
Lecture3: Diode model

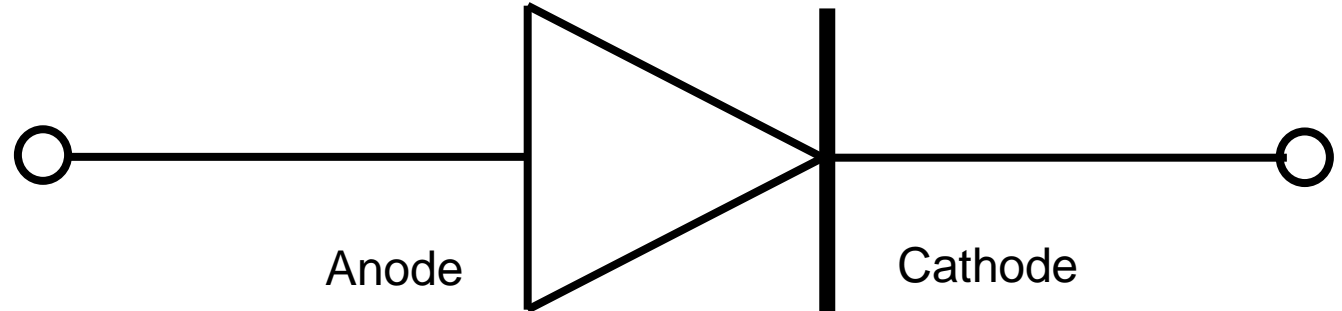
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Review

- Diode

- Its symbol



- Forward/reverse operation
- How to fabricate it: PN junction

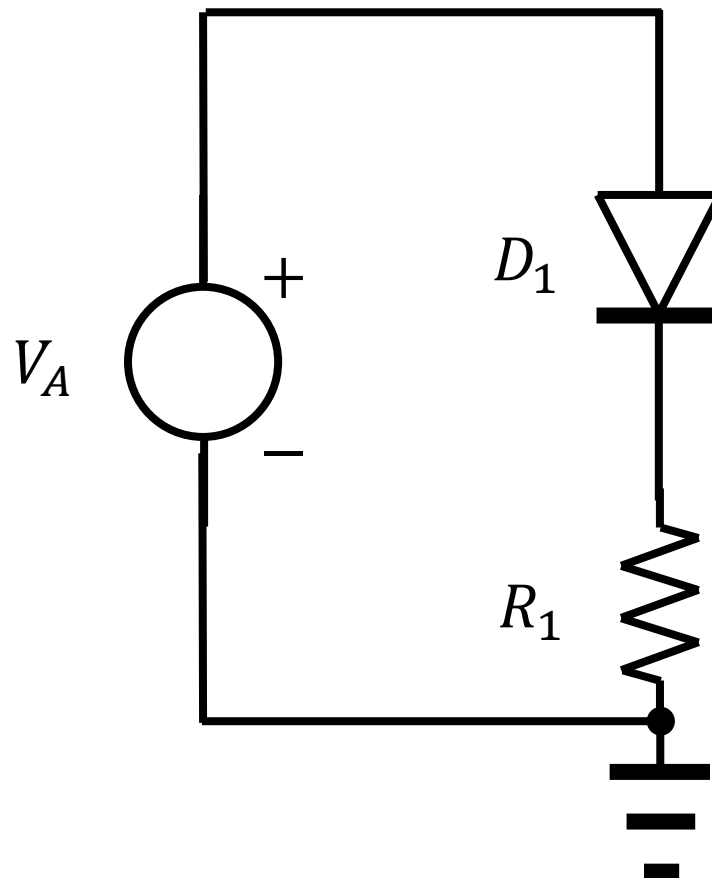
- IV characteristics of a diode

$$I_D = I_S \left(\exp \frac{V_D}{V_T} - 1 \right)$$

- Forward bias: $I_D \approx I_S \exp \frac{V_D}{V_T}$
- Reverse bias: $I_D \approx -I_S \approx 0$

General solution (1)

- Analyze the following circuit. (A diode-resistor combination)
 - Calculation of node voltages and terminal currents



General solution (2)

- Identify the nodes and apply the KCL.

- Two nodes are found.

$$I_V + I_D = 0$$

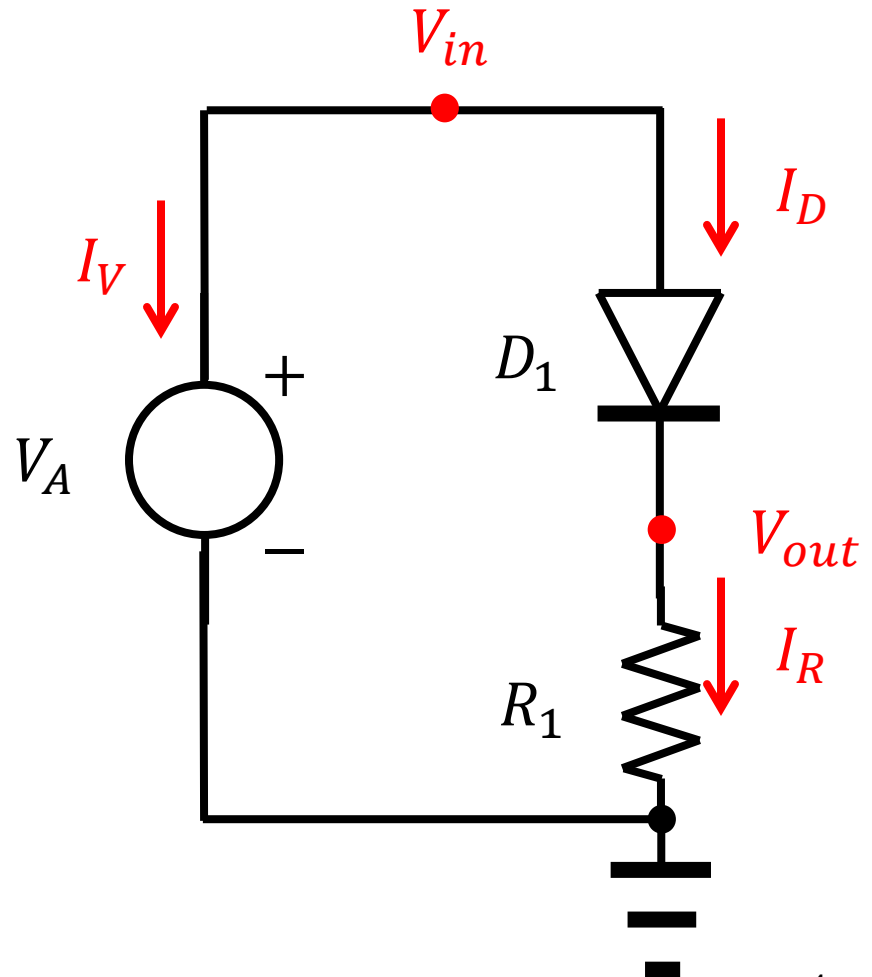
$$-I_D + I_R = 0$$

- Equations for terminal IVs

$$V_{in} = V_A$$

$$I_D = I_S \left(\exp \left(\frac{V_{in} - V_{out}}{V_T} \right) - 1 \right)$$

$$I_R = \frac{V_{out}}{R_1}$$



General solution (3)

- Solve the set of equations.

- After simple manipulation, it is easily found that

$$-I_S \left(\exp \left(\frac{V_A - V_{out}}{V_T} \right) - 1 \right) + \frac{V_{out}}{R_1} = 0$$

- An nonlinear equation for V_{out} is obtained.
- The solution, V_{out} , can be visualized by drawing the following two curves.

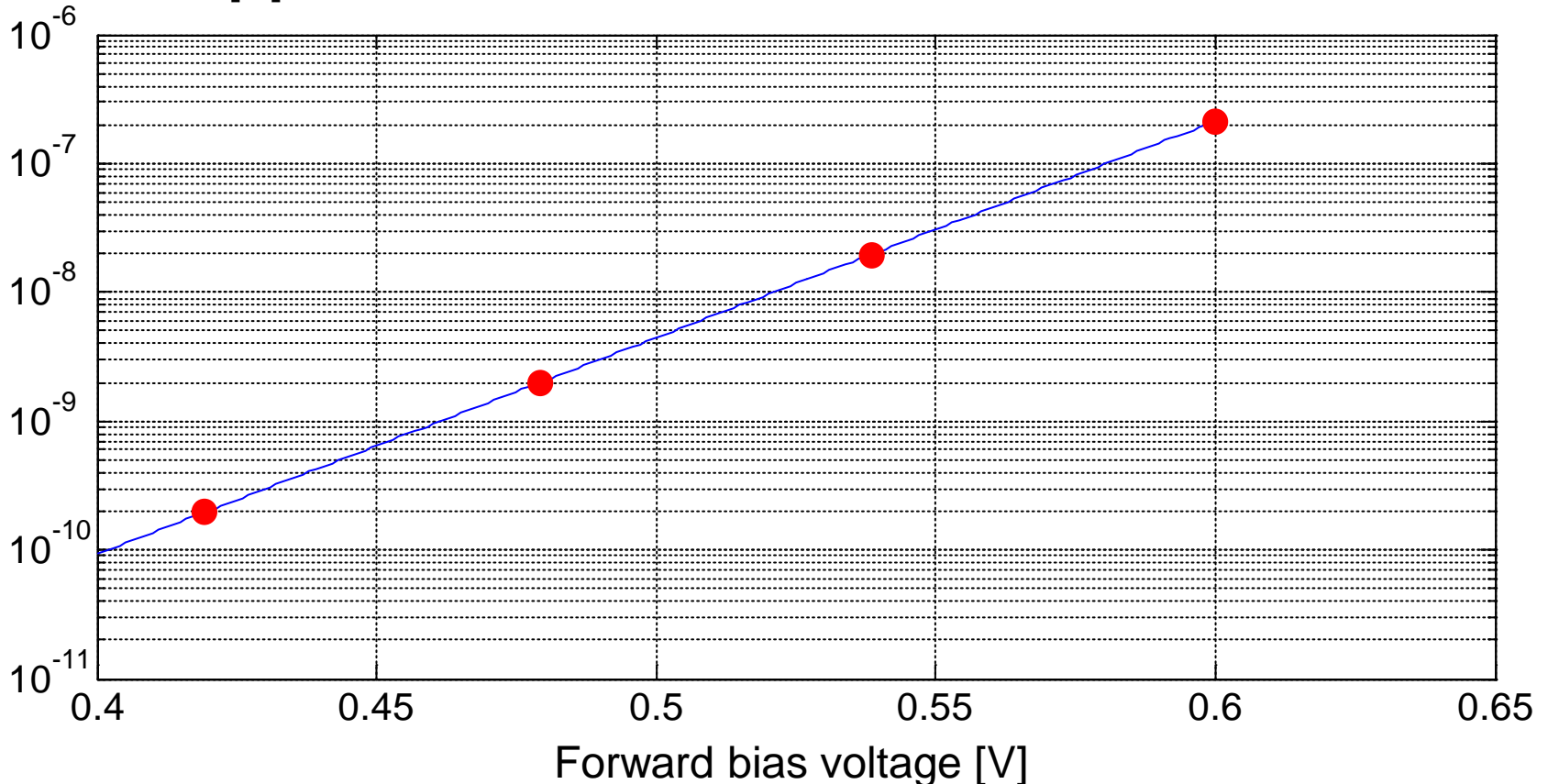
$$y = I_S \left(\exp \left(\frac{V_A - x}{V_T} \right) - 1 \right)$$
$$y = \frac{x}{R_1}$$

- The x coordinate of the intersecting point is V_{out} .
- Of course, a general solver for the nonlinear equation is desirable.
- Simulation Program with Integrated Circuit Emphasis

Important observation

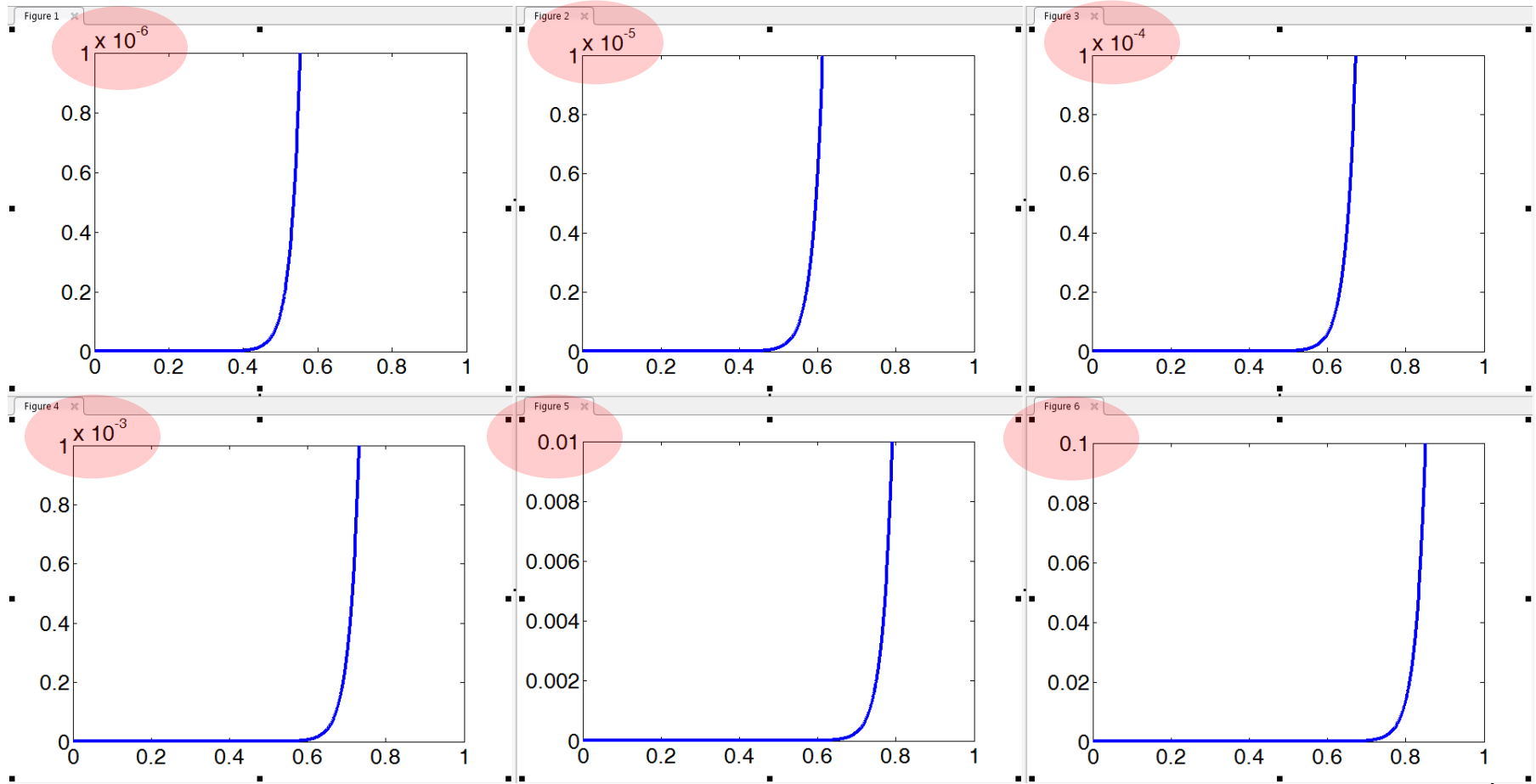
- In order to obtain 10x large current,
 - We must apply only 60 mV additionally. (300K)

Diode current [A]



IV curves

- A diode with $I_S = 5 \times 10^{-16} \text{ A}$ (Only different y scales)
 - How do they look like?



Homework#2 (1)

- Due: 09:00, March 19
- Update your program.
 - Read the input file.
 - Print out the names of voltage sources, current sources, resistors, capacitors, and inductors.
 - Print out the name of each node.
 - For each node, print out a list of the connected elements and their terminal names.
 - An example of the input file is uploaded in our GitHub repository.

Homework#2 (2)

- Calculate the current in the circuit.
 - Obtain the numerical value for the following parameters.
 $V_A = 2\text{ V}$
 $I_S = 5 \times 10^{-16}\text{ A}$
 $V_T = \frac{k_B T}{q}$
 $R_1 = 1\text{ k}\Omega$
 - Show the calculation method.

