PHILIPS CTT Hogeschool van Utrecht

Systeem en Regeltechniek

FMT / Mechatronica

Deel 2: Basisbegrippen regeltechniek

Oefening: Werken met Bode plots van mechanische systemen

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Cursus Systeem en Regeltechniek

Overzicht

Deel 1	Blok 1.	Inleiding
Wo. 14-04	Blok 2.	Basisprincipes modelvorming massa-veersystemen
	Blok 3.	De regelaar als veer-demper combinatie
Deel 2	Blok 4.	Frequentie-domein beschrijving
Wo. 21-04	Blok 5.	Basisconcepten in de regeltheorie
Deel 3	**Vervolg regeltechniek**	
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Deel 5	**Toepassing: PID regelaarontwerp**	
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20-sim exercise

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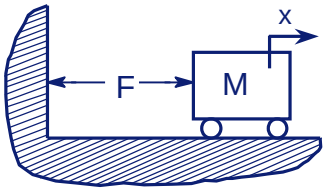
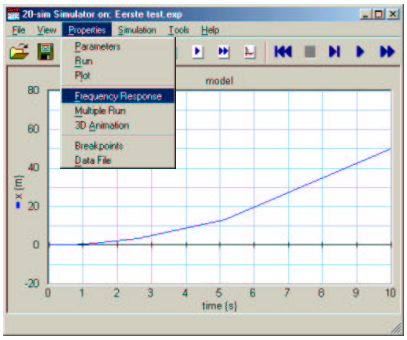
Exercise Bode plot of simple mass

Implement a simple mass in 20-sim:
- M = 10 kg
- F as force (actuator)
- x as position sensor



Generate a Bode plot of this system:
- Check model
- Run simulation (start simulator)
- Define frequency response…
- Generate Bode plot via CTRL-F



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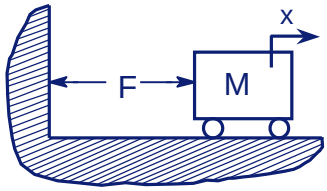
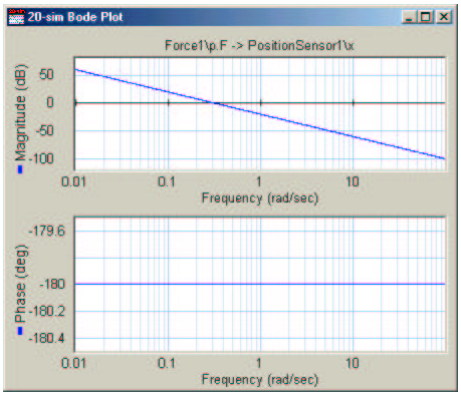
Exercise Bode plot of simple mass

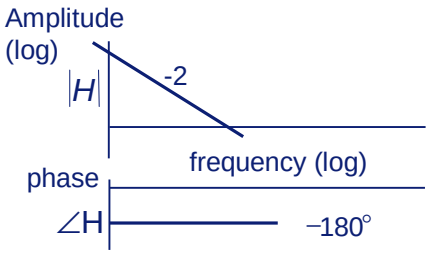
Recall FRF:

$$H = \frac{x}{F} = -\frac{1}{M\omega^2}$$

$$\frac{\hat{x}}{\hat{F}} = |H| = \frac{1}{M\omega^2}$$
$$\varphi = \angle H = -180\,^\circ$$







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Exercise Bode plot of simple mass
Assignments / Questions

- Check at which frequency the amplitude is 0 dB
- Increase the mass M ten times: M = 100 kg
  - Does the amplitude plot shift upwards or downwards?
  - What is the expected 0 dB crossing frequency?
  - How many dB is the amplitude response shifted?
  - Does the phase plot change? Why not?
- Which M should be chosen to get an amplitude of -20 dB @ 10 rad/s?

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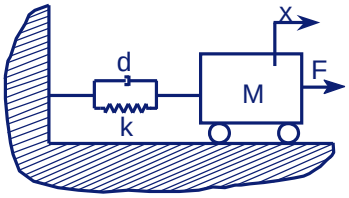
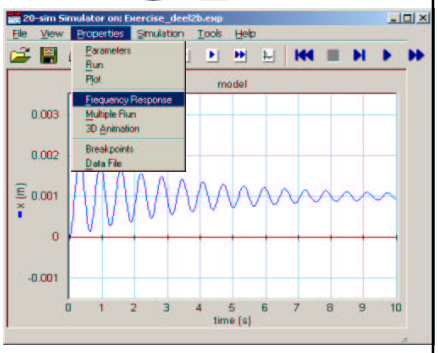
Exercise Bode plot of mass-spring system

Add a spring and damper to the model:
- M = 10 kg
- k = 1 kN/m
- d = 5 Ns/m



Generate a Bode plot of this system:
- Check model
- Run simulation (start simulator)
- Define frequency response…
- Generate Bode plot via CTRL-F



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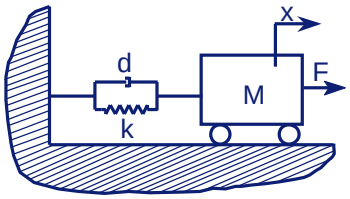
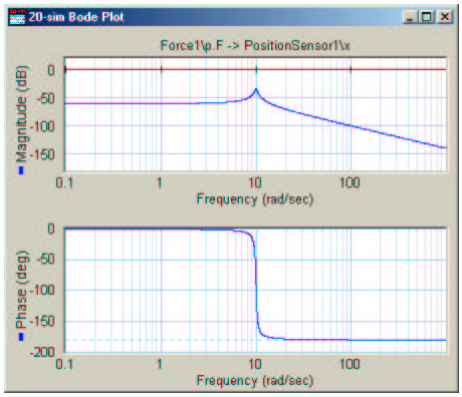
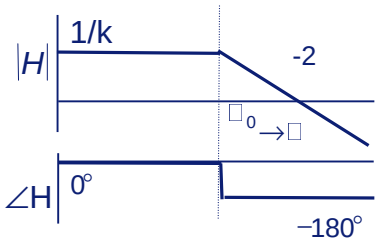
Exercise Bode plot of mass-spring system

Recall FRF:

$$H(j\omega) = \frac{1}{-M\omega^2 + jd\omega + k}$$







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Exercise Bode plot of simple mass Assignments / Questions

- Check the low-frequency asymptote:
  - What is the gain at low frequencies in dB ?
  - To which stiffness does this correspond?
- Check the resonance frequency
- Increase the mass M ten times: M = 100 kg
  - What is the expected resonance frequency?
  - How many dB is the amplitude response shifted?
  - Does the phase plot change? How?

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Exercise Bode plot of simple mass
Assignments / Questions

- Take M = 10 kg, and decrease k: k = 100 N/m
  - Compare Bode plots: increasing M <=> decreasing k
- Take original parameters; M=10; k=1000; d=5
  - What is the relative damping coefficient?
  - What is the peak value in the amplitude plot in dB?
  - What is the peak value in the amplitude plot in m/N?
  - What is the ratio between the peak and the static gain?
  - If this is called Q, check that Q = 1 / (2β)

$$H(s) = \frac{1/M}{s^2 + 2\beta\omega_0 s + \omega_0^2}$$

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Exercise Bode plot of simple mass
Assignments / Questions

- Increase d with a factor 10: d = 50 Ns/m
  - What is the relative damping coefficient?
  - Check again that Q = 1 / (2β)
- Increase d with once more: d = 500 Ns/m
  - What happens?

$$H(s) = \frac{1/M}{s^2 + 2\beta\omega_0 s + \omega_0^2}$$

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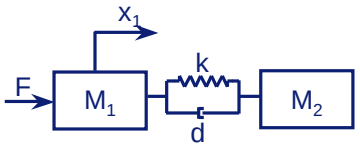
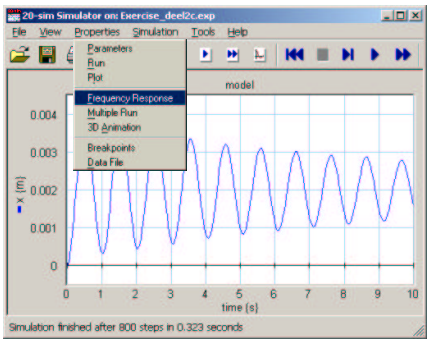
Exercise other Bode plots

Build the two-mass-spring model:
- M_1 = 10 kg; M_2 = 10 kg
- k = 1 kN/m
- d = 5 Ns/m

(Simply use copy-paste)



Generate a Bode plot of this system:
- Check model
- Run simulation (start simulator)
- Define frequency response…
- Generate Bode plot via CTRL-F



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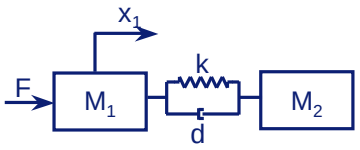
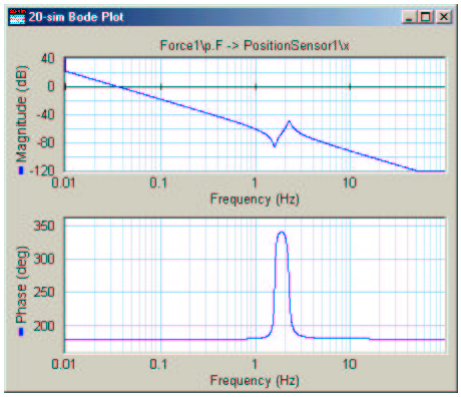
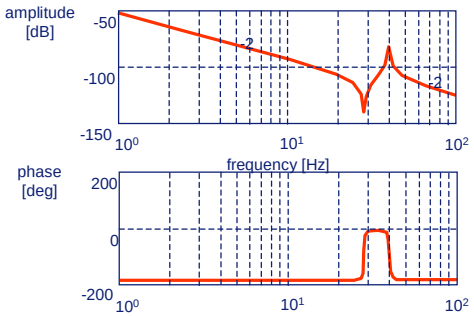
Exercise other Bode plots

Recall FRF:

$$H(s) = \frac{\omega_o^2/\omega_n^2}{Ms^2} \frac{s^2+2\beta\omega_n s+\omega_n^2}{s^2+2\beta\omega_o s+\omega_o^2}$$







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Exercise other Bode plots
Assignments / Questions

- Change the parameters of the model and check the results:
  - Masses M_1 and M_2
  - Stiffness k
  - Damping d
- Check that anti-resonance frequency is determined by M_2 and k!
- Generate also Bodeplot for $x_{2...}$

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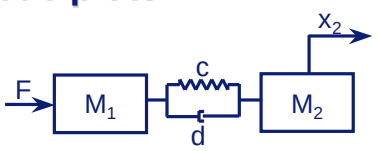
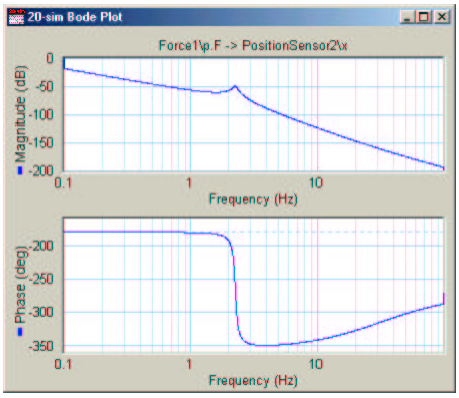
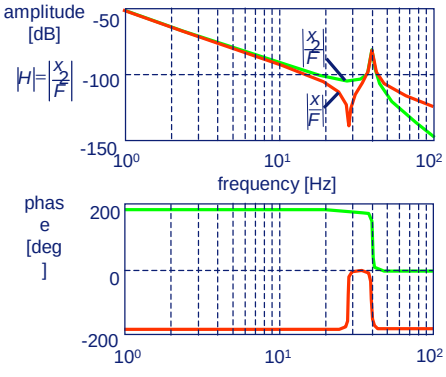
Exercise other Bode plots

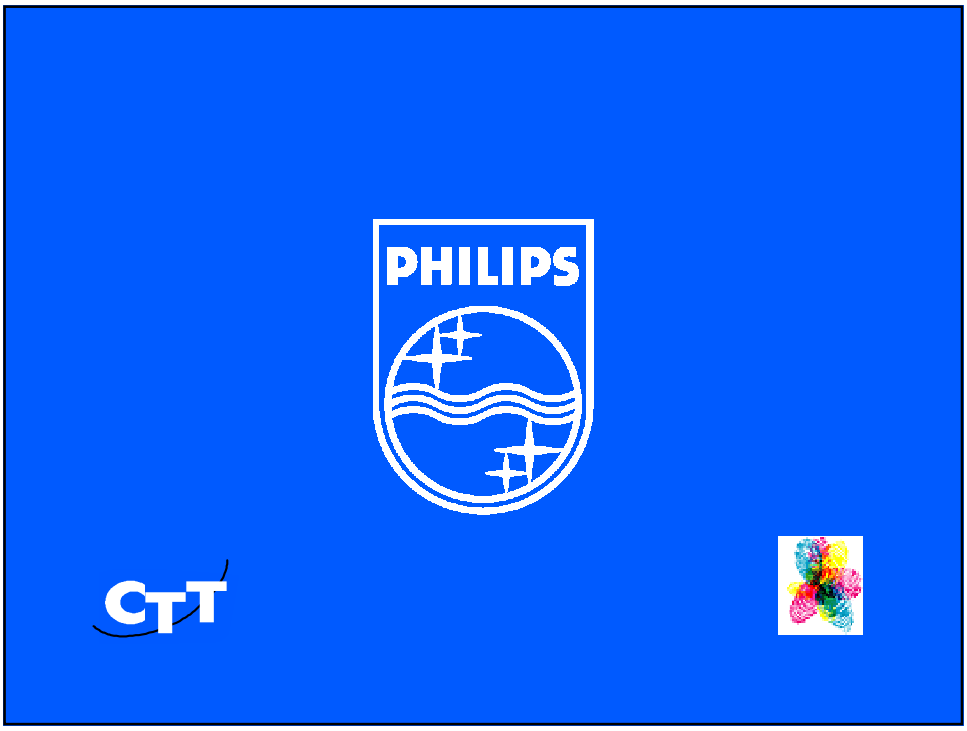
Recall FRF:

$$H(s) = \frac{1}{Ms^2} \frac{\omega_0^2}{s^2 + 2\beta\omega_0 s + \omega_0^2}$$





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