SCHOOL OF ELECTRICAL ENGINEERING

ELECTRONIC DEVICES – EE090IU

SOLUTION TO HOMEWORK #2

April 2020

Question 1:

a) For the circuit shown in Figure 1, both diodes are identical, $V_T = 25mV, n = 1$. Find the value of R for which $V_R = 60mV$ [10pts]. (Hint: $i_D = I_s\, e^{\frac{V_D}{nV_T}}, find\ \frac{i_{D2}}{i_{D1}}$)

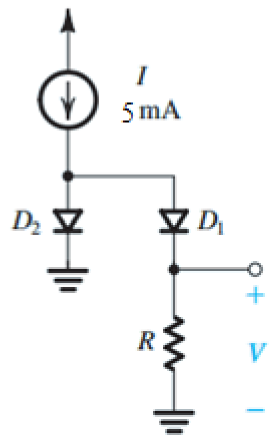


Figure 1

b) Given that $I_S = 2 * 10^{-14}\ A$, find the values of V_{D1} and V_{D2}. [10pts]

Answer:

a. We have

. $V_R = V_{D2} - V_{D1}$

. $\frac{i_2}{i_1} = \frac{I_s\, e^{\frac{V_{D2}}{nV_T}}}{I_s\, e^{\frac{V_{D1}}{nV_T}}} = e^{\frac{V_{D2}-V_{D1}}{V_T}} = e^{\frac{V_R}{V_T}} = e^{\frac{0.06}{0.025}} = 11.02$

. $i_1 + i_2 = 0.005 \rightarrow\ \ i_1 = 0.416mA; i_2 = 4.58\ mA$

$$R = \frac{V_R}{i_1} = 144.2\ \Omega$$

b. $V_{D1} \approx nV_T \ln\left(\frac{i_1}{I_s}\right) = 0.025 \ln\left(\frac{0.416mA}{2*10^{-14}}\right) = 0.59\ V$

$V_{D_2} = V_R + V_{D1} = 0.65\ V$

Question 2.

Figure 2 shows diodes logic gates, v_A , v_B, v_C are inputs, v_Y is output. Assume the diodes are ideal

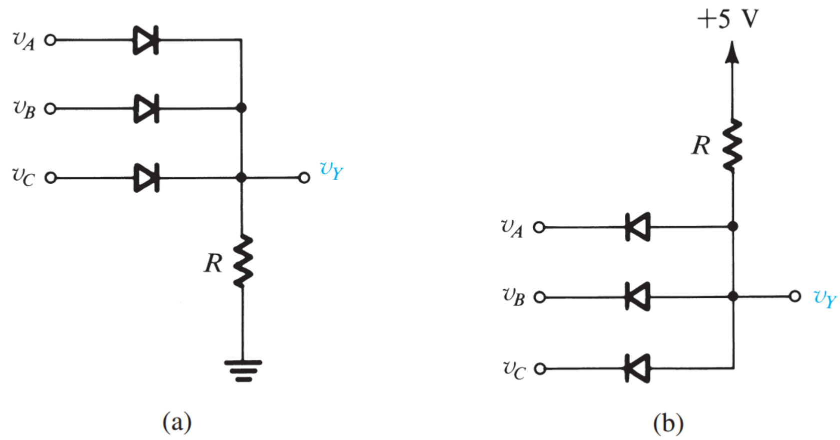


Figure 2

a. Fill in blank of the table for circuit in figure 2.a [10pts]. What is this logic gate?

v_A [Volts]	v_B [Volts]	v_C [Volts]	v_Y [Volts]
0	0	0	0
0	0	5	5
0	5	0	5
0	5	5	5
5	0	0	5
5	0	5	5
5	5	0	5
5	5	5	5

b. Fill in blank of the table for circuit in figure 2.b [10pts]. What is this logic gate?

v_A [Volts]	v_B [Volts]	v_C [Volts]	v_Y [Volts]
0	0	0	0
0	0	5	0
0	5	0	0
0	5	5	0
5	0	0	0
5	0	5	0
5	5	0	0
5	5	5	5

ANSWER: a. OR gate; b. AND gate

Question 3

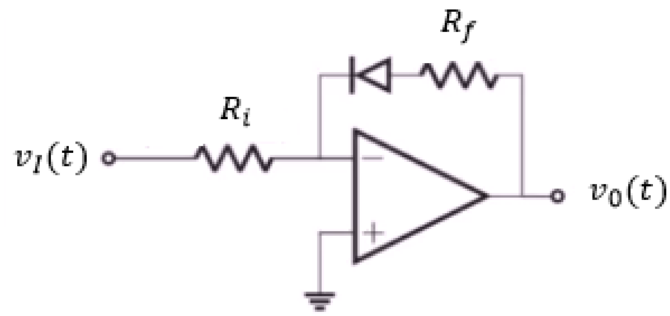


Figure 3

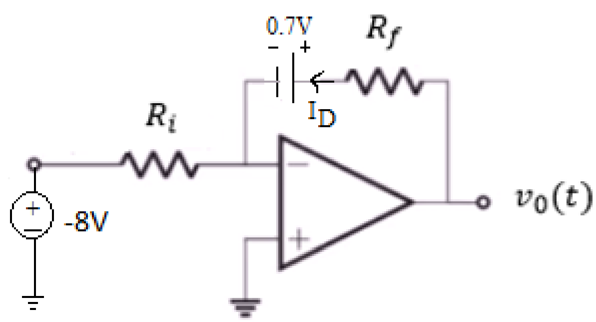
Given that $v_I(t) = -8 + 0.02\sin(\omega t)\ (V), R_i = 2k\Omega$ and $R_f = 4k\Omega$. Assume the OP-AM is ideal, the diode has constant voltage drop of 0.7V;$V_T = 25mV; n = 1$.

a. Find DC and AC component of $v_I(t)$ [5pts]
b. Use DC & AC analysis to find the output voltage $v_0(t)$ in figure 3. Circuit at DC and AC must be included. [15 pts]

Answer:

a. DC component: -8V; AC component: $0.02\sin(\omega t)$
b.

DC analysis:



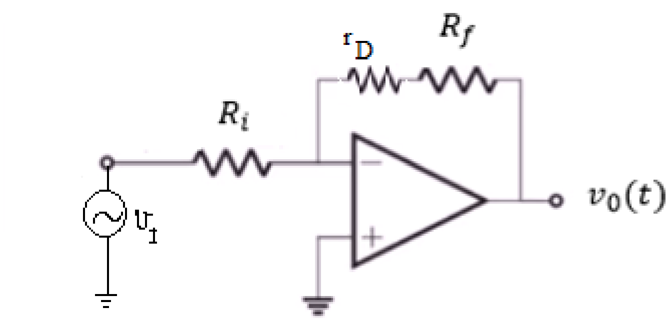
We have: $V^- = V^+ = 0V$

. $I_D = I_{R_i} = \frac{0-(-8)}{R_i} = \frac{8}{2000} = 4mA$

By KVL: $V_o = 0.7 + I_D R_f = 0.7 + 4mA * 4000 = 16.7\ (V)$

. Diode small signal resistance: $r_d = \frac{nV_T}{I_D} = \frac{25mV}{4mA} = 6.25\ \Omega$

AC analysis:



$. v_o(t)_{AC} = -\frac{R_f+r_D}{R_i} v_i(t) = -\frac{4000+6.25}{2000} \times 0.02\sin(\omega t) \approx -0.04\sin(\omega t)\ (V)$

Finally, $v_o(t) = V_o + v_o(t)_{AC} = 16.7 - 0.04\sin(\omega t)\ (V)$

Question 4

The 5-V Zener diode in the circuit of Figure 4 is specified to have $V_Z = 5V$ at $I_Z = 20mA, r_z = 5\ \Omega\ and\ I_{Zmin} = 0.25\ mA$. The voltage supply $V_s = 10V$ but can vary as much as $\pm\ 2V$.

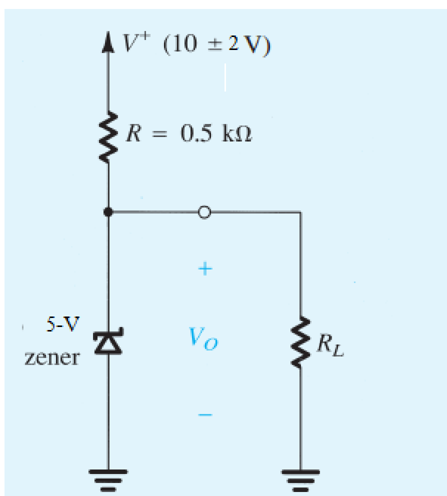
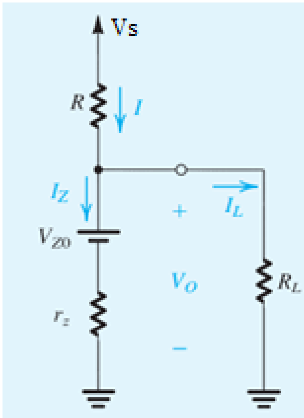


Figure 4

a. Find V_{Z0} and draw equivalent circuit model of the circuit [5pts]
b. When $V_s = 10V$. Find V_0 with no load connected. [5pts]
c. In case of no load connected, find the change of V_0 (ΔV_0) resulting from $\pm\ 2V$ change in V_s. [5pts]
d. Find the minimum R_L for which the diode still operates in break-down region and the current supplied through R is minimum. [5pts]
Hint: For Zener to be at the edge of breakdown region, $I_z = I_{Zmin}$; $V_Z \approx V_{Z0}$

Answer:

a. $V_{Z0} = V_z - r_z I_z = 5 - 5 * 20mA = 4.9$V
Equivalent circuit:



b. With no load, $I_z = I = \frac{V_s - V_{Z0}}{R + r_z} = \frac{10-4.9}{500+5} = 10.1mA$

. $V_o = V_{z0} + I_z r_z = 4.9 + 10.1mA * 5 = 4.95\ V$

c. $\Delta V_0 = \Delta V_s \frac{r_z}{r_z + R} = \pm\, 2 \frac{5}{5+500} = \pm\, 19.8\ mV$

d. The lowest current supplied through R: $I_{Rmin} = \frac{8-4.9}{500} = 6.2mA$

So $I_L = I_{Rmin} - I_{Zmin} = 6.2 - 0.25 = 5.95\ mA \rightarrow R_L = \frac{4.9}{5.95mA} = 0.82\ k\Omega$

Question 5:

A voltage stablizer supply a voltage of 230V (rms), 50 Hz to a full-wave bridge rectifier with 2 $k\Omega$ load through a 10-to-1 step-down transformer having a single secondary winding. It uses four diodes, each of which can be modelled to have a 0.85V drop for any current (constant voltage drop model with VDO = 0.85V).

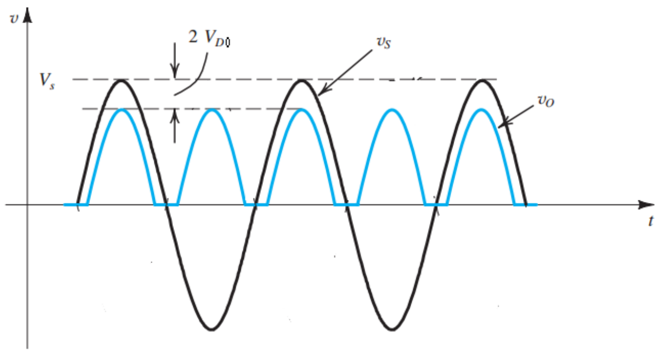
a. Find the peak voltage across the secondary winding (V_s) [5pts]
b. Find the peak value of the rectified voltage across the load (V_o) . Plot the v_S and v_o in one graph. (Graph must have axis labels, correct levels) [5pts]
c. For what fraction (percentage) of each cycle during $v_o > 0$ [10 pts]. *Hint: a cycle in ωt is* $= \pi$ rad

Answer:

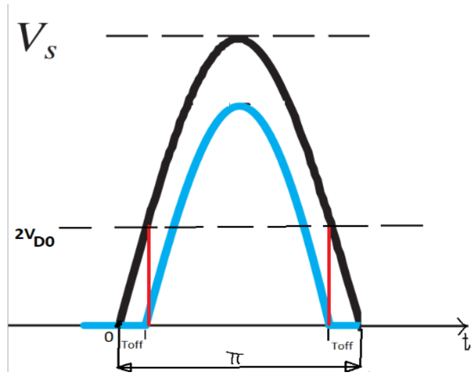
a. Peak voltage of V_S is compute from :

$$\frac{N_{primary}}{N_{secondary}} = \frac{v_{primary}(peak)}{V_s} \rightarrow V_s = \frac{v_{primary}(peak) * N_{secondary}}{N_{primary}} = \frac{230\sqrt{2} * 1}{10} = 32.5\ V$$

b. Peak voltage of V_o is: $V_o = V_s - 2V_{D0} = 32.5 - 2 * 0.85 = 30.8\ V$



c.



The angle in which the diodes are ON is:

$$\pi - 2\sin^{-1}\left(\frac{2V_{D0}}{V_s}\right) =$$

$$\pi\ - 2\sin^{-1}\left(\frac{2*0.85}{32.5}\right) = 3.04\, rad$$

So the fraction of each cycle during $v_o > 0$ is $\frac{3.04}{\pi} = 96.6\%$