Impedance Basics

Last updated 4/26/22

Impedance Basics

- Impedance
  - Combination of Resistance and Reactance
  - $Z = \sqrt{R^2 + X^2}$
- Resistance
  - R
  - Resists current flow
    - Not dependent on changes in voltage or current
- Reactance
  - X
  - Opposes a change in current or voltage
  - Depends on the frequency of the changes

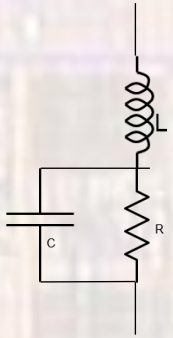
Impedance Basics

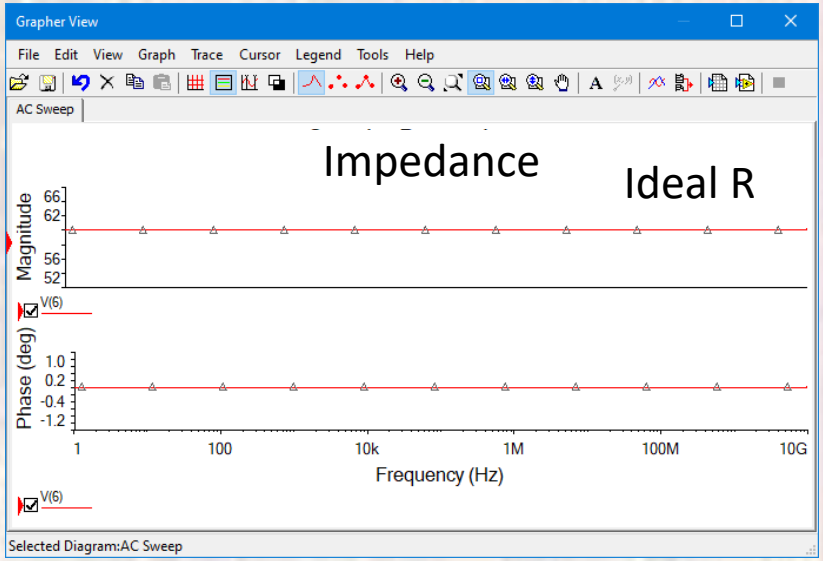
- Bode Plot
  - Magnitude/Phase vs Frequency
  - Magnitude measured in dB
    - dB → 20log(value)
    - 100V → 20log(100) = 40dbV
    - gain = 10,000 → 20log(10,000) = 80dB
    - 20mA → 20log(20mA) = -33.98dBA

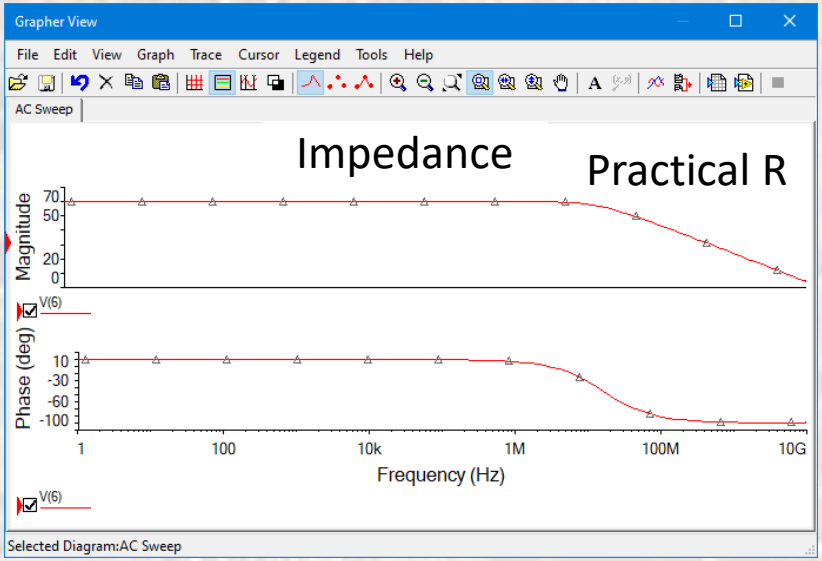
Impedance Basics

- Resistor

  - R = V/I
  - No frequency dependence (in theory)
    - Real resistors have parasitic components

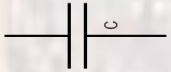






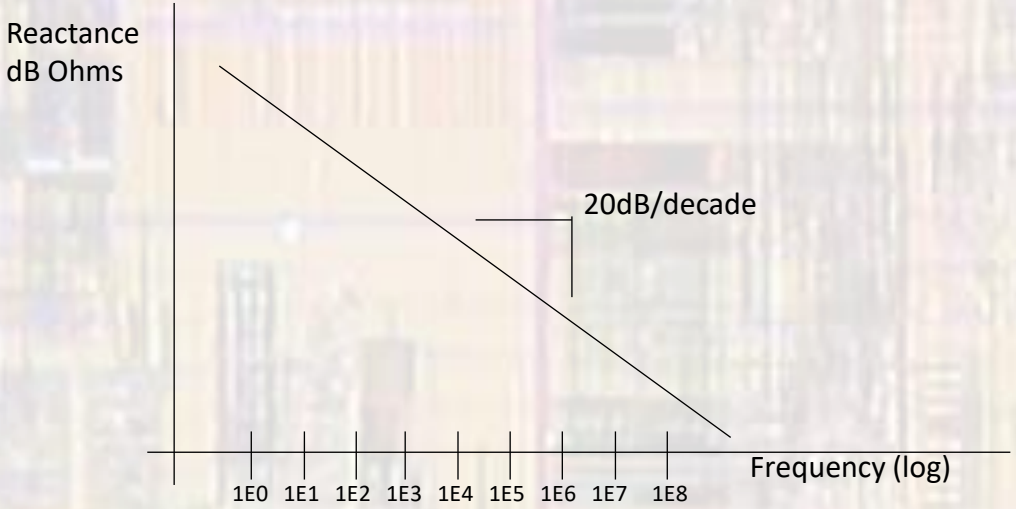
Impedance Basics

- Capacitor



  - $I = C\frac{dv}{dt}$
  - $X_C = \frac{1}{j\omega C} = \frac{1}{j2\pi f C}$
  - $|X_C| = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

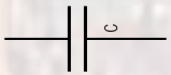
C(F)	Frequency (Hz)	Reactance (Ohms)	Reactance (dBOhms)
1.00E-06	1.00E+00	159155.0775	104
	1.00E+01	15915.50775	84
	1.00E+02	1591.550775	64
	1.00E+03	159.1550775	44
	1.00E+04	15.91550775	24
	1.00E+05	1.591550775	4
	1.00E+06	0.159155078	-16
	1.00E+07	0.015915508	-36
	1.00E+08	0.001591551	-56
	1.00E+09	0.000159155	-76



Note: 20dB reduction in reactance per decade of frequency

Impedance Basics

- Capacitor



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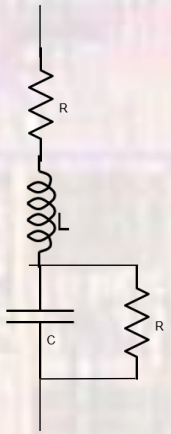
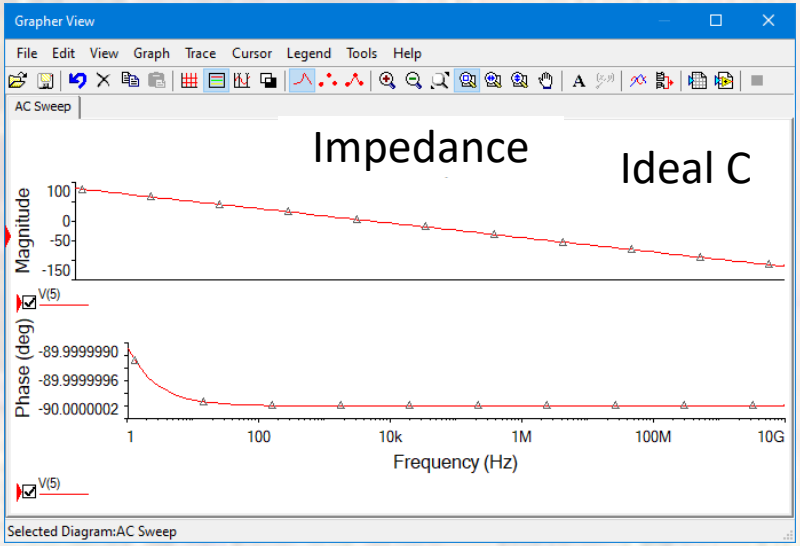
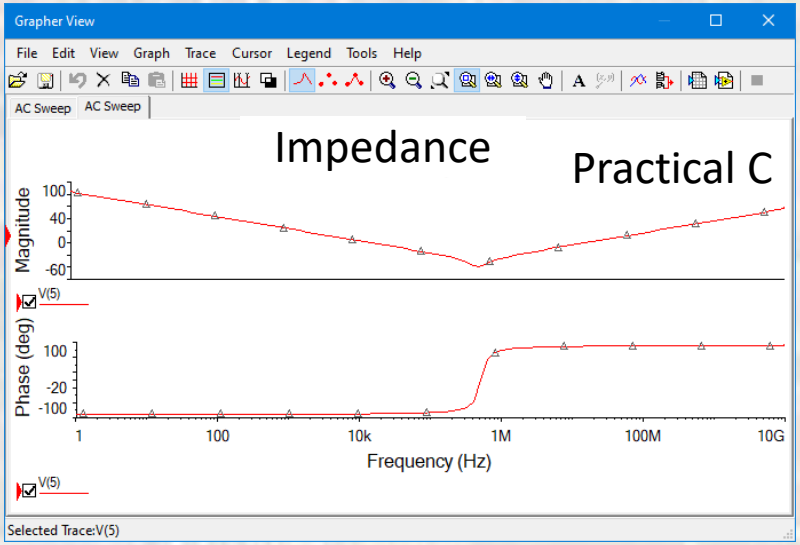
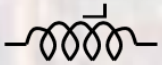


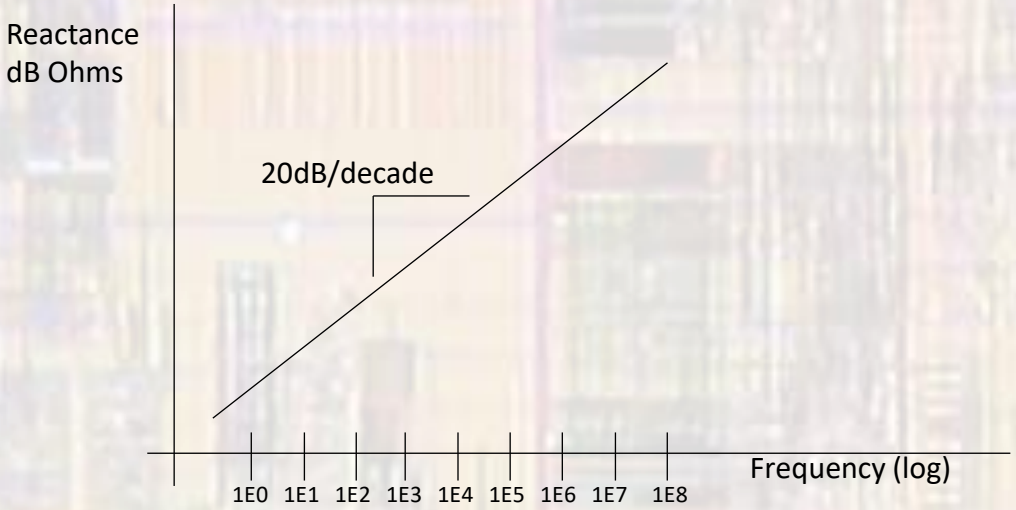




Impedance Basics

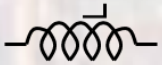
- Inductor 
  - $V = -L\frac{di}{dt}$
  - $X_L = j\omega L = j2\pi f L$
  - $|X_L| = \omega L = 2\pi f L$

L(H)	Frequency (Hz)	Reactance (Ohms)	Reactance (dBOhms)
1.00E-03	1.00E+00	6.28E-03	-44
	1.00E+01	6.28E-02	-24
	1.00E+02	6.28E-01	-4
	1.00E+03	6.28E+00	16
	1.00E+04	6.28E+01	36
	1.00E+05	6.28E+02	56
	1.00E+06	6.28E+03	76
	1.00E+07	6.28E+04	96
	1.00E+08	6.28E+05	116
	1.00E+09	6.28E+06	136



Note: 20dB increase in reactance per decade of frequency

Impedance Basics

- Inductor 
  - $V = -L\frac{di}{dt}$
  - $|X_L| = \omega L = 2\pi f L$