Electronics II, Spring 2018 Exam1 Solution 2018/3/30

#1

dc analysis

$$I_D = \frac{V^+ - V_{SG}}{R_S} = K_P\left(V_{SG} + V_{TP}\right)^2$$

$$5 - V_{SG} = (1)(4)\left(V_{SG} - 0.8\right)^2$$

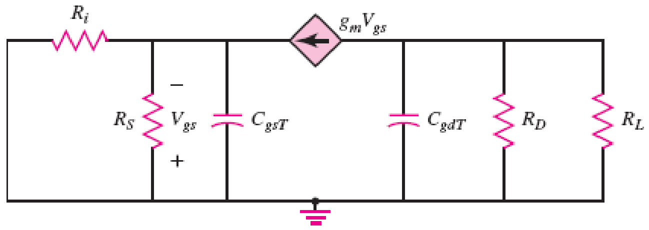
$$= 4\left(V_{SG}^2 - 1.6V_{SG} + 0.64\right)$$

$$4V_{SG}^2 - 5.4V_{SG} - 2.44 = 0$$

$$V_{SG} = \frac{5.4 \pm \sqrt{(5.4)^2 + 4(4)(2.44)}}{2(4)} = 1.707$$

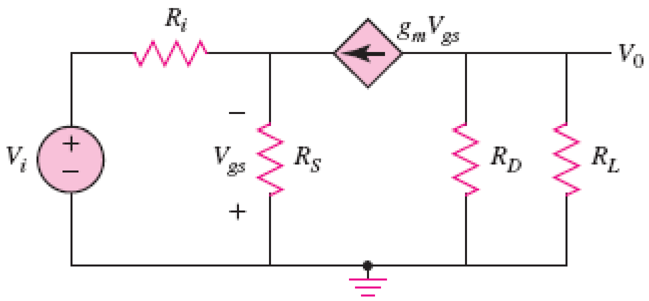
$$g_m = 2K_P\left(V_{SG} + V_{TP}\right) = 2(1)(1.707 - 0.8)$$

$$g_m = 1.81\ mA/V$$



3-dB frequency due to C_{gsT} : $R_{eq} = \frac{1}{g_m} \| R_S \| R_i$

Midband gain



$$V_{gs} = \frac{-\frac{1}{g_m} \| R_S}{\frac{1}{g_m} \| R_S + R_i} \cdot V_i = \frac{-\frac{1}{1.81} \| 4}{\frac{1}{1.81} \| 4 + 0.5} \cdot V_i$$

$$= -0.492V_i$$

$$V_0 = -g_m V_{gs}\left(R_D \| R_L\right)$$

$$A_v = (0.492)(1.81)(4\|2) \Rightarrow \underline{A_v = 1.19}$$

$$f_A = \frac{1}{2\pi R_{eq} \cdot C_{gsT}}$$

$$R_{eq} = \frac{1}{1.81} \| 4 \| 0.5 = 0.246\ \text{k}\Omega$$

$$f_A = \frac{1}{2\pi(246)\left(4\times10^{-12}\right)} = 162\ \text{MHz}$$

3-dB frequency due to C_{gdT}

$$f_B = \frac{1}{2\pi\left(R_D \| R_L\right)C_{gdT}}$$

$$= \frac{1}{2\pi(2\|4)\times10^3\times10^{-12}}$$

$$\underline{f = 119\ \text{MHz}}$$

#2

Solution (DC Analysis): We find, for each stage,

$$R_{TH} = R_1 \| R_2 = 55 \| 31 = 19.83\ \text{k}\Omega$$

and

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC} = \left(\frac{31}{31 + 55}\right)(5) = 1.802\ \text{V}$$

Now

$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1+\beta)R_E} = \frac{1.802 - 0.7}{19.83 + (201)(1)} \Rightarrow 4.99\ \mu\text{A}$$

so that

$$I_{CQ} = 0.998\ \text{mA}$$

Solution (AC Analysis): The small-signal diffusion resistance is

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{(200)(0.026)}{0.988} = 5.21\ \text{k}\Omega$$

The input resistance looking into each base terminal is

$$R_i = r_\pi + (1+\beta)R_E = 5.21 + (201)(1) = 206.2\ \text{k}\Omega$$

Solution (AC Design): The small-signal equivalent circuit is shown in Figure 7.74. The time constant of the first stage is

$$\tau_A = (R_1 \| R_2 \| R_i) C_{C1}$$

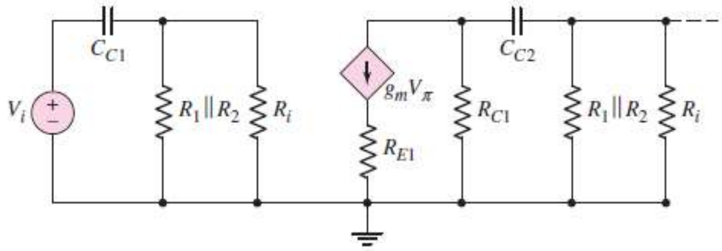


Figure 7.74 Small-signal equivalent circuit of two-stage BJT amplifier with coupling capacitors for design application

and the time constant of the second stage is

$$\tau_B = (R_{C1} + R_1 \| R_2 \| R_i) C_{C2}$$

If the 3 dB frequency of each stage is to be 20 Hz, then

$$\tau_A = \tau_B = \frac{1}{2\pi f_{3\text{-dB}}} = \frac{1}{2\pi(20)} = 7.958 \times 10^{-3}\ \text{s}$$

The coupling capacitor of the first stage must be

$$C_{C1} = \frac{\tau_A}{R_1 \| R_2 \| R_i} = \frac{7.958 \times 10^{-3}}{(55 \| 31 \| 206.2) \times 10^3} \Rightarrow 0.44\ \mu\text{F}$$

and the coupling capacitor of the second stage must be

$$C_{C2} = \frac{\tau_B}{R_{C1} + R_1 \| R_2 \| R_i} = \frac{7.958 \times 10^{-3}}{(2.5 + 55 \| 31 \| 206.2) \times 10^3} \Rightarrow 0.386\ \mu\text{F}$$

#3

$$V_{B1} = \left(\frac{R_3}{R_1 + R_2 + R_3}\right)(12) = \left(\frac{7.92}{58.8 + 33.3 + 7.92}\right)(12) = 0.9502 \text{ V}$$

Neglecting base currents

$$I_C = \frac{0.9502 - 0.7}{0.5} = 0.50 \text{ mA}$$

$$r_\pi = \frac{\beta V_T}{I_C} = \frac{(100)(0.026)}{0.5} = 5.2 \text{ K}$$

$$g_m = \frac{I_C}{V_T} = \frac{0.5}{0.026} = 19.23 \text{ mA/V}$$

From Eq (7.119(a)),

$$\tau_{p\pi} = (R_S \| R_{B1} \| r_\pi)(C_{\pi 1} + C_{M1})$$

$$R_{B1} = R_2 \| R_3 = 33.3 \| 7.92 = 6.398 \text{ k}\Omega$$

$$C_{M1} = 2C_{\mu 1} = 6 \text{ pF}$$

Then

$$\tau_{p\pi} = (1 \| 6.398 \| 5.2) \times 10^3 \times (24 + 6) \times 10^{-12} \Rightarrow \tau_{p\pi} = 22.24 \text{ ns}$$

$$f_{H\pi} = \frac{1}{2\pi \tau_{p\pi}} = \frac{1}{2\pi(22.24 \times 10^{-9})} \Rightarrow f_{H\pi} = 7.15 \text{ MHz}$$

From Eq (7.120(a)),

$$\tau_{p\mu} = (R_C \| R_L) C_{\mu 2} = (7.5 \| 2) \times 10^3 \times 3 \times 10^{-12} \Rightarrow \tau_{p\mu} = 4.737 \text{ ns}$$

$$f_{H\mu} = \frac{1}{2\pi \tau_{p\mu}} = \frac{1}{2\pi(4.737 \times 10^{-9})} \Rightarrow f_{H\mu} = 33.6 \text{ MHz}$$

From Eq. (7.125),

$$|A_\upsilon|_M = g_{m2}(R_C \| R_L)\left[\frac{R_{B1} \| r_{\pi 1}}{R_{B1} \| r_{\pi 1} + R_S}\right] = (19.23)(7.5 \| 2)\left[\frac{6.40 \| 5.2}{6.40 \| 5.2 + 1}\right]$$

$$|A_\upsilon|_M = 22.5$$