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

1. Determine which lamps light up brightly.

SolutionResult

Number the lamps from left to right:

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

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

A lamp is assumed to light brightly if

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

The simulation shows that the outer lamps have a sufficiently large voltage across them, while the inner lamps are bypassed by conducting diodes.

The lamps

$$L_1 \quad \text{and} \quad L_5$$

light up brightly.

2. Determine which lamps remain dark.

SolutionResult

The inner lamps are connected in parts of the circuit that are bypassed by forward-biased diodes.

A forward-biased diode has only a small voltage drop. Therefore, a lamp in parallel with such a diode path receives only a small voltage.

If

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

the lamp does not light brightly.

The lamps

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

remain dark or almost dark.

3. Explain the role of the diodes.

SolutionResult

A conducting diode can create a low-voltage bypass path.

That means:

$$\begin{align*} \text{forward-biased diode} \quad \Rightarrow \quad \text{small voltage drop} \end{align*}$$

If this low-voltage path is parallel to a lamp or to part of the lamp chain, the lamp voltage becomes too small for bright operation.

The diodes route the current mainly through low-voltage bypass paths.

Therefore, only the outer lamps receive enough voltage to light brightly.

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

1. Calculate the current through R_1.

SolutionResult

The current through R_1 passes through 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} &=

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

4.0~{\rm V}-0.6~{\rm V} \\ &= 3.4~{\rm V}. \end{align*} \]

Now apply Ohm's law:

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

2. Calculate the current through \(R_2\).

SolutionResult

The current through \(R_2\) passes through 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:

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

Now apply Ohm's law:

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

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

3. Calculate the current through \(D_1\).

SolutionResult

The diode D_1 supplies both current paths.

Therefore, by Kirchhoff's current law,

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

Insert the values:

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

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

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

1. Calculate the currents for open switch S.

SolutionResult

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

The conducting diode clamps the node voltage to approximately

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

The resistor current is therefore

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

Since only D_1 conducts,

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

For open switch:

$$\begin{align*} I_{R1}&=4.3~{\rm mA}, \\ I_{D1}&=4.3~{\rm mA}, \\ I_{D2}&=0. \end{align*}$$

2. Calculate the currents for closed switch S.

SolutionResult

With the switch closed, D_1 and D_2 are connected in parallel.

The resistor current is still determined

For closed switch:

$$\begin{align*} I_{R1}=4.3~{\rm mA} \end{align*}$$

by the source voltage, the forward diode voltage, and R_1:

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

Kirchhoff's current law gives

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

With the ideal constant-voltage diode model, the individual currents through two parallel diodes are not uniquely determined.

If both real diodes are approximately identical, the current splits approximately equally:

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

and

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

For approximately identical real diodes:

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

3. Explain why the current sharing is not unique in the simple model.

SolutionResult

The constant-voltage diode model assumes that each conducting diode has exactly the same voltage drop:

$$\begin{align*} U_{\rm D}=U_{\rm F}. \end{align*}$$

For two parallel diodes, this condition is true for many possible current distributions.

The constant-voltage diode model determines only

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

It does not uniquely determine I_{D1} and I_{D2} separately.

Therefore, the model only determines the sum

$$\begin{align*} I_{D1}+I_{D2}, \end{align*}$$

not the individual diode currents.

Parallel diodes are sensitive to small differences in real diode characteristics. Current sharing should not be assumed to be perfect without checking the design.