Subject Name Solutions

4341105 – Winter 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

What is negative feedback? List out advantages and disadvantages of negative feedback.

Solution

Negative feedback is feeding a portion of output signal back to the input with $180^\circ phaseshifttoreducetheinputsignal.$

Advantages	Disadvantages
Increased stability	Reduced gain
Reduced distortion	Complex circuit design
Increased bandwidth	More components required
Reduced noise	Higher power consumption

Mnemonic

"SIRS" - Stability Improved, Reduced distortion, Sensitivity decreased

Question 1(b) [4 marks]

Describe the effect of negative feedback on frequency response and distortion of an amplifier.

Solution

Negative feedback improves both frequency response and reduces distortion in amplifiers.
Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Amplifier without feedback] {-{-}{} B[Narrow bandwidth]}
    C[Amplifier with negative feedback] {-{-}{} D[Wider bandwidth]}
    E[Input with harmonics] {-{-}{} F[Amplifier without feedback] {-}{-}{} G[Output with more harmonics
    E {-{-}{} H[Amplifier with negative feedback] {-}{-}{} I[Output with fewer harmonics]}
{Highlighting}
{Shaded}
```

Effect on	Without feedback	With negative feedback
Frequency response	Narrow bandwidth	Wider bandwidth
Distortion	Higher harmonics	Reduced harmonics

Mnemonic

"WIDE" - With negative feedback, Improved response, Distortion reduced, Extended bandwidth

Question 1(c) [7 marks]

Derive an equation for overall gain of negative feedback voltage amplifier.

Solution

The equation for overall gain of negative feedback voltage amplifier can be derived as follows:
Diagram:

```
Input +{-{-}{-}{-}{-}+      +{-}{-}{-}{-}{-}{-}{-}+}
Vi {-{-}|  Σ  |{-}{-}{-}{-}{-}|       |{-}{-}{-}{-} Vo (Output)}
      +{-{-}{-}{-}{-}+      |   A   |}
         \^{        |       |}
         |        +{-{-}{-}{-}{-}{-}{-}+}
         |            |
         |        +{-{-}{-}{-}{-}{-}{-}+}
         +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}|      |}
                  +{-{-}{-}{-}{-}{-}{-}+}
```

- **Input equation**: V' = Vi - Vo
- **Output equation**: Vo = AV'
- **Substituting**: Vo = A(Vi - Vo)
- **Solving for Vo**: Vo = AVi - A Vo
- **Rearranging**: Vo(1 + A) = AVi
- **Final equation**: Vo/Vi = A/(1 + A) = Af

Mnemonic

"LOOP" - Look at Original Open-loop gain and Proceed with feedback

Question 1(c) OR [7 marks]

Compare voltage shunt amplifier and current series amplifier.

Solution

Parameter	Voltage Shunt Amplifier	Current Series Amplifier
Input	Voltage	Current
Output	Current	Voltage
Feedback network connection	Parallel at input	Series at input
Input impedance	Decreased	Increased
Output impedance	Increased	Decreased
Gain	Current gain decreases	Voltage gain decreases
Application	Current amplification	Voltage amplification

Diagram:

```
graph TB
    subgraph "Voltage Shunt"
        A1[Input voltage] {-{-} B1[Shunt connected  ]}
        B1 {-{-} C1[Amplifier]}
        C1 {-{-} D1[Output current]}
    end
    subgraph "Current Series"
        A2[Input current] {-{-} B2[Series connected  ]}
        B2 {-{-} C2[Amplifier]}
        C2 {-{-} D2[Output voltage]}
    end
```

Mnemonic

"VICS" - Voltage shunt In, Current out Series has opposite

Question 2(a) [3 marks]

Discuss Barkhausen's criteria for oscillation.

Solution

Barkhausen's criteria states that for sustained oscillations, the following conditions must be met:

Criteria	Requirement
Loop gain	|A | = 1 (magnitude equals 1)
Phase shift	Total phase shift around loop = $0° or 360°$

Diagram:

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

Mnemonic

"LOOP" - Loop gain One, Oscillation needs Phase shift zero

Question 2(b) [4 marks]

Draw circuit diagram of Hartley oscillator and Colpitts oscillator.

Solution

Hartley Oscillator:

```
 +{-{-}{-}{-}{-}+     +{-}{-}{-}{-}||{-}{-}{-}{-}{-}{-}+}
 |     |     |           |
 +     |     C1          |
===    +{-{-}{-}{-}{-}+           |}
GND    |     |           |
       |     Z    +{-{-}{-}{-}{-}{-}+}
       |     Z    |      |
       |     Z    |      |
       +{-{-}{-}{-}{-}+    |      |}
         L1  |    |  L2  |
             |    |      |
             +{-{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}+}
             |    |
             |    |
       +{-{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}+}
       |     |    |     |
       |  Q  |    |     |
       |     |    |     |
       +{-{-}+{-}{-}+    |     |}
          |       |     |
          +{-{-}{-}{-}{-}{-}{-}+     |}
          |             |
         === GND        |
                        |
 +{-{-}{-}{-}||{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
 |       C2
 |
=== GND
```

Colpitts Oscillator:

```
 +{-{-}{-}{-}{-}+    +{-}{-}{-}{-}||{-}{-}{-}{-}{-}+}
 |     |     |     C1    |
 +     |     |           |
===    +{-{-}{-}{-}{-}+           |}
GND    |     |           |
       |     |    +{-{-}{-}{-}{-}{-}+}
       |     |    |      |
       |     Z    |      |
       +{-{-}{-}{-}{-}Z    |      |}
         L   Z    |      |
             |    |      |
             |    |      |
             +{-{-}{-}{-}+{-}{-}{-}{-}{-}{-}+}
             |    |
             |    |
       +{-{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}+}
       |     |    |     |
       |  Q  |    |     |
       |     |    |     |
       +{-{-}+{-}{-}+    |     |}
          |       |     |
          +{-{-}{-}{-}{-}{-}{-}+     |}
          |             |
         === GND        |
          |             |
          +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
          |
         ===
         C2
         ===
         GND
```

Mnemonic

"HaLs CoCs" - Hartley has inductors in series, Colpitts has Capacitors in series

Question 2(c) [7 marks]

Explain UJT as a relaxation oscillator.

Solution

UJT (Unijunction Transistor) works as a relaxation oscillator by repeatedly charging and discharging a capacitor.

Diagram:

```
      RB1
 B2 +{-{-}{-}///{-}{-}{-}+ VCC}
      |          |
      |          |
      |          |
 +{-{-}{-}{-}|          |}
 |    |          |
 |    |  UJT     |
 |    |          |
 |    |          |
 |    |          |
 |    +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}+ B1}
 |    |
 |    |
 |    |
 C    R
```

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

Phase	Description
Charging	Capacitor charges through R until voltage reaches VP (peak voltage)
Firing	UJT turns ON when emitter voltage reaches VP
Discharge	Capacitor discharges rapidly through UJT
Reset	Voltage falls below valley voltage, UJT turns OFF, cycle repeats

- **Intrinsic standoff ratio**: = RB1/(RB1+RB2)
- **Peak voltage**: VP = + VD
- **Frequency**: f = 1/[R(1/(1-))]

Mnemonic

"CFDR" - Charge, Fire, Discharge, Repeat

Question 2(a) OR [3 marks]

Classify Oscillators.

Solution

Classification	Types
Based on feedback	RC, LC, Crystal
Based on waveform	Sinusoidal, Non-sinusoidal
Based on frequency	Audio, Radio, VHF, UHF
Based on circuit	Hartley, Colpitts, Wien-bridge, RC-phase shift

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Oscillators] {-{-}{} B[RC Oscillators]}
    A {-{-}{} C[LC Oscillators]}
    A {-{-}{} D[Crystal Oscillators]}
    A {-{-}{} E[Relaxation Oscillators]}
    B {-{-}{} F[Wien Bridge]}
    B {-{-}{} G[Phase Shift]}
    C {-{-}{} H[Hartley]}
    C {-{-}{} I[Colpitts]}
    C {-{-}{} J[Clapp]}
    E {-{-}{} K[UJT based]}
    E {-{-}{} L[IC 555 based]}
{Highlighting}
{Shaded}
```

Mnemonic

"SRLC" - Sine waves from RC, LC, and Crystal oscillators

Question 2(b) OR [4 marks]

Explain construction of UJT with its symbol.

Solution

UJT (Unijunction Transistor) consists of a lightly doped N-type silicon bar with electrical connections at both ends (bases) and a P-type emitter junction.

Diagram:

```
Symbol:              Structure:

  B2                     B2
   |                      |
   |                 +{-{-}{-}+{-}{-}{-}+}
   |                 |    |    |
  +{-{-}{-}+          +{-}{-}{-}+{-}{-}{-}+{-}{-}{-}+{-}{-}{-}+}
       |          |   |    |    |    |
       +          |   | N{-type     |}
       |          |   |    |    |    |
  +{-{-}{-}+          |   +{-}{-}{-}+{-}{-}{-}+   |}
   |              |        |         |
   |              |        |         |
  E               |        | P       |
   |              |        |         |
   |             +{-{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}+}
   |                      |
   |                      |
   |                      |
  B1                     B1
```

Component	Description
Base 1 (B1)	Connected to one end of N-type bar
Base 2 (B2)	Connected to other end of N-type bar
Emitter (E)	Connected to P-type region diffused into N-type bar
RB1	Resistance between emitter and B1
RB2	Resistance between emitter and B2

Mnemonic

"BEB" - Bases at Ends, Emitter in Between

Question 2(c) OR [7 marks]

Explain working of Wien Bridge oscillator circuit. List out its application.

Solution

Wien Bridge oscillator produces sine waves using RC network for positive feedback and negative feedback for amplitude stability.

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph "Positive Feedback"
        R1 {-{-}{-} C1}
        R2 {-{-}{-} C2}
    end
    subgraph "Negative Feedback"
        R3
        R4
    end
    A[Op{-Amp] {-}{-}{} Output}
```

```
    R1 \& C1 \& R2 \& C2 {-{-}{} A}
    A {-{-}{} R3 {-}{-}{} R4 {-}{-}{} A}
{Highlighting}
{Shaded}
```

Component	Function
R1, C1 (series)	Positive feedback, phase lead
R2, C2 (parallel)	Positive feedback, phase lag
R3, R4	Negative feedback, amplitude control
Op-Amp	Active amplifier element

Applications:

- Audio signal generators
- Function generators
- Musical instrument tuning
- Test equipment
- Filter circuits

Mnemonic

"APPS" - Audio Production, Pure Sine waves, Stable frequency

Question 3(a) [3 marks]

Differentiate between voltage and power amplifier.

Solution

Parameter	Voltage Amplifier	Power Amplifier
Primary function	Increases voltage level	Increases power level
Output	Low current capability	High current capability
Efficiency	Not critical	Critical parameter
Heat dissipation	Low	High, needs heat sink
Biasing	Class A typically	Class A, B, AB, or C
Applications	Pre-amplification stages	Driving speakers, motors

Mnemonic

"VICE" - Voltage amplifiers Increase voltage, Current not important, Efficiency not critical

Question 3(b) [4 marks]

Derive an equation for Efficiency of class B push pull amplifier.

Solution

Efficiency ( ) of a Class B push-pull amplifier is derived as follows:
Diagram:

```
          +VCC
           |
           |
    +{-{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+}
    |             |
    |      T1     |
   +++            |
    |             |
```

```
   +++     +{-{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+}
    |       |       |       |
Input+{-{-}{-}+ |       |       +{-}{-}{-}+Output}
    |       |       |       |
   +++     +{-{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+}
    |              |
    |       T2     |
    +{-{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+}
           |
           |
          {-VCC}
```

- **AC power output**: $\mathrm{P}_0 = Vrms \times Irms = (Vm/\sqrt{2}) \times (Im/\sqrt{2}) = Vm \times Im/2$
- **DC power input**: PDC = VCC $\times IDC = VCC \times (2/)$
- **Efficiency**: $= \mathrm{P}_0/PDC = (Vm/2)/(VCC \times 2/) = (Vm)/(4)$
- **For maximum swing**: Vm = VCC, so $= /4 = 78.5\%$

Mnemonic

"POP" - Push-pull Output Power = /4 or 78.5%

Question 3(c) [7 marks]

Explain working of Class-B Push Pull Amplifiers along with waveform.

Solution

Class B push-pull amplifier uses two transistors to amplify opposite halves of the input waveform.
Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input Signal] {-{-}{} B[Driver Stage]}
    B {-{-}{} C[Upper Transistor]}
    B {-{-}{} D[Lower Transistor]}
    C {-{-}{} E[Output Transformer]}
    D {-{-}{} E}
    E {-{-}{} F[Output Signal]}

    subgraph "Waveforms"
    direction LR
    G[Input] {-{-}{-} H[T1 Conducts] {-}{-}{-} I[T2 Conducts]}
    end
{Highlighting}
{Shaded}
```

Phase	Description
Positive half	Upper transistor (T1) conducts, T2 is off
Negative half	Lower transistor (T2) conducts, T1 is off
Crossover	Both transistors are near cutoff, causing distortion

Key points:

- **Efficiency**: Approximately 78.5% (/4)
- **Conduction angle**: 180° $foreachtransistor$
- **Crossover distortion**: Due to both transistors being off near zero crossing
- **Advantages**: Higher efficiency, less heat, suitable for high power

Mnemonic

"HOPE" - Half cycle Operation, Push-pull, Efficiency high

Question 3(a) OR [3 marks]

Explain Classification of Power amplifier.

Solution

Class	Conduction Angle	Efficiency	Distortion
Class A	360°	25-30%	Low
Class B	180°	78.5%	Medium
Class AB	$180° - 360°$	50-78.5%	Low-Medium
Class C	<180°	>78.5%	High

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Power Amplifiers] {-{-}{} B[Class A]}
    A {-{-}{} C[Class B]}
    A {-{-}{} D[Class AB]}
    A {-{-}{} E[Class C]}
    B {-{-}{} F[Low distortion, Low efficiency]}
    C {-{-}{} G[Medium distortion, High efficiency]}
    D {-{-}{} H[Low distortion, Medium efficiency]}
    E {-{-}{} I[High distortion, Very high efficiency]}
{Highlighting}
{Shaded}
```

Mnemonic

"ABCE" - As Biasing Changes, Efficiency increases

Question 3(b) OR [4 marks]

Derive an equation for Efficiency of class A power amplifier.

Solution

Efficiency of Class A power amplifier is derived as follows:
Diagram:

```
     +VCC
       |
       |
       Z
       Z RL
       Z
       |
```

```
    +{-{-}{-}+Output}
    |
    |
    Q
    |
    |
  Input
    |
   GND
```

- **Maximum AC power output**: $\mathrm{P}_0 = (Vrms)^2/RL = (VCC/2\sqrt{2})^2/RL = VCC^2/8RL$
- **DC power input**: PDC = VCC $\times IDC = VCC \times (VCC/2RL) = VCC^2/2RL$
- **Efficiency**: $= \mathrm{P}_0/PDC = (VCC^2/8RL)/(VCC^2/2RL) = 1/4 = 25\%$

Mnemonic

"ONE" - Output Never Exceeds 25% efficiency in Class A

Question 3(c) OR [7 marks]

Explain working of Class-A transformer coupled Amplifiers along with waveform.

Solution

Class A transformer coupled amplifier conducts for the full input cycle $(360°)usingatransformerforoutputcoupling.$

Diagram:

```
  +VCC
    |
    |
 +{-{-}+{-}{-}+}
 |     |
 | Pri |
 |     |
 +{-{-}+{-}{-}+}
    |
    +{-{-}{-}+}
    |   |
 Q  |   |
    |   |
    |   +{-{-}+Output}
    |      |
   === C   +{-{-}+{-}{-}+}
    |      |     |
   GND     | Sec |
           |     |
           +{-{-}+{-}{-}+}
              |
             GND
```

Component	Function
Transformer	Matches impedance, removes DC, provides isolation
Transistor	Conducts for full $360°cycle$
Capacitor	AC coupling
VCC	DC power supply

Waveform characteristics:

- Input and output waveforms are in phase
- No crossover distortion
- Full cycle amplification
- Low efficiency (25%)
- Low distortion

Mnemonic

"FACT" - Full cycle Amplification in Class-a with Transformer

Question 4(a) [3 marks]

Define (i) CMRR (ii) Slew Rate

Solution

Parameter	Definition	Typical Value
CMRR	Common Mode Rejection Ratio, the ratio of differential gain to common mode gain	90 dB (IC 741)
Slew Rate	Maximum rate of change of output voltage per unit of time	0.5 V/ s (IC 741)

CMRR: CMRR = 20 $\log_{10}(Ad/Acm) where Adis differential gain and Acm is common mode gain$
Slew Rate: SR = dVout/dt (V/ s)

Mnemonic

"CRiSp" - CMRR Rejects common signals, Slew Rate limits speed

Question 4(b) [4 marks]

Explain inverting amplifier of operational amplifiers with sketch.

Solution

Inverting amplifier provides gain with 180°$phase shift using negative feedback$.
Diagram:

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

Component	Function
Ri	Input resistor
Rf	Feedback resistor

Op-Amp	Amplifies signal with high gain

Key equations:

- **Gain**: A = -Rf/Ri
- **Input impedance**: Z = Ri
- **Bandwidth**: Depends on op-amp and gain

Mnemonic

"IRON" - Inverting, Resistance ratio gives gain, Output Negative phase

Question 4(c) [7 marks]

Explain Op-amp as a Summing amplifier.

Solution

Summing amplifier adds multiple input signals with weighted contributions.
Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    V1[V1] {-{-}{}|R1| A(({}+))}
    V2[V2] {-{-}{}|R2| A}
    V3[V3] {-{-}{}|R3| A}
    A {-{-}{-} B[Op{-}Amp]}
    B {-{-}{-} C[Vout]}
    C {-.{-}{}|Rf| A}
{Highlighting}
{Shaded}
```

Circuit:

```
       R1              Rf
    +{-{-}///{-}{-}+{-}{-}{-}///{-}{-}{-}+}
    |          |            |
V1  |          |            |
    +          |    +{-{-}{-}{-}{-}{-}{-}+}
               |    |       |
    +{-{-}///{-}{-}+    |   +   |}
    |          |{-{-}{-}{-}+{-}{-}{-}+   +{-}{-}{-}{-}+ Vout}
V2  +   R2     |    |   {-   |}
               |    |       |
    +{-{-}///{-}{-}+    +{-}{-}{-}{-}{-}{-}{-}+}
    |          |        |
V3  +   R3     |        |
               |       === GND
              === GND
```

Parameter	Value
Output voltage	Vout = -(Rf/R1)V1 - (Rf/R2)V2 - (Rf/R3)V3 ...
Gain for each input	-Rf/Rn where Rn is input resistor
Equal weight summing	All input resistors equal: R1 = R2 = R3 = Rf

Applications:

- Audio mixers
- Signal processing
- Analog computers
- Weighted averages

Mnemonic

"SARI" - Summing Amplifier Requires Inverting configuration

Question 4(a) OR [3 marks]

Sketch basic Block diagram of an operational amplifier.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input Differential Stage] {-{-}{} B[Intermediate Stage]}
    B {-{-}{} C[Level Shifter]}
    C {-{-}{} D[Output Stage]}
    E[Bias Circuit] {-{-}{} A}
    E {-{-}{} B}
    E {-{-}{} C}
    E {-{-}{} D}
{Highlighting}
{Shaded}
```

Stage	Function
Input differential stage	High input impedance, rejects common mode signals
Intermediate stage	High gain, frequency compensation
Level shifter	Shifts DC level for output stage
Output stage	Low output impedance, current amplification
Bias circuit	Provides proper operating points

Mnemonic

"DILO" - Differential Input, Level shifting, Output amplification

Question 4(b) OR [4 marks]

Explain non inverting amplifier of operational amplifiers with sketch.

Solution

Non-inverting amplifier provides gain without phase inversion using negative feedback.
Diagram:

```
              +{-{-}{-}{-}{-}{-}{-}{-}{-}+}
              |       |
              |   +   |
Vin +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}){-}{-}{-}+   +{-}{-}{-}{-}+ Vout}
              |   {-   |}
              |       |
              +{-{-}{-}+{-}{-}{-}+}
```

```
                 |
                 |
        Ri       |
    +{-{-}{-}///{-}{-}{-}{-}+}
    |
    |
    |    Rf
    +{-{-}{-}///{-}{-}{-}{-}+}
    |             |
    |             |
   === GND        |
                  |
                  +
```

Parameter	Value
Gain	A = 1 + Rf/Ri
Input impedance	Very high (depends on op-amp)
Phase	In-phase with input
Common application	Voltage follower (when Rf=0, Ri=∞)

Mnemonic

"NIPS" - Non-inverting, Input and output In Phase, Same polarity

Question 4(c) OR [7 marks]

Explain Op-amp as an Integrator.

Solution

Op-amp integrator produces output proportional to the time integral of the input.
Diagram:

```
          C
    +{-{-}{-}{-}{-}{-}||{-}{-}{-}{-}{-}{-}+}
    |              |
    |              |
    |      +{-{-}{-}{-}{-}{-}{-}+}
    |      |       |
    |      |   +   |
Vin +{-{-}{-}{-}{-}+{-}{-}{-}+   +{-}{-}{-}{-}+ Vout}
    R      |   {-   |}
           |       |
           +{-{-}{-}{-}{-}{-}{-}+}
                |
                |
               === GND
```

Parameter	Formula
Output voltage	Vout = -(1/RC)dt
Transfer function	Vout/Vin = -1/(sRC) in Laplace domain
Gain	Decreases at 20dB/decade with frequency
Phase shift	-90°(*ideally*)

Applications:

- Analog computers
- Waveform generators
- PID controllers
- Active filters
- Signal processing

Mnemonic

"TIME" - Takes Input and Makes time-dependent Effect

Question 5(a) [3 marks]

Draw Pin Diagram of IC 555.

Solution

Diagram:

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

Pin Number	Name	Function
1	GND	Ground
2	TRIGGER	Starts timing cycle
3	OUTPUT	Timer output
4	RESET	Resets timer
5	CONTROL	Modifies timing
6	THRESHOLD	Ends timing cycle
7	DISCHARGE	Discharges timing capacitor
8	VCC	Positive supply

Mnemonic

"GTOR-CTD" - Ground, Trigger, Output, Reset, Control, Threshold, Discharge

Question 5(b) [4 marks]

Explain astable multivibrator of timer IC 555.

Solution

Astable multivibrator using IC 555 generates continuous square wave output without any external trigger.
Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[VCC] {-{-}{} B[R1]}
    B {-{-}{} C[Pin 7]}
    B {-{-}{} D[Pin 6/2]}
```

```
    C {-{-}{} E[IC 555]}
    D {-{-}{} E}
    F[R2] {-{-}{} D}
    F {-{-}{} G[Pin 7]}
    G {-{-}{} E}
    H[C] {-{-}{} D}
    H {-{-}{} I[GND]}
    E {-{-}{} J[Output Pin 3]}
{Highlighting}
{Shaded}
```

Parameter	Formula
Charging time	$t_1 = 0.693(R_1 + R_2)C$
Discharging time	$t_2 = 0.693(R_2)C$
Frequency	$f = 1.44/((R_1 + 2R_2)C)$
Duty cycle	$D = (R_1 + R_2)/(R_1 + 2R_2)$

Mnemonic

"FREE" - FREquency Established by External RC network

Question 5(c) [7 marks]

Explain working of Complementary symmetry Push Pull Amplifiers.

Solution

Complementary symmetry push-pull amplifier uses complementary transistors (NPN and PNP) to amplify both halves of the waveform.

Diagram:

```
            VCC
             |
             |
        Q1  /+{  NPN}
             |
             +{-{-}{-}{-}{-}{-}+}
             |      |
Input +{-{-}{-}{-}{-}{-}+      +{-}{-}{-}+ Output}
             |      |
             +{-{-}{-}{-}{-}{-}+}
             |
        Q2  {{-}/  PNP}
             |
             |
            GND
```

Transistor	Conduction	Current Flow
Q1 (NPN)	Positive half-cycle	Source to load
Q2 (PNP)	Negative half-cycle	Sink from load

Key features:

- **No center-tapped transformer**: Simpler design than transformer-coupled push-pull
- **Crossover distortion**: Requires biasing to minimize
- **Efficiency**: About 78.5% (Class B operation)
- **Thermal runaway**: Risk if not properly designed
- **Applications**: Audio power amplifiers, output stages of op-amps

Mnemonic

"COPS" - Complementary Opposing Pair of transistors for Symmetrical operation

Question 5(a) OR [3 marks]

Draw the diagram of Sequential Timer.

Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Start] {-{-}{} B[555 Timer 1]}
    B {-{-}{} C[555 Timer 2]}
    C {-{-}{} D[555 Timer 3]}
    D {-{-}{} E[Optional additional timers]}
    B {-{-}{} B1[Output 1]}
    C {-{-}{} C1[Output 2]}
    D {-{-}{} D1[Output 3]}
{Highlighting}
{Shaded}
```

```
   +{-{-}{-}{-}{-}+      +{-}{-}{-}{-}{-}+      +{-}{-}{-}{-}{-}+}
   |     |      |     |      |     |
   | 555 |      | 555 |      | 555 |
   |  1  |      |  2  |      |  3  |
   |     |      |     |      |     |
   +{-{-}|{-}{-}+      +{-}{-}|{-}{-}+      +{-}{-}|{-}{-}+}
      |            |            |
      v            v            v
   Output 1     Output 2     Output 3
      |            |            |
   Start        Trigger      Trigger
   Input          from         from
                Timer 1      Timer 2
```

Mnemonic

"SET" - Sequential Events Triggered one after another

Question 5(b) OR [4 marks]

Explain bistable multivibrator of timer IC 555.

Solution

Bistable multivibrator using IC 555 has two stable states and changes state only when triggered.
Diagram:

```
        VCC
         |
     +{-{-}{-}+{-}{-}{-}+}
     |       |
     +{-{-}{-}+{-}{-}{-}+         +{-}{-}{-}{-}{-}+}
     |    |R  |         |     |
     |    +{-{-}{-}+{-}{-}{-}{-}+{-}{-}{-}{-}+ 555 |}
     |           |    4|     |
     |         +{-+     |     |}
```

```
     |   Set   | |     |     |
     +{-{-}{-}{-}o{-}{-}{-}{-}+ +{-}{-}{-}{-}{-}+  3  +{-}{-}{-}{-} Output}
               |       |     |
     +{-{-}{-}{-}o{-}{-}{-}{-}+ +{-}{-}{-}{-}{-}+     |}
     |   Reset | |    2|     |
     |         +{-+     +{-}{-}{-}{-}{-}+}
     |             |      |
     |             |      |
    === GND       === GND
```

Terminal	Function	Operation
Pin 2 (TRIGGER)	SET input	When pulled below 1/3 VCC, output goes HIGH
Pin 4 (RESET)	RESET input	When pulled LOW, output goes LOW
Pin 3	Output	Remains in last state until triggered

Mnemonic

"FLIP" - Firmly Latched In Position until triggered

Question 5(c) OR [7 marks]

Compare different types of power Amplifiers.

Solution

Parameter	Class A	Class B	Class AB	Class C
Conduction angle	360°	180°	180° – 360°	<180°
Efficiency	25-30%	78.5%	50-78.5%	>78.5%
Distortion	Very low	Moderate	Low	High
Biasing	Above cutoff	At cutoff	Slightly above cutoff	Below cutoff
Circuit complexity	Low	Medium	Medium	Low
Heat dissipation	High	Medium	Medium	Low
Applications	High fidelity audio	Audio power amps	Audio power amps	RF transmitters

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Power Amplifier Classes] {-{-}{} B[Class A: 360^ conduction]}
    A {-{-}{} C[Class B: 180^ conduction]}
    A {-{-}{} D[Class AB: 180^{-}360^ conduction]}
    A {-{-}{} E[Class C: {}180^ conduction]}
    B {-{-}{-} B1[25{-}30\% efficient]}
    C {-{-}{-} C1[78.5\% efficient]}
    D {-{-}{-} D1[50{-}78.5\% efficient]}
    E {-{-}{-} E1[{}78.5\% efficient]}
{Highlighting}
{Shaded}
```

Mnemonic

"ABCE" - As Biasing Condition changes, Efficiency increases