Universidad
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Session 6
Semiconductor devices fundamentals

Electronic Components and Circuits

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www.uc3m.es/portal/page/portal/dpto_tecnologia_electronica/Personal/IsabelPerez

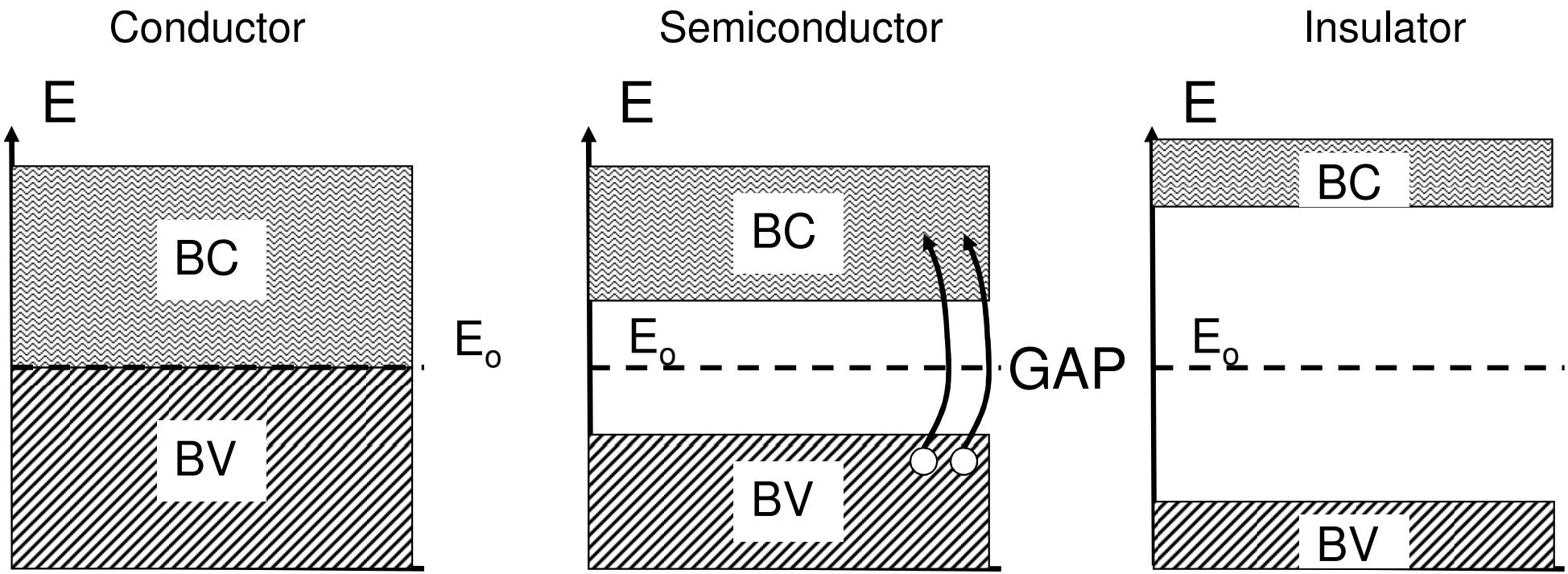
Semiconductor Materials and Diodes

SKILLS

- To know the semiconductors fundamentals
  - Intrinsic semiconductors. Electron and hole.
  - Extrinsic semiconductors. Impurity atoms (donors and aceptors).
  - n-type and p-type semiconductors
- To understand the p-n junction fundamentals
  - p-n junction equilibrium . The space charge region.
  - p-n junction biased (forward bias and reverse bias)
- To understand the i-v characteristic of the diode

Semiconductor Materials

Bands Theory

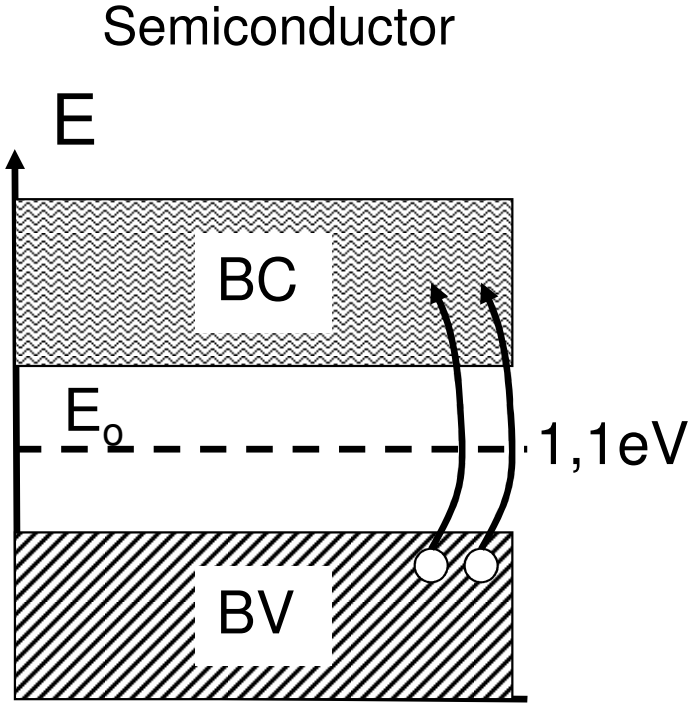


Basic Semiconductor Concepts

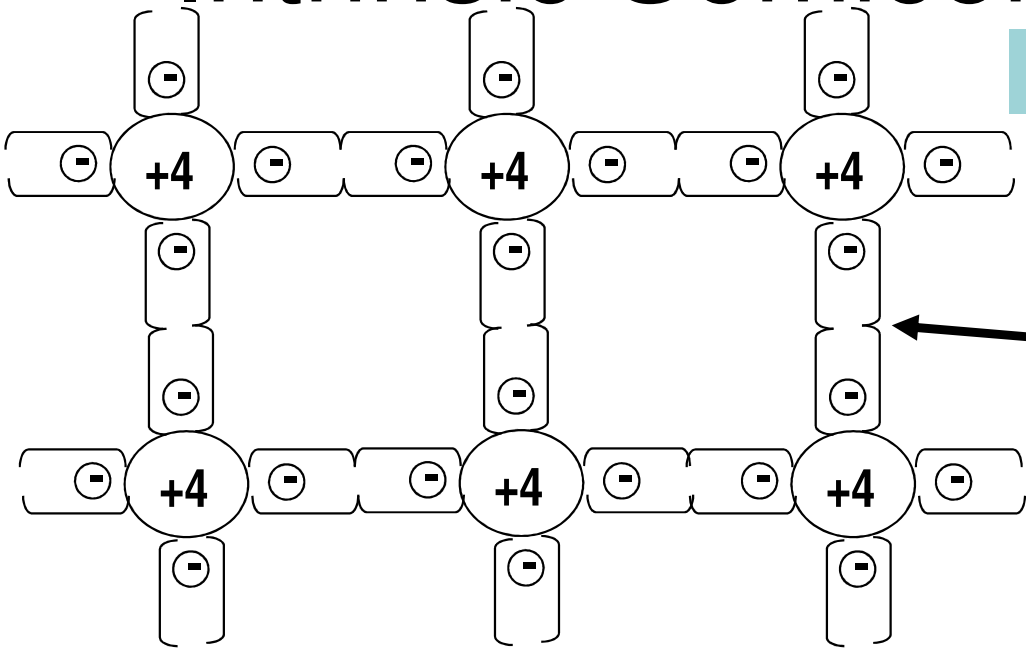
Intrinsic semiconductor. Electron -hole pair

$n_i^2(T)=n \cdot p$ n=p (intrinsic)

$$\sigma = 1/\rho = q_e\left[n \cdot \mu_e + p \cdot \mu_h\right]$$

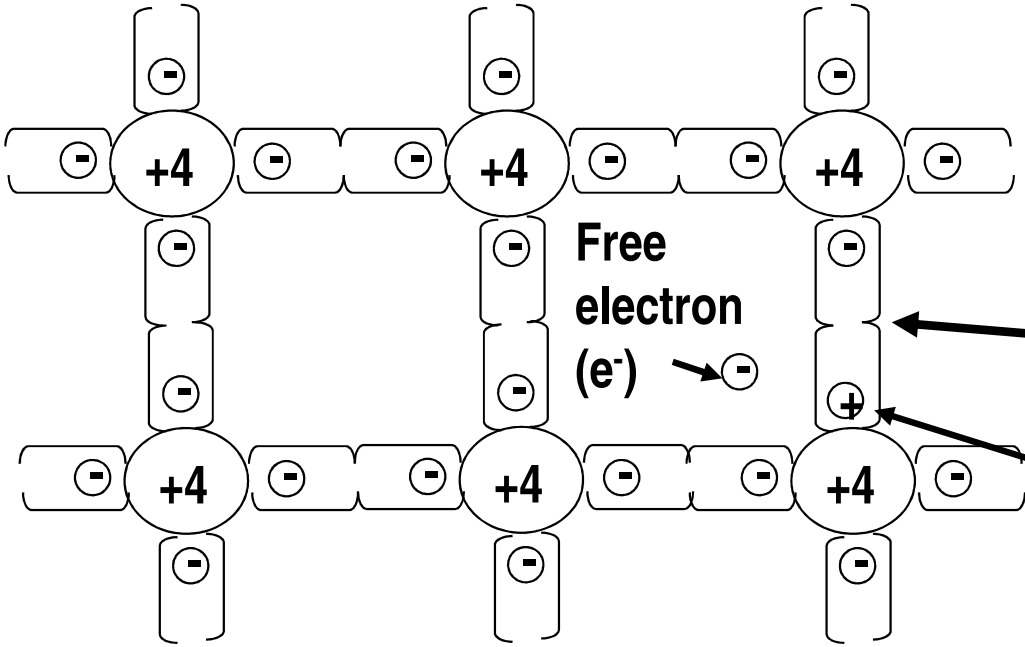


Intrinsic Semiconductors (Si)



T=0ºK (thermal equilibrium)

Covalent bond



T > 0ºK

Covalent bond broken

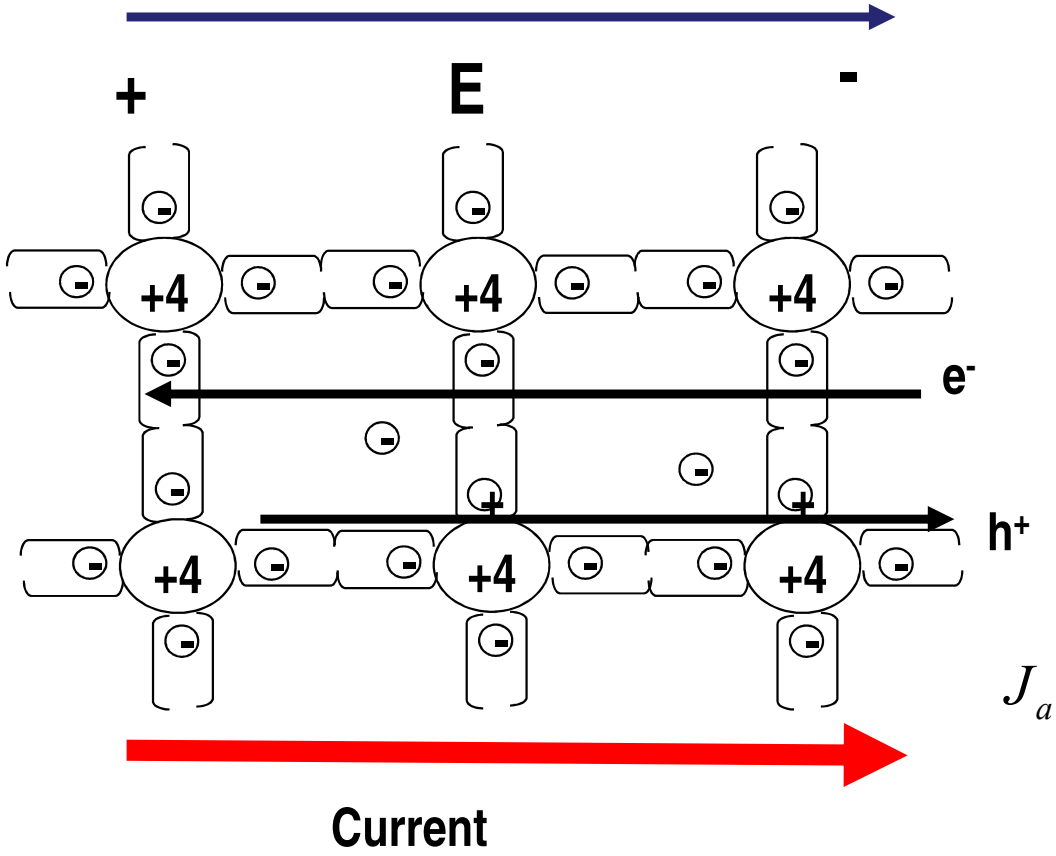
Free hole(h^+)

Semiconductor Currents

• **DIFFUSION:** If free electrons concentration is made higher in one part of the piece of Si than in another, then the electrons will diffuse from the region of high concentration to the region of low concentration⇒diffusion current density(J_d [A/cm^2])

$$J_d = J_{dn} + J_{dp} = q \bullet D_n \bullet \frac{dn}{dx} - q \bullet D_p \bullet \frac{dp}{dx}$$

• **DRIFT:** An electric (E [V/cm^2) field is applied]

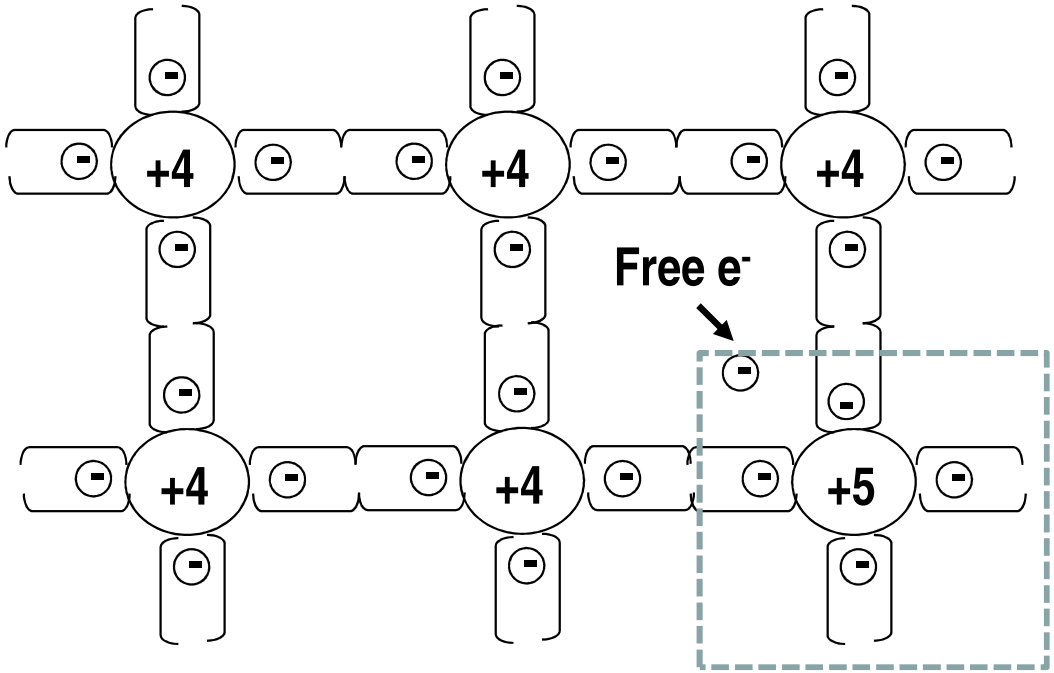


Two charge carriers:
e^- and h^+

$$J_a = J_{an} + J_{ap} = q \bullet n \bullet \mu_n \bullet E + q \bullet p \bullet \mu_p E$$

Extrinsic Semiconductors

n-type: Donor impurity atoms. Example: Phosphorus(P).



$n_i^2(T) = n \cdot p$

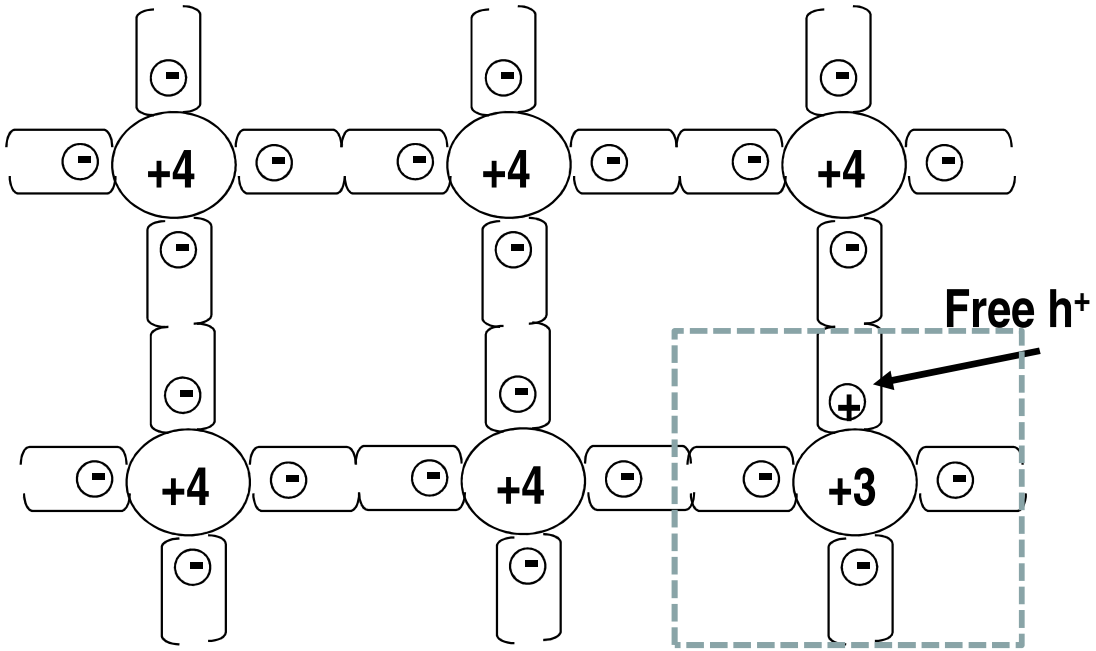
$n > p$ (n-type)

e^- : mayority carriers

h^+ : minority carriers

Extrinsic Semiconductors

p- type: Acceptor impurity atoms. Example: Boron (B)



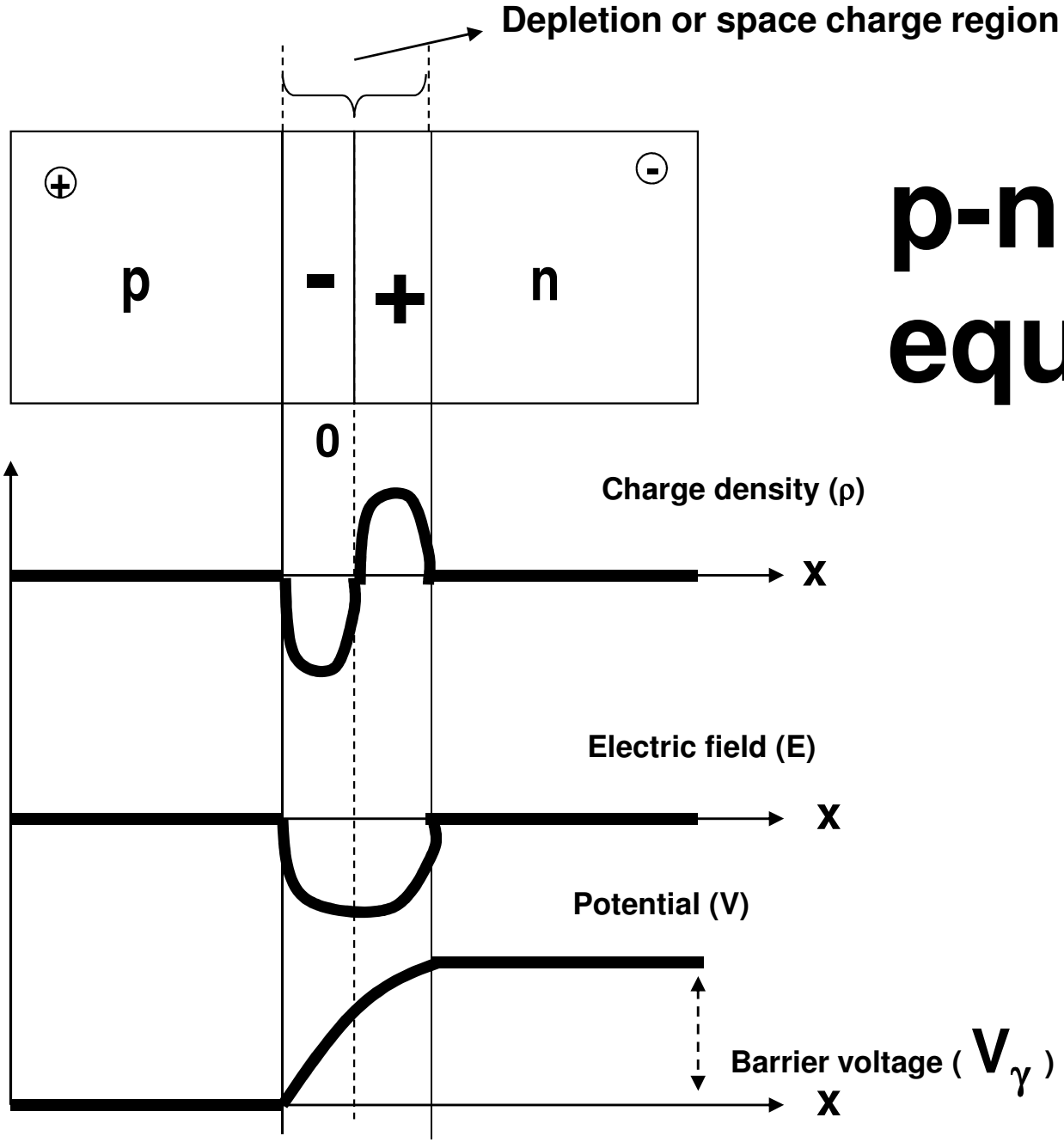
$n_i^2(T) = n \cdot p$

$p > n$ (p-type)

h^+ : mayority carriers

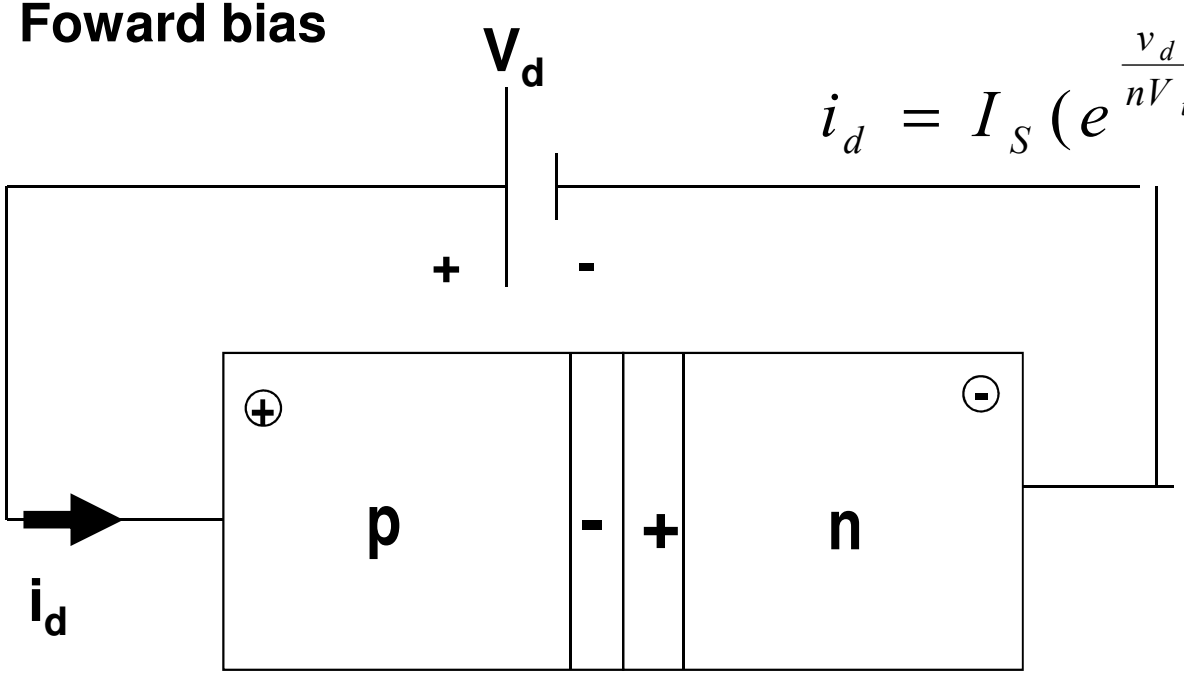
e^- : minority carriers

p-n Junction equilibrium



Biased p-n Juntion

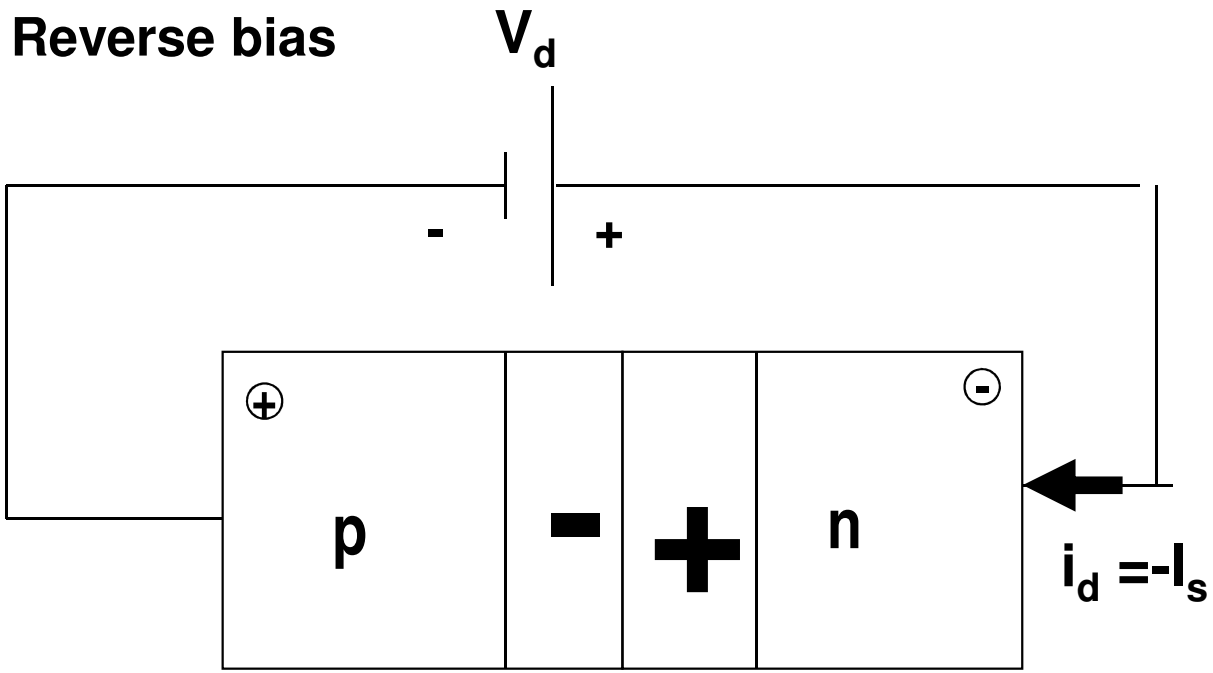
Foward bias



$$i_d = I_S\left(e^{\frac{v_d}{nV_t}} - 1\right)$$

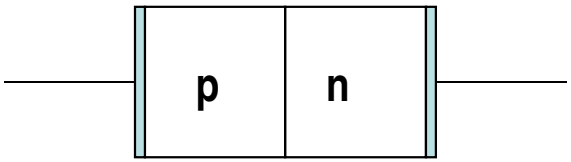
- i_d: Mayority carriers current

Reverse bias

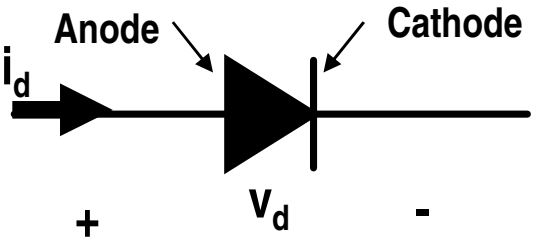


- i_d: Minority carriers current

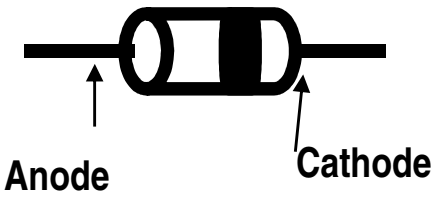
The p-n Junction Diode



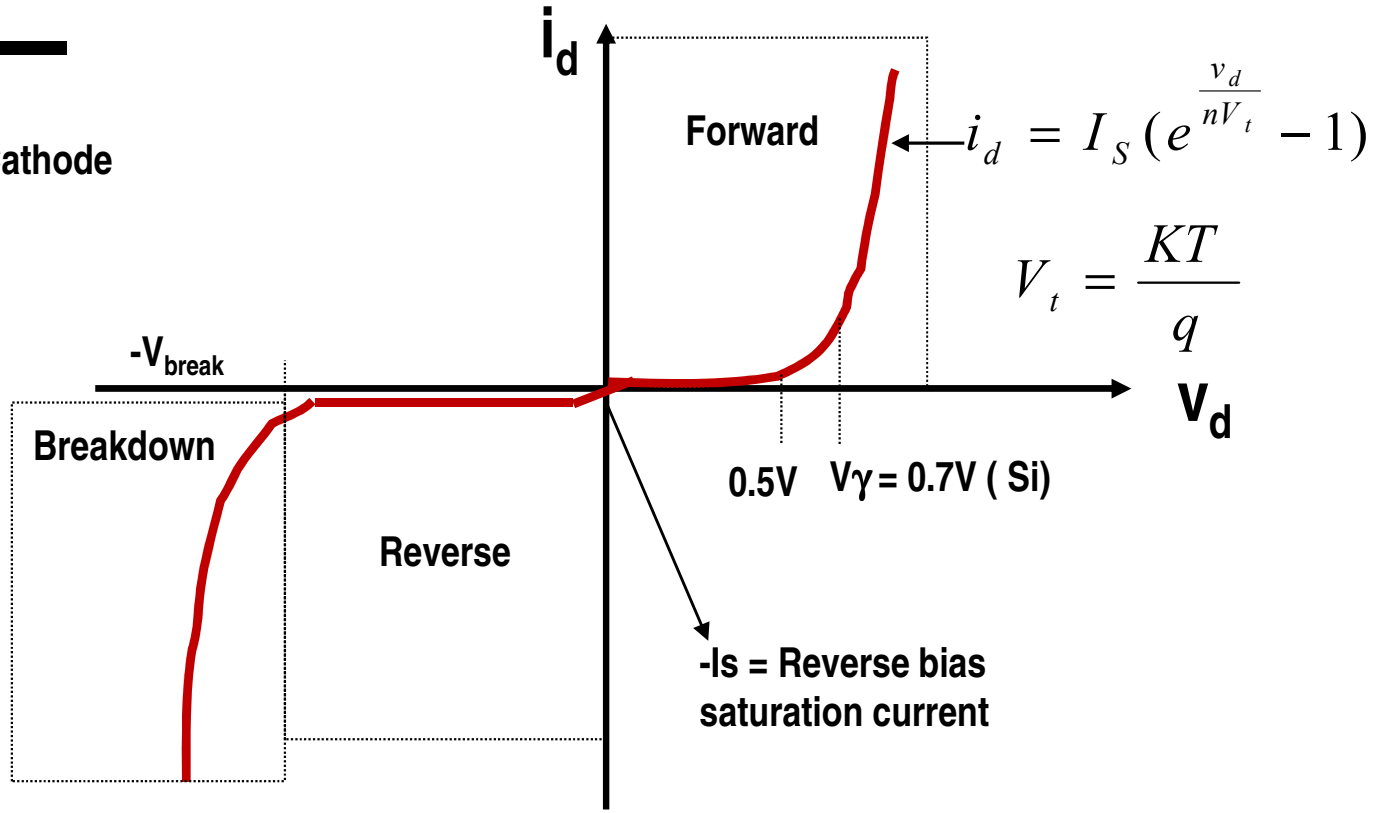
Symbol



Package



I-V CAHARACTERISTIC

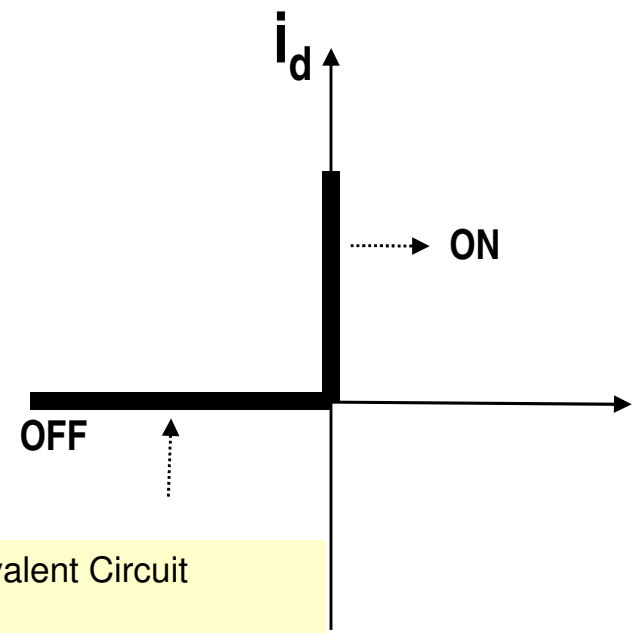


Diodes and Applications

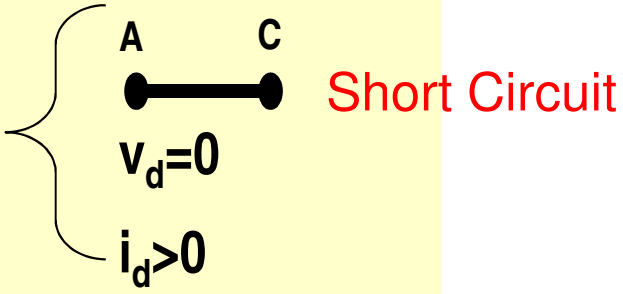
SKILLS

- To know the diode basic work as a circuit component and to know the diode models
- To understand the conduction threshold and its use in diode circuits
- To know the types of diode circuits

Ideal Diode

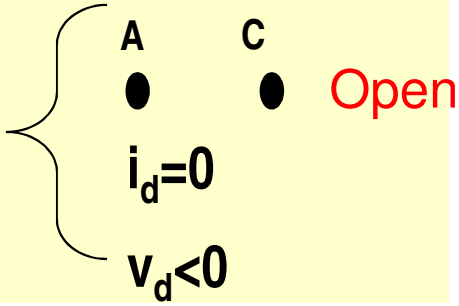


Equivalent Circuit

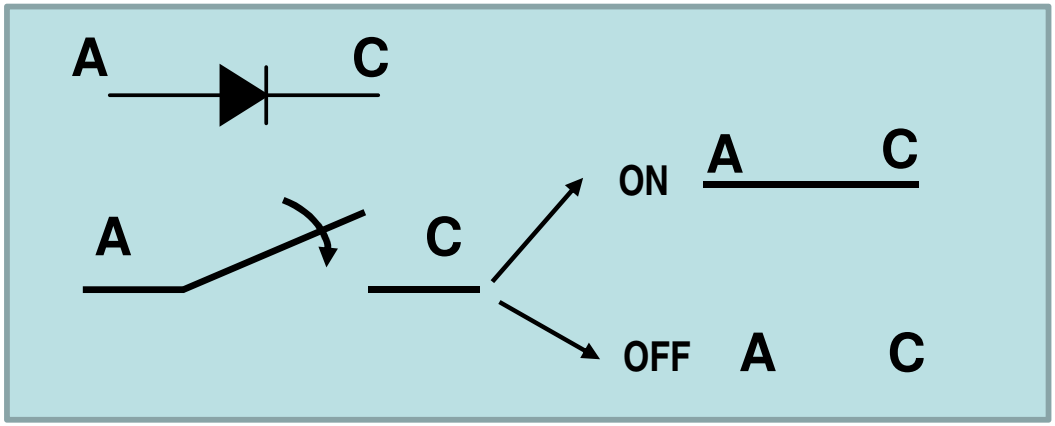


Short Circuit

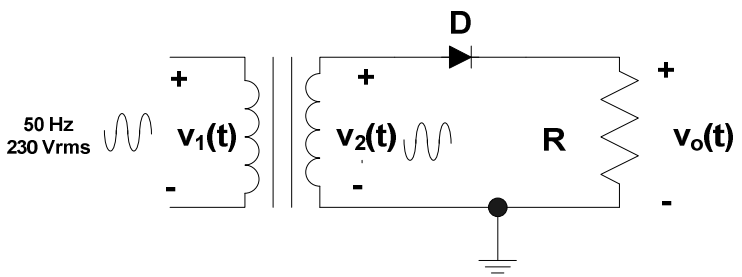
Equivalent Circuit

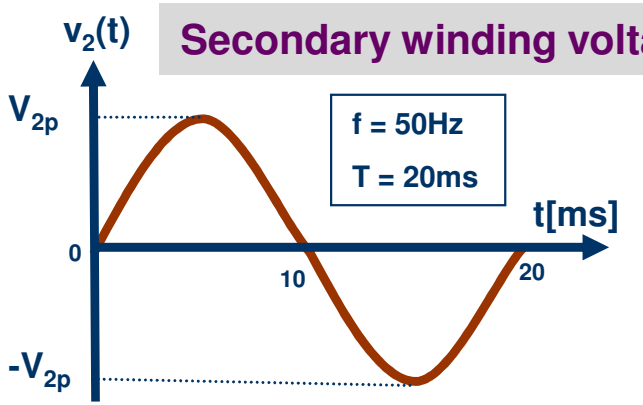


Open Circuit



Example: Half-Wave Rectifier

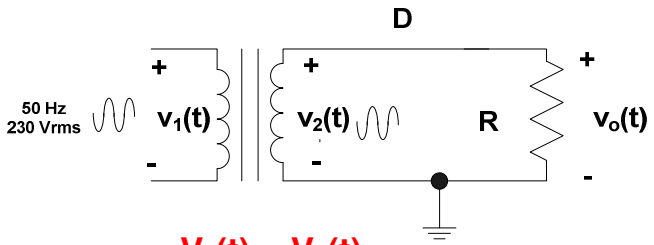




Secondary winding voltage

$V_2(t) > 0$

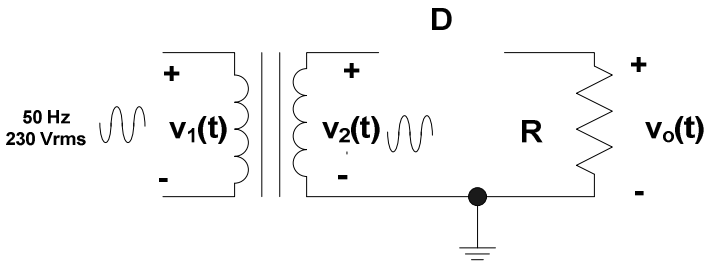
D ON



$V_o(t) = V_2(t)$

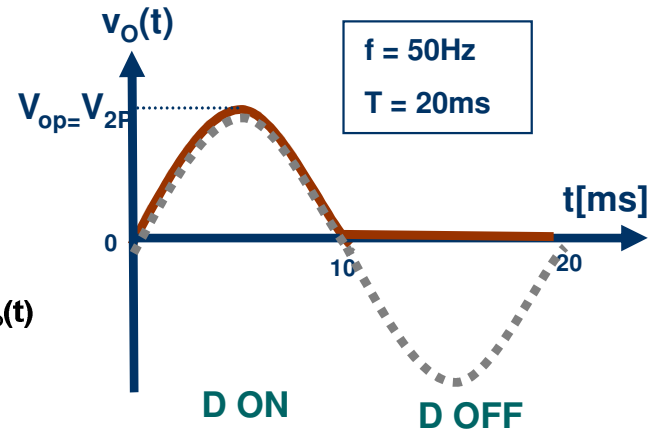
$V_2(t) < 0$

D OFF

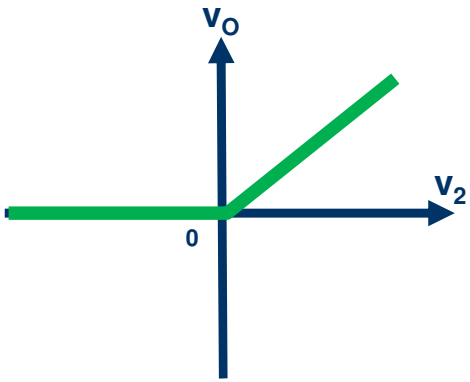


$V_o(t) = 0$

Output waveform

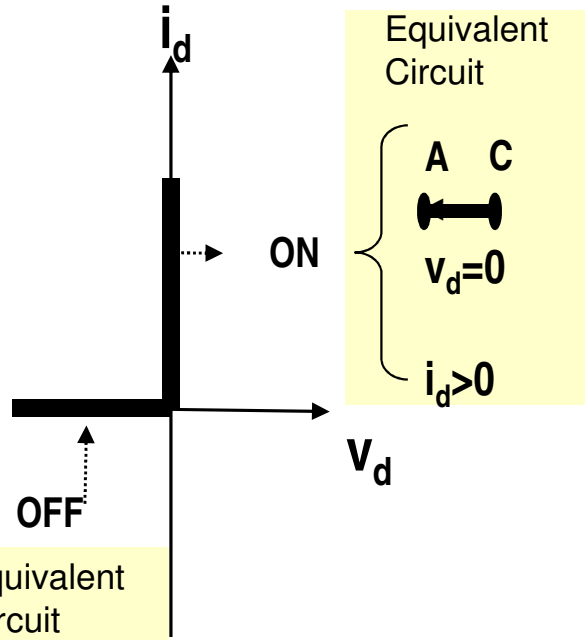


Transfer function



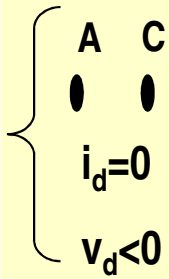
Diode Equivalent Circuits

1ª Approximation: Ideal Diode

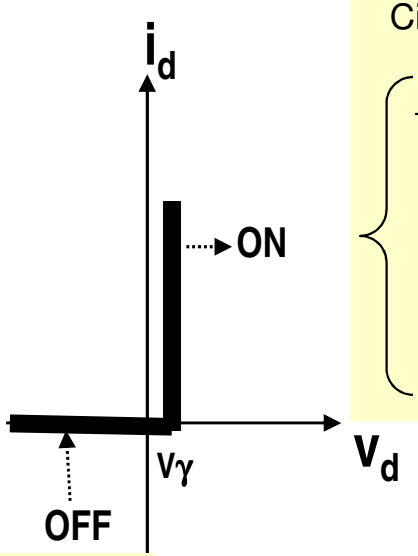


Equivalent Circuit

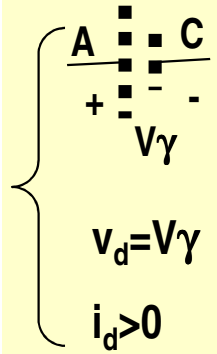
Equivalent Circuit



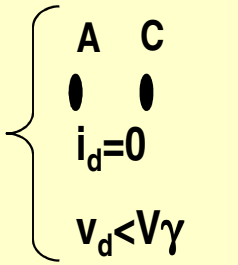
2ª Approximation



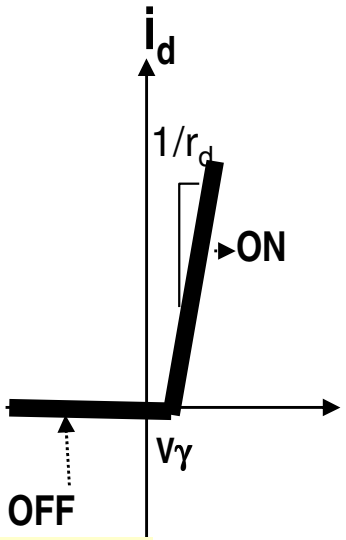
Equivalent Circuit



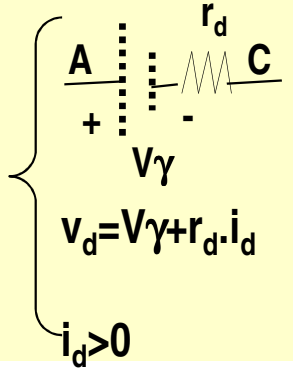
Equivalent Circuit



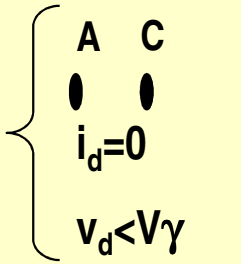
3ª Approximation



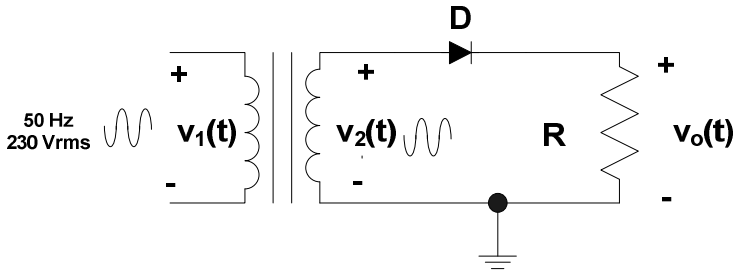
Equivalent Circuit

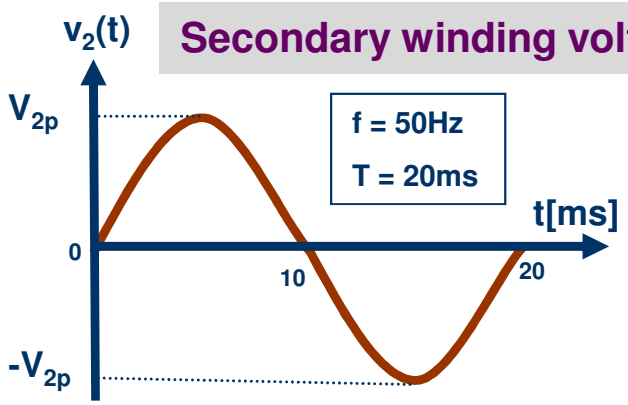


Equivalent Circuit



Rectifier Circuits



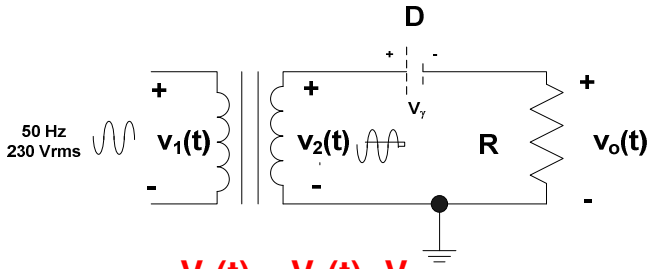


Secondary winding voltgage

2ª Approximation

$V_2(t) > V\gamma$

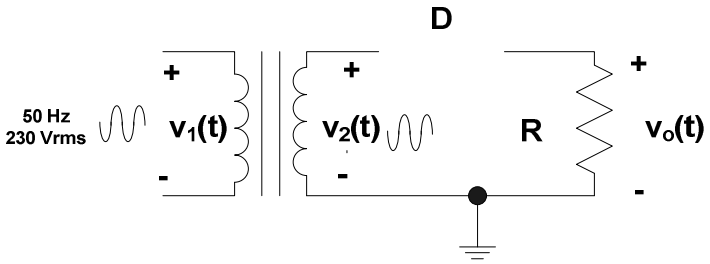
D ON



$V_o(t) = V_2(t) - V_\gamma$

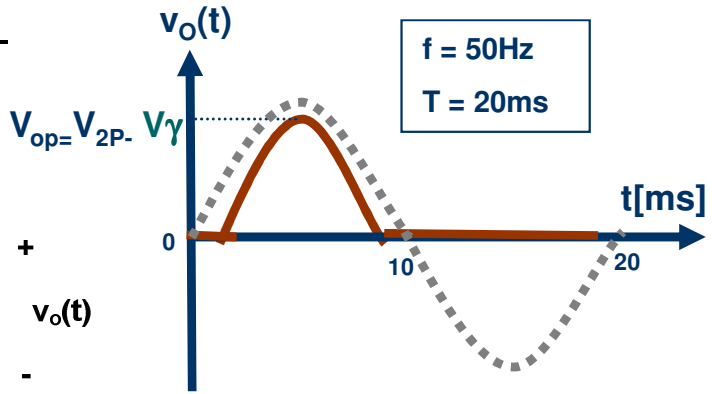
$V_2(t) < V\gamma$

D OFF



$V_o(t) = 0$

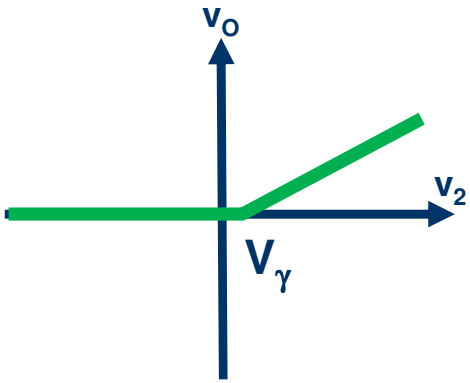
Output waveform



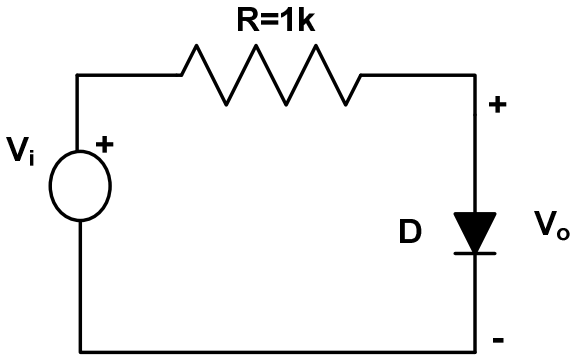
D ON $V_2(t) > V\gamma$

D OFF $V_2(t) < V\gamma$

Transfer function

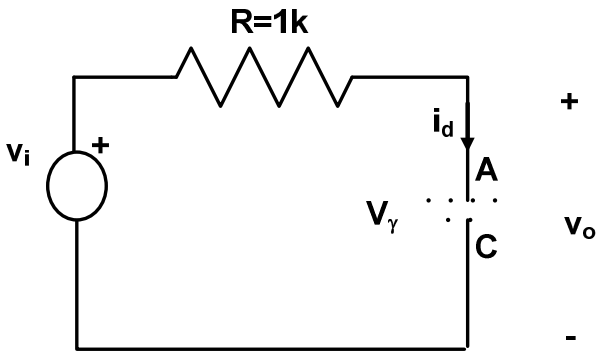


Limiter Circuits



$V_i > V\gamma$

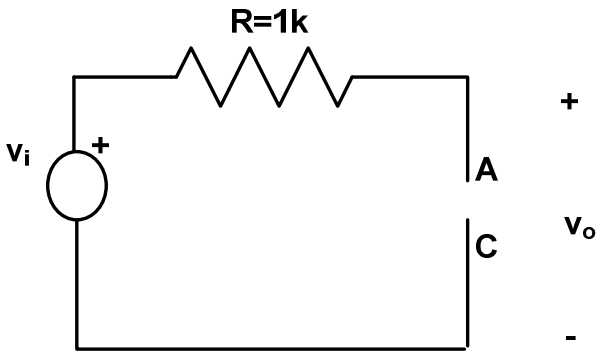
D ON



$V_o = V_\gamma$

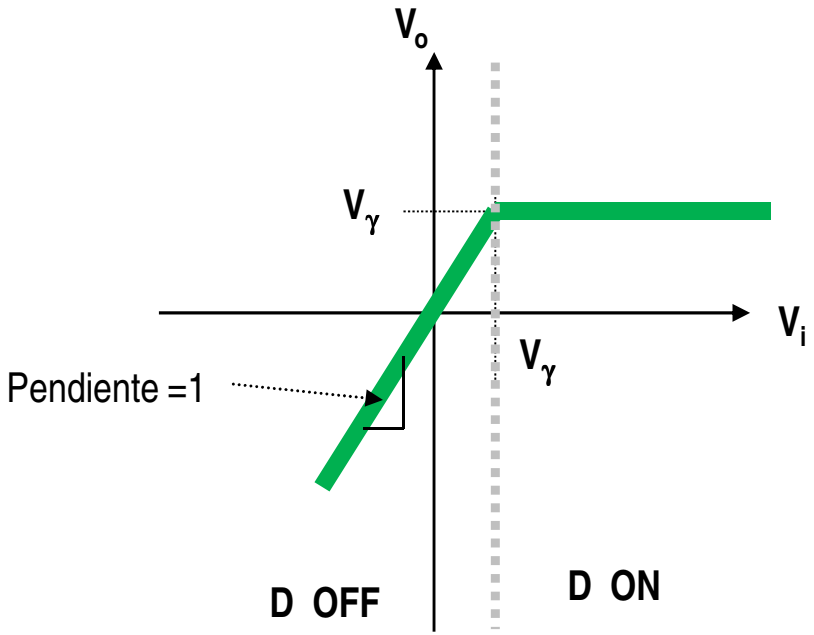
$V_i < V\gamma$

D OFF



$V_o = V_i$

Transfer function



Output waveform