Fundamentals of Electronics (DI01000051) - Summer 2025 Solution

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Contents

1 Question 1

1.1 Question 1(a) [3 marks]

Draw Bi-stable multivibrator using 555 timer IC.

1.1.1 Solution

A **Bi-stable Multivibrator** is a circuit that has **two stable states** (High and Low). It stays in one state until triggered to switch to the other. Using a 555 timer, this is achieved by controlling the Trigger (Pin 2) and Reset (Pin 4) inputs. When the Trigger pin goes low, the output goes High. When the Reset pin goes low, the output goes Low. No timing capacitor is required in this configuration as the states are manually controlled.

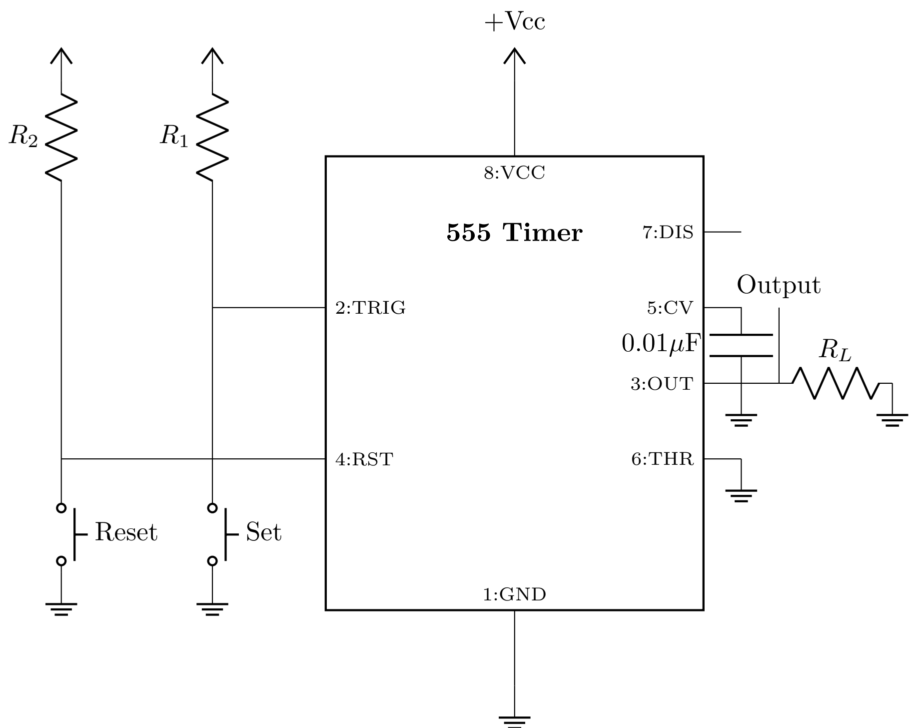

Figure 1: Bi-stable Multivibrator using 555 Timer

Circuit Diagram:

Working Principle:

- **Stable State 1 (Set):** When the *Set* button (connected to Pin 2) is pressed, the Trigger input goes Low ($< 1/3V_{cc}$). This sets the internal Flip-Flop, and the Output (Pin 3) goes **High**.
- **Stable State 2 (Reset):** When the *Reset* button (connected to Pin 4) is pressed, the Reset input goes Low. This resets the internal Flip-Flop, and the Output (Pin 3) goes **Low**.

Note: Pin 5 (Control Voltage) is grounded via a 0.01μF capacitor to prevent false triggering from noise.

Mnemonic: *Bi-Stable: Buy Two Switches (Set and Reset) to control Two States.*

1.2 Question 1(b) [4 marks]

Draw pin diagram of IC 555 timer and explain it.

1.2.1 Solution

The 555 Timer is an 8-pin integrated circuit used for timing and pulse generation. Standard package is 8-pin DIP.

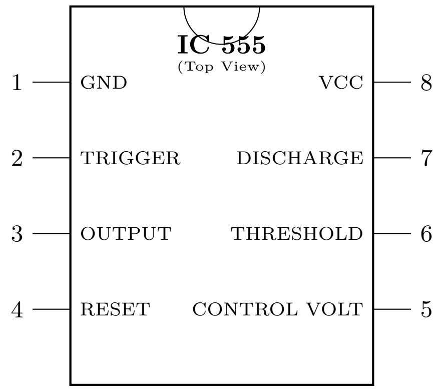

Figure 2: Pin Diagram of IC 555

Pin Diagram:

Pin Functions:

- **Pin 1 (Bottom Left) - Ground:** Connected to negative supply (0V).
- **Pin 2 (Bottom Left) - Trigger:** Negative pulse ($<$ 1/3 Vcc) triggers the output High.
- **Pin 3 (Bottom Left) - Output:** Push-pull output, can source/sink up to 200mA.
- **Pin 4 (Bottom Left) - Reset:** Making this pin Low resets the output. Usually tied to Vcc.
- **Pin 5 (Top Left) - Control Voltage:** Access to internal divider (2/3 Vcc). Typically grounded via 0.01μF capacitor.
- **Pin 6 (Top Left) - Threshold:** Voltage $>$ 2/3 Vcc resets the output Low.
- **Pin 7 (Top Left) - Discharge:** Open collector output affecting capacitor discharge.
- **Pin 8 (Top Left) - Vcc:** Positive supply voltage (+4.5V to +15V).

Package: Available in 8-pin DIP (Dual Inline Package) and metal can packages.

Mnemonic: *G-T-O-R (Ground, Trigger, Out, Reset) on Left; V-D-T-C (Vcc, Dis, Thresh, Control) on Right.*

1.3 Question 1(c) [7 marks]

Draw and Explain block diagram of IC 555 timer.

1.3.1 Solution

The 555 timer internal architecture consists of key components: a voltage divider, two comparators, an SR flip-flop, a discharge transistor, and an output stage.

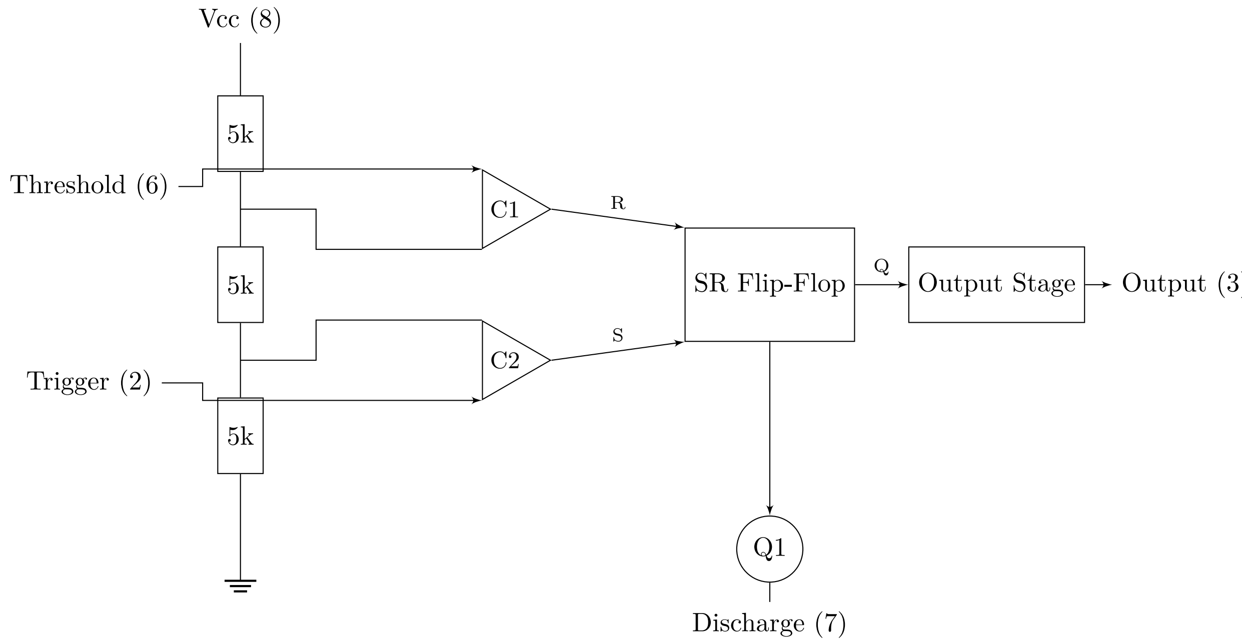

Figure 3: Internal Block Diagram of 555 Timer

Block Diagram:

Explanation of Blocks:

Voltage Divider: Three $5k\Omega$ resistors divide supply voltage Vcc into two ref voltages: $2/3V_{cc}$ and $1/3V_{cc}$.

Comparators: Comparator 1 (Threshold): Compares Input at Pin 6 with $2/3V_{cc}$. If Pin 6 $> 2/3V_{cc}$, Output is High (Reset FF).

Comparator 2 (Trigger): Compares Input at Pin 2 with $1/3V_{cc}$. If Pin 2 $< 1/3V_{cc}$, Output is High (Set FF).

SR Flip-Flop: Stores the state. Set makes output High, Reset makes output Low.

Output Stage: Inverts the Q output of FF to drive current at Pin 3.

Discharge Transistor: When Output is Low, Transistor turns ON to discharge external capacitor at Pin 7.

Note: The term "555" comes from the three $5k\Omega$ resistors used in the voltage divider.

Mnemonic: *Div-Comp-FF-Out (Divider, Comparators, Flip-Flop, Output) - The 555 Recipe.*

1.4 Question 1(c) OR [7 marks]

Draw and Explain A-stable and mono-stable multivibrator using 555 timer IC.

1.4.1 Solution

1. A-stable Multivibrator (Free Running Oscillator) Generates continuous rectangular pulses without external trigger.

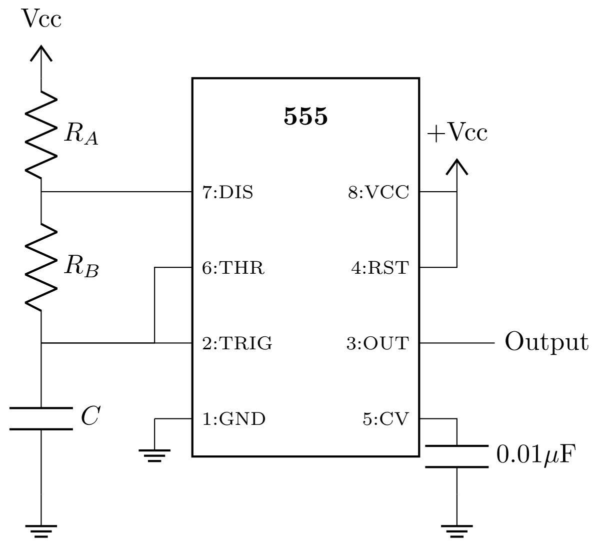

Figure 4: Astable Multivibrator Circuit

Working: Capacitor C charges through $R_A + R_B$ until voltage reaches $2/3V_{cc}$ (Threshold). Then, it discharges through R_B into Pin 7 until typical voltage drops to $1/3V_{cc}$ (Trigger). This cycle repeats, producing a square wave.

2. Mono-stable Multivibrator (One-Shot) Produces a single output pulse of fixed duration when triggered.

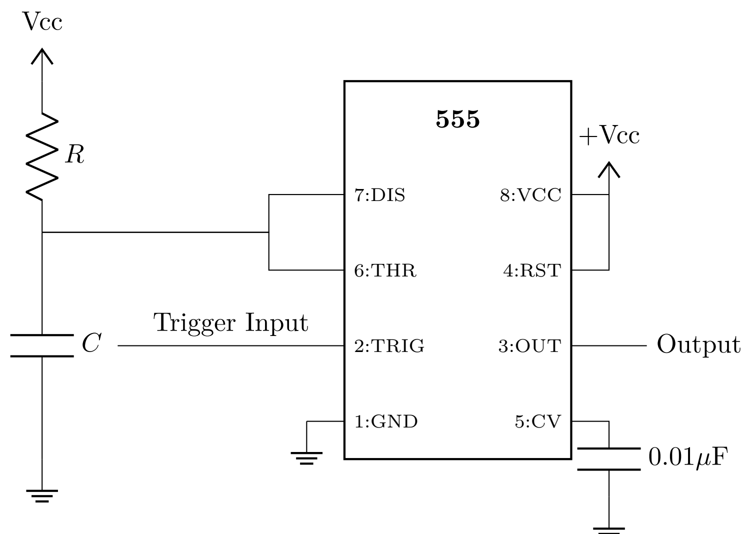

Figure 5: Monostable Multivibrator Circuit

Working: In stable state, Output is Low. When a negative trigger pulse (< 1/3 Vcc) is applied to Pin 2, Output goes High and capacitor C charges through R. When voltage reaches $2/3V_{cc}$, timer resets (Output

Low) and capacitor discharges. Pulse width $T = 1.1RC$.

Mnemonic: *Astable = All Resistors Charge (Free running); Mono = One Trigger, One Pulse.*

2 Question 2

2.1 Question 2(a) [3 marks]

Write shot note on Active components and passive components.

2.1.1 Solution

Active Components: Active components are electronic devices that require an external source of energy to operate. They are capable of controlling, amplifying, or switching the flow of electric current.

- **Key Feature:** Can provide power gain ($P_{out} > P_{in}$).
- **Examples:** Transistors (BJT, FET), Diodes (LED, Zener), Integrated Circuits (IC 555, Op-Amp).

Passive Components: Passive components are devices that do not require external power to operate. They cannot amplify a signal but can attenuate, store, or resist energy.

- **Key Feature:** Power gain is always less than or equal to 1.
- **Examples:** Resistors (Dissipate energy), Capacitors (Store electric energy), Inductors (Store magnetic energy).

Mnemonic: *Active Acts (Controls/Amplifies); Passive Pacifies (Resists/Stores).*

2.2 Question 2(b) [4 marks]

Write color band of following resistance. (1) $47\Omega \pm 5\%$

2.2.1 Solution

Resistor color codes are a standardized system used to mark the value and tolerance of resistors. This system is essential because components are often too small for printed text. The four-band code is the most common, consisting of two bands for significant digits, one multiplier band, and one tolerance band.

To determine the color code for a $47\Omega \pm 5\%$ resistor, we decompose the value:

1. Significant Figures: 4 and 7.
2. Multiplier: 10^0 (since $47 = 47 \times 1$).
3. Tolerance: $\pm 5\%$.

Mapping these to the standard color chart:

1st Significant Digit (4): Yellow - Represents the tens digit.

2nd Significant Digit (7): Violet - Represents the units digit.

Multiplier ($\times 1$): Black - Represents the power of 10 ($10^0 = 1$).

Tolerance ($\pm 5\%$): Gold - Indicates the precision of the component.

Result: The color band sequence is: **Yellow, Violet, Black, Gold**.

Calculation Verification: Checking the range: $47 \times 0.05 = 2.35\Omega$. So the actual resistance lies between 44.65Ω and 49.35Ω. This confirms the standard value.

Mnemonic: *B-B-R-O-Y-G-B-V-G-W: Black(0), Brown(1), Red(2), Orange(3), Yellow(4), Green(5), Blue(6), Violet(7), Grey(8), White(9).*

2.3 Question 2(c) [7 marks]

Explain working of Full wave center tap rectifier with circuit diagram and wave form.

2.3.1 Solution

A **Center-Tap Full Wave Rectifier** converts both halves of the AC cycle into DC using a center-tapped transformer and two diodes.

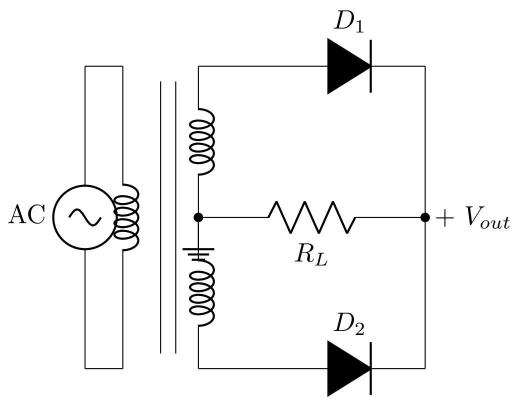

Figure 6: Full Wave Center Tap Rectifier

Circuit Diagram:

Working Principle:

1. **Positive Half Cycle:** Terminal A (Top) is positive wrt Center Tap (CT). Diode D_1 is forward biased (ON) and D_2 is reverse biased (OFF). Current flows through D_1 and R_L.
2. **Negative Half Cycle:** Terminal B (Bottom) is positive wrt CT. Diode D_2 is forward biased (ON) and D_1 is reverse biased (OFF). Current flows through D_2 and R_L.
3. **Direction:** In both cycles, current flows through the load R_L in the same direction, producing a pulsating DC output.

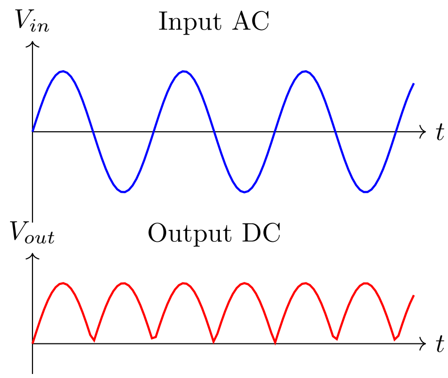

Figure 7: Input and Output Waveforms

Waveforms:

Advantages: Higher efficiency (81.2%) and lower ripple factor (0.48) compared to half-wave rectifier.

Mnemonic: *Center-Tap: Two Diodes take turns using the Middle Path.*

2.4 Question 2(a) OR [3 marks]

Explain concept of capacitors.

2.4.1 Solution

A **Capacitor** is a passive electronic component that stores electrical energy in an electric field. It consists of two conductive plates separated by an insulating material called a dielectric.

Key Concepts:

- **Function:** Opposes change in voltage and blocks DC while passing AC.
- **Capacitance (C):** The ability to store charge. Measured in Farads (F).
- **Formula:** $Q = C \times V$ where Q is charge, V is voltage.
- **Physical Construction:** $C = \frac{\epsilon A}{d}$ (Increases with area A, decreases with distance d).

Mnemonic: *Capacitor Capacity: Stores Charge on Plates separated by Dielectric.*

2.5 Question 2(b) OR [4 marks]

Calculate value of resistor and tolerance for following color bands on resistor: (1) Brown, Green, yellow, gold (2) Grey, blue, brown

2.5.1 Solution

Resistor values are determined by decoding the colored bands printed on the component body. This standardization allows for easy identification of resistance and tolerance values.

1. Brown, Green, Yellow, Gold:

Bands: Brown (1), Green (5), Yellow ($\times 10^4$), Gold ($\pm 5\%$).

Calculation: First digit 1, Second digit 5, Multiplier 10^4.

$$R = 15 \times 10,000\Omega = 150,000\Omega = 150k\Omega$$

Tolerance: Gold band indicates $\pm 5\%$.

Result: 150 kΩ $\pm 5\%$.

2. Grey, Blue, Brown:

Bands: Grey (8), Blue (6), Brown ($\times 10^1$), No Fourth Band (Default $\pm 20\%$).

Calculation: First digit 8, Second digit 6, Multiplier 10^1.

$$R = 86 \times 10\Omega = 860\Omega$$

Tolerance: Absence of a fourth band implies $\pm 20\%$ tolerance.

Result: 860 Ω $\pm 20\%$.

Significance: Correctly identifying resistor values is critical for circuit stability. A tolerance of 20% means the actual value of the 860Ω resistor could vary between 688Ω and 1032Ω.

Mnemonic: *First Two Digits → Multiplier → Tolerance.*

2.6 Question 2(c) OR [7 marks]

Explain working of Full wave bridge rectifier with circuit diagram and wave form.

2.6.1 Solution

A **Bridge Rectifier** uses four diodes in a bridge configuration to convert AC to DC without requiring a center-tapped transformer.

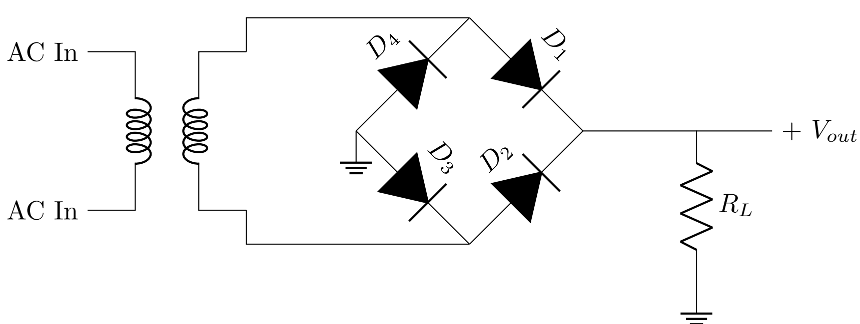

Figure 8: Full Wave Bridge Rectifier

Circuit Diagram:

Working Principle:

1. **Positive Half Cycle:** Top terminal is positive. Diodes D_1 and D_3 are Forward Biased (ON). D_2 and D_4 are OFF. Current flows through $D_1 \rightarrow R_L \rightarrow D_3$.
2. **Negative Half Cycle:** Bottom terminal is positive. Diodes D_2 and D_4 are Forward Biased (ON). D_1 and D_3 are OFF. Current flows through $D_2 \rightarrow R_L \rightarrow D_4$.
3. **Result:** Current always flows through R_L in the same direction.

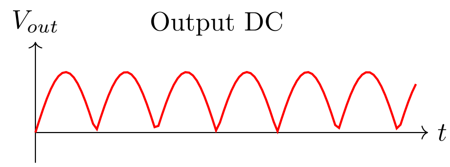

Figure 9: Output Waveform

Waveforms:

Advantages: Does not require bulky center-tapped transformer. PIV rating of diodes is half that of center-tap circuit (V_m vs $2V_m$).

Mnemonic: *Bridge Crosses Current One Way Using 4 Diodes.*

3 Question 3

3.1 Question 3(a) [3 marks]

Explain Light dependent resistor (LDR).

3.1.1 Solution

A **Light Dependent Resistor (LDR)**, also known as a photoresistor, is a passive component whose resistance decreases as the intensity of incident light increases. It is made of high-resistance semiconductor material like Cadmium Sulfide (CdS).

Working Principle:

- **Darkness:** In the absence of light, LDR has very high resistance (Mega-ohms), effectively acting as an open switch.
- **Light:** When photons fall on the surface, electron-hole pairs are generated, increasing conductivity and drastically reducing resistance (to a few hundred ohms).

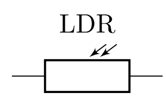

Figure 10: Symbol of LDR

Symbol:

Applications: Automatic street lights, camera exposure meters, and optical alarms.

Mnemonic: *Light Down, Resistance Up (Dark = High R); Light Up, Resistance Down (Bright = Low R).*

3.2 Question 3(b) [4 marks]

Explain half wave rectifier circuit with wave form.

3.2.1 Solution

A **Half Wave Rectifier** uses a single diode to convert AC voltage into pulsating DC voltage by allowing current to flow during only one half-cycle of the input.

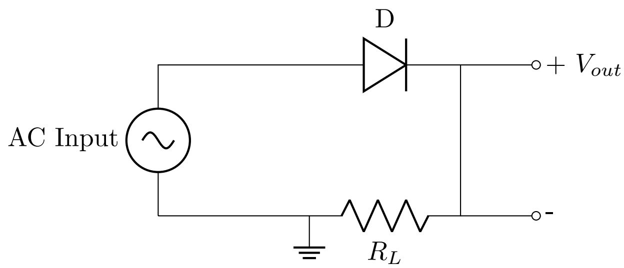

Figure 11: Half Wave Rectifier Circuit

Circuit Diagram:

Operation:

1. **Positive Half Cycle:** The diode is forward biased and conducts current through the load resistor R_L. Output voltage closely follows the input positive half.
2. **Negative Half Cycle:** The diode is reverse biased and blocks current. The output voltage is zero.

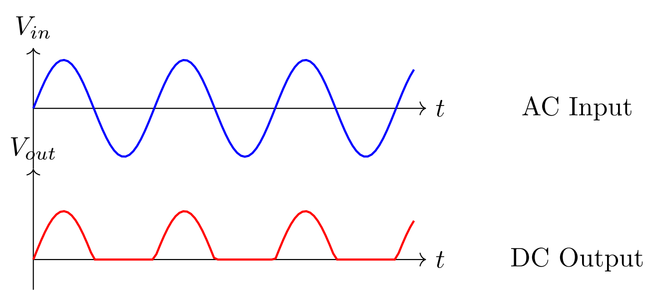

Figure 12: Input and Output Waveforms

Waveforms:

Mnemonic: *Half Wave: One Diode, One Bump per Cycle.*

3.3 Question 3(c) [7 marks]

List different types of clipper circuits and draw any two types of clipper circuits with its wave forms.

3.3.1 Solution

Clippers are wave-shaping circuits that remove or "clip" a portion of the input signal without distorting the remaining part.

Types of Clippers:

1. Series Positive Clipper
2. Series Negative Clipper
3. Shunt (Parallel) Positive Clipper
4. Shunt (Parallel) Negative Clipper
5. Biased Clipper (Positive/Negative)
6. Combination Clipper

1. Series Positive Clipper: This circuit removes the positive half-cycle of the input AC signal.

- **Operation:** When the input voltage is positive, the diode is reverse biased (open circuit), and no current flows to the load. The output is zero. When the input is negative, the diode is forward biased (short circuit), and the negative half-cycle appears across the load.

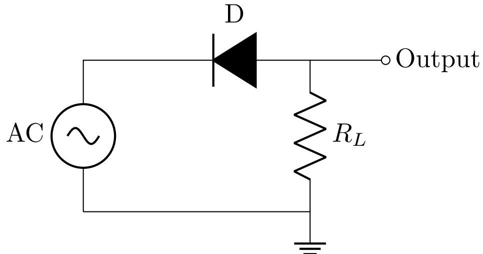

Figure 13: Series Positive Clipper

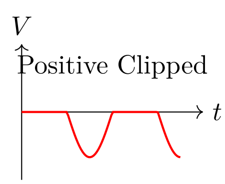

Figure 14: Output of Positive Clipper

Waveform:

2. Series Negative Clipper: This circuit removes the negative half-cycle of the input signal.

- **Operation:** During the positive half-cycle, the diode is forward biased, allowing current to flow to the load. The output follows the input. During the negative half-cycle, the diode is reverse biased, blocking current flow. The output is zero.

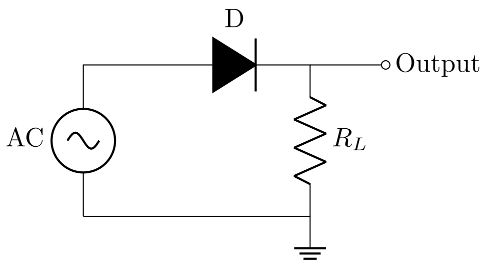

Figure 15: Series Negative Clipper

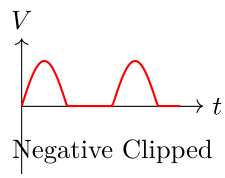

Figure 16: Output of Negative Clipper

Waveform:

Applications: Clippers are widely used in noise limiters, protection of sensitive circuits from voltage spikes, and modifying waveform shapes in communication systems.

Mnemonic: *Series Clipper: Diode in Series with Load. Direction of Diode determines which half passes.*

3.4 Question 3(a) OR [3 marks]

Explain self and mutual inductance in brief.

3.4.1 Solution

Inductance is the property of a conductor to oppose changes in current flowing through it.

Self Inductance (L): It is the phenomenon where a changing current in a coil induces an EMF in the *same* coil. This induced EMF opposes the change in current (Lenz's Law).

- **Unit:** Henry (H).
- **Formula:** $E = -L\frac{dI}{dt}$.

Mutual Inductance (M): It is the phenomenon where a changing current in one coil (Primary) induces an EMF in a neighboring coil (Secondary). This is the working principle of transformers.

- **Coupling:** Depends on the magnetic linkage between coils.
- **Formula:** $E_2 = -M\frac{dI_1}{dt}$.

Mnemonic: *Self = One Coil acting on itself; Mutual = Two Coils interacting.*

3.5 Question 3(b) OR [4 marks]

Explain the following terms in brief. (1) Ripple factor (2) Ripple frequency.

3.5.1 Solution

In rectifier circuits, the output is not pure DC but contains AC components called ripples.

1. Ripple Factor (γ): Ripple factor is a measure of the effectiveness of a rectifier in converting AC to DC. It is defined as the ratio of the RMS value of the AC component to the DC component in the output.

- **Formula:** $\gamma = \frac{V_{ac(rms)}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$.
- **Values:** Half Wave = 1.21, Full Wave = 0.48. Lower is better.

2. Ripple Frequency (f_r): It is the frequency of the ripple voltage appearing at the output of the rectifier.

- **Half Wave:** $f_r = f_{in}$ (Fundamentals frequency same as input).
- **Full Wave:** $f_r = 2f_{in}$ (Ripple frequency is double the input).

Mnemonic: *Factor = Quality (AC/DC); Frequency = Rate (Hz).*

3.6 Question 3(c) OR [7 marks]

List different types of clamper circuits and draw any two types of clamper circuits with its wave forms.

3.6.1 Solution

A **Clamper Circuit** (or DC Restorer) shifts the entire signal voltage level up or down without changing the shape of the waveform. It essentially adds a DC component to the AC signal.

Types of Clampers:

1. Positive Clamper (Shifts signal Up)
2. Negative Clamper (Shifts signal Down)
3. Biased Positive Clamper
4. Biased Negative Clamper

1. Positive Clamper: This circuit shifts the input waveform in the positive direction such that the negative peak sits on the zero level (or reference level).

- **Mechanism:** During the negative half-cycle, the diode conducting charges the capacitor. During the positive half-cycle, the diode is off, and the capacitor voltage adds to the input voltage.

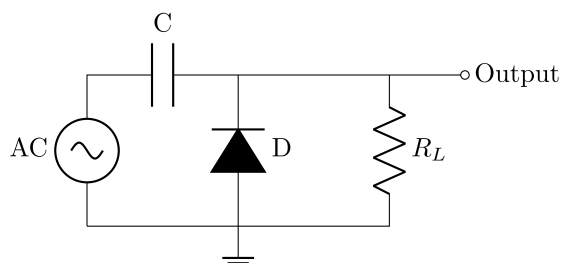

Figure 17: Positive Clamper Circuit

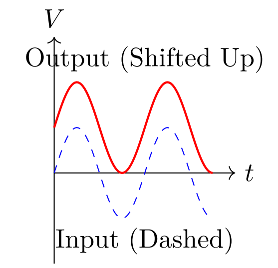

Figure 18: Input and Positive Clamped Output

Waveform:

2. Negative Clamper: This circuit shifts the input waveform in the negative direction such that the positive peak touches the zero level.

- **Mechanism:** The diode polarity is reversed compared to the positive clamper. The capacitor charges with opposite polarity, effectively subtracting a DC voltage from the input signal.

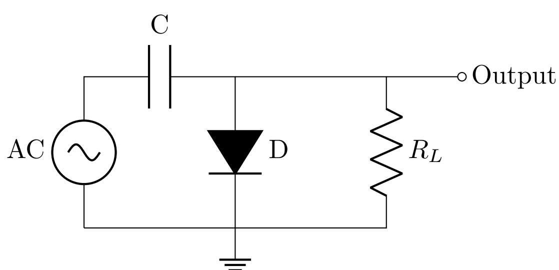

Figure 19: Negative Clamper Circuit

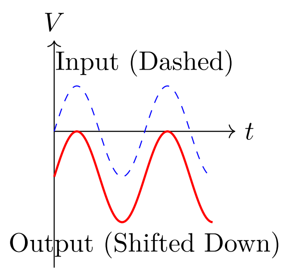

Figure 20: Input and Negative Clamped Output

Waveform:

Mnemonic: *Clamp Up (Positive) or Clamp Down (Negative). Capacitor holds the DC offset.*

4 Question 4

4.1 Question 4(a) [3 marks]

Draw Symbols of Zener diode, LED, and Varactor diode.

4.1.1 Solution

1. **Zener Diode:** Designed to operate in the reverse breakdown region. The symbol has "bent" cathode lines resembling the letter 'Z'.
2. **Light Emitting Diode (LED):** Emits light when forward biased. The symbol is a standard diode with arrows pointing *away*, indicating light emission.
3. **Varactor Diode:** Acts as a variable capacitor under reverse bias. The symbol includes a capacitor-like double line at the cathode.

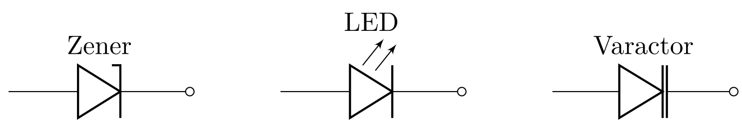

Figure 21: Symbols of Zener, LED, and Varactor Diodes

Symbols:

Mnemonic: *Zener is "Z"; LED radiates Light (Arrows Out); Varactor varies like a Capacitor (Parallel plates).*

4.2 Question 4(b) [4 marks]

Explain Photodiode.

4.2.1 Solution

A **Photodiode** is a semiconductor device that converts light energy into electrical energy (current). It is designed to operate in **Reverse Bias** condition.

Construction and Symbol: It consists of a PN junction housed in a package with a transparent window or lens to allow light to strike the junction.

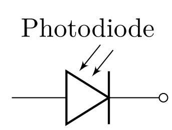

Figure 22: Photodiode Symbol

Working Principle:

- **Dark Current:** When no light falls on the reverse-biased photodiode, a very small leakage current flows due to minority carriers. This is called Dark Current.
- **Illumination:** When light (photons) strikes the depletion region, it breaks covalent bonds, generating electron-hole pairs.
- **Photocurrent:** These carriers are swept across the junction by the electric field, creating a reverse current that is linearly proportional to the intensity of incident light.

Applications: Optical communication receivers, smoke detectors, remote controls, and solar cells (in photovoltaic mode).

Mnemonic: *Photo-Diode: Photons IN (Arrows In) → Current flows (Reverse Bias).*

4.3 Question 4(c) [7 marks]

Explain construction, characteristics and working of Zener diode.

4.3.1 Solution

A **Zener Diode** is a heavily doped silicon PN junction diode designed to operate in the reverse breakdown region without damage.

Construction: It is similar to a normal PN junction diode but with **heavy doping** (impurity concentration is high). This results in a very narrow depletion region along with a very strong electric field intensity. This enables the quantum tunneling effect or avalanche breakdown at specific voltages.

Working Principle:

- **Forward Bias:** It acts exactly like a normal diode. It starts conducting around 0.7V (for Silicon).
- **Reverse Bias (Pre-Breakdown):** Initially, only a small leakage current flows.
- **Reverse Breakdown:** When the reverse voltage reaches a specific value called the **Zener Voltage (V_Z)**, the current increases sharply.
  - **Zener Effect ($< 6V$):** Due to heavy doping, the intense electric field pulls electrons from covalent bonds (Tunneling).
  - **Avalanche Effect ($> 6V$):** Accelerated minority carriers collide with atoms, knocking out more electrons (Chain reaction).
- **Voltage Regulation:** In the breakdown region, the voltage across the Zener diode remains constant (V_Z) even if the current through it changes significantly.

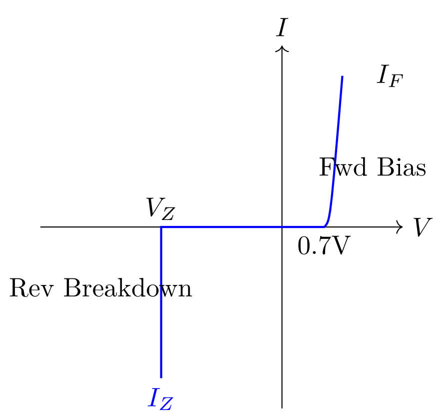

Figure 23: V-I Characteristics of Zener Diode

V-I Characteristics:

Mnemonic: *Zener: Zoo for electrons in Reverse. Heavily Doped, Voltage Constant.*

4.4 Question 4(a) OR [3 marks]

List applications of LED and Varactor diode.

4.4.1 Solution

Applications of LED (Light Emitting Diode):

1. **Indicators:** widely used as power status indicators on electronic devices, computer peripherals, and traffic lights due to their long life and low power consumption.
2. **Illumination:** Used in domestic and industrial lighting, street lights, and automotive headlamps because of their high energy efficiency and durability compared to incandescent bulbs.
3. **Display:** They form the pixel elements in large outdoor displays, seven-segment displays for digital clocks, and backlight modules for LED TV screens.
4. **Communication:** Infrared LEDs act as light sources in short-range optical fiber communication systems and in remote controls for televisions and AC units.

Applications of Varactor Diode:

1. **Tuning Circuits:** Primarily used in the tuning stages of radio receivers and television sets to replace bulky mechanical variable capacitors. This allows for electronic tuning (Automatic Frequency Control - AFC).
2. **Frequency Modulation (FM):** Used in FM transmitters where the audio signal modulates the diode's capacitance, thereby varying the carrier frequency.
3. **Active Filters:** Employed in tunable active filter circuits and voltage-controlled oscillators (VCOs) to adjust the resonant frequency electronically.
4. **Microwave Applications:** Used in parametric amplifiers and frequency multipliers (dividers) in high-frequency microwave communication circuits.

Mnemonic: *LED Lights up world; Varactor Varies Frequency (Tuning).*

4.5 Question 4(b) OR [4 marks]

Explain Zener diode as a voltage regulator.

4.5.1 Solution

A **Voltage Regulator** maintains a constant output voltage despite changes in input voltage or load current. A Zener diode operating in the breakdown region is ideal for this purpose because its voltage (V_Z) remains constant.

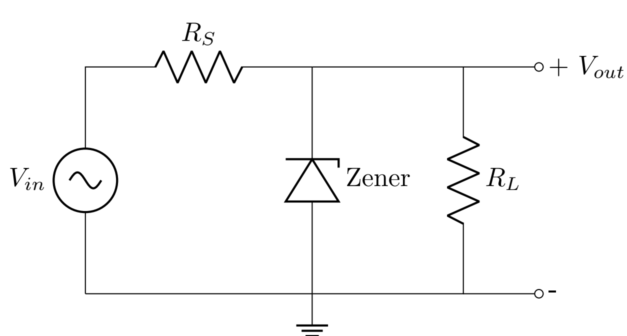

Figure 24: Zener Voltage Regulator

Circuit Diagram:

Working:

1. **Input Regulation (Line Regulation):** If input voltage V_{in} increases, total current increases. The Zener diode absorbs the extra current (I_Z increases), keeping the voltage drop across parallel load R_L constant at V_Z. Voltage drop across R_S increases to balance the excess V_{in}.
2. **Load Regulation:** If load current I_L increases (load decreases), the Zener current I_Z decreases by the same amount, keeping total current through R_S constant. Thus, output voltage $V_{out} = V_Z$ remains stable.

Mnemonic: *Zener absorbs the shock (Current changes) to keep Voltage steady.*

4.6 Question 4(c) OR [7 marks]

Explain construction, characteristics and working of Varactor diode.

4.6.1 Solution

A **Varactor Diode** (or Varicap) is a variable capacitance diode that works under **reverse bias**. Measurements of its junction capacitance depend on the applied reverse voltage.

Construction: It is a PN junction diode optimized for variable capacitance.

- **Junction:** The P and N regions are heavily doped to minimize series resistance.
- **Depletion Region:** Acts as the dielectric of a capacitor.
- **P and N Layers:** Act as conductive plates of the capacitor.
- **Package:** Encased in glass or plastic to protect the junction.

Working Principle: The Varactor diode is always operated in **reverse bias**. The basic principle is based on the variation of depletion layer width with the applied reverse voltage.

1. **Depletion as Dielectric:** The depletion region allows no current to flow and acts as an insulator (dielectric) between the P-type and N-type conductive regions.
2. **High Reverse Voltage:** When the reverse voltage (V_R) increases, the depletion layer widens. This effectively increases the distance (d) between the conductive plates. Since capacitance is inversely proportional to distance ($C \propto \epsilon A/d$), the junction capacitance **decreases**.
3. **Low Reverse Voltage:** When the reverse voltage decreases, the depletion layer narrows. The distance (d) decreases, causing the junction capacitance to **increase**.
4. **Mathematical Relationship:** The transition capacitance C_T is given by:

$$C_T = \frac{C(0)}{\left(1 + \frac{V_R}{V_B}\right)^n}$$

Where $C(0)$ is the zero-bias capacitance, V_B is the barrier potential (approx 0.7V for Si), and n is a doping-dependent constant (0.5 for abrupt junction). This confirms that $C_T \propto \frac{1}{\sqrt{V_R}}$.

Characteristics: The graph shows Capacitance (C) versus Reverse Voltage (V_R). It is a non-linear curve where C decreases as V_R increases.

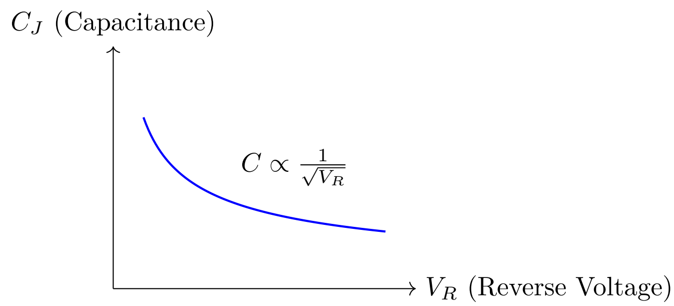

Figure 25: C-V Characteristics of Varactor Diode

Mnemonic: *Reverse Up → Width Up → Cap Down. (Like pulling capacitor plates apart).*

5 Question 5

5.1 Question 5(a) [3 marks]

Explain transistor as a switch.

5.1.1 Solution

A BJT transistor works as an electronic switch by operating in two specific regions: **Cut-off** (OFF state) and **Saturation** (ON state).

Operation:

1. **OFF State (Cut-off):** When the base-emitter junction is not forward-biased (Input = 0V), no collector current flows ($I_C = 0$). The transistor acts like an open switch. Output Voltage matches V_{CC}.
2. **ON State (Saturation):** When sufficient base current flows, the transistor conducts fully ($V_{CE} \approx 0$). Maximum collector current flows. It acts like a closed switch. Output Voltage is approx 0V.

Mnemonic: *Cut-off = Open (No current); Saturation = Closed (Full current).*

5.2 Question 5(b) [4 marks]

Draw Common Emitter (CE) configuration of NPN transistors and its input characteristics.

5.2.1 Solution

In Common Emitter configuration, the Emitter terminal is common to both input and output.

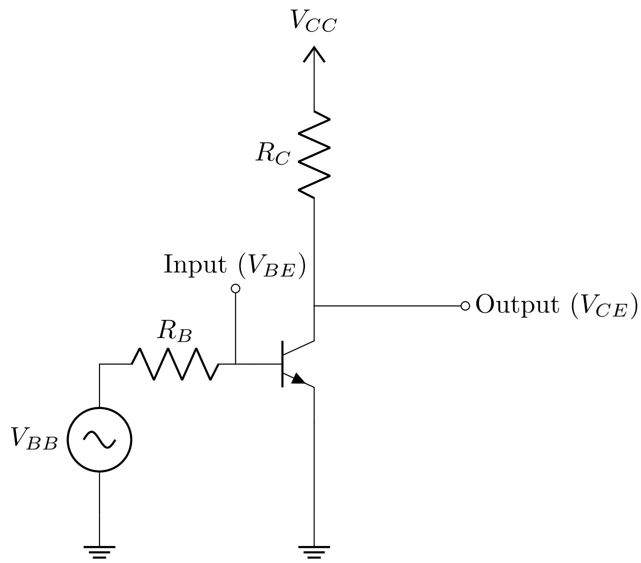

Figure 26: NPN Common Emitter Configuration

Circuit Diagram:

Input Characteristics: It is the graph of Input Current (I_B) vs Input Voltage (V_{BE}) at constant Output Voltage (V_{CE}). It resembles a forward-biased diode curve.

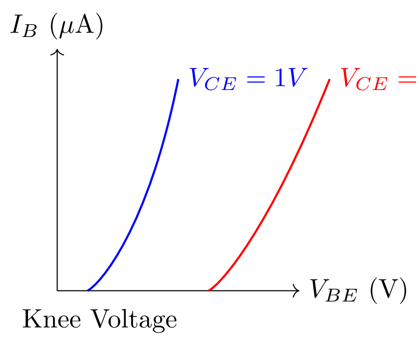

Figure 27: Input Characteristics of CE Config

Mnemonic: *Input Graph is like a Diode. I_B rises after 0.7V.*

5.3 Question 5(c) [7 marks]

Draw symbol and construction of NPN Transistor and explain its working.

5.3.1 Solution

An **NPN Transistor** consists of a P-type semiconductor layer sandwiched between two N-type layers.

Structure and Symbol:

- **Emitter (E):** Heavily doped, emits electrons.
- **Base (B):** Lightly doped and very thin, controls current.

- **Collector (C):** Moderately doped and large in size, collects electrons.

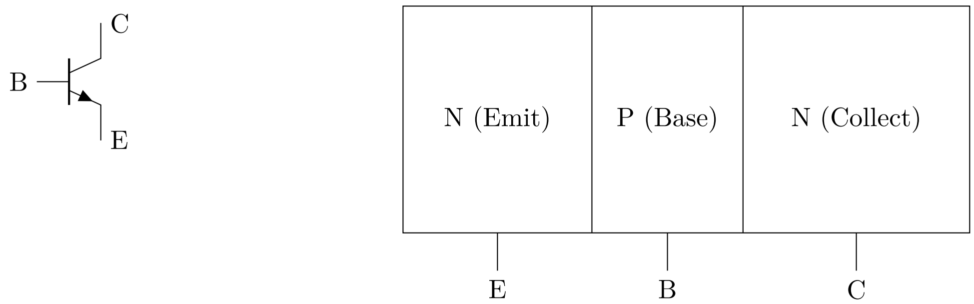

Figure 28: Symbol and Construction of NPN

Working Principle: To operate as an amplifier (Active Region), the Emitter-Base junction is **Forward Biased** and Collector-Base junction is **Reverse Biased**.

1. **Injection:** The forward bias (V_{BE}) causes electrons from the N-type Emitter to cross into the P-type Base.
2. **Recombination:** Since the Base is thin and lightly doped, only a few electrons (approx 2-5%) recombine with holes to form Base Current (I_B).
3. **Collection:** The remaining majority of electrons (approx 95-98%) diffuse across the base and are attracted by the high positive potential of the Collector (V_{CB}). They cross the reverse-biased junction to form Collector Current (I_C).
4. **Equation:** The total emitter current is the sum of base and collector currents:

$$I_E = I_B + I_C$$

Mnemonic: *NPN = Not Pointing In (Arrow out). Emitter shoots, Base controls, Collector catches.*

5.4 Question 5(a) OR [3 marks]

Compare CB, CE and CC configuration of transistor.

5.4.1 Solution

Table 1: Comparison of Transistor Configurations

Parameter	**Common Base (CB)**	**Common Emitter (CE)**	**Common Collector (CC)**
Input/Output	Input: E, Output: C	Input: B, Output: C	Input: B, Output: E
Input Resistance	Very Low ($\approx 20\Omega$)	Medium ($\approx 1k\Omega$)	Very High ($\approx 500k\Omega$)
Output Resistance	Very High ($\approx 1M\Omega$)	Medium ($\approx 40k\Omega$)	Very Low ($\approx 50\Omega$)
Current Gain	Low ($\alpha < 1$)	High ($\beta \approx 100$)	High ($\gamma \approx 100$)
Voltage Gain	High	Medium	Low (< 1)
Phase Shift	$0°$	$180°$	$0°$
Application	High Freq Applications	Audio Amplifiers	Impedance Matching

Detailed Comparison:

- **Common Base (CB):** Characterized by very low input impedance and very high output impedance. It provides voltage gain but no current gain ($\alpha < 1$). It is primarily used for high-frequency applications and impedance matching between low sources and high loads.
- **Common Emitter (CE):** This is the most widely used configuration because it provides both high voltage gain and high current gain (β). It has moderate input and output impedance. However, it introduces a 180° phase shift between input and output signals. It is the standard for audio amplification.
- **Common Collector (CC):** Also known as the Emitter Follower. It has extremely high input impedance and low output impedance. It provides current gain but no voltage gain (Aux gain ≈ 1). It is exclusively used for impedance matching (buffer) stages to drive low-impedance loads like speakers.

Mnemonic: *CB (Base Common) = Voltage Gain; CC (Collector Common) = Current Gain (Buffer); CE (Emitter Common) = Power Gain (Best of Both).*

5.5 Question 5(b) OR [4 marks]

Explain transistor as a single stage common emitter amplifier.

5.5.1 Solution

A Common Emitter (CE) amplifier uses a transistor in CE configuration to amplify weak signals.

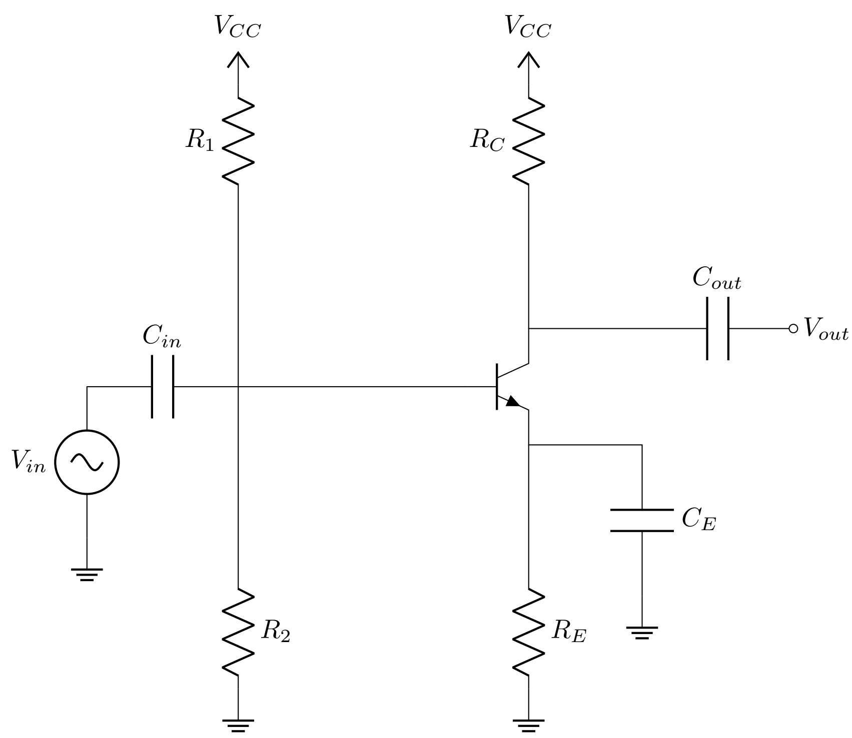

Figure 29: Single Stage CE Amplifier

Circuit Diagram:

Working:

1. **Biasing:** Resistors R_1, R_2 provide voltage divider bias to keep the transistor in the active region. R_E provides thermal stability.
2. **Input:** The weak AC signal enters through capacitor C_{in}, which blocks DC.
3. **Amplification:** A small change in base current (I_b) causes a large change in collector current ($I_c = \beta I_b$). This varying current flows through R_C, producing a large voltage drop ($I_c R_C$).
4. **Output:** The amplified output voltage is taken across the collector, but it is 180° **phase shifted** relative to the input.

Mnemonic: *Weak Signal In → Large Current Swing → Large Voltage Drop → Strong Signal Out (Inverted).*

5.6 Question 5(c) OR [7 marks]

Explain common base (CB) configuration of NPN transistors with its input-output characteristics.

5.6.1 Solution

In Common Base (CB) configuration, the Base terminal is grounded and common to both input and output.

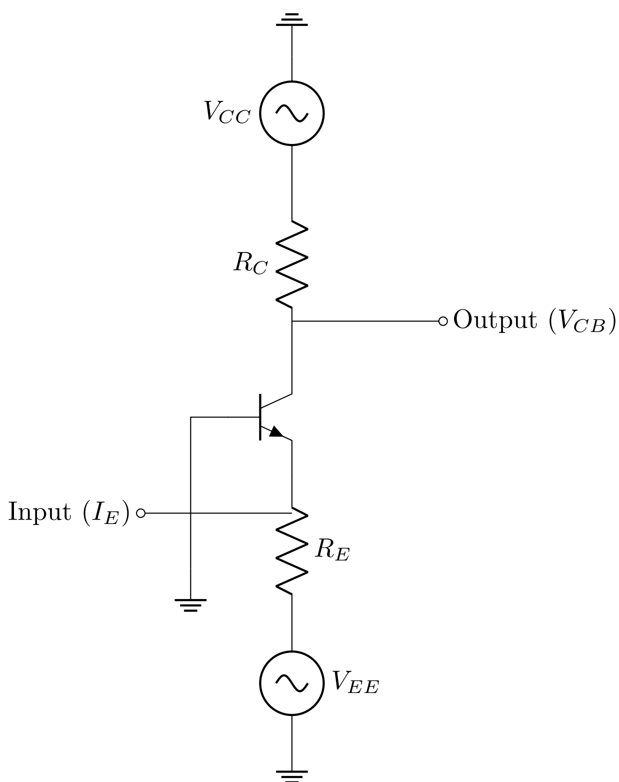

Figure 30: Common Base Configuration

Circuit Diagram:

1. Input Characteristics: Graph of Input Current (I_E) vs Input Voltage (V_{EB}) at constant Output Voltage (V_{CB}).

- Since the Emitter-Base junction is forward biased, the curve behaves like a normal diode. Increasing V_{EB} drastically increases I_E.
- The effect of V_{CB} (Early Effect) is minimal but increasing V_{CB} shifts the curve slightly to the left.

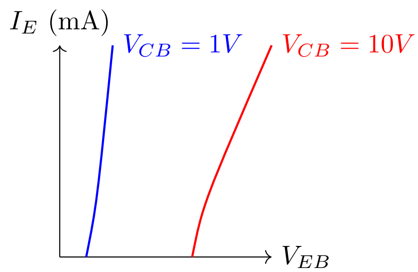

Figure 31: CB Input Characteristics

2. Output Characteristics: Graph of Output Current (I_C) vs Output Voltage (V_{CB}) at constant Input Current (I_E).

- **Active Region:** I_C is almost constant and equal to I_E (since $\alpha \approx 1$). It is independent of V_{CB}.
- **Saturation Region:** When V_{CB} is negative (forward biased), I_C drops rapidly to zero.

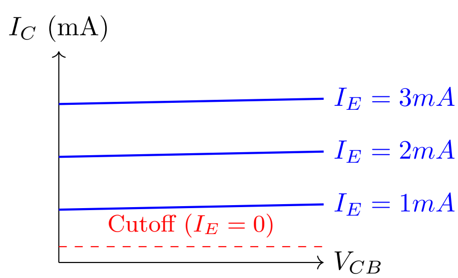

Figure 32: CB Output Characteristics

Mnemonic: *Common Base: Input is Emitter (Current In), Output is Collector (Current Out). Gain is Voltage, not Current.*