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EPE 2165—Analog Electronics

HOMEWORK #2—diode circuits

Question:	1	2	3	4	5	Total
Points:	20	10	10	20	40	100
Score:						

Issued on: *July 9, 2022*
Due on: July 16, 2022

1. Figure 1 represents a portion of battery-charger circuit for a battery with a voltage V_B. The sine-wave input $v_S = 12\,\text{V}(rms)$, while the battery voltage varies from 12 V to 14 V from the discharged to fully charged states. The charging-source resistance $R_S = 10\,\Omega$. Assuming that D is an ideal diode, and $R_C = 50\,\Omega$ is a current-controlling resistor established by the designer:

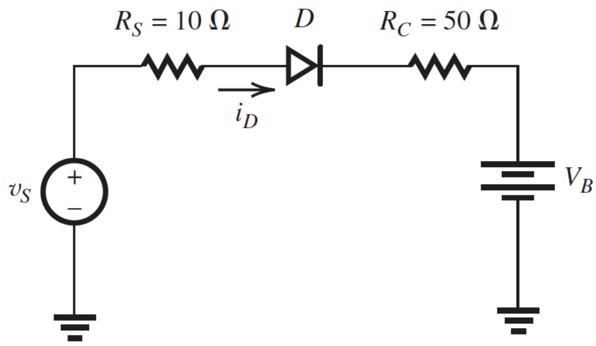
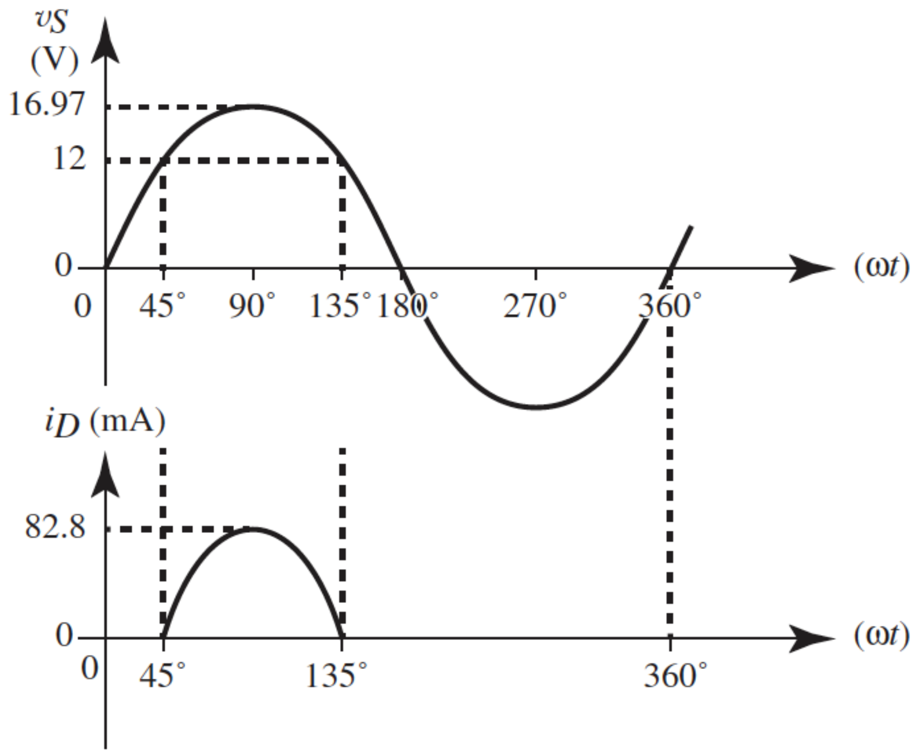


FIGURE 1. Battery-charger circuit

(a) (10 points) Sketch and label the voltage waveforms of the voltage accros the diode and the current through the diode for $V_B = 12\,\text{V}$.

Solution: The current and voltages for r $V_B = 12\,\text{V}$ is shown below



Note: To receive the full marks, the student should show:

- Clear units
- Clear labels and their values
- That the peak is at 90 degrees

(b) (10 points) What is the peak diode current?

Solution: For a battery voltage VB and an ideal diode, the diode current is

$$\begin{aligned} i_D &= \frac{v_s - V_B}{R_S + R_C} \\ &= \frac{V_S' sin(\omega t) - V_B}{10\,\Omega + 50\,\Omega} \end{aligned} \tag{1}$$

where $V_S' = \sqrt{2} \times 12V = 16.97V$. Thus, for $V_B = 12V$, the current is given in Equation (2)

$$i_D = \frac{16.97 sin(\omega t)V - 12V}{60\,\Omega} \tag{2}$$

Equation (2) shows that the peak current would be (Equation (3))

$$i_{Dmax} = \frac{16.97V - 12V}{60\,\text{V}} = 82.8\,\text{mA} \tag{3}$$

2. (10 points) For the circuits shown in Figure 2, using ideal diodes, find the values the output voltage V_O and the currents I_{D1} and I_{D2}.

Solution: The diode D_1 will is off while D_2 is conducting, Thus,

$$V_O = 0V + V_{D2} = 0.7V \tag{4}$$

Consequently, D_1 has a 4.3V reverse, which keeps it off. Thus,

$$I_{D1} = 0A \tag{5}$$

$$I_{D2} = \frac{5V - 0.7V}{10k} = 0.43mA \tag{6}$$

3. (10 points) The diode in the circuit shown in Figure 3 has a reverse-saturation current of $I_s = 5 \times 10^{-11} A$. Determine the diode voltage $V_D$and current I_D.

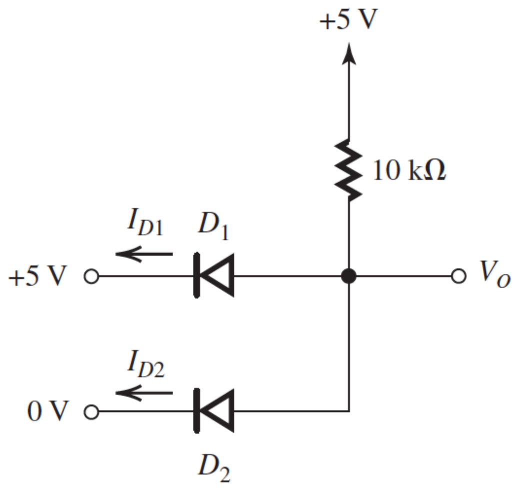


FIGURE 2

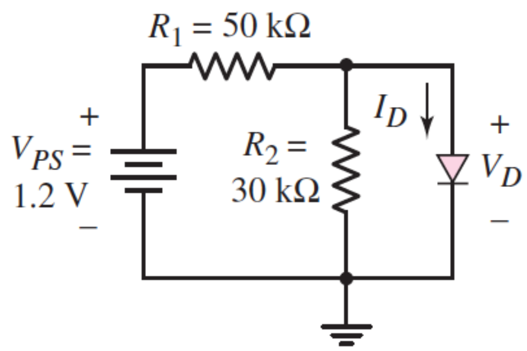


FIGURE 3

Solution: The voltages through the circuit can be expressed as

$$V_{PS} = I_D R + V_D \Leftrightarrow 2.8V = I_D \cdot 1 \times 10^6 + V_D \tag{7}$$

The current through a diode is expressed as

$$I_D = 5 \times 10^{-11} \cdot e^{\frac{V_D}{0.025}} \tag{8}$$

Such equation can be solved either graphically or by trial and error. The approximate solution is

$$V_D = 0.282V, I_D = 2.52\,\mu\text{A} \tag{9}$$

4. (20 points) Figure 4 shows a 4 diode circuit. The 4 diodes are identical and each diode exhibits a voltage drop of $V_D = 0.7V$ at a 1 mA current. For small input signals (e.g., 10-mV peak), find the small-signal equivalent circuit and use it to determine values of the small-signal transmission vo/vi for a current $I = 1\,\mu\text{A}$

Solution: Since the diodes are identical, the current through each diode is:

$$I_{D1} = I_{D2} = I_{D3} = I_{D4} = \frac{I}{2} \tag{10}$$

Thus, the small signal resistance is

$$r_d = \frac{V_T}{I/2} = \frac{2V_T}{I} = \frac{0.05}{I} \tag{11}$$

On the other hand, from Figure 4 the two diodes in the circuits are in series and in parallel with the remaining two diodes. Thus, the output voltage can be expressed as

$$\frac{v_o}{v_i} = \frac{R}{R + (2r_d||2r_d)} = \frac{R}{R + r_d} \tag{12}$$

Consequently, for $I = 1\,\mu\text{A}$,

$$r_d = \frac{0.05V}{1\,\mu\text{A}} = 50\,\text{k}\Omega \tag{13}$$

5. Consider a half-wave rectifier circuit shown in Figure 5.

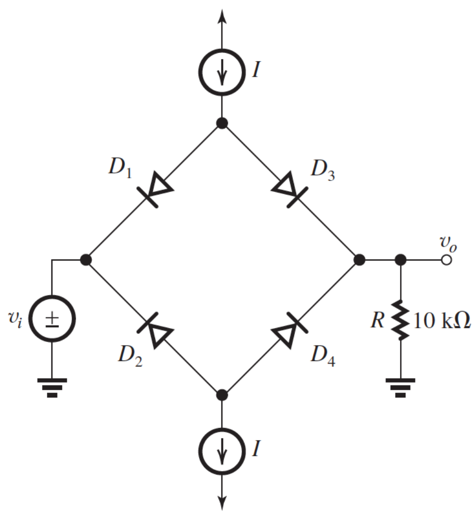


FIGURE 4

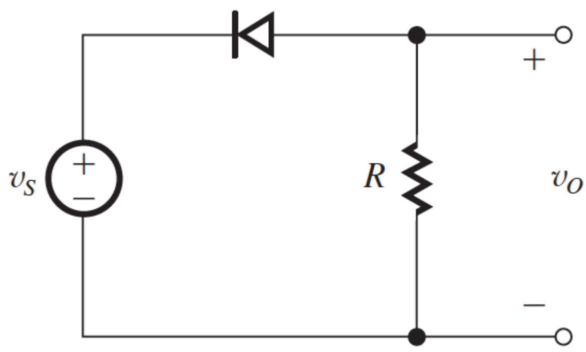


FIGURE 5

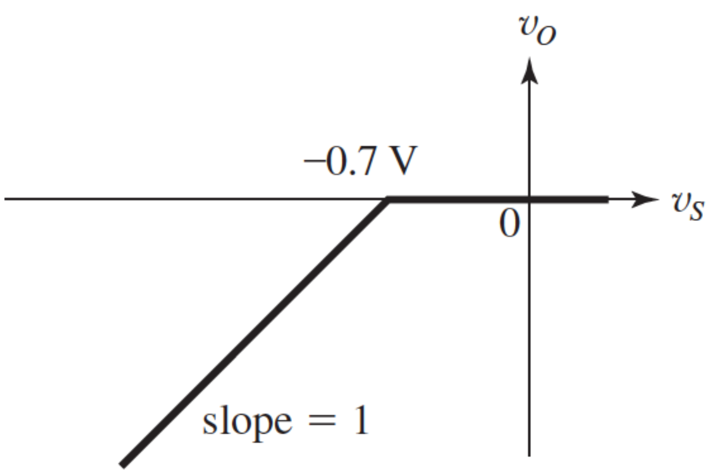
Let v_s be a sinusoid with 10V peak amplitude, and let $R = 1k$. Use the constant-voltage-drop diode model with $V_D = 0.7V$.

(a) (10 points) Sketch the transfer characteristic.

Solution: Assuming a constant voltage drop model for the diode, the output voltage is:

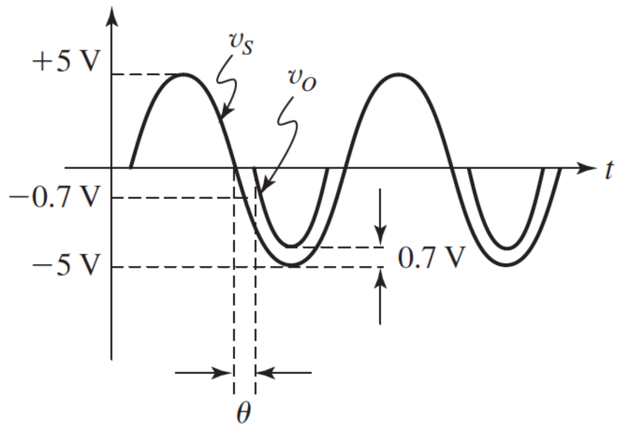
$$v_o = \begin{cases} v_s + V_D, & \text{if } v_s < -V_D. \\ 0, & \text{otherwise.} \end{cases} \tag{14}$$

Thus, the output voltage can be sketched as



(b) (10 points) Sketch the waveform of v_O.

Solution: The output voltages can be sketched as follows:



(c) (10 points) Find the peak current in the diode.

Solution: Peak current in diode is:

$$\frac{5V - V_D}{R} \tag{15}$$

(d) (10 points) Find the PIV of the diode

Solution: PIV occurs when v_S is at its peak and $v_O = 0$. Thus, $PIV = 5V$