dummy8

Student Group

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Table of Contents

Exercise E1.1 Circuit with multiple diodes: which lamps light up?

The following simulation includes multiple diodes and several lamps. A lamp lights brightly when a voltage of approximately

$$\begin{align*} U_{\rm lamp}\geq 5~{\rm V} \end{align*}$$

drops across it.

Close the switch in the simulation.

- Which lamps light up brightly?
- Which lamps remain dark?
- Explain the result using the idea of diode bypass paths.

Simulation: multiple diodes and lamps

Result

Solution path

Number the lamps from left to right:

$$\begin{align*} L_1,\;L_2,\;L_3,\;L_4,\;L_5. \end{align*}$$

After closing the switch, check the voltage across each lamp in the simulation.

The important idea is:

- a forward-biased diode behaves approximately like a low-voltage path,
- if a diode is connected in parallel to a lamp or a group of lamps, it can bypass this part of the circuit,
- a bypassed lamp has too little voltage across it and therefore remains dark.

The middle lamps are bypassed by forward-biased diode paths. Therefore, their lamp voltage is much smaller than the required value of approximately $5~{\rm V}$.

The outer lamps are not bypassed in the same way. They have a sufficiently large voltage across them and light up brightly.

Result

$$\begin{align*} \boxed{ L_1 \text{ and } L_5 \text{ light up brightly.} } \end{align*}$$

\[\begin{align*} \boxed{ L_2,\;L_3,\;L_4 \text{ remain dark or almost dark.} }

\end{align*} \]

The reason is not that the dark lamps are defective. They are bypassed by conducting diodes.

Exercise E2.1 Circuit with multiple diodes II: current calculation

The following simulation includes two diodes and two resistors.

Assume a simple constant-voltage diode model:

$$\begin{align*} U_{\rm F}=0.6~{\rm V}. \end{align*}$$

The source voltage is

$$\begin{align*} U_0=4.0~{\rm V}. \end{align*}$$

The resistors are

$$\begin{align*} R_1=200~\Omega, \qquad R_2=100~\Omega. \end{align*}$$

Calculate the currents through

- D_1,
- R_1,
- R_2.

Simulation: two diodes and two resistors

Result

Solution path

First decide which diodes conduct. With the given polarity, both diodes are forward-biased.

The current through R_1 flows after one forward-biased diode. Therefore, the voltage across R_1 is

$$\begin{align*} U_{R1} = U_0-U_{\rm F}. \end{align*}$$

Insert the values:

$$\begin{align*} U_{R1} = 4.0~{\rm V}-0.6~{\rm V} = 3.4~{\rm V}. \end{align*}$$

Thus

$$\begin{align*} I_{R1} = \frac{U_{R1}}{R_1} = \frac{3.4~{\rm V}}{200~\Omega} = 17~{\rm mA}. \end{align*}$$

The current through R_2 flows after two forward-biased diodes. Therefore, the voltage across R_2 is

$$\begin{align*} U_{R2} = U_0-2U_{\rm F}. \end{align*}$$

Insert the values:

$$\begin{align*} U_{R2} = 4.0~{\rm V}-2\cdot 0.6~{\rm V} = 2.8~{\rm V}. \end{align*}$$

Thus

$$\begin{align*} I_{R2} = \frac{U_{R2}}{R_2} = \frac{2.8~{\rm V}}{100~\Omega} = 28~{\rm mA}. \end{align*}$$

The diode D_1 supplies both branches. Therefore, Kirchhoff's current law gives

$$\begin{align*} I_{D1} = I_{R1}+I_{R2}. \end{align*}$$

So

$$\begin{align*} I_{D1} = 17~{\rm mA}+28~{\rm mA} = 45~{\rm mA}. \end{align*}$$

Result

$$\begin{align*} \boxed{ I_{R1}=17~{\rm mA} } \end{align*}$$

$$\begin{align*} \boxed{ I_{R2}=28~{\rm mA} } \end{align*}$$

$$\begin{align*} \boxed{ I_{D1}=45~{\rm mA} } \end{align*}$$

Exercise E3.1 Circuit with multiple diodes III: switch-dependent currents

The following simulation includes two diodes and a switch.

Assume a simple constant-voltage diode model:

$$\begin{align*} U_{\rm F}=0.7~{\rm V}. \end{align*}$$

The source voltage is

$$\begin{align*} U_0=5.0~{\rm V}. \end{align*}$$

The resistor is

$$\begin{align*} R_1=1.0~{\rm k}\Omega. \end{align*}$$

Calculate the currents through

- R_1,
- D_1,
- D_2,

depending on the switch state S.

Simulation: switch-dependent diode circuit

Result

Solution path

First consider the switch open.

With the switch open, only D_1 is connected to the resistor path. The conducting diode clamps the node voltage approximately to

$$\begin{align*} U_{\rm node} \approx U_{\rm F} = 0.7~{\rm V}. \end{align*}$$

The resistor current is therefore

$$\begin{align*} I_{R1} = \frac{U_0-U_{\rm F}}{R_1}. \end{align*}$$

Insert the values:

$$\begin{align*} I_{R1} = \frac{5.0~{\rm V}-0.7~{\rm V}}{1.0~{\rm k}\Omega} = 4.3~{\rm mA}. \end{align*}$$

Since only D_1 conducts,

$$\begin{align*} I_{D1}=I_{R1}, \qquad I_{D2}=0. \end{align*}$$

Now consider the switch closed.

With the switch closed, D_1 and D_2 are connected in parallel. The node voltage is still approximately clamped to

$$\begin{align*} U_{\rm node} \approx 0.7~{\rm V}. \end{align*}$$

Therefore, the total resistor current is still

$$\begin{align*} I_{R1} = \frac{5.0~{\rm V}-0.7~{\rm V}}{1.0~{\rm k}\Omega} = 4.3~{\rm mA}. \end{align*}$$

This current now splits between the two parallel diodes:

$$\begin{align*} I_{D1}+I_{D2}=I_{R1}. \end{align*}$$

With the ideal constant-voltage model, the individual diode currents are not uniquely determined. The model can calculate the total current, but not how two idealized parallel diodes share this current.

If the two real diodes are approximately identical, the current is approximately shared equally:

$$\begin{align*} I_{D1} \approx I_{D2} \approx \frac{I_{R1}}{2}. \end{align*}$$

Result

For open switch:

$$\begin{align*} \boxed{ S \text{ open: } I_{R1}=4.3~{\rm mA}, \quad I_{D1}=4.3~{\rm mA}, \quad I_{D2}=0 } \end{align*}$$

For closed switch, the total current is

$$\begin{align*} \boxed{ S \text{ closed: } I_{R1}=4.3~{\rm mA}, \quad I_{D1}+I_{D2}=4.3~{\rm mA}. } \end{align*}$$

For approximately identical real diodes:

$$\begin{align*} \boxed{ I_{D1}\approx I_{D2}\approx 2.15~{\rm mA}. } \end{align*}$$

> This exercise shows a limitation of the constant-voltage diode model. For parallel diodes, the total current can be calculated, but the current sharing between idealized identical diodes is not uniquely determined.