

Field Effect Transistors

LECTURE 9

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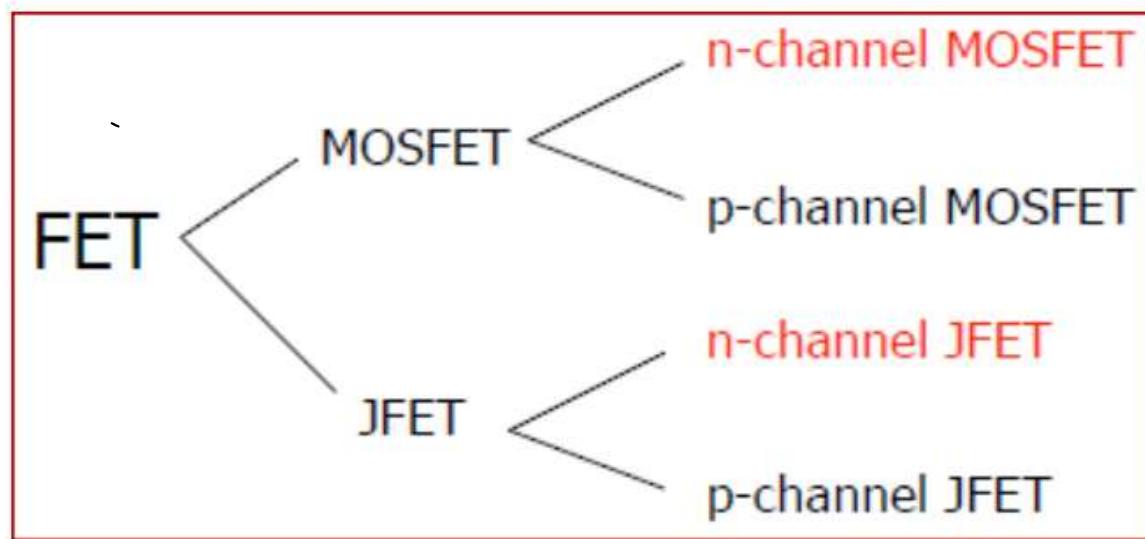
FETs vs. BJTs

Similarities:

- Amplifiers
- Switching devices
- Impedance matching circuits

Differences:

- FETs are voltage-controlled devices. BJTs are current controlled devices.
- FETs have a higher input impedance. BJTs have higher gains.
- FETs are less sensitive to temperature variations and are more easily integrated on ICs.
- FETs are generally more static sensitive than BJTs.



JFET Construction

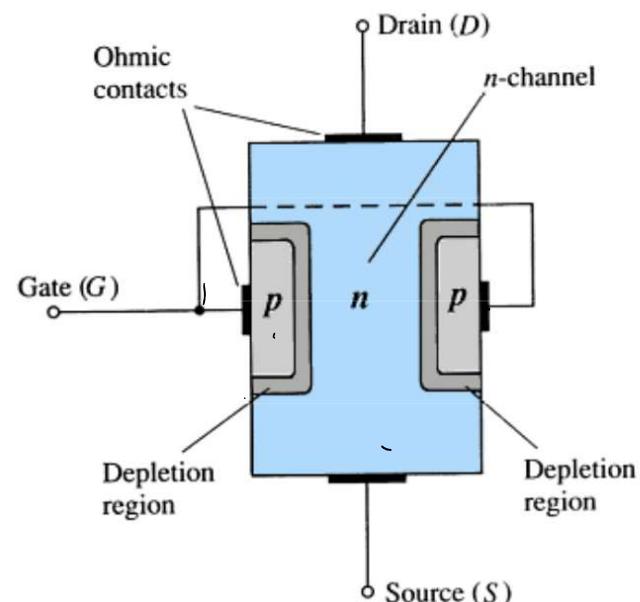
There are two types of JFETs

- n-channel**
- p-channel**

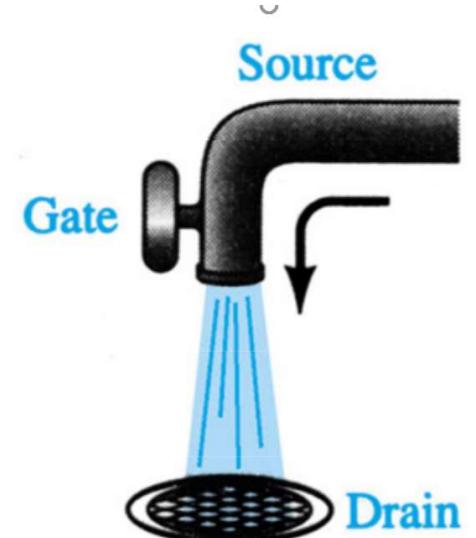
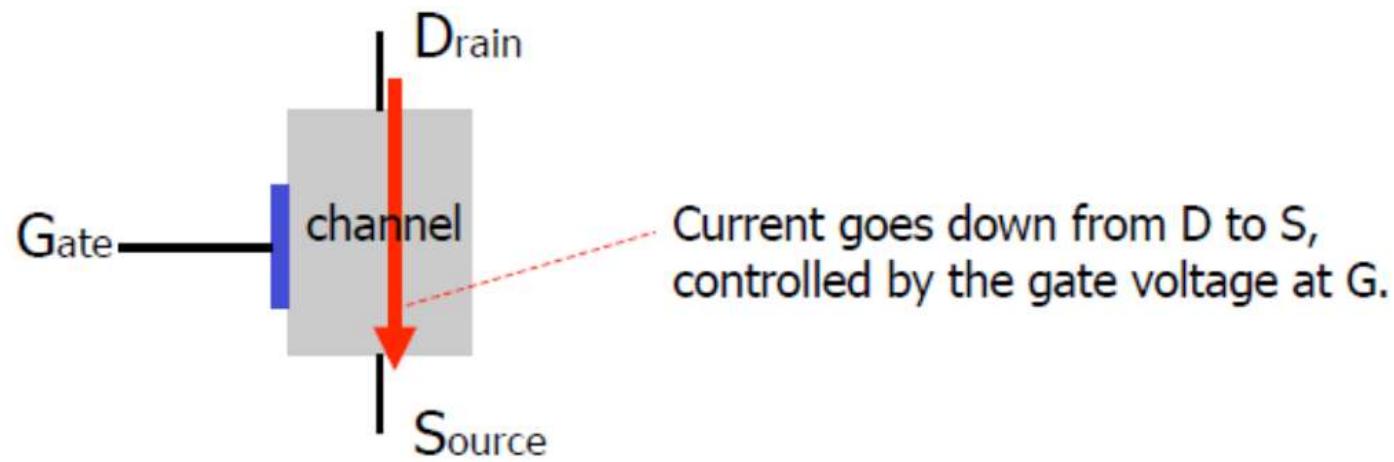
The n-channel is more widely used.

There are three terminals:

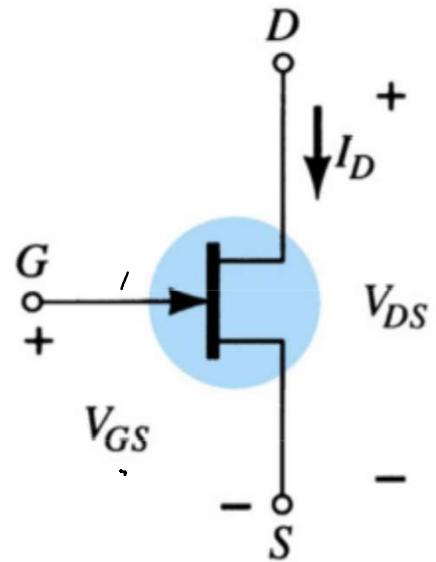
- Drain (D)** and **Source (S)** are connected to the **n**-channel
- Gate (G)** is connected to the **p**-type material



JFET Operation: The Basic Idea



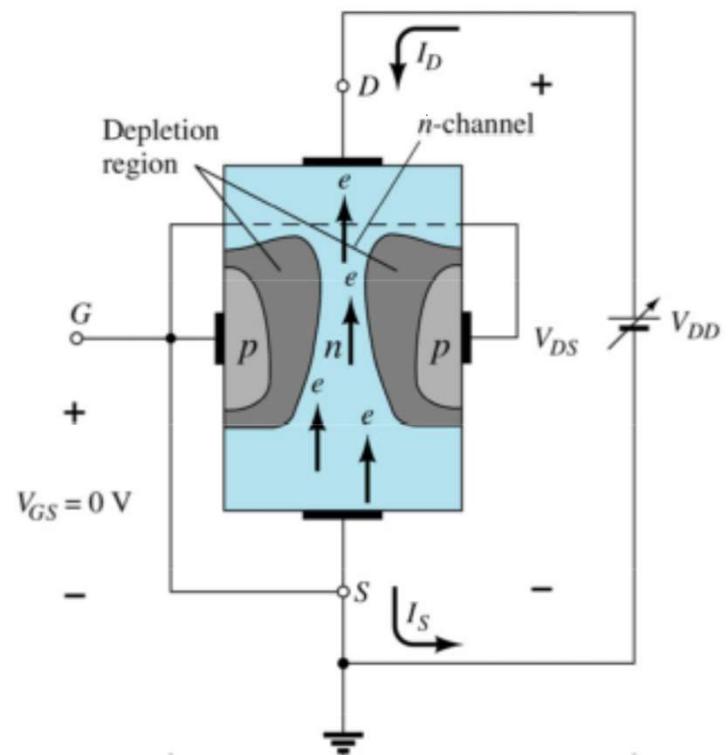
n-Channel JFET Symbol



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

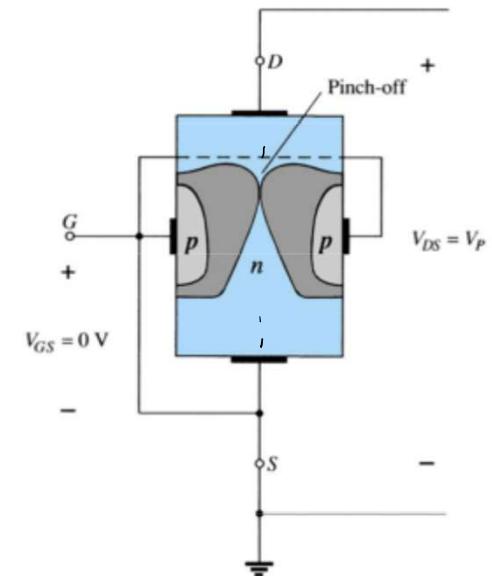
- The depletion region between p-gate and n-channel increases as electrons from n-channel combine with holes from p-gate.
- Increasing the depletion region, decreases the size of the n-channel which increases the resistance of the n-channel.
- Even though the n-channel resistance is increasing, the current (I_D) from source to drain through the n-channel is increasing. This is because V_{DS} is increasing.



JFET Operating Characteristics: 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.

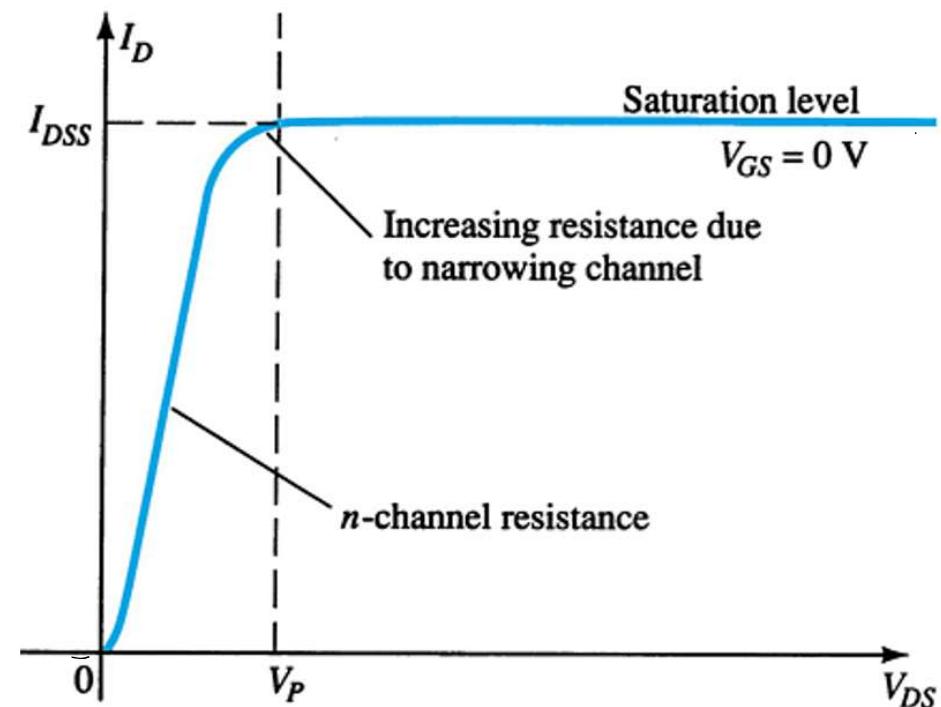
This suggests that the current in the n-channel (I_D) would drop to 0A, but it does just the opposite—as V_{DS} increases, so does I_D .



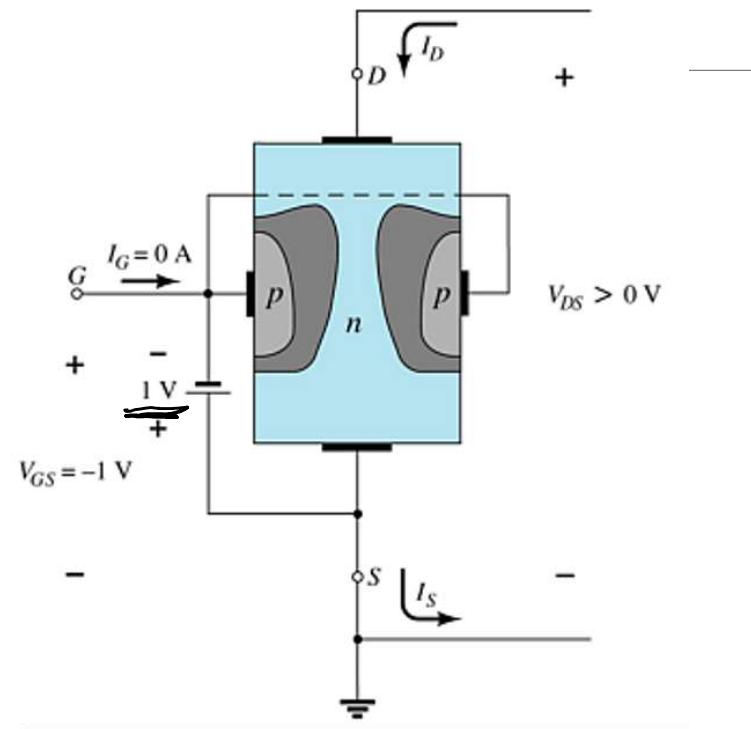
JFET Operating Characteristics: Saturation

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 maximum.



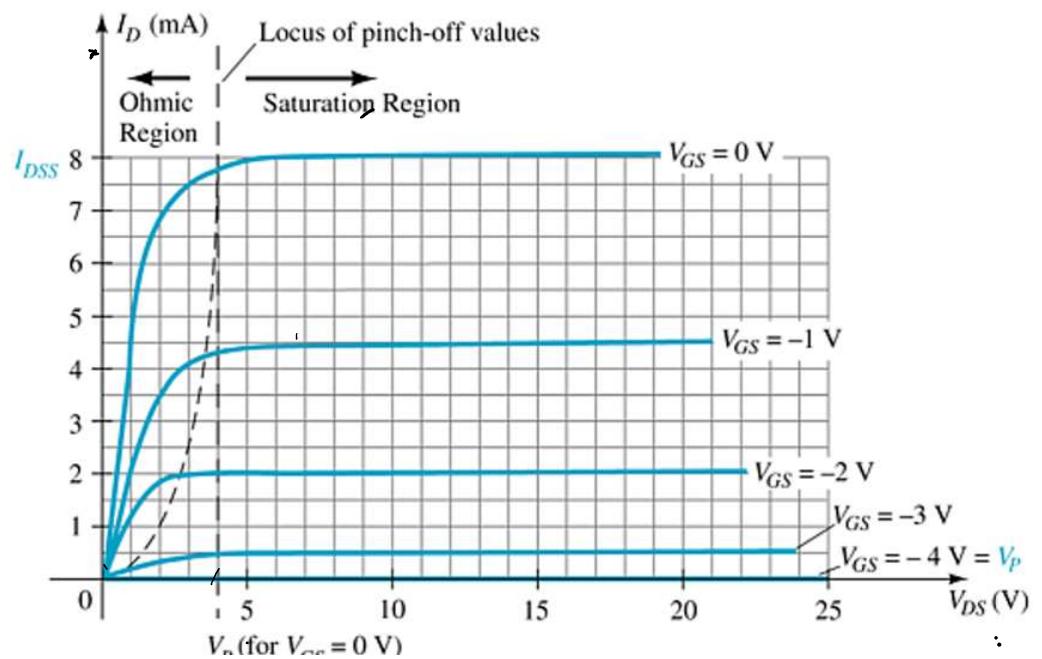
As V_{GS} becomes more negative, the depletion region increases.



JFET Operating Characteristics

As V_{GS} becomes more negative:

- The JFET experiences pinch-off at a lower voltage (V_p).
- I_D decreases ($I_D < I_{DSS}$) even though V_{DS} is increased.
- Eventually I_D reaches 0 A. V_{GS} at this point is called V_p or $V_{GS(off)}$.

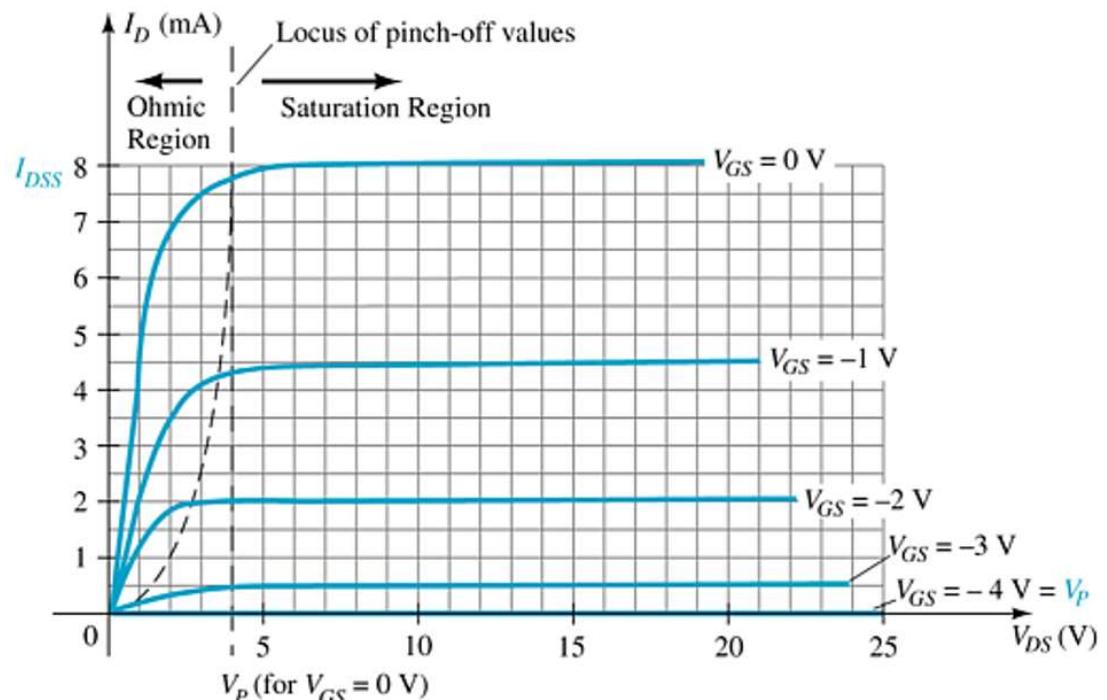


Ohmic Region - Voltage-Controlled Resistor

The region to the left of the pinch-off point is called the **ohmic region**.

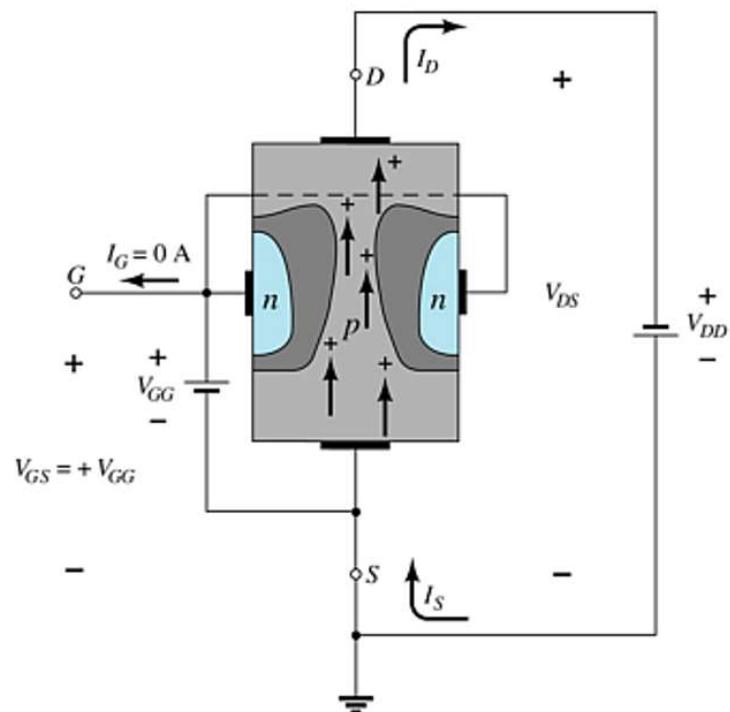
The JFET can be used as a variable resistor, where V_{GS} controls the drain-source resistance (r_d). As V_{GS} becomes more negative, the resistance (r_d) increases.

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



p-Channel JFETS

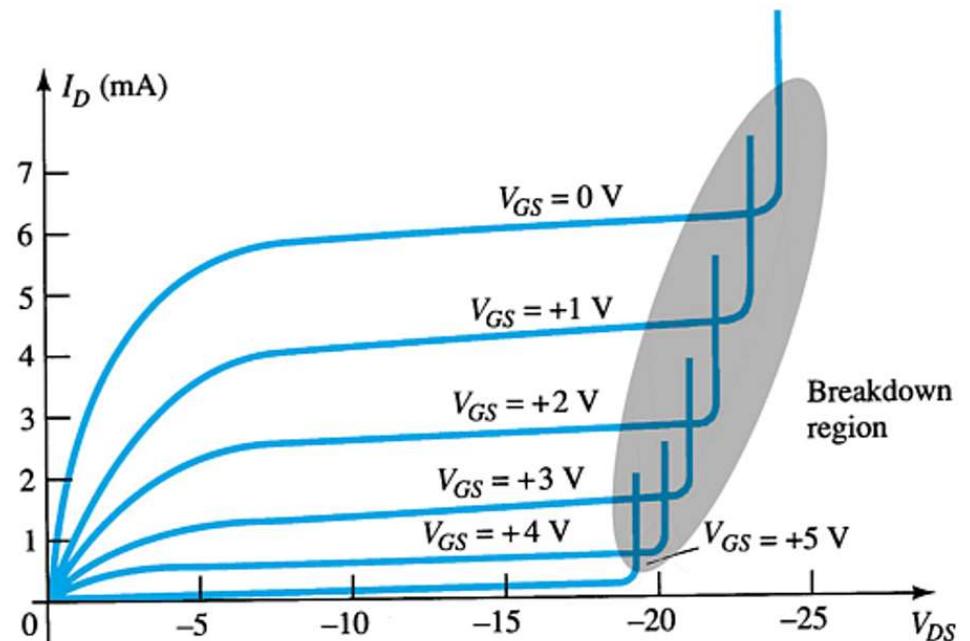
The **p**-channel JFET behaves the same as the **n**-channel JFET, except the voltage polarities and current directions are reversed.



p-Channel JFET Characteristics

As V_{GS} increases more positively

- The depletion zone increases
- I_D decreases ($I_D < I_{DSS}$)
- Eventually $I_D = 0$ A



Also note that at high levels of V_{DS} the JFET reaches a breakdown situation: I_D increases uncontrollably if $V_{DS} > V_{DSmax}$.

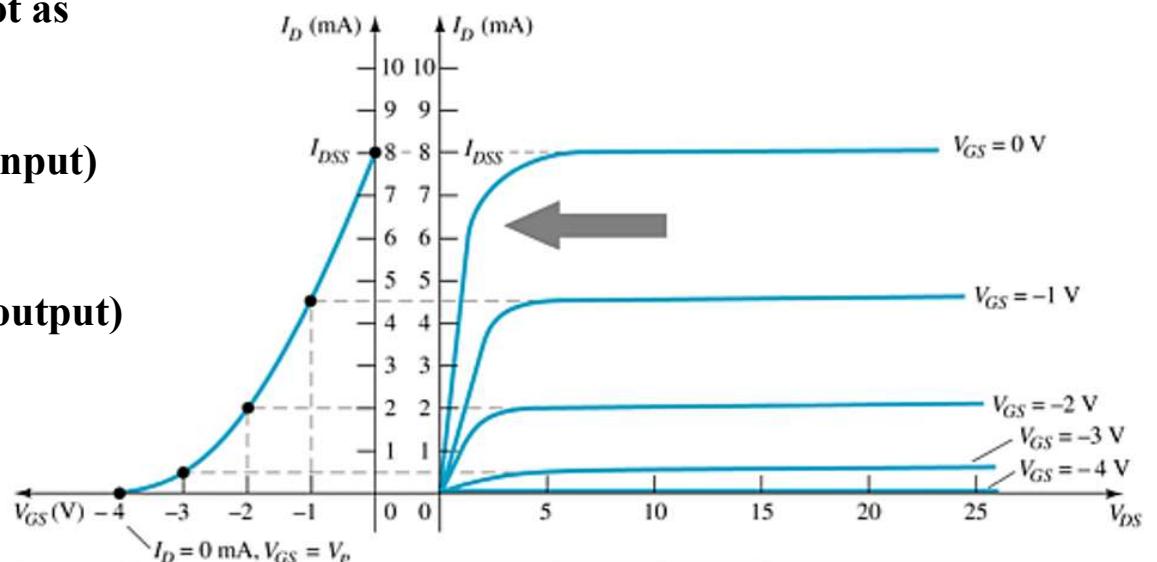
JFET Transfer Curve

The transfer characteristic of input-to-output is not as straightforward in a JFET as it is in a BJT.

In a BJT, β indicates 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:

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



MOSFETs

MOSFETs have characteristics similar to JFETs and additional characteristics that make them very useful.

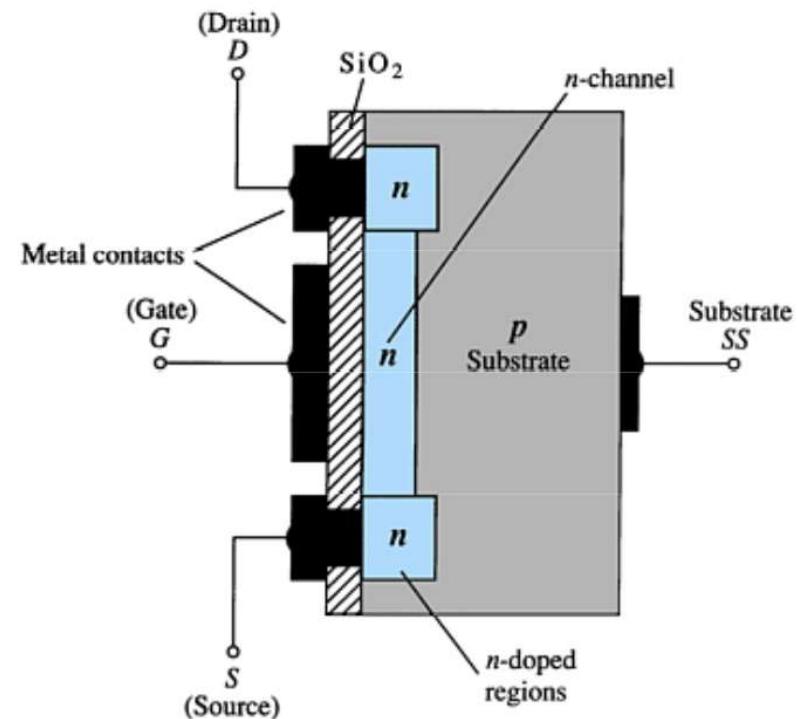
There are two types of MOSFETs:

- Depletion-Type
- Enhancement-Type

MOSFET Construction

The **Drain (D)** and **Source (S)** connect to the to *n*-doped regions. These *n*-doped regions are connected via an *n*-channel. This *n*-channel is connected to the **Gate (G)** via a thin insulating layer of SiO_2 .

The *n*-doped material lies on a *p*-doped substrate that may have an additional terminal connection called **Substrate (SS)**.



Thank You

