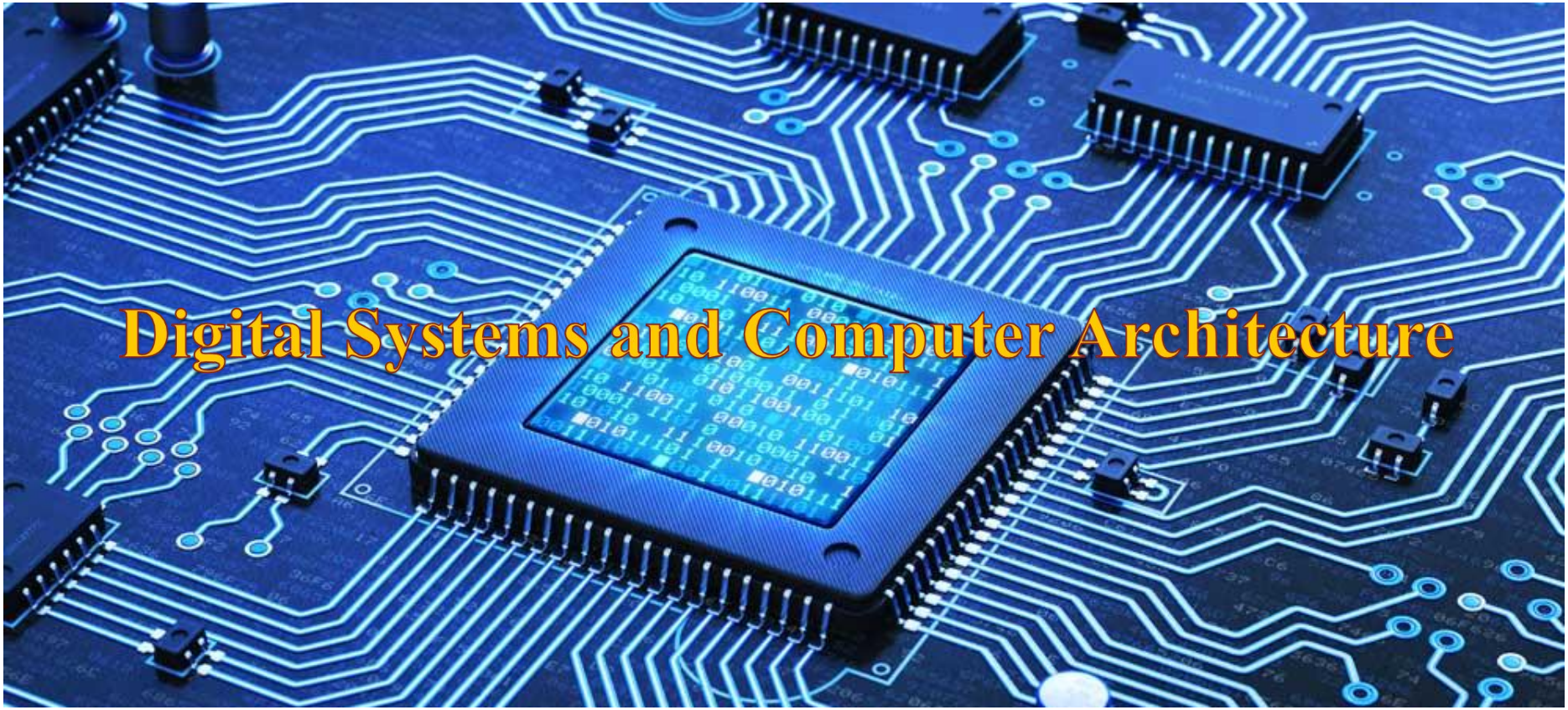


Digital Systems and Computer Architecture

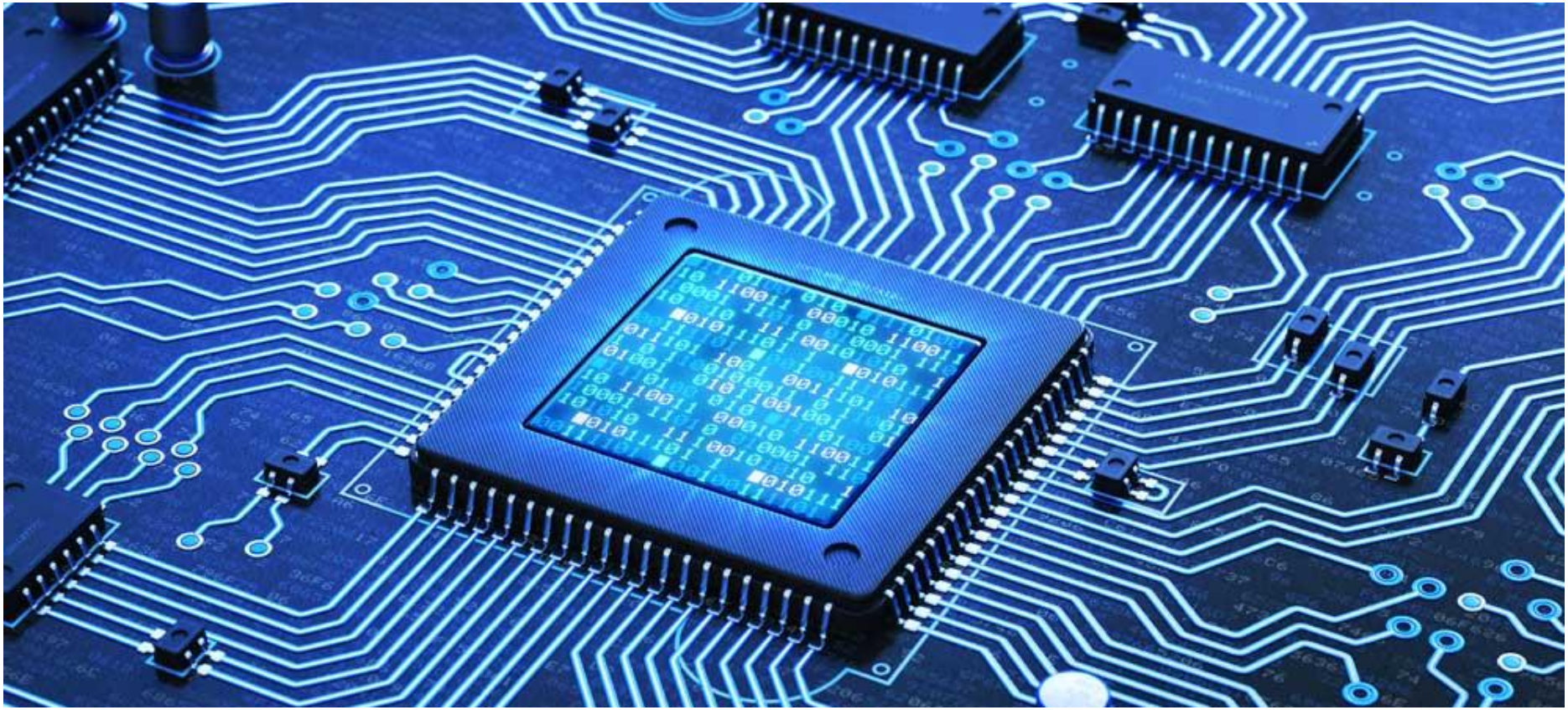
Session 1.7

Module 1b

PN Junction Diodes

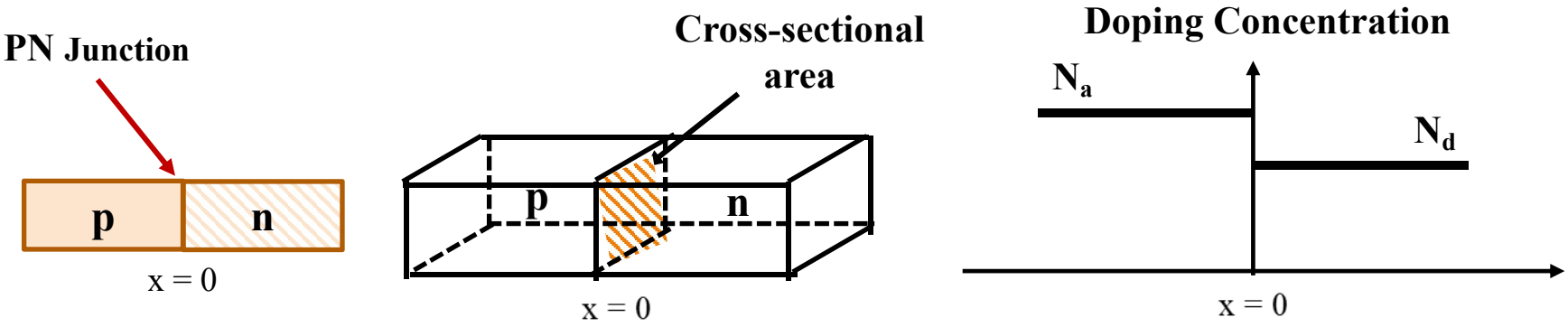
Session 1.7: Focus

- PN junction
  - Diode construction and its symbols
- Biasing of diodes
  - Forward and Reverse biasing
- Various types of diodes
- Depletion region
- Diode characteristics
  - Forward biasing and Cut-in voltage
- Reverse biasing
  - Breakdown voltage
- I-V characteristics of diode
  - Q-point of a diode
- Sample Circuits with Diodes



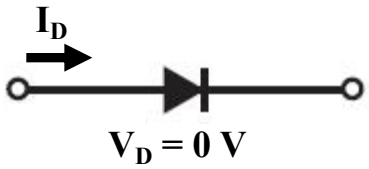
Diode Construction

Diode Construction

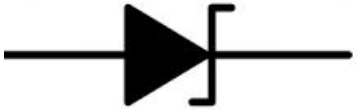


- A silicon crystal is taken, the left side is doped with **acceptors** (**p-type**) and the right side is doped with the **donors** (**n-type**).
- This results in a junction between p-type and n-type material.
- The diagram on the right shows the doping concentration of acceptors ($\mathbf{N_a}$) and donors ($\mathbf{N_d}$) where $\mathbf{N_a > N_d}$
- The **doping** of impurities is **uniform** on both p-type and n-type.

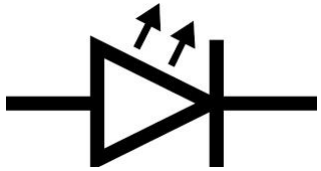
Diode: Symbols



Diode has **two** terminals,
an **anode** and a **cathode**

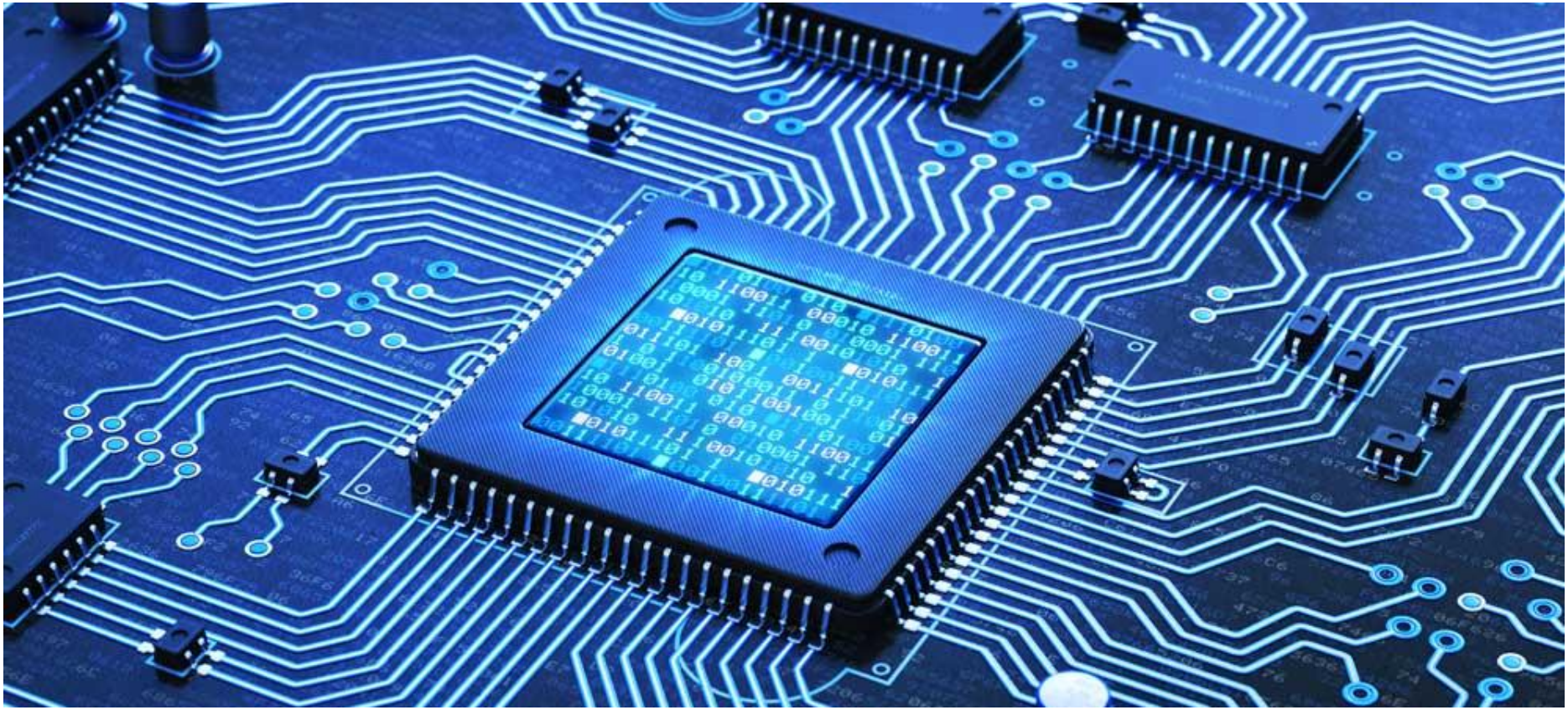


Zener Diode



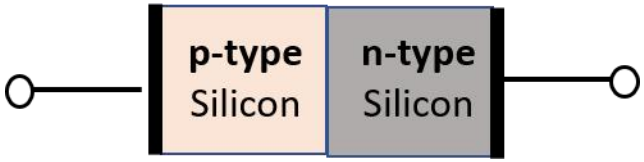
Light Emitting Diode

Photo Diode



Biasing of Diode

Diode: No Bias

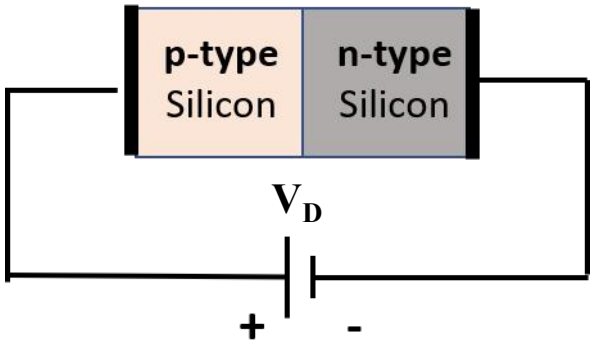


No bias, leads of PN junction are left open

- **No bias** means that there is no external voltage applied to the diode.
- It is equivalent to a diode kept on a table with both its terminals open.

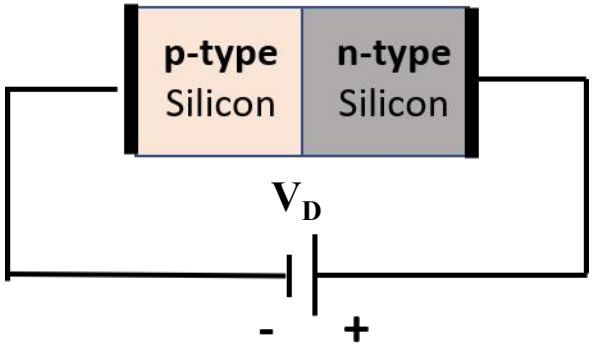
Diode: Biasing

Diode has **different behaviours** under **each conditions.**



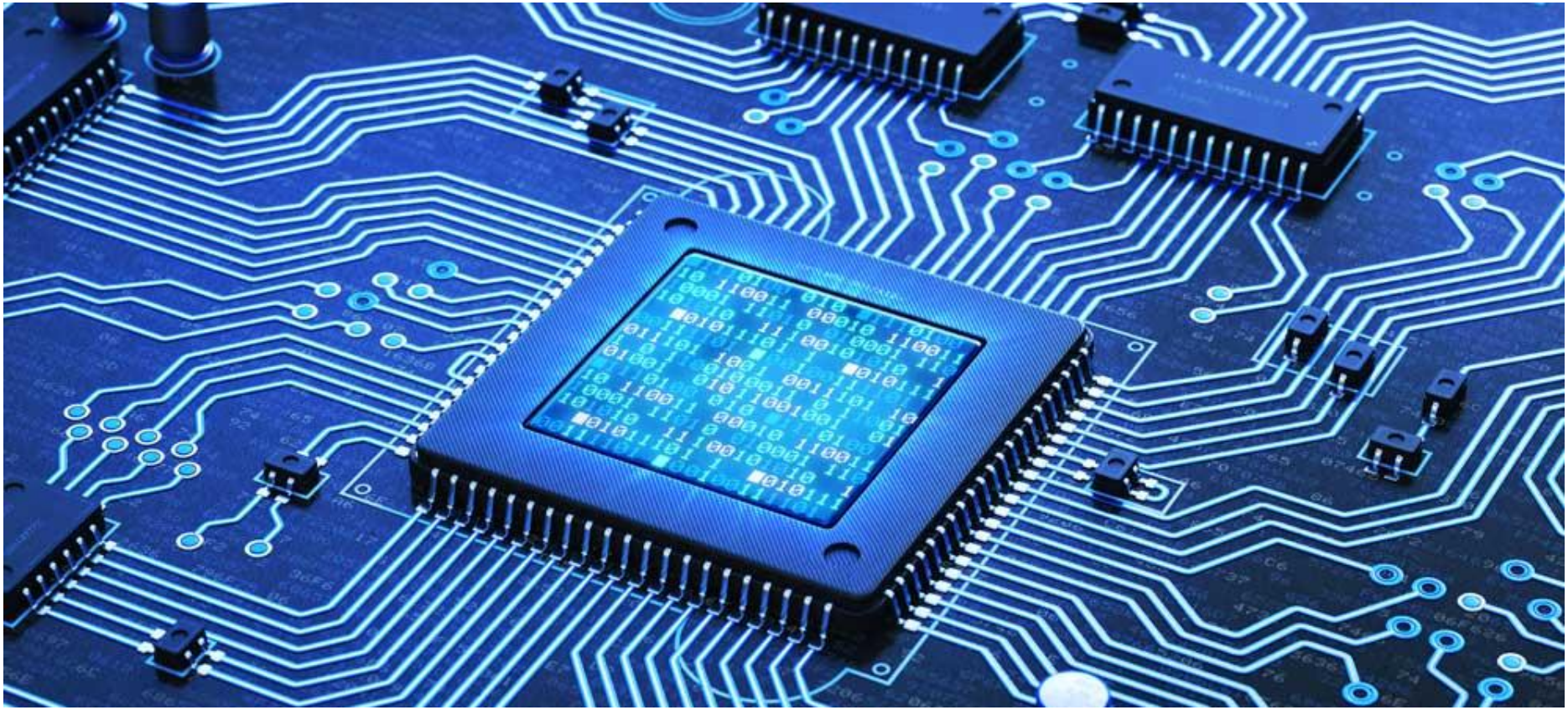
Forward bias

Anode (p-type) is connected to **+ve terminal** of **bias voltage** and the **cathode (n-type)** to **-ve terminal**



Reverse bias

Anode (p-type) is connected to **–ve terminal** of **bias voltage** and the **cathode (n-type)** to **+ve terminal**



Various types of Diodes

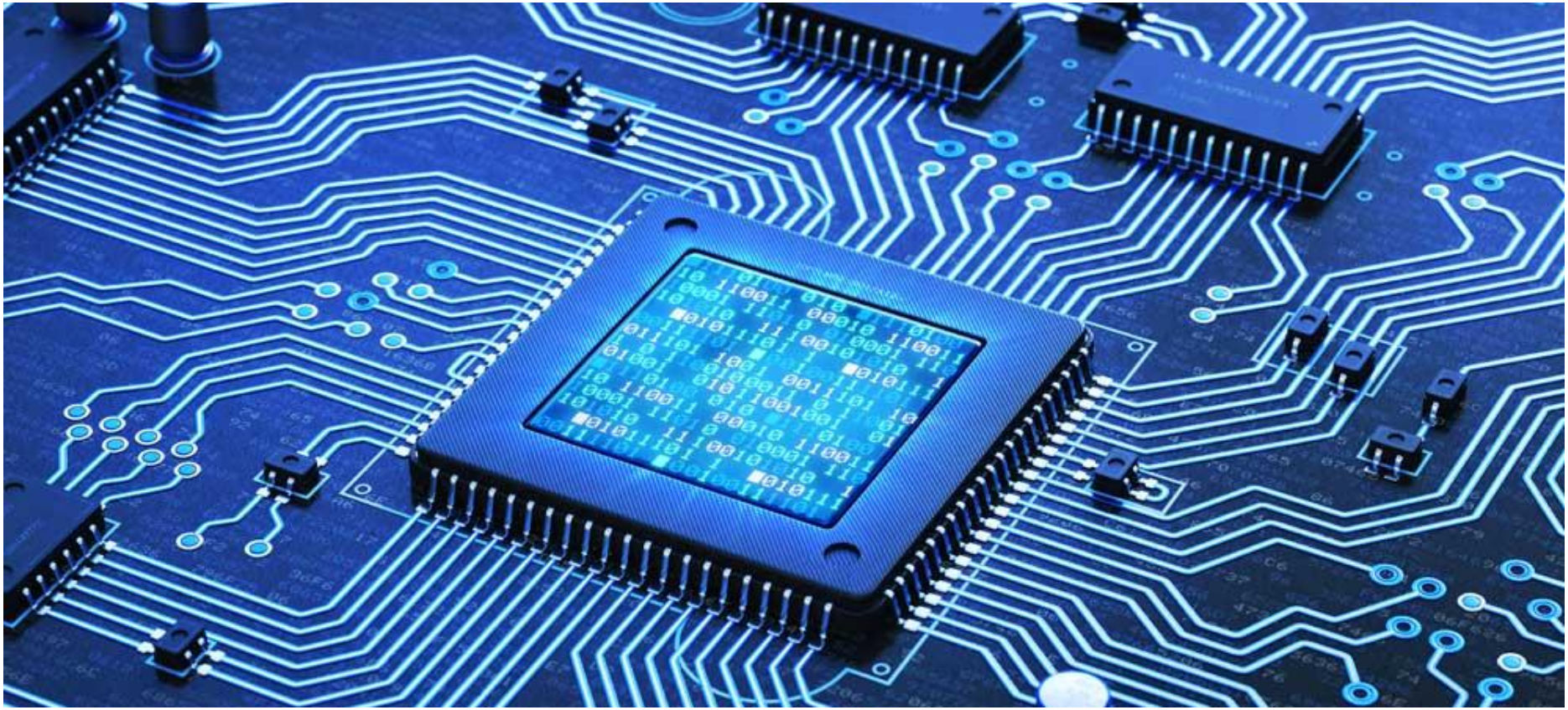
Various Types of Diodes

Note: A silver line on the diode signifies the cathode terminal.

LEDs: Light Emitting Diodes

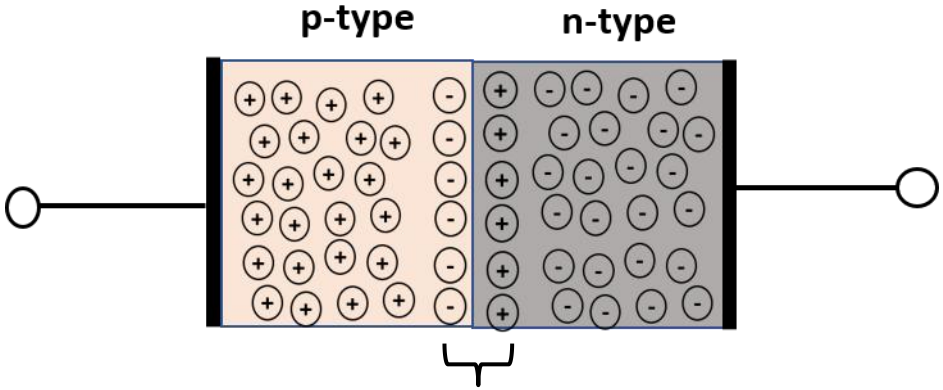
Note: The longer terminal is the anode.

Power Diode

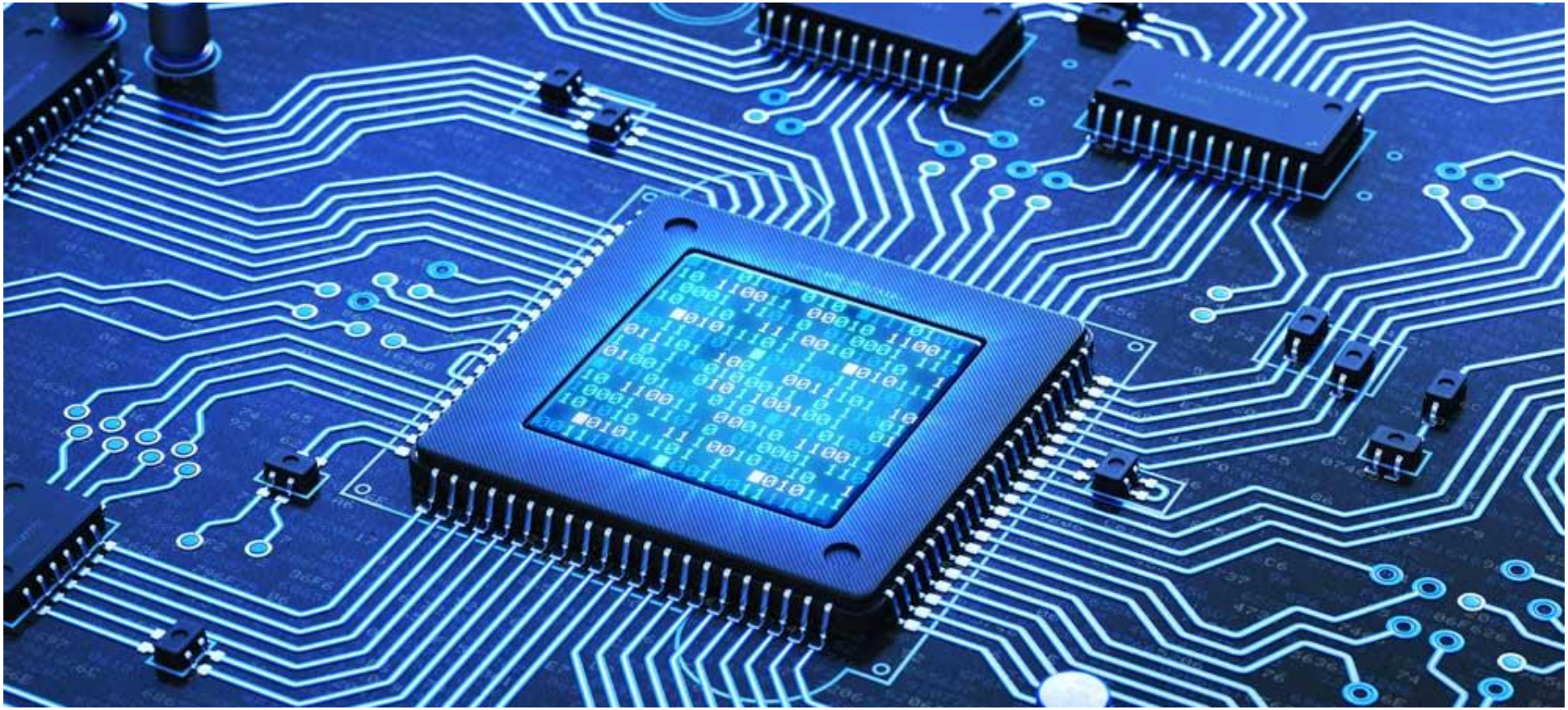


Depletion Region

Diode: Depletion Region



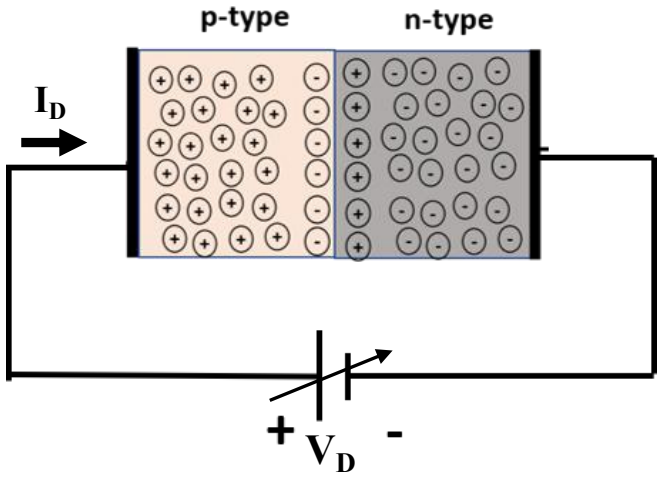
- Majority carriers on each side cross the junction of the p-type and n-type materials.
- The electrons entering the p-region combine with the holes, depleting or reducing the holes in the p-region, near the junction.
- Similarly electrons around the junction on n-type material are also depleted.
- The region thus formed is called **depletion region**.
- Further crossing of majority carriers prevented by the formation of depletion region.

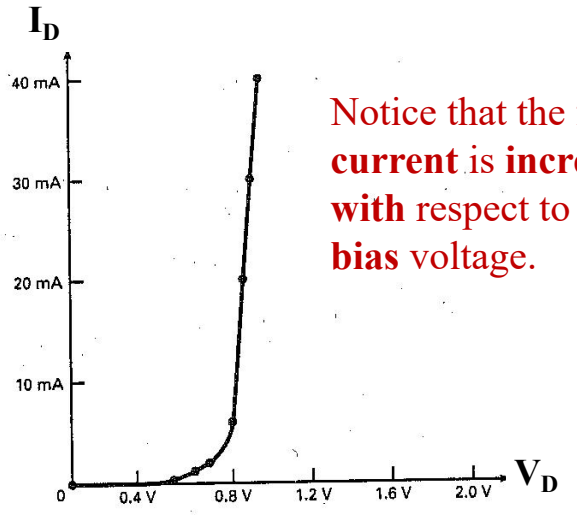


Diode Characteristics

Forward Biasing

Forward Biasing: Explained

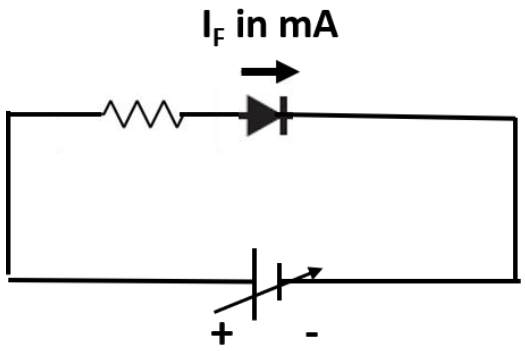


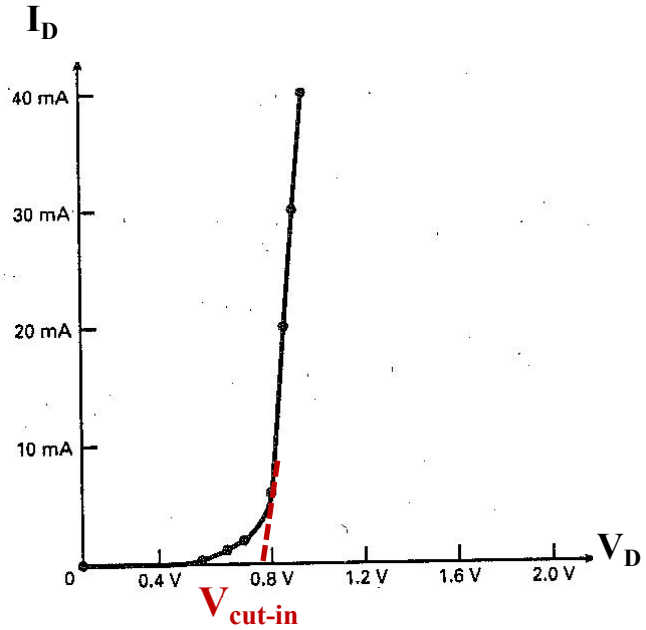


Notice that the **forward bias current** is **increasing exponentially with** respect to the **forward bias** voltage.

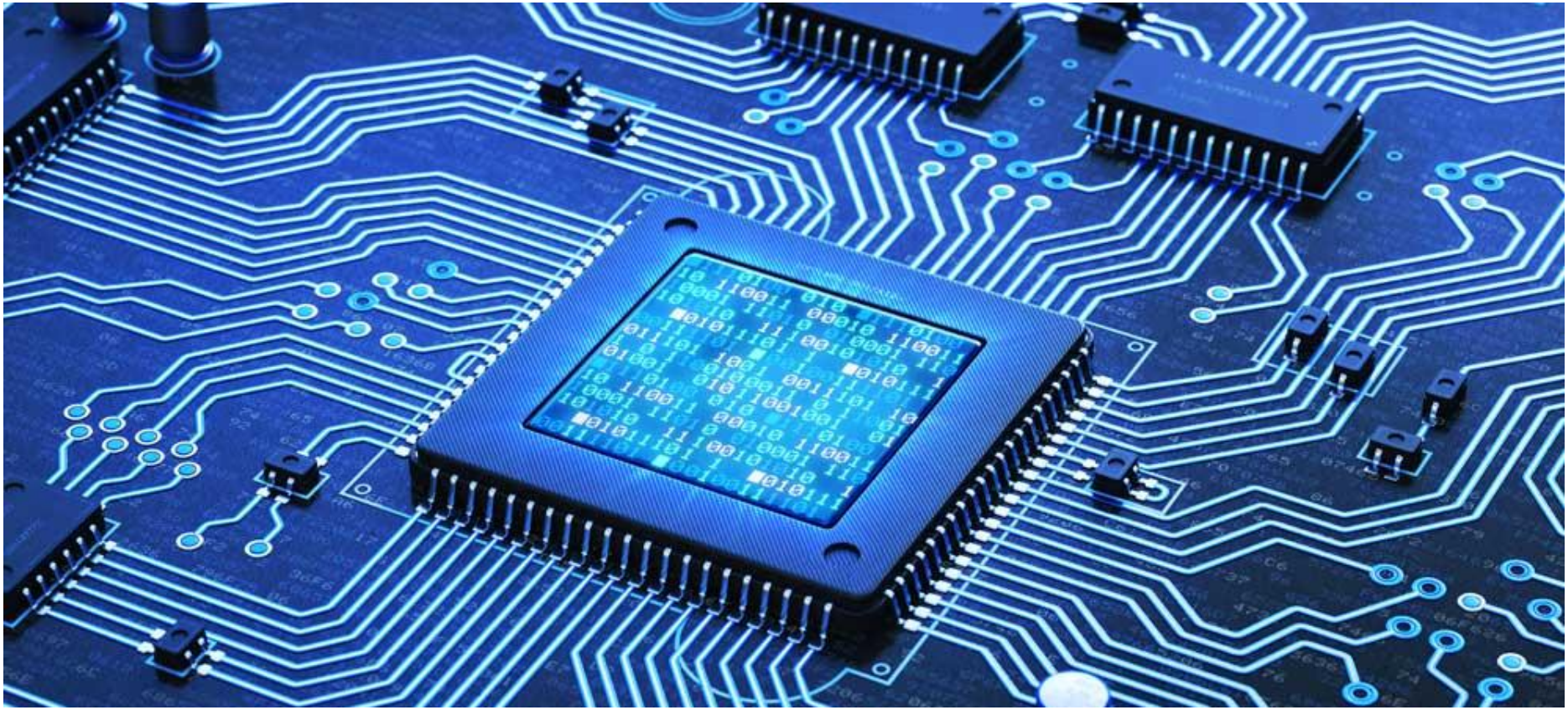
- Positive potential applied at the anode repels the holes (majority carriers) on p-type pushing them towards the junction.
- Similarly the negative potential on the cathode repels the electrons (majority carriers) on n-type pushing them as well towards the junction.
- When $\mathbf{V_D}$ crosses a threshold, majority carriers on either side cross the depletion region causing the flow of current through the diode.
- Since current is passing through the diode it is said to be in **ON state**.

Cut-in Voltage





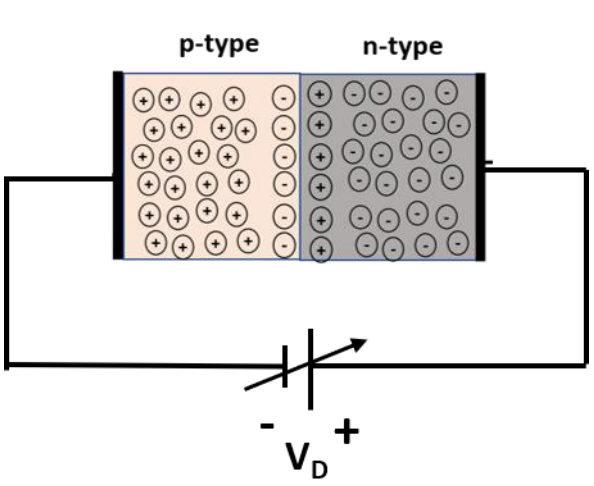
- When the applied forward bias (V_F) crosses $V_{cut\text{-}in}$ or V_{Knee}, diode starts conducting and allows current (I_F) to flow through.
- Cut-in voltage or knee voltage is the voltage at which the forward bias current of a diode starts increasing rapidly.
- Cut-in voltage of a silicon diode is approximately 0.7V, and for germanium diode it is approximately 0.3V.

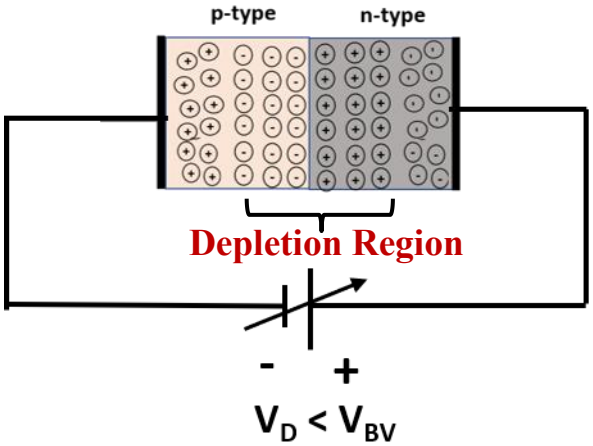


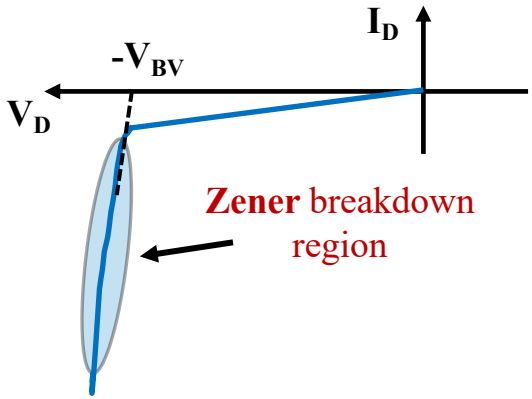
Diode Characteristics

Reverse Biasing

Reverse Biasing: Explained

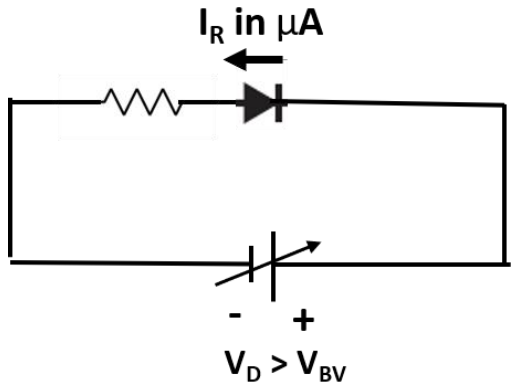


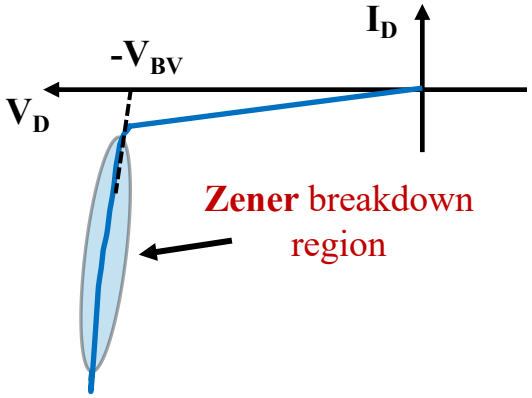




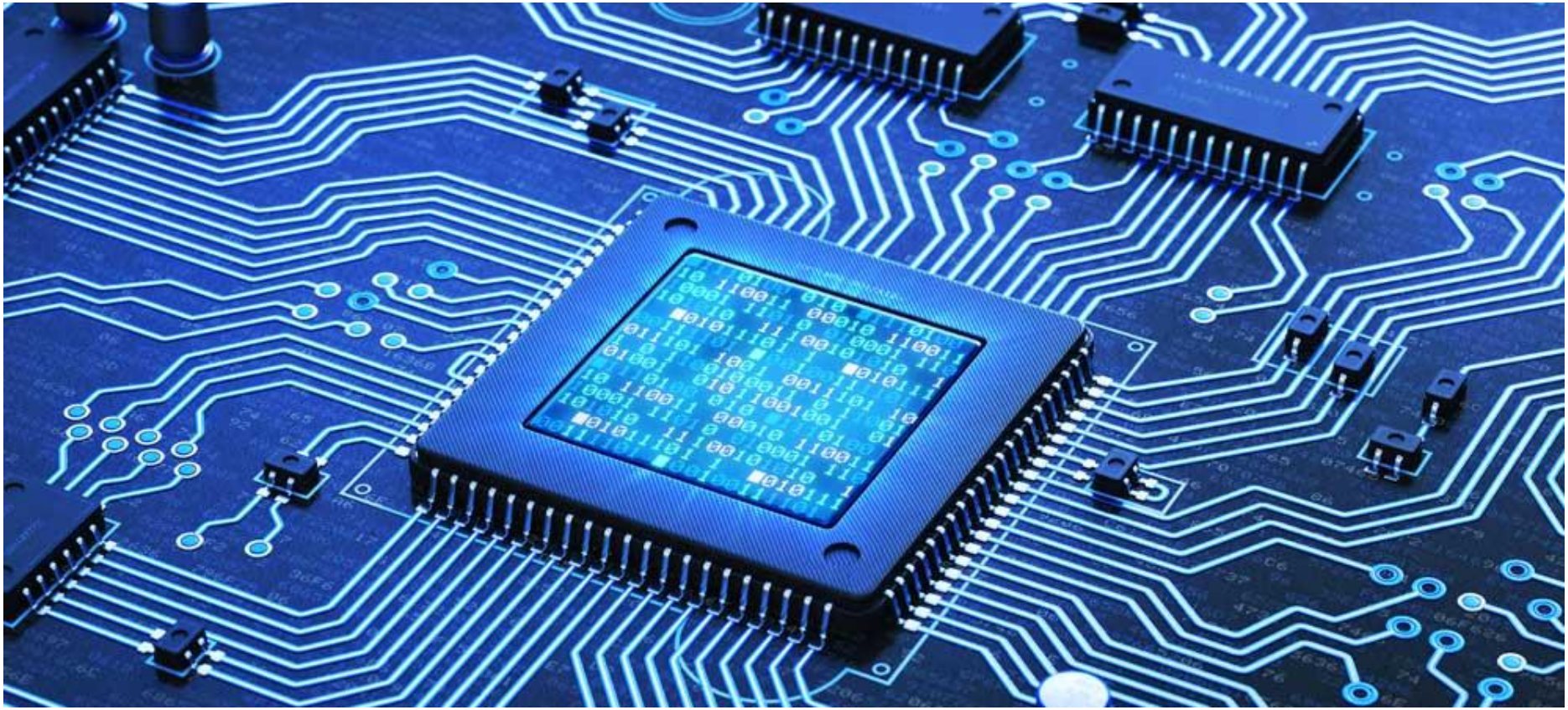
- Because of reverse bias, large number of free electrons are drawn to the positive potential of the applied voltage (on n-region), which in turn increases the width of the depletion region at the junction.
- The diode is said to be in OFF state because current passing through it is very minimal.
- There are a very few charges crossing the junction, in micro amperes.
- When the reverse voltage is increased continuously beyond **breakdown voltage**, the diode starts conducting heavily, reaching the **Zener region**.

Reverse Bias Current



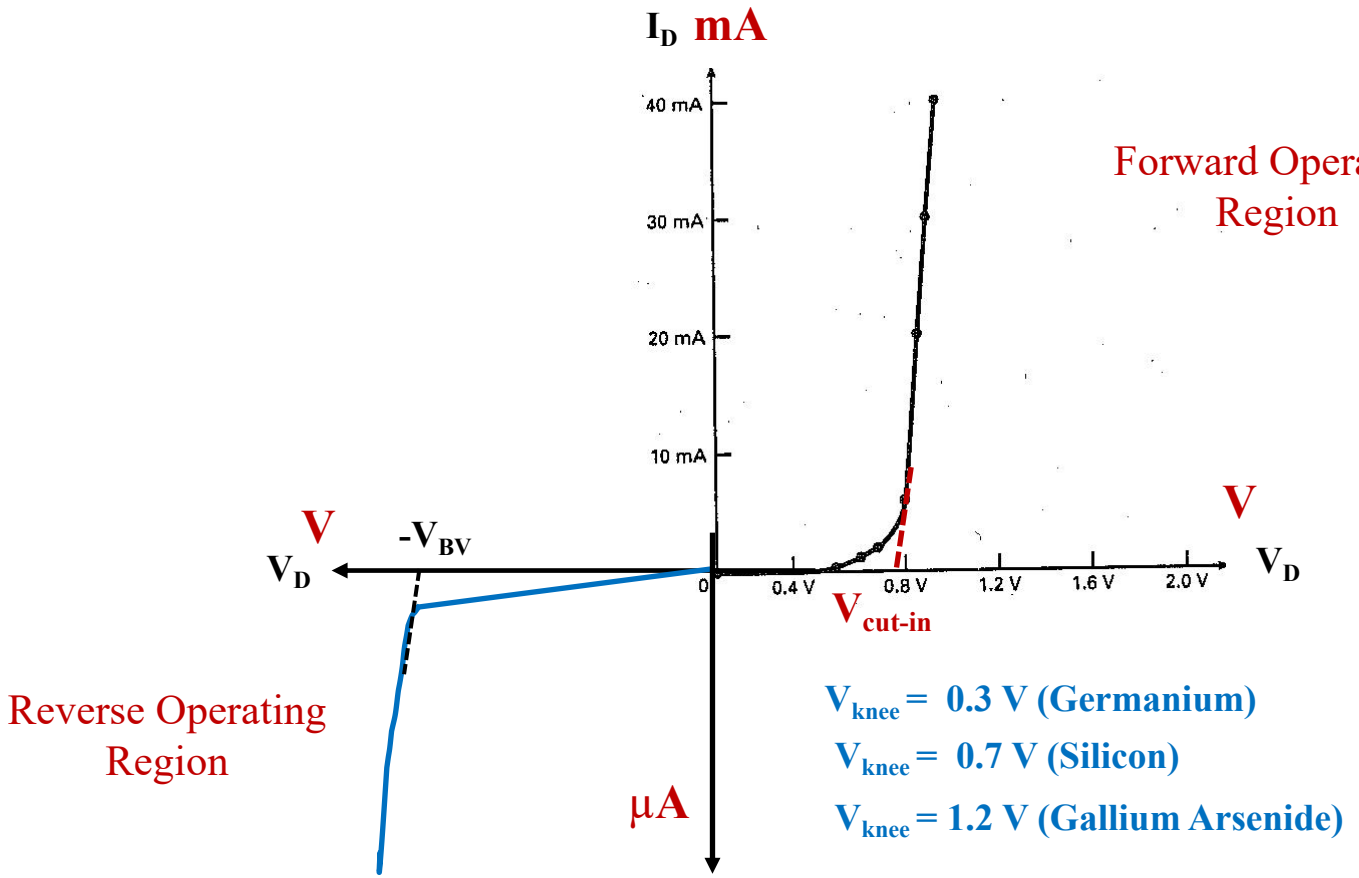


- When the reverse voltage goes beyond $-V_{BV}$ the **minority carriers** move quickly across the depletion region.
  - Minority carriers in p material are electrons.
  - Minority carriers in n material are holes.
- Note that electrons flow from left to right and the holes from right to left.

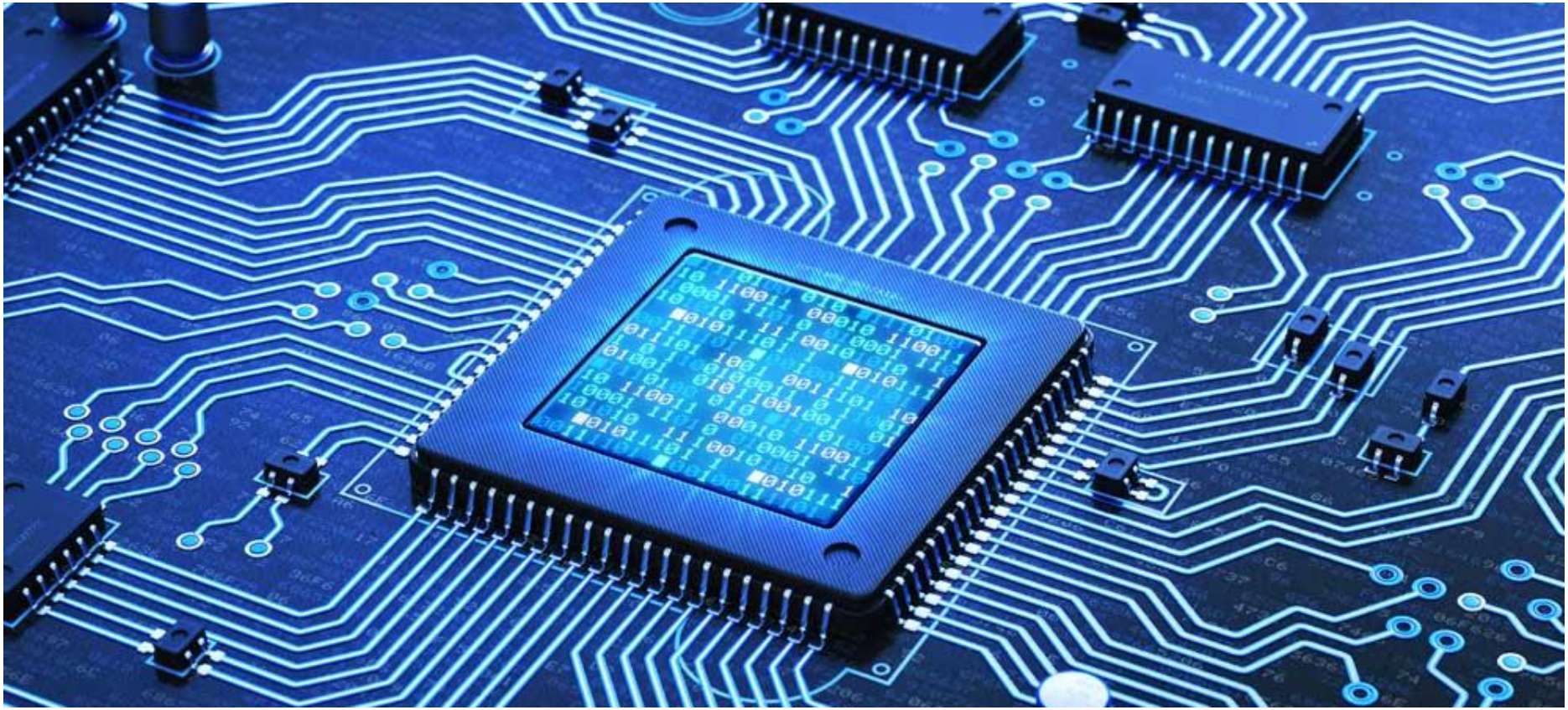


I-V Characteristics

I-V Characteristics

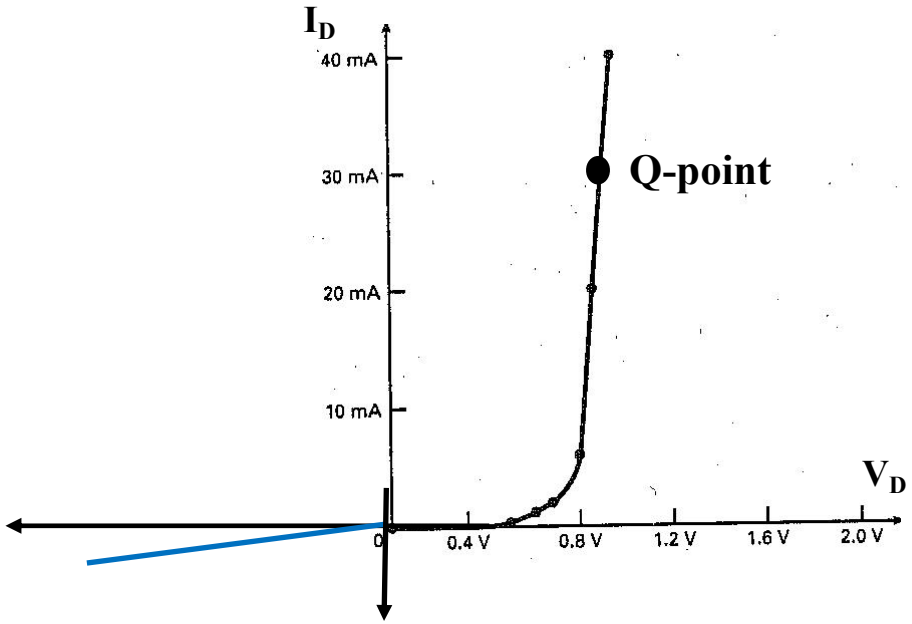


- It's **characteristics** have **non-linear shapes** at **different operating voltages/currents**, so **diode** is a **non-linear element**.

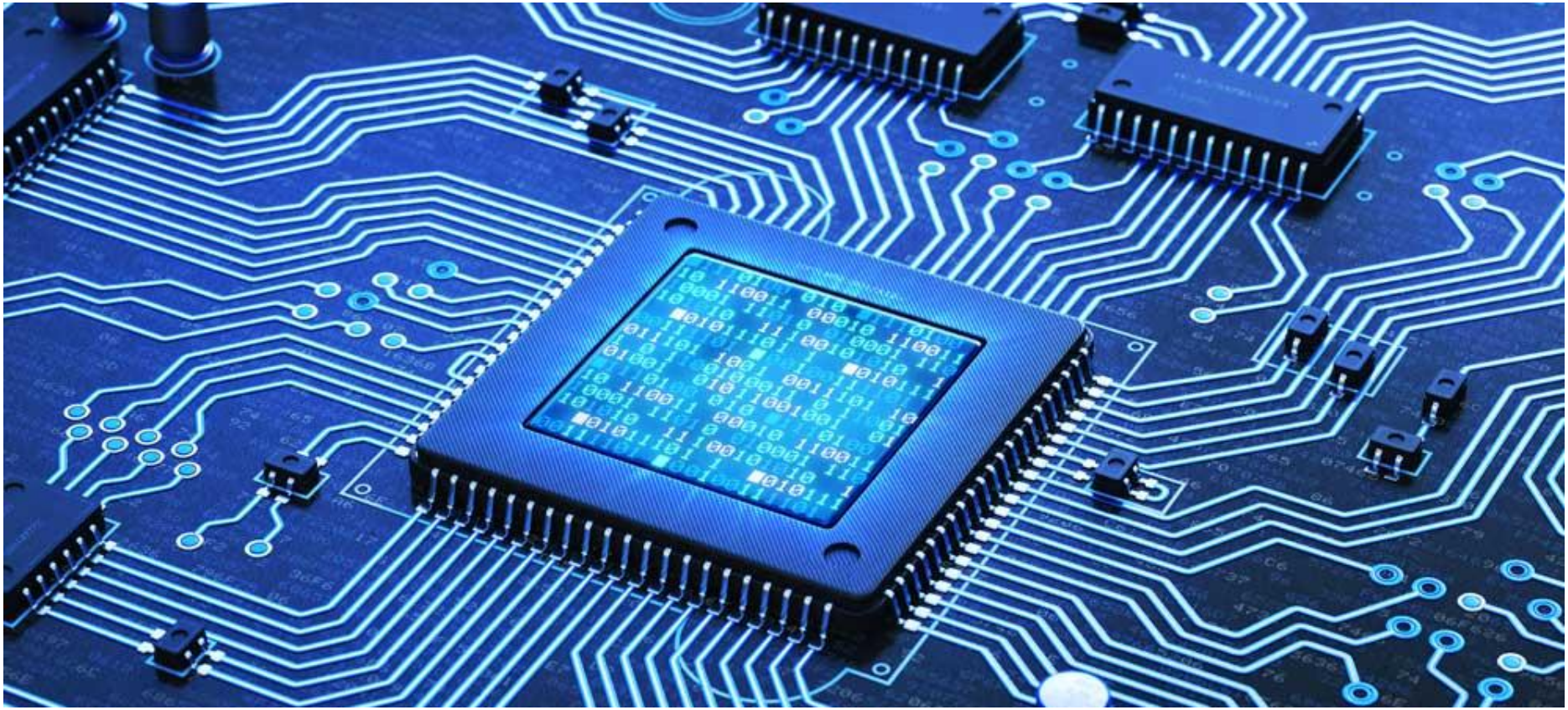


Q-Point of a Diode

Q-point: Explained

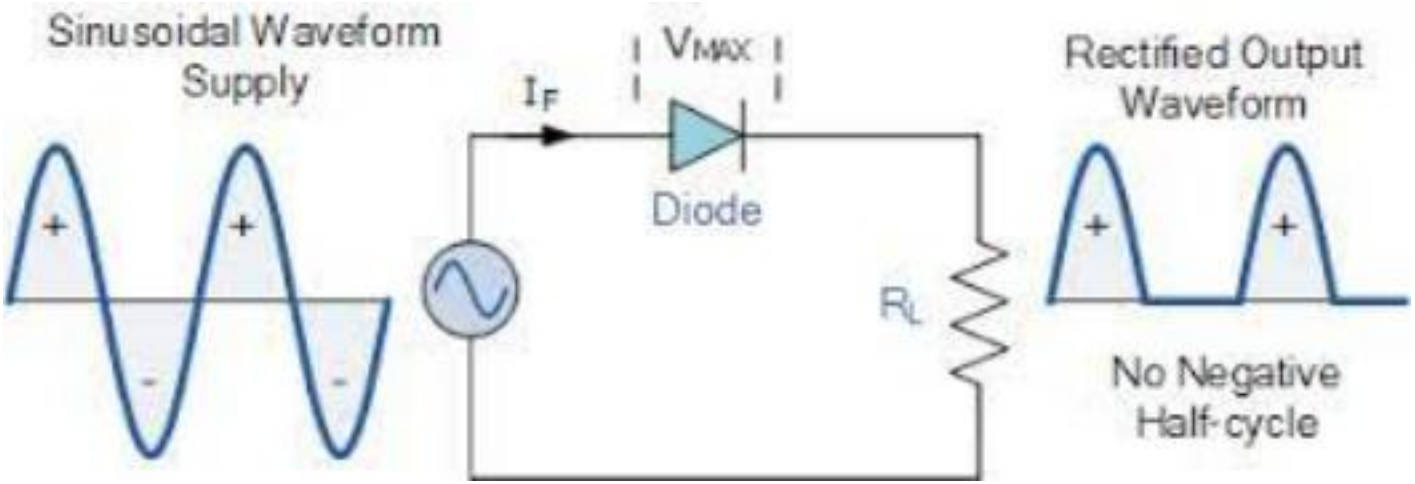


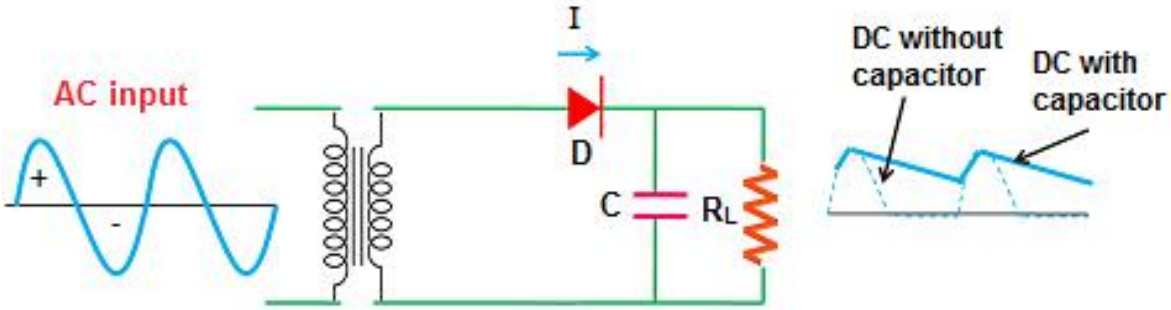
- **Q-point** is the **operating** or **quiescent point** at which a **diode operates.**
- It is specific to a **circuit** with which a diode is part of.
- The Q-point of a diode is decided by the circuit elements (resistors and power supplies) that are used to bias a diode.
- The circuit **designer** chooses the **Q-point** such that **diode** operates within its safe limits.



Sample Circuits using Diodes

Sample Circuits using Diodes

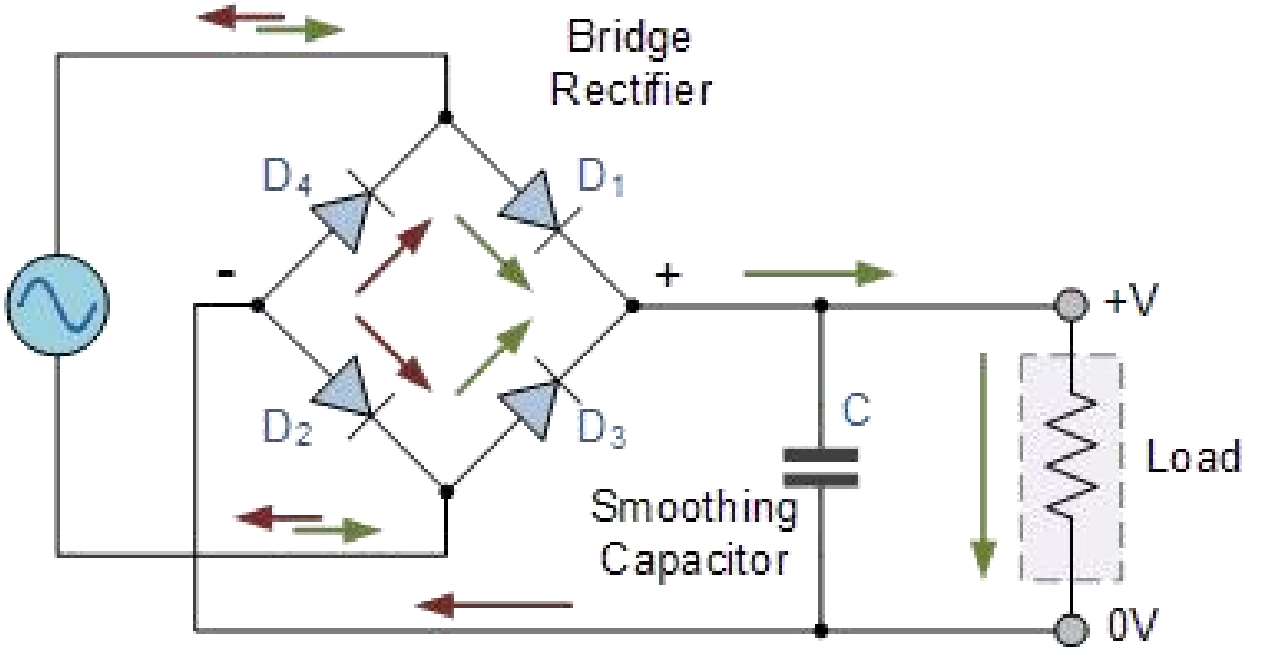


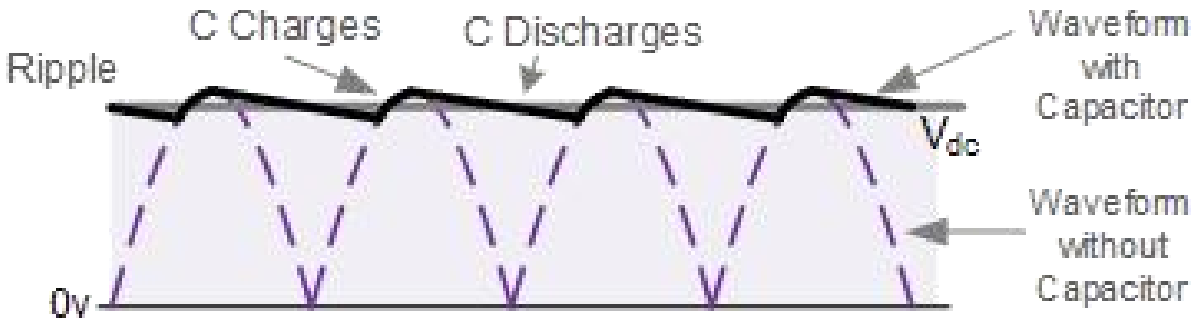


D = Diode
C = Capacitor
R_L = Load resistor
I = Current

Half wave rectifier with capacitor filter

Sample Circuits using Diodes: Full-wave Rectifier





Resultant Output Waveform

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