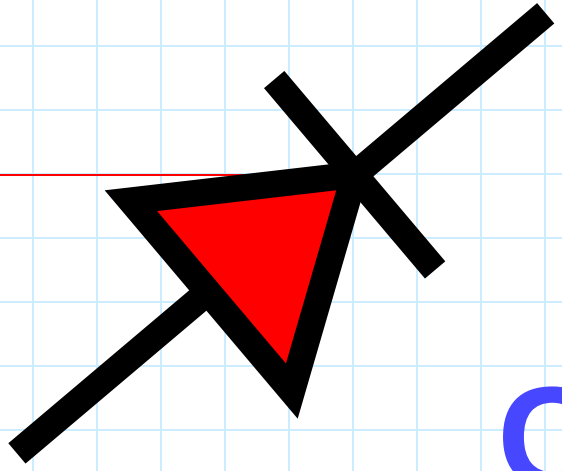
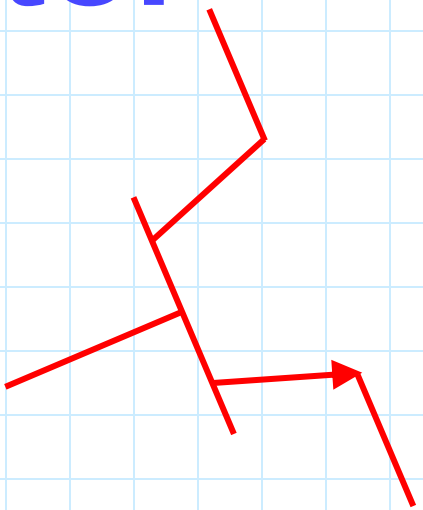


Chapter I: Basic semiconductor devices



Objectives (1)

At the end of this chapter, the student should:

- Know and understand the basic operation of semiconductor diodes.
- Know the different models of diodes and how to apply them to the analysis of digital circuits with diodes.
- Know and understand the applications of diodes in digital circuits.
- Know and understand the basic operation and some applications of special-purpose diodes, such as Schottky, LEDs and photodiodes.

Objectives (2)

At the end of this chapter, the student should:

- Know and understand the basic operation of bipolar junction transistors (BJTs).
- Know and understand the different regions of operation of a BJT.
- Know and understand the operation of a BJT transistor as a switch.
- Apply the knowledge of BJTs to implement basic logic gates.

Contents

1.1. Bibliography

THEORY:

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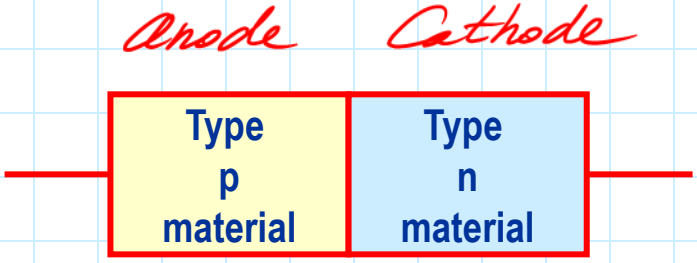
- Randy H. Katz and Gaetano Borriello, "*Contemporary Logic Design*", Prentice Hall; 2nd Ed., 2004.

PROBLEMS:

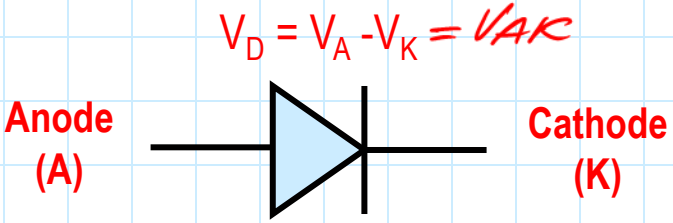
- G.Benet; J.V.Benlloch; J.V.Busquets; D.Gil; P.Perez, *Ejercicios Resueltos de Tecnologia de Computadores, Cap.1,* SPUPV 2006.916

1.1 The junction diode. Foundations



P-N junction

- The P-N junction conducts more easily in forward (from p to n) than in reverse mode.
- The rectification concept appears
- Device name: DIODE
- Terminals:
  - Anode: type p material
  - Cathode: type n material



Diode symbol

Diodes { - Vacuum tubes
- Semiconductor { - Discrete
- Integrated

1.1 The junction diode. Foundations

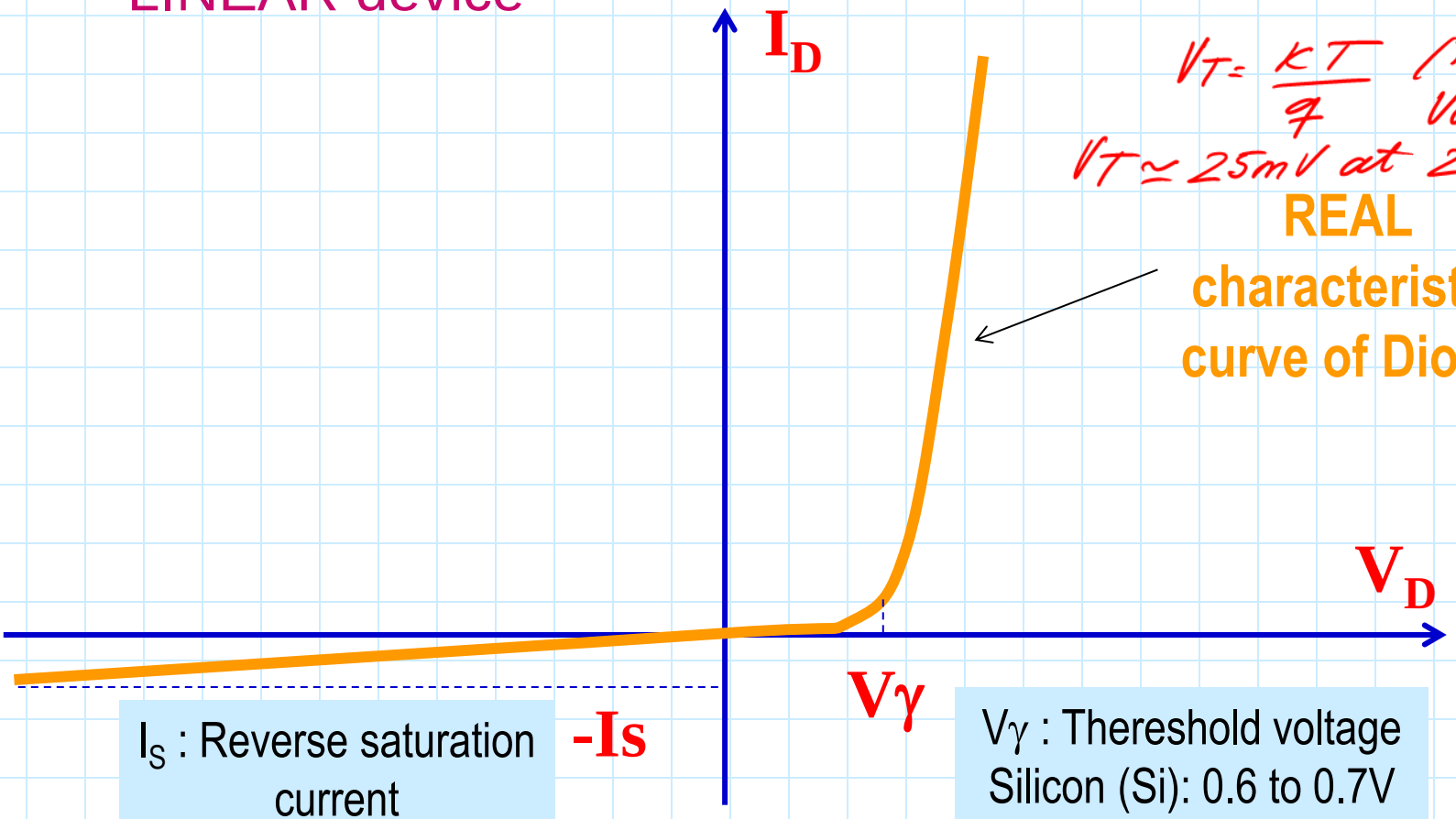
$\eta \rightarrow$ Quality factor ($\simeq 1$)

- The Diode is a NON-LINEAR device

$$I_D = I_S(e^{V_D/\eta V_T} - 1)$$

$V_T = \frac{kT}{q}$ (Termal Voltage)

$V_T \simeq 25mV$ at 25 ºC



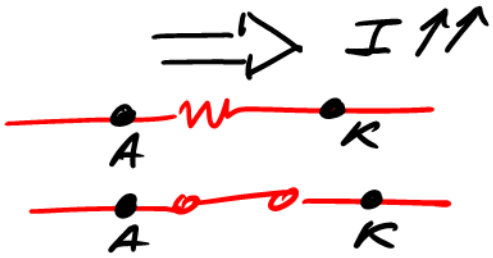
REAL characteristic curve of Diode

I_S : Reverse saturation current

Vγ : Thereshold voltage
Silicon (Si): 0.6 to 0.7V

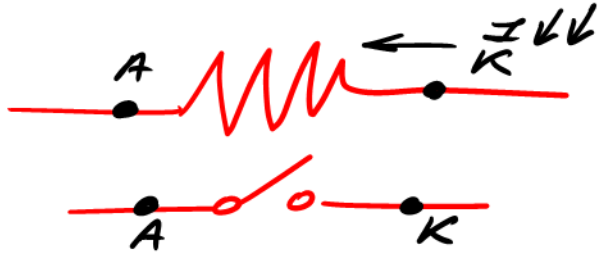
Forward bias (ON)

$V_{AK} > V_\gamma \Rightarrow R_{ON} \downarrow\downarrow\downarrow$

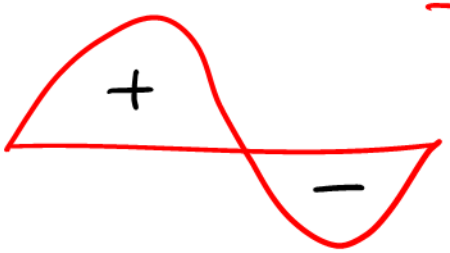


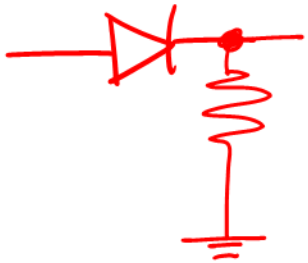
Reverse bias (OFF)

$V_{AK} \leq V_\gamma \Rightarrow R_{ON} \uparrow\uparrow\uparrow$



Rectification

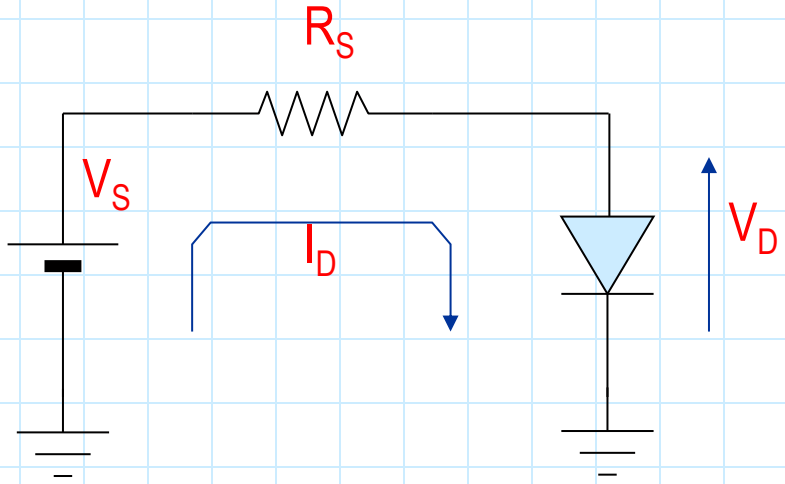




AC ⟶ DC

1.2 Load line

When we connect the diode with a voltage generator (Vs) and a series resistor (Rs), these devices bias the diode, putting it in an operating point.



$$I_D = f(V_D)$$

Applying the 2nd Kirchoff law:

$$V_S - I_D R_S - V_D = 0$$

$$I_D = \frac{V_S}{R_S} - \frac{V_D}{R_S}$$

1.2 Load line

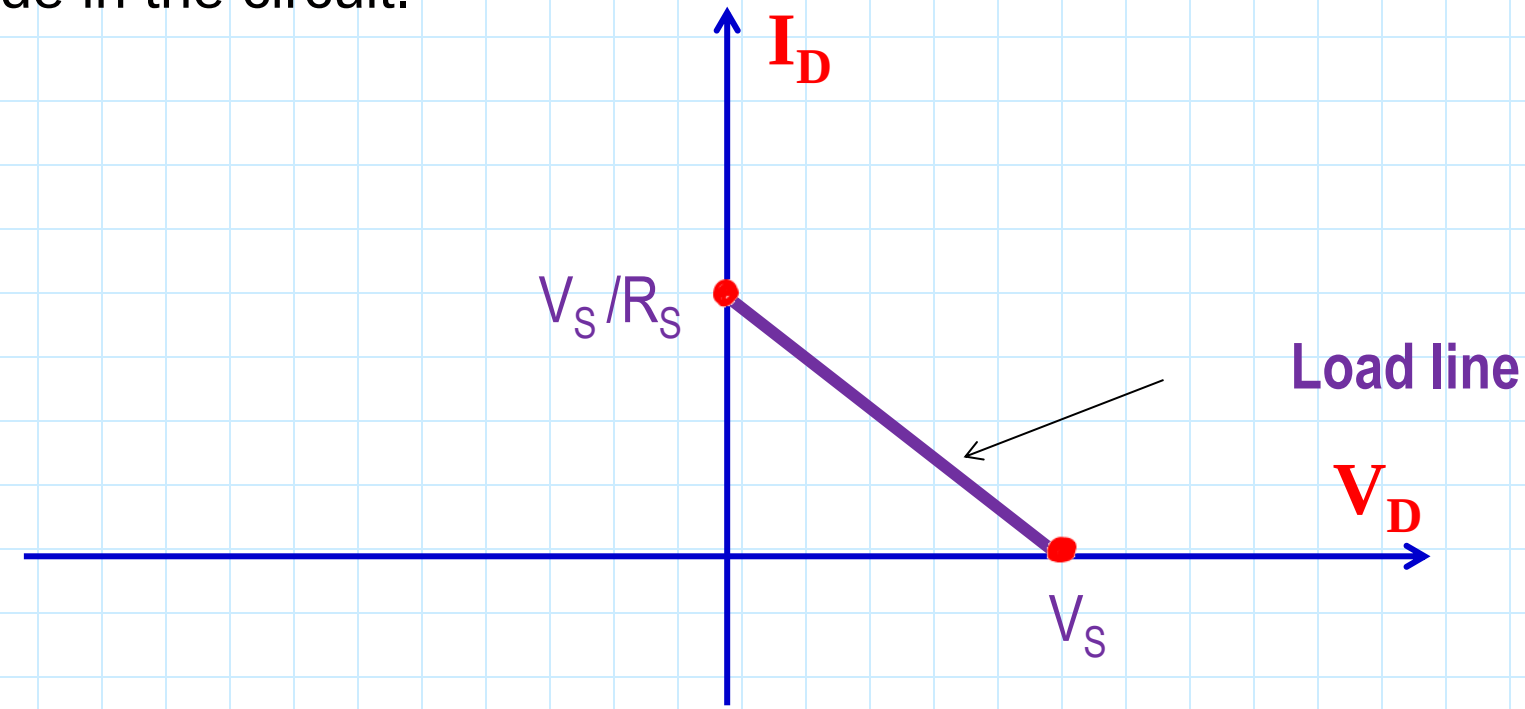
$$I_D = \frac{V_S}{R_S} - \frac{V_D}{R_S}$$

Cross points with the X(V_D) and Y (I_D) axes:

When $I_D = 0$ → $V_D = V_S$

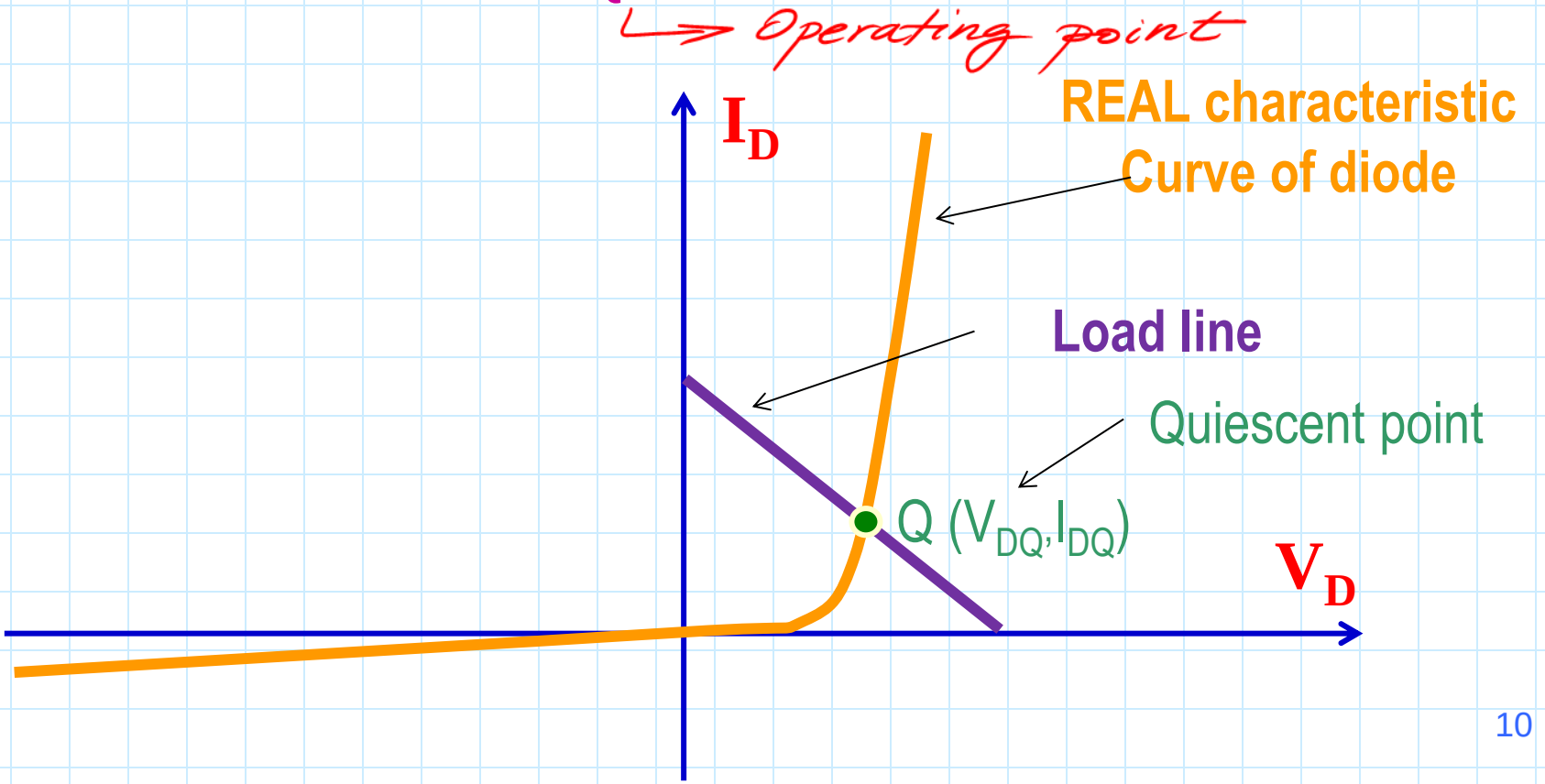
When $V_D = 0$ → $I_D = V_s / R_s$

The LOAD LINE depends only of elements added to the diode in the circuit.



1.2 Quiescent point

- The diode has to met its CHARACTERISTIC CURVE
- The intersection point of the real characteristic curve of diode and the load line defines the QUIESCENT POINT of diode

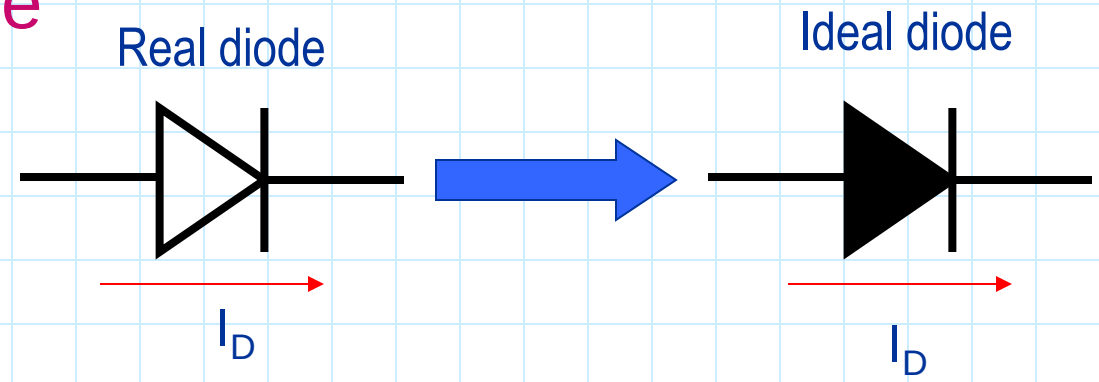


1.2 Diode approximations and models

- We can define diode MODELS that approximate its beviour with an increasing accuracy:
  1. Ideal model
  2. Ideal model with threshold voltage.
  3. …

1.2 Diode models (1)

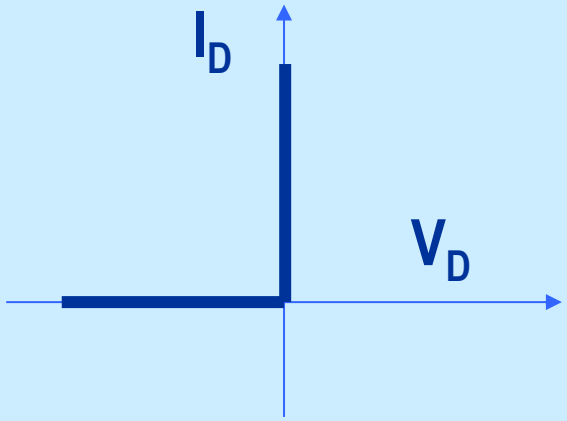
1. Ideal diode



The behaviour is similar to a switch:

- Direct bias: closed (ON)
  - $V_D = 0$ for all $I_D > 0$

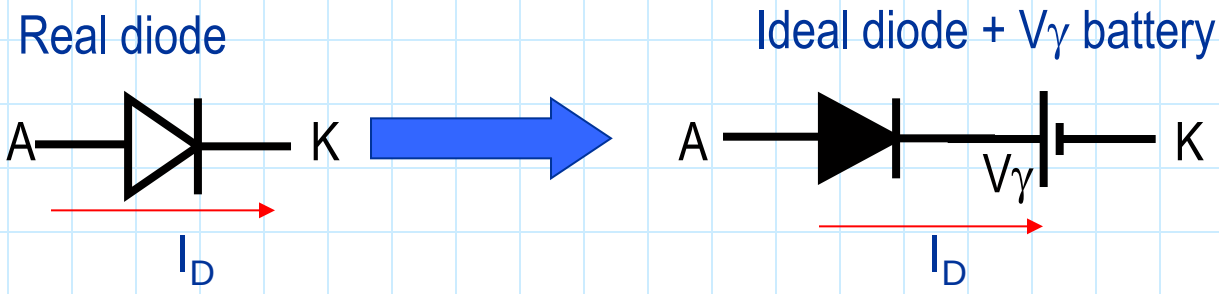
- Reverse bias: open (OFF)
  - $I_D = 0$ for all $V_D < 0$



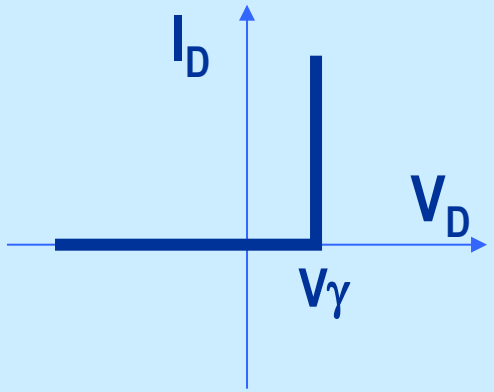
Characteristic curve
1st diode approximation

1.2 Diode models (2)

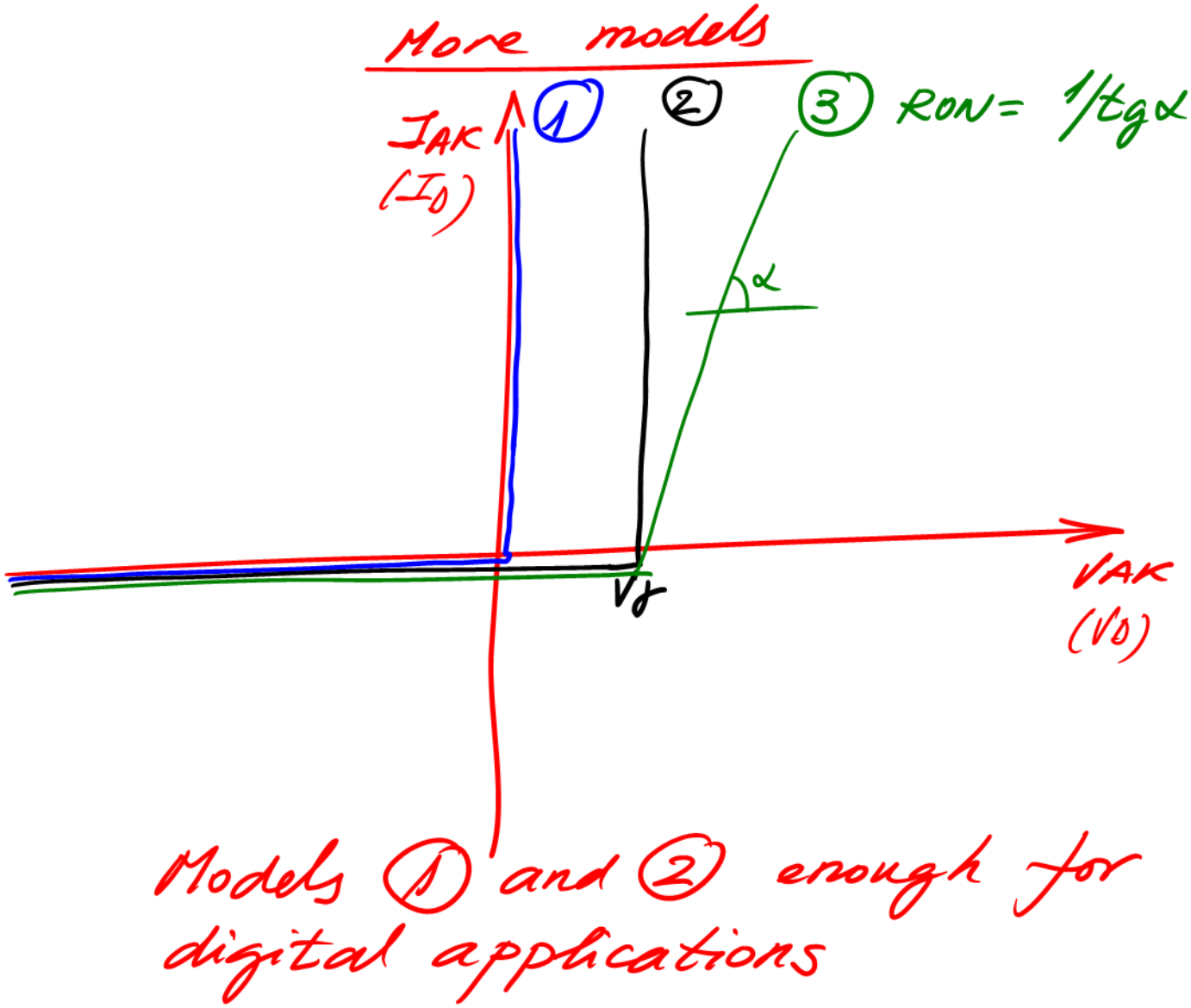
2. Ideal diode with threshold voltage Vγ



- $V_D = V\gamma$ for all $I_D > 0$



Characteristic curve
2nd diode approximation


More models
I_{AK}
(I_D)
1
2
3
$R_{ON} = 1/tg\alpha$
α
V_J
V_{AK}
(V_D)
Models 1 and 2 enough for digital applications