Q.5. Determine the following for the voltage dividing bias network of Figure 5

a) I_{DQ} & V_{GSQ}

b) V_D

c) V_S

d) V_{DS}

e) V_{DG}

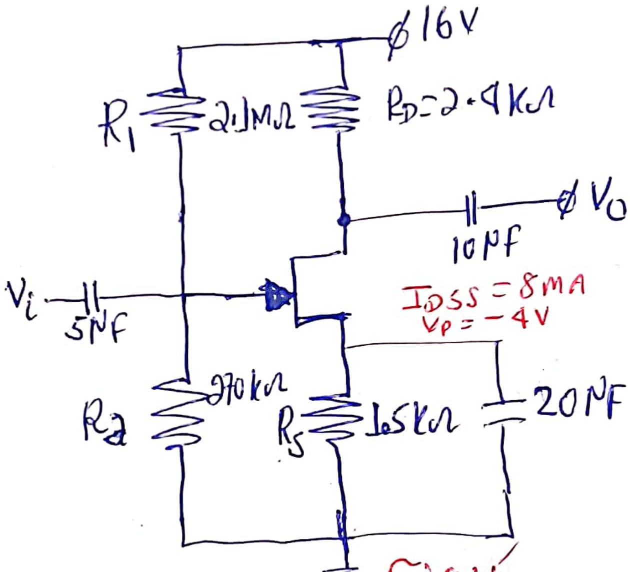


Fig:5

Sol^n Compute the Thevenins Equivalent cct.

$$V_{TH} = V_{GG} = \frac{R_2}{R_1+R_2} V_{DD} = \frac{270k\Omega}{2100k\Omega + 270k\Omega} * 16V$$

$$= \frac{270k\Omega}{2370k\Omega} \times 16V = 1.82V$$

$$R_{TH} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{2100 * 270}{2370} = 239.24k\Omega$$

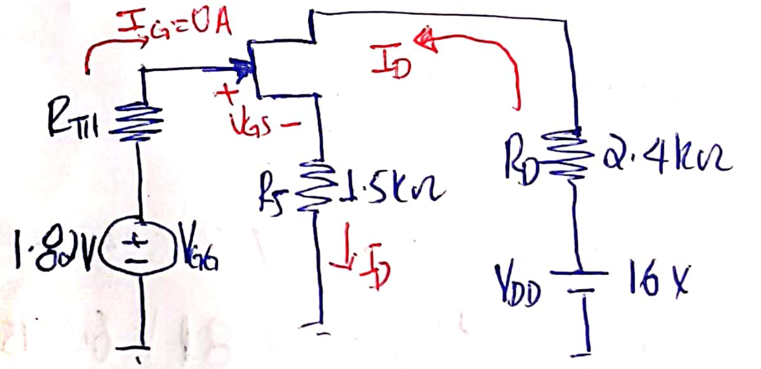


Fig:- Thevenins Equivalent cct

* Apply KVL for the I/p loop

$$V_{GG} - \cancel{I_G} R_{TH} - V_{GS} - I_D R_S = 0$$

$$\Rightarrow V_{GS} = V_{GG} - I_D R_S$$

$$V_{GS} = 1.82V - 1.5 I_D$$

* Now use Schockley's Eq^n to find I_D

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

$$= 8\left(1 - \frac{1.82 - 1.5I_D}{-4}\right)^2$$

$$I_D = 8\left(1 + \frac{1.82 - 1.5I_D}{4}\right)^2 = 8\left(\frac{5.82 - 1.5I_D}{4}\right)^2$$

$$I_D = \frac{8}{16}(5.82 - 1.5I_D)^2 = \frac{1}{2}\{33.8724 - 17.46I_D + 2.25I_D^2\}$$

$$I_D = 16.9362 - 8.73I_D + 1.125I_D^2$$

$$\Rightarrow 1.125I_D^2 - 9.73I_D + 16.9362 = 0$$

$$I_D^2 - 8.65I_D + 15.0544 = 0$$

$$I_D = \frac{8.65 \pm \sqrt{8.65^2 - 4\times 15.0544}}{2} = \frac{8.65 \pm 3.82}{2}$$

$$= 6.235mA \text{ or } 2.415mA$$

Since both the solutions are less than I_{DSS}, compute V_{GS} using both values & see for contradiction.

Using $I_D = 6.235mA$

$V_{GS} = 1.82 - 1.5I_D$

$= 1.82 - 1.5\times 6.235$

$= -7.5325V$

$\Rightarrow$ Invalid since $V_{GS} < V_P$

Using $I_D = 2.415mA$

$V_{GS} = 1.82 - 1.5I_D$

$= 1.82 - 1.5\times 2.415$

$= -1.8025V$

Valid since $V_{GS} > V_P$

b) $V_D = V_{DD} - I_D R_D = 16V - 2.415mA\times 2.4k\Omega$

$= 16V - 5.796V = \underline{10.204V}$

c) $V_S = I_D R_S = 2.415mA \times 1.5k\Omega = \cancel{3.675V}$ $3.6225V$

d) $V_{DS} = V_D - V_S = (10.204 - 3.6225)V = \cancel{6.529V}$ $6.5815V$

e) ~~$V_G = V_{GS} + V_S = (-1.8025 + 3.675)V \cong 1.8725V$~~

$V_G = V_{GG} = 1.82V$

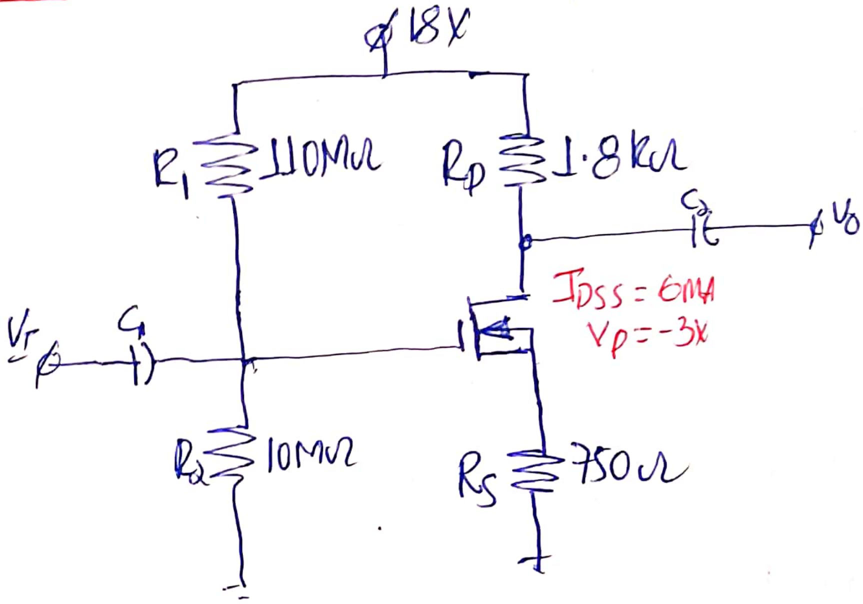
or $V_G = V_{GS} + V_S = -1.8025V + 3.6225V = 1.82V$

V_D - V_S = 10.204V - 1.82V = 8.384V

Q.6 For the n-channel depletion type MOSFET of Fig 6, determine

a) I_{DQ} & V_{GSQ}

b) V_{DS}



Soln

$$V_G = \frac{R_2}{R_1+R_2} V_{DD} = \frac{10}{120} \times 18V = \cancel{0.81818V}\ 1.5V$$

applying KVL for the i/p loop

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

$$V_{GS} = V_G - I_D R_S = 1.5V - 0.75 I_D$$

using Shockley's Equation

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 6\left(1 - \left[\frac{1.5 - 0.75 I_D}{-3}\right]\right)^2$$

$$= 6\left\{1 + \frac{1.5 - 0.75 I_D}{3}\right\}^2 = 6\left(1 + 0.5 - 0.25 I_D\right)^2$$

$$= 6\left(1.5 - 0.25 I_D\right)^2 = 6\left(\frac{6 - I_D}{4}\right)^2$$

$$I_D = \frac{6}{16}\left(6 - I_D\right)^2$$

$$\frac{16}{6} I_D = 36 - 12 I_D + I_D^2$$

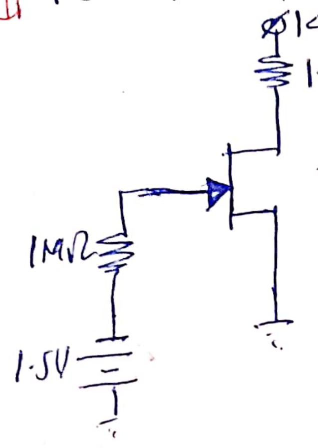
$$I_D^2 - 14.67 I_D + 36 = 0$$

Solving the quadratic Equation

$I_D = 3.115\ mA$ and $11.55\ mA$

FIXED BIAS EXAMPLE

Q1. For the fixed bias configuration shown



$I_{DSS} = 12mA$
$V_p = -4V$

a) Sketch the transfer characteristic of the device

b) Superimpose the n/w equation on the same graph

c) determine I_{DQ} & V_{DSQ}

d) Using Schockley's Equation, solve for I_{DQ} & V_{DSQ}. Compare the solutions of part c

1n

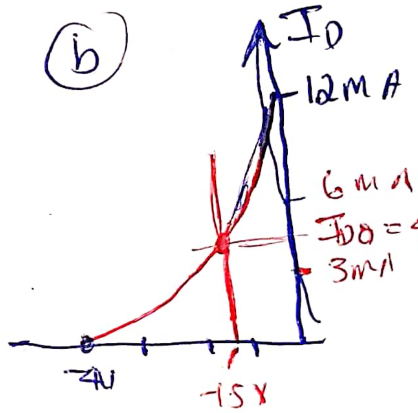
a) $V_{GS} = 0V$, $I_D = I_{DSS} = 12mA$

$V_{GS} = V_p = -4V$, $I_D = 0mA$

$V_{GS} = \frac{V_p}{2} = -2V$, $I_D = \frac{I_{DSS}}{4} = 3mA$

$V_{GS} = 0.3V_p = -1.2V$, $I_D = \frac{I_{DSS}}{2} = 6mA$

(b)



(c) $I_{DQ} = 4.7mA$

$V_{DSQ} = V_{DD} - I_{DQ}R_D = 14V - (4.7mA)(1.8k\Omega)$

$= \underline{5.54V}$

(d) $I_D = I_{DSS}(1 - V_{GS}/V_p)^2 = 12mA\left(1 - \frac{(-1.5V)}{-4V}\right)^2$

$= 12mA\left(1 - \frac{1.5}{4}\right)^2 = 12mA \times \frac{25}{64} = 4.6875mA$

$\simeq 4.69mA$

$V_{DSQ} = V_{DD} - I_{DQ}R_D$

$= 14V - (4.69mA)(1.8k\Omega)$

$= 5.56V$

Q.2 For the fixed bias configuration of Fig 2, determine

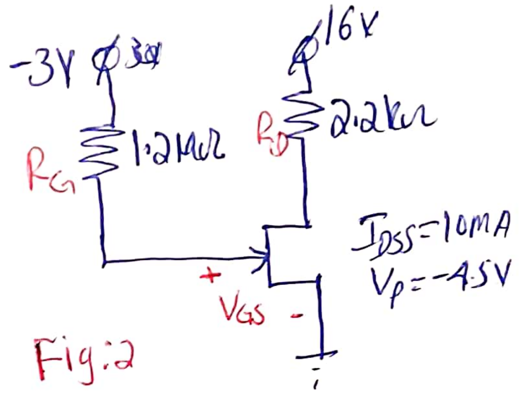


Fig:2

a) I_{DQ} & V_{GSQ} using a purely mathematical approach

b) Repeat 'a' using a graphical approach & compare results

c) V_{DS}, V_D, V_G & V_S using the results of part 'a'

Soln $I_G=0A$

@ Using KVL for the i/p loop

$$-3V - I_G \times R_G - V_{GS} = 0$$

$$-3V - V_{GS} = 0$$

$$\underline{\underline{V_{GS} = \cancel{3V} -3V}}$$

Using Schockley's Eqn

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

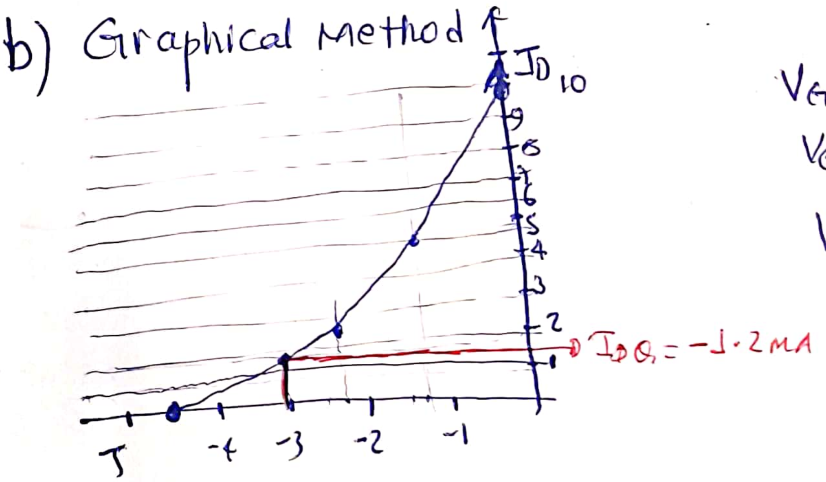
$$= 10mA\left(1-\left(\frac{-3V}{-4.5V}\right)\right)^2$$

$$= 10mA\left(1-\frac{3}{4.5}\right)^2$$

$$= 10mA(1-2/3)^2 = \frac{10}{9} mA$$

$$= 1.11mA$$

b) Graphical Method



$V_{GS}=0V$, $I_D=10mA$

$V_{GS}=\frac{V_p}{2}=-2.25$, $I_D=2.5mA$

$V_{GS}=0.3V_p=-1.35V$, $I_D=5mA$

c) Using KVL in the o/p loop

$$16V - I_D R_D - V_{DS} = 0$$

$$16V - 1.11mA \times 2.2k\Omega - V_{DS} = 0$$

$$V_{DS} = 16V - 1.11 \times 2.2V$$

$$= 16V - 2.442V = 13.558V$$

$V_D = V_{DS} = 13.558V$

$V_G = V_{GS} = -3V$

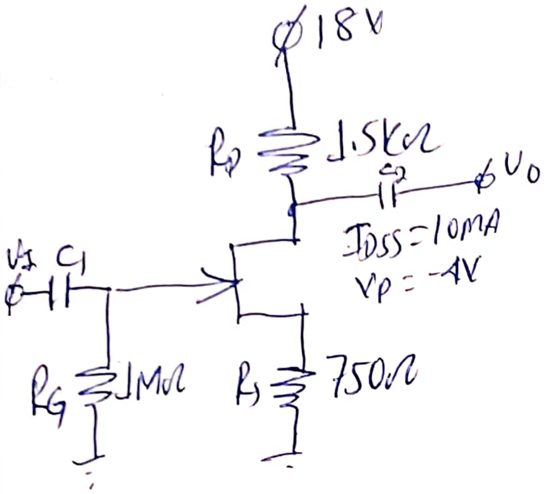
$V_S = 0V$

SELF BIAS

Q.3 For the self bias configuration shown, determine

a) I_{DQ} & V_{GSQ}

b) V_{DS}, V_D, V_G & V_S



Soln using KVL for the o/p loop

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

$$V_{GS} = -I_D R_S = -750 I_D = -0.75 I_D, \quad I_D \text{ in mA}$$

using Shockley's Eqn

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 10\left(1 - \frac{0.75 I_D}{4}\right)^2$$

$$I_D = 10\left(1 - \frac{1.5}{4} I_D + \frac{0.75^2 I_D^2}{4^2}\right)$$

$$I_D = 10 - 3.75 I_D + 0.352 I_D^2$$

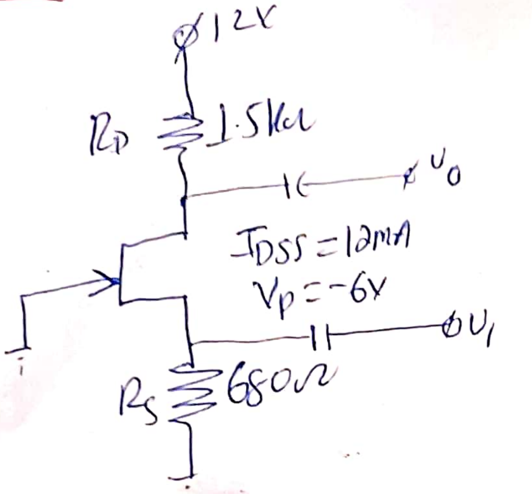
$$0.352 I_D^2 - 4.75 I_D + 10 = 0$$

$$I_D^2 - 13.49 I_D + 28.41 = 0$$

$$I_D = \frac{13.49 \pm \sqrt{13.49^2 - 4 \times 28.41}}{2} = \frac{13.49 \pm \sqrt{181.9801 - 113.64}}{2}$$

$$= \frac{13.49 \pm \sqrt{68.3401}}{2} = \frac{13.49 \pm 8.27}{2} = \frac{21.76}{2} \text{ or } \frac{5.22}{2}$$

Q.4 Determine the following for the common-gate configuration



a) V_{GSQ}

b) I_{DQ}

c) V_D

d) V_G

e) V_S

f) V_{DS}

Soln $V_{GS} = -I_D R_S = -0.68 I_D$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right) = 12\left(1 - \left(\frac{-0.68 I_D}{-6V}\right)\right)^2$$

$$= 12(1 - 0.113 I_D)^2$$

$$I_D = 12 - 2.712 I_D + 0.1532 I_D^2$$

$$0.1532 I_D^2 - 3.712 I_D + 12 = 0$$

$$I_D^2 - 24.23 I_D + 78.33 = 0$$

$$I_D = \frac{24.23 \pm \sqrt{(24.23)^2 - 4 \times 78.33}}{2}$$

$$= \frac{24.23 \pm 16.55}{2} = 20.39 mA \text{ or } 3.84 mA$$

Invalid (20.39 mA) Valid (3.84 mA)

$$V_{GS} = -0.68 I_D = -0.68 \times 3.84 = \underline{-2.6112 V}$$

(c) $V_D = V_{DD} - I_D R_D = 12V - 3.84 mA \times 1.5 k\Omega$
$= 6.24V$

(d) $V_G = 0V$

(e) $V_S = I_D R_S = +3.84 mA \times 0.68 = 2.6112V$

(f) $V_{DS} = V_D - V_S = 6.24V - 2.6112V = 3.6288V$

Compute V_{GS} for both values of I_D & rule out the valid solution

For $I_D = 3.115mA$

$$V_{GS} = 1.5 - 0.75 I_D$$
$$= 1.5 - 0.75 \times 3.115$$
$$= -0.83625V$$

Valid since $V_{GS} > V_P$

For $I_D = 11.555mA$

$$V_{GS} = 1.5 - 0.75 * I_D$$
$$= 1.5 - 0.75 * 11.555$$
$$= -7.16625V$$

Invalid since $V_{GS} < V_P$

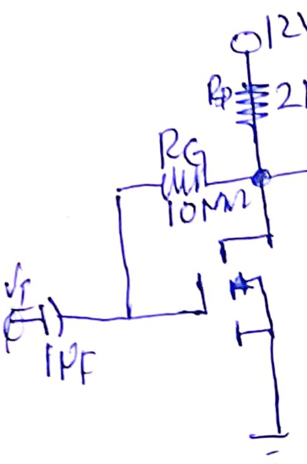
Therefore, the correct value of I_D is $\underline{3.115mA}$

$$I_{DQ} = 3.115mA$$
$$V_{GS} = -0.83625V \simeq \underline{-0.84V}$$

3) using KVL in the o/p loop

$$V_{DD} - I_D R_D - V_{DS} - I_D R_S = 0$$
$$V_{DS} = V_{DD} - I_D (R_D + R_S)$$
$$= 18V - 3.115mA * (1.8k\Omega + 0.75k\Omega)$$
$$= 18V - 3.115mA * 2.55k\Omega$$
$$= 18V - 7.94325V$$
$$= \underline{10.06V}$$

Q.7 Determine I_{DQ} & V_{DSQ} for Enhancement-type MOSFET shown in Fig 7



$I_D(on) = 6mA$
$V_{GS}(on) = 8V$
$V_{GS}(Th) = 3V$

Fig 7

Sol^n

$$k = \frac{I_D(on)}{(V_{GS}(on) - V_{GS}(Th))^2}$$

$$= \frac{6mA}{(8V-3V)^2} = 0.24 \frac{mA}{V^2}$$

Since no-current flows through R_G, V_D & V_S are Equal

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

$$V_{DS} = V_{DD} - I_D R_D = 12 - 2I_D$$

Now using the I_D Expression

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

$$= 0.24(12 - 2I_D - 3)^2 = 0.24(9 - 2I_D)^2$$

$$= 0.96(4.5 - I_D)^2$$

$$1.042 I_D = (4.5 - I_D)^2 = I_D^2 - 9I_D + 20.25$$

$$I_D^2 - 10.042 I_D + 20.25 = 0$$

Solving for I_D

~~$I_D = 4.9mA$ or $I_D = 14.942mA$~~

$$I_D = \frac{10.042 \pm 4.454}{2} = 2.7938mA \text{ or } 7.2482mA$$

To get the valid value of I_D, compute V_{GS}

For $I_D = 2.7938mA$

$$V_{GS} = 12 - 2I_D$$
$$= 12 - 2 \times 2.7938$$
$$= 6.4124V$$

Valid since $V_{GS} > 3V$

For $I_D = 7.2482mA$

$$V_{GS} = 12 - 2 \times 7.2482mA$$
$$= -2.4964V$$

Invalid b/c $V_{GS} > 3V$

Q.8 Determine I_{DQ}, V_{GSQ} & V_{DS} for the n/w of Fig 8

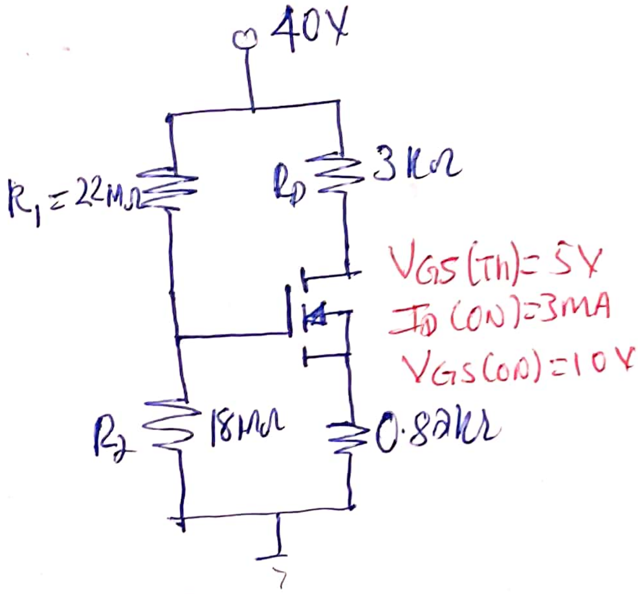


Fig 8

Sol^n

$$K = \frac{I_D(ON)}{(V_{GS}(on) - V_{GS}(Th))^2}$$

$$= \frac{3\,mA}{(10V - 5V)^2} = \frac{3}{25}\,mA/V^2$$

$$= 0.12\,mA/V^2$$

Since $I_G = 0\,mA$, V_G can be found as

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

$$V_G = \frac{18}{40} \times 40V = 18V$$

applying KVL for the o/p loop

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

$$V_{GS} = V_G - I_D R_S = 18 - 0.82 I_D$$

Now using the I_D Equation

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

$$I_D = 0.12(18 - 0.82 I_D - 5)^2$$

$$I_D = 0.12(13 - 0.82 I_D)^2$$

$$I_D = 20.28 - 2.5584 I_D + 0.081 I_D^2$$

$$0.081 I_D^2 - 3.5584 I_D + 20.28 = 0$$

$$I_D^2 - 43.93 I_D + 250.37 = 0$$

⇒ solving for I_D

$$I_D = \frac{43.93 \pm 30.47}{2} = 6.73\,mA \text{ (Valid)}$$

or $37.2\,mA$ (not valid)

Now solve for V_{GS}

$$V_{GS} = 18 - 0.82 I_D$$

$$= 18 - 0.82 \times 6.73$$

$$\simeq 12.48V$$

applying KVL for the o/p loop

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

$$= 40V - 6.73 \times 3.82$$

$$= 14.2914V$$

Q·9 For the network of fig 9, Determine

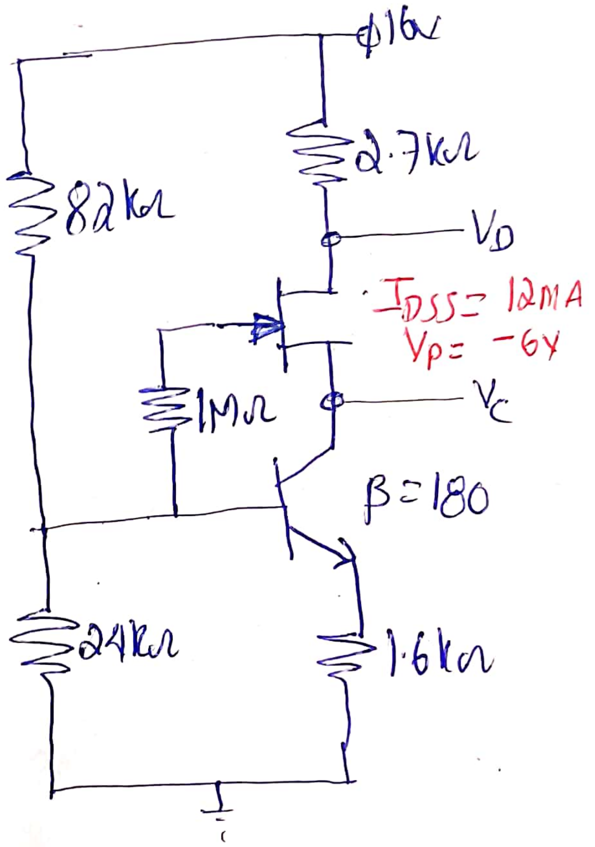


Fig 9

a) V_B & V_G

b) V_E

c) I_E, I_C & I_D

d) I_B

e) $V_C, V_S,$ & V_D

f) V_{CE}

g) V_{DS}

Sol^n $V_{TH} = \frac{R_2}{R_1+R_2} V_{DD} = \frac{24}{106} \times 16V \simeq 3.62V$

$R_{TH} = R_1 \parallel R_2 = 18.57k\Omega$

For a voltage divider bias, I_B is given as

$$I_B = \frac{V_{TH} - 0.7}{R_{TH} + (\beta+1)R_E} = \frac{3.62V - 0.7V}{18.57k\Omega + 181 \times 1.6k\Omega}$$

$I_B = 9.47\mu A$

$I_C = \beta I_B = 180 \times 9.47\mu A = 1.70mA$

$I_E = (\beta+1) I_B = 181 \times 9.47\mu A = 1.71mA$

$V_E = I_E R_E = 1.71mA \times 1.6k\Omega = 2.736V$

$V_B = V_{BE} + V_E = 0.7V + 2.736V = 3.436V$

Since $I_G = 0mA$, $V_B = V_G = 3.436V$

$I_D = I_C = 1.70mA$

$V_D = V_{DD} - I_D R_D = 16V - 1.70mA \times 2.7k\Omega = 11.41V$

Now compute V_{GS} using ~~s~~ the shockley's Eqⁿ

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

$$V_{GS} = V_P\left(1 - \sqrt{\frac{I_D}{I_{DSS}}}\right) = V_P\left(1 - \sqrt{\frac{1.70mA}{12mA}}\right)$$

$$= 0.624V_P = 0.624 \times (-6) = -3.744V$$

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

$$\Rightarrow V_C = V_B - V_{GS} = 3.436V + 3.744V = 7.18V$$

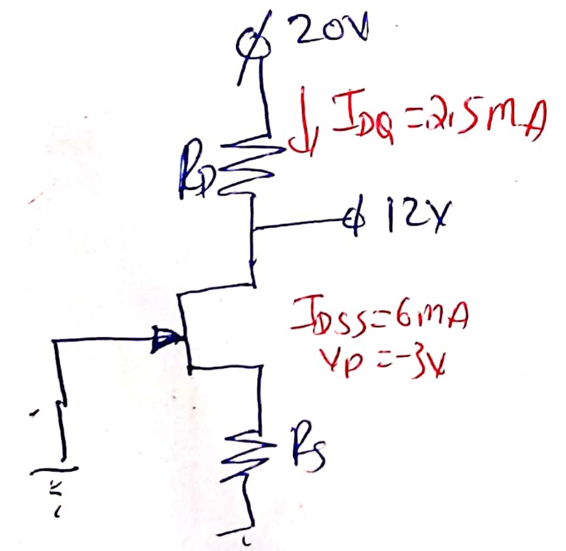
$$V_C = V_S = 7.18V$$

$$V_{CE} = V_C - V_E = 7.18V - 2.736V = \underline{4.444V}$$

$$V_{DS} = V_D - V_S = 11.41V - 7.18V$$

$$= \underline{4.23V}$$

Q.10 For the n/w of fig 10, the levels of V_{DQ} & I_{DQ} are specified. Determine R_D & R_S



Solⁿ $R_D = \frac{20V - 12V}{2.5mA} = 3.2k\Omega$

Use shockley's Eqⁿ to solve for V_{GS}

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

$$= -3V\left(1 - \sqrt{\frac{2.5}{6}}\right) =$$

$$= -3V \times 0.3545$$

$$= \underline{-1.064V}$$

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

$$R_S = \frac{-V_{GS}}{I_D} = \frac{-1.064V}{2.5mA} = \underline{425.6\Omega}$$