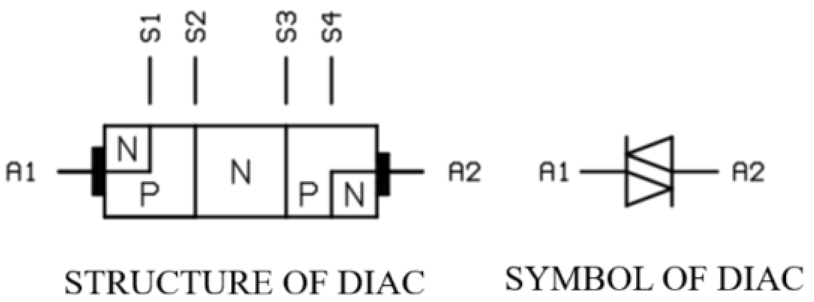
DIMMER CIRCUIT APPLICATION

1. PURPOSE OF THE EXPERIMENT

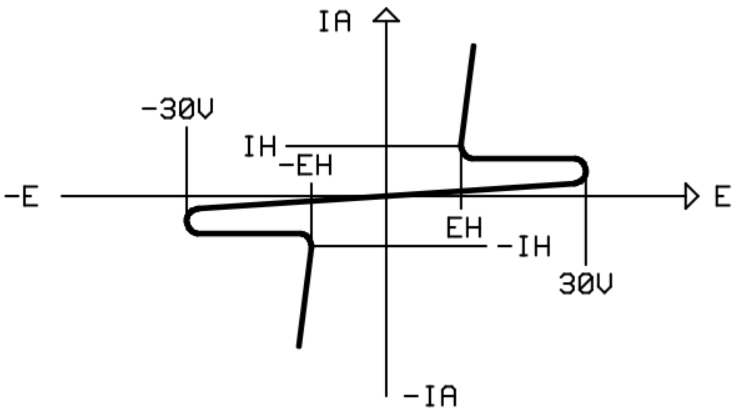
The purpose of this experiment is to examine the structure and operation of the dimmer circuit.

2. THEORY

Diodes are alternating current diodes. Up to a certain voltage (breakdown voltage), the element is insulating in both directions, but after this voltage value, it is conductive in both directions. The basic arrangement of the diode's semiconductor layers and its graphical symbol are shown in Figure. Neither terminal is a cathode. Instead, there are anode 1 and anode 2. When anode 1 is positive relative to anode 2, the semiconductor layers used are P1N2P1 and N3. When anode 2 is positive relative to anode 1, the layers are P2N2P1 and N1.



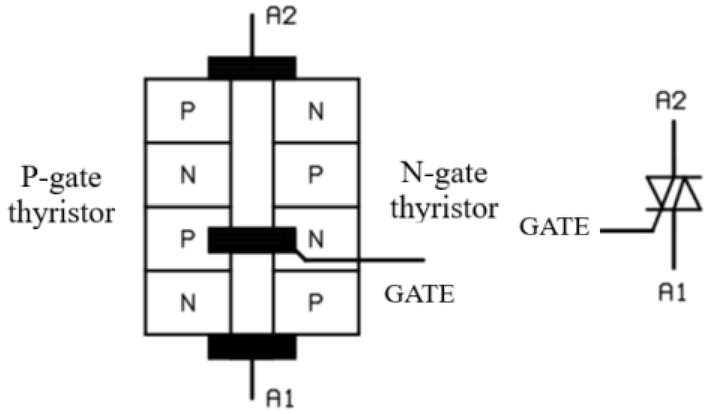
The breaking voltages of different types of diodes vary. The breaking voltages of diodes on the market range from 28 volts to 42 volts. The characteristic curve of the diode is shown in Figure 4.



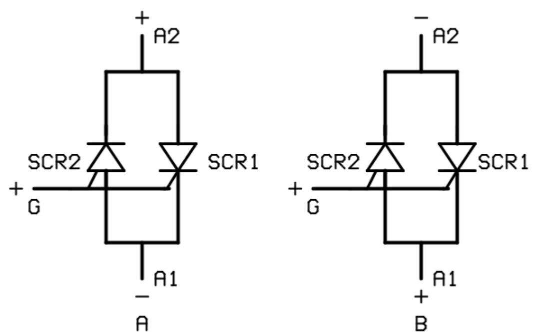
A diac is commonly referred to as a bidirectional triggering element. It has the same breakdown voltage in both directions. The operation of a diac can be explained as follows, using a breakdown voltage of 33 V as an example: It is equivalent to two 33-volt Zener diodes connected in series in opposite directions. It does not conduct current up to 33 volts. When the voltage across its terminals exceeds 33 volts, it becomes conductive. Due to these properties, diacs are connected in series to the gates of triacs and thyristors to trigger them. The triggering time of the thyristor or triac is determined based on the breakdown voltage of the diac.

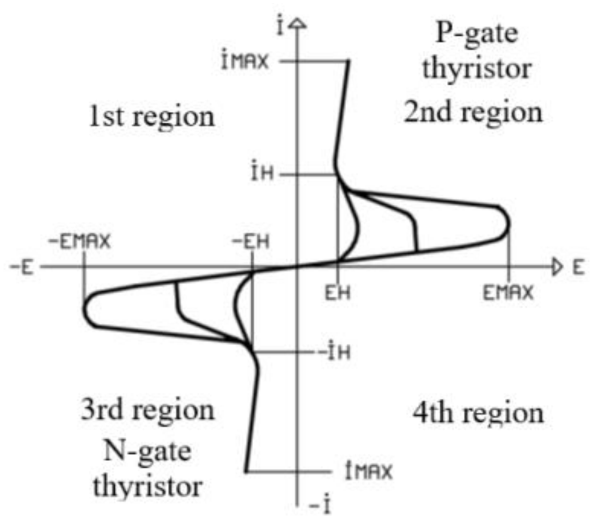
Dimmer Circuit Application

A triac is a semiconductor switch capable of controlling the load in both alternating phases of AC operation. The following figure shows the structure and symbol of a triac. The terminals of the triac that have the same characteristics are called A1 (Anode 1) and A2 (Anode 2). The load is usually connected to the A2 anode circuit. The control terminal is called the gate, as in a thyristor.



The equivalent circuit of the triac, consisting of a “P”-gate thyristor (SCR1) and an “N”-gate thyristor (SCR2), is shown in the figure below. In the left polarity, SCR1 is conductive, and in the right polarity, SCR2 is conductive. When the triac operates on AC, one thyristor conducts in one half-cycle and the other thyristor conducts in the other half-cycle, resulting in full-wave load control.





Dimmer Circuit Application

There are four operating modes associated with the gate polarity in AC.

1st Region + Mode A2+ , A1- , G+,

3rd Region + Mode A2- , A1+ , G+,

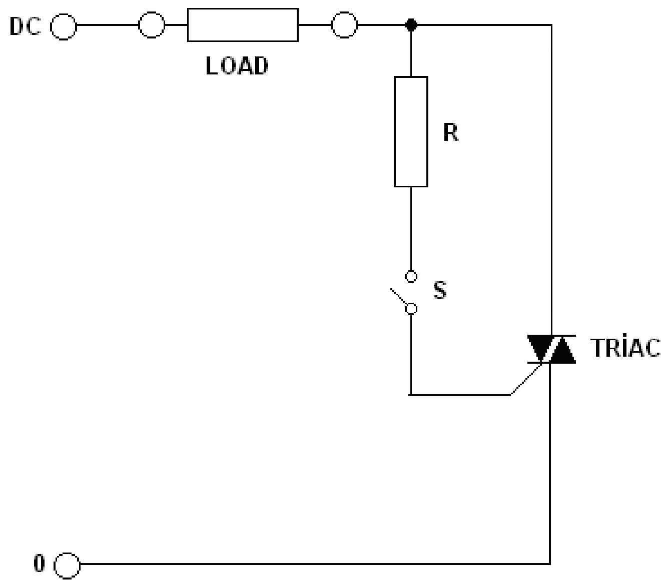
1st Region - Mode A2+ , A1- , G- ,

3rd Region - Mode A2- , A1+ , G- ,

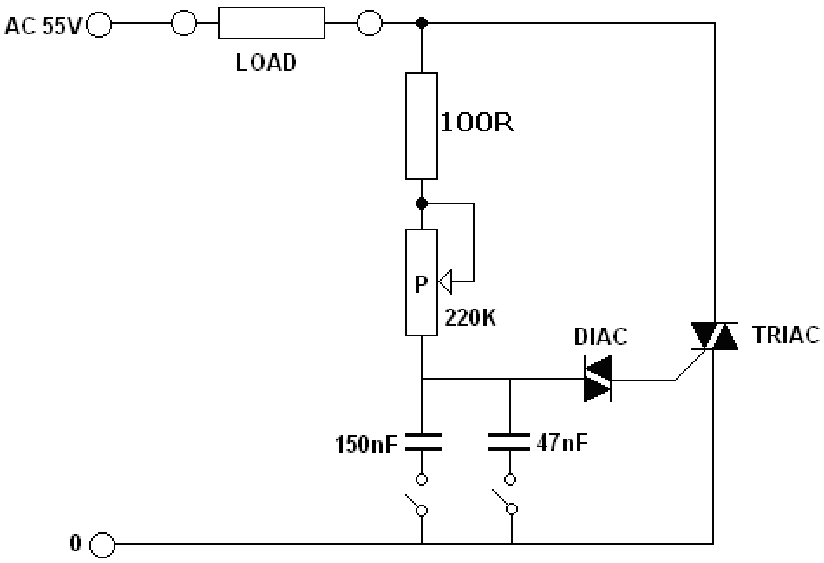
The P-gate thyristor operates in the "1st region +" and "3rd region +" modes where the gate is triggered by a positive pulse. The N-gate thyristor operates in the "1st region -" and "3rd region -" modes where the gate is triggered by a negative pulse. Modes where the A2 anode and gate polarity are the same (Zone 1+ and Zone 3-) are modes where the triac is triggered very sensitively. The triac is usually operated in these modes. A gate voltage of 5V to 30V is required for triacs to conduct. In modes where the A2 anode and gate polarity are the same, the triac conducts with 5V, and current flows through the load in both alternations. Modes where the A2 anode and gate polarity are different (Zone 1- and Zone 3+) are modes where the thyristor cannot be triggered stably; operation in these modes is not preferred. The standard operating circuit of a triac is shown in the figure below.

DC is applied to the circuit. When the "S" button is pressed, the triac receives sufficient gate polarization through RG and becomes conductive. Current begins to flow through the load. When the button is released, current continues to flow through the load. This means that triacs, like thyristors, have a latching feature. In DC operation, the polarity of the power source is also irrelevant.

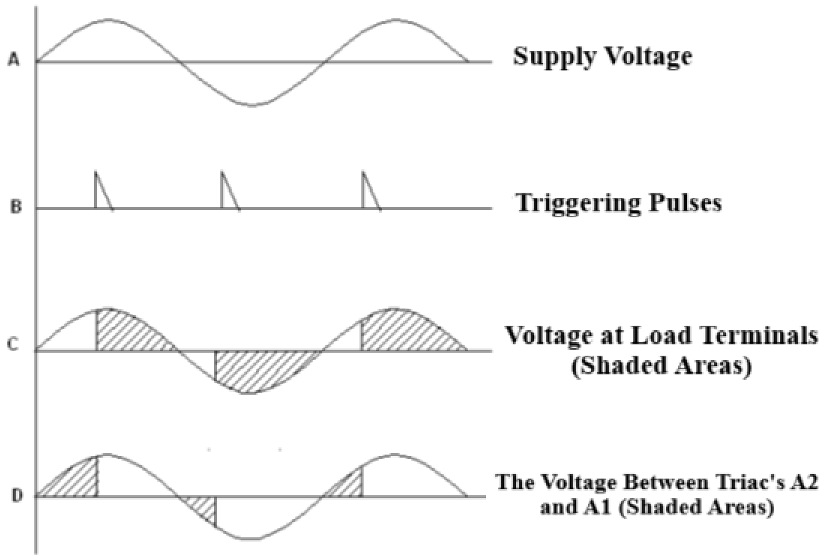
AC is applied to the circuit. When the "S" button is pressed, the triac again receives sufficient gate polarization and becomes conductive. Current flows through the load. When the button is released, the load current is also cut off. This is because the instantaneous value of AC is zero during the alternation change. At this moment, no voltage is applied to the A1 and A2 anodes of the triac, and operation stops.



Operation of the dimmer circuit:



The dimmer circuit is a circuit that adjusts the phase angle and operates at 55V AC voltage and 50 Hz mains frequency in our experimental circuit. The circuit adjusts the phase angle via the P potentiometer. The power consumed in the load due to the conductivity of the triac is controlled by the pulse signals applied to the gate terminal. This can be better explained by the waveforms.



If no voltage is applied to the gate terminal, the triac is non-conductive in both alternations. Almost all of the voltage drops across the triac terminals, and no energy is charged. The timing intervals of the trigger pulses determine the energy charging intervals of the load. If signal B in the figure is applied to the gate terminal, signal D (shaded sections) appears at the triac terminals and signal C (shaded sections) appears at the load terminals. The result is that load control is not performed until the gate current flows in both alternations. The triac becomes conductive in the alternations where the gate current starts. This conductivity continues until the end of those alternations.

Dimmer Circuit Application

Triacs operating in AC mode are always triggered by the voltages generated by pulse generators with a phase difference. However, they can also be operated using a simpler and more practical method, which involves applying the gate terminal voltage through an adjustable phase delay circuit. This adjustable phase delay circuit is an RC time delay circuit. It ensures that the phase of the AC voltage received from the A2 anode is applied to the gate terminal, generally adjusted between 00 and 1800 using a potentiometer. In addition to the RC time delay circuit, such circuits also require a triggering element. This triggering element can be SUS, SBS, DIAC, etc.

The calculation of a phase delay circuit is as follows:

1- The alternation period is calculated according to the frequency of the voltage at which the load operates.

2- Since one alternation is 1800, the 10-second interval is calculated.

3- Given a 10-second period, the product of the two values gives the phase delay time.

For example, the load in the circuit is to be operated with a 600-millisecond delay.

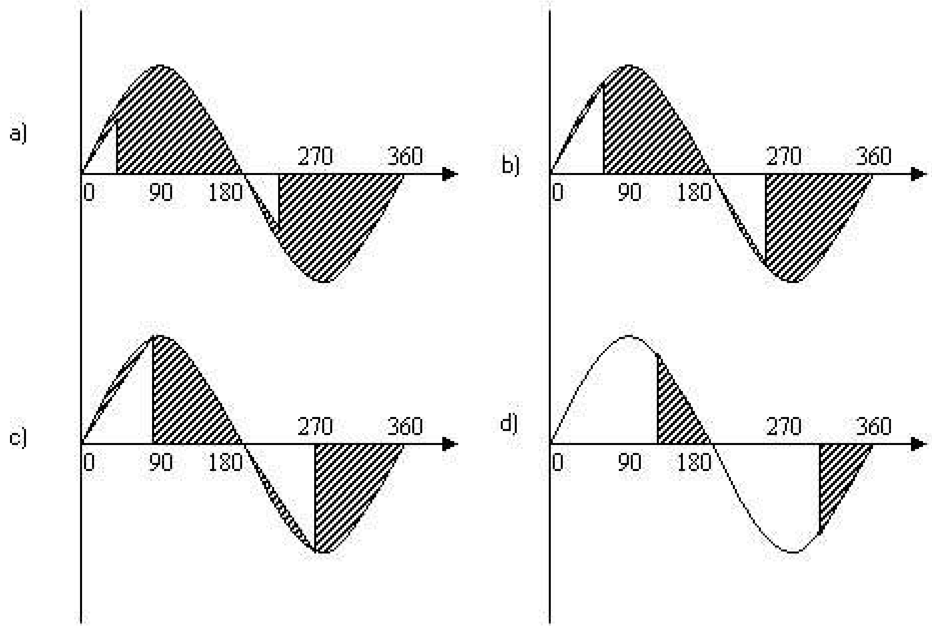
Given that U=220V AC 50Hz, the phase delay time is;

1. Duration of one alternation = 1 second / 50 * 2 (alternations) = 1/100 = 10 ms
2. 10 ms duration = 10 / 180^0 =55,5 µs
3. 600 phase delay = 10 time delay * 60

   = 55,5 * 60 = 3330 µs

The R and C values to be used for the selected phase delay are calculated by selecting one of them as fixed. When power is supplied to the dimmer circuit, the charging and discharging times of the capacitor are determined by the P and R1 resistors using the equation T = R*C. This time determines the trigger angle of the triac. However, this angle cannot exceed 900. For this reason, the C2 capacitor is added to the circuit to delay the triggering angle. However, it still cannot reach 1800. For this reason, a diac is also added to the circuit. Thus, the triac is triggered between approximately 00 and 1800. When the setting of the P potentiometer is changed, this triggering angle is adjusted.

For the triac to conduct, the charge voltage at the C2 terminals must reach the triac's firing voltage. The triac's firing voltage in this circuit is 29V. Within less than 0.01 seconds after the mains voltage is applied to the input, the triac's firing voltage is established at the C2 terminals. This is because the mains frequency changes direction every 0.01 s to (+) and (-). If the time constant T=PxC2 is selected to be greater than 0.01 s, the C2 charge cannot reach 29 volts and the diac cannot be ignited. Therefore, since the triac cannot switch to conduction, no current flows through the load. When the resistance value of the potentiometer is reduced, this time the charging voltage of C2 reaches the firing voltage of the diac at the very beginning of the alternations, and the triac conducts at the beginning of the alternations. Most of the voltage drops across the load, and a small portion drops across the triac. (Shaded areas are load, white areas are triac voltage) Maximum current flows through the load. When the resistance value of the potentiometer is increased, this time the charging voltage of C2 reaches the ignition voltage of the diac towards the end of the alternations, and the triac conducts towards the end of the alternations. Most of the voltage drops across the triac, and a small portion drops across the load. (Shaded portions are load, white portions are triac voltage) A small current flows through the load.



The triac

a) is triggered immediately at the start of the alternation,

b) is triggered 45 degrees after the alternation begins,

c) is triggered 90 degrees after the alternation begins,

d) is triggered 135 degrees after the alternation begins. In a) above, the triac is conductive immediately at the start of the alternation, and the waveform of the current passing through the load at maximum power is seen (the shaded areas of the load are wide). In b), the triac becomes conductive 45 degrees after the start of alternation and ¾ of the power is obtained (the shaded load area is slightly reduced). In c), the triac becomes conductive 90 degrees after the start of alternation and ½ of the power is obtained (the shaded load area is reduced by half). In d, the triac conducts 135 degrees after the start of alternation. In this case, ¼ of the power is obtained (the shaded load area is the smallest).

3. EXPERIMENT PROCEDURE

Set up the circuit shown in the diagram.

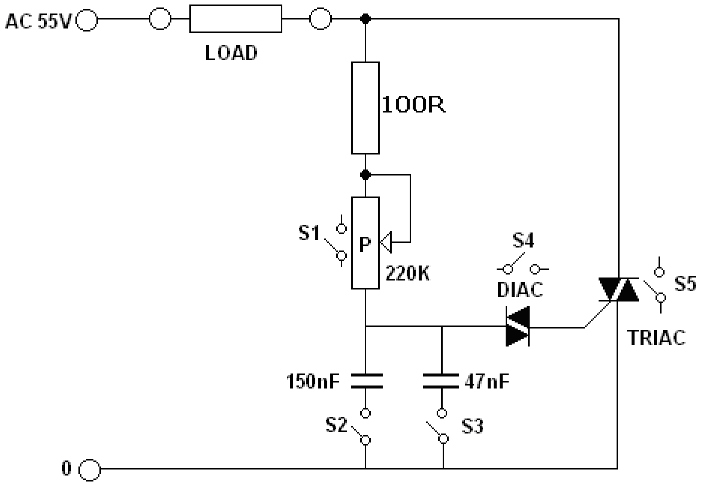


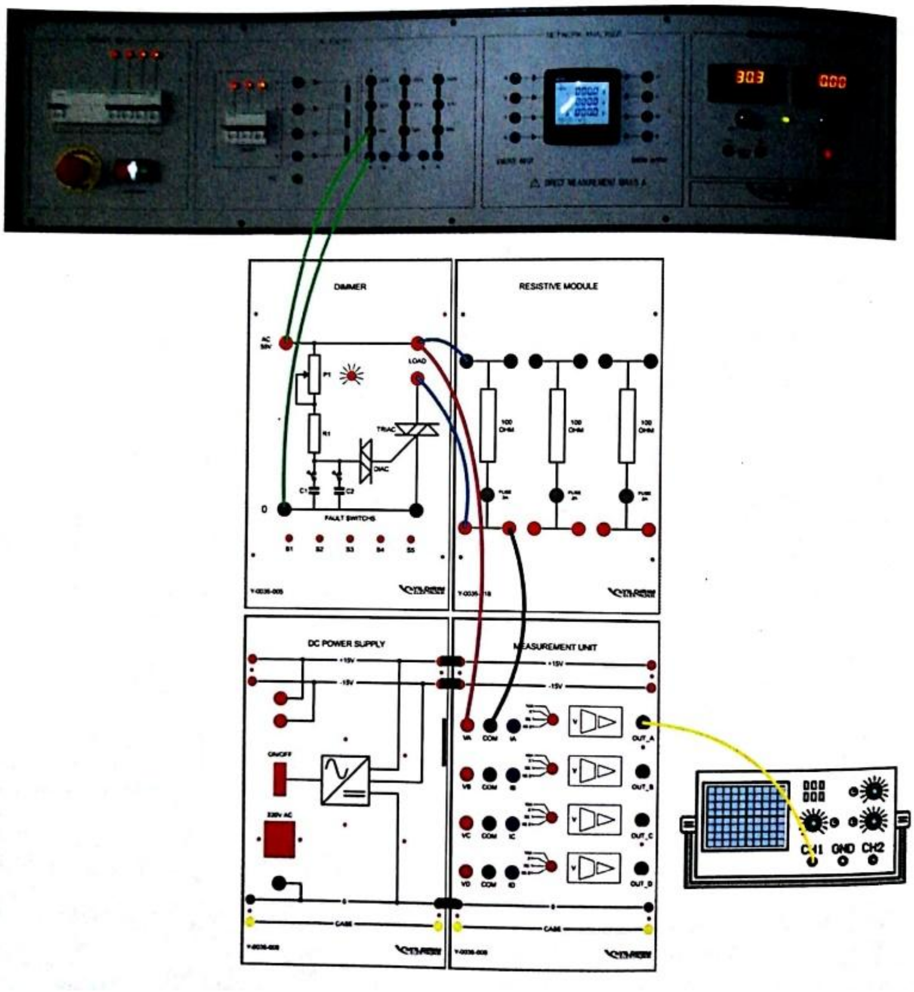
Figure. Experimental connection diagrams

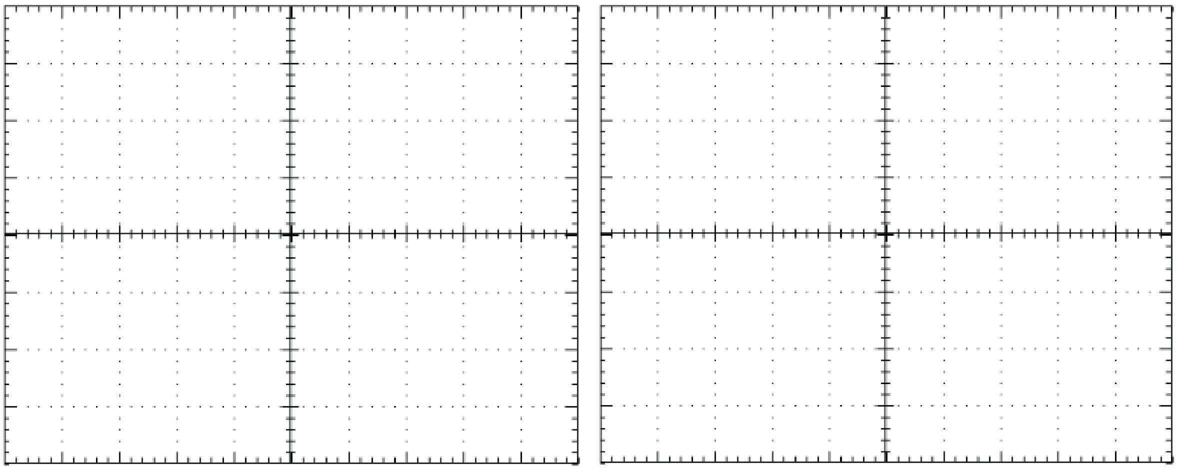
1- Connect the oscilloscope as shown in the diagram and supply power. (R=100Ω)

2- Oscilloscope positions: Probe= measurement unıt x0,1 Volt/Div=5V, Time/Div=5mS

3- When the S switches are in the = ⥣ position, the circuit components operate normally. When moved to the down position, a short circuit occurs and no control is performed.

4- Explain the image on the oscilloscope screen when all switches are in the down position.



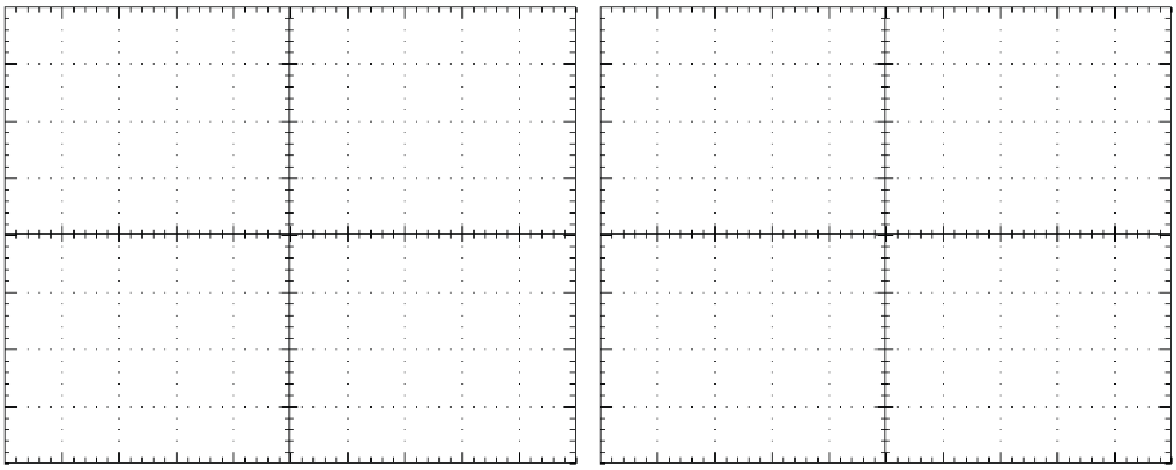


(a) When the potentiometer is in the maximum position

(b) When the potentiometer is in the minimum position

Figure. Waveforms according to the potentiometer's position

5- Explain the image on the oscilloscope screen only when the S5 switch is in the up position.



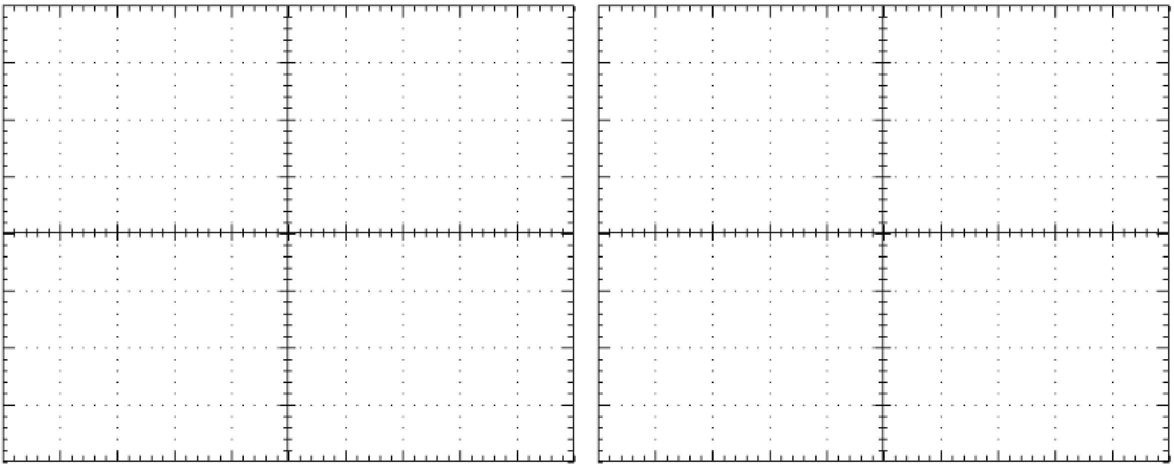
(a) When the potentiometer is in the maximum position

(b) When the potentiometer is in the minimum position

Figure. Waveforms according to the potentiometer's position

6- Explain the situation that occurs only when the S2 and S3 switches are in the up position.

7- Explain the image on the oscilloscope screen when all switches are in the up position.

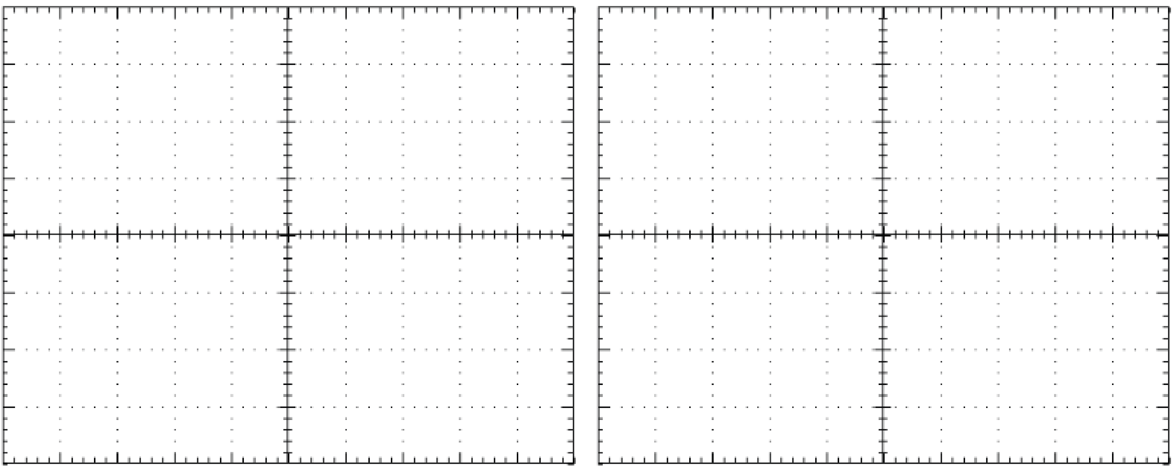


(a) When the potentiometer is in the maximum position

(b) When the potentiometer is in the minimum position

Figure. Waveforms according to the potentiometer's position

8- After the previous operation, explain the image on the oscilloscope screen only when the S2 switch is in the down position.



(a) When the potentiometer is in the maximum position

(b) When the potentiometer is in the minimum position

Figure. Waveforms according to the potentiometer's position