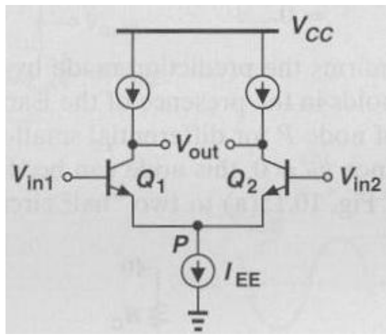
ELEC 312: ELECTRONICS – II ASSIGNMENT-Set #1

Department of Electrical and Computer Engineering

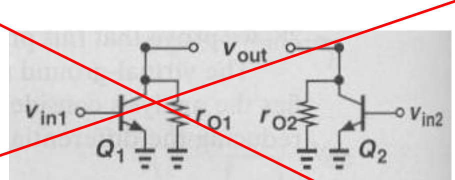
Winter - 2013

1. Find an expression for the differential gain of the following circuit, where ideal current sources are used as loads to maximize the gain. V_{in1}, V_{in2} may be assumed to be balanced differential signals.



Hints:

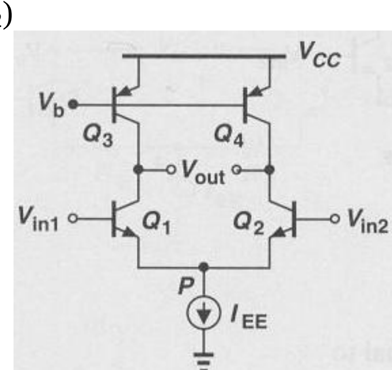
With ideal current sources, the Early effect in Q_1 and Q_2 cannot be neglected, and the half circuits must be visualized as depicted in the following figure:



see at the end

$v_{out1} = -g_m r_o v_{in1}$, $v_{out2} = -g_m r_o v_{in2}$, and hence $(v_{out1} - v_{out2}) / (v_{in1} - v_{in2}) = - g_m r_o$

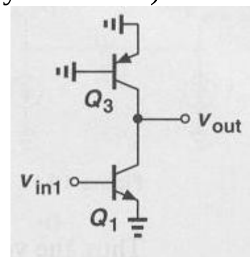
2. The following figure illustrates an implementation of a differential amplifier with active load using complementary BJT devices. Calculate the differential voltage gain $V_{out}/(V_{in1} - V_{in2})$



Hints:

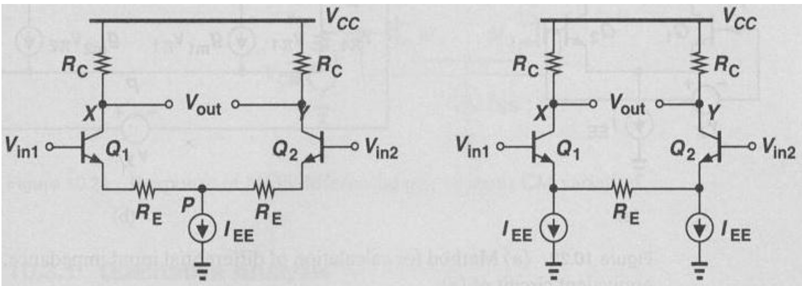
We will assume (since it is not stated otherwise) that the input signals are balanced-differential. Sp node P is at virtual ground.

Noting that each pnp device introduces a resistances a resistance of r_{OP} at the output nodes and drawing the half circuit as the bellow figure, we have (considering each half-circuit and combining differentially at the end)



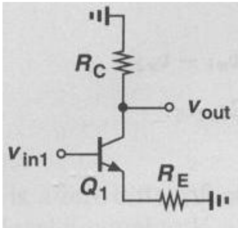
$(v_{out1} - v_{out2}) / (v_{in1} - v_{in2}) = - g_m (r_{ON} // r_{OP})$. Where r_{ON} denotes the output impedance of the npn transistors.

3. Determine the gain of the emitter degenerated differential pairs shown in the following figure. Assume $V_A = \infty$.



Hints:

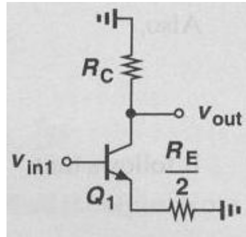
In the 1st figure, node P is a virtual ground, yielding the half circuit depicted in the following figure,



we have (like a CE amplifier with emitter load)

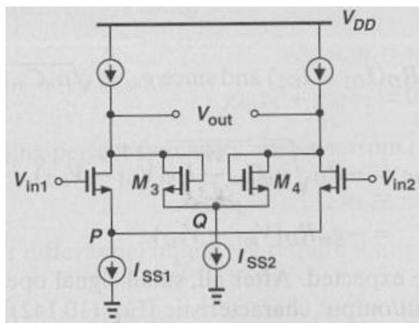
$A_v = - R_C / (R_C + 1/g_m)$.

In the 2nd figure, the line of symmetry passes through the "midpoint" of R_E. In other words, if R_E is regarded as two $R_E/2$ units in series, then the node between the units acts as a virtual ground as the following figure,



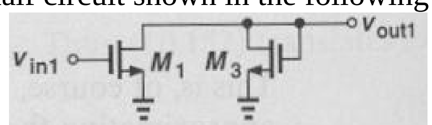
We have, $A_v = - R_C / (R_E/2 + 1/g_m)$.

4. Assuming $\lambda = 0$, compute the voltage gain of the following circuit. I_{SS2} is used to bias the transistors M_3 and M_4. Consider all I-sources are identical.



Hints:

Assume balanced differential operation. Identifying both nodes P and Q as virtual grounds, we construct the half circuit shown in the following figure,



And we have, $A_v = - g_{m1} / g_{m3}$

Q5: Use square law eqn. for M2

$I_{out} = 100\mu A = \mu_n C_{ox} \frac{W}{2L}(V_{GS} - V_{THN})^2 = 300 \times 4 \times (V_{GS} - 0.5)^2 \mu A$

This gives $V_{GS} - .5 = \sqrt{\frac{100}{1200}} = \pm 0.289$

∵ V_{GS} is required to be $> V_{THN}$ for M2 to conduct,
we take $V_{GS} = 0.5 + .289 = 0.789$ V

∵ $V_{SS} = 0$, $V_G = 0.789$ V Then

Using M1, $\frac{V_{DD} - V_G}{R} = 100\mu A$; $R = \frac{1.5 - .789}{100} M\Omega$

i) So $R = 7110\Omega$ or $7.11 K\Omega$

ii) For proper operation, M2 should be in saturation.

So $V_O - V_S \geq V_{GS} - V_{THN} \rightarrow 0.289$; but $V_S = V_{SS} = 0$ V

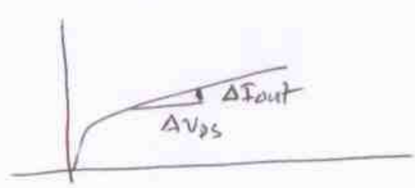
∵ $V_S = 0$; $V_O \geq 0.289$. Lowest value of $V_O = 0.289$ V.

iii) $r_O = \frac{V_A}{I_{out}} = \frac{20}{100} M\Omega = 200 K\Omega$

iv) Considering Early effect $I_{out} \sim (1 + \lambda V_{DS})$ with $\lambda = \frac{1}{|V_A|}$

So $\Delta I_{out} = \lambda \Delta V_{DS} = \frac{\Delta V_{DS}}{|V_A|} = \frac{\pm 0.5}{20} = \pm 0.025 \rightarrow \pm 2.5\%$

Alt: $r_O = \frac{V_A}{I_{out}} = \frac{\Delta V_{DS}}{\Delta I_{out}}$ from the output characteristic



So $\Delta I_{out} = \frac{\Delta V_{DS}}{r_o} = \pm \frac{0.5}{200 \times 10^3}$

$= \pm 0.0000025$ Amp $= \pm 2.5 \mu A$

$\frac{\Delta I_{out}}{I_{out}} = \frac{\pm 2.5}{100} \rightarrow \pm 2.5\%$

Q6: Because of finite β we can write

$$I_{C1} = I_{in} - \frac{I_{B1}}{\beta} - \frac{I_{B2}}{\beta} = I_{in} - \frac{2}{\beta} I_B$$

if $I_{B1} = I_{B2} = I_B$ (matched Q_1, Q_2)

But $I_{C1} = \beta I_B$ as well.

Thus, $\left(\beta + \frac{2}{\beta}\right) I_B = I_{in}$

$$I_B = \frac{I_{in}}{\beta + \frac{2}{\beta}}$$

Now $I_{out} = \beta I_B = \frac{\beta}{\beta + \frac{2}{\beta}} \cdot I_{in}$

So $$\frac{I_{out}}{I_{in}} = \frac{\beta}{\beta + \frac{2}{\beta}}$$

If $\beta = \beta_{min} = 50$; $\frac{I_{out}}{I_{in}} = \frac{50}{50 + \frac{2}{50}} =$ ~~0.999~~ 0.961