chapter one

1.1 Basic concepts in electricity and electronics

1.1.1 electrical circuit

All material is made up of atoms) a toms , (and atoms are made up of protons) protons)positive electric charge, neutrons(neutrons)neutral or without electric charge and electrons (electrons (Negative electric charge . The atoms are held together by a force resulting from the electrical attraction between the nuclei of the atoms and the surrounding electrons in their outer orbits . This force leads to the stability of any substance as a result of the stability of its atoms, but the case is different for individual atoms, where they are less stable.

The electronic circuit is a collection of individual electronic components, such as resistors, transistors, capacitors and crystal diodes) diode , (connected by conductive wires that can flow through which the power supply . The presence of **a closed electric circuit** allows the free electrons in the outer orbits of the atoms, as is found in metal atoms such as copper, to flow through the conducting wires, creating an electric current . This electric current arises as a result of the presence of a voltage source so that the value of this current is directly proportional to the value of the voltage source used . However, there is an electrical component known as resistance that impedes the flow of electric current and thus reduces the value of the current through the circuit.

All basic electrical or electronic circuits consist of three separate but closely related electrical quantities called : voltage, current and resistance . We will briefly explain the basic principles of these three quantities.

1.1.2Electrical voltage

voltage) **Vlt** is the potential energy of an electrical source stored in the form of an electric charge . Voltage can be thought of as a force that pushes electrons through a conductive material, and the higher the voltage, the more it can " push " electrons through a circuit . Since energy has the ability to do work, this potential energy can be described as the work required in **joules** to move electrons in the form of an electric current around a circuit from one point to another . Therefore, the greater the effort, the greater the pressure) or thrust (**and the** greater the ability to do work greater.

Voltage is always measured in terms of the difference between any two points in a circuit, and the voltages between these two points are usually referred to as " potential gradient ." Voltage is generally expressed in volts and is denoted in electrical circuits by V .There are prefixes used to denote sub-multiples of voltage such as micro - volts 10^{-6}Vand millivolts 10^{-3}V or kilo-volts 10^{3}V. The voltage value can be either positive or negative

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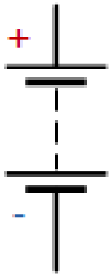


Figure **A**) **1.1**(

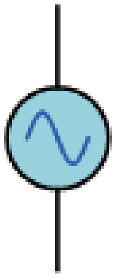


Figure **B**) **1.1**(

A voltage source with a constant value over time is called a constant voltage direct volt) (**DC** And an alternating voltage source alternating volt) (**AC** When there is a change in voltage periodically with time . The circuit symbol for a constant voltage source is usually given as the symbol for the battery) see Figure**1.1 A** (with a positive (+) and negative (-) sign indicating the direction of polarity . Circuit symbol for AC voltage source) see Fig **1.1** (is a circuit with a sine wave inside . Batteries are used mostly to produce a source of constant current constant , such as **5** volts **12** ,volts **24** ,volts, etc. in electronic circuits . While voltage sources are available**AC** .In domestic use, industrial energy, lighting as well as power transmission.

1.1.3electric current

electric current) **I** (is the movement and continuous flow of electrons drifting around the circuit that are “ pushed ” by the voltage source . Current is measured in amperes**(Amperes)** . is defined **amp** or **ampere** as the number of electrons or charge)) **Q** (Pal**Coulombs**)that passes a certain point in the circle in one second(**t** in seconds .(There are prefixes used to denote sub-multiples of current such as micro - amperes 10^{-6}Aand milli -amp10^{-3}A.

The electric current can be positive in value or negative in value depending on the direction of flow around the circuit .The current that flows in one direction is called direct current, or**DC** .The current that alternates back and forth through the circuit is known as alternating current, or**AC**.

In general, two definitions used to determine the direction of current flow in electronic circuits are conventional and real current flow direction . Conventional current flow refers to the flow of positive charge around an electric circuit . The arrows are shown in the figure **1.2 A** The movement of positive charge) holes (around a closed circuit as it flows from the positive terminal of the battery through the circuit and then back to the negative terminal of the battery) more information on the holes will be given in the next chapters .(As for the real current flow) see the arrows indicated in the figure**1.2 B** (It is the result of the flow of electrons around the circle , a reversal of the current flow idiomatic . Electrons flow in an electric circuit from the negative pole of the battery and back again to the positive pole of the battery because the electron has a negative charge and is therefore attracted to the positive terminal.

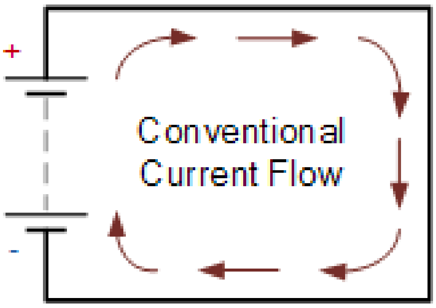


Figure **A**) **1.2**(

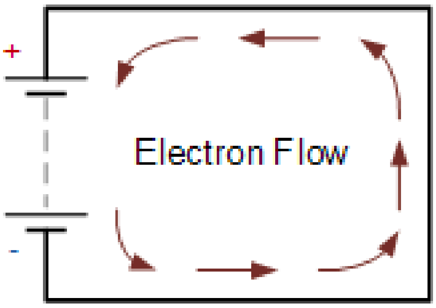


Figure **B**) **1.2**(

In any case, to facilitate the understanding of electronic circuits during our study, we will rely on the direction of the conventional current flow, that is, the current flows from the positive to the negative terminal of the battery.

1.1.4 Electrical resistance

Resistance **(R)** It is the ability of a substance to impede or prevent the flow of current, or more specifically, the flow of electric charge within an electronic circuit . A circuit element that does just this is called a " resistor ." Resistance is the circuit element measured in ohms, and is denoted by the Greek symbol) Ω ,omega) **and** with the prefixes used to denote kilo - ohms(10^3Ω (Mika- Om)10^6Ω . (It should be noted that the resistance can not be negative in its value, but only positive.

The amount of resistance of a resistor is determined by the relationship of the current through it to the voltage applied to it, which determines whether the circuit element is a " good conductor - " low resistance, or a " bad conductor - " high resistance . Low resistance, for example, **1** Ω or less indicates that in the circuit a good conductor made of materials such as copper, aluminum or carbon while high resistance,**1 M** Ω One or more means that the circuit has a bad conductor made of insulating materials such as glass, ceramic or plastic**.** The " semiconductor " **On** the other hand , such as silicon or germanium, is a material that is the value of resistance between the value of a good insulator and a good conductor . Hence the name " semiconductors ." Semiconductors are used to manufacture diodes, transistors, etc) .**the** topic of semiconductors will be discussed in Chapter Two.(

The resistor is classified **as a negative circuit element (passive element)** ,And as such can not transfer or energy storage . Instead, it absorbs energy that appears in the form of heat or light . The energy in a resistance is always positive regardless of the polarity of the voltage and the direction of the current.

Resistors in nature can be linear or non-linear, but they are never negative . Linear resistance obeys **Ohm's law** because the voltage across a resistor is directly proportional to the current through it . A non-linear resistance does not obey Ohm's law, but there is a slope in the voltage across it that is proportional to some strength of the current.

electronic circuit in shape **1.3 A** It is used to study Ohm's law . The relationship between voltage) **V** (and current) **I**)in a constant value resistance circuit(**R** (will produce a straight line relationship**IV** With a **slope** equal to the resistance value as shown in the figure**1.3 B**.

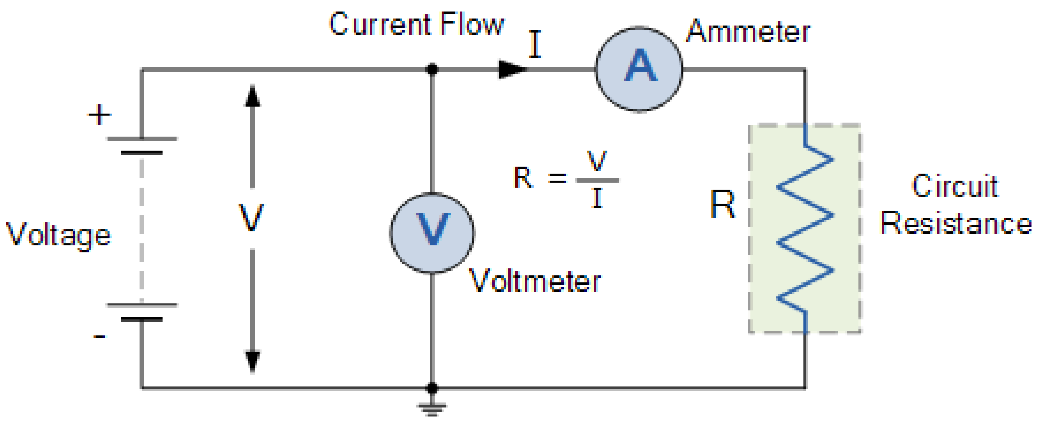


Figure **A**) **1.3**(

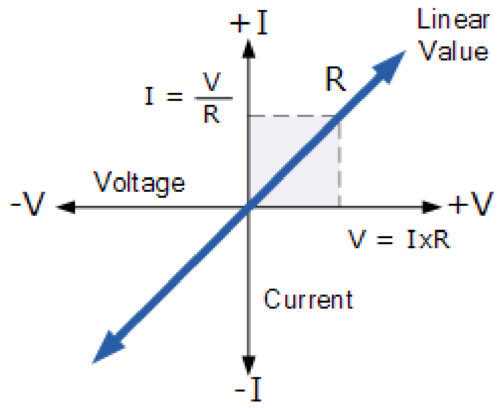
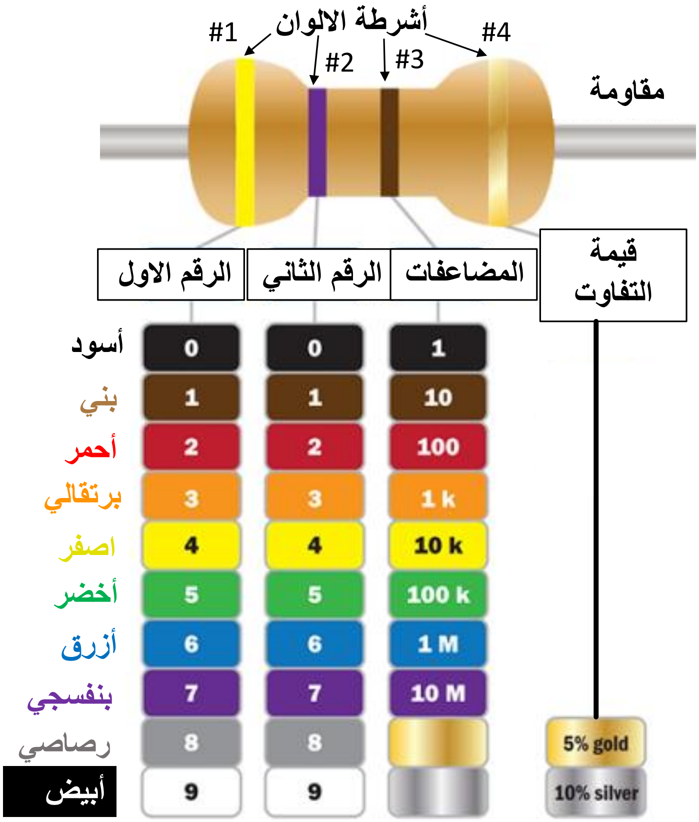


Figure **B**) **1.3**(

1.1.4.1 Read the electrical resistance

There are many different resistors in their value and types that can be used in both electrical and electronic circuits to control the flow of current or to produce voltage gradients in many different ways . But in order to do this, a real resistor needs some form of " resistance " where the resistors are available in different values ranging from fractions of ohms. to millions of ohms**.** Obviously it would be impractical to have resistors available for every possible value eg ,Ω, **1** Ω**2** , Ω**3** ,Ω , **4**etc., because tens of hundreds of thousands, if not tens of millions of different resistors, need to exist to cover all possible values . Instead, the resistors are manufactured with so-called " preferred values " with the value of their resistance printed on the body in colored ink.

So to get around this, small resistors use colored bars . These colored bands printed on the body of the resistance can tell us everything we need to know about the value and tolerance of a resistance, as long as we understand how to read it by knowing the colors because each value of the resistance has its own unique combination.



	الرقم الاول	الرقم الثاني	المضاعفات	قيمة التفاوت
أسود	0	0	1	
بني	1	1	10	
أحمر	2	2	100	
برتقالي	3	3	1 k	
اصفر	4	4	10 k	
أخضر	5	5	100 k	
أزرق	6	6	1 M	
بنفسجي	7	7	10 M	
رصاصي	8	8		5% gold
أبيض	9	9		10% silver

(**1.1**) **Figure**

Here is an example showing how the above diagram can be used **(1.1)** To find out the value of the resistance by proving that yellow-brown-violet is in fact Ω **470** We follow the following steps:

- 1 We refer to the first tape(#1) with the code **A** And the second tape (#2) NS **B** And the third (#3)NS **C** and the fourth (#4) NS **T**.

- 2 We use the following equation to calculate the resistance

Equation No(**1.1**) .

If the color of **the first bar is** yellow, which means that the leftmost number is **4** and the color of the **second** bar is violet, which means that the next number is **7** and **the** color of **the third bar** is brown . Since brown is , **1** that means adding one zero to the right of the first two numbers and **the fourth bar** The farthest to me is gold, its value is**0.05** ,if using equation No (**1.1**) .we get

)(

Although the first and second color bands are fairly straightforward, the third and fourth bands may require further explanation.

Resistor values can be a very large number, and there is often not enough space to use a bar for each number . To get around this, the third bar indicates that a certain number of zeros must be added after the first two digits to make up for the full value of the resistance . In the example above, the third bar is brown, indicating that one zero should be added to the right of the first two digits**.**

If we want to dig deeper into the calculations, this third bar is officially referred to as a multiplier . The color of the bar determines the power of **10** so we need to multiply the first two numbers of resistance by the value of the multiplier . For example, the third orange bar with a numeric value **3** indicates a multiple of.^{3} **10**

The fourth color bar indicates the varying resistance values . Tolerance is **the percentage error** in the resistance value, or how far we can expect the actual value as recorded by the manufacturer . The gold color tolerance bar is , % **5** the silver is , % **10** and the tolerance bar value if without color is**20** % **.**

for example**:**

- If the resistance value is Ω **220** and has a silver tolerance bar.
- The value of the tolerance = **the** value of the resistance **x** The value of the tolerance bar is equal to

- The resistance registered from the manufacturer is and the tolerance value is .This means that the actual resistance value ranges between its highest value to its lowest value

▪

Some projects require our measurements to be more accurate than others, which is why tolerance bars are useful in determining the resistance that will give us a more accurate resistance reading . The smaller the tolerance ratio) ie the lower the error rate , (the greater the accuracy of our measurements, but the more expensive the quality of these resistors!

1.2 Connect resistors in series and parallel in electronic circuits.

The student should review the laws of connecting resistors in series and parallel . For example, if we have 3 resistors connected to each other in series or parallel, what is required here is to find the formula by which the total resistance, the total current, the total voltage, and the voltage across the two ends of one resistance with respect to the other resistances can be calculated.

1.3 Kirchhoff's Circle Law.

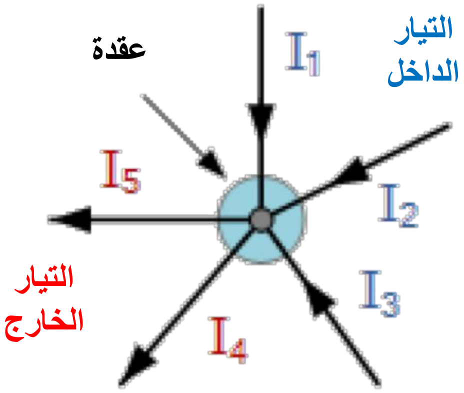
We have seen in paragraph **1.2** The above for resistors is that the total equivalent resistance ,**(RT)** It can be found when two or more resistors are connected together in parallel or in parallel, and that these circuits obey Ohm's Law . However, sometimes as in complex circuits, we simply cannot use Ohm's Law alone to find the voltages or currents that are circulating within the circuit . For these types of calculations, we need certain rules that allow us to get the equations of the circle, and for this we can use Kirchhoff's circle law.

In , **1845** German physicist Gustav Kirchhoff developed a set of rules or laws dealing with the conservation of current and energy in electric circuits . These two laws are commonly known as Kirchhoff's circuit laws with one of Kirchhoff's laws dealing with current flowing around a closed circuit, Kirchhoff's law of current, while the other law deals with voltage sources present in a closed circuit, Kirchhoff's voltage law.

1.3.1 Kirchhoff's First Law - Law of Current

Kirchhoff's Law of Current states that" **the** total of the current or charge entering a connection point or **node** is exactly equal to the charge leaving the node where it has nowhere else to go but to leave, since no charge is lost within the node ." In other words, it must be the algebraic sum of all the currents that enter and leave the node is equal to zero) ,total current) outside + (total current) inside .(**0** = (This idea is known by Kirchhoff as charge conservation, as shown in the figure**(1.4)**.

The term node in an electrical circuit generally refers to any point on a circuit where the terminals of two or more circuit elements meet.



(**1.4**) shape

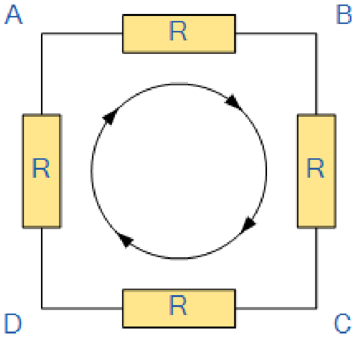
The values of the three currents entering the node ,I_1 ,I_2 ,I_3 All are positive, and the two leave the knot I_4 And I_5 negative in value . Then this means that we can also write an equation for the current as follows:

equation

number) **1.2**(or

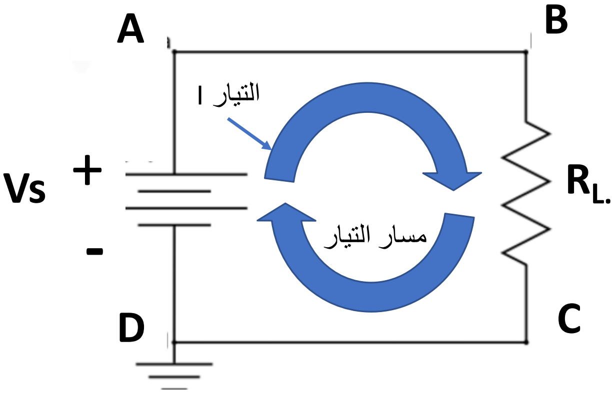
1.3.2 Kirchhoff's Second Law - Law of Effort

Kirchhoff's voltage law states that " in any closed-loop network, as shown in Fig. **1.5** , (the total voltage around the loop is equal to the sum of all voltage regressions within the loop itself ”. In other words, the algebraic sum of all voltages inside the loop must be equal to zero i.e. N .( ) This idea by Kirchhoff is known as energy conservation .



(**1.5**) shape

Kirchhoff's second law can be given in another form, which is for any closed path) a closed path *is any continuous path in the circuit that ends where it started* (*starting* from a certain point of an electrical circuit, the sum of the high voltages equals the sum of the low voltages . If the voltage and current calculations for an electrical circuit are moved from the negative pole to the positive pole of the voltage source, a rise in voltage occurs due to the increase in electrical voltage. As for the voltage drop, it occurs when the current passes from the positive pole to the negative pole of the voltage source due to the decrease in electrical voltage.



shape) 1.6(

Let's see how to apply Kirchhoff's second law to a simple circuit as shown in the figure) **1. 6** , (my agencies:

✓ Here we will have a cross-source voltage **V_s** voltage across both ends of the resistance **V_{RL}**.

✓ And because it is a simple circuit, we will have one current and its direction is in the direction of the flow of positive charge, ie in a clockwise direction, from the positive pole of the voltage source) battery (to the negative pole.

✓ Determine a reference point in the circuit from which to start the calculations . If the point is selected**A** As a reference point, moving with the **direction of the current** to the points) **B** Then **C** Then **D** then back to **A** (On the basis of which the total voltage of the circuit will be calculated as follows:

- 1 between the point **B** And **C** There is an element of resistance, if the direction of our calculations is from the point **B** to the point **C** With the direction of the current , there will be a decrease in voltage capacity) **$-V_{RL} = -IR_L$**.(

- 2 But if the calculations are done from the point **B** to the point **C** And in the opposite direction of the current ,there will be a rise in voltage i.e.)$+V_{RL} = +IR_{L}$.(

- 3 between the point **D** And **A** There is a source of voltage, since the direction of our calculations is with the direction of the current as well as we cross from the negative pole to the positive pole of the battery ,there will be a rise in voltage capacity) V_s (+Any positive voltage value, for example **5** + volts.

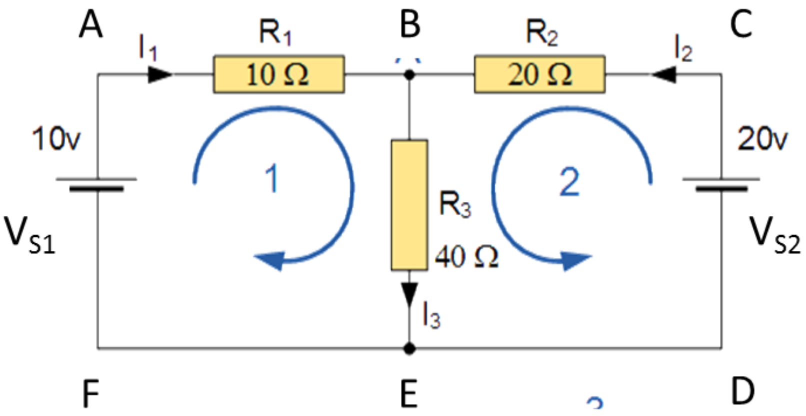
- 4 But if the direction of our calculations is with the direction of the current and we cross from the positive pole to the negative pole of the battery ,there will be a decrease in the voltage capacity) V_s (-Any positive voltage value, for example - **5**volts.

- 5 If the formula of Kirchhoff's law in the second is fulfilled, provided that it is

$V_s = V_{RL}$ or $V_s - V_{RL} = 0$

Example:(**1**)

in the figure below) **1.7** , (find the value of the **current through the** resistanceR_3 What is **the potential difference** between its two ends?



shape) **1.7**(

The circuit contains two nodes And two separate episodes . Episode No (**1**) .its path is) **A - B - E - F - A** (That is, path (**1**) is a closed path that ends where it started . And ring No (**2**) .and its path is determined as follows) **C – B – E – D – C**.(

Using Kirchhoff's current law, the current equations are given as:

equation number) **1.3** , (currents about the node**B**

equation number) **1.4** , (currents about the node**E**

Using Kirchhoff's voltage law, the voltage equations are given as:

Source voltage constant = voltage applied to the ends of any resistance within a single track CSS : ie , that

$\mathbf{V_{s1} = V_{R1} + V_{R2} = 1_{1} R_{1} + I_{2} R_{2}}$

The voltage around path **1** #is

equation number) **1.5** , (efforts relative to the track number**1**

$\mathbf{V_{s2} = V_{R2} + V_{R3} = 1_{2} R_{2} + I_{3} R_{3}}$

Voltage around path number**2** he is

equation number) **1.6** , (efforts relative to the track number**2**

as $\mathbf{I_3}$ is sum $\mathbf{I_1 + I_2}$ equation number) **1.4** , (we can rewrite the equations as:

equation number) **1. 7**(

equation number) **1. 8**(

equation number) **1. 9**(

equation number) **1.1 0**(

Now we have two " simultaneous equations) **1. 9** (and) **1. 10** " (And resolved after hitting the equation) **1. 9** (In **3** and hit the equation) **1.1 0** (in **2** as follows:

equation number) **1.1 1**(

equation number) **1.1 2**(

by subtracting the equation) **1.1 1**)from the equation (**1.1 2** (produces

To get the value of the current I_2 ,compensate the value I_1in the equation) **1.9**(

Since: $I_3 = I_1 + I_2$

If the current flowing in the resistor is given R_3 as follows:

-0.143 + 0.429 = 0.286 Amps $= I_3 = I_1 + I_2$

And the voltage is given across the resistor R_3 as follows:

11.44 volts= **40** Ω × **A** = **0.286**$V_{R3} = I_3 R_3$

In the end, we must mention that choosing to trade path No (**1**) .or (**2**) is optional and should not be restricted to the path set in example .(**1**) That is, the direction of path number **1** **could** be) **A - F - E - B - A** (But the voltage values for the source of constant voltage will change at both ends of the resistors.

In Example ,**1** what is your interpretation of the negative sign of current?I_1?	duty number**1**

Reverse the path **1** # in Example **1** # and recalculate the current and voltage around the resistanceR_3	Duty No**2** .

Lectures Elctronic - Chapter II Phase III Department of Physics d . Omar Mhaidi Al-Rawi

Semiconductor Physics

2.1General introduction:

Nowadays, semiconductor materials are of great importance for their use in the manufacture of most modern electronic devices . In order to study its electrical properties, it is necessary to understand its atomic structure and how electrons are distributed around its atoms, as well as how the atoms are related to each other.

The properties of materials vary according to their composition and components . Matter is made up of atoms, and these atoms may consist of one or more elements . These atoms are held together by chemical bonds that bind each other . These bonds vary according to the atomic structure of the conjugated elements . There are four basic models used to explain the atomic structure of materials:

First : **Thomson** model **:** This model describes the atom as regular spherical bodies with radii) 10 $^{-10}$ m (carrying positive charges studded with electrons.

Second : **Rutherford's model :** The scientist Rutherford corrected the concept of Thomson's model by conducting an experiment on a plate of gold and shedding alpha particles on it. Through the experiment, he found that some of these particles escaped from the gold plate) **which means that most of the atom is empty ,(** while others are scattered at a certain angle and others It bounces back in the opposite direction to its original direction, despite the fact that the speed of these falling particles is very fast and their mass is **7000** times heavier than the electron . He concluded through these results that there is a very large electric field that works to bounce the alpha particles and the reason for the emergence of this field is the presence of **a** heavy positively charged **nucleus** stationed in a very small space in the center of the atom and that the negatively charged **electrons** move in circular paths and at relatively large distances from the nucleus.

Third : **Bohr's** model : The problem with Rutherford's model lies in that the atom will be unstable because the electron will lose energy during its rotation around the nucleus and thus will disappear . Therefore, the scientist Bohr corrected Rutherford's model and gave an accurate and very important explanation to clarify the structure of the atom . Bohr explained that the electron revolves around the nucleus continuously in a circular path without radiating energy, and that what keeps the electron in its orbit is the reason for the balance between the coulombic force of attraction between the electron and the nucleus with the repulsive force that the electron is subjected to during its circular path around the nucleus.

Through the results of the Bohr model, we can explain that the electrons are distributed around the nucleus in levels with different energies . Only) discrete and distinct (values of electron energies exist within the atomic structure . Therefore, the electrons should only orbit at separate distances from the nucleus . The plane close to the nucleus is called the ground plane, in which electrons are tightly bound with the nucleus . As for the higher energy levels, they are called excited levels, where the strength of the electron's bonding with the nucleus begins to decrease as we go up in the levels.

Each discrete distance) orbit (from the nucleus corresponds to a specific energy level . In an atom, orbitals are grouped into energy levels known as husks . A given atom has a fixed number of shells and each shell has a more fixed number of electrons . Is determined crust) energy levels (number 1 and 2 and 3 etc., the cortex No 1 .to be closer to the nucleus.

Fourth : the quantitative model

Although the model Bohr The atom is widely used because of its simplicity and ease of visualization, however it is not a complete model . The quantum model, a newer model, is considered more accurate . Using the quantum model, the electrons in the energy levels around the nucleus will have four quantum numbers

1. Principal quantitative number n It determines the number and value of the orbit around the nucleus n = 1,2,3 ,,,, n.
2. orbital quantum number L And the value unites with the value of the number n my agencies L = 0,1,2 ,,, n-1.
3. Magnetic Quantum Number m_L Its value is determined by the number L my agencies m_L= (2L+1) if it was l = 1 van m_L= -1,0,1.
4. Permian quantum number m_s It is an important number that determines how the electron spins around itself when there is a magnetic field . If the electron spins in the direction of the field, then the value ofms = + ½ But if it is opposite to the trend, then the value of ms = - ½.

>*Here is the term **quantum number** as a result of using quantum mechanics calculations to explain the four numbers.* <

The main quantum number determines the number of main scales distributed over the nucleus, and these main scales are divided into sub scales, of course for the values of the orbital quantum number L and she) s , p , d , f (at) L = 0, 1, 2, 3 .(The number of electrons for each type of these subshells is as follows:

1. when n = 1 The sub peel is $1s^2$ It must contain sOn two electronics only.

2. when $n = 2$ The sub crusts are $2p^6$ $2s^2$ It must contain s On two electronics only either p It should contain only 6 electrons.
3. when $n = 3$ The sub crusts are $3d^{10}$ $3p^6$ $3s^2$ It must contain s On two electronics only either p It should only have 6 electrons$d$ It must contain 10 Electrons only.
4. And so for the rest of the rest of the crusts.

If we take the silicon atom as an example , the number of electrons is .14 We start first by filling the plane closest to the nucleus, which is$1s^2$With two electrons, then we complete the rest of the distribution of electrons as follows: $1s^2 2s^2 2p^6 3s^2 3p^2$.

2-2valence electrons:

Electrons in orbits farther from the nucleus have higher energy and are less bound to the atom than those closer to the nucleus . This is because the gravitational force between the positively charged nucleus and the negatively charged electron decreases with increasing distance from the nucleus . The electrons with the highest energy are located in the outer shell of the atom as shown in Figure (1) and are relatively related to the atom . This outer shell ,known as **valence cortex** called electrons in the crust **electrons parity**.

These valence electrons contribute to chemical reactions and bonding within the material's structure and to determine its electrical properties . When a valence electron gains enough energy from an external source, that electron can be released from its atom and become a **free electron** . This is the basis for electrical conductivity in materials.

3-2Pauli Exclusion Principle:

There is a basic rule that determines the electronic structure of multi-electron atoms, which is that any atomic structure is more stable if its total energy is of a minimum value . In addition, the existence of electrons in different energy levels is based on the Pauli exclusion principle, which states) it is **not possible to have two electrons in an atom at a certain energy level with the same four quantum numbers mentioned above .(** For example, if we write a helium atom with atomic number , 2 that is, it contains two electrons in its first orbit . In order for the electronic arrangement in this atom to be consistent with the Pauli principle, one of the quantum numbers of the two electrons must be different, and on the other hand, the two electrons must have the lowest possible energy, so they must be arranged as follows:

	n	L	m_L	m_s
first electron	1	0	0	+ ½
second	1	0	0	- ½

electron				

4-2Energy Packs for Crystals

As it is known to us that solid materials differ from gaseous materials in that the latter do not have specific locations because of their random movement, unlike solid materials, where their atoms are arranged in a certain pattern due to the strength of cohesion between their atoms . The pattern of bonding of atoms with each other is the key that distinguishes and classifies solids in terms of electrical and optical properties and many other properties . Solid materials are characterized by having a crystalline structure, and a crystal is a solid substance where its components) atomic , molecular or ionic (are lined up in an orderly and repeating pattern in three dimensions.

The question that concerns us here is : Does the electronic structure of materials remain the same in single atoms ?Or in other words, does the distribution of electrons on energy levels in solids remain the same as in the individual free atoms of the same substance ?The answer to this question can be deduced from the following explanation:

Let's take a lithium atom Li It contains 3 electrons . Figure 2) a (represents the distribution of the three electrons on a single atom of lithium) two electrons on the secondary cortex$1s^2$ And one electron on the shell $2s^1$.(The curved line indicates the potential energy of the electron near the nucleus, calculated from Coulomb's law.

Suppose that another lithium atom approaches this atom to the extent that a reaction occurs between these two atoms to form the lithium molecule .Li_2 .The proximity of the two atoms to each other in this way will lead to each atom trying to attract all electrons to it) the electrons belonging to it and those of the other atom ,(

which results in a decrease in the value of the energy needed to free the outer electrons of both atoms) which are called valence electrons (than it was before in a single atom . In this case, as shown in Figure2) b , (the electron will be shared between the two atoms and the lithium molecule will contain 6 electrons instead of 3 for the single lithium atom . The six electrons will be distributed as follows : Four in the shell1 s And two in the crust 2 s .We will notice that there are four electrons in the shell1 s It would conflict with Pauli's exclusion principle, so it is reasonable to say that the crust 1 s It will **fission into two levels ,**each level containing **two** electrons, whose existence and stability is achieved according to the Pauli principle . In the same way, the peel separates2 s to two levels.

Following the same analysis above, we find that the approach N of lithium atoms, as in solids, will lead to the separation of the shell 1 s to me N From levels and crust 2 s to me N Levels, separating them prohibited area of energy - see Figure 2) c .(From the foregoing, it becomes clear to us that the N of atoms will lead to the cleavage of atomic levels to N of energy levels . Since the difference in energy between these levels is small Very therefore, these levels seem to be going on and called for this **energy package .** The energy beam is in the lithium atom of the level1 s ,Filled with electrons and called **package parity** either Tier package2 s In the lithium atom, it is half-occupied) because it basically contains one electron from a total of two electrons (and is called the **conduction band** . As for the area separating the two bands, it is called the **energy gap**.

Perhaps it is worth noting that the amount of fission) not the number of levels because it is fixed, but the difference in energy between levels (depends on:

First : The extent of the interaction between atoms, i.e. the distance between them, the greater the distance, the greater the fission . **Second : The** distance of the atomic plane from the nucleus, the closer it is to the nucleus, the smaller the orbital radius is The electrons were affected by the nucleus of their atoms, the greater, which reduces the effect of other shifts, as well as other electrons on them, and therefore the less the amount of fission is, and vice versa For electrons in orbits farthest from the nucleus, **.**

5-2Conductors, insulators and semiconductors:

The picture that we drew in Figure (2) of the energy levels of the electrons in the crystal is known **Bundle** Model **- Energy** This model is of great use in determining the electrical properties of any solid material, as it shows how it moves The electron is in the crystal, so the differences between conductors, semiconductors and insulators can be Identifying them through the difference between the models of the energy bundles belonging to each of them .

1-5-2Conductors:

A conductor is a material that easily conducts electric current . Most metals are good conductors . The best conductors are single-component materials, such as copper, silver, gold, and aluminum.

Figure shows **3**) **a** (a blueprint for power packs in the conductive material . It is noted in this diagram that the energy levels have been drawn continuously in the valence band so that this band appears **overlapping** with the conduction band and therefore **there is no longer** an energy gap . The disappearance of the energy gap in conducting crystals means that any valence electron will be free to roam through the crystal as well as move in response to the electric field when present in it, and this is the direct reason for its conduct**.**

Electrons are distributed in bundles, as is known **,**According to rule of exclusion of Pauli and at a temperature of absolute zero can not heat the electrons move through the crystal so because they are all strongly linked to atoms and thus fills a package parity of the lowest energy level in which to the highest level of energy where and who claims to the **Fermi level Fermi level -** See Figure 3) a (or in other words that the delivery package at a temperature of absolute zero temperature is **empty .** This means that there are no sufficient power when any electron in order to move in an orbit delivery package **.**

On the other hand, when the temperature rises above absolute zero, the thermal energy that the electrons will acquire will enable some of these electrons to escape from their atoms and move to the conduction beam, where they can move there in orbits with larger radii than before, and the bonding of these electrons to the atoms is very weak when It is in the orbits of the conduction beam, and therefore it can move from one atom to another easily, forming what is called an **electron gas**.

When a **potential difference** is applied across the conductor ,**an electric field** will be generated inside the conductor that accelerates the free electrons in the conduction bundle due to the force **F**to which it is subjected and which is equal to

(2-1)

whereas **e** represent the charge of the electron and **E** electric field strength.

In free space, the electron is accelerated and its speed) **energy** (increases constantly. In crystalline matter, the progress of the electron is **hindered by** continuous **collision** with the **vibrating atoms** around their positions in the crystal, and quickly, the **speed of the electron** reaches a fixed average value . This speed is called **drift velocity** V_d .

The drift velocity is linearly related to the electric field strength **E**By the **kinetics of the electron** in the given material, we symbolize the kinetics with the symbol **(μ)** So that

(2-2)

The negative sign means that the velocity of the electron is opposite to the direction of the applied electric field.

Electron mobility is a measure of how free charge carriers) negative or positive (are to move in the crystal without colliding . Electron mobility has a positive value by definition, measured in units of square metres, per volt - th intent) **m^2/VS** (and typical values are0012 . 0for aluminum and **0.0032**for copper and **0.0056**for silver **.**

It is worth noting that at a constant voltage and the temperature of the conductor is raised, the number of **Collisions** between the electron and the atoms around their shaky in the crystal will be increased and thus less drift velocity and thus increasing the **resistance of Mosul ,** it said then that the connector has a **positive coefficient of resistance** which increases its resistance with increasing temperature **.**

2-5-2Insulators:

An insulator is a material that does not pass electric current through it under normal conditions . Most good insulators are composites rather than single-component materials and have very high resistances . The valence electrons are tightly bound to the atoms ;Therefore, there are very few free electrons in the insulator . Examples of insulators include rubber, plastic, glass, mica, and quartz.

Shown in Figure 3) b(A typical diagram of the energy bands in insulating materials, in which it is noted that the valence band is separated from the conduction band by the energy gap. That claims the forbidden gap **.** This energy gap is wide and is about (5 eV) **Thus** , the electrons in the valence band cannot move to the conduction band except when they receive sufficient energy equal to the energy of the forbidden gap . At normal temperatures, the electrons in the valence band do not have the energy that enables them to move to the conduction band. Therefore, it can be said that the insulating crystal is characterized by having a wide energy gap and the valence band is **filled with** electrons while the conduction band is **empty**. Increasing the temperature may lead to melting of the insulating material before it becomes a good conductor.

From the above, it is clear to us that there are no free charges in the insulating materials, but rather they are restricted in their places by atomic and molecular forces. When a potential difference is applied to these materials, the generated electric field will only **shift** these electrons a little from their original positions, that is, it works to **polarize them.** This displacement against a constraining force is similar to lifting a weight or stretching a spiral, and represents **potential energy .**The source of energy and the external field and movement of the displaced charges **may** produce an accidental **current called the displacement current .**

2-3-2Semiconductors:

Semiconductors are materials that lie between conductors and insulators in their conductive properties, ie their ability to conduct electric current . A semiconductor in its pure) essential (state is neither a good conductor nor a good insulator . The single-component semiconductor is antimonySb ,arsenic) As , (astatine) At , (boron) B , (silicon) Si , (germanium) Ge(Compound semiconductors such as gallium arsenide and indium phosphide are also used . Single-element semiconductors are characterized by atoms with four valence electrons . Silicon is the most widely used semiconductor.

The power diagram of a semiconductor is no different - See Figure 3) c (for his counterpart in Insulators are only in the energy gap capacitance, where their value in semiconductors is in the range **1.1 eV** or less . These materials are **insulating** at absolute zero temperature Where the conduction band is empty, that is ,there is not enough energy at any electron to move to the **conduction** band **and conductive** at high temperatures . On the other hand, at room temperature) 27°C = 300°K (Acquires a number of electrons sufficient energy in order to move to the delivery package , **but** the output current is **small** so that they can not take advantage of it in most applications and when this degree agenesis semiconductor material well as a buffer agenesis well connected to **this claim semi - conductor.**

6-2energy gap E_g

The difference in energy between the valence band and the conduction band is called the energy gap E_g .It is given by the following relationship

(2-3)

where . represents E_c The value of the energy level at the lower edge of the conduction beam and E_v The level of energy value at the upper edge of the package parity as shown in Figure 3) b and c.(

The energy gap can also be defined as the amount of energy that a valence electron must possess in order to jump from the valence band to the conduction band, provided that there are energy levels available in the conduction band . Once it enters the conduction beam, the electron is free to move throughout the material and is not bound to any particular atom.

Figure 3 shows the power diagrams of insulators, semiconductors, and conductors . Depending on the quantum theory ,**the power** gap in insulators and semiconductors can be described as **a forbidden energy region** , because the electron is prohibited in it because there are no available energy levels . Although the electron may not be located in this region, it can " **jump** " across the energy gap under certain conditions . **For insulators** , the gap can only be crossed when **electrical breakdown conditions** occur — such as when extremely high voltage is applied across the insulator . In semiconductors, the energy gap is smaller, which allows the electron in the valence band to jump into the conduction band if the electron absorbs an energy) photon (equal to the value of the energy gap . In conductors, the conduction band and the valence band overlap, so there is no gap. This means that the electrons in the valence band move freely in the conduction band, so there are always electrons available as free electrons.

7-2pure semiconductors:

A pure semiconductor, also called undoped semiconductor or type I semiconductor, is a pure semiconductor due to the absence of any significant type of impurities . Thus, the number of charge carriers is determined by the properties of the material itself rather than the amount of impurities.

We saw in the past that the valence band in **conductors** interferes with the conduction band, and therefore the number of free electrons is limited in the conduction band, and that raising the temperature **will** only **lead** to an increase in the vibration of the atoms in their positions, which **increases the** resistance of the conductor due to the increase in the number of collisions that the electrons make with These atoms, therefore, conductors have **a positive coefficient of resistance .** In semiconductors, increasing the temperature will lead to an increase in the energy of the valence electrons, and then the number of electrons that reach the conduction band **will increase** with the increase in temperature, and therefore the **conductivity σ of** these materials will increase with the increase in temperature, which means that they have **a negative resistance coefficient** . **Conductivity** is a basic property of a material that determines the ability of a material to pass an electric current through it. It is measured in units^{-1})**Ω-m** . (Conductivity is the reciprocal of the **resistivity ,**ρ ,which is a fundamental property of a material that determines how well a material is able to prevent the flow of electric current through it .It is measured in units) **Ω-m**.(

However, the number of electrons in the conduction band can be calculated by a function Subject **to Fermi statistics** - **Dirac** It is called the **distribution function of the power** which expresses probability **f(E)** No electron to occupy an energy level **(E)** at degree heat **T** It is given by **the Fermi function**

(2-4)

whereas K_B It is the Boltzmann constant and is measured in units **eV /°K** ,and**T** Represents the temperature in Kelvin **°K** ,andE_f It is the Fermi energy level of a crystal in electron - flute**eV**.

We can deduce from the equation) **2-4** (Three important things related to the Fermi level at **absolute zero** temperature ,i.e.**T = 0 °K**:

First : In the absence of an energy gap, as is the case in the conductor, the probability of the electron occupying the Fermi level will be equal to**50%** .This can be demonstrated assuming that the energy level**E** Equivalent to the Fermi level energy E_f , so the probability will be

(2-5)

Therefore, any energy level at the Fermi level will have an equal probability of occupying an electron **½**.

Second : For energy levels**E** Which **increase** about$E_f$so that the difference result approaches) **-** $E\ E_f$ (in the equation(**2-4** (from **infinity** (∞) then the probability of occupying that energy level approaches **zero** , this can be demonstrated by my

(2-6)

In other words, very high energy levels) higher than the Fermi level (are devoid of electrons.

Third : For energy levels**E** which is **less** than$E_f$so that the difference result approaches) **-** $E\ E_f$ (in the equation(**2-4**)from negative **infinity** (**-** ∞ (then the probability of occupying that energy level approaches100%I can prove that,

(2-7)

In other words, very low energy levels) below the Fermi level (are filled with electrons . Therefore, another definition of the Fermi level can be given, which is the greatest energy that any electron can possess at the temperature of absolute zero.

8-2Covalent bonds:

A bond is a force that holds atoms together to form compounds or molecules, including covalent, polar and ionic bonds . The bonds that bind silicon and germanium atoms are covalent, and their formation can be explained as follows:

Possesses the elements of the fourth group From the periodic table, four Electrons Tkavaah claims crystals that are including material **crystals covalent** arise forces cohesion in the crystals covalent of the presence of electrons **shared** between neighboring atoms , every atom shared Basurrah covalent with its neighbor ,**contributing to an** electron and one in Asrh and be Alaketronan subscribers between the two atoms instead of each private property be to one of the two atoms, as in the case of ionic bonds and between the form) **4**The composition of one of these crystals at the degree of absolute zero, and its atoms are drawn in two dimensions and symbolically according to the Bohr model **Bohr** Simplified atom) by drawing only valence electrons and their equivalent positive charge (

9-2Pure semiconductor under the influence of external influence:

If **an electric** potential is **applied** to a crystal of a pure semiconductor or exposed to **energizing radiation,** Sufficient or **heat** energy has been gained, this acquired energy will serve to **break** the covalent bonds and **transfer the** electron to the conduction beam to participate in the electrical conduction process . The energy needed and sufficient to break the covalent bonds must be equal to the energy gap E_g or older **.** be E_g equal to **0.72** Electron volts for the germanium crystal m and **1.1** Electron volts for a silicon crystal . These two elements are among the most important elements of the fourth group used in electronic industries and silicon **(14)** An electron in its atomic structure is distributed in the form of 8 , 2 and 4 electrons, while the germanium element has (32) electrons that are distributed in the form 18 , 8 , 2 and 4 electrons.

However, the transition of the electron from the valence band to the conduction band will **leave** behind an **empty** space in the covalent bond - see Fig. **5** - (Uma is called the **gap hole .** .The atom is now ion The gap is shown as a constant positive charge +) (with effective mass m_h It is not equal to the mass of the electron m_e .This difference between the two masses appears when an electric field is applied to a pure semiconductor crystal.

The movement of negative charge carriers of electrons is much **faster** than the movement of positive charges through the holes . A **gap is** defined as a place ready to receive a valence electron from a neighboring atom . The gap is quickly filled with a valence electron, as this electron leaves the atom due to the breaking of its bond with the atom when there is an electric field, thus generating a second gap that is also filled with another valence electron, and so the process continues, leading to the movement of charges - see figure) **6** - (thus generating a **current called the gaps current**.

The generation of these **pairs** of **electron - hole** It is called the process of forming an electron - hole pair , as this process continues until it stops from thermal equilibrium . At **thermal equilibrium** The number of left holes is **equal to the** number of electrons transferred . It can be expressed in another form, which is the number of electrons transferred to the conduction beam per unit volume) electron concentration**n** (is equal to the number of gaps hidden in the valence band per unit volume) the concentration of gaps**p** .(Therefore, the concentration of electrons must be equal to the concentration of holes in thermal equilibrium:

(2-8)

whereas n_i It is the pure concentration of charge carriers in a pure semiconductor.

Thermal energy is the most sources generate these couples and **called the** process of conduction resulting from the movement of cargo carriers of these) gaps and electrons (the process of **self -conduction**.

10-2Calculation of the conductivity of a pure semiconductor:

When an external electric field is applied, the energy gained by these carriers will be added to their thermal energy, thus accelerating it and gaining a speed that reaches after a certain period **,** As we mentioned, to a constant value called the drift velocity in which

(2-9)

where . refers **h** to the gaps **hole** And **e** to electrons **electron**and be v_e opposite direction v_hIt is larger than it, except that the current resulting from them is in the same direction **.**

We know that the current

(2-10)

So is the identifier that

(2-11)

where is the volumetric density of the current and **ΔV** It is a scalar element . About compensation for the value **ΔQ** by equation) **2-10** ,(we get

(2-12)

or by dividing the current On the area element we get

(2-13)

where . represents **J** surface current density and **ΔS** It is a superficial element.

For pure semiconductors , we have

(2-14)

or

(2-15)

where . represents **n** And **p** Electron density and generated holes, respectively

(2-16)

When compensating for the value of **v_e** And **v_h** from the equation) **2- 9** , (we get

(2-17)

In a pure semiconductor, the electron density is **n** In the conduction bundle equal to the density of the holes **p** Those electrons left in the valence band , I $n_i = n = p$where . refersn_i to pure or subjective concentration and is measured in units) m^{-3} i.e /1 .cubic meter (and the letter indicates **(i)** to pure semiconductor **intrinsic .** Therefore,

(2-18)

The relationship between **E** And **J** It can also be determined by accessibility **σ**Via

(2-19)

Therefore,

(2-20)

For pure or intrinsic germanium, the electron and hole motions are **0.36** And **0.17** In order, while for silicon, the two motions are in order **0.12** And **0.025** These values are given in square meters per volt **-** seconds and ranges from 10 to 100 times greater than that of aluminium, copper, silver and other metallic conductors at the same temperature **300 °K**.

11-2Effect of temperature on a pure semiconductor

It should be mentioned that increasing the temperature of the semiconductor will lead to an increase in the number of electron-gap pair, which leads to an increase in the conductivity of the pure semiconductor . So the relationship between self-focus**ni** And temperature is an exponential relationship given by my

(2-21)

whereas **K_B** is the Boltzmann constant and its value) **J/K 1.381 x 10^{-23}** (And is the effective mass of the electron is calculated by multiplying the mass of the free electron **m_o = 9.1093 x 10^{-31} kg)** (In a constant fixed value of this depends on the user 's semiconductor) silicon or germanium (and is Planck 's constant and its value) **J . s 6.626 x 10^{-34}** .(The equation) **2-21** (until the number of electrons in the conduction beam is proportional to**T** Therefore, the concentration of carriers will **increase with the** increase in the temperature of the material . **On the other hand, the** number decreases with the increase in the energy of the gap**Eg** at temperature **T** .This explains why there are fewer electrons in the conduction beam of insulators than in the same beam of semiconductors.

There is an important relationship between the value of the energy gap **E_g** As the temperature of the semiconductor changes from **T_1** to me **T_2** Which results in a change in the resistance of the semiconductor from to and is written in the following formula

(2-22)

12-2Impurity semiconductors:

We mentioned above that the number of electrons reaching the conduction band as well as the gaps left in the valence band in semiconducting materials is **very small** at normal temperatures so that the resulting current is not suitable for many practical applications . We also found that raising the temperature of semiconductors leads to an increase in the conductivity of these materials, that is, an increase in the number of electrons transferred to the conduction beam, and thus an increase in the output current.

Despite the above , the increase in the conductivity of semiconducting materials by Raising its temperature is **not considered desirable from a practical point of view, and** that is (1) because this method requires heating devices and the necessary increase in costs (2) as well as an increase in consumption Ability (3) and most importantly the difficulty of controlling or controlling the electrical properties of the likes conductors through this method **.**

However, the electrical properties of semiconductors are currently controlled by the addition of small and limited amounts of impurities to a semiconductor crystal, and this process is called **grafting** .In a semiconductor manufacturing process, doping is the deliberate introduction of impurities into a pure semiconductor **for the purpose of** modifying its electrical, optical, and structural properties . The grafted materials are referred to as impurity semiconductors . The amount of impurities added is known as the vaccination level . Adding impurity atoms to pure semiconductors **in** small **proportions** increases the conductivity of these materials **.For example ,**if impurities are added in the proportion of **one atom** of the impurities to the **10** ^{8} Germanium atom, this is enough to increase the conductivity by 10 to 15 times . Also, the addition of impurity atoms to pure semiconductors **gives us the** possibility to control the density of free electrons in the semiconductor or the density of the holes in it independently . Impurities are usually added in the ratio of one **impurity atom** to one **million** silicon or germanium **atoms**.

There are two types of impurities (1) : Impurities that increase the conductivity by increasing the number of electrons and are of the elements of the fifth group of the periodic table) pentavalent .(And (2) impurities increase the conductivity by increasing the number of holes, gaps, and are among the elements of the third group) trivalent .(Therefore, the grafted semiconductor is classified into two main types, according to the type of impurities added to it **..**

1-12-2type negative semiconductor N-Type

We have seen previously that the current carriers in semiconductors are electrons and holes **.** In this type of semiconductor, the **majority of** current carriers They are the **electrons resulting** from the introduction of a **pentavalent** impurity such as the **antimony** atom For example . There is in this atom **five** electrons in the outer orbit while containing an atom of silicon **four** electrons when external and **replace** atom arsenic atom replaces silicon in silicon crystal, the **four** external electrons of the arsenic atom **contributes four** bonds covalent With neighboring silicon atoms, the fifth electron **remains** in the atom. The electron **is** attached to the atom Mother without **entering** within the bonds that bind atoms - see Figure 7) a.(

This fifth electron is semi **-loose ,**and a small energy that does not exceed **0.04**Electron Volt for Germanium and**0.01** Electron volts for silicon to be **transferred** to the conduction package . Thus, the presence of impurity atoms increases the number of free electrons in the The conduction band with **only a small amount of energy** and this number of electrons may double The looseness is a **thousand times** higher than in the case of pure silicon **.**

It is worth noting that the appearance of excess electrons in the conduction beam as a result of the presence of impurities is not **matched by the** appearance of **holes** in the valence beam. These electrons are not **transferred** from the beam The equivalence also occurs in a pure substance ,**but rather** it moves from energy levels located below the edge of the conduction band) **within the energy gap** (and at a very low energy depth) **0.04 eV** or **0.01 eV**(See Figure 7) b .(This new level of energy is called the **donor** level It represents the energy level of the impurity atoms ,**which** is **why they** are called atoms Entering the donating atoms. Therefore, the **majority of the** current is the result of) negative (electron charges , hence the name of this type of **crystal negative. N-type** .As for the **density of the holes, it is determined** by the electrons that leave the valence beam to the conduction beam, and their effect on conduction is negligible. Therefore, they are called minority carriers.

2-12-2Positive-type semiconductor P-Type

Now if we add some material atoms flawless **triple** parity **Kalcaleom** or aluminum or boron to crystallize silicon, the different phenomenon will occur . Calium atoms have **three** electrons in their outer orbit, distributed in the form of **$4s^2 4p^1$** So the existence of These atoms are in a silicon crystal **$3s^2 3p^2$** Generates Mـکanat **vacant** in the electronic structure claims gaps **holes -** See Figure 8) a - (requires the electron to very little power in order to enter into a certain gap, but this process leaves behind him a new gap When shed an electric field on the crystallization of silicon dopant this, the movement of the gaps will be organized in which the drift towards the **cathode** thereby generating a **current** claims **stream gaps** This type of substance is called a semiconductor of **the positive type**P-Type Called atoms dopant atoms entering **acceptor** To accept electrons from the atoms of the original crystal **.**

As with donor impurities, acceptor impurities are energy levels new within the energy gap and very close to the valence band It is called attributable **acceptor-** see figure 8)b - (has a value of about**0.01 eV** For germanium and **0.16 eV** For silicone . The existence of this level **makes it easier** to The process of transferring electrons from the valence band **to it** and that the electron transfer leads to a gap in the valence band, and these gaps help in the flow of current

13-2Density of charges in an impurity semiconductor :

We talked earlier that in a pure semiconductor we have a concentration of electrons equal to the concentration of holes . Now after adding the donating or accepting impurities, it will change the concentration of negative or positive charges as follows

1. When pentavalent atoms are added, the concentration of donating impurities is $\mathbf{N_d}$ Electron concentration will be added **n** The number of negative charges / unit volume is$\mathbf{m^3}$)concentration of negative charges (equal to$\mathbf{[n + N_d]}$.
2. When three valence atoms are added, the concentration of soluble impurities is $\mathbf{N_a}$ Gaps concentration will be added **p** The number of positive charges / unit volume is$\mathbf{m^3}$)concentration of positive charges (equal to$\mathbf{[p + N_a]}$.

Since the semiconductor is now electrically neutral, the concentration of negative charges is equal to the concentration of positive charges , that is,

(2-23)

If we take the case of a semiconductor of the type **N** ,whereas **$N_a = 0$** ,since the number of electrons is much greater than the holes, i.e) **.$n >> p$**)The equation(**2-23** (Will be written as follows

(2-24)

or

Indicates **n_n** To the concentration of the majority carriers) electrons (in the semiconductor**N Type** .So we can say that the concentration of free electrons in the semiconductor**N-type** It is approximately equal to the density of the donor atoms.

As for the concentration of gaps) minority carriers (in semi-conductor**N Type** It is calculated using the following equation

(2-25)

Therefore, the value of the gap concentration is

(2-26)

Indicates **p_n** To the concentration of minority carriers) gaps (in semi-conductor**N Type** at room temperature) **300 K °** .(With regard to pure focus**n_i** The calculated value for silicon is) **$n_i = 10^{13}$ cm $^{-3}$** (For germanium van) **$n_i = 10^{12}$ cm $^{-3}$**.(

Similarly, the concentration of electron minority charge carriers can be calculated) **n_p** (in semi-Mosul**P Type** And the value of **$N_d = 0$** .Where the concentration of gaps) majority carriers) (**p_p** (is much greater than the concentration of electrons . The concentration of the gaps is approximately equal to the concentration of the acceptor atoms**N_a** l

(2-27)

or

so the n_p

(2-28)

From the foregoing, it becomes clear to us that conductivity of impurities is **dominant** over self conductivity **if the** concentration of weak impurities is N_d or receptive N_a greater than the concentration of intrinsic charge carriers $n_i = p_i$.

In the impurity semiconductor, the concentration of minority carriers **decreases** p_n The same number of times the concentration of the majority carriers **increases** n_n . if it was $n_i = n_n = p_n = 10^{13}\,cm^{-3}$ In germanium ,**the** electron concentration **doubled** After adding the donor atoms to it **1000** once so that became $n_n = 10^{16}\,cm^{-3}$ The concentration of the gaps will be reduced by **1000** once and becomes $p_n = 10^{10}\,cm^{-3}$ That is, a **million** times less than the concentration of electrons, and the **reason for this is** that the **recombination** is **directly** proportional **to the** concentration of electrons, and thus the number of electrons that recombine with the holes will double by 1000 times, so the holes will become 1000 times **less** than they were **.** For a negative semiconductor, the relationship

(2-29)

What was said about the negative semiconductor is correct to say about the positive semiconductor, and it can be considered that $p_p = N_a$,that is

(2-30)

It remains for us to mention that when **the** temperature of the impurity semiconductor is much higher than the room temperature, the electrons or the original holes will **dominate** the electrons and the impurity holes and the electron density in the conduction band becomes **equal again to the** gaps in the valence band. Thus, the **high temperature** is undesirable as It removes semiconductor elements from performing their normal operation **.**

14-2Current flow in impurity semiconductors :

The current flows in materials in general if there are:

1. voltage drop
2. Regression in the density of carriers of negative or positive charges or
3. Change in electrical displacement with time

The current resulting from a change in electrical **displacement is called displacement current** It appears in the insulators only. As for the current resulting from the presence of a voltage drop, it is called **the load current or the conduction current, and** it appears in conductors and semiconductors, and we have talked about it in the past . We call the current resulting from the mobility of all the electrons in the conduction band or the gaps in the valence band in a semiconductor when the electric field is **applied by the drift current.** In line with the final velocity reached by the charge carriers, that is, the **velocity of drift**.

On the other hand, there **is another current that appears only in semiconductors** when **the electric field is absent and** when the distribution of charges inside the semiconductor **is not uniform, it**

is called **current Diffusion** means that the electrons move from areas of high density towards the region of low density **.** For example, if the concentration of electrons at the point **(A) -** see figure **(9) -** The inside of the semiconducting material is larger than it is in the point **(B)** The presence of this **regression** in focus It will push the electrons to scatter from the point **(A)** towards the point **(B)** This leads to the creation of **a diffusion current** .

It was found that the density of the diffusion current resulting from the diffusion of electrons J_{Dn} fit **Directly** with the concentration

gradient of these electrons In the negative semiconductor where

(2-31)

Called with a constant of proportionality D_n It is the diffusion factor or diffusivity, and it is defined as the ability of electrons to propagate, which is the characteristic of the diffusing particle and

the medium in which it propagates .D_n a value equal to

Also, the current density of the gaps resulting from the diffusion of the gaps **J_{Dp}** directly proportional to The concentration gradient for

these gaps in the cationic semiconductor material where

(2-32)

where . represents **,D_p** The proportionality constant is equal to and

the **negative sign** comes above because the direction of the holes flow is in the opposite direction to the holes diffusion current, while the electrons diffusion current is in the same direction as the electrons flow.

From the foregoing, it becomes clear to us that if an electric field is applied to a semiconductor, it exhibits a gradient In the concentration of charges inside it, two types of current will flow in it : **the drift current and the diffusion current .**Therefore, the total current density **J_n** Caused by electrons for example example, she **.**

(2-33)

The same is true for the total current density **J_p** caused by holes

(2-34)

So the total current is

(2-35)

Original text

المادة تتكون من ذرات وهذه الذرات قد تتكون من عنصر واحد او لعدة عناصر .

Contribute a better translation

Diode

3-1 Introduction:

We saw above that it is possible to obtain a semiconductor material of a positive type P Or a negative type ?N By introducing a trivalent or pentavalent impurity into a pure semiconductor, respectively . Although both types of semiconductors contain majority carriers) whose number depends on the concentration of the impurity atoms entering (as well as minority charge carriers) which are thermally produced and therefore their number depends on the temperature of the material , (these materials are not of equal importance. Practical when used, in circuits ,**individually**.

On the other hand, it represents a two-link PN One of the most important electronic devices, and this duo can perform the work of the vacuum diode and is distinguished by it in many respects - which we will mention later.

Therefore, here we will learn how to get a link to PN And then study the physical processes that occur in them, as well as their electrical behavior

The study of this Diodes are not only necessary Learn about its many applications We will come in a later chapter of but Also because understanding the work of these binaries , and on the face of special double link pN ,is necessary to understand the operation of the transistor, which forms the **basis modern electronic engineering**

3-2 double link pN Junction Diode

.is obtained on the double link pN when **collecting** combine qualitative, negative The positive from the semi-conductor to each other . The plural here does not mean an approximation of one of the two types . to me The other type so that they touch ,**but** it is **meant** that both types of semiconductor material Negative and positive , done Manufactured on a single crystal of a substance semiconductor, so that One half of it becomes negative and the other half positive, by inserting the appropriate impurity into the two halves crystal . Figure) 1 a (shows a two-link pN Binary abbreviation diode and symbolizes It usually has the form) 1 b.(

)b (Binary code rolling)A :(The . link pN

)C (Distribution of majority and minority carriers across my regionsP And n

shape(1)

Figure) 1 c (shows the distribution of majority and minority carriers across two regionsP And n .The area containsp It has many holes) majority carriers (of impurity atoms and only a few thermally generated free electrons) minority carriers .(The area containsn On many free electrons) majority carriers (of the impurity atoms and only a few holes that are thermally generated) minority carriers.(

3-3area attrition : depletion layer

when sum the halves of the . link PN In the above way and because of that the concentration of carriers The charge is in either type) electrons are in the negative type and holes are in the positive type.((he is Larger much Than he is In the other type, which indicates that there is no regularity in the distribution of any from This is amazing Cross-link carriers or in the

words Others having a descent in concentration Electrons ( )in the negative

region, as well as a gradient in the concentration of the holes) (in a Positive region see Figure) 2 a (The existence of such a slope will therefore lead to move o Spread some electrons to the positive region across the boundary in semi-Mosul as well some Holes in the opposite direction .
The passage of electrons to the region P It will make him a minority carrier and with the presence of numbers Big gaps Around him, the time of his stay is short, so once he enters the area P He falls in a A hole and when this is done, the gap disappears and becomes the electron Free valence electron. The same is the case with the trans-regional gaps N Where do you get an electron? free Among the great numbers surrounding it .
that Spread Carriers and their transfer from one side to the other does not mean the transfer of parent atoms affiliate, This is because the latter . be associated with similar atoms Others with covalent bonds hard breaking it, but leads to the formation of two charges of different signs on both sides of the boundary separator , in the . link pN ,due to the lag of positive ions in the region N and ions Negative in the area P See Figure) 2 b(

)b :(link to pN With the stabilization layer

)A :(the depletion layer P -

shape(2)

Each pair of positive and negative ions in Figure) 2 b (is called a dipole dipole The existence of such a dipole **means** that an electron One of the electrons of the conduction band and one hole has stopped wandering and the number of these dipoles increases Leave the area adjacent to the boundary between my arrival to PN of **shipments Animated** she claims This is an empty area of shipments **with attrition layer** depletion leuyer - see figure) 2 b (It is worth noting that **most of the resistance link** to pN **Concentrated** in the depletion area where Its resistance is large compared to other semiconductor parts PAnd N .

3-4 roadblock Effort : The potential barrier

Anytime a positive charge and a negative charge are near each other, there is a force acting on the charges as described in Coulomb's Law . In the depletion region there are many positive charges and many negative charges on either side of the junctionPN .Forces between opposite charges form **an electric field** , as shown in Figure)2 b (by blue arrows between positive and negative charges . **This electric field** is a barrier to free electrons in the regionn And energy must be consumed to move the electron through the electric field . **In other words** , external energy must be used to make the electrons move across the electric field barrier in the depletion region . **The electric field potential difference** across the depletion region is the amount of effort required to move electrons through the electric field . This potential difference is called the **diaphragm** and is expressed in volts . In other words, a certain amount of voltage equal to the diaphragm voltage and of appropriate polarity must be applied across the junctionPN before electrons begin to flow through the junction . Depends on the barrier potential of the intersectionPN It depends on several factors, including the type of semiconducting material, the amount of impurities, and temperature . A typical barrier capacity is about 0.7 eV for silicon and 0.3 eV for germanium at° 25 C.

And from the most we can talk about that Increasing the concentration of impurities Lead to an increase in the concentration of the majority carriers, and then Its numbers are increasing across the boundary and thus charge density grows lagging and so increasing The value of the barrier voltage increases, and this is accompanied by a decrease in thickness area Attrition symbolizes this Fish is usually symbolized by dAs for germanium, for example, At the average values of the impurity concentration, the value of . ranges V_B between 0.2 to 0.3 volts andd between 10^{-5} to me 10^{-4} cm.

3-5 power diagrams in intersection PN and drain area

The valence and conduction bands are in a substance of type n At energy levels slightly **lower** than the valence and conduction bands in a material of typep .Remember that the material is of typep It has triple inclusions and that the material is of type n It has pentavalent impurities . Trivalent impurities exert less forces on the outer shell electrons than pentavalent impurities . Means **low forces** in materials of typep The electron orbitals are **slightly larger and** therefore have more energy than the electron orbitals in materials of this typen.

Shows the power diagram of a junction PN At the moment of formation in Fig)3 .a .(As we can see, the valence and conduction beam are in the regionn At energy levels **lower** than those in the areap , but there is a great deal of overlap . Free electrons in the region cann which occupy the upper part of the conduction band in terms of their energy to **spread** easily across the junction) no additional energy gain is necessary (and temporarily become free electrons in the lower part of the conduction band for a regionp .After crossing the junction, the electrons rapidly **lose** their energy and fall into the gaps in the region's valence band bandp As shown in Figure)3 a.(

)a :(power diagrams in the intersectionPN

)B :(The area of depletion from equilibrium

shape(3)

With the continued deployment ,**attrition area begins** in the formation and decreases the energy level in the conductivity zone packagen .The decrease in the energy level is due to the conduction band in the regionn to the loss of electrons that scattered across the junction to the region p **its energy** . After a short period of time, there will be no electrons in the conduction band of the region n With enough power to cross the junction to the area conduction

beam p or in other words Another thing is that any other electron comes into the region It will need more energy than before to enter to orbit Delivery range in the regionP ,as indicated by the alignment of the top of the conduction band to the regionn And below the range the delivery range of the area p In Figure)3 b .(At this point ,**the intersection is in equilibrium** ; And the area of depletion was completed because the proliferation **stopped** . There **is an energy gradient** across the depletion region which acts as an " **energy hill** " that the region electron must climbn To get to the area p.
Note that as the energy level shifts in the conduction range of the region n Down, the energy level in the valence band has also shifted downwards . It still requires the same amount of energy for a valence electron to become a free electron . **In other words** , the energy gap between the valence band and the conduction band remains the same.

3-6 . link PN In case stability

We mentioned earlier that there is descent in focus Electrons and holes across the junction PN It will spread these majority carriers over the link . The transmission of the majority carriers As a result of diffusion will lead to Creating a propagation current according to the following propagation equation :

)3-1(

where represents the density The diffusion current produced by Electrons scatter from the side N to me the side P .represents The diffusion constant of electrons is measured in square meters per second There is an equation Similar to the current propagation density of holes

(3-2)

where . means The presence of the negative sign, in the above equation, indicates that the movement of the holes is opposite to the movement of electrons, and therefore the net diffusion current density in the . link PN be equal to

(3-3)

Figure 4 shows the distribution of Concentration of carriers in the . link PN in germanium . Due to the different concentration of carriers the majority And the minority, millions of times, has drawn the vertical axis, which represents the concentration of electrons The gaps are on a logarithmic scale . The concentration of impurities usually differs in the two regions N And P, The figure corresponds to this particular case It is noted that Carrier concentration The majority and the minority semi-conductor the negative are) $n_n = 10^{16} cm^{-3}$ where n_n It is the concentration of majority carriers) electrons (in a regionn And $n_p = 10^{10} cm^{-3}$ where n_p It is the concentration of minority carriers) electrons (in the . regionp (and in semi-Mosul Positive are two)$p_p = 10^{18} cm^{-3}$ where p_p It is the concentration of majority carriers) gaps (in an areap And $p_n = 10^{8} cm^{-3}$ where p_n is the concentration of minority carriers) gaps (in an arean(

distribution Concentration of carriers in the . link PN for germanium

shape(4)

On the other hand The presence of the barrier voltage and the resultant due to the diffusion process, will Works on Moving the solution to the minority in each of the two regions N And P thus leading to events A current called conduction current . and where that carriers The minority, also made up, from There are two types : electrons and holes The conduction current also consists of two components
conduction current density of electrons

(3-4)

and conduction current density for gaps

(3-5)

where . represents n And p The number of both electrons and minority holes and respectively while representing The kinetics of both electrons and holes . When adding the two equations) 3-4 (and) 3-5 (The current density Your delivery to me is equal to

(3-6)

From the foregoing it becomes clear us to resultant current, The sari is in the . link PN cause of movement Electrons ,be equal to the **diffusion current** + **Stream conduction** or sports formula :

(3-7)

The same applies to the net current resulting from the movement of the gaps

(3-8)

However, the resultant total current is (J) in a link to PN ,in a condition **No external voltage** , equal to the sum of the propagation current What yar delivery, time

(3-9)

in a equilibrium state Kinetic to link to pN These two currents are estimated to be equal and opposite direction ,so the current is total (J) pass-through link to PN equal **to zero** , and this It is assumed in the absence of external effort, or in other words, that **the barrier effort** will always take that value or condition that **ensures a balance** between the diffusion and conduction currents . let's say right Now that stream spread may Increased due to the increase in temperature, this increase in the diffusion current meaning to cross More number of electrons to one side as well Crossing more gaps to the area N thus leading to an increase number ions backward Thus, to increase the value of the barrier voltage . that voltage spike growth The barrier will lead to a corresponding increase in the conduction current i.e to the transmission of carriers The minority is in the opposite direction and as long as ( ) continues growth Height Effort Barrier, and in the end ,as a result of an increase equilibrium occurs i.e growth stops V_B

3-7 account barrier voltage

We mentioned, above, that **the barrier voltage** always take those The value or condition that guarantees Equilibrium occurs between the diffusion or conduction currents, and this can be expressed mathematically by making which of the two equations) 3-7 (o (3-8) equal to zero, that is,

(3-10)

or that

(3-11)

We have from Einstein's diffusion equation

(3-12)

And when compensation About Values from the equation) 3-12 (in the equation(3-11 (we get On

(3-13)

It takes integration via the junction) Multaqa (PN Which Assuming that the width of the drain area) $x_2 - x_1$(as well as from n_p to me n_n where . represents n_n number Electrons at the edge of the depletion region on the side N from the link And n_p number Electrons on edge side drain area P from the link . i.e. that

(3-14)

We have that and therefore the equation) 3-14 (becomes after the integration in the form

(3-15)

This equation represents the relationship between the electron density at the edge of the depletion layer in the area N and its density at the edge of the layer in the region P from duo link . from On the other hand, it represents the

foundations **Percentage** The value of the voltage barrier to the average energy of the charges or in other words is A measure of the rate at which these charges are able to cross this voltage barrier .
By following the same steps above, you can access to me same equation similar to the equation) 3-15 (for the density of the gaps i.e that

(3-16)

the two equations) 3-15 (and) 3-16 (Tarafan Bmadlta **Boltzmann** On Anyway

when setting and substituting them into the equation) 3-15(We get

(3-17)

that the significance of the equation) 3-17 (lie In fact, it has been Calculate it in terms of the density of atoms The duality that caused it to exist .

3-8 link to pN Under the influence of external bias voltage :

we knew while previously ,the emergence of the depletion layer via the . link PN Accompanied by the emergence of effort roadblock At this connection, the propagation of the majority carriers is obstructed and works so to reach condition poise kinematic to make the resultant current flowing through the . junction PN , equal to zero . Show shape) 5 (link to PN With the diaphragm voltage , which is equal to (0.7) volts at approximately room temperature) °c(25 For a silicon semiconductor and (0.3) Volt For the semiconductor of germanium .

shape) 5 : (link PN with bulkhead voltage V_B

Now if we put an outside effort This effort will be either similar l is called Then in **reverse biased** or contrary For , claims of **bias front** and we will study here The effect of these two types of bias On the bias link and we'll start with .

3-8-1 Forward bias of the link The PN Forword bias

To bias the diode, you apply a DC voltage across it . Forward bias is the condition in which current is allowed through a junctionpn .Figure)6 a (shows a DC voltage source connected by a conductive material) conductors and wire (via a bidirectional to produce a forward bias . This external bias voltage is set asV_{BIAS} .Limit the resistance of the forward current to a value that will not prevent diode damage . Note that the negative side ofV_{BIAS} Connected to the area n From the second and the positive side is connected to the region p .This is a requirement for forward bias . The second condition is that the bias voltage,V_{BIAS} , it must be greater than **the barrier voltage.**

)b (Major carriers pass through the diode	)a (Forward bias diode conduction
shape(6)	

Figure)6 b (shows the basic picture of what happens when the diode is forward biased . Since like charges repel, the negative side of the bias voltage source " pushes " the free electrons, which represent the majority of carriers in the regionn , towards the intersection . This flow of free electrons is called the electron **current** . The negative side of the source also provides a continuous flow of electrons through the external contact) the conductor wire (and into the regionn As described.

The bias voltage source transfers enough energy to the free electrons so that they can overcome the barrier voltage of the depletion region and move into the p .Once you reach the areap , these conduction electrons lose enough energy to instantly combine with holes in the valence band.
Now, the electrons are in the valence band of the region p , simply because it lost too much energy to overcome the barrier's ability to stay in the conduction band . Since in contrast to charges attracting, the positive side of the bias voltage source attracts the valence electrons towards the left end of the regionp .Availability of holes in the areap The middle or " path " for these valence electrons to travel through the regionp .The valence electrons move from one hole to the other towards the left . Moving holes, which represent the majority of vectors in the areap , effectively) but not actually (to the right toward the intersection, as you can see in Figure)6 b .(This effective flux of holes is the hole **current** . You can also view **the gap current** as being generated by the flow of valence electrons through the regionp , where holes provide the only means for the flow of these electrons.
When electrons flow from the region p Through the outer wire) conductor (and to the positive side of the voltage source, they leave holes in the areap ; At the same time, these electrons become conductive electrons in the metallic conductor . **Remember that** the conduction band in a conductor overlaps the valence band so that it requires much **less energy for an** electron to be a free electron in a conductor than in a semiconductor and that metallic conductors **do not have holes in their structure** . There is a constant availability of holes that actively move towards an intersectionpn to combine with the direct current of electrons when they come across the junction in the region p.

The effect of forward bias on the attrition area . As more electrons flow into the depletion region, the number of positive ions decreases . With more holes effectively flowing into the drain area on the other side of the junctionpn , the number of negative ions is reduced . This decrease in positive and negative ions during forward bias leads to a narrowing of the depletion region, as shown in Figure.(7)

Figure(7)

Effect of diaphragm voltage during forward bias . Remember that the electric field between the positive and negative ions in the depletion region on either side of the junction creates an " energy hill " that prevents free electrons from spreading through the junction at equilibrium . This is known as **the barrier voltage**.

When forward bias is applied, the free electrons are supplied with sufficient energy from the bias voltage source to overcome the barrier voltage and effectively “ climb the energy hill ” and cross the depletion region . The energy required by the electrons to pass through the depletion region is equal to the barrier potential . In other words, the electrons give up an amount of energy equal to the barrier voltage when they cross the depletion region . This power loss results in a voltage drop across the junctionpn equal to the diaphragm voltage 0.7) V , (as shown in Figure .7 A small additional voltage drop occurs across the two regionsp And n Because of the internal resistance of the material . For doped semiconductor materials, this resistance, called kinetic resistance, is very small and can usually be neglected.

anyway case ,You can rewrite the equation Boltzmann) equation (3-15) and) 3-16 ((in the way the following

(3-18)

And

(3-19)

when shedding biasing effort positive)+ V (from an external source on the link The pN The barrier voltage then becomes equal for) V_B - V(The density of the gaps becomes equal to

(3-20)

This increase in the number of gaps ( )Be because more gaps you have sufficient energy that enables it to cross a barrier The new voltage is reduced to a lower value . And of course This is due to the bias effort V .Also, the number of electrons increases in the side Corresponding from the depletion layer so that :

(3-21)

When subtracting the equation (3-18) ,from the equation) 3-20 (we get The amount of increase in the density of the gaps

(3-22)

In the same way, when subtracting the equation) 3-19)from the equation(3-21 , (we get On the amount of increase in the electron density

(3-23)

Now assuming that A represent the junction area and V_h The speed of the gaps, the rate holds multiplication) ΔpeV$_h$(It will represent the vehicle of the current The result of the injected gaps to the logic N .
i.e. that

(3-24)

In the same way, we will find that the component of the current produced by the electrons is injected into the area P be equal to

(3-25)

And therefore The total current will be equal to

(3-26)

3-8-2 bias reverse link pN

Reverse bias is the condition that essentially prevents current through the diode . Figure)8 a (shows a DC voltage source connected across the diode in the direction to produce a reverse bias . This external bias voltage is set asV_{BIAS} Just as it was for the forward bias . Note that the positive side ofV_{BIAS} Connected to the area n From the diode and the negative side connected to the region p .Also note that the region of depletion appears much wider than in the forward bias . Now suppose that External voltage done Tie it so that it affects the same The direction of the barrier voltage, ie The pole has been tied Positive for external voltage source to semi-conductor Negative N The negative electrode leads to the positive semiconductor P - Look Figure) 8 a .(In this case The electric field due to the application of voltage affects External through the forum pN at the same The direction of the barrier potential field and therefore the majority of carriers) holes and electrons (will move towards the ends of the crystal away from the junction)PN (To leave behind negative ions and the additional positive, and for this reason the width of the depletion layer increases with Bias increased reverse - See Figure)8 b.(

)b (Electrons and holes move through the reverse bias

)a (How to conduct a diode in reverse bias

)c (A very small saturation current is generated during the reverse bias

Figure :(7) The . campaign pN With effort reverse

In spite of The last sentence above is correct, but it is not accurate We have to ask : when A certain value for bias voltage reverse ,to any limit can Increases the width of the attrition layer ?Can this reverse voltage be increased to?. endless? that the answer About the first part of this question is summed up as The following : the electrons fugitive will fall behind Positive ions behind it And leaving vacuoles leave negative ions on it the ions The new will increase the voltage difference on layer Attrition the greater the width The depletion layer increases the potential difference across it and the growth stops Attrition layer when diff equals her effort External voltage Reverse overlay . but regarding For the second part of the question ,Van the answer about it be In the negative . This is because continuing to increase the reverse voltage will lead to, as We mentioned, to increase the barrier effort, which increases the obstruction of passage current idlers The majority on both sides of the link, but at the same time working to push carriers Minority current of electron and hole pairs thermally produced inside Area attrition to my end crystal, electrons to Right and Gaps to the left. See Figure) 8 c.(

and what that Thermal energy produces electron - hole pairs , near The link, constantly, there is a current Small runs continuously in the outer circle . The number of these minority current carriers is finite at a given temperature, so van Increasing the negative voltage will not cause To increase the reverse current for this reason It is sometimes called a stream saturation saturation current symbolizes it I_s , but it works of course On Accelerate these carriers and from Then increase its speed significantly . Accordingly, increasing the reverse bias voltage above a certain limit) breaking potential break down voltoge (will work on These carriers gain a lot of energy It

is able to release valence electrons to other atoms when they collide with them .
These last electrons have You have some energy Makes it able to edit other electrons from atoms other and in this way we will get a number of The free electrons multiply in number very quickly, resulting in what It's called collapse electric electrical breakdown It disturbs the thermal stability of the junction The PN Or in other words, the amount of heat obtained by the double junction as a result of heating In reverse current it becomes greater than The amount of heat withdrawn from the junction and therefore the temperature rises The temperature of the junction decreases, its resistance decreases, and the current increases, causing overheating of the diode and thermally shattering For this reason, most Diodes are not allowed to reach refraction or In other words that applied reverse voltage On the duo should stay less than Effort Alanks R .

However, when substituting into equation () for (V) b)] V $_B$+ V [-(the limit It will become as small as it can be neglect . i.e. that

(3-27)

So, the voltage - current equation is for the couple The crystal becomes in the following form :

(3-28)

where ,as mentioned, is the reverse saturation bar due to the movement of Pairs The electron - gap is thermally produced , so raising the junction temperature will lead to to increase number of pairs carriers The generated minority current, i.e. the concentration of these carriers increases and grow The conductivity and therefore the properties of semiconducting diodes are very temperature dependent that well of curve) I - V (for the dicrystalline, Figure, (9) decree According to the above equation taken at two different temperatures for a diploid crystal of germanium

Figure (9) is a curve) I - V (for the pair

Notes in the figure (9) The growth of the two forward currents And vice versa when the temperature is raised Until the rate of increase the current The reverse is greater . in Germanium current doubles reverse twice Almost every

time the temperature rises by 10 degrees Celsius, for example if it rises The temperature is from ° 20 C to ° 70 C, then it doublese ^{5} That is 32 times As for silicon, Thermal energy is produced Minority carriers In fewer numbers than you can produce in pairs Germanium or in the words other . that in a Silicon is much lower than in duplexes germanium . this feature The greatness of silicon is one of the reasons why it has prevailed in the field of semiconductors .
On the other hand, it is noted in Figure , (9) that the forward current does not grow when the degree of . is raised The heat is as strong as the reverse current, and the reason for that is Huan forward current depends Mainly on the concentration of impurities) the donor and midwife (and it has nothing to do with the temperature, except that raising The temperature increases and, as mentioned, the saturation current increases , so the higher the barrier voltage It must be reduced to allow then the majority carriers to propagate to reach the state of kinetic equilibrium assuming The external voltage applied is zero, and therefore it can be said that Low voltage bulkhead with Overheating is the direct cause of increased forward current .

It is noteworthy in Figure (9) that The forward current does not begin to flow until A specific effort is called effort threshold threshold voltage or the cutting force is equal to D 0.2 to0.3 Volts in germanium and within 0.5 to0.7 volts in silicon . This is the difference between my effort The cutoff 0.4) volts (is due to the reverse saturation current . In germanium, this current is greater than it is It is in silicone about a thousand times . While its value in germanium is estimated in microamps) (We find that its value is in silicon be in nano amps) (
It is also noted in Figure (9) that the voltage Refraction begins at the value higher when temperature rise . Why? .

Example (1)

If the saturation current , Changes from $10^{.14}$ to^{9}10^{-} when temperature change from 20°C to me ° C 125 . I think V_{B} in Clay In both cases, assuming that the forward current remains fixed at value (I mA)
The solution
we have from The equation is

or that

and whereas T = 20 + 273 = 293°K So the:

Therefore

when T = 125 + 273 = 388°K become valuable equal to 34 millivolts Therefore

Therefore, it decreases with increasing temperature, despite the stability of the forward current) Provided forward bias effort .(

3-9 curved properties IV For the diode in the forward bias

When the forward bias voltage is applied across the diode, current is present . This current is called the forward current and is designated I_F .The figure shows) 10 a (What happens when the front increases in a positive bias voltage of 0 volts . A resistor is used to limit the forward current to a value that does not overheat the diode and cause damage . With 0 volts across the diode, there is no forward current . As the forward bias voltage gradually increases, the forward current and voltage across the diode gradually increase, as shown in Figure .10 A portion of the forward bias voltage is dropped across the limiting resistor . When the forward bias voltage increases to a value where the voltage across the diode is approximately 0.7 V) barrier potential , (the forward current begins to increase rapidly, as shown in Figure)10 b.(

)a :(small forward bias effort) $V_F <$ 0.7 volts , (a very small forward current.

)b :(The forward voltage has reached a nearly constant voltage of 0.7 volts . The forward current continues to increase as the bias voltage increases.

shape(10)

We continue to increase front bias voltage, the current continues to increase rapidly, but the voltage across the diode increases gradually just above 0.7 volts . This small increase in the diode voltage above the diaphragm voltage is due to the voltage drop across the internal dynamic resistance of the semiconductor.

Plotting an isotropic curve : If you plot the results of the type of measurements shown in Figure 10 on a graph, you will get a characteristic curve VI for forward biased diode, as shown in Figure .10 The forward voltage of the diode increases) V_F (to the right along the horizontal axis, and the forward current increases) I_F (up along the vertical axis.

Figure :(11) voltage-current relationship of the crystal diode in the case of forward bias

As you can see in Figure , 11 the forward current increases quite a bit until the forward voltage reaches across a junctionpn to approximately 0.7 volts at the knee of the curve . After this point, the forward voltage remains roughly constant at 0.7 ~ V, butI_F increases rapidly . As mentioned earlier, there is a slight increase inV_F Above 0.7 V the current increases due to the voltage drop across the motor resistance . ScaleI_F Usually in milliamperes, as specified.

Three dots appear A , B , C On the curve in Figure ,11 point A corresponds to the zero bias condition . corresponding pointB Figure 11 where the front voltage is lower than the probability barrier of 0.7 volts . corresponding pointC Figure 11 where the forward voltage is approximately equal to the septal potential . With the continued increase in the external bias voltage and current front above the knee, the front will increase the voltage slightly above 0.7 volts . In fact, the forward voltage can reach approximately 1 V, depending on the forward current.

Diode static resistance R_F:

The resistance provided by the diode to the connection is called pn When connected to a DC circuit static resistance . Static resistance is also defined as the ratio of the DC voltage applied through the diode to the DC current or direct current flowing through the diode . The resistance provided by the diode to the junction is indicatedpn Under the forward-biased condition as R_F.

where the letter R_F Writes in a capital letter . The resistance provided by the diode to the junction is indicatedpn Under the forward biased condition by R_f :

) .(

One value for voltage and current must be determined on the isotropic curve in calculating the static resistance) R_F(

Figure :(12) Diode static resistance

Example :(2) Calculate the forward static resistance of the diode if you know that the value of**V_F = 0.33 V** and value **I_F = 60 mA.**

In Example :(2) What is the quality of the diode used?

Diode's Kinetic Resistance r_d:

Figure 12 is an enlarged view of a characteristic curve VI Figure 11 shows the kinetic resistance . In contrast to linear resistance, the resistance of a forward biased diode is not constant over the entire curve . Because the resistance changes as you move along a curveVI It is called kinetic resistance or alternating current resistance . The internal resistance of electronic devices is usually indicated by a small italic character, rather thanR .The kinetic resistance of the diode is setr_d.

Below the curve knee the resistance is larger because the current increases very little for a given voltage change) , (the resistance starts to decrease in the curve knee region and becomes smaller above the knee as there is a large change in current for a given voltage change.

Two values of voltage and current must be determined on the isotropic curve in calculating the kinetic resistance) r_d(

There is another way to calculate the kinetic resistance, the formula) .(

Example : 3 Calculate the kinetic forward resistance of the diode if you know that the value ofV_F change from **0.71 V** to me **0.721 V** and value **I_F** from **2 0 mA to me 60 mA**.

In Example :(3) Does the calculated resistance value remain constant or change, explain this? Also, how can we increase or decrease the value of the kinetic resistance **?**

3-9 curved properties IV for the diode in reverse bias

When a reverse bias voltage is applied across the diode, there is only a very small reverse current) I_R (through the intersectionPN .With 0 volts across the diode, there is no reverse current . As the reverse bias voltage gradually increases, there is a very small reverse current and the voltage across the diode increases . When the applied bias voltage is increased to a value at which the reverse voltage across the diode) V_R (to the collapse value) V_B , (the reverse current begins to increase rapidly.

Figure :(13) Voltage-current relationship of the diodes in the case of reverse bias

As the bias voltage continues to increase, the current continues to increase very rapidly, but the voltage across the diode increases very slightly above V_B .Breakdown, with exceptions, is not a normal mode of operation for most plug devicespn.
curve graph VI If you plot the results of the reverse bias measurements on a graph, you get a characteristic curve VI for reverse biased diode . A typical curve is shown in Figure .(13) The reverse voltage of the diode increases) V_R (to the left along the horizontal axis, the reverse current increases) I_R (down along the vertical axis.
There is very little reverse current) usuallynA nano-amperes) until the reverse voltage across the diode is approximately the breakdown value(V_B (at the knee bend . After this point, the reverse voltage remains atV_B Roughly, but I_R They increase very quickly, resulting in overheating and potential damage if the current is not limited to a safe level . The diode breakdown voltage depends on the level of impurities, which is determined by the manufacturer, depending on the type of diode . A typical rectifier diode) the type most commonly used (has a breakdown voltage greater

than 50 volts . Some specialized diodes have a breakdown voltage of only 5 volts.

Example :4 Calculate the static reverse resistance of the diode if you know that the value of **$V_R = 20$ V** and value **$I_R = 90$ nA.**

In Example :(4) What is the reason for the high value of the calculated resistance?

9-3characteristics curveVI full.

Combine the curves for both forward bias and reverse bias, and you get a characteristic curve VI The full diode, as shown in the figure (14)

Figure :14 CurveVI Diode Full Feature

10-3Effects of temperature on the forward and reverse properties of the diode

For a forward biased diode, as the temperature increases, the forward current increases for a given value of the forward voltage . Also, for a given value of the forward current, the forward voltage drops . This is shown with property curvesVI in Figure .(15) The blue curve is at room temperature° 25) C (and the red curve is at high temperature . The barrier voltage decreases by 2 mV for each degree of temperature increase° 25) C+ TΔ.(

Figure :(15) The effect of temperature on the properties of a curveIV

For reverse biased diode, as the temperature increases, the reverse current increases . Keep in mind that the reverse current below the breakdown remains extremely small and can usually be neglected.

11-3Binary circuit analysis : pregnancy line

Figure) 16 a (shows a simple and basic diode circuit consisting of a voltage source outer ,Vs and resistance R straight tethered With the duo and what is required now is to determine The value of the current passing through Resistance R Or in other words get to know The nature and amount of the output voltage .

)a :(circle Frontally Biased Duo)B :(Dichrystalline pregnancy line
Figure(16)

In spite of that there are ways Too many to know, but we will limit our attention Here On the line method of pregnancy Load line given what This method is of particular importance In defining a number of points The task related to the duo as well because it It is also used as an analysis tool For many other devices, such as a transistor, for example .
obviously in This is amazing Circle, that the bilateral forward biased where It was completed Connect the anode from diode to the positive pole of the

voltage source and therefore it is expected that the current in the circuit (I_F)it will be from Forward current type - see the shape) 16b(And therefore So what is required becomes Find the value of this current , as well as its value ar Voltage drop across the diode .V_F

On Verse case, we have in Circle - Figure) 14 a(that

(3-29)

And assuming
that the current in the circle is I_F so

(3-30)

or

(3-31)

represents the equation) 3-31 (Equation of a straight line and connects V_F And I_F see figure) 16b(Certain values of ,V_S And R_L It is called This line is the line of pregnancy Load line And it is drawn as follows :

-1The first point of this line is set, on the axis y where that valueV_F zero and from the equation (3-30) ,Van

(3-32)

Thus, the first point is determined b) 0 , (

-2The second point is located on the x-axis, where the value of I_F zero so that

(3-33)

And the second point is (, 0)

-3Finally done draw a straight line between These two points - see Figure 16)b - (and claim this The line then is the load line of the dual circuit, and it is called the point of intersection of the load line with the curve)I - V(For a binary with a binary operating point operating point It is symbolized by Q It represents The current value I_{FQ} In the duo circle and the amount of drop in the effort V_{FQ} through this duo .

It is worth noting that the same method above can be used to determine an action point Bi-crystalline reverse-biased in circle set out In Figure)7 a.(

Questions and problems of the third chapter

-1Why The semiconductor material is not N or Type - P self benefit proces?

-2 explain In detail how to create the depletion layer in a link to pN

-3what The reason for the concentration of resistance .link pN In the drain area?

-4What is meant by the sudden link ?explain what Says

-5Explain in detail what is meant voltage barrier ?Show how it happens

-6What is meant by diffusion current ?And how does it happen?

-7 In Figure () explain The reason for the appearance of the package P a little higher Who pack?

-8 Derive equation (1) and state its meaning

-9Explain what is the role of the gaps in the semi-conductor

-10What is the magnitude of the current flowing through .link pN In the case of equilibrium ?Explain this

-11Do Depends on the number of cargo carriers The minority on the temperature ?and how?

-12prove on the correctness of the equation Einstein - Equation (11) - Then between its meaning .

-13 Derive equation (17) and then state the meaning of each symbol In which

-14Explain how conduction current arises in each From pure semiconductor and impurity . which of these Larger ?

15th -What is the relationship of conduction current? diffusion current in semiconductor stationary in case A - kinetic balance B - when applying a forward bias effort C - a reverse bias effort

-16what Effect of all bias Forward and reverse over voltage spike ?Explain it - with drawing .

-17Why doesn't it change? Conduction current when shedding an effort Frontal siding on the link The pN

-18Explain how it applies to current in Semiconductor binary circuit when shedding an effort bias In front of me

-19What is reverse current? Do Increasing the negative voltage on the junction causes pN to increase it?

-20Explain in detail 20) draw curve (V - 1) explained on it all points the mission

-21explain in detail The effect of temperature on the work of a link to pn

-22Derive equation ,(34) then state its meaning .

-23in a Figure (13) Why was chosen , instead of ? And why was it added? ,R ?

-24In Figure (15) why add the voltage source continuous ?Explain this

-25What is meant by pregnancy line? How is it appointed? ?Mention its benefit

-26 what What is the point of operation? How is it set her

Electronic lectures - fourth semester - physics department - third stage **d . Omar Mehadi Dawood**

Applications of Diode

4.1Introduction:

The most common function of a diode is to allow electric current to pass in one direction) the forward direction of the diode , (while preventing it in the opposite direction) the reverse direction .(It is used to convert alternating current) ac (to direct stream) dc .(Formats of rectifiers and diodes can be used for tasks such as extracting modulation from radio signals in radio receivers.

However, diodes can have more complex behavior than this simple procedure, due to their nonlinear voltage properties . Semiconductor diodes only start conducting electricity if a certain threshold voltage or cut-off voltage is present in the forward direction) a condition in which the diode is said to be forward biased .(The voltage drop across the forward-biased diode changes only slightly with current, and is a function of temperature ;This effect can be used as a temperature sensor or as a voltage reference . Also, the high resistance of a diode for current flowing in the reverse direction suddenly drops to a low resistance when the reverse voltage across the diode reaches a value called breakdown voltage.

The current and voltage characteristic of a semiconductor diode can be adapted by selecting the semiconductor materials and activating impurities introduced into the materials during manufacturing . These technologies are used to create special-purpose binaries that perform many different functions . For example, the diodes are used for voltage regulation) binaries Zener , (to protect the circuit from the heights of high - voltage) binaries collapse Altdhaafee , (and to set the radio receivers and television electronically) diodes Varactor , (to generate oscillations RF) tunneling diodes, diodes Gan, diodesIMPATT , (and to produce light) light-emitting diodes .(Binaries are shownTunnel And Gunn And IMPATT Negative resistance, which is useful in microwave and switching circuits.

The development of semiconductor devices thus lead over time to increase its deployment in various types of equipment and then the identification of the use of these devices and applications it becomes necessary important things and we will try in this chapter to address some of the applications of these devices such as calendar and the selection CRAM .... and others.

2-4Calendar:

All active electronic devices require a constant DC source that can be supplied by a battery or DC power source . Fortunately, the required current is not, in most cases, large, and this explains that dry batteries are one of the most used sources in mobile devices such as radios, neon lights, electronic pocket calculators ... and others. . On the other hand, given the limited life of these batteries and their rapid consumption And for the ever-present need for

DC sources, these sources are usually obtained from the familiar AC power lines by converting the alternating current.)AC (to DC (DC) using a double crystal . The conversion process is called This is in the calendar The duo is called the **rectifier**.

The rectifying property of the waves that the crystal diode has, comes from the fact that this diode shows **a small resistance** to the passage of current in one direction) the forward direction, i.e. when the elevator voltage is positive with respect to the cathode (**and a** very **large resistance** in the other direction) conducting current in one direction and preventing current in the other direction(

Converts the AC power provider constant current voltage AC 120 V and 60 Hz available in standard wall outlets to a constant DC voltage . A DC power supply is one of the most common circuits you'll find, so it's important to understand how it works . The output voltage is used to power all types of electronic circuits including consumer electronics) TVs, tabletsDVD etc , (. computers, industrial controllers, and most laboratory systems and equipment . The level of DC voltage required depends on the application, but most applications require a **relatively low** voltage**.**

A basic diagram of the complete power supply is shown in Figure 1-4)a .(Generally, the AC input line voltage is reduced to a lower AC voltage using a transformer . As we learned in DC / AC circuits , the transformer changes the AC voltage based on the ratio between the primary and secondary coil . If the secondary has more cycles than the primary, the output voltage across the secondary will be higher and the current will be smaller . If the secondary has fewer windings than the primary, the output voltage across the secondary will be lower and the current will be higher.

)a
(

)b
(

Figure(1-4)

The rectifier can be either **a half-wave rectifier or a full-wave rectifier** . The rectifier converts the AC input voltage into a **pulsed** DC voltage , called a rectifier half-wave voltage, as shown in Figure)1-4 b .(The filter eliminates fluctuations in the rectifier voltage and produces a relatively smooth DC voltage .. A voltage regulator is a circuit that maintains a constant DC voltage to changes in the input line voltage or in the load . Regulators vary from a single semiconductor device to more complex integrated circuits . A load is a circuit or device that is connected to the output of a power source and operates from mains voltage and current.

1-2-4Half-wave straightening process

Figure) 2-4 a (illustrates a process called half-wave rectification . The diode is connected to an AC source and the load resistor,R_L , forming a half-wave rectifier . Keep in mind that all earth symbols represent the same electrical point . We will examine what happens during one cycle of the input voltage using the ideal diode model .

A *load resistance is any electrical device or component that consumes electrical energy and converts it into another form of energy . such as electric lamps, air conditioners, and engines*[

]The *ideal diode is a diode that has no forward resistance and voltage applied across it.* $R_F = 0\ \Omega$ *And* $V_F = 0$ *volts . In the case of reverse bias, it will not be ideal for any diode reverse current, regardless of the reverse voltage and reverse resistance at the end of any that.* $V_R = \infty$,$I_R = 0$ *As for the practical diode, it is the one that has a front resistance ranging from 5 to 20 ohms, a forward voltage of about 0.6 to 1 volt, and a small reverse current of the order of some micro amperes*[.

When the sinusoidal input voltage) V_{in} (positive, the diode is forward biased and conducts current through the load resistance, as described in Section 2-4)a .(The current produces an output voltage across the loadR_L , which has the same shape as the positive half-cycle of the input voltage.

)a(

)b(

)C(

Figure (2-4) Operation of the half-wave rectifier . The diode is ideal.

When the input voltage becomes negative during the second half of its cycle, the diode is reverse biased . There is no current through the load resistor, so the voltage across the load resistor is 0 volts, as shown in Figure) 2-4 b .(The net result is that only half of the positive cycles of the AC input voltage appear across the load . Since the **output** does not change polarity, it is **a pulsating DC voltage of 60 Hz** , as described in Part) 2-4 c.(

4.2.2The average value of the output voltage of the rectifier migraine

The average value of the output voltage half **-** wave rectifier is the value that measure them on a scale of **DC voltage**) ammeter .(Mathematically, it **is determined by finding the area under the curve over a complete cycle** , as shown in Figure , 4-3 and then dividing by 2π The number of diagonal angles in a complete revolution . The result of this is expressed in equation-4 , 1whereV $_p$ is **the peak value of the voltage** . This equation shows thatV $_{AVG}$ It accounts for about % 31.8 ofV $_p$ For a half-wave voltage rectifier.

(1-4)

Figure :(3-4) The average value of the half-rectifier signal

Example :(1) What is the average value of the half-wave rectified voltage in Figure? 22-2

Solution:

3-2-4Effect of the diaphragm voltage on the output voltage rectifier halfway

In the previous discussion, the diode was considered ideal . When the working diode model is used with a voltage threshold of 0.7 volts in mind, this is what happens . During the positive half-cycle, the input voltage must overcome the diaphragm voltage before the diode becomes forward biased . This results in a half-wave output **with a peak value 0.7 volts lower than the peak value of the input voltage** , as shown in Figure.4-4

Expression of the peak output voltage:

(2-4)

Figure(4-4)

It is usually acceptable to use the ideal diode model, which neglects the effect of the diaphragm voltage, when the peak value of the applied voltage is much greater than the diaphragm voltage) at least 10 volts, as a general rule .(However, we will use the working model of the diode, taking into account the diaphragm voltage of 0.7 V unless otherwise stated.

Example :2 Plot the output voltages of each rectifier for the indicated input voltages, as shown in the figure below, being 1 N4001 and1 N4003 of the specified rectifier diodes.

Solution:

)a( )b(

)a (The maximum value of the output voltage in circuit) A (in relation to the input voltage is:

)b (The maximum value of the output voltage in circuit) B (with respect to the input voltage is:

The waveforms of the output voltage in circuits) a (and) b (are shown below . Note that the barrier potential in circuit) b (can be neglected with very little error 0.7) percent ; (But if it is neglected in circle) A , (it will result in a large error 14) percent.(

4-2-4Reverse Peak Voltage) PIV(

equal to the reverse peak voltage) PIV (Peak input voltage value, and must be able to withstand Diodes this amount of repetitive reverse voltage . For the diode in Figure , 5-4 the maximum value of the reverse voltage occurs, designated asPIV , at the peak of each negative alternating voltage of the input when the diode is reverse biased . The diode must be at least % 20 higher thanPIV.

(3-4)

Figure(5-4)

Figure (5-4) occursPIV at the peak of each half-cycle of the input voltage when the diode is reverse biased . In this circuit, it happensPIV At the height of each negative half cycle.

5-2-4Coupling Transformer

As you have seen, a transformer is often used to connect the AC input voltage from the source to the rectifier, as shown in Figure .6-4 Transformer coupling offers two advantages . **First** , it allows the source voltage to be reduced as needed . **Second** , the AC source is electrically isolated from the rectifier, thus preventing the risk of shock in the secondary circuit.

Figure(6-4)

The amount of voltage being lowered is determined by the ratio of the windings of the transformer . The definition of the winding ratio of a transformer is" the number of turns in the secondary winding" N_{sec} (divided by the number of turns in the primary file) N_{pri} " .(Thus, the adapter that will be sessions ratio less than 1 is a type of effort depressor and the other with the largest turnover ratio of 1 is the lifter for the type of effort.

The secondary voltage of the transformer is equal to the ratio of the windings ,n , multiplied by the initial voltage, that is:

(4-4)

if it was $n > 1$ The secondary voltage is greater than the primary voltage . if it was$n < 1$ The secondary voltage is less than the primary voltage . if it was$n$ 1 , Then $V_{sec} = V_{pri}$.

secondary voltage peak) $V_{p(sec}$, in the half-wave rectifier coupled to the transformer is the same $V_{p(in)}$ In Equation .2-4 Therefore, equation 2-4 written in terms of V_{sec} become:

And equation 3-4 in terms of) $V_{p(sec}$ she

The ratio of the windings is useful for understanding the transfer of voltage from primary to secondary . However, transformer datasheets rarely show the ratio of the windings . The transformer is generally selected based on the secondary voltage rather than the ratio of the windings.

Example : **3** Determine the peak value of the output voltage of the figure below if the winding ratio is.0.5

Solution:

6-2-4full wave rectifier

The maximum conversion efficiency that can be obtained from a half-wave rectifier circuit is ,% 40 and this decrease in the efficiency value was caused by the absence of the negative part of the incoming vector throughR_L Which constitutes a loss of %60 of the input capacity and therefore it becomes necessary to exploit this negative half to obtain a higher evaluation efficiency and then a greater continuous output capacity.

Although half-wave rectifiers have some applications, full-wave rectifiers are the most commonly used type in DC power supplies . In this section, you will use what you learned about half-wave rectifiers and extend it to full-wave rectifiers . You will learn about two types of full wave components : midpoint and arch.

A full-wave rectifier allows unidirectional) one-way (current through the load during the entire input cycle, while a half-wave rectifier allows current through the load only for half the cycle . The result of the full wave rectifier is an output voltage at a frequency twice the input frequency which pulsates every half-cycle of the input, as shown in Figure.7-4

Figure(7-4)

The number of positive rotations that make up the full-wave rectifier voltage is twice the half-wave voltage for the same time period . The average value, which is the value measured on a DC voltmeter, of the full-wave rectifier sinusoidal voltage is twice the value of the half-wave, as shown by the following formula:

(1-4)

Represent V_{AVG} About % 63.7 ofV_p for full wave rectifier voltage.

Example :4 Find the average value of the full-wave rectifier voltage in the figure below.

Solution:

7-2-4Complete evaluation using a mid-point power transformer

A center rectifier is a type of full wave rectifier that uses two diodes connected to the secondary winding of a midpoint transformer CT , as shown in Figure-4 .8The input voltage is coupled through the transformer to the sub-point.

The incoming wave appeared divided into two equal parts : the first part appeared at a point X The second appeared at the point . Despite the fact that the two parts are equal in magnitude, it is noticed that there is a **phase difference between them of** , **°180** which allows to exploit the negative half of the incoming wave as follows:

Figure(8-4)

For a positive half-cycle of the input voltage, the poles of the secondary voltages are shown in Fig) 9-4 .a .(In this case : the diodeD_1 forward biased and D_2 Reverse biased, then the current will pass through D_1 and resistance to pregnancy R_L , as specified . For a negative half-cycle of the input voltage, the voltage poles of the secondary are as shown in Fig) 9-4 .b .(This condition reflects biases : the diodeD_1 inversely biased and D_2 Frontally aligned . Then the current will pass throughD_2 And R_L , as specified . Since the output current during both the positive and negative portions of the input cycle is in the **same direction through the load** , the rectified output voltage across the load resistor is **a fully** rectified **DC voltage** , as shown.

)a(

)b(

Figure(9-4)

-2-48 peak reverse voltage

Each diode in a full-wave rectifier is alternately forward-biased and then reverse-biased . The maximum reverse voltage that each diode must withstand is the peak secondary voltage$V_{p(sec)}$This is shown in Figure-4 10where it is assumed thatD_2 It is reverse biased) red (and . is assumed to beD_1 Forward biased) green (to illustrate the concept.

Figure(10-4)

The peak reverse voltage across any diode can be calculated as follows:

The reverse peak voltage in a full-wave rectifier circuit **is twice or more** than in a half-wave rectifier circuit, and therefore the diode must be chosen here with greater caution.

Example) **:5** a (Show the voltage waveforms across each half of the secondary winding and throughR_L When a peak sine wave of 100 volts is applied to the primary winding in the figure below) b (what is the minimum ratePIV Who Should Own Binaries?

Solution:

)a (The ratio of the number of turns is n = 0.5 .The total peak secondary voltage is

There is a peak of 25 V across each half of the secondary with respect to ground . The resulting load voltage has a peak value of 25 volts, less than the drop of 0.7 volts across the diode . The waveforms are shown in the figure below

)b (Each diode must have a minimum rating PIV reach

-2-49 Full wave straightening using gantry

Despite the high efficiency of a full-fledged rectifier circuit using the midpoint principle compared to a half-wave rectifier circuit, there are some disadvantages that accompany this circuit, including: :-

a - The absence of a central-connected transformer at all times, as well as setting the half-point on the secondary winding, for this transformer, is not an easy process.
b- Also, the use of the transformer means an increase in the size of the circuit and an increase in its costs.
T- The crystal diodes used must have a high reverse peak voltage .

The need for a midpoint transducer will be eliminated when an orthodontic bridge is used

The bridge rectifier uses four connected diodes as shown in Figure-4 .11When the input cycle is positive as in Part) 11-4 a , (the diodes areD_1 And D_2 It is biased forward and flows in the direction shown . A voltage is generated viaR_L which is similar to the positive half of the input cycle . During this time, the diodes areD_3 And D_4 reverse biased.

)a(

)b(

Figure(11-4)

When the input cycle is negative as in Figure) 11-4 b , (the diodesD_3 And D_4 It is forward biased and conducts current in the same direction through R_L As is the case during the positive half-cycle . During the negative half-cycle, it isD_1 And D_2 Reverse biases . A full-wave rectifier output voltage appears acrossR_L As a result of this procedure.

10-2-4bridge output voltage

The bridge rectifier with an inlet coupled to the transformer is shown in Figure) 12-4 a .(During the positive half-cycle of the total secondary voltage, the diodes areD_1 And D_2 forward biased . Neglecting the voltage drop on both ends of the diode, the secondary voltage appears across the load resistor . The same is true when it isD_3 And D_4 Biased forward during the negative half-cycle. I.N:

As you can see in Figure) 12-4 b , (two diodes are always present in series with the load resistance during both the positive and negative half-cycles . If the diode voltage drop is taken into account, the output voltage

)a(

)b(

Figure(12-4)

The main disadvantage of the bridge circuit is that it uses four diodes, and this creates a problem when the input wave is small, as 1.4 volts are required to drop on the two diodes, in order to start conducting current, and therefore it is preferable to use a full wave rectifier in applications that need low voltages.

11-2-4Reverse peak voltage of the bridge rectifier

suppose that D_1 And D_2 forward biased and check the reverse voltage across D_3 And D_4 .ImagineD_1 And D_2 As a short form) perfect form , (you can see thatD_3 And D_4 They have an inverse peak voltage equal to the peak secondary voltage . Since the output voltage is ideally equal to the secondary voltage, if the diode voltage of the forward-biased diodes is included, the peak reverse voltage across each reverse-biased diode is where it is

Rate PIV The arched diodes are less than that required to form the midpoint . If the diode drop is neglected, the bridge rectifier requires half-rate diodesPIV to those in the central rectifier for the same output voltage . Thus, the reverse peak voltage will be distributed to both diodes, and this will be half of what it is in a full directed rectifier circuit for the same required output voltage . The second characteristic of the rectifier bridge is the possibility of obtaining the same output voltage, but by using half the number of turns of the secondary coil of the transformer to be used in the full-wave rectifier circuit.

Example :6 Determine the maximum output voltage of the bridge rate in the figure below, assuming the working model, what is the rate PIV Required for binaries ?The transformer is selected with a secondary voltage$V_{rms} = 12$ V Relative to 120 volts across the primary.

4-3Filters and regulators for power supplies

The power supply filter perfectly eliminates fluctuations in the output voltage of a half-wave rectifier or full-wave rectifier and produces a constant-level DC voltage . Filtering is necessary because electronic circuits require a constant source of DC voltage and current to provide power and bias for proper operation . Filters are implemented with expanders as you will see in this section . Voltage regulation in power supplies is usually regulated using integrated circuit voltage regulators . The voltage regulator prevents changes in the filtered DC voltage due to variations in the input or load voltage.

Figure(13-4)

In most power supply applications, the standard 60 Hz AC power line voltage must be converted to approximately constant DC voltage . The pulsed DC output of 60 Hz for a half-wave rectifier or the pulse output of 120 Hz for a full-wave rectifier should be filtered to reduce large voltage differences . Figure-4 13illustrates the filtering concept which shows a nearly smooth DC output voltage from the filter . The small amount of fluctuation in the filter output voltage is called ripple.

1-3-4filter circuits

A half-wave rectifier with a capacitive input filter is shown in Figure . 14-4 The filter is simply a capacitor connected from the rectifier output to ground . representR_L Equivalent resistance to the load . We'll use a half-wave rectifier to illustrate the basic principle and then extend the concept to a full-wave retracement . During the positive first quarter cycle of the input, the diode is forward biased, allowing the capacitor to charge within 0.7 V of the input peak, as shown in Fig) 14-4 .a .(When the input begins to drop below its peak, as shown in part) b , (the capacitor retains its charge and the diode becomes reverse biased because the cathode is more positive than the anode . During the remainder of the cycle, the capacitor can only discharge by impeding the load at a rate determined by a time constantR_LC , which is usually long compared to the input period . The higher the time constant, the lower the capacitive discharge . During the first quarter of the next cycle, as shown in part) c , (the diode will become forward-biased again when the input voltage exceeds the capacitor voltage by about 0.7 volts.

)a(

The primary charge of the capacitor) forward-biased diode (occurs only once when the power is turned on.

)b(

The dilator is discharged through R_L After the positive alternating peak when the diode is reverse biased . This discharge occurs during the portion of the input voltage indicated by the dark blue curve.

)C
(

The capacitor returns to the input peak when the diode becomes forward biased . This charging occurs during the portion of the input voltage indicated by the dark blue curve.

Figure **(14-4)** Operating a half-wave rectifier with a scaling input filter . Current refers to the charging or discharging of the capacitor.

2-3-4ripple voltage

As we have seen, the capacitive charges quickly at the beginning of the cycle and discharges slowly through R_L After the positive peak of the input voltage) when the diode is reverse biased .(The variation in the capacitive voltage due to charging and discharging is called the ripple voltage . In general, corrugation is undesirable ;Thus, the smaller the ripple, the better the filtration procedure, as shown in Fig.15-4 .

)a (Bigger ripple) blue (means less effective filtration.

)b (Less ripple means more effective filtration . In general, the higher the capacitive value, the smaller the ripple of the same input and the load.

Figure(15-4)

For a given input frequency, the output frequency of a full-wave rectifier is twice that of a half-wave rectifier, as shown in Figure .16-4 This makes it easier to filter out the full wave rectifier due to the short time between peaks . When filtered, the full-wave rectifier voltage has a smaller ripple than the half-wave voltage of the same load impedance and capacitance values . The dilator discharges smaller amounts during the shorter period between full wave pulses, as shown in Figure.17-4

Figure (16-4) The period of the full-wave rectified voltage is half the period of the half-wave rectified voltage . The output frequency of a full-wave rectifier is twice that of the half-wave rectifier.

Figure (17-4) Comparison of ripple voltages for half-wave and full-wave rectified voltages with the same filter and load capacitance derived from the same sinusoidal input voltage.

3-3-4ripple factor

ripple factor) r (is an indicator of the candidate's effectiveness and is defined as

(2-4)

where is the peak-to-peak ripple voltage and is the DC value) average (of the filter output voltage, as shown in Figure .18-4 The lower the ripple factor, the better the filter . The ripple factor can be reduced by increasing the value of the filter capacitance or increasing the load resistance.

Figure(18-4)

For a full wave rectifier with a capacitive input filter, approximations are given for the peak ripple voltage , ,and the DC value for the filter output voltage,V_{DC} , in the following equations . It is the peak unfiltered rectifier voltage . Note that in the case of an increase R_L or C The ripple voltage decreases and the DC voltage increases.

Example : 7Determine the ripple factor of the filtered bridge rectifier with a load as shown in the figure below.

4-3-4Voltage Regulator Circuit

While filters can reduce ripple from power sources to a low value, the most effective method is to combine a capacitive input filter used with a voltage regulator . The voltage regulator is connected to the output of the filter rectifier and maintains a constant output voltage) or current (despite changes in input, load current, or temperature . The input widening filter reduces the input ripple to the regulator to an acceptable level . The combination of a large capacitor and a voltage regulator helps produce an excellent power supply . Most regulators are integrated circuits and have three terminals - an input terminal, an output terminal, and a reference) or tuning (terminal . The input to the regulator is first filtered using a ripple-reducing capacitor to the regulator, which reduces ripple to a small amount . Additionally, most regulators have an internal voltage reference, short circuit protection, and thermal shutdown circuit . They are available in a variety of voltages, including positive and negative outputs, and can be designed for variable outputs with minimal external components . Typically, voltage regulators can provide a constant output of one or more amperes of current with a high ripple rejection . Three-terminal regulators designed for a constant output voltage require only external capacitors to complete the regulatory part of the power supply, as shown in Figure .50-2 Filtering is done by a large value capacitor between the input voltage and the ground . An output capacitor is) usually (connected from the output to ground to improve transient response.

It is shown in Figure 19-4 a constant power source with a basic voltage regulator 5 + volts.

4-4pruning and binding circles

Diode circuits, called limiters or trimmings, are sometimes used to clip portions of a signal voltage above or below certain levels . Another type of diode circuit, called compelling, is used to add or restore a constant current level to an electrical signal . Both diode circuits will be examined in this section.

1-4-4pruning circles

Figure) 20-4 a (shows a positive diode limiter) also called a clipper (that limits or cuts off the positive portion of the input voltage . When the input voltage becomes positive, the diode becomes forward biased and transmits current . the pointA It is limited to0.7 + V when the input voltage exceeds this value . When the input voltage returns below 0.7 volts, the diode is reverse biased and appears as open . The output voltage looks like the negative portion of the input voltage, but with a size determined by the voltage divider consisting ofR_1 and resistance to pregnancy R_L , as follows:

(3-4)

)a
(

)b
(

Figure(20-4)

if it was R_1 small compared to R_L , Van

Then if the diode is rotated, as in Figure) 20-4 b , (the negative portion of the input voltage is cut off . When the diode is forward biased during the negative portion of the input voltage, the point is kept A when -0.7 volts by diode voltage drop . When the input voltage exceeds -0.7 volts, the diode is no longer forward biased ;The voltage is shown across R_L proportional to the input voltage.

Example : What would you expect to see displayed on an oscilloscope connected through R_L In the determinant shown in the figure below?

Solution:

The diode is forward biased and conducts current when the input voltage drops below -0.7 Volts, for the negative limiter, determine the peak output voltage across R_L With the following equation:

2-4-4biased pruning circles

The level at which the AC voltage is limited can be adjusted by adding a bias voltage ,V_{BIAS} , respectively with the diode, as shown in Figure .21-4 The voltage must be equal to the pointA $V_{BIAS}+ 0.7$ V before the diode becomes forward biased and conducts . Once the diode begins to conduct, the voltage is at the pointA Limited to $V_{BIAS}+ 0.7$ V So that all input voltage is cut off above this level.

Figure(21-4)

To limit the voltage to a specified negative level, the diode and bias voltage must be connected as in Fig .22-4 . In this case, the voltage should drop at the pointA to less than) - $V_{BIAS}- 0.7$ (volts to bias the diode forward and start a limiter procedure as described.

Figure(22-4)

By rotating the diode, the positive limiter can be adjusted to limit the output voltage to a portion of the input voltage waveform higher than V $V_{BIAS}- 0.7$ As shown in the resulting waveform in Figure) 23-4 a .(Similarly, the negative limiter can be modified to limit the output voltage to a portion of the input voltage waveform less thanV $V_{BIAS}+ 0.7$ volts, as shown in the output waveform in part) b(

)a(

)b(

Figure(23-4)

3-4-4Obligation circle

The compulsion adds the DC level to the AC voltage . Committing circuits are sometimes known as DC voltage and current retrieval circuits . Figure-4 24illustrates the role of a diode that inserts a positive DC level into the output waveform.

)a
(

)b
(

Figure(24-2)

The operation of this circuit can be seen by looking at the first negative half-cycle of the input voltage . When the input voltage initially becomes negative, the diode is forward biased, allowing the capacitor to charge near the input peak as shown in Figure) 24-4 a .(Immediately after the negative peak, the diode is reverse biased . This is because the cathode is fixed close to the capacitive charge . The dilator can only discharge through the high resistance ofR_L.Therefore, from the peak of one negative half-cycle to the other, the dilatant discharges very little . The amount spent depends of course on the value ofR_L.

If the capacitor is discharged during the period of the input waveform, the commit action is affected . If it is a time constantRC equal to 100 times the period, the cram action is excellent . time constantRC Ten times the period will have a small amount of distortion at ground level due to the charging current.

The net effect of binding is that the capacitor retains a charge approximately equal to the input peak value minus the voltage drop across the diode . The capacitor voltage basically works as a battery connected to the input voltage . The DC voltage of the capacitor is added to the input voltage by superposition, as in Figure)24-4 b .(If the diode is rotated, a negative DC voltage is added to the input voltage to produce the output voltage as shown in Figure25-4

Figure(25-4)

Example : What is the output voltage that you expect to notice via R_L In the installation circuit as below ?suppose thatRC Large enough to prevent a large expansive discharge.

Ideally, a negative DC value equal to the input peak less than the diode drop is inserted by the force circuit.

In fact, the capacitive will discharge slightly between the peaks, and as a result, the average output voltage will have a value slightly lower than that calculated above . The resulting waveform travels to about 0.7+ volts, as shown in the figure below

5-4voltage multiplier circuit

Voltage multipliers use the behavior of the compulsion circuit to increase the maximum rated voltage without the need to increase the voltage rating of the transformer . Voltage amplification factors of two, three and four are common . Voltage multipliers are used in high voltage and low current applications such as cathode ray tubes) CRTs (and particle accelerators.

)a( )b(

Figure(26-4)

The full wave multiplier is shown in Figure , 26-4 when the secondary voltage is positive,D_1 forward biased and charged C_1 to me V_p Roughly, as shown in part) a .(During the negative half-cycle, it isD_2 forward biased and charges C_2 to me V_p Roughly, as shown in part) b .(The output voltage is taken, Vp , 2across the two diagonals, respectively.

Experiments indicate that the last sentence of the above paragraph is correct in the event that the voltage multiplier circuit is unloaded) no load resistance.(R_L About (C_2)In this case, the output voltage is free from oscillation, i.e. continuous, and its value is equal to The double peak of the incoming wave is the reason that it can not widen ,C_2 to devote during ,D_2 Because of the bias of the latter, .

On the other hand, if the resistance R_L About C_2 Then it becomes possible to expand C_2 It discharges through this resistance and thus a ripple appears in the outgoing voltage . This ripple can be reduced when the frequency of the incoming wave is increased, and it was found that if)$2 \pi f R_L C_2 > 200$ (Van$V_{DC} = 2 V_P$