Linear Integrated Circuit (4341105) - Summer 2024 Solution

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June 15, 2024

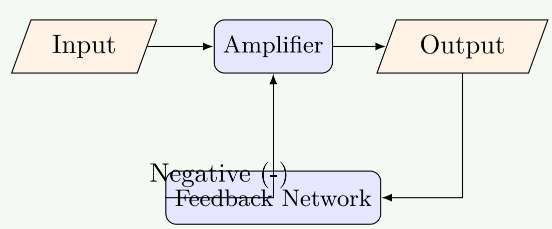
Question 1 [a marks]

3 State and explain the difference between positive and negative feedback with diagram.

Solution

Parameter	Negative Feedback	Positive Feedback
Signal	Output signal is fed back to input with opposite phase	Output signal is fed back to input with same phase
Gain	Decreases	Increases
Stability	Improves	Reduces
Applications	Amplifiers	Oscillators

Diagram:



Feedback Diagram

- **Phase relationship**: In negative feedback, signal is 180° out of phase while in positive feedback, signal is in phase.
- **Purpose**: Negative feedback stabilizes system while positive feedback creates oscillations.

Mnemonic

"Negative Needs Stability, Positive Produces Oscillations"

Question 1 [b marks]

4 Explain the effect of negative feedback on input impedance of the Amplifier.

Solution

Type of Feedback	Effect on Input Impedance	Formula
Voltage Series	Increases	$Z_{in-f} = Z_{in}(1 + A\beta)$
Current Series	Increases	$Z_{in-f} = Z_{in}(1 + A\beta)$
Voltage Shunt	Decreases	$Z_{in-f} = Z_{in}/(1 + A\beta)$
Current Shunt	Decreases	$Z_{in-f} = Z_{in}/(1 + A\beta)$

- **Series feedback**: When feedback signal is in series with input, input impedance increases.
- **Shunt feedback**: When feedback signal is in parallel with input, input impedance decreases.
- **Magnitude**: Change is proportional to $(1 + A\beta)$ where A is gain and β is feedback factor.

Mnemonic

"Series Soars, Shunt Shrinks"

Question 1 [c marks]

7 List the advantages and Disadvantages of negative feedback.

Solution

Advantages	Disadvantages
Stabilizes gain	Reduces overall gain
Increases bandwidth	Requires additional components
Reduces distortion	May cause oscillation if improperly designed
Reduces noise	Requires careful phase compensation
Improves input/output impedance	Increases power consumption
Reduces temperature sensitivity	Makes circuit more complex
Controls frequency response	May reduce signal-to-noise ratio in some cases

- **Performance tradeoff**: Sacrifices gain to achieve better stability and linearity.
- **Frequency considerations**: May require compensation to prevent oscillations at high frequencies.
- **Design complexity**: More complex to design properly but offers better long-term performance.

Mnemonic

"Stability Grows As Gain Drops"

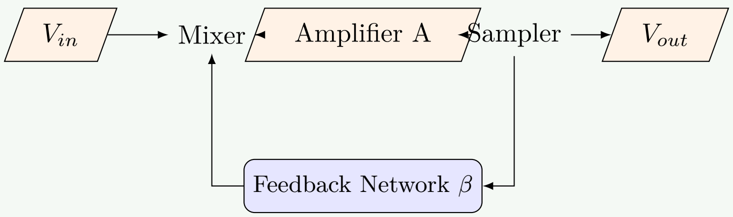
Question 1 [c marks]

7 Explain Voltage series feedback amplifier in detail with block diagram and draw the Practical voltage series feedback circuit.

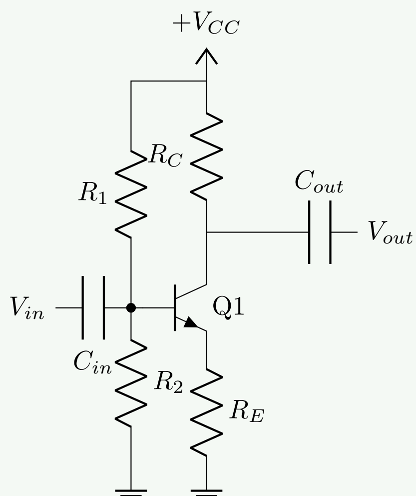
Solution

Parameter	Effect in Voltage Series Feedback
Input signal	Voltage
Feedback signal	Voltage
Input impedance	Increases
Output impedance	Decreases
Gain stability	Improves
Bandwidth	Increases

Block Diagram:



Practical Circuit:



- **Sampling method**: Output voltage is sampled and fed back to input.
- **Mixing method**: Feedback signal is mixed in series with input signal.
- **Working principle**: Reduces gain for improved stability and linearity.
- **Applications**: Audio amplifiers, instrumentation amplifiers.

Mnemonic

"Voltage Series - Impedance In Up, Out Down"

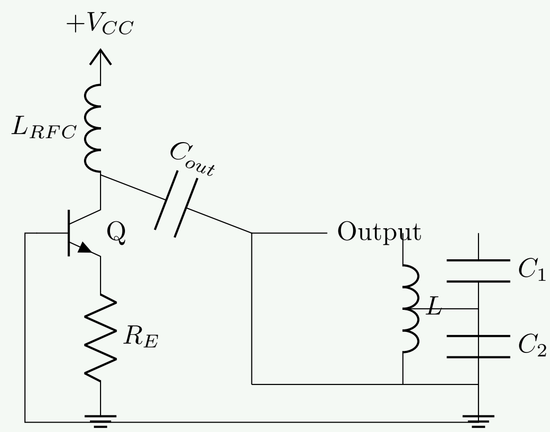
Question 2 [a marks]

3 Write short note on Colpitts oscillator circuit.

Solution

Component	Function
LC Tank	Determines oscillation frequency
Capacitive Voltage Divider	Provides feedback
Active Device	Provides gain to sustain oscillations

Circuit Diagram:



- **Frequency formula**: $f = \frac{1}{2\pi\sqrt{L\frac{C_1C_2}{C_1+C_2}}}$
- **Feedback**: Provided by capacitive voltage divider (C_1 and C_2).
- **Applications**: RF oscillators, communication circuits.

Mnemonic

"Colpitts Contains Capacitive divider"

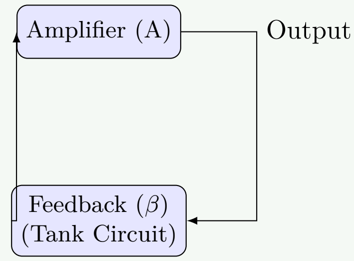
Question 2 [b marks]

4 Explain requirement of oscillator. i) Barkhausen Criterion. ii) Tank circuit. iii) Amplifier.

Solution

Requirement	Function	Explanation
Barkhausen Criterion	Ensures sustained oscillation	Loop gain $A\beta = 1$, Phase shift $= 0°$ or $360°$
Tank Circuit	Determines frequency	Resonant LC circuit that stores energy
Amplifier	Provides gain	Compensates for circuit losses

Block Diagram:



Barkhausen Criterion: $|A\beta| = 1, \angle A\beta = 0°/360°$

- **Barkhausen Criterion**: Mathematical condition for sustained oscillations without damping.
- **Tank Circuit**: LC circuit that determines frequency of oscillations.
- **Amplifier**: Active device that provides energy to maintain oscillations.

Mnemonic

"BAT - Barkhausen Amplifies Tank"

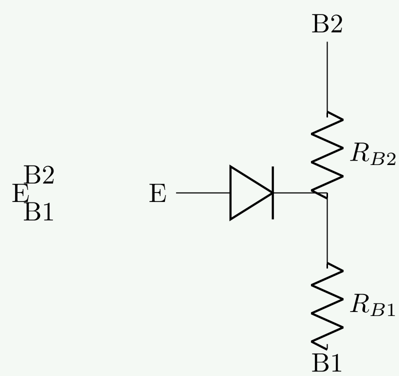
Question 2 [c marks]

7 Explain construction, working and V-I characteristics of UJT.

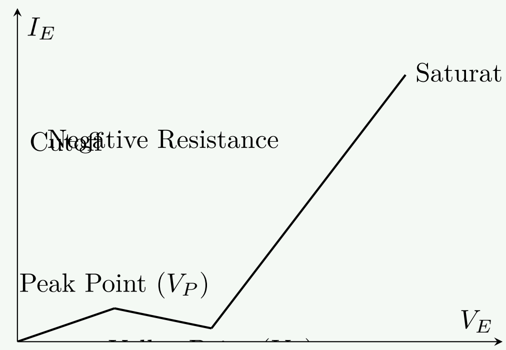
Solution

- **Construction**: Silicon bar with two base connections (B_1, B_2) and one P-type emitter (E).
- **Symbol**: Triangle with emitter on one side pointing in.
- **Working**: When emitter voltage $V_E > \eta V_{BB}$, the PN junction becomes forward biased and R_{B1} drops significantly (Negative Resistance).
- **Intrinsic Standoff Ratio** (η): Ratio determining the triggering voltage.

Symbol and Equivalent Circuit:



V-I Characteristics:



Mnemonic

"UJT Peaks Then Valleys - Negative Resistance Rules"

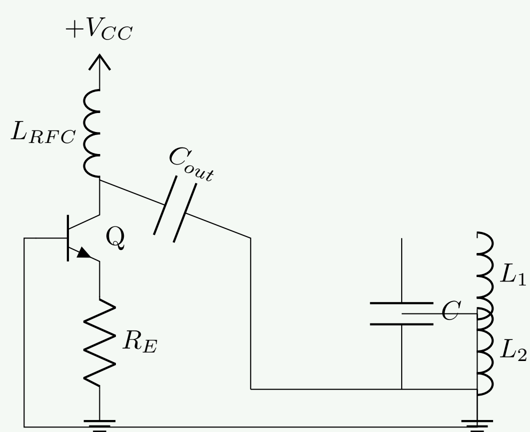
Question 2 [a marks]

3 State the advantages, disadvantages and applications of Hartley oscillator.

Solution

Advantages	**Disadvantages**	**Applications**
Easy tuning	Bulky inductors	RF generators
Wide frequency range	Mutual inductance issues	Radio receivers
Simple design	Difficult at high frequencies	Amateur radio
Good frequency stability	Requires center-tapped coil	Communication equipment

Circuit Diagram:



- **Frequency**: $f = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$
- **Feature**: Split inductor tank circuit.

Mnemonic

"Hartley Has tapped Inductor"

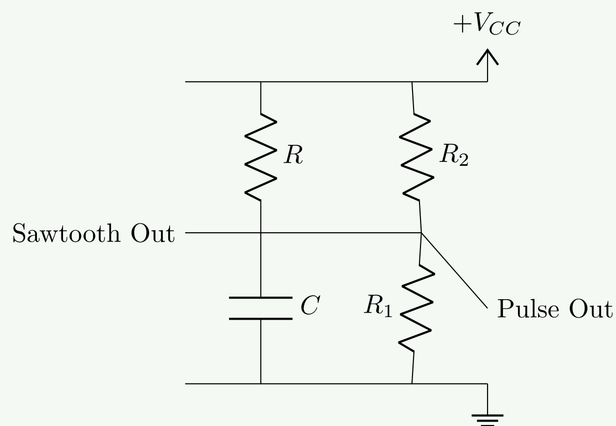
Question 2 [b marks]

4 Explain UJT as relaxation oscillator.

Solution

Component	Function
UJT	Provides switching action
Capacitor	Timing element
Resistor	Controls charging rate
Output	Sawtooth waveform

Circuit Diagram:



- **Operation**: Capacitor charges via R until V_P. UJT turns on, discharging C via R_1.
- **Frequency**: $f \approx \frac{1}{RC \ln(1/1-\eta)}$

Mnemonic

"Charge-Fire-Repeat - Sawtooth's Beat"

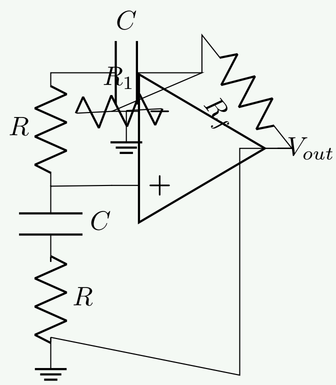
Question 2 [c marks]

7 Explain working of weinbridge oscillator with neat diagram also state the advantage, disadvantage and application for the same.

Solution

- **Configuration**: Uses RC bridge network for feedback. Non-inverting amplifier.
- **Conditions**: $f = \frac{1}{2\pi RC}$, Gain $A \geq 3$.
- **Phase**: Net phase shift is 0°.

Circuit Diagram:



Advantages	Disadvantages
High frequency stability	Limited frequency range
Low distortion output	Amplitude stabilization needed
Simple RC components	Sensitive to component variations
Easy to tune	Difficult to start oscillations

- **Applications**: Audio signal generators, musical instruments.

Mnemonic

"Wien Works at R1C1=R2C2 frequency"

Question 3 [a marks]

3 Give classification of power Amplifier.

Solution

Classification Basis	Types
Conduction Angle	Class A (360°), B (180°), AB (180°-360°), C (< 180°)
Configuration	Single-ended, Push-pull, Complementary
Coupling	RC coupled, Transformer coupled, Direct coupled

- **Class A**: Highest linearity, lowest efficiency.
- **Class B**: Push-pull, crossover distortion.
- **Class C**: Tuned loads, highest efficiency.

Mnemonic

"A All-time, B Bisects, AB Almost-Bisects, C Cuts-more"

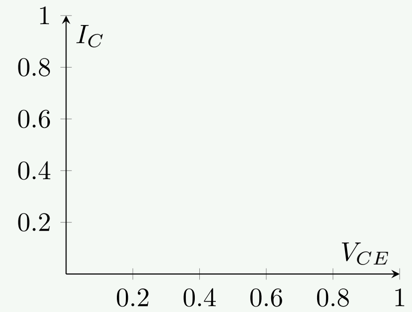
Question 3 [b marks]

4 Explain class A power amplifier.

Solution

Parameter	**Class A Amplifier**
Conduction Angle	360° (full cycle)
Q-point	Center of load line
Efficiency	Low (25-30% practical, 50% max theoretical)
Distortion	Very low (High Fidelity)

Load Line Diagram:



Mnemonic

"Class A - Always conducting, All cycle"

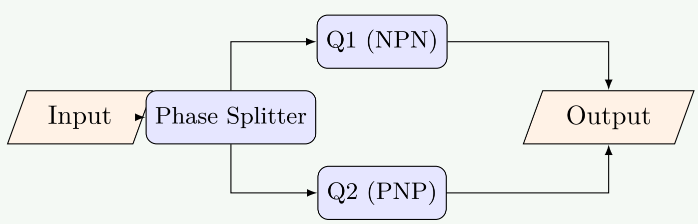
Question 3 [c marks]

7 Explain the principle of push pull amplifiers and write short note on class B push pull amplifier.

Solution

- **Principle**: Uses two active devices driven in antiphase. One pushes current into load, other pulls current from load.
- **Class B Push-Pull**: Biased at cutoff. Transistor 1 conducts for positive half, Transistor 2 for negative half.

Block Diagram:



Advantages and Disadvantages:

- **Efficiency**: High (78.5%).
- **Harmonics**: Even harmonics cancel out.
- **Issue**: Crossover distortion due to V_{BE} drop.

Mnemonic

"Push-Pull: Pair Processes alternate Pulses"

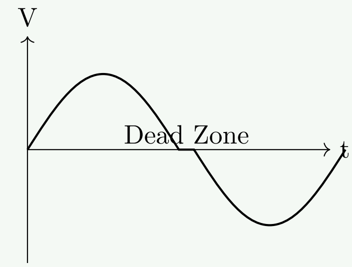
Question 3 [a marks]

3 Discuss crossover distortion in push pull amplifier. How it can be removed.

Solution

- **Problem**: Power transistors in Class B need $\approx 0.7V$ to turn on. Input signal between -0.7V and +0.7V is not amplified, creating a dead zone.
- **Effect**: Distortion at the zero-crossing of the waveform.

Waveform:



- **Removal**: Use Class AB operation. Pre-bias the transistors using diodes or resistors so they are on the verge of conduction even with zero input.

Mnemonic

"Cross to Class AB Smooths the Gap"

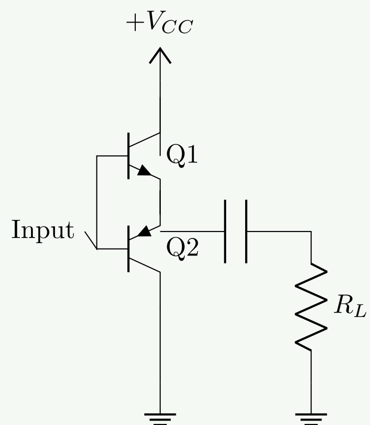
Question 3 [b marks]

4 Explain complimentary symmetry push-pull amplifier.

Solution

- **Concept**: Uses matched pair of NPN and PNP transistors.
- **Operation**: NPN conducts for positive half, PNP for negative half.
- **Advantage**: No phase splitter transformer needed.

Circuit:



Mnemonic

"NPN Pulls-up, PNP Pulls-down"

Question 3 [c marks]

7 Derive the equation of efficiency for class B push pull Amplifier.

Solution

- **Input Power** (P_{DC}): Total current from supply $I_{dc} = \frac{2I_m}{\pi}$.

$$P_{DC} = V_{CC} \times I_{dc} = \frac{2V_{CC}I_m}{\pi}$$

- **Output Power** (P_{AC}): RMS values $V_{rms} = \frac{V_m}{\sqrt{2}}$, $I_{rms} = \frac{I_m}{\sqrt{2}}$.

$$P_{AC} = V_{rms}I_{rms} = \frac{V_mI_m}{2}$$

- **Efficiency** (η):

$$\eta = \frac{P_{AC}}{P_{DC}} \times 100\%$$

$$\eta = \frac{V_mI_m/2}{2V_{CC}I_m/\pi} \times 100\% = \frac{\pi}{4}\frac{V_m}{V_{CC}} \times 100\%$$

- **Maximum Efficiency**: When $V_m = V_{CC}$,

$$\eta_{max} = \frac{\pi}{4} \times 100\% \approx 78.5\%$$

Mnemonic

"Pi-over-4 gives 78.5% - Class B's best"

Question 4 [a marks]

3 Define.(i) CMRR (ii)slew rate.(iii)Input offset Current.

Solution

Parameter	Definition	Typical
CMRR	Ratio of differential gain to common-mode gain (A_d/A_{cm}). Rejection capability.	90 dB
Slew Rate	Max rate of change of output voltage (dV_o/dt). Speed of response.	0.5 V/μs
Input Offset Current	Difference between base currents ($\lvert I_{B1} - I_{B2}\rvert$).	20-200 nA

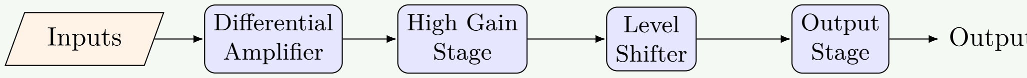
Mnemonic

"Cancelling Mistakes Requires Ratios"

Question 4 [b marks]

4 Draw and explain the basic block diagram of an operational amplifier.

Solution



- **Differential Amp**: High input impedance, noise rejection.
- **High Gain**: Provides most voltage gain.
- **Level Shifter**: Resets DC level to zero.
- **Output Stage**: Low output impedance, current drive.

Mnemonic

"Diff-Amp Gain Shift Out"

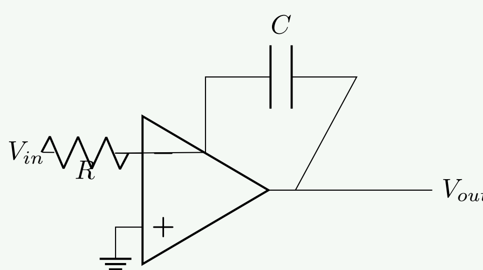
Question 4 [c marks]

7 Explain in detail operational amplifier as integrator.

Solution

- **Function**: Output is time integral of input.
- **Equation**: $V_{out} = -\frac{1}{RC}\int V_{in}dt$.
- **Components**: Resistor in input, Capacitor in feedback.

Circuit Diagram:



Waveforms: Square wave input → Triangular wave output.

Mnemonic

"Square-In Triangle-Out, RC sets the Slope"

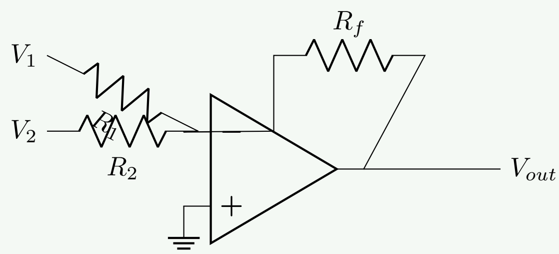
Question 4 [a marks]

3 Explain operational amplifier as summing amplifier.

Solution

- **Function**: Adds multiple input voltages.
- **Equation**: $V_{out} = -(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \ldots)$.

Circuit:



Mnemonic

"Many Inputs, One Output - Sum It All"

Question 4 [b marks]

4 State the applications of operational amplifier.

Solution

- **Linear**: Adder, Subtractor, Integrator, Differentiator, Instrumentation Amp.
- **Non-Linear**: Comparator, Schmitt Trigger, Rectifiers, Log amplifiers.
- **Waveform Generation**: Oscillators, Multivibrators.
- **Active Filters**: Low pass, High pass, Band pass filters.

Mnemonic

"SMWIG-CR: Signal, Math, Wave, Instrument, Gate, Convert, Regulate"

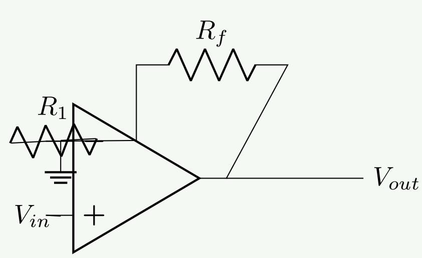
Question 4 [c marks]

7 Explain op-amp as inverting and non-inverting amplifier.

Solution

Inverting Amplifier	**Non-Inverting Amplifier**
Input at inverting terminal (-)	Input at non-inverting terminal (+)
Phase shift 180°	Phase shift 0°
Gain $A_v = -R_f/R_1$	Gain $A_v = 1 + R_f/R_1$
Input Impedance $\approx R_1$	Input Impedance $\approx \infty$

Non-Inverting Circuit:



Mnemonic

"Invert: Negative is Input, Non-invert: Positive gets signal"

Question 5 [a marks]

3 Give pin description of IC555.

Solution

Pin	Name	Function
1	GND	Ground
2	Trigger	Starts timing ($< 1/3V_{CC}$)
3	Output	High/Low output
4	Reset	Resets timer (Active Low)
5	Control	Access to divider network
6	Threshold	Ends timing ($> 2/3V_{CC}$)
7	Discharge	Discharges capacitor
8	V_{CC}	Supply Voltage

Mnemonic

"Ground Triggers Output Reset Control Threshold Discharges Voltage"

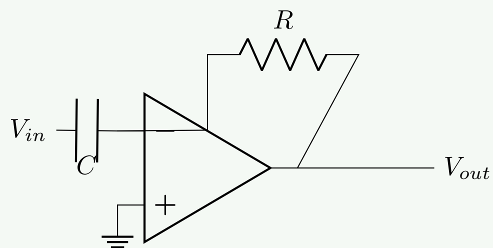
Question 5 [b marks]

4 Explain op-amp as differentiator.

Solution

- **Function**: Output is proportional to rate of change of input.
- **Equation**: $V_{out} = -RC\frac{dV_{in}}{dt}$.
- **Components**: Capacitor in input, Resistor in feedback.

Circuit:



Mnemonic

"Differentiator Delivers Derivatives - RC determines speed"

Question 5 [c marks]

7 Explain IC 555 as astable and Monostable multivibrator.

Solution

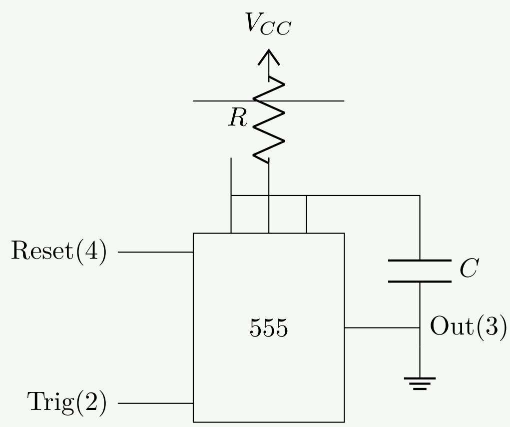
Astable (Free Running):

- Does not need external trigger.
- Output toggles between High and Low continuously.
- **Period**: $T = 0.693(R_A + 2R_B)C$.
- **Duty Cycle**: $D = \frac{R_A+R_B}{R_A+2R_B}$.

Monostable (One Shot):

- Needs external trigger on Pin 2.
- Output goes High for fixed duration T then returns Low.
- **Pulse Width**: $T = 1.1RC$.

Monostable Circuit:



Mnemonic

"Astable Always Alternates, Monostable Makes One pulse"

Question 5 [a marks]

3 Explain IC555 as Bistable multivibrator.

Solution

- **Definition**: Has 2 stable states (High and Low).
- **Operation**: Trigger (Pin 2) sets Output High. Reset (Pin 4) sets Output Low. Threshold (Pin 6) is grounded.
- **No Timing Components**: Frequency depends on trigger pulses, not RC.

Truth Table:

Trigger	Reset	Output
Low	High	High (Set)
High	Low	Low (Reset)

Mnemonic

"Bistable Bounces Between two states"

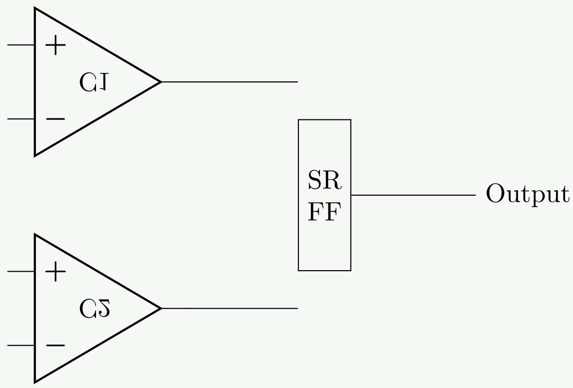
Question 5 [b marks]

4 Explain the basic operation of IC555 with internal block diagram.

Solution

- **Voltage Divider**: Three $5k\Omega$ resistors split V_{CC} into $2/3V_{CC}$ and $1/3V_{CC}$.
- **Comparators**: Compare inputs with reference voltages.
- **Flip-Flop**: SR Flip-flop sets/resets based on comparators.
- **Output Stage**: High current driver.
- **Discharge**: Transistor Q1 discharges external capacitor.

Block Diagram:



Mnemonic

"Comparators Control Flip-flop For Timing"

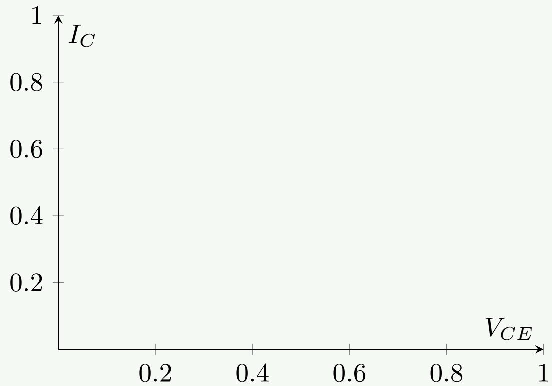
Question 5 [c marks]

7 Explain how class A, Class B, Class C and Class AB Power amplifier are classified based on their Q Point location on load line, with diagram.

Solution

Class	Q-Point	Conduction Angle
A	Center of Load Line	$360°$
B	Cutoff (X-axis)	$180°$
AB	Just above Cutoff	$180° - 360°$
C	Below Cutoff	$< 180°$

Load Line Diagram:



Mnemonic

"Above center, Below center, Cut-off point, Down below - ABCD order for Q-point location"