

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

$$U_{\text{lamp}} \geq 5 \text{ V}$$

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.

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

$$U_{\text{lamp}} \geq 5 \text{ V}.$$

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

$$U_{\text{lamp}} < 5 \text{ V},$$

the lamp does not light brightly.

The lamps

$$L_2, L_3, L_4$$

remain dark or almost 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:

$$U_{\text{F}} = 0.6 \text{ V}.$$

The source voltage is

$$U_0 = 4.0 \text{ V}.$$

The resistors are

$$R_1 = 200 \text{ } \Omega, \quad R_2 = 100 \text{ } \Omega.$$

Calculate the currents through

- (D_1) ,
- (R_1) ,
- (R_2) .

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

$$U_{R1} = U_0 - U_{\text{F}}$$

Insert the values:

$$U_{R1} = 4.0 \text{ V} - 0.6 \text{ V} = 3.4 \text{ V}$$

Now apply Ohm's law:

$$I_{R1} = \frac{U_{R1}}{R_1} = \frac{3.4 \text{ V}}{200 \Omega} = 17 \text{ mA}$$

$$I_{R1} = 17 \text{ mA}$$

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

$$U_{R2} = U_0 - 2U_{\text{F}}$$

Insert the values:

$$U_{R2} = 4.0 \text{ V} - 2 \cdot 0.6 \text{ V} = 2.8 \text{ V}$$

$$I_{R2} = 28 \text{ mA}$$

Now apply Ohm's law:

$$\begin{aligned} I_{R2} &= \frac{U_{R2}}{R_2} = \\ \frac{2.8 \text{ V}}{100 \Omega} &= 28 \text{ mA}. \end{aligned}$$

3. Calculate the current through (D_1) .

SolutionResult

The diode (D_1) supplies both current paths.

Therefore, by Kirchoff's current law,

$$I_{D1} = I_{R1} + I_{R2}$$

Insert the values:

$$I_{D1} = 17 \text{ mA} + 28 \text{ mA} = 45 \text{ mA}$$

$$I_{D1} = 45 \text{ mA}$$

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:

$$U_F = 0.7 \text{ V}$$

The source voltage is

$$\left[\begin{array}{l} U_0=5.0 \text{ V} \end{array} \right]$$

The resistor is

$$\left[\begin{array}{l} R_1=1.0 \text{ k}\Omega \end{array} \right]$$

Calculate the currents through

- I_{R_1} ,
- I_{D_1} ,
- I_{D_2} ,

depending on the switch state S .

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

$$\left[\begin{array}{l} U_{\text{node}} \approx U_F = 0.7 \text{ V} \end{array} \right]$$

The resistor current is therefore

$$\left[\begin{array}{l} I_{R_1} = \frac{U_0 - U_F}{R_1} = \frac{5.0 \text{ V} - 0.7 \text{ V}}{1.0 \text{ k}\Omega} = 4.3 \text{ mA} \end{array} \right]$$

Since only D_1 conducts,

$$\left[\begin{array}{l} I_{D_1} = I_{R_1}, \\ I_{D_2} = 0 \end{array} \right]$$

For open switch:

$$\left[\begin{array}{l} I_{R_1} = 4.3 \text{ mA}, \\ I_{D_1} = 4.3 \text{ mA}, \\ I_{D_2} = 0 \end{array} \right]$$

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

$$\begin{aligned} I_{R1} &= \frac{U_0 - U_F}{R_1} = \\ &= \frac{5.0 \text{ V} - 0.7 \text{ V}}{1.0 \text{ k}\Omega} = \\ &= 4.3 \text{ mA}. \end{aligned}$$

Kirchhoff's current law gives

$$I_{D1} + I_{D2} = I_{R1}.$$

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:

$$\begin{aligned} I_{D1} &\approx \\ I_{D2} &\approx \frac{4.3 \text{ mA}}{2} = 2.15 \text{ mA}. \end{aligned}$$

For closed switch:

$$I_{R1} = 4.3 \text{ mA}$$

and

$$I_{D1} + I_{D2} = 4.3 \text{ mA}.$$

For approximately identical real diodes:

$$\begin{aligned} I_{D1} &\approx \\ I_{D2} &\approx 2.15 \text{ mA}. \end{aligned}$$

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

SolutionResult

The constant-voltage diode model

The constant-voltage diode model determines only

assumes that each conducting diode has exactly the same voltage drop:

$$\begin{aligned} U_{\text{D}} = U_{\text{F}}. \end{aligned}$$

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

Therefore, the model only determines the sum

$$\begin{aligned} I_{\text{D1}} + I_{\text{D2}}, \end{aligned}$$

not the individual diode currents.

$$\begin{aligned} I_{\text{D1}} + I_{\text{D2}} = 4.3 \text{ mA}. \end{aligned}$$

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

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

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