INDUCTANCE

Objectives

In these projects you will connect circuits that illustrate the property of an inductor to oppose a change in current and the resultant total inductance of two inductors connected either in series or in parallel.

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 inductance:

- The property of inductance
- Effect of changing value of *L*
- Total inductance of inductors in series and in parallel

Project/Topic Correlation Information

PROJECT	TEXT CHAPTER	SECTION	RELATED TEXT TOPIC(S)
40 Total Inductance in Series and Parallel	13	13-5	Inductance in Series Inductance in Parallel

Special Notes to Students and Instructors

Note 1: Circuit Options

Beginning with *this project* and continuing through the *Series Resonance* and *Parallel Resonance* series of projects there are a number of projects in which two types of circuits are shown. These are a “lower-frequency” circuit and a “higher-frequency” circuit that can be used to perform the project. The instructor has the option of having the students perform each project using either the lower-frequency circuit or the higher-frequency circuit, depending on component availability and instructional program preferences. The instructor may also opt to have students connect and make required measurements and calculations for both types of circuits, as time permits.

Note 2: Measurement Cautions

1. For the *lower-frequency circuit* option, the inductors used in this project and a number of projects that follow are iron-core, filter-choke-type inductors. Under normal operating conditions, this inductor has dc current as well as ac signal components present. The manufacturer has rated the inductance value based on the normal operating environment for this type inductor. *Students and instructors* should be aware that this inductor will exhibit "apparent" inductance values in our projects that are quite different from the manufacturer's rating. Due to the inductor being used under operating conditions different from those specified by the manufacturer, such factors as "incremental permeability," and so forth, enter into the results in terms of how much acting inductance the inductor "appears" to have. Also, the voltage dropped by the inductor is due to the inductor's impedance—not just its reactance. Add into this scenario the tolerance of component values, variances in calibration of signal sources, test equipment, and so on, and it is obvious that results will vary from those that would result if the inductor were truly acting at the manufacturer-rated value and all the components and test equipment were perfectly calibrated.

2. For the *higher-frequency circuit* option, there are several important things to keep in mind. Be aware that the inductor called for in the circuits is a 100-mH inductor. Typically, the tolerance on these inductors is large; therefore, they may act like inductances from 80 mH to 100 mH+, even though rated at 100 mH.

   Most handheld DMMs have frequency limitations in terms of measuring ac voltages and currents. In many cases, the highest frequencies they should be used to measure are signals up to about 1 kHz. For other, more expensive, true RMS meters, the specifications may allow for voltage and current measurements up to about 10 kHz.

   Since a number of the higher-frequency circuit options for our projects ask for frequency runs as high as 5 kHz to 10 kHz, the measurements must be made with a DMM (bench-type or otherwise) rated to measure ac up to at least 10 kHz. Ideally, the meter should be a *True RMS* reading instrument; although, the more common *averaging type* reading instrument will probably work as long as its frequency rating is sufficient.

   Alternatively, a scope can be used for measurements. However, great caution must be used to make sure that the signal source ground and the scope ground(s) are connected to the same end of the component across which voltage measurement is being made. If they are not, the two ground locations can short out a component or a portion of the circuit under test! In some cases, this may mean changing positions of components in the circuit for each measurement; in other cases, this may not be necessary.

3. Students should be careful to set the signal sources to the correct frequencies and voltage levels for changes in the circuit conditions they are examining. Normally, it will be necessary to check and reset the voltage level whenever source frequency settings, circuit components, or conditions are changed.

Inductance

Total Inductance in Series and Parallel

PROJECT 40

Name: ______________________ Date: __________

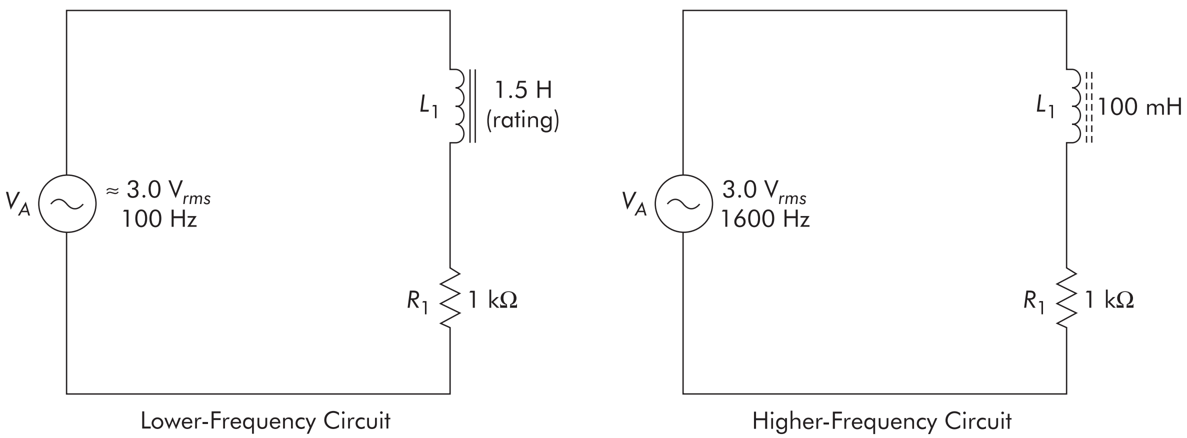


FIGURE 40-1

PROJECT PURPOSE To demonstrate, through circuit connections and measurements, that inductances in series add like resistances in series and that inductances in parallel are analyzed in the same fashion as resistances in parallel are analyzed.

PARTS NEEDED

- ☐ DMM
- ☐ Low voltage ac source (function generator)
- ☐ CIS
- ☐ Inductors, 1.5 H, 95 Ω, or approximate (2)
- ☐ 100 mH (2)
- ☐ Resistor, 1 kΩ

SPECIAL NOTE:

For this project, we will observe the property of inductance to oppose a change in current by applying a continuously changing ac voltage to the circuit and noting the current limiting effects. The higher the inductance, or *L*, the higher the opposition to ac current. By noting the ac circuit current with a single inductor, then two inductors in series, then two inductors in parallel, we will illustrate the effects on total inductance of connecting two coils in series and in parallel.

For convenience, the voltage drop across a 1-kΩ resistor will be used as a current indicator. Since $I = V/R$, the number of volts divided by 1 kΩ automatically yields *I* in mA, e.g., 10 volts across a 1-kΩ resistor indicates 10 mA through the resistor, and so on.

PROCEDURE

1. Measure the dc resistance of the two inductors that will be used for this project. Also, set the ac source voltage that will be used to 3 V_{rms}.

OBSERVATION

Lower f	Higher f
L_1 = __________ Ω.	L_1 = __________ Ω.
L_2 = __________ Ω. (approximately)	L_2 = __________ Ω. (approximately)
V = __________ V_{rms}. (no load)	V = __________ V_{rms}. (no load)

2. Connect the initial circuit as shown in Figure 40-1.

CONCLUSION If V_A were dc, what would be the current through this circuit? ________ mA.

3. Measure V_1 (voltage drop across R_1) and calculate the ac current.

OBSERVATION

Lower f	Higher f
V_1 = __________ V.	V_1 = __________ V.
I = __________ mA.	I = __________ mA.

CONCLUSION The back emf produced by the ____________________ is limiting the current to a lower value than it would be if dc were applied to the circuit.

4. Insert the second L (L_2) in series with the circuit. With V_A again set to 3 V_{rms}, measure V_1 and calculate the ac current.

OBSERVATION

Lower f	Higher f
V_1 = __________ V.	V_1 = __________ V.
I = __________ mA.	I = __________ mA.

CONCLUSION Since the current was lower with the two inductors in series, the L total is obviously (*more, less*) __________________ than with one inductor. We conclude that inductors in series add like resistors in (*series, parallel*) ____________________.

5. Change the circuit so L_2 is in parallel with L_1. Measure V_1 and calculate the ac current.

OBSERVATION

Lower f	Higher f
V_1 = __________ V.	V_1 = __________ V.
I = __________ mA.	I = __________ mA.

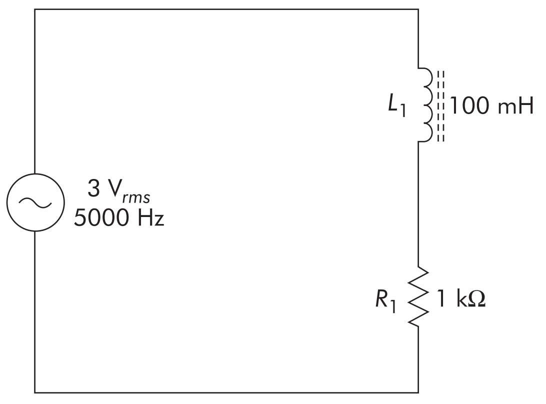
CONCLUSION Since the current is higher with the two inductors in parallel, then L total must be (*more, less*) ________________ than with one inductor. We conclude that inductors in parallel add like resistors in (*series, parallel*) ____________________.

PART 9

Story Behind the Numbers

Inductance

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.

GENERAL INFORMATION For this project, you will observe the property of inductance to oppose a change in current. You will do this by applying a continuously changing ac voltage to the circuits and noting the current-limiting effects. The higher the inductance (*L*), the higher the opposition to ac current. By noting the ac circuit current with a single inductor, two inductors in series, and two inductors in parallel, you will be able to illustrate the effects of total inductance on circuit current when the ac applied voltage is the same in all cases.

Procedure

1. Measure the dc resistances of the inductors that will be used for this project and record these values in the appropriate locations on the Data Table.
2. Connect the initial one-inductor circuit, as shown in the circuit diagram.

   NOTE ➤ For this project, we are using the higher-frequency circuit and circuit parameters set up.

3. Measure the voltage drop across the 1-kΩ resistor and record this value in the appropriate location on the Data Table.

4. Use the measured voltage value and the color-coded value of R_1 to calculate the circuit current value. Record on the Data Table, as appropriate.
5. Turn off the signal source and modify the circuit by adding a second inductor *in series* with the original inductor.
6. Turn on the signal source and set V_A to 3 V_{rms} again. Measure the voltage across the 1-kΩ resistor again. Record this value on the Data Table, as appropriate.
7. Calculate the circuit current for the circuit with the two inductors in series and record this value on the Data Table.
8. Turn off the signal source and modify the circuit by moving the second inductor so that it is now connected *in parallel* with the original circuit inductor.
9. Once again, measure the voltage drop across the 1-kΩ resistor and calculate the circuit current for the circuit having the two inductors in parallel. Record these parameters on the Data Table, as appropriate.
10. After completing the Data Table, answer the Analysis Questions and create the brief Technical Lab Report to complete the project.

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. Explain why the current through the initial circuit was lower than it would have been if the applied voltage had been dc, rather than ac.
2. Explain why the current through the circuit with the two inductors in series was lower than when there was only one inductor in the circuit.
3. Was the circuit current with the two inductors *in series* equal to exactly one-half the value of the current in the single-inductor circuit? Should it have been? If not, explain what circuit parameters could account for this not being true.
4. Was the circuit current with the two inductors *in parallel* equal to exactly double the value of current in the single-inductor circuit? What component(s) and circuit factors might cause it to be less than double in this case?
5. If we had used *perfect* inductances (with no inherent coil resistance) and had not added an external resistance in series with the circuits, would the current value changes have been theoretically halved and doubled, as expressed in the previous steps?
6. List the mathematical expressions for total inductance of inductances in series and of inductances in parallel.

Data Table

Component and Parameter Identifiers	Higher *f* (1 inductor) $V_A = 3\ V_{rms}$; $f = 5000$ Hz Parameter Values
L_1 rated (H)	
L_1 measured R (Ω)	
R_1 color code (Ω)	
If V = dc, I would be:	
V_{R_1} measured (V_{rms})	
I (ac) calculated	
Component and Parameter Identifiers	**Higher *f* (2 series inductors) $V_A = 3\ V_{rms}$; $f = 5000$ Hz Parameter Values**
L_1 rated (H)	
L_2 rated (H)	
L_1 measured R (Ω)	
L_2 measured R (Ω)	
R_1 color code (Ω)	
V_{R_1} (ac) measured	
I (ac) calculated	
Component and Parameter Identifiers	**Higher *f* (2 parallel inductors) $V_A = 3\ V_{rms}$; $f = 5000$ Hz Parameter Values**
L_1 rated (H)	
L_2 rated (H)	
L_1 measured R (Ω)	
L_2 measured R (Ω)	
R_1 color code (Ω)	
V_{R_1} (ac) measured	
I (ac) calculated	

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.

PART 9

Summary

Inductance

Name: ______________________________ Date: ______________

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

1. Inductance is that property in an electrical circuit that opposes
   - ☐ a change in voltage
   - ☐ a change in current
   - ☐ a change in resistance
2. In an ac circuit, if *L* is increased, the circuit current will
   - ☐ increase
   - ☐ remain the same
   - ☐ decrease
3. If two equal inductances are connected in series, total inductance will be
   - ☐ two times that of one
   - ☐ neither of these
   - ☐ one-half that of one
4. If two equal inductances are connected in parallel, total inductance will be
   - ☐ two times that of one
   - ☐ neither of these
   - ☐ one-half that of one