RC CIRCUITS IN AC

Objectives

You will connect several ac *RC* 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 *RC* circuits:

- Relationship of circuit phase angle to R and X_C
- Relationships of current and voltage for capacitors and resistors
- Circuit impedance
- Simple vector diagram(s)
- Reference vector(s)

Project/Topic Correlation Information

PROJECT	TEXT CHAPTER	SECTION	RELATED TEXT TOPIC(S)
52 ***V*, *I*, *R*, *Z*, and θ Relationships in a Series *RC* Circuit**	19	19-2	Series *RC* Circuit Analysis
53 ***V*, *I*, *R*, *Z*, and θ Relationships in a Parallel *RC* Circuit**	19	19-4	Parallel *RC* Circuit Analysis

RC Circuits in AC

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

PROJECT 52

Name: ______________________ Date: ____________

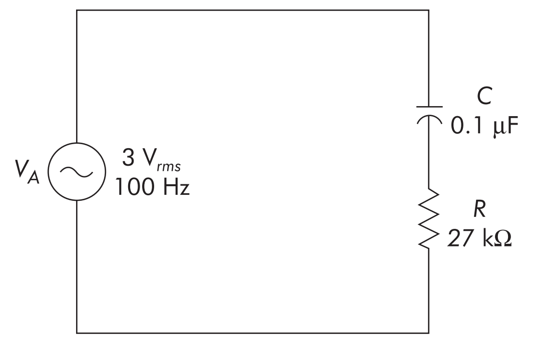


FIGURE 52-1

PROJECT PURPOSE To demonstrate the key electrical parameter relationships in a series *RC* 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
- ☐ Capacitor 0.1 μF
- ☐ Resistor 27 kΩ

SPECIAL NOTE:

By way of review, recall that in a purely resistive series ac circuit, the circuit current was in phase with the applied voltage. Also, the voltage drops across the individual resistors were in phase with current and with each other. The total opposition to current flow in the purely resistive circuit of this type was the arithmetic sum of the individual resistances. If a vector diagram of voltage and current were drawn, we would use the current as the reference vector, since it is the common factor in a series circuit. Summarizing: $Z = R_T$, $\theta = 0$ degrees, V_T = simple sum of $V_1 + V_2 + \ldots$ (etc.) for purely resistive series ac circuits. In this project, you will examine parameters for a series *RC* circuit.

PROCEDURE

1. Connect the initial circuit as shown in Figure 52-1.

2. Set the frequency of the function generator to 100 Hz and V_A to 3 volts. Measure V_A, V_R, and V_C.

OBSERVATION V_A = ______________________________ V. V_C = _____________________________ V.

V_R = ______________________________ V.

CONCLUSION Does the sum of V_R and V_C equal V_A? _____________. This is because V_R and V_C are (*in phase, out of phase*) ______________________________.

3. Calculate I_T from V_R/R; X_C from V_C/I, and Z from V_T/I_T.

OBSERVATION I_T = ____________________________ mA. Z = _____________________________ Ω.

X_C = _____________________________ Ω.

CONCLUSION Does Z equal the arithmetic sum of R and X_C? _________. We may conclude that since V_A is not equal to $V_R + V_C$ and Z in not equal to $R + X_C$,these values are the resultant of two out-of-phase vectors. We can solve for the resultant vectors by means of the Pythagorean theorem or trigonometry. Is the voltage across the resistor in phase with the current through it? ____________. Since a capacitor opposes a change in voltage, we might assume that the I_C (*leads, lags*) ________________________ V_C. In a perfect capacitor I_C (*leads, lags*) _______________________ V_C by 90 degrees. We should also conclude that since this is a series circuit, the larger the amount of X_C (the smaller the C), the more like a purely (*resistive, capacitive*) _________________________________ circuit the circuit will act. This means the larger the X_C compared to the R, the (*greater, smaller*) ______________________________ will be the resultant phase angle between V_A and I_T.

4. Calculate Z using the Pythagorean approach.

OBSERVATION Z calculated = ______________________ Ω.

5. Draw an impedance diagram for the circuit in the Observation section.

OBSERVATION

6. Use the *Z* diagram and trigonometry to determine the phase angle.

OBSERVATION θ = ________ degrees.

7. Repeat the previous steps 2 through 6. This time set f = 200 Hz and keep V_A at 3 volts.

OBSERVATION

V_A = ______________________________ V. X_C = ____________________________ Ω.

V_R = ______________________________ V. Z = _____________________________ Ω.

V_C = ______________________________ V. θ = _______________________ degrees.

I_T = ____________________________ mA.

CONCLUSION Increasing frequency while keeping all other factors the same caused *Z* to ________________________________, X_C to _________________________________, θ to ________________________________.

Optional Steps

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

OBSERVATION

9. Use trigonometry to determine the phase angle.

OBSERVATION θ = ________ degrees.

CONCLUSION Does the phase angle from the *V-I* vector diagram agree reasonably with the angle you determined from the *Z* diagram in step 5? ________.

10. Again, set the source for 100 Hz and a V_A of 3 volts. Use a dual-trace oscilloscope and perform a phase comparison of V_A and circuit current, (represented by the voltage across the resistor).

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

Determine the phase difference between the two signals.

OBSERVATION θ determined by the scope phase comparison:

θ = _______ degrees.

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

RC Circuits in AC

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

PROJECT

53

Name: ____________________ Date: ____________

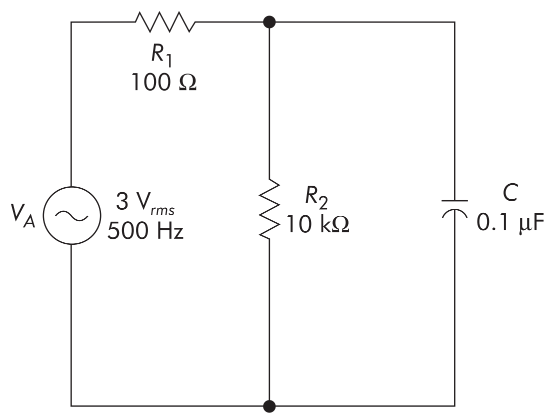


FIGURE 53-1

PROJECT PURPOSE To demonstrate the key electrical parameter relationships in a parallel *RC* 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. To compare results of computing circuit parameters using Ohm's Law and the Pythagorean Theorem.

PARTS NEEDED

- ☐ DMM
- ☐ Function generator or audio oscillator
- ☐ CIS
- ☐ Capacitor 0.1 μF
- ☐ Resistors 100 Ω 10 kΩ

SPECIAL NOTE:

By way of review, recall that in a purely resistive parallel ac circuit, the following conditions exist:

> $Z = R_T$; θ = 0 degrees; I_T = arithmetic sum of branch currents; and branch voltage is in phase with branch current for a purely resistive circuit.

In this project, you will examine parameters in a parallel *RC* circuit. It should be noted again that for this project we will be using the 100-Ω resistor in series with the main line as a circuit current indicator. (Current through R_1 equals ten times its voltage drop.)

PROCEDURE

1. Connect the initial circuit as shown in Figure 53-1.

2. Set the audio oscillator to a frequency of 500 Hz and V_A to 3 volts. Measure the circuit voltages.

OBSERVATION V_A = ______________________ V. V_2 = ______________________ V.
V_1 = ______________________ V. V_C = ______________________ V.

CONCLUSION Does the addition of the voltages around any closed loop equal V_A? __________. We conclude from this that V_R and V_C are (*in phase, out of phase*) ____________________ ____________________.

3. Calculate I_T from V_1. Calculate I_2 by Ohm's Law. Calculate X_C by using the X_C formula, then calculate I_C using the formula:

$I_C = V_C/X_C$

Also, calculate θ using the arctan of I_C/I_R.

OBSERVATION I_T = ______________________ mA. I_C = ______________________ mA.
I_2 = ______________________ mA. θ = ______________________ degrees.
X_C = ______________________ Ω.

CONCLUSION Does the total current equal the arithmetic sum of the branch currents? ____________. This is because the branch currents are ______________________________ ______________________ ______________________. Is the current through R_2 in phase with V_2? _________. The current through the capacitor branch (*leads, lags*) ____________________ the voltage across the capacitor by close to ______ degrees. Since I_T is the vector resultant of I_R and I_C, we would logically conclude that I_T (*leads, lags*) ______________ V_A by an angle that is between ______ and ______ degrees.

4. Calculate the circuit Z_T from V_T/I_T.

OBSERVATION Z_T = ______________________ Ω.

CONCLUSION It is interesting to note that the impedance of a circuit consisting of two parallel 10-kΩ branches, whose currents are 90 degrees out of phase, would ≅ 7.07 kΩ. Does our demonstration circuit result compare closely to this? _________. Why not? ____
____
____.

5. Use I_2 and I_C values and determine I_T by means of Pythagorean Theorem.

OBSERVATION I_T calculated = ________________ mA.

6. Repeat the previous steps 2 through 5. This time set f = 250 Hz and keep V_A at 3 volts.

OBSERVATION V_A = ______________________ V. I_2 = ______________________ mA.
V_1 = ______________________ V. X_C = ______________________ Ω.
V_2 = ______________________ V. I_C = ______________________ mA.
V_C = ______________________ V. Z_T = ______________________ Ω.
I_T = ______________________ mA. θ = ______________________ degrees.

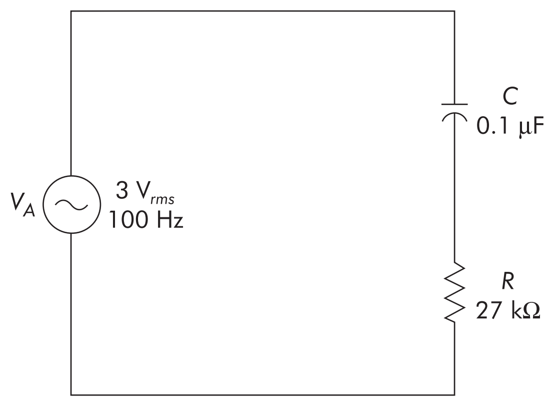
CONCLUSION Decreasing frequency caused Z to ______________, X_C to ______________, θ to ______________.

PART 15

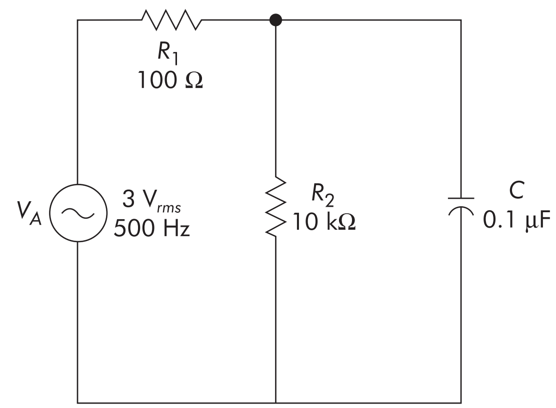
Story Behind the Numbers

RC Circuits in AC

Name: ______________________________ Date: ______________



Circuit 1



Circuit 2

Procedure

1. Connect the circuit shown in Circuit 1.
2. Set the frequency of the function generator to 100 Hz and set V_A to 3 volts.
3. Measure and record the values of V_A, V_R, and V_C on the Data Table, as appropriate.
4. From the measured value of V_R, calculate the value of I_T. Calculate the value of X_C, using V_C/I. Calculate the value of circuit impedance (Z) using V_T/I_T. Record this data on the Data Table.
5. Use the Pythagorean approach and calculate and record the value of Z again, as defined on the Data Table.
6. Use trigonometry to determine the circuit phase angle and record on the Data Table.
7. Change the circuit signal frequency input to 200 Hz, still maintaining V_A at 3 volts.
8. At this new frequency, repeat the measurements and calculations performed in steps 1 through 6. Record these new values in the appropriate locations on the Data Table.
9. Reset the source frequency to 100 Hz, still maintaining V_A at 3 volts.
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 bottom end of the resistor (as shown in the diagram) when making the measurements. This will prevent the source and scope grounds from shorting out a portion of the circuit!

Use the appropriate interpretation technique and determine the phase difference between V_A and I_T. If possible, demonstrate your scope patterns to the instructor.

11. Disconnect Circuit 1 and connect the circuit shown in the Circuit 2 diagram.
12. Set the signal source to a frequency of 500 Hz and V_A to 3 volts.
13. Measure the values of V_A, V_{R_1}, V_{R_2}, and V_C and record the results on the Data Table, as appropriate.
14. Calculate the value of I_T using the voltage drop across R_1 and Ohm's Law. Calculate the value of X_C using the X_C formula. Calculate the value of I_C by using $I_C = V_C/X_C$. Calculate the phase angle by using the arctan of I_C/I_R. Record all these values on the Data Table, as indicated.
15. Use the Ohm's Law approach to find Z_T. Record, as appropriate.
16. Use the Pythagorean approach and determine the value of circuit I_T using the calculated value of I_2 for I_R and the previously computed value of I_C for the I_C in the Pythagorean formula. Record the I_T value on the Data Table, as appropriate.
17. Set the signal source to a frequency of 250 Hz, keeping V_A at 3 volts.
18. Repeat all the measurements and calculations performed in steps 11 through 15 and record results in the appropriate locations on the Data Table.
19. After completing the Data Table, answer the Analysis Questions and produce 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. For Circuit 1, at either of the two frequencies used, did the arithmetic sum of the resistor voltage and capacitor voltage equal applied voltage? Explain.
2. For Circuit 1, does the circuit impedance equal the arithmetic sum of resistance and capacitive reactance? Is the impedance greater or less than the sum? Explain.
3. For Circuit 1, which, if any, voltage drops are in phase with the circuit current? Which voltage drops are out of phase with the circuit current? By how much?

Data Table

SERIES *RC*, CIRCUIT 1				
Component and Parameter I.D.'s	**Measured Values @ 100 Hz**	**Calculated Values @ 100 Hz**	**Measured Values @ 200 Hz**	**Calculated Values @ 200 Hz**
V_A (V)		—		—
V_R (V)		—		—
V_C (V)		—		—
I_T (mA)	—		—	
X_C (kΩ)	—		—	
Z, Ohm's Law (kΩ)	—		—	
Z, Pythagorean (kΩ)	—		—	
Phase angle (trig)	—			

PARALLEL *RC*, CIRCUIT 2				
Component and Parameter I.D.'s	**Measured Values @ 500 Hz**	**Calculated Values @ 500 Hz**	**Measured Values @ 250 Hz**	**Calculated Values @ 250 Hz**
V_A (V)		—		—
V_{R_1} (V)		—		—
V_{R_2} (V)		—		—
V_C (V)		—		—
I_T, Ohm's Law (mA)	—		—	
I_2 (mA)	—		—	
X_C (kΩ)	—		—	
I_C (mA)	—		—	
Z_T, Ohm's Law (kΩ)	—		—	
Phase angle (trig)	—		—	
I_T, Pythagorean (mA)	—			

4. For Circuit 1, what is the phase differential between circuit current and applied voltage called? For this circuit, what was this value when using 100 Hz as the source frequency? What was this value when using the circuit with the 200-Hz signal? Explain why there was a difference. Be specific.

5. When frequency was increased from 100 Hz to 200 Hz, did the circuit impedance increase or decrease? Did it either double or halve? Explain.
6. Did the circuit phase angle change? Was it greater or less at the 200-Hz frequency than at the 100-Hz frequency? Explain why this is true.
7. When using the scope to determine phase angle in step 10 of the procedure steps, were the results reasonably close to your mathematically determined phase angle?
8. For Circuit 2, if you added the voltage around a single "closed loop," did the sum equal the applied voltage? Explain.
9. For Circuit 2, if you arithmetically added the calculated branch currents, did they equal total circuit current? Explain.
10. For Circuit 2, is the current through the capacitor branch in phase with the voltage across the capacitor? If not, explain the relationship of these two parameters.
11. For Circuit 2, does the circuit current lead or lag the circuit applied voltage? Explain.
12. For Circuit 2, was the circuit phase angle greater at 500 Hz or 250 Hz? Explain why this is true.
13. Make a logical comparison between this fact and what was true when the frequency was changed for the series *RC* circuit (Circuit 1).
14. For Circuit 2, can you calculate circuit impedance using the product-over-the-sum approach? Explain.
15. In summary, answer the following questions with "I" for increase, "D" for decrease, or "RTS" for remain the same.

    For the series *RC* circuit: A decrease in frequency would cause Z to ________, X_C to ________, and θ to ________.

    For the parallel *RC* circuit: A decrease in frequency would cause Z to ________, X_C to ________, and θ to ________.

    For a series *RC* circuit: As X_C increases, circuit phase angle will ________.

    For a parallel *RC* circuit: As X_C increases, circuit phase angle will ________.

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 15

Summary

RC Circuits in AC

Name: ______________________________ Date: ______________

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

1. The higher the frequency of V_A applied to any *RC* circuit, either series or parallel, the ________ the circuit impedance will be.
   - ☐ higher
   - ☐ lower
2. In a purely capacitive series circuit, the arithmetic sum of the individual voltage drops equals V_A.
   - ☐ True
   - ☐ False
3. In a series *RC* circuit, the arithmetic sum of the individual voltage drops equals V_A.
   - ☐ True
   - ☐ False
4. In a parallel *RC* circuit, the arithmetic sum of the branch currents equals I_T.
   - ☐ True
   - ☐ False
5. In a series *RC* circuit, if frequency, resistance, or capacitance increases, the circuit phase angle will
   - ☐ increase
   - ☐ decrease
   - ☐ remain the same
6. In a parallel *RC* circuit, if frequency, resistance, or capacitance increases, the circuit phase angle will
   - ☐ increase
   - ☐ decrease
   - ☐ remain the same
7. As the resistance in a parallel *RC* circuit is increased, the circuit will become more
   - ☐ resistive
   - ☐ capacitive
8. As the capacitance in a series *RC* circuit is increased, the circuit will become more
   - ☐ resistive
   - ☐ capacitive

9. A circuit that is capacitive is one in which the circuit voltage is lagging the circuit current, and I_C and V_C are 90 degrees out of phase.
   - ☐ True
   - ☐ False

10. The impedance of a parallel *RC* circuit will increase as frequency is decreased.
    - ☐ True
    - ☐ False