Homework #8

Problems 4.35, 4.59, 4.62, 4.70, 4.72, and 4.87

Problem 4.35

Use the iterative-analysis procedure to determine the diode current and voltage in the circuit of Fig. 4.10 for V_{DD}=1 V, R=1 kΩ, and a diode having $I_S = 10^{-15}$ A.

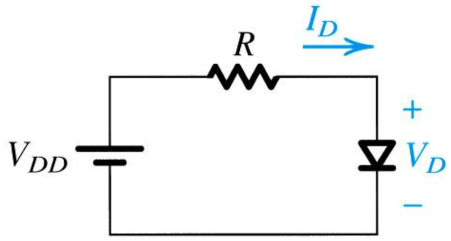


Figure 4.10 A simple circuit used to illustrate the analysis of circuits in which the diode is forward conducting.

Initial guess

$$I_{D1} = \frac{V_{DD} - V_D}{R} = \frac{1\text{V} - 0.7\text{V}}{1\text{k}\Omega} = 0.3\text{mA}$$

@ I_{D1}

$$V_D = V_T \ln\left(\frac{I_{D1}}{I_S}\right) = 0.6607\text{V}$$

But 0.6607 V is < the 0.7 V specification

$$I_{D2} = \frac{1\text{V} - 0.6607\text{V}}{1\text{k}\Omega} = 0.3393\text{mA}$$

@ I_{D2}

$$V_D = V_T \ln\left(\frac{I_{D2}}{I_S}\right) = 0.6638\text{V}$$

$$I_{D3} = \frac{1\text{V} - 0.6638\text{V}}{1\text{k}\Omega} = 0.3362\text{mA}$$

@ I_{D3}

$$V_D = V_T \ln\left(\frac{I_{D3}}{I_S}\right) = 0.6635\text{V}$$

$$I_{D4} = \frac{1\text{V} - 0.6635\text{V}}{1\text{k}\Omega} = 0.3365\text{mA}$$

@ I_{D4}

$$V_D = V_T \ln\left(\frac{I_{D4}}{I_S}\right) = 0.6635\text{V}$$

Problem 4.59

Partial specifications of a collection of zener diodes are provided below. For each, identify the missing parameter, and estimate its value. Note from Fig. 4.19 that $V_{ZK} \approx V_{Z0}$. Assuming that the power rating of a breakdown diode is established at about twice the specified zener current (I_{ZT}), what is the power rating of each of the diodes described above?

(a) V_Z = 10.0 V, V_{ZK} = 9.6 V, and I_{ZT} = 50 mA
(b) I_{ZT} = 10 mA, V_Z = 9.1 V, and r_Z = 30 Ω
(c) r_Z = 2 Ω, V_Z = 6.8 V, and V_{ZK} = 6.6 V
(d) V_Z = 18.0 V, I_{ZT} = 5 mA, and V_{ZK} = 17.6 V
(e) I_{ZT} = 200 mA, V_Z = 7.5 V, and, r_Z = 1.5 Ω

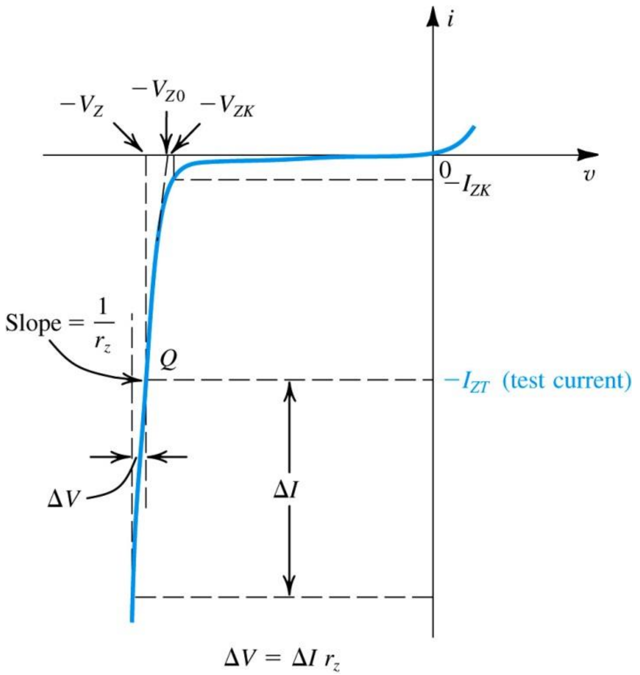


Figure 4.19 The diode i–v characteristic with the breakdown region shown in some detail.

Problem 4.59

Partial specifications of a collection of zener diodes are provided below. For each, identify the missing parameter, and estimate its value. Note from Fig. 4.19 that $V_{ZK} \approx V_{Z0}$. Assuming that the power rating of a breakdown diode is established at about twice the specified zener current (I_{ZT}), what is the power rating of each of the diodes described above?

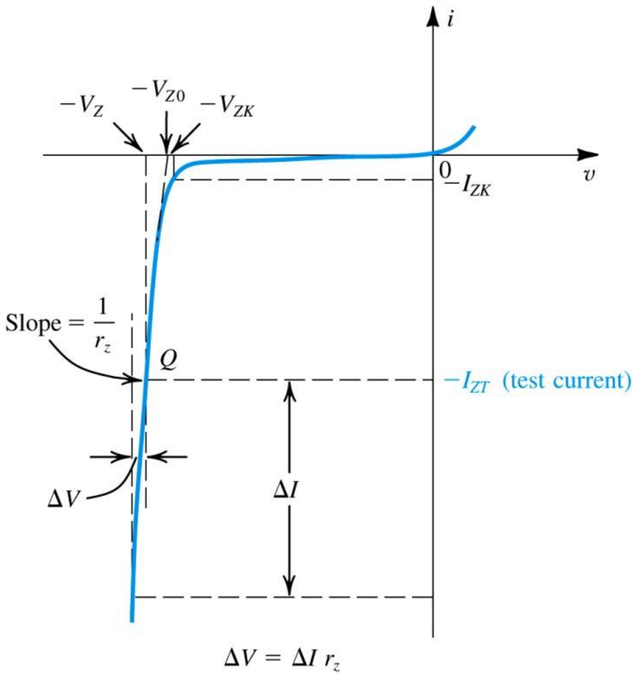


Figure 4.19 The diode *i*–*v* characteristic with the breakdown region shown in some detail.

(a) V_Z = 10.0 V, V_{ZK} = 9.6 V, and I_{ZT} = 50 mA

$$V_Z = V_{Z0} + r_z I_Z$$

$$r_Z = \frac{V_Z - V_{Z0}}{I_Z} = \frac{10 - 9.6}{0.05} = 8\Omega$$

$2I_{ZT}$ = 100 mA and V_Z at $2I_{ZT}$ is

$$V_Z = 9.6 + 8\Omega 100\text{mA} = 10.4\text{V}$$

$$P = I_Z V_Z = (0.1)(9.6 + 8 \times 0.1)$$

$$P = 1.04\text{W}$$

Problem 4.59

Partial specifications of a collection of zener diodes are provided below. For each, identify the missing parameter, and estimate its value. Note from Fig. 4.19 that $V_{ZK} \approx V_{Z0}$. Assuming that the power rating of a breakdown diode is established at about twice the specified zener current (I_{ZT}), what is the power rating of each of the diodes described above?

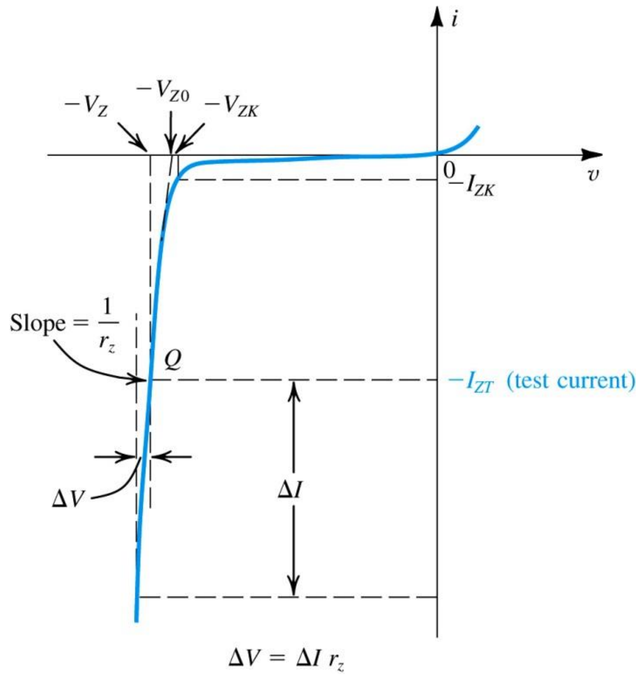


Figure 4.19 The diode i–v characteristic with the breakdown region shown in some detail.

(b) $I_{ZT} = 10$ mA, $V_Z = 9.1$ V, and $r_Z = 30\ \Omega$

$$V_Z = V_{Z0} + r_z I_Z$$

$$V_{Z0} = V_Z - r_z I_Z = 9.1\text{V} - 30 \times 0.01A$$

$$V_{Z0} = 8.8\text{V}$$

$$P = I_Z V_Z = (0.02)(8.8 + 30 \times 0.02)$$

$$P = 188\text{mW}$$

Problem 4.59

Partial specifications of a collection of zener diodes are provided below. For each, identify the missing parameter, and estimate its value. Note from Fig. 4.19 that $V_{ZK} \approx V_{Z0}$. Assuming that the power rating of a breakdown diode is established at about twice the specified zener current (I_{ZT}), what is the power rating of each of the diodes described above?

(c) $r_Z = 2\ \Omega$, $V_Z = 6.8$ V, and $V_{ZK} = 6.6$ V

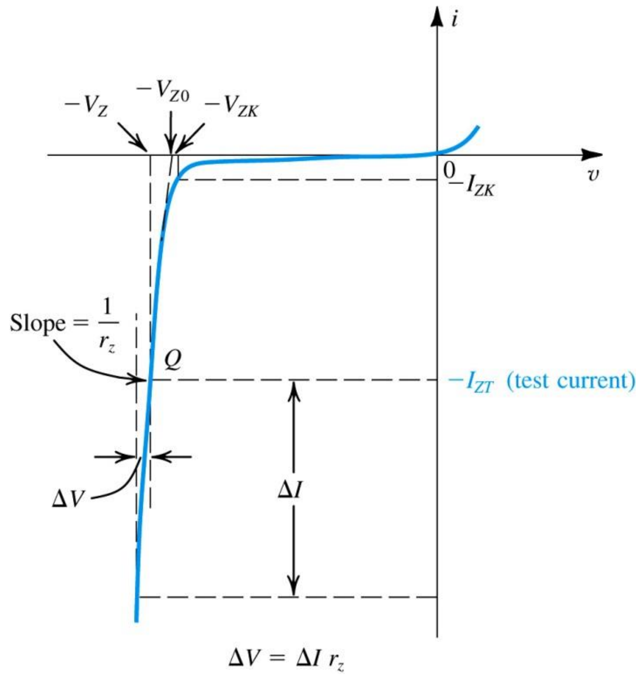


Figure 4.19 The diode i–v characteristic with the breakdown region shown in some detail.

$$V_Z = V_{Z0} + r_Z I_Z$$

$$I_Z = \frac{V_Z - V_{Z0}}{r_Z} = \frac{6.8 - 6.6}{2} = 0.1\text{A}$$

$$P = I_Z V_Z = (0.2)(6.6 + 2 \times 0.2)$$

$$P = 1.4\text{W}$$

Problem 4.59

Partial specifications of a collection of zener diodes are provided below. For each, identify the missing parameter, and estimate its value. Note from Fig. 4.19 that $V_{ZK} \approx V_{Z0}$. Assuming that the power rating of a breakdown diode is established at about twice the specified zener current (I_{ZT}), what is the power rating of each of the diodes described above?

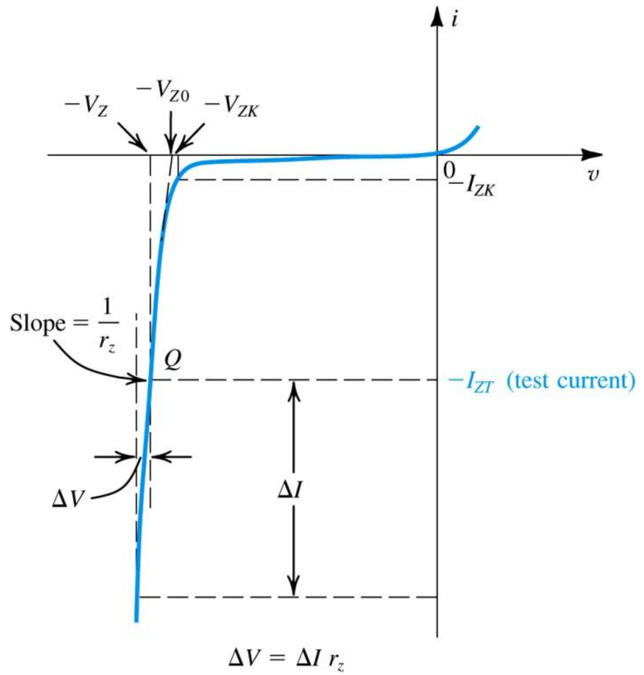


Figure 4.19 The diode *i*–*v* characteristic with the breakdown region shown in some detail.

(d) V_Z = 18.0 V, I_{ZT} = 5 mA, and V_{ZK} = 17.6 V

$$V_Z = V_{Z0} + r_z I_Z$$

$$r_Z = \frac{V_Z - V_{Z0}}{I_Z} = \frac{18 - 17.6}{0.005} = 80\Omega$$

$$P = I_Z V_Z = (0.01)(17.6 + 80 \times 0.01)$$

$$P = 184\text{mW}$$

Problem 4.59

Partial specifications of a collection of zener diodes are provided below. For each, identify the missing parameter, and estimate its value. Note from Fig. 4.19 that $V_{ZK} \approx V_{Z0}$. Assuming that the power rating of a breakdown diode is established at about twice the specified zener current (I_{ZT}), what is the power rating of each of the diodes described above?

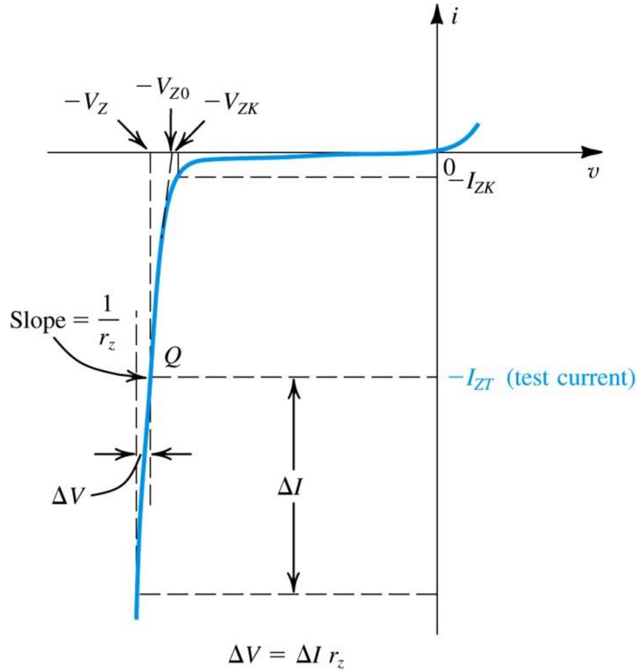


Figure 4.19 The diode i–v characteristic with the breakdown region shown in some detail.

(e) I_{ZT} = 200 mA, V_Z = 7.5 V, and, r_Z = 1.5 Ω

$$V_Z = V_{Z0} + r_z I_Z$$

$$V_{Z0} = V_Z - r_z I_Z = 7.5\text{V} - 1.5 \times 0.2\text{A}$$

$$V_{Z0} = 7.2\text{V}$$

$$P = I_Z V_Z = (0.4)(7.2 + 1.5 \times 0.4)$$

$$P = 3.12\text{W}$$

Problem 4.62

A 9.1-V zener diode exhibits its nominal voltage at a test current of 20 mA. At this current the incremental resistance is specified as 10 Ω. Find V_{Z0} of the zener model. Find the zener voltage at a current of 10 mA and at 50 mA.

$$V_Z = V_{Z0} + r_z I_Z$$

$$V_{Z0} = V_Z - r_z I_Z = 9.1 - (10)(.020) = 8.9\text{V}$$

At 10 mA

$$V_Z = 8.9 + 10 \times 0.01 = 9.0\text{V}$$

At 50 mA

$$V_Z = 8.9 + 10 \times 0.05 = 9.4\text{V}$$

Problem 4.70

A half-wave rectifier circuit with a l-kΩ load operates from a 120-V (rms) 60-Hz household supply through a 12-to-1 step-down transformer. It uses a silicon diode that can be modeled to have a 0.7-V drop for any current. What is the peak voltage of the rectified output? For what fraction of the cycle does the diode conduct? What is the average output voltage? What is the average current in the load?

$$V_o = 10\sqrt{2}\sin\phi - 0.7$$ When diode is "on"

$$V_o = 0\text{V}$$ When diode is "off"

$$V_{peak} = 10\sqrt{2} - 0.7 = 13.44\text{V}$$

diode is "on" when

$$10\sqrt{2}\sin\theta \geq 0.7\text{V} \qquad \theta = \sin^{-1}\left(\frac{0.7}{10\sqrt{2}}\right) = 0.0495\text{rad}$$

$$\frac{\pi - 2(0.0495)}{2\pi} = \frac{3.049}{6.283} = 48.4\%$$

Problem 4.70

A half-wave rectifier circuit with a l-kΩ load operates from a 120-V (rms) 60-Hz household supply through a 12-to-1 step-down transformer. It uses a silicon diode that can be modeled to have a 0.7-V drop for any current. What is the peak voltage of the rectified output? For what fraction of the cycle does the diode conduct? What is the average output voltage? What is the average current in the load?

Average output voltage

$$V_{O,avg} = \frac{1}{2\pi}\int_{0.0495}^{\pi-0.0495} \left(10\sqrt{2}\sin\phi - 0.7\right) d\phi$$

$$V_{Oavg} := \frac{1}{2\pi}\cdot\int_{0.0495}^{\pi\ -0.0495} \left(10\cdot\sqrt{2}\cdot sin(\phi\ ) - 0.7\right)\cdot \mathrm{V}\, d\phi \ = 4.157V$$

$$I_{D,avg} = \frac{4.157V}{1\mathrm{k}\Omega} = 4.157\mathrm{mA}$$

Problem 4.72

A full-wave bridge rectifier circuit with a 1-kΩ load operates from a 120-V (rms) 60-Hz household supply through a 12-to-1 step-down transformer having a single secondary winding. It uses four diodes, each of which can be modeled to have a 0.7-V drop for any current. What is the peak value of the rectified voltage across the load? For what fraction of a cycle does each diode conduct? What is the average voltage across the load? What is the average current through the load?

$$V_o = 10\sqrt{2}\sin\phi - (2 \times 0.7)$$ When diode is “on”

$$V_o = 0\text{V}$$ When diode is “off”

$$V_{peak} = 10\sqrt{2} - 2 \times 0.7 = 12.74\text{V}$$

diode is “on” when

$$10\sqrt{2}\sin\theta \geq 1.4\text{V} \qquad \theta = \sin^{-1}\left(\frac{1.4}{10\sqrt{2}}\right) = 0.0992\text{rad}$$

$$\frac{\pi - 2(0.0992)}{2\pi} \times 2 = \frac{2.943}{6.283} \times 2 = 93.7\%$$

Problem 4.72

A full-wave bridge rectifier circuit with a 1-kΩ load operates from a 120-V (rms) 60-Hz household supply through a 12-to-1 step-down transformer having a single secondary winding. It uses four diodes, each of which can be modeled to have a 0.7-V drop for any current. What is the peak value of the rectified voltage across the load? For what fraction of a cycle does each diode conduct? What is the average voltage across the load? What is the average current through the load?

Average output voltage

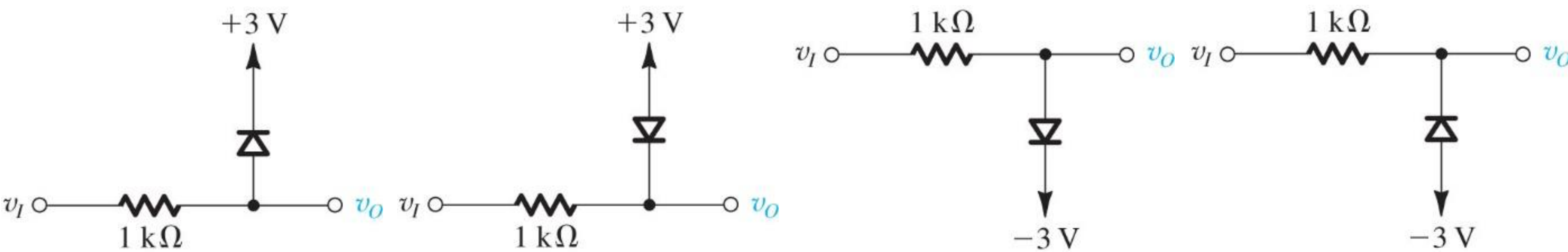
$$V_{O,avg} = \frac{2}{2\pi}\int_{0.0992}^{\pi-0.0992}\left(10\sqrt{2}\sin\phi - 2\times 0.7\right)d\phi$$

$$V_{Oavg} := \frac{2}{2\pi}\cdot\int_{0.0992}^{\pi\ -0.0992}\left(10\cdot\sqrt{2}\cdot sin(\phi\ ) - 2\cdot 0.7\right)\cdot \mathrm{V}\, d\phi\ = 7.647V$$

$$I_{D,avg} = \frac{7.647}{1\mathrm{k}\Omega} = 7.647\mathrm{mA}$$

Problem 4.87

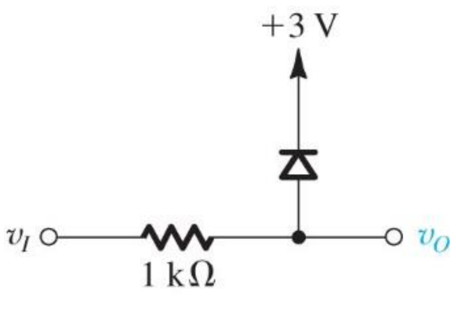
Sketch the transfer characteristic v_O versus v_I, for the limiter circuits shown in Fig. P4.87. All diodes begin conducting at a forward voltage drop of 0.5 V and have voltage drops of 0.7 V when conducting a current $i_D \geq$ 1 mA.



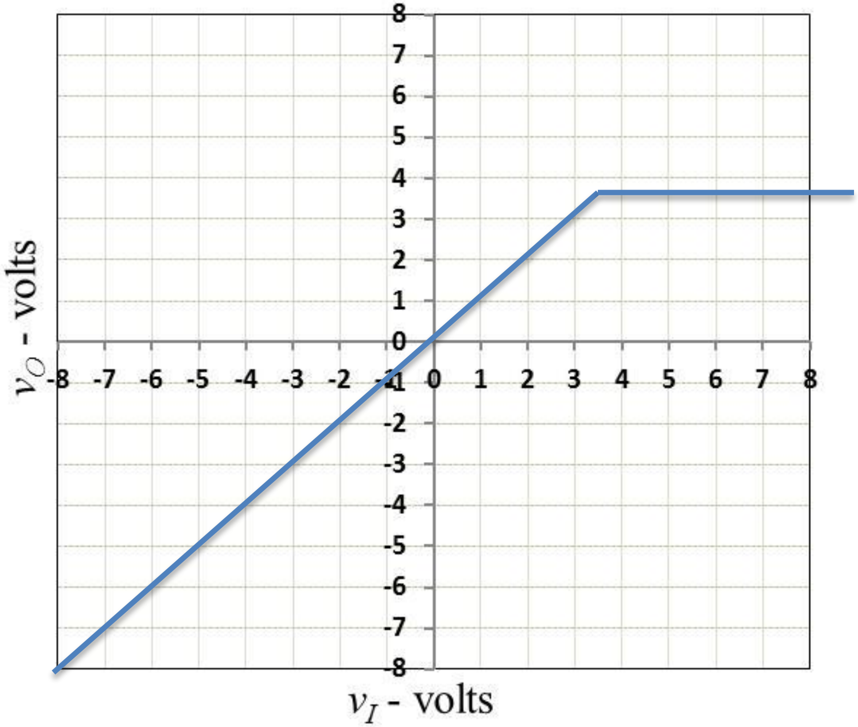
(a) (b) **Figure P4.87** (c) (d)

Problem 4.87

Sketch the transfer characteristic v_O versus v_I, for the limiter circuits shown in Fig. P4.87. All diodes begin conducting at a forward voltage drop of 0.5 V and have voltage drops of 0.7 V when conducting a current $i_D \geq 1$ mA.

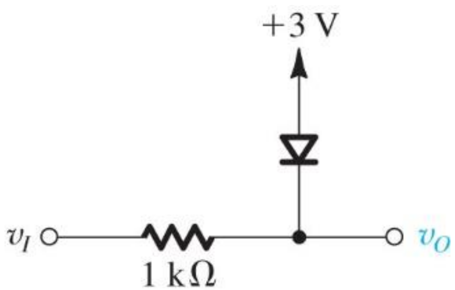


(a)

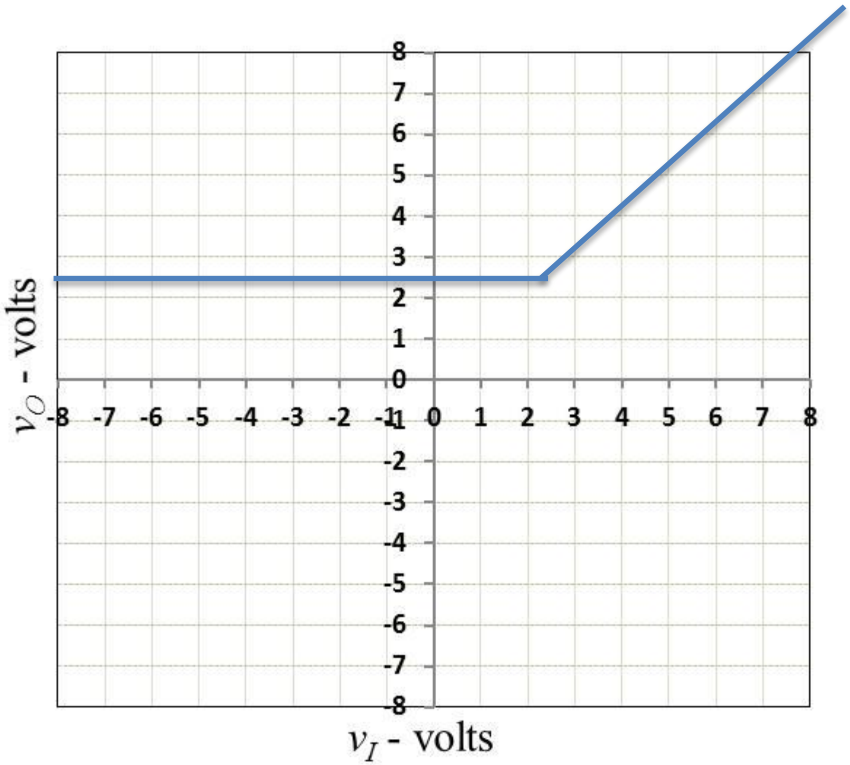


Problem 4.87

Sketch the transfer characteristic v_O versus v_I, for the limiter circuits shown in Fig. P4.87. All diodes begin conducting at a forward voltage drop of 0.5 V and have voltage drops of 0.7 V when conducting a current $i_D \geq$ 1 mA.

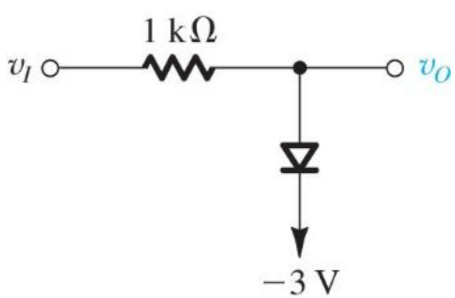


(b)

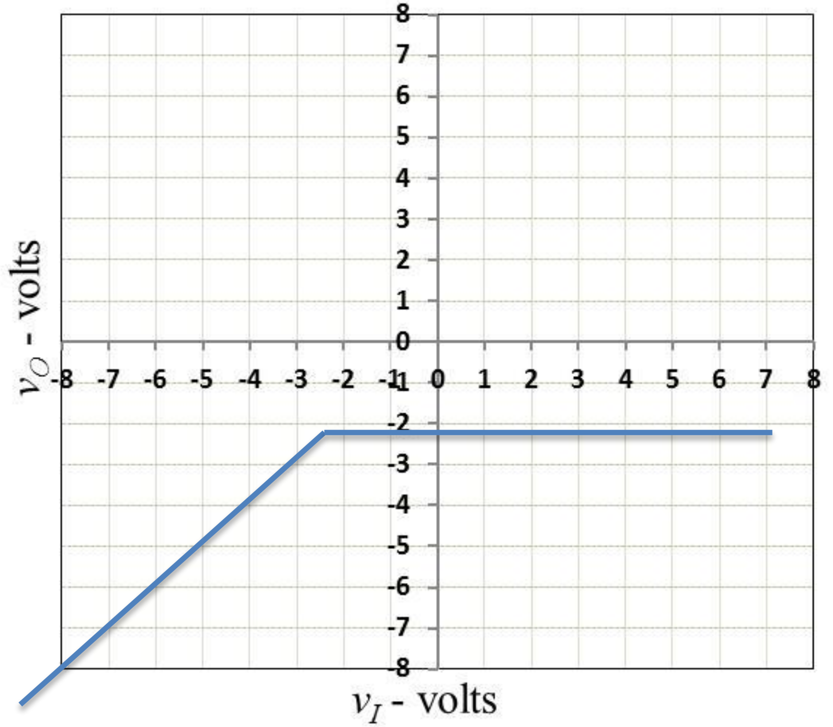


Problem 4.87

Sketch the transfer characteristic v_O versus v_I, for the limiter circuits shown in Fig. P4.87. All diodes begin conducting at a forward voltage drop of 0.5 V and have voltage drops of 0.7 V when conducting a current $i_D \geq$ 1 mA.

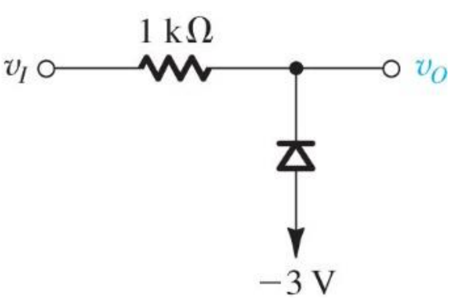


(c)



Problem 4.87

Sketch the transfer characteristic v_O versus v_I, for the limiter circuits shown in Fig. P4.87. All diodes begin conducting at a forward voltage drop of 0.5 V and have voltage drops of 0.7 V when conducting a current $i_D \geq$ 1 mA.



(d)