

Electronic Devices

Final Term Lecture - 04

Reference book:

Electronic Devices and Circuit Theory (Chapter-6)

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



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P-CHANNEL JFET CHARACTERISTICS

- As V_{GS} increases more positively:
 - The depletion zone increases
 - I_D decreases ($I_D < I_{DSS}$)
 - Eventually $I_D = 0A$
- Also note that at high levels of V_{DS} the JFET reaches a breakdown situation. I_D increases uncontrollably if $V_{DS} > V_{DSmax}$.

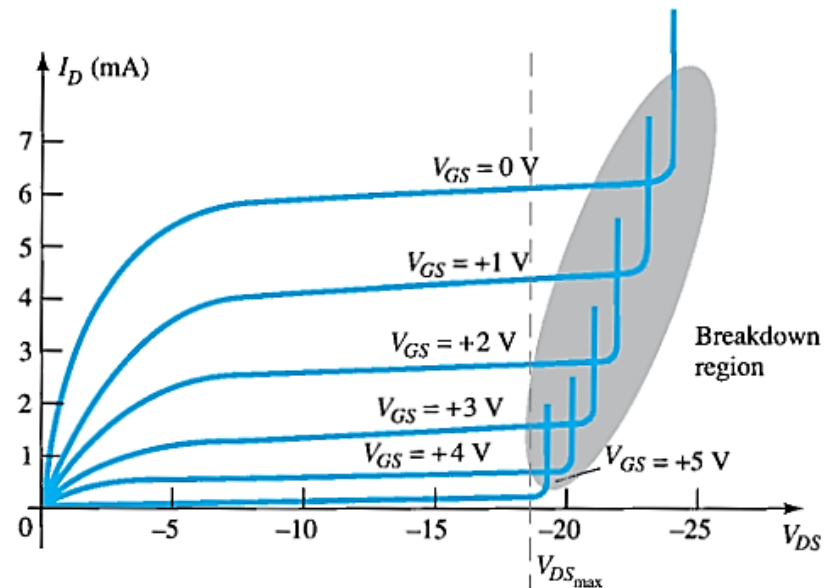


FIG. 6.13

p-Channel JFET characteristics with $I_{DSS} = 6$ mA and $V_P = +6$ V.

JFET SYMBOLS

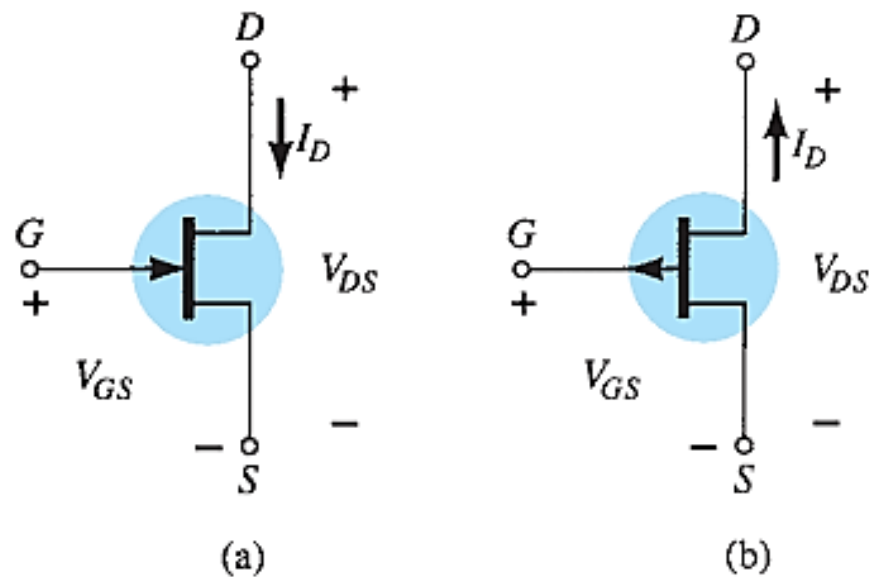


FIG. 6.14

JFET symbols: (a) n-channel; (b) p-channel.

SUMMARY TILL NOW

- The maximum current is defined as I_{DSS} and occurs when $V_{GS} = 0$ V and $V_{DS} \geq |V_p|$, as shown in Fig. 6.15a .
- For gate-to-source voltages V_{GS} is less than (more negative than) the pinch-off level, the drain current is 0 A ($I_D = 0$ A), as in Fig. 6.15b .
- For all levels of V_{GS} between 0 V and the pinch-off level, the current I_D will range between I_{DSS} and 0 A, respectively, as in Fig. 6.15c.
- A similar list can be developed for p-channel JFETs.



SUMMARY TILL NOW

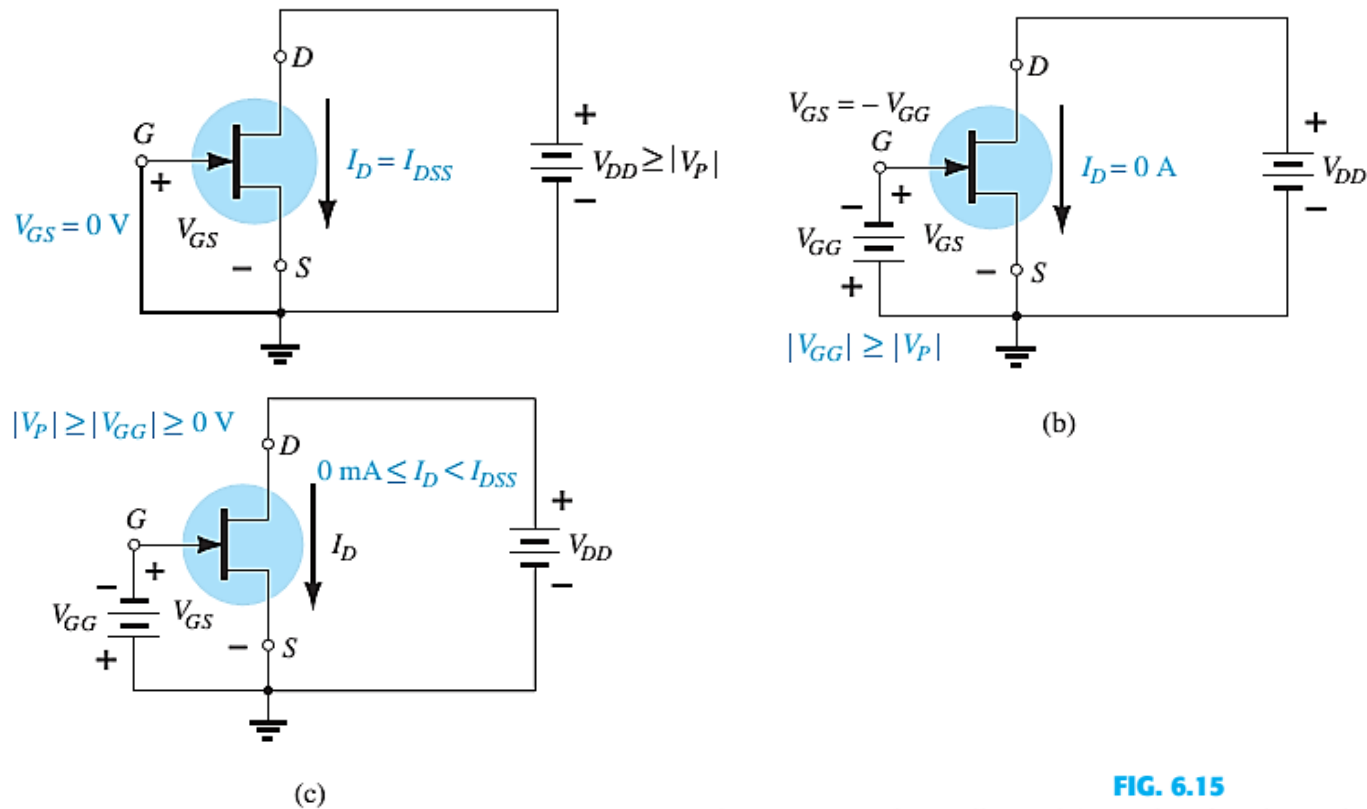


FIG. 6.15

(a) $V_{GS} = 0\text{ V}$, $I_D = I_{DSS}$; (b) cutoff ($I_D = 0\text{ A}$) V_{GS} less than the pinch-off level; (c) I_D is between 0 A and I_{DSS} for $V_{GS} \leq 0\text{ V}$ and greater than the pinch-off level.

JFET TRANSFER CHARACTERISTICS

- The transfer characteristic of **input-to-output** is not as straight forward in a JFET as it was in a BJT.
- In a BJT, β indicated the relationship between I_B (input) and I_C (output).
- In a JFET, the relationship of V_{GS} (input) and I_D (output) is a little more complicated (Shockley's equation):

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

control variable

constants

TRANSFER CURVE

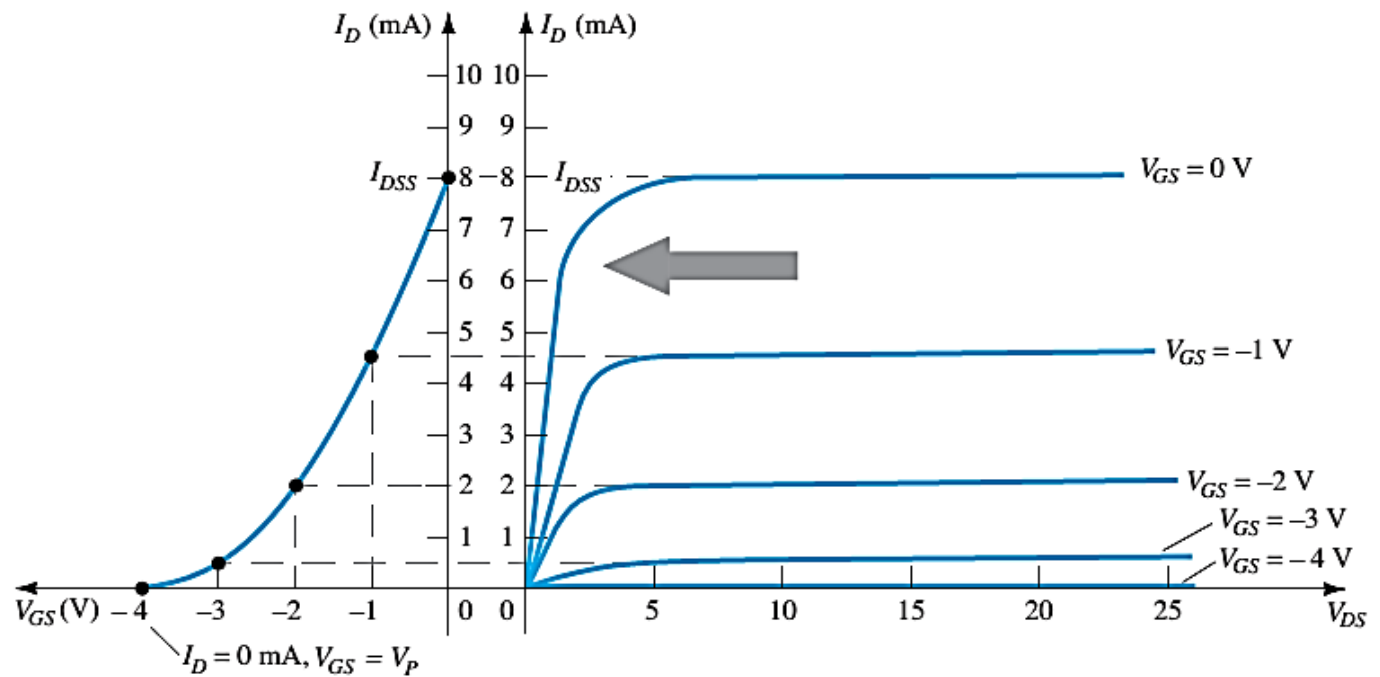


FIG. 6.17

Obtaining the transfer curve from the drain characteristics.

PLOTTING THE TRANSFER CURVE

- Using I_{DSS} and V_p ($V_{GS(off)}$) values found in a specification sheet, the Transfer Curve can be plotted using these 3 steps:

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

Solving for $V_{GS} = 0V$: $I_D = I_{DSS} \quad V_{GS} = 0V$

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

Solving for $V_{GS} = \frac{I_D = 0A}{I_{DSS}} V_P = V_P$

- Step 3:

Solving for $V_{GS} = 0V$ to V_P : $I_D = I_{DSS} \left(1 - \frac{V_{GS}}{V_P}\right)^2$

SHORTHAND METHOD

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

When $V_{GS} = 0\text{ V}$, $I_D = I_{DSS}$

When $V_{GS} = V_P$, $I_D = 0\text{ mA}$

EXAMPLE

EXAMPLE 6.1 Sketch the transfer curve defined by $I_{DSS} = 12 \text{ mA}$ and $V_P = -6 \text{ V}$.

Solution: Two plot points are defined by

$$I_{DSS} = 12 \text{ mA} \quad \text{and} \quad V_{GS} = 0 \text{ V}$$

and $I_D = 0 \text{ mA} \quad \text{and} \quad V_{GS} = V_P$

At $V_{GS} = V_P/2 = -6 \text{ V}/2 = -3 \text{ V}$ the drain current is determined by $I_D = I_{DSS}/4 = 12 \text{ mA}/4 = 3 \text{ mA}$. At $I_D = I_{DSS}/2 = 12 \text{ mA}/2 = 6 \text{ mA}$ the gate-to-source voltage is determined by $V_{GS} \cong 0.3V_P = 0.3(-6 \text{ V}) = -1.8 \text{ V}$. All four plot points are well defined on Fig. 6.18 with the complete transfer curve.

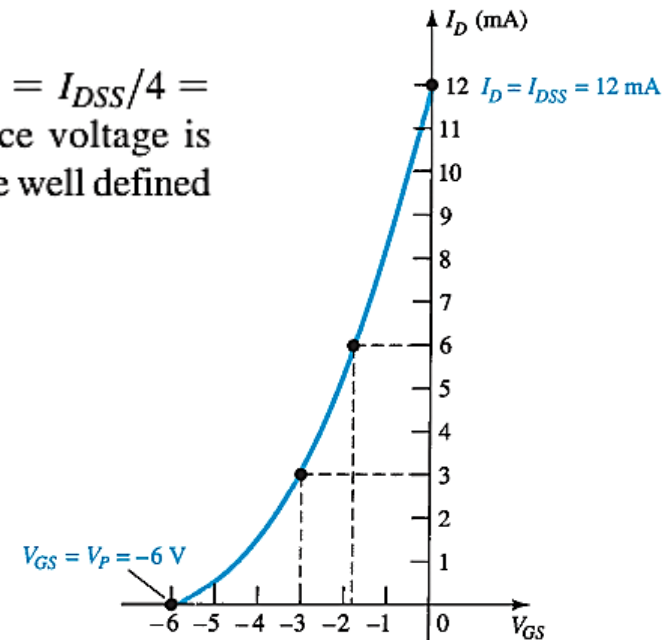


FIG. 6.18

Transfer curve for Example 6.1.



EXAMPLE

EXAMPLE 6.2 Sketch the transfer curve for a p -channel device with $I_{DSS} = 4 \text{ mA}$ and $V_P = 3 \text{ V}$.

Solution: At $V_{GS} = V_P/2 = 3 \text{ V}/2 = 1.5 \text{ V}$, $I_D = I_{DSS}/4 = 4 \text{ mA}/4 = 1 \text{ mA}$. At $I_D = I_{DSS}/2 = 4 \text{ mA}/2 = 2 \text{ mA}$, $V_{GS} = 0.3V_P = 0.3(3 \text{ V}) = 0.9 \text{ V}$. Both plot points appear in Fig. 6.19 along with the points defined by I_{DSS} and V_P .

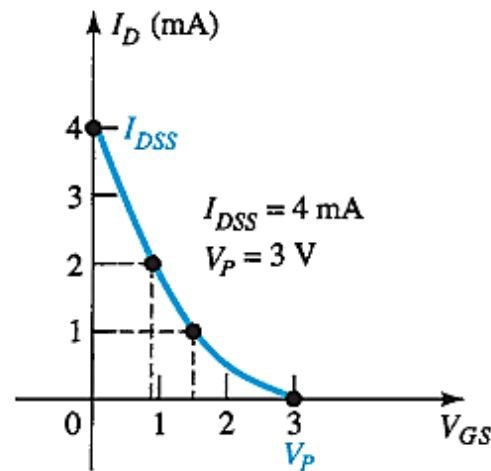
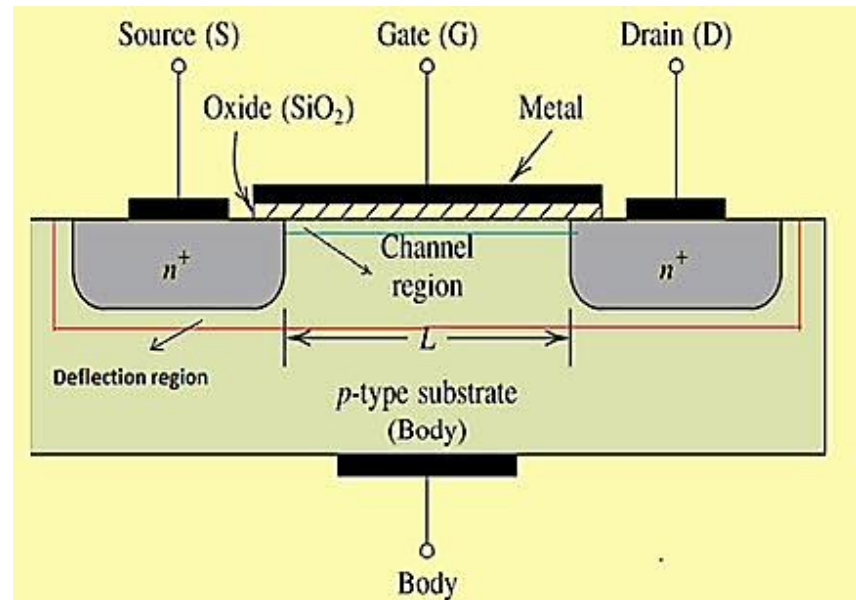


FIG. 6.19

Transfer curve for the p -channel device of Example 6.2.

MOSFETs

- MOSFETs have characteristics similar to JFETs and additional characteristics that make them very useful.
- There are 2 types:
 - Depletion-Type MOSFET
 - Enhancement-Type MOSFET



ENHANCEMENT-TYPE MOSFET CONSTRUCTION

- The Drain (D) and Source (S) connect to the n -doped regions.
- The Gate (G) connects to the p -doped substrate via a thin insulating layer of SiO_2 .
- There is no channel. The n -doped material lies on a p -doped substrate that may have an additional terminal connection called SS.
- In summary, therefore, the construction of an enhancement-type MOSFET is quite similar to that of the depletion-type MOSFET, except for the absence of a channel between the drain and source terminals.

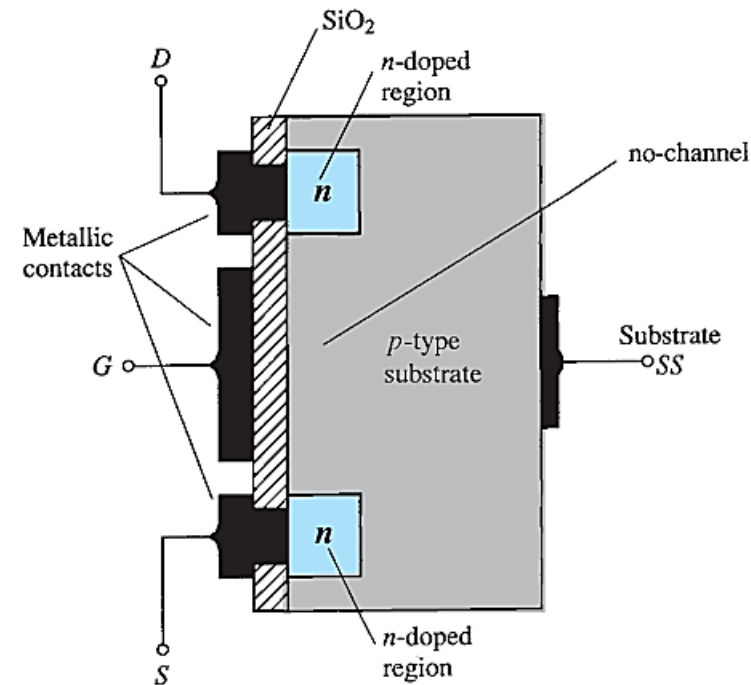


FIG. 6.32

n-Channel enhancement-type MOSFET.

CONTINUED...

- As V_{GS} increases in magnitude, the **concentration of electrons near the SiO₂ surface increases** until eventually the induced n-type region can support a measurable flow between drain and source.
- The level of V_{GS} that results in the **significant increase in drain current** is called the **threshold voltage** and is given the symbol V_T .
- Since the channel is nonexistent with $V_{GS}=0$ V and “enhanced” by the application of a positive gate-to-source voltage, this type of MOSFET is called an enhancement-type MOSFET.

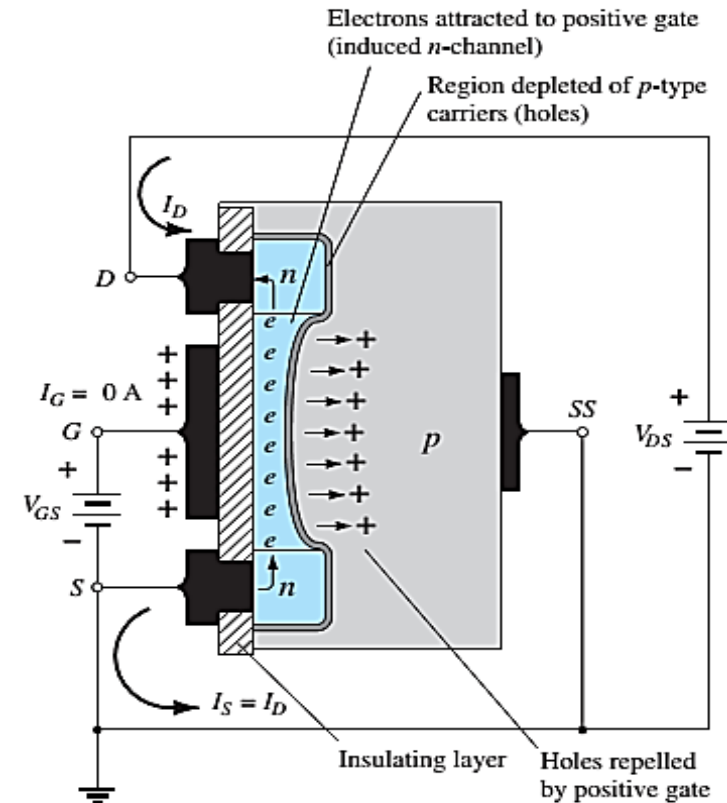


FIG. 6.33

Channel formation in the n-channel enhancement-type MOSFET.

CONTINUED...

- As V_{GS} is increased **beyond the threshold level**, the **density of free carriers** in the induced channel **will increase**, resulting in **an increased level of drain current**.
- However, if we hold V_{GS} constant and increase the level of V_{DS} , the drain current will eventually reach a saturation level. The levelling off of I_D is due to a pinching-off process depicted by the narrower channel at the drain end of the induced channel.
- By applying KVL we get –
$$V_{DG} = V_{DS} - V_{GS}$$
- If V_{GS} is **held fixed** at some value such as 8 V and V_{DS} is **increased** from 2 to 5V, the voltage will drop from -6 to -3 V. This **reduction in gate-to-drain voltage** will in turn **reduce the attractive forces for free carriers** (electrons) in this region of the induced channel, **causing a reduction in the effective channel width**.
- Eventually, the channel will be reduced to the point of pinch-off and a saturation condition will be established.



CONTINUED...

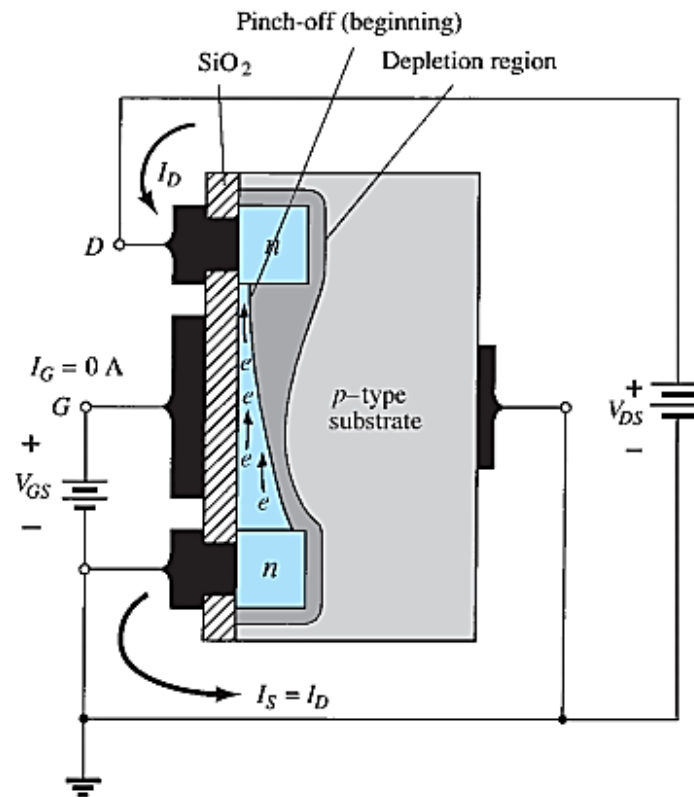


FIG. 6.34

Change in channel and depletion region with increasing level of V_{DS} for a fixed value of V_{GS} .

BASIC OPERATION

- The Enhancement-type MOSFET only operates in the enhancement mode.

- V_{GS} is always positive.
- As V_{GS} increases, I_D increases.
- But if V_{GS} is kept constant and V_{DS} is increased, then I_D saturates (I_{DSS}).
- The saturation level, V_{DSSat} is reached.

$$V_{Dsat} = V_{GS} - V_T$$

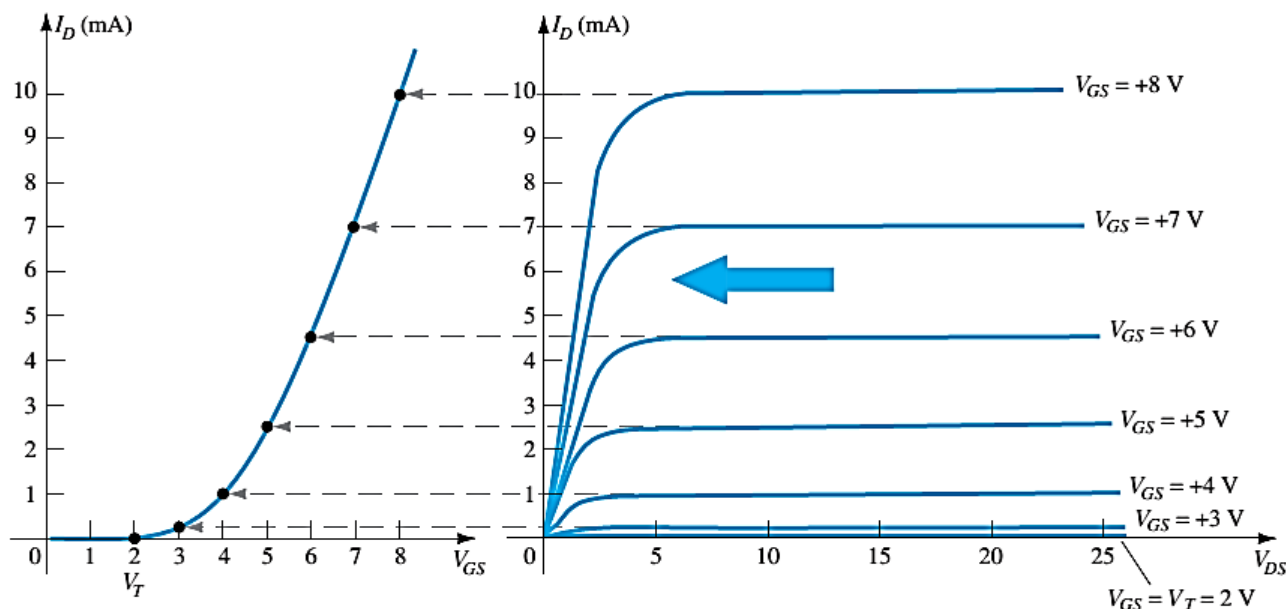


FIG. 6.36

Sketching the transfer characteristics for an n-channel enhancement-type MOSFET from the drain characteristics.

Check this: <http://www-g.eng.cam.ac.uk/mmg/teaching/linearcircuits/jfet.html>

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End of Lecture-4

