CMPE 314 Midterm Exam 2

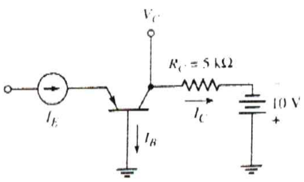
(April 5, 2012)

Problem 1 (15 points)

Describe the structure and operation of a pnp bipolar transistor. What are the biasing conditions (show relevant voltage connections in the structure figure) for cut-off, forward-active mode, and saturation mode?

Problem 2 (25 points)

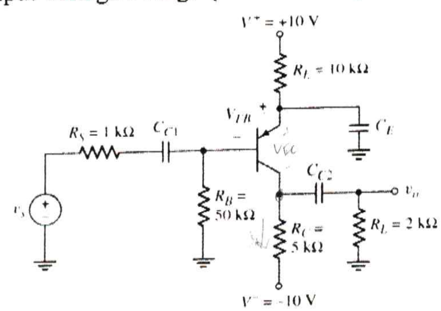
For the transistor circuit shown has properties β=80, V_{EB}(on)=0.7 V and V_{EC}(sat)=0.2 V. The bias current source has I_E=2.2 mA and V^+= 5 V. Determine V_C and the power dissipated in the transistor. Is the transistor biased in the forward-active mode. Why or why not?



Problem 3 (35 points)

(a) Derive the equations to determine I_{CQ} and V_{CEQ}. Find the DC load-line slope. What are the roles of R_E and C_E?

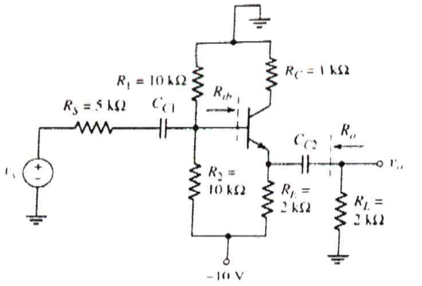
(b) Assume finite V_A. Draw the small-signal circuit with the hybrid-π model for the transistor. How to determine the hybrid-π model parameters? Find the AC load-line slope and the maximum symmetric output voltage swing. (Work with equations for Problem 3)



Problem 4 (25 points)

(a) Assume $V_A = \infty$. Draw the small-signal circuit, including the hybrid-π model.

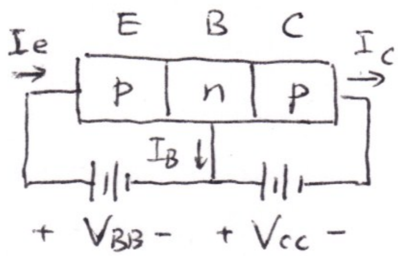
(b) Find the equivalent input resistance R_{ib} and the small-signal voltage gain. Comment on the type of amplifier configuration and its main features. (Work with equations for Problem 4)



CMPE 314 Midterm Exam II Spring 2012

Solutions

P1



· In forward-active mode

$V_{BB} > V_{EB}(on)$ forward biased

$V_{CB} < 0$ reverse biased

Holes injected from emitter into base and diffused to BC-junction, swept by the BC-junction space-charg field into collector

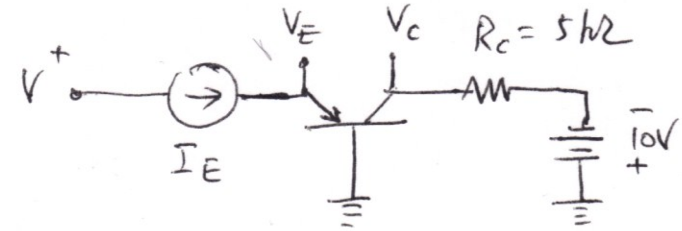
· $V_{EB} < V_{EB}(on) \doteq 0.7\,V$, BJT is in cut-off

$V_{EC} < V_{EC}(sat) \doteq 0.2\,V$, BJT is in saturation.

$$I_E = I_C + I_B$$

$I_E \downarrow$ from holes; $I_C \downarrow$ holes; $I_B \downarrow$ electrons

P2



$I_E = 2.2\ mA$

$R_c = 5\ k\Omega$

If BJT is in the forward-active mode

$$I_C = \frac{\beta}{1+\beta} = \frac{80}{81} \times 2.2\ mA = 2.173\ mA$$

$$V_{R_C} = R_C I_C = 5\ k\Omega \times 2.173\ mA = 10.865\ V$$

$$V_C = -10 + R_C I_C = 0.865\ V$$

$$V_E = 0.7\ V$$

$$V_{EC} = V_E - V_C = 0.7 - 0.865 = -0.165\ V < V_{EC}(sat)$$

BJT is in saturation.

$$V_C = V_{EC} - V_{EC}(sat) = 0.7 - 0.2 = 0.5\ V$$

$$I_C = \frac{V_C - (-10V)}{5\ k\Omega} = 2.1\ mA$$

$$I_B = I_E - I_C = 2.2 - 2.1 = 0.1\ mA$$

$$P_Q = V_{EB} I_B + V_{EC} I_C = 0.07 + 0.42 = 0.49\ mW$$

P3

(a)

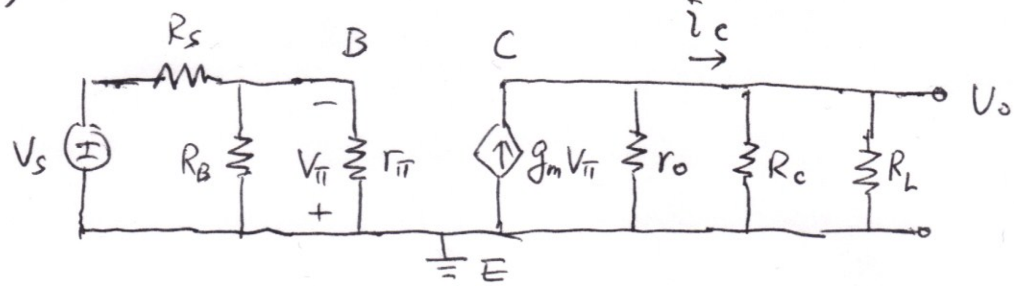
$$\begin{cases} V^+ = I_E R_E + V_{EB(on)} + I_B R_B \\ V^+ - V^- = I_E R_E + V_{EC} + I_C R_C \\ I_C = \beta I_B, \quad I_E = (1+\beta) I_B = \frac{1+\beta}{\beta} I_C \end{cases}$$

$$\text{DC loadline slope} = -\frac{1}{R_C + \frac{1+\beta}{\beta} R_E}$$

R_E is used to stabilize the Q-pt.

C_E is used to short R_E to increase the AC loadline slope

(b)



$$g_m = \frac{I_{CQ}}{V_T} \qquad r_\pi = \frac{V_T}{I_{BQ}} \qquad r_o = \frac{V_A}{I_{CQ}} \qquad V_T = \frac{k_B T}{e}$$

$$v_o = -v_{ec} = i_c (R_C \| R_L)$$

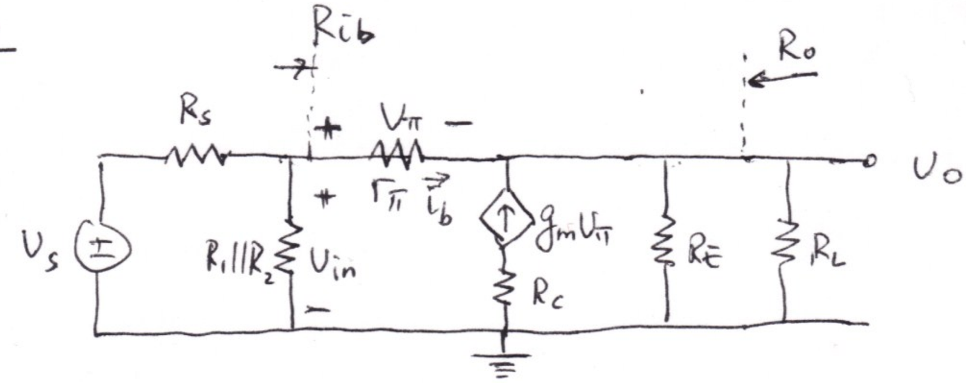
$$\text{AC loadline slope} = -\frac{1}{R_C \| R_L}$$

Maximum symmetric swing of i_c: $|\Delta i_c| = 2 I_{CQ}$

Maximum symmetric swing of v_o: $|\Delta v_o| = |\Delta i_c| (R_C \| R_L)$

P4

(a)



(b)

$$v_{in} = v_\pi + v_o$$

$$= i_b r_\pi + (1+\beta) i_b R_E \| R_L$$

$$v_\pi = \beta i_b$$

$$g_m v_\pi = \beta i_b$$

$$R_{ib} \equiv \frac{v_{in}}{i_b} = r_\pi + (1+\beta) R_E \| R_L$$

$$v_o = (1+\beta) i_b (R_E \| R_L) = \frac{(1+\beta)(R_E \| R_L)}{R_{ib}} v_{in}$$

$$v_{in} = v_s \frac{R_1 \| R_2 \| R_{ib}}{R_s + R_1 \| R_2 \| R_{ib}}$$

$$A_v = \frac{v_o}{v_s} = \frac{(1+\beta)(R_E \| R_L)}{R_{ib}} \cdot \frac{R_1 \| R_2 \| R_{ib}}{R_s + R_1 \| R_2 \| R_{ib}}$$

It is an emitter-follower circuit.

$A_v \lesssim +1$

$A_i > 1$

R_o is small