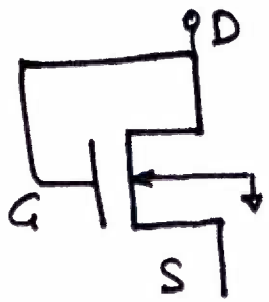
Loads in MOS Amplifiers

(i) Resistive Load — Actual Resistor as Load

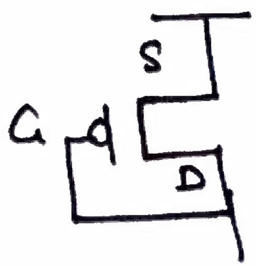
(ii) Active load — Device as Resistor

Active Loads :—

(A) Diode Connected Loads :



n-MOS



PMOS

In this case $V_{GD} = 0$

We have $V_{DS} = V_{GS} + V_{GD}$ for Normal case.

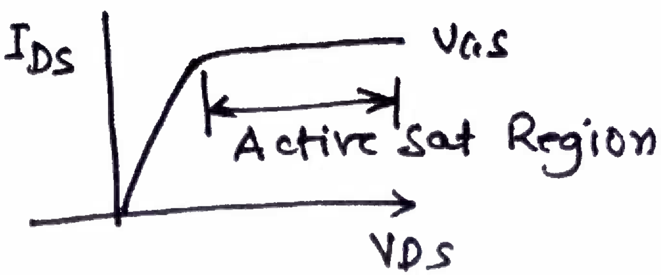
∴ Here $V_{DS} = V_{GS}$

or $V_{GS} - V_T < V_{DS}$ Device is Always in Saturation. Then

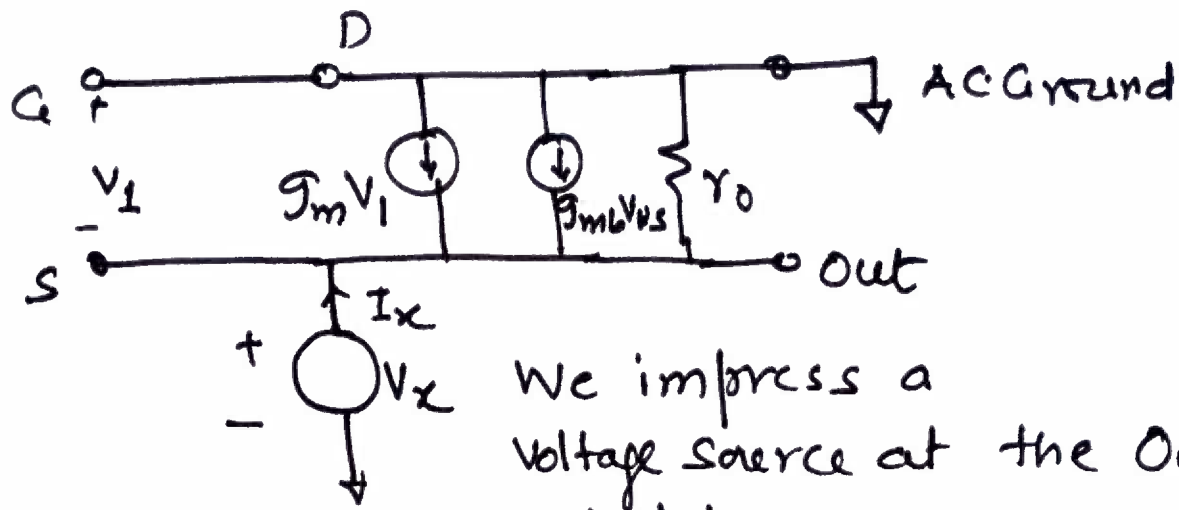
$$I_{DS} = \frac{\beta}{2} (V_{GS} - V_T)^2$$

If λ is v. small

This is constant Current Source.



Eq. Ckt to evaluate R_o of Current Source.



We impress a voltage source at the Output as V_x and let us say I_x is the current

Then $R_o = \dfrac{V_x}{I_x}$ Here $V_{bs} = 0 - V_x$

$$I_x = +(g_m + g_{mb})V_x + \frac{V_x}{r_o}$$

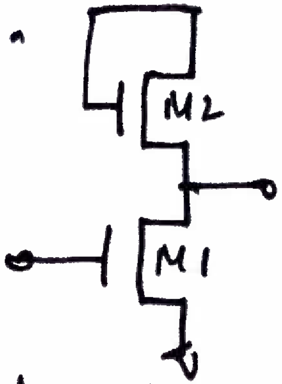
or $I_x = \left[g_m + g_{mb} + \frac{1}{r_o}\right] V_x$

$$\therefore R_o = \frac{V_x}{I_x} = \frac{r_o}{1 + (g_m + g_{mb})r_o} \simeq \frac{1}{g_m + g_{mb}}.$$

To improve of r_{out} we must reduce g_m of Load transistor. But

$$g_m = \sqrt{2\beta'\left(\frac{W}{L}\right)}\,(I_{DS})^{1/2}$$

For a set value of I_{DS}, reduction in W/L reduces g_m, or increases R_o of load source.



Amplifier

Then Gain $= -g_{m1} R_{out}$

Here $R_{out} = R_{o2} \,\|\, r_{o1} = \dfrac{r_{o1}}{g_{m2}+g_{mb2}} \Big/ \left(r_{o1} + \dfrac{1}{g'_m}\right)$

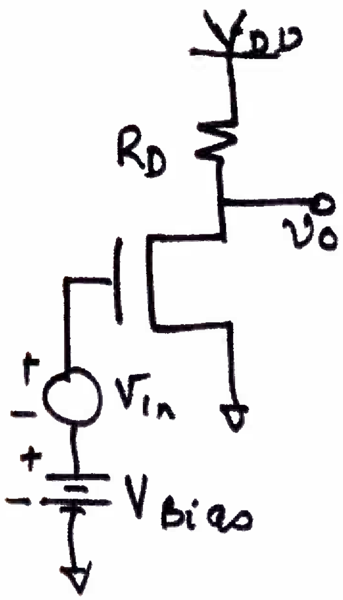
$$\therefore \quad A_{vo} = -\frac{g_{m1} r_{o1}}{g_{m2}} \cdot \frac{1}{1+\eta} \qquad \eta = \frac{g_{mb}}{g_m}$$

$$A_{vo} = -\frac{g_{m1} r_{o1}}{(1+\eta)\, g_{m2} r_{o1} + 1} \simeq -\frac{g_{m1}}{g'_{m2}} = -\frac{\sqrt{2\beta'(W/L)_1 I_{DS}}}{(1+\eta)\sqrt{2\beta'(W/L)_2 I_{DS}}}$$

or $A_{vo} = \sqrt{\dfrac{(W/L)_1}{(W/L)_2}} \cdot \dfrac{1}{1+\eta}$

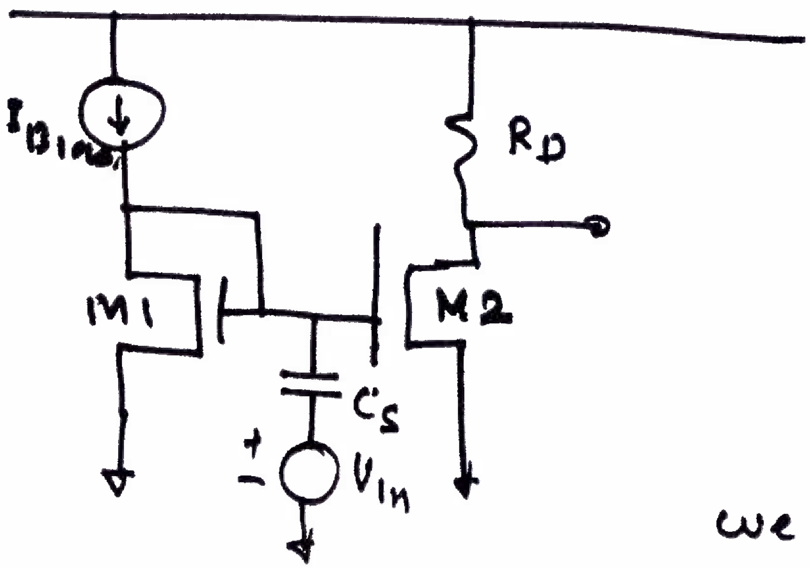
Differential Amplifier

In Single Stage Amplifier (CS, CG or CD), one of the issue is 'Biasing' for a Q-point. Since Gain of the Amplifier is constant only if g_m & r_o are constant. However position of V_{Bias} along with Input Signal V_{in}, cannot keep these two parameters (g_m & r_o) as constant. Stating Precisely, we observe that output voltage is not constant in particular case of large 'Gain' Amplifier.



If we use constant current Biasing, may be this issue can be addressed

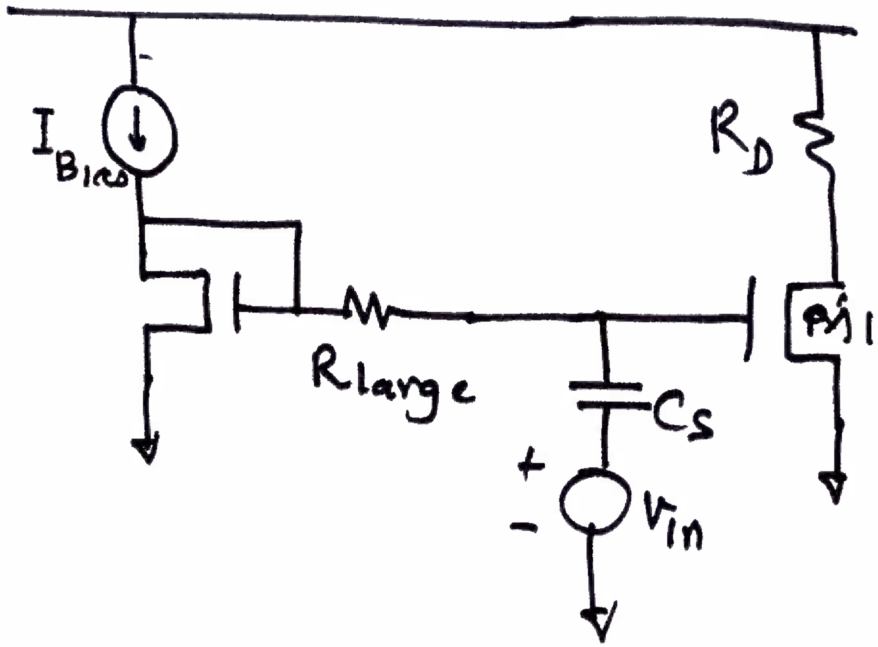
A typical Biasing System could be



C_s is large Series capacitance to block DC from v_{in}.

To achieve better blocking we need a High Pass Filter at Input.

Modified Biasing scheme may be



High Pass Filter Cut off frequency

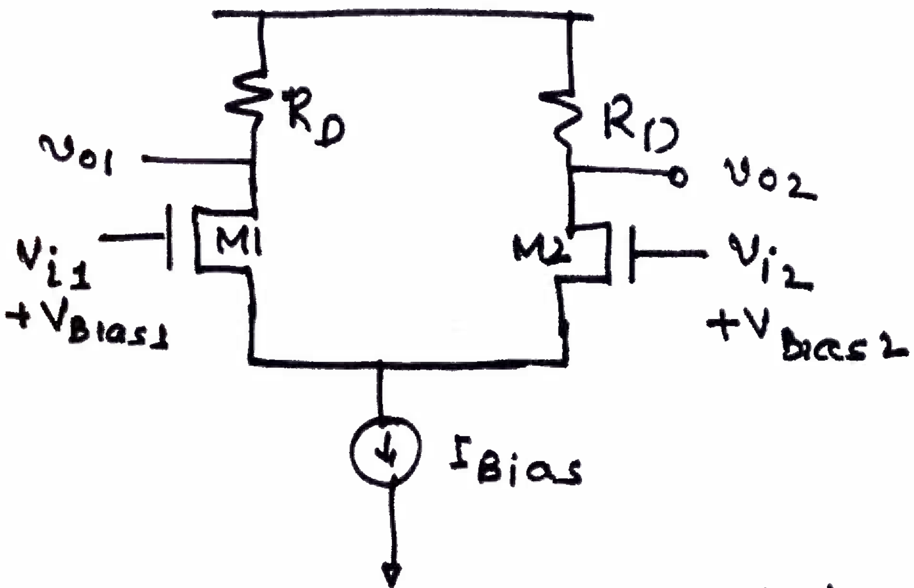
$$f_c = \frac{1}{2\pi R_{Large} C_s}$$

For f_c to be lower both R and C should be v. large.

Which means they will require large Area.

However with this Scheme, g_m of M1 will only be decided by I_{Bias} and not by V_{Bias}

Differential Amplifier is a better solution to this Biasing Problem

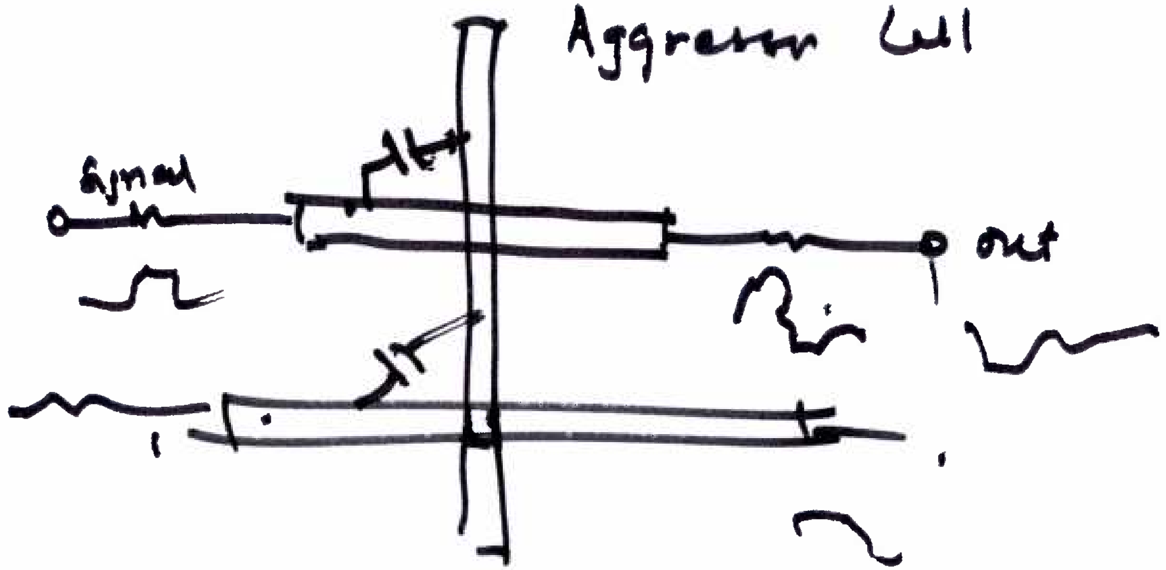


If $V_{Bias1} = V_{Bias2}$

then we see that

g_m for M1 & M2 are decided by Tail current Source I_{Bias}

An Interesting outcome is that Difference $(v_{o1} - v_{o2})$ Voltage is proportional to Input difference voltage $(v_{i1} - v_{i2})$



Aggressor Cell
Signal
out

We have

$$I_{DS} = \frac{\beta}{2}(V_{GS} - V_T)^2$$

or $$V_{GS} = \sqrt{\frac{2I_{DS}}{\beta}} + V_T$$

$$\therefore V_{in1} - V_{in2} = \sqrt{\frac{2I_{DS1}}{\beta}} + V_T - \sqrt{\frac{2I_{DS2}}{\beta}} - V_T$$

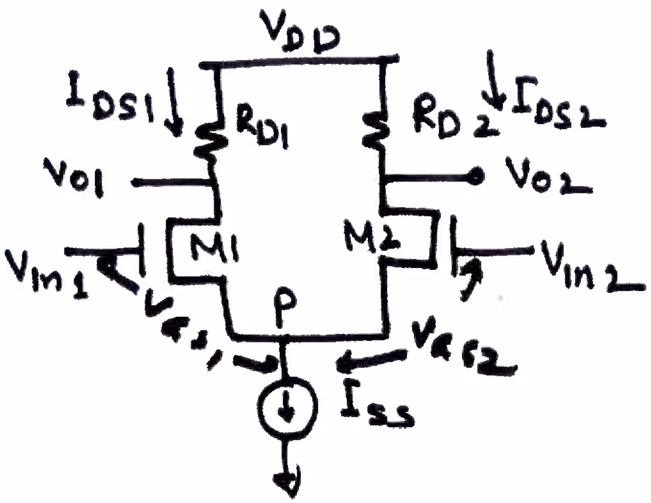
$$= \sqrt{\frac{2I_{DS1}}{\beta}} - \sqrt{\frac{2I_{DS2}}{\beta}}$$

Further $I_{DS_1} + I_{DS_2} = I_{SS}$ For all cases.

$$(V_{in1} - V_{in2})^2 = \frac{2I_{DS1}}{\beta} + \frac{2I_{DS_2}}{\beta} - \frac{4}{\beta}\sqrt{\frac{I_{DS1} I_{DS2}}{1}}$$

$$= \frac{2}{\beta}(I_{SS}) - \frac{4}{\beta}\sqrt{I_{DS1} I_{DS_2}}$$

Large Signal Behavior of DIFFAMP.



V_{in1} & V_{in2} are Inputs to M1 & M2

By Circuit Analysis

$$V_{o1} = V_{DD} - I_{DS_1} R_{D1}$$

$$V_{o2} = V_{DD} - I_{DS_2} R_{D2}$$

$$\therefore \quad V_{o1} - V_{o2} = I_{DS_2} R_{D2} - I_{DS_1} R_{D_1}$$

$$= (I_{DS_2} - I_{DS1}) R_D \quad \text{if } R_{D1} = R_{D2} = R_D$$

Further

$$V_{in1} - V_{in2} = V_{GS_1} - V_{GS_2}$$

We assume for all case now onward that $\lambda = 0$ if not stated otherwise.