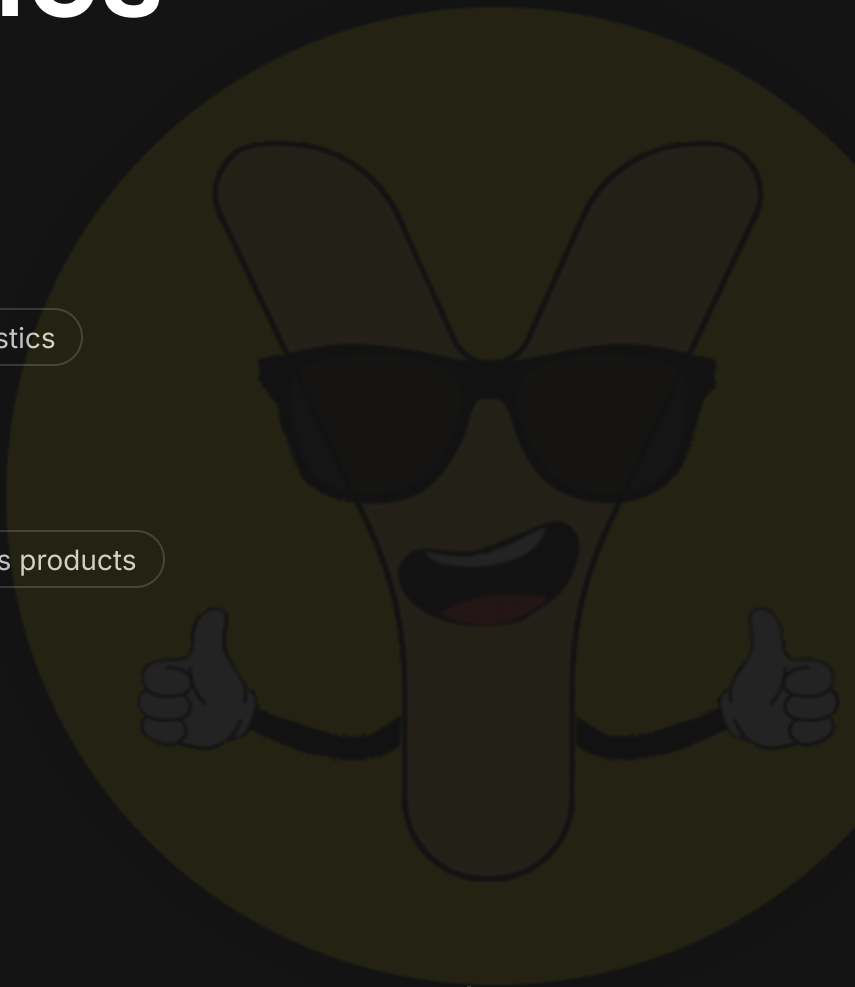
AKTU · 1ST YEAR · AEC101A / AEC201A

Fundamentals of Electronics Engineering

Unit 1 — Diodes and Power Supply Circuits

- p-n junction: concept of depletion layer, forward and reverse bias
- ideal diode vs real diode
- V-I characteristics
- diode as a switch
- half-wave and full-wave bridge rectifier
- filter capacitor
- Zener diode: Zener breakdown, voltage regulator circuit
- LED: working and current-limiting resistor
- applications: USB charger rectifier, 5V/3.3V regulated supply for Arduino/Raspberry Pi, LED indicators in electronics products



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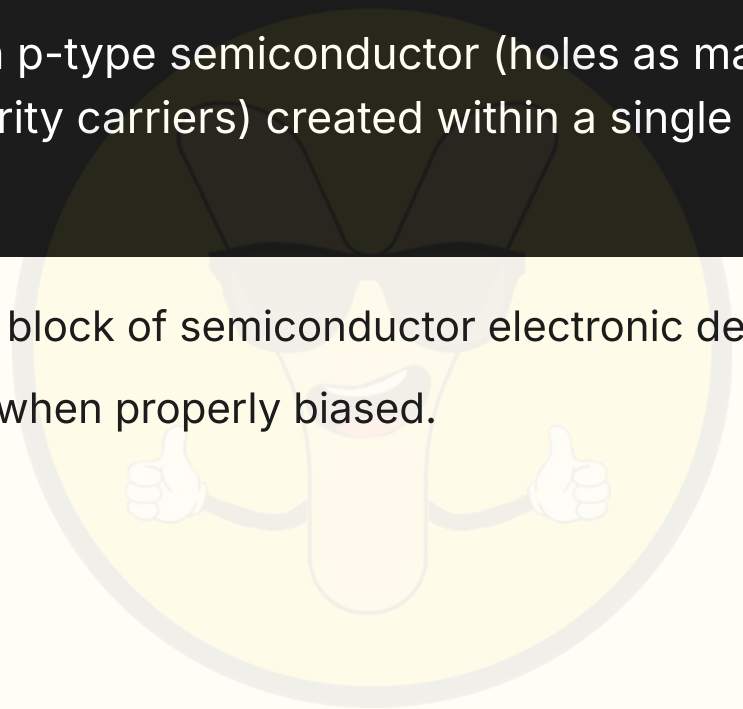
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Unit 1 Introduction: p-n Junction

P-N JUNCTION

An interface or boundary between p-type semiconductor (holes as majority carriers) and n-type semiconductor (electrons as majority carriers) created within a single crystal of semiconductor material.

- Serves as the fundamental building block of semiconductor electronic devices.
- Enables unidirectional current flow when properly biased.



Concept of Depletion Layer

DEPLETION REGION

An insulating region around the p-n interface devoid of free mobile charge carriers, formed due to the diffusion and recombination of electrons and holes.

- Leaving behind immobile positive donor ions on the n-side and negative acceptor ions on the p-side.
- Creates an internal electric field that opposes further diffusion, establishing equilibrium (Barrier potential: $0.7\ \mathrm{V}$ for Silicon, $0.3\ \mathrm{V}$ for Germanium).

Forward Bias vs Reverse Bias

Parameter	Forward Bias	Reverse Bias
Connection	p-type to positive terminal, n-type to negative.	p-type to negative terminal, n-type to positive.
Depletion Layer	Width decreases significantly.	Width increases significantly.
Resistance	Very low (allows heavy current).	Very high (blocks current, negligible leakage).
Current Flow	Large current due to majority carriers.	Tiny reverse saturation current due to minority carriers.

Ideal Diode vs Real Diode

Characteristic	Ideal Diode	Real Diode (Practical)
Forward Voltage Drop	$0\ \text{V}$ (acts as a perfect closed switch)	$\approx 0.7\ \text{V}$ for Silicon
Reverse Current	$0\ \text{A}$ (acts as a perfect open switch)	Extremely small reverse saturation current (μA or nA)
Reverse Breakdown	Infinite breakdown voltage	Specific breakdown voltage (V_{BR})
Equivalent Circuit	Short circuit (on) / Open circuit (off)	Battery ($0.7\ \text{V}$) + Forward Resistance in series

Diode V-I Characteristics

V-I CHARACTERISTICS CURVE

A graphical representation showing the relationship between diode voltage V_D and diode current I_D.

- Forward Region: Current remains near zero until knee voltage ($0.7\ \mathrm{V}$) is reached, after which current rises exponentially.
- Reverse Region: Current remains almost zero (leakage current) until breakdown voltage V_{BR} where avalanche or zener breakdown occurs.

Diode as a Switch

ELECTRONIC SWITCHING

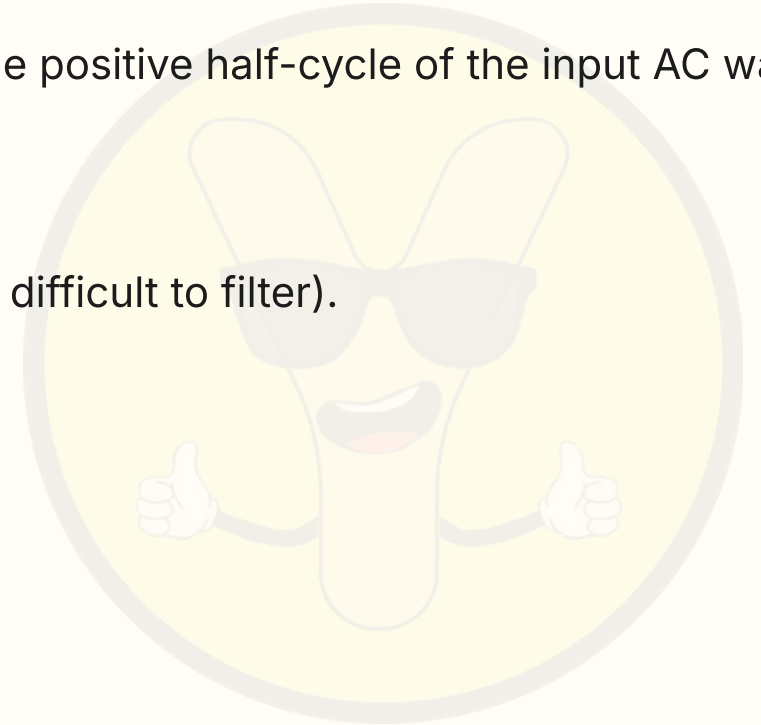
Using a diode to control the state of an electrical path between conducting (ON) and non-conducting (OFF) states.

- ON State (Closed Switch): Diode is forward-biased, voltage drop is $\approx 0.7\ \mathrm{V}$, allows maximum current flow.
- OFF State (Open Switch): Diode is reverse-biased, blocks voltage, current flow is practically zero.

Half-Wave Rectifier Analysis

Characteristics and formulas for half-wave rectification.

- Operation: Conducts only during the positive half-cycle of the input AC waveform, blocking the negative half-cycle.
- Maximum Efficiency (η): 40.6%.
- Ripple Factor (r): 1.21 (high ripple, difficult to filter).
- Key Formulas
  - \(V_{dc} = \frac{V_m}{\pi}\
  - \(I_{dc} = \frac{I_m}{\pi}\
  - $V_{rms} = \frac{V_m}{2}$



Full-Wave Bridge Rectifier Analysis

Superior performance compared to half-wave rectifiers.

- Operation: Uses four diodes arranged in a bridge. Conducts current through two alternate diodes during both positive and negative half-cycles.
- Maximum Efficiency (η): 81.2% (double of half-wave).
- Ripple Factor (r): 0.48 (smoother output, easier to filter).
- Key Formulas
  - \(V_{dc} = \frac{2V_m}{\pi}\
  - \(I_{dc} = \frac{2I_m}{\pi}\
  - $V_{rms} = \frac{V_m}{\sqrt{2}}$

Filter Capacitor

CAPACITOR INPUT FILTER

A large capacitor connected in parallel with the load resistor after the rectifier to smooth out the pulsating DC voltage into a nearly constant DC voltage.

- Charging: Capacitor charges rapidly to the peak voltage V_m of the rectified wave.
- Discharging: As the rectified voltage drops, the capacitor discharges slowly through the load resistor R_L, reducing ripple voltage amplitude.

Zener Diode and Breakdown

ZENER DIODE

A specially designed heavily doped semiconductor diode engineered to operate safely in the reverse breakdown region without being damaged.

- Zener Breakdown: Occurs in heavily doped diodes at low voltages ($< 5\ \mathrm{V}$) where high electric field pulls valence electrons directly into conduction band.
- Avalanche Breakdown: Occurs in lightly doped diodes at higher voltages ($> 6\ \mathrm{V}$) due to impact ionization by thermally generated carriers.

Zener Voltage Regulator Circuit

VOLTAGE REGULATION USING ZENER

A circuit that maintains a constant DC output voltage across a load despite variations in input voltage or load current.

- Working Principle: Connected in reverse bias across the load in series with a limiting resistor R_s.
- When input voltage rises, excess current flows through the Zener diode, keeping the voltage drop across the load fixed at V_Z.

Light Emitting Diode (LED)

LED WORKING PRINCIPLE

A p-n junction diode that emits light when forward-biased, operating on the principle of electroluminescence.

- Recombination: Electrons from n-side cross the barrier and recombine with holes in the p-side.
- Photon Emission: Energy released during recombination is emitted in the form of photons (light). Direct bandgap semiconductors like GaAsP or GaN are used.

LED Current-Limiting Resistor Design

Calculate the current-limiting resistor R_s required to drive a red LED (forward voltage $V_F = 2\ \text{V}$, forward current $I_F = 20\ \text{mA}$) from a $5\ \text{V}$ DC supply.

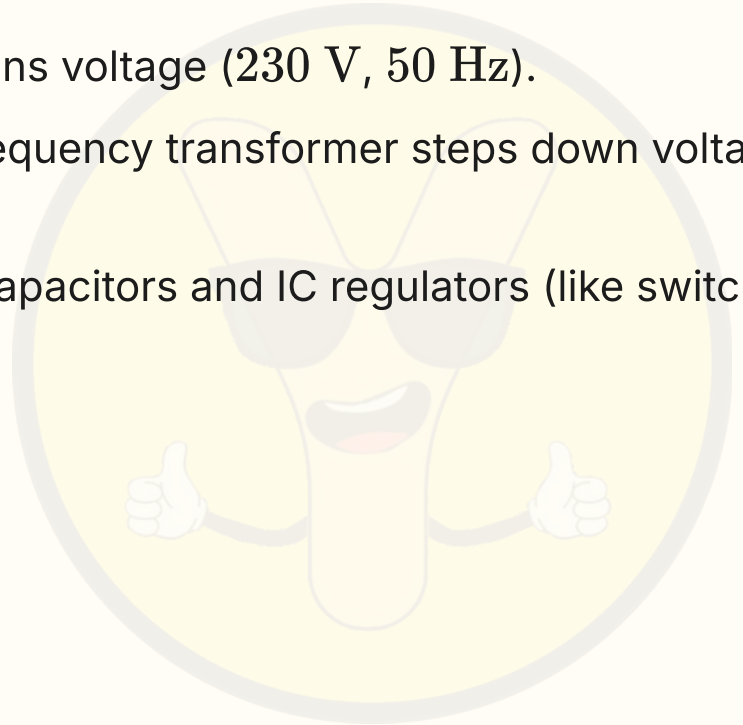
1. Identify given parameters: Supply voltage $V_s = 5\ \text{V}$, $V_F = 2\ \text{V}$, $I_F = 20\ \text{mA} = 0.02\ \text{A}$.
2. Apply Kirchhoff's Voltage Law across the loop: $V_s - V_F - (I_F \times R_s) = 0$.
3. Rearrange for resistor: $R_s = \frac{V_s - V_F}{I_F}$.
4. Substitute values: $R_s = \frac{5-2}{0.02} = \frac{3}{0.02} = 150\ \Omega$.

The required current-limiting resistor is $150\ \Omega$.

Application: USB Charger Rectifier

Practical implementation of power supply circuits in standard phone chargers.

- Input Stage: Takes standard AC mains voltage ($230\ \mathrm{V}$, $50\ \mathrm{Hz}$).
- Step-Down & Rectification: High-frequency transformer steps down voltage, followed by a full-wave bridge rectifier.
- Filtering & Regulation: High-value capacitors and IC regulators (like switch-mode controllers) output stable $5\ \mathrm{V}\ \mathrm{DC}$ at up to $2\ \mathrm{A}$.



Application: 5V/3.3V Regulated Supply for Microcontrollers

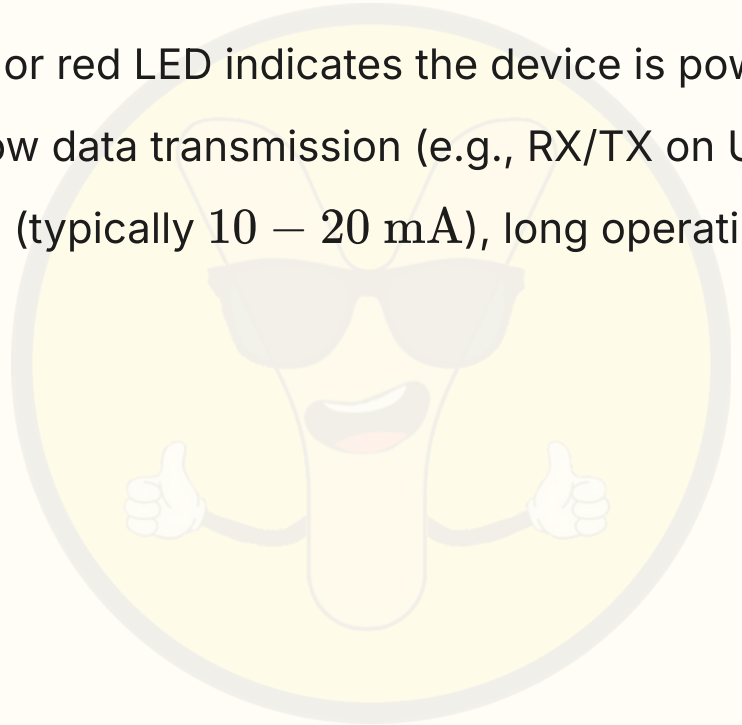
Powering development boards like Arduino and Raspberry Pi.

- Arduino Uno Requirement: Needs a regulated $5\ \mathrm{V}$ DC supply (often using AMS1117-5.0 or LM7805 linear regulators).
- Raspberry Pi Requirement: Needs a strict $5\ \mathrm{V}$, $2.5\mathrm{A}$ to $3\mathrm{A}$ input; internal PMICs step this down to $3.3\ \mathrm{V}$, $1.8\ \mathrm{V}$, and $1.1\ \mathrm{V}$ for the SoC.
- Role of Diodes: Reverse polarity protection diodes protect sensitive microcontroller boards from accidental backwards battery or power supply connections.

Application: LED Indicators in Electronics Products

Status monitoring and user interface feedback.

- Power Indicators: A constant green or red LED indicates the device is powered ON.
- Status Indicators: Blinking LEDs show data transmission (e.g., RX/TX on USB-Serial chips) or error states.
- Efficiency: Low power consumption (typically $10 - 20\ \mathrm{mA}$), long operating life, and instant switching make LEDs ideal status indicators.



Exam Corner

Q1 Explain the formation of depletion layer in a p-n junction and define barrier potential.

Q2 Draw and explain the V-I characteristics of a Silicon p-n junction diode under forward and reverse bias.

Q3 Derive the ripple factor and maximum efficiency of a full-wave bridge rectifier.

Q4 Explain why a filter capacitor is necessary in a power supply circuit. How does it reduce ripple?

Q5 Differentiate between Zener breakdown and Avalanche breakdown mechanisms.

Q6 With a neat circuit diagram, explain how a Zener diode acts as a voltage regulator.

Q7 Calculate the value of a current-limiting resistor for an LED connected to a $12\ \text{V}$ source given $V_F = 2.2\ \text{V}$ and $I_F = 15\ \text{mA}$.

Unit 1 done. You are exam-ready.

Revise the Exam corner once more, then open Unit 2 on theycotes.com. Every AKTU subject, unit by unit, free. Notes by Chirag Jain, Ycotes.

