Types of Amplifier (MOSFET based)

1. Common Source
2. Common Gate
3. Common Drain or Source Follower.

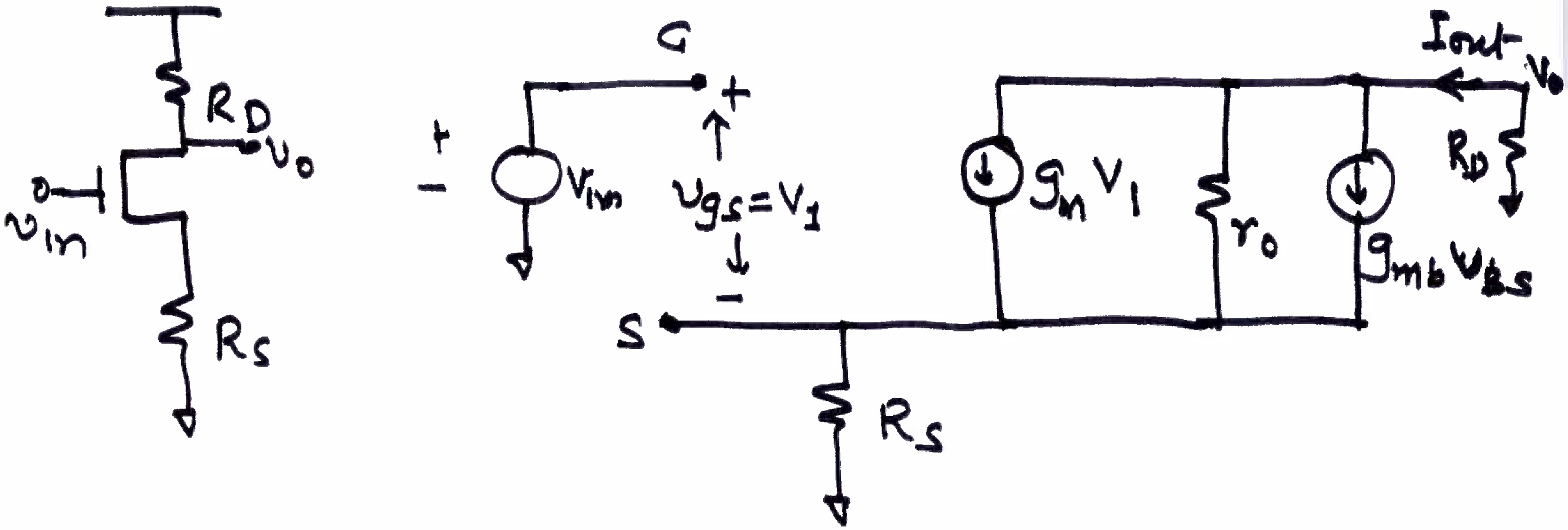
Loads in Amplifier

i Diode Connected (Active Load)

ii Current Source Load

iii Linear Loads

Common Source Amplifier with Source Degeration



We know V. Gain $= g_m \cdot r_{out}$

Also $$g_{meff} = \frac{i_{out}}{v_{in}} = \left.\frac{\partial I_{out}}{\partial V_{in}}\right|_{V_o = 0}$$

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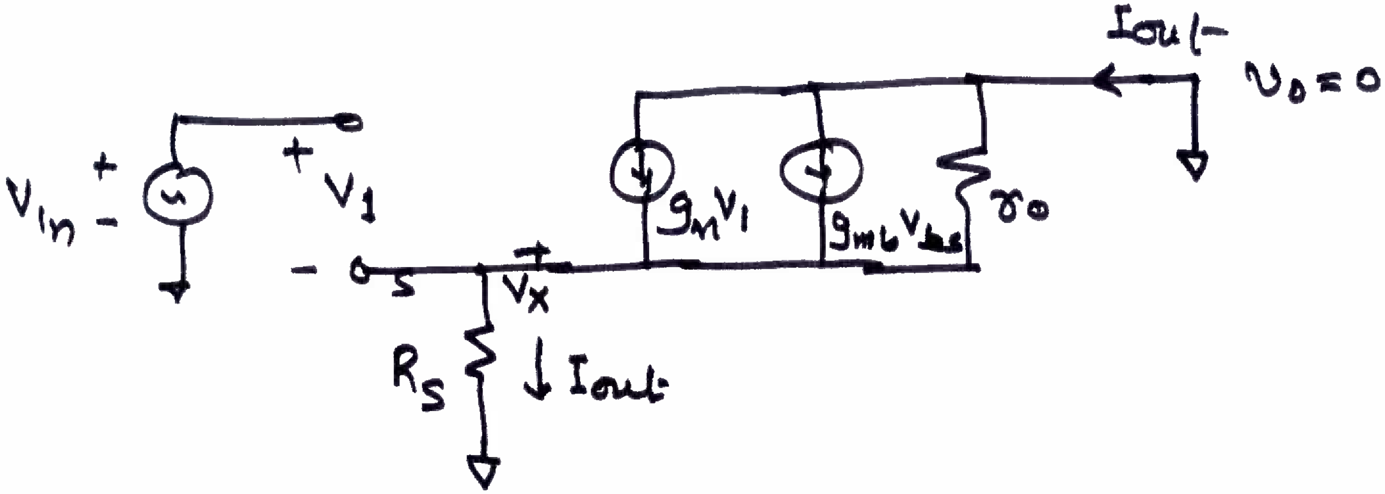
Then eq. ckt is

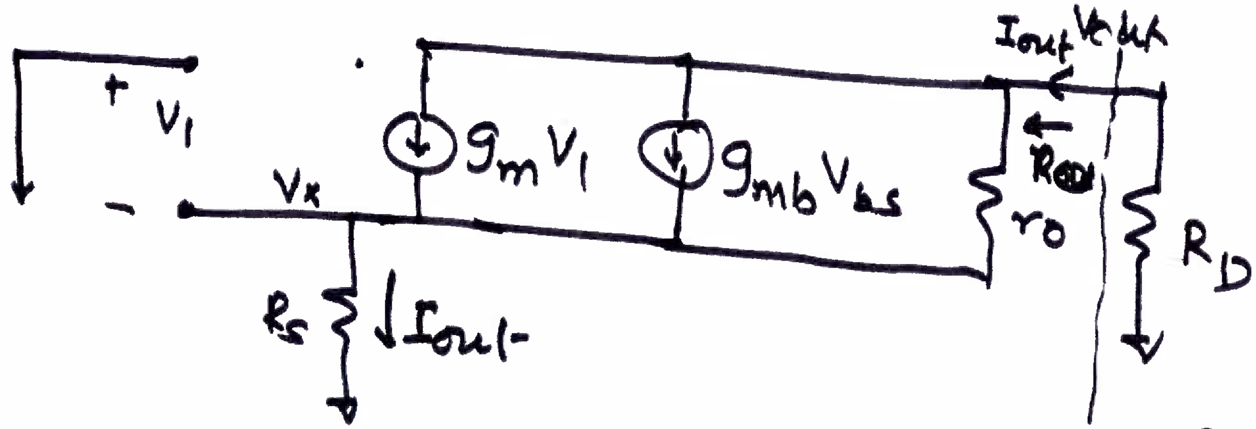


Now $V_{in} = V_1 + I_{out} \cdot R_s$ And $V_x = I_{out} R_s$

$$\therefore I_{out} = g_m (V_{in} - I_{out} R_s) + g_{mb} (- I_{out} \cdot R_s) + \left(\frac{0 - I_{out} R_s}{r_o} \right)$$

$$\therefore g_{meff} = \frac{I_{out}}{v_{in}} = \frac{g_m \cdot r_o}{R_s + [1 + (g_m + g_{mb}) R_s] r_o}$$

(ii) R_{out} $v_{in}=0$ & we have V_{out}, I_{out} at output



$R_o \parallel R_D = R_{out}$

Now $V_1 = -I_{out} \cdot R_S$ $\quad V_x = I_{out} \cdot R_S$

$$\therefore I_{out} = -g_m I_{out} R_S - g_{mb} I_{out} R_S + \frac{V_{out} - V_x}{R_o}$$

or $I_{out}\left[1+(g_m+g_{mb})R_s+\frac{R_s}{r_o}\right]=\frac{V_{out}}{r_o}$

$\therefore\ R_o=\frac{V_{out}}{I_{out}}=r_o\left[1+(g_m+g_{mb})R_s+\frac{R_s}{r_o}\right]$

$\therefore\ R_{out}=R_o \parallel R_D$

As R_o is quite large $\simeq (g_m+g_{mb})R_s r_o$

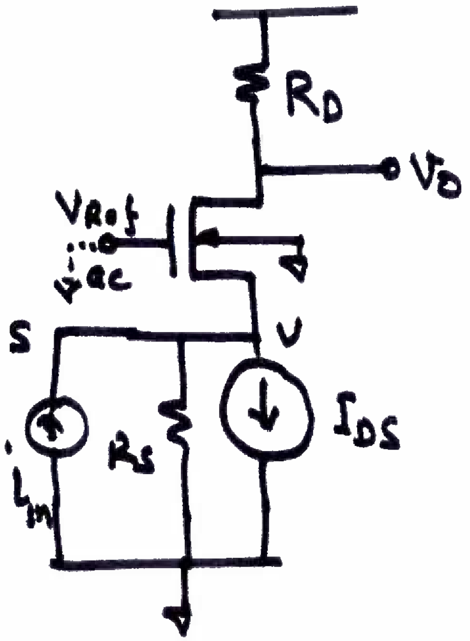
$\therefore\ R_{out}\simeq R_D$

$\therefore$ Voltage Gain $=-g_{meff}\cdot R_{out}$

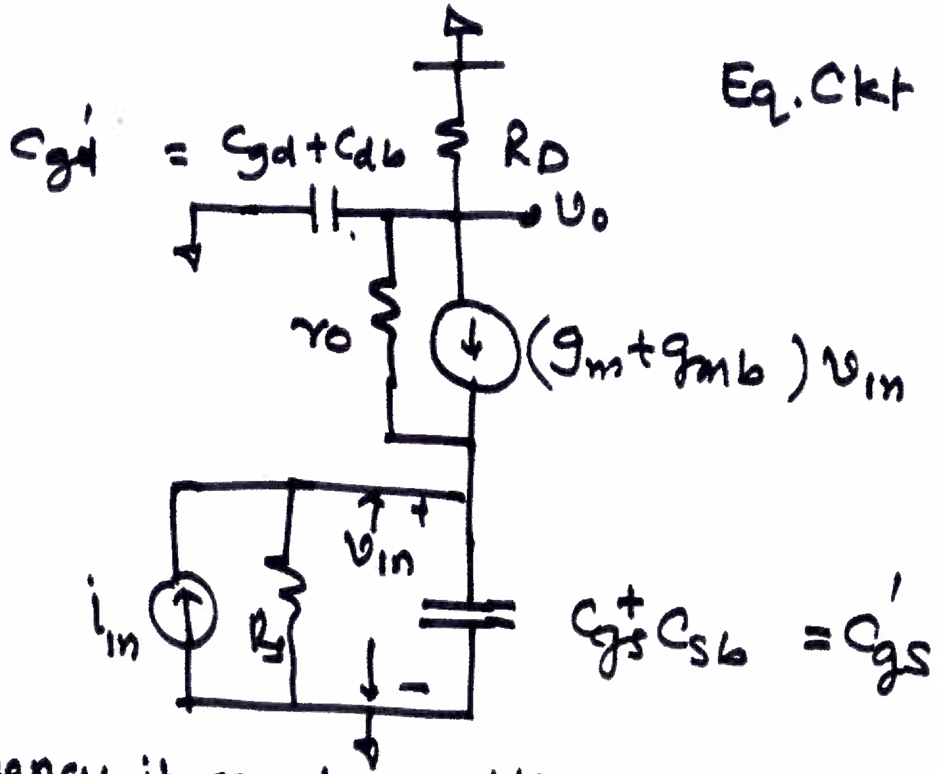
$$=-g_{meff}\cdot R_D=\frac{-g_m r_o R_D}{R_s+[1+(g_m+g_{mb})R_s]r_o}$$

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

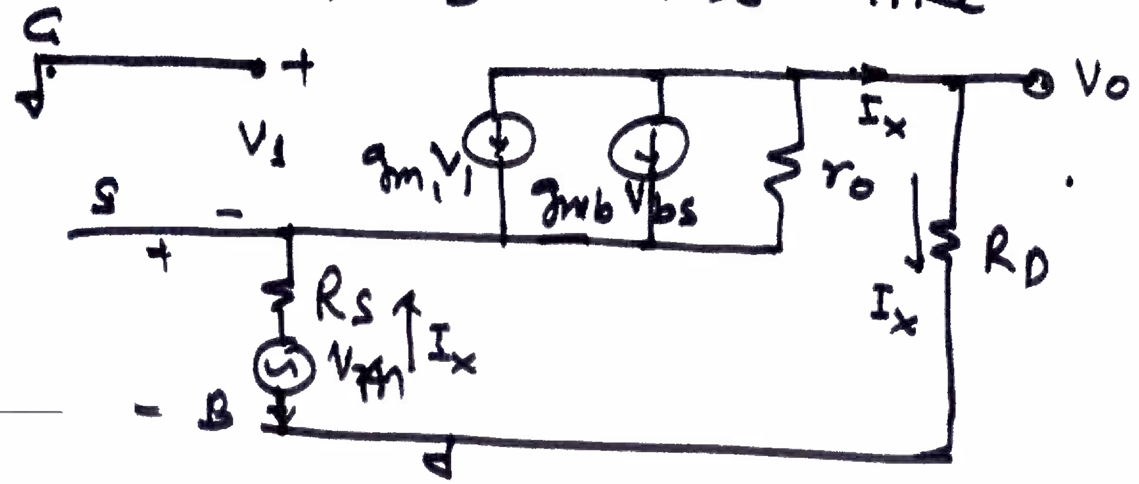
Common Gate Stage Amplifier



Eq. Ckt



At Low Frequency it can be like



$\therefore V_{sb} = V_1$

We have $I_x = \frac{V_0}{R_D}$ → (1)

Further $0 = V_{in} - I_x R_s + V_1$ → (2)a

or $V_1 + V_{in} - \frac{V_0}{R_D} R_s = 0$ — (2)

The $v_0 = i_{r0} \cdot r_0 - V_1$ — (3)

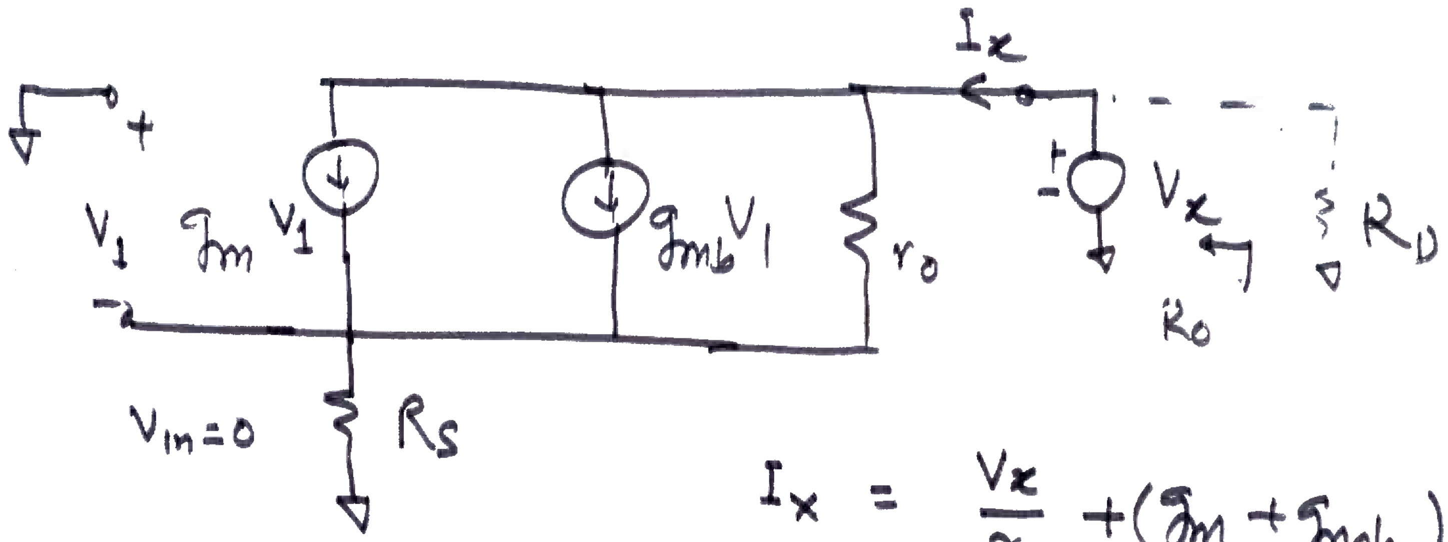
where $i_{r0} = I_x - g_m V_1 - g_{mb} V_1$ — (4)

$\therefore V_0 = \left(\frac{V_0}{R_D} - g_m V_1 - g_{mb} V_1 \right) r_0 - V_1$

or $v_0 = r_0 \left[-\frac{V_0}{R_D} - (g_m + g_{mb}) \left(\frac{v_0 R_s}{R_D} - v_{in} \right) \right] + v_{in}$

$\therefore \frac{v_0}{v_{in}} = A_{v0} = \frac{(g_m + g_{mb}) r_0 + 1}{r_0 + (g_m + g_{mb}) r_0 R_s + R_s + R_D} \cdot R_D$

Output Impedance R_o



$$I_x = \frac{V_x}{r_o} + (g_m + g_{mb}) V_1$$

But $I_x R_s = -V_1$

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

$$I_x [1 + (g_m + g_{mb}) R_s] = \frac{V_x}{r_o}$$

$$\therefore R_o = \frac{V_x}{I_x} = r_o [1 + (g_m + g_{mb}) R_s]$$

Then $R_{out} = R_o \| R_D$

Since $R_o \cong (g_m + g_{mb}) R_s r_o$ is quite large

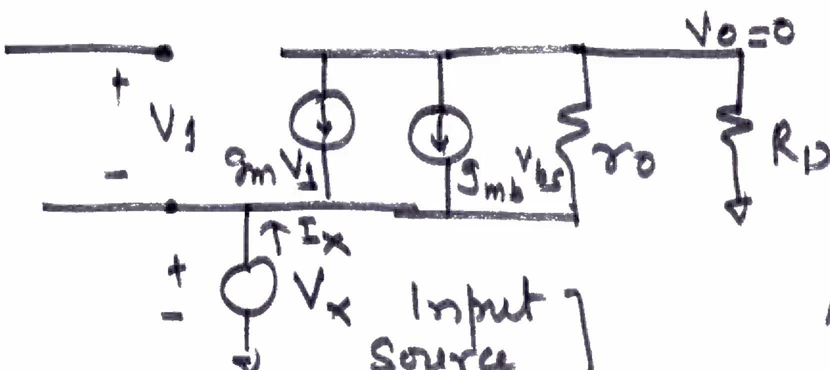
$\therefore$ $R_o >> R_D$ & Then $R_{out} = R_D$

However if $R_o < R_D$ (Current source load)

Then $R_{out} = R_o$

Input Resistance/Impedance

Take $v_o = 0$, $V_x = -V_1$



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

$$= g_m + g_{mb} + \frac{1}{r_o}$$

$$= [(g_m + g_{mb}) r_o + 1] / r_o$$

As $g_m r_o >> 1$ $\therefore$ Rin is quite low

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Current Gain $= A_i = \frac{i_o}{i_{in}} = \frac{I_x}{I_x} = 1$

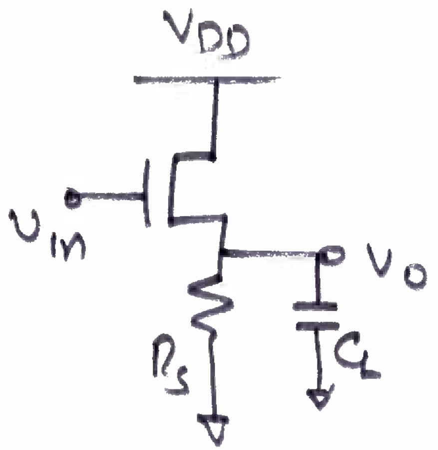
At Low Frequency $A_i = 1$ but will be function frequency through RC effect at higher frequency.

In CG Amplifier R_{in} is low but

Rout is quite high

Or to say we can convert a normal current source into great current source, which can be voltage controlled

Common Drain Amplifier (Source Follower)



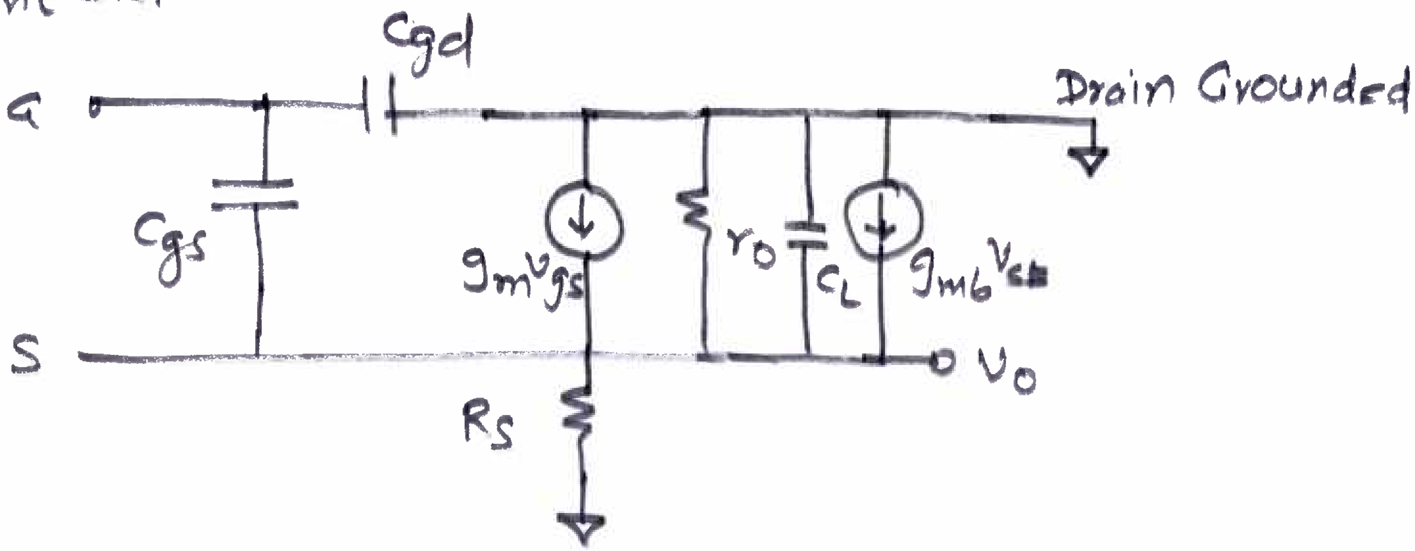
For $V_{in} > V_{TH}$

When Transistor is 'ON'

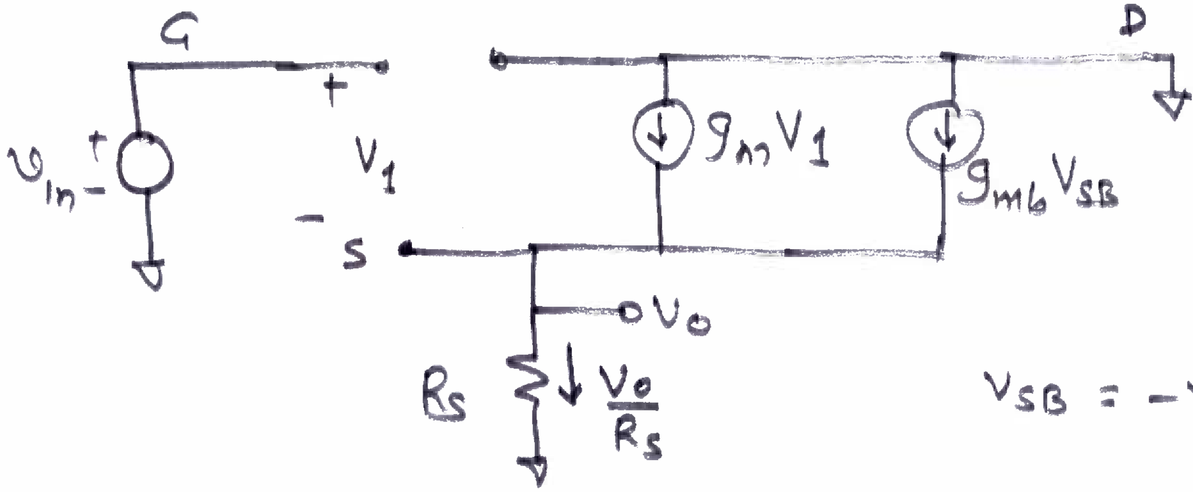
V_o follows V_{in} and hence the Circuit is called Source Follower

For ac circuit Drain is Grounded and hence the name Common Drain.

Equivalent ckt



Low Frequency Circuit is :



$V_{SB} = -V_o$

$$\frac{v_o}{R_S} = g_m V_1 + g_{mb} V_{SB} = g_m V_1 - g_{mb} v_o$$

or $$v_o \left(\frac{1}{R_S} + g_{mb} \right) = g_m V_1 \quad — (1)$$

Input Side $$v_{in} = v_o + V_1$$

or $$V_1 = -v_o + v_{in} \quad — (2)$$

Substituting ② in ①

$$v_o\left(\frac{1}{R_s}+g_{mb}\right) = -g_m v_o + g_m v_{in}$$

or $$v_o\left[\frac{1}{R_s}+g_m+g_{mb}\right] = g_m v_{in}$$

or $$v_o\left[1+(g_m+g_{mb})R_s\right] = g_m R_s \cdot v_{in}$$

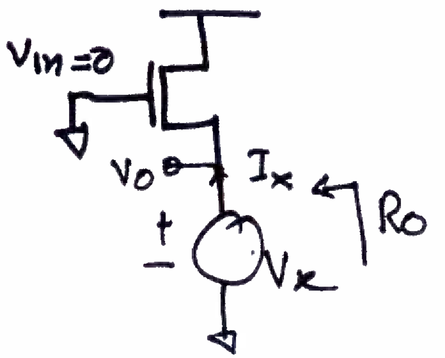
or $$A_{vo} = \frac{v_o}{v_{in}} = \frac{g_m R_s}{1+(g_m R_s+g_{mb} R_s)} \quad (< 1)$$

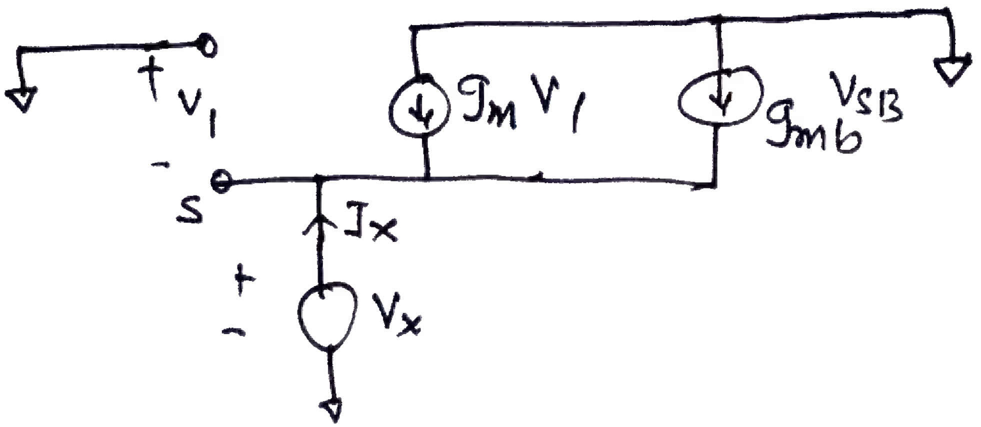
In Phase output.

Input Impedance is only due to Capacitance at the input side and hence very large as input capacitance $\simeq C_{gd} + C_{db} + C_{gs}$

Output Impedance

$$R_o = \frac{V_x}{I_x}$$





As $V_1 = -V_x$

$V_{SB} = -V_x$

$$\therefore I_x = g_m V_x + g_{mb} V_x$$

$$\therefore R_o = \frac{V_x}{I_x} = \frac{1}{g_m + g_{mb}}$$

Where one uses Source Followers

1. Buffer : High input Impedance
   Low output Impedance

Problems for Designer :

(i) V_T is now function of V_O through Body Bias.

(ii) Which leads to changes in I_{DS} & or V_{OV} with V_O

If (iii) R_S is low then effect of (ii) is even worse.

(iv) Input & Output Swings are lowered.

If $V_{DD} = 1.2V$ $V_T = 0.4V$ and $V_{ov} = 0.2V$

Then $V_h \simeq 0.4 + 0.2V = 0.6V$ which is Half of V_{DD}.

Thus for Low Power, Low Voltage application Source Follower is not good as it reduces 'Swings'

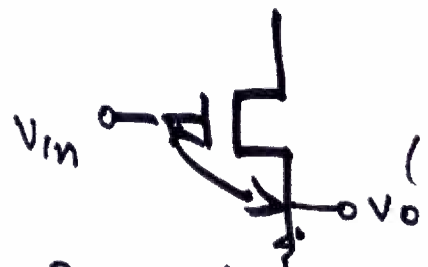
(v) Small Swing applications such as LNA and Pre-Amplifier in Signal Processing System, one uses CD Amplifier

Uses of ID Amplifiers (Cont.)

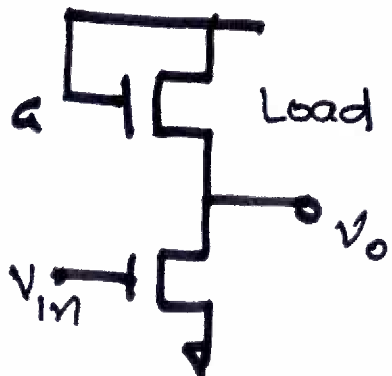
2. As Level Shifter

   Output Q-Point is lower than Input Q-Point

3. As Load devices in Common Source Amplifier



Q Point of output is $(V_{ov} + V_T)$ lower than Q point at Input



Saturated Load acts as current source