

Chapter 1 - Electric Circuit Variables

Lecture 1

Sections 1.2-1.5

MEMS 0031 Electrical Circuits

Mechanical Engineering and Materials Science Department
University of Pittsburgh

Learning Objectives

1.3 Systems of Units

1.2 Electric Circuits
and Current

1.4 Voltage

1.5 Power and
Energy

Summary



- ▶ The following scheme will be used within our notes:
 1. **Bold** words are definitions
 2. *Italic* words or letters represent variables
 3. Underlined words or phrases represent a law, theorem and/or hypothesis
- ▶ Each section (number and title) is displayed on the right navigation pane, following our text
- ▶ Important equations will be boxed

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Student Learning Objectives

Chapter 1 - Electric
Circuit Variables

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At the end of the lecture, students should be able to:

- ▶ Understand the concept and formulation of charge and current
- ▶ Understand the concept and formulation of voltage
- ▶ Recognize and understand active and passive sign conventions
- ▶ Understand and apply the formulation of power
- ▶ Understand and apply the conservation of energy

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- The units we will use in this course are as follows:

Quantity	Name	Formula	Symbol
Time	second		s
Electric Current	Ampere		A
Frequency	Hertz	s^{-1}	Hz
Energy or Work	Joule	N-m	J
Power	Watt	J/s	W
Electric Charge	Coulomb	A-s	C
Electric Potential	Volt	W/A	V
Electric Resistance	Ohm	V/A	Ω
Electric Conductance	Siemens	A/V	S
Electric Capacitance	Farad	C/V	F
Magnetic Flux	Weber	V-s	Wb
Inductance	Henry	Wb/A	H

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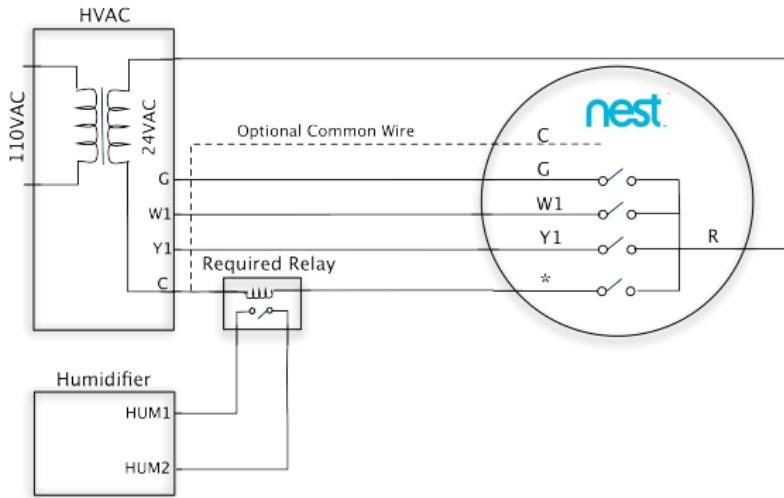
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Summary



Electric Circuit

- An **electric circuit**, or electric network, is an interconnection of electrical elements linked together in a closed path so that electric current may flow



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Charge and Current

- ▶ **Charge** (q , [C] (Coulomb), [A-s]) is the “quantity” of electricity, i.e. electrons, responsible for electrical phenomena

$$q(t) = \int_{-\infty}^t i d\tau = q(0) + \int_0^t i d\tau$$

- ▶ **Current** (i , [A], [C/s]) is the time rate of flow of charge past a point

$$i = \frac{dq}{dt}$$

- ▶ Current must be conserved! Charge carriers cannot be created nor destroyed.

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Example #1

- ▶ For $t < 0$, no charge exists at the terminal of a device. At $t = 0$, a 5 [A] current begins to flow into the device.
- ▶ Determine:
 1. The charge accumulated for $t > 0$
 2. If the current stopped after 10 [s], how much charge has accumulated?
- ▶ Solution:

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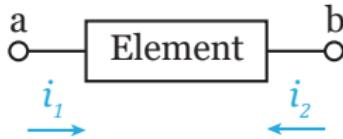
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Summary



Current in an Element

- ▶ **Current** has direction and magnitude - it is a vector - and can exist in, or through, an element
- ▶ The direction is indicated by either \rightarrow , \leftarrow , \uparrow or \downarrow , and the magnitude is represented by a variable i_1 , i_2 , etc. The units are assumed [A] unless otherwise noted.
- ▶ Consider a circuit element that exists between nodes a and b, carrying current i_1



- ▶ Based upon the opposing direction of i_1 and i_2 , we can say:

$$i_1 = -i_2$$

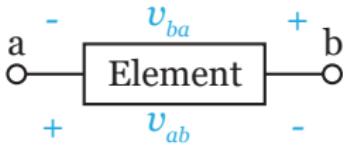


Voltage in an Element

- ▶ **Voltage** (V , [V]) is a potential that drives a current across or through an element
- ▶ The voltage across an element, ΔV , is the work (w) required to move a unit positive charge (q) from the $-$ to the $+$ terminal

$$V = \frac{dw}{dq}$$

- ▶ Note: our unit charge in this convention is positive, although an electron has a negative charge (Thanks Ben Franklin)



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- ▶ We first have to define a consistent convention based on the direction of current through, and direction of a voltage potential across, an element
- ▶ The **Passive Sign Convention** refers to an element that is a **Power Sink**
- ▶ The **Active Sign Convention** refers to an element that is a **Power Source**
- ▶ Let us look at each of these conventions individually

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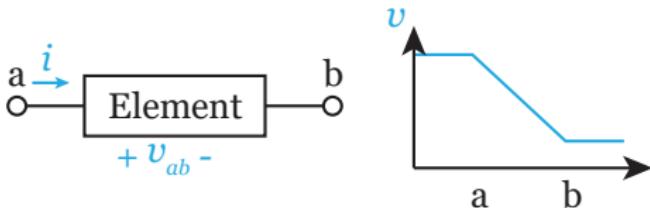
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Summary



Passive Sign Convection

- ▶ the **Passive Sign Convention** (PSC) means the circuit component is dissipating power within the circuit - if current is conserved, a decrease in power manifests through a decrease in potential
- ▶ Therefore, a passive component is decreasing the potential, i.e. voltage, of the charge carriers
- ▶ The PSC is depicted as follows:



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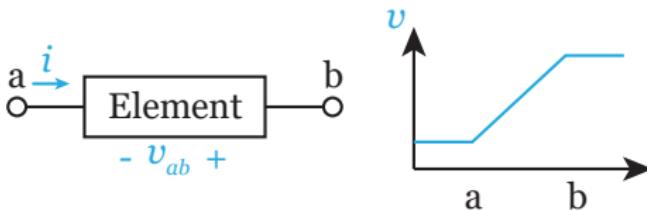
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Active Sign Convention

- ▶ The **Active Sign Convention** (ASC) means the circuit component is providing energy to the circuit - if current is conserved, an increase in power manifests through an increase in potential
- ▶ Therefore, an active component is increasing the potential, i.e. voltage, of the charge carriers
- ▶ The ASC is depicted as follows:



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Example #2

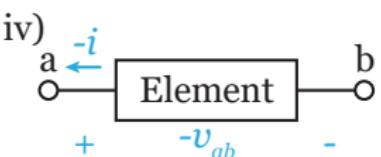
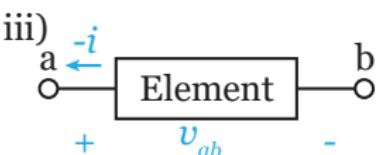
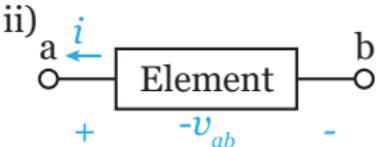
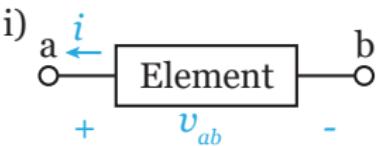
- ▶ For the four circuits shown, determine if they are active (i.e. a source), or passive (i.e. a sink):

i)

ii)

iii)

iv)



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- ▶ **Power** (P , [W]) is the time rate of expending or absorbing energy (work)

$$P = \frac{dw}{dt} = \frac{dw}{dq} \frac{dq}{dt} = Vi$$

- ▶ To determine the work of an element (either dissipated or supplied)

$$w = \int_{t_1}^{t_2} P d\tau$$

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Example #3

- ▶ Assume the current into the terminal of an element is $20e^{-5,000t}$ [A] and the voltage across the element is $10e^{-5,000t}$ [kV] for $t \geq 0$
- ▶ Determine
 1. The power supplied to the element at 1 [ms]
 2. The energy delivered to the element
- ▶ Solution:

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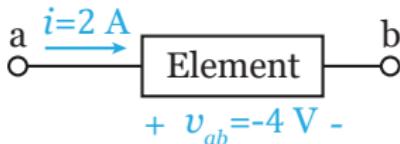
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Example #4

- ▶ Given the element below, determine
 1. The power dissipated
 2. The power supplied
 3. If this is a source or sink



- ▶ Solution:

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Summary



Conservation of Power

- ▶ The **Conservation of Energy**, or **Conservation of Electrical Power**, states the power dissipated must be equal to the power supplied:

$$P_{\text{supplied}} = P_{\text{dissipated}}$$

- ▶ The circuit cannot supply more energy than it is dissipating, nor can it dissipate more energy than is supplied

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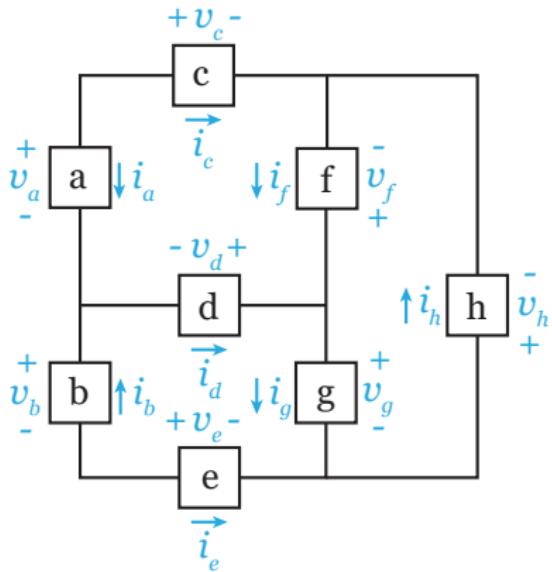
Summary



Example #5

- ▶ Using the passive sign convention, determine if the circuit obeys **conservation of energy**

	[V]	[A]
a	120	-10
b	120	9
c	10	10
d	10	1
e	-10	-9
f	-100	5
g	120	4
h	-220	-5



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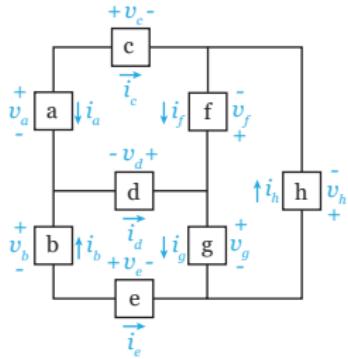
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Example #5

► Solution:



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	[V]	[A]	[W]
a	120	-10	1,200
b	120	9	1,080
c	10	10	100
d	10	1	10
e	-10	-9	90
f	-100	5	500
g	120	4	480
h	-220	-5	1,100



Example #5

► Solution:

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Chapter 1 - Electric Circuit Variables

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At the end of the lecture, students should be able to:

- ▶ Understand the concept and formulation of charge and current
 - ▶ Electric charge is the time-integral of electric current. Current is the flow of charge carriers (i.e. electrons) per unit time.
- ▶ Understand the concept and formulation of voltage
 - ▶ Voltage is a potential that is able to drive current through an element.
- ▶ Recognize and understand active and passive sign conventions
 - ▶ An active element is supplying power to the circuit - the potential is increasing as current runs through the device. The opposite for a passive element.

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Chapter 1 - Electric Circuit Variables

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- ▶ Understand and apply the formulation of power
 - ▶ Power is the time-rate of supplying or dissipating energy. Power is simply the voltage potential across an element times the current running through it.
- ▶ Understand and apply the conservation of energy
 - ▶ Energy can neither be created nor destroyed. The amount of energy supplied to a circuit is equal to the amount of energy dissipated by a circuit.

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Suggested Problems

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- ▶ 1.2-3, 1.2-5, 1.3-4, 1.5-1, 1.5-2, 1.7-3

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