EE 101: Basic Electronics

Diode Basics

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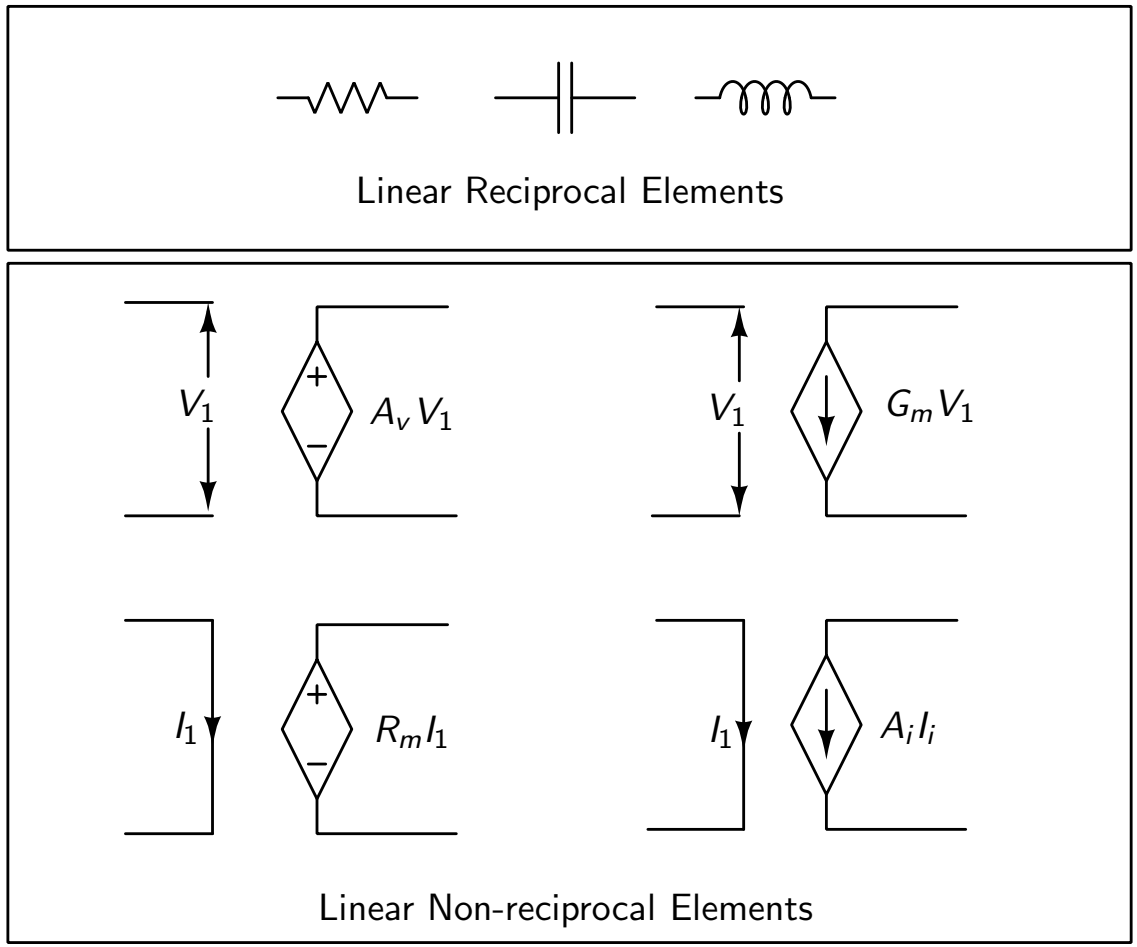
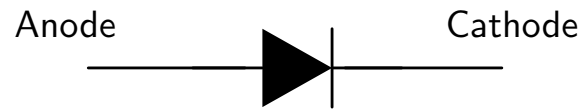
Linear Elements



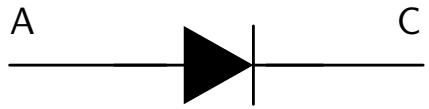
A Two Terminal Non-Linear Element



Diode Symbol

Non-linear + Non-Reciprocal

An Ideal Diode



$$R_{AC} = \begin{cases} 0 \text{ for } V_{AC} > 0 \\ \infty \text{ for } V_{AC} < 0 \end{cases}$$

Equivalent Circuit

for $V_{AC} > 0$

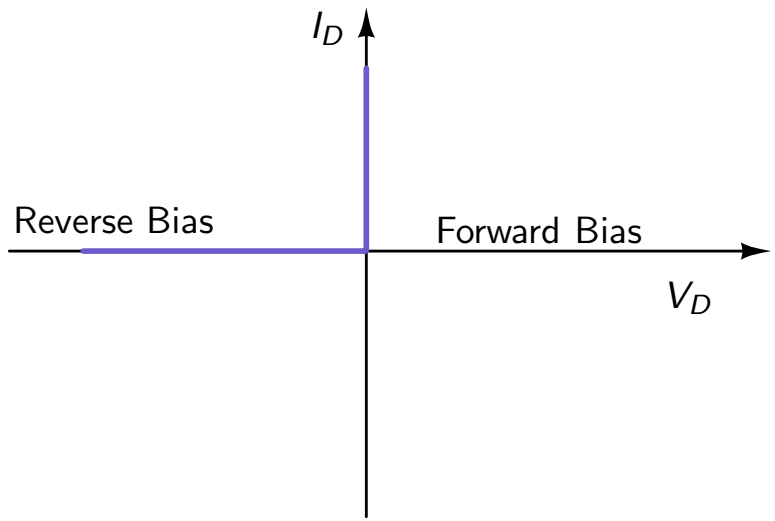
Diode is forward biased

Equivalent Circuit

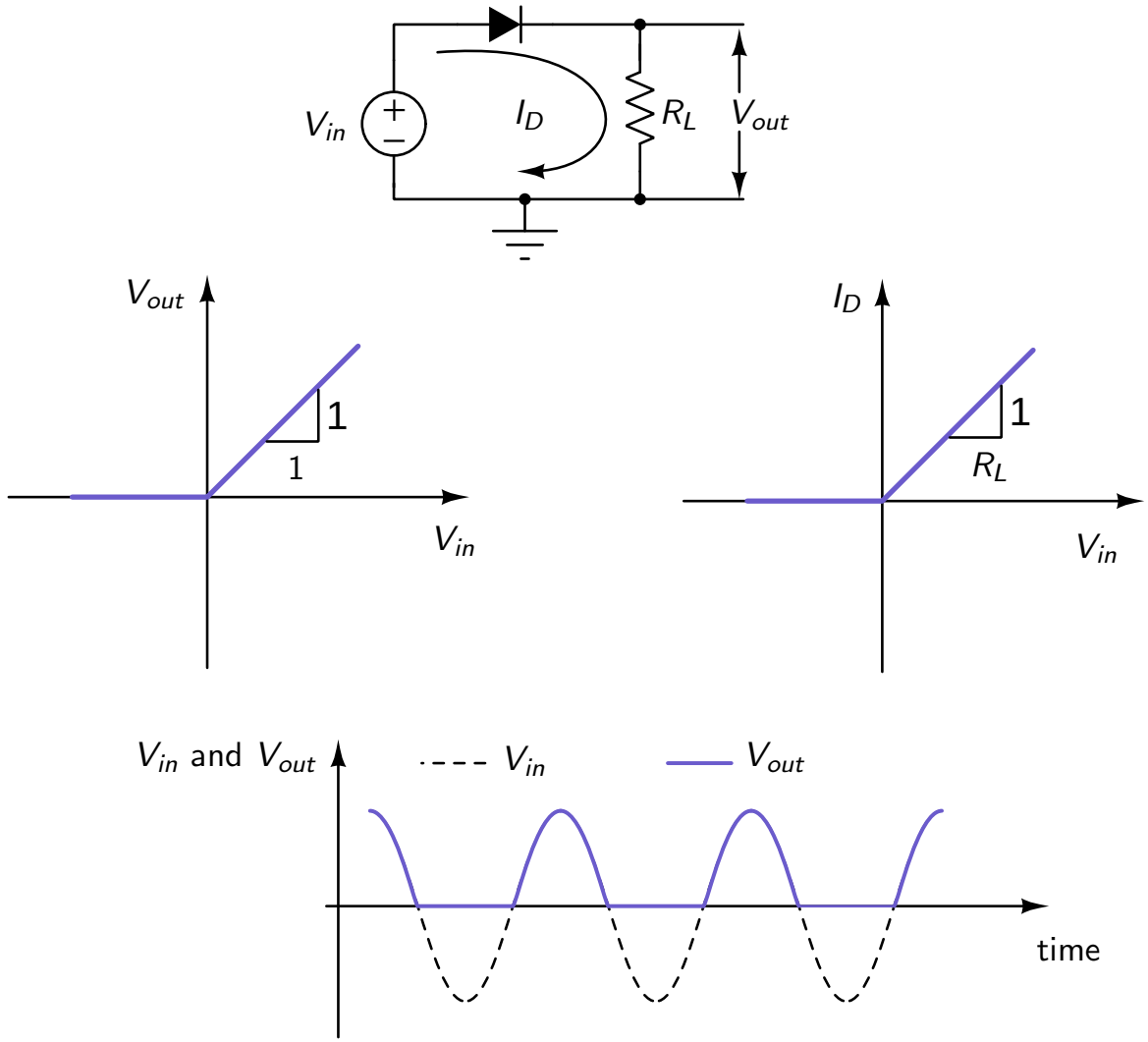
for $V_{AC} < 0$

Diode is reverse biased

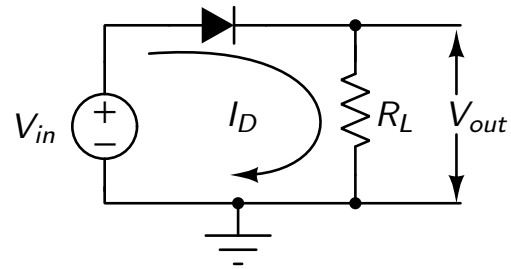
$I - V$ Characteristics of an Ideal Diode

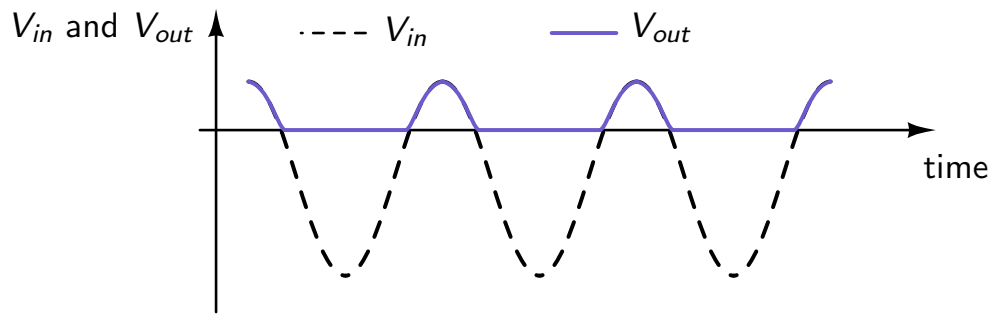


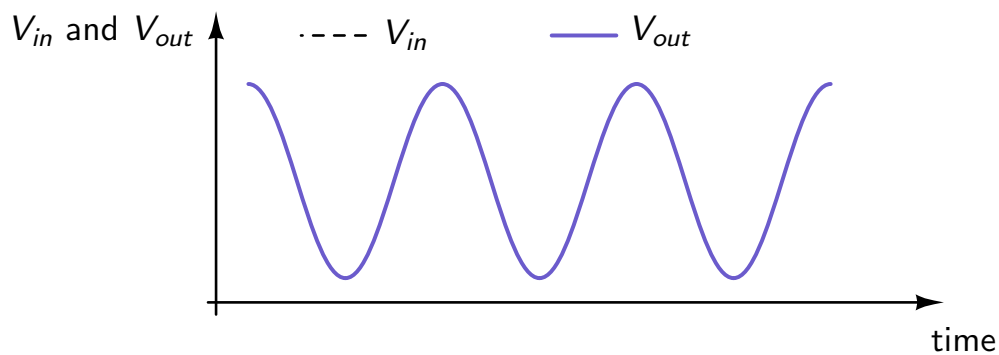
A Diode Circuit



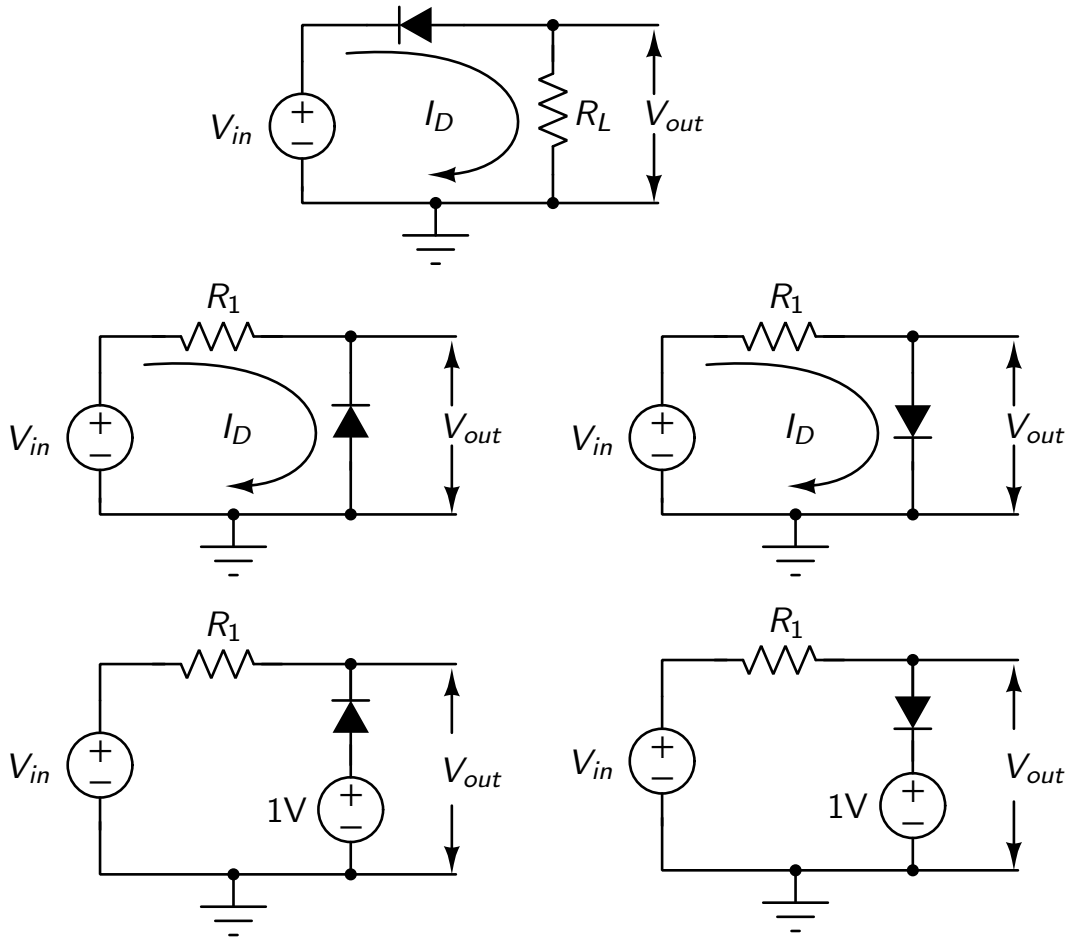
A Diode Circuit



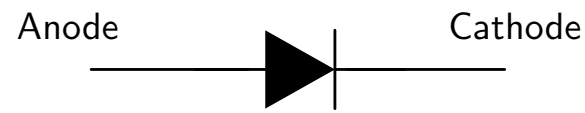




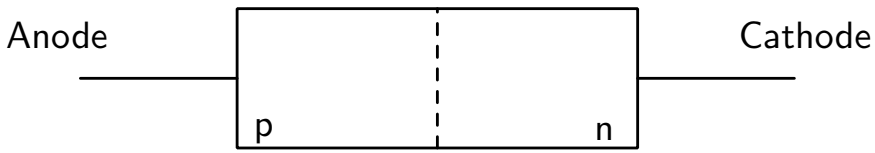
Draw the Transfer Characteristics



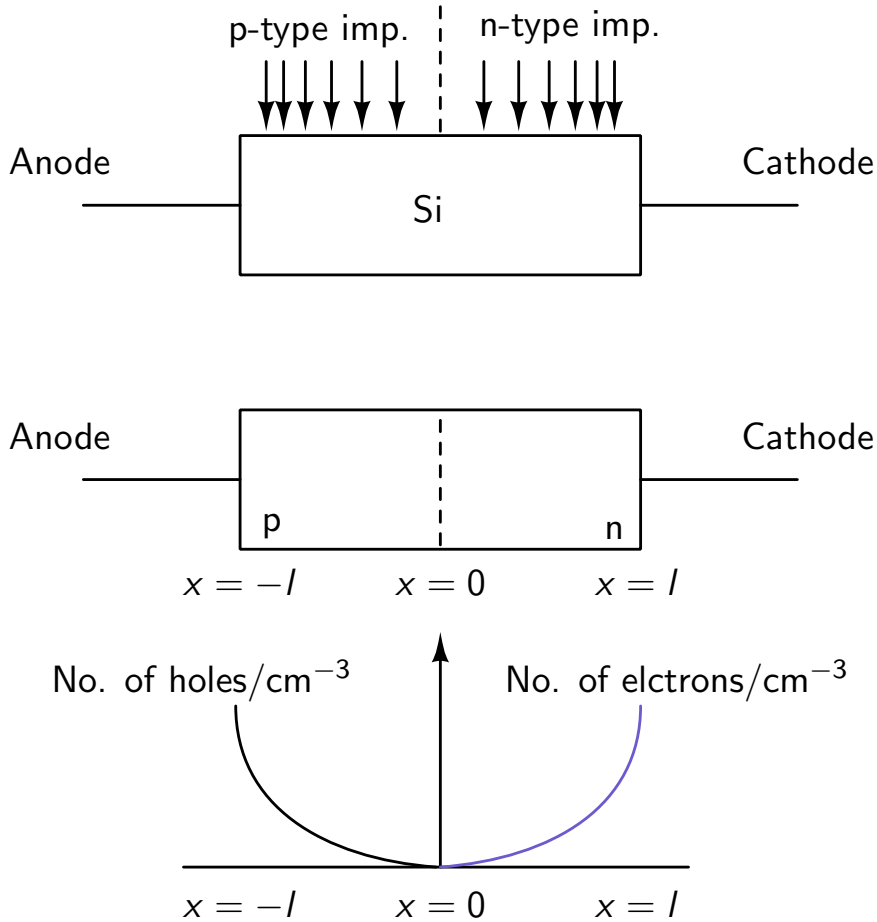
A Real Diode



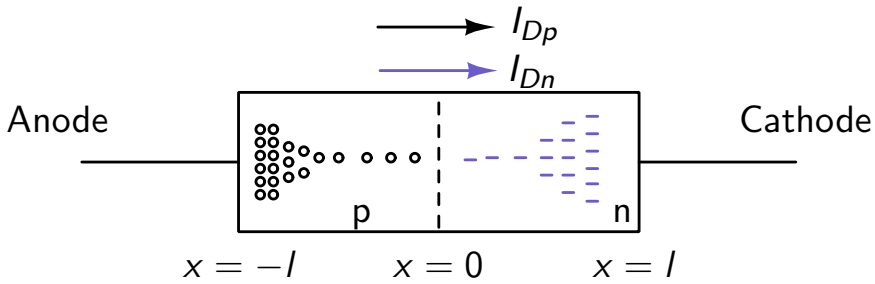
Diode Symbol



A PN Junction Diode

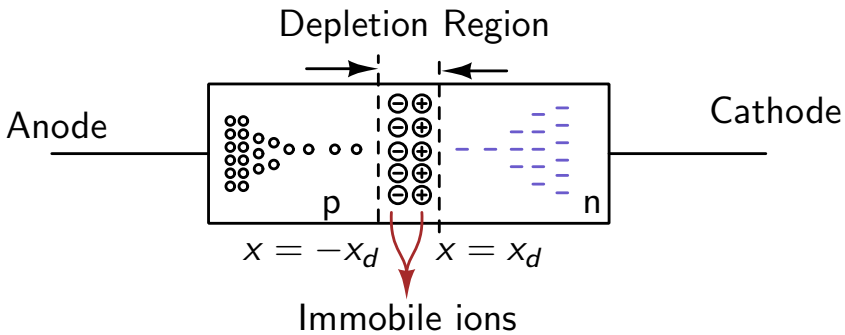


Diffusion Current in a PN Junction Diode

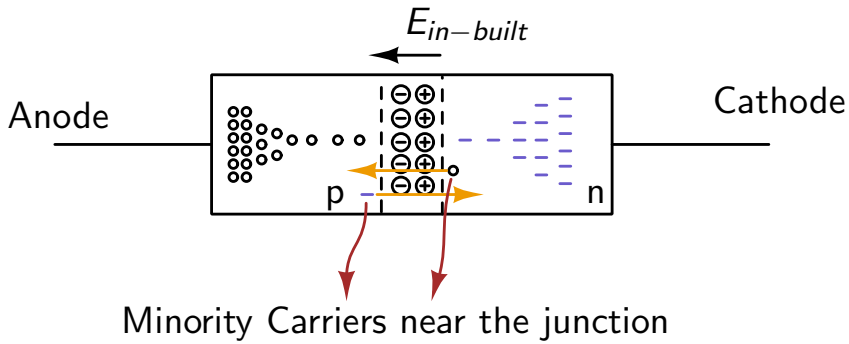


Diffusion Current $I_D = I_{Dp} + I_{Dn}$

Quick Recap: Diffusion current $\propto$ Carrier Gradient



Drift Current in a PN Junction Diode

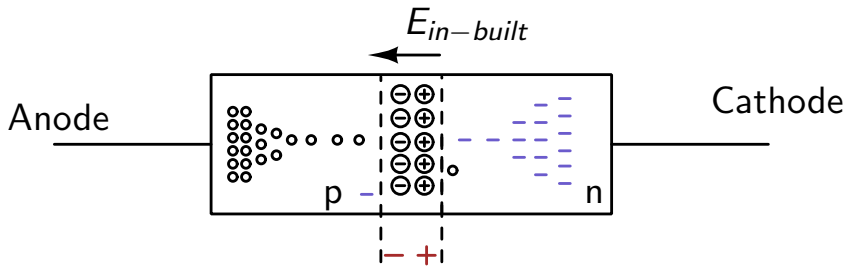


Quick Recap: Drift Current $\propto E$

Direction of drift curreent due to $E_{in-built}$ is n$\rightarrow$p

At equilibrium: Diffusion current = Drift current

Built-in potential in a PN Junction Diode



$$V_{in-built} \approx E_{in-built} \times 2x_d$$

$$\boxed{V_{in-built} = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right),}$$

Where $V_T = \frac{kT}{q}$ is the thermal voltage,

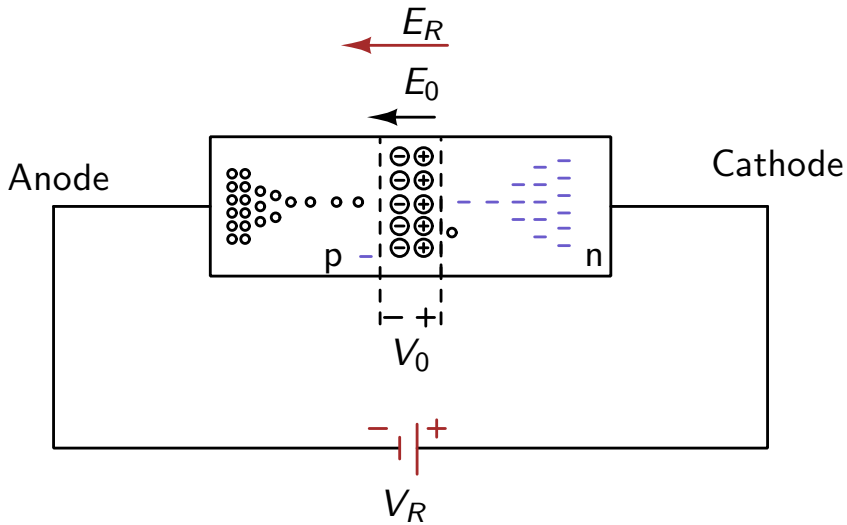
N_A is the acceptor atoms concentration on p-side,

N_D is the donar atoms concentration on n-side,

n_i is the intrinsic carrier concentration.

$$\boxed{\text{In Si PN junction diodes, } V_{in-built} \approx 0.7V}$$

PN Junction Diode in Reverse Bias



In reverse bias, drift current $>$ diffusion current

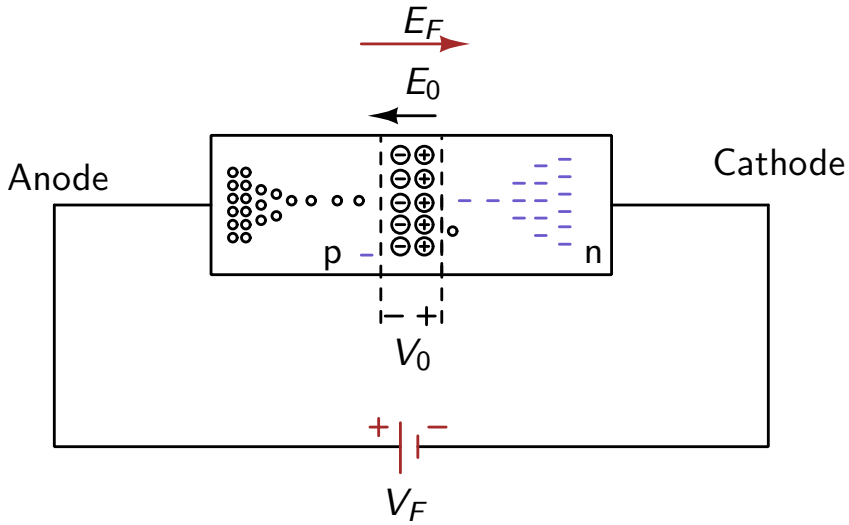
↓

due to minority carriers

↓

small current from n$\rightarrow$p

PN Junction Diode in Forward Bias



In Forward bias, diffusion current $>$ drift current

↓

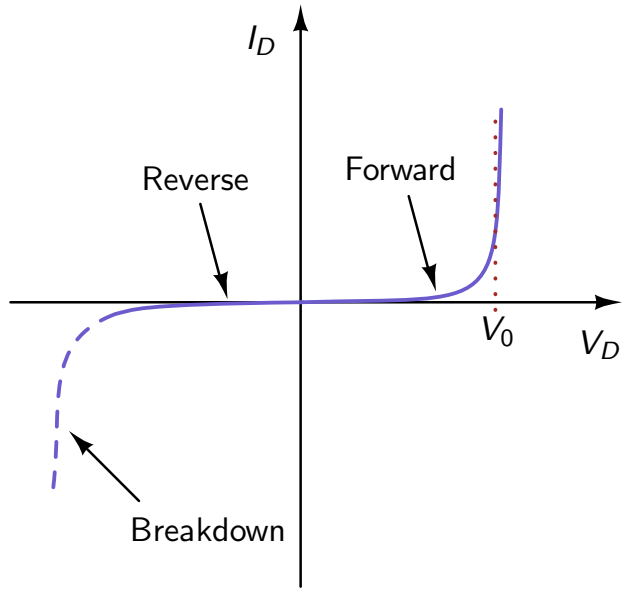
due to majority carriers

↓

small current from p$\rightarrow$n for $V_F < V_0$

large current from p$\rightarrow$n for $V_F \geq V_0$

I-V Characteristics of a PN Junction Diode

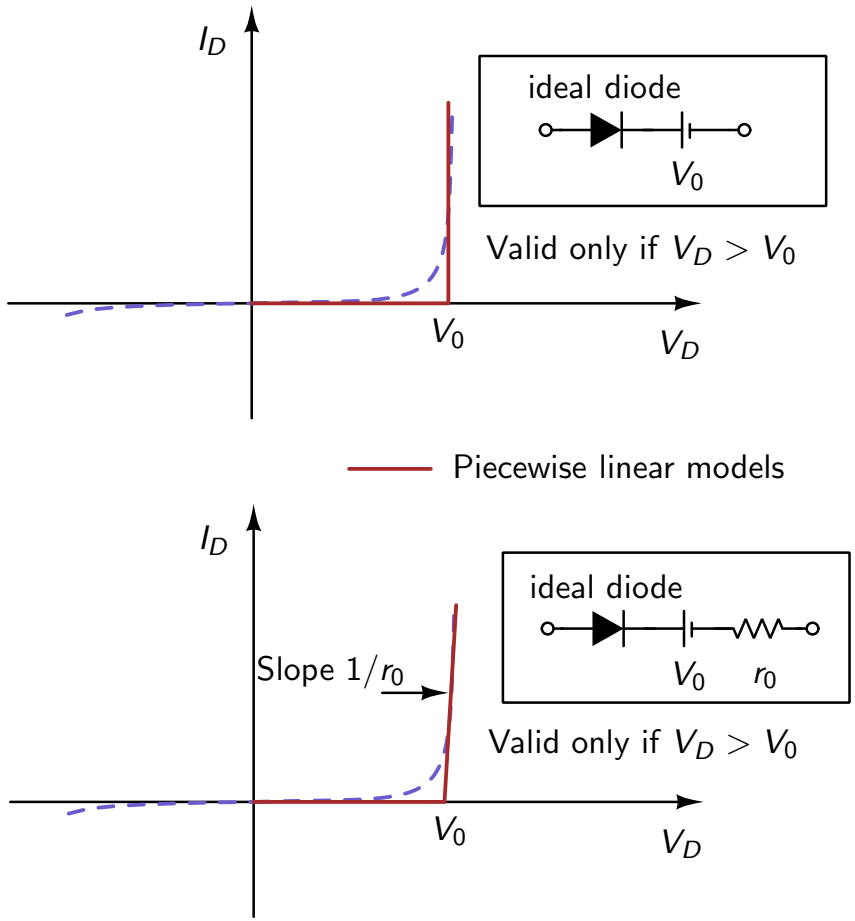


$$I_D = \begin{cases} I_s\left(e^{\left(\frac{V_D}{\eta V_T}\right)}\text{-1}\right) \text{ for } V_D > 0 \\ \\ -I_s \text{ for } V_D < 0 \end{cases}$$

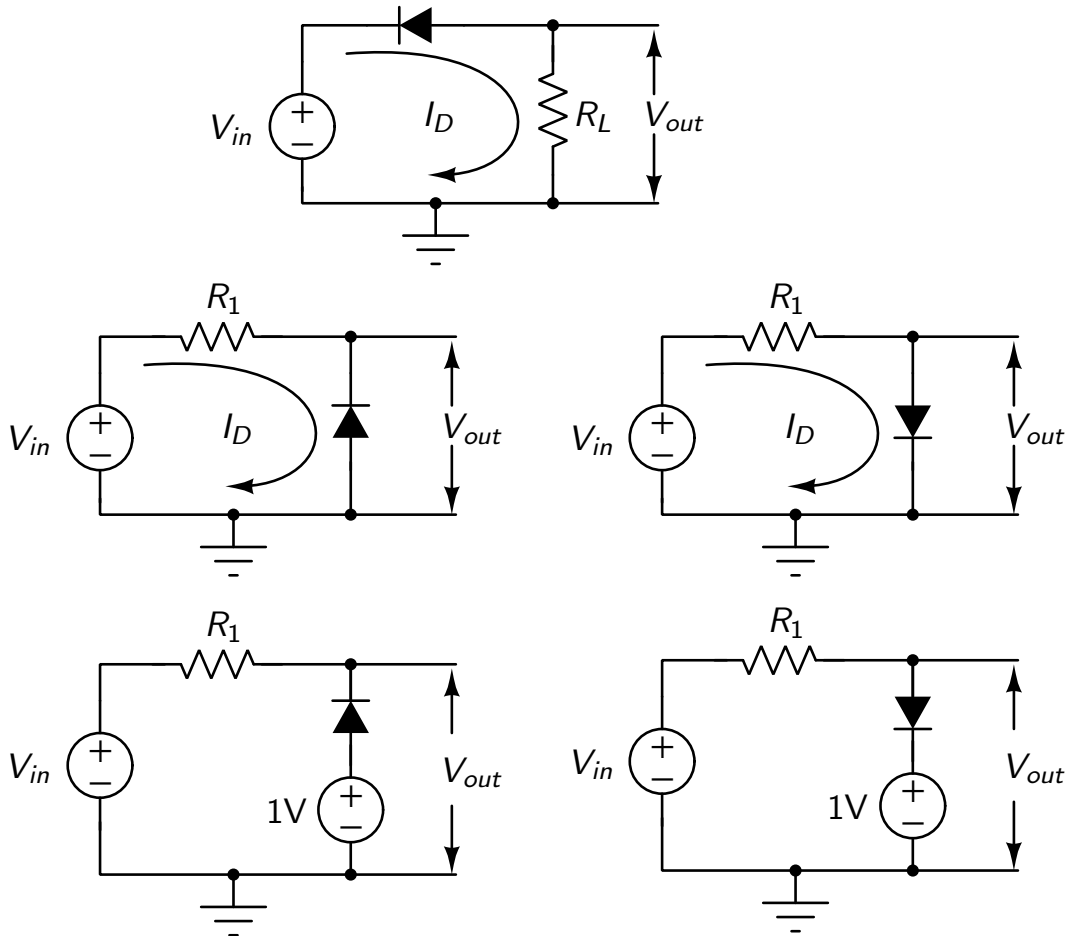
I_s is called saturation current.

η is a constant and has a value between 1 to 2.

Piecewise Linear Models



Draw the Transfer Characteristics



Assume Si based PN-junction diodes.

Summary

- Nonlinear, non-reciprocal element
- Ideal diode characteristics
- Review of semiconductor physics (not in slides)
- Operation of a PN junction diode
- I-V characteristics of a PN junction diode
- Piecewise linear models of a diode

Reference Book

[1] A. Sedra and K. C. Smith, "Microelectronic Circuits," 6th Ed., Oxford university press, 2011.