Subject Name Solutions

1323202 – Summer 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

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

Solution

Diagram:

```
SCR Symbol:        DIAC Symbol:       TRIAC Symbol:
   A                    A1                 MT2
   |                    |                   |






   |                    |                   |
   K                    A2                 MT1
  /                                        /
 /                                        /
G                                        G
```

- **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/ s)	Determines how fast op-amp responds to rapidly changing inputs

- **CMRR formula**: $\text{CMRR} = 20\ \log_{10}(Ad/Acm)dB$
- **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

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    V1 {-{-} R1 {-}{-}{} A}
    V2 {-{-} R2 {-}{-}{} A}
    V3 {-{-} R3 {-}{-}{} A}
    A {-{-} Rf {-}{-}{} B[Op{-}Amp]}
    B {-{-}{} Vout}
    B {-{-} {}{-} {-}{-}{} A}
    A {-{-} {}+ {-}{-}{} Ground}
{Highlighting}
{Shaded}
```

Operation of Summing Amplifier:

- **Circuit function**: Adds multiple input voltages with scaling
- **Output equation**: Vout = -(Rf/R1 $\times V1 + Rf/R2 \times V2 + Rf/R3 \times V3$)
- **Inverting configuration**: Input signals undergo 180°$phaseshift$
- **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)"

Question 1(c OR) [7 marks]

Draw and explain DA converter

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    D0 {-{-} 2^{0}R {-}{-}{} S1}
    D1 {-{-} 2^{1}R {-}{-}{} S2}
    D2 {-{-} 2^{2}R {-}{-}{} S3}
    D3 {-{-} 2^{3}R {-}{-}{} S4}
    S1 \& S2 \& S3 \& S4 {-{-}{} A[Summing Amp]}
    A {-{-}{} Vout}
{Highlighting}
{Shaded}
```

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 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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Increased Temperature] {-{-}{} B[Increased Collector Current]}
    B {-{-}{} C[More Power Dissipation]}
    C {-{-}{} A}
{Highlighting}
{Shaded}
```

- **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

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    Vin {-{-}{} A[Amplifier]}
    A {-{-}{} Vout}
    Vout {-{-} Feedback Network {-}{-}{} B[Subtractor]}
    B {-{-}{} A}
{Highlighting}
{Shaded}
```

Voltage Series Negative Feedback:

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 + A)

Mnemonic

"Series says Sample Voltage, Stabilize Gain"

Question 2(c) [7 marks]

Draw and explain DC load line for common emitter amplifier.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph DC Load Line
    direction LR
    A[Point A: IC=0, VCE=VCC] {-{-}{} B[Operating Point Q]}
    B {-{-}{} C[Point B: IC=VCC/RC, VCE=0]}
    end
{Highlighting}
{Shaded}
```

DC Load Line Characteristics:

- **Definition**: Graphical representation of all possible operating points
- **Equation**: IC = VCC/RC - VCE/RC
- **Key points**:
  - Saturation point (VCE $\approx 0V, IC = VCC/RC$)
  - Cutoff point (IC $\approx 0mA, VCE = VCC$)
  - 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"

Question 2(a OR) [3 marks]

Explain operating point(Q-point) in transistor

Solution

Q-Point (Operating Point):

```
      |
  Ic  |      DC Load Line
      |          /
      |         /
      |        /
      |       * Q-Point
      |      /
```

```
       |     /
       |    /
       |___/____________
          Vce
```

- **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"

Question 2(b OR) [4 marks]

Draw and explain hartley oscillator.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Transistor] {-{-} Feedback {-}{-}{} B[LC Tank Circuit]}
    B {-{-}{} A}
    B {-{-} L1, L2, C {-}{-}{} Output}
{Highlighting}
{Shaded}
```

Hartley Oscillator:

- **Configuration**: Common emitter with tapped inductor feedback
- **Frequency formula**: f = $1/[2\sqrt{(C \times (L1 + L2))}]$
- **Phase shift**: Ensures $360° totalphaseshiftforoscillation$
- **Feedback**: Inductive voltage divider provides positive feedback

Mnemonic

"Hartley Has two coils with inductance for LC oscillation"

Question 2(c OR) [7 marks]

Draw and explain AC load line for common emitter amplifier.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph AC and DC Load Lines
    direction LR
    A[DC Load Line] {-{-}{} B[Q{-}Point]}
    B {-{-}{} C[AC Load Line {-} Steeper]}
    end
{Highlighting}
{Shaded}
```

AC Load Line Characteristics:

- **Definition**: Represents dynamic operation during signal amplification
- **Equation**: ic = (VCC-VCEQ)/R'c - vce/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

Diagram:

```
      Vcc
       |
       R
       |
       |C
       |----Output
       |
      /|
     / |
    /--|
   /   |
  |    |
  B    E
  |    |
  Rb   |
  |    |
  |____|
  |
  Vin
```

- **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 = 1/[2 $\sqrt{(C \times (L1 + L2))}$]
- **Calculation**:
  - Total inductance LT = L1 + L2 = 5mH + 10mH = 15mH = 15×$10^{-3}H$

- C = 0.01µF = $1 \times 10^{-8} F$
- f = $1/[2\sqrt{(15 \times 10^{-3} \times 1 \times 10^{-8})}]$
- f = $1/[2\sqrt{(15 \times 10^{-11})}]$
- f = $1/[2 \times 3.873 \times 10^{-6}]$
- f = $1/[24.33 \times 10^{-6}]$
- f = 41,101 Hz $\approx 41.1 kHz$

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

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph Frequency Response
    direction LR
    A[Low Frequency] {-{-}{} B[Mid Frequency]}
    B {-{-}{} C[High Frequency]}
    end
{Highlighting}
{Shaded}
```

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 $\geq 70.7\% ofmaximumgain$
- **Cutoff frequencies**: Points where gain drops by 3dB (0.707 times max gain)

Mnemonic

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

Question 3(a OR) [3 marks]

Explain in detail barkhausen criterion for oscillation.

Solution

Barkhausen Criterion:

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

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

Mnemonic

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

Question 3(b OR) [4 marks]

Explain the effect of negative feedback on the gain of amplifier

Solution

Effect of Negative Feedback on Amplifier Gain:

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

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

Mnemonic

"Negative Feedback: Less Gain, More Stability"

Question 3(c OR) [7 marks]

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

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[AC Supply] {-{-}{} B[DIAC]}
    B {-{-}{} C[TRIAC]}
    C {-{-}{} D[Fan]}
    E[Variable Resistor] {-{-}{} F[RC Network]}
    F {-{-}{} B}
{Highlighting}
{Shaded}
```

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

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 Construction and Characteristics:

```
          MT2
           |
     ------+------
    /      |      \
   /  P    |    N  \
  +--------+--------+
```

```
   |        |        |
   |   N    |   P    |
   +--------+--------+
   |        |        |
   |   P    |   N    |
   +--------+--------+
    \       |       /
     \      |      /
      ------+------
            |
           MT1
            |
            G
```

I-V Characteristics:

```
    I
    ^
    |      /|
    |     / |
    |    /  |
    |---+---|----> V
    |   /   |
    |  /    |
    | /     |
```

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"

Question 4(a OR) [3 marks]

Write any three application of SCR.

Solution

Applications of SCR:

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"

Question 4(b OR) [4 marks]

Explain holding current and latching current with reference to SCR

Solution

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"

Question 4(c OR) [7 marks]

Draw and explain in detail block diagram of operational amplifier.

Solution

Operational Amplifier Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input Differential Stage] {-{-}{} B[Intermediate Stage]}
    B {-{-}{} C[Output Stage]}
    D[Bias Circuit] {-{-}{} A \& B \& C}
    E[Frequency Compensation] {-{-}{} B}
{Highlighting}
{Shaded}
```

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

Inverting Amplifier Circuit:

```
          Rf
          ___
    Vin---| |-----+
          ---     |
                  |
                 _|_
    +-------+   /   \
    |       |---+     +---Vout
    |       |   \___/
Vin-+       |     |
    |Op-Amp|      |
    +-------+     |
                  |
                 ---
                 ///
```

- **Gain formula**: Vout = -(Rf/Rin) $\times Vin$
- **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 Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Transformer] {-{-}{} B[Rectifier]}
    B {-{-}{} C[Filter]}
    C {-{-}{} D[Regulator]}
    D {-{-}{} E[Output]}
    F[Reference] {-{-}{} D}
    G[Feedback] {-{-}{} D}
{Highlighting}
```

```
{Shaded}
```

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
- **Reference**: Provides stable comparison voltage
- **Feedback**: Monitors output and adjusts regulation

Mnemonic

"Transform, Rectify, Filter, Regulate for Stable DC"

Question 5(c) [7 marks]

Draw and explain astable multivibrator.

Solution

Astable Multivibrator Using 555 Timer:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph 555 Timer
    A[Threshold] {-{-}{} B[Flip{-}Flop]}
    C[Trigger] {-{-}{} B}
    B {-{-}{} D[Output]}
    end
    E[R1] \& F[R2] \& G[C] {-{-}{} A \& C}
{Highlighting}
{Shaded}
```

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
- **Output waveform**: Rectangular with duty cycle based on R1/R2 ratio
- **Frequency formula**: f = 1.44/((R1+2R2))
- **Applications**: Clock generation, LED flashers, tone generators
- **Advantages**: Simple design, stable frequency, adjustable duty cycle

Mnemonic

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

Question 5(a OR) [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"

Question 5(b OR) [4 marks]

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

Solution

Negative Voltage Regulator Circuit:

```
     +---------+
     |         |
Vin--+         +---Vout (-5V)
     | 7905    |
     |         |
     +---------+
         |
        ---
        ///
```

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"

Question 5(c OR) [7 marks]

Draw and explain the block diagram of SMPS.

Solution

SMPS Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[AC Input] {-{-}{} B[EMI Filter]}
    B {-{-}{} C[Rectifier \& Filter]}
    C {-{-}{} D[High{-}Frequency Inverter]}
    D {-{-}{} E[Transformer]}
    E {-{-}{} F[Output Rectifier]}
    F {-{-}{} G[Output Filter]}
    G {-{-}{} H[DC Output]}
    I[Feedback \& Control] {-{-}{} D}
```

```
    H {-{-}{} I}
{Highlighting}
{Shaded}
```

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

Applications:

- Computer power supplies
- Electronic device chargers
- Industrial power systems

Mnemonic

"Switch More Power Smartly: High frequency saves size and energy"