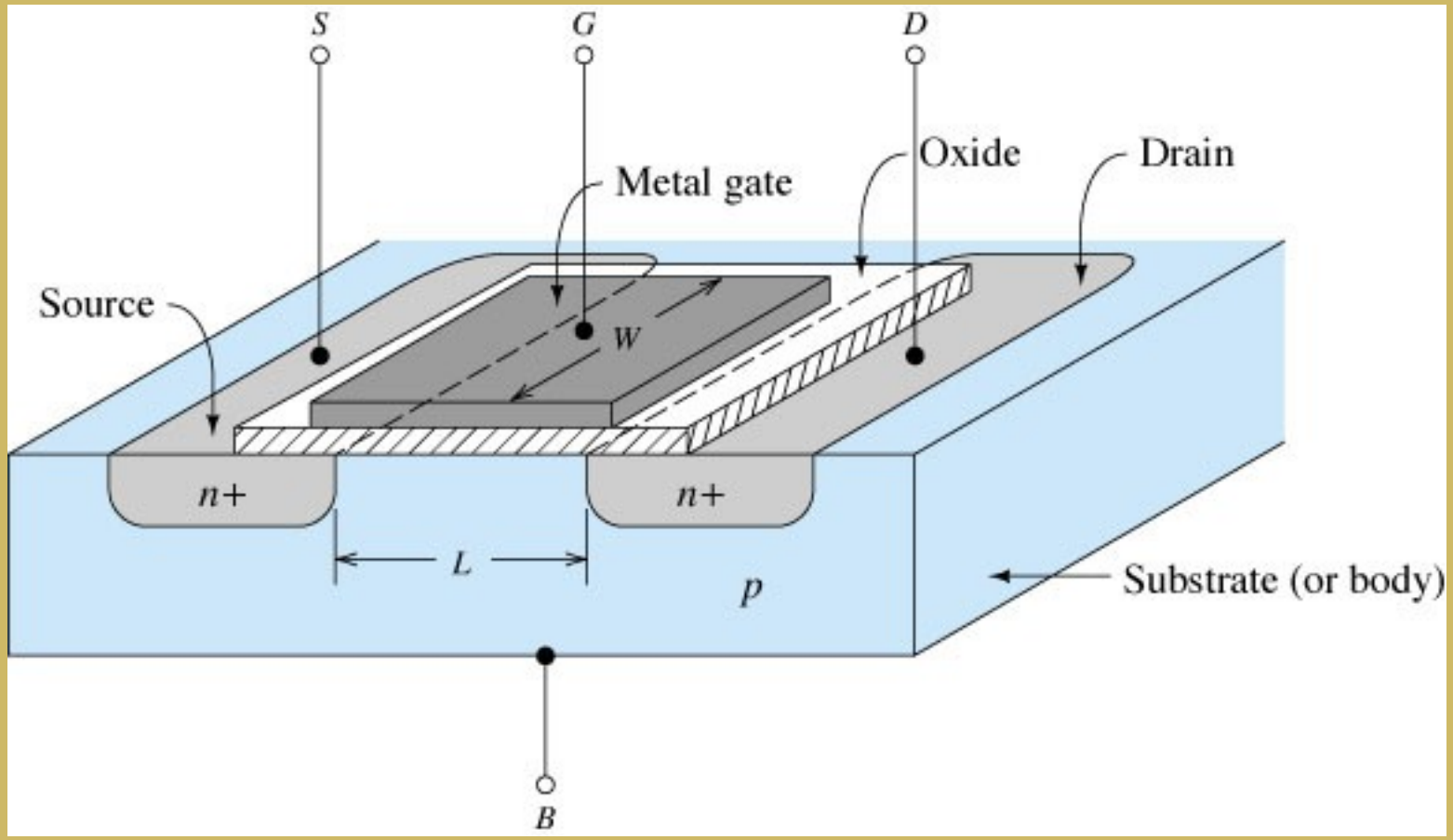
ANALOG ELECTRONICS

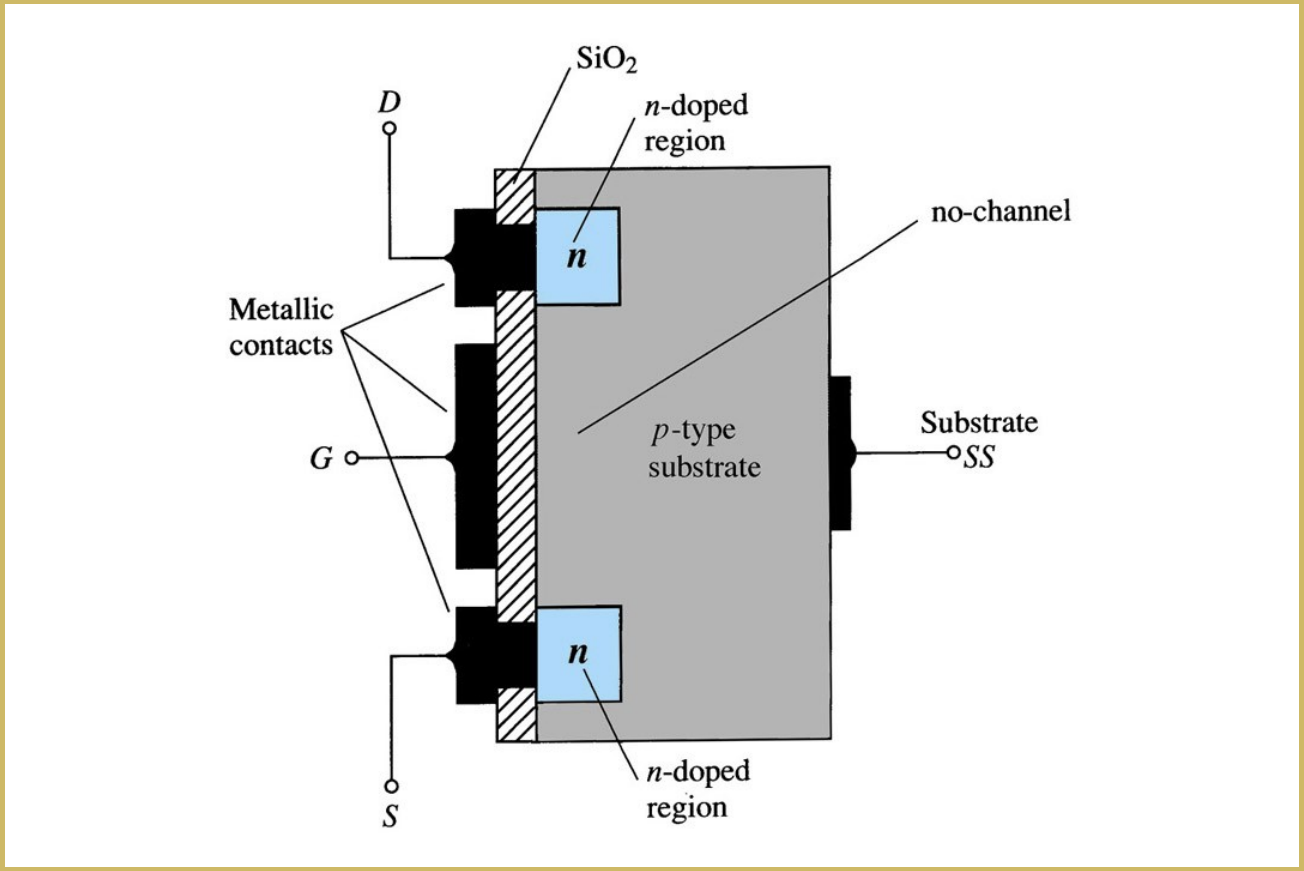
LECTURE NO. 11

ENHANCEMENT MODE MOSFET'S

n-Channel E-MOSFET showing channel length L and channel width W



Enhancement Mode MOSFET Construction

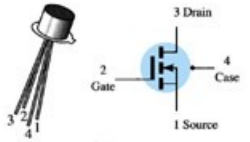


The Drain (D) and Source (S) connect to the to n-doped regions
These n-doped regions are not connected via an n-channel without an external voltage
The Gate (G) connects to the p-doped substrate via a thin insulating layer of SiO_2
The n-doped material lies on a p-doped substrate that may have an additional terminal connection called SS

Specification Sheet

2N4351

CASE 20-03, STYLE 2
TO-72 (TO-206AF)



MOSFET
SWITCHING
N-CHANNEL – ENHANCEMENT

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain–Source Voltage	V_{DS}	25	Vdc
Drain–Gate Voltage	V_{DG}	30	Vdc
Gate–Source Voltage*	V_{GS}	30	Vdc
Drain Current	I_D	30	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 1.7	mW mW/°C
Junction Temperature Range	T_J	175	°C
Storage Temperature Range	T_{stg}	–65 to +175	°C

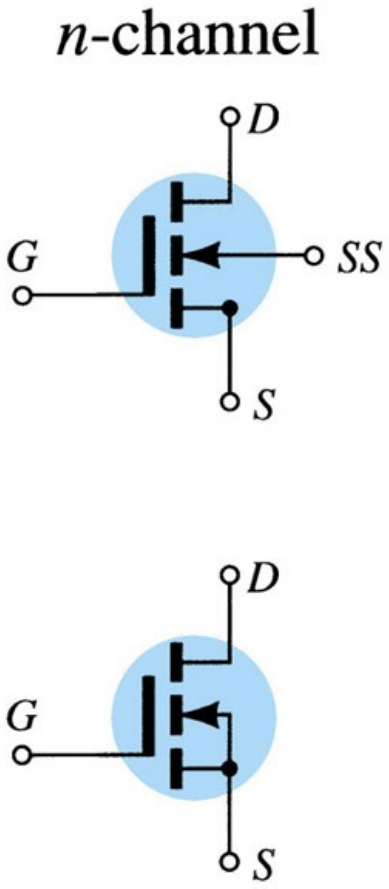
* Transient potentials of ± 75 Volt will not cause gate-oxide failure.

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

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Drain-Source Breakdown Voltage (I_D = 10 μA, V_{GS} = 0)	$V_{(BR)DSX}$	25	–	Vdc
Zero-Gate-Voltage Drain Current (V_{DS} = 10 V, V_{GS} = 0) T_A = 25°C T_A = 150°C	I_{DSS}	– –	10 10	nAdc μAdc
Gate Reverse Current (V_{GS} = ± 15 Vdc, V_{DS} = 0)	I_{GSS}	–	± 10	pAdc
ON CHARACTERISTICS				
Gate Threshold Voltage (V_{DS} = 10 V, I_D = 10μA)	$V_{GS(Th)}$	1.0	5	Vdc
Drain-Source On-Voltage (I_D = 2.0 mA, V_{GS} = 10V)	$V_{DS(on)}$	–	1.0	V
On-State Drain Current (V_{GS} = 10 V, V_{DS} = 10 V)	$I_{D(on)}$	3.0	–	mAdc
SMALL-SIGNAL CHARACTERISTICS				
Forward Transfer Admittance (V_{DS} = 10 V, I_D = 2.0 mA, f = 1.0 kHz)	$\|y_{fs}\|$	1000	–	μmho
Input Capacitance (V_{DS} = 10 V, V_{GS} = 0, f = 140 kHz)	C_{iss}	–	5.0	pF
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 0, f = 140 kHz)	C_{rss}	–	1.3	pF
Drain-Substrate Capacitance ($V_{D(SUB)}$ = 10 V, f = 140 kHz)	$C_{d(sub)}$	–	5.0	pF
Drain-Source Resistance (V_{GS} = 10 V, I_D = 0, f = 1.0 kHz)	$r_{ds(on)}$	–	300	ohms
SWITCHING CHARACTERISTICS				
Turn-On Delay (Fig. 5)	t_{d1}	–	45	ns
Rise Time (Fig. 6)	t_r	–	65	ns
Turn-Off Delay (Fig. 7)	t_{d2}	–	60	ns
Fall Time (Fig. 8)	t_f	–	100	ns

I_D = 2.0 mAdc, V_{DS} = 10 Vdc,
(V_{GS} = 10 Vdc)
(See Figure 9; Times Circuit Determined)

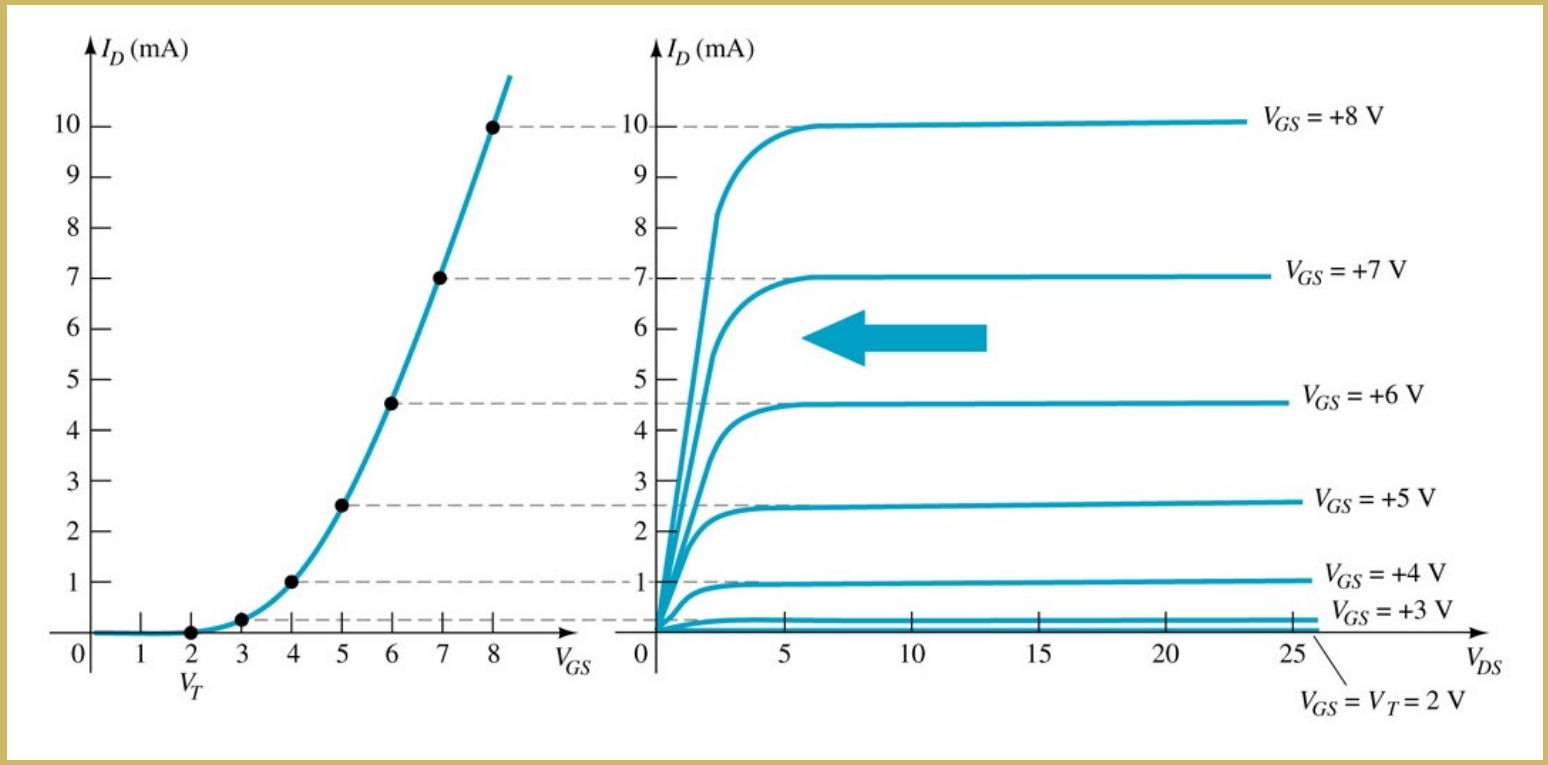
E-MOSFET Symbols



(a)

Basic Operation

The Enhancement mode MOSFET only operates in the enhancement mode.



V_{GS} is always positive

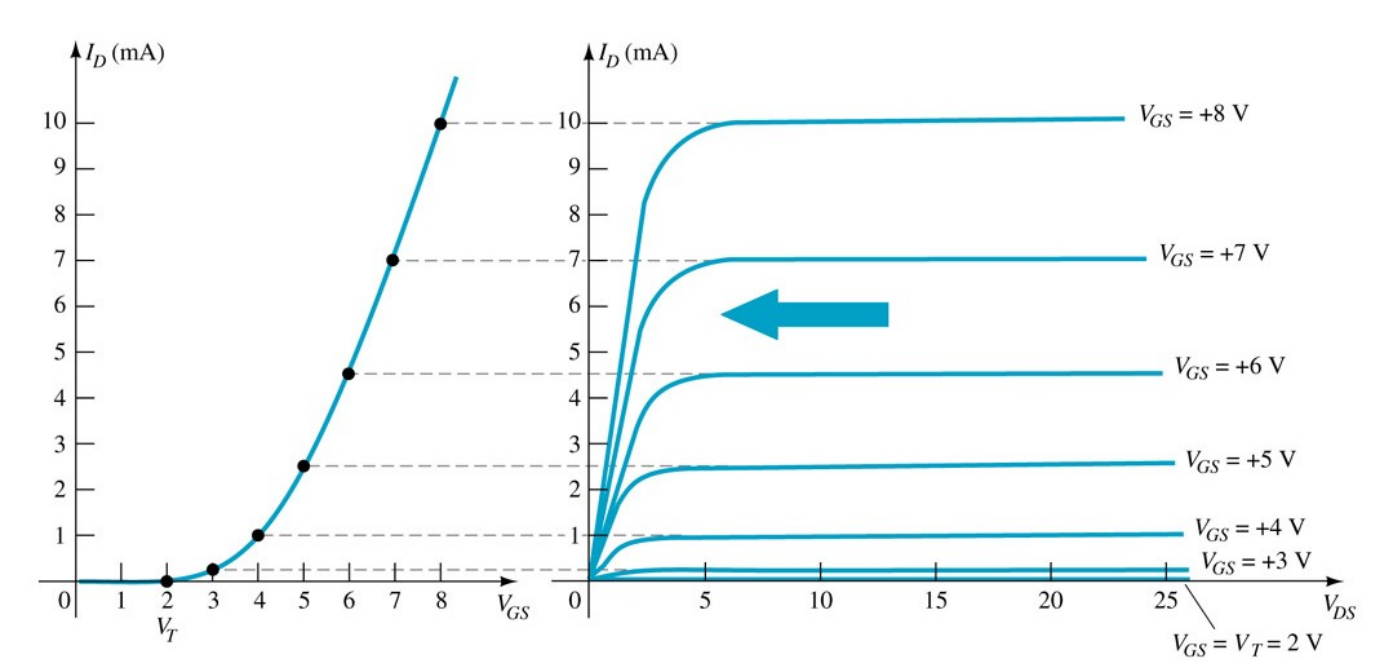
$I_{DSS} = 0$ when $V_{GS} < V_T$

As V_{GS} increases above V_T, I_D increases

If V_{GS} is kept constant and V_{DS} is increased, then I_D saturates (I_{DSS})

The saturation level, V_{DSsat} is reached.

Transfer Curve



To determine I_D given V_{GS}: $\mathbf{I_D = k\,(V_{GS} - V_T)^2}$ $\mathbf{k = \dfrac{I_{D(on)}}{(V_{GS(ON)} - V_T)^2}}$

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

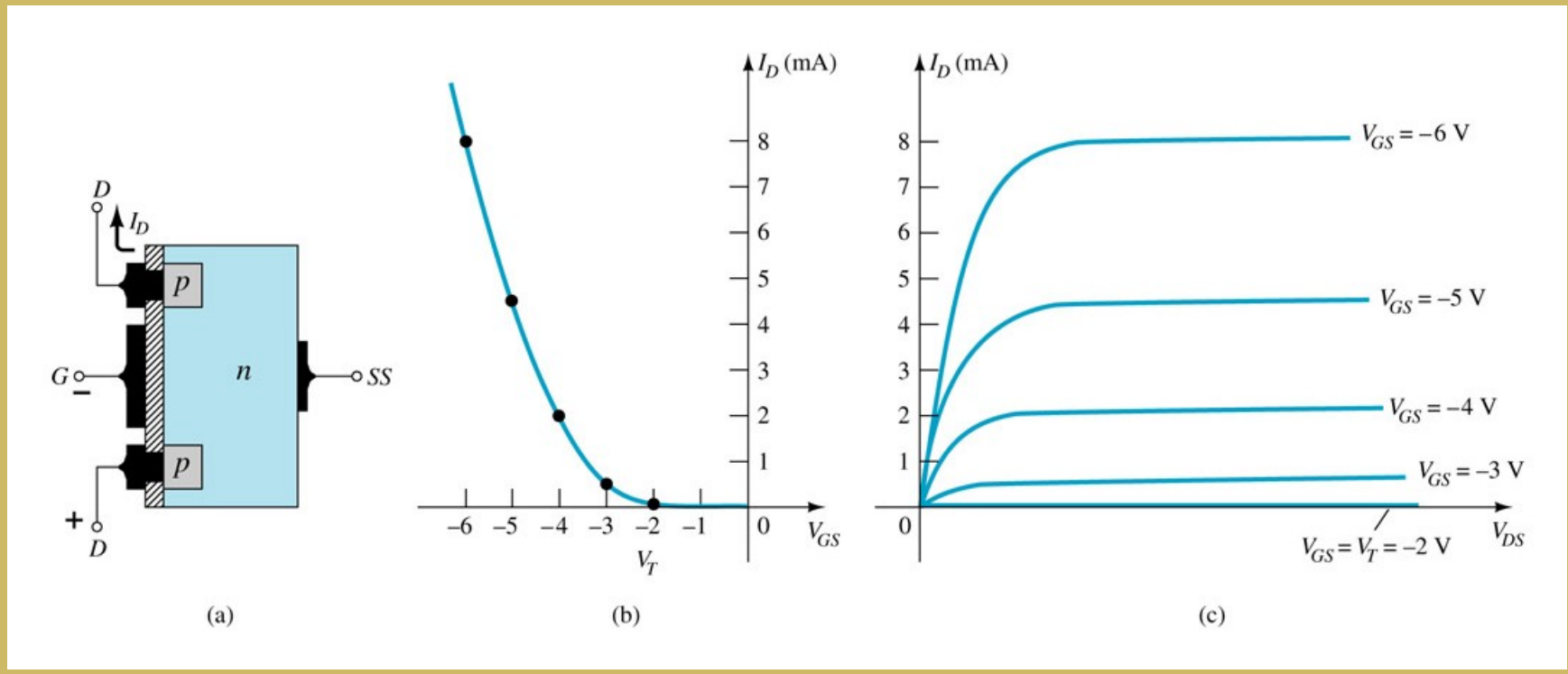
k = constant found in the specification sheet

The PSpice determination of k is based on the geometry of the device:

$$\mathbf{k = \left(\frac{W}{L}\right)\left(\frac{KP}{2}\right)} \quad \mathbf{where\ KP = \mu_N C_{OX}}$$

p-Channel Enhancement Mode MOSFETs

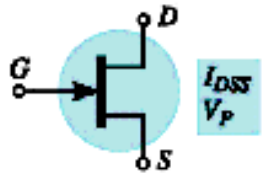
The p-channel Enhancement mode MOSFET is similar to the n-channel except that the voltage polarities and current directions are reversed.



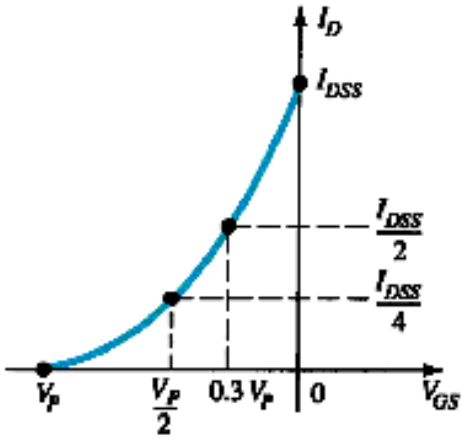
Summary Table

JFET

$I_G = 0\ \text{A}, I_D = I_S$

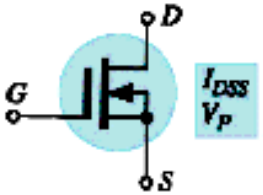


$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$



D-MOSFET

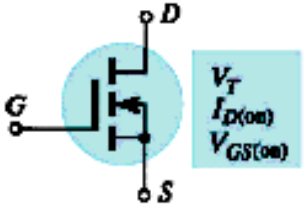
$I_G = 0\ \text{A}, I_D = I_S$



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

E-MOSFET

$I_G = 0\ \text{A}, I_D = I_S$



$$I_D = k(\ _{GS} - V_{GS(Th)})^2$$

$$k = \frac{I_{D(on)}}{(V_{GS(on)} - V_{GS(Th)})^2}$$