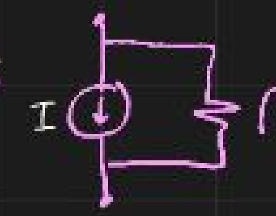
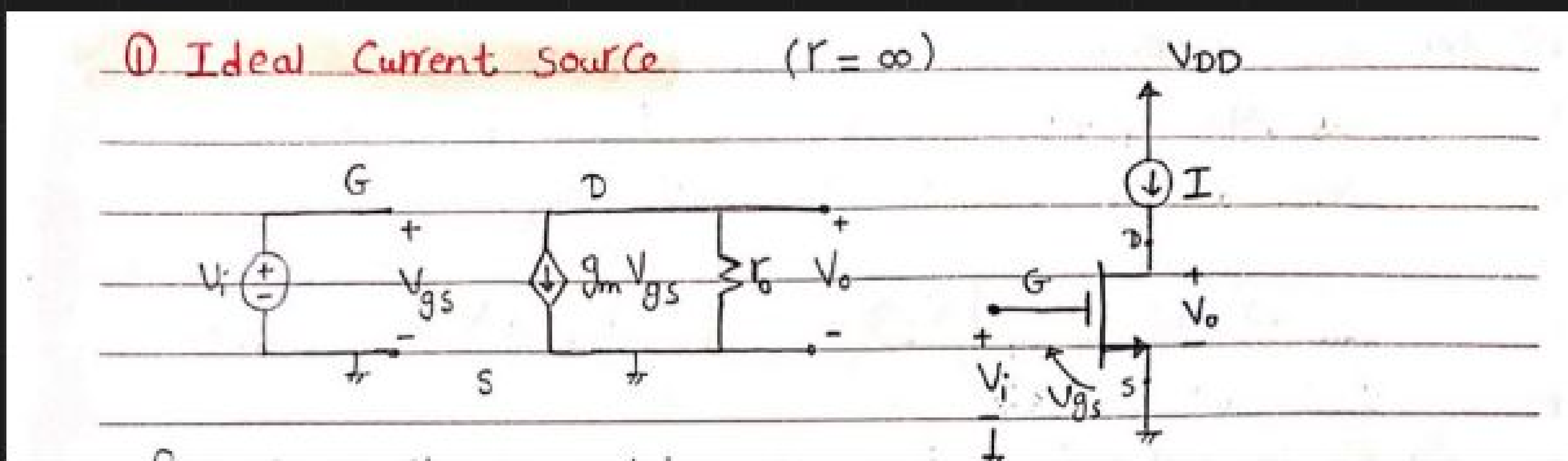
- active Loads in Common Source amp. can be current source or Mosfet.
- Current Source model:

① Ideal C.S 

$r = \infty$

② Practical C.S 

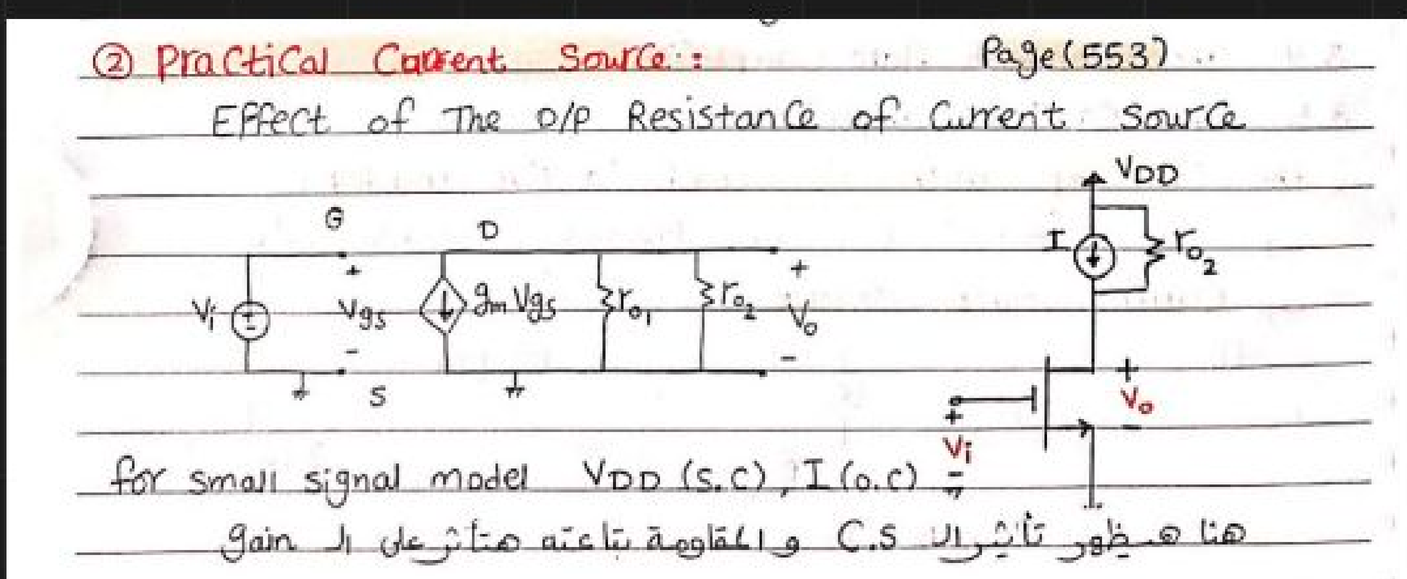
$r$ exists




1) $R_{in} = \frac{V_i}{i_i} = \frac{V_i}{0} = \infty$

2) $R_{out}$ at $V_i = 0 \leadsto \therefore V_{gs} = 0 \leadsto \therefore R_{out} = r_o$

3) $A_{v_o} = \frac{V_o}{V_i} = \frac{-g_m \cancel{V_{gs}} r_o}{\cancel{V_{gs}}} \leadsto \therefore A_{v_o} = -g_m r_o$ "intrinsic gain"



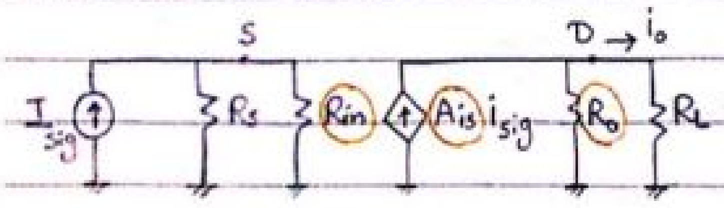

1) $R_{in} = \infty$

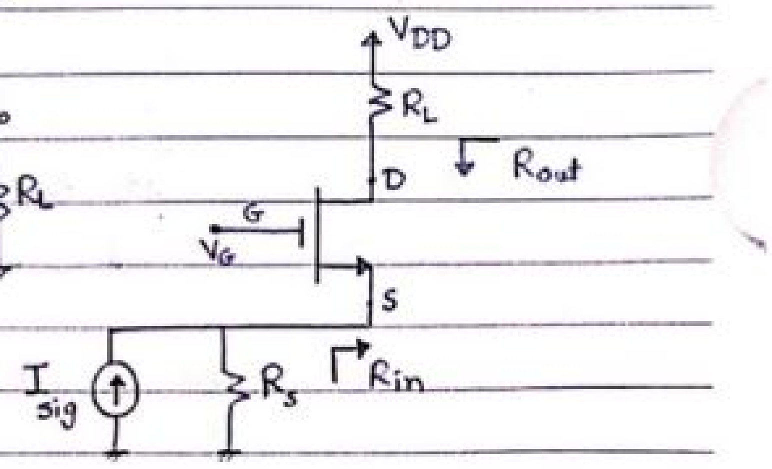
2) $R_{out} = r_{o1} // r_{o2}$

3) $A_v = -g_m (r_{o1} // r_{o2})$ , if $r_{o1} = r_{o2} \leadsto A_v = \frac{1}{2} A_{v_o}$

# * Common gate amplifer:

8.4 Common gate amplifier




_ ال model ده ملوش لازمة
غير إنه بيعرفنا النظام عامل
ازاي لكن عشان نجيب أي
حاجة بيكون من ال equivalent اللي
احنا عارفينه.

Elzahraa

* $R_{in}$, $R_{out}$, $A_v$

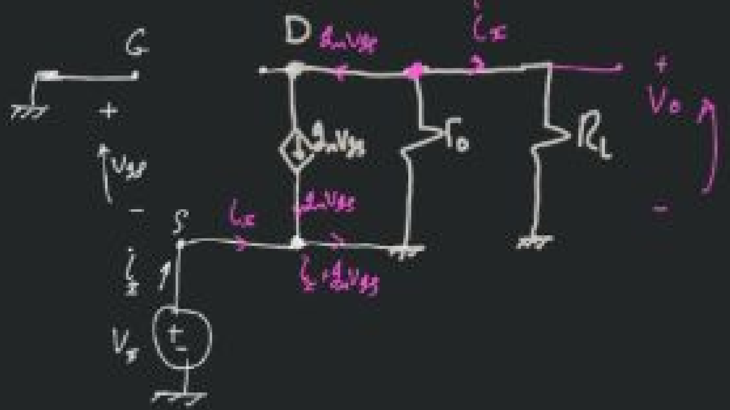
$V_x = (i_x + g_m V_{gs}) r_o + i_x R_L$ .... (1)

$\because V_{gs} = V_g^{\,0} - V_s = -V_s$ , $\because V_x = V_s$ , $\therefore V_{gs} = -V_x$

$\therefore V_x = i_x r_o - g_m V_x r_o + i_x R_L$

$\therefore V_x [1 + g_m r_o] = i_x [r_o + R_L]$

$\therefore \boxed{R_{in} = \frac{V_x}{i_x} = \frac{r_o + R_L}{1 + g_m r_o}}$ $\quad R_{in} \simeq \frac{1}{g_m}$




$A_{is} = \frac{i_o}{i_i}\Big|_{R_L=0}$ , $V_{gs} = V_g^{\,0} - V_s = -V_s$

①: $i_i - \frac{V_s}{R_s} = i_o$

$\therefore i_i + \frac{V_{gs}}{R_s} = i_o$ ...... (1)

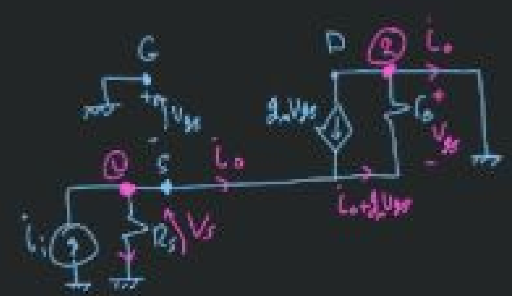
②: $i_o + g_m V_{gs} + \frac{V_{gs}}{r_o} = 0$ ..... (2)

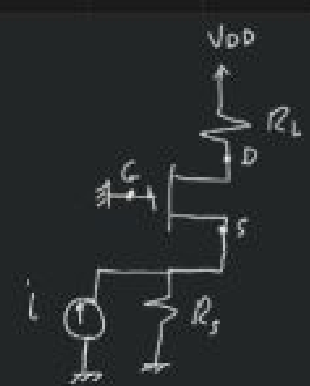
From (2)

$V_{gs} = (i_o - i_i) R_s$

$\therefore i_o + g_m (i_o - i_i) R_s + (i_o - i_i) R_s / r_o = 0$

$\therefore i_o [1 + g_m R_s + \frac{R_s}{r_o}] = i_i [+ g_m R_s + \frac{R_s}{r_o}]$ ⟶ $\therefore \boxed{A_{is} = \frac{i_o}{i_i} = \frac{g_m R_s + R_s/r_o}{1 + g_m R_s + R_s/r_o}}$ ☆



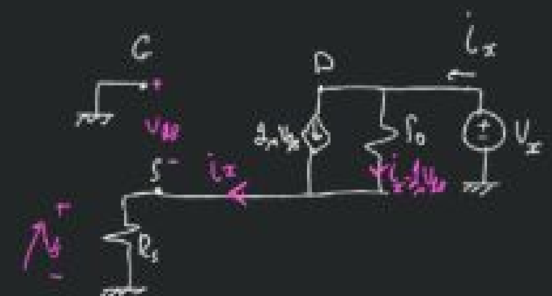

$R_o$

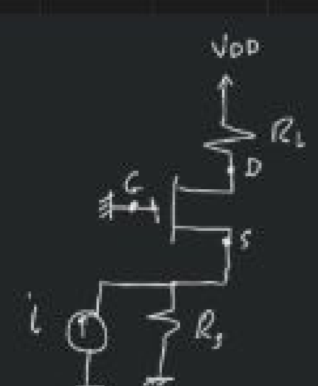
$V_x = (i_x - g_m V_{gs}) r_o + i_x R_s = 0$ .... (1)

$\because i_x = \frac{V_s}{R_s} = \frac{-V_{gs}}{R_s}$ ⟶ $\therefore V_{gs} = -i_x R_s$

$\therefore V_x = i_x r_o + i_x g_m R_s + i_x R_s = 0$

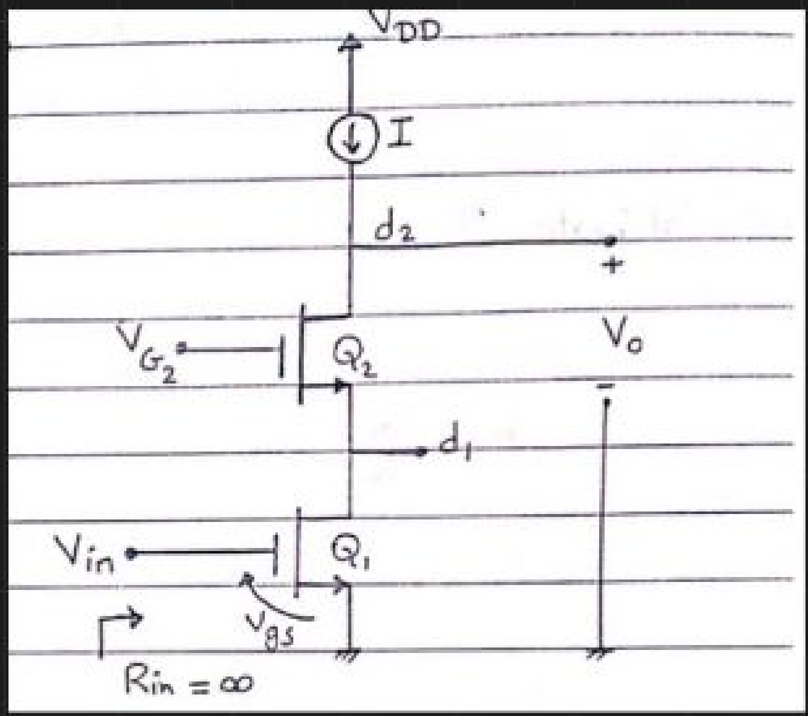
$\therefore V_x = i_x [r_o + g_m R_s + R_s]$ ⟶ $\therefore \boxed{R_o = \frac{V_x}{i_x} = r_o + g_m R_s + R_s}$ ☆ ⟶ $R_o \simeq g_m r_o R_s$



# Cascode amplifier:

→ is a CG amp. but it's $R_{in} \neq \infty$, so we use it with CS amp who has $R_{in} = \infty$
So there is no current drop at i/p. the cascode gain higher.




. $Q_1$: CS , $Q_2$: CG

. $R_{in} = R_{in}(Q_1) = \infty$

. $A_{is}(CG) = \dfrac{g_m R_s + \cancel{R_s/r_o}^{\,0}}{1 + g_m R_s + \cancel{R_s/r_o}_{\,0}} \simeq \dfrac{g_m R_s}{g_m R_s} = 1$ " $r_o >>$ "

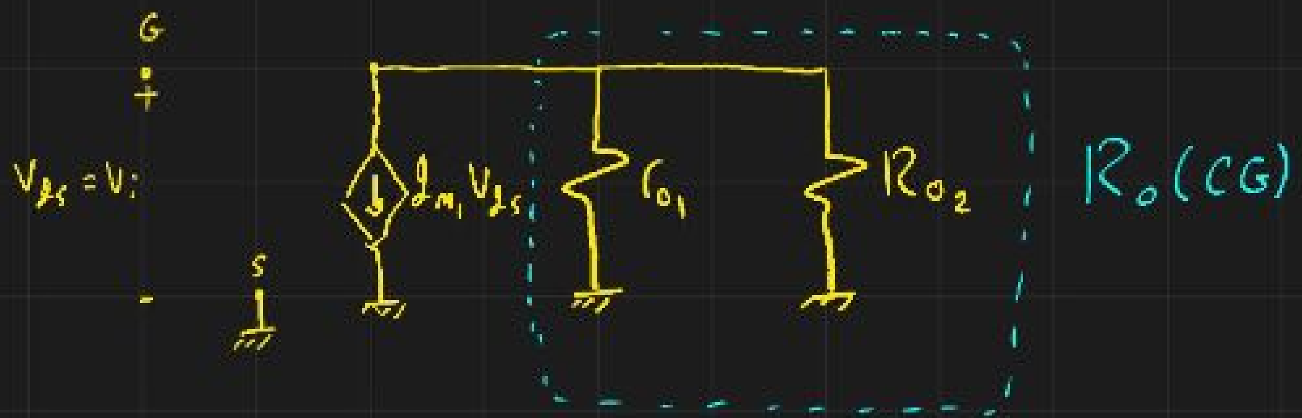
. $R_o(CG) = g_{m_2} r_{o_2} R_s = g_{m_2} r_{o_2} r_{o_1}$

$\therefore A_{v_o} = -g_{m_1} R_o(CG)$

$\therefore A_{v_o} = -g_{m_1}(g_{m_2} r_{o_2} r_{o_1})$

$\therefore \boxed{A_{v_o} = -(g_{m_1} r_{o_1})(g_{m_2} r_{o_2})}$

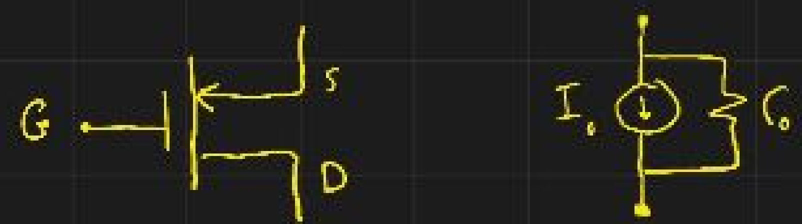
$\therefore \boxed{A_{v_o} = -A_{v_{o_1}} \cdot A_{v_{o_2}}}$

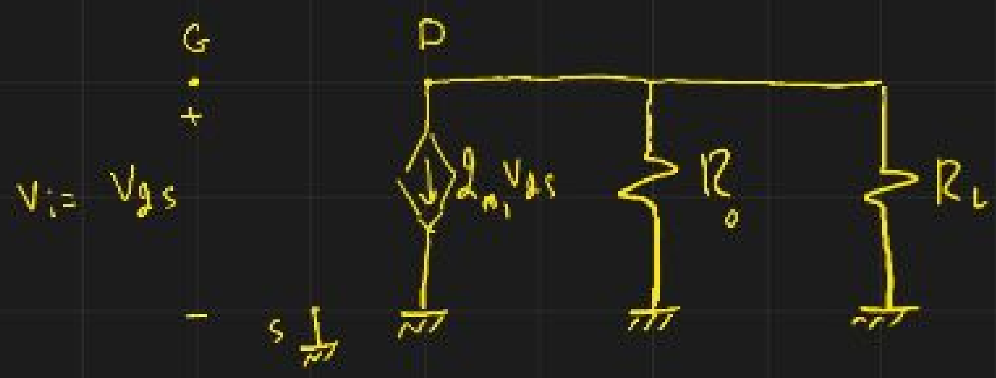


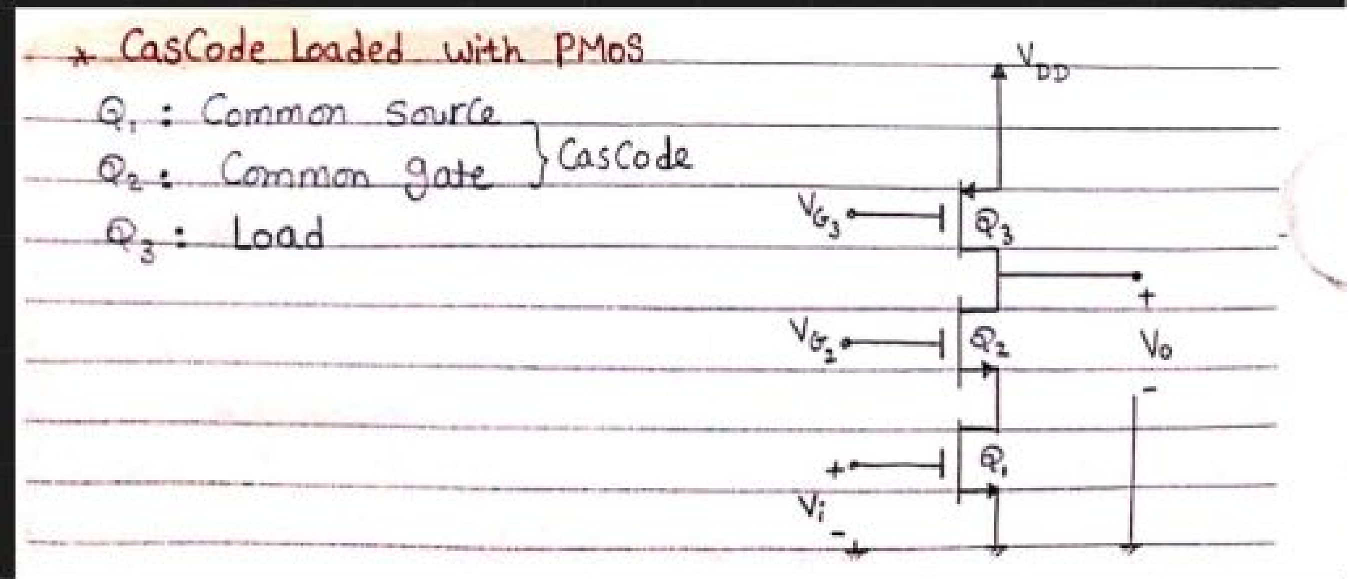

. if $g_{m_1} = g_{m_2}$, $r_{o_1} = r_{o_2}$ ⟶ $\boxed{A_v = -A_{v_o}^2}$ ↑↑ 2-times intrinsic gain ↑↑

→ the gain ↑↑ in this case because we used ideal c.s $r_o \simeq \infty$, it's practical equivilent is c.s PMOS.

→ also the MOS will drive constant current.






→ $R_o = R_o(Q_2) = g_{m_2} r_{o_2} R_s = g_{m_2} r_{o_2} r_{o_1}$

→ $R_L$ : is the resitance at the drain of $Q_2$ → which is $r_{o_3}$ → ∴ $R_L = r_{o_3}$

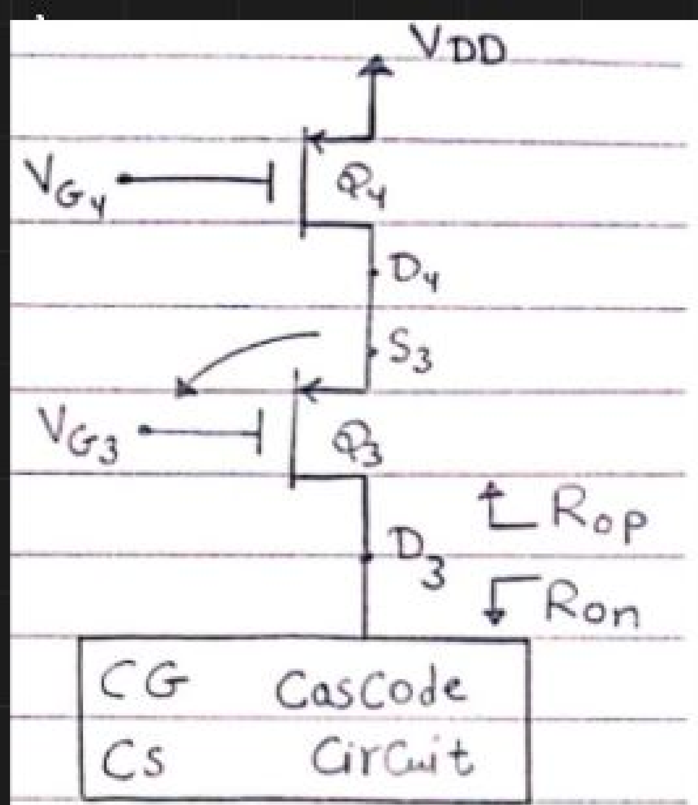
$\therefore A_v = -g_{m_1}(R_o // R_L)$

$\therefore \boxed{A_v = -g_{m_1}\left[(g_{m_2} r_{o_2} r_{o_1} // r_{o_3})\right]}$

. if $r_{o_1} = r_{o_2} = r_{o_3} = r_o$ → $\therefore g_{m_2} r_{o_2} r_{o_1} >> r_{o_3}$ → $\therefore$ $\boxed{A_v = -g_{m_1} r_o}$ ↓↓

## * Cascode with 2 PMos as load:

→ the gain has decreased ↓↓ , to increase it we'll use 2 PMos as load.


→ $Q_1, Q_2$ are C.S followed by C.G (N mos)

↳ $R_{o_n} = g_{m_2} r_{o_2} R_s = g_{m_2} r_{o_2} r_{o_1}$ → $R_o$

→ $Q_3, Q_4$ are C.S followed by C.G (PMos)

↳ $R_{o_p} = g_{m_3} r_{o_3} R_s = g_{m_3} r_{o_3} r_{o_4}$ → $R_L$

$\therefore A_v = -g_{m_1}(R_{o_n} // R_{op})$

$\therefore \boxed{A_v = -g_{m_1}(g_{m_2} r_{o_2} r_{o_1} // g_{m_3} r_{o_3} r_{o_4})}$

→ if $g_{m_1} = g_{m_2} = g_{m_3} = g_{m_4} = g_m$ and $r_{o_1} = r_{o_2} = r_{o_3} = r_{o_4} = r_o$

↳ $\boxed{A_v = -\frac{1}{2} g_m^2 r_o^2 = -\frac{1}{2} A_{v_o}^2}$ ↑↑

**Ex (8.4)** Very important Page (573) علي الرحمه اللي فاتت

Design a CasCode Current Source to Provide a Current of 100 μA and an o/p resistance of 500 KΩ, assume the availability of 0.18 μm CMOS technology for which $V_{DD} = 1.8$ V, $V_{tp} = -0.5$ V, $\mu_p C_{ox} = 90\ \mu A/V^2$ and $V_A' = -5$ V/μm. use $|V_{ov}| = 0.3$ V and determine L and W/L for each transistor, and the values of the bias voltage $V_{G3}$, $V_{G4}$.

$I_D = 100\ \mu A$ $\quad \mu_p C_{ox} = 90\ \mu m/V^2$

$R_{out} = 500 K\Omega$ $\quad V_A' = -5\ V/\mu m \longrightarrow V_A = V_A' L$

$V_{DD} = 1.8$ V $\quad |V_{ov}| = 0.3$ V

$V_{tp} = -0.5$ V $\quad Q_3$ & $Q_4$ are matched

find: $L$, $\frac{W}{L}$, $V_{G_3}$, $V_{G_4}$

$\because R_{op} = g_{m_3} r_{o_3} r_{o4}$ $\quad \because Q_3, Q_4$ matched

$R_{op} = g_m r_o^2 \longrightarrow ①$ $\quad r_{o_3} = r_{o4} = r_o$

$\because g_m = \dfrac{2 I_D}{|V_{ov}|} \longrightarrow ②$

$\because r_o = \dfrac{|V_A|}{I_D} \longrightarrow ③$

from ①, ②, ③

$$R_{op} = \frac{2 I_D}{|V_{ov}|} \cdot \left(\frac{|V_A|}{I_D}\right)^2 = \frac{2 |V_A'|^2 L^2}{|V_{ov}|\ I_D}$$

$$500 * 10^3 = \frac{2\ |-5|^2 * 10^{12}\ L^2}{|0.3| * 100 * 10^{-6}} \qquad L^2 = 3 * 10^{-13}$$

$\boxed{L = 5.478 * 10^{-7} m}$

$\boxed{L = 0.56\ \mu m}$

$\because V_{SG4} = |V_{tp}| + |V_{ov}|$

$= 0.5 + 0.3 = 0.8$ V

$V_{SG4} = V_{S4} - V_{G4}$ $\quad V_{S4} = V_{DD} = 1.8$ V

$0.8 = 1.8 - V_{G4}$

$\boxed{V_{G4} = 1\ V}$

* for saturation :-

$V_{SD_4} \geq |V_{ov}| = 0.3$ $\quad \underset{1.8}{V_{S4}} - V_{D4} \geq 0.3$

$V_{SD_3} \geq |V_{ov}| = 0.3$ $\quad \boxed{V_{D4} \leq 1.5 V}$

$V_{S_3} - V_{D_3} \geq 0.3$

$V_{D4} = 1.5$ $\quad \boxed{V_{D4} \leq 1.2 V}$

$V_{SG4} = V_{SG_3} = V_{S_3} - V_{G_3}$

$0.8 = 1.5 - V_{G_3}$

$\boxed{V_{G3} = 0.7 V}$

$$I_D = \frac{1}{2} \mu_p C_{ox} \frac{W}{L} |V_{ov}|^2 (1 + \lambda V_{SD}) \qquad \lambda = \frac{1}{|V_A|}$$

$$100 \mu = \frac{1}{2}\ 90 \mu\ \frac{W}{L}\ |0.3|^2 \left(1 + \frac{0.3}{|V_A|}\right)$$

$|V_A| = |V_A'|\ L = 5(0.55) = 2.75$ V

$\boxed{V_A = 2.75 V}$

$\boxed{\frac{W}{L} = 22.3}$