PHILIPS CTT Hogeschool van Utrecht

Systeem en Regeltechniek
FMT / Mechatronica

Deel 4: Stabiliteit van regelsystemen
Oefening: Polen / Nulpunten / Nyquist / Stabiliteit / Filters

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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	Blok 6.	Verdere inleiding in de regeltheorie
Wo. 28-04	Blok 7.	De PD regelaar als veer-demper combinatie
Deel 4	Blok 8.	Stabiliteit van regelsystemen
Wo. 12-05	Blok 9.	De PID regelaar in het frequentie domein
Deel 5 *Wo. 19-05*	**Toepassing: PID regelaarontwerp**	
Deel 6 *Wo. 26-05*	**Extra regeltechniek**	

20-sim exercise

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Exercises

- Poles / Zeros
- Nyquist plot
- Stability (margins)
- Filter design (Lead-Lag & Notch)
- Loop shaping

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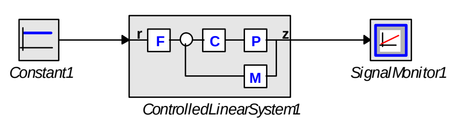
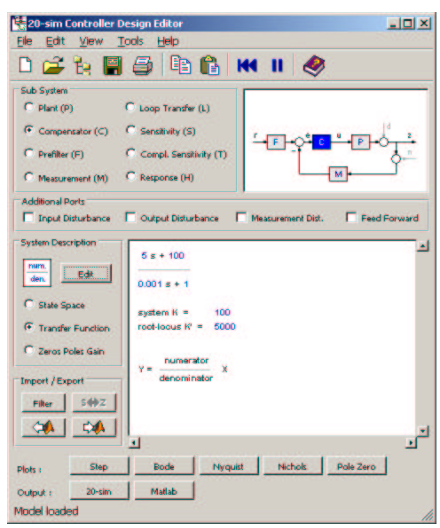
Exercise Poles / Zeros

Take the system of last week:

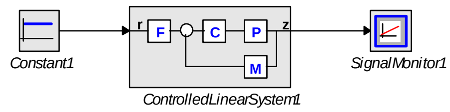




- Check the poles / zeros of:
  - Plant
  - Controller
  - Loop Transfer
  - (Compl.) Sensitivity
- Additional questions…

Exercise Poles / Zeros

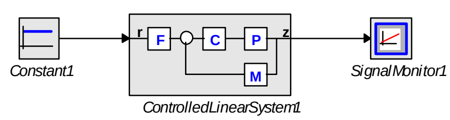
Additional questions:



- What is the relation between the poles / zeros of plant, controller and loop transfer?
- What is the relation between the poles / zeros and the Bode plot?
- Is the open loop stable? And the closed loop?
- What happens with the poles when you increase the gain of the controller?
- Investigate the root locus of the open loop (via Pole Zero)

Exercise Nyquist plot

Take the same system:



- Sketch the Nyquist plots of (on paper):
  - Plant
  - Controller
  - Loop Transfer
  - (Compl.) Sensitivity
- Check with 20-sim…
- Is the closed loop stable? Why?
- What happens with the Nyquist plot for increasing gain?

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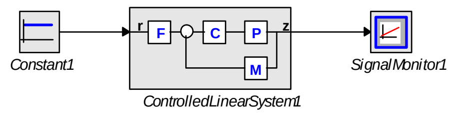
Exercise stability margins

Take the same system:



- What are the stability margins for $K_p = 100$ and $K_v = 5$?
- Is the system well-tuned? How can it be improved?
- Increase K_p and K_v with a factor 100 and check margins…
- Compare the effect both in Nyquist and Bode!
- Compare also closed loop responses (step, Bode)
- Explain what you see...

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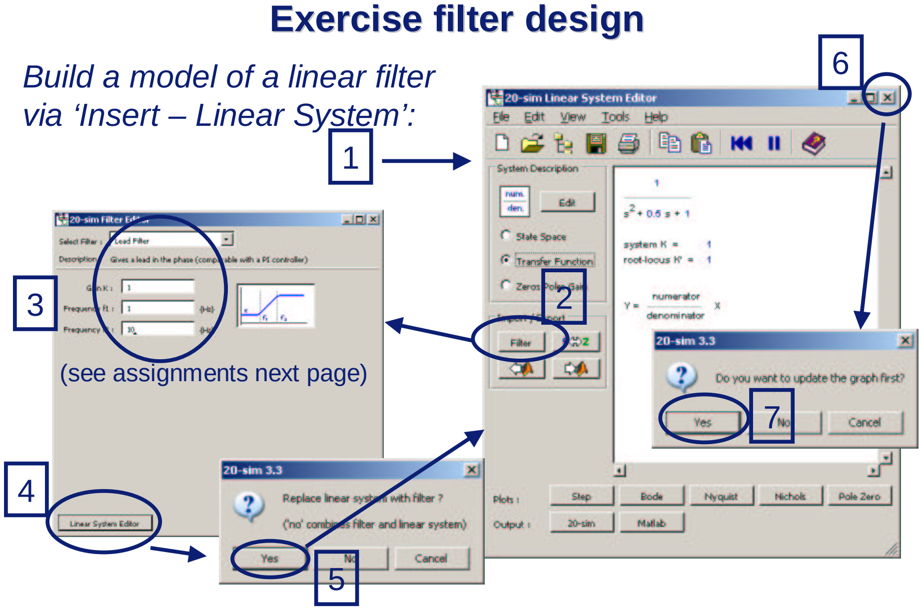
Exercise filter design

Build a model of a linear filter via 'Insert – Linear System':



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Exercise filter design

Assignment 1:
Design a lead lag filter with a maximum phase lead of 35° at 80 Hz, and a gain of 100 dB at 80 Hz.

Assignment 2:
Design a notch filter with a notch at 150 Hz with a ‘depth’ of 20 dB, while at the same time keeping the phase lag at 100 Hz at a minimum of 5°.

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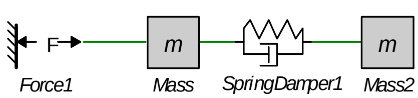
Exercise Loopshaping

Build the following double mass-spring system:



M_1 = 10 kg

M_2 = 8 kg

K = 10^6 N/m

d = 100 Ns/m

Make a linear system description of it via ‘Model Linearization’,with F as input and x_2 as output

Copy the system properties (Transfer Function) into the plant-model of a ‘Controlled Linear System’

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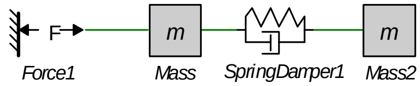
Exercise Loopshaping



Assignment:

Tune this 4th order system with load feedback, using the available filters (leadlag, 2nd order low-pass, notch, …). Maximize the bandwidth, while taking the "standard" gain and phase margin into account.

Target: BW = 10 Hz, PM = 30°, GM = -6dB

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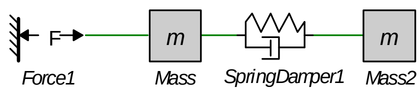
Exercise Disturbance Rejection



- Take the same mechanical system as before
- Start with the stabilising controller with bandwidth approximately 10 Hz; use lead-lag filter only
- Apply a sine (cosine) wave disturbance at plant input of amplitude 1 and with frequency 1 Hz; set setpoint to none
- Determine response of the system (20 mu)
- Improve the controller to achieve the specification: error less than 2 mu within 1 sec

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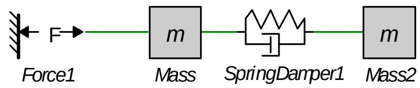
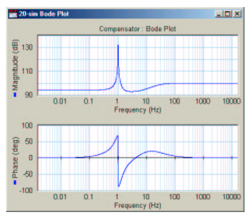
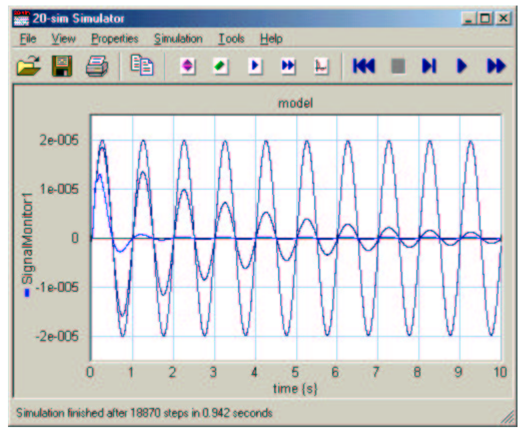
Exercise Disturbance Rejection



Hint: use so-called ‘inverse notch filter’ (implement via ‘universal notch filter’)





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