Solutions to Tutorial Sheet - 11 IEC103

Q1 Find the Q points (V_{CE1}, I_{C1}) and (V_{CE2}, I_{C2}) of transistors Q_1 and Q_2 respectively in the amplifier circuit shown in Fig. Q1

Take $I_C \simeq I_E$, $|V_{BE}| = 0.7\,V$

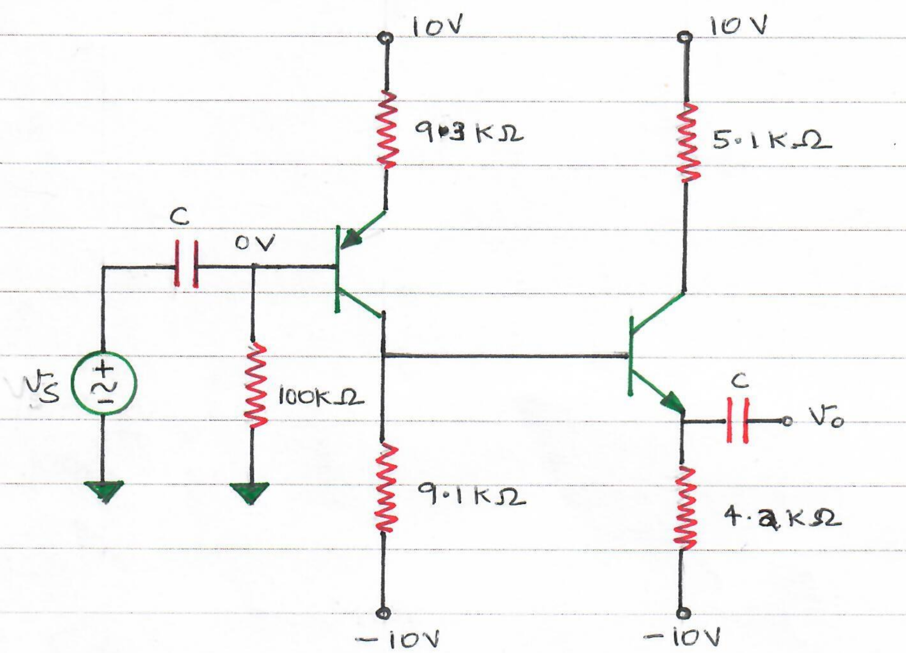


Fig. Q1

Sol.

i)

$$I_{C1} = \frac{10 - 0.7}{9.3K} = \frac{9.3}{9.3K} = 1\,mA \simeq I_{E1}$$

$$V_{E1} = 10 - 1 \times 10^{-3} \times 9.3 \times 10^{3} = 10 - 9.3 = 0.7\,V$$

$$V_{C1} = -10 + 9.1 \times 10^{3} \times 1 \times 10^{-3} = -10 + 9.1 = -0.9\,V$$

$$V_{CE1} = V_{C1} - V_{E1} = -0.9 - 0.7 = -1.6\,V$$

Q point of transistor Q_1 is $(-1.6V, 1mA)$

ii)

$$V_{E2} = V_{C1} - V_{BE} = -0.9 - 0.7 = -1.6\,V$$

$$I_{E2} = \frac{V_{E2} - (-10)}{4.2K} = \frac{-1.6 + 10}{4.2K} = \frac{8.4}{4.2K} = 2mA \simeq I_{C2}$$

$$V_{C2} = 10 - I_{C2} \times 5.1K = 10 - 5.1 \times 10^{3} \times 2 \times 10^{-3} = -0.2$$

$$V_{CE2} = V_{C2} - V_{E2} = -0.2 - (-1.6) = 1.4\,V$$

Q point of transistor Q_2 is $(1.4V, 2mA)$

(Q2) Calculate the quiscent points of transistors Q_1 and Q_2 shown in Fig. Q2. Assume that the base currents are negligible and take $V_{BE} = 0.7\,V$ for both Q_1 and Q_2.

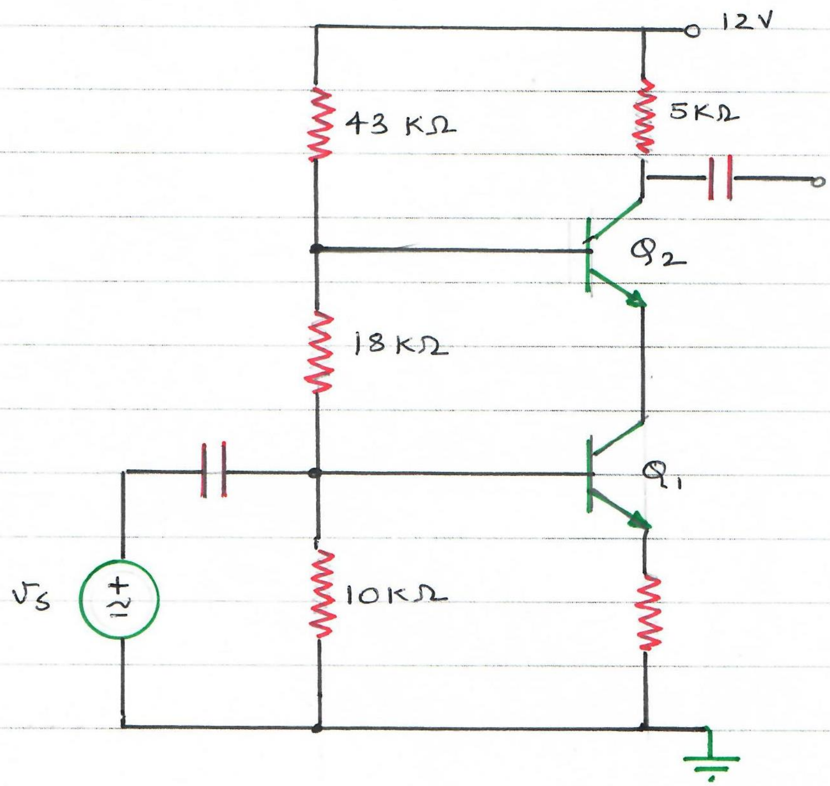
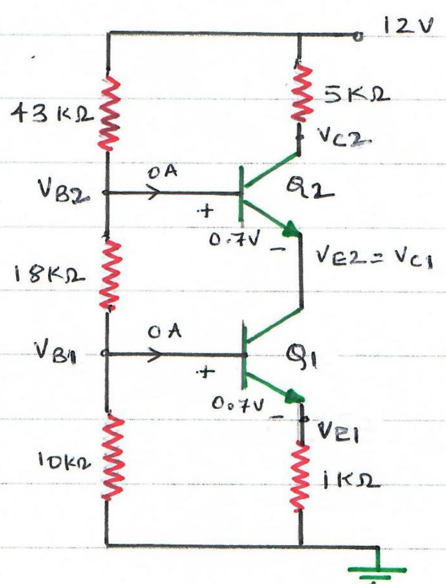


Fig. Q2

Sol. DC equivalent circuit



$I_{B1} = I_{B2} = 0A$

$V_{BE1} = V_{BE2} = 0.7\,V$

$V_{B1} = \frac{10}{10+18+43} \times 12 \simeq 1.7\,V$

$V_{B2} = \frac{10+18}{10+18+43} \simeq 4.7\,V$

$V_{E1} = V_{B1} - 0.7 = 1.7 - 0.7 = 1V$

$V_{E2} = V_{B2} - 0.7 = 4.7 - 0.7 = 4V$

$I_{E1} = \frac{V_{E1}}{1K}\,A = \quad = 1\,mA \simeq I_{C_1}$

$I_{C_1} \simeq I_{E2} = 1mA = I_{C2}$

$V_{C2} = 12 - I_{C2} \times 5K$

$= 12 - 1 \times 5 = 7V$

$V_{CE1} = V_{C1} - V_{E1} = V_{E2} - V_{E1}$

$= 4 - 1 = 3V$

$$V_{CE2} = V_{C2} - V_{E2}$$

$$= 7 - 4 = 3V$$

$\therefore$ Q point for Q_1 and Q_2 are

$V_{CE1} = 3V$, $I_{C1} = 1mA$ and

$V_{CE2} = 3V$, $I_{C2} = 1mA$

Q3 For the amplifier circuit shown below, calculate the voltage gain $A_V \left(\frac{v_o}{v_s}\right)$, current gain (i_o/i_s), input resistance (R_{in}), and output resistance (R_o).

Given that the transistor is of silicon and $\beta = 100$.

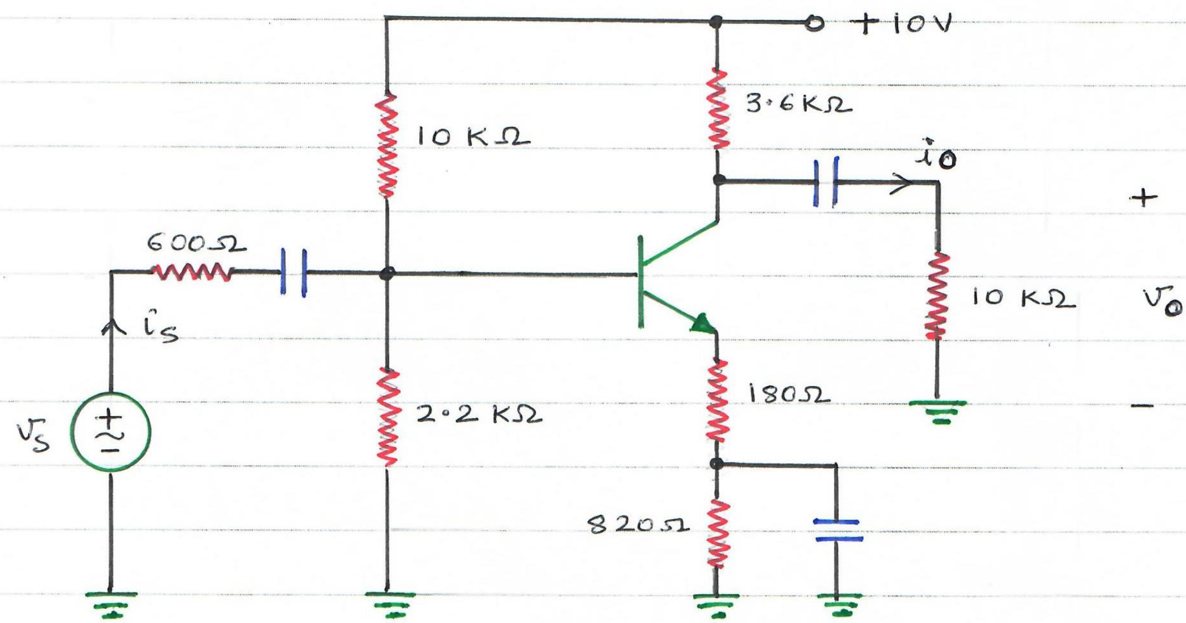
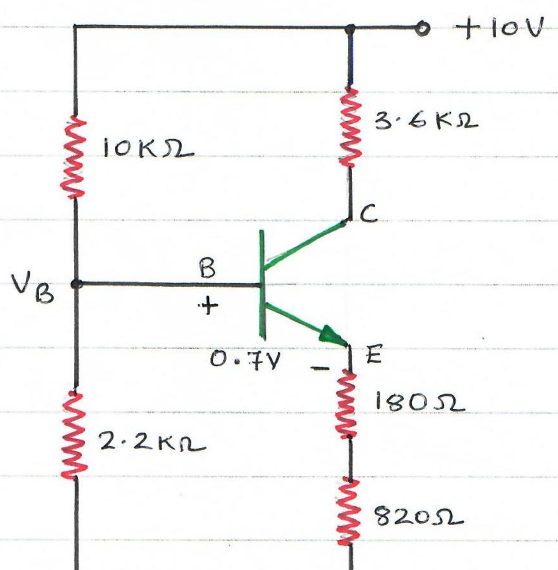


Fig. Q3

Sol.

Capacitors act as open circuit to DC and short circuit to AC.

DC equivalent circuit



$$V_B \simeq \frac{10 \times 2{\cdot}2}{(2{\cdot}2 + 10)} = 1{\cdot}803\ V$$

$$V_E = V_B - 0{\cdot}7 = 1{\cdot}103\ V$$

$$I_E = \frac{1{\cdot}103}{(180+820)} = \frac{1{\cdot}103}{1000} = 1{\cdot}103\ mA$$

$$I_C \simeq I_E = 1{\cdot}103\ mA$$

$$V_C = 10 - I_C \times 3{\cdot}6K$$

$$= 10 - 3{\cdot}6 \times 10^3 \times 1{\cdot}103 \times 10^{-3}$$

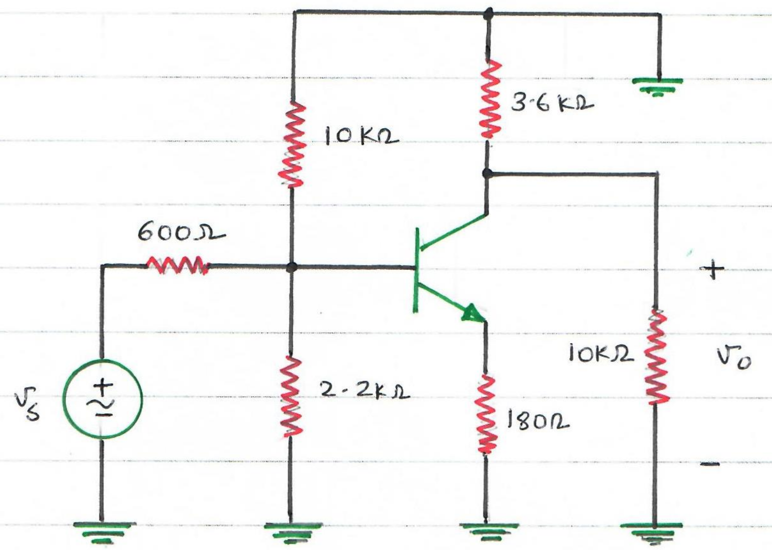
$$= 10 - 3{\cdot}6 \times 1{\cdot}103$$

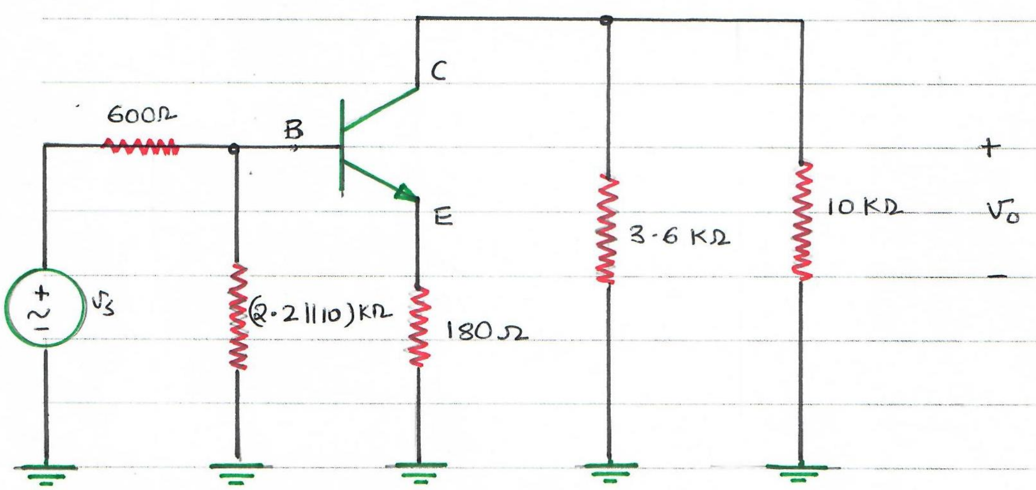
$$= 6{\cdot}03\ V$$

$V_{CB} = V_C - V_B = 6.03 - 1.803 = 4.227\ V$

So, collector base junction is reverse biased. So, the transistor is in active region.

AC equivalent circuit

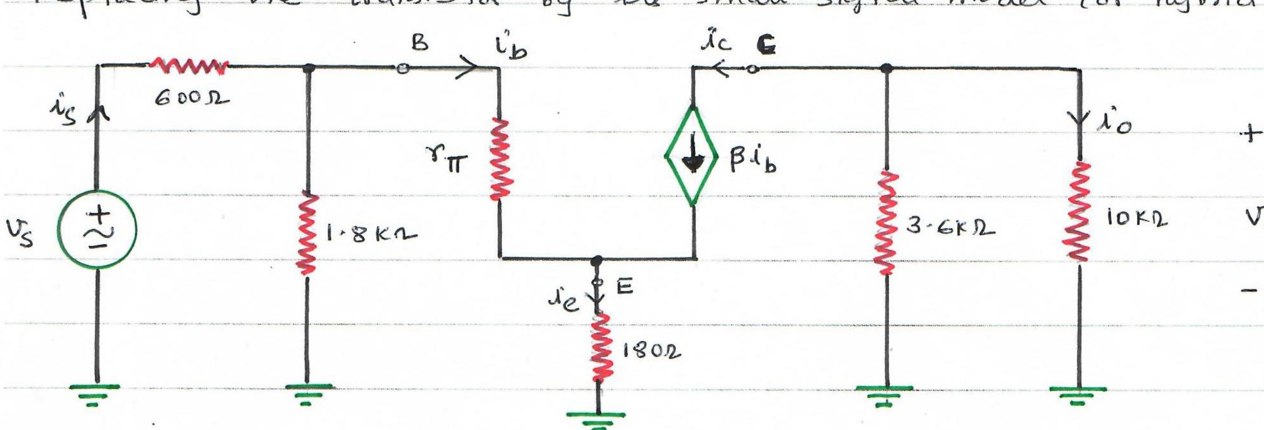




2·2 KΩ || 10 KΩ

≃ 1·8 KΩ

Replacing the transistor by its small-signal model (or hybrid-π model)



$$r_\pi = \frac{25\times10^{-3}}{I_B} = \frac{25\times10^{-3}}{(I_C/\beta)} = \frac{25\times10^{-3}\times100}{I_C}$$

$$= \frac{2\cdot5}{1\cdot103\times10^{-3}} = 2\cdot27\ K\Omega$$

Voltage gain

$$v_b = r_\pi i_b + v_e$$

$$= r_\pi i_b + 180 i_e$$

$$= r_\pi i_b + 180(1+\beta) i$$

$$\simeq r_\pi i_b + 180\beta i_b$$

$$= (r_\pi + 180\beta) i_b$$

$$= (2\cdot27K + 18K) i_b$$

$$20\cdot27K i_b$$

$$i_s = i_b + \frac{v_b}{1\cdot8K}$$

$$= i_b + \frac{20\cdot27K i_b}{1\cdot8K} = i_b + \frac{20\cdot27 i_b}{1\cdot8}$$

$$\Rightarrow i_s = 11\cdot26 i_b + i_b = 12\cdot26 i_b$$

$$v_s = v_b + i_s \times 600$$

$$= 600\times12\cdot26 i_b + v_b$$

$$= 7356 i_b + 20270 i_b$$

$$= 27626 i_b$$

$$v_o = -i_c \times 3\cdot6K \parallel 10K$$

$$= -2\cdot65K i_c$$

$$= -2\cdot65K\times\beta i_b$$

$$= -2\cdot65K\times100 i_b = -265000 i_b$$

$$\text{Voltage gain} = \frac{v_o}{v_s} = \frac{-265000}{27626}$$

$$= -9\cdot5924$$

current gain

$$\hat{i}_o = -i_c \times \frac{3.6}{10+3.6}$$

$$= -0.265 i_c$$

$$= -0.265 \times \beta i_b$$

$$= -26.5 i_b$$

Already we know that $i_s = 12.26 i_b$

$$\text{current gain} = \frac{i_o}{i_s} = \frac{-26.5 i_b}{12.26 i_b} = -2.16 = A_i$$

Input resistance

$$R_{in} = \frac{v_s}{i_s} = \frac{27626 i_b}{12.26 i_b} = 2253.3 = 2.253\ K\Omega$$

or

$$R_{in} = 600 + 1.8K \parallel [r_\pi + (\beta+1)\times 180]$$

$$\simeq 600 + 1.8K \parallel [r_\pi + \beta \times 180]$$

$$= 600 + 1.8K \parallel [2.27K + 18K]$$

$$= 600 + 1.8K \parallel 20.27K$$

$$= 600 + 1.6532K$$

$$= 0.6K + 1.6532K = 2.2532\ K\Omega$$

output resistance

$$R_o = 3.6K\Omega \parallel 10K\Omega$$

$$= 2.647\ K\Omega$$

(Q4) For the CC amplifier shown in Fig. Q4 shown below draw the small signal equivalent of the circuit and compute the voltage gain of the circuit $= A_V = \frac{V_o}{V_s}$

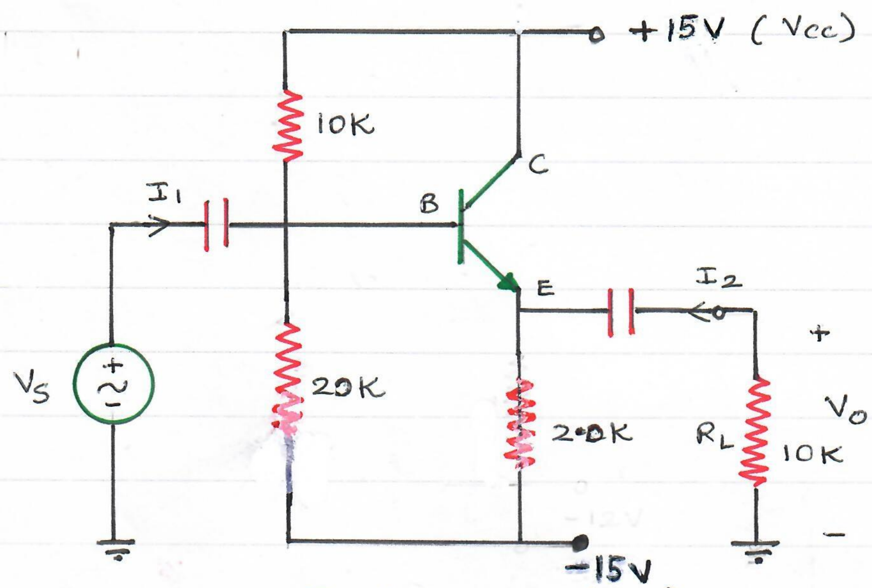


Fig. Q4

Assume that capacitors act as short circuit in the frequency range of interest. Take $\beta = 100$, $V_{BE} = 0.7V$

Sol.

Calculating the Quiescent values

$$V_B = \frac{15 \times 20}{20+10} \quad \frac{-15 \times 10}{20+10} = 5V$$

$$V_E = V_B - V_{BE} = 5 - 0.7 = 4.3V$$

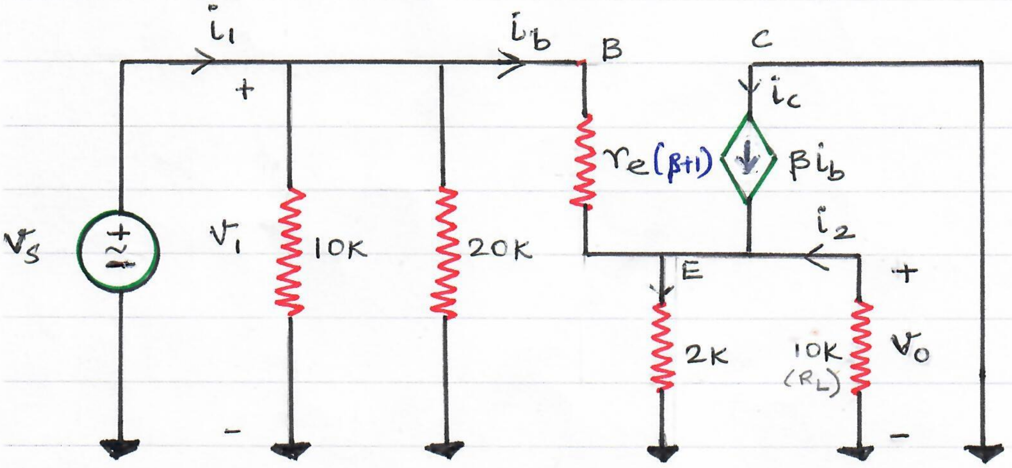
$$I_E = \frac{V_E}{2K} = \frac{4.3}{2K} = 2.15mA$$

$$I_C = \frac{\beta}{\beta+1} I_E = \frac{100}{101} I_E \simeq I_E = 2.15mA$$

$$V_{CE} = V_C - V_E = 15 - 4.3 = 11.7V$$

$$r_e = \frac{25}{I_C(\text{in } mA)} = \frac{25}{2.15} = 11.6\,\Omega$$

Small signal equivalent of the circuit is as given below.



i) $A_V = \frac{v_o}{v_s}$

$$v_o = 10K \times -i_2 = 2K \times i_e$$
$$= 2K \times (\beta+1) i_b$$

$$v_1 = v_s = (\beta+1) r_e i_b + (\beta+1) \times 2K \times i_b$$
$$= (\beta+1) \times (r_e + 2K) i_b$$

$$A_V = \frac{v_o}{v_s} = \frac{2K \times (\beta+1) i_b}{(\beta+1)(r_e + 2K) i_b} \simeq 1 \quad \because r_e + 2K \approx 2K$$