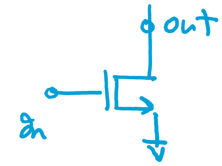
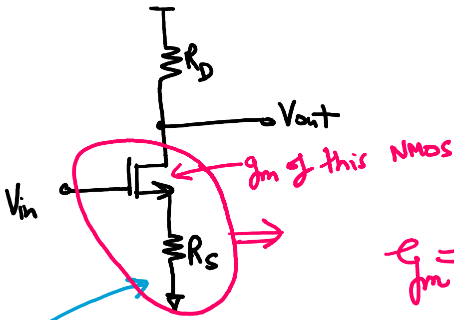
ECE 310 - Lecture 24

Wednesday, March 21, 2018 10:30 AM

Common Source with Source-Degeneration:

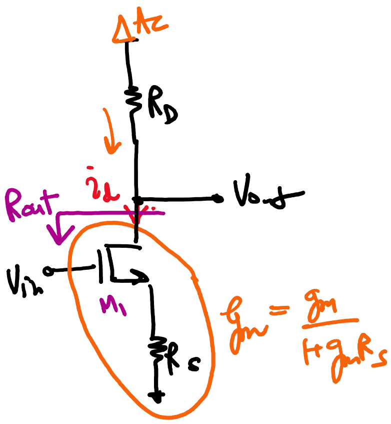




Source Degeneration

$$G_m = \frac{g_m}{1+g_m R_s}$$

$$= \frac{g_m \text{ of NMOS}}{1+ g_m \times R_s} \longrightarrow \text{more linear input-output behavior}$$

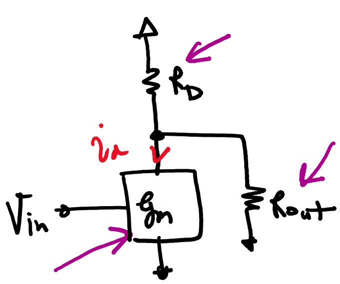


$$i_d = G_m v_{in}$$

$$v_{out} = -i_d (R_D \| R_{out})$$

$$\simeq -i_d R_D$$

$$= -\frac{g_m}{1+g_m R_s} \cdot R_D \cdot v_{in}$$



assume $r_{o_1} \to \infty$

$\rightarrow R_{out} \to \infty$

$$\Rightarrow A_v = \frac{v_{out}}{v_{in}} = -\frac{g_m R_D}{1+g_m R_s}$$

$$= -\frac{R_D}{\frac{1}{g_m}+R_s}$$

if $\frac{1}{g_m} \ll R_s$

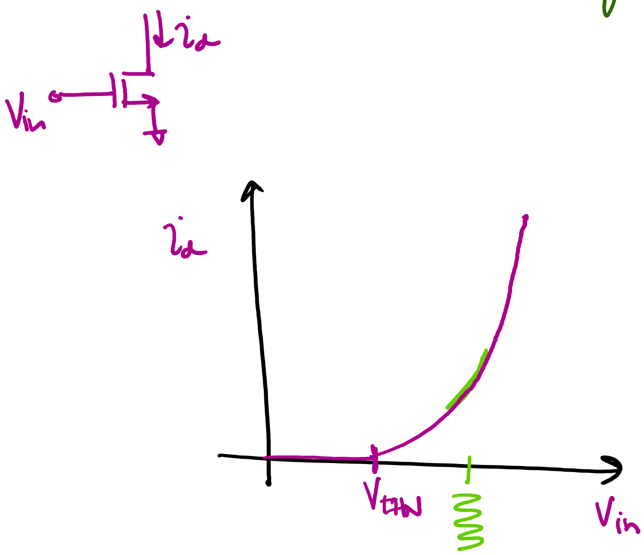
$\Rightarrow g_m R_s \gg 1$

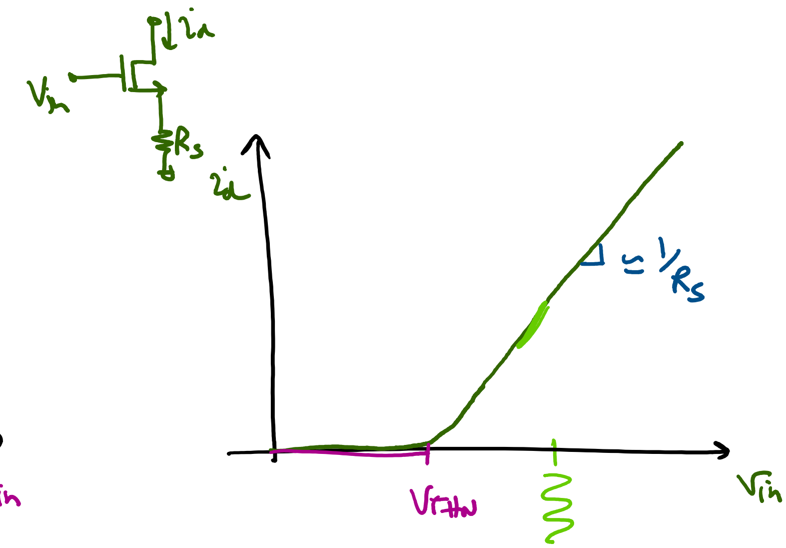
$$= -\frac{R_D}{R_s}$$

for large $g_m R_s \gg 1$

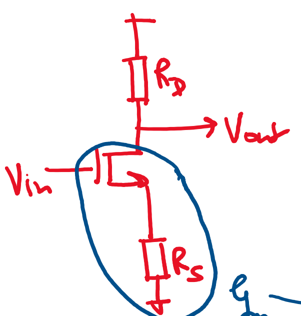
$$\Rightarrow \quad A_v \simeq -\frac{R_D}{R_S} \Rightarrow \text{independent of } g_m$$

gain is insensitive to NMOSFET variations.





"Linearized CS Amplifier"



$$\Rightarrow \quad A_v \simeq -\left(\frac{g_m}{1+g_m R_S}\right) \times R_D$$

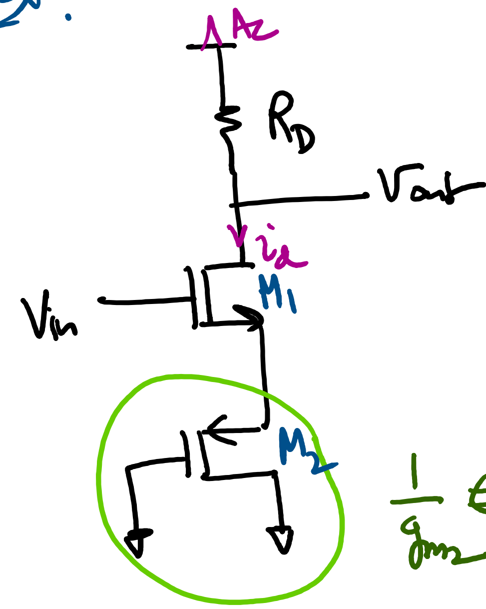
$g_m \longrightarrow G_m$

gain is reduced by a factor of
$(1+g_m R_s)$
↳ Trading gain with linearity.

Ex.

Assume

$\lambda = 0 \Rightarrow r_o \Rightarrow \infty$

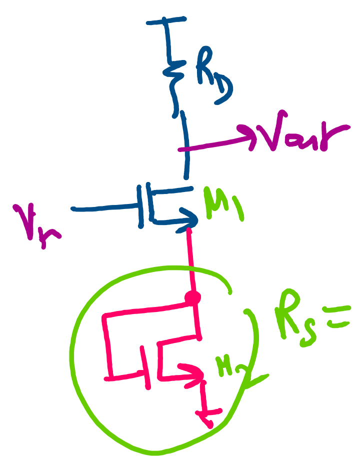


$\frac{1}{g_{m2}} \in R_S$

$$A_v = -G_m \cdot R_D$$

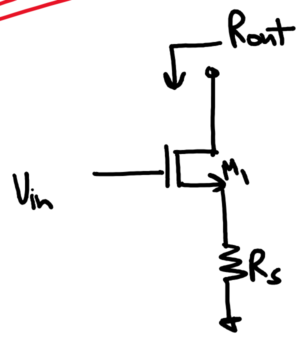
$$= -\frac{g_{m1}}{1 + g_{m1} \cdot \frac{1}{g_{m2}}} \cdot R_D$$

$$= -\frac{R_D}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}}$$

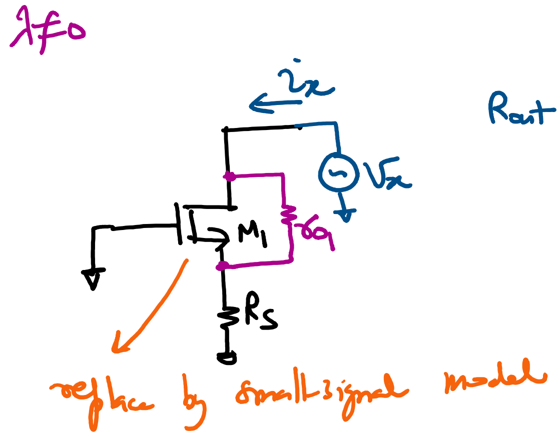


$R_S = \frac{1}{g_{m2}}$

Important

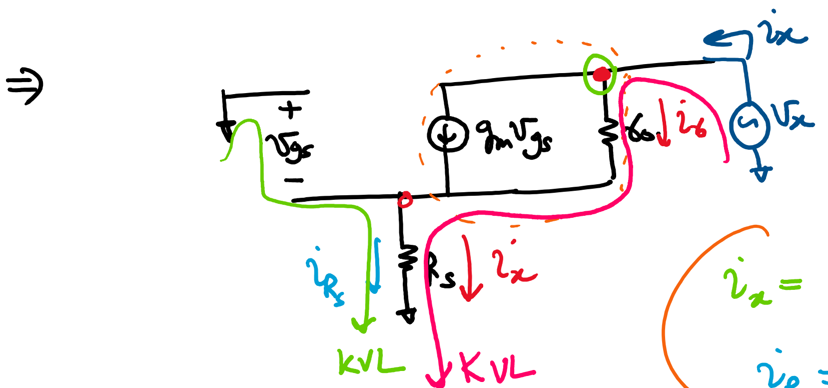


$\Rightarrow$



$$R_{out} = \frac{v_x}{i_x}$$

$\Rightarrow$



$$i_x = i_{r_o} + g_m v_{gs}$$

$$i_{R_s} = g_m v_{gs} + i_{r_o} = i_x$$

KVL: $v_{gs} + i_x R_s = 0$

$\Rightarrow \quad v_{gs} = -i_x R_s \longrightarrow ①$

KVL: $v_x = \underbrace{(i_x - g_m v_{gs})}_{i_{r_o}} \times r_o - v_{gs} \longrightarrow ②$

Combine ① & ②

$$v_x = \left[i_x - g_m(-i_x R_s)\right] r_o - (-i_x R_s)$$

$$= i_x r_o + (g_m R_s r_o) i_x + i_x R_s$$

$$= i_x \left[g_m r_o R_s + R_s + r_o \right]$$

$= $ [illegible]

$= i_x [\, g_m r_o R_s + R_s + r_o \,]$

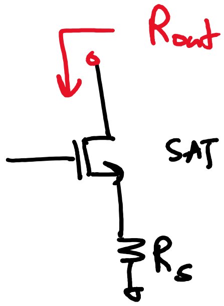
$\Rightarrow$

$$R_{out} = \frac{v_x}{i_x} = (1 + g_m R_s) r_o + R_s = \boxed{(g_m r_o) R_s + R_s + r_o}$$

if $g_m R_s \gg 1$

$$\simeq (g_m r_o) R_s$$

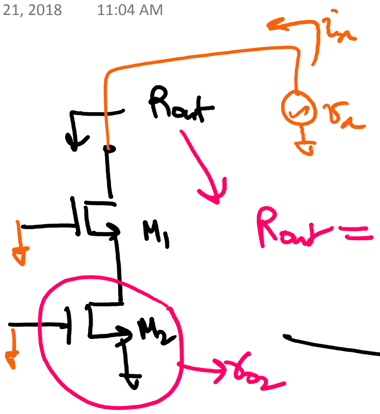
$R_{out} \simeq R_s \times g_m r_o$



R_{out} is raised from r_o to $(g_m r_o) R_s$

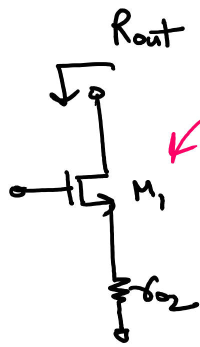
$\Rightarrow$ Method to obtain higher output resistance

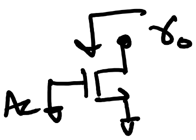
$\Rightarrow$ "CASCODING"



$R_{out} =$

$R_{out} = g_{m1} r_{o1} R_s + r_{o1} + R_s$



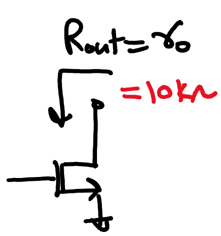


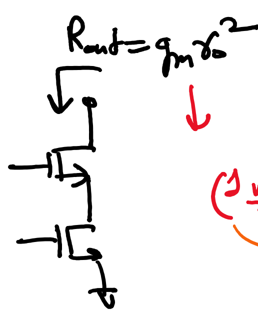
$R_{out} = g_{m1} r_{o1} r_{o2} + r_{o1} + r_{o2}$

Let M_1 & M_2 are identical

$\Rightarrow$ $g_{m_{1,2}} = g_m$ $\quad r_{o1} = r_{o2} = r_o$

$R_{out} \simeq g_m r_o^2 + 2r_o \simeq g_m r_o^2$

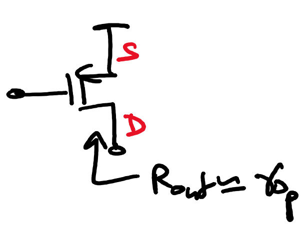


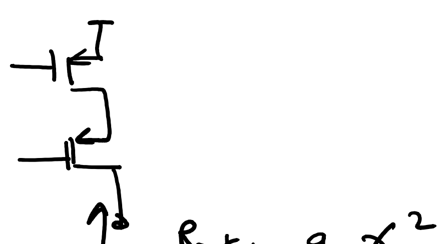


$\underbrace{\left(1 \frac{mA}{V} \times 10k\Omega\right)}_{10} 10k\Omega = 100k\Omega$

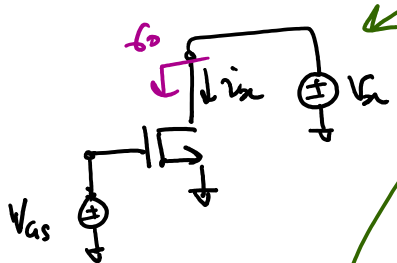
Let $r_o = 10k\Omega$

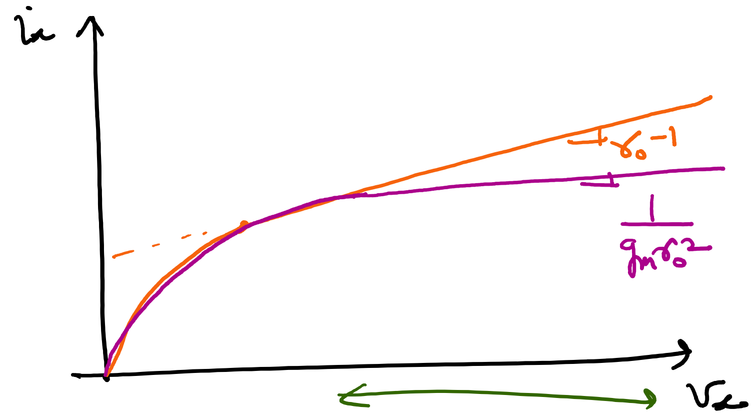
$g_m = 1 \frac{mA}{V}$

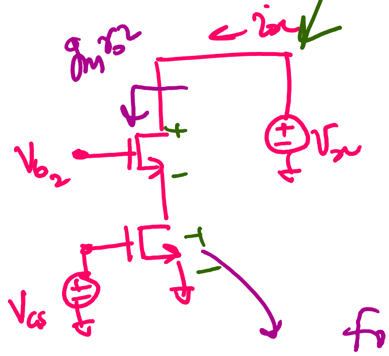




Current source







forms a more precise current source (reference)

$\Rightarrow R_{out} = g_m r_o^2 \gg r_o$

CASCODE current mirror/source

→ Cascade of Common Source & Common Gate

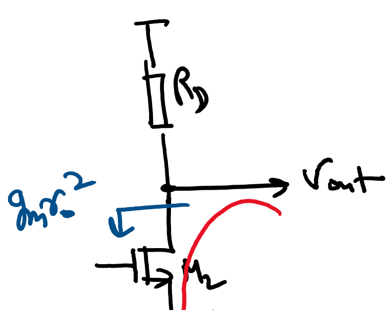
~ 1910

Common Source

→ CS + SD

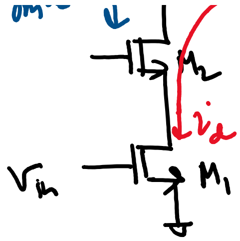
→ output resistance ($g_m r_o^2$)

→ cascode structures



$v_{out} = -i_d (R_D \| g_m r_o^2)$

$= -g_m v_i (R_D \| g_m r_o^2)$



$$v_{out} = -i_d \left(R_D \,\|\, g_m r_o^2\right)$$

$$= -g_{m1} v_{in} \left(R_D \,\|\, g_m r_o^2\right)$$

$$\Rightarrow A_v = -g_{m1} \left(R_D \,\|\, g_m r_o^2\right)$$

$R_D = g_{mp} r_{op}^2$

$$= -g_{mn} \underbrace{\left(g_{mp} r_{op}^2\right) \,\|\, \left(g_{mn} r_{on}^2\right)}_{1M\Omega}$$

get gains boosted by 100 – 1000x