EE210A: Microelectronics I - Mini-Quiz 6

NAME (in capital) | Roll No

Time: 20 minutes

1) : Consider all transistors are identical. Neglect body effect.

R_{in}

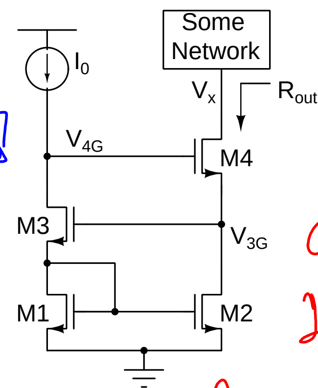


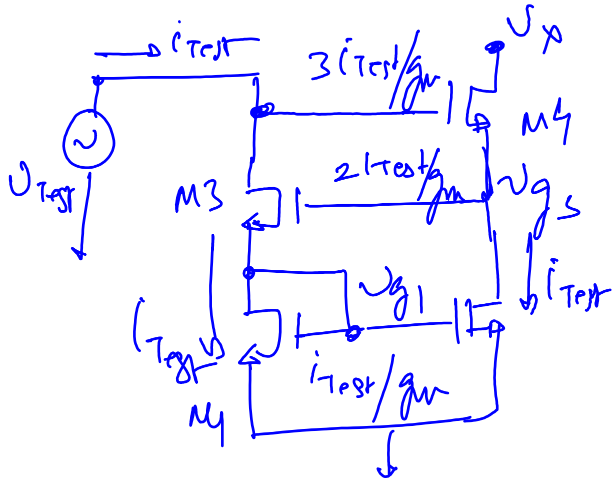
Fig. 1. Problem 1

An alternate possible approach is to express $V_{4G} = V_{th} + \sqrt{\frac{2I_0}{\mu C_{ox}\left(\frac{W}{L}\right)}}$ and the replace I_0 by $I_0 + \Delta I$. It should yield the same result..

a) : Assuming all transistors are biased in saturation, if I_0 changes by ΔI, what will the change in the voltage at V_{4G} be? Neglect channel length modulation for all transistors for this part. **[4]**

$\Delta V_{4G} = \Delta I \times R_{in}$

To find R_{in}



All g_ms are same as W/L are identical and currents are also identical due to 1:1 mirroring ratio.

Current through M1

$\Rightarrow i_{Test} = g_m v_{g1}$

$\Rightarrow v_{g1} = \frac{i_{Test}}{g_m}$

Current through M3

$\Rightarrow i_{Test} = g_m(v_{g3} - v_{g1})$

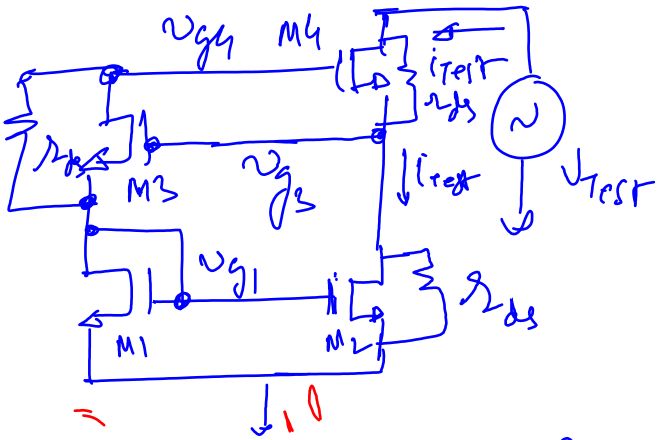
$\Rightarrow v_{g3} = \frac{2\, i_{Test}}{g_m}$

Current through M4

$\Rightarrow i_{Test} = g_m(v_{Test} - v_{g3})$

$\Rightarrow v_{Test} = 3 i_{Test}/g_m$

$\therefore R_{in} = \frac{3}{g_m}$ $\therefore \Delta V_{4G} = \frac{\Delta I \times 3}{g_m}$ +1 *b) :* Find the output resistance R_{out} looking into the drain of $M4$ as indicated in the figure. Neglect channel length modulation for $M1$ for this purpose and assume identical quiescent current in both the branches. **[6]**



No incremental current can flow into M1. ($\therefore$ No current can flow out of the drain of M3)

$\therefore v_{g1} = 0$

$\therefore v_{g3} = i_{Test}\, r_{ds}$

KCL @ $v_{g1} \Rightarrow g_{m_3} v_{g3} + \frac{v_{g4}}{r_{ds}} = 0 \quad (\because v_{g1} = 0)$

$\Rightarrow v_{g4} = -g_{m_3} r_{ds} v_{g3}$

$= -g_m r_{ds}\, i_{Test}\, r_{ds}$

KCL @ $v_{Test} \Rightarrow \quad i_{Test} = g_m(v_{g4} - v_{g3}) + \frac{v_{Test} - v_{g3}}{r_{ds}}$

$\Rightarrow \quad i_{Test} = -g_m^2 r_{ds}^2 i_{Test} - g_m r_{ds} i_{Test} + \frac{V_{Test}}{r_{ds}} - i_{Test}$

$\Rightarrow i_{Test}\left(2 + g_m r_{ds} + g_m^2 r_{ds}^2\right) = \frac{V_{Test}}{r_{ds}}$

$\Rightarrow R_{out} = \frac{V_{Test}}{i_{Test}} = 2 r_{ds} + g_m r_{ds}^2 + g_m^2 r_{ds}^3$