RL CIRCUITS IN AC

Objectives

You will connect several ac *RL* circuits and make measurements and observations regarding their important electrical characteristics.

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 *RL* circuits:

- Relationship of R and X_L to circuit phase angle
- Relationships of current and voltage for an inductor and for a resistor
- Circuit impedance
- Simple vector diagram(s)
- Reference vector(s)

Project/Topic Correlation Information

PROJECT	TEXT CHAPTER	SECTION	RELATED TEXT TOPIC(S)
43 ***V, I, R, Z*, and θ Relationships in a Series *RL* Circuit**	15	15-4	Fundamental Analysis of Series *RL* Circuits
44 ***V, I, R, Z*, and θ Relationships in a Parallel *RL* Circuit**	15	15-5	Fundamental Analysis of Parallel *RL* Circuits

RL Circuits in AC

V, *I*, *R*, *Z*, and θ Relationships in a Series *RL* Circuit

PROJECT
43

Name: ______________________ Date: ____________

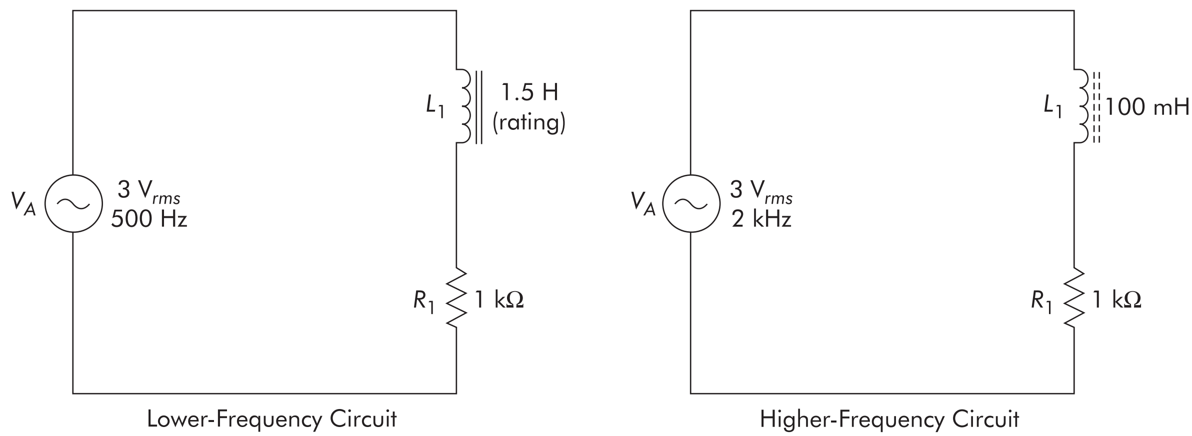


FIGURE 43-1

PROJECT PURPOSE To demonstrate the key electrical parameter relationships in a series *RL* circuit. To observe that due to out-of-phase elements, simple dc analysis techniques cannot be used to determine circuit parameters in ac circuits containing reactive components. Furthermore, to provide practice in using simple ac analysis techniques and in drawing ac circuit vector diagrams.

PARTS NEEDED

- ☐ DMM
- ☐ Function generator or audio oscillator
- ☐ Dual-trace oscilloscope
- ☐ CIS
- ☐ Inductors 1.5 H, 95 Ω
- ☐ 100 mH
- ☐ Resistor 1 kΩ

PROCEDURE

1. Connect the initial circuit as shown in Figure 43-1.

2. Set the frequency of the function generator to the frequency indicated for the circuit option you are using. Set the circuit input voltage to 3 volts. Measure V_A, V_R, and V_L.

OBSERVATION

Lower *f*	Higher *f*
V_A = ______________ V.	V_A = ______________ V.
V_R = ______________ V.	V_R = ______________ V.
V_L = ______________ V.	V_L = ______________ V.

CONCLUSION Does V_A equal the arithmetic sum of V_R and V_L? ________. We conclude that to find V_A we must vectorially (*add, subtract*) ____________________ V_R and V_L. We can also use the __________________ theorem.

3. Calculate I_T from V_R/R. Calculate X_L from V_L/I. Calculate circuit total impedance from $Z = V_T/I_T$.

OBSERVATION

Lower *f*	Higher *f*
I_T = ____________________ mA.	I_T = ____________________ mA.
X_L = ____________________ Ω.	X_L = ____________________ Ω.
Z = ____________________ Ω.	Z = ____________________ Ω.

4. Determine the apparent value of L from the known frequency and X_L parameters.

OBSERVATION

Lower *f*	Higher *f*
L = ____________________ H.	L = ____________________ H.

5. Determine Z using the Pythagorean Theorem (using the R and X_L parameters).

OBSERVATION

Lower *f*	Higher *f*
Z = ____________________ Ω.	Z = ____________________ Ω.

6. Draw an impedance diagram in the Observation section.

OBSERVATION

7. Use trigonometry and determine the phase angle.

OBSERVATION

Lower *f*	Higher *f*
θ = ____________________ degrees.	θ = ____________________ degrees.

CONCLUSION These conclusions are drawn for steps 3 through 7.

Does Z equal the arithmetic sum of R and X_L? ________. We again conclude that we must use the vector sum or the Pythagorean Theorem used in analysis of right ____________________. From the observations of steps 2 and 3 we may conclude that V_R and V_L are (*in phase, not in phase*) __________________. Since inductance opposes a change in current, we may assume that V_L (*leads, lags*) ________________ I_L by some angle. If L were a perfect inductor, ____________________ would lead ____________________ by 90 degrees. Since the circuit is not composed of purely resistance in which the phase angle between V and I = _________ degrees, nor purely inductance in which the phase angle between V and I equals __________ degrees, but rather a composite of both, we might expect the phase angle between V_T and I_T to be between ________ and ________ degrees. Further, the larger the X_L is compared to the circuit R, the more like a purely inductive circuit the results will be; thus the (*greater, lesser*) ______________________ will be the circuit phase angle. The converse is also true.

Optional Steps

8. Use the measured and calculated data in steps 2 and 3, and draw a V-I vector diagram in the Observation section.

OBSERVATION

9. Use trigonometry and determine the phase angle.

OBSERVATION Lower f Higher f

θ = ______________________ degrees. θ = _____________________ degrees.

CONCLUSION Does the phase angle from the V-I vector diagram agree reasonably with the phase angle you determined from the Z diagram? ________.

10. Use a dual-trace oscilloscope and perform a phase comparison of V_A and circuit current, (represented by the voltage across the resistor).

CAUTION: **Be sure the signal source ground and the scope ground(s) are connected to the same end of the resistor when making the measurements to prevent the two grounds from shorting out a portion of the circuit!**

Determine the phase difference between the two signals. (If possible, demonstrate your scope waveforms and calculations to your instructor.)

OBSERVATION θ determined by the scope phase comparison:

Lower f	Higher f
θ = ______________________ degrees.	θ = _____________________ degrees.

CONCLUSION Do the scope phase measurements and the phase angle calculations agree reasonably with your earlier findings? (Considering tolerances in components, source and scope frequency calibration tolerances, etc.) ________.

RL Circuits in AC

V, *I*, *R*, *Z*, and θ Relationships in a Parallel *RL* Circuit

PROJECT

44

Name: ______________________________ Date: ______________

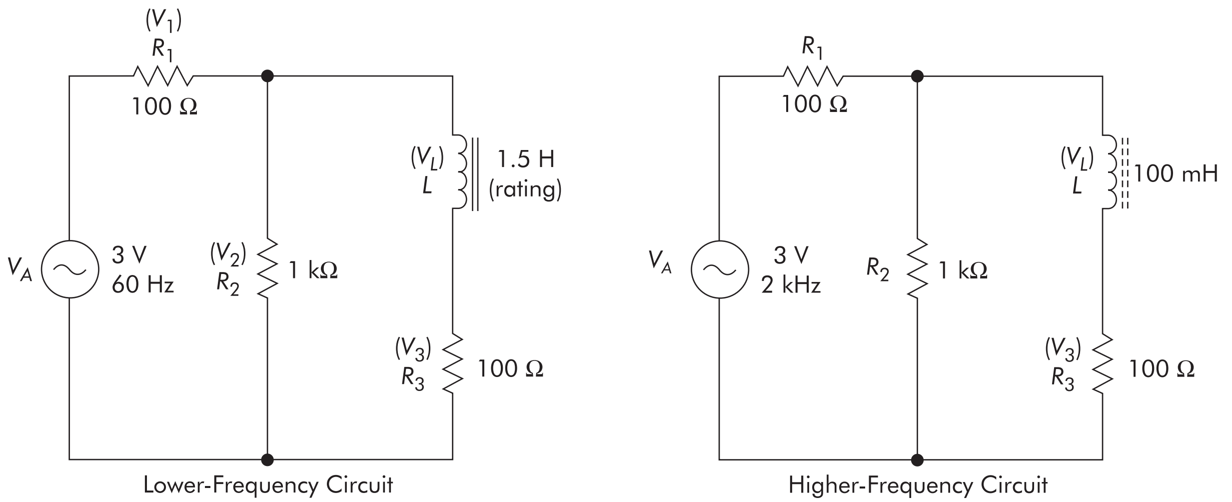


FIGURE 44-1

PROJECT PURPOSE To demonstrate the key electrical parameter relationships in a parallel *RL* circuit. To observe that due to out-of-phase elements, simple dc analysis techniques cannot be used to determine circuit parameters in ac circuits containing reactive components. Also, to provide practice in using simple ac analysis techniques and in drawing ac circuit vector diagrams.

PARTS NEEDED

- ☐ DMM
- ☐ Function generator or audio oscillator
- ☐ Low voltage 60-Hz ac source
- ☐ CIS
- ☐ Inductors
  1.5 H, 95 Ω (or approximate)
- ☐ 100 mH
- ☐ Resistors
  100 Ω (2)
  1 kΩ (1)

SPECIAL NOTE:

It should be noted that once again, we will be using the 100-Ω resistor in series with the main line as a circuit current indicator. The current equals 10 times the voltage drop.

PROCEDURE

1. Connect the initial circuit as shown in Figure 44-1.

2. Set the source for 60 Hz, 3 V_{rms} for the lower f circuit and for 2,000 Hz, 3 V_{rms} for the higher f circuit. Measure the circuit voltages.

OBSERVATION

Lower f	Higher f
V_A = __________ V.	V_A = __________ V.
V_1 = __________ V.	V_1 = __________ V.
V_2 = __________ V.	V_2 = __________ V.
V_3 = __________ V.	V_3 = __________ V.
V_L = __________ V.	V_L = __________ V.

CONCLUSION Do the voltages around any given closed loop add up by addition to V_A? __________.
From this we conclude that the circuit current(s) and voltage(s) are (*in phase, out of phase*) __________.

3. Calculate the total circuit current from V_1. Calculate the current through R_2 by Ohm's Law. Calculate the current through L by using the voltage drop across R_3. Use Ohm's Law to solve for I_L ($I_L = V_3/R_3$) and X_L ($X_L = V_L/I_L$).

OBSERVATION

Lower f	Higher f
I_T = __________ mA.	I_T = __________ mA.
I_2 = __________ mA.	I_2 = __________ mA.
I_L = __________ mA.	I_L = __________ mA.
X_L = __________ Ω.	X_L = __________ Ω.

4. Use measured and calculated values of I_2 and I_L. Apply the Pythagorean Theorem formula and calculate I_T.

OBSERVATION

Lower f	Higher f
I_T calculated = __________ mA.	I_T calculated = __________ mA.

5. Draw the appropriate *V-I* vector diagram in the Observation section.

OBSERVATION

6. Use trigonometry and determine the phase angle. (Neglect R_1 parameters and use only R_2 and L parameters.)

OBSERVATION

Lower *f* — θ = ______________________ degrees.
Higher *f* — θ = ______________________ degrees.

CONCLUSION These conclusions are drawn for steps 3 through 6.

Does total current equal the arithmetic sum of the branch currents? __________. This is because the branch currents are ____________________ ____________________ ____________________. The current through R_2 is in phase with V_2 (*True* or *False*) _________________. The current through the coil (*leads, lags*) _________________ the voltage across the coil by close to ________ degrees. If the inductor were perfect, it would be exactly ________ degrees. Since the total circuit current is the vector resultant of the two branch currents, it would seem logical to assume the circuit total current would be (*leading, lagging*) ______________________ V_A by some angle between ________ and __________ degrees. Also note from our measurements and calculations that the total circuit impedance (Z) cannot be found by the product-over-the-sum method but is most easily solved by Ohm's Law, where $Z = V_T/I_T$.

Optional Step

7. Use a dual-trace oscilloscope and perform a phase comparison of the current through the R_2 branch and the current through the inductor branch. Do this by letting the voltage across R_2 represent the current through R_2 and the voltage across R_3 represent the current through the inductor branch.

STOP CAUTION: Be sure the signal source ground and the scope ground(s) are connected to the same end (the bottom end) of the circuit network when making the measurements to prevent the grounds from shorting out a portion of the circuit!

Determine the phase difference between the two signals. (If possible, demonstrate your scope waveforms and calculations to your instructor.)

OBSERVATION Measured θ between the resistor branch and the inductor branch as determined by the scope phase comparison:

Lower *f* — θ = ______________________ degrees.
Higher *f* — θ = ______________________ degrees.

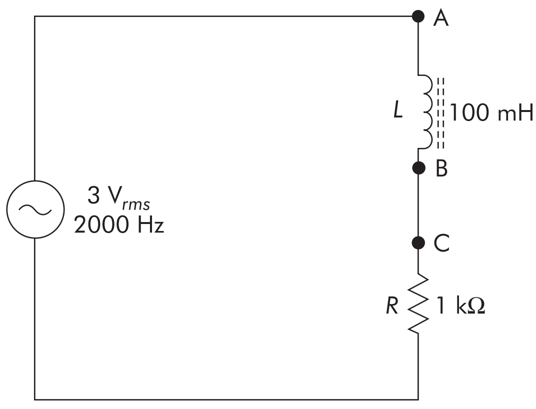
CONCLUSION Was the phase difference between the two branches reasonably close to 90°? ________. If not, what variables and factors might account for the difference? _____
____
____
____.

PART 11

Story Behind the Numbers

Section 1: *RL* (Series) Circuits in AC

Name: ______________________________ Date: ____________



NOTE ➤ Prior to performing project this 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 the circuit as shown.
2. Set the frequency of the function generator to 2,000 Hz and its output to 3 V.
3. Measure V_A, V_R, and V_L and record the values in the Data Table where indicated.
4. From the measured parameter values, calculate the circuit total current (V_R/R), the value of X_L (V_L/I), and the circuit total impedance (V_T/I_T) and record these values on the Data Table where indicated.
5. Use the Pythagorean Theorem and find the value of circuit Z using the rated value of R and the calculated value of X_L. Record this value on the Data Table where indicated.
6. Use the appropriate version of the X_L formula and determine the "apparent" value of L from the known frequency and X_L parameters. Record this value on the Data Table.
7. Use a dual-trace oscilloscope and perform a phase comparison of V_A and circuit current, (represented by the voltage across the resistor).

CAUTION: Be sure the signal source ground and the scope ground(s) are connected to the same end of the resistor when making the measurements to prevent the two grounds from shorting out a portion of the circuit!

Determine the phase difference between the two signals. If possible, demonstrate your scope pattern to your instructor.

8. After completing the Data Table, answer the Analysis Questions and develop a brief Technical Lab Report to complete the project.

Data Table

Component and Parameter I.D.'s	Measured Values	Calculated Values
V_A (V)		—
V_R (V)		—
V_L (V)		—
I_T (mA)	—	
X_L (kΩ)	—	
Z, Ohm's Law (kΩ)	—	
Z, Pythagorean Theorem (kΩ)	—	
Calculated apparent L (mH)	—	

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. Review any data you have collected and determine if V_A equals the arithmetic sum of the values of V_R and V_L. Explain your finding.
2. Does the circuit Z equal the sum of the values of R and X_L? Explain your finding.
3. Does the value you found for the "apparent" L match the manufacturer's rating for the inductor used? Is it reasonably close? List several factors that may cause differences.
4. Use the data you have collected to draw an impedance diagram for the circuit conditions you used in this project. Label all parts of the diagram appropriately.

5. Use trigonometry to find the phase angle represented in your impedance diagram.

6. Use the data you have collected and draw a *V*-*I* vector diagram. Label all parts of the diagram appropriately.

7. Use trigonometry to find the phase angle represented in your *V*-*I* vector diagram.

8. Record the computation you used for determining phase angle from your dual-trace scope pattern.

9. Define and list the changes that would occur (in general terms) for the various circuit parameters if the source frequency were doubled, while keeping the V_A at 3 volts. (Define each specific parameter in terms of whether it would increase, decrease, or remain the same.)

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.

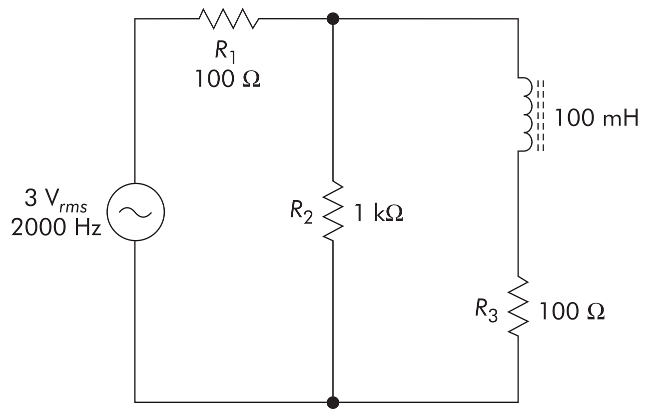
5. A summary statement listing the most positive aspects of the project and any parts of the project that were difficult because of equipment problems or unclear instructions. Include areas that might be improved.

PART 11

Story Behind the Numbers

Section 2: *RL* (Parallel) Circuits in AC

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 the circuit as shown.
2. Set the frequency of the function generator to 2,000 Hz and its output to 3 V.
3. Measure V_A, V_{R_1}, V_{R_2}, V_{R_3}, and V_L and record the values on the Data Table, as appropriate.
4. From the measured data, calculate I_T (V_{R_1}/R_1), I_2 (V_{R_2}/R_2), I_L (V_{R_3}/R_3), and X_L (V_L/I_L) and record results on the Data Table in the appropriate locations.
5. Use the Pythagorean Theorem formula and the measured and calculated values of I_2 (current through the resistive branch) and I_L (current through the inductive branch) to determine circuit I_T. Record on the Data Table where indicated.
6. Use a dual-trace oscilloscope and perform a phase comparison of the current through the resistive branch (R_2) by observing V_{R_2} and the current through the inductor branch by observing V_{R_3}.

CAUTION: Be sure the signal source ground and the scope ground(s) are connected to the same end (the bottom end) of the circuit network when making the measurements to prevent the grounds from shorting out a portion of the circuit!

Determine the phase difference between the two signals. If possible, demonstrate your scope waveforms to your instructor.

7. After completing the Data Table, answer the Analysis Questions and develop a brief Technical Lab Report to complete the project.

Data Table

Component and Parameter I.D.'s	Measured Values	Calculated Values
V_A (V)		—
V_{R_1} (V)		—
V_{R_2} (V)		—
V_{R_3} (V)		—
V_L (V)		—
I_T (mA)	—	
I_{R_2} (mA)	—	
X_L (kΩ)	—	
I_T, Pythagorean Theorem (mA)	—	

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 total circuit current does not equal the arithmetic sum of the branch currents in this circuit.
2. Are the current through R_2 and the voltage across R_2 in phase with each other?
3. Define the phase relationship between the current through the inductor and the voltage across the inductor.
4. Using the data from your Data Table, draw an appropriate *V-I* vector diagram showing the branch currents and total current in the circuit. Label all vectors appropriately.

5. Use trigonometry to determine the circuit phase angle. Add the angle data to your vector diagram.

6. Explain whether the circuit total current is leading or lagging the circuit applied voltage and by how much. Also, explain why there is a phase difference in this circuit.

7. Show your work for determining the difference in phase between the resistive and inductive branch currents, based on your scope patterns. Was the phase difference close to 90 degrees? What might cause it to not be precisely 90 degrees?

8. Define and list the changes that would occur (in general terms) for the various circuit parameters if the source frequency were doubled, while keeping the V_A at 3 volts. (Define each specific parameter in terms of whether it would increase, decrease, or remain the same.)

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 11

Summary

RL Circuits in AC

Name: ______________________________ Date: ______________

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

1. An ac circuit whose phase angle is 45 degrees is composed of
   - ☐ an equal amount of resistance and reactance
   - ☐ an unequal amount of resistance and reactance
   - ☐ purely resistance
   - ☐ purely reactance

2. The current through an inductor
   - ☐ leads V_L
   - ☐ lags V_L
   - ☐ is in phase with V_L

3. To find the Z of a series RL circuit
   - ☐ simply add X_L total and R total
   - ☐ subtract X_L from R
   - ☐ neither of these

4. When making a V-I vector diagram of a series RL circuit, the reference vector is
   - ☐ I_T
   - ☐ V_T
   - ☐ Z_T
   - ☐ R_T
   - ☐ none of these

5. When making a V-I vector diagram of a parallel RL circuit, the reference vector is
   - ☐ I_T
   - ☐ V_T
   - ☐ Z_T
   - ☐ R_T
   - ☐ none of these

6. In a series RL circuit, if L is increased while R remains the same, the circuit phase angle (angle between V_A and I_T) will
   - ☐ increase
   - ☐ decrease
   - ☐ remain the same

7. In a series RL circuit, if R is increased while L remains the same, the circuit phase angle will
   - ☐ increase
   - ☐ decrease
   - ☐ remain the same

8. In a parallel RL circuit, if L is increased while R remains the same, the circuit phase angle will
   - ☐ increase
   - ☐ decrease
   - ☐ remain the same

9. In a parallel *RL* circuit, if *R* is increased while *L* remains the same, the circuit phase angle will
   - ☐ increase
   - ☐ remain the same
   - ☐ decrease

10. The value of total circuit impedance (*Z*) for both series and parallel ac circuits can be solved by Ohm's Law.
    - ☐ True
    - ☐ False