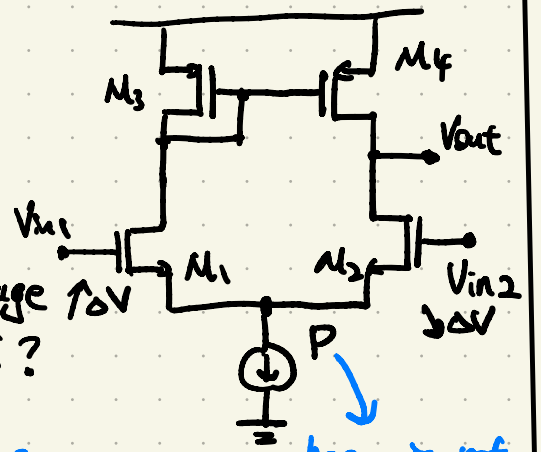
Lec 16

– Small-Signal Behavior of Diff Pair with Active Load

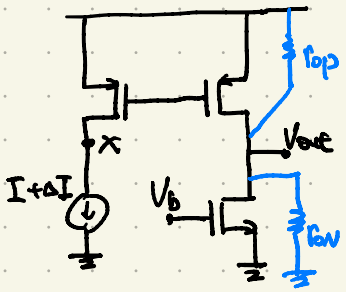


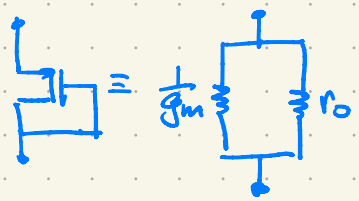
Question 1: How much is the voltage change of X?

$\uparrow \Delta V$

$\downarrow \Delta V$

here is not ac GND





$$\Delta V_{out} = \Delta I \left(\frac{1}{g_m} \| r_o\right) \approx \Delta I \cdot \frac{1}{g_m}$$

Quiz: How much is the change in Vout?

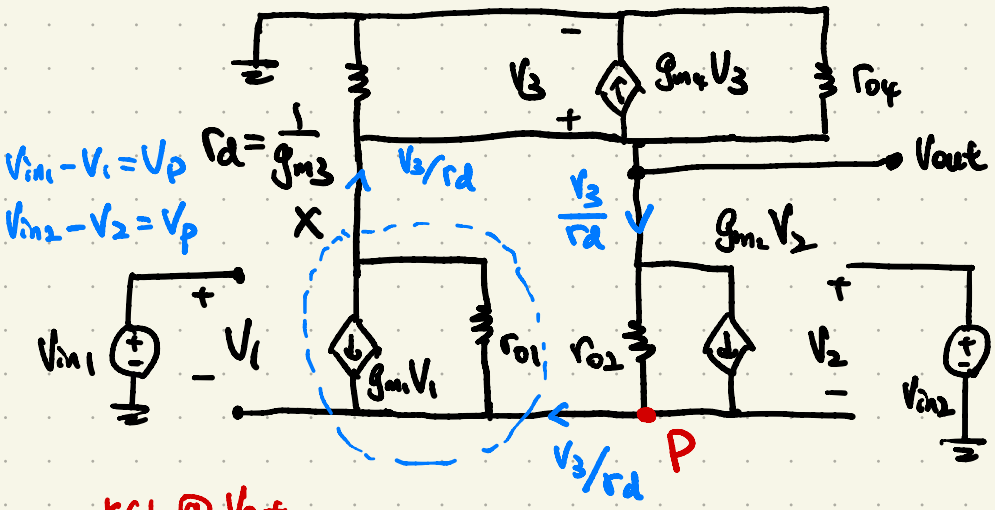
$A_V = -g_{mp}(r_{oN} \| r_{op})$

$A_V = \frac{\Delta I}{g_{mp}} \times -g_{mp}(r_{oN} \| r_{op})$

$= -\Delta I (r_{oN} \| r_{op})$

$\Rightarrow |\Delta V_x| < |\Delta V_{out}|$

Small-Signal Voltage Gain



KCL @ Vout:

$$\frac{V_3}{r_d} + \frac{V_{out}}{r_{o4}} + g_{m4} V_3 = 0$$

$$V_3 = \frac{-V_{out}}{r_{o4}(\frac{1}{r_d} + g_{m4})} = \frac{-V_{out}}{r_{o4} \times (2 g_{mp})}$$

KCL @ X: $g_{m1} V_1 + \frac{V_3 - V_p}{r_{o1}} + \frac{V_3}{r_d} = 0$

KCL @ Output: $g_{m2} V_2 + \frac{V_{out} - V_p}{r_{o2}} - \frac{V_3}{r_d} = 0$

$\Rightarrow g_{mN}(V_1 - V_2) + \frac{V_3 - V_{out}}{r_{oN}} + \frac{2V_3}{r_d} = 0$

$V_1 - V_2 = V_{in1} - V_{in2}$

$$g_{mN}(V_{in1}-V_{in2}) + \frac{V_3 - V_{out}}{r_{oN}} + \frac{2V_3}{r_d} = 0$$

$$V_3 = \frac{-V_{out}}{2 g_{mp} r_{op}}$$

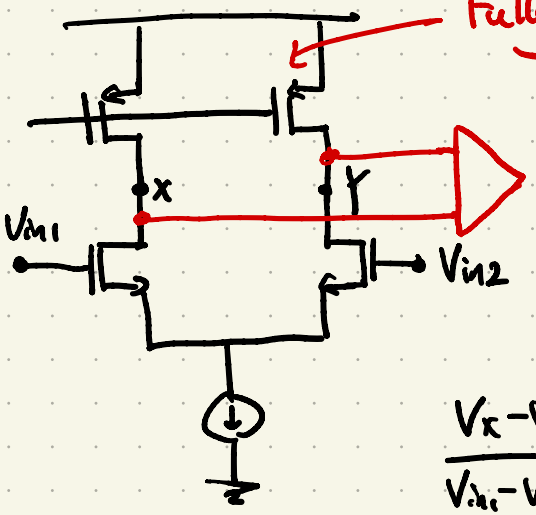
Then

$$g_{mN}(V_{in1}-V_{in2}) + \frac{-V_{out}}{2 g_{mp} r_{op} r_{oN}} - \frac{V_{out}}{r_{oN}} - \frac{2V_{out}}{2 g_{mp} r_{op} r_d} = 0$$

$$g_{mN}(V_{in1}-V_{in2}) = V_{out}\left[\frac{1}{2 g_{mp} r_{op} r_{oN}} + \frac{1}{r_{oN}} + \frac{1}{r_{op}}\right]$$

negligible

$$\frac{V_{out}}{V_{in1}-V_{in2}} = g_{mN}(r_{oN} \,//\, r_{op})$$



$$\frac{V_X - V_Y}{V_{in1}-V_{in2}} = -g_{mN}(r_{oN} \,//\, r_{op})$$