Subject Name Solutions

4311102 – Winter 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Give the difference between Passive components and Active components

Solution

Passive Components	Active Components
Do not require external power source	Require external power source to operate
Cannot amplify or process signals	Can amplify, switch or process signals
Examples: Resistors, Capacitors, Inductors	Examples: Transistors, Diodes, ICs
Cannot control current flow by another signal	Can control current flow using another signal
Store or dissipate energy	Generate energy or provide gain

Mnemonic

"PAPER-A" - Passive Are Power-free, Energy-storing/Resistive; Active Are Amplifying

Question 1(b) [4 marks]

Explain Working of Light dependent resistor with neat diagram.

Solution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Light] {-{-}{} B[LDR]}
    B {-{-}{} C[Change in Resistance]}
    style A fill:\#lightblue
    style B fill:\#lightgreen
    style C fill:\#lightpink
{Highlighting}
{Shaded}
```

Working of LDR:

- **Construction**: LDR consists of a semiconductor material (typically cadmium sulfide) with high resistance in darkness
- **Photoconductivity**: When light falls on the surface, photons transfer energy to electrons, creating free electron-hole pairs
- **Resistance variation**: Resistance decreases dramatically as light intensity increases - from megaohms in darkness to few hundred ohms in bright light
- **Applications**: Used in light sensing circuits, automatic street lights, camera exposure control

Mnemonic

"MILD" - More Illumination, Less resistance in Devices

Question 1(c) [7 marks]

Define Intrinsic and Extrinsic Semiconductor. Explain P type and N type semiconductors in detail.

Solution

Semiconductor Type	Description
Intrinsic	Pure semiconductor material with no impurities added
Extrinsic	Semiconductor with controlled impurities added through doping

P-type Semiconductor:

- **Doping**: Created by adding trivalent impurities (boron, gallium, indium) to pure silicon
- **Hole creation**: Each impurity atom creates a hole by accepting valence electrons
- **Majority carriers**: Holes are majority carriers
- **Minority carriers**: Electrons are minority carriers
- **Electrical properties**: Positive charge carriers dominate conduction

N-type Semiconductor:

- **Doping**: Created by adding pentavalent impurities (phosphorus, arsenic, antimony) to pure silicon
- **Electron creation**: Each impurity atom donates an extra electron
- **Majority carriers**: Electrons are majority carriers
- **Minority carriers**: Holes are minority carriers
- **Electrical properties**: Negative charge carriers dominate conduction

Diagram:

```
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+   +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
| N{-type         |   | P{-}type         |}
|                 |   |                 |
| Si Si Si Si Si |   | Si Si Si Si Si |
|                 |   |                 |
| Si Si P  Si Si |   | Si Si B  Si Si |
|      |          |   |      |          |
| Si Si|Si Si Si |   | Si Si|Si Si Si |
|      v          |   |      v          |
| Si Si e{- Si Si |   | Si Si h+ Si Si |}
|                 |   |                 |
| Si Si Si Si Si |   | Si Si Si Si Si |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+   +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
  Extra electron       Extra hole
```

Mnemonic

"PINE" - Positive Impurities make N-type Electrons, Pentavalent donors

Question 1(c) OR [7 marks]

What is filter circuit? Give type and necessity of Filter and Explain "PI" Filter circuit in brief.

Solution

Filter Circuit: Electronic circuit that removes unwanted frequency components from a signal, allowing desired frequencies to pass through.

Necessity of Filters:

- **Ripple reduction**: Reduces AC ripple from rectifier output
- **Clean DC**: Provides smoother DC output voltage
- **Component protection**: Protects downstream components from voltage fluctuations
- **Efficiency**: Improves overall power supply efficiency

Types of Filters:

Filter Type	Components	Application
Shunt Capacitor	Single capacitor in parallel	Basic filtering
L-Type	Inductor and capacitor	Better filtering
(Pi) Filter	Two capacitors and one inductor	Superior filtering
RC Filter	Resistor and capacitor	Low-power applications

Pi ( ) Filter:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input] {-{-}{} B[Capacitor C1]}
    B {-{-}{} C[Inductor L]}
    C {-{-}{} D[Capacitor C2]}
    D {-{-}{} E[Output]}
    style A fill:\#lightblue
    style B fill:\#lightgreen
    style C fill:\#lightpink
    style D fill:\#lightgreen
    style E fill:\#lightblue
{Highlighting}
{Shaded}
```

- **Working**: First capacitor (C1) reduces initial ripple, inductor (L) blocks AC components, second capacitor (C2) filters remaining ripples
- **Advantage**: Provides superior filtering with ripple factor typically below 0.5%
- **Applications**: Used in high-current power supplies where clean DC is critical

Mnemonic

"PIRO" - Pi filters Input Ripples Out effectively

Question 2(a) [3 marks]

Write down different types of capacitors and explain any two.

Solution

Types of Capacitors:

- Ceramic capacitors
- Electrolytic capacitors
- Tantalum capacitors
- Film capacitors
- Mica capacitors
- Variable capacitors

Ceramic Capacitors:

- **Construction**: Made from ceramic material as dielectric between metal plates
- **Capacity**: 1pF to 1 F
- **Advantages**: Low cost, high stability, non-polarized
- **Applications**: High-frequency filtering, coupling/decoupling

Electrolytic Capacitors:

- **Construction**: Aluminum foil with oxide layer as dielectric
- **Capacity**: 1 F to 10,000 F
- **Characteristics**: Polarized, higher leakage current
- **Applications**: Power supply filtering, audio coupling

Mnemonic

"CAPEX" - Ceramics Are Precise, Electrolytics Expand capacity

Question 2(b) [4 marks]

Explain air core and toroidal inductor.

Solution

Air Core Inductor:

```
  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
  |    Air     |
  |            |
+{-|{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}|{-}{-}+}
| |            |  |
| |            |  |
| |            |  |
| |            |  |
| |            |  |
+{-|{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}|{-}{-}+}
  |            |
  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
  Wire windings
```

- **Construction**: Wire coiled around non-magnetic material (plastic, air)
- **Properties**: Lower inductance, no magnetic core saturation
- **Applications**: High-frequency circuits, RF applications
- **Advantages**: No core losses, linear operation, no saturation

Toroidal Inductor:

```
     +{-{-}{-}{-}{-}{-}{-}+}
    /         {}
   /           {}
  /     Air     {}
 |       +       |
 |      / {      |}
 |     /   {     |}
 |    +{-{-}{-}{-}{-}+    |}
  {   |     |   /}
   {  |     |  /}
    { |     | /}
     ++{-{-}{-}{-}{-}++}
    Wire windings
     around core
```

- **Construction**: Wire wound around a ring-shaped magnetic core
- **Properties**: Higher inductance, self-shielding magnetic field
- **Applications**: Power supplies, filters, transformers
- **Advantages**: Low electromagnetic interference, efficient flux containment

Mnemonic

"TACO" - Toroids Are Contained, Omnidirectional field reduction

Question 2(c) [7 marks]

Explain Half wave rectifier and Compare different rectifier circuits.

Solution

Half Wave Rectifier:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[AC Input] {-{-}{} B[Transformer]}
    B {-{-}{} C[Diode]}
    C {-{-}{} D[Load]}
    C {-{-}{} E[Ground]}
    style A fill:\#lightblue
    style B fill:\#lightpink
    style C fill:\#lightyellow
    style D fill:\#lightgreen
    style E fill:\#lightgray
{Highlighting}
{Shaded}
```

Working Principle:

- During positive half-cycle: Diode conducts, current flows through load
- During negative half-cycle: Diode blocks, no current flows
- Output contains only positive half-cycles of input waveform

Comparison of Rectifiers:

Parameter	Half Wave	Full Wave (Center-Tap)	Bridge Rectifier
Diodes required	1	2	4
Output frequency	$f_1 = fin$	$f_2 = 2$	$f_2 = 2$
Ripple factor	1.21	0.48	0.48
Efficiency	40.6%	81.2%	81.2%
PIV	2Vm	2Vm	Vm
TUF	0.287	0.693	0.812
DC output	Vm/	2Vm/	2Vm/

Mnemonic

"BRIEF" - Bridge Rectifiers Improve Efficiency Fundamentally

Question 2(a) OR [3 marks]

Write down different capacitor specifications and explain any two in detail.

Solution

Capacitor Specifications:

- Capacitance value
- Voltage rating
- Tolerance
- Temperature coefficient
- ESR (Equivalent Series Resistance)
- Leakage current
- Dielectric type

Capacitance Value:

- **Definition**: Amount of electric charge stored per volt
- **Units**: Measured in farads (F), typically microfarads (F), nanofarads (nF), or picofarads (pF)
- **Importance**: Determines application suitability for coupling, filtering, timing
- **Marking**: Directly printed or color-coded on component

Voltage Rating:

- **Definition**: Maximum voltage that can be applied without breakdown

- **Specification**: Working voltage (WVDC) and surge voltage
- **Importance**: Exceeding rating causes dielectric breakdown and failure
- **Safety factor**: Typically use capacitors rated 50% higher than circuit voltage

Mnemonic

"CAVERN" - Capacitance And Voltage Ensure Reliable Network

Question 2(b) OR [4 marks]

Explain classification of Resistor based on materials.

Solution

Resistor Type	Material	Properties	Applications
Carbon Composition	Carbon particles + Ceramic binder	High temperature coefficient, noisy	General purpose, surge protection
Carbon Film	Carbon film on ceramic	Better stability than carbon composition	General purpose circuits
Metal Film	Nickel chromium film on ceramic	Low noise, stable, precise	Audio circuits, instrumentation
Wire Wound	Resistance wire around ceramic	High power, low temperature coefficient	Power supplies, high current applications
Metal Oxide	Metal oxide film on ceramic	Stable, high temperature tolerance	High stability applications, power supplies

Characteristics of Carbon Film Resistors:

- Temperature coefficient: -250 to 500 ppm/
- Tolerance: 5% to 10%
- Noise: Moderate to low

Characteristics of Metal Film Resistors:

- Temperature coefficient: 50 to 100 ppm/
- Tolerance: 0.1% to 2%
- Noise: Very low

Mnemonic

"COMFORT" - Carbon Offers Moderate Films, Others Resist Temperature better

Question 2(c) OR [7 marks]

Explain full wave bridge and center tapped rectifier with diagram and waveform.

Solution

Full Wave Bridge Rectifier:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[AC Input] {-{-}{} B[Transformer]}
    B {-{-}{} C[Bridge{}br /{}Rectifier]}
    C {-{-}{} D[D1]}
    C {-{-}{} E[D2]}
    C {-{-}{} F[D3]}
    C {-{-}{} G[D4]}
```

```
    D \& E \& F \& G {-{-}{} H[Load]}
    H {-{-}{} I[Ground]}
    style A fill:\#lightblue
    style B fill:\#lightpink
    style C fill:\#lightyellow
    style H fill:\#lightgreen
    style I fill:\#lightgray
{Highlighting}
{Shaded}
```

Working:

- **Positive half-cycle**: D1 and D3 conduct, current flows through load
- **Negative half-cycle**: D2 and D4 conduct, current still flows through load in same direction
- **Output**: Both half-cycles of input converted to positive output

Center Tapped Full Wave Rectifier:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[AC Input] {-{-}{} B[Center{-}Tapped{}br /{}Transformer]}
    B {-{-}{}|Upper Half| C[D1]}
    B {-{-}{}|Lower Half| D[D2]}
    C \& D {-{-}{} E[Load]}
    E {-{-}{} F[Ground]}
    F {-{-}{} B}
    style A fill:\#lightblue
    style B fill:\#lightpink
    style C fill:\#lightyellow
    style D fill:\#lightyellow
    style E fill:\#lightgreen
    style F fill:\#lightgray
{Highlighting}
{Shaded}
```

Working:

- **Positive half-cycle**: D1 conducts, D2 blocks
- **Negative half-cycle**: D2 conducts, D1 blocks
- **Output**: Both half-cycles of input converted to positive output

Waveforms:

```
Input:
         |
         v
Bridge:
Rectifier
         |
         v
Output:
(with filter)
```

Mnemonic

"FOUR-TWO" - FOUr diodes for Bridge, TWO diodes for Center-Tap

Question 3(a) [3 marks]

Explain the characteristic of Varactor diode.

Solution

Varactor Diode Characteristics:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Reverse Bias{br /{}Voltage] {-}{-}{} B[Depletion{}br /{}Layer Width]}
    B {-{-}{} C[Junction{}br /{}Capacitance]}
    C {-{-}{} D[Frequency{}br /{}Tuning]}
    style A fill:\#lightblue
    style B fill:\#lightpink
    style C fill:\#lightgreen
    style D fill:\#lightyellow
{Highlighting}
{Shaded}
```

- **Operating principle**: Junction capacitance varies with reverse bias voltage
- **C-V relationship**: Capacitance decreases as reverse voltage increases
- **Tuning ratio**: Typically 4:1 to 10:1 capacitance variation
- **Applications**: Voltage-controlled oscillators, FM modulation, tuning circuits

Mnemonic

"VARA" - Voltage Adjusts Reverse-biased capacitance Automatically

Question 3(b) [3 marks]

State and explain Faraday's laws of electromagnetic induction.

Solution

Faraday's Laws of Electromagnetic Induction:
First Law:

- **Statement**: Whenever a conductor cuts magnetic flux, an EMF is induced in the conductor
- **Mathematical expression**: EMF Rate of change of magnetic flux
- **Application**: Basis for generators, transformers, inductors

Second Law:

- **Statement**: The magnitude of induced EMF equals the rate of change of magnetic flux linkage
- **Mathematical expression**: EMF = -N $\times(d/dt)$
  - Where:
    N = number of turns, $d\Phi/dt$ = rate of change of flux
- **Negative sign**: Indicates direction (Lenz's Law) - induced current opposes the change

Diagram:

```
    N     S
    |     |
    v     v
  +{-{-}{-}+ +{-}{-}{-}+     }
  |   | |   |
  |   | |   |
  +{-{-}{-}+ +{-}{-}{-}+     }
    \^{     \^{}       }
    |     |
    |     |
  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}+    }
  |   Coil   |{-{-}{-}{-}{-} Induced EMF}
  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}+    }
```

Mnemonic

"FACE" - Flux Alteration Creates Electricity

Question 3(c) [7 marks]

Compare different Transistor Configurations.

Solution

Parameter	Common Emitter (CE)	Common Base (CB)	Common Collector (CC)
Input Terminal	Base	Emitter	Base
Output Terminal	Collector	Collector	Emitter
Common Terminal	Emitter	Base	Collector
Current Gain (, ,)	= IC/IB (20-500)	= IC/IE (0.95-0.99)	= IE/IB (+1)
Voltage Gain	High (250-1000)	Medium (150-800)	Less than 1
Input Impedance	Medium (1-2kΩ)	Low (30-150Ω)	High (50-500kΩ)
Output Impedance	High (30-50kΩ)	Very high (250kΩ-1MΩ)	Low (50-100Ω)
Phase Shift	180°	0°	0°
Applications	Amplifiers, oscillators	RF amplifiers, high-frequency circuits	Impedance matching, buffers

Relationship between , and :

- = /(1-)
- = /(1+)
- = +1

Mnemonic

"BEC" - Base input for Emitter output needs Collector as common terminal

Question 3(a) OR [3 marks]

What is forbidden energy gap? Draw the energy band diagram for insulator, conductor and semiconductor.

Solution

Forbidden Energy Gap: Energy range in a solid where no electron states exist, separating the valence band from the conduction band.

Energy Band Diagrams:

```
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-
|///////////////|  |///////////////|  |///////////////|
|/// Conduction |  |/// Conduction |  |/// Conduction |
|///////////////|  |///////////////|  |///////////////|
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-
|               |  |///////////////|  |       |       |
|               |  |///////////////|  |       | Small  |
| Large         |  | Overlap       |  |       | Gap    |
| Forbidden     |  |///////////////|  |       |        |
| Gap ({5eV)    |  |///////////////|  |       | (1eV)  |}
|               |  |///////////////|  |       |        |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-
|///////////////|  |///////////////|  |///////////////|
|/// Valence    |  |/// Valence    |  |/// Valence    |
|///////////////|  |///////////////|  |///////////////|
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+  +{-}{-
    Insulator          Conductor        Semiconductor
```

- **Insulator**: Large forbidden gap (>5eV) prevents electrons from reaching conduction band
- **Conductor**: Overlapping bands allow free electron movement
- **Semiconductor**: Small gap (~1eV) allows some electrons to cross at room temperature or when excited

Mnemonic

"IBCS" - Insulators Block, Conductors Share, Semiconductors have gap Between

Question 3(b) OR [4 marks]

Explain the function of Zener diode as a voltage regulator

Solution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Unregulated{br /{}DC Input] {-}{-}{} B[Series{}br /{}Resistor]}
    B {-{-}{} C[Load]}
    B {-{-}{} D[Zener{}br /{}Diode]}
    D {-{-}{} E[Ground]}
    style A fill:\#lightblue
    style B fill:\#lightpink
    style C fill:\#lightgreen
    style D fill:\#lightyellow
    style E fill:\#lightgray
{Highlighting}
{Shaded}
```

Working Principle:
- **Normal operation**: Zener diode is reverse biased and conducts when voltage reaches breakdown voltage
- **Voltage regulation**: When input voltage rises, more current flows through Zener diode, maintaining constant voltage across it
- **Load variation**: When load draws more current, less current flows through Zener, keeping voltage stable
- **Series resistor**: Limits current and drops excess voltage

Circuit behavior:
- **Vout = Vz** (Zener breakdown voltage)
- **Iz = (Vin - Vz)/R - IL**

Mnemonic

"SERZ" - Series resistor Enables Regulation with Zener

Question 3(c) OR [7 marks]

Explain V-I char of P-N junction diode and give comparison between P-N junction diode and Zener diode.

Solution

V-I Characteristics of P-N Junction Diode:

```
                 I
                 \^{}
                 |             /
                 |            /
                 |           /
                 |          /
Forward current  |         /
```

```
                 |         /
                 |        /
                 |       /
                 |  Knee/
                 |     /
        {-V {-}{-}{-}{-}{-}|{-}{-}{-}{-}+{-}{-}{-} +V}
                 |   /|
                 |    |
                 |    |
Reverse current  |    |
                 |    |    Breakdown
                 |    |       |
                 |    |       v
                 |    |       \_\_\_\_\_
```

Key Points:

- **Forward bias**: Conducts easily after exceeding knee voltage (~0.7V for silicon)
- **Reverse bias**: Very small leakage current until breakdown voltage
- **Breakdown region**: Occurs at high reverse voltage, causes damage in normal diodes

P-N Junction Diode vs. Zener Diode:

Parameter	P-N Junction Diode	Zener Diode
Symbol	|—	|—
Forward operation	Conducts easily	Same as normal diode
Reverse breakdown	At high voltage, causes damage	Controlled, non-destructive
Doping level	Moderate	Heavily doped
Operating region	Forward biased	Reverse biased (breakdown region)
Applications	Rectification, switching	Voltage regulation, reference
Breakdown mechanism	Avalanche	Zener effect and avalanche
Temperature coefficient	Negative	Can be positive or negative

Mnemonic

"FORD" - Forward Operation for Rectifiers, Diodes; reverse operation for Zeners

Question 4(a) [3 marks]

Describe working principle of Photodiode.

Solution

Working Principle of Photodiode:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Light] {-{-}{} B[P{-}N Junction]}
    B {-{-}{} C[Electron{-}Hole{}br /{}Pairs]}
    C {-{-}{} D[Photocurrent]}
    style A fill:\#lightyellow
    style B fill:\#lightpink
    style C fill:\#lightblue
    style D fill:\#lightgreen
{Highlighting}
{Shaded}
```

- **Construction**: P-N junction diode with transparent window or lens
- **Operation**: Reverse biased operation for light detection
- **Photon absorption**: Incoming photons create electron-hole pairs in depletion region
- **Current generation**: Electric field sweeps carriers to respective terminals, creating photocurrent

- **Light sensitivity**: Current proportional to light intensity

Mnemonic

"LIGER" - Light Induces Generation of Electrons in Reverse-bias

Question 4(b) [4 marks]

Explain the characteristic of Schottky barrier diode.

Solution

Schottky Barrier Diode Characteristics:

```
                 I
                 \^{}
                 |             /
                 |            / Schottky
                 |           /
                 |          /   PN Junction
Forward current  |         / ,/
                 |        / /
                 |       / /
                 |      / /
                 |     / /
                 |    //
        {-V {-}{-}{-}{-}{-}|{-}{-}{-}{-}|{-}{-}{-} +V}
                 |    |
                 |    |
                 |    |
Reverse current  |    |
                 |    |
```

- **Low forward voltage drop**: 0.2-0.3V compared to 0.7V for silicon PN junction
- **Fast switching**: No minority carrier storage, minimal reverse recovery time
- **Construction**: Metal-semiconductor junction instead of P-N junction
- **No reverse recovery time**: Majority carrier device (no stored charge)
- **Applications**: High-frequency applications, rectifiers in power supplies

Mnemonic

"FAST" - Forward voltage low, Allows Switching Timely

Question 4(c) [7 marks]

Explain working principle of PNP and NPN transistor.

Solution

NPN Transistor Structure and Working:

```
+{-{-}{-}{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}{-}{-}+}
|       |     |       |     |       |
|   N   |     |   P   |     |   N   |
|       |     |       |     |       |
+{-{-}{-}{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}{-}{-}+}
Emitter       Base        Collector
    |            |            |
    |            |            |
    v            v            v
Electron      Hole        Electron
```

```
    source     controller      collector
```

- **Biasing**: Emitter-base junction forward biased, collector-base junction reverse biased
- **Current flow**: Electrons from emitter to collector through thin base region
- **Amplification principle**: Small base current controls larger collector current
- **Current relationship**: IE = IB + IC
- **Majority carriers**: Electrons

PNP Transistor Structure and Working:

```
+{-{-}{-}{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}{-}{-}+     +{-}{-}{-}{-}{-}{-}{-}+}
|       |     |       |     |       |
|   P   |     |   N   |     |   P   |
|       |     |       |     |       |
+{-{-}{-}{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}{-}{-}+     +{-}{-}{-}{-}{-}{-}{-}+}
Emitter        Base       Collector
    |            |            |
    |            |            |
    v            v            v
  Hole        Electron       Hole
  source     controller     collector
```

- **Biasing**: Emitter-base junction forward biased, collector-base junction reverse biased
- **Current flow**: Holes from emitter to collector through thin base region
- **Amplification principle**: Small base current controls larger collector current
- **Current relationship**: IE = IB + IC
- **Majority carriers**: Holes
- **Current direction**: Opposite to NPN (conventional current from emitter to collector)

Mnemonic

"NPNP" - Negative carriers in NPN, Positive carriers in PNP

Question 4(a) OR [3 marks]

Describe working principle of LED.

Solution

Working Principle of LED:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Forward Bias] {-{-}{} B[Electron{-}Hole{}br /{}Recombination]}
    B {-{-}{} C[Energy Release{}br /{}as Photons]}
    C {-{-}{} D[Light Emission]}
    style A fill:\#lightblue
    style B fill:\#lightpink
    style C fill:\#lightyellow
    style D fill:\#lightgreen
{Highlighting}
{Shaded}
```

- **Construction**: P-N junction made from direct bandgap semiconductor materials
- **Forward biasing**: Electrons from n-region and holes from p-region recombine at junction
- **Recombination**: Electrons fall from conduction band to valence band
- **Energy emission**: Energy released during recombination emits photons (light)
- **Color determination**: Bandgap energy determines wavelength (color) of emitted light

Mnemonic

"REBEL" - Recombination of Electrons and holes By Energetic Light emission

Question 4(b) OR [4 marks]

Explain function of transistor as switch in cut off and application of saturation region.

Solution

Transistor as a Switch:

```
       Input                        Output
         |                            |
         |                            |
         v                            v
   +{-{-}{-}{-}{-}{-}{-}{-}{-}+                 +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
   |    R1    |                 |    RC    |
   +{-{-}{-}{-}{-}{-}{-}{-}{-}+                 +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
         |                            |
         |                            |
         |     +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+      |}
         +{-{-}{-}{-}|     B     C   |{-}{-}{-}{-}{-}{-}+}
               |       |       |
               |       |       |
               |     E         |
               +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
                    |
                    |
                Ground
```

Cut-off Region (Switch OFF):

- **Base voltage**: Below 0.7V (for silicon)
- **Base current**: Approximately zero
- **Collector current**: Approximately zero
- **Collector-emitter voltage**: Equal to supply voltage
- **Applications**: Logic gates, digital circuits, relay drivers

Saturation Region (Switch ON):

- **Base voltage**: Well above 0.7V
- **Base current**: Sufficient to ensure minimum VCE
- **Collector current**: Maximum (limited by collector resistor)
- **Collector-emitter voltage**: Very low (0.2V - 0.3V)
- **Applications**: Digital switches, motor drivers, LED drivers

Mnemonic

"COSI" - Cutoff Opens Switch, Input saturates to close

Question 4(c) OR [7 marks]

Explain common emitter (CE) configuration of Transistor. Derive relation between and for transistor amplifier.

Solution

Common Emitter Configuration:

```
graph TB
    A[Input Signal] {-{-} B[Base]}
    C[Output Signal] {-{-} D[Collector]}
    E[Ground] {-{-} F[Emitter]}
    style A fill:\#lightblue
```

```
style B fill:\#lightpink
style C fill:\#lightgreen
style D fill:\#lightyellow
style E fill:\#lightgray
style F fill:\#lightcyan
```

Characteristics of Common Emitter Configuration:

- **Input terminal**: Base
- **Output terminal**: Collector
- **Common terminal**: Emitter (grounded)
- **Current gain ( )**: High (20-500)
- **Voltage gain**: High (250-1000)
- **Input impedance**: Medium (1-2kΩ)
- **Output impedance**: High (30-50kΩ)
- **Phase shift**: $180°(output inverted from input)$

Relationship between and :

By definition:

- = IC/IE (Common Base current gain)
- = IC/IB (Common Emitter current gain)

From Kirchhoff's Current Law:

- IE = IB + IC

Dividing both sides by IE:

- 1 = IB/IE + IC/IE
- 1 = IB/IE +

Therefore:

- IB/IE = 1 -

Now,

= IC/IB = (IC/IE)/(IB/IE) = /(1-)

And conversely:

- = /(1+)

Mnemonic

"BEAR" - Beta Equals Alpha divided by (1-alpha) Relation

Question 5(a) [3 marks]

What do you mean by E-waste? What are the different methods of E-waste disposal?

Solution

E-waste (Electronic Waste): Discarded electronic devices and components that have reached end of life or are no longer useful.

Methods of E-waste Disposal:

Disposal Method	Description
Recycling	Separating valuable materials like metals, plastics for reuse
Landfilling	Disposing in designated landfills (not recommended)
Incineration	Burning waste at high temperatures (creates toxic emissions)
Reuse/Refurbishment	Repairing and upgrading for extended use
Extended Producer Responsibility	Manufacturers take back and handle disposal

Mnemonic

"RIPER" - Recycling Is Preferable to Environmentally-harmful Remedies

Question 5(b) [4 marks]

Explain methods of handling electronic waste with examples.

Solution

Methods of Handling Electronic Waste:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[E{-waste{}br /{}Collection] {-}{-}{} B[Sorting]}
    B {-{-}{} C[Dismantling]}
    C {-{-}{} D[Material{}br /{}Recovery]}
    D {-{-}{} E[Safe{}br /{}Disposal]}
    style A fill:\#lightblue
    style B fill:\#lightpink
    style C fill:\#lightyellow
    style D fill:\#lightgreen
    style E fill:\#lightgray
{Highlighting}
{Shaded}
```

Collection and Segregation:

- **Example**: Dedicated e-waste bins in public places, e-waste collection drives
- **Benefit**: Prevents mixing with general waste, enables proper processing

Dismantling and Resource Recovery:

- **Example**: Recovering gold, silver, copper from circuit boards and connectors
- **Benefit**: Recovers valuable metals, reduces mining demands

Refurbishment and Reuse:

- **Example**: Repairing old computers for educational institutions
- **Benefit**: Extends product lifecycle, reduces waste generation

Proper Disposal of Hazardous Components:

- **Example**: Specialized treatment for mercury-containing components
- **Benefit**: Prevents toxic substances from entering environment

Mnemonic

"CREED" - Collect, Recover, Extract, Extend, Dispose safely

Question 5(c) [7 marks]

What is ripple factor? Derive the equation of the ripple factor for rectifier.

Solution

Ripple Factor: Measure of effectiveness of a rectifier's filtering - the ratio of AC component (ripple) to DC component in the output.

Definition:

- Ripple factor ( ) = RMS value of AC component / DC value
- Lower ripple factor indicates better filtering

Derivation for Half Wave Rectifier:

Let's assume sinusoidal input: v = Vmsin t

For half wave rectifier:

- Output is v = Vmsin t for $0 \leq t \leq$
- Output is v = 0 for $\leq t \leq 2$

Step 1: Find DC component (average value)

- VDC = (1/2) $\int 02v(t)d(t)$
- VDC = (1/2) $\int 0Vmsintd(t)$
- VDC = Vm/

Step 2: Find RMS value

- VRMS =
-
-
- $VRMS =$
-
-
-
- $VRMS = Vm/2$

Step 3: Find AC component

- $\text{VAC}^2 = VRMS^2 - VDC^2$
- $\text{VAC}^2 = (Vm/2)^2 - (Vm/)^2$
- $\text{VAC}^2 = Vm^2(1/4 - 1/^2)$

Step 4: Calculate ripple factor

- $= \text{VAC}/\text{VDC}$
- $= \sqrt{(}Vm^2(1/4 - 1/^2))/(Vm/)$
- $= \sqrt{(}1/4 - 1/^2)$
- $= 1.21$ (for half wave rectifier)

For Full Wave Rectifier: Following similar steps leads to $= 0.48$

Mnemonic

"ROAD" - Ripple is Output's AC Divided by DC component

Question 5(a) OR [3 marks]

Which are the toxic substances present in e-waste?

Solution

Toxic Substances in E-waste:

Toxic Substance	Source in Electronics	Health/Environmental Impact
Lead (Pb)	Solder, CRT monitors, batteries	Neurological damage, developmental issues
Mercury (Hg)	Switches, backlights, batteries	Neurological and kidney damage
Cadmium (Cd)	Rechargeable batteries, circuit boards	Kidney damage, bone disease
Brominated Flame Retardants	Plastic casings, circuit boards	Endocrine disruption, bioaccumulation
Hexavalent Chromium	Corrosion protection in metal parts	Allergic reactions, DNA damage
Beryllium (Be)	Connectors, springs	Lung disease, skin disorders

Mnemonic

"LMBCHB" - Lead, Mercury, and Beryllium Cause Harmful Bodily effects

Question 5(b) OR [4 marks]

Write important parameters for selecting the right transistor for your application and explain any two.

Solution

Important Transistor Selection Parameters:

- Maximum collector current (IC)
- Maximum collector-emitter voltage (VCEO)
- Maximum collector-base voltage (VCBO)
- Current gain (hFE or)

- Frequency response (fT)
- Power dissipation (Ptot)
- Package type (TO-3, SMT, etc.)
- Temperature range

Maximum Collector Current (IC):

- **Definition**: Maximum current that can flow through collector without damage
- **Importance**: Must exceed application's peak current requirements with safety margin
- **Typical values**: 100mA to 100A depending on transistor type
- **Application consideration**: Select 50% higher rating than maximum required current

Current Gain (hFE or):

- **Definition**: Ratio of collector current to base current
- **Importance**: Determines amplification capability and required base drive
- **Typical values**: 20-500 for general-purpose transistors
- **Application consideration**: For switching, high gain reduces base current requirement; for amplifiers, consistent gain across operating range is important

Mnemonic

"GIVE" - Gain and Ic are Very Essential parameters

Question 5(c) OR [7 marks]

What is rectifier efficiency? Find out efficiency of the full wave rectifier.

Solution

Rectifier Efficiency: The ratio of DC output power to the AC input power, expressed as a percentage.
Definition:

- Efficiency ( ) = (PDC/PAC) ×100%
- Higher efficiency means better conversion of AC to DC power

Derivation for Full Wave Rectifier:
Step 1: Calculate DC output power

- IDC = VDC/RL
- PDC = IDC$^2 \times RL = VDC^2/RL$
- For full wave, VDC = 2Vm/
- PDC = (2Vm/)$^2/RL = 4Vm^2/(^2RL)$

Step 2: Calculate AC input power

- IRMS = VRMS/RL
- PAC = IRMS$^2 \times RL = VRMS^2/RL$
- For sine wave, VRMS = Vm/$\sqrt{2}$
- PAC = (Vm/$\sqrt{2}$)$^2/RL = Vm^2/(2RL)$

Step 3: Calculate efficiency

- = (PDC/PAC) ×100%
- = [4Vm$^2/(^2RL)]/[Vm^2/(2RL)] \times 100\%$
- = [4/(^{2})] × 2 × 100%
- = 8/(^{2}) × 100%
- = 8/9.87 ×100%
- = 81.2%

Full Wave Rectifier Efficiency = 81.2%
For comparison:

- Half Wave Rectifier Efficiency = 40.6%
- Bridge Rectifier Efficiency = 81.2%

Mnemonic

"PIDE" - Power Input Determines Efficiency