ANALOG ELECTRONICS

LECTURE NO. 9

MOSFET’S

MOSFETs

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

There are 2 types of MOSFET's:

- Depletion mode MOSFET (D-MOSFET)
  - Operates in Depletion mode the same way as a JFET when $V_{GS} \leq 0$
  - Operates in Enhancement mode like E-MOSFET when $V_{GS} > 0$
- Enhancement Mode MOSFET (E-MOSFET)
  - Operates in Enhancement mode
  - $I_{DSS} = 0$ until $V_{GS} > V_T$ (threshold voltage)

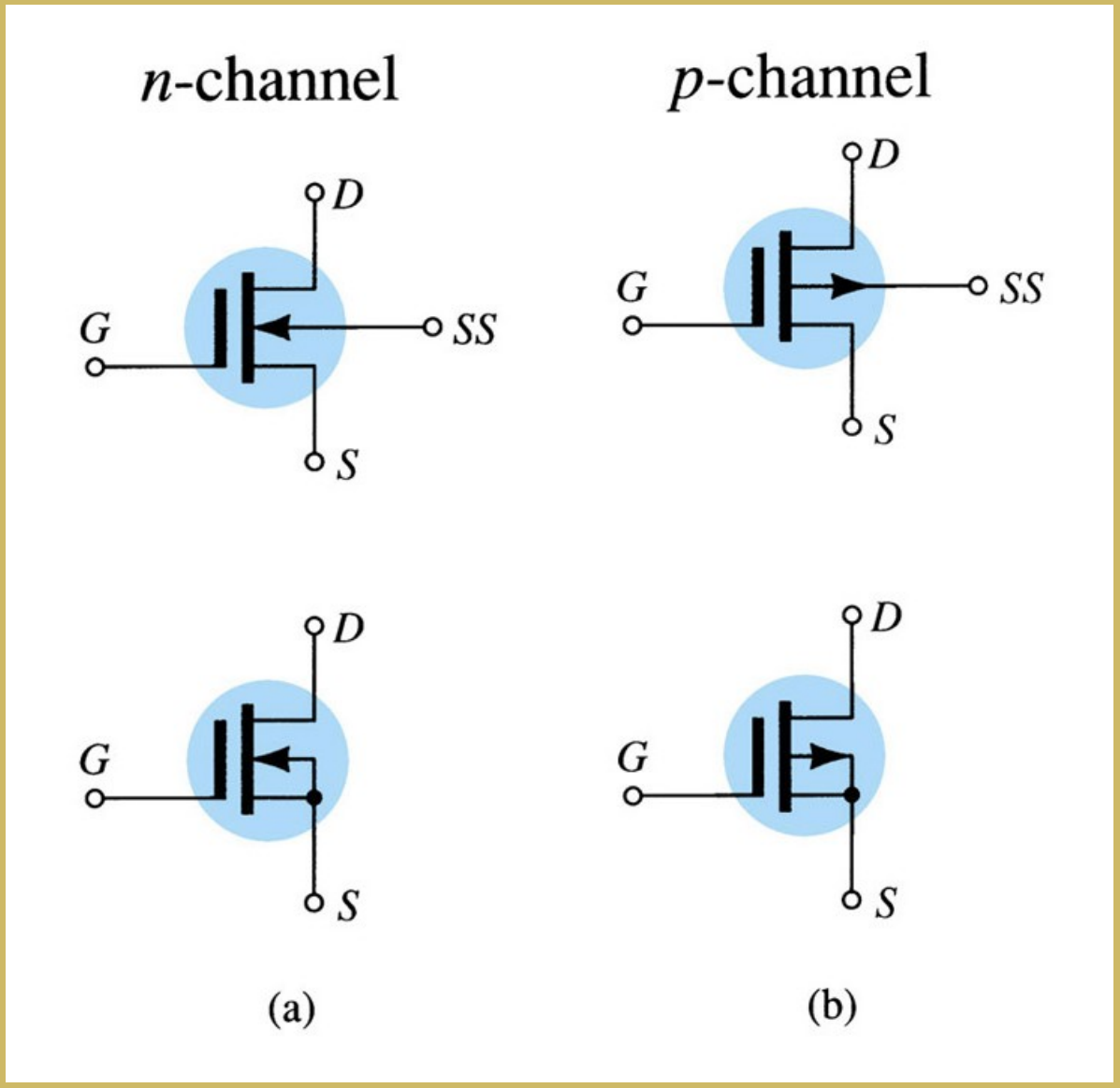
MOSFETs

MOSFETs are very static sensitive. Because of the very thin SiO_2 layer between the external terminals and the layers of the device, any small electrical discharge can stablish an unwanted conduction.

Protection:

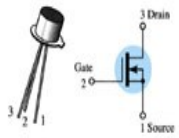
- Always transport in a static sensitive bag
- Always wear a static strap when handling MOSFETS
- Apply voltage limiting devices between the Gate and Source, such as back-to-back Zeners to limit any transient voltage

D-MOSFET Symbols



2N3797

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



MOSFETs
LOW POWER AUDIO

N-CHANNEL – DEPLETION

MAXIMUM RATINGS

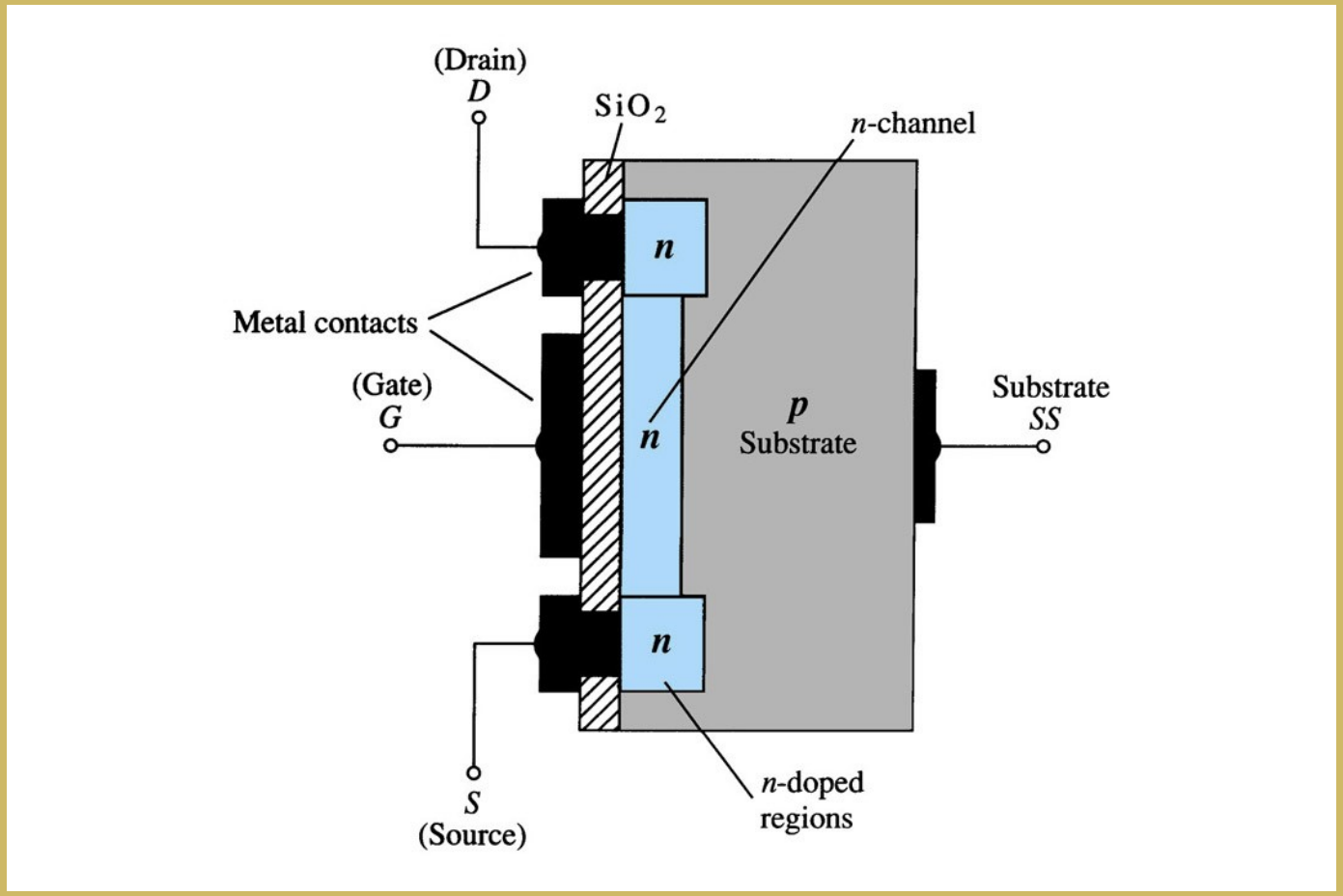
Rating	Symbol	Value	Unit
Drain–Source Voltage 2N3797	V_{DS}	20	Vdc
Gate–Source Voltage	V_{GS}	±10	Vdc
Drain Current	I_D	20	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	200 1.14	mW mW/°C
Junction Temperature Range	T_J	+175	°C
Storage Channel Temperature Range	T_{stg}	–65 to +200	°C

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.

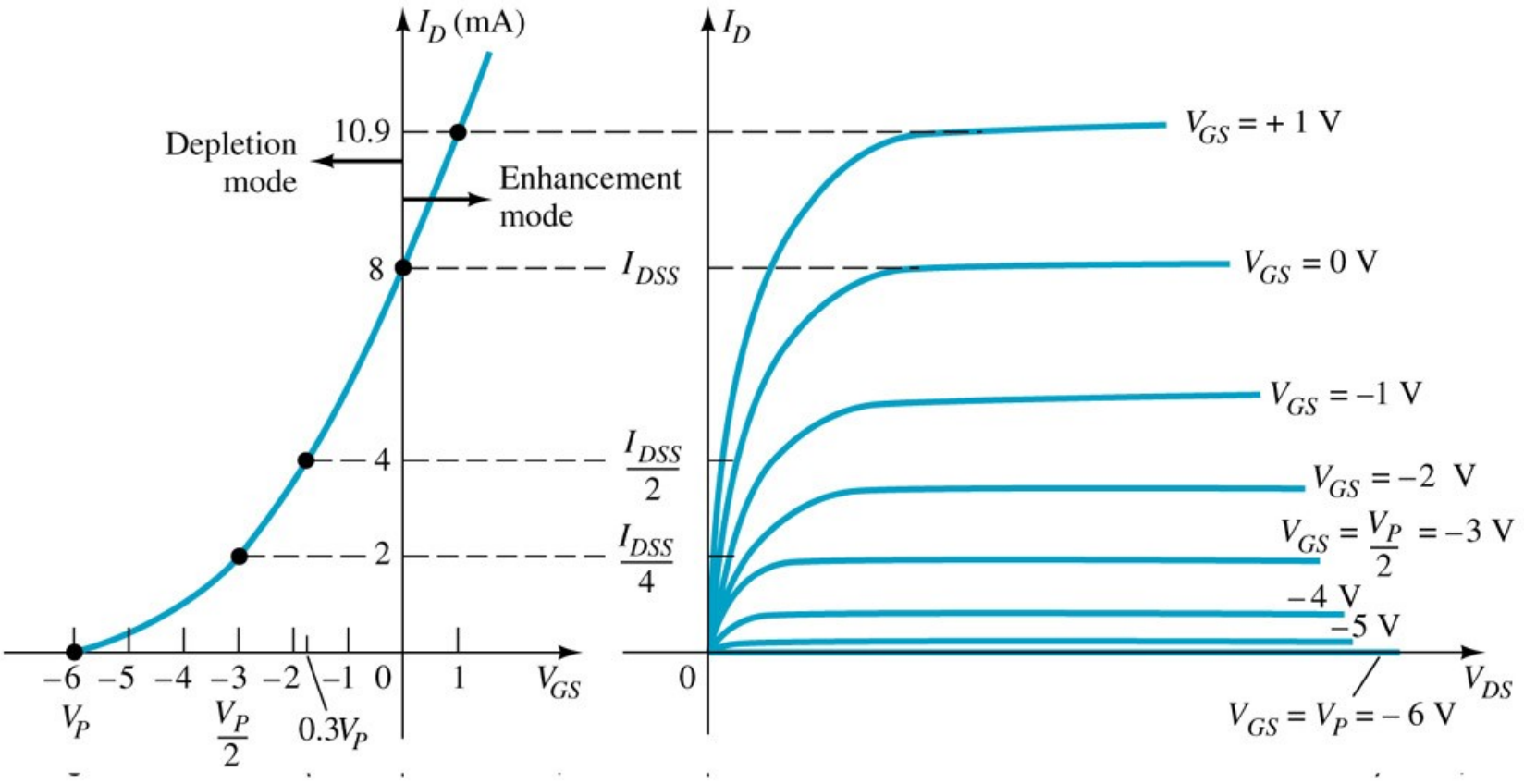
Depletion Mode MOSFET Construction



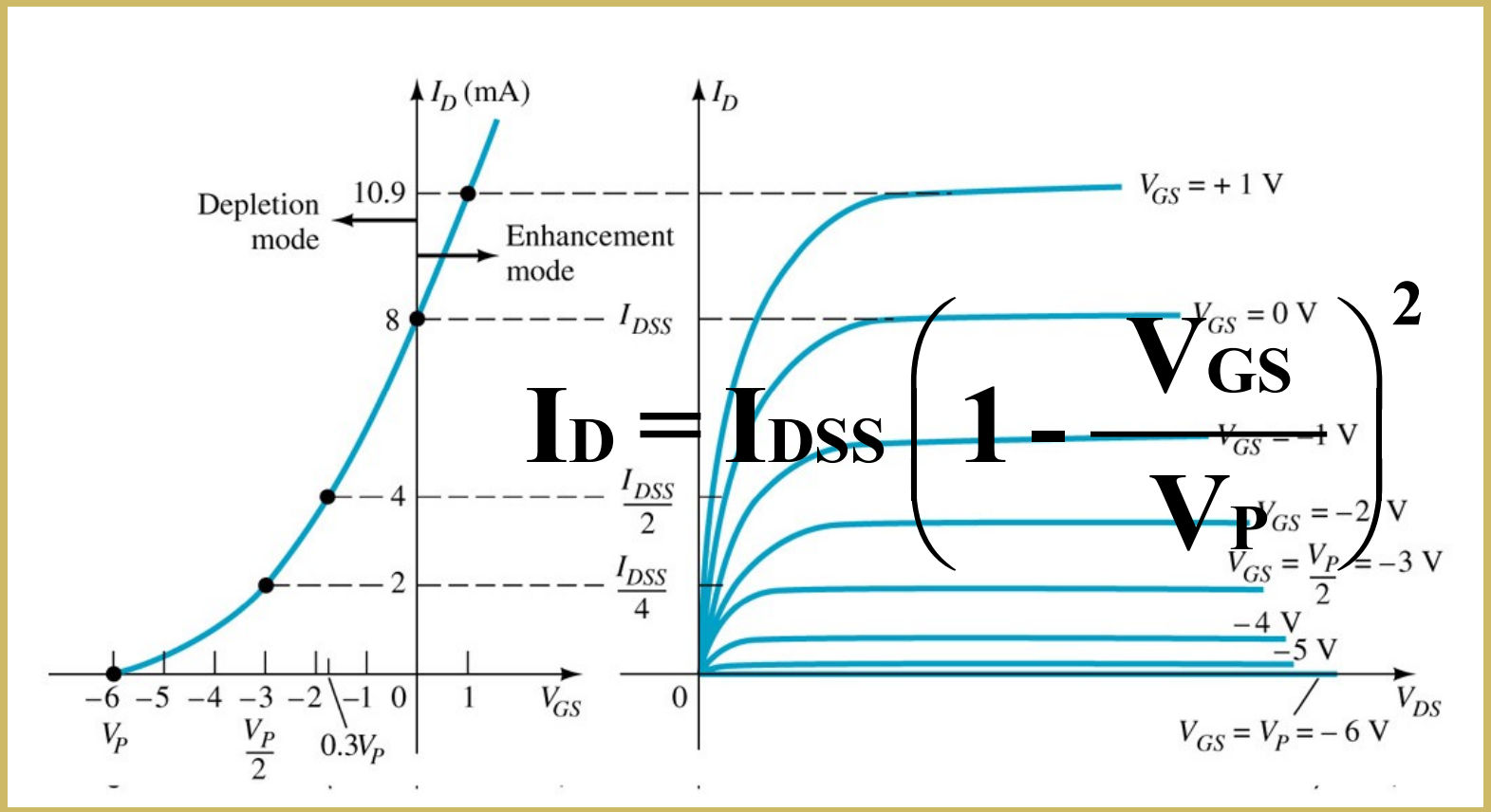
The Drain (D) and Source (S) leads connect to the to n-doped regions
These N-doped regions are connected via an n-channel
This n-channel is connected to the Gate (G) via a thin insulating layer of SiO_2
The n-doped material lies on a p-doped substrate that may have an additional terminal connection called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

Basic Operation

A D-MOSFET may be biased to operate in two modes: the **Depletion** mode or the **Enhancement** mode



D-MOSFET Depletion Mode Operation



The transfer characteristics are similar to the JFET

In Depletion Mode operation:

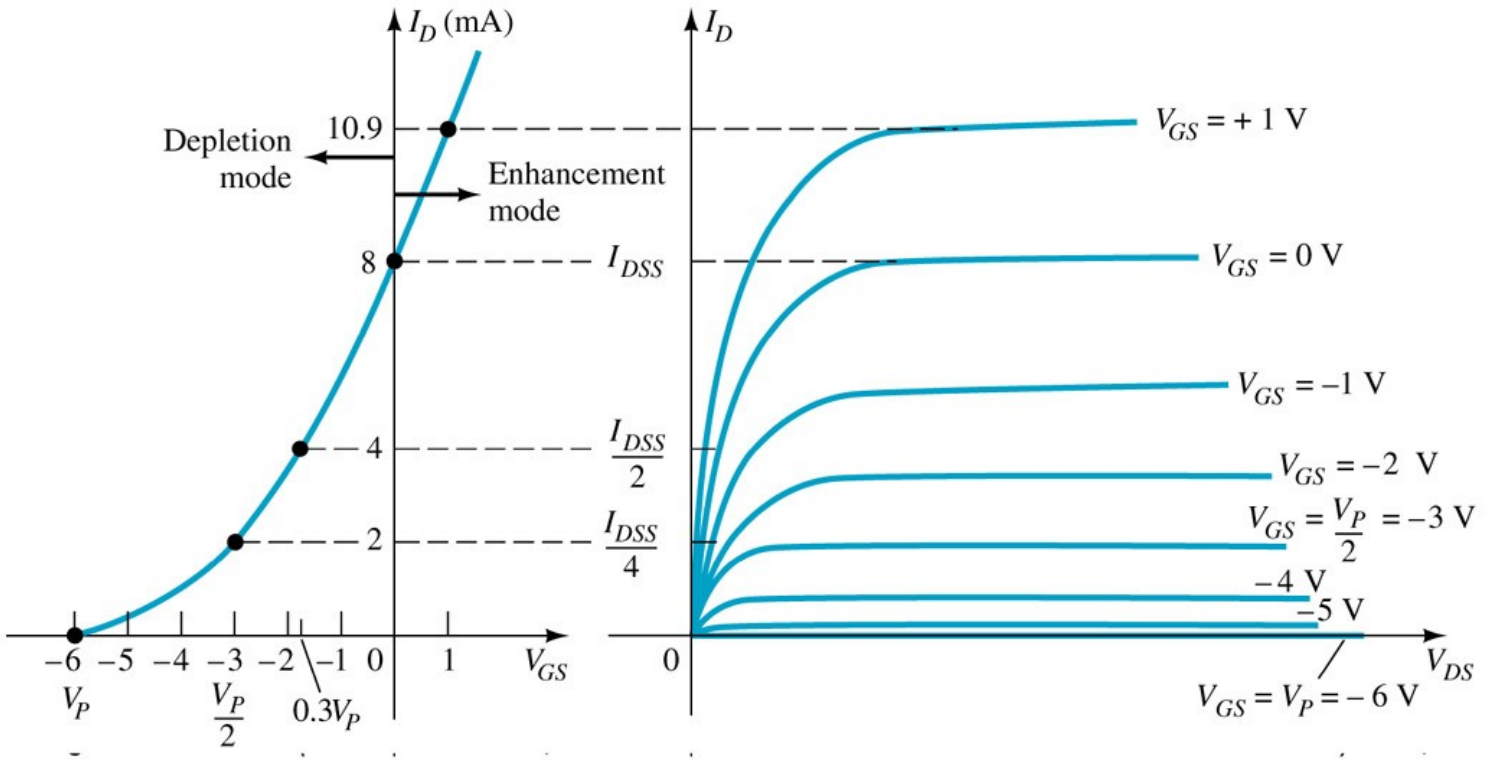
When $V_{GS} = 0V$, $I_D = I_{DSS}$

When $V_{GS} < 0V$, $I_D < I_{DSS}$

When $V_{GS} > 0V$, $I_D > I_{DSS}$

The formula used to plot the Transfer Curve, is:

D-MOSFET Enhancement Mode Operation

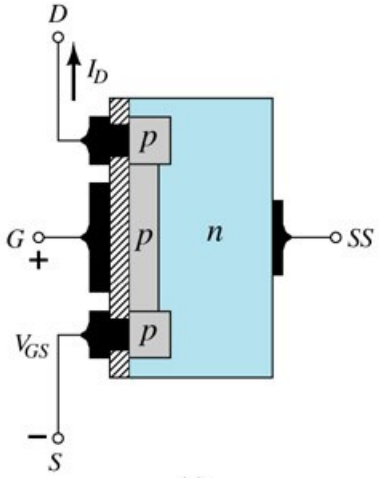


Enhancement Mode operation

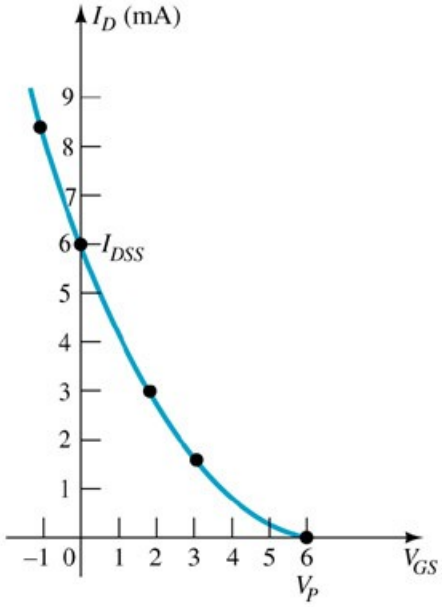
In this mode, the transistor operates with $V_{GS} > 0V$, and I_D increases above I_{DSS} Shockley's equation, the formula used to plot the Transfer Curve, still applies but V_{GS} is positive:

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

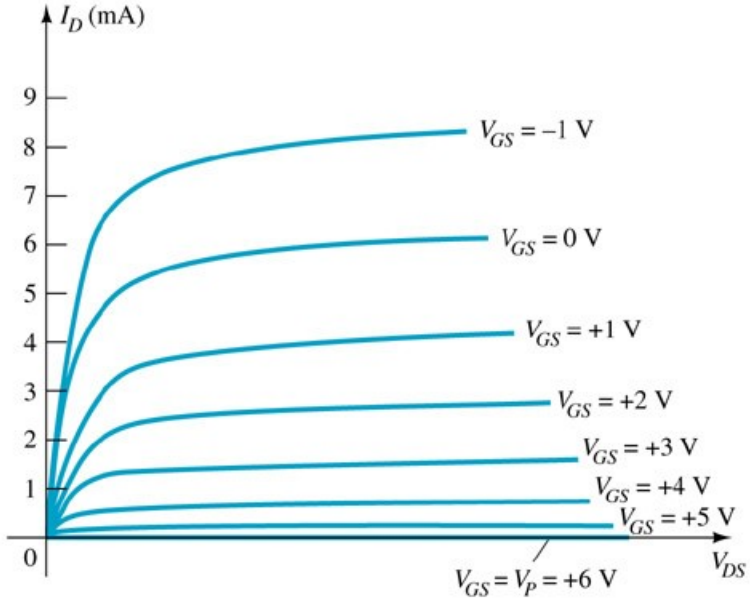
p-Channel Depletion Mode MOSFET



(a)



(b)



(c)