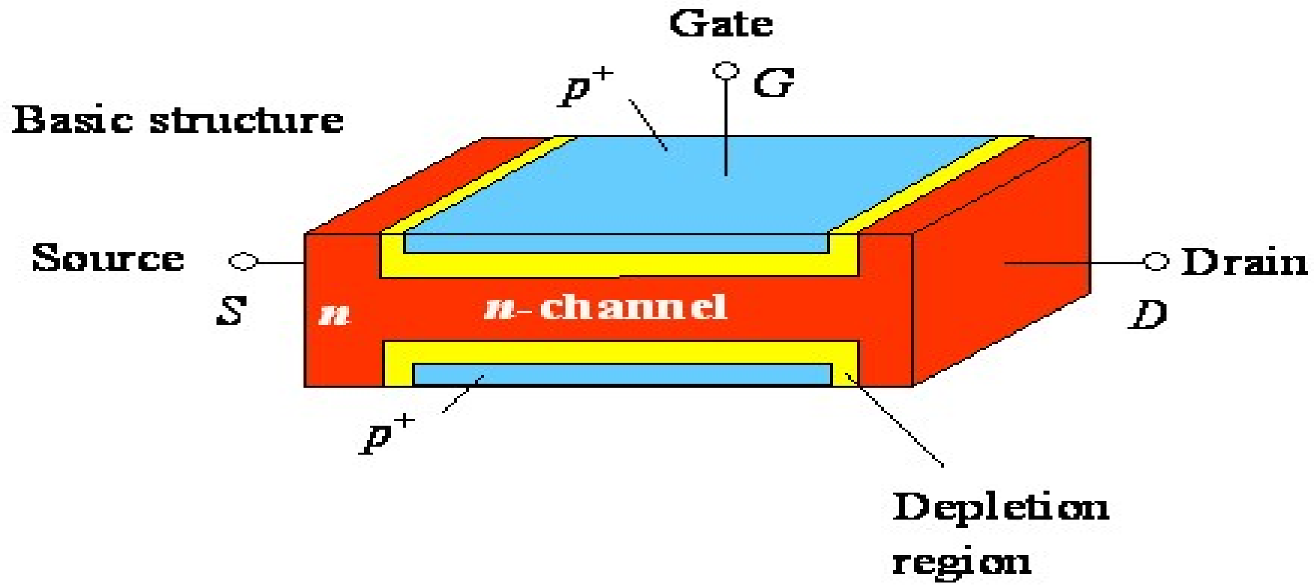
Field Effect Transistors

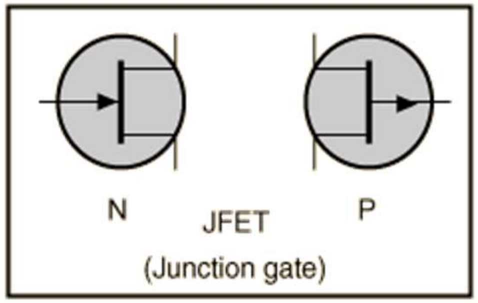
Transistor problems

- Power density increased
- Device variability
- Reliability
- Complexity
- Leakage
- Power dissipation limits device density
- Transistor will operate near ultimate limits of size and quality – eventually, no transistor can be fundamentally better

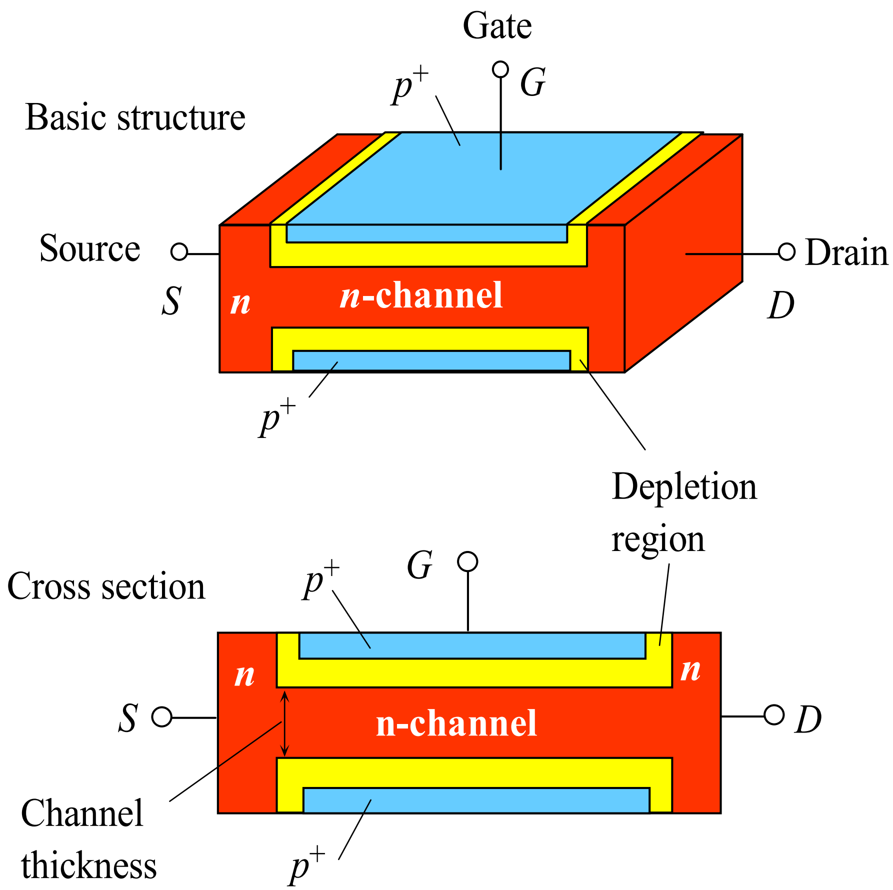
Junction FETs (JFETs)

- A piece of semiconductor material which constitutes a channel
- Conducting semiconductor channel between two ohmic contacts – source & drain





The Symbol



(a)

n type bar acts as a simple semiconductor resistor

Electrons flow from Source to drain if an electric field is applied between them

Only one carrier – electrons (for n-channel) or holes (for p channel) - **unipolar**

Depletion region exists for p-n junctions

Due to depletion region, the conduction portion of channel constricts

Channel thickness is dependent on both V_{DS} and V_{GS}

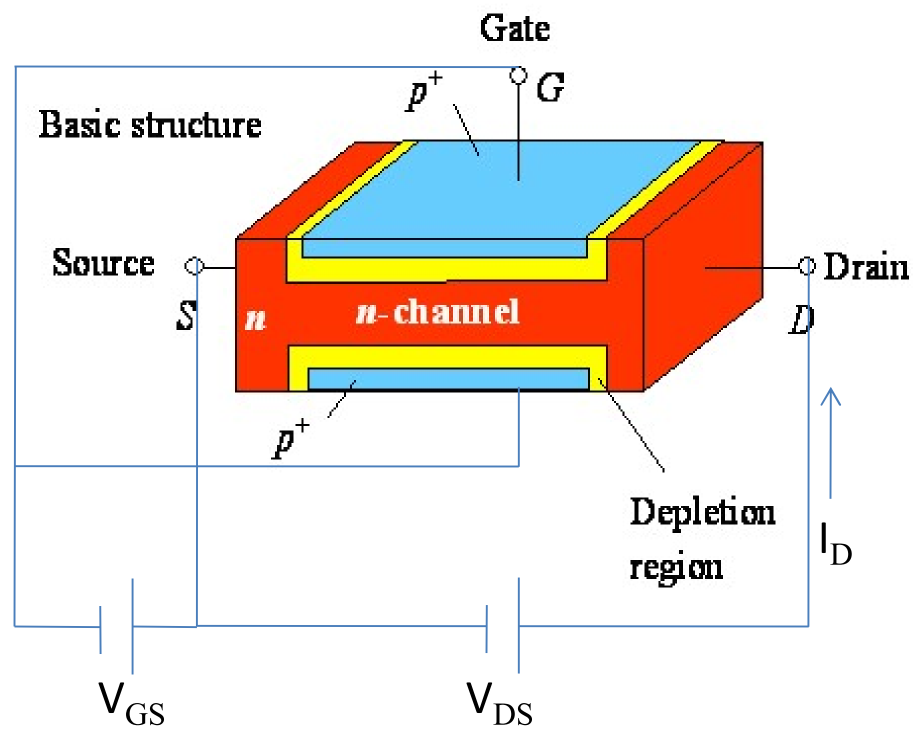
Electrons flow from source to Drain

Current I_D flows through channel

For a fixed V_{DS}, I_D is also dependent on V_{GS} as it increases or decreases the reverse bias

Mechanism of current is the effect of field produced by V_{DS} and V_{GS}

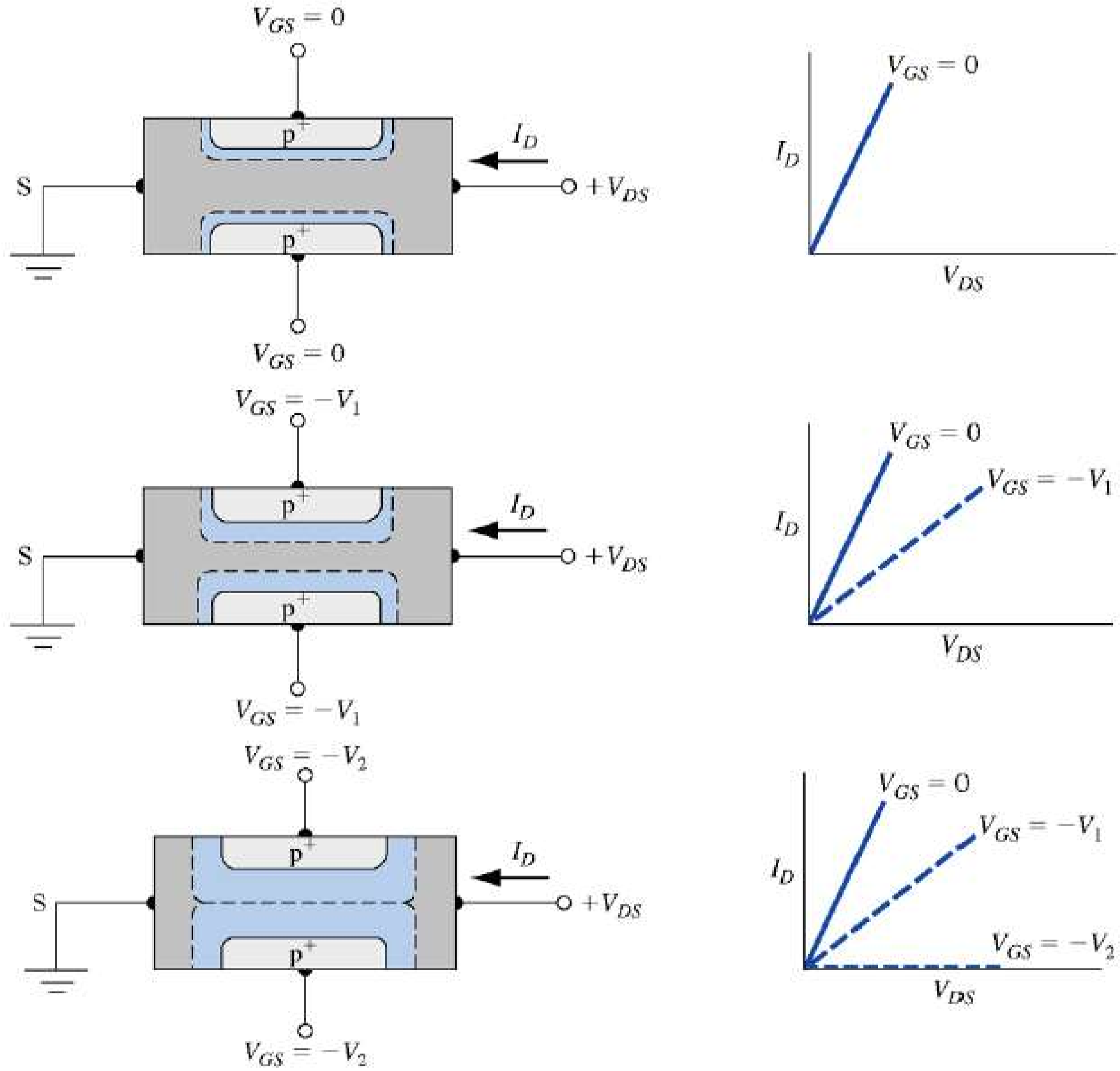
(FIELD EFFECT TRANSISTOR)



I-V characteristics

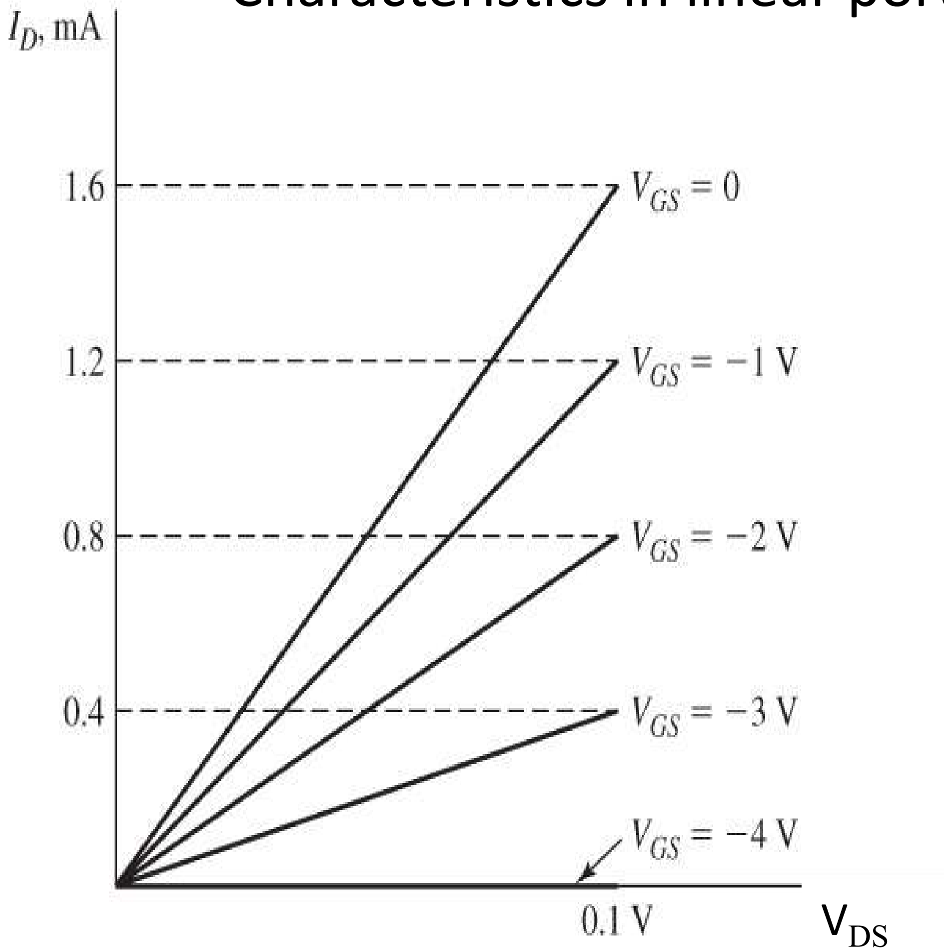
More V_{GS} (more –ve) implies

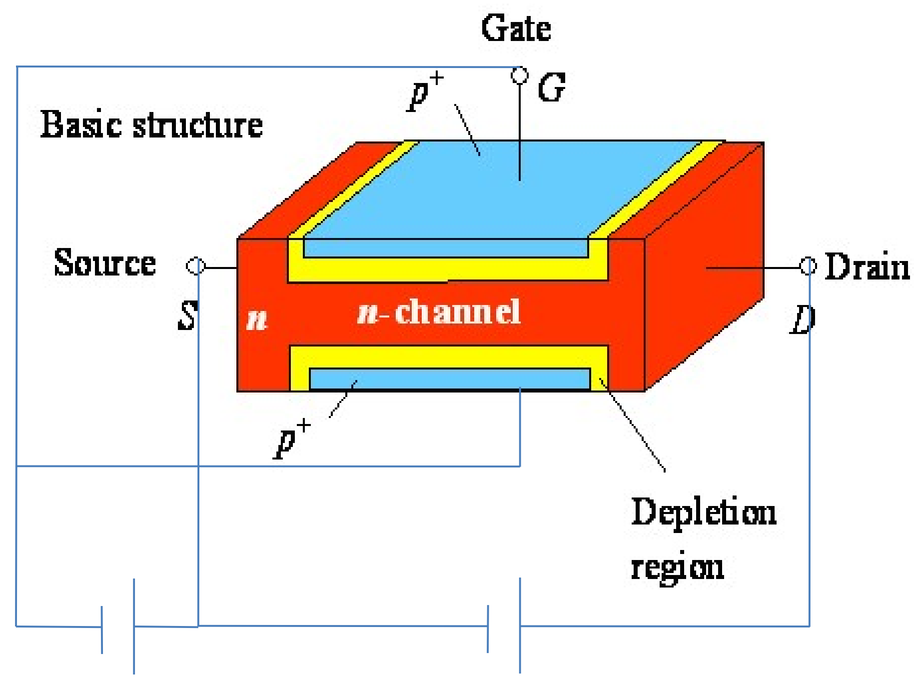
- More reverse bias
- More depletion region
- Less channel width
- Less current I_D



V_G controls the channel width → V_G control I_d

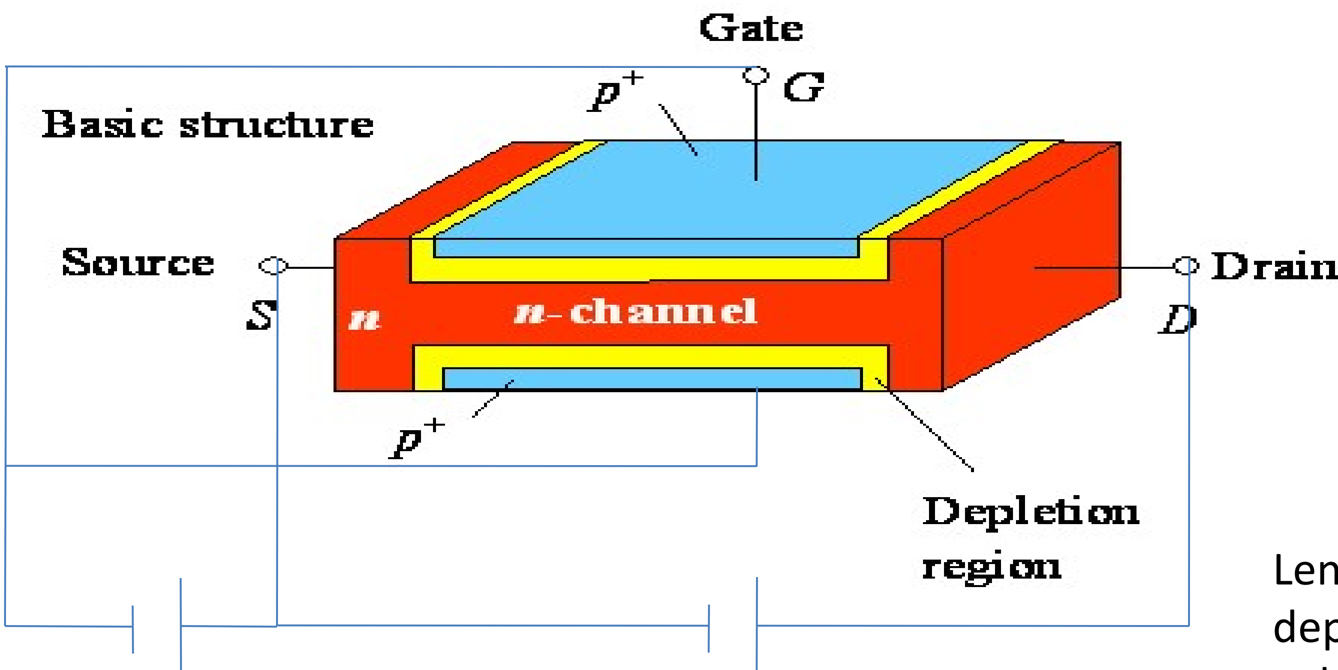
Characteristics in linear portion of the ohmic region.

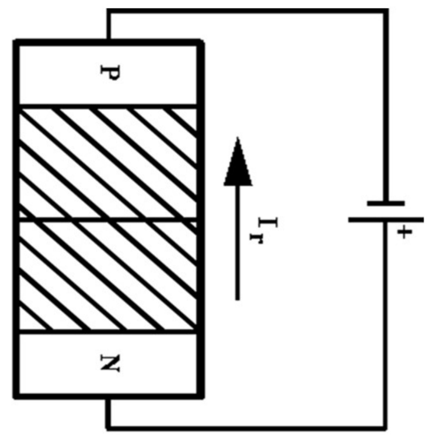




Current I_D flows through channel following Ohm's law

Junction FETs (JFETs)





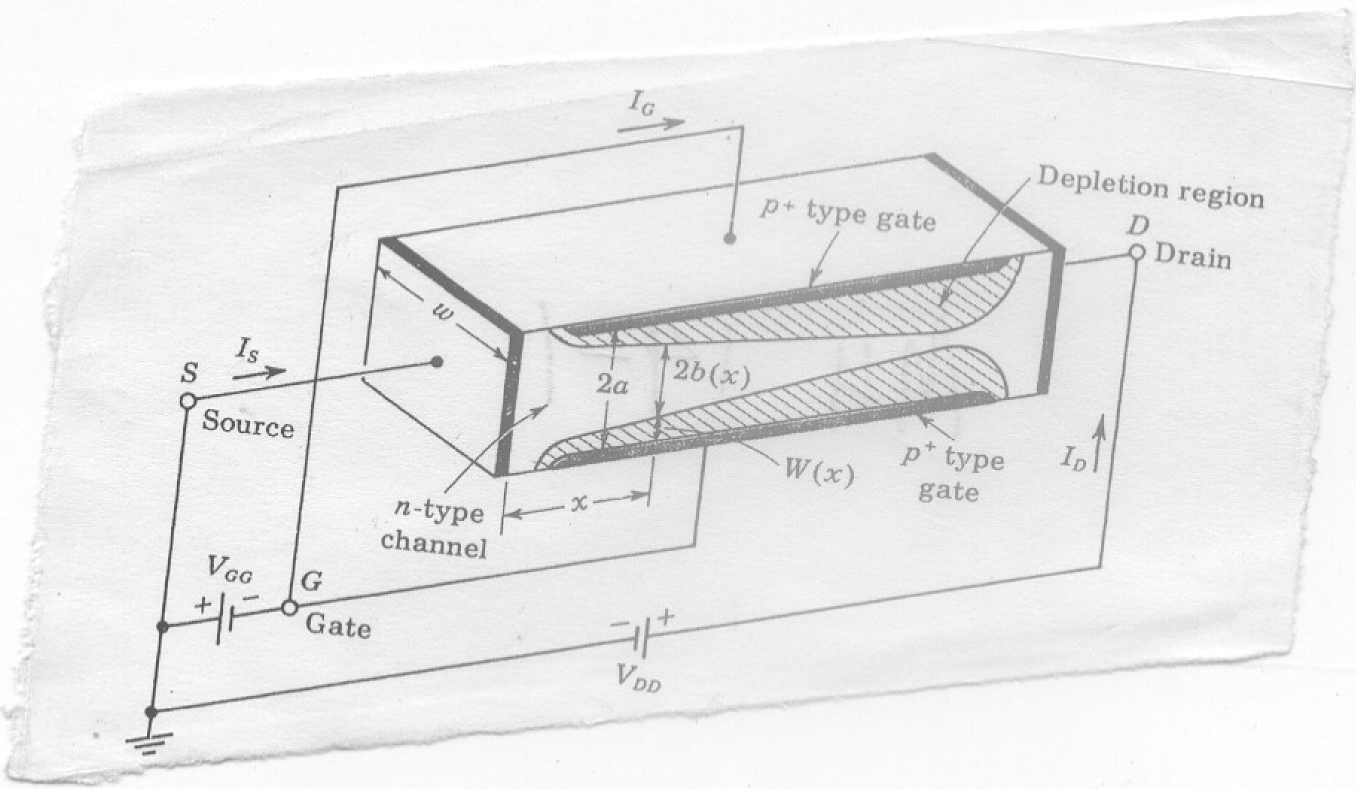
Length of Depletion region depends on the reverse bias voltage

Length of Depletion region depends on the voltage difference between channel and gate

The voltage at channel is dependent on position , as ohmic drop varies along the channel

Thus the constriction of conduction channel is not uniform

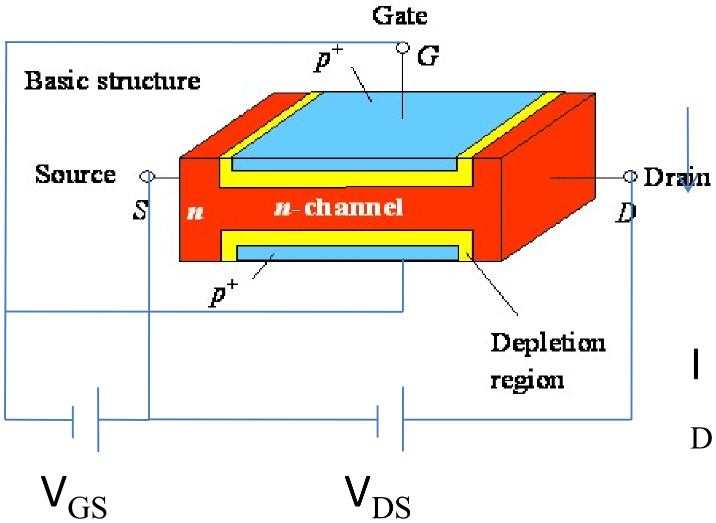
The structure of a n-Channel FET

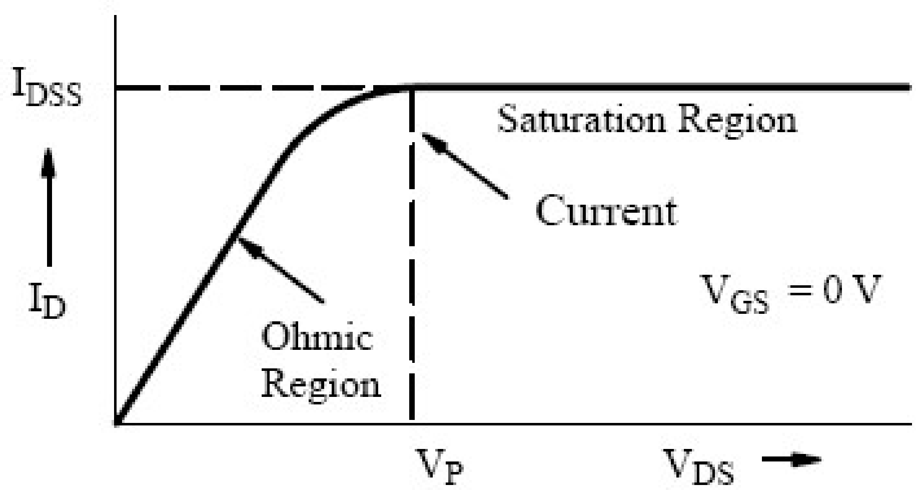


The constriction is more pronounced at distance farther from the source

The constriction is dependent on the current (which is dependent on both V_{GS} and V_{DS})

The structure of a n-Channel FET





For a fixed V_{GS}, if increase V_{DS} more and more, I_D will increase, - and channel will constrict more and more

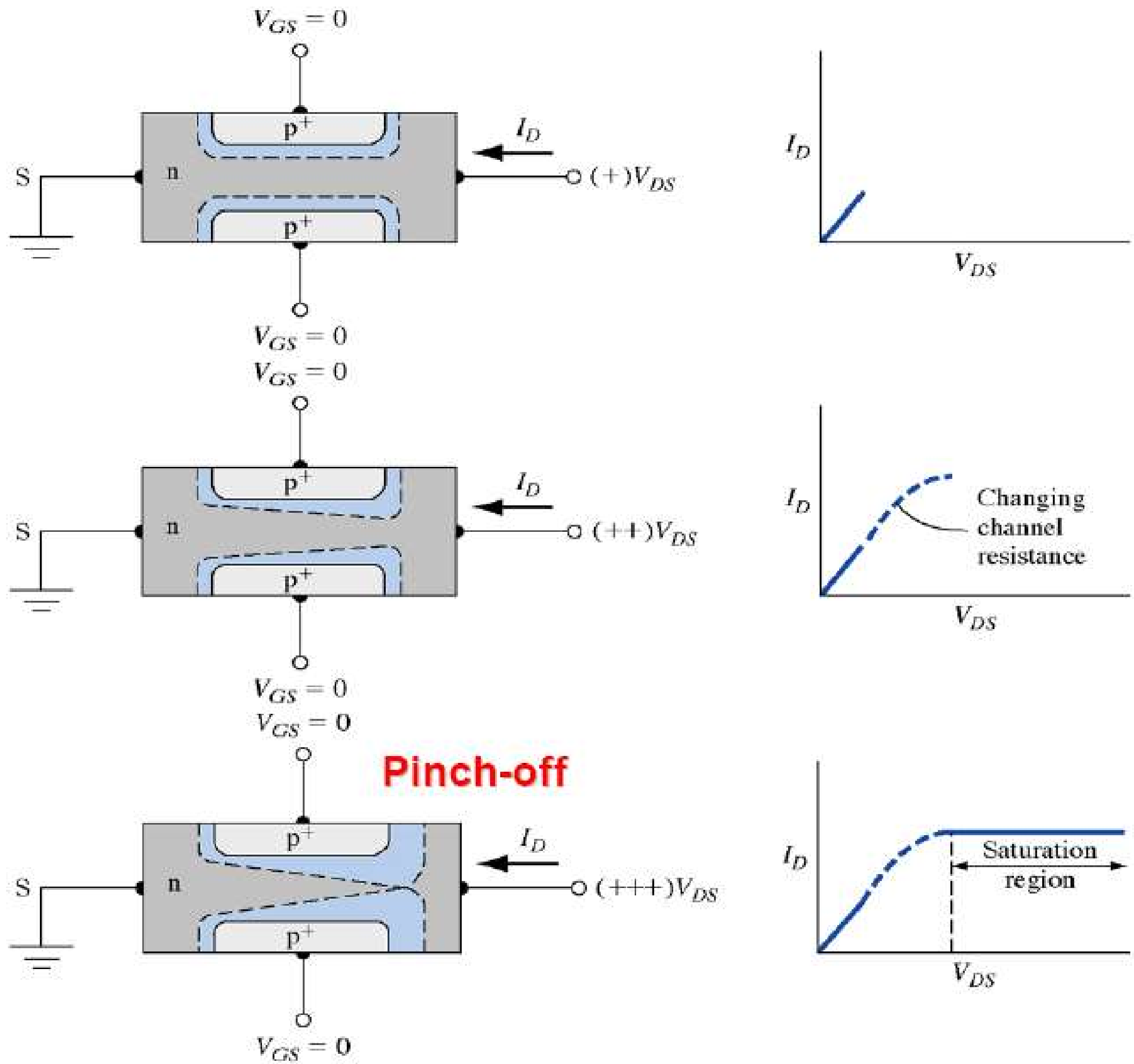
Eventually I_D is reached to such a level (I_{DSS}) such that the channel is pinched off

At this point I_D begins to level off and approach a constant value

pinch-off voltage, V_P , which is the value of V_{DS} at which the maximum I_{DSS} flows

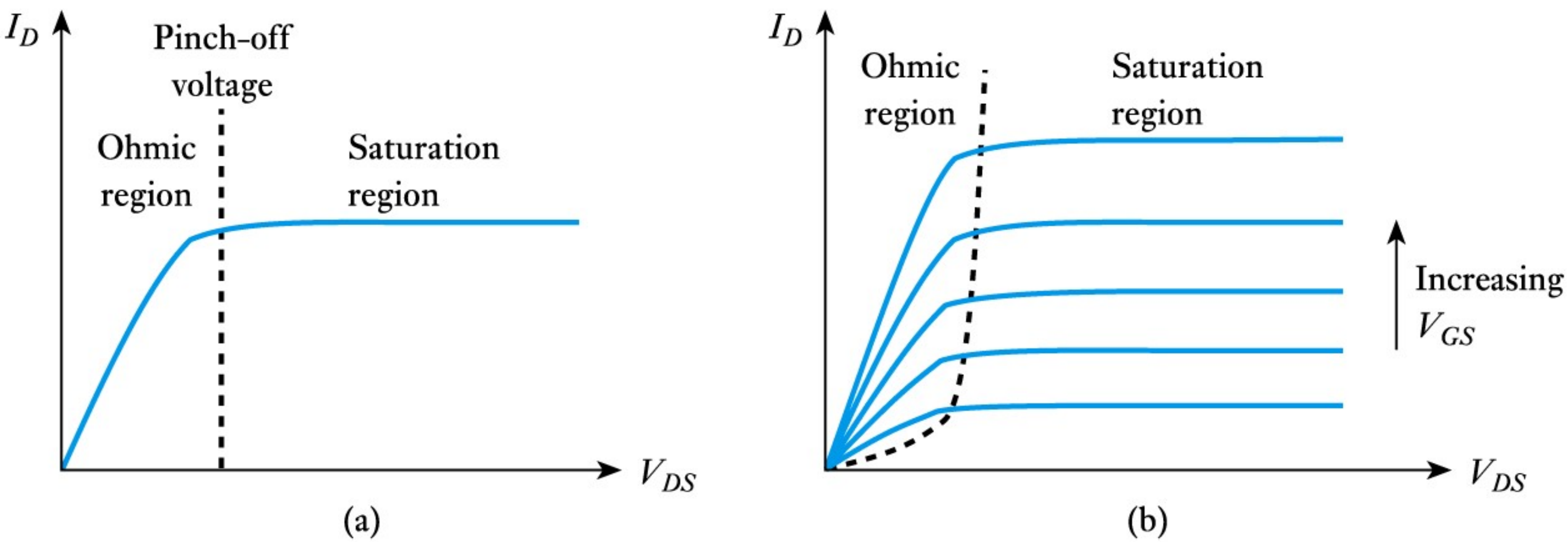
Note: channel never completely closes as that reduces I_D to zero

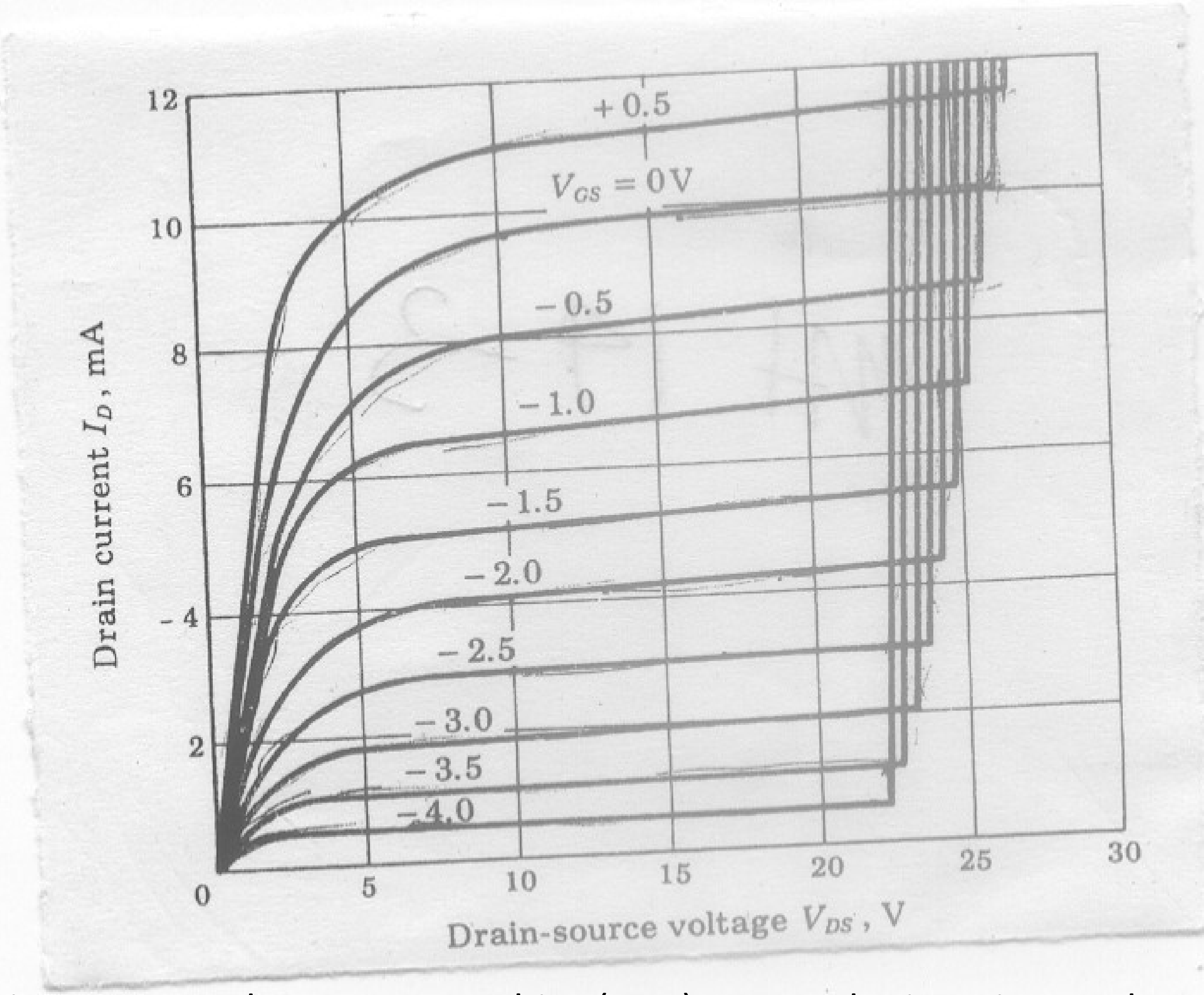
I-V characteristics



After pinch-off: $I_D \neq f(V_D)$; $I_D = f(V_G)$ - current source

- **FET output characteristics**

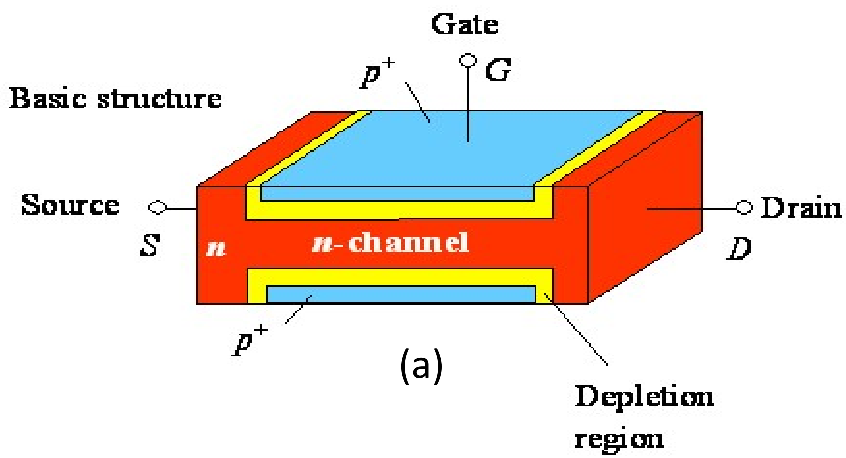




Increasing more and more reverse bias (V_{DS}) causes the junctions to breakdown

If V_{GS} is more negative, the breakdown occurs at early V_{DS}

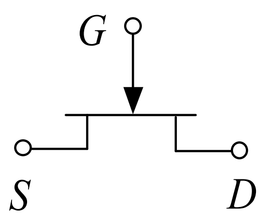
More practical n-channel JFET

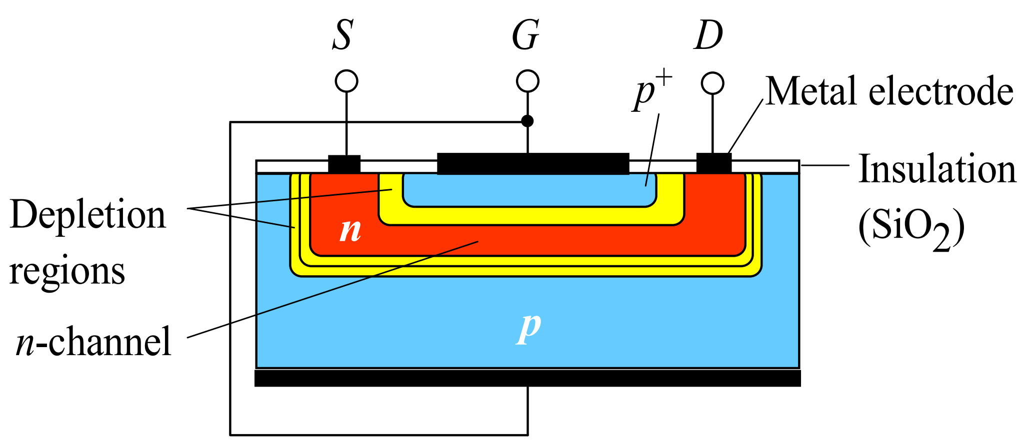


(a)

Difficult in diffusing impurities into both sides of a semiconductor

Circuit symbol for n-channel FET





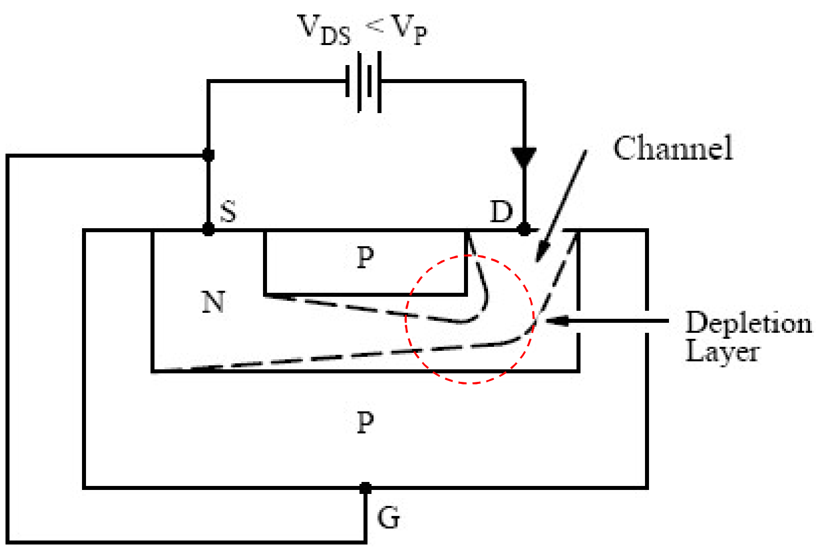
(b)

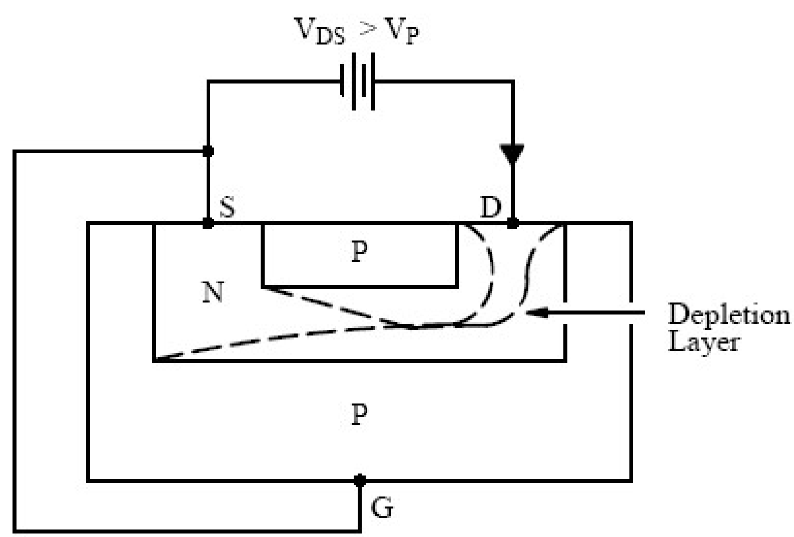
Single-ended-geometry junction FET

Diffusion is from one side only

N-type channel is epitaxially grown in p-type substrate

Depletion layer thickness is changing with V_{DS}





Bipolar Junction Transistor versus Field Effect Transistor

FET is unipolar. – there is only majority carrier. BJT is bipolar (there are both majority and minority carrier)

No offset voltage at zero drain current

High input resistance

Has thermal stability

Less noisy

Relatively immune to radiation

Simpler to fabricate and takes less space in integrated form