873



Bourbouce's electric engine, 1881



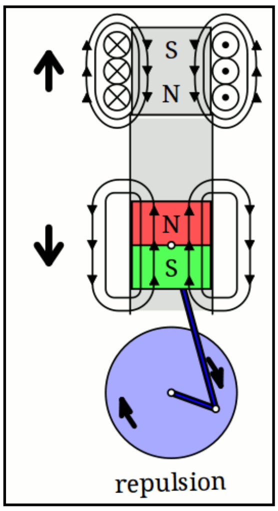
Design

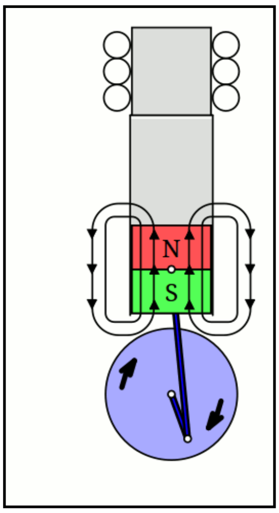
A reciprocating electric motor uses an alternating magnetic field to move its armature back and forth, rather than circularly as in a conventional electric motor. A single field coil may be placed at one end of the armature's possible movement, or a field coil may be used at each end.

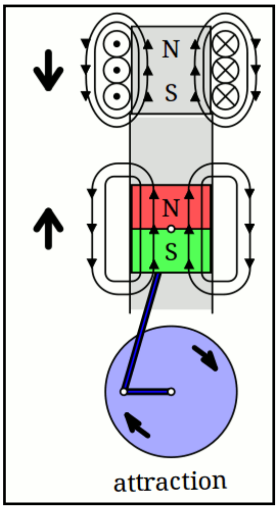
The armature may be a permanent magnet, in which case the coil or coils can exert both repulsive and attractive force on the armature. If there are two coils, they will be wound and connected so that their like poles face each other, so that when (for example) the poles facing the armature are both negative, one pole will attract the armature's south pole while the other will repel its north pole. When the armature reaches the extreme of its movement, polarity to the coils is reversed.

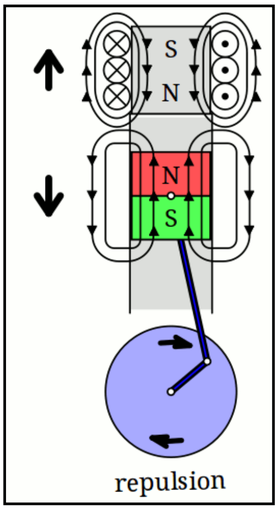
The armature may instead be made of ferromagnetic material, as in an electromagnetic solenoid. In this case the current in the coils will alternate between on and off, rather than between polarities. A single-coil motor with a non-magnetic armature would require a spring or some other "return" mechanism to move the armature away from the coil upon completion of the "attract" cycle. An "interrupter"-style electromechanical buzzer operates on this same principle. A dual-coil motor would alternately energize the two coils. Where the motor is adapted to produce rotary motion, the return mechanism consists of a crankshaft and flywheel.

This is an extremely simple motor, such that demonstration models may be easily constructed for teaching purposes. As a practical motor it has several disadvantages. Magnetic field strength drops off rapidly with increasing distance. In the reciprocating electric motor the distance between armature and field coil must necessarily increase considerably over its minimum value; this reduces the motor's output power and starting force. Vibration is also an issue









Component Used

555 timer:

555 timer IC is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications. The 555 can be used to provide time delays, as an oscillator, and as a flip-flop element. Derivatives provide two (556) or four (558) timing circuits in one package.

Introduced in 1972 by Signetics, the 555 is still in widespread use due to its low price, ease of use, and stability. It is now made by many companies in the original bipolar and in low-power CMOS technologies. As of 2003, it was estimated that 1 billion units were manufactured every year. The 555 is the most popular integrated circuit ever manufactured.

One of the most versatile linear ICs is the 555 timer which was first introduced in early 1970 by Signetic Corporation giving the name as SE/NE 555 timer. This IC is a monolithic timing circuit that can produce accurate and highly stable time delays or oscillation. Like other commonly used op-amps, this IC is also very much reliable, easy to use and cheaper in cost. It has a variety of applications including monostable and astable multivibrators, dcdc converters, digital logic probes, waveform generators, analog frequency meters and tachometers, temperature measurement and control devices, voltage regulators etc. The timer basically operates in one of the two modes either as a monostable (one-shot) multivibrator or as an astable (free-running) multivibrator.The SE 555 is designed for the operating temperature range from – 55°C to 125° while the NE 555operates over a temperature range of 0° to 70°C.

The important features of the 555 timer are:

• It operates from a wide range of power supplies ranging from + 5 Volts to + 18 Volts supply voltage.

• Sinking or sourcing 200 mA of load current.

• The external components should be selected properly so that the timing intervals can be made into several minutes Proper selection of only a few external components allows timing intervals of several minutes along with the frequencies exceeding several hundred kilo hertz.

• It has a high current output; the output can drive TTL.

• It has a temperature stability of 50 parts per million (ppm) per degree Celsius change in temperature, or equivalently 0.005 %/ °C.

• The duty cycle of the timer is adjustable with the maximum power dissipation per package is 600 mW and its trigger and reset inputs are logic compatible.

Pin con figuration:

Pin 1: Grounded Terminal: All the voltages are measured with respect to this terminal.

Pin 2: Trigger Terminal: This pin is an inverting input to a comparator that is responsible for transition of flip-flop from set to reset. The output of the timer depends on the amplitude of the external trigger pulse applied to this pin.

Pin 3: Output Terminal: Output of the timer is available at this pin. There are two ways in which a load can be connected to the output terminal either between pin 3 and ground pin (pin 1) or between pin 3 and supply pin (pin 8). The load connected between pin 3 and ground supply pin is called the normally on load and that connected between pin 3 and ground pin is called the normally of load.

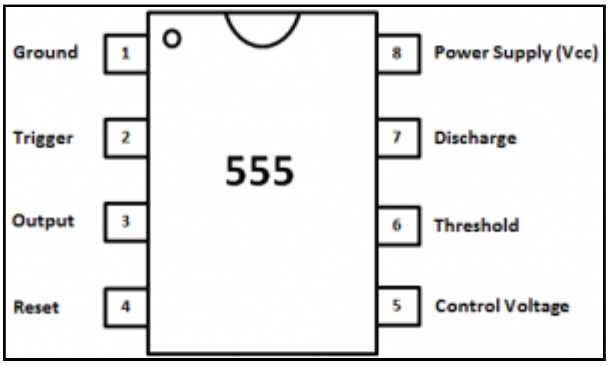
Pin 4: Reset Terminal: To disable or reset the timer a negative pulse is applied to this pin due to which it is referred to as reset terminal. When this pin is not to be used for reset purpose, it should be connected to + VCC to avoid any possibility of false triggering.

Pin 5: Control Voltage Terminal: The function of this terminal is to control the threshold and trigger levels. Thus either the external voltage or a pot connected to this pin determines the pulse width of the output waveform. The external voltage applied to this pin can also be used to modulate the output waveform. When this pin is not used, it should be connected to ground through a 0.01 micro Farad to avoid any noise problem.

Pin 6: Threshold Terminal: This is the non-inverting input terminal of comparator 1, which compares the voltage applied to the terminal with a reference voltage of 2/3 VCC. The amplitude of voltage applied to this terminal is responsible for the set state of flip-flop.

Pin 7: Discharge Terminal: This pin is connected internally to the collector of transistor and mostly a capacitor is connected between this terminal and ground. It is called discharge terminal because when transistor saturates, capacitor discharges through the transistor. When the transistor is cut-off, the capacitor charges at a rate determined by the external resistor and capacitor.

Pin 8: Supply Terminal: A supply voltage of + 5 V to + 18 V is applied to this terminal with respect to ground (pin 1).



<u>4017 counter:</u>

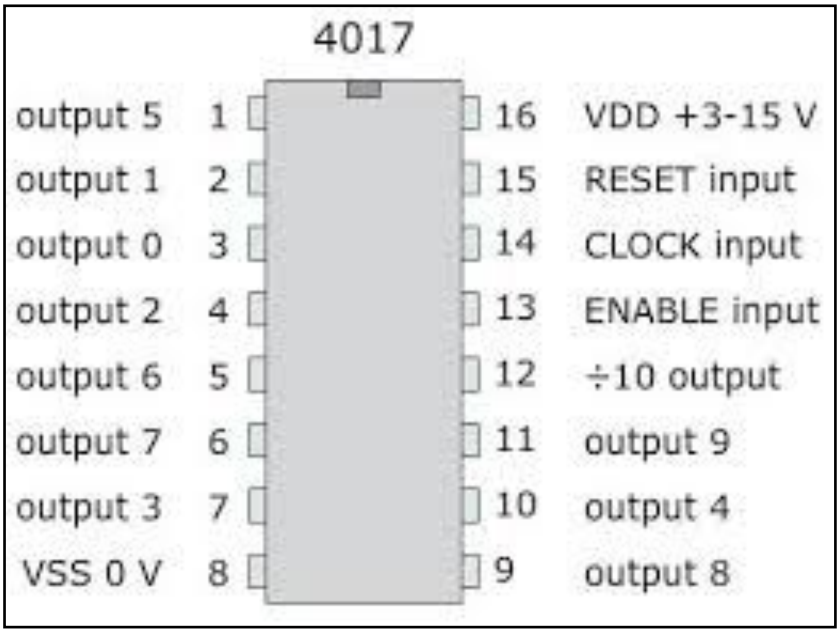
Most of us are more comfortable with 1, 2, 3, 4… rather than 001, 010, 011, 100. We mean to say that we will need a decimal coded output in many cases rather than a raw binary output. We have many counter ICs available but most of them produce binary data as an output. We will again need to process that output by using decoders or any other circuitry to make it usable for our application in most of the cases.

Let us now introduce you a new IC named IC 4017. It is a CMOS decade counter cum decoder circuit which can work out of the box for most of our low range counting applications. It can count from zero to ten and its outputs are decoded. This saves a lot of board space and time required to build our circuits when our application demands using a counter followed by a decoder IC. This IC also simplifies the design and makes debugging easy.

It has 16 pins and the functionality of each pin is explained as follows:

- Pin-1: It is the output 5. It goes high when the counter reads 5 counts.
- Pin-2: It is the output 1. It goes high when the counter reads 0 counts.
- Pin-3: It is the output 0. It goes high when the counter reads 0 counts.
- Pin-4: It is the output 2. It goes high when the counter reads 2 counts.
- Pin-5: It is the output 6. It goes high when the counter reads 6 counts.
- Pin-6: It is the output 7. It goes high when the counter reads 7 counts.
- Pin-7: It is the output 3. It goes high when the counter reads 3 counts.

- Pin-8: It is the Ground pin which should be connected to a LOW voltage (0V).
- Pin-9: It is the output 8. It goes high when the counter reads 8 counts.
- Pin-10: It is the output 4. It goes high when the counter reads 4 counts.
- Pin-11: It is the output 9. It goes high when the counter reads 9 counts.
- Pin-12: This is divided by 10 output which is used to cascade the IC with another counter so as to enable counting greater than the range supported by a single IC 4017. By cascading with another 4017 IC, we can count up to 20 numbers. We can increase and increase the range of counting by cascading it with more and more IC 4017s. Each additional cascaded IC will increase the counting range by 10. However, it is not advisable to cascade more than 3 ICs as it may reduce the reliability of the count due to the occurrence glitches. If you need a counting range more than twenty or thirty, I advise you to go with conventional procedure of using a binary counter followed by a corresponding decoder.
- Pin-13: This pin is the disable pin. In normal mode of operation, this is connected to ground or logic LOW voltage. If this pin is connected to logic HIGH voltage, then the circuit will stop receiving pulses and so it will not advance the count irrespective of number of pulses received from the clock.
- Pin-14: This pin is the clock input. This is the pin from where we need to give the input clock pulses to the IC in order to advance the count. The count advances on the rising edge of the clock.
- Pin-15: This is the reset pin which should be kept LOW for normal operation. If you need to reset the IC, then you can connect this pin to HIGH voltage.
- Pin-16: This is the power supply (Vcc) pin. This should be given a HIGH voltage of 3V to 15V for the IC to function.



Resistance:

Resistance is the opposition that a substance offers to the flow of electric current. It is represented by the uppercase letter R. The standard unit of resistance is the ohm, sometimes written out as a word, and sometimes symbolised by the uppercase Greek letter omega: Ω

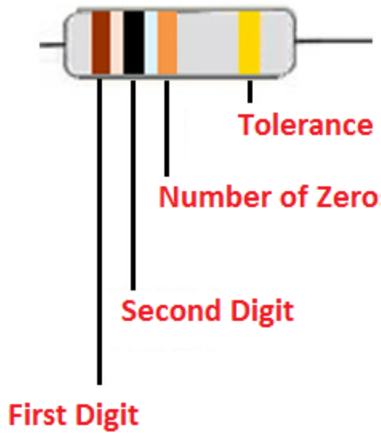
When an electric current of one ampere passes through a component across which a potential difference (voltage) of one volt exists, then the resistance of that component is one ohm. (For more discussion of the relationship among current, resistance and voltage, see Ohm's law.)

In general, when the applied voltage is held constant, the current in a direct-current (DC) electrical circuit is inversely proportional to the resistance. If the resistance is doubled, the current is cut in half; if the resistance is halved, the current is doubled. This rule also holds true for most low-frequency alternating-current (AC) systems, such as household utility circuits. In some AC circuits, especially at high frequencies, the situation is more complex because some components in these systems can store and release energy, as well as dissipating or converting it.

The electrical resistance per unit length, area, or volume of a substance is known as resistivity. Resistivity figures are often specified for copper and aluminium wire, in ohms per kilometre.

Opposition to AC, but not too DC, is a property known as reactance. In an AC circuit, the resistance and reactance combine vectorially to yield impedance.

Color Name	Value As Figure	As Decimal Multiplier
Black	0	x 1
Brown	1	x 10^{1}
Red	2	x 10^{2}
Orange	3	x 10^{3}
Yellow	4	x 10^{4}
Green	5	x 10^{5}
Blue	6	x 10^{6}
Violet	7	x 10^{7}
Grey	8	x 10^{8}
White	9	x 10^{9}
Golden	-	x 10^{-1}
Silver	-	x 10^{-2}



Capacitor:

The capacitor is a component which has the ability or "capacity" to store energy in the form of an electrical charge producing a potential difference (Static Voltage) across its plates, much like a small rechargeable battery.

There are many different kinds of capacitors available from very small capacitor beads used in resonance circuits to large power factor correction capacitors, but they all do the same thing, they store charge.

In its basic form, a capacitor consists of two or more parallel conductive (metal) plates which are not connected or touching each other, but are electrically separated either by air or by some form of a good insulating material such as waxed paper, mica, ceramic, plastic or some form of a liquid gel as used in electrolytic capacitors. The insulating layer between a capacitors plates is commonly called the Dielectric.

Due to this insulating layer, DC current can not flow through the capacitor as it blocks it allowing instead a voltage to be present across the plates in the form of an electrical charge.

The conductive metal plates of a capacitor can be either square, circular or rectangular, or they can be of a cylindrical or spherical shape with the general shape, size and construction of a parallel plate capacitor depending on its application and voltage rating.

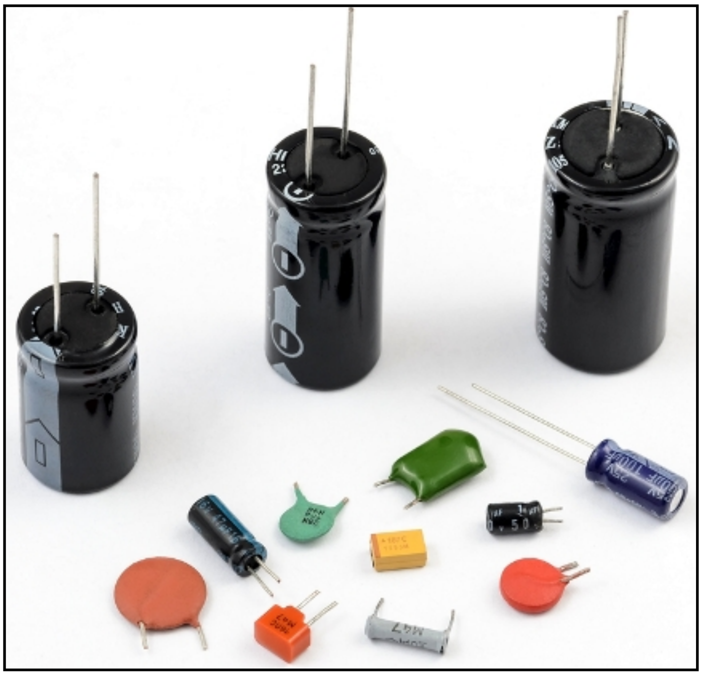
When used in a direct current or DC circuit, a capacitor charges up to its supply voltage but blocks the flow of current through it because the dielectric of a capacitor is non-conductive and basically an insulator. However, when a capacitor is connected to an alternating current or AC circuit, the flow of the current appears to pass straight through the capacitor with little or no resistance.

There are two types of electrical charge, a positive charge in the form of Protons and a negative charge in the form of Electrons. When a DC voltage is placed across a capacitor, the positive (+ve) charge quickly accumulates on one plate while a corresponding and opposite negative (-ve) charge accumulates on the other plate. For every particle of +ve charge that arrives at one plate a charge of the same sign will depart from the -ve plate.

Then the plates remain charge neutral and a potential difference due to this charge is established between the two plates. Once the capacitor reaches its steady state condition an electrical current is unable to flow through the capacitor itself and around the circuit due to the insulating properties of the dielectric used to separate the plates.

The flow of electrons onto the plates is known as the capacitors Charging Current which continues to flow until the voltage across both plates (and hence the capacitor) is equal to the applied voltage Vc. At this point the capacitor is said to be "fully charged" with electrons.

The strength or rate of this charging current is at its maximum value when the plates are fully discharged (initial condition) and slowly reduces in value to zero as the plates charge up to a potential difference across the capacitors plates equal to the source voltage.



Transformer

A **transformer** is a passive electrical device that transfers electrical energy from one electrical circuit to another, or multiple circuits. A varying current in any one coil of the transformer produces a varying magnetic flux in the transformer's core, which induces a varying electromotive force across any other coils wound around the same core. Electrical energy can be transferred between separate coils without a metallic (conductive) connection between the two circuits. Faraday's law of induction, discovered in 1831, describes the induced voltage effect in any coil due to a changing magnetic flux encircled by the coil.

Transformers are most commonly used for increasing low AC voltages at high current (a step-up transformer) or decreasing high AC voltages at low current (a step-down transformer) in electric power applications, and for coupling the stages of signal processing circuits. Transformers can also be used for isolation, where the voltage in equals the voltage out, with separate coils not electrically bonded to one another.

Since the invention of the first constant-potential transformer in 1885, transformers have become essential for the transmission, distribution, and utilisation of alternating current electric power.A wide range of transformer designs is encountered in electronic and electric power applications. Transformers range in size from RF transformers less than a cubic centimetre in volume, to units weighing hundreds of tons used to interconnect the power grid.

Principles

An ideal transformer is a theoretical linear transformer that is lossless and perfectly coupled. Perfect coupling implies infinitely high core magnetic permeability and winding inductances and zero net magnetomotive force (i.e. $i_p n_p - i_s n_s = 0$).

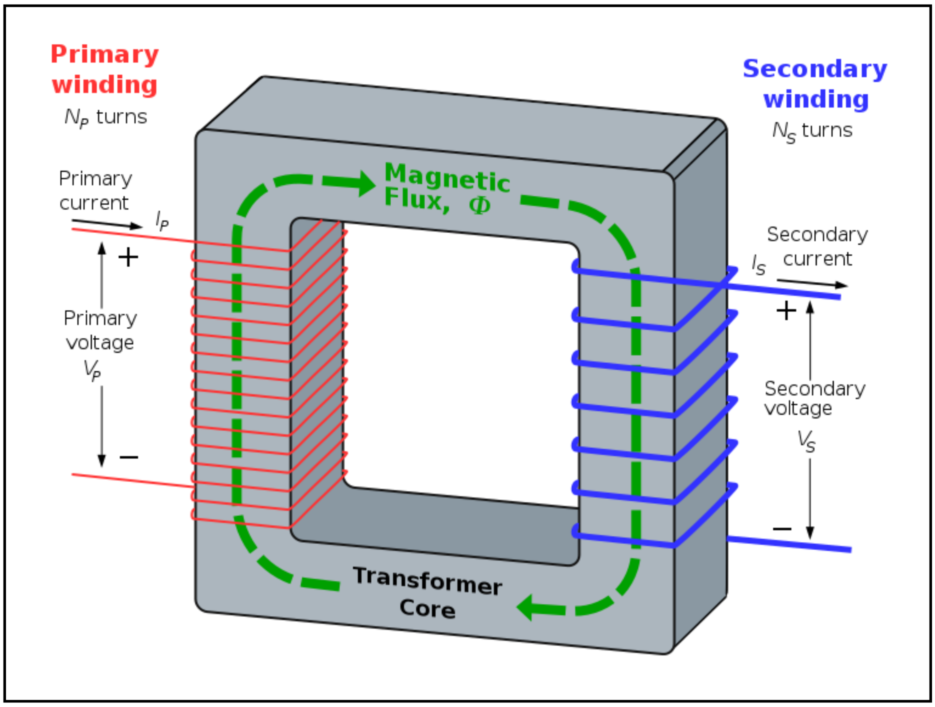
A varying current in the transformer's primary winding attempts to create a varying magnetic flux in the transformer core, which is also encircled by the secondary winding. This varying flux at the secondary winding induces a varying electromotive force (EMF, voltage) in the secondary winding due to electromagnetic induction and the secondary current so produced creates a flux equal and opposite to that produced by the primary winding, in accordance with Lenz's law.

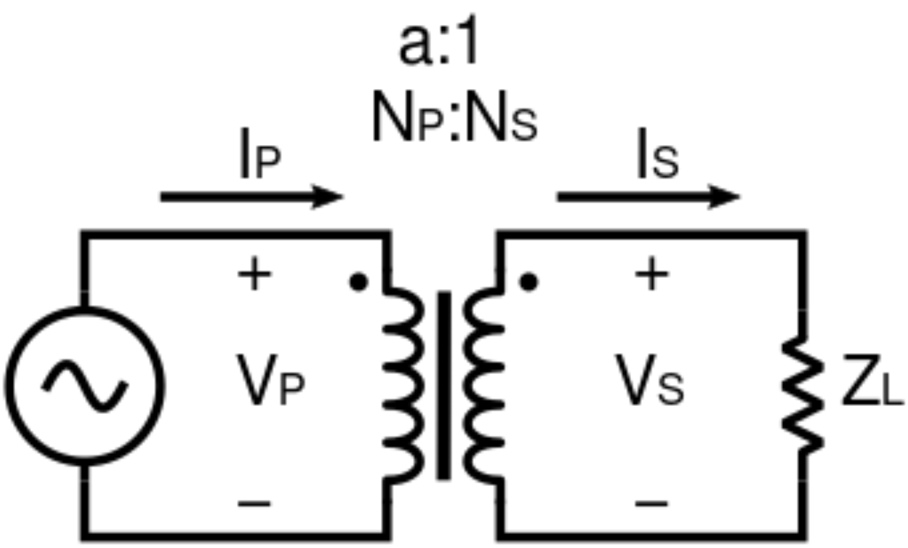
The windings are wound around a core of infinitely high magnetic permeability so that all of the magnetic flux passes through both the primary and secondary windings. With a voltage source connected to the primary winding and a load connected to the secondary winding, the transformer currents flow in the indicated directions and the core magnetomotive force cancels to zero.

According to Faraday's law, since the same magnetic flux passes through both the primary and secondary windings in an ideal transformer, a voltage is induced in each winding proportional to its number of windings. The transformer winding voltage ratio is directly proportional to the winding turns ratio.

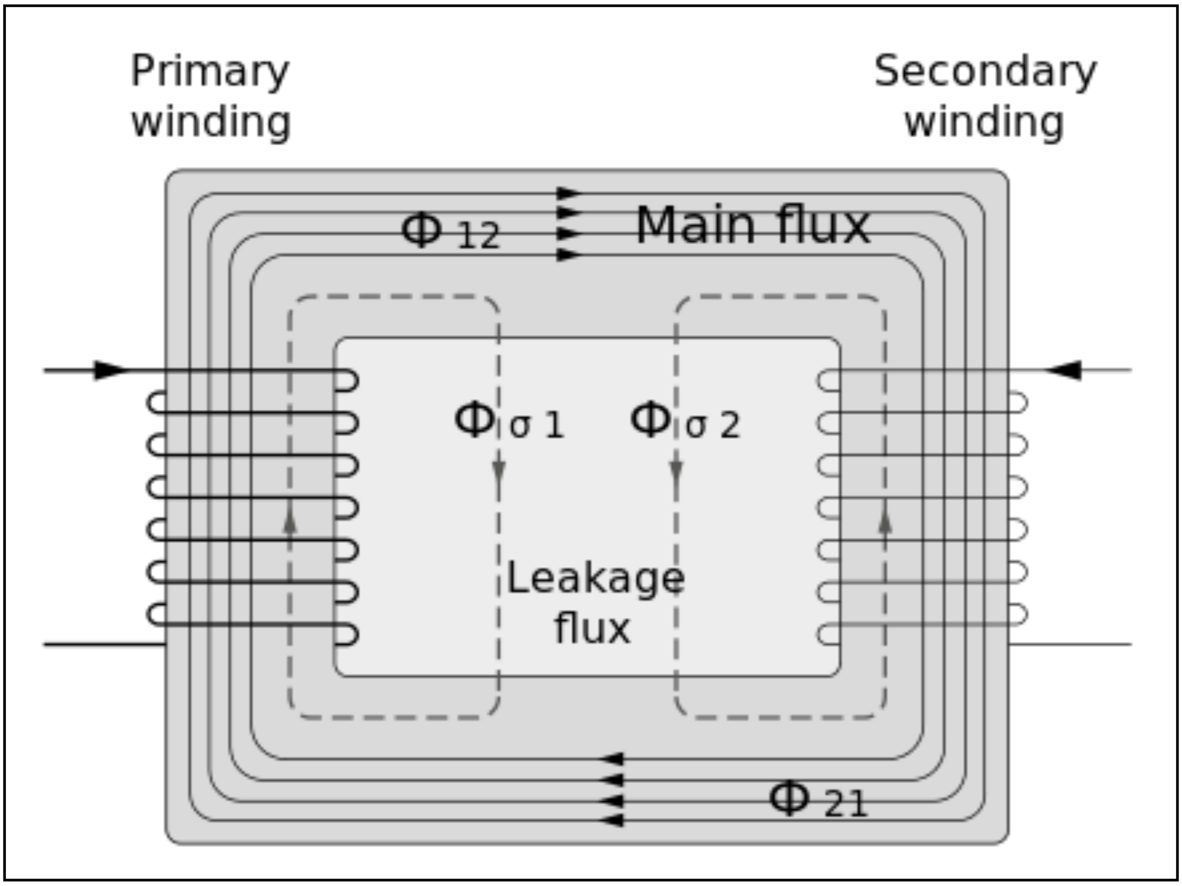
The ideal transformer identity shown in eq. 5 is a reasonable approximation for the typical commercial transformer, with voltage ratio and winding turns ratio both being inversely proportional to the corresponding current ratio.

The load impedance *referred* to the primary circuit is equal to the turns ratio squared times the secondary circuit load impedance.





Real transformer



Leakage flux of a transformer

Deviations from ideal transformer

The ideal transformer model neglects the following basic linear aspects of real transformers:

(a) Core losses, collectively called magnetizing current losses, consisting of

- Hysteresis losses due to nonlinear magnetic effects in the transformer core, and
- Eddy current losses due to joule heating in the core that are proportional to the square of the transformer's applied voltage.

(b) Unlike the ideal model, the windings in a real transformer have non-zero resistances and inductances associated with:

- Joule losses due to resistance in the primary and secondary windings
- Leakage flux that escapes from the core and passes through one winding only resulting in primary and secondary reactive impedance.

(c) similar to an inductor, parasitic capacitance and self-resonance phenomenon due to the electric field distribution. Three kinds of parasitic capacitance are usually considered and the closed-loop equations are provided

- Capacitance between adjacent turns in any one layer;
- Capacitance between adjacent layers;
- Capacitance between the core and the layer(s) adjacent to the core;

Inclusion of capacitance into the transformer model is complicated, and is rarely attempted; the 'real' transformer model's equivalent circuit does not include parasitic capacitance. However, the capacitance effect can be measured by comparing open-circuit inductance, i.e. the inductance of a primary winding when the secondary circuit is open, to a short-circuit inductance when the secondary winding is shorted.

Leakage flux

The ideal transformer model assumes that all flux generated by the primary winding links all the turns of every winding, including itself. In practice, some flux traverses paths that take it outside the windings. Such flux is termed *leakage flux*, and results in leakage inductance in series with the mutually coupled transformer windings. Leakage flux results in energy being alternately stored in and discharged from the magnetic fields with each cycle of the power supply. It is not directly a power loss, but results in inferior voltage regulation, causing the secondary voltage not to be directly proportional to the primary voltage, particularly under heavy load. Transformers are therefore normally designed to have very low leakage inductance.

In some applications increased leakage is desired, and long magnetic paths, air gaps, or magnetic bypass shunts may deliberately be introduced in a transformer design to limit the short-circuit current it will supply. Leaky transformers may be used to supply loads that exhibit negative resistance, such as electric arcs, mercury- and sodium- vapor lamps and neon signs or for safely handling loads that become periodically short-circuited such as electric arc welders.

Air gaps are also used to keep a transformer from saturating, especially audio-frequency transformers in circuits that have a DC component flowing in the windings. A saturable reactor exploits saturation of the core to control alternating current.

Knowledge of leakage inductance is also useful when transformers are operated in parallel. It can be shown that if the percent impedance and associated winding leakage reactance-to-resistance (X/R) ratio of two transformers were the same, the transformers would share the load power in proportion to their respective ratings. However, the impedance tolerances of commercial transformers are significant. Also, the impedance and X/R ratio of different capacity transformers tends to vary.

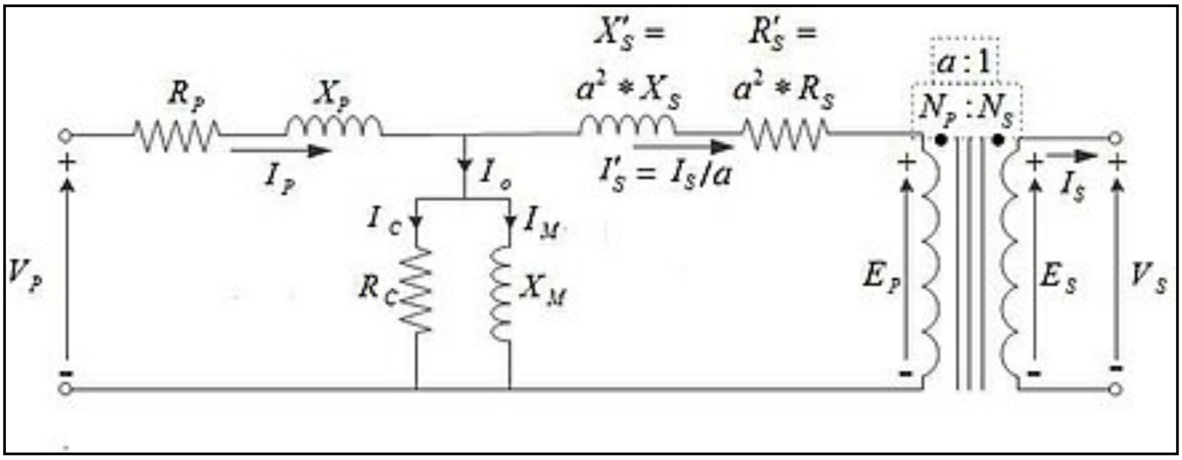
Equivalent circuit

Referring to the diagram, a practical transformer's physical behaviour may be represented by an equivalent circuit model, which can incorporate an ideal transformer.

Winding joule losses and leakage reactances are represented by the following series loop impedances of the model:

- Primary winding: R_P, X_P
- Secondary winding: R_S, X_S.

In normal course of circuit equivalence transformation, R_S and X_S are in practice usually referred to the primary side by multiplying these impedances by the turns ratio squared, $(N_P/N_S)^2 = a^2$.



Real transformer equivalent circuit

Core loss and reactance is represented by the following shunt leg impedances of the model:

- Core or iron losses: R_C
- Magnetizing reactance: X_M.

R_C and X_M are collectively termed the *magnetizing branch* of the model.

Core losses are caused mostly by hysteresis and eddy current effects in the core and are proportional to the square of the core flux for operation at a given frequency. The finite permeability core requires a magnetizing current I_M to maintain mutual flux in the core. Magnetizing current is in phase with the flux, the relationship between the two being non-linear due to saturation effects. However, all impedances of the equivalent circuit shown are by definition linear and such non-linearity effects are not typically reflected in transformer equivalent circuits. With sinusoidal supply, core flux lags the induced EMF by 90°. With open-circuited secondary winding, magnetizing branch current I_0 equals transformer no-load current.

Instrument transformer, with polarity dot and X1 markings on LV side terminal

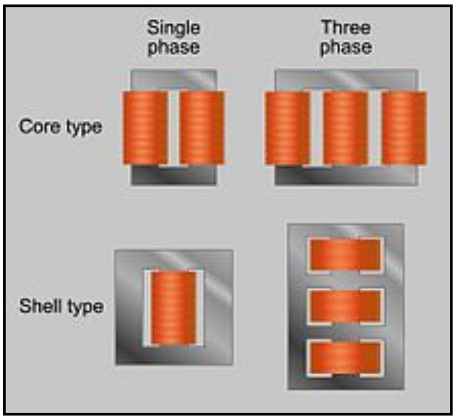
The resulting model, though sometimes termed 'exact' equivalent circuit based on linearity assumptions, retains a number of approximations. Analysis may be simplified by assuming that magnetizing branch impedance is relatively high and relocating the branch to the left of the primary impedances. This introduces error but allows combination of primary and referred secondary resistances and reactances by simple summation as two series impedances.

Transformer equivalent circuit impedance and transformer ratio parameters can be derived from the following tests: open-circuit test, short-circuit test, winding resistance test, and transformer ratio test.

Construction

Cores

Closed-core transformers are constructed in 'core form' or 'shell form'. When windings surround the core, the transformer is core form; when windings are surrounded by the core, the transformer is shell form. Shell form design may be more prevalent than core form design for distribution transformer applications due to the relative ease in stacking the core around winding coils. Core form design tends to, as a general rule, be more economical, and therefore more prevalent, than shell form design for high voltage power transformer applications at the lower end of their voltage and power rating ranges (less than or equal to, nominally, 230 kV or 75 MVA). At higher voltage and power ratings, shell form transformers tend to be more prevalent. Shell form design tends to be preferred for extra-high voltage and higher MVA applications because, though more labor-intensive to manufacture, shell form transformers are characterized as having inherently better kVA-to-weight ratio, better short-circuit strength characteristics and higher immunity to transit damage.



Core form = core type; shell form = shell type

Laminated steel cores

Transformers for use at power or audio frequencies typically have cores made of high permeability silicon steel. The steel has a permeability many times that of free space and the core thus serves to greatly reduce the magnetizing current and confine the flux to a path which closely couples the windings. Early transformer developers soon realised that cores constructed from solid iron resulted in prohibitive eddy current losses, and their designs mitigated this effect with cores consisting of bundles of insulated iron wires. Later designs constructed the core by stacking layers of thin steel laminations, a principle that has remained in use. Each lamination is insulated from its neighbors by a thin non-conducting layer of insulation. The transformer universal EMF equation can be used to calculate the core cross-sectional area for a preferred level of magnetic flux.

The effect of laminations is to confine eddy currents to highly elliptical paths that enclose little flux, and so reduce their magnitude. Thinner laminations reduce losses, but are more laborious and expensive to construct. Thin laminations are generally used on high-frequency transformers, with some of very thin steel laminations able to operate up to 10 kHz.

One common design of laminated core is made from interleaved stacks of E-shaped steel sheets capped with I-shaped pieces, leading to its name of 'E-I transformer'. Such a design tends to exhibit more losses, but is very economical to manufacture. The cut-core or C-core type is made by winding a steel strip around a rectangular form and then bonding the layers together. It is then cut in two, forming two C shapes, and the core assembled by binding the two C halves together with a steel strap. They have the advantage that the flux is always oriented parallel to the metal grains, reducing reluctance.

A steel core's remanence means that it retains a static magnetic field when power is removed. When power is then reapplied, the residual field will cause a high inrush current until the effect of the remaining magnetism is reduced, usually after a few cycles of the applied AC waveform. Overcurrent protection devices such as fuses must be selected to allow this harmless inrush to pass.

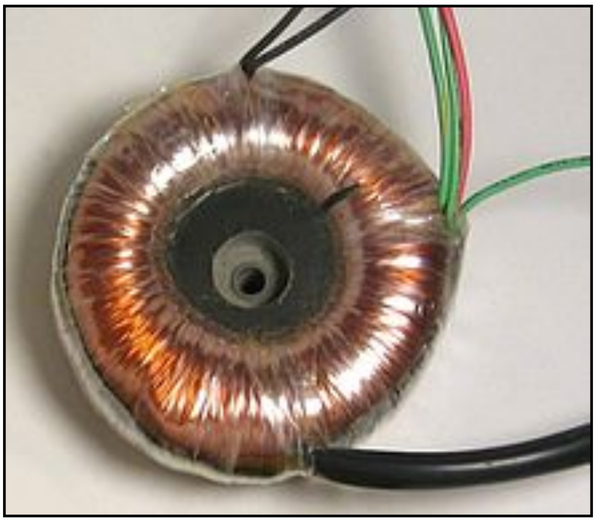
On transformers connected to long, overhead power transmission lines, induced currents due to geomagnetic disturbances during solar storms can cause saturation of the core and operation of transformer protection devices.

Distribution transformers can achieve low no-load losses by using cores made with low-loss high-permeability silicon steel or amorphous (non-crystalline) metal alloy. The higher initial cost of the core material is offset over the life of the transformer by its lower losses at light load.

Solid cores

Powdered iron cores are used in circuits such as switch-mode power supplies that operate above mains frequencies and up to a few tens of kilohertz. These materials combine high magnetic permeability with high bulk electrical resistivity. For frequencies extending beyond the VHF band, cores made from non-conductive magnetic ceramic materials called ferrites are common. Some radio-frequency transformers also have movable cores (sometimes called 'slugs') which allow adjustment of the coupling coefficient (and bandwidth) of tuned radio-frequency circuits.

Toroidal cores



Small toroidal core transformer

Toroidal transformers are built around a ring-shaped core, which, depending on operating frequency, is made from a long strip of silicon steel or permalloy wound into a coil, powdered iron, or ferrite. A strip construction ensures that the grain boundaries are optimally aligned, improving the transformer's efficiency by reducing the core's reluctance. The closed ring shape eliminates air gaps inherent in the construction of an E-I core. The cross-section of the ring is usually square or rectangular, but more expensive cores with circular cross-sections are also available. The primary and secondary coils are often wound concentrically to cover the entire surface of the core. This minimises the length of wire needed and provides screening to minimise the core's magnetic field from generating electromagnetic interference.

Toroidal transformers are more efficient than the cheaper laminated E-I types for a similar power level. Other advantages compared to E-I types, include smaller size (about half), lower weight (about half), less mechanical hum (making them superior in audio amplifiers), lower exterior magnetic field (about one tenth), low off-load losses (making them more efficient in standby circuits), single-bolt mounting, and greater choice of shapes. The main disadvantages are higher cost and limited power capacity (see Classification parameters below). Because of the lack of a residual gap in the magnetic path, toroidal transformers also tend to exhibit higher inrush current, compared to laminated E-I types.

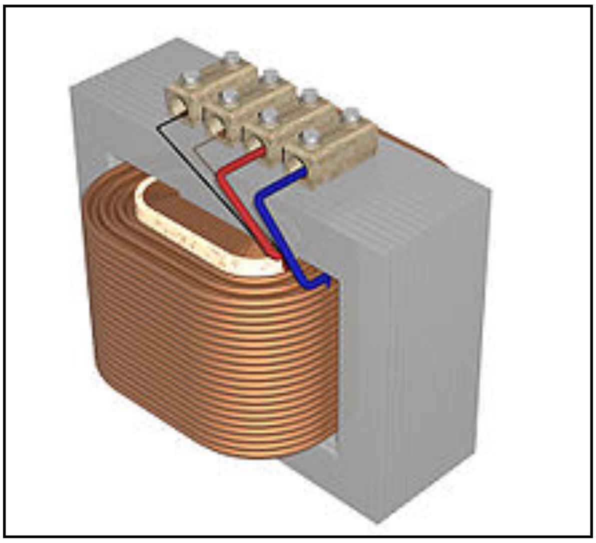
Ferrite toroidal cores are used at higher frequencies, typically between a few tens of kilohertz to hundreds of megahertz, to reduce losses, physical size, and weight of inductive components. A drawback of toroidal transformer construction is the higher labor cost of winding. This is because it is necessary to pass the entire length of a coil winding through the core aperture each time a single turn is added to the coil. As a consequence, toroidal transformers rated more than a few kVA are uncommon. Relatively few toroids are offered with power ratings above 10 kVA, and practically none above

25 kVA. Small distribution transformers may achieve some of the benefits of a toroidal core by splitting it and forcing it open, then inserting a bobbin containing primary and secondary windings.

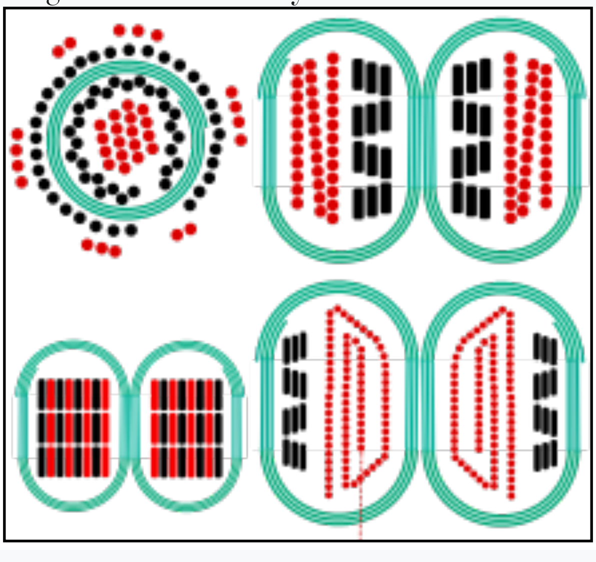
Air cores

A transformer can be produced by placing the windings near each other, an arrangement termed an "air-core" transformer. An air-core transformer eliminates loss due to hysteresis in the core material. The magnetizing inductance is drastically reduced by the lack of a magnetic core, resulting in large magnetizing currents and losses if used at low frequencies. Air-core transformers are unsuitable for use in power distribution, but are frequently employed in radio-frequency applications. Air cores are also used for resonant transformers such as Tesla coils, where they can achieve reasonably low loss despite the low magnetizing inductance.

Windings



Windings are usually arranged concentrically to minimize flux leakage.



Cut view through transformer windings. Legend:

White: Air, liquid or other insulating medium
Green spiral: Grain oriented silicon steel
Black: Primary winding
Red: Secondary winding

The electrical conductor used for the windings depends upon the application, but in all cases the individual turns must be electrically insulated from each other to ensure that the current travels throughout every turn. For small transformers, in which currents are low and the potential difference between adjacent turns is small, the coils are often wound from enamelled magnet wire. Larger power transformers may be wound with copper rectangular strip conductors insulated by oil-impregnated paper and blocks of pressboard.

High-frequency transformers operating in the tens to hundreds of kilohertz often have windings made of braided Litz wire to minimize the skin-effect and proximity effect losses. Large power transformers use multiple-stranded conductors as well, since even at low power frequencies non-uniform distribution of current would otherwise exist in high-current windings. Each strand is individually insulated, and the strands are arranged so that at certain points in the winding, or throughout the whole winding, each portion occupies different relative positions in the complete conductor. The transposition equalizes the current flowing in each strand of the conductor, and reduces eddy current losses in the winding itself. The stranded conductor is also more flexible than a solid conductor of similar size, aiding manufacture.

The windings of signal transformers minimize leakage inductance and stray capacitance to improve high-frequency response. Coils are split into sections, and those sections interleaved between the sections of the other winding.

Power-frequency transformers may have *taps* at intermediate points on the winding, usually on the higher voltage winding side, for voltage adjustment. Taps may be manually reconnected, or a manual or automatic switch may be provided for changing taps. Automatic on-load tap changers are used in electric power transmission or distribution, on equipment such as arc furnace transformers, or for automatic voltage regulators for sensitive loads. Audio-frequency transformers, used for the distribution of audio to public address loudspeakers, have taps to allow adjustment of impedance to each speaker. A center-tapped transformer is often used in the output stage of an audio power amplifier in a push-pull circuit. Modulation transformers in AM transmitters are very similar.

Cooling

Cutaway view of liquid-immersed transformer. The conservator (reservoir) at top provides liquid-to-atmosphere isolation as coolant level and temperature changes. The walls and fins provide required heat dissipation.

It is a rule of thumb that the life expectancy of electrical insulation is halved for about every 7 °C to 10 °C increase in operating temperature (an instance of the application of the Arrhenius equation).

Small dry-type and liquid-immersed transformers are often self-cooled by natural convection and radiation heat dissipation. As power ratings increase, transformers are often cooled by forced-air cooling, forced-oil cooling, water-cooling, or combinations of these. Large transformers are filled with transformer oil that both cools and insulates the windings. Transformer oil is a highly refined mineral oil that cools the windings and insulation by circulating within the transformer tank. The mineral oil and paper insulation system has been extensively studied and used for more than 100 years. It is estimated that 50% of power transformers will survive 50 years of use, that the average age of failure of power transformers is about 10 to 15 years, and that about 30% of power transformer failures are due to insulation and overloading failures. Prolonged operation at elevated temperature degrades insulating properties of winding insulation and dielectric coolant, which not only shortens transformer life but can ultimately lead to catastrophic transformer failure. With a great body of empirical study as a guide, transformer oil testing including dissolved gas analysis provides valuable maintenance information.

Building regulations in many jurisdictions require indoor liquid-filled transformers to either use dielectric fluids that are less flammable than oil, or be installed in fire-resistant rooms. Air-cooled dry transformers can be more economical where they eliminate the cost of a fire-resistant transformer room.

The tank of liquid filled transformers often has radiators through which the liquid coolant circulates by natural convection or fins. Some large transformers employ electric fans for forced-air cooling, pumps for forced-liquid cooling, or have heat exchangers for water-cooling. An oil-immersed transformer may be equipped with a Buchholz relay, which, depending on severity of gas accumulation due to internal arcing, is used to either alarm or de-energize the transformer. Oil-immersed transformer installations usually include fire protection measures such as walls, oil containment, and fire-suppression sprinkler systems.

Polychlorinated biphenyls have properties that once favored their use as a dielectric coolant, though concerns over their environmental persistence led to a widespread ban on their use. Today, non-toxic, stable silicone-based oils, or fluorinated hydrocarbons may be used where the expense of a fire-resistant liquid offsets additional building cost for a transformer vault.

Some transformers, instead of being liquid-filled, have their windings enclosed in sealed, pressurized tanks and cooled by nitrogen or sulfur hexafluoride gas.

Experimental power transformers in the 500-to-1,000 kVA range have been built with liquid nitrogen or helium cooled superconducting windings, which eliminates winding losses without affecting core losses.

Insulation

Substation transformer undergoing testing.

Insulation must be provided between the individual turns of the windings, between the windings, between windings and core, and at the terminals of the winding.

Inter-turn insulation of small transformers may be a layer of insulating varnish on the wire. Layer of paper or polymer films may be inserted between layers of windings, and between primary and secondary windings. A transformer may be coated or dipped in a polymer resin to improve the strength of windings and protect them from moisture or corrosion. The resin may be impregnated into the winding insulation using combinations of vacuum and pressure during the coating process, eliminating all air voids in the winding. In the limit, the entire coil may be placed in a mold, and resin cast around it as a solid block, encapsulating the windings.

Large oil-filled power transformers use windings wrapped with insulating paper, which is impregnated with oil during assembly of the transformer. Oil-filled transformers use highly refined mineral oil to insulate and cool the windings and core. Construction of oil-filled transformers requires that the insulation covering the windings be thoroughly dried of residual moisture before the oil is introduced. Drying may be done by circulating hot air around the core, by circulating externally heated transformer oil, or by vapor-phase drying (VPD) where an evaporated solvent transfers heat by condensation on the coil and core. For small transformers, resistance heating by injection of current into the windings is used.

Bushings

Larger transformers are provided with high-voltage insulated bushings made of polymers or porcelain. A large bushing can be a complex structure since it must provide careful control of the electric field gradient without letting the transformer leak oil.

Relay

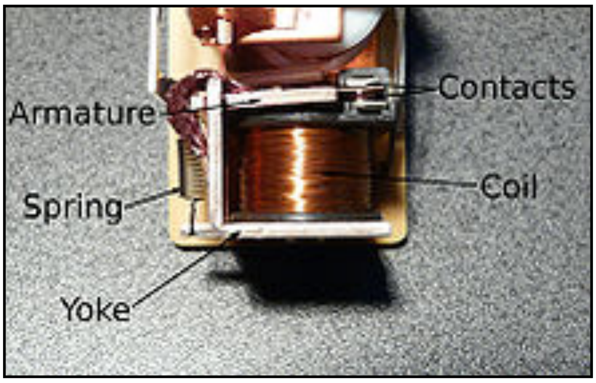
A **relay** is an electrically operated switch. It consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals. The switch may have any number of contacts in multiple contact forms, such as make contacts, break contacts, or combinations thereof.

Relays are used where it is necessary to control a circuit by an independent low-power signal, or where several circuits must be controlled by one signal. Relays were first used in long-distance telegraph circuits as signal repeaters: they refresh the signal coming in from one circuit by transmitting it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

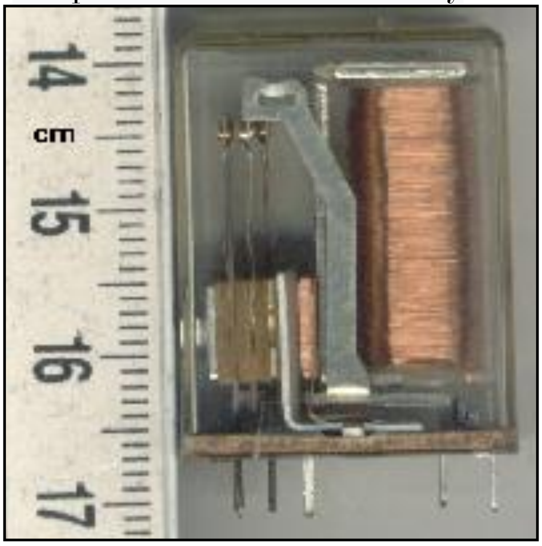
The traditional form of a relay uses an electromagnet to close or open the contacts, but other operating principles have been invented, such as in solid-state relays which use semiconductor properties for control without relying on moving parts. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called *protective relays*.

Latching relays require only a single pulse of control power to operate the switch persistently. Another pulse applied to a second set of control terminals, or a pulse with opposite polarity, resets the switch, while repeated pulses of the same kind have no effects. Magnetic latching relays are useful in applications when interrupted power should not affect the circuits that the relay is controlling.

Basic design and operation



Simple electromechanical relay



A small cradle relay often used in electronics. The "cradle" term refers to the shape of the relay's armature.

Operation of a 12 A relay

A simple electromagnetic relay consists of a coil of wire wrapped around a soft iron core (a solenoid), an iron yoke which provides a low reluctance path for magnetic flux, a movable iron armature, and one or more sets of contacts (there are two contacts in the relay pictured). The armature is hinged to the yoke and mechanically linked to one or more sets of moving contacts. The armature is held in place by a spring so that when the relay is de-energized there is an air gap in the magnetic circuit. In this condition, one of the two sets of contacts in the relay pictured is closed, and the other set is open. Other relays may have more or fewer sets of contacts depending on their function. The relay in the picture also has a wire connecting the armature to the yoke. This ensures continuity of the circuit between the moving contacts on the armature, and the circuit track on the printed circuit board (PCB) via the yoke, which is soldered to the PCB.

When an electric current is passed through the coil it generates a magnetic field that activates the armature, and the consequent movement of the movable contact(s) either makes or breaks (depending upon construction) a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movement opens the contacts and breaks the connection, and vice versa if the contacts were open. When the current to the coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to its relaxed position. Usually this force is provided by a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low-voltage application this reduces noise; in a high voltage or current application it reduces arcing.

When the coil is energized with direct current, a diode is often placed across the coil to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a voltage spike dangerous to semiconductor circuit components. Such diodes were not widely used before the application of transistors as relay drivers, but soon became ubiquitous as early germanium transistors were easily destroyed by this surge. Some automotive relays include a diode inside the relay case.

If the relay is driving a large, or especially a reactive load, there may be a similar problem of surge currents around the relay output contacts. In this case a snubber circuit (a capacitor and resistor in series) across the contacts may absorb the surge. Suitably rated capacitors and the associated resistor are sold as a single packaged component for this commonplace use.

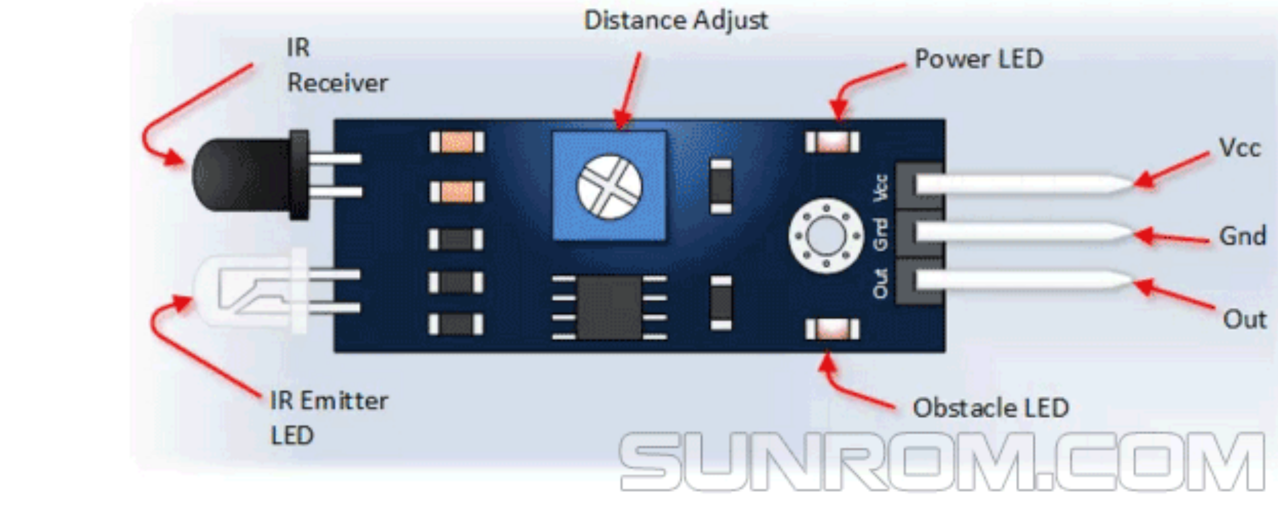
If the coil is designed to be energized with alternating current (AC), some method is used to split the flux into two out-of-phase components which add together, increasing the minimum pull on the armature during the AC cycle. Typically this is done with a small copper "shading ring" crimped around a portion of the core that creates the delayed, out-of-phase component, which holds the contacts during the zero crossings of the control voltage.

Contact materials for relays vary by application. Materials with low contact resistance may be oxidized by the air, or may tend to "stick" instead of cleanly parting when opening. Contact material may be optimized for low electrical resistance, high strength to withstand repeated operations, or high capacity to withstand the heat of an arc. Where very low resistance is required, or low thermally-induced voltages are desired, gold-plated contacts may be used, along with palladium and other non-oxidizing, semi-precious metals. Silver or silver-plated contacts are used for signal switching. Mercurywetted relays make and break circuits using a thin, self-renewing film of liquid mercury. For higher-power relays switching many amperes, such as motor circuit contactors, contacts are made with a mixtures of silver and cadmium oxide, providing low contact resistance and high resistance to the heat of arcing. Contacts used in circuits carrying scores or hundreds of amperes may include additional structures for heat dissipation and management of the arc produced when interrupting the circuit. Some relays have field-replaceable contacts, such as certain machine tool relays; these may be replaced when worn out, or changed between normally open and normally closed state, to allow for changes in the controlled circuit.

IR Proximity Sensor

Proximity Sensor are used to detect objects and obstacles in front of sensor. Sensor keeps transmitting infrared light and when any object comes near, it is detected by the sensor by monitoring the reflected light from the object. It can be used in robots for obstacle avoidance, for automatic doors, for parking aid devices or for security alarm systems, or contact less tachometer by measuring RPM of rotation objects like fan blades.

Digital low output on detecting objects in front.



Pin, Control Indicator	Description
Vcc	3.3 to 5 Vdc Supply Input
Gnd	Ground Input
Out	Output that goes low when obstacle is in range
Power LED	Illuminates when power is applied
Obstacle LED	Illuminates when obstacle is detected
Distance Adjust	Adjust detection distance. CCW decreases distance. CW increases distance.
IR Emitter	Infrared emitter LED
IR Receiver	Infrared receiver that receives signal transmitted by Infrared emitter.

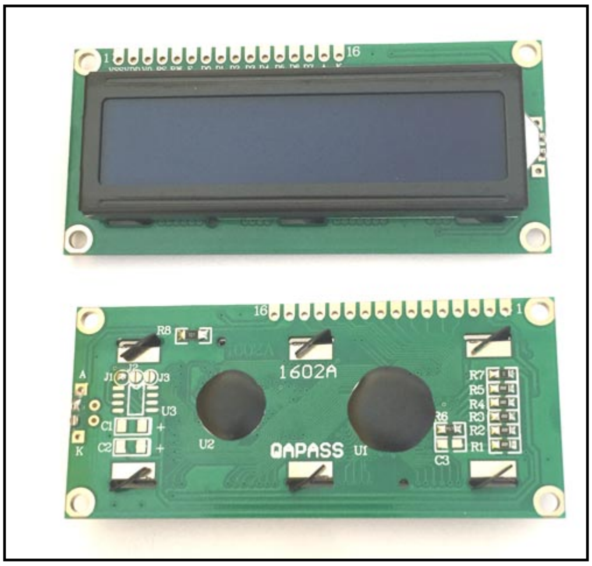
Features

- IR transmitter
- Ambient light protected IR receiver
- 3 pin easy interface connectors
- Indicator LED & Power LED
- Distance 2cm to 30cm
- Can differentiate between dark and light colours
- Active Low on object detection
- 3.3 to 5V operation

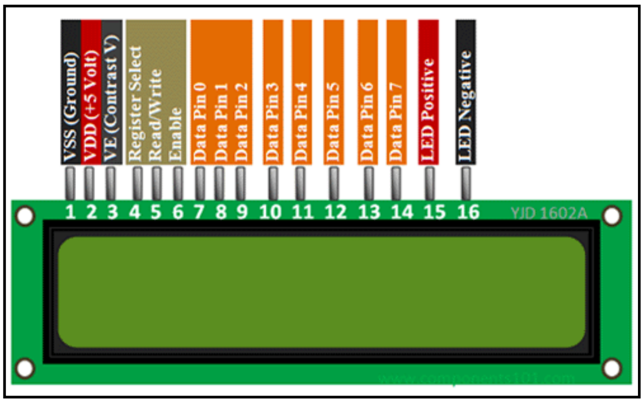
Applications

- Proximity Sensor
- Obstacle Detector Sensor
- Line Follower Sensor
- Wall Follower Sensor

16x2 LCD Module



16x2 LCD Module



16x2 LCD Module Pinout

Pin Configuration

Pin No:	Pin Name:	Description
1	Vss (Ground)	Ground pin connected to system ground
2	Vdd (+5 Volt)	Powers the LCD with +5V (4.7V – 5.3V)
3	VE (Contrast V)	Decides the contrast level of display. Grounded to get maximum contrast.
4	Register Select	Connected to Microcontroller to shift between command/ data register
5	Read/Write	Used to read or write data. Normally grounded to write data to LCD
6	Enable	Connected to Microcontroller Pin and toggled between 1 and 0 for data acknowledgement
7	Data Pin 0	Data pins 0 to 7 forms a 8-bit data line. They can be connected to Microcontroller to send 8-bit data. These LCD's can also operate on 4-bit mode in such case Data pin 4,5,6 and 7 will be left free.

8	Data Pin 1	
9	Data Pin 2	
10	Data Pin 3	
11	Data Pin 4	
12	Data Pin 5	
13	Data Pin 6	
14	Data Pin 7	
15	LED Positive	Backlight LED pin positive terminal
16	LED Negative	Backlight LED pin negative terminal

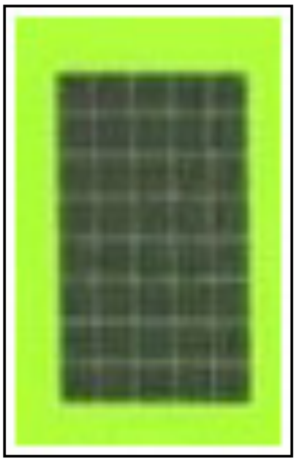
Features of 16×2 LCD module

- Operating Voltage is 4.7V to 5.3V
- Current consumption is 1mA without backlight
- Alphanumeric LCD display module, meaning can display alphabets and numbers
- Consists of two rows and each row can print 16 characters.
- Each character is build by a 5×8 pixel box
- Can work on both 8-bit and 4-bit mode
- It can also display any custom generated characters
- Available in Green and Blue Backlight

Brief Description on LCD modules

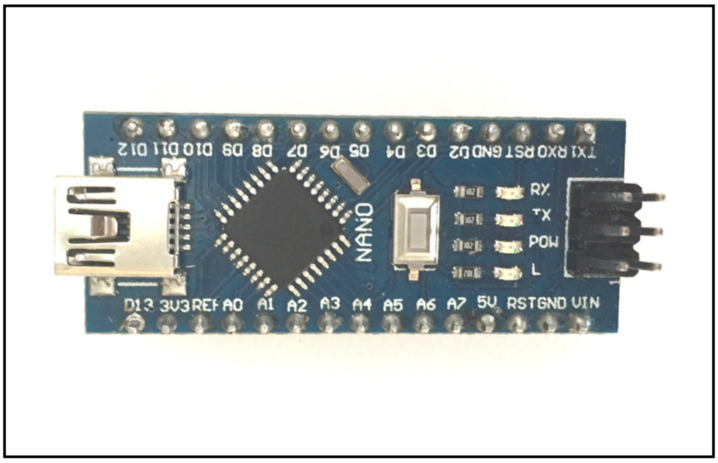
LCD modules are very commonly used in most embedded projects, the reason being its cheap price, availability and programmer friendly. Most of us would have come across these displays in our day to day life, either at PCO's or calculators. The appearance and the pinouts have already been visualized above now let us get a bit technical.

16×2 LCD is named so because; it has 16 Columns and 2 Rows. There are a lot of combinations available like, 8×1, 8×2, 10×2, 16×1, etc. but the most used one is the 16×2 LCD. So, it will have (16×2=32) 32 characters in total and each character will be made of 5×8 Pixel Dots. A Single character with all its Pixels is shown in the below picture.

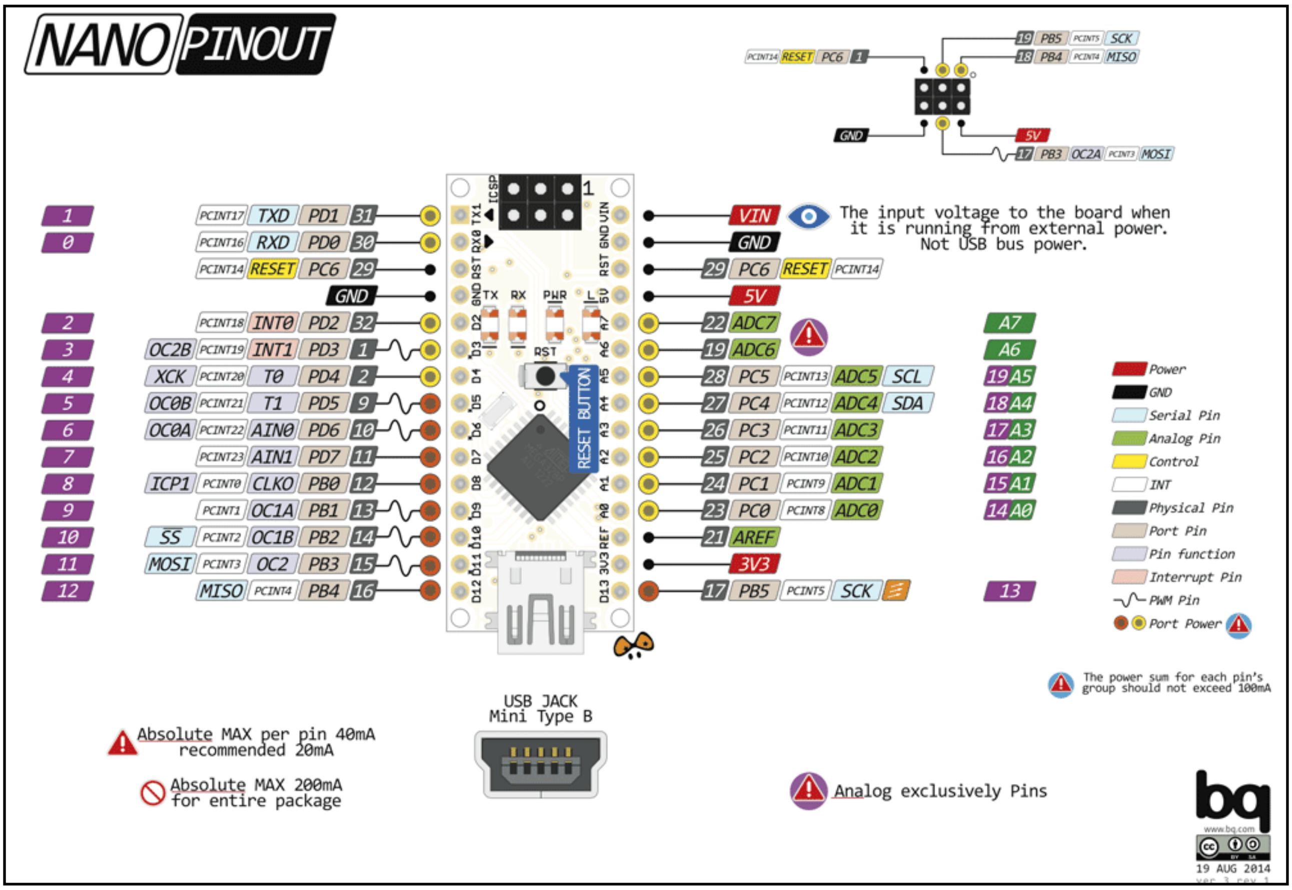


Now, we know that each character has (5×8=40) 40 Pixels and for 32 Characters we will have (32×40) 1280 Pixels. Further, the LCD should also be instructed about the Position of the Pixels. Hence it will be a hectic task to handle everything with the help of MCU, hence an **Interface IC like HD44780**is used, which is mounted on the backside of the LCD Module itself. The function of this IC is to get the **Commands and Data** from the MCU and process them to display meaningful information onto our LCD Screen. You can learn how to interface an LCD using the above mentioned links. If you are an advanced programmer and would like to create your own library for interfacing your Microcontroller with this LCD module then you have to understand the HD44780 IC is working and commands which can be found its data-sheet.

Arduino Nano



Arduino Nano



Arduino Nano Pin Diagram

Arduino Nano Pin Configuration

Pin Category	Pin Name	Details

Power	**Vin, 3.3V, 5V, GND**	**Vin:** Input voltage to Arduino when using an external power source (6-12V). **5V:** Regulated power supply used to power microcontroller and other components on the board. **3.3V:** 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. **GND:** Ground pins.
Reset	**Reset**	Resets the microcontroller.
Analog Pins	**A0 – A7**	Used to measure analog voltage in the range of 0-5V
Input/Output Pins	**Digital Pins D0 - D13**	Can be used as input or output pins. 0V (low) and 5V (high)
Serial	Rx, **Tx**	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	**13**	To turn on the inbuilt LED.
IIC	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	**AREF**	To provide reference voltage for input voltage.

Arduino Nano Technical Specifications

Microcontroller	ATmega328P – 8 bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage for Vin pin	7-12V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (2 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz
Communication	IIC, SPI, USART

Understanding Arduino Nano

The Arduino board is designed in such a way that it is very easy for beginners to get started with microcontrollers. This board especially is breadboard friendly is very easy to handle the connections. Let's start with powering the Board.

Powering you Arduino Nano:

There are totally three ways by which you can power your Nano.

USB Jack: Connect the mini USB jack to a phone charger or computer through a cable and it will draw power required for the board to function

Vin Pin: The Vin pin can be supplied with a unregulated 6-12V to power the board. The on-board voltage regulator regulates it to +5V

+5V Pin: If you have a regulated +5V supply then you can directly provide this o the +5V pin of the Arduino.

Input/output:

There are totally 14 digital Pins and 8 Analog pins on your Nano board. The digital pins can be used to interface sensors by using them as input pins or drive loads by using them as output pins. A simple function like pinMode() and digitalWrite() can be used to control their operation. The operating voltage is 0V and 5V for digital pins. The analog pins can measure analog voltage from 0V to 5V using any of the 8 Analog pins using a simple function liken analogRead()

These pins apart from serving their purpose can also be used for special purposes which are discussed below:

- **Serial Pins 0 (Rx) and 1 (Tx):** Rx and Tx pins are used to receive and transmit TTL serial data. They are connected with the corresponding ATmega328P USB to TTL serial chip.
- **External Interrupt Pins 2 and 3:** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- **PWM Pins 3, 5, 6, 9 and 11:** These pins provide an 8-bit PWM output by using analogWrite() function.
- **SPI Pins 10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK):** These pins are used for SPI communication.
- **In-built LED Pin 13:** This pin is connected with an built-in LED, when pin 13 is HIGH – LED is on and when pin 13 is LOW, its off.
- **I2C A4 (SDA) and A5 (SCA):** Used for IIC communication using Wire library.
- **AREF:** Used to provide reference voltage for analog inputs with analogReference() function.

- **Reset Pin:** Making this pin LOW, resets the microcontroller.

Applications

- Prototyping of Electronics Products and Systems

- Multiple DIY Projects.
- Easy to use for beginner level DIYers and makers.
- Projects requiring Multiple I/O interfaces and communications.

Conclusion

The four-stroke solenoid engine has been designed and fabricated. We have measured the speed at the wheel and at the crankshaft using IR sensor successfully. The project was mainly concerned with fabricating a revolutionary engine that runs with the help of solenoid coil. Basically, it's advancement to the electric vehicles where electric motor is used to run the engine but in our project we have used solenoid coils in order to increase the battery life and eliminate the losses of the electric motor so as to enhance the power of the vehicle.

This innovative technology allows extraction of energy in a clean way and reduces the emission to zero level due to which pollution is minimised to a large extent. It has been cost effective as the design is much simpler than the conventional engines of electric vehicle. No cooling is required and many other parts such as valves, cam, ports etc. were eliminated.

We can conclude that the proposed engine is a simple and excellent technique to run the electric vehicle in a highly efficient manner and if used at a large scale production by considering the recommendations mentioned in the future scope the power, speed and efficiency can be enhanced to a greater extent.

Future Scope

The power obtained through the model cannot be compared to the power of an electric vehicle because these vehicles use electric motor to run the engine. But the power of the solenoid engine can be reached to the extent of the power obtained through the electric motor if the number of turns in the solenoid coil are increased, doing this would increase the force applied on the piston, hence increasing the power and apart from it studying the effect of other parameters and improving them would also increase the power. This engine would eliminate the drawbacks of the electric motor used in electric vehicle.

Advantages

1. It has less running cost than an internal combustion engine.
2. It does not create pollution and can help in checking global warming.
3. It takes less amount of charge from battery in every revolution of the crankshaft for few seconds.