Topics Covered in Chapter 17
17-1: Alternating Current in a Capacitive Circuit
17-2: The Amount of $X_C$ Equals $1/(2\pi fC)$
17-3: Series or Parallel Capacitive Reactances
17-4: Ohm's Law Applied to $X_C$
17-5: Applications of Capacitive Reactance
17-6: Sine Wave Charge and Discharge Current
Capacitive reactance is the opposition a capacitor offers to the flow of sinusoidal current.

- Symbol: $X_C$
- Units: Ohms

Formula (this applies only to sine wave circuits):

$$X_C = \frac{1}{2\pi f C}$$
Current flows with ac voltage applied to a series connected capacitor and light bulb.

There is NO current through the capacitor’s dielectric.

While the capacitor is being charged by increasing applied voltage, the charging current flows in one direction in the conductors to the plates.

While the capacitor is discharging, when the applied voltage decreases, the discharge current flows in the reverse direction.

With alternating voltage applied, the capacitor alternately charges and discharges.
17-1: Alternating Current in a Capacitive Circuit

Fig. 17-1: Current in a capacitive circuit. (a) The 4-μF capacitor allows enough current I to light the bulb brightly. (b) Less current with smaller capacitor causes dim light. (c) Bulb cannot light with dc voltage applied because a capacitor blocks the direct current.
Summary:

- Alternating current flows in a capacitive circuit with ac voltage applied.
- A smaller capacitance allows less current, which means more $X_C$ with more ohms of opposition.
- Lower frequencies for the applied voltage result in less current and more $X_C$.
  - With a steady dc voltage source (zero frequency), the capacitor’s opposition is infinite and there is no current. In this case the capacitor is effectively an open circuit.
Summary, cont.

- $X_C$ depends on the frequency of the applied voltage and the amount of capacitance.
  - $X_C$ is less for more capacitance.
  - $X_C$ is less for higher frequencies.
17-2: The Amount of $X_C$
Equals $\frac{1}{(2\pi f C)}$

- Factors Affecting $X_C$
  - The value of $X_C$ is inversely proportional to the value of capacitance:
    - Increasing $C$ decreases $X_C$
    - Decreasing $C$ increases $X_C$
  - The value of $X_C$ is inversely proportional to the frequency:
    - Increasing $f$ decreases $X_C$
    - Decreasing $f$ increases $X_C$
17-2: The Amount of $X_C$ Equals $1/(2\pi f C)$

- Summary of the $X_C$ Formulas:

- When $f$ and $C$ are known: 
  \[ X_C = \frac{1}{2\pi f C} \]

- When $X_C$ and $f$ are known: 
  \[ C = \frac{1}{2\pi f X_C} \]

- When $X_C$ and $C$ are known: 
  \[ f = \frac{1}{2\pi C X_C} \]
Capacitive reactance is an opposition to AC, so series or parallel reactances are combined in the same way as resistances.

Combining capacitive reactances is opposite to the way capacitances are combined. The two procedures are compatible because of the inverse relationship between $X_C$ and $C$. 
17-3: Series or Parallel Capacitive Reactances

- **Series Capacitive Reactance:**
  - Total reactance is the sum of the individual reactances.
    \[ X_{CT} = X_{C1} + X_{C2} + X_{C3} + \ldots + \text{etc.} \]
  - All reactances have the same current.
  - The voltage across each reactance equals current times reactance.
    \[ V_{C1} = I \times X_{C1} \]
Parallel Capacitive Reactances

Total reactance is found by the reciprocal formula:

\[ \frac{1}{X_{CT}} = \frac{1}{X_{C1}} + \frac{1}{X_{C2}} + \frac{1}{X_{C3}} + \ldots + \text{etc.} \]

All reactances have the same voltage.

The current through each reactance equals voltage divided by reactance.

\[ I_C = \frac{V_C}{X_C} \]
Current in an ac circuit with $X_C$ alone is equal to the applied voltage divided by the ohms of $X_C$.

Fig. 17-6: Example of circuit calculations with $X_C$. (a) With a single $X_C$, the $I = V/X_C$. (b) Sum of series voltage drops equals the applied voltage $V_T$. (c) Sum of parallel branch currents equals total line current $I_T$. 

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The general use of $X_C$ is to block direct current but provide low reactance for alternating current.

Ohms of $R$ remain the same for dc or ac circuits, but $X_C$ depends on frequency.

The required $C$ becomes smaller for higher frequencies.
## Table 17-1: Capacitance Values for a Reactance of 100 Ω

<table>
<thead>
<tr>
<th>C (Approx.)</th>
<th>Frequency</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>27 µF</td>
<td>60 Hz</td>
<td>Power-line and low audio frequency</td>
</tr>
<tr>
<td>1.6 µF</td>
<td>1000 Hz</td>
<td>Audio frequency</td>
</tr>
<tr>
<td>0.16 µF</td>
<td>10,000 Hz</td>
<td>Audio frequency</td>
</tr>
<tr>
<td>1600 pF</td>
<td>1000 kHz (RF)</td>
<td>AM radio</td>
</tr>
<tr>
<td>160 pF</td>
<td>10 MHz (HF)</td>
<td>Short-wave radio</td>
</tr>
<tr>
<td>16 pF</td>
<td>100 MHz (VHF)</td>
<td>FM radio</td>
</tr>
</tbody>
</table>
17-5: Applications of Capacitive Reactance

Summary of Capacitance vs. Capacitive Reactance:

- **Capacitance**
  - Symbol is $C$
  - Unit is $F$
  - Value depends on construction
  - $i_C = C(dv/dt)$

- **Capacitive Reactance**
  - Symbol is $X_C$
  - Unit is $\Omega$
  - Value depends on $C$ and $f$
  - $X_C = \frac{v_c}{i_c}$ or $\frac{1}{2\pi fC}$
17-5: Applications of Capacitive Reactance

- Summary of Capacitive Reactance vs. Resistance:

  - **Capacitive Reactance**
    - Symbol is $X_C$
    - Unit is Ω
    - Value decreases for higher $f$
    - Current leads voltage by 90° ($\Theta = 90°$).

  - **Resistance**
    - Symbol is $R$
    - Unit is Ω
    - Value does not change with $f$
    - Current and voltage are in phase ($\Theta = 0°$).
17-6: Sine Wave Charge and Discharge Current

V_A is positive and increasing, charging C.

V_C decreases by discharging.

V_A increases but in the negative direction. C charges but in reverse polarity.

Negative V_A decreases and C discharges.

Fig. 17-7: Capacitive charge and discharge currents. (a) Voltage V_A increases positive to charge C. (b) The C discharges as V_A decreases. (c) Voltage V_A increases negative to charge C in opposite polarity. (d) The C discharges as reversed V_A decreases.

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Charge and discharge current of a capacitor can be found if we know two factors:

1. The capacitance value of the capacitor
2. The rate of voltage change across the capacitor

Capacitive current, $i_C$ depends on the rate of voltage change across its plate.
Calculating the Values of $i_c$.

- The greater the voltage change, the greater the amount of capacitive current.
- Capacitive current is calculated

\[ i_c = C \frac{dv}{dt} \]

- $i$ is in amperes
- $C$ is in farads
- $dv/dt$ = volts per second.
90° Phase Angle
  - $i_C$ leads $v_C$ by 90°.
  - ICE

The difference results from the fact that $i_C$ depends on the $dv/dt$ rate of change, not $v$ itself.

The ratio of $v_C/i_C$ specifies the capacitive reactance in ohms.
17-6: Sine Wave Charge and Discharge Current

\[ \frac{dv}{dt} \text{ for Sinusoidal Voltage is a Cosine Wave} \]

\[ i_c = C \frac{dv}{dt} \]

\[ V_{\text{inst.}} = V_{\text{max}} \times \cos \theta \]