

Electronic Devices

Final Term Lecture - 03

Reference book:

Electronic Devices and Circuit Theory (Chapter-6)

Robert L. Boylestad and L. Nashelsky , (11th Edition)



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OBJECTIVES

- Become familiar with the construction and operating characteristics of Junction Field Effect (JFET), Metal-Oxide Semiconductor FET (MOSFET), and Metal-Semiconductor FET (MESFET) transistors.
- Be able to sketch the transfer characteristics from the drain characteristics of a JFET, MOSFET, and MESFET transistor.
- Understand the vast amount of information provided on the specification sheet for each type of FET.
- Be aware of the differences between the dc analysis of the various types of FETs.



FETs vs BJT's

- FET's (Field – Effect Transistors) are much like BJT's (Bipolar Junction Transistors).
- **Similarities:**
 - Amplifiers
 - Switching devices
 - Impedance matching circuits
- **Differences:**
 - FET's are voltage controlled devices whereas BJT's are current controlled devices.
 - FET's are unipolar devices whereas BJT's are bipolar devices.
 - FET's also have a higher input impedance, but BJT's have higher gains.
 - FET's are less sensitive to temperature variations and because of their construction they are more easily integrated into IC's.



FET TYPES

- JFET: Junction Field-Effect Transistor
- MOSFET: Metal-Oxide Semiconductor Field-Effect Transistor
 - »D-MOSFET ~ Depletion type MOSFET
 - »E-MOSFET ~ Enhancement type MOSFET



JFET CONSTRUCTION

- There are two types of JFETs
 - n- channel
 - p- channel
- The n-channel is more widely used.
- There are *three terminals*:
 - **Drain (D)** and **Source (S)** are connected to n-channel
 - **Gate (G)** is connected to the p-type material
- Check this: <http://www-g.eng.cam.ac.uk/mmg/teaching/linearcircuits/jfet.html>

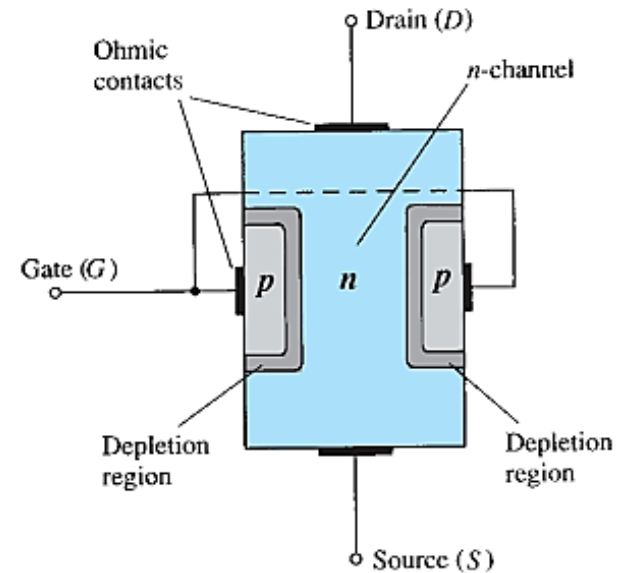


FIG. 6.3

Junction field-effect transistor (JFET).

BASIC OPERATION OF JFET

- JFET operation can be compared to a water spigot.
- The **source of water** pressure is the **accumulation of electrons** at the **negative pole of the drain-source voltage**.
- The **drain of the water** is the **electron deficiency (or holes)** at the **positive pole of the applied voltage**.
- The **control of flow of water** is the **gate voltage** that **controls the width of the n channel** and therefore, the **flow of charges** from source to drain.



FIG. 6.4

Water analogy for the JFET control mechanism.

JFET OPERATING CHARACTERISTICS

- There are three basic operating conditions for a JFET:
 - $V_{GS} = 0$, V_{DS} increasing to some positive value
 - $V_{GS} < 0$, V_{DS} at some positive value
 - Voltage-Controlled Resistor

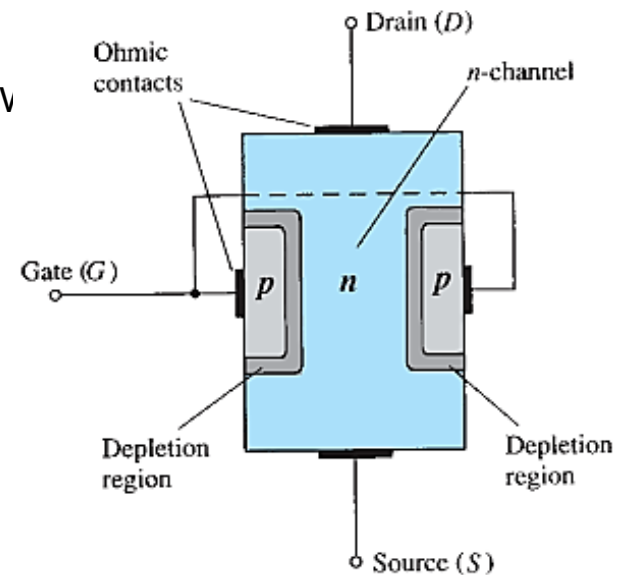


FIG. 6.3

Junction field-effect transistor (JFET).

JFET OPERATING CHARACTERISTICS: $V_{GS} = 0\text{ V}$

- Three things happen when $V_{GS} = 0$ and V_{DS} is increased from 0 to a more positive voltage:
 - The depletion region between p-gate and n-channel increases as **electrons from n-channel combine with holes from p-gate**.
 - Increasing the depletion region**, decreases the size of the n-channel which **increases the resistance of the n-channel**.
 - But even **though the n-channel resistance is increasing**, the **current (I_D) from Source to Drain** through the n-channel **is increasing**. This is because **V_{DS} is increasing**.

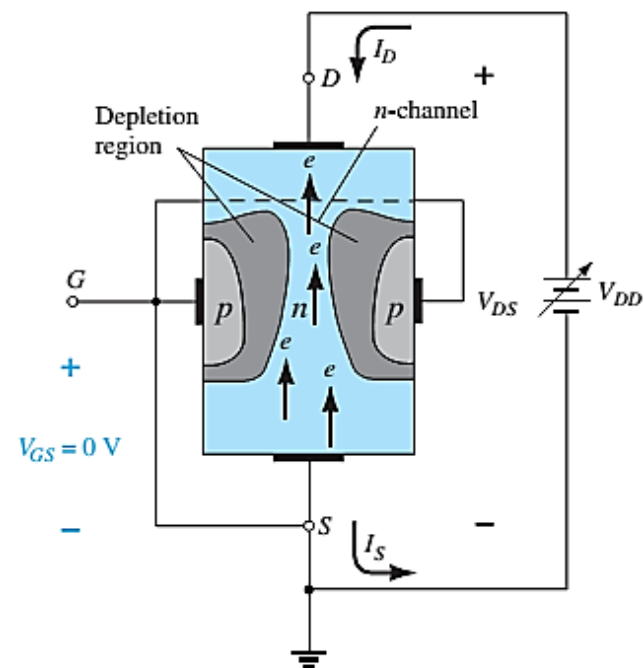


FIG. 6.5

JFET at $V_{GS} = 0\text{ V}$ and $V_{DS} > 0\text{ V}$.

JFET OPERATING CHARACTERISTICS: $V_{GS} = 0 \text{ V}$

- It is important to note that the **depletion region is wider near the top of both p-type Materials.**
- Assuming a uniform resistance in the n-channel, the resistance of the channel can be broken down to the divisions appearing in Figure.
- **The current I_D will establish the voltage levels through the channel** as indicated on the same figure. The result is that the upper region of the p-type material will be reverse biased by about 1.5 V, with the lower region only reverse-biased by 0.5 V.
- **The greater the applied reverse bias, the wider the depletion region**—hence the distribution of the depletion region as shown in figure. The fact that the **p-n junction is reverse-biased for the length of the channel results** in a **gate current of zero amperes.**

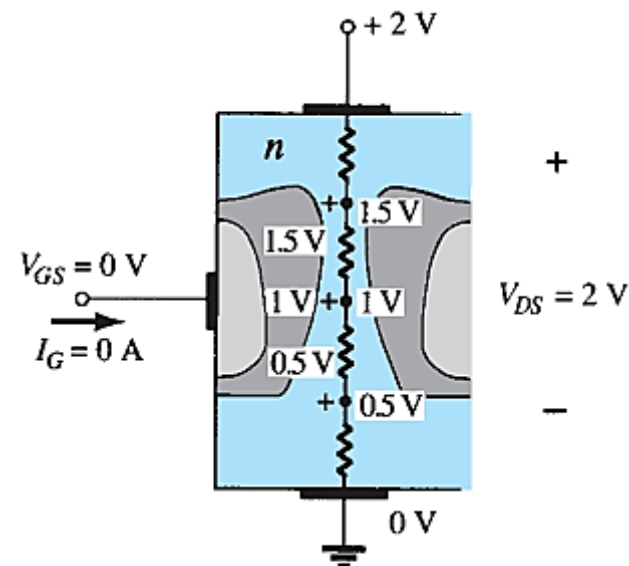


FIG. 6.6

Varying reverse-bias potentials across the p-n junction of an n-channel JFET.

PINCH-OFF

- If $V_{GS} = 0$ and V_{DS} is further increased to a more **positive voltage**, then the depletion zone gets so large that it **pinches off the n-channel**.
- This suggests that **the current in the n-channel (I_D) would drop to 0A**, but it does just the opposite: as V_{DS} increases, so does I_D .

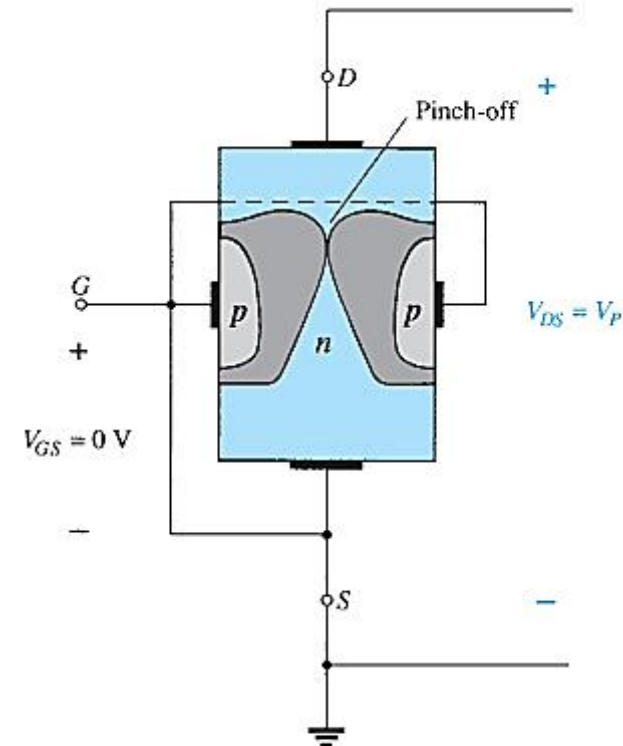


FIG. 6.8

Pinch-off ($V_{GS} = 0\text{ V}$, $V_{DS} = V_P$).

SATURATION

At the pinch-off point:

- Any further increase in V_{DS} does not produce any increase in I_D . V_{DS} at pinch-off is denoted as V_p .
- I_D is at saturation or maximum. It is referred to as I_{DSS} .
- The ohmic value of the channel is at maximum.

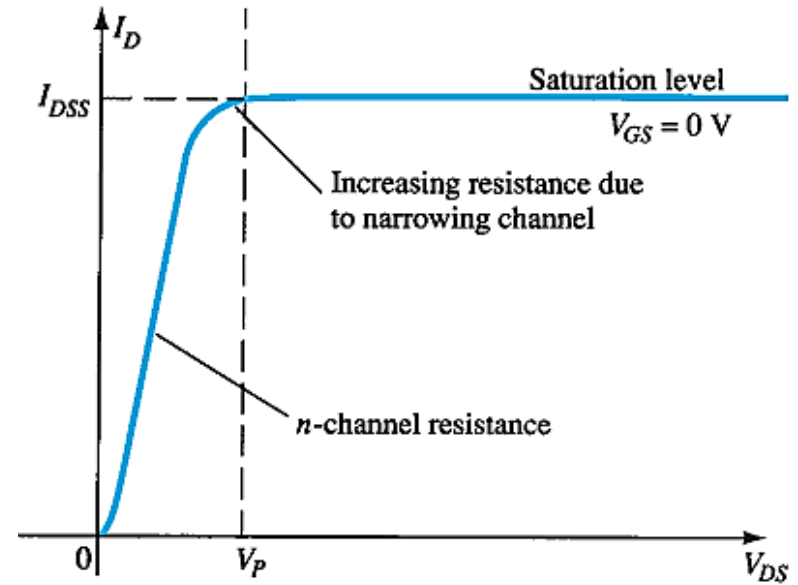


FIG. 6.7

I_D versus V_{DS} for $V_{GS} = 0$ V.

JFET modeling when $I_D = I_{DSS}$, $V_{GS} = 0$, $V_{DS} > V_P$

- I_{DSS} is the maximum drain current for a JFET and is defined by the conditions

$$V_{GS} = 0 \text{ V and } V_{DS} > V_P.$$

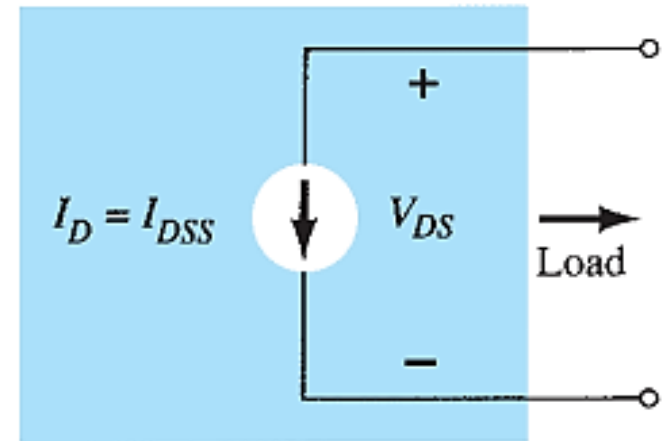


FIG. 6.9

*Current source equivalent for
 $V_{GS} = 0 \text{ V}$, $V_{DS} > V_P$.*

$V_{GS} < 0$, V_{DS} AT SOME POSITIVE VALUE

- As V_{GS} becomes more negative the depletion region increases.

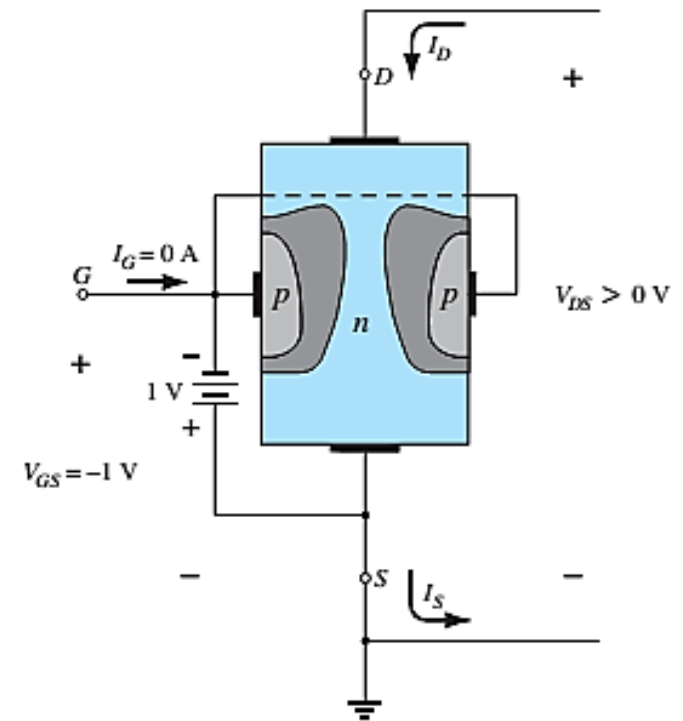


FIG. 6.10

Application of a negative voltage to the gate of a JFET.

$$I_D < I_{DSS}$$

As V_{GS} becomes more negative:

- The JFET will pinch-off at a lower value of V_{DS} .
- I_D decreases ($I_D < I_{DSS}$) even though V_{DS} is increased.
- Eventually I_D will reach 0A. V_{GS} at this point is called V_p or $V_{GS(off)}$.
- Also note that at high levels of V_{DS} the JFET reaches a breakdown situation. I_D will increase uncontrollably if $V_{DS} > V_{DSmax}$.

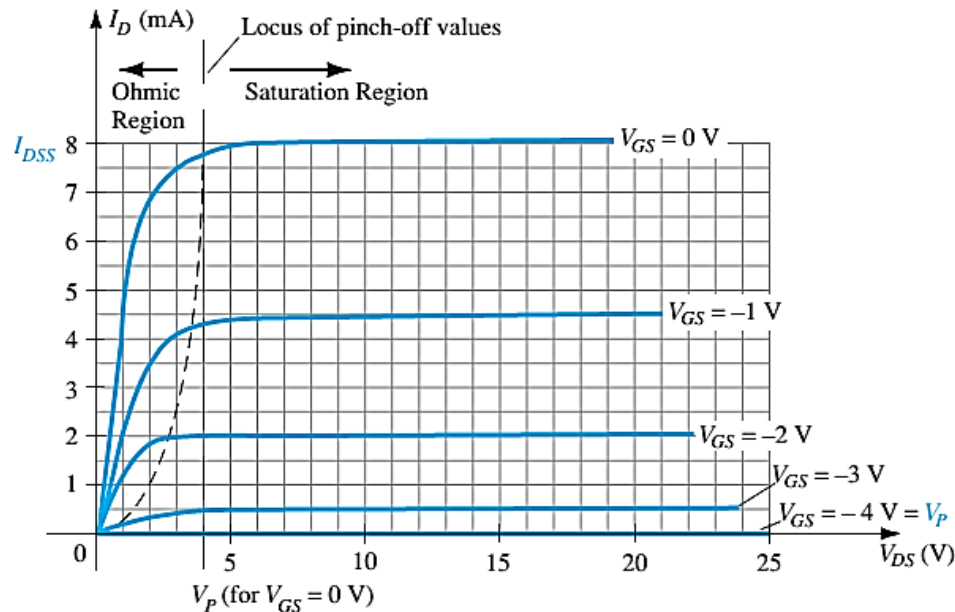


FIG. 6.11

n-Channel JFET characteristics with $I_{DSS} = 8$ mA and $V_P = -4$ V.

JFET OPERATING CHARACTERISTICS: VOLTAGE CONTROLLED RESISTOR

- The region to the left of the pinch-off point is called the ohmic region.
- The JFET can be used as a variable resistor, where V_{GS} controls the drain-source resistance (r_d).
- The slope of each curve and therefore the resistance of the device between drain and source for $V_{DS} < V_P$ is a function of the applied voltage V_{GS} .
- As V_{GS} becomes more negative, the resistance (r_d) increases.

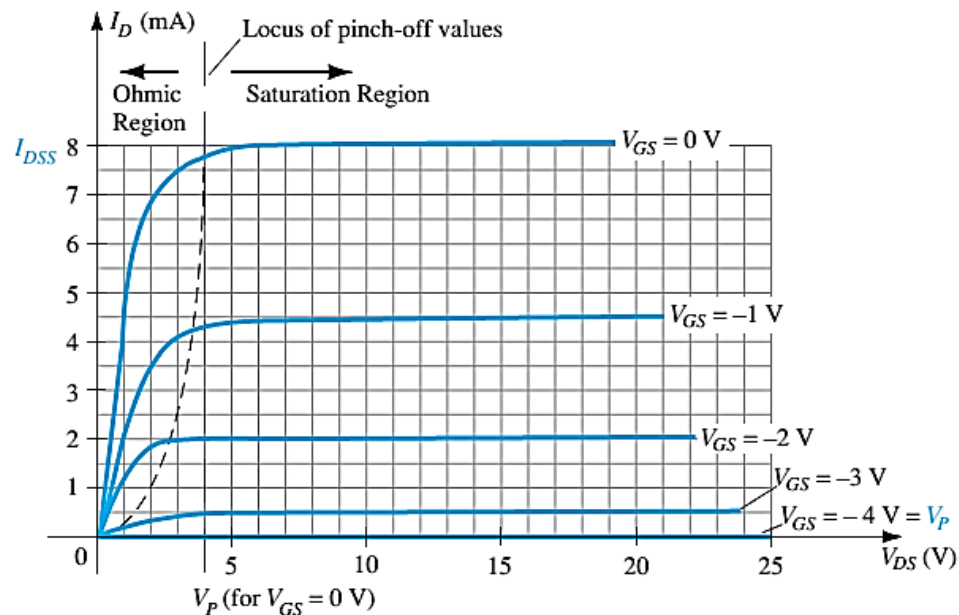


FIG. 6.11

n-Channel JFET characteristics with $I_{DSS} = 8 \text{ mA}$ and $V_P = -4 \text{ V}$.

$$r_d = \frac{r_o}{(1 - V_{GS}/V_P)^2}$$

P-CHANNEL JFETS

- p-Channel JFET acts the same as the n-channel JFET, except the polarities and currents are reversed.

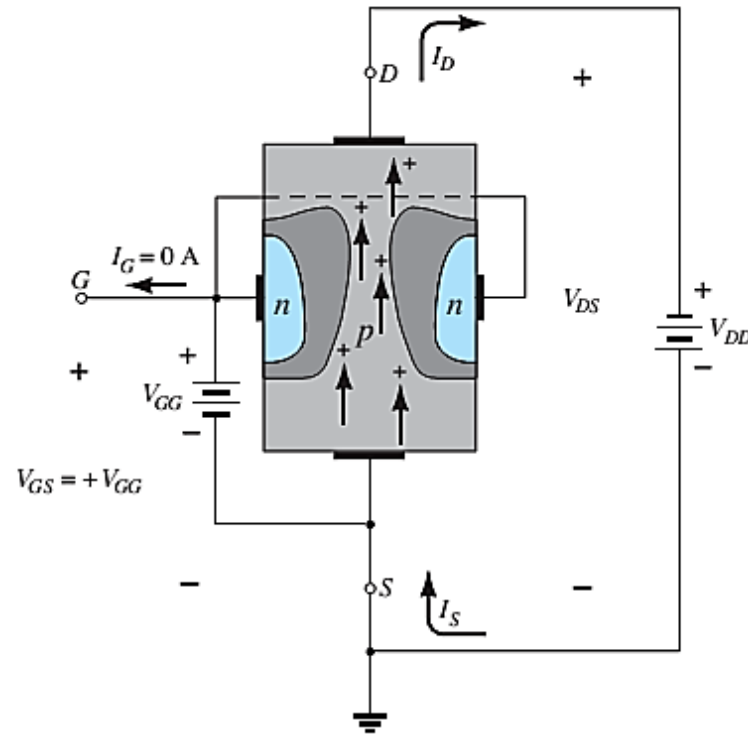


FIG. 6.12
p-Channel JFET.

End of Lecture-3

