CONCEPT OF PASSIVE COMPONENTS

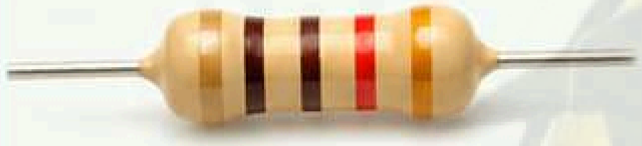
RESISTORS • CAPACITORS • INDUCTORS

Passive components do not add energy to a circuit. They store, dissipate, or release energy to help control voltage, current and signals in electronic circuits.

RESISTORS

WHAT IS IT?

A resistor opposes the flow of electric current and dissipates energy as heat.



CIRCUIT SYMBOL

KEY FORMULA

Ohm's Law: $\boxed{V = IR}$

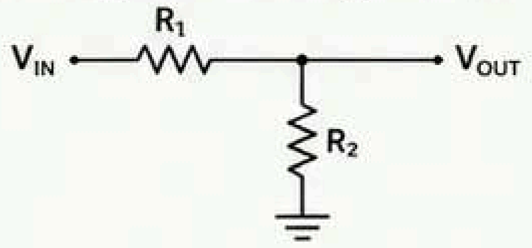
Where, V = Voltage (V)
I = Current (A)
R = Resistance (Ω)

UNIT

Ohm (Ω)

USES / APPLICATIONS

- Current limiting
- Voltage division
- Biasing active components
- Pull-up / Pull-down in digital circuits

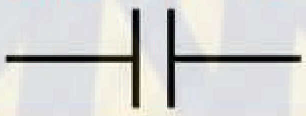


CAPACITORS

WHAT IS IT?

A capacitor stores energy in the form of an electric field between two plates.

CIRCUIT SYMBOL



KEY FORMULA

Capacitance: $\boxed{C = \frac{Q}{V}}$

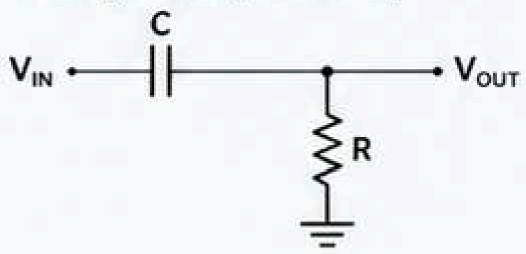
Where, C = Capacitance (F)
Q = Charge (C)
V = Voltage (V)

UNIT

Farad (F)
(μF, nF, pF commonly used)

USES / APPLICATIONS

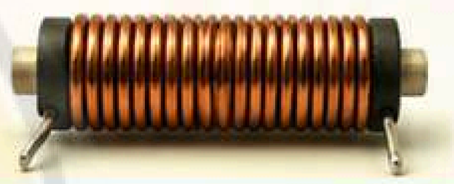
- Energy storage
- Filtering & smoothing
- Coupling & decoupling
- Timing circuits (RC circuits)



INDUCTORS

WHAT IS IT?

An inductor stores energy in the form of a magnetic field when current flows through it.



CIRCUIT SYMBOL

KEY FORMULA

Inductance: $\boxed{V = L\frac{dI}{dt}}$

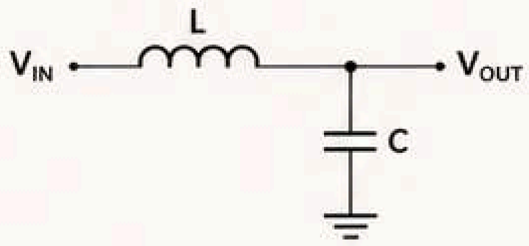
Where, L = Inductance (H)
I = Current (A)
t = Time (s)

UNIT

Henry (H)
(mH, μH commonly used)

USES / APPLICATIONS

- Energy storage in magnetic field
- Filtering (chokes)
- DC-DC converters
- Tuning in LC circuits



WHY ARE THEY IMPORTANT?

✓ They form the foundation of all electronic circuits.

They help in controlling voltage, current and frequency.

They store, release or dissipate energy.

They are used in almost every electronic device you use daily.

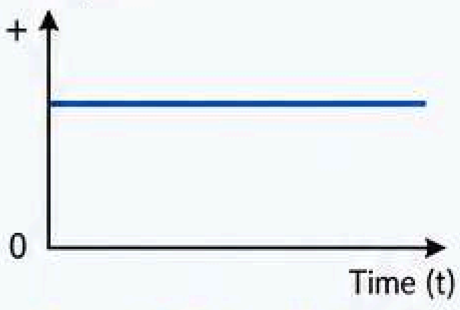
DIFFERENT TYPES OF
SIGNAL WAVEFORMS

- A signal waveform represents how a physical quantity (voltage or current) varies with respect to time.

1. DC vs AC SIGNALS

DC (Direct Current)

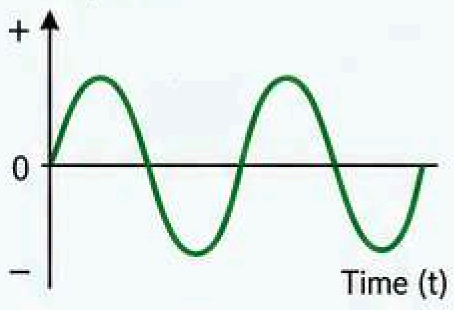
- Constant in magnitude and direction.
- Does not change with time.



Example: Battery Voltage

AC (Alternating Current)

- Magnitude and direction change with time.
- Has positive and negative values.



Example: AC Mains Supply

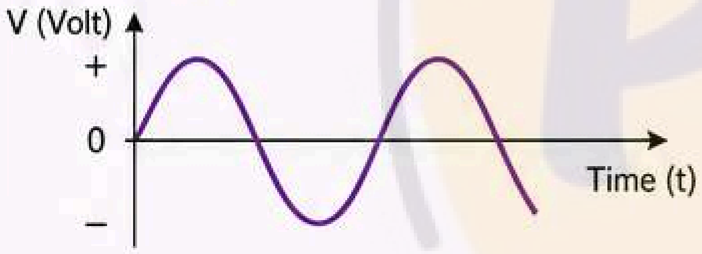
Key Difference: DC flows in one direction only, whereas AC reverses direction periodically.

2. VOLTAGE vs CURRENT SIGNALS

VOLTAGE SIGNAL

Represents electrical potential difference between two points.

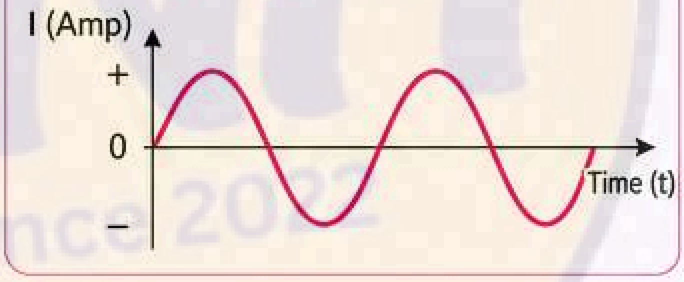
Unit: Volt (V)



CURRENT SIGNAL

Represents the flow of electric charge through a conductor.

Unit: Ampere (A)



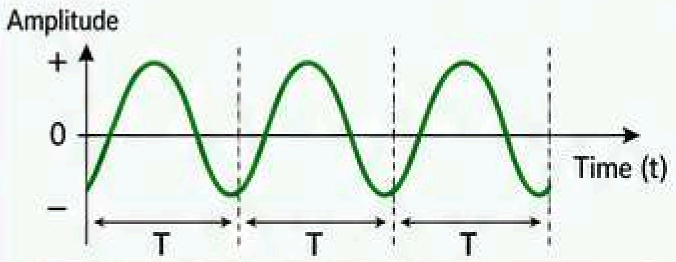
NOTE

Voltage causes current to flow. Both can be DC or AC.

3. PERIODIC vs NON-PERIODIC SIGNALS

PERIODIC SIGNAL

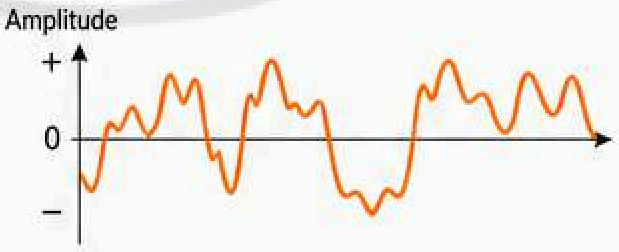
Repeats its pattern at regular time intervals.



- Has a fixed time period (T).
- Frequency (f) = $\frac{1}{T}$ Hz

NON-PERIODIC SIGNAL

Does not repeat at regular intervals.



- No fixed pattern or time period.
- Frequency is not defined.

Important

Most practical signals are either periodic (like AC, clock signals) or non-periodic (voice, music, random noise).

QUICK SUMMARY

DC SIGNAL
Constant value, one direction.

AC SIGNAL
Alternates in magnitude and direction.

VOLTAGE
Potential difference (Volt).

CURRENT
Flow of charge (Ampere).

PERIODIC
Repeats after regular interval.

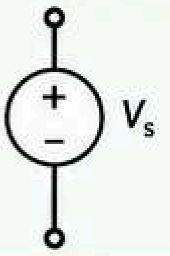
NON-PERIODIC
Does not have regular repetition.

VOLTAGE / CURRENT SOURCES

Sources are the heart of any circuit. They supply electrical energy to the circuit. They can be classified as **Ideal** / **Non-Ideal** and **Independent** / **Dependent**.

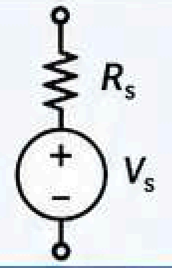
1. IDEAL vs NON-IDEAL SOURCES

IDEAL VOLTAGE SOURCE



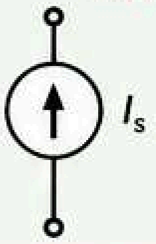
- Maintains constant voltage regardless of load current.
- Internal resistance = 0 Ω
- Short circuit current = ∞

NON-IDEAL VOLTAGE SOURCE



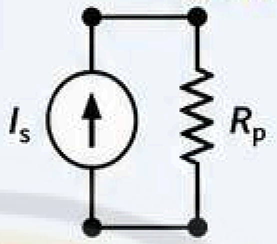
- Has internal resistance (R_s).
- Terminal voltage decreases with load current.
- $V_{terminal} = V_s - I_L R_s$

IDEAL CURRENT SOURCE



- Maintains constant current regardless of load voltage.
- Internal resistance = ∞
- Open circuit voltage = ∞

NON-IDEAL CURRENT SOURCE



- Has internal resistance (R_p) in parallel.
- Output current varies with load voltage.
- $I_{terminal} = I_s - \frac{V}{R_p}$

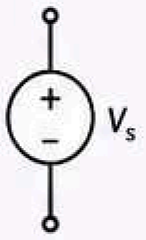
Ideal sources are theoretical. In practice, all sources are non-ideal.

2. INDEPENDENT vs DEPENDENT SOURCES

INDEPENDENT SOURCES

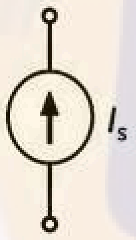
Value is independent of any other circuit variable.

Independent Voltage Source



Value = V_s
(Constant)

Independent Current Source

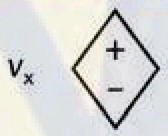


Value = I_s
(Constant)

DEPENDENT (CONTROLLED) SOURCES

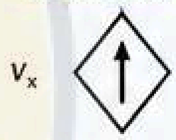
Value depends on some other voltage or current in the circuit.

Voltage Controlled Voltage Source (VCVS)



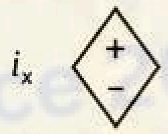
Output = μv_x
(μ: Gain)

Voltage Controlled Current Source (VCCS)



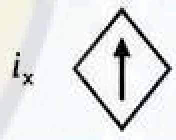
Output = $g v_x$
(g: Transconductance)

Current Controlled Voltage Source (CCVS)



Output = $r i_x$
(r: Transresistance)

Current Controlled Current Source (CCCS)



Output = βi_x
(β: Current Gain)

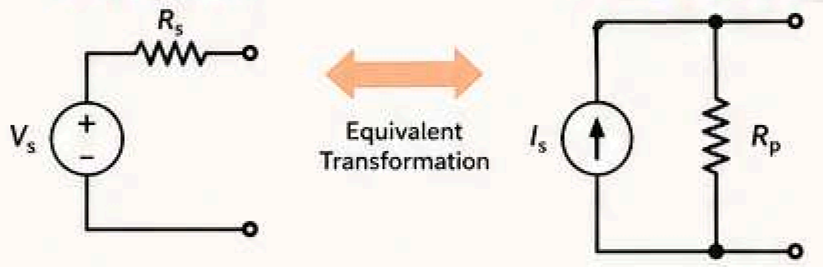
Dependent sources are shown using a diamond symbol.

3. SOURCE TRANSFORMATION

VOLTAGE SOURCE ↔ CURRENT SOURCE

Voltage Source with Series Resistance

Current Source with Parallel Resistance



CONVERSION FORMULAS

Voltage Source (V_s) with Series Resistance (R_s)
↔ Current Source (I_s) with Parallel Resistance (R_p)

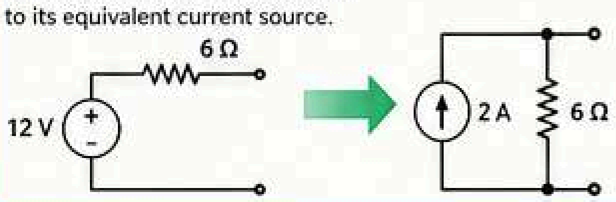
$$I_s = \frac{V_s}{R_s} \qquad R_p = R_s$$

Current Source (I_s) with Parallel Resistance (R_p)
↔ Voltage Source (V_s) with Series Resistance (R_s)

$$V_s = I_s R_p \qquad R_s = R_p$$

Example

Convert the voltage source circuit to its equivalent current source.

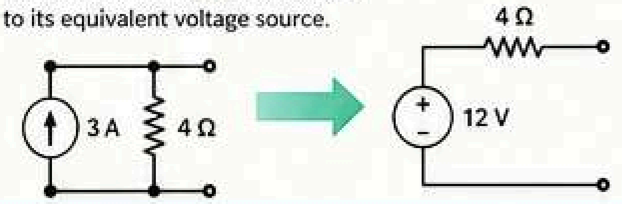


$I_s = \frac{12}{6} = 2$ A

$R_p = 6$ Ω

Example

Convert the current source circuit to its equivalent voltage source.



$V_s = 3 \times 4 = 12$ V

$R_s = 4$ Ω

QUICK SUMMARY

- Ideal: No internal resistance (theoretical).
- Non-Ideal: Has internal resistance (practical).
- Independent: Value is constant.
- Dependent: Value depends on another variable.
- Source transformation helps in simplifying circuits.

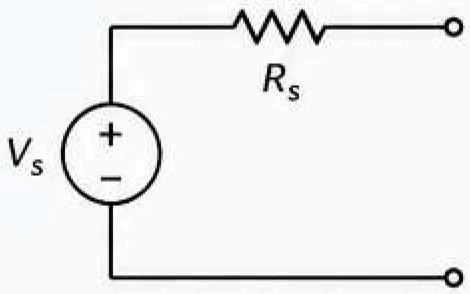
APPLICATIONS

- Modeling batteries, power supplies, and generators.
- Used in circuit analysis and network theorems.
- Transformations simplify calculations and analysis.

SOURCE TRANSFORMATION

Convert a voltage source with series resistance ↔ current source with parallel resistance

VOLTAGE SOURCE FORM



Voltage Source (V_s) in series with resistance (R_s)

TRANSFORMATION FORMULAS

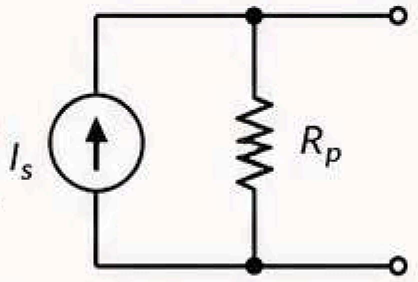
From Voltage Source → Current Source

$$I_s = \frac{V_s}{R_s}, \quad R_p = R_s$$

From Current Source → Voltage Source

$$V_s = I_s \times R_p, \quad R_s = R_p$$

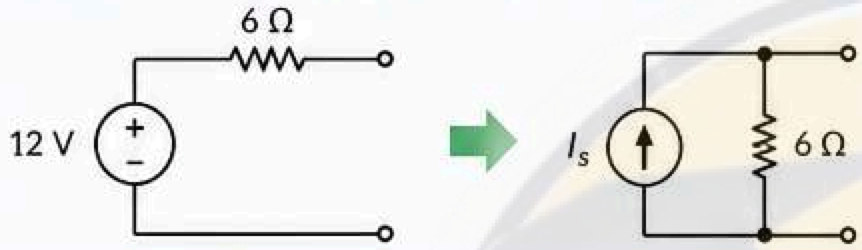
CURRENT SOURCE FORM



Current Source (I_s) in parallel with resistance (R_p)

SOLVED EXAMPLES

Example 1: Convert the voltage source circuit into an equivalent current source circuit.

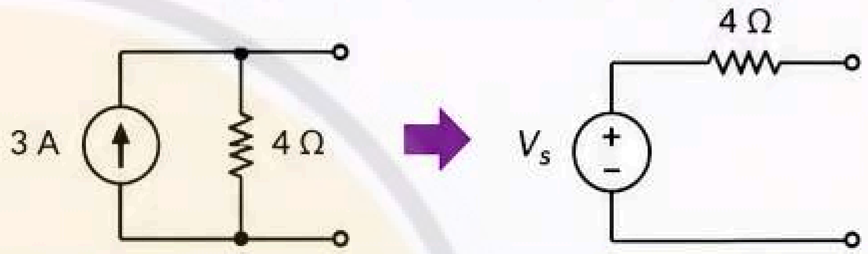


Solution: $I_s = \frac{V_s}{R_s} = \frac{12}{6} = 2\text{ A}$

$R_p = R_s = 6\,\Omega$

Equivalent: 2 A current source in parallel with 6 Ω

Example 2: Convert the current source circuit into an equivalent voltage source circuit.

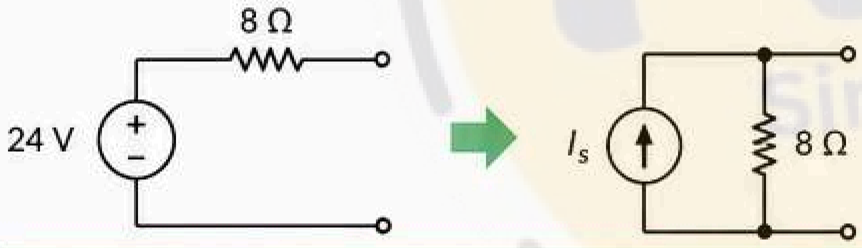


Solution: $V_s = I_s \times R_p = 3 \times 4 = 12\text{ V}$

$R_s = R_p = 4\,\Omega$

Equivalent: 12 V voltage source in series with 4 Ω

Example 3: A 24 V voltage source is in series with an 8 Ω resistor. Find the equivalent current source and R_p.

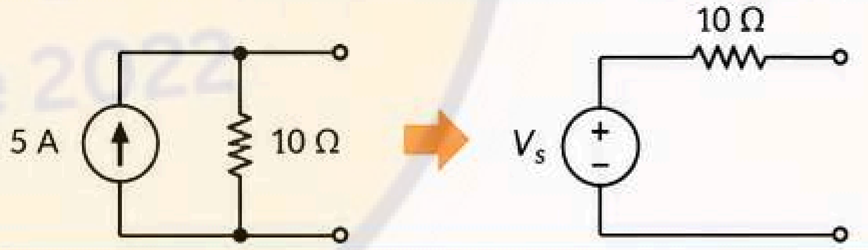


Solution: $I_s = \frac{V_s}{R_s} = \frac{24}{8} = 3\text{ A}$

$R_p = R_s = 8\,\Omega$

Equivalent: 3 A current source in parallel with 8 Ω

Example 4: A 5 A current source is in parallel with a 10 Ω resistor. Find the equivalent voltage source and R_s.

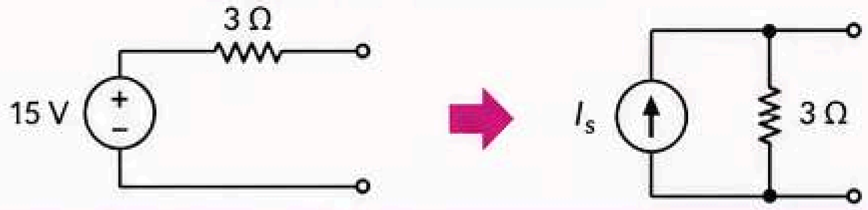


Solution: $V_s = I_s \times R_p = 5 \times 10 = 50\text{ V}$

$R_s = R_p = 10\,\Omega$

Equivalent: 50 V voltage source in series with 10 Ω

Example 5: Convert a 15 V source in series with 3 Ω to an equivalent current source.



Solution: $I_s = \frac{V_s}{R_s} = \frac{15}{3} = 5\text{ A}$

$R_p = R_s = 3\,\Omega$

Equivalent: 5 A current source in parallel with 3 Ω

Example 6: Convert a 2 A current source in parallel with 7 Ω to an equivalent voltage source.

Solution: $V_s = I_s \times R_p = 2 \times 7 = 14\text{ V}$

$R_s = R_p = 7\,\Omega$

Equivalent: 14 V voltage source in series with 7 Ω

- Series (V, R_s) ↔ Parallel (I, R_p)
- $R_s = R_p$ (resistance remains the same)
- $I_s = V_s / R_s$
- $V_s = I_s \times R_p$