CMPE 314 Midterm Exam-1 Solutions

Fall 2017

P1

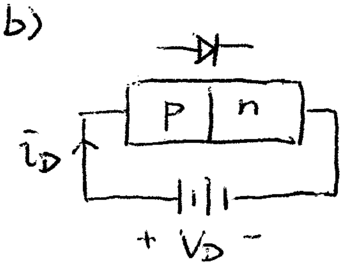
(a) Dopant type: acceptor, group III atoms

Dopant concentration $N_a = p_o = 8 \times 10^{14} \frac{1}{cm^3}$

Minority carrier is electron

Electron concentration $n_o = \frac{n_i^2}{p_o} = \frac{n_i^2}{N_a}$

(b)



Forward bias: majority carriers

electrons moving from n-region to p-region.

holes moving from p-region to n-region

Reverse bias: minority carriers

holes moving from n-region to p-region

electrons moving from p-region to n-region

Reverse break down: excess carriers

electrons and holes generated in the space-charge region. Holes moving to p-region, electrons moving to n-region

P2

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

$I_{R_1} = \frac{V_o}{R_1}$

$I_D = I_S(e^{V_D/V_T} - 1)$

$V_o = V_B + V_D$

(b) ① When I_I is too small, $I_D = 0$, diode is off

$V_o = R_1 I_I \le V_B + V_\gamma$

② When $R_1 I_I > V_B + V_\gamma$, diode is on

$I_I = I_{R_1} + I_D$

$I_{R_1} = \frac{V_o}{R_1}$

$V_D = V_\gamma + r_f I_D$

$V_o = V_B + V_D$

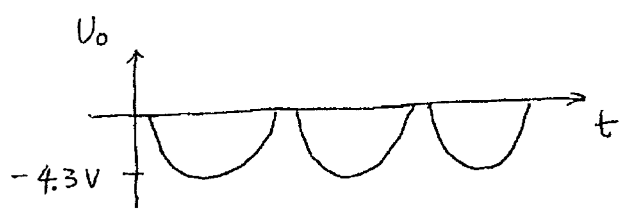
P3

When $U_s > V_\gamma \rightarrow$ D_1 off, D_2 on $\rightarrow$ $U_o = -U_s + V_\gamma$

$U_{o,max} = -5 + 0.7 = -4.3\,V$

When $U_s < -V_\gamma \rightarrow$ D_1 on, D_2 off $\rightarrow$ $U_o = U_s + V_\gamma$

$U_{o,max} = -5 + 0.7 = -4.3\,V$



negative full-wave rectifier

P4

(a) $v_I < V_B - V_\gamma$, diode on

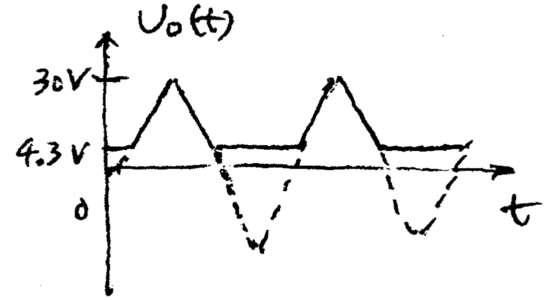
$v_o = V_B - V_\gamma$

$v_I > V_B - V_\gamma$, diode off

$v_o(t) = v_I(t)$

(b) $V_B - V_\gamma = 5 - 0.7 = 4.3\,V$

clipper circuit



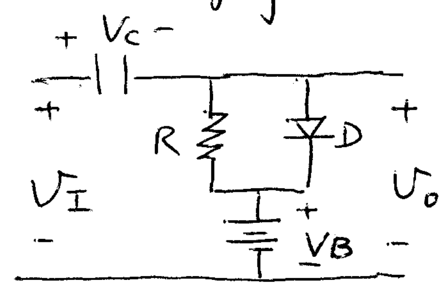
P5

(a) Let $v_C(0) = 0$

When $v_I > V_B + V_\gamma$, diode on, capacitor charging

$v_C(t) = v_I(t) - (V_B + V_\gamma)$

$v_C(max) = v_I(max) - (V_B + V_\gamma)$



When $v_I < V_B + V_\gamma$, diode off

capacitor discharging slowly

$v_C \doteq v_C(max)$

In steady state

$v_o(t) = v_I(t) - v_C(max)$

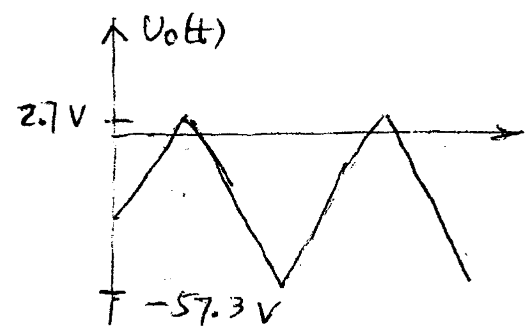
$v_D(t) = v_o(t) - V_B = v_I(t) - v_I(max) + V_\gamma < V_\gamma$, diode off.

(b) $v_C(max) = 30 - (2 + 0.7)$

$= 27.3\,V$

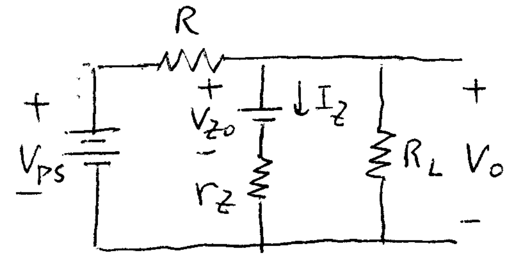
$v_C(t) = v_I(t) - 27.3\,V$

clamper circuit



P6

(a) $V_{ps} > V_{Z0}$



Zener diode is reverse break down

$$V_Z = V_{Z0} + r_Z I_Z$$

$$\frac{V_o - V_{ps}}{R} + \frac{V_o - V_{Z0}}{r_Z} + \frac{V_o}{R_L} = 0$$

$V_{ps} = 10\ V$
$R = 500\,\Omega$
$R_L = 2\ k\Omega$
$V_{Z0} = 5V,\ r_Z = 10\,\Omega$

$$V_o\left(\frac{1}{R} + \frac{1}{r_Z} + \frac{1}{R_L}\right) = \frac{V_{ps}}{R} + \frac{V_{Z0}}{r_Z}$$

$$\rightarrow V_o = V_Z = 5.073\ V$$

$$I_Z = \frac{V_Z - V_{Z0}}{r_Z} = \frac{5.073 - 5}{10} = 7.3\ mA$$

$$P_Z = V_Z I_Z = (5.073\ V) \times (7.3\ mA) = 3.7\ mW$$

(b) $R_L = \infty$

$$\frac{V_o - V_{ps}}{R} + \frac{V_o - V_{Z0}}{r_Z} = 0$$

$$V_o\left(\frac{1}{R} + \frac{1}{r_Z}\right) = \frac{V_{ps}}{R} + \frac{V_{Z0}}{r_Z}$$

variation of V_o due to variation of V_{ps}

$$\Delta V_o\left(\frac{1}{R} + \frac{1}{r_Z}\right) = \frac{\Delta V_{ps}}{R}$$

$$\rightarrow \frac{\Delta V_o}{\Delta V_{ps}} = \frac{r_Z}{R + r_Z} = \frac{10}{500 + 10} = 1.96\%$$