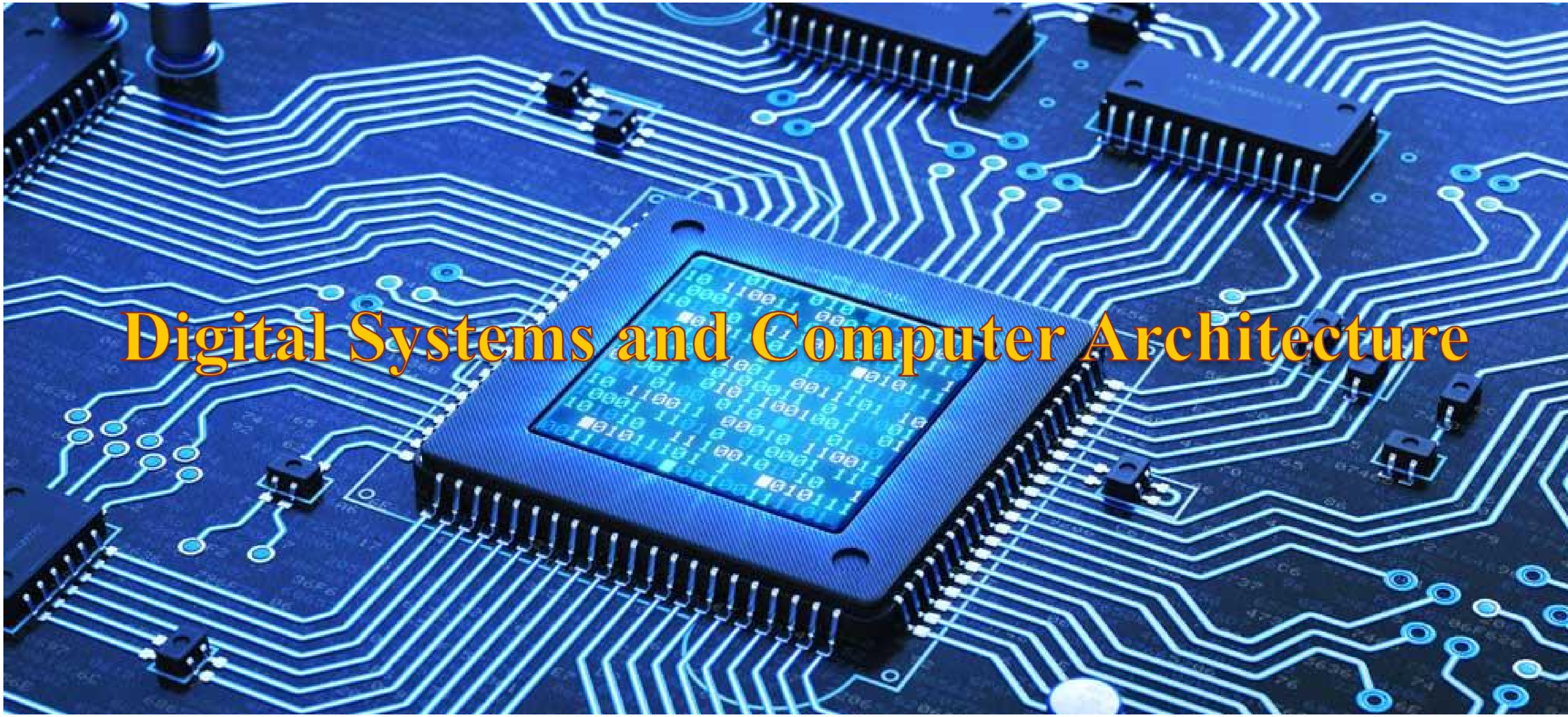
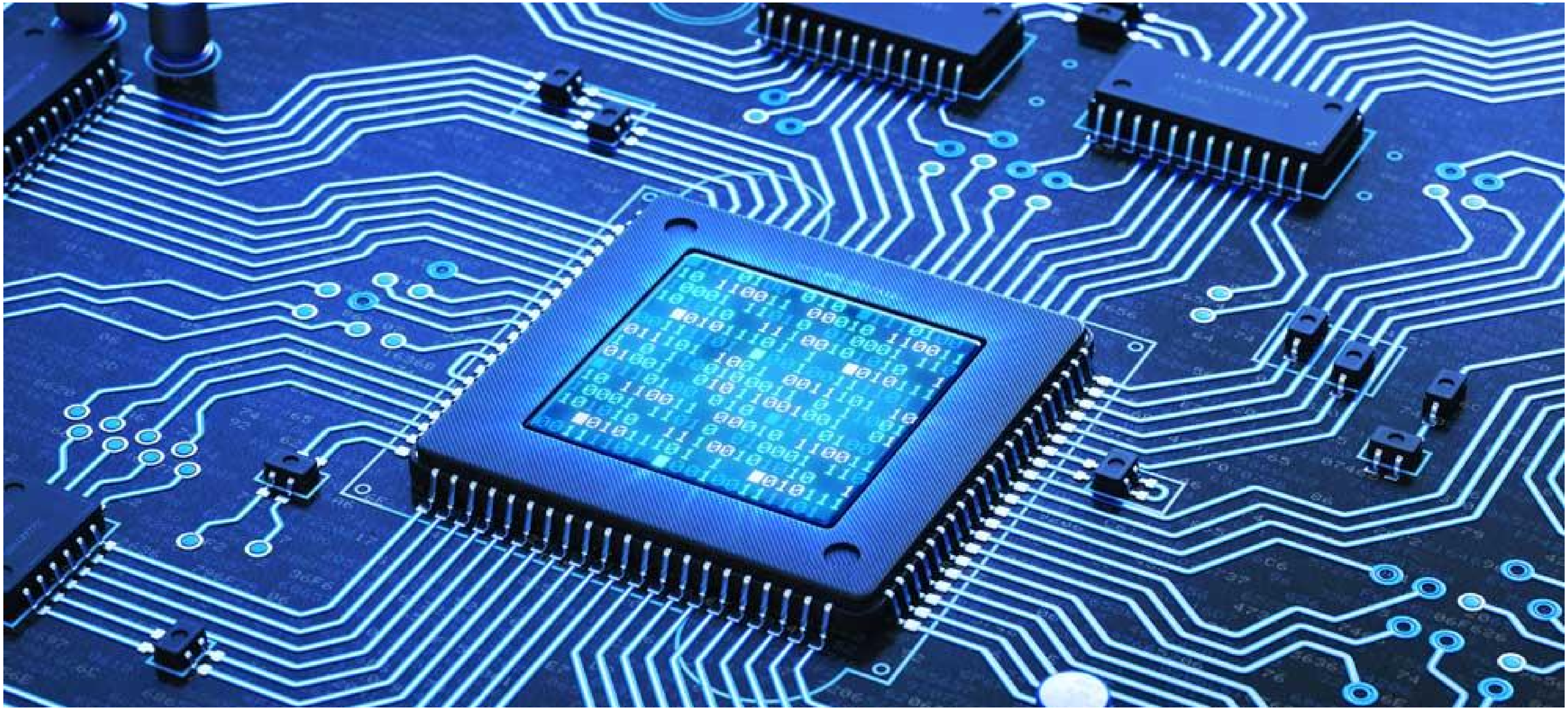


Session 1.4

Module 1a: Capacitors and Inductors

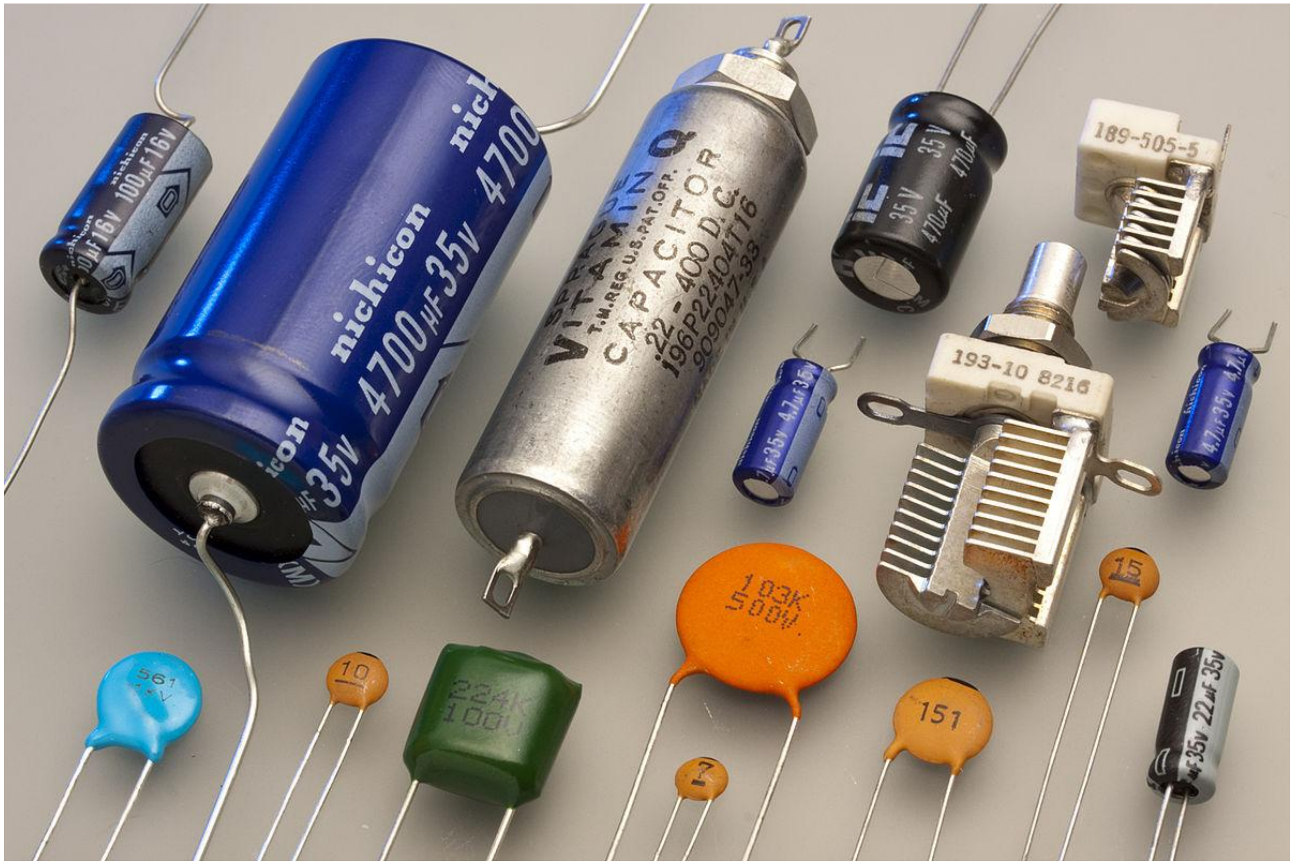
Session 1.4: Focus

- Introduction to Capacitors
- Capacitance Value
  - V-I Relationship
- Construction of Inductors
  - V-I Relationship
- Passive Filters
- Use of Capacitors and Inductors



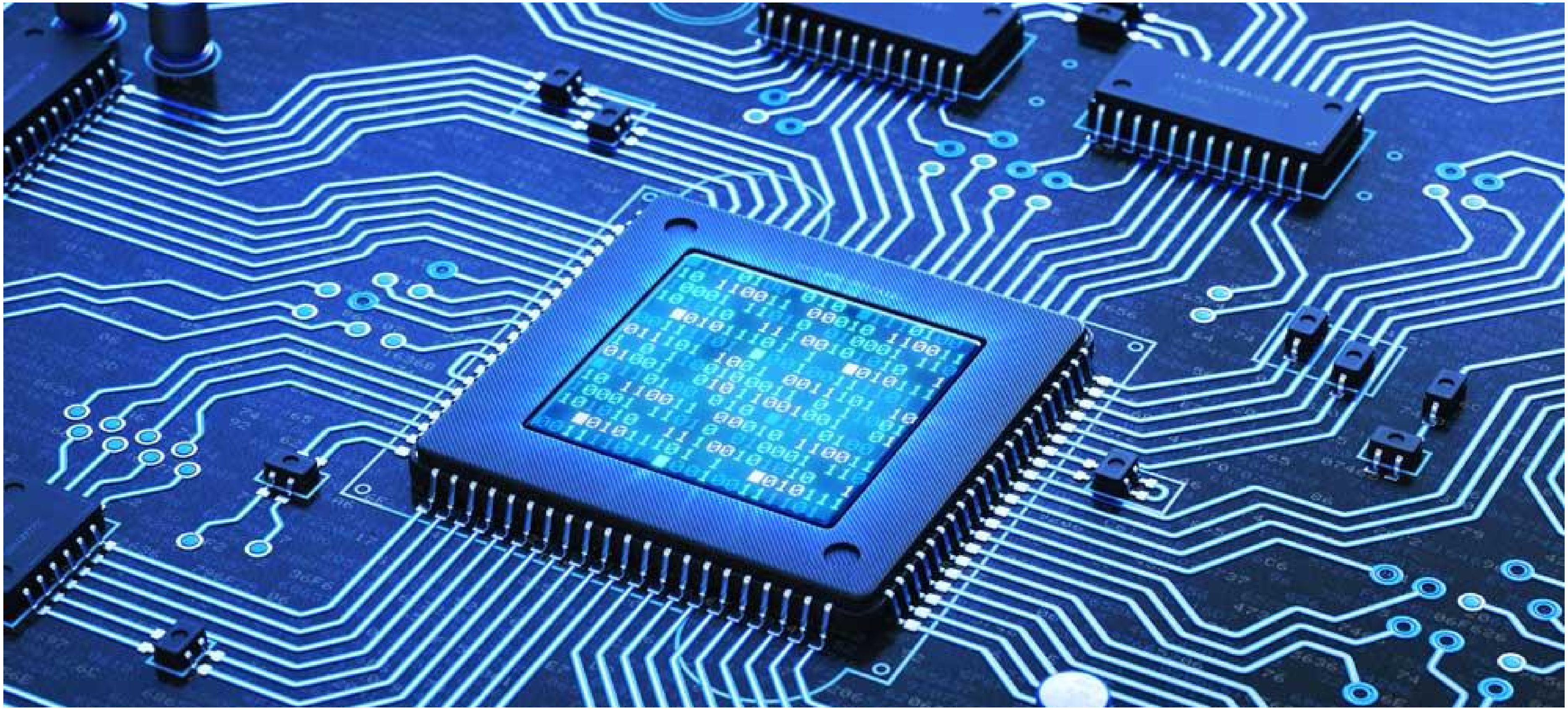
Introduction to Capacitors

Capacitors


nichicon
4700μF 35V
100μF 16V
SPRAGUE
VITAMIN Q
CAPACITOR
22 - 400 D.C.
35V
470μF
189-505-5
193-10 8216
103K
500V
224K
100V
561
10
151
15
22μF 35V

What is a Capacitor?

- **Capacitors** (sometimes known as **condensers**) are **energy-storing devices** that are used widely in various products.
  - Television, Radios, electronic equipment, etc.
  - To construct Filters (frequency based)
- **Tune** a **radio** into a station, **take** a **flash photo** with a digital camera, you're making **use of capacitors.**
- **Capacitors** have the **ability** to both **store** and **deliver** ***finite amounts of energy.***
- They **differ** from **ideal voltage sources** because Capacitors **cannot** sustain a **finite average power** flow over an **infinite time interval.**

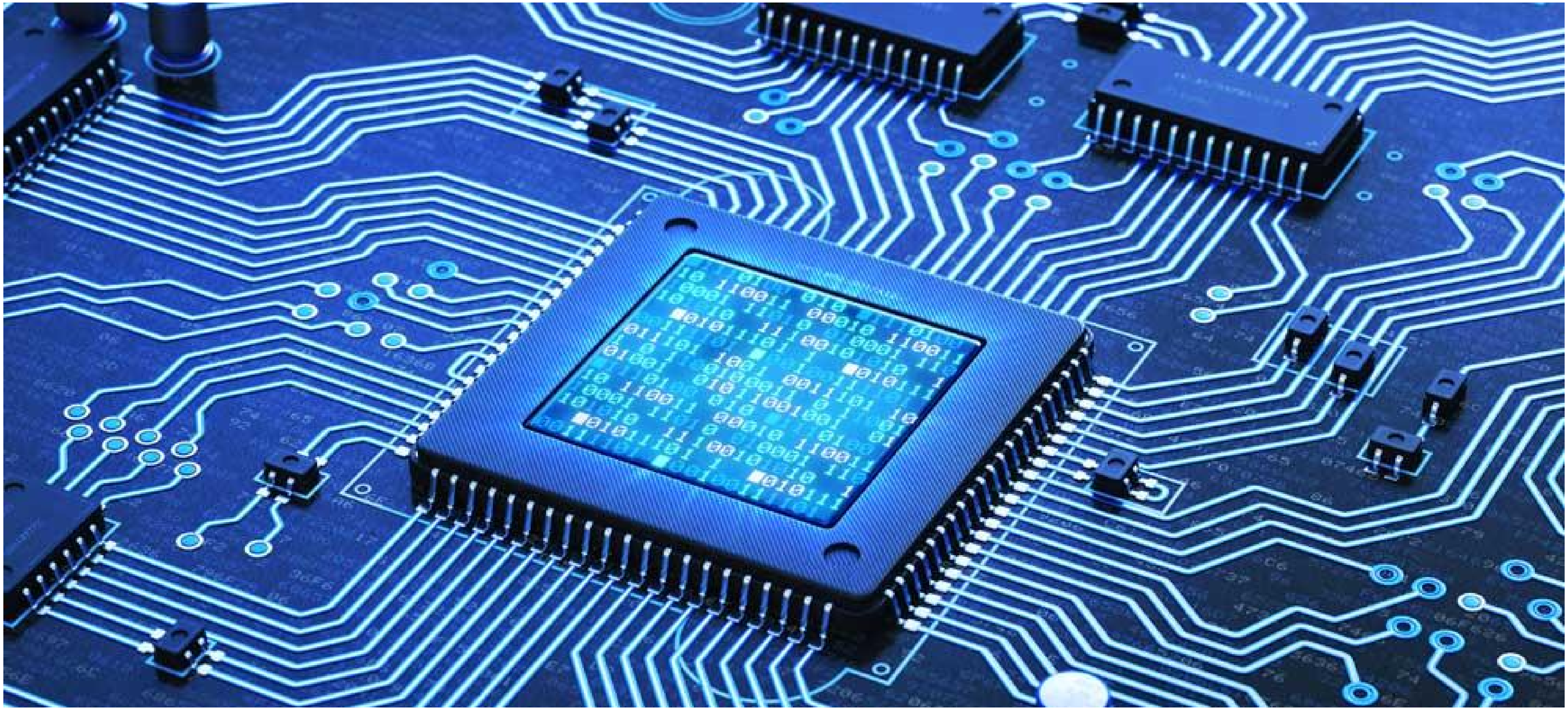


Nature’s Huge Capacitors

Huge Capacitors in Nature!!!

Clouds are the floating Huge Capacitors!!!

Discharging of Nature's Huge Capacitors is Lightning!!

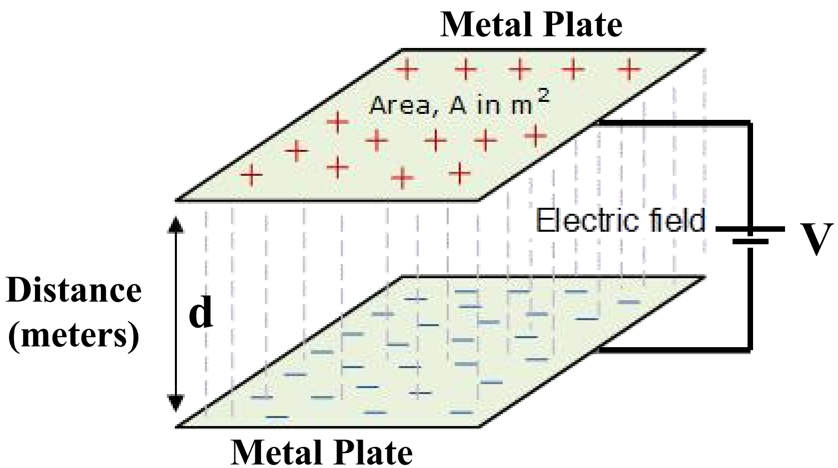


Construction of Capacitors

Definition of a Capacitor

- **Capacitor** is a **component** which has the **ability** or "**capacity**" **to store energy** in the **form** of an **electrical energy** producing a **potential difference (static voltage) across its plates**, much like a **small rechargeable battery.**

Construction of a Capacitor



- Two electrical plates are **separated** with an **insulator**.
  - Which is a **dielectric material** that doesn't allow electricity to flow through it very well.
- A **capacitor** is made!!

- Capacitor is capable of **storing electrical energy**.
- There are basically two operations that can be done on a Capacitor:
  - **Adding electrical energy** to a **capacitor** is called as **charging**;
  - **Releasing** the **energy** from a **capacitor** is known as **discharging**.

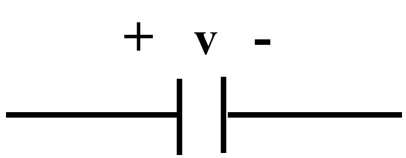
Unit of Capacitor (Farad)

- **Capacitance** is the **electrical property** of a **capacitor**.
- It is a **measure** of a capacitor's **ability** to **store** **electrical energy** onto **its two plates.**
- The **unit of capacitance** is the **Farad** (abbreviated to **F**) named after the **British physicist Michael Faraday.**
- A **capacitor** has the capacitance of **One Farad** when **electrical energy equivalent** to **One Coulomb of charge** stored in it by a voltage of **One volt.**
  - **C = Q/V**

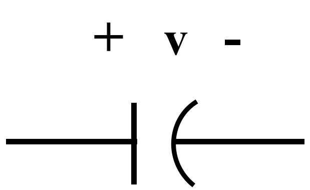
Unit of Capacitor and Symbols

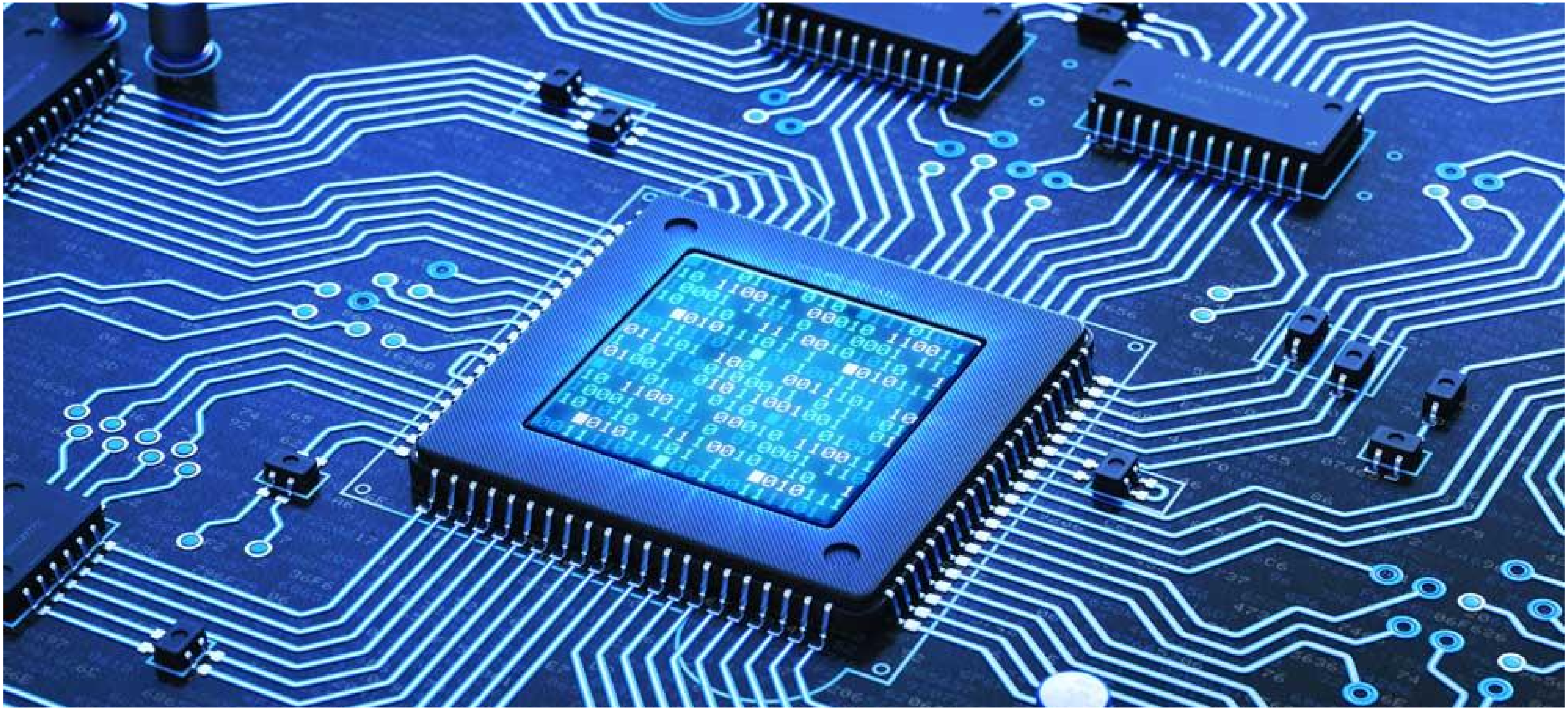
- Capacitance, **C** is **always positive** and has no negative units.
- However, **Farad** is a **very large unit** of **measurement** to **use**.
  - **One Coulomb of charge = 6.25×10^{18} electrons.**
- So, **sub-multiples** of the **Farad** are generally **used,** such as:
  - **1 micro-farads (μF) = 10^{-6} F**
  - **1 nano-farads (nF) = 10^{-9} F**
  - **1 pico-farads (pF) = 10^{-12} F**

Capacitor Symbols



Commonly Used



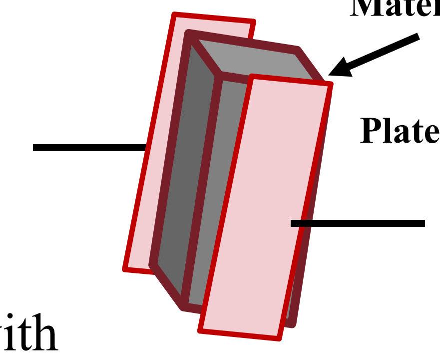


Capacitance Value

Capacitance Value

- $C = \frac{\varepsilon A}{d}$

  ε: Dielectric constant of dielectric material used
  A: Area of metallic plates
  d: Distance between the plates

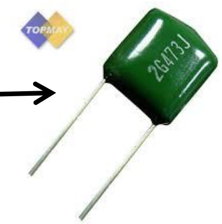


- If **Area** of the plates is **large**, more **charge** (**Q**) imbalance can be **created** within the **capacitor.**
- If **d is smaller**, the **attractive force** between the **plates** (with opposite charges) **help** in **holding** more **charges of the same sign** on each plates, thus **improving** the **capacitance.**

- **ε** represents the **absolute permittivity** of the **dielectric material** used, in between the **plates.**

Capacitor Types (Different Dielectrics)

- **Electrolytic Capacitors** (Aluminium/Tantalum)
  - Large capacitance (~10μF with smaller size)
  - Polarized (has +v & -ve terminals)
  - Permanently damaged, if connected incorrectly
- **Mylar capacitors**

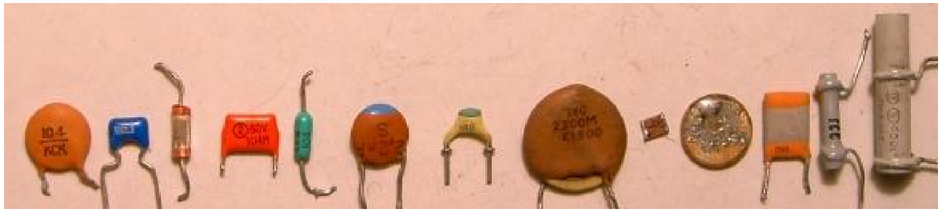


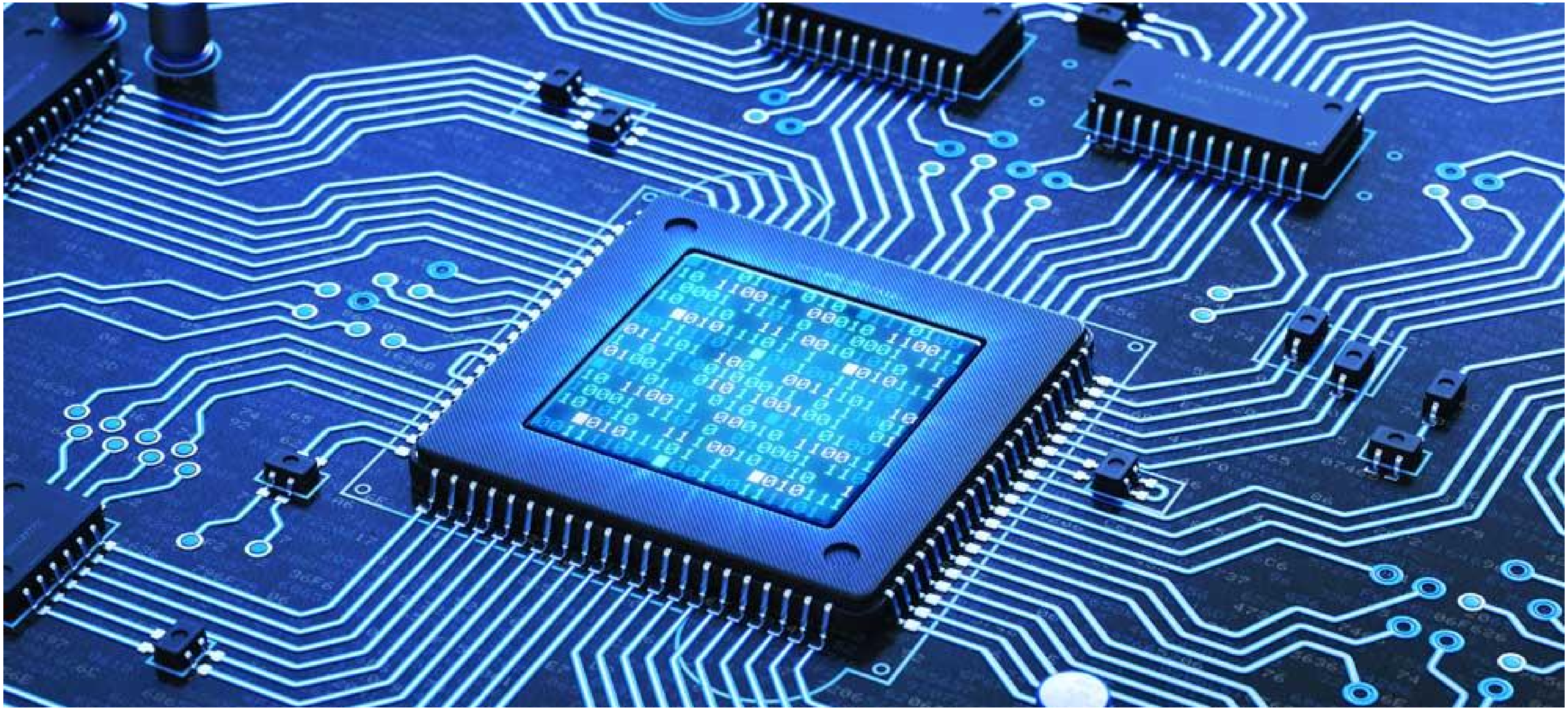
- **Gang capacitors**

Air as **dielectric**

- **Paper Capacitors**

- **Ceramic Capacitors:**
  - **A few pF to 1or 2 μF**

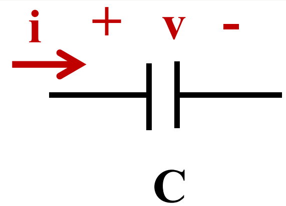




V-I Relationship

V-I Relationship of a Capacitor

- Capacitor Symbol:

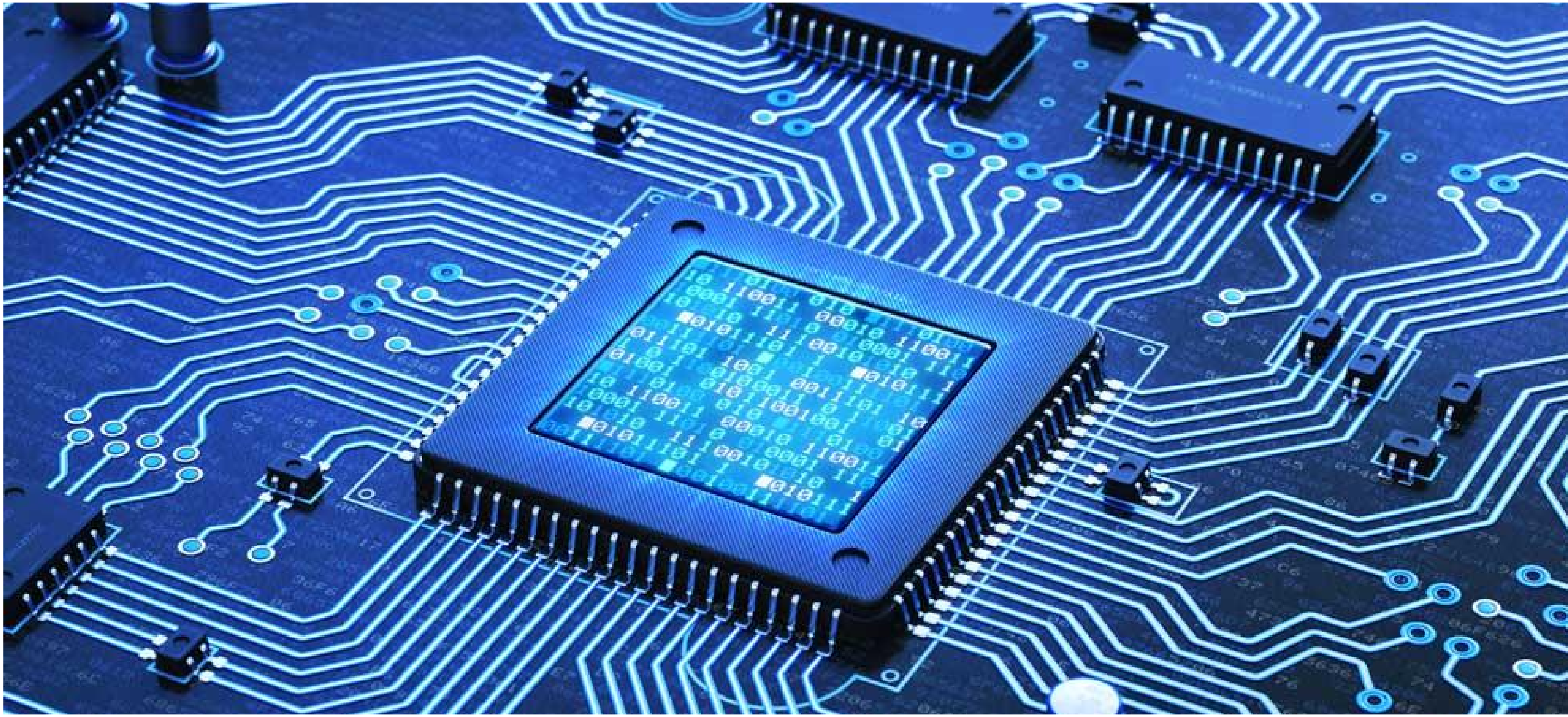


Note the signs of potential across C

- **C satisfies** the **conventions** for a **passive element.**
- **Voltage-Current Relationship**:

$$\boxed{i = C\frac{dv}{dt}}$$

- This equation tells us that when the **voltage doesn't change across the capacitor**, **current doesn't flow**;
- To **have** a **current flow** through the capacitor, the **voltage must change**.
- For a constant **DC voltage source**, **capacitors** act as **open-circuit** because there is no change in the voltage, thus **no current can flow** though it.

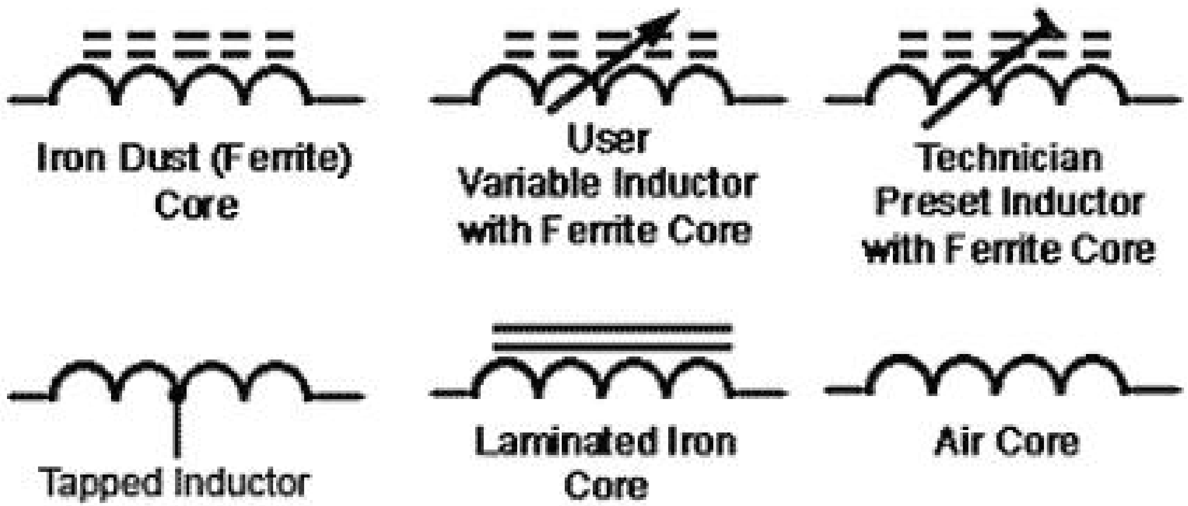


Inductors

What is Inductance?

- **Inductance** is the **property** whereby an inductor exhibits **opposition** to the **change of current** flowing through it, measured in **henrys (H)**.

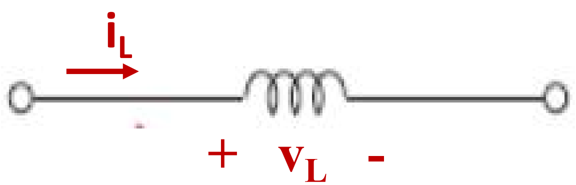
Inductor Symbols



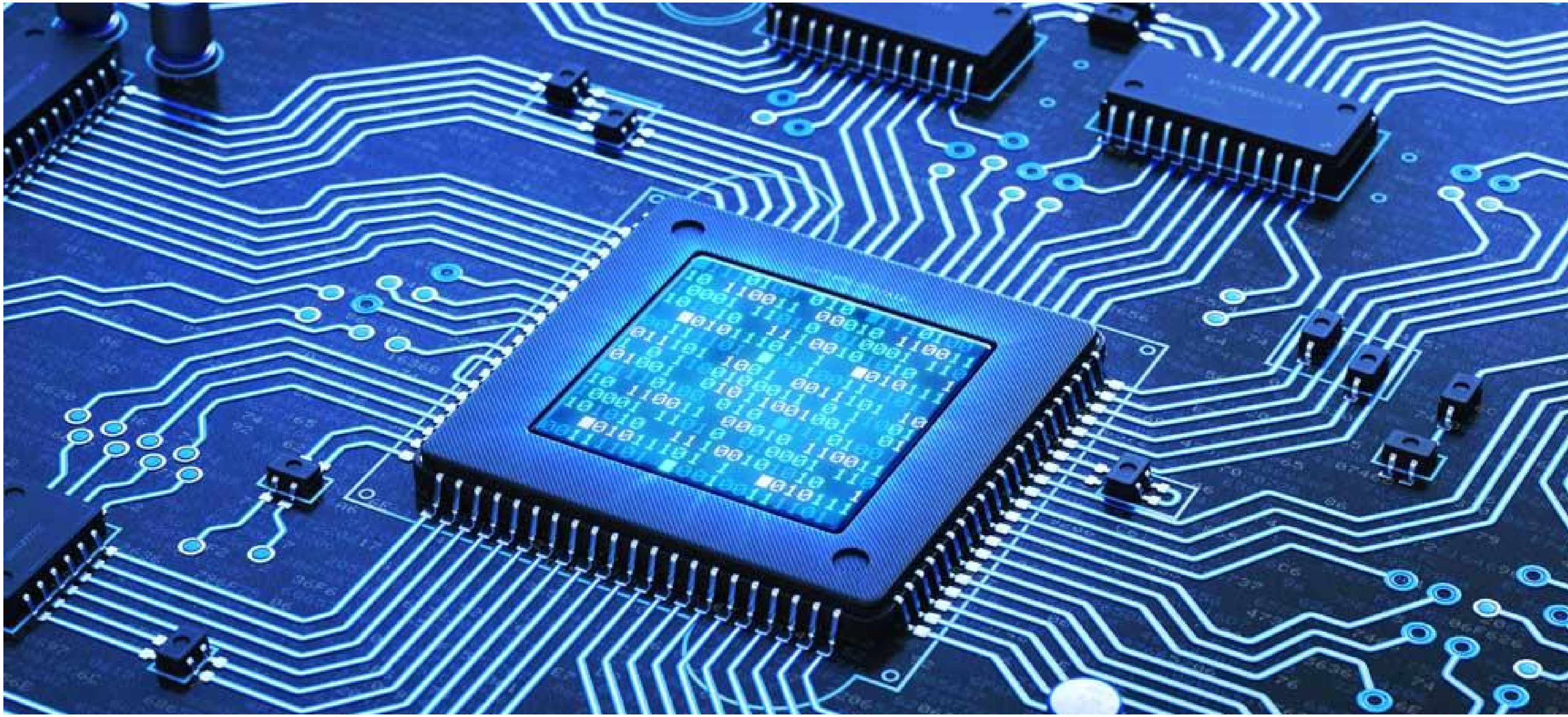
Inductors: Invention

- **Michael Faraday** and **Joseph Henry** discovered almost simultaneously that a **changing magnetic field** could **induce** a **voltage** in a **neighbouring circuit.**
- The **voltage** induced is **proportional** to the **time rate of change** of the **current producing** the **magnetic field.**
- The **constant** of **proportionality** is what we call the **inductance**, symbolized by **L**, and therefore

$$\boxed{v = L\frac{di}{dt}}$$



- The **unit** in which **inductance** is measured is the **henry (H)**
- Equation shows that **henry** is just a **shorter expression** for a **volt-second per ampere**.

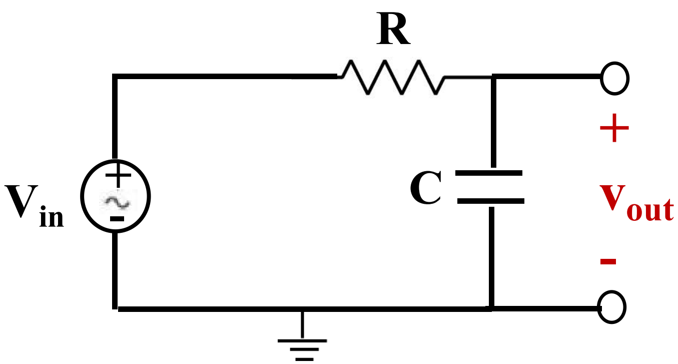


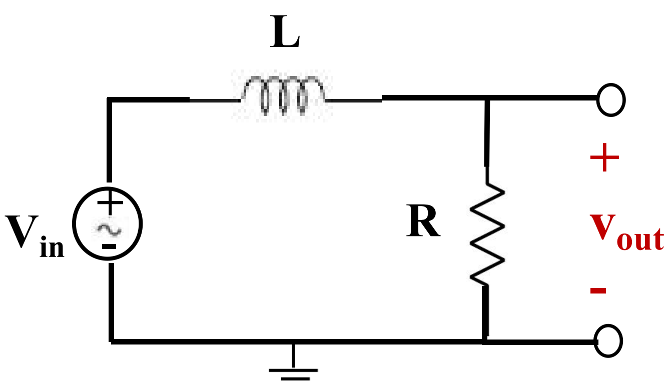
Capacitors and Inductors in AC Circuits

Passive Filters

- Filters are circuits which allow certain input frequency signals to pass through or to get blocked before reaching the output of the circuit.
- Filters which are built only with passive components (Resistors, Capacitors, Inductors) are called passive filters.
- Frequency of the signals is the rate of change of signal amplitude with time.
- What we normally see in real-life are sinusoidal voltages which will be covered shortly.

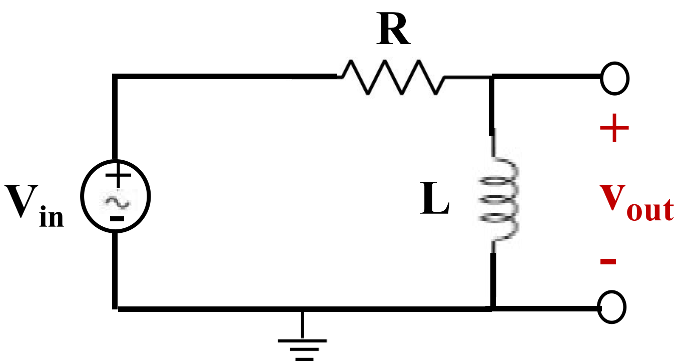
Low Pass Filter (LPF): AC

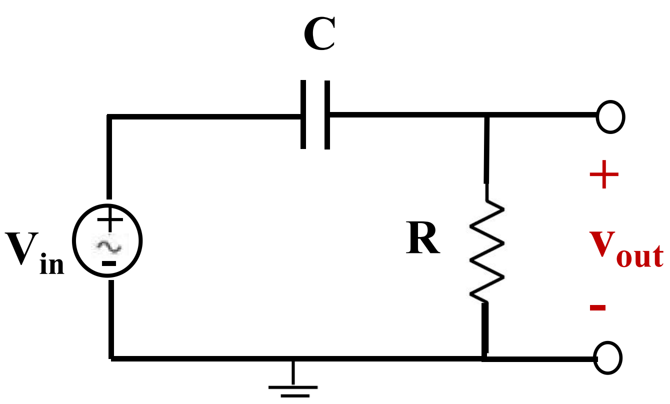




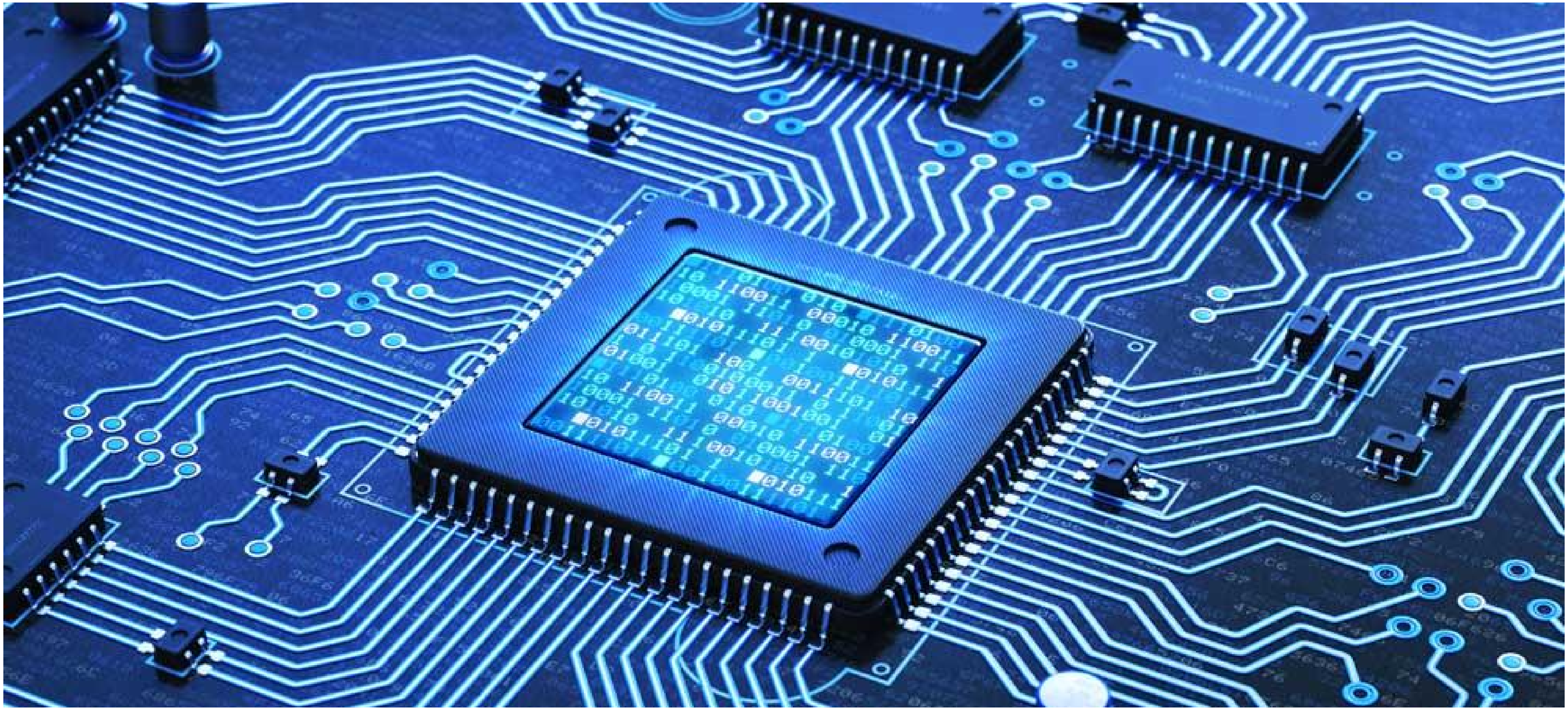
- At lower frequencies the capacitive reactance of the circuit will be higher, having higher voltage drop across the capacitor, where the output is taken.
  - $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$
- At higher frequencies reactance of the capacitor becomes very low that no output can be seen at $\mathbf{v_{out}}$.
- In the lower circuit with inductor, lower frequency signals are allowed because of inductive reactance being low.
  - $X_L = \omega L = 2\pi f L$
- At higher frequencies, due to higher X_L no output can be seen at $\mathbf{v_{out}}$.

High Pass Filter (HPF): AC





- At higher frequencies the inductive reactance of the circuit will be higher, having higher voltage drop across the inductor, where the output is taken.
  - $X_L = \omega L = 2\pi f L$
- At lower frequencies reactance of the inductor becomes very low that no output can be seen at $\mathbf{v_{out}}$.
- In the lower circuit with capacitor, higher frequency signals are allowed because of capacitive reactance being low.
  - $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$
- At lower frequencies, due to higher X_C no output can be seen at $\mathbf{v_{out}}$.



Use of Capacitors and Inductors

Use of Capacitors and Inductors

- Inductors, combined with capacitors and resistors, are used extensively to create **filters** for analogue circuits and in-signal processing.
- **Induction motors** change the electrical energy into mechanical energy.
- Inductors that share the magnetic path are combined together and form a **transformer**.
- Inductors can be used for energy storage.
- Unlike capacitors, they do not store energy for a long time.
- In the case of inductors, energy is stored in the form of the magnetic field; however, this fails when there is no power supply.
- Capacitors act as an insulator for DC circuits.

Ref: Use of Inductors and Capacitors

Session 1.4: Summary

- Introduction to Capacitors
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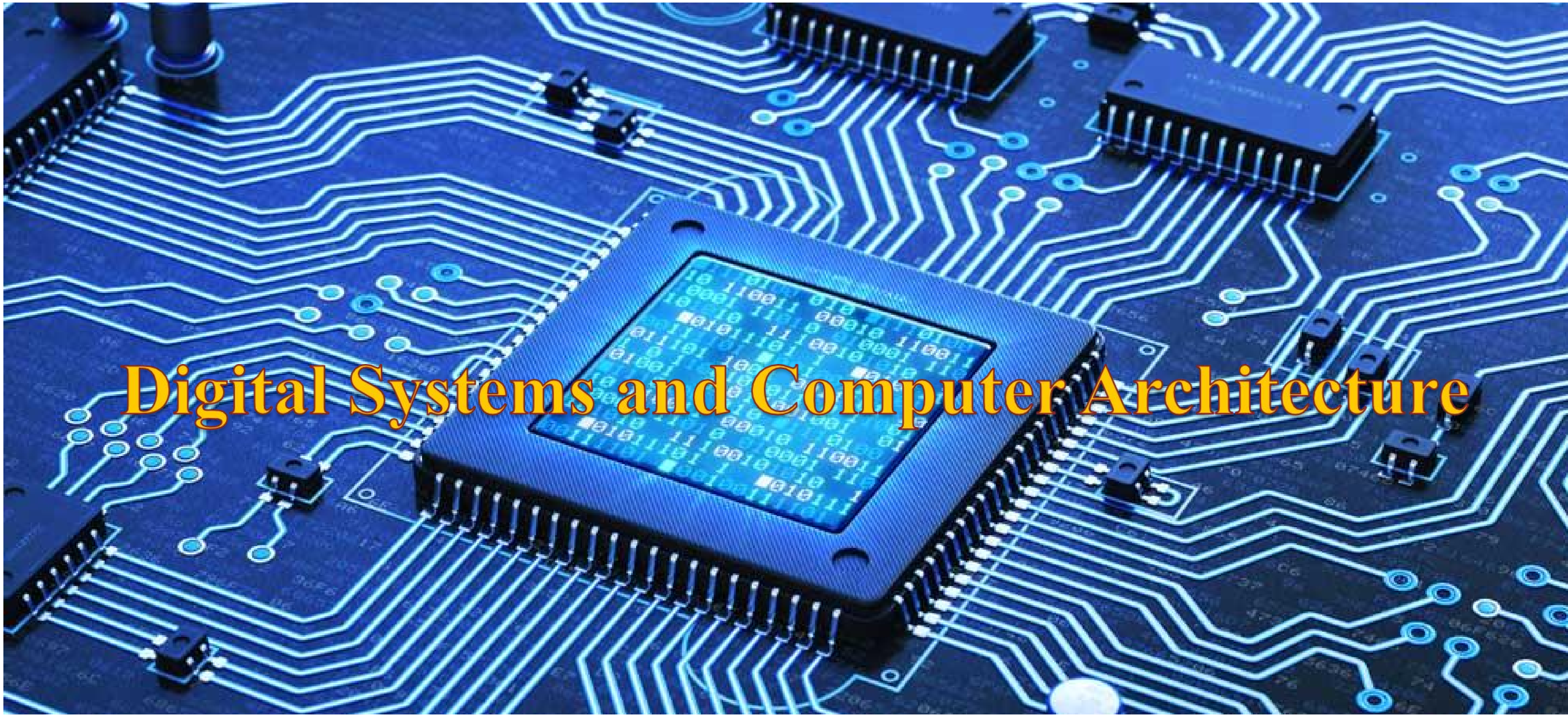
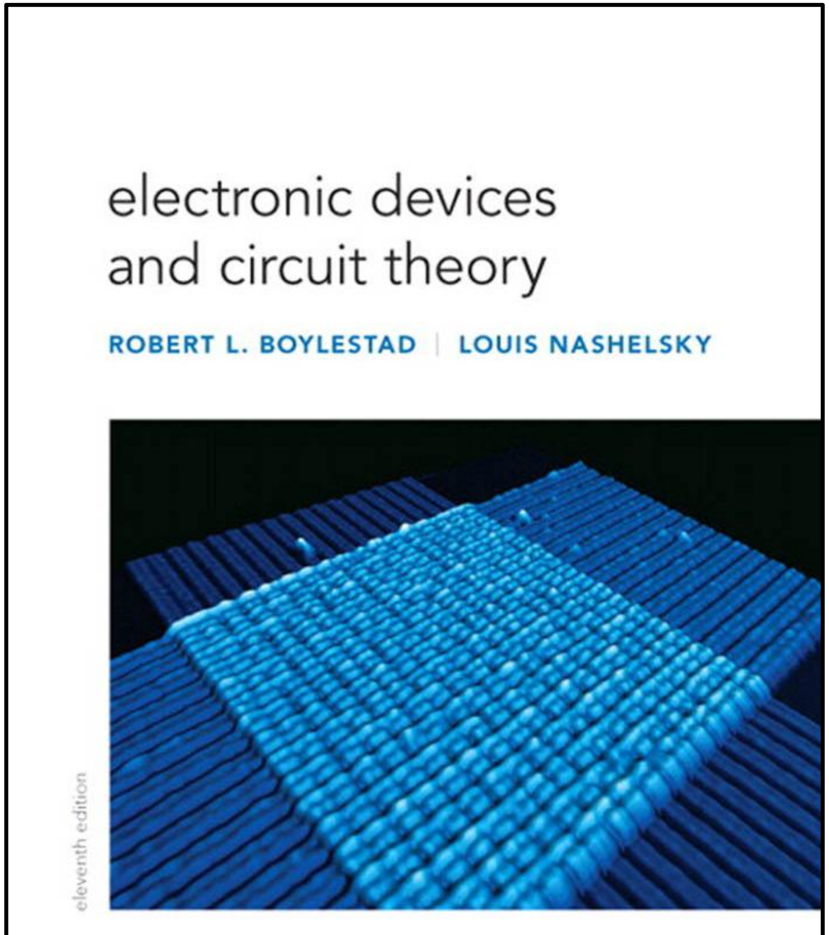
  - V-I Relationship
- Construction of Inductors
  - V-I Relationship
- Passive Filters
- Use of Capacitors and Inductors



References

Reference 1: DS & CA

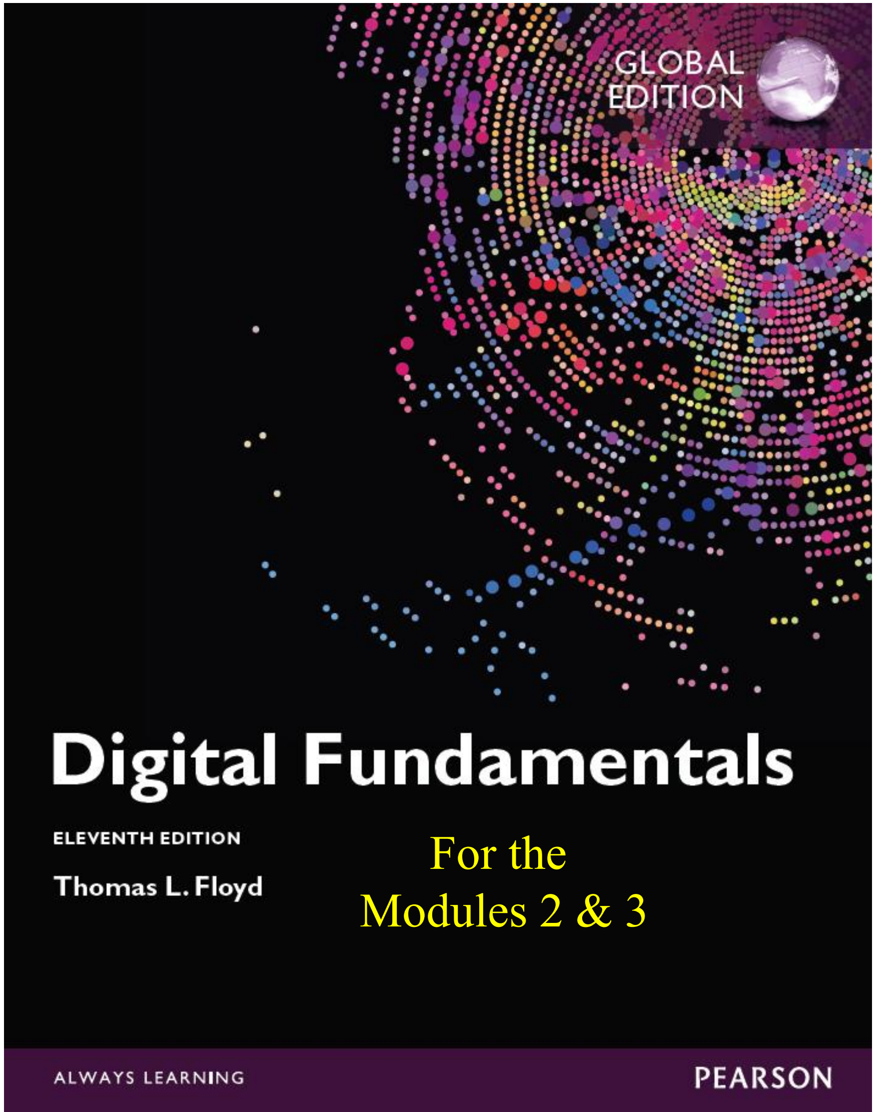
Ref 1



For the
Module 1

References 2 & 3: DS & CA

Ref 2



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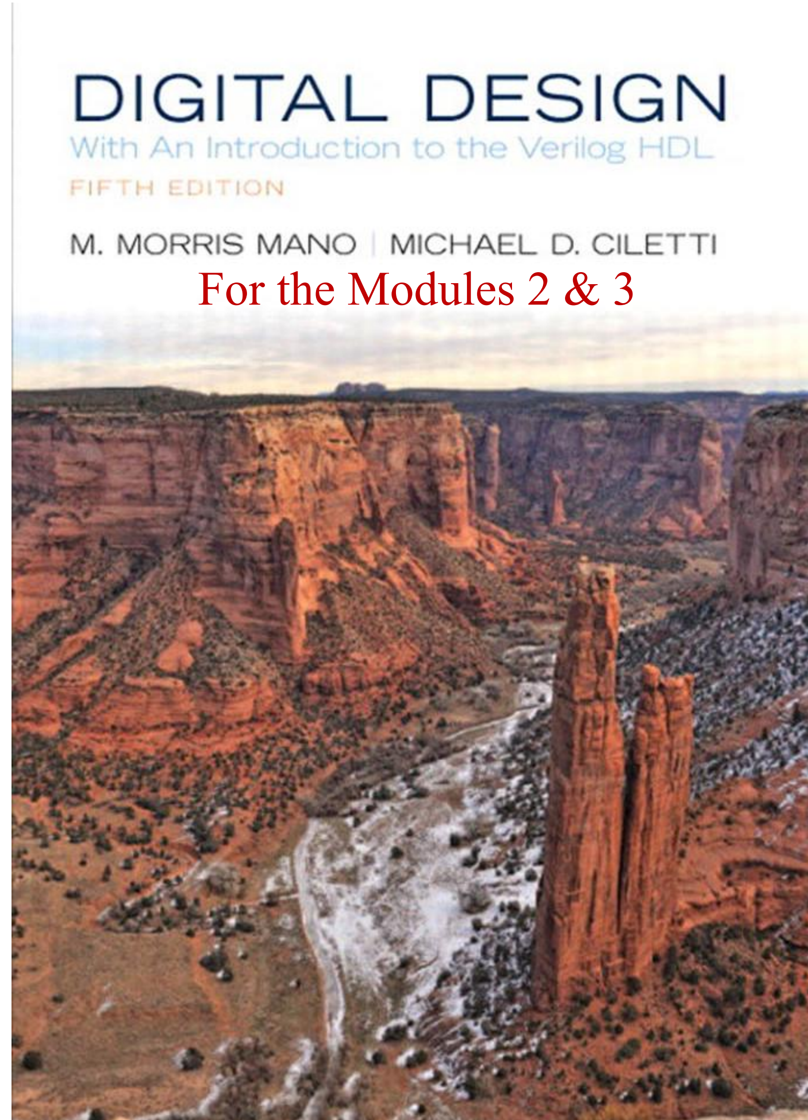
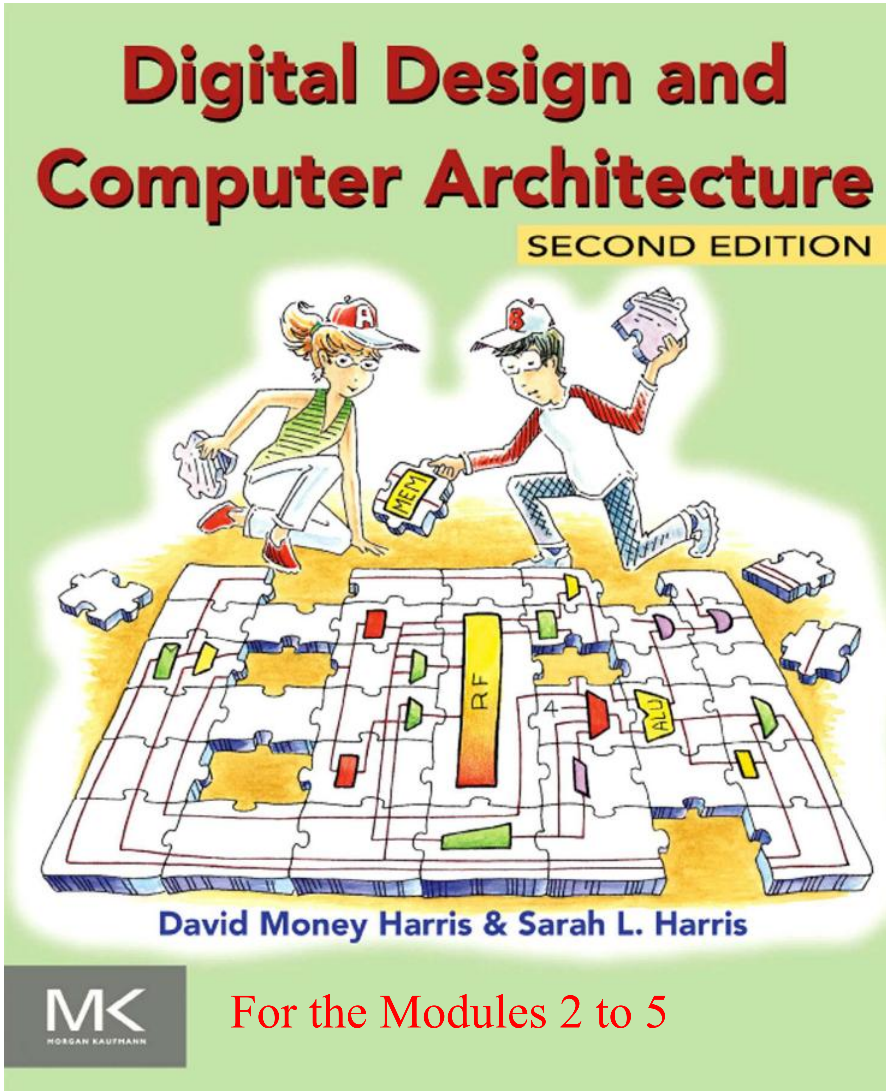


References 4 & 5: DS and CA

Ref 4



For the Modules 2 to 5

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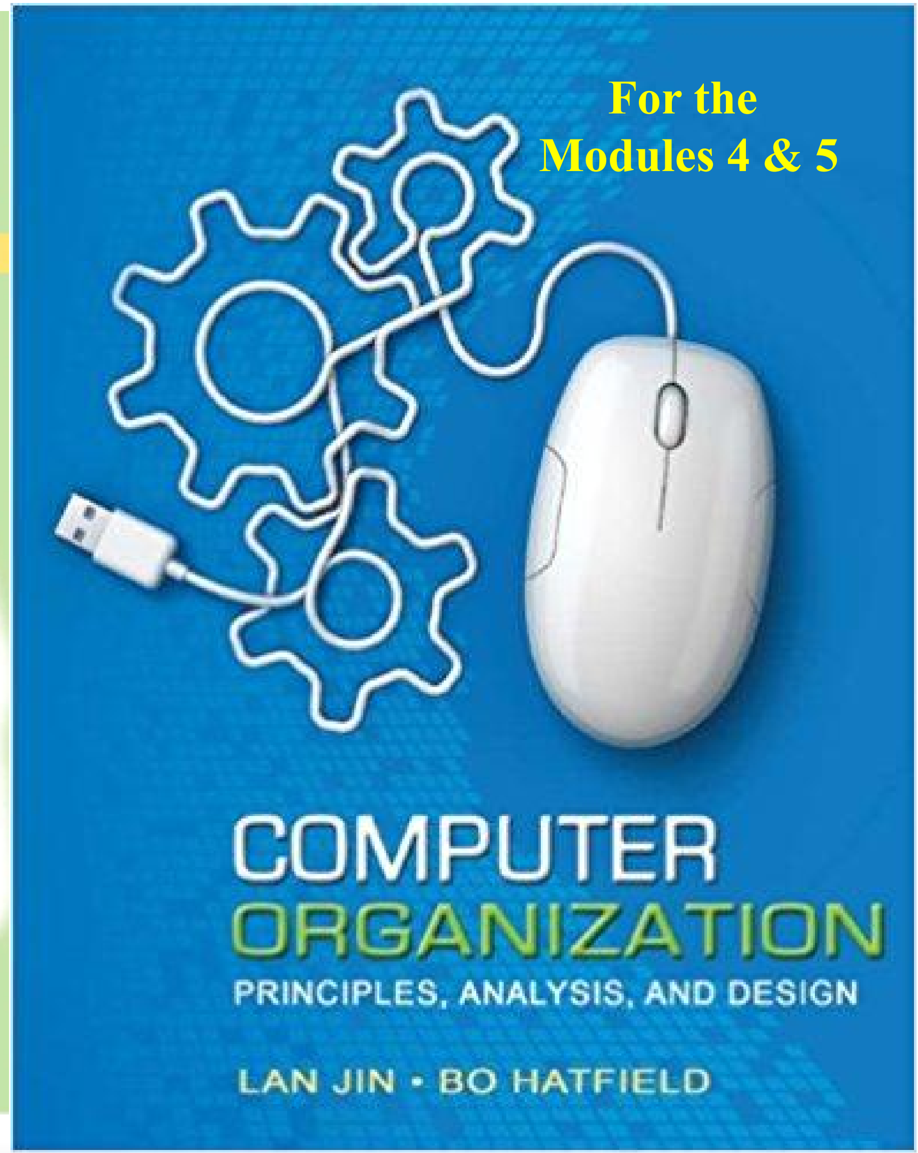

For the Modules 4 & 5