Subject Name Solutions

1323202 – Winter 2023

Semester 1 Study Material

Detailed Solutions and Explanations

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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    style O fill:\#fff,stroke:\#000
    style Vcesat fill:\#fff,stroke:\#000
    style Icsat fill:\#fff,stroke:\#000
    style Vcc fill:\#fff,stroke:\#000
    O((O)) {-{-}{-} Icsat((Icsat))}
    O {-{-}{-} Vcc((Vcc))}
    Icsat {-{-}{-} Vcesat((Vcesat))}
    Vcesat {-{-}{-} Vcc}
{Highlighting}
{Shaded}
```

- **Collector saturation current**: When VCE = 0, IC = VCC/RC
- **Cutoff voltage**: When IC = 0, VCE = VCC
- **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:

```
flowchart LR
    A[Temperature Increases] {-{-} B[Leakage Current Increases]}
    B {-{-} C[Collector Current Increases]}
    C {-{-} D[More Power Dissipation]}
    D {-{-} E[Further Temperature Rise]}
    E {-{-} A}
```

- **Heat generation**: Power dissipation = VCE $\times IC$
- **Critical effect**: Increased junction temperature decreases VBE
- **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.

Diagram:

```
+{-{-}{-}{-}{-}{-}+           +{-}{-}{-}{-}{-}{-}+}
|      |           |      |
|  Q1  |           |  Q2  |
|      |           |      |
+{-{-}{-}{-}{-}{-}+           +{-}{-}{-}{-}{-}{-}+}
   |                 |
   |                 |
   R1       C2        R2
   |        ||        |
   +{-{-}{-}||{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
        C1

Vin o{-{-}{-}{-}||{-}{-}{-}+        +{-}{-}{-}{-}{-}{-}o Vout}
             |         |
             R3        R4
             |         |
             +         +
```

Frequency Response:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    title["Frequency Response: Gain (dB) vs Frequency"]

    F10["10 Hz{nGain: 10 dB"] {-}{-}{} F100["100 Hz{}nGain: 30 dB"]}
    F100 {-{-}{} F1k["1 kHz{}nGain: 40 dB"]}
    F1k {-{-}{} F10k["10 kHz{}nGain: 40 dB"]}
    F10k {-{-}{} F100k["100 kHz{}nGain: 30 dB"]}
    F100k {-{-}{} F1M["1 MHz{}nGain: 10 dB"]}
{Highlighting}
{Shaded}
```

- **Coupling capacitors**: Block DC, allow AC signal transfer between stages
- **Biasing resistors**: Establish proper Q-point for transistor operation
- **Bypass capacitors**: Prevent gain reduction from negative feedback
- **Bandwidth**: Range between low and high 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.

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:

```
flowchart TD
    A[Amplifier] {-{-} B[Feedback Network]}
    B {-{-} A}
    A {-{-} "Loop Gain = 1" {-}{-} C[Sustained Oscillation]}
    A {-{-} "Loop Gain  1" {-}{-} D[Damped Oscillation]}
    A {-{-} "Loop Gain  1" {-}{-} E[Growing Oscillation]}
```

- **Gain condition**: Loop gain (A) must equal 1 (unity)
- **Phase condition**: Total phase shift must be $0° or 360°$
- **Practical implementation**: Initial loop gain > 1, then stabilizes at 1

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.

Parameter	Fixed Bias	Collector-Base Bias	Voltage Divider Bias
Stability	Poor	Better	Excellent
Circuit complexity	Simple	Medium	Complex
Temperature stability	Poor	Medium	Good
Components	1 Resistor	1 Resistor	3-4 Resistors

Stability factor (S)	High	Medium	Low

- **Fixed bias**: Single resistor from base to VCC
- **Collector-base bias**: Feedback resistor from collector to base
- **Voltage divider**: Two resistors create stable reference voltage

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.
Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Amplifier] {-{-}{-} B[Feedback Network]}
    B {-{-}{-} A}
    subgraph "Feedback Network"
    direction LR
    L1[L1] {-{-}{-} L2[L2]}
    L1 {-{-}{-} C1[C]}
    L2 {-{-}{-} C1}
    end
{Highlighting}
{Shaded}
```

- **Circuit components**: Amplifier, tapped inductor (L1+L2), capacitor C
- **Frequency formula**: f = 1/[2 $\sqrt(LC)]whereL = L1 + L2$
- **Advantages**: Simple design, good frequency stability
- **Drawbacks**: Size of inductors, limited frequency range
- **Applications**: RF signal generators, radio receivers, communication

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:

```
flowchart LR
    A[Input] {-{-} B\{Transistor\}}
    B {-{-} "Saturation (ON)" {-}{-} C[Output LOW]}
    B {-{-} "Cutoff (OFF)" {-}{-} D[Output HIGH]}
```

- **Cutoff region**: VBE < 0.7V, acts as open switch, VCE $\approx VCC$

- **Saturation region**: VBE > 0.7V, acts as closed switch, VCE $\approx 0.2V$
- **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.
Diagram:

```
     ||||||||
    /||||||||{ Heat Sink}
   /||||||||||{}
  /||||||||||||{}
 /|||||||||||||{}
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
|  Transistor  |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
```

Types of Heat Sinks:

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

- **Purpose**: Prevents thermal runaway and component failure
- **Materials**: Aluminum, copper, or alloys with high thermal conductivity

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.

Advantages	Disadvantages
Stabilizes gain	Reduces overall gain
Increases bandwidth	More components needed
Reduces distortion	More power consumption
Decreases noise	Complex circuit design
Controls input/output impedance	Potential oscillation if improperly designed
Improves linearity	Signal loss in feedback network

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input] {-{-}{} B[Amplifier]}
    B {-{-}{} C[Output]}
    C {-{-} "Feedback Network" {-}{-}{} D[Subtractor]}
    D {-{-}{} B}
{Highlighting}
{Shaded}
```

- **Gain stabilization**: Makes gain dependent on passive components
- **Bandwidth extension**: Increases by factor equal to gain reduction
- **Feedback factor**: determines amount of improvement

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:

```
      A(Anode)
       |
       |
       v
    +{-{-}{-}{-}{-}+}
    |     |
G{-{-}|     |}
    |     |
    +{-{-}{-}{-}{-}+}
       \^{}
       |
       |
      K(Cathode)
```

- **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, Cathode, Gate

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 junctions.
Diagram:

```
       Anode
         |
    +{-{-}{-}{-}|{-}{-}{-}{-}+}
    |    v    |
    |  +{-{-}{-}  |}
    |  | PNP  |
    |  +{-{-}{-}{-}+ |}
    |       | |
Gate |       v |
 {-{-}{-}{-}|{-}{-}{-}+  +{-}{-}}
    |   |  | NPN
    |   +{-{-}+{-}{-}{-}{-}+}
    |          |
    +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}|{-}{-}}
              |
              v
           Cathode
```

- **PNP section**: Upper transistor with collector connected to NPN base
- **NPN section**: Lower transistor with collector connected to PNP base
- **Triggering**: Small gate current turns on NPN, which turns on PNP
- **Regenerative action**: Each transistor supplies base current to other

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 through phase control.
Circuit Diagram:

```
        +{-{-}{-}+  R1}
AC o{-{-}{-}{-}+   +{-}{-}//{-}{-}+}
        |           |
        | C1        |
        +{-{-}{-}||{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}+}
                    |    |
                    Z   MT1
                    |    |
                   G|    |
                    |   \_V\_
                   +{-{-}|   |{-}{-}+{-}{-}o Fan}
                      |\_\_\_|  |
                        MT2   |
                              |
                              |
AC o{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}|}
```

- **Phase control**: Varies firing angle of TRIAC to control power
- **Diac**: Provides bidirectional triggering for TRIAC
- **RC timing circuit**: R1 and C1 set phase delay
- **Variable resistor**: Adjusts phase delay for speed control
- **Protection**: RC snubber prevents false triggering

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 characteristics.
DIAC Characteristics:

```
xychart{-beta}
    title "DIAC V{-I Characteristics"}
    x{-axis [{-}40, {-}30, {-}20, {-}10, 0, 10, 20, 30, 40]}
    y{-axis "Current (mA)" {-}30 {-}{-} 30}
    line [30, 5, 0, 0, 0, 0, 0, 5, 30]
```

TRIAC Characteristics:

```
xychart{-beta}
    title "TRIAC V{-I Characteristics"}
    x{-axis [{-}40, {-}30, {-}20, {-}10, 0, 10, 20, 30, 40]}
    y{-axis "Current (mA)" {-}40 {-}{-} 40}
    line [40, 40, 40, 5, 0, 5, 40, 40, 40]
```

- **DIAC**: Bidirectional diode that conducts after breakover voltage
- **TRIAC**: Three-terminal device that conducts in both directions when triggered

Mnemonic

"BIBO" - "Bidirectional In, Bidirectional Out"

Question 3(b) [4 marks]

Explain the Gate triggering method of SCR.

Solution

Gate triggering is the most common method to activate an SCR.
Diagram:

```
        A
        |
     +{-{-}{-}{-}{-}+}
     |     |
     |     |
     |  +{-|}
RC {-{-}|{-}{-}+  |}
     |     |
     +{-{-}{-}{-}{-}+}
        |
        K
```

- **Gate pulse**: Small current applied between gate and cathode
- **Triggering methods**: DC, AC, or pulse signals
- **Current requirements**: Typically 5-20mA gate current
- **Advantages**: Low power control of high-power circuits

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 at variable duty cycles.
Circuit:

```
     +{-{-}{-}{-}{-}{-}{-}+       SCR}
     |       |       / |
DC{-{-}|{-}{-}{-}{-}{-}{-}|{-}{-}{-}{-}{-}/{-}{-}|{-}{-}+{-}{-}{-}o Output}
     |       |          |   |
     | PWM   |          |   |
     | Ctrl  |{-{-}{-}{-}.     |   |}
     |       |    |     |   |
     +{-{-}{-}{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}|{-}{-}{-}+}
                        |
                        |
     +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}|}
     |                  |
     GND{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
```

- **Phase control**: Varies firing angle to control average power
- **PWM control**: Pulse width modulation for efficient control
- **Applications**: DC motor speed control, dimming, heating
- **Advantages**: High efficiency, no moving parts, reliable
- **Limitations**: Unidirectional current flow, needs commutation

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.

Characteristic	Ideal Value
Open loop gain	Infinite
Input impedance	Infinite
Output impedance	Zero
Bandwidth	Infinite
CMRR	Infinite
Slew rate	Infinite
Offset voltage	Zero

- **Practical values**: Actual op-amps have limitations
- **Implications**: Circuit design must account for real limitations

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.
Circuit:

```
            R2
     +{-{-}{-}{-}{-}{-}//{-}{-}{-}{-}{-}{-}+}
     |                |
     |           +{-{-}{-}{-}+}
     |           |    |
     |    R1     |    |
V1 o{-+{-}{-}{-}//{-}{-}{-}{-}+    +{-}{-}{-}{-}o Vout}
                \_|+   |
               /      |
              /       |
             /\_\_\_\_\_\_  |
                {-|    |}
     |    R1     |    |
V2 o{-+{-}{-}{-}//{-}{-}{-}{-}+    |}
     |                |
     |                |
     +{-{-}{-}{-}{-}{-}//{-}{-}{-}{-}{-}{-}+}
            R2
```

- **Gain formula**: Vout = (V1-V2) $\times(R2/R1)$
- **Common mode rejection**: Suppresses signals common to both inputs
- **Applications**: Instrumentation, medical equipment, audio

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:

```
          Rf
     +{-{-}{-}{-}//{-}{-}{-}{-}+}
     |            |
     |            |
     |    +{-{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}o Vout}
     |    |       |
     |    |   +{-{-}{-}+}
Vin o+{-{-}{-}{-}+{-}{-}{-}|+  |}
     |        |   |
     |  Ri    |   |
     +{-{-}//{-}{-}+{-}{-}{-}+}
           {-|}
            |
            |
            |
     +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
     |
    GND
```

Gain Derivation:

- Apply KCL at inverting input: $I_1 + I_2 = 0$
- $I_1 = (Vin - V^-)/RiandI_2 = (Vout - V^-)/Rf$
- At virtual ground, $V^- \approx 0$
- Therefore: Vin/Ri + Vout/Rf = 0
- Solving for Vout/Vin: Av = -Rf/Ri
- **Characteristics**: Output $180° outofphasewithinput$
- **Feedback**: Creates virtual ground at inverting input
- **Closed loop gain**: Controlled by external resistors

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.

Parameter	Definition	Importance
CMRR	Ratio of differential gain to common-mode gain	Higher is better for rejecting noise
Slew Rate	Maximum rate of output voltage change (V/ s)	Determines large-signal bandwidth
Gain-Bandwidth Product	Product of gain and frequency (MHz)	Measures high-frequency performance

- **CMRR**: Typically 80-120dB in quality op-amps
- **Slew Rate**: Limits output for high-frequency, high-amplitude signals
- **GBP**: Remains constant as frequency increases

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 weighted sum of input voltages.
Circuit:

```
              Rf
       +{-{-}{-}{-}{-}{-}//{-}{-}{-}{-}{-}{-}+}
       |                 |
       |           +{-{-}{-}{-}+}
       |           |     |
       |    R1     |     |
  V1 o{-+{-}{-}{-}//{-}{-}{-}{-}+    +{-}{-}{-}{-}o Vout}
       |           |+    |
       |    R2    /      |
```

```
V2 o{-+{-}{-}{-}//{-}{-}{-}+     |}
     |          {\_\_\_\_\_|}
     |    R3     |{-   |}
V3 o{-+{-}{-}{-}//{-}{-}{-}{-}+    |}
     |                |
     |                |
   {-{-}{-}{-}{-}              |}
    {-{-}{-}               |}
     {-                |}
```

- **Output formula**: Vout = -Rf(V$_1/R_1 + V_2/R_2 + V_3/R_3$)
- **Applications**: Audio mixer, analog computers, signal processing
- **Advantage**: Multiple inputs can be processed simultaneously

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 when triggered.

Pin Diagram:

```
    +{-{-}{-}{-}{-}{-}{-}+}
  1 |o       | 8
    |        |
  2 |o       | 7
    |  555   |
  3 |o       | 6
    |        |
  4 |o       | 5
    +{-{-}{-}{-}{-}{-}{-}+}
```

```
1: GND     5: Control
2: Trigger  6: Threshold
3: Output   7: Discharge
4: Reset    8: VCC
```

Circuit and Waveform:

```
graph TB
    subgraph "Monostable Circuit"
    VCC {-{-}{-} R1 {-}{-}{-} A}
    A {-{-}{-} C1 {-}{-}{-} GND}
    A {-{-}{-} Pin6 \& Pin7}
    Pin2 {-{-}{-} Trigger}
    Pin3 {-{-}{-} Output}
    Pin4 {-{-}{-} Reset}
    Pin8 {-{-}{-} VCC}
    Pin1 {-{-}{-} GND}
    end

    subgraph "Waveforms"
    direction TB
    Trig[Trigger] {-{-} O1[Output]}
    end
```

- **Operation**: Negative trigger starts timing cycle

- **Time period**: T = 1.1 $\times R \times C$
- **Applications**: Timers, pulse generation, debouncing
- **Advantages**: Simple, reliable, widely available

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:

```
flowchart LR
    A[AC Input] {-{-} B[EMI Filter]}
    B {-{-} C[Rectifier]}
    C {-{-} D[Filter]}
    D {-{-} E[Switching Circuit]}
    E {-{-} F[Transformer]}
    F {-{-} G[Output Rectifier]}
    G {-{-} H[Output Filter]}
    H {-{-} I[Output]}
    J[Feedback Control] {-{-} E}
    I {-{-} J}
```

Applications:

- Computer power supplies
- Mobile phone chargers
- TV power supplies
- Industrial power systems
- LED lighting drivers
- **Advantages**: High efficiency, small size, lightweight
- **Types**: Buck, boost, buck-boost, flyback converters

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:

```
flowchart LR
    A[AC Input] {-{-} B[Transformer]}
    B {-{-} C[Rectifier]}
    C {-{-} D[Filter]}
    D {-{-} E[Regulator]}
    E {-{-} F[Output]}
    G[Feedback] {-{-} E}
    F {-{-} G}
```

- **Transformer**: Steps down AC voltage to required level
- **Rectifier**: Converts AC to pulsating DC (diode bridge)

- **Filter**: Smooths DC with capacitors
- **Regulator**: Maintains constant output voltage
- **Feedback**: Compensates for input/load variations

Mnemonic

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

Question 5(c) [7 marks]

Explain basic block diagram of OP-AMP with diagram.

Solution

Operational amplifier's internal structure consists of several stages performing specific functions.
Block Diagram:

```
flowchart LR
    A[Differential Input Stage] {-{-} B[Intermediate Stage]}
    B {-{-} C[Level Shifter]}
    C {-{-} D[Output Stage]}
    E[Bias Circuit] {-{-} A \& B \& C \& D}
```

- **Differential input stage**: High impedance, amplifies difference
- **Intermediate stage**: Provides additional gain
- **Level shifter**: Adjusts DC level between stages
- **Output stage**: Low impedance, current amplification
- **Bias circuit**: Establishes operating points for all stages
- **Compensation**: Internal capacitor for stability

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 versatile adjustable positive voltage regulator with output range of 1.25V to 37V.
Circuit:

```
    Vin              LM317            Vout
     o{-{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}o}
           |        Vin     |
           |         |      |
           |       +{-{-}{-}+    |}
           |       |317|    |
           |       +{-{-}{-}+    |  C2}
           |      Adj|Out   +{-{-}||{-}{-}+}
           |         |         |   |
           |         +{-{-}{-}{-}{-}{-}{-}{-}+   |}
           |                   |   |
     C1    |        R1         |   |
     ||    +{-{-}{-}{-}{-}{-}//{-}{-}{-}{-}{-}{-}+   |}
     ||    |                   |   |
     ||    |                   |   |
     ++{-{-}{-}{-}+       R2         |   |}
```

```
    |            /{/{-}{-}{-}{-}{-}{-}{-}{-}{-}+   |}
    |            |          |   |
   GND          GND        GND  GND
```

- **Formula**: Vout = 1.25(1 + R2/R1)
- **Advantages**: Simple adjustment, built-in protection
- **Applications**: Variable power supplies, battery chargers

Mnemonic

"AVR" - "Adjustable Voltage Regulation"

Question 5(b) [4 marks]

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

Solution

Voltage regulator ICs differ in their configurability and application requirements.

Parameter	Fixed Voltage Regulator	Variable Voltage Regulator
Output voltage	Predetermined (e.g., 5V, 12V)	Adjustable over a range
External components	Minimal (capacitors only)	Requires resistors for setting
Series	78xx (positive), 79xx (negative)	LM317 (positive), LM337 (negative)
Applications	Standard equipment	Custom designs, laboratory supplies
Flexibility	Limited to fixed values	Highly adaptable
Pin count	Typically 3 pins	3 or more pins

- **Fixed regulators**: Simple to use, limited adjustment
- **Variable regulators**: More versatile, require calculation

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

Op-amps have numerous applications; D/A converters transform digital signals to analog.

Applications of OP-AMP:

- Amplifiers (inverting, non-inverting)
- Filters (active filters)
- Oscillators
- Comparators
- Integrators and differentiators
- Voltage followers
- Instrumentation circuits

R-2R Ladder DAC Circuit:

```
    D3   D2   D1   D0
     |    |    |    |
     v    v    v    v
     SW   SW   SW   SW
     |    |    |    |
   2R|   2R|  2R|  2R|
```

```
|    |    |    |
+{-{-}{-}{-}+{-}{-}{-}{-}+{-}{-}{-}{-}+}
|    |    |    |
R    R    R    R
|    |    |    |
+{-{-}{-}{-}+{-}{-}{-}{-}+{-}{-}{-}{-}+{-}{-}{-}+}
                 \_|+
                /
               /
              /\_\_\_
                 {-|}
                  |
         Rf       |
         /{/{-}{-}{-}{-}{-}+{-}{-}{-}{-}o Vout}
         |        |
         |        |
        GND      GND
```

- **Working principle**: Digital inputs weight currents through resistor network
- **Resistance values**: Binary-weighted or R-2R ladder network
- **Conversion**: Output voltage proportional to digital input value
- **Resolution**: Determined by number of bits ($2^n levels$)

Mnemonic

"DART" - "Digital to Analog Resistor Translation"