Introduction

Electrical & Electronic Circuits and Elements

Embedded Systems & Embedded Programming

Electrical and Electronic Circuits/ Devices (Differences)

Electrical Circuits & Devices	**Electronic Circuits & Devices**
Convert the electrical current into another form of energy like heat, light, etc.	Control the electrical current to perform a task
Use copper and aluminum wires for the flow of current	Use semiconductor materials like silicone
Mainly use alternating current (AC)	Use direct current (DC)
Work on high voltages	Work on low voltages
High power consumption	Low power consumption
High conductivity	Low conductivity
Do not process information	Process and store information

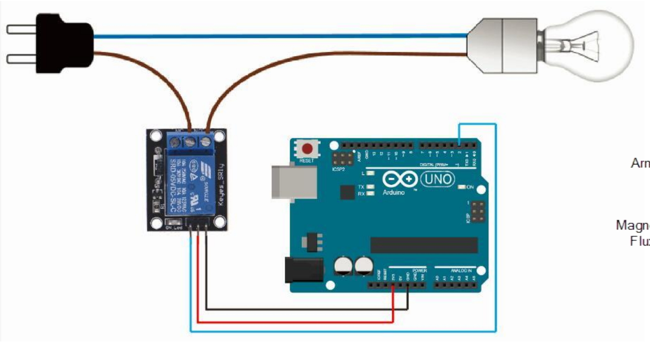
Electrical and Electronic Circuits/ Devices (Differences)

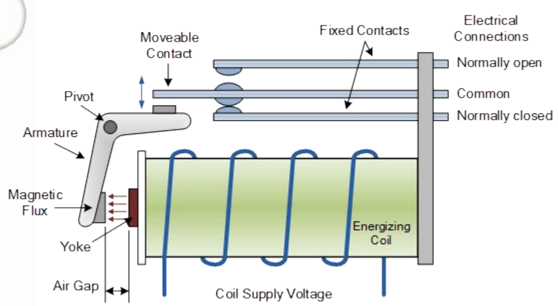
Electrical Circuits & Devices	**Electronic Circuits & Devices**
Operate on analog signals	Operate on digital signals
Deal with kA, kV and MW	Deal with mA, mV and mW
Usually heavy and larger in size	Very small and may contain thousands of tiny components
Use **passive elements**[1] like resistors, capacitors and inductors	Use **active elements**[2] like transistors, battery, diodes and amplifiers
Usually operate in low frequencies	Usually operate in high frequencies
More dangerous if short circuit occurs	Less dangerous

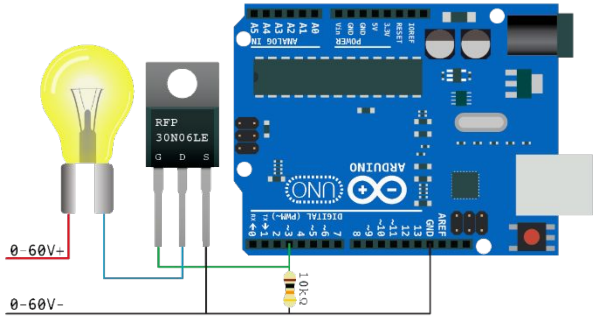
1. Elements incapable of controlling current by means of another electrical signal
2. Elements with ability to electrically control electric charge flow or supplying energy to the circuit

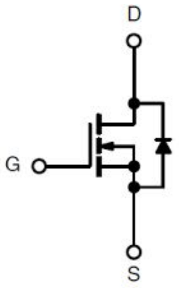
Electrical and Electronic Circuits/ Devices (Similarities)

- Both use the electrical energy for doing work
- Both are interrelated with each other
- The link between them is typically provided by relays or transistors
- Briefly, all electronic devices are also electrical devices
- Both are manufactured in commercial, industrial and military categories







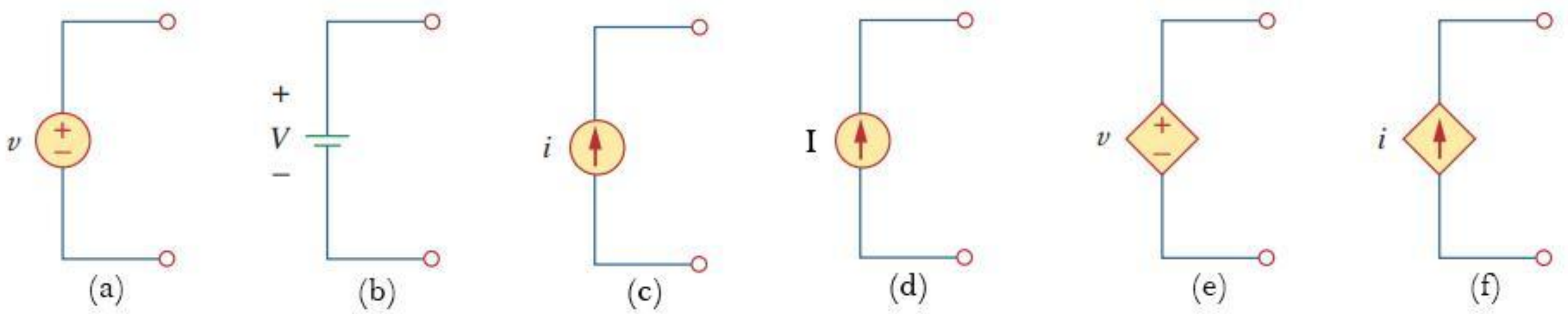


N-Channel MOSFET

[What is a Relay?]

Fundamentals of Electric Circuits (Definitions)

- **Ideal independent source**: An active element that provides a specified voltage or current that is completely independent of other circuit elements
- **Ideal dependent source**: An active element that is controlled by another source



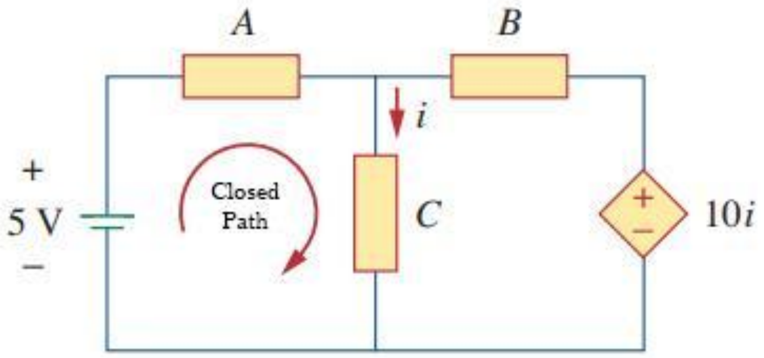
General symbol for ideal independent voltage source.
(a) time-varying voltage
(b) constant voltage (DC)

General symbol for ideal independent current source.
(c) time-varying current
(d) constant current (DC)

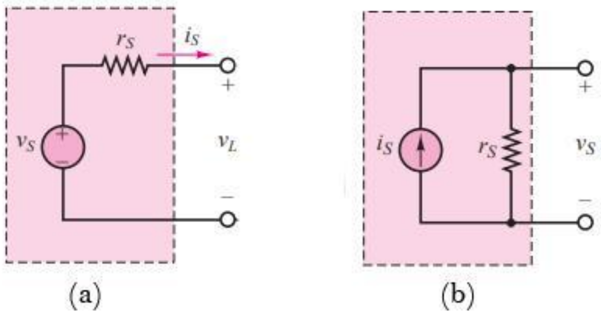
General symbol for ideal dependent source.
(e) dependent voltage
(f) dependent current

Fundamentals of Electric Circuits (Definitions)

- **Practical Sources:** Because of the internal resistor of a voltage/current source the delivered power is not infinite and depends on the load.
- **Network**: Topology of interconnection of electrical elements or devices
  - Study the properties relating to the placement of elements in the network
- **Circuit**: A network providing one or more closed paths



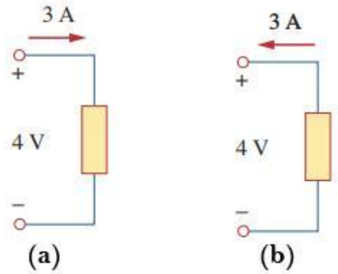
Network and circuit example
Dependent & Independent Sources



Practical Source Models
(a) Voltage Source
(b) Current Source

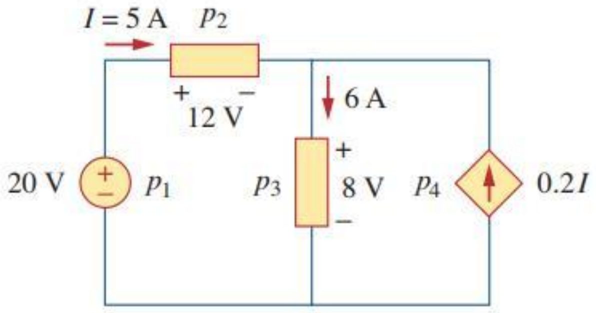
Fundamentals of Electric Circuits (Definitions)

- The law of conservation of energy
  - In a circuit, at any instant of time, **consumed power** + **supplied power** = **0**, ($\sum$**p = 0**)
- Current direction and voltage polarity play a major role in circuit analysis
- **Passive sign convention**
  - Positive current enters through the positive polarity of the voltage
  - If power (v.i) is greater than 0 then the element is consuming power
  - If power (v.i) is lesser than 0 then the element is supplying power
  - For passive elements, current always flows into the positive terminal



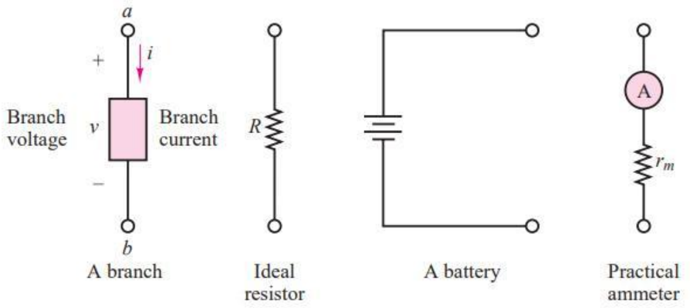
Reference polarities for power using the passive sign convention
(a) Absorbing power, 12 watt
(b) Supplying power, -12 watt

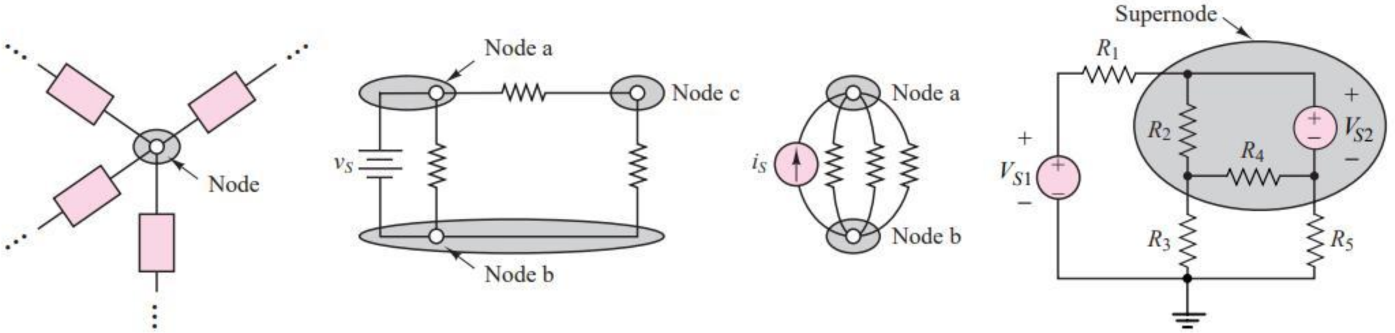
P1 = -100 W (Supplied power)
P2 = 60 W (Absorbed power)
P3 = 48 W (Absorbed power)
P4 = -8 W (Supplied power)



Fundamentals of Electric Circuits (Definitions)

- ❖ Branch
  - ➢ Any portion of a circuit with two terminals connected to it
  - ➢ May consist of one or more circuit elements
- ❖ Node: The junction of two or more branches
- ❖ Super node
  - ➢ A region that encloses more than one node
  - ➢ Can be treated in the same way as nodes

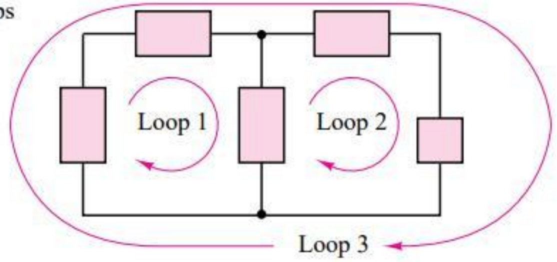


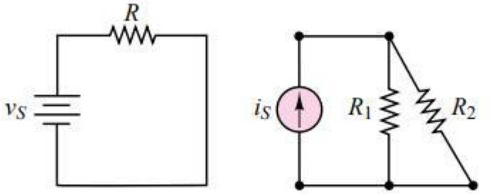


Fundamentals of Electric Circuits (Definitions)

- ❖ Loop
  - ➢ Any closed connection of branches

Note how two different loops in the same circuit may include some of the same elements or branches.



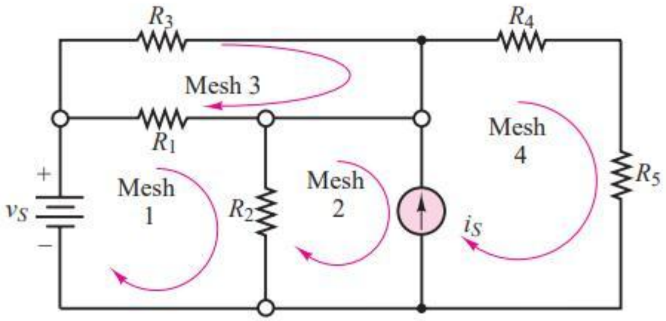


1-loop circuit

3-loop circuit (How many nodes in this circuit?)

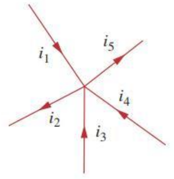
- ❖ Mesh
  - ➢ A loop that does not contain other loops

How many loops can you identify in this four-mesh circuit? (Answer: 15)

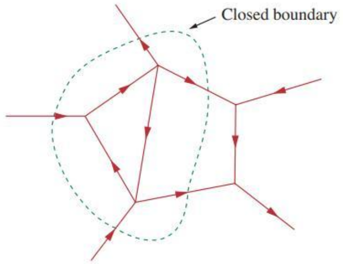


Fundamentals of Electric Circuits (KCL)

- In order to flow current, there must exist a closed circuit
- The law of conservation of charge
  - Charge cannot be created or destroyed
- Kirchhoff’s current law (KCL)
  - The algebraic sum of currents at a node (or a closed boundary) is zero
  - May be interpreted as **total entering currents** = **total leaving currents**



Currents at a node illustrating KCL.



Applying KCL to a closed boundary.

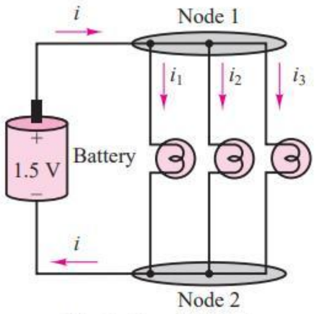


Illustration of KCL at node 1: $-i + i_1 + i_2 + i_3 = 0$

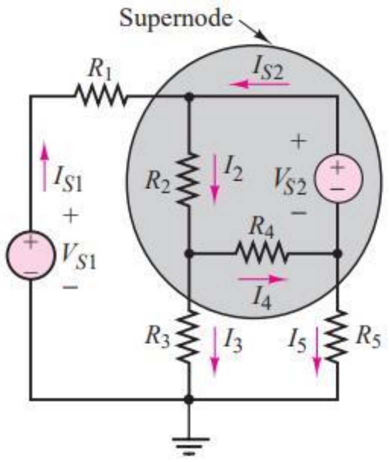
$$\sum_{n=1}^{N} i_n = 0$$ Kirchhoff’s current law

Fundamentals of Electric Circuits (KCL)

❖ Application of KCL (examples)

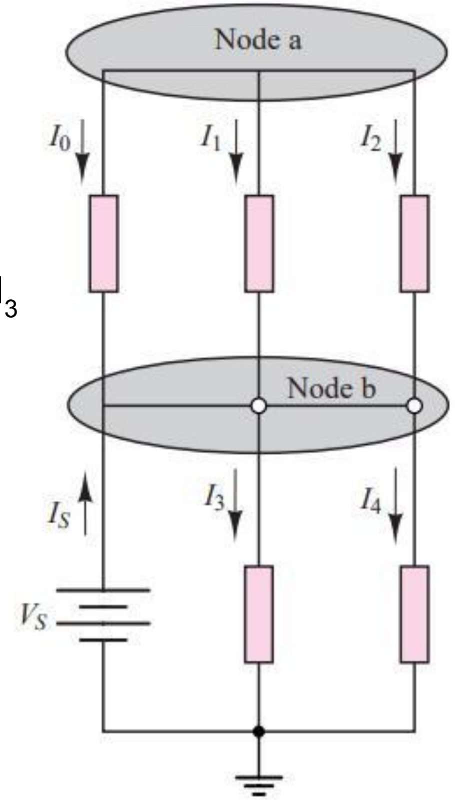
If I_2 = 3 A, I_3 = 2 A, I_4 = 1 A, I_5 = 0 A, find I_{S1} and I_{S2}

Answer:
I_{S1} = 2 A, I_{S2} = 1 A



if I_S = 5 A, I_1 = 2 A, I_2 = −3 A, I_3 = 1.5 A find I_0 and I_4

Answer:
I_0 = 1 A, I_4 = 3.5 A

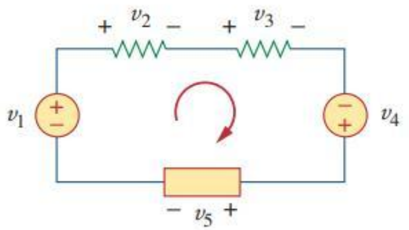


Kirchhoff's current law

Fundamentals of Electric Circuits (KVL)

- The law of conservation of energy
  - Energy is not lost or created in an electric circuit
- Kirchhoff’s voltage law (KVL)
  - The algebraic sum of all voltages around a closed path (or loop) is zero
  - May be interpreted as **Sum of voltage drops** = **Sum of voltage rises**

KVL can be applied in two ways: by taking either a clockwise or a counterclockwise trip around the loop. Either way, the algebraic sum of voltages around the loop is zero.



A single-loop circuit illustrating KVL.

$$-v_1 + v_2 + v_3 - v_4 + v_5 = 0$$

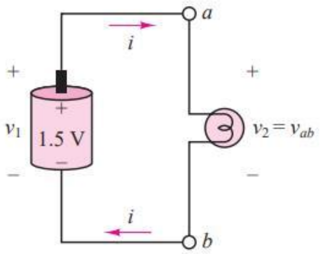
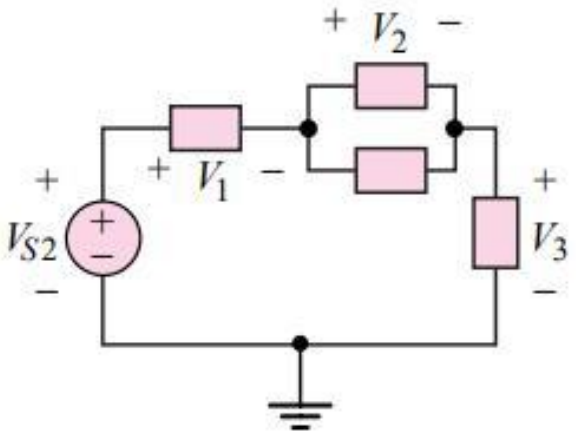


Illustration of Kirchhoff’s voltage law: $v_1 = v_2$

$$\sum_{n=1}^{N} v_n = 0 \qquad \text{Kirchhoff's voltage law}$$

Fundamentals of Electric Circuits (KVL)

❖ Application of KVL (examples)



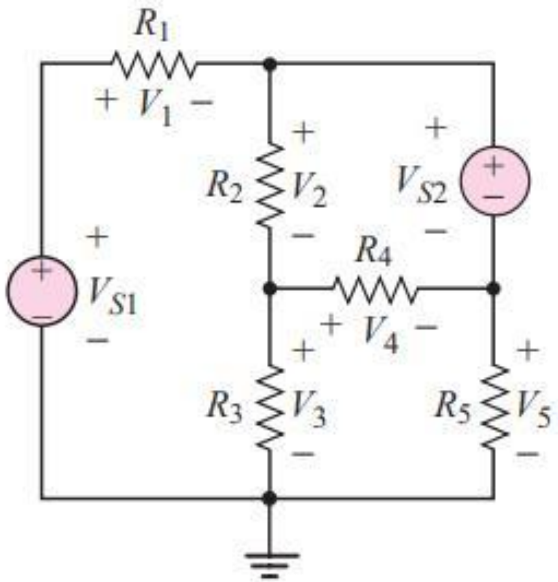
If V_{S2} = 12 V, V_1 = 6 V, V_3 = 1 V, find V_2

Answer: V_2 = 5 V

If V_{S1} = 12 V, V_{S2} = −4 V, V_2 = 2 V, V_3 = 6 V, V_5 = 12 V, find V_1, V_4.

Answer: By applying the KVL clockwise around each of the three meshes:

V_1 = 4V and V_4 = -6 V



[Kirchhoff's voltage law]

Fundamentals of Electric Circuits

- References
  - Fundamentals of Electric Circuits, 5th Edition, Charles K. Alexander and Matthew N.O. Sadiku, ISBN 978-0-07-338057-5
  - Fundamentals of Electrical Engineering, First Edition, Giorgio Rizzoni, ISBN 978-0–07–338037–7
  - ***Most of the images have been copied from these books***
- Some useful links
  - Sign convention for passive components and sources
  - Differences Between Active and Passive Elements

The SI prefixes.

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a