Fundamentals of Electronics

ECE 101

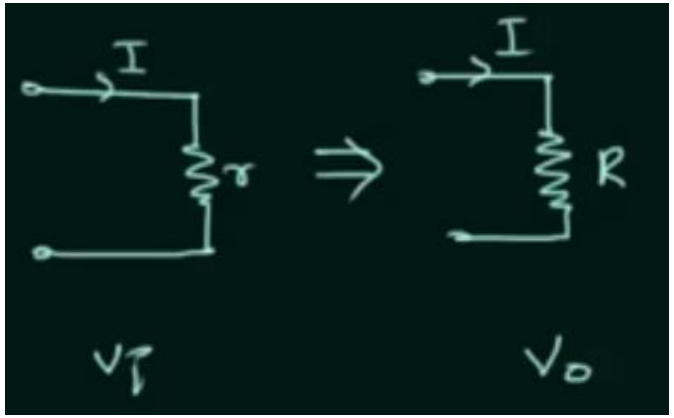
The Transistor

Amplification and switching

Transistor

- Key characteristic:
  - The transistor is a three-terminal device with the feature that the current through two terminals can be controlled by small changes we make in the current or voltage at the third terminal.
  - This control feature allows us to amplify small ac signals or to switch the device from an *on* state to an *off* state and back.
  - These two operations, *amplification* and *switching*, are the basis of a host of electronic functions.
  - This forms the basis for both bipolar junction transistors (BJT) and field effect transistors (FET).

The transistor action - 1



$V_i = I \times r$ $\quad V_o = I \times R$

$V_i < V_o$ (amplification)

Active mode

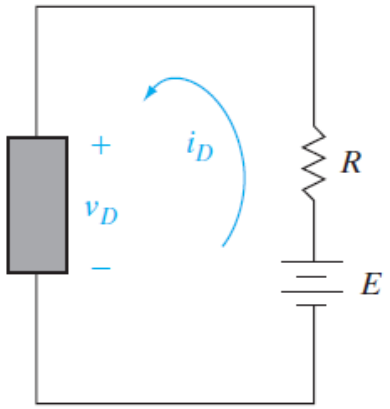
$J_1 \rightarrow$ f.b. $\quad$ Res = 0

$J_2 \rightarrow$ r.b. $\quad$ Res = ∞

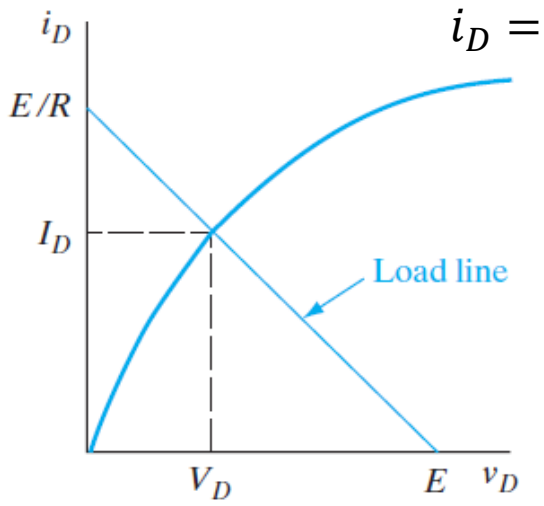
BJT

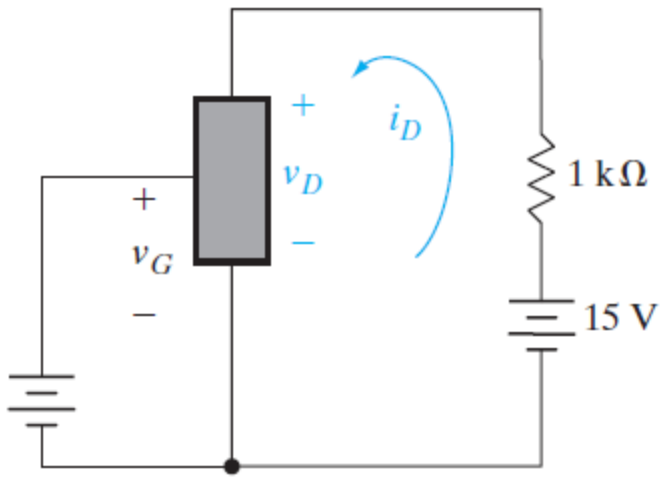
The transistor action - 2

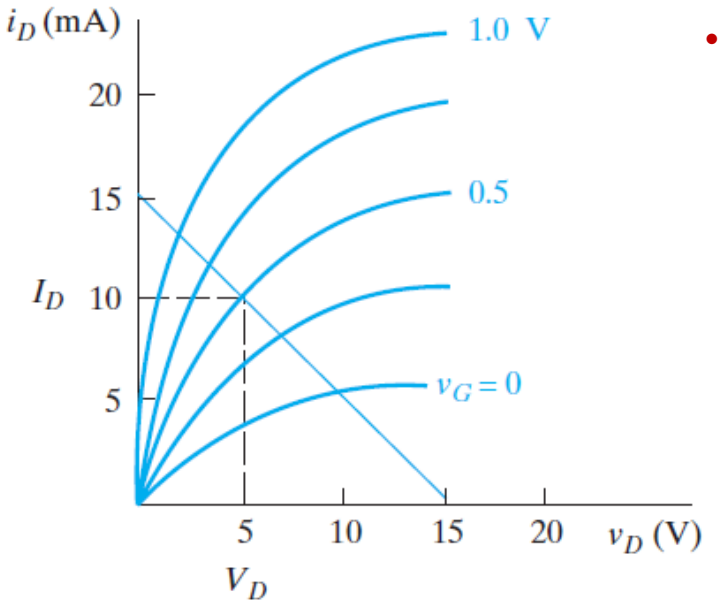
Load line $E = i_D R + v_D$



$i_D = f(V_D)$







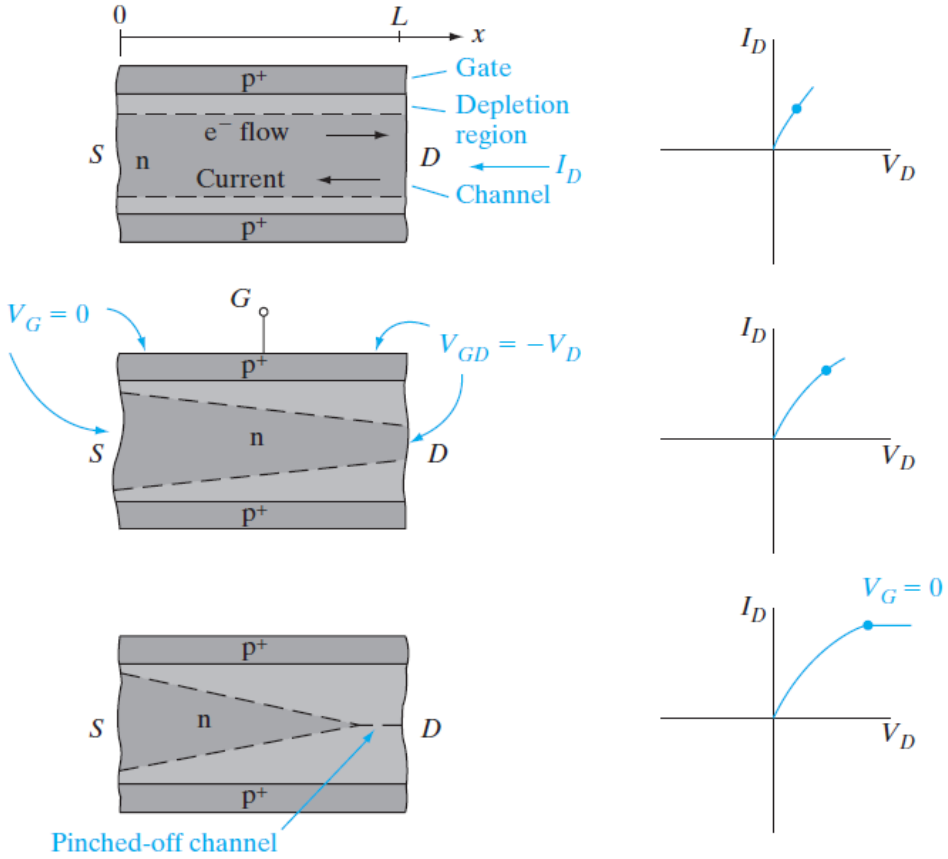
- If an ac source is added to the control voltage
  - We can achieve large variations in *iD* by making small changes in V*G*
  - For example if V*G* changes by value of 0.25V, *Vd* varies about its dc 2V.
  - Thus the amplification of the ac signal is 2/0.25 = 8.
  - we can switch from the bottom of the load line to almost the top by appropriate changes in V_G.

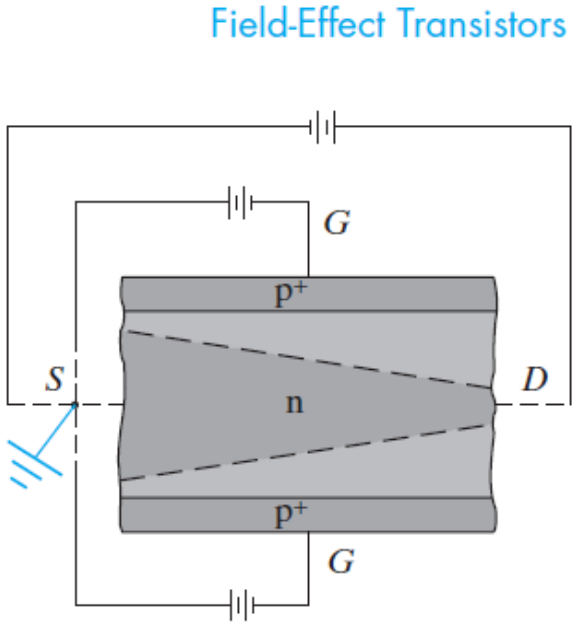
For BJTs, this kind of control is achieved by current control.

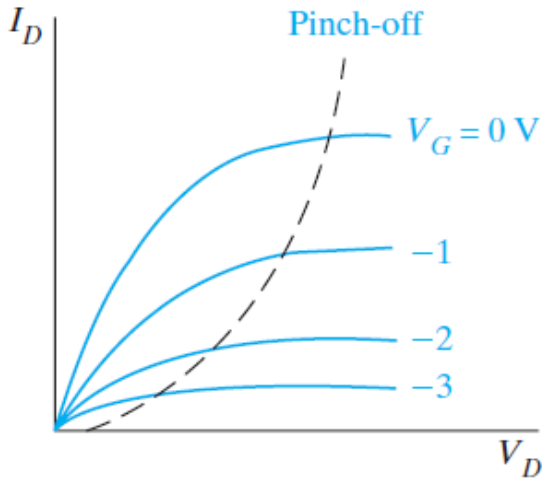
Field Effect Transistors

The idea

Junction Field Effect Transistor: JFETs





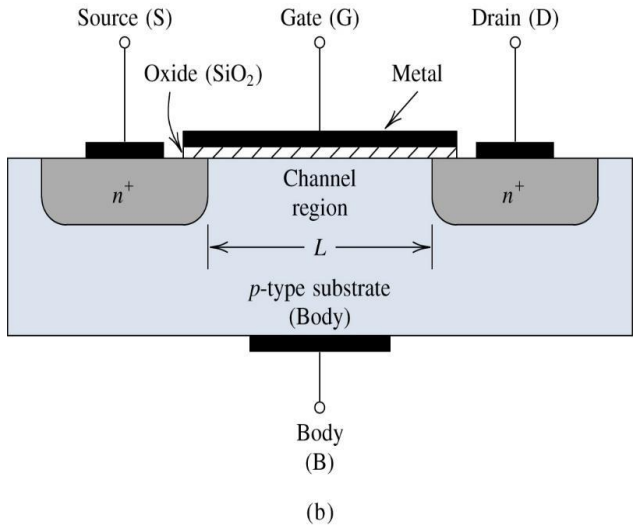


Gate control

$$v_d = \frac{I}{neA}$$

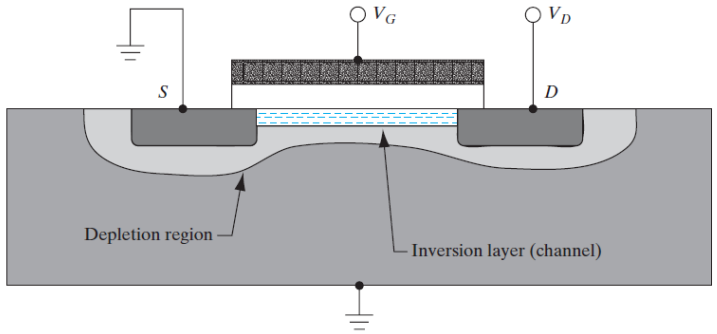
MOSFET (Metal–Oxide–Semiconductor Field-Effect Transistor)

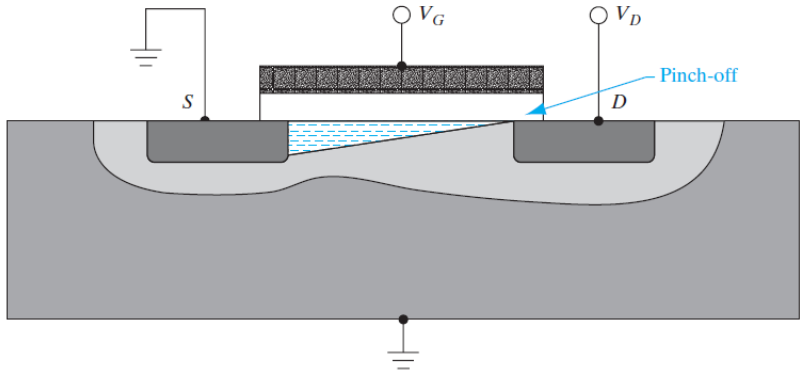
MOSFET

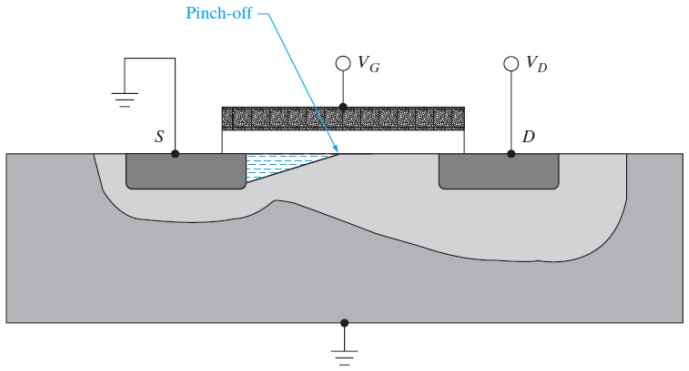


(b)

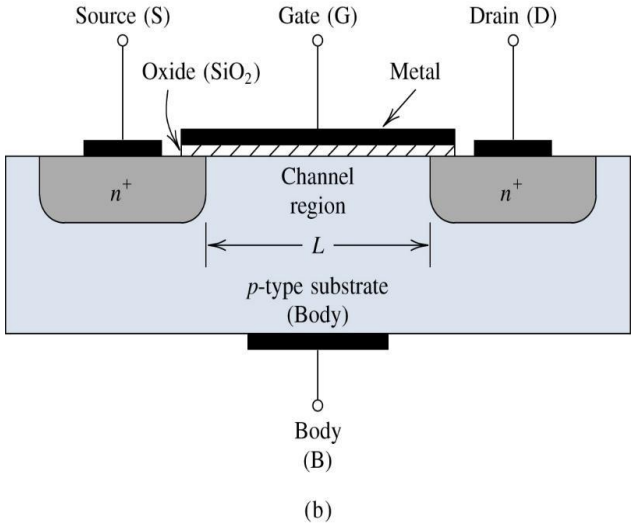
Different regimes as V_D is varied.



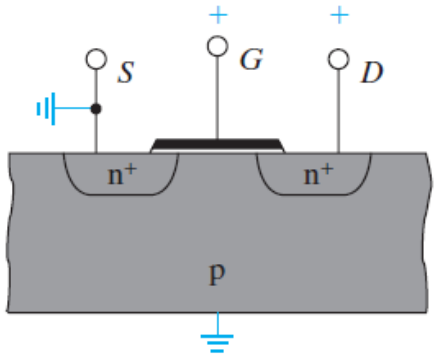


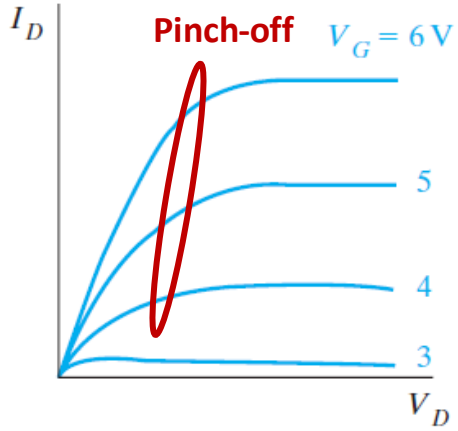


Field Effect Transistors



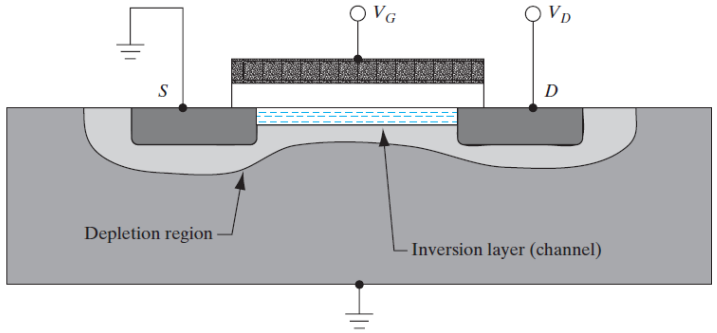
Characteristics

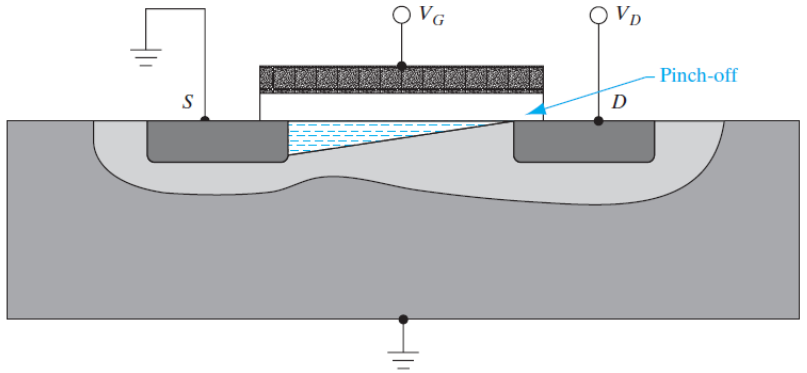


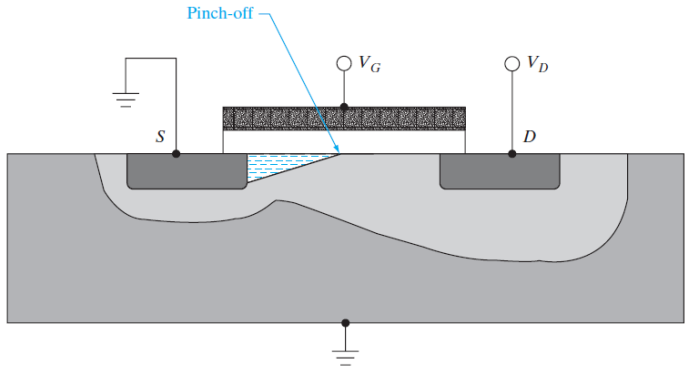


Threshold voltage

Different regimes as V_D is varied.





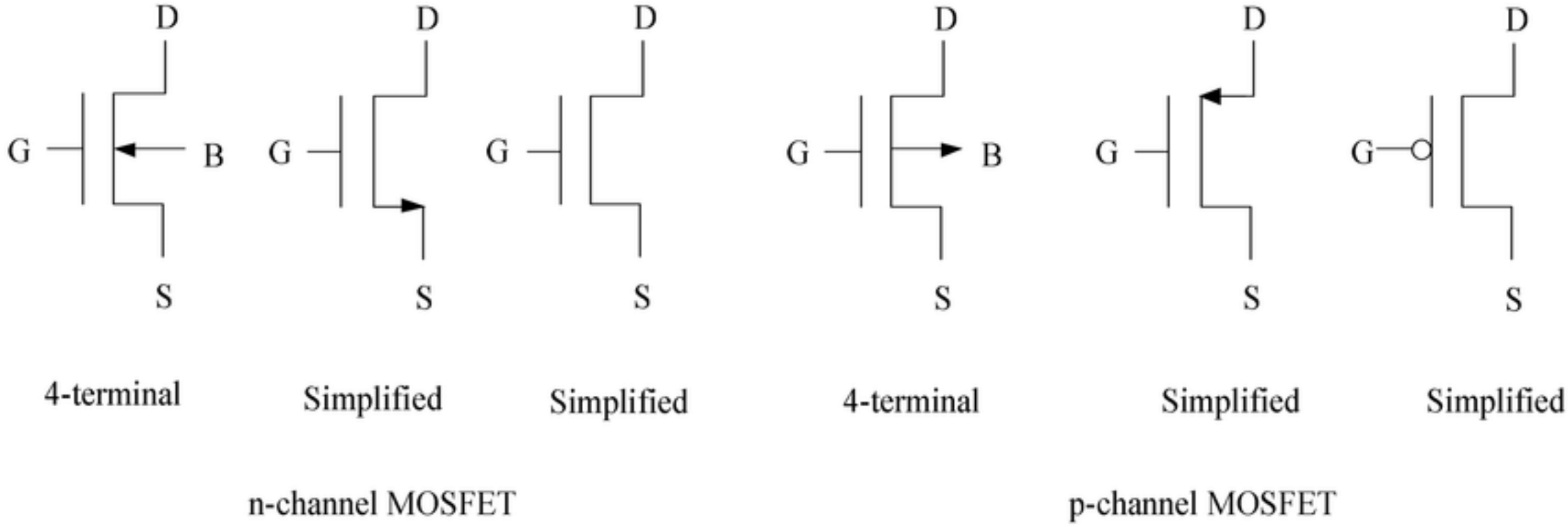


Pinch-off

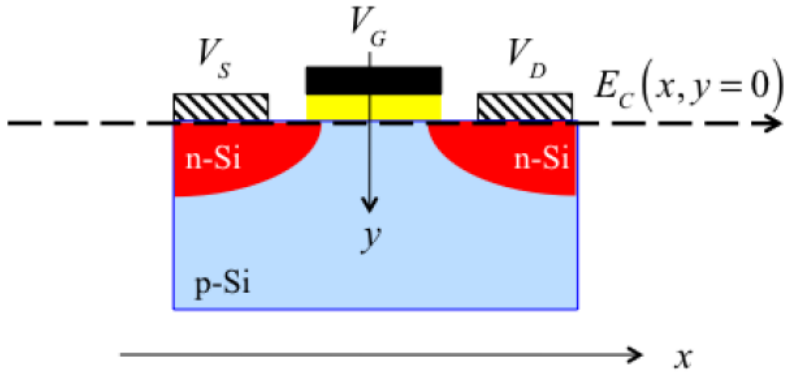
MOSFET (Metal–Oxide–Semiconductor Field-Effect Transistor)

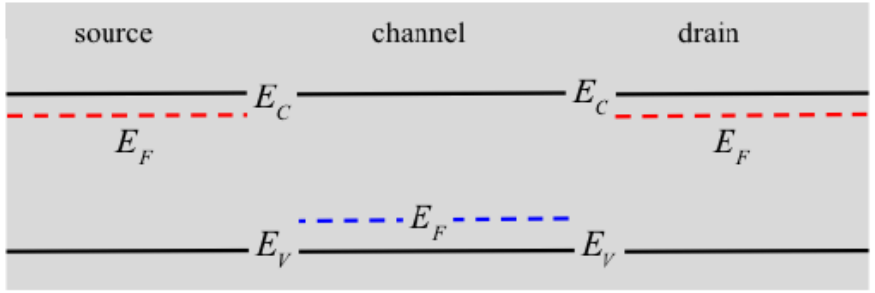
N-Channel MOSFETs use electron flow as the charge carrier. P-Channel MOSFETs use hole flow as the charge carrier, which has less mobility than electron flow.

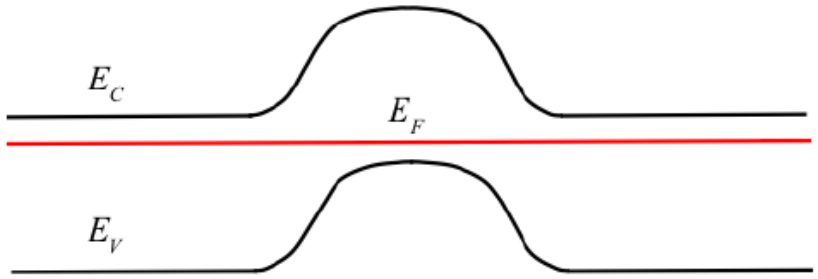
Symbols



MOSFET Band Diagram





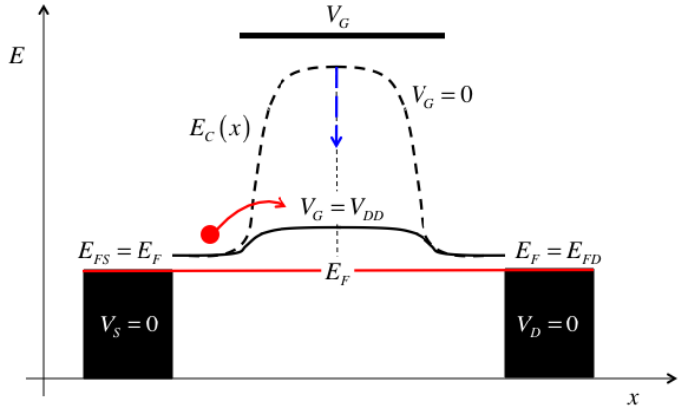


N-channel MOSFET

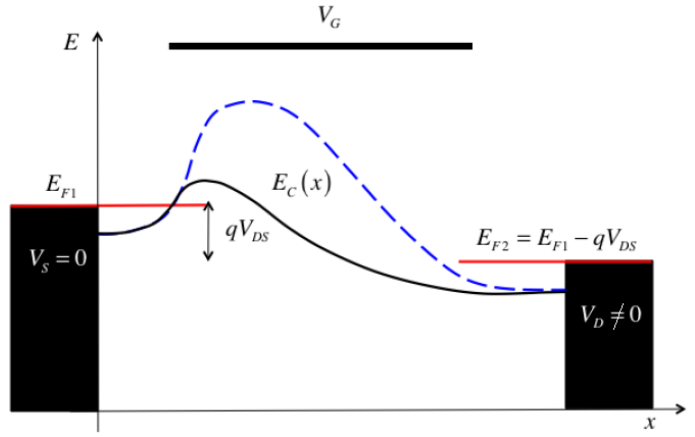
Most transistors operate by controlling the height of an energy barrier with an applied voltage.

Note: that there is a potential energy barrier that separates electrons in the source from electrons in the drain.

Application of a positive voltage

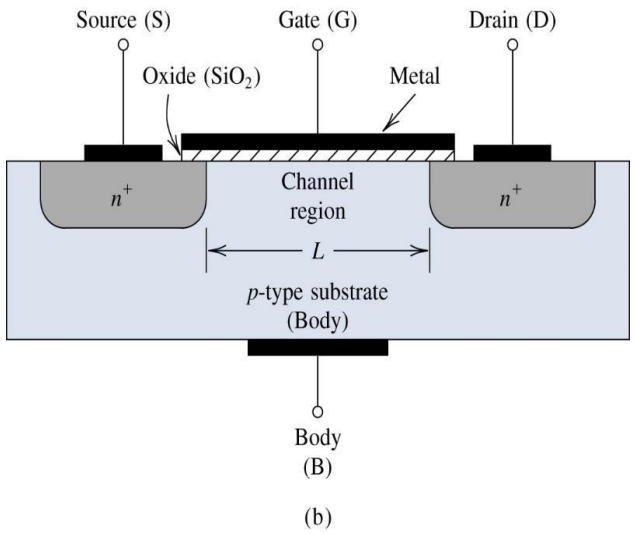


Gate voltage

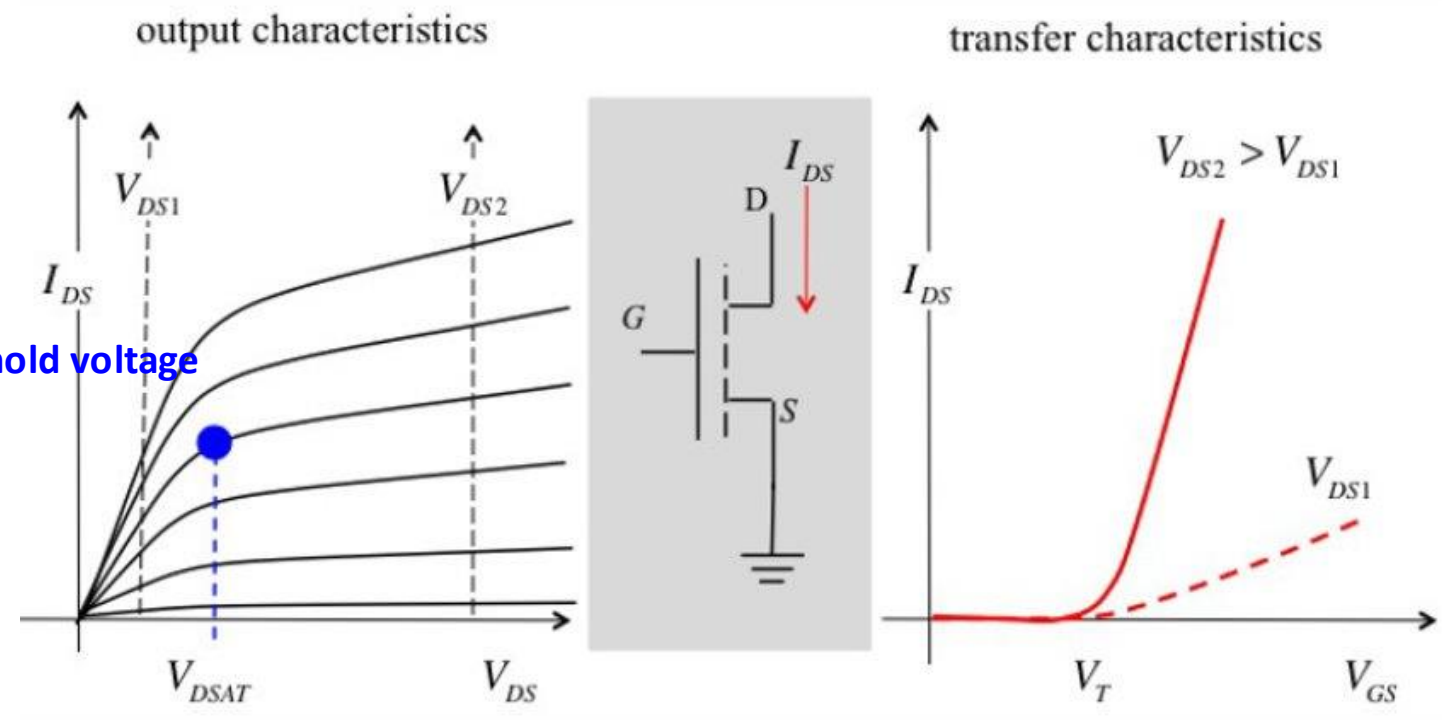


Drain voltage

MOSFET Characteristics



Threshold voltage



Output Characteristics

Transfer Characteristics

Thank you