ELECTRICAL SCIENCE-2 (15B11EC211) UNIT-6

Lecture 1

Lecture Overview

- History
- Construction
- symbols
- Naming of transistor regions
- Important features
- Diode Equivalent of a Transistor
- Transistor operation
- Operation of npn transistor
- Operation of pnp transistor

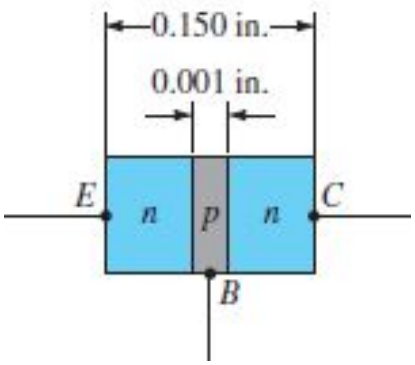
History of Transistor [1]

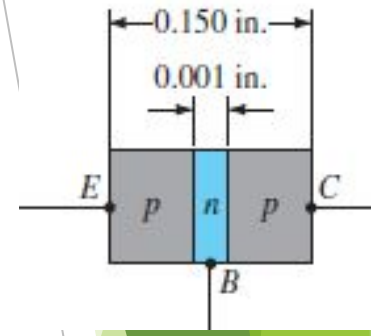
- Bell Labs (1947): Bardeen, Brattain, and Shockley
- All shared the Nobel Prize in 1956 for this contribution.
- Originally made of germanium
- Current transistors made of doped silicon

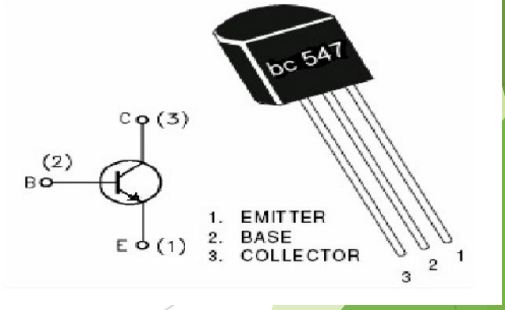
The first transistor

Construction of Transistor

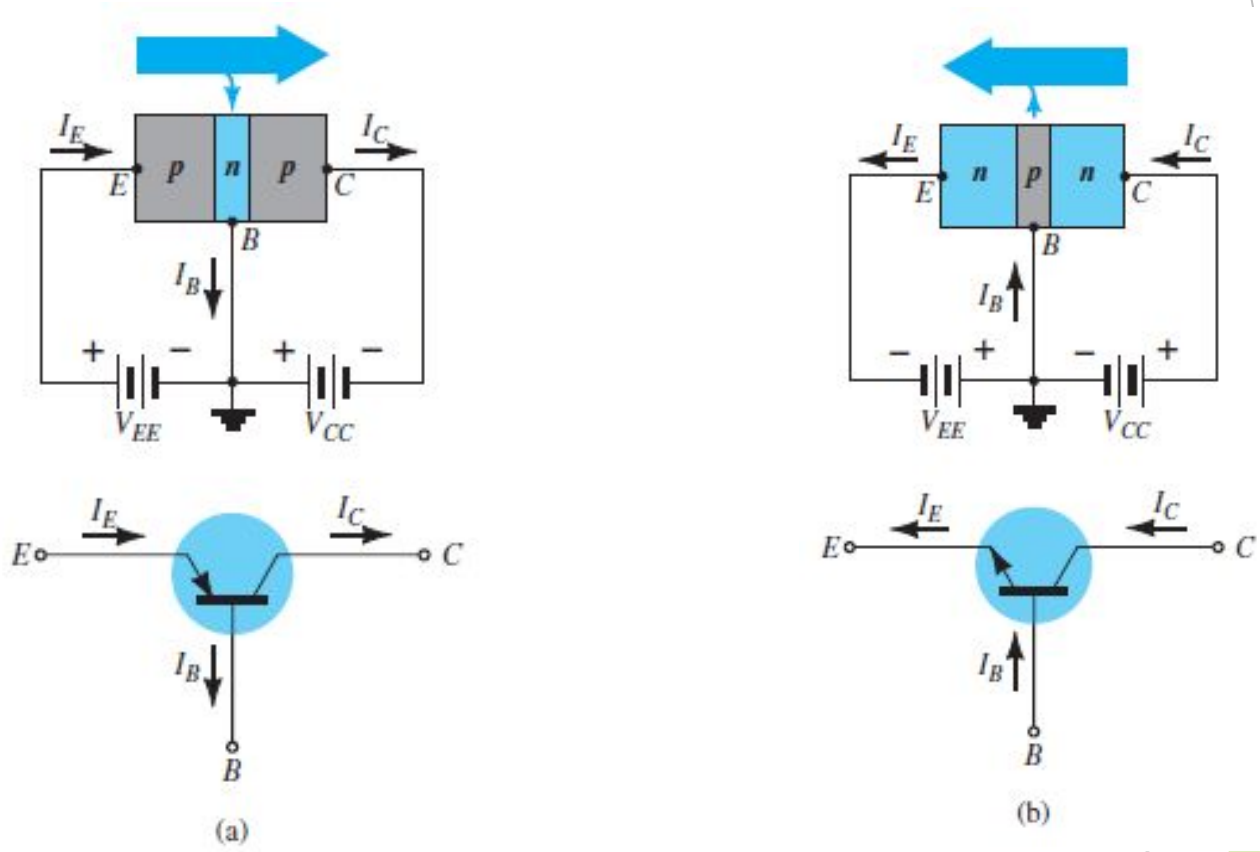
- It is a three-layered semiconductor device consisting of either two n and one p type region or two p and one n type region.
- There are two junctions
- Three terminals
- Three regions
- The middle region is kept thinner than other two
- Both electrons and holes movements are accountable- so Bipolar
- Both minority and majority carrier movement are considered
- Two types:
  - npn
  - pnp







Symbol[2]



Notation and symbols used with the common-base configuration: (a) pnp transistor; (b) npn transistor.

Naming of transistor terminals

- Emitter

The section of one side that supplies carriers is called emitter

Emitter is always forward biased w.r.t. base so it can supply carriers.

For npn transistor emitter supply electrons to its junction

For pnp transistor emitter supply holes to its junction

Naming of transistor terminals

- Collector

The section on the other side that collects carrier is called collector

The collector is always reversed biased w.r.t base

For npn transistor collector receives electrons to its junction

For pnp transistor collector receives holes to its junction

- Base

Middle section which form two junctions with emitter and collector is called base.

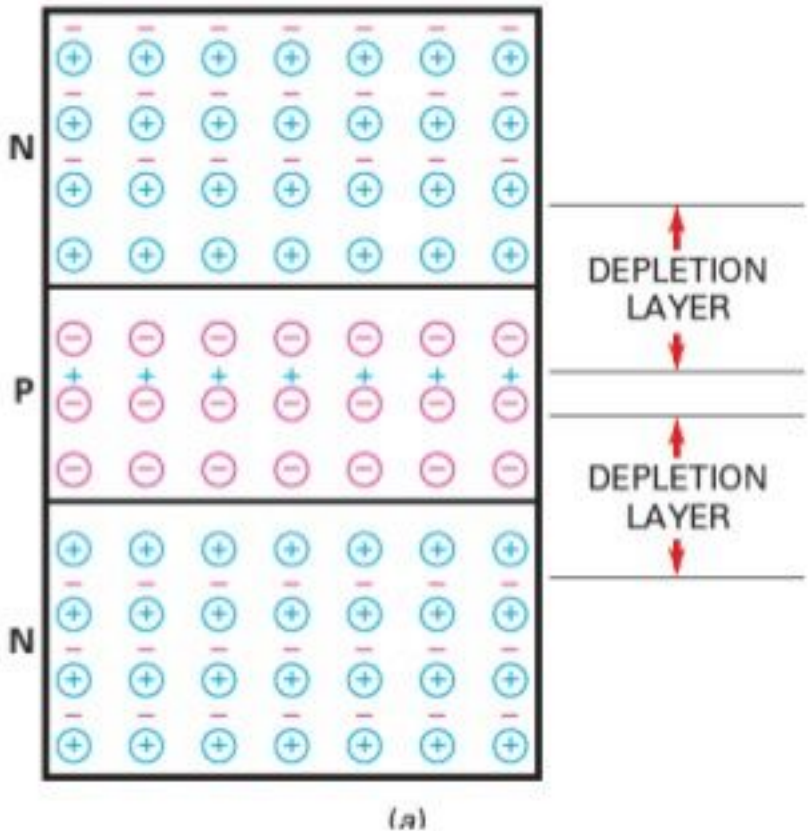
Important features

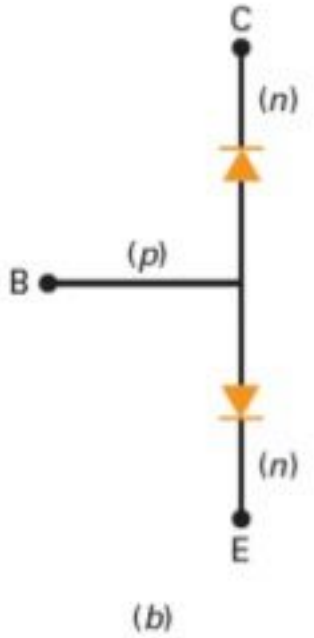
- The transistor has three regions named E, B and C
- The base is much thinner than other regions
- Emitter is heavily doped so it can inject large amount of carriers into the base
- Base is lightly doped so it can pass most of the carrier to the collector
- Collector is moderately doped.

Important features

- The junction between emitter and base is called EB junction(emitter diode) and junction between collector base junction is called as CB junction(collector diode)
- The emitter diode is always forward biased and collector diode is revered biased.
- The resistance of emitter diode is very small and resistance of collector diode is very high.

Diode Equivalent of a Transistor[2]



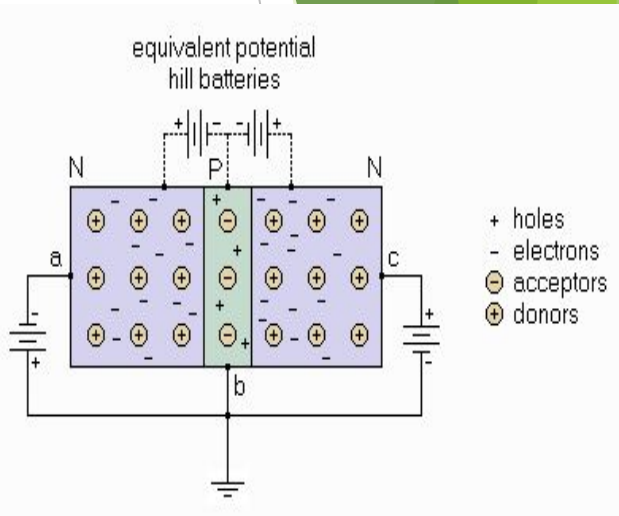


Transistors operation

- Doping: adding small amounts of other elements to create additional protons or electrons
- P-Type: dopants lack a fourth valence electron (Boron, Aluminum)
- N-Type: dopants have an additional (5^{th}) valence electron (Phosphorus, Arsenic)
- Importance: Current only flows from P to N

Basic working of transistor [1]

- At the junction, a built-in potential is set up by the action of the fixed donor and acceptor atoms. Since the emitter battery acts to flatten this emitter-base potential hill, a number of electrons pass this barrier and enter the P base region.
- The number of electrons crossing the barrier is proportional to the value of emitter battery potential. Some of these electrons combine with holes in the P base region, but most pass through and enter the N collector region.
- The loss of electrons in the P base region remains low (approximately five percent) because: (1) the base section is thin, and (2) the potential at the collector-base junction acts to accelerate the electrons into the N collector region. In the N region, the electrons are attracted to the positive collector.



Operation of transistors

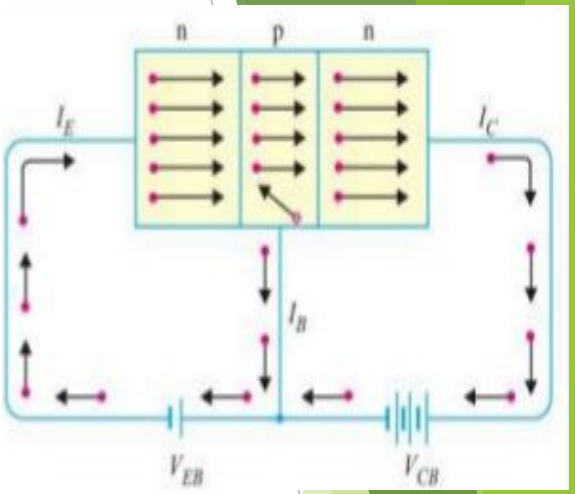
- Deferent region of operation
  - Active region
    - Used as an amplification
  - Cut-off region
    - Used as switching action
  - Saturation region
    - Used as switching action

Operation of npn Transistor[1]

- EB junction: Forward Biased
- CB junction: Reverse Biased

The forward bias in the emitter –base junction causes electrons to move towards base, constituting emitter current, I_e

- N-type of emitter: more heavily doped than collector.
  - Electrons diffuse from Emitter to Base (from n to p).
  - There's a depletion layer on the Base-Collector junction □no flow of e^- allowed

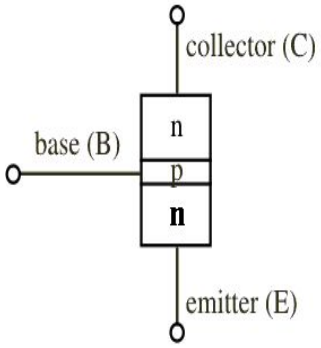


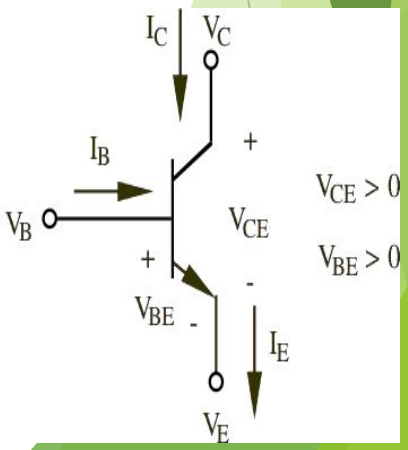
Operation of npn Transistor

- As this electron flow towards p-type base, they try to recombine with holes. As base is lightly doped only few electrons recombine with holes within the base.
- These recombined electrons constitute small base current, I_b
- The remainder electrons crosses base and constitute collector current, I_c

With $V_C > V_B > V_E$

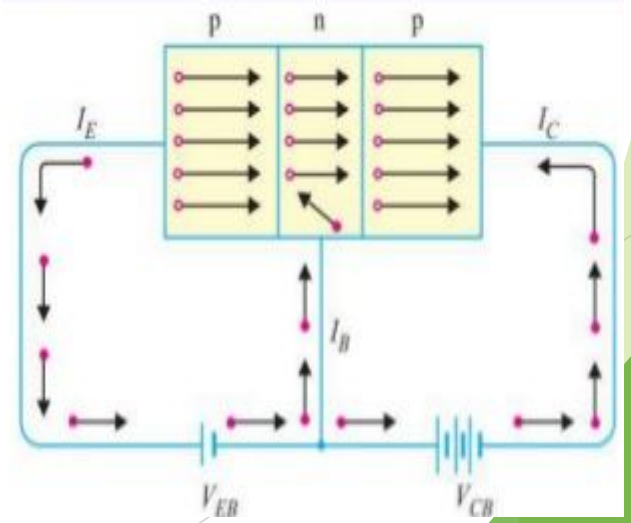
$$I_E = I_C + I_B$$
$$V_{BE} = V_B - V_E$$
$$V_{CE} = V_C - V_E$$
$$I_C = \beta I_B$$





Operation of pnp Transistor[1]

- EB junction Forward bias
- CB junction is Reverse bias
- The FB in EB junction causes holes to move towards base, which constitutes emitter current, I_e



Operation of pnp Transistor

- As this holes flow towards n-type base, they try to recombine with electrons. As base is lightly doped only few holes recombine with electrons within base.
- These recombined holes constitute small base current, I_b
- The remainder holes crosses base and constitute collector current, I_c

References

[1] A. S. Sedra,, and K. C. Smith, 'Microelectronic Circuits'. Oxford Oxford University Press, 7th Edition, 2012.

[2] R. Boylestad and L. Nashelsky, 'Electronic Devices and Circuit Theory', PHI, 7e, 2001

[3] D.C. Kulshreshtha, 'Electronic Devices and Circuits', New Age, 2e, 2006.