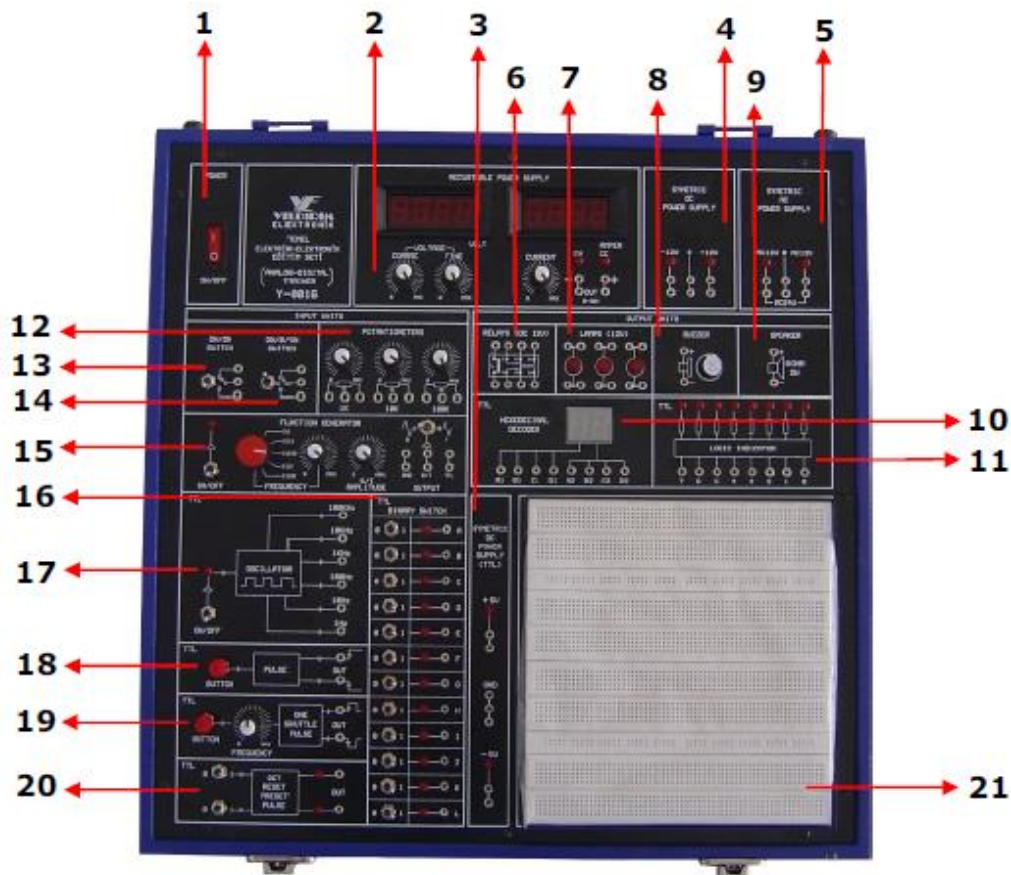# PREFACE

1. Power ON/OFF
2. 0-36V, 0-1A Current protected, adjustable power supply
3. (-5V)-0(+5V) Electronically protected, symmetric DC power supply
4. (-12V)-0(+12V) Electronically protected symmetric DC power supply
5. 12V-0-12V AC supply
6. Relay (DC 12V)
7. 3xLamp (12V)
8. Buzzer
9. 8 Ohm – 2 W Speaker
10. Hexadecimal Decoder
11. 8 bit Logic Indicator
12. Potentiometers (1k-10k-100k)
13. Switch (on-on)
14. Switch (on-0-on)
15. 1 Hz-100 KHz Function Generator (SINE, TRIANGLE, TTL)
16. 12 bit TTL Binary Switch
17. 1Hz–10Hz-100Hz-1KHz-10KHz- 100KHz Oscillator
18. TTL Pulse
19. One Shuttle TTL Pulse
20. Set, Reset, Preset Pulse
21. Protoboard

USAGE OF THE CIRCUITS IN BASIC ELECTRICS – ELECTRONICS EDUCATION SET

1- POWER (ON-OFF)
It is used to give energy to the training set and the experiment circuitry.

2- ADJUSTABLE DC POWER SUPPLY
When the power switch position is "ON", energy is given to 0-36V, 0-1A adjustable power supply. When the energy is given to the power supply, current and voltage potentiometer displays will illuminate. You can adjust the current using CURRENT potentiometer, and voltage using VOLTAGE potentiometer. Make sure that the CURRENT potentiometer is rotated to the leftmost position. So that there will be no voltage at the circuit and CC LED will be illuminating. At normal operating condition, CV LED will be illuminating. In order to obtain a desired current, first make the output nodes short circuited by rotating the CURRENT potentiometer to the leftmost position. Then rotate the potentiometer to the right up to the desired current value. The voltage is adjusted roughly by using COARSE potentiometer first, then the accurate adjustment is done by using FINE potentiometer.

3-(-5V) 0 (+5V) SYMMETRIC DC SUPPLY
When the output is shorted, the supply protects itself and the related LED in the TTL power on-off block becomes off. In order to operate the system again turn off the power on-off switch, wait for 5 seconds and turn on the switch.
NOTE: The ground pin is independent. Be careful about this when connecting the circuit.

4- (-12V) 0 (+12V) SYMMETRIC DC SUPPLY
When the output is shorted, the supply protects itself and the LED in the output socket becomes off. In order to operate the system again turn off the power on-off switch, wait for 5 seconds and turn on the switch.
NOTE: The ground pin is independent. Be careful about this when connecting the circuit.

5- 12V-0-12V SYMMETRIC AC SUPPLY
When the output is shorted, the supply protects itself and the LED in the output socket becomes off. In order to operate the system again turn off the power on-off switch, wait for 5 seconds and turn on the switch.
NOTE: The ground pin is independent. Be careful about this when connecting the circuit.

6- RELAY
A DC 12V double group contactor relay

7- LAMPS
3 incandescent lamp (12 V)

8- BUZZER
The element that produces sound with constant frequency when voltage is applied on the input terminals

9- SPEAKER
It includes an 8 Ohm - 2 Watt speaker in order to be used in analog experiments. It is connected by using the input terminals.

10- HEXADECIMAL DECODER
It is the circuitry that converts BINARY coded data to HEXADECIMAL form. It converts the BINARY data in the form of 0's and 1's at the input into HEXADECIMAL codes between 0 and F.

11- 8 BIT LOGIC INDICATOR

It is used for the data in the form of 0-1 to be indicated by LEDs. If the data is "0", LED does not illuminate and if the data is "1", LED illuminates.

12- POTENTIOMETERS
3 Potentiometers (1K, 10K and 100K)

13- SWITCH (ON-ON)
A (on-on) switch

14- SWITCH (ON-0-ON)
A (on-0-on) switch

15- FUNCTION GENERATOR
A function generator that can produce sinusoidal, triangular and square waves with frequencies between 1HZ to 100 KHz and with adjustable amplitudes.
NOTE: The ground pin is independent. Be careful about this when connecting the circuit.

16- 12 BIT TTL BINARY SWITCH
It is used to obtain logic levels "0" and "1". 12 switches are used for 12 bit data. LEDs are used in order to show the switch position and output data.

17- CONSTANT FREQUENCY SELECTIVE TTL OSCILLATOR
It is the oscillator circuit that produces 1Hz-10 KHz-100Hz-1 kHz-10 KHz-100 KHz signals in the TTL level. Desired frequency can be obtained from the output terminals.

18- TTL PULSE CIRCUIT
It is used to obtain logic pulse. When the button is pressed, both negative and positive pulses are generated. The desired pulse can be taken from the related output terminal.

19- ONE SHUTTLE TTL PULSE CIRCUIT
It is the circuit that can produce positive and negative pulses with adjustable frequency. Whenever the button is pressed, a pulse is generated at the adjusted frequency.

20- TTL SET-RESET-PRESET PULSE CIRCUIT
It is a general purpose PULSE generator of which output is determined according to the position of its input switch.

21- PROTOBOARD (BREADBOARD)
It is the component on which the circuits can be set up and external experiments can be done. The information about usage is given in the figure below.
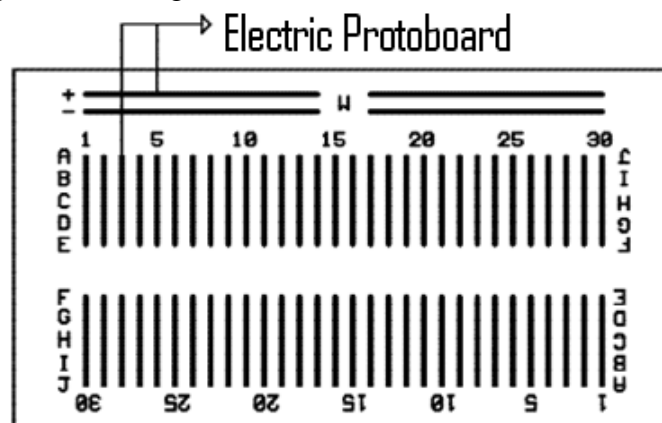
Standard experiments are done by replacing the Protoboard with Y-0016/001-014 modules.

PRELIMINARIES 1
RESISTORS' COLORED CODES.
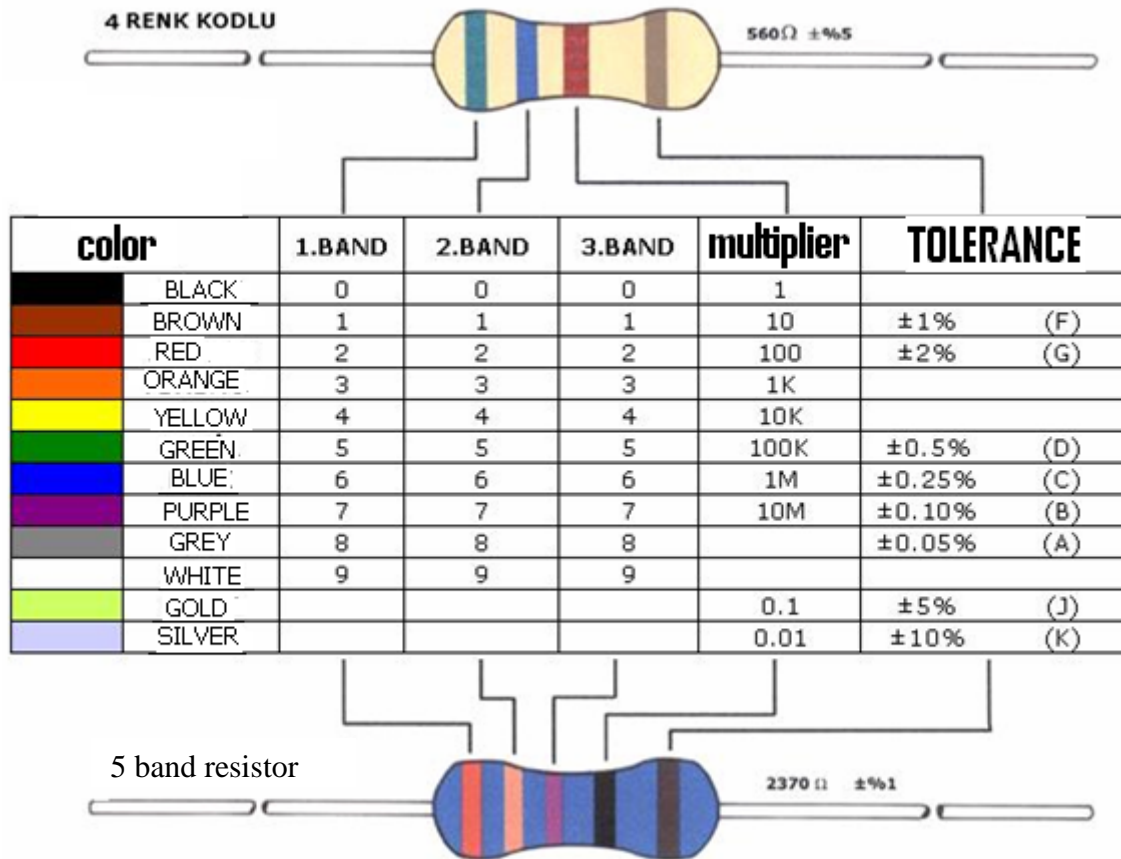
4 band resistor

Figure 1.12

As we see, the last color shows the tolerance. Tolerance determines the maximum and minimum values of resistance. Carbon resistors have higher tolerances than metal film resistors. Because of that, metal film resistors are used in precision-bored (delicate) circuits while carbon resistors are used in circuits which are not precision-bored. For instance, let's calculate the value of resistance and limits of resistance values according to the tolerance of a four band resistor on which there are colors of brown, black, red and gold.

1.Colour (1.Number)	2.Colour (2.Number)	3.Colour (Multiplier)	Value (Ohm)	Tolerance (%)
1	0	00	1000R	5

% ±5 tolerance = 1000*(5/100) = 50R
This means that the resistance is between 1000-50= 950 R and 1000+50=1050 R.

For instance, let's calculate the value of resistance and limits of resistance values according to the tolerance of a five band resistor on which there are colors of red, red, black, brown and purple.

1.Colour (1.Number)	2. Color (2.Number)	3. Color (3.Number)	4. Color (Multiplier)	Value (Ohm)	Tolerance (%)
2	2	0	0	2200R	0.1

% ±0,1 tolerance = 2200*(0.1/100) = 2.2R
This means that, the resistance value is between 2200-2.2=2197,8R and 2200+2.2=2202.2
Smaller the tolerance limits of a resistor, better is the resistor.

In delicate electronic circuits, tolerances of some resistors are specifically shown on a schema. If these kinds of circuits are being applied, attention must be paid to the tolerance value. Another point to pay attention is the power of resistor. Power of resistors is determined as Watt (W). If too great currents pass through the resistors and if the resistors do not have enough power they may be heatened and deformed. Because of that, you should use the resistors which have enough power suitable for the structure of the

circuit. Resistors present the same opposition to the direct current (DC) and alternating current (AC). This opposition is called "ohmic resistance".

PRELIMINARIES 2
MEASUREMENTS with DIGITAL MULTIMETER.

Digital multimeter is a multifunctional instrument. It can measure resistance, capacitance, DC and AC voltage, DC and AC current, short-circuit. It can help us to define transistor's base, emitter and collector, anode and cathode for diode.

Process of measurement.

Before the work it needs to check if the instrument ready to work. For this purpose in the mode "measurement of resistance" it needs to connect test leads (range of measurement is 200 Ω). The sound signal will appear to inform us about short-circuit. It means that the instrument is suitable for measurement. This mode is used for searching short-circuit somewhere in the electric circuit. In other positions of the pointer (not "measurement of resistance") we can see 0 on the display without contact between the leads.

1. Measurement of resistance.

Resistances are measured by "Ohmmeter". The resistance that ohmmeters measure is ohmic resistance. Ohmmeters are devices that contain a DC (direct current) in themselves. A small current passes through the resistor during the measurement; ohmmeter examines this current and makes the measurement. The direction of this current does not affect the measurement. Ohmmeters are produced in two types: analog and digital (or numerical) types. It is difficult to measure delicate values with analog ohmmeters because their quadrants are not linear and they need selection of applicable level and caliber adjustment. There is also room for delusions of eye while reading the values. So, their production is very limited. Digital devices are commonly used by electricians. They can measure electric current (Amper), electric voltage (volt) and resistance (ohm). These devices are also called "MULTIMETER" (Amper-Volt-Ohm). Delicate values can be read by digital multimeters and they are easy to use. A typical multimeter can be seen in figure 1.13
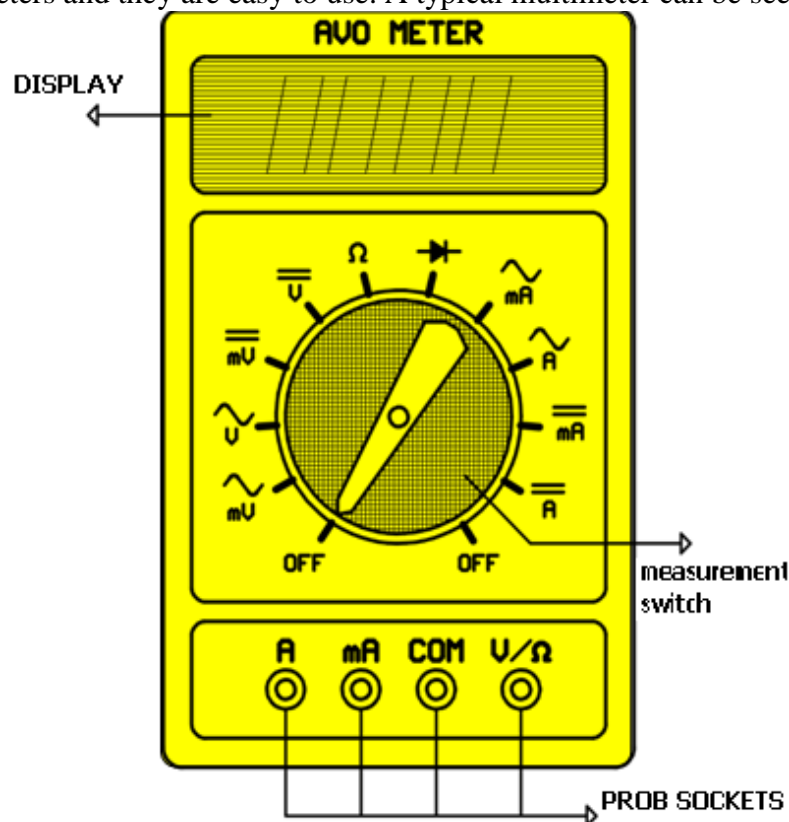

Figure 1.13

The cables that are used to connect the terminals of the measured component to the multimeter are called "probes". Probes have special plugs on both sides. The part of the probe that we grab by the hand is made of good insulators and the parts (terminals) that are used for measurement are made of good conductors. The conducting parts are also called "live terminals". In order to prevent problems of usage,

probes are produced as black and red. Black probe is called (-) negative probe and red probe is called (+) positive probe. Resistance measurement with multimeter is shown in figure 1.14
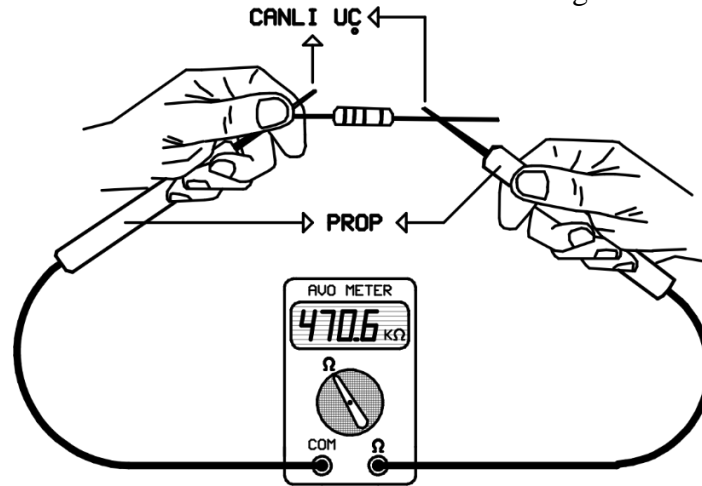

Figure 1.14 (prop: probe, canlı uç: active terminals)

Black probe will be plugged to "com" socket in all measurements. Red probe will be plugged to the socket of related measurement unit. In resistance measurement, the red probe will be plugged to ohm socket. The switch will be adjusted to "ohm.

If the resistance is connected to a circuit, it should be disconnected from the circuit before measurement. Otherwise, supply of the circuit will damage the ohmmeter. If there is not a supply connected to the circuit, even so, the resistance should be disconnected from the circuit because the other components cause miss-measurement. The second point to pay attention is that if the measured resistance has a big value, you should not touch the terminals of the probe. Otherwise, resistance of your body will also be measured and the result will be wrong.

2. *Measurement of DC voltage.*

Set the FUNCTION switch to the position "measurement of DC voltage" and connect the test leads across the source or load under measurement. Connect the BLACK test lead to the COM jack and the RED test lead to the V/Ω jack. After checking define range of measurement. Range for DCV-200mV-1000V. For DCV: if polarity is wrong, indications will be with sigh "-". About correctness of measurement range we can judge comparing measuring parameter and chosen range. If measuring parameter is over the lower measuring range, you should switch the FUNCTION switch to it to increase measurement accuracy. If measuring parameter is out of the range there is 1 on the display. In case of measurement of the same value in different ranges the accuracy of measurement will be different. For example, if V=1.5V: range 2V- the result is 1.505 V(three digits after decimal point); range 20V-the result is 1.51V(two digits after decimal point); range 200V-01.5V (one digit after decimal point). To increase accuracy it needs to choose the range, which corresponds to measuring parameter.

3. *Definition of p-n-junction resistance.*

In spite of the fact that it is resistance, we can't use position of the FUNCTION switch "measurement of resistance". We will see 1 on the display in this case. We must use for the switch a special position, where convention of the diode is situated. Test leads are in the position for voltage measurement. We touch pins of the diode by test leads. If we have reverse bias, we can see 1 on the display. If it is forward bias, we can see some definite value on the display. It is the diode's resistance and it is definition of the diode's anode and cathode. RED test lead in this case is connected with anode. If the diode is LED one, it can light.

DEFINITIONS

Electricity: It is a type of energy. Electrical energy is generated by two different points having different number of electrons in any condition. The number of electrons that a point has is called the electrical charge or the electrical potential of that point. The thunderbolt which comes into being between the earth and the clouds can be given as an example to electrical energy.

Coulomb: the unit showing the number of electrons. 1 coulomb=625.10^{16} electrons

Electric current: it is the flow of electron between two different points. "Amper" is its unit. Amper is the speed of the flow of 1 coulomb electrons in 1 second between any two different points. The point that has more electrons is electrically negative. The point to where the electrons move is positive. Those points are called "poles". So, the electron flow is from negative to positive. Electric current is just the flow of electrons. The direction of the electric current is assumed as from positive to negative (opposite to the direction of electron flow) in order to avoid showing negative sign in mathematical operation. Measurement devices of electrics and electronics are produced in compliance with the direction of circuit.

Direct current: The current of which the direction does not change. Direct current is symbolized by "DC". Some DC types are shown in figure 2.
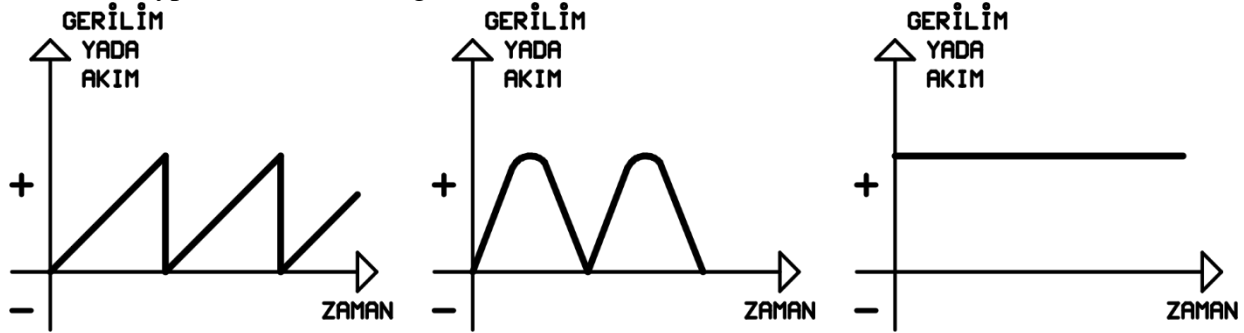

Figure 2 (gerilim yada akım: voltage or current, zaman: time)

The change in the magnitude of voltage or current in the direct current supply does not affect the working of some electrical devices. However, direct current is required to be constant in electronical devices. The supplies in the direct current circuits are used as voltage supply, adjustable voltage supply, current supply or adjustable current supply. Output voltage of the adjustable voltage supply and the current that is given by the adjustable current supply can be adjusted. DC supply symbols are shown in figure 3.
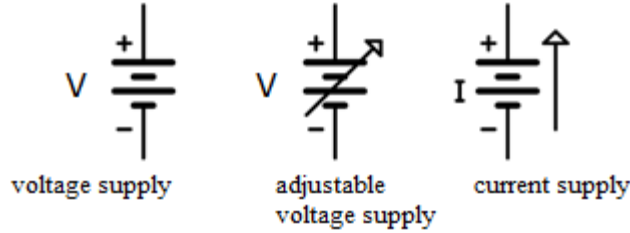

Figure 3

The units which the electric energy makes work is called load. In figure 4, a load is connected to the terminals of a DC supply. During the work time, the direction of the current passing through the load does not change.
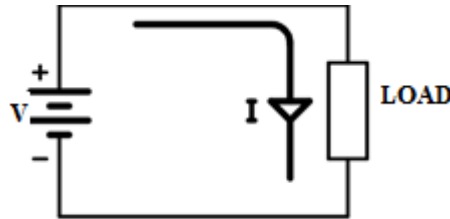

Figure 4

Also, the magnitude of DC does not change in the supplies that we use in daily life. DC is generally generated by using chemical ways. For example, batteries or accumulators.

Alternating Current (AC): Electrical current which periodically reverses direction and magnitude. It is symbolized by "AC" (Alternating Current). Pendulum swing is an example of periodical move. Pendulum swing is from the midpoint and at equal distance to both sides. Half of the pendulum move is called "Alternation". A complete move of the pendulum consisting of two alternations is called a "period." A period is shown in figure 5.
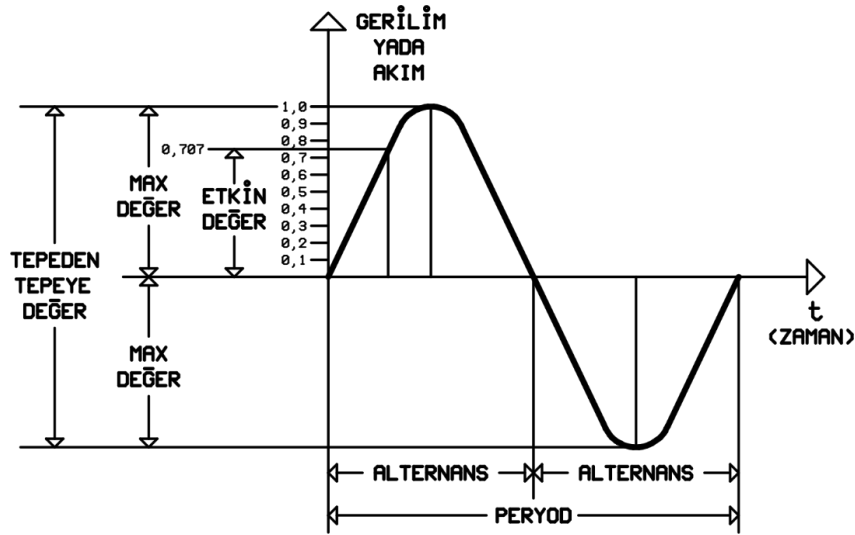
Figure 5

City network, generators are the sources of alternating current. Magnitude of the alternating current also varies during the work time. The magnitude of AC at any moment is called "instantaneousvalue." Instantaneous value is shown by "e" for voltage and by "i" for current. Measurement devices measure the effectivevalue of the AC. Effective value is also called RMS (Root-Mean-Square). Effective value is the one we use in daily life. Effective value is shown by "E" for voltage and by "I" for current. The maximum value of an alternation is called "maximum value." Maximum value appears twice in a period: one in negative alternation and one in positive alternation. Maximum value is shown by "Emax" for voltage and by "Imax" for current. In the experiments of this book, mostly, the oscilloscope will be used. Oscilloscopes are the devices by which we can see and measure the electrical wave forms. "Peak to peak value" is the AC value which is the easiest one to measure by oscilloscope. Peak to peak value is the sum of two maximum values in a period. It is shown by "Epp" for voltage and by "Ipp" for current. "pp" means peak to peak. Commonly used values for AC is shown in figure 5.

The number of period in a second is called "frequency." Its unit is Hertz (Hz). Commonly used values of frequency are the Kilohertz (KHz) and Megahertz (MHz). Mathematical relations of these units are shown in figure 6.

upper multiples	(MHz) MEGAHERTZ	1M= 1 000 000 Hz
	(KHz) KİLOHERTZ	1KHz= 1 000 Hz
: main unit	(Hz) HERTZ	
lower multiples		

Figure 6

AC supplies are used as voltage and current sources. Ac supply symbols are shown in figure
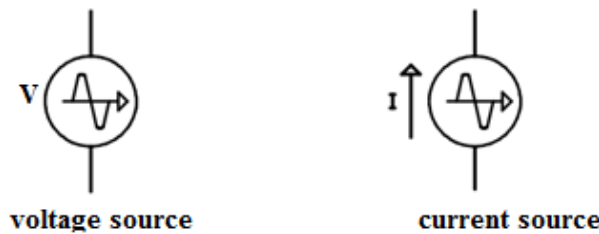

voltage source   current source

Figure 7

In figure 8, a load is connected to the terminals of an AC supply. The direction of the current passing through the load varies during the work time depending on the change of the supply poles.
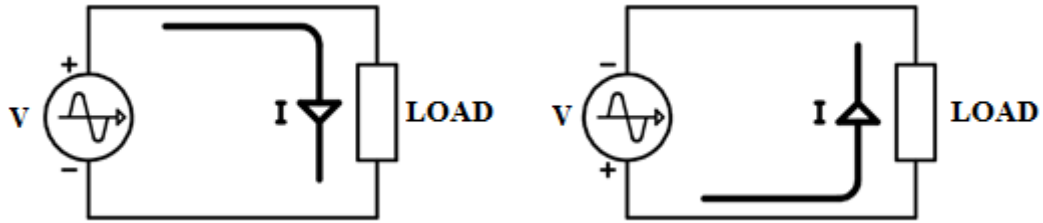
Figure 8

AC is the electrical energy which is used in domestic electrical and electronical devices, industry and almost in every aspect of life. AC can be converted to DC by basic methods. Supply is also called "generator."

Electric Voltage: Voltage is a representation of the electric potential energy per unit charge. It is shown by "V" and its unit is "Volt".

Conductor: The materials that allow electric current to pass through. Gold, silver and copper are good conductors.

Non-Conductor: The materials that does not allow electric current to pass through. Air, plastic and mica are non-conductors.

Semiconductor: A semiconductor is a solid whose electrical conductivity can be controlled over a wide range, either permanently or dynamically. Semiconductors are tremendously important.

Passive Components: Component of a circuit should be learned well in order to accommodate electrical circuits. Circuit arrangements and fault determination processes will be eased if the structures and properties of components are learned well. The component which doesn't do amplification is called "passive circuit components". Commonly used passive components are resistors, inductors and capacitors.

LABORATORY WORK # 1
## DIODE and TRANSISTOR APPLICATIONS

Aims: investigate properties of diodes, LEDs, and transistors. Define what logic gates are realized schematically, learn the gates' properties. Improve skills of the scheme mounting. Compare experimental results with theoretical foundations about diodes.

PREPARATION TO LAB WORK
1. Learn the information about diodes, LEDs, and transistors.
2. Show semiconductor diode i-v-characteristic.
3. Show bipolar transistor's characteristics.
4. Consider experiments' schemes and draw them with application of Scheme Design System. Analyze what gates are realized on the schemes' basis. Fill in the tables theoretically.
5. Answer the questions below in written form.
   5.1 What is a semiconductor diode?
   5.2 What is diode's forward/reverse bias?
   5.3 What is diode's cathode/anode?
   5.4 How can you define cathode and anode for real diode?
   5.5 Explain a semiconductor diode's behavior according to its i-v-characteristic.
   5.6 What is LED?
   5.7 What is a bipolar transistor?
   5.8 What are names of a bipolar transistor's electrodes?
   5.9 How to define situation of a bipolar transistor's electrodes?
   5.10 What are conditions to have a bipolar transistor ON(OFF)?
   5.11 What types of bipolar transistors do you know?
   5.12 What are typical silicon transistor's parameters?
   5.13 What modes of a bipolar transistor's operation do you know?

LAB WORK PERFORMANCE
1. Demonstrate presence of your home preparation for lab work to your instructor.
2. Pass test of 10 questions.
3. Get a permission to begin the work.
4. Mount the schemes of experiment 1A on the breadboard and perform them.
5. Make a conclusion about functionality of the schemes. Compare your results with theoretical ones.
6. Demonstrate your results to your instructor. If your results are correct you may dismount your scheme, if no – find the mistake.
7. Repeat steps 4 to 6 for experiment 1B, 1C.
8. Be ready to answer your instructor's questions in process of work.
9. Complete your work, dismount your schemes, and clean your working place.
10. Answer your instructor's final questions, obtain your mark.
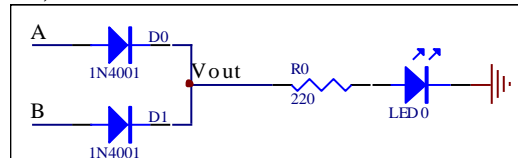11. Ask your instructor's permission to leave.

BC239

Footprint
TO-92

E B C
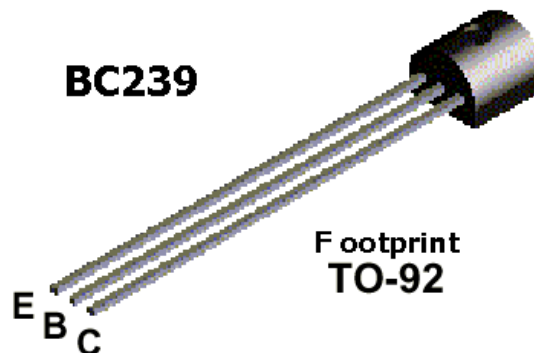
Experiment 1A. Realize the following circuit on a breadboard. Connecting A, and B inputs to either GND or VCC based on the following table, fill in the blanks. Write ON or OFF for LEDs. Measure Vout voltage.
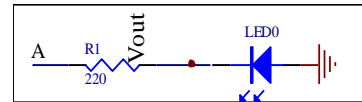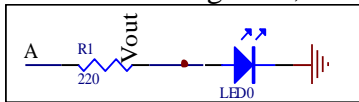
	INPUT	OUTPUT	
	A	**LED 0** (ON/OFF)	**Vout** (V)
1	5V		
2	0V		

	INPUT	OUTPUT	
	A	**LED 0** (ON/OFF)	**Vout** (V)
1	5V		
2	0V		

Experiment 1B. Realize the following circuit on a breadboard. Connecting A, and B inputs to either GND or VCC based on the following table, fill in the blanks. Write ON or OFF for LEDs. Measure Vout voltage.

	INPUTS		OUTPUTS	
	A	**B**	**LED0**	**Vout (V)**
1	0V	0V		
2	0V	5V		
3	5V	0V		
4	5V	5V		

Experiment 1C. Realize the following circuit on a breadboard. Connecting A, and B inputs to either GND or VCC based on the following table, fill in the blanks. Write ON or OFF for LEDs. Measure Vout voltage.
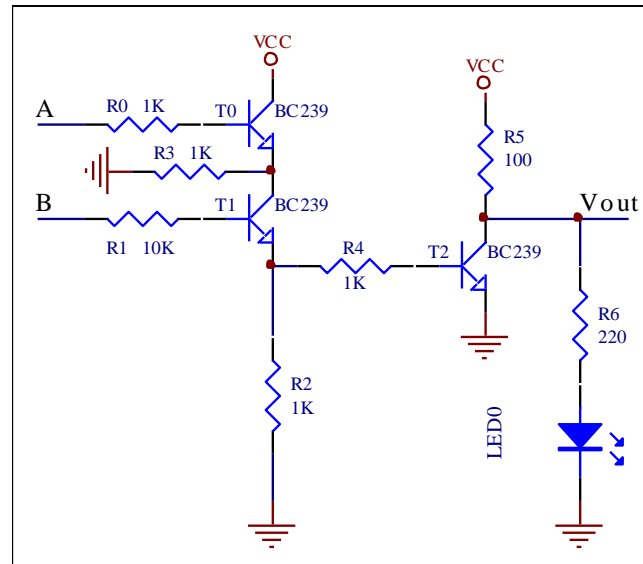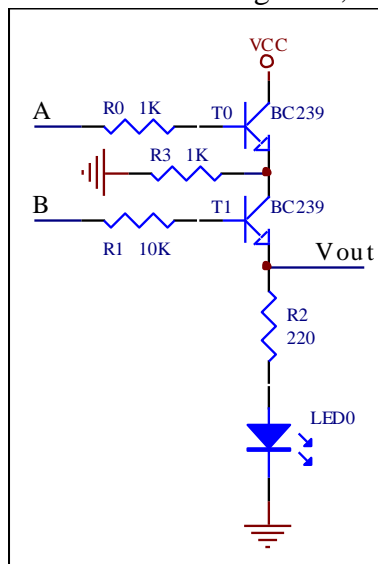
	INPUTS		OUTPUTS	
	A	**B**	**LED**	**Vout**
1	0V	0V		
2	0V	5V		
3	5V	0V		
4	5V	5V		

This is …………… Gate

	INPUTS		OUTPUTS	
	A	**B**	**LED**	**Vout**
1	0V	0V		
2	0V	5V		
3	5V	0V		
4	5V	5V		

This is a ……………. Gate

LABORATORY WORK #1 - TEST QUESTIONS

1. Voltages V_1, V_3, V_4 in the scheme below equal to _____ respectively.
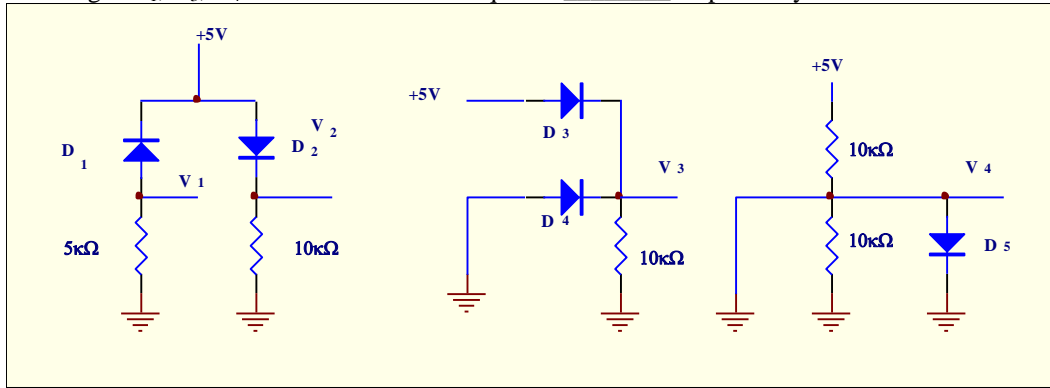
A. 4.3 V, 0, 0   B. 0, 4.3V, 0   C. 4.3 V, 4.3 V, 0   D. 0, 0, 0   E. 4.3 V, 0, 4.3 V

2. How many states has the switch got?
A. 1   B. 2   C. 3   D. 4   E. 5

3. What can you say about state of diodes 1, 2, 3 in the picture in question 1?
A. reverse, forward, reverse   B. reverse, forward, forward
C. forward, reverse, forward   D. Reverse, reverse, forward
E. forward, forward, reverse

4. The second strip to obtain resistance 560 Ω must be
A. blue   B. Green   C. Brown   D. Yellow   E. red

5. Value of resistance is 9.6 kΩ. It means that the first three strips on the resistance case (in whole the case has got 4 strips) are:
A. white, blue, red   B. gray, brown, black   C. Black, brown, green
D. brown, black, brown   E. brown, black, red

6. Analyze the information. Fill in the gaps.
Anode voltage is +5V, cathode V is +3V. The diode is _____. Anode voltage is -5V, cathode V is -3V. The diode is _____.
A. ON, ON   B. OFF,OFF   C. ON, OFF   D. OFF, ON   E. all answers are wrong

7. Forward bias means that for diode
A. anode voltage is more positive than its cathode one
B. anode voltage is equal to or is more negative than its cathode one
C. anode voltage is positive   D. anode voltage is negative   E. all answers are wrong

8. For the circuit below if V_A=5V V_B=0V D_0 is _____, D_1 is _____, and LED_0 is_____.
A. open, closed, ON   B. open, open, ON   C. closed, closed, OFF
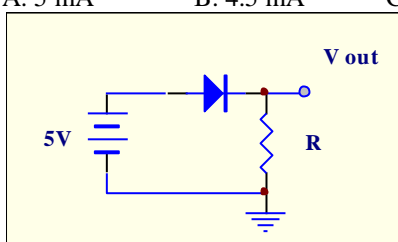D. closed, open, ON   E. open, open, OFF
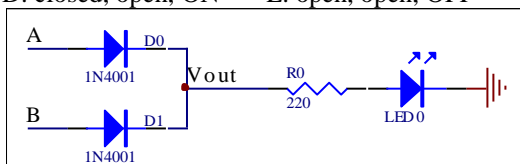
9. Calculate current through typical red LED if resistor for its limitation is equal to 330 Ω. Anode voltage of LED is 5V.
A. 10 mA   B. 15 mA   C. 20 mA   D. 25 mA   E. 30 mA

10. For the circuit below define current through diode if R=2kΩ
A. 5 mA   B. 4.5 mA   C. 4.3 mA   D. 2.15 mA   E. 0.86 mA

7. Serial binary adder consists of
   A. n full adders, connected in cascade, where n-number of digits for addition
   B. n half adders, connected in cascade, where n-number of digits for addition
   C. n full adders and a storage device, where n-number of digits for addition
   D. n half adders and a storage device, where n-number of digits for addition
   E. one full adder and a storage device

8. A half-subtractor is a _____ circuit, that subtracts _____ bits and produces their difference.
   A. sequential; three
   B. sequential; two
   C. combinational; two
   D. combinational; three
   E. sequential or combinational; three

9. Make addition of binary numbers: 1001 and 1010. Result is
   A. 10011   B. 1001   C. 1100   D. 11001   E. 10101

10. To construct 6-bit parallel adder we must use cascade of such full-adders IC s as
    A. two 2-bit and one 1-bit   B. one 2-bit and one 3-bit   C. one 4-bit and one 1-bit
    D. five 1-bit   E. none of above mentioned, because 5-bit parallel adder IC exists itself

1. The content of register when we enter 249 in BCD is:

A	0	0	1	0	0	1	0	0	1	0	0	1
B	0	0	1	0	0	1	0	0	1	0	0	0
C	0	1	0	0	0	0	1	0	1	0	0	1
D	0	0	1	1	0	1	0	0	1	0	0	0
E	0	0	1	0	0	0	1	1	1	0	0	1

2. A small-scale integration (SSI) device contains _____ gates in a single chip.
A. thousands of   B. From10 to 1000   C. More than 100
D. From 10 to 100   E. less than 10

3. Number of functions of n variables can be determined according to the formula
A. 2^{2^n} B. 2^{2n} C. 2^n D. 2^{3^n} E. 2^{3n}

4. A half-subtractor is a _____ circuit, that subtracts _____ bits and produces their difference.
A. sequential; three
B. sequential; two
C. combinational; two
D. combinational; three
E. sequential or combinational; three

5. What is the result of the following BCD addition?
        0011 0010 1001 0101
+   0111 0000 0110
A. 0011 1001 1001 1011   B. 0100 0000 0000 0001   C. 0011 1001 1001 0001
D. 0100 0000 0000 1011   E. 0011 0000 0000 1011

6. Add in octal: 541+326
A. 967   B. 867   C. 1067   D. 947   E. 948

7. Full adder forms _____, but half-adder forms _____.
A. the sum of two bits, ….   the sum of two bits and a previous carry.
B. the sum of two bits, ….   the sum of two bits and a carry
C. the sum of two bits, ….   the sum of two bits and a present carry
D. the sum of two bits and a carry,… the sum of two bits
E. the sum of two bits and a previous carry, … the sum of two bits

8. Add in hex: A8D5+3CA9
A. D56D   B. D56E   C. D46D   D. E56E   E. E57E

9. A Boolean function is an expression, formed with
A. binary numbers
B. binary variables
C. binary variables and operators
D. binary variables, the two binary operators OR and AND, the unary operator NOT, parentheses, and equal sign.
E. binary variables, the binary operators OR, AND, and NOT, parentheses, and equal sign

10. Equation for carry output of the second stage of look-ahead carry generator is
A. $C_2=G_1+P_1C_1$ B. $C_2=G_1+P_1$ C. $C_2=G_1+C_1$ D. $C_2=G_1+P_2C_1$ E. $C_2=G_1+P_1C_2$