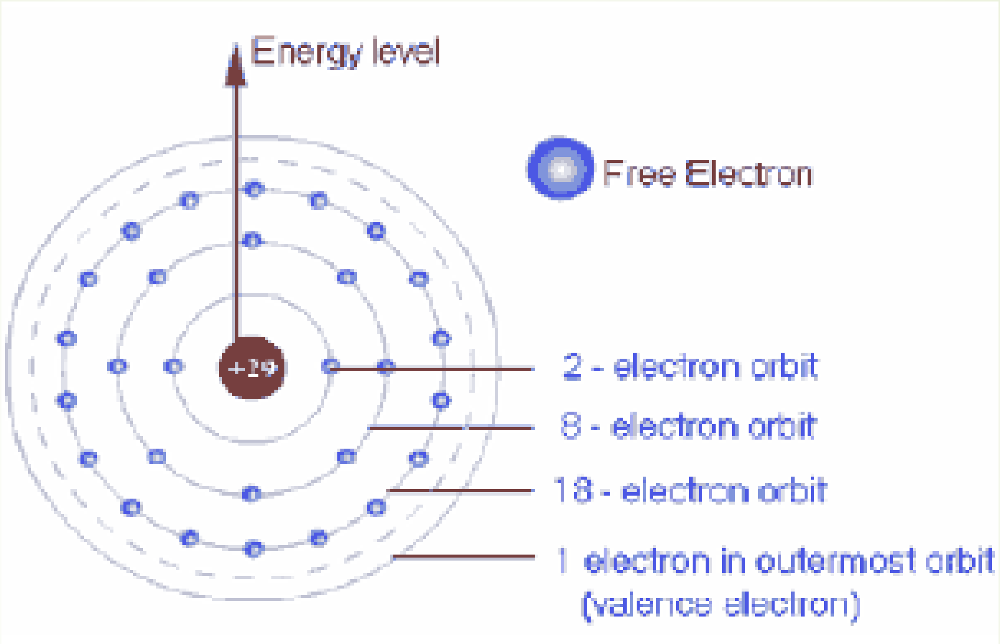
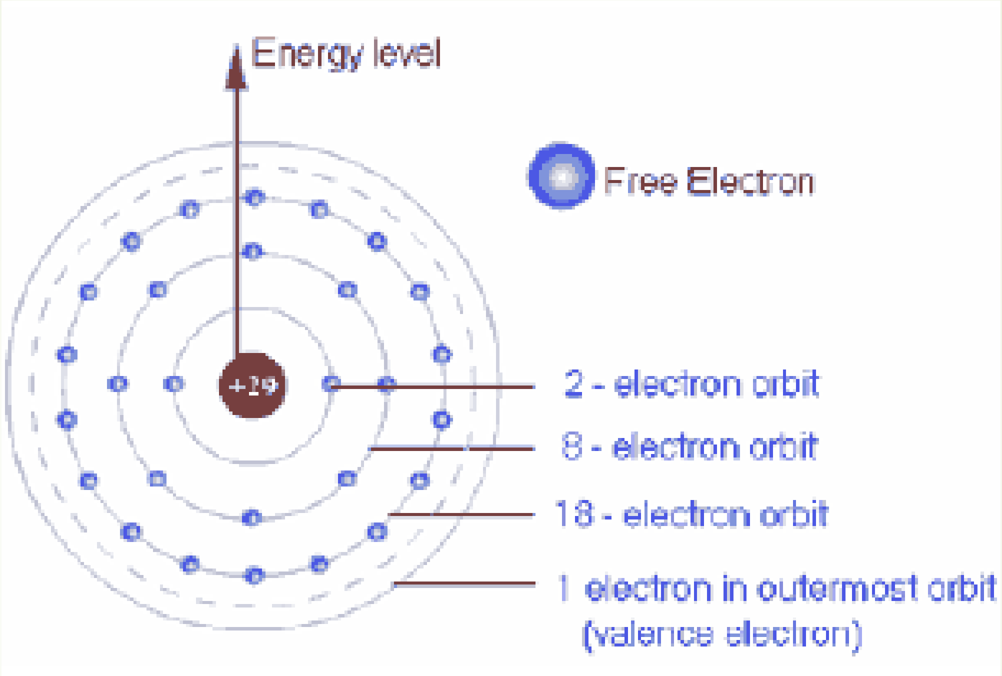
Semiconductor Basics



- Electrons that are in orbits further from the nucleus have higher energy & are less tightly bound to the atom.
- The force attraction between the positive charged nucleus & the negatively charged electron decreases with increasing distance from the nucleus.
- This outermost shell is known as the valence shell & electrons in this shell are called valence electrons.

Semiconductor Basics (Cont.)



- When a valence electron absorb energy from a heat or light source it can actually escape from the outer shell and the resulting is a positive charged (more protons than electrons) atom is called positive ion i.e. H+. The escaped valence electron is called a free electron.
- When a free electron loses energy and falls into the outer shell of an atom, the atom becomes negatively charged (more electrons than protons) and is called a negative ion i.e. H– .

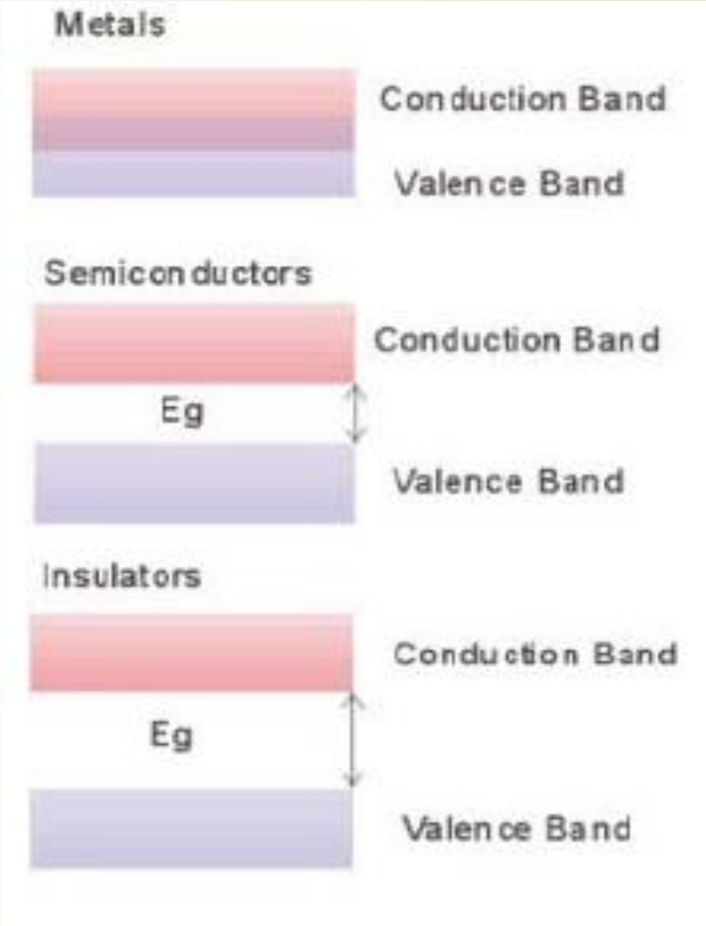
Semiconductor Basics (Cont.)

- Materials can be categorized into conductors, semiconductors or insulators by their ability to conduct electricity.

- Conductors: Metals conduct electricity easily because there is no band gap since the conduction overlaps the valence band.

- Semiconductors: The band gap is small enough that electron that absorb thermal energy can bridge the gap to the conduction band.

- Insulators: Very large band gap between the valence & conduction bands makes it hard for electrons to bridge the gap.



Semiconductor Basics (Cont.)

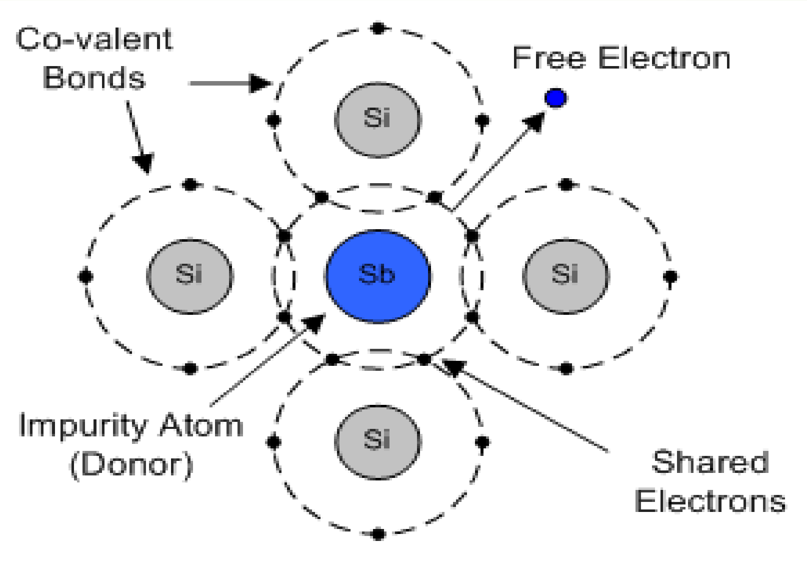
- Two types of semi conductive materials are silicon and germanium. Both have four valence electrons.
- The valence electrons in germanium are in 4th shell while the ones in silicon are in 3rd shell, closer to the nucleus.
- This means that the germanium valence electrons are at higher energy levels than those in silicon. Thus require a smaller amount of additional energy to escape from the atom.
- This property makes germanium more unstable than silicon at high temperatures, which is the main reason silicon, is the most widely used semi conductive material.

Semiconductor Basics (Cont.)

- Semiconductors have intermediate energy gape. In their pure state (Intrinsic), semiconductors are neither good conductors nor good insulators.
- Semiconductors do not used in their pure state because at room temperature very few electrons can jump the energy gap to the conduction band and become free electrons that causing conduction current.
- To effectively increase the conductivity of semiconductors we have to add impurities (Extrinsic semiconductors) to intrinsic semiconductors to increase the free electron in conduction band (diffusion process or doping impurities).

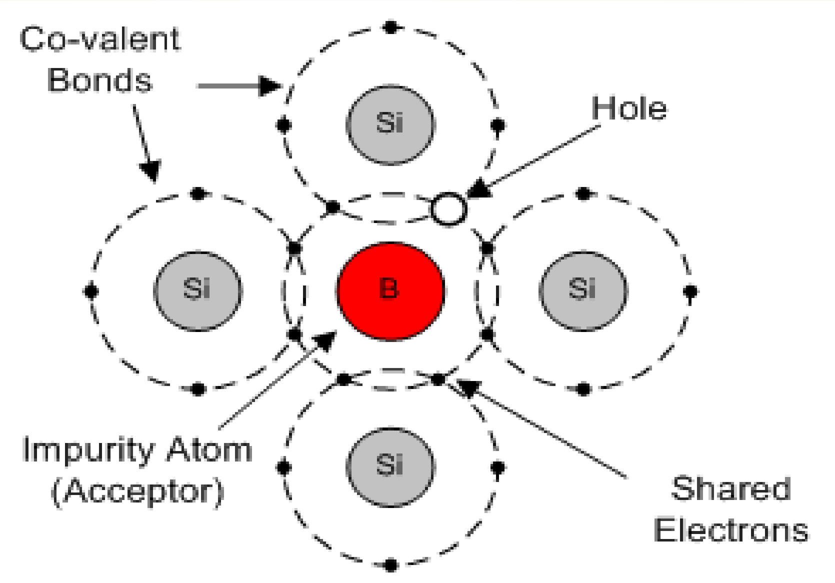
Semiconductor Basics (Cont.)

- There are two types of semiconductors; N-type and P-type.



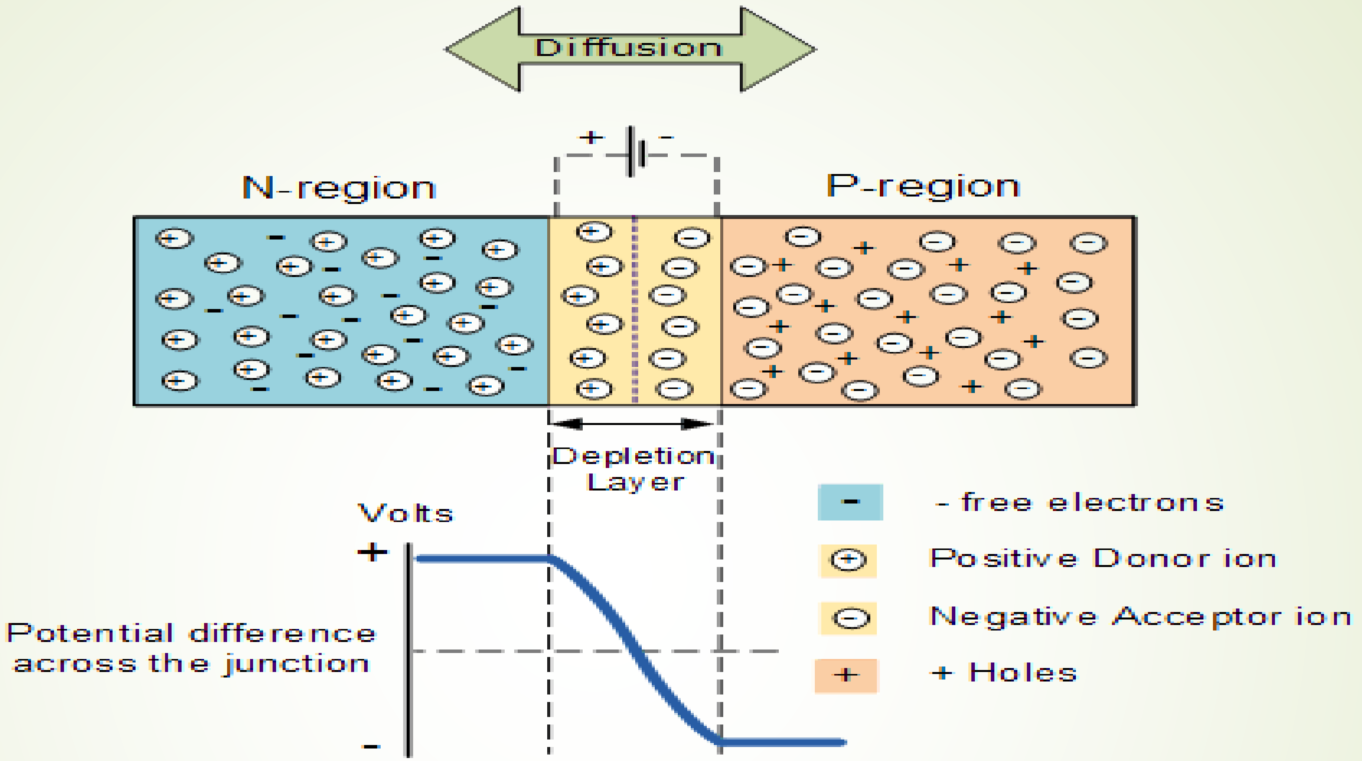
- In N-type semiconductors, penta-valent impurity atoms (atoms with five electrons in the valence band) are added to intrinsic semiconductors. Four electrons of these five are bonding with different four atoms of semiconductors substance leaving one free electron.

Semiconductor Basics (Cont.)



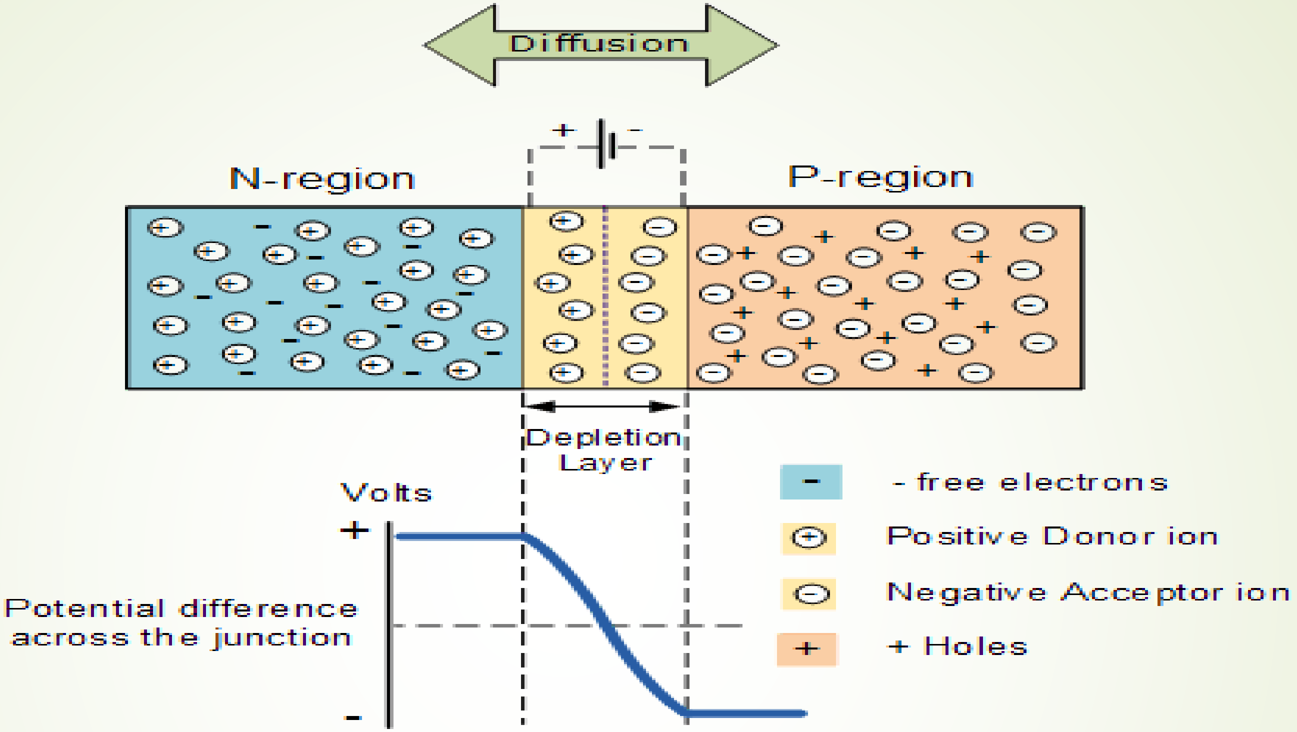
- While for P-type semiconductors, tri-valent impurity atoms (atoms with three electrons in the valence band) are added to intrinsic semiconductor. These three electrons are bonding with three semiconductor's atoms. The fourth semiconductor adjacent atom find no valence electron to share but instead imaginary hole (same but positively charge as electron).

Semiconductor Basics (Cont.)



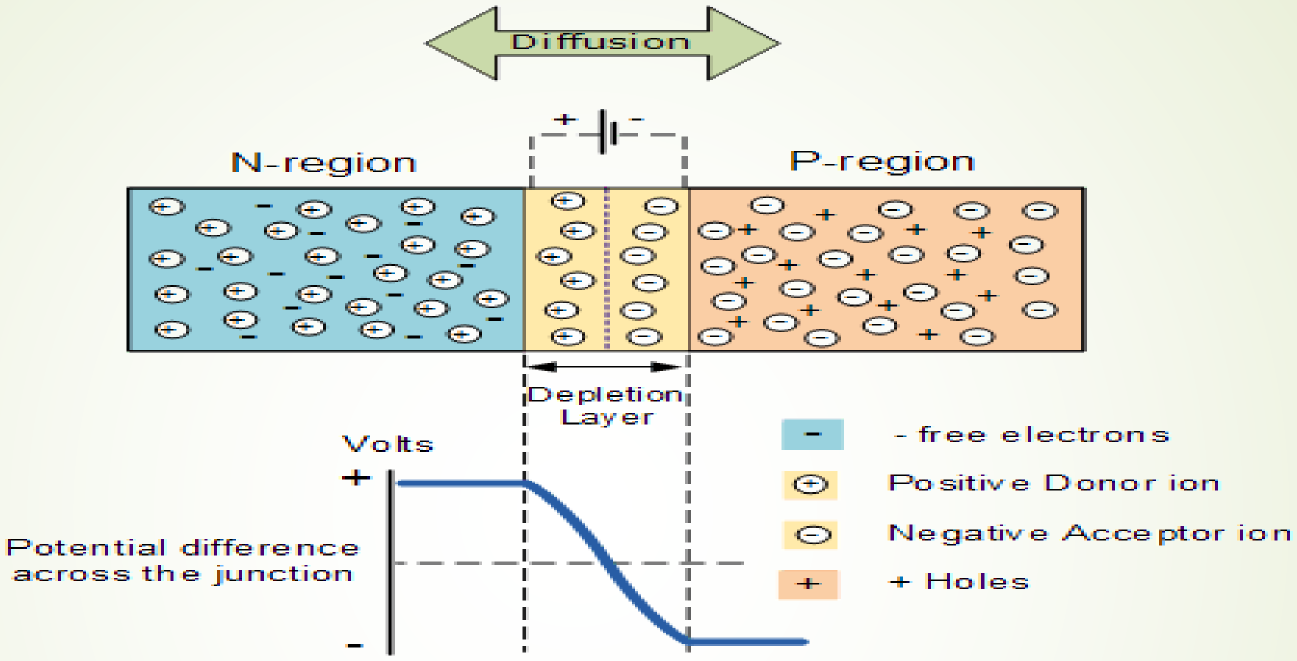
- When the N and P-type semiconductor materials are first joined together a very large density gradient exists between both sides of the junction
- So some of the free electrons from the donor impurity atoms begin to migrate across this newly formed junction to fill up the holes in the P-type material producing negative ions.

Semiconductor Basics (Cont.)



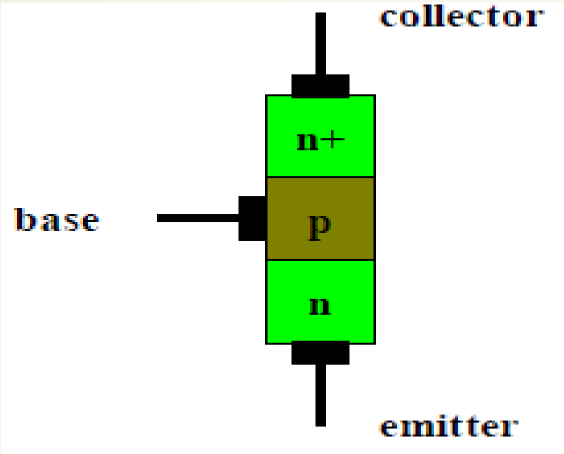
- However, because the electrons have moved across the junction from the N-type silicon to the P-type silicon, they leave behind positively charged donor ions (N_D) on the negative side and now the holes from the acceptor impurity migrate across the junction in the opposite direction into the region were there are large numbers of free electrons.

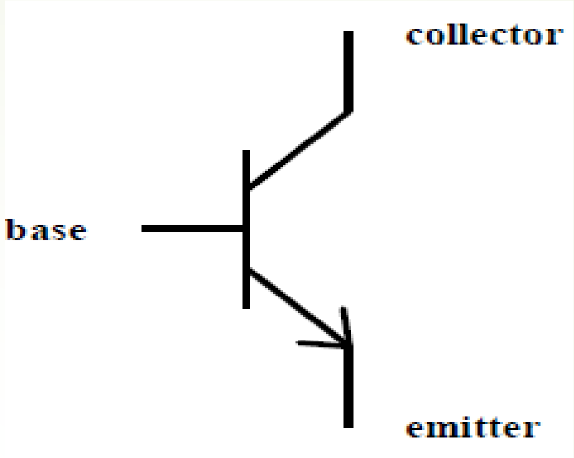
Semiconductor Basics (Cont.)



- As a result, the charge density of the P-type along the junction is filled with negatively charged acceptor ions (N_A), and the charge density of the N-type along the junction becomes positive. This charge transfer of electrons and holes across the junction is known as diffusion.

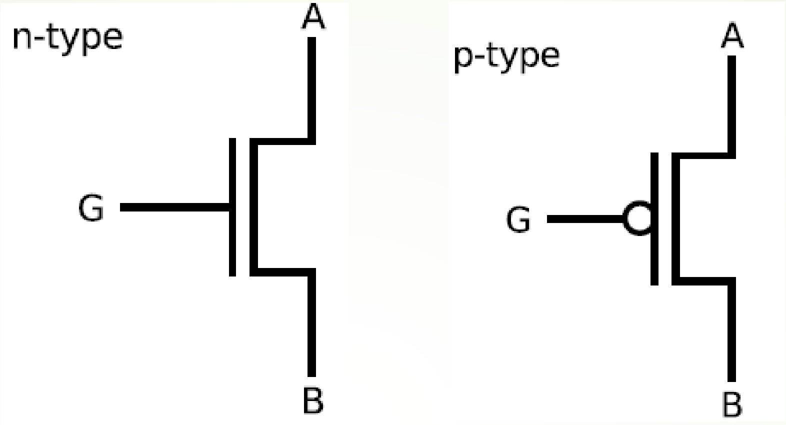
Bipolar circuits





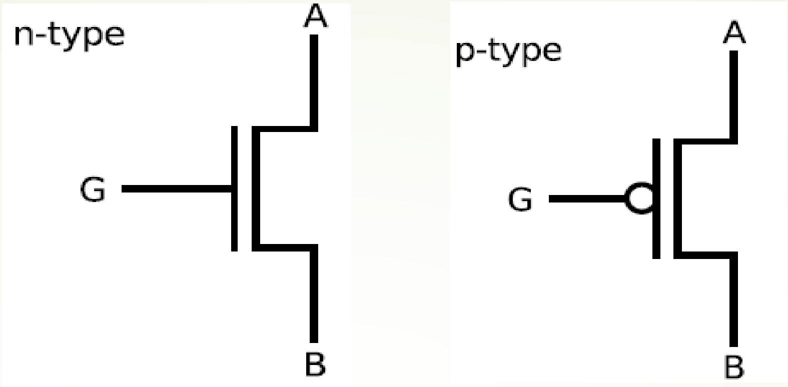
- A *bipolar* transistor is formed by a sandwich of n-type, p-type and n-type regions in a single crystalline lattice.
- It can be thought of two diodes connected a node–to–a node such that a current through the forward biased diode overwhelms the reverse biased diode.
- A small current flowing from the base to the emitter of an npn transistor induces a large current from the collector to the emitter. A pnp transistor has the opposite polarity.

nMOS, pMOS and CMOS



- There are many different kinds of transistors, but the one most commonly used in digital electronics is the MOSFET (Metal-Oxide Semiconductor Field Transistor). There are two kinds of MOSFETs:
  - N-type (the n-type MOSFET are commonly called nMOS transistors) and
  - P-type (the p-type MOSFET are commonly called pMOS transistors)

nMOS, pMOS and CMOS



- The nMOS and pMOS transistors differ in how they switch based on the input G (called the Gate).
- For an nMOS transistor:
  - If the Gate is "0", then A and B are not connected (the circuit between A and B is "open"
  - If the Gate is "1", then A and B are connected (the circuit between A and B is "closed"
- For an pMOS transistor, it is exactly the opposite:
  - If the Gate is "0", then A and B are connected (the circuit between A and B is "closed"
  - If the Gate is "1", then A and B are not connected (the circuit between A and B is "open"

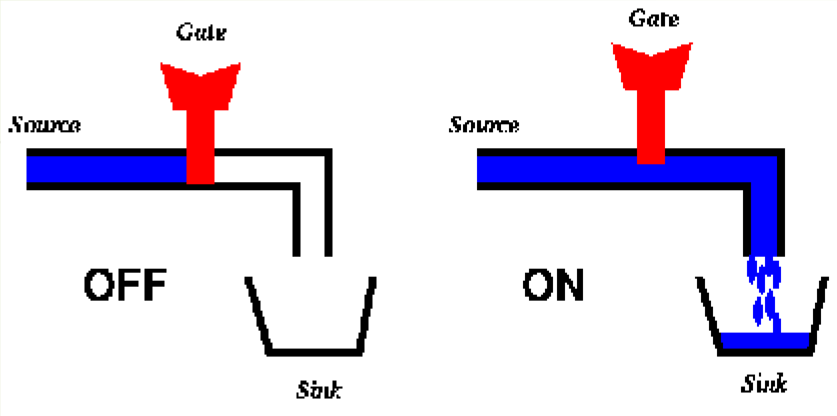
nMOS, pMOS and CMOS

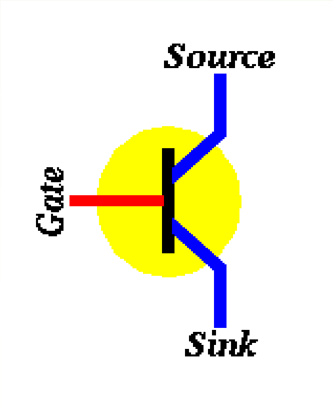
Type	Gate	A and B
n-type	0	not connected
	1	connected
p-type	0	connected
	1	not connected

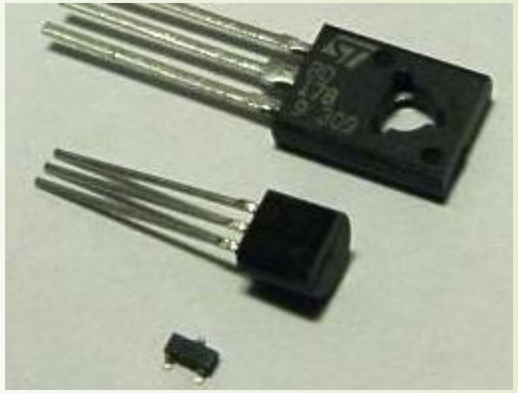
Type	Transmit 0	Transmit 1
n-type	good	ok
p-type	ok	good

- In addition, because of their construction, nMOS transistors are good at transmitting a'0' signal between A and B, but are not so good at transmitting a "1".
- The opposite is true for pMOS transistors: they are good at transmitting a "1', but not so good at transmitting a "0".
- Because of this, nMOS and pMOS are commonly used together so that the resulting both "0" and "1" values. Devices that are built using combination of nMOS and pMOS transistors are known as CMOS (Complementary MOS).
- In these devices, the pMOS transistors control the connections to POWER (the "1" value) and the nMOS transistors control the connections to GROUND (the "0" value).

Transistors

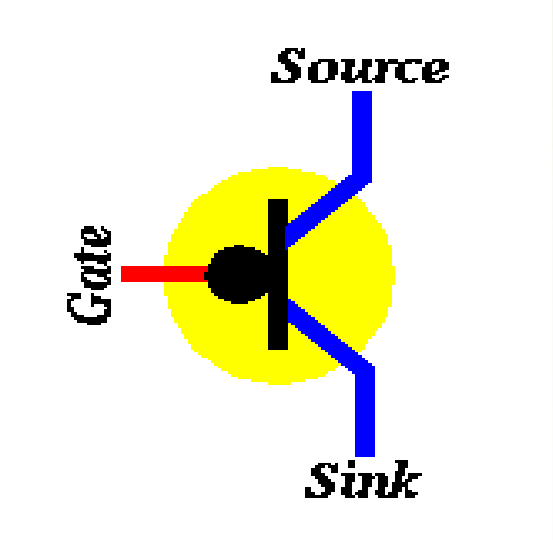






- If we represent the fact that water flows from the source to the sink with a **1** (or ON) and the fact that water does not flow from the source to the sink with a **0** (or OFF), we can understand how a transistor works simply by changing "water" to "electricity". In particular:

  - When the gate of a transistor is **ON** (or has a value **1**) then electricity flows from the source to the sink and the transistor is said to be **ON**
  - Otherwise when the gate of a transistor is **OFF** (or has a value **0**) then electricity does not flow from the source to the sink and the transistor is said to be **OFF**.



- Is another kind of transistors, which is turned ON when the gate is OFF and is turned OFF when the gate is ON.
- In other words, its operation is "complementary" (or opposite) to the one we just described above. The symbol for this complementary type of transistors is shown obove.
- The symbol is quite similar to the transistor we described, except for the "bubble" connected to the gate. This bubble means that this transistor works in the opposite way (it's ON when the gate is OFF and OFF when the gate is ON.