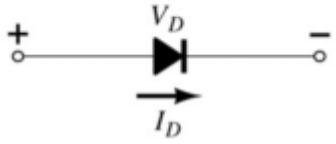
CHAPITRE 1

DIODES

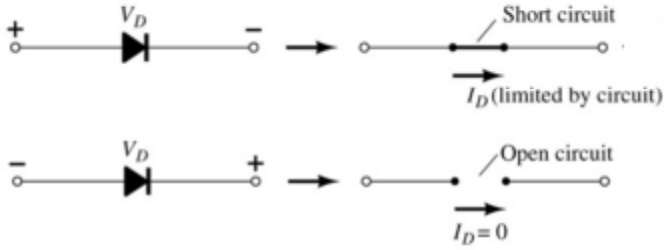
Avec la permission de Prentice Hall

Diodes

La diode est un composant de deux broches.

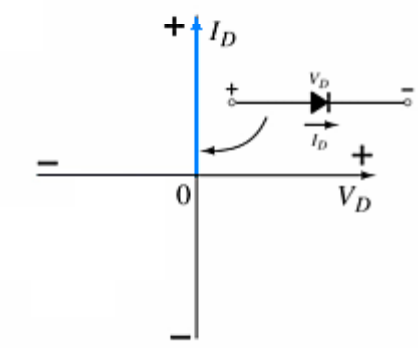


Une diode idéale conduit uniquement dans un sens.



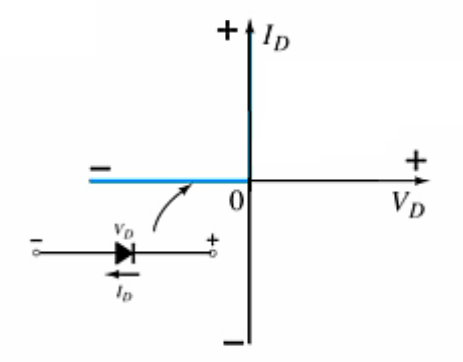
Caractéristiques de la diode

Zone de conduction



- **La tension a travers la diode est de 0 V**
- **Le courant est iindeterminé. (dépend du circuit externe)**
- **La résistance directe est: $R_F = V_F / I_F$**
- **La diode fonctionne comme un court-circuit**

Zone de non-conduction



- **Toute la tension est aux bornes de la diode**
- **Le courant est 0 A**
- **La resistance inverse est $R_R = V_R / I_R$**
- **La diode fonctionne comme un circuit ouvert**

Matérieux semi-conducteurs

Les matériaux utilisés dans la construction des sémi-conducteurs sont:

- **Silicium (Si)**
- **Germanium (Ge)**
- **Gallium Arsenide (GaAs)**

Dopage

Les caractéristiques électriqus du silicium et du germanium sont améliorées en ajoutant des matériaux dans un processus appelé dopage.

Il y a deux types de matériau de dopage semi-conducteur:

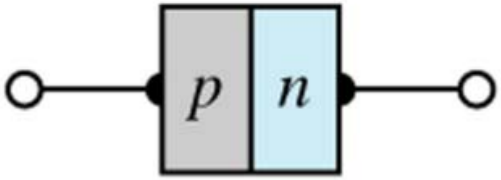
Type-*n*
Type-*p*

- **Le materiau type-*n* comporte un excès d'electrons.**
- **Le materiau type-*p* comporte un exceès de trous.**

Jonctions *p-n*

Un bout d'un crystal de silicium ou germanium peut être dopé comme materiau type-*p* et l'autre bout comme matériau *type-n* .

Le resultat est une junction *p-n*.

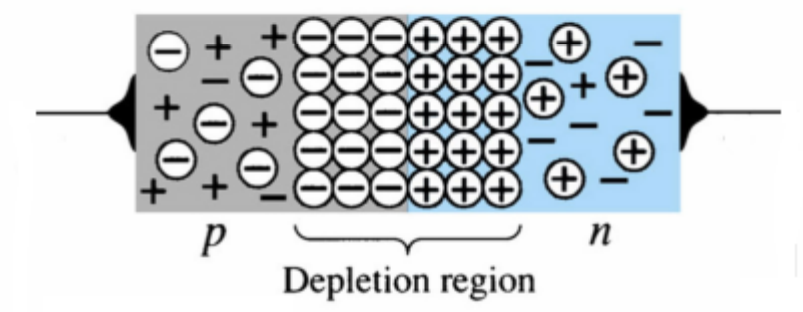


Jonctions *p-n*

Dans la jonction *p-n*, l'excès d'electrons dasn la bande de conduction du cõté de type-n sont attirés vers les trous du cõté de type-p.

The electrons in the *n*-type material migrate across the junction to the *p*-type material (electron flow).

The electron migration results in a negative charge on the p-type side of the junction and a positive charge on the n-type side of the junction.



The result is the formation of a depletion region around the junction.

Conditions de fonctionement de la diode

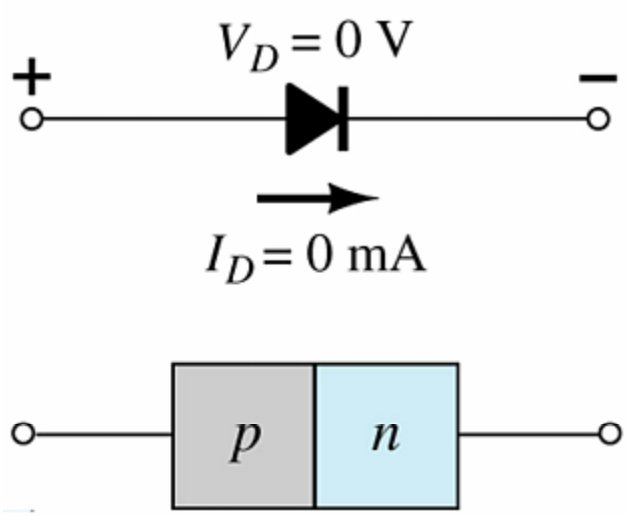
A diode has three operating conditions:

- **No bias**
- **Forward bias**
- **Reverse bias**

Conditions de fonctionnement de la diode

No Bias

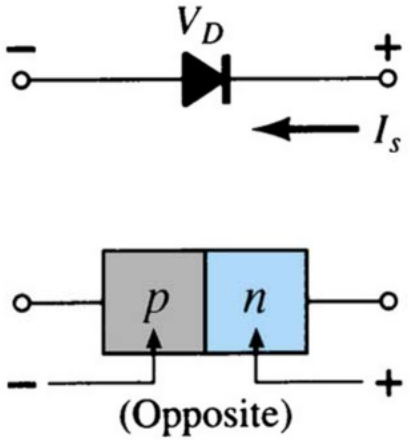
- **No external voltage is applied: V_D = 0 V**
- **No current is flowing: I_D = 0 A**
- **Only a modest depletion region exists**

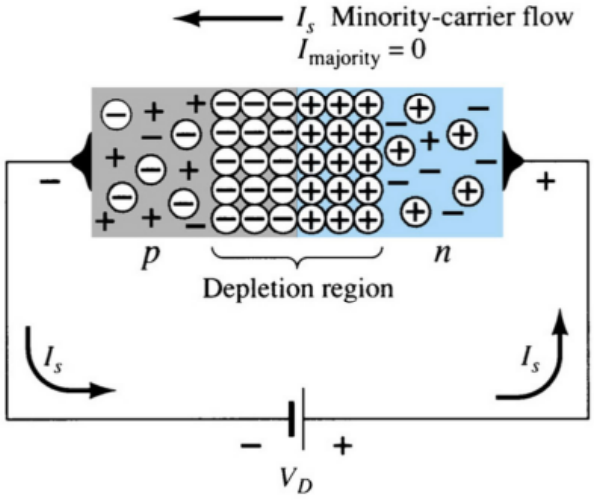


Conditions de fonctionnement de la diode

Reverse Bias

External voltage is applied across the *p*-*n* junction in the opposite polarity of the *p*- and *n*-type materials.



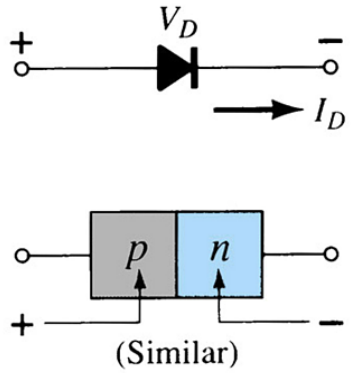


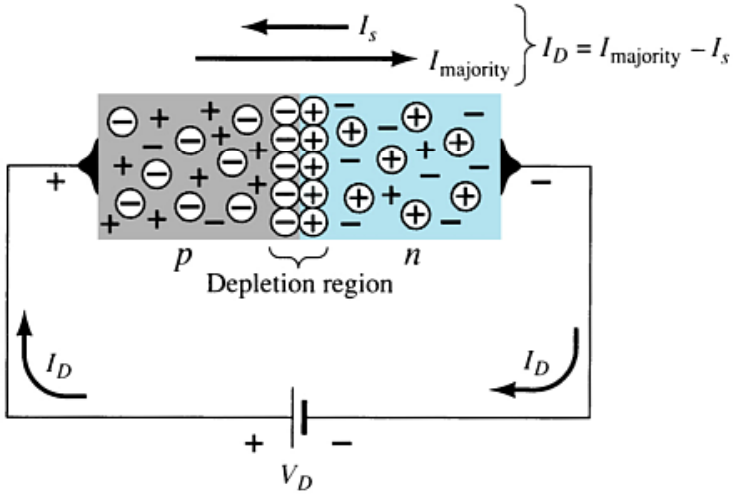
- **The reverse voltage causes the depletion region to widen.**
- **The electrons in the *n*-type material are attracted toward the positive terminal of the voltage source.**
- **The holes in the *p*-type material are attracted toward the negative terminal of the voltage source.**

Conditions de fonctionnement de la diode

Forward Bias

External voltage is applied across the *p-n* junction in the same polarity as the *p*- and *n*-type materials.



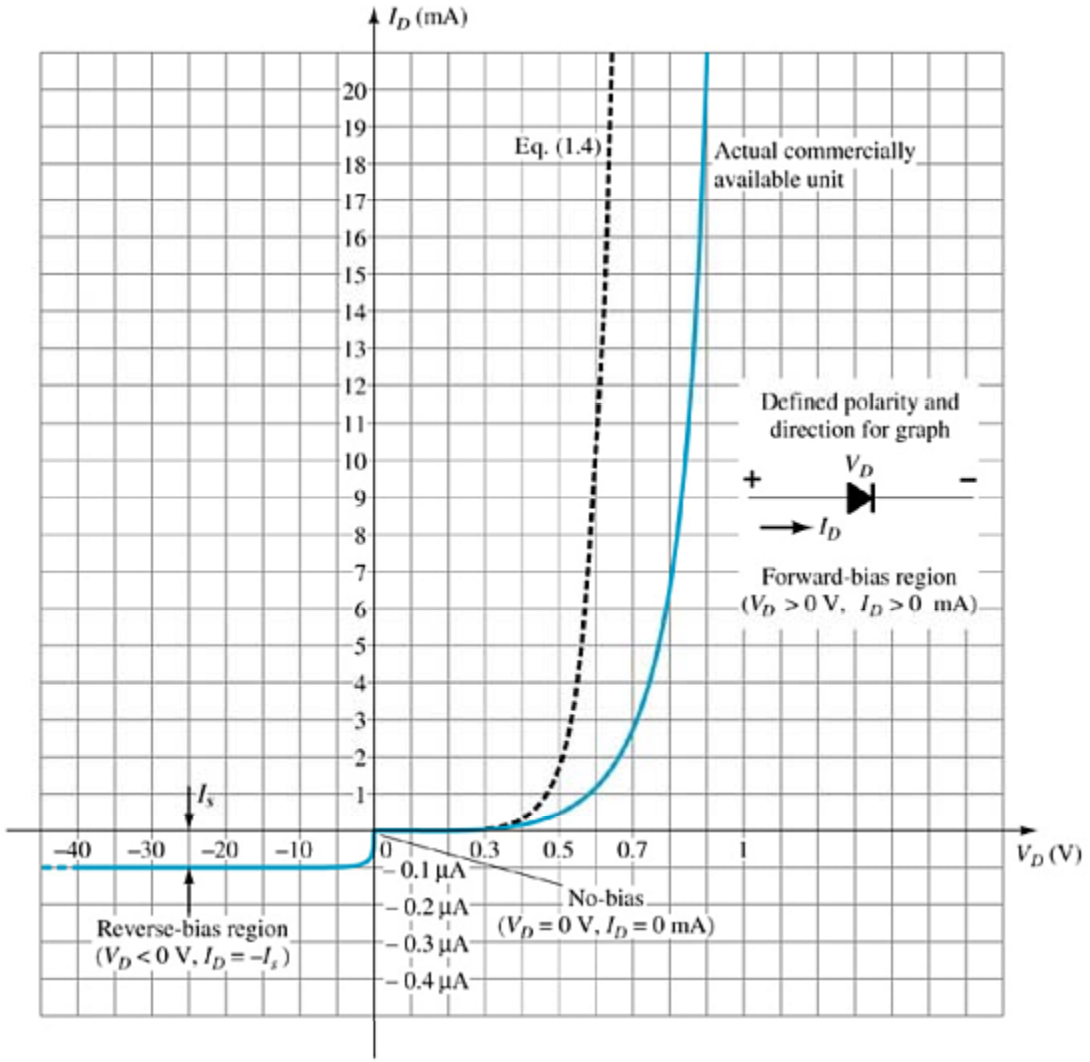


- **The forward voltage causes the depletion region to narrow.**
- **The electrons and holes are pushed toward the *p-n* junction.**
- **The electrons and holes have sufficient energy to cross the *p-n* junction.**

Caractéristiques réeles de la diode

Note the regions for no bias, reverse bias, and forward bias conditions.

Carefully note the scale for each of these conditions.



Portateurs minoritaires et majoritaires

Two currents through a diode:

Majority Carriers

- **The majority carriers in *n*-type materials are electrons.**
- **The majority carriers in *p*-type materials are holes.**

Minority Carriers

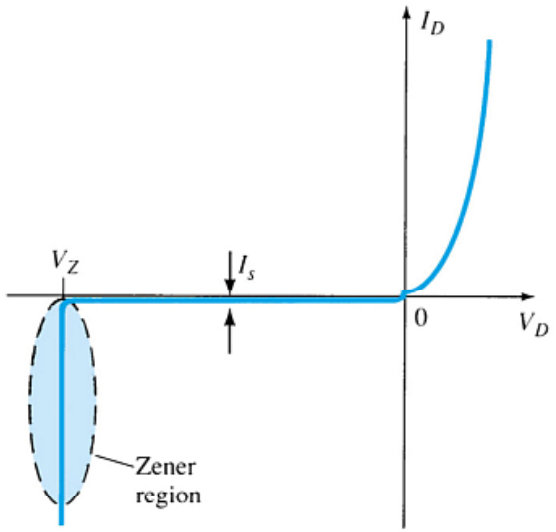
- **The minority carriers in *n*-type materials are holes.**
- **The minority carriers in *p*-type materials are electrons.**

Zone Zener

The Zener region is in the diode's reverse-bias region.

At some point the reverse bias voltage is so large the diode breaks down and the reverse current increases dramatically.

- **The maximum reverse voltage that won't take a diode into the zener region is called the peak inverse voltage or peak reverse voltage.**
- **The voltage that causes a diode to enter the zener region of operation is called the zener voltage (V_Z).**



Tension de polarisation positive

The point at which the diode changes from no-bias condition to forward-bias condition occurs when the electrons and holes are given sufficient energy to cross the *p-n* junction. This energy comes from the external voltage applied across the diode.

The forward bias voltage required for a:

- **gallium arsenide diode ≅ 1.2 V**
- **silicon diode ≅ 0.7 V**
- **germanium diode ≅ 0.3 V**

Effet de la température

As temperature increases it adds energy to the diode.

- **It reduces the required forward bias voltage for forward-bias conduction.**
- **It increases the amount of reverse current in the reverse-bias condition.**
- **It increases maximum reverse bias avalanche voltage.**

Germanium diodes are more sensitive to temperature variations than silicon or gallium arsenide diodes.

Niveaux de résistance

Semiconductors react differently to DC and AC currents.

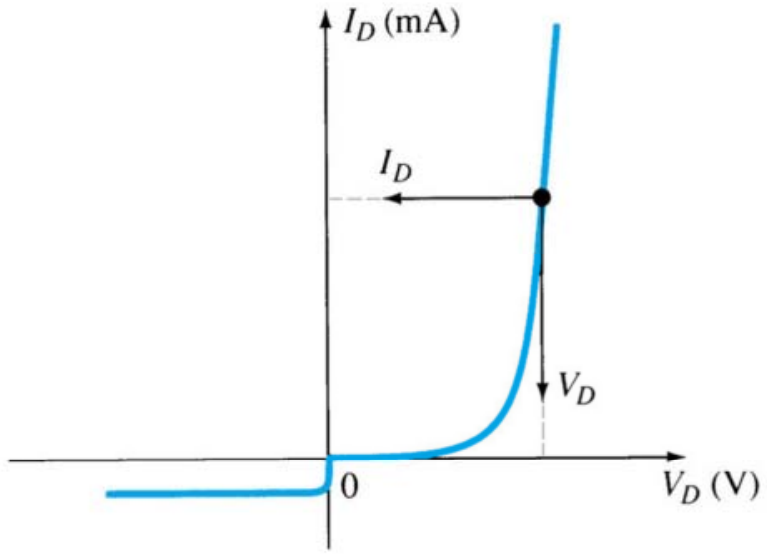
There are three types of resistance:

- **DC (static) resistance**
- **AC (dynamic) resistance**
- **Average AC resistance**

Résistance DC (Statique)

For a specific applied DC voltage V_D, the diode has a specific current I_D, and a specific resistance R_D.

$$R_D = \frac{V_D}{I_D}$$



Résistance AC (Dynamique)

In the forward bias region:

$$r'_d = \frac{26\text{mV}}{I_D} + r_B$$

- **The resistance depends on the amount of current (I_D) in the diode.**
- **The voltage across the diode is fairly constant (26 mV for 25°C).**
- **r_B ranges from a typical 0.1 Ω for high power devices to 2 Ω for low power, general purpose diodes. In some cases r_B can be ignored.**

In the reverse bias region:

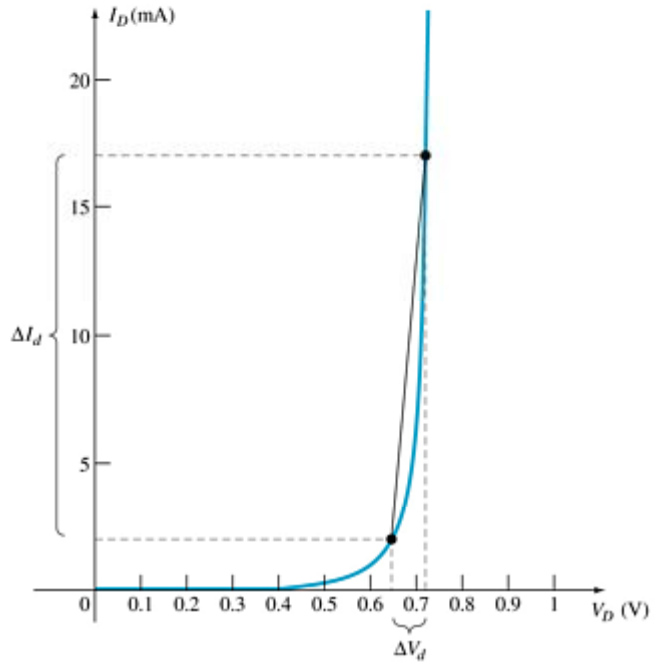
$$\mathbf{r'_d = \infty}$$

The resistance is effectively infinite. The diode acts like an open.

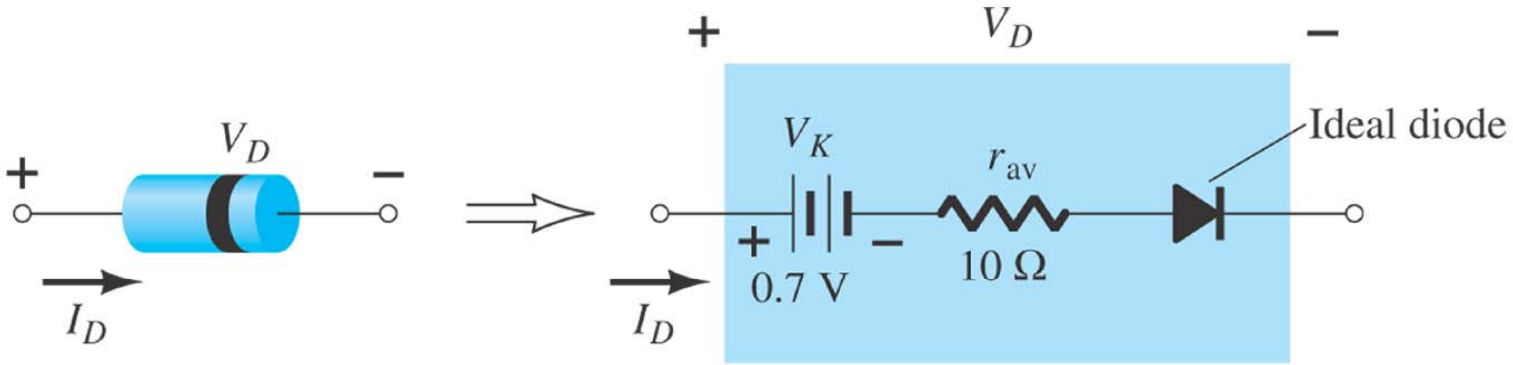
Résistance AC moyenne

$$r_{av} = \frac{\Delta V_d}{\Delta I_d} \Big| \text{ pt. to pt.}$$

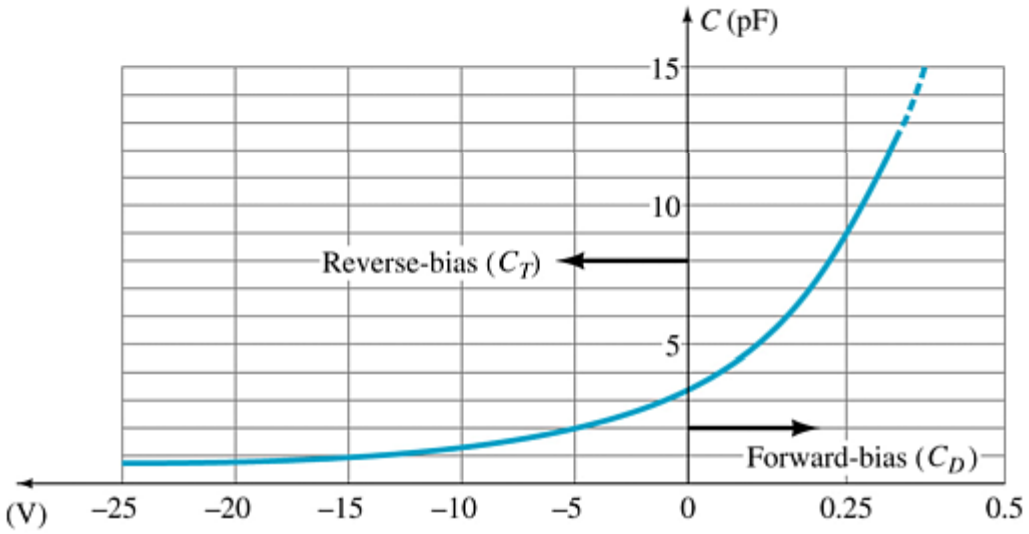
AC resistance can be calculated using the current and voltage values for two points on the diode characteristic curve.



Circuit équivalent de la diode



Capacitance de la diode

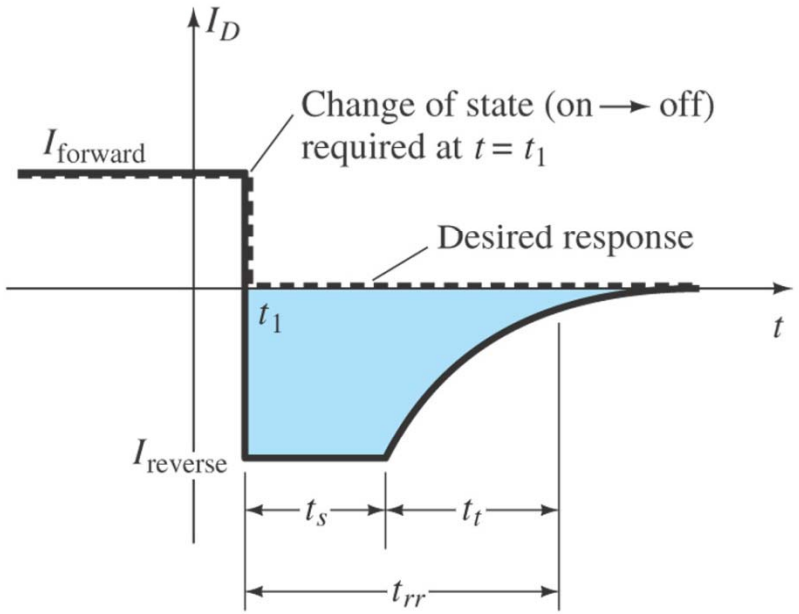


In reverse bias, the depletion layer is very large. The diode's strong positive and negative polarities create capacitance, C_T. The amount of capacitance depends on the reverse voltage applied.

In forward bias storage capacitance or diffusion capacitance (C_D) exists as the diode voltage increases.

Temps de recouvrement(t_{rr})

Reverse recovery time is the time required for a diode to stop conducting once it is switched from forward bias to reverse bias.

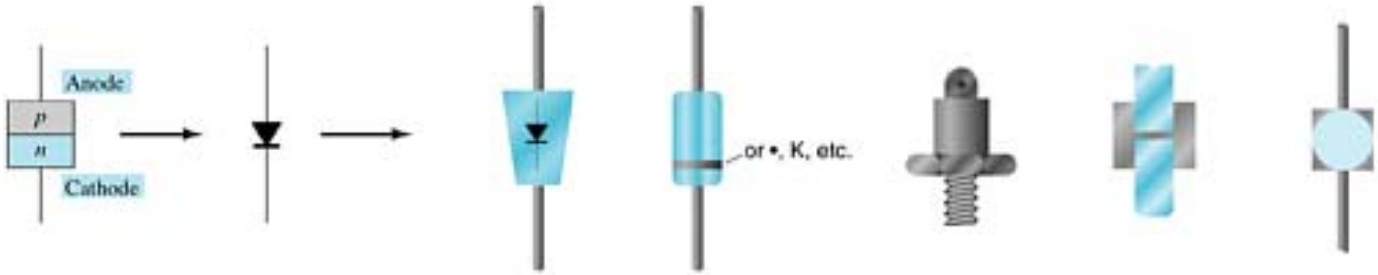


Specifications

Data about a diode is presented uniformly for many different diodes. This makes cross-matching of diodes for replacement or design easier.

1. **Forward Voltage (V_F) at a specified current and temperature**
2. **Maximum forward current (I_F) at a specified temperature**
3. **Reverse saturation current (I_R) at a specified voltage and temperature**
4. **Reverse voltage rating, PIV or PRV or V(BR), at a specified temperature**
5. **Maximum power dissipation at a specified temperature**
6. **Capacitance levels**
7. **Reverse recovery time, t_{rr}**
8. **Operating temperature range**

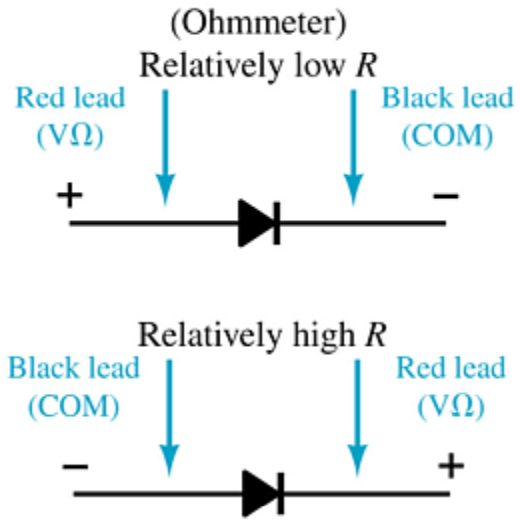
Symboles



The anode is abbreviated A
The cathode is abbreviated K

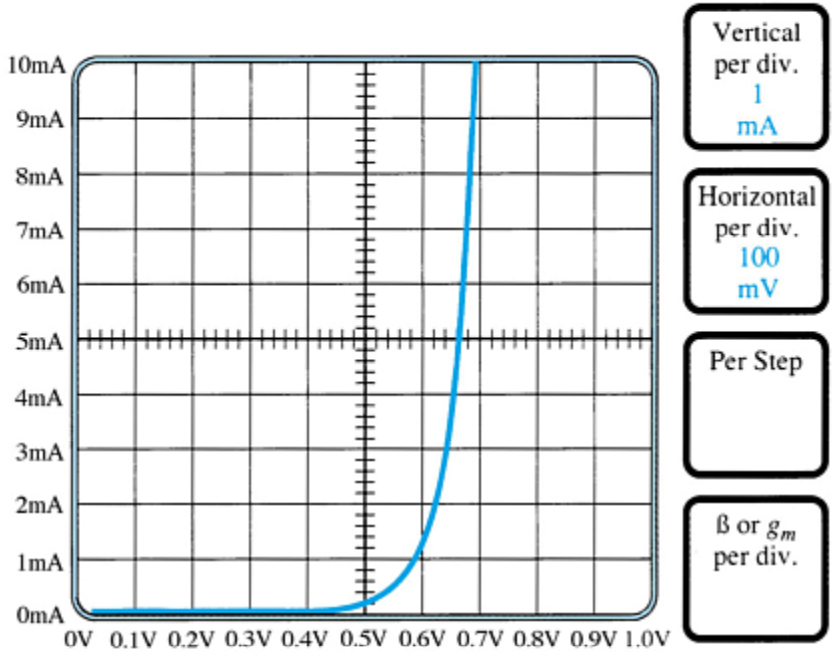
Ohmmètre

An ohmmeter set on a low Ohms scale can be used to test a diode. The diode should be tested out of circuit.



Traceur de courbe

A curve tracer displays the characteristic curve of a diode in the test circuit. This curve can be compared to the specifications of the diode from a data sheet.



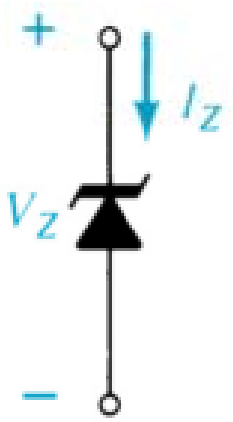
Autres Types de Diodes

Zener diode
Light-emitting diode
Diode arrays

Diode Zener

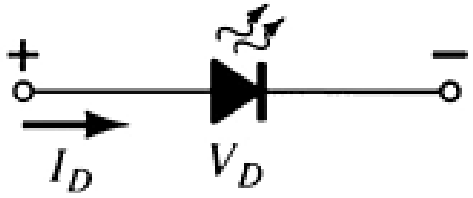
A Zener is a diode operated in reverse bias at the Zener voltage (V_Z).

Common Zener voltages are between 1.8 V and 200 V



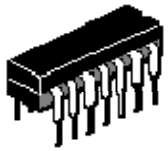
Diode Electro-luminiscent (DEL)

An LED emits photons when it is forward biased.
These can be in the infrared or visible spectrum.
The forward bias voltage is usually in the range of 2 V to 3 V.



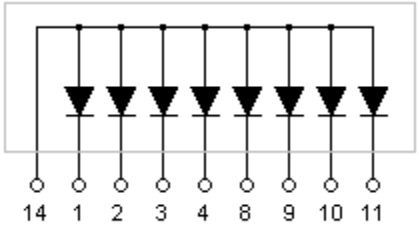
Array de diodes

Multiple diodes can be packaged together in an integrated circuit (IC).



A variety of combinations exist.

Common Anode



Common Cathode