Note Title 2/17/2013

ELEC 312, Feb 2013, MT test (sol/hint)

Q 1:

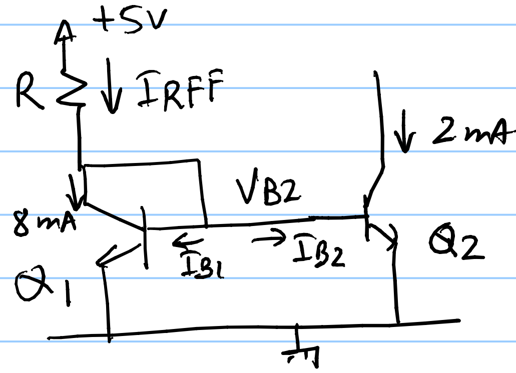
$$I_O = I_{C2} = I_{S2} \exp(V_{BE2}/V_T) = 2\,mA$$

$\because$ $I_{S1} = 10^{-14}$ Amp $= 4$ times I_{S2}

$I_{C1} = 4 I_{C2} = 8$ mA

Then $I_{B1} = \frac{8\,mA}{100}$, $I_{B2} = \frac{2\,mA}{100}$

$I_{REF} = I_{C1} + I_{B1} + I_{B2} = (8 + .08 + .02)$
$= 8.1$ mA



$V_{BE2} = V_{B2} = V_T \ln\left(\frac{2\,mA}{.25 \times 10^{-14} A}\right)$
$= .025 \times 27.41 = 0.685$ V

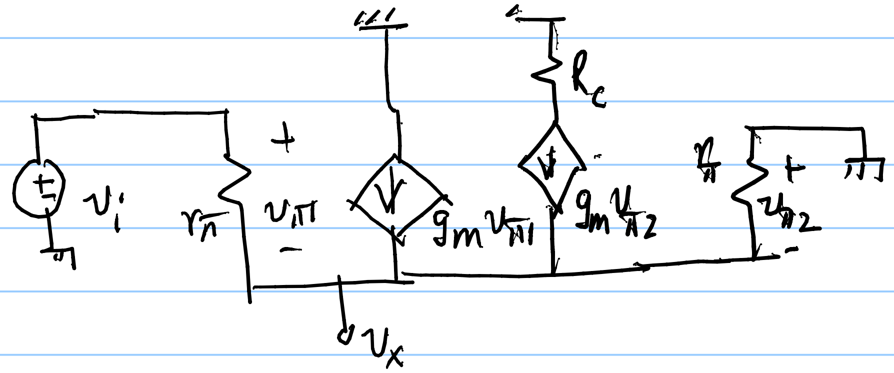
Then $\frac{5V - 0.685}{R} = I_{REF}$

Thus $R = 532.7$ ohms

——————— X ———————

Q.2.

AC equivalent circuit is:



KCL

$$-(v_i - v_x)\, g_\pi - g_m (v_i - v_x)$$
$$- g_m (0 - v_x) + v_x g_\pi = 0$$

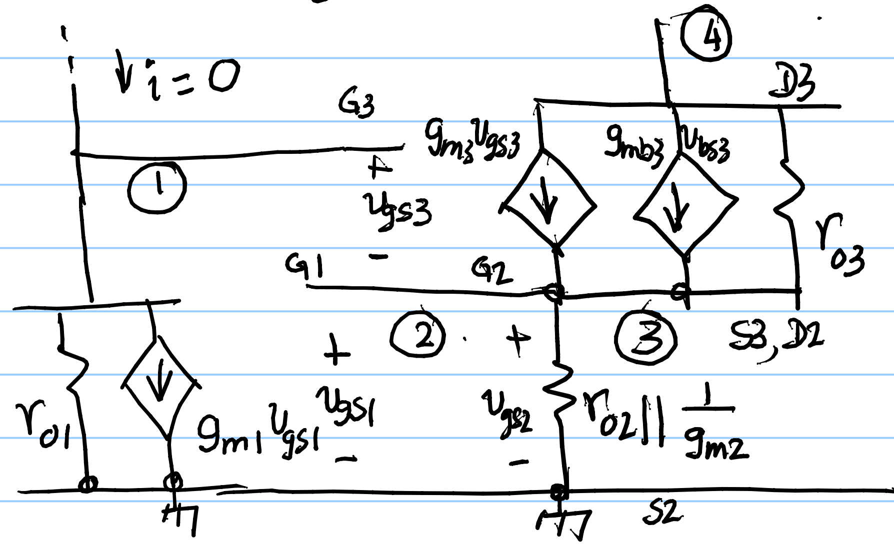
$$-(g_\pi + g_m)\, v_i + v_x (g_\pi + g_m + g_m + g_\pi) = 0$$

So $$v_x = + \frac{g_m + g_\pi}{2g_m + 2g_\pi}\, v_i = \frac{v_i}{2}$$

$$v_o = -g_m v_{\pi 2} R_c$$
$$= -g_m (0 - v_x) R_c = g_m R_c \frac{v_i}{2}$$

So $$\frac{v_o}{v_i} = \frac{g_m R_c}{2}$$

Q.3: The ac equivalent circuit is:



From $g_m = \mu C_{ox} \frac{W}{L}(V_{GS} - V_{TH})$

$= 100 \times 10^{-6} \times 10 \times 1 = 10^{-3}$ mho

$r_o = \frac{V_A}{I_D} = \frac{20}{I_D}$

But, $I_D = \mu C_{ox} \frac{W}{2L}(V_{GS} - V_{TH})^2$

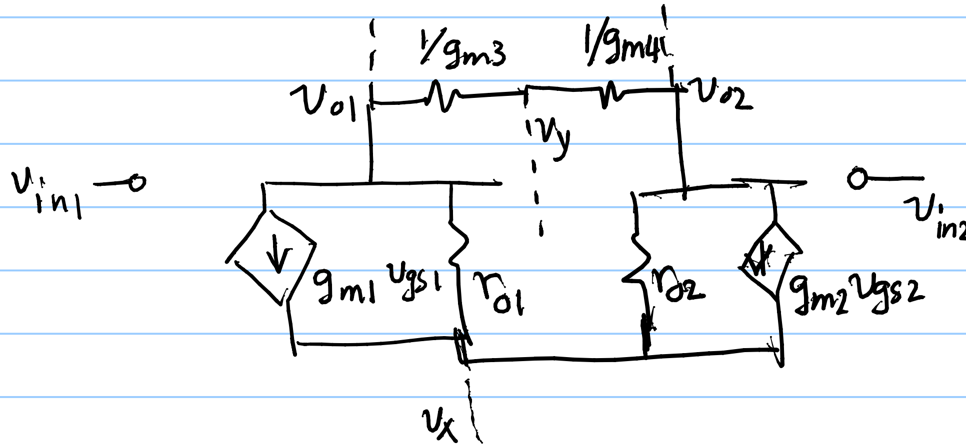
(by square-law formula)

$= 100 \times 10^{-6} \times 5 \times 1 = 500\ \mu A$

So $r_o = \frac{20}{500} \times 10^6 = 4 \times 10^4\ \Omega$

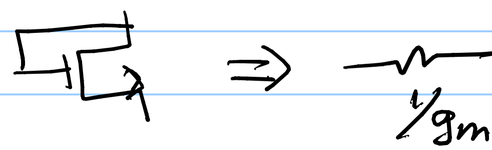
$R_{out} = 10^{-3} \times 16 \times 10^8 = 16 \times 10^5\ \Omega$

Q 4: The ac equivalent circuit is:



--- means open circuit i.e. $R \to \infty$

Further, we used



$\Rightarrow$ $1/g_m$ for the MOS

$$v_{out} = v_{o1} - v_{o2}$$

KCL @ v_{o1} gives

$$g_{m1}(v_{in1} - v_x) + (v_{o1} - v_x)g_{o1} + (v_{o1} - v_y)g_{m3} = 0$$

where $g_{o1} = \frac{1}{r_{o1}}$, similarly,

@ v_{o2} node, KCL is

$$g_{m2}(v_{in2} - v_x) + (v_{o2} - v_x)g_{o2} + (v_{o2} - v_y)g_{m4} = 0$$

Considering matched pair of transistors

$g_{m1} = g_{m2}$; $g_{o1} = g_{o2}$; $g_{m3} = g_{m4}$

By subtraction

Q4 (Contd.)

$$g_{m1}(v_{in1} - v_{in2}) + g_{o1}(v_{o1} - v_{o2}) + g_{m3}(v_{o1} - v_{o2}) = 0$$

$$g_{m1}(v_{in1} - v_{in2}) + (g_{m3} + g_{o1})(v_{o1} - v_{o2}) = 0$$

So $$\frac{v_{o1} - v_{o2}}{v_{in1} - v_{in2}} = -\frac{g_{m1}}{g_{m3} + g_{o1}} = \frac{v_{out}}{v_{in1} - v_{in2}}$$