CAPACITANCE (DC CHARACTERISTICS)

Objectives

You will connect circuits illustrating the characteristics of capacitor(s) in dc 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 capacitance in dc circuits:

- Charge and discharge action
- *RC* time
- Total capacitance of series capacitors
- Total capacitance of parallel capacitors

Project/Topic Correlation Information

PROJECT	TEXT CHAPTER	SECTION	RELATED TEXT TOPIC(S)
47 Charge and Discharge Action and *RC* Time	17	17-3 17-10	Charging and Discharging Action The *RC* Time Constant
48 Total Capacitance in Series and Parallel	17	17-8	Total Capacitance in Series and Parallel

Capacitance (DC Characteristics)

Charge and Discharge Action and *RC* Time

PROJECT 47

Name: ________________________ Date: ____________

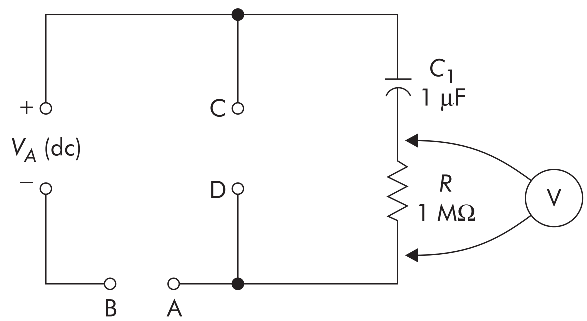


FIGURE 47-1

PROJECT PURPOSE To demonstrate the charging and discharging action of a capacitor and to observe that a capacitor takes five *RC* time constants to change from one set voltage level to another.

PARTS NEEDED

- ☐ DMM
- ☐ VVPS (dc)
- ☐ CIS
- ☐ Capacitors
  0.1 μF, 1.0 μF
- ☐ Resistors
  100 kΩ
  1 MΩ
  10 MΩ

SAFETY HINTS Remember that charged capacitors remain charged and can shock you (until they are discharged).

PROCEDURE

1. Connect the initial circuit as shown in Figure 47-1.
2. Set V_A at 20 volts. Insert a jumper wire between points A and B and observe the meter action.

OBSERVATION Current flowed for approximately ___________ seconds as evidenced by the voltage measured across *R*. The rate of charge was (*linear, nonlinear*) __________________.

CONCLUSION The current that flowed was the charging current that charged the capacitor to a voltage equal to (V_R, V_A) ____________________. Was charging current maximum at the beginning of the charge time or near the end? _________. At the beginning of the charge time, the voltage across *R* was equal to (V_C, V_A) ______________________ (the first instant). At the end of the charge time, the voltage across the resistor is ________ volts; the voltage across the capacitor is equal to V_A.

NOTE ➤ The charged capacitor voltage is equal to V_A and series opposing the source. Hence, no current can flow once the capacitor is charged.

3. Remove the jumper from points A and B. Reverse the polarity of the voltmeter. Insert a jumper between points C and D and observe the meter action during discharge of the capacitor.

OBSERVATION Discharge time was approximately _____ seconds. The *rate* of discharge was (*linear, nonlinear*) ____________________.

CONCLUSION Did the capacitor take the same time to discharge through *R* as it did to charge? ________. At the end of the discharge time V_C = ________ ; V_R = ________ V.

4. Remove the jumper from points C and D. Change the DMM polarity from the original setup if it is not an "autopolarity"-type meter. Change *R* to a 10-MΩ resistor. Repeat the sequence of steps 2 and 3.

OBSERVATION Charge time was approximately _________ seconds. Discharge time was _________ seconds.

CONCLUSION Increasing *R* increased the charge time because the charging current was limited to a smaller value. Thus, it took longer to obtain a given potential difference or ____________________ across the *C*.

5. Change the *C* value to a 0.1-μF capacitor. Insert a jumper between points A and B and note the charge time.

OBSERVATION Charge time was approximately ________ seconds.

CONCLUSION Changing *C* from a 1.0-μF to a 0.1-μF capacitor caused the charge time to ____________________. We conclude that both the value of ____________________ and of ____________________ determine charge and discharge time. It should be noted that if it were not for the effect of the multimeter resistance, the time to charge the capacitor or discharge it would be directly proportional to *R* and to *C*. The formula relating to this is called the formula for the *time constant*. This formula states that one *RC* time constant = *R* in ohms times *C* in farads, and the answer is in seconds.

Also, it should be observed that it takes 5 time constants to charge or discharge the capacitor. Calculate the R_e of *R* and the meter circuit's resistance in parallel and determine if the charge time is about equal to the expected 5 TC. Is it? ________.

6. Use the *RC* time constant formula and determine how long it would take to charge a 1-μF capacitor in series with a 100-kΩ resistor.

OBSERVATION 5 *RC* time constants = ________ seconds.

7. Connect the circuit described in step 6 and note the charge time.

OBSERVATION Charge time measured approximately ________ seconds.

CONCLUSION A multimeter with a meter circuit *R* of 5 MΩ or greater does not alter the circuit resistance of 100 kΩ very much. The measured charge time was (*close, not close*) ____________________ to the theoretical value.

Capacitance (DC Characteristics)

Total Capacitance in Series and Parallel

PROJECT 48

Name: ______________________________ Date: ______________

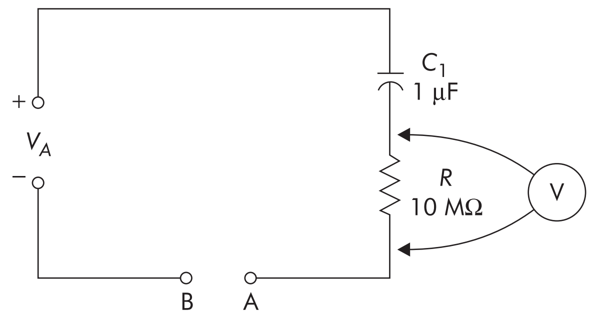


FIGURE 48-1

PROJECT PURPOSE To demonstrate that capacitors in series add like resistances in parallel and that capacitors in parallel add like resistances in series, using circuit observations or *RC* times.

PARTS NEEDED

- ☐ DMM
- ☐ VVPS (dc)
- ☐ CIS
- ☐ Capacitors 1.0 µF (2)
- ☐ Resistors
  10 MΩ

SAFETY HINTS REMEMBER: Capacitors hold their charge unless a discharge path is provided! Don't let that discharge path be you!

SPECIAL NOTE:

For this project, we will take advantage of the fact that the charge time of a capacitor is directly proportional to capacitance. By noting the charge time of a single capacitor, then noting the charge time for two capacitors in series and then in parallel, we should be able to conclude the effect on total capacitance of connecting capacitors in series or parallel. A DMM is highly preferred over a VOM for voltage measurements here.

PROCEDURE

1. Connect the initial circuit as shown in Figure 48-1.

2. Set V_A to 20 volts. Insert a jumper between points A and B and note the charge time by observing the voltmeter.

OBSERVATION Charge time was approximately ________ seconds.

CONCLUSION One *RC* time is approximately ________ seconds. This means that the R_e of the meter and the 10-MΩ resistor is approximately ________ Ω.

3. Obtain a second 1-μF capacitor. Remove the jumper from points A and B. Carefully discharge C_1, then insert the second capacitor (C_2) in series with C_1. Insert a jumper between points A and B and note the charge time of C_1 and C_2 in series.

OBSERVATION Charge time was approximately ________ seconds.

CONCLUSION Since the charge time has decreased to ____________________ the value it was with only C_1 in the circuit, it may be concluded that the total capacitance has (*increased, decreased*) __________________________. Since the new *RC* time is (*double, half*) ______________________ the original and the *R* has not been changed, we conclude that the new total capacitance is _______ μF. Our observations tell us that capacitors in series add like resistors in (*series, parallel*) ____________________.

4. Remove the jumper from points A and B. Discharge the capacitors. Change the circuit as required to achieve a circuit with C_1 and C_2 in parallel, and this combination in series with *R*. Insert the jumper again, and note the charge time of C_1 and C_2 in parallel.

OBSERVATION Charge time was approximately ________ seconds.

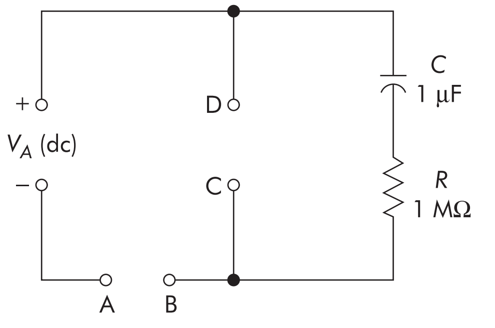
CONCLUSION The charge time for this step is approximately (*2, 3, 4*) _____ times the time recorded in step 2. This indicates that the total capacitance of C_1 and C_2 in parallel is (*1/2, 2*×, *3*×) ________ the capacitance of C_1 alone. We may conclude that capacitors in parallel add like resistors in (*series, parallel*) ____________________. If C_2 were not the same value as C_1, would the statements concerning total capacitance of capacitors in series and parallel still hold true? (That is, series *C*s add like parallel *R*s, and parallel *C*s add like series *R*s.) ________.

PART 13

Story Behind the Numbers

Capacitance (DC Characteristics)

Name: ______________________________ Date: ______________



Procedure

1. Connect the circuit as shown.
2. Connect a DMM to measure the voltage across R. Set V_A at 20 volts. While observing and timing the meter action, carefully place a jumper lead between points A and B and time the approximate number of seconds it takes for the meter to reach a zero volts reading. (This is the approximate capacitor "charge time.") Record this time on the Data Table.
3. Carefully remove the jumper lead from between points A and B. *If* your meter needs polarity protection, reverse the polarity of meter connections across R. Now insert a jumper lead between points C and D while observing the approximate time it takes to discharge the capacitor. Record this time on the Data Table.
4. Turn off the power supply and remove the jumper lead between points C and D.
5. Modify the circuit by changing the R value from 1 MΩ to 10 MΩ and the C value from 1 µF to 0.1 µF.
6. Again, connect a DMM to measure the voltage across R. Set V_A at 20 volts. While observing and timing the meter action, carefully place a jumper lead between points A and B and time the approximate number of seconds it takes for the meter to reach a zero volts reading. (This is the approximate capacitor "charge time.") Record this time on the Data Table.
7. Turn off the power supply and remove the jumper lead between points A and B. Remove the meter from the circuit. Jumper points C and D in order to discharge the capacitor.
8. Use the RC time constant formula and calculate the charge time for a circuit consisting of a 1-µF capacitor and a 100-kΩ resistor. Record this number in the appropriate location on the Data Table.

9. Replace the 0.1-μF capacitor with a 1-μF capacitor and the 10-MΩ resistor with a 100-kΩ resistor. Again, connect a DMM to measure the voltage across *R*. Set V_A at 20 volts. While observing and timing the meter action, carefully place a jumper lead between points A and B and time the approximate number of seconds it takes for the meter to reach a zero volts reading. (This is the approximate capacitor "charge time" for this circuit.) Record this time on the Data Table.

10. Turn off the power supply and remove the jumper lead between points A and B. Remove the meter from the circuit jumper points C and D in order to discharge the capacitor.

11. After completing the Data Table, answer the Analysis Questions and develop a 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. Would it have taken the same amount of time to charge or discharge the capacitors in this circuit if V_A had been 30 volts instead of 20 volts? Explain.

2. If the capacitor had been "precharged" to 20 volts and V_A were changed to 30 volts, would it take the same amount of time for the capacitor to charge from 20 volts up to 30 volts as it did to charge from zero volts to 20 volts? Explain.

3. Were the charge and discharge times approximately equal when the circuit conditions were changed from a 1-μF capacitor and a 1-MΩ resistor to a 0.1-μF capacitor and a 10-MΩ resistor? Explain.

4. If a VOM were used for measurements rather than a DMM, would the time results have been different? Explain.

5. If the measurements would have been affected, which of the circuits would the VOM have affected the most?

6. How many *RC* time constants does it take for a capacitor to charge or discharge from one voltage level to another?

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.

Data Table

Component and Parameter I.D.'s	Measured Values	Calculated Values
V_A (V)	20	—
Charge time (1 μF & 1 MΩ) sec.		—
Discharge time (1 μF & 1 MΩ) sec.		—
Charge time (0.1 μF & 10 MΩ) sec.		—
Discharge time (0.1 μF & 10 MΩ) sec.		—
RC time, (1 μF & 100 kΩ calc.) sec.		

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 13

Summary

Capacitance (DC Characteristics)

Name: ______________________________ Date: ______________

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

1. A charged capacitor has a difference of potential between its plates due to
   - ☐ an excess of electrons on one plate and a deficiency of electrons on the other
   - ☐ an excess of electrons on both plates
   - ☐ neither of these

2. A capacitor in a given circuit will take the same amount of time to discharge as it does to charge.
   - ☐ True
   - ☐ False

3. If the value of *R* is doubled and the value of *C* is halved in a given *RC* circuit, the time it will take to charge the capacitor will
   - ☐ increase
   - ☐ decrease
   - ☐ remain the same

4. One *RC* time constant is equal to
   - ☐ $R + C$
   - ☐ R/C
   - ☐ $R - C$
   - ☐ $R \times C$
   - ☐ none of these

5. In order for a capacitor to fully charge or discharge, it takes
   - ☐ one time constant
   - ☐ two time constants
   - ☐ four time constants
   - ☐ five time constants

6. For a given *RC* circuit, increasing the value of V_A will cause the time needed for the capacitor to fully charge or discharge to
   - ☐ increase
   - ☐ decrease
   - ☐ remain the same

7. The total capacitance of a 0.05-μF capacitor and a 0.1-μF capacitor in parallel is
   - ☐ 0.05 μF
   - ☐ 0.1 μF
   - ☐ 0.06 μF
   - ☐ 0.15 μF
   - ☐ 0.033 μF
   - ☐ none of these

8. The total capacitance of a 0.05-μF capacitor and a 0.1-μF capacitor in series is
   - ☐ 0.05 μF
   - ☐ 0.1 μF
   - ☐ 0.06 μF
   - ☐ 0.15 μF
   - ☐ 0.033 μF
   - ☐ none of these

9. How long would it take two parallel 0.1-μF capacitors to charge through a 1-MΩ resistance?

- ☐ 0.2 seconds
- ☐ 1 second
- ☐ 0.1 seconds
- ☐ 5 seconds
- ☐ none of these

10. How long would it take two series 0.1-μF capacitors to charge through a 1-MΩ resistance?

- ☐ 1/4 second
- ☐ 1/2 second
- ☐ 3/4 second
- ☐ 1 second
- ☐ 2.5 seconds
- ☐ none of these