ELECTRONICS LAB.

PART 1

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DIODES

1.1 ATOM AND ITS STRUCTURE

The smallest part of an element that preserves its characteristics is called **"atom"**. In **Hata! Başvuru kaynağı bulunamadı.**, the structure of an atom is shown.

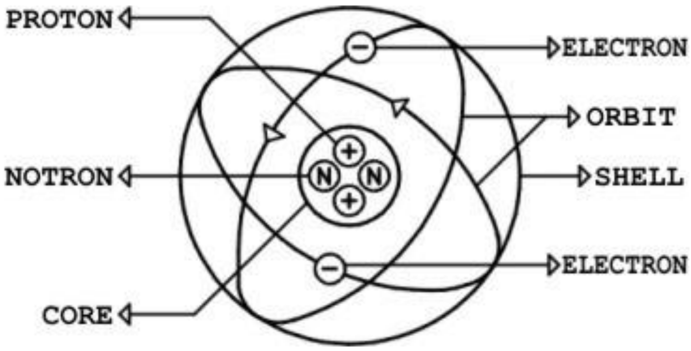

Figure 1. 1

The number of positive charges **(protons)** in nucleus is equal to negative charges **(electrons**). In terms of electricity, an atom is charge less (neutral).

The number of an atom is determined by number of protons it has. The weight of an atom is determined by number of protons and neutrons in the nucleus. The nucleus and the shell can be thought as equi-central spheres. There may be more than one shell in an atom, and they are numbered by their distance to the nucleus. The 1. shell is the closest shell to the nucleus. Electrons spins on their trajectories, in the shells, around the nucleus, The shells are actually non-existing spheres that carries electrons' trajectories.

At each shell, a known number of electrons can exist. The mathematical formula fort his number is shown below.

Maximum Electron number = (Shell number)^2 x 2

As an example, 3. shell can have at most 3^2x2=9x2=18 electrons. Except the outmost shell(called as **valance shell**), all shells must have their maximum number of electrons on them. The electrons that spin on the valance shell are called free electrons or **valance electrons**. These electrons can easily trespasses to another atom. If an electrical force is applied to an atom, one or more electrons can be taken from atom's valance shell. The conductivity, semi conductivity or insulation abilities depend on the number of the valance electrons.

1.2 CONDUCTORS

A good conducting atom has small number of valance electrons. As a general rule, a material is called conductor if it has less than 4 valance electrons, whereas the conductivity increases with decrease in the valance electrons. The best conductors are Silver, Gold and Copper. Copper atom has 1 valance electron, whereas Aluminum has 3 electrons, therefore we can conclude copper is a better conductor.

If an electrical power (voltage) is applied to the pins of a conductor, the valance electrons of the atoms connected to the positive pin of the voltage source is pulled by the source. Valance electrons of the neighboring atoms transpasses to the atoms that loses its valance electrons. The electrons that are pulled and gained by the source are pushed from the negative source pin at the same time.

When these valance electrons travel from an atom to another one, an electron flow emerges. That means an emerging electrical current.

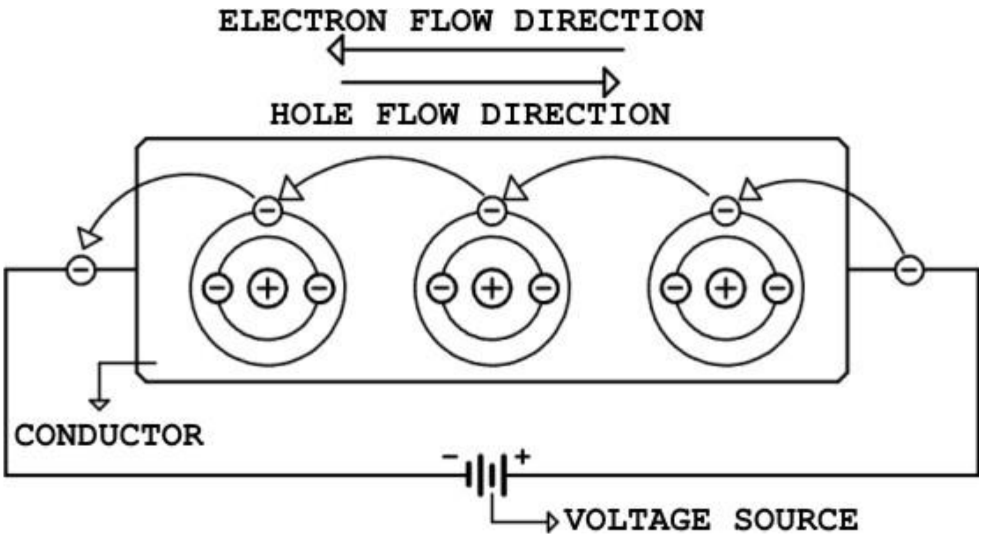

Figure 1. 2

1.3 INSULATORS

As a general rule, a material is called insulator if it has more than 4 valance electrons. A good insulator has more than 6 valance electrons. They do not give electrons, however they may absorb electrons in order to have 8 valance electrons. There isn’t a perfect insulator material over the world. Insulators may create an electron movement under certain frequency and voltage.

1.4 SEMICONDUCTORS

A material is called semiconductor if its atoms has exactly 4 valance electrons.

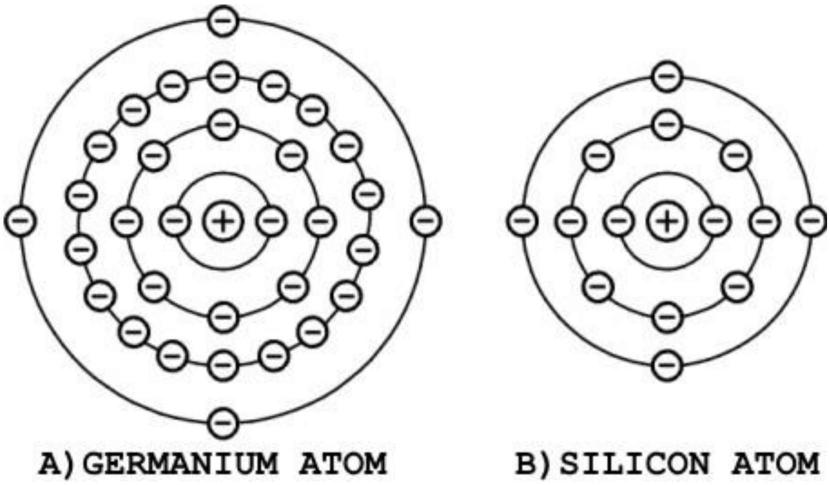

Figure 1. 3

In production of crystal diyotes and transistors, mostly Germanium and Silicon material is used. Semiconductors like Indium and Arsenic, are used as additional ingredients in production of those materials.

1.5 COVALENT BOND

The valance electrons of Silicon atom spins as if they are connected to the valance electrons of the neighboring atom. Each silicon atom has four valance pairs; these produce four difference electron bond pair.

In order to pass electrical current from Silicon or Germanium, these valance bonds have to be torn apart by heat or voltage, which is indeed hard.

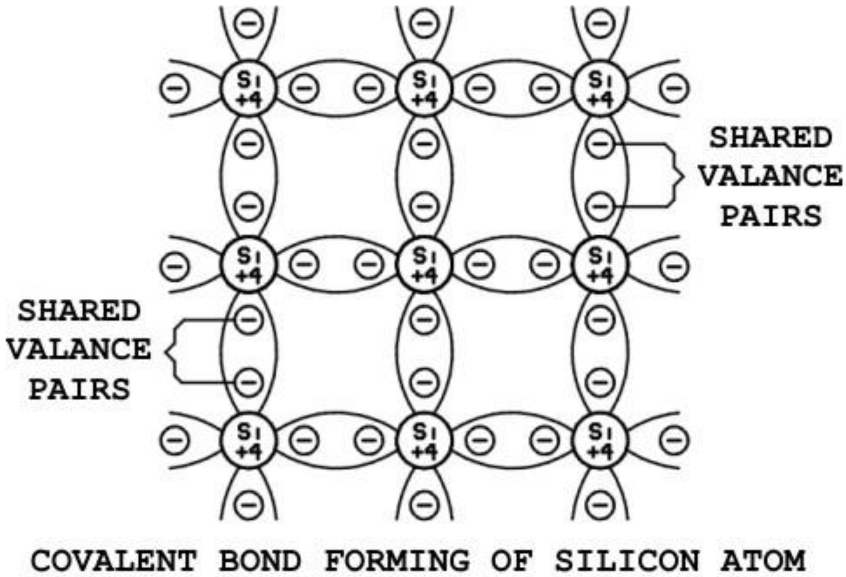

Figure 1. 4

1.6 FORMATION OF AN N TYPE SEMICONDUCTOR

In order to form an easy electron movement, free electrons between the covalent bonds have to be revealed. To achieve this purpose, arsenic material is doped (added) to the main semiconductor (silicon or germanium) atoms. The main semiconductors have four valance electrons, whereas Arsenic has five valance electrons. When main semiconductor atom forms a covalent bond with arsenic atom, a valance electron of arsenic remains unbonded and moves freely. This situation is depicted in Figure 1. 5 . The unbonded electrons in the crystal structure moves freely and allow an electron movement. This formation allows electric current to be conveniently conducted.

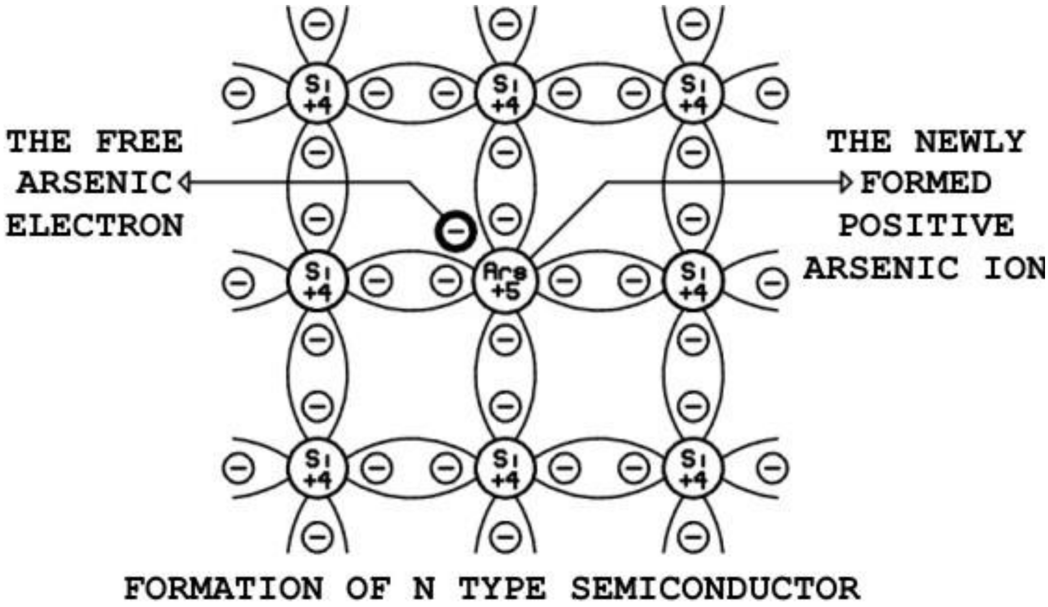

Figure 1. 5

The main carriers in N type material are electrons. In Figure 1. 6, the distribution of carriers and ions in N type material is illustrated.

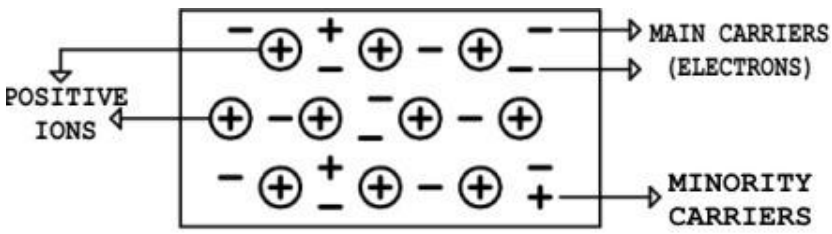

Figure 1. 6

1.7 FORMATION OF A P TYPE SEMICONDUCTOR

Forming a P type semiconductor has a similar methodology of forming an N type semiconductor, with the difference that Indium atoms are doped into main semiconductor atoms. Indium atom has 3 valance electrons; therefore the mixed atoms have an electron deficiency in formed covalent bond. These deficiencies are called holes. This formation is depicted in Figure 1. 7.

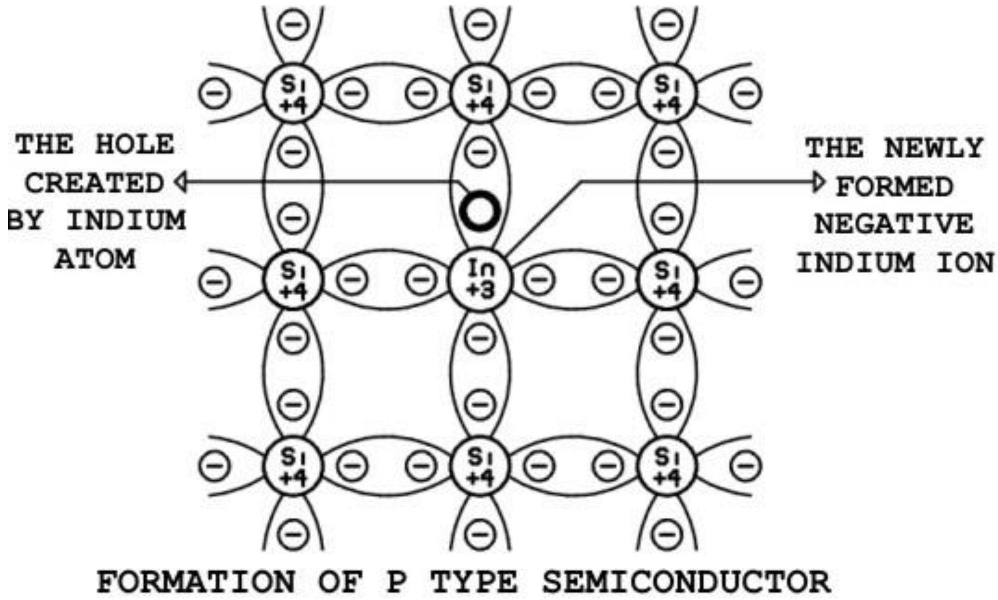

Figure 1. 7

The main carriers in P type material are electrons. In Figure 1. 8, the distribution of carriers and ions in P type material is illustrated.

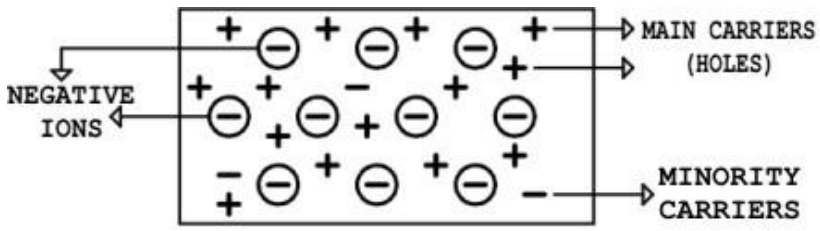

Figure 1. 8

1.8 FORMATION OF A P-N JUNCTION DIODE

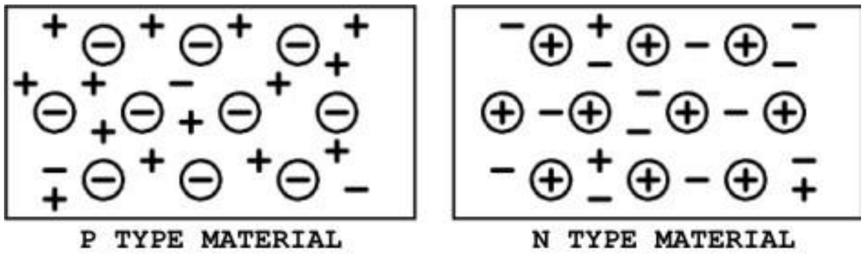

Figure 1. 9

In Figure 1. 9, the distribution of ions and carriers in P and N type materials are illustrated. If these two types are connected, positive and negative ions gathers in the junction area.

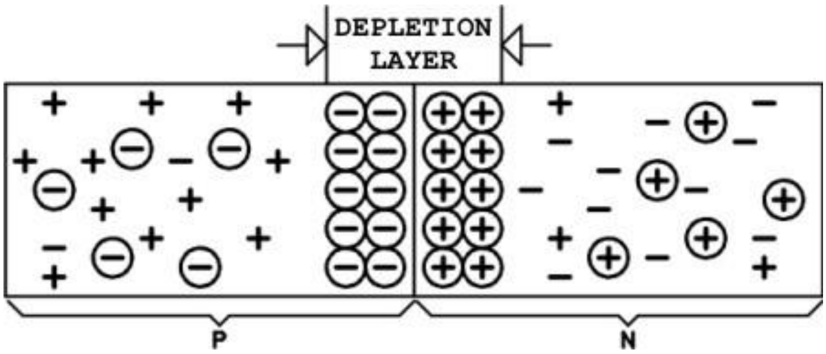

Figure 1. 10

When P type and N type materials are connected, the electrons in N type diffuse to form bonds with the holes in the P type material at the connection surface as shown in Figure 1. 10. Since the majority carriers (**holes and electrons**) are lost, this connection area is is called **depletion layer** or space charge region. The carriers in the connection surface is lost , and positive and negative ions are accumulated. Since there are no more carriers, the carriers of N type material (electrons), can not fill the carriers of P type material (holes). The electrons of N type materials must tackle the barrier formed by N type materials positive ions and P type material's negative ions. Therefore, excluding the initial contact and small amount of electron passing through, the electrons of N type material needs additional force to pass through the contact area and fill the holes of P type material. As a result, if no voltage is applied, the charge flow to any direction is zero.

The P and N type materials form Anode and Cathode of the diode, respectively. The circuit symbol of the diode is shown in Figure 1. 11.

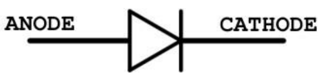

Figure 1. 11

1.9 APPLYING REVERSE BIAS TO P-N JUNCTION

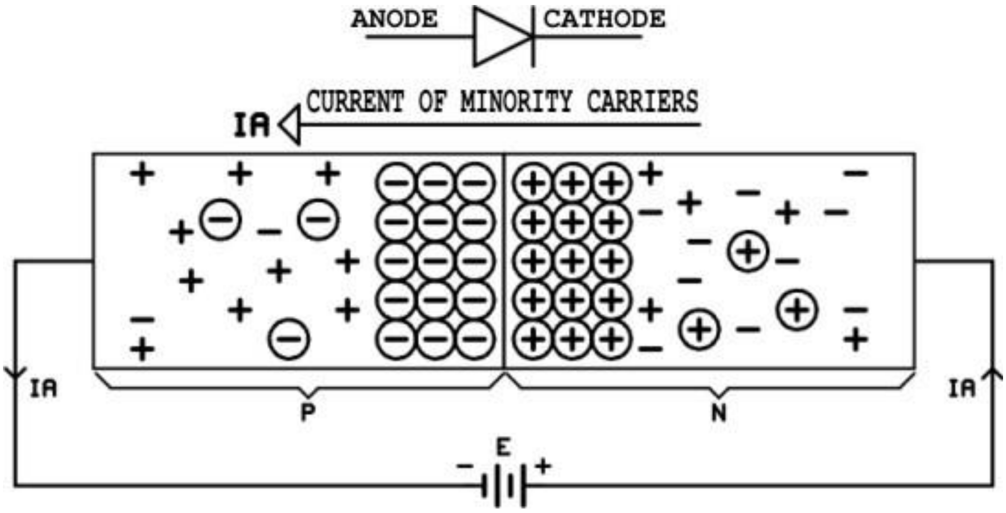

Figure 1. 12

Negative and positive potentials are applied to P and N type materials, respectively, as shown in Figure 1. 12. The electrons of N type material is pulled by the "+" pole of the source. Similarly, the holes of N type material near the junction surface is filled by the "- " pole of the source. In this situation, the result is the enlargement of the depletion layer. The diffusion of majority carrier is getting harder. Meanwhile, a small amount of minority current carriers produce a small circuit current. This is called "**reverse saturation current"**, which generally in the order of micro amperes

1.10 APPLYING FORWARD BIAS TO P-N JUNCTION

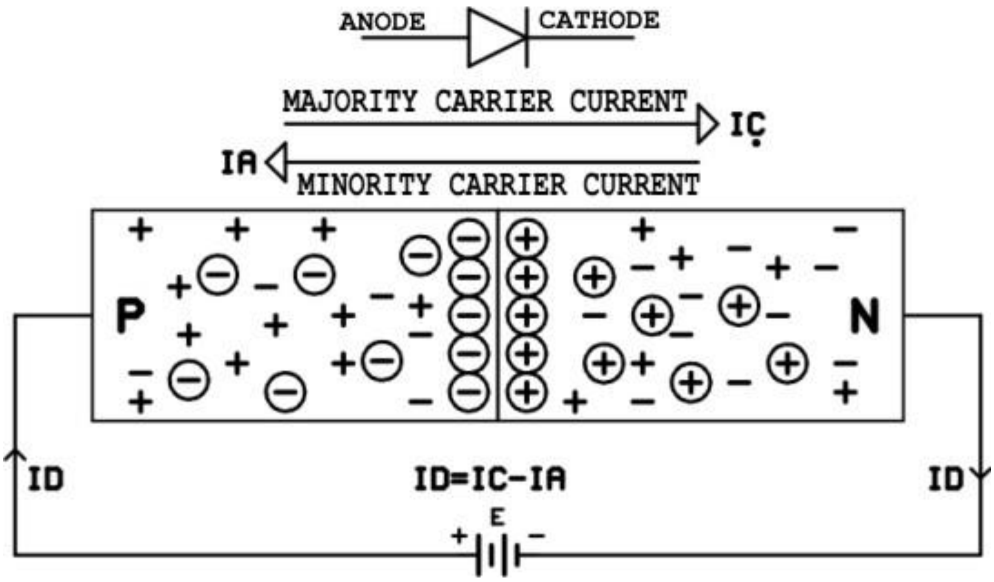

Figure 1. 13

Positive and negative potentials are applied to P and N type materials, respectively, as shown in Figure 1. 13. Majority carrier current remains same.

By following same arguments in reverse bias, the depletion layer diminishes; therefore high amount of flow of majority carriers is observed The flow of majority carriers increases with the increase in the applied voltage. I. and III. regions show positive and negative bias regions, respectively, in Figure 1. 14.

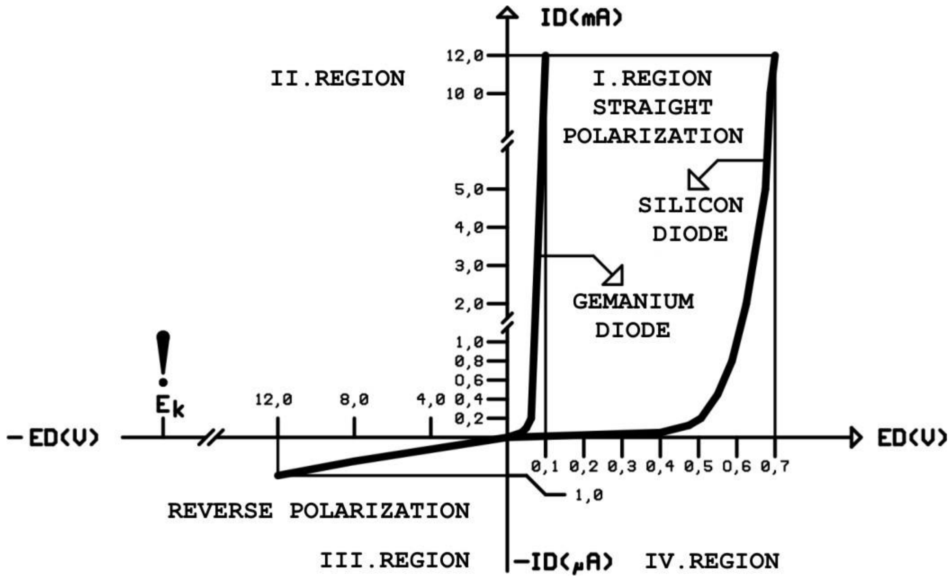

Figure 1. 14

If we examine the forward bias region in Figure 1. 14'de, the current passing increases at a noticeable rate when the applied voltage is 0.1 Volts and 0.7 Volts. These voltage values are called "**built in potential"** or on voltage. Summarizing above, built in potential is the smallest voltage value that allows a diode to conduct.

The Ek voltage that is shown in the reverse bias region is called breakdown voltage. This breakdown voltage changes with the characteristics of the diode. The Ek voltage of 1N4001 diode and 1N4007 diodes are 50V and 100V respectively. Ek voltage value is sufficient value that usually damages the diode. If the voltage is beyond Ek value, the diode will be damaged and a big current in the reverse direction will flow, which is called avalanche current, which renders the diode useless. Different diode types are shown in Figure 1. 15

Figure 1. 15

1.11 MEASURING DIODES

Diodes can be measured with analog or digital multimeters. When using analog multimeter, the measurement unit’s switch is changed to “RX1 “ in the ohmmeter section. There is a small amount of potential difference between the probes of analog ohmmeters. The poles of this voltage is reverse of the probe poles, that is, positive(red) probe of the measurement device is the negative pole of the inner battery and negative(black) probe of the measurement device is the positive pole of the inner battery. The diode to be measured is connected parallel with the probes of the ohmmeter part and the resistance in forward and reverse bias is measured. A healthy diode has a small resistance value in forward bias (**positive probe of multimeter connected to the cathode of diode, negative probe connected to the anod**e). A healthy diode has a very big resistance value in reverse bias (**positive probe of multimeter connected to the anode of diode, negative probe connected to the cathode**). Measuring with analog multimeters is considered not healthy.

If a digital multimeter will be used for diode measurement, the switch is changed to the special part to measure diodes. This part is shown with the diode symbol on the multimeter. In digital multimeters, the poles of the multimeter are same with the battery poles. The diode to be measured is connected parallel with the probes of the measurement unit. Digital multimeters measure the voltage of the diode created by the current passing on it. A current passes on a healthy diode and creates a voltage difference in forward bias (**positive probe of digital multimeter connected to the anode of the diode, negative probe on the cathode of the diode**). This voltage difference can be read from the screen of the digital multimeter. Within a special arrangement in digital multimeters, this value is **“0.6-0.7V”** and **“0.1-0.3V”** in Silicon and Germanium diodes, respectively. No current passes on a healthy diode in reverse bias (**positive probe of digital multimeter connected to the cathode of the diode, negative probe on the anode of the diode)** For this reason, the measurement unit displays a “no diode” symbol (**generally OL**) on the screen. Digital multimeters produce healty and reliable measurements compared to analog multimeters.

Using crocodile clips enhances the quality of the measurement, independent of the measurement unit. Measuring a silicon diode with a digital multimeter is shown in Figure 1. 16.

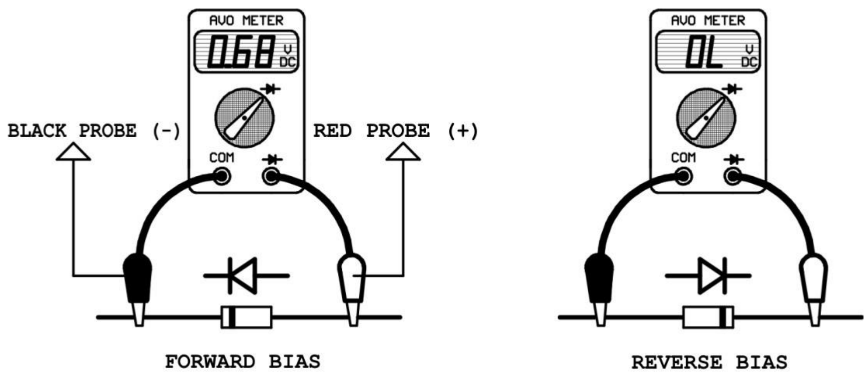

Figure 1. 16

RECTIFIERS

2.1 INTRODUCTION

Nearly all of today's widely used electronic devices (radio, tv, personal computers,etc) works with direct current (DC). hMost economic way to obtain direct current is using city electric network. However, the distributed electricity is alternating current (AC). The circuits or devices that convert alternating current to direct current are called rectifiers. Rectifiers mainly fall into two groups:
1- Half wave rectifiers
2- Full wave rectifiers

In order to understand the working principles of rectifiers, one need understanding the alternating current. Remembering the definitions chapter, alternating current is the current that has continiously changing direction and amplitude. Any voltage or current value at the change is called "instantaneous value". There are special values at certain points of change. Widely used special values in electronics in a period are marked on the vertical axis of Figure 2. 1. The vertical axis is often called "amplitude axis".

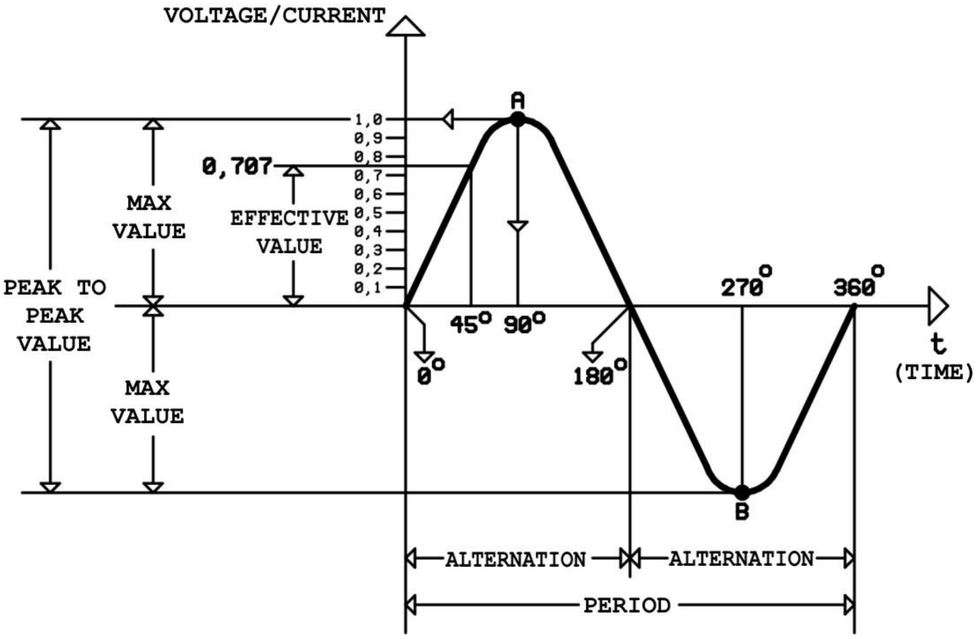

Figure 2. 1

The change in the alternating current in the period is called "sinusoidal change" or "sinusoidal curve". The horizontal axis is time axis. For defining a point on the time axis, generally angle with unit of degree is used. The upper and lower parts of time axis are positive (+) and negative(-) areas, respectively.

As shown in Figure 2. 1, there is a positive alternation followed by a negative alternation in a period. Time axis is 0 in terms of electrical value.

The highest possible value that sinusoidal curve can obtaion is point “A”. For finding the point corresponding to point “A” on time axis, a perpendicular line from point A is drawn to the time axis. The point of intersection is the time where point “A” is achieved. This time value, as shown in the figure, is “90^0”. The electrical amplitude of point “A” can be seen from the vertical axis. Using with a parallel line to the time axis, the point of intersection shows the amplitude of point “A”. This value in the figure is “1”.
The place and amplitude of any arbitrary point along the sinusoidal curve can be found by applying same methodology. The point “B” is the minimum point at the negative area. Points “A” and “B” are the maximum points in the positive and negative areas. If we normalize the curve by taking these values “1” unit, the mathematical relations in the special values in a period can be derived as shown below.

Peak to peak voltage (Epp) and current (Ipp);
Epp = 2.Emax
Ipp = 2.Imax

Effective voltage (E) ve current (I);
E = 0,707.Emax
I = 0,707.Imax

Instantaneous voltage (e) ve current (i);
e = sinθ.Emax
i = sinθ.Imax.

The “θ” is the crossing of the perpendicular line drawn by the instantenous angle’s point to horizontal axis. “Sinθ” is the sinusoidal value of angle “θ”, which can be obtained by calculators or trigonometry tables.
The multimeters used in daily life measures the effective current of the alternating current. Maximum or Peak to Peak voltage or current values can be evaluated by those simple mathematical relations.

Example:

Our city electricity network has an effective voltage of 220V. Evaluate maximum and peak to peak voltages.

Solution:

E = 0,707.Emax

$$E\max = \frac{E}{0,707} = \frac{220}{0,707} = 311,1 Volt$$

Epp = 2. Emax
Epp = 2. 311,1=622.2V

Typical working voltages of electronic devices are generally much lower then the city network. For operating these devices, the ciy electricity voltage must be lowered. This operation is accomplished by using transformers.

Transformers are circuit components working in alternating current. An basic transformer is built by winding two electrically unconnected coils onto a skeleton build onto core made of silicon plates. The transformer symbol is shown in Figure 2. 2.

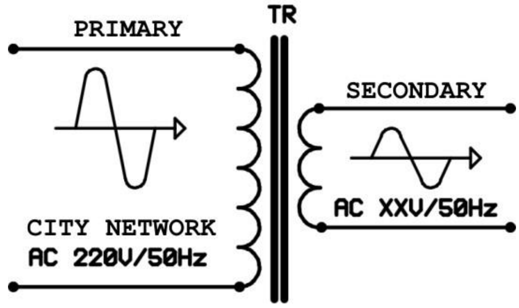

Figure 2. 2

The coil which unconverted voltage is applied called "primary". The coil which provides the converted voltage is called "secondary". The electrical energy that is taken from secondary is the alternating current with the same frequency of the primary. The secondary voltage is directly proportional to the spin number of the secondary. A secondary in a transformer can have more then one pins, middle-pinned, or level pinned. In electronic circuit drawings, coils and transformers are displayed with a simpler symbol then the classic symbol. The simpler symbols of middle-pinned and level-pinned transformers are shown in Figure 2. 3.

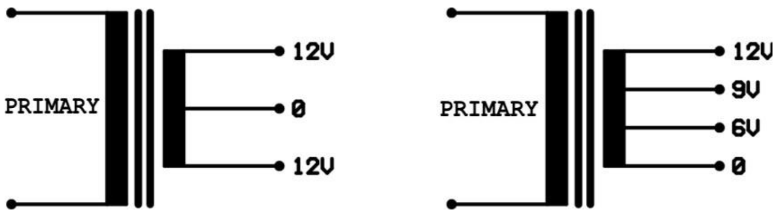

Figure 2. 3

The current that can be drawn from the transformer is directly proportional with the wire diameter of the secondary. The power of the transformer depends on the wire diameter of the primary and the physical dimensions of the transformer. Higher power transformers have bigger physical dimensions.

For experiments in alternating current circuits, the shape of the alternating current is also required in addition to the current values. For this reaspn, "oscilloscope" will be used.

2.2 HALF WAVE RECTIFIERS

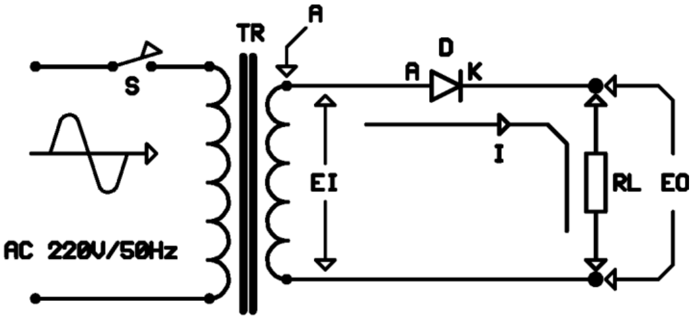

Figure 2. 4

A half wave rectifier is shown in Figure 2. 4. The secondary voltage is voltage EG, which is alternating. As mentioned in upper chapters, alternating current is the current type that the poles are varying in time. When point "A" is is positive, the anode of diode "D" is positive and the cathode is negative over "RL" load resistor. At these values, the diode is conducting. In the following alternation, point "A" becomes negative, meaning diode "D"'s anode is negative, therefore diode is not conducting. Following alternations result in same behaviour. The input and output signals are shown in Figure 2. 5.

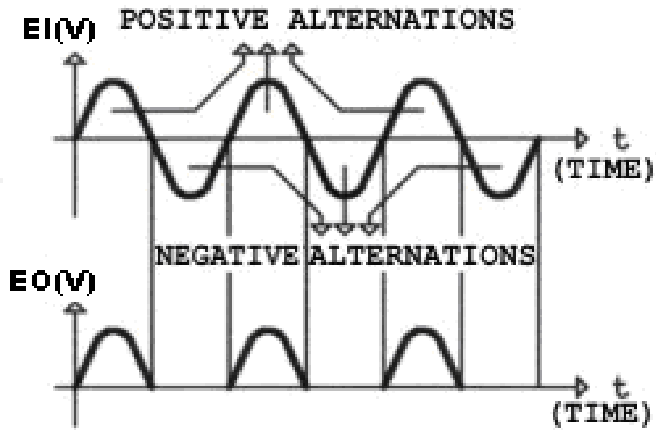

Figure 2. 5

When output signal (VO) is analyzed, there is an output only in positive alterations. The output is zero in negative alternations. The output voltage is direct voltage however not in a usable state, since the voltage has discrete amplitude. This discrete behaviour can be eliminated by using filter circuits. Filter circuits will be explained in Chapter 9. The relation between input and output voltages with no load has the following equation.

VO=0,45.VI

Input voltage (VI) is effective AC voltage (VI), output voltage(VO) is DC.

2.3 FULL WAVE RECTIFIER

A good direct voltage can not be obtained by half wave rectifiers since they conduct only in one alternation. This problem is solved in full wave rectifiers in which the input signal is used in both alternations. In order to produce a full wave rectifier, a transformer with middle pinned secondary is needed to be used. For a moment, if we seperae the middle pin of a middle pinned secondary, the sign of the output pins with respect to the sign of the input are shown in Figure 2. 6and Figure 2. 7.

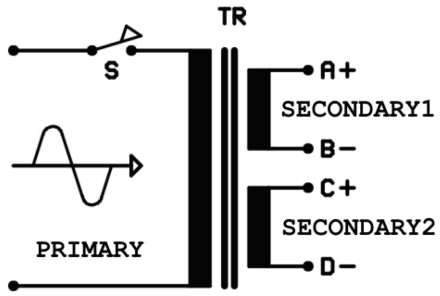

Figure 2. 6

The windings of secondary1 and secondary 2 of the transformer in Figure 2. 6 are winded in the same direction. Let us assume the sign of the input signal is positive on the upper pin of the primary and negative on the lower pin. As shown in figure, the A pin is positive whereas B pin in negative in secondary1. C pin is positive and D pin is negative in secondary2. If B and C pins are connected, the connected point has zero sign since negative and positive signs are connected. In the same time, A pin remains positive and D pin remains negative.

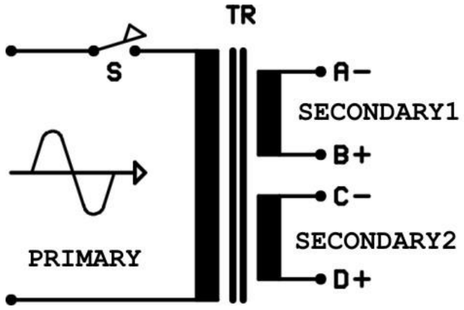

Figure 2. 7

The situation in the second alternation is shown in Figure 2. 7. The upper pin of the primary is negative and lower pin is positive in the second alternation. The sign of the secondary pins change in accordance with this change. This time B pin is positive and C pin is negative. The connected point has zero sign, point A became negative and point D is positive. It can be observed that the sign of the middle pin is zero for all alternations, one pin is negative and the other pin is positive. This change is equal to the frequency.

A full wave rectifier is shown in Figure 2. 8.

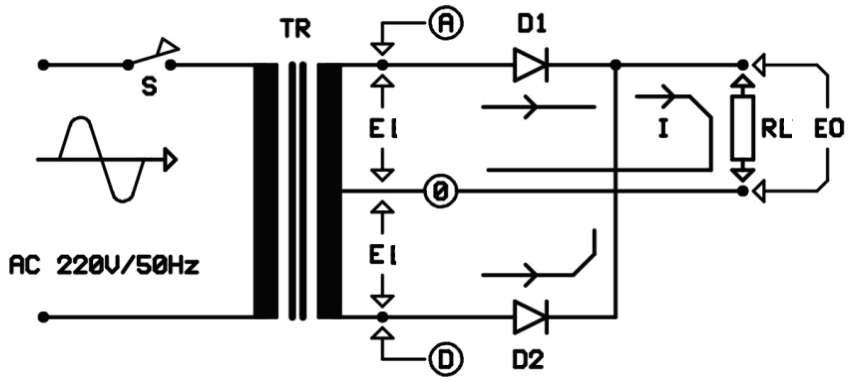

Figure 2. 8

The cathodes of diodes D1 and D2 are always connected to zero voltage over a load resistor. The signs of A and D points change with respect to the frequency of the signal. Assume point A is positive and point D is negative. At this moment, D1 is conducting and D2 is not conducting because of the anode voltages. In the second alternation, point A becomes negative and point D becomes positive. D1 is not conducting and D2 is conducting because of the signals in their anodes. Observe that only one diode is conducting at each alternation. If the input and output signals are analyzed in the oscilloscope, a figure as in Figure 2. 9 can be obtained.

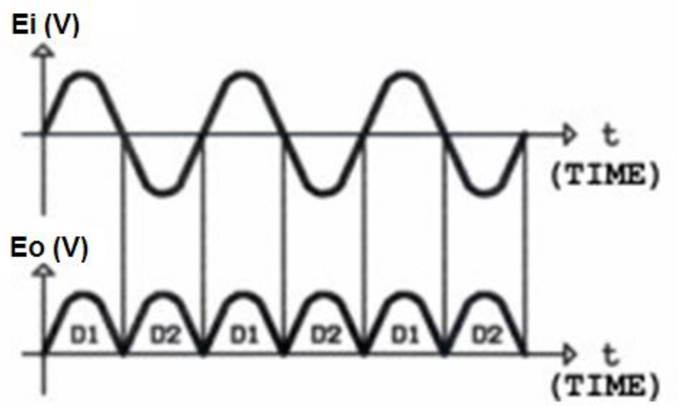

Figure 2. 9

The output direct voltage, though not like half wave rectifier’s zero lines, has still some zero points in it Çıkışta elde edilen DC de yarım dalga doğrultmaçlardaki gibi sıfırda geçen zaman dilimi olmasa da sıfır olan noktalar vardır. Therefore, it is also not usable by electronic devices.
The relation between input and output voltages with no load has the following mathematical representation.
Vo=0,9.Vi
Input voltage (**Vi**) is effective AC voltage (**Vi**) , output voltage(**Vo**) is DC.

2.4 BRIDGE FULL WAVE RECTIFIER

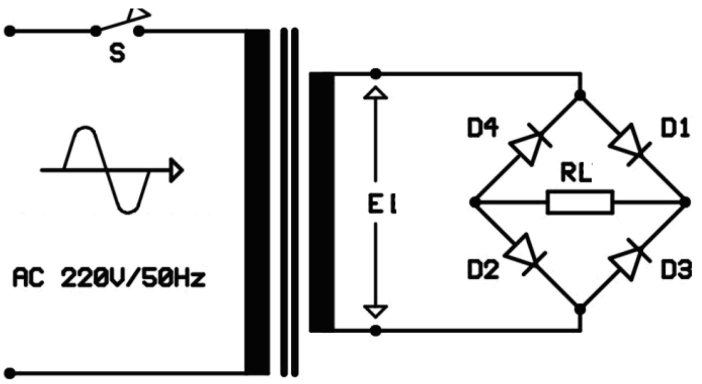

Figure 2. 10

A bridge full wave rectifier is shown in Figure 2. 10. These type of rectifiers does not use middle pinned transormers. The peak to peak voltage is applied to the pins of two diodes that are serially connected. At most half of the applied voltage can be seen at each diodes pin. The current directions for two sequential anternations are showed in Figure 2. 11and Figure 2. 12.

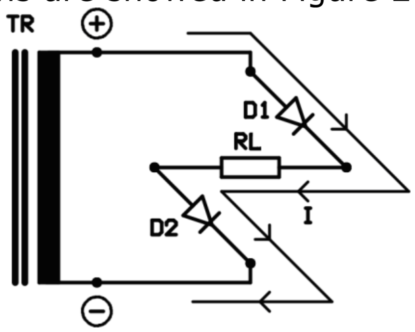

Figure 2. 11

The upper pin of the transformer is positive and the lower pin is negative in Figure 2. 11. The diodes that are conducting are D1-D2 diodes. D3 and D4 are in reverse bias and not conducting.
The following second alternation condition is showed in Figure 2. 12.

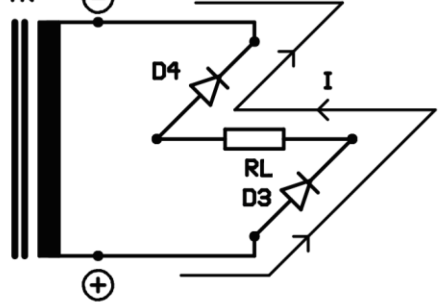

Figure 2. 12

This time upper pin of the transformer is negative and the lower pin is positive. In this alternation D3-D4 diodes are conducting, D1-D2 diodes are in reverse bias and not conducting. Observe that at each alternation a same direction current is passing over the load.
The only sideback of bridge full wave rectifiers are two diodes serially connected to the load in conducting. These diodes result in decrease in voltage. For silicon diodes, the built-in voltage is 0.7 V, so 2x0.7= 1.4V decrease in the voltage is observed.
The sign over the load is same as standart full wave rectifiers, with the only difference 0.7 volt amplitude difference. The relation between input and output voltages with no load has the following mathematical representation.

$$Vo = (0{,}9.VI) - 0{,}7$$

Input voltage (**Vi**) is effective AC voltage (**Vi**), output voltage (**Vo**) is DC.