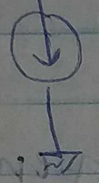
Chapter 9:

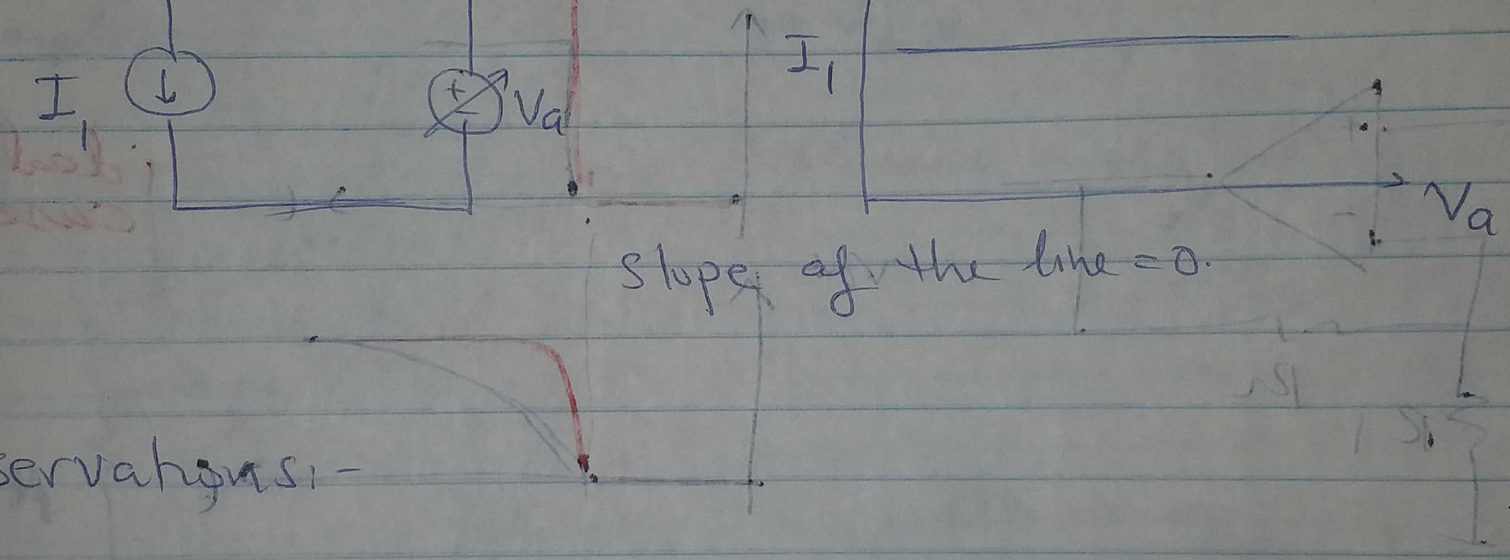
Today's lect.
Cascode Current Source topologies

* Ideal Current Source



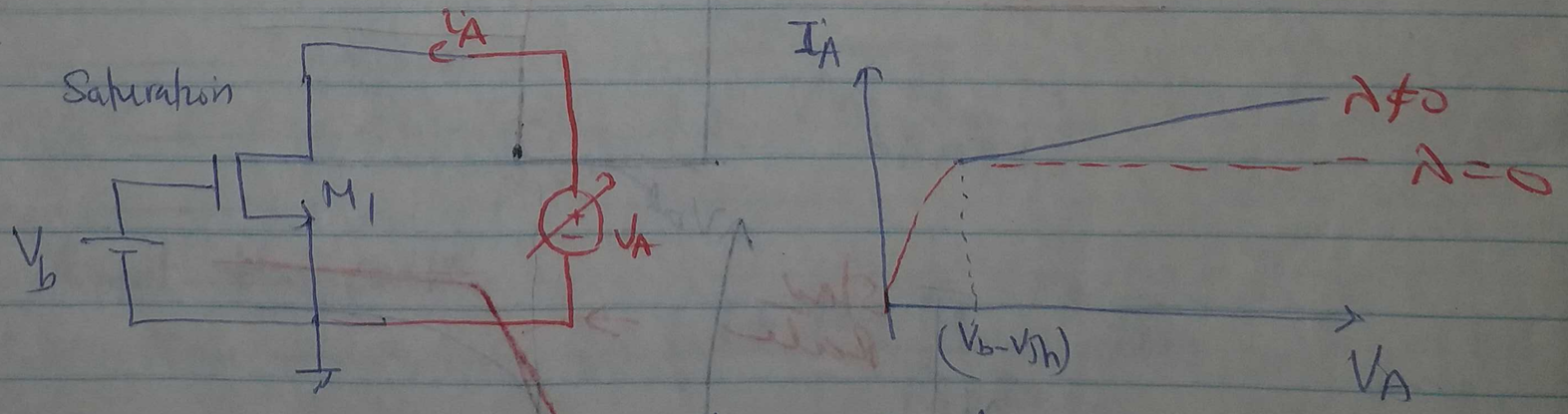
I_1 : current is constand and it is independent of voltage across it V_1

To test it by applying voltage and meause i_a.



Observations:-

1) Let's build a current source
MOS device in Saturation can operate as current source



* I_A: not constant due to channel length modulation

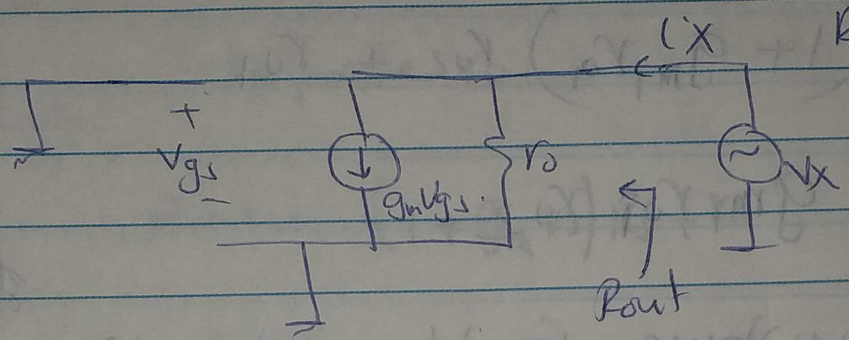
* When V_A decrease ⇒ MOS goes to triode region

We have two limitons :-

1) when $V_A > (V_b - V_{TH})$ ⇒ MOS operates as current source with slope due to channel length modulation (Saturation mode)

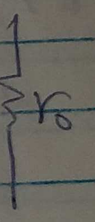
2) when $V_A < (V_b - V_{TH})$ ⇒ MOS operates as triode Mode not work as current source

Small Signal Model



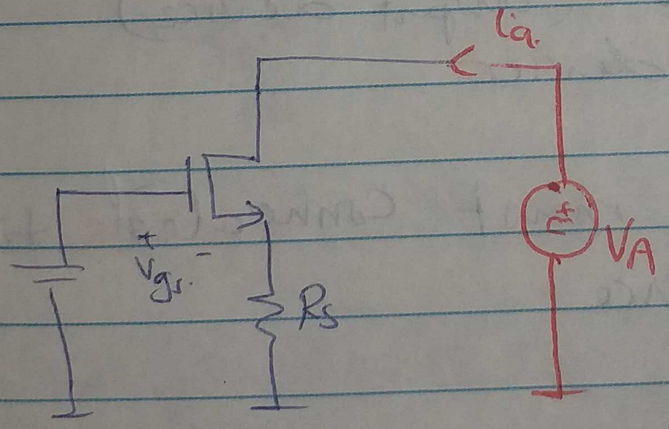
$R_{out} = \frac{V_x}{i_x}\Big|_{V_{in}=0}$

$R_{out} = r_o$ ⇒



2) The question, how to improve the current source :-
That can done by ~~cascode~~ degenerator Configuration

improve = get high Rout with flat



Using small Signal Analysis from electronic I

$R_{out} = \underbrace{(1 + g_m r_o)}_{\text{intrinsic gain}} R_s + r_o$

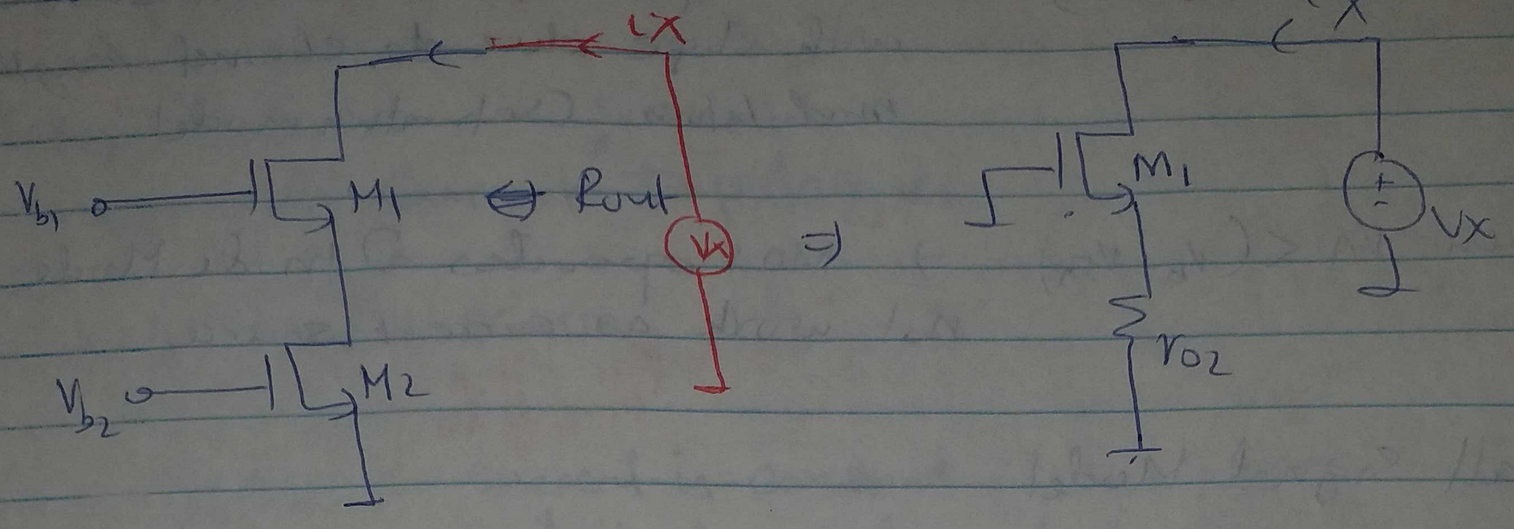
⇒ The result becomes greater than r_o.

$V_G = V_{gs} + R_s I_D$

In order to be @ sat $V_G - V_{TH} < V_{DS}$

$(V_{gs} + R_s I_D) - V_{TH} < V_{DS}$

3) Cascode Current Source



$$R_{out} = (1 + g_{m_1} r_{o_1}) r_{o2} + r_{o1}$$

$$\cong g_{m_1} r_{o_1} r_{o2}$$

The output resistance is the intrinsic gain of main transistor * output of second transistor.

Remmber:

1) * Both M_1 and M_2 have to be in Saturation

2) M_1 is called the cascode devices (output device)
M_2 is called the degeneration device

3) The source of cascode devices must connected to the drain of degeneration device

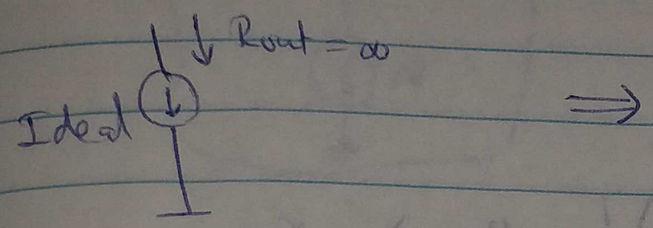
4) If we have M_2 (with r_{o2} output). To increase Rout of M_2 we put M_1 on the top of M_1.

5) In must application both M_1 and M_2 identical.

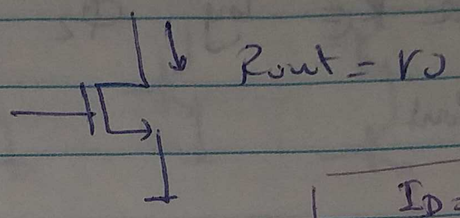
Question: What happens to Rout if the width of M_1 (W_1) and M_2 (W_2) are doubled. (I_D is constant)

Today's lect:
- MOS and Bipolar Cascode
- Current source
- P-Type Cascodes

Review:-



$\Rightarrow$



$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{gs}-V_{TH})^2$$

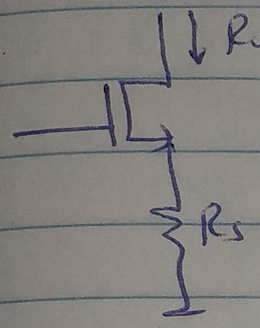
$$g_m = \frac{\partial I_D}{\partial V_{gs}} = \mu_n C_{ox}\frac{W}{L}(V_{gs}-V_{TH})$$

$$g_m = \sqrt{2 I_D \mu_n C_{ox} W/L}$$

$$g_m = \frac{2I_D}{V_{gs}-V_{TH}}$$

improve ro:-

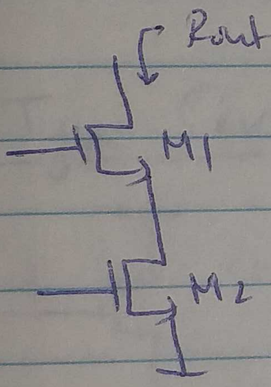
$\Rightarrow$



$$R_{out} = (1+g_m r_o)R_S + r_o$$

Both M_1, M_2 are saturated

$\Rightarrow$



$$R_{out} = (1+g_m r_o)r_{o2} + r_{o1} \cong g_{m_1} r_{o1} r_{o2}$$

$$g_{m_1} = \sqrt{2\mu_n C_{ox}(W/L) I_D}$$

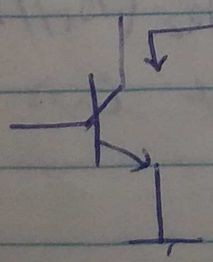
Question :- If W is doubled and I_D constant

$$R_{out} = \sqrt{2\mu_n C_{ox}\left(\frac{2W}{L}\right) I_D}\, r_{o1} r_{o2}$$

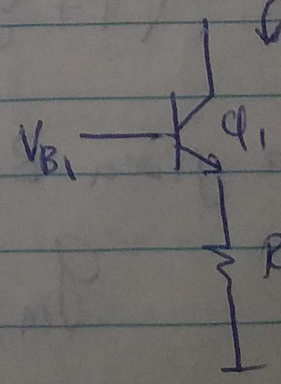
$$R_{out} = g_{m_1} r_{o1} r_{o2} = \sqrt{2\mu_n C_{ox}(W/L) I_D}\, r_{o1} r_{o2} \qquad W \to 2W$$

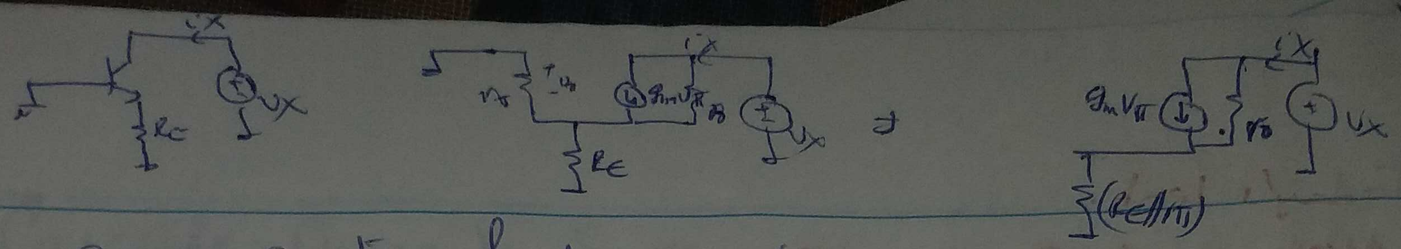
$$R_{out}' = \sqrt{2}\, R_{out}$$

Bipolar Cascode Current Sources:-



$\Rightarrow$ using degeneration to increase Rout

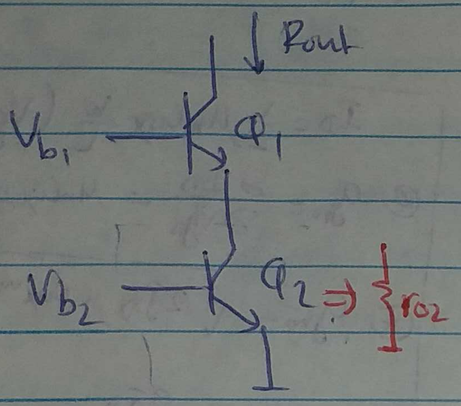




The same equation of degeneration

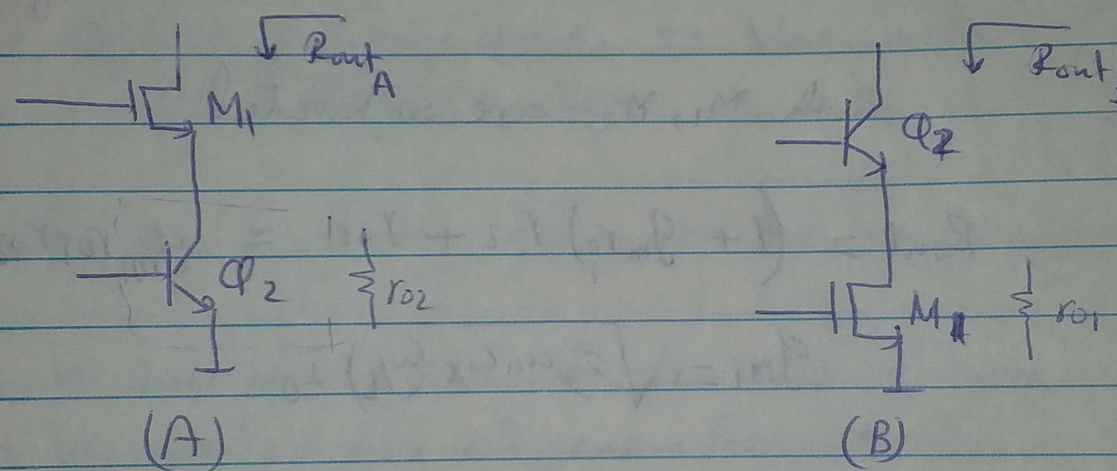
$$R_{out} = (1 + g_{m_1} r_{o_1})(R_E \,//\, r_{\pi_1}) + r_{o_1}$$

If we replace R_E by Q_2



$$R_{out} = (1 + g_{m_1} r_{o_1})(r_{o_2} \,//\, r_{\pi_1}) + r_{o_1}$$

Example:-



(A) (B)

Assume $r_{o_1} = r_{o_2}$

Find R_{out_A} , R_{out_B}

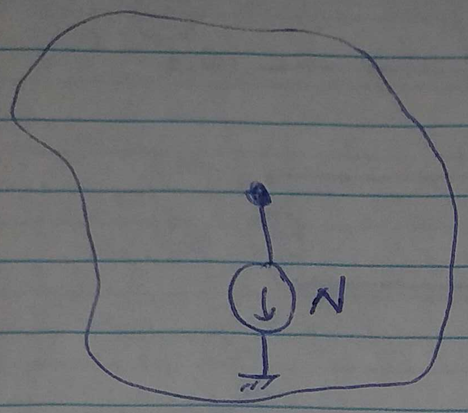
$$R_{out_A} = (1 + g_{m_1} r_{o_1})\, r_{o_2} + r_{o_1} \approx g_{m_1} r_{o_1} r_{o_2}$$

$$R_{out_B} = (1 + g_{m_2} r_{o_2})(r_{\pi_2} \,//\, r_{o_1}) + r_{o_1} = g_{m_2} r_{o_2} (r_{o_1} \,//\, r_{\pi_2})$$

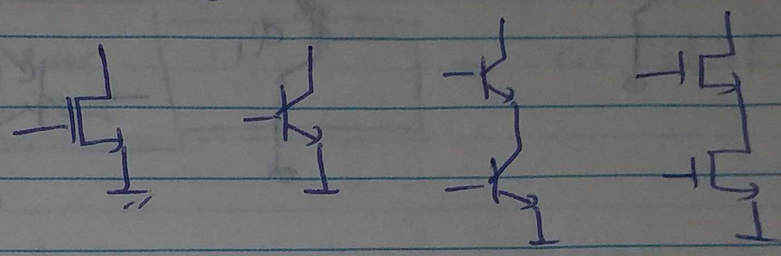
*** For a given Bias current

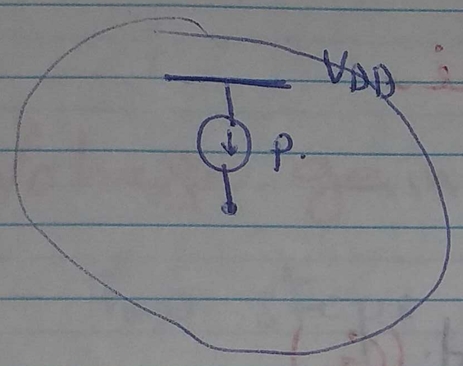
$$g_{m,MOS} < g_{m,BJT}$$

P-type current sources:-

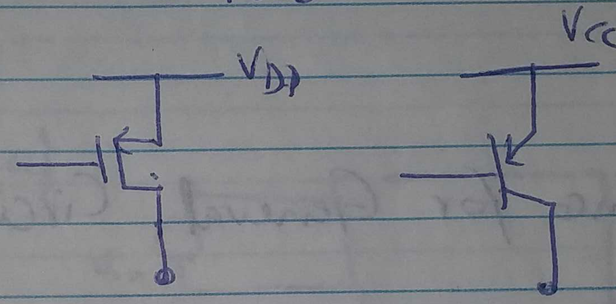


N-Type is current source that goes to gnd

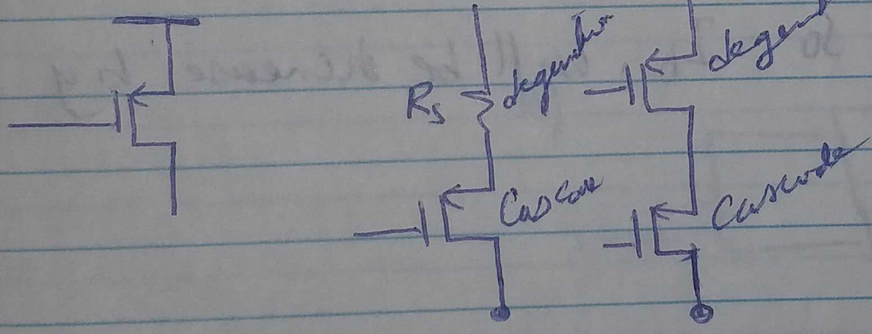




P-type ⇒ the current go in/o the node.

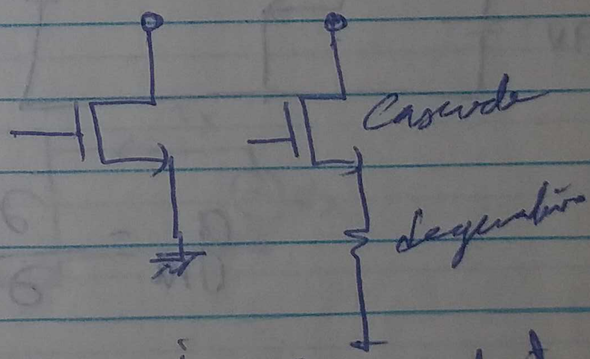


P- Type Cascode



Degeneration Connected from source to VDD

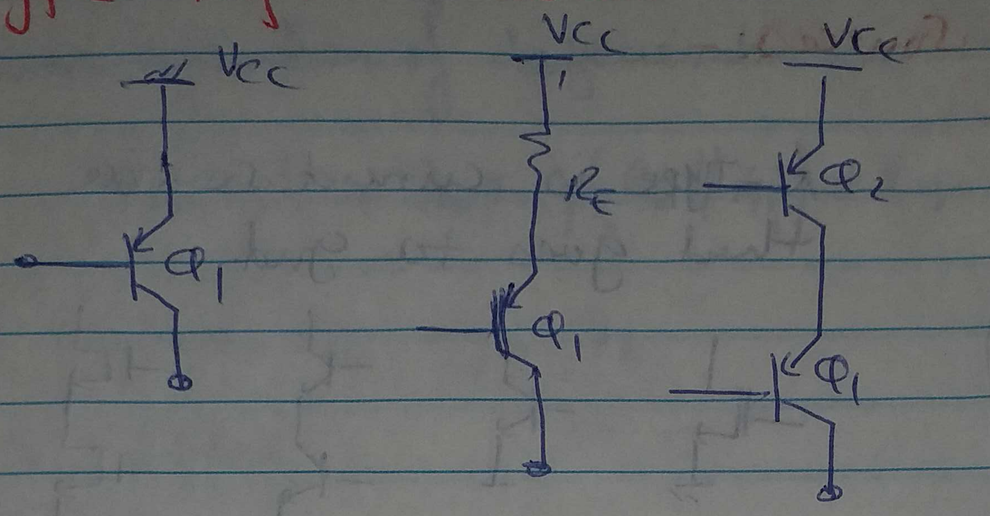
N-type Cascode



Degeneration Connected From source to gnd

The expression of Rout of P-type is the same as the Rout of N-type.

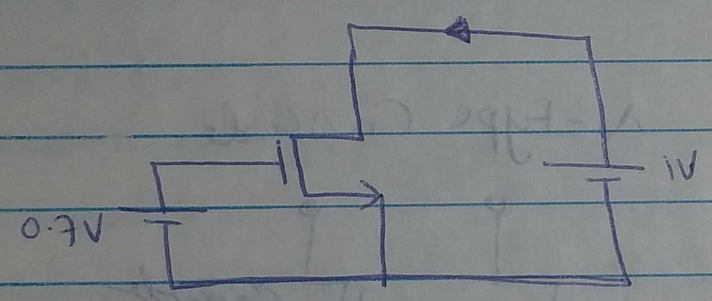
P-type Bipolar Cascode



Introduction to Cascode Amplifier

*Observations:-

1) Transconductance for General Circuit (Gm)



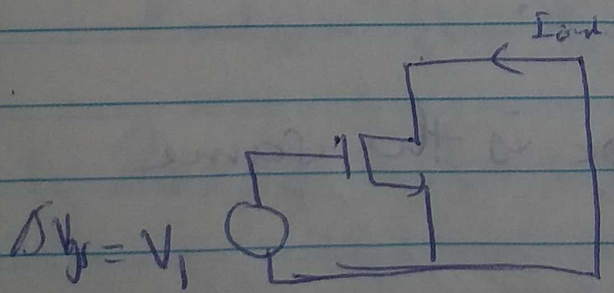
M2 saturation

If Vgs increase by ΔV_{GS}

So I_D will be increase by ΔI_D

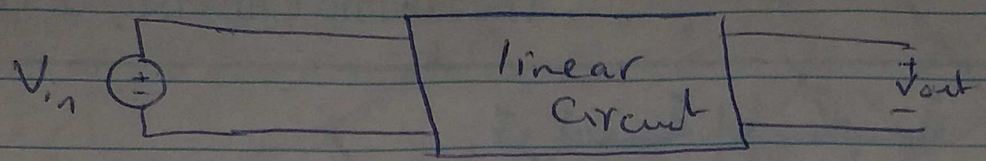
$$g_m = \frac{\partial I_D}{\partial V_{gs}}$$

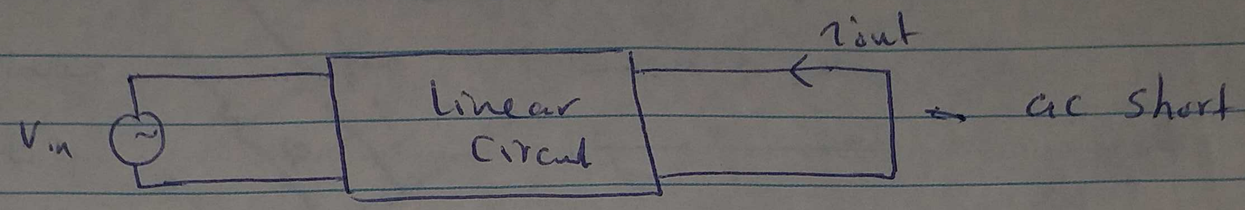
Using Small Signal Model



$$g_m = \frac{i_{out}}{v_1}$$

General Linear Circuit

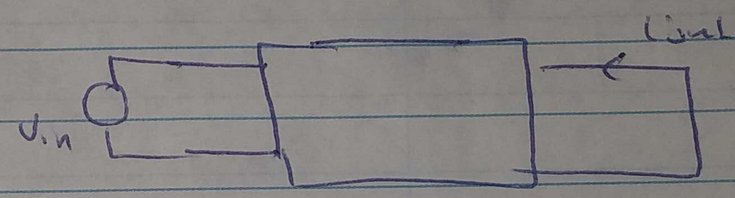




$$G_m = \left.\frac{i_{out}}{V_{in}}\right|_{V_{out}=0}$$

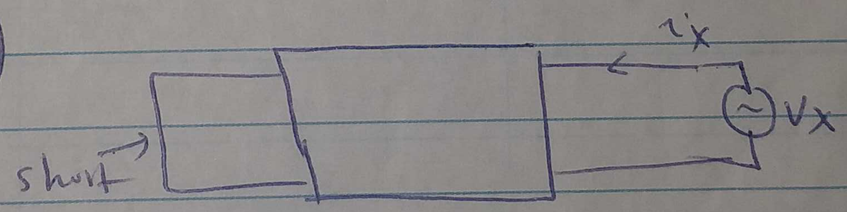
1) Voltage gain :

Two steps : a)



Find $G_m = \frac{i_{out}}{V_{in}}$.

b)



Find $R_{out} = \left.\frac{V_{out}}{i_{out}}\right|_{V_{in}=0}$ $\quad R_{out} = \frac{V_x}{i_x}$

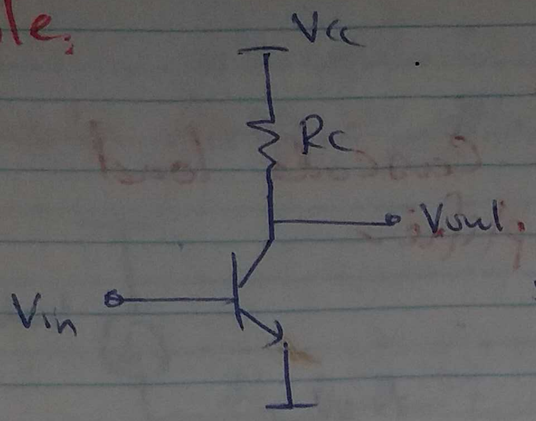
$$\Rightarrow \boxed{A_v = \frac{V_{out}}{V_{in}} = -G_m R_{out}}$$

To increase A_v ;- that can done by

1) increasing G_m

2) increase R_{out}

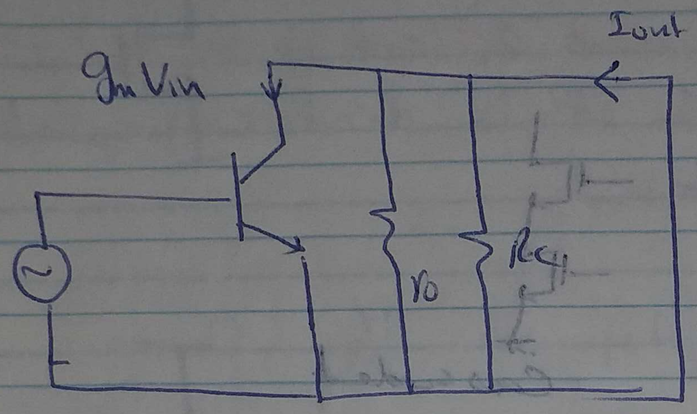
Example:



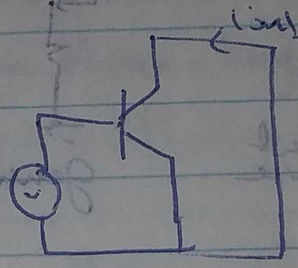
$V_A \neq \infty$

Find Voltage gain.

step(1):- Find transconductance G_m



$\Rightarrow$

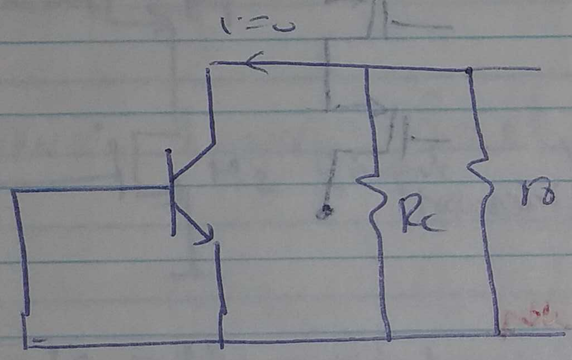


$$G_m = \frac{I_{out}}{V_{in}}$$

$$G_m = \frac{g_m V_{in}}{V_{in}}$$

$$= g_m$$

step(b). Calculate Rout



$\Leftarrow$ $R_{out} = R_c \| r_o$

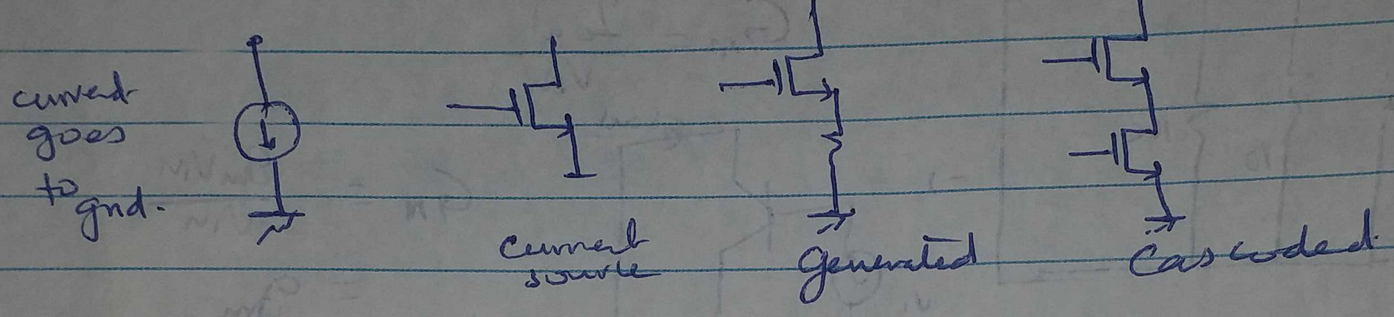
$$\Rightarrow A_v = -G_m R_{out} = -g_m (R_c \| r_o)$$

Today's lect.

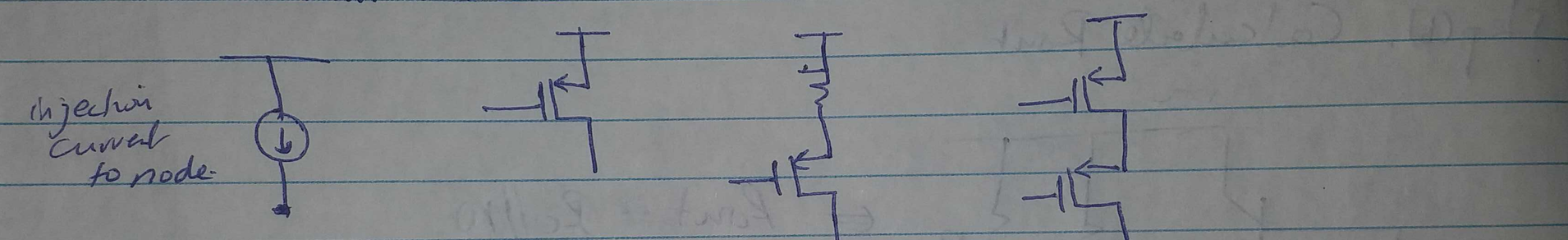
- MOS Cascode Amplifier
- Cascode Amplifier with Cascode load
- Bipolar Cascode Amplifier

Review:-

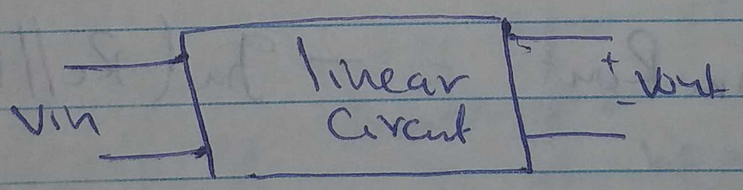
N-MOS Current source.



P-MOS Current source.

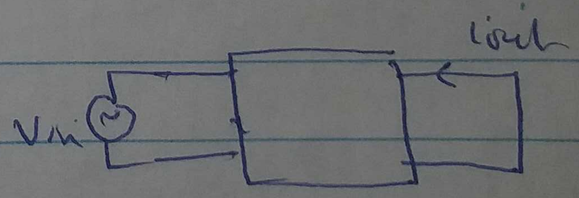


Alternative voltage Gain equation

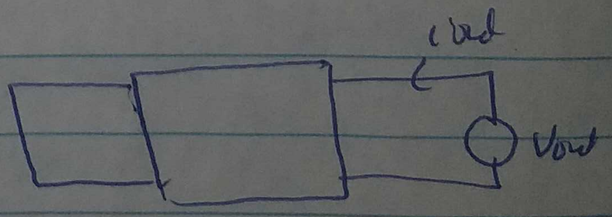


$$A_0 = -G_m R_{out}$$

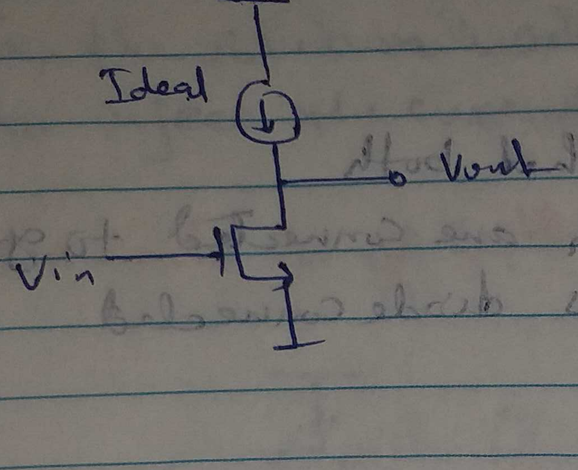
where a) $G_m = \left.\frac{I_{out}}{V_{in}}\right|_{V_{out}=0}$



b) $R_{out} = \left.\frac{V_{out}}{I_{out}}\right|_{V_{in}=0}$



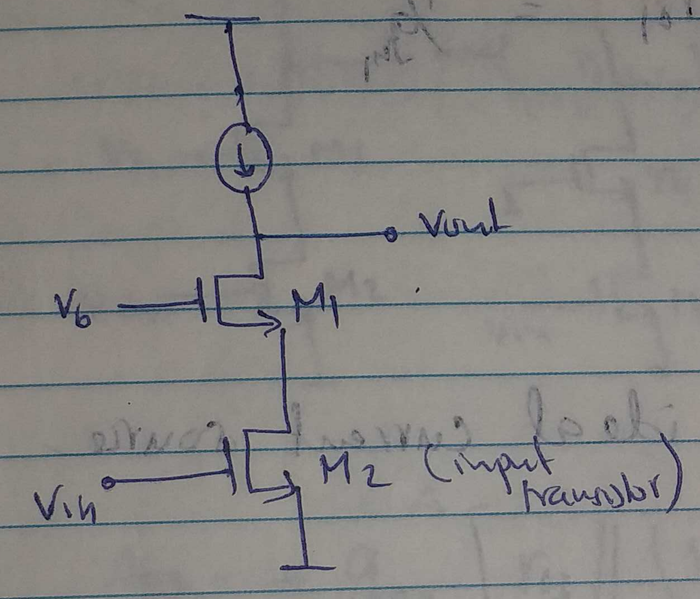
* Cascode Amp:-



$A_v = -g_m r_o$.
Can be written as

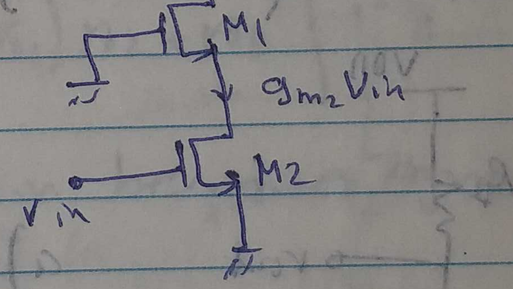
$A_v = -G_m R_{out}$

to increase R_{out} that can done by using Cascode.



$A_v = -G_m R_{out}$

a) Calculate Gm

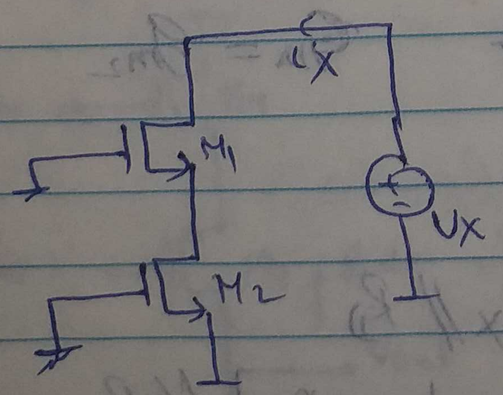


$i_{D_2} = i_{S_1} = i_{D_1} = i_{out}$

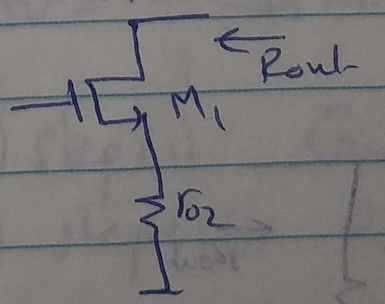
$i_{out} = g_{m_2} V_{in}$

$\Rightarrow G_m = \frac{i_{out}}{V_{in}} = g_{m_2}$

b) Calculate Rout



$\Rightarrow$ the same as generalled Configuration

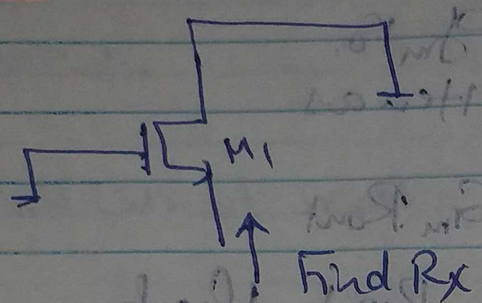


$R_{out} = (1 + g_{m_1} r_{O_1}) r_{O_2} + r_{O_1}$

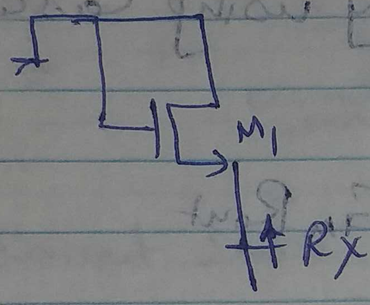
$\Rightarrow A_v = -g_{m_2}\left[(1+g_{m_1} r_{O_1}) r_{O_2} + r_{O_1}\right] \cong -g_{m_1} r_{O_1} g_{m_2} r_{O_2}$

⇒ The voltage gain of Cascode Configuration is the multiplication intrinsic gain of both M_1 / M_2

Quiz:-



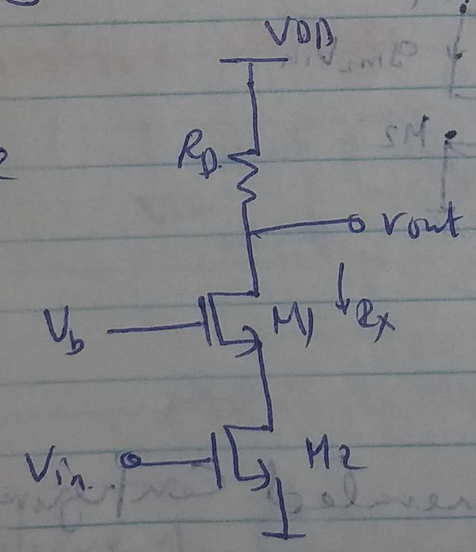
we see that both D and G are connected to gnd. So it is diode connected device



$$R = \frac{1}{g_{m_1}} \parallel r_{o_1} \cong 1/g_{m_1}$$

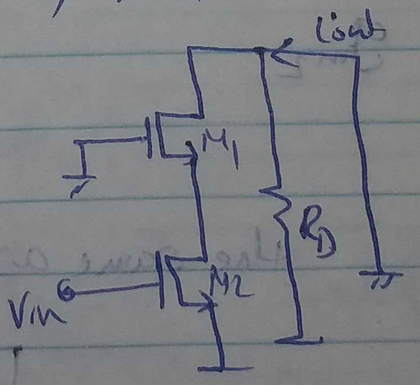
Now, we want to replace the ideal current source by load (resistor).

Example



$$A_v = -G_m R_{out}$$

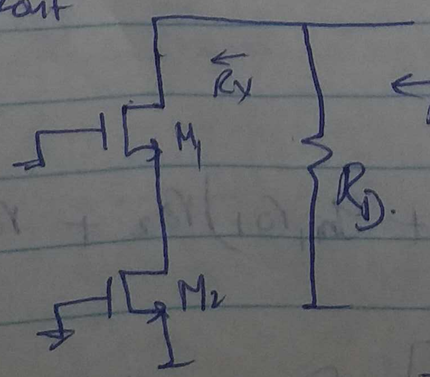
a) Find the G_m



$$G_m = \frac{i_{out}}{V_{in}} = \frac{g_{m_2} V_{in}}{V_{in}}$$

$$G_m = g_{m_2}$$

b) Find Rout



$$R_{out} = R_x \parallel R_D$$

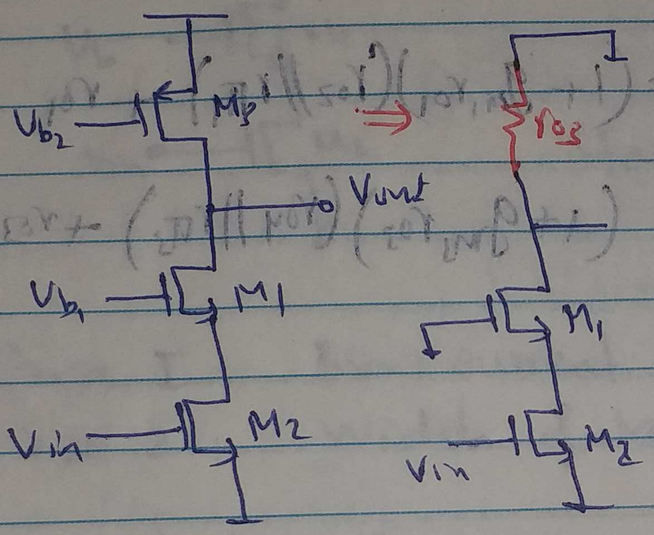
$$= \left[(1 + g_m r_{o1}) r_{o2} + r_{o1}\right] \parallel R_D$$

$$\Rightarrow A_v = -g_{m_2}(R_{out})$$

As we see using resistor load decrease Rout
so, the question how to remain Rout high

So, the solution using current source (P-type MOS)
to inject the current into the node

Cascode Amp with current source load:

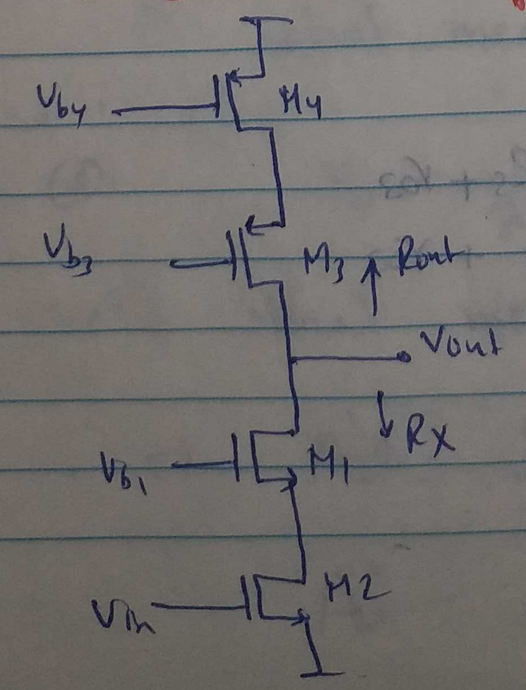


$$A_v = -g_{m_2}\left[r_{o_3} \,\|\, (1+g_{m_1}r_{o_1})r_{o_2} + r_{o_1}\right]$$

if $r_{o_3} > R_D \Rightarrow$ the gain becomes greater than before

⇒ So, the question now, can we increase r_{o_3} more
the answer, yes by using cascode current source

Cascode Amplifier with cascode load



$$A_v = -G_m R_{out}$$

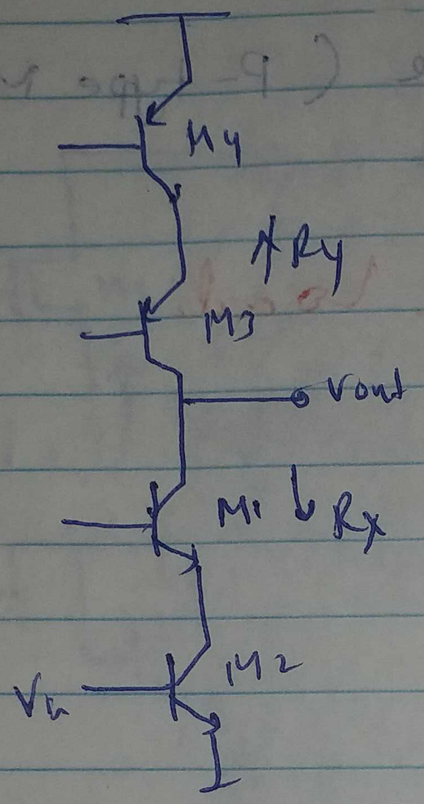
a) step (1) $G_m = g_{m_2}$

b) step (2) $R_{out} = R_x \,\|\, R_y$

$$R_x = (1+g_{m_1}r_{o_1})r_{o_2} + r_{o_1} \cong g_{m_1}r_{o_1}r_{o_2}$$

$$R_y = (1+g_{m_3}r_{o_3})r_{o_4} + r_{o_3} \cong g_{m_3}r_{o_3}r_{o_4}$$

Bipolar Cascode Amp



$A_v = -G_m R_{out}$

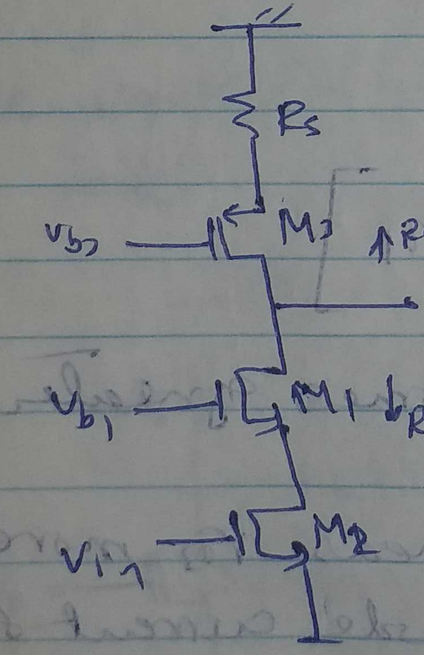
a) $G_m = g_{m_2}$

b) $R_{out} = R_x \parallel R_y$

$R_x = (1 + g_{m_1} r_{o_1})(r_{o_2} \parallel r_{\pi_1}) + r_{o_1}$

$R_y = (1 + g_{m_3} r_{o_3})(r_{o_4} \parallel r_{\pi_3}) + r_{o_3}$

Question :-



Calculate Av:

$A_v = -G_m R_{out}$

a) $G_m = g_{m_2}$

b) $R_{out} = R_x \parallel R_y$

$R_x = g_{m_1} r_{o_1} r_{o_2}$

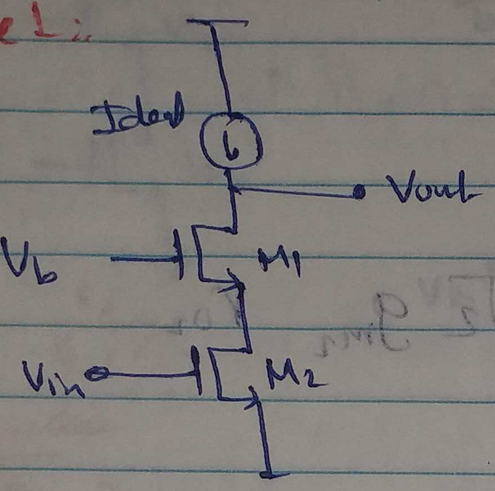
$R_y = (1 + g_{m_2} r_{o_3}) R_s + r_{o_3}$

$\simeq g_{m_3} r_{o_3} R_s + r_{o_3}$

Today's Lect.

- Additional Cascode Examples
- Cascode Amp with P- type input

Example 1:



$A_v = -g_{m_1} r_{o1} g_{m_2} r_{o2}$

Study the gain under 2 Cases

1) Case I : Bias current is halved
2) Case 2 : Width of transistors are doubled.

$A_v = -g_{m_1} r_{o1} g_{m_2} r_{o2}$ (1)

$g_m = \sqrt{2 \mu_n C_{ox} W/L \, I_D}$ $\quad g_m' = \sqrt{2}\, g_m$

if g_{m_1}, g_{m_2} ;
when I_D goes down by $I_D/2$

(*) $g_m' = \sqrt{2 \mu_n C_{ox} W/L \, I_D/2} = \frac{1}{\sqrt{2}} g_m$

that mean g_m' because lower than g_m by $\frac{1}{\sqrt{2}}$

(*) $r_o = \frac{1}{\lambda I_D}$ $\quad r_o' = \frac{1}{\lambda I_D/2} = \frac{2}{\lambda I_D} = 2 r_o$

that mean r_{o_1}, r_{o_2} goes up by factor 2

$\Rightarrow A_v' = \frac{g_{m_1}}{\sqrt{2}} 2 r_{o_1} \frac{g_{m_2}}{\sqrt{2}} \cdot 2 r_{o_2}$

$A_v' = 2 A_v \Rightarrow$ gain is doubled

2) when the W is doubled

$$g_m = \sqrt{2\mu_n C_{ox} \frac{W}{L} I_D}$$

when $W' = 2W \Rightarrow g_m' = \sqrt{2}\, g_m$

$$A_v' = -g_{m_1}' r_{O_1} g_{m_2}' r_{O_2}$$

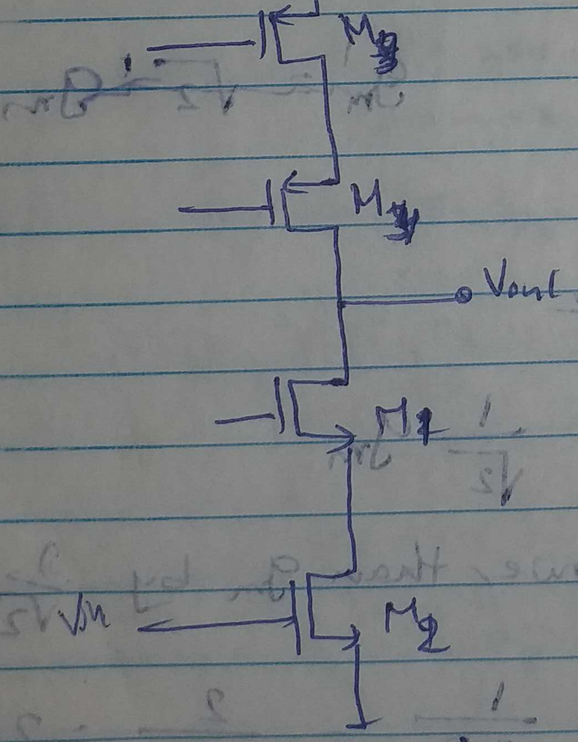
$$= \sqrt{2} g_{m_1} r_{O_1} \cdot \sqrt{2} g_{m_2} r_{O_2}$$

$$= 2 A_v$$

the gain is doubled

Example 2:

Repeate the required of example (1) for this circuit



$$A_v = -g_{m_2}\left(g_{m_1} r_{O_1} r_{O_2} \,//\, g_{m_4} r_{O_4} r_{O_3}\right)$$

$I_D \rightarrow I_D/2$ | $W \rightarrow \frac{1}{2}W$

$g_m' \rightarrow \frac{g_m}{\sqrt{2}}$ | $g_m' \rightarrow \frac{g_m}{\sqrt{2}}$

$r_O' = 2 r_O$

$A_v' = \sqrt{2} g_{m_2}\left(\sqrt{2} g_{m_1} r_{O_1} r_{O_2} \,//\, \sqrt{2} g_{m_4} r_{O_3} r_{O_4}\right)$

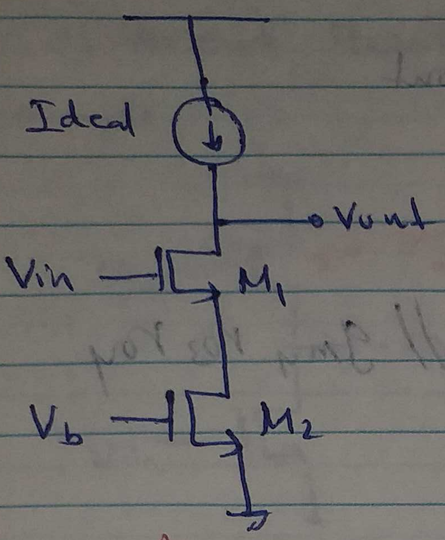
$$A_v' = \frac{-g_{m_2}}{\sqrt{2}}\left[\frac{g_{m_1}}{\sqrt{2}} \times 4 r_{O_1} r_{O_2} \,//\, \frac{g_{m_4}}{\sqrt{2}} \times 4 r_{O_3} r_{O_4}\right]$$

$$= \frac{-g_{m_2}}{\sqrt{2}} \times \frac{4}{\sqrt{2}}\left[g_{m_1} r_{O_1} r_{O_2} \,//\, g_{m_4} r_{O_3} r_{O_4}\right]$$

$$= 2 A_v$$

$A_v' = 2 A_v$

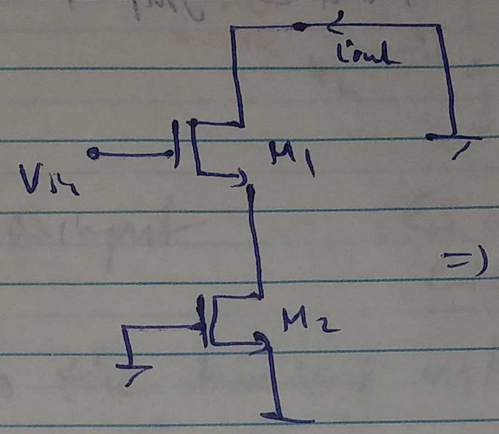
Quiz:



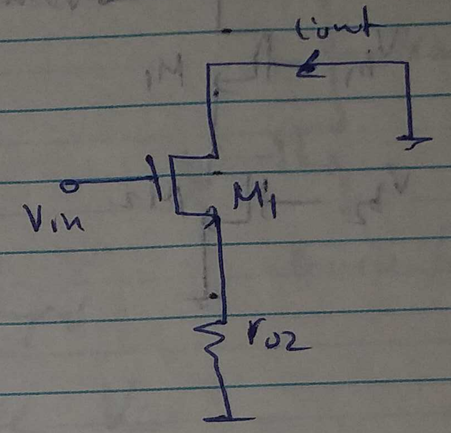
Calculate Av:

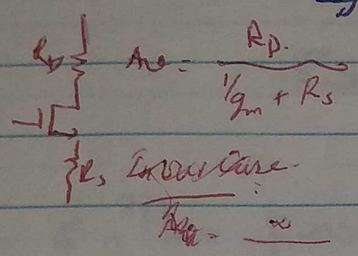
$A_v = -G_m R_{out}$

To Calculate G_m



=>





Let assume $r_{o1} = \infty$

from electronic I :-

$$G_m = \frac{g_{m1}}{1 + g_{m1} r_{o2}}$$

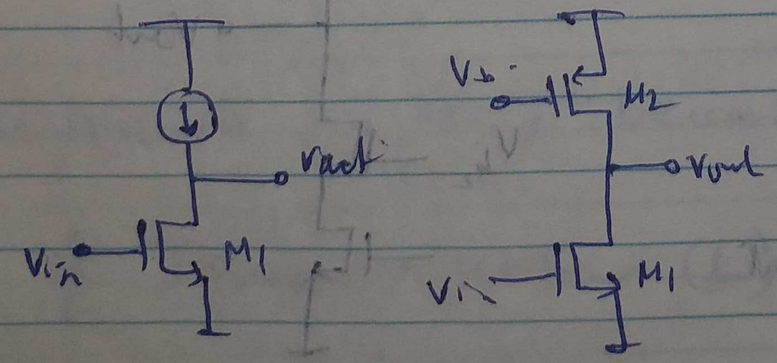
=> reduced considerably

=> the gain because lower

* The voltage gain of from the gate of the Cascode device to the output is very low.

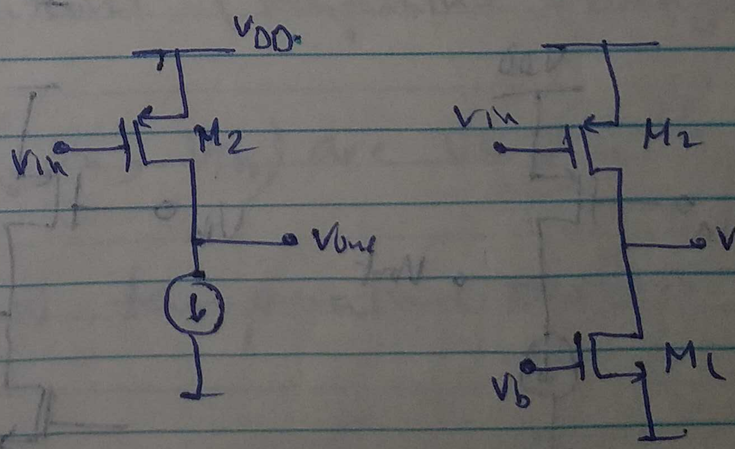
Cascode Amp with P-type input:-

Observation:-



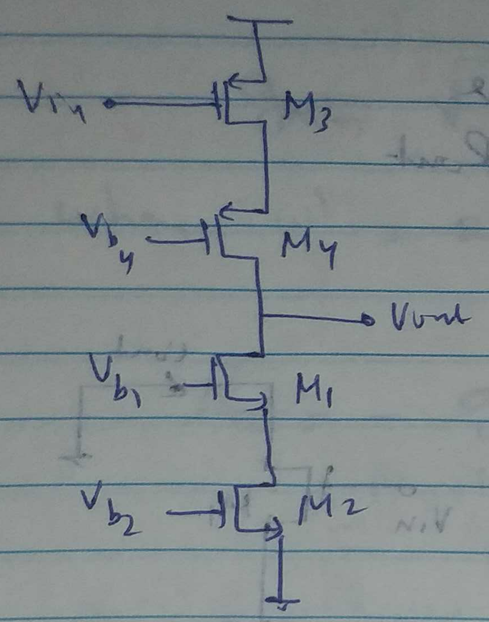
CS with N-MOS input

$A_v = -g_{m1}(r_{o1} // r_{o2})$



CS with P-MOS input

$A_v = -g_{m2}(r_{o1} // r_{o2})$



$A_v = -G_m R_{out}$

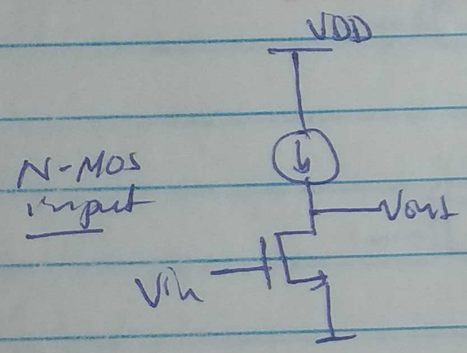
$G_m = g_{m3}$

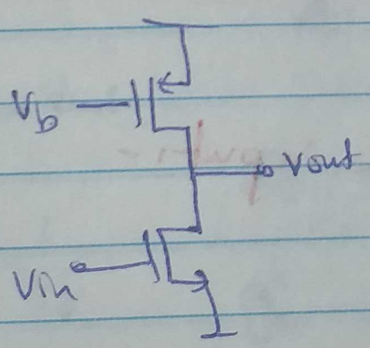
$R_{out} = g_{m1} r_{o1} r_{o2} // g_{m4} r_{o3} r_{o4}$

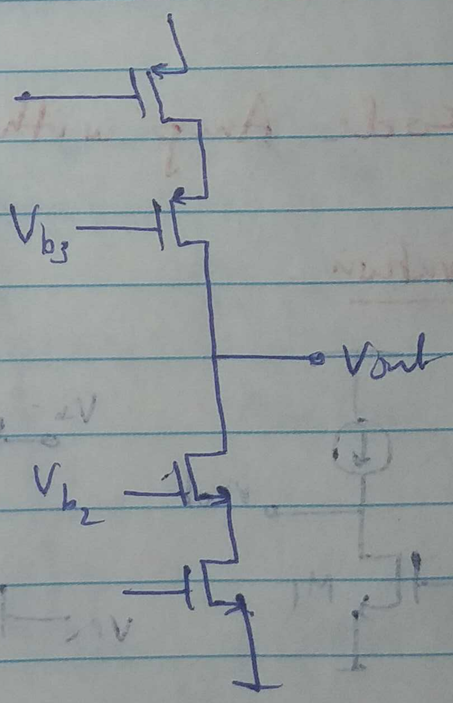
Today's lect.

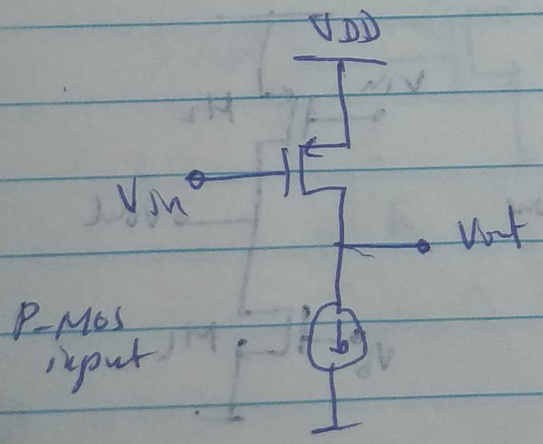
- The Need for current source
  - Problem of Biasing current sources
  - Current Mirror.

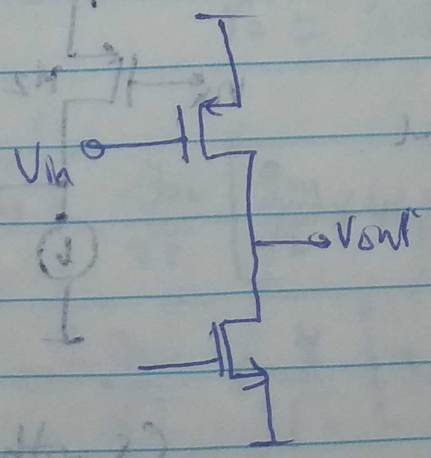
Review: CS stage with current source loads











CS stage.

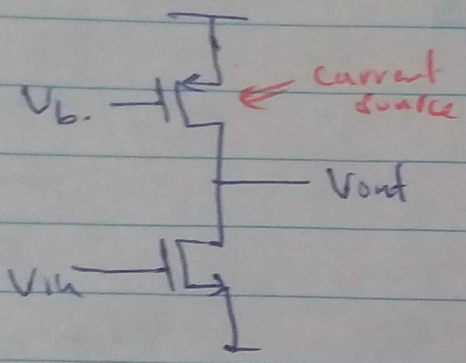
Cascode Style.

Can be N-MOS input OR P-MOS input

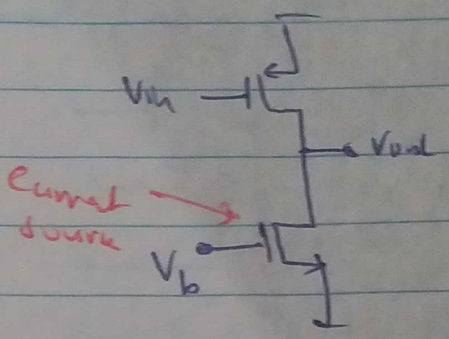
The Need of current source:

- Current sources are everywhere:-

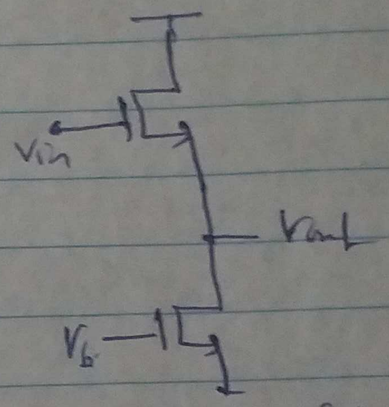
example



CS with NMOS input



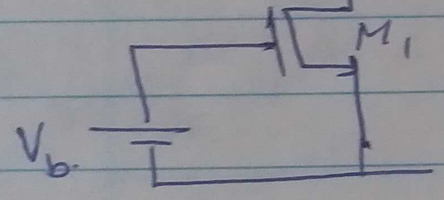
CS with PMOS input



Source follower

* The problem is the biasing voltage V_b where it comes from?

Problem of Biasing current sources:-



To be in good current source:
M_1 must be in saturation

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

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_b - V_{Th})^2$$

The question, if I_D is remain current constant in the various conditions. (temperature changes)

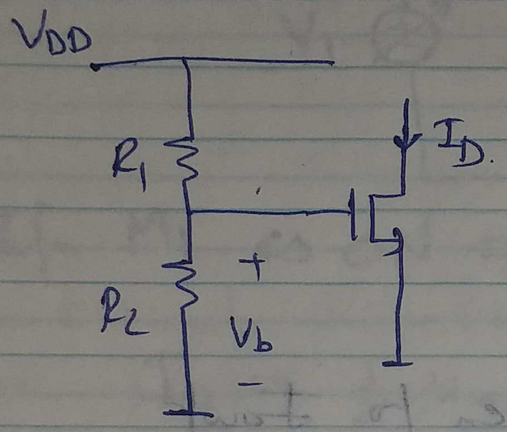
The answer: is No, because (μ_n, V_{Th}) are vary with temp.

1) Issue number (1) ⇒ temperature drop.

5) Suppose we have many current sources in the circuit so * for each current source needs a battery so the system becomes not practical.

But in general any circut has only one Battery so, the question becomes: how to create the other batteries from one battery (supply voltage)

How to generate V_b :-



$$V_b = \frac{R_2}{R_1+R_2} V_{DD}$$

$$I_D = \frac{1}{2} \mu_n C_{ox} \left[\frac{R_2}{R_1+R_2} V_{DD} - V_{Th} \right]^2$$

we can see when V_{DD} is changes so I_D is changing

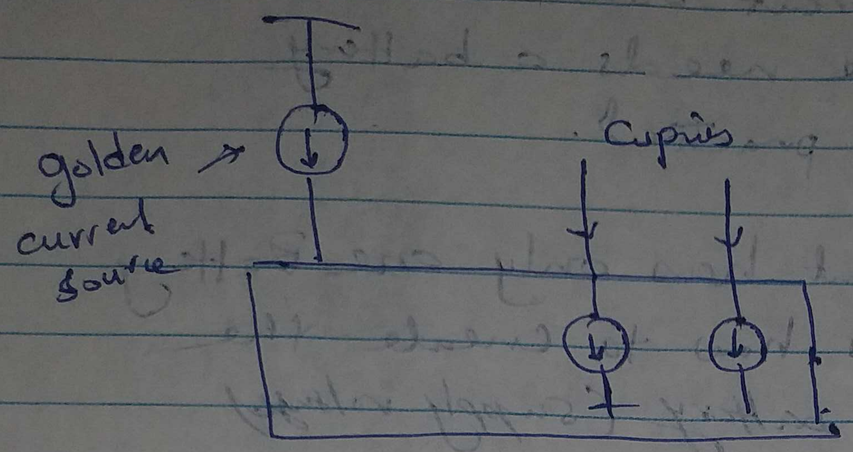
⇒ Issue # 2 : Supply dependent.
because V_{DD} may be battery changes with time.

Current Mirror :-

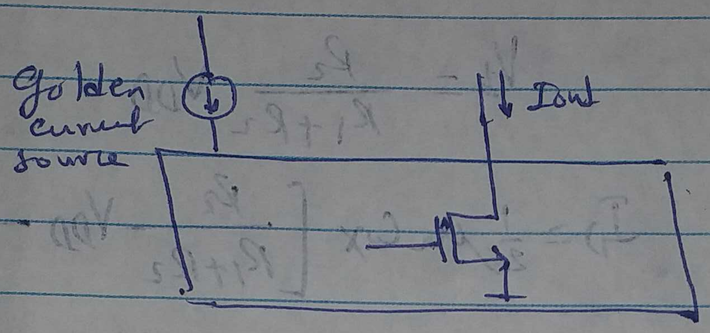
- Basic Concept :

⊛ First, build one Golden current source (stable temp and supply indep) using a Bandgap circuit [study in advanced course]

* Next we "copy" : "clone" this current source to build many others.



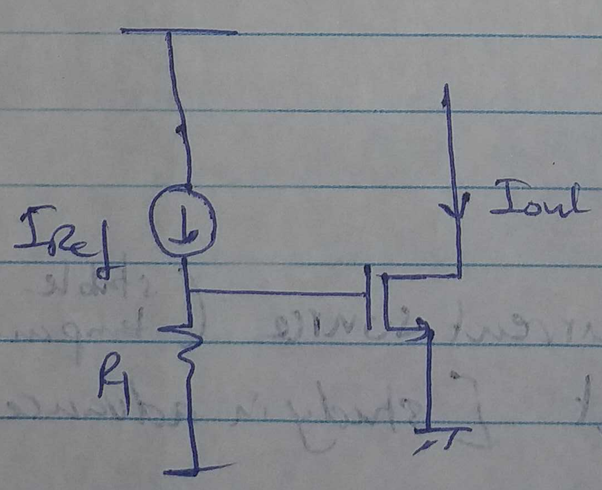
- The only device than can be build is MOS



The question how to goes from golden to Iout
The only wday is to connect G with golden current sour

The only way is to apply a voltage to G.

Quiz :



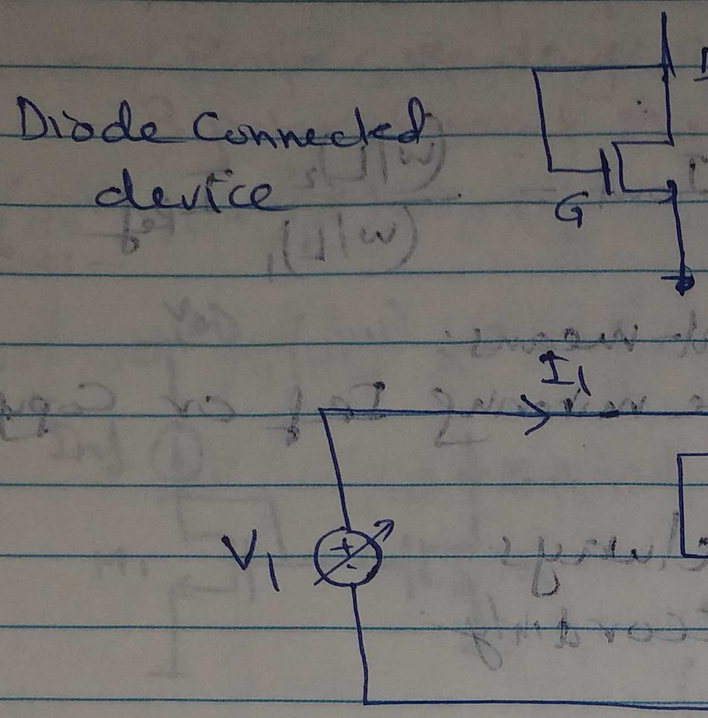
$$I_{out} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\left[R_1 I_{Ref} - V_{TH}\right]^2$$

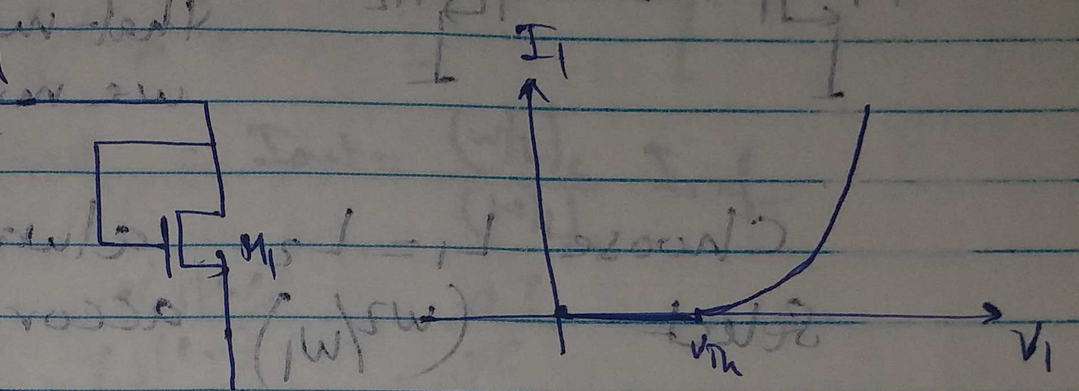
μ_n, R_1, V_{TH} ; Vary with temp.

Observations:-

1)

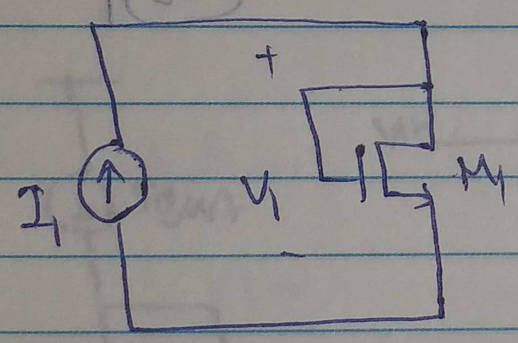
Diode Connected device

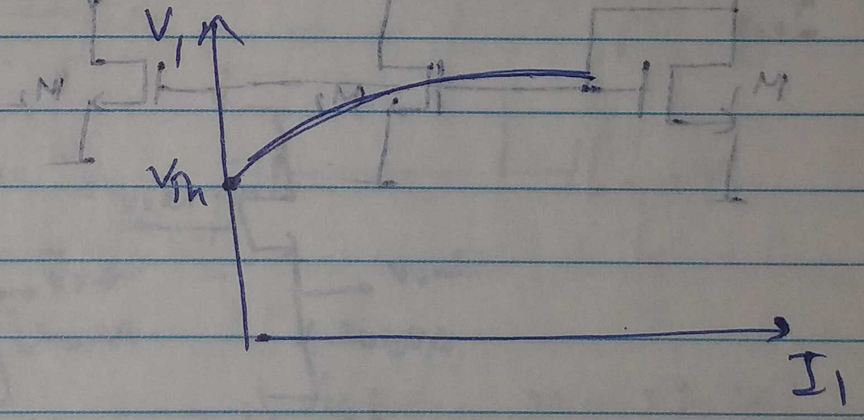




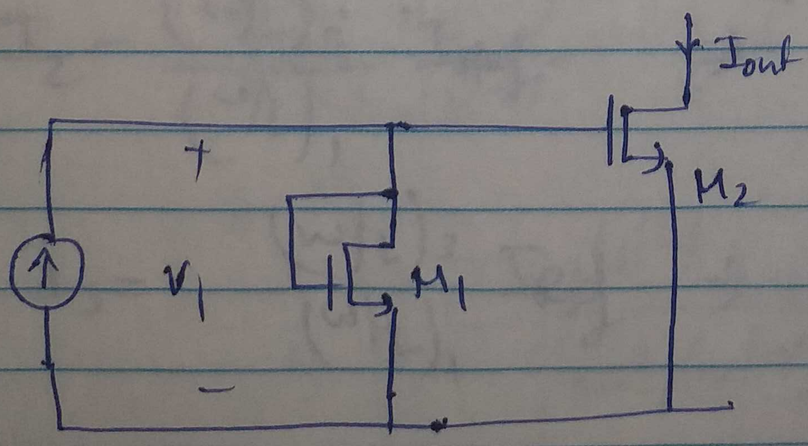
If M_1 is ON $\Rightarrow$ it is in saturation

$$I_1 = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\left[V_1 - V_{Th}\right]^2 \qquad \text{for } V_1 \geq V_{Th}$$





$$V_1 = \sqrt{\frac{2I_1}{\mu_n C_{ox}(W/L)_1}} + V_{Th}$$

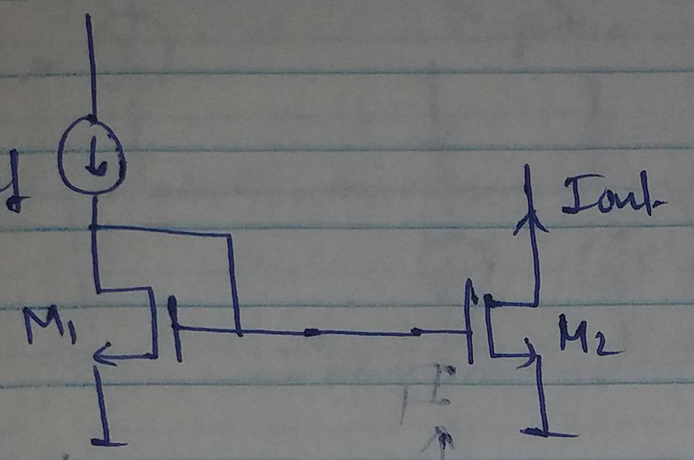


$$I_{out} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2\left[V_1 - V_{Th}\right]^2$$

$$= \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2\left[\left(\frac{2I_1}{\mu_n C_{ox} W/L} + V_{Th} - V_{Th}\right)\right]^2$$

$$I_{out} = \frac{(W/L)_2}{(W/L)_1} I_1$$

Current Mirror:-

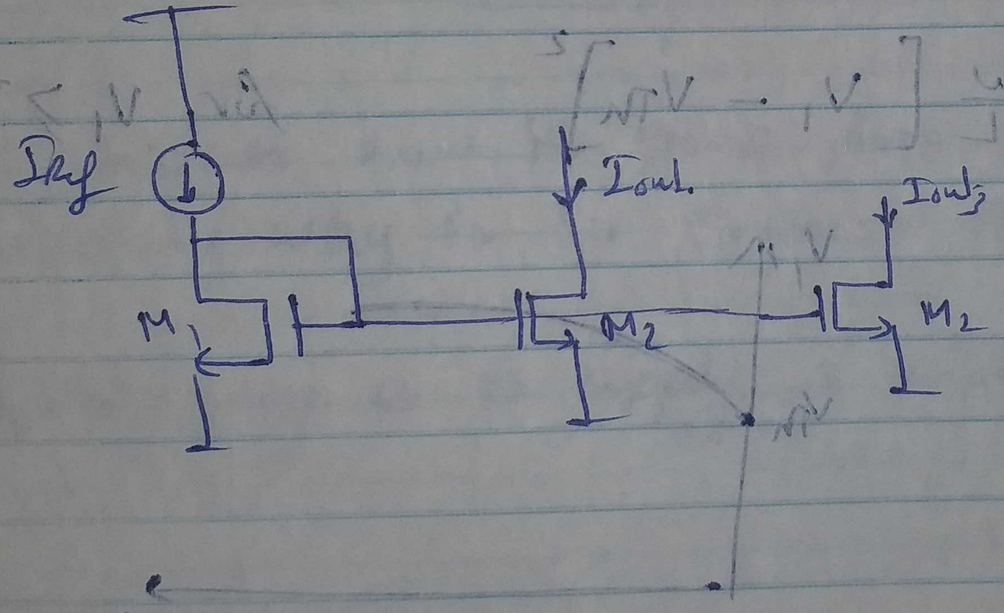


$$I_{out} = \frac{(W/L)_2}{(W/L)_1} I_{Ref}$$

that means we mirroring Iref or Copy

Choose $L_1 = L_2$ always

Select (W_2/W_1) accordingly

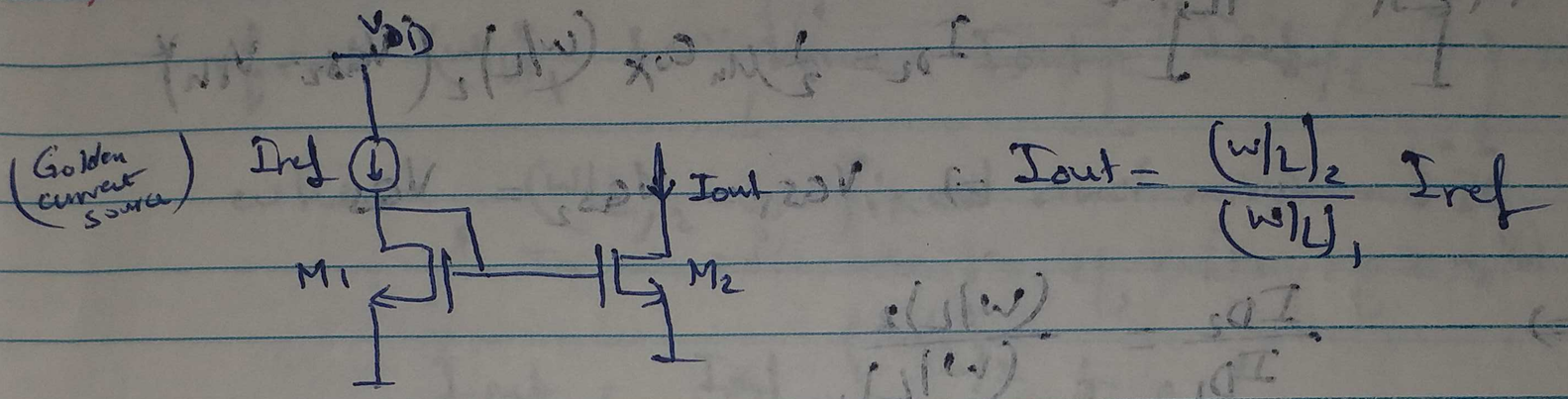


$$I_{out_3} = \frac{(W/L)_3}{(W/L)_1} I_{Ref}$$

Today's lect.

- Current Mirror Examples
- Alternative perspective
- Proper Scaling
- Bipolar Current Mirrors

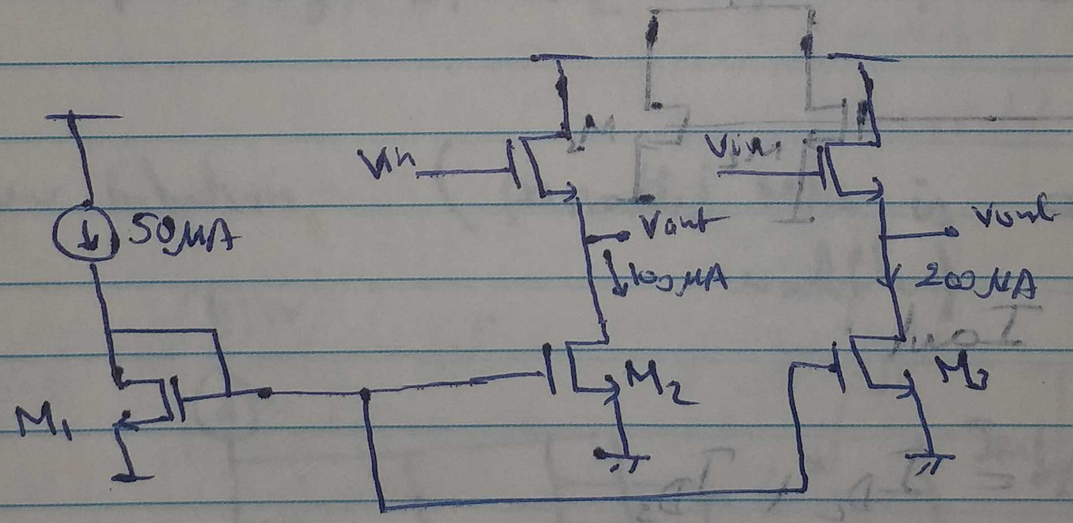
Review:-



$$I_{out} = \frac{(W/L)_2}{(W/L)_1} I_{ref}$$

Examples:-

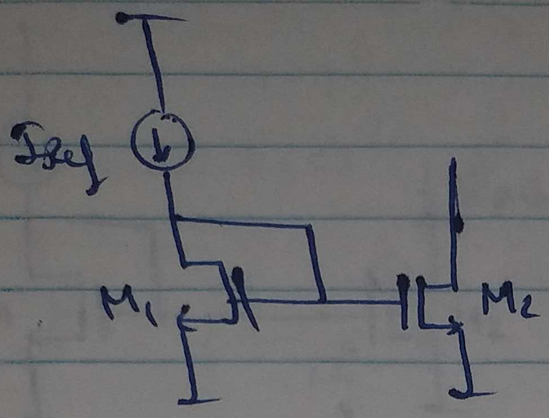
A circuit include two source followers biased at 100 μA and 200 μA. We have reference current of 50 μA. Create the current 100 μA and 200 μA



$$I_2 = \frac{(W/L)_2}{(W/L)_1} I_{Ref} \Rightarrow (W/L)_2 = 2(W/L)_1$$

$$I_3 = \frac{(W/L)_3}{(W/L)_1} I_{Ref} \Rightarrow (W/L)_3 = 4(W/L)_1$$

* Alternative Perspective:



Both M_1, M_2 @ saturation

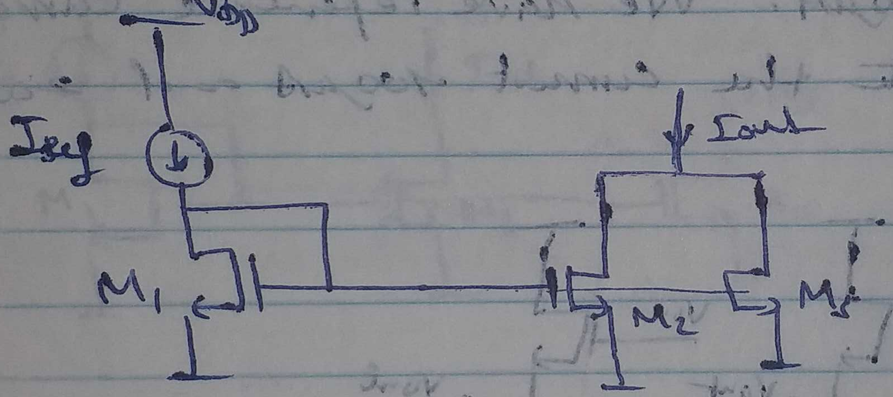
$$I_{D1} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS1} - V_{Th})^2$$

$$I_{D2} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2 (V_{GS2} - V_{Th})^2$$

$$\Rightarrow V_{GS1} = V_{GS2} = V_{GS}$$

$$\Rightarrow \frac{I_{D2}}{I_{D1}} = \frac{(W/L)_2}{(W/L)_1}$$

Example:-



Determine I_{out}

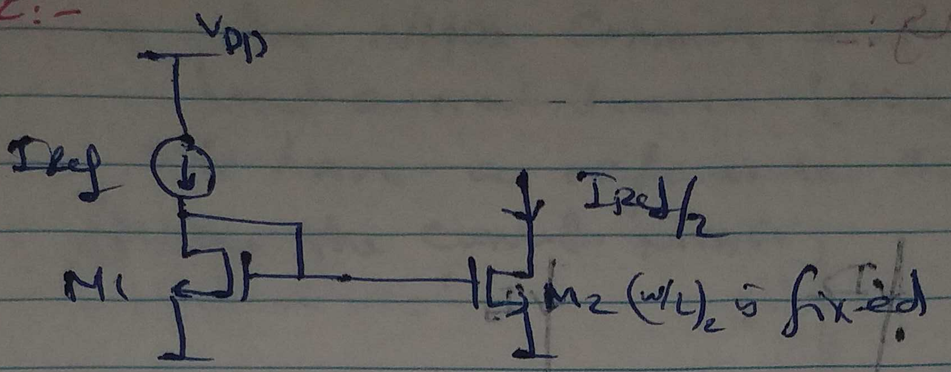
$$I_{out} = I_{D2} + I_{D3}$$

$$= \frac{(W/L)_2}{(W/L)_1} I_{Ref} + \frac{(W/L)_3}{(W/L)_1} I_{Ref}$$

$$= \frac{(W/L)_2 + (W/L)_3}{(W/L)_1} \cdot I_{Ref}$$

If we have two parrallel transistor
So we can doubk the I_{Ref} current.

Quiz:-



find $(W/L)_1$ to have $I_{out} = I_{Ref}/2$

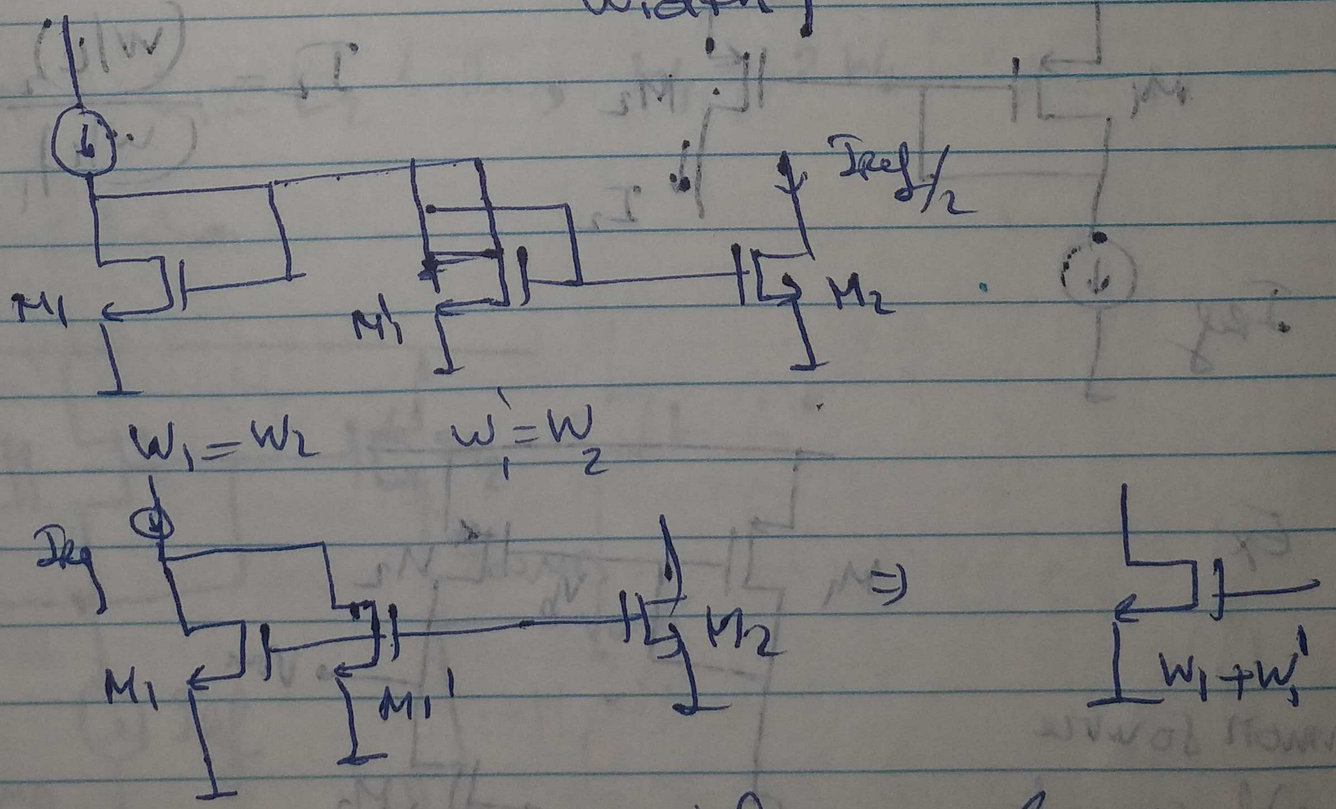
where $(W/L)_2$ is fixed and minimum size

$$I_{out} = \frac{I_{Ref}}{2} = \frac{(W/L)_2}{(W/L)_1} I_{Ref}$$

$$\Rightarrow (W/L)_1 = 2(W/L)_2$$

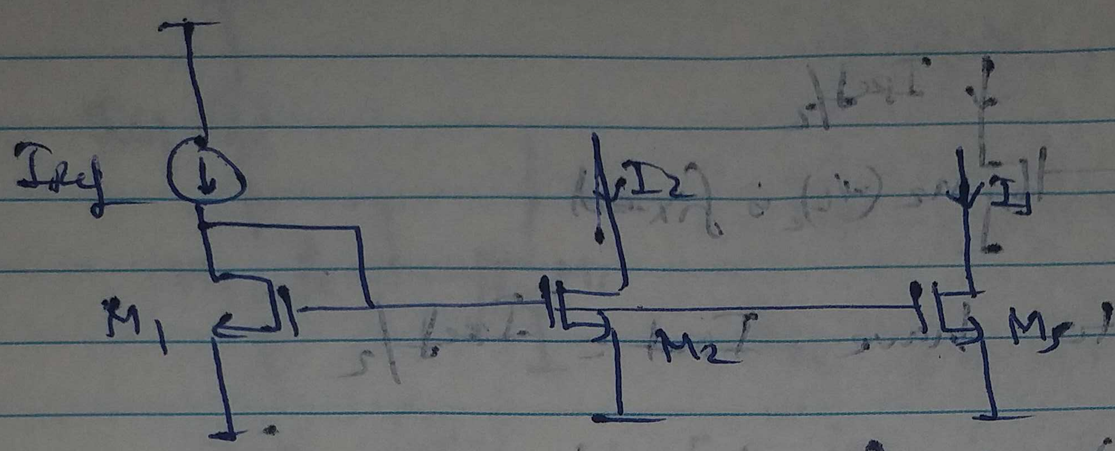
example: if $L_1 = L_2 \Rightarrow W_1 = 2W_2$

Another solution (parallel Mos is adding the width)



M_1 consists of two // transistor with W the same as W_2

* Proper Scaling:-



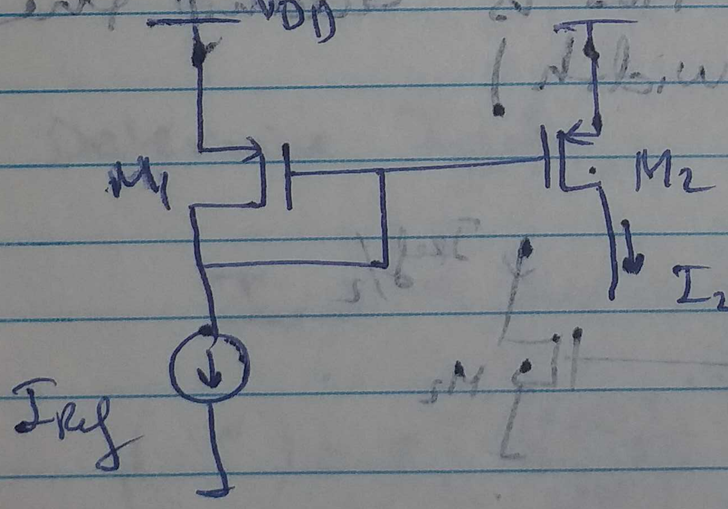
- ~~Always~~, always choose the same L.

$$L_1 = L_2 = L_3 = L$$

- Only scale W.

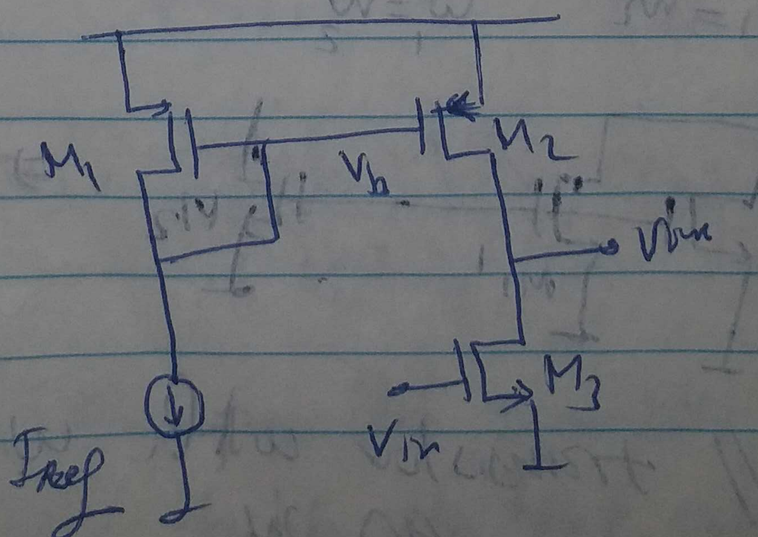
$$I_2 = \frac{W_2}{W_1} I_{Ref} \quad , \quad I_3 = \frac{W_3}{W_1} I_{Ref}$$

PMOS Current Mirror



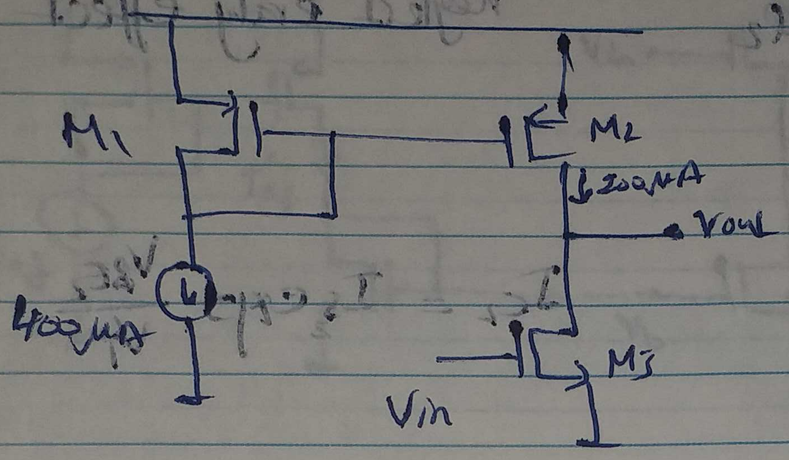
$$I_2 = \frac{(W/L)_2}{(W/L)_1} I_{Ref}$$

Ex.



Common source with current load.

Example: An NMOS common source requires a load current source (200μA).
We have a reference current of 400μA
Design the current mirror



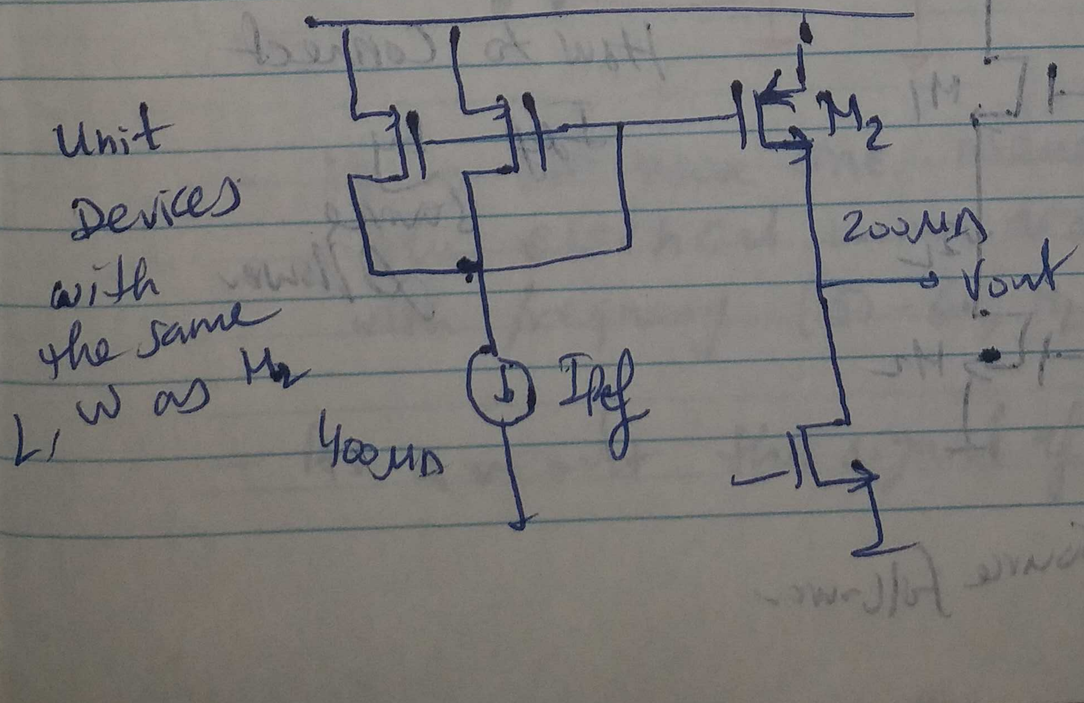
$$I_2 = \frac{(W/L)_2}{(W/L)_1} I_{ref}$$

$$200\mu A = \frac{(W/L)_2}{(W/L)_1} * 400\mu A$$

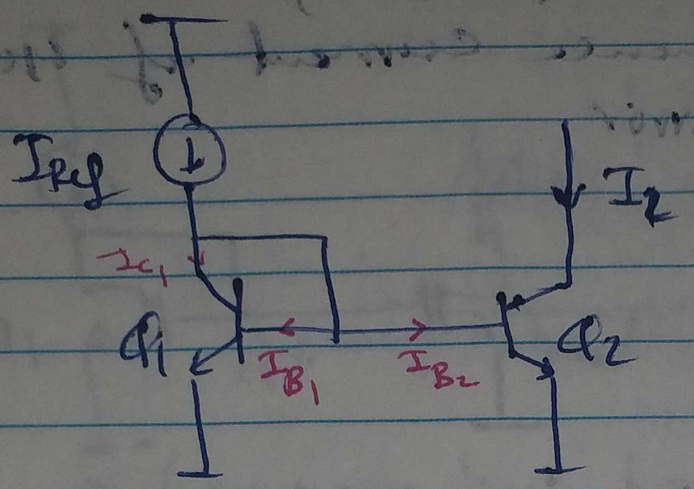
$$(W/L)_1 = 2(W/L)_2$$

Choose $L_1 = L_2$, $W_1 = 2W_2$

OR another solution



Bipolar Current Mirrors



$$I_C = I_S \exp \frac{V_{BE}}{V_T}$$

neglect early effect $V_A = \infty$

$$I_{C_1} = I_{S_1} \exp \frac{V_{BE_1}}{V_T}$$

$$I_{C_2} = I_{S_2} \exp \frac{V_{BE_2}}{V_T}$$

$$V_{BE_1} = V_{BE_2}$$

$$\frac{I_{C_2}}{I_{C_1}} = \frac{I_{S_2}}{I_{S_1}}$$

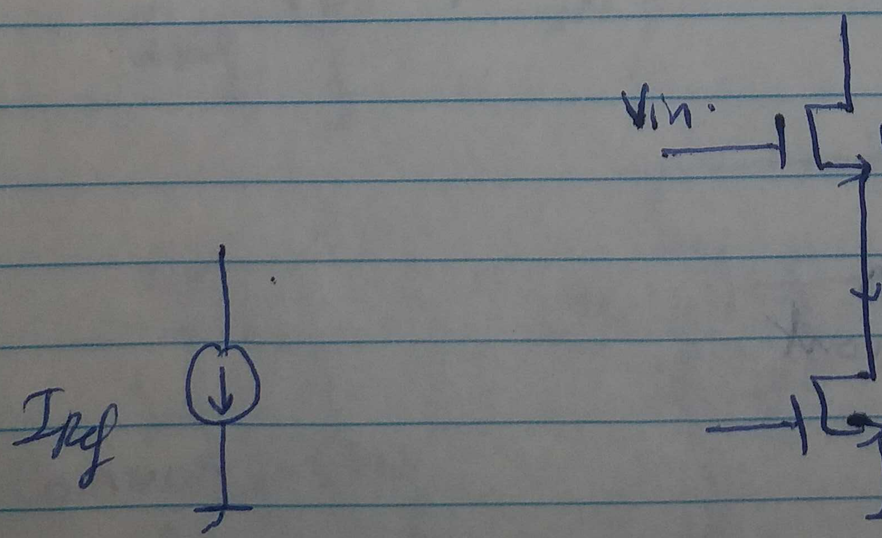
Remark:-

$$I_{Ref} = I_{C_1} + I_{B_1} + I_{B_2}$$

$$\cong I_{C_1}$$

It is approximated expression.

Problem:-

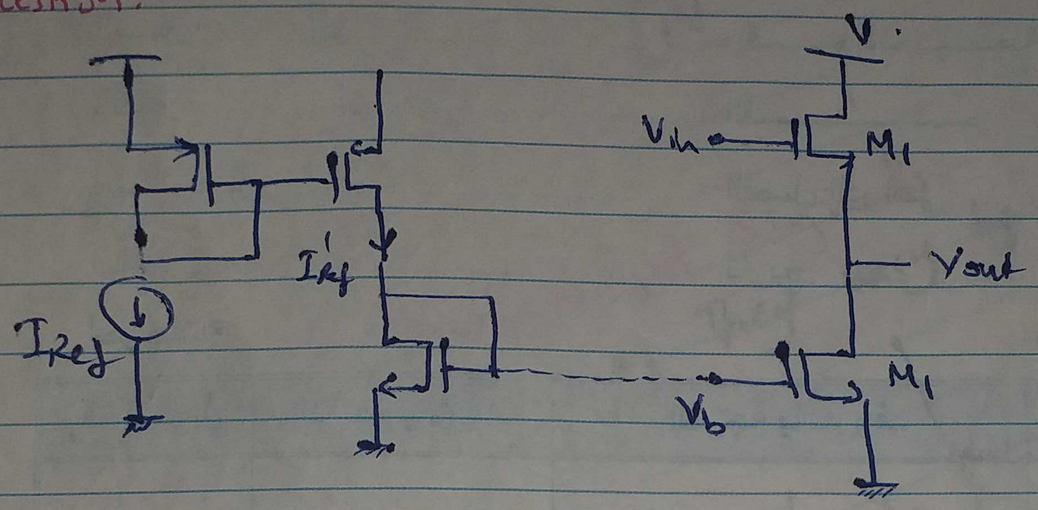


How to Connect I_{Ref} by source follower

Source follower

Today's lect:-
- Problem of Noise Coupling
- Differential Signals
- Differential pair

Question:-

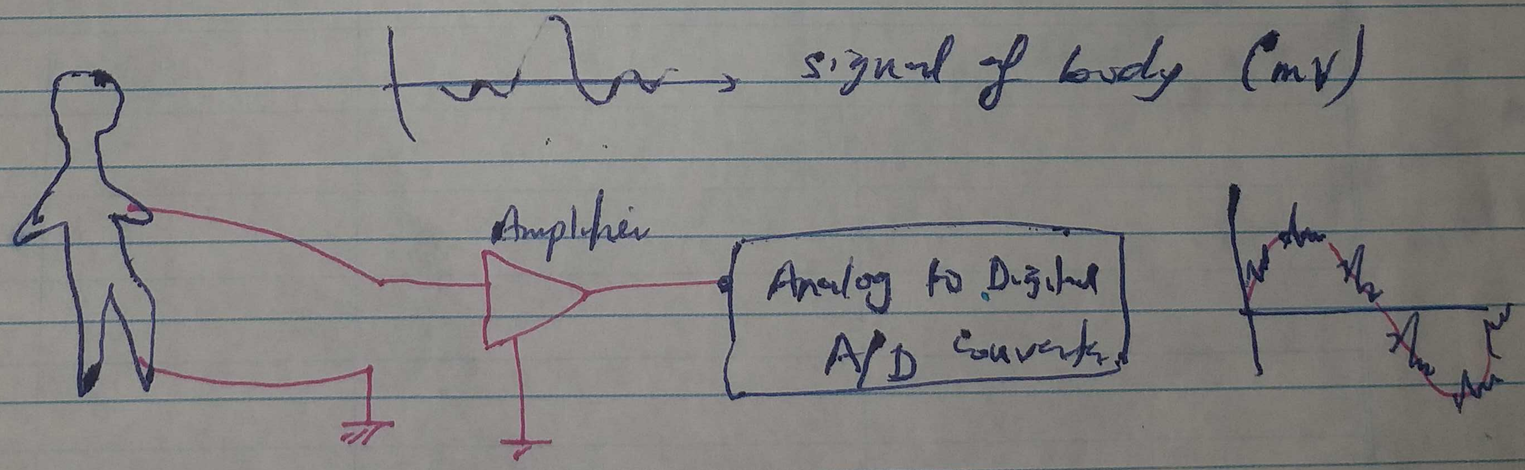


How to bias NMOS from PMOS current Source

* Problem of Noise Coupling:-

Noise: is something that we don't want

Electrocardiogram System (ECG)
measure heart activities:



- Here we have one measure problem the electrical wire around create signal with frequency (50-60) Hz

- As a result the signal of body is corrupted by this noise