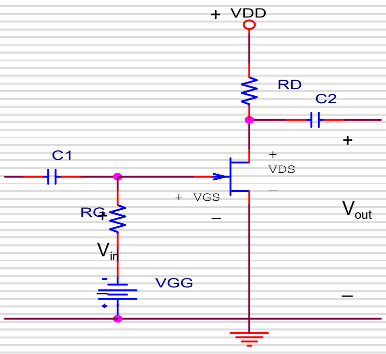
Field Effect Transistor

DC JFET Biasing

- Just as we learned that the BJT must be biased for proper operation, the JFET also must be biased for operation point (I_D, V_{GS}, V_{DS})
- In most cases the ideal Q-point will be at the middle of the transfer characteristic curve, which is about half of the I_{DSS}.
- 3 types of DC JFET biasing configurations :
  - Fixed-bias
  - Self-bias
  - Voltage-Divider Bias

Fixed-bias



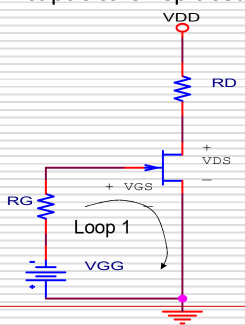
Fixed-bias

- Use two voltage sources: V_{GG}, V_{DD}
- V_{GG} is reverse-biased at the Gate – Source (G-S) terminal,
- what's the value of I_G ,V_{RG} and V_{GS} ?

no current flows through R_G ($I_G = 0$), V_{RG}=0 & V_{GS}=V_{GG}.

Fixed-bias..

- DC analysis
  - All capacitors replaced with open-circuit



Fixed-bias…

1. Input Loop
- By using KVL at loop 1:

$$V_{GG} + V_{GS} = 0$$
$$V_{GS} = -V_{GG}$$

- For graphical solution, use $\mathbf{V_{GS} = -V_{GG}}$ to draw the load line
- For mathematical solution, replace $\mathbf{V_{GS} = -V_{GG}}$ in Shockley's Eq. ,therefore:

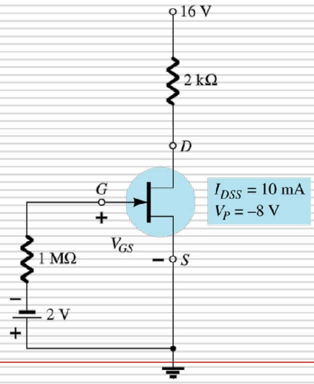
$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2 = I_{DSS}\left(1 + \frac{V_{GG}}{V_{GS(off)}}\right)^2$$

2. Output loop

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

3. Then, plot transfer characteristic curve by using Shockley's Equation

Example : Fixed-bias



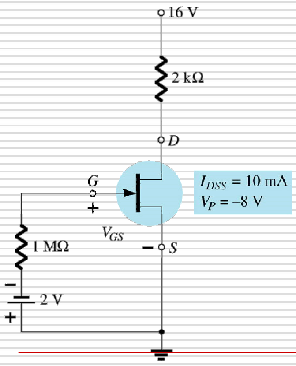
Determine the following network:

1. V_{GSQ}
2. I_{DQ}
3. V_D
4. V_G
5. V_S

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

Mathematical Solutions

$$V_{GSQ} = -V_{GG} = -2$$



$$I_{DQ} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 10mA\left(1 - \frac{-2}{-8}\right)^2$$
$$= 10mA\,(0.75)^2 = 5.625mA$$

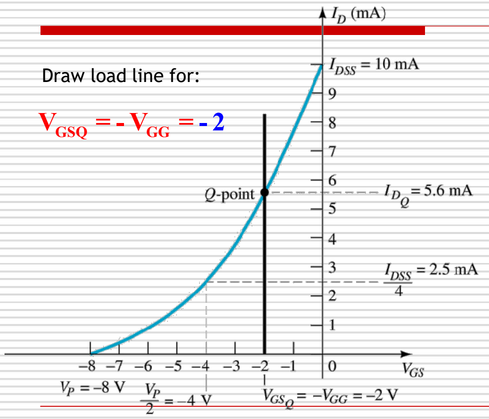
$$V_{DS} = V_{DD} - I_D R_D = 16 - (5.625mA)(2k\Omega)$$
$$= 16V - 11.25V = 4.75V$$

$$V_D = V_{DS} = 4.75V$$
$$V_G = V_{GS} = -2V$$
$$V_S = 0V$$

Graphical solution for the network

Draw load line for:

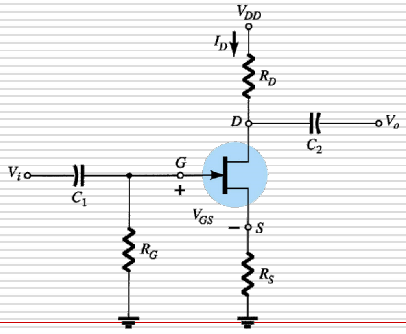
$$V_{GSQ} = -V_{GG} = -2$$



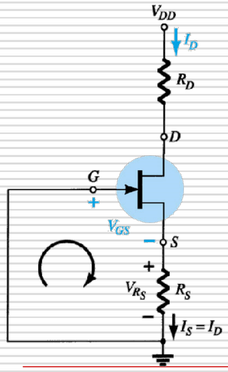
$$I_{DQ} = 5.6\ mA$$
$$V_{DS} = 4.75V$$
$$V_D = 4.75V$$
$$V_G = -2V$$
$$V_S = 0V$$

Self-bias

- Using only one voltage source



DC analysis of the self-bias configuration.



Since $I_G \approx 0A$, $V_{RG} = I_G R_G$

thus $V_{RG} = 0A$,

$$V_{RS} = I_D R_S$$

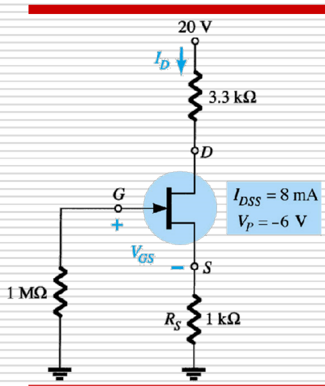
$$V_{GS} + V_{RS} = 0$$

$$V_{GS} = -V_{RS}$$

$$= -I_D R_S$$

Q point for V_{GS}

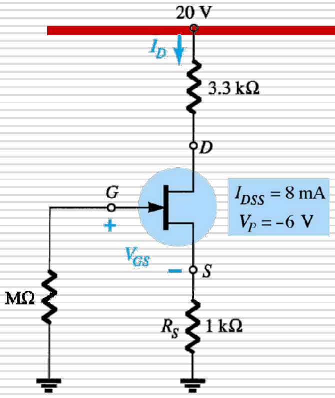
Example : Self-bias configuration



Determine the following for the network

1. V_{GSQ}
2. I_{DQ}
3. V_D
4. V_G
5. Vs

Graphical Solutions:



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

When $I_D = 4mA$,

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

$$= -(4mA)(1k\Omega) = -4V$$

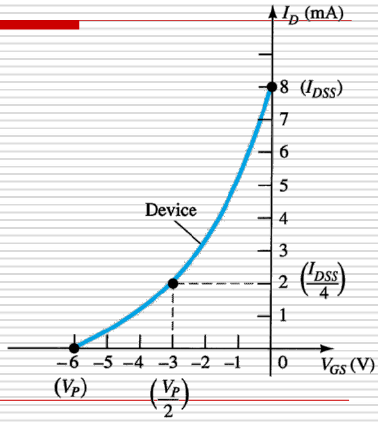
When $I_D = 8mA$, $V_{GS} = -I_D R_S$

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

$$= -8 \quad mA \quad (1k\Omega) = -8V$$

Sketching the transfer characteristics curve

Vgs	I_D
0	I_{DSS}
0.3Vp	$I_{DSS}/2$
0.5Vp	$I_{DSS}/4$
Vp	0 mA



Mathematical Solutions

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

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

$$I_D = 8m\left(1+\frac{I_D(1k)}{-6}\right)^2 = 8m\left(\frac{-6+I_D(1k)}{-6}\right)^2$$

$$= \frac{8m}{36}\left(36 - 6kI_D - 6kI_D + 1MI_D^{\,2}\right)$$

$$36\,I_D = 0.288 - 96\,I_D + 8kI_D^{\,2}$$

$$8kI_D^{\,2} - 132\,I_D + 0.288 = 0$$

$$I_{D_1} = 13.9mA \qquad I_{D_2} = 2.588\,mA$$

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

$$= -13.9mA\,(1k) \qquad = -2.588\,mA\,(1k)$$

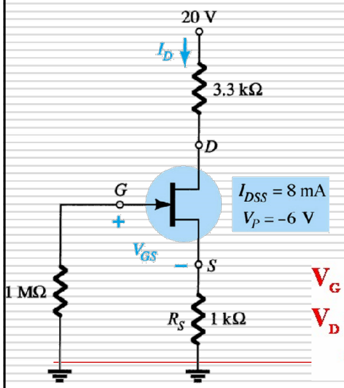
$$= -13.9V \qquad = -2.6V$$

$$therefore\ ;\ choose\ \ I_D = 2.588\,mA \ \ and \ \ V_{GS} = -2.6V$$

Solutions

$$V_{GSQ} = -2.6V$$

$$I_{DQ} = 2.6mA$$



$$I_D = I_S$$

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

$$= 20V - 2.6mA(4.3k\Omega)$$

$$= 8.82V$$

$$V_s = I_s R_s = (2.6mA)(1k\Omega)$$

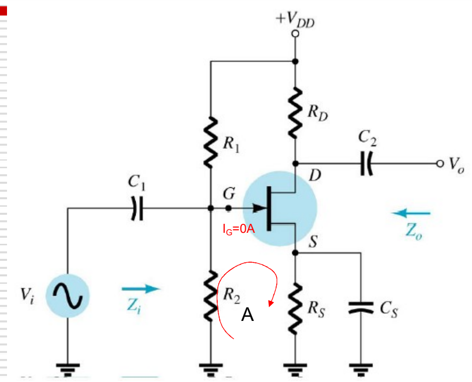
$$= 2.6V$$

$$V_G = V_{GS} + V_s = 0V$$

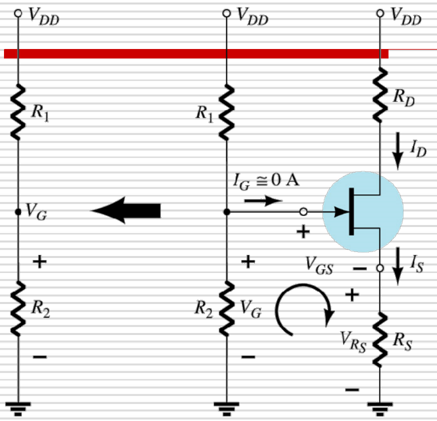
$$V_D = V_{DS} + V_s \text{ or } V_D = V_{DD} - I_D R_D$$

$$= V_{DS} + V_s = 8.82V + 2.6V = 11.42V$$

Voltage-divider bias

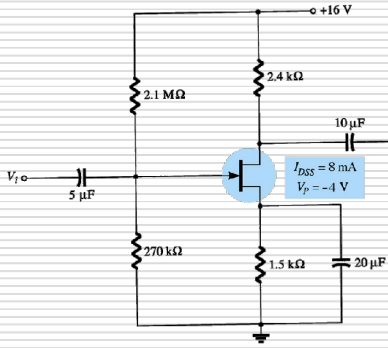


Redrawn network



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

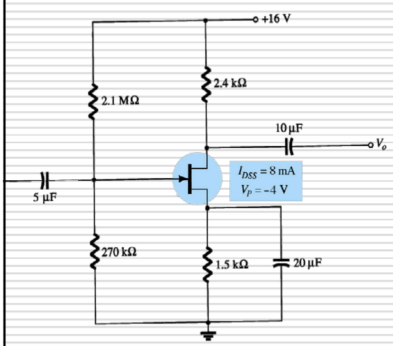
Example : Voltage-divider bias



Determine the following for the network

1. I_{DQ} and V_{GSQ}
2. V_D
3. V_S
4. V_{DS}
5. V_{DG}

Solutions



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

$$= \frac{(270\text{k}\Omega)(16\text{V})}{2.1\text{M}\Omega + 0.27\text{M}\Omega_2} V_{DD}$$

$$= 1.82\text{V}$$

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

$$= 1.82\text{V} - I_D(1.5\text{k}\Omega)$$

When $I_D = 0\text{mA}$, $V_{GS} = +1.82\text{V}$

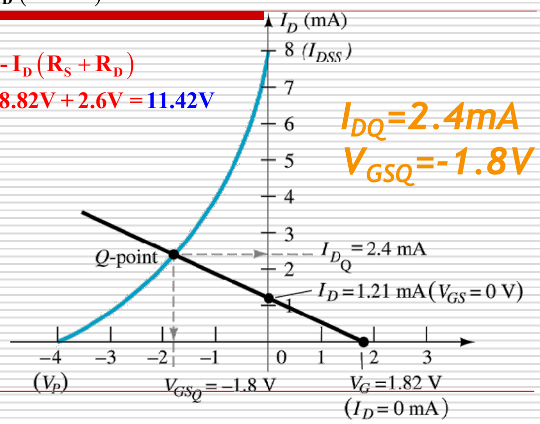
When $V_{GS} = 0\text{V}$, $I_D = \frac{+1.82\text{V}}{1.5\text{k}\Omega} = 1.21\text{mA}$

Determining the *Q*-point for the network

$$V_{GS} = 1.82\text{V} - I_D(1.5\text{k}\Omega)$$

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

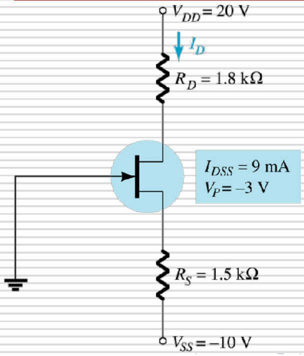
$$= V_{DS} + V_S = 8.82\text{V} + 2.6\text{V} = 11.42\text{V}$$



I_{DQ}=2.4mA

V_{GSQ}=-1.8V

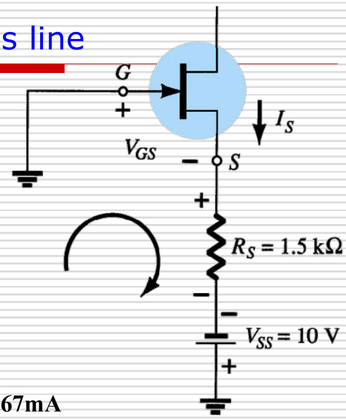
Exercise 3:



Determine the following for the network

1. I_{DQ} and V_{GSQ}
2. V_{DS}
3. V_D
4. V_S

Drawing the self bias line



$$V_{GS} + I_D R_S - 10V = 0$$

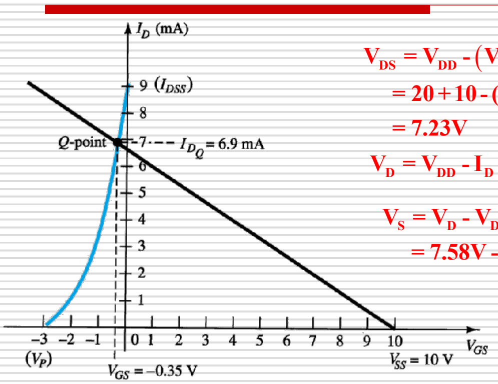
$$V_{GS} = 10V - I_D(1.5k\Omega)$$

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

When $V_{GS} = 0V$, $I_D = \dfrac{10V}{1.5k\Omega} = 6.67mA$

Determining the *Q*-point

I_{DQ}=6.9mA
V_{GSQ}=-0.35V

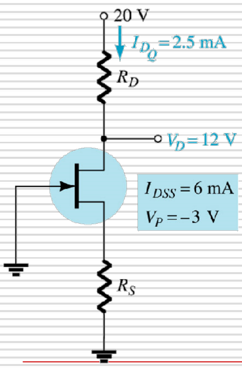


$$V_{DS} = V_{DD} - (V_{SS}) - I_D(R_S + R_D)$$
$$= 20 + 10 - (6.9mA)(1.8k\Omega + 1.5k\Omega)$$
$$= 7.23V$$

$$V_D = V_{DD} - I_D(R_D) = 7.58V$$

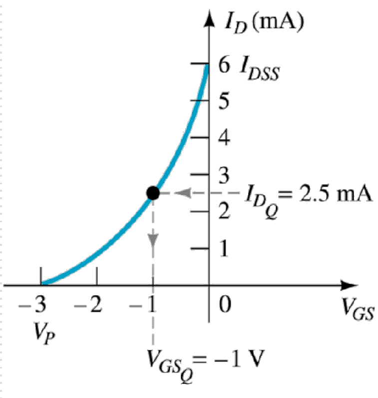
$$V_S = V_D - V_{DS}$$
$$= 7.58V - 7.23V = 0.35V$$

Exercise 4



Determine the required values of R_D and R_S

Determining V_{GS_Q} for the network

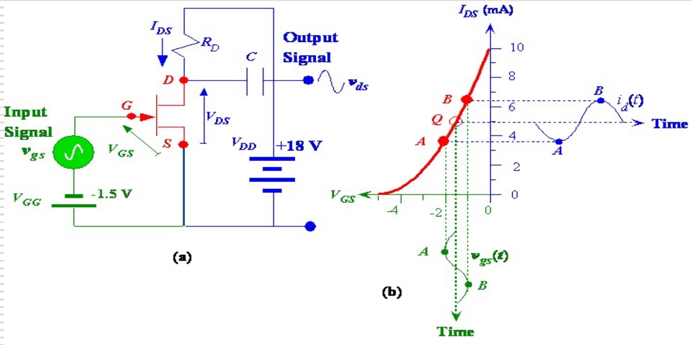


$$R_D = \frac{V_{RD}}{I_{DQ}} = \frac{V_{DD} - V_{DQ}}{I_{DQ}} = \frac{20V - 12V}{2.5mA}$$

$$= 3.2k\Omega$$

$$R_S = \frac{-(V_{GSQ})}{I_{DQ}} = \frac{-(-1)}{2.5mA} = 0.4k\Omega$$

A Simple CS Amplifier and Variation in I_{DS} with V_{gs}



(a) Common source (CS) ac amplifier using a JFET.
(b) Explanation of how I_D is modulated by the signal v_{gs} in series with the dc bias voltage V_{GG}.