Georgia Institute of Technology

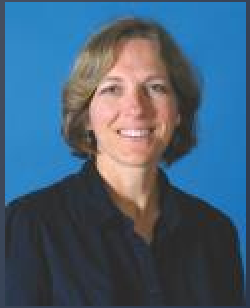
Introduction to Electronics

An introduction to electronic components and a study of circuits containing such devices.

School of Electrical and Computer Engineering

Week 1: Review

Georgia Institute of Technology



Review of Circuit Elements

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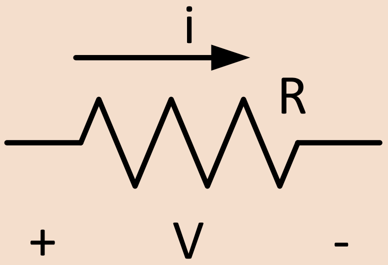
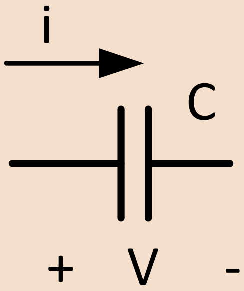
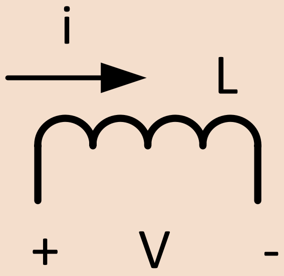
Review linear circuit components and properties

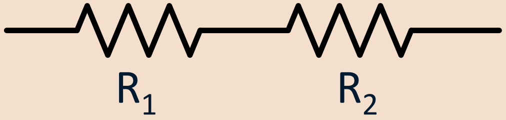
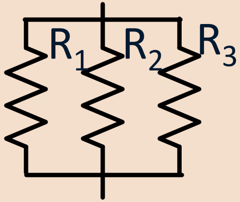
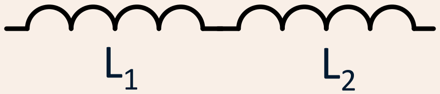
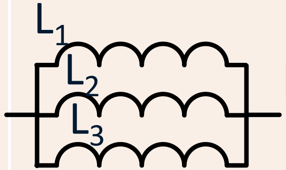
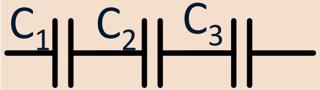
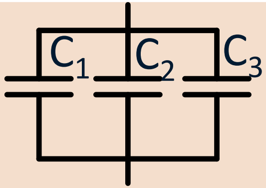
Lesson Objectives

- Review
  - Resistors, capacitors, inductors
    - i-v characteristics of these elements
  - Sources, nodes

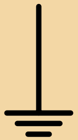
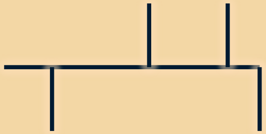
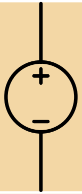
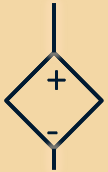
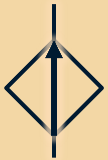
Passive Elements

Resistor	Capacitor	Inductor
		
$V = iR$	$i = C\frac{dV}{dt}$	$V = L\frac{di}{dt}$

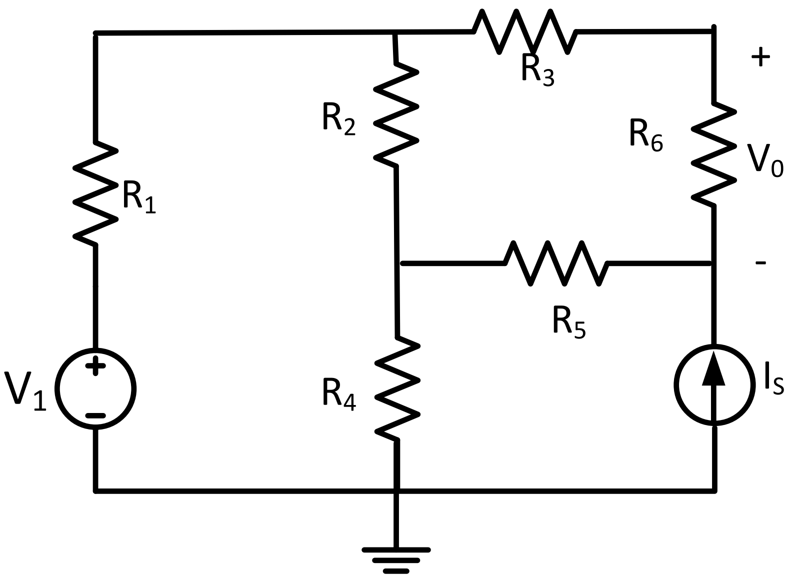
Series and Parallel Connections

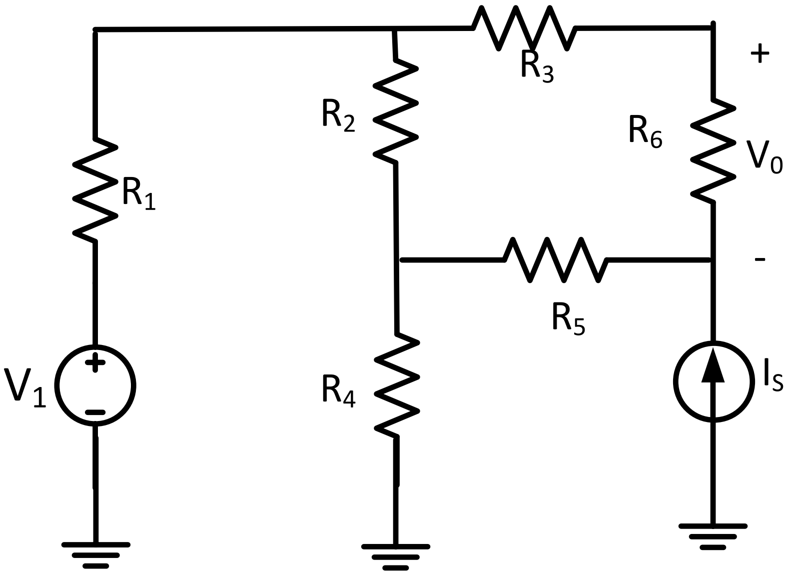
	Series	Parallel
Resistors	 $R = R_1+R_2$	 $R = \dfrac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}}$
Inductors	 $L = L_1+L_2$	 $L = \dfrac{1}{\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{L_3}}$
Capacitors	 $C = \dfrac{1}{\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}}$	 $C = C_1+C_2+C_3$

Connections and Sources

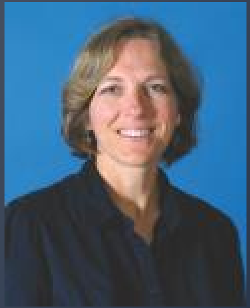
Ground	 Reference for 0 volts
Node	 Voltage level the same everywhere on the node
Voltage Source	Independent  Dependent 
Current Source	Independent  Dependent 

Circuit Connections





Review of Kirchoff’s Laws



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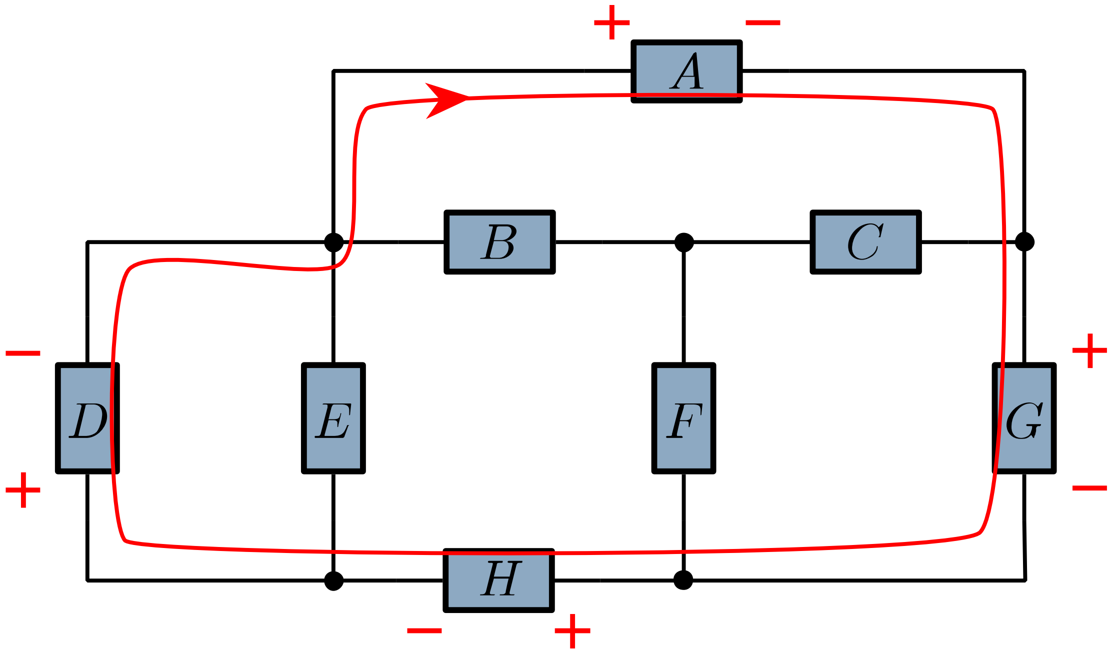
Review of KVL and KCL

Lesson Objectives

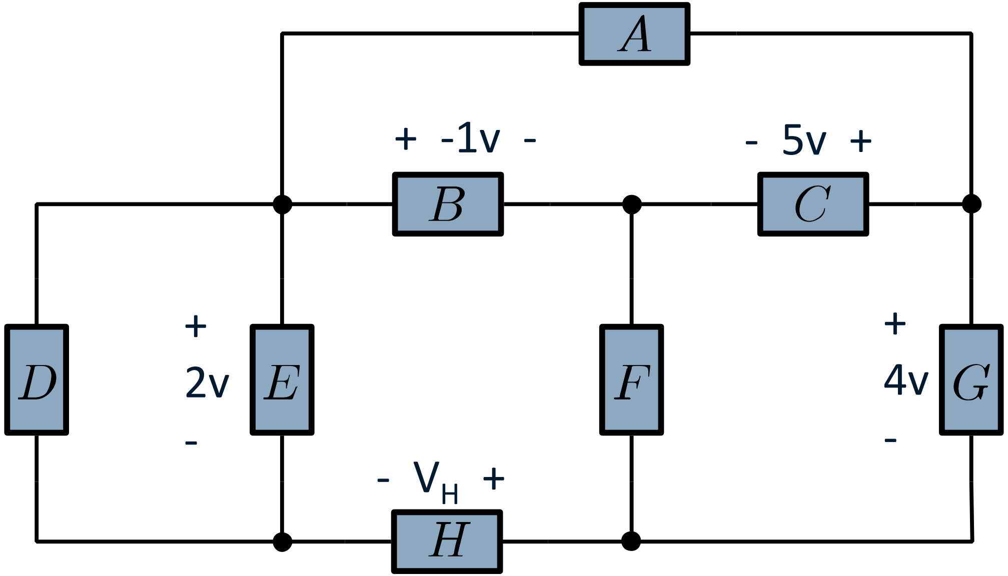
- Review
  - Kirchhoff's Current Law (KCL)
  - Kirchhoff's Voltage Law (KVL)

Kirchhoff's Voltage Law (KVL)

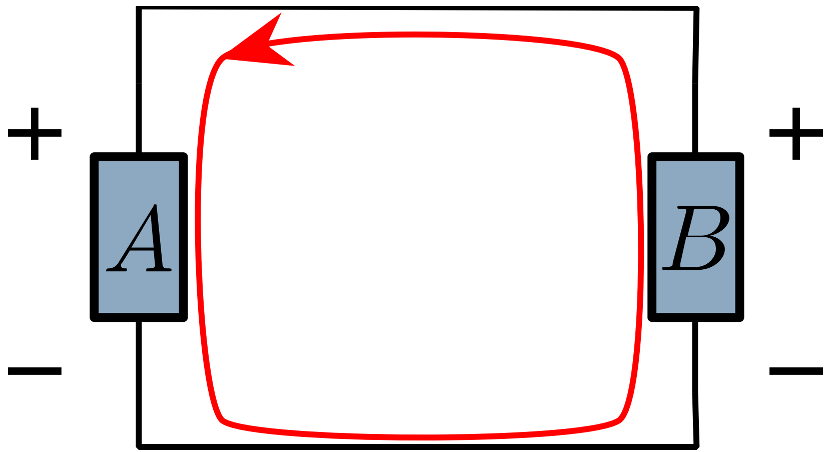


The sum of voltages around any closed loop is zero.

KVL Quiz

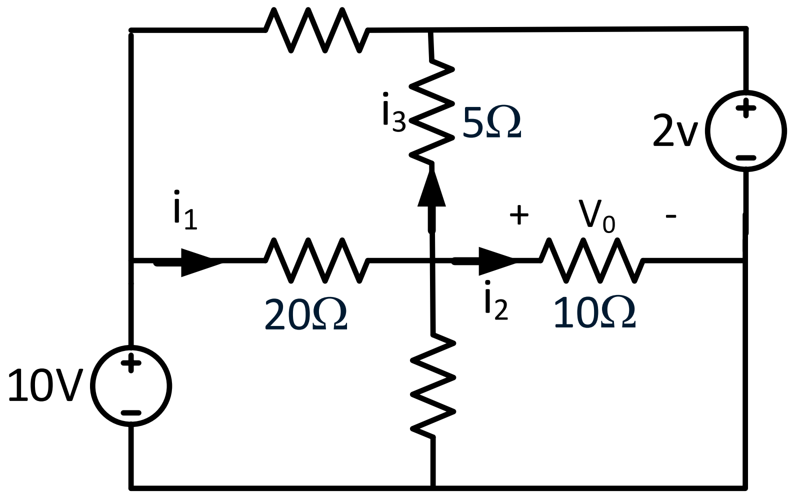


KVL and Parallel Circuits

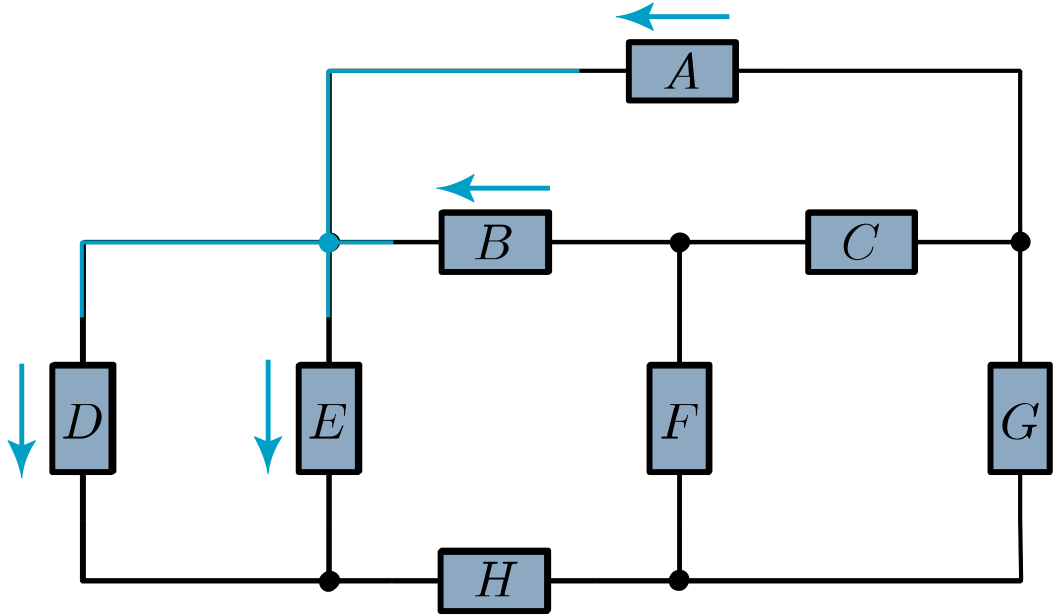


$$v_A - v_B = 0$$
$$v_A = v_B$$

KVL Example

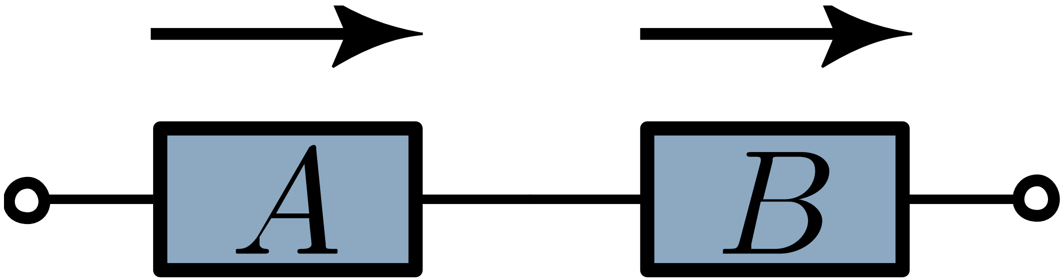


Kirchhoff's Current Law (KCL)



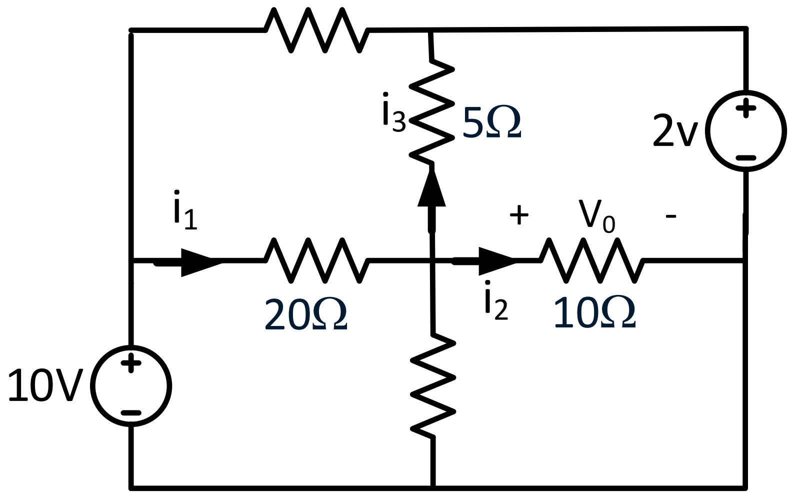
$$\sum i_{entering} = \sum i_{leaving}$$

KCL and Series Circuits



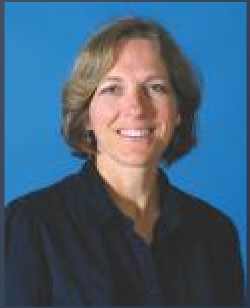
$$i_A = i_B$$

KCL Example



Summary

- Introduced KVL and KCL
- Applied KVL to parallel elements
- Applied KCL to series elements
- Solved a simple circuit using Kirchhoff's Laws



Review of Impedance

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Review of Impedance for Analyzing AC Circuits

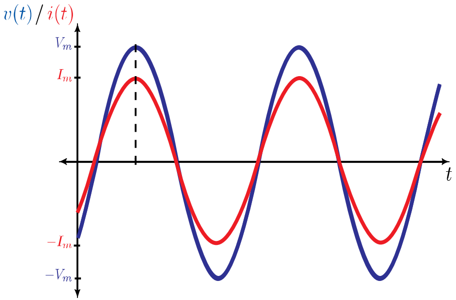
Lesson Objectives

- Review
  - Impedances for steady-state sinusoidal inputs (AC)

Impedances

R

$$Z_R = R$$

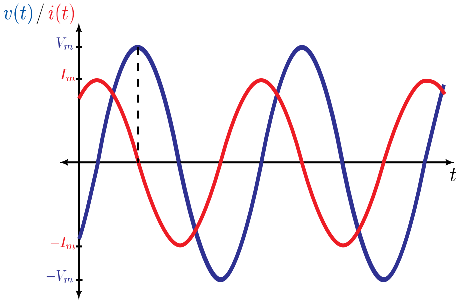


In-phase

Frequency invariant

C

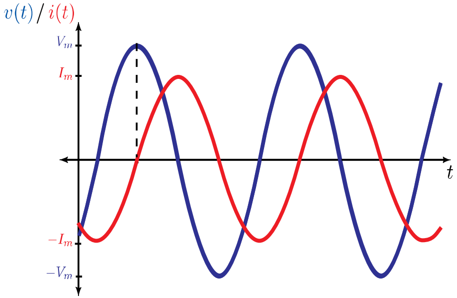
$$Z_C = \frac{1}{j\omega C}$$



Current leads voltage

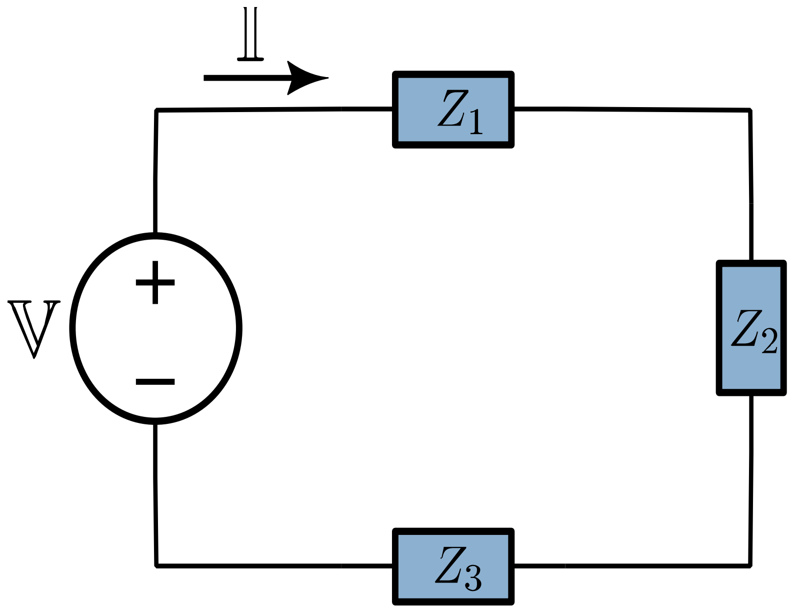
L

$$Z_L = j\omega L$$



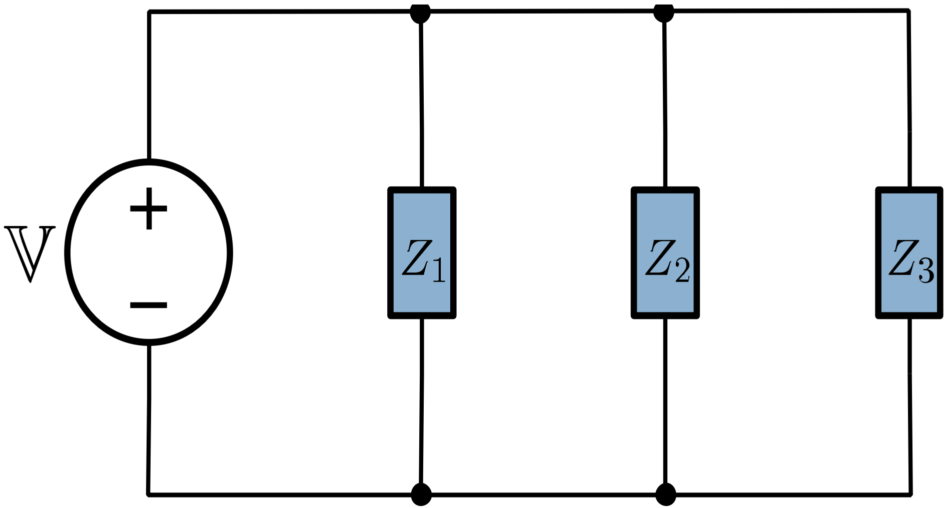
Current lags voltage

Impedances in Series



$$Z_{\mathrm{cq}} = \sum_i Z_i$$

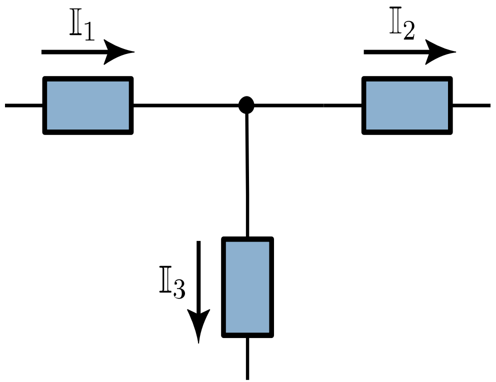
Impedances in Parallel

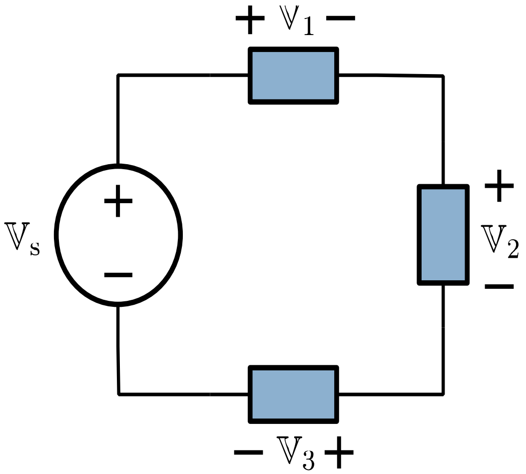


$$Z_{\text{eq}} = \left[\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right]^{-1}$$

$$Z_{\text{eq}} = \left[\sum_i \frac{1}{Z_i}\right]^{-1}$$

Kirchhoff's Laws

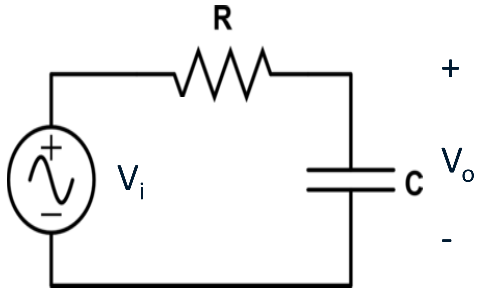




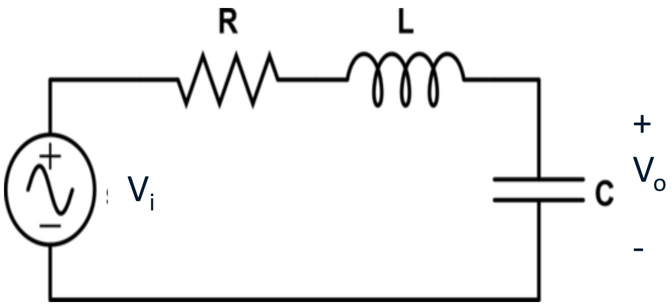
$$\mathbb{I}_1 = \mathbb{I}_2 + \mathbb{I}_3$$

$$\mathbb{V}_s = \mathbb{V}_1 + \mathbb{V}_2 + \mathbb{V}_3$$

Series RC



Series RLC



Summary

- Introduced KVL and KCL
- Applied KVL to parallel elements
- Applied KCL to series elements
- Solved a simple circuit using Kirchhoff's Laws

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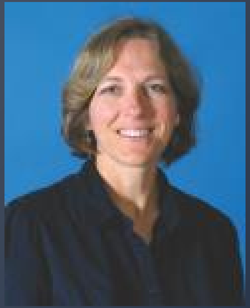

Review of Transfer Functions

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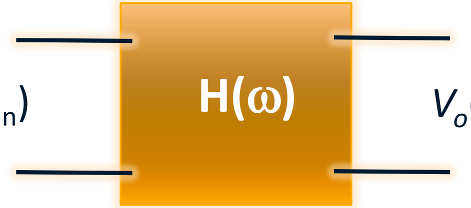
Review of transfer functions for characterizing circuits

Lesson Objectives

- Review transfer functions
  - To characterize a circuit
  - To find frequency response curves

Transfer Function Two-Port Networks

$V_i(t) = A_{in}\cos(\omega t + \theta_{in})$



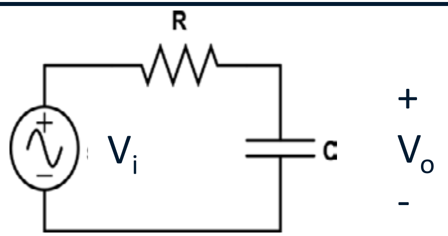
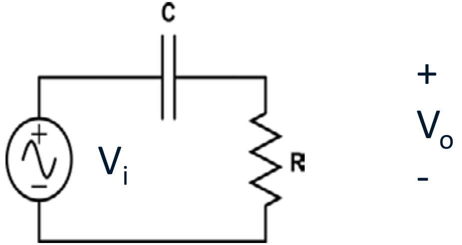
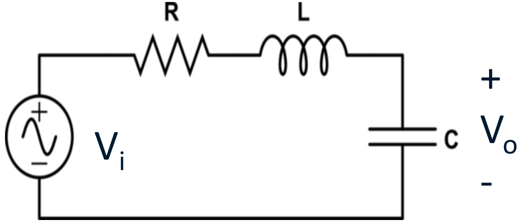
$V_o(t) = A_{out}\cos(\omega t + \theta_{out})$

$$H(\omega)V_i = V_o$$

$$H(\omega)A_{in}\angle\theta_{in} = A_{out}\angle\theta_{out}$$

$$A_{out} = |H(\omega)|A_{in} \qquad \theta_{out} = \angle H(\omega) + \theta_{in}$$

Summary of Simple Circuits

	$$H(\omega)=\frac{1}{1+RC\omega j}$$
	$$H(\omega)=\frac{RC\omega j}{1+RC\omega j}$$
	$$H(\omega)=\frac{1}{1-\omega^2 LC+RC\omega j}$$

Summary

- Defined transfer function for Two-Port Networks
  - Showed transfer functions of simple circuits

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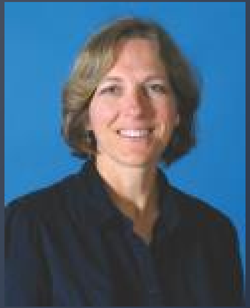

Review of Frequency Response Plots (Bode)

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Review of linear plots and Bode plots to show the frequency characteristics of signals and circuits

School of Electrical and Computer Engineering

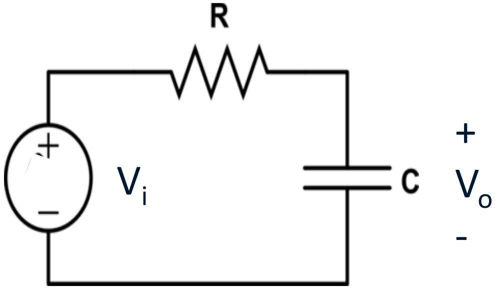
Lesson Objectives

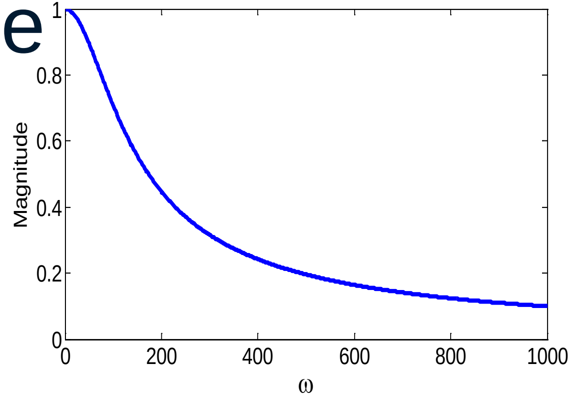
- Define the frequency response for a transfer function $H(\omega)$

Magnitude Plot: $|H(\omega)|$ vs ω
Angle Plot: $\angle H(\omega)$ vs ω

- Show linear plots and Bode plots

Frequency Response



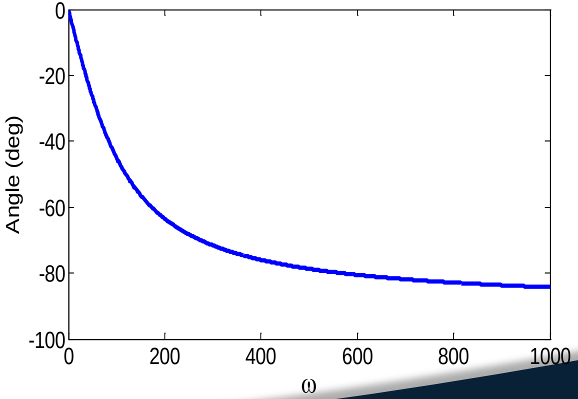


Transfer Function

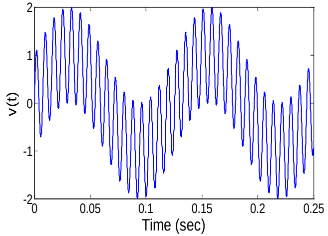
$$H(\omega) = \frac{1}{1 + RC\omega j}$$

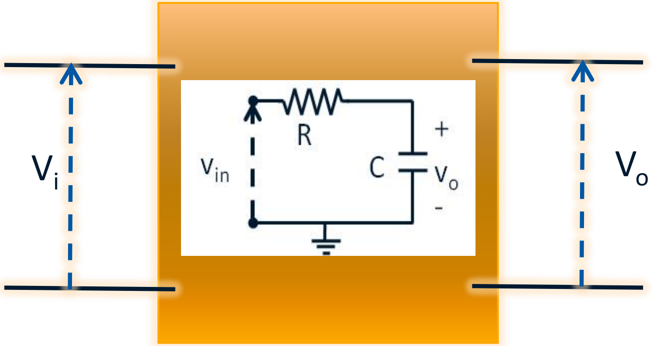
$$|H(\omega)| = \frac{1}{\sqrt{1 + (RC\omega)^2}}$$

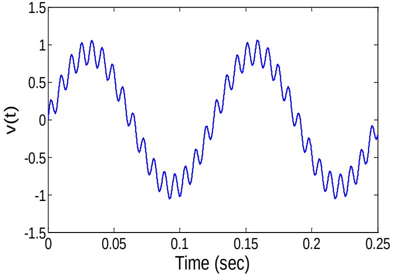
$$\angle H(\omega) = -\mathrm{atan}(RC\omega)$$



Circuit Response

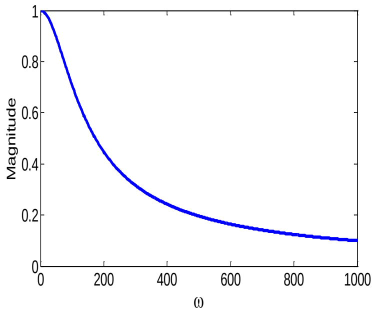


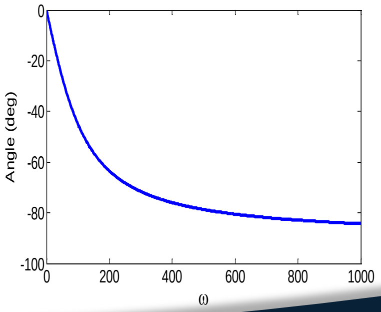




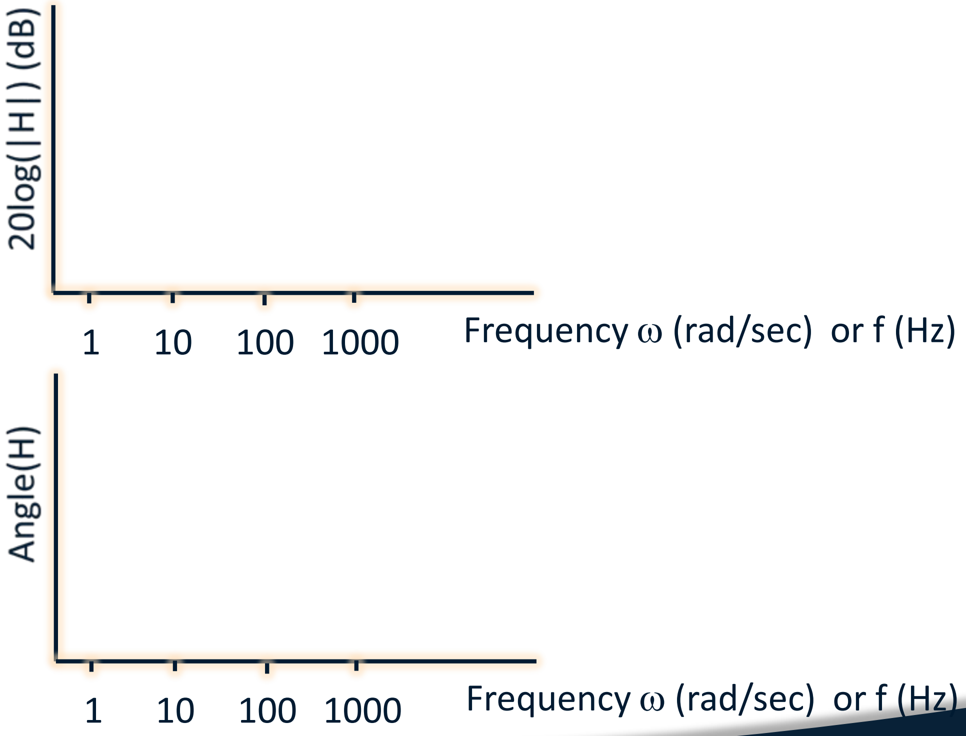
$V_i = \cos(50t) + \cos(800t)$

$V_o = 0.95\cos(50t\text{-}20^o) + 0.13\cos(800t\text{-}85^o)$

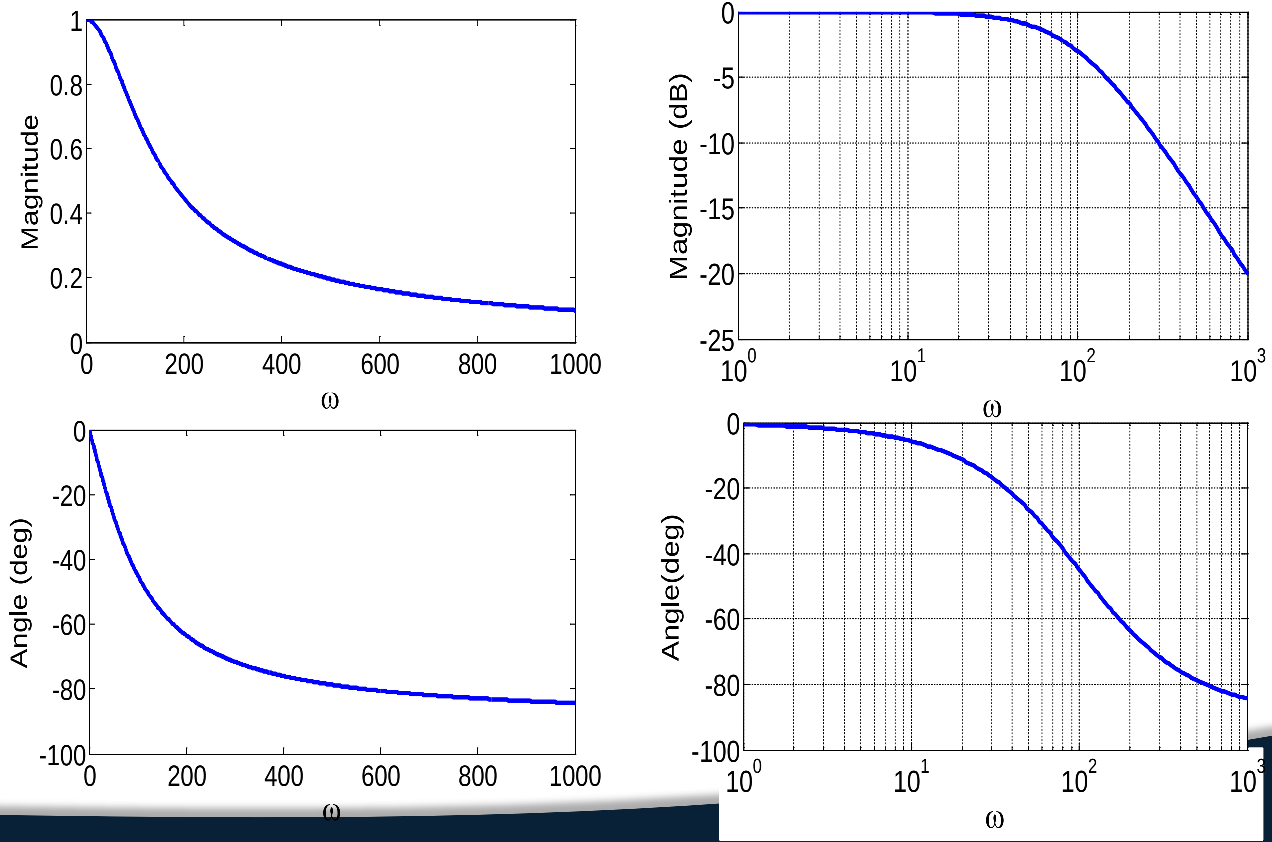




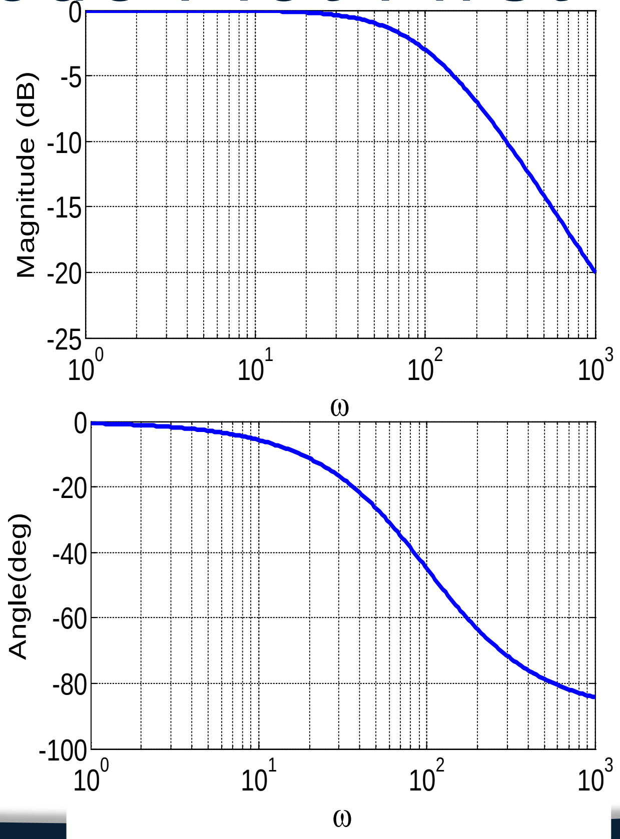
Bode Plots


20log(|H|) (dB)
1
10
100
1000
Frequency ω (rad/sec) or f (Hz)
Angle(H)
1
10
100
1000
Frequency ω (rad/sec) or f (Hz)

Linear Plot and Bode Plot



Bode Plot First-Order Characteristics

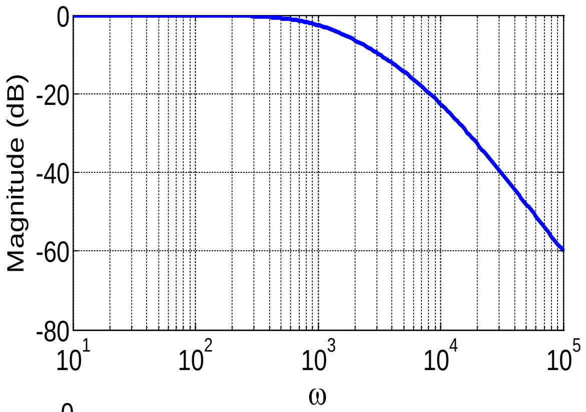


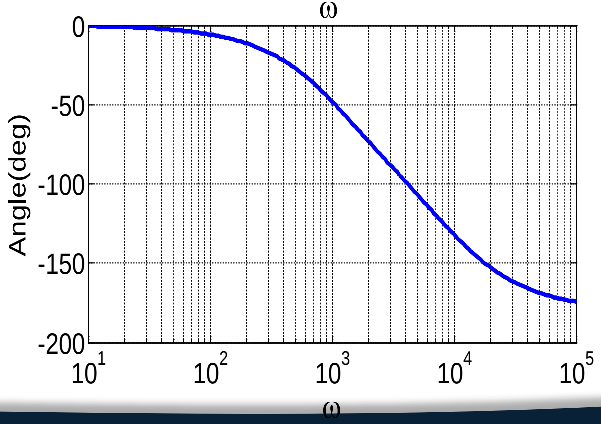
$$H(\omega) = \frac{1}{1 + j\omega RC}$$

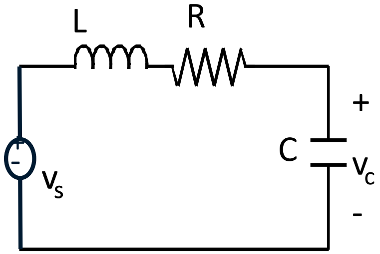
$$\left|H(\omega)\right| = \frac{1}{\sqrt{1 + (\omega RC)^2}}$$

$$\angle H(\omega) = -a\tan(\omega RC)$$

Bode Plot of RLC Circuit, Overdamped

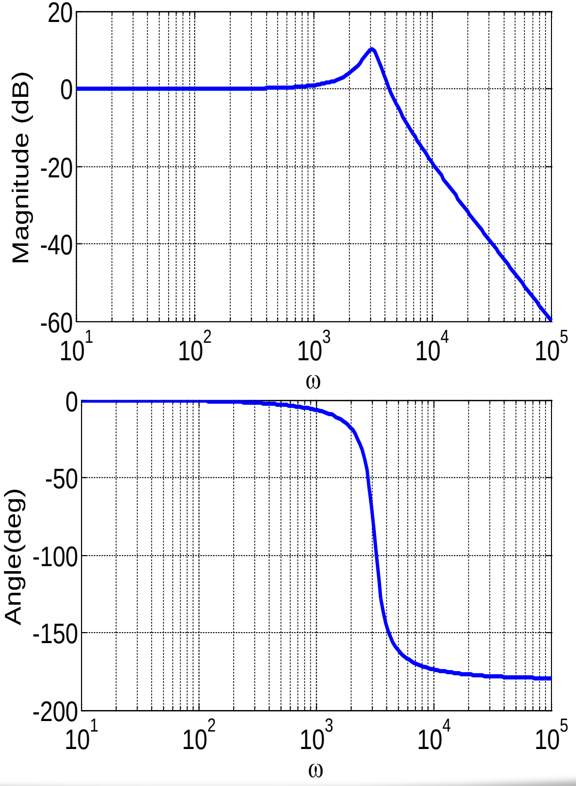






$$H(\omega) = \frac{1}{(1 - LC\omega^2) + RCj\omega}$$

Bode Plot of RLC Circuit, Underdamped



Summary

- A **frequency response** is a plot of the transfer function versus frequency
- The frequency response can be used to determine the steady-state sinusoidal response of a circuit at different frequencies