Today's Outline

1. Fundamentals

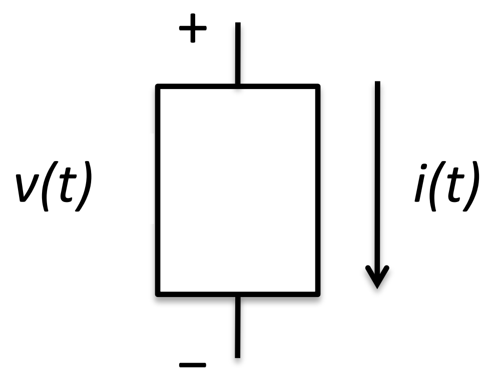
- Active and Passive Elements
- Linear Circuit Elements
- the Ideal Resistor and Ohm's Law
- Physical Resistors

Energy Transfer to and from Elements

We classify circuit elements in terms of their ability or inability to deliver a net positive energy to a circuit.

Let $p(t')=i(t')v(t')$ be the *instantaneous power* that is ***absorbed*** by a circuit element (passive sign convention for i and v)..

The **net energy absorbed** by the circuit element up to time t is:

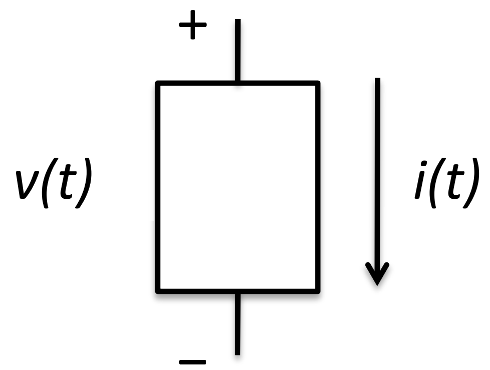


$$U(t) = \int_{-\infty}^{t} p(t')\,dt' = \int_{-\infty}^{t} i(t')v(t')\,dt'$$

Passive Elements

Passive element: a circuit element that *cannot* deliver more energy than it has already received from a circuit.

In other words, the net energy absorbed by a passive circuit element is always greater than or equal to zero.



$$U(t) = \int_{-\infty}^{t} p(t')\,dt' = \int_{-\infty}^{t} i(t')v(t')\,dt' \geq 0$$

Example: a piece of copper wire can be modeled by a passive circuit element.

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Active Elements

Active element: a circuit element that *can* deliver more energy than it has already received from a circuit.

In other words, all elements that are not passive are active.

Warning: Although active elements *can* deliver energy to a circuit, this does not mean that an active element *is* delivering energy in a particular circuit.

Questions:

Can a rechargeable battery be modeled as an active element or a passive element?

Can a non-rechargeable battery be modeled as an active element or a passive element?

Linear Circuit Element

Linear Circuit Element: An element where terminal voltage and current are related to each other by a linear function (or operator). Examples include ideal resistors, dependent sources and many others.

Linearity

Linearity: A *function* f (x) is **linear** in the argument x if and only if:

$$f(ax + by) = a f(x) + b f(y)$$

- To evaluate $f(ax + by)$, we can evaluate $f(x)$ and $f(y)$, and then sum appropriately.

- In some cases, it may be easier to evaluate $f(x)$ and $f(y)$ instead of $f(ax + by)$, for example:

$$f(x) = 2x$$

$$f(179) = f(170) + f(9)$$ [for evaluation *without* pen or paper]

$$= 340 + 18 = 358$$

Linearity (more general)

Linearity: An *operator* $F[\,x(t)\,]$ is **linear** in the function $x(t)$ if and only if:

$$F\,[\,a\,x(t) + b\,y(t)\,] = a\,F\,[\,x(t)\,] + b\,F\,[\,y(t)\,]$$

- To evaluate $F\,[\,a\,x(t) + b\,y(t)\,]$, we can evaluate $F[x(t)]$ and $F[y(t)]$, and then sum the appropriately.

- In some cases, it may be easier to evaluate $F[x(t)]$ and $F[y(t)]$ instead of $F\,[\,x(t) + y(t)\,]$, for example:

$$F[x(t)] = \frac{d}{dt}\left[x(t)\right]$$

$$\begin{aligned} F[C + D\exp(-kt)] &= F[C] + F[D\exp(-kt)] \\ &= 0 - Dk\exp(-kt) \end{aligned}$$

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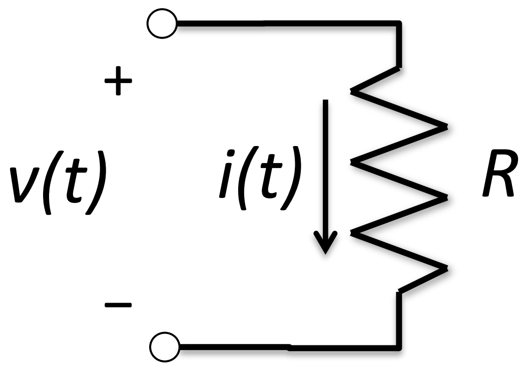
Ohm's Law

Ohm's Law: the voltage drop *v* across an **ideal resistor** is proportional to the current *i* flowing through the resistor



$$v = i\,R$$

– *v* and *i* are defined with passive sign convention

– the *positive* constant of proportionality is called the **resistance**, given the symbol *r* or *R*

– SI unit of resistance is the Ohm (abbreviated Ω)

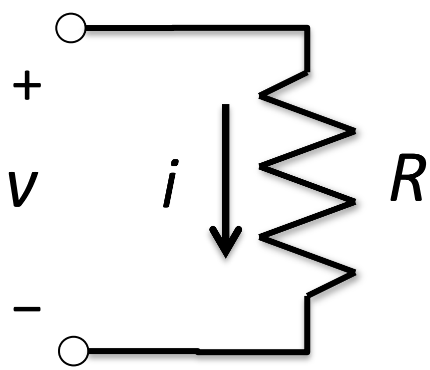
$$1\ \Omega = 1\ \text{V} / \text{A}$$

Georg Simon Ohm
(1789-1854)

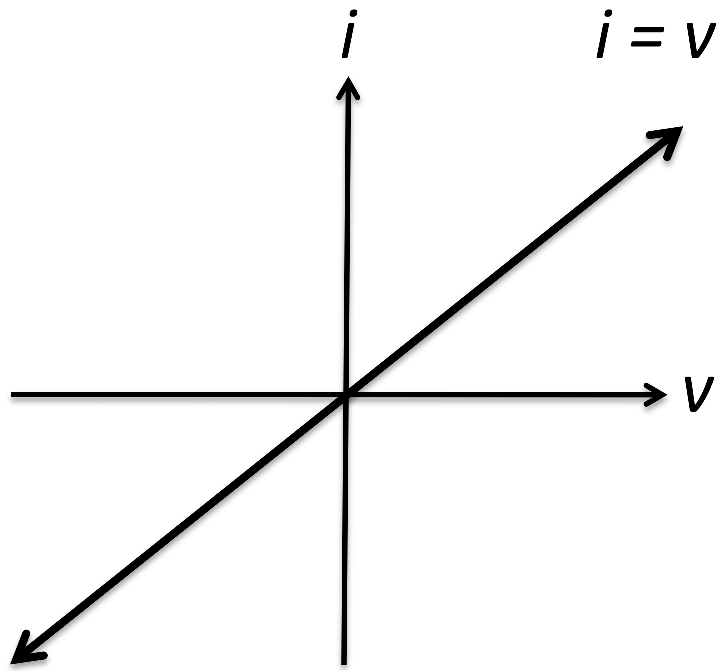
Ideal Resistor

Ideal Resistor: a circuit element that satisfies Ohm's law

$$v = i\,R$$



$$i = v \,/\, R$$



Conductance

Conductance can also be used to parameterize a resistor.

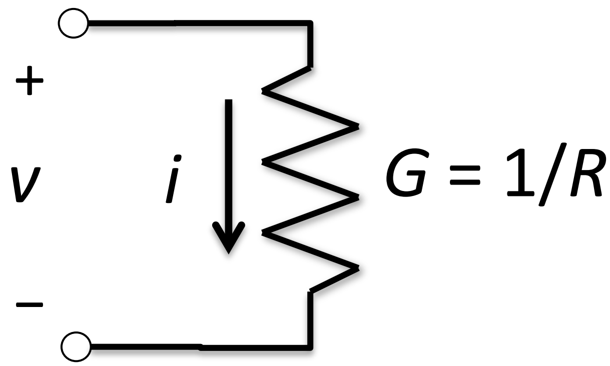
– given the symbol *G* or g

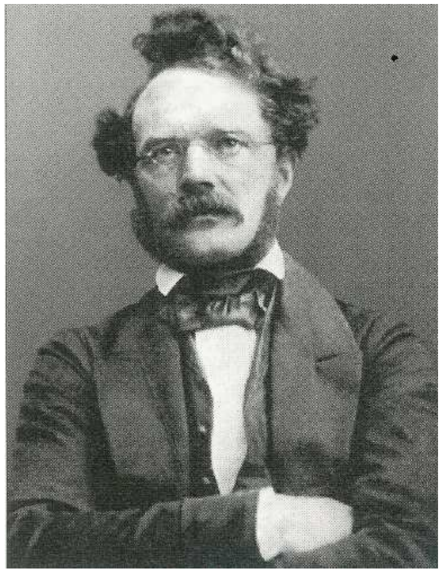
– related to resistance through $G = 1/R$

– SI unit is the siemens (abbreviated S)

$1\ \mathrm{S} = 1\ \Omega^{-1} = 1\ \mathrm{A}\ /\ \mathrm{V}$

– Ohm's law can be restated $i = G\,v$

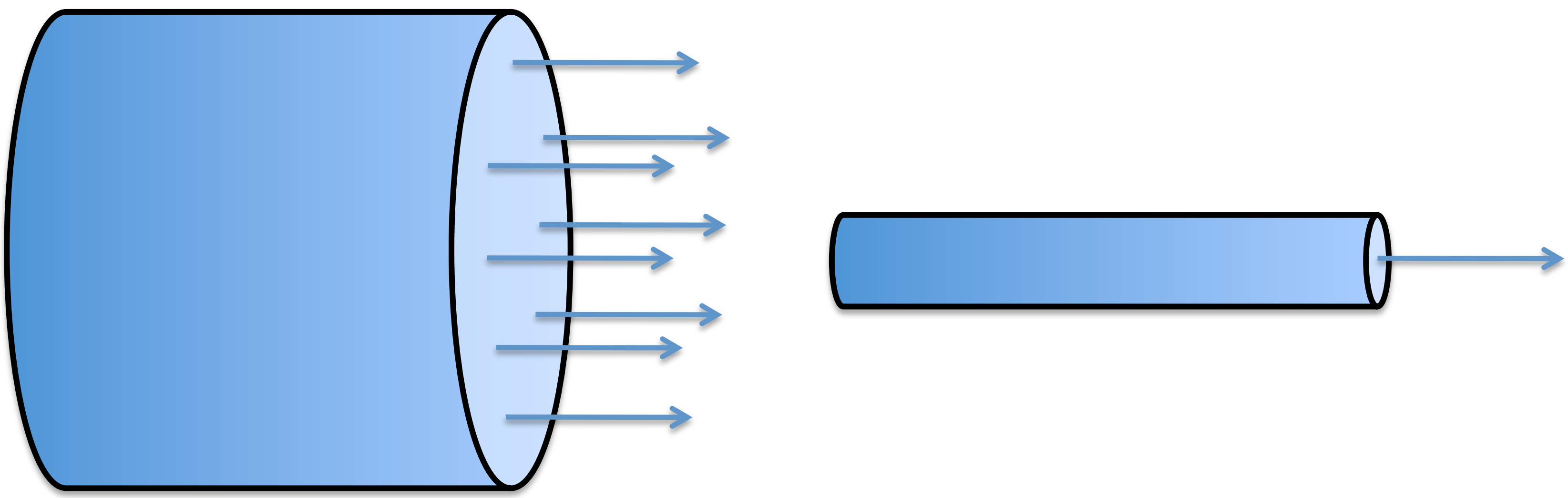




Werner von Siemens
(1816-1892)

Resistance and Conductance

The terminology of resistance and conductance is analogous to the terminology of fluid flow through pipes.



larger conductance G

smaller resistance R

more flow with applied pressure
more current I with applied voltage V

smaller conductance G

larger resistance R

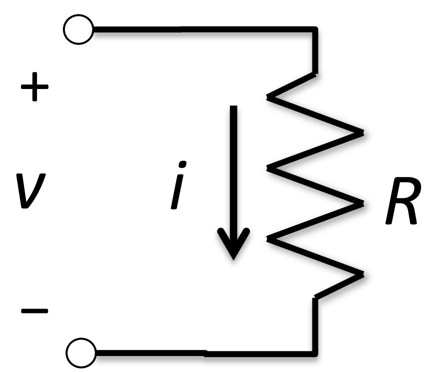
less flow with applied pressure
less current I with applied voltage V

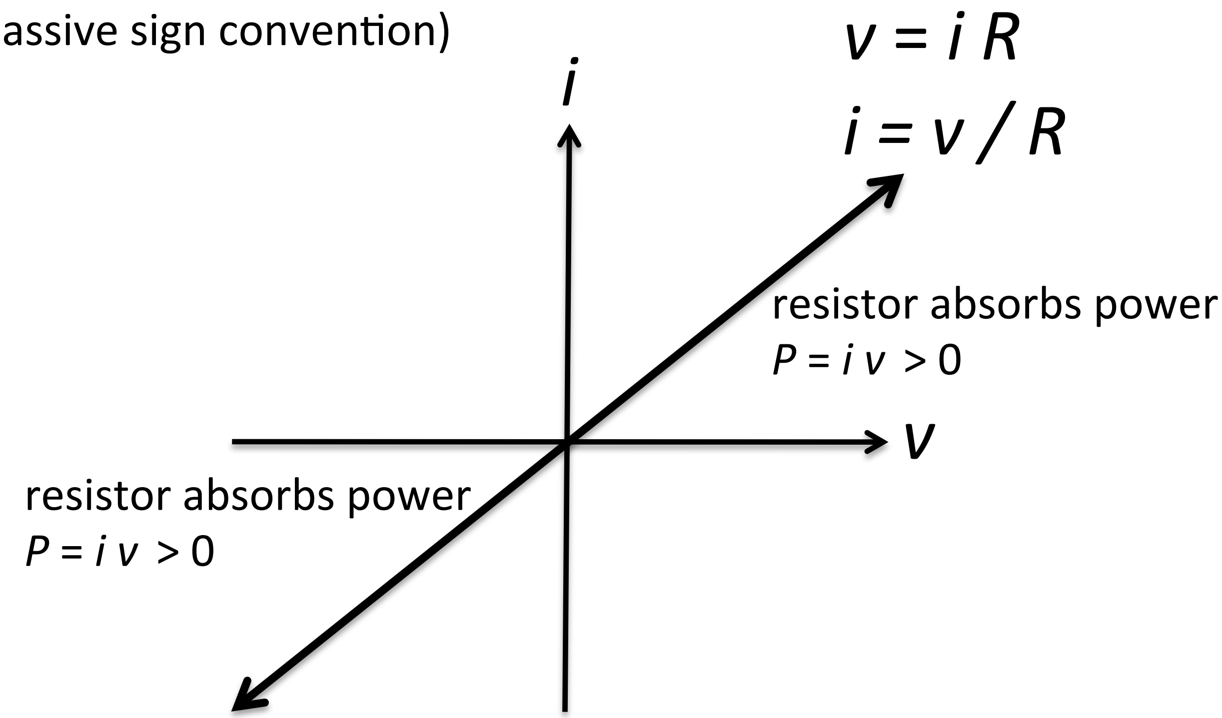
Power

A resistor is a **passive element**. The power absorbed by a resistor is always non-negative:

$$p = i\,v = i^2 R = v^2/R$$

(note the importance of passive sign convention)

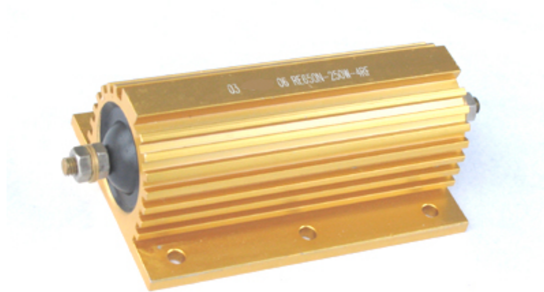




Physical Resistors

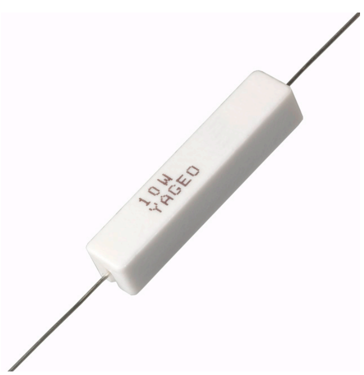
A **wirewound resistor** is typically of “small” resistance and “large” size, designed to dissipate heat effectively.

PostGlover



Chengdu Guozheng Electronics

Navatek Systems

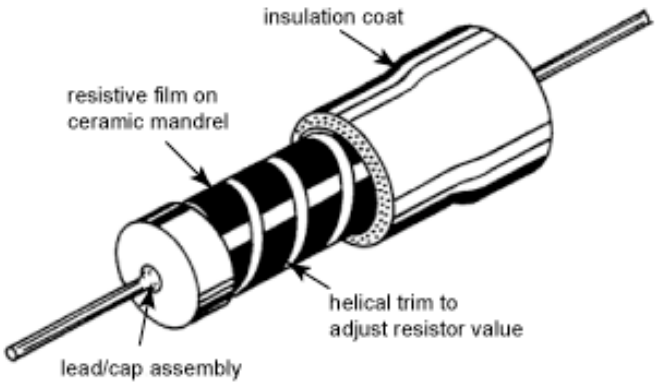


Yageo

Ceramic casing, and sometimes a metallic heatsink, is used to increase heat dissipation and maximum power rating.

Physical Resistors

A **carbon film resistor** and **metal film resistor** are well suited for resistance values of higher precision, with less power handling capability than a typical wirewound resistor.



Bolton University

Ohmcraft

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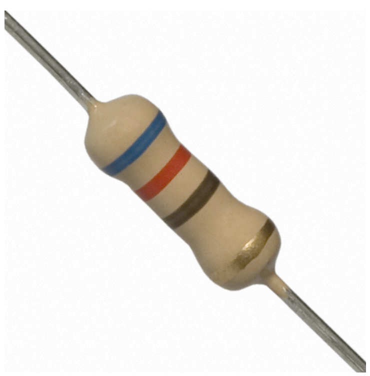

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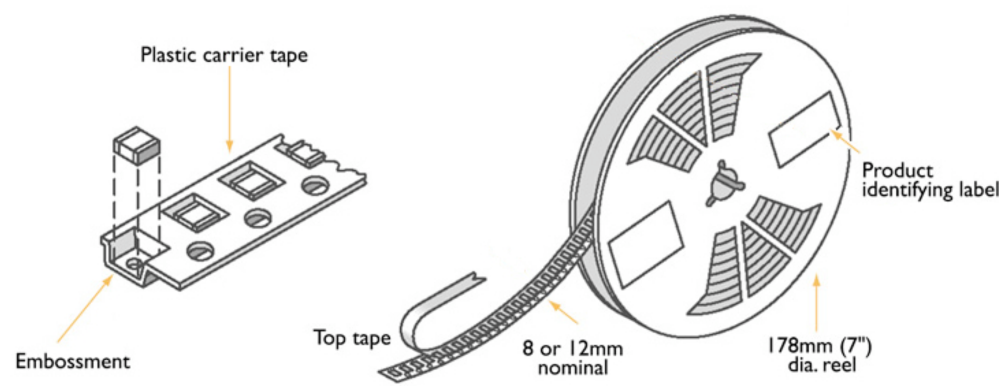
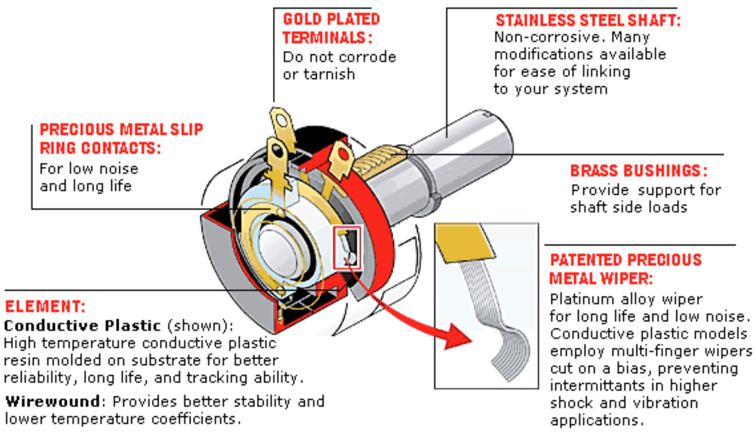


Charcroft Electronics

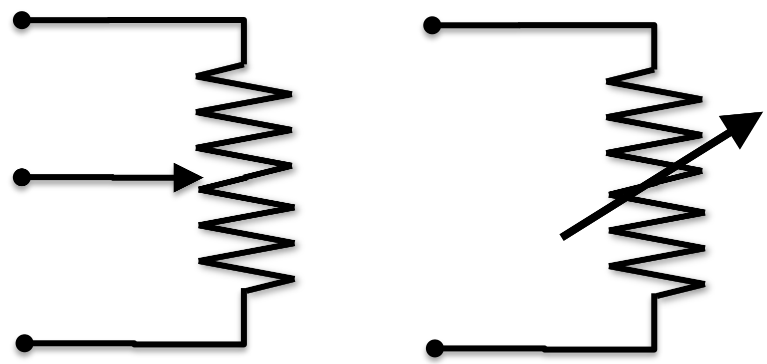
Physical Resistors

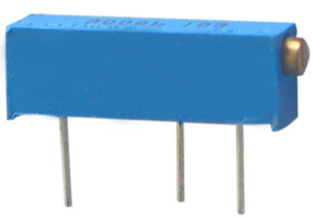
A **rheostat** is a variable resistor with a sliding contact. A **potentiometer** has three terminals, with one terminal being a sliding contact.



ETI Systems

The circuit symbols are:





Rongcheng Electronics

Oretronics