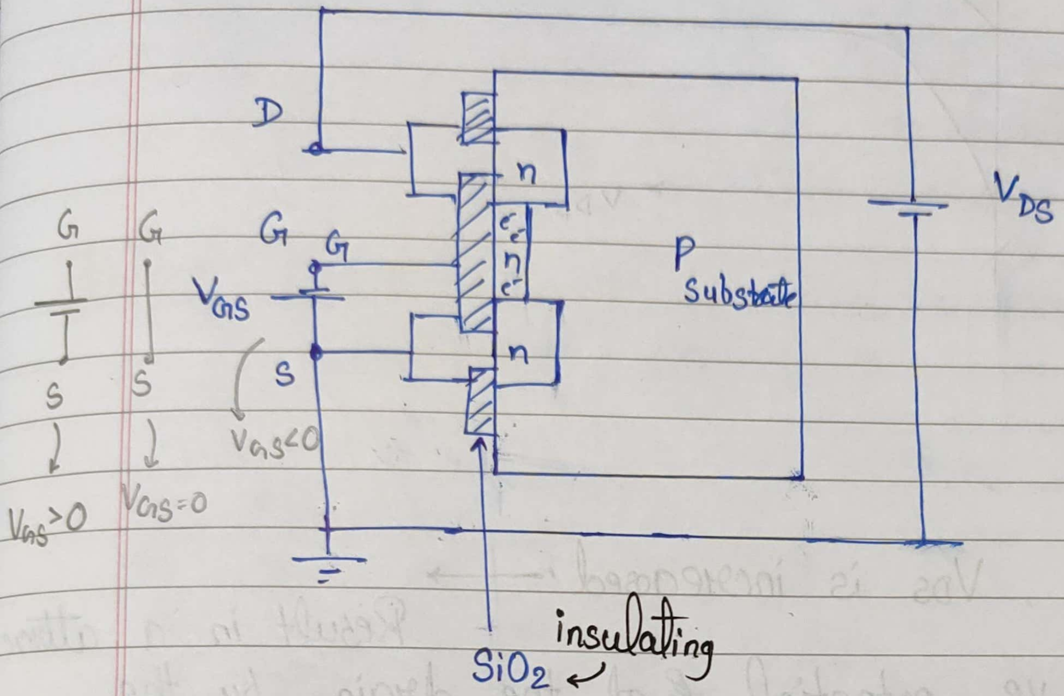
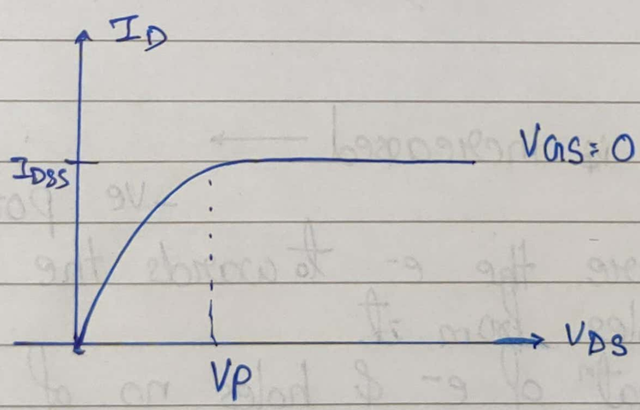
Depletion Type MOSFET ⇒

↳ Metal oxide semiconductor Field effect transistor

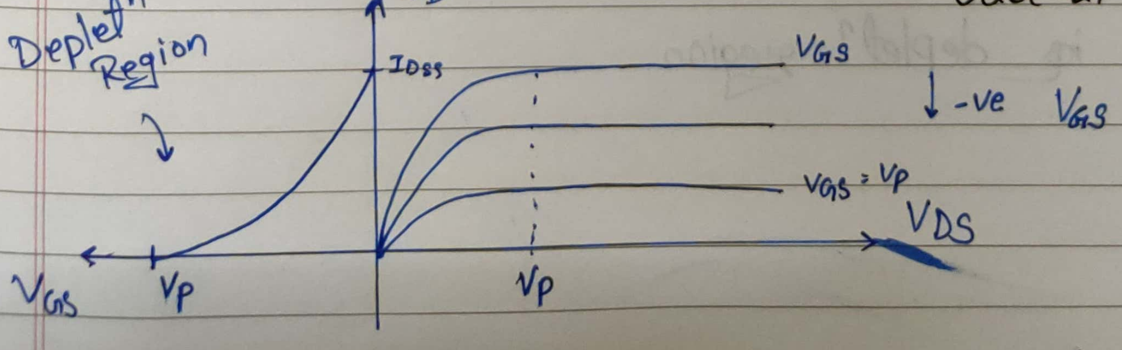


(i) $V_{GS} = 0\,v$
(ii) $V_{GS} < 0\,v$
(iii) $V_{GS} > 0\,v$

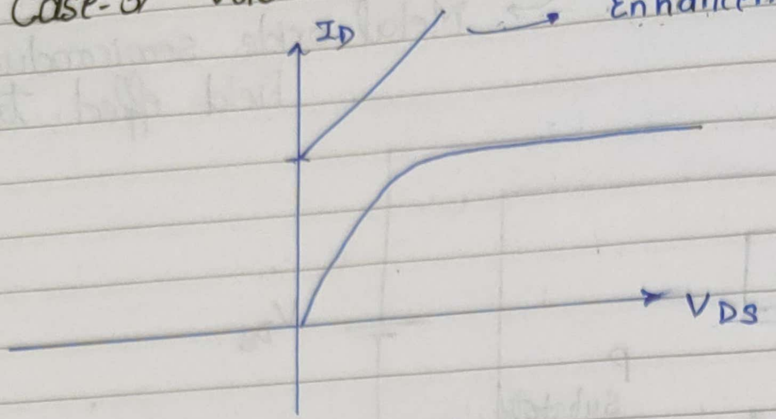
Case-1) $V_{GS} = 0\,v$



Case-2) $V_{GS} < 0\,v$



Case-3) $V_{GS} > 0V$ → Enhancement → I_D inc. rapidly



i) $V_{GS} = 0V$, V_{DS} is increased →

Result in a attract for a +ve potential at the drain by the free electrons of n-channel and current flows similar to J-FET

ii) $V_{GS} < 0V$, V_{DS} is increased →

-ve potential at gate will pressure the e⁻ towards the substrate & attract holes from it.

Due to recombinatⁿ of e⁻ & holes no. of free carriers will reduce so I_D is reduced.

This is depletⁿ region.

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iii) $V_{GS} > 0v$, V_{DS} inc. ⟶ This is the Enhancement region of depletion type MOSFET.
- The +ve potential will attract e^- and establise new carriers due to accelerating particle. So the current increases rapidly.

↳ Shockley's eqn is Valid in both Depletⁿ & Enhancement region.

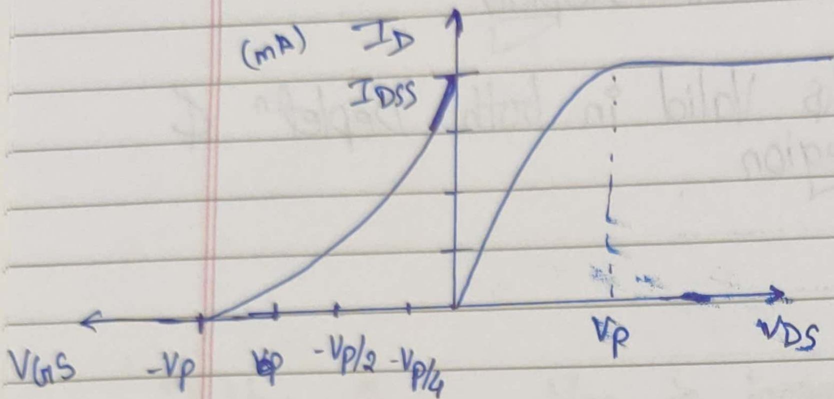
i) $I_D = I_S$
ii) $I_G = 0$
iii) $V_{DS} = V_P \Rightarrow I_D = I_{DSS}$
iv) $V_{GS} = V_P \Rightarrow I_D = 0$
v)

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

Que. 1) Sketch the transfer Curve for n-channel depletion type MOSFET having $I_{DSS} = 12mA$
$V_P = -6V$.

$\Rightarrow$ $\boxed{V_{GS} = V_P}$ Depletion

$$I_D = I_{DSS}\left(1 - \frac{V_G}{V_P}\right)^2$$



i) $V_{GS} = V_P$
$I_D = 0$

$V_{DS} = V_P$
$I_D = 12mA$

ii) $V_{GS} = V_P/2$
$I_D = 3\,mA$

iii) $V_{GS} = V_P/4$
$I_D = \cancel{9\,mA}\ \frac{27}{4}\ mA$

(A) Enhancement $\longrightarrow$

$V_{GS} = \frac{-V_P}{2} = +3V$

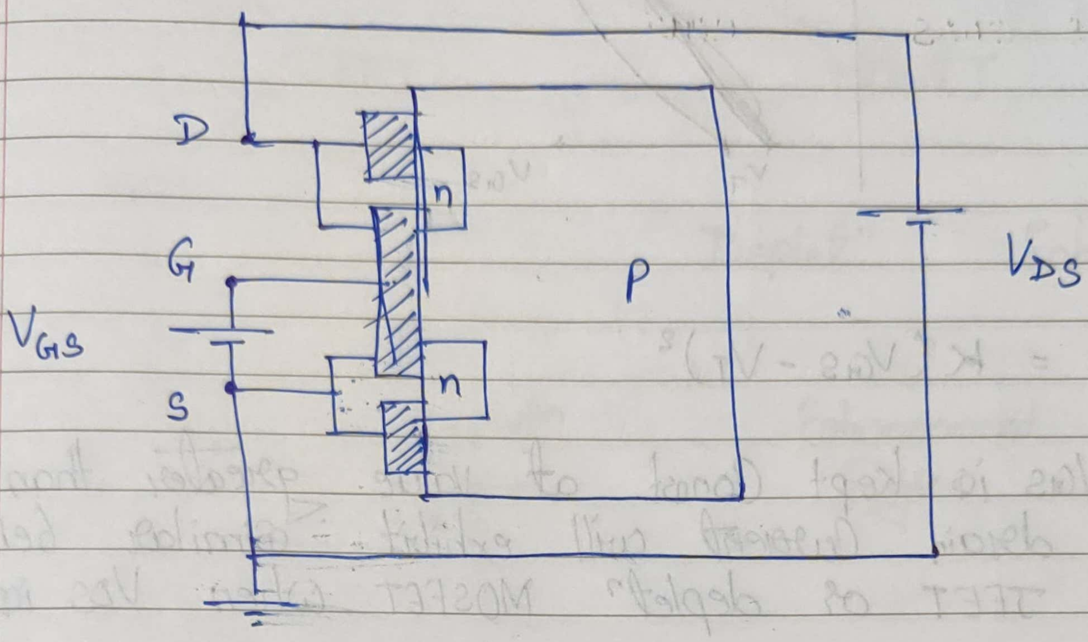
i) $V_{GS} = V_P$

$$I_D = I_{DSS}\left(1 - \frac{V_G}{V_P}\right)^2$$

Shockley's Eqn is not valid

There is only Enhancement Region & No Depletn Region.

Enhancement Type MOSFET →



Case-1) $V_{GS} = 0$ v, V_{DS} is increased → • Absence of n-channel makes $I_D = 0$.

Case-2) $V_{GS} > 0$ v, V_{DS} is inc. → • It will attract e⁻ from substrate. ~~but~~

- Both Gate & drain are +ve w.r.t. source, +ve potential of Gate will repel holes & attract e⁻. When V_{GS} reaches V_T (Threshold Voltage). Then Current is established in FET
- Channel is enhanced by +ve Gate to source.
- Once V_{GS} inc. beyond V_T, Current I_D will inc.

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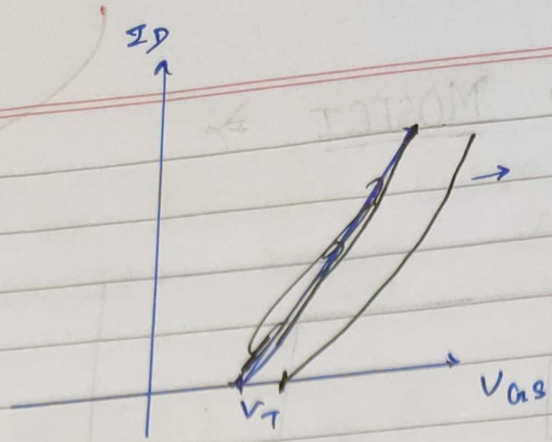
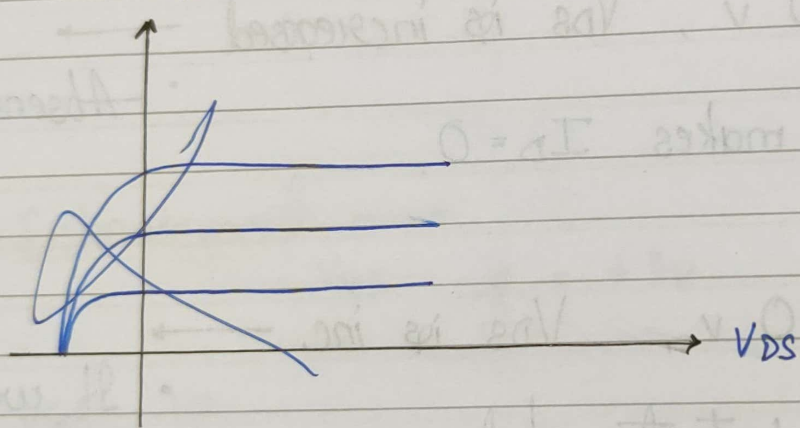


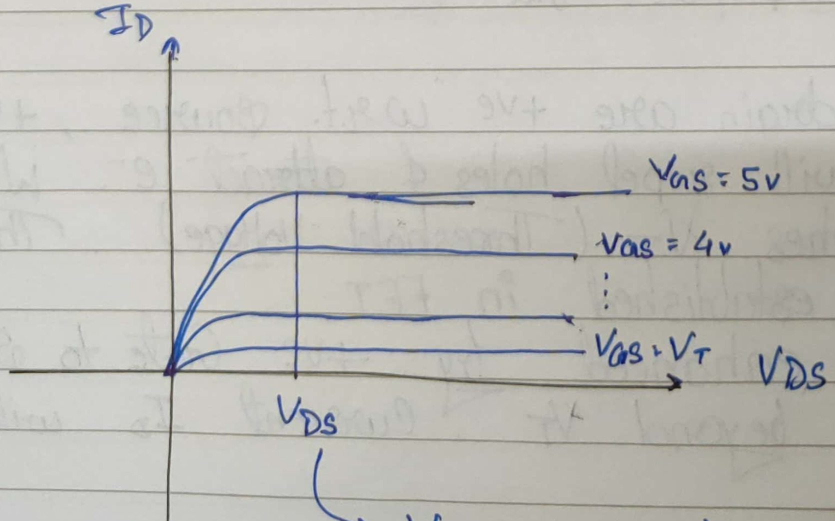
$\rightarrow I_D = K(V_{GS} - V_T)^2$

$$I_D = K(V_{GS} - V_T)^2$$

- If V_{GS} is kept Const. at value greater than V_T. The drain Current will exhibit similar behaviour as JFET or deplet^n MOSFET when V_{DS} is inc.

O/P





$\rightarrow V_{DS,sat} = V_{GS} - V_T$

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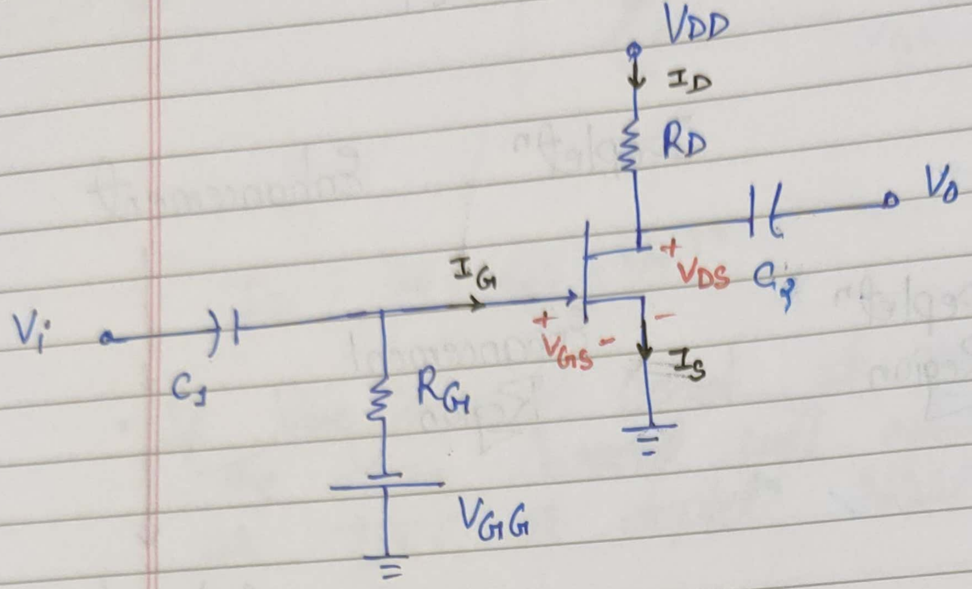
- FET
  - n-channel / P-channel
  - JFET
  - MOSFET
    - Depletⁿ
      - Depletⁿ Region
      - Enhancement Region
    - Enhancement
      - Only enhancement Region

⇒ DC Biasing of FET ⇒

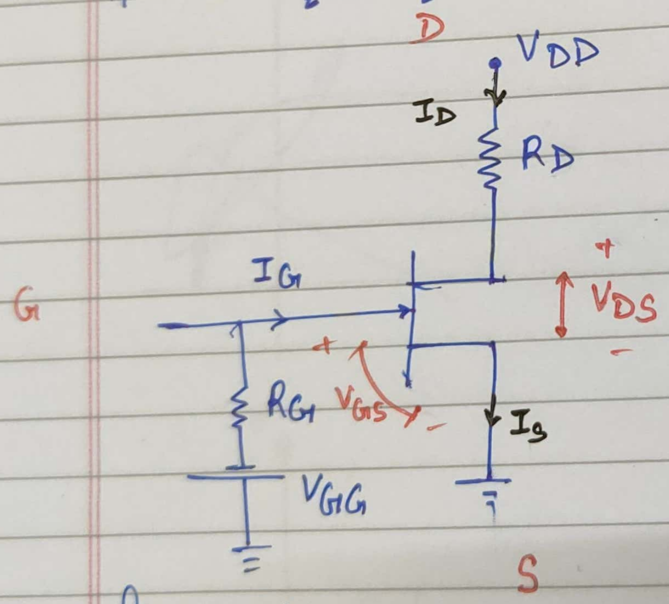
1) Fixed Bias Configuratⁿ ⟶



i) DC ~~Equa~~ Equivalent CKt ⇒

$f = 0$

$X_C = \infty$



$I_G = 0$

KVL → for DS Loop ⇒

$$V_{DD} - I_D R_D - V_{DS} = 0 \quad \text{—①}$$

for GS loop ⇒

$$-V_{GG} - \cancel{I_G}^{\,0} R_G - V_{GS} = 0 \quad \text{—②}$$

$$\boxed{V_{GS} = -V_{GG}}$$

↳ $V_{GS,Q}$

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Q

(i) V_{GS}

(ii) $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

(iii) $V_{DS} = V_{DD} - I_D R_D$

I_{DSS}, V_P (Given)

Que.1) In a fixed bias Configuratn $V_{DD} = 16v$, $V_{GG} = 2v$
$R_D = 2k\Omega$, $R_G = 1M\Omega$, $I_{DSS} = 10mA$, $V_P = -8v$.
Calculate (i) V_{GS_Q} (ii) I_{DQ} (iii) V_{DSQ} (iv) V_S (v) V_G (vi) V_D

⇒ $\boxed{V_S = 0v}$

$I_G = 0$

$V_{GS} = -V_{GG}$ ⇒ $\boxed{V_{GS_Q} = -2v}$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 10\left(1 - \frac{(-2)}{(-8)}\right)^2 = 10 \times \frac{9}{16}$

$I_D = \frac{45}{8} mA$

$\boxed{I_{D_Q} = 5.625 mA}$

$V_{DS} = V_{DD} - I_D R_D$

$\boxed{V_{DS_Q} = 4.75v}$

$V_{DS} = V_D - V_S$

$\boxed{V_D = V_{DS} = 4.75v}$

$V_{GS} = V_G - V_S$

$\boxed{V_G = V_{GS} = -2v}$

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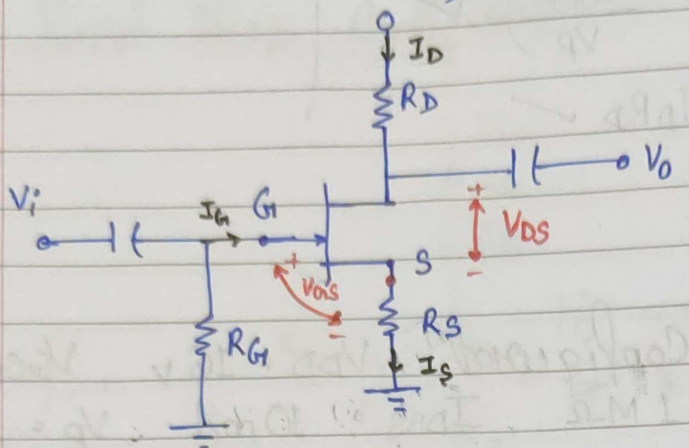
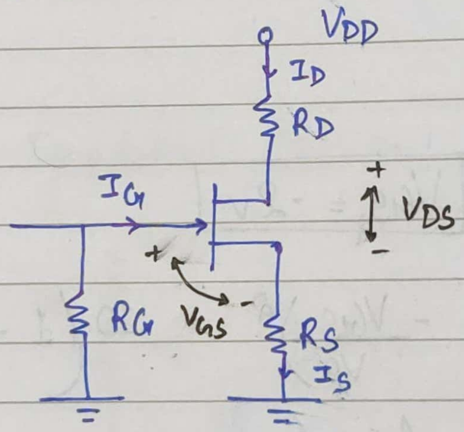
2) Self Bias Configuration →



DC Equivalent ckt ⇒

$I_G = 0$



(i) KVL in DS loop →

$$V_{DD} - I_D R_D - V_{DS} - I_S R_S = 0$$

$$V_{DS} = V_{DD} - I_D R_D - I_S R_S$$

(ii) KVL in GS loop →

$$-V_{GS} - I_S R_S = 0$$

$$V_{GS} = -I_S R_S$$

(iii) $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$$\boxed{V_{GS} = -I_D R_S}$$

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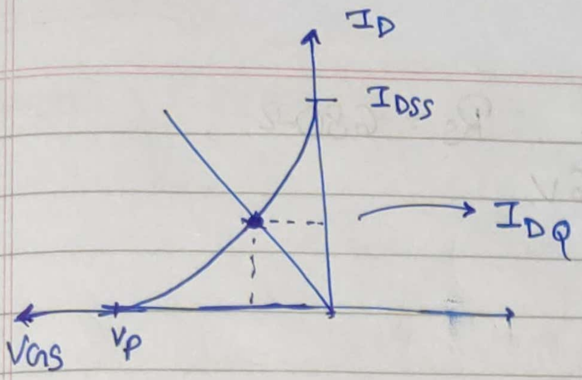

$$\boxed{V_{DS} = V_{DD} - I_D(R_D + R_S)}$$

Que.1) For a self bias confi. $V_{DD} = 20v$, $R_D = 3.3\,k\Omega$, $R_S = 1\,k\Omega$, $R_G = 1\,M\Omega$, $I_{DSS} = 8mA$, $V_P = -6v$.

⇒

$$V_{GS} = -I_S R_S = -I_D R_S$$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = I_{DSS}\left(1 + \frac{I_D R_S}{(-6)}\right)^2$$

$$I_D = 8\left(1 - \frac{10^3 I_D}{6}\right)^2 \Rightarrow \cancel{I_D = 5.83\times10^{-3}}$$

$$I_D = 2.587\ mA,\quad 13.9\ mA$$

$$I_{DSS} = 8mA \Rightarrow I_D = 2.587\ mA$$

$$\boxed{V_{GS} = -2.587\ v}$$

$$V_{DS} = 20 - 2.587\times3.3 - 2.587\times1$$

$$\boxed{V_{DS} = 8.876\ v}$$

$$V_{DS} = V_D - V_S \Rightarrow \boxed{\cancel{V_D = 11.463v}}$$

$$V_D = 11.46\,V$$

$$V_S = +I_D R_S$$

$$\boxed{V_S = +2.587\ v}$$

$$V_{GS} = V_G - V_S$$

$$V_G = \cancel{+5.174}\ 0v$$

Self Bias

Q.2) $V_{DD} = 12V$, $R_D = 1.5k\Omega$, $R_S = 680\Omega$,
$I_{DSS} = 12mA$, $V_P = -6V$

$\Rightarrow$

$$V_{GS} = -I_D R_S$$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$I_D = 12\times10^{-3}\left(1 - \frac{680 I_D}{6}\right)^2$$

$$I_D = 3.83\times mA, \quad 20.29\ mA$$

~~I_{DSS}~~ $I_D < I_{DSS} \Rightarrow \boxed{I_D = 3.83\ mA}$

$$\boxed{V_{GS} = -2.6\ V}$$

$$V_{DS} = V_{DD} - I_D(R_D + R_S)$$

$$\boxed{V_{DS} = 3.65V}$$

V

$V_S = I_D R_S$

$$\boxed{V_S = 2.6V}$$

$V_S = -I_D R_S$
$V_S = -2.6V$

$V_{DS} = V_D - V_S$

$$\boxed{V_D = 1.05V}$$

$V_{GS} = V_G - V_S$

$V_G = V_{GS} + V_S$

$$\boxed{V_G = 0V}$$

$V_{DS} = V_D - V_S$

$V_D = V_{DS} + V_S$

$$\boxed{V_D = 6.25V}$$

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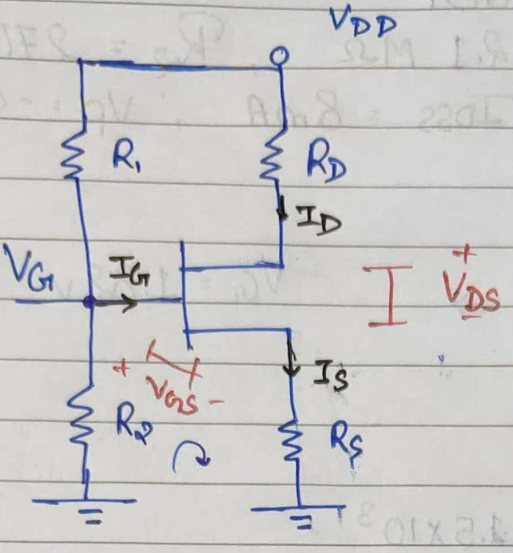
Que) #) Voltage Divider Bias ⟶



$I_G = 0$

(i) DC Equivalent ckt

$$V_G = \frac{R_2}{R_2 + R_1} \times V_{DD}$$

(ii) KVL in G-S loop ⇒

$$V_{GS} = V_G - V_S$$

$$V_{GS} = \frac{V_{DD} R_2}{R_1 + R_2} \mp I_D R_S$$

(iii) $I_D = I_{DSS} \left(1 - \frac{V_{GS}}{V_P}\right)^2$

(iv) KVL in DS loop ⇒

$$V_{DS} = V_{DD} - I_D (R_D + R_S)$$

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Que.1) Voltage Divider

$V_{DD} = 16V$, $R_1 = 2.1\ M\Omega$, $R_2 = 270\ k\Omega$, $R_D = 2.4\ k\Omega$

$R_S = 1.5\ k\Omega$, $I_{DSS} = 8\ mA$, $V_P = -4V$

⇒

$$V_G = \frac{V_{DD} R_2}{R_1 + R_2} \Rightarrow V_G = 1.82\ V$$

$$V_{GS} = V_G - V_S$$

$$V_{GS} = 1.82 - I_D\ 1.5 \times 10^3$$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 8 \times 10^{-3}\left(1 + \frac{1.82 - I_D \times 1.5 \times 10^3}{+4}\right)^2$$

$$I_D = \overset{\times}{6.23\ mA},\ \overset{\checkmark}{2.414\ mA}$$

↳ both values are less than I_{DSS}

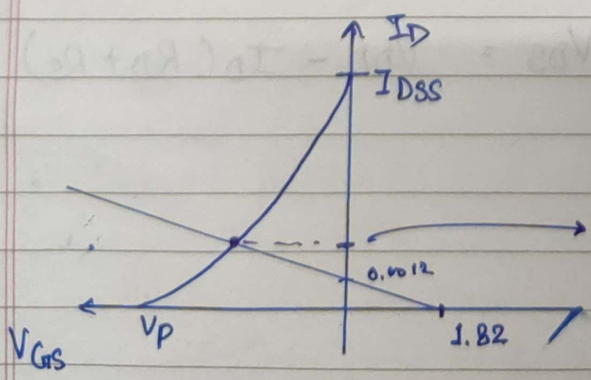
↓

Use Graphical method to select I_D

$$V_{GS} = 1.82 - I_D(1.5 \times 10^3)$$

$I_D = 0 \Rightarrow V_{GS} = 1.82$

$V_{GS} = 0 \Rightarrow I_D = 0.0012$



$$\boxed{I_D = 2.414\ mA}$$

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$V_{GS} = 1.82 - 2.414 \times 1.5$

$\boxed{V_{GS} = -1.801\ V}$

$V_{DS} = V_{DD} - I_D(R_D + R_S)$

$\boxed{V_{DS} = 6.58\ V}$

$V_S = I_D R_S$

$\boxed{V_S = 3.621\ V}$

$V_{GS} = 1.82 - 2.414 \times 1.5$

$\boxed{V_{GS} = -1.801\ v}$

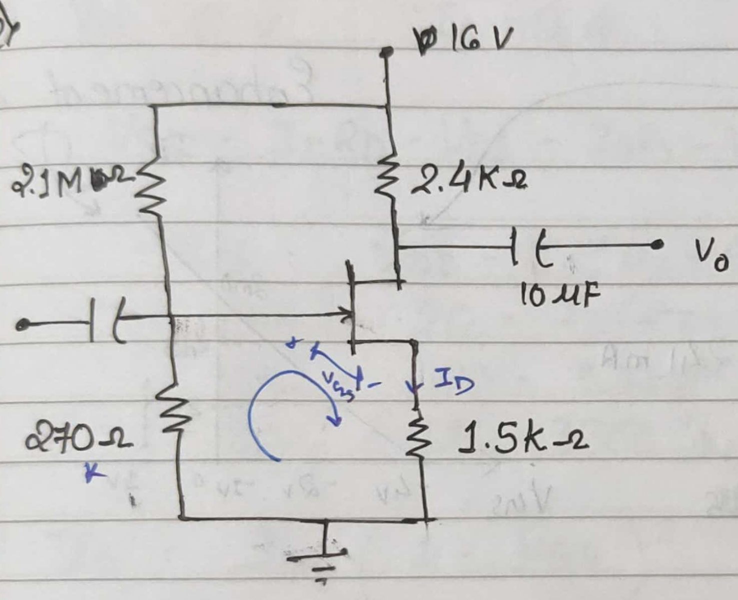
$V_S = I_D R_S$

$\boxed{V_S = 3.621\ v}$

$V_{DS} = V_{DD} - I_D(R_D + R_S)$

$\boxed{V_{DS} = 6.58\ v}$

Que.2)



$I_{DSS} = 8mA$

$V_P = -4v$

⇒

$$V_G = V_{DD}\frac{R_2}{R_2 + R_1} = \frac{16 \times 270 \times 10^3}{270 \times 10^3 + 2.1 \times 10^6} = \cancel{2.05 \times 10^{-3}}\ v \quad 1.82\ v$$

$V_{GS} = V_G - V_S$

$V_{GS} = \underset{1.82}{\cancel{2.05 \times 10^{-3}}} - I_D \times 1.5 \times 10^3$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$I_D = 8 \times 10^{-3}\left(1 + \frac{\overset{1.82\ v}{\cancel{2.05 \times 10^{-3}}} - I_D \times 1.5 \times 10^3}{4}\right)^2$$

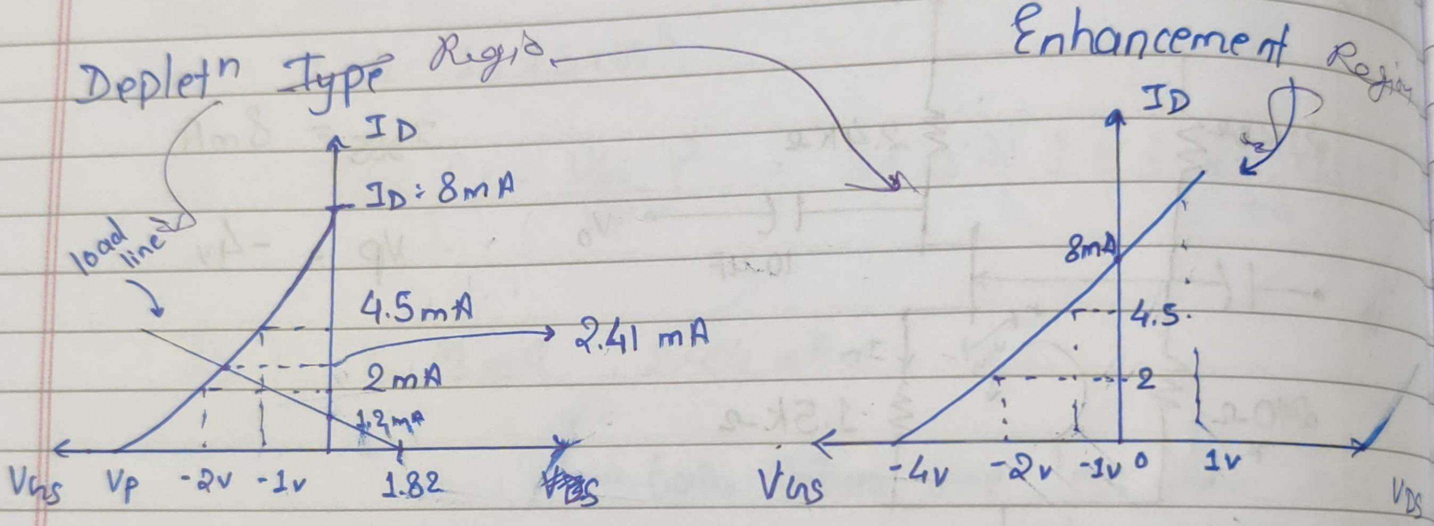
$I_D = 6.23\ mA$ ×, $2.414\ mA$ ✓

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

i) $V_{GS} = -1 \Rightarrow I_D = 8\times10^{3}\left(1 - \frac{(-1)}{(-4)}\right)^2 = 4.5\ mA$

ii) $V_{GS} = -2 \Rightarrow I_D = 2\ mA$

iii) $V_{GS} = 1 \Rightarrow I_D = 12.5\ mA$



$I_{D_Q} = 2.41\ mA$ ✓

$V_{GS_Q} = V_G - V_S = 1.82 - 2.41\times 1.5$

$V_{GS_Q} = -1.795\ V$

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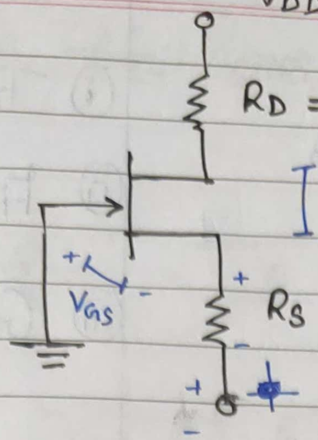
Que.



n-channel JFET

$I_{DSS} = 8mA$
$V_p = -3V$

⇒

$V_G = 0\ V$, $I_G = 0\ A$

$$V_{DD} - I_D R_D - V_{DS} - I_D R_S - V_{SS} = 0$$

$$V_{DS} = V_{DD} - I_D(R_D + R_S) - V_{SS}$$
$$V_{DS} = 20 - I_D(R_D + R_S) + 10$$
$$V_{DS} = 20 - 3.3\times10^3 I_D + 10$$
$$V_{DS} = 30 - 3300 I_D$$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$$

$$V_G - V_{GS} - I_D R_S - V_{SS} = 0$$

$$V_{GS} = -(V_{SS} + I_D R_S)$$

$$\cancel{V_{GS} = V_G - I_D R_S}$$

$$V_{GS} = -(-10 + I_D \times 1500)$$
$$V_{GS} = 10 - 1500 I_D$$

$$I_D = 8\times10^{-3}\left(1 - \frac{10 - 1500 I_D}{-3}\right)^2$$

$$I_D = 6.82 mA ,\quad 11.01 mA$$

$I_{DQ} = 6.82\,mA$

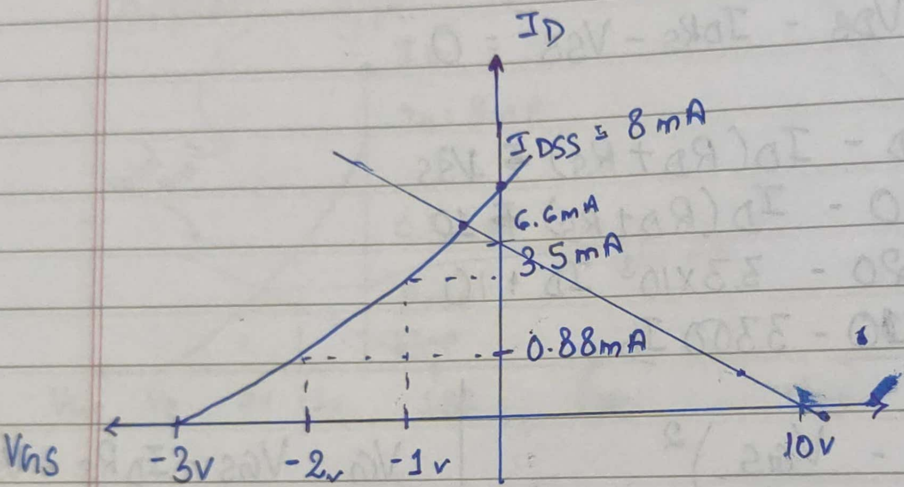
$V_{DS} = 30 - 3300 \times 6.82 \times 10^{-3}$

$V_{DS} = 7.494\ V$

$V_{GS} = 10 - 1500\, I_D$

~~V_G~~ $I_D = 0 \Rightarrow V_{GS} = 10V$

$V_{GS} = 0 \Rightarrow I_D = 6.6\ mA$



(i) Transfer char.

(ii) Find Q - Point

(iii) Graphical

~~$V_{GS} =$~~

$$I_D = 8\left(1 - \frac{V_{GS}}{(-3)}\right)^2$$

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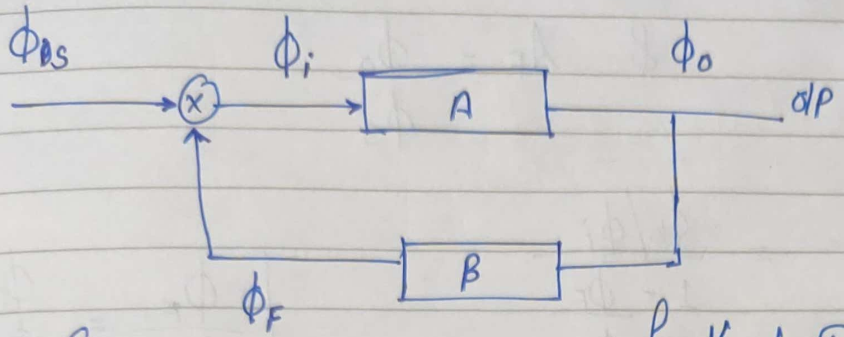
Feedback Amplifiers ->



open loop Gain

Feedback Ratio

A : Gain of Basic Amp.

β : feedback Ratio

$$\beta = \frac{\phi_F}{\phi_o}$$

ϕ_s : Source Signal

ϕ_F : Feedback Signal

ϕ_i : i/p signal to the Amp.

$$A_F = \frac{\phi_o}{\phi_s}$$

$$A = \frac{\phi_o}{\phi_i}$$

Overall Gain

AC Oscillator

Positive Feedback (Regenerative feedback) :-

$\phi_i = \phi_s + \phi_F$ & $A_F = \frac{\phi_o}{\phi_s}$

$A_F = \frac{\phi_o}{\phi_i - \phi_F} = \frac{\phi_o/\phi_i}{1 - \frac{\phi_F}{\phi_i}}$ $\left[\frac{\phi_F}{\phi_i} = \frac{\phi_F}{\phi_o} \cdot \frac{\phi_o}{\phi_i}\right]$

$A_F = \frac{A}{1 - \frac{\phi_F}{\phi_i}}$

$$\boxed{A_F = \frac{A}{1 - \beta A}}$$

✓ $|A| < |A_F|$

$A\beta \longrightarrow$ Closed loop Gain

↳ Diadvantage :-

Amplify noise also

Degenerative feedback

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-ve Feedback ⇒

$\phi_i = \phi_s - \phi_F$ & $A_F = \frac{\phi_o}{\phi_s}$

$$A_F = \frac{\phi_o}{\phi_i + \phi_F} = \frac{\phi_o/\phi_i}{1 + \phi_F/\phi_i}$$

$$A_F = \frac{A}{1 + \frac{\phi_F}{\phi_i}}$$

$$\frac{\phi_F}{\phi_i} = \underbrace{\frac{\phi_F}{\phi_o}}_{\beta} \cdot \underbrace{\frac{\phi_o}{\phi_i}}_{A}$$

$$\boxed{A_F = \frac{A}{1 + A\beta}}$$

$|A\beta|$

$|A_F| < |A|$

↳ Highly stable than +ve F.B.

Effect of -ve F.B. ⇁

$$A_F = \frac{A}{1 + A\beta}$$

$$\frac{\partial A_F}{\partial A} = \frac{(1 + A\beta) - \beta A}{(1 + A\beta)^2} = \frac{1}{(1 + A\beta)^2}$$

$$\frac{dA_F}{dA} = \frac{1}{(1 + A\beta)^2} \times \frac{A_F}{A_F}$$

$$\frac{dA_F}{A_F} = \frac{1}{(1+A\beta)^2} \times \frac{dA}{A_F}$$

$$\frac{dA_F}{A_F} = \frac{(1+A\beta)}{(1+A\beta)^2} \times \frac{dA}{A}$$

$$\frac{dA_F}{A_F} = \frac{1}{(1+A\beta)} \cdot \frac{dA}{A}$$

fractional change in Gain of the Amp. with feedback

$\frac{dA}{A}$ = —— " ———→ without feedback

$K = \frac{1}{1+A\beta} < 1$, $K < 1$

$$\frac{dA_F}{A_F} = K \frac{dA}{A}$$

$\frac{1}{1+A\beta}$ → Sensitivity

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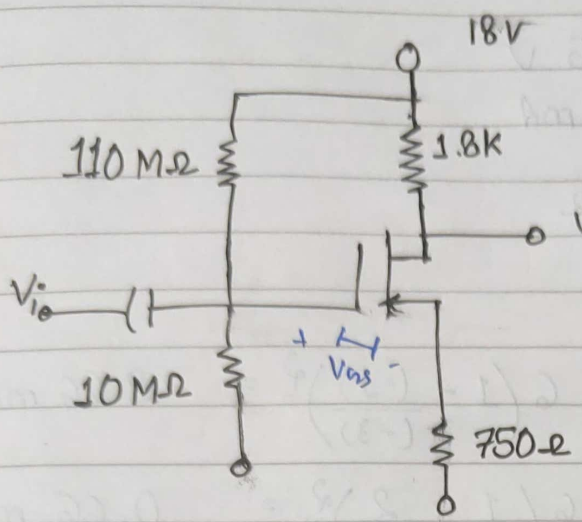
Depletion MOSFET ⇒

N-channel



$I_{DSS} = 6\ mA$

$V_P = -3V$

(i) Transfer Curve
(ii) I_{DQ}, V_{GSQ}, V_{DS}
(iii) Verify Graphically.
↳ C+R + C

⇒

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$V_G = V_{DD}\frac{R_2}{R_2+R_1} = 18 \times \frac{110}{110+10} = 1.5$$

$$V_{GS} = V_G - V_S$$

$$V_{GS} = V_G - I_D R_S = 1.5 - I_D \times 750$$

$$I_D = 6\times10^{-3}\left(1 - \frac{1.5 - 750 I_D}{-3}\right)^2$$

$I_D = 3.117\ mA$, $11.5\ mA$

V_{GS}

$$V_{GS} = 1.5 - I_D(750)$$

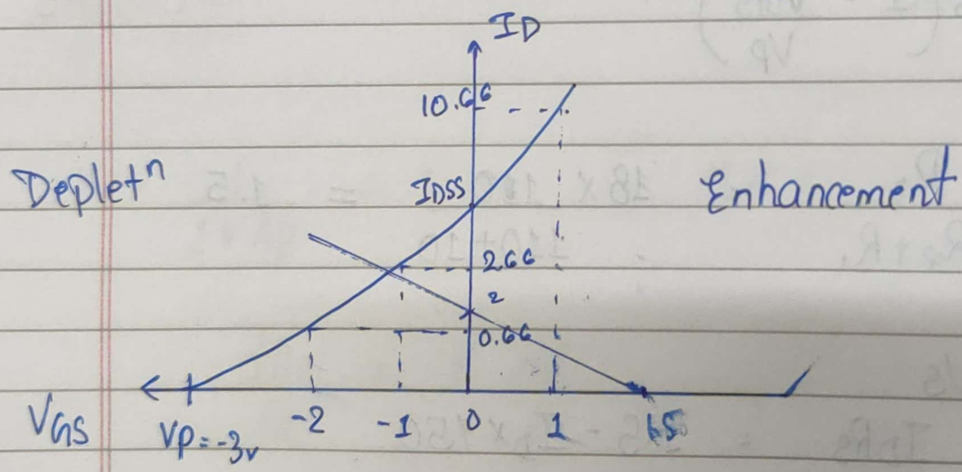
$$I_D = 0 \Rightarrow V_{GS} = 1.5\ V$$
$$V_{GS} = 0 \Rightarrow I_D = 2mA$$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$V_{GS} = -1 \Rightarrow I_D = 6\left(1 - \frac{(+1)}{(+3)}\right)^2 = 2.66\ mA$$

$$V_{GS} = -2 \Rightarrow I_D = 6\left(1 - \frac{2}{3}\right)^2 = 0.66\ mA$$

$$V_{GS} = 1 \Rightarrow I_D = 6\left(1 + \frac{1}{3}\right)^2 = 10.66\ mA$$



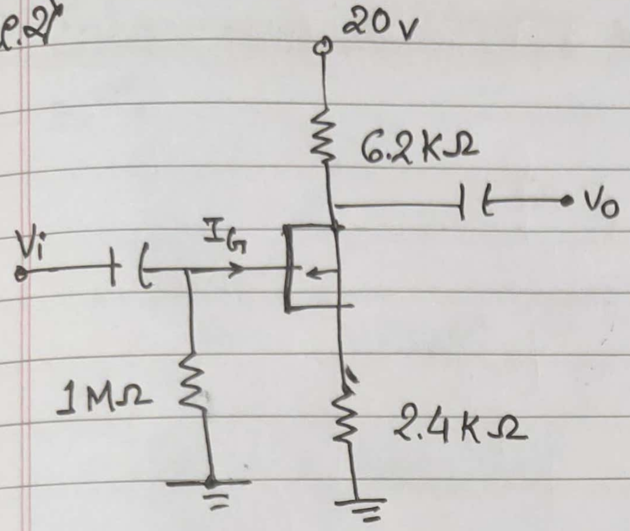
$$I_{D_Q} = 3.117\ mA$$

$$V_{GS_Q} = 1.5 - 3.117 \times 10^{-3} \times 750$$
$$V_{GS_Q} = -0.8325\ V$$

$$\cancel{V_{DS} = 18 - 1.8\times10^3 I_D - V_{DS} - I_D R_S} = 0$$

$$\cancel{V_{DS} = 18 - 1.8\times10^3(1.8\times10}$$
$$V_{DS} = 18 - I_D(R_D + R_S)$$
$$V_{DS} = 10.05\ V$$

Que.2)



$I_{DSS} = 8mA$

$V_P = -8V$

Ctr + V

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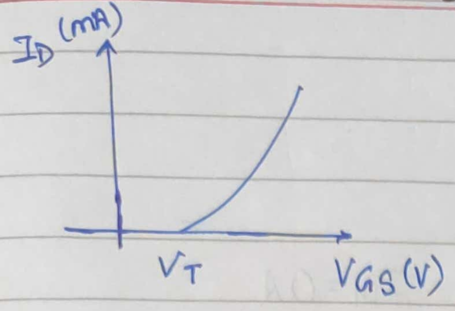
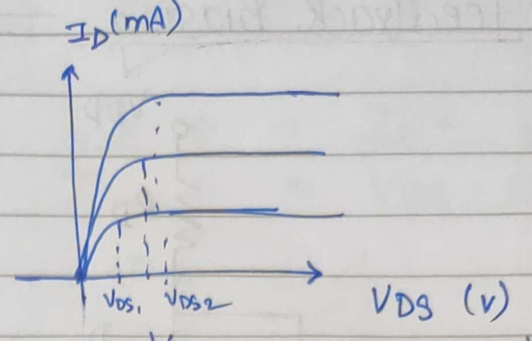
Enhancement MOSFET ⇒





$V_{DS\,sat} = V_{GS} - V_T$)

$$I_D = K(V_{GS} - V_T)^2$$

Q.1) Draw a transfer curve for n-channel Enhancement type MOSFET

$V_T = 3V$ $\quad I_{D(ON)} = 6\ mA$

$V_{GS(ON)} = +8V$

⇒

$$I_D = K(V_{GS} - V_T)^2$$

$$6\times10^{-3} = K(8-3)^2$$

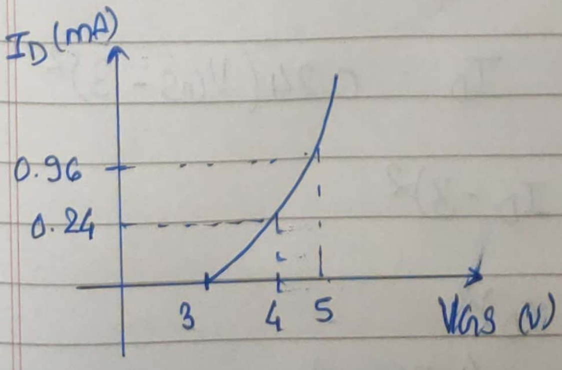
$$K = \frac{6\times10^{-3}}{25} \Rightarrow K = 2.4\times10^{-4}\ A/V^2$$

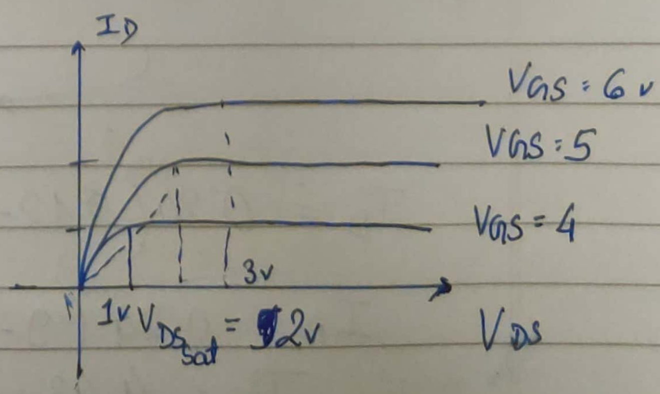
$$K = 0.24\ mA/V^2$$

$$I_D = 0.24(V_{GS} - 3)^2$$

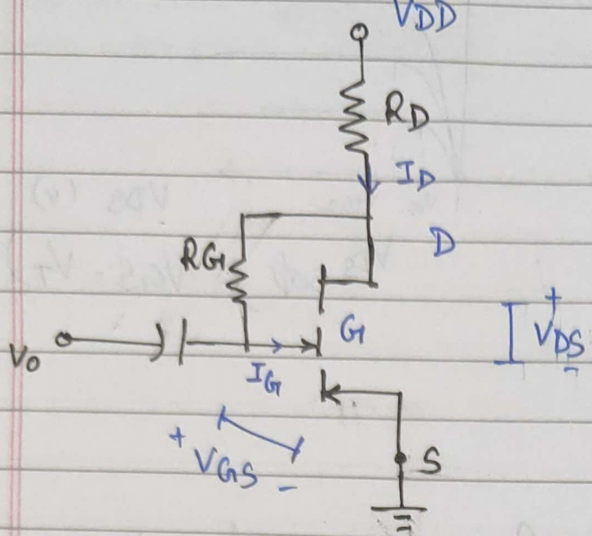
$V_{GS} = 4 \Rightarrow I_D = 0.24\ mA$

$V_{GS} = 5 \Rightarrow I_D = 0.96\ mA$





⋆ Feedback Biasing →

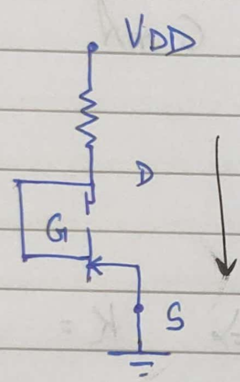


$I_G = 0A$

⇓

As $I_G = 0$

$R_G I_G = 0$



⊙ $V_G = V_D$

⊙ $V_{GS} = V_{DS}$

⊙ $V_{DS} = V_{DD} - I_D R_D$

⊙ $V_{GS} = V_{DD} - I_D R_D$

Que.1) ↓ $R_D = 2K\Omega$, $V_{DD} = 12V$, V_{DS} ?

Given: $K = 0.24$, $V_T = 3v$

⇒

$V_{GS} = V_{DS} = V_{DD} - I_D R_D$ | $I_D = K(V_{GS} - V_T)^2$

$I_D = 0.24(V_{GS} - 3)^2$

$I_D = 0.24 \times 10^{-3} (12 - 2\times10^3 I_D - 3)^2$

$I_D = 0.24 \times 10^{-3} (9 - 2\times10^3 I_D)^2$

$I_D =$ ~~4.43 mA~~ , ~~4.56 mA~~

2.79 mA , 7.24 mA

$I_D = 2.79 mA$

$V_{DS} = V_{GS} = 6.42 V$

$I_D = 0.24(V_{GS} - 3)^2$

$V_{GS} = 3 \Rightarrow I_D = 0$

$V_{GS} = 4 \Rightarrow I_D = 0.24 mA$

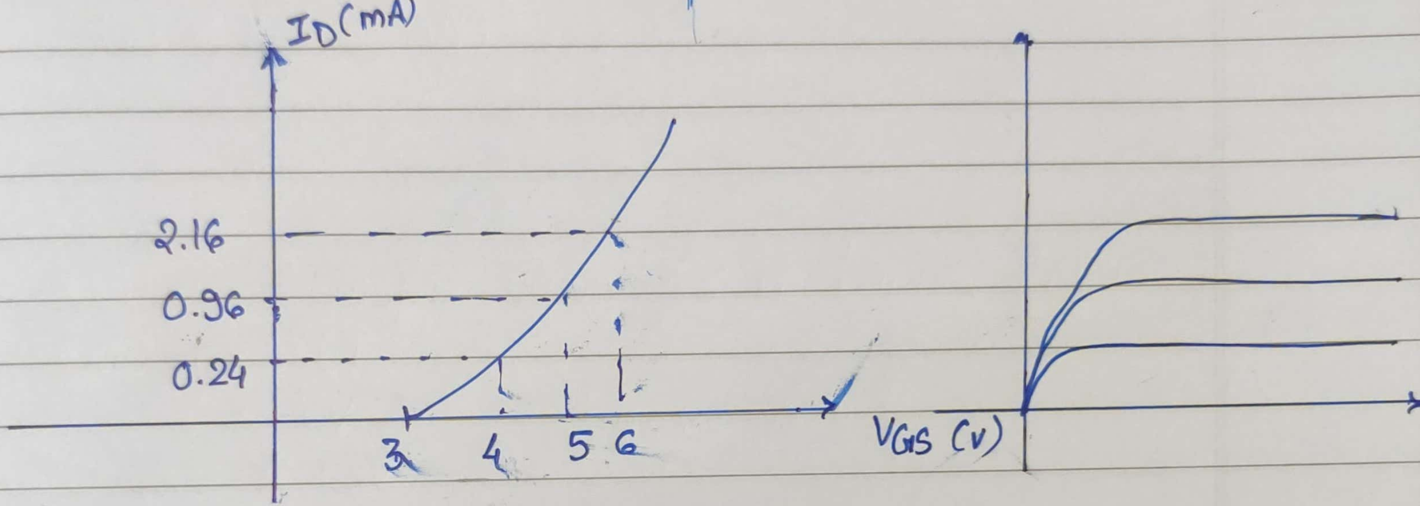
$V_{GS} = 5 \Rightarrow I_D = 0.96 mA$

$V_{GS} = 6 \Rightarrow I_D = 2.16 mA$

$V_{GS} = 12 - 2\times10^3 I_D$

$V_{GS} = 0 \Rightarrow I_D = 6 mA$

$I_D = 0 \Rightarrow V_{GS} = 12V$



$I_{DQ} = 2.79 mA$

$V_{GS} = V_{DS} = 6.42 V$

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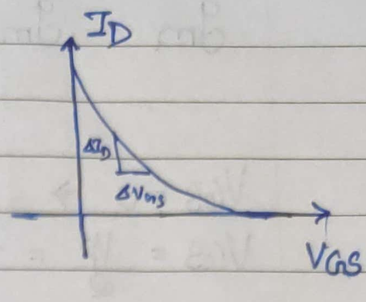
Small Signal Analysis of FET

$\Delta I_D = g_m \Delta V_{GS}$



$\frac{\Delta I_D}{\Delta V_{GS}} = g_m \Rightarrow$ Transconductance

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$g_m = \frac{dI_D}{dV_{GS}} = I_{DSS} \times 2\left(\frac{-1}{V_P}\right)\left(1 - \frac{V_{GS}}{V_P}\right)$$

$$\boxed{g_m = +\frac{2 I_{DSS}}{V_P}\left(1 - \frac{V_{GS}}{V_P}\right)}$$

↳ Transconductance can not be -ve

$V_{GS} = 0 \Rightarrow g_{mo} = \frac{2 I_{DSS}}{V_P}$

$$\boxed{g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)}$$

$g_{mo} \rightarrow$ max Value

Que.1) Calc. the Value of ① max value of g_m ② Plot g_m v/s V_{GS}. A JFET has $I_{DSS} = 8\,mA$ ~~& V_{GS} =~~ , $V_P = -4V$

⇒

$$g_{mo} = \frac{2 I_{DSS}}{V_P} = \frac{2 \times 8 \times 10^{-3}}{+4} = 4\,mA/V = 4\,mS$$

$1 - \frac{(-x)}{(-4)}$

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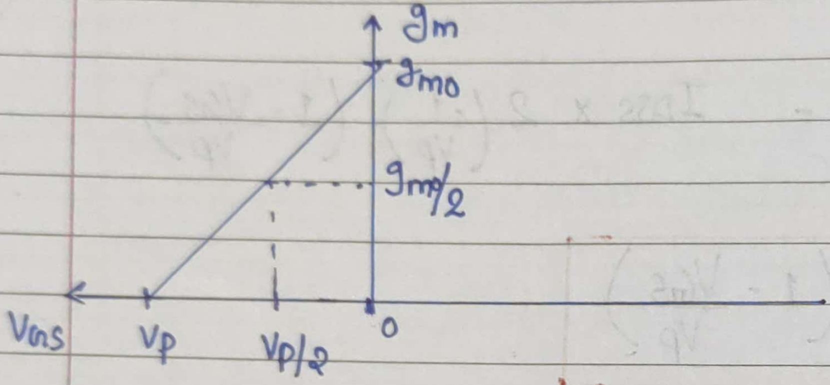
$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$$

$V_{GS} = 0 \rightarrow g_m = g_{mo}$

$V_{GS} = \frac{V_P}{2} = -2 \Rightarrow g_m = \frac{g_{mo}}{2}$

$V_{GS} = V_P = -4 \Rightarrow g_m = 0$



☆ Relation b/w I_D & g_m ⟶

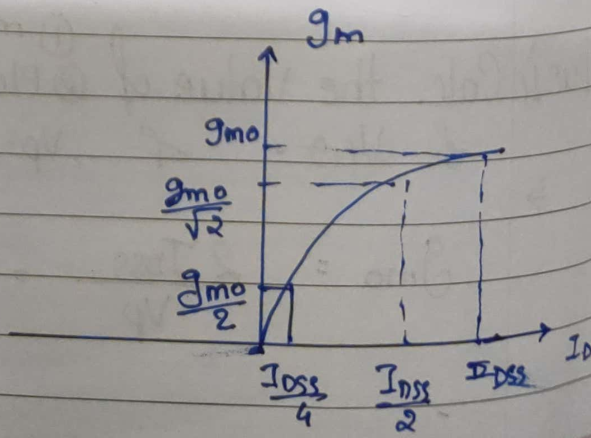
$\cancel{g_m} = \frac{I_D}{V_{GS}}$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$\frac{V_{GS}}{V_P} = 1 - \sqrt{\frac{I_D}{I_{DSS}}}$$

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$$

$$\boxed{g_m = g_{mo}\sqrt{\frac{I_D}{I_{DSS}}}}$$



$I_D = \frac{I_{DSS}\, g_m^2}{g_{mo}}$

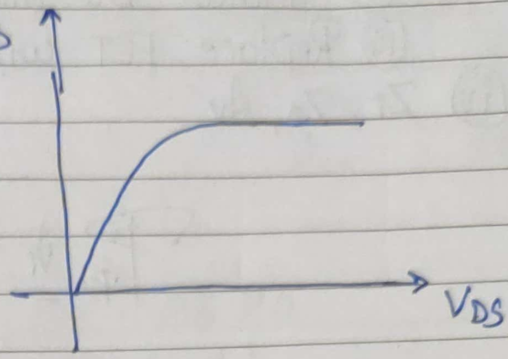
$x = y^2$

$x = y^2 \longrightarrow$ Parabola

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}} = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right) = g_{mo}\sqrt{\frac{I_D}{I_{DSS}}}$$

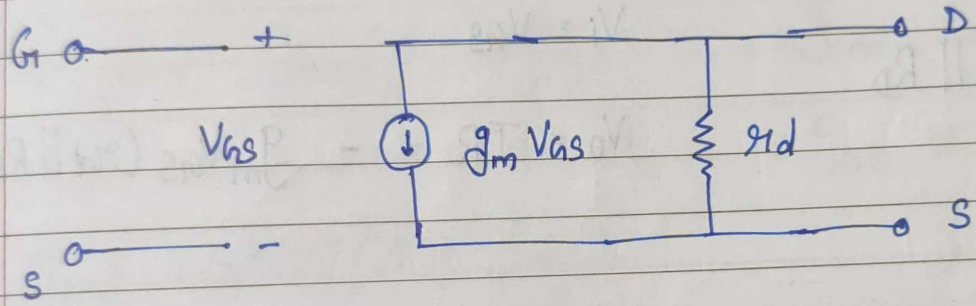
$$r_d = \frac{\Delta V_{DS}}{\Delta I_D}$$

drain resistance

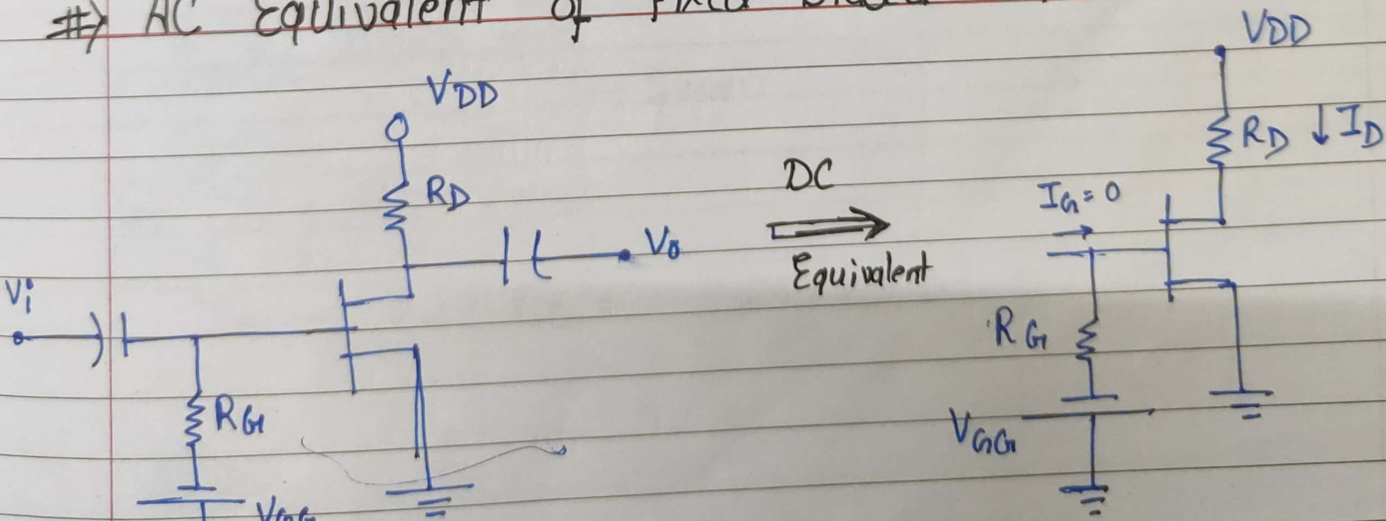


$r_d \rightarrow$ Very large

✶) AC equivalent ckt →



#) AC Equivalent of Fixed Biased FET →



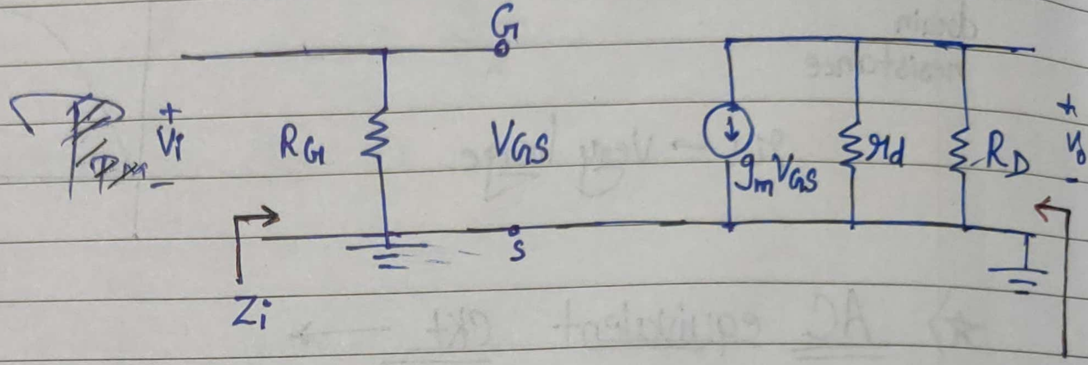
for AC equiv. ck ⟶

(i) Short ckt Capacitor

(ii) Make DC source zero.

(iii) Replace FET with small signal model.

(iv) Z_i, Z_o, A_v



$Z_i = R_G$

$Z_o = r_d \parallel R_D$

$A_v = \frac{V_o}{V_i}$

$V_i = V_{GS}$

$V_o = IR = -g_m V_{GS}(r_d \parallel R_D)$

$A_v = -g_m(r_d \parallel R_D)$

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Que) A fixed bias Config. has $V_{DD} = 20v$, $R_D = 2K\Omega$, $R_G = 1M\Omega$, $V_{GG} = 2V$, $I_{DSS} = 10mA$, $V_P = -8V$

(i) Draw DC equiv. Ckt

(ii) Calc. eq Q point

(iii) verify graphically.

(iv) Calc. ~~rd~~ g_m & g_{mo}

Q (V_{GSQ} , I_{DQ})
-2V , 5.625 mA

(v) Calc. Z_i, Z_o, A_v given $r_d = 25 K\Omega$ (drain Resst.)

(vi) D —, ——— ignoring rd.

⇒

(iv) $g_m = g_{mo}\left(1 - \frac{V_{GSQ}}{V_P}\right)$

$g_{mo} = \frac{2 I_D}{V_P}$

$g_{mo} = \frac{2 \times 10}{8} = 2.5\, mS$

$g_m = 2.5\times10^{-3}\left(1 - \frac{(-2)}{(-8)}\right)$

$= 2.5\times10^{-3}\left(1 - \frac{1}{4}\right) = \frac{2.5\times3\times10^{-3}}{4}$

$g_m = 1.875\ mS$
↳ Simen

(v) $Z_i = R_G = 1M\Omega$

$Z_o = r_d \,||\, R_D = \frac{25\times2\times10^3}{27} = 1.85\ K\Omega$

$A_v = -g_m Z_o$

$= -1.875\times1.85$

$A_v = -3.468$

(vi) Ignoring r_d

$Z_i = R_G = 1 M\Omega$

$Z_o = \cancel{R} R_D = 2 K\Omega$

$A_V = -g_m Z_o = 1.875 \times 2$

$A_V = -3.75$

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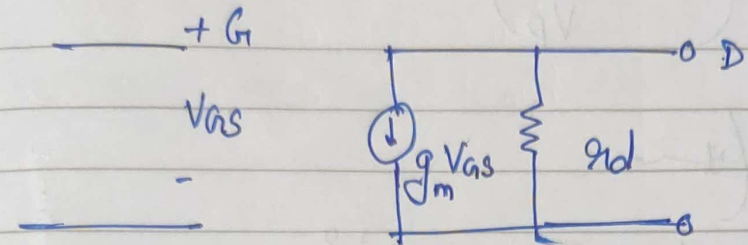
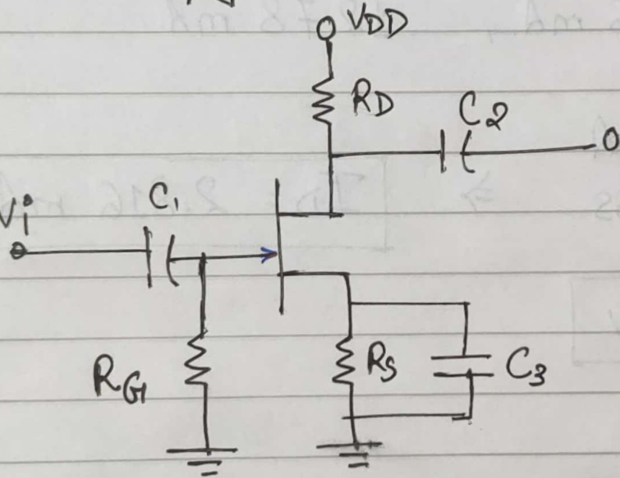
$$r_d = \frac{\Delta V_{DS}}{\Delta I_D} = \frac{1}{y_{os}}$$, y_{os} = Admittance o/p common source



Self Bias Configuration ⇒

JFET



The self bias configuratⁿ has $V_{DD} = 20V$, $R_D = 3.3\,k\Omega$, $R_S = 1\,k\Omega$, $R_G = 1\,M\Omega$, $I_{DSS} = 10\,mA$, $V_P = -6V$ & $y_{os} = 20\,\mu S$.

Small Signal Model → Ctr + C

(i) Draw the transfer ckt.
(ii) Find the Q point.
(iii) Verify graphically.
(iv) Draw the small signal equivalent model.
(v) Calc. Zi, Zo, Av taking rd into consideratⁿ
(vi) — , ——— ignoring rd.

⇒

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$I_D = 10\times10^{-3}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$V_{GS} = -I_D R_S$$

$$I_D = 10\times10^{-3}\left(1 - \frac{I_D\times10^{3}}{6}\right)^2$$

$$I_D = 2.816\ mA,\quad 12.78\ mA$$

$I_{DSS} = 10mA$

$I_D < I_{DSS}$ ⇒ $\boxed{I_D = 2.816\ mA}$

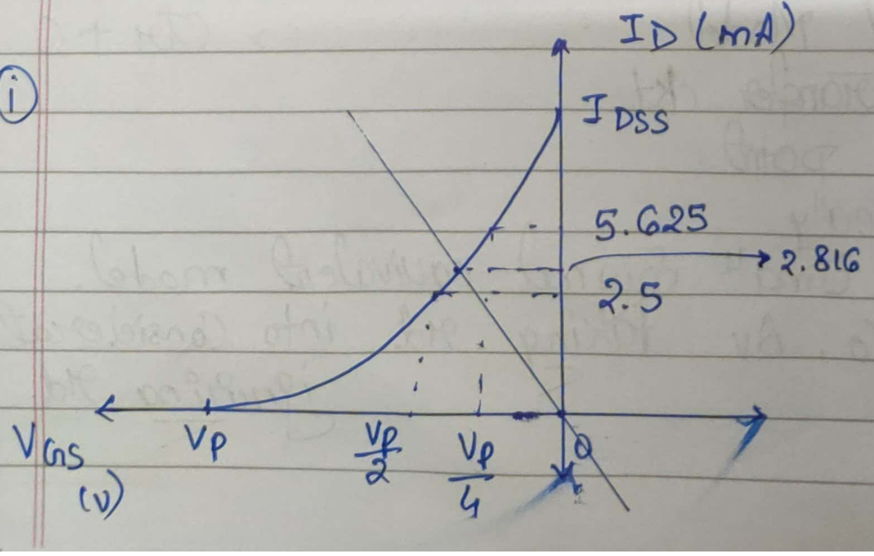
$\boxed{V_{GS} = -2.816\ V}$

I $V_{GS} = 0$ ⇒ $I_D = I_{DSS} = 10\ mA$

$V_{GS} = \frac{V_P}{2}$ ⇒ $I_D = \frac{I_{DSS}}{4} = 2.5mA$

$V_{GS} = \frac{V_P}{4}$ ⇒ $I_D = \frac{9 I_{DSS}}{16} = 5.625\ mA$

(i)



(ii) Q point $(V_{GSQ}, I_{DQ}) = (-2.816\ \text{V},\ 2.816\ \text{mA})$

(iii) $V_{GS} = -10^3 I_D$

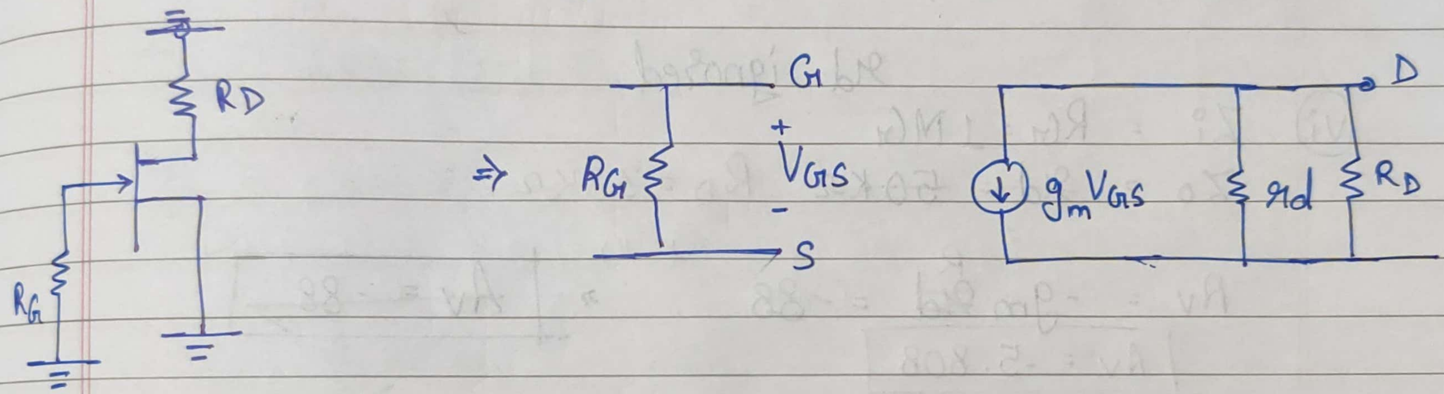
$V_{GS} = \cancel{V_G}^{\,0} - V_S$

$V_{GS} = -I_D R_S$

$\cancel{V_{GS}}\ \cancel{y = m}\ \ I_D = \frac{-1}{10^3} V_{GS}$

$y = mx$

(iv) Now for AC Analysis $\longrightarrow$



$\cancel{r_d\ g_m} = \frac{\cancel{1}}{\cancel{20}}$ $\quad r_d = \frac{1}{y_{os}} = \frac{1}{20\times10^{-6}} = 50\ K\Omega$

$g_{mo} = \frac{2 I_{DSS}}{V_P} = \frac{2\times 10\times10^{-3}}{+6} = 3.33\times10^{-3}$

$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right) = 3.33\times10^{-3}\left(1 - \frac{2.816}{6}\right)$

$g_m = 1.76\times10^{-3} = 1.76\ \text{mS}$

$g_m V_{GS} = 4.97\ \text{mA}$

(v) $Z_i = 1 M\Omega = R_G$

$Z_o = r_d \parallel R_D = \quad 50K \parallel 3.3K$

$Z_o = 3.09 \, K\Omega$

$A_V = -g_m (r_d \parallel R_D)$

$= -1.76 \times 3.09$

$\boxed{A_V = -5.448}$

r_d ignored

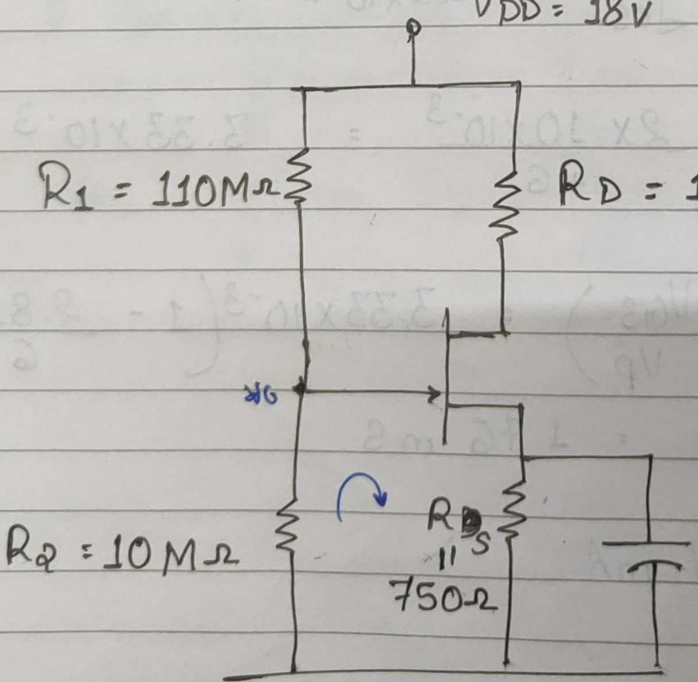
(vi) $Z_i = R_G = 1 MG$

$Z_o = \cancel{r_d = 50K\Omega} \quad R_D = 3.3K\Omega$

$A_V = -g_m \overset{R}{\cancel{r_d}} = \cancel{-88} \quad \Rightarrow \boxed{\cancel{A_V = -88}}$

$\boxed{A_V = -5.808}$

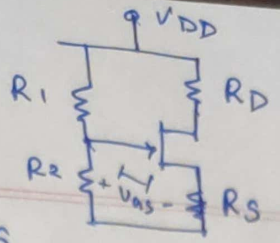
Que.) Voltage Divider



$I_{DSS} = 6mA$

$V_P = -3V$

Ctr +V



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⇒ DC Analysis

$V_G = \frac{V_{DD} R_2}{R_1 + R_2} = \frac{18 \times 10 \times 10^{6}}{120}$

$V_G = 1.5\ V$

$V_{GS} = V_G - V_S$

$V_{GS} = V_G - I_D R_S \Rightarrow \boxed{\cancel{V_{GS} = 1.5 V}}$

$\cancel{I_D =}\ V_{GS} = 1.5 - I_D \times 750$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$I_D = 6 \times 10^{-3}\left(1 + \frac{1.5 - 750 I_D}{3}\right)^2$

$I_D = 3.12\ mA\ ,\ 11.55\ mA$

$I_D < I_{DSS} \Rightarrow I_{D_Q} = 3.12\ mA$

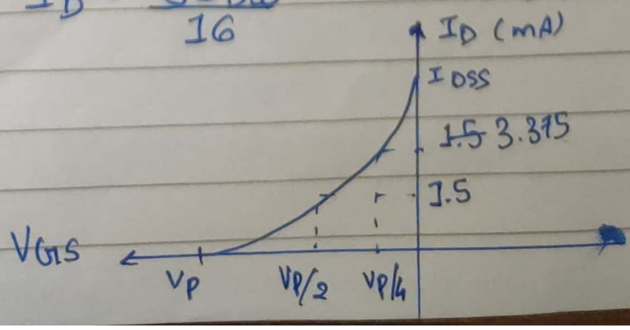
$V_{GS_Q} = -0.84\ V$

Q-point $\rightarrow (V_{GS_Q}, I_{D_Q}) = (-0.84\ V, 3.12\ mA)$

$V_{GS} = 0 \Rightarrow I_D = I_{DSS} = 6\ mA$

$V_{GS} = \frac{V_P}{2} \Rightarrow I_D = \frac{I_{DSS}}{4} = 1.5\ mA$

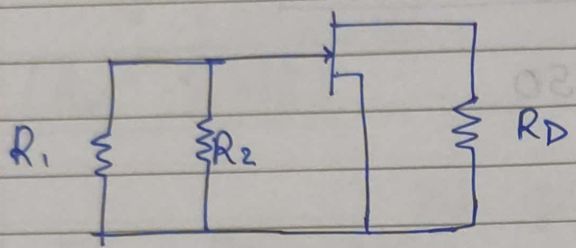
$V_{GS} = \frac{V_P}{4} \Rightarrow I_D = \frac{9 I_{DSS}}{16} = 3.375\ mA$

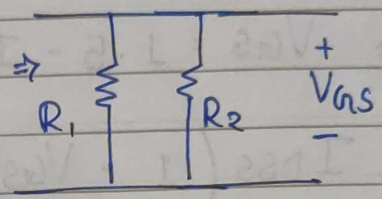


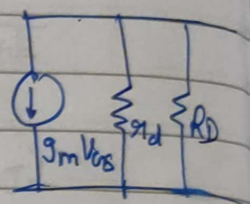
$g_{m0} = \left|\frac{2 I_{DSS}}{V_P}\right| = \left|\frac{2 \times 6 \times 10^{-3}}{-3}\right| = 4 \times 10^{-3}$

~~$g_m = g_m (1$~~

for AC







$g_m = g_{m0}\left(1 - \frac{V_{GS}}{V_P}\right) = 4 \times 10^{-3}\left(1 - \frac{(-0.84)}{(-3)}\right)$

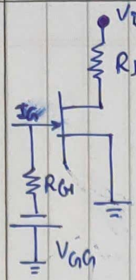
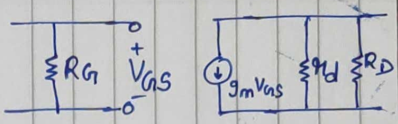
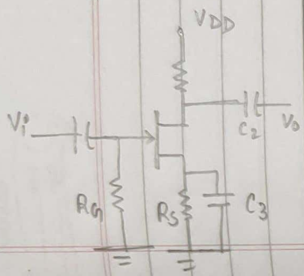
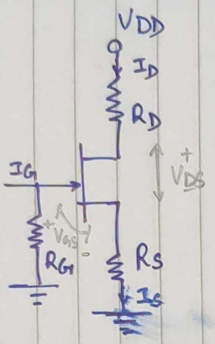
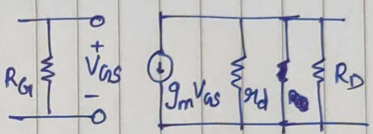
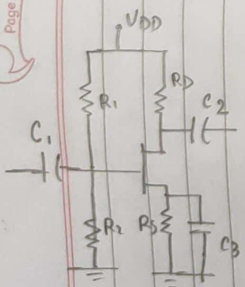
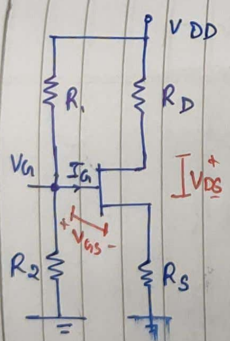
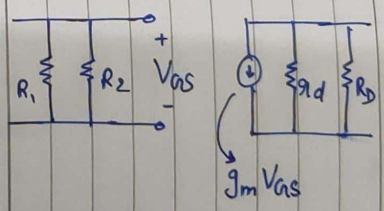
$g_m = 2.88 \text{ mS}$ $r_d = 50 K\Omega$

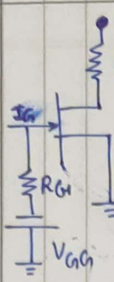
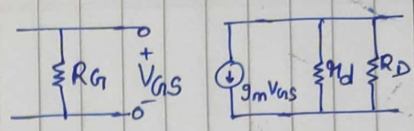
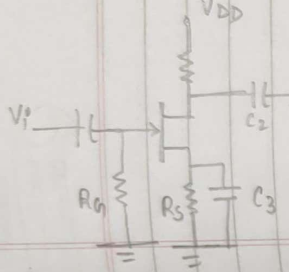
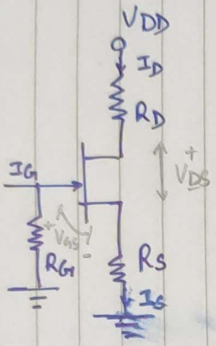
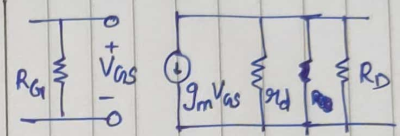
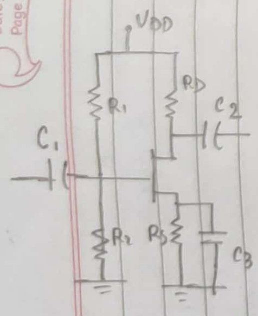
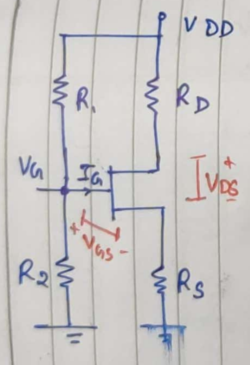
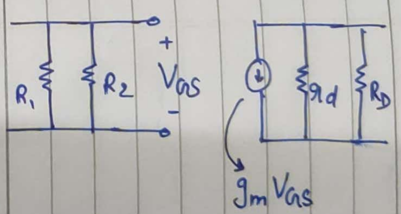
$Z_i = R_1 || R_2 = 9.16 \text{ M}\Omega$

$Z_o = r_d || R_D = 1.737 K\Omega$

$A_V = -g_m (r_d || R_D)$

$\boxed{A_V = -5.004}$

	DC eq. ckt		AC eq. ckt	
1) Fixed Bias		$I_G = 0$ $V_{GS} = V_G - V_S$ $V_{GS} = +V_{GG}$ $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ $V_{DS} = V_{DD} - I_D R_D$		$Z_i = R_G$ $Z_o = r_d \parallel R_D$ $A_v = -g_m Z_o$ $g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$ $g_{mo} = \frac{2 I_{DSS}}{V_P}$ $r_d = \frac{\Delta V_{DS}}{\Delta I_D}$
2) Self Bias 		$V_{GS} = -I_S R_S = -I_D R_S$ $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ $V_{DS} = V_{DD} - I_D(R_D + R_S)$		$r_d = \frac{1}{y_{os}}$ $g_{mo} = \frac{2 I_{DSS}}{V_P}$ $g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$ $Z_i = R_G$ $Z_o = r_d \parallel R_D$ $A_v = -g_m Z_o$
3) Voltage Divider 		$V_G = \frac{R_2}{R_1 + R_2} \times V_{DD}$ $V_{GS} = V_G - V_S$ $V_{GS} = V_{DD}\left(\frac{R_2}{R_1 + R_2}\right) - I_D R_S$ $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ $V_{DS} = V_{DD} - I_D(R_D + R_S)$		$Z_i = R_1 \parallel R_2$ $Z_o = r_d \parallel R_D$ $A_v = -g_m (r_d \parallel R_D)$ $g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$

	DC eq. Ckt		AC eq. Ckt	
1) Fixed Bias		$I_G = 0$ $V_{GS} = V_G - V_S$ $V_{GS} = +V_{GG}$ $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ $V_{DS} = V_{DD} - I_D R_D$		$Z_i = R_G$ $Z_o = r_d \parallel R_D$ $A_v = -g_m Z_o$ $g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$ $g_{mo} = \frac{2 I_{DSS}}{V_P}$ $r_d = \frac{\Delta V_{DS}}{\Delta I_D}$
2) Self Bias 		$V_{GS} = -I_S R_S = -I_D R_S$ $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ $V_{DS} = V_{DD} - I_D(R_D + R_S)$		$r_d = \frac{1}{y_{os}}$ $g_{mo} = \frac{2 I_{DSS}}{V_P}$ $g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$ $Z_i = R_G$ $Z_o = r_d \parallel R_D$ $A_v = -g_m Z_o$
3) Voltage Divider 		$V_G = \frac{R_2}{R_1 + R_2} \times V_{DD}$ $V_{GS} = V_G - V_S$ $V_{GS} = V_{DD}\left(\frac{R_2}{R_1 + R_2}\right) - I_D R_S$ $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ $V_{DS} = V_{DD} - I_D(R_D + R_S)$		$Z_i = R_1 \parallel R_2$ $Z_o = r_d \parallel R_D$ $A_v = -g_m (r_d \parallel R_D)$ $g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$

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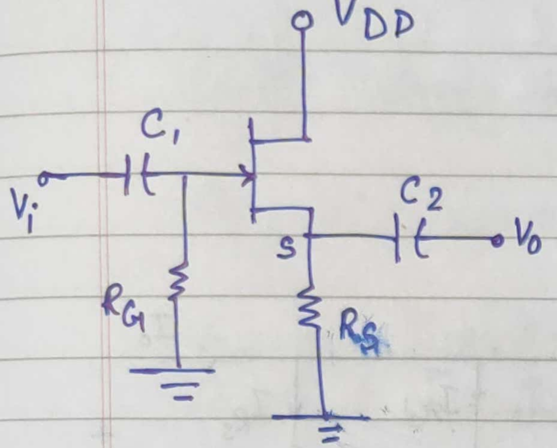
Source Follower (Common Drain) ⇒



o/p is taken at Source

AC equivalent → (Small Signal Analysis)

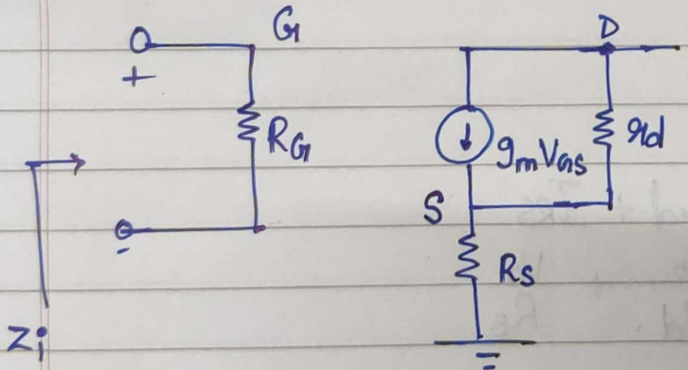


Fig-2

⇓

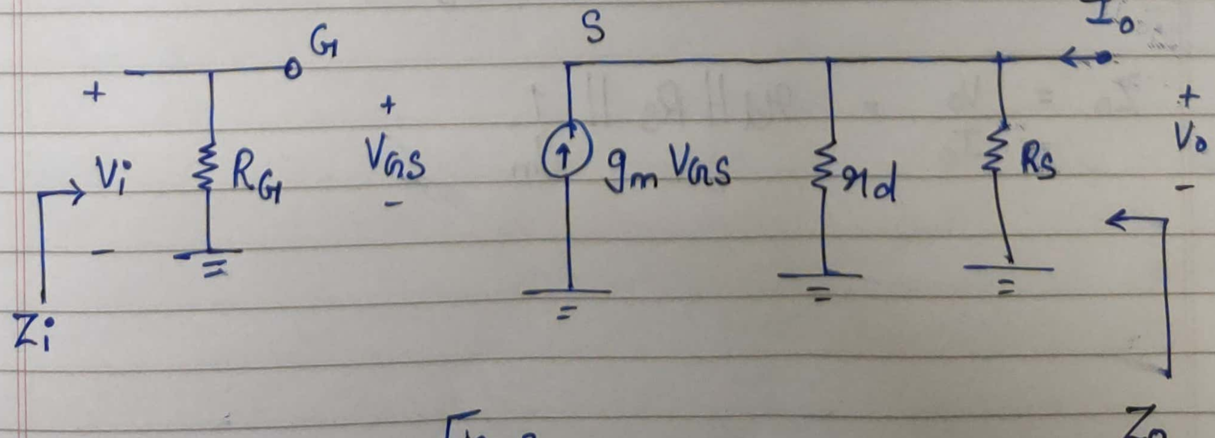
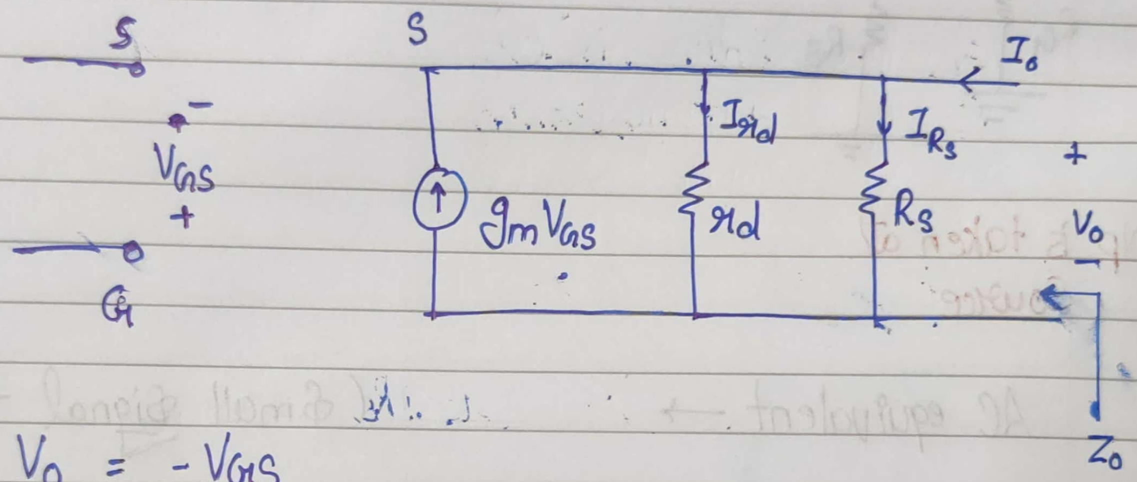


Fig-3

(i) $Z_i = R_G$

(ii) $Z_o = \left.\dfrac{V_o}{I_o}\right|_{V_i = 0}$



(a) $V_o = -V_{GS}$

(b) Applying KCL at S

$$g_m V_{GS} + I_o = I_{rd} + I_{RS}$$
$$= \frac{V_o}{r_d} + \frac{V_o}{R_S}$$

$$I_o - g_m V_o = \frac{V_o}{r_d} + \frac{V_o}{R_S} \Rightarrow I_o = V_o\left(g_m + \frac{1}{r_d} + \frac{1}{R_S}\right)$$

$$Z_o = \frac{V_o}{I_o} = r_d \parallel R_S \parallel \frac{1}{g_m}$$

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(iii) Voltage Gain $A_v = \frac{V_o}{V_i}$

fig ③ Apply KVL in loop

ⓐ $V_i = V_{gs} + V_o \Rightarrow V_{gs} = V_i - V_o$

$$\frac{V_o}{V_i} = \frac{g_m(r_d \| R_s)}{1 + g_m(r_d \| R_s)}$$

ⓑ $V_o = g_m V_{GS}(r_d \| R_s)$

$$V_o = g_m(V_i - V_o)(r_d \| R_s)$$

Que.) A Source follower ckt has $V_{GSQ} = -2.86V$
$I_{DQ} = 4.56 mA$, $I_{DSS} = 16mA$, $V_P = -4v$
$y_{os} = 25 \mu S$, $R_S = 2.2 K\Omega$, $R_G = 1 M\Omega$
$V_{DD} = 9v$

Determine
(i) g_m
(ii) r_d
(iii) Z_i
(iv) Z_o with & without r_d. Compare the result.
(v) Determine A_v with & without r_d.

→

(i) $g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$

$g_{mo} = \left|\frac{2 I_{DSS}}{V_P}\right| = \frac{2 \times 16 \times 10^{-3}}{4} = 8 mS$

$g_m = 8 \times 10^{-3}\left(1 - \frac{2.86}{4}\right)$

$g_m = 2.28 \ mS$

(ii) $r_d = \frac{1}{y_{os}} = \frac{10^6}{25} = 40 K\Omega$

(iii) $Z_i = R_G = 1 M\Omega$

(iv) with r_d

$Z_o = r_d \,||\, R_S \,||\, \frac{1}{g_m}$

$Z_o = 362.378 \ \Omega$

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without r_d.

$$Z_o = R_S \parallel \frac{1}{g_m} = \frac{1}{\cancel{R_S} + \frac{1}{R_S} + g_m}$$

$$Z_o = 365.69\,\Omega$$

(v) with r_d

$$A_V = \frac{g_m(r_d \parallel R_S)}{1 + g_m(r_d \parallel R_S)} = \frac{1}{1 + \frac{1}{g_m(r_d \parallel R_S)}}$$

$$A_V = 0.826$$

without r_d

$$A_V = 0.83$$

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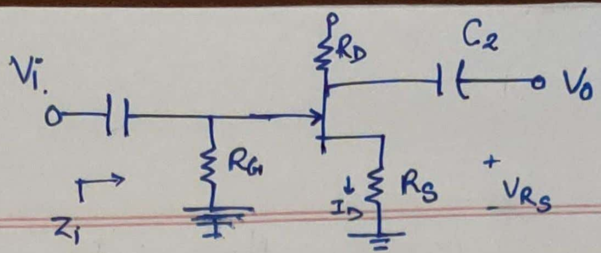
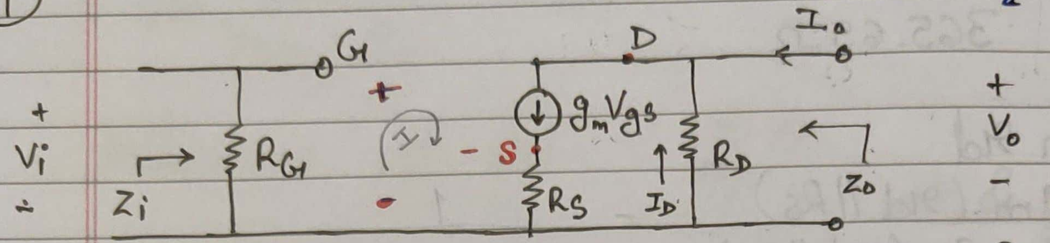


⇒ FET Self Bias Unbypassed R_s

(i)



(i) when r_d is not included in ckt

i) $Z_i = R_G$

ii) $Z_o = \left.\dfrac{V_o}{I_o}\right|_{V_i=0} = -\dfrac{I_D R_D}{I_o}$

Applying kcl at node D ⇒ $I_o + I_D = g_m V_{gs}$ —(i)

—, KVL GS loop ⇒ $V_{gs} = -(I_o + I_D) R_S$ —(ii)

$V_{gs} + V_{R_S} = 0$ | ↳ $V_i = 0$ ⇒ $V_{gs} + (g_m V_{gs}) R_S = 0$

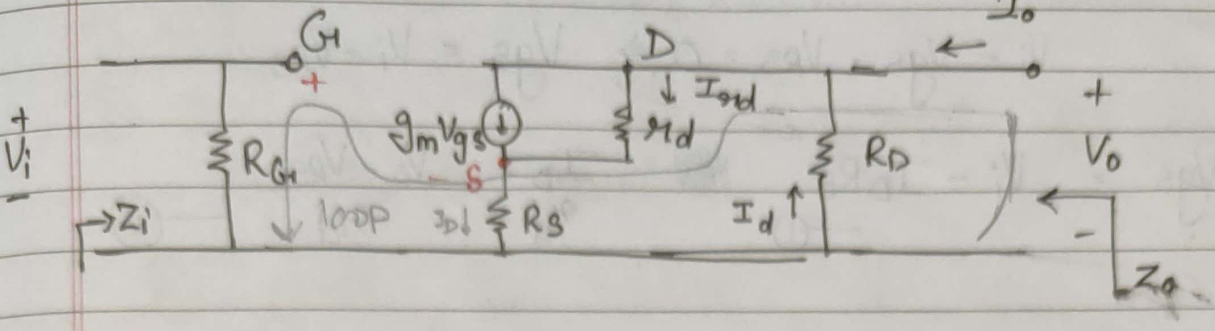
Substituting (ii) in (i)

$$I_D + I_o = -g_m (I_o + I_D) R_S$$

$(I_o + I_D)(1 + g_m R_S) = 0$ ⇒ $\boxed{I_o = -I_D}$

Hence, $\boxed{Z_o = R_D}$

(ii) When r_d is included in the ckt $\longrightarrow$



Applying KCL at Drain D $\Rightarrow$ $I_o = g_m V_{gs} + I_{rd} - I_D$ — (i)

Applying KVL at DSG loop $\Rightarrow$ $V_{rd} = V_o + V_{gs}$ — (ii)

$\hookrightarrow V_o - V_{rd} + V_{gs} = 0$

Substituting (ii) in (i)

$I_{rd} = \frac{V_{rd}}{r_d}$

$$I_o = g_m V_{gs} + \frac{V_o + V_{gs}}{\cancel{I_{rd}}\, r_d} - I_D \quad \text{— (iii)}$$

Substituting $V_o = -I_D R_D$ and $V_{gs} = -(I_o + I_D) R_S$ in (iii) and rearranging

$$I_o = \frac{-I_D\left[1 + g_m R_S + \frac{R_S}{r_d} + \frac{R_D}{r_d}\right]}{1 + g_m R_S + \frac{R_S}{r_d}} \quad \text{— (iv)}$$

$$Z_o = \frac{V_o}{I_o}$$

$$Z_o = \frac{-I_D R_D}{I_o}$$ Substituting I_o from (iv) we get

$$Z_o = \frac{1 + g_m R_S + \frac{R_D}{r_d}}{1 + g_m R_S + \frac{R_S}{r_d} + \frac{R_D}{r_d}} \times R_D$$

$V_o = -I_D R_D$, $V_{RS} = I_D R_S$

(iii) Applying KVL in I/P

$$V_i - V_{gs} - V_{RS} = 0 \Rightarrow V_{gs} = V_i - V_{RS}$$

$$V_{gs} = V_i - I_D R_S \quad \text{—(1)}$$

$$\frac{I_D}{r_d} = \frac{V_o - V_{RS}}{r_d} \quad \text{—(2)}$$

Apply KCL at S $\Rightarrow$ $I_D = g_m V_{gs} + \frac{V_o - V_{RS}}{r_d}$

$$I_D = g_m (V_i - V_{RS}) + \frac{V_o - V_{RS}}{r_d}$$

$$I_D = \frac{g_m V_i}{1 + g_m R_S + \frac{R_D + R_S}{r_d}} \quad \text{—(3)}$$

$$A_V = \frac{V_o}{V_i} = \frac{-I_D R_D}{V_i}$$

Substituting I_D from (3)

$$A_V = -\frac{g_m R_D}{1 + g_m R_S + \frac{R_D + R_S}{r_d}}$$

Que.1) A self bias Configuratⁿ has a operating point $V_{GSQ} = -2.6V$

$I_{DSS} = 8mA$, $V_p = -6V$, $y_{os} = 20\ \mu S$.

(i) Determine g_m, r_d, Z_i,

(ii) Calc. Z_o, A_v with & without effect of r_d. Compare the result.

$R_G = 1M\Omega$, $R_D = 3.3K\Omega$, $R_S = 1K\Omega$

⇒

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$$

$$g_{mo} = \left|\frac{2I_{DSS}}{V_P}\right| = \left|\frac{2 \times 8\times10^{-3}}{6}\right| = 2.66\times10^{-3}\ S$$

(i) $$g_m = 2.66\times10^{-3}\left(1 - \frac{2.6}{6}\right) =$$

$$g_m = 1.5\ mS$$

$$r_d = \frac{1}{y_{os}} = \frac{10^6}{20} = 5\times10^4\ \Omega$$

$$Z_i = R_G = 1M\Omega$$

(ii) $$Z_o = \frac{-I_D R_D}{I_o}$$ ⇒ $Z_o = R_D = 3.3\ K\Omega$ (Ignoring r_d)

without r_d ⟶ $$A_V = \frac{-g_m R_D}{1 + g_m R_S + \frac{R_D + R_S}{r_d}}$$

$$A_V = \frac{-1.5\times10^{-3} \times 3.8\times10^3}{1 + 1.5\times1 + \frac{(3.3+1)\times10^3}{5\times10^4}}$$

$$A_V = -1.914$$

if $r_d > 10(R_D + R_S) \Longrightarrow$ ignore r_d

Considering r_d, $\Rightarrow$

$$Z_o = \frac{1 + g_m R_S + \frac{R_D}{r_d}}{1 + g_m R_S + \frac{R_S}{r_d} + \frac{R_D}{r_d}} \times R_D$$

$Z_o = 3.299\ K\Omega$

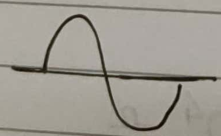
without $r_d \Rightarrow$

$A_V = -1.9$

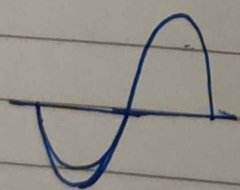
(iii) Sinosoidal i/p 1V peak-peak 1HZ. Draw o/p Sinosoidal waveform.

$\Rightarrow$

i/p → (1v)



o/p → (2V)



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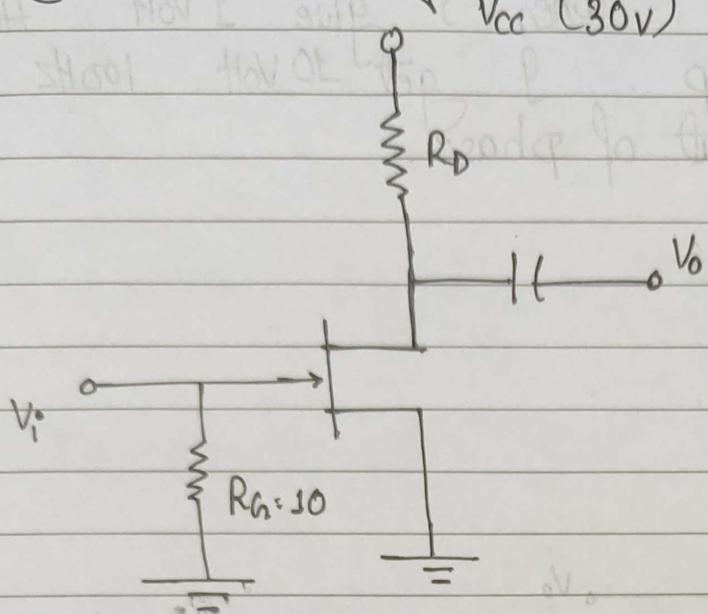
Que) Design a fixed bias ckt having ~~a~~ AC voltage gain of 10 as given in a fig.



$I_{DSS} = 10mA$
$V_p = -4v$
$Y_{os} = 20\mu S$

⇒

$V_{GS_Q} = 0v$, $R_S = 0$

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right) \Rightarrow g_m = g_{m_0}$$

$$g_{m_0} = \left|\frac{2 I_{DSS}}{V_P}\right| = \left|\frac{2\times10}{4}\right| = 5\ mS \Rightarrow \boxed{g_m = 5mS}$$

$$r_d = \frac{1}{Y_{os}} \Rightarrow \boxed{r_d = 5\times10^4\ \Omega}$$

AC Gain = -10 $\Rightarrow A_V = \cancel{\dfrac{-g_m R_D}{1 + g_m R_S + \dfrac{R_D + R_S^{\,0}}{r_d}}}$

$\cancel{R_D = r_d\left(\dfrac{-g_m R_D}{g_m}\right)}$

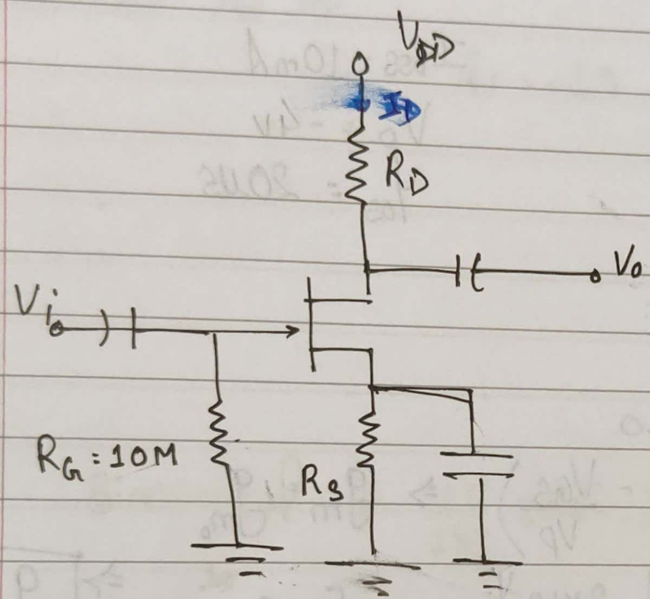
$$A_V = -g_m (r_d || R_D) \Rightarrow \frac{1}{\dfrac{1}{r_d} + \dfrac{1}{R_D}} = \frac{-A_V}{g_m}$$

$$\frac{1}{r_d} + \frac{1}{R_D} = \frac{-g_m}{A_V} = \frac{10^{-3}}{2} \Rightarrow \frac{1}{R_D} = \frac{10^{-3}}{2} - 20\times10^{-6}$$

$$\boxed{R_D = 2\ K\Omega}$$

Que.) Design a fixed bias network using JFET having $I_{DSS} = 10mA$, $V_p = -4v$, $R_G = 10M\Omega$, $y_{os} = 20\mu S$ Supply Volt < 30v. when I give 1 volt ~~Hz~~ 100 Hz Sinosoidal i/p. I get 10 Volt 100Hz Sin o/p with o/p 180° out of phase.

Que.2)



$I_{DSS} = 10mA$

$V_p = -4v$

$y_{os} = 20\mu S$

$A_v = -8$

$V_{GQ} = \frac{1}{4} V_p = -1v$

$g_{m_0} = ?\quad g_m$

$$\Rightarrow g_{mo} = \left| \frac{2 I_{DSS}}{V_p} \right| = \left| \frac{2 \times 10 \times 10^{-3}}{-4} \right| = 5 mS$$

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_p}\right) = 5\left(1 - \frac{1}{4}\right) = 3.75 mS$$

~~$r_d =$~~

$$A_v = -g_m (r_d \,||\, R_D) \Rightarrow \frac{1}{r_d} + \frac{1}{R_D} = \frac{-g_m}{A_v} = 4.68 \times 10^{-4}$$

$$\frac{1}{R_D} = 4.68 \times 10^{-4} - 20 \times 10^{-6} = 4.48 \times 10^{-4}$$

$$\boxed{R_D = 2.2 K\Omega}$$

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DC Analysis $\longrightarrow$

$$V_{GS_Q} = -I_D R_S$$

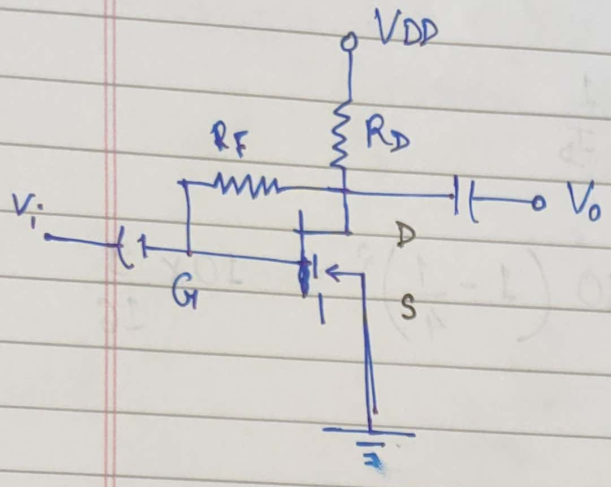
$$R_S = \frac{1}{I_D}$$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 10\left(1 - \frac{1}{4}\right)^2 = 10 \times \frac{9}{16}$$

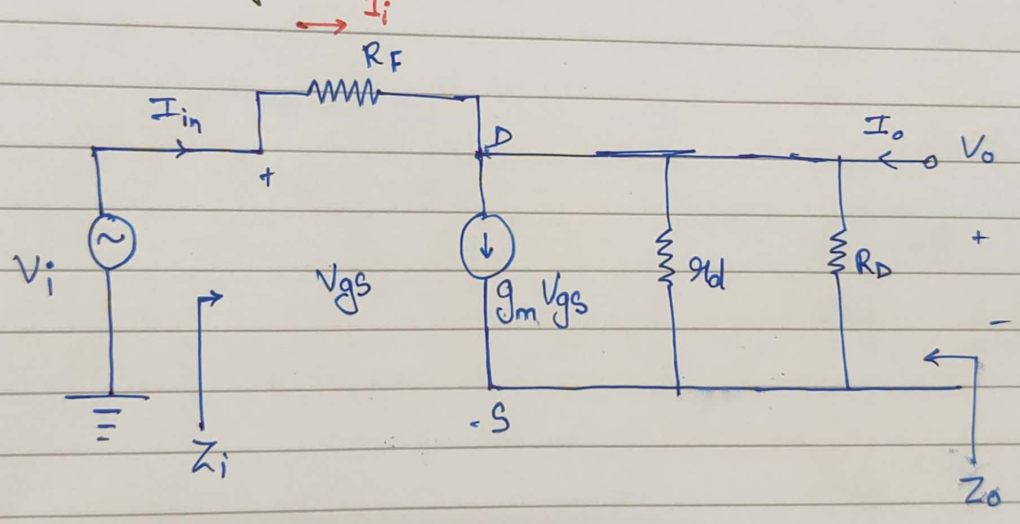
$$I_D = 5.625 \text{ mA}$$

Enhancement MOSFET

Drain Feedback Configuratⁿ →



Small Signal Equivalent model



~~Drain F~~

$$A_V = \left.\frac{V_o}{V_i}\right|_{R_L = \infty}$$

KCL at D

$$I_i = g_m V_{gs} + \frac{V_o}{r_d \parallel R_D} \qquad [V_{gs} = V_i]$$

$$\frac{V_i - V_o}{R_F} = g_m V_i + \frac{V_o}{r_d \parallel R_D}$$

$$A_V = \frac{V_o}{V_i} = \frac{\frac{1}{R_F} - g_m}{\left[\frac{1}{r_d \parallel R_D} + \frac{1}{R_F}\right]}$$

$$A_v = -g_m (R_F \parallel r_d \parallel R_D)$$

$$\cancel{A_v = \frac{-g_m R_D}{g_m}}$$ If $R_1 >> R_D \parallel r_d$

and $\frac{1}{R_F} + \frac{1}{r_d \parallel R_D} = \frac{1}{R_F \parallel r_d \parallel R_D}$

and $g_m >> \frac{1}{R_F}$

$$A_V = -g_m R_D$$

Drain feedback Configuratⁿ ⟶

$$Z_i = \frac{V_i}{I_i}$$

Applying kcl at D

$$I_i = g_m V_{GS} + \frac{V_o}{r_d \parallel R_D} \qquad [V_{gs} = V_i]$$

$$I_i - g_m V_i = \frac{V_o}{r_d \parallel R_D} \Rightarrow V_o = r_d \parallel R_D (I_i - g_m V_i)$$

$$I_i = \frac{V_i - V_o}{R_F} = \frac{V_i - (r_d \parallel R_D)(I_i - g_m V_i)}{R_F}$$

$$Z_i = \frac{V_i}{I_i} = \frac{R_F + r_d \parallel R_D}{1 + g_m (r_d \parallel R_D)}$$

If $R_F >> r_d \parallel R_D$ $\quad Z_i = \frac{R_F}{1 + g_m (r_d \parallel R_D)}$

$$Z_o = \left.\frac{V_o}{I_o}\right|_{V_i = 0} \Rightarrow \boxed{Z_o = R_F \parallel r_d \parallel R_D}$$

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}} = \frac{\partial I_D}{\partial V_{GS}}$$

$$I_D = k(V_{GS} - V_T)^2$$

$$\frac{\partial I_D}{\partial V_{GS}} = 2k(V_{GS} - V_T)$$

$$\boxed{g_m = 2k(V_{GS} - V_T)} \longleftrightarrow \text{Enhancement MOSFET}$$

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Que) For a Enhancement type MOSFET Connected in drain feedback Configuration ($K = 0.24 \times 10^{-3}$ A/V^2)

$V_{GS_Q} = 6.4V$, $V_T = 3V$, $y_{os} = 20\mu S$, $R_D = 2K\Omega$

$R_F = 10M\Omega$. Calculate

(i) g_m, r_d, Z_i, Z_o, A_v

⇒

$$g_m = 2K(V_{GS_Q} - V_T)$$

$$g_m = 2 \times 0.24 \times 10^{-3} (6.4 - 3) = 1.6 \times 10^{-3} \ S$$

$$r_d = \frac{1}{y_{os}} = 50 K\Omega$$

$$Z_i = \frac{R_F + r_d || R_D}{1 + g_m(r_d || R_D)} = \frac{10 \times 10^6 + (50 \times 10^3 || 2 \times 10^3)}{1 + 1.6 \times 10^{-3}(50 \times 10^3 || 2 \times 10^3)}$$

$$Z_i = 2.4 M\Omega$$

$$Z_o = R_F || r_d || R_D = \frac{1}{\frac{1}{R_F} + \frac{1}{r_d} + \frac{1}{R_D}}$$

$$Z_o = 1.9 K\Omega$$

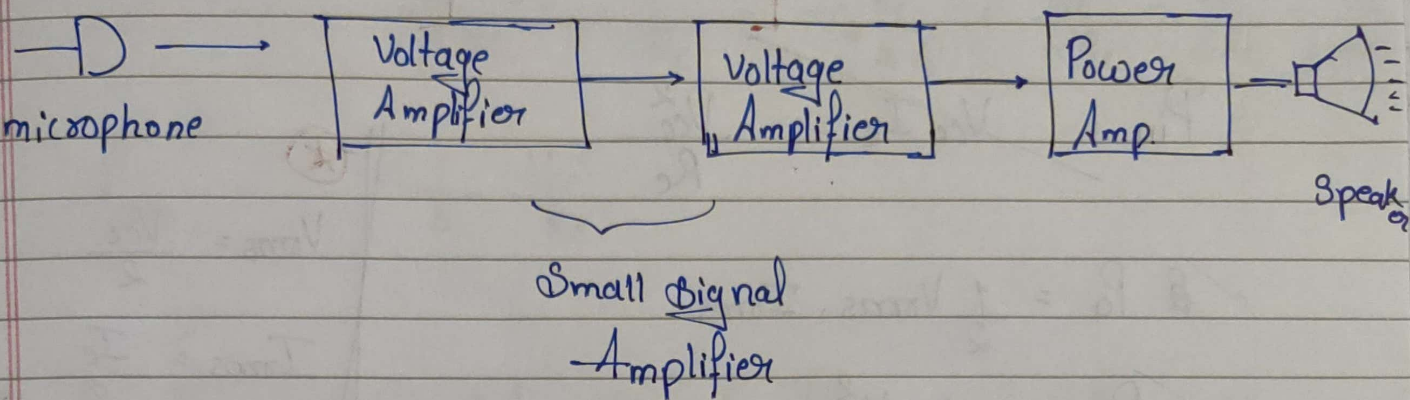
$$\cancel{A_v = -g_m R_D} = - \cancel{1.6 \times 10^{-3} \times 2 \times 10^3}$$

$$\cancel{A_v = -3.2} \qquad A_v = -g_m (R_F || r_d || R_D)$$

$$A_v = -1.6 \times 10^{-3} \times \overset{1.9}{\cancel{2.4}} \times 10^3$$

$$A_v = \cancel{-3.84} \ -3.04$$

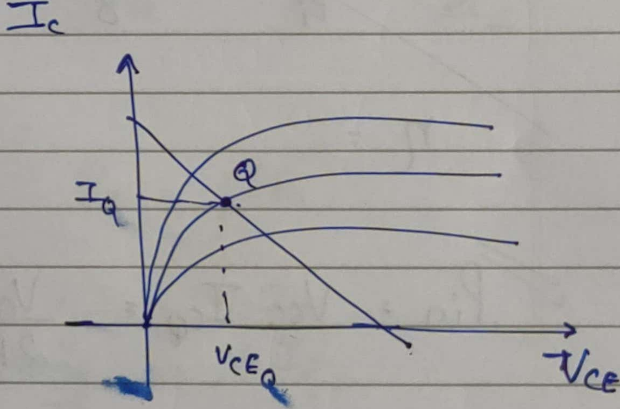
Large Signal Amplifier (Power Amplifier) ⇒



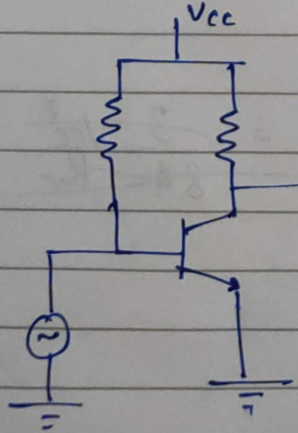
Common Collector ⟶ Z_o = Low

Types of Power Amplifier ⟶

1. Class A → conductⁿ angle is 360°
2. Class B ⟶ " — 180°
3. Class AB ⟶ b/w π to 2π
4. Class C ⟶ conductⁿ angle $\theta < \pi$



(i) Class A ⇒



$$P_{in} = V_{cc}(I_c + I_B)$$

$$P_o = \frac{V_{rms}}{\sqrt{2}} \times \frac{I_{rms}}{\sqrt{2}} = \frac{1}{2} V_{rms} I_{rms}$$

$I_C \gg I_B$

$$\boxed{I_c = \frac{V_{cc}}{R_c}}$$

$$\cancel{P_{in} = V_{cc} I_c} = \frac{V_{cc}^2}{R_c}$$

$$V_{rms} = \frac{V_{cc}}{2}$$

$$I_{rms} = \frac{I_c}{2} = \frac{V_{cc}}{2R_c}$$

$$P_o = \frac{1}{2} V_{rms} \cdot I_{rms}$$

$$P_o = \frac{1}{8} \frac{V_{cc}^2}{R_c}$$

$$\cancel{\eta = \frac{P_o}{P_i} = \frac{1}{8}}$$

$$\eta =$$

$$I_{C_Q} = \frac{I_c}{2}$$

$$P_{in} = V_{cc} I_{CQ} = \frac{V_{cc}^2}{2R_c}$$

$$\eta = \frac{P_o}{P_i} = \frac{1}{4} \Rightarrow \boxed{\eta = 25\%}$$

$$\cancel{P_{diss.} = P_{in} - P_o = \frac{V_{cc}^2}{2R_c} - \frac{V_{cc}^2}{8R_c} = \frac{3}{8} \frac{V_{cc}^2}{R_c}}$$

$$P_{R_c} = I_{C_Q}^2 R_c = \frac{I_c^2 R_c}{4}$$

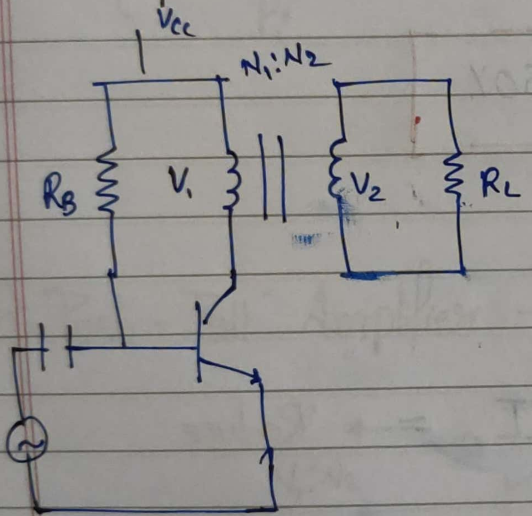
$$\frac{1}{2} - \frac{1}{8} - \frac{1}{4} = \frac{4-1-2}{8}$$

$$P_{dissipat^n} = P_{in} - P_o - P_{R_C}$$

$$= \frac{V_{CC}^2}{2R_C} - \frac{V_{CC}^2}{8R_C} - \frac{I_C^2 R_C}{4} = \frac{V_{CC}^2}{2R_C} - \frac{V_{CC}^2}{8R_C} - \frac{V_{CC}^2}{4R_C}$$

$$P_{diss.} = \frac{1}{8}\frac{V_{CC}^2}{R_C}$$

Transformer Coupled class A Power Amplifier →



$$n = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$$

$$R_C = f(R_L)$$

$$V_1 I_1 = V_2 I_2$$

$$\frac{V_1 I_1}{I_1^2} = \frac{V_2 I_2}{I_1^2}$$

$$\frac{V_1}{I_1} = \frac{V_2}{I_1} \times \frac{I_2}{I_1}$$

$$R_C = \frac{V_2}{I_2} n^2$$

$$\boxed{R_C = n^2 R_L}$$

$V_{CEQ} \approx V_{CC}$

$V_{rms} = V_{CC}$

$I_{rms} = \frac{V_{CC}}{R_C}$

$P_{in} = V_{CC} \cdot I_{CQ} = V_{CC} \cdot \frac{V_{CC}}{R_C}$

$P_{in} = \frac{V_{CC}^2}{R_C}$

$P_{out} = \frac{1}{2} V_{rms} I_{rms} = \frac{V_{CC}^2}{2R_C}$

$\eta = \frac{P_o}{P_i} = \frac{1}{2} \Rightarrow \boxed{\eta = 50\%}$

class B

$V_{rms} = V_{CC}$

$I_{rms} = \frac{V_{CC}}{R_C}$

$I_C \Longrightarrow$ Reduce

$P_{in} = V_{CC} \cdot I_{QC}$

$P_{in} = \frac{V_{CC}^2}{\pi R_C}$

$P_o = \frac{1}{2} V_{rms} I_{rms}$

$P_o = \frac{1}{2} V_{CC} \cdot \frac{V_{CC}}{R_C} = \frac{V_{CC}^2}{2R_C}$

$\eta = \frac{P_o}{P_i} = \frac{\pi}{2}$

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$$P_{out} = \frac{1}{2}\cancel{(V_{rms} \cdot I_{rms})}$$

Half wave

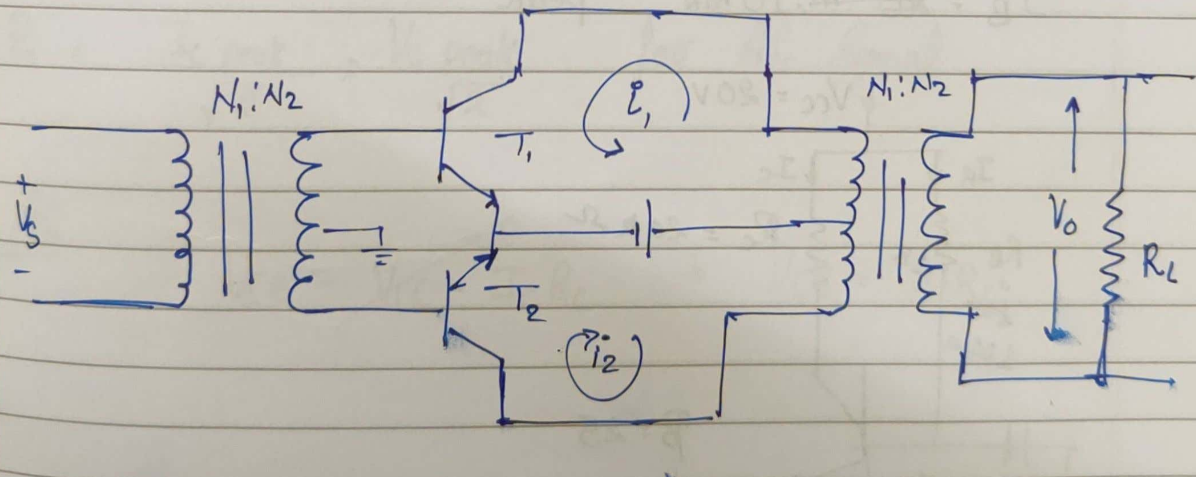
$$\cancel{P_o = \frac{1}{2}(V_m \cdot I_m)}$$

$$P_o = \frac{1}{2}\left(\frac{V_{rms}}{\sqrt{2}} \cdot \frac{I_{rms}}{\sqrt{2}}\right) = \frac{1}{4} V_{rms} I_{rm}$$

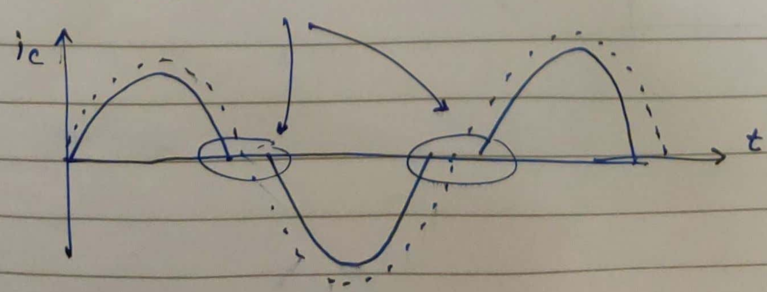
$$P_o = \frac{1}{4}\frac{V_{cc}^2}{R_C}$$

$$\eta = \frac{P_o}{P_i} = \frac{\pi}{4} \Rightarrow \boxed{\eta = 78.54\%}$$

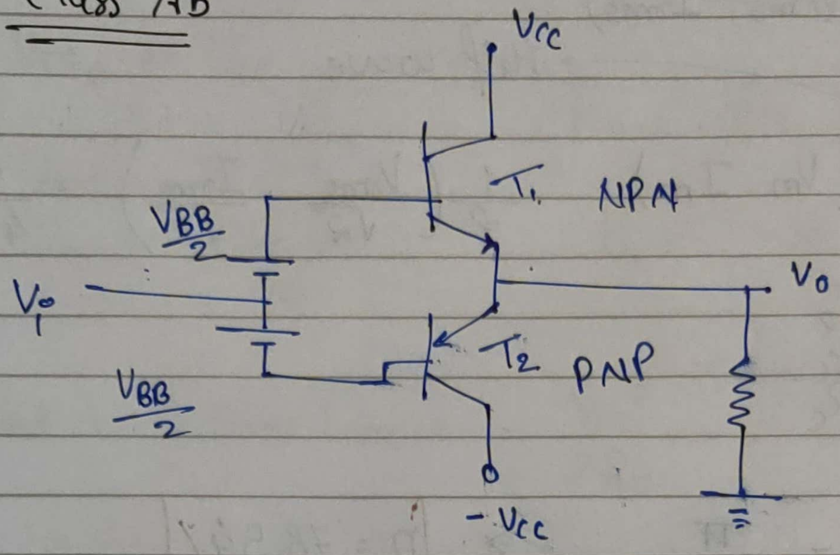
Push - Pull Amplifier ⟶



Cross over ~~Dis~~ Ditort^n

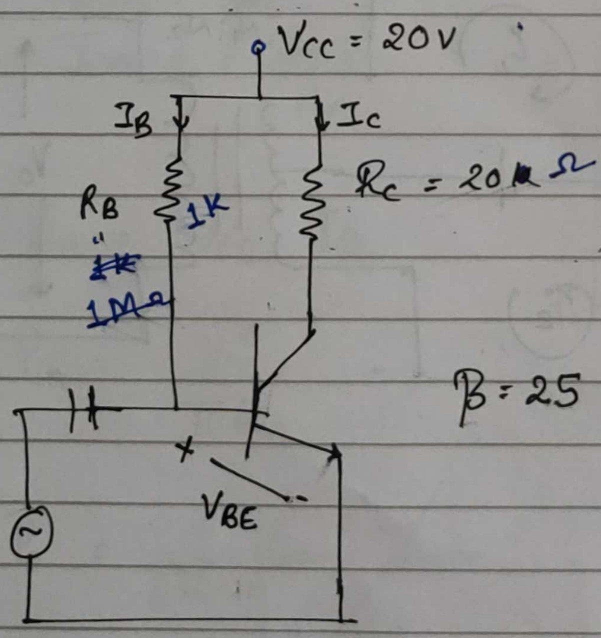


Class AB



Que. 1) P_{in}, P_o, η & ~~max.~~ Value ~~of these quantities~~

I_B = ~~20 m~~ .10 mA peak



$\beta = 25$

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$P_i = V_{cc} I_{CQ}$

$V_{cc} - I_C R_C - V_{CE} = 0$

$V_{CE} = 20 - 20 \times 10^3 I_C$

$V_{CE_Q} = 20(1 - 10^3 I_{C_Q})$

$V_{cc} - I_B R_B - V_{BE} = 0$

$I_B = \dfrac{20 - 0.7}{10^3} = 19.3 mA$

$I_{C_Q} = \beta I_B = 482.5\ mA$

$V_{CE_Q} = 20\left(1 - \dfrac{482.5}{10^3}\right)$

$\boxed{V_{CE_Q} = 10.35\ V}$

$I_{CQ} = 482.5 mA$

$=$

$\boxed{I_{CQ} = 0.48\ \mu A}$

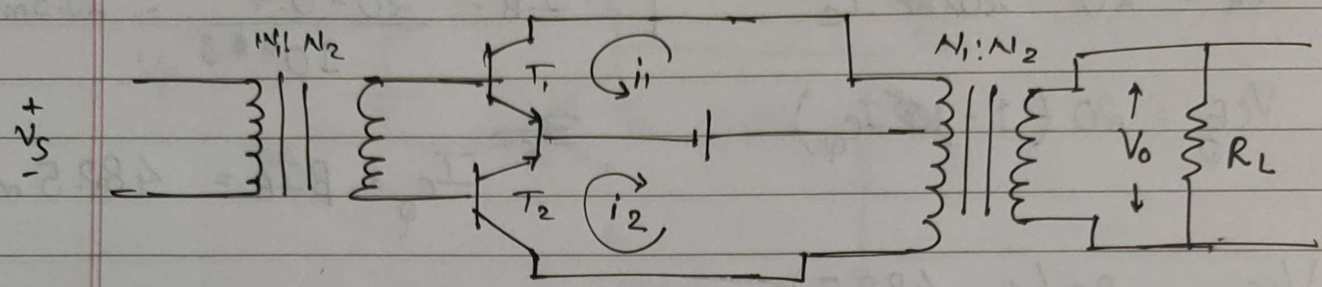
$P_i = 20 \times 0.482 \Rightarrow P_i = 9.64\ W$

$P_o = \dfrac{I_{c\ peak}}{\sqrt{2}} \times \dfrac{V_{c\ peak}}{\sqrt{2}}$ for AC Signal

AC

$V_{CE} = \cancel{V_{cc}}^{\,0} - I_C R_C \rightarrow V_{CE} = I_C R_C$

Ques) Determine P_i, P_o, η & maximum Value of these quantities for push pull amplifier shown below?



$V_{CC} = 30V$, $R_L = 16\Omega$, $\frac{N_1}{N_2} = 2$, $I_{peak} = 1A$

⇒

$P_{in} = V_{CC} I_{CQ}$

$\eta = \frac{N_1/2}{N_2} = 1$

$P_{in} = \frac{2 V_{CC}}{\pi} I_{peak}$

for

$P_{in\,max} = \frac{2 V_{CC}}{\pi} I_{peak\,(max)}$

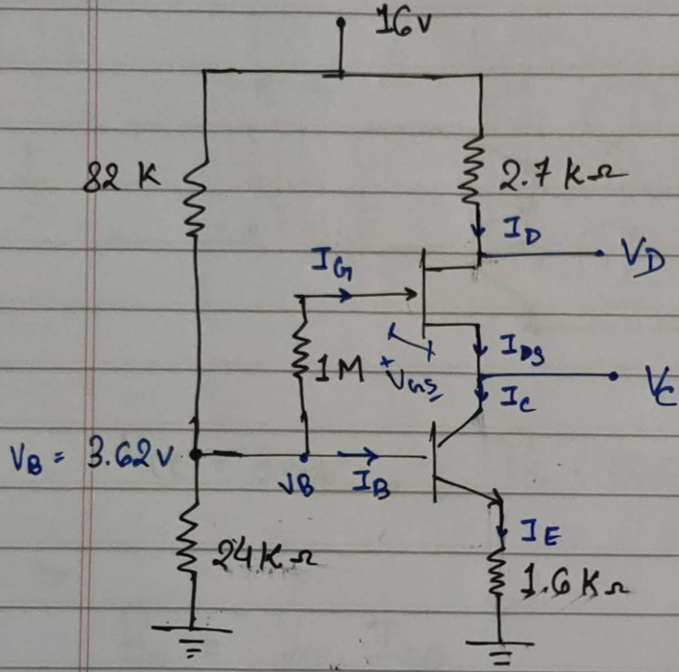
$R_L' = n^2 R_L$

$R_L' = 16$

$P_{o(ac)} = \frac{I_p^2 R_L'}{2} = 8W$

#) Combination Network ⇒

Que. 1) Find V_D & V_C , $V_B \simeq 3.62\ V$, $\beta = 180$
$I_{DSS} = 12\ mA$
$V_P = -6V$



$I_D = I_S$
$I_S = I_C$

$I_E = I_C + I_B$

⇒ $I_G = 0$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$V_{GS} = V_G - V_S$
$= V_G - V_C$

3.62 − V_{BE} − $I_E R_E$ = 0

$I_E = \frac{3.62 - 0.7}{1.6 \times 10^3}$

✓ $I_E = \cancel{1.14\ A}\ 1.82\ mA$

$I_C \simeq I_E = 1.82\ mA$

$I_E = \frac{V_E}{R_E} =$

$I_C = I_S$
$I_S = I_D = 1.82\ mA$

$$V_D = V_{DD} - I_D R_D$$
$$= 16 - 1.82 \times 2.7$$
$$V_D = 11.086 \text{ V}$$

$$I_C = \beta I_B \Rightarrow I_B = 10.1 \, \mu A$$

$$V_B - \cancel{R_G I_G}^{\,0} - V_{GS} = V_C \Rightarrow V_C = V_B - V_{GS}$$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

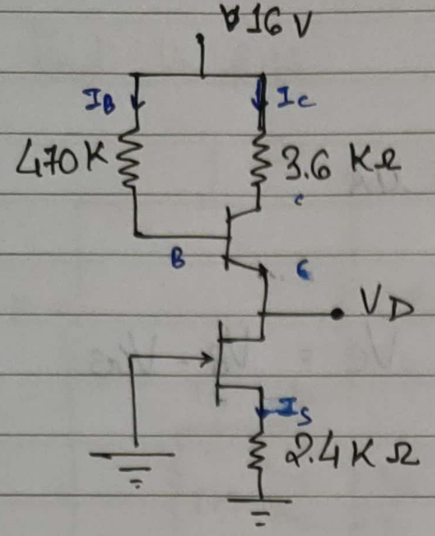
$$V_{GS} = V_P\left(1 - \sqrt{\frac{I_D}{I_{DSS}}}\right) = -6\left(1 - \sqrt{\frac{1.82}{12}}\right)$$

$$V_{GS} = -3.66 \text{ V}$$

$$V_{GS} < \begin{matrix} -3.66 \text{ v} \\ -8.33 \text{ v} \end{matrix}$$

$$V_C = 3.62 - ($$

Que. 2) V_D ?



$\beta = 80$

$I_{DSS} = 8\,mA$

$V_P = -4V$

→

$$16 - 3.6\times10^3 I_D - V_{CE} = V_D$$

$$I_E = I_D = I_S$$

$$-V_{GS} - R_S I_S = 0$$
$$V_{GS} = -I_S R_S$$
$$V_{GS} = -I_D R_S$$

$$I_D = I_{DD}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$I_D = 8\times10^{-3}\left(1 + \frac{I_D\times2.4\times10^3}{(-4}\right)^2$$

$$I_D = 1.1\ mA,\ 2.62\ mA$$

$$V_{GS} = -1.1\times2.4$$
$$V_{GS} = -2.64$$

$$I_E = 1.1mA$$

$$I_E = (\beta+1) I_B$$

$$I_B = 13.5\ \mu A$$

$$16 - 470\times10^3 I_B - V_{BE} = V_D$$

$$V_D = 16 - 470\times10^3\times13.5\times10^{-6} - 0.7$$
$$V_D = 8.955\ V$$

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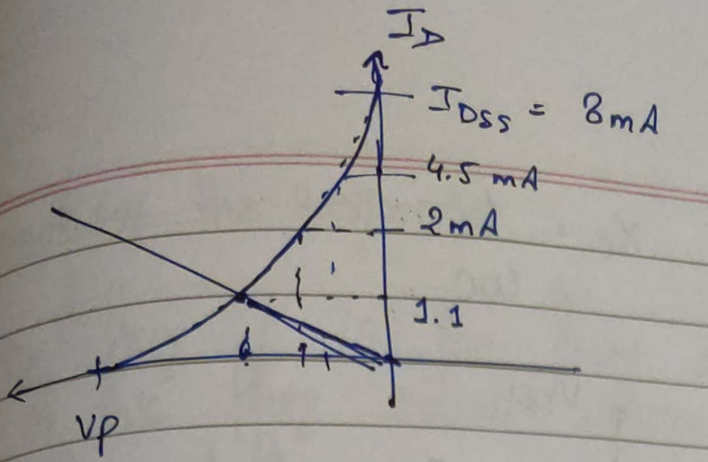
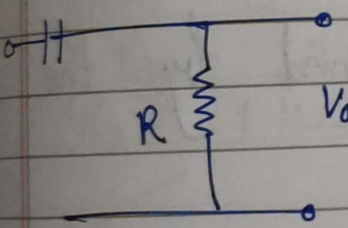


$V_{GS} = \frac{V_P}{2} \Rightarrow I_D = 2mA$

$V_{GS} = \frac{V_P}{4} \Rightarrow I_D = 4.5mA$

Frequency Response of JFET ⇒

— Low freq.
— High freq.



$V_0 = \frac{R}{R + X_C} V_i$

$|V_0| = \frac{R V_i}{\sqrt{R^2 + X_C^2}}$

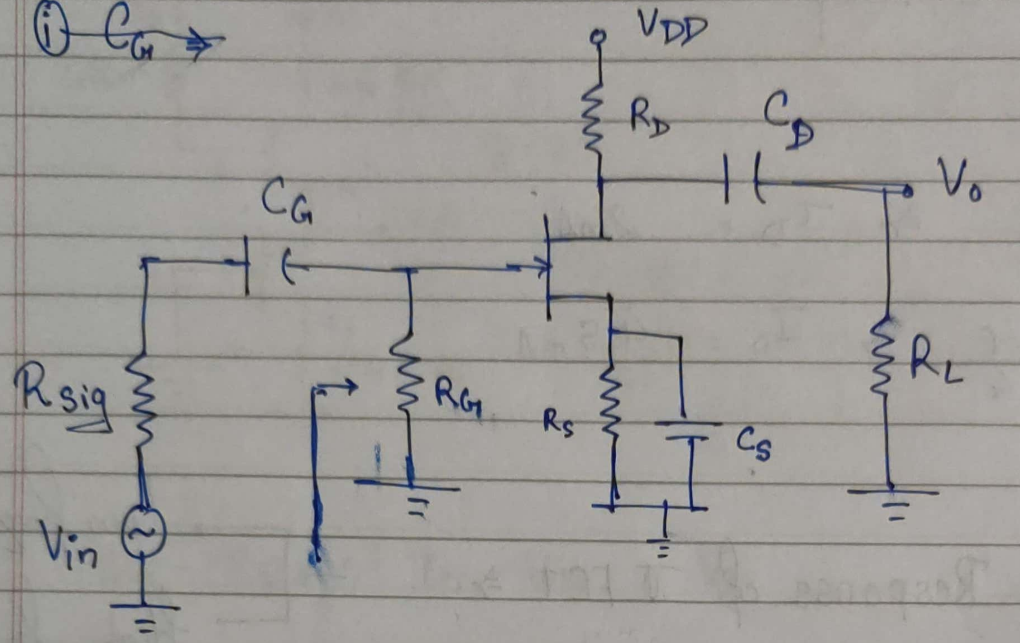
where $X_C = R$, $V_0 = \frac{1}{\sqrt{2}} V_i$

the frequency of at which $X_C = R$

$\boxed{X_C = R} \Rightarrow \frac{1}{2\pi f C} = R \Rightarrow \boxed{f = \frac{1}{2\pi RC}}$

i) Low frequency ⇒ $X_C = \frac{1}{\omega C}$

(i) C_G ⇒



The low freq. Response is determined by the Coupling & Bypass Capacitor.

(i) C_G ⇒

$$f_{C_G} = \frac{1}{2\pi(R_{sig}+Z_i)C_G} \quad , \quad Z_i = R_G$$

(ii) C_D ⇒

$$f_{C_D} = \frac{1}{2\pi(R_L+Z_o)C_D} \quad , \quad Z_o = R_D$$

(iii) C_S ⇒ $Z_o = R_S \parallel \frac{1}{g_m}$

$$f_{C_S} = \frac{1}{2\pi\left(R_S \parallel \frac{1}{g_m}\right)C_S}$$

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~~Measure the response~~

The freq. of is the freq. at which $X_C = R$.
at this freq. output voltage $V_o = 0.707\ V_i$ &
$P_o = \frac{1}{2} P_i$.

Or in terms of Gain, Gain is 3dB less.

Que.) Determine lower Cutoff freq. using low freq. response given $C_G = 0.01\ \mu F$, $C_D = 0.5\ \mu F$, $C_S = 2\ \mu F$
$R_{sig} = 10\ k\Omega$, $R_G = 1\ M\Omega$, $R_D = 4.7\ k\Omega$,
$R_S = 1\ k\Omega$, $R_L = 2.2\ k\Omega$, $I_{DSS} = 8\ mA$, $V_P = -4v$

⇒

$$f_{C_G} = \frac{1}{2\pi(10\times10^3 + 10^6)\times 0.01\times10^{-6}} = \cancel{1.57\ Hz}\ \ 15.7\ Hz$$

$$f_{C_D} = \frac{1}{2\pi(2.2\times10^3 + 4.7\times10^3)\,0.5\times10^{-6}} = 46\ Hz$$

$$g_{mo} = \left|\frac{2 I_{DSS}}{V_P}\right| = \left|\frac{-16}{4}\right| = 4mA$$

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$$

$V_{GS} = -I_D R_S$ | $I_D = I_{DSS}\left(1 + \frac{I_D R_S}{(-4)}\right)^2$

$$I_D = 8\times10^{-3}\left(1 - \frac{I_D\times10^3}{4}\right)^2$$

$$I_D = 2mA,\ 8mA$$

$$V_{GS} = -2V$$

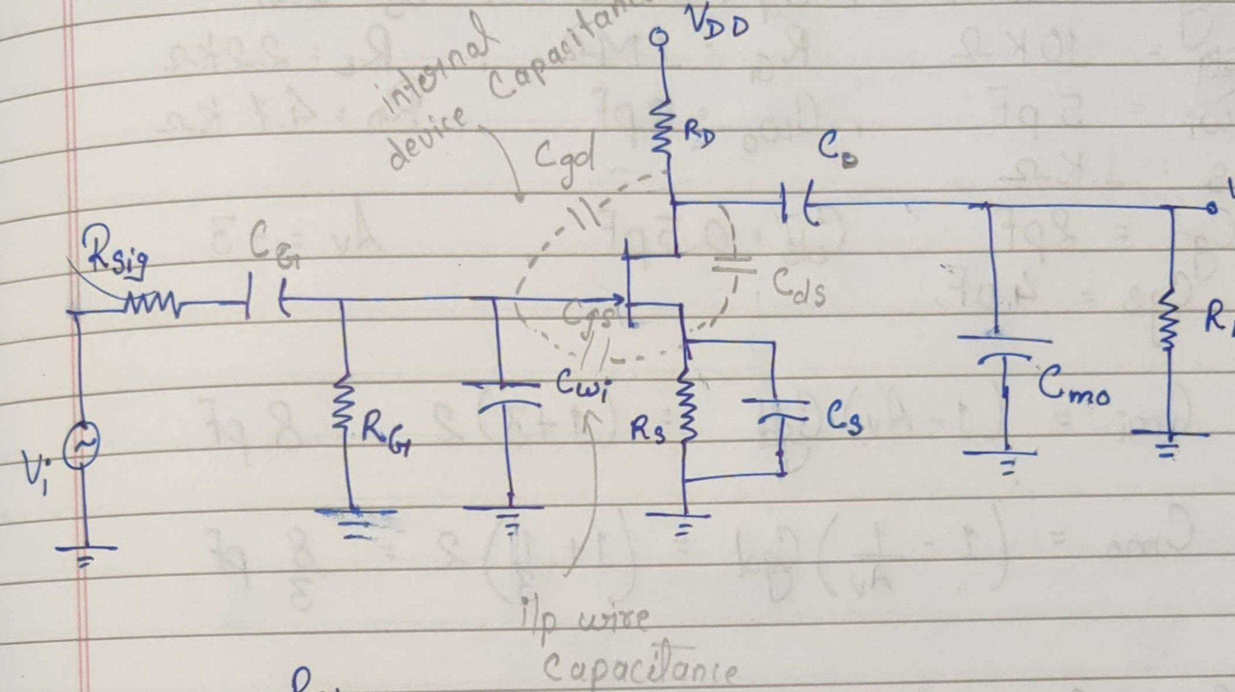
$$g_m = 4\left(1-\frac{2}{4}\right) = 2\ mS$$

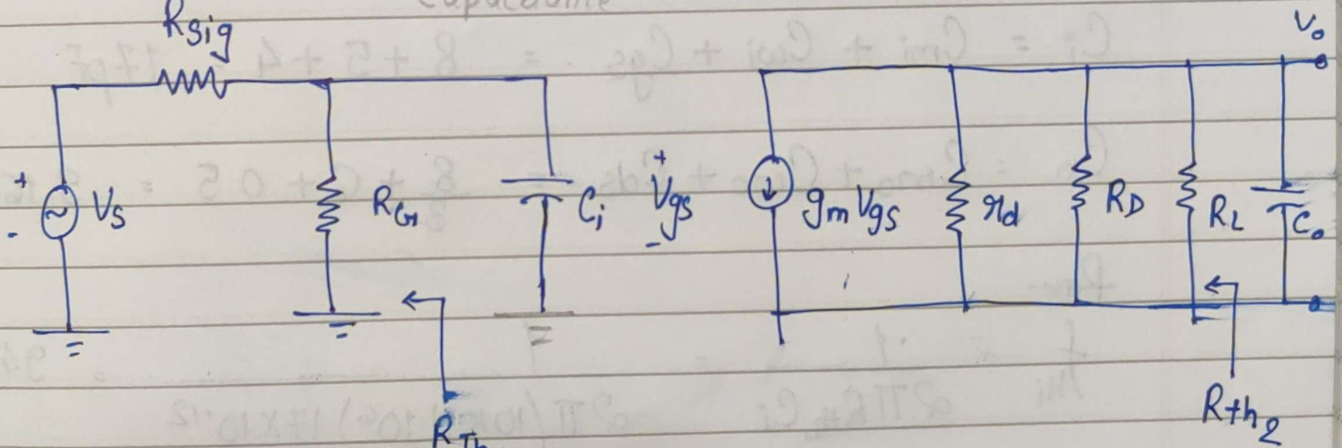
$$f_{C_S} = \frac{1}{2\pi\left(R_S \| \frac{1}{g_m}\right)C_S} = \frac{1}{2\pi\left(10^3 \| \frac{10^3}{2}\right)2\times10^{-6}}$$

$$f_{CS} = 238.73\ Hz$$

Lower cutoff freq $= f_L = f_{CS} = 238.73\ Hz$

High Frequency Response of FET ⇒





$$f_{H_i} = \frac{1}{2\pi R_{th_1} C_i}$$

$$R_{th_1} = R_{sig} \parallel R_G$$

$$C_i = C_{wi} + C_{gs} + C_{mi}$$

$$C_{mi} = (1 - A_v)\, C_{gd}$$

$$f_{H_o} = \frac{1}{2\pi R_{th_2} C_o}$$

$$R_{th_2} = r_d \parallel R_D \parallel R_L$$

$$C_o = C_{wo} + C_{ds} + C_{mo}$$

$$C_{mo} = \left(1 - \frac{1}{A_v}\right) C_{gd}$$

Que.) Determine High Cutoff freq for the fig.

$C_g = 0.01\mu F$, $C_d = 0.5\mu F$, $C_S = 2\mu F$

$R_{sig} = 10K\Omega$, $R_G = 1M\Omega$, $R_L = 2.2k\Omega$

$C_{wi} = 5pF$, $C_{wo} = 6pF$, $R_D = 4.7k\Omega$

$R_S = 1K\Omega$

$C_{gd} = 2pF$, $C_{ds} = 0.5pF$, $A_v = -3$

$C_{gs} = 4pF$

⇒

$$C_{mi} = (1-A_v)C_{gd} = (1+3)2 = 8pF$$

$$C_{mo} = \left(1-\frac{1}{A_v}\right)C_{gd} = \left(1+\frac{1}{3}\right)2 = \frac{8}{3}pF$$

$$C_i = C_{mi} + C_{wi} + C_{gs} = 8+5+4 = 17pF$$

$$C_o = C_{mo} + C_{wo} + C_{ds} = \frac{8}{3} + 6 + 0.5 = 9.166\ pF$$

~~R_{TH}~~

$$f_{Hi} = \frac{1}{2\pi R_{th} C_i} = \frac{1}{2\pi(10K \| 10^6)\,17\times10^{-12}} = 945.5\ KHz$$

$$= 0.94\ MHz$$

$$f_{Ho} = \frac{1}{2\pi R_{th} C_o} = \frac{1}{2\pi(r_d \| R_D \| R_L)\,C_o}$$

$$= \frac{\frac{1}{r_d} + \frac{1}{R_D} + \frac{1}{R_L}}{2\pi(9.166\times10^{-12})} = 11.6\ MHz$$

Higher Cutoff = min(f_{Hi}, f_{Ho}) = 0.94 MHz