Electronics Devices & Circuits (1323202) - Winter 2023 Solution

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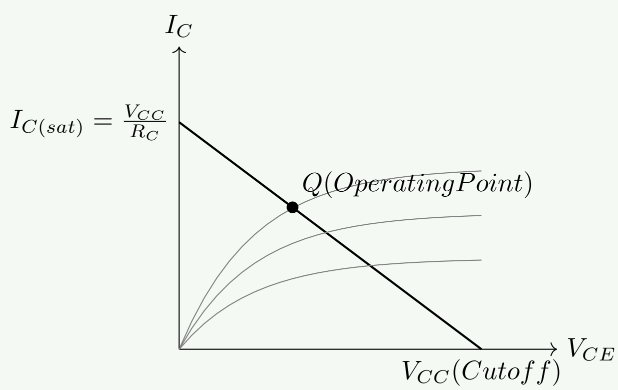
Question 1(a) [3 marks]

Explain the concept of dc load line with the help of neat diagram.

Solution

DC load line is a straight line on output characteristics that shows all possible operating points of a transistor.
Diagram:



DC Load Line

- **Collector saturation current**: When $V_{CE} = 0$, $I_C = V_{CC}/R_C$
- **Cutoff voltage**: When $I_C = 0$, $V_{CE} = V_{CC}$
- **Q-point**: Operating point along load line

Mnemonic

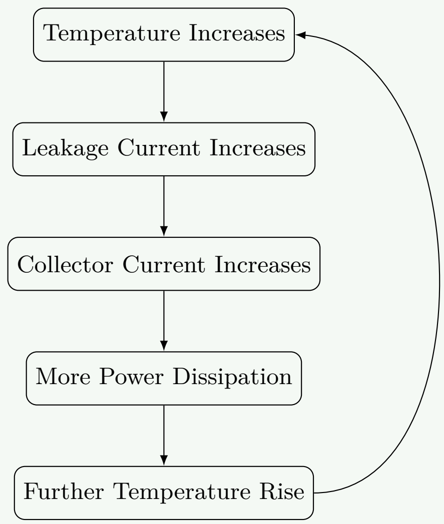
"LEVEL" - "Load line Establishes Voltage and current for Every Load condition"

Question 1(b) [4 marks]

Explain thermal runaway in detail.

Solution

Thermal runaway is a condition where heat causes transistor's collector current to increase, which generates more heat, leading to destruction.
Diagram:



- **Heat generation**: Power dissipation = $V_{CE} \times I_C$
- **Critical effect**: Increased junction temperature decreases V_{BE}
- **Prevention**: Heat sinks, thermal stabilization circuits, proper biasing
- **Danger**: Can destroy transistor if not controlled

Mnemonic

"HEAT" - "Higher Emission Amplifies Temperature"

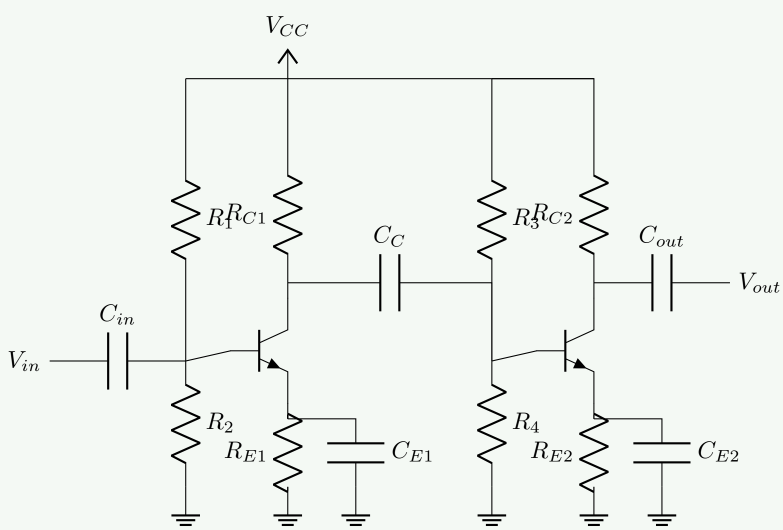
Question 1(c) [7 marks]

Draw the circuit diagram and frequency response of a two stage R-C coupled amplifier. Explain the importance of each component.

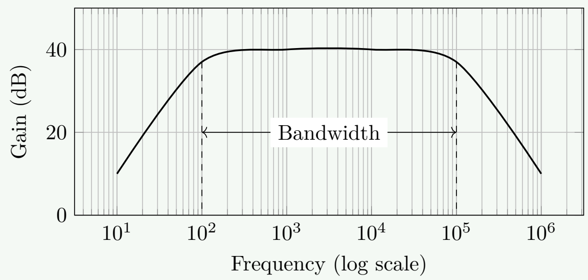
Solution

R-C coupled amplifier uses capacitors to connect multiple transistor stages for higher gain.

Circuit Diagram:



Frequency Response:



- **Coupling capacitors (C_C)**: Block DC, allow AC signal transfer between stages
- **Biasing resistors (R_1, R_2)**: Establish proper Q-point for transistor operation
- **Bypass capacitors (C_E)**: Prevent gain reduction from negative feedback across R_E
- **Bandwidth**: Range between low (f_L) and high (f_H) cutoff frequencies

Mnemonic

"CARS" - "Coupling capacitors Allow Resistance Separation"

OR

Question 1(c) [7 marks]

Compare negative and positive feedback in amplifier.

Solution

Feedback systems return a portion of output to the input with different effects based on polarity.

Table 1. Comparison of Feedback Types

Parameter	Negative Feedback	Positive Feedback
Gain	Decreases	Increases
Bandwidth	Increases	Decreases
Stability	Improves	Decreases
Distortion	Reduces	Increases
Noise	Reduces	Amplifies
Input/Output Impedance	Can be controlled	Unpredictable
Applications	Amplifiers, regulators	Oscillators, Schmitt triggers

- **Negative feedback**: Output is out of phase with input (180° shifted)
- **Positive feedback**: Output is in phase with input (0° shifted)
- **Barkhausen criteria**: Positive feedback with unity gain creates oscillation

Mnemonic

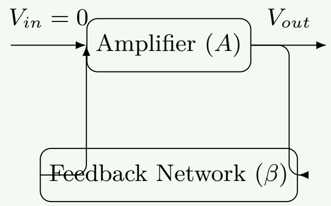
"SIGN" - "Stability Increases with Gain Negation"

Question 2(a) [3 marks]

State and explain Barkhausen's criteria for oscillations.

Solution

Barkhausen's criteria define conditions for sustained oscillations in a feedback system.
Diagram:



Conditions:
1. Loop Gain $|A\beta| = 1$
2. Phase Shift $\angle A\beta = 0°$ or $360°$

- **Gain condition**: Loop gain ($A \times \beta$) must equal 1 (unity)
- **Phase condition**: Total phase shift around the loop must be 0° or 360°
- **Practical implementation**: Initial loop gain > 1 to start, then stabilizes at 1 due to nonlinearity

Mnemonic

"LOOP" - "Loop's Overall Output Phase"

Question 2(b) [4 marks]

Compare Fixed bias, Collector to base bias & Voltage divider bias methods.

Solution

Different biasing techniques provide varying degrees of stability and temperature compensation.

Table 2. Comparison of Biasing Methods

Parameter	Fixed Bias	Collector-Base Bias	Voltage Divider Bias
Stability	Poor	Better	Excellent
Circuit Complexity	Simple	Medium	Complex
Temp Stability	Poor	Medium	Good
Components	1 Resistor	1 Resistor	3-4 Resistors
Stability Factor (S)	High (Unstable)	Medium	Low (Stable)

- **Fixed bias**: Single resistor from base to V_{CC}
- **Collector-base bias**: Feedback resistor from collector to base provides negative feedback
- **Voltage divider**: Two resistors create stable reference voltage independent of β

Mnemonic

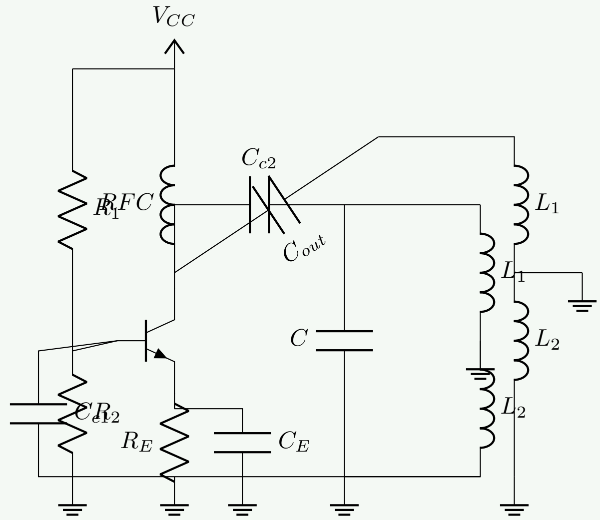
"STORM" - "Stability Through Optimized Resistor Methods"

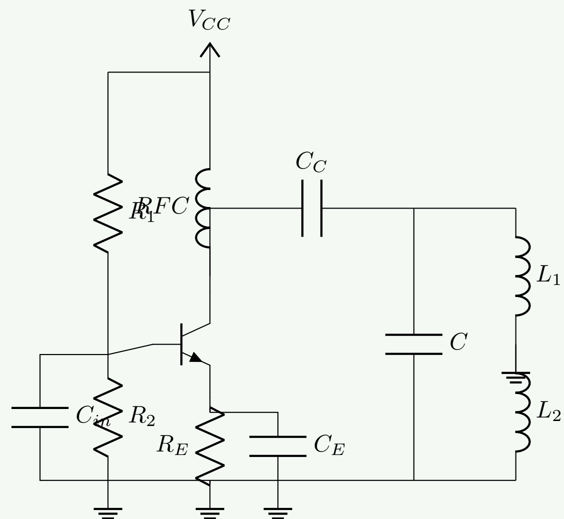
Question 2(c) [7 marks]

Write short note on Hartley oscillator.

Solution

Hartley oscillator is an LC oscillator with a tapped inductor for feedback.
Circuit Diagram:





- **Circuit components**: Amplifier (CE Mode), Tank Circuit (L_1, L_2, C)
- **Frequency formula**: $f = \frac{1}{2\pi\sqrt{L_{eq}C}}$ where $L_{eq} = L_1 + L_2$
- **Feedback**: Voltage across L_2 is fed back to base (180° phase shift by tank + 180° by amp = 360°)
- **Applications**: RF signal generators, radio receivers

Mnemonic

"TILC" - "Tapped Inductor with LC Circuit"

OR

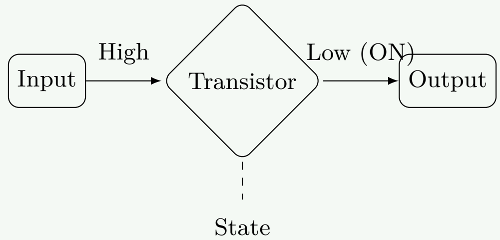
Question 2(a) [3 marks]

Explain working of transistor as a switch.

Solution

Transistor switches between cutoff (OFF) and saturation (ON) regions for digital applications.

Diagram:



- **Cutoff region**: $V_{BE} < 0.7V$, acts as open switch, $V_{CE} \approx V_{CC}$ (Output High)
- **Saturation region**: $V_{BE} > 0.7V$, acts as closed switch, $V_{CE} \approx 0.2V$ (Output Low)
- **Switching time**: Limited by junction capacitance

Mnemonic

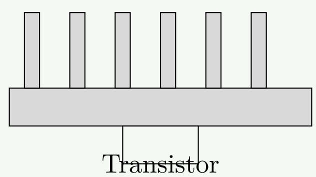
"COPS" - "Cutoff-On-Produces Switching"

Question 2(b) [4 marks]

Define heat sink. List types of heat sink and give its applications.

Solution

Heat sink is a thermal conductor that transfers heat away from electronic components to prevent overheating.
Diagram:



Types of Heat Sinks:

Table 3. Heat Sink Types and Applications

Type	**Description**	**Application**
Passive	No moving parts, natural convection	Low-power devices
Active	With fans or pumps	High-power amplifiers, CPUs
Liquid-cooled	Uses fluid for heat transfer	Supercomputers, high-end PCs
Finned	Multiple fins increase surface area	Power transistors

Mnemonic

"COOL" - "Conducting Out Of Local heat"

Question 2(c) [7 marks]

Explain advantages and disadvantages of negative feedback in amplifiers in detail.

Solution

Negative feedback returns a portion of output signal to input with opposite phase to improve performance stability.
Feedback Block Diagram:

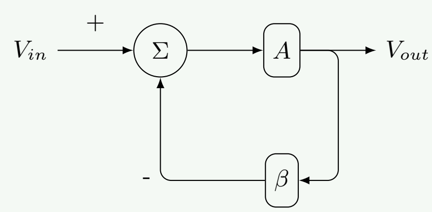


Table 4. Pros and Cons of Negative Feedback

Advantages	Disadvantages
Stabilizes gain against parameter changes	Reduces overall gain
Increases bandwidth	Requires more components
Reduces non-linear distortion	More power consumption in feedback circuit
Decreases noise	Complexity of design
Controls Input/Output Impedance	Potential for oscillation if phase margin low

Mnemonic

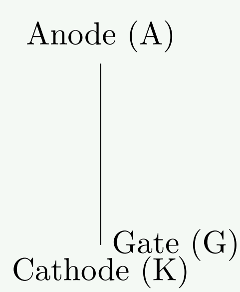
"STABLE" - "Stabilized Transmission And Bandwidth with Less Error"

Question 3(a) [3 marks]

Draw symbol of SCR and explain working of SCR.

Solution

Silicon Controlled Rectifier (SCR) is a four-layer PNPN device with three terminals.
Symbol:



- **Structure**: P-N-P-N four-layer semiconductor device
- **Operation**: Remains OFF until gate triggered, then conducts until current falls below holding value
- **Terminals**: Anode (A), Cathode (K), Gate (G)

Mnemonic

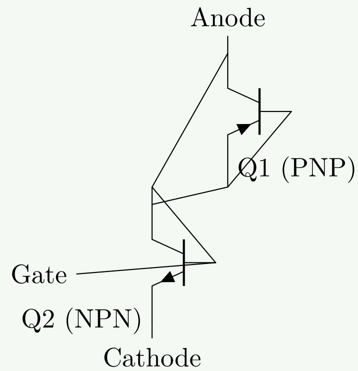
"AGK" - "Anode-Gate controls Kathode current"

Question 3(b) [4 marks]

Explain two transistor analogy of SCR with circuit diagram.

Solution

SCR can be represented as interconnected PNP and NPN transistors sharing semiconductor layers.
Circuit Diagram:



- **PNP section**: Upper transistor with collector connected to NPN base
- **NPN section**: Lower transistor with collector connected to PNP base
- **Regenerative Feedback**: Collector current of Q1 feeds Base of Q2; Collector current of Q2 feeds Base of Q1. Once triggered, the loop sustains standard conduction.

Mnemonic

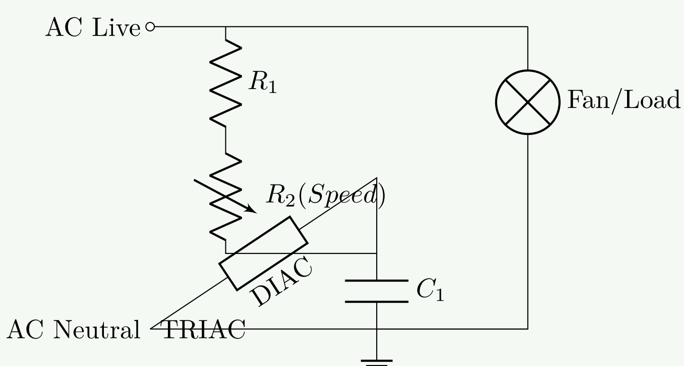
"PNPN" - "Positive-Negative-Positive-Negative layers"

Question 3(c) [7 marks]

Explain the working of TRIAC based fan regulator with circuit diagram.

Solution

TRIAC-based fan regulator controls AC power delivered to the load through phase control.
Circuit Diagram:



- **Phase control**: Varies firing angle of TRIAC to control effective RMS voltage
- **Diac**: Provides bidirectional triggering pulse for TRIAC
- **RC timing circuit**: R_1, R_2, C_1 determine the delay angle; Changing R_2 changes speed
- **Operation**: When capacitor voltage reaches DIAC breakover, TRIAC fires

Mnemonic

"TRIAC" - "Triggered Response In AC Circuits"

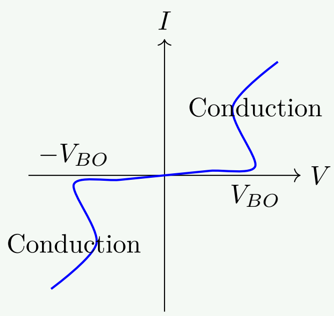
OR

Question 3(a) [3 marks]

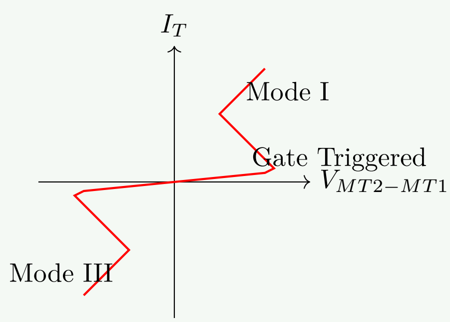
Draw V-I characteristics of DIAC and TRIAC.

Solution

DIACs and TRIACs are bidirectional devices with symmetrical forward and reverse characteristics.
DIAC Characteristics:



TRIAC Characteristics:



Mnemonic

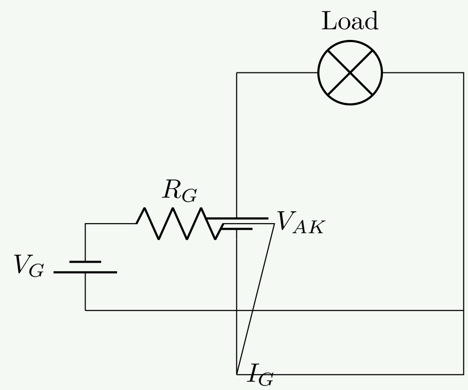
"BIBO" - "Bidirectional In, Bidirectional Out"

Question 3(b) [4 marks]

Explain the Gate triggering method of SCR.

Solution

Gate triggering applies a control signal to the gate terminal to turn on the SCR at a precise moment.
Diagram:



- **Gate pulse**: Positive current applied between gate and cathode
- **Timing**: Controls the firing angle (α) in AC circuits
- **Requirement**: Gate current must persist until anode current reaches latching current

Mnemonic

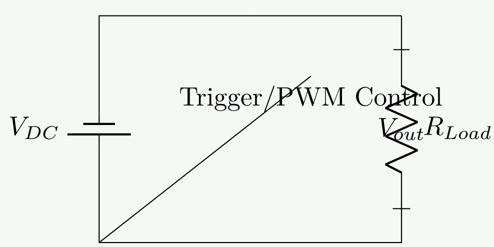
"GATE" - "Gain Activation Through Electron flow"

Question 3(c) [7 marks]

Explain SCR application for DC power control.

Solution

SCR controls DC power by chopping the supply voltage using PWM or phase control techniques (if input is AC rectified). For pure DC, it needs a commutation circuit, but here we assume general DC control concept.
Circuit Diagram:



- **Chopping**: SCR acts as a switch, turning ON and OFF rapidly
- **Power Control**: Average output voltage $V_{avg} = V_{in} \times$ Duty Cycle
- **Commutation**: In DC circuits, SCR requires a forced commutation circuit to turn OFF (not shown for simplicity)

Mnemonic

"POWER" - "Pulse Operation With Electronic Regulation"

Question 4(a) [3 marks]

List characteristics of Ideal OP-AMP.

Solution

Ideal operational amplifiers have perfect characteristics that real devices approximate.

Table 5. Ideal Op-Amp Characteristics

Characteristic	Ideal Value
Open Loop Gain (A_{OL})	Infinite (∞)
Input Impedance (Z_{in})	Infinite (∞)
Output Impedance (Z_{out})	Zero (0Ω)
Bandwidth (BW)	Infinite (∞)
CMRR	Infinite (∞)
Slew Rate	Infinite (∞)
Offset Voltage	Zero ($0V$)

Mnemonic

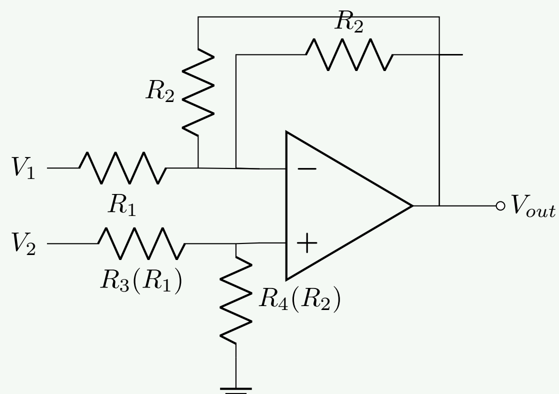
"IBOCSS" - "Infinite Bandwidth, Open-loop gain, CMRR, Slew rate, and Sensitivity"

Question 4(b) [4 marks]

Explain working of differential amplifier using OP-AMP with circuit diagram.

Solution

Differential amplifier amplifies the voltage difference between two inputs while rejecting common signals.
Circuit Diagram:



- **Gain formula**: $V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$ (assuming $R_3 = R_1, R_4 = R_2$)
- **Common mode rejection**: Suppresses signals common to both inputs (noise)
- **Applications**: Instrumentation, medical equipment, audio balanced inputs

Mnemonic

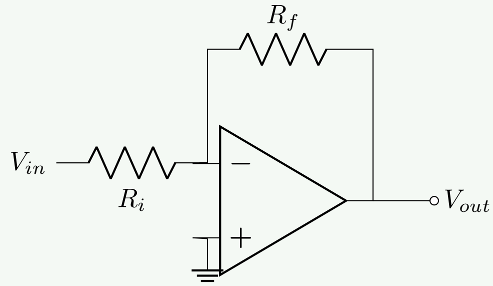
"DIFF" - "Dual Input For Feedback"

Question 4(c) [7 marks]

Explain OP-AMP as an inverting amplifier (Closed loop) and derive the formula of voltage gain.

Solution

Inverting amplifier produces output that is inverted and amplified version of input.
Circuit Diagram:



Gain Derivation:

- Apply KCL at inverting input (Virtual Ground Node V^-):

$$I_1 + I_2 = 0$$

- Since Op-amp input impedance is infinite, current into terminals is zero.

$$I_1 = \frac{V_{in} - V^-}{R_i}, \quad I_2 = \frac{V_{out} - V^-}{R_f}$$

- Due to Virtual Ground concept ($V^+ = 0$), $V^- \approx 0$.

$$\frac{V_{in}}{R_i} + \frac{V_{out}}{R_f} = 0$$

$$\frac{V_{out}}{R_f} = -\frac{V_{in}}{R_i}$$

$$A_v = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$$

Mnemonic

"VAIN" - "Virtual ground Amplification Inverts Negative"

OR

Question 4(a) [3 marks]

Define the following parameters of OPAMP: 1) CMRR, 2) Slew rate, 3) Gain Bandwidth Product

Solution

These parameters define key performance characteristics of operational amplifiers.

Table 6. Op-Amp Parameters

Parameter	**Definition**	**Importance**
CMRR	Ratio of differential gain to common-mode gain (A_d/A_{cm})	High CMRR rejects noise
Slew Rate	Max rate of output voltage change (dV/dt) in V/μs	Limits high-freq performance
Gain-Bandwidth	Product of Open Loop Gain and Frequency	Constant for a given op-amp

Mnemonic

"CSG" - "Common-mode rejection, Speed, and Gain"

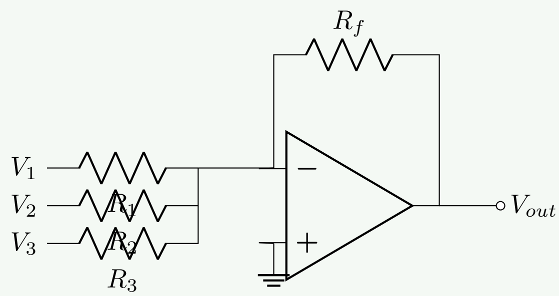
Question 4(b) [4 marks]

Draw and explain summing amplifier using OP-AMP.

Solution

Summing amplifier produces output proportional to the weighted algebraic sum of input voltages.

Circuit Diagram:



- **Output formula**: $V_{out} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right)$
- **Averaging**: If $R_1 = R_2 = R_3 = R$ and $R_f = R/3$, output is negative average
- **Applications**: Audio mixer, analog addition

Mnemonic

"SUM" - "Several Unified Multipliers"

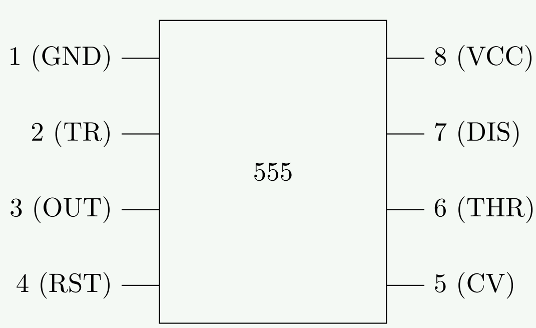
Question 4(c) [7 marks]

Draw the pin diagram of IC 555 and explain Monostable multivibrator using IC555 with waveform.

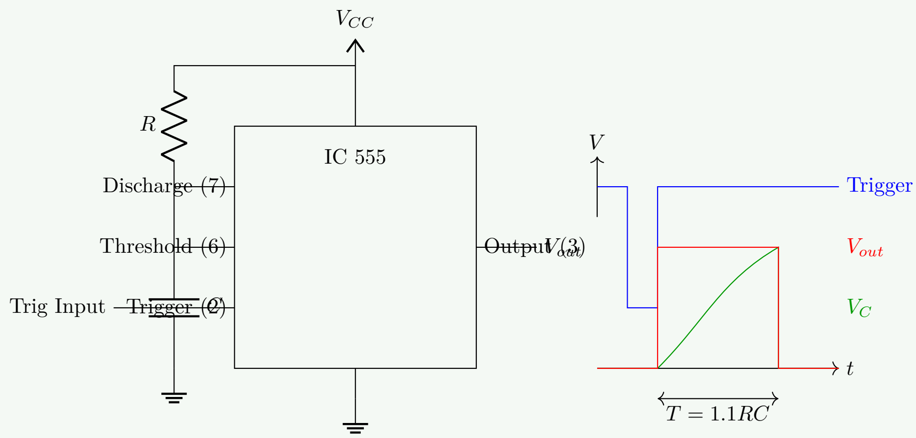
Solution

IC 555 timer in monostable mode produces a single pulse of fixed duration (T) when triggered.

Pin Diagram:



Monostable Circuit & Waveforms:



- **Operation**: Trigger (Pin 2) low pulse starts timing cycle. Output goes high. Capacitor charges via R.
- **End of Cycle**: When $V_C = 2/3V_{CC}$, output goes low, capacitor discharges.
- **Pulse Width**: $T = 1.1 \times R \times C$ seconds.

Mnemonic

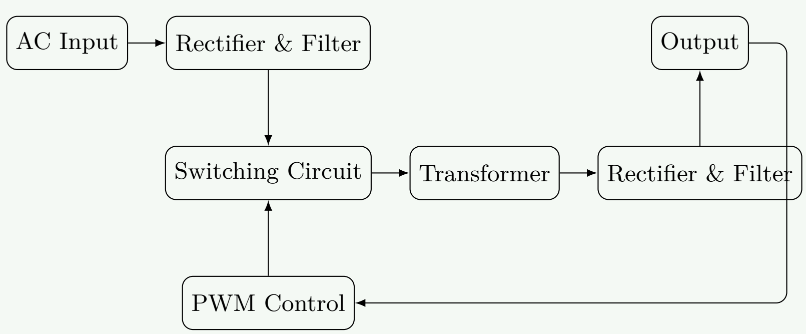
"TIMER" - "Triggered Input Makes Extended Response"

Question 5(a) [3 marks]

Draw block diagram of SMPS and give its applications.

Solution

Switch Mode Power Supply (SMPS) uses switching elements for efficient power conversion.
Block Diagram:



Applications:
- Computer power supplies (ATX)
- Mobile phone chargers
- TV power supplies
- LED lighting drivers

Mnemonic

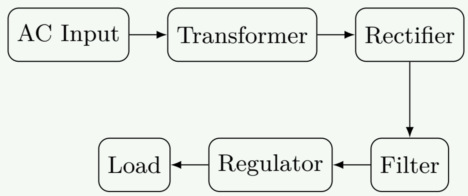
"SAFE" - "Switching Achieves Filtered Energy"

Question 5(b) [4 marks]

Explain working of Regulated Power Supply with diagram.

Solution

Regulated power supply maintains constant output despite input or load variations.
Block Diagram:



- **Transformer**: Steps down AC voltage to required level
- **Rectifier**: Converts AC to pulsating DC (diode bridge)
- **Filter**: Smooths DC ripple with capacitors
- **Regulator**: Stabilizes DC voltage (e.g., 7805, LM317)

Mnemonic

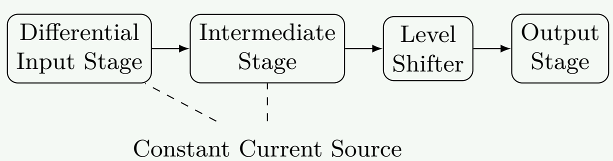
"TRFRO" - "Transform, Rectify, Filter, Regulate, Output"

Question 5(c) [7 marks]

Explain basic block diagram of OP-AMP with diagram.

Solution

Operational amplifier consists of four cascaded stages performing specific functions.
Block Diagram:



- **Differential Input Stage**: Provides high input impedance and CMRR (Dual Input Balanced Output)
- **Intermediate Stage**: Provides high voltage gain (Dual Input Unbalanced Output)
- **Level Shifter**: Shifts DC level to zero volts (Emitter Follower)
- **Output Stage**: Provides low output impedance and current drive (Push-Pull Amplifier)

Mnemonic

"DILO" - "Differential Input, Level shift, Output"

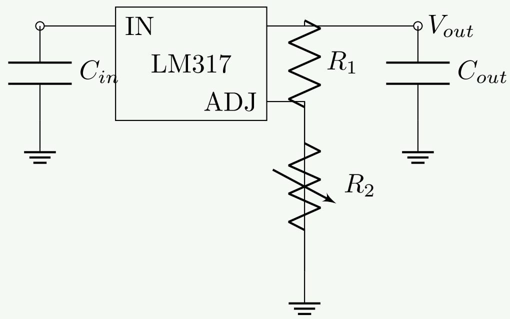
OR

Question 5(a) [3 marks]

Explain adjustable voltage regulator using LM317 with diagram.

Solution

LM317 is a variable positive voltage regulator that adjusts output from 1.25V to 37V.
Circuit Diagram:



- **Formula**: $V_{out} = 1.25V \times (1 + \frac{R_2}{R_1}) + I_{adj}R_2$ where $1.25V$ is reference voltage (V_{ref})
- **Resistors**: R_1 sets reference current, R_2 adjusts output voltage
- **Protection**: Internal thermal overload and short circuit protection

Mnemonic

"AVR" - "Adjustable Voltage Regulation"

Question 5(b) [4 marks]

Give the difference between Fixed voltage regulator IC and Variable voltage regulator IC.

Solution

Comparison between fixed output regulators (like 78XX) and adjustable ones (like LM317).

Table 7. Fixed vs Variable Regulators

Parameter	Fixed Regulator	Variable Regulator
Output Voltage	Preset (e.g., 5V, 12V)	Adjustable Range (e.g., 1.2V-37V)
Components	Minimum (2 Capacitors)	More (Resistors + Capacitors)
Flexibility	Low (Fixed application)	High (Universal application)
Examples	7805, 7812, 7905	LM317, LM337, LM723
Cost	Generally Cheaper	Slightly Higher
Pin Config	In, Ground, Out	In, Adjust, Out

Mnemonic

"FOCUS" - "Fixed Output Compared to User-Set"

Question 5(c) [7 marks]

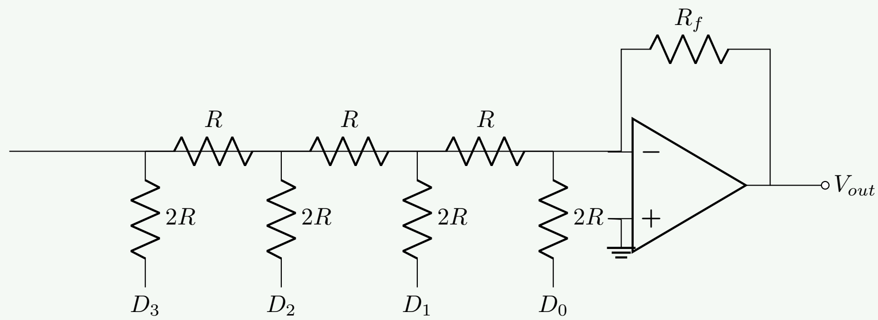
List applications of OP-AMP. Explain working operation of D to A converter with circuit diagram using OP-AMP.

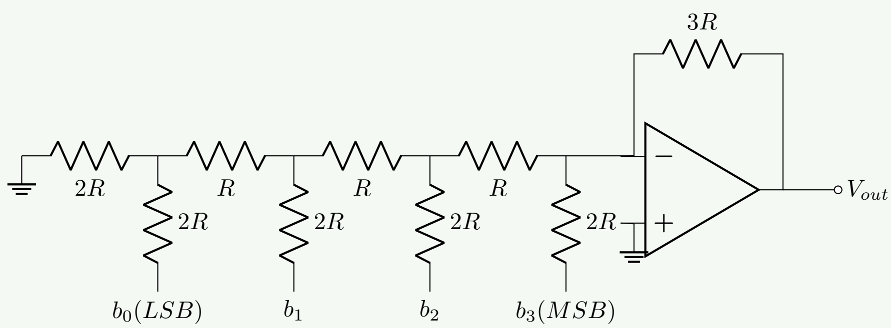
Solution

DAC converts digital binary input into equivalent analog voltage.
Applications of OP-AMP:

1. Amplifiers (Inverting, Non-inverting, Differential)
2. Filters (Active Low Pass, High Pass)
3. Oscillators (Wein Bridge, Phase Shift)
4. Comparators and Schmitt Triggers
5. Mathematical Operations (Summing, Integrator, Differentiator)

R-2R Ladder DAC Circuit:





- **Principle**: Ladder network creates binary weighted currents
- **Output**: $V_{out} \propto -(b_3 2^{-1} + b_2 2^{-2} + b_1 2^{-3} + b_0 2^{-4})V_{ref}$
- **Advantages**: Only two resistor values ($R, 2R$) needed, scalable

Mnemonic

"DART" - "Digital to Analog Resistor Translation"