Electronic Devices

Final Term
Lecture - 03

Reference book:

Electronic Devices and Circuit Theory (Chapter-6)

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

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 BJTs

- 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.

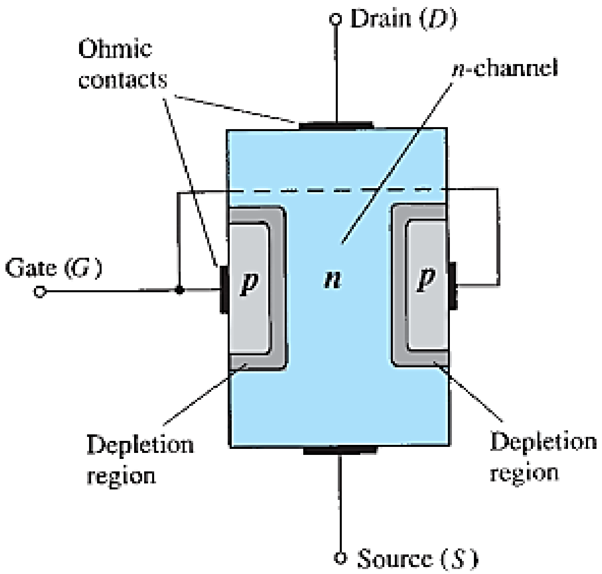

FIG. 6.3
Junction field-effect transistor (JFET).

- There are ***three terminals***:
  - ***Drain (D)*** and ***Source (S)*** are connected to n-channe
  - ***Gate (G)*** is connected to the p-type material
- Check this: http://www-g.eng.cam.ac.uk/mmg/teaching/linearcircuits/jfet.html

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:

A. $V_{GS} = 0$, V_{DS} increasing to some positiv

B. $V_{GS} < 0$, V_{DS} at some positive value

C. Voltage-Controlled Resistor

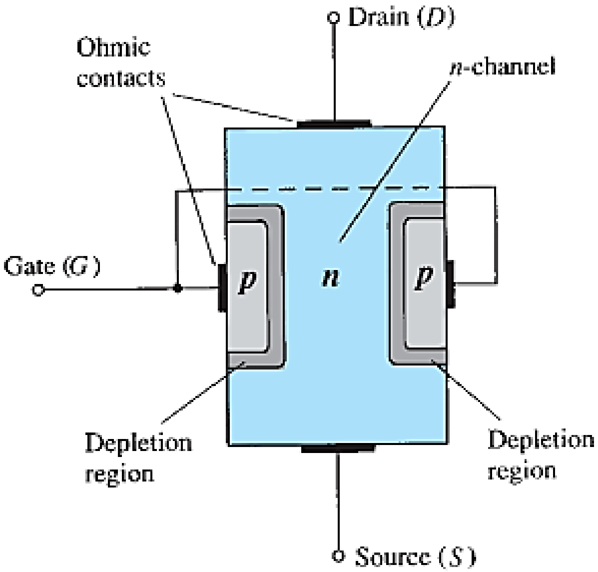

FIG. 6.3
Junction field-effect transistor (JFET).

JFET OPERATING CHARACTERISTICS: V_{GS} = 0 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 Drai***n through the n-channel ***is increasing***. This is because ***V_{DS} is increasing***.

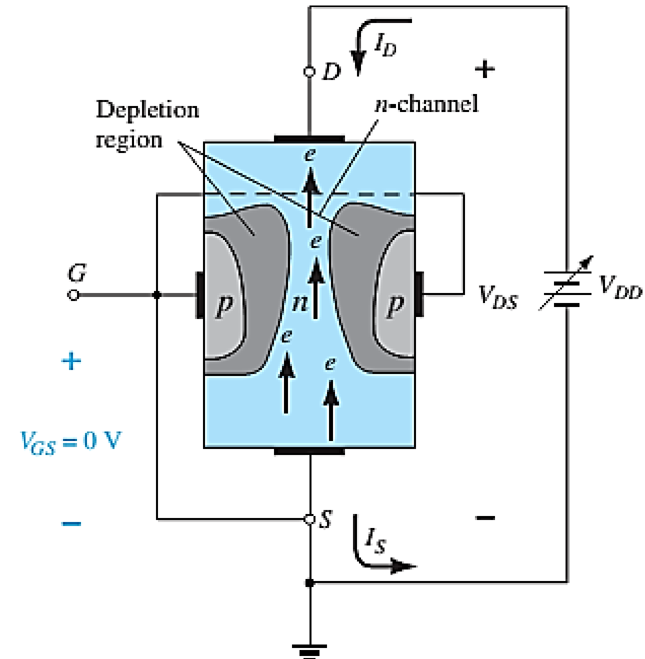

FIG. 6.5
JFET at V_{GS} = 0 V and V_{DS} > 0 V.

JFET OPERATING CHARACTERISTICS: V_{GS} = 0 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***.

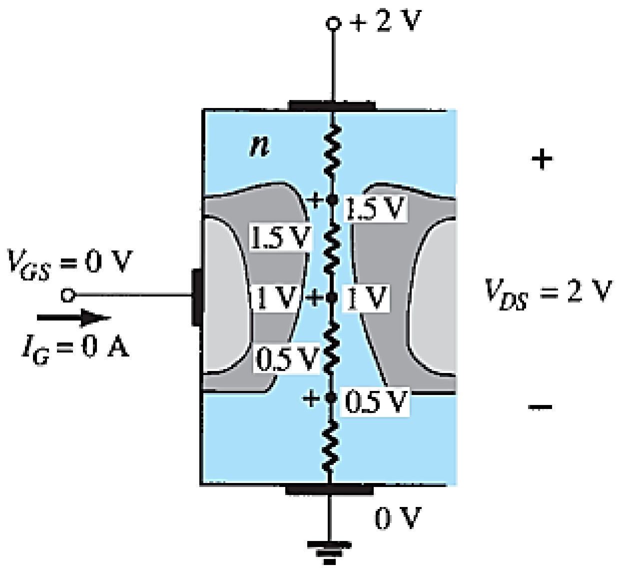

FIG. 6.6
Varying reverse-bias potentials across the p–n junction of an n-channel JFET.

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.

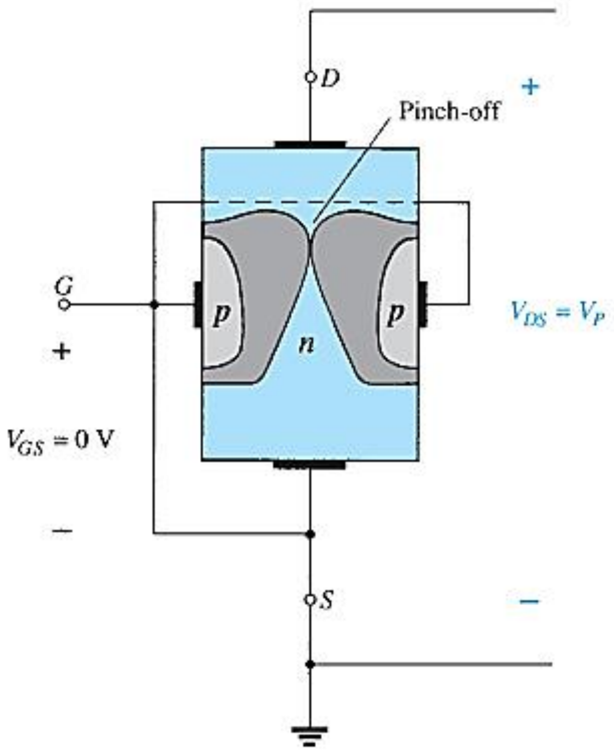

FIG. 6.8
Pinch-off ($V_{GS} = 0$ V, $V_{DS} = V_P$).

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.

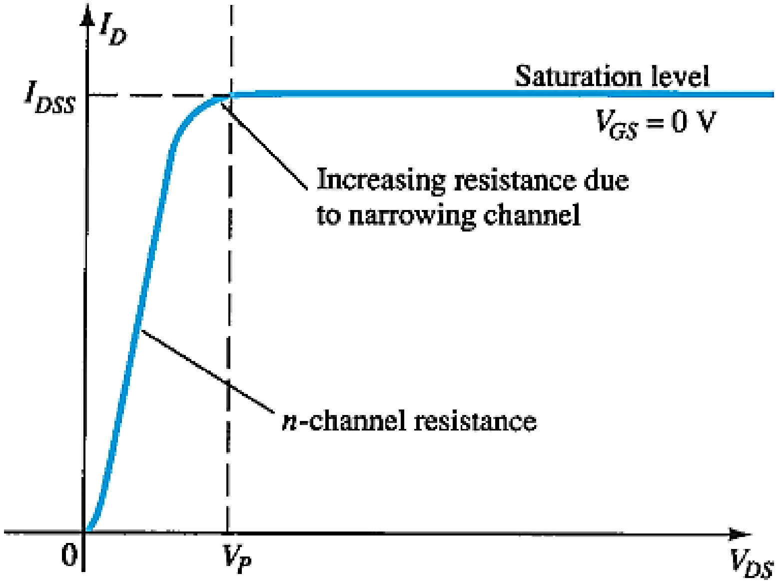

FIG. 6.7
I_D versus V_{DS} for $V_{GS} = 0$ V.

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

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

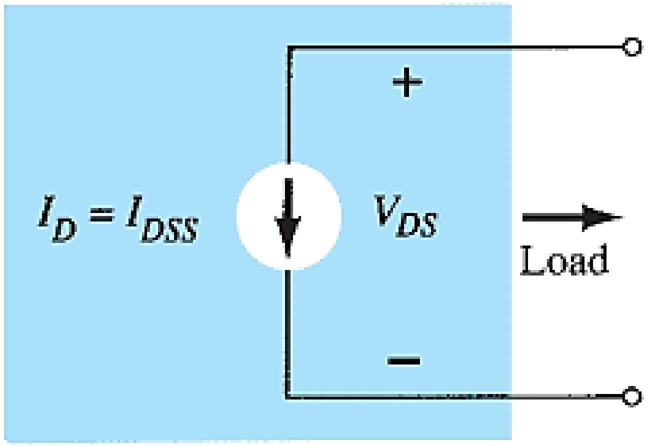

FIG. 6.9

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

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

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

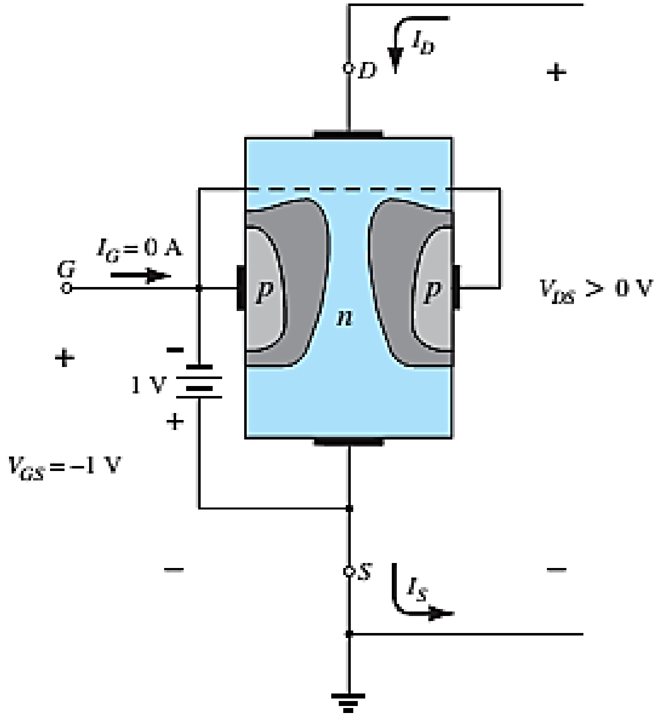

FIG. 6.10
Application of a negative voltage to the gate of a JFET.

$I_D < I_{DSS}$

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 increases uncontrollably if $V_{DS} > V_{DSmax}$.

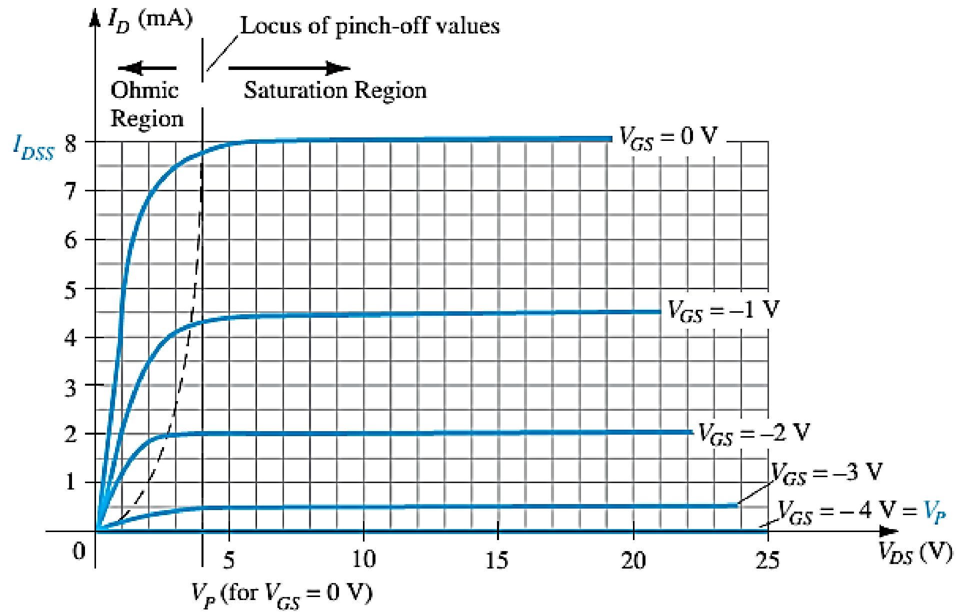

FIG. 6.11

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.

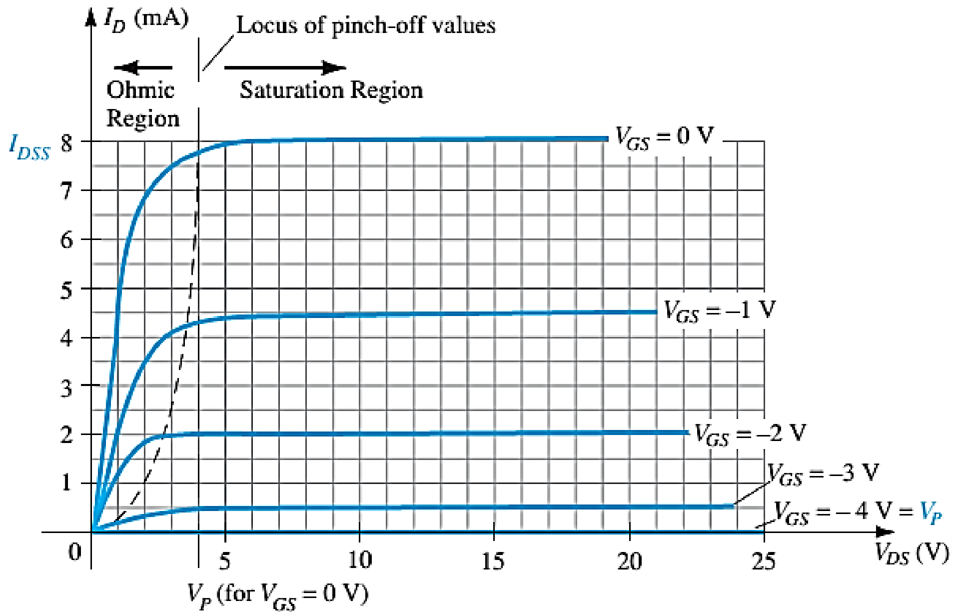

FIG. 6.11
n-Channel JFET characteristics with $I_{DSS} = 8$ mA and $V_P = -4$ V.

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

P-CHANNEL JFETS

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

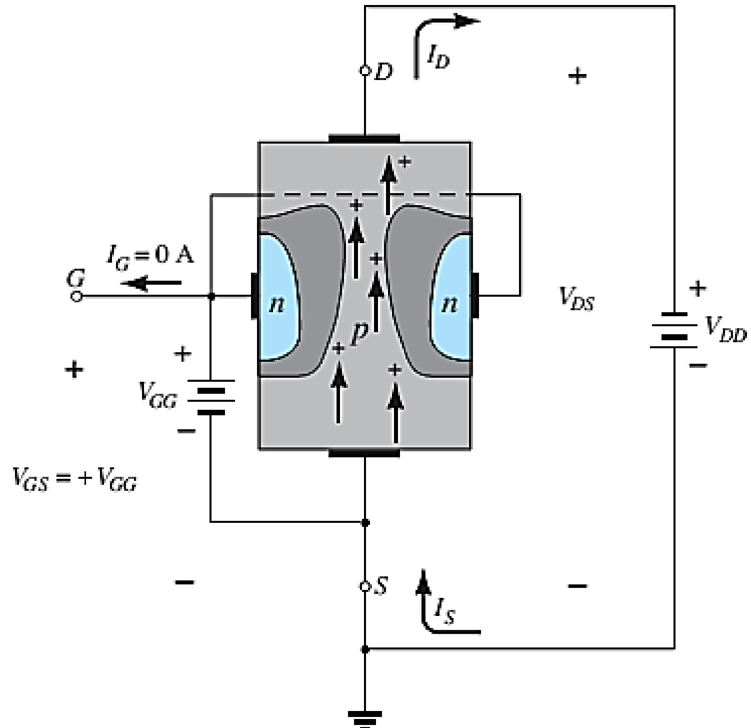

FIG. 6.12
p-Channel JFET.

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