Technik

Informatik & Medien

Hochschule Ulm

University of

Applied Sciences

Computerlab 4: LTI-Viewer
Prof. Dr. A. Beckmann

1 How to use the LTI Viewer

The LTI Viewer is a GUI for analysing the response of a LTI-system. The following plots can be shown:

- Initial response (only for state space models)
- Step response
- Impulse response
- Frequency response (Bode plot, Nichols plot, Nyquist plot)
- Pole/zero plots

1.1 Define a System

The LTI-Viewer needs the transfer function of the system to be analysed. We want to use the LTI-Viewer for the analysis of the normalized car suspension system. To define the transfer function of the car suspension system, we modify the program CSS_normalized.m from Computerlab3. We save the program file using the name CSS_normalized_Viewer and delete the highlighted lines:

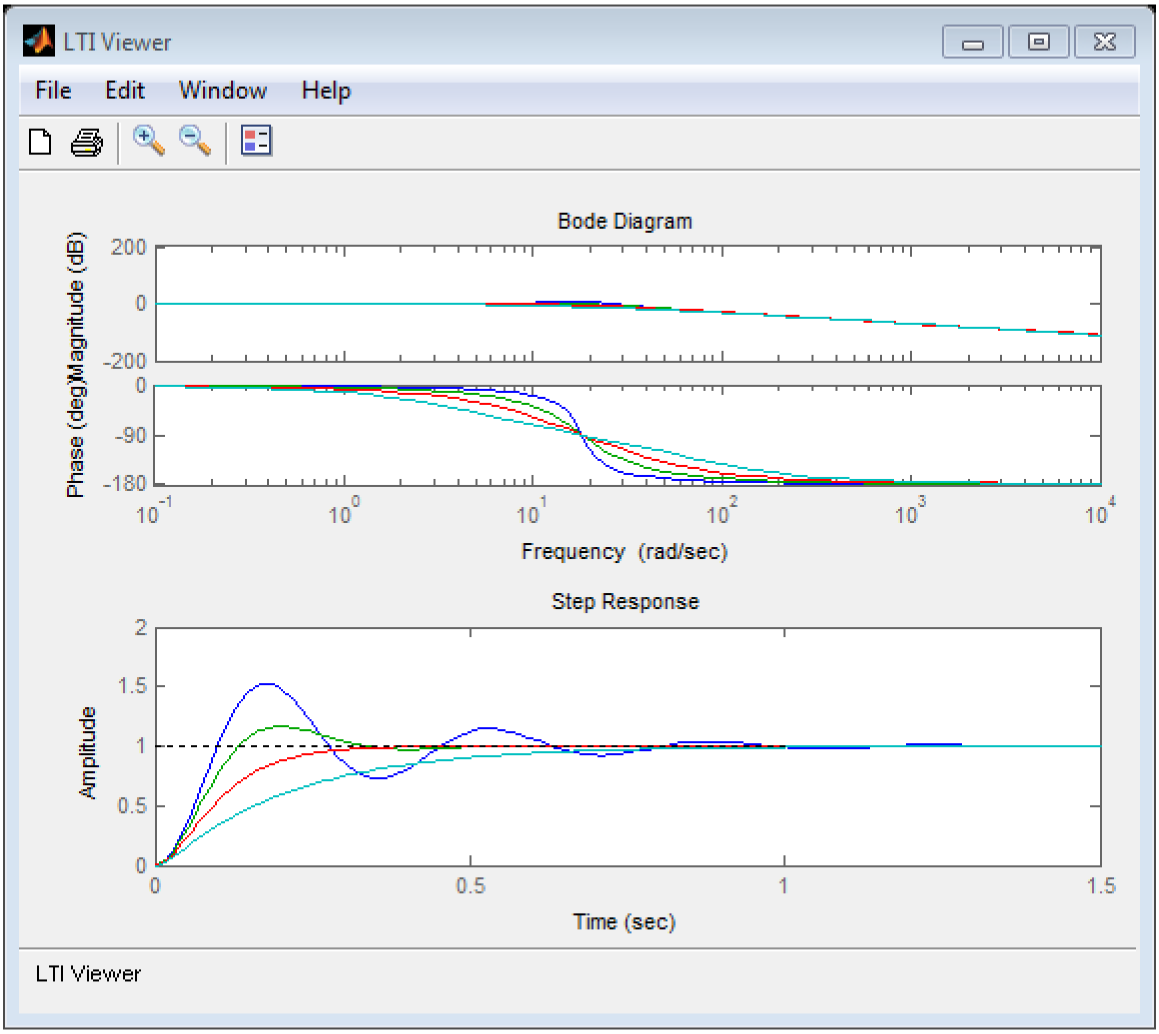
```
% normalized car suspension system
clear               % delete all variables
close all           % close all figure windows

% Parameters of the suspension system
CSS_parameters

% Parameters for diagrams
Dia_parameters

% system parameters of the normalized system
% coefficients of numerator of transfer function
num = [0 0 1;...
       0 0 1;...
       0 0 1;...
       0 0 1];
% coefficients of denominator of transfer function as a matrix
den = [1/w_0^2  2*delta(1)/w_0^2  1;...
       1/w_0^2  2*delta(2)/w_0^2  1;...
       1/w_0^2  2*delta(3)/w_0^2  1;...
       1/w_0^2  2*delta(4)/w_0^2  1];

% define system by its transfer function
G1 = tf(num(1,:),den(1,:));
G2 = tf(num(2,:),den(2,:));
G3 = tf(num(3,:),den(3,:));
G4 = tf(num(4,:),den(4,:));

lti_analysis_4   % call program lti_analysis_4.m
```

Then we add the following lines at the end of the new program:

```
% open the LTI-Viewer showing Bode plots and Step response
ltiview({'bode','step'},G1,G2,G3,G4)
```

This command will open the LTI-Viewer and display the bode plots and the step response of the 4 systems defined by the transfer functions G1, G2, G3 and G4.

As the program uses the parameterfile CSS_parameters.m, make sure that both file are in your folder before you start the simulation by typing **CSS_normalized_Viewer** in the MatLab command window. After running the program, the LTI-Viewer will show the bode plots and the step response of the car suspension system for 4 different values of damping as you can see in the following figure:



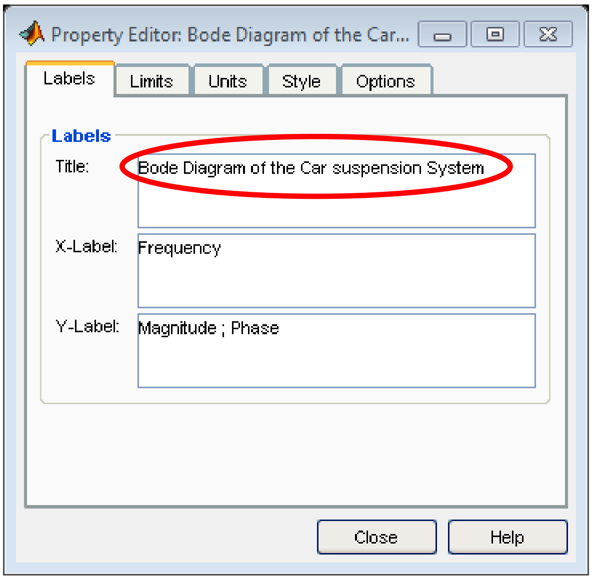
1.2 Change settings of the diagrams

The settings of the diagrams can be changed by right-clicking on the diagram that you want to change. You can access the following LTI Viewer controls and options:

- **Plot Type** — Here the type of plot can be changed: Step, Impulse, Bode, . . .
- **Systems** — Selects or deselects any of the models loaded in the LTI Viewer.
- **Characteristics** — Shows values of characteristic parameters of the displayed response like peak response, settling time, rise time and steady state.
- **Grid** — Adds grids to the selected plot.
- **Full View** — if selected automatic limits are used to make the entire curve visible.
- **Properties . . .** — Opens the Property Editor, where you can customize plot attributes.

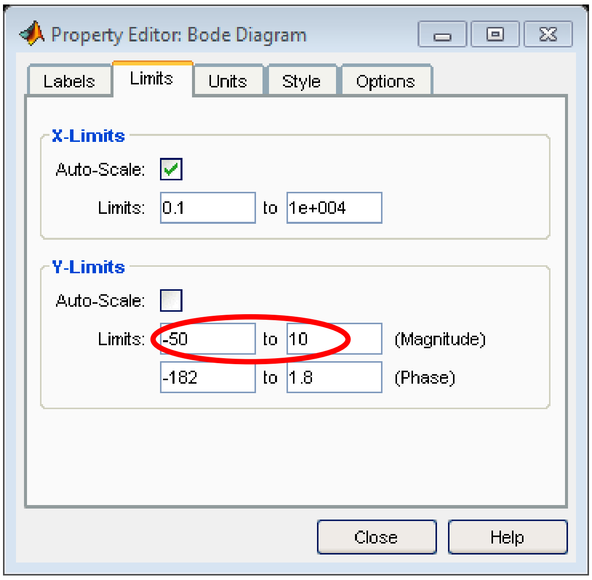
1.2.1 Change Title and Labels

We want to use a new title for the bode plot. We use a right mouse click on the displayed bode plot to open a window where we select **Properties…** . A new window will be opened: the Property Editor with all settings for the diagram. Here select **Labels** and write a new title: e.g. “Bode Diagram of the Car suspension system”.



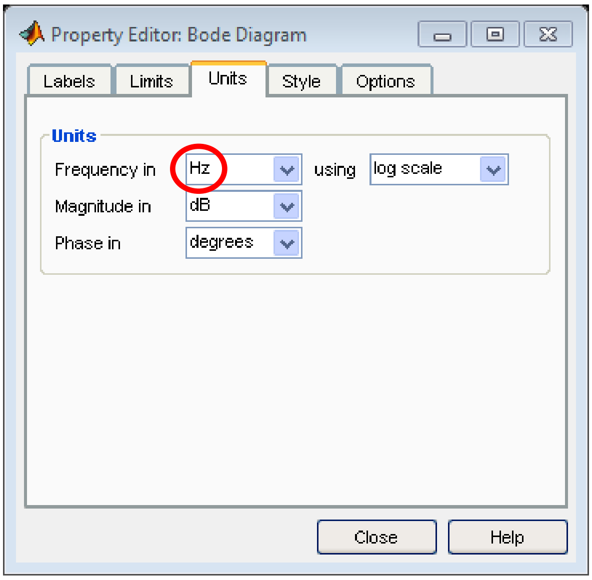
1.2.2 Change Limits

In our bode plot of the car suspension systems we cannot distinguish between the plots for the 4 different dampings in the spectral magnitude characteristics. Therefore we have to change the limits of the displayed magnitude. For this we use a right mouse click on the displayed bode plot to open a window where we select **Properties…** . In the Property Editor select **Limits** and use -50 dB to 10 dB for the Y-limits as shown in the next screen shot:



1.2.3 Change Units

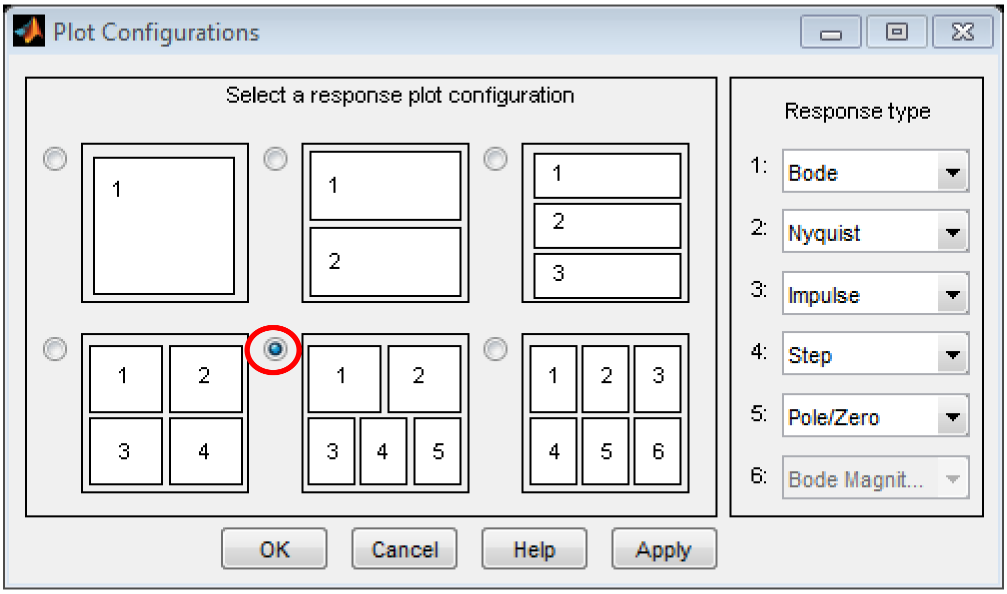
If we want the X-axis of the bode plot to be the frequency in Hertz we have to click on **Units** and select Frequency in **Hz**:



1.3 Diagrams to be displayed

Now we want to add other diagrams:

We select **Edit** in the window of the LTI-Viewer and click on **Plot Configurations**. We get the following window and select the desired plot types. In our case we use 5 plots: Bode, Nyquist, Impulse, Step and Pole/Zero.



Print the set of diagrams for documentation:
Select **File** in the toolbar of the LTI-Viewer
Select **Print** in the drop down menu

Write a short summary of the results:

- Bode plots:____

  ____

  ____

  ____

- Nyquist:____

  ____

- Impulse response:____

  ____

- Step response:____

____

____

- Poles and zeros:____

____

____

1.4 Characteristic Response Parameters

For control design it is important to derive the values of the characteristic response parameters to see whether they are within the limits of the specifications.

We want to deduce the peak response time, rise time and settling time from the step response:

Step 1: Use a right-mouse-click on the diagram of the step response to open the menu.
Step 2: Select **Characteristics** and then the parameter you want to know. Now there appear dots to mark the characteristic points in the step response.
Step 3: Move the cursor on the dot. Then the value of the parameter is shown.

Document the results in the following table:

	underdamping $\delta_1 < \omega_0$	underdamping $\delta_1 < \delta_2 < \omega_0$	critical damping $\delta_3 = \omega_0$	over-damping $\delta_4 > \omega_0$
Color of the plot	Blue			
Peak response time in s				
Rise time in s				
Settling time in s				

2 Analysis of the RL-Circuit using the LTI Viewer

An RL-circuit can act as a low-pass-filter or a high-pass-filter (see Exercise on Modelling of Electrical Systems No. 1 and 2).

The corresponding differential equations, the system parameters and the transfer functions are:

Low-pass-filter: $\frac{L}{R}\frac{du_{out}}{dt} + u_{out} = u_{in}$ **PT1-element**

$$a_1 = L/R,\ a_0 = 1, b_1 = 0,\ b_0 = 1$$

$$G(s) = \frac{b_1 s + b_0}{a_1 s + a_0} = \frac{1}{\frac{L}{R}s + 1}$$

High-pass-filter: $\frac{L}{R}\frac{du_{out}}{dt} + u_{out} = \frac{L}{R}\frac{du_{in}}{dt}$ **DT1-element**

$$a_1 = L/R,\ a_0 = 1, b_1 = L/R,\ b_0 = 0$$

$$G(s) = \frac{b_1 s + b_0}{a_1 s + a_0} = \frac{\frac{L}{R}s}{\frac{L}{R}s + 1}$$

The time constant of both filters is: $T_1 = \frac{L}{R}$.

So the cut-off-frequency can be calculated from: $\omega_c = \frac{1}{T_1} = \frac{R}{L}$.

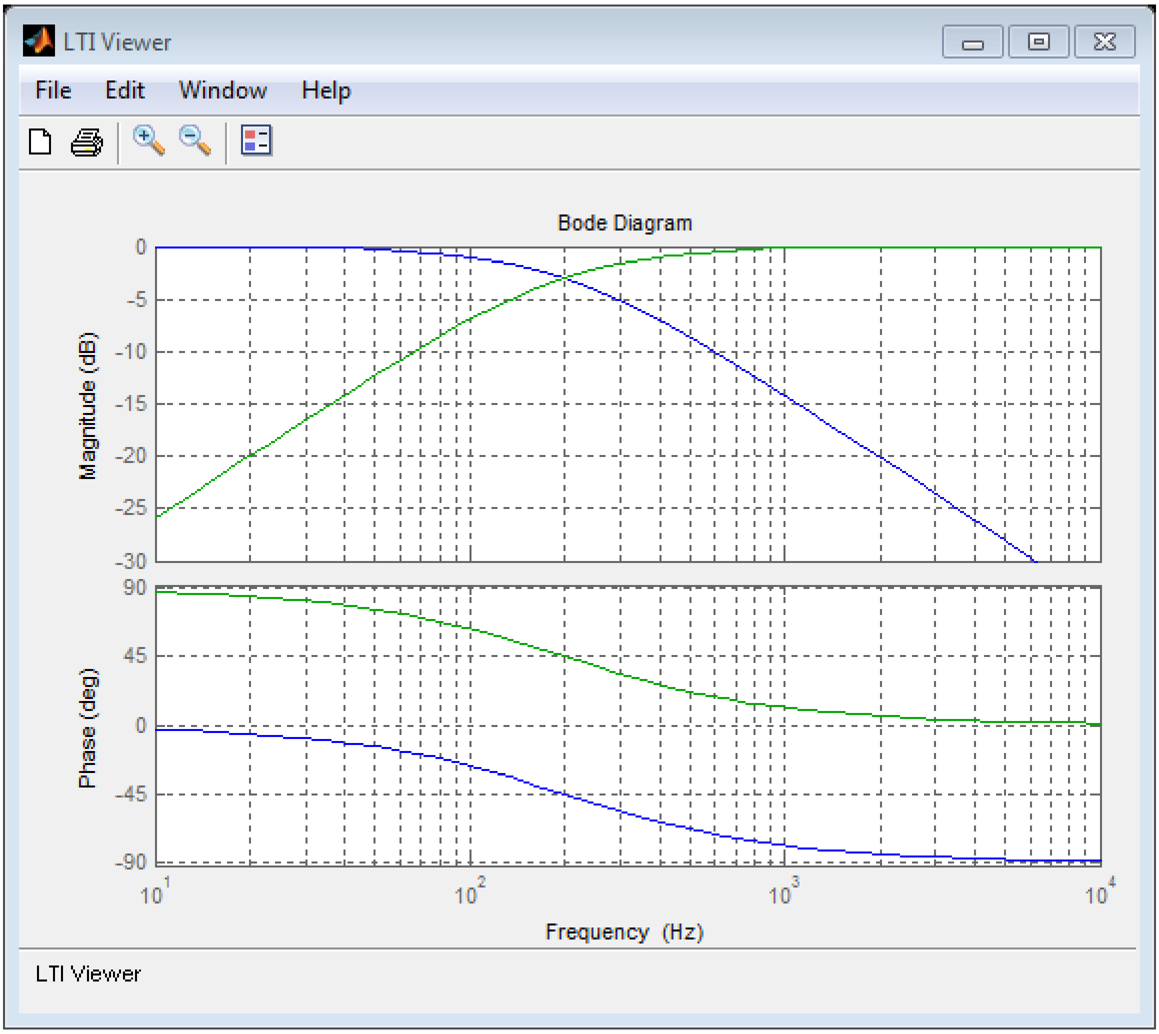
Write a program to create the transfer functions of the two systems. For the resistance and the inductance use:

R = 100 Ω,
L = 80 mH.

Use the LTI-Viewer to display the bode plots of the 2 systems. Print out the diagrams and deduce the cut-off-frequency ($\Leftrightarrow \varphi(f_c) = \pm 45° \Leftrightarrow u_{out}(f_c) = -3\text{dB}$).

Cut-off-frequency from simulation: f_c = ______________________________

Cut-off-frequency from theory: $f_c = \frac{\omega_c}{2\pi} = \frac{1}{2\pi}\cdot\frac{1}{T_1} = \frac{1}{2\pi}\cdot\frac{R}{L} =$ ____________________


LTI Viewer
File
Edit
Window
Help
Bode Diagram
Magnitude (dB)
0
-5
-10
-15
-20
-25
-30
Phase (deg)
90
45
0
-45
-90
10^1
10^2
10^3
10^4
Frequency (Hz)
LTI Viewer

3 Analysis of the RC-Circuit using the LTI Viewer

An low-pass-filter or a high-pass-filter can also be build with a capacitor instead of the inductor. The values shall be: $R = 100\ \Omega$, $C = 150\ \mu F$.

a) Derive the differential equations for both filters (the low pass filter you have already studied in the “Exercise on Modelling of Electrical Systems” No. 3):

Low-pass-filter:

System parameters:

Transfer function:

High-pass-filter:

System parameters:

Transfer function:

The time constant of both filters is: $T_1 = \text{——} =$

So the cut-off-frequency can be calculated from: $\omega_c = \frac{1}{T_1} =$ ____________________________ .

Write a program to create the transfer functions of the two systems like you did in Chapter 2 and use the LTI-Viewer to display the bode plots of the 2 systems.

Deduce the cut-off-frequency ($\Leftrightarrow$ $\varphi(f_c) = \pm 45° \Leftrightarrow u_{out}(f_c) = -3\text{dB}$):

Cut-off-frequency from simulation: $f_c =$ ____

Cut-off-frequency from theory: $f_c = \frac{\omega_c}{2\pi} = \frac{1}{2\pi} \cdot \frac{1}{T_1} =$ ___________________________________

Customize the diagrams and transfer them to your Word-document. Print the document.