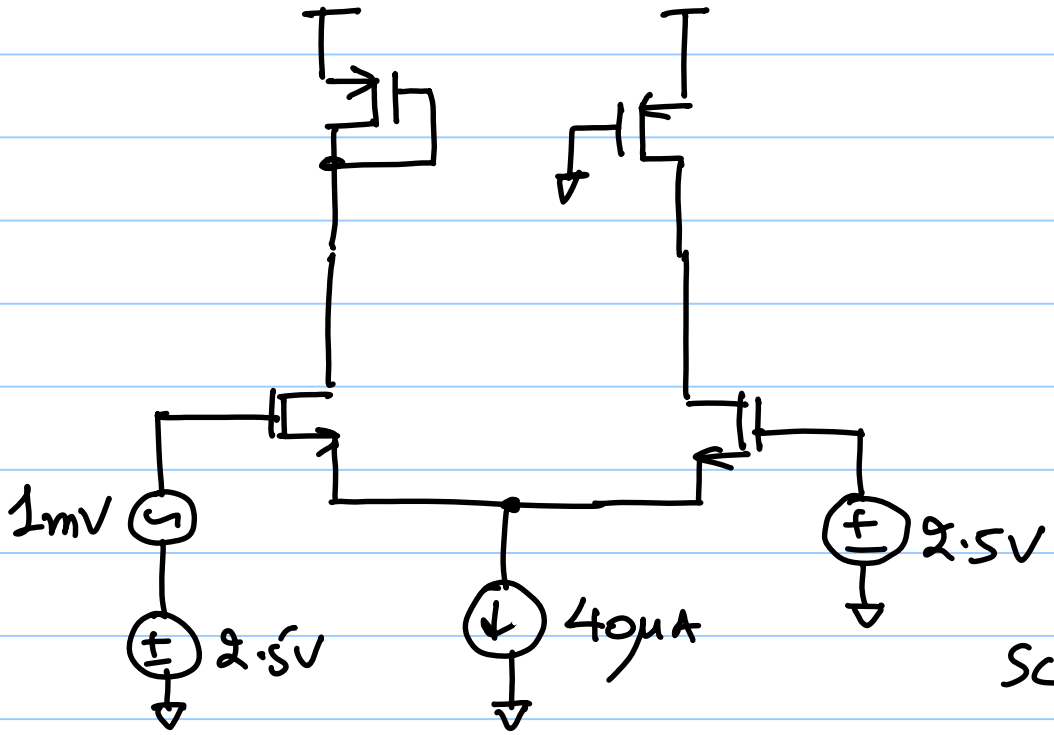
ECE 511 – Lecture 3

Note Title 1/20/2015



$V_{DD} = 5V$

1μm CMOS

All NMOS → 10/2

All PMOS → 30/2

Solve all DC & AC voltages & currents

Scale = μm

$V_{DD} = 5V$

$V_{THN} = 0.8$ $V_{THP} = 0.9$

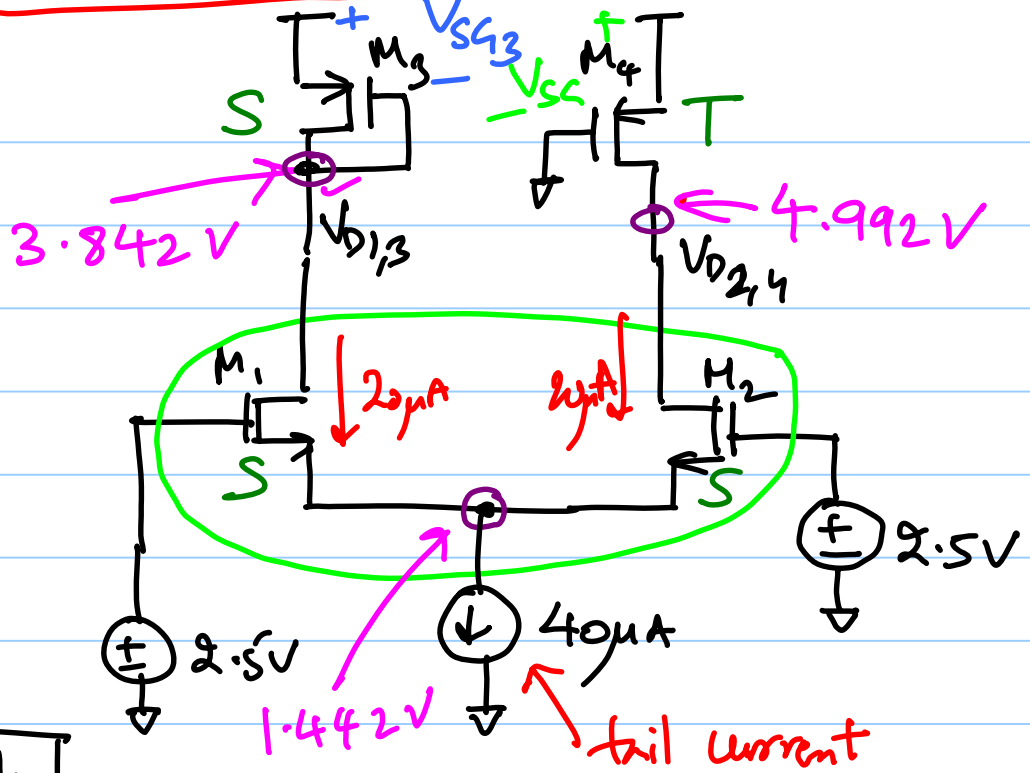
$KP_n = 120 \frac{\mu A}{V^2}$ $KP_p = 40 \frac{\mu A}{V^2}$

$\lambda = 0$ ⇒

Ignore channel length modulation

I

DC Picture



M_1 & M_2

Irrespective of the load, The diff-pair tail current is equally split as long as $V_{GS1,2}$ are the same

↳ "Symmetry"

CMOS Ex 9.5

Assume M_1 & M_2 are in saturation ✓

$$V_{GS1} = V_{GS2} = \sqrt{\frac{2I_D}{KP_n W/L}} + V_{THN} = \sqrt{\frac{40\mu}{120\mu}\cdot\frac{2}{10}} + 0.8$$

$$= \boxed{1.058\,V}$$

$$V_{DS,sat\,1,2} = V_{GS1,2} - V_{THN} = \boxed{258\,mV}$$

$$V_{S1,2} = 2.5 - V_{GS1,2} = 2.5 - 1.058 = \boxed{1.442\,V}$$

M_3 → SAT

$$V_{SG_3} = \sqrt{\frac{2 \times 2m}{43\mu} \times \frac{2}{30}} + 0.9 = 1.158V \Rightarrow V_{SD,sat_3} = 250mV$$

drain potential of M_3 & M_1

$$V_{D_1} = V_{D_3} = V_{DD} - V_{SG_3} = \boxed{3.842V}$$

check for M_1:

V_{DS} $V_{DS,sat}$

$2.4V > 250mV$: M_1 is indeed in SAT

M_4 $V_{SG} = 5V \Rightarrow$ most likely in Triode (initial guess)

for saturation we must have for M_4:

$$V_{SD} \geq V_{SG} - V_{THP}$$

$$\cancel{V_S} - V_D \geq \cancel{V_S} - V_G - V_{THP}$$

$$\Rightarrow V_G \geq V_D - V_{THP}$$

$$0$$

$$\Rightarrow \quad V_D \leq 0.9V$$

$$20\mu = 40\mu \times \frac{30}{2}\left[(5-0.9)V_{SD} - \frac{V_{SD}^2}{2}\right]$$

$$\Rightarrow V_{SD} = 8.13\,mV$$

$$\Rightarrow V_{D4} = 5V - V_{SD} = 4.992V$$

II Find small-signal parameters

M_1, M_2: $g_m = \sqrt{2\beta_n I_D} = \boxed{150\,\frac{\mu A}{V}}$

$r_o = \frac{1}{\lambda I_{DSat}} \longrightarrow \infty\,\Omega$

M_3: $g_{m3} = 150\,\frac{\mu A}{V}$

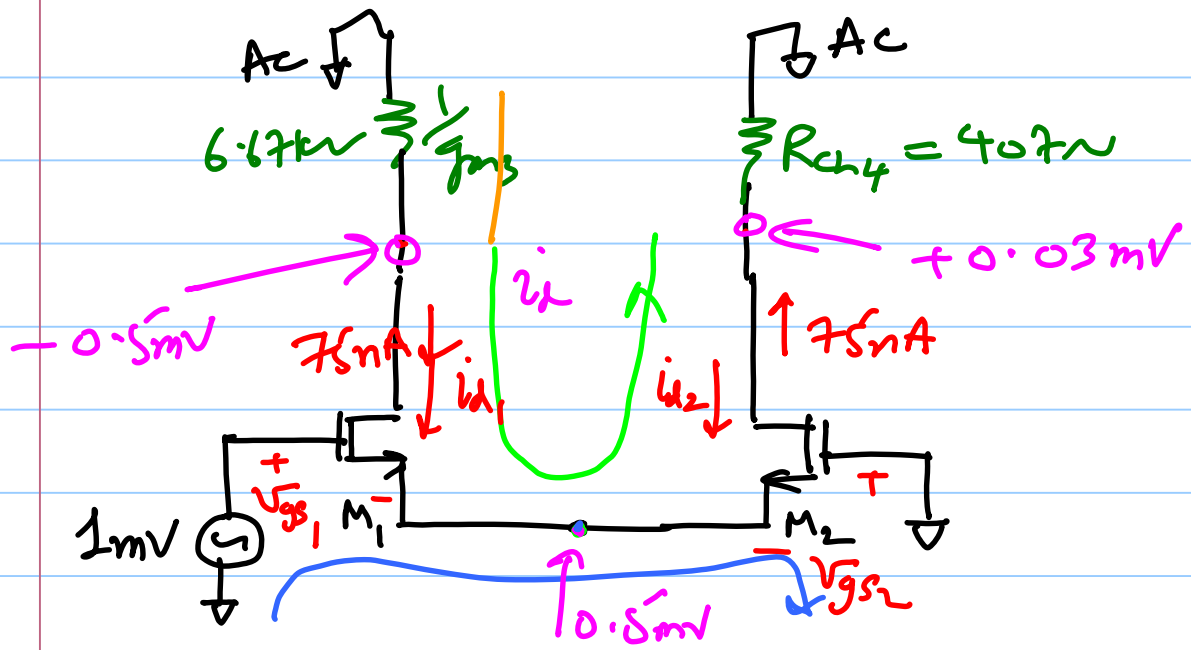
$\frac{1}{g_{m3}} = 6.67\,k\Omega$

M_4: $R_{ch} = \frac{1}{\beta(V_{SG} - V_{THP})}$

$= 407\,\Omega$

III

AC picture



$r_o \to \infty$

$i_{d1} = g_{m1} v_{gs1}$

$i_{d2} = g_{m2} v_{gs2}$

KVL: $1mV = v_{gs1} - v_{gs2}$ ⟶ (1)

KCL: $i_{d2} = -i_{d1}$

$\Downarrow \quad \Downarrow$

$i_x \quad -i_x$

(1) & (2)

$$v_{gs1} = \boxed{0.5\,mV} = -v_{gs2}$$

$$i_{d1} = -i_{d2} = g_m v_{gs1} = \boxed{75mA}$$

$i_{d2} = -i_{d1}$

$g_m v_{gs2} = -g_m v_{gs1}$

$\Rightarrow v_{gs2} = -v_{gs1}$ → (1)

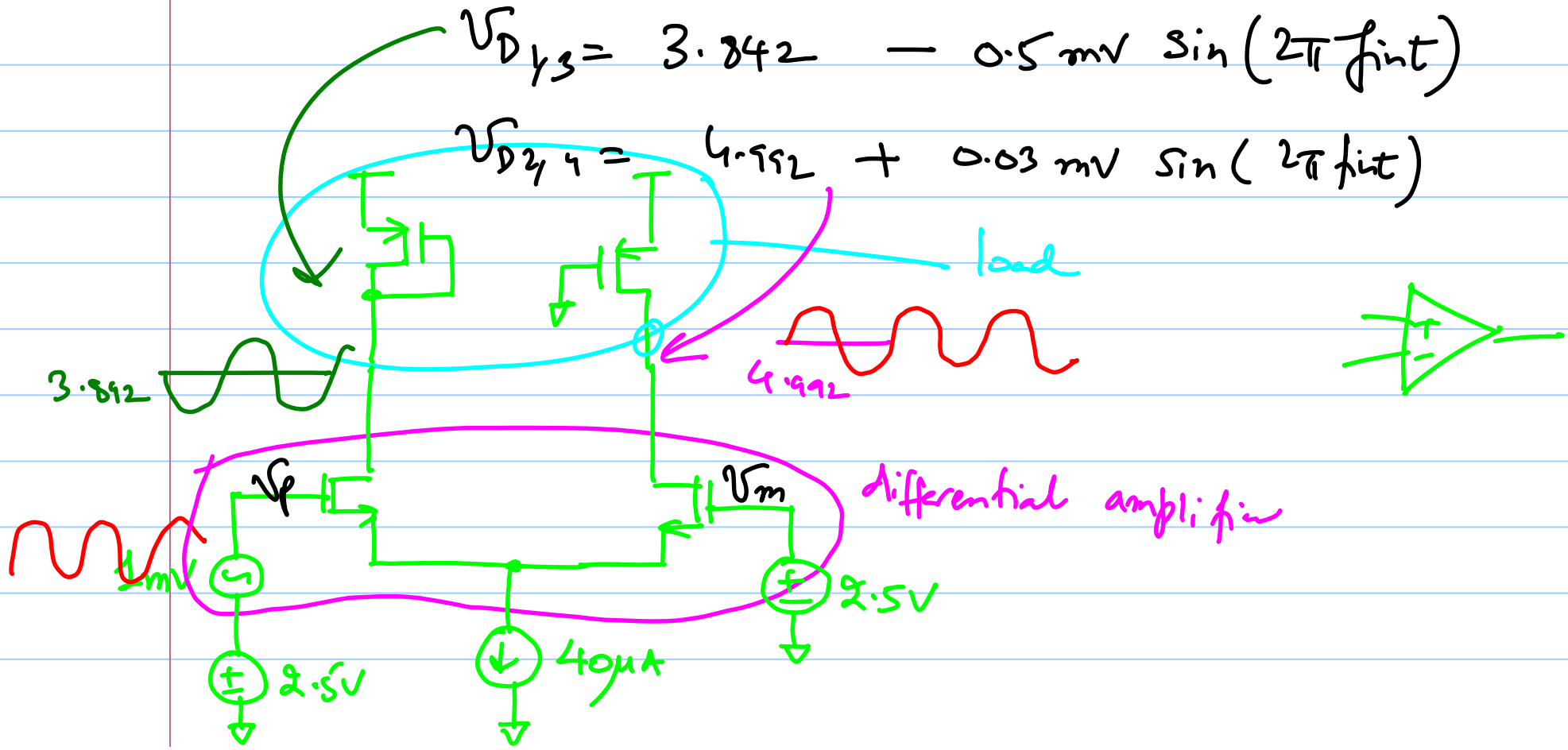
$$v_{d_1} = v_{d_3} = -i_{d_1} \cdot \frac{1}{g_{m3}} = -0.5\,mV$$

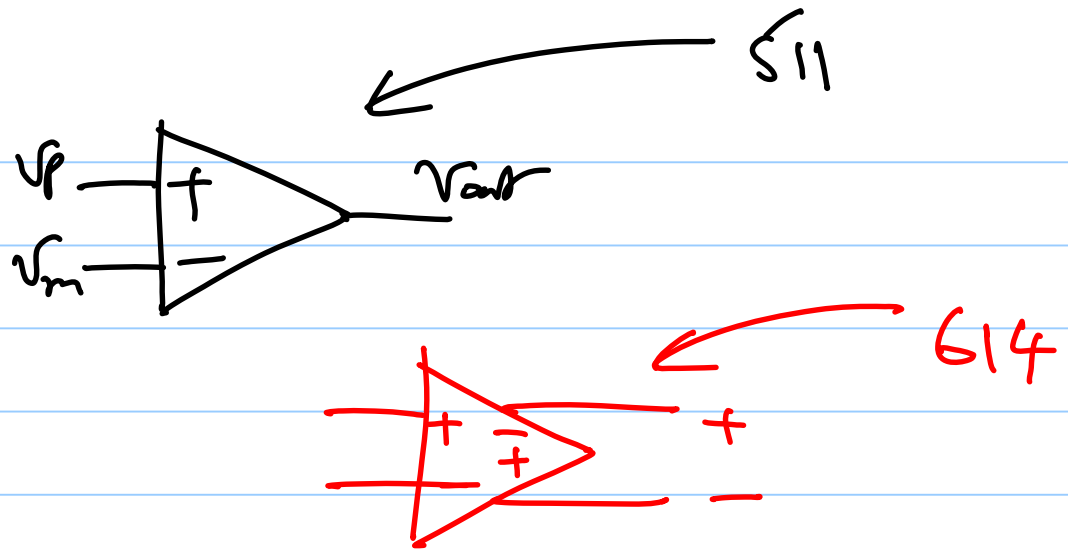
$$v_{d_2} = v_{d_4} = -i_{d_4} \cdot R_{ch_4} = -i_{d_2} \cdot R_{ch_4} = 0.03\,mV$$

IV :

$$v_{D_{y3}} = 3.842 - 0.5\,mV \sin(2\pi f_{int})$$

$$v_{D_{y4}} = 4.992 + 0.03\,mV \sin(2\pi f_{int})$$




5.11
V_p
V_m
V_{out}
6.14
+
−
+
−