EE292: Fundamentals of ECE

Fall 2012
TTh 10:00-11:15 SEB 1242

Lecture 7
120918

http://www.ee.unlv.edu/~b1morris/ee292/

ENGINEERING TUTORING

Courses tutored include:

CEE – CPE – CS –EE –ME courses + much more

MATH: 181, 182, 283, 431

PHYS: 151, 152, 180, 181

General information:

- Free drop-in lab * no appt needed
- TBE – A 207L * Next door to the advising center
- Mon-Fri 12 - 5:00pm
- Sept. 4 – Dec 7, 2012
- (702) 774-4623
- UNLV student ID required

Staff

UNLV graduate & undergraduate engineering majors

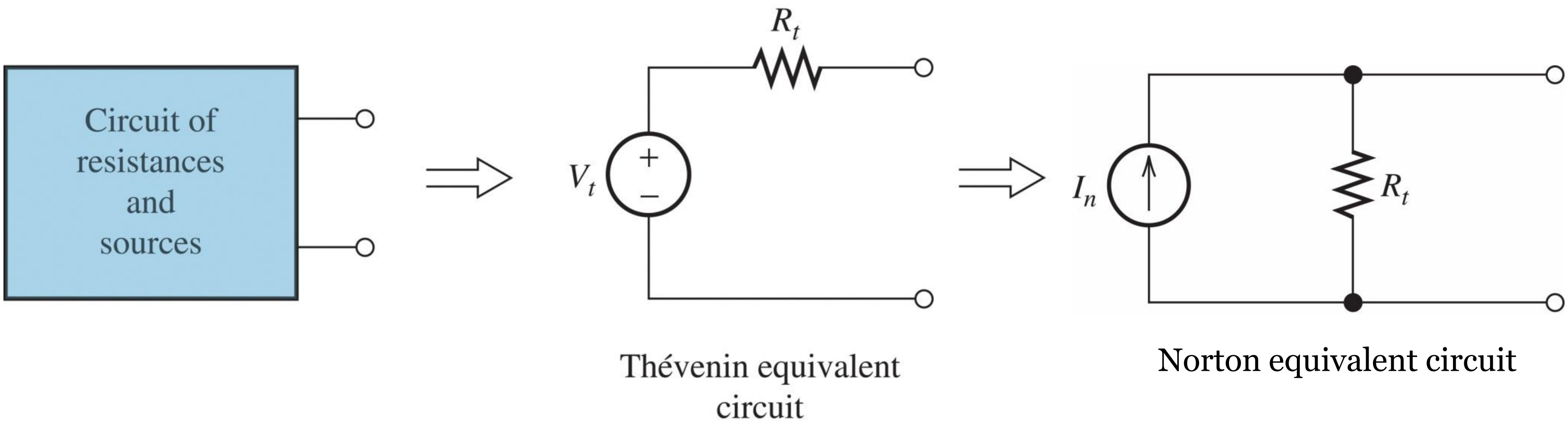
*Accepting applications for new tutors this semester *

http://academicsuccess.unlv.edu/learningsupport/Tutoring/

Outline

- Review Thevenin/Norton Equivalent Circuits
- Capacitance
- Inductance

Thevenin/Norton Equivalent Circuit



- View circuit from two terminals
  - Thevenin qquivalent circuit consists of a voltage source in series with a resistance
  - Norton equivalent circuit consists of a current source in parallel with a resistance
- We care about three things
  - Open circuit voltage
  - Short circuit current
  - Equivalent resistance (same value for both)
- It is possible to switch between Thevenin and Norton easily

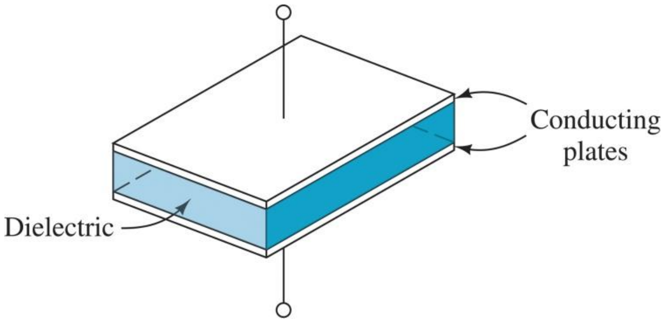
Chapter 3: Inductance & Capacitance

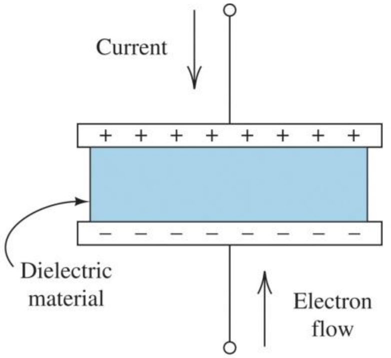
- Inductors, capacitors are energy-storage devices.
- They are passive elements because they don't generate energy
  - Only energy put in can be later extracted.

- **Capacitance:** circuit property to deal with energy in electric fields
- **Inductance:** circuit property to deal with energy in magnetic fields

Capacitance

- Capacitors are two conductors separated by a dielectric
  - Dielectric – an insulator which does not allow charge to flow through like a conductor





(a) As current flows through a capacitor, charges of opposite signs collect on the respective plates

- Charge accumulates on either side of the capacitor and creates an electric field in the dielectric.
  - A voltage forms across dielectric

Charge/Voltage Relationship

- The stored charge in a capacitor is proportional to voltage

$$q = \underbrace{C}_{\text{Capacitance with units Farads } (F) \, = \, \frac{C}{V}} v$$

- Normal range we encounter is:

$$F = [\, 1pF, \qquad 0.01\, F \,]$$

Current/Voltage Relationship

- Since $i = \frac{dq}{dt}$ and $q = Cv$

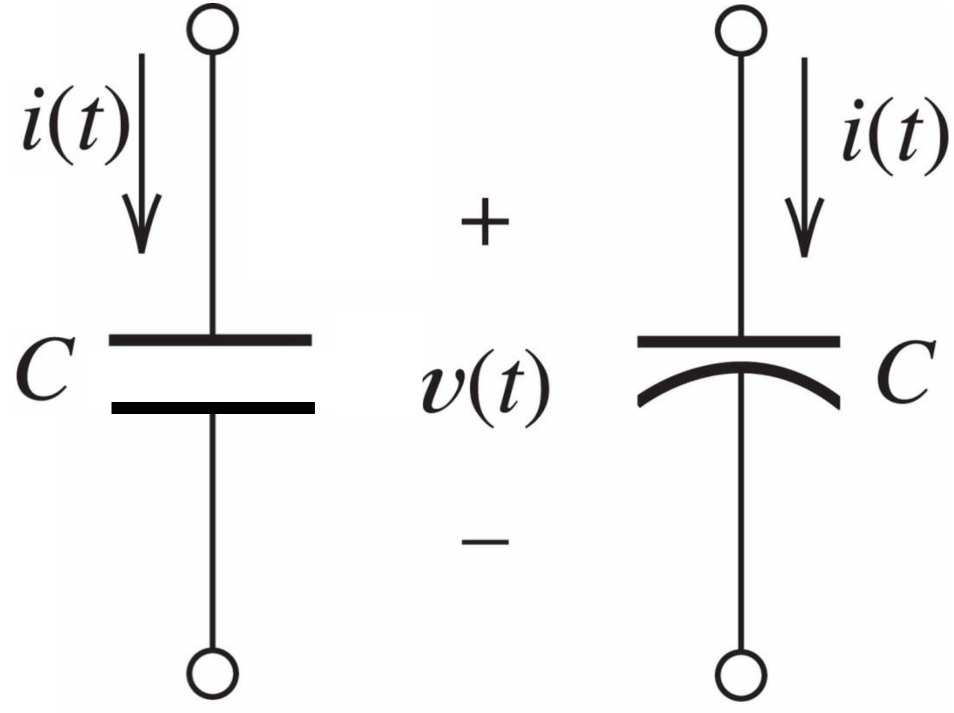
$$\frac{dq}{dt} = \frac{d}{dt}Cv \quad \Rightarrow \quad i = C\frac{dv}{dt}$$

Not a function of time

Constant voltage → no current → "open" circuit

Passive Reference Configuration

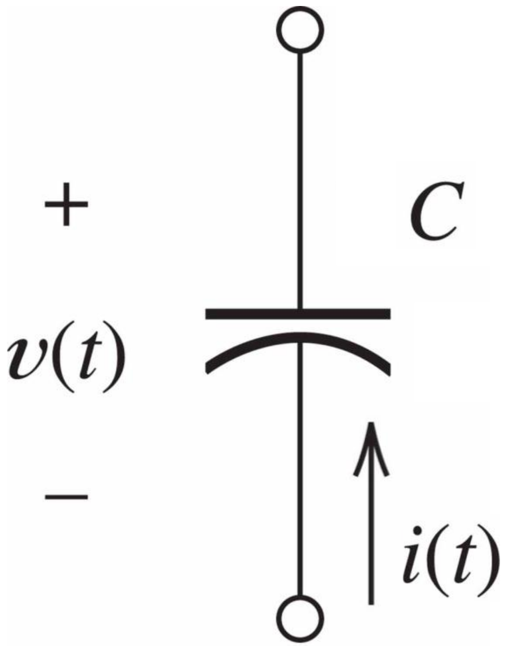
- Circuit symbol of capacitor
  - Sometimes with flat plates and other times with a curve



Curved capacitor is used for electrolytic capacitors which have explicit terminal polarity

- Flat = positive
- Curved = negative

Non-Passive Reference



Current into negative terminal

→ $i = -C\,\frac{dv}{dt}$

Voltage from Current

- Since $i = \frac{dq}{dt}$ and $q = Cv$

- $q(t) = \int i(t)\,dt = Cv$

$$\Rightarrow v = \frac{1}{C}\int i(t)\ dt$$

$$= \frac{1}{C}\int_{t_0}^{t} i(t)\ dt + \underbrace{v(t_0)}$$

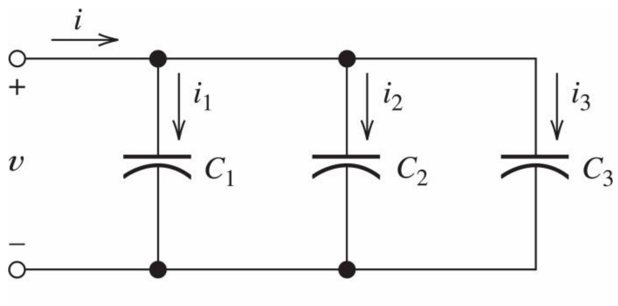
Initial voltage a time t_0

If $v(t_0) = 0 \ \Rightarrow$ capacitor uncharged

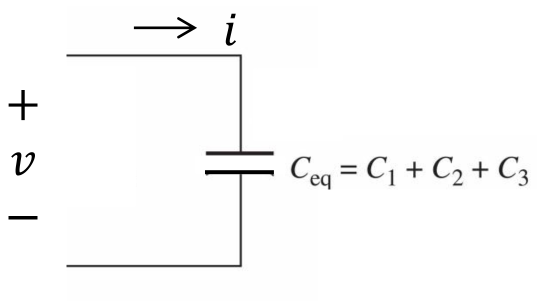
Power/Energy in a Capacitor

- In passive configuration (current into positive terminal)
- Power
  - $p(t) = v(t)\, i(t)$
  - $\quad = v(t)\, C\, \frac{dv}{dt}$
- Energy
  - $w(t) = \int_{t_0}^{t} p(t)\, dt = \int_{t_0}^{t} Cv(t)\, \frac{dv}{dt} dt$
  - $\quad = \int_{0}^{v(t)} Cv(t)\; dv$
  - $\quad = \frac{1}{2}\, Cv^2(t)$ ← for initially charged capacitor

Capacitances in Parallel



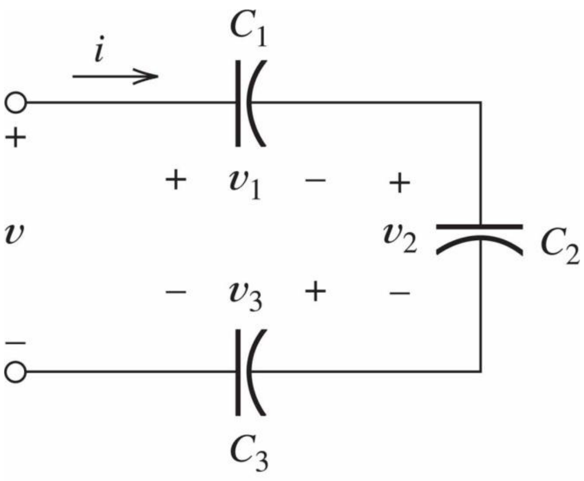
- By KCL
  - $i = i_1 + i_2 + i_3$
  - $= C_1 \frac{dv}{dt} + C_2 \frac{dv}{dt} + C_3 \frac{dv}{dt}$
  - $= \underbrace{(C_1 + C_2 + C_3)}_{C_{eq}} \frac{dv}{dt} = C_{eq} \frac{dv}{dt}$



Capacitance adds in parallel

Capacitances in Series

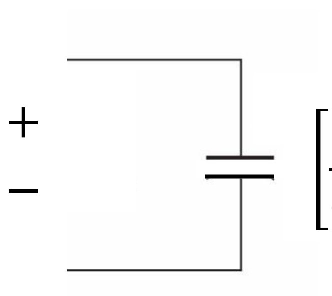
- Series connection so *i* flows through each capacitor



KVL

$$v - v_1 - v_2 - v_3 = 0$$

$$i = C_{eq}\frac{d}{dt}(v_1 + v_2 + v_3)$$
$$= C_{eq}\left(\frac{dv_1}{dt} + \frac{dv_2}{dt} + \frac{dv_3}{dt}\right)$$
$$= C_{eq}\left(\frac{i}{c_1} + \frac{i}{c_2} + \frac{i}{c_3}\right)$$
$$= iC_{eq}\left(\frac{1}{c_1} + \frac{1}{c_2} + \frac{1}{c_3}\right)$$

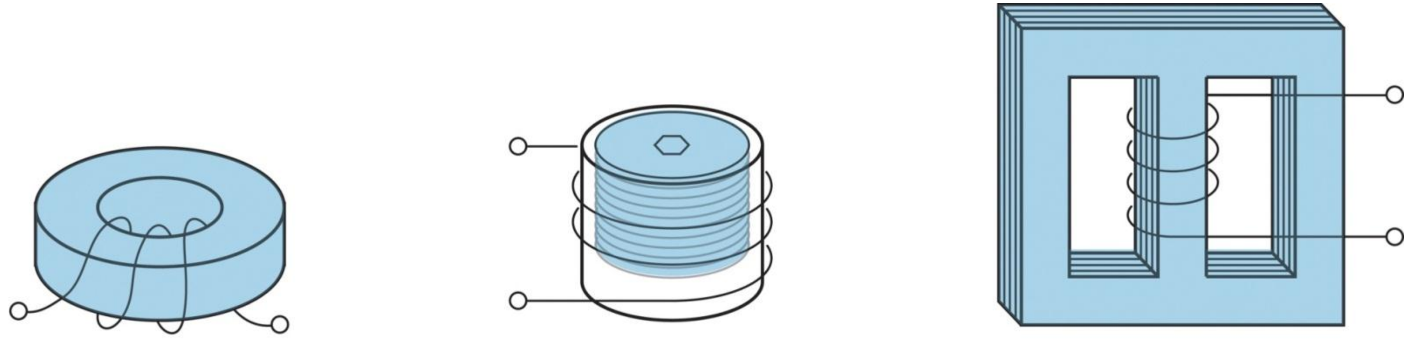


$$\left[\frac{1}{c_1} + \frac{1}{c_2} + \frac{1}{c_3}\right]^{-1}$$

$$\Rightarrow \qquad {}_{eq} = \frac{1}{\frac{1}{c_1} + \frac{1}{c_2} + \frac{1}{c_3}}$$

Inductance

- Device to store energy in a magnetic field
  - Often made from wire wrapped around a magnetic material
  - Current through the coil induces a magnetic field in the material

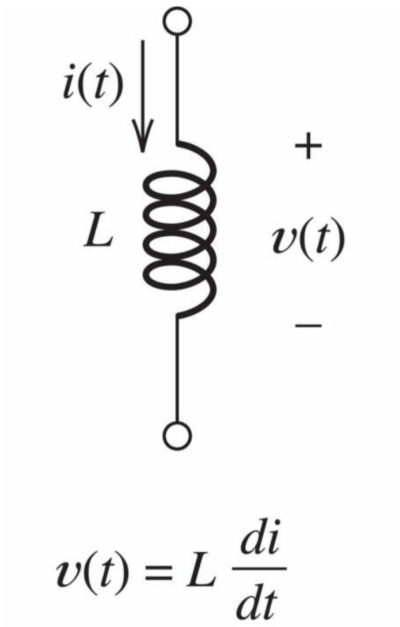


(a) Toroidal inductor

(b) Coil with an iron-oxide slug that can be screwed in or out to adjust the inductance

(c) Inductor with a laminated iron core

Inductor



- $v(t) = L\,\frac{di}{dt}$ passive reference configuration
  - Has units of henries $[H = {}^{V\,sec}/_{A}]$
  - In range μH to H

Current in terms of Voltage

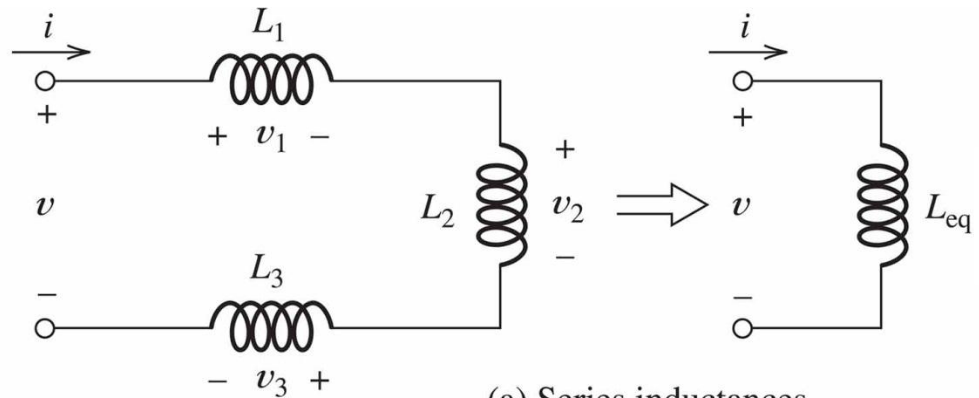
- $i(t) = \frac{1}{L}\int_{t_0}^{t} v(t)dt + \underbrace{i(t_0)}$
  - Initial current
  - If $i(t_0) = 0 \Rightarrow$ inductor stores no energy

Power/Energy in an inductor

- Power
  - $p(t) = v(t)\, i(t)$
  - $\qquad = L\,\frac{di}{dt}\, i(t)$

- Energy
  - $w(t) = \int_{t_0}^{t} p(t)\, dt = \int_{t_0}^{t} Li(t)\,\frac{di}{dt}\, dt$
  - $\qquad = \int_{0}^{i(t)} Li(t)\; di$
  - $\qquad = \frac{1}{2}\, Li^2(t)$ ← for no initial energy

Inductors in Series

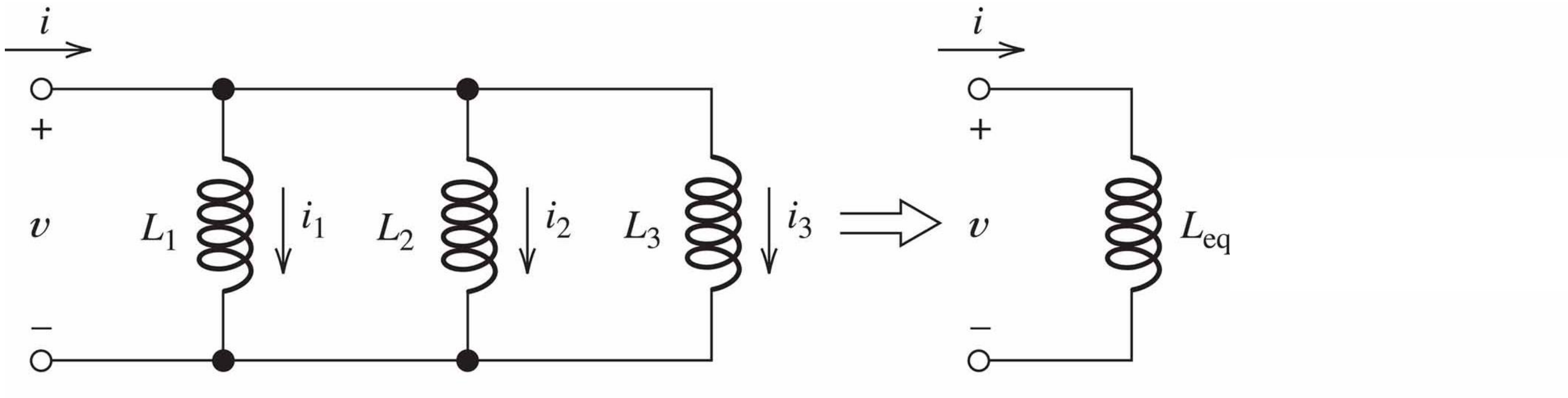


(a) Series inductances

- Using KVL
  - $v - v_1 - v_2 - v_3 = 0$
  - $v = L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + L_3 \frac{di}{dt}$
  - $= \underbrace{(L_1 + L_2 + L_3)}_{L_{eq}} \frac{di}{dt} = L_{eq} \frac{di}{dt}$

Inductors add in series (like resistors)

Inductors in Parallel



(b) Parallel inductances

$$v = L_{eq}\frac{di}{dt} = L_{eq}\frac{d}{dt}(i_1 + i_2 + i_3)$$
$$= L_{eq}\left(\frac{di_1}{dt} + \frac{di_2}{dt} + \frac{di_3}{dt}\right)$$
$$= L_{eq}\left(\frac{i}{vL_1} + \frac{i}{vL_2} + \frac{i}{vL_3}\right)$$
$$= vL_{eq}\left(\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}\right)$$

$$i = i_1 + i_2 + i_3$$

$$v = L_1\frac{di_1}{dt} = L_2\frac{di_2}{dt} = L_3\frac{di_3}{dt}$$

$$\Rightarrow L_{eq} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}}$$