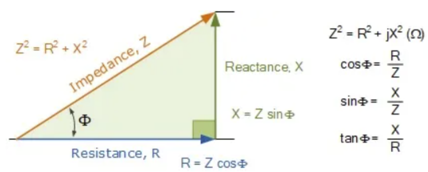
0.0.1 Resistance, Reactance, Impedance and Admittance

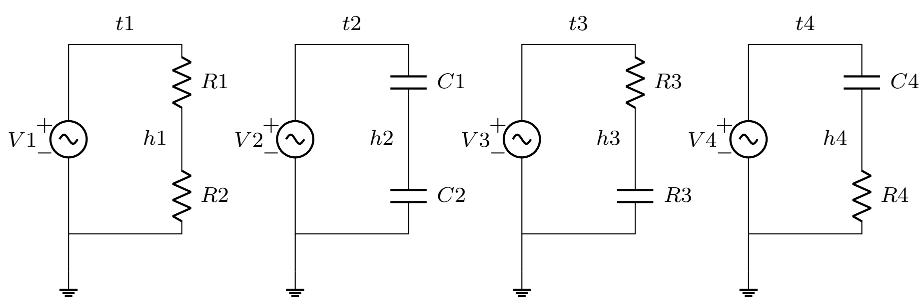
Useful website link.



Impedance : Ability to stop/resist current at a specific frequency.
Resistance : Ability to stop electric current flow.
Reactance : Ability to store and release energy.
Admittance : Ability to allow/let current flow through at a specific frequency.

- if energy is stored and release in **magnetic field**, reactance is inductive. $+jX_L$, voltage leads current by 90 (voltage peak first as time progress)
- if energy is stored and released in **eletric field**, reactance is capacitive. $-jX_C$, current leads voltage by 90 (current peak first as time progress)

So given this circuit



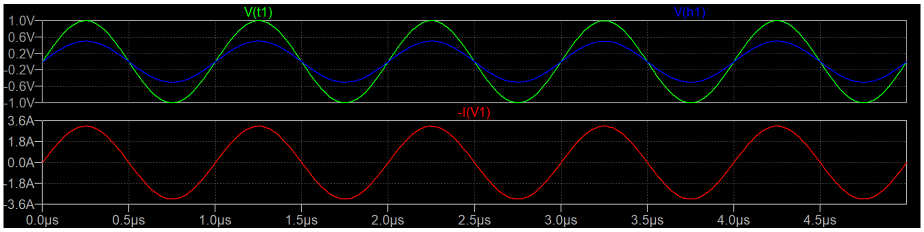
$$f = 1 \times 10^6 = 1 \text{ MHz}, \ All \ Vx = \sin(2\pi f t)$$

$$All \ Cx = 1 \text{ µF}, \ All \ Rx = \frac{1}{2\pi f C} = 0.159154 \ \Omega$$

For circuit with $V1$

$$I(R1) = \frac{1 \text{ V}}{2 \times 0.159154\Omega} \ = \ 3.1416 \text{ A}$$

Current is a sine wave with peak amplitude of 3.1416 A, and it is in phase with the voltage sinusoidal source. Just like a voltage divider.



For circuit with $V2$

Amplitude wise(at node $h2$) it is also like a voltage divider, the signal at node $h2$ is half of $t2$, that's obvious.

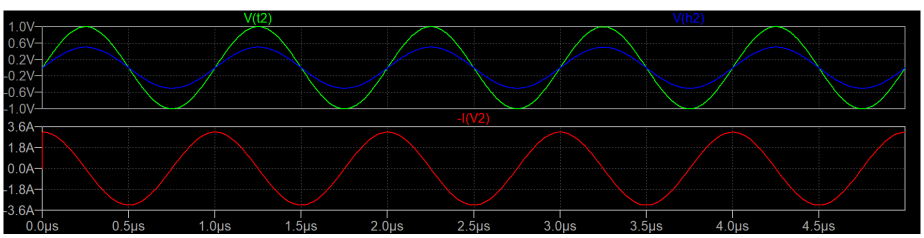
$$V(h2) = V(t2) \times \frac{Z_{C1}}{Z_{C1} + Z_{C2}} = V(t2) \times \frac{-j\frac{1}{2\pi f C_1}}{-j\frac{1}{2\pi f C_1} + -j\frac{1}{2\pi f C_2}} = \frac{V(t2)}{2}$$

Current wise it is 90 degree out of phase, current lead voltage by $\frac{\pi}{2}$

$$I(C1) = \frac{V(t2)}{-j\frac{2}{2\pi f C_1}} = \frac{V(t2)}{-j\frac{2}{2\pi f C_1}} \times \frac{+j\frac{2}{2\pi f C_1}}{+j\frac{2}{2\pi f C_1}} = 0 + j\frac{V(t2) \times \frac{2}{2\pi f C_1}}{(\frac{2}{2\pi f C_1})^2}$$

$$\arctan(\frac{\frac{V(t2)\times\frac{2}{2\pi f C_1}}{(\frac{2}{2\pi f C_1})^2}}{0}) = \arctan(\infty) = 90^\circ$$

This is saying that our current signal will start at positive 90 degrees which is peak amplitude.



For circuit with $V3$

At node $h3$, it is also like a voltage divider but noticed it is not divided by half.

$$V(h3) = V(t3)\ \frac{Z_{C3}}{Z_{R3} + Z_{C3}} = V(t3)\ \frac{-j0.159154}{0.159154 - j0.159154} = V(t3)\ \frac{-j}{1-j}$$
$$= V(t3)\ \frac{1-j}{2}$$

$$\left\| V(t3)\ \frac{1-j}{2} \right\| = V(t3)\ \sqrt{\left(\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2} = 0.707108\ V(t3)$$

$$\angle V(t3)\ \frac{1-j}{2} = arctan\left(\frac{-\frac{1}{2}}{\frac{1}{2}}\right) = -45^\circ$$

-45 ° means it's "lagging" original sine wave by 45 degrees, moving the original waveform to the right.
Note that we're taking the voltage across the capacitor $C3$. $V(t3) - V(h3)$ is the voltage across the resistor, and its phase is +45 °.

$$I(C3) = \frac{V(t3)}{0.159154 - j0.159154} = \frac{V(t3)}{0.318308}(1+j)$$

$$\left\| \frac{V(t3)}{0.318308}(1+j) \right\| = 4.4429\ V(t3)$$

$$\angle \frac{V(t3)}{0.318308}(1+j) = +45^\circ$$

Current wise it is leading voltage $V(h3)$ by 45 °, notice that it is not our original 90 °. We can intuitively explain this as the resistance is slowing down the current, which makes charging and discharging the capacitor slower, thus we have a phase compromise between having both resistor and having both capacitors.