The University of Jordan
Electrical Engineering Department

Electronics II, EE 3 — First Exam — Date: 3/8/ 2017

Name (in Arabic): Dr. El-Ghezawi — KEY SOLUTION — Reg. #:

Answer all questions in ink — Exam Duration : 50 min — Mark out of 20: 20

Q1 a) A common emitter amplifier with $V_{CC} = 15\ V$, $R_C = 3\ K\Omega$ $R_E = 2\ K\Omega$ is properly biased in the forward active mode. It is excited with a small signal such that $i_C = 2\times10^{-3} + 5\times10^{-5}\sin(\omega t)\ A$. $\Rightarrow I_{CQ} = 2\ mA$, $i_c = 50 \sin\omega t\ \mu A$

Given that $r_\pi = 2\ K\Omega$, $\beta_{dc} = \beta_{ac}$ and $V_T = 25mV$. **Calculate**

$i_e = (1+\beta_{ac})\, i_b = \frac{\beta+1}{\beta} i_c$

$\beta_{ac} = g_m r_\pi$

$g_m = \frac{I_{CQ}}{V_T} = \frac{2\times10^{-3}}{25\times10^{-3}} = 0.08\ A/V = 80\ mA/V$

$\beta_{ac} = 80\times10^{-3}\times2\times10^{3} = 160$

$i_e = \frac{161}{160}\times i_c = \frac{161}{160}\times 50\sin\omega t\ \mu A \simeq 50.3125 \sin\omega t\ \mu A$

v_{be}

$v_{be} = r_\pi i_b = r_\pi \frac{i_c}{\beta_{ac}} = \frac{2000\times5\times10^{-5}}{160}\sin\omega t = 62.5\times10^{-5}\sin\omega t\ V$

$= 0.625 \sin\omega t\ mV$

v_{ce} — 5

$(R_C+R_E)i_c + v_{ce} = 0$

$v_{ce} = -5\times10^{3}\times5\times10^{-5}\sin\omega t = -0.25\sin\omega t\ V$

V_{CEQ}

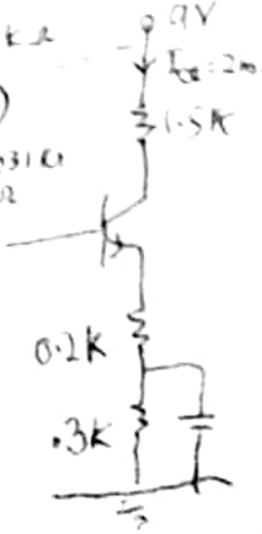
$-V_{CC} + R_C I_{CQ} + V_{CEQ} + \frac{\beta+1}{\beta} I_{CQ} R_E = 0$

$V_{CQ} = 15 - 3\times2 - \frac{161}{160}2\times2 \simeq 5V$ or $4.975V$

b) A **common emitter** amplifier with $R_1 \| R_2 = 50\ K\Omega$, $R_C = 1.5\ K\Omega$, $R_{E1} = 200\ \Omega$, $R_{E2} = 300\ \Omega$ and bypassed by a large capacitance, $R_s = 1\ K\Omega$, $r_\pi = 2.5K\ \Omega$, $r_o = \infty\Omega$, $V_{CC} = 9V$, $I_{CQ} = 2\ mA$, and $V_T = 25\ mV$. **Calculate**

the input resistance R_i

$R_i = R_1 \| R_2 \| R_{ib} = 50 \| (2.5 + (1+\beta_{ac})R_{E1}$; $R_{ib} = 42.7\ k\Omega$



$\beta_{ac} = g_m r_\pi = \frac{2}{25}\times2500 = 200 \Rightarrow R_i = 50 \| (2.5 + 201\times0.2)$

$= 50 \| 42.7 \simeq 23.031\ k\Omega$

$\simeq 23\ k\Omega$

the exact voltage gain

$A_V = \frac{-\beta R_C}{r_\pi + (1+\beta)R_{E1}} \frac{R_i}{R_i + R_s} = \frac{-200\times1.5}{42.7}\times\frac{23}{24}$

$= -6.733$

the approximate voltage gain

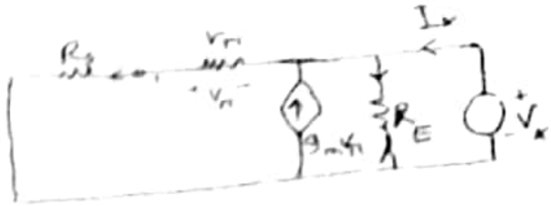
$A_V \simeq -\frac{R_C}{R_{E1}} = \frac{-1.5}{0.2} = -7.5$

the value of V_{CEQ}

$V_{CEQ} = V_{CC} - (R_C + R_{E1} + R_{E2}) I_C \left(\frac{1+\beta}{\beta}\right) = 9 - 2\times2\times1 = 5V$ or $4.975V$

Q2 a) **Draw** the **small signal low frequency** equivalent circuit of a **common collector** (**emitter follower**) amplifier, assuming $R_1 \| R_2$ is infinity ohm , R_s is finite , and $r_o = \infty\Omega$

Derive the **output resistance**



$$R_o = \frac{V_x}{I_x}$$

$$I_x + g_m V_\pi = \frac{V_x}{R_E} + \frac{V_x}{r_\pi + R_s}$$

$$V_\pi = -\frac{r_\pi}{R_s + r_\pi} V_x$$

$$\therefore I_x = \left(\frac{g_m r_\pi}{R_s + r_\pi} + \frac{1}{r_\pi + R_s} + \frac{1}{R_E} \right) V_x$$

$$\frac{I_x}{V_x} = \frac{1}{R_o} = \frac{1+\beta}{r_\pi + R_s} + \frac{1}{R_E}$$

$$\therefore R_o = \frac{r_\pi + R_s}{1+\beta} \| R_E$$

$$= \frac{\frac{R_E (r_\pi + R_s)}{1+\beta}}{\frac{r_\pi + R_s}{1+\beta} + R_E} = \frac{R_E (r_\pi + R_s)}{r_\pi + R_s + (1+\beta) R_E}$$

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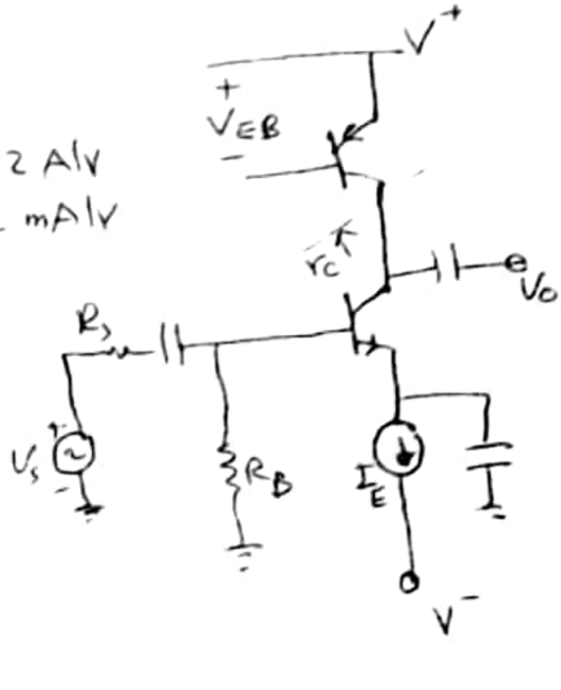
b) **Draw** a **two** transistor common emitter amplifier circuit employing an **active load** . The circuit is biased by an independent current source I_E and a base resistance R_B together with any needed voltage sources.

Given that $I_E = 2\ mA$, $\beta_{dc} = \beta_{ac} = 99$, $V_T = 25\,mV$, and $V_A = 396\,V$, **calculate** the small signal voltage gain , given that $r_c = 150\ K\Omega$.



$$A_V = -g_m (r_o \| r_c) \quad ; I_{CQ} = 1.98\,mA$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{\beta}{1+\beta} \frac{I_E}{V_T} = \frac{99}{100} \times \frac{2}{25} = 0.0792\ A/V$$

$$= 79.2\ mA/V$$

$$r_o = \frac{V_A}{I_{CQ}} = \frac{396}{1.98\,mA} = 200\,k\Omega$$

hence $A_V = -79.2 (200 \| 150)$

$$= -79.2 \times 85.7$$

$$= -6788.5$$

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