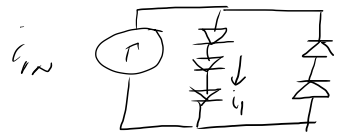
ESAME 22/06/21 — PART II

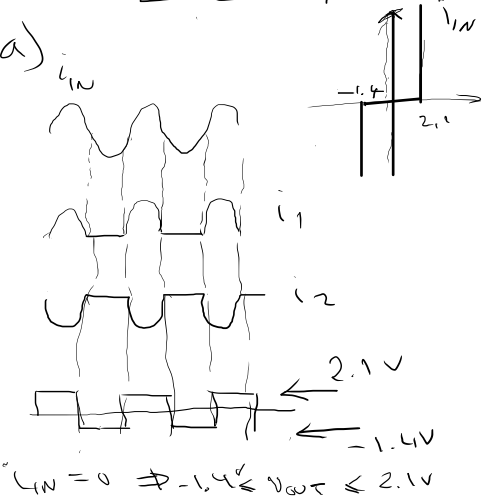
$i_{IN} = 10 \sin(\omega t)$ mA



a) $V_{ON} = 0.7$ V

$i_{IN} > 0 \Rightarrow i_1 = i_{IN}$, $i_2 = 0$, $v_{OUT} = 3V_{ON} = 2.1$ V

$i_{IN} < 0 \Rightarrow i_1 = 0$, $i_2 = -i_{IN}$, $v_{OUT} = -2V_{ON} = -1.4$ V



$i_D = I_S\left(e^{\frac{v_D}{V_T}} - 1\right)$, $V_T = 25$mV, $I_S = 1$pA

$i_{IN} > 0 \Rightarrow i_1 = I_S\left(e^{\frac{v_D}{V_T}} - 1\right)$, $i_2 < 1$pA $\Rightarrow i_2 \simeq 0$

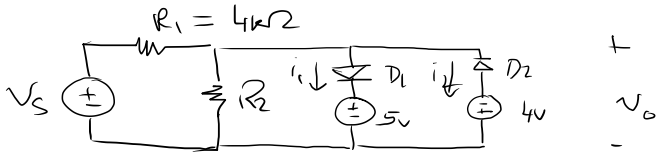
$i_1 \simeq i_{IN}$ $\quad i_2 \ll i_1$

$v_{OUT} = 3v_D = 3V_T \ln\left(\frac{i_{IN}}{I_S} + 1\right)$

$i_{IN} < 0 \Rightarrow i_1 \simeq 0$, $i_2 \simeq i_{IN}$

$v_{OUT} = -2V_T \ln\left(\frac{-i_{IN}}{I_S} + 1\right)$

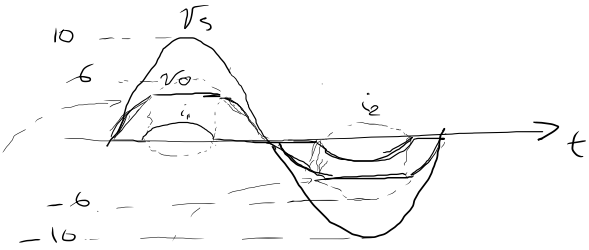
2.

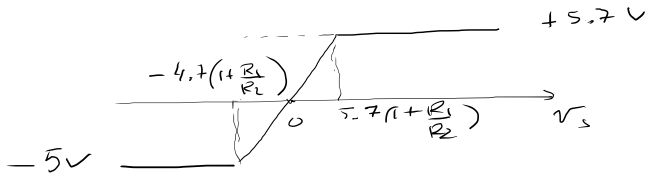


$$v_o = \frac{R_2}{R_1+R_2} v_s \quad \text{if } D_{1,2} \text{ OFF}$$

$$v_o = 5 + 0.7 \quad \text{if } \frac{R_2}{R_1+R_2} v_s > 5.7\text{V}$$

$$v_o = -4 - 1 \quad \text{if } \frac{R_2}{R_1+R_2} v_s < -5\text{V}$$





Voltage divider with upper and lower limits

$$\frac{R_2}{R_1+R_2} = \frac{6}{10} = 0.6$$

When $v_o = 5.7\text{V}$: $-v_{D2} = 5.7 - (-4\text{V}) = 9.7\text{V}$ → max reverse voltage

When $v_o = -4.7\text{V}$: $-v_{D1} = 5 - (-5) = 10\text{V}$

3. a)

$V_c = 6V \Rightarrow I_c = \frac{V_{CC} - 6}{R_C} = 1mA$

(K.V.L)

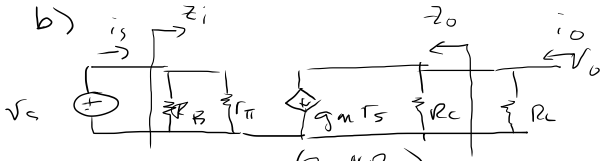
$$-V_{CC} + R_B I_B + V_{BEON} + R_E I_E = 0$$

$$I_B = \frac{I_c}{\beta}, \quad I_E = I_c \frac{\beta}{1+\beta} \approx I_c$$

$$R_B = \frac{V_{CC} - V_{BEON} - R_E I_E}{I_B}$$

$$= \frac{12 - 0.65 - 100 \times 10^{-3}/200}{10^{-3}/200} \approx 2.25\ M\Omega$$

b)



$A_V = -g_m (R_C \| R_L)$

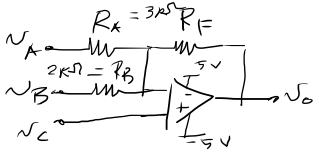
$z_i = R_B \| r_\pi \quad \left(\frac{v_i}{i_i}\Big|_{R_L=\infty}\right)$

$z_o = R_C \quad \left(\frac{v_o}{i_o}\Big|_{v_s=0}\right)$

$g_m = \frac{I_c}{V_T}$, $r_\pi g_m = \beta$, $r_o = \infty$ pq $V_A = \infty$ (not given)

c)

$$\omega_{Low} = \frac{1}{R_B \| r_\pi \, C_I}$$

4. a) 

Use superposition

Note that

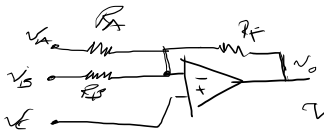
$v_A, v_B \rightarrow v_o$ INVERTING AMP.

$v_C \rightarrow v_o$ NON-INVERTING AMP.

$v_A = 2V,\ v_B = 0V,\ v_C = 2V$

Hence $v_o = -\frac{R_F}{R_A} v_A - \frac{R_F}{R_B} v_B + \left(1 + \frac{R_F}{R_A \| R_B}\right) v_C = -2v_A - 3v_B + 6v_C = 8V$

Because $v_{omax} = 5V \Rightarrow v_o = 5V$

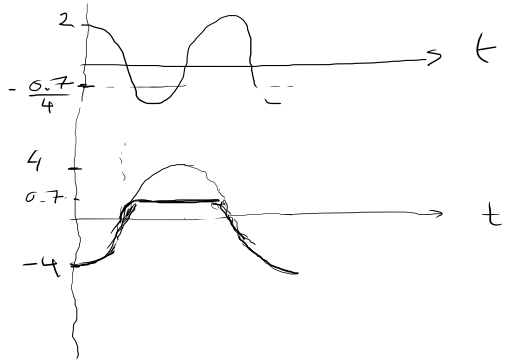
b) 

$V_B = 4V$

$v_C = 2V$

$v_A = 2\cos(\omega t)$

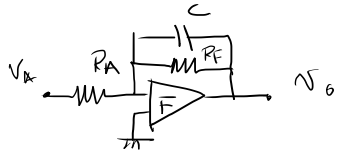
$v_o = -2 \times 2\cos(\omega t) - 3 \times 4 + 2 \times 6 = -4\cos(\omega t)$



c) $v_o = -4\cos(\omega t)$ with $v_{omax} = 0.7\ V$

$-4\cos\omega t < 0.7 \Leftrightarrow \cos(\omega t) > -\frac{0.7V}{4}$

d)



$$\frac{V_o(s)}{V_a(s)} = -\left(\frac{1}{sC} \| R_F\right) / R_A = -\frac{\frac{1}{sC + \frac{1}{R_F}}}{R_A} = -\frac{R_F}{R_A}\frac{1}{1+sR_FC}$$

$s = j\omega$

$\omega = 2\pi \times 513$ rad/s

$$\tilde{V}_A = 2e^{j0}$$

$$\tilde{V}_o = -\frac{R_F}{R_A}\frac{1}{1+j2\pi\times 513 \times 6\times 10^3 \times 200\times 10^{-9}} \times \tilde{V}_A$$

$$v_o(t) = |\tilde{v}_o| \cos(\omega t + \angle \tilde{v}_o)$$