

SERIES RESONANCE



Objectives

You will connect several ac *RLC* circuits that illustrate the important characteristics of series resonant circuits.

In completing these projects, you will connect circuits, make measurements, perform calculations, draw conclusions, and be able to answer questions about the following items related to series resonant circuits:

- Definition of resonance
- Relationships of V , I , R , Z , θ , Q , bandwidth, and frequency in series *RLC* circuits
- Finding a circuit's resonant frequency
- Outstanding characteristics of a circuit at series resonance

Project/Topic Correlation Information

PROJECT	TEXT CHAPTER	SECTION	RELATED TEXT TOPIC(S)
54 X_L and X_C Relationships to Frequency	21	21-1	X_L , X_C , and Frequency
55 V , I , R , Z , and θ Relationships when $X_L = X_C$	21	21-2	Series Resonance Characteristics
56 Q and Voltage in a Series Resonant Circuit	21	21-5	Q and Resonant Rise of Voltage
57 Bandwidth Related to Q	21	21-10	Selectivity, Bandwidth, and Bandpass

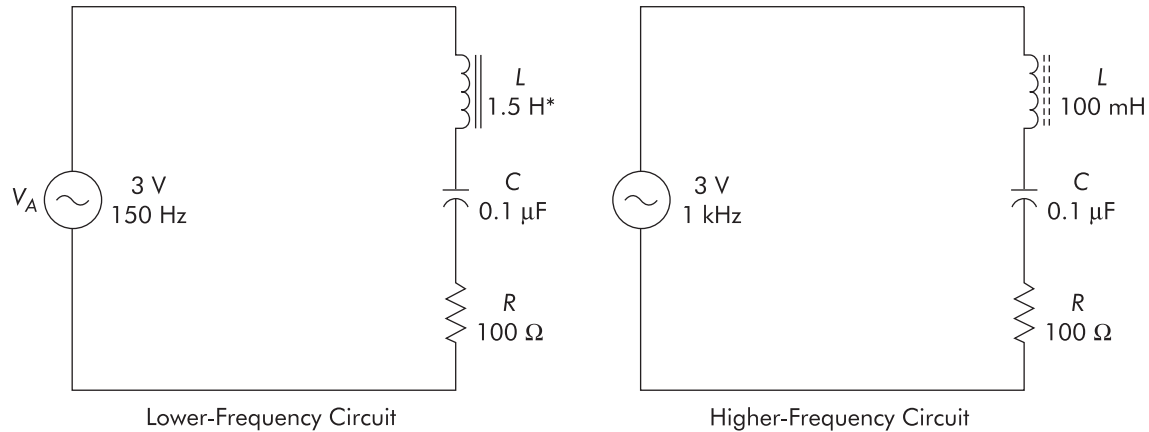
Series Resonance

X_L and X_C Relationships to Frequency

PROJECT

54

Name: _____ Date: _____



*Mfg. rated value under specified conditions

FIGURE 54-1

PROJECT PURPOSE To verify the opposite effects on X_L and X_C when the frequency of signal applied to a circuit containing both is changed.

PARTS NEEDED

- | | |
|---|--|
| <input type="checkbox"/> DMM | <input type="checkbox"/> Inductors |
| <input type="checkbox"/> Function generator or audio oscillator | 1.5 H, 95 Ω (or approximate) |
| <input type="checkbox"/> CIS | <input type="checkbox"/> 100 mH |
| <input type="checkbox"/> Capacitor 0.1 μ F | <input type="checkbox"/> Resistor 100 Ω |

PROCEDURE

1. Connect the initial circuit as shown in Figure 54-1.
2. Set the function generator to the frequency indicated for the circuit option you are using. Set V_A to 3 volts. Measure V_R and calculate I_T . Measure V_L and V_C and calculate X_L and X_C by Ohm's Law.

▲OBSERVATION

	Lower f	Higher f
$V_A =$	_____ V.	$V_A =$ _____ V.
$V_R =$	_____ V.	$V_R =$ _____ V.
$I_T =$	_____ mA.	$I_T =$ _____ mA.
$V_L =$	_____ V.	$V_L =$ _____ V.
$V_C =$	_____ V.	$V_C =$ _____ V.
$X_L =$	_____ Ω .	$X_L =$ _____ Ω .
$X_C =$	_____ Ω .	$X_C =$ _____ Ω .

CONCLUSION If the X_C formula were used, the X_C of a 0.1- μ F capacitor at 150 Hz would be calculated as _____ ohms for the lower f circuit. For the higher f circuit, the X_C at 1 kHz would be calculated as _____ ohms. Can the difference between the Ohm's Law results and the X_C formula be attributed to meter loading effects, capacitor tolerance, and audio oscillator dial calibration tolerance? _____.

3. Change the function generator frequency to 300 Hz for the lower-frequency circuit or to 2 kHz for the higher-frequency circuit. Keep V_A at 3 volts. Measure V_R and calculate I_T . Measure V_L and V_C and calculate X_L and X_C by Ohm's Law.

OBSERVATION	Lower f	Higher f
$V_A =$ _____ V.	$V_A =$ _____ V.	$V_A =$ _____ V.
$V_R =$ _____ V.	$V_R =$ _____ V.	$V_R =$ _____ V.
$I_T =$ _____ mA.	$I_T =$ _____ mA.	$I_T =$ _____ mA.
$V_L =$ _____ V.	$V_L =$ _____ V.	$V_L =$ _____ V.
$V_C =$ _____ V.	$V_C =$ _____ V.	$V_C =$ _____ V.
$X_L =$ _____ Ω .	$X_L =$ _____ Ω .	$X_L =$ _____ Ω .
$X_C =$ _____ Ω .	$X_C =$ _____ Ω .	$X_C =$ _____ Ω .

CONCLUSION When frequency was doubled, the X_L (*increased, decreased*) _____ by approximately _____ times, and the X_C (*increased, decreased*) _____ by about _____ times. We conclude from these results that X_L is (*directly, inversely*) _____ proportional to frequency, and X_C is (*directly, inversely*) _____ proportional to frequency. In a circuit that has both inductance and capacitance, there must be some frequency where X_L and X_C would be _____. In our circuit, would the frequency where this would occur have to be higher or lower than the present settings? _____.

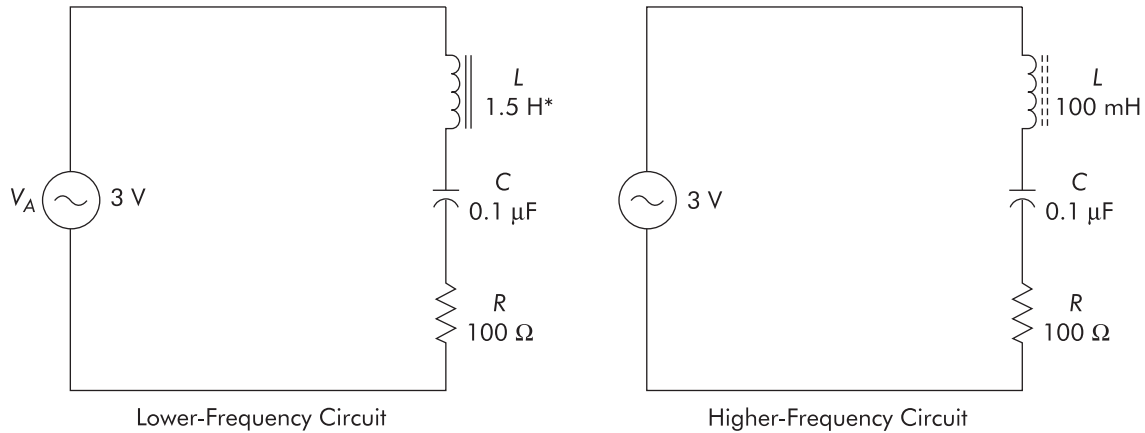
Series Resonance

$V, I, R, Z,$ and θ Relationships when $X_L = X_C$

PROJECT

55

Name: _____ Date: _____



*Mfg. rated value under specified conditions

FIGURE 55-1

PROJECT PURPOSE To demonstrate the resonance effects at a frequency where $X_L = X_C$. To show that the series RLC circuit basically acts resistively at resonance, inductively above resonance, and capacitively below resonance.

PARTS NEEDED

- | | |
|---|---|
| <input type="checkbox"/> DMM | <input type="checkbox"/> Inductors |
| <input type="checkbox"/> Function generator or audio oscillator | 1.5 H, 95 Ω (or approximate) |
| <input type="checkbox"/> CIS | <input type="checkbox"/> 100 mH |
| <input type="checkbox"/> Capacitor 0.1 μF | <input type="checkbox"/> Resistor 100 Ω |

PROCEDURE

1. Connect the initial circuit as shown in Figure 55-1.
2. Set V_A at 3 volts and adjust the function generator frequency while monitoring V_R until V_R is maximum. Measure V_R and calculate I_T . Measure V_L and V_C . Calculate X_L and X_C by Ohm's Law.

▲ OBSERVATION

Lower f	Higher f
$V_A =$ _____ V.	$V_A =$ _____ V.
Frequency = _____ Hz. (approximately)	Frequency = _____ Hz. (approximately)

Lower f	Higher f
$V_R =$ _____ V.	$V_R =$ _____ V.
$I_T =$ _____ mA.	$I_T =$ _____ mA.
$V_L =$ _____ V.	$V_L =$ _____ V.
$V_C =$ _____ V.	$V_C =$ _____ V.
$X_L =$ _____ Ω .	$X_L =$ _____ Ω .
$X_C =$ _____ Ω .	$X_C =$ _____ Ω .

CONCLUSION

Are X_L and X_C close to being equal at the frequency of maximum V_R ? _____.

Would they be equal if circuit and measurement conditions were perfect? _____.

The voltage across the coil (*leads, lags*) _____ the current by about _____ degrees; whereas, the voltage across the capacitor (*leads, lags*) _____ the current by close to _____ degrees. This means that V_L and V_C are close to _____ degrees out of phase with each other. Since I is the same throughout the series circuit and the $I \times X_L$ drop is essentially _____ degrees out of phase with the $I \times X_C$ drop, we may conclude that X_L and X_C reactances are opposite (vectorially) and at resonance are equal. They therefore cancel each other's effects on Z . Notice that V_L and V_C both are greater than V_A . This is due to the cancelling effect of the reactances. If X_L and X_C perfectly cancelled (as would be true with perfectly equal and opposite reactances), the circuit Z would equal _____. The resultant circuit current would be (*in phase, out of phase*) _____ with V_A , and the circuit would be acting purely _____.

3. Change the frequency to a new frequency that is well above resonance. Measure V_L and V_C and determine whether the circuit is now acting inductively or capacitively.

OBSERVATION V_L is now _____ than V_C .

CONCLUSION The circuit is now acting like an (*RL, RC*) _____ circuit, since X _____ is more than cancelling out X _____. Thus, the circuit is acting like R in series with a resultant X _____. The value of this resultant X is equal to a value of X _____ total minus X _____. The result is that I_T (*leads, lags*) _____ V_A by an angle between _____ and _____ degrees; thus the circuit is (*inductive, capacitive*) _____.

4. Keep the same circuit as shown in Figure 55-1.

5. Change the input frequency to a new frequency that is well below the resonant frequency determined in the earlier steps. Measure V_L and V_C and determine whether the circuit is now acting inductively or capacitively.

OBSERVATION New frequency is lower than _____.
 V_L is now _____ than V_C .

▲ CONCLUSION

Since V _____ is now greater than V _____ and the current is the same through both reactances, it indicates that X _____ is greater than X _____. This means that X _____ is more than cancelling X _____ and the circuit is equivalent to an (RL, RC) _____ circuit. The circuit impedance therefore would equal the vector resultant of R and a series X _____ whose value equals the difference between _____ and _____. We may conclude from the preceding that at a frequency where $X_L = X_C$ (resonance), the circuit acts essentially like a pure _____ circuit. At frequencies below resonance, a series RLC circuit will act equivalent to a simple R _____ circuit. At frequencies above resonance, a *series RLC* circuit will act equivalent to a simple R _____ circuit. We may also conclude that the larger the value of C or L , the (*lower, higher*) _____ will be the resonant frequency and vice versa. Summarizing our observations for a series resonant circuit, we conclude that at resonance Z is (*minimum, maximum*) _____ since X_L and X_C cancel.

Series Resonance

Q and Voltage in a Series Resonant Circuit

PROJECT

56

Name: _____ Date: _____

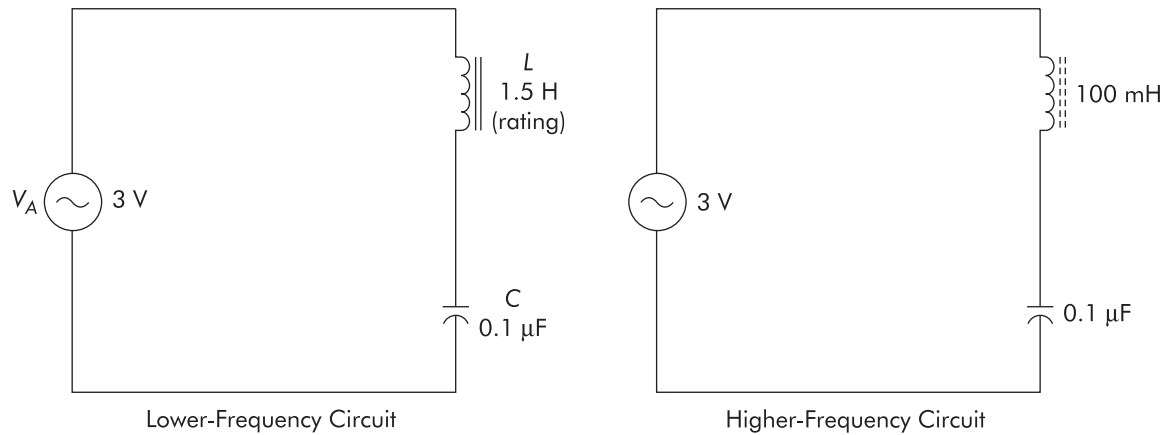


FIGURE 56-1

PROJECT PURPOSE To show, via circuit measurements, that the voltage across reactive components in a series resonant circuit is greater than V applied. To demonstrate that the amount of this voltage across each reactive component is related to the circuit Q factor.

PARTS NEEDED

- | | |
|--|--|
| <ul style="list-style-type: none"> <input type="checkbox"/> DMM <input type="checkbox"/> Function generator or audio oscillator <input type="checkbox"/> CIS <input type="checkbox"/> Capacitor 0.1 μF | <ul style="list-style-type: none"> <input type="checkbox"/> Inductors 1.5 H, 95 Ω (or approximate) <input type="checkbox"/> 100 mH |
|--|--|

SPECIAL NOTE:

The figure of merit for a resonant circuit is called “ Q .” In general terms, the higher the ratio of reactance at resonance to series resistance, the higher the Q . If we had a perfect inductor and capacitor tuned to resonance and there were zero resistance in the circuit, the circuit impedance would be zero. Thus, current would be infinite. However, this is impossible in practical circuits. Therefore, Q is considered to be the relationship X_L/R , or X_C/R for series resonant circuits. Also, because the cancelling effect of X_L and X_C may allow high circuit current at resonance, there is a voltage magnification across the reactive components at resonance. During this project we will illustrate some of these facts.

PROCEDURE

1. Connect the initial circuit as shown in Figure 56-1.
2. Set V_A at 3 volts and adjust the frequency, while monitoring V_L , for maximum V_L . Measure V_A and V_L and calculate the circuit Q from the ratio of V_L to V_A .

▲ OBSERVATION

	Lower f	Higher f
$V_A =$	_____ V.	$V_A =$ _____ V.
$V_L =$	_____ V. (approximately)	$V_L =$ _____ V. (approximately)
$Q =$	_____. (approximately)	$Q =$ _____. (approximately)
$f =$	_____.	$f =$ _____.

▲ CONCLUSION

The ratio of X_L/R for this circuit must be approximately _____

 _____.

3. With the same V_A and frequency as the previous step, measure V_C and calculate the circuit Q from V_C/V_A .

▲ OBSERVATION

	Lower f	Higher f
$V_A =$	_____ V.	$V_A =$ _____ V.
$V_C =$	_____ V. (approximately)	$V_C =$ _____ V. (approximately)
$Q =$	_____. (approximately)	$Q =$ _____. (approximately)
$f =$	_____.	$f =$ _____.

▲ CONCLUSION

The ratio of X_C/R for this circuit must be approximately _____.
 What is the X_C of the capacitor according to the X_C formula? Approximately _____.
 From the preceding, we may conclude that V_L or V_C equals _____
 times V_A ; that Q equals the ratio of _____ or _____ to R ; and the higher the Q ,
 the (*higher, lower*) _____ the circuit current will be at resonance.

Optional Steps

4. Assuming that the 0.1- μF capacitor is very close to its rated value, determine what the resonant frequency of the circuit would be if the initial circuit inductor were acting at its rated value.

▲ OBSERVATION

If the inductor really were acting as rated, the resonant frequency would be approximately

_____ Hz. _____ Hz.
 (Lower f) (Higher f)

5. Assuming a C of $0.1 \mu\text{F}$ and based on the measured resonant frequency in step 2, how much apparent inductance does this inductor have under the operating conditions used?

▲ OBSERVATION “Apparent” inductance is approximately
 _____ H. _____ mH.
 (Lower f) (Higher f)

▲ CONCLUSION It may be concluded that for a given capacitance value, the higher the inductance value used in conjunction with the capacitor, the (*higher, lower*) _____ the resonant frequency will be.

6. Perform appropriate calculations and compare the Q calculated from data in step 2 of Project 55 to the Q determined in step 2 of this Project (Project 56).

▲ OBSERVATION Q calculated from step 2 of Project 55 =
 _____.
 (Lower f) (Higher f)
 Q calculated from step 2 of this project =
 _____.
 (Lower f) (Higher f)

▲ CONCLUSION Since the same values of L , C , and V_A are used in both projects, what accounts for the difference in Q values? _____

Series Resonance

Bandwidth Related to Q

PROJECT

57

Name: _____ Date: _____

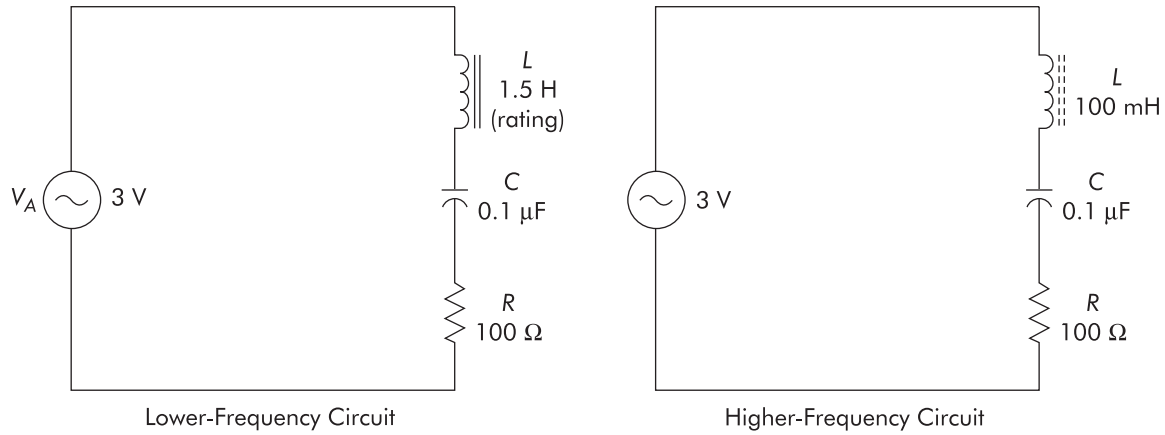


FIGURE 57-1

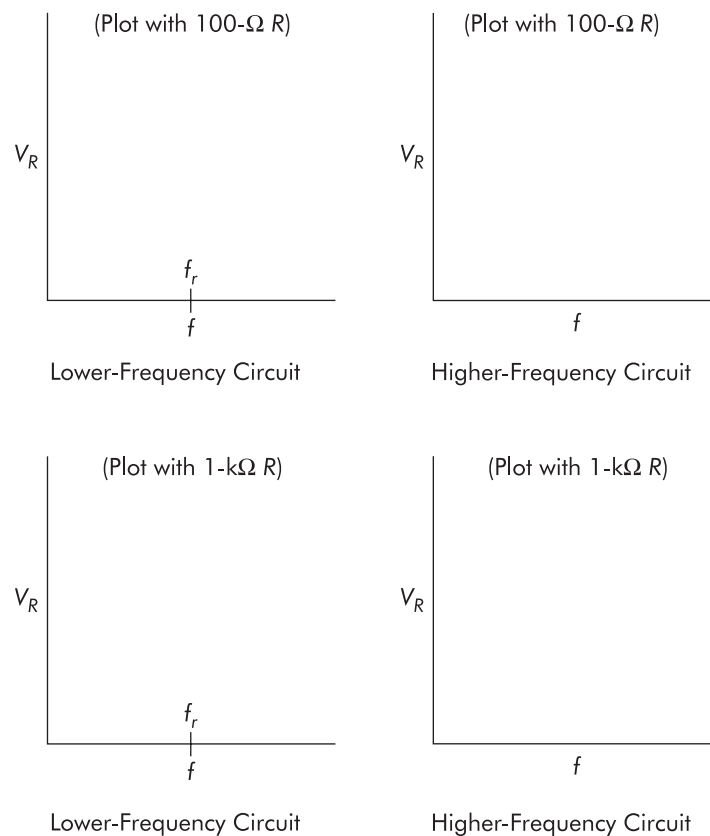


FIGURE 57-2 Sample graph coordinates

NOTE Label f_r and upper and lower bandpass frequencies on each graph. Use separate sheets of graph paper.

PROJECT PURPOSE To provide practical experience and practice in making measurements to find “half-power points” and from these measurements to determine the series RLC circuit bandwidth.

PARTS NEEDED

- | | |
|---|-------------------------------------|
| <input type="checkbox"/> DMM | <input type="checkbox"/> Inductors |
| <input type="checkbox"/> Function generator or audio oscillator | 1.5 H, 95 Ω (or approximate) |
| <input type="checkbox"/> CIS | <input type="checkbox"/> 100 mH |
| <input type="checkbox"/> Capacitor | <input type="checkbox"/> Resistors |
| 0.1 μF | 100 Ω 1 k Ω |

SPECIAL NOTE:

Bandwidth for a series resonant circuit may be defined as the difference in frequency between the two frequencies (one below resonance and one above) at which the circuit current is 0.707 (70.7%) of the maximum current (which occurs at resonance). It is interesting to note that the higher the Q of a circuit, the higher the maximum current will be at resonance for any given V_A . If a graph is made of current versus frequency, it will be shown that the higher the Q , (and thus the I), the steeper will be the slope of the resonance curve and the smaller the bandwidth. Since Q and bandwidth are related, one formula for bandwidth is: Bandwidth = f_r (resonant frequency)/ Q and therefore $Q = f_r/\text{bandwidth}$.

PROCEDURE

1. Connect the initial circuit as shown in Figure 57-1.
2. Set V_A to 3 volts. While monitoring V_R , set the frequency of the audio oscillator for resonance (maximum V_R). Measure V_R , V_L , and V_C . Calculate I at resonance.

▲ OBSERVATION

	Lower f	Higher f
$V_A =$ _____ V.		$V_A =$ _____ V.
$V_R =$ _____ V. (approximately)		$V_R =$ _____ V. (approximately)
$V_L =$ _____ V. (approximately)		$V_L =$ _____ V. (approximately)
$V_C =$ _____ V. (approximately)		$V_C =$ _____ V. (approximately)
$I =$ _____ mA. (approximately)		$I =$ _____ mA. (approximately)

▲ CONCLUSION

The approximate Q of this circuit (V_L/V_A): Lower $f =$ _____; Higher $f =$ _____.
According to the formula, Bandwidth = f/Q , the bandwidth of this circuit should be approximately: Lower f circuit = _____ Hz; Higher f circuit = _____ Hz.

If circuit current decreased to 70.7% of I_{max} , the current would be approximately:
 Lower f circuit = _____ mA; Higher f circuit = _____ mA. Then, V_R
 would equal: Lower f circuit = _____ V; Higher f circuit = _____ V.

3. Keeping V_A at 3 volts at each frequency setting, adjust frequency to a frequency below resonance where V_R equals 0.707 of V_{Rmax} . Note this frequency, then change the frequency above resonance until V_R equals 0.707 of V_{Rmax} and note this frequency. From these two frequencies determine the measured bandwidth.

▲ OBSERVATION

	(Lower f)	(Higher f)
Bandwidth = _____ Hz.		Bandwidth = _____ Hz.
f below resonance where V_R is at 70%:		
_____ Hz.		_____ Hz.
(Lower f)		(Higher f)
f above resonance where V_R is at 70%:		
_____ Hz.		_____ Hz.
(Lower f)		(Higher f)

▲ CONCLUSION Does the measured bandwidth approximate the value calculated from the bandwidth formula in step 2? _____.

4. If time permits, change R to a 1-k Ω resistor and repeat the steps above. Note whether the Q and bandwidth increased or decreased with the higher R value.

▲ OBSERVATION

	(Lower f)	(Higher f)
Q = _____.		Q = _____.
Bandwidth = _____ Hz.		Bandwidth = _____ Hz.

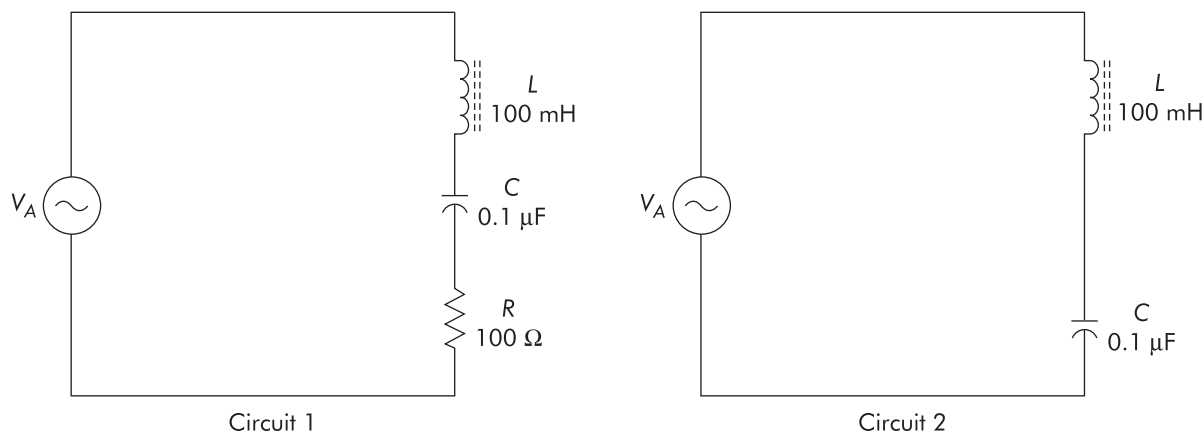
▲ CONCLUSION The higher the Q , the _____ the bandwidth. The higher the circuit R , the _____ the bandwidth.

5. Make graphic plots of V_R versus f that illustrate bandpass and bandwidth characteristics. Use the data collected in steps 2 through 4 and make your plots on coordinates similar to those shown in Figure 57-2. Use separate graph paper for these plots.

Story Behind the Numbers

Series Resonance

Name: _____ Date: _____



NOTE ► Prior to performing this project and the upcoming projects that will use inductors, be sure to read the **Special Notes to Students and Instructors** at the beginning of Part 9. For this project you will use the higher-frequency circuit option; therefore, pay attention to the cautions regarding DMM measuring limitations (frequency limits). If you are using a DMM, be sure it is rated to properly read voltages at the frequencies required in this project. If a scope is to be used, observe the critical ground connection precautions necessary to prevent shorting out components.

Procedure

1. Connect Circuit 1 as shown.
2. Set the signal source to a frequency of 1,000 Hz and V_A to 3 V.
3. Measure V_R and calculate I_T and circuit Z . Record this information on the Data Table, as appropriate.
4. Measure V_L and V_C and calculate the values of X_L and X_C using Ohm's Law. Record this data on the Data Table, as indicated.
5. Change the signal source frequency to 2,000 Hz, keeping V_A at 3 V. Make all the measurements and calculations called for in steps 3 and 4. Record your results on the Data Table, as appropriate.
6. With the signal source output still set at 3 V, vary the signal source frequency to higher and lower frequency settings while monitoring V_R so as to achieve the resonant frequency setting (maximum voltage across the resistor). While set at the frequency for maximum resistor voltage (resonance), measure V_R and calculate I_T as before. Calculate Z again. Measure V_L and V_C

- and calculate X_L and X_C , again using Ohm's Law. Record this data on the Data Table.
7. Change the frequency to a new frequency of 3 kHz (a frequency that is above resonant frequency). Measure and record V_L and V_C at this frequency.
 8. Change the frequency of signal input to a new frequency of 1 kHz (a frequency that is below the resonant frequency). Measure and record V_L and V_C at this frequency.
 9. Keeping V_A at 3 V, make a "frequency run" to enable graphing circuit current versus frequency. (Circuit current is calculated from the value of V_R/R). Make the frequency run from 1400 Hz to 2200 Hz in 200-Hz increments. At each new frequency setting, verify that V_A is 3 V. Measure and record V_R at that frequency to enable calculating circuit current at that frequency.
 10. Using the data collected in the preceding step, make a line graph of I_T versus f over the frequency run.

HINT ► If you set up the Excel program worksheet to log your current and frequency data, the "Chart" creation capabilities will help you create this graph!
 11. Determine the value that equals $0.707 \times$ current value at resonance (I_{max}). Use this information and the graph to label (1) the approximate resonant frequency, (2) the circuit's bandwidth points, and (3) identify the approximate bandpass frequencies on the graph. Record these data, as appropriate, on the Data Table.
 12. Disconnect the signal source from the circuit and remove the resistor so that the circuit now resembles Circuit 2.
 13. Set V_A at 3 V and vary the signal source frequency while monitoring V_L . Adjust the frequency so that V_L is maximum. Reset V_A to 3 V at this frequency (if necessary). Measure V_L and calculate the circuit Q from the ratio of V_L to V_A . Record these measurements and calculation(s) on the Data Table, as appropriate.
 14. With the same V_A and frequency as in the preceding step, measure V_C and calculate Q using the ratio of V_C to V_A . Record on the Data Table.
 15. **Optional step:** If time permits you may connect a 1-k Ω resistor in place of the 100- Ω resistor shown in Circuit 1. Vary frequency, as appropriate, to determine what happens to Q and *bandwidth* with the higher resistance in the circuit. Use the V_C/V_A approach for determining Q and use the $0.707 I_{max}$ points to determine bandwidth.
 16. After completing the Data Table, answer the Analysis Questions and develop a brief Technical Lab Report to complete the project.

Data Table

CIRCUIT 1: STEPS 1–8					
Component Parameter I.D.'s	Measured Values @ 1,000 Hz	Calculated Values @ 1,000 Hz	Measured Values @ 2,000 Hz	Calculated Values @ 2,000 Hz	
V_A (V)		—		—	
V_R (V)		—		—	
Calculated I_T (mA)	—		—		
Calculated Z (k Ω)	—		—		
V_L (V)		—		—	
V_C (V)		—		—	
Calculated X_L (Ω)	—		—		
Calculated X_C (Ω)	—		—		
V_R (V) @ resonance		—	—	—	
I_T (mA) @ resonance	—		—	—	
Calculated Z (Ω) @ resonance	—		—		
V_L (V) @ resonance		—	—	—	
V_C (V) @ resonance		—	—	—	
X_L (Ω) @ resonance	—		—	—	
X_C (Ω) @ resonance					
V_L (V) @ above resonance		—	—	—	
V_C (V) @ above resonance		—	—	—	
V_L (V) @ below resonance		—	—	—	
V_C (V) @ below resonance		—	—	—	
CIRCUIT 1: FREQUENCY RUN STEPS 9–10					
Component Parameter I.D.'s	1400 Hz	1600 Hz	1800 Hz	2000 Hz	2200 Hz
Value of $I_T(V_R/R) =$ (mA)					

Data Table (*continued*)

CIRCUIT 1: BW, BP STEP 11					
Parameter I.D.'s	Observed Frequencies 100 Ω	Observed Frequencies 1 k Ω			
$f @ 0.707 \times I$ at resonance (below resonance)					
$f @ 0.707 \times I$ at resonance (above resonance)					
Approx. Bandwidth = _____ (Hz)					
Approx. Bandpass = from _____ to _____ Hz					
Circuit 2: Q Steps 12–14					
Component and Parameter I.D.'s	Measured Values with V_L max	Calculated Values with V_L max			
V_A (V)		—			
V_L (max) (V)		—			
Circuit Q (V_L/V_A)	—				
V_C (max) (V)		—			
Circuit Q (V_C/V_A)	—				

Analysis Questions

NOTE Answers to these Analysis Questions should be clearly numbered and documented on separate sheets of paper with your name and the date at the top of each page. These answer sheets are to be turned in with the rest of the project documentation, as appropriate.

1. When frequency was doubled from 1,000 Hz to 2,000 Hz, which reactive parameter approximately doubled and which one decreased to approximately half the original frequency value? Identify which type of reactance is *directly* proportional to frequency and which one is *inversely* proportional to frequency.
2. At the resonant frequency, which component in Circuit 1 was predominant, C , L , or R ? Explain.

3. Was the circuit acting inductively, capacitively, or resistively at frequencies above resonance? Does this indicate that the circuit was acting like an RL circuit, an RC circuit, or like a pure resistive circuit at frequencies above the resonant frequency? Explain.
4. Was the circuit acting inductively, capacitively, or resistively at frequencies below resonance? Does this indicate that the circuit was acting like an RL circuit, an RC circuit, or like a pure resistive circuit at frequencies below the resonant frequency? Explain.
5. What is the general phase relationship between the voltage across the inductor and the voltage across the capacitor? Is this only true at the resonant frequency? Explain.
6. For Circuit 1 and Circuit 2, does the *circuit* phase angle change as frequency is changed? Explain.
7. From the data on your Data Table, determine whether the circuit Q was higher for Circuit 1 or for Circuit 2. Explain your answer.
8. Indicate if the voltage across the reactive components at the resonant frequency was approximately equal to $Q \times V_A$. What might cause any differences here?
9. At the resonant frequency for both circuits, determine if the calculated values of X_C were approximately the same when using Circuit 1 as when using Circuit 2. List the values in both cases, and explain why this is true.

Technical Lab Report

Write a brief technical lab report summarizing the technical facts learned from this project. The report should be organized to provide the following:

1. An introductory paragraph describing the type of circuit being analyzed and the key parameters that will be discussed relating to this circuit.
2. A section describing the most important characteristics of this type of circuit that were shown via the collected data in the tables and graphs.
3. Any special facts or characteristics about this type of circuit that were highlighted in answering the Analysis Questions.
4. A practical example of how the information learned in this project might help you in operating, troubleshooting, error analysis, or adjusting a circuit of this type in your home setting, in your training program setting, or in a job setting in the real world.
5. A summary statement listing the most positive aspects of the project and any parts of the project that were difficult because of equipment problems or unclear instructions. Include areas that might be improved.

Name: _____ Date: _____

Complete the following review questions, indicating the appropriate response by placing a check in the box next to the correct answer.

- Resonance is sometimes defined as the circuit condition when
 - $R = X_L$
 - $R = X_C$
 - $X_L = Z$
 - $X_C = Z$
 - $X_C = X_L$
- Three circuit factors that determine whether an RLC circuit will be equivalent to an RC , an RL , or a resistive circuit are
 - V , I , and Z
 - f , L , and C
 - f , R , and V_A
 - none of these
- If a series RLC circuit is at resonance and f is then increased, the circuit will begin to act
 - capacitively
 - inductively
 - resistively
- What is the phase relationship between V_C and V_L in a series RLC circuit?
 - 0 degrees
 - 45 degrees
 - 90 degrees
 - 180 degrees
 - none of these
- What is the phase relationship between I_C and I_L in a series RLC circuit?
 - 0 degrees
 - 45 degrees
 - 90 degrees
 - 180 degrees
 - none of these
- As the resonant frequency is approached for any RLC circuit, the phase angle will
 - increase
 - decrease
 - remain the same
- Is it possible for an RLC circuit to change from capacitive to inductive simply by changing the frequency of the applied voltage?
 - Yes
 - No
- Impedance in a series RLC circuit at resonance is
 - maximum
 - minimum
 - neither of these

9. The voltage across either reactive component in a series resonant RLC circuit is equal to

- | | |
|---|--|
| <input type="checkbox"/> 0 volts | <input type="checkbox"/> $V_T - V_R$ |
| <input type="checkbox"/> $R \times C$ | <input type="checkbox"/> none of these |
| <input type="checkbox"/> $Q \times V_T$ | |

10. If the series resistance in a series resonant RLC circuit is decreased, the Q of the circuit will

- | | |
|-----------------------------------|--|
| <input type="checkbox"/> increase | <input type="checkbox"/> remain the same |
| <input type="checkbox"/> decrease | |