Charge, Current, and Capacitance

Charge

Charge is fundamental property of matter and its units are called coulombs. An individual electron or proton has a quantified charge of $1x10^{-19}$ C, the electron is negatively charged ($-1x10^{-19}$ C and a proton is positively charge($+1x10^{-19}$ C). A normal atom has the same number of electrons and protons and its total charge is zero. Opposite charges attract each other and same charges repel each other.

Current

The amount of charge passing through a point over a given period of time produces an electric current. Such that

$$I = Q/t \qquad [1]$$

where I is the current in amps, Q is charge in coulombs and t is time in seconds.

Electric current supplies our modern day appliance with the energy to operate the device.

While there are many different ways to supply electric current to a device, it would also be beneficial to be able to store an accumulated amount of charge to be used at a later time.

Capacitance

A capacitor is a device which can store a charge. A capacitor can be described as a device which consists of two conductive plates separated by a small distance; with the distance and surface area of the plates playing a role in the total capacitance of the capacitor.

A capacitor can be *charged* by first passing a current through it. One plate of the capacitor will acquire a positive charge and the other a negative charge. As the charge builds up on each plate a voltage potential builds up between the plates. This voltage potential across the capacitor will continue to build until it matches the voltage source.

The amount of charge stored in a capacitor can be determined by the equation

$$Q = CV \qquad [2]$$

Where Q is the stored charge in coulombs, C is the capacitance of the device in farads and V is the DC voltage across the device.

A device which you are familiar with that uses a capacitor to store a charge is the flash unit of a camera. This charge when discharged through the lamp produces the flash. Defibrillators are also a device which uses a capacitor to store a charge.

The relationship between charge, current and capacitance will be explored in this experiment.

First let's discuss another device that will be used in this experiment. A **resistor** opposes the flow of an electric current. The relationship between current, resistance and voltage is called Ohm's Law and is shown in the following equation.

$$I = V/R \qquad [3]$$

The resistor has a resistance in units of Ohms.

In this experiment a known voltage will be supplied across the capacitor using a power supply, thus charging the capacitor. The capacitor will then be switched so that it is across a known resistance. The capacitor will then discharge the energy stored in it through the resistor producing a current though the resistor.

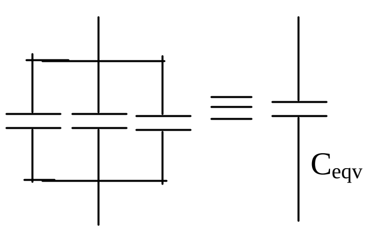
A computer will be used to measured the voltage across the resistor and then using equation [3] the computer will calculate the current though the resistor. A graph on the computer screen will show a representation of current vs. time for the discharge of the capacitor through the resistor.

The area under the graph of Current vs. time will yield the charge which was stored in the capacitor, this calculation is performed by the computer the results being in terms of Amp s. Looking at equation [1] and solving for Q it can be seen that

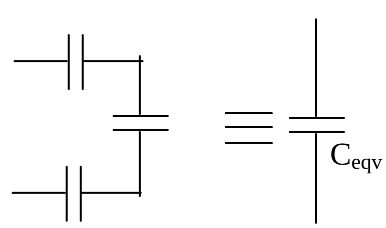
$Q = I\ t$ which has units of A s and is in agreement with the computer results.

Combinations of capacitors

Capacitors can be connected in series and in parallel, to form different values of capacitance, and are shown schematically in the figures below. Each combination shown while using the same three capacitors will have a different equivalent capacitance.



Capacitors in parallel



Capacitors in Series

To solve for the equivalent capacitance the following equations are used.

Parallel $$C_{eqv} = C1 + C2 + C3 \ldots Cn \qquad [4]$$

Series $$1/C_{eqv} = 1/C_1 + 1/C_2 + 1/C_3 \cdots 1/C_n \qquad [5]$$

Energy

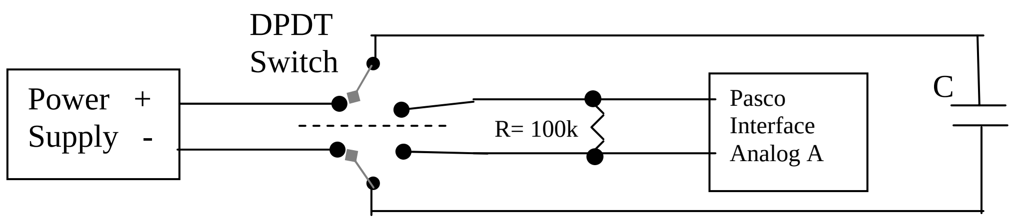
Capacitors primary function is to store electro-static energy. This stored energy is a potential energy, which is stored and ready to do some form of work. This energy can be used to discharge through a flash lamp to produce light for a camera or produce the charge necessary to restart a heart.

The amount of energy can be quantified by the equation below, energy has units of Joules

$$\text{Energy} = \frac{CV^2}{2}$$

Procedure

First let's examine and become familiar with the DPDT switch, (Double Pole, Double Throw). It contains two separate switches, in figure below the schematic representation of the two switches are separated by a dash line. Physically there are three terminal points to a side, each side represents one switch. The center terminal is the common and is indicated in figure below by the gray arrow. This is the connection that is switched from one terminal to the other.



1. Turn on the computer and from the 1402 folder select lab1.sws. On your table there are 3 devices, a black box with 3 unknown capacitors, a 100k resistor and a switch with 6 connections. **The capacitor, C, is connected to the center terminals on either side of the DPDT switch and the power supply to one end and the resistor to the other end.** As shown in the diagram above.

2. Connect the circuit in the diagram using the supplied wires.

3. Have the lab instructor verify your connections. Use the Digital voltmeter and set the Range switch to the 20 V ⎓.

4. Place probe across the power supply red to red , black to black. Turn on the power supply and adjust the dial so that the meter reads 1.00. This is 1 volt DC.

5. Move the switch so that it connects the capacitor to the power supply. This charges the capacitor. On the computer select the window with the REC button and then select the REC button. A blue flashing icon appears below the button and you can observe data being collected in the graph display. Now move the switch to the other side so that the capacitor discharges through the resistor. You should see a graph which rises sharply then slowly falls to a predefined stopping point. If the graph does not stop automatically select the STOP button and reverse the red and black wires that are connected to the resistor.

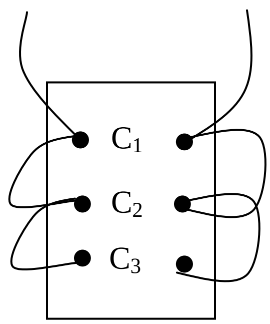
6. On the computer display the window will show the graph and also has a frame next to it with a numeric value followed by **microamps s**. This value represents the measured charge Q_1 on the capacitor C_1. Enter this value into the table. Use equation [2] to determine the capacitance C_1.

7. Repeat steps 4 – 6 setting the power supply for 2 ,3 ,4 and 5 volts. Find the average value for C_1.

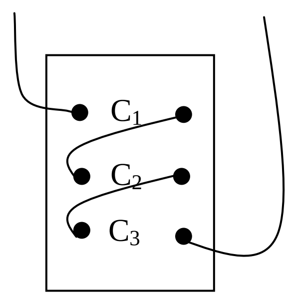
8. Repeat the process outlined above for C_2 and C_3.

9. Once all the capacitors have a value calculate the value of the equivalent capacitor as if all the capacitors were connect in series or in parallel. Record your findings.

10. Connect the capacitors in series use what you have learned to determine the single capacitor value to verify your calculations. Repeat for the capacitors connect in parallel.



Parallel



Series

Data Sheet

Volts	Q_1	C_1 F	Q_2	C_2 F	Q_3	C_3 F
1v						
2v						
3v						
4v						
5v						

Average value of C_1 = ____________

Average value of C_2 = ____________

Average value of C_3 = ____________

Calculated value of C_1, C_2, C_3 in parallel ________________

Calculated value of C_1, C_2, C_3 in series ________________

Volts	Q_{series}	C_{series}	$Q_{parallel}$	$C_{parallel}$
1				
2				
3				
4				
5				

Measured value of C_1, C_2, C_3 in parallel ________________

Measured value of C_1, C_2, C_3 in series ________________

Using the average values for C_1, C_2 C_3 and the calculated values for C_{series} and $C_{parallel}$ determine the energy stored in each at 1 volt and at 5 volts. Show work below.