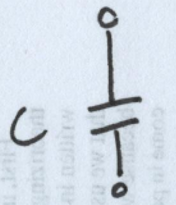
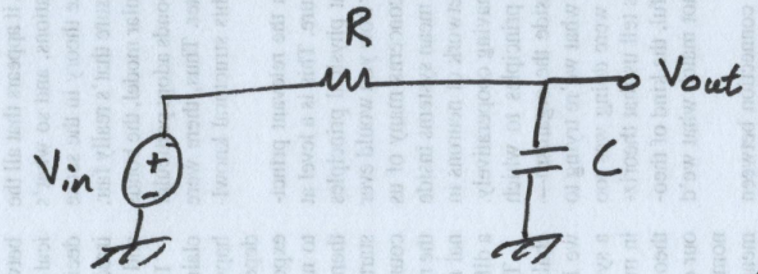
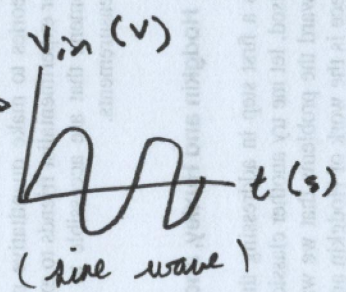


← Capacitor ('cap' for short)

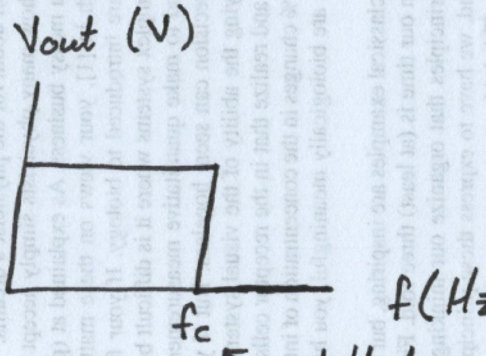
Common application: RC low-pass filter.
(Passes low-freq signals, kills high-freq signals)



V_{in} is some waveform like: →



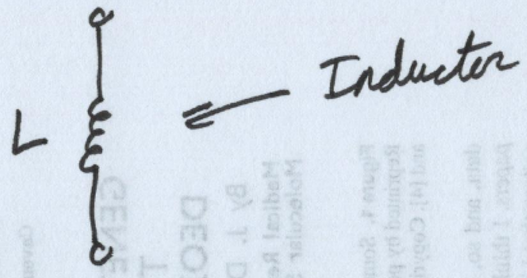
V_{out}:



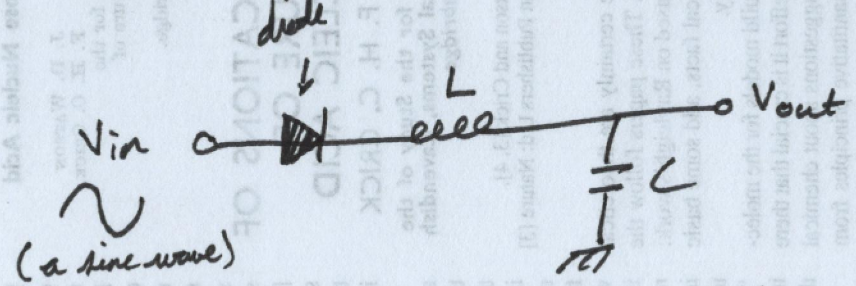
↖ cutoff freq

If $f < f_c$, signal passes.

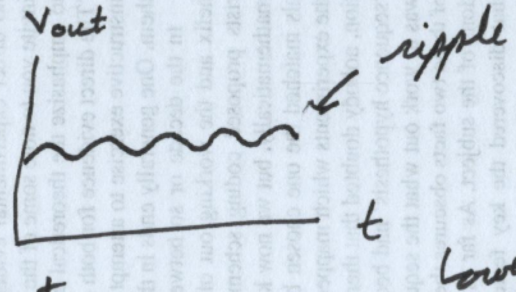
If $f > f_c$, signal gets killed.
So 'low' frequencies 'pass'.
⇒ 'low-pass' filter.



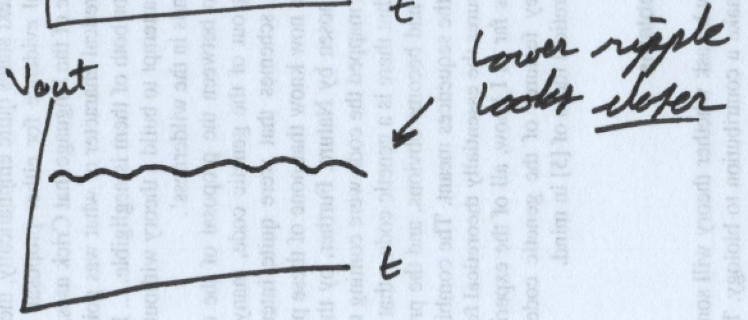
Common application: killing current I's ripple in AC/DC conversion circuits.



Vout with L shorted:



Vout with L included:



Memory aid for complex number relationships:

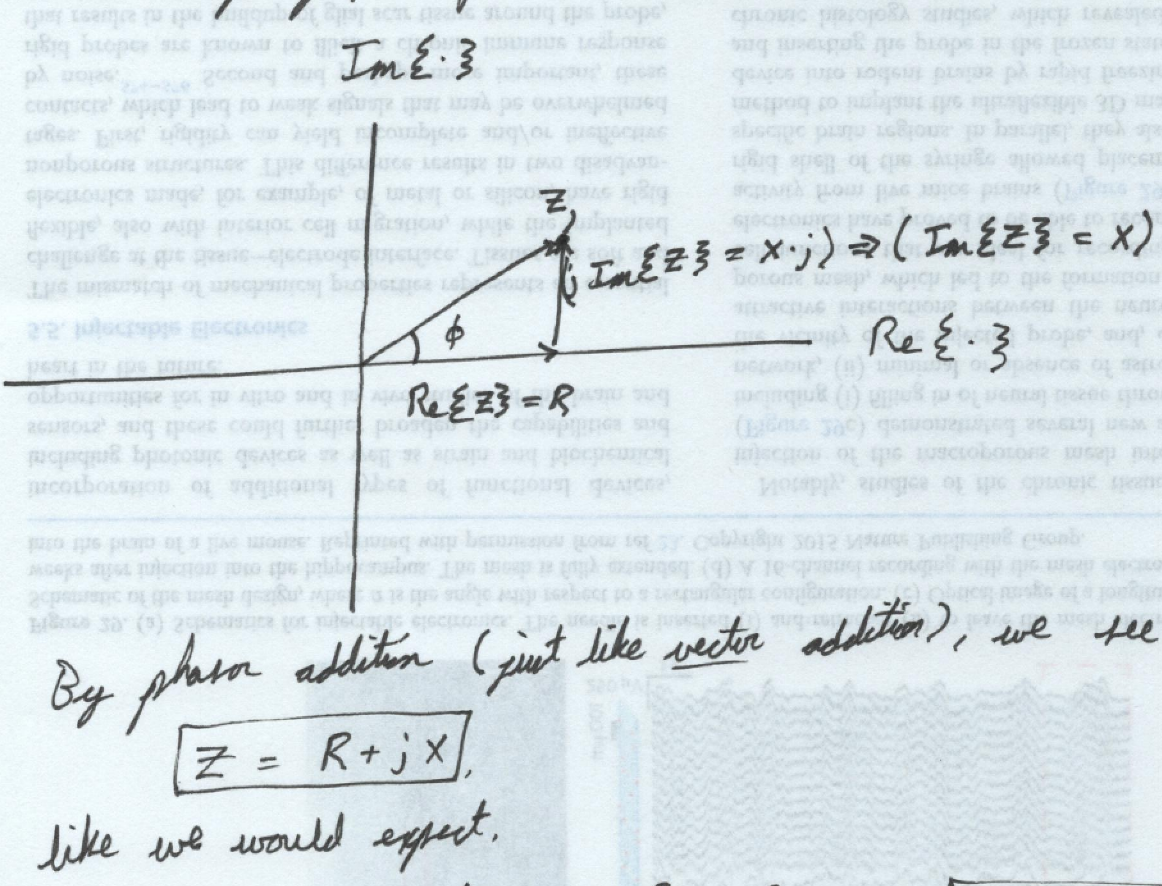
Argand diagram.

If Z is a complex number (i.e., $Z \in \mathbb{C}$), its rectangular form is

$$Z = R + jX.$$

The real part of Z is $\boxed{Re\{Z\} = R.}$

The imaginary part of Z is $\boxed{Im\{Z\} = X.}$



By phasor addition (just like vector addition), we see that

$$\boxed{Z = R + jX},$$

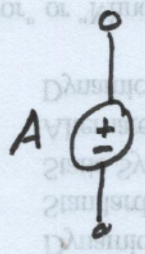
like we would expect.

By the Pythagorean Thm. $Z^2 = R^2 + X^2 \Rightarrow \boxed{|Z| = \sqrt{R^2 + X^2}.}$

The phase angle ϕ is defined by

$$\tan\phi = \frac{X}{R} \Rightarrow \boxed{\phi = \arctan\left(\frac{X}{R}\right)},$$

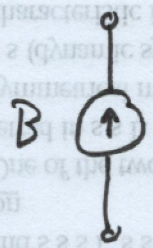
Voltage source (ideal)



equation: $V = A$

$I = ?$ Can't tell.

Current source (ideal)

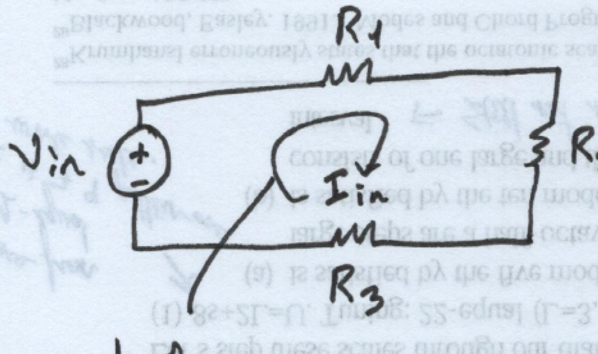


equation: $I = B$

$V = ?$ Can't find it with just $I = B$.

KVL

$\sum_k V_k = 0$ is valid here.

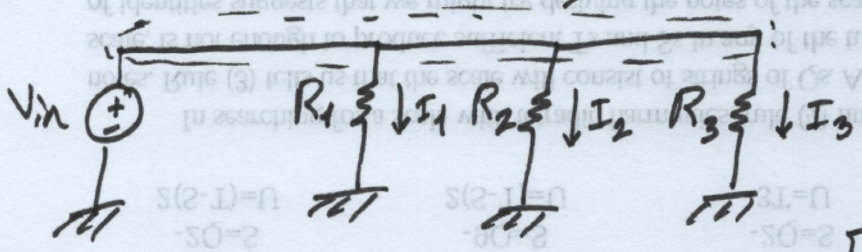


$V_{in} + I_{in}R_1 + I_{in}R_2 + I_{in}R_3 = 0.$

loop, mesh.

KCL

node at voltage V_{in}



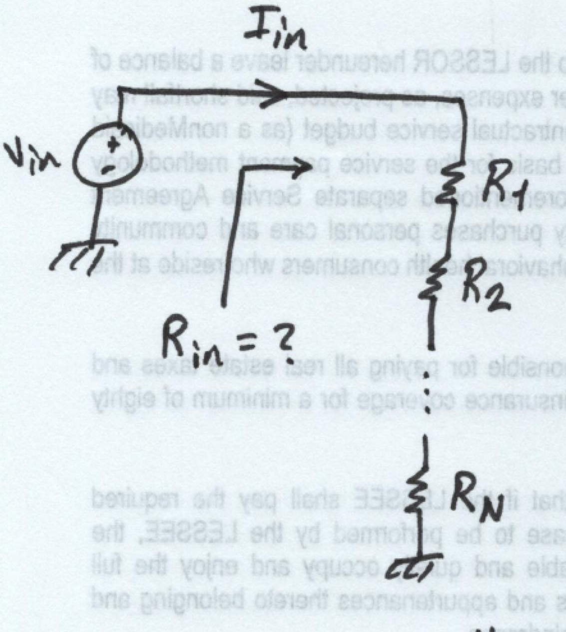
$\sum_k I_k = 0$ is valid here

$I_1 + I_2 + I_3 = 0$ Ohm's law.

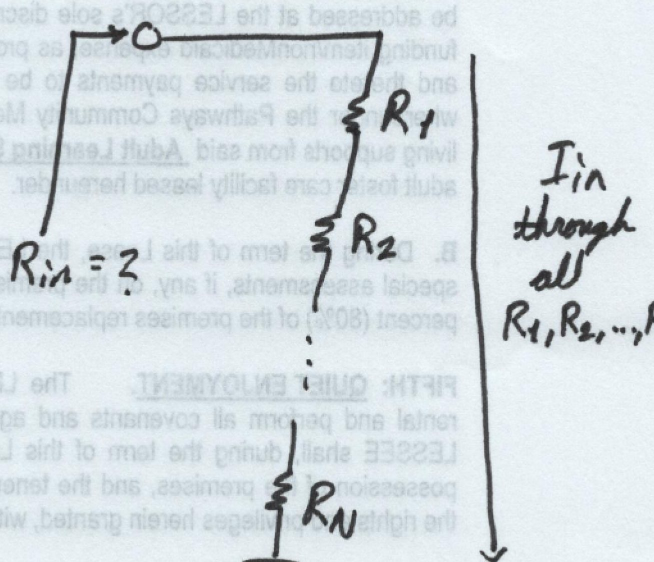
$$\frac{V_{in}}{R_1} + \frac{V_{in}}{R_2} + \frac{V_{in}}{R_3} = 0$$

AKA nodal analysis, KCL.

Series Impedances



$\Longleftrightarrow$



$$R_{in} = \frac{V_{in}}{I_{in}}$$

KVL

$$V_{in} + I_{in} R_1 + I_{in} R_2 + \ldots + I_{in} R_N = 0$$

$$V_{in} + I_{in}(R_1 + R_2 + \ldots + R_N) = 0$$

Polarity? $\leftarrow V_{in} = -I_{in}(R_1 + R_2 + \ldots + R_N) = 0$

From persp. of circuit, I_{in} is negative.

apply that fact.

$\cancel{V_{in} + I_{in}(R_1}$

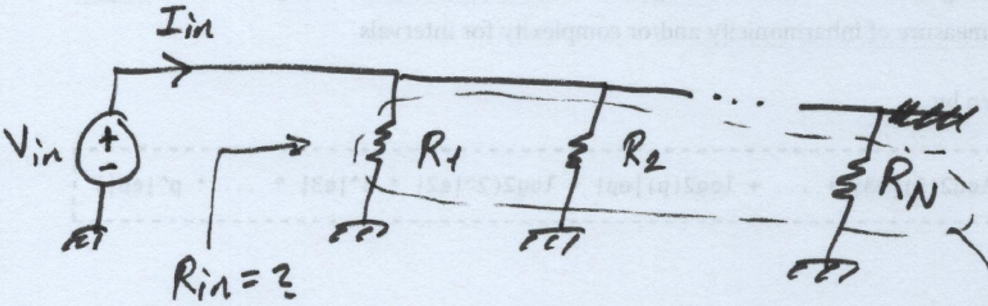
$$V_{in} = I_{in}(R_1 + R_2 + \ldots + R_N)$$

$$R_{in} = \frac{V_{in}}{I_{in}} = R_1 + R_2 + \ldots + R_N$$

Series Rs have the same current through them.

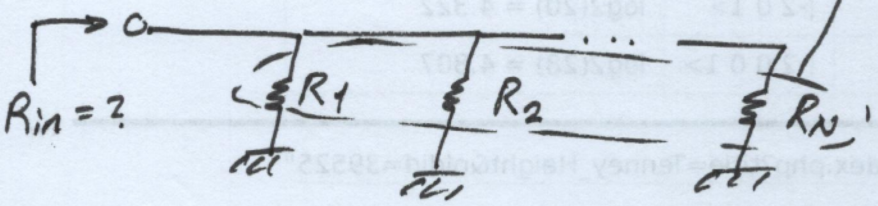
Parallel Impedances

Parallel operator: $a \parallel b = \dfrac{ab}{a+b}$



$R_1 \parallel R_2 \parallel \ldots \parallel R_N$

$\Leftrightarrow$

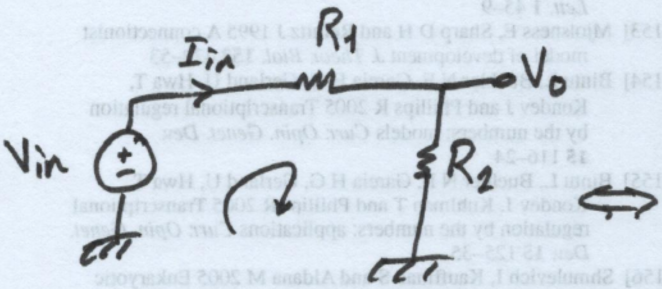


$$I_{in} = \frac{V_{in}}{R_1 \parallel R_2 \parallel \ldots \parallel R_N} \longrightarrow R_{in} = \frac{V_{in}}{I_{in}}$$

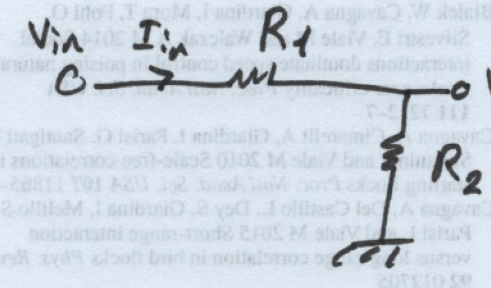
$$R_{in} = R_1 \parallel R_2 \parallel \ldots \parallel R_N$$

Parallel Rs have the same voltage across them.

Voltage divider



$\Longleftrightarrow$



$V_o(V_{in}) = ?$

KVL

$$-V_{in} + I_{in}(R_1 + R_2) = 0$$

$$V_o = I_{in} R_2$$

Solve for I_{in} → plug I_{in} into V_o.

$$I_{in}(R_1 + R_2) = V_{in}$$

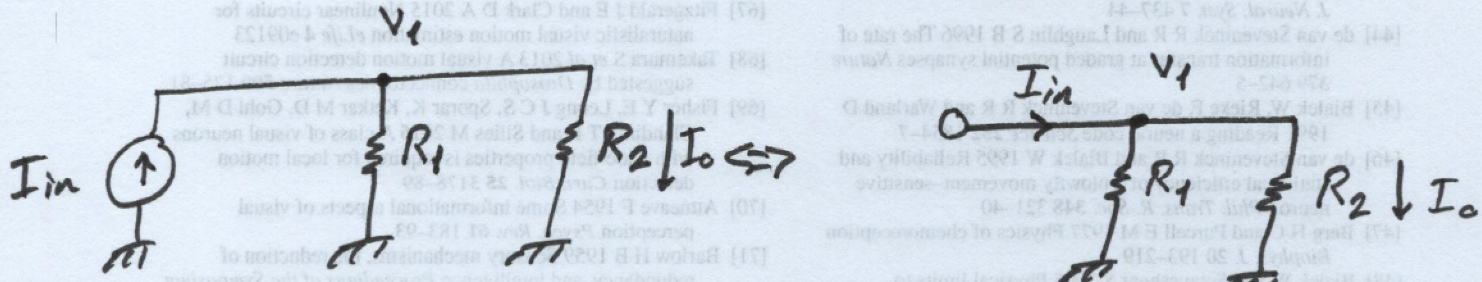
$$I_{in} = \frac{V_{in}}{R_1 + R_2}$$

$$V_o = \frac{V_{in}}{R_1 + R_2} R_2$$

Typically we want a gain function, $A_v = \frac{V_o}{V_{in}}$, so let's put it in that form

$$A_v = \frac{V_o}{V_{in}} = \frac{R_2}{R_1 + R_2} = \frac{1}{1 + \frac{R_1}{R_2}}.$$

Current Divider



KCL

$$-I_{in} + \frac{V_1}{R_1} + \frac{V_1}{R_2} = 0$$

$$I_o = \frac{V_1}{R_2}$$

Solve for V_1, plug it into $I_o = \frac{V_1}{R_2}$

$$V_1\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = I_{in}$$

$$V_1 = \frac{I_{in}}{\frac{1}{R_1} + \frac{1}{R_2}}$$

$$I_o = \frac{\frac{1}{R_2} I_{in}}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{I_{in}}{1 + \frac{R_2}{R_1}}$$

Gain form:

$$A_I = \frac{I_o}{I_{in}} = \frac{1}{1 + \frac{R_2}{R_1}} = \frac{R_1}{R_1 + R_2}$$