N-Type Semi-conductors

From: http://en.wikipedia.org/wiki/N-type_semiconductor

An **N-type semiconductor** (N for *Negative*) is a material obtained by carrying out a process of doping, that is, by adding some amount of an element with more electrons to a semiconductor element with fewer electrons, in order to increase the number of free charge carriers. In this case the charge carriers are negatively-charged, hence "N-type". The impurity is called a "donor material," because it gives away (donates) weakly-bound outer electrons to the semiconductor atoms. The resulting impure crystal compound has useful conduction characteristics.[*citation needed*]

The purpose of **N-type doping** is to produce an abundance of mobile or "carrier" electrons in the material. To help understand how N-type doping is accomplished, consider the case of silicon (Si). Si atoms have four valence electrons, each of which is covalently bonded with each of the four adjacent Si atoms. If an atom with five valence electrons, such as those from group 15 (old group VA, a.k.a. nitrogen group) of the periodic table (eg. phosphorus (P), arsenic (As), or antimony (Sb)), is incorporated into the crystal lattice in place of a Si atom, then that atom will have four covalent bonds and one unbonded electron. This extra electron is only weakly bound to the atom and can easily be excited into the conduction band. At normal temperatures, virtually all such electrons are excited into the conduction band. Since excitation of these electrons does not result in the formation of a hole, the number of electrons in such a material far exceeds the number of holes. In this case the electrons are the *majority carriers* and the holes are the *minority carriers*. Because the five-electron atoms have an extra electron to "donate", they are called donor atoms. Note that each movable electron within the semiconductor is never far from an immobile positive dopant ion, and the N-doped material normally has a net electric charge of zero.

To a first approximation, a sufficiently doped N-type semiconductor can be thought of as only conducting electrons.[*citation needed*]

In an N-type semiconductor, the fermi level lies closer to the conduction band edge.[*citation needed*]

From: http://www.tpub.com/content/neets/14179/css/14179_26.htm

N-Type Semiconductor The N-type impurity loses its extra valence electron easily when added to a semiconductor material, and in so doing, increases the conductivity of the material by contributing a free electron. This type of impurity has 5 valence electrons and is called a PENTAVALENT impurity. Arsenic, antimony, bismuth, and phosphorous are pentavalent impurities. Because these materials give or donate one electron to the doped material, they are also called DONOR impurities. When a pentavalent (donor) impurity, like arsenic, is added to germanium, it will form covalent bonds with the germanium atoms. Figure 1-10 illustrates this by showing an arsenic atom (AS) in a germanium (GE) lattice structure. Notice the arsenic atom in the center of the lattice. It has 5 valence electrons in its outer shell but uses only 4 of them to form covalent bonds with the germanium atoms, leaving 1 electron relatively free in the crystal structure. Pure germanium may be converted into an N-type semiconductor by "doping" it with any donor impurity having 5 valence electrons in its outer shell. Since this type of semiconductor (N-type) has a surplus of electrons, the electrons are considered MAJORITY carriers, while the holes, being few in number, are the MINORITY carriers.

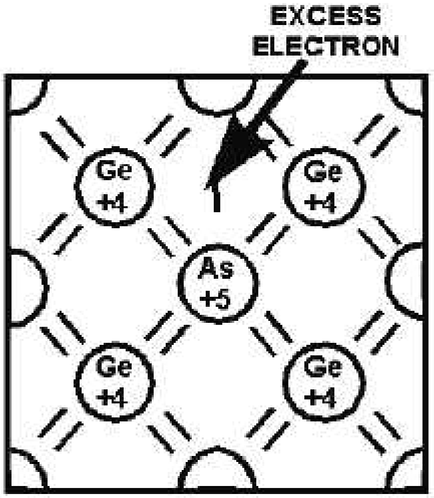


Figure 1-10.—Germanium crystal doped with arsenic.

P Type Semiconductor

From: http://en.wikipedia.org/wiki/P-type_semiconductor

A **P-type semiconductor** (P for *Positive*) is obtained by carrying out a process of doping, that is adding a certain type of atoms to the semiconductor in order to increase the number of free charge carriers (in this case positive).

When the doping material is added, it takes away (accepts) weakly-bound outer electrons from the semiconductor atoms. This type of doping agent is also known as an *acceptor material* and the vacancy left behind by the electron is known as a *hole*.

The purpose of **P-type doping** is to create an abundance of holes. In the case of silicon, a trivalent atom (typically from group IIIA of the periodic table, such as boron or aluminium) is substituted into the crystal lattice. The result is that one electron is missing from one of the four covalent bonds normal for the silicon lattice. Thus the dopant atom can accept an electron from a neighboring atom's covalent bond to complete the fourth bond. This is why such dopants are called acceptors. The dopant atom accepts an electron, causing the loss of half of one bond from the neighboring atom and resulting in the formation of a "hole". Each hole is associated with a nearby negatively-charged dopant ion, and the semiconductor remains electrically neutral as a whole. However, once each hole has wandered away into the lattice, one proton in the atom at the hole's location will be "exposed" and no longer cancelled by an electron. For this reason a hole behaves as a quantity of positive charge. When a sufficiently large number of acceptor atoms are added, the holes greatly outnumber the thermally-excited electrons. Thus, the holes are the *majority carriers*, while electrons are the *minority carriers* in P-type materials. Blue diamonds (Type IIb), which contain boron (B) impurities, are an example of a naturally occurring P-type semiconductor.

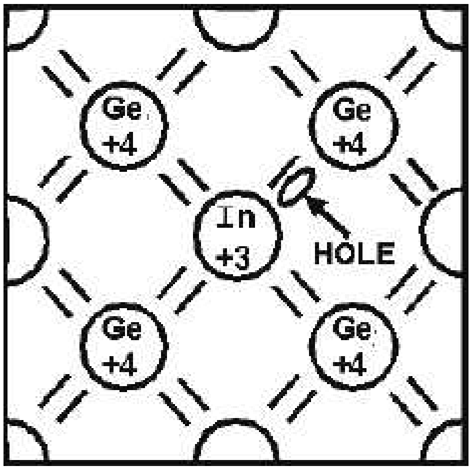
Therefore, to a first approximation, sufficiently doped P-type semiconductors can be thought of as only conducting holes.

From: http://www.tpub.com/content/neets/14179/css/14179_26.htm

P-Type Semiconductor The second type of impurity, when added to a semiconductor material, tends to compensate for its deficiency of 1 valence electron by acquiring an electron from its neighbor. Impurities of this type have only 3 valence electrons and are called TRIVALENT impurities. Aluminum, indium, gallium, and boron are trivalent impurities. Because these materials accept 1 electron from the doped material, they are also called ACCEPTOR impurities. A trivalent (acceptor) impurity element can also be used to dope germanium. In this case, the impurity is 1 electron short of the required amount of electrons needed to establish covalent bonds with 4 neighboring atoms. Thus, in a single covalent bond, there will be only 1 electron instead of 2. This arrangement leaves a hole in that covalent bond.

From: http://www.tpub.com/content/neets/14179/css/14179_50.htm

A **P-TYPE SEMICONDUCTOR** is one which is doped with a P-TYPE or acceptor impurity (an impurity that reduces the number of free electrons causing more holes). The holes in this type semiconductor are the majority current carriers since they are present in the greatest quantity while the electrons are the minority current carriers.

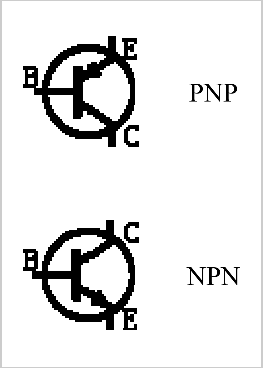


The **SEMICONDUCTOR DIODE**, also known as **a PN JUNCTION DIODE**, is a two-element semiconductor device that makes use of the rectifying properties of a PN junction to convert alternating current into direct current by permitting current flow in only one direction.

Bipolar Junction Transistor

From: http://en.wikipedia.org/wiki/Bipolar_junction_transistor

A **bipolar (junction) transistor** (**BJT**) is a three-terminal electronic device constructed of doped semiconductor material and may be used in amplifying or switching applications. *Bipolar* transistors are so named because their operation involves both electrons and holes. Charge flow in a BJT is due to bidirectional diffusion of charge carriers across a junction between two regions of different charge concentrations. This mode of operation is contrasted with *unipolar transistors*, such as field-effect transistors, in which only one carrier type is involved in charge flow due to drift. By design, most of the BJT collector current is due to the flow of charges injected from a high-concentration emitter into the base where they are minority carriers that diffuse toward the collector, and so BJTs are classified as *minority-carrier* devices.



From: http://www.electronics-tutorials.ws/transistor/tran_1.html

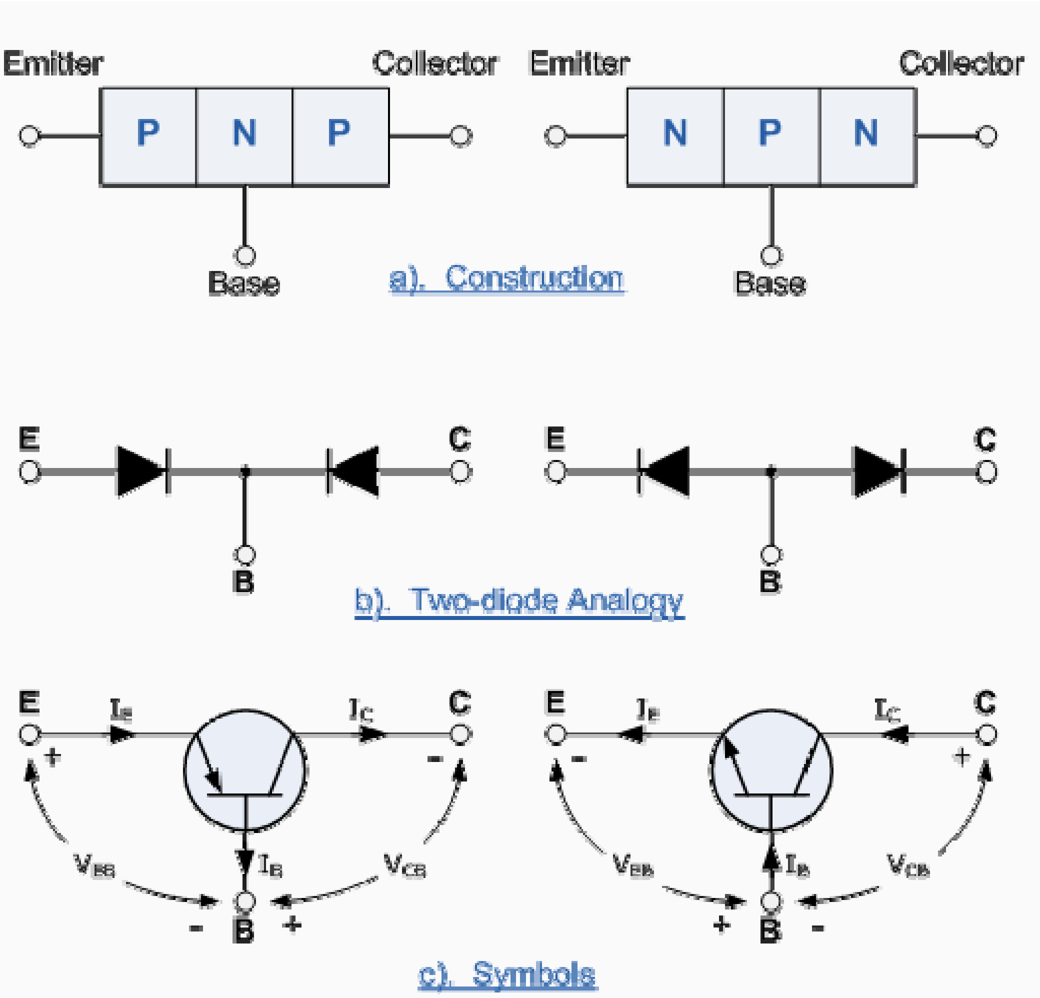
Bipolar Transistor Basics

In the **Diode** tutorials we saw that simple diodes are made up from two pieces of semiconductor material, either Silicon or Geranium to form a simple PN-junction and we also learnt about their properties and characteristics. If we now join together two individual diodes end to end giving two PN-junctions connected together in series, we now have a three layer, two junction, three terminal device forming the basis of a **Bipolar Junction Transistor**, or **BJT** for short. This type of transistor is generally known as a **Bipolar Transistor**, because its basic construction consists of two PN-junctions with each terminal or connection being given a name to identify it and these are known as the Emitter, Base and Collector respectively.

The word Transistor is an acronym, and is a combination of the words Transfer Varistor used to describe their mode of operation way back in their early days of development. There are two basic types of bipolar transistor construction, NPN and PNP, which basically describes the physical arrangement of the P-type and

N-type semiconductor materials from which they are made. Bipolar Transistors are "CURRENT" Amplifying or current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing current applied to their base terminal. The principle of operation of the two transistor types NPN and PNP, is exactly the same the only difference being in the biasing (base current) and the polarity of the power supply for each type.

Bipolar Transistor Construction



a). Construction

b). Two-diode Analogy

c). Symbols

The construction and circuit symbols for both the NPN and PNP bipolar transistor are shown above with the arrow in the circuit symbol always showing the direction of conventional current flow between the base terminal and its emitter terminal, with the direction of the arrow pointing from the positive P-type region to the negative N-type region, exactly the same as for the standard diode symbol.

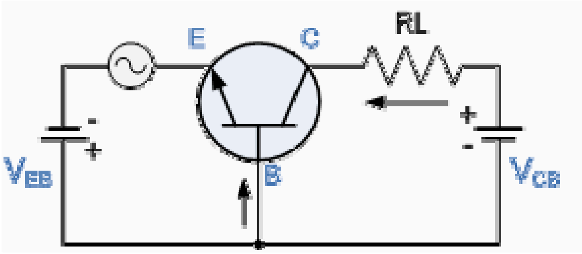
There are basically three possible ways to connect a **Bipolar Transistor** within an electronic circuit with each method of connection responding differently to its input signal as the static characteristics of the transistor vary with each circuit arrangement.

- 1. Common Base Configuration - has Voltage Gain but no Current Gain.
-
- 2. Common Emitter Configuration - has both Current and Voltage Gain.
-
- 3. Common Collector Configuration - has Current Gain but no Voltage Gain.

The Common Base Configuration.

As its name suggests, in the **Common Base** or Grounded Base configuration, the BASE connection is common to both the input signal AND the output signal with the input signal being applied between the base and the emitter terminals. The corresponding output signal is taken from between the base and the collector terminals as shown with the base terminal grounded or connected to a fixed reference voltage point. The input current flowing into the emitter is quite large as its the sum of both the base current and collector current respectively therefore, the collector current output is less than the emitter current input resulting in a Current Gain for this type of circuit of less than "1", or in other words it "Attenuates" the signal.

The Common Base Amplifier Circuit



This type of amplifier configuration is a non-inverting voltage amplifier circuit, in that the signal voltages Vin and Vout are In-Phase. This type of arrangement is not very common due to its unusually high voltage gain characteristics. Its Output characteristics represent that of a forward biased diode while the Input characteristics represent that of an illuminated photo-diode. Also this type of configuration has a high ratio of Output to Input resistance or more importantly "Load" resistance (RL) to "Input" resistance (Rin) giving it a value of "Resistance Gain". Then the Voltage Gain for a common base can therefore be given as:

Common Base Voltage Gain

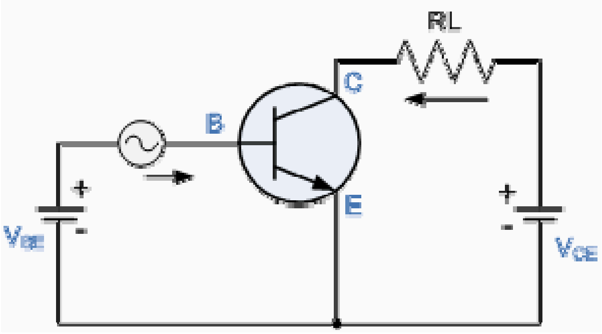
$$A_V = \frac{I_c \times R_L}{I_e \times R_{IN}} = \alpha \times \frac{R_L}{R_{IN}}$$

The Common Base circuit is generally only used in single stage amplifier circuits such as microphone pre-amplifier or RF radio amplifiers due to its very good high frequency response.

The Common Emitter Configuration.

In the **Common Emitter** or Grounded Emitter configuration, the input signal is applied between the base, while the output is taken from between the collector and the emitter as shown. This type of configuration is the most commonly used circuit for transistor based amplifiers and which represents the "normal" method of connection. The common emitter amplifier configuration produces the highest voltage, current and power gain of all the three bipolar transistor configurations. This is mainly because the input impedance is LOW as it is connected to a forward-biased junction, while the output impedance is HIGH as it is taken from a reverse-biased junction.

The Common Emitter Amplifier Circuit



In this type of configuration, the current flowing out of the transistor must be equal to the currents flowing into the transistor as the emitter current is given as Ie = Ic + Ib. Also, as the load resistance (RL) is connected in series with the collector, the Current gain of the Common Emitter Transistor Amplifier is quite large as it is the ratio of Ic/Ib and is given the symbol of Beta, (β). Since the relationship between these three currents is determined by the transistor itself, any small change in the base current will result in a large change in the collector current. Then, small changes in base current will thus control the current in the Emitter/Collector circuit.

By combining the expressions for both Alpha, α and Beta, β the mathematical relationship between these parameters and therefore the current gain of the amplifier can be given as:

$$I_E = I_C + I_B$$

$$\alpha = \frac{I_C}{I_E} \quad \text{and} \quad \beta = \frac{I_C}{I_B}$$

$$\alpha = \frac{\beta}{\beta + 1} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

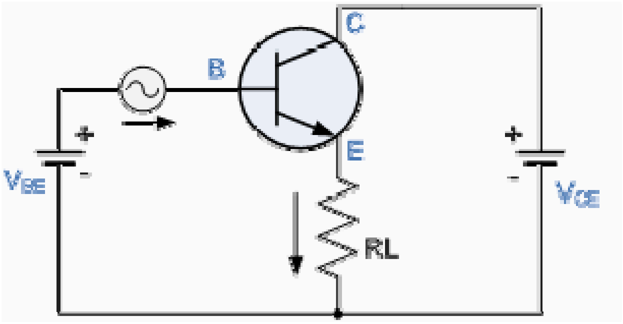
Where: "Ic" is the current flowing into the collector terminal, "Ib" is the current flowing into the base terminal and "Ie" is the current flowing out of the emitter terminal.

Then to summarise, this type of bipolar transistor configuration has a greater input impedance, Current gain and Power gain than that of the common base configuration but its Voltage gain is much lower. The common emitter is an inverting amplifier circuit resulting in the output signal being 180^{o} out of phase with the input voltage signal.

The Common Collector Configuration.

In the **Common Collector** or Grounded Collector configuration, the collector is now common and the input signal is connected to the base, while the output is taken from the emitter load as shown. This type of configuration is commonly known as a **Voltage Follower** or **Emitter Follower** circuit. The emitter follower configuration is very useful for impedance matching applications because of the very high input impedance, in the region of hundreds of thousands of Ohms, and it has relatively low output impedance.

The Common Collector Amplifier Circuit



The common emitter configuration has a current gain equal to the β value of the transistor itself. In the common collector configuration the load resistance is situated in series with the emitter so its current is equal to that of the emitter current. As the emitter current is the combination of the collector AND base currents combined, the load resistance in this type of amplifier configuration also has both the collector current and the input current of the base flowing through it. Then the current gain of the circuit is given as:

$$I_E = I_C + I_B$$

$$A_i = \frac{I_E}{I_B} = \frac{I_C + I_B}{I_B}$$

$$A_i = \frac{I_C}{I_B} + 1$$

$$\therefore\ A_i = \beta + 1$$

This type of bipolar transistor configuration is a non-inverting amplifier circuit in that the signal voltages of Vin and Vout are "In-Phase". It has a voltage gain that is always less than "1" (unity). The load resistance of the common collector amplifier configuration receives both the base and collector currents giving a large current gain (as with the Common Emitter configuration) therefore, providing good current amplification with very little voltage gain.

Bipolar Transistor Summary.

The behaviour of the bipolar transistor in each one of the above circuit configurations is very different and produces different circuit characteristics with regards to Input impedance, Output impedance and Gain and this is summarised in the table below.

Transistor Characteristics

The static characteristics for **Bipolar Transistor** amplifiers can be divided into the following main groups.

Input Characteristics:-	Common Base -	$I_E \div V_{EB}$
	Common Emitter -	$I_B \div V_{BE}$
Output Characteristics:-	Common Base -	$I_C \div V_C$
	Common Emitter -	$I_C \div V_C$

Transfer Characteristics:-	
	Common Base - $I_E \div I_C$
	Common Emitter - $I_B \div I_C$

with the characteristics of the different transistor configurations given in the following table:

Characteristic	Common Base	Common Emitter	Common Collector
Input impedance	Low	Medium	High
Output impedance	Very High	High	Low
Phase Angle	0^o	180^o	0^o
Voltage Gain	High	Medium	Low
Current Gain	Low	Medium	High
Power Gain	Low	Very High	Medium

FET & FET Depletion

From: http://en.wikipedia.org/wiki/Field-effect_transistor#FET_operation

The FET controls the flow of electrons (or electron holes) from the source to drain by affecting the size and shape of a "conductive channel" created and influenced by voltage (or lack of voltage) applied across the gate and source terminals. (For ease of discussion, this assumes body and source are connected). This conductive channel is the "stream" through which electrons flow from source to drain.

Consider an **n-channel "depletion-mode" device**. A negative gate-to-source voltage causes a *depletion region* to expand in width and encroach on the channel from the sides, narrowing the channel. If the depletion region expands to completely close the channel, the resistance of the channel from source to drain becomes large, and the FET is effectively turned off like a switch. Likewise a positive gate-to-source voltage increases the channel size and allows electrons to flow easily.

Now consider an **n-channel "enhancement-mode" device**. A positive gate-to-source voltage is necessary to create a conductive channel, since one does not exist naturally within the transistor. The positive voltage attracts free-floating electrons within the body towards the gate, forming a conductive channel. But first, enough electrons must be attracted near the gate to counter the dopant ions added to the body of the FET; this forms a region free of mobile carriers called a depletion region, and the phenomenon is referred to as the *threshold voltage* of the FET. Further gate-to-source voltage increase will attract even more electrons towards the gate which are able to create a conductive channel from source to drain; this process is called *inversion*.

For either enhancement- or depletion-mode devices, at drain-to-source voltages much less than gate-to-source voltages, changing the gate voltage will alter the channel resistance, and drain current will be proportional to drain voltage (referenced to source voltage). In this mode the FET operates like a variable resistor and the FET is said to be operating in a *linear mode* or *ohmic mode*.[1][2]

If drain-to-source voltage is increased, this creates a significant asymmetrical change in the shape of the channel due to a gradient of voltage potential from source to drain. The shape of the inversion region becomes "pinched-off" near the drain end of the channel. If drain-to-source voltage is increased further, the pinch-off point of the channel begins to move away from the drain towards the source. The FET is said to be in *saturation mode*;[3] some authors refer to it as *active mode*, for a better analogy with bipolar transistor operating regions.[4][5] The saturation mode, or the region between ohmic and saturation, is used when amplification is needed. The in-between region is sometimes considered to be part of the ohmic or linear region, even where drain current is not approximately linear with drain voltage.

Even though the conductive channel formed by gate-to-source voltage no longer connects source to drain during saturation mode, carriers are not blocked from flowing. Considering again an n-channel device, a depletion region exists in the p-type body, surrounding the conductive channel and drain and source regions. The electrons which comprise the channel are free to move out of the channel through the depletion region if attracted to the drain by drain-to-source voltage. The depletion region is free of carriers and has a resistance similar to silicon. Any increase of the drain-to-source voltage will increase the distance from drain to the pinch-off point, increasing resistance due to the depletion region proportionally to the applied drain-to-source voltage. This proportional change causes the drain-to-source current to remain relatively fixed independent of changes to the drain-to-source voltage and quite unlike the linear mode operation. Thus in saturation mode, the FET behaves as a constant-current source rather than as a resistor and can be used most effectively as a voltage amplifier. In this case, the gate-to-source voltage determines the level of constant current through the channel.

From: http://en.wikipedia.org/wiki/Field-effect_transistor

The **field-effect** **transistor** (FET) relies on an electric field to control the shape and hence the conductivity of a channel of one type of charge carrier in a semiconductor material. FETs are sometimes called *unipolar transistors* to contrast their single-carrier-type operation with the dual-carrier-type operation of bipolar (junction) transistors (BJT). The *concept* of the FET predates the BJT, though it was not physically implemented until *after* BJTs due to the limitations of semiconductor materials and the relative ease of manufacturing BJTs compared to FETs at the time.

High-power N-channel field-effect transistor

MOSFET

From: http://en.wikipedia.org/wiki/MOSFET

The **metal–oxide–semiconductor field-effect transistor** (**MOSFET**, **MOS-FET**, or **MOS FET**) is a device used to amplify or switch electronic signals. The basic principle of the device was first proposed by Julius Edgar Lilienfeld in 1925. The MOSFET includes a channel of n-type or p-type semiconductor material (see article on semiconductor devices), and is accordingly called an NMOSFET or a PMOSFET (also commonly nMOS, pMOS). It is by far the most common transistor in both digital and analog circuits, though the bipolar junction transistor was at one time much more common.

Two power MOSFETs in the surface-mount package D2PAK. Each of these components can sustain a blocking voltage of 120 volts and a continuous current of 30 amperes. A matchstick is pictured for scale.

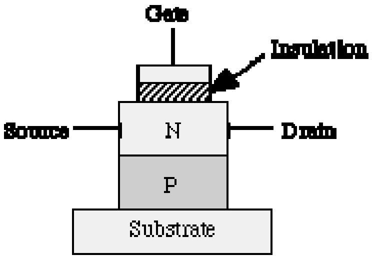
From: http://encyclobeamia.solarbotics.net/articles/mosfet.html

Metal **O**xide **S**emiconductor **F**ield **E**ffect **T**ransistor.

A class of voltage-driven devices that do not require the large input drive currents of bipolar devices; a type of field-effect transistor that operates and functions similar to a junction field effect transistor (JFET). The distinction is that in the MOS device the controlling gate voltage is applied to the channel region across an oxide insulating material, rather than across a P-N junction. The term can be applied either to transistors in an IC or to discrete transistors. The major advantage of a MOSFET is low power due to its insulation from source and drain. MOSFETs are of both P-channel and N-channel types. Sometimes called "insulated gate field effect transistor" (IGFET).

Schematic symbols for an N-channel MOSFET

Schematic symbols for a P-channel MOSFET



Structure of an N-channel MOSFET

Diodes

From: http://en.wikipedia.org/wiki/Diode

In electronics, a **diode** is a two-terminal P-N junction device (thermionic diodes may also have one or two ancillary terminals for a heater).

Diodes have two active electrodes between which the signal of interest may flow, and most are used for their unidirectional electric current property.

The unidirectionality most diodes exhibit is sometimes generically called the *rectifying* property. The most common function of a diode is to allow an electric current in one direction (called the *forward biased* condition) and to block the current in the opposite direction (the *reverse biased* condition). Thus, the diode can be thought of as an electronic version of a check valve.

Real diodes do not display such a perfect on-off directionality but have a more complex non-linear electrical characteristic, which depends on the particular type of diode technology. Diodes also have many other functions in which they are not designed to operate in this on-off manner.

Early diodes included "cat's whisker" crystals and vacuum tube devices (also called thermionic valves). Today most diodes are made of silicon, but other semiconductors such as germanium are sometimes used.

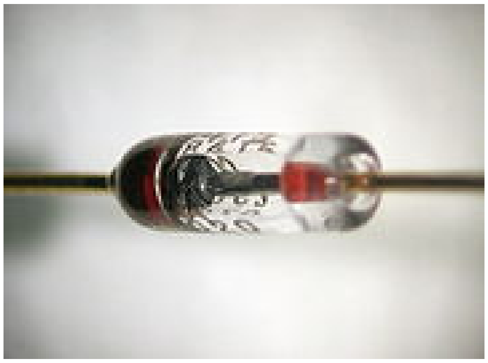


Figure 1: Closeup of a diode, showing the square shaped semiconductor crystal

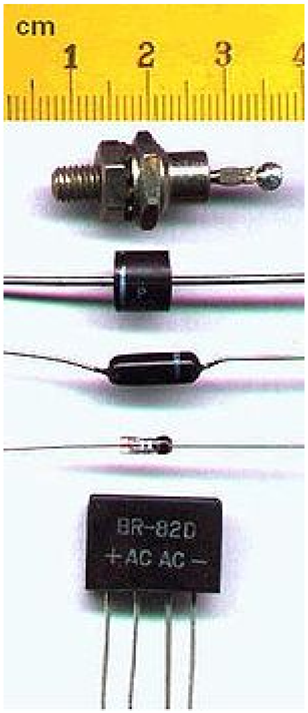


Figure 2: Various semiconductor diodes. Bottom: A bridge rectifier

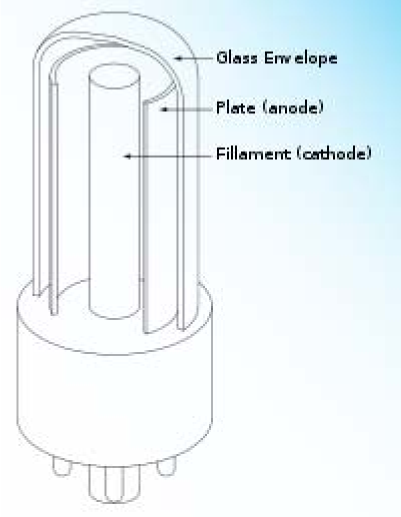


Figure 3: Structure of a vacuum tube diode

Zener Diodes

From: http://en.wikipedia.org/wiki/Zener_diode

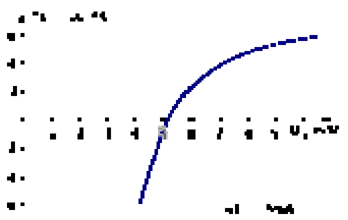
A **Zener diode** is a type of diode that permits current in the forward direction like a normal diode, but also in the reverse direction if the voltage is larger than the breakdown voltage known as "Zener knee voltage" or "Zener voltage". The device was named after Clarence Zener, who discovered this electrical property.

A conventional solid-state diode will not allow significant current if it is reverse-biased below its reverse breakdown voltage. When the reverse bias breakdown voltage is exceeded, a conventional diode is subject to high current due to avalanche breakdown. Unless this current is limited by external circuitry, the diode will be permanently damaged. In case of large forward bias (current in the direction of the arrow), the diode exhibits a voltage drop due to its junction built-in voltage and internal resistance. The amount of the voltage drop depends on the semiconductor material and the doping concentrations.

A **Zener diode** exhibits almost the same properties, except the device is specially designed so as to have a greatly reduced breakdown voltage, the so-called **Zener voltage**. A Zener diode contains a heavily doped p-n junction allowing electrons to tunnel from the valence band of the p-type material to the conduction band of the n-type material. In the atomic scale, this tunneling corresponds to the transport of valence band electrons into the empty conduction band states; as a result of the reduced barrier between these bands and high electric fields that are induced due to the relatively high levels of dopings on both sides. A reverse-biased Zener diode will exhibit a controlled breakdown and allow the current to keep the voltage across the Zener diode at the Zener voltage. For example, a diode with a Zener breakdown voltage of 3.2 V will exhibit a voltage drop of 3.2 V if reverse bias voltage applied across it is more than its Zener voltage. However, the current is not unlimited, so the Zener diode is typically used to generate a reference voltage for an amplifier stage, or as a voltage stabilizer for low-current applications.

The breakdown voltage can be controlled quite accurately in the doping process. While tolerances within 0.05% are available, the most widely used tolerances are 5% and 10%.

Another mechanism that produces a similar effect is the avalanche effect as in the avalanche diode. The two types of diode are in fact constructed the same way and both effects are present in diodes of this type. In silicon diodes up to about 5.6 volts, the Zener effect is the predominant effect and shows a marked negative temperature coefficient. Above 5.6 volts, the avalanche effect becomes predominant and exhibits a positive temperature coefficient.

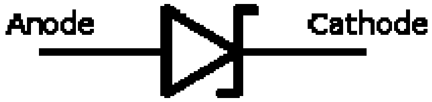


TC depending on zener voltage

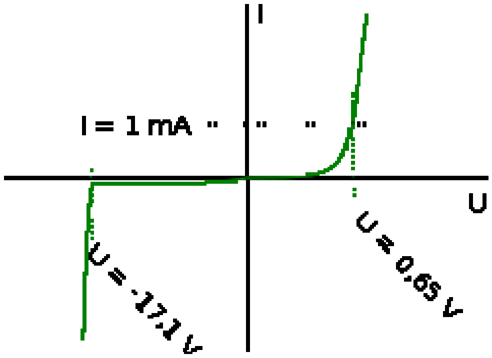
In a 5.6 V diode, the two effects occur together and their temperature coefficients neatly cancel each other out, thus the 5.6 V diode is the component of choice in temperature-critical applications.

Modern manufacturing techniques have produced devices with voltages lower than 5.6 V with negligible temperature coefficients, but as higher voltage devices are encountered, the temperature coefficient rises dramatically. A 75 V diode has 10 times the coefficient of a 12 V diode.

All such diodes, regardless of breakdown voltage, are usually marketed under the umbrella term of "Zener diode".



Zener diode schematic symbol



Current-voltage characteristic of a Zener diode with a breakdown voltage of 17 volt. Notice the change of voltage scale between the forward biased (positive) direction and the reverse biased (negative) direction.

Tunnel Diode

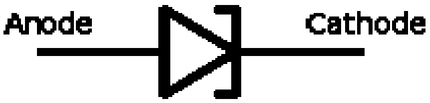
From: http://en.wikipedia.org/wiki/Tunnel_diode

A **tunnel diode** or **Esaki diode** is a type of semiconductor diode which is capable of very fast operation, well into the microwave frequency region, by using quantum mechanical effects.

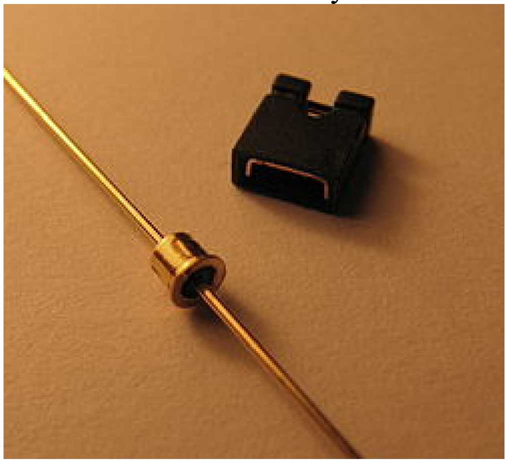
It was invented in August 1957 by Leo Esaki when he was with Tokyo Tsushin Kogyo (now known as Sony), who in 1973 received the Nobel Prize in Physics for discovering the electron tunneling effect used in these diodes.

These diodes have a heavily doped p–n junction only some 10 nm (100 Å) wide. The heavy doping results in a broken bandgap, where conduction band electron states on the n-side are more or less aligned with valence band hole states on the p-side.

Tunnel diodes were manufactured by SONY for the first time in 1957[1] followed by General Electric and other companies from about 1960, and are still made in low volume today.[2] Tunnel diodes are usually made from germanium, but can also be made in gallium arsenide and silicon materials. They can be used as oscillators, amplifiers, frequency converters and detectors.[3]:7–35



Tunnel diode schematic symbol



1N3716 tunnel diode (with jumper for scale)

Schottky Diodes

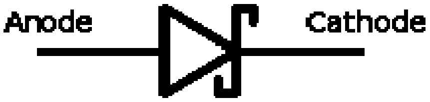
From: http://en.wikipedia.org/wiki/Schottky_diode

"Schottky effect" redirects here. For the enhancement of thermionic emission with applied voltage, see Thermionic emission.

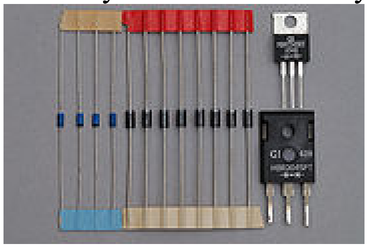
The **Schottky diode** (named after German physicist Walter H. Schottky; also known as **hot carrier diode**) is a semiconductor diode with a low forward voltage drop and a very fast switching action. The cat's-whisker detectors used in the early days of wireless can be considered as primitive Schottky diodes.

A Schottky diode is a special type of diode with a very low forward-voltage drop. When current flows through a diode there is a small voltage drop across the diode terminals. A normal diode has between 0.7-1.7 volt drops, while a Schottky diode voltage drop is between approximately 0.15-0.45 – this lower voltage drop translates into higher system efficiency

Jump to: navigation, search



Schottky diode schematic symbol



Various Schottky barrier diodes: Small signal rf devices (left), medium and high power Schottky rectifying diodes (middle and right).

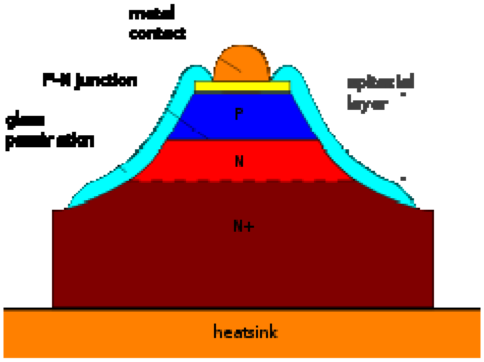
Varactor Diodes

From: http://en.wikipedia.org/wiki/Varicap

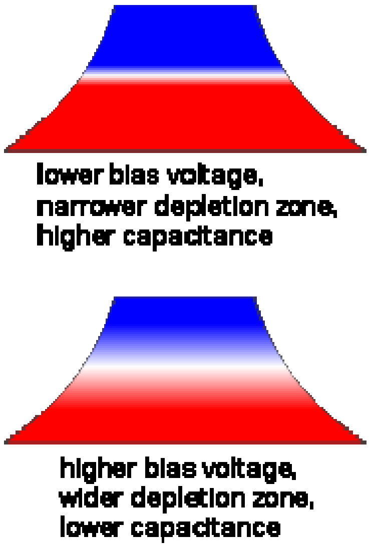
In electronics, a **varicap diode**, **varactor diode**, **variable capacitance diode**, **variable reactance diode** or **tuning diode** is a type of diode which has a variable capacitance that is a function of the voltage impressed on its terminals.

Varicap schematic symbol

[edit] Operation



Internal structure of a varicap



Operation of a varicap

Varactors are operated reverse-biased so no current flows, but since the thickness of the depletion zone varies with the applied bias voltage, the capacitance of the diode can be made to vary. Generally, the depletion region thickness is proportional to the square root of the applied voltage; and capacitance is inversely proportional to the depletion region thickness. Thus, the capacitance is inversely proportional to the square root of applied voltage.

All diodes exhibit this phenomenon to some degree, but specially made varactor diodes exploit the effect to boost the capacitance and variability range achieved - most diode fabrication attempts to achieve the opposite.

In the figure we can see an example of a crossection of a varactor with the depletion layer formed of a p-n-junction. But the the depletion layer can also be made of a MOS-diode or a Schottky diode. This is of big importance in CMOS and MMIC technology.

TTL

From: http://en.wikipedia.org/wiki/Transistor%E2%80%93transistor_logic

Transistor–transistor logic (**TTL**) is a class of digital circuits built from bipolar junction transistors (BJT) and resistors. It is called *transistor–transistor logic* because both the logic gating function (e.g., AND) and the amplifying function are performed by transistors (contrast this with RTL and DTL).

TTL is notable for being a widespread integrated circuit (IC) family used in many applications such as computers, industrial controls, test equipment and instrumentation, consumer electronics, synthesizers, etc. The designation *TTL* is sometimes used to mean TTL-compatible logic levels, even when not associated directly with TTL integrated circuits, for example as a label on the inputs and outputs of electronic instruments.[1]

CMOS Logic

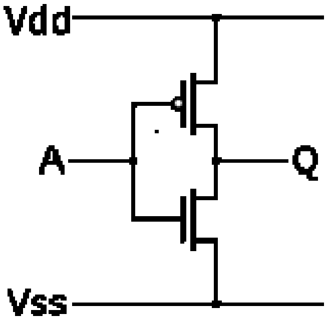
From: http://en.wikipedia.org/wiki/CMOS

Complementary metal–oxide–semiconductor (**CMOS**) (pronounced /ˈsiːmɒs/) is a technology for making integrated circuits. CMOS technology is used in microprocessors, microcontrollers, static RAM, and other digital logic circuits. CMOS technology is also used for a wide variety of analog circuits such as image sensors, data converters, and highly integrated transceivers for many types of communication. Frank Wanlass successfully patented CMOS in 1967 (US Patent 3,356,858).
CMOS is also sometimes referred to as **complementary-symmetry metal–oxide–semiconductor** (or COS-MOS). The words "complementary-symmetry" refer to the fact that the typical digital design style with CMOS uses complementary and symmetrical pairs of p-type and n-type metal oxide semiconductor field effect transistors (MOSFETs) for logic functions.

Two important characteristics of CMOS devices are high noise immunity and low static power consumption. Significant power is only drawn when the transistors in the CMOS device are switching between on and off states. Consequently, CMOS devices do not produce as much waste heat as other forms of logic, for example transistor-transistor logic (TTL) or NMOS logic, which uses all n-channel devices without p-channel devices. CMOS also allows a high density of logic functions on a chip. It was primarily this reason why CMOS won the race in the eighties and became the most used technology to be implemented in VLSI chips.

The phrase "metal–oxide–semiconductor" is a reference to the physical structure of certain field-effect transistors, having a metal gate electrode placed on top of an oxide insulator, which in turn is on top of a semiconductor material. Aluminum was once used but now the material is polysilicon. Other metal gates have made a comeback with the advent of high-k dielectric materials in the CMOS process, as announced by IBM and Intel for the 45 nanometer node and beyond [1].

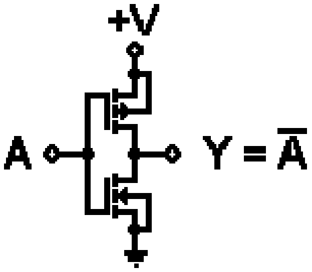
Besides these *static CMOS logic* circuits there are also dynamic CMOS logic circuits that have some advantages in certain circumstances. This article is dedicated to static logic circuits.



CMOS inverter (NOT logic gate)

From: http://www.play-hookey.com/digital/electronics/cmos_gates.html

CMOS logic is a newer technology, based on the use of complementary MOS transistors to perform logic functions with almost no current required. This makes these gates very useful in battery-powered applications. The fact that they will work with supply voltages as low as 3 volts and as high as 15 volts is also very helpful.



CMOS gates are all based on the fundamental inverter circuit shown to the left. Note that both transistors are enhancement-mode MOSFETs; one N-channel with its source grounded, and one P-channel with its source connected to +V. Their gates are connected together to form the input, and their drains are connected together to form the output.

The two MOSFETs are designed to have matching characteristics. Thus, they are complementary to each other. When off, their resistance is effectively infinite; when on, their channel resistance is about 200 Ω. Since the gate is essentially an open circuit it draws no current, and the output voltage will be equal to either ground or to the power supply voltage, depending on which transistor is conducting.

When input A is grounded (logic 0), the N-channel MOSFET is unbiased, and therefore has no channel enhanced within itself. It is an open circuit, and therefore leaves the output line disconnected from ground. At the same time, the P-channel MOSFET is forward biased, so it has a channel enhanced within itself. This channel has a resistance of about 200 Ω, connecting the output line to the +V supply. This pulls the output up to +V (logic 1).

When input A is at +V (logic 1), the P-channel MOSFET is off and the N-channel MOSFET is on, thus pulling the output down to ground (logic 0). Thus, this circuit correctly performs logic inversion, and at the same time provides active pull-up and pull-down, according to the output state.

Gates

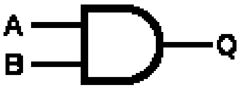
From: http://en.wikipedia.org/wiki/AND_gate

The **AND gate** is a digital logic gate that implements logical conjunction - it behaves according to the truth table to the right. A HIGH output (1) results only if both the inputs to the AND gate are HIGH (1). If neither or only one input to the AND gate is HIGH, a LOW output results. In another sense, the function of AND effectively finds the *minimum* between two binary digits, just as the OR function finds the *maximum*.

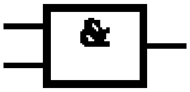
INPUT		**OUTPUT**
A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

Symbols

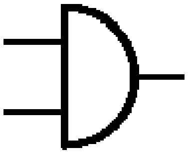
There are three symbols for AND gates: the American (ANSI or 'military') symbol and the IEC ('European' or 'rectangular') symbol, as well as the deprecated DIN symbol. For more information see Logic Gate Symbols.



MIL/ANSI Symbol



IEC Symbol



DIN Symbol

The AND gate with inputs *A* and *B* and output *C* implements the logical expression $C = A \cdot B$.

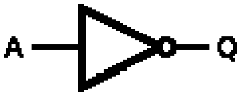
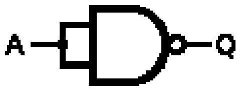
NAND Gate

From: http://en.wikipedia.org/wiki/NAND_logic

This article is about NAND Logic in the sense of building other logic gates using just NAND gates. For information on NAND Gates, see NAND gate. For NAND in the purely logical sense, see Logical NAND. For logic gates generally, see Logic gate.

NAND gates are one of the two basic logic gates (along with NOR gates) from which any other logic gates can be built. Due to this property, NAND and NOR gates are sometimes called "universal gates". However, contrary to popular belief, modern integrated circuits are not constructed exclusively from a single type of gate. Instead, EDA tools are used to convert the description of a logical circuit to a netlist of complex gates (standard cells) or transistors (full custom approach).

NOT gate is made by joining the inputs of a NAND gate. Since a NAND gate is equivalent to an AND gate followed by a NOT gate, joining the inputs of a NAND gate leaves only the NOT part.

Desired Gate	NAND Construction
	

Truth Table

Input A	Output Q
0	1
1	0

Bistable Circuit

From: http://en.wikipedia.org/wiki/Multivibrator

A **multivibrator** is an electronic circuit used to implement a variety of simple two-state systems such as light emitting diodes, timers and flip-flops. It is characterized by two amplifying devices (transistors, electron tubes or other devices) cross-coupled by resistors and capacitors.

There are three types of multivibrator circuit:

- **astable**, in which the circuit is not stable in either state—it continuously oscillates from one state to the other.
- **monostable**, in which one of the states is stable, but the other is not—the circuit will flip into the unstable state for a determined period, but will eventually return to the stable state. Such a circuit is useful for creating a timing period of fixed duration in response to some external event. This circuit is also known as a **one shot**. A common application is in eliminating switch bounce.
- **bistable**, in which the circuit will remain in either state indefinitely. The circuit can be flipped from one state to the other by an external event or trigger. Such a circuit is important as the fundamental building block of a register or memory device. This circuit is also known as a flip-flop.

In its simplest form the multivibrator circuit consists of two cross-coupled transistors. Using resistor-capacitor networks within the circuit to define the time periods of the unstable states, the various types may be implemented. Multivibrators find applications in a variety of systems where square waves or timed intervals are required. Simple circuits tend to be inaccurate since many factors affect their timing, so they are rarely used where very high precision is required.

Before the advent of low-cost integrated circuits, chains of multivibrators found use as frequency dividers. A free-running multivibrator with a frequency of one-half to one-tenth of the reference frequency would accurately lock to the reference frequency. This technique was used in early electronic organs, to keep notes of different octaves accurately in tune. Other applications included early television systems, where the various line and frame frequencies were kept synchronized by pulses included in the video signal.

Klystron

From: http://en.wikipedia.org/wiki/Klystron

A **klystron** is a specialized linear-beam vacuum tube (evacuated electron tube). Klystrons are used as amplifiers at microwave and radio frequencies to produce both low-power reference signals for superheterodyne radar receivers and to produce high-power carrier waves for communications and the driving force for modern particle accelerators.

Klystron amplifiers have the advantage (over the magnetron) of coherently amplifying a reference signal so its output may be precisely controlled in amplitude, frequency and phase. Many klystrons have a waveguide for coupling microwave energy into and out of the device, although it is also quite common for lower power and lower frequency klystrons to use coaxial couplings instead. In some cases a coupling probe is used to couple the microwave energy from a klystron into a separate external waveguide.
All modern klystrons are amplifiers, since reflex klystrons, which were used as oscillators in the past, have been surpassed by alternative technologies.

High-power klystron used at the Canberra Deep Space Communications Complex. (Klystrons used for generating heterodyne reference frequencies in radar receivers are about the size of a whiteboard pen.)

The pseudo-Greek word *klystron* comes from the stem form κλυσ- (*klys*) of a Greek verb referring to the action of waves breaking against a shore, and the end of the word *electron*.