

# 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



CDEEP  
IIT Bombay

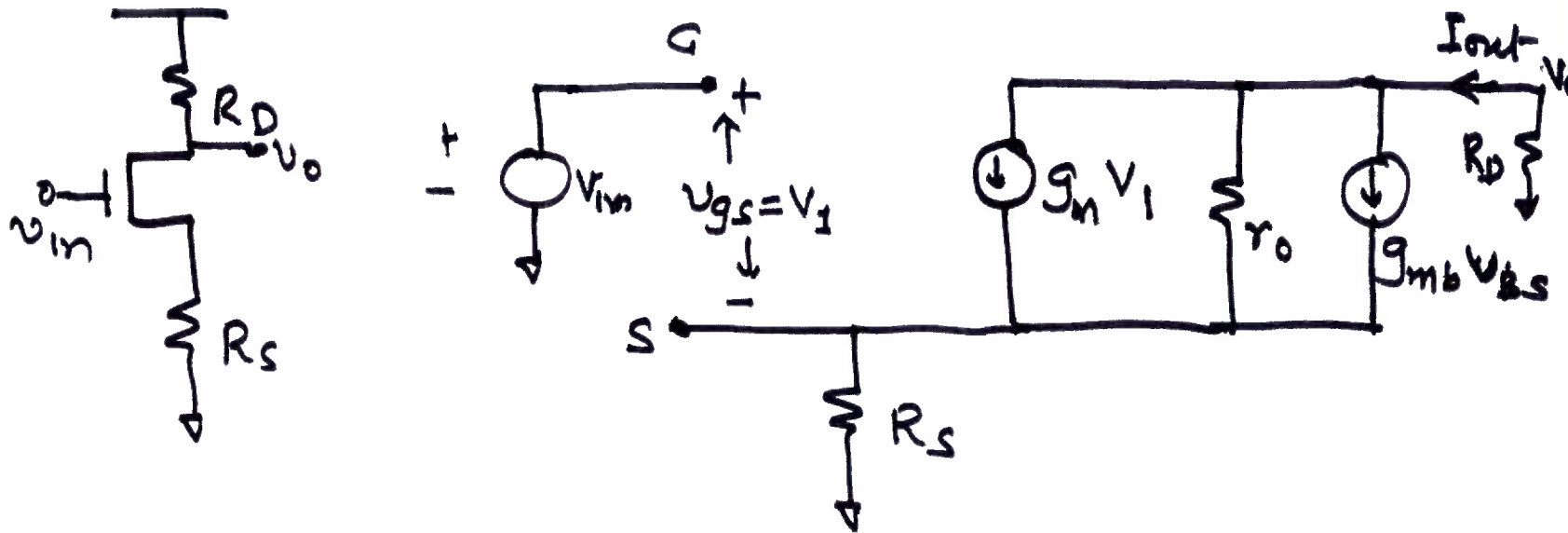
EE 618 L 9 / Slide 1



CDEEP  
IIT Bombay

EE 618 L 9 / Slide 2

# Common Source Amplifier with Source Degeneration



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

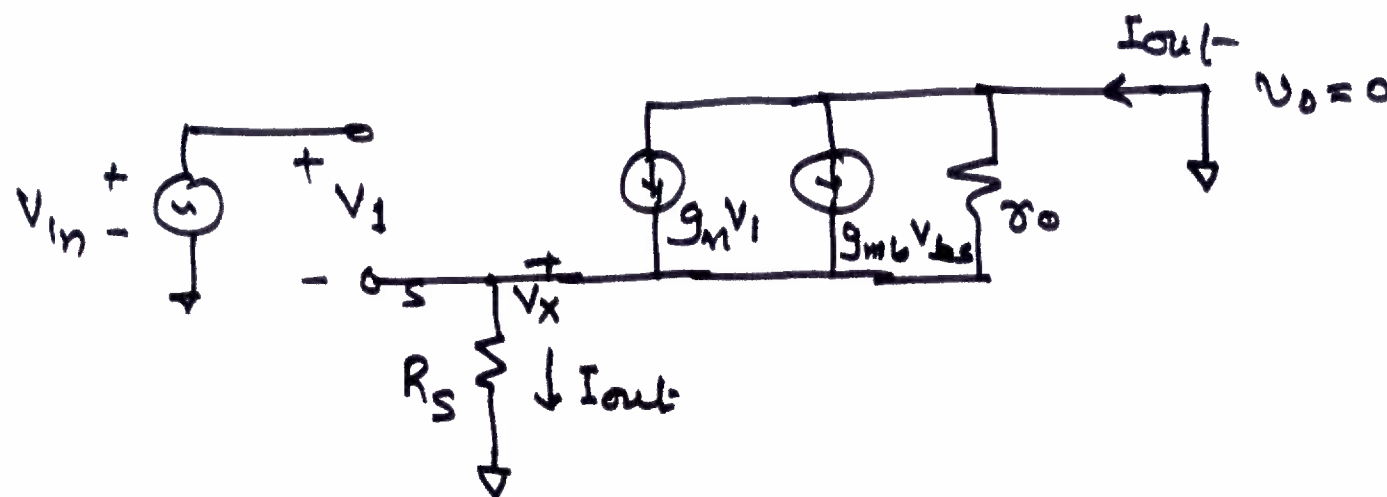
$$\text{Also } g_{m,eff} = \frac{i_{out}}{v_{in}} = \left. \frac{\partial I_{out}}{\partial v_{in}} \right|_{v_o=0}$$



CDEEP  
IIT Bombay

EE 618 L 9 / Slide 9

Then eq. ckt is



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

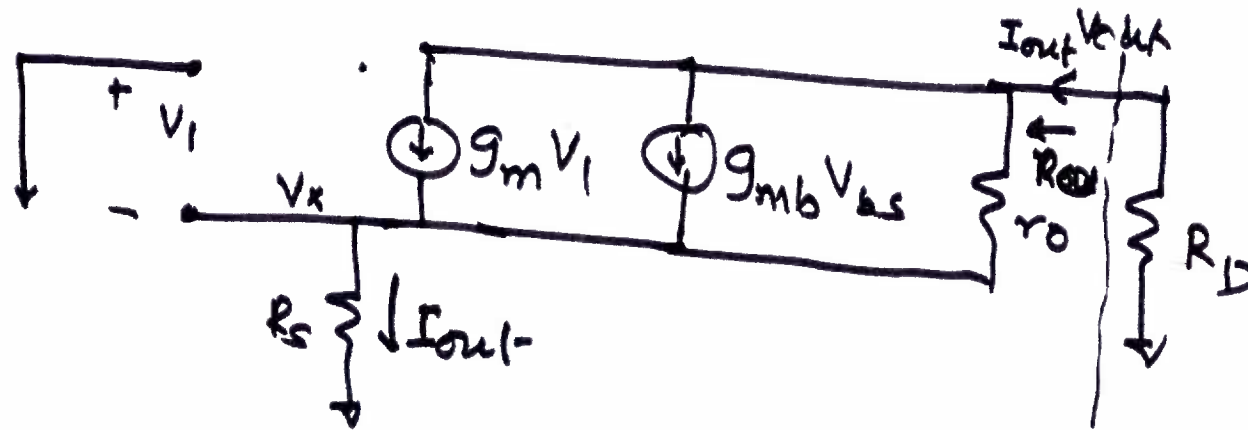
$$\therefore I_{out} = g_m (V_{in} - I_{out} R_s) + g_{mb} (-I_{out} \cdot R_s)$$

$$+ \frac{(0 - I_{out} R_s)}{r_o}$$

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

(ii)  $R_{out}$

$V_{in} = 0$  & we have  $V_{out}$ ,  $I_{out}$  at output-



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

Now

$$V_i = -I_{out} \cdot R_S$$

$$V_x = I_{out} \cdot R_S$$

$$\begin{aligned} \therefore I_{out} &= -g_m I_{out} R_S - g_{mb} I_{out} R_S \\ &\quad + \frac{V_{out} - V_x}{R_o} \end{aligned}$$



CDEEP  
IIT Bombay

EE 618 L 9 / Slide 4



CDEEP  
IIT Bombay

EE 618 L 9 / Slide 5

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

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

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

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

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

$$\therefore \text{Voltage Gain} = -g_{m_{eff}} \cdot R_{out}$$

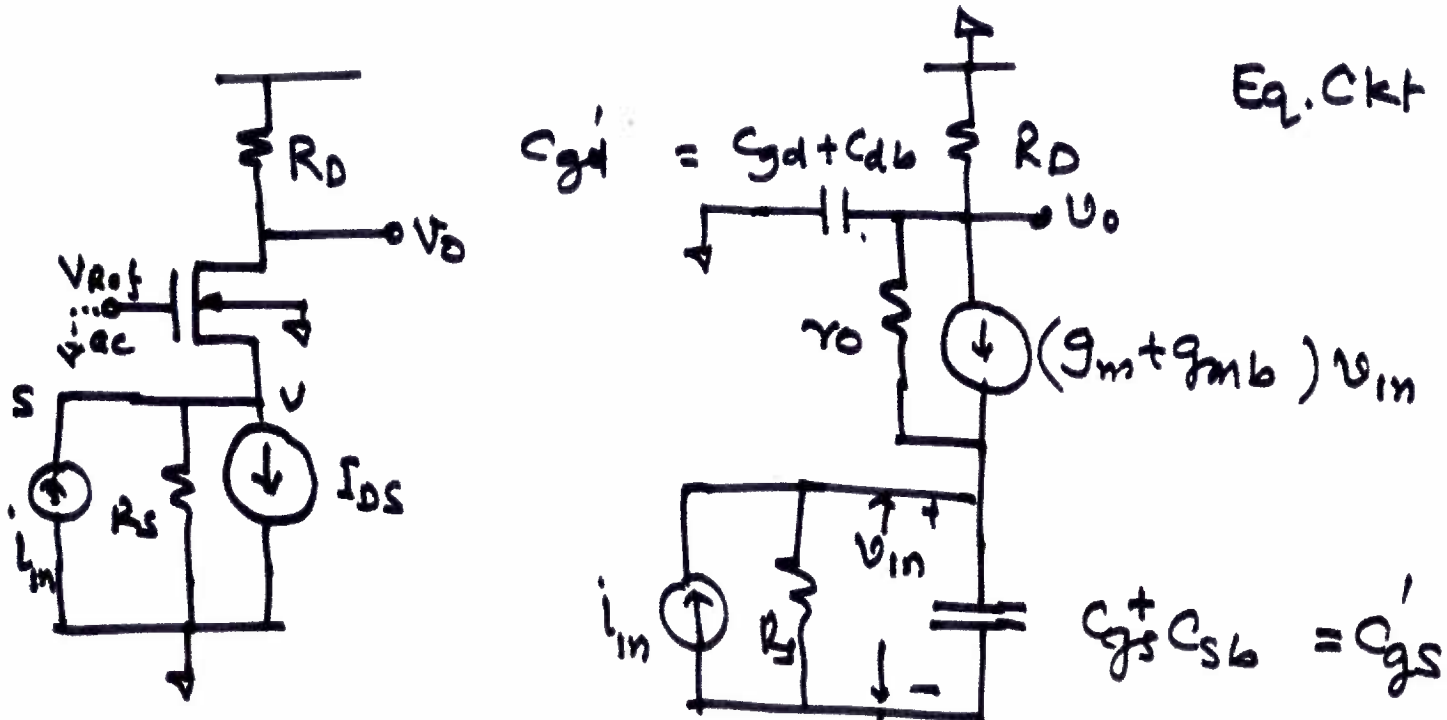
$$= -g_{m_{eff}} \cdot R_D = \frac{-g_m r_o R_D}{R_s + [1 + (g_m + g_{mb}) R_s] r_o}$$
$$\approx -\frac{R_D}{R_s}$$

# Common Gate Stage Amplifier

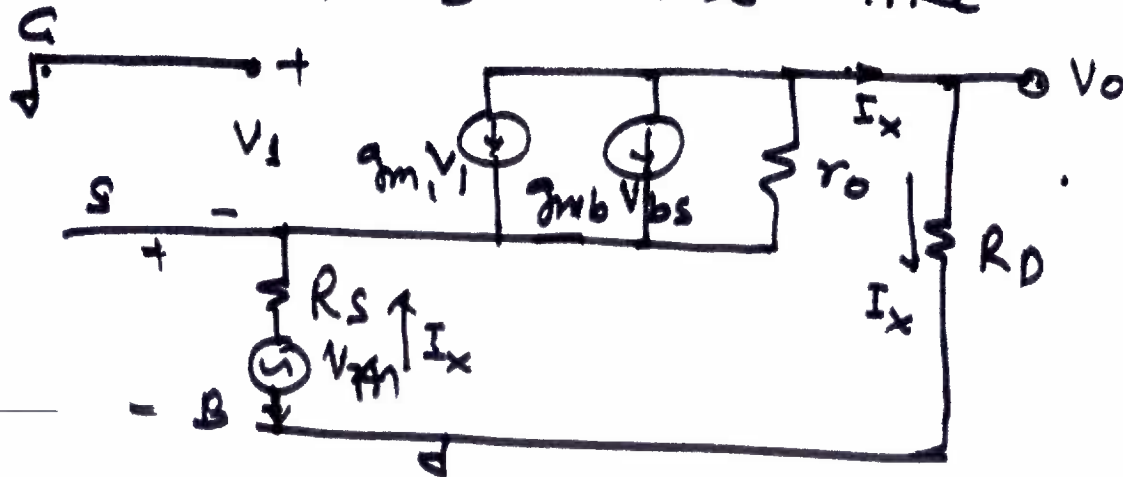


CDEEP  
IIT Bombay

EE 618 L 9 / Slide 6



At Low Frequency it can be like



$$\therefore V_{sb} = V_i$$

We have  $I_x = \frac{V_o}{R_D} \rightarrow (1)$

Further  $0 = V_{in} - I_x R_S + V_1 \rightarrow (2)$

or  $V_1 + V_{in} - \frac{V_o}{R_D} R_S = 0 \rightarrow (2)$

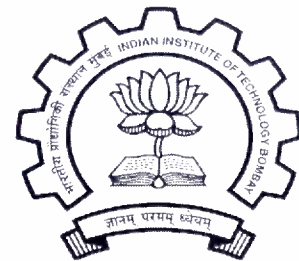
The  $V_o = i_{r_o} \cdot r_o - V_1 \rightarrow (3)$

where  $i_{r_o} = I_x - g_m V_1 - g_{mb} V_1 \rightarrow (4)$

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

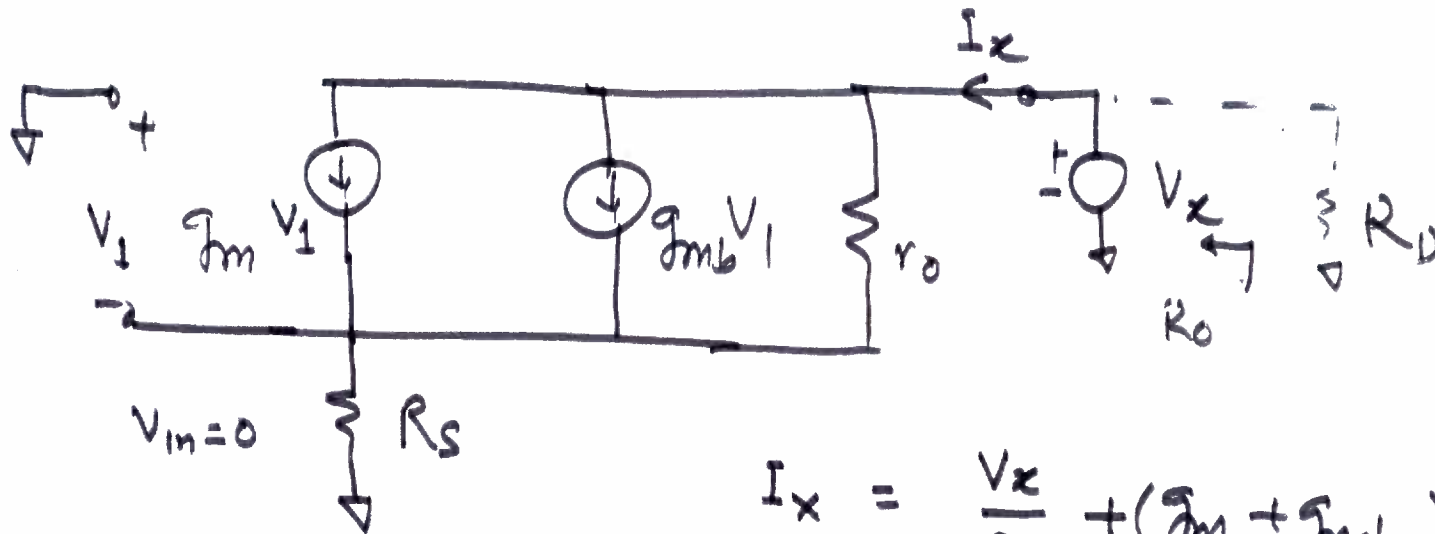
or  $V_o = r_o \left[ -\frac{V_o}{R_D} - (g_m + g_{mb}) \left( \frac{V_o R_S}{R_D} - V_{in} \right) \right] + V_{in}$

$\therefore \frac{V_o}{V_{in}} = A_{vo} = \frac{(g_m + g_{mb}) r_o + 1}{r_o + (g_m + g_{mb}) r_o R_S + R_S + R_D} \cdot R_D$



CDEEP  
IIT Bombay

# Output Impedance $R_o$



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

But  $I_x R_s = -V_1$

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

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

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



CDEEP  
IIT Bombay

EE 618 L 9 / Slide 8





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

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

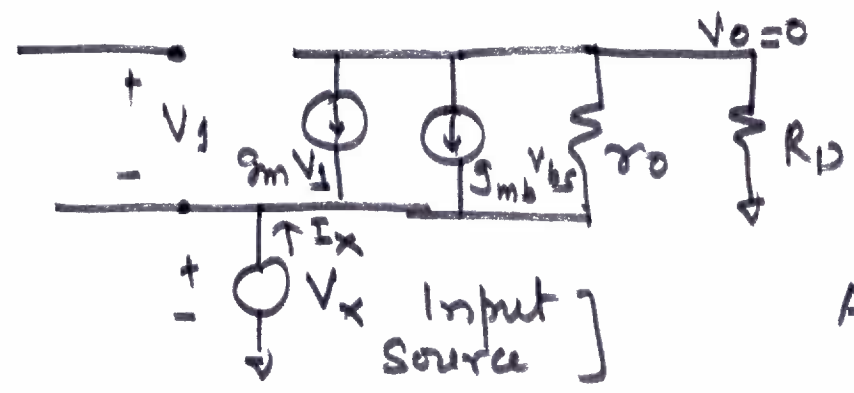
$\therefore R_o \gg R_D$  & Then  $R_{out} = R_D$

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

Then  $R_{out} = R_o$

### Input Resistance/Impedance

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



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

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

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

As  $g_m r_o \gg 1 \therefore R_{in}$  is quite low



CDEEP  
IIT Bombay

EE 618 L9 / Slide 10

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

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

In CC Amplifier  $R_{in}$  is low but  $R_{out}$  is quite high

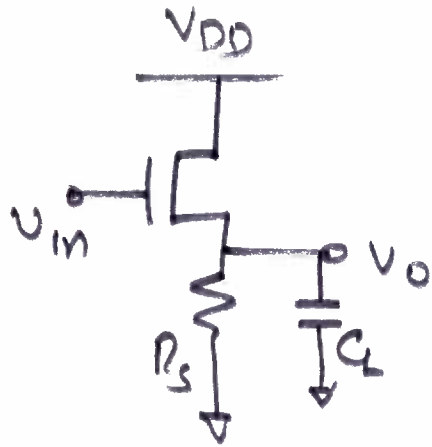
Or to say we can convert a normal current source into a great current source, which can be voltage controlled

# Common Drain Amplifier (Source Follower)



CDEEP  
IIT Bombay

EE 618 L 9 / Slide 11



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

