



NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Revisiting BJT-Characteristic

CONCEPTS COVERED

Concepts Covered:

- ☐ Basic structure and bias condition of BJT
- ☐ Current of p-n junction
- ☐ Junction currents of BJT
- ☐ Terminal currents of BJT



Flow of Discussion (Bottom-up) - Components

- **System / Sub-systems**(*for specific application*)
 - **Modules** (*performing specific tasks*)
 - **Building blocks** (*having specific characteristics*)
 - **Components** (*devices/circuit elements*)
- **Week 1:**
 - Introduction and objective of this course;
 - Revisit to pre-requisite topics (Electrical Theory);
 - Starting with simple diode circuit and its analysis.
 - Revisiting BJT and MOSFET- operating principles, characteristic equations and equivalent circuits



Basic structure, Characteristic equations of BJT

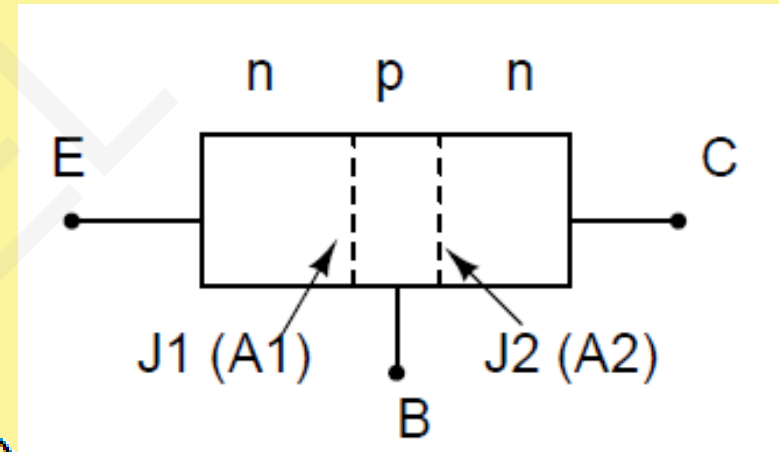
- **Bipolar Junction Transistor – for normal operation,**

- Base-Emitter junction (J1) is in F.B
- Base-Collector junction (J2) is in R.B.

- **Current through J1 when J2 is far away:**

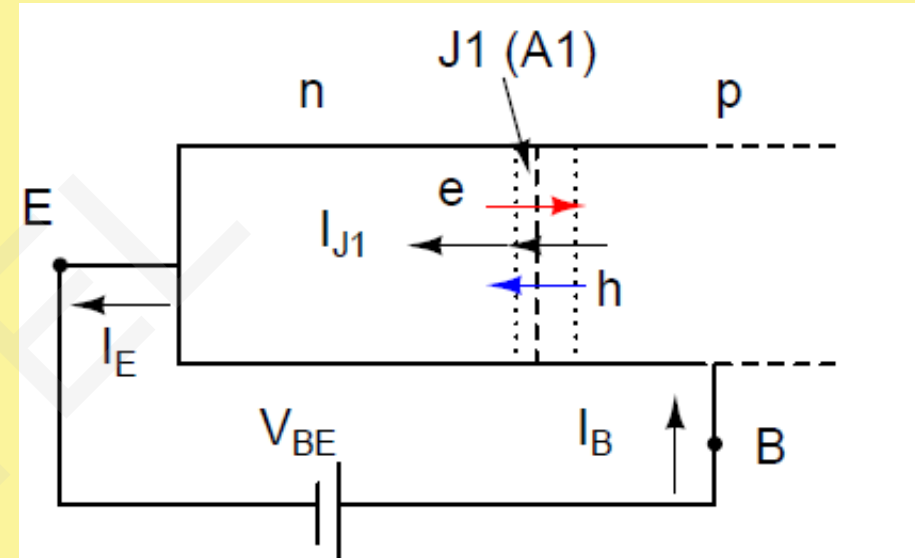
$$I_B = I_E = (I_{no} + I_{po}) \cdot \left(e^{\frac{V_{BE}}{V_T}} - 1 \right)$$

- **Current through J1 when J2 is in “Near vicinity” = ??**



Current through and isolated n-p junction in FB

- **Current through J1 when J2 is far away:**



- **Minority carrier concentration around J1 in FB condition**

$$n_p(x) = (n_p(0) - n_{po}) \cdot e^{-\frac{x}{L_n}} + n_{po}$$
$$n_p(0) = (n_{po}) \cdot e^{\frac{V_{BE}}{V_T}} \quad n_{po} = \frac{n_i^2}{N_A}$$

Current through an isolated n-p junction in FB

- **Minority carrier concentration around J1 in FB condition**

$$n_p(x) = (n_p(0) - n_{po}) \cdot e^{-\frac{x}{L_n}} + n_{po} \quad n_p(0) = (n_{po}) \cdot e^{\frac{V_{BE}}{V_T}} \quad n_{po} = \frac{n_i^2}{N_A}$$

- **Electron diffusion current:**

$$I_{n1} = -qA_1 D_n \cdot \frac{d(n_p(x))}{dx}$$

$$I_{n1} = qA_1 \frac{D_n}{L_n} \cdot (n_p(0) - n_{po}) \cdot e^{-\frac{x}{L_n}}$$

- **Electron diffusion current at x :**

$$I_{n1} = qA_1 \frac{D_n}{L_n} \cdot n_{po} \left(e^{\frac{V_{BE}}{V_T}} - 1 \right) \cdot e^{-\frac{x}{L_n}}$$



Current through an isolated n-p junction in FB

- **Hole's concentration in Emitter region near J1 in FB condition**

$$p_n(y) = (p_n(0) - p_{no}) \cdot e^{-\frac{y}{L_p}} + p_{no} \quad p_n(0) = (p_{no}) \cdot e^{\frac{V_{BE}}{V_T}} \quad p_{no} = \frac{n_i^2}{N_D}$$

- **Hole's diffusion current:**

$$I_{p1} = qA_1 D_p \cdot \frac{d(p_n(y))}{dy}$$

$$I_{p1} = qA_1 \frac{D_p}{L_p} \cdot (p_n(0) - p_{no}) \cdot e^{-\frac{y}{L_p}}$$

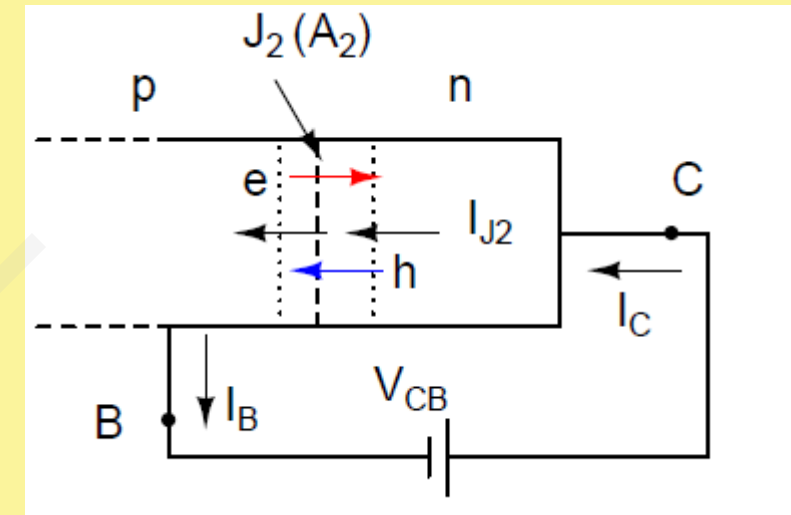
- **Total current across the junction:**

$$I_E = I_B = (I_{no} + I_{po}) \cdot (e^{\frac{V_{BE}}{V_T}} - 1)$$



Current through an isolated n-p junction in RB

- **Current through J2 when J1 is far away:**



- **Minority carrier concentration around J2 in RB condition**

$$n_p(x) = (n_p(0) - n_{po}) \cdot e^{-\frac{x}{L_n}} + n_{po} \quad n_p(0) = (n_{po}) \cdot e^{\frac{-V_{CB}}{V_T}} \ll n_{po}$$

$$p_n(y) = (p_n(0) - p_{no}) \cdot e^{-\frac{y}{L_p}} + p_{no} \quad p_n(0) = (p_{no}) \cdot e^{\frac{-V_{CB}}{V_T}} \ll p_{no}$$

Current through an isolated n-p junction in RB

- **Electron diffusion current:**

$$I_{n2} = qA_2 \frac{D_n}{L_n} \cdot (n_p(0) - n_{po}) \cdot e^{-\frac{x}{L_n}} \approx -qA_2 \frac{D_n}{L_n} \cdot n_{po} \cdot e^{-\frac{x}{L_n}}$$

- **Hole's diffusion current:**

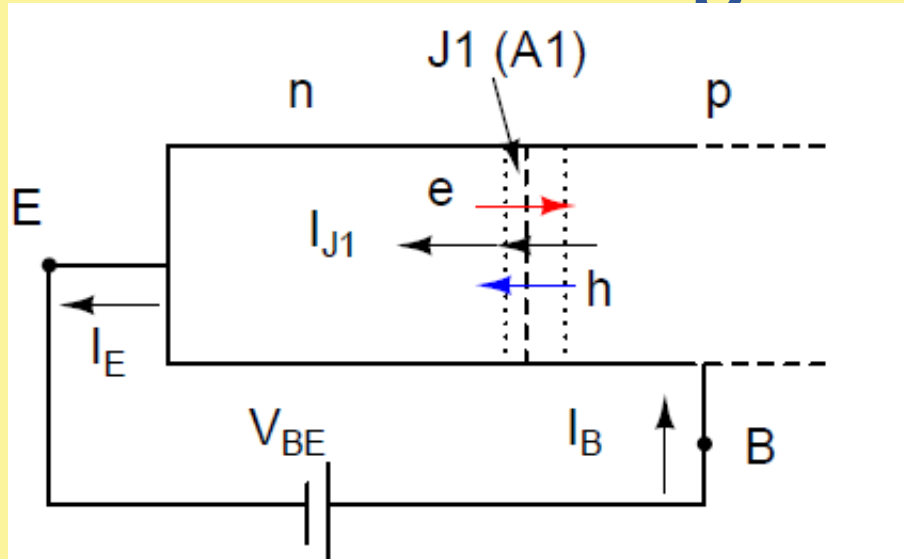
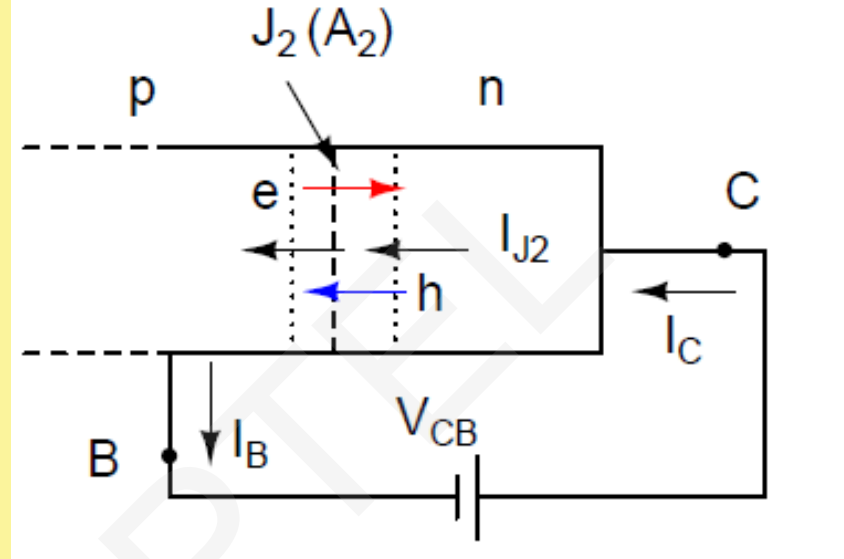
$$I_{p2} = qA_2 \frac{D_p}{L_p} \cdot (p_n(0) - p_{no}) \cdot e^{-\frac{y}{L_p}} \approx -qA_2 \frac{D_p}{L_p} \cdot p_{no} \cdot e^{-\frac{y}{L_p}}$$

- **Total current through the junction (from n region to p region):**

$$I_C = I_B = - (I_{n2} + I_{p2})$$



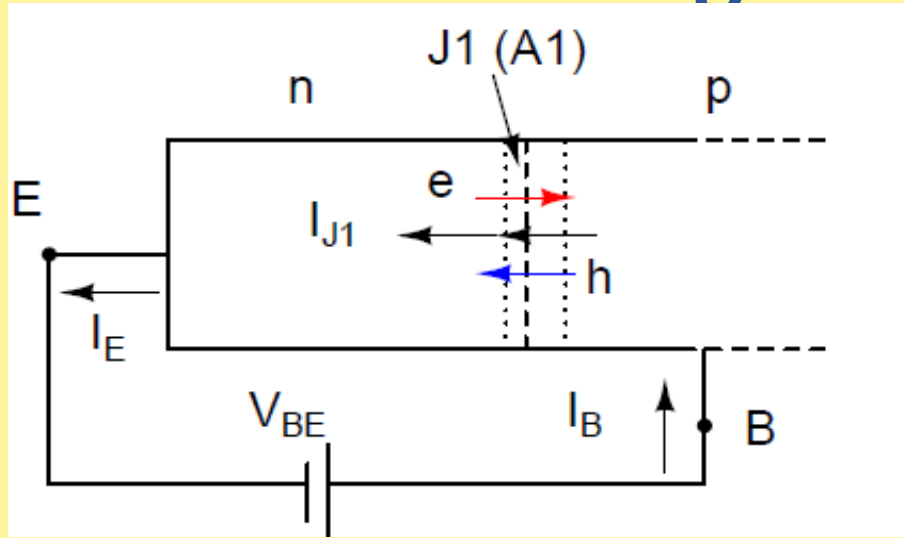
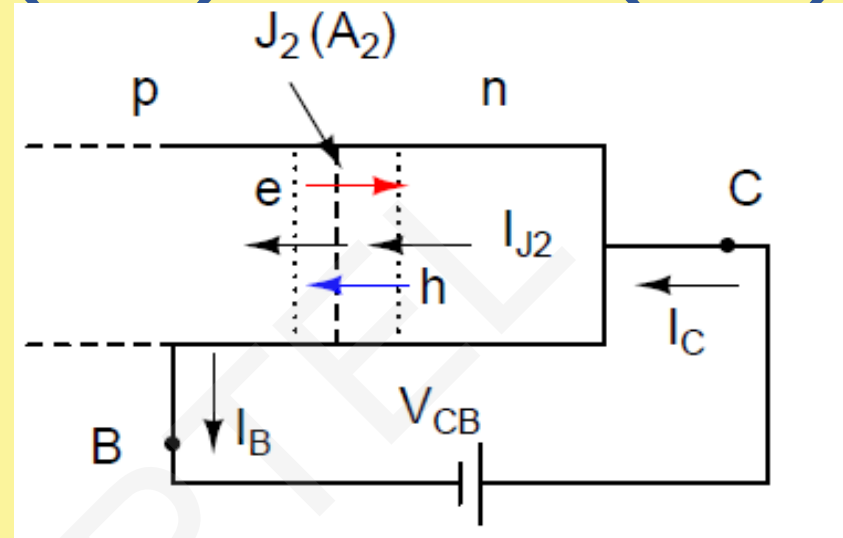
Current through J1 (FB) and J2 (RB) in proximity



- Minority carrier concentration



Current through J1 (FB) and J2 (RB) in proximity



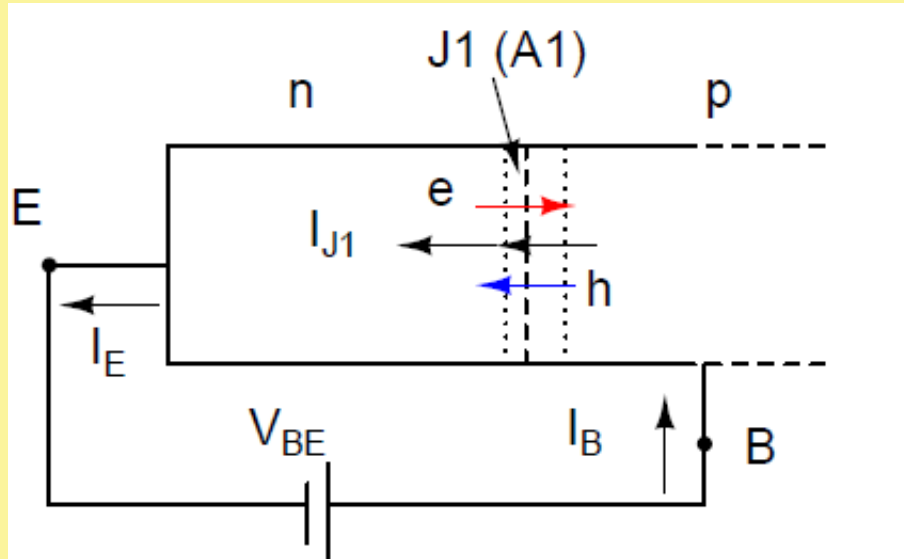
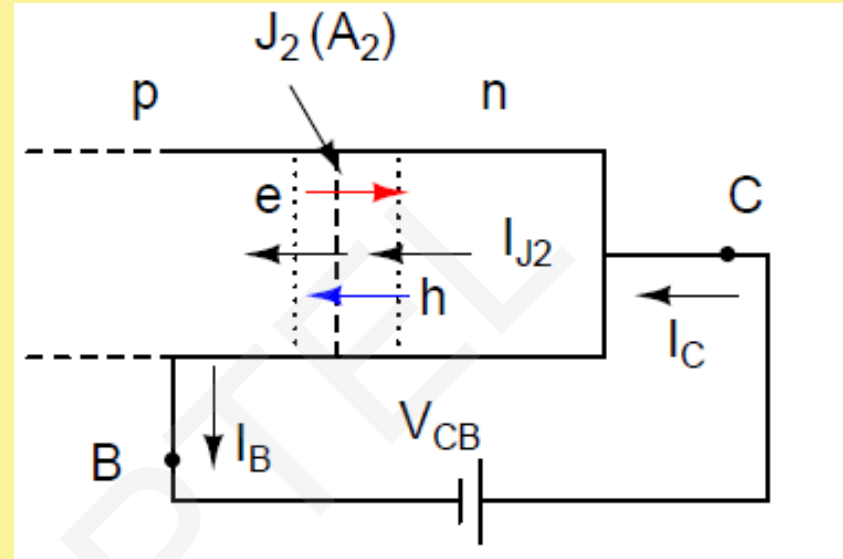
• Different current components

$$I_{n1} = qA_1 \frac{D_n}{W_B} \cdot n_p(0) + qA_1 \frac{W_B}{2 \cdot \tau_n} \cdot n_p(0) = qA_1 \frac{D_n}{W_B} \cdot n_{po} \left(e^{\frac{V_{BE}}{V_T}} \right) + qA_1 \frac{W_B}{2 \cdot \tau_n} \cdot n_{po} \left(e^{\frac{V_{BE}}{V_T}} \right)$$

- I_{p1}
- I_{n2}
- I_{p2}



Terminal currents of BJT



- **Different Terminal currents**

- $I_B =$
- $I_C =$
- $I_E =$

Conclusion

Conclusion:

- ❑ Basic structure and bias condition of BJT
- ❑ Current of p-n junction in FB and in RB
- ❑ Junction currents of BJT normal operation
- ❑ Terminal currents of BJT





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*Thank
you*





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Topic:

Revisiting BJT-Characteristic (contd..)

CONCEPTS COVERED

Concepts Covered:

- ☐ Currents of isolated p-n junction
- ☐ Junction currents of BJT in active region
- ☐ Terminal currents of BJT in active region
- ☐ Consolidated I-V Char. Equations
- ☐ Graphical I-V Char. of BJT (n-p-n and p-n-p)
- ☐ Equivalent model of BJT and usage

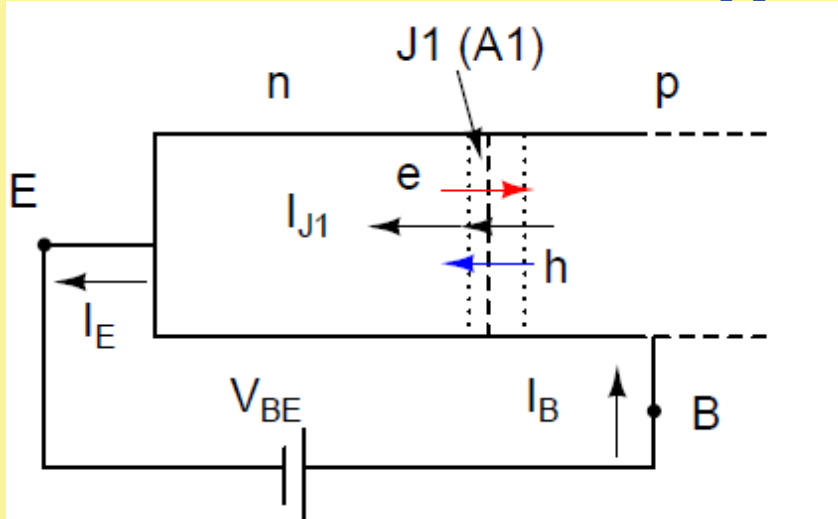
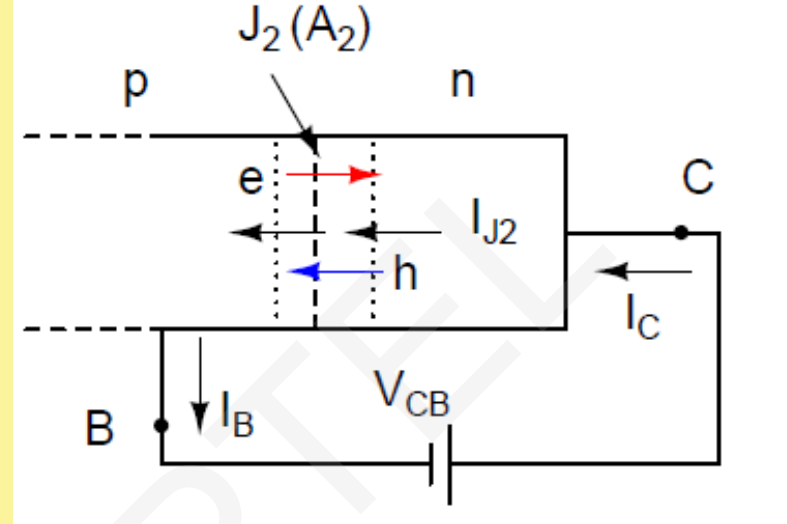


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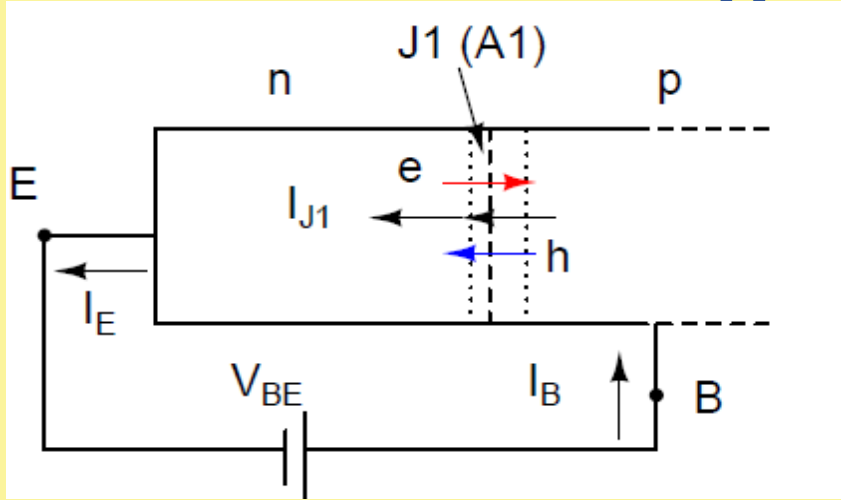
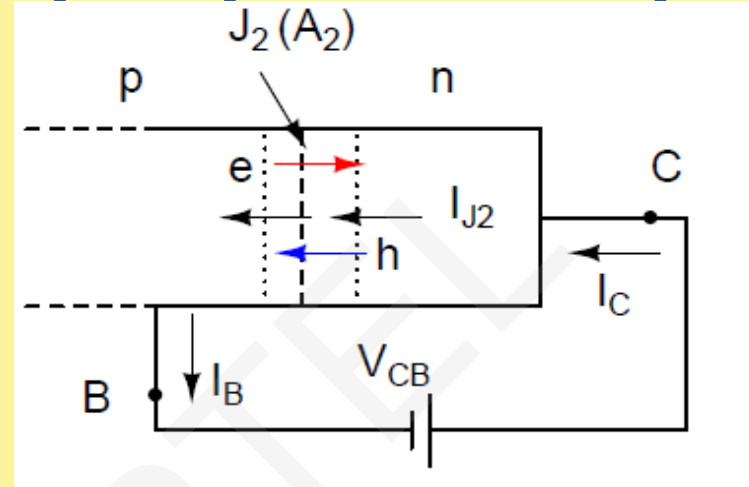


Current through J1 (FB) and J2 (RB) in isolation



- Minority carrier concentration

Current through J1 (FB) and J2 (RB) in isolation



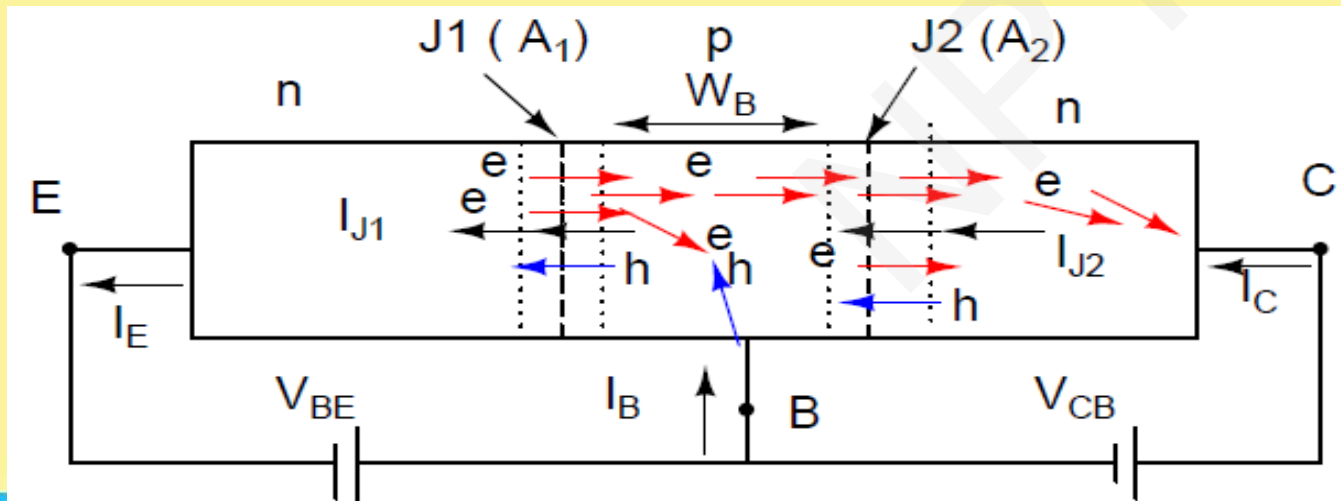
• Different current components

$$\bullet \mathbf{I_{n1}} = qA_1 \frac{D_n}{L_n} \cdot n_{po} \left(e^{\frac{V_{BE}}{V_T}} - 1 \right) \quad \mathbf{I_{p1}} = qA_1 \frac{D_p}{L_p} \cdot p_{no} \left(e^{\frac{V_{BE}}{V_T}} - 1 \right)$$

$$\bullet \mathbf{I_{n2}} \approx -qA_2 \frac{D_n}{L_n} \cdot n_{po} \quad \mathbf{I_{p2}} \approx -qA_2 \frac{D_p}{L_p} \cdot p_{no}$$

Junctions J1 (FB) and J2 (RB) are in proximity

- Change of minority carrier concentrations



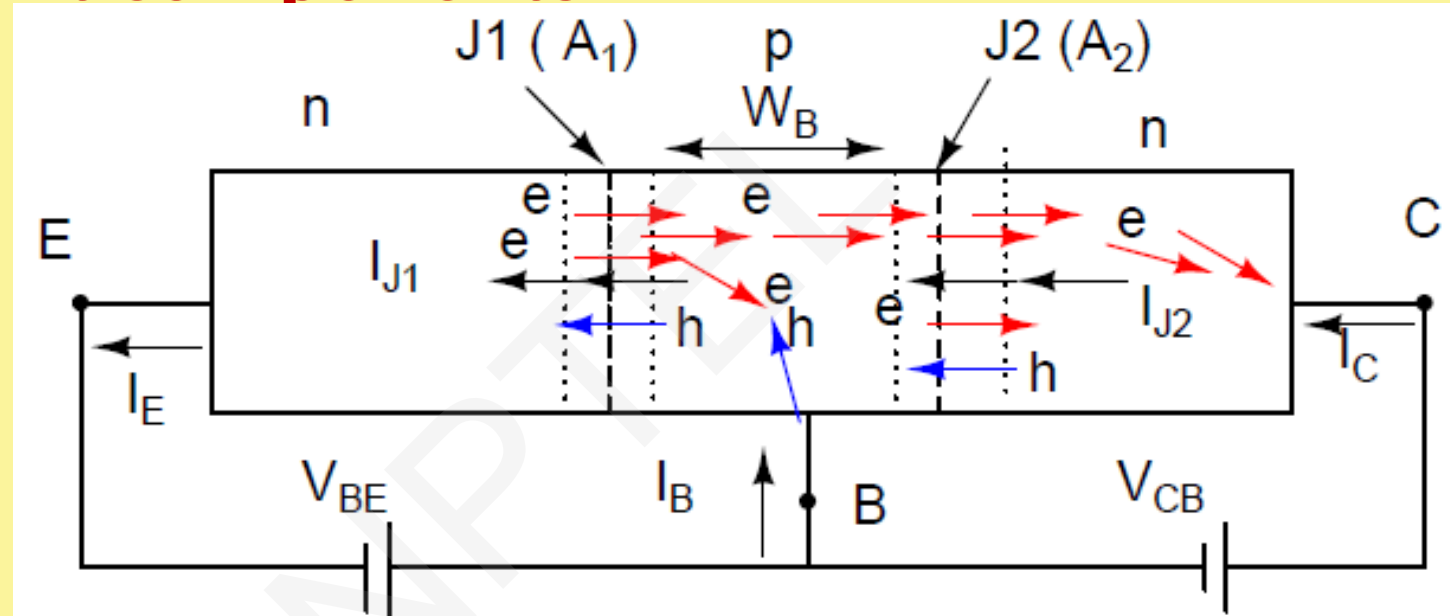
Current through J1 (FB) and J2 (RB) in proximity

• Unchanged current components

- I_{p1}

- I_{n2}

- I_{p2}



• Changed current components

$$I_{n1} = qA_1 \frac{D_n}{W_B} \cdot n_p(0) + qA_1 \frac{W_B}{2 \cdot \tau_n} \cdot n_p(0)$$

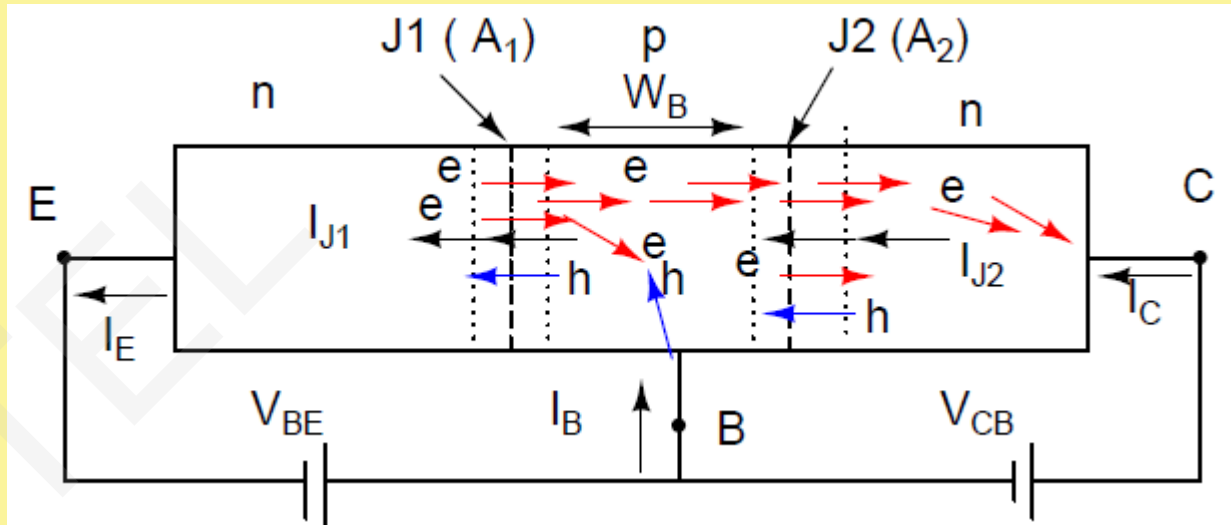
Current through J1 (FB) and J2 (RB) in proximity

• Unchanged current components

- $I_{p1} = qA_1 \frac{D_p}{L_p} \cdot p_{no} \left(e^{\frac{V_{BE}}{V_T}} - 1 \right)$

- $I_{n2} \approx -qA_2 \frac{D_n}{L_n} \cdot n_{po}$

- $I_{p2} \approx -qA_2 \frac{D_p}{L_p} \cdot p_{no}$



• Changed current components: *Inj. & Rec. currents*

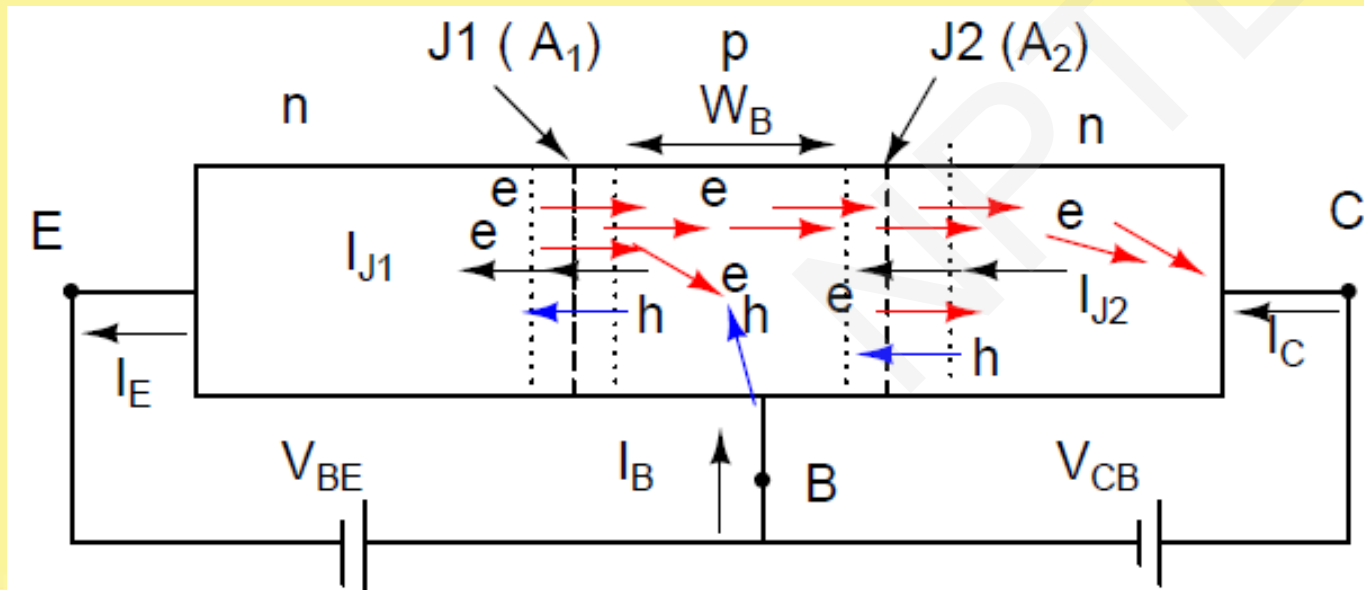
$$I_{n1} = qA_1 \frac{D_n}{W_B} \cdot n_p(0) + qA_1 \frac{W_B}{2 \cdot \tau_n} \cdot n_p(0)$$

$$= qA_1 \frac{D_n}{W_B} \cdot n_{po} \left(e^{\frac{V_{BE}}{V_T}} \right) + qA_1 \frac{W_B}{2 \cdot \tau_n} \cdot n_{po} \left(e^{\frac{V_{BE}}{V_T}} \right)$$

Terminal currents of BJT

- **Different Terminal currents**

- $I_B = I_{n2} + I_{p2} + I_{p1} + (\text{Rec. Curr})$
- $I_C = I_{n2} + I_{p2} + (\text{Inj. curr.})$
- $I_E = I_{p1} + (\text{Rec. Curr}) + (\text{Inj. Curr.})$



I-V equations and Important parameters of BJT

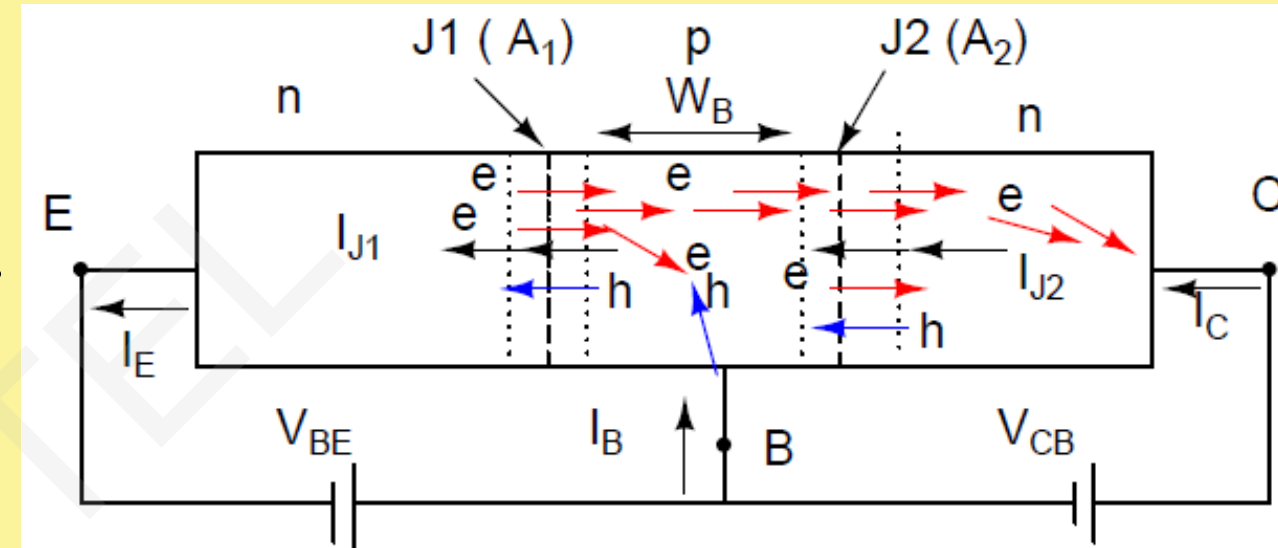
• Ratios of Terminal currents:

$$I_C / I_B = \beta_F = \frac{qA_1 \frac{D_n}{W_B} \cdot n_{po}}{\left\{ qA_1 \frac{D_p}{L_p} \cdot p_{no} + qA_1 \frac{W_B}{2 \cdot \tau_n} \cdot n_{po} \right\}}$$

$$I_C / I_E = \alpha_F = \frac{\beta_F}{(\beta_F + 1)}$$

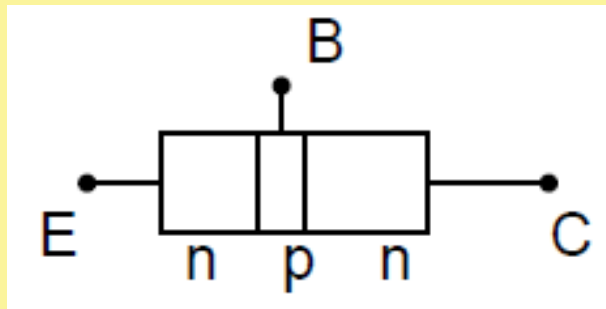
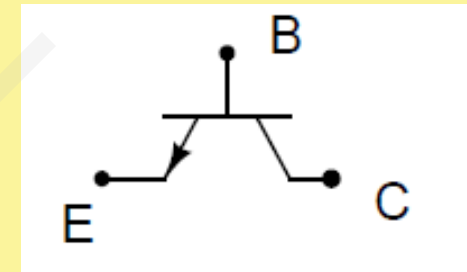
• Influence of V_{CB} on I_C

$$I_C \approx qA_1 \frac{D_n}{W_B} \cdot n_{po} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)} = I_s^{(C)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)} \times \left(1 + \frac{V_{CB}}{V_A}\right)$$



Biasing and usage I-V Characteristic of BJT

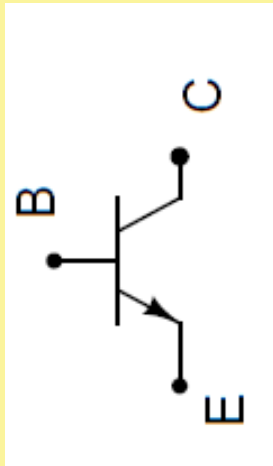
- **Biasing arrangement**



$$I_B \approx I_s^{(B)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)}$$
$$I_C \approx I_s^{(C)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)} \times \left(1 + \frac{V_{CE}}{V_A}\right)$$
$$I_E \approx I_s^{(E)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)}$$

Biasing and usage I-V Characteristic of BJT(Contd...)

- Graphical representation of I-V char.

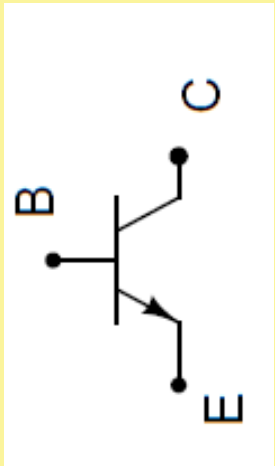


$$I_B \approx I_s^{(B)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)}$$

$$I_C \approx I_s^{(C)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)} \times \left(1 + \frac{V_{CE}}{V_A}\right)$$

Equivalent circuit of BJT and its Usage

- Analysis through Equivalent circuit

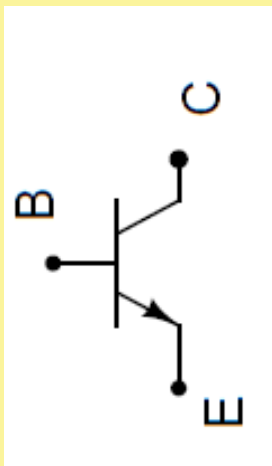


$$I_B \approx I_s^{(B)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)}$$

$$I_C \approx I_s^{(C)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)} \times \left(1 + \frac{V_{CE}}{V_A}\right)$$

Usage of Equivalent circuit of BJT (Contd...)

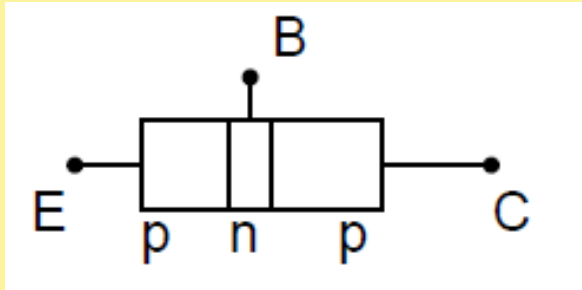
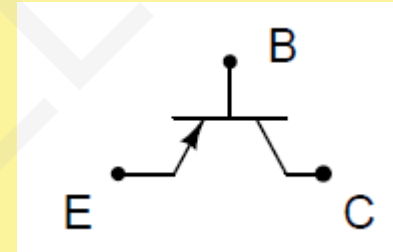
- **Exercise: Analysis through Equivalent circuit**



$$I_B \approx I_s^{(B)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)} \quad I_C \approx I_s^{(C)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)} \times \left(1 + \frac{V_{CE}}{V_A}\right)$$

Biasing and I-V Characteristic Equations of p-n-p BJT

- **Biasing arrangement**

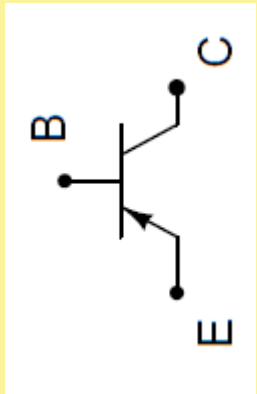
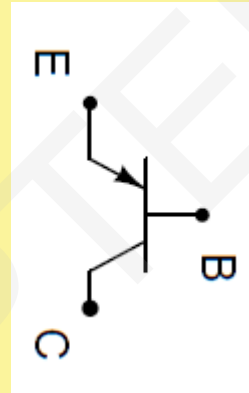


- **Characteristic equations – *modifications of notations***

$$I_B \approx I_s^{(B)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)} \quad I_C \approx I_s^{(C)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)} \times \left(1 + \frac{V_{CE}}{V_A}\right) \quad I_E \approx I_s^{(E)} \cdot e^{\left(\frac{V_{BE}}{V_T}\right)}$$

V- and I- Polarity Conventions of p-n-p BJT

- **Biasing rearrangement and polarity convention.**

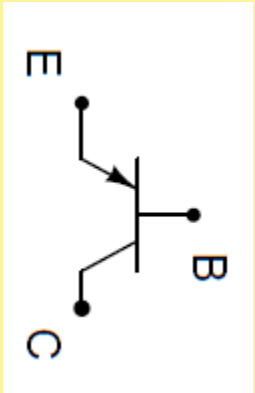


$$I_B \approx I_s^{(B)} \cdot e^{\left(\frac{V_{EB}}{V_T}\right)}$$

$$I_C \approx I_s^{(C)} \cdot e^{\left(\frac{V_{EB}}{V_T}\right)} \times \left(1 + \frac{V_{EC}}{V_A}\right)$$

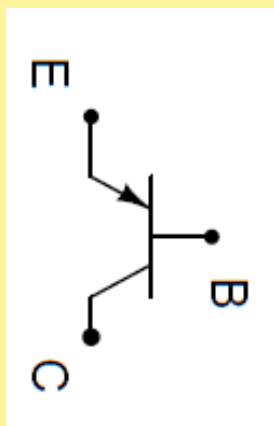
V- and I- Polarity Conventions of p-n-p BJT (*Contd...*)

- **Graphical representation of I-V char.**



Equivalent circuit of p-n-p BJT and its Usage

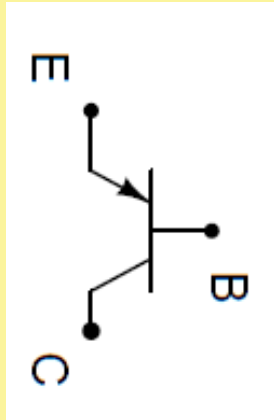
- Analysis using Equivalent circuit



$$I_B \approx I_s^{(B)} \cdot e^{\left(\frac{V_{EB}}{V_T}\right)} \quad I_C \approx I_s^{(C)} \cdot e^{\left(\frac{V_{EB}}{V_T}\right)} \times \left(1 + \frac{V_{EC}}{V_A}\right)$$

Usage of Equivalent circuit of p-n-p BJT

- **Exercise: Analysis using Equivalent circuit**



$$I_B \approx I_s^{(B)} \cdot e^{\left(\frac{V_{EB}}{V_T}\right)} \quad I_C \approx I_s^{(C)} \cdot e^{\left(\frac{V_{EB}}{V_T}\right)} \times \left(1 + \frac{V_{EC}}{V_A}\right)$$

Conclusion:

- ❑ Junction currents of BJT in active region
- ❑ Terminal currents of BJT in active region
- ❑ Consolidated I-V Char. Equations of BJT
- ❑ Biasing arrangement and Graphical I-V Char.
- ❑ Equivalent model of BJT and usage

Conclusion





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Revisiting MOSFET

CONCEPTS COVERED

Concepts Covered:

- ☐ Basic structure of n-MOSFET
- ☐ Biasing and Operating principle
- ☐ Characteristic Equation of n-MOSFET
- ☐ Graphical representation of the Ch. Equation
- ☐ Basic structure of p-MOSFET
- ☐ Biasing and Operating principle
- ☐ Characteristic Equation of p-MOSFET
- ☐ Graphical representation of the Ch. Equation
- ☐ Solving Numerical problems



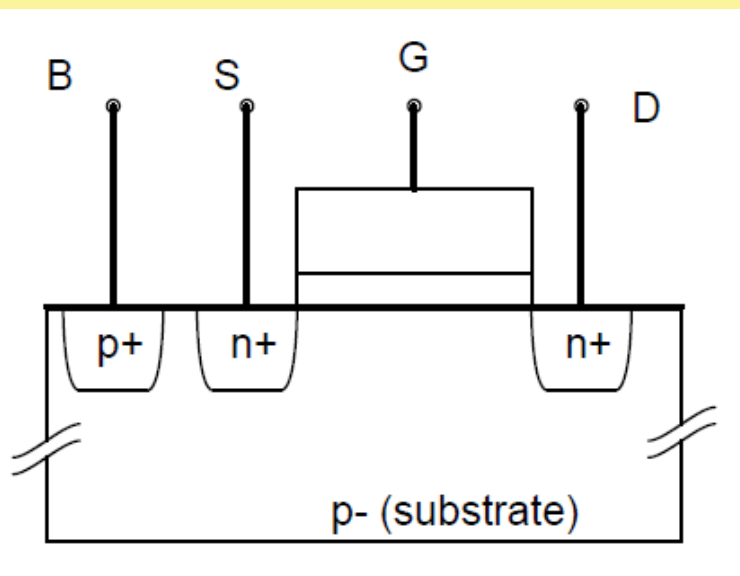
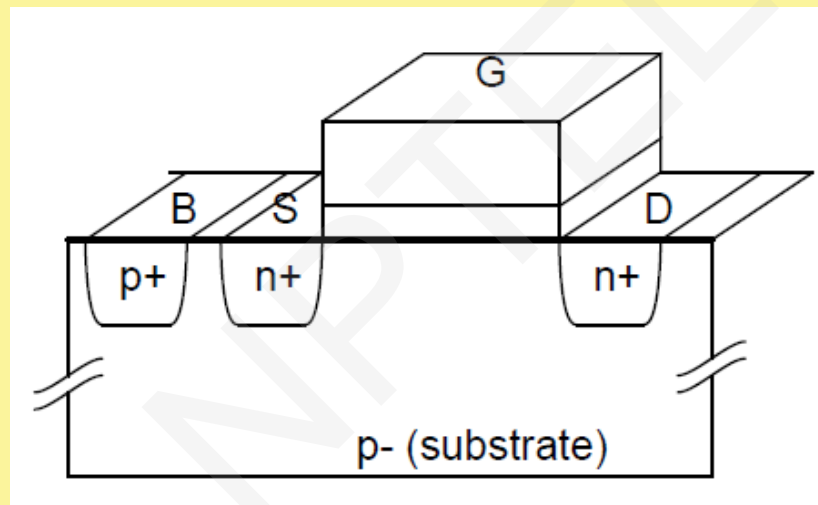
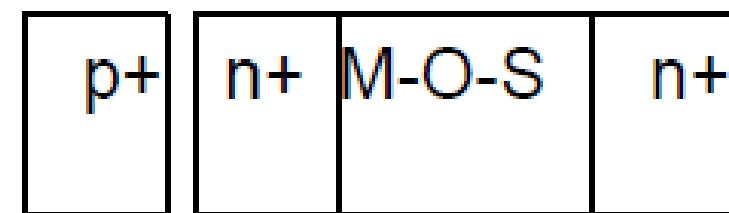
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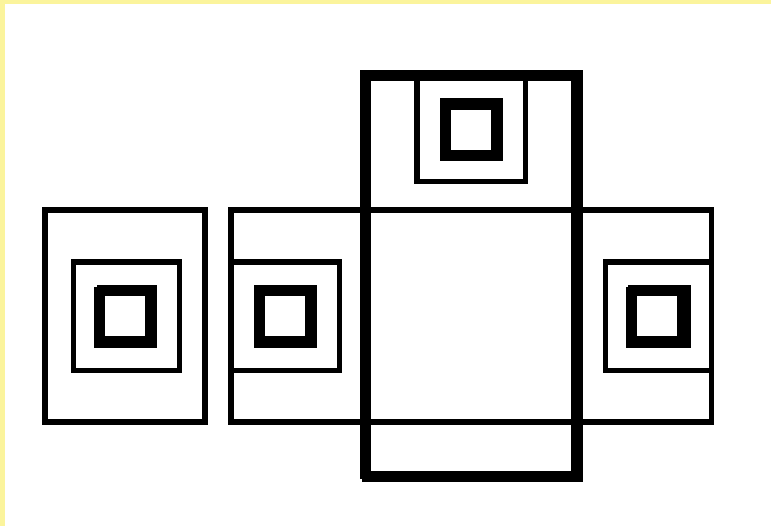
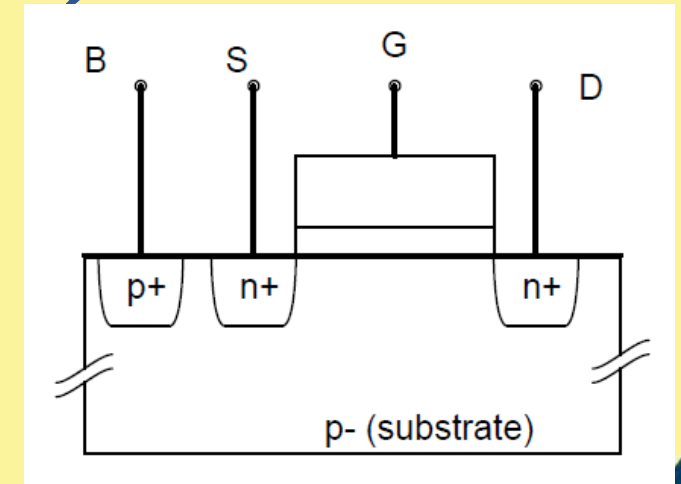
Metal-Oxide-Semiconductor Field-Effect Transistor

- **Basic Structure - *Idealistic views***



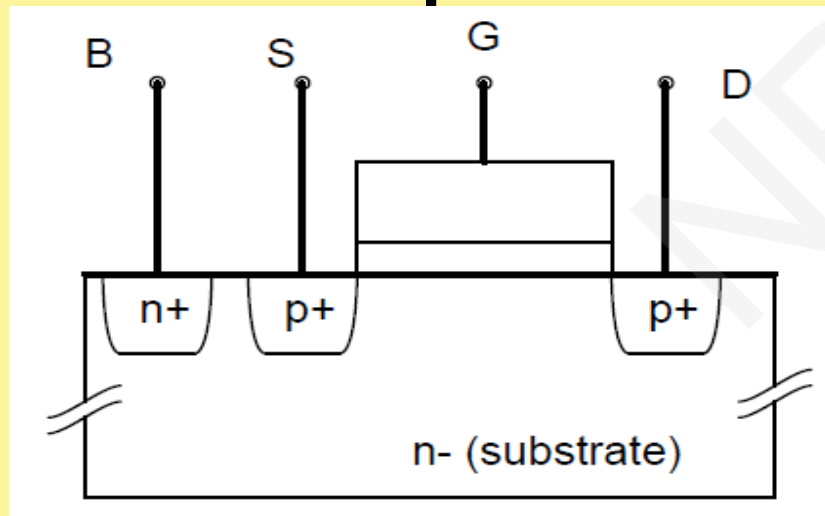
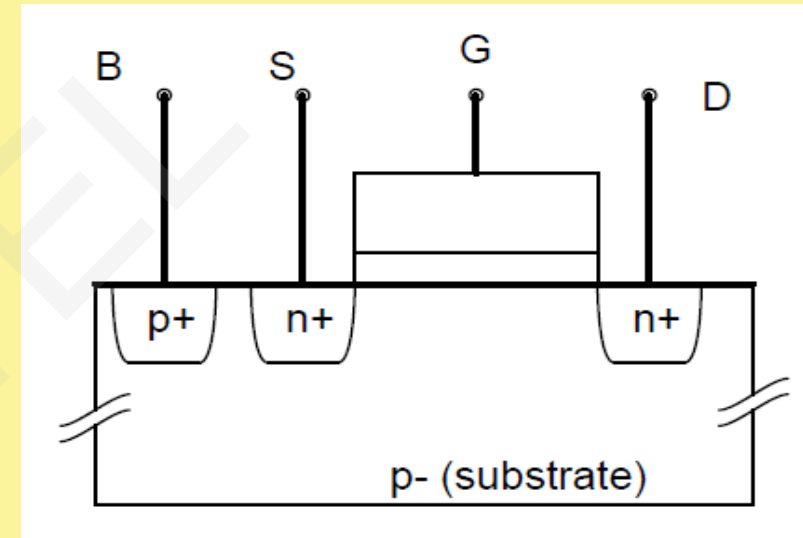
n-type MOSFET (*contd...*)

- **Basic Structure – *More realistic views***



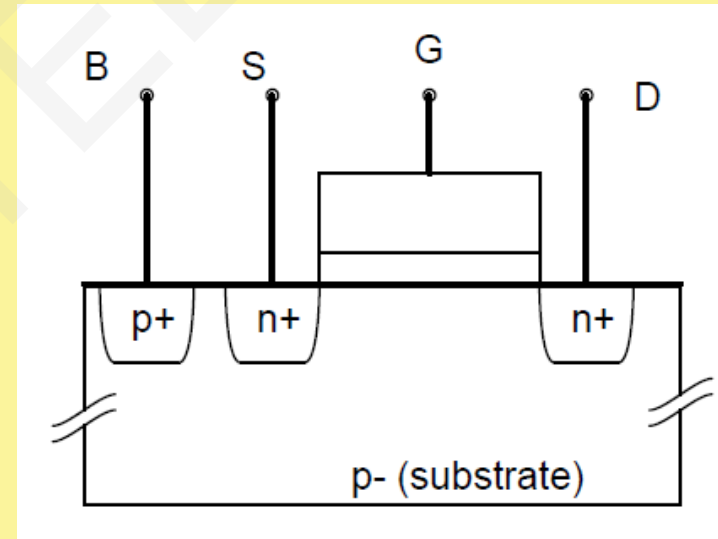
Important Notes about MOSFET

- Most of further discussions are on the idealistic front view
- Substrate is weakly doped
- It is a planar device
- Accesses are from the top side only
- Similar structure of p-MOSFET



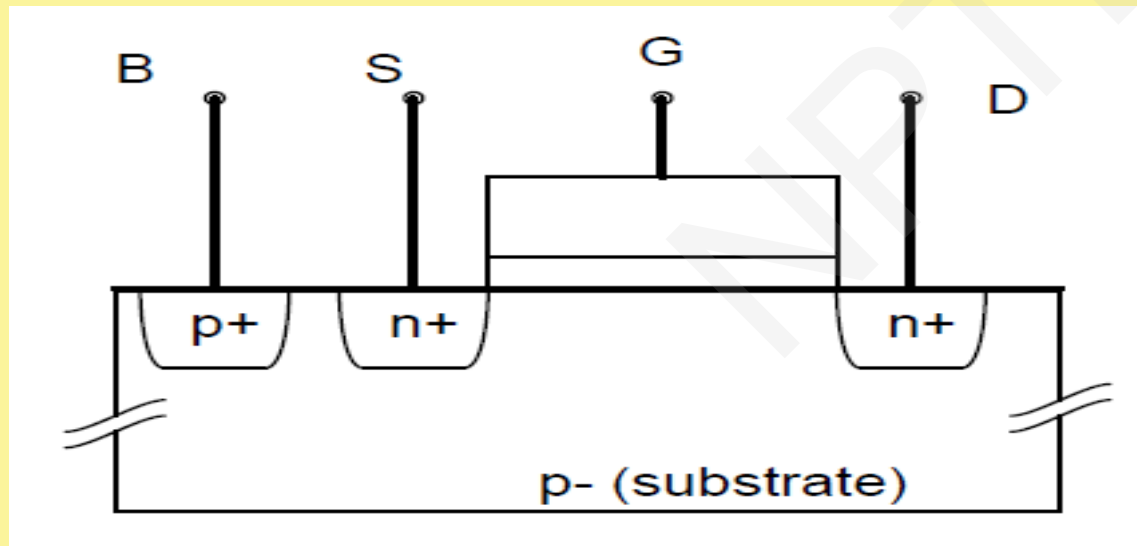
Working Principle of n-type MOSFET

- **$V_{GS} > 0$:**
 - Holes are depleted from Channel region
 - Leaving behind static negative ions as depletion region)
- **Further increase of V_{GS} :**
 - Accumulates electrons
 - Channel gets inverted
- **At $V_{GS} = V_{th}$ (!): ??**
- **Further increase of V_{GS} :**
 - enhances the conductivity of the channel

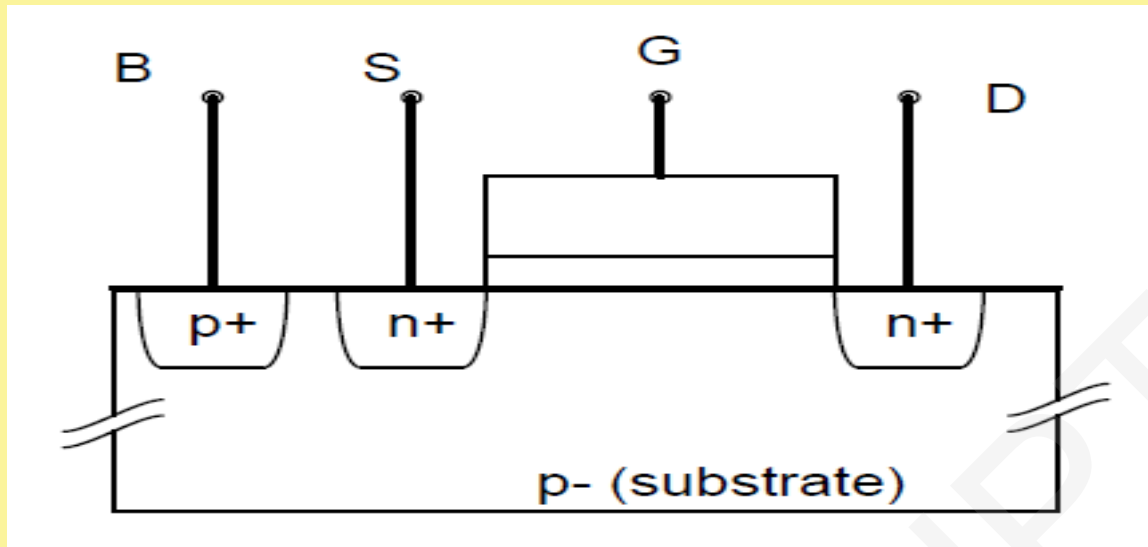


Working Principle and Biasing of n-type MOSFET

- **V_{GS} and V_{DS} are applied :**
 - Current Flows through the V_{DS} :
 - I_{DS} is strong function of *device parameters*, **W , L** , V_{GS} and V_{DS}

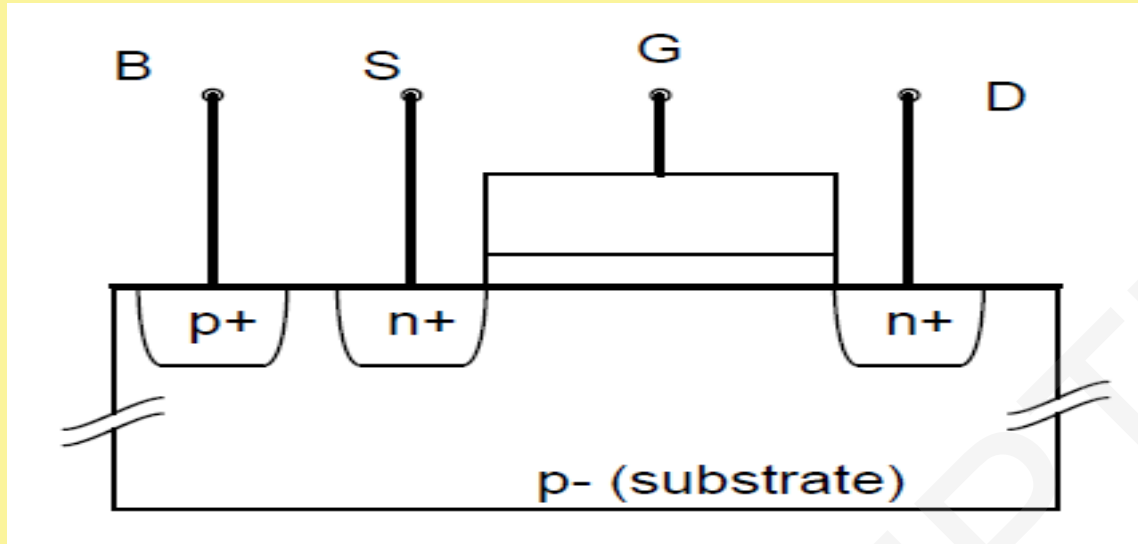


I-V Characteristic of n-type MOSFET



• $I_{DS} =$

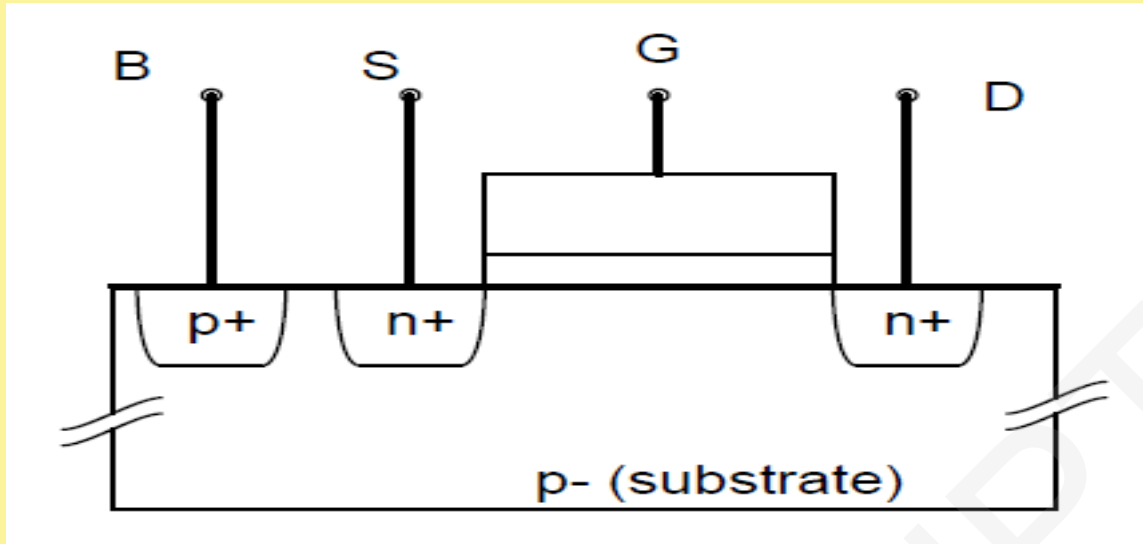
I-V Characteristic of n-type MOSFET (*Contd...*)



- For Significant V_{DS} , Conduction along “L” changes and hence,

$$I_{DS} =$$

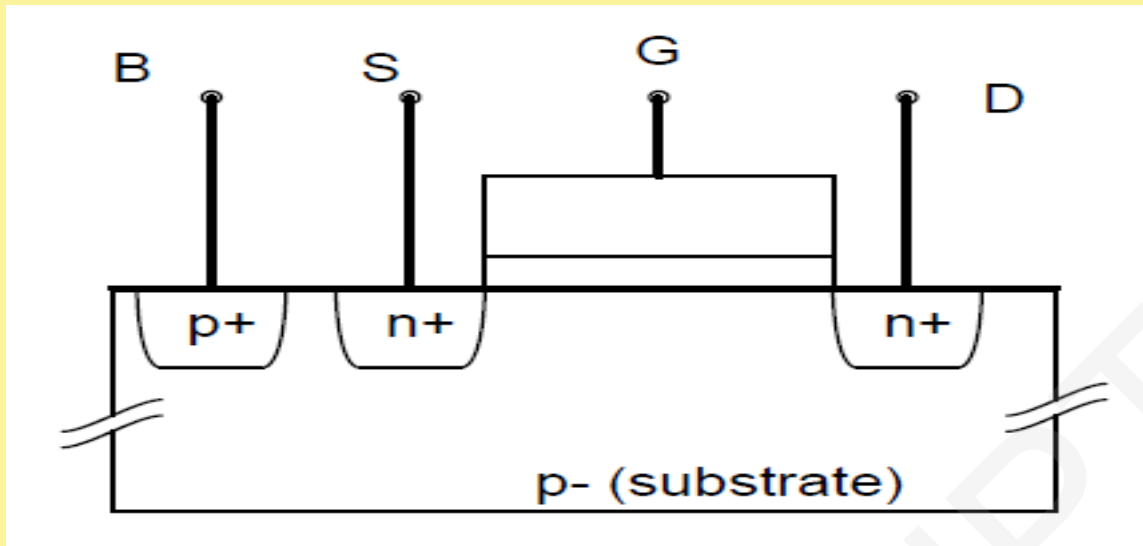
I-V Characteristic of n-type MOSFET (Contd...)



- For $V_{GD} = V_{th} \Rightarrow V_{DS} = (V_{GS} - V_{th})$:

$$I_{DS} =$$

I-V Characteristic of n-type MOSFET (*Contd...*)



- For $V_{DS} > (V_{GS} - V_{th})$:

$$I_{DS} =$$

Graphical representation of I-V Characteristic

- **For $V_{GS} < V_{th}$:**

$$I_{DS} =$$

- **For $V_{GS} > V_{th}$ and $V_{DS} < (V_{GS} - V_{th})$:**

$$I_{DS} =$$

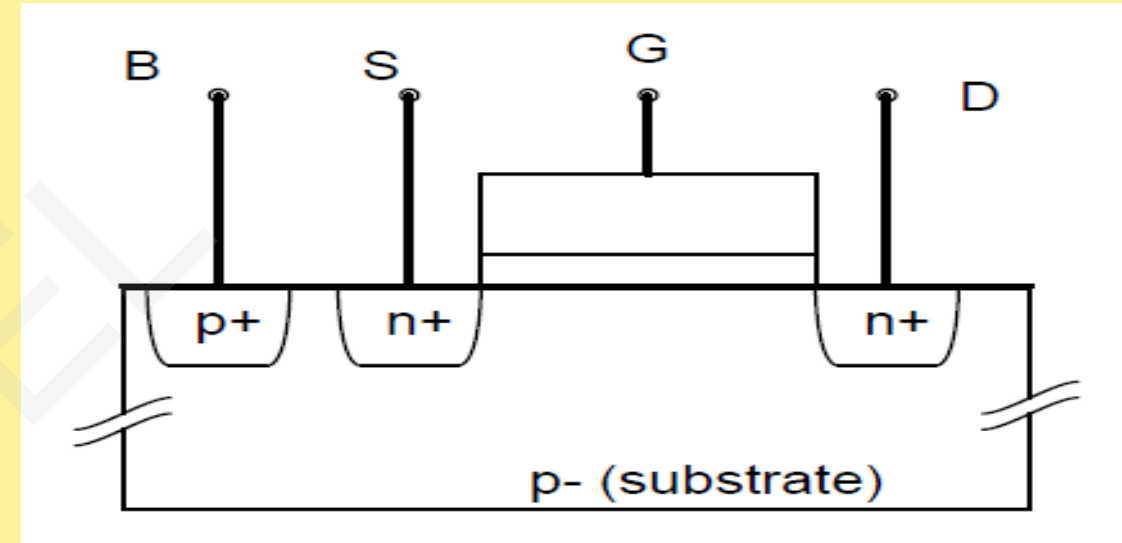
- **For $V_{GS} > V_{th}$ and $V_{DS} > (V_{GS} - V_{th})$:**

$$I_{DS} =$$



Summarization of I-V Characteristic of n-type MOSFET

- **For $V_{GS} < V_{th}$:**
 $I_{DS} =$
- **For $V_{GS} > V_{th}$ and $V_{DS} < (V_{GS} - V_{th})$:**
 $I_{DS} =$
- **For $V_{GS} > V_{th}$ and $V_{DS} > (V_{GS} - V_{th})$:**
 $I_{DS} =$



Conclusion:

- ❑ Basic structure of n-MOSFET
- ❑ Biasing and Operating principle
- ❑ Characteristic Equation of n-MOSFET
- ❑ Graphical representation of the Ch. Equation

Conclusion





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*Thank
you*





NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Revisiting MOSFET (Contd...)

CONCEPTS COVERED

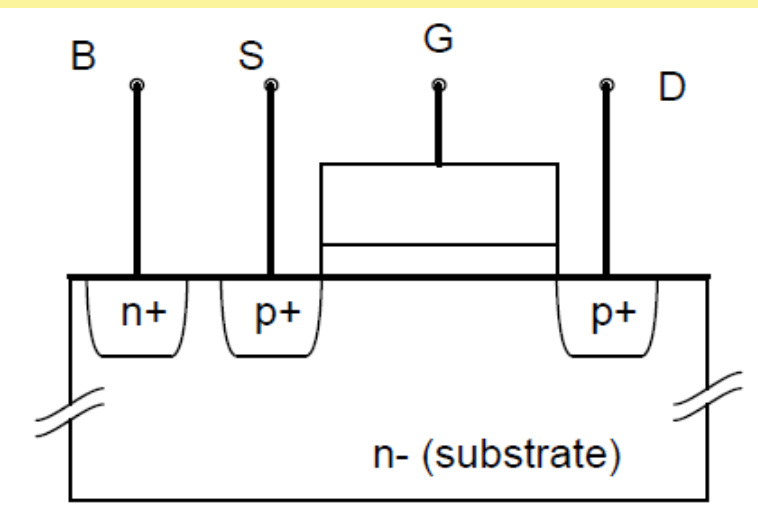
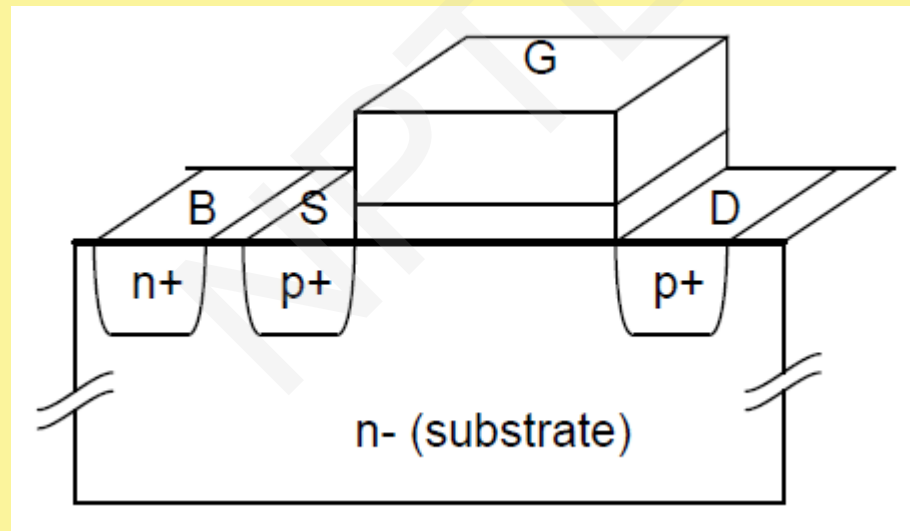
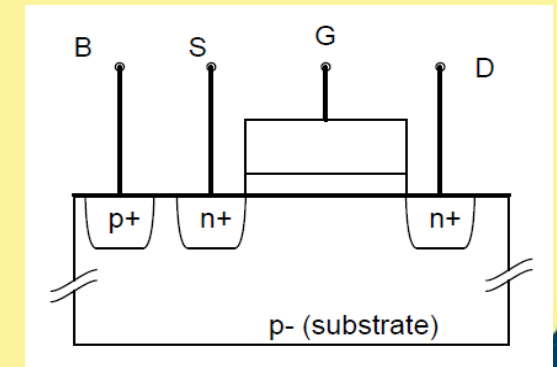
Concepts Covered:

- ☐ Basic structure of n-MOSFET
- ☐ Biasing and Operating principle
- ☐ Characteristic Equation of n-MOSFET
- ☐ Graphical representation of the Ch. Equation
- ☐ Basic structure of p-MOSFET
- ☐ Biasing and Operating principle
- ☐ Characteristic Equation of p-MOSFET
- ☐ Graphical representation of the Ch. Equation
- ☐ Solving Numerical problems



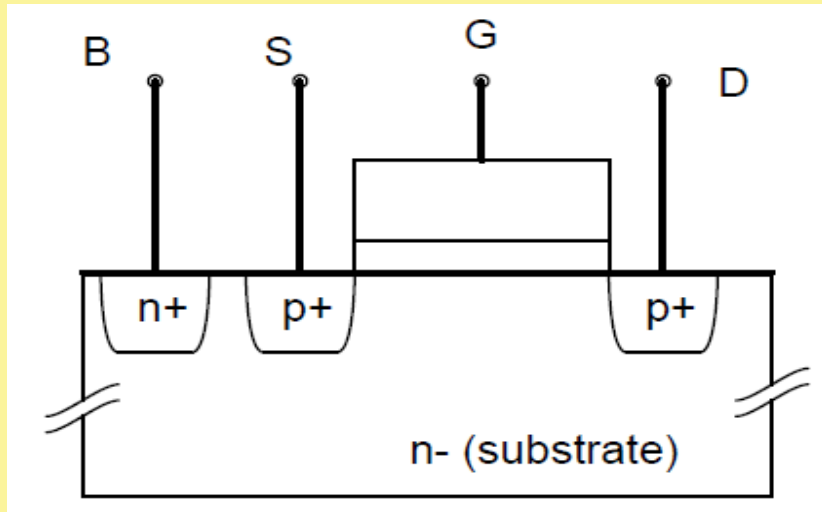
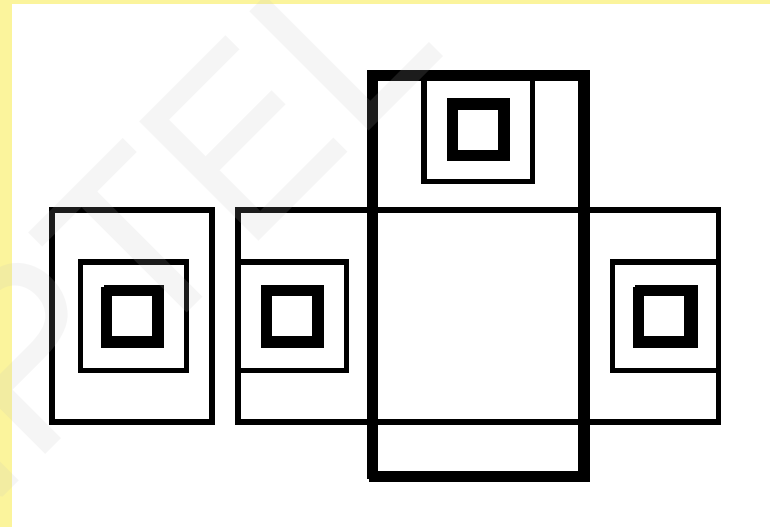
Metal-Oxide-Semiconductor Field-Effect Transistor

- **Basic Structure – Cross sectional and oblique views**



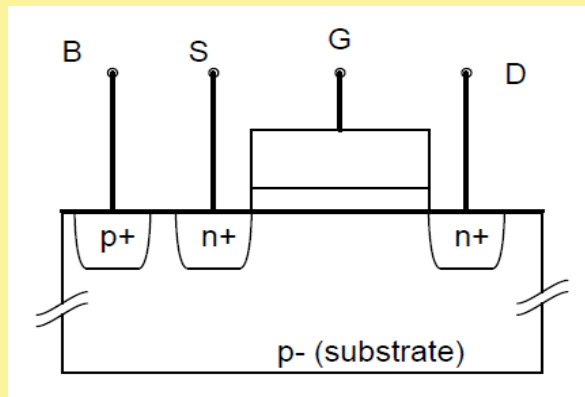
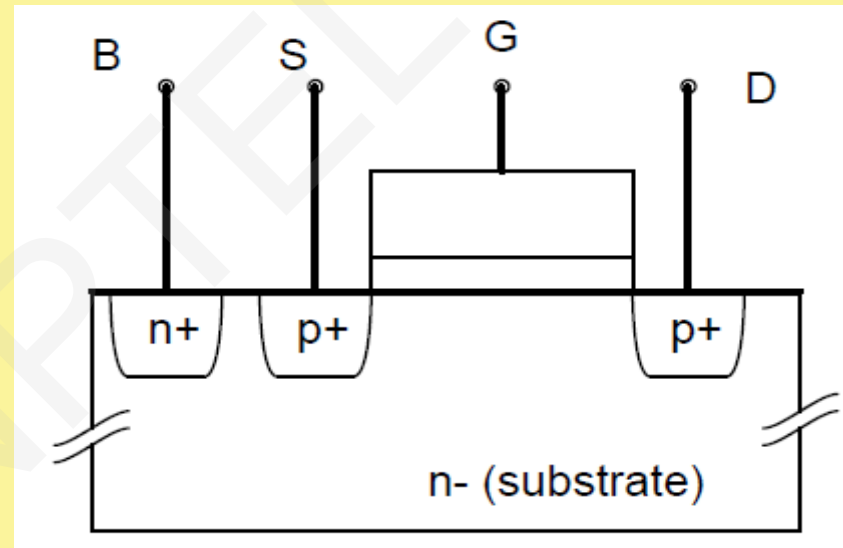
p-type MOSFET (*contd...*)

- **Basic Structure – *More realistic views***



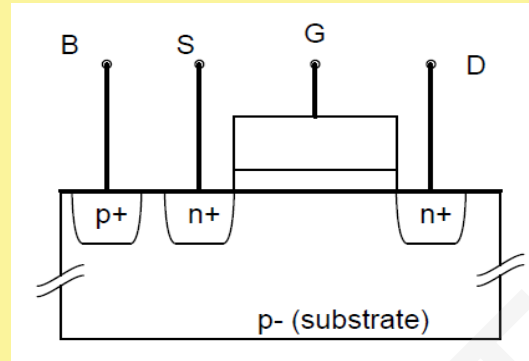
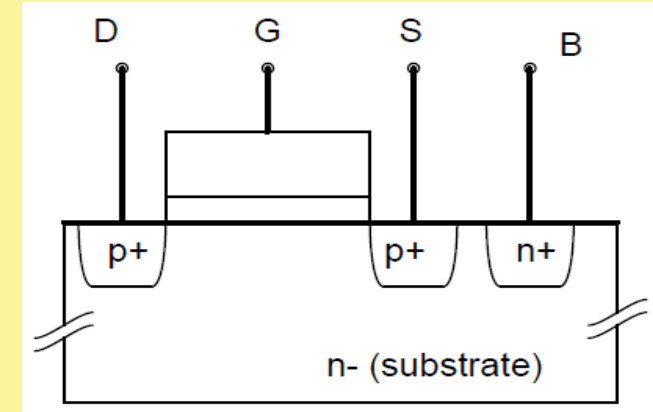
Biasing of MOSFETs

- Biasing of MOSFETs

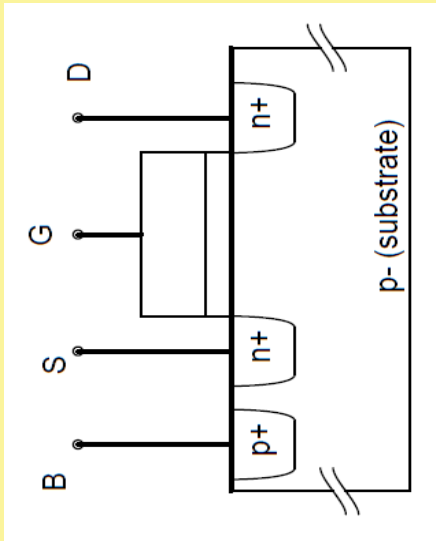
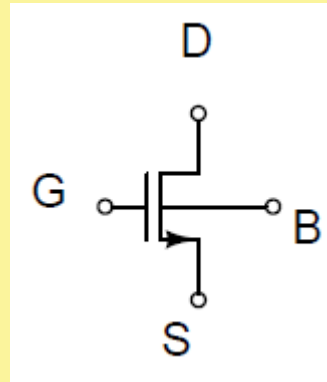
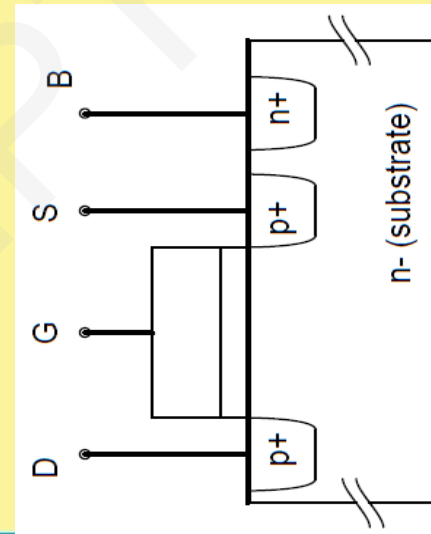
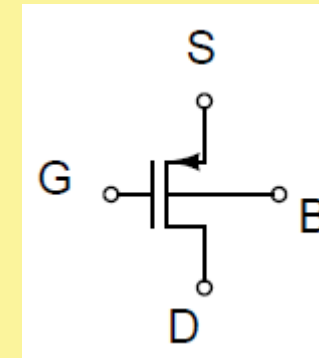


Reorienting MOSFETs for convenience of biasing

- Flipping p-MOSFET



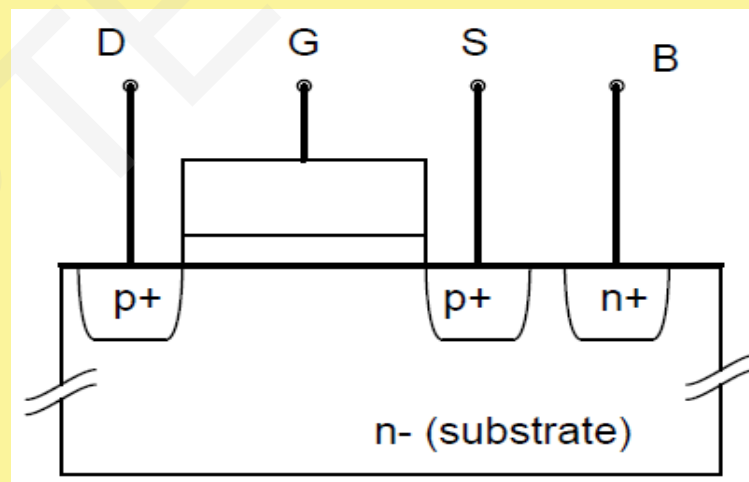
- Rotating 90 deg.



Working Principle of p-type MOSFET

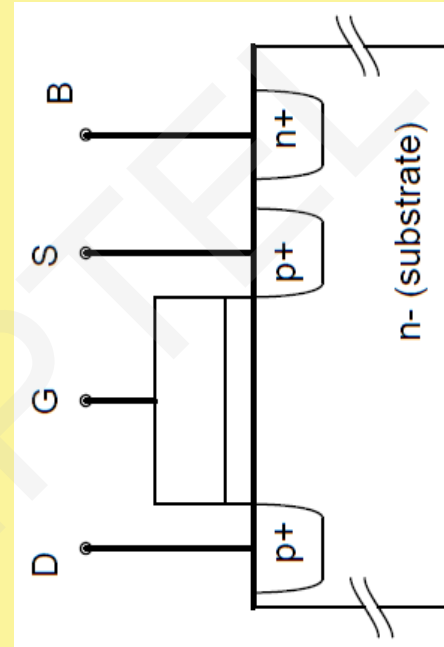
- **$V_{SG} > 0$:**
 - Electrons are depleted from the Channel region
 - Leaving behind static positive ions (as depletion region)
- **Further increase of V_{SG} :**
 - Accumulates holes
 - Channel gets inverted
- **At $V_{SG} = |V_{th}|$:**

Holes concentration at channel equal to electron concentration in the substrate
- **Further increase of V_{SG} :**
 - Enhances the conductivity of the channel



I-V Characteristic of p-type MOSFET

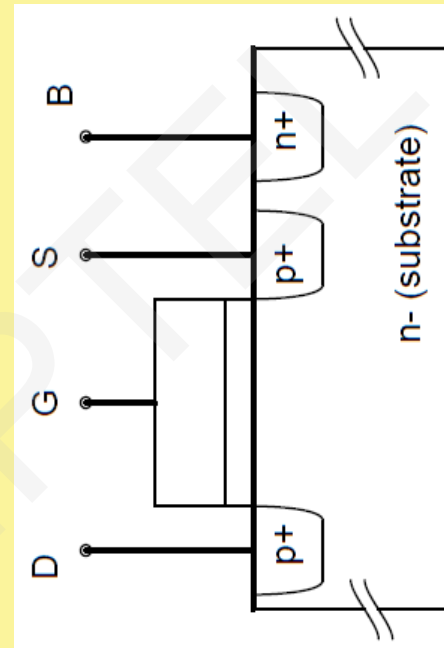
• $I_{SD} =$



I-V Characteristic of p-type MOSFET (*Contd...*)

For Significant V_{SD} , Conduction along “L” changes and hence,

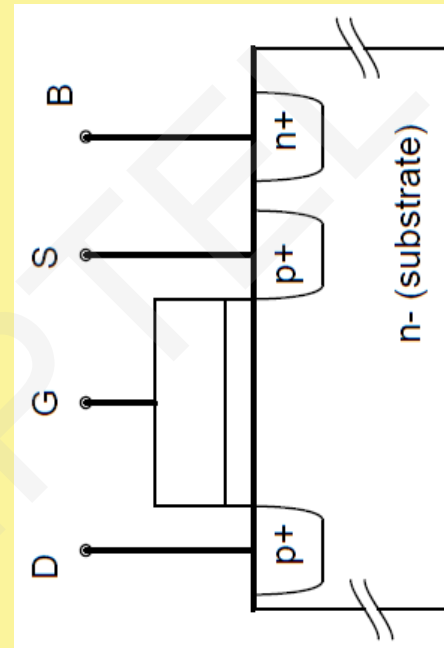
• $I_{SD} =$



I-V Characteristic of p-type MOSFET (*Contd...*)

For $V_{DG} = |V_{th}| \Rightarrow V_{SD} = (V_{SG} - |V_{th}|)$:

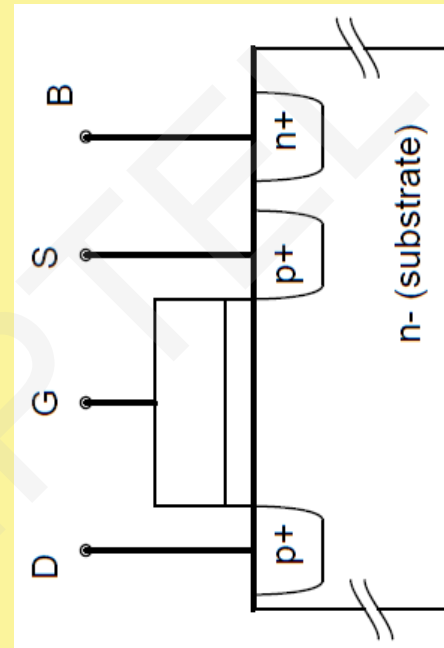
• $I_{SD} =$



I-V Characteristic of p-type MOSFET (*Contd...*)

For $V_{SD} > (V_{SG} - V_{th})$:

• $I_{SD} =$



Summarization of I-V Characteristic of p-type MOSFET

- **For $V_{SG} < |V_{th}|$:**

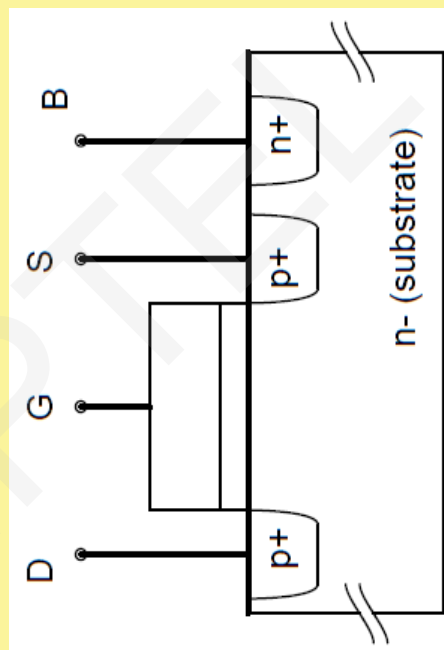
$$I_{SD} =$$

- **For $V_{SG} > |V_{th}|$ and $V_{SD} < (V_{SG} - |V_{th}|)$:**

$$I_{SD} =$$

- **For $V_{SG} > |V_{th}|$ and $V_{SD} > (V_{SG} - |V_{th}|)$:**

$$I_{SD} =$$



Graphical representation of I-V Characteristic

- **For $V_{SG} < |V_{th}|$:**

$$I_{SD} =$$

- **For $V_{SG} > |V_{th}|$ and $V_{SD} < (V_{SG} - |V_{th}|)$:**

$$I_{SD} =$$

- **For $V_{SG} > |V_{th}|$ and $V_{SD} > (V_{SG} - |V_{th}|)$:**

$$I_{SD} =$$



Alternate Graphical representation of I-V Characteristic

- **For $V_{GS} > -|V_{th}|$:**

$$I_{DS} =$$

- **For $V_{GS} < -|V_{th}|$ and $V_{DS} > (V_{GS} + |V_{th}|)$:**

$$I_{SD} =$$

- **For $V_{GS} < -|V_{th}|$ and $V_{DS} > (V_{GS} + |V_{th}|)$:**

$$I_{SD} =$$



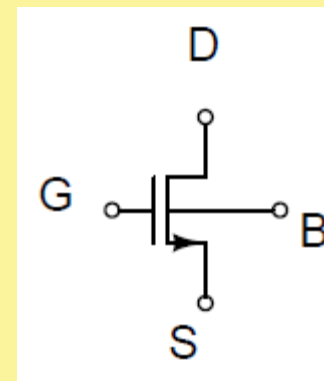
Numerical Examples on n-MOSFET circuit

• **Given:** $K = 1 \text{ mA/V}^2$

$$V_{th} = 1 \text{ V}$$

$$\lambda = 0$$

$$W/L = 2$$



(a) Find: I_{DS} for $V_{GS} = 3\text{V}$ and $V_{DS} = 0.5\text{V}$

(b) Find: I_{DS} for $V_{GS} = 3\text{V}$ and $V_{DS} = 3\text{V}$

(c) Find: I_{DS} for $V_{GS} = 3\text{V}$ and $V_{DS} = 5\text{V}$

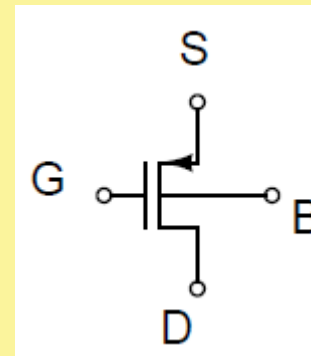
Numerical Examples on p-MOSFET circuit

• **Given:** $K = 0.5 \text{ mA/V}^2$

$$|V_{th}| = 1.5 \text{ V}$$

$$\lambda = 0$$

$$W/L = 2$$



(a) Find: I_{DS} for $V_{SG} = 2.5 \text{ V}$ and $V_{SD} = 0.5 \text{ V}$

(b) Find: I_{DS} for $V_{SG} = 2.5 \text{ V}$ and $V_{SD} = 3 \text{ V}$

(c) Find: I_{DS} for $V_{SG} = 3.5 \text{ V}$ and $V_{SD} = 5 \text{ V}$

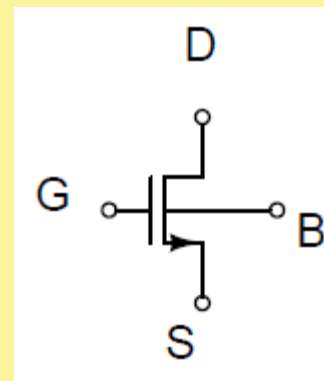
Numerical Examples on n-MOSFET circuit

• **Given:** $K = 1 \text{ mA/V}^2$

$$V_{th} = 1 \text{ V}$$

$$\lambda = 0$$

$$W/L = 2$$



(a) Find: I_{DS} for $V_{dd} = 5 \text{ V}$ and $R = 1 \text{ k}\Omega$

(b) Find: I_{DS} for $V_{dd} = 5 \text{ V}$ and $R = 200 \Omega$

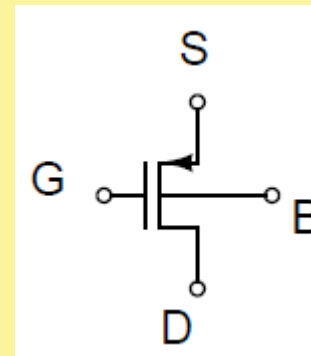
Numerical Examples on p-MOSFET circuit

• **Given:** $K = 1 \text{ mA/V}^2$

$$|V_{th}| = 1 \text{ V}$$

$$\lambda = 0$$

$$W/L = 2$$



(a) Find: I_{DS} for $V_{dd} = 5 \text{ V}$ and $R = 1 \text{ k}\Omega$

(b) Find: I_{DS} for $V_{dd} = 5 \text{ V}$ and $R = 200 \Omega$

Conclusion:

- ❑ Basic structure of p-MOSFET
- ❑ Biasing and Operating principle
- ❑ Characteristic Equation of p-MOSFET
- ❑ Graphical representation of the Char. Equations
- ❑ Numerical Examples

Conclusion





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