Linear Circuits and Systems

Capacitors and Inductors– Part 1 of 4

Capacitors

Course: Linear Circuits and Systems
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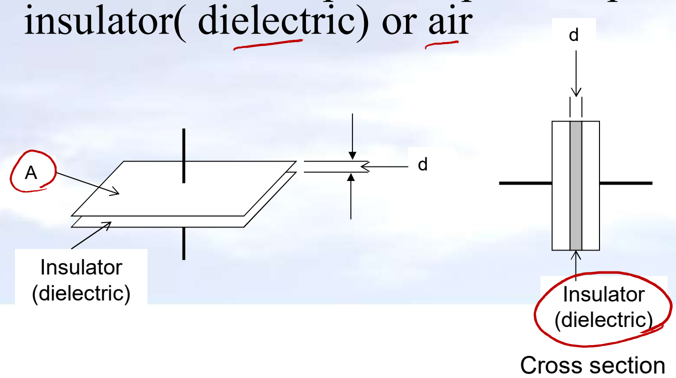
What is a capacitor?

- A device that can hold or store a reasonable amount of electric charge
- It is made of two parallel plates separated by insulator(dielectric) or air



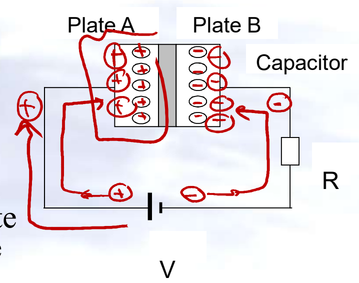
What is a capacitor?

- The ability to store amount of charges for a particular values of voltage is called capacity or capacitance and measured in Farad (F) .
- Capacitance of a capacitor depends on its physical construction and given as:

$$C = \varepsilon A/d \qquad [F]$$

Property of capacitor

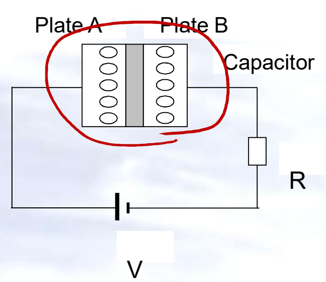
- Positive terminal of a battery repels the positive charges (positive ions) towards plate A and attracts negative charges (electrons) towards it – Plate A then becomes positive.
- Negative terminal of a battery repels negative charges (electron) towards plate B and attracts positive charges (positive ion) towards it – Plate B then becomes negative charge.



- Positive charges accumulate in plate A reduces more positive charges from the battery terminal to enter it and at the same time negative charges in also reduces more negative charges from the negative terminal of the battery.– the current flow from the battery the plate will be reduced.

Property of capacitor

- Charges develop the potential different between the plates and increase with the increase of charges.
- When the potential different is same as the voltage of the battery, the entering of charges stop.



- Charges are stored in the capacitor plates after the connection to the battery is disconnected.
- Ratio of Q:V is constant and is called as capacitance, thus

$C = Q/V$ or $Q = CV$

Changing with time

When the voltage applied to the capacitor changing with time , the charges also will change with time . Thus Q = CV becomes

$$dq = C\,dv$$

Then differentiate with time , we have $\frac{dq}{dt} = C\frac{dv}{dt}$

note $\frac{dq}{dt} = i$ therefore $i = C\frac{dv}{dt}$

integrates $v = \frac{1}{C}\int i dt$

Power in capacitor

$i = C\frac{dv}{dt}$

Power in capacitor is given by $p = vi = Cv\frac{dv}{dt}$

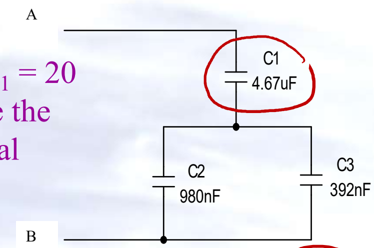
Energy for time dt is given by $dw = pdt = Cvdv$

Total Energy $W = C\int_0^V vdv = C\left[\frac{v^2}{2}\right]_0^V$

Thus Energy stored in capacitor is $W = \frac{1}{2}CV^2$

Example

Charges in the capacitors C_1 and C_2 are $Q_1 = 20$ µC and $Q_2 = 5$ µC respectively, determine the energy stored in C_1, C_2 and C_3 and the total energy in all capacitors.



$C_1 = 4.67$ µF; $Q_1 = 20$ µQ

Therefore $V_1 = Q_1/C_1$

$= (20 \times 10^{-6})/(4.67 \times 10^{-6})$

$= 4.3$ V

And $W_1 = \frac{1}{2}C_1(V_1)^2$

$= \frac{1}{2} \times 4.67 \times 10^{-6} \times 4.3^2$

$= 43.2$ µJ

$C_2 = 980$ nF; $Q_2 = 5$ µQ

Then $V_2 = Q_2/C_2$

$= (5 \times 10^{-6})/(980 \times 10^{-9})$

$= 5.1$ V

W2 $= \frac{1}{2}C_2(V_2)^2$

$= \frac{1}{2} \times 980 \times 10^{-9} \times 5.1^2$

$= 12.7$ µJ

W3 $= \frac{1}{2}C_3(V_2)^2$

$= \frac{1}{2} \times 392 \times 10^{-9} \times 5.1^2 = 5.1$ µJ

- Conclusion

$$Q = C V$$

$$i = C \frac{dv_c}{dt} \; ; \; v = \frac{1}{C}\int i \, dt$$

$$W = \frac{1}{2} C V^2$$

Acknowledgement

This material is based upon work partially supported by the National Science Foundation under Grant# 2335802. Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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