

# Electronic Devices

## Final Term Lecture - 06

Reference book:

**Electronic Devices and Circuit Theory (Chapter-7)**

Robert L. Boylestad and L. Nashelsky , (11<sup>th</sup> Edition)



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# OBJECTIVES

- Be able to perform a dc analysis of JFET, MOSFET, and MESFET networks.
- Become proficient in the use of load-line analysis to examine FET networks.
- Develop confidence in the dc analysis of networks with both FETs and BJTs.
- Understand how to use the Universal JFET Bias Curve to analyze the various FET configurations.



# GENERAL RELATIONSHIPS

- For all FETs:  $I_G \approx 0A$        $I_D = I_S$
- For JFETs and Depletion-Type MOSFETs:  $I_D = I_{DSS} \left(1 - \frac{V_{GS}}{V_P}\right)^2$
- For Enhancement-Type MOSFETs:  $I_D = k(V_{GS} - V_T)^2$
- BJT: **Linear Relationship** between  $I_B$  and  $I_C$
- FET: **Non-linear Relationship** between  $V_{GS}$  and  $I_D$ .



# COMMON FET BIASING CIRCUITS

- JFET
  - Fixed – Bias
  - Self-Bias
  - Voltage-Divider Bias
- Depletion-Type MOSFET
  - Self-Bias
  - Voltage-Divider Bias
- Enhancement-Type MOSFET
  - Feedback Configuration
  - Voltage-Divider Bias



# FIXED-BIAS JFET

- The simplest biasing arrangements:

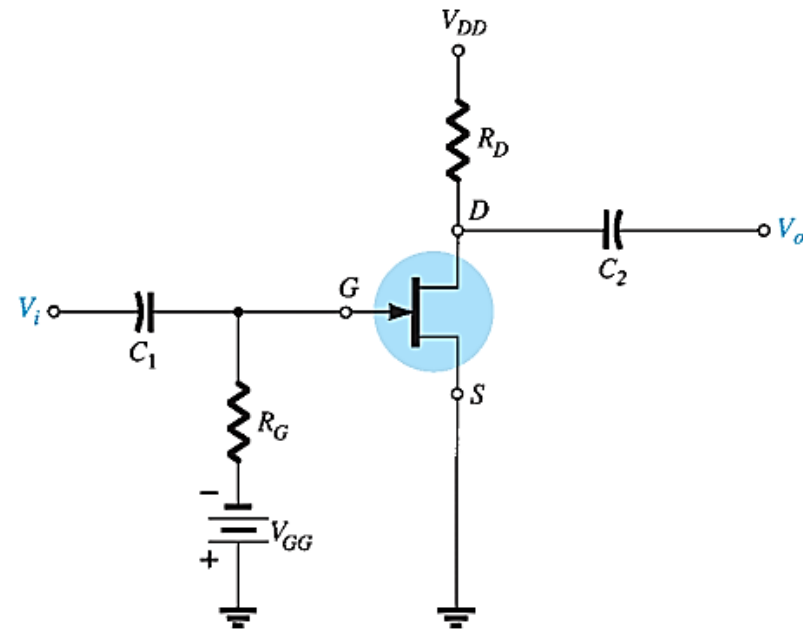
$$I_G \approx 0A \quad I_D = I_S$$

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

- For the DC analysis,
  - Capacitors are open circuits

$$I_G \cong 0A \quad V_{RG} = I_G R_G = (0A) R_G = 0V$$

- The **zero-volt drop across  $R_G$**  permits **replacing  $R_G$  by a short-circuit**.

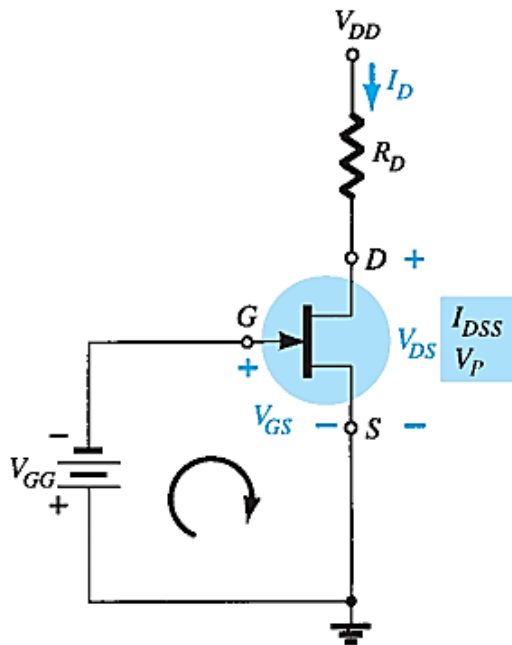


**FIG. 7.1**

*Fixed-bias configuration.*

# FIXED-BIAS JFET

- Can be solved using either **Mathematical Approach** or **Graphical Approach**:



**FIG. 7.2**

Network for dc analysis.

## Mathematical Approach

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

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

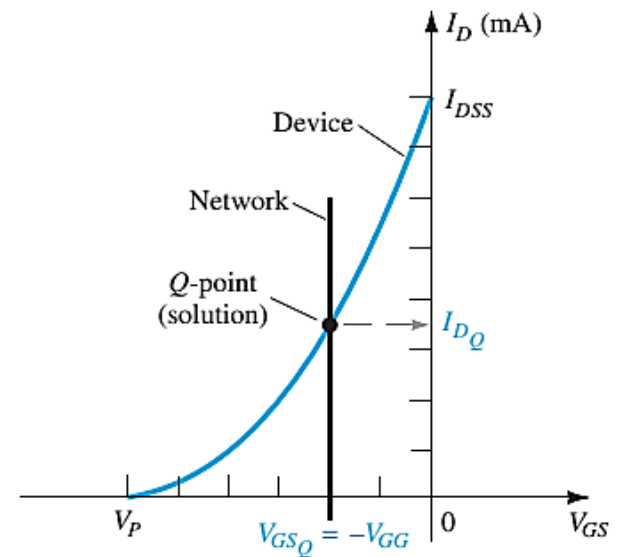
$$V_S = 0$$

$$V_D = V_{DS}$$

$$V_G = V_{GS}$$

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

## Graphical Approach



**FIG. 7.4**

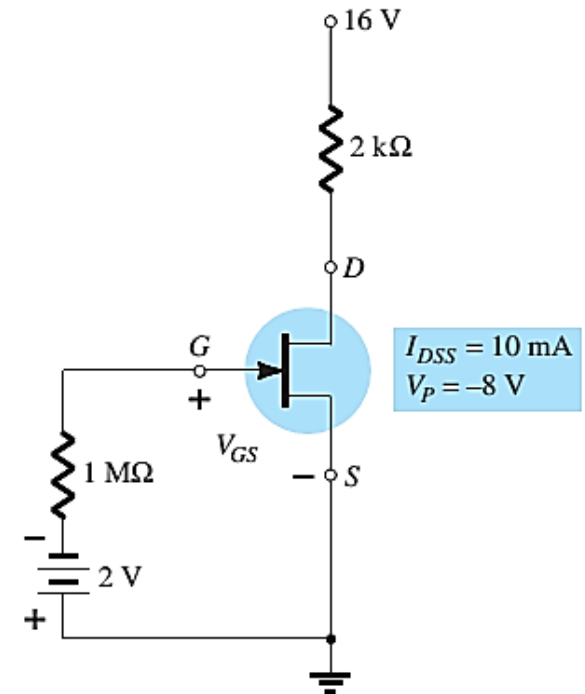
Finding the solution for the fixed-bias configuration.

# FIXED-BIAS JFET EXAMPLE

- Determine  $V_{GSQ}$ ,  $I_{DQ}$ ,  $V_{DS}$ ,  $V_D$ ,  $V_G$ ,  $V_S$ .

## Mathematical Approach

- $V_{GSQ} = -V_{GG} = -2 \text{ V}$
- $$I_{DQ} = I_{DSS} \left( 1 - \frac{V_{GS}}{V_P} \right)^2 = 10 \text{ mA} \left( 1 - \frac{-2 \text{ V}}{-8 \text{ V}} \right)^2$$
$$= 10 \text{ mA} (1 - 0.25)^2 = 10 \text{ mA} (0.75)^2 = 10 \text{ mA} (0.5625)$$
$$= 5.625 \text{ mA}$$
- $$V_{DS} = V_{DD} - I_D R_D = 16 \text{ V} - (5.625 \text{ mA})(2 \text{ k}\Omega)$$
$$= 16 \text{ V} - 11.25 \text{ V} = 4.75 \text{ V}$$
- $V_D = V_{DS} = 4.75 \text{ V}$
- $V_G = V_{GS} = -2 \text{ V}$
- $V_S = 0 \text{ V}$



**FIG. 7.6**

Example 7.1.

# FIXED-BIAS JFET EXAMPLE

## Graphical Approach

$$V_{GS_Q} = -V_{GG} = -2 \text{ V}$$

$$I_{D_Q} = 5.6 \text{ mA}$$

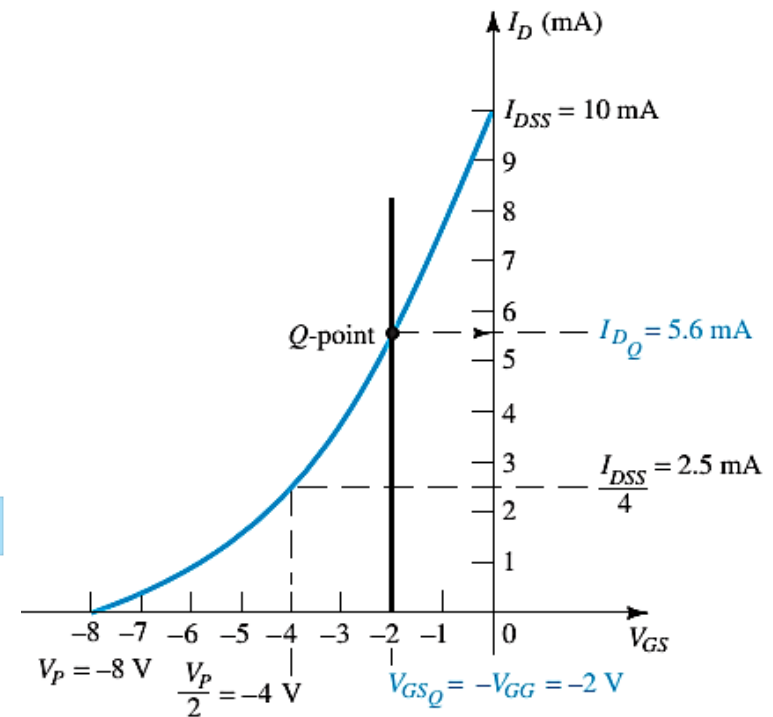
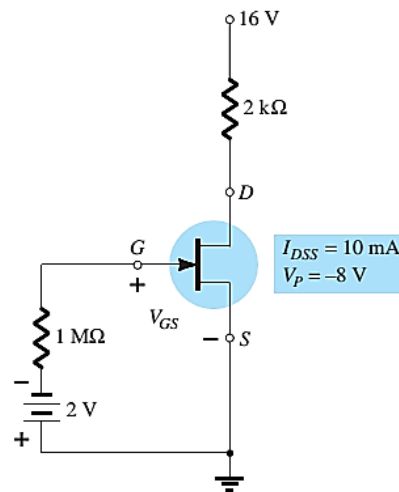
$$V_{DS} = V_{DD} - I_D R_D = 16 \text{ V} - (5.6 \text{ mA})(2 \text{ k}\Omega) \\ = 16 \text{ V} - 11.2 \text{ V} = 4.8 \text{ V}$$

$$V_D = V_{DS} = 4.8 \text{ V}$$

$$V_G = V_{GS} = -2 \text{ V}$$

$$V_S = 0 \text{ V}$$

$V_{GS}$	$I_D$
0	$I_{DSS}$
$0.3V_P$	$I_{DSS}/2$
$0.5V_P$	$I_{DSS}/4$
$V_P$	0mA





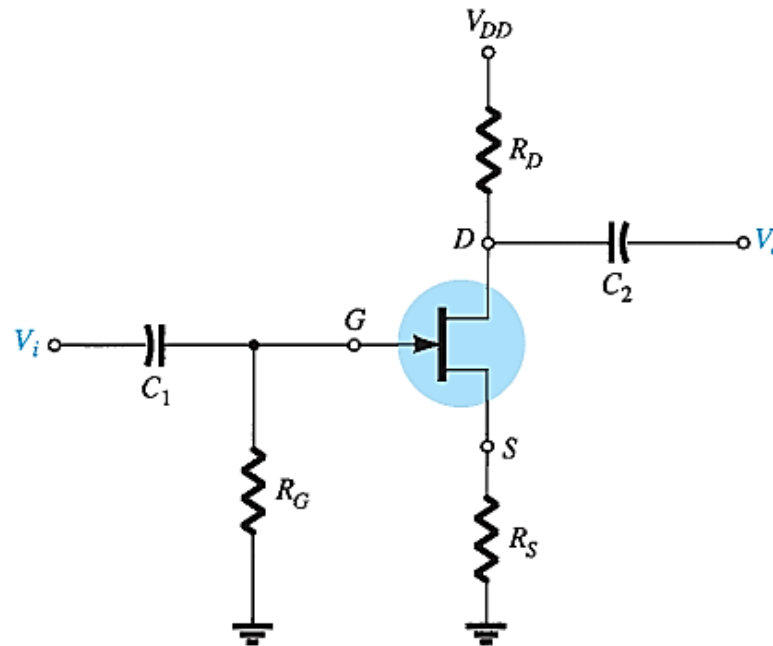
# JFET: SELF-BIAS CONFIGURATION

- The self-bias configuration *eliminates the need for two dc supplies.*

$$I_G \approx 0A$$

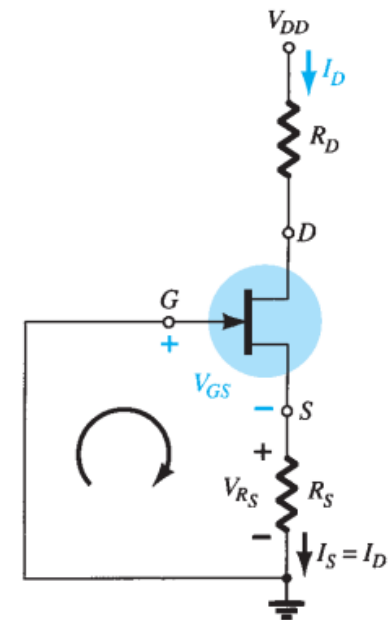
$$I_D = I_S$$

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



**FIG. 7.8**

JFET self-bias configuration.



**FIG. 7.9**

DC analysis of the self-bias configuration.

# SELF-BIAS CONFIGURATION

- Can be solved using either **Mathematical Approach** or **Graphical Approach**:

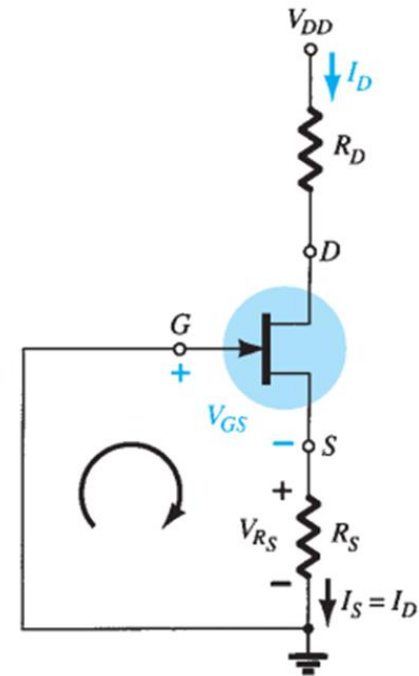
## Mathematical Approach

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

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

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

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



**FIG. 7.9**

*DC analysis of the self-bias configuration.*

# SELF-BIAS CONFIGURATION

## Graphical Approach

- Draw the device transfer characteristic using **shorthand method**.
- Draw the network load line

- Use  $V_{GS} = -I_D R_S$  to draw straight line.
- First point,  $I_D = 0, V_{GS} = 0$
- Second point, any point from  $I_D = 0$  to  $I_D = I_{DSS}$ . Choose

$$I_D = \frac{I_{DSS}}{2} \text{ then}$$

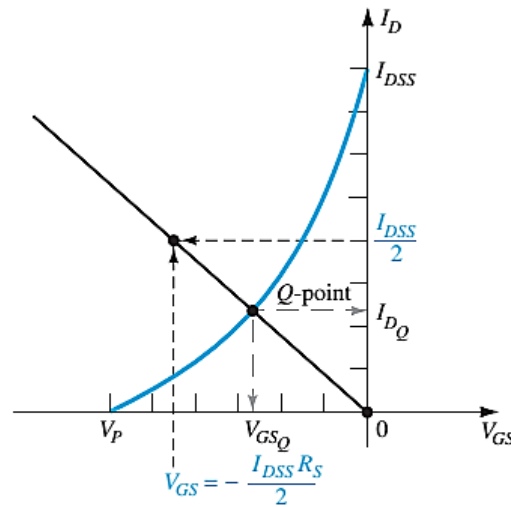
$$V_{GS} = -\frac{I_{DSS} R_S}{2}$$

- The Q-point obtained at the intersection of the straight line plot and the device characteristic curve.
- The quiescent value for  $I_D$  and  $V_{GS}$  can then be determined and used to find the other quantities of interest.



# SELF-BIAS CONFIGURATION

## Graphical Approach



**FIG. 7.11**

*Sketching the self-bias line.*

# SELF-BIAS EXAMPLE

- Determine  $V_{GSQ}$ ,  $I_{DQ}$ ,  $V_{DS}$ ,  $V_S$ ,  $V_G$  and  $V_D$ .

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

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

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

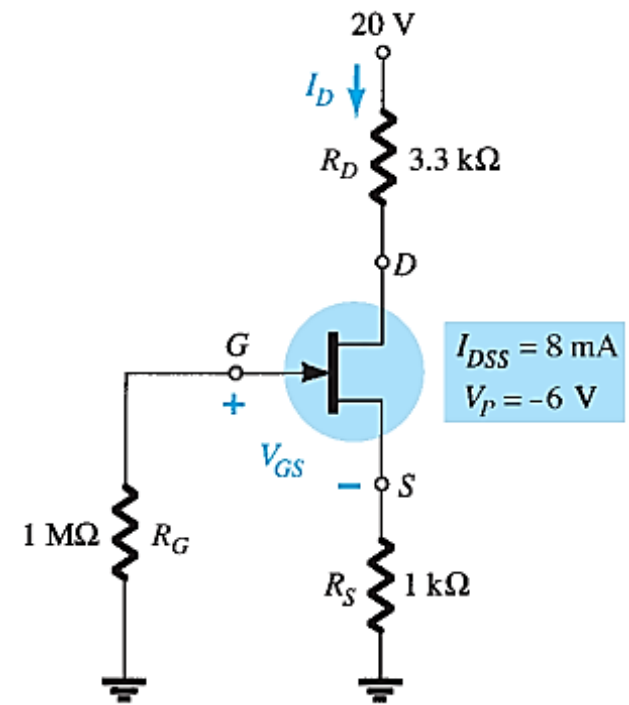
$$\begin{aligned} V_{DS} &= V_{DD} - I_D (R_S + R_D) \\ &= 20 \text{ V} - (2.6 \text{ mA})(1 \text{ k}\Omega + 3.3 \text{ k}\Omega) \\ &= 20 \text{ V} - 11.18 \text{ V} \\ &= 8.82 \text{ V} \end{aligned}$$

$$\begin{aligned} V_S &= I_D R_S \\ &= (2.6 \text{ mA})(1 \text{ k}\Omega) \\ &= 2.6 \text{ V} \end{aligned}$$

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

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

$$V_D = V_{DD} - I_D R_D = 20 \text{ V} - (2.6 \text{ mA})(3.3 \text{ k}\Omega) = 11.42 \text{ V}$$

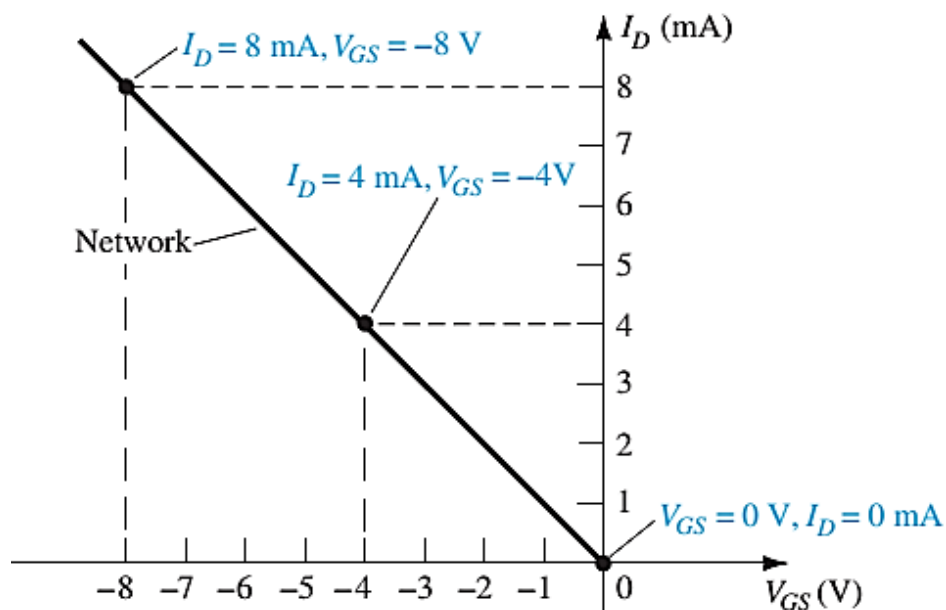


**FIG. 7.12**  
Example 7.2.



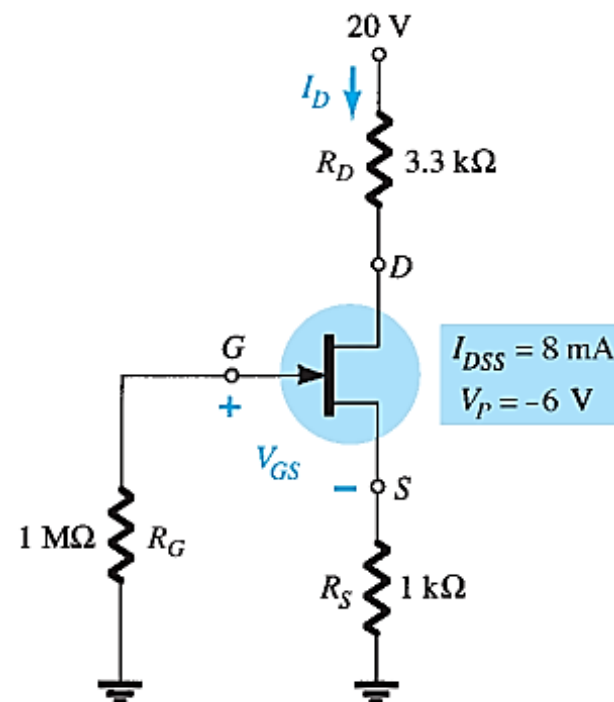
## SELF-BIAS EXAMPLE Contd.

- Plot  $I_D$  vs  $V_{GS}$  and draw a line from the origin of the axis.



**FIG. 7.13**

*Sketching the self-bias line for the network of Fig. 7.12.*



**FIG. 7.12**

*Example 7.2.*

# End of Lecture-6

