

Capacitors and Capacitance

The basic **capacitor** is **composed of two parallel metallic plates** separated by a non-conducting material called a **dielectric**. You will construct one for your crystal radio. The dielectric material can be a vacuum, air, paper, polystyrene, mica, or glass. Capacitors can be fixed (non-adjustable) or variable.

The **dielectric** material is used to: **1)** increase the voltage storing capabilities of the capacitor and **2)** support the electrostatic force of the electric charge across the plates.

The basic **function** of a **capacitor** is to store electric energy in an electric field between the parallel metallic plates.

Capacitance is the **property** of an electronic component that describes its ability to store an electric charge. Capacitance is directly proportional to the electrostatic force field between the plates of the capacitor. The symbol for capacitance is **C** and the units for capacitance is the **Farad (F)** in honor of Michael Faraday (1791-1867).

Capacitance is proportional to the quantity of a charge that can be stored for each volt difference in the potential across the plates of the capacitor. The formula for capacitance is:

$$C = Q/V$$

C = capacitance in Farads

Q = charge in Coulombs

V = potential difference in volts

The chart below shows the dielectric constant of the insulating materials commonly used in the construction of capacitors.

Material Dielectric	Constant
Vacuum	1.0
air	1.0006
polystyrene	2.5
paper	3.5
mica	5.6
glass	7

There is a miniscule difference in the dielectric constant between a vacuum and air, therefore in mathematical calculations of capacitance the dielectric constant for air will be given as one.

Two formulas are used to calculate capacitance from the physical dimensions and makeup of a capacitor with two parallel plates.

Imperial formula: $C = \frac{.223KA}{d}$

Metric formula: $C = \frac{8.855KA}{d}$

C = Capacitance in picoFarads (pF)

K is the dielectric constant

A is the area of one plate in inches² (Imperial formula) or meters² (metric formula)

d is the distance between the two plates

Series and Parallel Capacitors

Like resistors, capacitors are manufactured with standardized values. Sometimes a capacitor is needed is a value that is not manufactured or a person must place capacitors in series or parallel to achieve the desired value.

The formula for capacitors in **series** is:

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

The formula for capacitors in **parallel** is:

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

Time Constant Circuits

Capacitors are often used in timing circuits. A classic example is the little coupon dispensers in grocery stores that have a flashing LED to attract your attention. A capacitor is placed in series with a resistor that will control the charge rate of the capacitor. An LED is placed across the circuit and when the voltage reaches a prescribed level, it will discharge through the LED causing it to flash. The process repeats itself over and over. The capacitor charge time is controlled by the **RC** (resistor/capacitor) circuit.

The formula for calculating the **RC time constant** is:

$$t = C \times R$$

t = time in seconds

C = capacitance in Farads

R = Resistance in ohms

The **RC time constant** is the time interval for the capacitor to reach a value of approximately **63%** of the applied voltage.

Example: A circuit is composed of a 1 microfarad capacitor in series with a 1 megaohm resistor connected across a 10V battery. What is the RC time constant of the circuit?

Time constant = $R \times C = (1,000,000\Omega)(.000001F) = 1 \text{ second}$

This means that it takes **1 second** for the capacitor to charge to **63%** of **10V**, or **6.3V**. The voltage in the circuit is **10V**.

The next second of charge time, the capacitor will increase its charge by **63%** of the remaining voltage of **3.7V**. That is **2.3V**. After **2s** the capacitor has a **8.4V** charge.

The third second of charge time, the capacitor will increase its charge by **63%** of the remaining voltage of **1.4V**. That is **0.88V**. After **3s** the capacitor has a **9.28V** charge.

Five time constants are the standard for the charge of the capacitor to be "close enough" to the source voltage.

In a perfect world, the capacitor will hold its charge indefinitely. Capacitors will lose their charge over a period of time due to "leakage." Air variable capacitor will "leak" their charge into the atmosphere, others will "leak" their charge through the dielectric material. A resistor across a capacitor will control the discharge of the capacitor

Note: Some capacitor, especially the very large value, high voltage electrolytics, can hold a potentially dangerous charge for a considerable amount of time. When in doubt, use a "chicken stick" to discharge the capacitor. A chicken stick will be a metal rod with an insulated handle. Hold the "chicken stick" by the insulated handle and place the metal part across the terminals of the capacitor. This will discharge the capacitor (look for a spark) and render it harmless.