

Semi Conductors

What
is a
SEMICONDUCTOR?

A person wearing a maroon sweater is using a yellow and black soldering iron to solder a component on a circuit board. The circuit board is placed on a wooden surface. A battery and some wires are also visible on the surface.

Semiconductors

Semiconductors are substances with a solid chemical element or compound that can conduct electricity under some conditions but not in others, making them ideal for the control of electrical current.

Its conductance varies depending on the current or voltage applied.

Semiconductors sit between **conductors and insulators**, being neither good conductors, nor good insulators. Semiconductor materials also contain

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electrons in their outer electron shell (valence shell).

Semiconductors

Most group 14 elements in the periodic table can be semiconductors. The arrangement of atoms in the semiconductor is very important, semiconductors must have a cubic crystal structure to function properly. Silicon or Germanium are the most common

Semiconductors

Materials

Semiconductors include, Arsenic, Boron, Carbon, Germanium, Silicon, Sulphur. Silicon is the best known of these, forming the basis of most integrated circuits (IC's).

Doping “P Type” Material

Two different types of semiconductor can be made by adding tiny amounts of impurities to the semiconductor material in a process known as doping.

One type of semiconductor is the P type which is made by adding a small amount of Boron.

Boron (B) is a group 13 element, that has 3 electrons in its outer shell, so when its added to the crystal structure it leaves a gap known as a '**hole**'.

Because of this it is known as an acceptor impurity because the hole can accept an electron.

Periodic Table of the Elements

Periodic Table of the Elements																		18						
1													13	14	15	16	17	2						
1IA	2A												3A	4A	5A	6A	7A	VIIIA						
1 H Hydrogen 1.0079	2 He Helium 4.00260												5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797						
3 Li Lithium 6.941	4 Be Beryllium 9.01218											11 Na Sodium 22.989768	12 Mg Magnesium 24.305											18 Ar Argon 39.948
		3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 Al Aluminum 26.981539	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Kr Krypton 83.80							
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.64	33 As Arsenic 74.92159	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80							
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98.9072	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29							
55 Cs Cesium 132.90543	56 Ba Barium 137.327	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium [208.9824]	85 At Astatine 209.9871	86 Rn Radon 222.0176							
87 Fr Francium 223.0197	88 Ra Radium 226.0254	89-103 Actinide Series	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Uuq Ununquadium [289]	115 Uup Ununpentium unknown	116 Uuh Ununhexium [288]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown							
		57 La Lanthanum 138.9055	58 Ce Cerium 140.115	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.9655	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967								
		89 Ac Actinium 227.0278	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium 237.0482	94 Pu Plutonium 244.0642	95 Am Americium 243.0614	96 Cm Curium 247.0703	97 Bk Berkelium 247.0703	98 Cf Californium 251.0796	99 Es Einsteinium [254]	100 Fm Fermium 257.0951	101 Md Mendelevium 258.1	102 No Nobelium 259.1009	103 Lr Lawrencium [262]								
		Alkali Metal	Alkaline Earth	Transition Metal	Basic Metal	Semimetals	Nonmetals	Halogens	Noble Gas	Lanthanides	Actinides													

Doping “N Type” Material

The other type is the N type semiconductor which is doped with Phosphorous (P) which is a group 15 element that has 5 electrons in its outer shell,

When added to the crystal structure it leaves a free electron, known as a donor impurity therefore has surplus electrons.

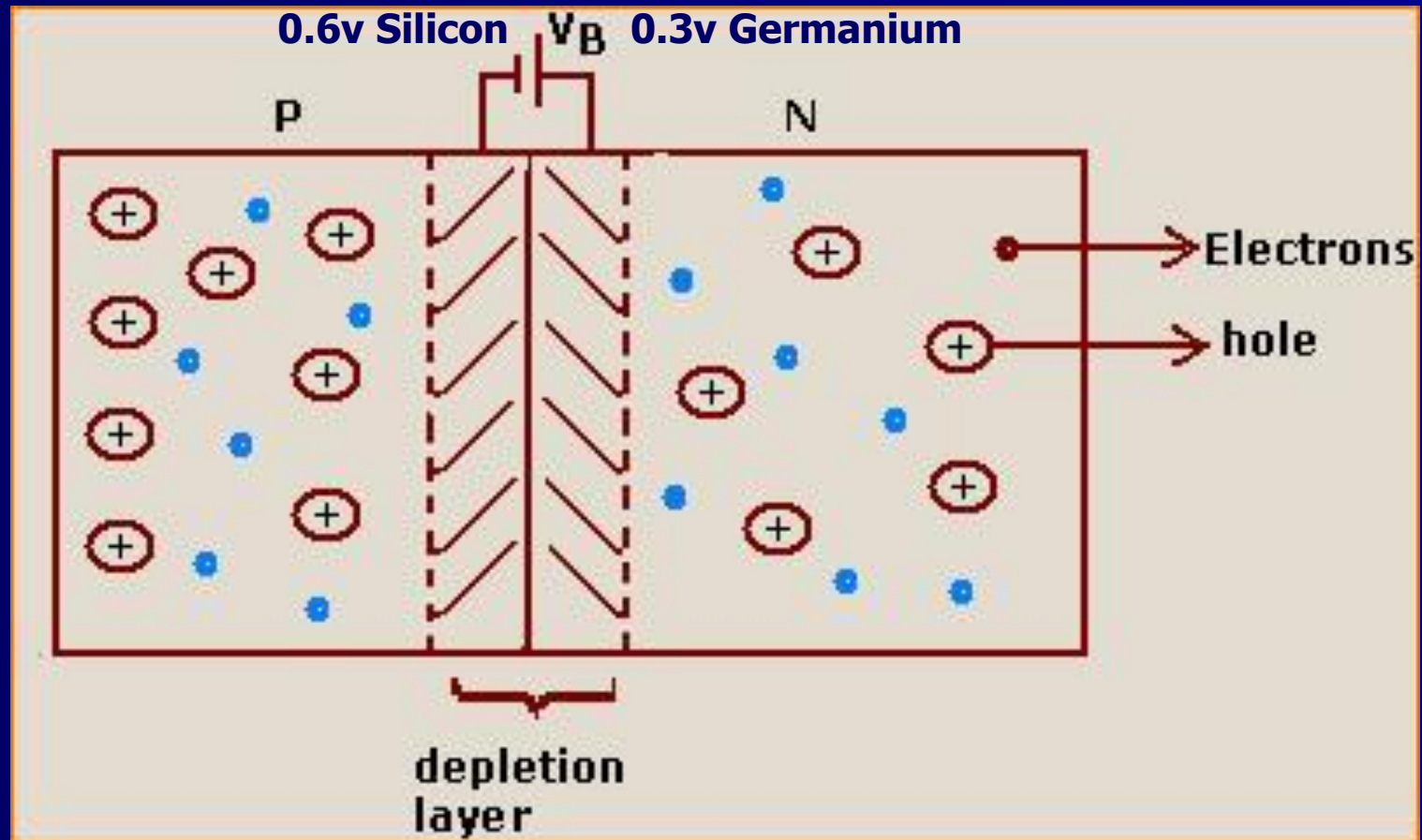
Diode

This semiconductor device is produced by placing the P type and N type semiconductor together.

This results in some of the electrons from the N material jumping over to fill some of the holes in the P material.

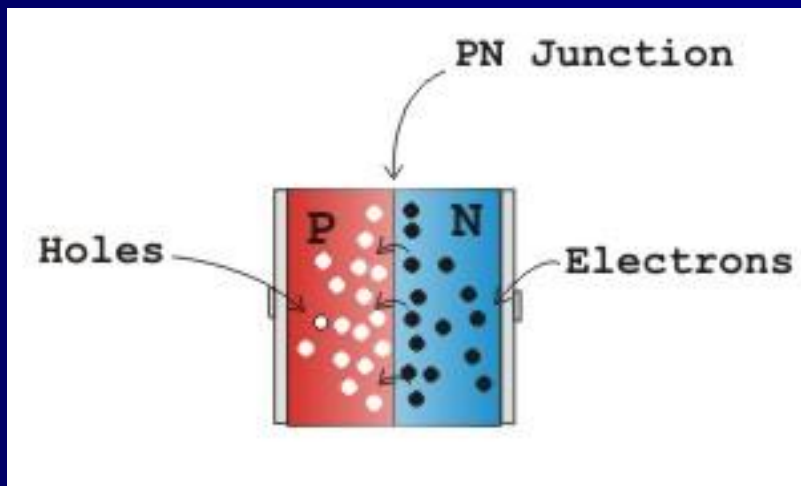
This results in a small region forming where the materials touch known as the depletion layer.

P N Junction



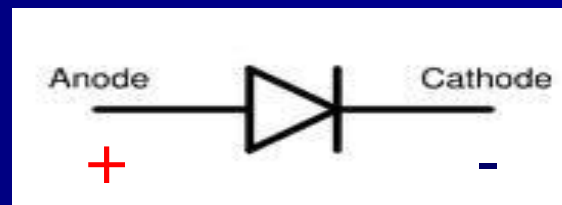
Depletion Layer

This depletion layer has a direct effect upon which direction current can flow through the junction. The PN junction diagram shown below indicates a barrier that has in fact been created by its depletion layer at the junction between the two materials



DI

ODE



Forward Biased Junction Diode

When a diode is connected in **Forward Bias**

i.e. negative side of a voltage is applied to the N-type material (Cathode) and a positive to the P-type material (Anode).

And this external voltage becomes greater than the value of the potential barrier, approx for silicon.

0.6 – 0.7 volts

& for germanium

0.3 volts

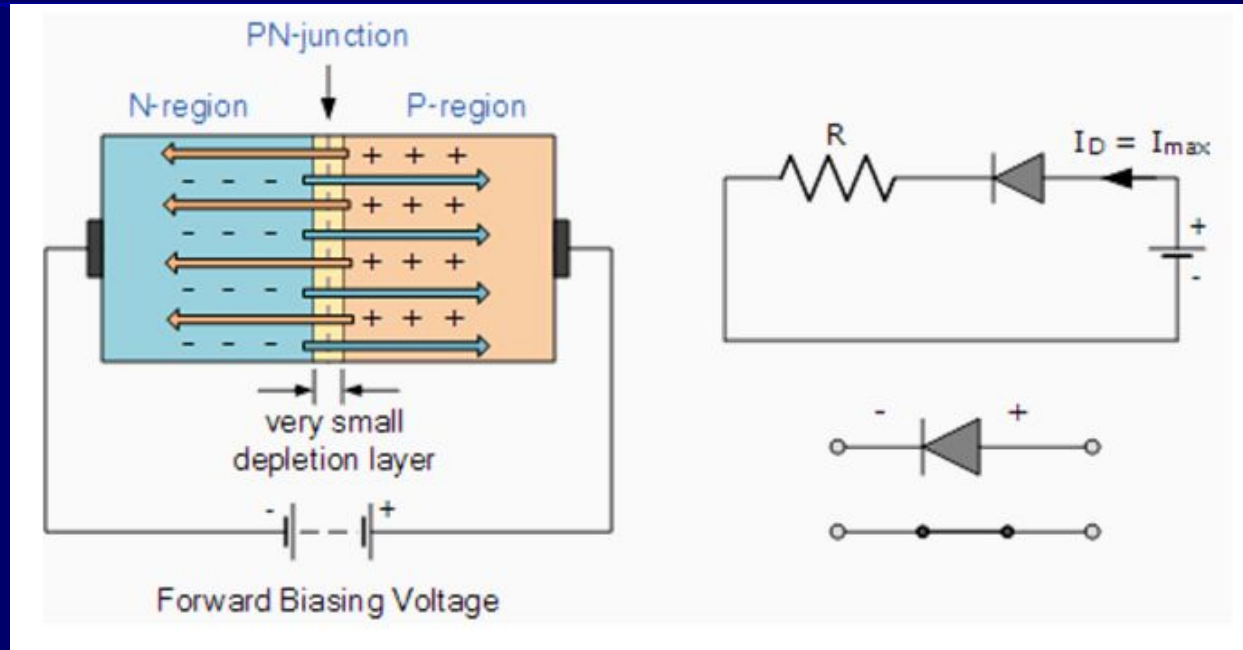
The potential barriers opposition will be overcome and current will start to flow.

Forward Biased Junction Diode

This results in a graphical characteristics curve of zero current flowing up to this voltage point, called the "knee"

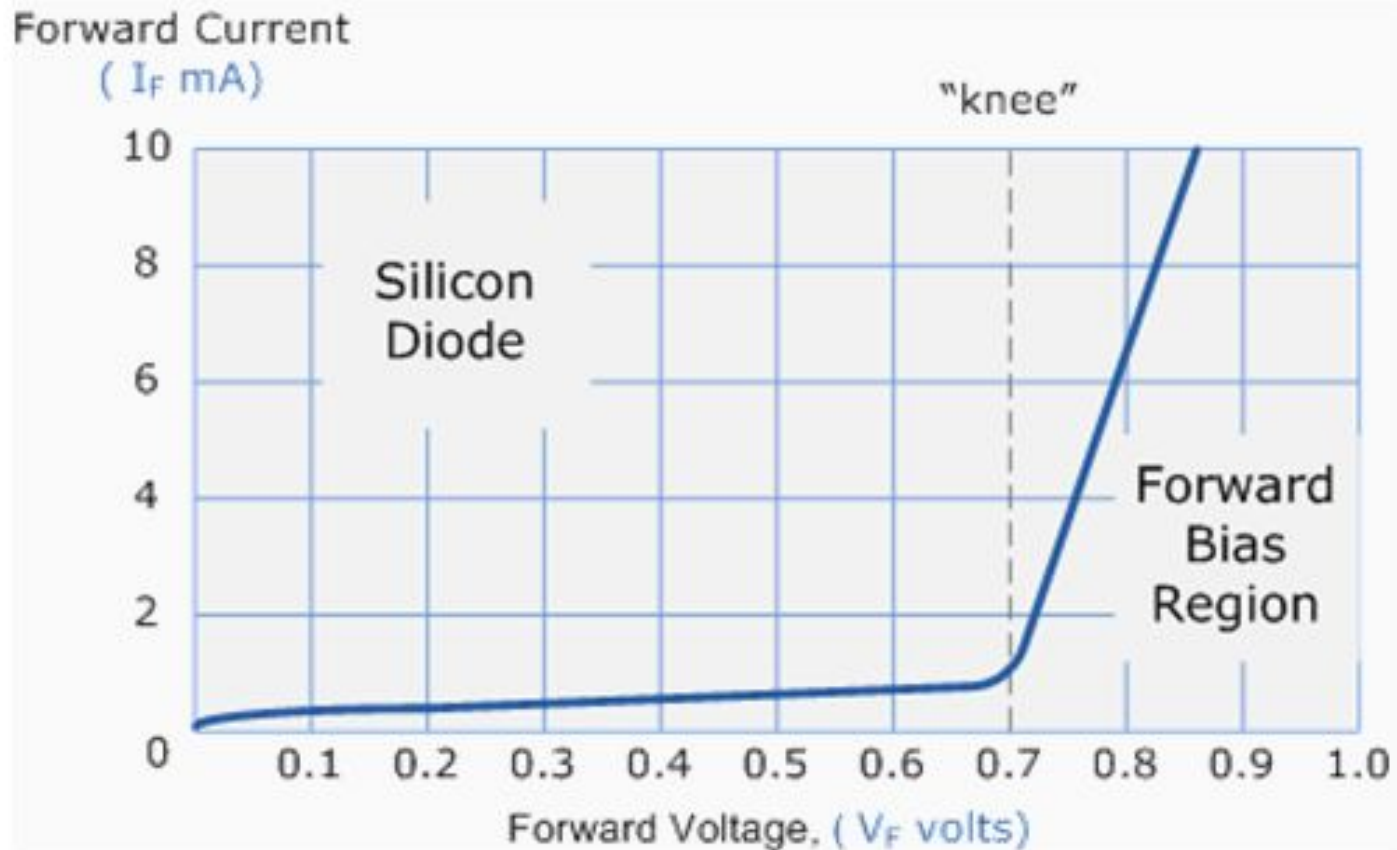
And then a high current flows through the diode for little increase in the external voltage.

Forward Characteristics

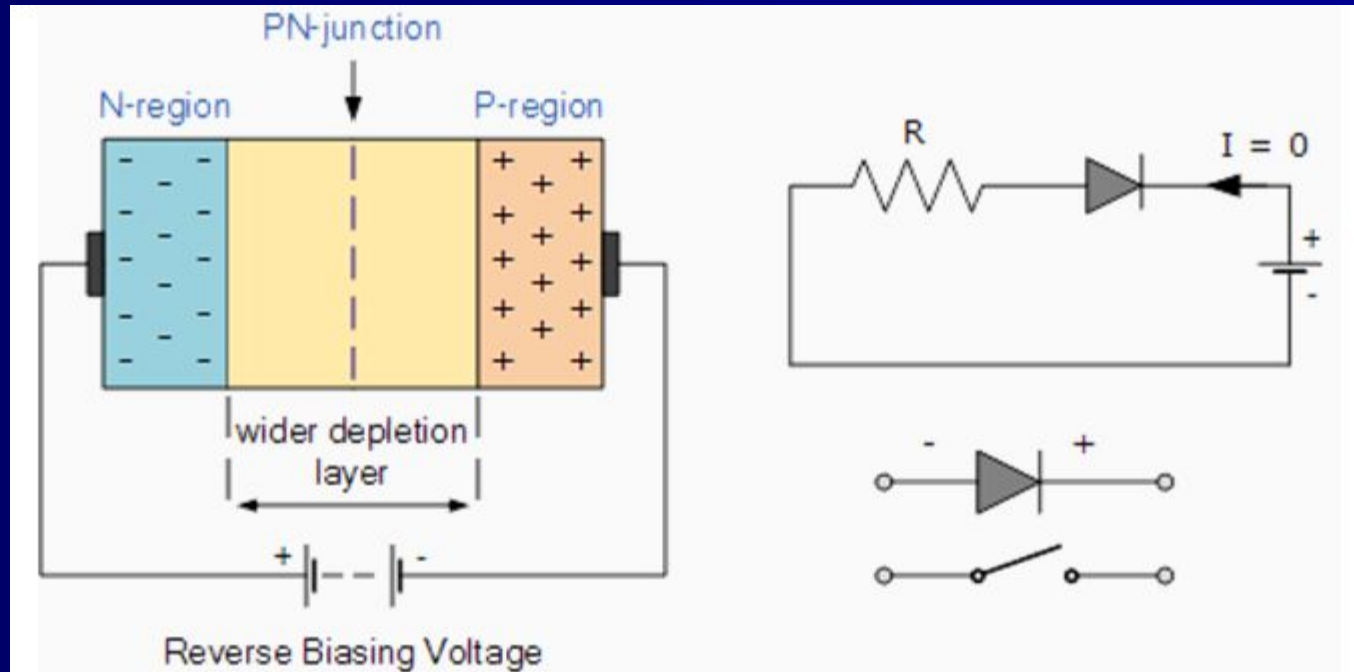


The application of a forward biasing voltage on the junction diode results in the depletion layer becoming very thin and narrow, which represents a low resistance path through the junction thereby allowing currents to flow.

Forward Characteristics

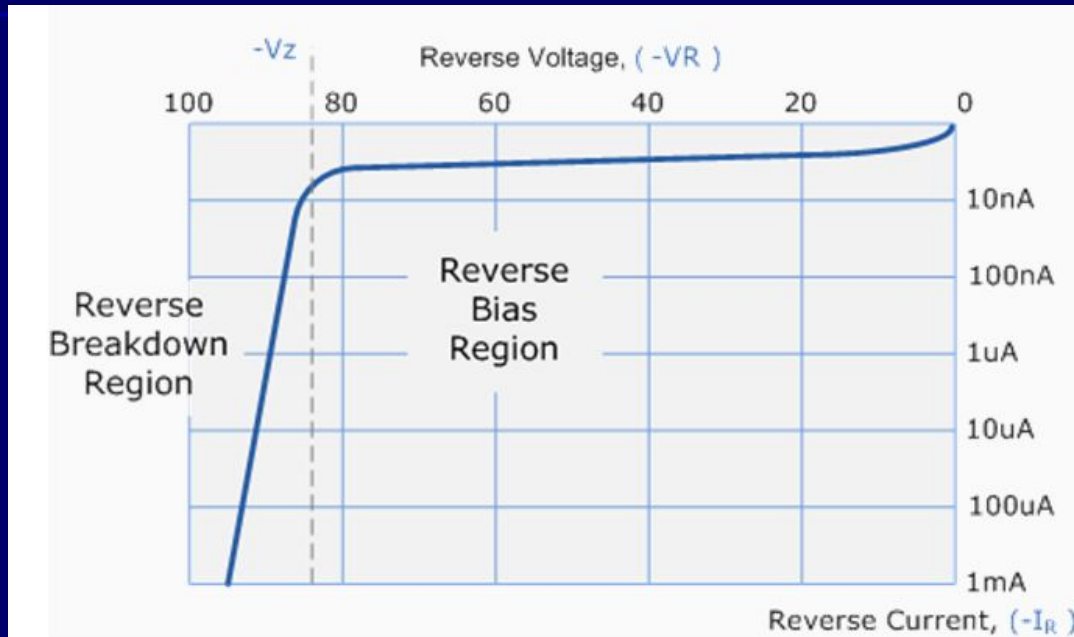


Reverse Characteristics



This condition represents a high resistance value to the PN junction and practically, zero current flows through the junction diode with an increase in bias voltage

Breakdown Characteristics



If the reverse bias voltage $-V_r$ applied to the diode is increased to a sufficiently high enough value, it will cause the PN junction to overheat and fail due to the avalanche effect around the junction. This may cause the diode to become short circuited and will result in the flow of maximum circuit current.

Reverse Biased Junction Diode

When a diode is connected in **Reverse Bias**

i.e. positive side of a voltage is applied to the N-type material (Cathode) and a negative to the P-type material (Anode).

Under this condition the positive electrode attracts **electrons** away and the negative electrode attracts **holes** away from the junction.

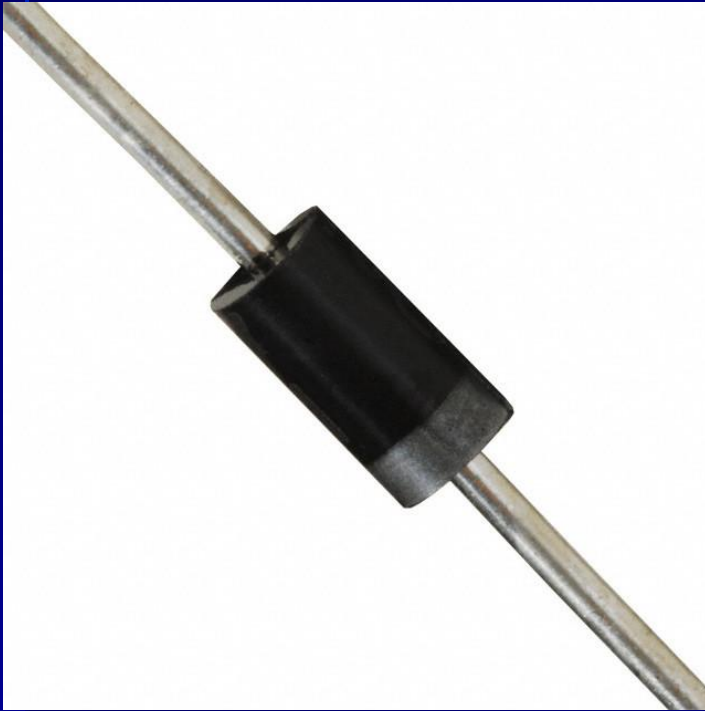
The net result is that the depletion layer grows wider due to a lack of electrons and holes and presents a high impedance path, almost an insulator.

The result is that a high potential barrier is created thus preventing current from flowing through the semiconductor material.

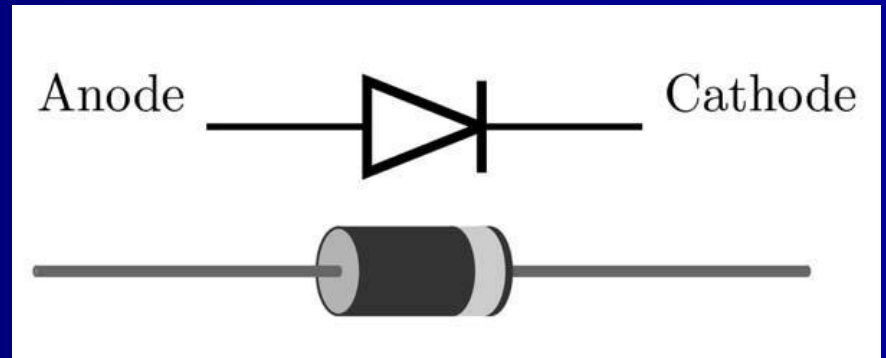


n-type

Types of Diodes

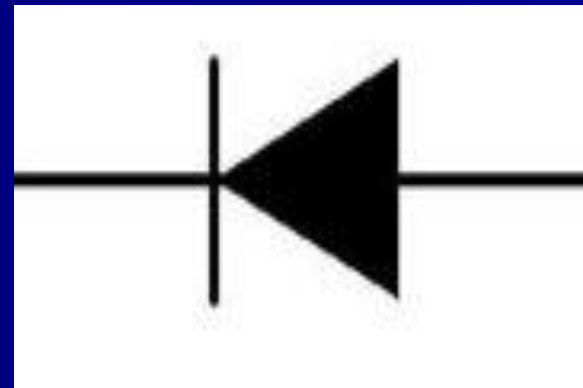


IN4007 General purpose low power



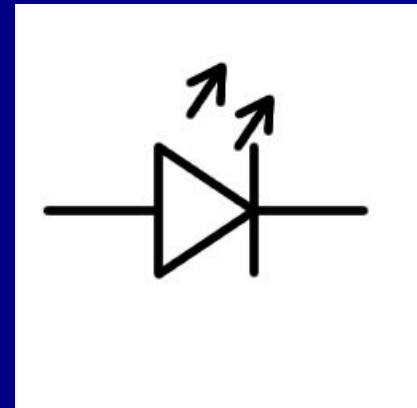
Types of Diodes

Rectifier Diode: These diodes are used to rectify alternating power inputs in power supplies. They can rectify current levels that range from an amp upwards. Generally these diodes are PN junction diodes. Think of a diode as a one way valve!



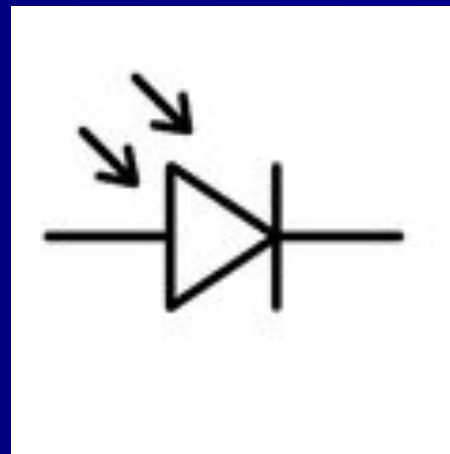
Types of Diodes

Light Emitting Diode (LED): Light is produced when current flows between the electrodes. In most of the diodes, the light (infrared) cannot be seen as they are at frequencies that do not permit visibility. When the diode is switched on or forward biased, the electrons recombine with the holes and release energy in the form of light (electroluminescence). The colour of light depends on the energy gap of the semiconductor.



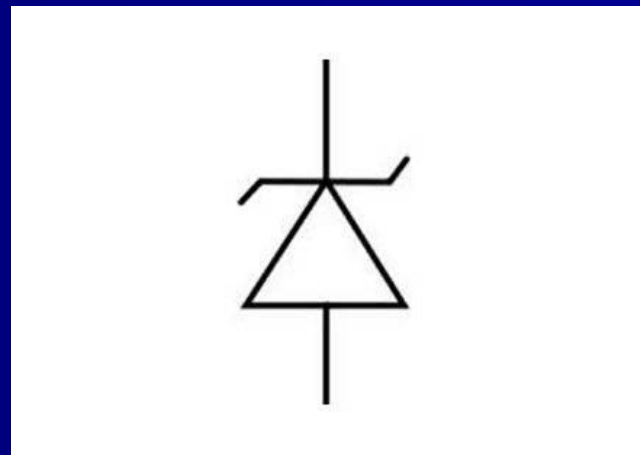
Types of Diodes

Photodiode: Photodiodes are used to detect light. Generally, these diodes operate in reverse bias mode, when small amounts of current flow, resulting in light being detected with ease. Photodiodes can also be used to generate electricity and hence used in solar cells and in photometry.

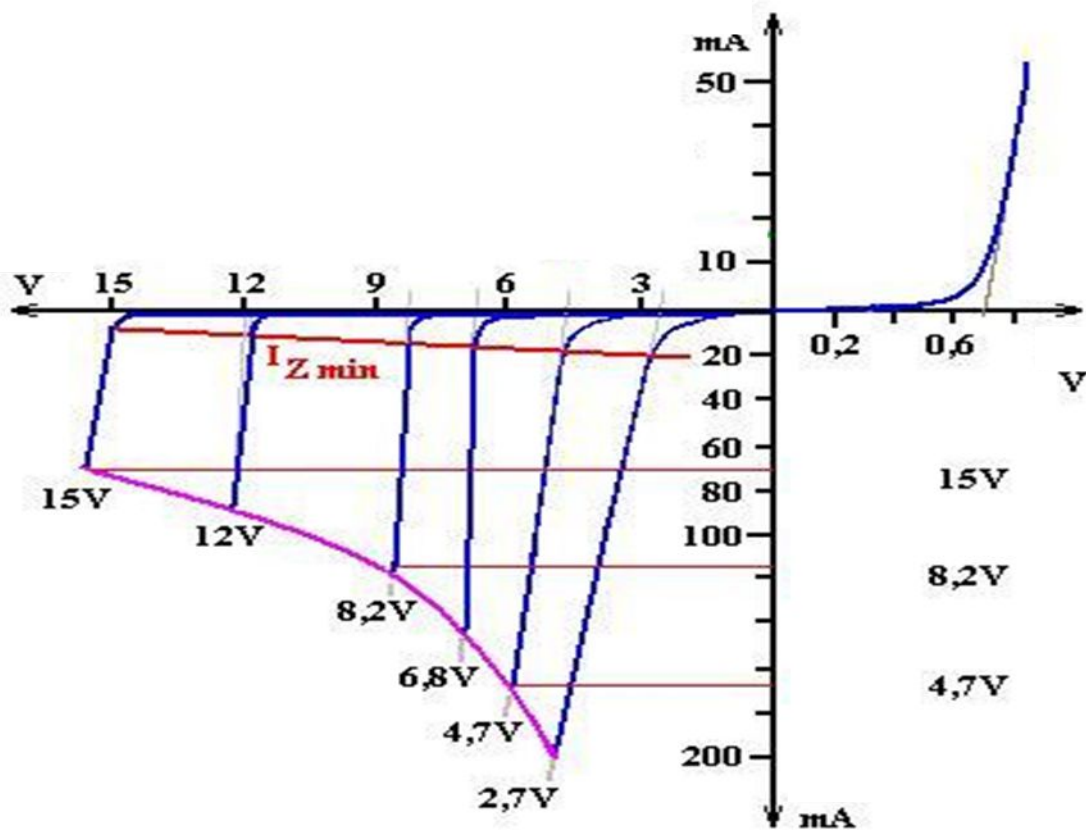


Types of Diodes

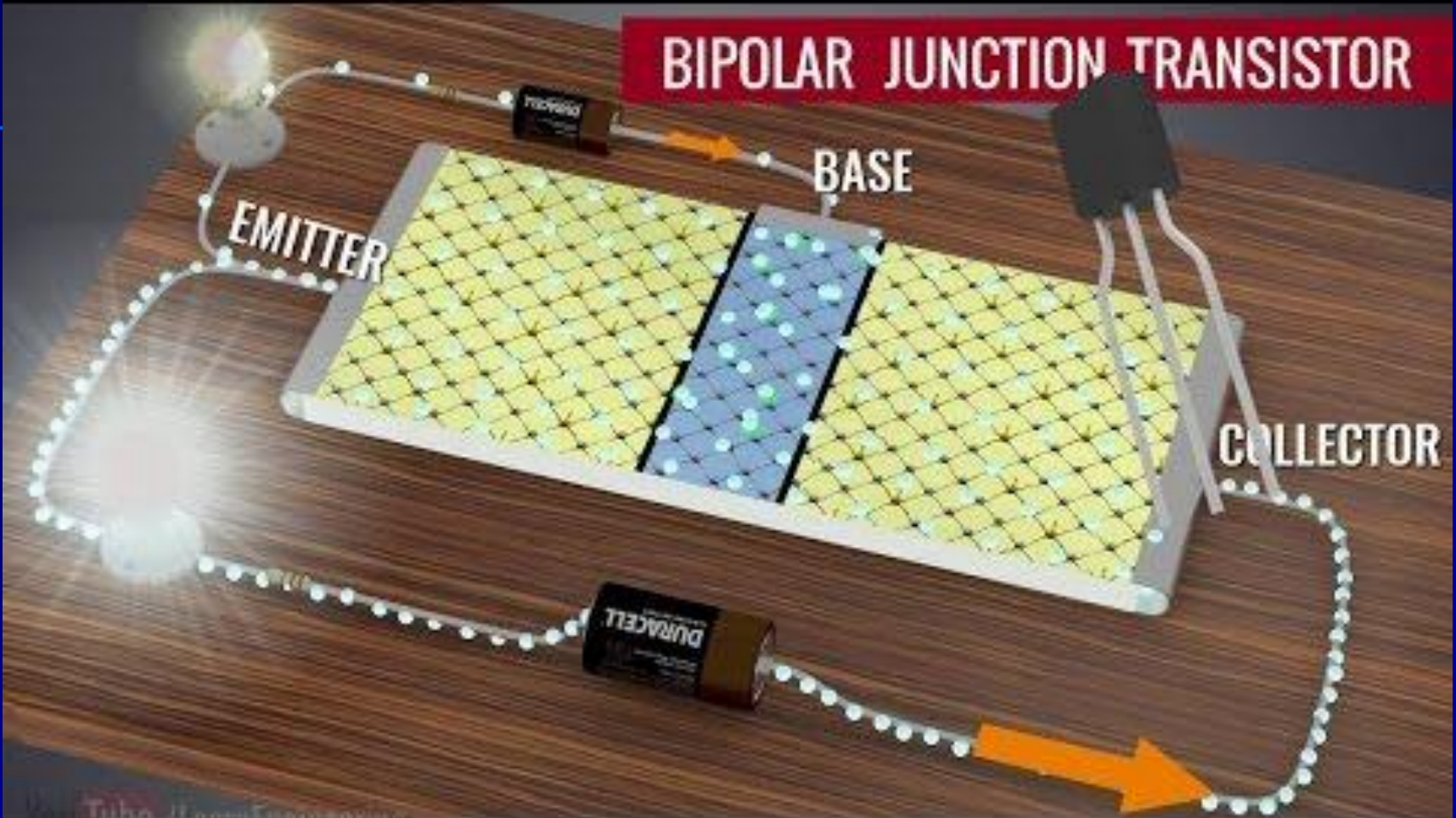
Zener diode: This type of diode provides a stable reference voltage, thus is a very useful type. The diode runs in reverse bias, and breaks down on the arrival of a certain voltage. A stable voltage is produced, if the current through the resistor is limited. In power supplies, these diodes are widely used to provide a reference voltage.



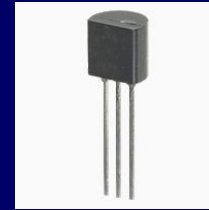
Zener Breakdown Voltage



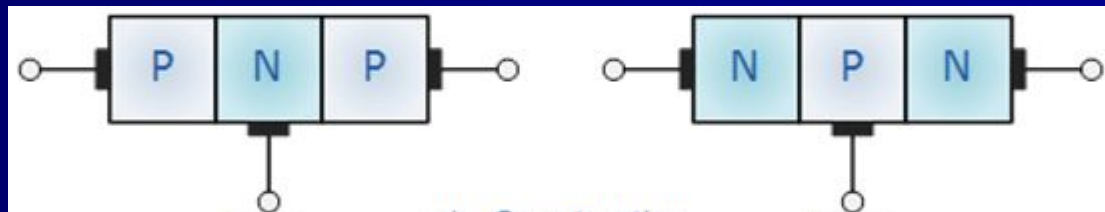
BIPOLAR JUNCTION TRANSISTOR



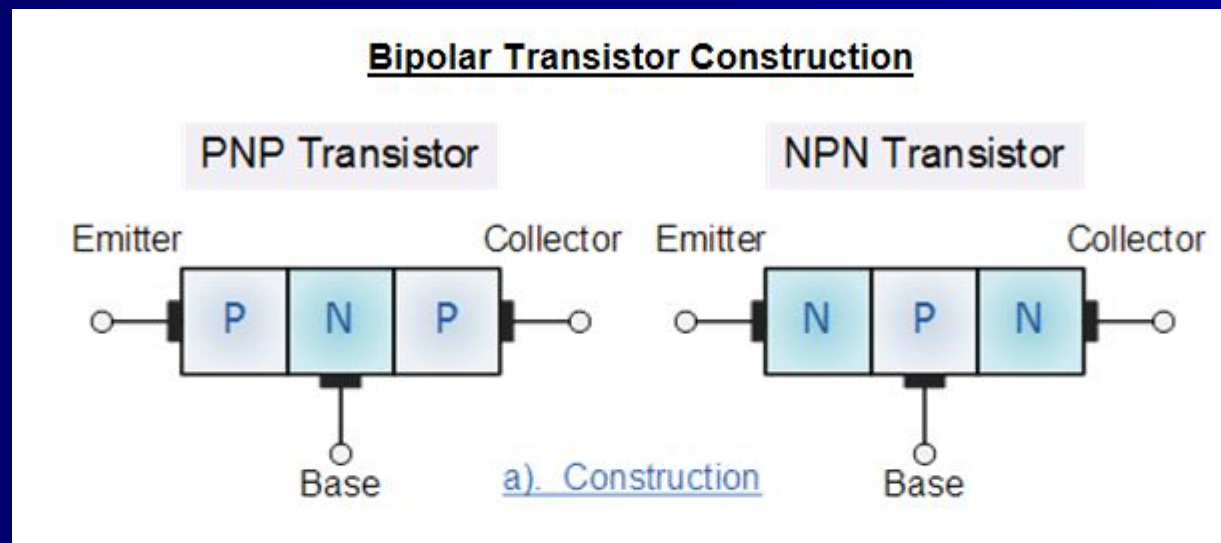
Transistors



These devices combine three doped semiconductor materials and can therefore be PNP or NPN

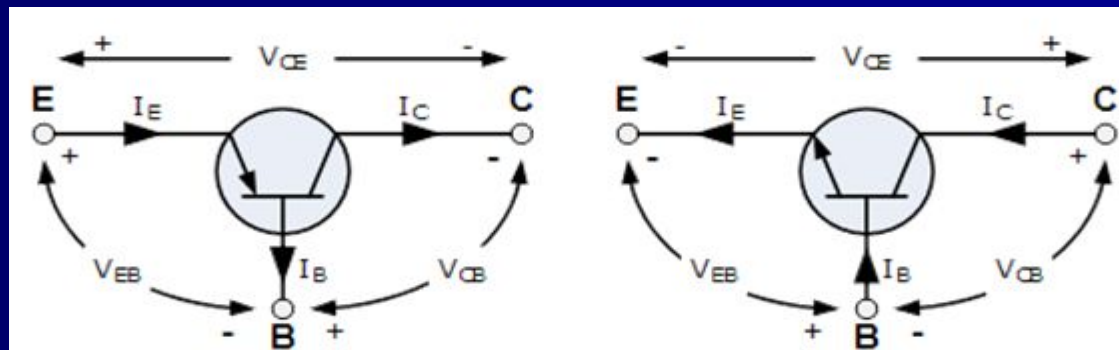


In this configuration we get three terminal connections called the Base, Collector and Emitter

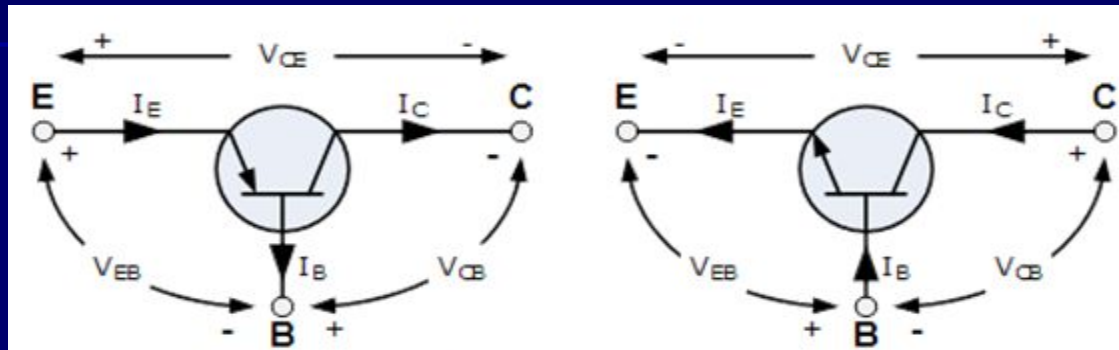


Transistors

Bipolar Transistors are current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing voltage applied to their base terminal acting like a current-controlled switch. The principle of operation of the two transistor types PNP and NPN, is exactly the same the only difference being in their biasing and the polarity of the power supply for each type.



Transistor Symbols



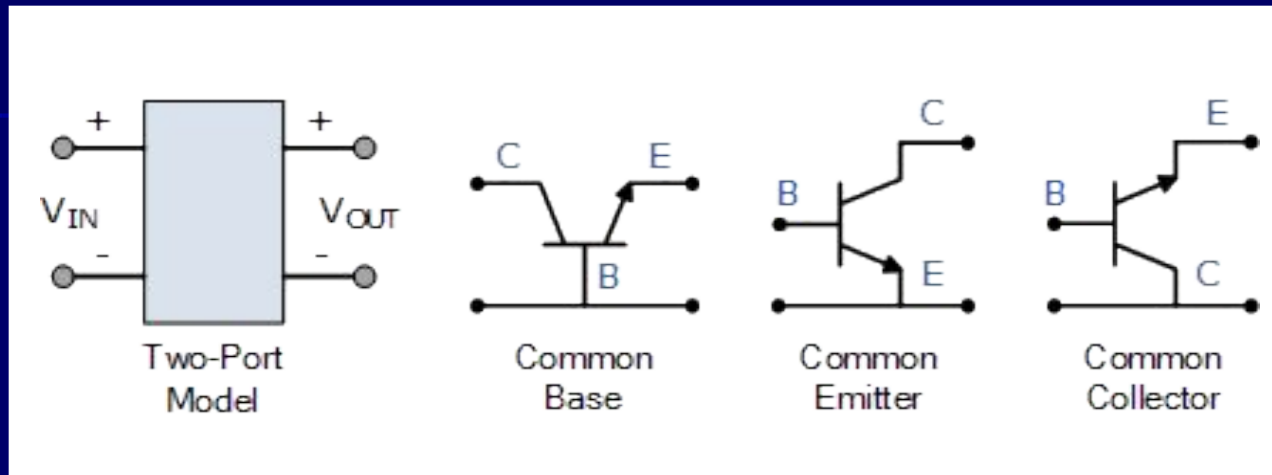
The construction and circuit symbols for both the PNP and NPN bipolar transistor are given above with the arrow in the circuit symbol always showing the direction of "conventional current flow" between the base terminal and its emitter terminal. The direction of the arrow always points from the positive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

Configuration

As the **Bipolar Transistor** is a three terminal device, there are basically three possible ways to connect it within an electronic circuit with one terminal being common to both the input and output. Each method of connection responding differently to its input signal within a circuit as the static characteristics of the transistor varies with each

1. Common Base Configuration
2. Common Emitter Configuration
3. Common Collector Configuration

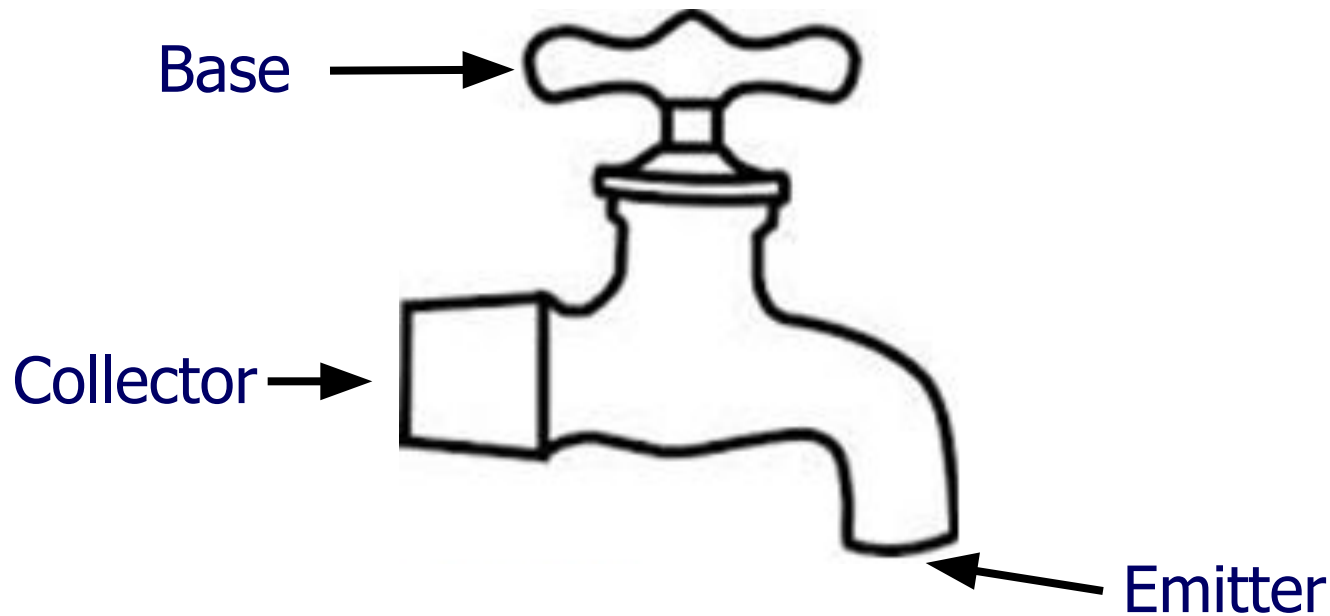
Configuration



Characteristic	Common Base	Common Emitter	Common Collector
Input Impedance	Low	Medium	High
Output Impedance	Very High	High	Low
Phase Angle	0°	180°	0°
Voltage Gain	High	Medium	Low
Current Gain	Low	Medium	High
Power Gain	Low	Very High	Medium

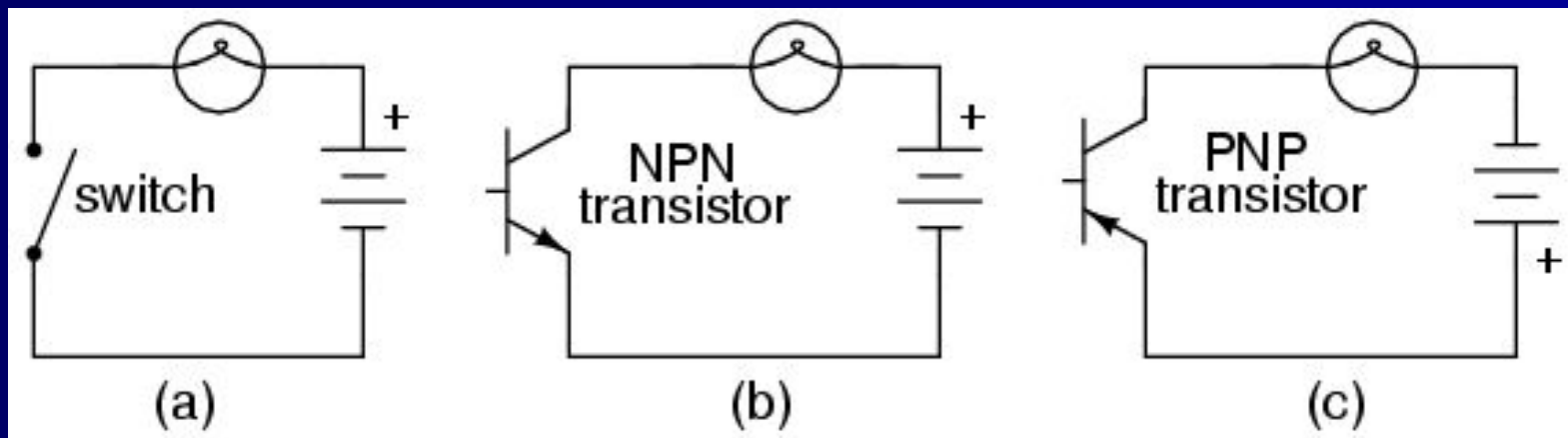
Analogy

Think of it as a water tap where the main flow is controlled by the small amount of pressure applied to the gate valve.



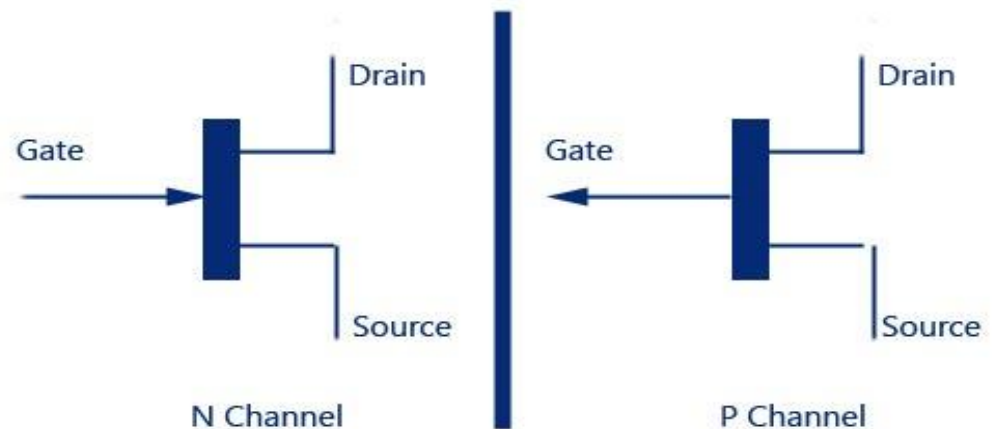
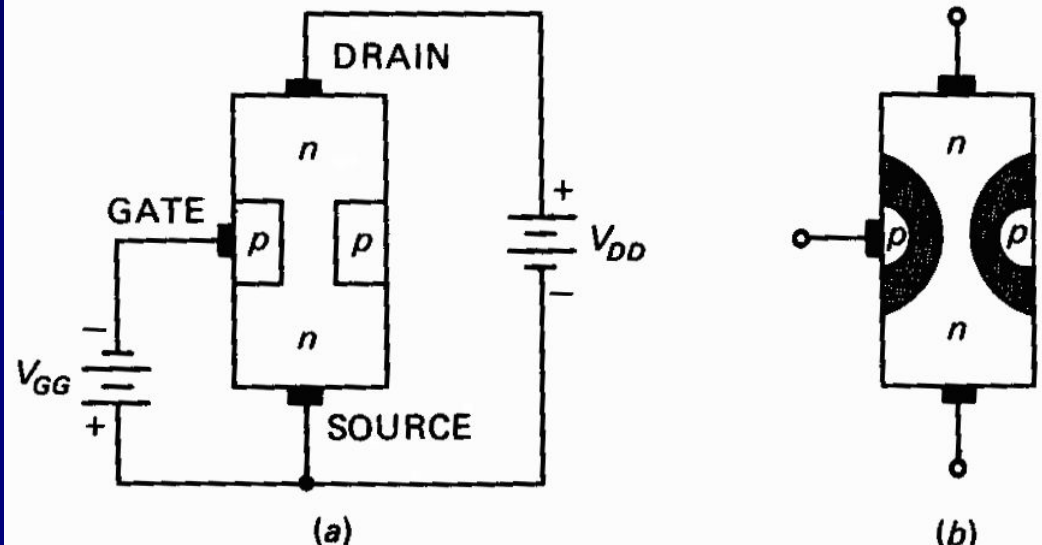
Transistor as a Switch

Because a transistor's collector current is proportionally limited by its base current, it can be used as a sort of current-controlled switch. A relatively small flow of electrons sent through the base of the transistor has the ability to exert control over a much larger flow of electrons through the collector.



Field Effect Transistor FET

FET is made of three terminals known as 'Gate', 'Source' and 'Drain'. Here drain current is controlled by the gate voltage. Therefore, FETs are voltage controlled devices.



FET

Field Effect Transistor FET

Difference between BJT and FET

Bipolar Junction (BJT) is basically a current driven device, though FET is considered as a voltage controlled device.

Terminals of BJT are known as emitter, collector and base, whereas FET is made of gate, source and drain.

In most of the new applications, FETs are used than BJTs.

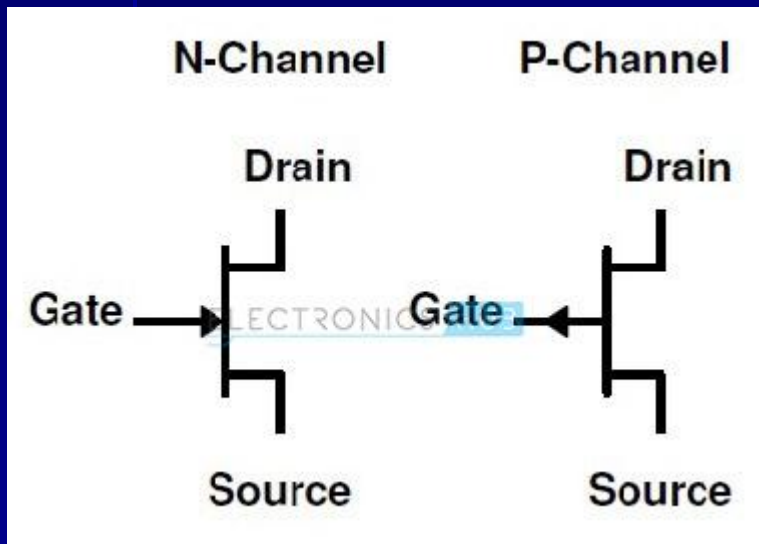
FET can be made quite small as compared to BJT.

FETs are more power efficient than BJTs.

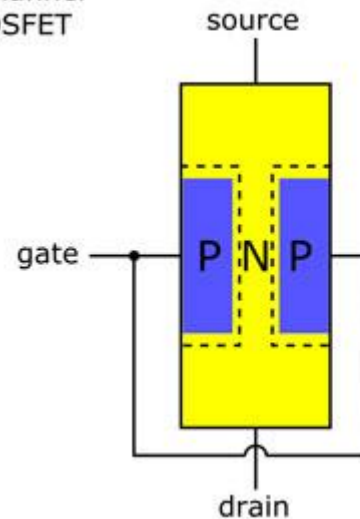
FETs are more widely used and more popular than BJTs. FETs can be manufactured smaller and load the power supply less.

FET

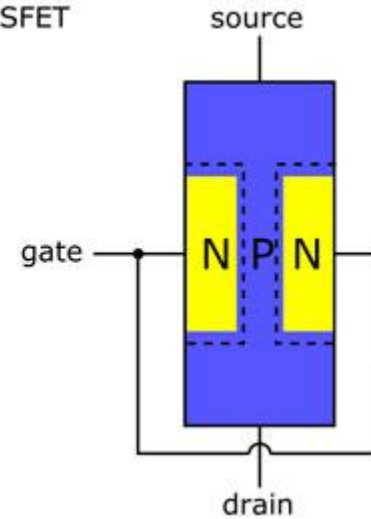
N- Channel and P-Channel



N-channel MOSFET



P-channel MOSFET



element14
presents ▶

THE
LEARNING
CIRCUIT 31

HOW
FETS
FUNCTION

