
Capacitance
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Objectives

- On completion, you should be able to:
  – Define **Capacitance** and **Capacitive Reactance**;
  – Do **simple calculations** involving capacitance; and
  – Explain the **role** of the capacitor in a circuit.

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Capacitance

- **Capacitance** is the property of an electrical circuit that **opposes a change in voltage**.
- When a **voltage** applied across a circuit is **increased or decreased, capacitance resists that change.**
- Capacitors do this by **storing** and **releasing electrical energy.**

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Without the ability to store electrical energy, radio would not be possible. One may build and hold an electrical charge in an *electrostatic field*. This phenomenon is called *capacitance*, and the devices that

exhibit capacitance are called *capacitors*.

Construction of a Capacitor

- A basic capacitor consists of **2 conducting metallic plates** separated by a **layer of air or other insulating material** such as glass, mica or even oil.
- The **insulating material** is called the **Dielectric.**

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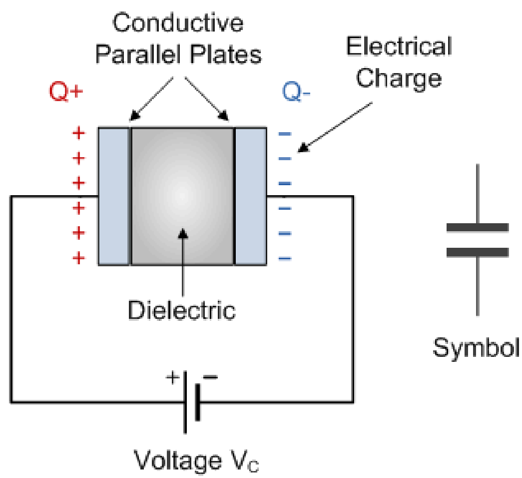
The capacitor is a component which has the ability or “capacity” to store energy in the form of an electrical charge producing a potential difference (*Static Voltage*) across its plates, much like a small rechargeable battery.

There are many different kinds of capacitors available from very small capacitor beads used in resonance circuits to large power factor correction capacitors, but they all do the same thing, they store charge.

In its basic form, a capacitor consists of two or more parallel conductive (metal) plates which are not connected or touching each other, but are electrically separated either by air or by some form of a good insulating material such as waxed paper, mica, ceramic, plastic or some form of a liquid gel as used in electrolytic capacitors. The insulating layer between a capacitors plates is commonly called the **Dielectric**.

Capacitor



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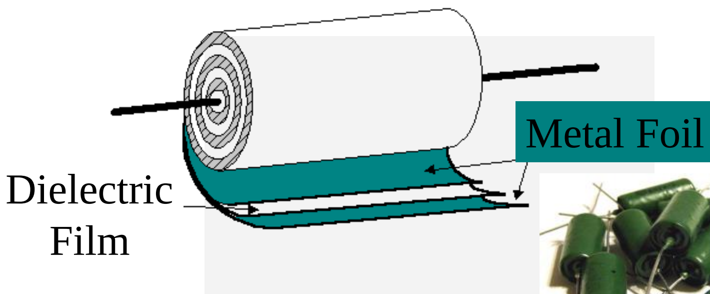
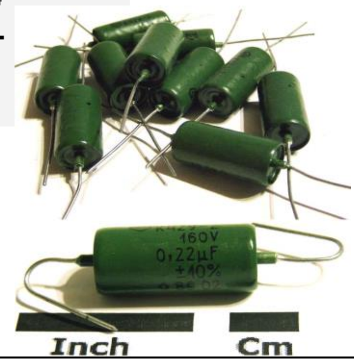
Due to this insulating layer, DC current can not flow through the capacitor as it blocks it allowing instead a voltage to be present across the plates in the form of an electrical charge.

The conductive metal plates of a capacitor can be either square, circular or rectangular, or they can be of a cylindrical or spherical shape with the general shape, size and construction of a parallel plate capacitor depending on its application and voltage rating.

Axial Lead Capacitor





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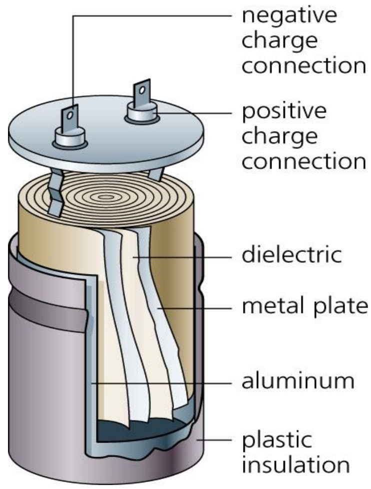
Often paper is used as a dielectric.

Electrolytic Capacitor



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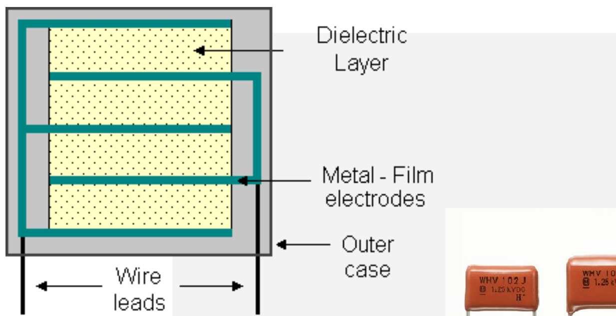
Internally, the electrolytic capacitor is constructed similarly to the paper capacitor. The positive plate consists of aluminum foil covered with an extremely thin film of oxide. This thin oxide film (which is formed by an electrochemical process) acts as the dielectric of the capacitor. Next to and in contact with the oxide is a strip of paper or gauze which has been impregnated with a paste-like electrolyte. The electrolyte acts as the negative plate of the capacitor. A second strip of aluminum foil is then placed against the electrolyte to provide electrical contact to the negative electrode (the electrolyte). When the three layers are in place they are rolled up into a cylinder as shown in figure 3-18(A).

An electrolytic capacitor has two primary disadvantages compared to a paper capacitor in that the electrolytic type is POLARIZED and has a LOW LEAKAGE RESISTANCE. This means that should the positive plate be accidentally connected to the negative terminal of the source, the thin oxide film dielectric will dissolve and the capacitor will become a conductor (i.e., it will short). The polarity of the terminals is normally marked on the case of the capacitor. Since an electrolytic capacitor is polarity sensitive, its use is ordinarily restricted to a dc circuit or to a circuit where a small ac voltage is superimposed on a dc voltage. Special electrolytic capacitors are available for certain ac applications, such as a motor starting capacitor. Dry electrolytic capacitors vary in size from about 4 microfarads to several thousand microfarads and have a working voltage of approximately 500 volts.

The type of dielectric used and its thickness govern the amount of voltage that can safely be applied to the electrolytic capacitor. If the voltage applied to the capacitor is high enough to cause the atoms of the dielectric material to become ionized, arcing between the plates will occur. In most other types of capacitors, arcing will destroy the capacitor. However, an electrolytic capacitor has the ability to be self-healing. If the arcing is small, the electrolytic will regenerate itself. If the arcing is too large, the capacitor will not self-heal and will become defective.

Radial Lead Capacitor



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Ceramic Disc Capacitor

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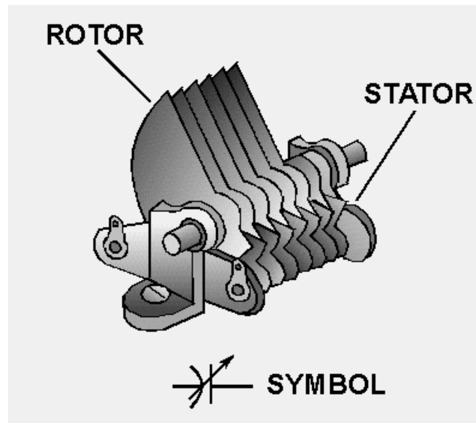
Variable Capacitor



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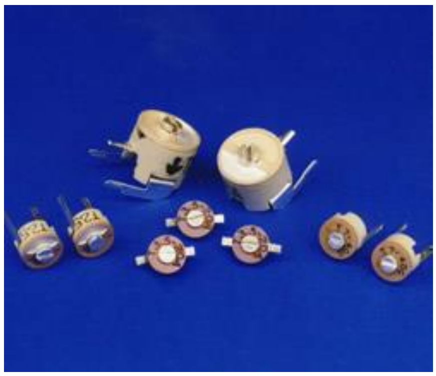
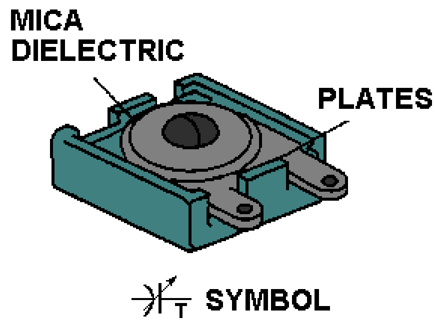
Trimmer Capacitors





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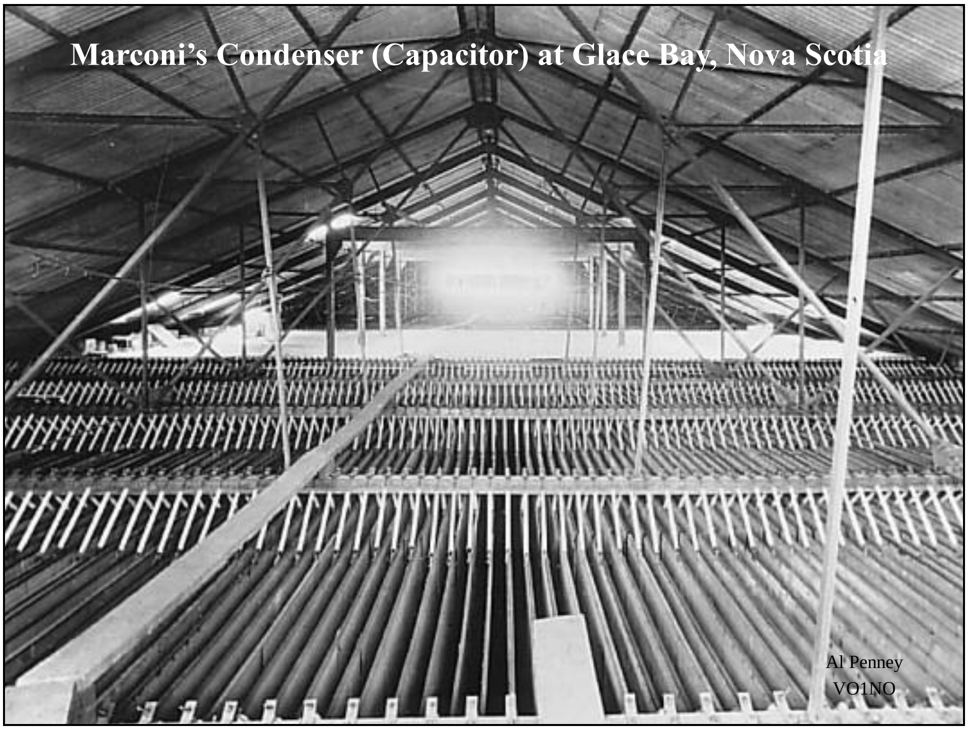
Marconi’s Condenser (Capacitor) at Glace Bay, Nova Scotia
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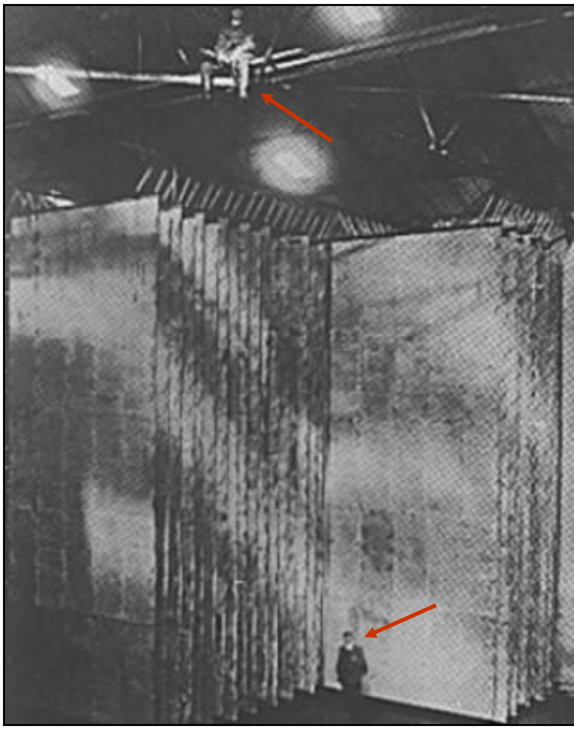

A similar capacitor at Marconi's station in Clifden, Ireland. Note the size of the two men!

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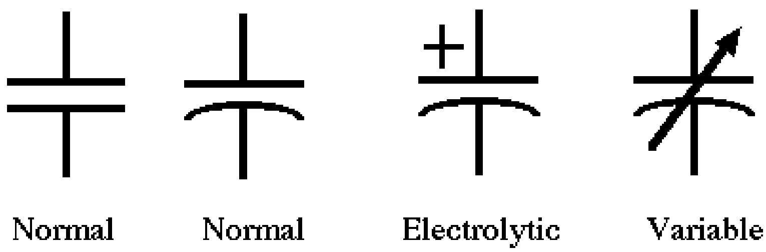
The power supply charged a capacitor made from 288 sixty foot by twenty foot wide metal sheets separated about 6 inches from each other (Figure 5). The sheets were suspended from rafters at the top of the building and hung vertically down almost to ground level. This capacitor (or "condenser," to use the original terminology) occupied most of the 160 foot long transmitter building. Thus, the building became known as the condenser building.

This great array of plates provided only 1.7 microfarads with a voltage rating of 15 kilovolts. An "air insulated" design was chosen rather than a more compact glass dielectric design because it was relatively-trouble free and easy to construct from locally available materials. If a draft caused the plates to move and short out, the "spot welded" plates were simply knocked apart.

Capacitor Symbols



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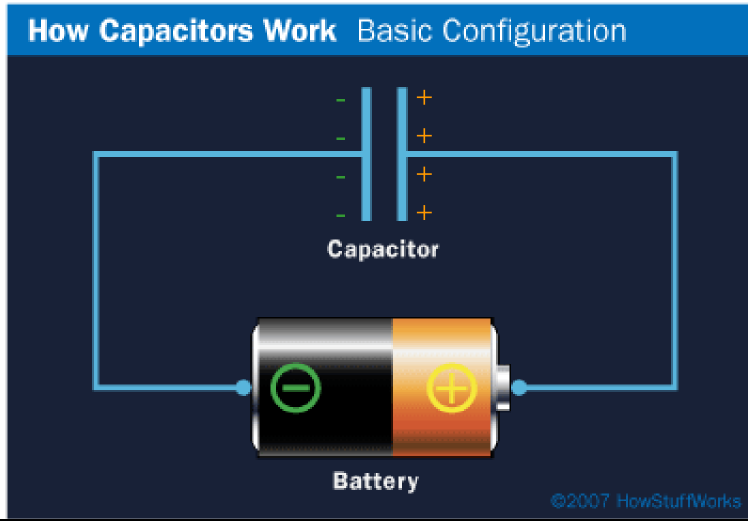
Capacitors in a DC Circuit



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Capacitors in a DC Circuit

- When **first connected** to a battery, **electrons flow** from the **negative battery terminal** to the **capacitor plate** and remain there because the dielectric prevents them from travelling to the opposite plate.
- **Electrons** on the **opposite plate** are **attracted** to the **positive battery terminal.**
- Eventually, the capacitor reaches the **same voltage** as the battery, and **no more electrons flow.**
- The capacitor is then said to be **Charged.**
- **Capacitors block the flow of DC.**

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When used in a direct current or DC circuit, a capacitor charges up to its supply voltage but blocks the flow of current through it because the dielectric of a capacitor is non-conductive and basically an insulator. However, when a capacitor is connected to an alternating current or AC circuit, the flow of the current appears to pass straight through the capacitor with little or no resistance.

The property of a capacitor to store charge on its plates in the form of an electrostatic field is called the **Capacitance** of the capacitor. Not only that, but capacitance is also the property of a capacitor which resists the change of voltage across it.

Capacitors in an AC Circuit

- **Current cannot** pass through a capacitor but **Alternating Current appears to.**
- If the **voltage** across the plates of the capacitor is **continuously varied,** the **number of electrons varies.**
- As the voltage changes then, **it appears as though a current is flowing** even though **electrons do not actually traverse** the dielectric.

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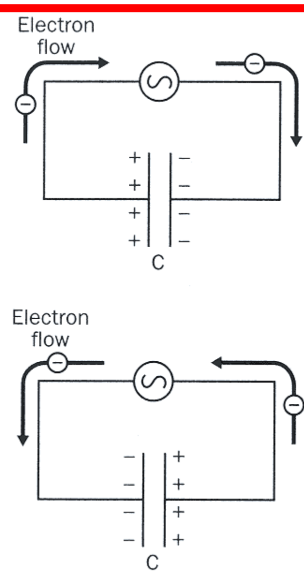
However, when a capacitor is connected to an alternating current or AC circuit, the flow of the current appears to pass straight through the capacitor with little or no resistance.

Capacitors in an AC Circuit



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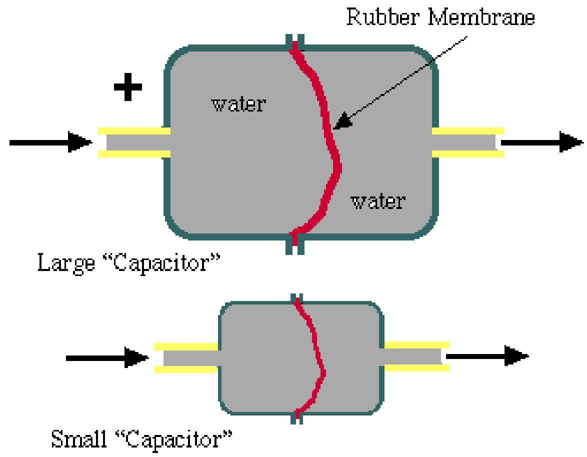
Water Reservoir Analogy



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A capacitor stores electricity. If you pump electrical current into it, the capacitor develops a voltage that exerts a force that resists additional current. In this experiment, you will use a hand crank that pumps current into very large capacitors. These capacitors are constructed such that for each Coulomb of charge you pump in it will push back with one volt. These capacitors are a lot like rechargable batteries. The big difference between batteries and capacitors is that a battery supplies a nearly constant voltage, whereas a capacitor works at all voltages up to its maximum safe rating. As you charge the capacitors with the hand cranked generator you can actually feel the capacitor "filling up."

A capacitor is like a closed water tank with two inlets separated by a rubber membrane. The more water (charge) you pump in one inlet (wire), the more back pressure (voltage) will build up. The pressure (voltage) opposes the addition of more water (charge). So, the more water (charge) you add the harder it gets to add more. Also note that whatever water (charge) flows in one inlet (wire), the same amount of water (charge) comes out the other. But because of the membrane, no steady water flow (current) can be maintained through the tank (capacitor). A large tank (capacitor) can absorb a lot of water (charge) before generating a large back pressure (voltage). We could measure the capacity of a tank (capacitor) as the ratio of water volume to pressure (charge to voltage, which is the definition of a farad).

Electrons

- **Individual electrons** are **too small** to have an effect in everyday electronics, so we use a **larger number** of them to make **practical measurements.**
- The **Coulomb** is equal to (approximately) **6.24 x 10^{18} electrons** (6,240,000,000,000,000,000 electrons).
- For example, one Ampere = 1 Coulomb per Second.

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The **coulomb** (symbol: **C**) is the International System of Units (SI) unit of electric charge. It is the charge (symbol: *Q* or *q*) transported by a constant current of one ampere in one second:

Thus, it is also the amount of excess charge on a capacitor of one farad charged to a potential difference of one volt:

Under the 2019 redefinition of the SI base units, which took effect on 20 May 2019, the elementary charge (the charge of the proton and of the electron, but also of other fundamental particles) is exactly $1.602176634 \times 10^{-19}$ coulombs. Thus the coulomb is the charge of exactly $1/(1.602176634 \times 10^{-19})$ elementary charges, which is approximately $6.2415090744 \times 10^{18}$ elementary charges (1.036×10^{-5} mol). The same number of electrons has the same magnitude but opposite sign of charge, that is, a charge of −1 C.

The Farad

- The **unit of measure** for capacitance is the **Farad.**
- One **Farad** is the **capacitance** in which a charge of **1 Coulomb** produces a **difference of 1 Volt** between the plates.
- One **Farad** is **much too large** a value for practical circuits however.

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Capacitance is the electrical property of a capacitor and is the measure of a capacitors ability to store an electrical charge onto its two plates with the unit of capacitance being the **Farad** (abbreviated to F) named after the British physicist Michael Faraday.

Capacitance is defined as being that a capacitor has the capacitance of **One Farad** when a charge of **One Coulomb** is stored on the plates by a voltage of **One volt**. Note that capacitance, C is always positive in value and has no negative units. However, the Farad is a very large unit of measurement to use on its own so sub-multiples of the Farad are generally used such as micro-farads, nano-farads and pico-farads, for example.

Standard Units of Capacitance

•Microfarad (μF) 1μF = 1/1,000,000 = 0.000001 = 10^{-6} F

•Nanofarad (nF) 1nF = 1/1,000,000,000 = 0.000000001 = 10^{-9} F

•Picofarad (pF) 1pF = 1/1,000,000,000,000 = 0.000000000001 = 10^{-12} F

Practical Capacitor Units

- Practical capacitors are measured in:
  - **Microfarads**, or **millionths of a Farad.** They are abbreviated as **µf**, and equal to **1 x 10^{-6} Farads.** The old abbreviation was mfd.
  - **Picofarads**, or **millionth millionths of Farads**, are equal to **1 x 10^{-12} Farads.** They are abbreviated as pf. They were originally called Micromicrofarads, and you may still encounter the abbreviation mmf.

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Factors Affecting Capacitance

- **Plate Area:** The **larger the plate area**, the **greater the capacitance.**
- **Distance Between the Plates:** The **closer together** the plates, the **greater the capacitance.** Of course, it is necessary to **prevent the charge** from **jumping the gap (arcing).**
- **Changing the Dielectric: Greater capacitance** can be obtained by using a **dielectric other than air.** Glass, mica, oil and mylar are some of the materials that have a greater **Dielectric Constant** than air. This is because they **permit the plates** to be **closer together,** and because they have **electrons** that can **move slightly.**

The Dielectric of a Capacitor

As well as the overall size of the conductive plates and their distance or spacing apart from each other, another factor which affects the overall capacitance of the device is the type of dielectric material being used. In other words the "Permittivity" (ε) of the dielectric.

The conductive plates of a capacitor are generally made of a metal foil or a metal film allowing for the flow of electrons and charge, but the dielectric material used is always an insulator. The various insulating materials used as the dielectric in a capacitor differ in their ability to block or pass an electrical charge.

This dielectric material can be made from a number of insulating materials or combinations of these materials with the most common types used being: air, paper, polyester, polypropylene, Mylar, ceramic, glass, oil, or a variety of other materials.

The factor by which the dielectric material, or insulator, increases the capacitance of the capacitor compared to air is known as the **Dielectric Constant**, **k** and a dielectric material with a high dielectric constant is a better insulator than a dielectric material with a lower dielectric constant. Dielectric constant is a dimensionless quantity since it is relative to free space.

Dielectric Materials

Relative Dielectric Constants of Common Capacitor Dielectric Materials

Material	*Dielectric Constant (k)*	*(O)rganic or (I)norganic*
Vacuum	1 (by definition)	I
Air	1.0006	I
Ruby mica	6.5 - 8.7	I
Glass (flint)	10	I
Barium titanate (class I)	5 - 450	I
Barium titanate (class II)	200 - 12000	I
Kraft paper	≈ 2.6	O
Mineral Oil	≈ 2.23	O
Castor Oil	≈ 4.7	O
Halowax	≈ 5.2	O
Chlorinated diphenyl	≈ 5.3	O
Polyisobutylene	≈ 2.2	O
Polytetrafluoroethylene	≈ 2.1	O
Polyethylene terephthalate	≈ 3	O
Polystyrene	≈ 2.6	O
Polycarbonate	≈ 3.1	O
Aluminum oxide	≈ 8.4	I
Tantalum pentoxide	≈ 28	I
Niobium oxide	≈ 40	I
Titanium dioxide	≈ 80	I

(Adapted from: Charles A. Harper, *Handbook of Components for Electronics*, p 8-7.)

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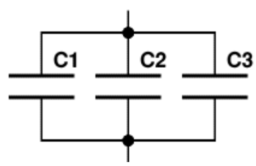
Capacitors in Parallel

- **Capacitors** in **Parallel add their values.**
- This is because it is **equivalent** to a **single capacitor** with a **greater surface area.**



$$C_T = C1 + C2 + C3$$

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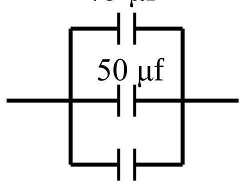
When capacitors are connected together in parallel the total or equivalent capacitance, C_T in the circuit is equal to the sum of all the individual capacitors added together. This is because the top plate of capacitor, C_1 is connected to the top plate of C_2 which is connected to the top plate of C_3 and so on.

The same is also true of the capacitors bottom plates. Then it is the same as if the three sets of plates were touching each other and equal to one large single plate thereby increasing the effective plate area in m^2.

Since capacitance, C is related to plate area ($C = \varepsilon(A/d)$) the capacitance value of the combination will also increase. Then the total capacitance value of the capacitors connected together in parallel is actually calculated by adding the plate area together. In other words, the total capacitance is equal to the sum of all the individual capacitance's in parallel. You may have noticed that the total capacitance of parallel capacitors is found in the same way as the total resistance of series resistors.

Example of Capacitors in Parallel



$C_T = C1 + C2 + C3$

$C_T = 75\mu f + 50\mu f + 75\mu f$

$C_T = 200\mu f$

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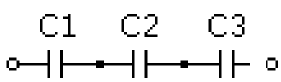
Capacitors in Series

- Capacitors in Series must be treated the same way that parallel resistors and inductors are treated.

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

NOTE:
Same equation!



$$C_T = \frac{1}{\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}}$$

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In the previous parallel circuit we saw that the total capacitance, C_T of the circuit was equal to the sum of all the individual capacitors added together. In a series connected circuit however, the total or equivalent capacitance C_T is calculated differently.

In the series circuit above the right hand plate of the first capacitor, C_1 is connected to the left hand plate of the second capacitor, C_2 whose right hand plate is connected to the left hand plate of the third capacitor, C_3. Then this series connection means that in a DC connected circuit, capacitor C_2 is effectively isolated from the circuit.

The result of this is that the effective plate area has decreased to the smallest individual capacitance connected in the series chain.

When adding together **Capacitors in Series**, the reciprocal (1/C) of the individual capacitors are all added together (just like resistors in parallel) instead of the capacitance's themselves. Then the total value for capacitors in series equals the reciprocal of the sum of the reciprocals of the individual capacitances.

Example of Capacitors in Series

50 µf 75 µf 25 µf

$$C_T = \frac{1}{\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}}$$

$$C_T = \frac{1}{\frac{1}{50} + \frac{1}{75} + \frac{1}{25}}$$

$$C_T = \frac{1}{\frac{3}{150} + \frac{2}{150} + \frac{6}{150}}$$

$$C_T = \frac{1}{\frac{11}{150}} = 150/11\mu f = 13.64\mu f$$

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Working Voltage

- All capacitors have a **characteristic working voltage**, sometimes called the **voltage rating.**
- It is the **maximum DC voltage** that the capacitor can **sustain continuously** without **excessive leakage** or **breaking down** – ie: having the charge jump from one plate to the other **(arc).**
- **Arcing** will **destroy most capacitors.** Electrolytics can **self-heal** after small arcs. Even **air-gap variable capacitors** can be **damaged** by arcing.

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Working Voltage, (WV)

The **Working Voltage** is another important capacitor characteristic that defines the maximum continuous voltage either DC or AC that can be applied to the capacitor without failure during its working life. Generally, the working voltage printed onto the side of a capacitors body refers to its DC working voltage, (WVDC).

DC and AC voltage values are usually not the same for a capacitor as the AC voltage value refers to the r.m.s. value and NOT the maximum or peak value which is 1.414 times greater. Also, the specified DC working voltage is valid within a certain temperature range, normally -30°C to +70°C.

Any DC voltage in excess of its working voltage or an excessive AC ripple current may cause failure. It follows therefore, that a capacitor will have a longer working life if operated in a cool environment and within its rated voltage. Common working DC voltages are 10V, 16V, 25V, 35V, 50V, 63V, 100V, 160V, 250V, 400V and 1000V and are printed onto the body of the capacitor.

Surge Voltage

- **Surge voltage** is the **maximum voltage** that can be **withstood** for a **few seconds** after the start-up of a circuit.
- It was an important parameter for **tube circuits,** but is **not very relevant** for modern solid-state circuits.

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Reactance

- **Reactance** is the **opposition** to the **flow of Alternating Current (AC)** due to **capacitance** or **inductance.**
- **Reactance** has **no effect** on the flow of **Direct Current (DC).**

In electric and electronic systems, **reactance** is the opposition of a circuit element to the flow of current due to that element's inductance or capacitance. Larger reactance leads to smaller currents for the same voltage applied. Reactance is similar to electric resistance, but it differs in several respects.

Capacitive Reactance

- **Capacitive Reactance** is the **opposition** to the **flow of AC by capacitance.**
- As the **frequency of the AC increases, Capacitive Reactance decreases.**
- The **Symbol** for **Capacitive Reactance** is **X_C.**
- **X_C** is expressed in **ohms.**
- Even though it is expressed in ohms, **power is not dissipated by Reactance!** Energy **stored in a capacitor** during **one part of the AC cycle** is simply **returned to the circuit** during the **next part of the cycle!**

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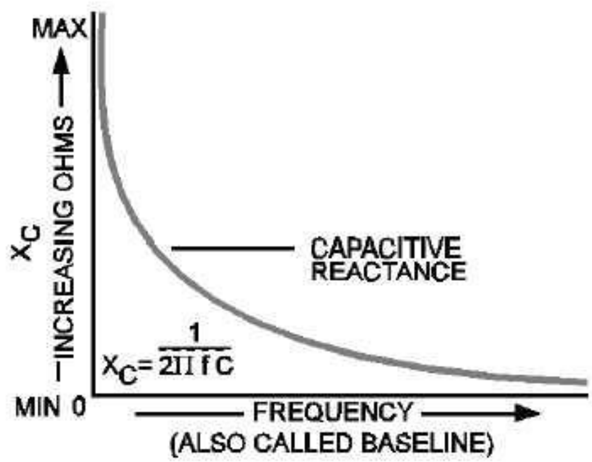
Capacitive reactance is an opposition to the change of voltage across an element. Capacitive reactance is inversely proportional to the signal frequency (or angular frequency ω) and the capacitance c .

Capacitive Reactance



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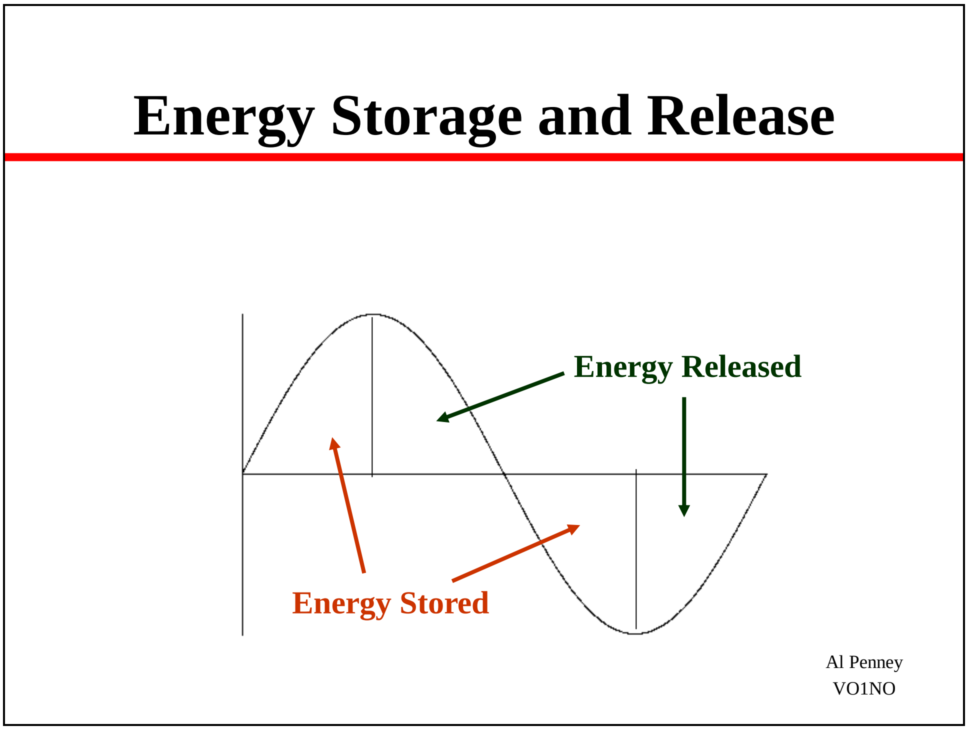
At low frequencies a capacitor is an open circuit so no current flows in the dielectric.

A DC voltage applied across a capacitor causes positive charge to accumulate on one side and negative charge to accumulate on the other side; the electric field due to the accumulated charge is the source of the opposition to the current. When the potential associated with the charge exactly balances the applied voltage, the current goes to zero.

Driven by an AC supply (ideal AC current source), a capacitor will only accumulate a limited amount of charge before the potential difference changes polarity and the charge is returned to the source. The higher the frequency, the less charge will accumulate and the smaller the opposition to the current.



Capacitors store energy on their conductive plates in the form of an electrical charge. When a capacitor is connected across a DC supply voltage it charges up to the value of the applied voltage at a rate determined by its time constant.

A capacitor will maintain or hold this charge indefinitely as long as the supply voltage is present. During this charging process, a charging current, i flows into the capacitor opposed by any changes to the voltage at a rate which is equal to the rate of change of the electrical charge on the plates. A capacitor therefore has an opposition to current flowing onto its plates.

The relationship between this charging current and the rate at which the capacitors supply voltage changes can be defined mathematically as: $i = C(dv/dt)$, where C is the capacitance value of the capacitor in farads and dv/dt is the rate of change of the supply voltage with respect to time. Once it is “fully-charged” the capacitor blocks the flow of any more electrons onto its plates as they have become saturated and the capacitor now acts like a temporary storage device.

A pure capacitor will maintain this charge indefinitely on its plates even if the DC supply voltage is removed. However, in a sinusoidal voltage circuit which contains “AC Capacitance”, the capacitor will alternately charge and discharge at a rate determined by the frequency of the supply. Then capacitors in AC circuits are constantly charging and discharging respectively.

Capacitive Reactance

$$X_C = \frac{1}{2 \pi f C}$$

- Where:

X_C = capacitive reactance in ohms
F = frequency in Hertz
C = capacitance in Farads
π = 3.14

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From the above formula we can see that the value of capacitive reactance and therefore its overall impedance (in Ohms) decreases towards zero as the frequency increases acting like a short circuit. Likewise, as the frequency approaches zero or DC, the capacitors reactance increases to infinity, acting like an open circuit which is why capacitors block DC.

Capacitive Reactance

$$X_C = \frac{1}{2 \pi f C}$$

However, Farads and Hertz are **cumbersome units,** so we can use other units:

F = frequency in Megahertz (MHz)

C = capacitance in Microfarads (µf)

π = 3.14

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Capacitive Reactance Example 1

- What is the capacitive reactance of a 470 pf capacitor at a frequency of 7.15 MHz?
  - Remember that 470 pf = 0.000470 µf.

$$X_C = \frac{1}{2\pi f C}$$

$$= \frac{1}{2\pi \times 7.15 \text{ MHz} \times 0.000470 \text{ µF}}$$

$$= \frac{1\,\Omega}{0.0211} = 47.4\,\Omega$$

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Capacitive Reactance Example 2

- What is the capacitive reactance of that same 470 pf capacitor at a frequency of 14.29 MHz?
  - Again, remember that 470 pf = 0.000470 µf.

$$X_C = \frac{1}{2\,\pi\,f\,C}$$

$$= \frac{1}{2\,\pi \times 14.30\ \text{MHz} \times 0.000470\ \mu\text{F}}$$

$$= \frac{1\,\Omega}{0.0422} = 23.7\,\Omega$$

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Capacitive Reactance Examples

- Note that as the **frequency increased** from 7.15 MHz to 14.290 MHz, the **Capacitive Reactance decreased** from 47.4 ohms to 23.7 ohms.
- **Remember:**
  - **Capacitors block DC;**
  - Capacitors **store energy** as an electrical charge; and
  - As the **frequency increases, capacitive reactance decreases (and vice versa!).**

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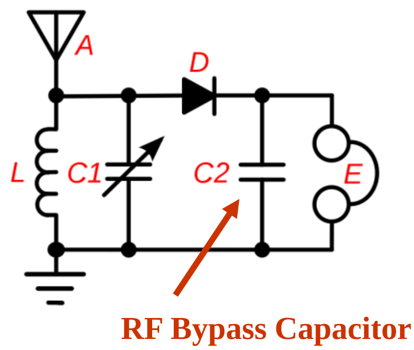
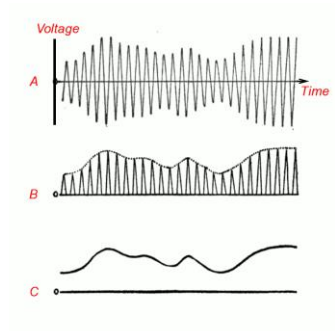
RF Bypass Capacitor





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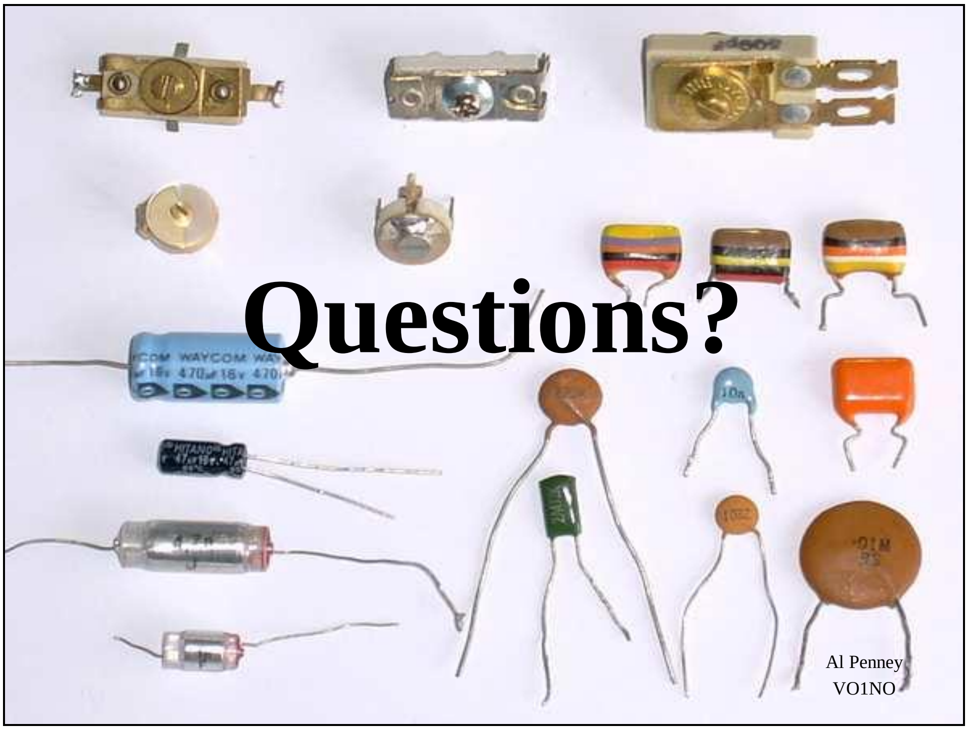
How the crystal detector works.

(A) The amplitude modulated radio signal from the tuned circuit. The rapid oscillations are the radio frequency carrier wave. The audio signal (the sound) is contained in the slow variations (modulation) of the amplitude (hence the term amplitude modulation, AM) of the waves. This signal cannot be converted to sound by the earphone, because the audio excursions are the same on both sides of the axis, averaging out to zero, which would result in no net motion of the earphone's diaphragm. (B) The crystal conducts current better in one direction than the other, producing a signal whose amplitude does not average to zero but varies with the audio signal. (C) A bypass capacitor is used to remove the radio frequency carrier pulses, leaving the audio signal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Review Question 1

If two equal-valued capacitors are connected in parallel, what is their total capacitance?

- Half the value of one capacitor
- Twice the value of one capacitor
- The same as the value of either capacitor
- The value of one capacitor times the value of the other

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Review Question 1

If two equal-valued capacitors are connected in parallel, what is their total capacitance?

- Half the value of one capacitor
- Twice the value of one capacitor
- The same as the value of either capacitor
- The value of one capacitor times the value of the other

< Twice the value of one capacitor >

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Review Question 2

If two equal-valued capacitors are connected in series, what is their total capacitance?

- The value of one capacitor times the value of the other
- Half the value of either capacitor
- Twice the value of one capacitor
- The same as the value of either capacitor

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Review Question 2

If two equal-valued capacitors are connected in series, what is their total capacitance?

- The value of one capacitor times the value of the other
- Half the value of either capacitor
- Twice the value of one capacitor
- The same as the value of either capacitor

< Half the value of either capacitor >

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Review Question 3

What determines the capacitance of a capacitor?

• The material between the plates, the area of one plate, the number of plates and the material used for the protective coating

• The material between the plates, the surface area of the plate, the number of plates and the spacing between the plates

• The material between the plates, the number of plates and the size of the wires connected to the plates

• The number of plates, the spacing between the plates and whether the dielectric material is N type or P type

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Review Question 3

What determines the capacitance of a capacitor?

• The material between the plates, the area of one plate, the number of plates and the material used for the protective coating

• The material between the plates, the surface area of the plate, the number of plates and the spacing between the plates

• The material between the plates, the number of plates and the size of the wires connected to the plates

• The number of plates, the spacing between the plates and whether the dielectric material is N type or P type

< The material between the plates, the surface area of the plate, the number of plates and the spacing between the plates >

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Review Question 4

The total capacitance of two or more capacitors in series is:

- found by adding each of the capacitors together and dividing by the total number of capacitors
- found by adding each of the capacitors together
- always greater than the largest capacitor
- always less than the smallest capacitor

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Review Question 4

The total capacitance of two or more capacitors in series is:

• found by adding each of the capacitors together and dividing by the total number of capacitors

• found by adding each of the capacitors together

• always greater than the largest capacitor

• always less than the smallest capacitor

< always less than the smallest capacitor >

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Review Question 5

Which series combinations of capacitors would best replace a faulty 10 microfarad capacitor?

- Two 20 microfarad capacitors
- Two 10 microfarad capacitors
- Twenty 2 microfarad capacitors
- Ten 2 microfarad capacitors

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Review Question 5

Which series combinations of capacitors would best replace a faulty 10 microfarad capacitor?

- Two 20 microfarad capacitors
- Two 10 microfarad capacitors
- Twenty 2 microfarad capacitors
- Ten 2 microfarad capacitors

< Two 20 microfarad capacitors >

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Review Question 6

How does a capacitor react to AC?

• As the amplitude of the applied AC increases, the reactance decreases

• As the frequency of the applied AC increases, the reactance decreases

• As the frequency of the applied AC increases, the reactance increases

• As the amplitude of the applied AC increases, the reactance increases

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Review Question 6

How does a capacitor react to AC?

• As the amplitude of the applied AC increases, the reactance decreases

• As the frequency of the applied AC increases, the reactance decreases

• As the frequency of the applied AC increases, the reactance increases

• As the amplitude of the applied AC increases, the reactance increases

< As the frequency of the applied AC increases, the reactance decreases >

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Review Question 7

The reactance of capacitors increases as:

- frequency increases
- frequency decreases
- applied voltage increases
- applied voltage decreases

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Review Question 7

The reactance of capacitors increases as:

• frequency increases

• frequency decreases

• applied voltage increases

• applied voltage decreases

< frequency decreases >

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Review Question 8

What property allows an RF bypass capacitor to have little effect on an audio circuit?

- Low reactance at low frequencies
- High reactance at low frequencies
- Low reactance at high frequencies
- High reactance at high frequencies

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Review Question 8

What property allows an RF bypass capacitor to have little effect on an audio circuit?

- Low reactance at low frequencies
- High reactance at low frequencies
- Low reactance at high frequencies
- High reactance at high frequencies

< High reactance at low frequencies >

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It is all about frequency. Audio circuits means audio frequencies (AF), which have much lower frequencies

than radio frequencies (RF). In a capacitor, the higher the frequency the smaller the capacitive reactance or

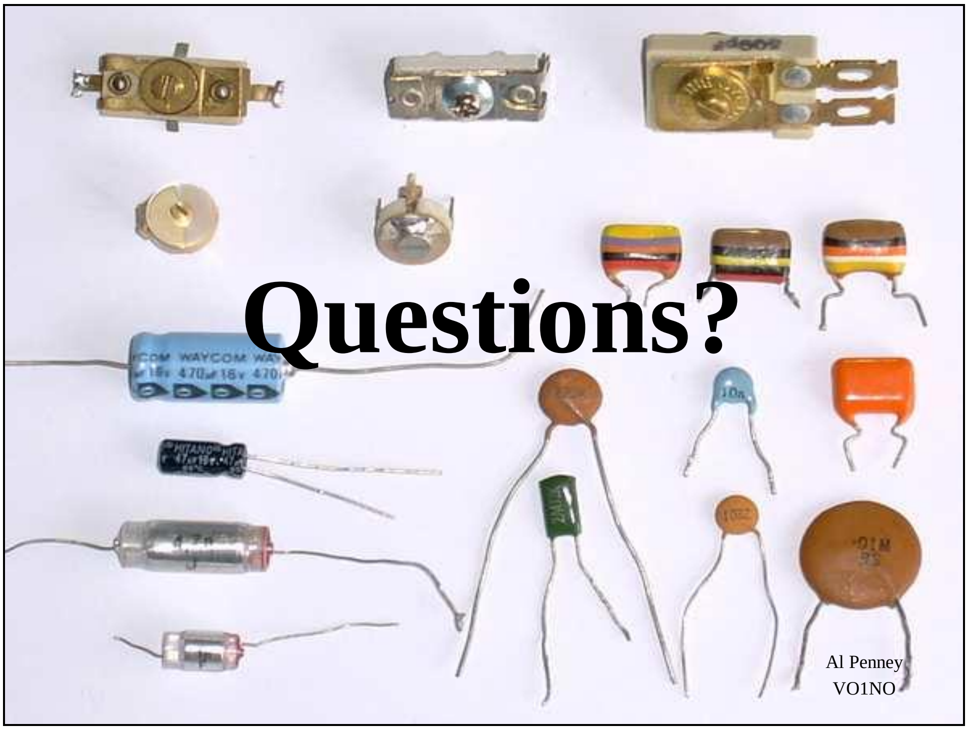
opposition to the flow of AC. To allow audio frequencies to flow unimpeded one uses a large capacitance to

provide a low capacitive reactance. An RF bypass capacitor is used to divert or force RF to flow unimpeded in

a desired direction, in this case, away from or out of the audio circuit. This means the RF capacitor will have

low value, as it will present a high reactance to the ***AF*** *flow through the audio circuit.* ***NOTE CORRECTION!***

Capacitors used in **bypass** applications are implemented as shunt elements and serve to carry **RF** energy from a specific point in the circuit to ground. Proper selection of a **bypass capacitor** will provide a very low impedance path to ground.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For Next Class:

- Review Chapter 4 of Basic Study Guide; and
- Read Chapter 5 of Basic Study Guide