

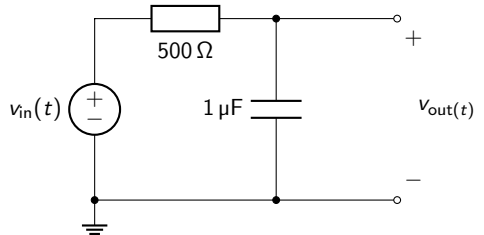
ELE20: Basis Elektrotechniek - Week 7

Hogeschool Rotterdam - Opleiding Elektrotechniek

1. Decibel, decade en octaaf
2. Eerste orde laagdoorlaatfilters
3. Eerste orde hoogdoorlaatfilters
4. Huiswerk

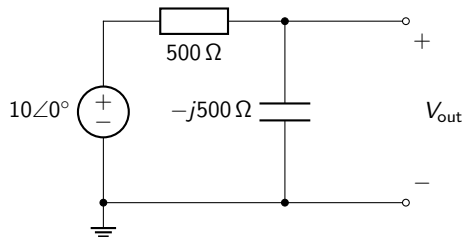
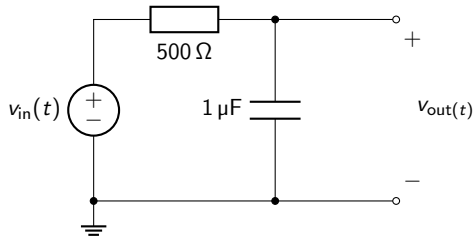
$$V_{in}(t) = 10 \cdot \cos(2000t)$$

Bereken $V_{out}(t)$.



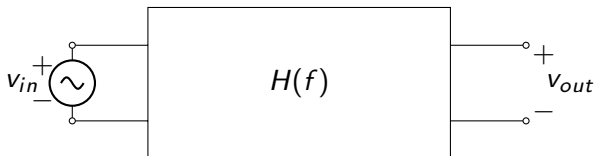
$$\begin{aligned} V_o &= V_{in} \cdot \frac{Z_C}{Z_C + Z_R} \\ &= 10\angle 0^\circ \cdot \frac{-500j}{-500j + 500} = 10 \cdot \frac{-j}{1-j} \\ &= \frac{-10j}{1-j} \cdot \frac{1+j}{1+j} = \frac{-10j + 10}{2} = 5 - 5j \\ &= 7.07\angle -45^\circ \end{aligned}$$

$$v_o(t) = 7.07 \cos(2000t - 45^\circ) \text{ V}$$



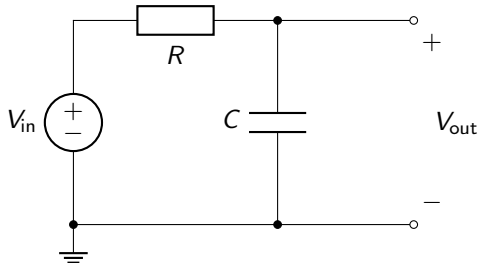
De overdrachtsfunctie $H(f)$ is de verhouding tussen de uitgangsspanning phasor en de ingangsspanning phasor als functie van de frequentie.

- De overdrachtsfunctie is complex.
- $|H(f)|$ is de verhouding tussen de amplitudes.
- $\angle H(f)$ is het verschil tussen de hoeken.



$$H(f) = \frac{V_{out}}{V_{in}}$$

Eerste orde laagdoorlaatfilter



Bepaal een formule voor $H(f)$ als functie van f , R en C .

Eerste orde laagdoorlaatfilter

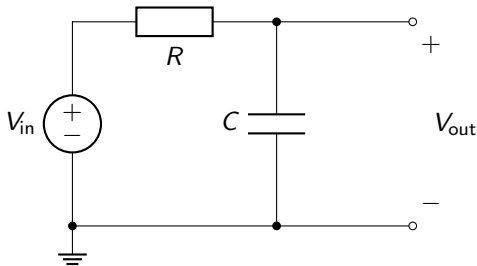
$$Z_C = \frac{1}{j\omega C}$$

$$V_o = V_{in} \cdot \frac{Z_C}{Z_C + R}$$

$$= V_{in} \cdot \frac{\frac{1}{j\omega C}}{\frac{1}{j\omega C} + R}$$

$$= V_{in} \cdot \frac{1}{1 + j\omega RC} = V_{in} \cdot \frac{1}{1 + j2\pi f RC}$$

$$H(f) = \frac{V_o}{V_{in}} = \frac{1}{1 + j2\pi f RC}$$



Decibel, decade en octaaf

$$|H(f)|_{dB} = 20 \cdot \log_{10} (|H(f)|)$$

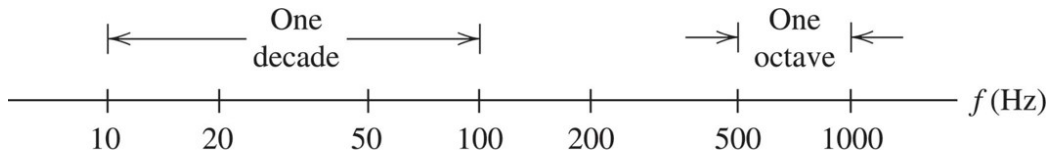
From Hambley, table 6.2:

$ H(f) $	$ H(f) _{dB}$
100	40
10	20
2	6
$\sqrt{2}$	3
1	0
$\frac{1}{\sqrt{2}}$	-3
$\frac{1}{2}$	-6
0.1	-20
0.01	-40

Vul deze tabel verder in:

$ H(f) $	$ H(f) _{dB}$
50	?
?	15
?	30
?	36

Decade en Octaaf



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- Een verdubbeling van de frequentie: octaaf
- Een vertienvoudiging van de frequentie: decade

Bepaal:

- 2 octaven hoger dan 1000 Hz
- 3 octave lager dan 1000 Hz
- 2 decaden hoger dan 1000 Hz
- Welke frequentie ligt halverwege 10 en 100 op een $\log_{10}()$ schaal?

Bode diagram 1^e orde laagdoorlaatfilter

$$H(f) = \frac{1}{1+j \cdot \frac{f}{f_B}}, \quad |H(f)| = \frac{1}{\sqrt{1 + \left(\frac{f}{f_B}\right)^2}}, \quad \angle H(f) = -\arctan\left(\frac{f}{f_B}\right)$$

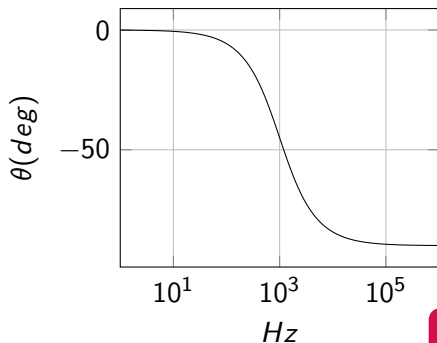
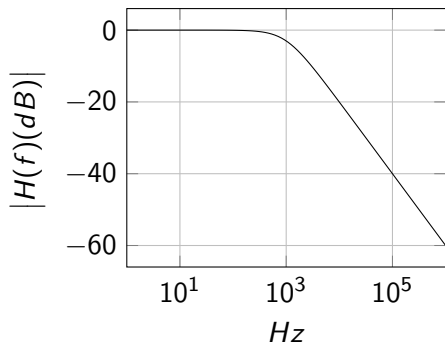
$$A(f) = |H(f)|_{dB} = 20 \cdot \log_{10}(|H(f)|) = 20 \cdot \log_{10}\left(\frac{1}{\sqrt{1 + \left(\frac{f}{f_B}\right)^2}}\right)$$

$$A(f) = -20 \cdot \log_{10}\left(\sqrt{1 + \left(\frac{f}{f_B}\right)^2}\right) = -10 \cdot \log_{10}\left(1 + \left(\frac{f}{f_B}\right)^2\right)$$

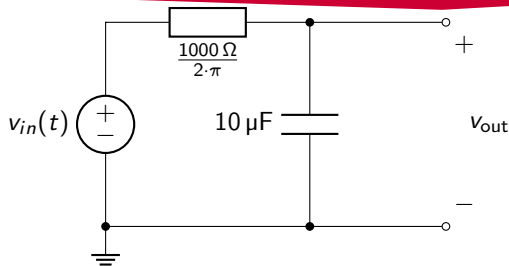
Bode plot

Zo'n Bode-plot heeft 3 frequentiegebieden:

$$A(f) = |H(f)|_{dB} = \begin{cases} -20 \cdot \log_{10} \left(\frac{f}{f_B} \right) & f \gg f_B \\ -10 \cdot \log_{10}(2) = -3 & f = f_B \\ 20 \cdot \log_{10}(1) = 0 & f \ll f_B \end{cases}$$



Eerste orde laagdoorlaatfilter

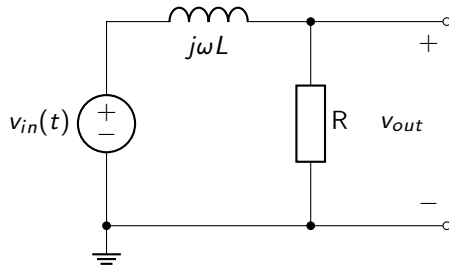


$$V_{in}(t) = 5 \cdot \cos(20\pi t) + 5 \cdot \cos(200\pi t) + 5 \cdot \cos(2000\pi t)$$

Bereken:

- f_B
- De overdracht $H(f = 10 \text{ Hz})$, $H(f = 100 \text{ Hz})$ en $H(f = 1000 \text{ Hz})$
- $V_{out}(t)$
- Een schets van het bode-diagram

Eerste orde laagdoorlaatfilter met spoel



$$H(f) = \frac{V_{out}}{V_{in}} = \frac{R}{R + j\omega L} = \frac{1}{1 + \frac{j\omega L}{R}} = \frac{1}{1 + j \cdot \frac{2\pi f L}{R}} = \frac{1}{1 + j \cdot \frac{f}{f_B}}$$

$$\text{Hierbij is } \frac{1}{f_B} = \frac{2\pi L}{R}, \text{ dus } f_B = \frac{R}{2\pi L}$$

Eerste orde laagdoorlaatfilter met spoel

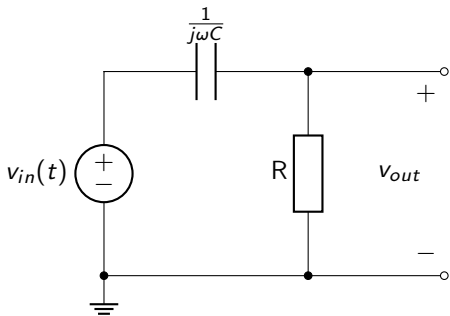
$$H(f) = \frac{1}{1 + j \frac{f}{f_B}}, \quad |H(f)| = \frac{1}{\sqrt{1 + \left(\frac{f}{f_B}\right)^2}}, \quad \angle H(f) = -\arctan\left(\frac{f}{f_B}\right)$$

Bereken $|H(f)|$, $|H(f)|_{dB}$ en $\angle H(f)$ voor:

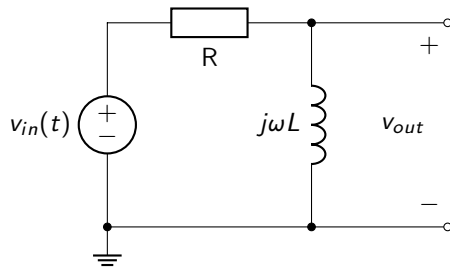
- $f = 0 \text{ Hz}$
- $f = \infty$
- $f = f_B$

Schets ook het Bodediagram van $H(f)_{dB}$.

Eerste orde hoogdoorlaatfilters



(a) RC hoogdoorlaatfilter



(b) RL hoogdoorlaatfilter

RC hoogdoorlaatfilter

Spanningsdeling: $V_{out} = V_{in} \cdot \frac{R}{R+Z_C}$

$$H(f) = \frac{V_{out}}{V_{in}} = \frac{R}{R+Z_C} = \frac{R}{R + \frac{1}{j\omega C}} = \frac{R \cdot j\omega C}{R \cdot j\omega C + 1} = \frac{j2\pi f RC}{1 + j2\pi f RC} = \frac{j \cdot \frac{f}{f_B}}{1 + j \cdot \frac{f}{f_B}}$$

Hierbij is: $f_B = \frac{1}{2\pi RC}$

$$|H(f)| = \frac{\frac{f}{f_B}}{\sqrt{1 + \left(\frac{f}{f_B}\right)^2}} \quad \angle H(f) = 90^\circ - \arctan\left(\frac{f}{f_B}\right)$$

Bode diagram 1^e orde RC hoogdoorlaatfilter

$$H(f) = \frac{j \cdot \frac{f}{f_B}}{1 + j \cdot \frac{f}{f_B}}, \quad |H(f)| = \frac{\frac{f}{f_B}}{\sqrt{1 + \left(\frac{f}{f_B}\right)^2}}, \quad \angle H(f) = 90^\circ - \arctan\left(\frac{f}{f_B}\right)$$

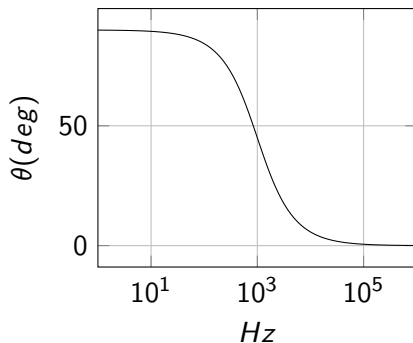
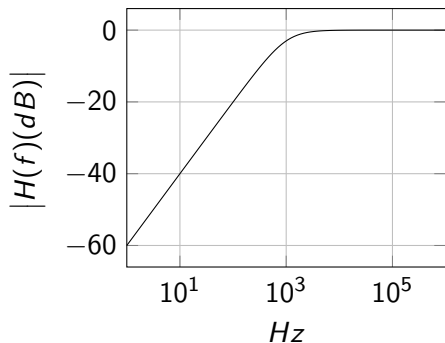
$$A(f) = |H(f)|_{dB} = 20 \cdot \log_{10}(|H(f)|) = 20 \cdot \log_{10}\left(\frac{\frac{f}{f_B}}{\sqrt{1 + \left(\frac{f}{f_B}\right)^2}}\right)$$

$$A(f) = 20 \cdot \log\left(\frac{f}{f_B}\right) - 10 \cdot \log_{10}\left(1 + \left(\frac{f}{f_B}\right)^2\right)$$

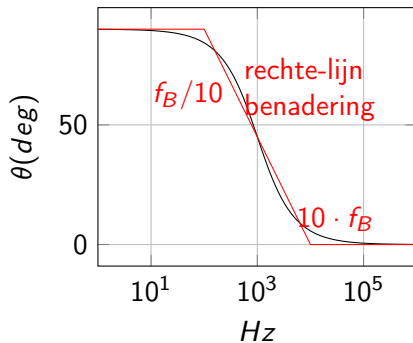
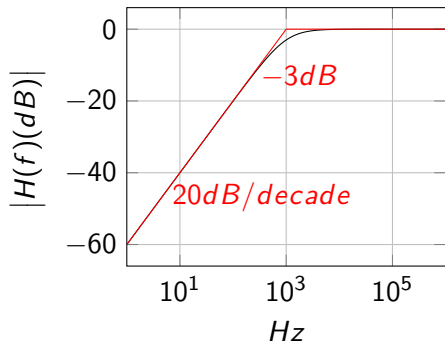
Bode plot 1^e orde RC hoogdoorlaatfilter

Zo'n Bode-plot heeft 3 frequentiegebieden:

$$A(f) = |H(f)|_{dB} = \begin{cases} 20 \cdot \log_{10} \left(\frac{f}{f_B} \right) & f \ll f_B \\ -10 \cdot \log_{10}(2) \approx -3 & f = f_B \\ 20 \cdot \log_{10}(1) = 0 & f \gg f_B \end{cases}$$



Bode plot belangrijke info



Huiswerk

- Hambley H6 opgaven P6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.59, 6.62 ,6.63, 6.65, 6.66, 6.67, 6.68 en 6.69
- Zie ook de cursushandleiding