(1) Phys 1402 2014-10-21

AC Circuits

$V(t)$ oscillates w/ frequency f.

V_0, V_{peak}, V_{max} are all the amplitude.

$V_{RMS} = V_0/\sqrt{2}$ is the effective voltage.

Current also oscillates. Same f.

AC Ohm's Law $V_{RMS} = I_{RMS} Z$

Resistor (R) $Z_R = R$

Inductor (L) $Z_L = 2\pi f L$

Opposes change in I

High-f has huge change in I.

This requires high-V.

$V = IZ$: Z must be high

Capacitor $Z_C = \frac{1}{2\pi f C}$

Takes time to fill and empty.

High-f has rapid changes in V.

This requires high-I.

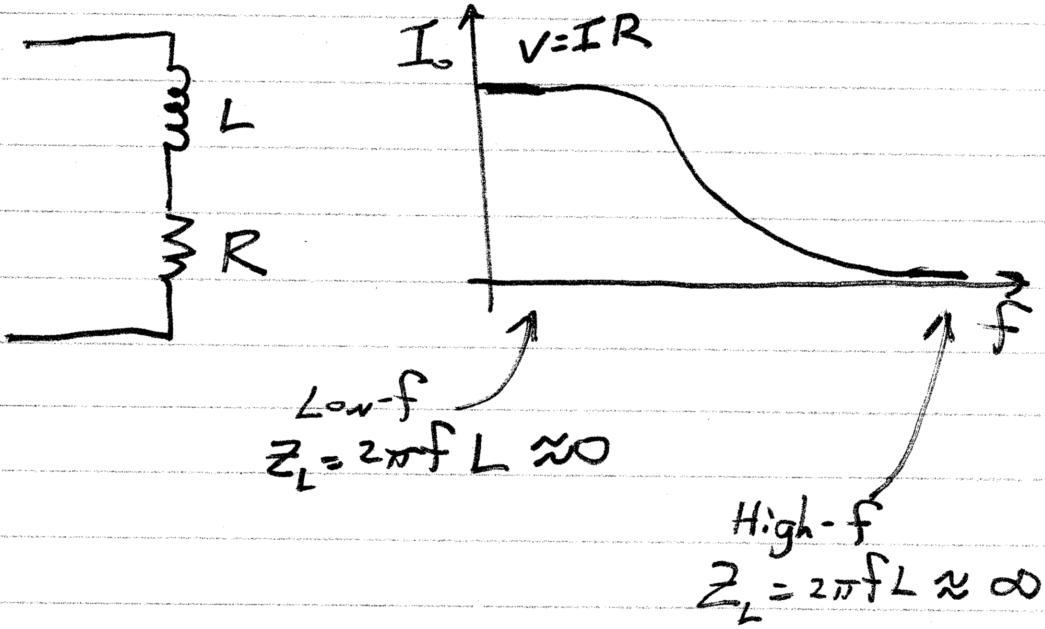
$V = IZ$: Z is Low

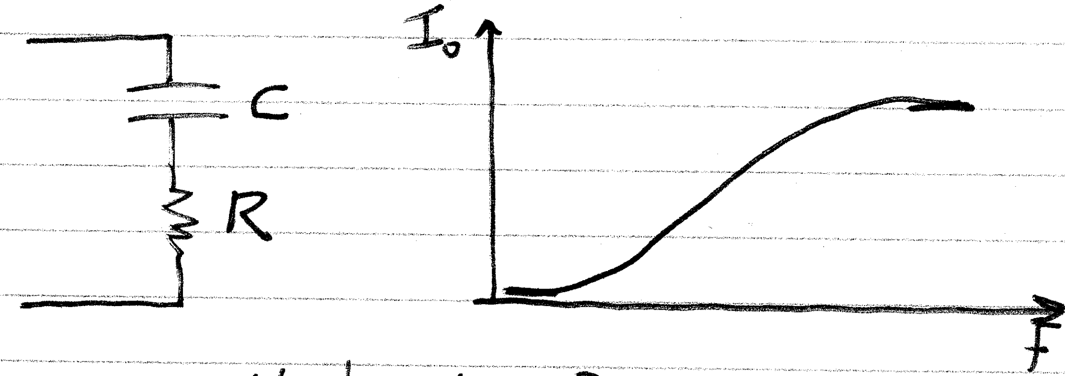
②

Filters:

High-Z in series blocks current.

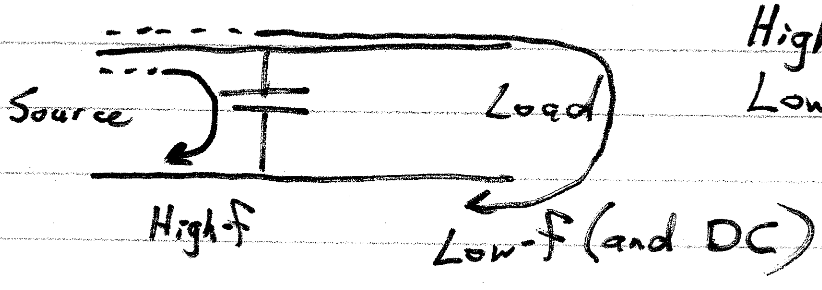
$V_0 = I_0 Z$ High Z requires high-V





Capacitor blocks Low-f.

Capacitor in parallel



High-f go thru C.
Low-f go to Load.

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Series AC Circuit

Each component has its own Z.

Z_R, Z_L, and Z_C combine separately.

Then add as vectors.

$R \rightarrow Z_R$ in $+\hat{x}$ dir.

$L \rightarrow Z_L = 2\pi f L$ $+\hat{y}$ dir.

$C \rightarrow Z_C = 1/(2\pi f C)$ $-\hat{y}$ dir.

Procedure:

$$Z_L, Z_C \Rightarrow X = Z_L - Z_C$$

$$X, R \rightarrow Z = \sqrt{R^2 + X^2}$$

X = reactance = impedance from inductors & capacitors.

R always increases Z.

Z_L and Z_C can cancel!

If $Z_L = Z_C$, $X = 0$. This gives the lowest possible Z, which is $Z = R$.

How does this happen?

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

$$(2\pi f)^2 \frac{\cancel{L}}{\cancel{L}} = 1/LC$$

$$2\pi f = \frac{1}{\sqrt{LC}}$$

Resonant frequency.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

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Ex: $f_R = 2.4\ GHz = 2.4 \times 10^9\ Hz$

$C = 1\ pF = 10^{-12}\ F$

Note: 10^{-12} is 1e-12

$$f_R = \frac{1}{2\pi\sqrt{LC}}$$

$$2\pi f_R = \frac{1}{\sqrt{LC}}$$

$$(2\pi f)^2 = \frac{1}{LC}$$

$$L = \frac{1}{C(2\pi f)^2} = \frac{1}{(10^{-12}F)(2\pi\, 2.4\times10^9 Hz)^2}$$

$$= 4.4 \times 10^{-9} H = 4.4\ nH$$

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Power in AC

Resistor: When V is $+$, I is $+$, P is $+$
V is 0, I is 0, P is 0
V is $-$, I is $-$, P is $+$

Power is only used by resistor (not generated).
Power is used in pulses. $P_R = \frac{1}{2} P_{max}$

Inductor - has energy $= \frac{1}{2} L I^2$
When I = strong, energy is high.
When I = weak, energy is low.
The inductor takes energy and gives it back!
Overall, $P_L = 0$ (on average)

Capacitor: energy $= \frac{1}{2} C V^2$
$P_C = 0$ (on average)

Transformer: shuttles energy from primary to secondary.
$P_1 = P_2$

Only resistors use power.
Key: Find I of resistor. $P = V_R I_R = \boxed{I^2 R}$

RMS V, I go with average power.

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Ex: 120 V AC (RMS) 60 Hz

36 W Light bulb, resistive

$P_{ave} = V_{RMS} I_{RMS}$ (for resistor)

$(36W) = (120v) I_{rms}$

$I_{rms} = 0.3 A$

$V_{RMS} = I_{RMS} Z$

$Z = \frac{120 V}{0.3 A} = 400 \Omega$

Since it is resistive, $R = 400 \Omega$

Put a capacitor in series.

$C = 8.84 \mu F$ $f = 60 Hz$

$Z_C = \frac{1}{2\pi f C} = \frac{1}{2\pi (60 Hz)(8.84 \times 10^{-6} F)}$

$Z_C = 300 \Omega$

$Z_{Tot} = \sqrt{(400\Omega)^2 + (300\Omega)^2} = 500 \Omega$

$I = \frac{V}{Z} = \frac{120 V}{500 \Omega} = 0.24 A$

$V_R = IR = (0.24 A)(400\Omega) = 96 V$

$P = V_R I_R = (96 v)(\cancel{400\Omega}\ 0.24A) = 23 W$