Electronics for Robotics Part I

Index

1: Semiconductor Junction Diode

PN Junction Diode

The PN junction diode is the most basic form of semiconductor device and its technology forms the basis of many other devices.

The PN junction diode is the basic semiconductor diode format. It is used for many forms of rectification for current levels both large and small, as well as high and low voltage levels, and it finds many uses in all manner of electronic circuits.

The PN junction has the very useful property that electrons are only able to flow in one direction. As current consists of a flow of electrons, this means that current is allowed to flow only in one direction across the structure, but it is stopped from flowing in the other direction across the junction.

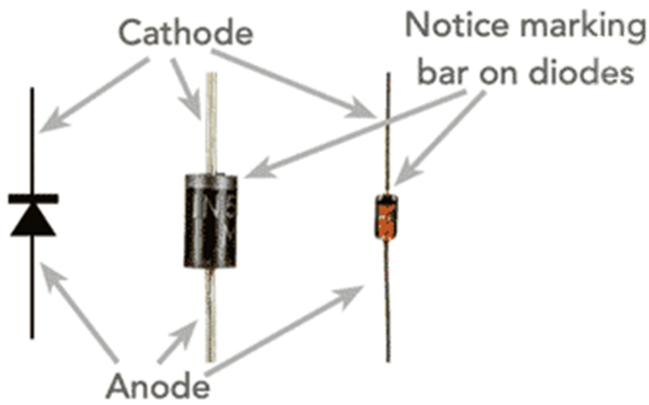
PN junction diodes can be obtained in a number of semiconductor materials - the earliest diodes tended to be made from germanium, but most of them today are silicon diodes.

The diode is simple in its basic concept, being formed from the junction of N-type and P-type materials, although in reality the manufacture and theory of operation are more complex.

Diode circuit symbol and polarity

The PN junction diode has two connections or electrodes. This gives it its name: "di-" meaning two and "-ode" as a shortening of electrode.

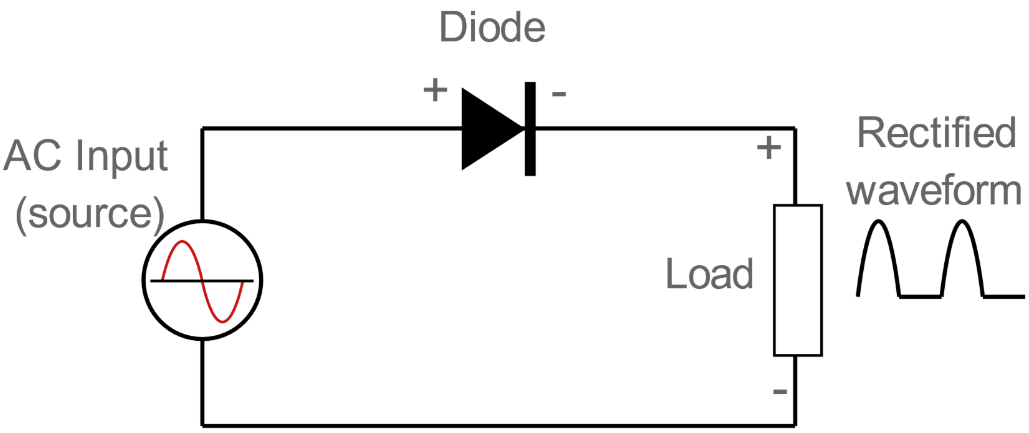
One electrode is termed the anode and the other is termed the cathode. For a current to flow across the PN diode junction it must be forward biased. Under these conditions conventional current flows from the anode to the cathode, but not the other way around.



Diode circuit symbol and physical diode orientation

It is easy to determine the polarity of many wired diodes. The "bar" on the circuit symbol corresponds to the cathode of the diode and this is often marked by a white line around the circumference of the actual diode.

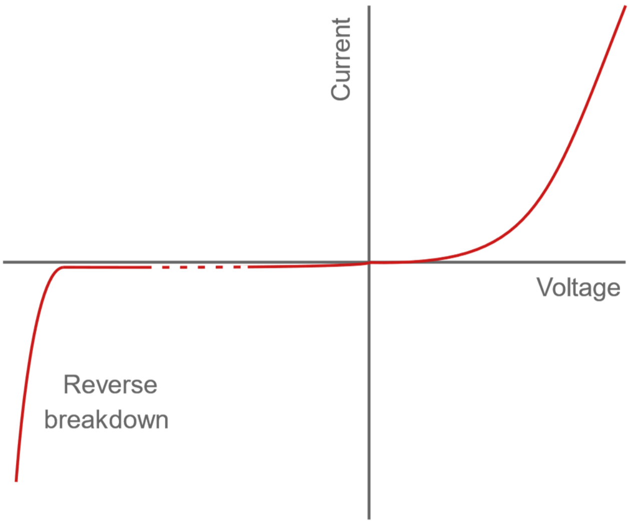
When a PN junction diode is forward biased, the anode is positive with respect to the cathode, and conversely, when reverse biased the cathode is positive with respect to the anode. This means that when a diode is used in a circuit like a rectifier, the cathode provides the positive output - the anode still remaining more positive as shown in the circuit below.



PN junction characteristics

While the PN junction provides an excellent rectifying action, it is not a perfect diode having infinite resistance in the reverse direction and zero resistance in the forward direction. In order that the PN junction can be used, it is necessary to know a little about its properties and characteristics with forward and reverse bias.

Looking at the characteristic plot of the PN junction, it can be seen that in the forward direction (forward biased) it can be seen that very little current flows until a certain voltage has been reached. This represents the work that is required to enable the charge carriers to cross the depletion layer. This voltage varies from one type of semiconductor to another. For germanium it is around 0.2 or 0.3 volts and for silicon it is about 0.6 volts. It is possible to measure a voltage of about 0.6 volts across most small current diodes when they are forward biased as most diodes are silicon. A small number will show a lower voltage and are likely to be germanium. Power rectifier diodes normally have a larger voltage across them but this is partly due to the fact that there is some resistance in the silicon, and partly due to the fact that higher currents are flowing and they are operating further up the curve.



In the reverse direction, a perfect diode would not allow any current to flow. In reality a small amount of current does flow, although this is likely to be very small and in the region of pico amps or microamps. It has been exaggerated on the diagram so that it can be seen. Although it is normally very low, the performance of any diode will degrade at higher temperatures and it is also found that germanium is not as good as silicon.

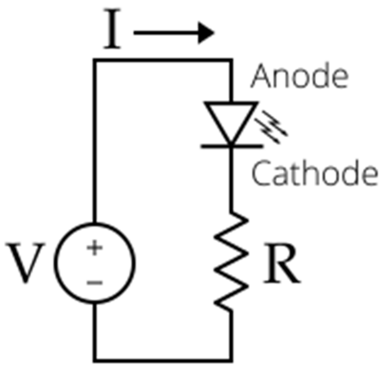
This reverse current results from what are called minority carriers. These are a very small number of electrons found in a P type region or holes in an N type region. Early semiconductors has relatively high levels of minority carriers, but now that the manufacture of semiconductor materials is very much better the number of minority carriers is much reduced as are the levels of reverse currents.

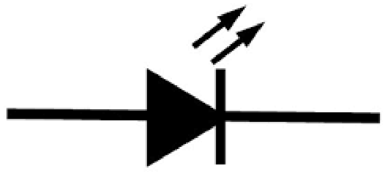
2. Light Emitting Diode (LED)

Light emitting diodes, LEDs are very widely used in today's electronics equipment and they are one of the major display technologies in use today.

Light emitting diodes, LEDs are used for many jobs. Not only are they used as panel indicators on everything from televisions, radios and other forms of domestic electronic and industrial equipment, but they are also replacing more traditional technologies for lighting applications. To accommodate all these needs, there are many different types of LED that are available.

The LED symbol comprises a diode symbol with two arrows indicating outwards to signify that light emanated from the diode.





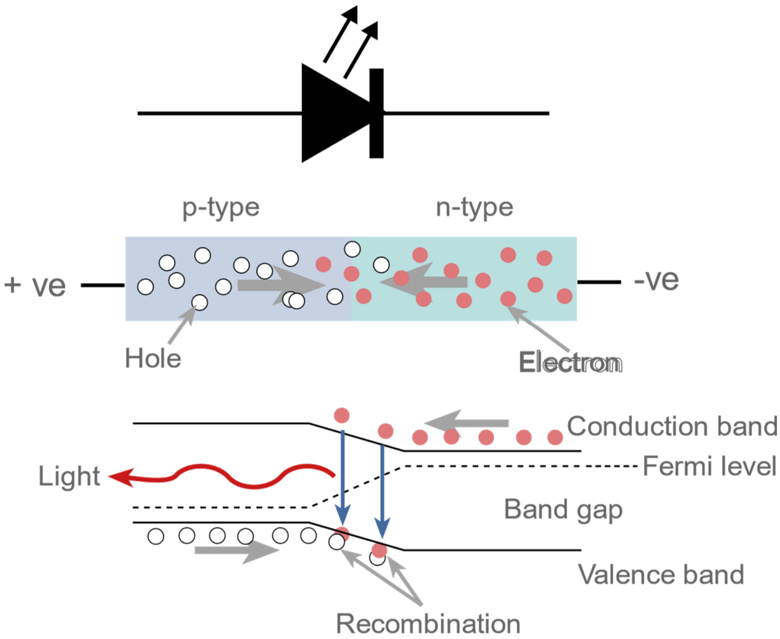
Sometimes the light emitting diode symbol is shown only as an outline and without the filled in shapes. The outline shape is equally acceptable

The light emitting diode emits light when it is forward biased.

LED technology: how a LED works

The LED is a specialized form of PN junction that uses a compound junction. The semiconductor material used for the junction must be a compound semiconductor. The commonly used semiconductor materials including silicon and germanium are simple elements and junction made from these materials do not emit light. Instead compound semiconductors including gallium arsenide, gallium phosphide and indium phosphide are compound semiconductors and junctions made from these materials do emit light.

These compound semiconductors are classified by the valence bands their constituents occupy. For gallium arsenide, gallium has a valency of three and arsenic a valency of five and this is what is termed a group III-V semiconductor and there are a number of other semiconductors that fit this category. It is also possible to have semiconductors that are formed from group III-V materials.



When a voltage is applied across the junction to make it forward biased, current flows as in the case of any PN junction. Holes from the p-type region and electrons from the n-type region enter the junction and recombine like a normal diode to enable the current to flow. When this occurs energy is released, some of which is in the form of light photons.

It is found that the majority of the light is produced from the area of the junction nearer to the P-type region. As a result the design of the diodes is made such that this area is kept as close to the surface of the device as possible to ensure that the minimum amount of light is absorbed in the structure.

To produce light which can be seen the junction must be optimized and the correct materials must be chosen. Pure gallium arsenide releases energy in the infra read portion of the spectrum.

To bring the light emission into the visible red end of the spectrum aluminium is added to the semiconductor to give aluminium gallium arsenide (AlGaAs).

Phosphorus can also be added to give red light.

Gallium phosphide gives green light and aluminium indium gallium phosphide is used for yellow and orange light.

Most LEDs are based on gallium semiconductors.

3. Bipolar junction transistor BJT

Bipolar transistor definition:

The bipolar transistor was invented by three researchers working at Bell Laboratories: John Bardeen, Walter Brattain, and William Schockley. They had been working on an idea that used a field effect to control the current in a semiconductor, but they were unable to make the idea work.

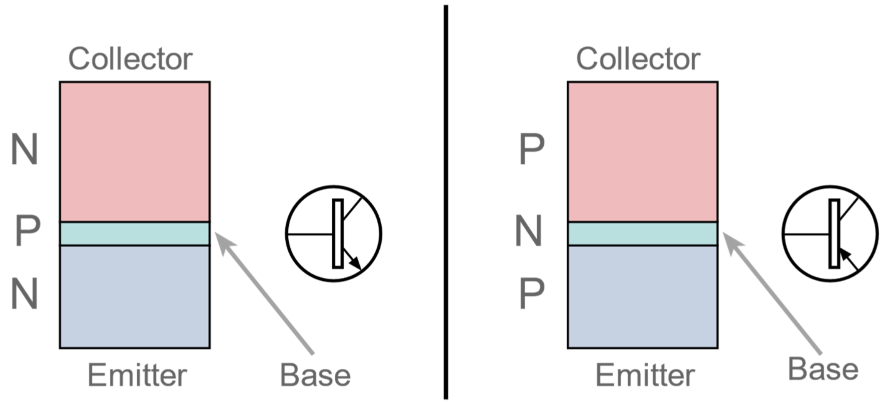
They turned their focus onto another possibility and made a three terminal device using two closely spaced point contacts on a wafer of germanium. This idea worked and they were able to demonstrate it provided gain in late 1949.

A bipolar transistor is a semiconductor device consisting of three areas either P-type or N-type - an area of one type is sandwiched between areas of the other. The transistor fundamentally amplifies current but it can be connected in circuits designed to amplify voltage or power.

Basic transistor structure

The transistor is a three terminal device and consists of three distinct layers. Two of them are doped to give one type of semiconductor and the there is the opposite type, i.e. two may be n-type and one p-type, or two may be p-type and one may be n-type.. They are arranged so that the two similar layers of the transistor sandwich the layer of the opposite type. As a result these semiconductor devices are designated as either PNP transistors or NPN transistors according to the way they are made up.

Basic structure and circuit symbols for NPN & PNP transistors



The names for the three electrodes meaning:

- ***Base:*** The base of the transistor gains its name from the fact that in early transistors, this electrode formed the base for the whole device. The earliest point contact transistors had two point contacts placed onto the base material. This base material formed the base connection . . . and the name stuck.
- ***Emitter:*** The emitter gains its name from the fact that it emits the charge carriers.
- ***Collector:*** The collector gains its name from the fact that it collects the charge carriers. For the operation of the transistor, it is essential that the base region is very thin. In today's transistors the base may typically be only about 1µm across. It is the fact that the base region of the transistor is thin that is the key to the operation of the device

How does a transistor work? the basics--

A transistor can be considered as two P-N junctions placed back to back. One of these, namely the base emitter junction is forward biased, whilst the other, the base collector junction is reverse biased. It is found that when a current is made to flow in the base emitter junction a larger current flows in the collector circuit even though the base collector junction is reverse biased.

For clarity the example of an NPN transistor is taken. The same reasoning can be used for a PNP device, except that holes are the majority carriers instead of electrons.

When current flows through the base emitter junction, electrons leave the emitter and flow into the base. However the doping in this region is kept low and there are comparatively few holes available for recombination. As a result most of the electrons are able to flow right through the base region and on into the collector region, attracted by the positive potential.

- Only a small proportion of the electrons from the emitter combine with holes in the base region giving rise to a current in the base-emitter circuit. This means that the collector current is much higher.
- The ratio between the collector current and the base current is given the Greek symbol B. For most small signal transistors this may be in the region 50 to 500. In some cases it can be even higher. This means that the collector current is typically between 50 and 500 times that flowing in the base. For a high power transistor the value of B is somewhat less: 20 is a fairly typical value.

- Only a small proportion of the electrons from the emitter combine with holes in the base region giving rise to a current in the base-emitter circuit. This means that the collector current is much higher.
- The ratio between the collector current and the base current is given the Greek symbol Β. For most small signal transistors this may be in the region 50 to 500. In some cases it can be even higher. This means that the collector current is typically between 50 and 500 times that flowing in the base. For a high power transistor the value of Β is somewhat less: 20 is a fairly typical value.

Why NPN transistors are used more than PNP transistors

- When looking at circuits and also in datasheets, etc, it will be seen that NPN transistors are far more popular than PNP transistors.
- There are several reasons for this:
- ***Carrier mobility:*** NPN transistors use electrons as the majority carriers rather than holes that are the majority carriers in PNP transistors. As holes move far more easily within the crystal lattice than electrons, i.e. they have a higher mobility, they can operate faster and provide a much better level of performance.
- ***Negative grounding:*** Over the years, a negative ground has become standard, e.g. within automotive vehicles, etc, and the polarity of NPN transistors means that the basic transistor configurations operate with a negative ground.
- ***Production costs:*** The manufacture of silicon based semiconductor components is most economically undertaken using large N type silicon wafers. Whilst it is possible to manufacture PNP transistors, requires 3 times more surface area of the wafer, and this significantly increases the costs. As the wafer costs form a major part of the overall component cost, this increased production costs significantly for PNP transistors.
- Bipolar transistors, BJTs, were the first form of transistor that was invented, and they are still very widely used today in many areas. They are easy to use, cheap and they come with specifications to meet most requirements. They are ideal for many circuits although, naturally the specification of the bipolar transistor needs to be matched to that of the circuit.

Operating Modes of Transistors

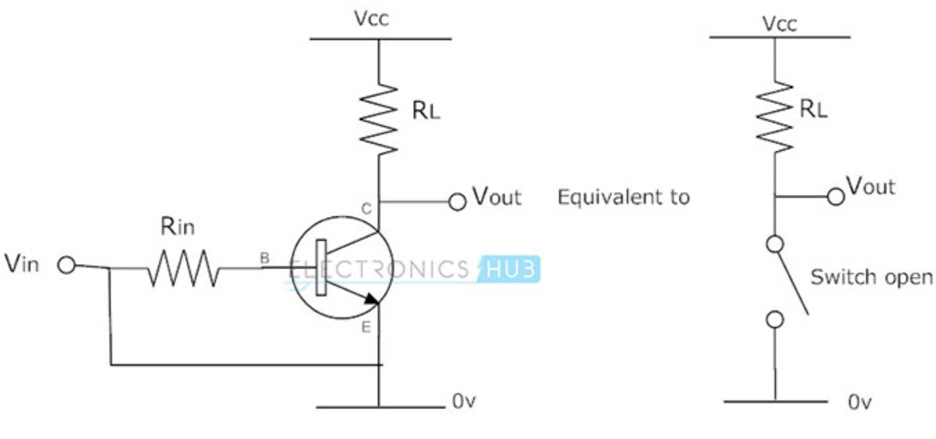
Depending on the biasing conditions like forward or reverse, transistors have three major modes of operation namely cutoff, active and saturation regions.

Active Mode

In this mode transistor is generally used as a current amplifier. In active mode, two junctions are differently biased that means emitter-base junction is forward biased whereas collector-base junction is reverse biased. In this mode current flows between emitter and collector and amount of current flow is proportional to the base current.

Cutoff Mode

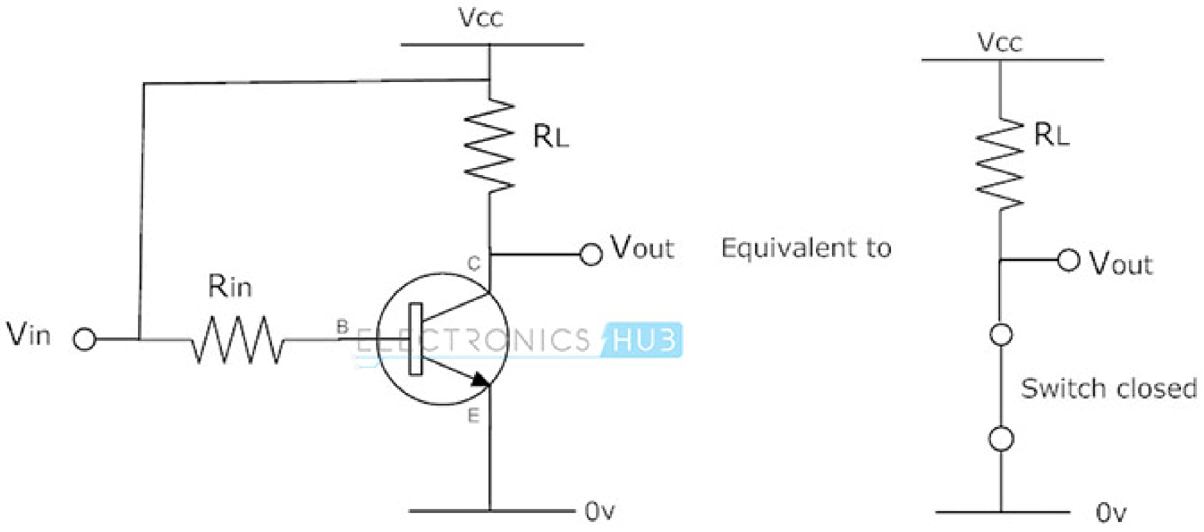
In this mode, both collector base junction and emitter base junction are reverse biased. This will block the current to flow from collector to emitter when the base-emitter voltage is low. In this mode device is completely switched off as the result the current flowing through the device is zero.



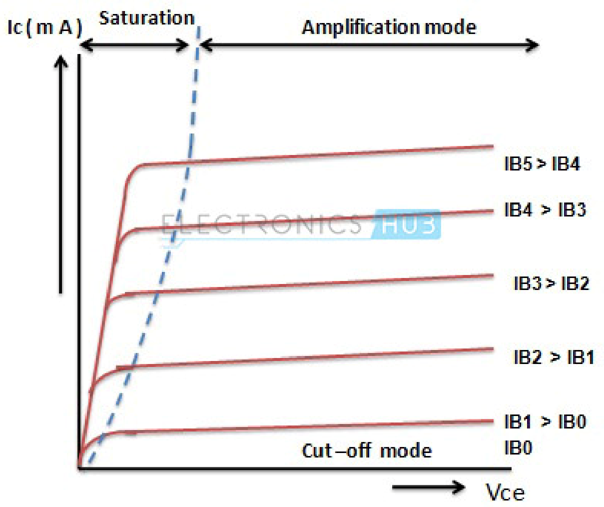
Saturation Mode

In this mode of operation, both the emitter base and collector base junctions are forward biased. Current flows freely from collector to emitter when the base-emitter voltage is high.

In this mode device is fully switched ON.



The below figure shows the output characteristics of a BJT Transistor. In the below figure cutoff region has the operating conditions as zero collector output current, zero base input current and maximum collector voltage. These parameters cause a large depletion layer which further doesn’t allow current to flow through the transistor. Therefore, the transistor is completely in OFF condition.



Similarly, in the saturation region, a transistor is biased in such a way that maximum base current is applied that results maximum collector current and minimum collector-emitter voltage. This causes the depletion layer to become small and to allow maximum current flow through the transistor. Therefore, the transistor is fully in ON condition.

4. Transistor as a Switch

From the above discussion, we can say that transistors can be made to work as ON/OFF solid state switch by operating transistor in cutoff and saturation regions. This type of switching application is used for controlling motors, lamp loads, solenoids, etc.

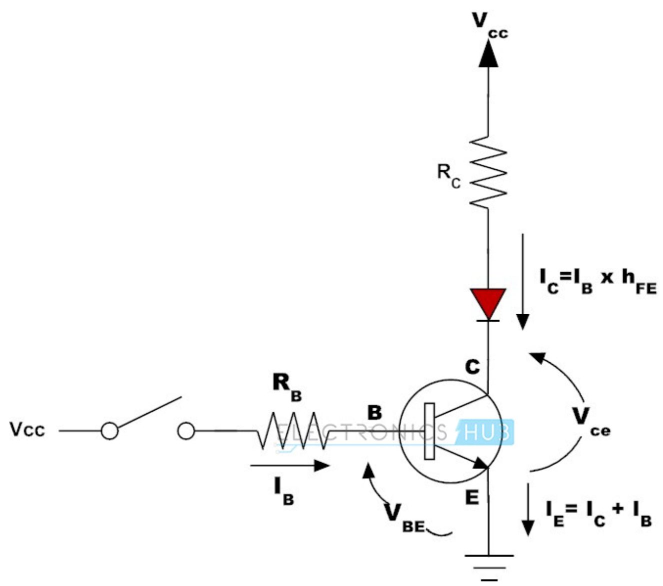
A transistor is used for switching operation for opening or closing of a circuit. This type solid state switching offers significant reliability and lower cost as compared with conventional relays.

Both NPN and PNP transistors can be used as switches. Some of the applications use a power transistor as switching device, at that time it may necessary to use another signal level transistor to drive the high power transistor.

NPN Transistor as a Switch

When a sufficient voltage (V_{in} > 0.7 V) is applied between the base and emitter, collector to emitter voltage is approximately equal to 0. Therefore, the transistor acts as a short circuit. The collector current V_{cc}/R_c flows through the transistor.

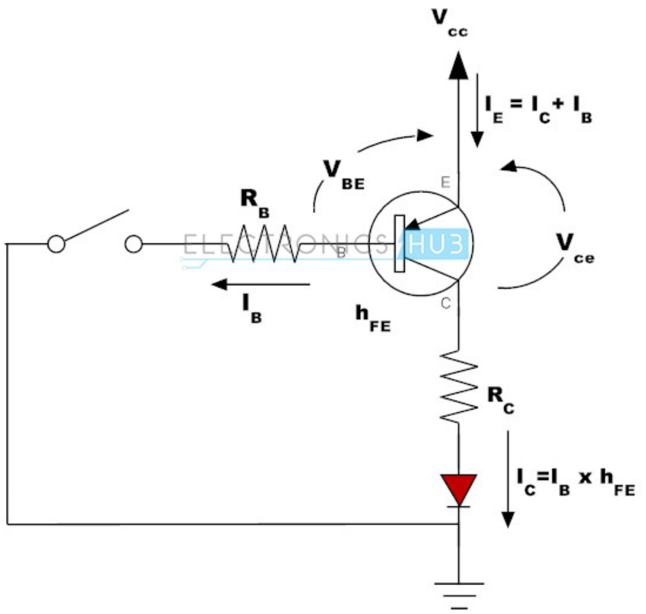
When no voltage or zero voltage is applied at the input, transistor operates in cutoff region and acts as an open circuit. In this type of switching connection, load (here LED lamp) is connected to the switching output with a reference point. Thus, when the transistor is switched ON, current will flow from source to ground through the load.

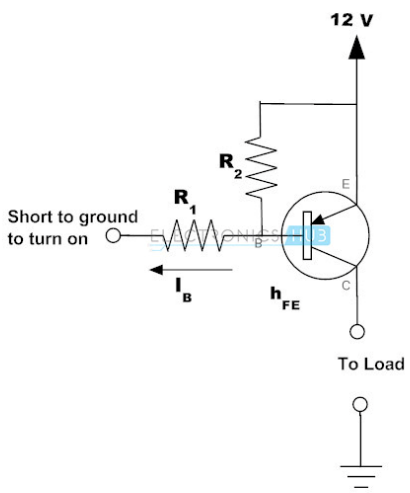


PNP Transistor as a Switch

PNP transistor works same as NPN for a switching operation, but the current flows from the base. This type of switching is used for negative ground configurations. For the PNP transistor, the base terminal is always negatively biased with respect to the emitter. In this switching, base current flows when the base voltage is more negative. Simply a low voltage or more negative voltage makes transistor to short circuit otherwise it will be open circuited or high impedance state.

In this connection, load is connected to the transistor switching output with a reference point. When the transistor is turned ON, current flows from the source through transistor to the load and finally to the ground.





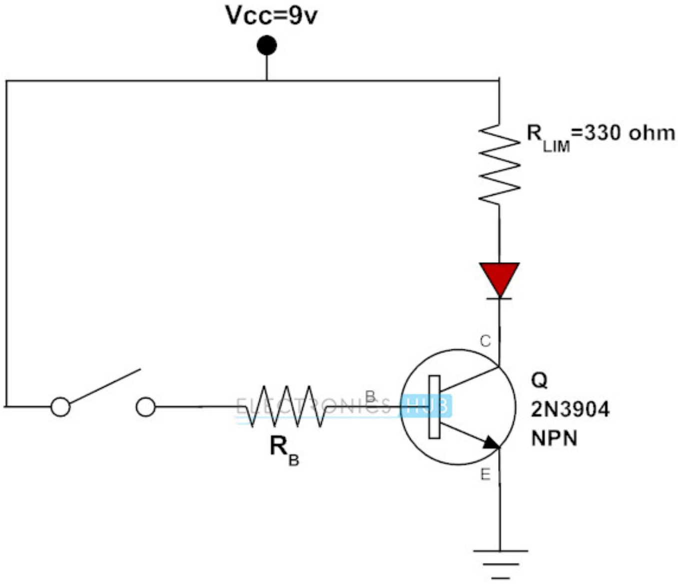
Common Practical Examples of Transistor as a Switch

Transistor to Switch the LED

As discussed earlier that the transistor can be used as a switch. The schematic below shows how a transistor is used to switch the Light Emitting Diode (LED).

- When the switch at the base terminal is open, no current flows through the base so the transistor is in the cutoff state. Therefore, the circuit acts as open-circuit and the LED becomes OFF.
- When the switch is closed, base current starts flowing through the transistor and then drives into saturation results to LED become ON.

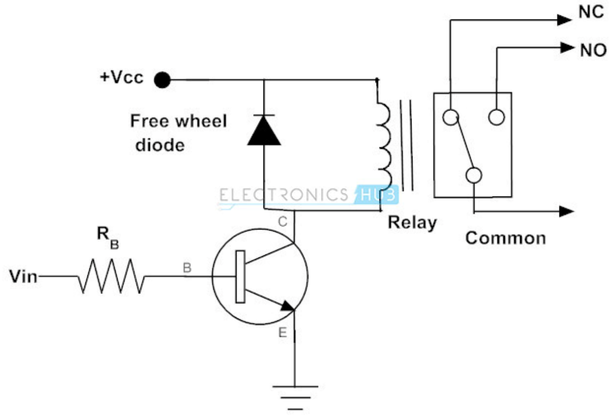
- Resistors are placed to limit the currents through the base and LED. It is also possible to vary the intensity of LED by varying the resistance in the base current path.



Transistor to Operate the Relay

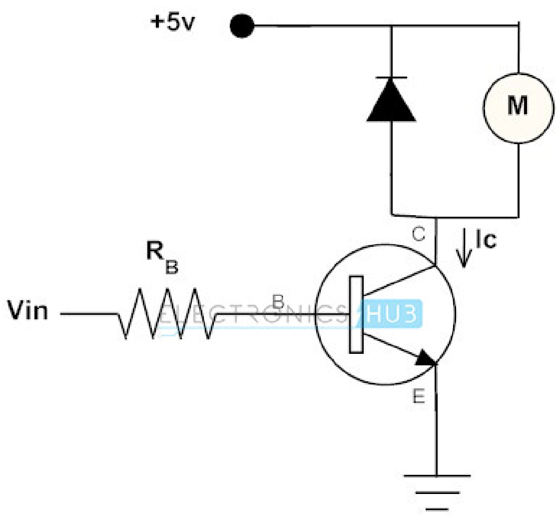
It is also possible to control the relay operation using a transistor. With a small circuit arrangement of a transistor able to energize the coil of the relay so that the external load connected to it is controlled.

- Consider the below circuit to know the operation of a transistor to energize the relay coil. The input applied at the base causes to drive the transistor into saturation region, which further results the circuit becomes short circuit. So the relay coil gets energized and relay contacts get operated.
- In inductive loads, particularly switching of motors and inductors, sudden removal of power can keep a high potential across the coil. This high voltage can cause considerable damage to the rest circuit. Therefore, we have to use the diode in parallel with inductive load to protect the circuit from induced voltages of the inductive load.



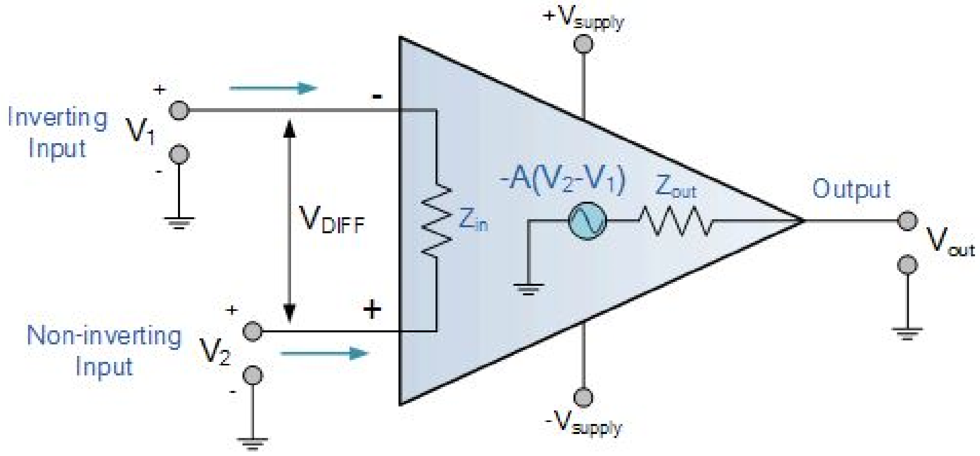
Transistor to Drive the Motor

- A transistor can also used to drive and regulate the speed of the DC motor in a unidirectional way by switching the transistor in regular intervals of time as shown in the below figure.
- As mentioned in above, the DC motor is also an inductive load so we have to place a freewheeling diode across it to protect the circuit.
- By switching the transistor in cutoff and saturation regions, we can turn ON and OFF the motor repeatedly.
- It is also possible to regulate the speed of the motor from standstill to full speed by switching the transistor at variable frequencies. We can get the switching frequency from control device or IC like microcontroller.



5. Operational Amplifier OPAMP basics

An Operational Amplifier or op-amp is a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals. It is a high-gain electronic voltage amplifier with a differential input and usually a single-ended output. Op-amps are among the most widely used electronic devices today, being used in a vast array of consumer, industrial, and scientific devices.



Op-amp operation

The amplifier's differential inputs consist of a non-inverting input with voltage (V+) and an inverting input with voltage (V−). Ideally, an op-amp amplifies only the difference in voltage between the two, also called differential input voltage. The output voltage of the op-amp V_{out} is given by the equation,

$V_{out} = A_{OL} (V_+ - V_-)$

where A_{OL} is the open-loop gain of the amplifier.

In a linear operational amplifier, the output signal is the amplification factor, known as the amplifiers gain (A) multiplied by the value of the input signal.

Op-amp parameters

- Open-loop gain is the gain without positive or negative feedback. Ideally, the gain should be infinite, but typical real values range from about 20,000 to 200,000 ohms.
- Input impedance is the ratio of input voltage to input current. It is assumed to be infinite to prevent any current flowing from the source to amplifiers.

- The output impedance of the ideal operational amplifier is assumed to be zero. This impedance is in series with the load, thereby increasing the output available for the load.
- The bandwidth of an ideal operational amplifier is infinite and can amplify any frequency signal from DC to the highest AC frequencies. However, typical bandwidth is limited by the Gain-Bandwidth product. GB product is equal to the frequency where the amplifiers gain becomes unity.
- The ideal output of an amplifier is zero when the voltage difference between the inverting and the non-inverting inputs is zero. Real world amplifiers do exhibit a small output offset voltage.

An op-amp only responds to the difference between the two voltages irrespective of the individual values at the inputs. External resistors or capacitors are often connected to the op-amp in many ways to form basic circuits including Inverting, Non-Inverting, Voltage Follower, Summing, Differential, Integrator and Differentiator type amplifiers. Op-amp is easily available in IC packaging, the most common of them is the -741.

Inverting & Non-Inverting Amplifier Basics

An “ideal” or perfect operational amplifier has following characteristics---

1. infinite open-loop gain,
2. infinite input resistance,
3. zero output resistance,
4. infinite bandwidth and zero offset.

Operational amplifiers are used extensively in signal conditioning or perform mathematical operations as they are nearly ideal for DC amplification.

An operational amplifier is basically a three-terminal device

1. The inverting input (–) and the other one called
2. The non-inverting input (+).
3. The third terminal represents the operational amplifiers output port which can both sink and source either a voltage or a current.

Negative feedback

OPAMP offers very high gain. This makes the amplifier unstable & hard to control.

This can be controlled by connecting a resistor across the amplifier from the output terminal, back to the inverting input terminal to control the final gain of the amplifier. This is commonly known as negative feedback and produces a more stable op-amp.

Negative feedback is the process of feeding a part of the output signal back to the input. But to make the feedback negative, it is fed to the negative or "inverting input" terminal of the op-amp using a resistor.

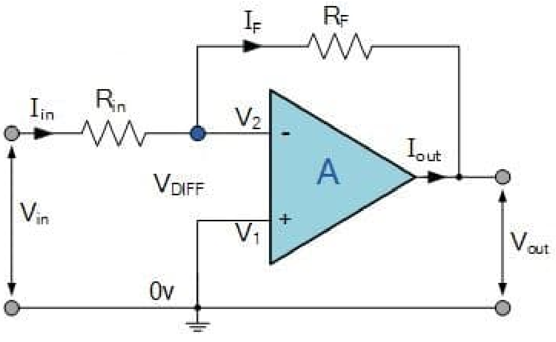
This effect produces a closed loop circuit resulting in Closed-loop Gain. A closed-loop inverting amplifier uses negative feedback to accurately control the overall gain of the amplifier, but causes a reduction in the amplifiers gain.

Inverting amplifier

In an inverting amplifier circuit, the operational amplifier inverting input receives feedback from the output of the amplifier.

Assuming the op-amp is ideal and applying the concept of virtual short at the input terminals of op-amp, the voltage at the inverting terminal is equal to non-inverting terminal.

The non-inverting input of the operational amplifier is connected to ground. As the gain of the op amp itself is very high and the output from the amplifier is a matter of only a few volts, this means that the difference between the two input terminals is exceedingly small and can be ignored. As the non-inverting input of the operational amplifier is held at ground potential this means that the inverting input must be virtually at earth potential.



Voltage gain (A) $= \frac{Vout}{Vin} = -\frac{Rf}{Rin}$

Non-Inverting Amplifier

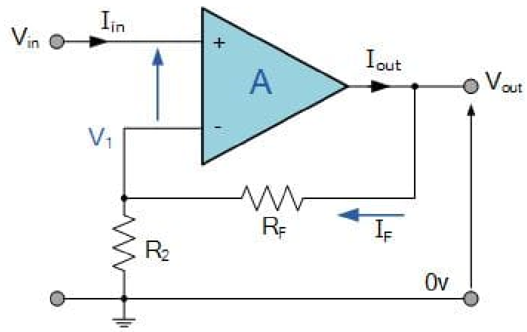
The non-inverting amplifier is one in which the output is in phase with respect to the input.

The feedback is applied at the inverting input.

The input is now applied at the non-inverting input. The output is a non-Inverted (in terms of phase) amplified version of input.

The gain of the non-inverting amplifier circuit for the operational amplifier is easy to determine.

The basic important concept is virtual ground. The voltage at both inputs is the same. (The gain of the amplifier is exceedingly high) If the output of the circuit remains within the supply rails of the amplifier, then the output voltage divided by the gain means that there is virtually no difference between the two inputs. The voltage gain can be calculated by applying KCL at the inverting node.



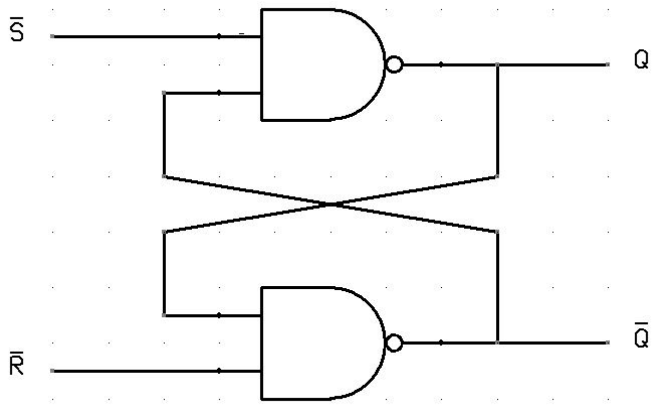
$$\text{Voltage gain (A)} = \frac{Vout}{Vin} = 1 + \frac{Rf}{Rin}$$

6. Basics and Overview of Flip Flops

A flip flop is an electronic circuit with two stable states that can be used to store binary data. The stored data can be changed by applying varying inputs. Flip-flops and latches are fundamental building blocks of digital electronics systems used in computers, communications, and many other types of systems. Flip-flops and latches are used as data storage elements. It is the basic storage element in sequential logic.

SR latch

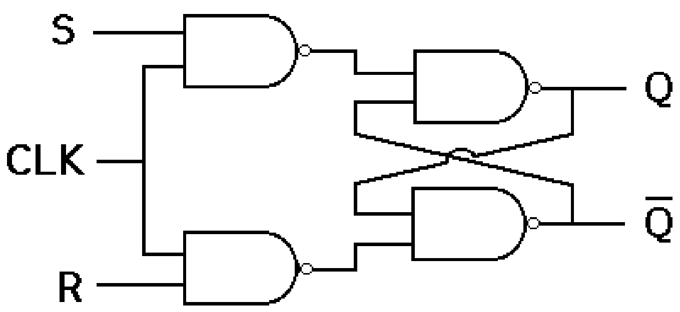
Following diagram shows SR latch. In this circuit when you Set S as active the output Q would be high and Q' will be low. This is irrespective of anything else. (This is an active-low circuit so active here means low, but for an active high circuit active would mean high)



The basic difference between a latch and a flip-flop is a gating or clocking mechanism. A flip flop is also known as gated or clocked SR latch.

SR (Set-Reset) flip flop

There are majorly 4 types of flip flops, with the most common one being SR flip flop.

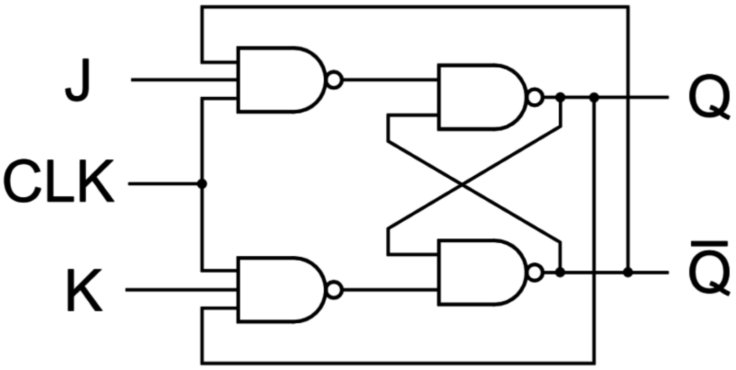


This simple flip flop circuit has a set input (S) and a reset input (R). And third is a clock signal. The output will change (i.e. the stored data is changes) only when you give an active clock signal. Otherwise, even if the S or R is active the data will not change. In this circuit when you Set “S” as active the output “Q” would be high and “Q**”** will be low. Once the outputs are established, the wiring of the circuit is maintained until “S” or “R” go high, or power is turned off. The two outputs, as shown above, are the inverse of each other. The truth table of SR Flip Flop is as below.

S	R	Q	Q’
0	0	0	1
0	1	0	1
1	0	1	0
1	1	∞ indefinite	

JK Flip-flop

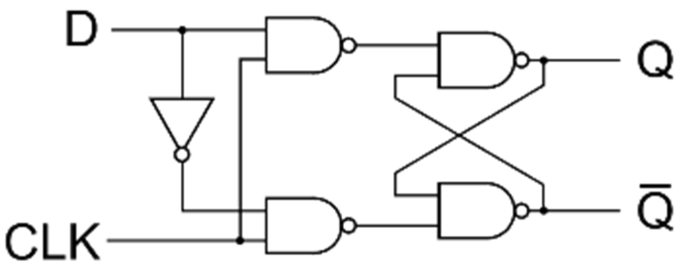
Due to the undefined state in the SR flip flop, another flip flop is required in electronics. The JK flip flop is an improvement on the SR flip flop where S=R=1 is not a problem.



In simple words, If J and K data input are different (i.e. high and low) then the output Q takes the value of J at the next clock edge. If J and K are both low then no change occurs. If J and K are both high at the clock edge then the output will toggle from one state to the other. JK Flip Flop can function as Set or Reset Flip flop

D Flip Flop

D flip flop is a better alternative that is very popular with digital electronics. They are commonly used for counters and shift-registers and input synchronization.

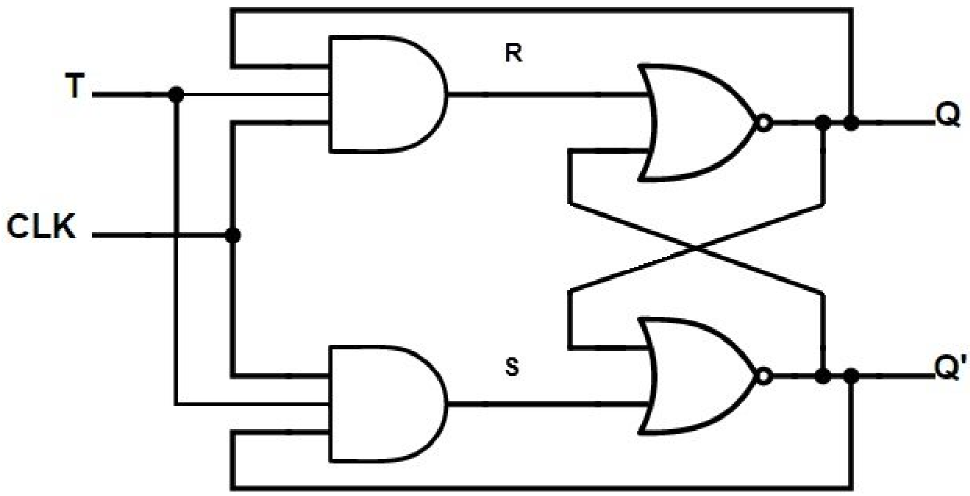


In a D flip flop, the output can be only changed at the clock edge, and if the input changes at other times, the output will be unaffected.

The change of state of the output is dependent on the rising edge of the clock. The output (Q) is same as the input and can only change at the rising edge of the clock.

T Flip Flop

A T flip flop is like JK flip-flop. These are basically a single input version of JK flip flop. This modified form of JK flip-flop is obtained by connecting both inputs J and K together. This flip-flop has only one input along with the clock input.



T Flip-Flop

<u>These flip-flops are called T flip-flops because of their ability to complement its state (i.e.) Toggle, hence the name Toggle flip-flop.</u>

T	**Q initial state**	**Q (t+1) toggled**
0	0	0
1	0	1
0	1	1
1	1	0

Applications of Flip-Flops

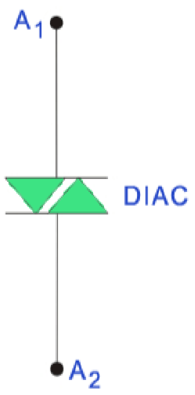
These are the various types of flip-flops being used in digital electronic circuits and the applications of Flip-flops are as specified below.

1. Counters
2. Frequency Dividers
3. Shift Registers
4. Storage Registers

7. Power Electronics --DIAC

What is DIAC?

A DIAC is a diode that conducts electrical current only after its breakover voltage (V_{BO}) has been reached. DIAC stands for “Diode for Alternating Current”. A DIAC is a device which has two electrodes, and it is a member of the thyristor family. DIACs are used in the triggering of thyristors. The figure below shows a symbol of a DIAC, which resembles the connection of two diodes in opposition.



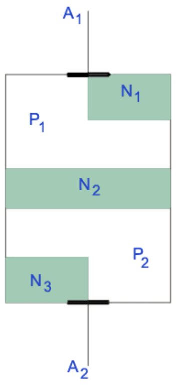
Diac Symbol

The advantage of a DIAC is that it can be turned on or off simply by reducing the voltage level below its avalanche breakdown voltage. DIACs are also known as a transistor without a base. It should also be noted that a DIAC can be either turned on or off for both polarities of voltage (i.e. positive or negative voltage). They also still work when avalanche breakdown occurs.

Construction of DIAC

It is a device which consists of four layers and two terminals. The construction is almost the same as that of the transistor. But there are certain points which deviate from the construction from the transistor. The differentiating points are-

1. There is no base terminal in the DIAC
2. The three regions have almost the same level of doping
3. It gives symmetrical switching characteristics for either polarity of voltages



Construction of Diac

Application of DIAC

The main application of a DIAC is its use in a TRIAC triggering circuit. The DIAC is connected to the gate terminal of the TRIAC. When the voltage across the gate decreases below a predetermined value, the gate voltage will be zero and hence the TRIAC will be turned off.
Some other applications of a DIAC include:

1. It can be used in the lamp dimmer circuit
2. It is used in a heat control circuit
3. It is used in the speed control of a universal motor

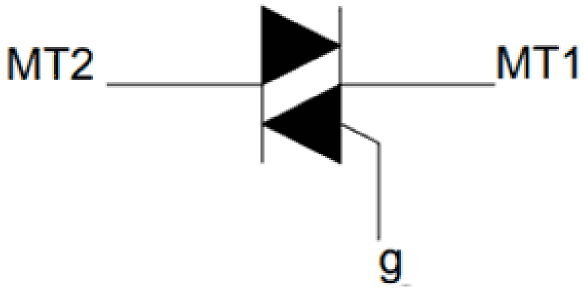
A DIAC can be used with a TRIAC in a series combination for triggering. The gate of TRIAC is connected with a terminal of the DIAC. When the applied voltage across the DIAC increases above the avalanche breakdown voltage, only then it can conduct.

However, when the voltage across DIAC decreases below its avalanche breakdown voltage it will be turned off, and hence the TRIAC will also remain in the off state.

8. Power Electronics: TRIAC

The term **TRIAC** stands for **TRI**ode for **A**lternating **C**urrent. It is a three terminal switching device similar to SCR (Thyristor) but it can conduct in both the directions since it is constructed by combining two SCR in anti-parallel state.
Basically switch like transistor.

The symbol and pin out of TRIAC is shown below.



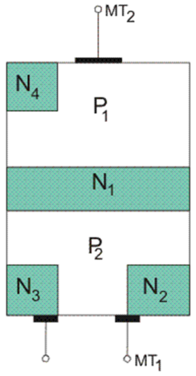
Pin No.	Marking	Pin Name
1	MT1	Main Terminal 1
2	MT2	Main Terminal 2
3	G	Gate

Triac is a three terminal AC switch which can conduct in both the directions that is whether the applied gate signal is positive or negative, it will conduct. Thus, this device can be used for AC systems as a switch.

This is a three terminal, four-layer, bi-directional semiconductor device that controls AC power. The triac of maximum rating of 16 kw is available in the market.

Construction of Triac

Two SCRs are connected in inverse parallel with gate terminal as common. Gate terminals is connected to both the N and P regions due to which gate signal may be applied which is irrespective of the polarity of the signal. Here, we do not have anode and cathode since it works for both the polarities which means that device is bilateral.

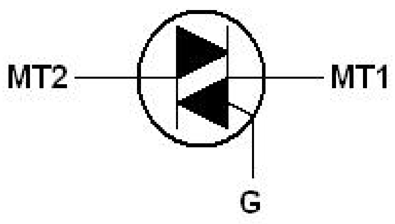


Operation of TRIAC

The TRIAC can be turned on by applying the gate voltage higher than break over voltage. However, without making the voltage high, it can be turned on by applying the gate pulse of 35 micro seconds to turn it on. When the voltage applied is less than the break over voltage, we use gate triggering method to turn it on.

Triggering a TRIAC

Usually 4 modes of triggering is possible in TRIAC:



Triac Symbol

1. A positive voltage at MT2 and a positive pulse at the gate
2. A positive voltage at MT2 and a negative pulse at the gate
3. A negative voltage at MT2 and positive pulse at the gate
4. A negative voltage at MT2 and a negative pulse at the gate

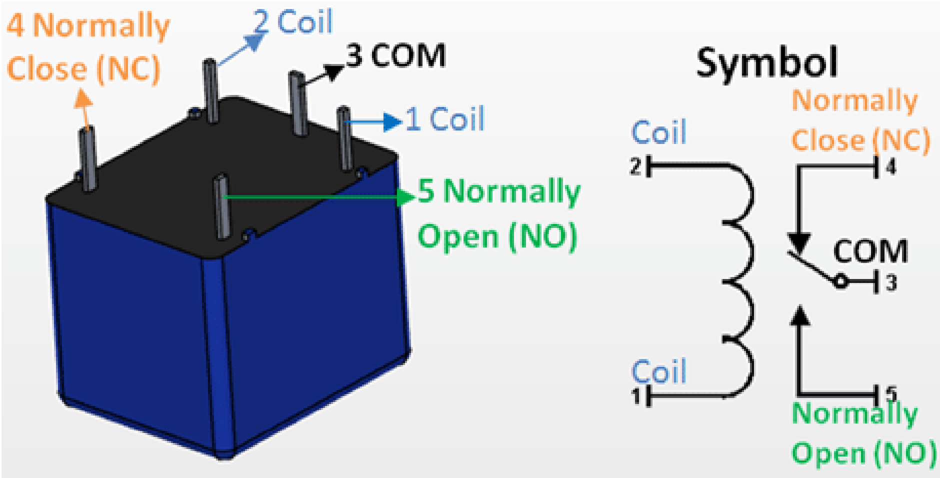
TRIAC Applications

TRIAC (Triode for AC) is the semiconductor device widely used in power control and switching applications. It finds applications in switching, phase control, chopper designs (High power), brilliance control in lamps, speed control in fans, motors etc. The power control system is designed to control the distribution level of AC or DC. Such power control systems can be used to switch power to appliances manually or when temperature or light levels go beyond a pre-set level.

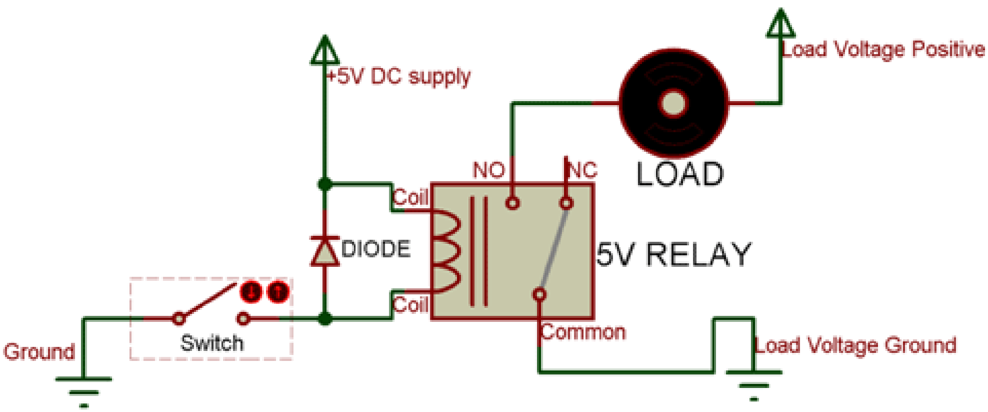
Comparison with MOSFET (Field effect transistors)

1. MOSFET, by themselves, can only switch DC current. TRIAC can switch DC and AC current.
2. MOSFET is a voltage-driven device and TRIAC is a current driven device.
3. TRIAC is self-sustaining and MOSFET is (practically) not self-sustaining. Once you have turned on a TRIAC (it starts to conduct), it will remain conducting all by itself until the current reverses. MOSFET, because of its leakage, will turn off over time.
4. MOSFETs can switch at much higher frequencies than a triac can. TRIAC can switch much higher current than MOSFET can.
5. Being inherently a transistor, TRIAC's voltage drop is independent of current it switches. MOSFET's voltage drop is linear to the current it switches, making the MOSFET unsuitable for high current switching applications.

9 Electromagnetic Relay

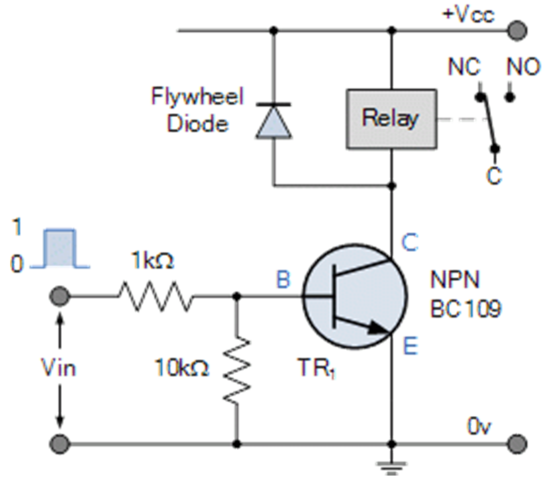


Relays are electromechanical devices that use an electromagnet to operate a pair of movable contacts from an open position to a closed position.



The above circuit shows a bare-minimum concept for a relay to operate. Since the relay has 5V trigger voltage we have used a +5V DC supply to one end of the coil and the other end to ground through a switch. This **switch** can be anything from a small transistor to a microcontroller or a microprocessor which can perform switching operating. You can also notice a diode connected across the coil of the relay, this diode is called the **Fly back Diode or freewheeling diode** . The purpose of the diode is to protect the switch from high voltage spike that can be produced by the relay coil. As shown one end of the load can be connected to the Common pin and the other end is either connected to NO or NC. If connected to NO the load remains disconnected before trigger and if connected to NC the load remains connected before trigger.

Following circuit shows relay control from transistor as a switch.



The advantage of relays is that it takes a relatively small amount of power to operate the relay coil, but the relay itself can be used to control motors, heaters, lamps or AC circuits which themselves can draw a lot more electrical power.

The electro-mechanical relay is an output device (actuator) which come in a whole host of shapes, sizes and designs, and have many uses and applications in electronic circuits. But while electrical relays can be used to allow low power electronic or computer type circuits to switch relatively high currents or voltages both “ON” or “OFF”, some form of **relay switch circuit** is required to control it.

The design and types of relay switching circuits is huge, but many small electronic projects use transistors and MOSFETs as their main switching device as the transistor can provide fast DC switching (ON-OFF) control of the relay coil from a variety of input sources so here is a small collection of some of the more common ways of switching relays.

Applications of Relay

- Commonly used in switching circuits.
- For Home Automation projects to switch AC loads
- To Control (On/Off) Heavy loads at a pre-determined time/condition
- Used in safety circuits to disconnect the load from supply in event of failure
- Used in Automobiles electronics for controlling indicators glass motors etc.