16.682 - Prototyping Avionics
Spring 2006

LECTURE 3

February 15, 2006

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

Alvar Saenz-Otero

Outline

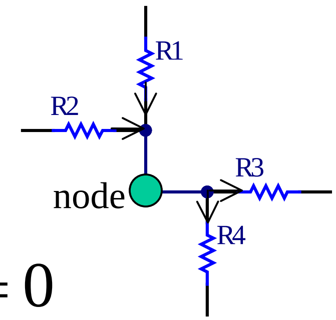
- **More on Components**
  - **Resistors, Capacitors, Inductors: ideal vs. real**
  - **First and second order systems**
  - **Diodes**
- **Amplifiers**

Last time...

- **Four component laws**
  - $v = iR$
  - $i = C\dfrac{dv}{dt}$
  - $v = L\dfrac{di}{dt}$
  - $P = iv = i^2 R = \dfrac{v^2}{R}$

- **Two network laws**
  - **KCL - Kirchoff's Current Law**

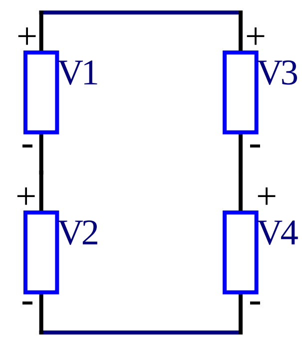
$$\sum_{\text{In/out of node}} i_n = 0$$



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

  - **KVL - Kirchoff's Voltage Law**

$$\sum_{\text{Around a loop}} v_n = 0$$

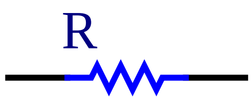


$$v_1 + v_2 = v_3 + v_4$$

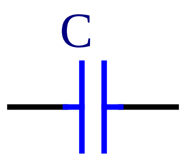
Ideal vs. Real

- Ideal
  - Wire

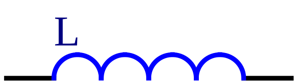
    - R=0, C=0, L=0
  - Resistor



    - C=0, L=0
  - Capacitor

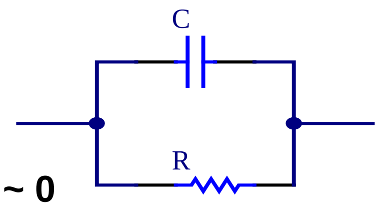


    - R=0, L=0
  - Inductor

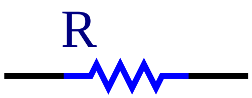


    - R=0, C=0

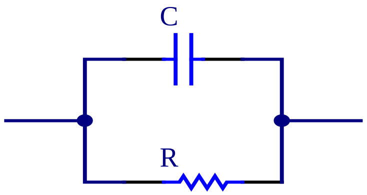
- Real



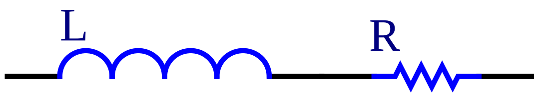
    - R ≠0, C ≠0, L ~ 0



    - C ~ 0,L ~ 0

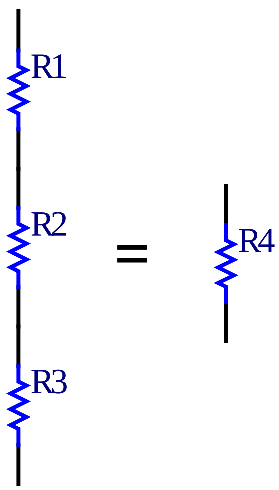


    - R ≠0, L ~ 0
    - R ≠0, C ~ 0



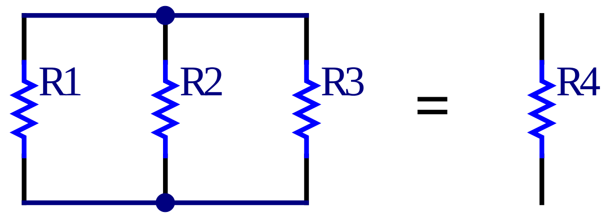
Review of Resistors

- **Serial**



$$R_1 + R_2 + R_3 = R_4$$

- **Parallel**

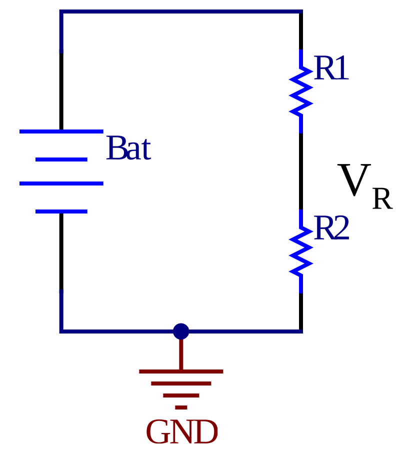


$$\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{R_4}$$

- **For two resistors**

$$R_4 = \frac{R_1 R_2}{R_1 + R_2}$$

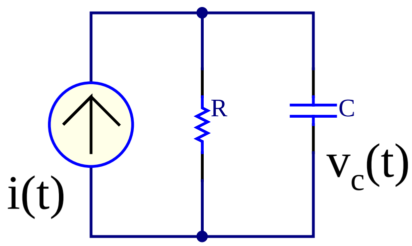
- **Voltage divider**



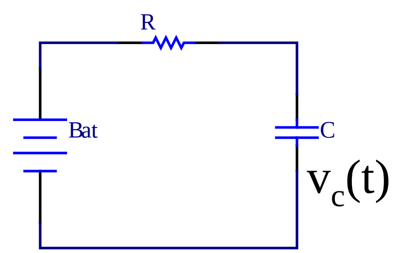
$$V_R = V_{Bat} \frac{R_2}{R_1 + R_2}$$

First Order Systems

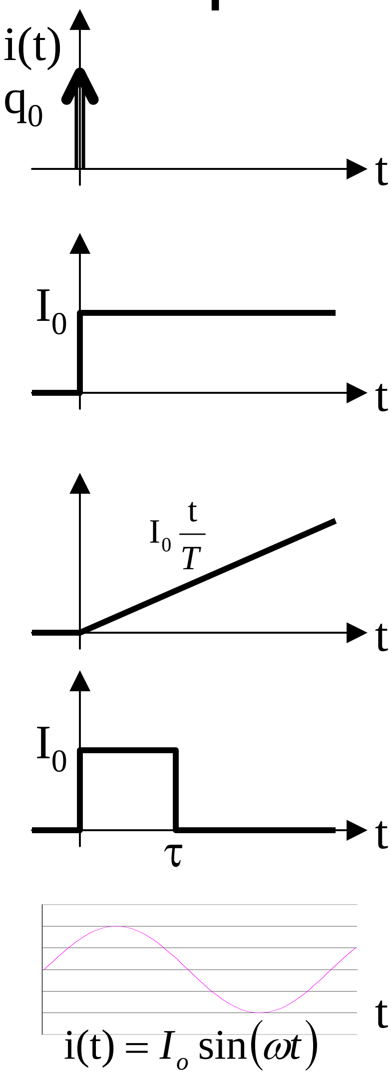
- **Relation of different inputs**



or



$$V_{Bat} = i(t)R$$



$$V_{out} = \frac{q_0}{C} e^{-\frac{t}{RC}}$$

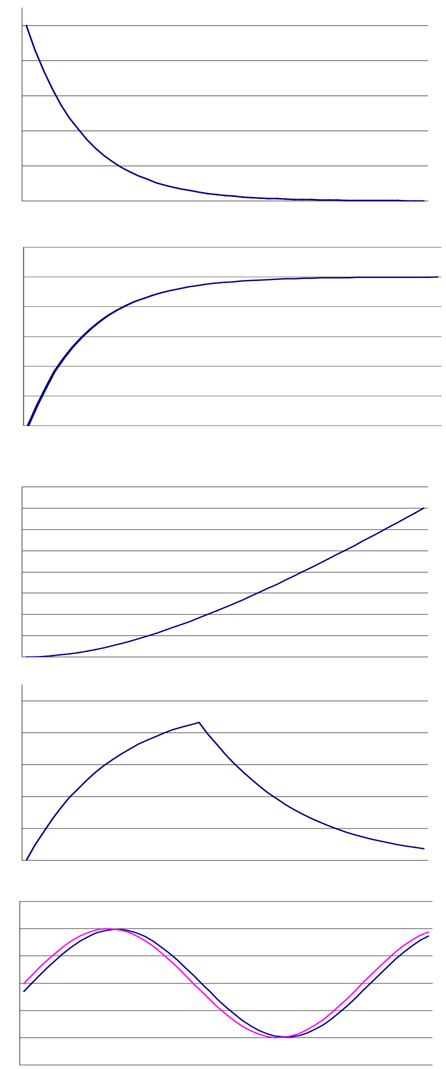
$$V_{out} = I_0 R\left(1 - e^{-\frac{t}{RC}}\right)$$

$$V_{out} = \frac{I_0 R}{T}\left(t + RC\left(e^{-\frac{t}{RC}} - 1\right)\right)$$

$$0 < t < \tau \rightarrow V_{out} = I_0 R\left(1 - e^{-\frac{t}{RC}}\right)$$

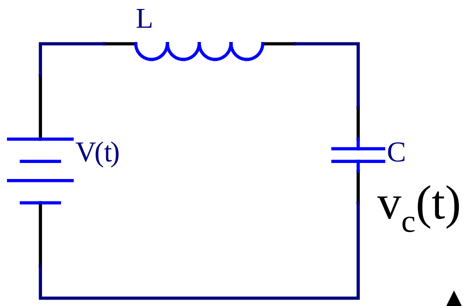
$$t > \tau \rightarrow V_{out} = I_0 R\left(1 - e^{-\frac{t}{RC}}\right) e^{-\frac{(t-\tau)}{RC}}$$

$$V_{out} = \frac{I_0 R}{\sqrt{1 + (\omega RC)^2}} \sin\left(\omega t - \tan^{-1}(\omega RC)\right)$$



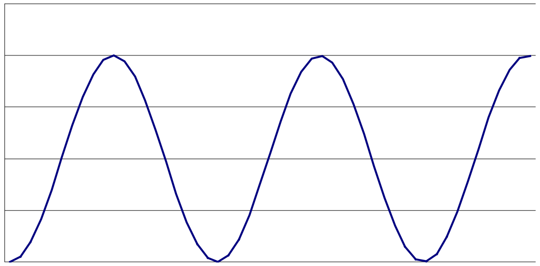
Second Order Systems

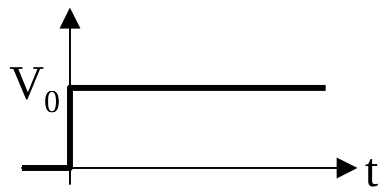
- **Circuits that combine capacitors and inductors are higher order**

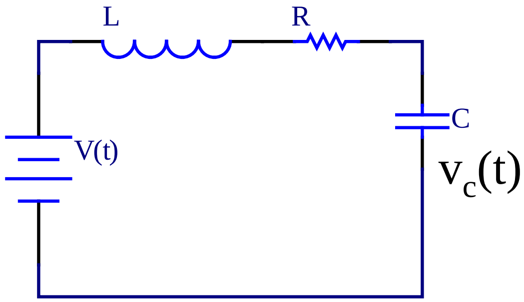


$$V_{out} = V_0\left(1 - \cos(\omega_0 t)\right)$$

$$\omega_0 = \frac{t}{\sqrt{LC}}$$

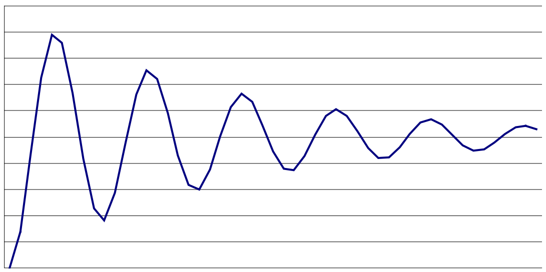






$$V_{out} \approx V_0\left(1 - \cos(\omega_0 t) \cdot e^{-\xi \cdot t}\right)$$

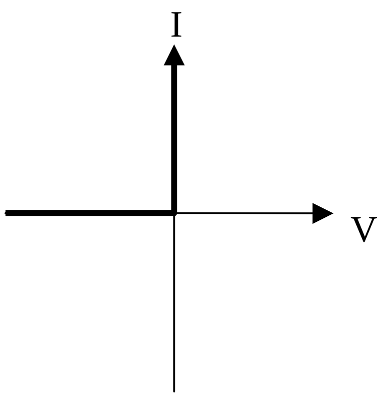
$$\omega_0 = \frac{t}{\sqrt{LC}}, \xi = \frac{R}{2L}$$

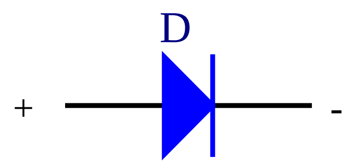


Resistor adds dampening

Diodes

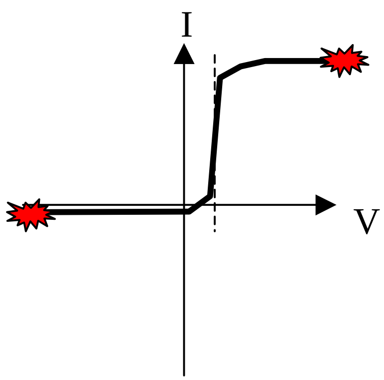
- **Ideal**





  - **Does not allow current flow when voltage is reversed**
    - **Stops all current**
  - **Allows infinite current flow when positive voltage is applied**

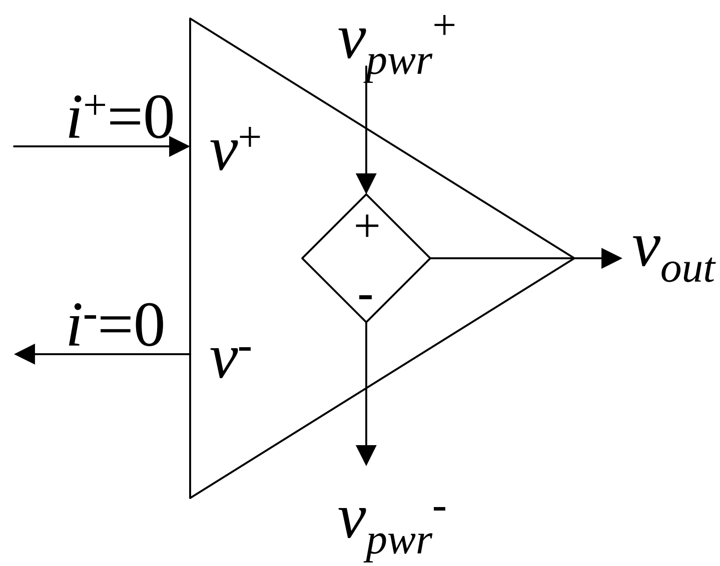
- **Real**



  - **Voltage drop: minimum voltage before current can go through**
  - **Current leak: small amount of current goes through in reverse**
  - **Maximum/Minimum voltage in both forward and reverse**
  - **Maximum current in forward**

Introduction to Operational Amplifiers

- **Utilize an "external" power source to amplify/modify an input signal**
  - **Allow the use of feedback to closely track the signal**



  - **Adjusts the output voltag V_{out} to try make v^+ and v^- be the same**
    - **The users adds elements (wires, resistors, capacitors, etc) which create current loops between the output and inputs to create feedback loops**