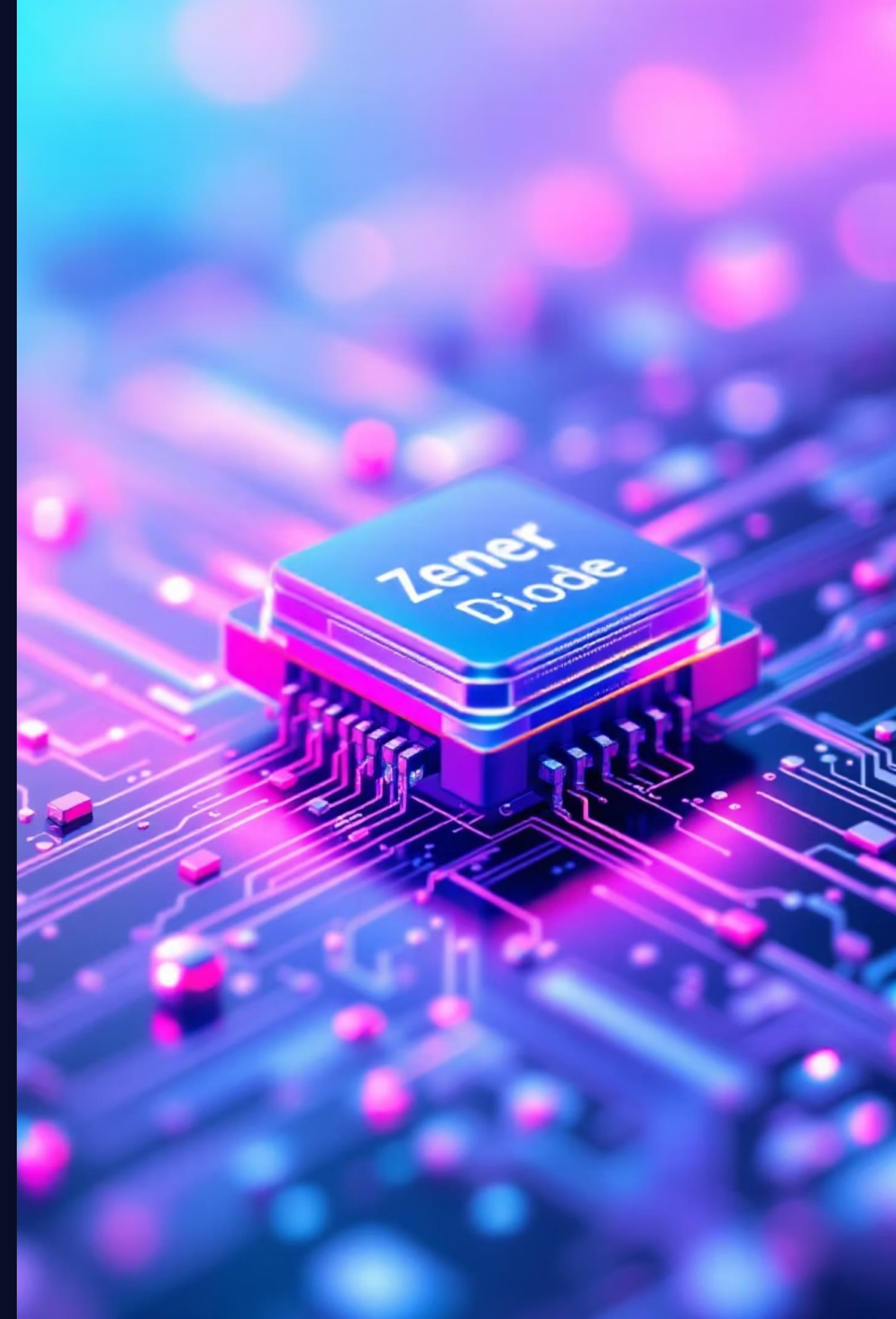


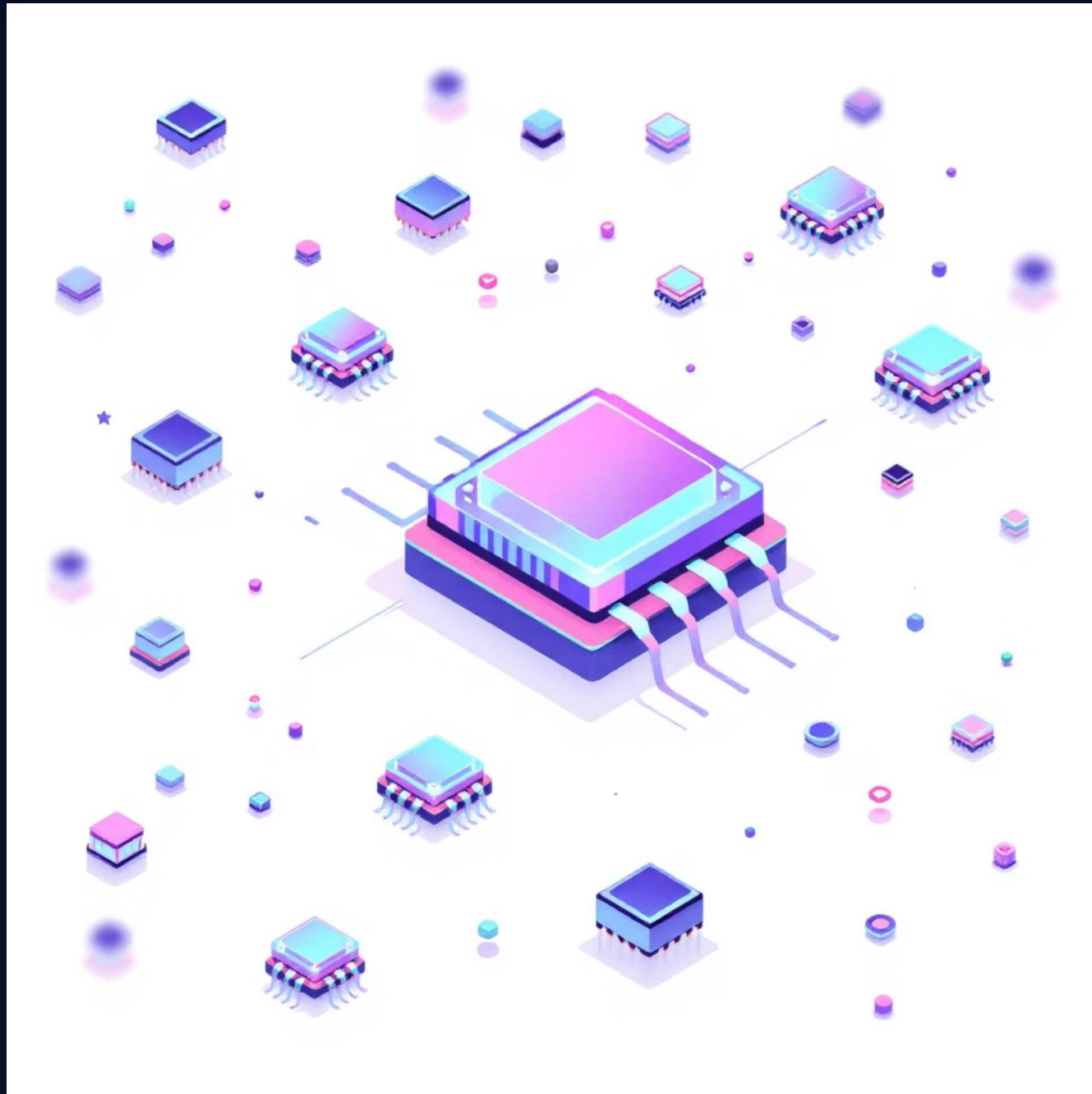
UNIVERSITY OF ABOUBEKR BELKAID, TLEMCEŃ
FACULTY OF SCIENCE
COMPUTER SCIENCE DEPARTMENT

The Zener Diode

- L1 Computer Engineering
- By Dr. Loubna BENHABIB
 - 2025-2026



1. Introduction



What is a Diode? The Basics

Fundamental behaviour

- One-way valve for electrical current: anode $\rightarrow$ cathode.
- Forward bias: conducts when V_{forward} exceeds $\sim 0.7\text{V}$ for silicon.
- Reverse bias: blocks current until destructive breakdown for ordinary diodes.



Use series resistance and correct orientation to prevent damage under reverse breakdown.



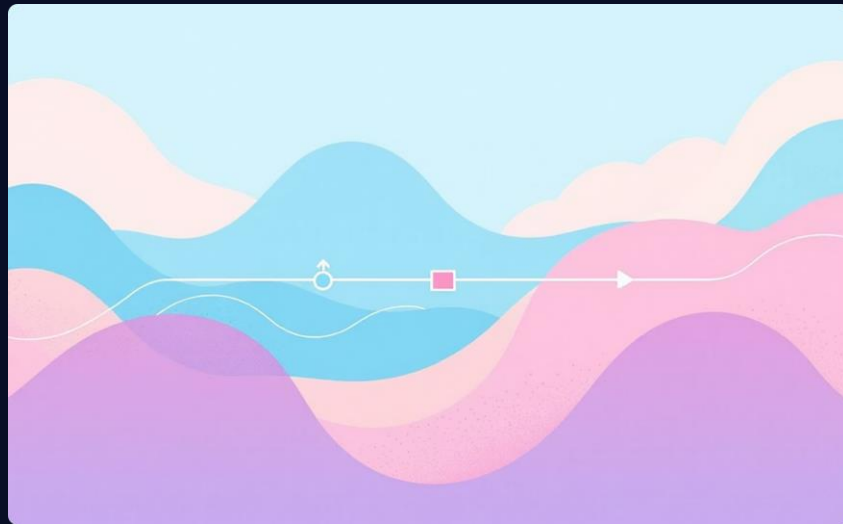
Introducing the Zener Diode: A Special Kind of Diode

- Named after Clarence M. Zener (1934).- Designed to conduct in reverse at a precise Zener voltage (V_z).- Can operate safely in the reverse breakdown region when correctly biased and current-limited.

Concise introduction: Zener diodes are specialised semiconductor devices that keep voltage steady using controlled reverse breakdown. This deck explains what they are, how they work, the physics involved, typical characteristics, circuit use and real-world applications.

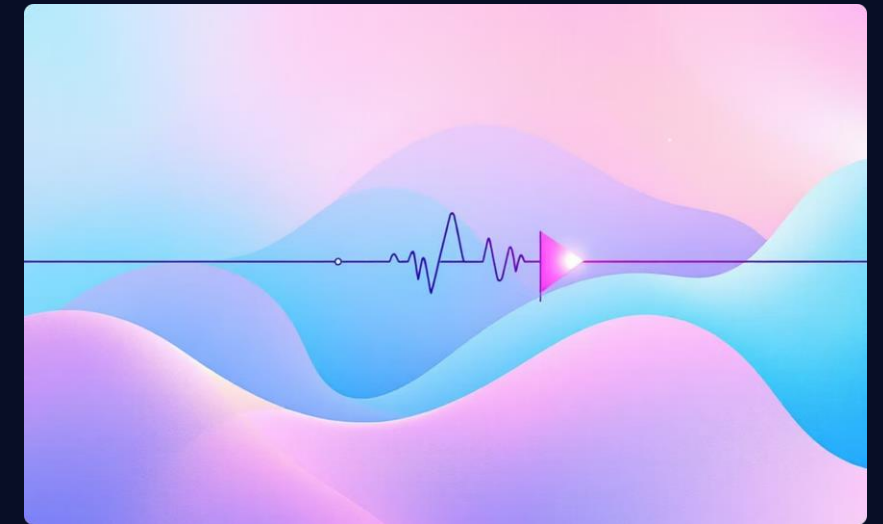
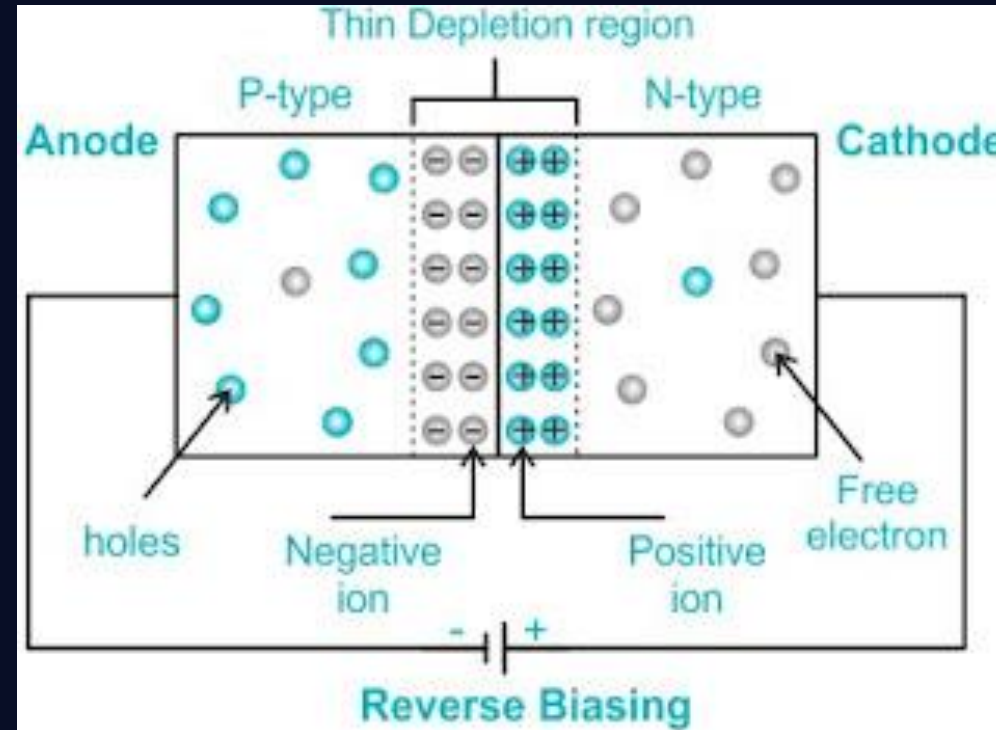
Practical note: manufacturers specify V_z , tolerance, maximum power dissipation and dynamic resistance—choose the part to match the application.

2. How Does a Zener Diode Work? Forward vs Reverse Bias



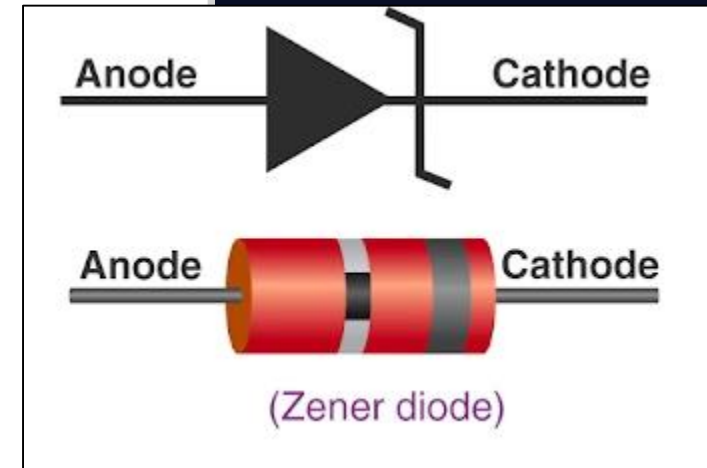
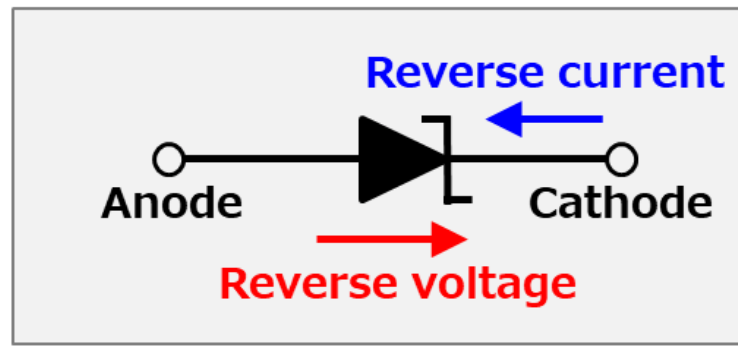
Forward Bias

Behaves like a normal diode: conducts when anode is about 0.7V higher than cathode (silicon). Small forward resistance limits current.

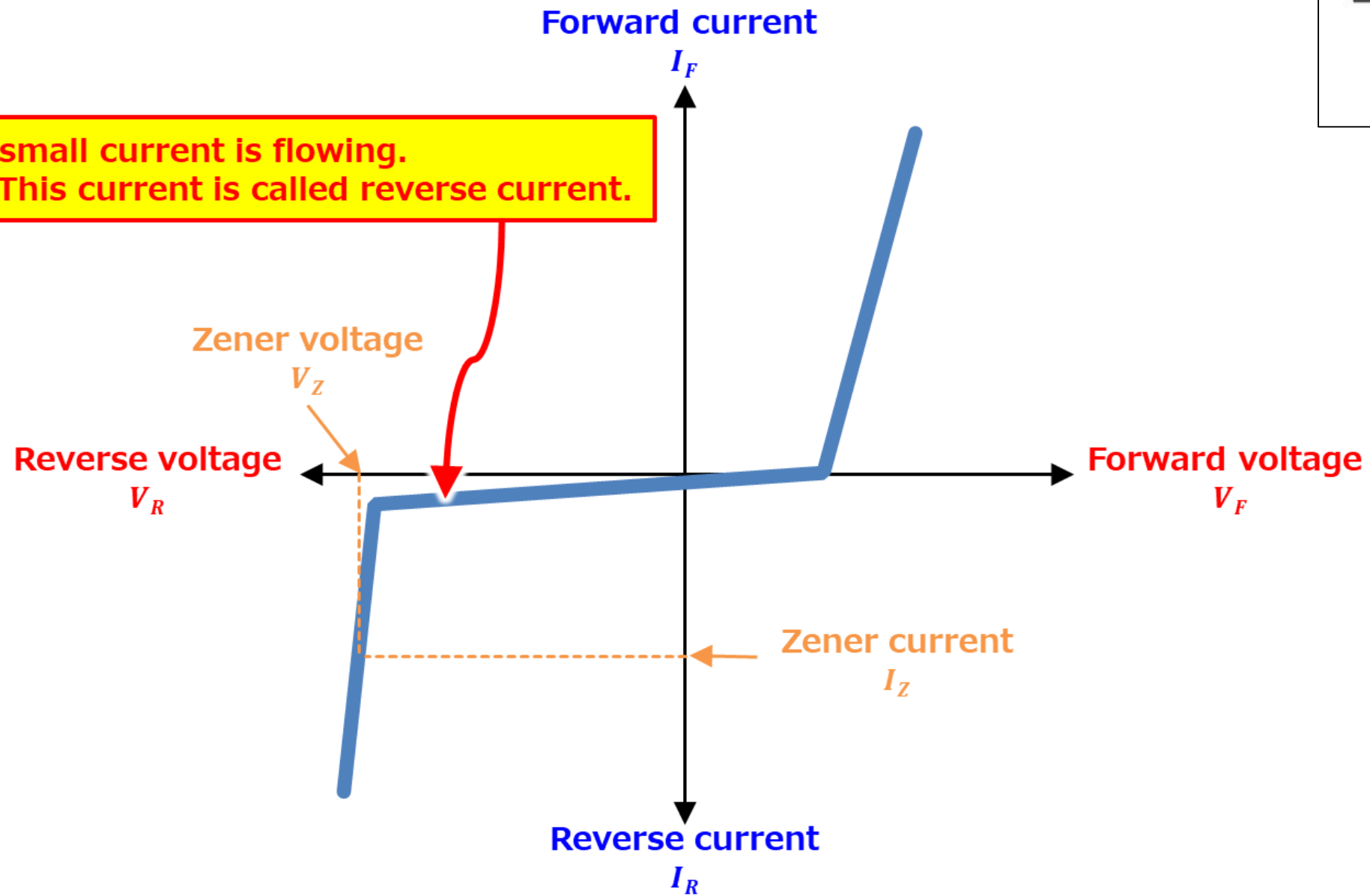


Reverse Bias

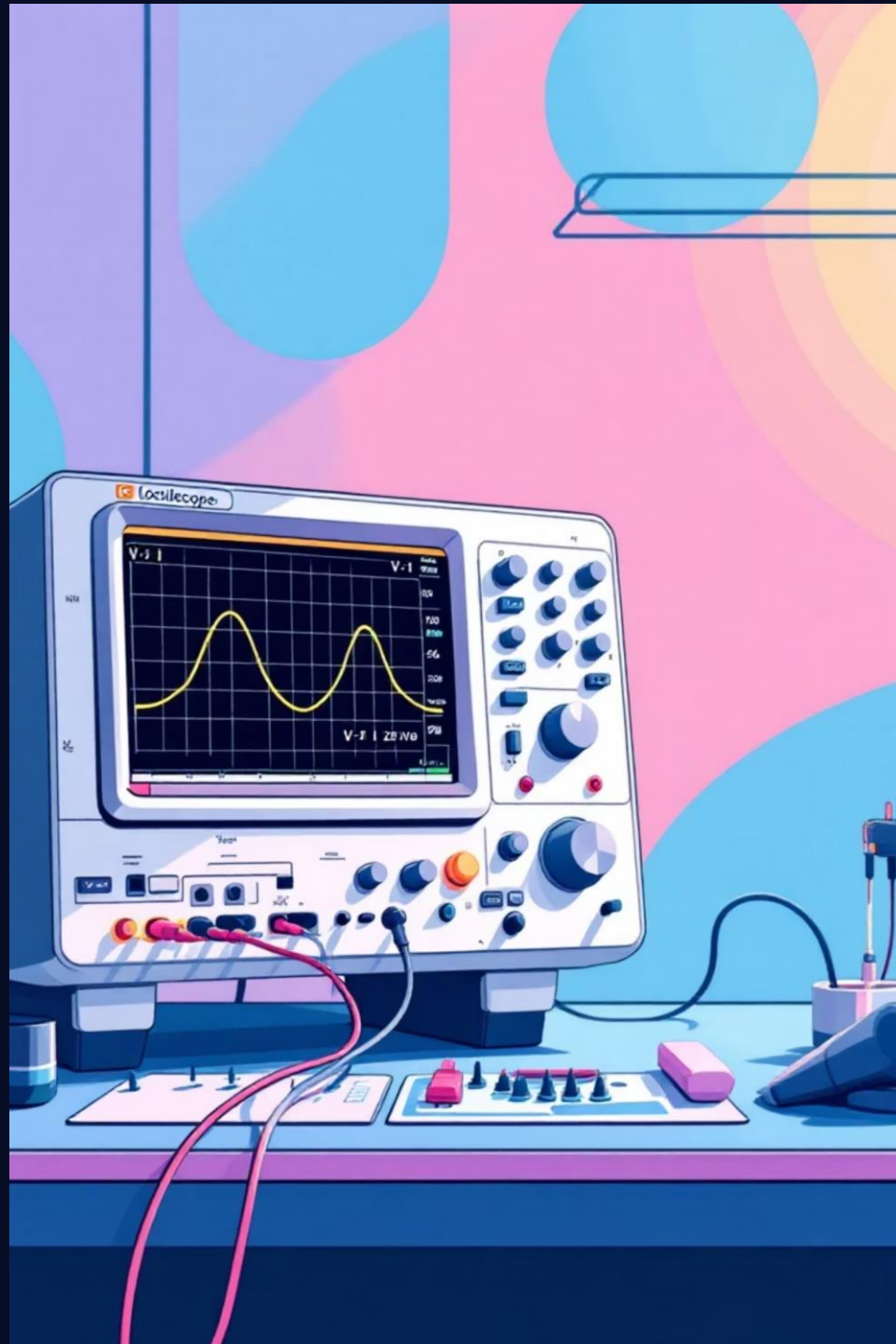
Minor leakage current flows until reverse voltage reaches V_z . At V_z the diode clamps voltage by allowing reverse current while holding voltage nearly constant.



A small current is flowing.
→ This current is called reverse current.



The Physics Behind Breakdown



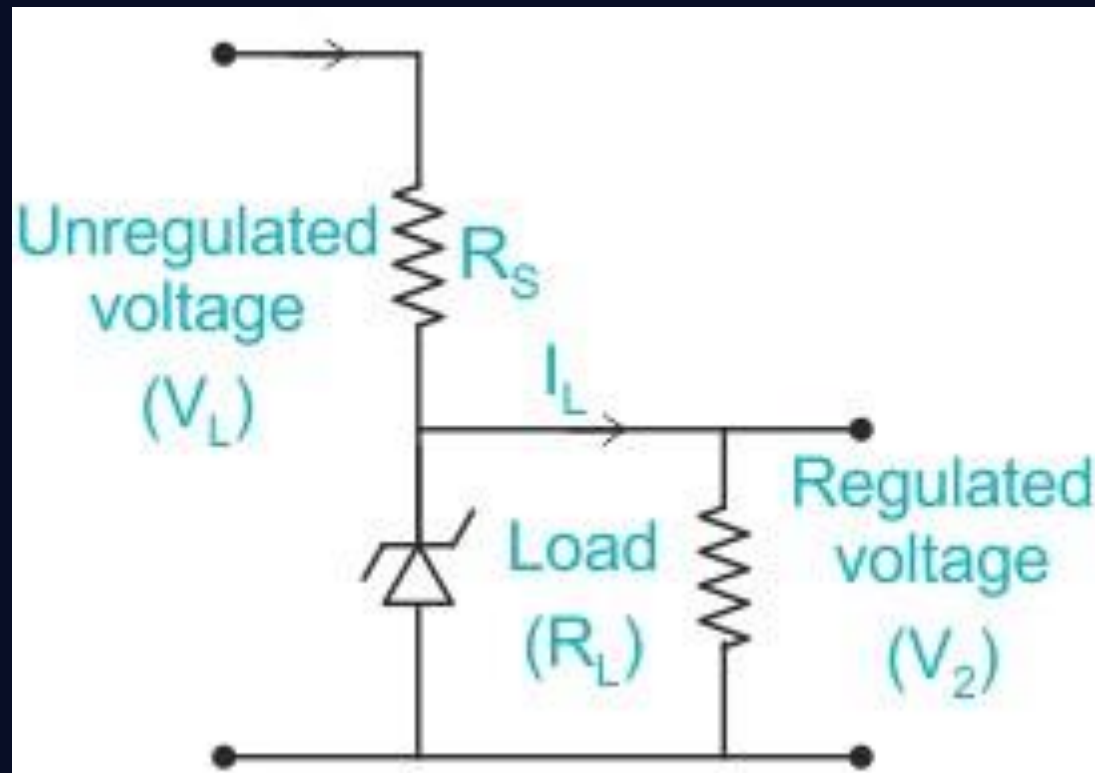
Two mechanisms

- Zener effect: quantum tunnelling in heavily doped, thin depletion regions (dominant below $\sim 5.5\text{V}$).
- Avalanche breakdown: carrier multiplication by impact ionisation (dominant above $\sim 5.5\text{V}$).

At $\sim 5.6\text{V}$ both mechanisms contribute, producing low temperature coefficient and good stability.

The reverse V-I curve: voltage remains near V_z across a wide current range while current changes significantly. Low but finite dynamic (Zener) impedance limits perfect regulation—choose proper operating current for best regulation and power safety.

3. Circuit Integration



How to use it

- Connect Zener diode in reverse across the load; use a series resistor to limit current from the supply.- The resistor drops excess voltage and sets operating current: $I_z = (V_s - V_z)/R$ (approx).- Ensure I_z stays within minimum knee current and below maximum power dissipation.

📌 Practical tip: add a small bypass capacitor for noise suppression in sensitive circuits.

1. Voltage Regulator Circuit (Shunt Regulator)

Principle: The diode is connected in **reverse bias** and in **parallel (shunt)** with the load (the component that needs a stable voltage). A series resistor (R_S) is placed between the power source and the Zener/Load combination to limit the total current.

- As long as the input voltage (V_{IN}) is below V_Z , the diode acts like an open circuit (it is blocked).
- As soon as V_{IN} exceeds V_Z , the diode enters its reverse breakdown region. It then maintains a constant output voltage (V_{OUT}) equal to its Zener voltage ($V_{OUT} = V_Z$), regardless of variations in V_{IN} or the load current.
- Any excess current is safely diverted through the Zener diode, ensuring the voltage across the load remains stable.

2. Clipper Circuit (Voltage Limiter)

This circuit is used to protect sensitive components against overvoltage or to shape signals. **Principle:** The Zener diode limits the voltage peaks of a signal (usually AC or fluctuating) to a predefined level.

- **Simple Clipper (One Diode):** If the diode is reverse-biased: It limits the positive alternation (forward bias) to approximately $0.7V$ (the turn-on voltage of a standard diode). It limits the negative alternation (reverse bias) to its Zener voltage ($-V_Z$).
- **Symmetrical Clipper (Two Back-to-Back Zener Diodes):** Two Zener diodes are connected in series, in opposing directions (anode of one connected to cathode of the other).

4. Key Applications of Zener Diodes



Voltage regulation

Simple shunt regulator for low-power supplies and local reference rails.



Voltage reference

Stable reference for ADCs, comparators and control circuits when tight tolerances are available.



Overvoltage protection

Clamps transients and protects sensitive components from spikes and surges.



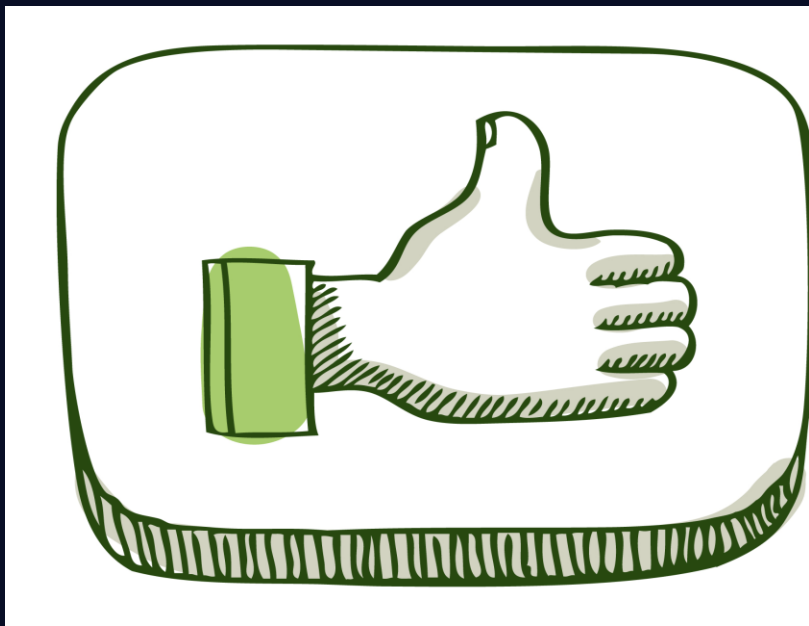
Everyday devices

Found in consumer electronics, industrial controllers and communication gear for robust voltage control.



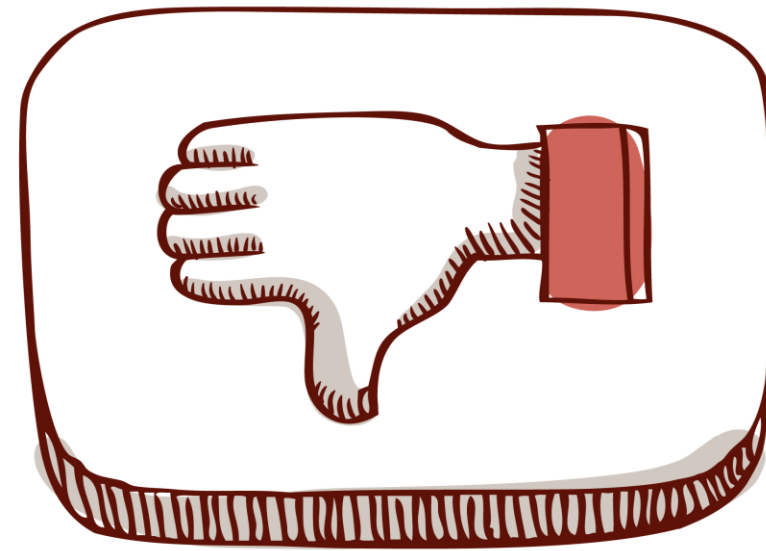
5. Conclusion: Why Zener Diodes Matter

- Zener diodes offer a compact, inexpensive way to stabilise and protect voltages by exploiting controlled breakdown.- They are indispensable for many low-power regulation and protection tasks, bridging theory (Zener effect) and practical electronics.- Small component, big impact: choose and design with care for reliable, precise operation.



Advantages

- Zener diode protects from voltage spikes and over-voltage.
- It is smaller in size.
- It can easily and efficiently stabilize the voltage.
- It can handle high voltages.
- It is cheaper and cost-effective.



Disadvantages

- It cannot handle a very large current.
- It provides a fixed output voltage that cannot be changed.
- The Zener current depends on the load current.