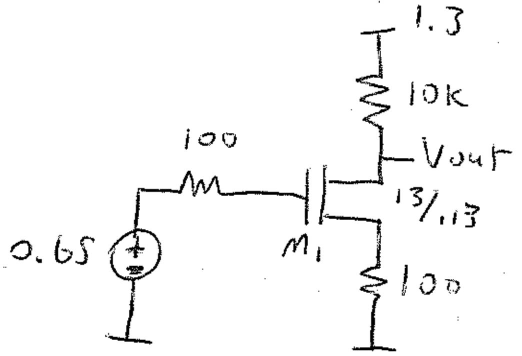
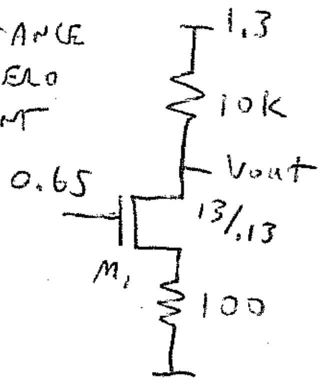
LECTURE 4

SLIDE 16)



GATE RESISTANCE HAS ZERO CURRENT $\Rightarrow$



TO SOLVE FOR OPERATING POINT (I.E., LARGE SIGNAL), FIRST TRY ASSUMING THAT M_1 IS IN SATURATION

NOTE THAT $V_{GS} = 0.65 - I_D \cdot 100$, IGNORE λ FOR NOW

$$\Rightarrow I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\left(V_{GS}-V_T\right)^2$$

$$= \frac{1}{2}\,50\times10^{-6}\,(100)\left(0.65 - I_D\cdot100 - 0.5\right)^2$$

$$= 2.5\times10^{-3}\left(0.15 - I_D\cdot100\right)^2$$

$$\Rightarrow \frac{I_D}{2.5\times10^{-3}} = (0.15)^2 - 2\,(0.15)(100)\,I_D + 100^2\,I_D^2$$

$$\Rightarrow 0 = (0.15)^2 - 430\,I_D + 10\times10^3\,I_D^2$$

$$\Rightarrow I_D = \frac{430 \pm \sqrt{430^2 - 4\cdot10\times10^3\cdot(0.15)^2}}{2\cdot10\times10^3}$$

$$= 21.5\times10^{-3} \pm 21.4476\times10^{-3}$$

$$= 42.9476\times10^{-3} \text{ OR } 52.39\times10^{-6}$$

BUT 42mA IS NOT POSSIBLE SINCE THAT WOULD IMPLY A VOLTAGE DROP ACROSS THE 100Ω RESISTOR OF 4.2V $\Rightarrow V_{GS} = 0.65 - 4.2 << 0$!

THEREFORE, $\boxed{I_D = 52.39\,\mu A}$ $\left(V_S = 52.39\mu A\cdot100 = 5.239\text{ mV}\right)$

SINCE V_S IS ONLY 5.2 mV, THE IMPACT ON V_{TH} IS QUITE SMALL AND CAN BE IGNORED

$I_D = 52.39\,\mu A \Rightarrow V_{out} = 1.3 - 10K \cdot 52.39\,\mu A$

$= 0.776\ V$

$\Rightarrow V_{DS} = 0.776 - 0.0052 \simeq 0.77\ V$

$\Delta V = 0.65 - 0.0052 - V_{THN} \simeq 0.145\ V$

SINCE $V_{DS} > \Delta V$, **DEVICE IS INDEED IN SATURATION**

NOW WE CAN CALCULATE SMALL SIGNAL ~~PARAM~~ PARAMETERS

$$g_m \simeq \sqrt{2\mu_n C_{ox} \frac{W}{L} I_D} = \sqrt{2(50\times10^{-6})\cdot 100 \cdot 52.4\,\mu A}$$

$$= \boxed{723.9\times10^{-6} = g_m}$$

$g_{mb} = 0$ SINCE $\gamma = 0$

$$r_o = \frac{1}{\lambda I_D} = \frac{1}{\frac{1}{10}\cdot 52.4\,\mu A} = 191\,k\Omega$$

NOW WE CAN PLUG IN THE THEVENIN MODEL, BUT FIRST CALCULATE ITS PARAMETERS:

$$R_{TH_G} = \boxed{\infty}$$

$$R_{TH_D} = r_o\left(1 + (g_m + g_{mb})R_S\right) + R_S$$

$$= 191K\left(1 + (723.9\times10^{-6} + 0)100\right) + 100$$

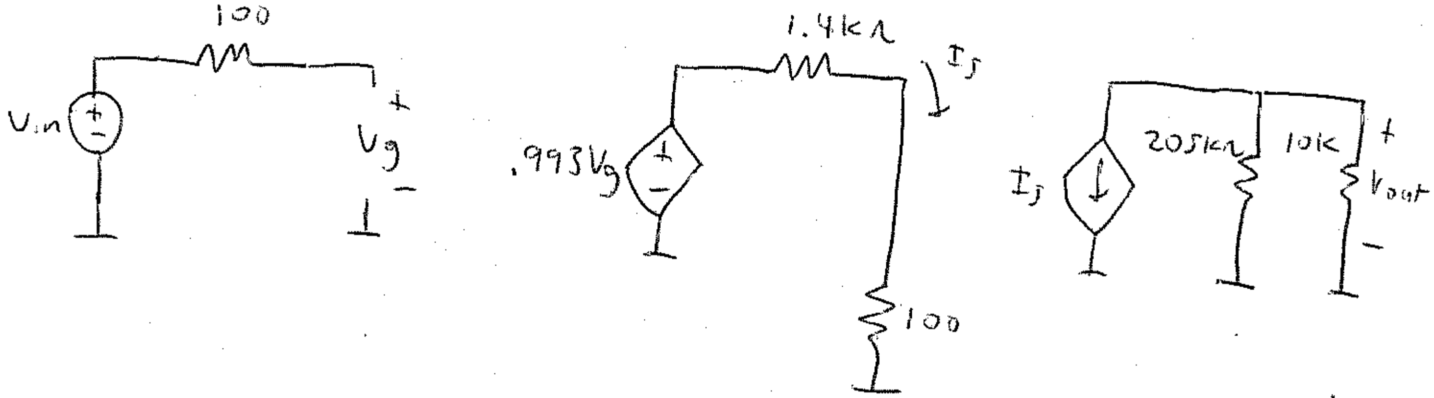
$$\simeq \boxed{205\,K\Omega}$$

$$R_{TH_S} = \left(1 + \frac{R_D}{r_o}\right)\left(r_o \,\|\, \frac{1}{g_m + g_{mb}}\right)$$

$$= \left(1 + \frac{10k}{191k}\right)\left(191k \,\|\, \frac{1}{723.9\times10^{-6}}\right) \simeq \boxed{1.4\,K\Omega}$$

$$A_v = g_m r_o \,\|\, \frac{g_m}{g_m + g_{mb}} = 723.9\times10^{-6}\cdot 191\times10^{3} \,\|\, 1$$

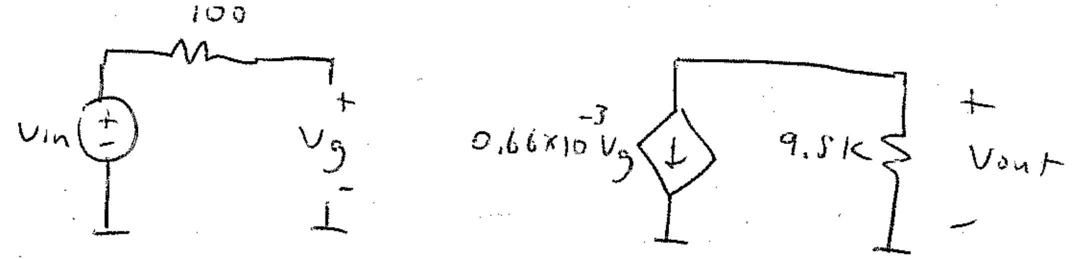
$$\simeq 0.993$$



$$\Rightarrow I_s = \frac{0.993\ V_g}{1.4k + 100} = 662\times10^{-6}\ V_g$$

ALSO: $10k \,\|\, 205k \simeq 9.5\,k\Omega$

$\Rightarrow$



THEREFORE, DC GAIN $= \frac{V_{out}}{V_{in}} = 0.66\times10^{-3}\cdot 9.5K$

$= \boxed{6.27}$