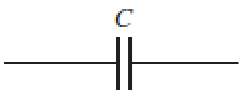
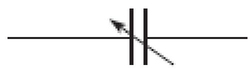
Applied Physics Lecture 7

Types of Capacitors

Two general categories (a) fixed capacitor and (b) variable capacitor





Fixed Capacitors

(a) Non electrolytic (No polarity requirement)

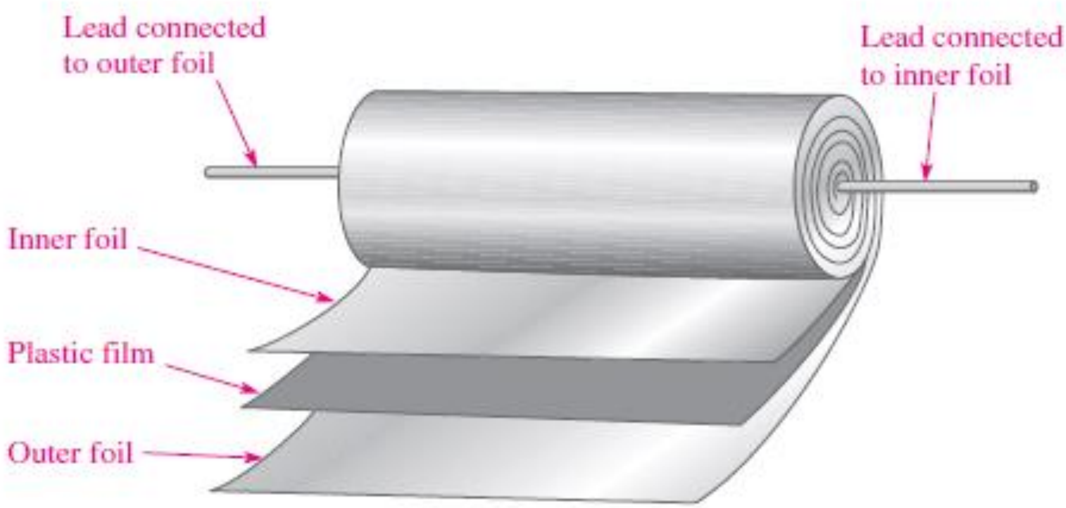
(b) Electrolytic (have polarity requirement)

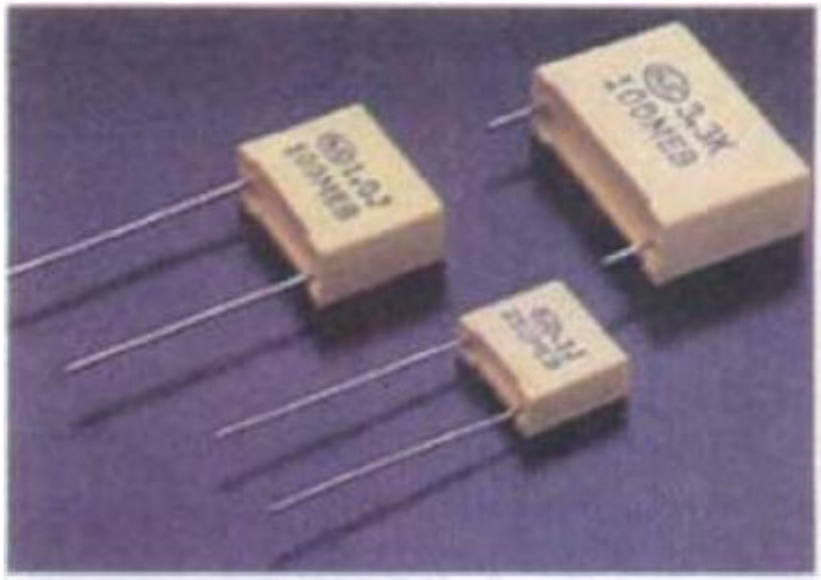
(a) Non electrolytic

It includes paper, mica and ceramic capacitors.

(i) Paper Capacitor (or Plastic Capacitor)

Two thin conductive (tin) sheets separated by thin paper or tissue then enrolled in a cylindrical shape. Finally enclosed in plastic capsule. Connective leads attached to the metal foil are outside the capsule for making connections.

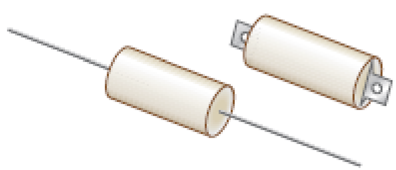




They have *low capacitances* about 0.001 to 2 micro F and high voltage rating of 2000 volt. They have *large physical size* but low capacitances so they are not efficient at high frequencies.

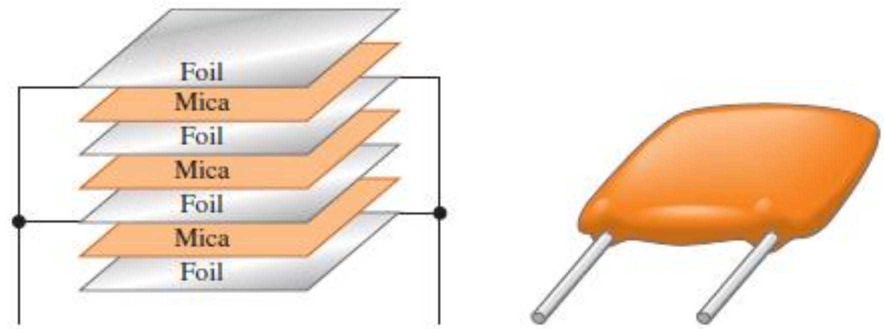
Instead of paper, a thin plastic film is used as dielectric. They have advantages over paper capacitor as

- They have low power losses
- High insulation resistance
- Longer shelf life (length of time to store the electrical charge without leakage) without breakdown or leakage.



(ii) Mica Capacitor

It is a sandwich of many metal plates separated by thin sheets of mica. The assembly is enclosed in plastic or Bakelite capsule. They have capacitance values 50-500pF and high working voltage about 500 and above. Due to their smaller capacitances, ceramic capacitors are preferred over them.



(a) Stacked layer arrangement

(b) Layers are pressed together and encapsulated.

(iii) Ceramic Capacitor

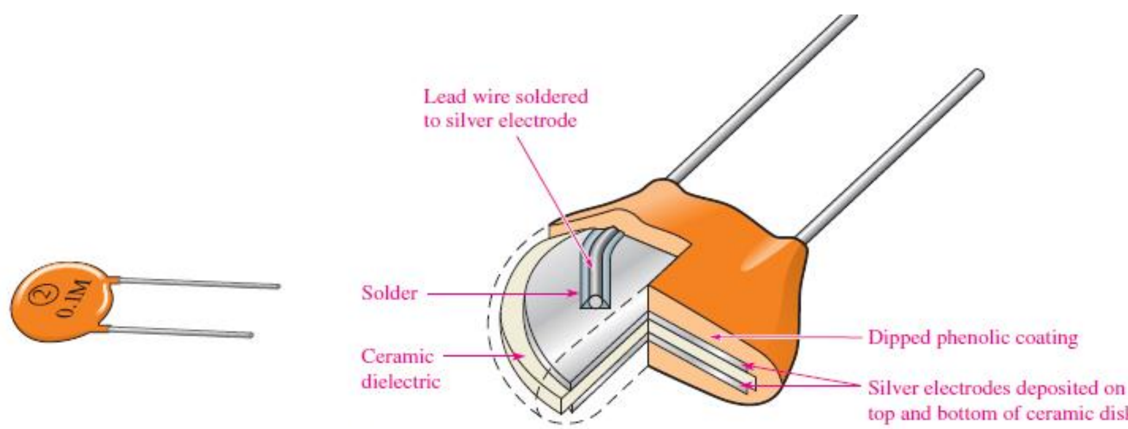
Disc shaped ceramic material (like titanium dioxide and barium titanate) is coated with thin silver layer on both sides which act as capacitor plates.

They have large capacitance (up to 0.01 micro F) because of high dielectric constant of ceramic material.

They also have tubular shape in which hollow tube is silver coated on inside and outside. They have capacitance 1-500pF.

The advantages of ceramic capacitors over paper and mica capacitor are

- Economical (inexpensive)
- small size as compared to large capacitance values
- high working voltage rating
- low power losses.

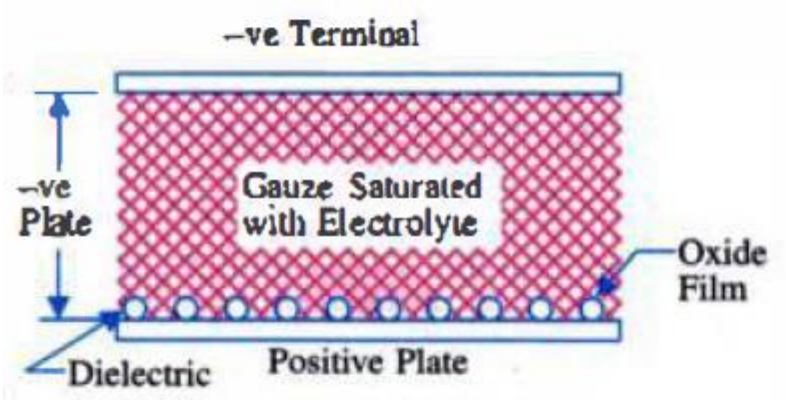


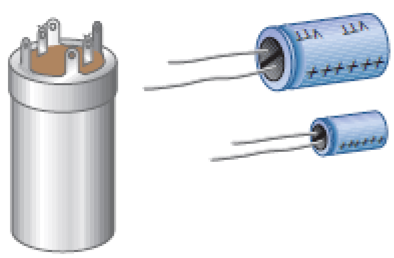
(a) (b)

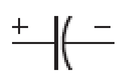
(b) Electrolytic Capacitor

Other capacitors use two similar plates but in these capacitors both plates are different. It contains

- one electrolytic (charged) plate as negative plate
- one aluminium plate as positive terminal
- molecular thin insulating film of aluminium oxide as a dielectric medium is electrochemically deposited on aluminium plate (anode)
- an absorbent gauze saturated with the electrolyte is kept in contact with the dielectric.
- another aluminium plate attached with the gauze act as a negative terminal.
- The entire assembly is rolled into metal cylinder (act as negative terminal) and then in a paper or insulating case.







(c) Symbol for an electrolytic capacitor.

SAFETY NOTE

Be extremely careful with electrolytic capacitors because it does make a difference which way an electrolytic capacitor is connected. Always observe the proper polarity. If a polarized capacitor is connected backwards, it may explode and cause injury.

They have very large capacitances due to thin layer of dielectric and are very small in size (1-10,000 micro F). They are known as "*polarized"* capacitors because they have electrolyte as negative plate so they must be connected in circuit according to plus and minus sign marked on it.

They have two disadvantages

- High leakage current because dielectric is not perfect insulator.
- Polarity sensitive

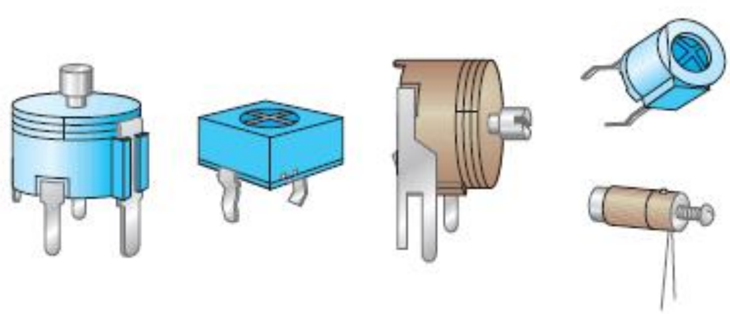
Variable Capacitor

They are used when there is a need to adjust the capacitance value so its capacitance can be varied by rotating the shaft. It contains two sets of metal plates with air as dielectric. One set is called *stator* because it is fixed and other set is called *rotor* because it is connected to the shaft and can be rotated easily. The knob helps to move the rotor plates in and out of the fixed (stator) plates.

$$C = \frac{(n-1)\varepsilon_o A}{d}$$

Where n is number of plates. C is maximum when rotor plates are all inside and C is minimum when they are outside.

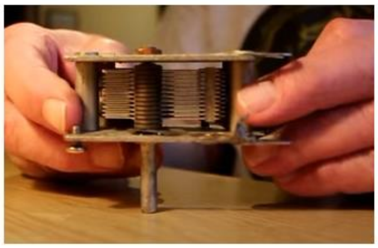
When two or more capacitors are operated by single shaft known as *ganged capacitor.* Adjustable capacitors that have screw type adjustments and are used for very fine adjustment on total capacitance in circuit are called *trimmer*.

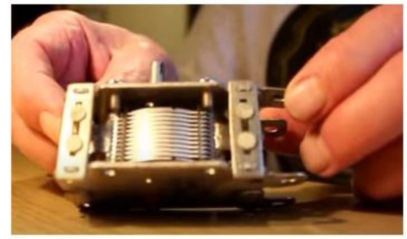


FIGURE

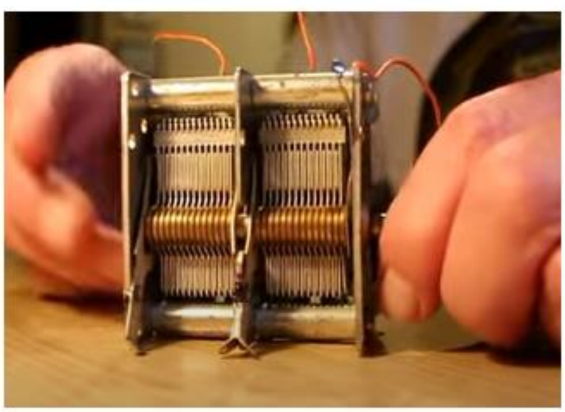
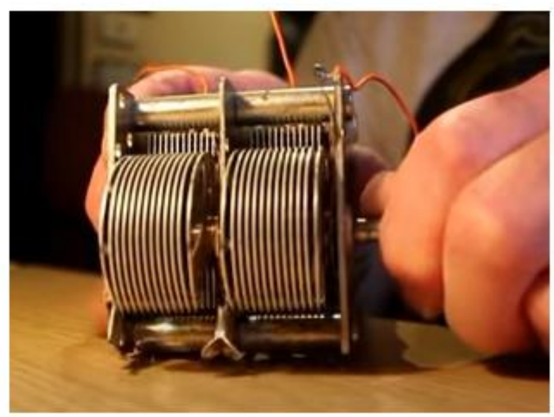
Trimmer capacitors.







Voltage ratings

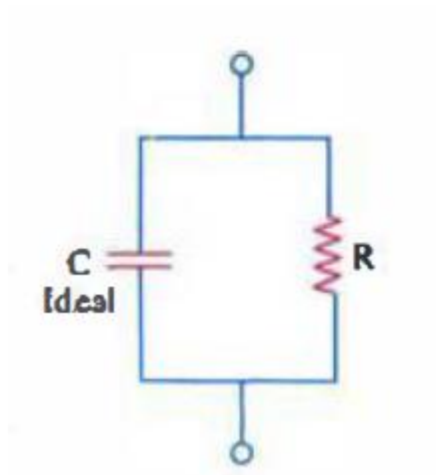
The maximum potential difference that can be applied across a capacitor without breaking its dielectric. This voltage is called *breakdown voltage*. The voltage rating should always be above the maximum voltage expected in a particular application.

Stray Circuit Capacitance

In electronic circuit any other components can act as capacitor and have some value of capacitance with reference to grounded plate. The components should not be too close to develop potential between them.

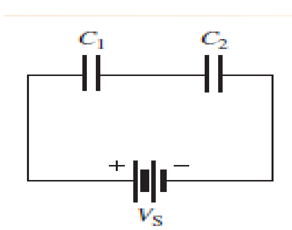
Leakage Resistance

Dielectric is an insulator having very high resistance. Practically they are not perfect insulators and cause small leakage current through dielectric and capacitor discharges in a long run. An actual capacitor is represented by an ideal capacitor with leakage resistance shown below.



Capacitors in series

The total capacitance of a series connection of capacitors is less than the individual capacitance. Capacitors in series divide voltage across them in proportion to their capacitance.



In a series circuit current is same and I = Q/t, so charge on each capacitor is same irrespective of its capacitance value. Total charge is equal to charge on each capacitor.

$$Q_T = Q_1 = Q_2$$

In series circuit voltage is different across each capacitor

$$V_S = V_1 + V_2$$

Using the formula $V = Q/C$,

$$\frac{Q}{C_T} = \frac{Q}{C_1} + \frac{Q}{C_2} \quad (\text{where } Q = Q_T = Q_1 = Q_2):$$

$$\frac{\not{Q}}{C_T} = \not{Q}\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$$

Thus, you have the following relationship for two capacitors in series:

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$$

Taking the reciprocal of both sides of this equation gives the formula for the total capacitance for two capacitors in series.

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}$$

This equation can also be expressed equivalently as

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

Capacitors in series have high breakdown voltage rating but low capacitance values.

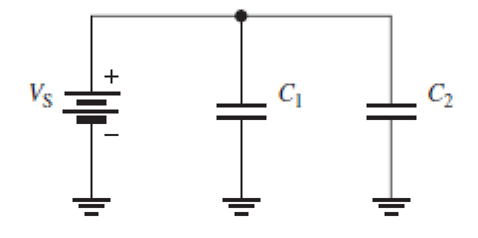
The formula for total capacitance for any number of capacitors in series is developed as follows; the subscript n can be any number.

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots + \frac{1}{C_n}$$

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots + \frac{1}{C_n}}$$

Capacitors in parallel

In parallel capacitors, the total capacitance is sum of individual capacitances. In parallel combination voltage is same across each component so $V_s = V_1 + V_2 = V$



$Q_T = Q_1 + Q_2$

Since $Q = CV$,

$$C_T V_S = C_1 V_S + C_2 V_S$$

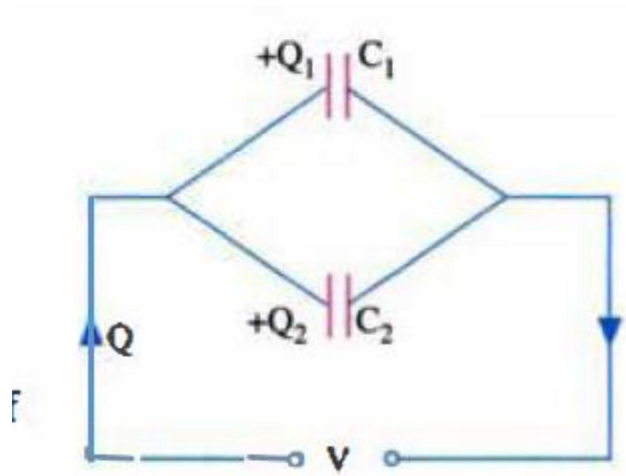
Because all the V_S terms are equal, they can be canceled. Therefore, the total capacitance for two capacitors in parallel is

$$C_T = C_1 + C_2$$

For many capacitors in parallel the formula will be

$$C_T = C_1 + C_2 + C_3 + \cdots + C_n$$

When *only two unequal capacitors are connected in parallel* then it can be expressed as



since V is the same across both capacitors

$$\because \quad V = \frac{Q_1}{C_1} = \frac{Q_2}{C_2}$$

$$\therefore \quad \frac{Q_1}{C_1} = \frac{Q_2}{C_2} \text{ or } \frac{Q_1}{Q_2} = \frac{C_1}{C_2}$$

the two capacitor charges can be expressed in terms of the total charge Q taken from the power source.

$$Q_1 = Q\frac{C_1}{C_1 + C_2}; \; Q_2 = Q\frac{C_2}{C_1 + C_2}$$

Energy stored in a capacitor

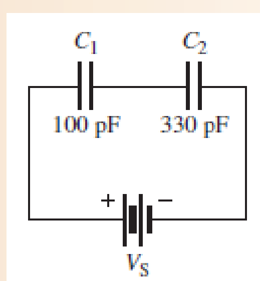
During charging a capacitor, energy is stored in electric field between the plates. On discharging the capacitor this energy is released and it can produce an electric shock if you touch its two ends.

$$\text{Stored energy} = \frac{1}{2}CV^2 \text{ joules}$$

Examples

Find the total capacitance C_T in Figure .

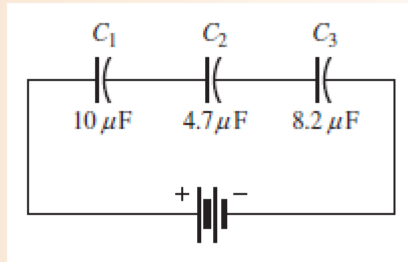
▶ FIGURE



$$C_T = \frac{C_1C_2}{C_1 + C_2} = \frac{(100 \text{ pF})(330 \text{ pF})}{100 \text{ pF} + 330 \text{ pF}} = 76.7 \text{ pF}$$

Determine the total capacitance in Figure [illegible].

▶ **FIGURE [illegible]**



$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}} = \frac{1}{\frac{1}{10\ \mu F} + \frac{1}{4.7\ \mu F} + \frac{1}{8.2\ \mu F}} = \mathbf{2.30\ \mu F}$$