SOLUTION

Habib University

Electrical Engineering Department

Dhanani School of Science & Engineering

Course	EE – 211 – Basic Electronics
Semester	Fall 2022
Section	Section L2
Exam	Midterm Exam – 1
Instructor	Dr. Ahmad Usman
Total Marks	25

Name: Solution ______________ **Student ID:** ______________

Question # 1 (CLO – 1 – Points: 5, 2.5 + 2.5)

A pn junction is operating in forward bias.

(a) To obtain a current of 1 mA with an applied voltage of 750mV, what should I_S be and how should it be chosen?

$$I_D = I_s\left(\exp\frac{V_D}{V_T} - 1\right)$$

$$I_s = Aqn_i^2\left[\frac{D_n}{N_A L_n} + \frac{D_p}{N_D L_p}\right]$$

$$1m = I_s\left(\exp\frac{750m}{26m} - 1\right)$$

$$\boxed{I_s \propto A}$$

$$\boxed{I_s = 2.9667\times10^{-16}\ A}$$

The I_s can be chosen by controlling the cross-sectional area of the diode.

(b) If the diode cross section area is doubled, what voltage yields a current of 1mA?

$$I_s \propto A$$

$$2A \propto 2I_s$$

$$I_s = 2(2.9667\times10^{-16})$$

$$I_D = 1mA$$

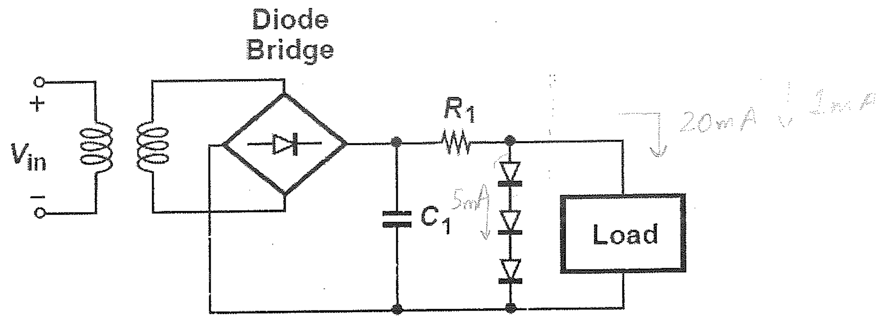
$$\rightarrow \quad 1m = 2(2.9667\times10^{-16})\left[\exp\frac{V_D}{26m} - 1\right]$$

$$\boxed{V_D = 0.7319\ V}$$

$$\boxed{V_D = 731.9\ mV}$$

Question # 2 (CLO – 1 – Points: 5)

In the figure shown below, the diodes are carrying a 5mA current and the load draws 20 mA of current. If the load current increases by 1 mA, what is the change in the total voltage across the three diodes? Assume that the three diodes are similar diodes, having resistance of r_d. Assume R_1 to be greater that $3r_d$. Remember $r_d = V_T / I_D$.



$$r_d = \frac{V_T}{I_D} = \frac{26m}{5m} = 5.2\,\Omega$$

$$\text{Total } r_d = 3r_d = \boxed{15.6\,\Omega}$$

$$\frac{\Delta I_D}{\Delta V_D} = \frac{I_D}{V_T}$$

$$\Delta V_D = \left(\frac{26m}{5m}\right)(1\,mA) \times 3$$

$$\boxed{\Delta V_D = 15.6\,mV}$$

Question # 3 (CLO – 2 – Points: 7.5, 5 + 2.5)

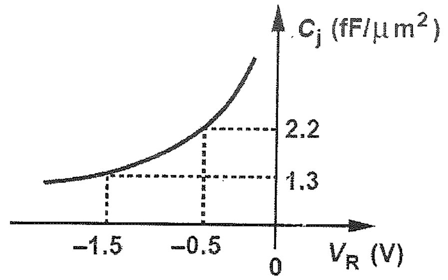
An oscillator application requires a variable capacitance with the characteristic shown in the figure.
Assume the area of the device as 1000 μm^2.

Hint: You have to assume a value of N_A (say 2×10^{18} cm^{-3}) after calculating the ratio of (N_AN_D / N_A+N_D).

$$C_j = \frac{C_{j0}}{\sqrt{1 - V_R/V_0}}$$

$$C_{j0} = \sqrt{\frac{\epsilon_{si} q}{2}\left(\frac{N_A N_D}{N_A + N_D}\right)\frac{1}{V_0}}$$

$$V_0 = \frac{KT}{q} \ln \frac{N_A N_D}{n_i^2}$$



(a) Determine N_A and N_D.

$$2.2\ \text{fF}/\mu m^2 = \frac{C_{j0}}{\sqrt{1 + \frac{0.5}{V_0}}} \quad \text{—— } (1)$$

$$1.3\ \text{fF}/\mu m^2 = \frac{C_{j0}}{\sqrt{1 + \frac{1.5}{V_0}}} \quad \text{—— } (2)$$

From Eq (1), we get

$$4.84\left(\frac{fF}{\mu m^2}\right)^2 = \frac{C_{j0}^2}{1 + \frac{0.5}{V_0}}$$

$$4.84 + \frac{2.42}{V_0} = C_{j0}^2 \quad \text{—— } (3)$$

$$1.69 + 2.535/V_0 = C_{j0}^2 \quad \text{—— } (4)$$

$$4.84 + \frac{2.42}{V_0} = 1.69 + \frac{2.535}{V_0}$$

$$(4.84 - 1.69) = \frac{2.535}{V_0} - \frac{2.42}{V_0}$$

$$V_0 = (0.115)/3.15$$

$$\boxed{V_0 = 0.0365\ V.}$$

$$C_{j0}^2 = 4.84 + \frac{2.42}{0.0365} \ \frac{(fF)^2}{(\mu m^2)^2}$$

$$\boxed{C_{j0} = 8.4336\ \frac{fF}{\mu m^2}}$$

$$C_{j0} = 8.4336\ fF \times 1000$$

$$\boxed{C_{j0} = 8.4336\ pF} \text{ @ } V_R = 0$$

(b) Calculate the value of inductance required to oscillate this device a 5 GHz (at V_R = 0V).

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$2\pi\,[5\times10^9] = \frac{1}{\sqrt{L \times C_{j0}}}$$

$$\boxed{L = 120.1398\ pH}$$

$$C_{j0} = \sqrt{\frac{\epsilon_{si} q}{2}\left(\frac{N_A N_D}{N_A + N_D}\right)\left(\frac{1}{V_0}\right)}$$

$$\frac{N_A N_D}{N_A + N_D} = 3.1343\times10^{17}\ cm^{-3}$$

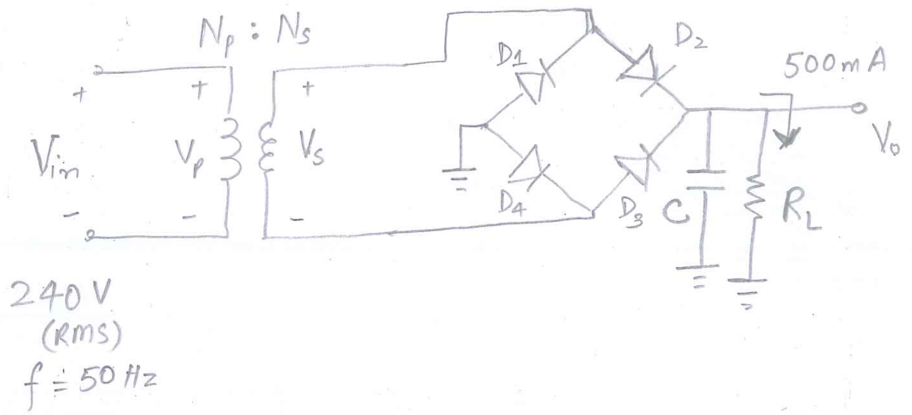
Let $N_A = 2\times10^{18}\ cm^{-3}$

then $\boxed{N_D = 3.71\times10^{17}\ cm^{-3}}$

Question # 4 (CLO – 3 - Points: 7.5, 2 + 1.5 + 4)

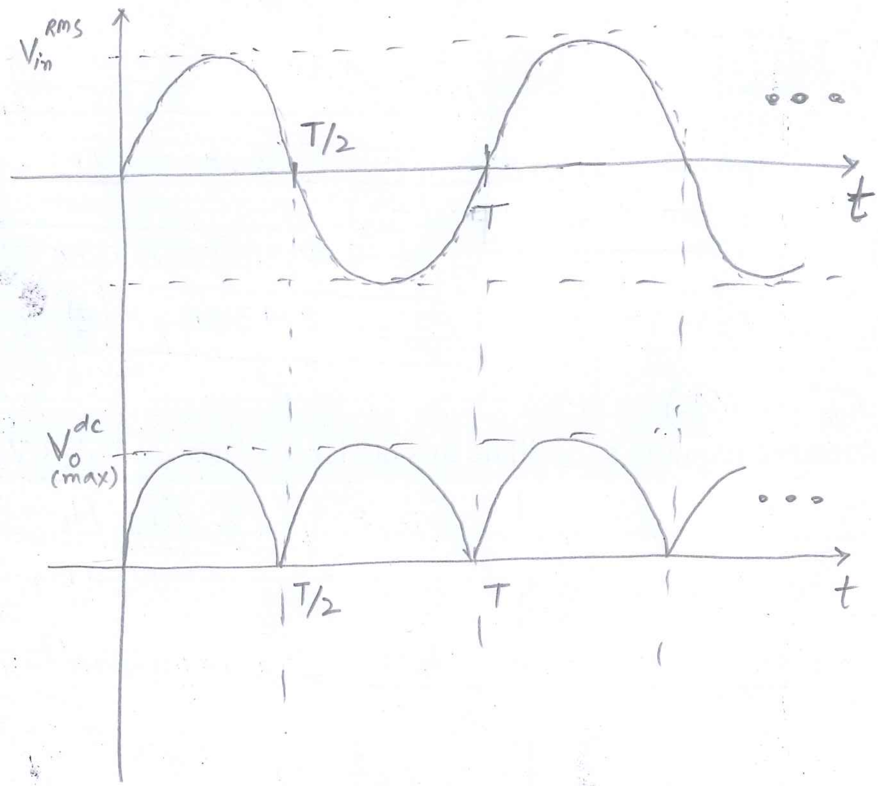
Design a dc power supply using a bridge-rectifier to develop a certain dc voltage across the load R_L. The current through the load is 500 mA. Use a stepdown transformer whose primary side is connected to 240 V (RMS) at a mains frequency of 50 Hz.

(a) Draw the circuit diagram.



$$\boxed{V_o^{(DC)} = \frac{2 V_{o(max)}}{\pi}}$$

(b) Draw the input and output voltage waveforms of the designed dc power supply.



(c) Specify the PIV-rating, $I_{d,max}$ rating, and the power-rating of the diodes. Assume practical silicon diodes ($V_{D,ON}$ = 0.7V), safety factor of 1.5, and R_L = 15 Ω. Show all your working properly.

Note: You don't need to derive the formulas. Just use them for your calculations.

$$V_{dc} = I_L R_L = (500m)(15) = 7.5\ V$$

$$V_{o(max)} = \frac{\pi V_{dc}}{2} = \frac{7.5 \times 3.142}{2} = \boxed{11.7825\ V}$$

$$\boxed{V_s = V_{o(max)} + V_{\substack{drop\\diode}}} \quad \text{OR} \quad \boxed{V_s = V_{o(max)} + 2V_{\substack{drop\\diode}}}$$

$$V_s = 11.7825 + 0.7$$

$$\boxed{V_s = 12.4825\ V} \longleftarrow RMS \longrightarrow \boxed{V_s = 13.1825\ V}$$

$$V_s^{Peak} = \sqrt{2}\, V_s^{RMS} \qquad V_s^{Peak} = \sqrt{2}\, V_s^{RMS}$$

$$\boxed{V_s^{Peak} = 17.6529\ V} \qquad \boxed{V_s^{Peak} = 18.6428\ V}$$

PIV Rating:

$$V_{o(max)} = 11.7825 \times 1.5$$

$$\boxed{V_{o(max)}^{PIV} \geq 17.673\ V}$$

$I_{d(max)}$ Rating:

$$I_{o(max)}^{dc} = \frac{\pi I_{dc}}{2} = 785.5\ mA$$

$$\boxed{I_{o(max)}^{dc} \geq 1.17825\ A}$$

$P_{d(max)}$ Rating:

$$P_{d(max)}^{dc} = I_{d(max)}^{dc} V_{diode} = 785.5 \times 0.7$$

$$P_{d(max)}^{dc} = 549.85\ mW$$

$$\boxed{P_{d(max)}^{dc} \geq 824.775\ mW}$$