EHB 335 E HW#4

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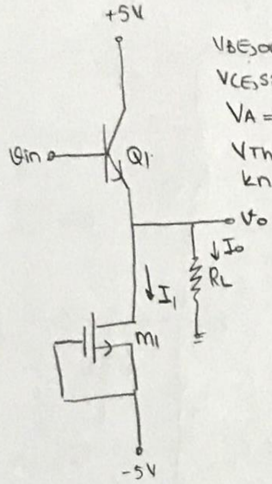
(1)



$V_{BE,on} = 0{,}7V$
$V_{CE,sat} = 0{,}2V$
$V_A = \infty$
$V_{Th} = -1{,}8V$
$k_n = 12\ mA/V^2$

a) Determine Voutmax & Voutmin and the corresponding input voltages for the circuit operate in Class-A region for
→ $R_L = \infty$
→ $R_L = 500\Omega$.

When $V_{in} > V_{BE}$ → $V_{out,max} = V_{CC} - V_{CE,sat} = 4{,}8V$

When $V_{in} < V_{BE}$ → BJT is off → $V_{outmin} = -I \cdot R_L$

↳ $I_1 = I_D = 12 \cdot 10^{-3} \cdot (V_{GS} - V_T)^2 = 38{,}9mA$

for $R_L = \infty$

$V_{out,max} = V_{CC} + V_{CE,sat} = 4{,}8V$

$v_{in} - v_{out} = v_{BE} = 0{,}7V$

$v_{in} = 5{,}5V$

$v_{out,min} = -V_{CC} + V_{DS}$

$V_{DS} = V_{GS} - V_{TH} = 1{,}8V$

$v_{out,min} = -5 + 1{,}8V = -3{,}2V$

$v_{in} = 0{,}7 - 3{,}2V = -2{,}5V$

for $R_L = 500\Omega$

? $I_o = \dfrac{v_{omin}}{R_L} = \dfrac{-3{,}2}{500} = -6{,}4mA$

$-6{,}4mA < 38{,}9mA$

Therefore Vomax, Vomin values are the same.

$V_{omax} = 4{,}8V$

$V_{omin} = -3{,}2V$

Q1 still derives!

b) What is the smallest value of RL possible if a 2V peak sine wave is produced at the output?

$P_{av} = (V_{CC} - V_P/2) I_1 = V_{CC} I_1 - \dfrac{V_P^2}{2R_L}$ if $\boxed{V_P = I_1 \cdot R_L}$

$4 \cdot I_1 = 5 I_1 - \dfrac{4}{2R_L}$

$R_L \cdot I_1 = 2V$

$R_L = \dfrac{2}{I_1} = \dfrac{2}{38{,}9 \times 10^{-3}} = 51{,}4\ \Omega$

c) What is the corresponding power conversion efficiency?

$$\boxed{\eta = \frac{P_{L,av}}{P_{S,av}}}$$

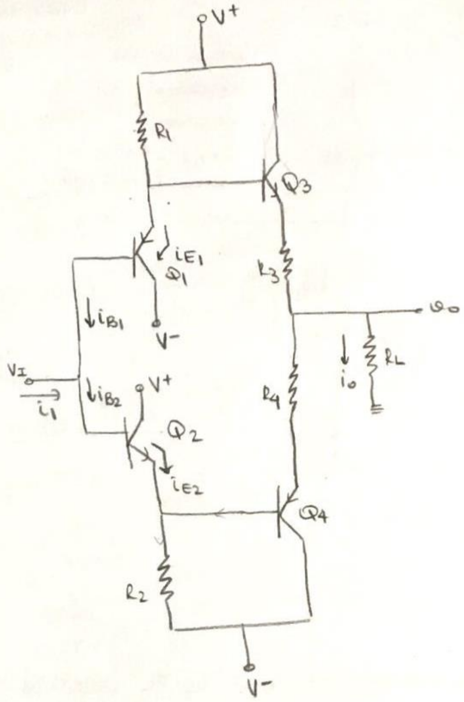
$$P_{L,av} = \frac{1}{T}\int_0^T \frac{(V_p \sin^2 wt)}{R_L}\,dt = \frac{V_p^2}{2R_L} = \frac{4}{2 \cdot 51{,}4} = 38{,}9mW.$$

$V_{out} = V_p \sin wt$ $\quad P_{S,av} = \dfrac{1}{T}\displaystyle\int_0^T (V_{CC} - V_{EE}) \cdot I_1\,dt = 10 \cdot 38{,}9mA = 389mW$

$$\eta = \frac{38{,}9}{389} = 0{,}1 \rightarrow 10\%$$

(2) Consider the class-AB output stage in Figure. Assume all transistors are matched, with parameters $V_+ = V_- = 12V$ and $\beta = 40$, $V_{BE}(npn) = V_{BE}(pnp) = 0{,}7V$, $R_1 = R_2 = 250\Omega$, $R_3 = R_4 = 0\Omega$, $R_L = 8\Omega$

a) For $v_I = 0V$ determine i_{E1}, i_{E2}, i_{B1} & i_{B2}.



$v_i = 0 \Rightarrow V_{B1} = V_{B2} = 0V$ $\qquad \alpha = \dfrac{\beta}{1+\beta} = \dfrac{40}{41}$

$12 - R_1.(i_{E1} + i_{B3}) = 0{,}7V$

$-V_{E_1} - \cancel{V_{B_1}} = 0{,}7V$

$V_{E_1} = +0{,}7V \qquad V_{E2} = -0{,}7V$

$\dfrac{-0{,}7-(-12)}{R_2} = i_{E2} - i_{B4}$

$v_i = 0 \Rightarrow v_o = 0 \Rightarrow i_o = 0 \Rightarrow i_{E3} = i_{E4}$, $i_{B3} = i_{B4}$ $\qquad i_1 = 0 \Rightarrow i_{B1} = i_{B2}$, $i_{E1} = i_{E2}$

$12 - 250(i_{E1} + i_{B3}) = 0{,}7V$

$\left.\begin{array}{l} \dfrac{11{,}3}{250} = i_{E2} - i_{B4} \\ \dfrac{11{,}3}{250} = i_{E2} + i_{B4} \end{array}\right\} \begin{array}{l} i_{E1} = i_{E2} = 45{,}2mA \\ i_{B1} = i_{B2} = \dfrac{45{,}2 \times 10^{-3}}{41} \cong 1{,}1mA \end{array}$

b) For $v_I = 5V$ determine i_I, i_o, i_{E1} & i_{E2}, i_{B1} & i_{B2}.

$v_i = 5V = V_{B1} = V_{B2}$

$\left.\begin{array}{l} V_{B3} = V_{E1} = 5{,}7V \rightarrow v_{E3} = v_{B3} - 0{,}7 = 5V = v_o \\ V_{B4} = V_{E2} = 4{,}3V \rightarrow v_{E4} = 5V \rightarrow = v_o \end{array}\right\} R_3 = R_4 = 0\Omega$

$v_o = 5V \Rightarrow \dfrac{v_o}{R_L} = i_o = \dfrac{5}{8} = 625mA$

$i_o + i_{E4} = i_{E3} \rightarrow i_{B3}.\dfrac{\beta}{\alpha}$

$\quad \hookrightarrow i_{B4}.\dfrac{\beta}{\alpha}$

$41(i_{B3} - i_{B4}) = 625 \times 10^{-3} A$

$i_{B3} - i_{B4} = 0{,}015244A$

$i_{E3} - i_{E4} = 0{,}015 \times 41 \approx 0{,}625A$

$* \ \dfrac{v_{B4} - (-12)}{R_2} - i_{B4} = i_{E2} \longrightarrow +(i_{E2} + i_{B4}).R_2 = 4{,}3 + 12$

$i_{E2} + i_{B4} = 0{,}0652$

$* \ \dfrac{12 - V_{B3}}{R_1} = +i_{B3} + i_{E1} \longrightarrow +i_{B3} + i_{E1} = 0{,}0252$

$i_{E2} - i_{E1} = 0{,}04 + (i_{B3} - i_{B4})$
$= 0{,}04 + 0{,}015244$
$= 0{,}055244$

$i_I = i_{B2} - i_{B1} = \dfrac{1}{41} 0{,}055244$

$= 1{,}3474\ mA$

if we assume $i_{E3} = i_o = 0{,}625\ A$

$i_{B3} = \dfrac{1}{41}.0{,}625 = 15{,}244\ mA$

$i_{E1} = 9{,}956mA \qquad i_{B1} = 242{,}83\mu A$

$i_{E2} = 65{,}2mA \qquad i_{B2} = 1{,}6mA$

$i_o = 625mA \qquad i_{in} = 1{,}3474\ mA$

c) Current gain = ?

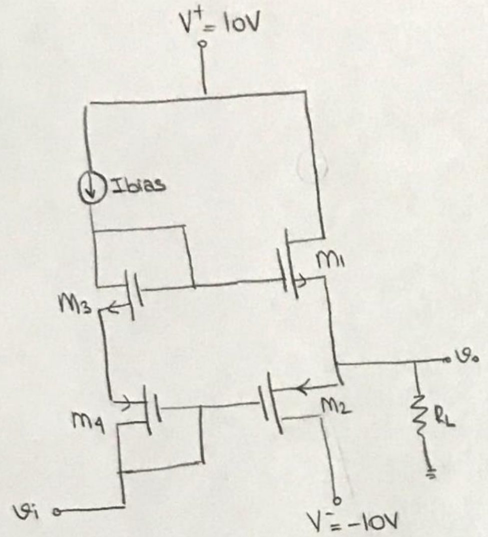
$\dfrac{i_o}{i_{in}} = \dfrac{0{,}625}{1{,}3474 \times 10^{-3}} = 463{,}856316$

(3) Consider the class-AB MOSFET Output stage in Figure.

$I_{bias} = 0{,}2\,mA$, $R_L = 1k\Omega$, $V_{TH,n} = 0{,}8V$, $k'_n = 100\mu A/V^2$, $V_{TH,p} = -0{,}8V$, $k'_p = 40\mu A/V^2$

For the quiescent condition, assume $V_{GS,3} = V_{SG,4}$, $\lambda = 0$ for all transistors.

$V_{GS,1} = V_{GS,2}$



a) If $V_i = -1{,}5V$, $V_o = 0V$, $i_{D1} = i_{D2} = 0{,}5mA$; determine W/L ratios.

$V_I = -1{,}5V$, $V_o = 0V$ $\Rightarrow$ $V_{S2} = 0V$

$V_{G2} = V_{D4} = V_i = -1{,}5V$

$V_{SG2} = V_{GS1} = 1{,}5V$

$i_{D1} = i_{D2} = 0{,}5 = \frac{0{,}1}{2}\left(\frac{W}{L}\right)_1 \underbrace{(V_{GS1} - V_{TH,n})^2}_{(1{,}5-0{,}8)^2 = 0{,}49}$

$\left(\frac{W}{L}\right)_1 = 20{,}4$ //

$0{,}5 = \frac{0{,}04}{2}\left(\frac{W}{L}\right)_2 \cdot 0{,}49$

$\left(\frac{W}{L}\right)_2 = 51$ //

$\Rightarrow V_{G4} = v_i$ $\quad V_{G3} = V_{G1} = 1{,}5V$

$V_{S4} = V_{S3}$

$V_{G3} - V_{S3} = V_{S4} - V_{G4}$

$1{,}5 - V_{S3} = V_{S3} + 1{,}5$

$V_{S3} = V_{S4} = 0$

$V_{GS3} = V_{SG4} = 1{,}5V$

$I_{bias} = 0{,}2 = \frac{0{,}1}{2}\left(\frac{W}{L}\right)_3 (1{,}5 - 0{,}8)^2$

$4 = \left(\frac{W}{L}\right)_3 \cdot 0{,}49$

$\left(\frac{W}{L}\right)_3 = 8{,}16$ //

$0{,}2 = \frac{0{,}04}{2} \cdot \left(\frac{W}{L}\right)_4 \cdot 0{,}49$

$\left(\frac{W}{L}\right)_4 = 20{,}4$ //

b) Assuming voltage drop across I_{bias} of 0.2 V, $V_i = -1{,}5V$ find the max. and min. limits of V_o.

$V_{omax,1} = V^+ - V_{o(Ibias)} - V_{GS1} = 10 - 0{,}2 - 1{,}5 = 8{,}3V$

$V_{omax,2} = V^+ - V_{DS,1} = 10 - 0{,}7 = 9{,}3V$ //

$\hookrightarrow V_{GS} - V_{TH} = 0{,}7$

$\hookrightarrow \overset{?}{\geq} V_{GS} - V_{Th} = 0{,}7$

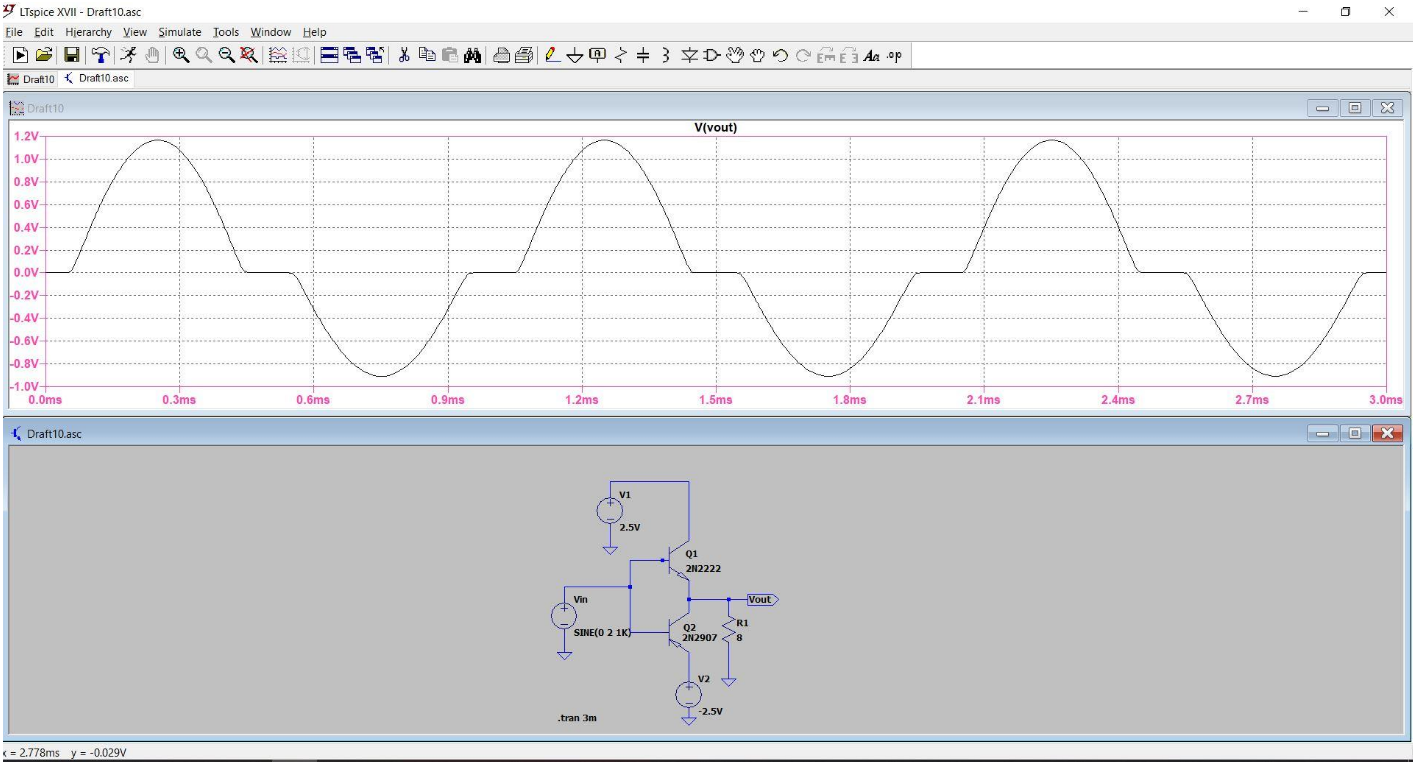
$V_{omin,1} = V^- + |V_{SD,2}| = -9{,}3V$

$V_{omin,2} = V_{ov(in)} + |V_{SG,2}| = 0$

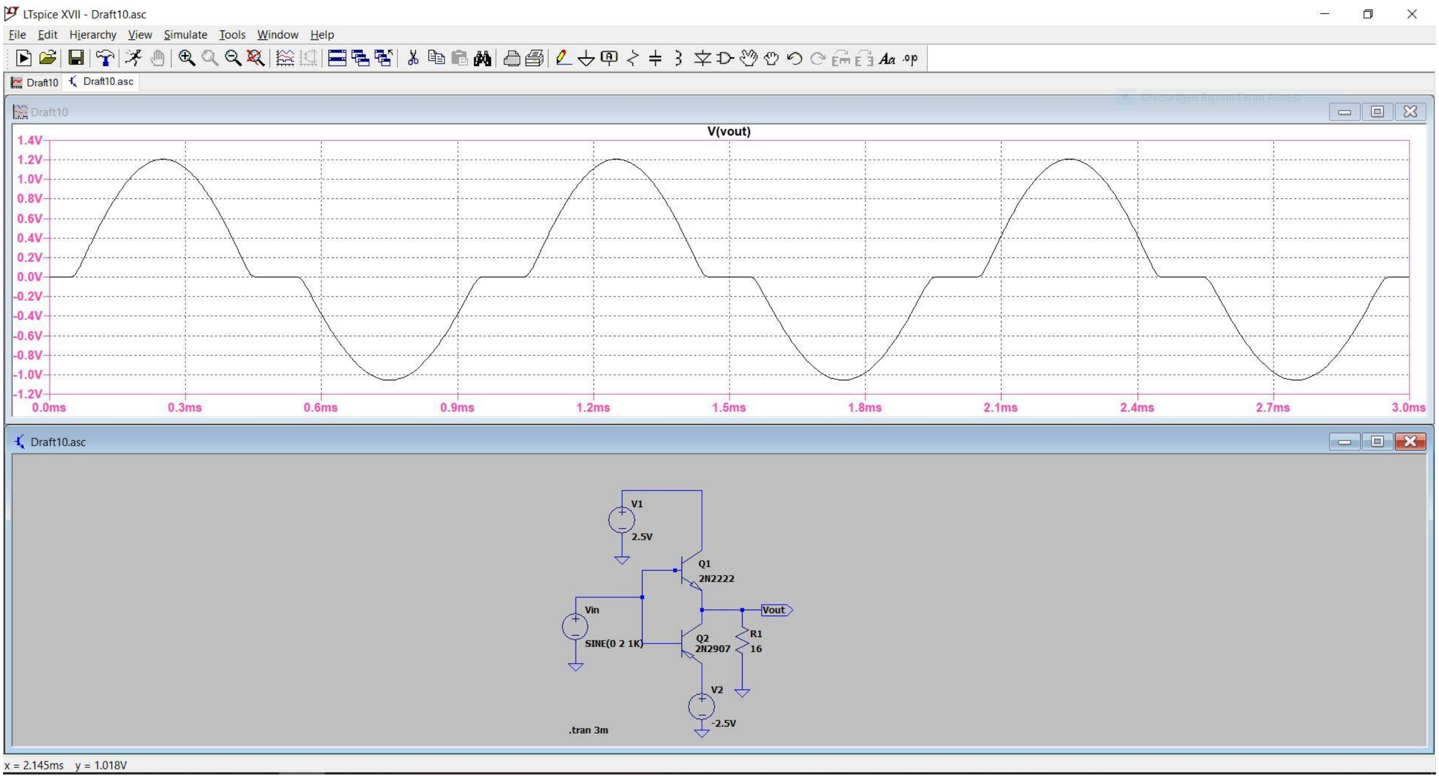
$0 \leq V_o \leq 8{,}3V$ //

Question 4

a) When R= 8 ohms



b) When R=16 ohms



->When the value of R increases, Vout_max increases but the Vout_min decreases.