Basic Electronics Part 13
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Suppose we apply a sine wave voltage to a capacitor. If the voltage applied to the top capacitor plate is positive during the first sine wave half cycle, this voltage increases from zero so there is a sudden rush of current as the capacitor begins to charge. The flow of electrons is onto the bottom plate since the top plate is positive. That current tapers off as the charge increases. The sine-wave voltage reaches a maximum and begins to decrease to zero again. When the voltage begins to decrease, the capacitor begins to return its stored energy to the circuit. In this case, the current direction changes. Instead of electrons moving onto the bottom capacitor plate, the electrons move off the bottom plate, because the capacitor is returning energy to the circuit.

During the next half cycle, the voltage polarity reverses, so the voltage applied to the top capacitor plate is negative. Electrons continue to move off the bottom plate, and onto the top plate. The capacitor returns all the original charge to the circuit and it begins to charge in the opposite direction. As the capacitor charge increases the current decreases.

After the sine-wave voltage reaches its maximum negative value, the voltage begins to decrease to zero again. Now the capacitor returns its stored energy to the circuit again.

It would seem that capacitors don't like the applied voltage to change. They react to a voltage change by opposing that change. When the voltage is increasing, they take energy from the voltage supply. This could be thought of as an attempt to prevent the voltage from increasing. When the voltage is decreasing, the capacitor returns stored energy to the circuit. This action works to prevent the voltage from decreasing. This opposition to voltage change is called reactance. It is similar to the opposition to current of a resistor. Because of this we measure reactance in ohms.

So when a capacitor charges and discharges with a varying voltage applied, alternating current can flow. There can't be any current through the dielectric of the capacitor, however, the charge and discharge of the capacitor produces an alternating current in the circuit connected to the capacitor plates. If the voltage applied to a capacitor varies as a sine wave, then the amount of current that results depends on the capacitor's capacitive reactance. The symbol for capacitive reactance is X_C and its unit is the ohm. The capacitive reactance of a capacitor depends on the capacitance, C, and the frequency of the applied voltage, f. The formula for capacitive reactance in terms of f and C is

$$X_C = \frac{1}{2\pi fC},$$

where the frequency, f, is in hertz and the capacitance, C, is in farads. Note that X_C decreases for higher frequencies and for higher capacitance.

As an example, consider a 4-µF capacitor in a circuit with a 120 volt, 60 Hz, applied (Fig. 1).

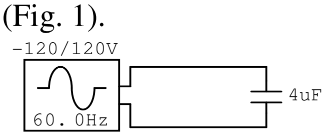

Fig. 1

Here the capacitive reactance of the capacitor is

$$X_C = \frac{1}{2\pi(60)(4 \text{ X } 10^{-6})} = 663 \text{ ohms.}$$

If we replace the 4-μF capacitor in Fig. 1 with a 1-μF capacitor, the capacitive reactance will be 2652 ohms. So, as we decrease the capacitance, we increase the capacitive reactance. If the frequency of the applied voltage in Fig. 1 is changed to 4 MHz (4 X 10^6 Hz), then the capacitive reactance will be 0.01 ohms. In this case we have increased the frequency of the applied voltage so the capacitive reactance decreases.

We can use a form of ohm's law to also calculate capacitive reactance. If we know the voltage across the capacitor in Fig 1, V_C, and the current in the circuit, I_C, then the value of X_C can be measure as V_C / I_C. If we place an ammeter in the circuit in Fig. 1, the meter will read the amount of charge and discharge current. If this meter shows that I_C is 0.181 A, then the capacitive reactance is

$$X_C = \frac{120}{0.181} = 663 \text{ ohms.}$$