Problem 4 - Analog and Digital Electronics - Solutions

a)

$$I_{EQ} = \frac{\beta+1}{\beta} I_{CQ} = 10.1\ mA$$

$$\therefore R_E = \frac{V_{EQ}}{I_{EQ}} = 990\ \Omega$$

$$I_B R_B = \frac{I_{CQ}}{\beta} R_B = 15 - 0.7 - 10 = 4.3$$

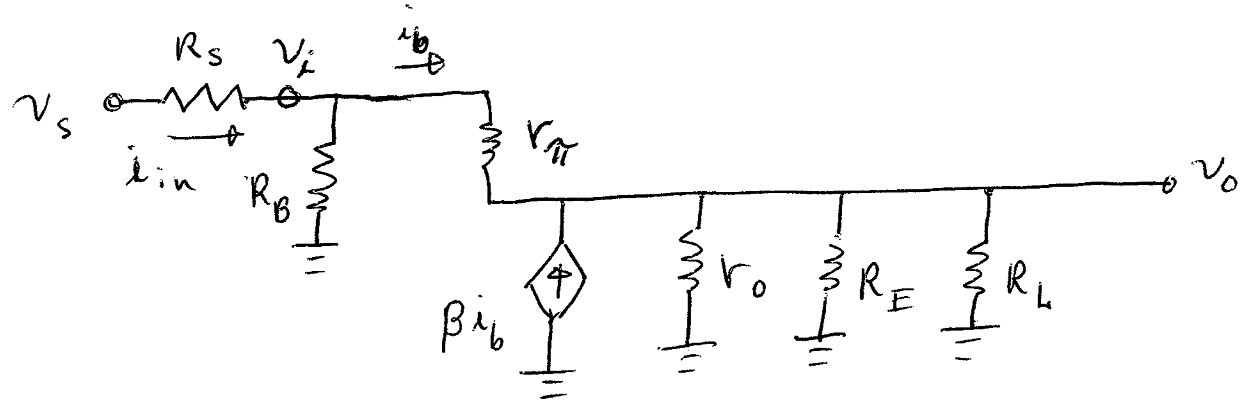
$$\therefore R_B = 43\ K\Omega$$

b)

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = 260\ \Omega$$

$$r_o = \frac{V_A}{I_{CQ}} = 20\ K\Omega$$

Small Signal CKT. at midband:




For Rin: Let $R_L' = R_L \,//\, r_o \,//\, R_E = 794\ \Omega$

$$i_{in} = \frac{v_i}{R_B} + i_b$$

$$v_i = i_b r_\pi + (\beta+1) i_b R_L'$$

$$\therefore i_b = v_i / [r_\pi + (\beta+1) R_L']$$

$$\therefore R_{in} = v_i / i_{in} = \frac{1}{1/R_B + 1/[r_\pi + (\beta+1) R_L']} = 28\ K\Omega$$

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**For $R_{out}$:** Ground $V_s$ and apply $v_x$ to $v_o$ and determine $i_x$ without $R_L$.

Let $R_E' = R_E // r_o = 943\,\Omega$

$R_s' = R_s // R_B = 249\,\Omega$

$$\therefore\ i_x = \frac{v_x}{R_E'} + \frac{v_x}{r_\pi + R_s'} + \beta \frac{v_x}{r_\pi + R_s'}$$

$$\therefore\ R_{out} = \frac{v_x}{i_x} = \frac{1}{1/R_E' + \frac{1+\beta}{r_\pi + R_s'}} = 5\,\Omega$$

**For $A_v$:**

$$i_b = \frac{v_i - v_o}{r_\pi}$$

$$v_o = (\beta+1)\, i_b\, R_L' = \frac{(\beta+1) R_L'}{r_\pi}(v_i - v_o)$$

$$\therefore\ A_v = \frac{v_o}{v_i} = \frac{(\beta+1)R_L'}{[r_\pi + (1+\beta)R_L']} = 0.997$$

**For $G_v$:**

$$G_v = \frac{v_o}{v_s} = \frac{v_o}{v_i}\frac{v_i}{v_s} = A_v \frac{R_{in}}{R_{in} + R_s} = 0.988$$

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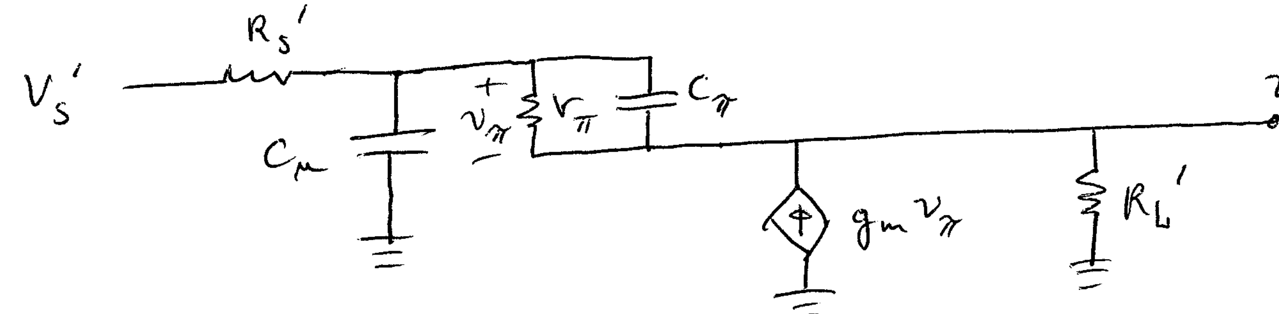
c) i) $f_{LC1} = \dfrac{1}{2\pi(R_s+R_{in})C_1} = 0.56\ Hz$

$f_{LC2} = \dfrac{1}{2\pi(R_{out}+R_L)C_2} = 31.8\ Hz.$

$\therefore f_L \simeq 31.8\ Hz.$

ii)

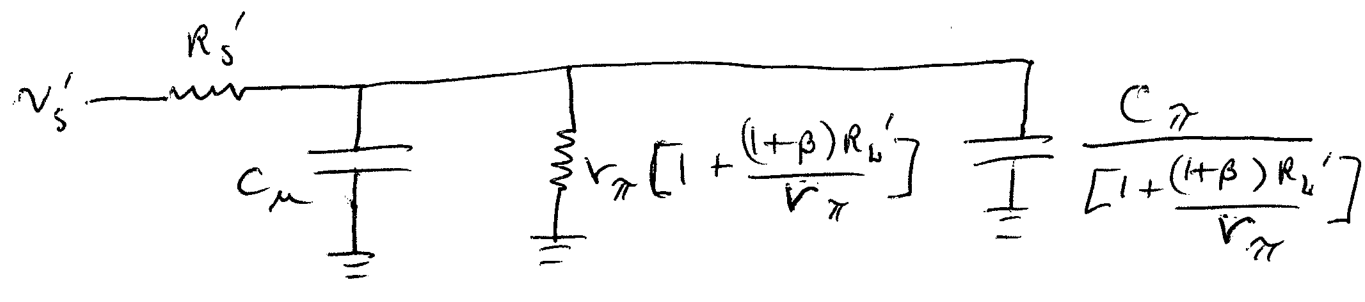
Small Signal Ckt. at high frequency:




Now Use Miller. Effect: $g_m = \dfrac{I_{CQ}}{V_T} = 385\ mA/V$

Now: $1 - A_v = 1/[1 + \dfrac{(1+\beta)R_L'}{r_\pi}] = 1/309$

Yields on input side:



Problem 4 - Analog and Digital Electronics - Solutions

Let: $C_T = C_\mu + \dfrac{C_\pi}{\left[1 + \dfrac{(1+\beta)R_L'}{r_\pi}\right]} = 5\,pF$

Let: $R_T = R_s' \,//\, r_\pi \left[1 + \dfrac{(1+\beta)R_L'}{r_\pi}\right] = 248\,\Omega$

$\therefore\; f_H = \dfrac{1}{2\pi C_T R_T} \simeq 128\ MHz.$