SIERRA COLLEGE	MECH 10 - Lab 16 Resonant Filters	Mechatronics Real Skills Real Jobs
Name: Cayce Beames Date: November 17, 2019 Professor Steven Gillette		

Abstract

In this course, I used the circuit modeling software Electronics Workbench to model and analyze two AC circuits with inductive and capacitive reactant components and compare the modeled circuit to the same physical circuit using the discrete components, a function generator, and a digital oscilloscope.

Learning Objectives

- Simulate and test circuits using circuit analysis software
- Create Bode plots of RLC frequency performance
- Build and analyze band pass filter performance
    - Cutoff frequency
    - Bandwidth

Notes:

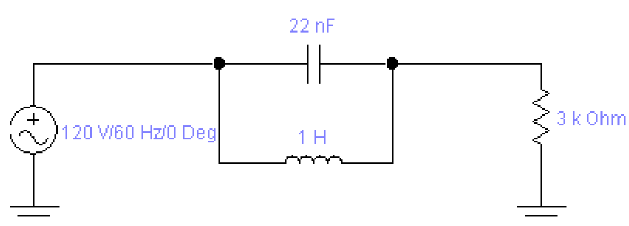
1. Took all voltage measurements relative to ground (unless otherwise stated)
2. Recorded relevant measurements and calculation results in data tables
3. Recorded all measured values on the circuit schematics
4. Used all available precision in calculations, round off answers to 3 significant figures

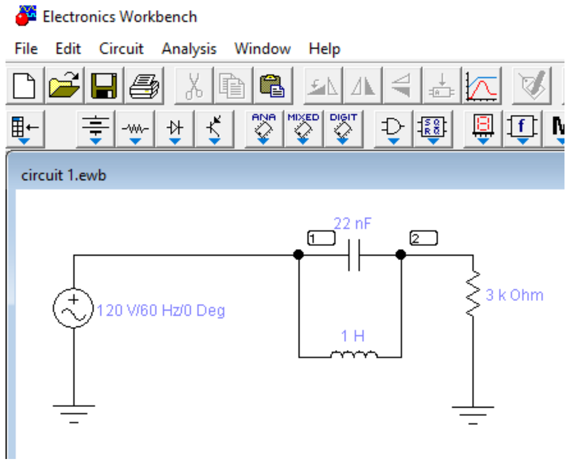
Materials

Quantity	Description
	Circuit 1
1	PC w Electronic Workbench & printer
	Circuit 2
1	Capacitor, 0.022µF, measured: 0.02µ
1	Inductor, 50 mH, measured: 51mH
1	Resistor, 470Ω, measured, 462.3Ω
1	Global Specialties Trainer
1	Digital oscilloscope

Procedure – Circuit 1

1. Built Circuit 1 in Electronic Workbench. Set component values by right clicking the resistor, capacitor, and inductor to set the resistance, capacitance and inductance values.
2. Connected an AC voltage source to the circuit. The circuit should look like the illustration below.





3. From the menu bar, chose ***Circuit – Schematic Options – Show Nodes***
4. From the menu bar, chose ***Analyze – AC Frequency***.
    a. Set the frequency range for 20Hz to 20kHz.
    b. Set the sweep type to Decade.
    c. Set the number of points to 100.
    d. Set the vertical scale to Linear.
    e. Added the output node, marked above in the screenshot as node 2 located between the inductor and the load resistor.
5. Selected Simulate to produce the response graph. Added gridlines before **printing** the Bode plot. See Attachment A – Circuit 1 Bode plot.
6. Circled the two half-power points (70.7%) on the Bode Plot. Recorded the frequencies as f_{COhigh} & f_{COlow} on the Bode plot. Had the instructor or lab technician ***review and approve*** the Bode plot markup.

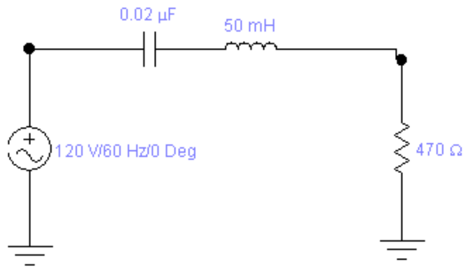
   See Appendix C for signature

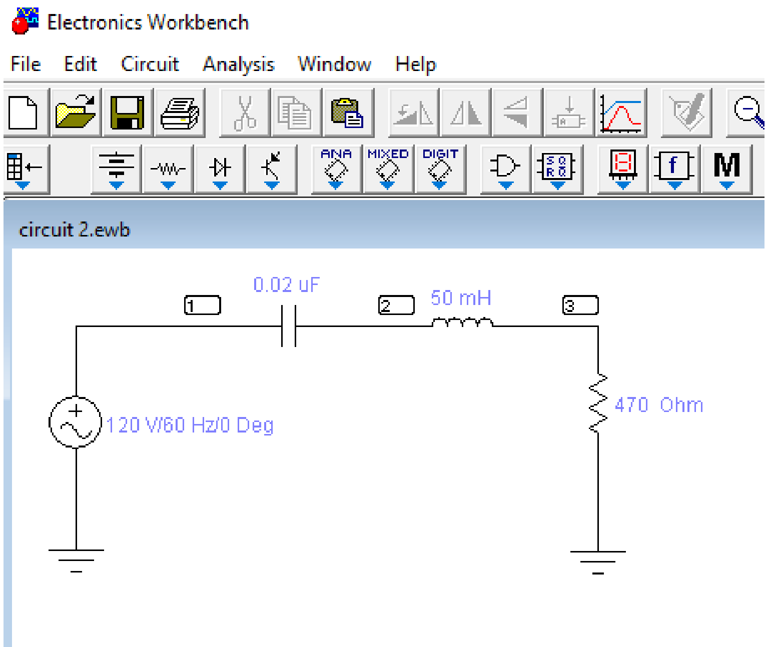
7. ***Calculated and recorded*** the bandwidth of this circuit using the ***Bandwidth*** formula.
8. ***Calculated and recorded*** the resonant frequency for circuit 1 using the *Resonant Frequency* formula.
9. ***Calculated and recorded*** X_L & X_C at resonant frequency using the *Inductive and Capacitive Reactance* formulas

Procedure – Circuit 2

10. Built Circuit 2 in Electronic Workbench. Set component values by right clicking the resistor, capacitor and inductor to set the resistance, capacitance and inductance values.

11. Connected an AC voltage source to the circuit. The circuit should look like the illustration below.





12. From the menu bar, chose ***Circuit – Schematic Options – Show Nodes***

13. From the menu bar, choose ***Analyze – AC Frequency***.

    a. Set the frequency range for 1kHz to 20kHz.

    b. Set the sweep type to Decade.

    c. Set the number of points to 100.

    d. Set the vertical scale to Linear.

    e. Add the output node, marked above in the screenshot as node 3, located between the inductor and the load resistor.

14. Selected ***Simulate*** to produce the Bode graph.

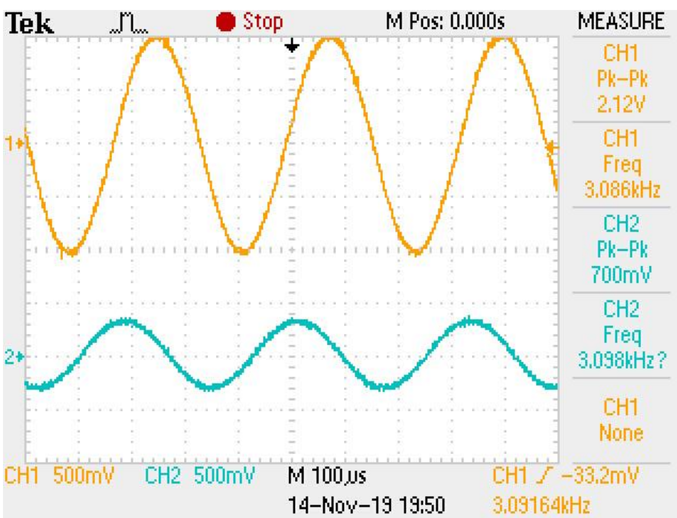
15. Added gridlines before printing. See Attachment B – Circuit 2 Bode plot.

16. Used the EWB cursor feature to identify the two half-power points (70.7%) on the Bode Plot. Recorded the frequencies as f_{COhigh} & f_{COlow} on the Bode plot.
17. ***Calculated and recorded*** the bandwidth of this circuit using the ***Bandwidth*** formula.
18. ***Built Circuit 2 on the Global Specialties trainer***.
19. Connected the oscilloscope channel 1 set for AC coupling to the filter input.
20. Connected oscilloscope channel 2 set for AC coupling to the filter output.
21. ***Calculated and recorded*** the resonant frequency for circuit 2 using the *Resonant Frequency* formula.
22. Adjusted the function generator and frequency slider to input a sine wave to the filter circuit with a frequency equal to the ***resonant frequency calculated above***.
23. Adjusted the function generator amplitude slider until the filter output (channel 2) read 1.0 V_{p-p} ± 0.1V.
24. Had the instructor or lab assistant verify circuit function with initials.

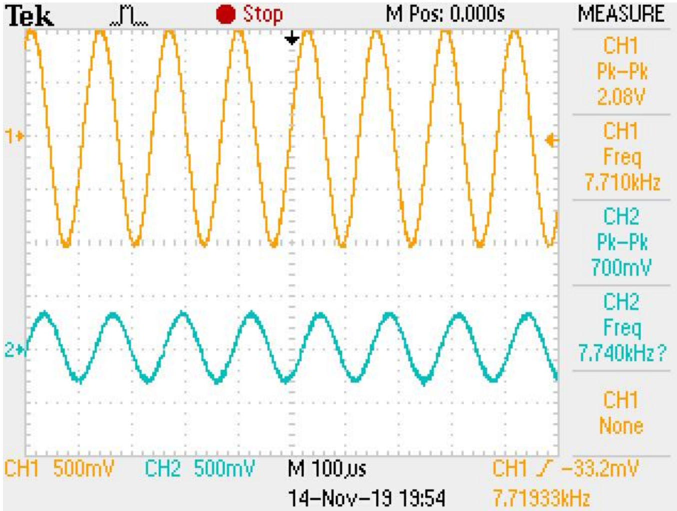
See Appendix C for signature

25. Adjusted the frequency ***below*** f_{RES} until the filter output amplitude was approximately 707 mV_{p-p} . Recorded this frequency as f_{COlow}.

The filter output is taken across the 470Ω resistor to ground



26. Adjusted the frequency ***above*** f_{RES} until the filter output amplitude was approximately $707mV_{p-p}$. Noted the frequency as f_{COhigh}.



27. ***Calculated and recorded*** the measured filter bandwidth and compare it with the expected value found using Electronic Workbench.

Electronic Workbench bandwidth: 1.494Khz

Measured bandwidth: 4.642KHz

$$\boldsymbol{Error}\ \% = \frac{\mathbf{4.624}\boldsymbol{khz} - \mathbf{1.494}\boldsymbol{kHz}}{\mathbf{1.494}\boldsymbol{kHz}} * \mathbf{100}$$

$$\boldsymbol{Error}\ \% = \frac{\mathbf{3.13}\boldsymbol{kHz}}{\mathbf{1.494}\boldsymbol{kHz}} * \mathbf{100}$$

$$\boldsymbol{Error}\ \% = \frac{\mathbf{3.13}\boldsymbol{kHz}}{\mathbf{1.494}\boldsymbol{kHz}} * \mathbf{100}$$

$$\boldsymbol{Error}\ \% = \mathbf{2.095} * \mathbf{100}$$

$$\boldsymbol{Error}\ \% = \mathbf{209.5\%}$$

Results Data

Circuit 1

f_{cohigh}	f_{colow}	Bandwidth	f_{res}	X_C	X_L
2.82kHz	407.7kHz	2.41kHz	1.07kHz	6.74kΩ	6.74kΩ

Circuit 2

EWB f_{cohigh}	*EWB* f_{colow}	EWB Bandwidth	Circuit f_{cohigh}	Circuit f_{colow}	Circuit Bandwidth
5.83kHz	4.34kHz	1.49kHz	7.74kHz	3.1kHz	4.64kHz

Formulas

Resonant Frequency

$$f_{resonant} = \frac{1}{2\pi\sqrt{LC}}$$

Where;
$f_{resonant}$ = resonant frequency (Hertz)
π = pi (3.14159…)
L = inductance (Henrys)
C = capacitance (Farads)

Bandwidth

$$BW = f_{COhigh} - f_{COlow}$$

Where;
BW = bandwidth (Hertz)
F_{COhigh} = high cutoff frequency (1/2 power)
F_{COlow} = low cutoff frequency (1/2 power)

Capacitive Reactance

$$X_C = \frac{1}{2\pi f C}$$

Where;
X_C = capacitive reactance (Ohms)
π = pi (3.14159…)
f = frequency (Hz)
C = capacitance (Farads)

Inductive Reactance

$$X_L = 2\pi f L$$

Where;
XL = inductive reactance (Ohms)
π = pi (3.14159…)
f = frequency (Hz)
I = inductance (Henrys)

Critical Thinking

1. Describe an application for a band stop filter.

Band stop filters are also known as notch filters. Notch filters are very common in graphic equalizers.

2. A parallel RLC filter has a 10mH inductor and a 50nF capacitor. What is the resonant frequency of the circuit?

$$f_{res} = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10mH * 50nF}} = 7.118kHz$$

3. Describe an application for a band pass filter.

A band pass filter will pass certain frequencies within a certain range and blocks frequencies outside that range. An example would be an audio crossover filter or tone adjustment in an amplifier.

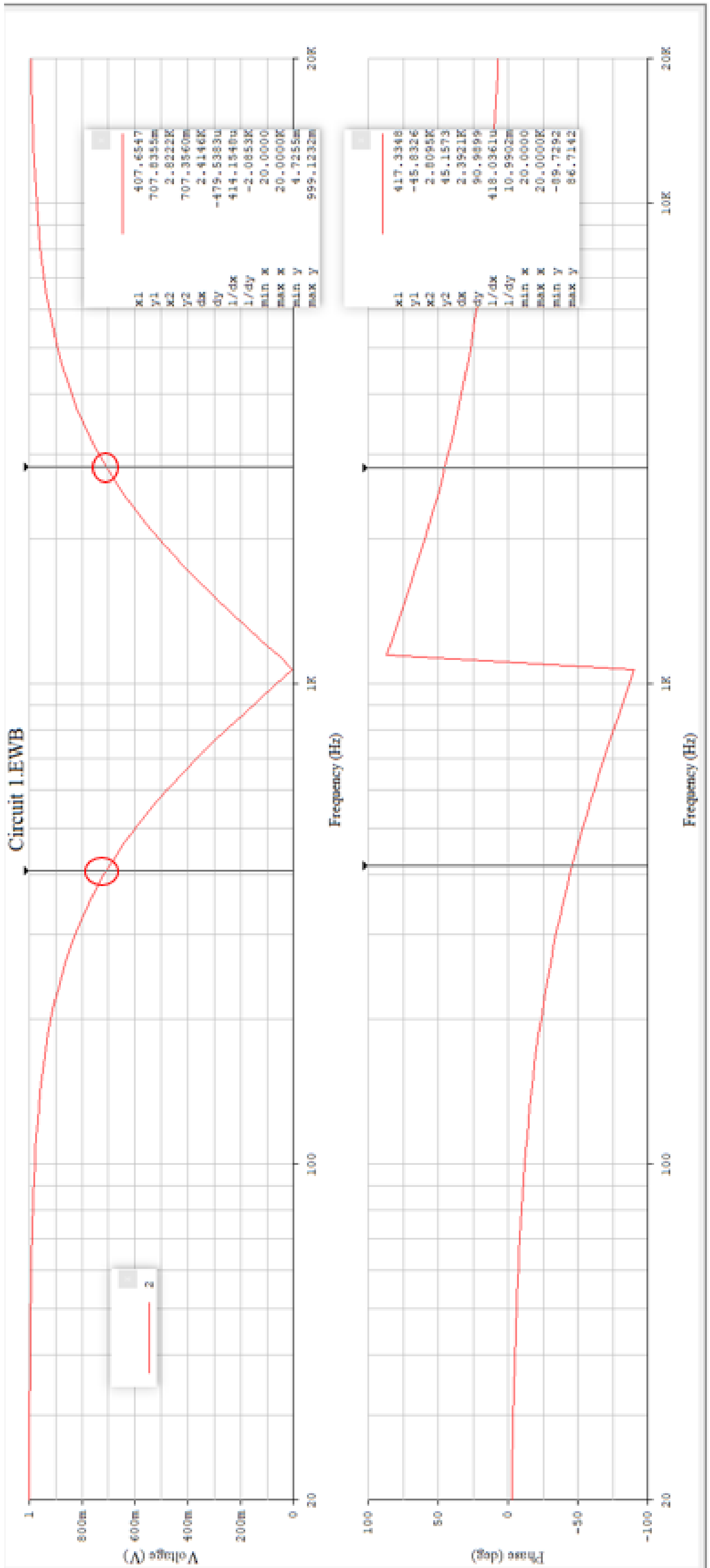
4. A series RLC filter has a 10μH inductor and a 50μF capacitor. What is the resonant frequency of the circuit?

$$f_{res} = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10\mu H * 50\mu F}} = 7.118kHz$$

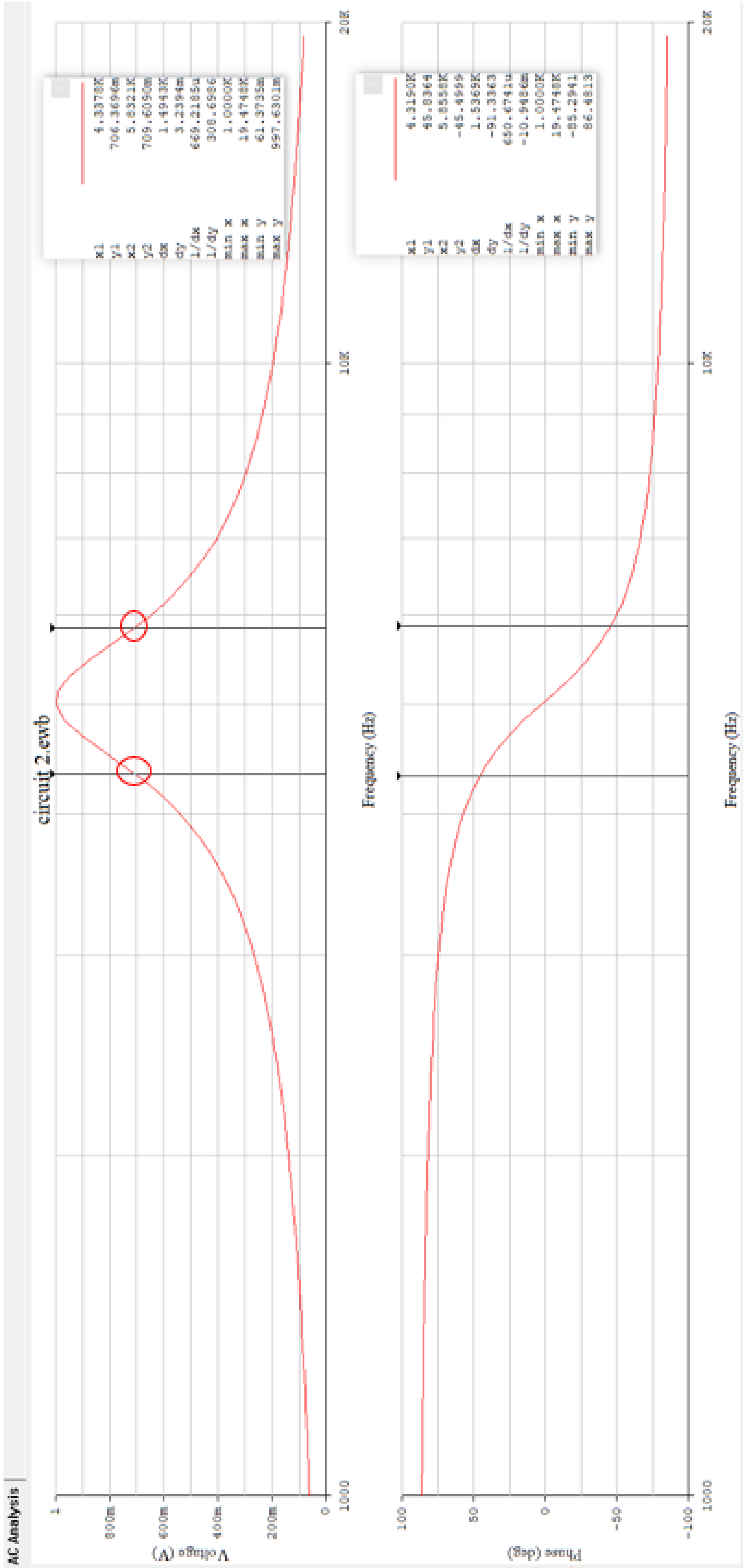
5. What did you learn from this lab?

In this lab, I learned about the basic operations of the Electronics Workbench software and circuit simulation and analysis. I further learned about what is happening behind common products in my life such as audio crossover circuits, tone and bass adjustments as well as graphic equalizers in audio applications. Additionally, I learned about bandwidth calculations that have an application in radio, wireless and wired networking.

Appendix A – Circuit 1 Bode Plot



Appendix B – Circuit 1 Bode Plot



Appendix C – Signature and Lab Notes

SIERRA COLLEGE	MECH 10 - Lab 16 Resonant Filters	Mechatronics Real Skills Real Jobs
Name		

Learning Objectives

- Simulate and test circuits using circuit analysis software
- Create Bode plots of RLC frequency performance
- Build and analyze band pass filter performance
  - Cutoff frequency
  - Bandwidth

Notes:

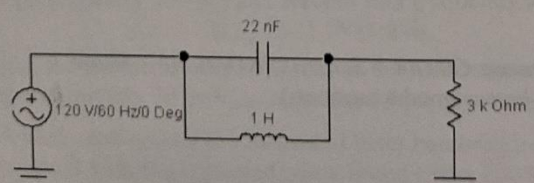
1. Take all voltage measurements relative to ground (unless otherwise stated)
2. Record relevant measurements and calculation results in data tables
3. Record all measured values on the circuit schematics
4. Use all available precision in calculations, round off answers to 3 significant figures

Materials

Quantity	**Description**
	Circuit 1
1	PC w Electronic Workbench & printer
	Circuit 2
1	Capacitor, 0.022μF
1	Inductor, 50 mH
1	Resistor, 470Ω
1	Global Specialties Trainer
1	Digital oscilloscope

Procedure – Circuit 1

1. Build Circuit 1 in Electronic Workbench. Set component values by right clicking the resistor, capacitor, and inductor to set the resistance, capacitance and inductance values.
2. Connect an AC voltage source to the circuit. Your circuit should look like the illustration below.



3. From the menu bar, choose ***Circuit – Schematic Options – Show Nodes*** (each wire will be assigned a number.)

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4. From the menu bar, choose ***Analyze – AC Frequency***.
   a. Set the frequency range for 20Hz to 20kHz.
   b. Set the sweep type to Decade.
   c. Set the number of points to 100.
   d. Set the vertical scale to Linear.
   e. Add the output node located between the inductor and the load resistor.
5. Select Simulate to produce the response graph. Add gridlines before **printing** the Bode plot.
6. Circle the two half-power points (70.7%) on the Bode Plot. Record the frequencies as f_{COhigh} & f_{COlow} on the Bode plot. Have the instructor or lab technician ***review and approve*** the Bode plot markup.

$f_{COhigh} = 2.8222k$
$f_{COlow} = 407.6547$
SDA

7. ***Calculate and record*** the bandwidth of this circuit using the **Bandwidth** formula.

2.8222000
407.6547
$\boxed{2.415kHz}$

8. ***Calculate and record*** the resonant frequency for circuit 1 using the *Resonant Frequency* formula.

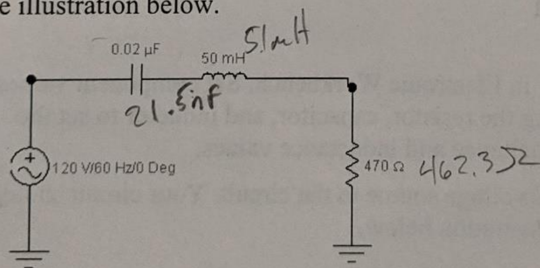
$\frac{1}{2\pi\sqrt{LC}} = 1.073kHz$

9. ***Calculate and record*** X_L & X_C at resonant frequency using the *Inductive and Capacitive Reactance* formulas

$X_L = 2\pi f L$
$= 6.742k\Omega$
$X_C = \frac{1}{2\pi f C}$
$= 6.742k\Omega$

Procedure – Circuit 2

10. Build Circuit 2 in Electronic Workbench. Set component values by right clicking the resistor, capacitor and inductor to set the resistance, capacitance and inductance values.
11. Connect an AC voltage source to the circuit. Your circuit should look like the illustration below.



12. From the menu bar, choose ***Circuit – Schematic Options – Show Nodes*** (each wire will be assigned a number.)

13. From the menu bar, choose ***Analyze – AC Frequency***.
    a. Set the frequency range for 1kHz to 20kHz.
    b. Set the sweep type to Decade.
    c. Set the number of points to 100.
    d. Set the vertical scale to Linear.
    e. Add the output node located between the inductor and the load resistor.
14. Select ***Simulate*** to produce the Bode graph.
15. Add gridlines before printing. ***Print*** the Bode plot for your lab report.
16. Use the EWB cursor feature too identify the two half-power points (70.7%) on the Bode Plot. Record the frequencies as f_{COhigh} & f_{COlow} on the Bode plot.
17. ***Calculate and record*** the bandwidth of this circuit using the **Bandwidth** formula.

$$\begin{array}{r} 5.8321 \\ 4.3378 \\ \hline 1.494\text{kHz} \end{array}$$

18. ***Build Circuit 2 on the Global Specialties trainer.***
19. Connect oscilloscope channel 1 set for AC coupling to the filter input.
20. Connect oscilloscope channel 2 set for AC coupling to the filter output.
21. ***Calculate and record*** the resonant frequency for circuit 2 using the *Resonant Frequency* formula. $f_r = \frac{1}{2\pi\sqrt{LC}}$

$$\frac{1}{2\pi\sqrt{51mH \times 0.0215\mu F}} = \underline{4.806kHz}$$

22. Adjust the function generator and frequency slider to input a sine wave to the filter circuit with a frequency equal to the ***resonant frequency calculated above***.
23. Adjust the function generator amplitude slider until the filter output (channel 2) reads 1.0 $V_{p\text{-}p} \pm 0.1V$.
24. Have the instructor or lab assistant verify circuit function with initials. [illegible]

The filter output is taken across the 470Ω resistor to ground

25. Adjust the frequency ***below*** f_{RES} until the filter output amplitude is approximately 707 $mV_{p\text{-}p}$. Record this frequency as f_{COlow}.
$f_{COlow} = 3.098$ kHz
26. Adjust the frequency ***above*** f_{RES} until the filter output amplitude is approximately $707mV_{p\text{-}p}$. Note the frequency as f_{COhigh}. $= 7.74$ kHz
27. ***Calculate and record*** the measured filter bandwidth and compare it with the expected value found using Electronic Workbench.
Measured: 4.642 kHz

$$\frac{4.642kHz - 1.494kHz}{1.494kHz} \times 100 = 210.7\%$$

Results Data

Circuit 1

f_{cohigh}	f_{colow}	Bandwidth	f_{res}	X_C	X_L
2.8222 kHz	407.6947 Hz	2.415 kHz	1.073 kHz	6.742 kΩ	6.742 kΩ

Circuit 2

EWB f_{cohigh}	*EWB* f_{colow}	EWB Bandwidth	Circuit f_{cohigh}	Circuit f_{colow}	Circuit Bandwidth
5.8321 kHz	4.3378 kHz	1.494 kHz	7.74 kHz	3.098 kHz	4.642 kHz

Formulas

Resonant Frequency

$$f_{resonant} = \frac{1}{2\pi\sqrt{LC}}$$

Where;
$f_{resonant}$ = resonant frequency (Hertz)
π = pi (3.14159…)
L = inductance (Henrys)
C = capacitance (Farads)

Bandwidth

$$BW = f_{COhigh} - f_{COlow}$$

Where;
BW = bandwidth (Hertz)
F_{COhigh} = high cutoff frequency (1/2 power)
F_{COlow} = low cutoff frequency (1/2 power)

Capacitive Reactance

$$X_C = \frac{1}{2\pi fC}$$

Where;
X_C = capacitive reactance (Ohms)
π = pi (3.14159…)
f = frequency (Hz)
C = capacitance (Farads)

Inductive Reactance

$$X_L = 2\pi fL$$

Where;
XL = inductive reactance (Ohms)
π = pi (3.14159…)
f = frequency (Hz)
l = inductance (Henrys)

Critical Thinking

1. Describe an application for a band stop filter. also known as a notch filter graphic equalizer
2. A parallel RLC filter has a 10mH inductor and a 50nF capacitor. What is the resonant frequency of the circuit? $f_{res} = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{50nF \times 10mH}} = 7.118kHz$
3. Describe an application for a band pass filter. Pre-amplifier tone control
4. A series RLC filter has a 10µH inductor and a 50µF capacitor. What is the resonant frequency of the circuit? $f_{res} = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10\mu H \times 50\mu F}} = 7.118kHz$
5. What did you learn from this lab?

I dont remember analyzing + calculating resonant frequencies when I was in school previously. in this lab, I learned alot about what is happening behind frequency crossovers, tone + bass adjustments on stereos, graphic equalizers and more
Also, understanding the frequency & bandwidth calculations behind radio and other analog frequencies

Grading Criteria

		Points Possible	Points Earned
Documentation	Abstract, introduction, experiment, data results, conclusions, attachments, clarity, spelling, grammar	**10**	
Band Stop Filter	Bode plot included & annotated w ½ power points, bandwidth, X_L, X_C, f_{res}, calculated and recorded in data table	**10**	
Band Pass Filter	Bode plot included & annotated w ½ power points, bandwidth	**10**	
	Circuit function verified, cutoff frequencies compared with EWB values	**10**	
Critical Thinking	Questions answered completely & accurately. State conclusions drawn and lessons learned from the lab	**10**	
On-time submittal	Lab report is submitted in accordance with the assignment due date as posted on Canvas	**5**	
	Total	**55**	

Lab Report Format

Abstract - a summary and high-level overview of the lab and its results
Introduction - State the objectives of the laboratory and list the equipment required
Experiment - Describe the procedure used to carry out the lab
Results Data - list data taken in table or graphical format where appropriate
Critical Thinking - State the conclusions drawn and lessons learned from the laboratory activities. Answer any questions found within the lab procedure.
Attachments – grading criteria, verification signatures, circuit diagrams, lab procedures & notes