Fundamentals of Electronics (4311102) - Winter 2024 Solution

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Question 1(a) [3 marks]

Give the difference between Passive components and Active components

Solution

Answer:

Table 1. Passive vs Active Components

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

Question 1(b) [4 marks]

Explain Working of Light dependent resistor with neat diagram.

Solution

Answer:

Figure 1. LDR Working Principle

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

Question 1(c) [7 marks]

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

Solution

Answer:

Table 2. Semiconductor Types

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:

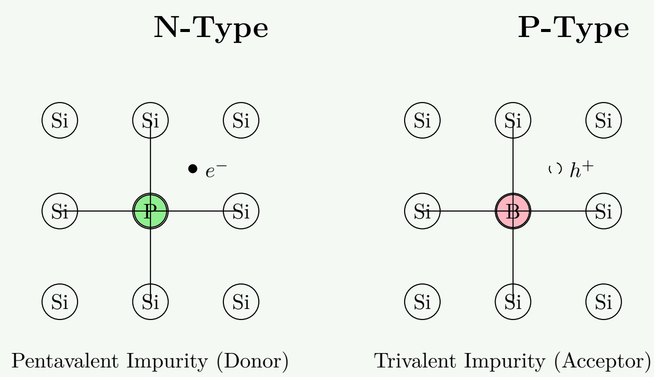


Figure 2. Semiconductor Doping

Question 1(c) OR [7 marks]

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

Solution

Answer:
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:

Table 3. Filter Types

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:

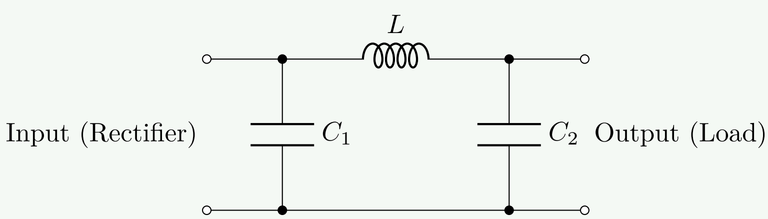


Figure 3. Pi Filter Circuit

- **Working**: First capacitor (C_1) reduces initial ripple, inductor (L) blocks AC components, second capacitor (C_2) 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

Question 2(a) [3 marks]

Write down different types of capacitors and explain any two.

Solution

Answer:
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

Question 2(b) [4 marks]

Explain air core and toroidal inductor.

Solution

Answer:
Air Core Inductor:

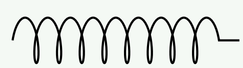


Figure 4. Air Core Inductor

- **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:

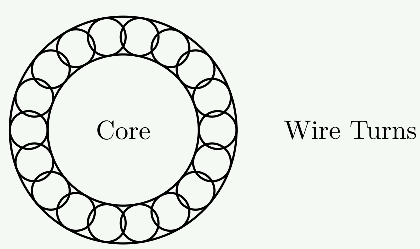


Figure 5. Toroidal Inductor

- **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

Question 2(c) [7 marks]

Explain Half wave rectifier and Compare different rectifier circuits.

Solution

Answer:
Half Wave Rectifier:

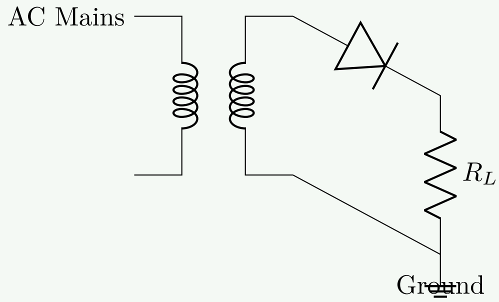


Figure 6. Half Wave Rectifier

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:

Table 4. Rectifier Comparison

Parameter	Half Wave	Full Wave (Center-Tap)	Bridge Rectifier
Diodes required	1	2	4
Output frequency	$f_1 = f_{in}$	$f_2 = 2 \times f_{in}$	$f_2 = 2 \times f_{in}$
Ripple factor	1.21	0.48	0.48
Efficiency	40.6%	81.2%	81.2%
PIV	$2V_m$	$2V_m$	V_m
TUF	0.287	0.693	0.812
DC output	V_m/π	$2V_m/\pi$	$2V_m/\pi$

Question 2(a) OR [3 marks]

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

Solution

Answer:

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

Question 2(b) OR [4 marks]

Explain classification of Resistor based on materials.

Solution

Answer:

Table 5. Resistor Classification

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/°C
- Tolerance: 5% to 10%
- Noise: Moderate to low

Characteristics of Metal Film Resistors:

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

Question 2(c) OR [7 marks]

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

Solution

Answer:
Full Wave Bridge Rectifier:

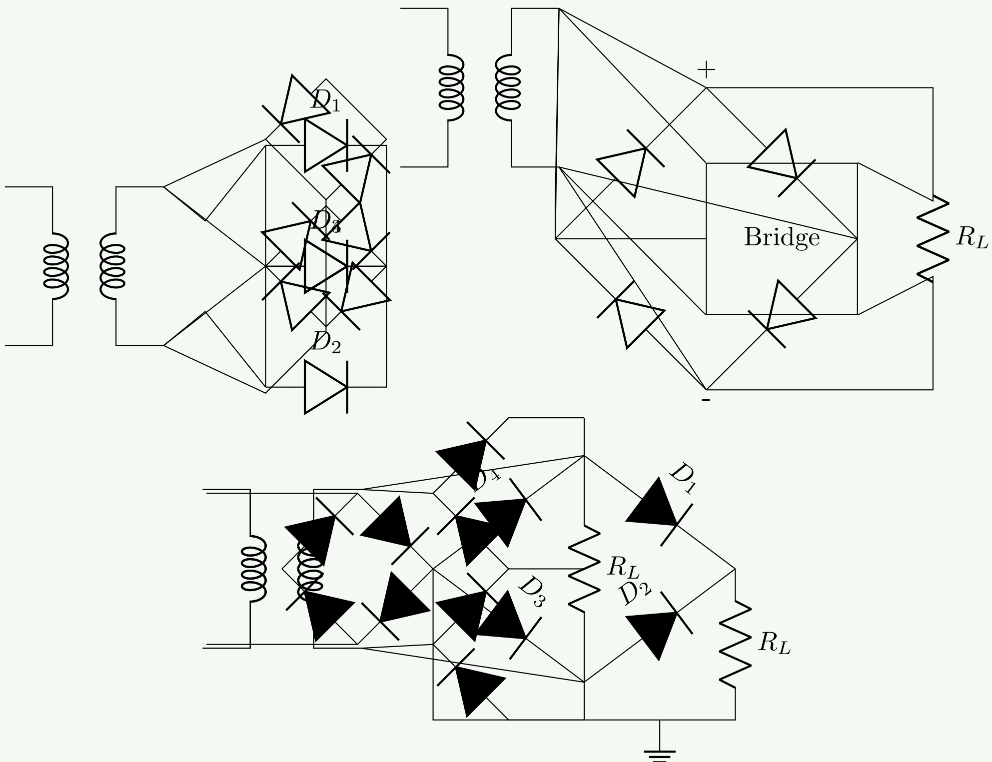


Figure 7. Full Wave Bridge Rectifier

Working:

- **Positive half-cycle**: D_1 and D_3 conduct, current flows through load
- **Negative half-cycle**: D_2 and D_4 conduct, current still flows through load in same direction
- **Output**: Both half-cycles of input converted to positive output

Center Tapped Full Wave Rectifier:

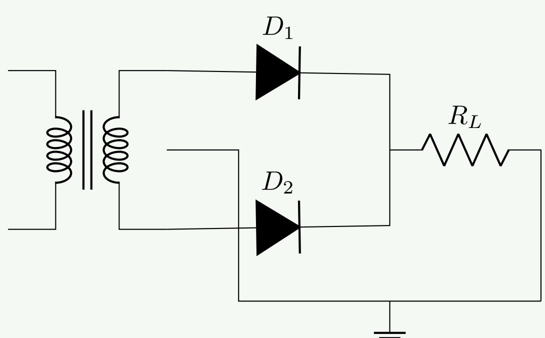
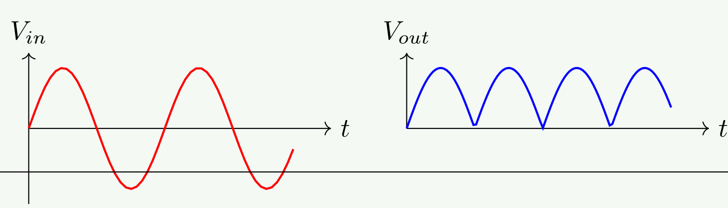


Figure 8. Center Tapped Rectifier

Working:

- **Positive half-cycle**: D_1 conducts, D_2 blocks
- **Negative half-cycle**: D_2 conducts, D_1 blocks
- **Output**: Both half-cycles of input converted to positive output

Waveforms:



Question 3(a) [3 marks]

Explain the characteristic of Varactor diode.

Solution

Answer:
Varactor Diode Characteristics:

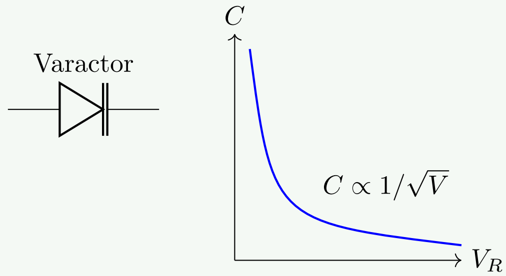


Figure 10. Varactor Diode C-V Curve

- **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

Question 3(b) [3 marks]

State and explain Faraday's laws of electromagnetic induction.

Solution

Answer:
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 $\propto$ 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**: $EMF = -N \times (d\Phi/dt)$
  - 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:

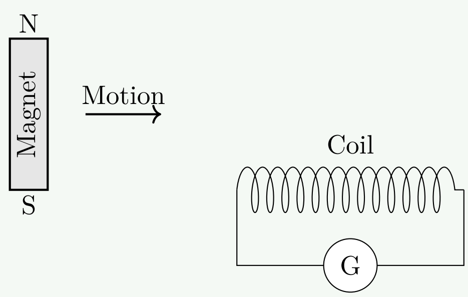


Figure 11. Electromagnetic Induction

Question 3(c) [7 marks]

Compare different Transistor Configurations.

Solution

Answer:

Table 6. Transistor Configurations Comparison

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	$\beta = I_C/I_B$ (20-500)	$\alpha = I_C/I_E$ (0.95-0.99)	$\gamma = I_E/I_B$ $(\beta + 1)$
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	Impedance matching, buffers

Relationship between α, β and γ:

- $\beta = \alpha/(1 - \alpha)$
- $\alpha = \beta/(1 + \beta)$
- $\gamma = \beta + 1$

Question 3(a) OR [3 marks]

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

Solution

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

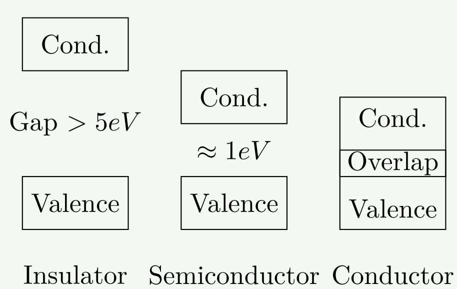


Figure 12. Energy Band Diagrams

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

Question 3(b) OR [4 marks]

Explain the function of Zener diode as a voltage regulator

Solution

Answer:

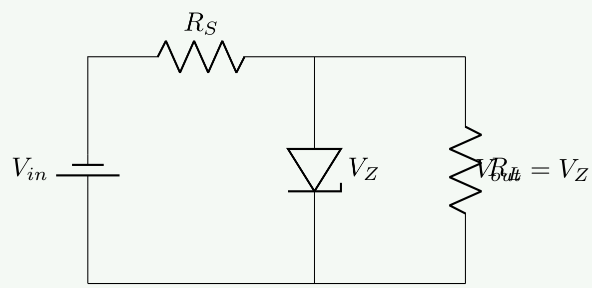


Figure 13. Zener Voltage Regulator

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:

- $V_{out} = V_z$ (Zener breakdown voltage)
- $I_z = (V_{in} - V_z)/R - I_L$

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

Answer:
V-I Characteristics of P-N Junction Diode:

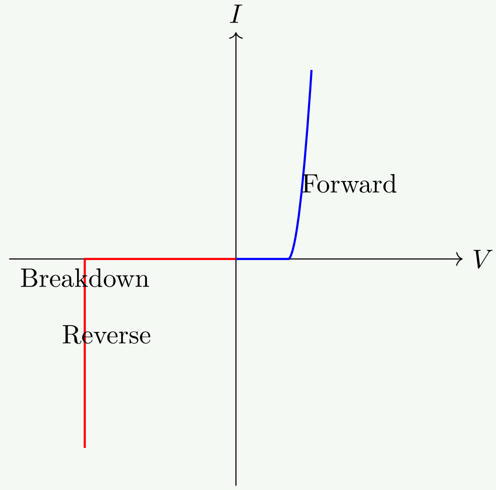


Figure 14. Diode V-I Characteristics

Key Points:

- **Forward bias**: Conducts easily after exceeding knee voltage ($\approx 0.7V$ 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:

Table 7. Comparison P-N vs Zener

Parameter	P-N Junction Diode	Zener Diode
Symbol	Standard Diode Symbol	Z-Symbol Diode
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

Question 4(a) [3 marks]

Describe working principle of Photodiode.

Solution

Answer:
Working Principle of Photodiode:

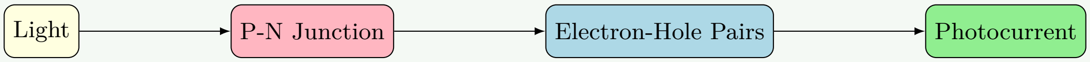


Figure 15. Photodiode Flow

- **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

Question 4(b) [4 marks]

Explain the characteristic of Schottky barrier diode.

Solution

Answer:
Schottky Barrier Diode Characteristics:

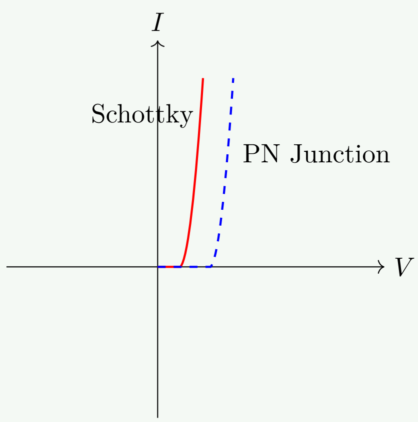


Figure 16. Schottky vs PN Junction

- **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

Question 4(c) [7 marks]

Explain working principle of PNP and NPN transistor.

Solution

Answer:
NPN Transistor Structure and Working:

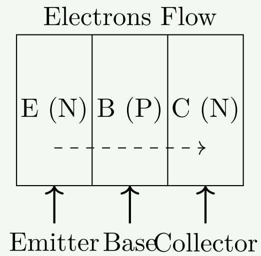


Figure 17. NPN Structure

- **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**: $I_E = I_B + I_C$
- **Majority carriers**: Electrons

PNP Transistor Structure and Working:

- **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**: $I_E = I_B + I_C$
- **Majority carriers**: Holes
- **Current direction**: Opposite to NPN (conventional current from emitter to collector)

Question 4(a) OR [3 marks]

Describe working principle of LED.

Solution

Answer:
Working Principle of LED:

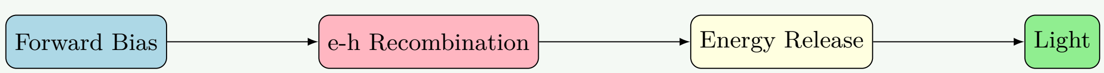


Figure 18. LED Principle

- **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)

Question 4(b) OR [4 marks]

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

Solution

Answer:
Transistor as a Switch:

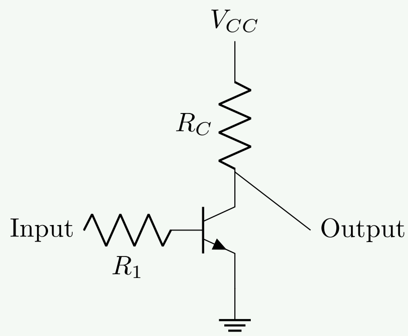


Figure 19. Transistor Switch Circuit

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 V_{CE}
- **Collector current**: Maximum (limited by collector resistor)
- **Collector-emitter voltage**: Very low (0.2V - 0.3V)
- **Applications**: Digital switches, motor drivers, LED drivers

Question 4(c) OR [7 marks]

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

Solution

Answer:
Common Emitter Configuration:

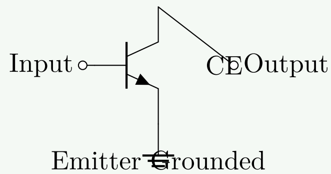


Figure 20. CE Configuration

Characteristics:
- **Input/Output**: Base / Collector
- **Gains**: High Current (β), High Voltage
- **Impedance**: Medium Input, High Output

Relationship between α and β:
By definition:
- $\alpha = I_C/I_E$
- $\beta = I_C/I_B$

From Kirchhoff's Current Law:

$$I_E = I_B + I_C$$

Dividing by I_E:

$$1 = \frac{I_B}{I_E} + \frac{I_C}{I_E} = \frac{I_B}{I_E} + \alpha$$

$$\frac{I_B}{I_E} = 1 - \alpha$$

Now,

$$\beta = \frac{I_C}{I_B} = \frac{I_C/I_E}{I_B/I_E} = \frac{\alpha}{1-\alpha}$$

Question 5(a) [3 marks]

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

Solution

Answer:
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:

Table 8. Disposal Methods

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

Question 5(b) [4 marks]

Explain methods of handling electronic waste with examples.

Solution

Answer:
Methods of Handling Electronic Waste:

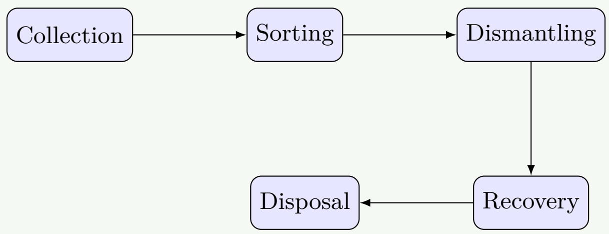


Figure 21. E-waste Handling Flow

- **Collection and Segregation**: Dedicated bins, prevents mixing (e.g., e-waste bins).
- **Dismantling and Resource Recovery**: Recovering gold/copper from PCBs.
- **Refurbishment and Reuse**: Repairing old computers.
- **Proper Disposal**: Specialized treatment for hazardous parts (mercury).

Question 5(c) [7 marks]

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

Solution

Answer:
Ripple Factor: Ratio of RMS value of AC component to DC component in the output ($\gamma = V_{AC}/V_{DC}$).
Derivation for Half Wave Rectifier:
Assume $v = V_m \sin \omega t$.
Step 1: Find DC component (average value)

$$V_{DC} = \frac{1}{2\pi} \int_0^{\pi} V_m \sin \omega t \, d(\omega t) = \frac{V_m}{\pi}$$

Step 2: Find RMS value

$$V_{RMS} = \sqrt{\frac{1}{2\pi} \int_0^{\pi} V_m^2 \sin^2 \omega t \, d(\omega t)} = \frac{V_m}{2}$$

Step 3: Find AC component

$$V_{AC} = \sqrt{V_{RMS}^2 - V_{DC}^2} = \sqrt{\left(\frac{V_m}{2}\right)^2 - \left(\frac{V_m}{\pi}\right)^2}$$

Step 4: Calculate ripple factor

$$\gamma = \frac{V_{AC}}{V_{DC}} = \frac{\sqrt{V_{RMS}^2 - V_{DC}^2}}{V_{DC}} = \sqrt{\left(\frac{V_{RMS}}{V_{DC}}\right)^2 - 1}$$

$$\gamma = \sqrt{\left(\frac{V_m/2}{V_m/\pi}\right)^2 - 1} = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1} = \sqrt{1.57^2 - 1} = 1.21$$

For Full Wave Rectifier, $\gamma = 0.48$.

Question 5(a) OR [3 marks]

Which are the toxic substances present in e-waste?

Solution

Answer:

Table 9. Toxic Substances in E-waste

Toxic Substance	Source	Impact
Lead (Pb)	Solder, CRT, batteries	Neurological damage
Mercury (Hg)	Switches, backlights	Kidney damage
Cadmium (Cd)	Batteries, PCBs	Bone disease
Flame Retardants	Plastics	Endocrine disruption
Beryllium (Be)	Connectors	Lung disease

Question 5(b) OR [4 marks]

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

Solution

Answer:
Selection Parameters:
- Maximum collector current (I_C)
- Maximum collector-emitter voltage (V_{CEO})
- Current gain (h_{FE} or β)
- Power dissipation (P_{tot})

Maximum Collector Current (I_C):
- Maximum current that can flow through collector without damage.
- Must exceed application's peak requirement.

Current Gain (β):
- Ratio of collector current to base current.
- Determines amplification capability; high gain needed for switching to reduce base drive.

Question 5(c) OR [7 marks]

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

Solution

Answer:
Rectifier Efficiency (η): Ratio of DC output power to AC input power ($\eta = P_{DC}/P_{AC} \times 100\%$).
Derivation for Full Wave Rectifier:
Step 1: Calculate DC output power

$$V_{DC} = \frac{2V_m}{\pi}, \quad I_{DC} = \frac{V_{DC}}{R_L}$$

$$P_{DC} = I_{DC}^2 R_L = \frac{4V_m^2}{\pi^2 R_L}$$

Step 2: Calculate AC input power

$$V_{RMS} = \frac{V_m}{\sqrt{2}}, \quad I_{RMS} = \frac{V_{RMS}}{R_L}$$

$$P_{AC} = I_{RMS}^2 R_L = \frac{V_m^2}{2R_L}$$

Step 3: Calculate efficiency

$$\eta = \frac{P_{DC}}{P_{AC}} = \frac{4V_m^2/(\pi^2 R_L)}{V_m^2/(2R_L)} = \frac{8}{\pi^2}$$

$$\eta = \frac{8}{9.87} \approx 0.812 = 81.2\%$$

Comparison:
- Half Wave: 40.6%
- Full Wave: 81.2%