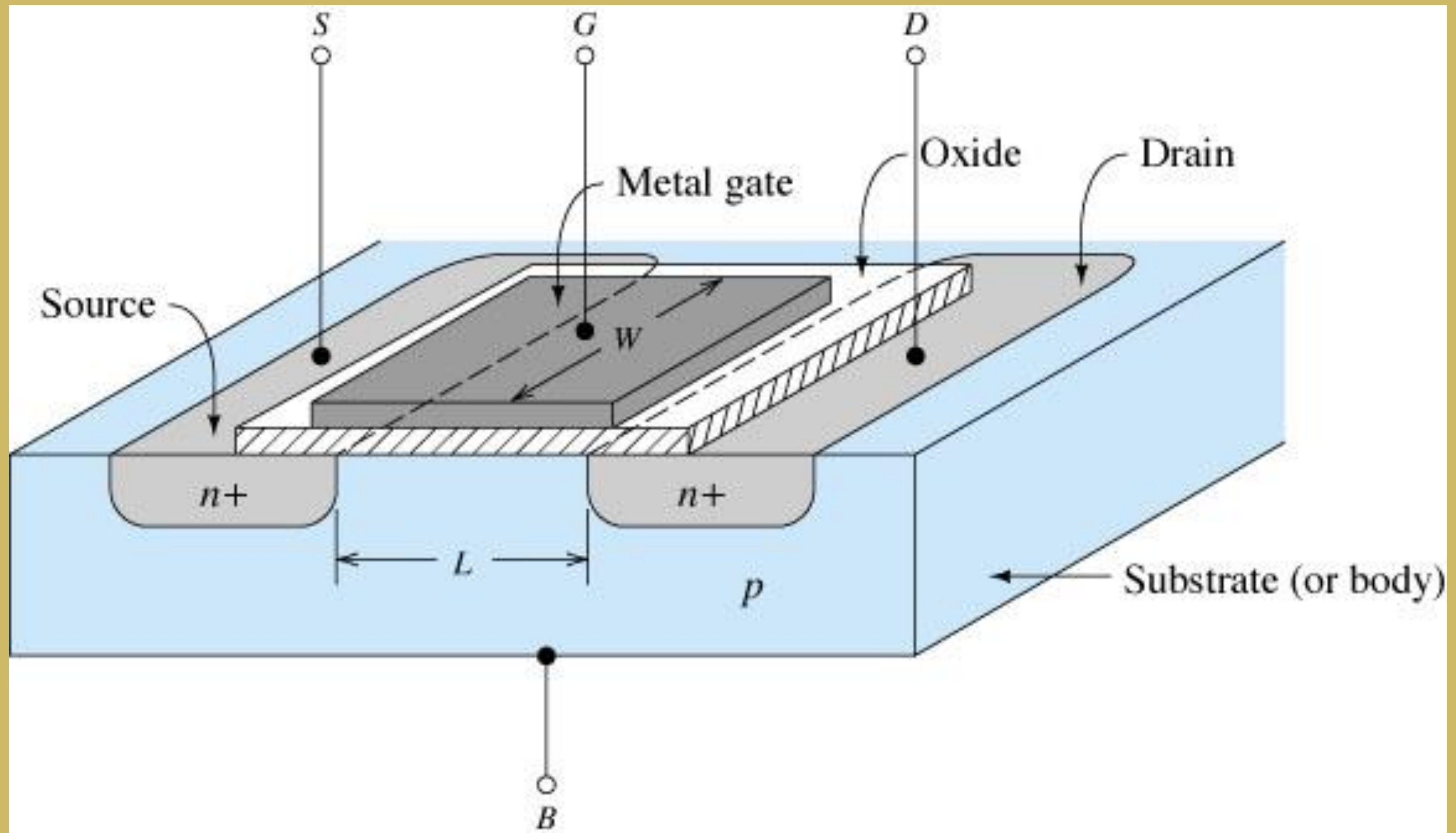
ANALOG ELECTRONICS

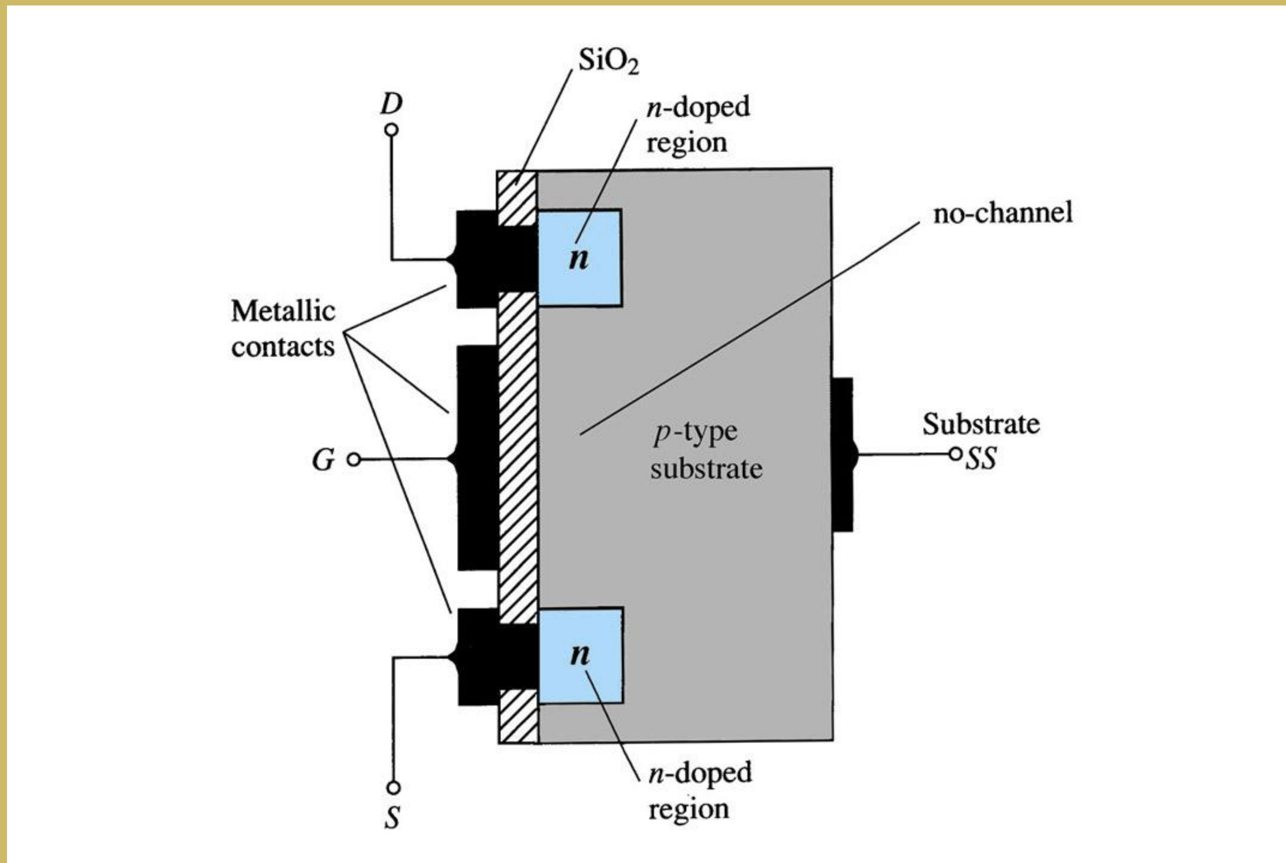
LECTURE NO. 10

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

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.)

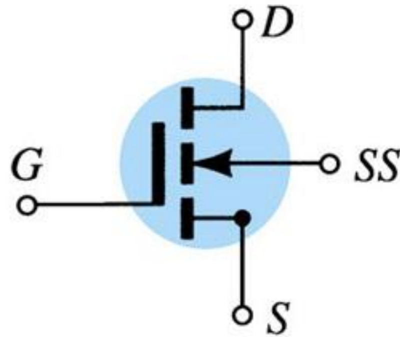
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Drain-Source Breakdown Voltage ($I_D = 10\ \mu A$, $V_{GS} = 0$)	$V_{(BR)DSX}$	25	–	Vdc
Zero-Gate-Voltage Drain Current ($V_{DS} = 10$ V, $V_{GS} = 0$) $T_A = 25°C$ $T_A = 150°C$	I_{DSS}	– –	10 10	nAdc µAdc
Gate Reverse Current ($V_{GS} = \pm 15$ Vdc, $V_{DS} = 0$)	I_{GSS}	–	± 10	pAdc
ON CHARACTERISTICS				
Gate Threshold Voltage ($V_{DS} = 10$ V, $I_D = 10\ \mu A$)	$V_{GS(Th)}$	1.0	5	Vdc
Drain-Source On-Voltage ($I_D = 2.0$ mA, $V_{GS} = 10$V)	$V_{DS(on)}$	–	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)	$\lvert y_{fs} \rvert$	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

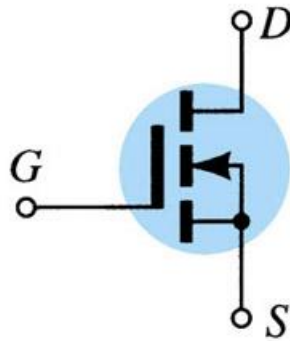
SWITCHING CHARACTERISTICS

Characteristic	Conditions	Symbol	Min	Max	Unit
Turn-On Delay (Fig. 5)	$I_D = 2.0$ mAdc, $V_{DS} = 10$ Vdc, ($V_{GS} = 10$ Vdc) (See Figure 9; Times Circuit Determined)	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

E-MOSFET Symbols

n-channel

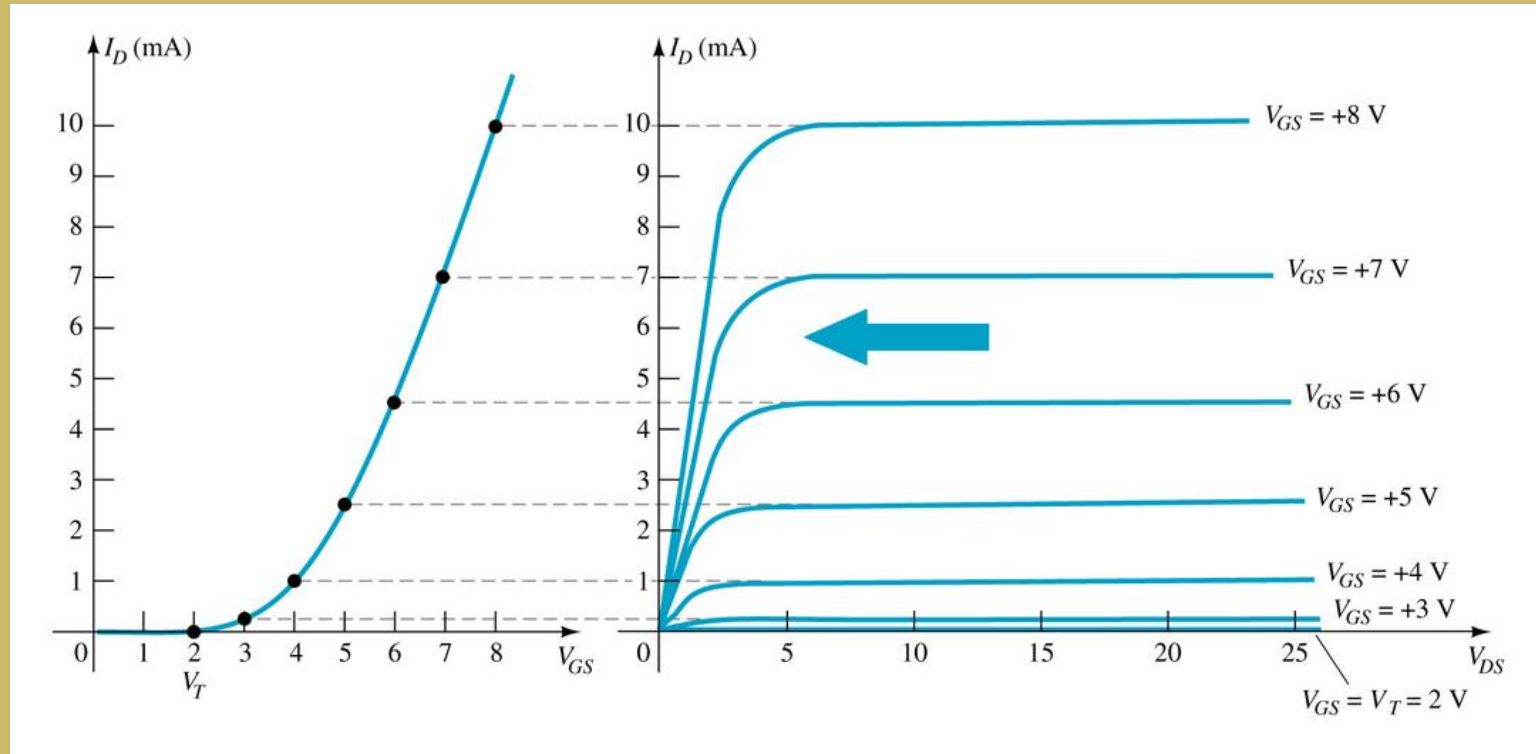




(a)

Basic Operation

The Enhancement mode MOSFET only operates in the enhancement mode.



V_{GS} is always positive

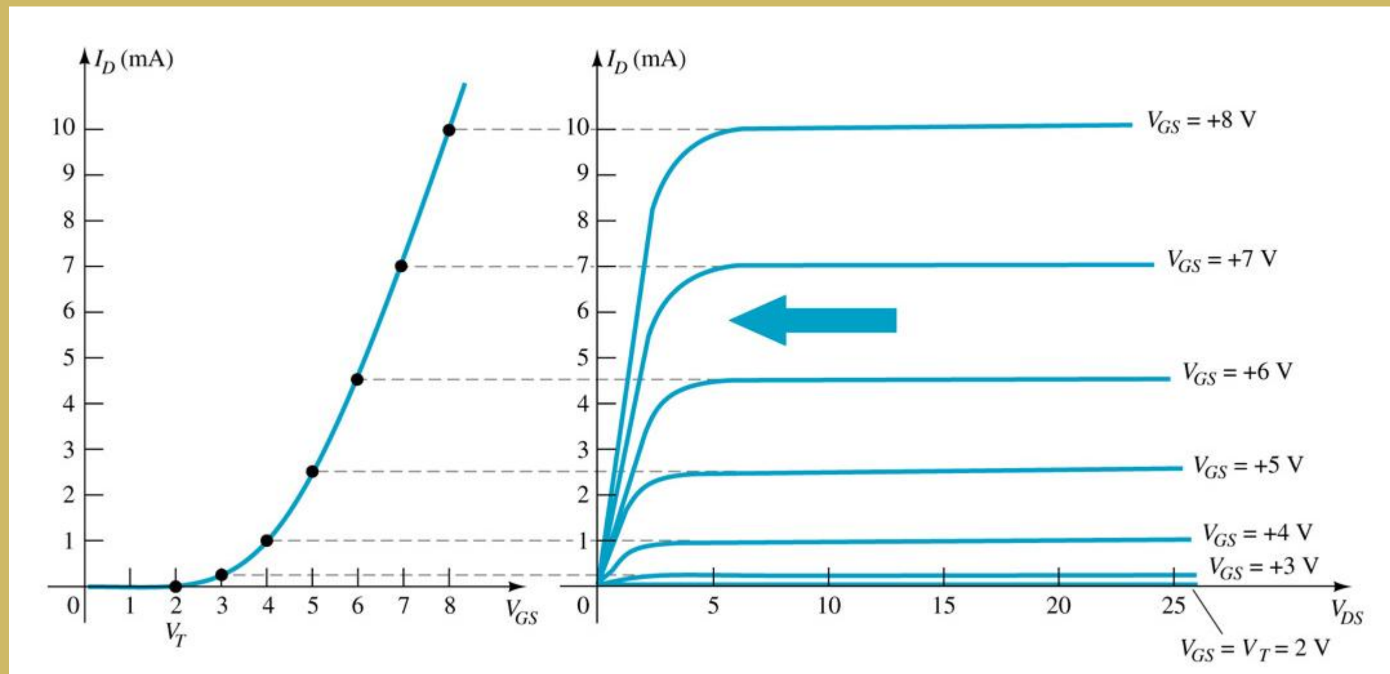
$I_{DSS} = 0$ when $V_{GS} < V_T$

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



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

To determine I_D given V_{GS}: $\quad I_D = k\,(V_{GS} - V_T)^2$

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

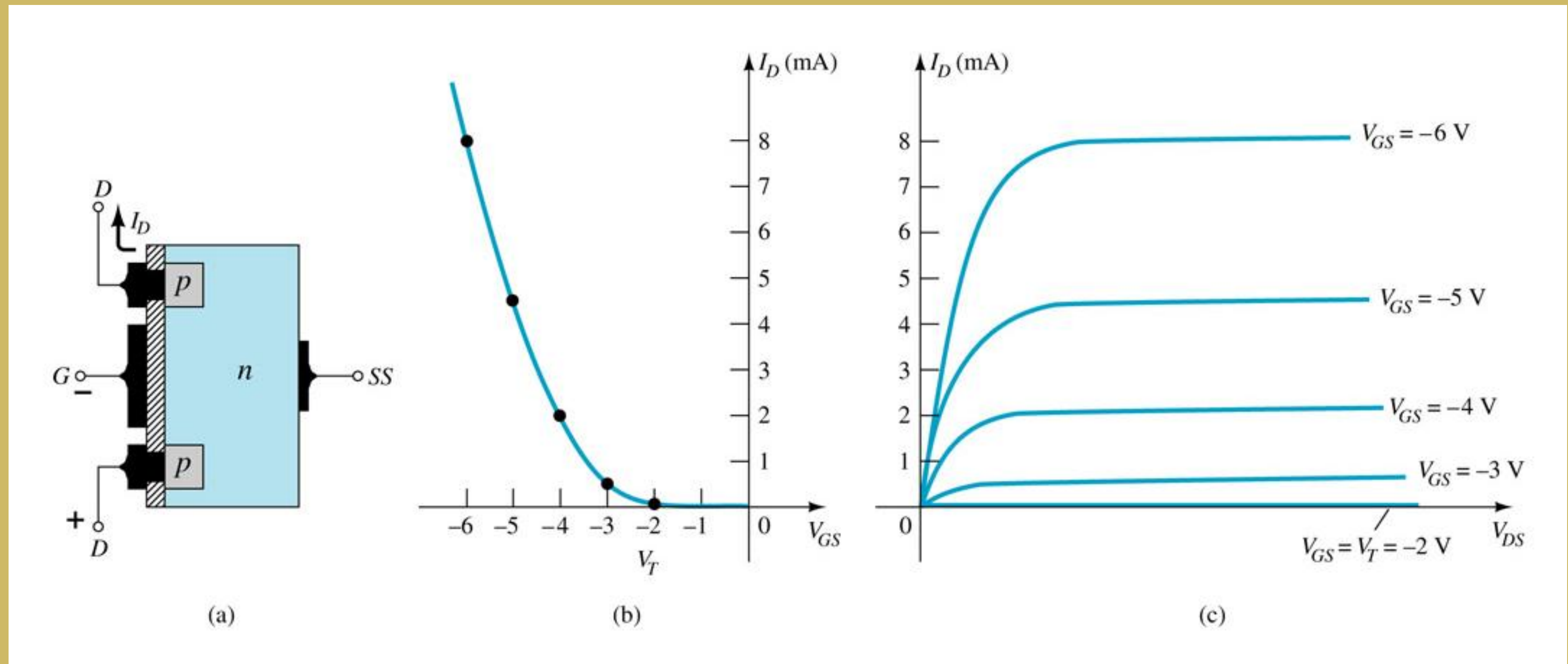
k = constant found in the specification sheet

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

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

p-Channel Enhancement Mode MOSFETs

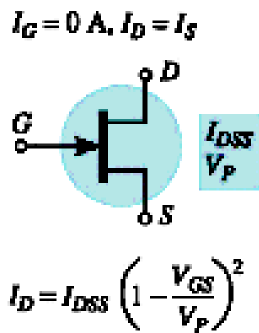
The p-channel Enhancement mode MOSFET is similar to the n-channel except that the voltage polarities and current directions are reversed.

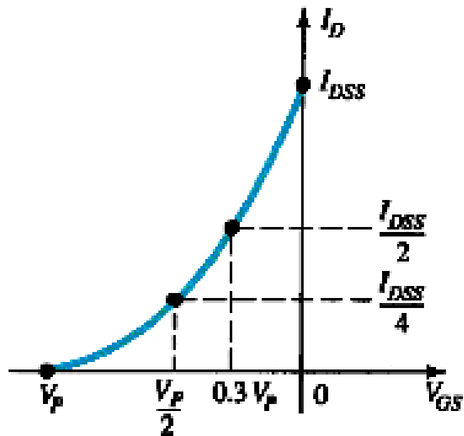


(a) (b) (c)

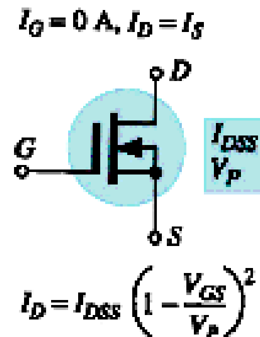
Summary Table

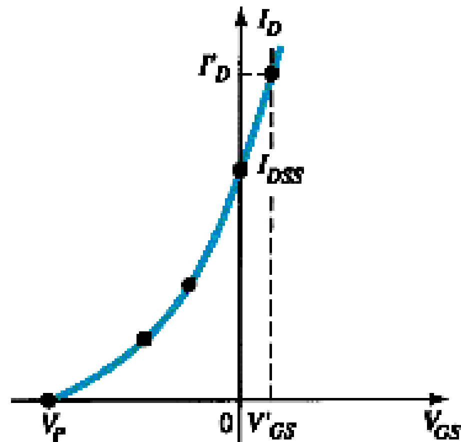
JFET





D-MOSFET





E-MOSFET