Faculty of Engineering
Benha university
Electrical Eng.Dept.
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Microelectronics (E302)
Final-Term Exam (corrective)
Data: 12 /5/2013
Time: 3 Hours

Answer the following questions:

Q1:(a) The NMOS transistors in the circuit of fig.(1) have V_t =2V, $\mu_n C_{ox}$= 20 μA/ V^2. λ = 0 and L_1=L_2 =10μm. Find the required values of gate width for each of Q1 and Q2 and the value of R, to obtain the voltages and Current values indicated.

(b) The basic op amp in fig.(2) is ideal. Find V_o and determine what mathematical operation is performed by the amplifier circuit.

Q2: Consider the source follower shown in fig.(3) with transistor parameters V_t=1.2V , k_n = 1 mA/V^2, and λ=0.01V^{-1}. If I=1mA using T-model determine the small signal voltage gain $A_v = v_o/v_i$, and the output resistance R_o.

Q3: For the NMOS amplifier of fig.(4), V_t = 2V and V_A= l00V. Find the dc bias voltage at the drain to obtain a voltage gain of -100. If K=0.25 mA/V^2 find the required bias current I. If R_G = 10MΩ, find the input resistance of the amplifier.

Q4: The op amp shown in fig.(5) is ideal. Calculate i_a, v_a, v_o, and i_o.

Q5: Find the overall voltage gain v_o/v_s and the differential input resistance of the amplifier shown in fig. (6). Assuming β = 100.

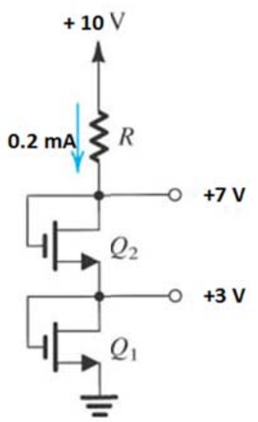


Fig.(1)

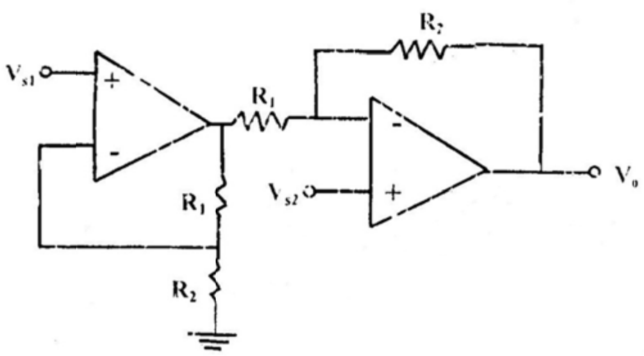


Fig.(2)

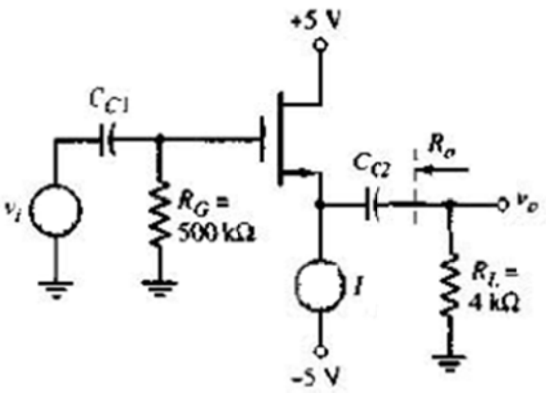


Fig.(3)

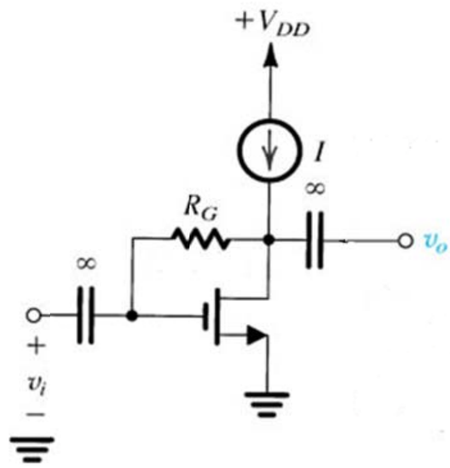


Fig.(4)

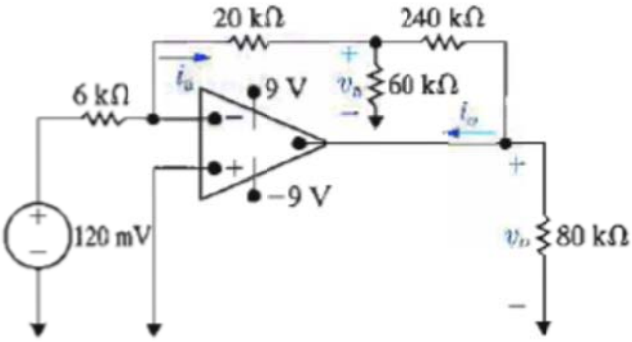


Fig.(5)

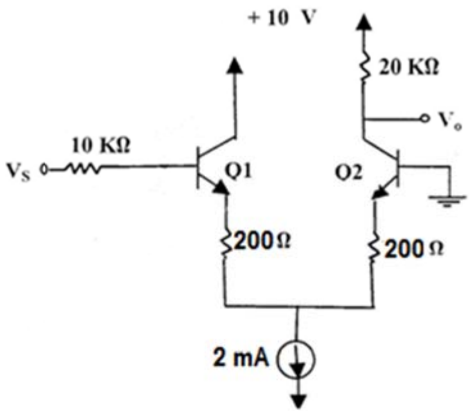
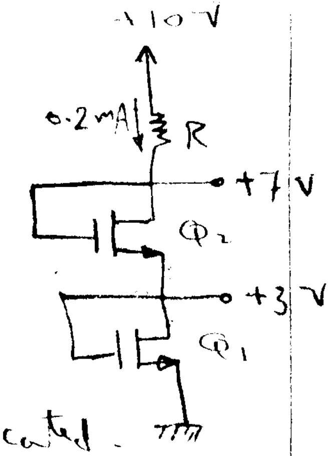


Fig.(6)

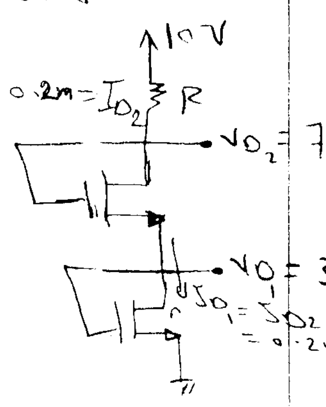
BEST WISHES

Hossam Labib

Q1(a) The NMOS transistor shown have $V_t = 2\,V$, $\mu_n C_{ox} = 20\ \mu A/V^2$; $\lambda = 0$ and $L_1 = L_2 = 10\ \mu m$. Find the required values of gate width for each of Q_1 and Q_2 and the value of R, to obtain the voltages and current values indicated.



Solution



To find R

$V_{D_2} = V_{DD} - I_D R$

$R = \frac{V_{DD} - V_D}{I_{D_2}} = \frac{10 - 7}{0.2\,m} = 15\ K\Omega$.

For Q_1

$V_{S1} = 0$ & $V_{G1} = V_{D1} = 3\,V$; $V_{GS_1} = V_{G1} - V_S = 3\,V$

$V_{DS_1} = V_{D_1} - V_{S_1} = V_{D1} = 3\,V$

$V_{DS_1}|_{sat} = V_{GS_1} - V_t = 3 - 2 = 1$

$\therefore V_{DS_1} > V_{DS_1}|_{sat}$ $\therefore Q_1$ in saturation region

$\therefore I_{D_1} = I_{D_2} = 0.2\,mA$

$I_{D_1} = K_1 (V_{GS_1} - V_t)^2$

$0.2\,m = K_1 (3 - 2)^2 \Rightarrow K_1 = \frac{0.2\,m}{1} = 0.2\,m\ A/V^2$

$\therefore K_1 = \frac{1}{2} \mu_n C_{ox} \frac{W_1}{L_1} \Rightarrow W_1 = \frac{2 K_1 L_1}{\mu_n C_{ox}} = \frac{2 \times 0.2 \times 10^{-3} \times 10 \times 10^{-6}}{20 \times 10^{-6}}$

$W_1 = 200\ \mu m$

For Q_2

$V_{S2} = V_{D1} = 3\,V$ & $V_{G2} = V_{D2} = 7\,V \Rightarrow V_{GS_2} = V_{G2} - V_{S2}$

$V_{GS_2} = 7 - 3 = 4\,V$ & $V_{DS_2} = V_{D_2} - V_{S_2} = 7 - 3 = 4$

$V_{DS_2}|_{sat} = V_{GS_2} - V_t = 4 - 2 = 2\,V$

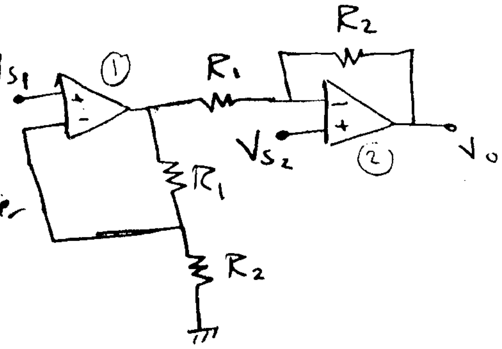
$\therefore V_{DS_2} > V_{DS_2}|_{sat}$ $\therefore Q_2$ in sat. region

$\therefore I_{D_2} = K_2 (V_{GS_2} - V_t)^2 \Rightarrow K_2 = \frac{I_{D_2}}{(V_{GS_2} - V_t)^2}$

$K_2 = \frac{0.2\,m}{(4-2)^2} = 500\ m\ A/V^2$

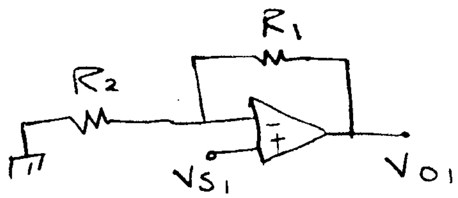
$W_2 = \frac{2 K_2 L_1}{\mu_n C_{ox}} = \frac{2 \times 500 \times 10^{-3} \times 10 \times 10^{-6}}{20 \times 10^{-6}} = 50\ \mu m$

Q1(b) The basic op Amp. shown is ideal. Find V_o and determine what mathematical operation is performed by the Amplifier circuit.



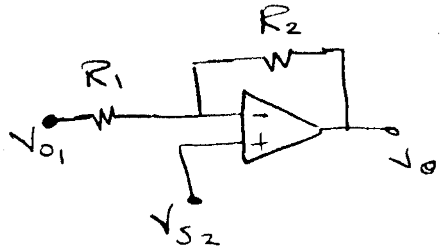
Solution

For op Amp ①



$$V_{o_1} = \left(1 + \frac{R_1}{R_2}\right) V_{S1}$$

For op Amp ②



$$V_o = \left(1 + \frac{R_2}{R_1}\right) V_{S2} + \left(\frac{-R_2}{R_1}\right) V_{O1}$$

$$V_o = \left(1 + \frac{R_2}{R_1}\right) V_{S2} - \left(\frac{R_2}{R_1}\right)\left(1 + \frac{R_1}{R_2}\right) V_{S1}$$

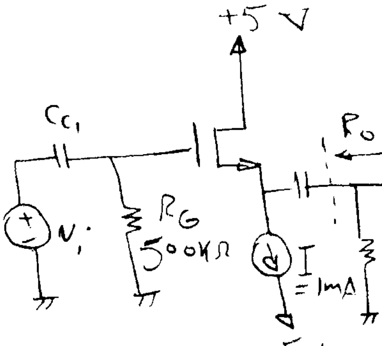
$$= \left(1 + \frac{R_2}{R_1}\right) V_{S2} - \left(\frac{R_2}{R_1} + 1\right) V_{S1}$$

$$= \left(1 + \frac{R_2}{R_1}\right) (V_{S2} - V_{S1})$$

The operation is difference (subtractor) op Amp.

(7) Consider the source follower shown in Fig. (2) with transistor parameters $V_t = 1.2\,V$, $K_n = 1\,mA/V^2$, and $\lambda = 0.01\,V^{-1}$. If $I = 1\,mA$, using T-model determine the small signal voltage gain $A_v = v_o / v_i$, and the output resistance R_o.

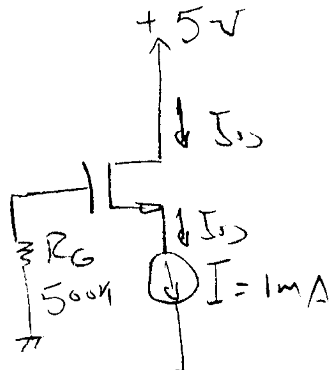
solution



DC Analysis

- All Cap. o.c
- reduce AC sources

$I_D = I = 1\,mA$



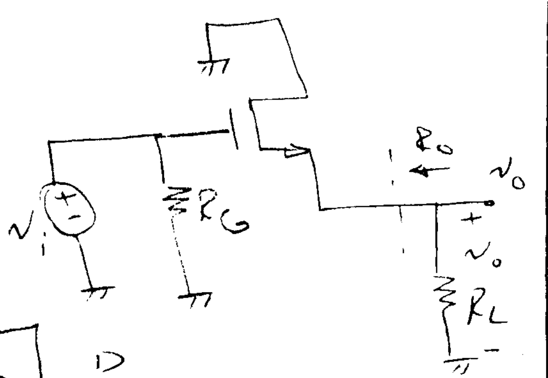
$$g_m = 2\sqrt{K_n I_D}$$
$$= 2\sqrt{1m \times 1m} = 2\,mA/V \longrightarrow (1)$$

$$r_o = \frac{V_A}{I_D} \; ; \; V_A = \frac{1}{\lambda} \Rightarrow r_o = \frac{1}{\lambda I_D} \longrightarrow (1)$$

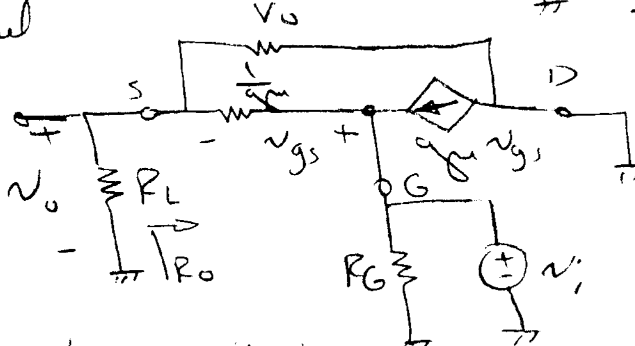
$$r_o = \frac{1}{0.01 \times 1m} = 100\,K\Omega.$$
$$\frac{1}{g_m} = \frac{1}{2m} = 500\,\Omega.$$

AC Analysis

- All Cap. s.c
- reduce DC sources



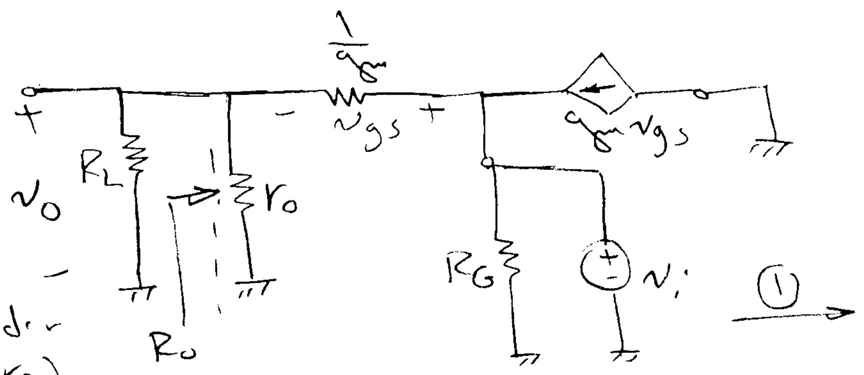
Using T-model



$\longrightarrow (1)$

$r_o \parallel R_L \Rightarrow$ The circuit becomes.

Q2 (cont.)



from voltage divider

$$v_O = v_i \cdot \frac{(R_L \parallel r_o)}{(R_L \parallel r_o) + \frac{1}{g_m}}$$

$$A_v = \frac{v_o}{v_i} = \frac{(R_L \parallel r_o)}{(R_L \parallel r_o) + \frac{1}{g_m}} \longrightarrow ②$$

$$= \frac{(4K \parallel 100K)}{(4K \parallel 100K) + 500}$$

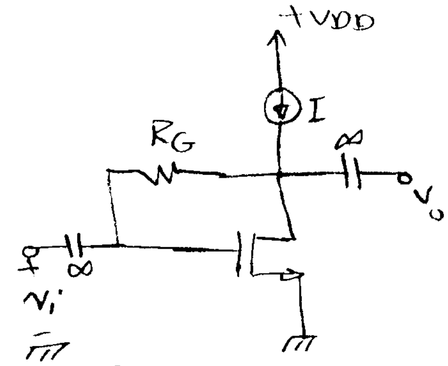
$$= \frac{3.846K}{3.846K + 500} = 0.885 \text{ V/V} \longrightarrow ②$$

To find Ro

$$R_o\Big|_{v_i=0} = r_o \parallel \frac{1}{g_m} \longrightarrow ①$$

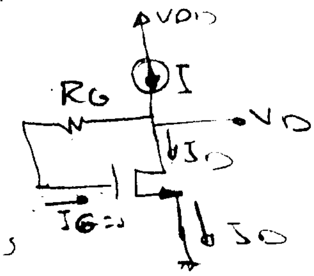
$$= 100K \parallel 0.5K$$

$$= 0.498 K\Omega \simeq 0.5 K\Omega \simeq \frac{1}{g_m} \longrightarrow ①$$



(1) For the NMOS amplifier shown $V_t = 2\,V$ and $V_A = 100\,V$. Find the dc bias voltage at the drain to obtain a voltage gain of -100. If $K = 0.25\,mA/V^2$ find the required bias current I. If $R_G = 10\,M\Omega$, find the I/P resistance of amplifier.

Solution



DC analysis: All capacitor o.c

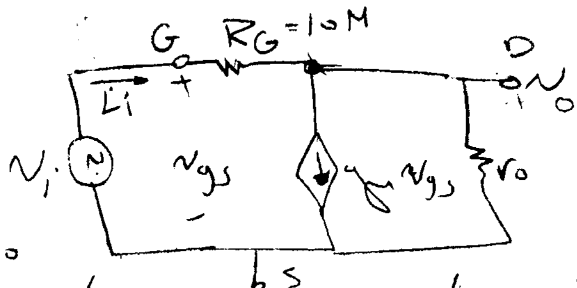
$I_D = I$; $I_G = 0 \Rightarrow V_{DG} = 0 \Rightarrow V_{DS} = V_{GS}$

$\because V_S = 0 \Rightarrow V_G = V_D$

AC analysis

C.S = o.c & All capacitor s.c

$V_A = 100 \Rightarrow r_o$ exist ; $r_o = \frac{V_A}{I_D}$



given

$A_v = \frac{v_o}{v_i} = -100$

let $R_G \gg r_o$ (then we can neglect the current through R_G)

$\because v_o \simeq -g_m v_{gs} r_o$

$v_{gs} = v_i \Rightarrow v_o = -g_m v_i r_o \Rightarrow \frac{v_o}{v_i} = -g_m r_o$

$\therefore -100 = -g_m r_o \Rightarrow g_m r_o = 100$

$\frac{2 I_D}{V_{GS} - V_t} * \frac{V_A}{I_D} = 100 \Rightarrow \frac{2 * 100}{V_{GS} - 2} = 100$

$V_{GS} - 2 = 2 \Rightarrow V_{GS} = 4 \Rightarrow V_G = 4 = V_D$

$\because I_D = K(V_{GS} - V_t)^2 = I$

$= 0.25(4-2)^2 = 1\,mA$

Q3 (Cont.)

To find R_{in}

$$R_{in} = \frac{v_i}{i_i}$$

$$\therefore i_i = \frac{v_i - v_o}{R_G} = \frac{v_i}{R_G} - \frac{v_o}{R_G}$$

$$= \frac{v_i}{R_G}\left(1 - \frac{v_o}{v_i}\right)$$

$$= \frac{v_i}{R_G}(1 - A_v)$$

$$R_{in} = \frac{v_i}{i_i} = \frac{v_i R_G}{v_i(1 - A_v)}$$

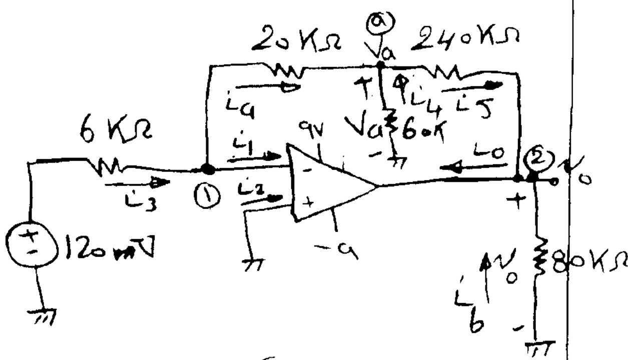
$$= \frac{R_G}{1 - A_v} = \frac{10M}{1+100} = 99\,K\Omega.$$

Q4

The op amp shown in Fig. is ideal. Calculate the following:

(a) V_a (b) V_o (c) i_a (d) i_o

Solution



$\because i_1 = i_2 = 0$ → (1)

$\bar{V} = \overset{+}{V} = 0\,V$

at node (1)

$i_3 = i_a + i_1$; $i_1 = 0$

$i_a = i_3$ →

$i_a = \dfrac{120\,mV - \bar{V}}{6\,K\Omega} = \dfrac{120m - 0}{6K} = 20\,\mu A$ → (2)

$\therefore i_a = i_3 = 20\,\mu A$

$\because i_a = \dfrac{\bar{V} - V_a}{20K} \Rightarrow 20 \times 10^{-6} = \dfrac{0 - V_a}{20K}$ →

$\Rightarrow V_a = -20 \times 10^{3} * 20 \times 10^{-6} = -0.4\,V$ → (2)

at node (a)

$i_a + i_4 = i_5$ →

$i_5 = 20\,\mu A + \dfrac{0 - V_a}{60K} = 20\,\mu A + \dfrac{+0.4}{60K}$

$= 20\,\mu A + 6.67\,\mu A = 26.67\,\mu A$ → (1)

$\because i_5 = \dfrac{V_a - V_o}{240K} \Rightarrow 26.67\,\mu = \dfrac{-0.4 - V_o}{240K}$ →

$-V_o - 0.4 = 26.67\mu * 240K$

$V_o = -0.4 - 6.4 = -6.8\,V$ → (2)

at node (2)

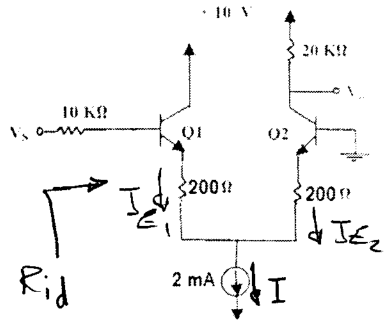
$i_o = i_5 + i_6$ → (1)

$= 26.67\,\mu + \dfrac{0 - V_o}{80K}$

$= 26.67\mu + \dfrac{+6.8}{80K} = 26.67\,\mu A + 85\,\mu A$

$i_o = 111.67\,\mu A$ → (2)

Q5: Find the overall voltage gain v_o/v_s and the differential input resistance of the amplifier shown in figure. Assuming $\beta = 100$.



Soution:

Dc Analysis

$$I_{E_1} = I_{E_2} = I_E = \frac{I}{2}$$

$$I_E = \frac{2mA}{2} = 1\ mA$$

$$I_C = \alpha I_E \simeq I_E = 1mA \quad ; \alpha \simeq 1$$

$$r_e = \frac{V_T}{I_E} = \frac{25mV}{1mA} = 25\ \Omega$$

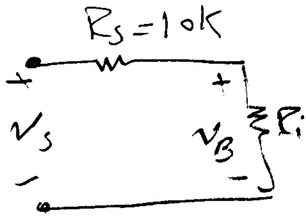
$$g_m = \frac{I_C}{V_T} = \frac{1mA}{25mV} = 40\ mA/V$$

$$R_{id} = (1+\beta)(2R_E + 2r_e)$$

$$= (1+100)(2*200 + 2*25) = 45.45\ K\Omega$$

$$\frac{v_o}{v_s} = \frac{v_o}{v_B} * \frac{v_B}{v_s}$$

$$\frac{v_o}{v_B} = \frac{R_C}{2R_E + 2r_e} = \frac{20K}{2*200 + 2*25} = 44.44$$



$$v_B = v_s \frac{R_{id}}{R_{id} + R_s} = \frac{v_s\, 45.45K}{45.45K + 10K} = 0.82\, v_s$$

$$\frac{v_B}{v_s} = 0.82$$

$$\frac{v}{v_s} = 0.82 * 44.44 = 36.44\ V/V$$