Fundamentals of Electronics (4311102) - Winter 2023 Solution

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Question 1(a) [3 marks]

Define Forward and reverse bias of diode.

Solution

Answer:

Forward Bias of Diode:

- **Connection Method**: P-type connected to positive terminal and N-type connected to negative terminal of battery
- **Barrier Width**: Barrier width decreases
- **Resistance**: Low resistance (typically 100-1000Ω)
- **Current Flow**: Allows current to flow easily through the diode

Reverse Bias of Diode:

- **Connection Method**: P-type connected to negative terminal and N-type connected to positive terminal
- **Barrier Width**: Barrier width increases
- **Resistance**: Very high resistance (typically several MΩ)
- **Current Flow**: Blocks current flow (only small leakage current flows)

Diagram:

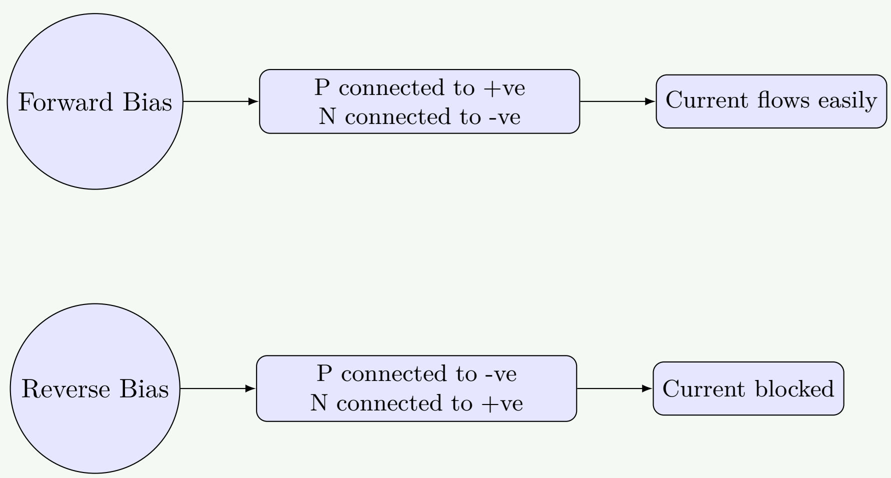


Figure 1. Forward and Reverse Bias Logic

Mnemonic

"PFNR: "Positive to P Forward, Negative to P Reverse""

Question 1(b) [4 marks]

Explain construction and working of LDR.

Solution

Answer:
Construction of LDR:

- **Material**: Made of semiconductor material (Cadmium Sulfide)
- **Pattern**: Zigzag pattern of photosensitive material on ceramic base
- **Electrodes**: Metal electrodes at both ends
- **Package**: Encapsulated in transparent plastic or glass case

Working Principle:

- **Photoconductivity**: Based on photoconductivity principle
- **Dark Resistance**: High resistance (MΩ range) in dark conditions
- **Light Exposure**: When exposed to light, photons release electrons
- **Resistance Drop**: Resistance decreases (kΩ range) in bright light

Diagram:

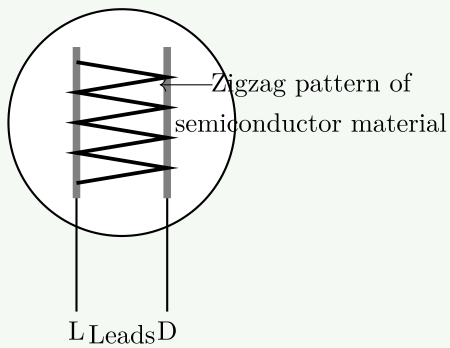


Figure 2. LDR Construction

Mnemonic

"MILD: "More Illumination, Less Dark-resistance""

Question 1(c) [7 marks]

Explain the color band coding method of Resistor. Write color band of 47kΩ ±5% resistance.

Solution

Answer:
Color Band Coding Method:

Table 1. Resistor Color Code

Color	Value	Multiplier	Tolerance
Black	0	10^0	-
Brown	1	10^1	$\pm1\%$
Red	2	10^2	$\pm2\%$
Orange	3	10^3	-
Yellow	4	10^4	-
Green	5	10^5	$\pm0.5\%$
Blue	6	10^6	$\pm0.25\%$
Violet	7	10^7	$\pm0.1\%$
Grey	8	10^8	$\pm0.05\%$
White	9	10^9	-
Gold	-	10^{-1}	$\pm5\%$
Silver	-	10^{-2}	$\pm10\%$
Colorless	-	-	$\pm20\%$

4-Band Resistor Color Code:
- **First Band**: First significant digit
- **Second Band**: Second significant digit
- **Third Band**: Multiplier
- **Fourth Band**: Tolerance

For 47kΩ $\pm$5%:
- First digit: 4 = Yellow
- Second digit: 7 = Violet
- Multiplier: 10^3 = Orange (for kΩ)
- Tolerance: $\pm5\%$ = Gold

Color bands for 47kΩ $\pm$5%: Yellow-Violet-Orange-Gold

Diagram:

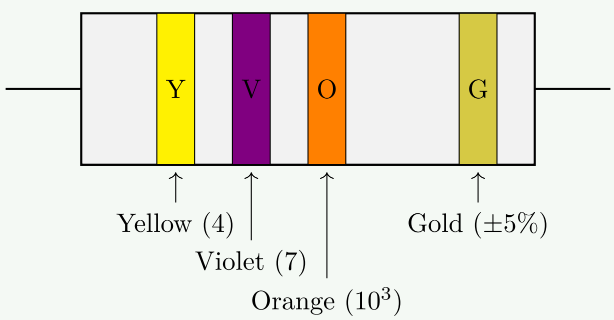


Figure 3. Resistor Color Bands: Yellow-Violet-Orange-Gold

Mnemonic

"BAND: "Beginning digits, Amplify with Multiplier, Note tolerance with last band, Decode carefully""

Question 1(c OR) [7 marks]

Explain Aluminum Electrolytic wet type capacitor.

Solution

Answer:
Aluminum Electrolytic Wet Type Capacitor:
Construction:
- **Plates**: Two aluminum foils (anode and cathode)
- **Dielectric**: Aluminum oxide layer on anode foil
- **Electrolyte**: Liquid electrolyte (boric acid, sodium borate, etc.)
- **Separator**: Paper separator soaked in electrolyte
- **Enclosure**: Aluminum can with rubber seal

Working Principle:
- **Oxide Layer**: Thin aluminum oxide layer acts as dielectric
- **Electrolyte**: Acts as cathode connection to second plate
- **Polarization**: Has defined polarity (+ and -) terminals

Characteristics:
- **Capacitance Range**: 1μF to 47,000μF
- **Voltage Rating**: 6.3V to 450V
- **Polarity**: Polarized (must connect correctly)
- **Leakage Current**: Higher than other capacitor types
- **ESR**: Higher equivalent series resistance

Diagram:

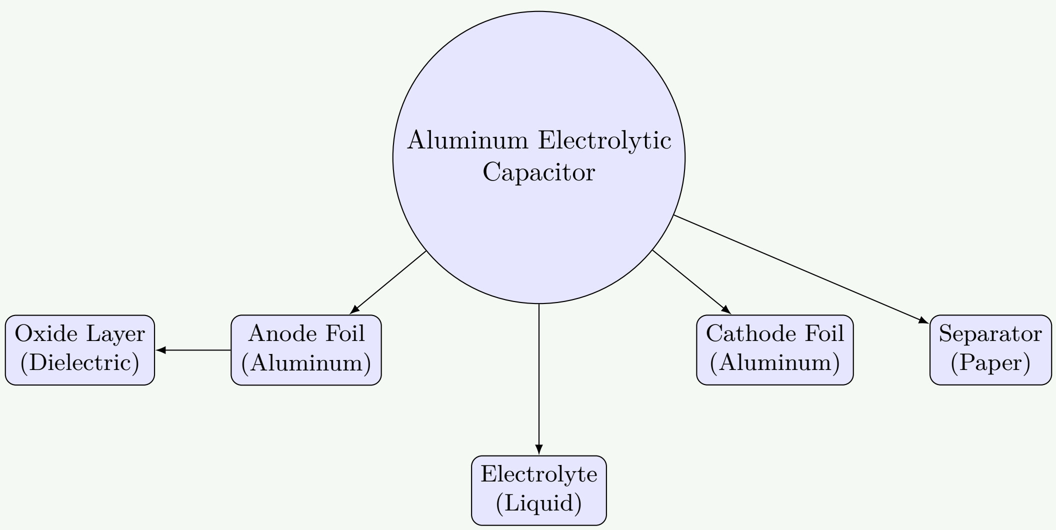


Figure 4. Aluminum Electrolytic Capacitor Components

Mnemonic

"POLE: "Polarized, Oxide layer, Liquid electrolyte, Enormous capacitance""

Question 2(a) [3 marks]

Draw the symbol of Schottkey diode, LED and Photo-diode.

Solution

Answer:
Symbols:

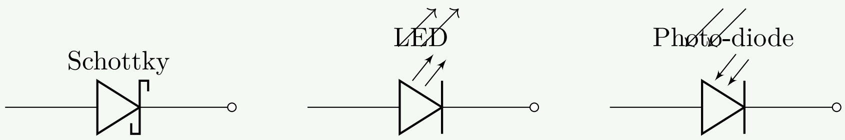


Figure 5. Symbols: Schottky Diode, LED, Photo-diode

Key Features:

- **Schottky Diode**: Standard diode symbol with curved bar (represents metal-semiconductor junction)
- **LED**: Standard diode symbol with two arrows pointing away (represents light emission)
- **Photo-diode**: Standard diode symbol with two arrows pointing toward diode (represents light detection)

Mnemonic

"SLP: "Schottky has curve, LED emits, Photo-diode absorbs""

Question 2(b) [4 marks]

Define Active and Passive Components with example.

Solution

Answer:
Passive Components:

Table 2. Passive vs Active Components

Characteristic	Description	Examples
Passive Components		
Power	Cannot generate power	Resistors, Capacitors, Inductors
Signal	Cannot amplify signals	Transformers, Diodes
Control	No control over current flow	Connectors, Switches
Energy	Store or dissipate energy	Fuses, Filters
Active Components		
Power	Can generate power	Transistors, ICs
Signal	Can amplify signals	Op-amps, Amplifiers
Control	Control current flow	SCRs, MOSFETs
Dependency	Require external power	Voltage regulators, Microcontrollers

Diagram:

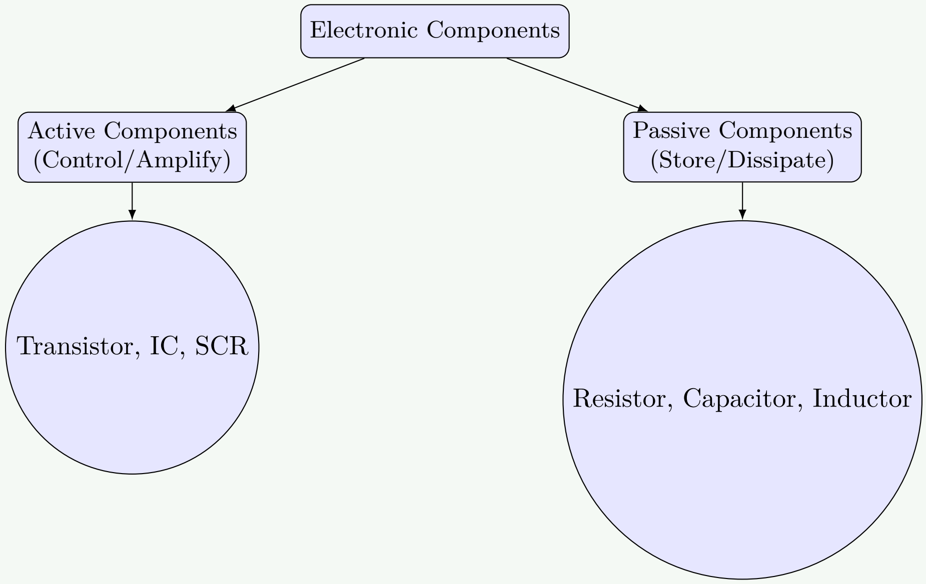


Figure 6. Classification of Electronic Components

Mnemonic

"PASS-ACT: "Passive stores or dissipates, Active controls or amplifies""

Question 2(c) [7 marks]

Explain working of full wave bridge rectifier.

Solution

Answer:
Full Wave Bridge Rectifier:
Circuit Construction:
- **Diodes**: Four diodes arranged in bridge configuration
- **Input**: AC supply from transformer secondary
- **Output**: Pulsating DC across load resistor with filter capacitor

Working Principle:
- **Positive Half Cycle**: D1 and D3 conduct, D2 and D4 block
- **Negative Half Cycle**: D2 and D4 conduct, D1 and D3 block
- **Current Flow**: Always flows through load in same direction

Performance Parameters:
- **Ripple Frequency**: $2\times$ input frequency (100 Hz for 50 Hz input)
- **Efficiency**: 81.2%
- **PIV**: $V_0(max)$ per diode
- **TUF**: 0.812 (Transformer Utilization Factor)

Diagram:

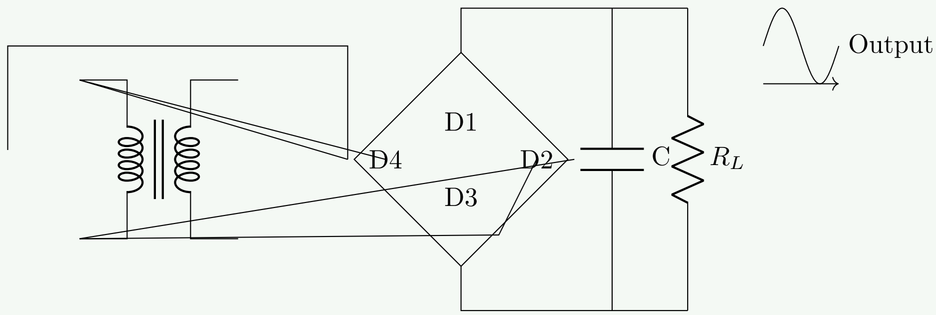


Figure 7. Full Wave Bridge Rectifier Circuit

Mnemonic

"BRIDGE: "Better Rectification with Improved Diode Geometry Efficiency""

Question 2(a OR) [3 marks]

Explain construction and working of LED.

Solution

Answer:
Construction of LED:

- **Material**: Semiconductor (GaAs, GaP, AlGaInP, etc.)
- **Junction**: P-N junction with heavily doped semiconductors
- **Package**: Encased in transparent or colored epoxy lens
- **Cathode**: Identified by flat side on package or shorter lead

Working Principle:

- **Forward Bias**: Applied to P-N junction
- **Recombination**: Electrons and holes recombine at junction
- **Energy Release**: Energy released as photons (light)
- **Wavelength**: Determined by band gap of semiconductor material

Diagram:

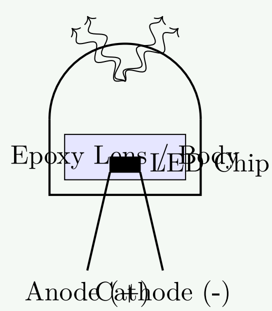


Figure 8. LED Construction

Mnemonic

"LEDS: "Light Emits During electron-hole recombination in Semiconductor""

Question 2(b OR) [4 marks]

Explain composition type resistors.

Solution

Answer:
Composition Resistors:
Construction:
- **Core Material**: Carbon particles mixed with insulating material (clay/ceramic)
- **Binding**: Resin binder forms solid cylindrical shape
- **Terminals**: Metal caps with leads attached to ends
- **Protection**: Coated with insulating paint or plastic

Characteristics:
- **Resistance Range**: 1Ω to $22M\Omega$
- **Power Rating**: 1/8W to 2W
- **Tolerance**: $\pm5\%$ to $\pm20\%$
- **Temperature Coefficient**: -500 to +500 ppm/°C

Advantages & Limitations:
- **Cost**: Low cost
- **Noise**: Higher noise level
- **Stability**: Less stable with temperature
- **Applications**: General purpose, non-critical applications

Diagram:

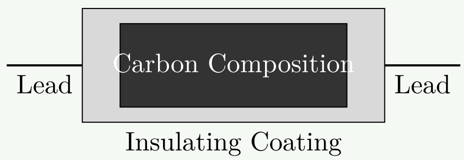


Figure 9. Carbon Composition Resistor Structure

Mnemonic

“CCRI: ”Carbon Composition Resistors are Inexpensive””

Question 2(c OR) [7 marks]

Explain working of full wave rectifier with two diodes.

Solution

Answer:
Full Wave Rectifier with Two Diodes (Center-tap):
Circuit Construction:
- **Transformer**: Center-tapped transformer secondary
- **Diodes**: Two diodes connected to opposite ends of secondary
- **Output**: Taken between center tap and diode junction

Working Principle:
- **Positive Half Cycle**: Upper half of secondary positive, D1 conducts, D2 blocks
- **Negative Half Cycle**: Lower half of secondary positive, D2 conducts, D1 blocks
- **Current Flow**: Always flows through load in same direction

Performance Parameters:
- **Ripple Frequency**: $2\times$ input frequency (100 Hz for 50 Hz input)
- **Efficiency**: 81.2%
- **PIV**: $2V_0(max)$ per diode (twice the center-tap rectifier)
- **TUF**: 0.693 (Transformer Utilization Factor)

Diagram:

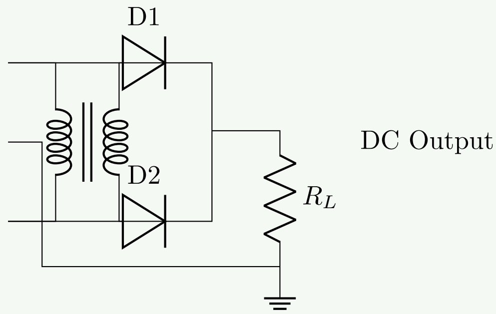


Figure 10. Center-Tap Full Wave Rectifier

Mnemonic

"CTFWR: "Center Tap Facilitates Whole-cycle Rectification""

Question 3(a) [3 marks]

Explain working of schhotkey diode.

Solution

Answer:
Working of Schottky Diode:

- **Junction Type**: Metal-Semiconductor (M-S) junction instead of P-N
- **Charge Carriers**: Majority carrier device (electrons in N-type)
- **Barrier**: Schottky barrier formed at metal-semiconductor interface
- **Forward Voltage**: Lower forward voltage drop (0.2-0.4V vs 0.7V for Si diode)

Key Characteristics:

- **Switching Speed**: Very fast switching (no minority carrier storage)
- **Applications**: High-frequency circuits, power supplies
- **Recovery Time**: Negligible reverse recovery time

Diagram:

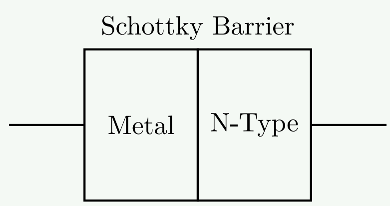


Figure 11. Schottky Structure

Mnemonic

"SFAM: "Schottky's Fast And Metal-based""

Question 3(b) [4 marks]

Explain N type semiconductor.

Solution

Answer:
N-type Semiconductor:
Formation:

- **Base Material**: Intrinsic semiconductor (Silicon or Germanium)
- **Doping Element**: Pentavalent impurity (P, As, Sb)
- **Doping Process**: Thermal diffusion or ion implantation
- **Concentration**: Typically 1 part impurity to 10^8 parts silicon

Characteristics:

- **Majority Carriers**: Electrons (negative charge carriers)
- **Minority Carriers**: Holes
- **Conductivity**: Higher than intrinsic semiconductor
- **Fermi Level**: Closer to conduction band

Diagram:

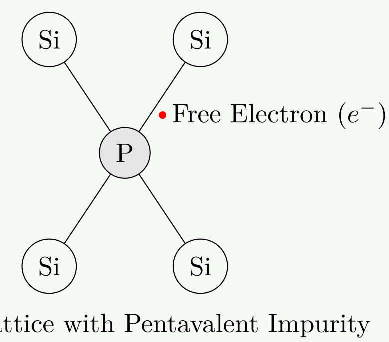


Figure 12. N-Type Doping

Mnemonic

"PENT: "Pentavalent Element makes N-Type with free electrons""

Question 3(c) [7 marks]

Explain construction and working of PN Junction Diode.

Solution

Answer:
Construction of PN Junction Diode:

- **Materials**: P-type and N-type semiconductor regions
- **Junction**: Formed by diffusion or epitaxial growth
- **Depletion Region**: Forms at junction interface
- **Contacts**: Metal contacts attached to both regions
- **Packaging**: Sealed in glass, plastic, or metal case

Working Principle:

- **Depletion Region**: Forms due to diffusion of carriers
- **Barrier Potential**: Created across junction (0.7V for Si, 0.3V for Ge)
- **Forward Bias**: Current flows when forward voltage > barrier potential
- **Reverse Bias**: Only small leakage current flows until breakdown

Diagram:

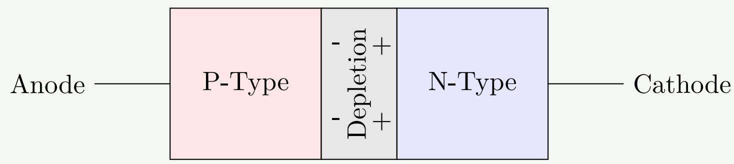


Figure 13. PN Junction Structure

Mnemonic

"BIRD: "Barrier forms at Interface, Rectifies Direct current""

Question 3(a OR) [3 marks]

Explain working of photo diode.

Solution

Answer:
Working of Photo Diode:

- **Operation**: Always operated in reverse bias
- **Dark Current**: Small leakage current flows when no light incident (due to thermal generation)
- **Light Incidence**: When light falls on junction, energy breaks covalent bonds
- **Carrier Generation**: Electron-hole pairs generated in depletion region
- **Photocurrent**: Electric field sweeps carriers across junction, increasing reverse current
- **Proportionality**: Current increases linearly with light intensity

Diagram:

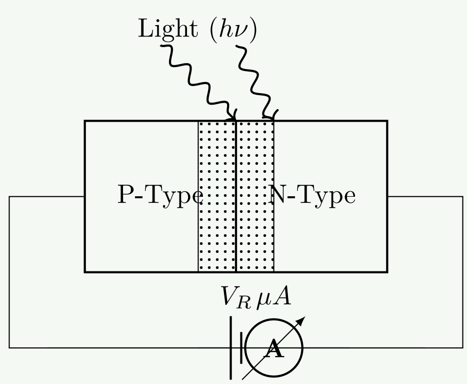


Figure 14. Photo Diode Operation

Mnemonic

"DARK: "Dark current exists, Absorbs photons, Reverse bias, K-urrent increases""

Question 3(b OR) [4 marks]

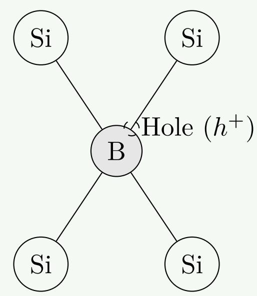
Explain P type semiconductor.

Solution

Answer:
P-type Semiconductor:
Formation:
- **Base Material**: Intrinsic semiconductor (Si or Ge)
- **Doping Element**: Trivalent impurity (Boron, Aluminum, Indium, Gallium)
- **Process**: Adding trivalent atoms creates vacancies (holes)

Characteristics:
- **Majority Carriers**: Holes (positive charge carriers)
- **Minority Carriers**: Electrons
- **Fermi Level**: Closer to valence band
- **Acceptor Ions**: Negative ions created when holes accept electrons

Diagram:



Crystal Lattice with Trivalent Impurity

Figure 15. P-Type Doping

Mnemonic

"TRIP: "Trivalent Impurity produces Positive holes""

Question 3(c OR) [7 marks]

Compare half wave and full wave rectifier.

Solution

Answer:
Comparison of Rectifiers:

Table 3. Rectifier Comparison

Parameter	**Half Wave**	**Full Wave (Center Tap)**	**Bridge Rectifier**
No. of Diodes	1	2	4
Max Efficiency	40.6%	81.2%	81.2%
Ripple Factor	1.21	0.48	0.48
Ripple Freq	f_{in}	$2f_{in}$	$2f_{in}$
PIV Rating	V_m	$2V_m$	V_m
TUF	0.287	0.693	0.812
Output Voltage	$V_{dc} = V_m/\pi$	$V_{dc} = 2V_m/\pi$	$V_{dc} = 2V_m/\pi$
Transformer	Simple	Center Tapped Required	Simple
Cost	Lowest	Medium	Highest (due to 4 diodes)

Question 4(a) [3 marks]

Draw the symbol and construction of PNP and NPN transistor with proper labelling.

Solution

Answer:
Construction and Symbols:

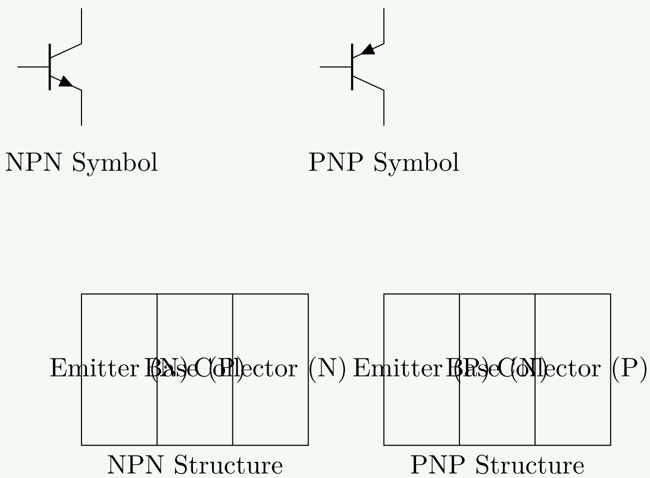


Figure 16. Transistor Symbols and Construction

Mnemonic

"P-POINT: "PNP Points In, NPN Points Out""

Question 4(b) [4 marks]

Explain working of transistor amplifier.

Solution

Answer:
Transistor Amplifier Working:

- **Biasing**: Emitter-Base junction is forward biased, Collector-Base junction is reverse biased (Active Region)
- **Input**: Weak AC signal applied across Emitter-Base
- **Control**: Small variations in Base current (I_B) cause large variations in Collector current (I_C)
- **Gain**: Current Gain $\beta = \Delta I_C/\Delta I_B$ is typically large (50-300)
- **Output**: Amplified voltage developed across load resistor connected in collector circuit
- **Process**: I_E electrons injected into Base, most cross to Collector (due to reverse bias attraction), forming I_C

Diagram:

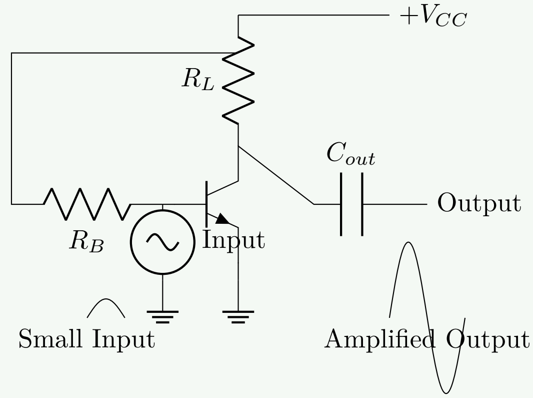


Figure 17. Common Emitter Amplifier Concept

Question 4(c) [7 marks]

Explain working of Zener diode.

Solution

Answer:
Zener Diode:
Construction:

- Heavily doped P-N junction diode
- Designed to operate in reverse breakdown region

Working Principle:

- **Forward Bias**: Acts like normal diode
- **Reverse Bias**: Blocks current up to breakdown voltage (V_Z)
- **Breakdown**: At V_Z, sharp increase in current occurs due to Zener effect (quantum tunneling) or Avalanche effect
- **Voltage Regulation**: Voltage across diode remains constant (V_Z) despite large changes in current

Applications:

- Voltage Regulator
- Reference voltage source
- Over-voltage protection

Characteristics Diagram:

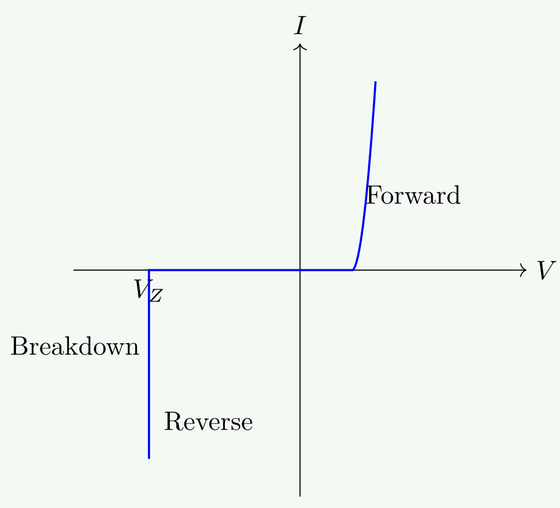


Figure 18. Zener V-I Characteristics

Mnemonic

"ZAP: "Zener Always Provides constant voltage""

Question 4(a OR) [3 marks]

Explain transistor as a switch.

Solution

Answer:
Transistor as Switch: Operates in Cut-off and Saturation regions.

- **OFF State (Open Switch)**:
  - Base current $I_B = 0$
  - Operates in **Cut-off Region**
  - Collector current $I_C \approx 0$
  - Output voltage $V_{CE} = V_{CC}$
- **ON State (Closed Switch)**:
  - Sufficient Base current supplied
  - Operates in **Saturation Region**
  - Maximum Collector current flows (I_{sat})
  - Output voltage $V_{CE} \approx 0.2V$ (Saturation voltage)

Diagram:

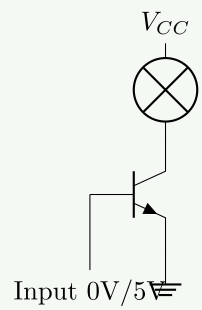


Figure 19. Transistor Switch Circuit

Mnemonic

"CO-SI: "Cut-off is Open, Saturation is Closed""

Question 4(b OR) [4 marks]

Draw and explain characteristics of CE amplifier.

Solution

Answer:
Common Emitter Characteristics:
1. Input Characteristics (I_B vs V_{BE} at constant V_{CE}):

- Resembles forward biased diode characteristic
- Beyond knee voltage (0.7V for Si), I_B increases rapidly with small increase in V_{BE}
- Increasing V_{CE} shifts curve slightly to right (Early effect - ignoring for basic explanation)

2. Output Characteristics (I_C vs V_{CE} at constant I_B):

- **Cut-off Region**: $I_B = 0$, $I_C \approx 0$. Transistor OFF.

- **Active Region**: I_C is constant for given I_B, almost independent of V_{CE}. Used for amplification. Linear region.
- **Saturation Region**: V_{CE} is very low ($< 0.2V$). I_C increases rapidly with V_{CE}. Transistor ON.

Diagram:

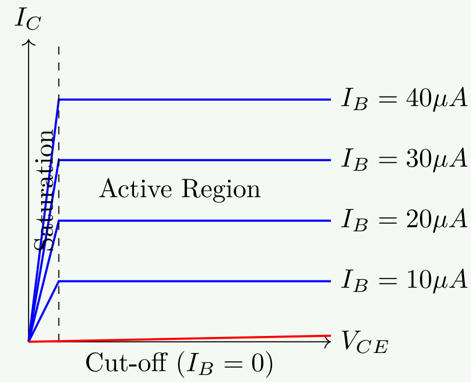


Figure 20. CE Output Characteristics

Question 4(c OR) [7 marks]

Explain working of varactor diode.

Solution

Answer:
Working of Varactor Diode:

- **Function**: Acts as a voltage-controlled variable capacitor
- **Operation**: Always operated in reverse bias
- **Principle**:
  - Reverse bias voltage increases width of depletion region
  - Depletion region acts as dielectric between P and N regions (acting as plates)
  - Capacitance $C = \epsilon A/d$ (where d is depletion width)
  - As Reverse Voltage (V_R) increases → Width (d) increases → Capacitance (C) decreases
- **Relationship**: $C_T \propto \frac{1}{\sqrt{V_R}}$
- **Application**: Tuning circuits (Radio/TV tuners), VCOs (Voltage Controlled Oscillators)

Diagram:

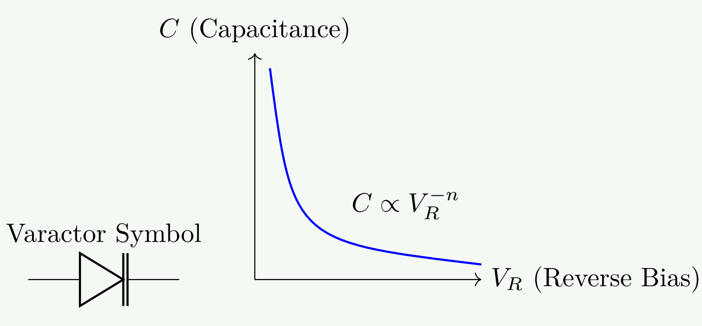


Figure 21. Varactor Diode Characteristics

Mnemonic

"VARY: "Voltage Adjusts Reverse-bias Yielding capacitance""

Question 5(a) [3 marks]

Define Active, Saturation and Cut-Off region for transistor amplifier.

Solution

Answer:

- **Active Region**:
  - Emitter-Base junction: Forward Biased
  - Collector-Base junction: Reverse Biased
  - Use: Amplification
- **Saturation Region**:
  - Emitter-Base junction: Forward Biased
  - Collector-Base junction: Forward Biased
  - Use: ON Switch (Closed)
- **Cut-Off Region**:
  - Emitter-Base junction: Reverse Biased
  - Collector-Base junction: Reverse Biased
  - Use: OFF Switch (Open)

Question 5(b) [4 marks]

Check current gain α and β if $I_c = 10mA$ and $I_b = 100\mu A$.

Solution

Answer:
Given:

- $I_C = 10mA$
- $I_B = 100\mu A = 0.1mA$

Calculations:

1. **Calculate β**:

$$\beta = \frac{I_C}{I_B} = \frac{10mA}{0.1mA} = 100$$

2. **Calculate Emitter Current I_E**:

$$I_E = I_C + I_B = 10mA + 0.1mA = 10.1mA$$

3. **Calculate α**:

$$\alpha = \frac{I_C}{I_E} = \frac{10mA}{10.1mA} \approx 0.9901$$

Alternatively using relation:

$$\alpha = \frac{\beta}{1+\beta} = \frac{100}{101} \approx 0.9901$$

Result:

- $\beta = 100$
- $\alpha = 0.99$

Question 5(c) [7 marks]

Discuss strategies for Electronic Waste management in small electronic industries.

Solution

Answer:
E-Waste Management Strategies:

1. **Inventory Management**: Keep track of all electronic equipment and lifespan to plan replacements efficiently.
2. **Reduce**: Minimize purchase of unnecessary equipment. Opt for upgradable modular devices instead of replacing entire units.
3. **Reuse**: refurbish old electronics for less demanding tasks (e.g., using older PCs for data entry or print servers).
4. **Recycle**: Partner with certified e-waste recyclers who safely extract valuable metals (Au, Ag, Cu) and dispose of hazardous materials (Pb, Hg).
5. **Segregation**: Set up separate bins for e-waste (batteries, cables, circuit boards) to prevent mixing with general waste.
6. **EPR Compliance**: Adhere to Extended Producer Responsibility (EPR) guidelines if involved in manufacturing.
7. **Employee Training**: Educate staff about proper disposal methods and data wiping before disposal.

Diagram:

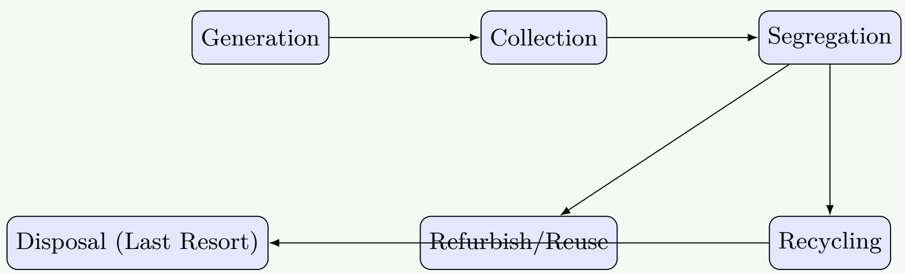


Figure 22. E-Waste Flow

Mnemonic

"3R: "Reduce, Reuse, Recycle""

Question 5(a OR) [3 marks]

Draw circuit configuration of CB, CE and CC transistor.

Solution

Answer:

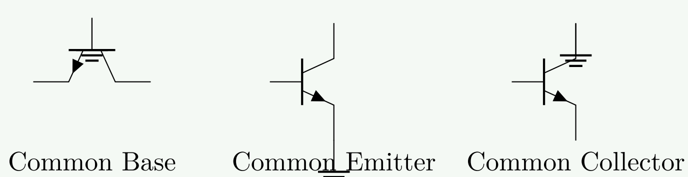


Figure 23. Transistor Configurations

Question 5(b OR) [4 marks]

Derive the relation between current gain α and β.

Solution

Answer:
Derivation:
1. We know transistor currents:

$$I_E = I_C + I_B$$

2. Divide entire equation by I_C:

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

$$\frac{1}{\alpha} = 1 + \frac{1}{\beta}$$

(Because $\alpha = I_C/I_E$ and $\beta = I_C/I_B$)
3. Solve for α:

$$\frac{1}{\alpha} = \frac{\beta + 1}{\beta}$$

$$\alpha = \frac{\beta}{1+\beta}$$

4. Solve for β:

$$\frac{1}{\beta} = \frac{1}{\alpha} - 1 = \frac{1-\alpha}{\alpha}$$

$$\beta = \frac{\alpha}{1-\alpha}$$

Conclusion:

$$\alpha = \frac{\beta}{1+\beta}, \quad \beta = \frac{\alpha}{1-\alpha}$$

Question 5(c OR) [7 marks]

Define E-waste and explain disposal of Electronic waste.

Solution

Answer:
Definition: **E-Waste (Electronic Waste)** refers to discarded electrical or electronic devices such as computers, phones, printers, and appliances that have reached the end of their useful life.
Disposal Methods:
1. **Landfilling**: Dumping waste in trenches. Least preferred method as toxic substances (Lead, Cadmium) leach into soil and groundwater.
2. **Incineration**: Controlled burning of waste. reduces volume but can release toxic gases into atmosphere if not filtered properly.
3. **Acid Bath**: Soaking circuits in acid to extract gold. Highly hazardous to workers and environment.
4. **Mechanical Recycling (Preferred)**:
   - Shredding: Breaking devices into small pieces.
   - Separation: Using magnets and eddy currents to separate metals from plastic.
   - Recovery: Smelting metals for reuse.
5. **Reuse/Refurbishing**: Extending life by repairing. Best for environment.

Pyramid of E-Waste:

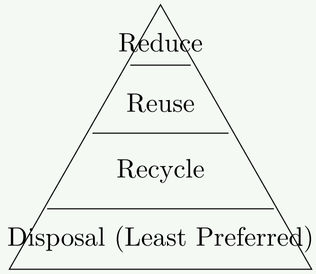


Figure 24. Waste Management Hierarchy