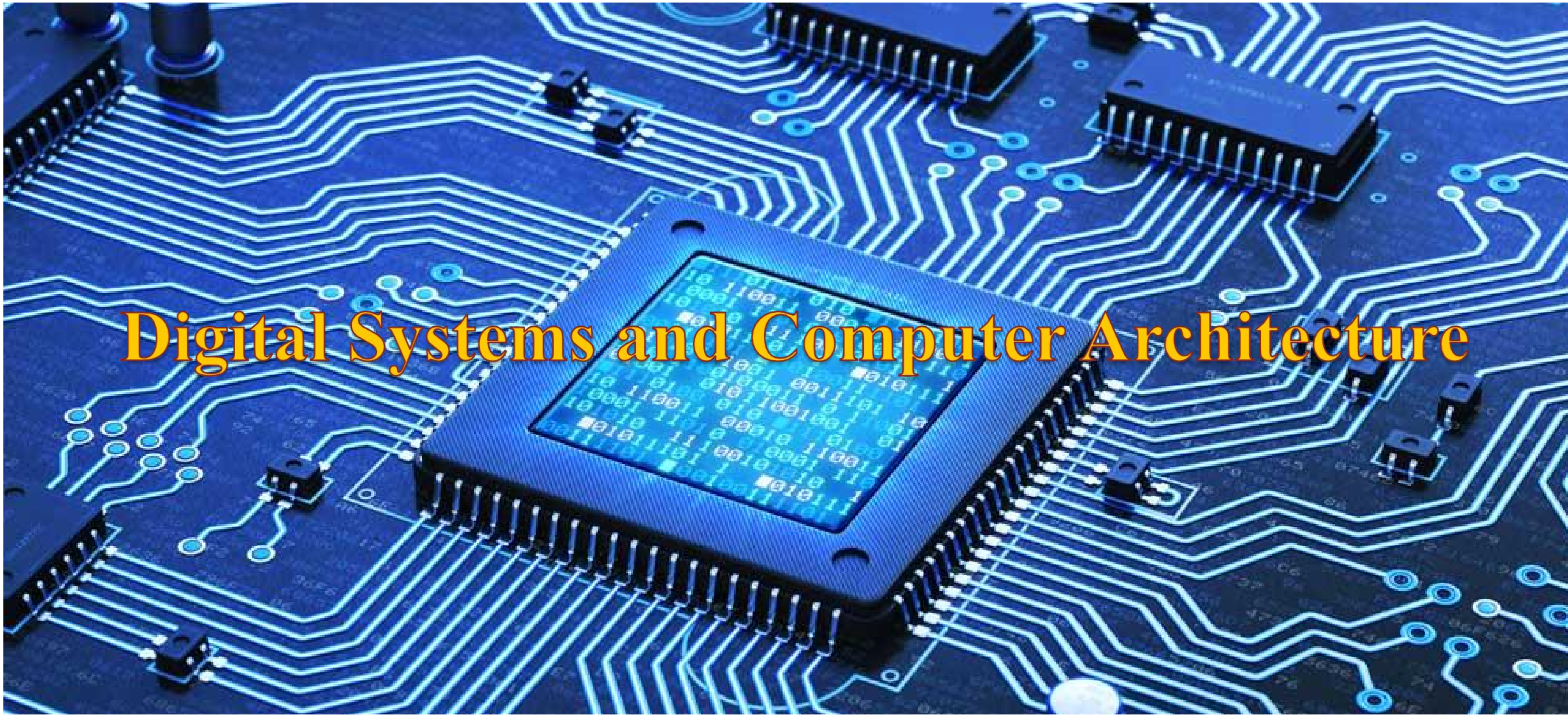


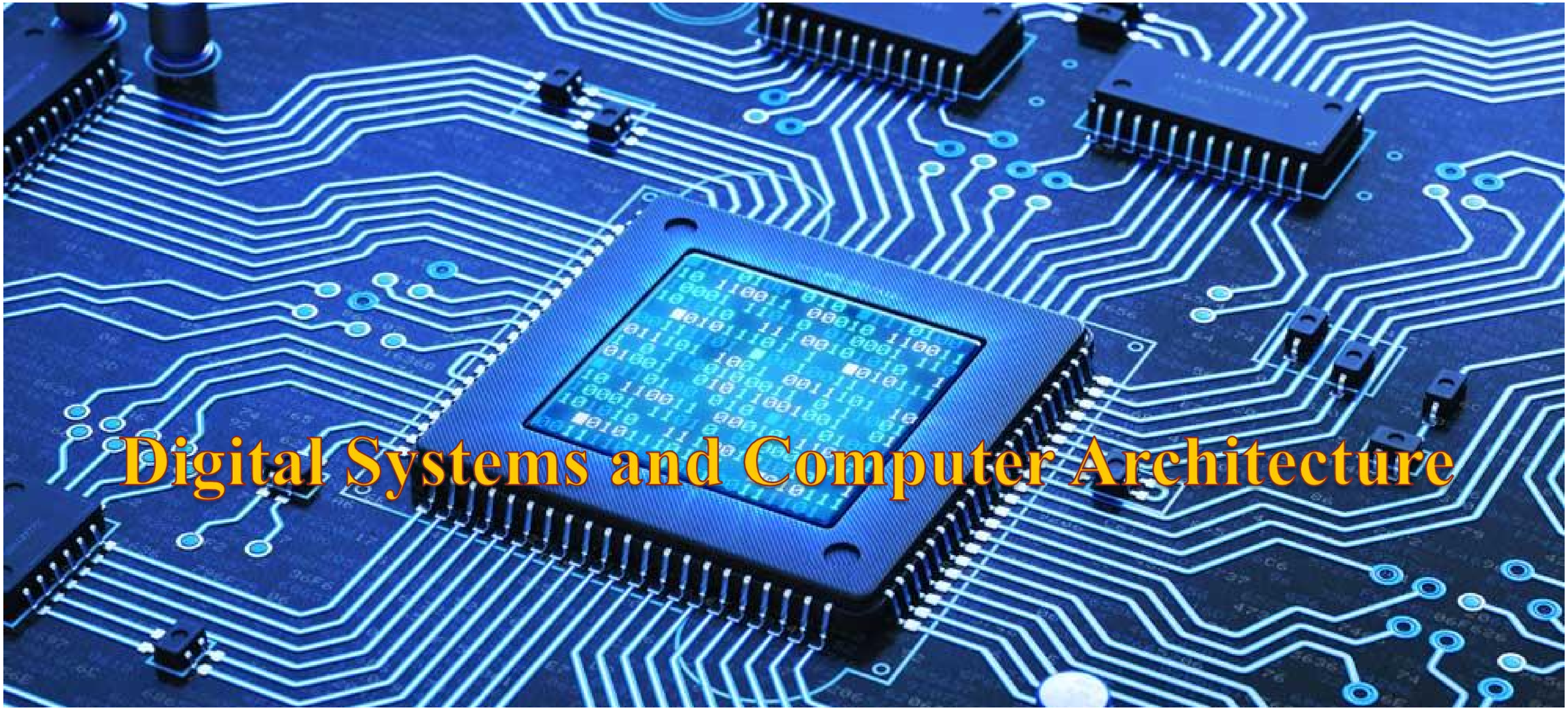
Digital Systems and Computer Architecture

Session 1.1

Module 1a: Basic Electric Circuits

Session 1.1: Focus

- Current, Voltage, Power: Definitions
  - System of Units (SI)
  - What is an Electrical Circuit?
  - Current flow and Electric Charge
  - Electric Potential
  - Energy and Power
- Resistivity and Resistance
  - Resistors and Ohm's Law
  - Resistor Colour Codes
  - Power Ratings of Resistors

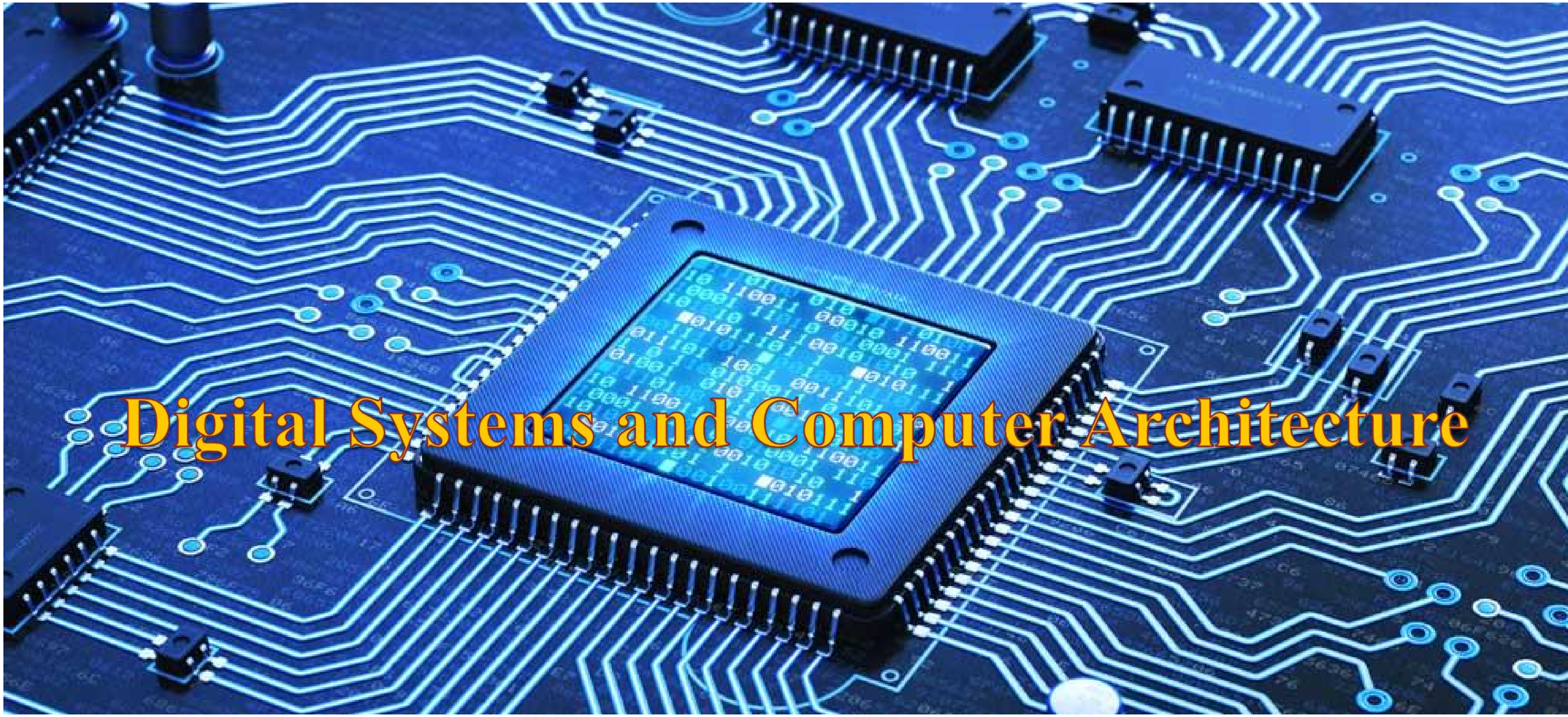


Digital Systems and Computer Architecture

Electric and Electronic Circuits

Electric and Electronics Circuits

- This module will introduce you to both Electrical and Electronic Circuits.
  - The interconnection between various electrical components to form a closed path is called an electrical circuit.
  - Electronic circuits are made of electronic components which are constructed using semiconductor materials.
- Electrical and Electronic circuits are used to solve important problems to the society.
- They are widely used in Information Technology (IT) for
  - Storing, retrieving and sending information.
- Engineers of all disciplines need to be thorough with the concepts of electrical and electronic circuits.



System of Units (SI)

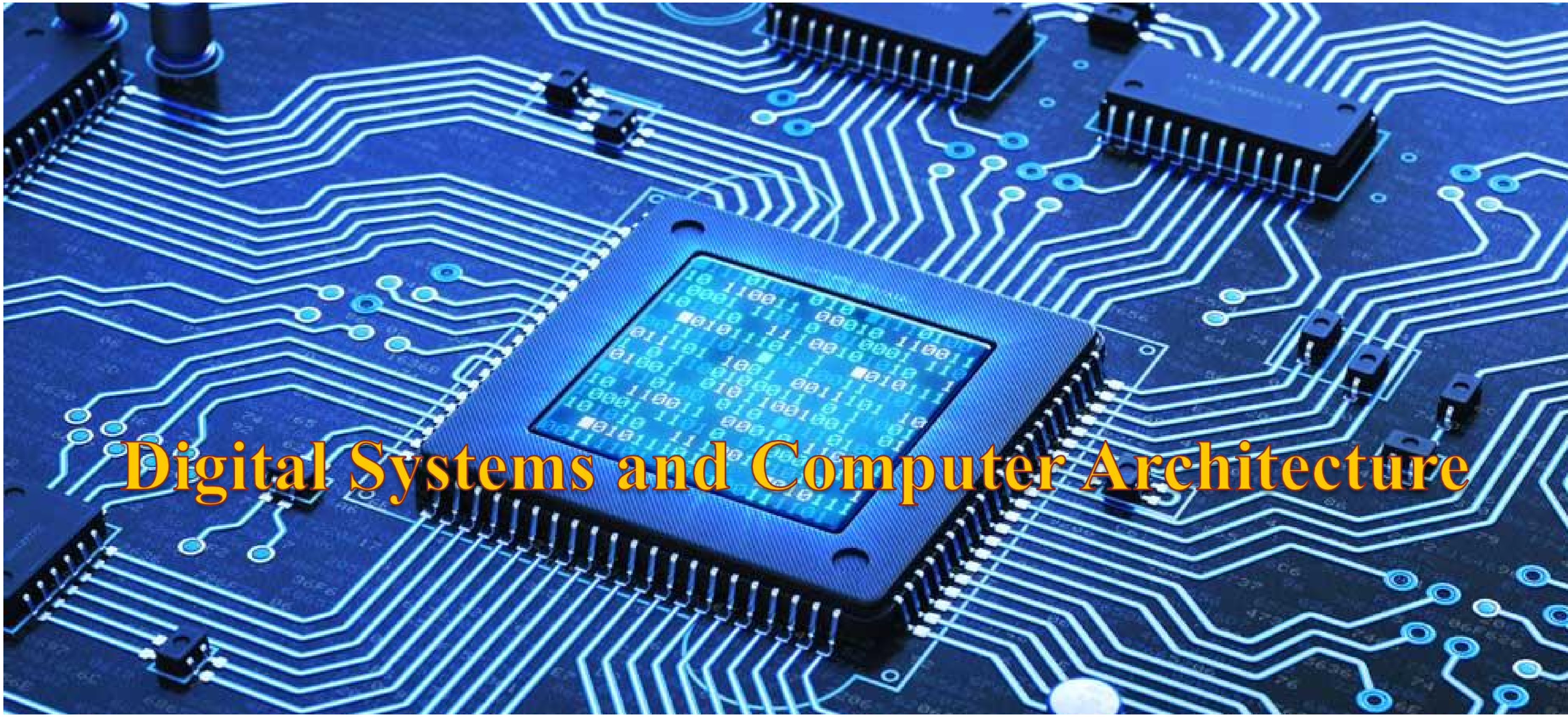
System of Units

- The system of units we use is the International System of Units.
  - Normally referred to as SI standard system.
- The SI system is also called the metric system.
- SI include the basic units for:
  - **Length**: meter (m)
  - **Mass**: kilogram (kg)
  - **Time**: second (s)
  - **Current**: ampere (A)
  - **Temperature**: kelvin (K)

Standard SI Prefixes & Engineering Units

10^{-12}	10^{-9}	10^{-6}	10^{-3}	1	10^{3}	10^{6}	10^{9}	10^{12}
pico (p)	**nano (n)**	**micro (μ)**	**milli (m)**		**kilo (k)**	**mega (M)**	**giga (G)**	**tera (T)**

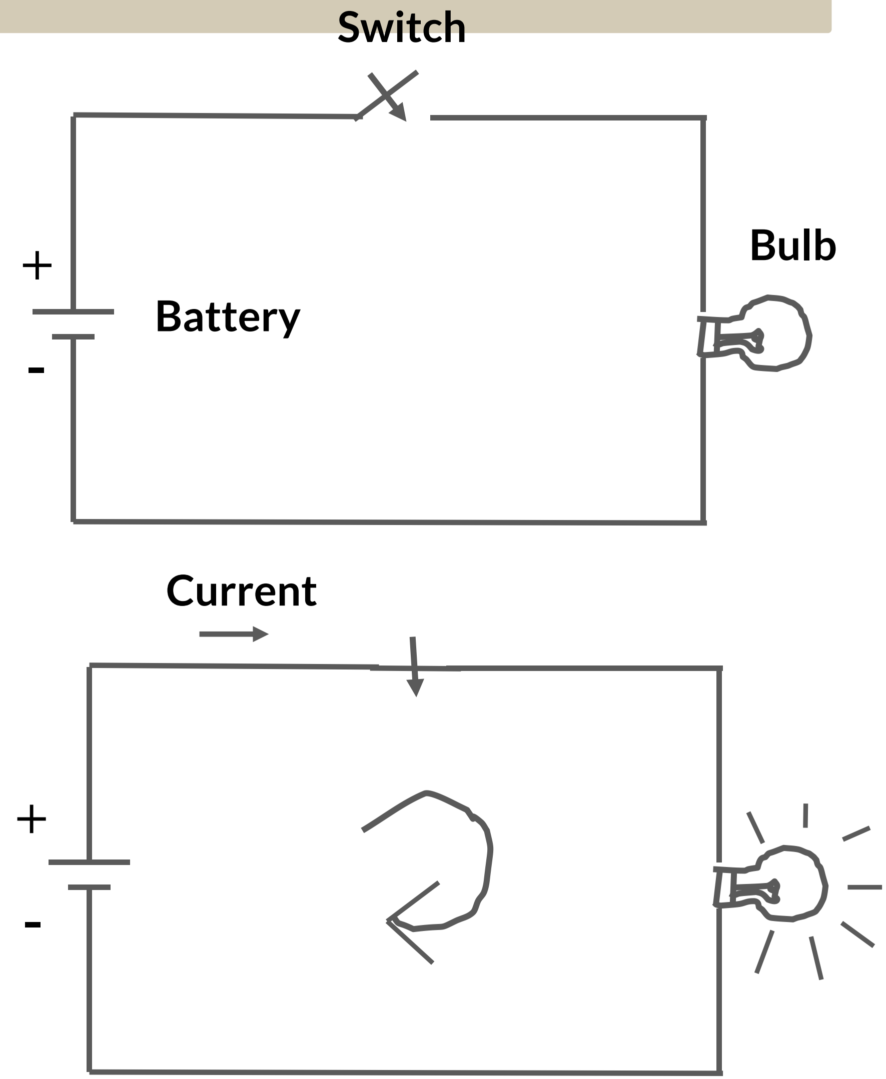
- These are the standard prefixes employed in the study of engineering.
- Commonly numbers are expressed in "**engineering units.**"
- In **engineering notation,** any quantity is represented by a **number** between **1 and 999** and an appropriate **metric unit** using a **power divisible by 3.**
- 0.056 g → 56 x 10^{-3} g → 56 mg
- 2.3 x 10^{-4} A → 230 x 10^{-2} x 10^{-4} A → 230 μA
- 13000 m → 13 x 10^{3} m → 13 km



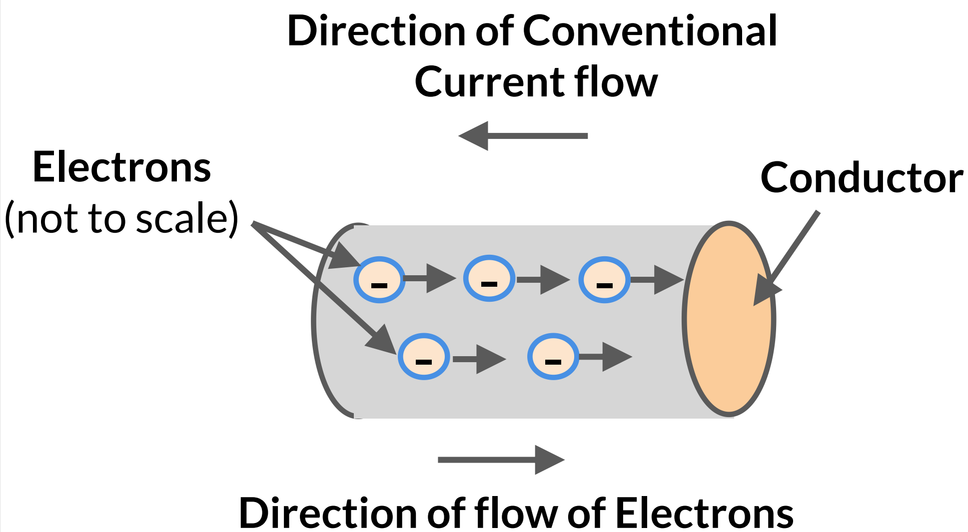
Current Flow and Electric Charges

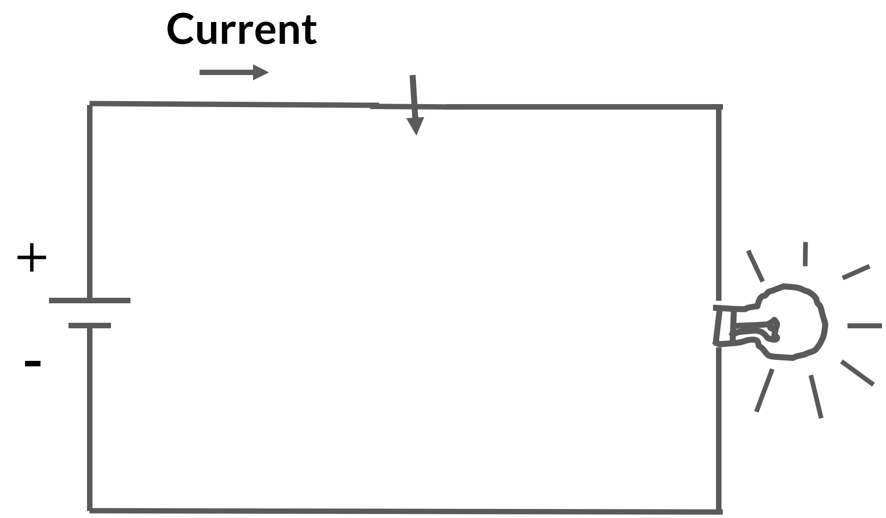
What is an Electrical Circuit?

- An electrical circuit is an interconnection of electrical components.
- Electric charge is the most elementary quantity in electric circuits.
- We are interested in the effect of charge in motion (current) within a circuit.
- An electrical circuit facilitates transfer of charge from one point to another within a closed path.



Current Flow and Electric Charge





- Motion of electrons results in current flow in metallic conductors.
- The conventional current flow is the reverse of the direction of flow of electrons, which is universally adopted.
- A single electron has a charge (Q) of $\mathbf{-1.602 \times 10^{-19}}$ **Coulomb**.

Definition of Electric Current

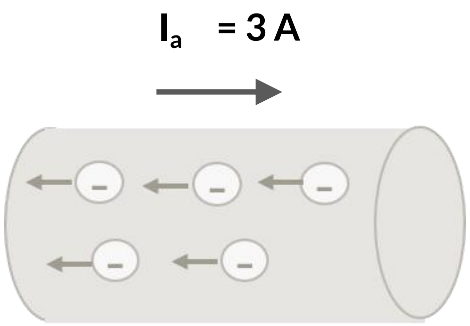
- An electric current is the rate of flow of electric charge through a point or a region.

$$i(t) = \frac{dq(t)}{dt}$$

- i(t) and q(t) represent instantaneous current and instantaneous charge respectively.
- Lowercase letters represent time dependent quantities.
- Capital letters are reserved for constant quantities.
- The basic unit of current is the ampere (A).
- A current of **1 A** refers to the flow of **1 coulomb of charges per second**.
- Note: One electron has a negative charge of 1.602×10^{-19} Coulomb.

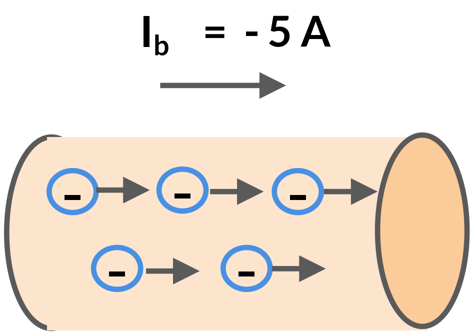
Current Flow: Electric Charge

- A single electron has a negative charge of 1.602×10^{-19} Coulomb.
- Thus, 6.24×10^{18} electrons would constitute 1 C of –ve charge.
- i.e., $1/ 1.602 \times 10^{-19} \rightarrow 6.24 \times 10^{18}$
- Assume, Ia = 3 A of current is flowing through the conductor.



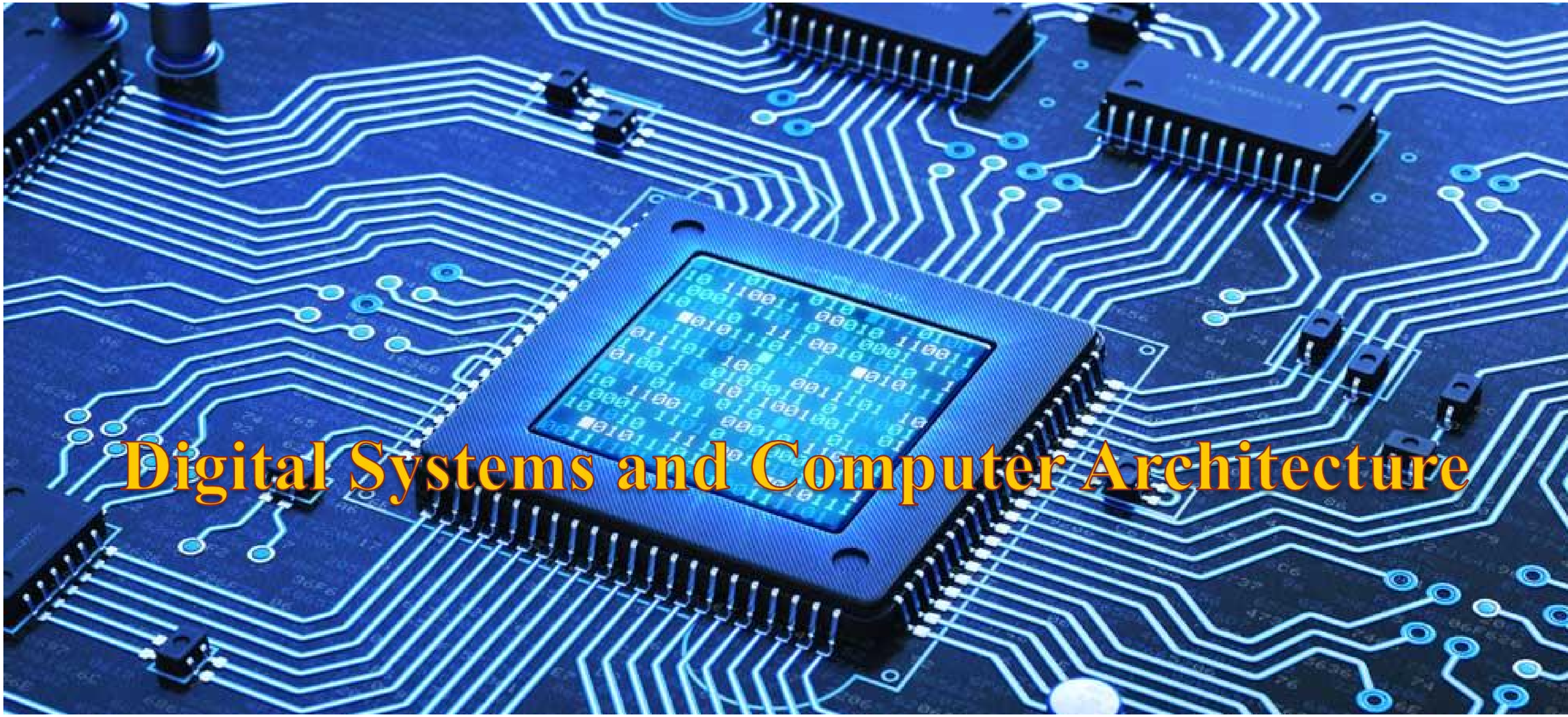
- Then, how many electrons are flowing in one second from right to left?
- $3 * 6.24 \times 10^{18}$ electrons are flowing in one second.

Negative Current Flow



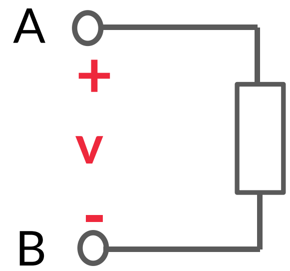
- Notice that the value of I_b is given as a negative because I_b is shown to be flowing from left to right, in the same direction of electron flow.

- The direction of movement of electrons in the above figure is left to right.
- How many electrons are flowing in a second?
- 5 * 6.24 x 10^{18} electrons flow in a second.



Electric Potential

Voltage or Potential Difference

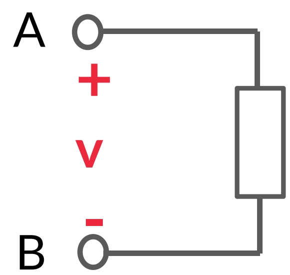


A general two-terminal circuit element

- Voltage across a terminal pair is a measure of the work required to move an unit of charge through the element.
- The unit of voltage is the volt.
- 1 volt is defined as 1 joule per coulomb.
- Voltage is represented by V or v.

Note: **Work** or **energy**, is measured in **joules (J)**;

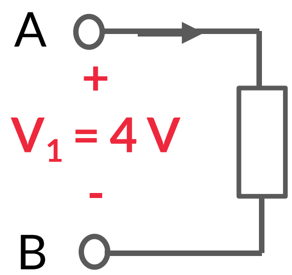
Voltage or Potential Difference



A general two-terminal circuit element

- Assume, a Direct Current (DC) is sent into the terminal A, through a circuit element, and it comes out through terminal B.
- Direct current (DC) is the one directional or unidirectional flow of electric charge.
- Pushing of charges through the element requires an expenditure of energy.
- The energy spent is defined as an electrical voltage (or a potential difference) that exists between the two terminals.
- There is a voltage "across" the element.

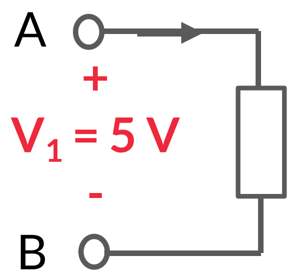
Example: Voltage or Potential Difference



Terminal A is 4 V positive with respect to terminal B

- The variable (V_1) represents the voltage between points A and B and that point A is assumed to be at a higher potential than point B.
- If $V_1 = 4$ V then the difference in potential of points A and B is 4 V and point A is at a higher potential compared to point B.

Example: Voltage or Potential Difference

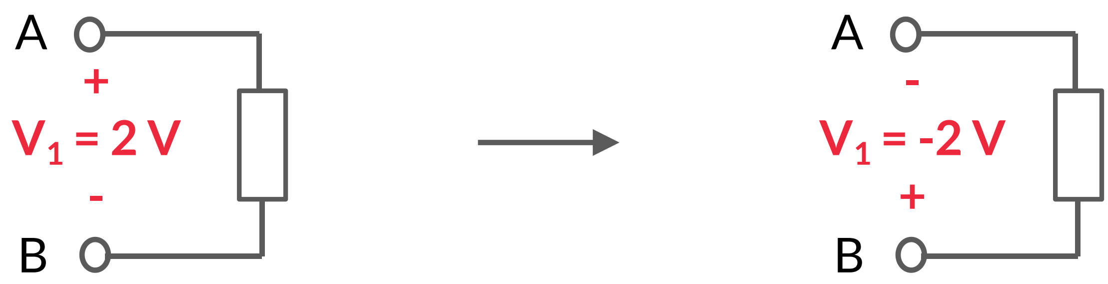


Terminal A is 5 V positive with respect to terminal B

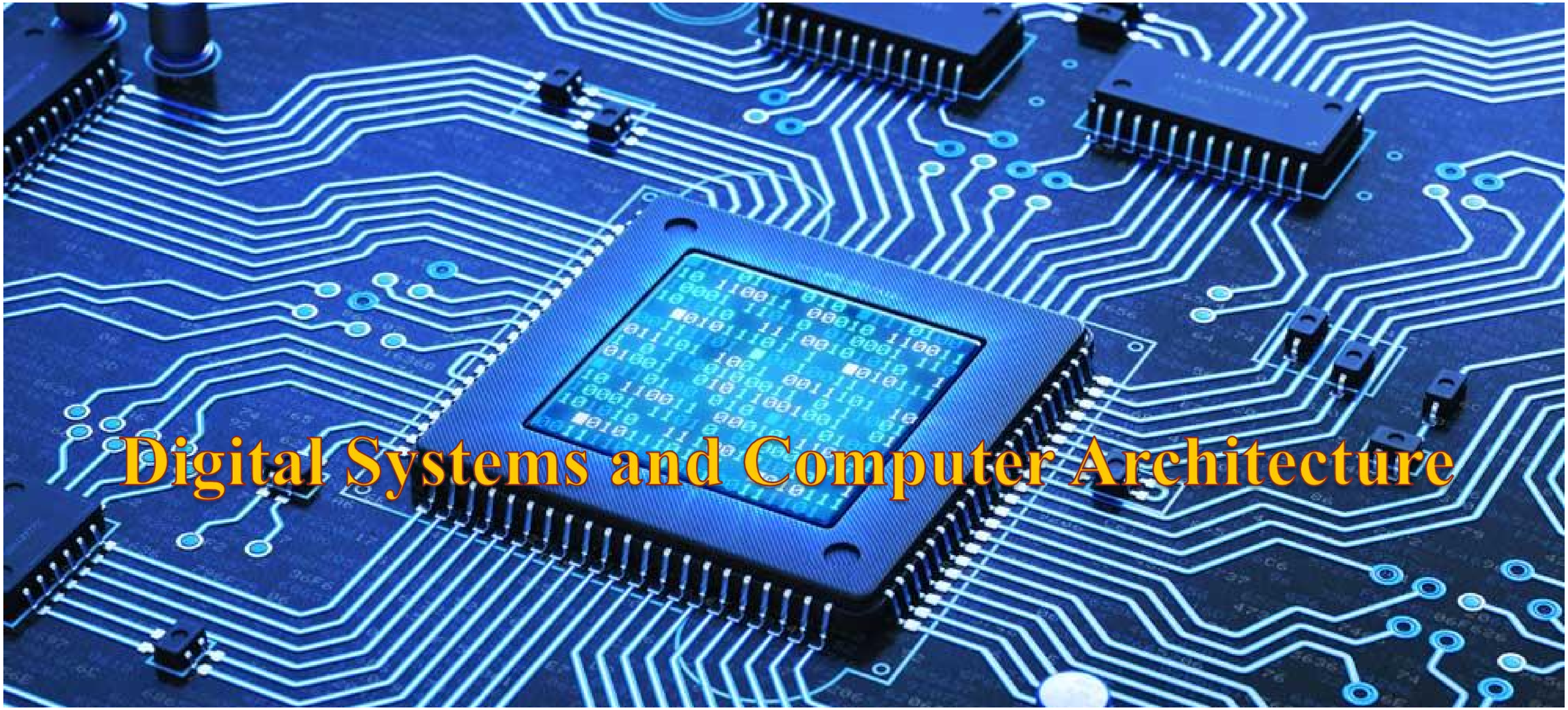
- If a unit positive charge is moved from point A through the circuit to point B.
- It will give up energy to the circuit and have 5 Joules less energy when it reaches point B.
- It means that the voltage source is delivering energy to the circuit element connected to the points A and B.
- Or the circuit elements are said to absorb energy from the voltage source.

Example: Voltage or Potential Difference

Terminal **A** is **2 V** with respect to terminal **B**



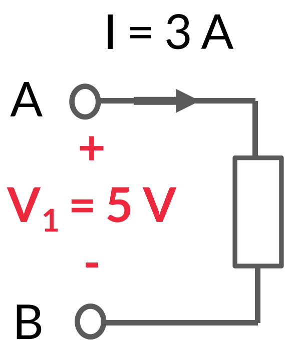
- V_1 = 2 V means that the potential between points A and B is 2 V and point A is at the higher potential.
- The same can also be represented as V_1 = -2 V, with point A at a higher potential with respect to B.
- Notice the changes to the signs on the terminals A and B.
- Hence, whenever either **current** or **voltage** is defined, it is mandatory that both the magnitude and **direction** or **polarities** are specified.



Digital Systems and Computer Architecture

Power and Energy

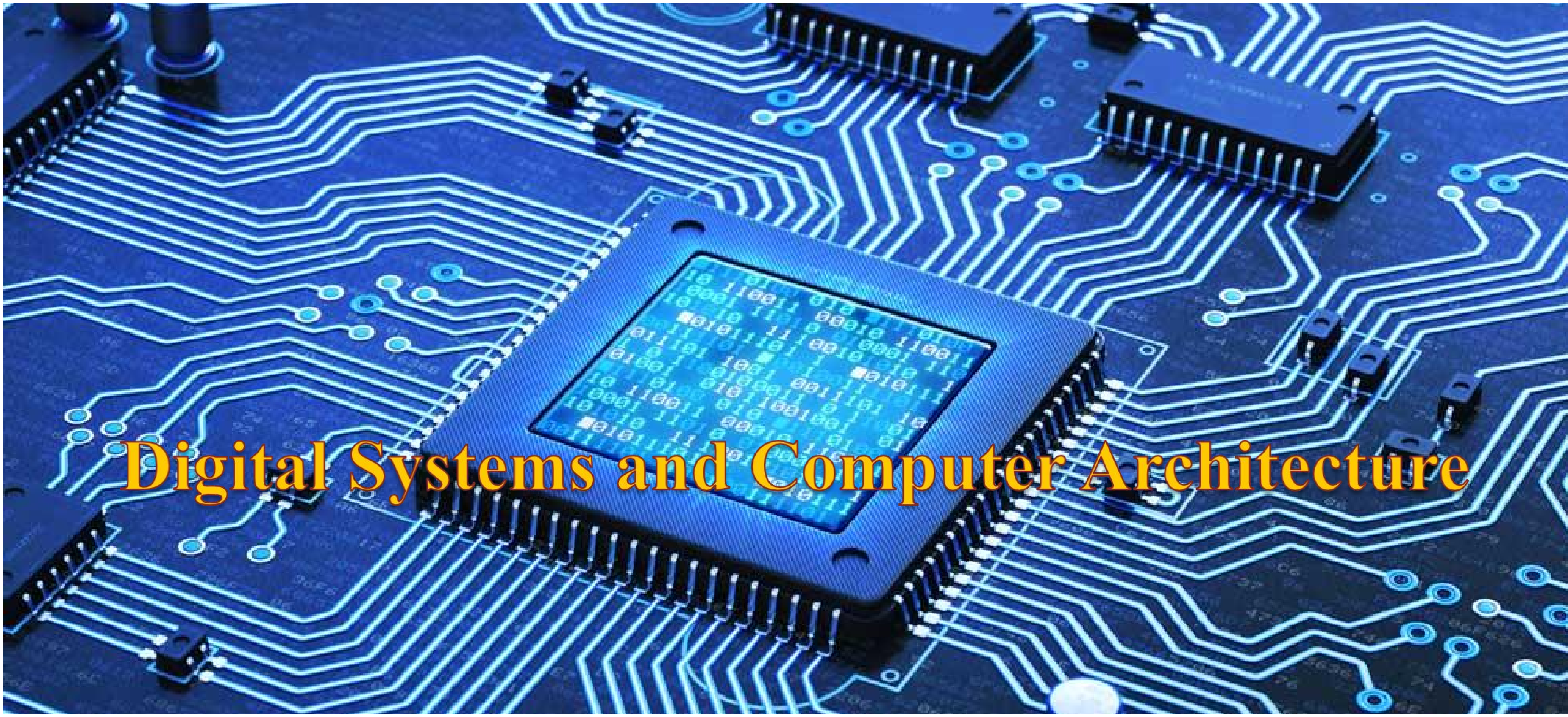
Power and Energy



Power absorbed by the element
= Voltage * Current
= 5 * 3
= 15 watts

- Electric power is the rate, per unit time, at which electrical energy is transferred by an electric circuit.
- Energy is the capacity of doing work. SI unit of Energy is joule.
- The SI unit of **power** is **watt**, which is one joule per second.
- Power absorbed by an element = Voltage across it * Current passing through it.
- Power = P = Work done per unit of time = V * I
- Electric power is usually produced by electric generators, but can also be supplied by sources such as electric batteries.

Source: Definition: Electric power | Open Energy Information.
https://openei.org/wiki/Definition:Electric_power



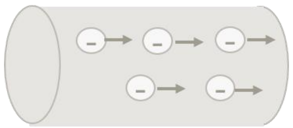
Resistors

Resistivity and Resistance

- Resistivity and Resistance
- Resistors
- Ohm's Law
- Resistor Colour Codes
- Power Rating of Resistors

Resistivity and Resistance

- Resistivity (ρ) is an inherent property of materials, which is a measure of the ease with which electrons can travel through them.



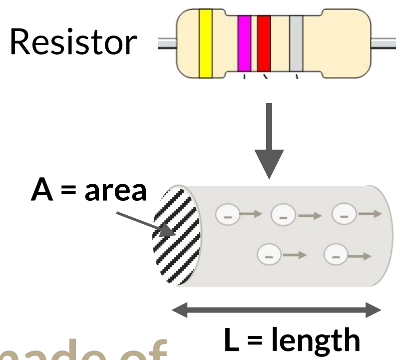
- Materials that are good conductors of electric current have low values of resistivity.
  - Copper, aluminum, gold and silver are good examples of conductors.

Materials that are good electrical insulators have a high value of resistivity.

  - Air, plastic, glass, rubber and wood are good examples of insulators.
- Resistance (R) is determined by
  - Inherent resistivity of the material and
  - The geometry of the resistor.
- Thus, resistance of resistors depends on the material used to construct them and the dimensions (length and area) of the resistor.

Relationship between Resistivity and Resistance

- Assume a resistor having a physical dimensions of:
  - Cross-sectional area : A m^2
  - Length: L meters
- Then Resistance is defined by:
  - $R = \rho * (L / A)$
- ρ is the resistivity of the material the resistor is made of.
- Resistance is indirectly proportional to the Area and it is directly proportional to the Length, of the resistor.
- SI unit of Resistance is Ohms (Ω).
- SI unit of Resistivity is Ohms-meter (Ωm).



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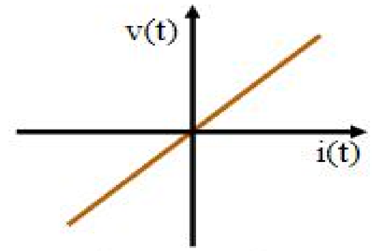
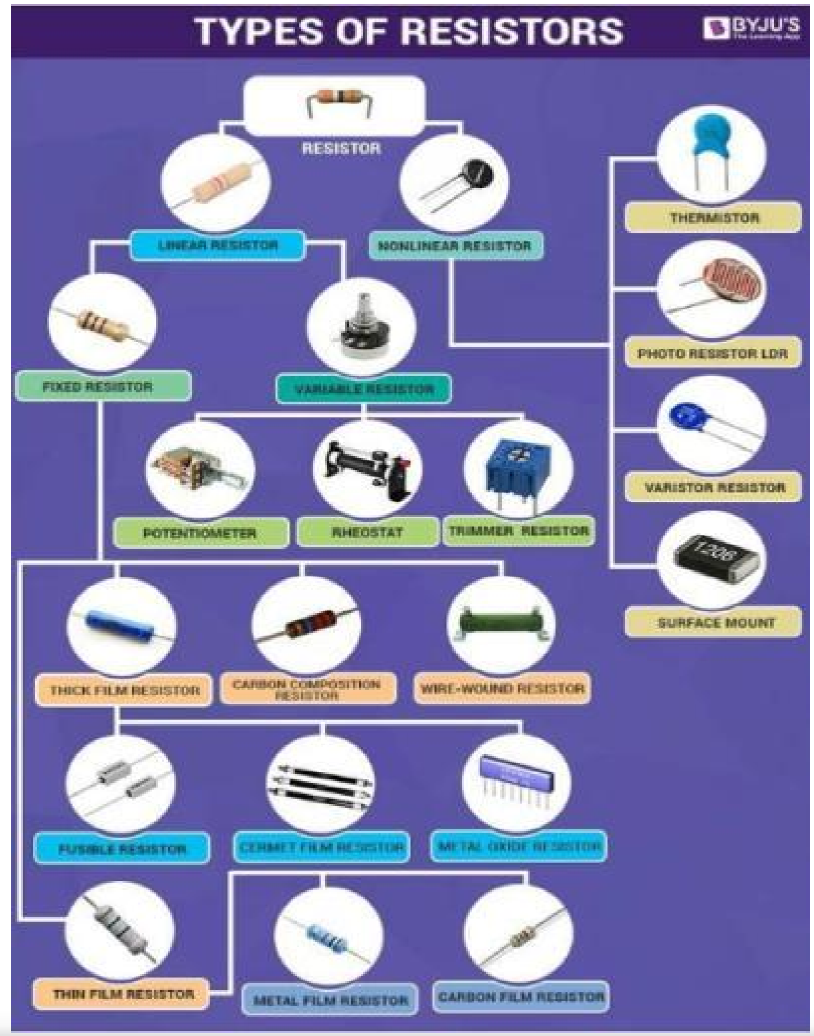
Resistors

- Symbol for Resistor is: 

- Resistance is normally considered to be a positive quantity.
- Resistors can be easily manufactured and they are relatively cheaper too.
- Relationship between the voltage across a resistor and the current passing through it is normally linear.
- Though ideal resistors are considered to be linear, it becomes non-linear with changes in temperature.

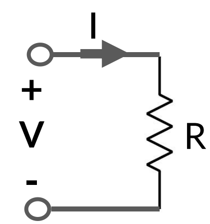


Linear Resistor

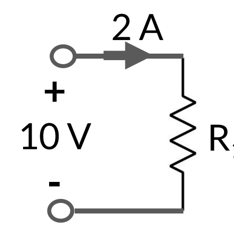


Ohm's Law

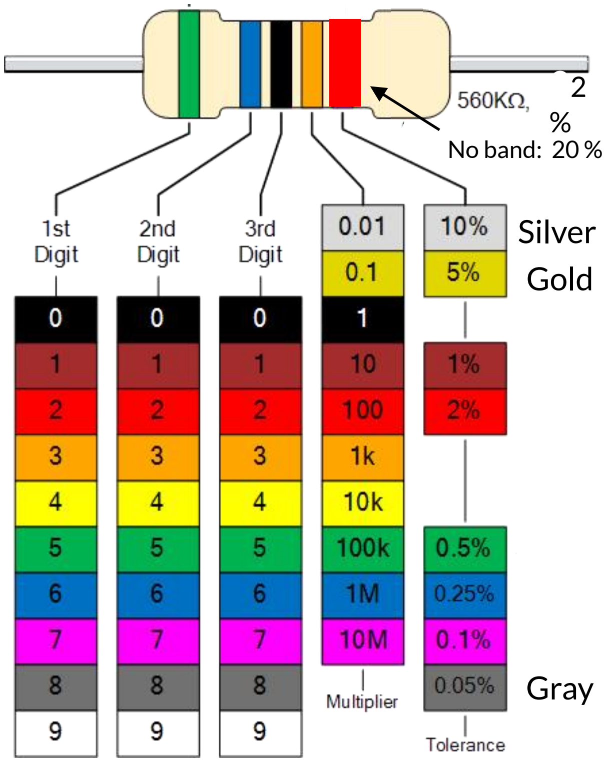
- Ohm's law states that the voltage across a material is directly proportional to the current flowing through the it.
  - V $\propto$ I
  - The constant of proportionality R is called the Resistance.
  - $V = R * I$ where R is >= 0
  - $R = V / I$
  - Unit of R is Volt/Ampere which is Ohms (Ω)

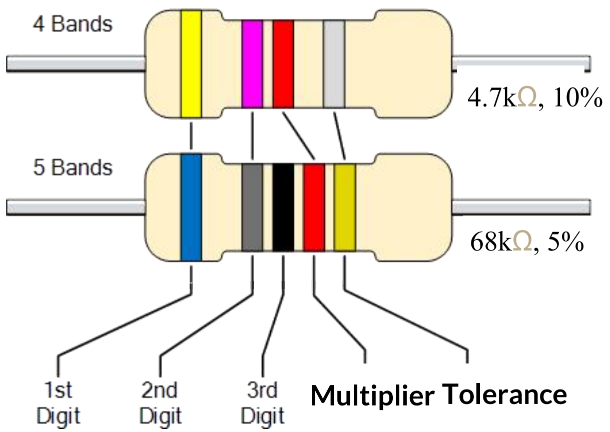


- Find the value of Resistor if the voltage across R_1 is 10 V and the current passing through it is 2 A.
  - $R_1 = V / I = 10 / 2 = 5$ Ohms.



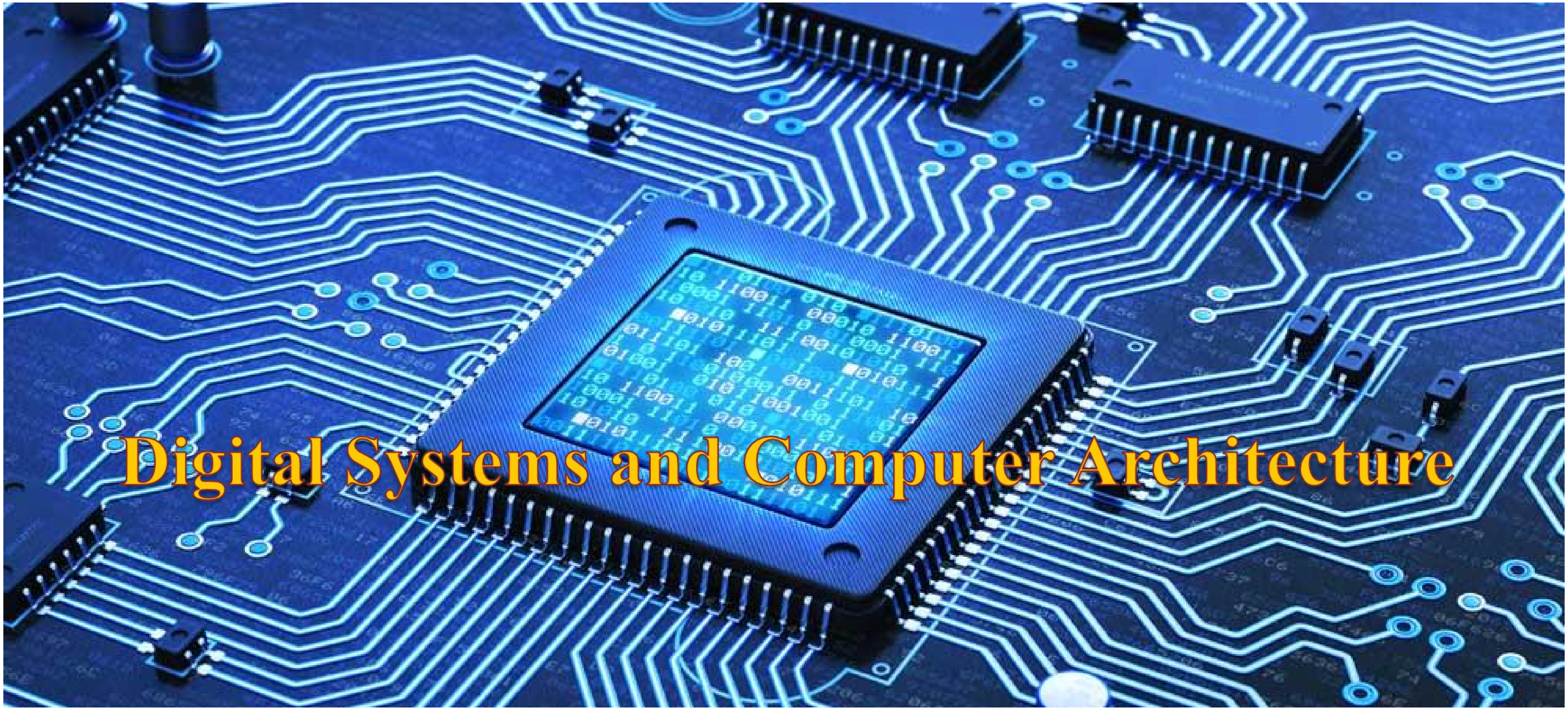
Resistor Colour Codes





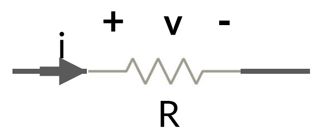
- Keep the lead to your left where the colour band is closer to the lead, while reading the colour codes.
- The tolerance band which is larger than the rest will be to your right.

Mnemonic: B.B. ROY of Great Britain Had a Very Good Wine.



Power Ratings of Resistors

Power Absorbed by Resistor



- The current (i) passing through **R** and voltage (v) across it are given in **passive sign convention.**
- **Current entering** through the **positive terminal** indicates that the **element** is **absorbing** the **power.**
- The **product** of **v** and **i** gives **power absorbed** by the **Resistor.**
  - $P_R = V * I$ in **watts.**
- The **absorbed power** is always **positive** and it appears physically as **heat** or **light.**
- A resistor is a **passive element** that **cannot deliver power** or **store energy.**

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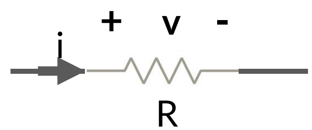
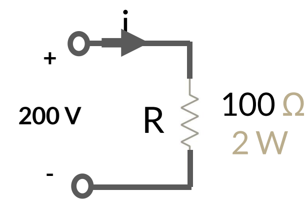
Power Ratings of Resistor



- Alternative expressions for the absorbed power by a resistor are:
  - $P = vi = i^2 R = v^2 / R$
- Every resistor along with its Resistance value (Ohm) also has the maximum power that it can withstand.
- Which is called the power rating of the resistor.
- For example: Let us assume a Resistor of 100 Ω with power rating of 2 W, is connected across 200 V of DC source by mistake.



  - Compute the current (i) flowing through R.
  - $i = v / R = 200/100 = 2$ A ; Using Ohm's law
  - Power dissipated by $R = i^2 R = (2)^2 * 100 = 400$ W.
  - **This value is much above the rated power, resulting in fire and smoke!!!**

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  - Resistors and Ohm's Law
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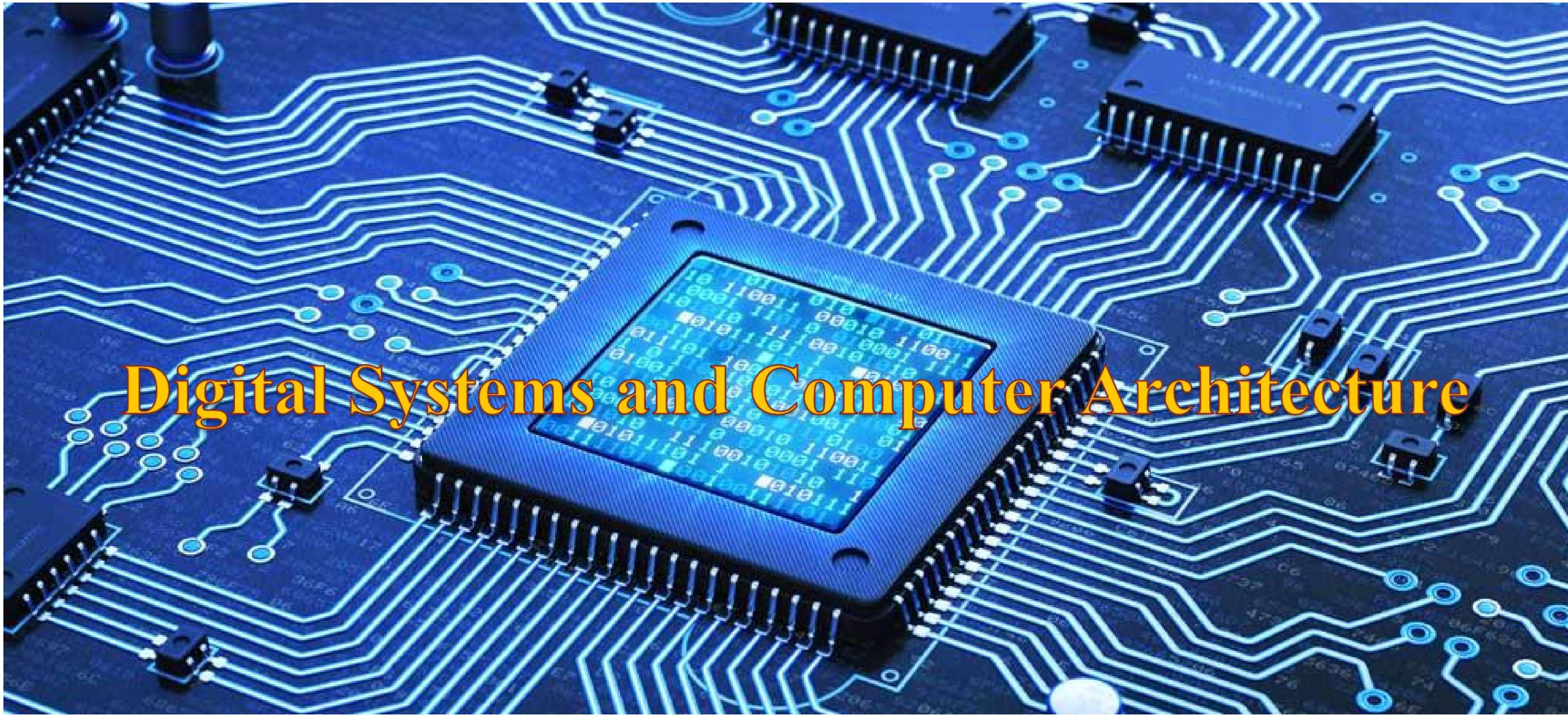
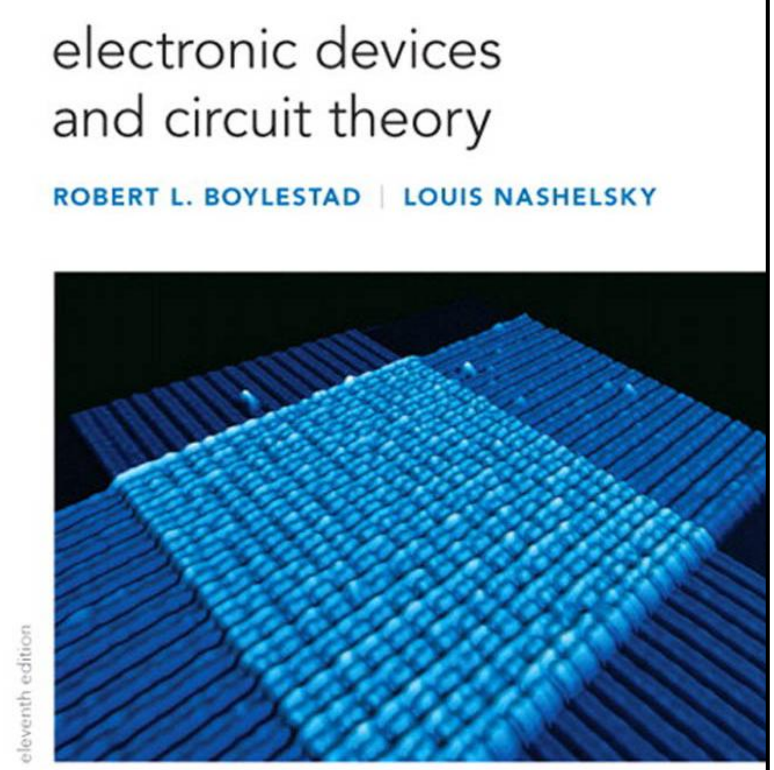


References

Reference 1: DS & CA

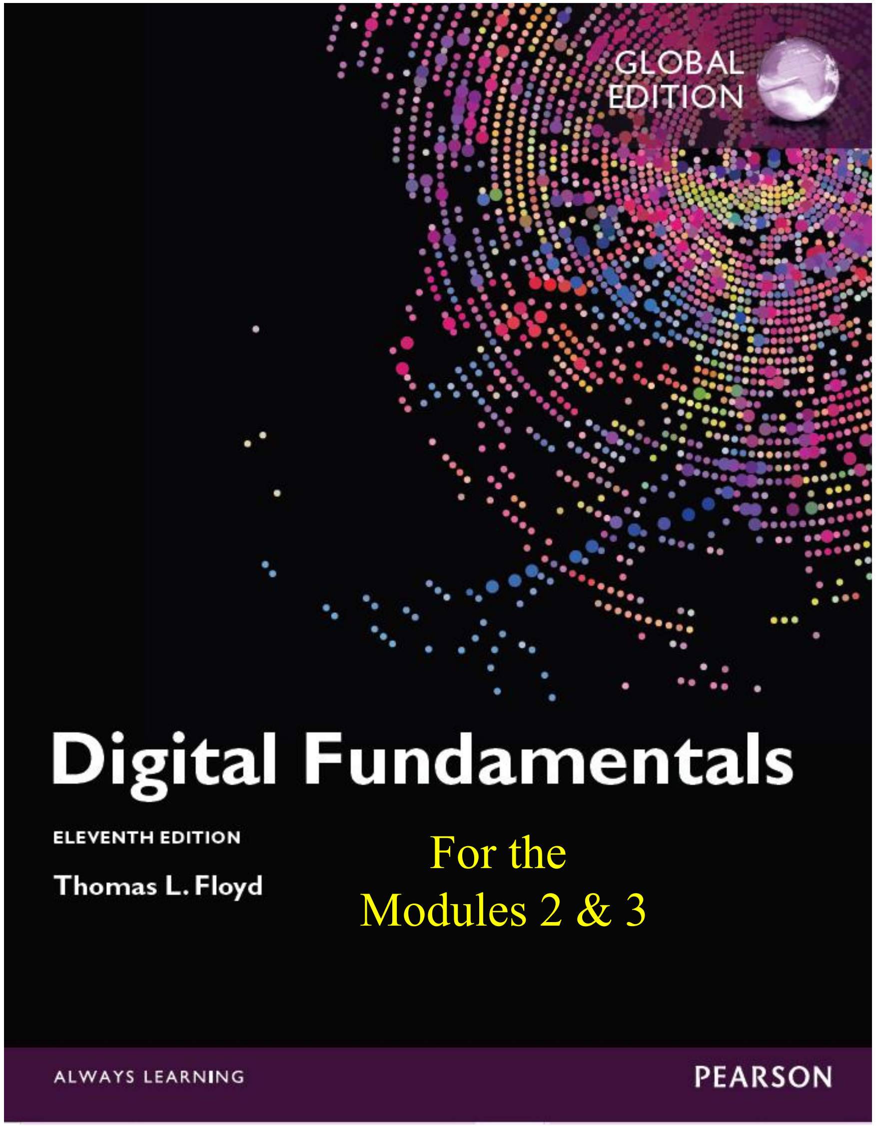
Ref 1



For the
Module 1

References 2 & 3: DS & CA

Ref 2



For the Modules 2 & 3

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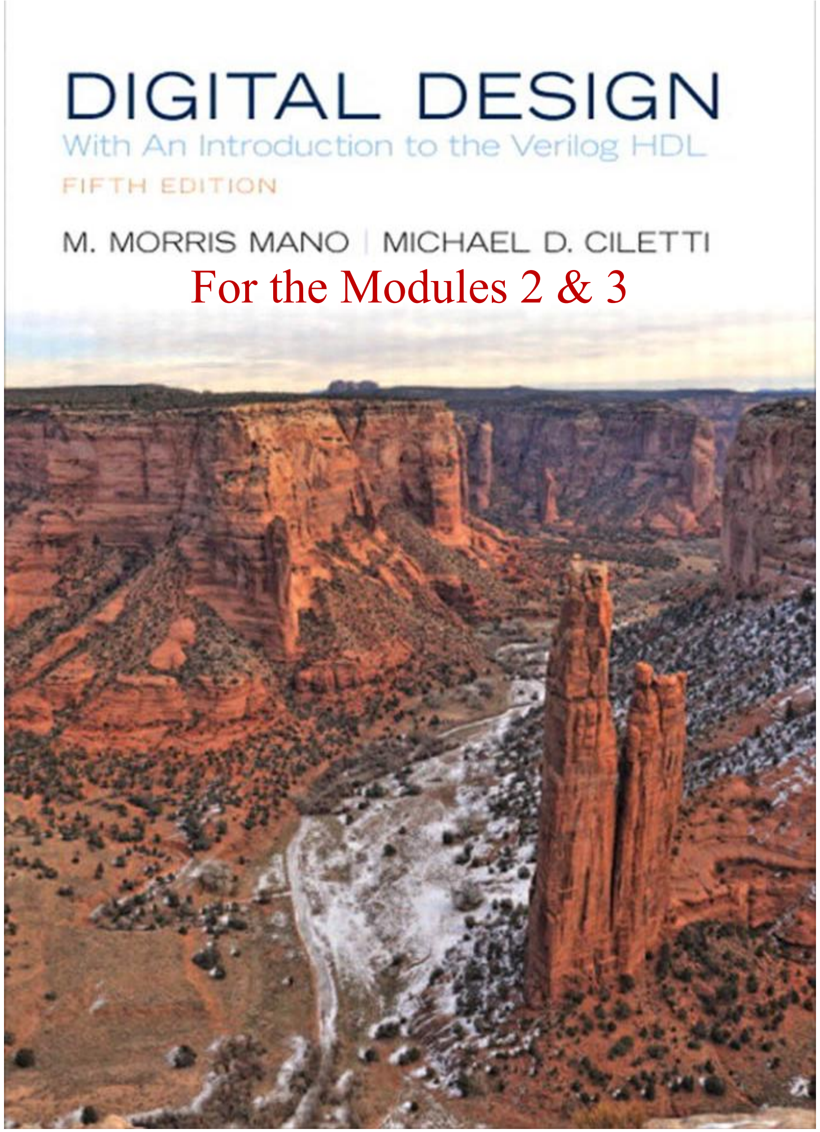
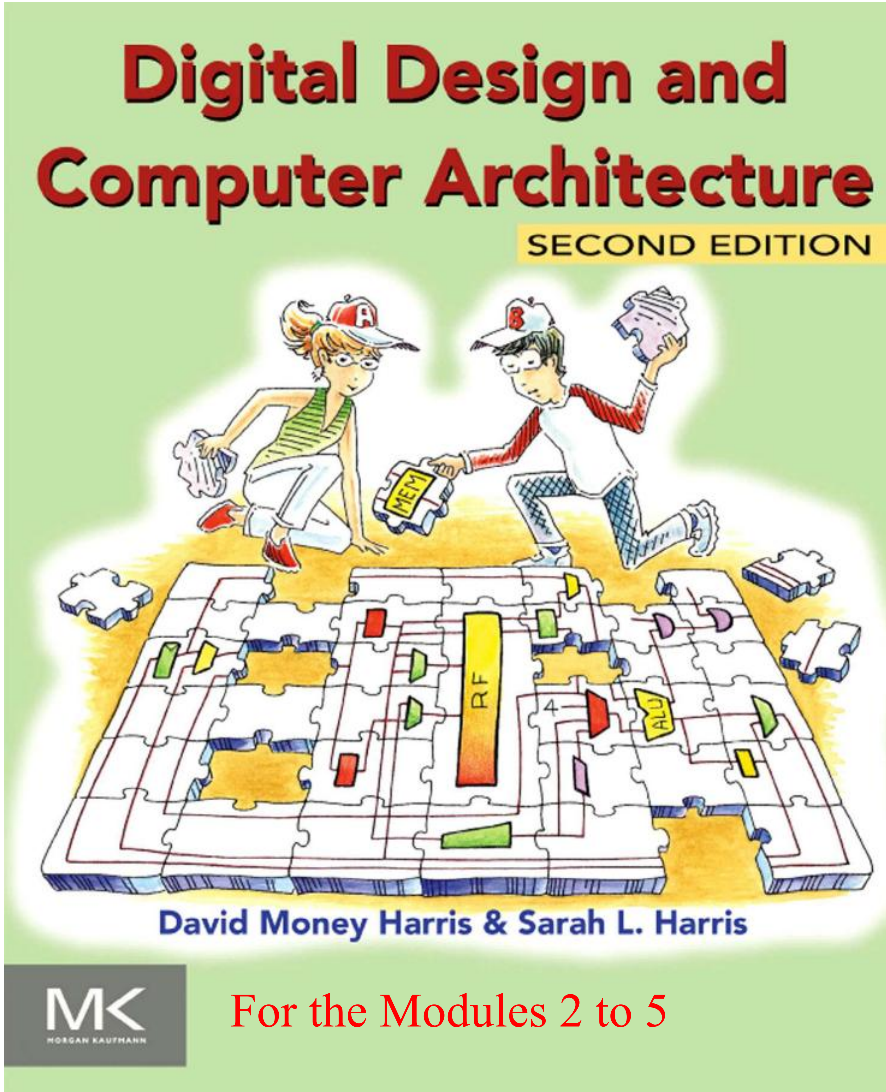


For the Modules 2 & 3

References 4 & 5: DS and CA

Ref 4



For the Modules 2 to 5

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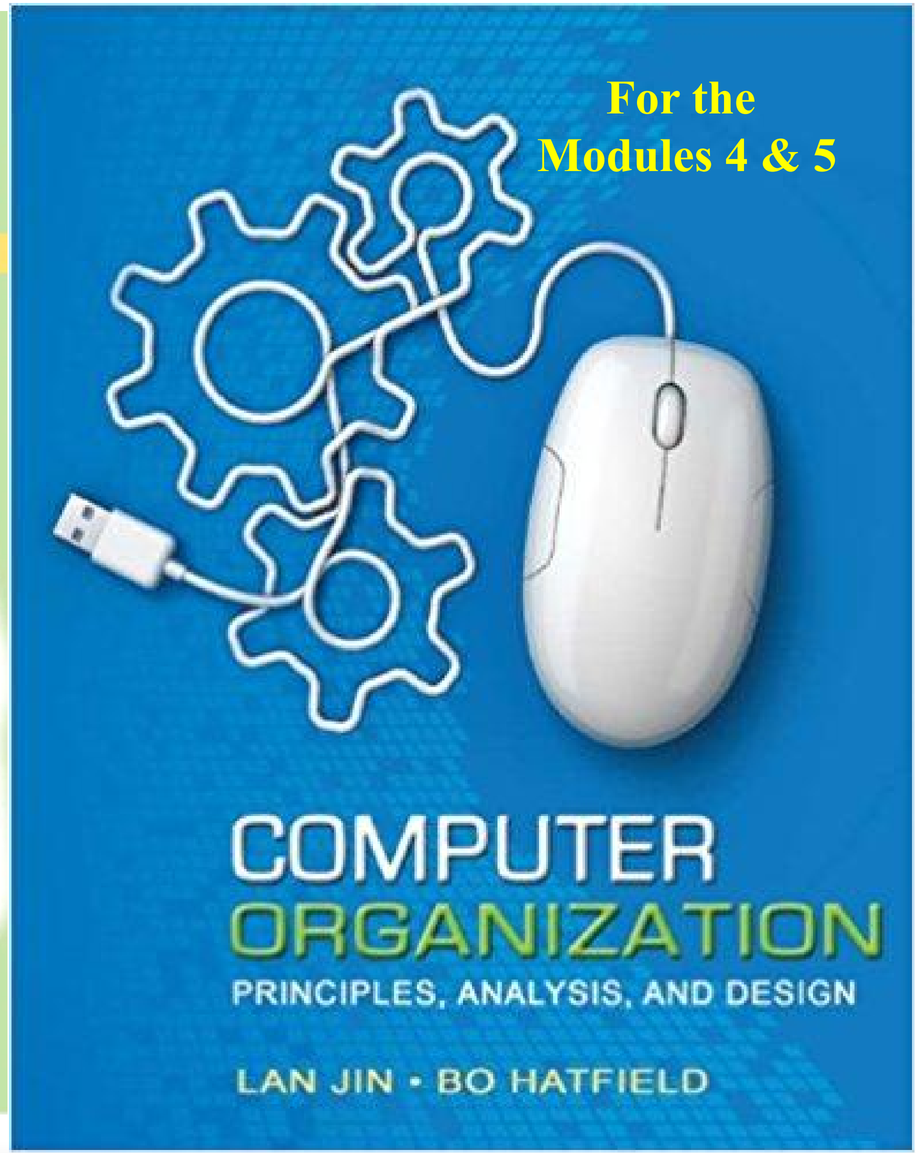

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