Budapest University of Technology and Economics
Faculty of Transportation Engineering and Vehicle Engineering
Department of Control for Transportation and Vehicle Systems

Electronics - electronic measuring systems

Four poles, diodes and transistors

Ernő Simonyi
simonyi.erno@sztaki.mta.hu

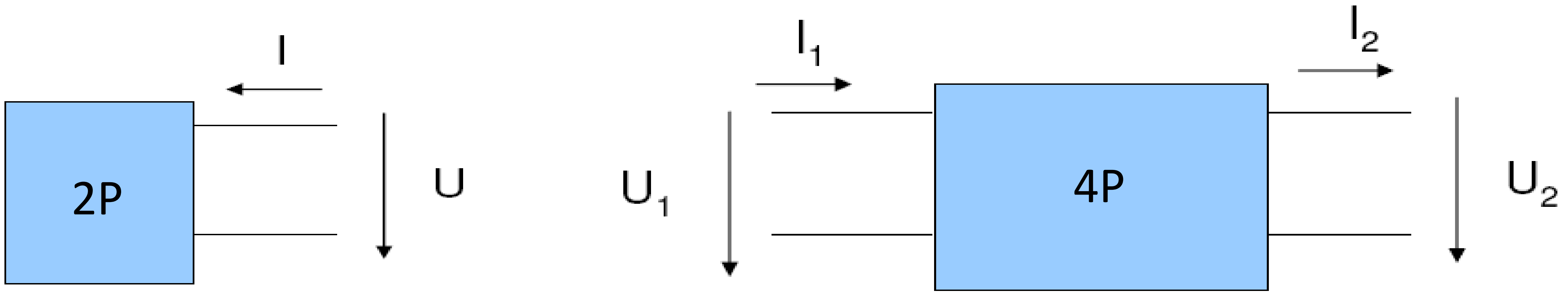
Four poles

Two poles:

Circuits with two terminals (1 pair)

Four poles:

Circuits with 4 terminals (2 pairs)



Four poles

2 pole characteristics

Impedance (Z); Admittance (Y)

$$V = ZI; \quad I = YV$$

$$Z = \frac{V}{I}; \quad Y = \frac{I}{V}$$

Four poles

4 pole characteristics

Parametric equations (V~U)

Impedance (Z); Admittance (Y), Chain (A), Hybrid (H)

Imepdance parameters:

$$U_1 = Z_{11} I_1 + Z_{12} I_2$$

$$U_2 = Z_{21} I_1 + Z_{22} I_2$$

Impedance parameters

Impedance parameters

$$Z_{11} = \frac{U_1}{I_1} \; if \, I_2 = 0$$

$$Z_{12} = \frac{U_1}{I_2} \; if \, I_1 = 0$$

$$Z_{21} = \frac{U_2}{I_1} \; if \, I_2 = 0$$

$$Z_{22} = \frac{U_2}{I_2} \; if \, I_1 = 0$$

Budapest University of Technology and Economics
Faculty of Transportation Engineering and Vehicle Engineering
Department of Control for Transportation and Vehicle Systems

Admittance parameters

$$I_1 = Y_{11} U_1 + Y_{12} U_2$$

$$I_2 = Y_{21} U_1 + Y_{22} U_2$$

Chain parameters

$$U_1 = A_{11} U_2 + A_{12} I_2$$

$$I_1 = A_{21} U_2 + A_{22} I_2$$

Hybrid parameters

Hybrid parameters

$$U_1 = H_{11} I_1 + H_{12} U_2$$

$$I_2 = H_{21} I_1 + H_{22} U_2$$

Four poles

Calculations:

$$U_x = 0 \ - short\ circuit$$
$$I_x = 0 \ - open\ circuit$$

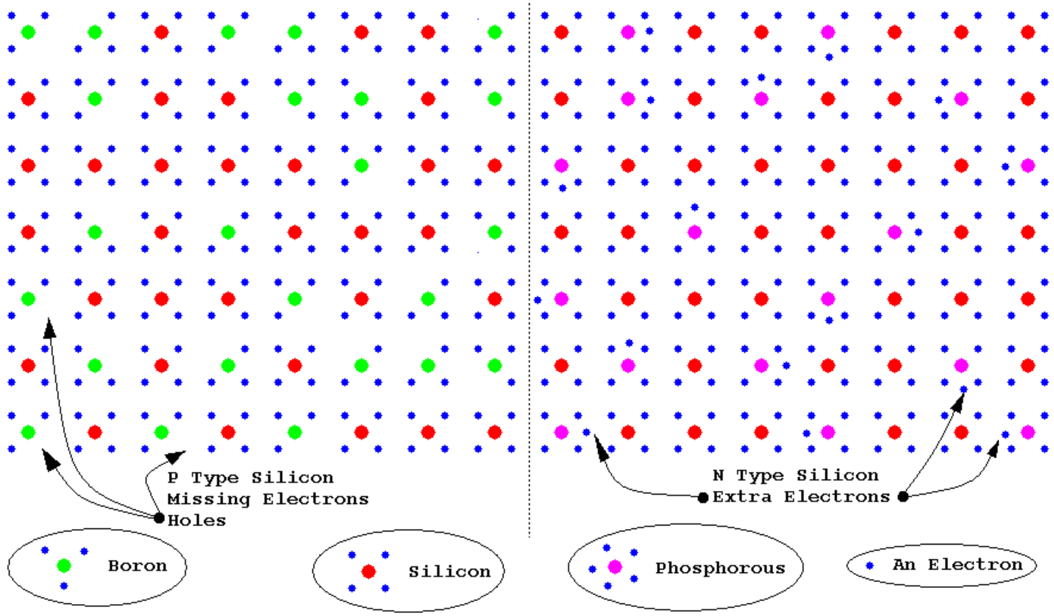
Diodes

- **Diode** is a very basic but important semiconductor device
  - Two different layers
  - Mostly made from Silicon or Germanium
- Semiconductors – materials that can either allow or stop the flow of current

Semiconductor Basics

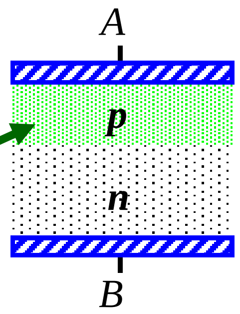
Two types of intrinsic carriers

- Electrons (n) and holes (p)
- In an intrinsic (no doping) material, n=p
- Use doping to improve conductivity



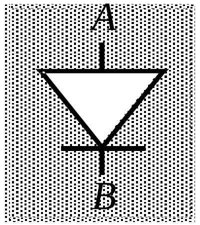
Diodes

Simplified structure



One-dimensional representation

The pn region is assumed to be thin

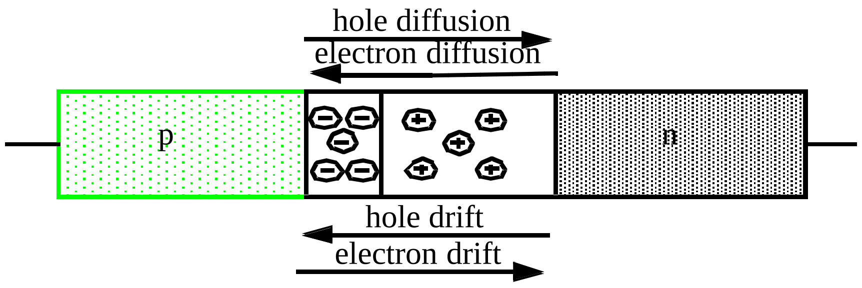


diode symbol

Different concentrations of electrons (and holes) of the p and n-type regions cause a concentration gradient at the boundary

Diodes

- Concentration Gradient causes electrons to diffuse from n to p, and holes to diffuse from p to n
- This produces immobile ions in the vicinity of the boundary
- Region at the junction with the charged ions is called the depletion region or space-charge region



Diodes

Forward Bias:

Vapplied > 0

- In forward bias the depletion region shrinks slightly in width.
- With this shrinking the energy required for charge carriers to cross the depletion region decreases exponentially.
- Therefore, as the applied voltage increases, current starts to flow across the junction.

Diodes

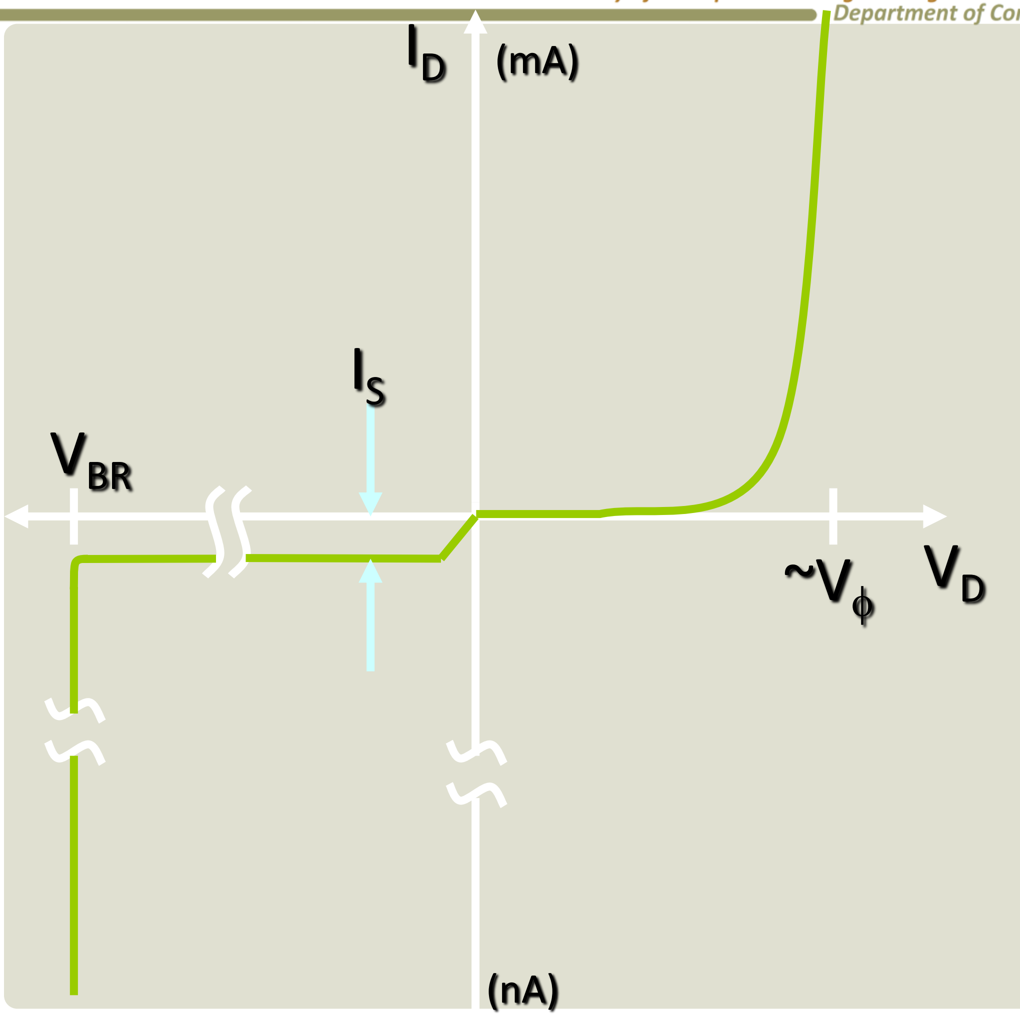
Reverse bias

Vapplied < 0

- Under reverse bias the depletion region widens.
- A small leakage current, Is (saturation current) flows under reverse bias conditions. This saturation current is made up of electron-hole pairs being produced in the depletion region.

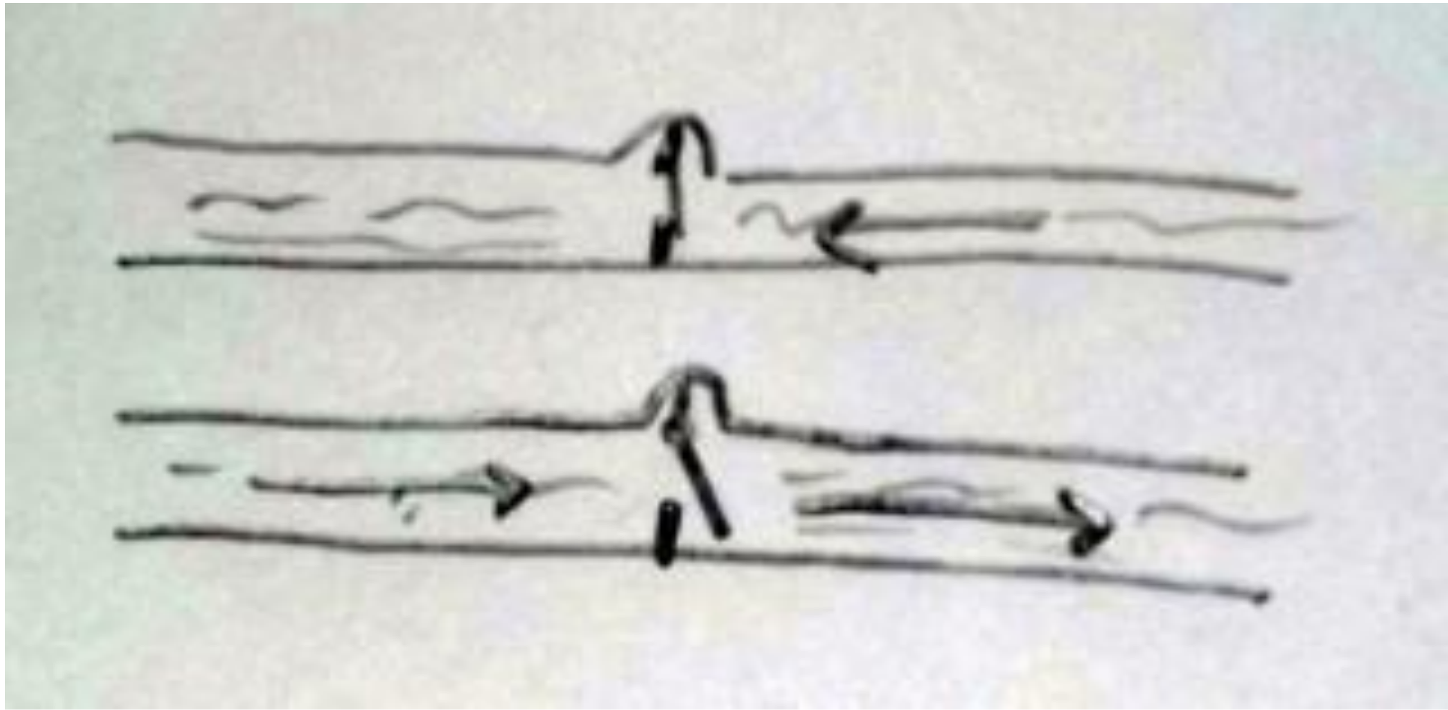
Diodes

Budapest University of Technology and Economics
Faculty of Transportation Engineering and Vehicle Engineering
Department of Control for Transportation and Vehicle Systems



- VD = Bias Voltage
- ID = Current through Diode. ID is Negative for Reverse Bias and Positive for Forward Bias
- IS = Saturation Current
- VBR = Breakdown Voltage
- Vϕ = Barrier Potential Voltage

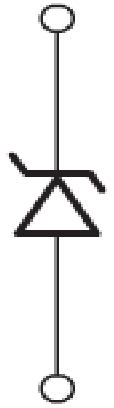
Diodes



Zener diodes

Zener diodes

- Works as a regular diode in the forward bias
- But are intended to operate in the breakdown region
- Used as a voltage stabilizer



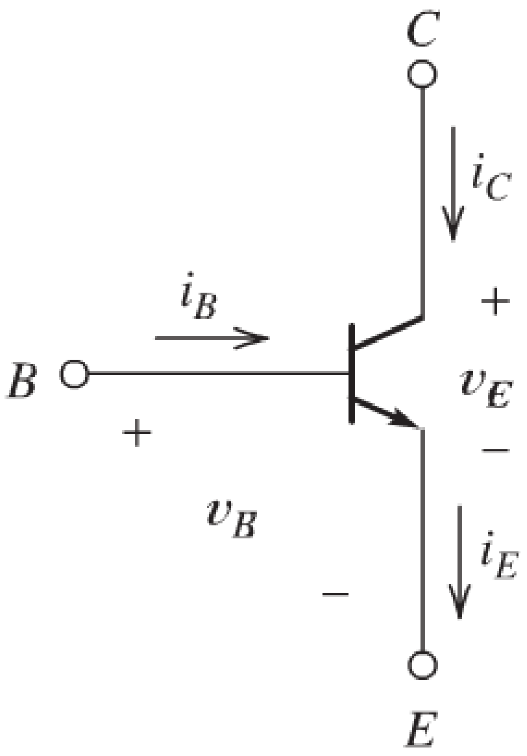
Transistors

Transistors

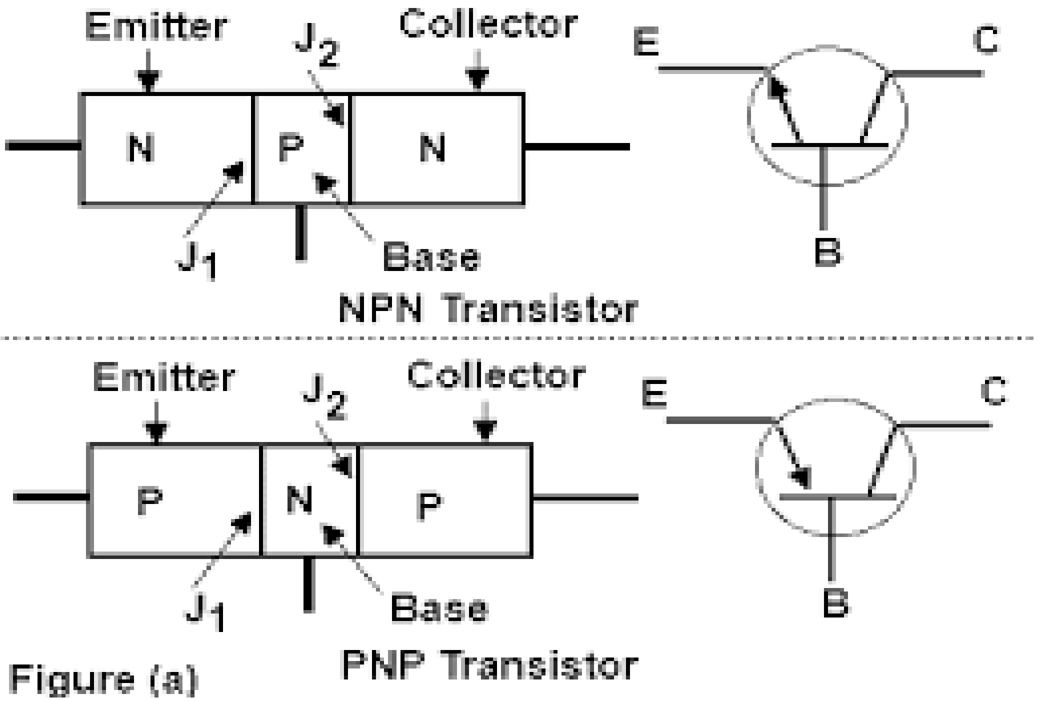
- 3 layered semi-conductors
- FET – Field Effect Transistors
  - Can occupy less chip area, is more easily fabricated
- BJC – Bipolar Junction Transistors
  - Can produce large output currents
- Both are used in amplifiers and logic gates

BJT

- Can be npn or pnp
- 3 legs/layers
  - Base
  - Emitter
  - Collector
- Multiple build variations
- 2 mode of use
  - Switch or linear/amplifier modes



Transistors



Transistors

How does it work?

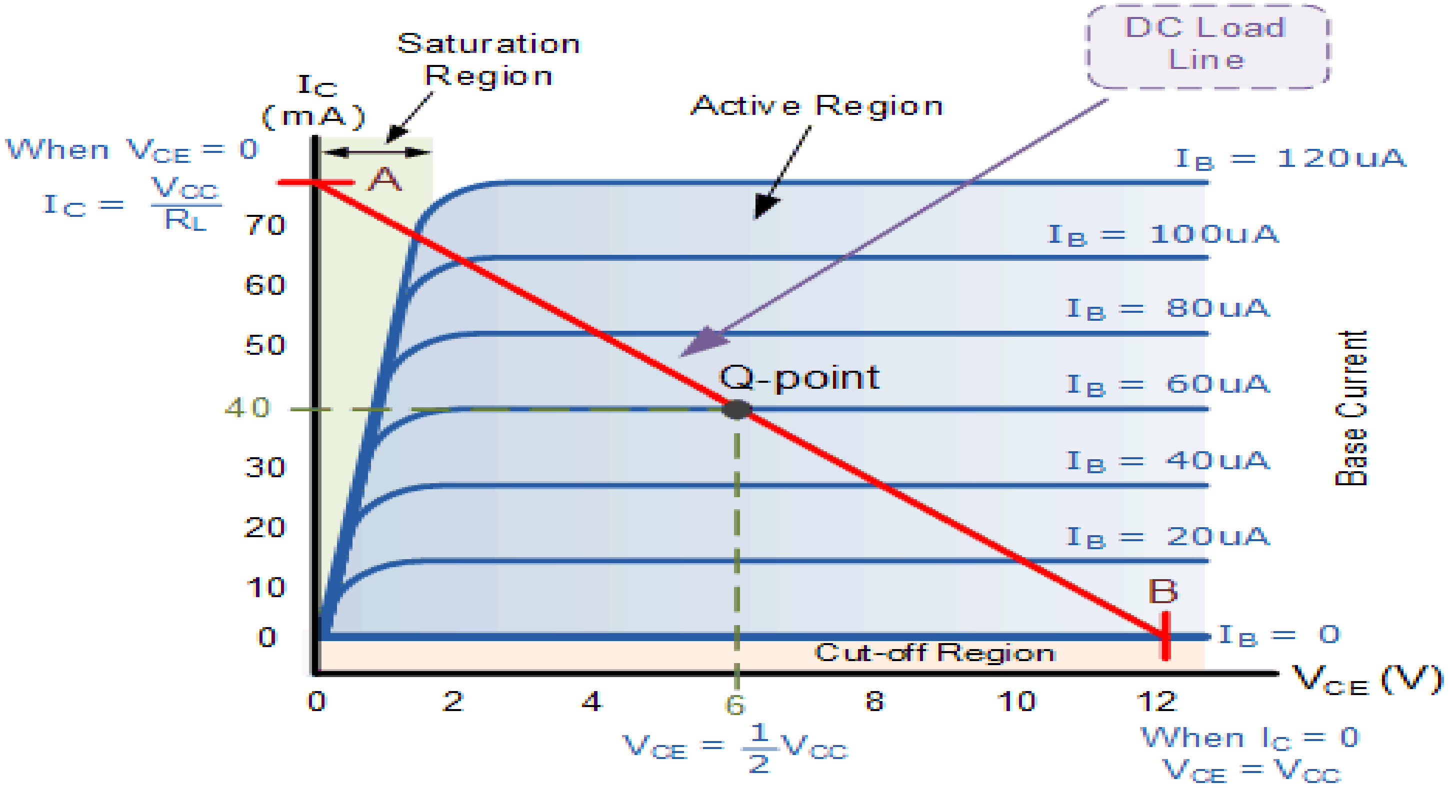
A combination of a PN and an NP layer

- When the transistor conducts, electrons are attracted from the emitter by holes appearing in the base. A few electrons will combine with holes to form base current, which is indicated by a few free electrons flowing around the base–emitter circuit.
- With Vce turned on, the majority of free electrons in the base area are attracted across the collector–base depletion layer to form the large current flowing in the collector–emitter circuit.
- As a small base current, caused by forward biasing the base–emitter junction causes a large collector current to flow, the transistor is acting as a current amplifier.

$$i_c = \beta i_B$$

http://www.learnabout-electronics.org/Semiconductors/bjt_04.php

Transistor characteristics



Amplifiers

Amplify input voltage or current

Operational amplifier