## Lecture \#12

## ANNOUNCEMENTS

- Graduate school workshop tomorrow (9/23)
- 3-4 PM, Wozniak Lounge (Soda Hall)


## OUTLINE

- Capacitors in series and in parallel
- Practical capacitors
- The inductor
- Inductors in series and in parallel


## Reading

Chapter 6.1-6.3

## Correction to Lecture 9, Slide 3

- If there are no independent sources in a circuit, $\boldsymbol{V}_{\mathrm{Th}}=0$.
- If there are dependent sources in the circuit, we need to apply an external voltage in order to determine $\boldsymbol{R}_{\mathrm{Th}}$.
Example: Circuit used in $R_{\text {Th }}$ Calculation Example \#2, Lecture 8:


Definition of $\mathbf{i}_{\Delta}: i_{\Delta}=\frac{-V_{x}}{80}$

$$
\} \Rightarrow V_{x}=\frac{8}{25} V_{\text {TEST }}
$$



## Capacitors in Parallel



Equivalent capacitance of capacitors in parallel is the sum


## Capacitive Voltage Divider

Q: Suppose the voltage applied across a series combination of capacitors is changed by $\Delta v$. How will this affect the voltage across each individual capacitor?


Note: Capacitors in series have the same charge.
EECS40, Fall 2003

## Application Example: MEMS Accelerometer

- Capacitive position sensor used to measure acceleration (by measuring force on a proof mass)


FIXED OUTER PLATES

## Sensing the Differential Capacitance

- Fixed electrodes are biased at $+V_{s}$ and $-V_{s}$
- Movable electrode (proof mass) is biased at $V_{0}$


## Circuit model



## Practical Capacitors

- A capacitor can be constructed by interleaving the plates with two dielectric layers and rolling them up, to achieve a compact size.

- To achieve a small volume, a very thin dielectric with a high dielectric constant is desirable. However, dielectric materials break down and become conductors when the electric field (units: V/cm) is too high.
- Real capacitors have maximum voltage ratings
- An engineering trade-off exists between compact size and high voltage rating


## The Inductor

- An inductor is constructed by coiling a wire around some type of form.

(a) Toriodal inductor

(b) Coil with an iron-oxide slug that can be screwed in or out to adjust the inductance
 iron core
he coil creates a magnetic field or flux that links the coil: $L i_{L}$
- When the current changes, the magnetic flux changes $\rightarrow$ a voltage across the coil is induced:

Note: In "steady state" (dc operation), time derivatives are zero $\rightarrow L$ is a short circuit

$$
v_{L}(t)=L \frac{d i_{L}}{d t}
$$

## Symbol:

$\qquad$
$L$
Units: Henrys (Volts • second / Ampere)
(typical range of values: $\mu \mathrm{H}$ to 10 H )
Current in terms of voltage:
$d i_{L}=\frac{1}{L} v_{L}(t) d t$
$i_{L}(t)=\frac{1}{L} \int_{t_{0}}^{t} v_{L}(\tau) d \tau+i\left(t_{0}\right)$


Note: $i_{L}$ must be a continuous function of time

## Stored Energy

Consider an inductor having an initial current $i\left(t_{0}\right)=i_{0}$

$$
\begin{aligned}
& p(t)=v(t) i(t)=L i(t) \frac{d i}{d t} \\
& w(t)=\int_{t_{0}}^{t} p(\tau) d \tau=\int_{i_{0}}^{i} L l \frac{d v}{d \tau} d \tau=\int_{i_{0}}^{i} L t d l \\
& w(t)=\frac{1}{2} L i^{2}-\frac{1}{2} L i_{0}{ }^{2}
\end{aligned}
$$

## Inductors in Series



Equivalent inductance of inductors in series is the sum


## Summary



