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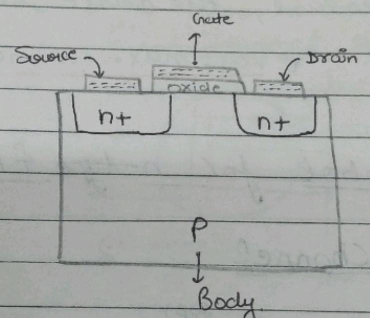
Unit-3

MOSFET Circuits

★ **MOSFET** → Metal oxide Silicon field Effect Transistor
↓
Semiconductor

- It is an electronic device used to switch or amplify voltage in circuit.
- It is voltage control device and is constructed by three terminals. There are 3 types of terminals →

(I) Source (I/P)
(II) Gate
(III) Drain (O/P)



(Fig →)

Working Principle of MOSFET →

When voltage is applied to the gate.
An electric field is generated that changes the width of the channel region.
where the e^- flow wider the channel region,
The bettery conductivily of a device will be form

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☞ **Types of MOSFET** →
It is of 2 types
- (1) Enhancement mode
  - (i) n-channel
  - (ii) p-channel
- (2) Depletion mode
  - (i) n-channel
  - (ii) p-channel

(1) **Enhancement mode** →
When there is no voltage across the gate terminal, then Device does not conduct.

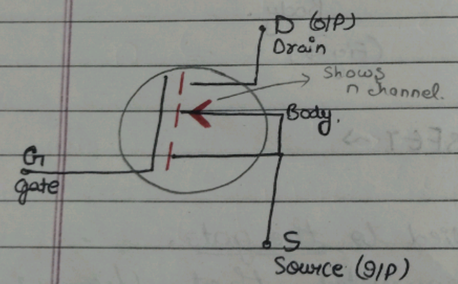
{ $V_{GS} = 0$, Does not conduct. }

When there is max. voltage across the gate terminal, the device shows Enhanced conduction.

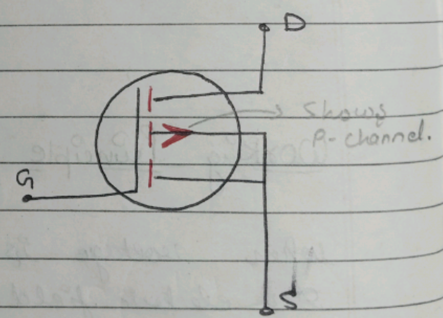
{ $V_{GS} = max$, Enhanced conduction }

Symbol for ~~n-type~~ & P- channel. →

(i) • **n- Channel** (Inward)



(ii) • **P- Channel** (outward)



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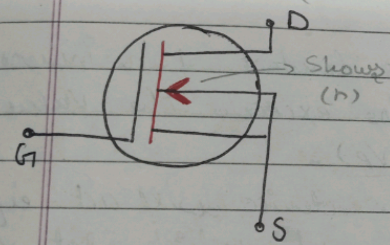
(2) Depletion-Mode →
When there is no voltage across the gate terminal, then channel shows max. conductance.
{ $V_{GS} = 0$, max conductance }

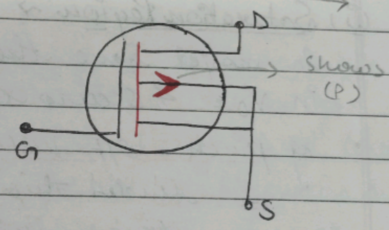
When there the voltage across the gate terminal is either +ve or -ve, then channel shows conductance decreases.
{ V_{GS} = + or -, decrease conductance }

Symbol for n & P Channel →

(i) n Channel (Inward ←)



(ii) P Channel (outward →)



☆ Terminals of MOSFET →

(1) Source → The maj of carriers req. for the device, enters through this terminal. (S)
- I_S → Source current.

(2) Drain → The maj. of carriers in the channel leaves through the ~~channel~~ terminal. (D)
- I_D → Drain current.

(3) Gate (G) → It always controls the conductivity of the channel,
Hence, The flow of current in O/P is controlled with the help of voltage level across the Gate terminal.

✻ Operating regions of MOSFET →

(i) Ohmic Region (voltage ↑↓, current ↑↓)

current (I_{DS}) ↑ with an ↑ on the Value of (V_{DS}) voltage.

(ii) Saturation Region →
In mosfet have their I_{DS} Constant of an increase in V_{DS} & occurs once V_{DS} exceeds the value of pinch off voltage (V_P).
Under this cond. device will act as closed switch through which sat. value of I_{DS} flows.

(iii) Cut off Region →
In this region Mosfet behaves like open switch
In this no conduction take place.

✻ Application of MOSFET →

- It behaves as a passive circuit element.
- Used in design of chopper circuit.
- Radio freq. app. use Mosfet amplifiers extensively.
- Power Mosfet used to regulate DC motors.

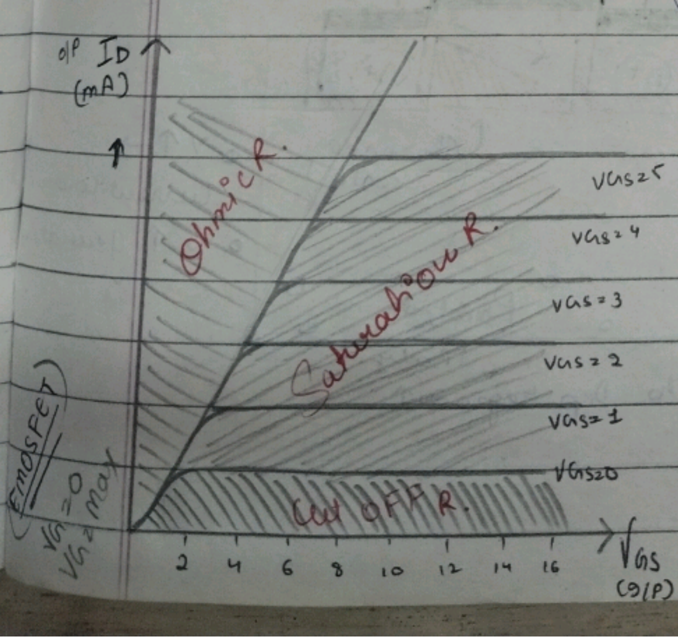
- Advantage & Disadvantage of Mosfet →

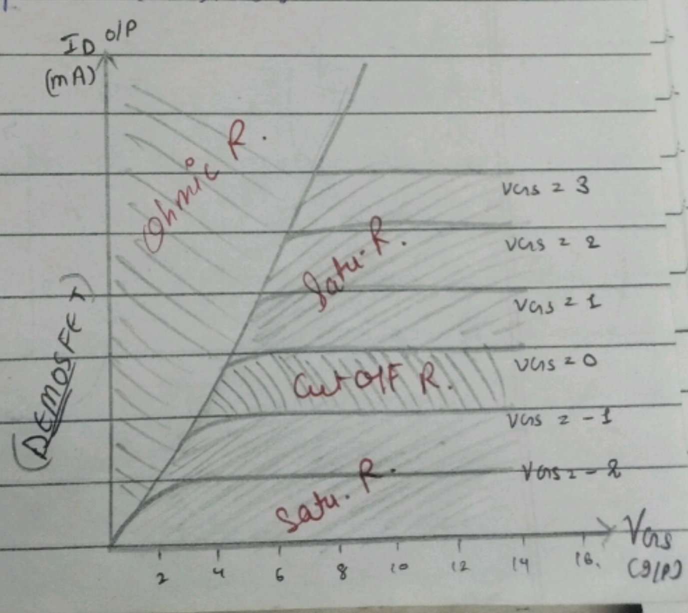
• Advantage	Disadvantages
(i) It has very high switching speed.	(i) Due to thin oxide layer Mosfet are vulnerable to damage by electrostatic charges.
(ii) Absence of gate current result in high input impedence producing high switch speed.	(ii) Overload voltage makes mosfet unstable..

I-V Characteristics of MOSFET →

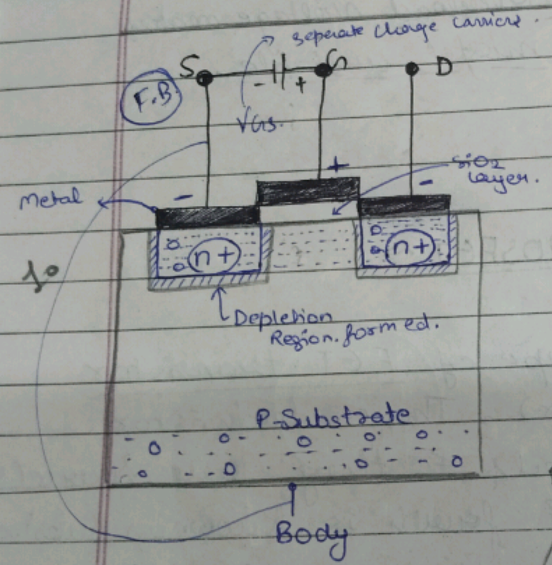
MOSFET is one of the type of FET transistor (field effect transistor). These transistor have three terminals & they are Source(S), Gate(G), Drain(D). & fourth is known as Substrate. These transistor are classified into two →

(i) Depletion type Transistor
(ii) Enhancement type Transistor.





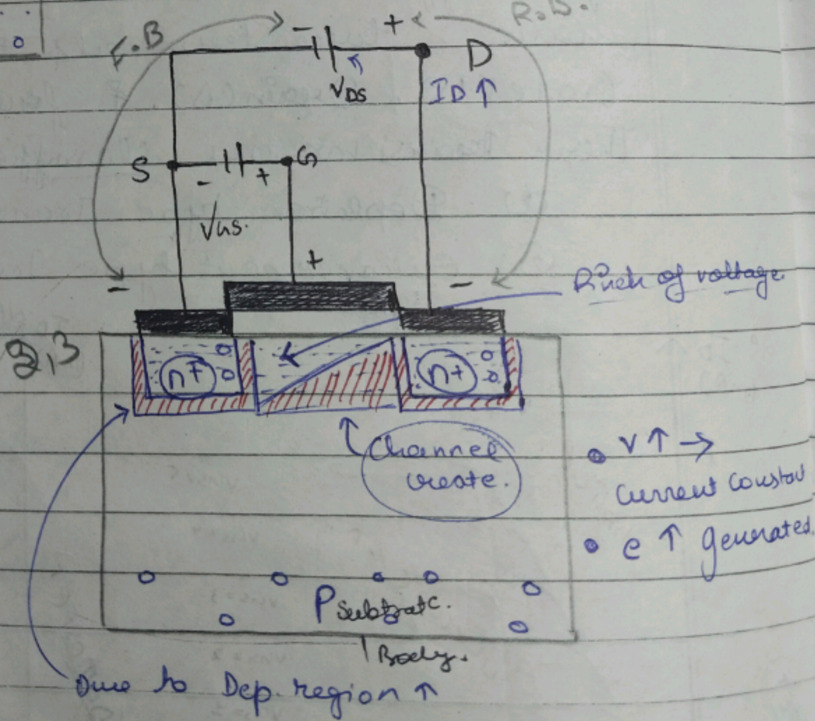
MOSFET	BJT
(i) There are 2 type of MOSFET. (i) Enhancement (ii) Depletion	(i) BJT is of 2 two types (i) PNP (ii) NPN
(ii) It is volt. control device.	(ii) BJT is current control device.
(iii) The I/P resistance is high ↑	(iii) I/P resistance is low &
(iv) used in high current applications.	(iv) used in low current application.



I↑

- Current flows in F.B.
- Electric field is generated.

(E-type)



- V ↑ → current constant
- e ↑ generated.

Continue below MOSFET

Trans. → (i) switching - ON or OFF
(ii) amplifying.

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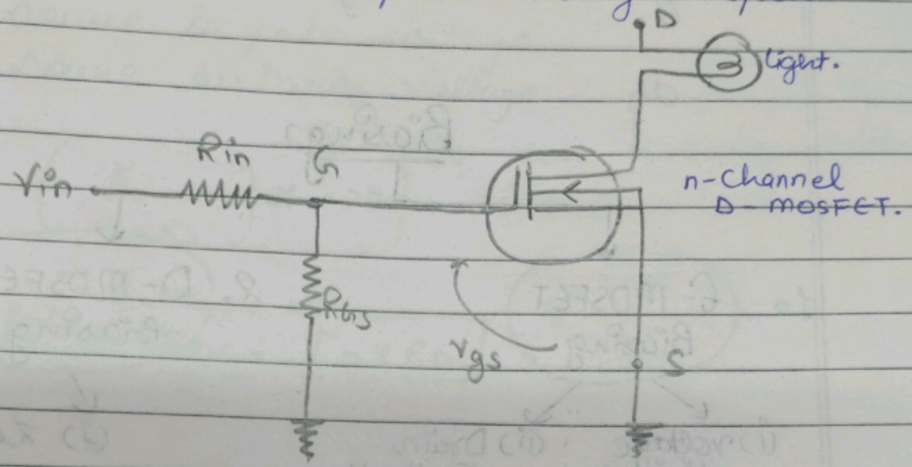
☆ MOSFET As a Switch →

- The MOSFET can be used as a switch in a wide variety of electronic application. The transistor switch provide high speed and.



- This is the simple circuit where n-Channel d-MOSFET will turn ON & OFF a light.
- Assume the device is initially OFF, then V across gate & Source (Vgs) made app. +Ve value at the gate. MOSFET transistors enters in region & the switch is ON this makes light turn ON.
- If the gate voltage (VG) is zero. the MOSFET enters cut off region. & turns the light OFF.

★ Biasing Circuit of MOSFET →

Biasing is the process of creating a circuit to establish the desired output in terms of voltage & current for an amplifier to operate.

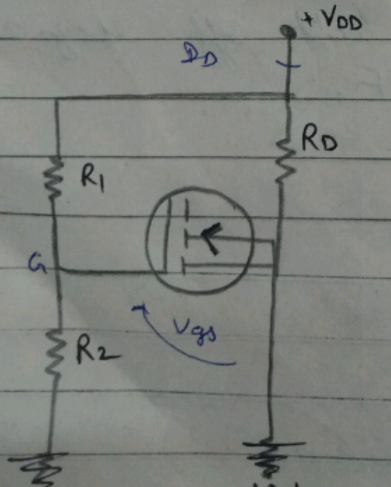
Biasing

1. E-MOSFET Biasing
   - (i) voltage divider bias
   - (ii) Drain Feedback bias
2. D-MOSFET Biasing
   - (i) Zero Biasing.

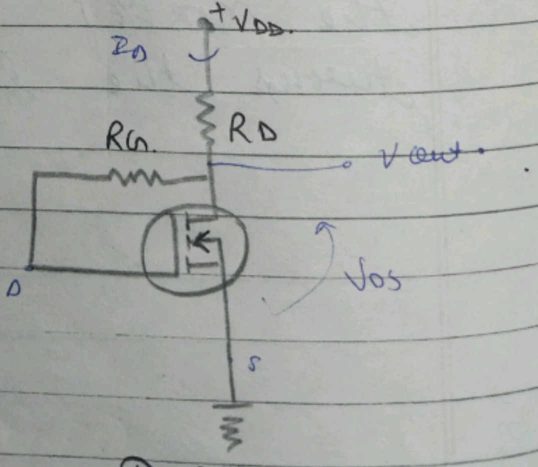
1. EMOSFET Biasing → (Configuration)

- For E-MOSFET the value of V_{GS} should be larger than the $V_{GS(Th)}$, threshold value. So, zero bias can't used.

- In this n-Channel MOSFET is used.



(a) voltage divider.



(b) Drain feedback

It used two Resistance R_1 & R_2 to establish gate voltage and other components of circuit are →

R_D = Drain resistance (O/P)

I_D = Drain current.

V_{GS} = Source to gate voltage.

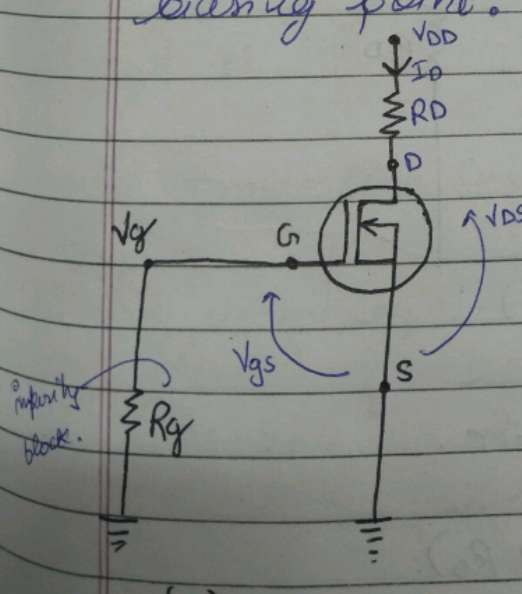
V_{DS} = Source to Drain voltage.

$$\boxed{V_{GS} = \left(\frac{R_2}{R_1+R_2}\right) \times V_{DD}}$$ Eqn for Voltage divider bias.

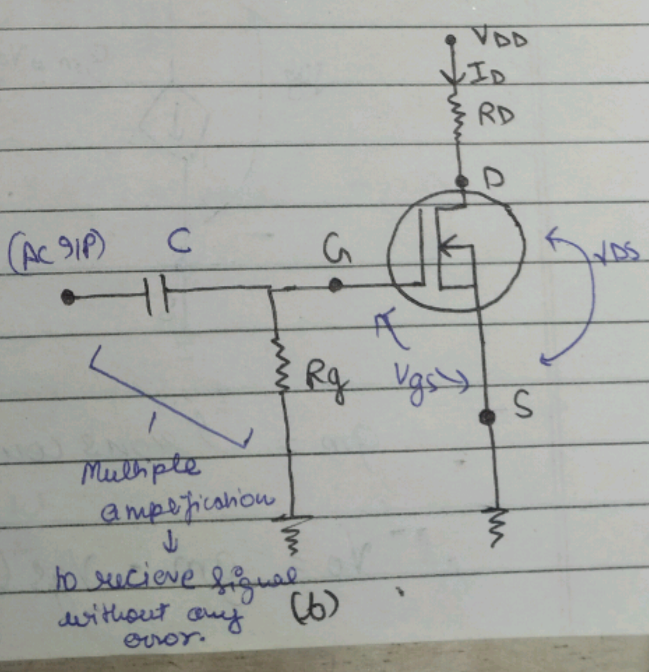
Overall Voltage $\boxed{V_{DS} = V_{DD} - I_D \times R_D}$

2. D-MOSFET Biasing → (Configuration)

D-MOSFET can operate with both positive & negative values of V_{GS} voltage.
The basic method of biasing is to make $V_{GS} = 0$ so dc voltage at gate terminal changes the gate to source voltage over this zero voltage biasing point.



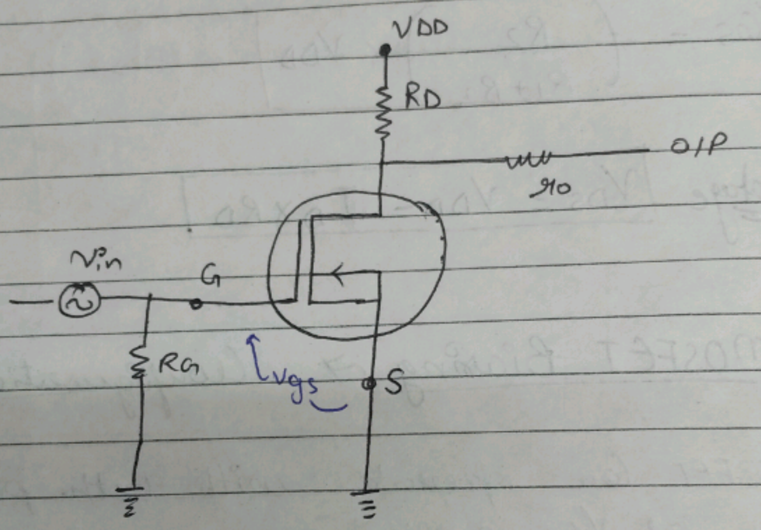
(a)



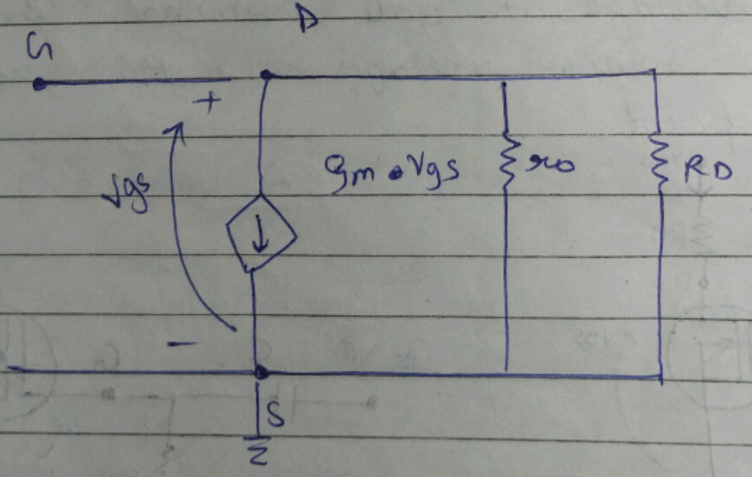
(b)

The main f^n of R_G is to sustain AC voltage input by separating it from ground as shown in fig. As there is no DC gate current, their will be no effect of R_G on zero gate to source bias.

* Small signal Model of MOSFET →



Small signal equivalent Circuit →



g_m = transconductance.

$V_0 = g_m \cdot V_{gs} (r_o \,||\, R_D)$.

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1. Perform the DC analysis of ckt & check whether the MOSFET is biased in the saturation region.
2. Replace the MOSFET by its small signal equ. symbol
3. Analyse the small signal equ. ckt, making DC source components equal to zero.

Transconductance (g_m)

$$g_m = \frac{\text{Change in } I_{out}}{\text{Change in } V_{inp.}}$$

$$g_m = \frac{\Delta I_D}{\Delta V_{gs}}.$$

- Derivation -

mobility. width of transistor source to gate voltage Threshold voltage.

$$\boxed{I_D = \frac{1}{2} \mu n . C_{ox} . \frac{W}{L} . (V_{gs} - V_t)^2} \quad — (1)$$

coff. value of x length of transistor

Diffⁿ eqⁿ (1), →

$$\frac{\partial I_D}{\partial V_{gs}} = \frac{1}{2} \mu n . C_{ox} . \frac{W}{L} . 2 (V_{gs} - V_t).$$

$$g_m = \mu n . C_{ox} . \frac{W}{L} . (V_{gs} - V_t) \quad — (2)$$

By using eqⁿ - (1)

$$(V_{gs} - V_t)^2 = \frac{2 I_D}{\mu n . C_{ox} . \frac{W}{L}}$$

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$$V_{gs} - V_t = \sqrt{\frac{2I_D}{\mu_n \cdot C_{ox} \cdot W/L}}$$

Put above in eq^n (2),

$$g_m = \mu_n \cdot C_{ox} \cdot \frac{W}{L} \left(\sqrt{\frac{2I_D}{\mu_n \cdot C_{ox} \cdot W/L}} \right)$$

S.B.S.

$$g_m^2 = \mu_n^2 \cdot C_{ox}^2 \cdot \left(\frac{W}{L}\right)^2 \cdot \left(\frac{2I_D}{\mu_n \cdot C_{ox} \cdot W/L} \right)$$

using 1st eq^n split the square value.

$$I_D = \frac{1}{2} \mu_n \cdot C_{ox} \cdot \frac{W}{L} (V_{gs} - V_t)(V_{gs} - V_t).$$

$$I_D = \frac{1}{2} g_m (V_{gs} - V_t)$$

$$g_m = \frac{2 I_D}{(V_{gs} - V_t)}$$

If $V_t = 0$ then

$$\boxed{g_m = \frac{2 I_D}{V_{gs}}}$$

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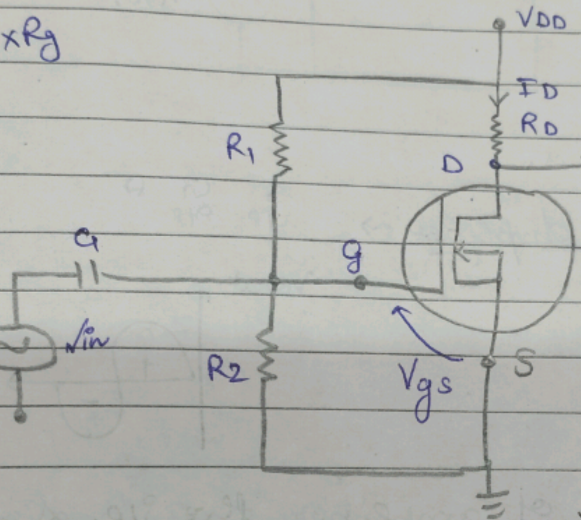
MOSFET as an amplifier →

(1) Common Source Amplifier -

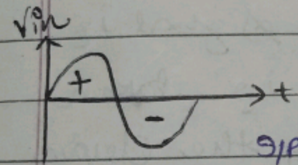
S com, G i/p, D o/p

The i/p signal is applied at the gate terminal. while the o/p signal is sampled at the drain terminal then the source itself is grounded that means the source is common.

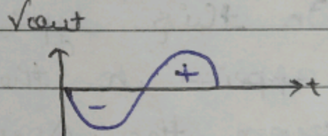
$V_g = I_g \times R_g$



$V_{gs} = V_g - V_s$



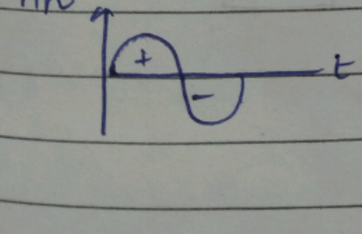
i/p waveform

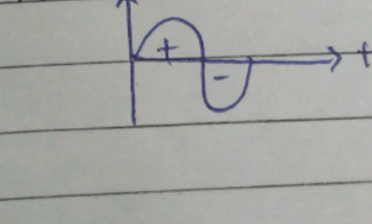


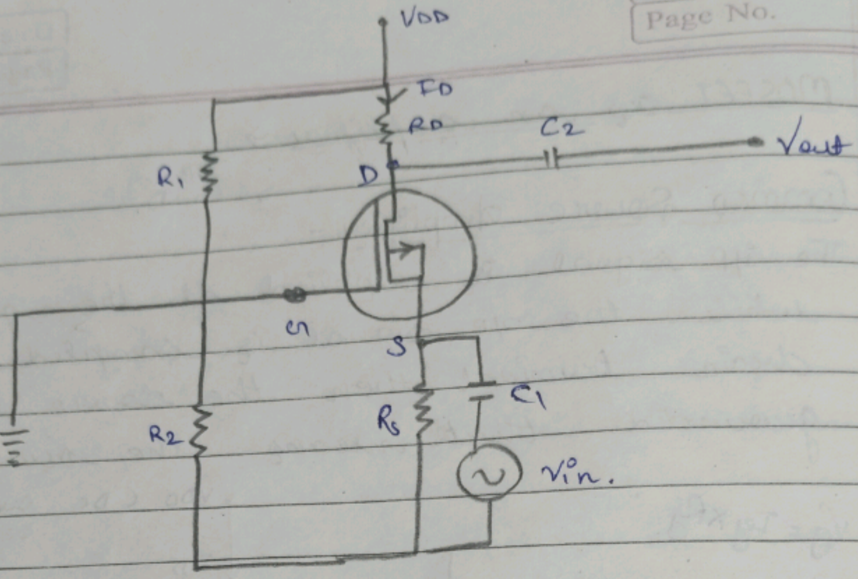
o/p waveform.
180° Phase shift)
(because of C source Term)

(2) Common Gate Amplifier.

ground.



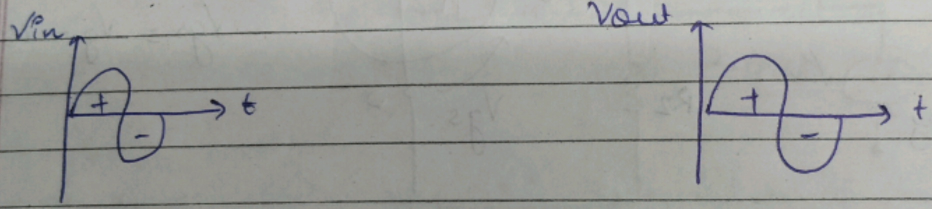




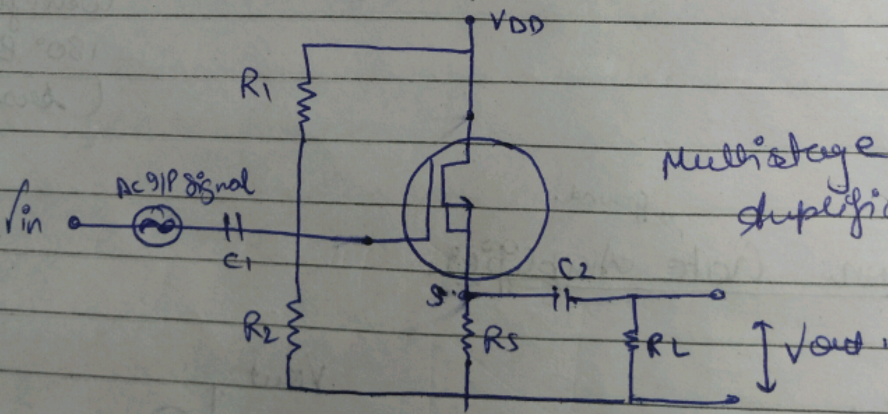
ground.

③ Common Drain Amplifier ~>

S G D
o/p. i/p



In this type of amplifier the i/p signal is applied to the gate and output is taken from the source terminal. making the drain terminal common or grounded.



Multistage duplification.

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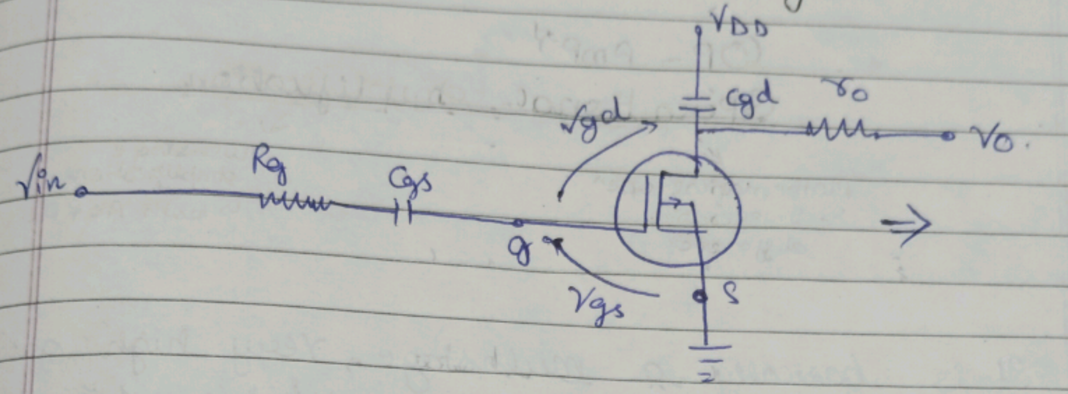
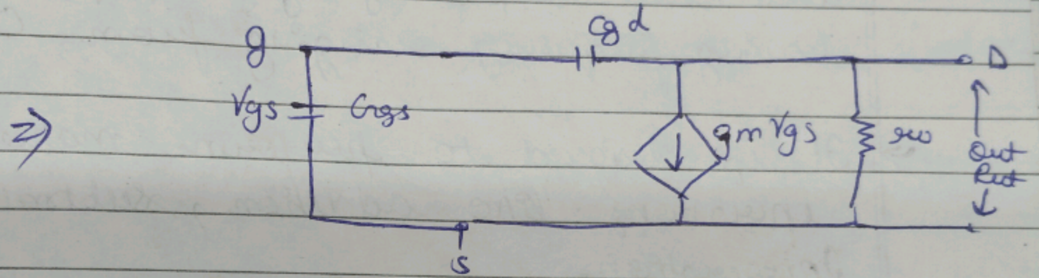
* High frequency Equivalent circuit of MOSFET →





Simplified high frequency equivalent circuit.