LAB MANUAL

EECS LAB I (ECS327)

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Lab Experiment List

Experiment 1: Familiarization with DC and AC sources

- **Objective 1.1:** IV characteristics of ohm's law (DC input).
- **Objective 1.2:** IV characteristics of ohm's law (AC input).

Experiment 2: RC and RL circuit

- **Objective 2.1:** Charging and discharging characteristics of capacitor using DC source.
- **Objective 2.2:** Effect on the output of RC circuit for a square wave input signal.
- **Objective 2.3:** Experiment with RL circuit with DC source. Record the voltage and current across the L with time.

Experiment 3: RLC circuit

- **Objective 3.1:** For the given RLC circuit, apply input signals of different frequencies and vary the resistance values for a fixed value of L and C and measure output voltage, $V_{out}(t)$.
- **Objective 3.2**: Measuring V_{out} for these combinations for observing underdamp, overdamp and critically damped behavior after adjusting the appropriate values of RLC.

Experiment 4: Diode behavior

- **Objective 4.1**: I-V characteristics of a diode.
- **Objective 4.2:** Study of Full-wave and Half-wave rectifier circuit
- **Objective 4.3:** Study of Clipper and clamper circuit.

Experiment 5: Bipolar Junction Transistor (BJT) analysis

- **Objective 5.1:** Study of common emitter configuration (I_C vs V_{CE} for different V_{BE}).

Experiment 1: Familiarization with DC and AC sources

- **Objective 1.1:** Verification of ohm's law using IV characteristics (DC input).
- **Objective 1.2:** Verification of ohm's law using IV characteristics (AC input).

Objective 1.1: IV characteristics of ohm's law (DC input)

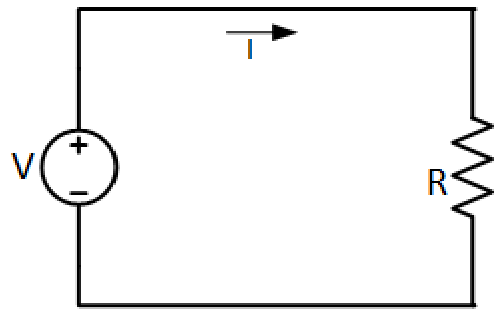

Figure 1.1: Circuit diagram of the experiment

Equipment/Components Required

Sl. No.	Component	Specifications/Value	Quantity
1	Resistor	100 Ω, 500 Ω, 100 kΩ, 500 kΩ, 100 MΩ	01 each
2	Variable Voltage Source	0 – 12 V with resolution 0.5 V or higher	01

Brief Theory: Current through an ohmic resistor increases proportionally with the increase in applied voltage i.e. $V = R \times I$, where V is applied voltage, and I is the current through the ohmic resistor and R is the proportionality constant which is known as resistance.

Procedure:

1. Make the circuit shown in Figure 1.1 in a breadboard or kit provided
2. Sweep the voltage from 0 volt to V_{max} in a small steps (say 0.5 V)
3. Measure the current using the digital multimeter and record the values
4. Plot the I-V characteristics in laboratory book
5. Repeat the experiment from step 2 to step 4 for different values of R.

Take V_{max} = 5 V and voltage step = 0.5 V.

Perform the test for 5 different resistances, R = 100 Ω, 500 Ω, 100 kΩ, 500 kΩ, 100 MΩ

Note: *The values of V_{max}, voltage step and R will be given by your instructor in the lab.*

Make a table as shown below and record the values you get from the multimeter. Specify the units of both voltage and current. It is extremely important to mention the unit.

Sl. No.	**Voltage (V), Unit = V**	**Current (I), Unit = ??**
1	0	
2	0.5	
3	1.0	
4	1.5	
5	2.0	

From the values you recorded in the table above, plot the curve keeping voltage (V) in the X-axis and Current (I) in the Y-axis.

Calculate the value of the resistance from the plot.

Objective 1.2: IV characteristics of ohm's law (AC input)

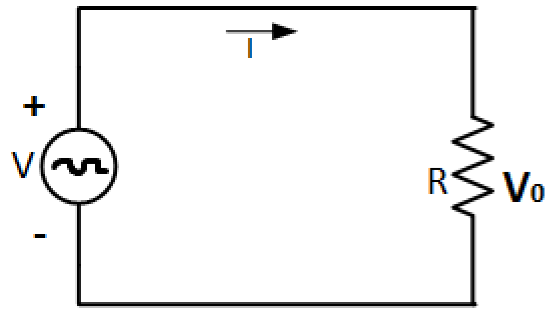

Fig. 1.2: *Circuit diagram of the experiment*

Equipment/Components Required

Sl. No.	Component	Specifications/Value	Quantity
1	Resistor	100 Ω, 500 Ω, 100 kΩ, 500 kΩ, 100 MΩ	01 each
2	Variable Voltage Source (AC signal)	Function Generator	01

Brief Theory: Resistors are bidirectional electronic passive component and hence the behavior of the resistor does not change with the direction of current flowing through it. **In** AC circuits as shown in Fig. 1.2, the direction of the current flowing through a component changes with time and the change in the direction of has no effect on the behavior of the resistor, thus the current will rise and fall as the applied voltage rises and falls. In this case, the current through and voltage across the resistor reach to a maximum value, then fall through zero and reach to a minimum value at exactly the same time. i.e, they rise and fall simultaneously and are said to be "in-phase".

Procedure:

1. Make the circuit shown in Fig.1.2 in a breadboard or kit provided.
2. Apply the AC voltage signal at the input side.
3. Measure the AC current using the digital multimeter/ digital oscilloscope and record the values.

4. Plot the I-V characteristics in laboratory book.
5. Change the value of resistor *R.*
6. Repeat the experiment from step 2 to step 4.

Take V_{max} = and voltage step =

Perform the test for 5 different resistances, R = 100 Ω, 500 Ω, 100 kΩ, 500 kΩ, 100 MΩ

Note: *The values of V_{max}, voltage step and R will be given by your instructor in the lab.*

Make a table as shown below and record the values you get from the multimeter. Specify the units of both voltage and current. It is extremely important to mention the unit.

Sl. No.	**Voltage (V), Unit = V**	**Current (I), Unit = ??**
1		
2		
3		
4		
5		

From the values you recorded in the table above, plot the V-I phase diagram and calculate the value of the resistance.

Experiment 2: RC and RL circuit

- **Objective 2.1:** Charging and discharging characteristics of capacitor using DC source.
- **Objective 2.2:** Effect on the output of RC circuit for a square wave input signal.
- **Objective 2.3:** Experiment with RL circuit with DC source. Record the voltage and current across the L with time.

Objective 2.1: Charging and discharging characteristics of capacitor using DC source.

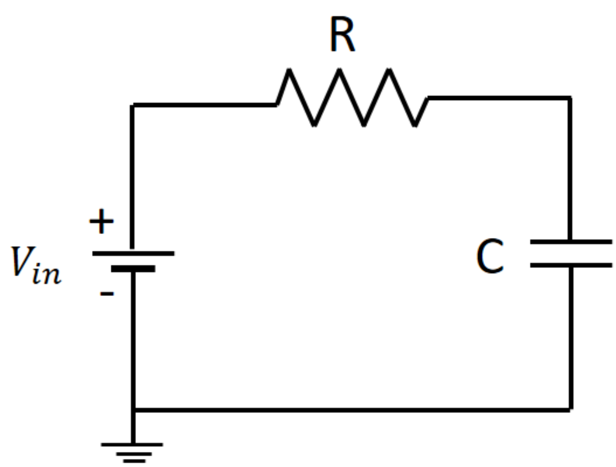

Figure 1.3: Circuit diagram of the experiment

Equipment/Components Required

S.No	Components	Specification values	Quantity
1	Resistors	As instructed in lab	3
2	Capacitors	As instructed in lab	3
3	DC voltage source	0-12 V	1
4	Multimeter/Oscilloscope	Digital	1

Brief Theory: A discharged capacitor connected to a DC voltage source charges up with increase in the voltage of the source. Similarly, a charged capacitor discharges in opposite direction when the applied voltage of the DC source is reduced. Capacitors in this line can be compared with small batteries. The charge stored in a capacitor plates is proportional to the applied voltage and can be defined as, $Q = C \times V$, where Q is the stored charge, V is the applied voltage, and C is the proportionality constant which is known as capacitance.

The charging and discharging of capacitor generally takes some time and depends on the time constant (τ) i.e. the time taken for a certain percentage of charging and discharging of capacitor.

As per the RC circuit given in Fig. 1.3, the capacitor will charge up through the resistor connected in series with time until the voltage across the capacitor (V_C) becomes equal to supply voltage (V_S). The time constant specifies the rate of charge or discharge and can be defined as, $\tau = R \times C$, where R is in ohm and C is in Farad where the τ is in seconds. In the given circuit, at any point of time (t) the voltage across the capacitor can be given by, $V_C = V_S\left(1 - e^{-t/\tau}\right)$.

From the above equation, it is clear that at $t = 5\tau$, the capacitor becomes ~100% charged, i.e. $V_C \cong V_S$; at $t = 4\tau$, the capacitor becomes ~98% charged, i.e. $V_C \cong 0.98V_S$; and at $t = \tau$, the capacitor becomes ~63% charged, i.e. $V_C \cong 0.63V_S$. In this situation, $t \leq 4\tau$ is known as transient period and $t > 4\tau$ is known as steady state where at $t = 5\tau$, the capacitor can be treated as fully charged. Similar is the case for discharging condition.

Procedure:

1. Connect the circuit as per the Figure 1.3. and make sure the capacitor is completely discharged.
2. Apply a DC input and observe the charging cycle of capacitor.
3. Note at least 5 readings during the charging cycle with time using storage feature of multimeter/oscilloscope or simply recording the multimeter screen.
4. Choose at least three different combination of RC and record the output voltage and output current using multimeter.

Observation Table:

Resistance (R)	Capacitance (C)	Time constant (T)	Output V at 1T	Output V at 5T
R1=	C1=	R1C1=		
R2=	C2=	R2C2=		
R3=	C3=	R3C3=		

For any of the given values of RC time constant, attach charging characteristics.

Perform similar experiment to check the discharging characteristics by shorting the leads of the capacitor.

Objective 2.2: Effect on the output of RC circuit for a square wave input signal.

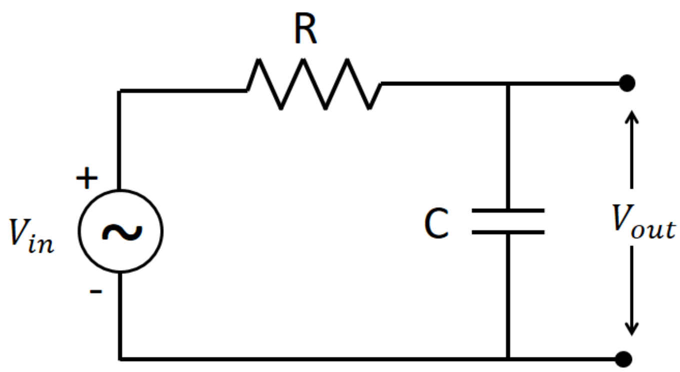

Figure 2.2: *RC circuit diagram of the experiment*

Equipment/Components Required

S.No	Components	Specification values	Quantity
1	Resistors	As instructed in lab	3
2	Capacitors	As instructed in lab	3
3	AC voltage source/ Function Generator	0 – 3 MHz or Higher	1
4	Digital Oscilloscope i.e. DSO	0 – 300 MHz or Higher	1

Brief Theory: The basic charging discharging operation has been discussed in the previous section of this experiment. In this case, the difference is that the input is no longer a constant DC voltage instead, it is a square wave where the voltage will be high for a certain period of time and zero for a certain period of time consecutively. For the sake of understanding, one can argue that a square wave is a constant DC current source for a specific period time. From the theory discussed in previous section, it is now clear that in a RC circuit, a capacitor charges fully i.e. ~100% of the applied voltage in $t = 5\tau$. Similarly, discharges down to zero in $t = 5\tau$ when it is removed. In both RC charging and discharging circuits, the time $t = 5\tau$ always remains true as it is determined by the resistor-capacitor (RC) combination. In this case of square wave, if the voltage remains high for $t \geq 5\tau$, then the capacitor will charge completely. Similarly, if the voltage remains zero for $t \geq 5\tau$, the battery will discharge completely. Any time period $t < 5\tau$ for high and zero voltage will lead to a distorted or nearly equivalent triangular wave at the output across the capacitor.

Procedure:

1. Connect the circuit as per the Figure 2.2.
2. Apply a square wave input and observe the output voltage.

3. Choose at least three different square wave having 2T, 5T, 8T (ON time with 50% duty cycle) and record the output voltage.

Observation Table:

Resistance (R)	Capacitance (C)	Time constant (T)	Max. Voltage	Rise Time	Fall Time
R1=	C1=	R1C1=			
R2=	C2=	R2C2=			
R3=	C3=	R3C3=			

For any of the given values of RC time constant, attach your output waveforms images.

Perform the same experiment with a sinusoidal input and record the output across R and C.

Perform similar experiment after interchanging the position of R and C.

Objective 2.3: Experiment with RL circuit with DC source. Record the voltage and current across the L with time.

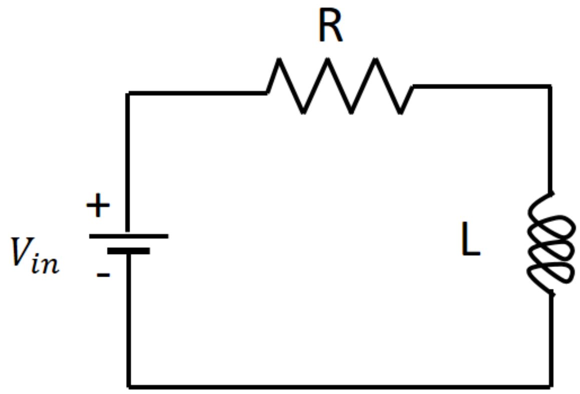

Fig. 2.3: *Circuit diagram of the LC experiment*

Equipment/ Components Required:

S.No.	Components	Specification values	Quantity
1	AC Source/ Function Generator	0 – 3 MHz or Higher	1
2	Inductors	As instructed in lab	4
3	Capacitors	As instructed in lab	4
4	Digital Oscilloscope i.e. DSO	0 – 300 MHz	1
5	Multimeter	Digital	1

Brief Theory:

The series LR circuit is composed of an inductor (L) and resistor (R) connected in series along with a constant DC voltage source V. This is similar to that of RC circuit discussed in the previous experiment where capacitor (C) was used instead of inductor (L). Once the circuit is connected to a constant DC voltage source, the current starts flowing through the circuit but takes some time to reach to the maximum value as per ohms law i.e. V/R.

The reason behind the delay of reaching maximum current is the self-induced emf within the coil i.e. inductor due to the magnetic flux as per Lenz's law. Thus, it takes some time to for the applied voltage source to neutralize the self-induced emf and thereafter the current becomes constant.

The rate of change of current and voltage depends on the time constant (τ), similar to that of RC circuit. In case of RL circuit, the time constant is determined and defined as, $\tau = L/R$, where τ is in seconds when inductance L is in Henry and resistance R is in ohms.

The voltage across the L (V_L) at any time t can be given by, $V_L = Ve^{-t/\tau}$, where V is the applied voltage.

Similarly, the current through the L (I_L) at any time t can be given by, $I_L = \frac{V}{R}\left(1 - e^{-t/\tau}\right)$, where V is the applied voltage and R is the resistance.

Procedure:

1. Connect the circuit as per the Figure 2.3.
2. Apply a DC input and observe the voltage and current across the L.
3. Choose at least three different combination of RL and record the output voltage and output current using multimeter.

Observation Table:

Resistance (R)	Inductance (C)	Time constant (T)	Output V at 1τ	Output V at 5τ
R1=	L1=	L1/R1=		
R2=	L2=	L2/R2=		
R3=	L3=	L3/R3=		

For any of the given values of RC time constant, attach your output waveforms images.

Perform the same experiment with a sinusoidal input and record the output across R and L.

Experiment 3: RLC circuit

- **Objective 3.1:** For the given RLC circuit, apply input signals of different frequencies and vary the resistance values for a fixed value of L and C and measure output voltage, $V_{out}(t)$.
- **Objective 3.2**: Measuring V_{out} for these combinations for observing underdamp, overdamp and critically damped behavior after adjusting the appropriate values of RLC.

Objective 3.1: For the given RLC circuit, apply input signals of different frequencies and vary the resistance values for a fixed value of L and C and measure output voltage, $V_{out}(t)$.

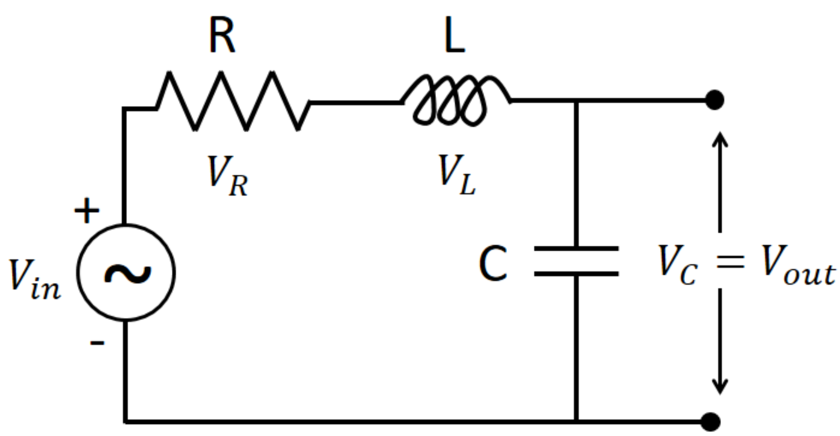

Fig 3.1: *Circuit diagram of the RLC experiment*

Equipment/ Components Required:

S.No	Components	Specification values	Quantity
1	AC power source/ Function Generator	0 – 3 MHz or Higher	1
2	Resistance	1 kΩ or as instructed	1
3	Inductors	10 µH or as instructed	1
4	Capacitors	10 µF or as instructed	1
5	Digital Oscilloscope i.e. DSO	0 – 300 MHz or Higher	1
6	Multimeter	Digital	1

Brief Theory: The series RLC circuit is composed of a resistor (R), a capacitor (C), and an inductor (L) connected in series as illustrated in Figure 2.2. In case of a pure ohmic resistor the voltage and current waveforms are in-phase with each other. In case of pure inductance surface the voltage waveform leads the current by 90º and for pure capacitance the voltage lags the current by 90º.

The mentioned phase difference between the voltage and current depends on the reactance (X) of circuit. For a purely resistive circuit element, $X = 0$; for purely inductive circuit element, $X > 0$; and for purely capacitive circuit element, $X < 0$.

The reactance and impedance of the circuit elements are,

Element	*Resistance*	*Reactance (X)*	*Impedance (Z)*
Resistor	R	0	$Z = R$
Inductor	0	ωL	$z = j\omega L$
Capacitor	0	$\frac{1}{\omega C}$	$Z = \frac{1}{j\omega C}$

$where\ \omega\ is\ angular\ frequency$

The RLC circuit in this case will help us to analyze each circuit element simultaneously. This circuit is similar to the series RL and RC circuits discussed previously, the difference in this case is that the reactance of both L and C will be counted together in overall reactance of the circuit. In the circuit under consideration consists a single loop with the same current flowing through all three circuit element. Since, the reactances of L and C are a function of frequency ($\omega = 2\pi f, f\ is\ frequency$), hence the sinusoidal response of the circuit will vary with input frequency, f. In this case, the individual voltage drop of each circuit element, R, L, and C will be out of phase with each other.

Procedure:

1. Connect the circuit as per Fig. 3.1 on breadboard using connecting wires.
2. Connect the function generator in the input of the circuit.
3. Connect one channel of the oscilloscope across the resistor (R) and the other channel with input.
4. Provide a sinusoidal signal of amplitude 5 V and a frequency of 50 Hz or as instructed by the lab instructor.
5. Record the output voltage signal across the resistor.

6. Thereafter, connect the oscilloscope across the inductor and record the output voltage signal.
7. Finally, connect the oscilloscope across the capacitor and record the output voltage signal.
8. Change the frequency and plot the frequency versus peak voltage to find the resonance frequency, $\omega_0 = 1/\sqrt{LC}$.

Result: Attach the image of the output waveform and frequency vs peak voltage plot. Indicate experimental and theoretical value of the resonance frequency.

Objective 3.2: Measuring V_{out} for these combinations for observing underdamp, overdamp and critically damped behavior after adjusting the appropriate values of RLC.

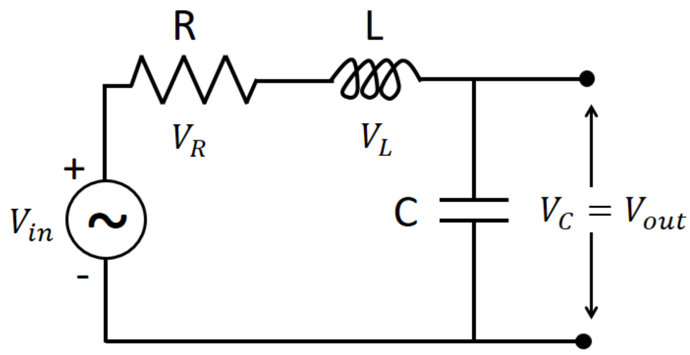

Fig: 3.2: *RLC circuit for the experiment.*

Equipment/ Components Required:

S.No.	Components	Specification values	Quantity
1	AC power source		1
2	Resistance	10, 51, 100, 200, 510, and 1000 Ω	4
3	Inductors	0.55, 2.5, 5 and 10mH	4
4	Capacitors	0.001, 0.01, 0.1 and 1.0□F	4
5	DSO		1

Brief Theory: The basic discussion on the RLC circuit has been discussed in the previous experiment. If we consider KVL the, $V_R + V_L + V_C = V(t)$ where V_R, V_L, and V_C are the voltages across, R, L , and C, respectively and $V(t)$ is the input voltage signal. Substituting the values of the voltages across each electronic components we get,

$RI(t) + L\frac{dI(t)}{dt} + V_0 + \frac{1}{C}\int_0^t I(\tau)d\tau = V(t)$, for a unchanging voltage signal the same will reduce to,

$$\frac{d^2}{dt^2}I(t) + \frac{R}{L}\frac{d}{dt}I(t) + \frac{1}{LC}I(t) = 0$$

This can be written as the following form, $\frac{d^2}{dt^2}I(t) + 2\alpha\frac{d}{dt}I(t) + \omega_0^2 I(t) = 0$

Where $\alpha = \frac{R}{2L}$, is the attenuation or Neper frequency and $\omega_0 = \frac{1}{\sqrt{LC}}$, is the angular frequency. The term α decides how fast the transient response will settle down. Depending on the electrical component values the circuit can be categorized as Overdamped, Critically damped, and under damped. The following are the conditions for the same.

If $\alpha > \omega_0$ then it is overdamped

If $\alpha = \omega_0$ then it is critically damped

If $\alpha < \omega_0$ then it is underdamped

Procedure:

1. Connect the circuit as per Figure 3.2 on breadboard using connecting wires.
2. Connect the function generator in the input of the circuit.
3. Connect one channel of the oscilloscope across the inductor (L) and the other channel with input.
4. Provide a square wave of amplitude 1 V and a frequency of 50 Hz (adjust the signal if necessary) or as instructed by the lab instructor.
5. Make the circuit for three different LC combinations as instructed by lab instructor for three different damping conditions.
6. Expand the time scale of the oscilloscope to get the damping behavior of the circuit.
7. Connect one channel of the oscilloscope across the capacitor (C) and the other channel with input.
8. Perform the same experiment (4-6) and observe the damping behavior.

Result: Attach the image of the output wave form

Experiment 4: Diode behavior

- **Objective 4.1**: I-V characteristics of a diode.
- **Objective 4.2:** Study of Full-wave and Half-wave rectifier circuit
- **Objective 4.3:** Study of Clipper and clamper circuit.

Objective 4.1: I-V characteristics of a diode.

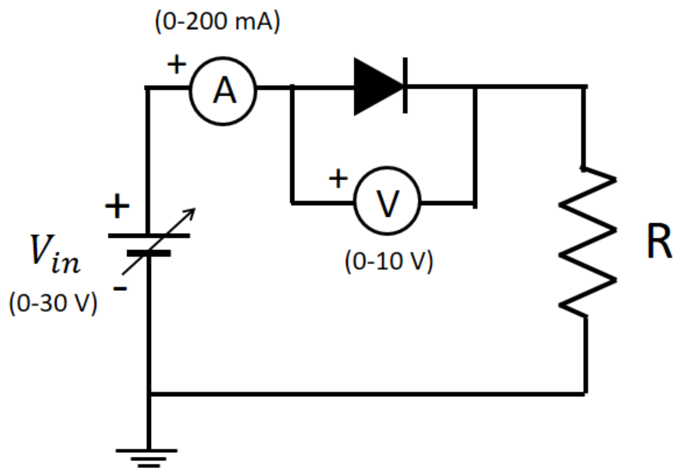

Fig. 4.1: *circuit diagram of PN diode*

Equipment/ Components Required:

S.No	Components	Specification values	Quantity
1	PN Diode	1N4007	1
2	Multimeters	Digital type	2
3	Voltage supply source	DC regulating type	1
4	load resistance	1 kΩ	1

Brief Theory: Diode is a unidirectional passive device and thus polarity of the power supply connected to a diode matters. An ideal diode is a perfect conductor for one direction of current whereas a perfect insulator for the opposite direction. However, in practice the diode does not behave as ideal conductor or insulator in any case. A junction diode is basically a semiconductor PN junction made of p-type and n-type semiconducting regions.

If the positive (negative) terminal of a voltage source is connected to P-side (N-side) of the diode then the diode is said to be in forward bias or ON, otherwise it is reverse biased or OFF. A real semiconductor diode made of Si needs approximately 0.7 V forward bias before it starts conducting current. In reverse bias, it conducts a negligible current which ideally should be zero. The forward current flows from p to n region.

The typical voltage – current (V-I) relationship in a real PN junction diode can be given by the following equation,

$$I = I_S\left(e^{\frac{V_D}{nV_T}} - 1\right)$$

Where, I is diode current, I_S is the reverse bias saturation current or scale current, V_D is the applied voltage across the diode, V_T is the thermal voltage ($(kT)/q$, k – Boltzmann constant, T – Temperature in K, q – charge of electron), and n is the ideality factor.

Procedure:

1. Connect the power supply, voltmeter, ammeter with the diode as shown in the Figure 4.1. Use two multimeters, one to measure current through diode and other to measure voltage across diode as shown in the Figure 4.1.
2. Increase voltage from the power supply from 0 V in step as shown in the observation table.
3. Measure voltage across diode and current through diode. Note down readings in the observation table.
4. Plot the graphs of Diode voltage vs. Diode current.

Observation tables:

Supply Voltage (V)	Diode voltage V (unit)	Diode Current (unit)
0		
0.1		
0.2		
0.3		
0.4		
0.5		
0.6		
0.7		
0.8		
0.9		
1		
2		
3		
4		
5		

Result: Plot the I-V characteristics of diode using the observation table reading.

Objective 4.2: Study of Full-wave and Half-wave rectifier circuit

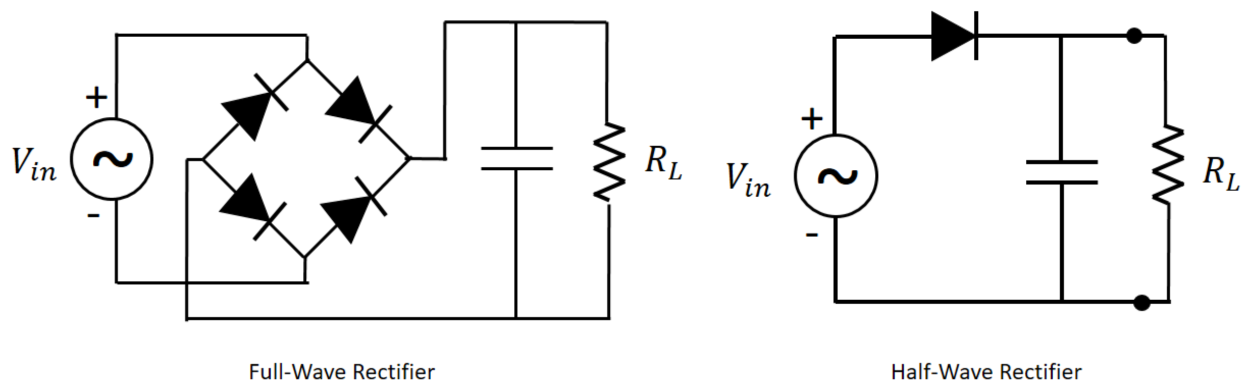

Fig 4.2: *Circuit Diagram of Full-Wave and Half Wave Rectifier*

Equipment/ Components Required:

S.No	Components	Specification values	Quantity
1	AC source	Function Generator	1
2	PN Diodes	1N4007 or Similar	4
3	Capacitors	100 µF	1
4	Resistors	1 kΩ	1
5	Digital Oscilloscope (DSO)	0-300 MHz or Higher	1

Brief Theory: Rectifiers are the electrical circuits that converts the alternating currents (i.e. the currents that changes its direction with time) to a direct current (i.e. the current that has only one direction) by either removing a section of the signal with one polarity or converting the polarity of the signal to a single one. Most commonly used two types of rectifiers are the half-wave and full-wave rectifiers. The associated circuits are given in Figure 4.2.

In case of half-wave rectifier, the diode conducts current only during the positive cycle of the sinusoidal input and blocks the negative cycle of the input. Hence, the output of the rectifier is only the positive cycle of the input signal. Thus, it is called half-wave rectifier as it only rectifies the half part of the full signal.

In case of full-wave rectifier, the 4 diodes are arranged in such a way that during positive cycle two of the 4 diodes conduct and during negative cycle the other two of the 4 diodes will conduct. In both the cases, the current follows different paths and reflect as a positive signal at the output.

Procedure:

1. Connect the circuit as shown in the circuit diagram (Figure 4.2).

2. Give the input signal as specified (say 50 Hz sine wave).
3. Switch on the power supply (12 V).
4. Note down the value of AC and DC voltages from the DSO.
5. Draw the necessary waveforms on the graph sheet/tracing paper with and without capacitor.

Precautions:

1. Connections should be verified before clicking run button.
2. The resistance to be chosen should be in kΩ range.
3. Best performance is being obtained within 50 Hz to 1 MHz

Result: Plot the waveform using the oscilloscope and tracing paper and note down the values i.e. voltage (Peak to Peak) and frequency. Trace the plots with and without capacitor.

Objective 4.3: Study of Clipper and clamper circuit.

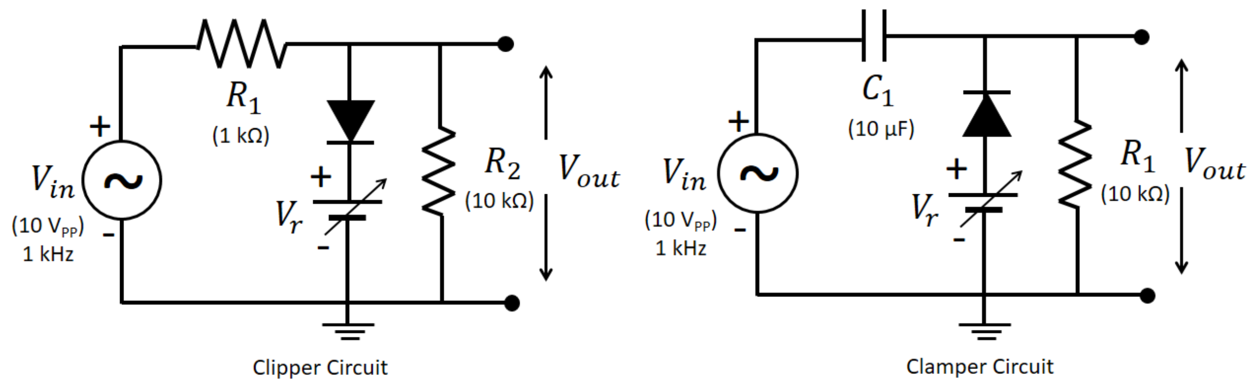

Fig 4.3: *Clipper and Clamper circuit*

Equipment/ Components Required:

S.No.	Components	Specification values	Quantity
1	Function Generator	0-3 MHz or Higher	1
2	Oscilloscope	0-300 MHz or Higher	1
3	DC power supply	0-12 V DC	2
4	Resistor	1, 10, 100, 330 kΩ	4
5	Diode	1N4007 or Similar	4

Brief Theory:

Clipper Circuit: Clipping circuits are used to remove a part of a signal which is above or below a reference level. Clipping circuits are also known as limiters, amplitude selectors, or slicers. Half-wave rectifier is also a good basic example of clipper circuit where the reference level is zero and the signal below zero voltage (i.e. negative) are not allowed to pass through. To alter the reference level to a desired value, a DC voltage source is put in series with the diode. Depending on the polarity of DC source and direction of diode the circuit will clip the input signal above or below the reference level set by the user. The circuit is given in Figure 4.3.

Clamping Circuits: A clamper circuit, on the other hand, shifts a signal to a defined value. Basically, this circuit adds a DC component to the input signal. The circuit can work with a bias or no-bias condition. If the signal shifts above the central line of a input wave, then it calls a positive clamper circuit and if it shifts downwards, then it is called a negative clamper circuit. The circuit arrangement of a diode clamper circuit is given in Figure 4.3.

Procedure:-

Clipping Circuit:

1. Connect the circuit shown in Figure 4.3.
2. Ensure that the variable DC is at minimum and the source is at 10VP.P.
3. Observe and Sketch the input and output waveforms.
4. Increase the variable DC voltage to 4V, and notice to what voltage are the positive peaks chopped off, sketch the waveforms.

Clamping Circuit:

1. Connect the circuit shown in Figure 4.3.
2. Ensure the variable DC is at minimum.
3. Set the sine wave generator frequency to 1 kHz and its output amplitude to 10 V_{P-P}
4. Observe and sketch the input waveform with the variable DC at minimum, Sketch the output waveform.

Result: Attach the output waveform result of the circuits.

Experiment 5: Bipolar Junction Transistor (BJT) analysis

- **Objective 5.1:** Study of common emitter configuration (I_C vs V_{CE} for different V_{BE}).

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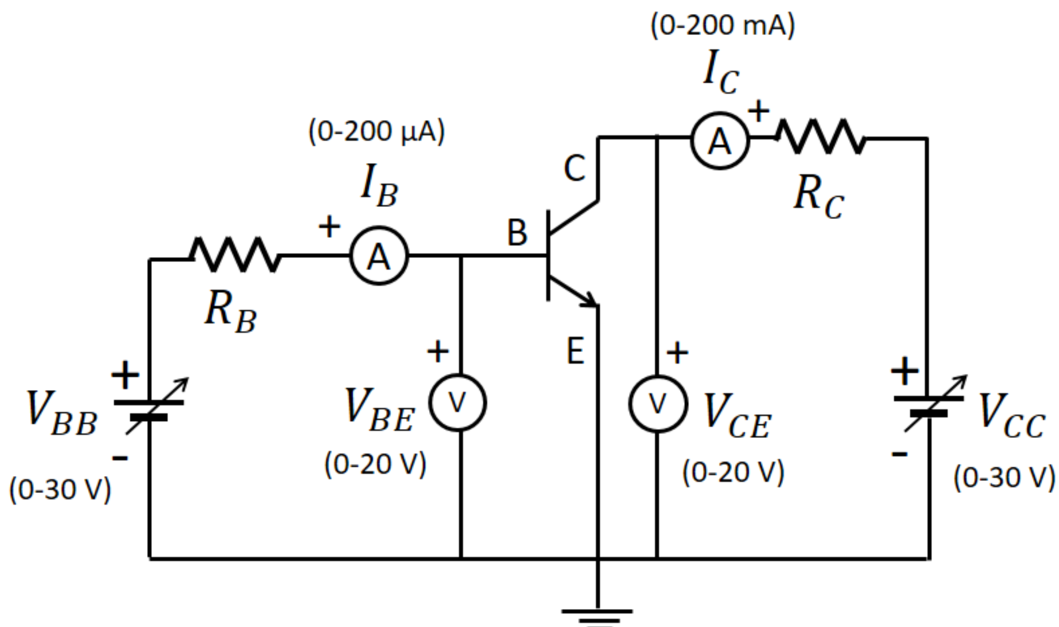
Circuit Diagram:-



Equipment/ Components Required:

S.No.	Components	Specification values	Quantity
1	DC power supply	0-12 V	2
2	NPN transistor	BC 547	2
3	Resistors	1 kΩ, 100 kΩ	4
4	Multimeter	Digital	3
5	Connecting Wires	Male-Male	10

Brief Theory:

Bipolar Junction Transistor (BJT) has three terminals namely, emitter (E), base (B), and collector (C). A BJT is composed of two PN junctions and the operation of BJT is mainly based on the PN junction characteristics. In case of a npn transistor in active region, under forward biased emitter-base (EB) junction, the majority carrier electrons in n-type emitter region are injected to thin p-type base region where the electrons as minority carrier diffuse towards the collector through the reverse biased collector-base (CB) junction. Some of the electrons recombine with holes in the thin p-type base region to produce a small base current (I_B) and the remaining reach collector as a collector current (IC). Hence, if there is no current from emitter (I_E), then there will be almost no I_C. Combining all the currents, the total emitter current, $I_E = I_B + I_C$.

In case of pnp transistor, the polarity of voltage sources must be reversed. Depending on the biasing of two junctions (i.e. EB and CB) transistor, the transistor can be said to be in different modes of operation.

Operating Region	**EB Junction**	**CB Junction**	**Remark**
Cut-off	Reverse	Reverse	$I_E \approx I_B \approx I_C \approx 0$, Off-state, $V_{BE} < 0.7\ V$
Active	Forward	Reverse	Amplifier gain (100-1000)
Saturation	Forward	Forward	Conducting
Reverse Saturation	Reverse	Forward	Reverse gain

Output characteristics are obtained between the output voltage and output current at constant input current. It is plotted between $\mathbf{V_{CE}}$ and $\mathbf{I_C}$ at constant $\mathbf{I_B}$ in CE configuration.

Procedure:

1. The input current or base current I_B is kept constant at 0 μA and the output voltage V_{CE} is increased from zero volts to different voltage levels. For each level of output voltage, the corresponding output current (I_C) is recorded**.**
2. The input current (I_B) is increased from 0 μA to 20 μA by adjusting the input voltage (V_{BE}). The input current (I_B) is kept constant at 20 μA. While increasing the input current (I_B), the output voltage (V_{CE}) is kept constant at 0 volts

3. After we kept the input current (I_B) constant at 20 μA, the output voltage (V_{CE}) is increased from zero volts to different voltage levels. For each voltage level of output voltage (V_{CE}), the corresponding output current (I_C) is recorded.
4. Steps are repeated for higher fixed values of input current I_B (I.e. 40 μA, 60 μA, 80 μA and so on)

Precautions:

1. While performing the experiment do not exceed the ratings of the transistor. This may lead to damage the transistor.
2. Connect voltmeter and ammeter in correct polarities as shown in the circuit diagram.
3. Do not switch ON the power supply unless you have checked the circuit connections as per the circuit diagram.
4. Make sure while selecting the emitter, base and collector terminals of the transistor.

Result: Plot the output (I_C vs V_{CE}) and input (I_B vs V_{BE}) characteristics of the transistor.

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