Subject Name Solutions

1323202 – Winter 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Explain thermal runaway in detail.

Solution

Thermal runaway is a destructive process where a transistor gets increasingly hotter until it fails.

Diagram:

```
flowchart LR
    A[Heat Increases] {-{-} B[Collector Current Rises]}
    B {-{-} C[More Power Dissipation]}
    C {-{-} D[More Heat Generated]}
    D {-{-} A}
```

- **Cause**: Increased temperature decreases base-emitter voltage
- **Effect**: Collector current increases with temperature
- **Result**: Self-reinforcing cycle of heating leads to destruction

Mnemonic

"Heat Rises, Current Climbs, Transistor Dies"

Question 1(b) [4 marks]

Draw and explain fixed bias method.

Solution

Fixed bias uses a single resistor from base to voltage supply for biasing.

Circuit Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VCC((+VCC)) {-{-}{-} RB[RB]}
    RB {-{-}{-} B[B]}
    B {-{-}{-} BE[BE Junction]}
    BE {-{-}{-} E[E]}
    E {-{-}{-} GND((GND))}
    B {-{-}{-} BC[BC Junction]}
    BC {-{-}{-} C[C]}
    C {-{-}{-} RC[RC]}
    RC {-{-}{-} VCC}
{Highlighting}
{Shaded}
```

- **Working**: Base current (IB) = (VCC - VBE)/RB
- **Characteristics**: Simple circuit but poor stability
- **Disadvantage**: Highly sensitive to temperature variations
- **Application**: Used in small signal circuits where stability isn't critical

Mnemonic

"Fixed Bias: One Resistor, Poor Stability"

Question 1(c) [7 marks]

List the biasing methods. Draw the circuit of voltage divider type bias method and explain it.

Solution

The biasing methods for transistors include several techniques for establishing proper operating points.

Table 1: Transistor Biasing Methods

Method	Stability	Complexity	Temperature Sensitivity
Fixed Bias	Poor	Simple	High
Collector-to-Base Bias	Medium	Medium	Medium
Voltage Divider Bias	Excellent	Complex	Low
Emitter Bias	Good	Medium	Low

Circuit Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VCC((+VCC)) {-{-}{-} R1[R1]}
    VCC {-{-}{-} RC[RC]}
    R1 {-{-}{-} N1((Node))}
    N1 {-{-}{-} R2[R2]}
    N1 {-{-}{-} B[Base]}
    B {-{-}{-} BE[BE Junction]}
    BE {-{-}{-} E[Emitter]}
    E {-{-}{-} RE[RE]}
    RE {-{-}{-} GND((GND))}
    B {-{-}{-} BC[BC Junction]}
    BC {-{-}{-} C[Collector]}
    C {-{-}{-} RC}
    R2 {-{-}{-} GND}
{Highlighting}
{Shaded}
```

- **Working**: R1-R2 divider creates stable base voltage
- **Advantage**: Less affected by variations and temperature
- **Key feature**: RE provides negative feedback stabilization
- **Application**: Most widely used in amplifier circuits

Mnemonic

"Divide and Rule for Stable Bias"

Question 1(c OR) [7 marks]

Draw and explain DC load line for common emitter amplifier.

Solution

DC load line represents all possible operating points of a transistor.
Graph:

Mermaid Diagram (Code)

```
{Shaded}
```

```
{Highlighting}[]
graph TD
    subgraph DC Load Line
    A["VCE=VCC (IC=0)"] {-{-}{-} B["IC=VCC/RC (VCE=0)"]}
    Q["Q{-Point (Operating Point)"] }
    end
    style Q fill:\#f00,stroke:\#333,stroke{-width:2px}
{Highlighting}
{Shaded}
```

Equation Table:

Parameter	Equation	Description
Maximum VCE	VCC	When IC = 0
Maximum IC	VCC/RC	When VCE = 0
Load Line Equation	IC = (VCC - VCE)/RC	All possible operating points
Q-point	Set by biasing	Stable operation point

- **Purpose**: Graphically shows relationship between IC and VCE
- **Significance**: Helps determine operating point (Q-point)
- **Application**: Essential for amplifier design and analysis

Mnemonic

"Maximum Current or Maximum Voltage, Never Both"

Question 2(a) [3 marks]

Explain term (i) Gain (ii) Bandwidth.

Solution

These are key parameters that describe amplifier performance.

Table 2: Amplifier Parameters

Parameter	Definition	Unit	Significance
Gain	Ratio of output to input signal	dB	Amplification power
Bandwidth	Range of frequencies with gain not less than 70.7% of maximum	Hz	Useful frequency range

- **Gain Types**: Voltage gain (Av), Current gain (Ai), Power gain (Ap)
- **Bandwidth Formula**: BW = fH - fL (Higher cutoff - Lower cutoff)
- **Related Parameter**: Gain-Bandwidth Product (constant for a specific amplifier)

Mnemonic

"Gain Makes Bigger, Bandwidth Makes Broader"

Question 2(b) [4 marks]

List advantages and disadvantages of negative feedback in amplifier.

Solution

Negative feedback significantly improves amplifier performance but with tradeoffs.

Table 3: Negative Feedback Characteristics

Advantages	Disadvantages
Increased bandwidth	Reduced gain
Reduced distortion	More input signal required
Improved stability	More complex circuit
Better noise immunity	Potential oscillation if improperly designed
Controlled input/output impedances	Higher power consumption

Mnemonic

"Stabilize Wide And Clean, Just Give Up Gain"

Question 2(c) [7 marks]

Draw and explain Hartley oscillator.

Solution

Hartley oscillator generates sine waves using inductive feedback.
Circuit Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VCC((+VCC)) {-{-}{-} RC[RC]}
    RC {-{-}{-} C[Collector]}
    C {-{-}{-} C1[C1]}
    C1 {-{-}{-} B[Base]}
    B {-{-}{-} RB1[RB1]}
    RB1 {-{-}{-} VCC}
    B {-{-}{-} RB2[RB2]}
    RB2 {-{-}{-} GND((GND))}
    C {-{-}{-} OUT((Output))}
    E[Emitter] {-{-}{-} L2[L2]}
    L2 {-{-}{-} GND}
    C1 {-{-}{-} L1[L1]}
    L1 {-{-}{-} L2}
    E {-{-}{-} BE[BE Junction]}
    BE {-{-}{-} B}
    E {-{-}{-} CE[CE]}
    CE {-{-}{-} GND}
{Highlighting}
{Shaded}
```

- **Frequency Determination**: By L1, L2 and C1 values (f = 1/2 $\sqrt(L \times C)$)
- **Feedback Mechanism**: Inductive voltage divider (L1 and L2)
- **Identifying Feature**: Tapped inductor or two inductors in series
- **Applications**: RF signal generation, radio transmitters, communication systems

Mnemonic

"Hartley Has Helpful Inductors"

Question 2(a OR) [3 marks]

State and explain Barkhausen criterion of oscillation.

Solution

Barkhausen criteria define conditions for sustained oscillations.
The Two Main Criteria:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A["Loop Gain = 1"] {-{-}{} C["Sustained Oscillation"]}
    B["Phase Shift = 360^"] {-{-}{} C}
{Highlighting}
{Shaded}
```

- **Loop Gain Condition**: |A | = 1 (exactly 1 for sustained oscillation)
- **Phase Shift Condition**: A $= 0° or 360° (signal reinforcement)$
- **Practical Design**: Initial |A | > 1, eventually stabilizes at |A | = 1

Mnemonic

"For Oscillation: Unit Gain, Zero Phase"

Question 2(b OR) [4 marks]

Compare negative and positive feedback amplifier.

Solution

Feedback type dramatically changes amplifier behavior.
Comparison Table:

Parameter	Negative Feedback	Positive Feedback
Gain	Decreases	Increases
Bandwidth	Increases	Decreases
Distortion	Reduces	Increases
Stability	Improves	Reduced (may oscillate)
Noise	Reduces	Amplifies
Applications	Stable amplifiers	Oscillators, triggers
Input/Output impedance	Controllable	Less predictable

Mnemonic

"Negative Stabilizes, Positive Oscillates"

Question 2(c OR) [7 marks]

Draw and explain colpitt's oscillator.

Solution

Colpitt's oscillator uses capacitive voltage divider for feedback.
Circuit Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VCC((+VCC)) {-{-}{-} RC[RC]}
    RC {-{-}{-} C[Collector]}
    C {-{-}{-} L[L]}
```

```
    L {-{-}{-} N((Node))}
    N {-{-}{-} C1[C1]}
    N {-{-}{-} C2[C2]}
    C2 {-{-}{-} GND((GND))}
    C1 {-{-}{-} B[Base]}
    B {-{-}{-} RB1[RB1]}
    RB1 {-{-}{-} VCC}
    B {-{-}{-} RB2[RB2]}
    RB2 {-{-}{-} GND}
    C {-{-}{-} CB[Coupling Capacitor]}
    CB {-{-}{-} OUT((Output))}
    E[Emitter] {-{-}{-} RE[RE]}
    RE {-{-}{-} GND}
    C1 {-{-}{-} E}
    E {-{-}{-} BE[BE Junction]}
    BE {-{-}{-} B}
{Highlighting}
{Shaded}
```

- **Frequency Determination**: By L, C1 and C2 values (f = 1/2 $\sqrt{(L \times Ceq)}$)
- **Feedback Mechanism**: Capacitive voltage divider (C1 and C2)
- **Identifying Feature**: Two capacitors in series across inductor
- **Advantage**: More stable frequency than Hartley

Mnemonic

"Colpitts Catches Capacitive Current"

Question 3(a) [3 marks]

Explain about DIAC.

Solution

DIAC (Diode for Alternating Current) is a bidirectional trigger diode.
Symbol and Structure:

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

- **Operation**: Conducts in both directions after breakdown voltage
- **Characteristic**: Symmetrical V-I curve in both directions
- **Key Parameter**: Breakover voltage (typically 30-40V)
- **Main Application**: Triggering TRIACs in AC power control

Mnemonic

"DIAC: Double Direction Breakdown Device"

Question 3(b) [4 marks]

Explain triggering methods of SCR.

Solution

SCR can be triggered to conduct by several methods.

Table 4: SCR Triggering Methods

Method	Description	Advantages	Limitations
Gate Triggering	Current pulse at gate	Most common, controllable	Requires control circuit
Temperature	High temperature	No external circuit	Uncontrolled, unreliable
Voltage	Exceeding breakover voltage	No external circuit	Stresses device, uncontrolled
dv/dt	Rapid voltage rise	Simple	Can cause unwanted triggering
Light	Photons hitting junction	Electrical isolation	Requires special packaging

Mnemonic

"Gate Voltage Temperature Rate Light"

Question 3(c) [7 marks]

Draw symbol and construction of SCR. Also draw and explain V-I characteristic of SCR.

Solution

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

Symbol:

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

Construction:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Anode: P+] {-{-}{-} J3[Junction J3]}
    J3 {-{-}{-} N[N{-}layer]}
    N {-{-}{-} J2[Junction J2]}
    J2 {-{-}{-} P[P{-}layer]}
    P {-{-}{-} G[Gate]}
    P {-{-}{-} J1[Junction J1]}
    J1 {-{-}{-} K[Cathode: N+]}
{Highlighting}
{Shaded}
```

V-I Characteristic:

Mermaid Diagram (Code)

```
{Shaded}
```

```
{Highlighting}[]
graph TD
    subgraph V{-I Characteristic}
    A["Forward Blocking{br /{}(OFF State)"] {-}{-}{} B["Forward Conduction{}br /{}(ON State)"]}
    C["Reverse Blocking"] {-{-}{} D["Reverse Breakdown"]}
    end
{Highlighting}
{Shaded}
```

- **Forward Blocking**: Low current until triggering
- **Forward Conduction**: High current after triggering (latched)
- **Holding Current**: Minimum current to maintain conduction
- **Latching Current**: Minimum current to start latching
- **Reverse Blocking**: Blocks current in reverse direction

Mnemonic

"Trigger Once, Conducts Forever, Until Current Falls"

Question 3(a OR) [3 marks]

Explain about natural commutation technique of SCR.

Solution

Natural commutation turns off SCR without external circuit when AC current naturally reaches zero.
Process Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A["AC Supply{br /{}Crosses Zero"] {-}{-}{} B["Current Falls{}br /{}Below Holding"]}
    B {-{-}{} C["SCR Turns OFF{}br /{}Naturally"]}
    C {-{-}{} D["Remains OFF Until{}br /{}Next Trigger"]}
{Highlighting}
{Shaded}
```

- **Principle**: Uses natural zero-crossing of AC supply
- **Advantage**: No additional commutation circuit required
- **Application**: AC power control circuits, light dimmers
- **Limitation**: Only works with AC supplies, not DC

Mnemonic

"Natural Commutation: Zero Current, Zero Effort"

Question 3(b OR) [4 marks]

Explain about Opto-couplers.

Solution

Opto-couplers provide electrical isolation using light transmission.
Structure:

```
  .{-{-}{-}{-}{-}{-}{-}{-}{-}.}
  |  LED    |{}
  |         | {}
  {{-}{-}{-}{-}{-}{-}{-}{-}  }
                {}
```

```
.{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}.  //}
|PhotoDet | //
|         |//
{{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}}
```

Table 5: Opto-coupler Types

Type	Photodetector	Speed	CTR	Applications
Standard	Phototransistor	Medium	20-100%	General isolation
High-speed	Photodiode	Fast	10-50%	Digital communication
TRIAC	Photo-TRIAC	Slow	N/A	AC power control
Linear	Photodarlington	Slow	100-1000%	Analog signals

- **CTR**: Current Transfer Ratio (output/input current)
- **Key Feature**: Complete electrical isolation between circuits
- **Benefits**: Noise immunity, voltage level shifting, safety

Mnemonic

"Light Leaps gaps Electrons Can't"

Question 3(c OR) [7 marks]

Draw symbol and construction of TRIAC. Also draw and explain V-I characteristic of TRIAC.

Solution

TRIAC (Triode for Alternating Current) is a bidirectional three-terminal semiconductor device.

Symbol:

```
    MT2
     |
     |
   {-{-}{-}{-}{-}}
   |   |
G{-{-}|   |}
   |   |
   {-{-}{-}{-}{-}}
     |
     |
    MT1
```

Construction:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    MT2[Main Terminal 2] {-{-}{-} P1[P{-}layer]}
    P1 {-{-}{-} N1[N{-}layer]}
    N1 {-{-}{-} P2[P{-}layer]}
    P2 {-{-}{-} N2[N{-}layer]}
    P2 {-{-}{-} G[Gate]}
    N2 {-{-}{-} MT1[Main Terminal 1]}
{Highlighting}
{Shaded}
```

V-I Characteristic:

Mermaid Diagram (Code)

```
{Shaded}
```

```
{Highlighting}[]
graph TD
    subgraph Quadrant I
    A1["MT2+, MT1{-{}br /{}Forward Blocking"] {-}{-}{} B1["MT2+, MT1{-}{}br /{}Forward Conducting"]}
    end
    subgraph Quadrant III
    A2["MT2{-, MT1+{}br /{}Reverse Blocking"] {-}{-}{} B2["MT2{-}, MT1+{}br /{}Reverse Conducting"]}
    end
{Highlighting}
{Shaded}
```

- **Bidirectional**: Conducts in both directions after triggering
- **Quadrant Operation**: Four triggering modes based on polarities
- **Applications**: AC power control, light dimmers, motor control
- **Advantage over SCR**: Controls both halves of AC cycle

Mnemonic

"TRIAC: Two-way Road In AC Circuits"

Question 4(a) [3 marks]

State characteristics of ideal Op-Amp.

Solution

An ideal Op-Amp has perfect characteristics that real Op-Amps approximate.

Table 6: Ideal Op-Amp Characteristics

Parameter	Ideal Value	Meaning
Open-loop gain	Infinite	Amplifies smallest input difference
Input impedance	Infinite	Draws no current from source
Output impedance	Zero	Can drive any load
Bandwidth	Infinite	Works at all frequencies
CMRR	Infinite	Rejects common-mode signals
Slew rate	Infinite	Instantaneous output change
Offset voltage	Zero	No output with zero input

Mnemonic

"Infinite Gain, Impedance, Bandwidth; Zero Offset, Output Z"

Question 4(b) [4 marks]

Draw and explain monostable multivibrator using 555 timer IC.

Solution

Monostable multivibrator produces single pulse of fixed duration when triggered.
Circuit:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VCC((+VCC)) {-{-}{-} R[R]}
    R {-{-}{-} DIS[7:DIS]}
    R {-{-}{-} RST[4:RST]}
    R {-{-}{-} VCC\_PIN[8:VCC]}
    TRG[2:TRIG] {-{-}{-} GND((GND))}
```

```
    THR[6:THRES] {-{-}{-} C[C]}
    C {-{-}{-} GND}
    TRG {-{-}{-} SW[Trigger Switch]}
    SW {-{-}{-} GND}
    DIS {-{-}{-} THR}
    VCC\_PIN {-{-}{-} IC[555 Timer]}
    RST {-{-}{-} IC}
    TRG {-{-}{-} IC}
    THR {-{-}{-} IC}
    IC {-{-}{-} OUT[3:OUT]}
    IC {-{-}{-} CTRL[5:CTRL]}
    CTRL {-{-}{-} CC[0.01µF]}
    CC {-{-}{-} GND}
    GND {-{-}{-} GND\_PIN[1:GND]}
    GND\_PIN {-{-}{-} IC}
    OUT {-{-}{-} Output((Output))}
{Highlighting}
{Shaded}
```

- **Operation**: Negative trigger produces output pulse with duration T = 1.1RC
- **Stable State**: Output LOW until triggered
- **Timing Control**: R and C values determine pulse width
- **Retriggering**: Can be retriggered after timeout

Mnemonic

"One Shot Wonder: Trigger Once, Pulse Once"

Question 4(c) [7 marks]

Draw and explain Inverting amplifier using IC 741. Also draw input and output waveforms.

Solution

Inverting amplifier reverses polarity while amplifying input signal.
Circuit:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    IN((Input)) {-{-}{-} Rin[Rin]}
    Rin {-{-}{-} INV[2:Inv]}
    INV {-{-}{-} FB[Feedback]}
    FB {-{-}{-} Rf[Rf]}
    Rf {-{-}{-} OUT((Output))}
    NINV[3:Non{-Inv] {-}{-}{-} GND((GND))}
    INV {-{-}{-} IC[741]}
    NINV {-{-}{-} IC}
    IC {-{-}{-} OUT}
    IC {-{-}{-} VCC[7:+VCC]}
    IC {-{-}{-} VEE[4:{-}VEE]}
{Highlighting}
{Shaded}
```

Waveforms:

```
Input:     /{-      /{-}}
          /   {    /   }
     \_\_\_\_/     {\_\_/     \_\_\_\_}

Output:   {    /    /}
```

```
          {  /    /}
      \_\_\_\_\_\_{/\_\_\_\_/\_\_\_\_\_\_\_\_}

             180^ phase shift
```

- **Gain Equation**: Av = -Rf/Rin (negative sign indicates inversion)
- **Input Impedance**: Equal to Rin
- **Virtual Ground**: Inverting input maintained near 0V
- **Bandwidth**: Depends on gain (higher gain = lower bandwidth)
- **Applications**: Signal conditioning, audio amplifiers

Mnemonic

"Flips and Multiplies by Rf/Rin"

Question 4(a OR) [3 marks]

Draw symbol and pin diagram of IC 741.

Solution

The 741 is a popular general-purpose operational amplifier.
Symbol:

```
        |{ }
        | {}
Input {-{-}|+ }
        |   {}
        |    |{-{-}{-}{-} Output}
        |   /
Input {-{-}|- /}
        | /
        |/
```

8-Pin DIP Package:

```
       \_\_\_\_\_\_\_\_
      |       |
NC 1{-{-}|       |{-}{-}8 Vcc+}
      |       |
{-IN 2{-}{-}|  741  |{-}{-}7 Output}
      |       |
+IN 3{-{-}|       |{-}{-}6 NC}
      |       |
Vcc{- 4{-}{-}|\_\_\_\_\_\_\_\_|{-}{-}5 Offset Null}
```

- **Pin Functions**: Inverting input, non-inverting input, output, power supplies
- **Optional Pins**: Offset null, no connection
- **Power Supply**: Typically $\pm 15V or \pm 12V dual supply$

Mnemonic

"Never Invert Plus, Very Output Not Connected"

Question 4(b OR) [4 marks]

Explain term (i) CMRR (II) Slew Rate.

Solution

These parameters define operational amplifier performance limits.

Table 7: Key Op-Amp Parameters

Parameter	Definition	Typical Value	Significance
CMRR (Common Mode Rejection Ratio)	Ratio of differential gain to common-mode gain	90-120 dB	Higher is better
Slew Rate	Maximum rate of output voltage change	0.5-50 V/ s	Higher for faster signals

- **CMRR Formula**: CMRR = 20 $\log_{10}(Ad/Acm)dB$
- **CMRR Importance**: Rejects noise common to both inputs
- **Slew Rate Formula**: SR = dVo/dt (max)
- **Slew Rate Limitation**: Causes distortion at high frequencies

Mnemonic

"CMRR Crushes Common Noise, Slew Rate Shows Speed"

Question 4(c OR) [7 marks]

Draw and explain Astable multivibrator using 555 timer IC.

Solution

Astable multivibrator generates continuous square waves without external trigger.
Circuit:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VCC((+VCC)) {-{-}{-} RA[RA]}
    RA {-{-}{-} RB[RB]}
    RB {-{-}{-} DIS[7:DIS]}
    RA {-{-}{-} RST[4:RST]}
    RA {-{-}{-} VCC\_PIN[8:VCC]}
    TRG[2:TRIG] {-{-}{-} C[C]}
    THR[6:THRES] {-{-}{-} C}
    C {-{-}{-} GND((GND))}
    TRG {-{-}{-} THR}
    VCC\_PIN {-{-}{-} IC[555 Timer]}
    RST {-{-}{-} IC}
    TRG {-{-}{-} IC}
    THR {-{-}{-} IC}
    IC {-{-}{-} OUT[3:OUT]}
    IC {-{-}{-} CTRL[5:CTRL]}
    CTRL {-{-}{-} CC[0.01µF]}
    CC {-{-}{-} GND}
    GND {-{-}{-} GND\_PIN[1:GND]}
    GND\_PIN {-{-}{-} IC}
    OUT {-{-}{-} Output((Output))}
    DIS {-{-}{-} THR}
{Highlighting}
{Shaded}
```

Output Waveform:

```
   HIGH  \_\_\_\_      \_\_\_\_      \_\_\_\_
```

```
        |    |    |    |    |    |
        |    |    |    |    |    |
   LOW  |\_\_\_\_|    |\_\_\_\_|    |\_\_\_\_|

        | T1 | T2 | T1 | T2 | T1 |
```

- **Timing**: T1 = 0.693(RA+RB)C, T2 = 0.693(RB)C
- **Frequency**: f = 1.44/((RA+2RB)C)
- **Duty Cycle**: Can be adjusted by RA and RB
- **Applications**: Clock generators, LED flashers, tone generators

Mnemonic

"Always Oscillating, Never Stopping"

Question 5(a) [3 marks]

Draw basic block diagram of regulated power supply and explain it.

Solution

A regulated power supply converts AC to stable DC voltage.
Block Diagram:

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

- **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
- **Output**: Stable DC voltage for electronic circuits

Mnemonic

"Transformer Rectifies Filters Regulates"

Question 5(b) [4 marks]

Draw and explain summing amplifier using Op-amp.

Solution

Summing amplifier adds multiple input signals with weighted proportions.
Circuit:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    IN1((V1)) {-{-}{-} R1[R1]}
    IN2((V2)) {-{-}{-} R2[R2]}
    IN3((V3)) {-{-}{-} R3[R3]}
    R1 {-{-}{-} SUM((Summing Point))}
    R2 {-{-}{-} SUM}
    R3 {-{-}{-} SUM}
    SUM {-{-}{-} INV[Inv Input]}
```

```
    INV {-{-}{-} IC[Op{-}Amp]}
    IC {-{-}{-} OUT((Output))}
    OUT {-{-}{-} Rf[Rf]}
    Rf {-{-}{-} SUM}
    NINV[Non{-Inv Input] {-}{-}{-} GND((GND))}
    NINV {-{-}{-} IC}
{Highlighting}
{Shaded}
```

- **Output Equation**: Vout = -Rf(V1/R1 + V2/R2 + V3/R3)
- **Special Case**: When all resistors equal, Vout = -Rf/R $\times(V1 + V2 + V3)$
- **Applications**: Audio mixing, analog computers, signal averaging
- **Variations**: Inverting and non-inverting configurations available

Mnemonic

"Multiple Inputs, One Output, Weighted Addition"

Question 5(c) [7 marks]

Draw and explain the circuit diagram of 3 terminal voltage regulator using IC LM317 with adjustable output voltage.

Solution

LM317 is a versatile adjustable voltage regulator with output range of 1.25V to 37V.
Circuit:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VIN((Vin)) {-{-}{-} C1[C1]}
    C1 {-{-}{-} IN[Input]}
    IN {-{-}{-} LM317[LM317]}
    LM317 {-{-}{-} OUT[Output]}
    OUT {-{-}{-} C2[C2]}
    C2 {-{-}{-} VOUT((Vout))}
    OUT {-{-}{-} R1[R1=240Ω]}
    R1 {-{-}{-} ADJ[Adjust]}
    ADJ {-{-}{-} R2[R2]}
    R2 {-{-}{-} GND((GND))}
    ADJ {-{-}{-} LM317}
    C2 {-{-}{-} GND}
    C1 {-{-}{-} GND}
{Highlighting}
{Shaded}
```

- **Output Voltage**: VOUT = 1.25V(1 + R2/R1)
- **Fixed Components**: R1 = 240Ω, reference voltage = 1.25V
- **Adjustability**: Changing R2 sets desired output voltage
- **Protection Features**: Current limiting, thermal shutdown
- **Applications**: Variable power supplies, battery chargers
- **Advantages**: Few external components, robust protection

Mnemonic

"Adjust with R2, Reference Stays at 1.25"

Question 5(a OR) [3 marks]

State full form of SMPS. Also state applications of SMPS.

Solution

SMPS stands for Switch Mode Power Supply, a modern efficient power conversion technology.
Applications Table:

Application	SMPS Type	Advantages
Computer Power Supply	ATX	High efficiency, multiple outputs
Mobile Phone Chargers	Flyback	Compact size, lightweight
LED Drivers	Buck	Efficient dimming capability
TV Power Supply	Forward	Good regulation, multiple outputs
Industrial Controls	Push-Pull	High power capability
Battery Chargers	Boost	Adjustable charging profiles

- **Key Benefits**: High efficiency (80-95%), small size, lightweight
- **Drawbacks**: EMI generation, more complex circuits

Mnemonic

"Switch Mode Powers Small devices"

Question 5(b OR) [4 marks]

Draw and explain differentiator using Op-amp.

Solution

Differentiator produces output proportional to rate of change of input.
Circuit:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    IN((Input)) {-{-}{-} C[C]}
    C {-{-}{-} INV[Inv Input]}
    INV {-{-}{-} IC[Op{-}Amp]}
    IC {-{-}{-} OUT((Output))}
    OUT {-{-}{-} Rf[Rf]}
    Rf {-{-}{-} INV}
    NINV[Non{-Inv Input] {-}{-}{-} GND((GND))}
    NINV {-{-}{-} IC}
{Highlighting}
{Shaded}
```

Input/Output Waveforms:

```
Input:      \_\_\_
           /   {}
          /     {\_\_\_}
         /
\_\_\_\_\_\_\_\_/

Output:    |
           |
     \_\_\_\_\_\_|\_\_\_\_\_
         / {}
        /   {}
```

- **Equation**: Vout = -RC $\times d(Vin)/dt$

- **Function**: Converts square wave to spikes, triangle to square
- **Practical Issue**: High noise sensitivity
- **Modification**: Small resistor in series with C to limit high-frequency gain
- **Applications**: Waveshaping, rate-of-change detection

Mnemonic

"Rate of Change Goes In, Amplitude Comes Out"

Question 5(c OR) [7 marks]

Draw and explain the circuit diagram of -12 V regulated dc power supply.

Solution

A -12V regulated supply provides stable negative voltage for analog circuits.
Circuit Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    AC((AC Input)) {-{-}{-} TRANS[Transformer]}
    TRANS {-{-}{-} D1[D1]}
    D1 {-{-}{-} D2[D2]}
    D2 {-{-}{-} C1[Filter Cap]}
    C1 {-{-}{-} IC[7912 IC]}
    IC {-{-}{-} C2[0.1μF]}
    C2 {-{-}{-} OUT(({}{-}12V Output))}
    C1 {-{-}{-} GND((GND))}
    IC {-{-}{-} GND}
    C2 {-{-}{-} GND}
    D3[D3] {-{-}{-} D4[D4]}
    D3 {-{-}{-} TRANS}
    D4 {-{-}{-} C1}
{Highlighting}
{Shaded}
```

- **Working Principle**: Full-wave rectifier creates negative voltage
- **Components**: Transformer, bridge rectifier, filter capacitors, 7912 regulator
- **Regulator IC**: 7912 provides fixed -12V output with internal protection
- **Filter Capacitors**: Input capacitor filters ripple, output capacitor improves transient response
- **Applications**: Op-amp negative rail, analog circuits, audio equipment

Mnemonic

"Full Bridge, Big Capacitor, 7912 Regulates Negative"