AERO ASTRO

16.682 - Prototyping Avionics
Spring 2006

Lecture 2

February 13, 2006

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

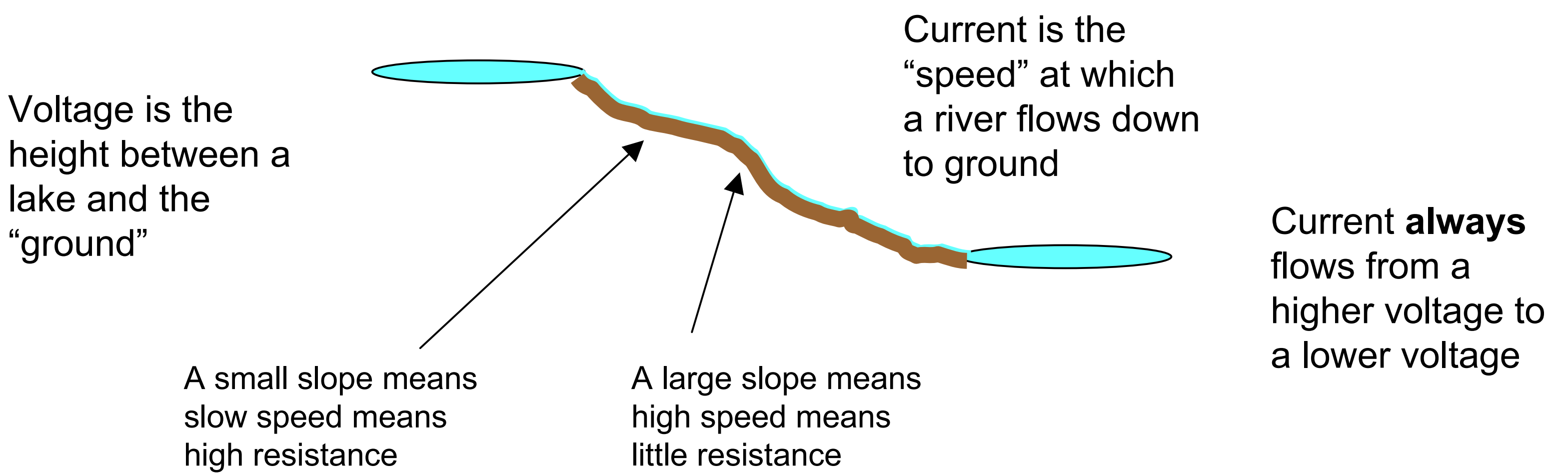
Alvar Saenz-Otero

Outline

- Voltage and Current
- 4 basic "component laws"
- 2 basic "network laws"
- Resistors
- Capacitors
- Inductors

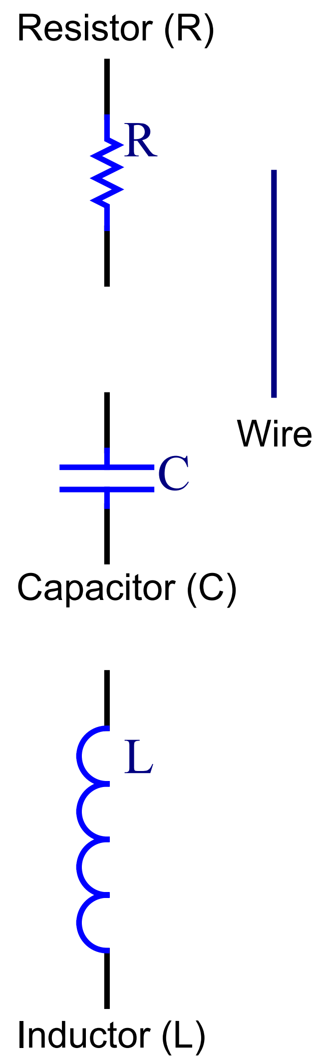
Voltage & Current

- **Any electronic project depends at the most basic level on:**
  - **Voltage**
    - **The electric potential <u>difference</u> between two points**
    - **Like "potential energy" of physics**
  - **Current**
    - **The flow of electricity through components and wires**
    - **Like "kinetic energy" of physics**
- **There are many ways people think about current and voltage, most involve a fluid like water, here is an example:**



Components

- **The most basic components of an electronic circuit are:**
  - **Resistor**
    - **Resistance is an inherent property of all materials**
    - **Conductive materials have small resistance, non-conductive high resistance**
    - **Wire is an approximately 0Ω resistor**
    - **Purely a passive element**
    - **Like the "slope" of the mountain**
  - **Capacitor**
    - **Stores energy: as current flows in the capacitor charges in voltage, as current flows out it discharges**
    - **Like a small intermediate "lake" in the mountain**
  - **Inductor**
    - **Stores energy: as voltage is applied, it makes current flow faster, as voltage goes down the current slows**
    - **Like a local "increase in gravity" in the mountain**



Units and Common Values

Description	Units	Symbol	Typical Values
Voltage	Volts	V	1mV→10kV
Current	Ampere	A	1μA→10A
Resistance	Ohms	Ω	1mΩ→MΩ
Capacitance	Farad	F	1μF→1mF
Inductance	Henry	H	1mH→1H

Component Laws

- **The most basic "laws" for these components are:**
  - **Resistor**

$$V = IR \leftrightarrow I \quad \frac{V}{R} \leftrightarrow R = \frac{V}{R}$$

$$P = IV \leftrightarrow P \quad I^2 R \leftrightarrow P = \frac{V^2}{R}$$

  - **Capacitor**

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

  - **Inductor**

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

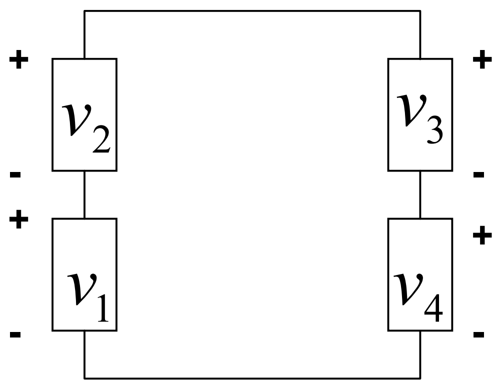
- ***Capacitors and Inductors are "dual" or each other***
  - ***What one does with voltage, the other does with current***

Network Laws

- A circuit is full of *nodes* and *loops*
  - The Kirchkoff Voltage Law (KVL) and Current Law (KCL) tell you how to figure out the voltage and current in a circuit

$$\sum_L v_l = 0$$

- *The sum of all voltages around a loop must be 0*

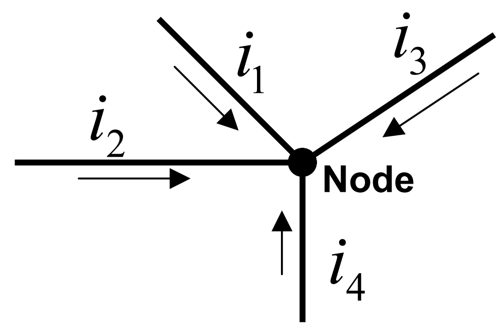


$$v_1 + v_2 + v_3 + v_4 = 0$$

Note: at least one voltage must be negative (the +/- signs are backwards)!

$$\sum_N i_n = 0$$

- *The sum of all currents into a node must be 0*



$$i_1 + i_2 + i_3 + i_4 = 0$$

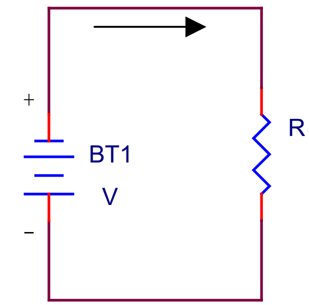
Note: at least one current must be negative (flow opposite of the arrow)!

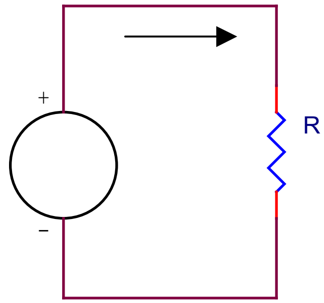
Supplies

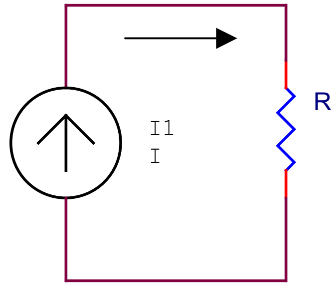
- **To make circuit analysis possible, we use models of voltage and current supplies:**

  - **Voltage supplies provide constant voltage and any necessary current**
    - **Current flows out of the positive side, through the circuit, and back into the negative side of a supply**

  - **Current supplies provide constant current in the direction of the arrow and work at any necessary voltage**







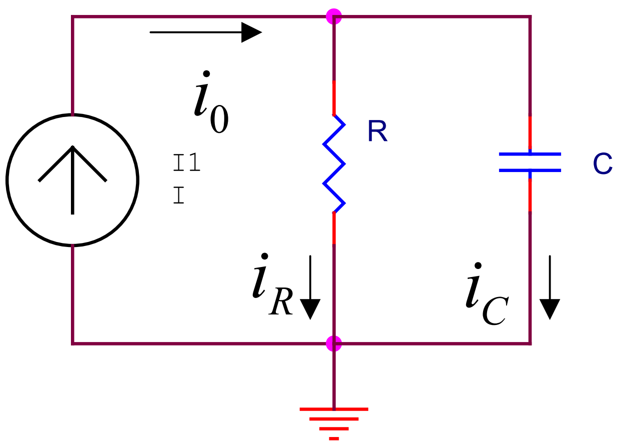
Basic Circuits

- **Node analysis: KCL**
  - $i_0 = i_R + i_C$

    $$i_0 = \frac{v}{R} + C\frac{dv}{dt}$$

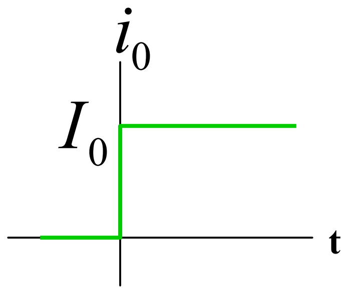
    $$v + RC\frac{dv}{dt} = i_0 R$$

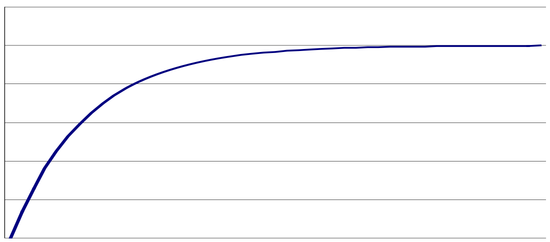
    - **Resistor/Capacitor circuits will always have a *time constant* of RC!**
  - **Actual response depends on input current**
    - **Example: i_0= step function**



$$V = I_0 R\left(1 - e^{-\frac{t}{RC}}\right)$$

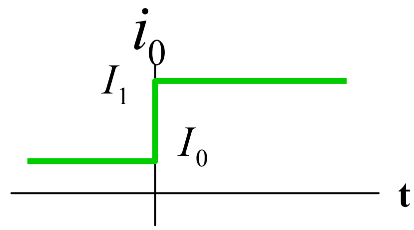
time constant!

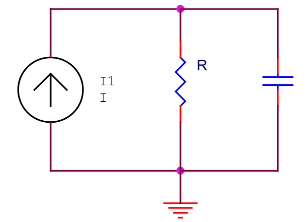




ZIR and ZSR

- **Solving circuits with inductors/capacitors is easiest if you use super-position to add the**
  - **Zero Input Response**
    - **The behavior which depends only on the “state” of the capacitor/inductor at time zero, without any change in the input**
  - **Zero State Response**
    - **The behavior which depends only on the response of the capacitor/inductor due to a change in the input**



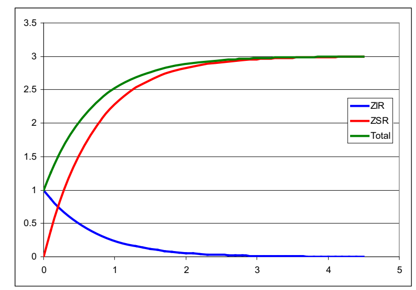


ZIR :

$$t<0,\ v=I_0R$$

$$t>0, i=C\frac{dv}{dt}\rightarrow v+RC\frac{dv}{dt} \quad 0$$

$$\rightarrow v=I_0R\cdot e^{-\frac{t}{RC}}$$



ZSR :

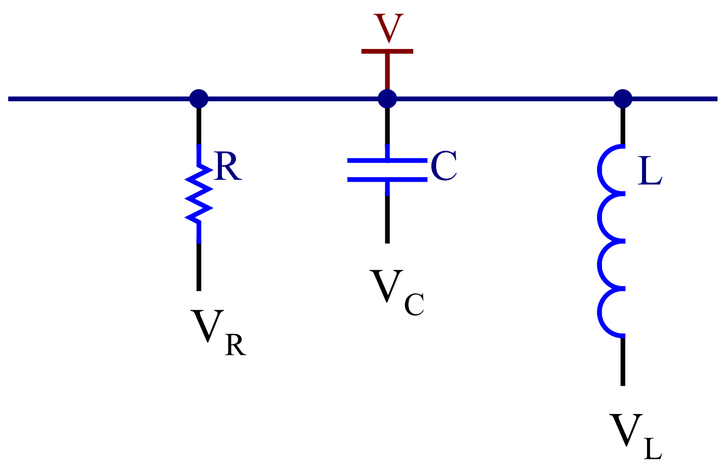
$$t<0,\ v=0$$

$$t>0, i=C\frac{dv}{dt}\rightarrow v+RC\frac{dv}{dt} \quad 0$$

$$\rightarrow v=I_1R\left(1-e^{-\frac{t}{RC}}\right)$$

Useful Clue

- **From** $v = iR$
  - **What happens with unconnected ends of components?**



  - **Because i=0 then v across are 0**
    - **V_R=V**
    - **V_C=V** ***it is not floating!***
    - **V_L=V**