7/01/19

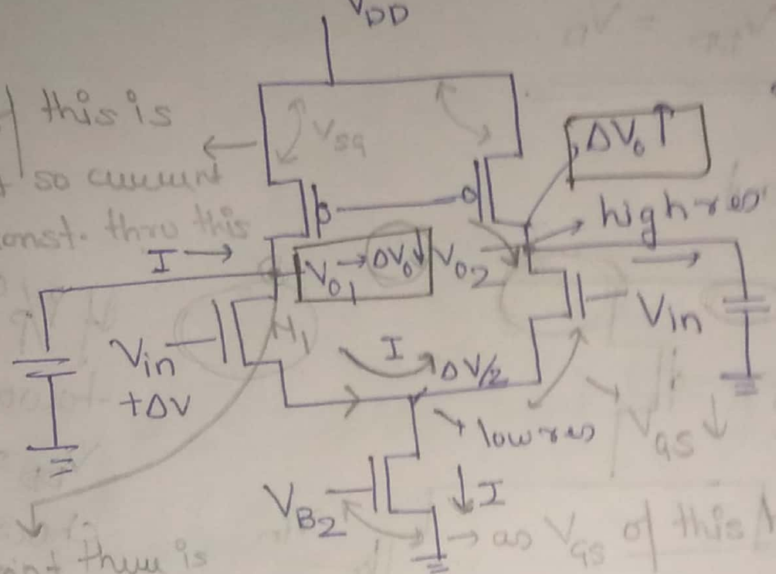
Multi-Stage Amplifier:

↓

Multiple amplifier connected in cascade

Differential i/p & Diff. o/p → I^{st} stage

(Balanced structure)



As V_{SG} of this is constant so current will be const. thru this

→ $V_{01} - V_{02}$ is be even higher & higher we get when in $\uparrow(V_{in} \rightarrow V_{in} + \Delta V)$

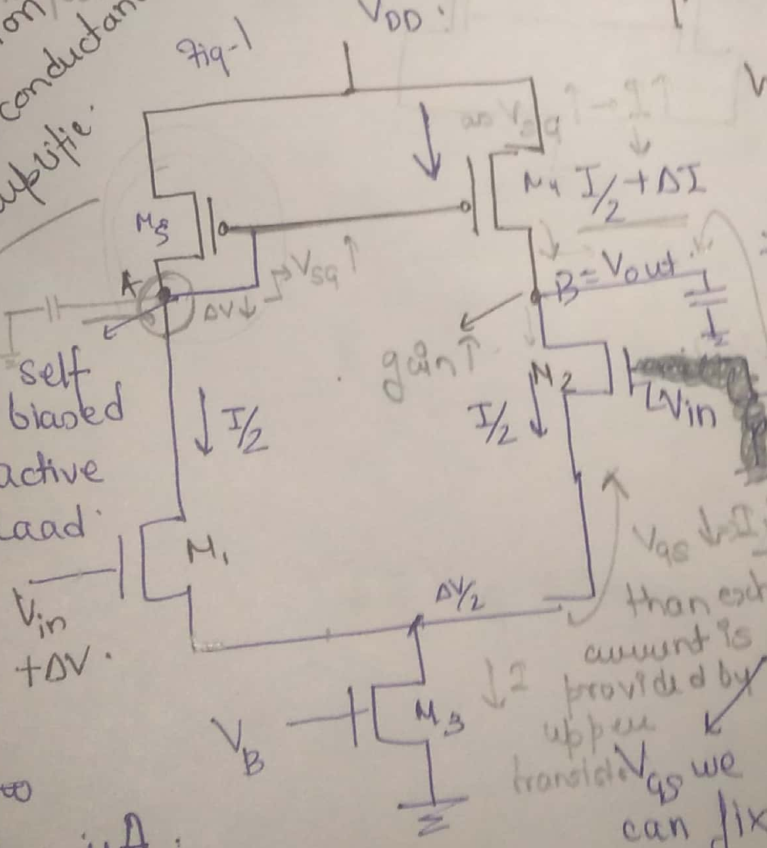
→ as V_{GS} of this transistor is not changing so current is fixed. so as V_{GS} of $M_1 \uparrow$ current will ↑ & moves towards

At this point there is high resistance $V_{01} \downarrow$ as $V_{in} \rightarrow V_{in} + \Delta V$ so ↑ in I need ΔV_{01} to ↓ in good amount

Single ended o/p :

Operation on "transconductance amplifier".

Fig-1



Why we can't take o/p from M_2 A ?

⇒ At $r_{out} = \frac{1}{g_m}$ & low resistance & can't get gain high. so take o/p from B.

current can change from this

self biased active Load.

then extra current is provided by upper transistor

$M_3 \Rightarrow V_{GS}$ fixed. $I \rightarrow$ is approx const.

V_{GS} we can fix & deciding current

⇒ I ~~flows~~ following in A.

When Vin is fixed as V_{gs}/V_{sg} of all transistor is fixed. $(V_{gs} = V_{gs})_{M_1,M_2}$ & $(V_{sg} = V_{sg})_{M_4 M_5}$ ~~approx~~.

$V_{in} \rightarrow V_{in} + \Delta |_{M_1}$

$I_{M_1} \rightarrow$ will ↑, V_A ↓ → $I|_{M_5}$ will ↑ $(V_{sg}$ ↑$) \rightarrow V_A$ ↓.

$\left.\begin{matrix} M_4 \end{matrix}\right] \rightarrow V_{sg} = V_{sg}|_{M_5}$.

I current through M_4 will ↑.

At B higher gain (I came from M_4 & M_2 both)

so current basically ↑.

⇒ As Vin is same. As V_{GS} is same than current is slightly same. (V_{DS} ~~change~~ don't) know $[M_1, M_2]$

⇒ V_{SG} same - Current approx same.

transconductance Am (I/V) (O/p current) ⇒ if Res. low it will support current change.

(R→∞)

Voltage amplifier -

↓

i/p imp - higher.

o/p imp - lower.

$V_{out} \rightarrow$ low imp.

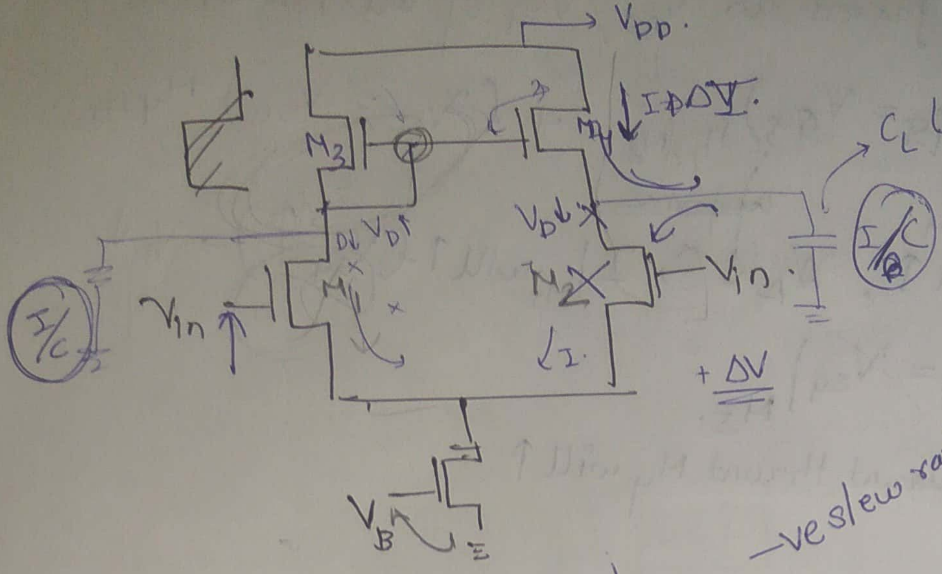
$V_{out} \rightarrow$ high imp.

as V_{out} has large impedance in fig-1 it will be followed by ~~Vo~~ Source follower.

Sew rate.

⇒ i/p imp. higher, o/p impedance high.

⇒ (V-I) Amp.



-ve slew rate

$$\left(\frac{dV_{out}}{dt}\right)_{max} = \pm I/C \qquad \left(\frac{dV_{out}}{dt}\right)_{min} = -I/C$$

$V_{SG} = V_{SG}$

★ $V_{SG} \to \downarrow$ $\qquad V_G = V_G = V_D$

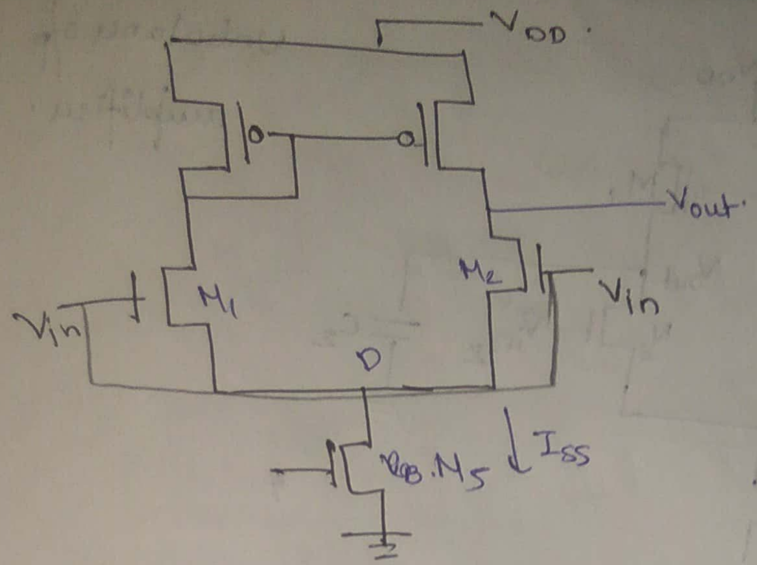
$\uparrow V_D > V_G - V_{th}$, $V_{GS} > V_{th}$

$\to V_{GS} < V_{th}$ — $V_{GS} \to 0$!

In here we are taking single o/p so (no add & subtraction)

⇒ As $V_{in} \uparrow \Rightarrow M_2$ got turn off.

⇒ than I amount of current will flow through M_3 & M_1 and V_{SG} of M_3 & M_4 are same so I amount of current will also flow thru M_4 ∴ slew rate $= +I/C$



Calculate ICMR.

for corresponding I_{SS} we will see V_{in}.

$\cancel{V_D > V_G - V_{th}}$

$V_{in} \rightarrow \cancel{V_{in}} + \Delta V \Rightarrow \cancel{V_{GS}} \uparrow$

When V_{in} is same.

$V_{in} \uparrow \rightarrow V_{GS}$ const.

$V_{GS} = V_{in} - V_D$

$V_{GS}\big|_{in} + V_{Dsat}\big|_5 = V_{in}$

$$\boxed{V_{in}\big|_{min} = V_{dsat}\big|_1 + V_{th}\big|_1 + V_{dsat}\big|_5 = \sqrt{\frac{I_{SS}}{\beta_1}} + V_{th_1}\Big| + \sqrt{\frac{2I_{SS}}{\beta_5}}\Big|_5}$$

$V_{in} + \Delta V, \rightarrow M_1, M_2$ can come out of sat

$V_{in} - \Delta V \rightarrow M_5$ — ll —

$V_{in}\big|_{max} =$

$V_{SG} = V_{DD} - V_D$.

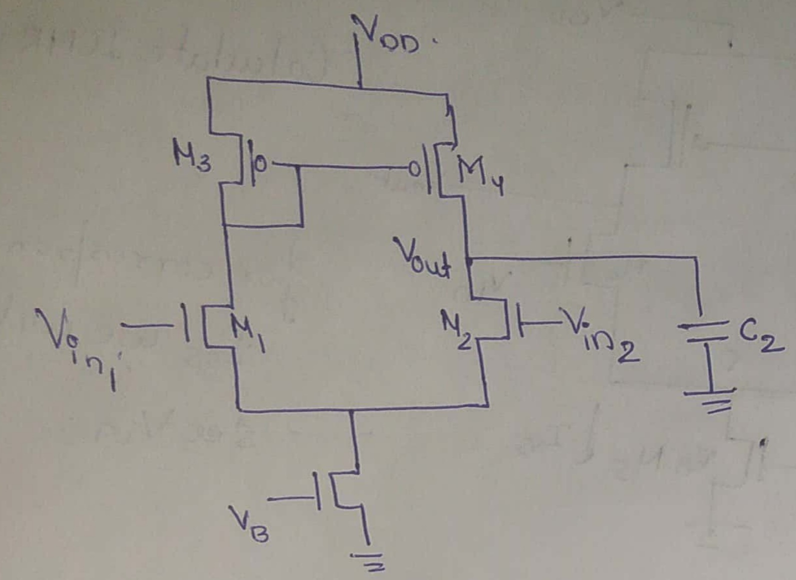
$V_D = V_{DD} - V_{SG}$.

$= V_{DD} - (V_{dsat}| + V_{th,P})$

$V_D > V_G - V_{th_{1,2}}$

$V_{DD} - (V_{dsat}\big|_{3,4} + V_{th_{3,4}}) + V_{th_{1,2}} > V_{in}$

8/09/19



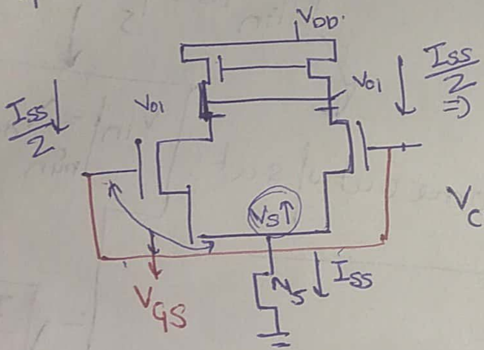
Unbalance o/p amplifier.

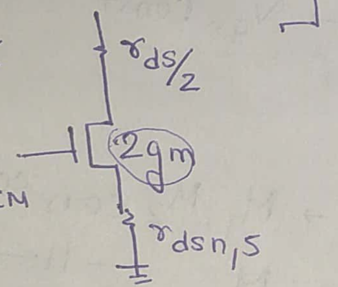
⇒ can't make half circuit like the previous one.

$A_{cm} \rightarrow$ o/p same ⇒ V_{out} = same.

$V_{GS} \rightarrow$ constant

$V_G \uparrow \rightarrow V_S \uparrow$





Q Common mode gain significance? & why we calculate

⇒ $V_{CM}\uparrow$, $\boxed{V_{o1} \Rightarrow \text{constant}}$ (const. current source) instead of M_5) [If I_{SS} amount of current flow thru ~~both~~ ~~transistor~~ current src. than $\frac{I_{SS}}{2}$ will flow thru both ~~thru~~ trans. as they are mirror image]

$r_{ds_n} \rightarrow \infty$

and

$V_{CM}\uparrow$ ∃ $V_{o1} \Rightarrow$ changing. (transistor M_5)

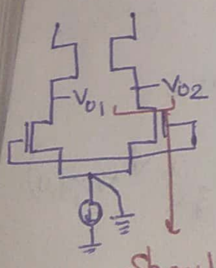
and we don't want DC shift/Constant Voltage change.

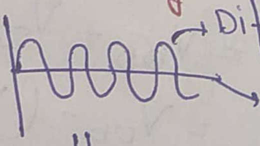
Common mode gain.

$$\frac{V_o}{V_{in}} = \frac{-\,r_{ds,P}/2}{\frac{1}{2g_m} + r_{dsn}}$$

$\rightarrow r_{ds,n} \rightarrow \infty$

$V_o = 0$





Differential

Common mode.

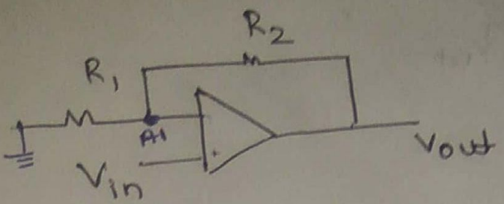
⇓

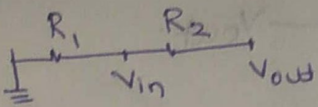
Non-linearity in circuit.

e o/p
ieu.

in→∞
=0

current ~~transistor~~ current src. than $\frac{I_{SS}}{2}$ will flow thru both ~~the~~ trans as they are [mirror image]





Ideal case ~~V_{in}~~
$A=\infty$

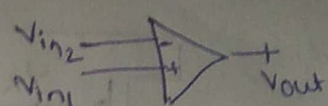
$$\frac{V_{in}-0}{R_1} = \frac{V_{out}-V_{in}}{R_2}$$

$$V_{in}\left(\frac{1}{R_1}+\frac{R_2}{R_2}\right) = \frac{V_{out}}{R_2}$$

$$\frac{R_1+R_2}{R_1 \cancel{R_2}} = \frac{V_{out}}{V_{in}}$$

$$\frac{\cancel{R_1}}{} \; 1+\frac{R_2}{R_1} = \frac{V_{out}}{V_{in}}$$

$R_1=R_2$ $\boxed{2=\frac{V_{out}}{V_{in}}}$



$$V_{out} = A(V_{in_1}-V_{in_2})$$

$$\frac{V_{out}R_1}{R_1+R_2} \Rightarrow A\left[V_{in}-\frac{V_{out}R_1}{R_1+R_2}\right] = V_{out}$$

$$V_{out}\left[1+\frac{AR_1}{R_1+R_2}\right] = AV_{in}$$

$$V_{out} = \frac{AV_{in}[R_1+R_2]}{R_1(1+A)+R_2}$$

$R_1=R_2$, $A=10$

$$\boxed{\frac{V_{out}}{V_{in}} = 1.66}$$

error ← 20%

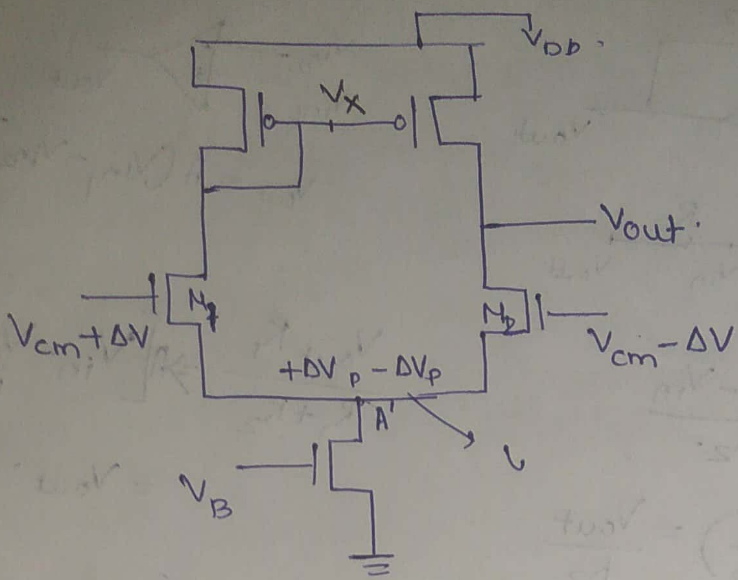
$\frac{0.2}{\cancel{0.4}} \times 100$ $\cancel{2}$ 2

⇒ We can't consider alway A1 as virtual shot, we can only consider that when A is ∞.

$$\boxed{\frac{V_{out}}{V_{in}} = \frac{A(R_1+R_2)}{R_1(1+A)+R_2}}$$

$$= \frac{AR_1\left(1+\frac{R_2}{R_1}\right)}{R_1(1+A)+R_2}$$

Scanned by CamScanner



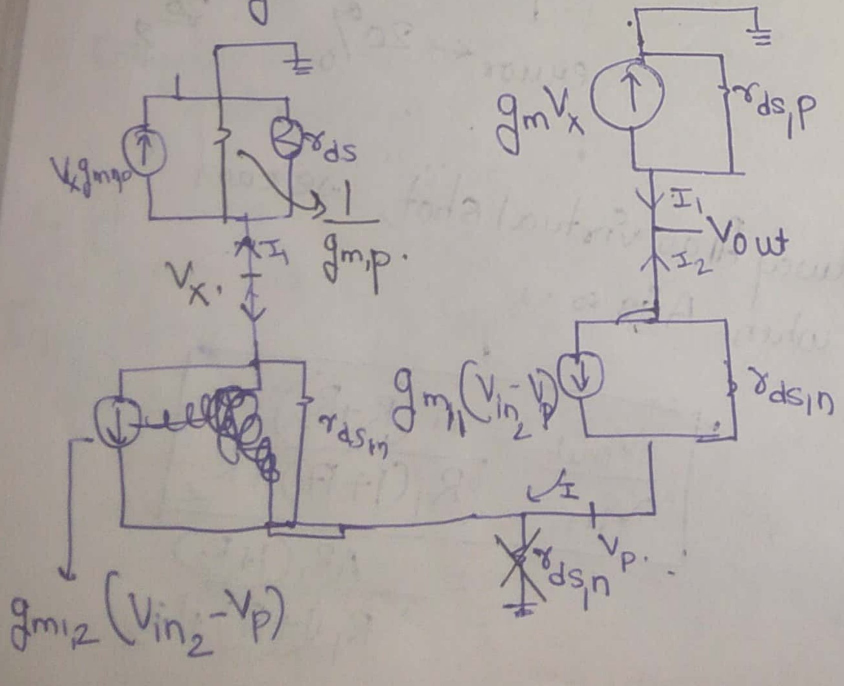
As we dont have mirror image so effect by M_2 & M_1 will not be same & for here we can't consider this as virtually grd.

$V_{out} \to V_{in_1}$ & V_{in_2}

AC analysis.

$g_m(V - V_x)$

V_x



$$I_1 = -g_m V_x - \frac{V_{out}}{r_{ds,p}}$$

$$I_2 = -g_{m,n}(V_{in_2} - V_p) - \frac{(V_{out} - V_p)}{r_{ds,n}}$$

$\cancel{g_m V_x}$ $I_1 + I_2 = 0$

$$-g_m V_x - \frac{V_{out}}{r_{ds,p}} = +g_{m,n}(V_{in_2} - V_p) + \frac{(V_{out} - V_p)}{r_{ds,n}}$$

$$\frac{V_x - 0}{\frac{1}{g_{m,p}}} = I_1 = -g_m V_x - \frac{V_{out}}{r_{ds,p}}$$

$$V_x\left(g_{m,p} + g_{m,p}\right) = \frac{-V_{out}}{r_{ds,p}}$$

$$V_x(2g_{m,p})\, r_{ds,p} = -V_{out}$$

$$\boxed{V_x = \frac{-V_{out}}{2g_{m,p}\, r_{ds,p}}}$$

$$\frac{V_{out}}{r_{ds,p}} - \frac{V_{out}\, \cancel{g_{m,p}}}{(2\cancel{g_{m,p}}\, r_{ds,p})} + g_{m,n}(V_{in_2} - V_p) + \frac{(V_{out} - V_p)}{r_{ds,n}} = 0$$

$= 0$

$$-\frac{V_{out}}{2\, r_{ds,p}} + \text{—}\parallel\text{—}$$

$$V_{out}\left(\frac{1}{r_{ds,p}}+\frac{1}{r_{ds,n}}\right) - \frac{V_{out}}{2r_{ds,p}} + V_{in_2} g_{m_{1,2}} - V_p g_{m,n} - \cancel{\frac{V_p}{r_{ds,n}}} = 0$$

$$\left(\frac{V_{out}}{g_{mn}}\left(\frac{1}{r_{ds,p}}+\frac{1}{r_{ds,n}}\right) - \frac{V_{out}}{2r_{ds,p}g_{m,p}} + V_{in,2}\right) = V_p$$

$$V_x(g_{m,p}) + (V_{in_1} - V_p) g_{m,1,2} + \frac{V_x - V_p}{r_{ds,n}} = 0$$

$$\frac{-V_{out}}{2(\cancel{g_{m,p}})r_{ds,p}}(\cancel{g_{m,p}}) + (V_{in_1} - V_p) g_{m1,2} + \frac{-V_{out}}{2r_{ds,p}g_m \times r_{ds,n}} - \frac{V_p}{r_{ds,n}} = 0$$

$$V_{out}\left[-\frac{1}{2r_{ds,p}} - \cancel{\frac{1}{2r_{ds,p}g_m r_{ds,n}}}\right] + \frac{V_p}{r_{ds,n}}\left[-\cancel{\frac{1}{r_{ds,n}}} - g_{m,p}\right]$$

$$+ V_{in_1} g_{m,1,2} = 0$$

$$V_p = -\frac{V_{out}}{2r_{ds,p}g_{m,p,2}} + V_{in_1}$$

$\Rightarrow$

$\frac{V_p}{r_{ds,n}} = 0$

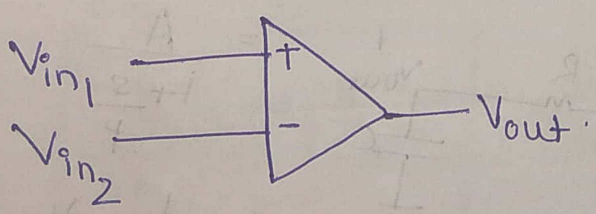
$$\cancel{\frac{-V_{out}}{2 r_{ds,p} g_{m1,2}}} + V_{in_1} = \frac{V_{out}}{g_{m,1,2}}\left(\frac{1}{r_{ds,p}}+\frac{1}{r_{ds,n}}\right)$$

$$\cancel{\frac{-V_{out}}{2 r_{ds} g_m}} + V_{in_2}$$

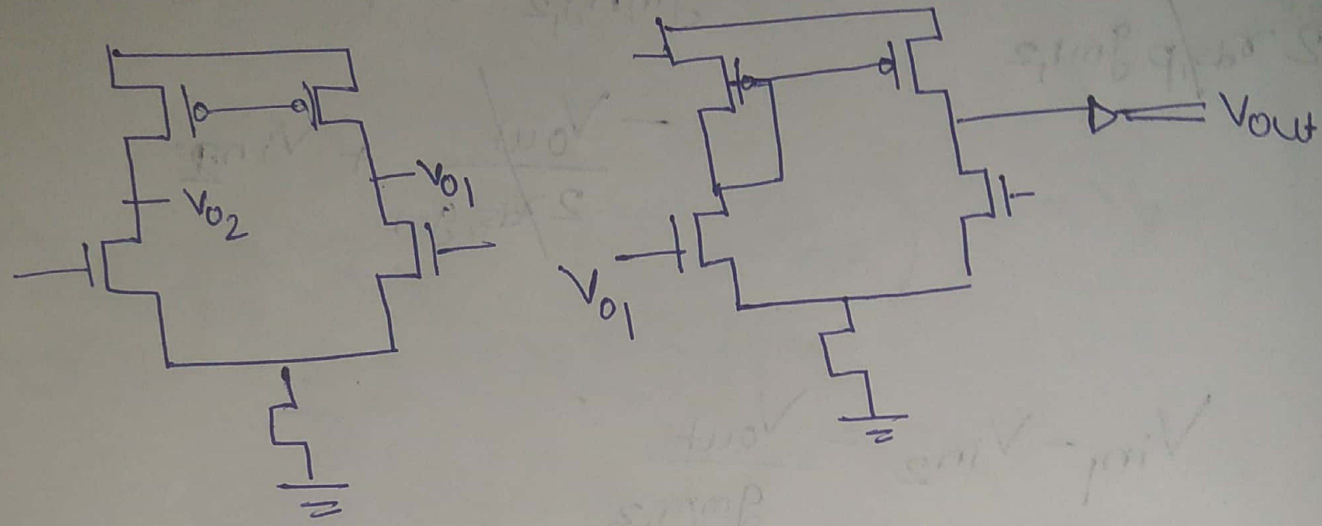
$$\frac{V_{in_1}-V_{in_2}}{\left(\frac{1}{r_{ds,p}}+\frac{1}{r_{ds,n}}\right)} = \frac{V_{out}}{g_{m,1,2}}$$

$$\frac{g_{m,1,2}\left(V_{in_1}-V_{in_2}\right)}{\left(\frac{1}{r_{ds,p}}+\frac{1}{r_{ds,n}}\right)} = V_{out}$$

$$\boxed{g_{m1,2}\left(r_{ds,p} \| r_{ds,n}\right) = \frac{V_{out}}{V_{in_1}-V_{in_2}}}$$

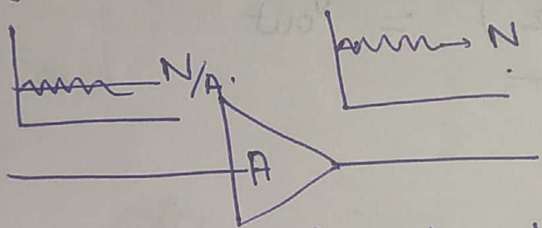


⇒ In previous circuit from only one node Gain was coms half of here calculated one node gain. So basically this is more benefical.



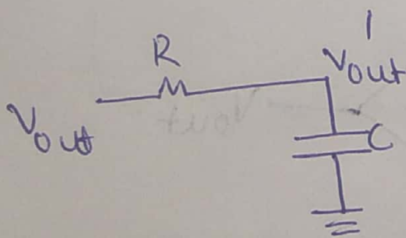
⇒ We use that in amplification

⇒ With high amplification ~~Noise~~ V_{min} (i/p) ↓.



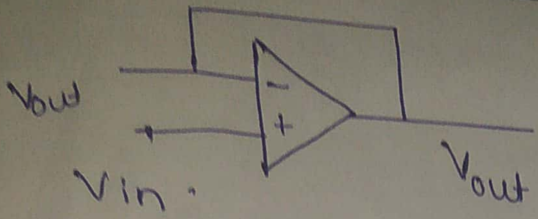
⇒ A↑, N/A ↓ and as V_{in} should be greater than N/A for detection of s/g it decides V_{min}

⇒ If s/g (V_{out}) ≤ N we can't detect s/g.



$$= \frac{A}{1+\frac{s}{p}}$$

$$V_{out}' = \frac{V_{out}}{1+\omega RC}$$



$$\frac{A}{1+\frac{s}{P}} = A_{open-loop}$$

$P \rightarrow$ 3dB B.W

$$V_{out} = \frac{A}{1+s/_{B.W}}\left[V_{in} - V_{out}\right]$$

$$\cancel{V_{out}} = \frac{A}{1+\frac{j\omega}{P}} = A_0$$

$$V_{out}\left[1+\frac{A}{1+\frac{s}{B.W}}\right] = V_{in}\left(\frac{A}{1+\frac{s}{B.W}}\right)$$

$$\boxed{\frac{V_{out}}{\cancel{V_{in}}\,V_{in}} = \frac{A}{A+1+\frac{s}{B.W}}}$$

$$\frac{V_{out}}{V_{in}} = \frac{\frac{A}{1+A}}{1+\frac{s}{BW(1+A)}}$$

When $B.W = 0$

$$A_{open} = A.$$

"We need very high open-lop amplifier"

$\cancel{V_{out}}$

$$\boxed{\frac{V_{out}}{V_{in}} = \frac{A}{1+A}}$$

11/03/18.

Frequency Response.

1) Magnitude 2) Phase.

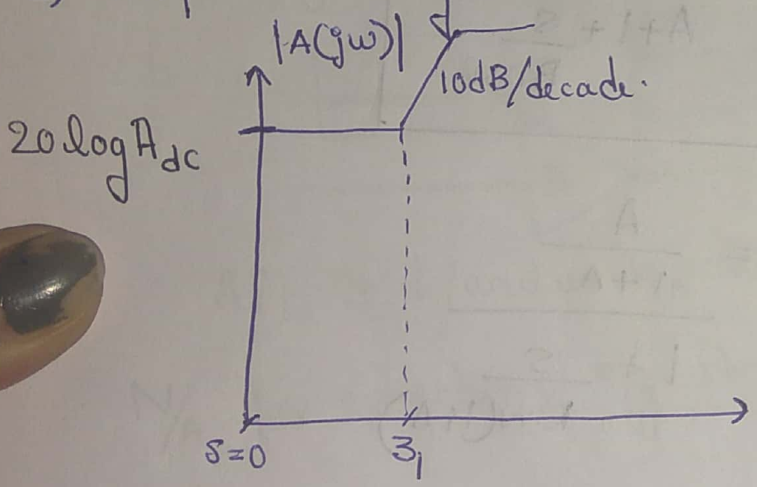
At time domain, we have huge analysis.

Why we use freq. analysis? b/c cap. ~~ind~~ is f^n of ω.

$\Rightarrow$ $$A(j\omega) = \frac{A_{dc}\left(1+\frac{s}{z_1}\right)\left(1+\frac{s}{z_2}\right)}{\left(1+\frac{s}{p_1}\right)\left(1+\frac{s}{p_2}\right)}$$

$\Rightarrow$ zeroes $\rightarrow$ extra path come.

$\Rightarrow$ Pole provide delay.



Assuming $z_1 < z_2 \ldots < p_1 < p_2 \ldots$

$$|A(j\omega)| = 20 \log A_{dc} + 10 \log\left(1+\frac{\omega^2}{z_1^2}\right) + 10 \log\left(1+\frac{\omega^2}{z_2^2}\right) - 10 \log\left(1+\frac{\omega^2}{p_1^2}\right) - 10 \log\left(1+\frac{\omega^2}{p_2^2}\right)$$

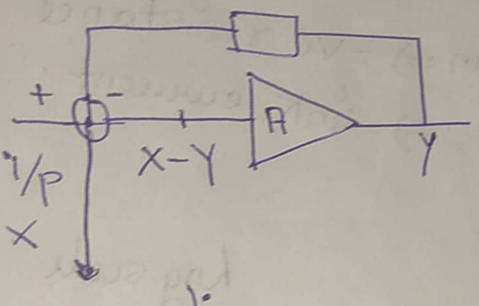
$$\angle A(j\omega) = \tan^{-1}\left(\frac{\omega}{z_1}\right) + \tan^{-1}\left(\frac{\omega}{z_2}\right) - \tan^{-1}\left(\frac{\omega}{p_1}\right) - \tan^{-1}\left(\frac{\omega}{p_2}\right)$$

What is physical s/g significance?

⇒ stability of s/s

⇒ closed loop → -ve feedback component

→ s/s not stable due to ω component.



When ω component come.

⇒ Phase shift is not dependent only on A_{dc} and depend on ω & can change.

A Negative f/b s/s may oscillate at ? ω if the phase shift around the loop is more -ve than -180°

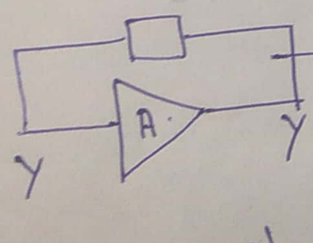
like Common source

⇒ $A_{dc} = -g_m R_{out}$ → 180°

→ phase at one pt. will be 0.

$-180° + \dots +$

and it will become X+Y & will increase.

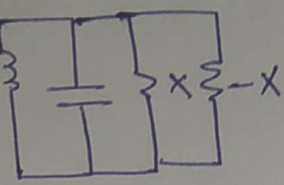


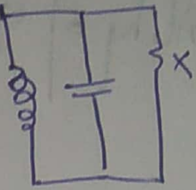
→ oscillation is genrated. (unwanted)

At a particular frequency it will get sustained & at

$\tan^{-1}\left(\frac{\omega}{P_2}\right)$

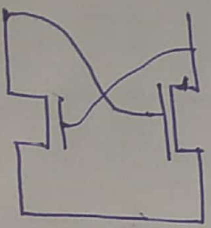
other frequency there will be damping. (~~fun~~)





$\sin \omega t$
↓
no damping.

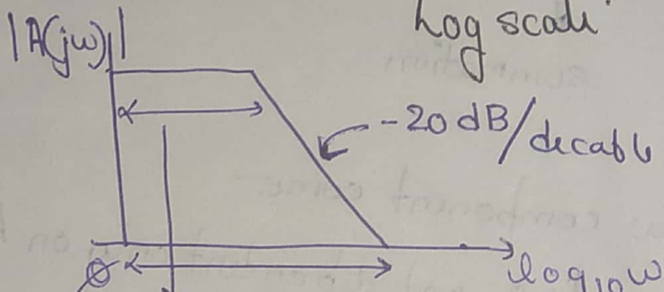
$e^{-x} \sin(\omega t)$



→ $-2/g_m$ ⇒ -ve resistance
⇒ sink current.

$$A(j\omega) = \frac{A}{(s+a)}$$

Log scale



$\boxed{\text{gain} \times B.W = \text{const.}}$

B.W ↑ gain ↓.

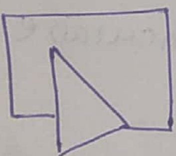
we want this particular to maximize. otherwise s/s will become non-linear.

Unity gain B.W

$\omega_{UGB} \times 1 = \omega_{3dB} \times A_{dc}$.

↓ Minimum gain

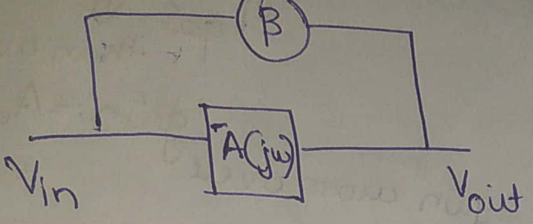
Maximum fre.



→ overall gain = 1

B.W =

Eg. ⇒ $$\frac{\boxed{\frac{A}{1+A}}}{1+\frac{s}{\boxed{B.W(1+A)}}}$$



$$= \frac{A(j\omega)}{1-\beta A(j\omega)} \Rightarrow \frac{-A(j\omega)}{1+\beta A(j\omega)} = A_{CL}(j\omega)$$

$(x+iy)$

$$= \frac{a+jb}{c+jb}.$$

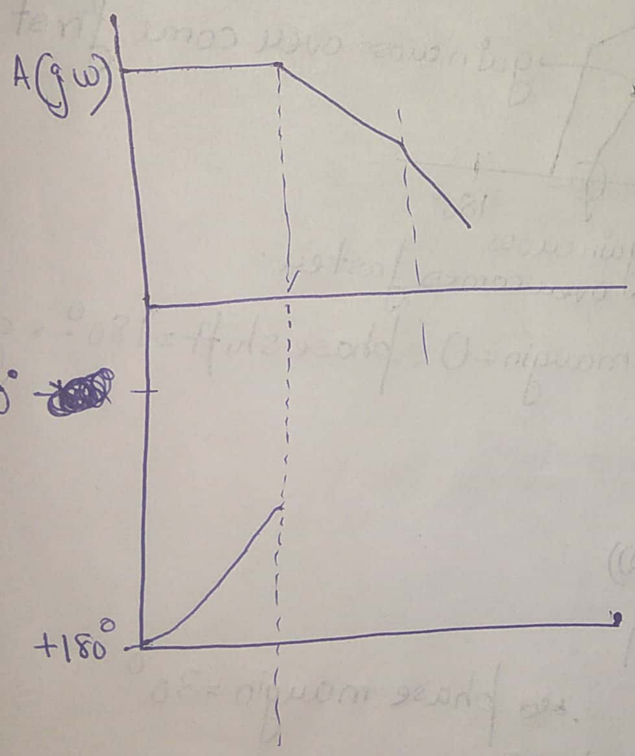
If $A(j\omega)$ has poles

$\Rightarrow A(j\omega) = -\frac{1}{\beta}$ → We don't want that.

$\Rightarrow A_{CL}(j\omega) = \infty$

left half phase shift → zero → $s+j\omega$

RHP → add extra phase shift



Right half phase shift → pole ; zero → $s-j\omega$ → ~~add~~

$$-\tan^{-1}\left(\frac{\omega}{3}\right)$$

$$= 180^\circ - \tan^{-1}\left(\frac{\omega}{3}\right)$$

$\{-\tan^{-1}()$ → -180°

$= 0^\circ$

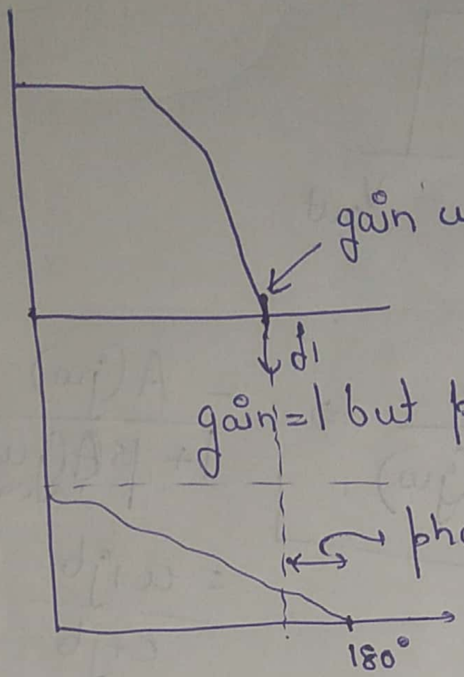
we don't want that.

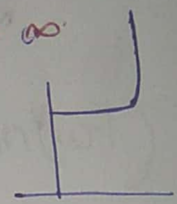
⇒ we don't want $\boxed{\text{RHPS}}$ zero

⇒ -"- want LHPS pole ($e^{+x} \to \infty$)

12/03/19

If $\angle \beta A(j\omega) = +180°$ {
~~gai~~ ⇓
than overall gain $= A_{CL}(j\omega)$
$= \infty$





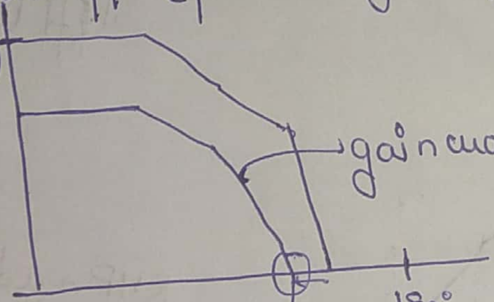
⇒ gain cross over should come before phase cross over.

Q How much phase margin one should have?

→ worst value of β. [feedback gain, $\beta<1$]

for $\beta=1$ ∈ $\beta(A(j\omega))$

$\beta<1$



$\beta A(j\omega)=1$ → phase margin = 0, phase shift = 180° → gain will be ∞.

β

$$= \frac{A(j\omega)}{1+\beta(A(j\omega))}$$

$\beta(A(j\omega)) = -1$

~~so~~ phase margin = 30°

$\beta A(j\omega) = |H(j\omega)|\, e^{j\theta}$

$\beta \leq 1$ considering worst case scenario of β. $[\beta = 1]$.

$$\Rightarrow \frac{Y(j\omega)}{X(j\omega)} = \frac{A(j\omega)}{1 + A(j\omega)}$$

$30^\circ \rightarrow$ phase Margin.

$$A(j\omega) = a + jb.$$

$|A(j\omega)| = 1$ & $\angle A(j\omega) = 150^\circ$

$$\Rightarrow A(j\omega) = 0.66 - 0.38j$$

$$\Rightarrow \frac{Y(\omega)}{X(j\omega)} = \frac{0.66 - 0.38j}{1 + 0.66 - 0.38j}$$

$$= \frac{0.66 - 0.38j}{1.66 - 0.38j}$$

$$= \frac{(0.66 - 0.38j)(1.66 - 0.38j)}{2.9}$$

$$= \cancel{1.0956} = \frac{0.9512 - [0.2508 + 0.6308]}{2.9}$$

$$= \frac{\cancel{0.0696}}{2.0}$$

$$= \frac{0.9512 - 0.8816j}{2.9}.$$

$$= \frac{1}{2.9}\sqrt{(0.9047) + 0.772}$$

$$= \frac{1}{2.9} \times (1.6819$$

$$= 0.447$$

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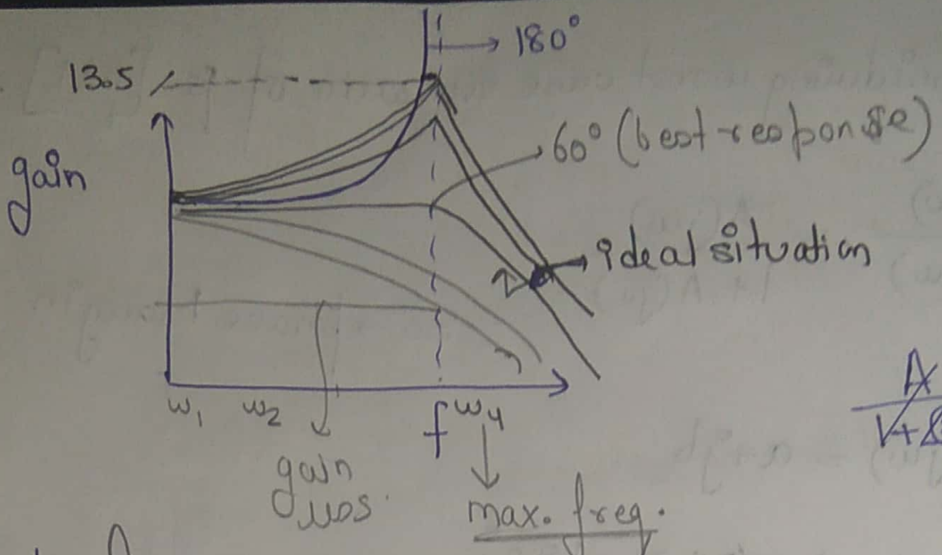
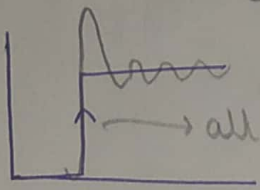
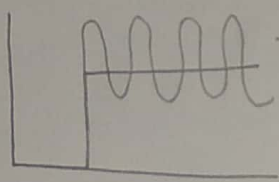


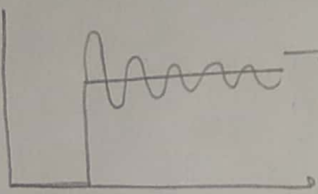
$\cancel{\frac{A}{1+A\beta(\omega)}}$



→ all λ's are present

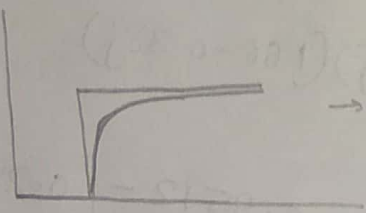


→ when gain is ∞ ⇒ 0° phase margin
undamped



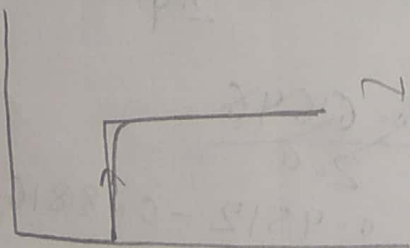
→ underdamped

< 60° phase margin



→ overdamped

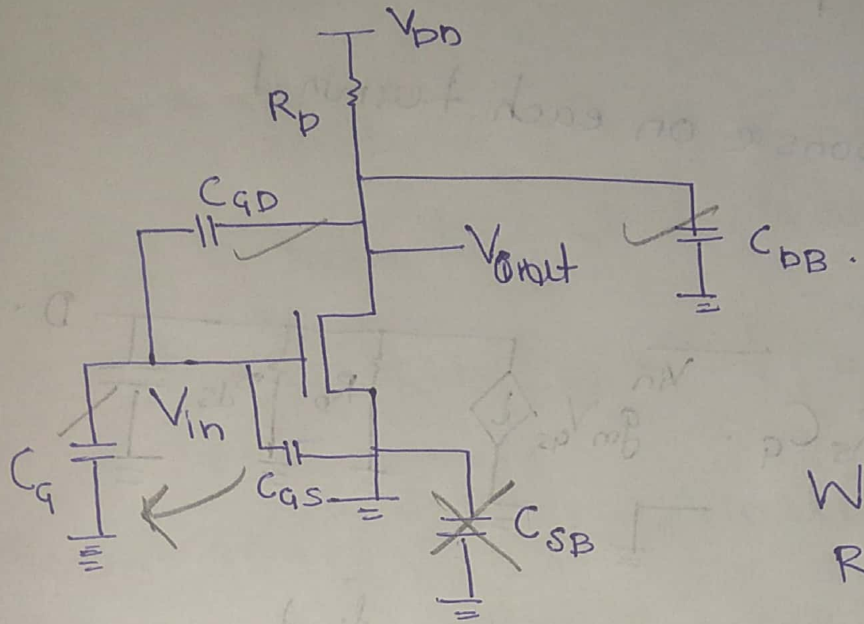
> 60° phase margin



→ critical

60° phase margin (best response)

$$\frac{A\left(1+\frac{s}{z_1}\right)}{\left(1+\frac{s}{P_1}\right)\left(1+\frac{s}{P_2}\right)}$$



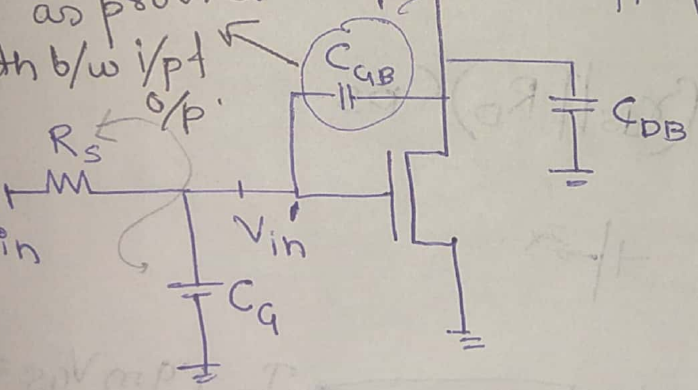
~~$s = \sigma + j\omega$~~

We are safe if R & C are less

→ provide pole and zero.

as provide extra path b/w i/p & o/p.

→ overlapping.

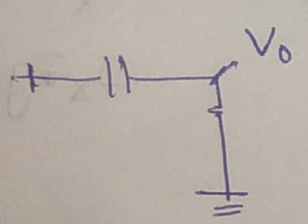


$$V_{in}' = \frac{V_{in}}{1 + sR_SC_G}$$

$R_S = 50\,\Omega$, $C_G = 100\ fF$ → 10^{-15}

$$-P = \frac{1}{R_SC_G} = \frac{1}{100\times 1}$$

C_{GB} → provides zero.



$$V_o' = \frac{V_o RSC}{1 + RSC}$$ → provides one pole & zero

∴ R_S ~~C_G~~ →

we need to see poles will are dominant & effect B.W.

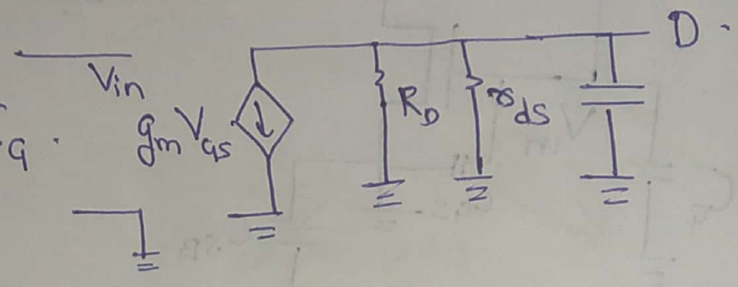
if R_S ↑ → pole location large.

$$= \frac{-g_m R_D \left(1+\frac{s}{z_1}\right)}{\left(1+\frac{s}{p_1}\right)\left(1+\frac{s}{p_2}\right)\left(1+\frac{s}{p_3}\right)}$$

⇒ We see ? response on each terminal

$\cancel{\tau}_{CG} = R_S C_G$.

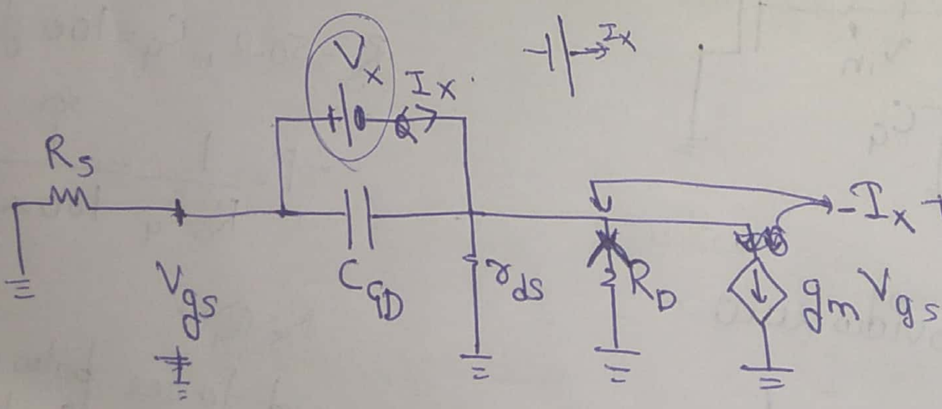
τ



when find $V_{in} = 0$

$\cancel{V_D = g_m V_G}$

$$\tau_{out} / \tau_{DB} = (r_{ds} \| R_D) C_{DS}$$



$-I_x + g_m V_{gs} = I_z$

$I_x = I_z + g_m V_{gs}$

$I_x - g_m V_{gs} = I_z$

$V_{gs} = R_S I_x$

$$(-I_x + g_m I_x R_S) R_o - V_x = -I_x R_S.$$

$$(R_S + R_o + g_m R_S R_o) = \frac{V_x}{I_x}$$

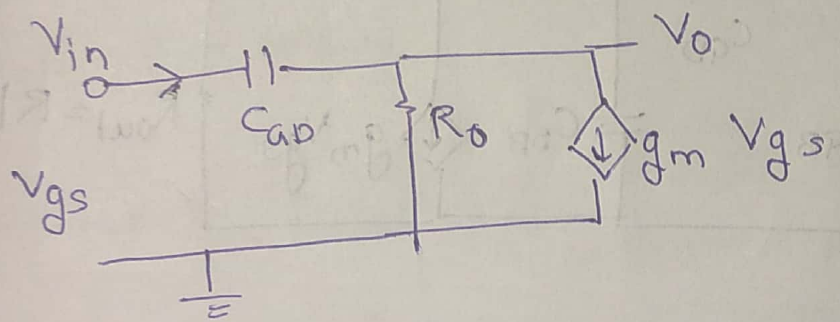
τ_{CD} = large

$\Rightarrow$ $\Sigma R_i C_i \rightarrow$ have to find dominant pole.

$$P_1 = \left[C_G R_S + C_{DB}(r_d \| R_D) + C_{GD}\, g_m R_S (r_{ds} \| R_D)\right]$$

Likewise other pole & zero as well.

At first pole $\rightarrow$ gain $\downarrow$ by 3dB $\rightarrow$ 3dB ?



$$(V_{in} - V_o)\, s C_{GD} = \frac{V_o}{R_o} + g_m V_{in}.$$

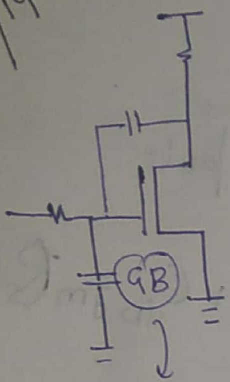
$$\cancel{\frac{(V_{in} - V_o)\, s C_{GD} R_o}{1 + s C_{GD} R_o}}$$

$$V_{in}(s C_{GD} - g_m) = V_o\left(\frac{1}{R_o} + s C_{GD}\right)$$

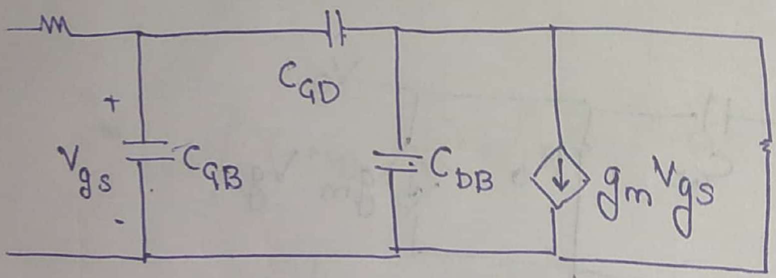
$$\frac{\cancel{\frac{1}{R_o} + s C_{GD}}\ \ s C_{GD} - g_m}{\frac{1}{R_o} + s C_{GD}} = \frac{V_o}{V_{in}}$$

Zero → Right half.
↓
supporting ↑ in phase shift & instability.

13/03/19



biggest cap.



$R_{out} = R \| r_{ds}$.

$$\frac{V_o}{V_{in}} = \frac{-g_m R_{out}\left(1 - \frac{s C_{GD}}{g_m}\right)}{s^2\left(C_{GD}C_{DB} + C_{DB}C_{GB} + C_{GB}C_{GD}\right)R_{out}R_S + s\left(C_{GB}R_S + C_{DB}R_{out} + C_{GD}\left(R_{out} + R_S + R_{out}R_S g_m\right)\right) + 1}$$

$(C_1C_2 + C_2C_3 + C_3C_1)$

$$= \frac{A_0\left(1+\frac{s}{z_1}\right)}{\left(\frac{s}{P_1}+1\right)\left(\frac{s}{P_2}+1\right)} = \frac{A_0\left(1+\frac{s}{z_1}\right)}{\frac{s^2}{P_1P_2}+s\left(\frac{1}{P_1}+\frac{1}{P_2}\right)+1}$$

⇒ Poles should be at distance - possibility will ↓ to reach 180° ($P_2 = 10P_1$)

⇒ gain slope changes gradually but phase decreases in higher amount so 180° will come fast.

$$PM = 180° - \tan^{-1}\frac{\omega_{UGB}}{P_1} - \tan^{-1}\frac{\omega_{UGB}}{P_2} - \tan^{-1}\frac{\omega_{UGB}}{z_1}$$

gain $=1 \rightarrow \omega_{UGB}$

We take $\boxed{\cancel{1\,UGB \leq 3_1}}$ $\boxed{10\,UGB \leq z_1}$

$UGB \times 1 = P_1 \times A_{dc}$

$\frac{UGB \times 1}{P_1} = A_{dc}$ (~~89~~ $\tan^{-1}(A_{dc})$)

$$60° = 180° - 89° - \tan^{-1}\left(\frac{UGB}{P_2}\right) - 5°$$

$\tan^{-1}\left(\frac{UGB}{P_2}\right) = 35°$ $[P_2 = 2.12\,UGB]$.

$\frac{UGB}{P_2} = 0.7$

0.70
1.30
- 0.7
71

71+5
76

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$\Rightarrow P_1 << P_2$ [Pole location should be away from each other]

$\Rightarrow$ f UGB should ~~we~~ come much ~~des~~ earlier than P_2.

So $\frac{1}{P_2} <<< \frac{1}{P_1}$

$$P_1 = \frac{1}{\cancel{C_{GB}R}\ \underbrace{C_{DB_1}R_{out_1} + C_{GD}g_m R_{out}R_S}_{\text{huge value}}} \quad (1)$$

3dB ~~b~~ BW

f BW will become less.

$$\frac{1}{P_1P_2} = R_{out}R_S(C_{GD} - - - -)$$

$$\boxed{\frac{\cancel{C_{GB}} - C_{DB}R_{out} + C_{GD}g_m R_{out}R_S}{R_{out}R_S(C_{GD}C_{GB} + C_{GB}C_{DB})} = P_2}$$

GB $\rightarrow$ high capacitance.

$\Rightarrow$ All pole location in left half.

if heavy load not there.

$$\boxed{P_2 = \frac{g_m C_{GD}}{C_{GB}(C_{GD} + C_{DB})}}$$

h other)

$$\boxed{3 = \frac{g_m}{C_{GD}}}$$

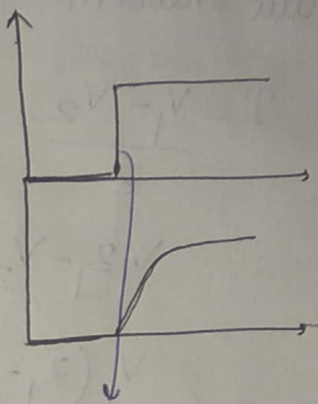
3-zero → right half. → Common Source Amplifier.

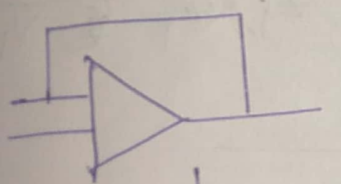
$$\boxed{P_1 = -\frac{1}{g_m R_{out} R_S C_{GD}}}$$

$A_{dc} = -g_m R_{out}$.

$UGB = P_1 \times A_{dc}$

$$\boxed{UGB = \frac{1}{R_S C_{GD}}}$$

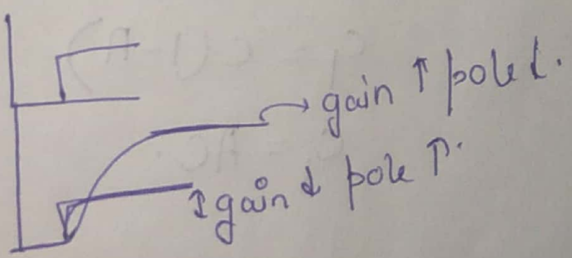


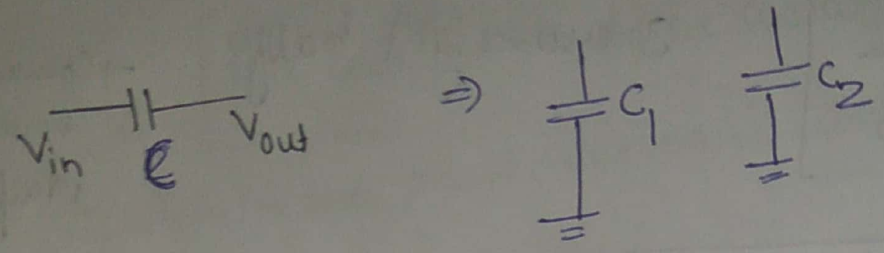


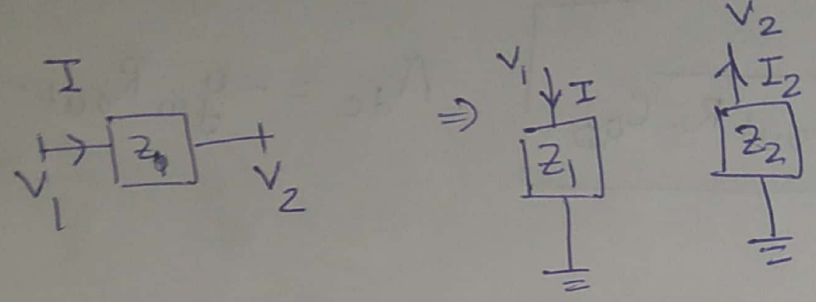
$$\downarrow$$

$$\frac{\frac{A}{1+A}}{1+\frac{1}{a(1+A)}}$$

if we ~~multiply~~ gain divide gain by 1+A, a gets multiply by same amount.







Miller theorem

$$I = \frac{V_1 - V_2}{Z} = \frac{V_1}{Z_1}$$

$$V_1 Z_1 - V_2 Z_1 = V_1 Z$$

$$V_1 (Z_1 - Z) = V_2 Z_1$$

$$\frac{\cancel{Z_1} - Z}{Z_1} = V_2$$

$$\frac{V_1 - V_2}{Z} = \frac{-V_2}{Z_1}$$

$$\frac{V_1}{Z_1} = V_2 \left(\frac{1}{Z} + \frac{1}{Z_1} \right)$$

$$\frac{1}{Z} \left(\frac{\cancel{V}}{Z} + \frac{1}{Z_1} \right) \cancel{Z_1} = \frac{V_2}{V_1}$$

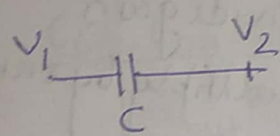
$$Z_2 = \frac{Z}{1 - \frac{1}{A}}$$

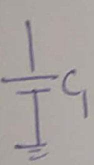
$$\frac{1}{\cancel{Z_1}} = A \left(\frac{Z_1 + Z}{Z \cancel{Z_1}} \right)$$

$$\cancel{Z = A}$$

$$Z(1 - A) = A Z_2$$

$$\boxed{Z_2 = \frac{Z}{1 - \frac{1}{A}}}$$





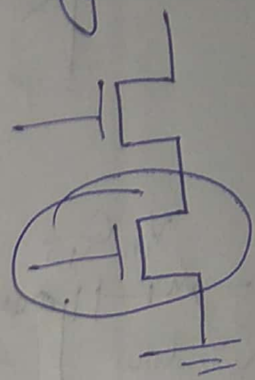
$$\frac{1}{s C_1} = \frac{\frac{1}{s C}}{1 - A}$$

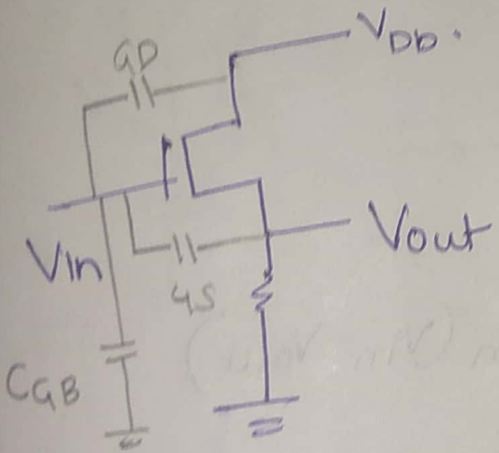
$$C_1 = C(1 - A)$$

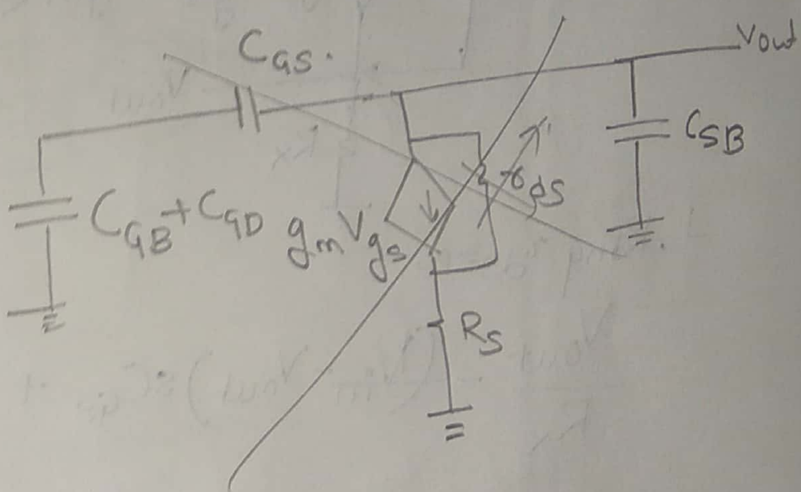
$$C_1 = AC.$$

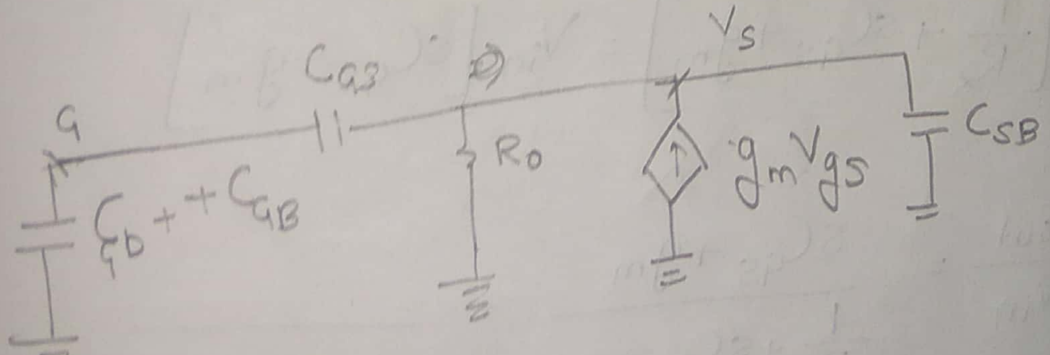
⇒ When gain is constant only we can apply miller.

⇒ Cascode one has B.W high



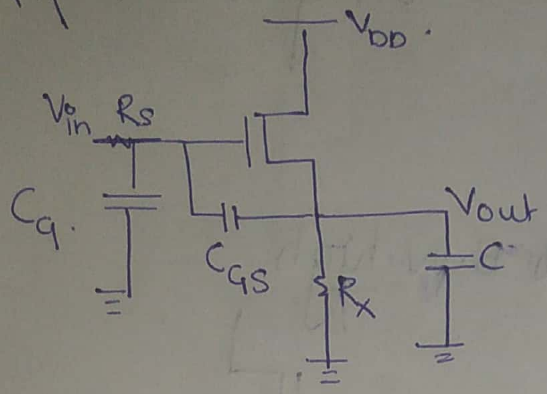




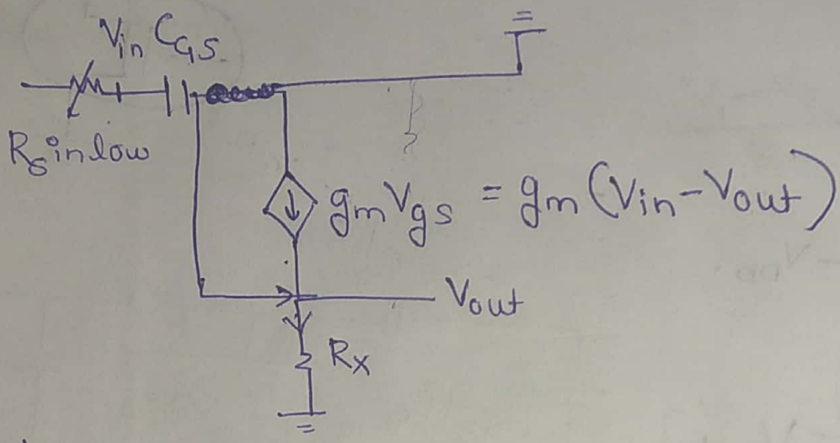


C_{SB}

14/08/19



To find zero location of the circuit



taking $r_{ds} = \infty$.

$$\frac{V_{out}}{R_x} = (V_{in} - V_{out})sC_{GS} + g_m(V_{in} - V_{out})$$

$$V_{out}\left[\frac{1}{R_x} + sC_{GS} + g_m\right] = V_{in}\left[sC_{GS} + g_m\right]$$

$$\frac{V_{out}}{V_{in}} = \frac{sC_{GS} + g_m}{\frac{1}{R_x} + sC_{GS} + g_m} = \underline{\qquad\qquad}$$

DC gain $= A_d = -g_m \times \left[\frac{1}{g_m} \| R_x\right]$

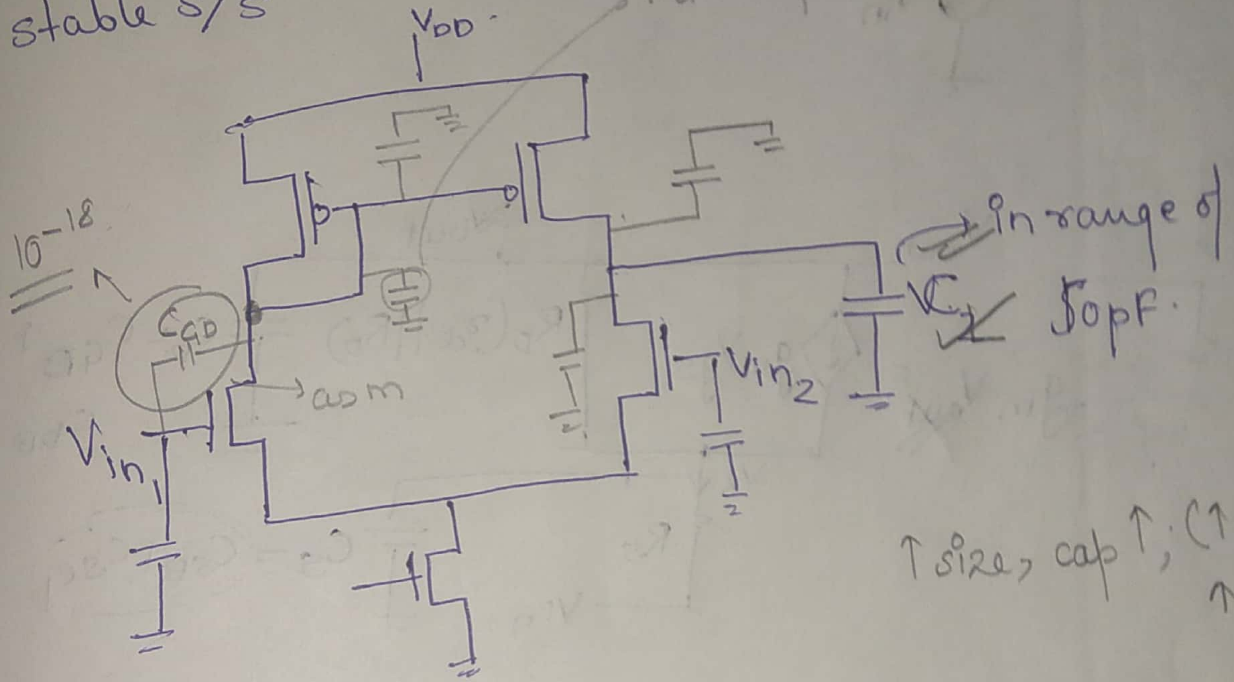
$$= g_m \times \left[\frac{\frac{1}{g_m}R_x}{\frac{1}{g_m} + R_x}\right] = \frac{g_m R_x}{1 + R_x g_m}$$

$z = \frac{-g_m}{C_{GS}}$

left half zero phase shift change.

Phase = $\tan^{-1}\left(\frac{\omega C_{GS}}{g_m}\right)$

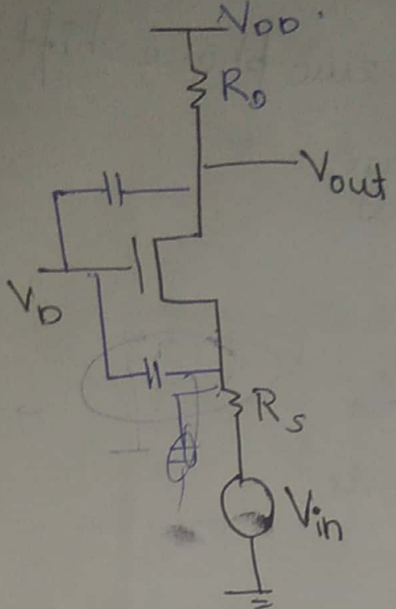
$\Rightarrow$ stable s/s.



↑ size, cap ↑, (↑ gain, ↑ gm)

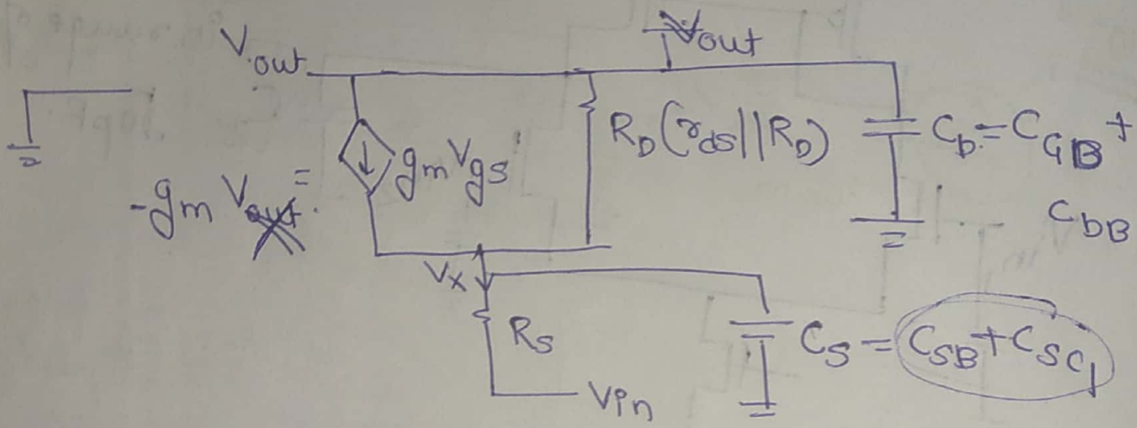
$\Rightarrow$ Cap lower, zero at higher?

$R = 100k\Omega$
$= 10^2 \times 10^3$
$= 10^5$
$C = 10^{-12}$
$w = \frac{1}{10^{-12} \times 10^5}$
$w = \frac{1}{10^{-7}}$
$\boxed{w = MHz}$
form



No zero is here.

B.W is higher as there is no zero.



$$\frac{V_x - V_{in}}{R_S} + (V_x - V_{in}) sC_S$$

$$= -g_m \cancel{V_{out}} + \frac{(V_{out} - V_x)}{R_D} + (V_{out} - V_x) C_D$$

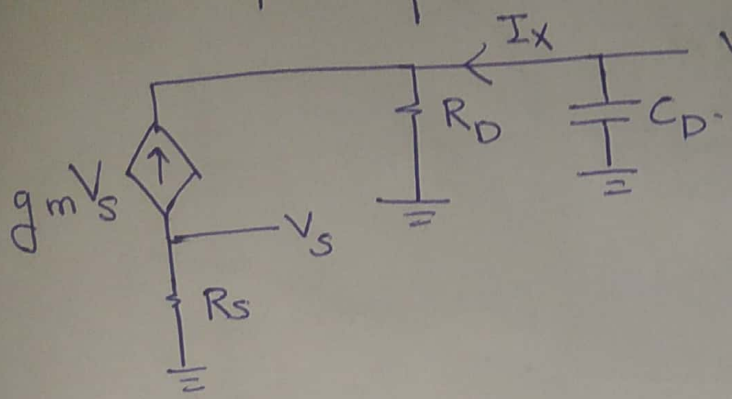
$$-g_m V_x = (V_{out} - V_x) R.$$

$$P_1 = \frac{1}{C_S R}$$

$$\frac{-g_m V_x}{V_0 - V_x} = R.$$

$$\frac{V_x - V_{in}}{R_S} =$$

When finding C_D:



$\Rightarrow \boxed{C_D R_D}$.

$\cancel{\frac{V_S}{R}}$ $\cancel{g_m V_S = -\frac{V_S}{R_S}}$

$\cancel{R_S = -\frac{1}{g_m}}$

$\cancel{R_D \| -\frac{1}{g_m}}$

$(g_m V_S) R = V_0 - V_S$.

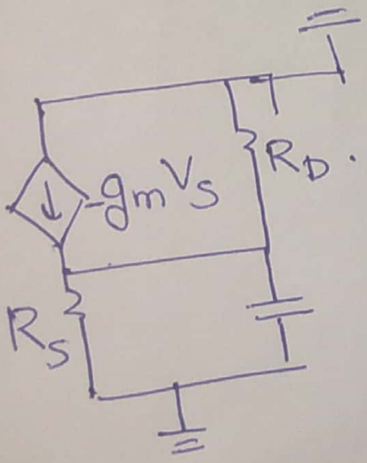
$R' = -\left(\frac{V_0 - V_S}{g_m V_S}\right)$

$R' = \frac{V_S - V_0}{g_m V_S}$

$\cancel{V_S} = ($

$\cancel{(g_m V_S)} \cancel{R} =$

$V_S = 0 \quad g_m + \frac{1}{R_S} = 0$



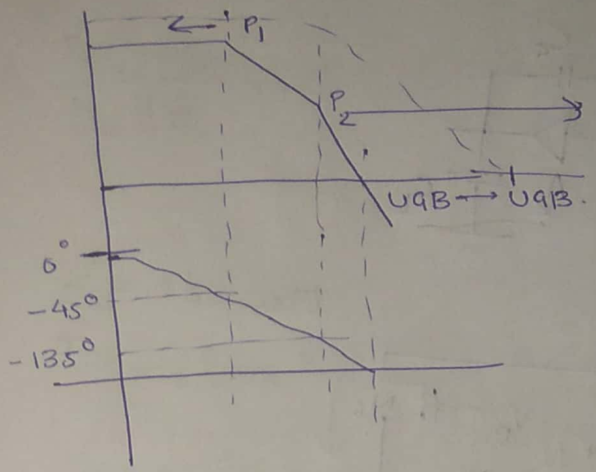
$\frac{R_D}{1 + g_m r_{ds}} \| R_S$

$\Rightarrow = R_S$.

$=$ Dominant pole $= C_S R_S + C_D R_D$

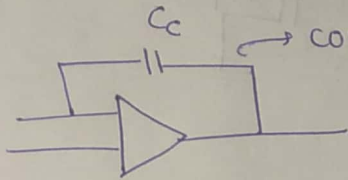
small value.

Dominant pole.



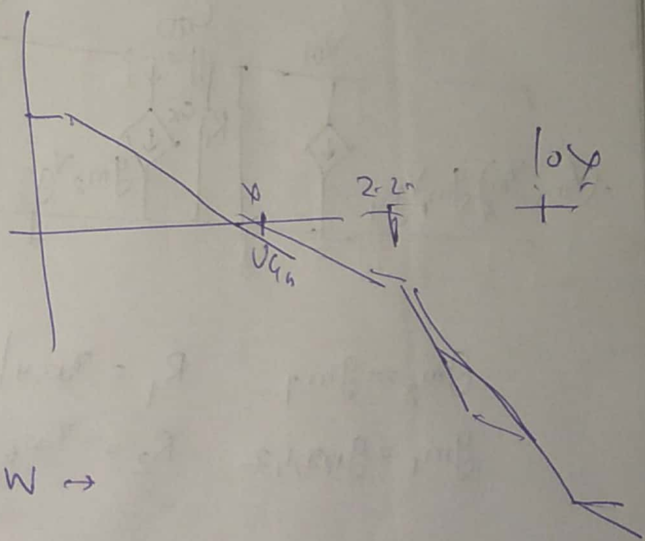
$$\frac{A}{1+\frac{S}{P_1}} = \frac{\frac{A}{1+A}}{1+\frac{S}{P(1+A)}}$$

$C_{GD}\uparrow$ → pole location

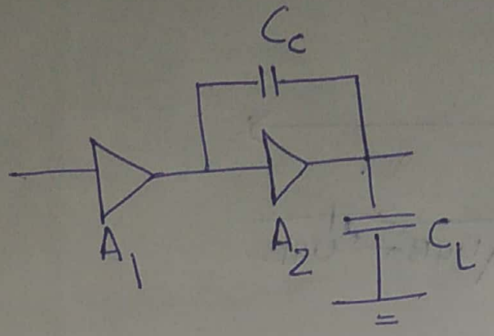


→ compensation capacitor

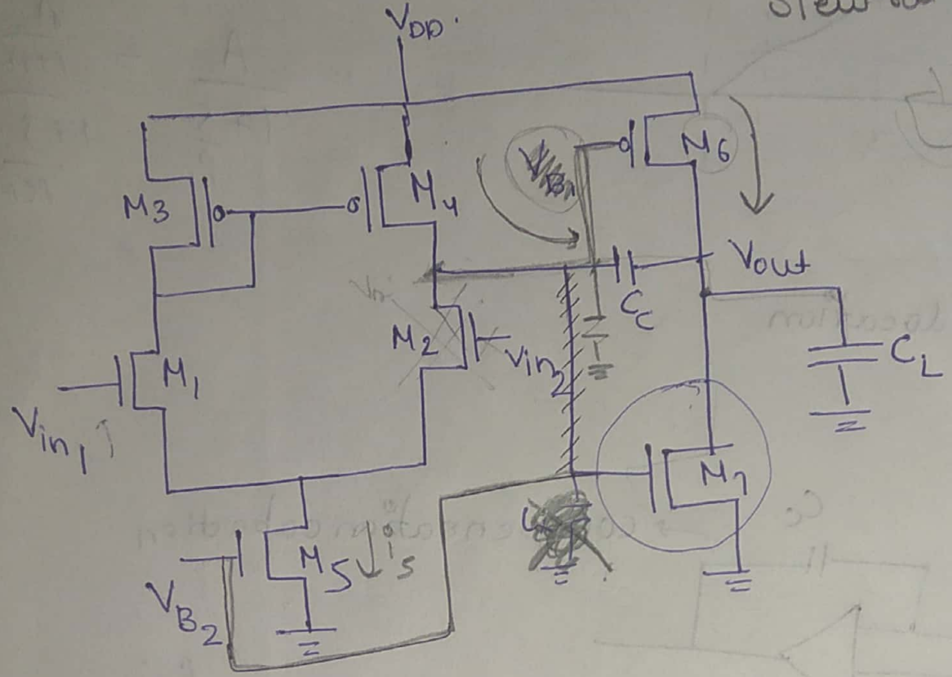
60°

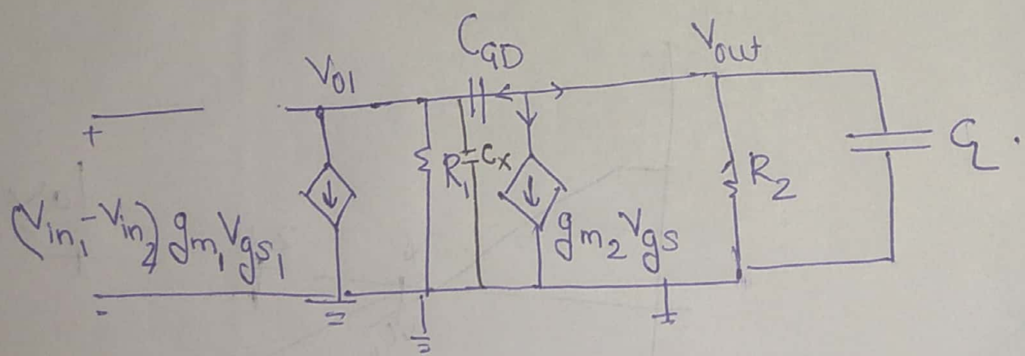


We are ↑stability not B.W →



Slew rate $= \dfrac{I_s}{C_c}$





$g_{m_2} = g_{m_7}$ $\quad R_1 = r_{ds,4} \| r_{ds,2}$

$g_{m_1} = g_{m_{1,2}}$ $\quad R_2 = r_{ds_6} \| r_{ds,7}$

$$\frac{V_{out}-0}{R_2 \| Z_L} + g_{m_2} V_{gs} +$$

V_{in} —||— V_{out}
→ single cap & V_{in} & V_{out} same than left half zero & opp. Right

$$\frac{V_{out}}{V_{in}} = \frac{-g_{m_I} g_{m_{II}} R_I R_{II} \left(1 - \frac{sC_c}{g_{m_7}}\right)}{\left[\underbrace{s^2 R_1 R_{II} (C_c C_x + C_x C_L + C_L C_c)}\, + s(C_c g_{m_{II}} R_I R_{II} + C_x R_1 + C_L R_{II}) + 1\right]}$$

→ right half.

C_x → femtofarad can be neglected.

$$P_1 = \frac{-1}{C_c g_7 R_1 R_2}$$

$$\frac{1}{P_1 P_2} =$$

$$P_2 = \frac{-g_{m_7} R_I R_{II} C_c}{R_I R_{II} C_c C_L} = \frac{-g_{m_7}}{C_L}$$

⇒ All pole are left ~~half~~ hand side.

$$UGB = \frac{g_{m_1} g_{II} R_{II} R_{II}}{g_{m_{II}} R_1 R_{II} C_c} = \frac{g_{m_1}}{C_c}$$

$zero = \frac{g_{m_2}}{C_c}$

$zero \geq 10UGB \rightarrow 60°$ phase margin.

$$\frac{g_{mII}}{C_c} \geq 10 \frac{g_{m_1}}{C_c}$$

$$\boxed{g_{mII} \geq 10 g_{m_1}}$$

$P_2 > 2.2UGB$.

$$\cancel{\frac{g_{mII}}{C_L} \geq 2}$$

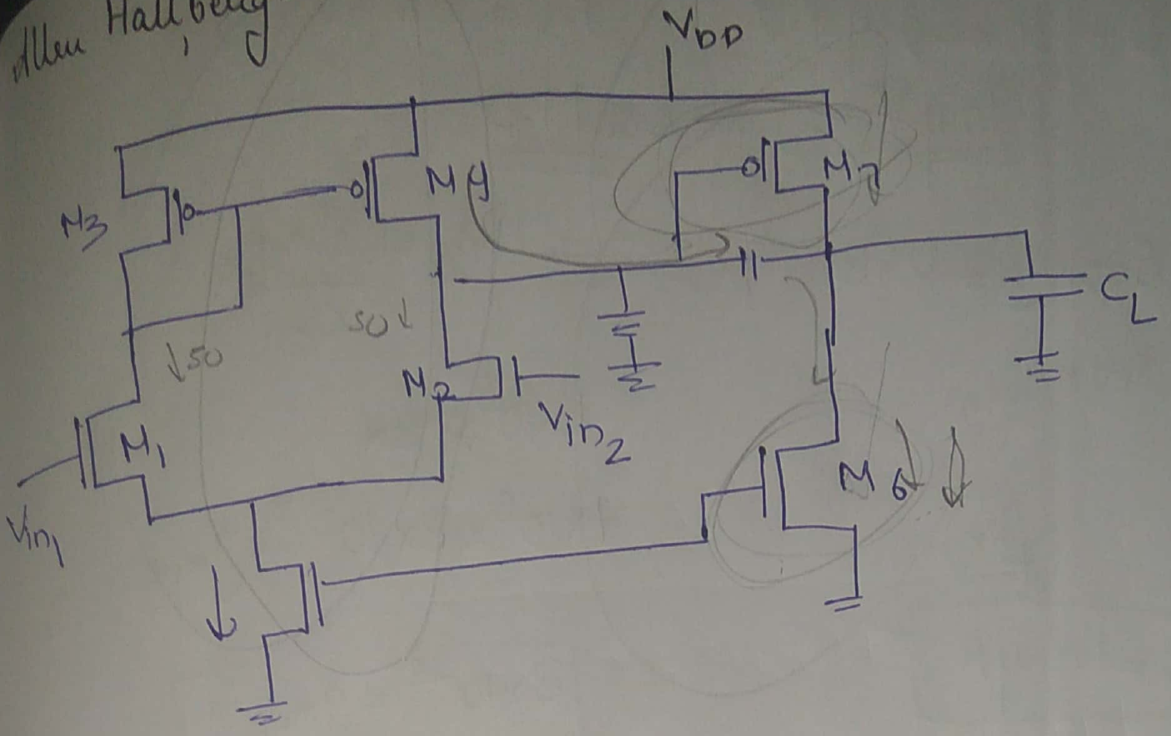
$$\frac{g_{m_2}}{C_L} \geq 2.2 \frac{g_{m_1}}{C_c}$$

$$\frac{10}{C_L} \geq \frac{2.2}{C_c}$$

$$\boxed{C_c \geq 0.22 C_L}$$

for slew rate := $\frac{i_{ss}}{C_c}$

Allen Hallberg -



$g_m = \beta V_{GS}$.

$$\frac{g_{m1}}{g_{m2}} = \frac{\beta_1 \cancel{V_{GT}}}{\beta_2 \cancel{V_{GS}}}$$

$r_{out} = \frac{1}{\lambda I_{DS}}$.

if V_{GT} are same.

$$\frac{g_{m1}}{g_{m2}} = \frac{I_{D1}}{I_{D2}}$$

$V_{DD} = 3V$, $\lambda = 0.05V^{-1}$, $|V_{th}| = 0.6V$ / gain = 5000V/V.

slew rate = $10V/\mu s$, PD = 10mW, $C_L = 10pF$

$\mu_n C_{ox} = 300\mu A/V^2$, $\mu_p C_{ox} = 100\mu A/V^2$ $V_{DD} - V_{GS} + V_{th}$

INH3. V_{DS}

ICMR = 1 - 2.6 V, B.W = 500KHz.

~~$C_c = 30pF$~~

$C_c = 3pF$.

$V_{dsat} = \sqrt{\frac{2I_D}{\beta}}$, $\cancel{\frac{i_{SS_5}}{C_C} = 10}$

$\cancel{i_{SS} = 10 \times 10 \times 10^{-6}}$

$(i_{SS})_5 = 10 \times 10^6 \times 3 \times 10^{-12}$ $\boxed{I_5 = \cancel{10^{-4}}}$ = 30

$= 30\,\mu A$

$P.D = (30 \times 3)\,\mu W$ $\quad$ $P.D = 10\,mW$

$= \underline{90\,\mu W}$, We can $\uparrow$ P.D

$500kHz = UGB$, $\quad$ $1MHz = \frac{g_{m1,2}}{C_c}$

$500\,kHz$

$\cancel{1 \times 10^6 \times 3 \times}$

$1 \times 10^6 \times 3 \times 10^{-12} = g_{m1,2}$

fix

$\boxed{I_5 = 100\,\mu A}$

$\boxed{3 \times 10^{-6} = g_{m1,2}}$

$g_m = \sqrt{2\beta I_D}$

$\beta_{1,2} = \frac{g_m^2}{2 I_D} = \frac{9 \times 10^{-12}}{2 \times 100 \times 10^{-6}}$

ICMR $\rightarrow$ Min

$1 = V_{dsat1,2}$

$\hookrightarrow \beta_{1,2}$

$= \frac{9 \times 10^{-6}}{2} \times 10^{-2}$

$\mu_n C_{ox} \frac{W}{L}$ $= 4.7 \times 10^{-8}$

ICMR $\rightarrow$ Max

$\downarrow$

$\beta_5\ \beta_7$

$= 4.7 \times 10^{-6} \times 10^{-2}$

size we will know

$= \underline{0.047 \times 10^{-6}}$

$\boxed{g_{M_{II}} \geq 10\, g_{M_I}}$