NAME ____**SOLUTIONS**__________________________ NETID _______________

MIDTERM EXAM 2

(Closed book)

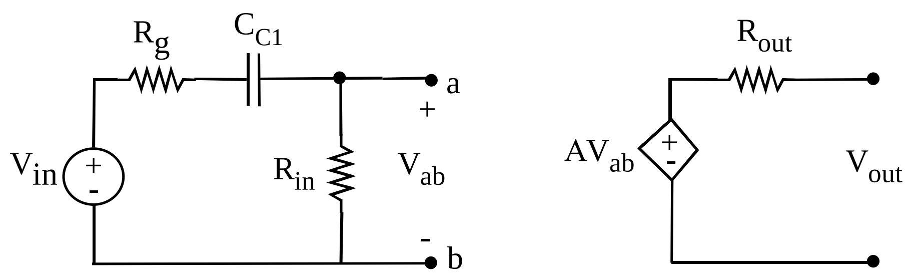
ECE 442 April 13, 2006

7:00 p..m. – 8:30 p.m.

Instructions: Write your name, and NetID where indicated. This examination consists of 4 problems. You are allowed to use a calculator and a formula sheet ($8^{1/2}$ by 11 in). Show all work.

Problem1 15 pts	Problem 2 25 pts	Problem 3 50 pts	Problem 4 10 pts	Total

1. In the circuit shown, assume R_g = 1 kΩ, R_{in}= 10 kΩ, and the midband voltage gain is -12 V/V. Choose a value for C_{c1} that will result in a 3-dB frequency of 6 Hz. (15 pts)



$$\frac{V_{ab}}{V_{in}} = \frac{R_{in}}{R_{in} + R_g + 1/j\omega C_{c1}} = \frac{R_{in}/(R_{in} + R_g)}{1 + j\omega C_{c1}(R_{in} + R_g)}$$

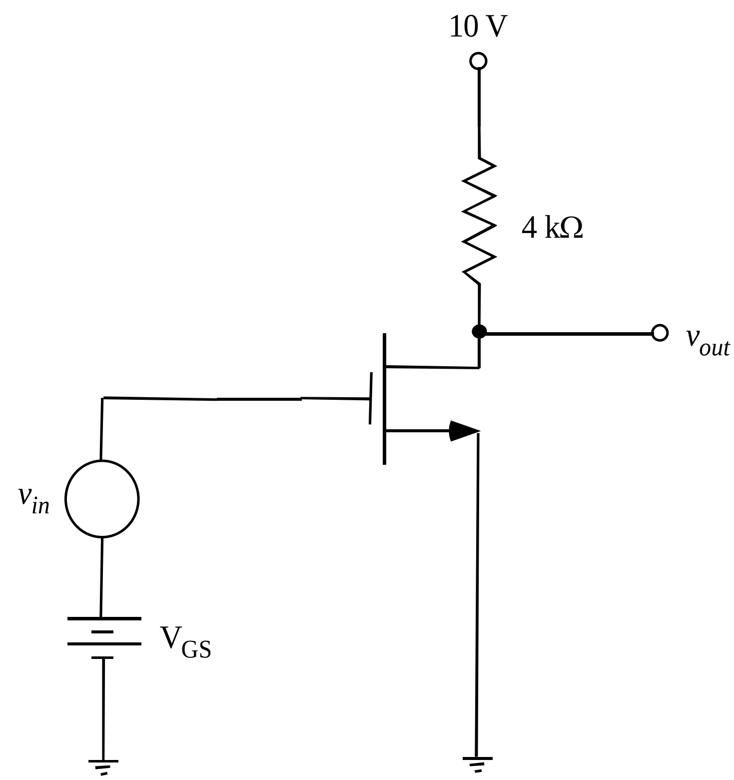
$$\frac{V_{ab}}{V_{in}} = \frac{R_{in}}{R_{in} + R_g} \cdot \frac{j\omega C_{c1}(R_{in} + R_g)}{1 + j\omega C_{c1}(R_{in} + R_g)} = \frac{R_{in}}{R_{in} + R_g} \cdot \frac{jf/f_l}{1 + jf/f_l}$$

$$C_{c1} = \frac{1}{2\pi f_l (R_{in} + R_g)} = \frac{1}{2\pi \times 6 \times 11,000} = 2.4\mu F$$

2. For the amplifier shown $\mu WC_{ox}/2L = 3$ mA/V^2, λ =0.02/V, and $V_T = 1.0$ V.

(a) Calculate V_{DSQ} when $V_{GSQ} = 1.5$ V (15 pts).

(b) Calculate the midband voltage gain for the stage (10 pts).



$$I_D = \frac{\mu C_{ox} W}{2L}(V_{GS} - V_T)^2\left[1 + \lambda V_{DSQ}\right]$$

$$1 + \lambda V_{DSQ} = \frac{I_D}{\frac{k_n W}{2L}(V_{GS} - V_T)^2}$$

$$V_{DSQ} = \frac{1}{\lambda}\left[\frac{I_D}{\frac{k_n W}{2L}(V_{GS} - V_T)^2} - 1\right] = \frac{1}{0.02}\left[\frac{I_D}{3(1.5-1)^2} - 1\right] = 66 I_D - 50$$

$$V_{DSQ} = V_{DD} - R_D I_D = 10 - 4 I_D$$

$$66 I_D - 50 = 10 - 4 I_D$$

$$70I_D = 60$$

$$I_D = 6/7 = 0.857\ mA$$

$$V_{DSQ} = V_{DD} - R_D I_D = 10 - 4 \times 0.857 = 6.57\ V$$

$$r_{ds} = \frac{1}{\lambda \frac{k_n W}{2L}\left(V_{GS} - V_T\right)^2} = \frac{1}{0.02 \times 3 \times 0.25} = 66.66\ \mathrm{k\Omega}$$

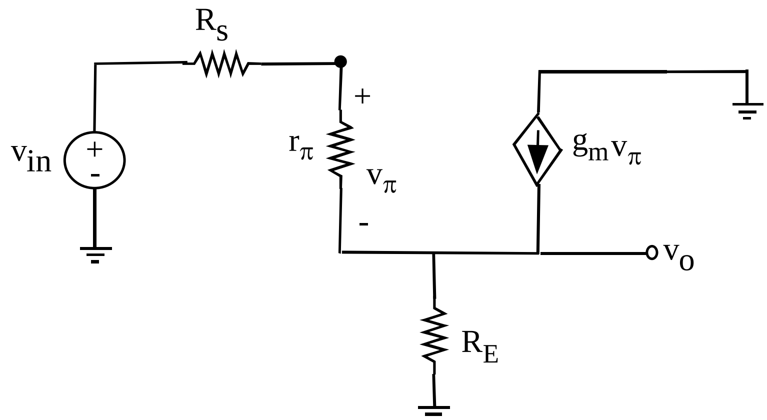
$$R_L = R_D \,||\, r_{ds} = 4 \,||\, 66.66 = 3.77\ \mathrm{k\Omega}$$

$$g_m = \sqrt{4 \frac{k_n W}{2L} I_D} = \sqrt{4 \times 3 \times 0.857} = 3.20\ \mathrm{mA/V}$$

$$A_{MB} = -g_m R_L = -3.20 \times 3.77 = -12.07\ \mathrm{V/V}$$

3. If $V_{BE}(on)$=0.6V and β = 100, calculate the midband voltage gain for the circuits shown.

It is best to derive the general solution for the midband voltage gain for (b) first.



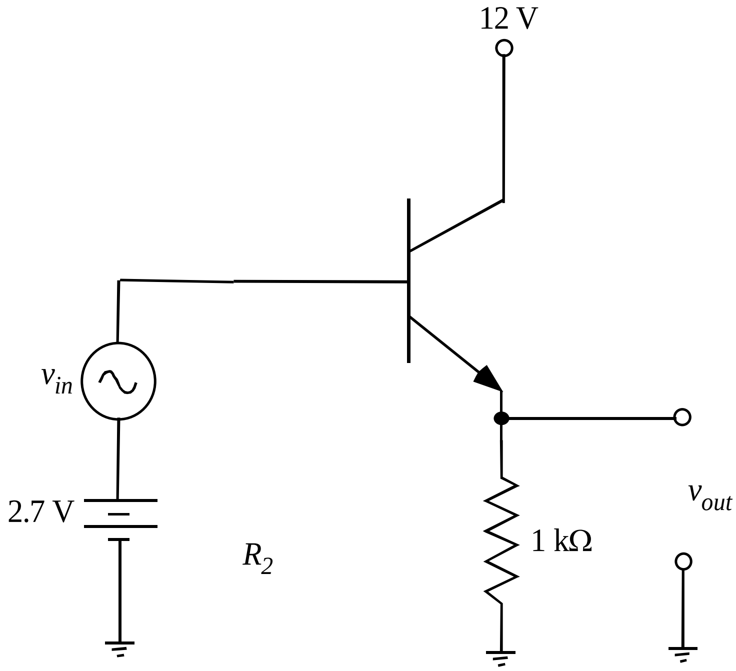
$$v_o = \left(g_m v_\pi + \frac{v_\pi}{r_\pi} \right) R_E = v_\pi R_E \left(g_m + \frac{1}{r_\pi} \right)$$

$$v_{in} = v_\pi + v_s + v_o = v_\pi + \frac{v_\pi}{r_\pi} R_S + v_o$$

$$v_{in} = v_\pi \left[1 + \frac{R_S}{r_\pi} + R_E \left(g_m + \frac{1}{r_\pi} \right) \right]$$

$$\frac{v_o}{v_{in}} = \frac{\left(g_m + \frac{1}{r_\pi} \right) R_E}{1 + \frac{R_S}{r_\pi} + R_E \left(g_m + \frac{1}{r_\pi} \right)} = \frac{\left(g_m r_\pi + 1 \right) R_E}{r_\pi + R_S + \left(g_m r_\pi + 1 \right) R_E} = \frac{\left(\beta + 1 \right) R_E}{r_\pi + R_S + \left(\beta + 1 \right) R_E}$$

(a) (15 pts)



Part (a), $R_S = 0,\ V_B = 2.7$V

V_E=2.7 – 0.6=2.1 V

I_E=2.1/1=2.1 mA

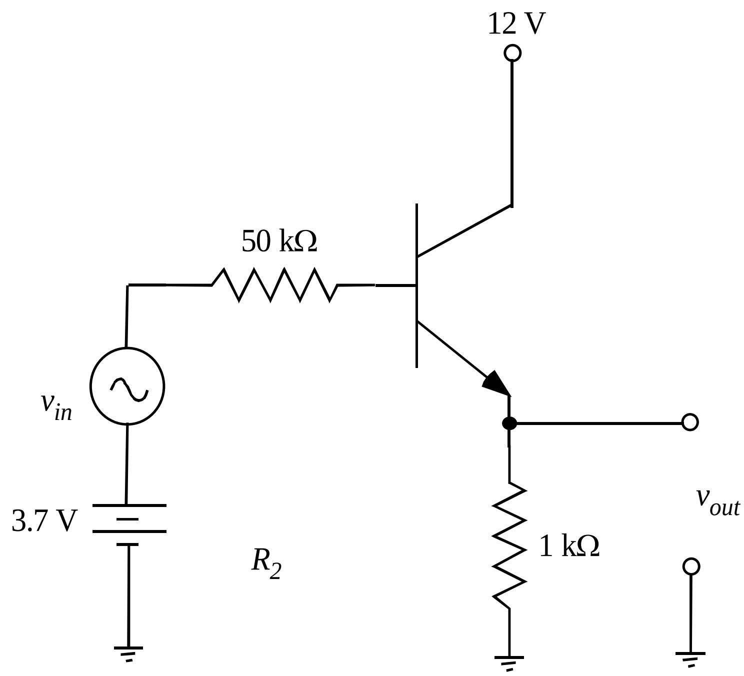
$I_C=\alpha I_E$=2.1(100/101)=2.07 mA

$g_m=I_C/V_T$=2.07/0.025=83.16 mA/V

$r_\pi=\beta/g_m$=100/83.6=1.2 kΩ

$$\frac{v_o}{v_{in}} = \frac{(\beta+1)R_E}{r_\pi + (\beta+1)R_E} = \frac{101\times 1}{1.2+1\times 101} = 0.988$$

(b) (35 pts)



Part (b), R_S = 50 kΩ, V_S = 3.7V

$$\frac{V_S - V_B}{R_S} = I_B = \frac{V_E \alpha}{R_E \beta} = \frac{\alpha}{R_E \beta}(V_B - V_{BEON})$$

$$V_S G_S - V_B G_S = \theta V_B - \theta V_{BEON}$$

$$G_S = 1/R_S = 1/50 = 0.02\ \Omega^{-1}$$

$$\theta = \frac{\alpha}{R_E \beta} = \frac{0.99}{100 \times 1} = 0.0099$$

$$V_S G_S + \theta V_{BEON} = \theta V_B + V_B G_S$$

$$V_B = \frac{V_S G_S + \theta V_{BEON}}{\theta + G_S} = \frac{3.7 \times 0.02 + 0.6 \times 0.0099}{0.02 + 0.0099} = 2.67\ V$$

V_E=2.67 – 0.6=2.07 V

I_E=2.071=2.07 mA

I_C=αI_E=2.07(100/101)=2.0495 mA

g_m=I_C/V_T=2.07/0.025=81.98 mA/V

r_π=β/g_m=100/81.98=1.219 kΩ

$$\frac{v_o}{v_{in}} = \frac{(\beta+1)R_E}{r_\pi + R_S + (\beta+1)R_E} = \frac{101\times 1}{1.219+50+1\times 101} = 0.6635$$

4. For the circuit shown, determine the values of:

(a) v_1 (2 pts) ⇒ $v_1 = 0$ since it is a virtual ground

(b) i_1 (2 pts) ⇒ $i_1 = \frac{1V - v_1}{1k\Omega} = \frac{1-0}{1} = 1 \text{ mA}$

(c) i_2 (1 pt) ⇒ $i_1 = i_2 = 1 \text{ mA}$

(d) v_o (2 pts) ⇒ $v_o = v_1 - R_2 i_2 = 0 - 10 \times 1 = -10 \text{ V}$

(e) i_L (2 pts) ⇒ $i_L = \frac{v_o}{1k\Omega} = -10 \text{ mA}$

(f) i_o (1 pt) ⇒ $i_o = i_L - i_2 = -10 \ -1 = -11 \text{ mA}$