dummy8

Student Group

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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

$$U_{\rm lamp}\geq 5~{\rm V}$$

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

Number the lamps from left to right:

$$L_1,\;L_2,\;L_3,\;L_4,\;L_5.$$

After the switch is closed, the outer lamps L_1 and L_5 light up brightly. The inner lamps L_2, L_3, and L_4 remain dark or almost dark.

The reason is that some diodes become forward-biased and provide low-voltage bypass paths around parts of the lamp chain.

In particular:

- one diode bypasses the middle part of the circuit,
- another diode bypasses one of the inner lamps,
- therefore the voltage across these bypassed lamps is too small to make them light brightly.

With the given circuit values, the voltage across the leftmost and rightmost lamps is clearly larger than $5~{\rm V}$, while the voltage across the bypassed inner lamps is far below $5~{\rm V}$.

So the result is:

$$\boxed{ L_1 \text{ and } L_5 \text{ light up brightly.} }$$

$$\boxed{ L_2,\;L_3,\;L_4 \text{ remain dark.} }$$

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

Both diodes are forward-biased.

The voltage after D_1 is

$$\begin{align*} U_{R1} = U_0-U_{\rm F} = 4.0~{\rm V}-0.6~{\rm V} = 3.4~{\rm V}. \end{align*}$$

Therefore the current through R_1 is

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

The voltage after D_2 is

$$\begin{align*} U_{R2} = U_0-2U_{\rm F} = 4.0~{\rm V}-2\cdot 0.6~{\rm V} =$$

2.8~{\rm V}. \end{align*} \]

Therefore the current through \(R_2\) is

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

The current through \(D_1\) supplies both branches:

\[\begin{align*} I_{D1} = I_{R1}+I_{R2} = 17~{\rm mA}+28~{\rm mA} = 45~{\rm mA}. \end{align*} \]

Thus:

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

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

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

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

With the switch open, only D_1 is connected to the resistor path.

The node voltage is clamped to approximately

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

Thus the current through R_1 is

$$\begin{align*} I_{R1} = \frac{U_0-U_{\rm F}}{R_1} = \frac{5.0~{\rm V}-0.7~{\rm V}}{1.0~{\rm k}\Omega} = 4.3~{\rm mA}. \end{align*}$$

Since only D_1 conducts,

$$\begin{align*} I_{D1}=4.3~{\rm mA}, \qquad I_{D2}=0. \end{align*}$$

So for open switch:

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

With the switch closed, D_1 and D_2 are connected in parallel. The resistor current remains

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

However, with the **ideal constant-voltage diode model**, the individual currents through two parallel diodes are not uniquely determined. The model says only that the sum is

$$\begin{align*} I_{D1}+I_{D2}=4.3~{\rm mA}. \end{align*}$$

If both diodes are assumed to be identical real diodes, the current would approximately split equally:

$$\begin{align*} I_{D1} \approx I_{D2} \approx \frac{4.3~{\rm mA}}{2} = 2.15~{\rm mA}. \end{align*}$$

So for closed switch:

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

and 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.