INTRODUCTION TO ELECTRONICS (21604)
HOMEWORK #7
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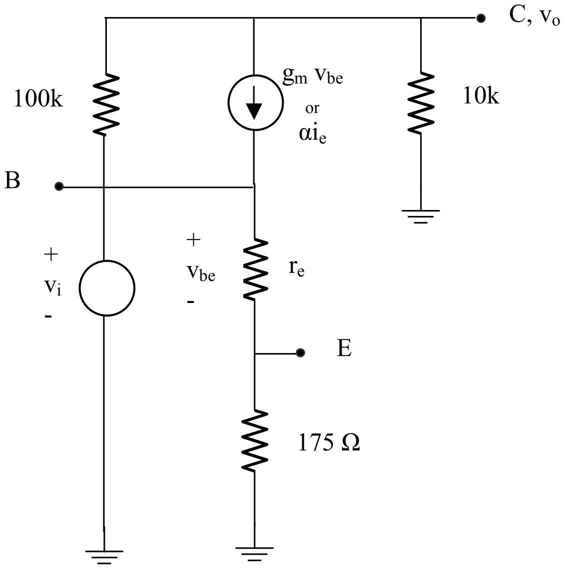
DUE DATE and TIME 2 May 2003 - 12.00

SOLUTIONS:

Problem *4.85: From the circuit on p. 344 of the book it is very obvious that $1mA = I_c + I_B = I_E$. Thus $I_C = \frac{\beta}{\beta+1} I_E = 0{,}99mA$. Also $V_C = I_B 100k + V_{BE} + I_E 175 = 1{,}77V$.



For AC analysis take the T-model in Fig. 4.27 on p. 261 with $r_e = \frac{1}{g_m} = 25\Omega$ as shown on the right. $v_i = v_b = i_e(r_e + 175\Omega) = g_m v_{be}(r_e + 175\Omega)$. Now try to solve for v_o *assuming there is no current flow through 100k*: $v_o = -10k \cdot g_m v_{be}$, thus, $A = \frac{v_o}{v_i} = \frac{10k}{r_e + 175\Omega} = -50$. With the current through 100k taken into consideration, the calculations are a bit more complicated because the current through 10k is not $-\alpha i_e = -0{,}99\ i_e$, but, $i_{10k} = \frac{r_e + 175\Omega - \alpha \cdot 100k}{100k + 10k} i_e = -0{,}9 \cdot i_e$.

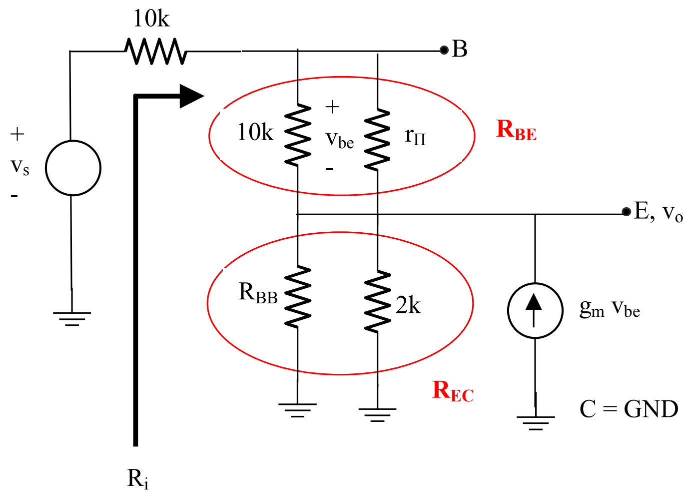
Subsequently, $A = \frac{v_o}{v_i} = \frac{10k \cdot i_{10k}}{i_e(r_e + 175\Omega)} \cong -45$.

Problem **4.95: This is the bootstrapped follower that has special properties we will see as we solve the problem. **(a)** To analyze DC conditions, we first need to (1) remember that all capacitors are open circuited and then (2) find the Thevenin equivalent of the two 20k resistors in series connected to 9 V power supply. $V_{BB} = \frac{20k}{20k + 20k} 9V = 4{,}5V$ and $R_{BB} = 20k \parallel 20k = 10k$. From V_{BB} via R_{BB} and 10k base resistor, over BE junction of the transistor via 2k resistor to ground one can write the following loop equation $-V_{BB} + I_B(R_{BB} + 10k) + V_{BE} + I_E 2k = 0$. Using the values provided and presumed known $I_B = \frac{4{,}5V - 0{,}6V}{(10k + 10k) + 101 \cdot 2k} = 17{,}5\mu A \Rightarrow I_E = (\beta+1) I_B = 1{,}77mA$. Also,

$$g_m = \frac{I_C}{V_T} = \frac{\beta I_B}{V_T} = 70mA/V; \quad r_e = \frac{V_T}{I_E} = 14{,}1\Omega; \qquad r_\Pi = (\beta+1) r_e = 1423{,}08\Omega \approx 1k4.$$

GOOD LUCK!

(b) To analyze AC conditions, look at the equivalent circuit on the right. It is obvious that the 4 resistors can be taken account as 2 resistors in series. To find $R_i = \frac{v_x}{i_x}$, we have to calculate the current i_{10k} through 10k resistor in R_{BE}; i_b flows through r_Π.and $i_x = i_b + i_{10k}$.



With $i_{10k} = \frac{v_{be}}{10k} = \frac{r_\Pi}{10k} i_b$ one can calculate

$$i_x = \left[\frac{1}{10k} + \frac{1}{r_\Pi}\right] v_{be} = \left[\frac{r_\Pi}{10k} + 1\right] i_b .$$

$v_x = v_{be} + v_{R_{EC}} = v_{be} + i_{R_{EC}} R_{EC}$ with $i_{R_{EC}} = \left[\frac{1}{10k} + \frac{1}{r_\Pi} + g_m\right] v_{be}$ resulting in

$$R_i = \frac{1 + \left[\frac{1}{10k} + \frac{1}{r_\Pi} + g_m\right] \cdot R_{EC}}{\frac{1}{10k} + \frac{1}{r_\Pi}} = 111k1.$$

Note that, (1) R_i is much larger than $R_{BE}+R_{EC}$. (2) $R_i >> 10k$, (3) $R_{BE} \approx R_{EC}$. We find $A_v = \frac{v_o}{v_s} = \frac{v_o}{v_i} \cdot \frac{v_i}{v_o} = \frac{v_o}{v_i} \cdot \frac{R_i}{R_i + 10k} = 0{,}917 \frac{v_o}{v_i}$ with $v_i = v_{be} + v_o$

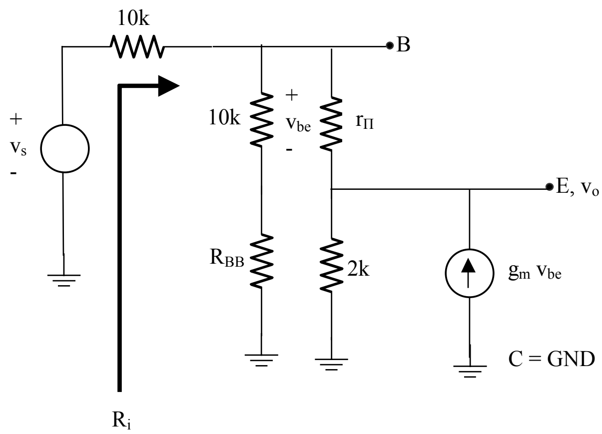
and $v_o = v_{R_{EC}}$. Thus,

$$\frac{v_o}{v_i} = \frac{v_{R_{EC}}}{v_{be} + v_{R_{EC}}} = \frac{R_{EC}\left[\frac{1}{10k} + \frac{1}{r_\Pi} + g_m\right]}{1 + R_{EC}\left[\frac{1}{10k} + \frac{1}{r_\Pi} + g_m\right]} = 0{,}99.$$

This was expected, because this is a common-collector circuit. Finally, $A_v = \frac{v_o}{v_s} = \frac{v_o}{v_i} \cdot \frac{v_i}{v_o} = 0{,}91$.

(c)

$$R_i = \frac{v_x}{i_x} = \frac{v_x}{i_b + \frac{v_x}{10k + R_{BB}}} = \frac{v_{be} + v_{2k}}{i_b + \frac{v_{be} + v_{2k}}{10k + R_{BB}}}$$



with $$v_{2k} = 2k(i_b + g_m v_{be}) = 2k \cdot v_{be}\left[\frac{1}{r_\Pi} + g_m\right].$$

$$R_i = \frac{r_\Pi + (1 + g_m r_\Pi)2k}{1 + \frac{r_\Pi + (1 + g_m r_\Pi)2k}{20k}} = 18k18 << 111k1!!$$

$$A_v = \frac{v_o}{v_i} \cdot \frac{R_i}{R_i + 10k} = 0{,}645 \frac{v_o}{v_i} = 0{,}645 \frac{v_o}{v_o + v_{be}}$$

$$\Rightarrow A_v = \frac{v_o}{v_s} = 0{,}645 \frac{\left[\frac{1}{r_\Pi} + g_m\right]2k}{1 + \left(\frac{1}{r_\Pi} + g_m\right)2k} = 0{,}644 < 0{,}91$$

GOOD LUCK!

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