Electronics Devices & Circuits (1323202) - Summer 2023 Solution

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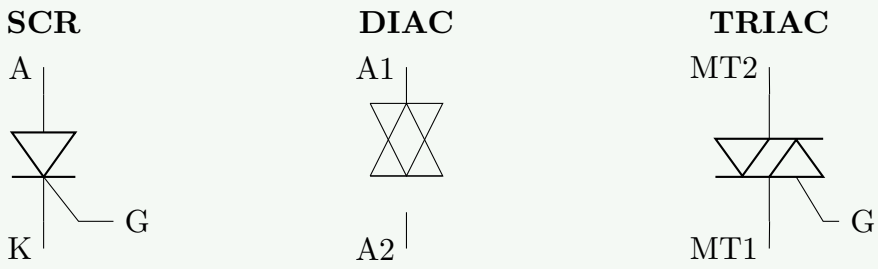
Question 1(a) [3 marks]

Draw the symbol of (1)SCR (2)Diac(3)Triac

Solution



- **SCR (Silicon Controlled Rectifier)**: Three-terminal device with Anode, Cathode, and Gate
- **DIAC (Diode AC switch)**: Two-terminal bidirectional device with terminals A1 and A2
- **TRIAC (Triode AC switch)**: Three-terminal bidirectional device with MT1, MT2, and Gate

Mnemonic

AGK for SCR, AA for DIAC, MMG for TRIAC

Question 1(b) [4 marks]

Explain the term(1) CMRR (2) Slew rate

Solution

Table 1. Op-Amp Parameters

Parameter	Definition	Significance
CMRR (Common Mode Rejection Ratio)	Ratio of differential gain to common mode gain expressed in dB	Higher CMRR means better rejection of common input signals
Slew Rate	Maximum rate of change of output voltage (V/μs)	Determines how fast op-amp responds to rapidly changing inputs

- **CMRR formula**: CMRR = 20 $\log_{10}$(Ad/Acm) dB
- **Slew Rate importance**: Affects high-frequency performance and prevents distortion

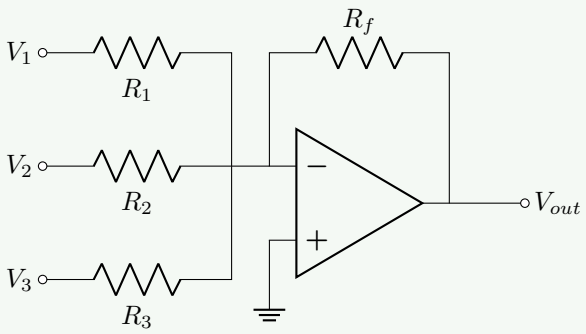
Mnemonic

Common Mode Rejected Rapidly, Slew shows Signal Speed

Question 1(c) [7 marks]

Draw and explain summing amplifier.

Solution



Operation of Summing Amplifier:

- **Circuit function**: Adds multiple input voltages with scaling
- **Output equation**: Vout = -(Rf/R1 × V1 + Rf/R2 × V2 + Rf/R3 × V3)
- **Inverting configuration**: Input signals undergo 180° phase shift
- **Gain control**: Rf/Rn determines weight of each input signal
- **Application**: Audio mixing, analog computation, signal processing
- **Key feature**: Virtual ground at inverting input simplifies analysis

Mnemonic

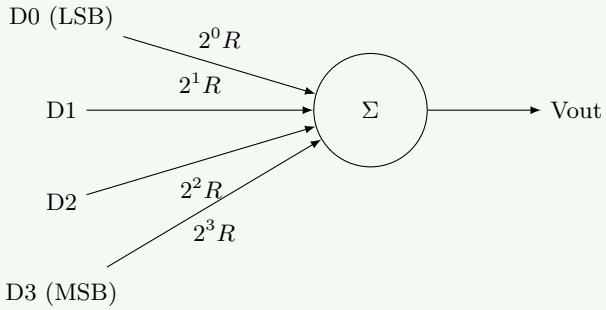
Sum with Weights: Vout = -Rf(V1/R1 + V2/R2 + V3/R3)

OR

Question 1(c) [7 marks]

Draw and explain DA converter

Solution



R-2R Ladder DAC Operation:

- **Function**: Converts digital binary input to analog output voltage
- **Working principle**: Weighted resistor network creates scaled currents
- **Binary weighting**: Each bit contributes voltage proportional to its position (2^n)
- **Resolution**: Determined by number of bits (N) as $1/2^N$ of full scale
- **Advantages**: Simple design, good accuracy, fast conversion
- **Applications**: Audio equipment, signal generation, control systems

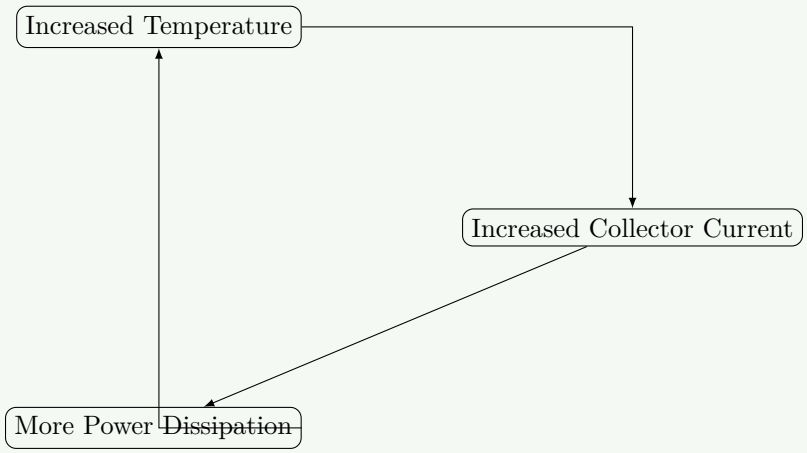
Mnemonic

Digital Bits to Analog Steps - R-2R makes the magic

Question 2(a) [3 marks]

Describe thermal run away of transistor.

Solution



Thermal Runaway Process:

- **Definition**: Self-accelerating process where transistor heats up and draws more current
- **Cause**: Negative temperature coefficient of base-emitter voltage
- **Prevention**: Use proper heat sink and stabilization circuits

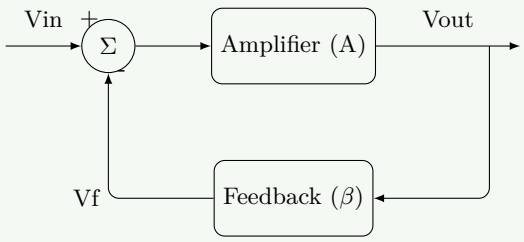
Mnemonic

Heat feeds Current feeds Heat - a dangerous loop

Question 2(b) [4 marks]

Draw and explain voltage series negative feedback.

Solution



Voltage Series Negative Feedback:

Table 2. Feedback Effects

Parameter	Effect of Negative Feedback
Gain stability	Improved, less dependent on amplifier parameters
Bandwidth	Increased proportional to feedback factor
Distortion	Reduced significantly
Input impedance	Increased

- **Working principle**: Output voltage is sampled and fed back to input
- **Gain formula**: Closed-loop gain = Open-loop gain/(1 + βA)

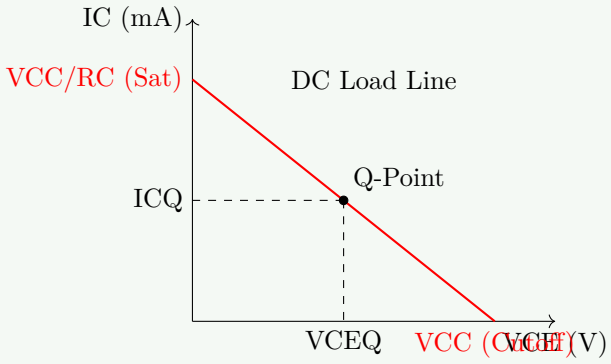
Mnemonic

Series says Sample Voltage, Stabilize Gain

Question 2(c) [7 marks]

Draw and explain DC load line for common emitter amplifier.

Solution



DC Load Line Characteristics:

- **Definition**: Graphical representation of all possible operating points
- **Equation**: IC = VCC/RC - VCE/RC
- **Key points**:
  - Saturation point (VCE ≈ 0V, IC = VCC/RC)
  - Cutoff point (IC ≈ 0mA, VCE = VCC)
  - Q-point (selected operating point for amplification)
- **Significance**: Determines biasing stability and output signal limits
- **Relationship**: DC load line is fixed by circuit components (VCC and RC)

Mnemonic

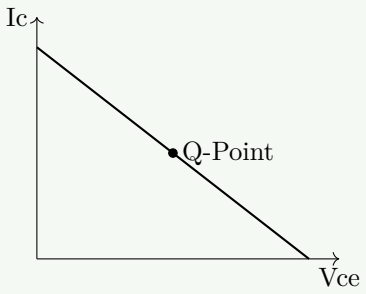
Connect Cutoff to Saturation for DC Load Line

OR

Question 2(a) [3 marks]

Explain operating point(Q-point) in transistor

Solution



Q-Point (Operating Point):

- **Definition**: Specific DC bias point where transistor operates in active region
- **Importance**: Determines output signal range without distortion
- **Selection criteria**: Center of load line for maximum swing

Mnemonic

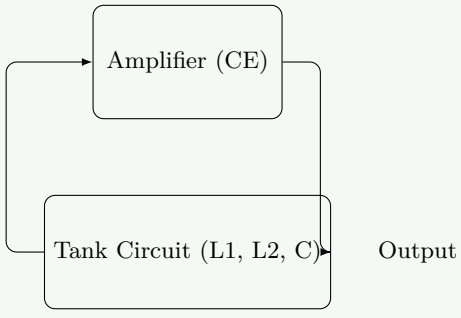
Quality amplification needs Quiet bias at Q-point

OR

Question 2(b) [4 marks]

Draw and explain hartley oscillator.

Solution



Hartley Oscillator:

- **Configuration**: Common emitter with tapped inductor feedback
- **Frequency formula**: $f = \frac{1}{2\pi\sqrt{C(L1+L2)}}$

- **Phase shift**: Ensures 360° total phase shift for oscillation
- **Feedback**: Inductive voltage divider provides positive feedback

Mnemonic

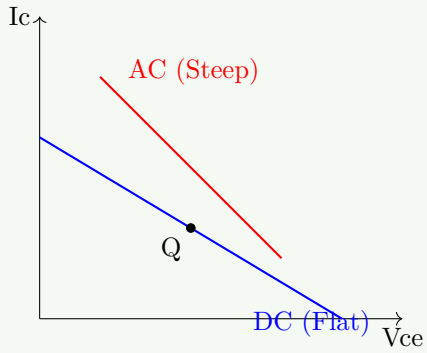
Hartley Has two coils with inductance for LC oscillation

OR

Question 2(c) [7 marks]

Draw and explain AC load line for common emitter amplifier.

Solution



AC Load Line Characteristics:

- **Definition**: Represents dynamic operation during signal amplification
- **Equation**: $i_c = \frac{V_{CC}-V_{CEQ}}{R'_c} - \frac{v_{ce}}{R'_c}$ where $R'_c = RC||RL$
- **Comparison with DC load line**:
  - AC load line is steeper than DC load line
  - Passes through Q-point
  - Determines voltage and current signal swings
- **Significance**: Defines maximum undistorted output signal
- **Limiting factor**: Avoiding saturation and cutoff regions

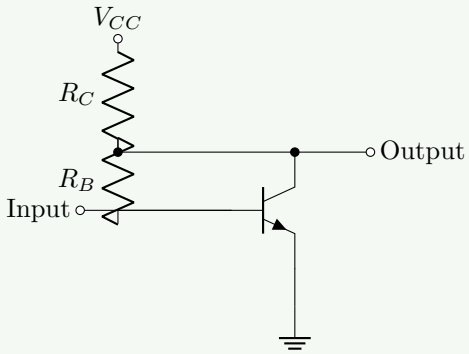
Mnemonic

AC Amplitude Controlled by Load line Angle

Question 3(a) [3 marks]

Draw the fixed bias circuit and explain working of it

Solution



- **Structure**: Base resistor connected to VCC, collector resistor for load
- **Operation**: Fixed base current biases transistor
- **Disadvantage**: Poor stability against temperature changes

Mnemonic

Fixed Bias Feeds Base from power supply

Question 3(b) [4 marks]

In hartley oscillator L1=5mH, L2=10mH, C=0.01μF. Calculate frequency of oscillations.

Solution

Solution:

- **Given**: L1=5mH, L2=10mH, C=0.01μF
- **Frequency formula**: $f = \frac{1}{2\pi\sqrt{C(L1+L2)}}$
- **Calculation**:
  - Total inductance LT = L1 + L2 = 5mH + 10mH = 15mH = 15×10^{-3} H
  - C = 0.01μF = 1×10^{-8} F
  - $f = \frac{1}{2\pi\sqrt{15\times10^{-3}\times1\times10^{-8}}}$
  - $f = \frac{1}{2\pi\sqrt{15\times10^{-11}}}$
  - $f = \frac{1}{2\pi\times3.873\times10^{-6}}$
  - $f = \frac{1}{24.33\times10^{-6}}$
  - $f = 41,101$ Hz ≈ 41.1 kHz

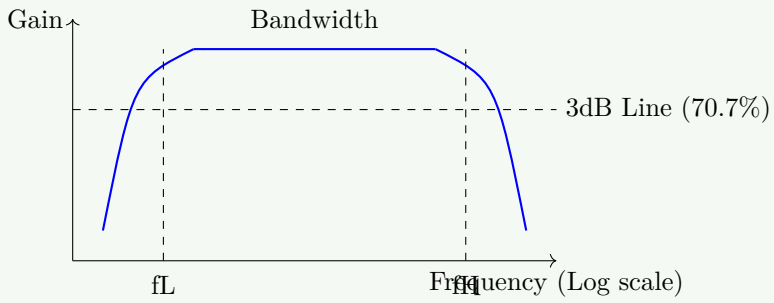
Mnemonic

For Hartley's frequency, add coils then take square root

Question 3(c) [7 marks]

Draw and explain the frequency response curve of two stage RC coupled amplifier.

Solution



Two-Stage RC Coupled Amplifier Frequency Response:

- **Low-frequency region**: Gain rises with frequency (< 50Hz)
  - Limited by coupling and bypass capacitors
- **Mid-frequency region**: Constant maximum gain (50Hz-20kHz)
  - Flat response, ideal operating region
- **High-frequency region**: Gain drops with frequency (> 20kHz)
  - Limited by transistor capacitances and Miller effect
- **Bandwidth**: Range of frequencies with gain $\geq 70.7\%$ of maximum gain
- **Cutoff frequencies**: Points where gain drops by 3dB (0.707 times max gain)

Mnemonic

Low-flat-high: capacitors block, amplify well, then roll off

OR

Question 3(a) [3 marks]

Explain in detail barkhausen criterion for oscillation.

Solution

Barkhausen Criterion:

Table 3. Conditions for Oscillation

Condition	Requirement
Loop Gain	Must equal exactly 1 ($A\beta = 1$)
Phase Shift	Must be 0° or 360° around loop

- **Purpose**: Ensures sustained oscillations without damping
- **Consequences**:
  - If $A\beta < 1$: Oscillations die out
  - If $A\beta > 1$: Oscillations grow until limited by nonlinearity
  - If $A\beta = 1$: Stable oscillations maintained

Mnemonic

Barkhausen's Balance: Loop Gain=1, Phase=360°

OR

Question 3(b) [4 marks]

Explain the effect of negative feedback on the gain of amplifier

Solution

Effect of Negative Feedback on Amplifier Gain:

Table 4. Feedback Comparison

Parameter	Without Feedback	With Feedback
Voltage Gain	A	A/(1+Aβ)
Stability	Less stable	More stable
Bandwidth	Lower	Higher
Distortion	Higher	Lower

- **Gain reduction**: Gain decreases by factor (1+Aβ)
- **Gain-bandwidth tradeoff**: Bandwidth increases as gain decreases
- **Gain stabilization**: Less affected by temperature and component variations

Mnemonic

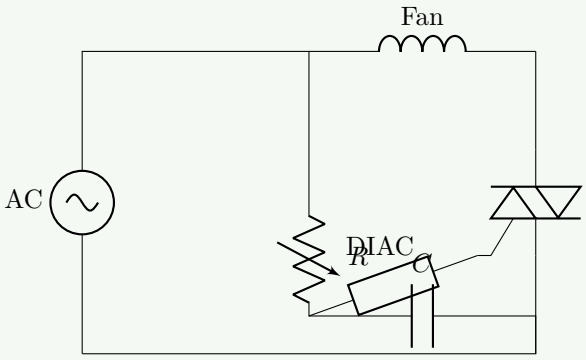
Negative Feedback: Less Gain, More Stability

OR

Question 3(c) [7 marks]

Draw fan regulator circuit and explain how it will control the speed of fan.

Solution



Fan Regulator Operation:

- **Control method**: Phase angle control using TRIAC and DIAC
- **Working principle**: RC network creates variable phase shift
- **Speed control**: Variable resistor adjusts RC time constant
- **Operation sequence**:
  - RC network delays DIAC firing
  - DIAC triggers TRIAC at adjustable point in AC cycle
  - TRIAC conducts for remaining portion of AC half-cycle
  - Less conduction time = lower power to fan = slower speed
- **Advantages**: Simple design, smooth control, energy efficient
- **Applications**: Ceiling fans, exhaust fans, cooling systems

Mnemonic

Delay the TRIAC firing, control fan's speed

Question 4(a) [3 marks]

Write short note on natural commutation

Solution

Natural Commutation:

- **Definition**: SCR turns off automatically when current falls below holding current
- **Process**: Occurs in AC circuits at each zero-crossing point
- **Requirements**: No external components needed, inherent to AC operation

Mnemonic

Natural Commutation: Zero Current Crossings Turn Off Thyristors

Question 4(b) [4 marks]

Explain the parameters gain and bandwidth of amplifier.

Solution

Table 5. Amplifier Parameters

Parameter	Definition	Formula
Gain (A)	Ratio of output to input signal	A = Vout/Vin
Bandwidth (BW)	Frequency range with gain $\geq$ 70.7% of maximum	BW = fH - fL

- **Gain-bandwidth product**: Remains constant (GBP = Gain $\times$ Bandwidth)
- **Cutoff frequencies**: Lower (fL) and higher (fH) frequencies where gain drops by 3dB
- **Significance**: Determines amplifier's ability to handle different frequencies

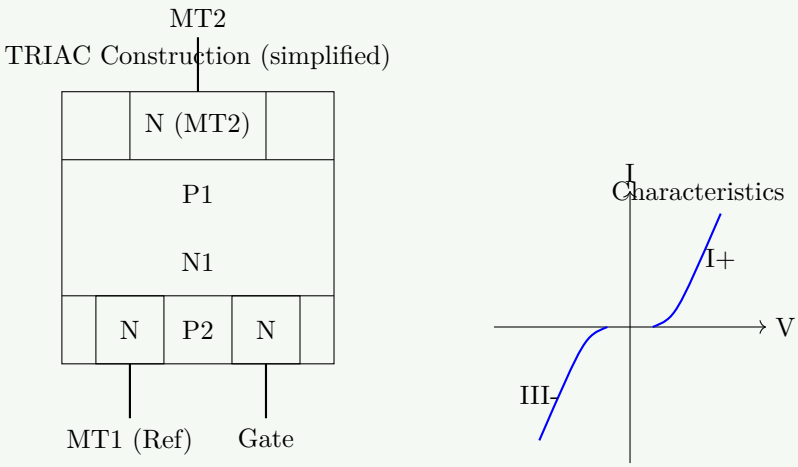
Mnemonic

Good Amplifiers Balance Width and Magnitude

Question 4(c) [7 marks]

Draw the construction and characteristics of triac and describe working of it, also write the application of triac.

Solution



TRIAC Operation:

- **Structure**: Five-layer PNPN bidirectional device
- **Switching**: Conducts in both directions when triggered
- **Triggering modes**: Four quadrant operation possible
- **Turn-off**: Natural commutation at current zero-crossing

Applications:

- Light dimmers, Fan speed controllers, Heater controls, Motor speed regulation, AC power switching

Mnemonic

TRIAC Takes AC Control in Both Directions

OR

Question 4(a) [3 marks]

Write any three application of SCR.

Solution

Applications of SCR:

Table 6. SCR Applications

Application	Function
DC Motor Speed Control	Provides variable DC to motors
Battery Chargers	Regulates charging current
Power Inverters	Converts DC to AC efficiently

- **Advantages**: High power handling, efficient control, robust operation
- **Limitations**: Requires forced commutation in DC circuits

Mnemonic

SCR Controls DC - Motors, Batteries, Inverters

OR

Question 4(b) [4 marks]

Explain holding current and latching current with reference to SCR

Solution

Table 7. SCR Current Parameters

Parameter	Definition	Typical Values
Holding Current (IH)	Minimum current to maintain conduction	5-40 mA
Latching Current (IL)	Minimum current to establish conduction	10-100 mA

- **Latching current**: Must be exceeded briefly after triggering for SCR to latch
- **Holding current**: Must be maintained to keep SCR in conduction
- **Relationship**: Usually IL > IH
- **Significance**: Critical for reliable switching operation

Mnemonic

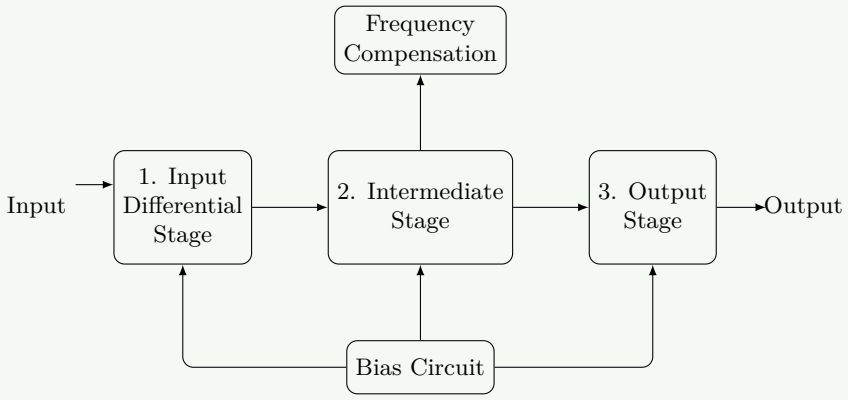
Latch with more, Hold with less, both keep SCR conducting

OR

Question 4(c) [7 marks]

Draw and explain in detail block diagram of operational amplifier.

Solution



Op-Amp Blocks and Functions:

- **Input differential stage**: High input impedance, Rejects common-mode signals, Provides differential voltage gain
- **Intermediate stage**: Additional voltage gain, Level shifting, Frequency compensation
- **Output stage**: Low output impedance, Current amplification, Power capability for driving loads
- **Bias circuit**: Establishes proper operating points, Temperature stability
- **Frequency compensation**: Prevents oscillation, Controls frequency response

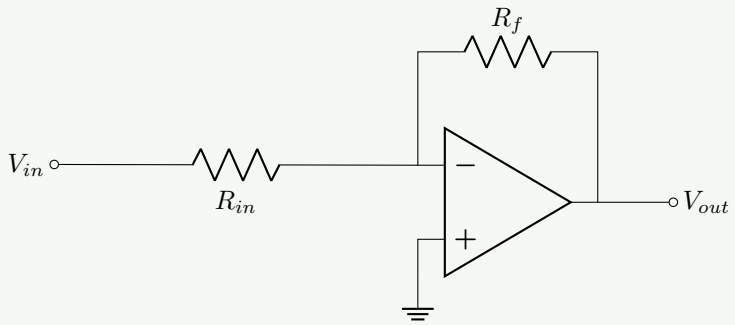
Mnemonic

Differential Input, Gain in Middle, Power at Output

Question 5(a) [3 marks]

Draw and explain in brief inverting amplifier.

Solution



- **Gain formula**: Vout = -(Rf/Rin) × Vin
- **Operation**: Input signal inverted with amplification
- **Virtual ground**: Inverting input maintained at 0V

Mnemonic

Inverting means Negative Gain equals -Rf/Rin

Question 5(b) [4 marks]

Draw and explain the block diagram of regulated power supply.

Solution

Regulated Power Supply Stages:

- **Transformer**: Steps down AC voltage to required level
- **Rectifier**: Converts AC to pulsating DC (diode bridge)
- **Filter**: Smooths pulsating DC (capacitors)
- **Regulator**: Maintains constant output despite variations

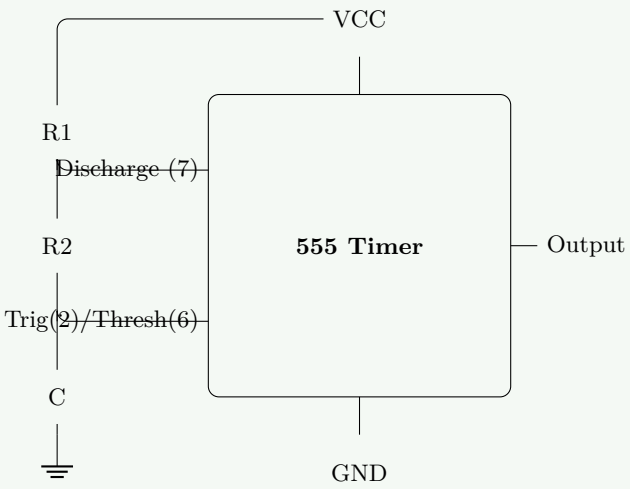
Mnemonic

Transform, Rectify, Filter, Regulate for Stable DC

Question 5(c) [7 marks]

Draw and explain astable multivibrator.

Solution



Operation of Astable Multivibrator:

- **Configuration**: Free-running oscillator with no stable states
- **Timing components**: External R1, R2, and C
- **Oscillation process**:
  - Capacitor charges through R1+R2
  - Capacitor discharges through R2
  - Continuous charging/discharging cycle
- **Frequency formula**: $f = \frac{1.44}{(R1+2R2)C}$
- **Output waveform**: Rectangular with duty cycle based on R1/R2 ratio
- **Applications**: Clock generation, LED flashers, tone generators

Mnemonic

Always Switching, Time set by RC, Both states Least stable

OR

Question 5(a) [3 marks]

In an op amp non-inverting amplifier R1=2kΩ and Rf=200kΩ. Find the voltage gain of non-inverting amplifier.

Solution

Solution:

- **Given**: R1 = 2kΩ, Rf = 200kΩ
- **Non-inverting amplifier gain formula**: A = 1 + (Rf/R1)
- **Calculation**:
  - A = 1 + (200kΩ/2kΩ)
  - A = 1 + 100
  - A = 101
- **Result**: Voltage gain of non-inverting amplifier is 101
- **Significance**: Output voltage will be 101 times the input voltage

Mnemonic

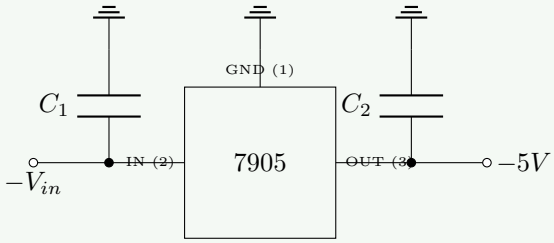
Non-inverting amplifier gain: One plus Feedback over Ground

OR

Question 5(b) [4 marks]

Draw and explain in brief circuit to get -5V regulated dc output voltage.

Solution



Circuit Operation:

- **Key component**: 7905 negative voltage regulator IC
- **Input requirement**: Negative DC voltage (typically -7V to -25V)
- **Filtering**: Input and output capacitors for stability
- **Regulation method**: Series pass element with feedback control
- **Output characteristics**: Fixed -5V with current up to 1A

Mnemonic

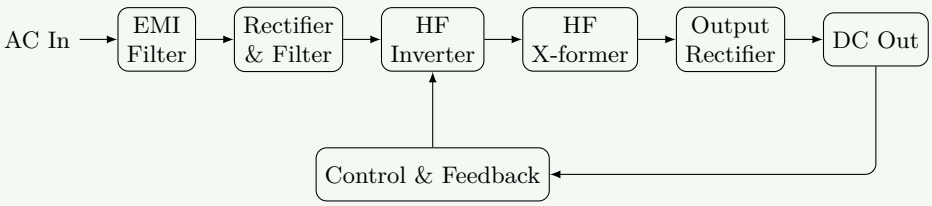
79XX for Negative, 78XX for Positive regulated voltage

OR

Question 5(c) [7 marks]

Draw and explain the block diagram of SMPS.

Solution



SMPS Operation:

- **Input stage**: Filters EMI, rectifies AC to high-voltage DC
- **Switching stage**: Converts DC to high-frequency AC (20-100 kHz)
- **Transformer**: Provides isolation and voltage transformation
- **Output stage**: Rectifies and filters to produce clean DC
- **Feedback control**: Regulates output by adjusting switching duty cycle

Advantages of SMPS:

- **High efficiency** (80-90%) due to switching operation
- **Small size and weight** from high-frequency transformer
- **Wide input voltage range** with stable output
- **Multiple output voltages** possible from single transformer

Mnemonic

Switching Efficiently Reduces Size