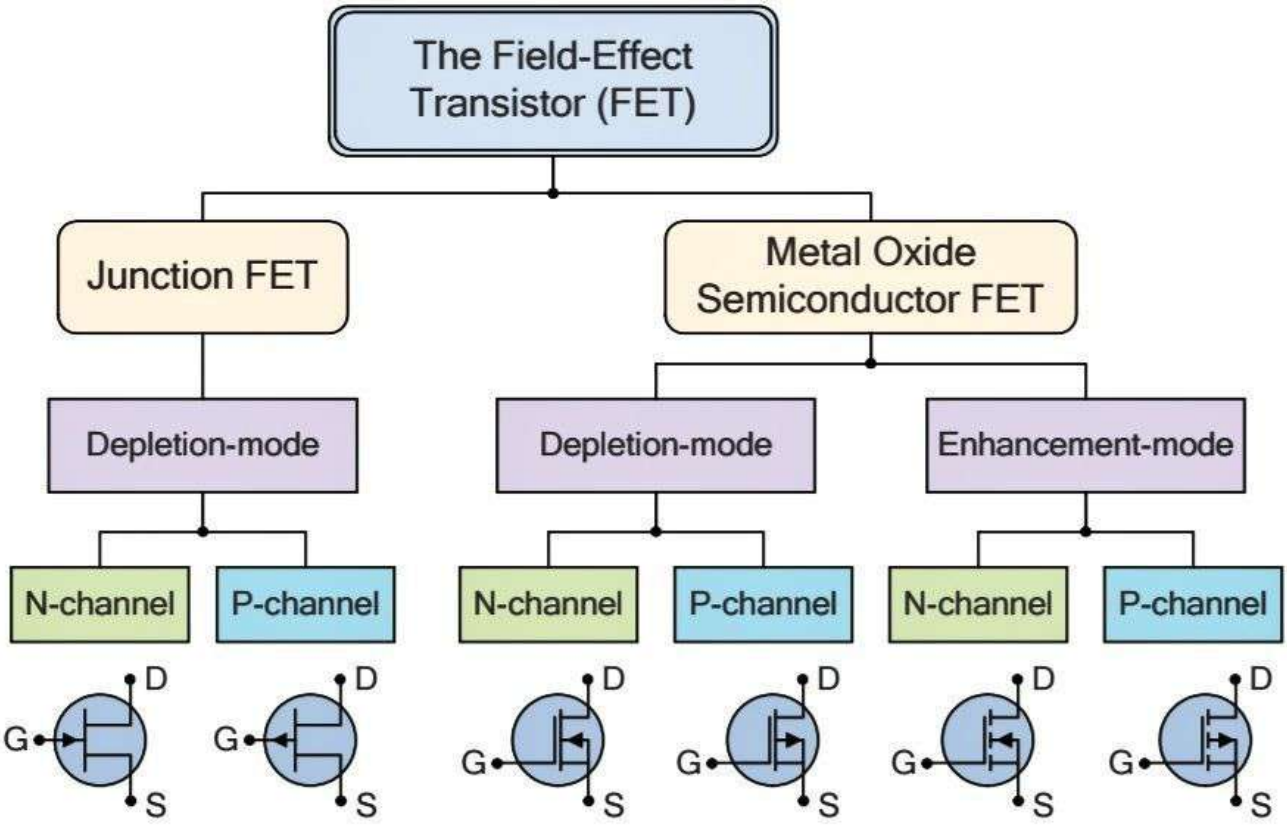
FET TYPES


The Field-Effect Transistor (FET)
Junction FET
Metal Oxide Semiconductor FET
Depletion-mode
Depletion-mode
Enhancement-mode
N-channel
P-channel
N-channel
P-channel
N-channel
P-channel
D
G
S

FET

FET's (Field – Effect Transistors) are much like BJT's (Bipolar Junction Transistors).

Similarities:

- Amplifiers
- Switching devices
- Impedance matching circuits

Differences:

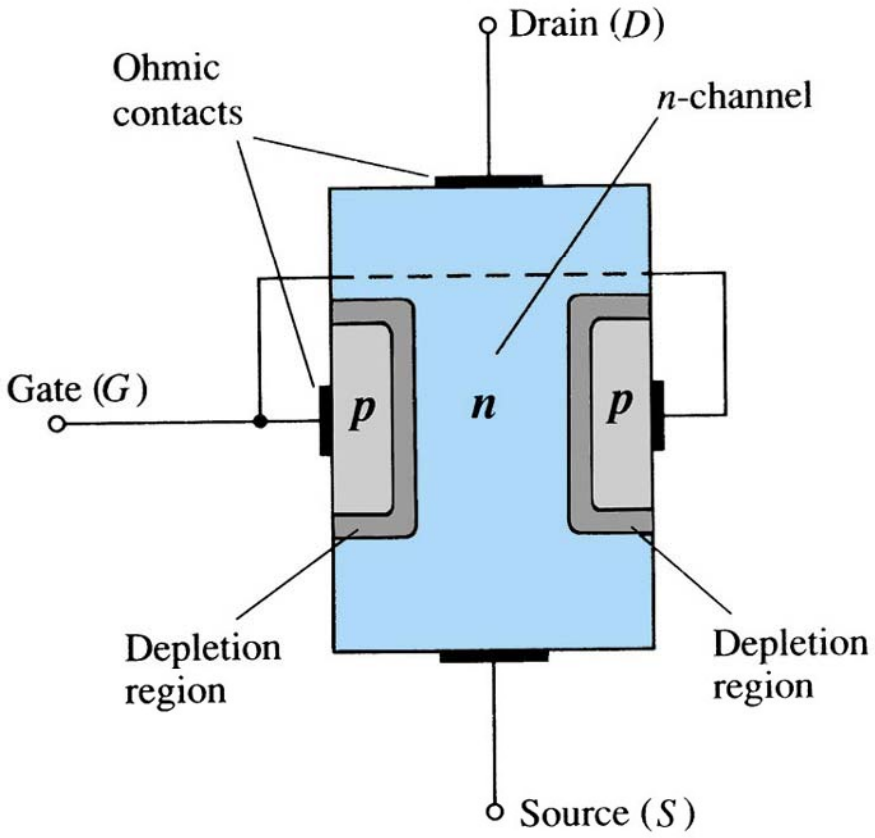
- FET's are voltage controlled devices whereas BJT's are current controlled devices.
- FET's also have a higher input impedance, but BJT's have higher gains.
- FET's are less sensitive to temperature variations and because of there construction they are more easily integrated on IC's.
- FET's are also generally more static sensitive than BJT's.

FET Types

- **JFET** ~ Junction Field-Effect Transistor
- **MOSFET** ~ Metal-Oxide Field-Effect Transistor
  - **D-MOSFET** ~ Depletion MOSFET
  - **E-MOSFET** ~ Enhancement MOSFET

JFET Construction

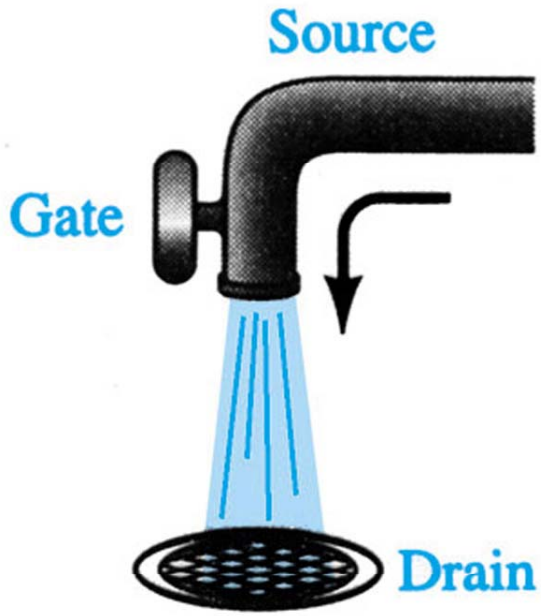
There are two types of JFET's: n-channel and p-channel.
The n-channel is more widely used.



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

Basic Operation of JFET

JFET operation can be compared to a water spigot:



The source of water pressure – accumulated electrons at the negative pole of the applied voltage from Drain to Source

The drain of water – electron deficiency (or holes) at the positive pole of the applied voltage from Drain to Source.

The control of flow of water – Gate voltage that controls the width of the n-channel, which in turn controls the flow of electrons in the n-channel from source to drain.

JFET Operating Characteristics

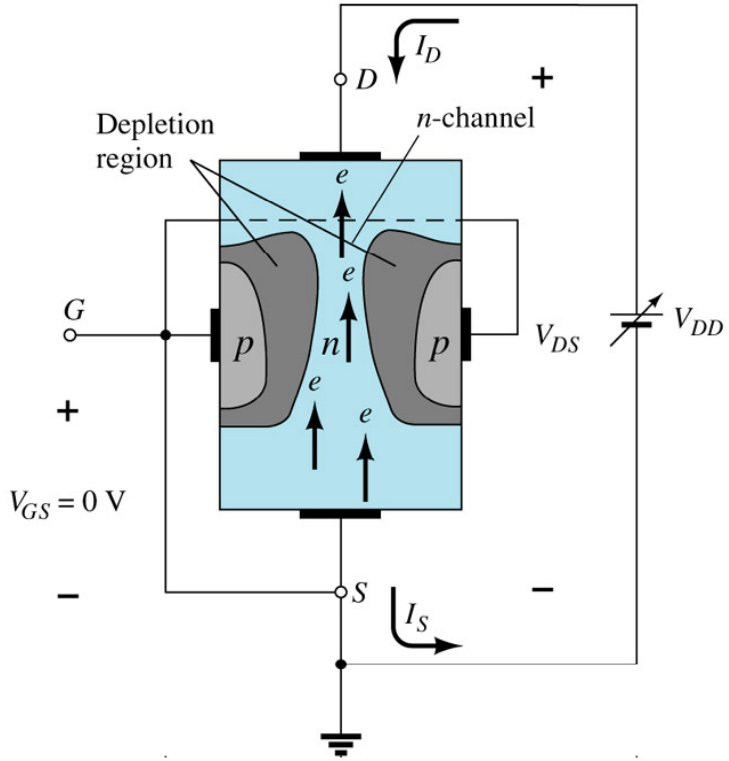
There are three basic operating conditions for a JFET:

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

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

C. Voltage-Controlled Resistor

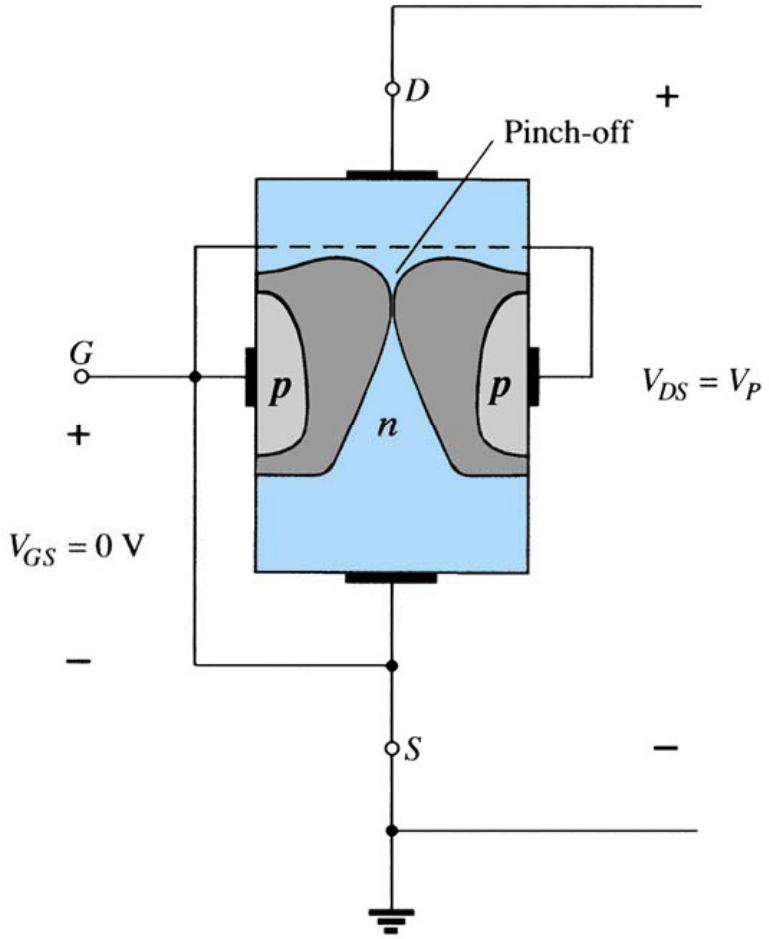
A. $V_{GS} = 0$, V_{DS} increasing to some positive value



Three things happen when $V_{GS} = 0$ and V_{DS} is increased from 0 to a more positive voltage:

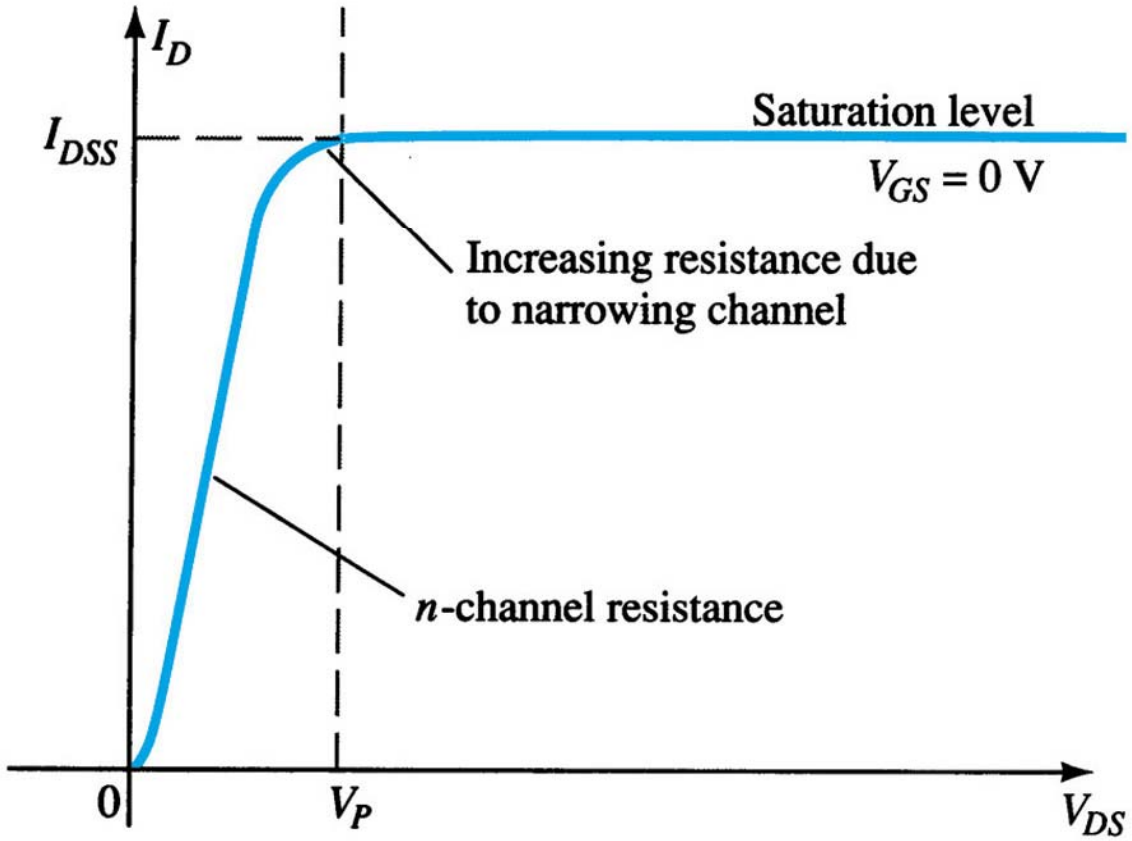
- the depletion region between p-gate and n-channel increases as electrons from n-channel combine with holes from p-gate.
- increasing the depletion region, decreases the size of the n-channel which increases the resistance of the n-channel.
- But even though the n-channel resistance is increasing, the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

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.

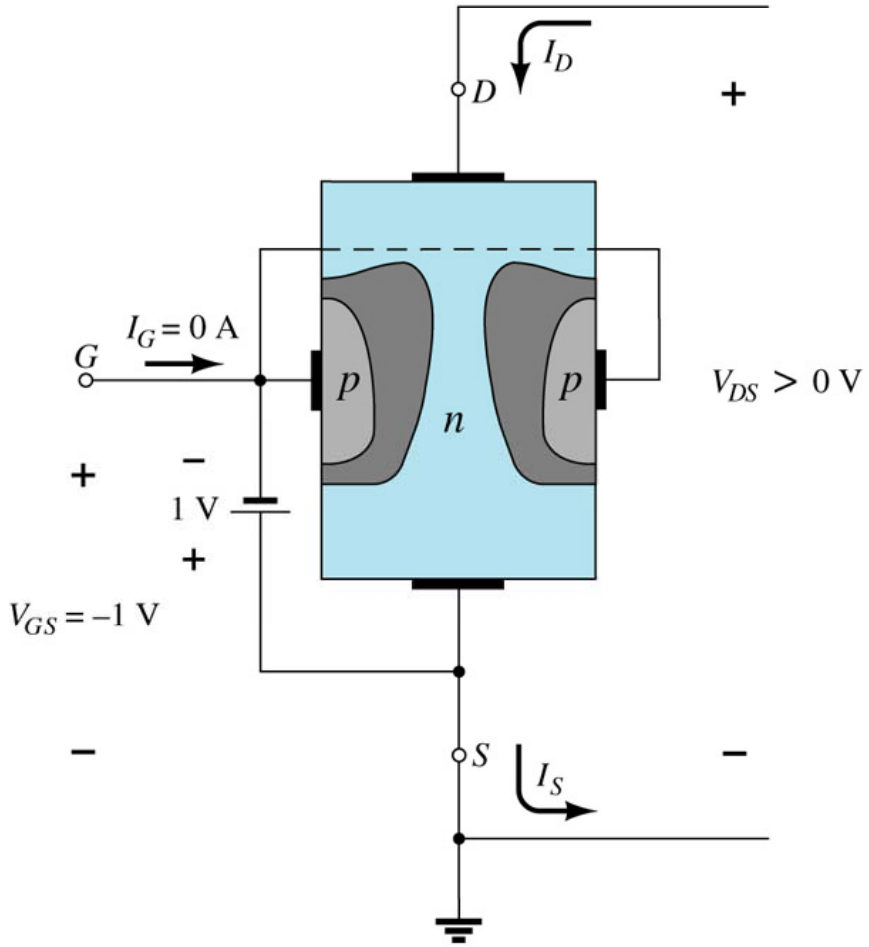
Saturation



At the pinch-off point:

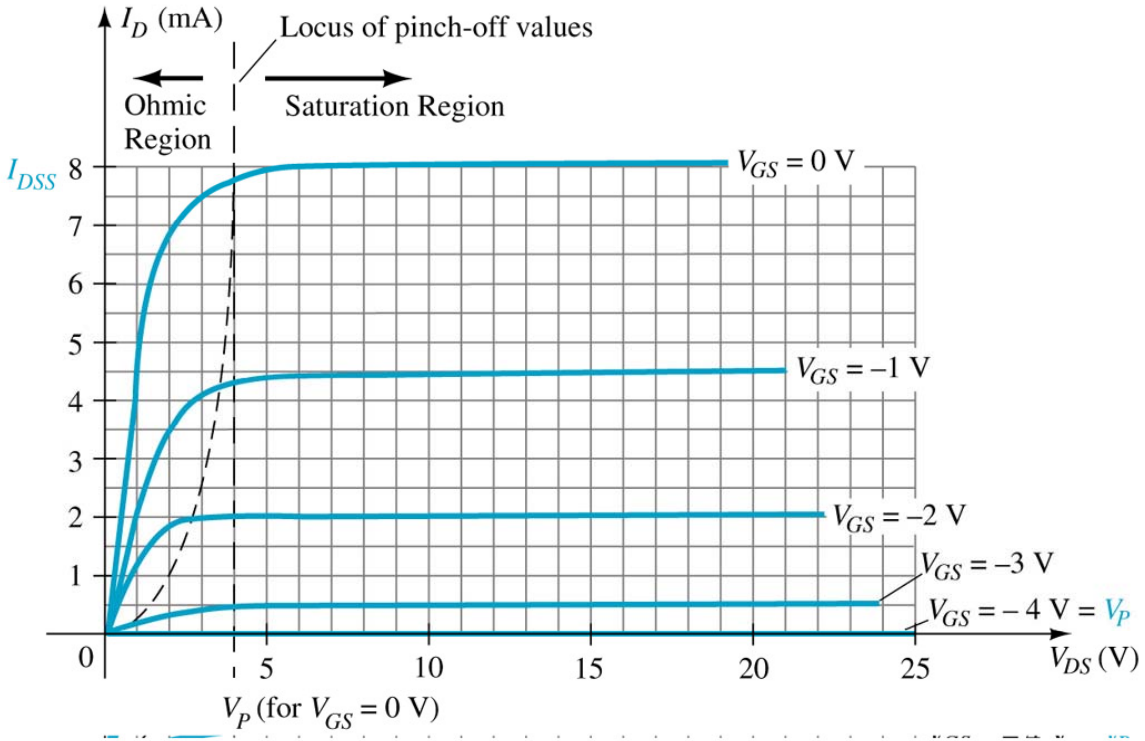
- any further increase in V_{GS} does not produce any increase in I_D. V_{GS} at pinch-off is denoted as Vp.
- ID is at saturation or maximum. It is referred to as I_{DSS}.
- The ohmic value of the channel is at maximum.

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



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

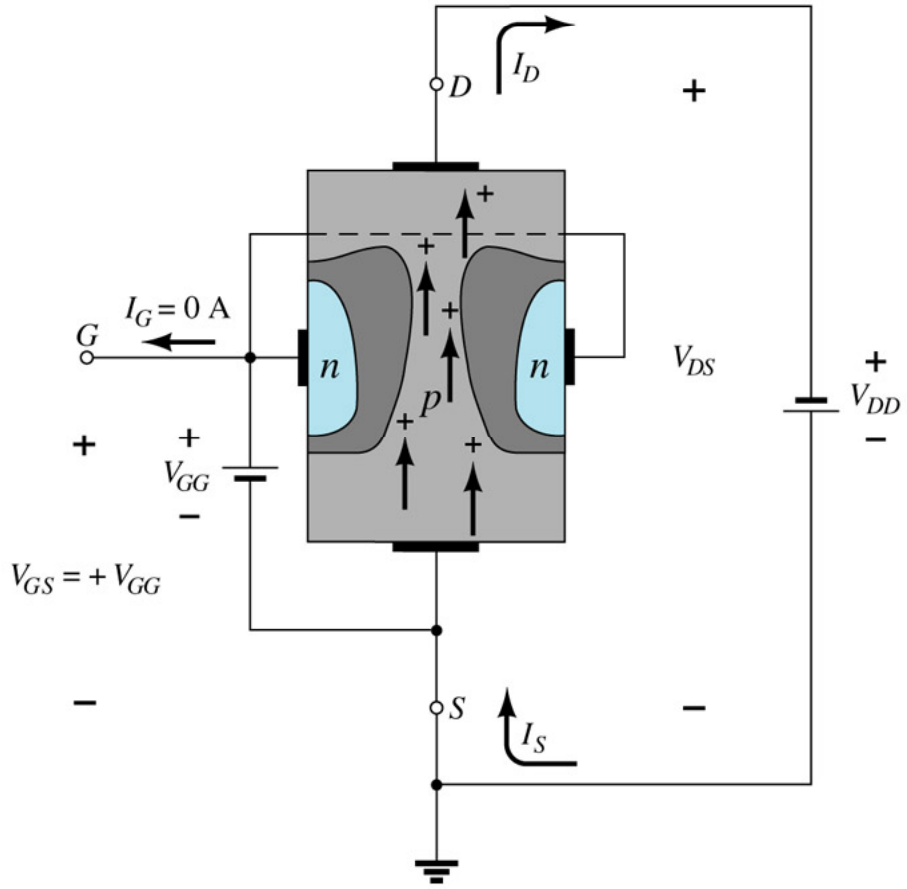
$I_D < I_{DSS}$



As V_{GS} becomes more negative:

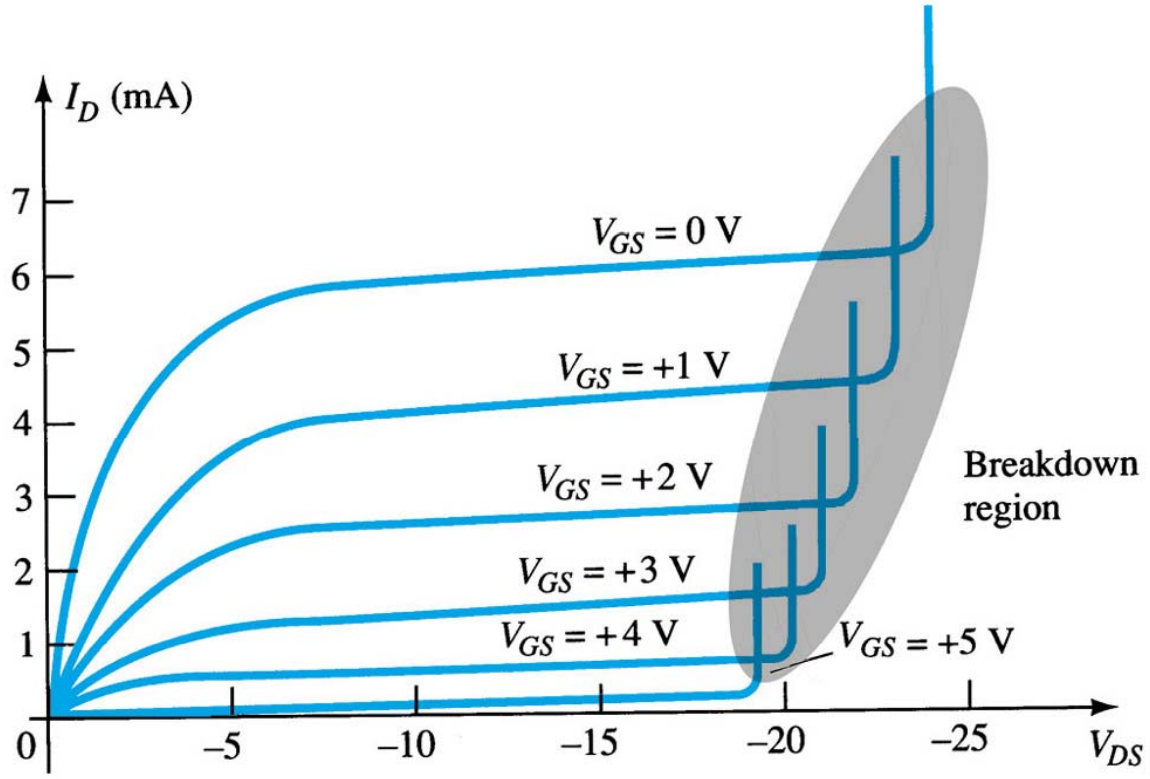
- the JFET will pinch-off at a lower voltage (Vp).
- I_D decreases ($I_D < I_{DSS}$) even though V_{DS} is increased.
- Eventually I_D will reach 0A. V_{GS} at this point is called Vp or $V_{GS(off)}$.
- Also note that at high levels of V_{DS} the JFET reaches a breakdown situation. ID will increases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

p-Channel JFETS



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

P-Channel JFET Characteristics

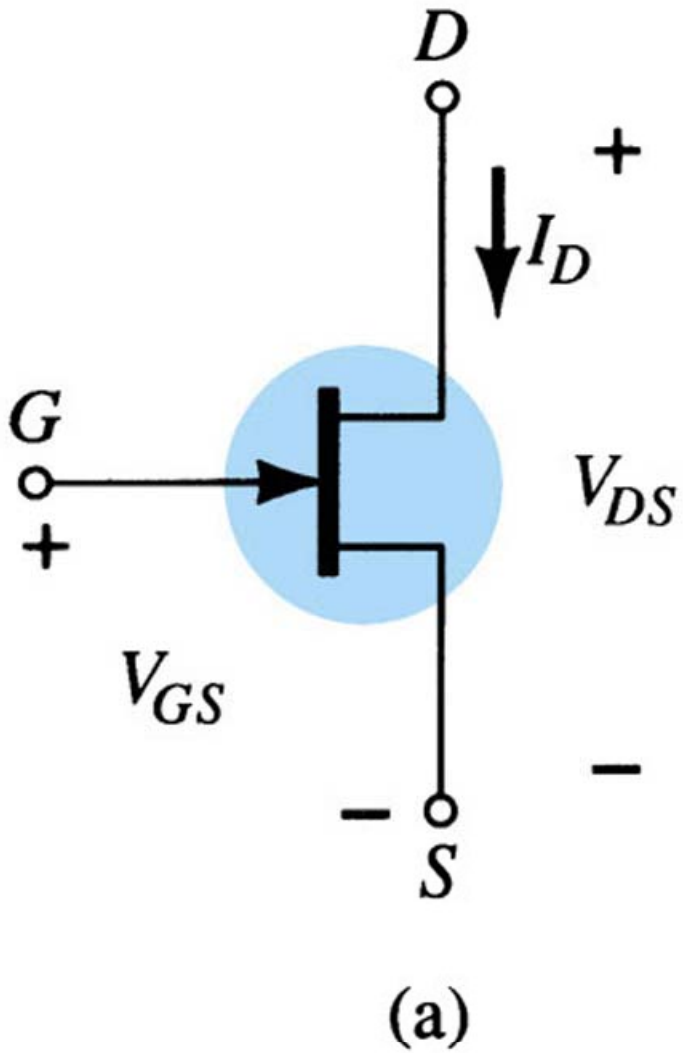


As VGS increases more positively:

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

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

JFET Symbols



(a)

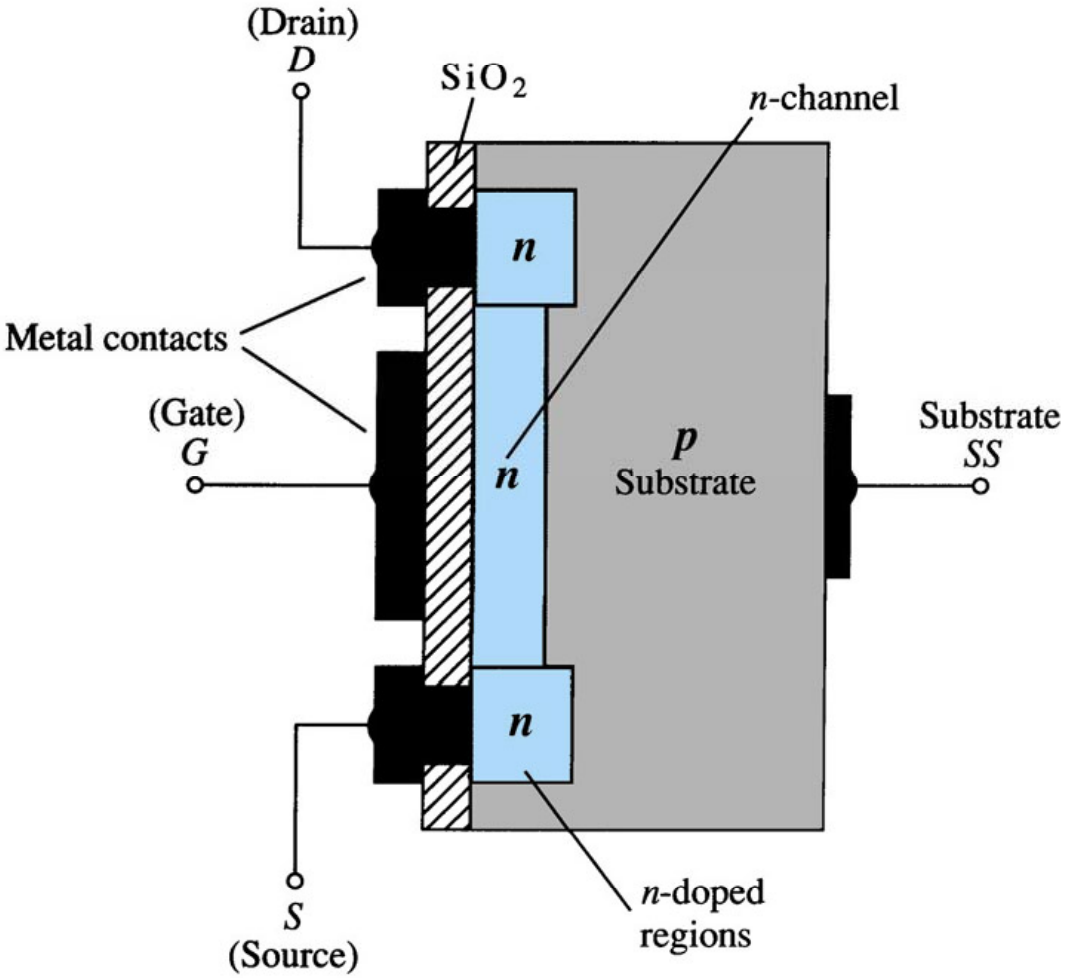
MOSFETs

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

There are 2 types:

- Depletion-Type MOSFET
- Enhancement-Type MOSFET

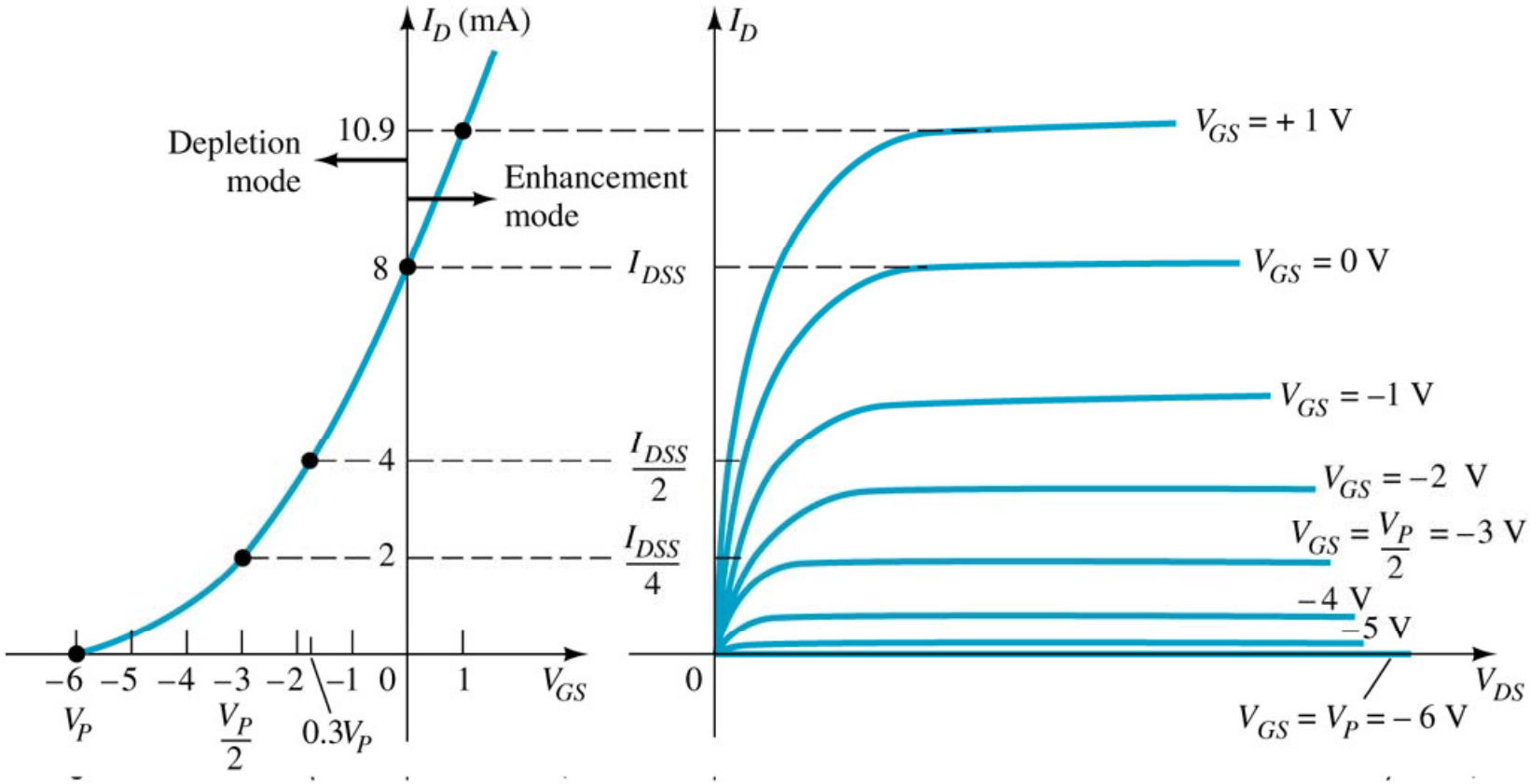
Depletion-Type MOSFET Construction



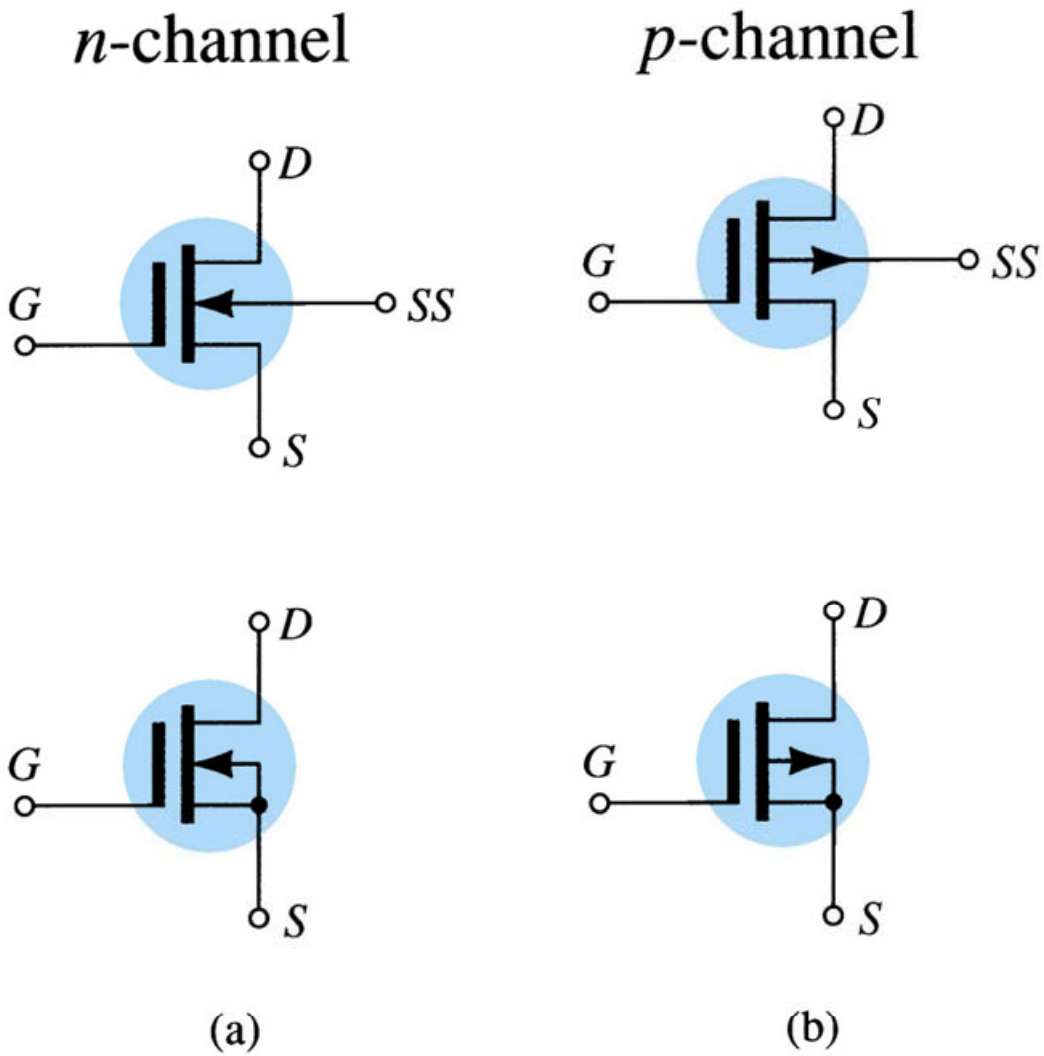
The Drain (D) and Source (S) connect to the to n-doped regions. These N-doped regions are connected via an n-channel. This n-channel is connected to the Gate (G) via a thin insulating layer of SiO_2. The n-doped material lies on a p-doped substrate that may have an additional terminal connection called SS.

Basic Operation

A Depletion MOSFET can operate in two modes: Depletion or Enhancement mode.



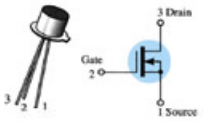
Symbols



Specification Sheet

2N3797

CASE 22-03, STYLE 2
TO-18 (TO-206AA)



MOSFETs
LOW POWER AUDIO

N-CHANNEL – DEPLETION

MAXIMUM RATINGS

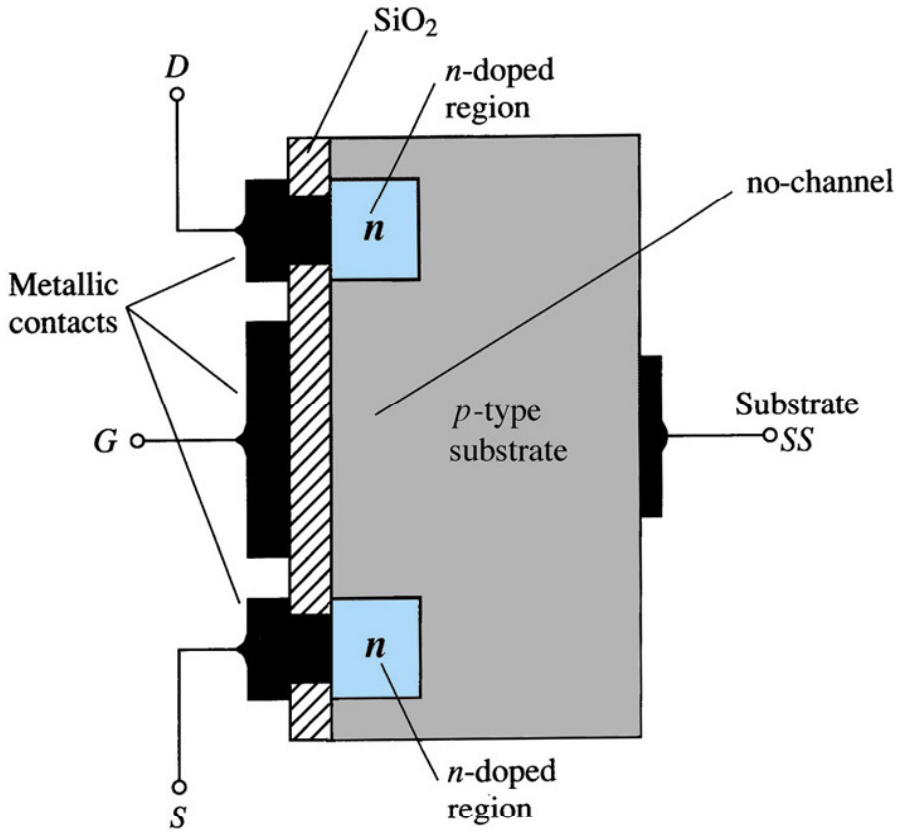
Rating	Symbol	Value	Unit
Drain–Source Voltage 2N3797	V_{DS}	20	Vdc
Gate–Source Voltage	V_{GS}	±10	Vdc
Drain Current	I_D	20	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	200 1.14	mW mW/°C
Junction Temperature Range	T_J	+175	°C
Storage Channel Temperature Range	T_{stg}	−65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Drain Source Breakdown Voltage (V_{GS} = −7.0 V, I_D = 5.0 μA)	2N3797	$V_{(BR)DSX}$	20	25	–	Vdc
Gate Reverse Current (1) (V_{GS} = −10 V, V_{DS} = 0) (V_{GS} = −10 V, V_{DS} = 0, T_A = 150°C)		I_{GSS}	– –	– –	1.0 200	pAdc
Gate Source Cutoff Voltage (I_D = 2.0 μA, V_{DS} = 10 V)	2N3797	$V_{GS(off)}$	–	−5.0	−7.0	Vdc
Drain-Gate Reverse Current (1) (V_{DG} = 10 V, I_S = 0)		I_{DGO}	–	–	1.0	pAdc
ON CHARACTERISTICS						
Zero-Gate-Voltage Drain Current (V_{DS} = 10 V, V_{GS} = 0)	2N3797	I_{DSS}	2.0	2.9	6.0	mAdc
On-State Drain Current (V_{DS} = 10 V, V_{GS} = +3.5 V)	2N3797	$I_{D(on)}$	9.0	14	18	mAdc
SMALL-SIGNAL CHARACTERISTICS						
Forward Transfer Admittance (V_{DS} = 10 V, V_{GS} = 0, f = 1.0 kHz)	2N3797	$\|y_{fs}\|$	1500	2300	3000	μmhos
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz)	2N3797		1500	–	–	
Output Admittance (I_{DS} = 10 V, V_{GS} = 0, f = 1.0 kHz)	2N3797	$\|y_{os}\|$	–	27	60	μmhos
Input Capacitance (V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz)	2N3797	C_{iss}	–	6.0	8.0	pF
Reverse Transfer Capacitance (V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz)		C_{rss}	–	0.5	0.8	pF
FUNCTIONAL CHARACTERISTICS						
Noise Figure (V_{DS} = 10 V, V_{GS} = 0, f = 1.0 kHz, R_S = 3 megohms)		NF	–	3.8	–	dB

(1) This value of current includes both the FET leakage current as well as the leakage current associated with the test socket and fixture when measured under best attainable conditions.

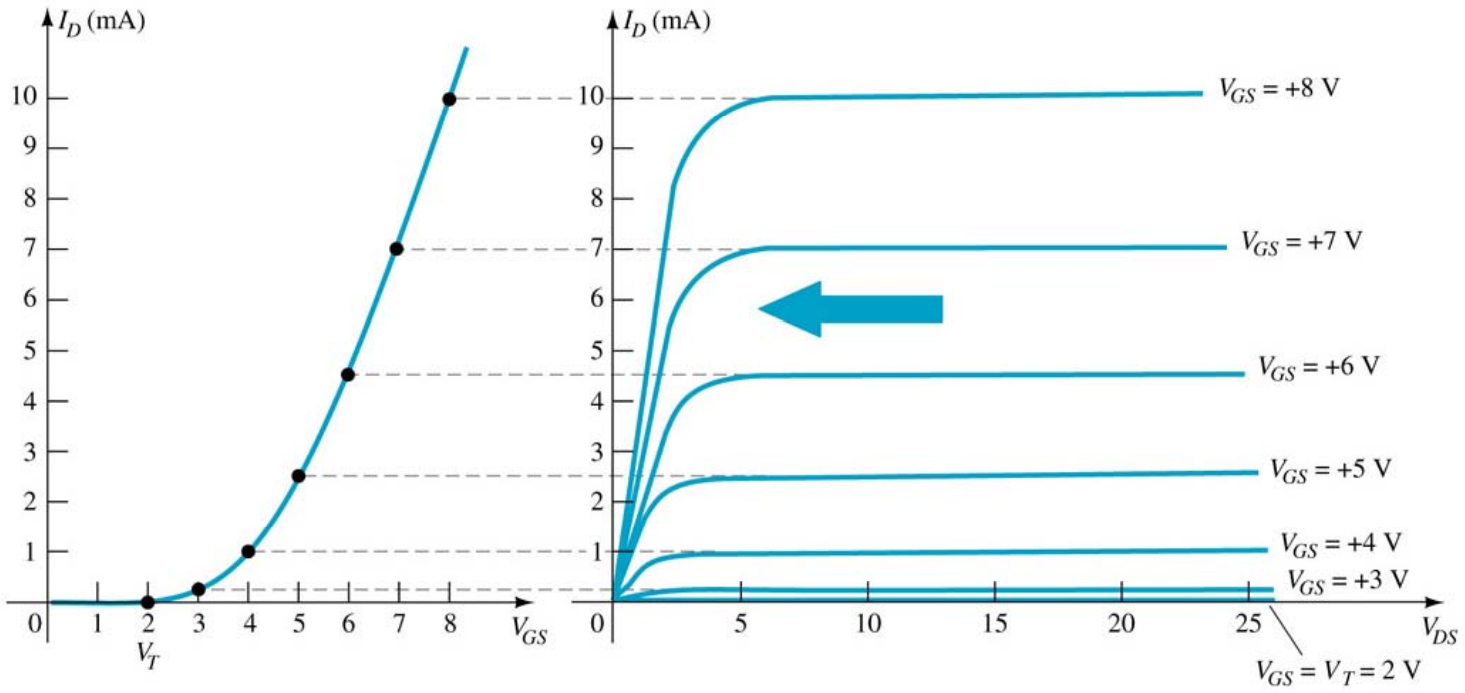
Enhancement-Type MOSFET Construction



The Drain (D) and Source (S) connect to the to n-doped regions. These n-doped regions are connected via an n-channel. 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.

Basic Operation

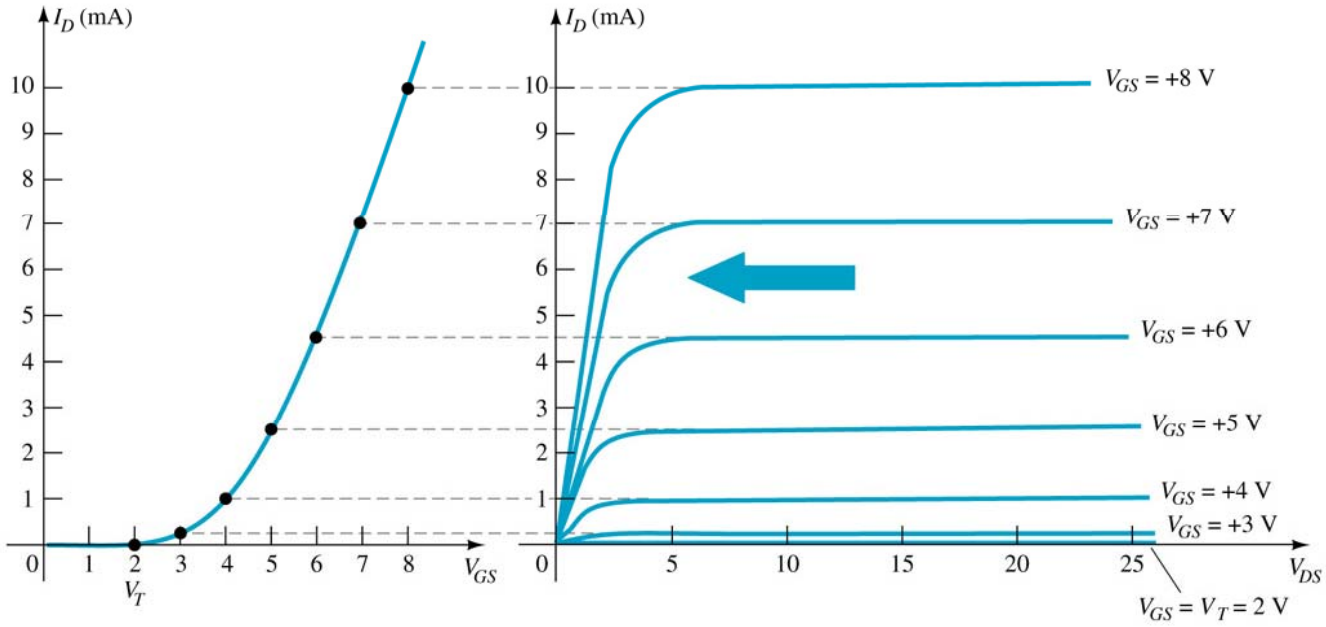
The Enhancement-type MOSFET only operates in the enhancement mode.



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.

$$V_{Dsat} = V_{GS} - V_T \qquad \text{[Formula 5.12]}$$

Transfer Curve



To determine I_D given V_{GS}: $I_D = k(V_{GS} - V_T)^2$ [Formula 5.13]

where V_T = threshold voltage or voltage at which the MOSFET turns on.

k = constant found in the specification sheet

k can also be determined by using values at a specific point and the formula:

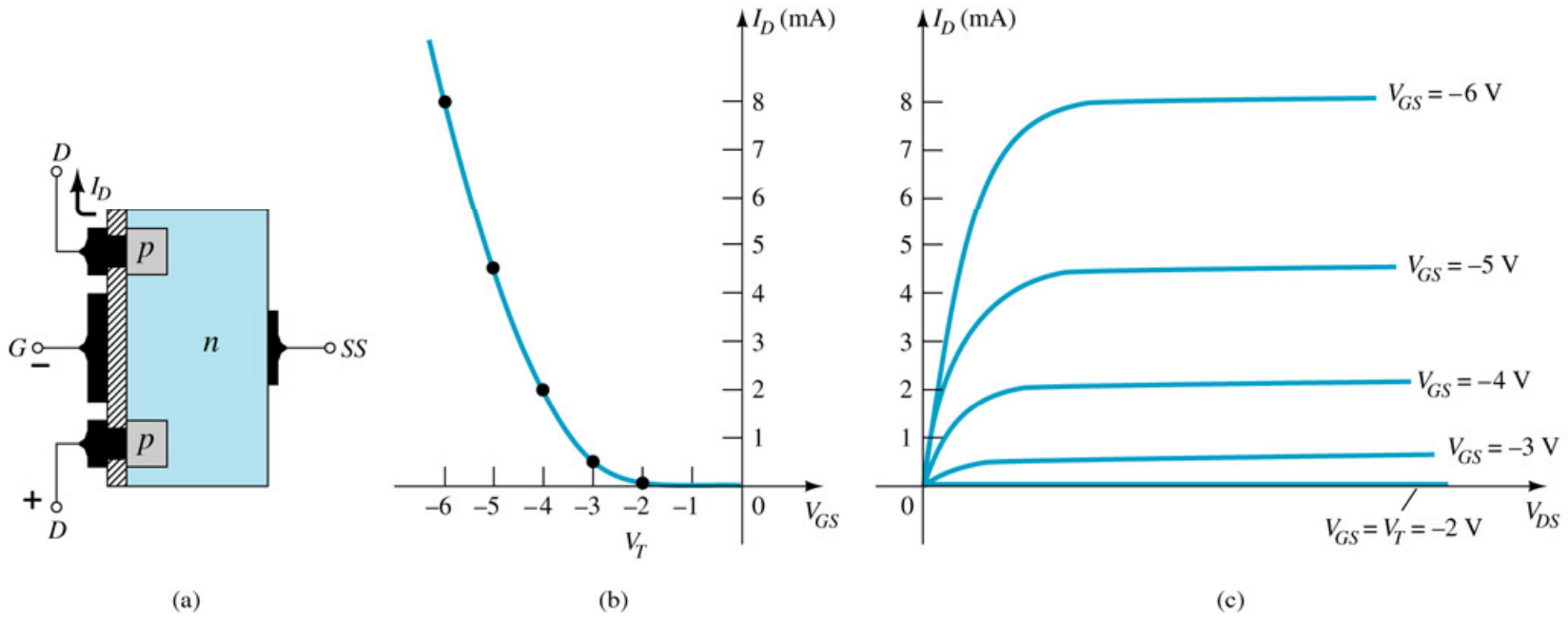
$$k = \frac{I_{D(on)}}{(V_{GS(ON)} - V_T)^2}$$ [Formula 5.14]

V_{DSsat} can also be calculated:

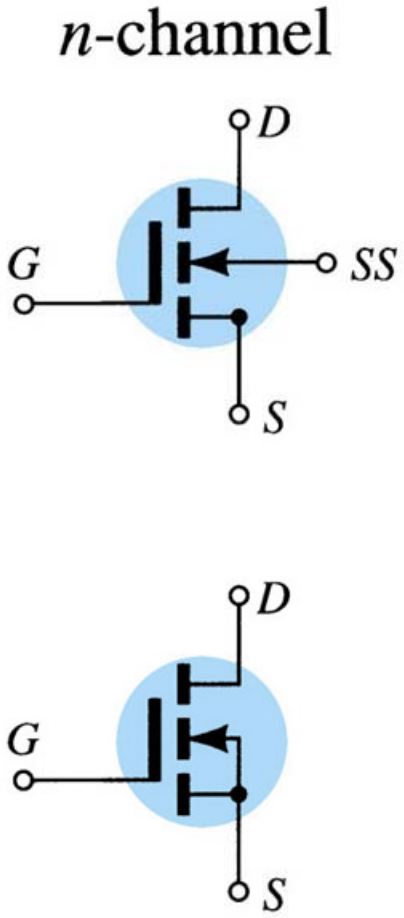
$$V_{Dsat} = V_{GS} - V_T$$ [Formula 5.12]

p-Channel Enhancement-Type MOSFETs

The p-channel Enhancement-type MOSFET is similar to the n-channel except that the voltage polarities and current directions are reversed.



Symbols



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