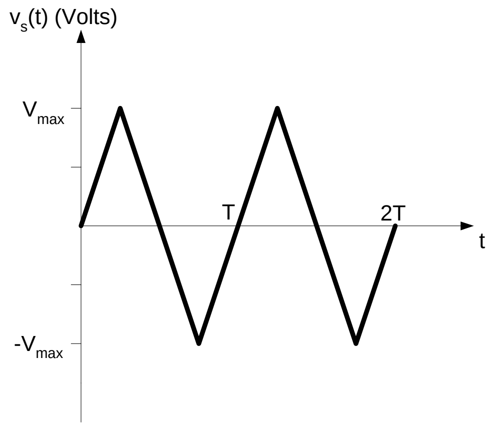
American University of Beirut
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

EECE 310 – Electronics Fall 2007 – 2008

Homework 3

1. Consider the waveform shown below.



The waveform is superimposed on a 9 V DC source, and applied to a circuit consisting of a 1 KΩ resistor and a (conducting) diode. Find the value of V_{max} for which small-signal analysis is applicable, if the variation in the diode voltage is limited to +/– 10 mV. Assume that the diode drops a voltage of 0.7 V when conducting, and that n = 1.7. Provide a plot of the *total* diode current, as derived from DC and small-signal analyses.

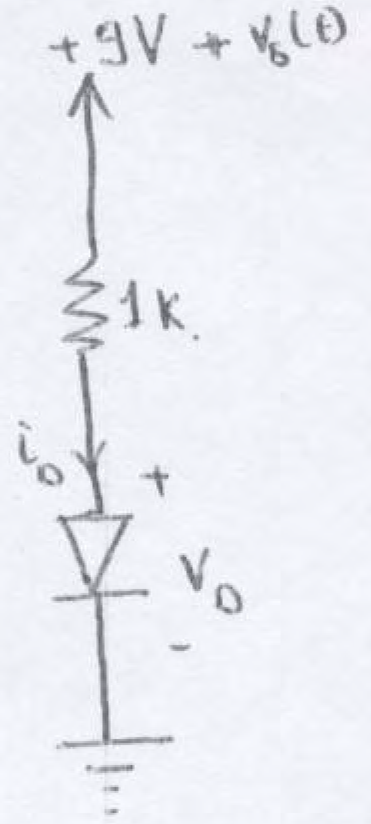
2. Repeat Problem 2, parts (a) and (b) in Homework 2 using the following model for the conducting diodes: V_{D0} = 0.68 V, r_D = 30 Ω.

3. Design a Zener voltage regulator to provide a regulated voltage of around 9 V. The available 9.1 V, ½ W Zener is specified to have a drop of 9.1 V at a test current of 16 mA. At this value of current r_Z is specified to be 6.25 Ω. The value of I_{ZK} for the Zener diode is 3 mA. The unregulated supply varies between 12 V and 15 V. The regulator is required to supply a load that dissipates 10 to 300 mW at 9 V.

a. Find V_{Z0} for the Zener diode.
b. Calculate the range of values for the resistor R in the circuit.
c. Using a value of R that is close, to the nearest *standard resistor value*, to the upper range:

    i. Find the change in load voltage that corresponds to the 12-to-15 V variation in the unregulated supply voltage. Assume that the load current is constant.
    ii. Find the change in load voltage that corresponds to the full change in load current. Assume that the supply voltage is fixed.
    iii. What is the maximum current that the Zener diode should be able to conduct? What is the Zener power dissipation under this condition?

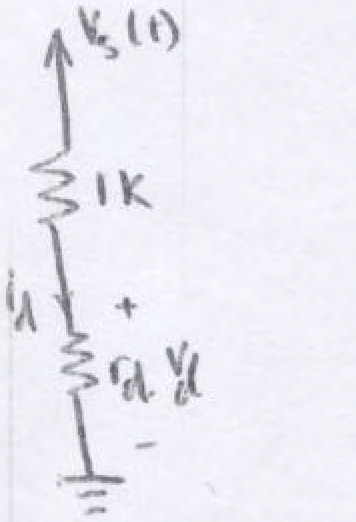
I



- DC analysis: $9 - RI_D - V_D = 0 \Rightarrow I_D = \dfrac{9-0.7}{1K} = 8.3mA$

- Small signal analysis for $n=1.7$ and $\pm 10mV$

$$r_d = \frac{nV_T}{I_D} = \frac{1.7\,(25mV)}{8.3mA} = 5.12\,\Omega$$



$$v_d = v_s \cdot \frac{r_d}{R+r_d}$$

max $\Delta V_d = 20mV$

$\Rightarrow$ max $\Delta V_s = \Delta V_d \dfrac{(R+r_d)}{r_d}$

$\Rightarrow$ max $\Delta V_s = 20\left(\dfrac{1000+5.12}{5.12}\right)$

$= 3.926V$

OR

$V_{d\,peak} = 10mV$

$\Rightarrow V_{s\,peak} = V_{d_{peak}} \cdot \dfrac{R+r_d}{r_d}$

$\Rightarrow V_{s\,peak} = 10\left(\dfrac{1000+5.12}{5.12}\right)$

$= 1.963V$

$$V_{s\,max} = \frac{\Delta V_{s\,max}}{2} = V_{s\,peak} = 1.963V$$

$i_D(t) = I_D + i_d(t)$

$I_D = 8.3\text{mA}$

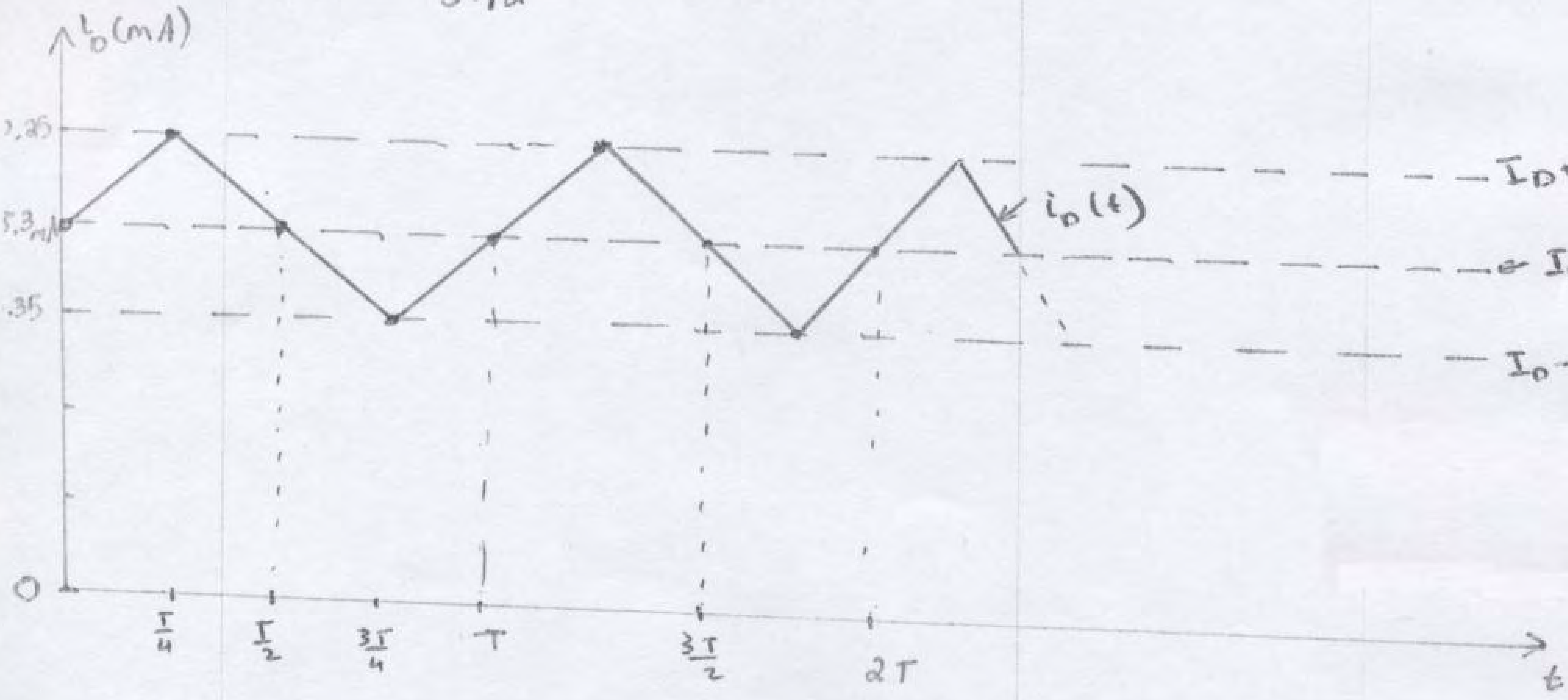
$i_d(t) = \frac{V_d(t)}{r_d} = \frac{V_d(t)}{5.12} = \frac{V_s(t)}{R + r_d}$

$i_d(t)_{peak} = \frac{V_{d\,peak}}{5.12} = \frac{10\text{mV}}{5.12} = 1.95\text{mA}$

$V_D = 0.7 \pm 10\text{mV}$.

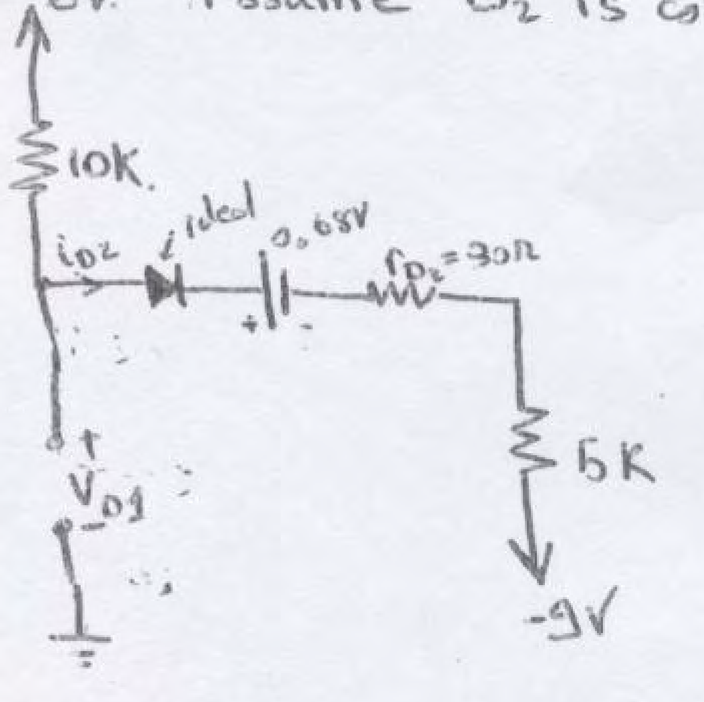
$i_D = 8.3 \pm 1.95\text{mA}$

$V_s(t)$ triangular wave $\Rightarrow i_d(t)$ triangular wave.



II

a) 6V. Assume D_2 is conducting & D_1 is not conducting



$\Rightarrow 6 - (-9) = 10(i_{D2}) + 0.68 + 0.03\, i_{D2} + 5\, i_{D2}$

$\Rightarrow i_{D2} = \frac{14.32}{15.03} = 0.953\text{ mA}$.

$V_{D2} = 0.68 + 0.03 \times i_{D2} = 0.708\text{V}$

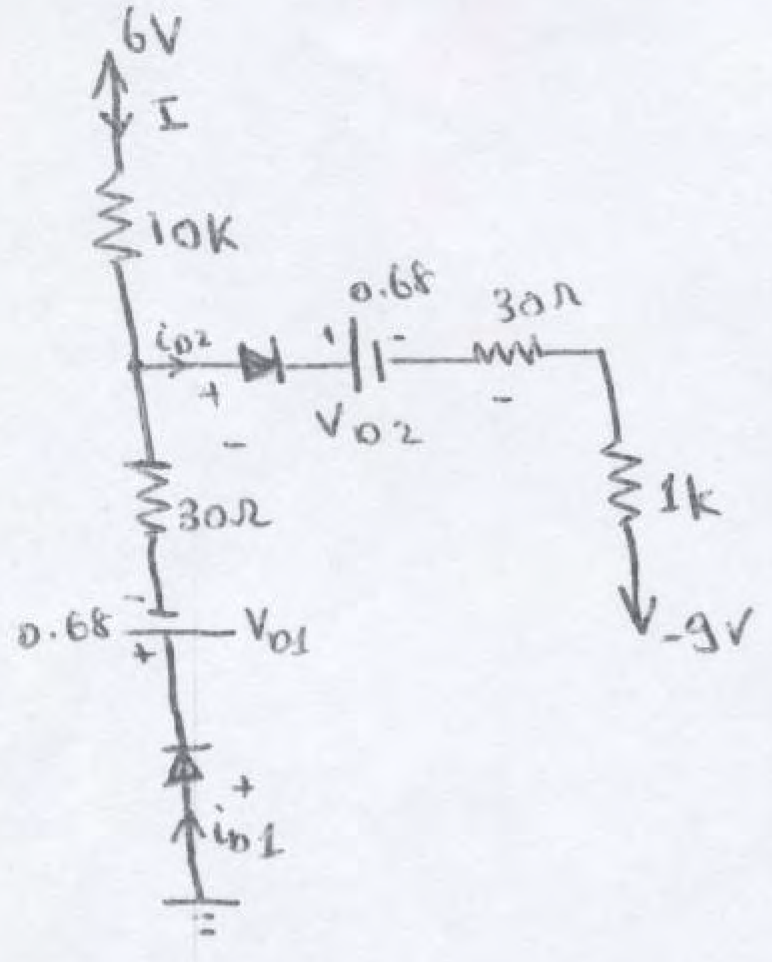
$i_{D1} = 0\text{ mA}$

$V_{D1} = 0.68 + 0.03 i_{D2} + 5 i_{D2} - 9 = -3.52\text{ V}$.

$\therefore$ D1 (0mA, -3.52V)

D2 (0.953mA, 0.708V)

b) Assume D_1 & D_2 conduct.



$$\begin{cases} 6-(-9) = 10I + 0.68 + 0.03\,i_{D2} + i_{D2} \\ 6 = 10I - 0.03\,i_{D1} - 0.68 \\ I = i_{D2} - i_{D1} \end{cases}$$

$\Rightarrow 14.32 = 11.03\,i_{D2} - 10\,i_{D1}$

$6.68 = 10\,i_{D2} - 10.03\,i_{D1}$

$\Rightarrow i_{D1} = 6.54\,mA$

$i_{D2} = 7.23\,mA$

$V_{D1} = 0.68 + 0.03\,i_{D1} = 0.8762\,V$

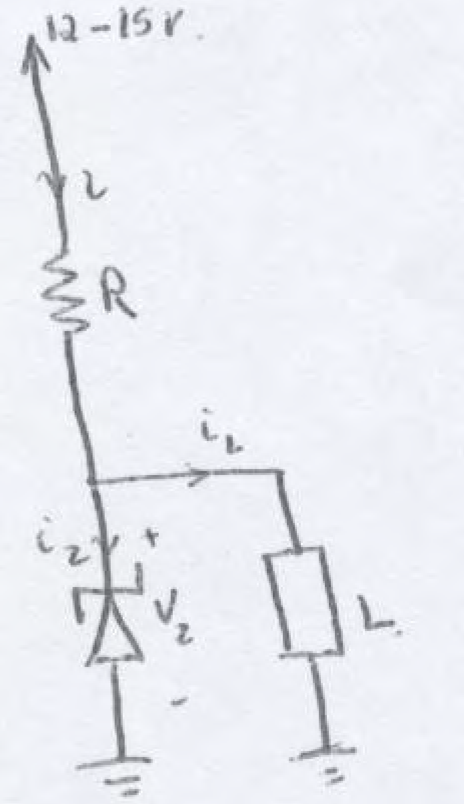
$V_{D2} = 0.68 + 0.03\,i_{D2} = 0.897\,V$

$\therefore$ D1 (6.54 mA, 0.8762 V)

D2 (7.23 mA, 0.897 V)

III a) $V_z = V_{z0} + r_z I_z \Rightarrow 9.1 = V_{z0} + 6.25\,(16\,mA) \Rightarrow V_{z0} = 9V$

b)



$*\; R = \dfrac{V_{source} - V_z}{i_z + i_L}$

- for $P_L = 10\,mW \Rightarrow i_{L\,min} = \dfrac{10\,mW}{9.1} = 1.09\,mA$
- for $P_L = 300\,mW \Rightarrow i_{L\,max} = \dfrac{300\,mW}{9.1} = 32.96\,mA$
- $i_{z\,min} = i_{zK} = 3\,mA$
- $i_{z\,max} = i_z$ at maximium power $= \dfrac{\frac{1}{2}W}{V_z} = \dfrac{0.5}{9.1} = 54.9\,mA$

$R = \dfrac{V_{source} - V_{z0} - r_z i_z}{i_z + i_L}$

$R_{max} = \dfrac{V_{source\,max} - V_{z0} - r_z i_{z\,max}}{i_{z\,max} + i_{L\,min}} = \dfrac{15 - 9 - 6.25\,(54.9\times10^{-3})}{54.9\times10^{-3} + 1.09\times10^{-3}} = 101\ \Omega$

$$R_{min} = \frac{V_{source\,min} - V_{z0} - r_z I_{ZK}}{i_{ZK} + i_{L\,max}} = \frac{12 - 9 - 6.25(3 \times 10^{-3})}{3 \times 10^{-3} + 32.96 \times 10^{-3}} = 82.9\,\Omega$$

$$82.9\,\Omega \leq R \leq 101\,\Omega$$

c) Using $R = 100\,\Omega$.

i) $i_L = \text{constant}$

$$V_{source} - V_{load} - Ri = 0$$

$$V_{load} = V_z = 9 + 6.25(i_z)$$

$$V_{source} - 9 - 6.25 i_z - 100 i_z - 100 i_L = 0$$

$$\therefore \Delta V_{source} - 106.25 \Delta i_z - 100 \cancel{\Delta i_L}^{0} = 0$$

$$\Rightarrow \Delta i_z = \frac{\Delta V_{source}}{106.25} = 28.2\,mA$$

$$\Delta V_z = \Delta V_{load} = 6.25\, \Delta i_z = 176.5\,mV. \Rightarrow V_{load} \text{ varies by } \pm 88.2\,mV$$

ii) $V_{source} = \text{constant}$

$$V_{source} - V_{load} - R(i_z + i_L) = 0$$

$$V_{load} = 9 + 6.25 i_z$$

$$\therefore \cancel{\Delta V_{source}}^{0} - \Delta V_{load} - R\Delta i_z - R\Delta i_L = 0.$$

and $\Delta V_{load} = 6.25 \Delta i_z$.

$$\Rightarrow -\Delta V_{load} - \frac{R}{6.25}\Delta V_{load} - R\Delta i_L = 0$$

$$\Rightarrow \Delta V_{load} = \frac{-R}{\left(1 + \frac{R}{6.25}\right)} \Delta i_L = \frac{-100}{\left(1 + \frac{100}{6.25}\right)} (32.96\,mA - 1.09\,mA) = 187.5\,mV$$

$\Rightarrow V_{load}$ varies by $\pm 93.7\,mV$.

iii) $V_{Load\,max} = 9.1 + \frac{\Delta V_{Load}}{2}_{\text{due to } i_L} + \frac{\Delta V_{Load}}{2}_{\text{due to } V_{source}}$

$= 9.1 + 88.2 \times 10^{-3} + 93.7 \times 10^{-3}$

$= 9.282\,V$

$i_z = \frac{V_{Load} - V_{z0}}{r_z}$

$i_{zmax} = \frac{V_{Load\,max} - 9}{6.25} = 45.1\,mA$

Powerdissipation at $i_{zmax} = P = i_{zmax} \cdot V_{zmax} = 45.1 \times 10^{-3} \times 9.282 = 0.41W < 0.5$