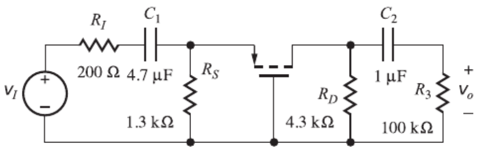
1.



$$g_m V = \frac{V_I - V}{R_I + 1/C_1 s} - \frac{V}{R_S}$$

$$V = \frac{\frac{V_I}{R_I + 1/C_1 s}}{g_m + \frac{1}{R_I + 1/C_1 s} + \frac{1}{R_S}}$$

$$= V_I \cdot \frac{R_S}{R_S + (g_m R_S + 1)(R_I + 1/C_1 s)}$$

$$V_O = g_m V \cdot \frac{R_D}{R_D + R_3 + 1/C_2 s} \cdot R_3$$

$$\frac{V_O}{V_I} = g_m \frac{R_S}{R_S + (g_m R_S + 1)(R_I + 1/C_1 s)} \frac{R_D}{R_D + R_3 + 1/C_2 s} R_3$$

$$= \frac{g_m R_S R_D R_3 C_1 s C_2 s}{[C_1 s(R_S + R_I + g_m R_S R_I) + g_m R_S + 1][C_2 s(R_D + R_3) + 1]}$$

$$\omega_{z_1} = \omega_{z_2} = 0$$

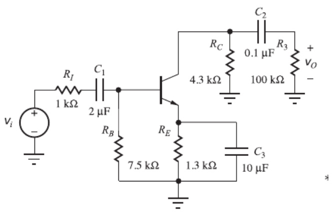
$$\omega_{p_1} = -\frac{g_m R_s + 1}{C_1(R_S + R_I + g_m R_S R_I)} \approx -569.91\,\text{rad/s}$$

$$\omega_{p_2} = -\frac{1}{C_2(R_D + R_3)} \approx -9.59\,\text{rad/s}$$

$$f_c = \frac{\omega_{p_1} + \omega_{p_2}}{2\pi} \approx 92.23\,\text{Hz}$$

$$A_{mid} = \frac{g_m(R_D \parallel R_3)}{1 + g_m(R_I \parallel R_S)} \cdot \frac{R_S}{R_I + R_S} \approx 9.57$$

2.



$$g_m = \frac{I_C}{V_T} = \frac{1\,\text{mA}}{0.025\,\text{V}} = 40\,\text{mS}$$

$$c_\pi = \frac{g_m}{2\pi f_T} = \frac{40\,\text{mS}}{2\pi \cdot 500\,\text{MHz}} \approx 12.73\,\text{pF}$$

$$r_\pi = \frac{\beta_0}{g_m} = \frac{100}{40\,\text{mS}} = 2.5\,\text{k}\Omega$$

$$r_{\pi_0} = (R_I \parallel R_B + r_x) \parallel r_\pi = [(1 \parallel 7.5 + 0.3) \parallel 2.5]\,\text{k}\Omega \approx 802\,\Omega$$

$$R_L = R_C \parallel R_3 = 4.123\,\text{k}\Omega$$

$$c_T = c_\pi + c_\mu \left(1 + g_m R_L + \frac{R_L}{r_{\pi_0}}\right) = \approx 141.03\,\text{pF}$$

$$f_{p_1} = \frac{1}{2\pi r_{\pi_0} c_T} = \frac{1}{2\pi \cdot 802\,\Omega \cdot 141.03\,\text{pF}} \approx 1.41\,\text{MHz}$$

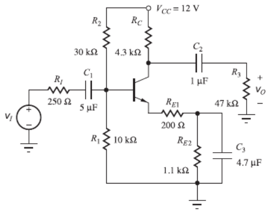
$$f_{p_2} = \frac{g_m}{2\pi c_\pi} = \frac{40\,\text{mS}}{2\pi \cdot 12.73\,\text{pF}} \approx 500.09\,\text{MHz}$$

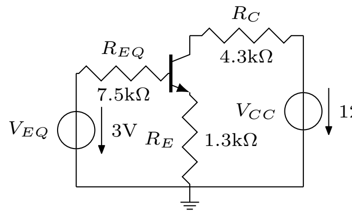
$$f_H = f_{p_1} = 1.41\,\text{MHz}$$

$$A_{mid} = \frac{R_L[R_B \parallel (r_\pi + r_x)]}{R_I + [R_B \parallel (r_\pi + r_x)]} \cdot \frac{-g_m r_\pi}{r_\pi + r_x} \approx -98.79$$

$$GBW = |A_{mid}| f_H = 139.29\,\text{MHz}$$

3.





Suppose $V_{BE} = 0.7V$,

$$I_C = \frac{V_{EQ} - V_{BE}}{\frac{R_{EQ}}{\beta_0} + \frac{\beta_0 + 1}{\beta_0} R_E} \approx 1.657\,\text{mA}$$

$$I_E = \frac{V_{EQ} - V_{BE}}{\frac{R_{EQ}}{\beta_0 + 1} + R_E} \approx 1.673\,\text{mA}$$

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E = 2.7\,\text{V}$$

So the Q point is $(1.657\,\text{mA},\ 2.7\,\text{V})$.

$$g_m = \frac{I_C}{V_T} = \frac{1.657\,\text{mA}}{0.025\,\text{V}} = 66.28\,\text{mS}$$

$$r_\pi = \frac{\beta_0 V_T}{I_C} = \frac{100 \cdot 0.025\,\text{V}}{1.657\,\text{mA}} \approx 1.508\,\text{k}\Omega$$

$$r_{\pi_0} = [(R_{EQ} \parallel R_I) + r_x] \parallel [r_\pi + (\beta_0 + 1)R_E] \approx 576\,\Omega$$

$$R_L = R_C \parallel R_3 = (4.3 \parallel 47)\,\text{k}\Omega = 3.94\,\text{k}\Omega$$

$$c_\pi = \frac{g_m}{2\pi f_T} - c_\mu = \frac{66.28\,\text{mS}}{2\pi \cdot 200\,\text{MHz}} - 1\,\text{pF} \approx 51.74\,\text{pF}$$

$$c_T = \frac{c_\pi}{1 + g_m R_E} + c_\mu \left(1 + \frac{g_m R_L}{1 + g_m R_E +} + \frac{R_L}{r_{\pi_0}}\right) \approx 29.79\,\text{pF}$$

For f_H,

$$f_{p_1} = \frac{1}{2\pi r_{\pi_0} c_T} = \approx 9.275\,\text{MHz}$$

$$f_{p_2} = \frac{g_m}{2\pi(1 + g_m R_E)c_\pi} = \approx 14.30\,\text{MHz}$$

$$f_z = \frac{g_m}{2\pi(1 + g_m R_E)c_\mu} = \approx 739.95\,\text{MHz}$$

$$f_H = \frac{1}{\sqrt{f_{p_1}^{-2} + f_{p_2}^{-2} - 2f_z^{-2}}} \approx 7.78\,\text{MHz}$$

For f_L,

$$R_{iB} = r_\pi + r_x + (\beta_0 + 1)R_E = 22.06\,\text{k}\Omega$$

$$R_{1s} = R_I + R_{EQ} \parallel R_{iB} = \approx 5.85\,\text{k}\Omega$$

$$R_{2s} = R_3 + R_C = (4.3 + 47)\,\text{k}\Omega = 51.3\,\text{k}\Omega$$

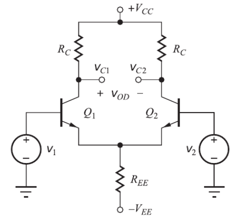
$$R_{3s} = R_{E2} \parallel \left[\frac{r_\pi + r_x + R_I \parallel R_{EQ}}{\beta_0 + 1} + R_{E1}\right] \approx 184\,\Omega$$

$$f_L = \frac{1}{2\pi(R_{1s}C_1)} + \frac{1}{2\pi(R_{2s}C_2)} + \frac{1}{2\pi(R_{3s}C_3)} \approx 197\,\text{Hz}$$

For A_{mid},

$$A_{mid} = \frac{-g_m R_L}{1 + g_m R_{E1}} \cdot \frac{R_{EQ} \parallel R_{iB}}{R_I + R_{EQ} \parallel R_{iB}} \cdot \frac{r_\pi + (\beta_0 + 1)R_{E1}}{r_\pi + r_x + (\beta_0 + 1)R_{E1}} \approx -17.26$$

4.



Suppose $V_{BE} = 0.7\,\text{V}$,

$$I_E = \frac{V_{EE} - V_{BE}}{2R_{EE}} = \frac{18\,\text{V} - 0.7\,\text{V}}{2 \cdot 47\,\text{k}\Omega} \approx 0.184\,\text{mA}$$

$$I_C = I_E \frac{\beta_F}{\beta_F + 1} = 0.368\,\text{mA} \cdot \frac{100}{101} \approx 0.182\,\text{mA}$$

$$V_C = V_{CC} - I_C R_C = 18\,\text{V} - 0.364\,\text{mA} \cdot 50\,\text{k}\Omega \approx 8.9\,\text{V}$$

$$V_{CE} = V_C + V_{BE} = 9.6\,\text{V}$$

So the Q point is $(0.184\,\text{mA},\ 9.6\,\text{V})$.

$$g_m = \frac{I_C}{V_T} = \frac{0.182\,\text{mA}}{0.025\,\text{V}} = 7.28\,\text{mS}$$

$$A_{dd} = -g_m R_C = -7.28\,\text{mS} \cdot 50\,\text{k}\Omega = -364$$

$$A_{cc} = -\frac{R_C}{2R_{EE}} = -\frac{50\,\text{k}\Omega}{2 \cdot 47\,\text{k}\Omega} \approx -0.53$$

$$CMRR = \frac{A_{dd}}{2A_{cc}} = \frac{-364}{2 \cdot -0.53} \approx 343$$

Differential-mode:

$$r_{id} = 2r_\pi = 2\frac{\beta_F}{g_m} = \frac{2 \cdot 100}{7.28\,\text{mS}} \approx 27.5\,\text{k}\Omega$$

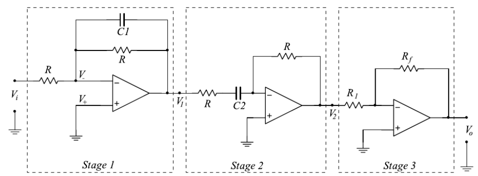
$$r_{od} \approx 2R_C = 100\,\text{k}\Omega$$

Common-mode:

$$r_{ic} = \frac{r_\pi}{2} + (\beta_F + 1)R_{EE} = \frac{\beta_F}{2g_m} + (\beta_F + 1)R_{EE} \approx 4.75\,\text{M}\Omega$$

$$r_{oc} \approx R_C = 50\,\text{k}\Omega$$

5.



Let $s = j\omega$,

$$\frac{V_i}{R} = -\frac{V_1}{R \parallel (1/C_1 s)} = -V_1 \frac{R + 1/C_1 s}{R/C_1 s}$$

$$\frac{V_1}{V_i} = -\frac{1/C_1 s}{R + 1/C_1 s} = -\frac{1}{RC_1 s + 1}$$

$$\frac{V_2}{V_1} = -\frac{R}{R + 1/C_2 s} = -\frac{RC_2 s}{RC_2 s + 1}$$

$$\frac{V_o}{V_2} = -\frac{R_f}{R_1}$$

$$\frac{V_o}{V_i} = \frac{V_1}{V_i} \cdot \frac{V_2}{V_1} \cdot \frac{V_o}{V_2} = -\frac{RR_f C_2 s}{R_1(RC_1 s + 1)(RC_2 s + 1)}$$

$$= -\frac{470s}{(47s + 1)(0.2s + 1)}$$

The poles are $\omega_{p_1} = -\frac{1}{47}$ rad/s and $\omega_{p_2} = -5$ rad/s. The zeros are $\omega_{z_1} = 0$.