Analog filters

mgr inż. Karol Kropidłowski
mgr inż. Tomasz Woźniak
dr inż. Michał Bujacz

INSTYTUT ELEKTRONIKI

Agenda

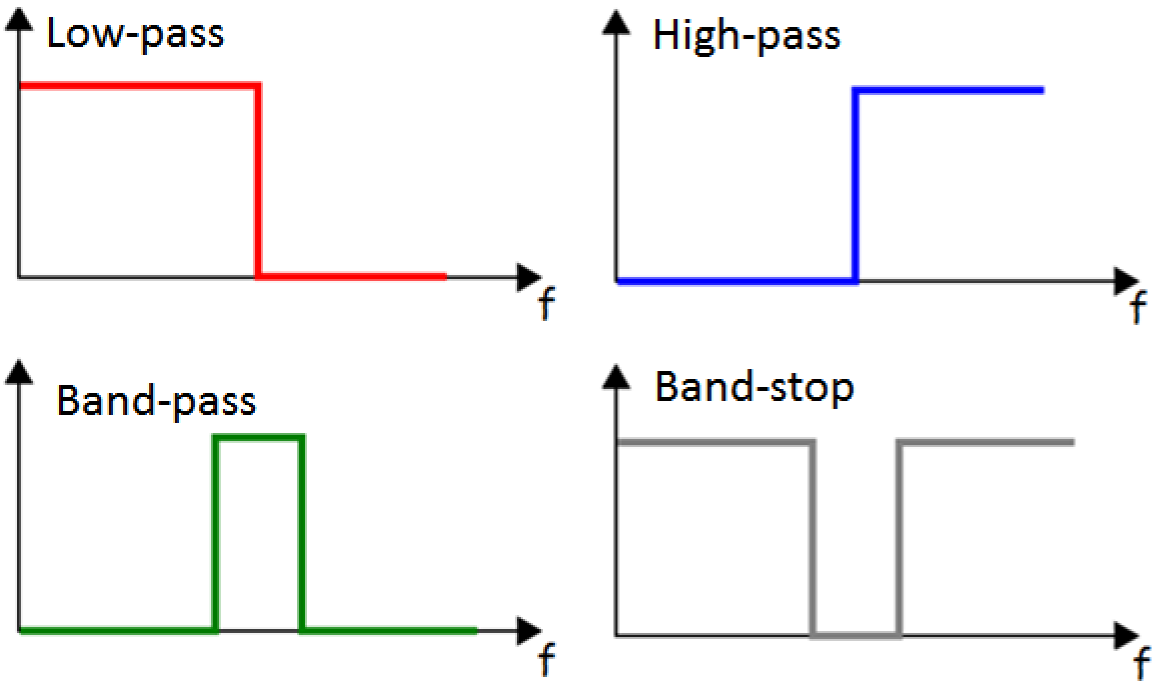
- What do we call a filter?
- Division
- Ideal and real filters
- More divisions
- Active and passive filters
- Combining filters
- Bonus Question

What do we call a filter?

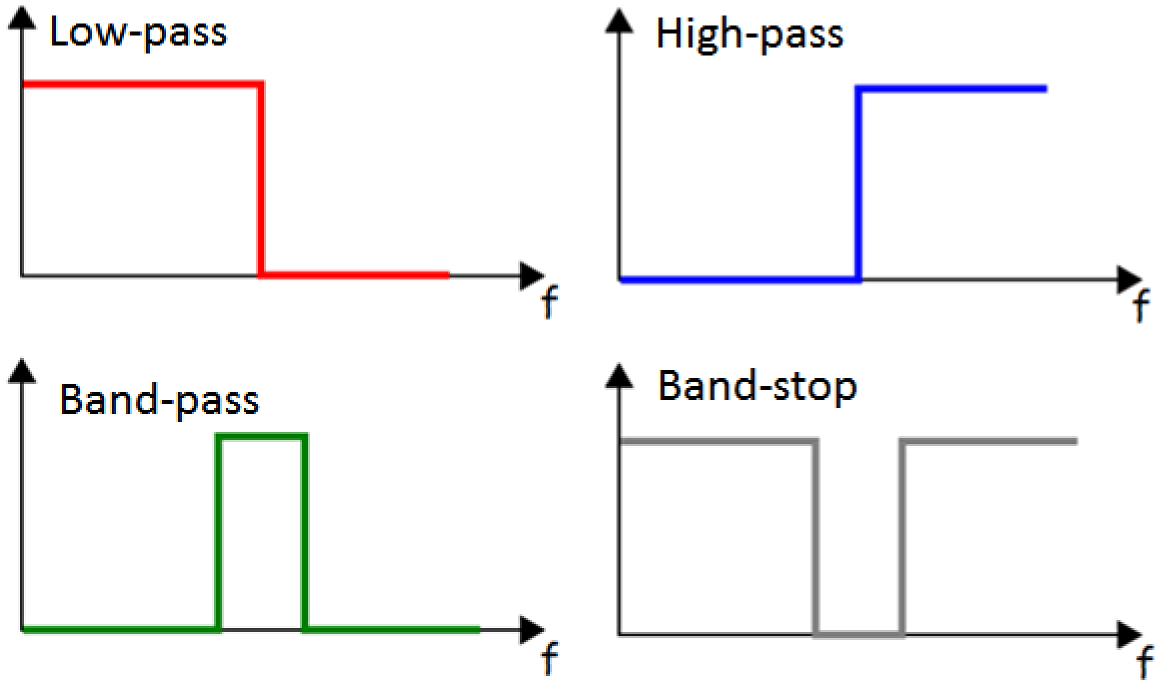
- Electronic filters are analog circuits which perform signal processing functions, specifically remove unwanted frequency components from the signal, enhance wanted ones, or both.

Division of filters

- A filter can be: low-pass, high-pass, band-pass, band-stop

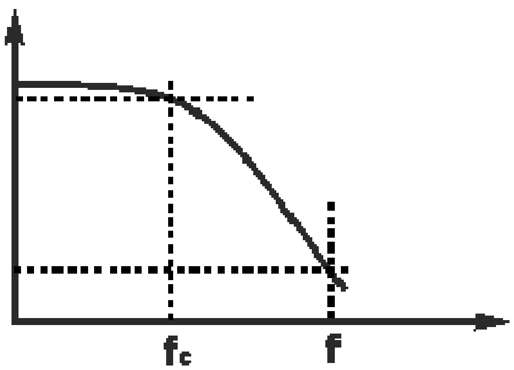


Ideal filters

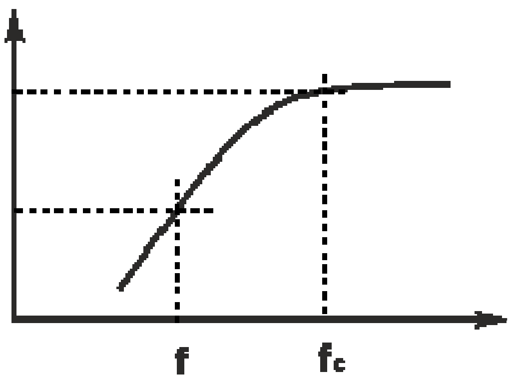


Ideal filters cannot be created.
The reason for this is the real characteristics of the electronic elements.

Filtry rzeczywiste



Low Pass



High Pass

Real filters never cut off signal with a sharp slope.
Every real filter has a gradual decrease in amplitude of the signal.

http://www.radio-electronics.com/info/rf-technology-design/rf-filters/

Cutoff frequency

Decrease of the power by half

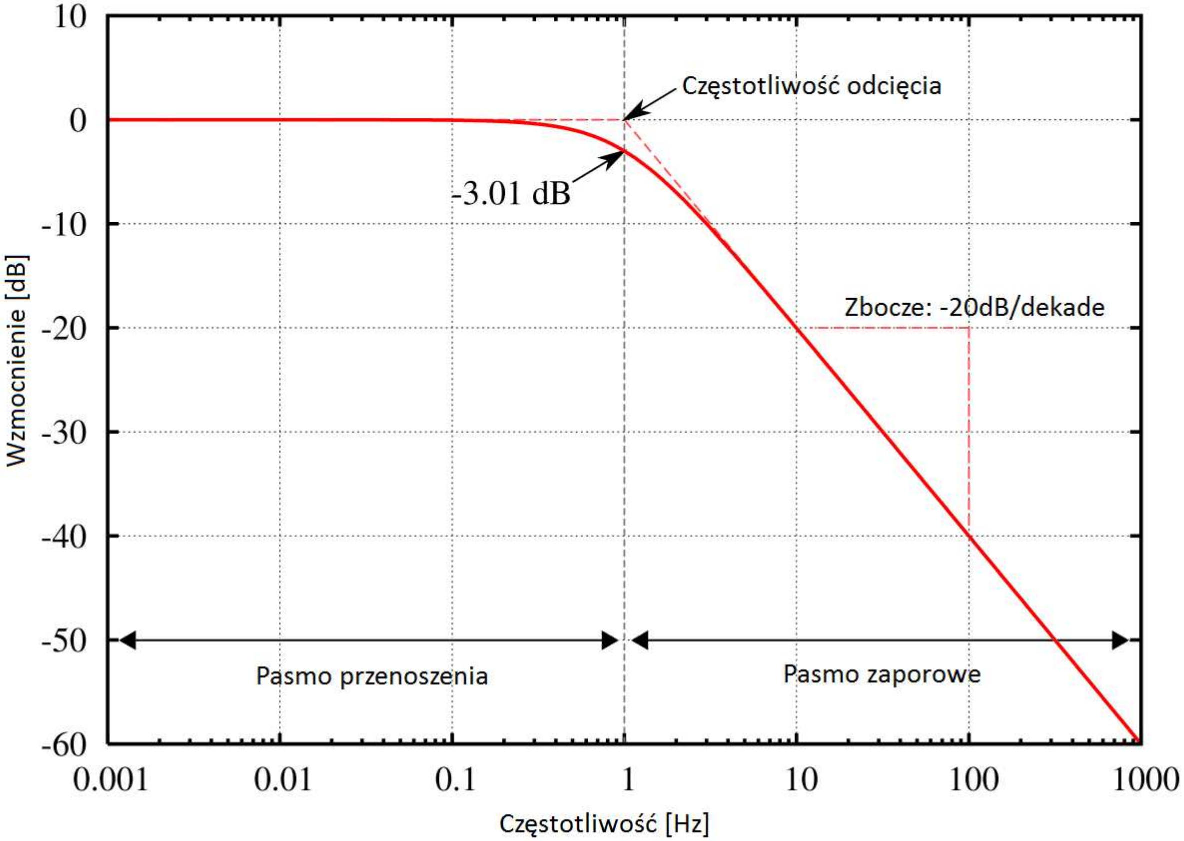
$$10\log_{10}\frac{1}{2} = -3.01dB$$

Decrease of amplitude

$$\frac{1}{\sqrt{2}} \approx 0,707$$

Drop (steepness)

–20 dB/decade

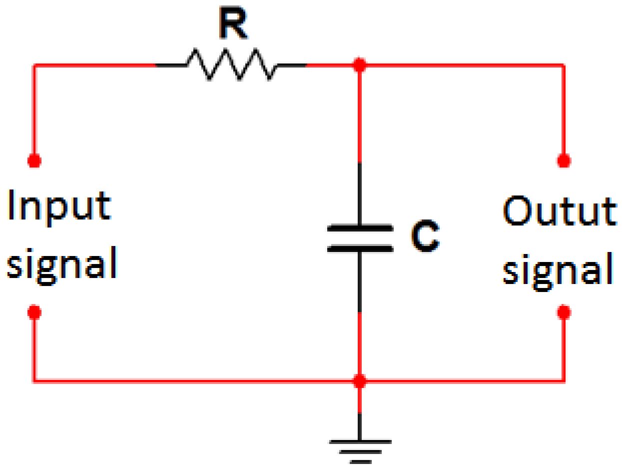


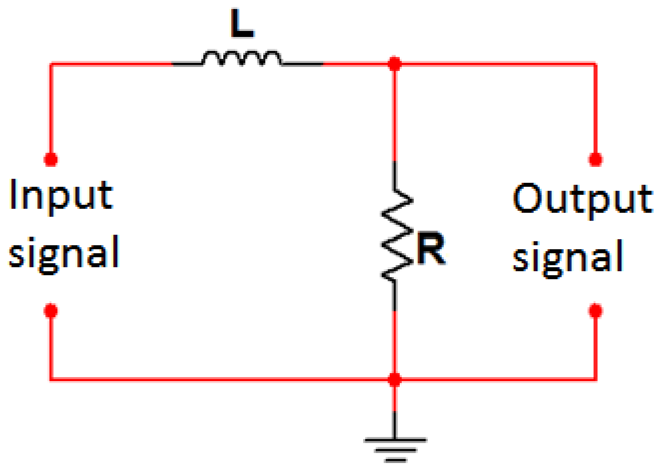
Other filter divisions

- Filter can be also:
  - **passive** – containing only RLC elements
  - **active** – containing elements which supply energy to the circuit. For example: amplifiers

Passive filters

- Basic low-pass filters:





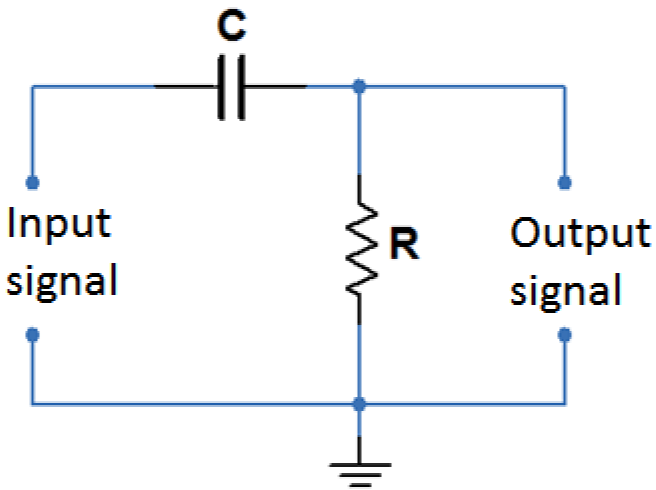
Cutoff frequency:

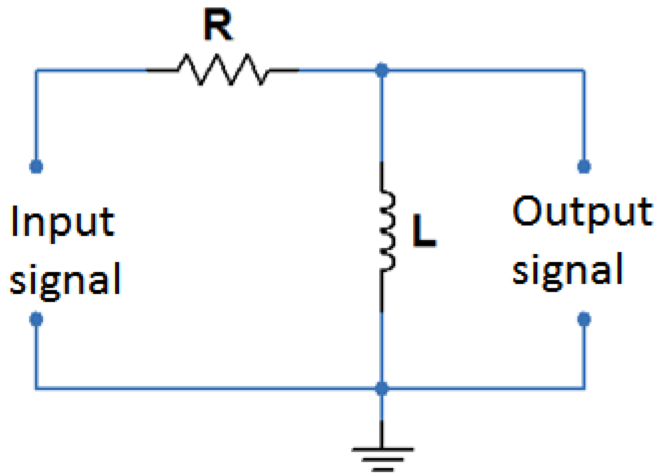
$$f_{odc} = \frac{1}{2\Pi RC}$$

$$f_{odc} = \frac{R}{2\Pi L}$$

Passive filters

- Basic high-pass filters





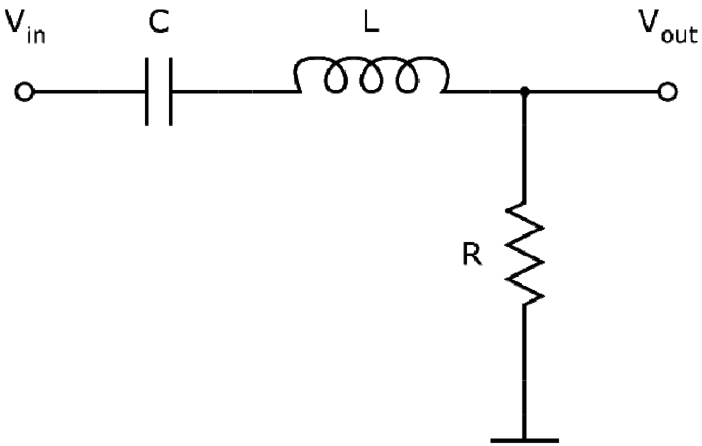
Cutoff frequency:

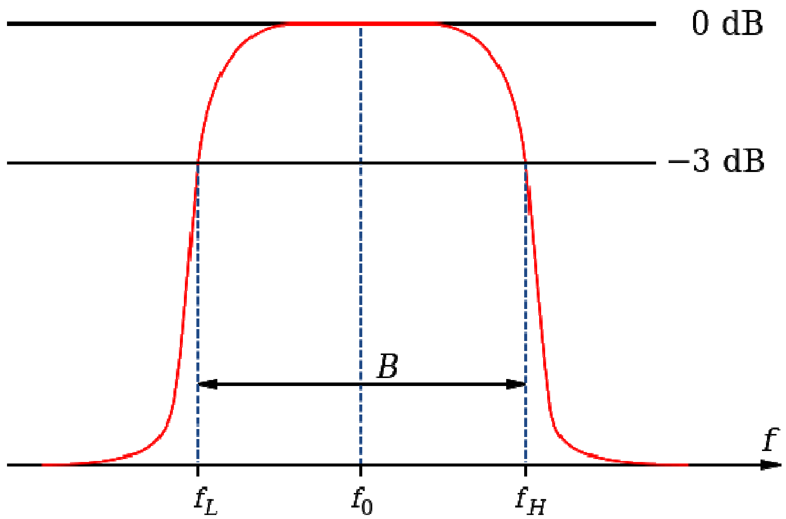
$$f_{odc} = \frac{1}{2\Pi RC}$$

$$f_{odc} = \frac{R}{2\Pi L}$$

Passive filters

- Basic band-pass filter:





Center frequency:

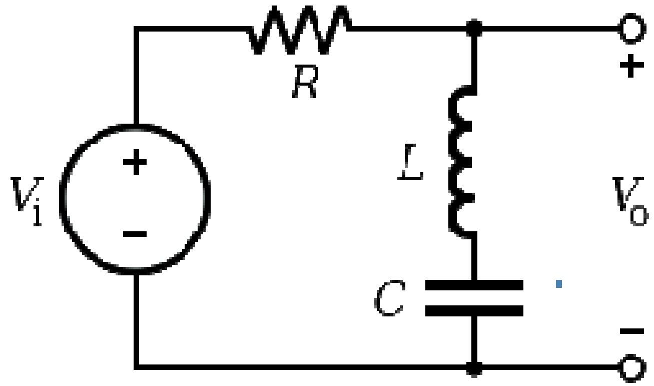
$$f_0 = \frac{1}{2\Pi\sqrt{LC}}$$

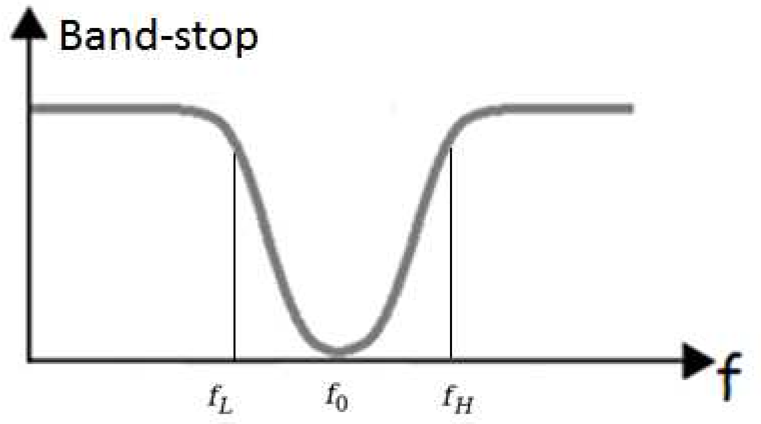
Bandwidth:

$$B = f_H - f_L$$

Passive filters

- Basic band-stop filter:





Center frequency:

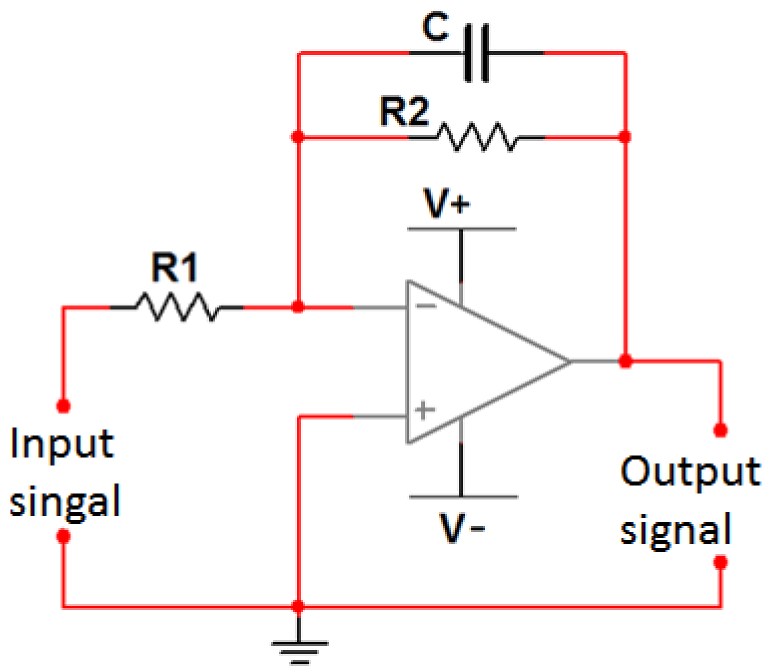
$$f_0 = \frac{1}{2\Pi\sqrt{LC}}$$

Bandwidth:

$$B = f_H - f_L$$

Active filters

- Basic avtive low-pass filter:



Cutoff frequency:

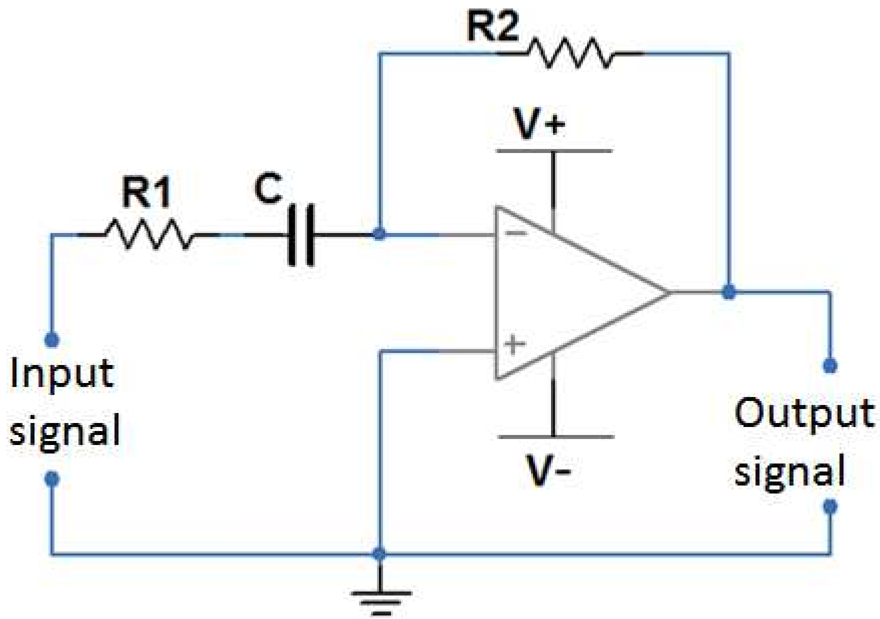
$$f_{odc} = \frac{1}{2\Pi R_2 C}$$

Gain:

$$K_u = -\frac{R_2}{R_1}$$

Active filters

- Basic active high-pass filter:



Cutoff frequency:

$$f_{odc} = \frac{1}{2\Pi R_1 C}$$

Gain:

$$K_u = -\frac{R_2}{R_1}$$

Combining filters

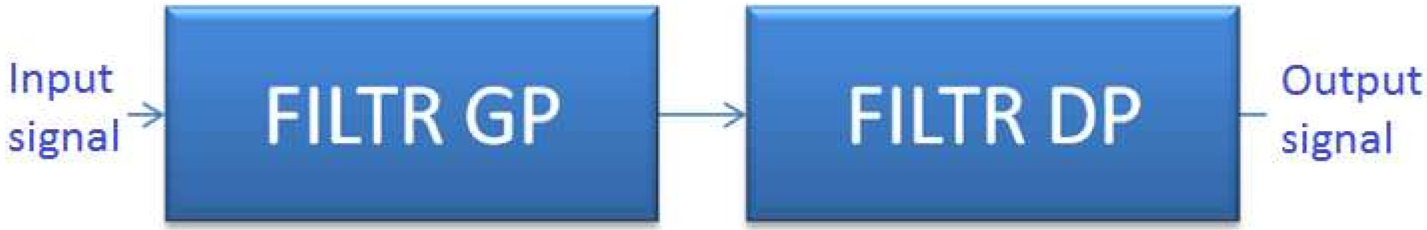
- Combining filters in series or in parallel, we can obtain every other kind of filter
- Through a combination of several filters of the same type, a higher order filter is obtained, which has an improved attenuation of unwanted frequencies; however, it also has a significant attenuation of amplitude in the pass band.

Parallel connection

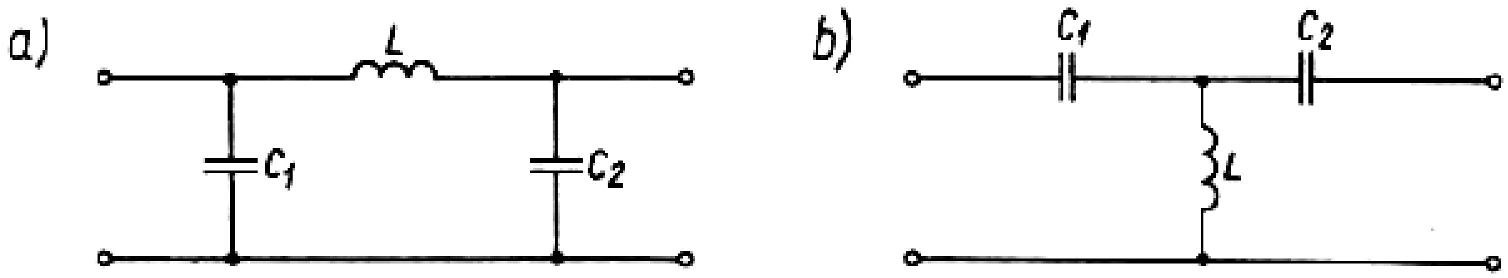
- By connecting two low-pass and high-pass filters we can obtain a band-stop filter

Series connection

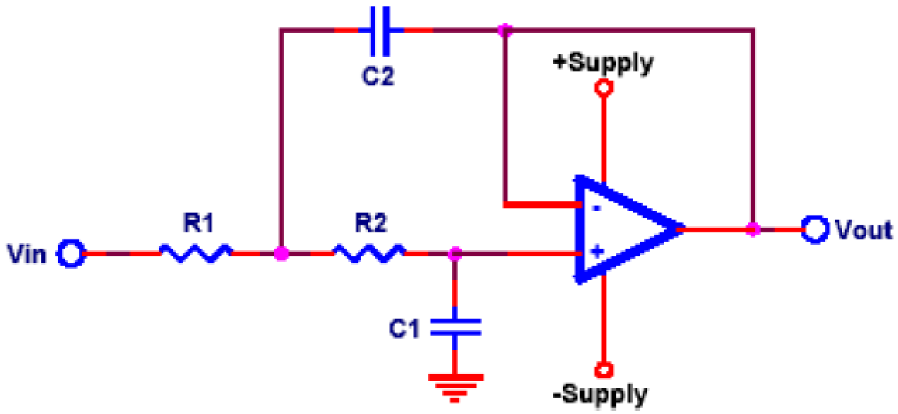
- By connecting low-pass and high-pass filter in series we can obtain a band-pass filter



A riddle



How to choose filter components?

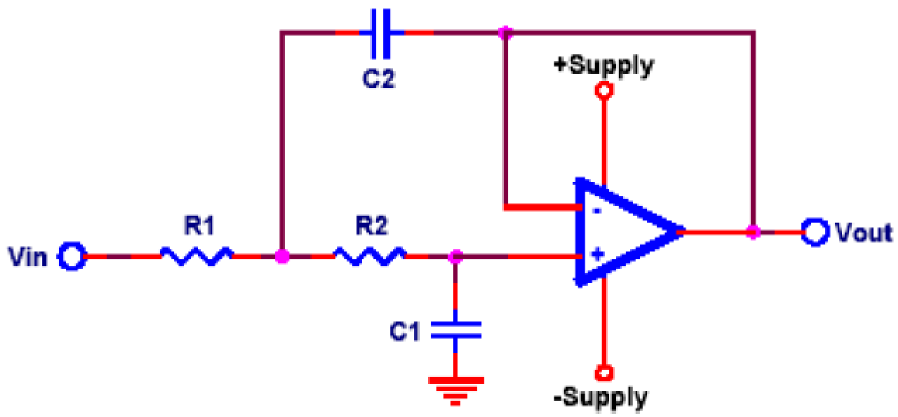


Active LP filter

We start by choosing an available value for C1, then we calculate the resistor values from the desired cutoff frequency.

$$R_1 = R_2 = \frac{1}{2\sqrt{2}\,\pi\, C_1\, f_c}$$

How to choose filter components?



Active LP filter

We can start by assuming R1 = R2, knowing that the cutoff frequencies depend on the capacitances C1 i C2 according to the formulas:

$$f = \frac{1}{2\sqrt{2}\,\pi\, R_1 C_1}$$

$$f = \frac{1}{\sqrt{2}\,\pi\, R_1 C_2}$$

Setting both equations equal gets us C2 = 2C1

Cutoff frequencies:

- For RC filters

$$f_{odc} = \frac{1}{2\Pi RC}$$

- For LR filters

$$f_{odc} = \frac{R}{2\Pi L}$$