CHAPTER 1: SEMICONDUCTOR BASICS.

★Materials:-

⇒Conductors:- Copper, Aluminum, Gold, Silver, ...

⇒Semiconductors:- Silicon, Germanium, Gallium Arsenide, indium-Gallium-Arsenide, ...

⇒non-conductors-insulators:- Paper, ruber, wood, plastic, Glass, ...

⇒Notes:-

★Gallium-arsenide:- Ga+As "جاليوم + زرنيخ"

★Indium-Gallium-arsenide:- In+Ga+As "جاليوم + زرنيخ + إنديوم"

⇒Semiconductors:- materials whose electrical properties between insulators & conductors.

⇒Conductivity:- "Siemen per meter":- a physical property of materials that represents the ability of a material to conduct electricity through it

- Siemen = $\frac{1}{\text{Ohm "}\Omega\text{"}}$

★Semiconductors are in the form of devices or Integrated circuits "ICs".

★Semiconductors are important because the most used semiconductor "Silicon" is extracted from desert sand "SiO_2" "Cheap".

الموضوع: Electronics   التاريخ: 12-2-2025

*Semiconductors are insulators at low temperaturs and conductors at high temperaturs.

*Electrical proper ties of semiconductors can be changed by introducing external atoms, "impuri ties" "شوائب".

*Silicon, Germanium are common semiconductors in the fourth group of the periodic table. Si_{14} - Ge_{32}

*four valence "تكافؤ" electrons in the outer "valence" shell "غلاف التكافؤ" in the Silicon, Germanium.

*the far you get from the nucleus the Higher energy ~~band~~ level you get.

*you must remember:-

→ Number of Si atoms per Cm^3 equals 5×10^{22} atoms.

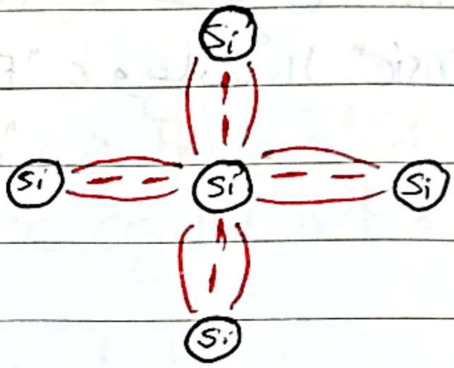
→ Number of Ge atoms per Cm^3 equals 4.4×10^{22} atoms.

التاريخ: 14/2/2025 الموضوع: ELECTRONICS

*Semiconductor crystal:- made up of atoms bonded together in a regular structure.

*semiconductor atom has 4 valence electrons which are shared, forming covalent bonds with four atoms.
"روابط تساهمية"

*This creates eight shared valence electrons for each atom and produces a state of chemical stability.



*تتكون بلورة أشباه الموصلات من ذرات مرتبطة ببعضها البعض في بنية منتظمة، تحتوي ذرات أشباه الموصلات على ٤ إلكترونات تكافؤ، فتكون روابط تساهمية مع كل أربعة ذرات، مما يكون ٨ روابط تساهمية بإلكترونات التكافؤ، وينتج حالة من الإستقرار الكيميائي، لأن المستوى الأخير يستقر بوجود ٨ إلكترونات.

*Intrinsic semiconductors crystals contains only Si or Ge atoms only.

*Extrinsic semiconductors crystals contains Si or Ge atoms plus impurities.

*اللي فيها ذرات من نفس النوع بدون شوائب هي ال "Intrinsic"
أما اللي فيها شوائب هي ال "Extrinsic" وعادةً ال "Extrinsic"
بيبقى فيها "hole" أو "extra electron"

Intrinsic semiconductors:- "Pure"

* contains only Si or Ge atoms only "No impurities".
* at temperature 0K, the valence band "نطاق التكافؤ" is fully occupied by the valence electrons, and the conduction band is completely empty of electrons.
* "يعني المادة بتكون عازلة تماماً، عند 0K بالأزم الالكترونات معندهاش طاقة كفاية تطلع للمستوى الخارجي".
* Because of no electrons are available in the conduction band the Intrinsic semiconductor crystal act as a insulator at 0K.
* Conductivity of intrinsic semiconductor = zero at 0K.

$$\sigma = 0 \quad \text{at } 0K \text{ or } -273C$$

* as temperature increase above 0K, a few valence electrons gain enough thermal energy "طاقة حرارة" to break the bond and jump into the conduction band, leaving a hole behind them.
* as temperature increases further more bonds break, and more electrons jump to the conduction band, and more holes "empty states" are created in the valence band.
* number of free electrons in the conduction band equals the number of holes left in the valence band.

• $n \Rightarrow$ free electrons concentration
• $p \Rightarrow$ hole concentration
• $n_i \Rightarrow$ intrinsic concentration, semiconductor atoms affected by temperature.

* in room temperature 300K = 27C :-

• $n_i(Si) = 1.5 \times 10^{10} = n = p$ ★ $n_i = \sqrt{np}$

• $n_i(Ge) = 2.5 \times 10^{13} = n = p$

* Conductivity of intrinsic semiconductor at 300K = 27C :-

$$\sigma = q(n\mu_n + p\mu_p)$$

$$\sigma = q n_i(\mu_n + \mu_p)$$

* where :-
* q ⇒ electron charge = 1.6×10^{-19}.
* n → Free electron concentration.
* p ⇒ Hole concentration.
* σ ⇒ Electrical conductivity.
* n_i ⇒ intrinsic concentration.
* μ_n ⇒ Electron mobility.
* μ_p ⇒ Hole mobility.

* Current density (J) = Conductivity (σ) x Electric field (E)
* $E = \frac{V}{L}$ V ⇒ voltage.   L ⇒ distance between two points.

$$J = \sigma \cdot E = \sigma \cdot \frac{V}{L} = \frac{q n_i(\mu_n + \mu_p) \cdot V}{L}$$ at 300K

* at 0K :- $J = 0$, $\sigma = 0$

★ Extrinsic semiconductors :-

⇒ Crystals contain Si or Ge plus impurities.

Impurities

Pentavalent atoms ("N_D") "تطعيم خماسي" "D"

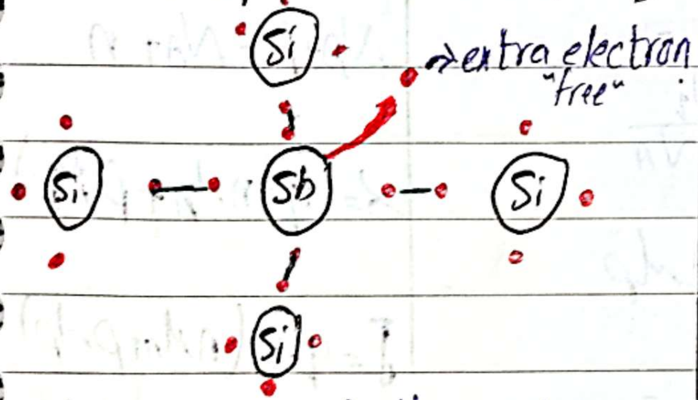
"atoms with 5 valence electrons like:-
arsenic (As), 33
phosphorus (P), 15
antimony (Sb) 51

Trivalent atoms ("N_A") "تطعيم ثلاثي" "A"

"atoms with 3 valence electrons like:-
boron (B), 5
indium (In), 49
Gallium (Ga) 31

Extrinsic Semiconductors

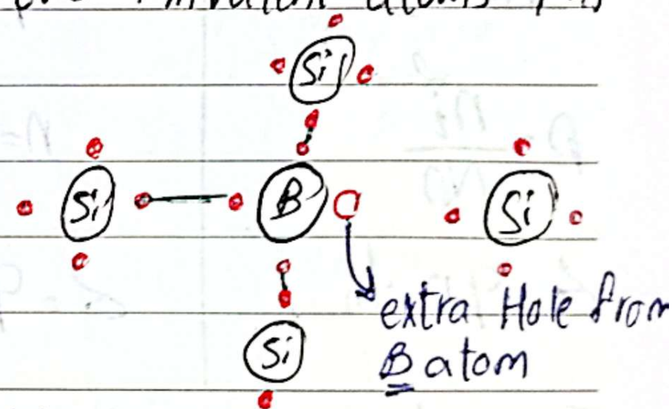
Si or Ge + Pentavalent atoms "N_D"



★ electrons are majority carriers.
★ holes are minority carriers.

n-type Semiconductor

Si or Ge + Trivalent atoms "N_A"



★ Holes are majority Carriers.
★ electrons are minority carriers.

p-type semiconductor.

• $n_i^2 = n \times p$

التاريخ: 15/12/2025 الموضوع: Electronics

Extrinsic semiconductors

N-type Semiconductors		P-type Semiconductors
$n = N_D \; , \; p = \frac{n_i^2}{N_D}$	$n_i^2 = np$	$p = N_A \; , \; n = \frac{n_i^2}{N_A}$
$\sigma = q n \mu_n = q N_D \mu_n$	$\sigma = q n_i (\mu_n + \mu_p)$	$\sigma = q p \mu_p = q N_A \mu_p$

$J = q n \mu_n E = q N_D \mu_n E$ $\qquad$ $J = q p \mu_p E = q N_A \mu_p E$

$N_D \Rightarrow$ Donors

Extrinsic semiconductors

5} N-type; Si or Ge $+ N_D$	3} P-type; Si or Ge $+ N_A$	Si or Ge $+ N_A + N_D$
$n = N_D$	$p = N_A$	$n \cdot p = n_i^2$
$p = \frac{n_i^2}{N_D}$	$n = \frac{n_i^2}{N_A}$	$N_D + p = N_A + n$
$\sigma = q n \mu_n$	$\sigma = q p \mu_p$	$\sigma = q(n \mu_n + p \mu_p)$
$J = q n \mu_n E$	$J = q p \mu_p E$	$J = q \cdot E (n \mu_n + p \mu_p)$

laws Ch-1

$$\sigma = q(n\mu_n + p\mu_p)$$

- $\sigma \Rightarrow$ Conductivity.
- $q \Rightarrow$ electron charge $= 1.6\times10^{-19}$.
- $n \Rightarrow$ free electrons concentration
- $p \Rightarrow$ Holes concentration.
- $\mu_n \Rightarrow$ Electron mobility.
- $\mu_p \Rightarrow$ Hole mobility.

$$J = \sigma \cdot E = q(n\mu_n + p\mu_p) \cdot E$$

- $J \Rightarrow$ Current density.
- $E \Rightarrow$ Electric field $= \frac{V}{L}$ ($V \rightarrow$ Voltage, $L \rightarrow$ distance)

$$n_i^2 = n \cdot p$$

- $n_i \Rightarrow$ free electrons concentration.

* Carrier concentration in doped semiconductors :-

* for N-type :-

$$n = N_D \quad , \quad p = \frac{n_i^2}{N_D}$$

- $N_D \Rightarrow$ Donor atom concentration.

* for P-type :-

$$p = N_A \, , \quad n = \frac{n_i^2}{N_A}$$

- $N_A \Rightarrow$ Acceptor atom concentration.

$$\rho = \frac{1}{\sigma} = \frac{1}{q(n\mu_n + p\mu_p)}$$

$$V_d = \mu_n \cdot E$$

- $\rho \Rightarrow$ resistivity.
- $V_d \Rightarrow$ drift velocity.

$$p + N_D = n + N_A$$

Remember the qudric formula :-

if $ax^2+bx+C=0$ then :-

$$\bullet\ x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

*Important note :-

* "لو الفرق بين الـ N_A, N_D أقل من الـ 2 هنستخدم القانون ده" :-

$$p+N_D=n+N_A$$

"ولو أكبر من أو يساوي الـ 2 نقارن الـ N_A, N_D عشان نعرف الأكبر ونعرف هي n-type ولا p-type وبعدين نستخدم القانون المناسب سواء الـ $n=\frac{n_i^2}{N_A}$ أو الـ $p=\frac{n_i^2}{N_D}$"

* الـ n_i بتعتمد على resistivity فلو أعطاك الـ resistivity أحسب الـ n_i من أول وجديد" :-

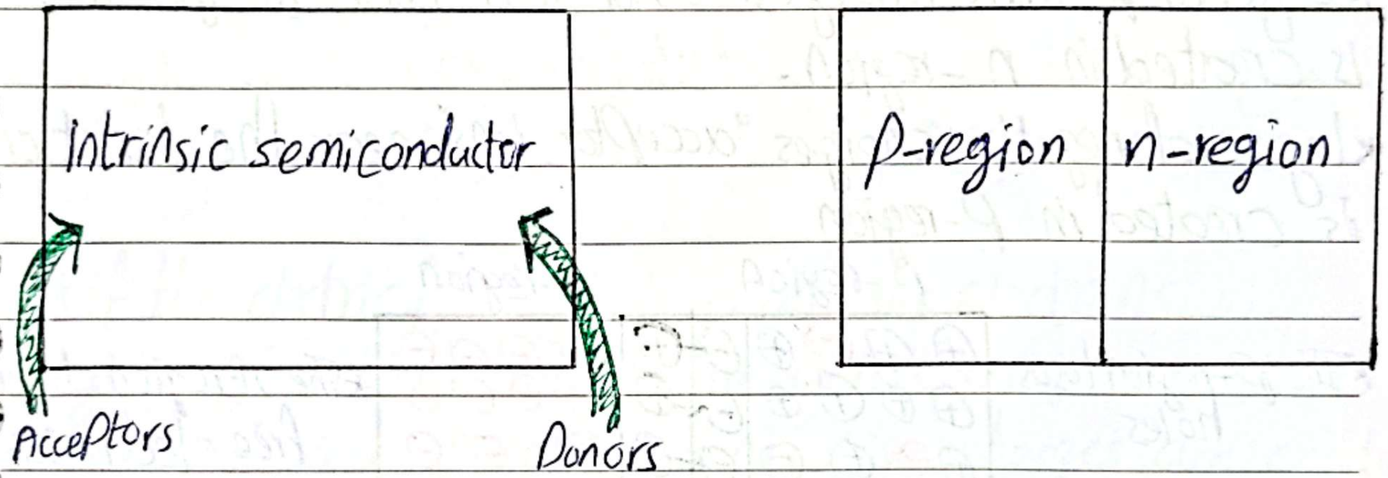
$$n_i=\frac{1}{q\rho(\mu_n+\mu_p)}$$

$$J=\frac{I}{A}=\sigma\cdot E=qn\mu_nE=qn\,v_d=qn\mu_n\frac{V}{L}=qn\mu_n\frac{IR}{L}$$

التاريخ: 21/2/2025 الموضوع: Electronics

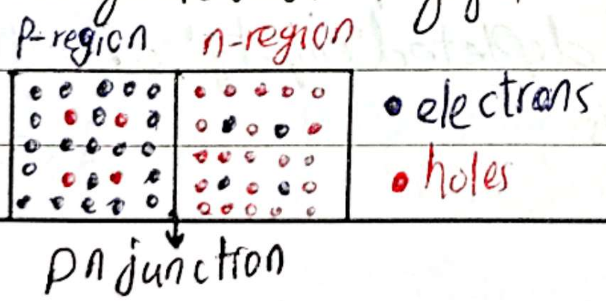
*if a piece of intrinsic semiconductor is doped with acceptors on one side and with donors on the other side, a boundry called pn junction is formed between the resulting p region and n region and a diode is created.

*Diode:- a piece of an intrinsic semiconductor doped from one side with acceptors "p-type" and donors from the other side "n-type".



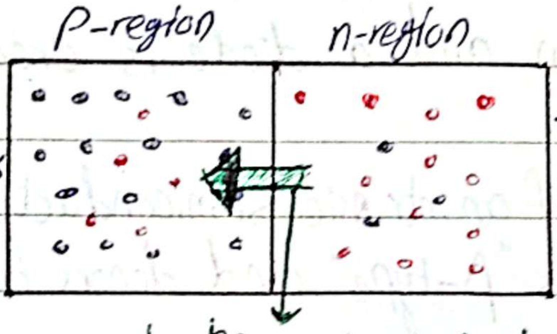
*the p-region has many holes "majority carriers" from acceptor atoms and only a few thermally generated electrons "minority carriers".

*the n-region has many electrons "majority carriers" from donor atoms and only a few thermally generated holes "minority carriers".



*free electrons near the Junction in n region diffuse "تنتشر" into the p-region where they combines with holes near the junction.

*The p-region loses holes as the electrons and holes combine



*The n-region loses free electrons as they diffuse across the junction.

*layer of positive charges "donor ions" near the junction is created in n-region.

*layer of negative charges "acceptor ions" near the junction is created in p-region

*The p-region loses holes

*The n-region loses free electrons

*The region near the junction is called a depletion region "منطقة النضوب".

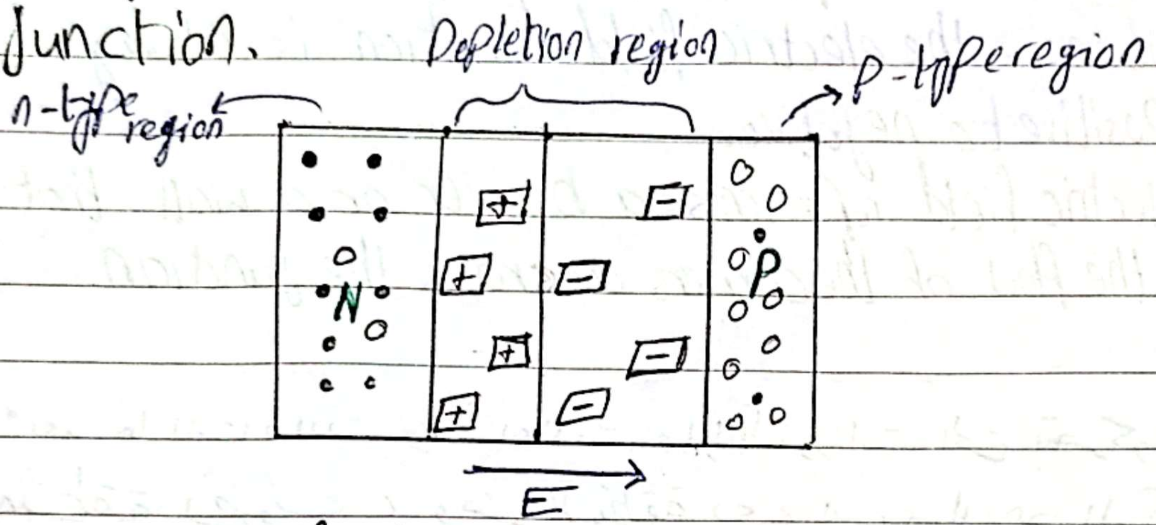
*The term depletion region refers to the fact that the region near the junction is depleted "empty" of mobile charges "free electrons & holes.

* the positive & negative charges in the depletion region creates an electric field.
* remember:- the electric field direction is always from positive to negative.
* This electric field represents a barrier or a wall that prevent the flow of the carriers across the junction.

* "بعد ما الناقلات والحاملات والإلكترونات الحرة بتحركوا ليعملوا منطقة نضوب ، وفي المنطقة دي بيتولد مجال كهربي بيمنع حركة الناقلات "إلكترونات وفجوات" من خلال منطقة النضوب".

* if the electric field E is small, the electrons in region n continue to diffuse across the junction, then more and more positive and negative charges are created near the junction.
* when the electric field E is large enough the diffusion process stops.
* "الإلكترونات بتفضل تتحرك لحد ما المجال الكهربي E يبقى كبير كفاية إنه يمنع مرورها".
* diffusion process stops when the layer of negative charges is strong enough to repel any further diffusion of electrons from n-region into P-region.

* This electric field represents a barrier or a wall that prevent the flow of the carriers across the junction.



* this electric field results in a difference of potential "V_B" called **barrier potential** across the depletion region.

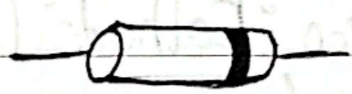
* Barrier potential "difference of potential" is expressed in volts and given by:-

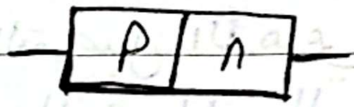
$$V_B = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

- V_T ⇒ Thermal voltage $= \frac{KT}{q}$, at $300K$ $= 0.025\,V$
- N_D ⇒ Donor doping concentration n-side.
- N_A ⇒ Acceptor doping concentration p-side.
- n_i ⇒ Intrinsic carrier concentration $Si = 1.5 * 10^{10}$, $Ge = 2.5 * 10^{13}$
- V_B ⇒ Barrier potential.

التاريخ: 21 / 2 / 2025 الموضوع: Electronics

* the p-region of diode is called the anode (A) "القطب الموجب" and is connected to a conductive "metal" terminal, the n-region is called the cathode (K) "القطب السالب" and is connected to a second conductive terminal.



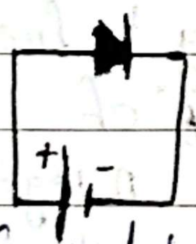


"Anode" "cathode"

* the anode is represented by a triangle, or an arrow and the cathode is represented by a vertical line.

* Diode Biasing :- refers to "applying an external voltage source across the diode to establish certain operating conditions".

* There are two biasing conditions :-



"Forward biasing"
"توصيل أمامياً"

موجب مع موجب
سالب مع سالب

"Reverse biasing"
"توصيل خلفي"

موجب مع سالب
سالب مع موجب

الموضوع: Electronics

Forward biasing

التاريخ: 21 / 12 / 2025

* Is a condition in which the Positive side of a voltage source is connected to the p-region "an ode" (the Positive side of the diode) of the diode and the negative side of the voltage source is connected to the n-region "Cathode" (the negative side of the diode) of the diode.

* "باختصار: في التوصيل الأمامي ← بنوصل الموجب بالموجب "الآنود" والسالب بالسالب "الكاثود"."

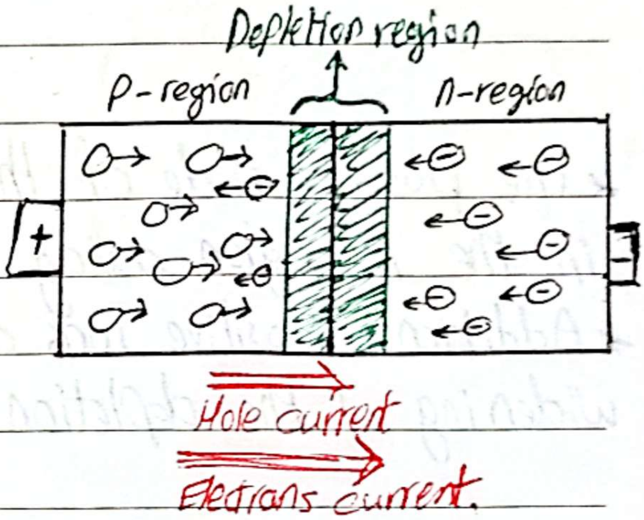
* The negative side of a voltage source pushes free electrons in the n-region towards the pn junction
* As electrons in n region flow into depletion region the number of the Positive ions is reduced.
* The reduction in the Positive ions results in the depletion region to narrow "يضيق".
* "لما بنستخدم التوصيل الأمامي الشحنات السالبة من البطارية بتدفع الشحنات السالبة اللي جوا الدايود فحجم منطقة النضوب بيقل".
* The voltage source imparts sufficient energy to free electrons to overcome the Barrier Potential "V_B" of the depletion region and move from the n-region to the p-region, and this flow of electrons results in electron current from p-region to n-region.

Continue :- Forward biasing

التاريخ: 21/2/2025 الموضوع: Electronics

* Similarly, the holes in the P-region moves toward the junction.
* As holes in P-region flow into the depletion region, number of negative ions is reduced, and the width of the depletion region is reduced.
* The flow of the holes results in the hole current.

* Forward current :- "I_f"



* I_f = Electron current + Hole current

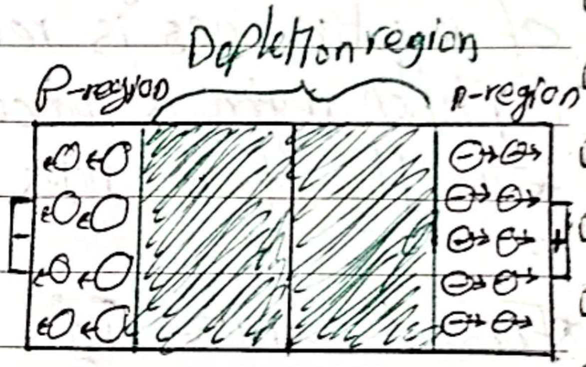
* $I_f = I_S \cdot e^{\left(\frac{V_D}{\eta V_T}\right)}$

* Where :-
* V_D :- Voltage accross the diode.
* η :- constant = 1 for Ge and 2 for Si
* V_T :- 0.025 V att 300°K
* I_S :- saturation current

Reverse Biasing

التاريخ: 2/12 2025 الموضوع: Electronics

* is a condition in which the negative side of a voltage source is connected to the p-region "anode" of the diode and the positive side is connected to the n-region "cathode" of the diode.



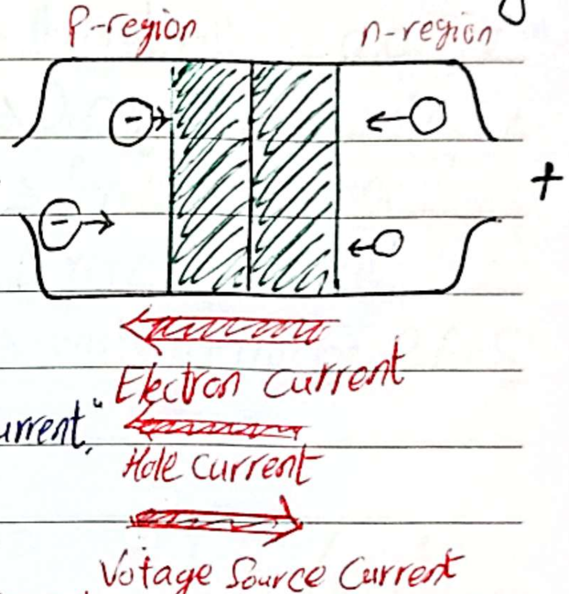
* the positive side of the voltage source attracts electrons in the n-region away from the junction.
* Additional positive ions are created that results in a widening of the depletion region.

* Similarly, holes in the p-region are pulled toward the negative side of the voltage source.
* additional negative ions are created that results in a widening of the depletion region.

Reverse Current I_r

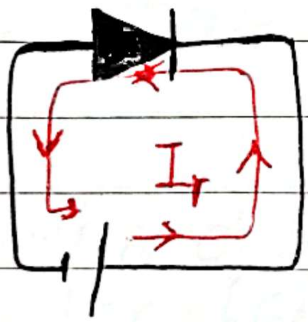
التاريخ: 21 / 2 / 2023 — الموضوع: Electronics

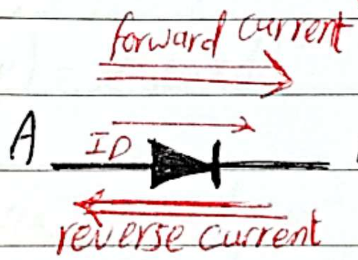
* Minority electrons in the p-region are pushed toward the junction by the negative side of the voltage source and pass through the depletion region.
* Similarly, minority holes in the n-region move away from the positive side of the voltage source.
* this flow of the minority carriers results in an extremely small current.



- I_r = Electron current + Hole current
- $I_r = I_s$

$I_s \rightarrow$ saturation current. "leakage current"
$I_r \rightarrow$ reverse current





* Diode current "I_D" :- The arrow direction in the diode symbol indicates the direction of the current through the diode.

- $I_D = I_f - I_r$
- $I_f = I_s \exp\left(\frac{V_D}{\eta V_T}\right)$

- $I_D = I_s \left[e^{\left(\frac{V_D}{\eta V_T}\right)} - 1 \right]$

ch2 part-1 laws summary

التاريخ: 24 / 2 / 2025 — الموضوع: Electronics

* • $V_B = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$ • $I_f = I_s e^{\left(\frac{V_D}{\eta V_T}\right)}$

• I_r = Electron current + Holes current • $I_r = I_s$

• $I_D = I_f - I_r = I_s \exp\left(\frac{V_D}{\eta V_T}\right) - I_s = I_s\left[\exp\left(\frac{V_D}{\eta V_T}\right) - 1\right]$

* V_B ⇒ Barrier potential * V_T ⇒ thermal voltage = 0.025 V at 300
* N_A ⇒ Acceptor doping concentration * N_D ⇒ Doping donor concentration
* n_i ⇒ Intrinsic carrier concentration * I_f ⇒ forward current
* I_s ⇒ saturation "leakage" current. * I_r ⇒ reverse current.
* V_D ⇒ Voltage across diode. * η ⇒ constant = 1 for Ge, 2 for Si
* I_D ⇒ Diode current.

* remember:- $n_i(Si) = 1.5 \times 10^{10}$ atoms/cm^3
  $n_i(Ge) = 2.5 \times 10^{13}$ atoms/cm^3

* number of Si atoms per 1 cm^3 :- 5×10^{22}
* number of Ge atoms per 1 cm^3 :- 4.4×10^{22}

* $\sigma = q(n\mu_n + p\mu_p)$
  - for Si: * $\mu_n = 1300$, * $\mu_p = 500$
  - for Ge: * $\mu_n = 3800$, * $\mu_p = 1800$

fast revision on chapter 1

18 13 /2025 التاريخ: الموضوع: Electronics

*intrinsic :- "ذرات شبه الموصل فقط بدون شوائب"
*Extrinsic :- "ذرات شبه الموصل مع الشوائب"
*Conductivity "σ" of intrinsic semi conductors at 0K = zero.

→ The number of free electrons in the conduction band is equal to the number of holes in the valence band. "غلاف التكافؤ"

*The conductivity of an intrinsic semiconductor "σ" at 300K :-

$$\sigma = q(n\mu_n + p\mu_p) = q\, n_i(\mu_n + \mu_p)$$

*where :-

- q → electron charge = 1.6×10^{-19}
- n → free electrons concentration
- p → holes concentration
- n_i → intrinsic carrier concentration
- μ_n → Electron mobility
- μ_p → Hole mobility

*when no doping is done "Intrinsic semiconductors" :-

$$n_i = n = p$$

*Current density "J" :-

$$J = \sigma \cdot E = \sigma \cdot \frac{V}{L} = q(n\mu_n + p\mu_p) \cdot \frac{V}{L} = q n_i(\mu_n + \mu_p) \cdot \frac{V}{L}$$

- V → Voltage
- L → distance between two points

Continue Ch1

التاريخ: 19 / 13 / 10 / 2025 — الموضوع: Electronics

* N_D "تطعيم خماسي" "pentavelant":- As, P, Sb more electrons
* N_A "تطعيم ثلاثي" "Trivalent":- B, In, Ga more Holes

in n-type "N_D"	in p-type "N_A"
$n = N_D \qquad p = \frac{n_i^2}{N_D}$	$p = N_A \qquad n = \frac{n_i^2}{N_A}$
$\sigma = q n \mu_n = q N_D \mu_n$	$\sigma = q p \mu_p = q N_A \mu_p$
$J = q n \mu_n E = q N_D \mu_n E$	$J = q p \mu_p E = q N_A \mu_p E$

* لو فيها "N_D:- Donors" و "N_A:- Acceptors" في نفس الوقت:-

- $n \cdot p = n_i^2$ • $n + N_A = p + N_D$
- $\sigma = q(n\mu_n + p\mu_p)$ • $J = q(n\mu_n + p\mu_p) \cdot E$

* Remember:- • $\rho = \frac{1}{\sigma}$ • $V_d = \mu_n \cdot E$
* where:-
- N_D:- Donor atoms concentration   • N_A:- Acceptors Atoms concentration
- ρ:- resistivity   • V_d:- drift velocity

* لو قالك: The current is due electrons يبقى هي n-type

ولو قال Holes يبقى p-type

Continue Ch 1

19 / 3 / 2025 :التاريخ

Electronics :الموضوع

*Remember:-

*if $ax^2+bx+c=0$ then:- $x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$

*لو الفرق في الأس بين الـ N_A ، N_D أقل من 2 ، هستخدم قانون الـ
$p+N_D=n+N_A$.

* ولو الفرق أكبر من 2 بتقارنه وتشوف أنهي أكبر عشان تعرف هي p-type ولا N-type ⇐ أو لو بيساوي 2 برضه

• n_i depends on T:-

* في قوانين الـ J ، V_d بنستخدم التر

• $n_i=\frac{1}{q\rho(\mu_n+\mu_p)}$

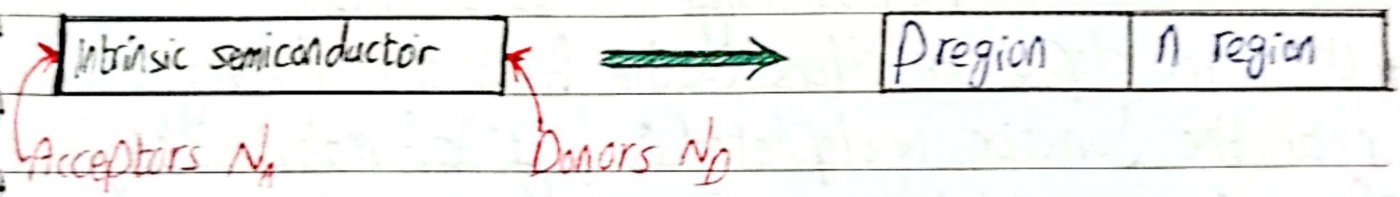
• $J=\frac{I}{A}=\sigma\cdot E=q(n\mu_n+p\mu_p)\cdot\frac{IR}{L}$

*Constants:-

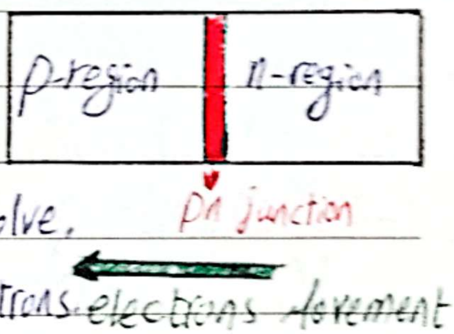
for Si:-	for Ge:-
$n_i=1.5\times10^{10}$ atoms/cm^3	$n_i=2.5\times10^{13}$ atoms/cm^3
$\mu_n=1300$ cm^2/V.s	$\mu_n=3800$ cm^2/Vs
$\mu_p=500$ cm^2/Vs	$\mu_p=1800$ cm^2/Vs
number of atoms per Cm^3 $=5\times10^{22}$	no. atoms per Cm^3 $=4.4\times10^{22}$

* ال diode هو عبارة عن "intrinsic semiconductor" حصوله تطعيم من النوع n من ناحية، وتطعيم من النوع p من الناحية الثانية.

* Diode:- a piece of intrinsic semiconductor doped with accepters from one side and with donors from the other side, a boundry called "pn" junction is formed between the resulting p region and n region.



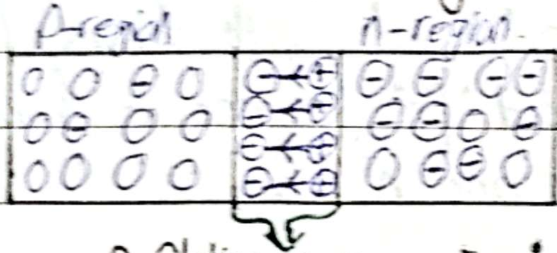
* The p-region has many holes "majority carriers" from acceptors atoms and only a few thermaly generated electrons "minority carriers".
* The n-region has many electrons "majority carriers" from Donors atoms, and only a few thermally generated holes "minority carriers".
* free electrons near the junction in n region diffuse into p region where they combine with holes near the junction.



* the n-region loses electrons as they dissolve.
* the p-region loses holes as they combine with electrons.

* layer of positive charges "donor ions" near the Junction is created in "n"-region.
* layer of negative charges "acceptor ions" near the junction is created in the "p"-region.

* the p-region loses holes



* the n-region loses electrons

Depletion range "نطاق النضوب"

* the term depletion refers to the fact that the region near the junction is depleted "empty" of mobile charges "free electrons & holes"

* الدايود هو عبارة عن إن إحنا بنجيب شبه موصل ونطعمه ثلاثياً من ناحية و خماسياً من ناحية ، وتبقى الإلكترونات في النظام "n" بتروح ناحية الفتحات في النظام "p" وبتندمج معاها ، وبعد كده بيستقر فيه طبقة من الشحنات الموجبة والسالبة ناحية منطقة النضوب "مكان مفيهوش ولا إلكترونات ولا فتحات".

* The Positive & negative charges in the depletion region create an electric field.
* This electric field represents a barrier or a wall that prevent the flow of the carriers accross the junction.
⇒ Remember:- the electric field direction is from the positive to negative. ("n" to "p")
* if the electric field "E" is weak, electrons in the n region will continue to diffuse across the junction, then more & more Positive & negative charges are created near the Junction.
* when the electric field is large enough the diffussion process stops.
* diffussion process stops when the layer of negative charges is strong enough to repel any further diffussion of electrons from "n" region into "p" region.
* This electric field results in a difference of potential "V_B" called barrier potential across the depletion region.
* Barrier Potential "difference of potential" is expressed in volts and given by:-

• $V_B = V_T \cdot \ln\left(\frac{N_A N_D}{n_i^2}\right)$

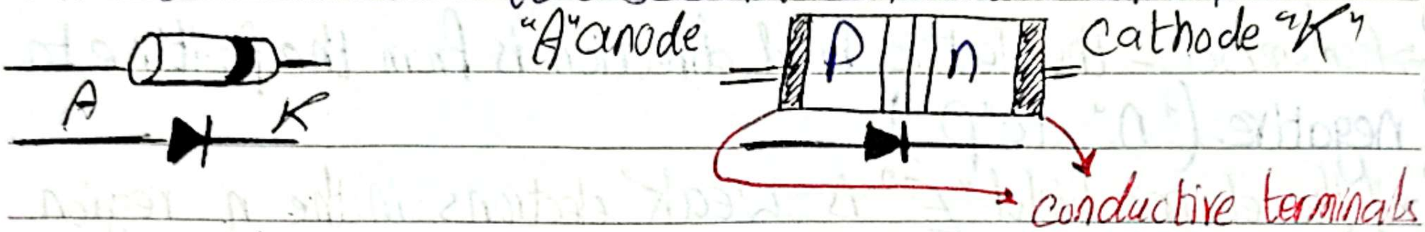
• V_T ⇒ thermal voltage, at room temperature "300 K":-

• $V_T = 0.025$ V

Continue

التاريخ: 20 / 3 / 2025 Chapter 2 الموضوع: Electronics

* Diode Symbol:- the p-region is called the "anode" "Positive side" and it's connected to a conductive "metal" terminal. the n-region is called a cathode "negative side" and it's connected to a second conductive terminal



* The anode is represented by a triangle, the cathode is represented by a vertical line.

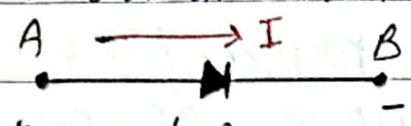
* الشحنات الموجبة والسالبة في منطقة النضوب بتعمل مجال كهربي اتجاهه من الموجب للسالب، وال "n" عندها أيونات موجبة، أما ال "p" عندها أيونات سالبة، الحال ده بيعلى كل ما منطقة النضوب تكبر، لحد ما منطقة النضوب توصل لمرحلة إنها تعمل مجال كهربي يوقف حركة الإلكترونات، الحركة دي بتوقف لما طبقة الأيونات السالبة في منطقة النضوب تبقى كبيرة بما فيه الكفاية إنها تمنع الإلكترونات من الحركة "تنقل الإلكترونات"، فرق الجهد اللي بيتكون ده بنسميه "الجهد الحاجز" "V_B"، ال "P" هو الأنود وال "n" هو الكاثود، الأنود موجب والكاثود سالب، ويتم توصيلهم ب "طرف معدني موصل للكهرباء"

Continue

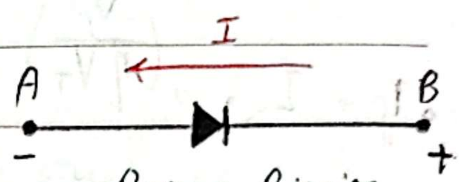
Chapter 2

التاريخ: 24/3/2025 — الموضوع: Electronics

*Diode biasing :- applying an external voltage source across it to establish certain operating conditions.



Forward Biasing



Reverse Biasing

Forward operation

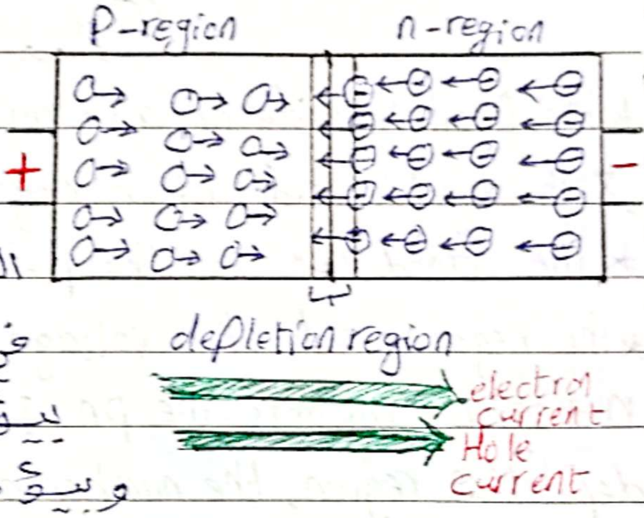
* the positive side of a voltage source is connected to the p-region & the negative side of a voltage source is connected to the n-region.
* the anode "+" is the p-region & the cathode "-" n-region
* the negative side of a voltage source pushes the electrons in the n-region towards the pn junction, and as they flow in the depletion region, the number of positive ions is reduced, resulting the depletion region to narrow.
* the voltage source imparts sufficient energy to free electrons to overcome the barrier potential of the depletion region & move into the p-region, this flow of free electrons results in electron current.
* Similarly the holes in the p-region move toward the junction, and as they flow into the depletion region, number of negative ions is reduced, and by that the width of the depletion region is reduced.
* the flow of Holes results in the hole current.

* Forward current "I_f" :- • I_f = Hole current + electron current.

• $I_f = I_s \cdot e^{\left(\frac{V_D}{\eta V_T}\right)}$

• $I_s \Rightarrow$ saturation current.
• $V_D \Rightarrow$ Voltage across diode.
• $\eta \Rightarrow$ constant = 1 for Ge, 2 for Si.
• $V_T \Rightarrow$ 0.025 at 300°K.

* في التوصيل الأمامي :-



* بنوصل الطرف الموجب بالـ "P" والطرف السالب بالـ "n" ، الجهد السالب من التيار بيسبب إن الإلكترونات الحرة في الـ "n" تتحرك ناحية الـ "P" وده بيؤدي إن اندماجها مع الفجوات هناك وبيؤدي لصغر المنطقة خالية النضوب ،
حركة الإلكترونات من الـ "n" للـ "P" بتؤدي لتولد تيار يعرف "بتيار الإلكترونات" إتجاهه من "P" للـ "n" ، وحركة الفجوات بتؤدي لتولد تيار يعرف بتيار الفجوات اتجاهه من "P" للـ "n" ، لما نجمع تيار الإلكترونات وتيار الفجوات بيدينا التيار الأمامي "I_f".

Continue

Chapter 3

Reverse Operation

* the negative side of a voltage source is connected to the "P-region" and the positive side is connected to the "n-region".
* the positive side of voltage source attracts the electrons in the "n-region", resulting in creating additional positive ions that results in widening of the depletion region.
* Similarly the holes in P-region are pulled towards the negative side of the voltage source, resulting in creating additional negative ions, resulting in widening of the depletion region.

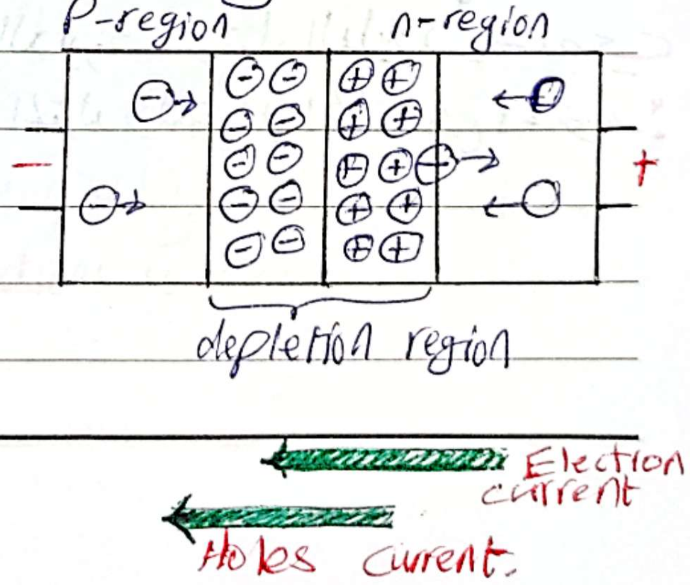
* Reverse Current:-
* minority electrons in the P-region are pushed toward the junction by the negative side of voltage source and pass through depletion region, Similarly minority Holes in the n-region are pushed toward the junction, moving away from the positive side of voltage source.
* This flow of carriers results in an extremely small current.

• I_r = Electron current + Hole current

• $I_r = I_s$

⇒ I_s ⇒ saturation current.

⇒ I_r ⇒ reverse current.



*Diode current "I_D": — the arrow direction in the diode symbol indicates the direction of current through the diode.

- $I_D = I_f - I_r = I_f - I_s$
- $I_D = I_s \cdot e^{\left(\frac{V_D}{\eta V_T}\right)} - I_s = I_s\left[e^{\left(\frac{V_D}{\eta V_T}\right)} - 1\right]$

*في حالة التوصيل الخلفي "العكسي للتيار":—

*يتم توصيل الطرف الموجب لمصدر الجهد بال "n" والطرف السالب بال "p"، مما يؤدي إلى تجاذب بين إلكترونات ال "n" والطرف الموجب للجهد، وبين فجوات ال "p" والطرف السالب للجهد، فتتوسع منطقة النضوب، وتتحرك أقلية الحاملات "بعض إلكترونات ال "p" و فجوات ال "n" نحو منطقة النضوب مما يؤدي إلى تولد تيار صغير جداً يسمى بالتيار العكسي.

*تيار الدايود:—

*السهم يشير إلى إتجاه تيار الدايود، وتيار الدايود يساوي الفرق بين التيار الأمامي المتولد والتيار الخلفي المتولد.

Continue

* Voltage-Current Characteristic of Diode:-

⇒ The Graphical relationship between the voltage and the current in a diode.

* with 0 volt across the diode, there is zero current.
* if a voltage across a diode is increased above zero volt and below the barrier volt "potential", the current increases very little.
* when a voltage across a diode reaches the barrier potential, the current increases rapidly.
* when a reverse voltage is applied across a diode there is an extremely little small reverse current through a diode.

• $I_D = I_f - I_s \Rightarrow I_D = -I_s$

* if the reverse current increased to a value called the break down voltage "V_{BD}", The high reverse voltage "V_{BD}" imparts energy to the minority electrons so that they speed through the p-region, they collide with atoms and knock valence electrons out of orbit and into the conduction band.

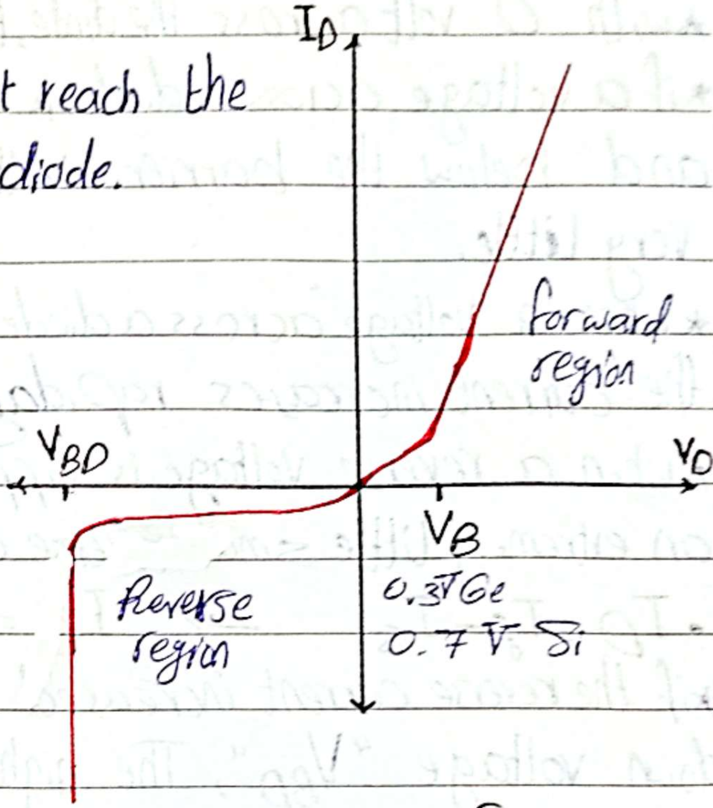
• $V_d = \mu_n . E = \mu_n . \frac{V}{L}$ → Drift velocity

* the newly created conduction electrons repeat the process.
* as a result the number of electrons quickly multiply, and the multiplication of conduction electrons is known as the "avalanche effect".

Continue Chapter 2

التاريخ: 21/3/2025 — الموضوع: Electronics

* the resulting conduction electrons go through the n-region and result in a very high reverse current.
* The resulting heating from the increased reverse current will damage the diode.
* the reverse votage does not reach the break down voltage of the diode.



* الدايود لما بيكون الفولت "صفر" بيكون التيار اللي ماشي فيه "صفر" / لو فضلنا نعلي الفولت هنلاحظ زيادة خفيفة في التيار لحد ما الجهد يوصل للجهد الحاجز ، وقتها التيار بيعلى جامد ودة في حالة التوصيل الأمامي.

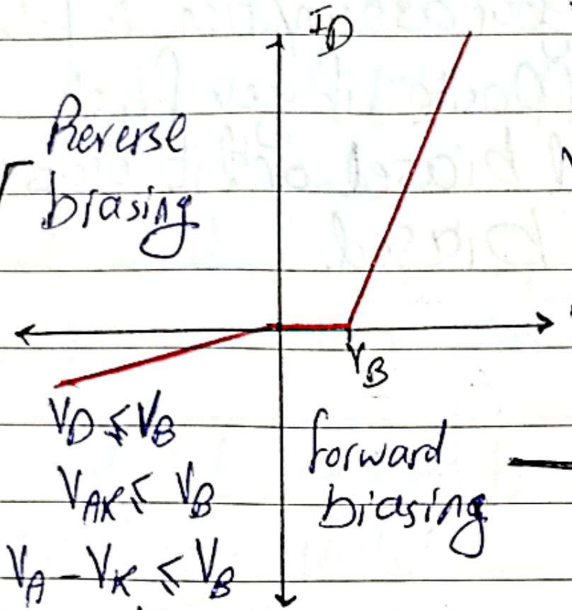
* أما في حالة التوصيل العكسي لما بتمرر جهد على الدايود بيفضل يعلى بقيم خفيفة لحد ما يوصل لقيمة جهد الانهيار "V_{BD}" وقتها التيار بيعدي عادي بعد ما الجهد يوصل لجهد الانكسار "الانهيار" وبنعرف تأثير أفلانتشي على إنه التضاعف بتاع الإلكترونات

الموصلة "اللي كانت إلكترونات رابطة التكافؤ قبل ما نمرر التيار"

Continue Chapter 2

التاريخ: 21/3/2025 الموضوع: Electronics

* Piecewise linea characteristics of practical Diode:-

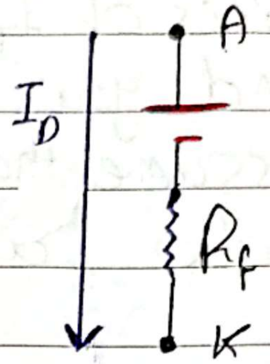


$V_D > V_B$

$V_{AK} > V_B$

$V_A - V_K > V_B$

$V_A > V_K + V_B$

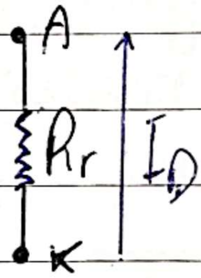


$V_D \leq V_B$

$V_{AK} \leq V_B$

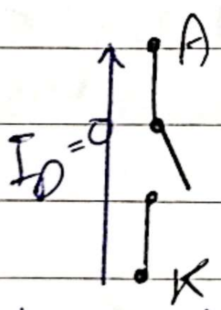
$V_A - V_K \leq V_B$

$V_A \leq V_K + V_B$



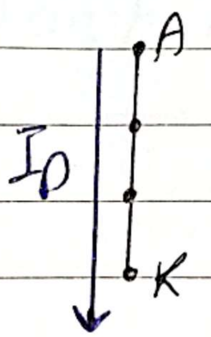
* Piecewise linear characteristics of Ideal Diode:-

Reverse biasing

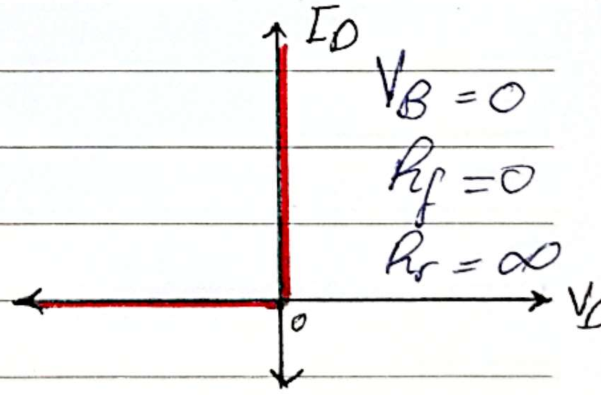


$V_A \leq V_K$

Forward biasing



$V_A > V_K$



$V_B = 0$

$R_f = 0$

$R_r = \infty$

Ideal diode neglects the effects of barrier potential, forward resistance & reverse current, working like a switch.

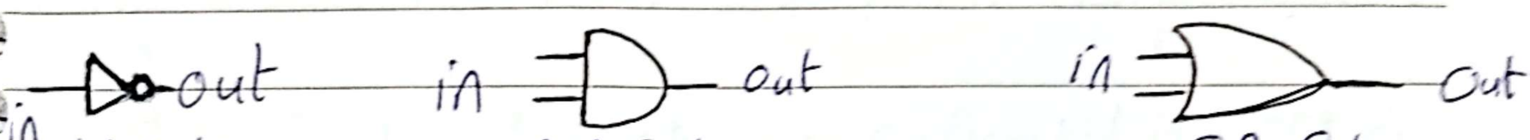
Continue
Chapter 2

2 / 8 / 2025 التاريخ: الموضوع: Electronics

* while solving with Kershoff's law if you get negative values of $I_1, I_2, \ldots, I_n$ then your assumption is false and you will assume the opposite, if you first assume the diode is forward biased and it was false, assume it reverse biased

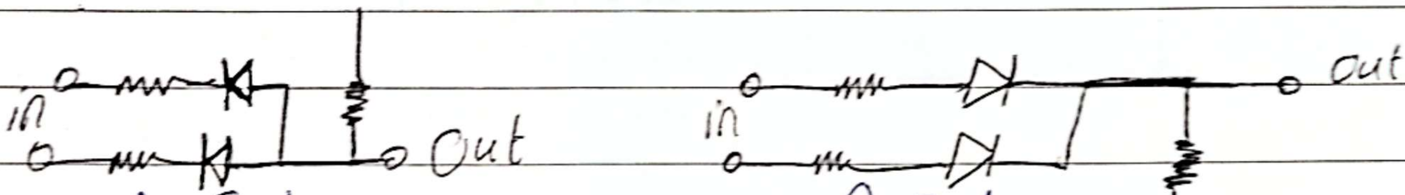
التاريخ: 21/3/202[2] Continue Chapter 2 الموضوع: Electronics

*Digital Circuits:- like microprocessors, Memory, ...
*logic gates:- hardware elements that perform the logical operations on binary numbers "0 and 1".



Not gate   And Gate   OR Gate

* in digital circuits, binary 1 and 0 are represented by two voltage levels.
⟹ any voltage between 0 and 0.9 represent 0 in binary, and any voltage between 2 and 5 represents 1 in binary, the rest are invalid votages.



and Gate   OR Gate

* logic gates (and, OR) can be made by combining diodes and resistors.

Chapter 3: Bipolar Junction Transistors "BJT's"

التاريخ: 2/3/2025 الموضوع: Electronics

*Bipolar Junction transistor:-

*the term bipolar refers to the use of both holes and free electrons as current carriers.

*BJT consists of three doped semiconductors regions

*NPN BJT:- has two "n" regions separated by "p" region.

E	B	C
N	P	N

*PNP BJT:- has two "p" regions separated by "n" region

E	B	C
P	N	P

*the three regions are called:-

- E ⇒ emitter
- B ⇒ base
- C ⇒ collector

*the emitter region is heavily doped.
*the collector region is moderately doped.
*the base region is lightly doped and very thin
*each region is connected to a conductive terminal "metallic lead"
These are labeled E,B,C for emitter, Base, Collector.

Continue

التاريخ: 21/3/2025 Chapter 3 الموضوع: Electronics

*Junctions of NPN BJT:- it has 2 junctions.

⇒ the base-emitter junction "BEJ":- the pn junction Joining the base region and the emitter region.

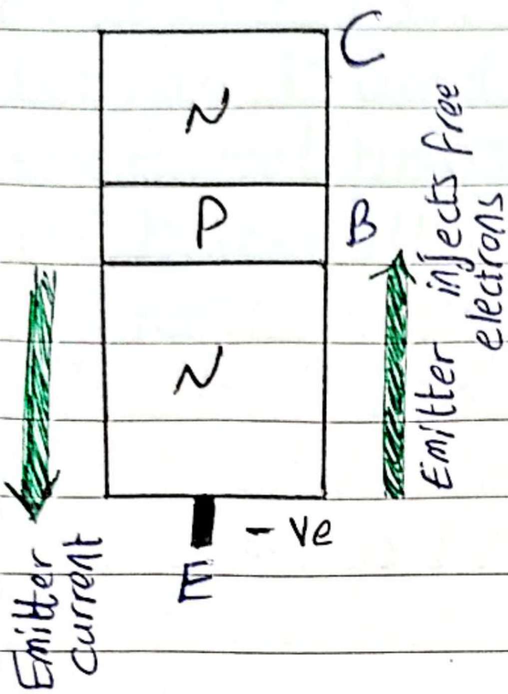
⇒ The base-collector junction "BCJ":- the pn junction joining the base region and the Collector region.

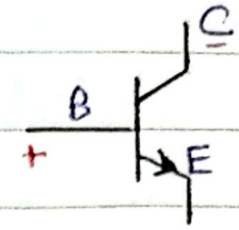
* Modes "operation regions" of NPN BJT:-

Modes	BEJ	BCJ	Applications
Active	forward	reverse	Amplifier
Saturation	forward	forward	Closed switch
Cutoff	reverse	reverse	Open Switch

: Digital circuits

★ Symbol of NPN BJT :-





★ the arrow on the emitter terminal refers to the flow direction of emitter current when the emitter-base Junction is forward biased.

Continue

التاريخ: 21 / 3 / 202_ — Chapter 3 — الموضوع: Electronics

*Active mode of NPN "Amplifier"- external dc voltages are applied to set BEJ is forward biased & BCJ is reverse biased

* the forward biasing between base and emitter narrows the base-emitter depletion region.

*the reverse biasing between base and collector regions widens the base-collector depletion region.

*operation of Active mode of NPN BJT :- in npn BJT, the heavily doped n-type emitter region has a very high free electrons density.

* these free electrons easily diffuse "move" into the "p" type base region, Most of the emitter electrons diffuse into the collector region by the attraction of the positive collector voltage source.

*small percentage of the emitter electrons recombine with holes at the base region.

* الباعث تقيل والجامع مظبوط والقاعدة خفيفة

* لما بيبقى توصيل الترانزيستور الاتنين أمامي بيعمل مفتاح مقفول

، ولو الاتنين عكسي بيعمل مفتاح مفتوح ، ولو ال BEJ أمامي و ال BCJ عكسي بيعمل مكبر للتيار.

* السهم اللي عالباعث بيحدد اتجاه تياره لما بيتوصل أمامي BEJ

* Just as in a forward biased diode:-
* the flow of electrons from emitter into base results in electron current I_{nE}.
* the flow of Holes from Base into emitter results in hole current I_{pE}
* the total emitter current is the sum of these two currents:

$$I_E = I_{nE} + I_{pE}$$

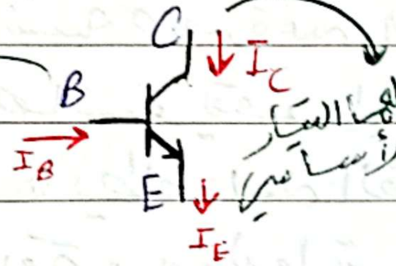
* the flow of the emitted electrons from emitter into collector results in electron current I_{nC}.
* The flow of minority holes from collector into base results in hole current I_{pC}
* the other part of the collector current I_{CB} is due to the flow of the minority electrons from base into collector.
* The total collector current is the sum of these currents:-

$$I_C = I_{CB} + I_{nC} + I_{pC}$$

التاريخ: 21/3/2025 Continue Chapter 3 الموضوع: Electronics

* In base region, a small percentage of emitter electrons recombine with holes.
* These recombined electrons move from one hole to the next and finally flow out of the base lead towards the positive side of external source forming the base electron current "I_B"
* This recombination are less in number because of smaller area and light doping of base.

* بتتحكم في كمية التيار اللي طالع من عند الـ E



بيطلع التيار الأساسي

- $I_C = I_{nC} + I_{pC} + I_{CB}$
- $I_E = I_{nE} + I_{pE}$

npn ⇐ بتتحكم في حركة الإلكترونات
pnp ⇐ بتتحكم في حركة الفجوات

* كل ما الـ I_B تقل الـ I_C ، كل ما الـ I_B تزيد الـ I_C تزيد
* لما بنوصل التيار بنوصل جهد موجب بالـ B E وجهد سالب بالـ E ، وبعد كده بسبب إن الـ emitter معمول doping جامد الإلكترونات الحرة اللي فيه بتطلع منه ، فيه جزء بيروح للـ collector وده المعظم وفيه نسبة صغيرة بتندمج مع فجوات القاعدة "base" ، حركة الإلكترونات بتولد تيار :- من الـ "E" للـ "B" بتولد I_{nE} ، وحركة الفجوات من الـ "B" للـ "E" بيولد برضه تيار I_{pE} ، وتيار الباعث بيساوي مجموعهم :-

$$I_E = I_{pE} + I_{nE}$$

* وبالنسبة للجامع "collector" :-
* حركة الإلكترونات من الباعث للجامع بتولد تيار I_{nC}
* حركة الفجوات من الجامع للقاعدة بتولد تيار I_{pC}
* حركة الإلكترونات من القاعدة للجامع بتولد تيار I_{CB}
* تيار الجامع الكلى I_C بيساوي مجموعهم.

$$I_C = I_{nC} + I_{pC} + I_{CB}$$

* في القاعدة نسبة صغيرة من الإلكترونات بتاعت الباعث تندمج مع الفجوات و يتحدوا ايه معوا مع الفجوات وكأنهم بيتحركوا لحد ما يطلعوا من القاعدة للناحية الموجبة من مصدر الطاقة و بيولدوا تيار القاعدة I_B.
* كل تيار بيتولد من إية؟

1- تيار القاعدة I_B من الإلكترونات الباعث.
2- تيار الباعث I_E من فجوات القاعدة ومن الإلكترونات الباعث
3- تيار الجامع I_C من الإلكترونات الباعث ومن فجوات الجامع ومن الإلكترونات القاعدة.

* الـ I_E هيا مجموع الـ I_B والـ I_C ، نسبة I_C على I_B = β
، نسبة I_C على I_E هيا = α

$$\cdot\ \beta = \frac{I_C}{I_B} \qquad \cdot\ \alpha = \frac{I_C}{I_E}$$

$$\cdot\ I_E = I_C + I_B = \beta I_B + I_B = (\beta + 1) \cdot I_B$$

$$\cdot\ I_C = \alpha I_E = \alpha I_C + \alpha I_B$$

$$\cdot\ \alpha I_B = I_C - \alpha I_C = I_C (1 - \alpha)$$

$$\cdot\ I_C = \frac{\alpha I_B}{1 - \alpha}$$

Continue

21 / 3 / 2025 :التاريخ

Chapter 3

الموضوع: Electronics

Summary of laws

- $I_C = I_{nC} + I_{pC} + I_{CB}$ • $I_E = I_{nE} + I_{pE}$

- $I_E = I_C + I_B$ • $\beta = \frac{I_C}{I_B}$ • $\alpha = \frac{I_C}{I_E}$

- $I_E = I_C + I_B = \beta I_B + I_B = (\beta+1) I_B$

$\Rightarrow I_E = I_C + I_B = \alpha I_E + I_B = \alpha(I_C + I_B) + I_B$

$\Rightarrow I_C = \alpha I_E = \alpha(I_C + I_B) = \alpha I_C + \alpha I_B$

$\Rightarrow I_C - \alpha I_C = \alpha I_B \Rightarrow I_C(1-\alpha) = \alpha I_B$

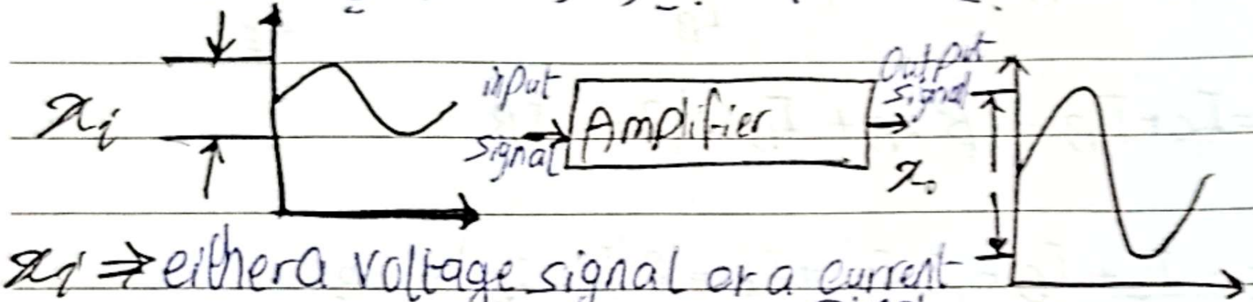
- $I_C = \frac{\alpha I_B}{1-\alpha} \Rightarrow$ • $\beta = \frac{\alpha}{1-\alpha}$, Since $I_C = \beta I_B$

- $\frac{\beta}{1+\beta} = \alpha$

Continue Chapter 3

التاريخ: 22/3/2025 الموضوع: Electronics

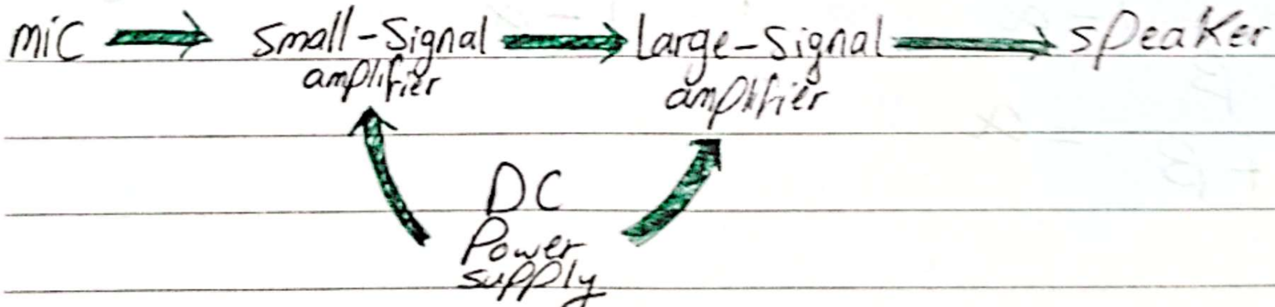
* the Application of Active mode BJT is Amplifier:-
* Amplifier is a device which used to increase the amplitude of the signal applied to its input.
* المكبر هو جهاز يستخدم لتكبير اي إشارة الي داخله.



• x_i ⇒ either a voltage signal or a current signal

* Amplifier Gain "A":- the ratio of output signal to the input Signal • $A = \frac{x_o}{x_i}$

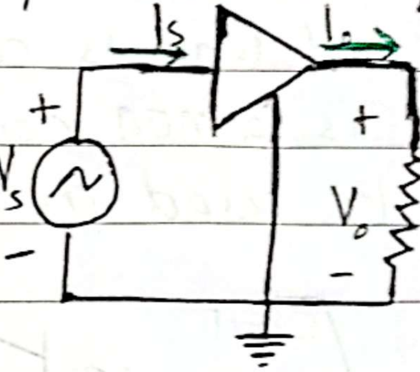
* Small signal amplifier vs. large signal amplifier:-



* Mic:- converts sound to electrical signal in microvolts/millivolts range.
* Small Signal Amplifier:- converts the millivolts signal to large output signal in the volt range and output power less than 1 watt.
* large Signal Amplifier:- produces power greater than 1 watt to the load "speaker".

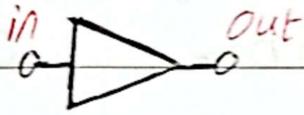
* speaker:- converts electrical signal to sound.

*in general, an amplifier has triangle symbol indicates the direction of signal flow from the input side to the output side.



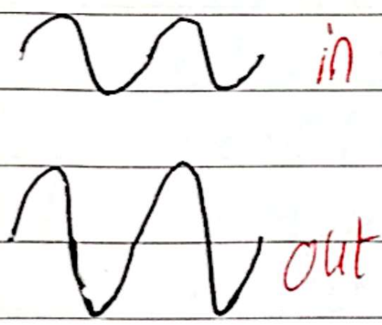
*R_{in}:- input resistance of the amplifier, is seen at the input terminal by the signal source "V_s" It is a ratio of the input voltage to the input current.

*R_{out}:- Output resistance of the amplifier, is seen at the output terminal by the load "R_L".

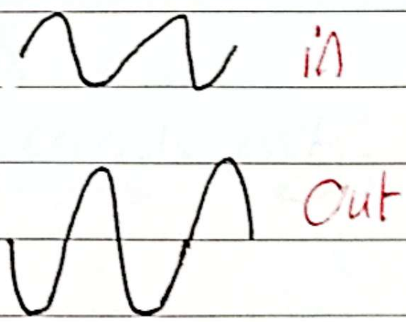


*Non-Inverting amplifier:- amplifies the signal with 0° phase shift between input & output signals.

*Inverting amplifier:- amplifies the signal with 180° phase shift between input and out signal.



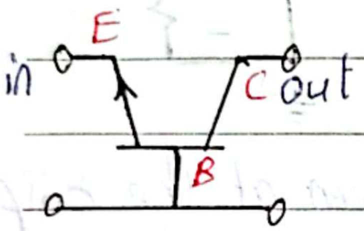
Non inverting amplifier.



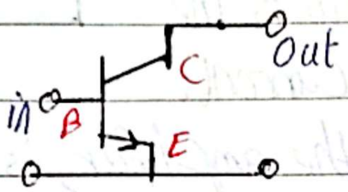
Inverting amplifier.

التاريخ: 22/3/2025 Continue Chapter 3 الموضوع: Electronics

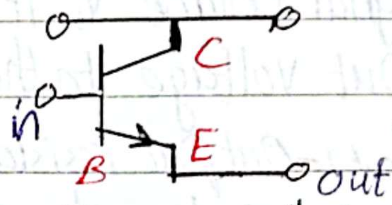
* Bipolar transistors can be connected in 3 different ways.
* in each one of the, one lead is connected to the input a second lead is connected to the output and a third lead is common connected to both input and output, and it's used as a circuit reference point



Common base



Common Emitter



Common Collector

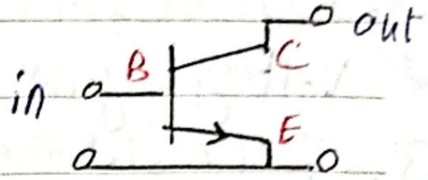
التاريخ 22/3/2025

Continue Chapter 3

الموضوع: Electronics

*Characteristics of Common-Emitter Amplifiers "CE":-

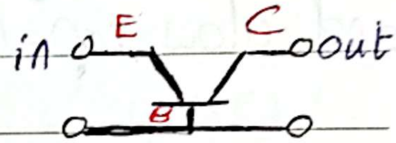
1. Current gain "A_I" is high.
2. voltage gain is high.
3. input resistance is medium.
4. output resistance is medium.



*Applications:- of the three Configrations the CE amplifier alone is capable to Provide both voltage gain and current gain, Hence, the CE amplifier is widely used for amplifications purpose.

* Characteristics of common-base amplifiers:-

1. Current gain is less than unity
2. Voltage gain "A_v" is high.
3. the input resistance is the lowest of all 3 configrations.
4. The output resistance R_o is the Highest of all 3 configrations.

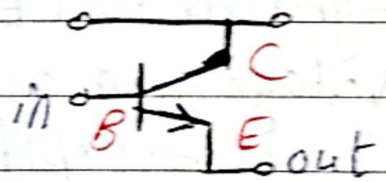


* Applications:- the CB amplifier is not commonly used for amplifacations purpose, It is used for:-

1. matching low impedance source
2. as an amplifier with a voltage gain exceeds unity.
3. for driving a high impedance load.
4. as a constant current source.

*المقاومة الـ R_{in} بتبقى متوصلة قبل الـ input على طول ونفس الكلام للـ R_{out}

*Characteristics of Common collector Amplifiers:-
1. Current gain is high and almost equal to CE Gain
2. Voltage gain is less than unity.
3. input resistance is the highest of all 3 of them
4. output resistance is the lowest of all 3 of them



*Applications:- The CC amplifier is commonly used as a buffer stage between a high impedance source and a low impedance source. معاوقة

*Cutoff mode of NPN BJT:- external dc voltages are applied to set BEJ and BCJ to reverse biasing.
*all the terminal currents are zero and the BJT acts like an open switch. $I_E = I_C = I_B =$ zero

*Saturation mode of NPN BJT:- In saturation mode, external DC voltages are applied to set BEJ and BCJ to forward biasing, and the BJT acts like a closed switch.
*when the base-emitter junction becomes forward biased, the base current is increased "I_B" the collector current is also increased ($I_C = \beta I_B$) and "V_{CE}" decreases as a result of more voltage drop across the collector resistor ($V_{CE} = V_{CC} - I_C R_C$)

• $V_{CE} = V_{CC} - I_C R_C$

⇒ V_{CE} → the voltage between the collector and emitter.
⇒ V_{CC} → the supply voltage.
⇒ I_C → the collector current.
⇒ R_C → the collector resistance.

V_{CE} in saturation mode $= 0.2$ V

and $V_{BE} = 0.7$ V

Chapter 1 laws summary

التاريخ: 23/3/2025 الموضوع: Electronics

* $Siemen = \frac{1}{ohm} = \frac{1}{\Omega}$

* Conductivity of intrinsic sem conductor "σ" = zero at $0K = -273\,C$
- $n_i^2 = n \cdot p$
- $\sigma = q(n\mu_n + p\mu_p)$
- $\sigma = q\,n_i(\mu_n + \mu_p)$ for intrinsic semiconductors only.
- $n_i = n = p$ • $n_i^2 = n^2 = p^2$ for intrinsic semiconductors only.

- $J = \sigma \cdot E = \sigma \cdot \frac{V}{L} = q \cdot (n\mu_n + p\mu_p) \cdot \frac{V}{L} = q(n\mu_n + p\mu_p) \cdot \frac{R \cdot I}{L} = \frac{I}{A}$

* N-type Semiconductors:-
- $n = N_D$, $p = \frac{n_i^2}{N_D}$
- $\sigma = q n \mu_n = q N_D \mu_n$

* P-type Semiconductors:-
- $p = N_A$, $n = \frac{n_i^2}{N_A}$
- $\sigma = q p \mu_p = q N_A \mu_p$

* in case of Si or Ge + N_A + N_D:-
- $N_D + p = n + N_A$

- $V_d = \mu_n \cdot E$
- $\rho = \frac{1}{\sigma}$

*لو الفرق في الأس بين N_A, N_D أقل من 2 ، نستخدم القانون ده ← $p + N_D = n + N_A$

*لو الفرق في الأس بين N_A, N_D أكبر من أو يساوي 2 ، شوف أنهي أكبر عشان تعرف هي N-type ولا P-type.

Continue Chapter 1

* Symbols meaning :-

- n → free electrons concenteration
- p → Holes concentration.
- n_i → intrinsic carrier Concentration.
- μ_n → free electrons mobility
- μ_p → Holes mobility.
- q → electron charge $= 1.6 \times 10^{-19}$
- E → Electric field
- σ → conductivity.
- ρ → resistivity
- V → Voltage
- L → distance between two Points
- R → resistance
- I → current
- A → Cross sectional area of the conductor.
- N_A → Acceptor Atoms concentration.
- N_D → Donor Atoms concentration.
- V_d → drift velocity.

→ remember :-

* if $ax^2 + bx + c = 0$ then :-

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Continue Chapter 1

23/3/2025 التاريخ:

الموضوع: Electronics

* Constants :-

→ for Si :-

- $n_i = 1.5 \times 10^{10}$ atoms/cm^3
- $\mu_n = 1300$ cm^2/V.s
- $\mu_p = 500$ cm^2/V.s
- number of atoms per cm^3 = 5×10^{22}

→ for Ge :-

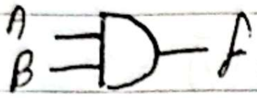
- $n_i = 2.5 \times 10^{13}$ atoms/cm^3
- $\mu_n = 3800$ cm^2/V.s
- $\mu_p = 1800$ cm^2/V.s
- number of atoms per cm^3 = 4.4×10^{22}

Chapter 4: Digital Circuits

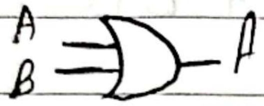
التاريخ: 13/4/2025 الموضوع: Electronics

* Types of logic gates:-

* AND Gate $(A \cdot B)$:- Outputs 1 only if all inputs are 1.



* OR Gate $(A+B)$:- Outputs 1 if at least one input is 1.



* NOT Gate $(\bar{A})$:- Inverts the input (if it's 1 it gives 0, and if it's 0 it gives 1).

"Truth table"

C	B	A	F(AND)	F(OR)
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	0	1
1	0	0	0	1
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

التاريخ: 13/4/2021 Continue الموضوع: Electronics

* Boolean Algebra rules:-

* $A+0=A$ * $A\cdot 1=A$ * $A+1=1$ * $A\cdot 0=0$

* $A+A=A$ * $A\cdot A=A$ * $A+\bar{A}=1$ * $A\cdot\bar{A}=0$

* $A+B=B+A$ * $A\cdot B=B\cdot A$ * $(A+B)+C=A+(B+C)$

* $(A\cdot B)\cdot C=A\cdot(B\cdot C)$ * $A\cdot(B+C)=A\cdot B+A\cdot C$

* $A+(B\cdot C)=(A+B)\cdot(A+C)$ * $A+A\cdot B=A$

* $A\cdot(A+B)=A$ * $A\cdot B+A\cdot\bar{B}=A=A\cdot(B+\bar{B})$

* $(A+B)\cdot(A+\bar{B})=A(A+B)+\bar{B}(A+B)=A\cdot A+A\cdot B+A\cdot\bar{B}+\bar{B}\cdot B$
$=A+A+0=A$

* $\overline{(A+B)}=\bar{A}\cdot\bar{B}$ * $\overline{(A\cdot B)}=\bar{A}+\bar{B}$

1.2 Introduction to number Systems

9 / 5 2025 :التاريخ   الموضوع: ELECTRONICS

* characteristics to define a number system:-
1. the number of Independent digits used in the number System.
2. the place values of the different digits constituting the number.
3. the maximum numbers that can be written with the given number of digits.

* the radix "base" of the number system:- the number of independent digits used in the number System, like:-
⇒ the decimal number System radix = 10, So it has 10 digits:-
1 2 3 4 5 6 7 8 9 0
⇒ the binary number System radix = 2, So it has 2 digits:-
0 1
⇒ the octal number System radix = 8, So it has 8 digits:-
0 1 2 3 4 5 6 7
⇒ the hexadicimal numbersystem radix = 16, So it has 16 digit:-
0 1 2 3 4 5 6 7 8 9 A B C D E F

* the place values of different digits in the integer part of a number are given by "$r^0, r^1, r^2, r^3, \ldots$", for the Fractional part these are "$r^{-1}, r^{-2}, r^{-3}, r^{-4}, \ldots$".
* the maximum numbers that can be written with "n" digits in a given number System are equal to "r^n".

1.3 Decimal Number System

9/5/2025 :التاريخ — الموضوع: Electronics

* it has a radix of 10, therefor it has 10 different digits:-

0 1 2 3 4 5 6 7 8 9

* the place values in a decimal number System:-

10^5	10^4	10^3	10^2	10^1	10^0	.	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}

* the value "magnitude" of a given decimal number can be given as the sum of various digits multiplied by their place values like this:-

Ex 3586.265 is:-

$3586 = 6 \times 10^0 + 8 \times 10^1 + 5 \times 10^2 + 3 \times 10^3$

$0.265 = 2 \times 10^{-1} + 6 \times 10^{-2} + 5 \times 10^{-3}$

1.4 Binary Number System

التاريخ: 9 / 5 / 2025 الموضوع: Electronics

* is a radix-2 number System with "0", "1" as the two independent digits.

* the Place values in a binary number System:-

2^5	2^4	2^3	2^2	2^1	2^0	.	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}

* the binary numbers from 0 to 64 are represented like this:-

0	1101	11010	100111	110100
1	1110	11011	101000	110101
10	1111	11100	101001	110110
11	10000	11101	101010	110111
100	10001	11110	101011	111000
101	10010	11111	101100	111001
110	10011	100000	101101	111010
111	10100	100001	101110	111011
1000	10101	100010	101111	111100
1001	10110	100011	110000	111101
1010	10111	100100	110001	111110
1011	11000	100101	110010	111111
1100	11001	100110	110011	1000000

1.7.1 Binary number System

9 / 5 / 2022 التاريخ: الموضوع: Electronics

*Bits:- the smallest unit of information, an abbreviation of the term "Binary digit", & it is either "0" or "1".

*Bytes:- a byte is a String of 8 bits, the byte is the basic unit of data operated upon a single unit in computers

*the 1's complement of a binary number is obtained by Complementing all its bits, i.e by replacing each "0" with "1" & each "1" with "0":-

⇒ $(10010110)_2$ 1's Complement = $(01101001)_2$

*the 2's complement of a binary number is obtained by adding 1 to its 1's complement:-

⇒ $(10010110)_2$ 2's complement = $(01101010)_2$

1.7.2 Decimal Number System

9 5 2025 Electronics

* Corresponding to the 1's & 2's complement in the binary number System. Decimals has a 9's & 10's Complements.

* 9's Complement:- Obtained by subtracting each digit from 9 for Example:-

$(2496)_{10}$ 9's complement = $(7503)_{10}$

* 10's complement:- Obtained by adding 1 to the 9's complement, like:-

$(2496)_{10}$ 10's complement = $(7504)_{10}$

1.8.1 Sign Bit Magnitude

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* in eight bit representation of a binary number we take the last bit to represent the sign:-

if $(+9)_{10} = (00001001)_2$

then $(-9)_{10} = (10001001)_2$

* An n-bit binary representation can be used to represent decimal numbers in the range:-

$$-(2^{n-1}-1) \text{ to } +(2^{n-1}-1)$$

* So 8-bits ranges from -127 to $+127$

1.8.2 1's Complement

التاريخ: 9 5 2025 — الموضوع: Electronics

* the Positive numbers remains unchanged.
* the negative numbers are obtained by taking the 1's complement of the positive counterparts:-

$$(-9)_{10} = (10001001)_2 \xrightarrow[\text{1's complement}]{} (11110110)_2$$

1.8.3 2's Complement

* the positive numbers only we add 1 to them to represent their 2's complement.
* the negative numbers are oplained by taking the 2's complement of their counter parts.

* the 2's complement of the magnitude of -9 equals $+9$

1.9.1 Binary-to-decimal Conversion

التاريخ: 9/5/2025 الموضوع: Electronics

* to convert a binary number to decimal multiply each number by it's place value:-

$(1001.0101)_2 =$

$(1001)_2 = 1\times2^0 + 0\times2^1 + 0\times2^2 + 1\times2^3 = 1+8 = 9$

$(0.0101)_2 = 0\times2^{-1} + 1\times2^{-2} + 0\times2^{-3} + 1\times2^{-4} = 0.25 + 0.0625$
$= 0.3125$

$9 + 0.3125 = 9.3125$

$(1001.0101)_2 = (9.3125)_{10}$

1.10 Decimal to Binary Conversion

التاريخ: 9/5/2025 — الموضوع: Electronics

*for the Integer Part the binary equivlant can be found by successfully dividing the integer Part of the number by 2 & recording the remainders until the quotient becomes "0", then the remainders are written in a reverse order.

*for the fractional part its found by successfully multiplying the fractional decimal Part by 2 & recording the carry until the result is "0", the carry sequence in forward order constitutes the binary equivlant of the fractional Part of the decimal number.

Ex. find the binary equivlant of $(13.375)_{10}$:-

*Integer Part :-

2	13	-
2	6	1
2	3	0
2	1	1
	0	1

$(13)_{10} = (1101)_2$

*fractional Part :-

$0.375 * 2 = 0.75$	0
$0.75 * 2 = 0.5$	1
$0.5 * 2 = 0.0$	1

$(0.375)_{10} = (0.011)_2$

$(13.375)_{10} = (1101.011)_2$

2.1.1 BCD to Binary Conversion

9 5 2022 التاريخ: الموضوع: Electronics

first write its decimal equivlant & then convert it to binary "but digit by digit" like this

$(0010\ 1001.0111\ 0101)_{BCD}$ to binary:-

0010	1001	.	0111	0101
↓	↓	↓	↓	↓
2	9	.	7	5

$(0010\ 1001.0111\ 0101)_{BCD} = (29.75)_{10}$

2	29	-
2	14	1
2	7	0
2	3	1
2	1	1
-	0	1

$(29)_{10} = (11101)_2$

$0.75 * 2 = 0.5$ 1

$0.5 * 2 = 0.0$ 1

$(0.75)_{10} = (0.11)_2$

$(0010\ 1001\ .0111\ 0101)_{BCD} = (11101.11)_2$

2.1.2 Binary to BCD Conversion

التاريخ: 9 / 5 / 2025 — الموضوع: Electronics

* write the given Binary numbur in decimal form the BCD "by turning each digit to binary":-

Ex. 10101011.101 to BCD:-

to decimal

$(10101011.101)_2 = (1\times2^0 + 1\times2^1 + 0\times2^2 + 1*2^3 + 0*2^4 + 1*2^5 + 0*2^6 + 1*2^7 + 1*2^{-1} + 0*2^{-2} + 1*2^{-3})_{10} = (171.625)_{10}$

1, 2, 8, 32, 128, 0.5, 0.125

to BCD:-

1	7	1	.	6	2	5
0001	0111	0001	.	0110	0010	0101

$(10101011.101)_2 = (000101110001.011000100101)_{BCD}$

3.1 Basic Rules of Binary Addition & Subtraction

التاريخ: 9 / 15 / 2025   الموضوع: Electronics

* Basic Rules of binary Addition:-

- $0+0=0$
- $0+1=1$
- $1+0=1$
- $1+1=0$ with a carry of 1
- $1+1+1=1$ with a carry of 1

* Basic Rules of Binary Subtraction:-

- $0-0=0$
- $1-0=1$
- $0-1=1$ with a borrow of 1 from the next more significant bit
- $1-1=0$

* 2's complement representation = Binary representation

3.2.1 Addition using the 2's complement Method.

التاريخ: 9 15 كلّه   الموضوع: Electronics

* we have 4 different Cases:-
1. Both the numbers are Positive.
2. larger of two numbers is positive.
3. larger of two numbers is negative.
4. Both the numbers are negative.

* for positive numbers 2's complement means the binary representation

* Case 1:- (37+18) =

00100101	=	37
00010010 +	=	18 +
00110111	=	55

* Case 2:- (37 + (-18)) =

```
 1 1  11
 00100101
 11101110 +
100010011
```

final carry

we remove the final carry so :- $(00010011)_2 = (19)_{10}$

* Case 3:- (-37 + 18) =

```
 11011011
 00010010 +
 11101101
```

→ which is in the 2's complement form is -19

$(10010011)_2 = -19$, if the first bit is for the sign

* Case 4: (−37 + (−18)) =

```
   1 1
 1110 1110
 1101 1011  +
 ----------
1 1100 1001
```

* Since there is an over flow of 1 it's negative

$(11001001)_2 \Rightarrow (1011\ 011\ 1)_2 = (-55)_{10}$

3.2 Addition of larger-bit Binary numbers

```
  01010111
  10101000  +
 ------------
 (11111111)_2 = (255)_10

     1      1 1
  1 1 0 1 0 0 1 1 0
  0 0 0 1 0 1 1 1 1  +
 --------------------
 (1 1 1 0 1 1 1 0 1)_2 = (237)_10
```

3.3 Subtraction of larger-bit binary number

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* we use the binary Subtraction Rules.
* wherever the bit to be subtracted is larger than the bit we are subtracting from it we borrow from the next adjacent higher bit position a "1".

*Ex $(1100)_2 - (1001)_2 =$

$$\begin{array}{rrrrl} & 0 & \overset{1}{\cancel{10}} & 10 & \\ 1 & \cancel{1} & \cancel{0} & \cancel{0} & \\ 1 & 0 & 0 & 1 & - \\ \hline 0 & 0 & 1 & 1 & \end{array}$$

3.3.1 Subtraction Using 2's complement Arthimitic

* subtrahend:- the bit to be subtracted
* minuend:- the bit we are subtracting from it

minuend - Subtrahend = result

* Here we have 6 Cases:-

1. minuend & Subtrahend are Positive, the subtrahend is the smallest.
2. minuend is positive, So as the subtrahend, the subtrahend is the largest.
3. minuend is Positive, subtrahend is negative & Smaller in magnitude.
4. minuend is Positive, subtrahend is negative & bigger in magnitude
5. both are negative, the minuend is the smallest.
6. both are negative, the minuend is the largest.

Continue

التاريخ: / /   الموضوع:

* Case 1 :- (24 - 14) =

$$\begin{array}{r} 0\,0\,0\,1\,1\,0\,0\,0 \\ 0\,0\,0\,0\,1\,1\,1\,0\ - \\ \hline 0\,0\,0\,0\,1\,0\,1\,0 \end{array} = 10$$

* Case 2 :- (14 - 24) =

$$\begin{array}{r} 0\,0\,0\,0\,1\,1\,1\,0 \\ 1\,1\,1\,0\,1\,0\,0\,0\ + \\ \hline 1\,1\,1\,1\,0\,1\,1\,0 \end{array}$$

we get it's 2's Complement

get it's 2's complement :-

$= (10001010)_2$

* Case 3 :- (24 - (-14)) = (24 + 14) =

$$\begin{array}{r} 0\,0\,0\,1\,1\,0\,0\,0 \\ 0\,0\,0\,0\,1\,1\,1\,0\ + \\ \hline 0\,0\,1\,0\,0\,1\,1\,0 \end{array} = 38$$

* Case 4 :- (14 - (-24)) = (14 + 24) =

$$\begin{array}{r} 0\,0\,0\,0\,1\,1\,1\,0 \\ 0\,0\,0\,1\,1\,0\,0\,0\ + \\ \hline 0\,0\,1\,0\,0\,1\,1\,0 \end{array} = 38$$

9 / 5 / 2025 :التاريخ Continue الموضوع: Electronics

*Case 5:- $(-24-(-14)) = (-24+14) = (14-24) =$

$\hookrightarrow$
$$\begin{array}{r} 11101000 \\ 00001110 + \\ \hline 11110110 \end{array} \Rightarrow (10001010)_2 = (10)_{10}$$

*OR:-
$$\begin{array}{r} 00001110 \\ 11101000 + \\ \hline 11110110 \end{array}$$

get it's 2's complement $= (10001010)_2 = (-10)_{10}$

Case 6:- $(-14-(-24)) = (-14+24) = (24-14) =$

$\hookrightarrow$
$$\begin{array}{r} 11110010 \\ 00011000 + \\ \hline 11101010 \end{array}$$

$\Rightarrow$ من الآلة -14

BCD Addition in Excess-3 Code

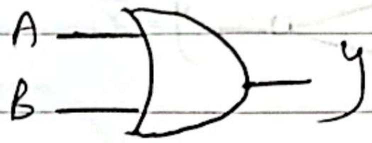
9 / 15 / 2025 التاريخ: الموضوع: Electronics

* Steps :-

1. Convert the BCD to Excess-3 by adding 0011 to each group
2. Add the two codes cesing binary addition Rules.
3. Correct if :-
   - Sum result > $(9)_{10}$ $(1001)_2$, subtract 0011
   - the group produces a carry , add 0011

4.3.1 OR Gate

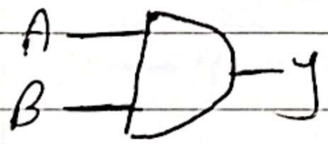
* A OR B = $A + B$ =
* returns 1 if atleast one of is the inputs is 1 & returns 0 otherwise.



A	B	y
0	0	0
0	1	1
1	0	1
1	1	1

4.3.2 AND Gate

* A AND B = $A \cdot B$ =
* returns 1 only & only if all the inputs equals 1, & returns 0 otherwise.



A	B	y
0	0	0
0	1	0
1	0	0
1	1	1

4.3.3 NOT Gate

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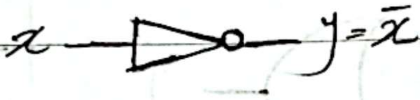
* $\bar{x} = x' = x$  $\bar{x}$
* returns the complement of the input, returns "0" if the input is "1" & return "1" if the input is "0".

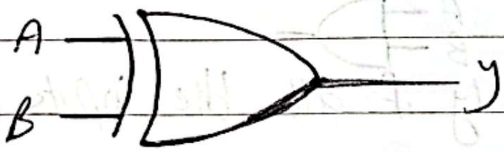


x	y
0	1
1	0

4.3.4 Exclusive OR Gate "XOR"

* $A \oplus B = \bar{A}B + A\bar{B} =$ 

* returns "1" if the inputs are different & return "0" other wise.



A	B	y
0	0	0
0	1	1
1	0	1
1	1	0

4.3.5 NAND Gate

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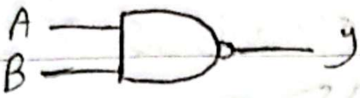
* $\overline{(A \cdot B)}$ = 

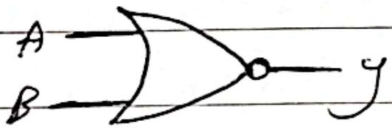
* gives 0 if all inputs are 1 & returns 1 otherwise

A	B	y
0	0	1
0	1	1
1	0	1
1	1	0

4.3.6 NOR Gate

* $\overline{(A+B)}$ = 

* gives one if all inputs = zero.

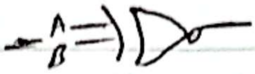


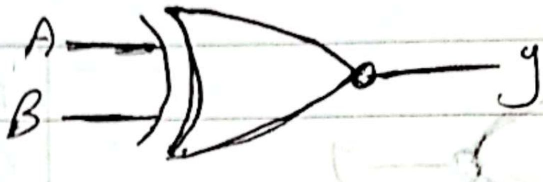
A	B	y
0	0	1
0	1	0
1	0	0
1	1	0

4.3.7 Exclusive NOR Gate

التاريخ: 10/5/2025 الموضوع: Electronics

* returns 1 is all inputs are same, & 0 otherwise.

* $\overline{(A \oplus B)} = (A \cdot B + \bar{A} \cdot \bar{B})$ 



A	B	y
0	0	1
0	1	0
1	0	0
1	1	1

6.1.1 Variables, literals & Terms in Boolean Expressions

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* Variables can take values either "0" or "1" in Boolean expressions.
* The complement of a variable is not considered as a separate variable

6.1.2 Equivalent & Complement of Boolean Expressions

* two given Boolean expressions are said to be equivalant if one of them equals "1" when the other equals "1" & also equals "0" only when the other equals zero.

Ex. get the complement of $\bar{A}\cdot B + A\cdot\bar{B}$:-

$$\bar{A}B + A\bar{B} \Rightarrow \overline{\bar{A}B + A\bar{B}} = \overline{\bar{A}B} \cdot \overline{A\bar{B}}$$

$$= (A + \bar{B})\cdot(\bar{A} + B)$$

Ex Get the Complement of $\bar{A}\cdot\bar{B} + A\cdot B$

$$\bar{A}\cdot\bar{B} + A\cdot B \Rightarrow \overline{\bar{A}\cdot\bar{B} + A\cdot B} = (\overline{\bar{A}\cdot\bar{B}})\cdot(\overline{A\cdot B})$$

$$= (A + B)\cdot(\bar{A} + \bar{B}$$

A Summary of Boolean Algebra rules

التاريخ: 13 / 5 / 2021 الموضوع: Electronics

"+" → OR "•" → AND "~", "¬", "‾", "!" → NOT

*** Identity Rules:-**

* $A + 0 = A$ * $A \cdot 1 = A$

*** NULL "Domination" laws:-**

* $A + 1 = 1$ * $A \cdot 0 = 0$

*** Idempotent laws:-**

* $A + A = A$ * $A \cdot A = A$

*** Complement laws:-**

* $A + \bar{A} = 1$ * $A \cdot \bar{A} = 0$

*** Double Negation law:-**

* $\neg(\neg A) = A = \bar{\bar{A}} = !!A$

*** Commutative laws:-**

* $A + B = B + A$ * $A \cdot B = B \cdot A$

*** Associative laws:-**

* $(A + B) + C = A + (B + C)$ * $(A \cdot B) \cdot C = A \cdot (B \cdot C)$

*** Distributive laws:-**

* $A \cdot (B + C) = A \cdot B + A \cdot C$ * $A + (B \cdot C) = (A + B) \cdot (A + C)$

*** Demorgans laws:-**

* $\neg(A + B) = \neg A \cdot \neg B$ * $\neg A \cdot B = \neg A + \neg B$

*** Absorbation laws:-**

* $A + (A \cdot B) = A$ * $A \cdot (A + B) = A$

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تعارف إنها زي ال "Absorbation" بس ، عمل إيه هي مكتوبة مرتين

*Redundancy Laws:-

* $A + A \cdot B = A$
* $A \cdot (A + B) = A$

*Consensus Theorem:-

* $A \cdot B + \bar{A} \cdot C + B \cdot C = A \cdot B + \bar{A} \cdot C$

*Definition of "XOR":-

$A \oplus B = (A \cdot \bar{B}) + (\bar{A} \cdot B)$

*inverse :- $A \oplus 1 = \neg A$

*Zero-Sum "Cancelation" :- $A \oplus B \oplus B = A$

*Complement law:- $A \oplus \neg B = \neg (A \oplus B)$

6.6.1 Construction of a Karnaugh Map

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* a Karnaugh Map is a graphical representation of the logic System, It can be drawn directly from the either min-term (sum-of-products) or max term (Product-of-sums) Boolean expressions.

* An n-variable Karnaugh Map has "2^n" Squares, & each Possible input is allotted a square, * In the case of a minterm Karnaugh Map, "1" is placed in all those squares for which the output is "1", & "0" is placed in all those squares for which the output is "0", "0"s are omitted for simplicity", "An "X" is placed in squares Corresponding to "don't care" conditions", * In the case of a maxterm Karnaugh Map "a "1" is placed in squares for which the output is "0"", and a "0" is placed for input entries corresponding to a "1" output", & also here "0"s are omitted for Simplicity" & "an "X" is placed in squares corresponding to "don't care" conditions" *

* يعني من الآخر - في حالة ال "minterm" :-

1- بنحط "1" في ال "K-map" لو ال "output" بـ "1".

2- بنحط "0" في ال "K-map" لو ال "output" بـ "0".

3- بنخفي ال "0" من الرسمة للتبسيط.

4- بنحط "X" في الأماكن اللي عندها حالة ال "don't care"

Continue

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* بالنسبة لل "maxterm" :-

1- بنحط "1" في ال "k-map" لو ال "output" ب "0".

2- بنحط "0" في ال "k-map" لو ال "output" ب "1".

3- بنحذف ال "0" في الرسمة للتبسيط.

4- بنحط "X" في الأماكن الي فيها حالة ال "don't care".

K-Maps

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* why K-maps?

⇒ Better & More Precise than Boolean Algebra.

* K-Maps only works for 5-variables at most.

* K-maps is a way to simplify Boolean expressions graphically → without having any doubt that it's in the simplist form.

* K-Maps "How to use":-

1. Make a table with a "2^n" squares in it ("n" is the variables count)
2. We number the squares like this:-

* for 2 variables:- ← بنحط احتمالات قيم كل متغير *

y \ x	0	1
0		
1		

* for 3 variables:- ← لازم وانت بترتب دول تغير قيمة واحدة كل ما تتحرك خانة *

z \ xy	00	01	11	10
0				
1				

* for 4 variables:-

zE \ xy	00	01	11	10
00				
01				
11				
10				

13/5/2025 التاريخ: Continue المضوع: Electronics

3. For each term, mark it wit 1 on the K-map:-

Ex $xyz + xy + xyzE + x$

zE \ xy	00	01	11	10
00	(0) 0	(1) 0	(3) 0	(2) 0
01	(4) 0	(5) 0	(7) 0	(6) 0
11	(12) 1	(13) 1	(15) 1	(14) 1
10	(8) 1	(9) 1	(11) 1	(10) 1

So $x, y, z \rightarrow$ Marked with 1
$\bar{x}, \bar{y}, \bar{z} \rightarrow$ Marked with 0

4. Group each 1's Group if they are next to each other & can be divided by 2 {8, $\cancel{6}$, 4, 2}
from 8 to 2 Ex:-

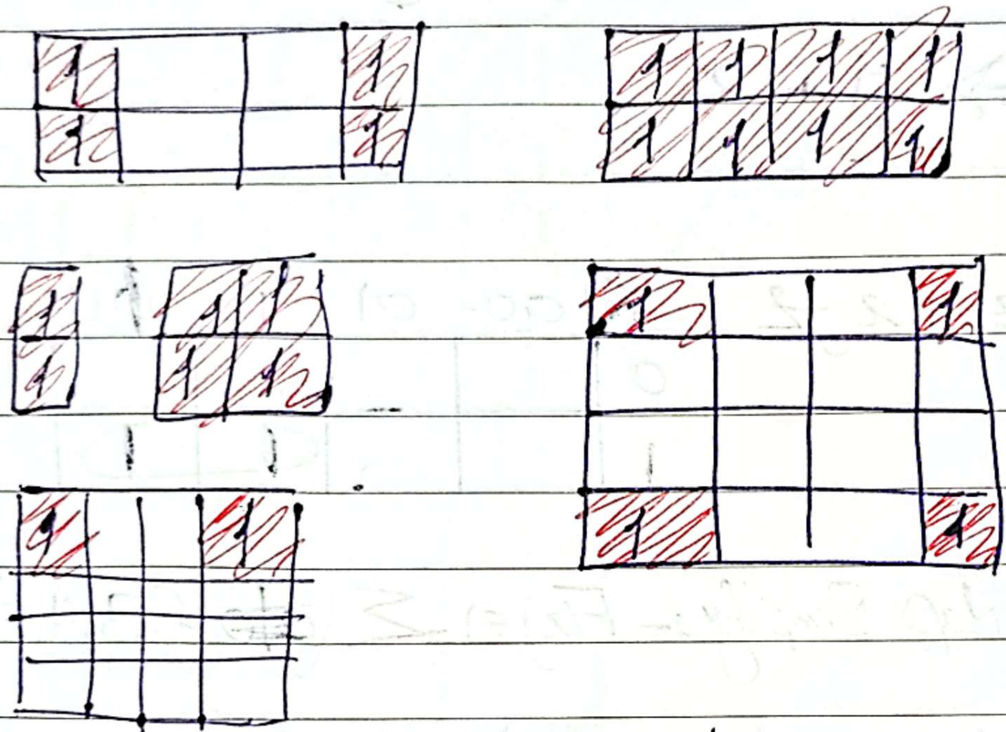
zE \ xy	00	01	11	10
00	(0) 1	(1)	(3)	(2) 1
01	(4)	(5) 1	(7)	(6)
11	(12) 1	(13)	(15) 1	(14)
10	(8) 1	(9)	(11) 1	(10)

5. write their corresponding values like this:-

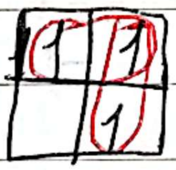
$xyz + \bar{x}\bar{y}\bar{z} + \bar{y}\bar{z}\bar{E} + \_\_$

التاريخ: 13, 5, 2022 Continue الموضوع: Electronics

*Shapes you can make:-



*Interception may occur but remember to take all ones



Continue

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Ex. $F = \bar{x}y + x\bar{y} + xy$, Simplify using K-map:-

$y \backslash x$	0	1
0	0	1
1	1	1

$\Rightarrow y + x$

Ex. $F = x\bar{y}z + xyz$

$z \backslash xy$	00	01	11	10
0				
1			1	1

$\Rightarrow xz$

Ex. Using K-map Simplify:- $F(x,y,z) = \Sigma(2,3,4,5)$

$= f = \Sigma(010, 011, 100, 101)$

$z \backslash xy$	00	01	11	10
0		1		1
1		1		1

$\Rightarrow x\bar{y} + \bar{x}y = x \oplus y$

Ex. $f(x,y,z) = \Sigma(3,4,6,7)$, Simplify using K-map:-

$= f = \Sigma(011, 100, 110, 111)$

$z \backslash xy$	00	01	11	10
0			1	1
1		1	1	

$\Rightarrow x\bar{z} + yz$

13/5/2025 :التاريخ Continue الموضوع: Electronics

Ex. Simplify $f=\bar a\bar b\bar c+\bar b c\bar d+\bar a b c\bar d+a\bar b\bar c$, using Kmap

cd \ ab	00	01	11	10
00	1			1
01	1			1
11				
10	1	1		1

$=\bar b\bar d$

cd \ ab	00	01	11	10
00	1			1
10	1	1		1
11				
01	1			1

$\Rightarrow \bar b\bar c+\bar a d\bar c+a d\bar b$

Ex. Simplify $y=\bar A\bar B\bar C D+\bar A B C\bar D+A B\bar C\bar D+A\bar B\bar C D$, using Kmap.

CD \ AB	00	01	11	10
00			1	1
10		1		
11				
01	1			1

$\Rightarrow AB\bar C\bar D+\bar A B C\bar D+\bar B\bar C D$

5 Variables K-Map

التاريخ: 13/5/2025 الموضوع: Electronics

* ممكن نعتبره 3d array كدة : $f(E,a,b,c,d)$

cd \ ab	00	01	11	10
00	0	1	3	2
01	4	5	7	6
11	12	13	15	14
10	8	9	11	10

$E=0$

cd \ ab	00	01	11	10
00	16	17	19	18
01	20	21	23	22
11	28	29	31	30
10	24	25	27	26

$E=1$

* دلوقتي أعمل ال Group لو نفس المكان بس لكل مختلف.

Ex. $f(a,b,c,d,e) = \bar{a}\bar{b}\bar{c}\bar{d} + \bar{b}\bar{c} + ab\bar{c} + ab\bar{e}$
$+ aeb + \bar{a}d + ad$

cd \ ab	00	01	11	10
00	1		1	1
01	1	1	1	1
11	1	1	1	
10			1	1

$e=0$

cd \ ab	00	01	11	10
00	1		1	1
01	1	1	1	1
11	1	1	1	
10			1	1

$e=1$

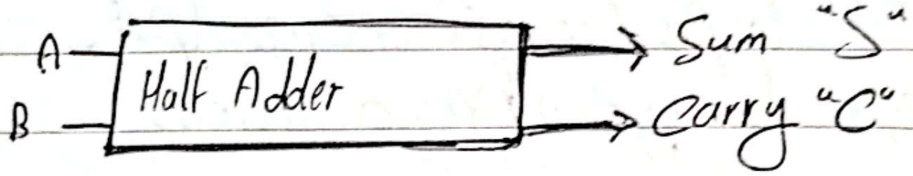
$$ab + \bar{b}\bar{c} + a\bar{d} + \bar{a}d$$

$$= ab + \bar{b}\bar{c} + (a \oplus d)$$

7.3.1 Half-Adder

التاريخ: 14/5 2015 الموضوع: Electronics

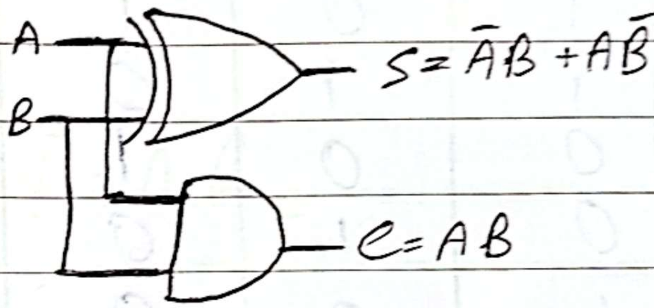
* an arithmetic circuit block that can be used to add two bits



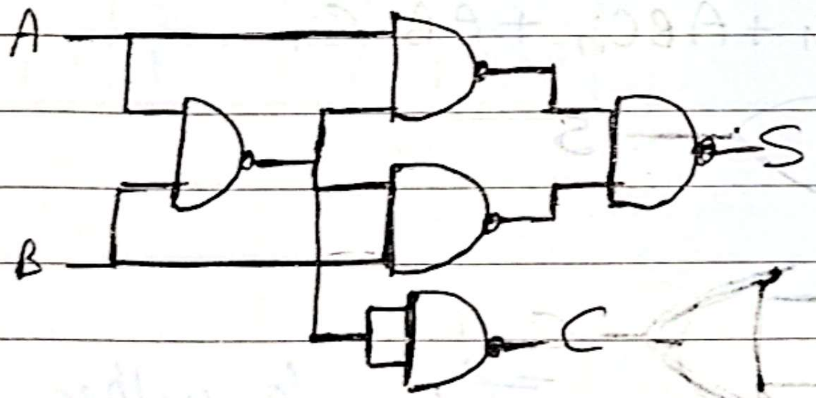
A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Sum "S" $= \bar{A}B + A\bar{B} = A \oplus B$

Carry $= A \cdot B$



* Half Adder using Nand Gates :-



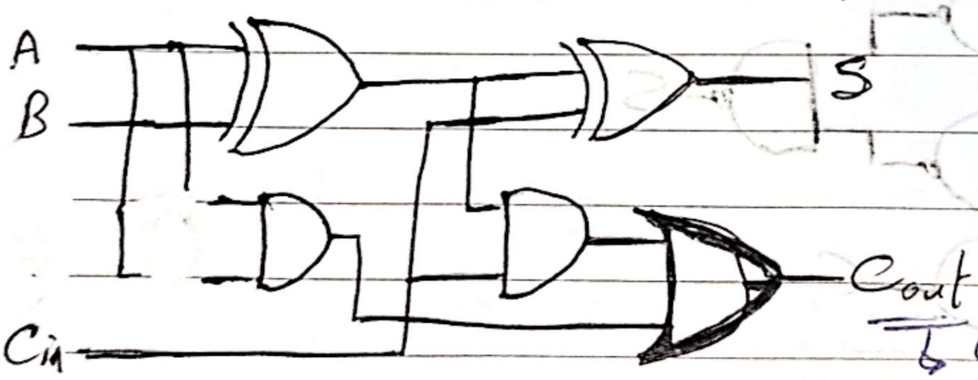
التاريخ: 14 15 2025 # 7.3.2 Full Adder الموضوع: Electronics

* an arithmetic circuit block that can be used to add three bits to produce a sum or carry output.
* used for larger binary numbers addition.

A	B	C_{in}	S	C_{out}
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

$S = \bar{A}\bar{B}C_{in} + \bar{A}B\bar{C}_{in} + A\bar{B}\bar{C}_{in} + ABC_{in}$

$C_{out} = \bar{A}BC_{in} + A\bar{B}C_{in} + AB\bar{C}_{in} + AB\,C_{in}$



↳ Goes to another Fulladder

7.3.3 Half Subtractor

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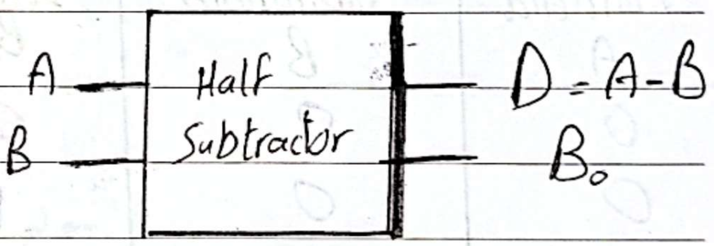
$$\text{minuend} - \text{Subtrahend} = \text{result}$$

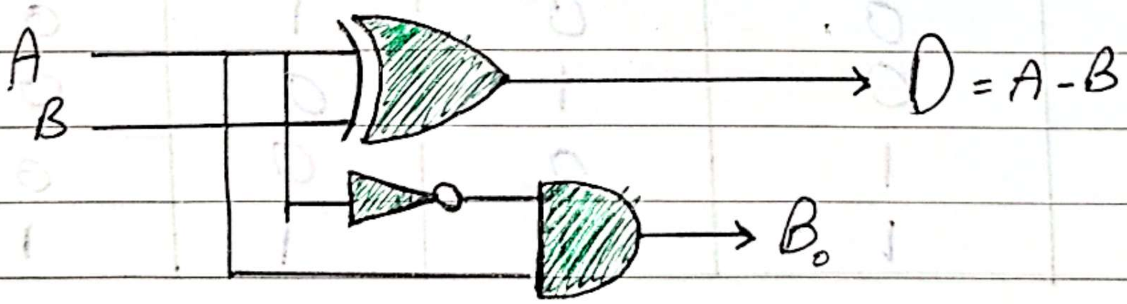
* we can also add the 2's Complement of the subtrahend to the minuend to get the same result.

* half subtractor:- a combinational circuit that can be used to subtract one binary digit from another, it produce a difference output & a borrow output the borrow specifies whether a "1" was borrowed to perform the subtraction or not.

- Difference "D" $= \bar{A}\cdot B + A\cdot\bar{B}$
- Borrow "B_o" $= \bar{A}\cdot B$

A	B	D	B_o
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0



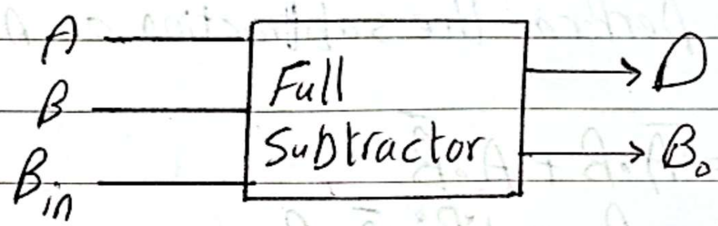


7-3.4 Full Subtractor

التاريخ: 14/5/2025 الموضوع: Electronics

* a full Subtractor perform subtraction on two bits, a minuend and a subtrahend, & it also takes in Consideration if a "1" was borrowed or not

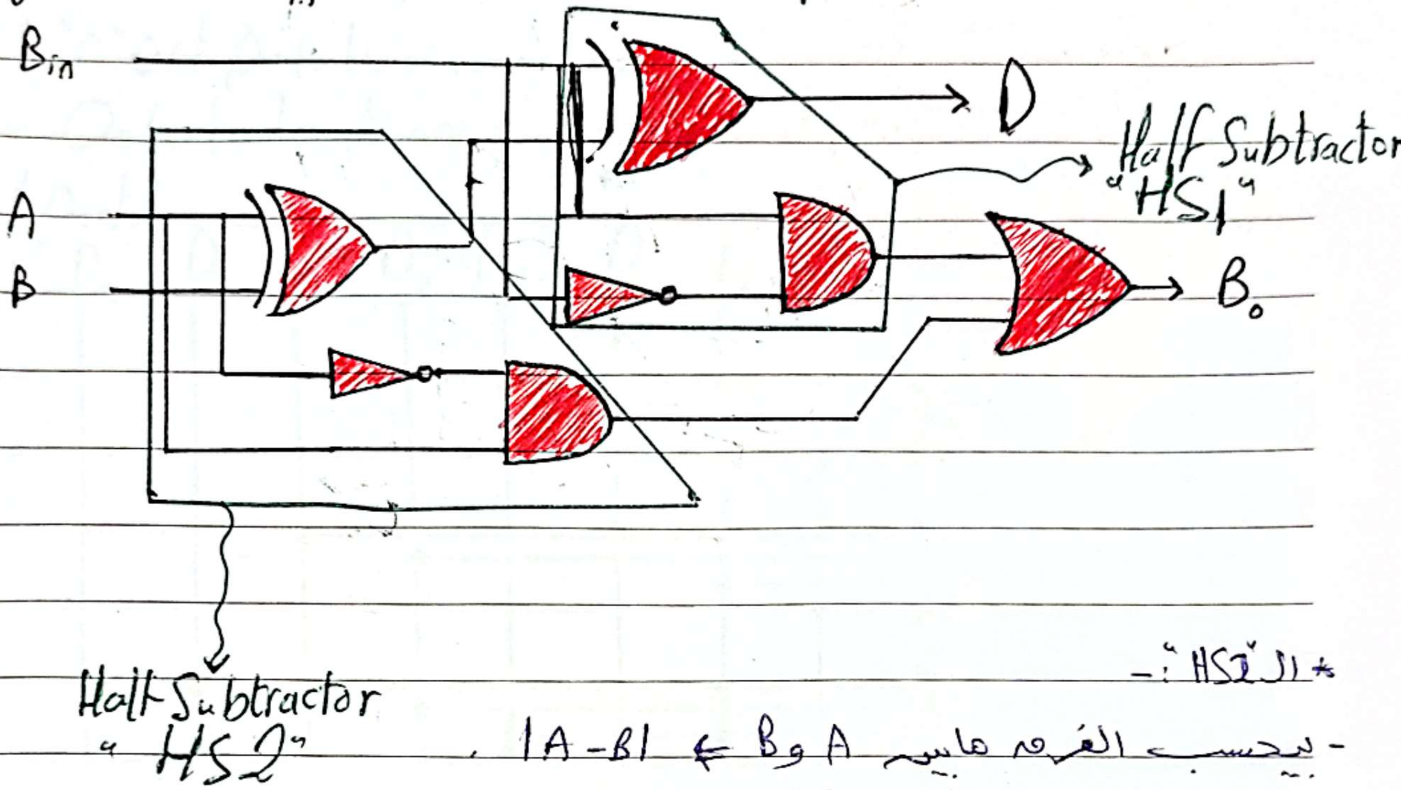
- Difference "D" = $\bar{A}\bar{B}B_{in} + \bar{A}B\bar{B}_{in} + A\bar{B}\bar{B}_{in} + ABB_{in}$
- Borrow "B_o" = $\bar{A}\bar{B}B_{in} + \bar{A}B\bar{B}_{in} + \bar{A}BB_{in} + ABB_{in}$



Minuend A	Subtrahend B	Borrow in B_{in}	Difference D	Borrow out B_o
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

التاريخ: 14 / 5 / 2025 Continue الموضوع: Electronics

* $D = \bar{A}\bar{B}B_o + \bar{A}B\bar{B}_o + A\bar{B}\bar{B}_o + ABB_o$
* $B_o = \bar{A}\cdot B + \bar{A}\cdot B_{in} + B\cdot B_{in}$ "Simplified version"



* الـ "HS2" :-
- بيحسب الفرق مابين A و B ← |A-B| .
- بيحسب هل فيه "Borrow" مابينهم ولا لأ.

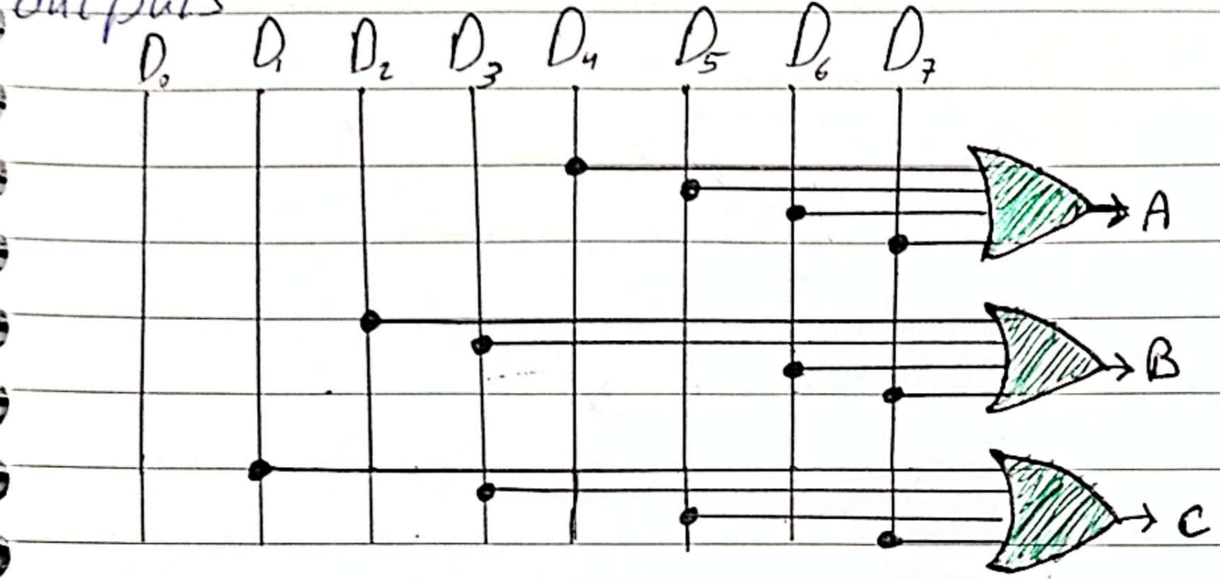
* الـ "HS1" :-
- بيحسب الفرق مابين "B_{in}" ← لو فيه "Borrow" من الـ "bit" اللي قبلها ولا لأ ، و الناتج من "HS1" (الفرق مابين A و B) ← |(A-B)-B|
- بيحسب هل فيه "Borrow" مابينهم ولا لأ.

8.2 Encoders

التاريخ: 14/5/2025 — الموضوع: Electronics

* An encoder is a multiplexer without its single output line, it's a Combinational logic function that has "2^n" or fewer input lines & "n" output lines.

* Ex. Octal to binary Encoder:- it has 8 inputs & three outputs



D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7	A	B	C
1	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	1
0	0	1	0	0	0	0	0	0	1	0
0	0	0	1	0	0	0	0	0	1	1
0	0	0	0	1	0	0	0	1	0	0
0	0	0	0	0	1	0	0	1	0	1
0	0	0	0	0	0	1	0	1	1	0
0	0	0	0	0	0	0	1	1	1	1