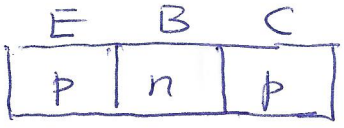
CMPE 314 Midterm Exam I Solutions Fall 2014

P1

(a)



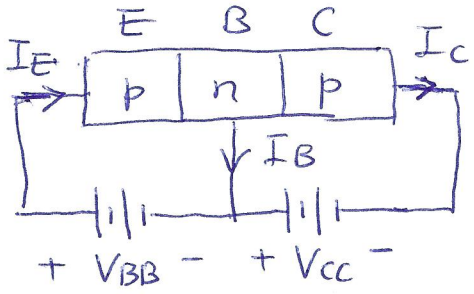
Emitter dopant type: group III, acceptor

dopant concentration $N_a = 8 \times 10^{18} \frac{1}{cm^3}$

minority carrier (electron) concentration:

$$n_o = \frac{n_i^2}{p_o} \doteq \frac{n_i^2}{N_a} = \frac{(1.5 \times 10^{10})^2}{8 \times 10^{18}} = 28.1 \frac{1}{cm^3}$$

(b)



In forward-active mode

$V_{BB} > V_{BE(on)}$

$V_{CC} > 0$

I_E = holes, I_C = holes, I_B = electrons

P2

(a) $I_I = I_{R_1} + I_D$

$$I_{R_1} = \frac{V_o}{R_1}, \quad I_D = I_s\left(e^{V_D/V_T} - 1\right), \quad V_o = V_B + V_D$$

$$I_I = \frac{V_o}{R_1} + I_s\left(e^{(V_o - V_B)/V_T} - 1\right)$$

(b) $I_I = I_{R_1} + I_D$

$$I_D = \frac{V_o - V_B - V_\gamma}{r_f}$$

$$I_I = \frac{V_o}{R_1} + \frac{V_o - V_B - V_\gamma}{r_f}$$

P3

When $v_s > 2V_\gamma$, D_3 and D_4 on

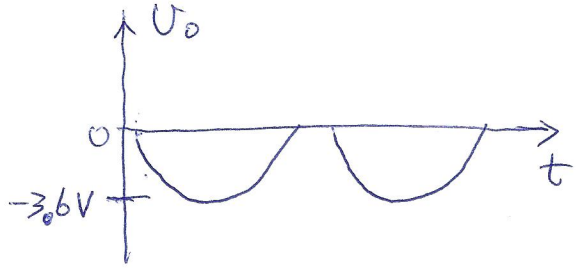
$$v_o = -v_s + 2V_\gamma$$

$$v_{o,peak} = -5 + 1.4 = -3.6\,V$$

When $v_s < -2V_\gamma$, D_1 and D_2 on

$$v_o = v_s + 2V_\gamma$$

$$v_{o,peak} = -5 + 1.4 = -3.6\,V$$



P4

When $v_I > V_{\gamma_1} + V_{Z_1}$ D_1 on D_{Z_1} on
D_2 off D_{Z_2} off

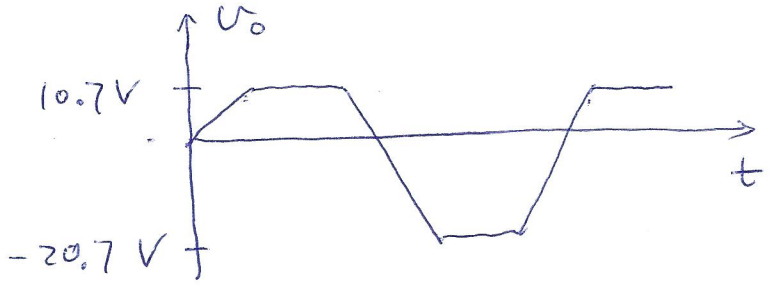
$$v_o = V_{\gamma_1} + V_{Z_1} = 10.7\,V$$

When $v_I < -(V_{\gamma_2} + V_{Z_2})$ D_1 off D_{Z_1} off
D_2 on D_{Z_1} on

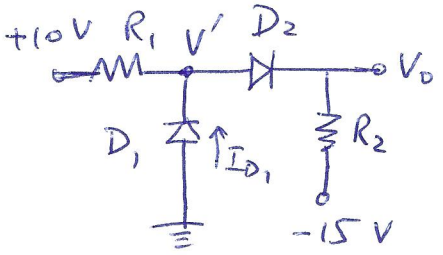
$$v_o = -(V_{\gamma_2} + V_{Z_2}) = -20.7\,V$$

When $-(V_{\gamma_2} + V_{Z_2}) < V_I < V_{\gamma_1} + V_{Z_1}$ all diodes are off

$$v_o = v_I$$



P5



① Assume D_1 off, D_2 on. $I_{D_1} = 0$

$$I_{D_2} = \frac{10 - (-15) - V_\gamma}{R_1 + R_2 + r_f} = \frac{24.3}{15\,K} = 1.62\ mA$$

$$V' = 10 - 1.62\ mA \times 10\ k\Omega = -6.2\ V$$

$$\rightarrow \quad V_{D_1} = 0 - (-6.2)\ V > V_\gamma \quad \text{so } D_1 \text{ is on}$$

② D_1 on, D_2 on

$$V' = -0.7\ V$$

$$V_o = V' - V_\gamma = -1.4\ V$$

$$I_{R_1} = \frac{10 - (-0.7)}{10\ k\Omega} = 1.07\ mA$$

$$I_{D_2} = \frac{V_o - (-15)}{5\ k\Omega} = 2.72\ mA$$

$$I_{D_1} = I_{D_2} - I_{R_1} = 1.65\ mA$$

$$P_{D_1} = V_\gamma I_{D_1} = 1.155\ mW$$

$$P_{D_2} = V_\gamma I_{D_2} = 1.904\ mW$$