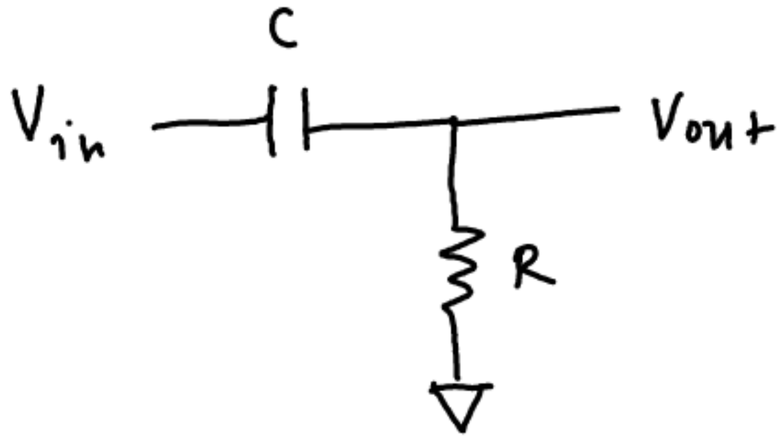
# RC filters

In Lab 4 we measured the Gain profile and phase shift from a high-pass filter




Transfer function

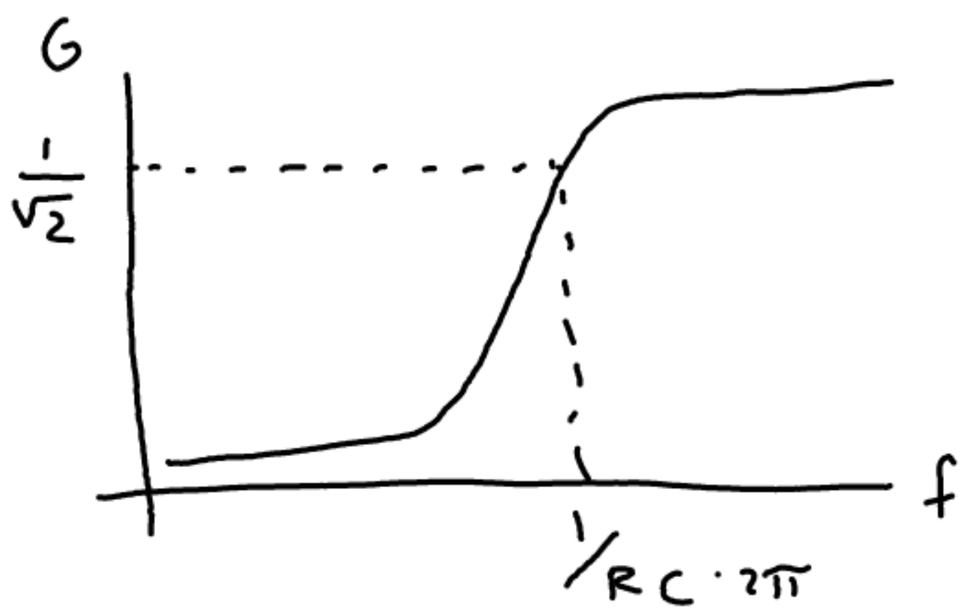
$$\frac{V_{out}}{V_{in}} = \frac{Z_2}{Z_1 + Z_2}$$

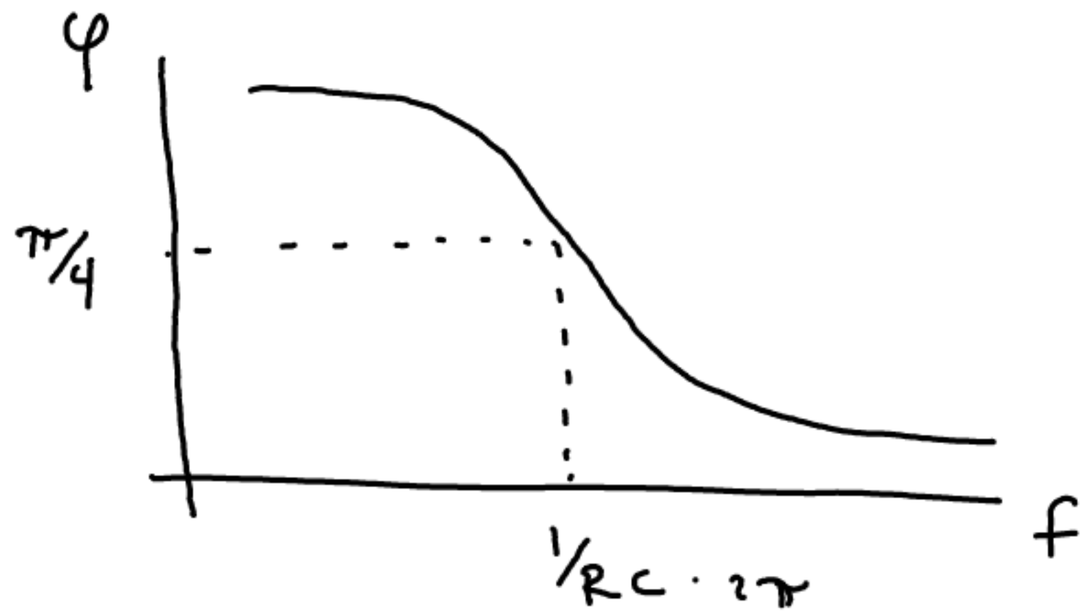
$$= \frac{Z_R}{Z_C + Z_R}$$

$$\frac{V_{out}}{V_{in}} = \frac{R}{-j/\omega C + R}$$

$$G = \left| \frac{V_{out}}{V_{in}} \right|$$

$$\varphi = \tan^{-1}\left( \frac{\mathrm{Im}(V_{out})}{\mathrm{Re}(V_{out})} \right)$$



We can see from the two plots that high frequencies will pass through with no effect (close to unity Gain and zero phase shift) while low frequencies will get heavily attenvated.

↖ reduced in amplitude

There is a special frequency to consider.

The crossover frequency $f_c = \frac{1}{2\pi RC}$

This is where $\varphi = 45°$

$G = \frac{1}{\sqrt{2}}$ ← Gain is amplitude

Power is $G^2$

So this is $\frac{1}{2}$ power

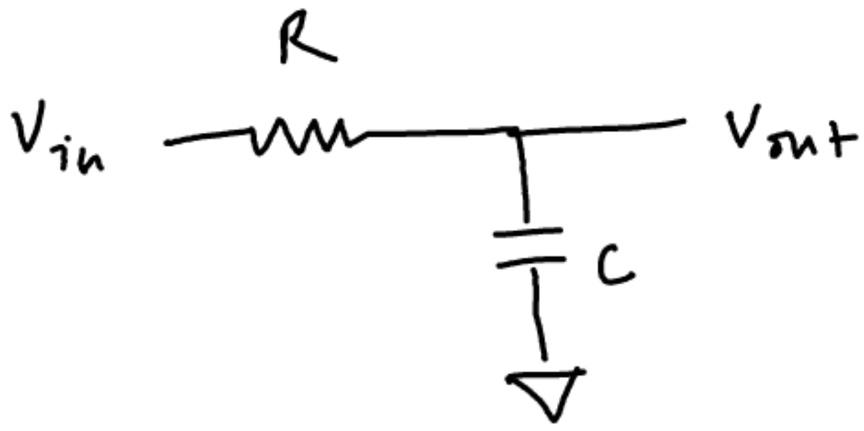
or 3 dB reduction

(see end for dB notes)

When we design a filter, we want our target frequencies (to pass) to be at least 10x higher than $f_c$. ↑

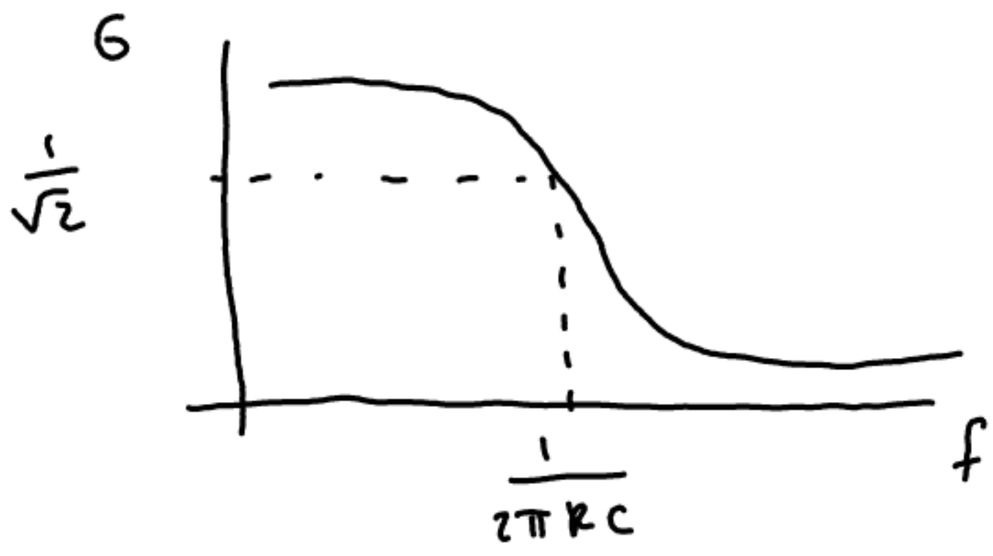
"one decade away"

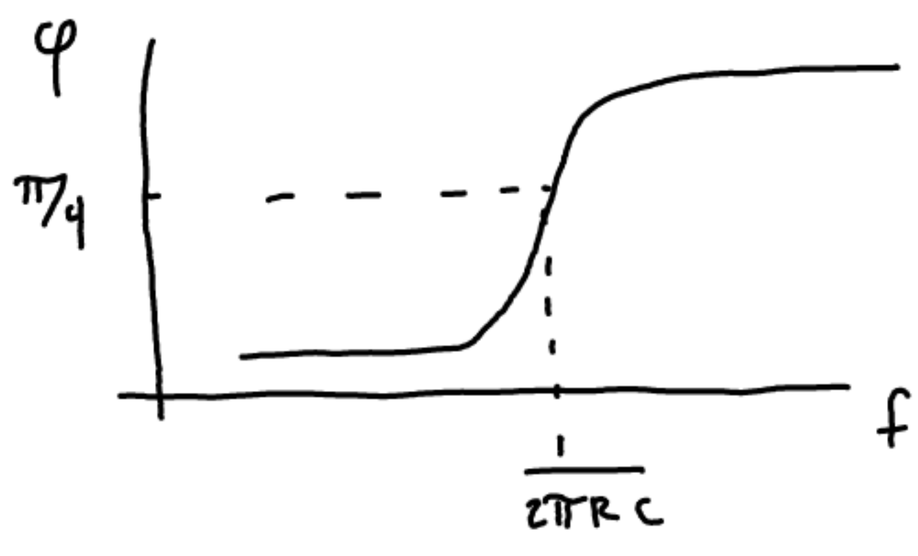
Low pass filter is exactly the opposite of the high-pass




$$\frac{V_{out}}{V_{in}} = \frac{-j/\omega C}{R - j/\omega C}$$

$$G = \left| \frac{-j/\omega C}{R - j/\omega C} \right| \qquad \varphi = \tan^{-1}(RC\omega)$$




passes low frequency, blocks high frequency.

Note that the crossover frequency

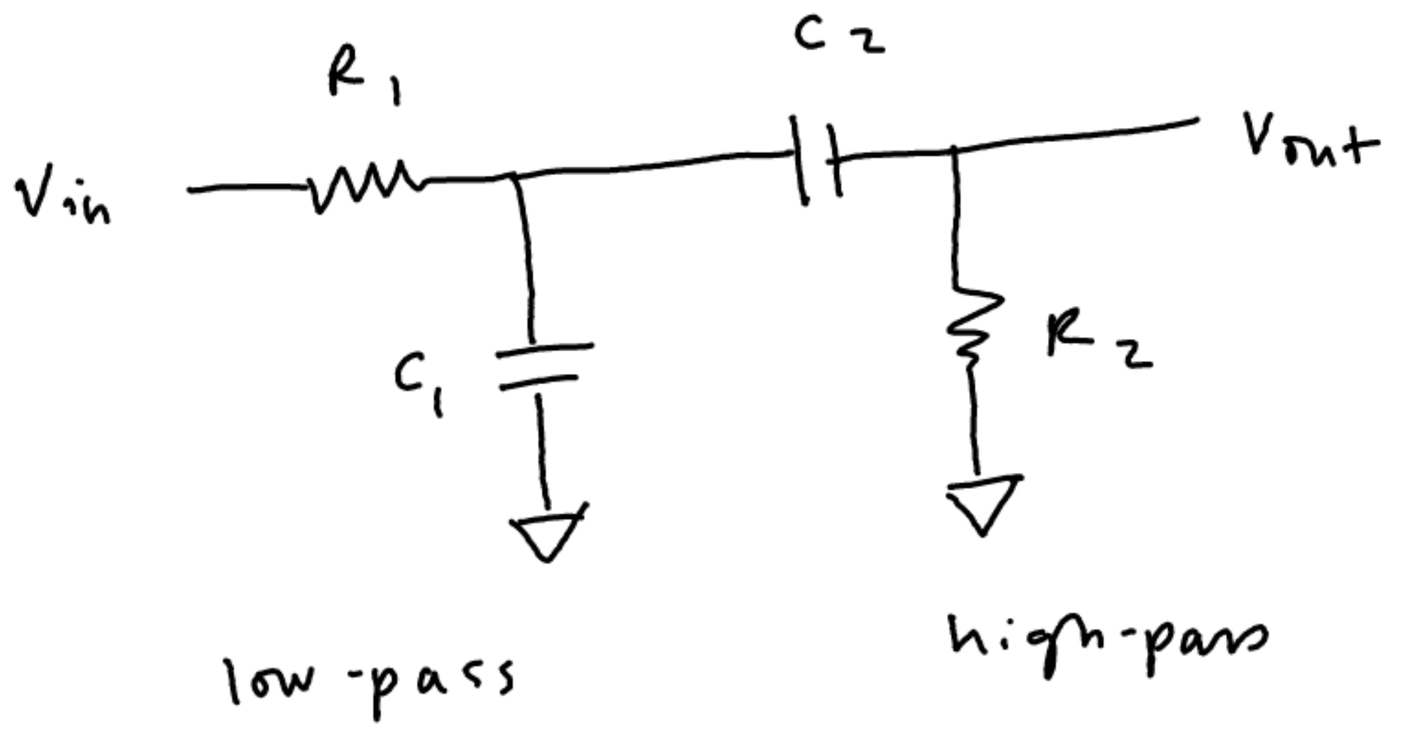
$$f_c = \frac{1}{2\pi RC}$$

has the same form as the high-pass filter.

# Band-pass filter

We might want to pass some range (band) of frequencies and exclude everything higher or lower.

We can "simply" combine the high-pass and low-pass filters:

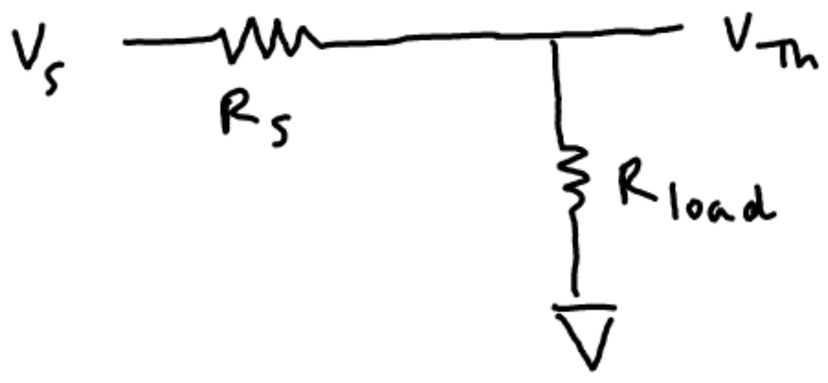



How to choose R, C values:

1. consider source + load impedance for each stage
2. decide on $f_c$ for each stage

1. Impedance matching

Thévenin model says




we typically want a large $V_{Th}$

↓

$R_{load} >> R_s$

we should take at least $\times 10$.

So at every stage,

$R_{load} \geq 10\, R_s$

2. Low pass $f_c$ should be $10\times$ higher than band center

High pass $f_c$ should be $10\times$ smaller than band center