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2k21/CO/487

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AE ASSIGNMENT-1

(5) Calculate change in V_D for

(A) 20 times change in diode current I_D at room temperature.

→ As

$$I_D \approx I_S e^{\left[\frac{V_D}{nV_T}\right]} \quad \text{for } V_D >> V_T$$

Let

$$I_{D_1} = I_S e^{V_{D_1}/nV_T} \quad — (1)$$

$$I_{D_2} = I_S e^{V_{D_2}/nV_T} \quad — (1)$$

Here $\frac{I_{D2}}{I_{D1}} = 20$

Dividing (2) & (1)

$$\frac{I_{D2}}{I_{D1}} = e^{(V_{D_2}-V_{D_1})/nV_T}$$

$$V_{D_2}-V_{D_1} = 2.303\, nV_T \log_{10}\left[\frac{I_{D2}}{I_{D1}}\right]$$

$$\Delta V_D = 2.303 \times 26\text{mV} \times n \times 1.30$$

$$\Delta V_D = 77.84 \times n$$

$n=1$ for Si $\quad \Delta V_D = 77.84$ mV

$n=2$ for Ge $\quad \Delta V_D = 155.68$ mV

(B) 20° Decrease in temperature keeping current as constant

→ Change is given by

$$\frac{dV_D}{dT} = -2.2\text{mV}/°C \quad \text{for } I_D \text{ constant}$$

$$\frac{\Delta V_D}{\Delta T} = -2.2 \times 10^{-3}$$

$$\Delta V_D = -2.2 \times 20 \times 10^{-3}$$

$$= -0.044\text{V}.$$

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(4) A diode has a leakage current of 10pA at room temperature. Find its value when temperature is increased by 25°c.

→ Current doubles at 10°c gap, so it can be used as:

$$I_{S_2} = I_{S_1} \cdot 2^{(T_2-T_1)/10}$$

where $I_{S_1} = 10pA$

$\Delta T = 25°c$

$I_{S_2} = 10 \times 5.658$

$= 56.58pA$

(3) If in a Ge substrate, donor type impurity is added to extent of 1 part in 10^8 Ge atoms. Find resistivity of doped Ge.

→ $\mu_n = 0.38 \frac{m^2}{V}$-sec $\qquad \rho = 5320 kg/m^3$

$\sigma = n_A e \mu_n$

$n_A = \frac{6.023 \times 10^{23} \times 5320 \times 10^3}{72.6 \times 10^6}$

$= \cancel{441.35 \times 10^{20}}$ $\quad 4.4 \times 10^{22}$

$\sigma = 4.4\cancel{135} \times 10^{22} \times 0.38 \times 1.6 \times 10^{-19}$

$= \cancel{2683 mho/m}$ $\quad \cancel{1.87 \times 10^2}$

2.67×10^3 mho/m

$\rho = \frac{1}{\sigma} = \frac{1}{2.67 \times 10^3} = \cancel{0.37 m\Omega}$ $\quad 0.37 \times 10^{-3}$ ohm m

(6) A slice of intrinsic Si bar is 50mm long & has rectangular cross section 50μm × 75μm at room temperature. Determine voltage across bar for steady current 5μA. Assume $\rho = 2.3 \times 10^5$ Ω cm at room temperature. Also compare voltage across the bar if Si is doped with 4×10^{16} donor atoms/cm^3

→ $\rho = 2.3\times10^{3}\ \Omega m$

$l = 5\times10^{-2}\ m$

$A = 3.75\times10^{-9}\ m^2$

$I = 5\times10^{-6}\ A.$

Now $J = \frac{1}{\rho}E$

where $J = \frac{I}{A}$

$\cancel{5\times10^{-6}}$

$\cancel{5\times10^{-3}}\ 3\Omega$

$$\frac{5\times10^{-6}}{3.75\times10^{-9}} = \frac{1}{2.3\times10^{3}}E$$

$E = 3.06\times10^{6}\ (V/m)$

Now $V = E.l$

$= 3.06\times10^{6}\times5\times10^{-2}$

$= 15.3\times10^{4}\ V.$

$N_D = 4\times10^{16}$ donor atoms/cm^3

$= 4\times10^{22}$ donor atoms/m^3

$\sigma = 4\times10^{22}\times1.6\times10^{-19}\times(\cancel{\mu_n+\mu_p})$

$= 4\times10^{22}\times1.6\times10^{-19}\times0.20\times0.015$

$= 1.28\times10^{3}$ mho/m $\times\frac{3}{4}$

$J = \sigma E$ & $E = \frac{V}{l}$

$\frac{J}{\sigma}\times l = V$

$$\frac{4}{3}\ \frac{5\times10^{-6}}{3.75\times10^{-9}\times1.28\times10^{3}}\times5\times10^{-2} = V$$

$5.208\times10^{-2} = V$

~~V = 52mV.~~ $V = 69.44\ mV$

⑧ Compute built in potential for P-N junction at room temperature having acceptor doping conc^n = $3\times10^{16}/cm^3$ & Donor doping conc^n = $1\times10^{17}/cm^3$.

$$V_{PN} = V_T \ln \left[\frac{N_D \cdot N_A}{n_i^2}\right]$$

where $V_T = 26\times10^{-3}$

$$V_{PN} = 0.026\times\ln\left[\frac{3\times10^{16}\times1\times10^{17}}{(1.45\times10^{10})^2}\right]$$ for n_i for Silicon

$$0.026\times\log\left(\frac{3}{1.45\times1.45}\times10\times10^{12}\right)$$

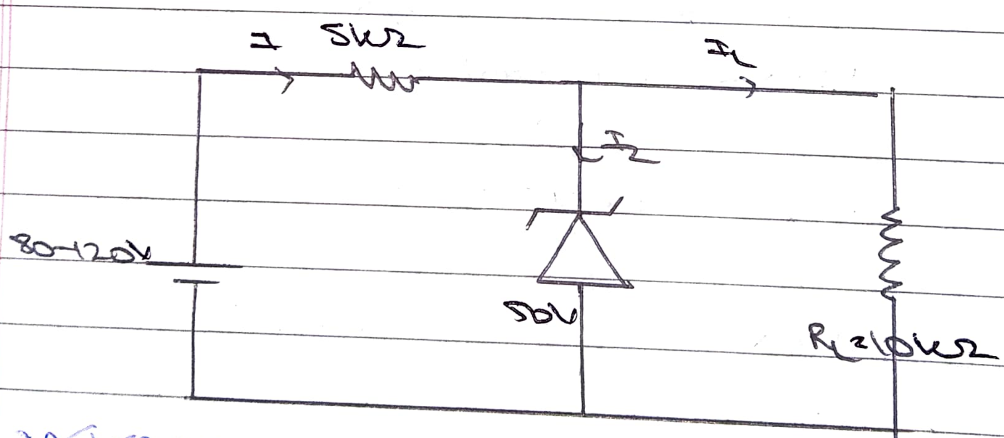
$$V_{PN} = 0.026\times\log\left[1.42\times10^{13}\right]$$

$\cancel{V_{PN} = 0.026}$

$$V_{PN} = 0.026\times2.303\,(13+0.15)$$

$= 0.78V$

⑨ For the following circuit. Find max & min value of I_Z.



If we remove zener then $V = R_x$

Minimum voltage across 5kΩ = 30V

Let I be current

I = 6mA.

Maximum voltage across 5kΩ = 70V

let I' be current

$I' = 14$ mA.

Now without diode

$$V = E_i\left[\frac{10}{10+5}\right]$$

$$= \frac{2}{3}E_i$$

which is greater than 50V

Hence diode works as voltage regulator.

Thus, current across 10kΩ

let current be I

$$I = \frac{50}{10000} = 5\text{mA}.$$

Hence, max current through zener diode

$$I_{max} = 14-5 = 9\text{mA}$$

min current through zener diode

$$I_{min} = 6-5 = 1\text{mA}.$$

(7) Find diode current for Si diode for 0.85V FV across it & 10nA reverse saturation current. Also determine voltage change in I_D changes by ±10%.

→ $$I_D = I_R\left[e^{\frac{V_D}{0.026}} - 1\right]$$

where $I_R = 10\text{nA} = 10^{-9}$ A.

$V_D = 0.85$V.

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$$I_D = 10^{-9}\left[e^{\frac{0.85}{0.026}} - 1\right]$$

$\approx 1.9 \times 10^{14} \times 10^{-9}$

$\approx 1.9 \times 10^{-5}$ A

(i) for +10% Δ in I_D.

$\cancel{I_D' = 2.09 \times 10^{-5}}$ $I_D' = 2.09 \times 10^{-5}$

$\cancel{2.9 \times 10^{-5}} =$ $2.09 \times 10^{-5} = 10^{-9}\, e^{\left[\frac{V_D}{0.026}\right]}$

$2.09 \times 10^{14} = e^{\frac{V_D}{0.026}}$

$0.026 \times 2.303\ [\log(2.09) + 14] = V_D'$

$0.026 \times 2.303\ (14 + 0.32) = V_D'$

$V_D' = 0.8574$ V

$\Delta V_D = 0.0074$ V.

(ii) for −10% change in I_D.

$I_D' = 1.71 \times 10^{-5}$

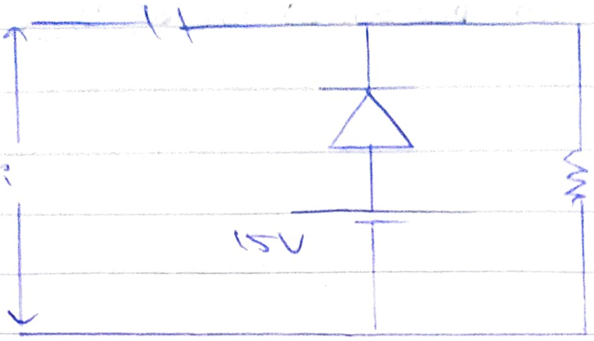
$1.71 \times 10^{-5} = 10^{-9}\, e^{(V_D/0.026)}$

$0.026 \times 2.303\ [\log(1.71) + 14] = V_D'$

$V_D' = \cancel{0.8224}$ 0.85224

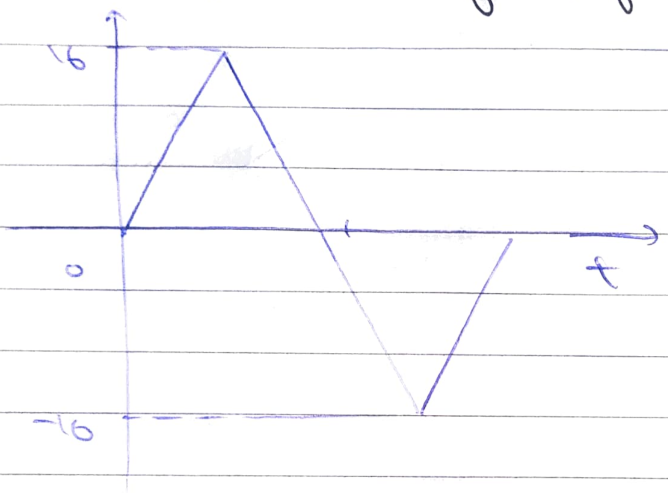
$\Delta V_D = 0.0022$ V.

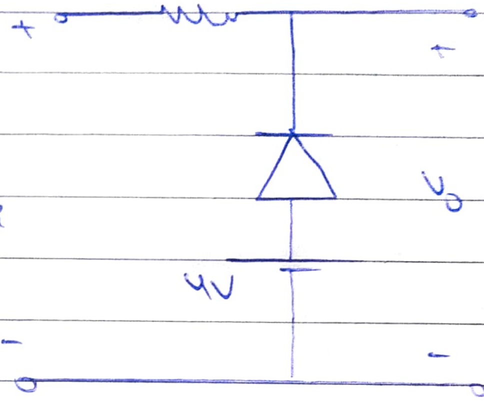
(9) Design a diode clamper circuit which produces an output of 20V peak to peak square wave symmetric at 5V:



(10) Draw output waveform for given circuit:

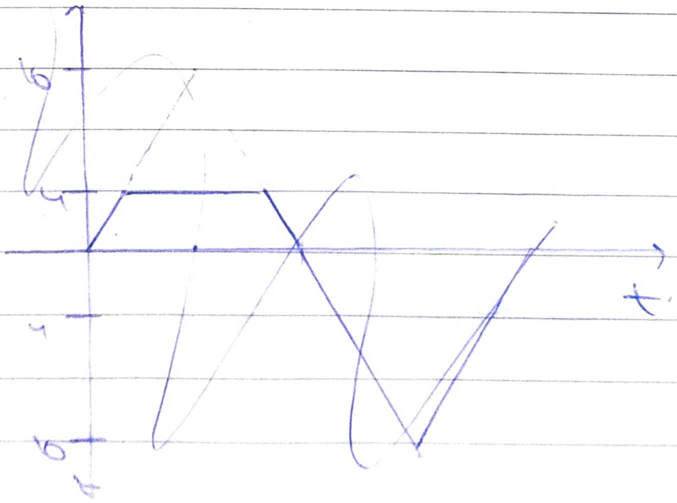
Input waveform

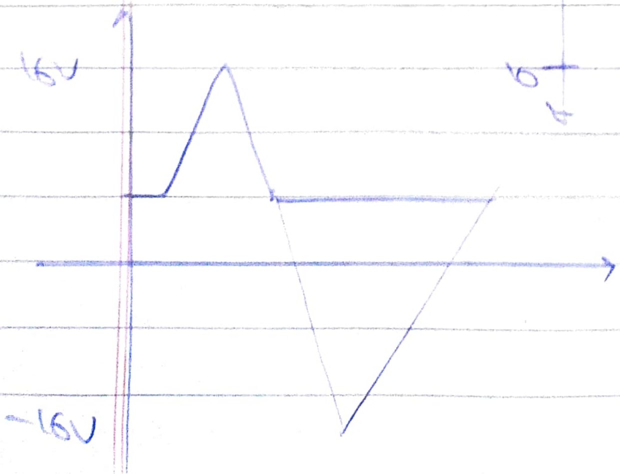




Circuit Diagram

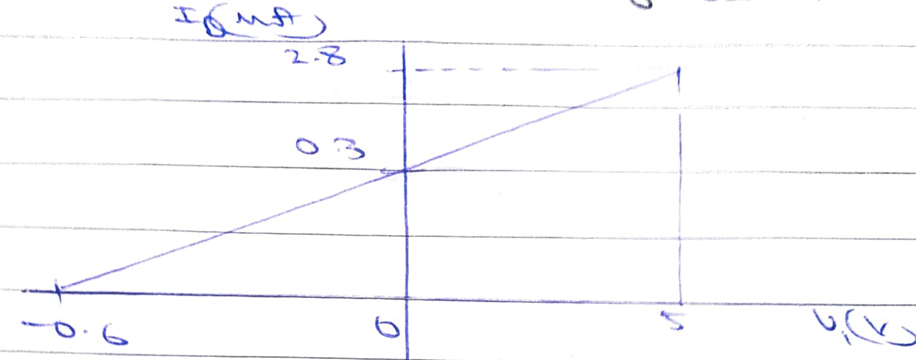
Output waveform:





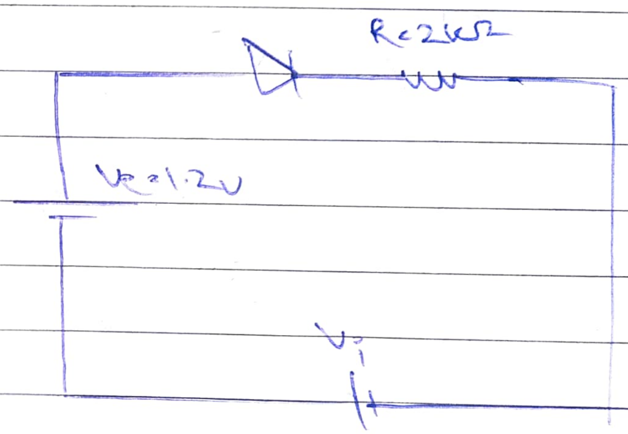
A little less than 16V as there will be some potential drop.

① Design a circuit to produce characteristics where I_D is diode current & V_i is input voltage. Assume diode piecewise linear parameters of $V_{cut\,in} = 0.6V$ & $R_f = 0$



In forward biasing,
applying KVL:

$V_i + V_e - 0.6 = I_D R$



$I_D = \left(\frac{1}{R}\right)V_i + \left(\frac{V_e - 0.6}{R}\right)$ — ①

from graph

$I_D = V_i\left(\frac{1}{2}\right) + \cancel{V_e - 0.6}\ 0.3$ — ②

Comparing

$R = 2k\Omega$

$V_e - 0.6 = 0.3 \times R$ ⟹ $V_e = 1.2$ volts.

* In reverse biased when $V_i + V_e \leq 0.6V$

$V_i + 1.2V \leq 0.6V$

$V_i \leq -0.6V$

$I_D = \cancel{0}$ amp.

$I_D = 0$ amp.