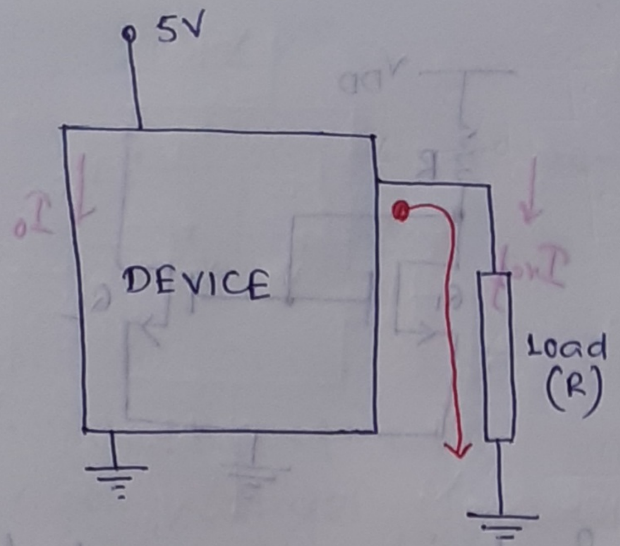
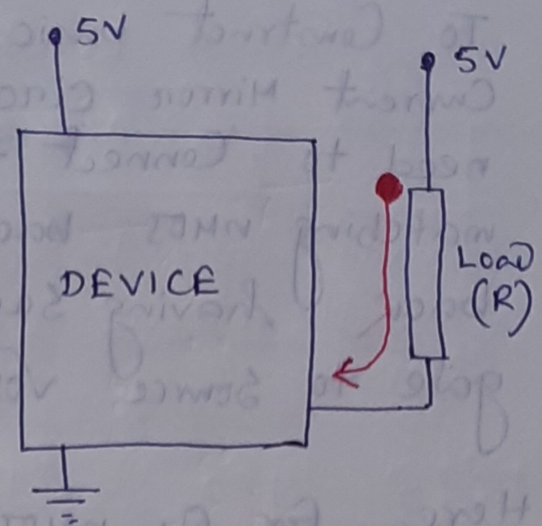
*) Current Source & Sink →



⟨Current Source⟩

[Current flow out of device]

Example :- A series resistors and LED Connected between μC pin and gnd. When μC pin become active high, the μC will source Current to the load & LED glow.



⟨Current Sink⟩

[Current flow into device]

Example :- Current flow from power supply through the load & into the device.

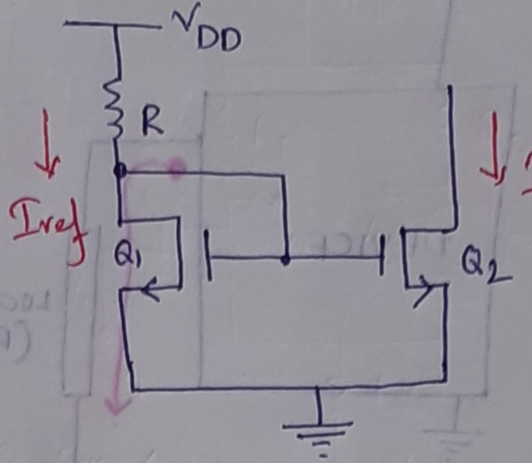
*) A Current Sink / source is a two terminal Component whose Current at any instant of time is independent of the voltage across it.

{ A simple Current source → PMOS
A simple Current sink → nMOS }

*) To act as a Current sink / source, MOS should be operated in saturation region; Because here I_{out} is Constant irrespective of V_{DS} for the given V_{gs} $[V_{DS_{min}} = V_{gs} - V_{Th}]$ to put in saturation.

*) MOSFET Current Mirror :-

To Construct basic Current Mirror circuit, need to Connect two matching nMOS back to back having same gate to source voltage.



Here, for Q_1 nMOS gate & drain are shorted. for both Q_1 and Q_2 V_{gs} are equal. $(V_{gs1} = V_{gs2})$.

We know that, Condition for saturation is,

$$V_{DS} \geq V_{gs} - V_{Th}$$

Now, for Q_1, drain & gate terminal are shorted

so, $\left\{ V_{DS} \geq V_{DS} - V_{Th} \quad \& \quad V_{gs} \geq V_{gs} - V_{Th} \right.$ both Condition fulfilled. $\left. \right\}$

It means Q_1 operated in saturation region.

Now,
$$I_0 = \frac{1}{2} K_{n_2} \cdot \left(\frac{W}{L}\right)_2 \left(V_{gs_2} - V_{Th_2}\right)^2 \quad \text{--- (i)}$$

and,
$$I_{ref} = \frac{1}{2} K_{n_1} \cdot \left(\frac{W}{L}\right)_1 \left(V_{gs1} - V_{Th_1}\right)^2 \quad \text{--- (ii)}$$

As both the transistors are identical

$$\frac{I_0}{I_{ref}} = \frac{0.5\, K_{n_2} \left(\frac{W}{L}\right)_2 \left(V_{gs_2} - V_{Th_2}\right)^2}{0.5\, K_{n_1} \left(\frac{W}{L}\right)_1 \left(V_{gs_1} - V_{Th_1}\right)^2} = \frac{\left(\frac{W}{L}\right)_2}{\left(\frac{W}{L}\right)_1}$$

[so, when $\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2$ $\longrightarrow$ act as Current mirror.]

$\boxed{I_0 = I_{ref}}$ act as Current mirror.

Applications →

i> Used as biasing element for superior ckt performance ⟨due to the variation in power supply, temperature⟩

ii> used as active load element for amplifier stages; which result high voltage gain at lower supply voltage; because of high output impedance of current mirror.

*> output impedance
$$= \frac{\text{output voltage}}{\text{output current}}$$
$$= \frac{\Delta V_0}{\Delta I_0}$$
$$= \infty$$

in saturation $\Delta I_0 \to 0$

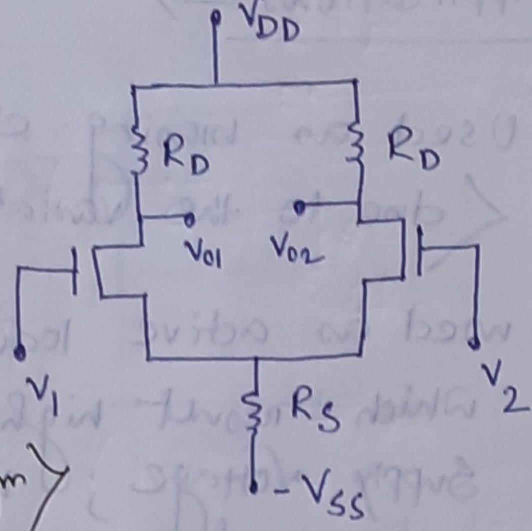
***> Small signal model vs Large signal model :-

The small signal model accounts for the behavior which is linear around an operating point.

When the signal is large in amplitude (more than Vcc/5, a rule of thumb); the behavior becomes non-linear.

*) Differential amplifier (using MOSFET) :- DIBO

Here Common Resistance → R_s.



$$\boxed{V_0 = A(V_1 - V_2)}$$

mainly used to amplify the difference of two input signals.

DC Analysis :- ⟨To determine g_m⟩

We know that,

i) $g_m = 2\sqrt{K_n \cdot I_D}$ --- ①

$I_D = K_n \cdot (V_{gs} - V_{Th})^2$

$\therefore \dfrac{\partial I_D}{\partial V_{gs}} = K_n \cdot 2(V_{gs} - V_{Th})$

$= K_n \cdot 2 \times \sqrt{\dfrac{I_D}{K_n}}$

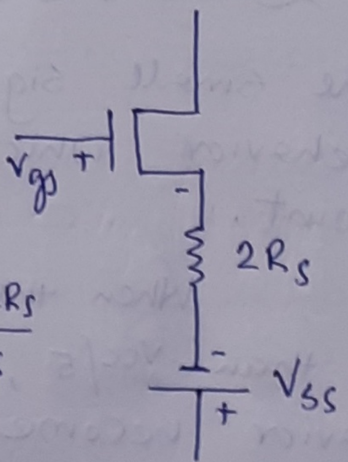
$= 2\sqrt{K_n \cdot I_D}$

ii) $I_D = K_n \cdot (V_{gs} - V_{Th})^2$ ---- ⑪

In eqn ⑪, I_D & V_{gs} are two unknown quantity.

To solve it, it required atleast two eqn having V_{gs} & I_D.

⟨need to break the ckt in two half.⟩



$2R_S \parallel 2R_S \Rightarrow \dfrac{2R_S \times 2R_S}{4R_S} \Rightarrow R_S$

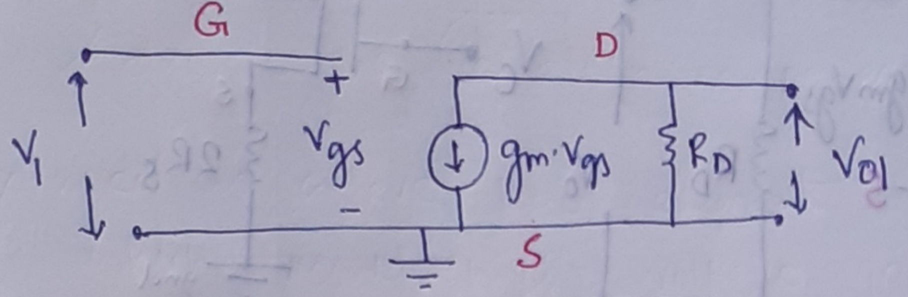
$\therefore -V_{gs} - I_D \times 2R_S + V_{SS} = 0$ -- ⑪⑪

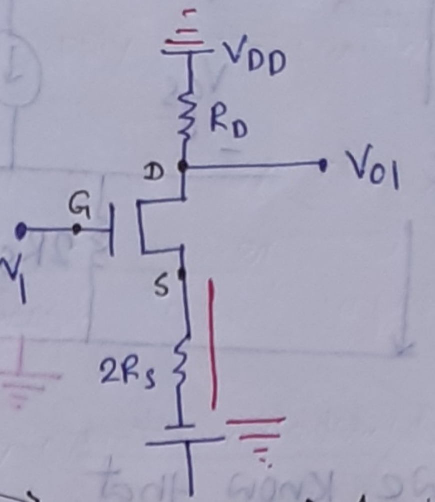
here value of V_{SS} & R_S given to the question. So using eqn ⑪ & ⑪⑪, we can evaluate the value of I_D & V_{gs}.

Then using eqn ① → easily find the value of g_m.

AC analysis ⟨To find A_d⟩

for AC analysis, all the biasing DC voltage source need to be grounded. R_S become shorted.





here, $V_{01} = (-g_m \times V_{gs}) \times R_D$

Similarly, $V_{02} = (-g_m \times V_{gs}) \times R_D$

As the current flowing in opposite direction.

~~for~~ MOSFET 1 $\longrightarrow V_{gs} = \frac{V_d}{2}$; $V_{01} = -g_m \times \frac{V_d}{2} \times R_D$

for MOSFET 2 $\longrightarrow V_{gs} = -\frac{V_d}{2}$; $V_{02} \rightarrow g_m \times \frac{V_d}{2} \times R_D$

non-inverting terminal voltage

$\therefore V_0 = V_{02} - V_{01} = \frac{V_d}{\cancel{2}} \times g_m \times \cancel{2} R_D = V_d \times g_m \times R_D$

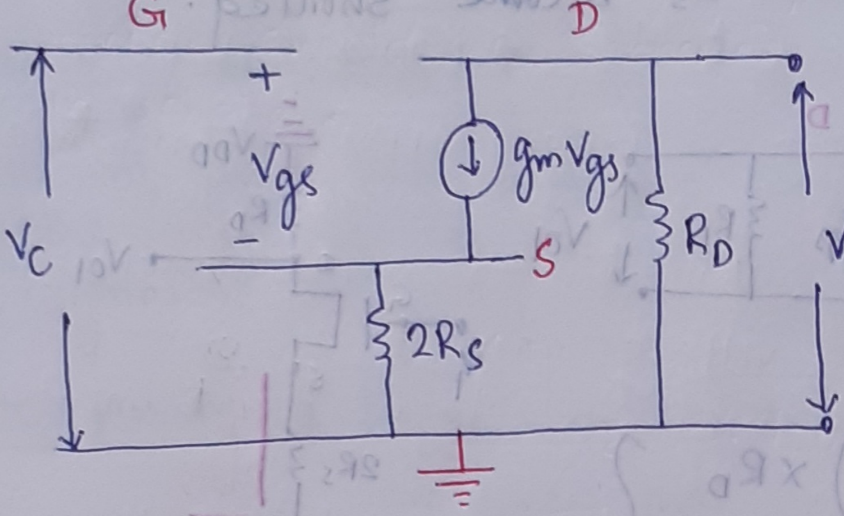
$\therefore \boxed{A_d = \frac{V_0}{V_d} = g_m \times R_D}$ {differential mode gain}

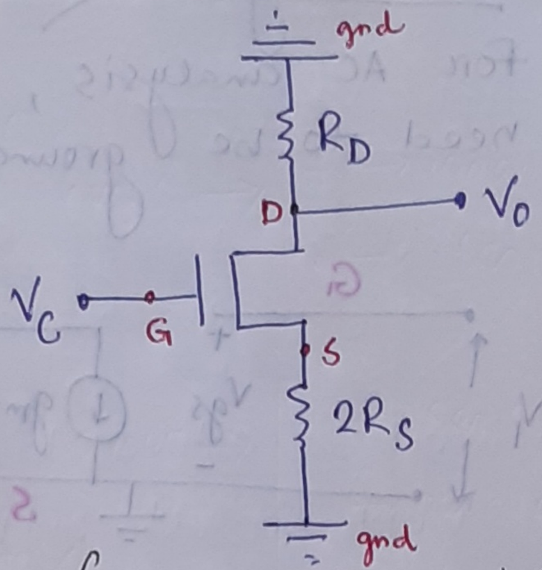
N.B ⇒ A_d = Differential mode gain.

Here, the amount of current flowing through the drain terminal (I_{DS}) = $g_m V_{gs}$

$$g_m \cdot V_{gs} = \frac{I_{DS}}{V_{gs}} \cdot V_{gs} = I_{DS}$$

Find Common mode gain (A_c) :-





{ Here, we are using mid-frequency model, where R_S should present in the ckt. }

we know that, $A_C = \dfrac{V_o}{V_C}$

here, $V_o = (-g_m \times V_{gs}) \times R_D$

we know that, $\boxed{V_{gs} = V_g - V_s}$ { here $V_g = V_C$ }

and, $V_s = (g_m \times V_{gs}) \times 2R_S$

$\therefore V_{gs} = V_C - (g_m \times V_{gs}) \times 2R_S$

$\Rightarrow V_C = V_{gs} + (g_m \times V_{gs}) \times 2R_S = V_{gs}(1 + g_m \times 2R_S)$

$$\therefore A_C = \frac{V_o}{V_C} = \frac{-g_m \times V_{gs} \times R_D}{V_{gs}(1 + g_m \times 2R_S)}$$

$$\therefore CMRR = \left|\frac{A_d}{A_c}\right| = \left|\frac{g_m \times R_D}{\dfrac{g_m \times R_D}{1 + g_m \times 2R_S}}\right| = 1 + g_m \times 2R_S$$

Ans