Exercises for Lecture Course on Modelling and System Identification (MSI)
Albert-Ludwigs-Universität Freiburg – Winter Term 2015

Exercise 8: Frequency Domain Identification

(to be returned on Feb 2, 2016, 8:15 in HS 26, or before in building 102, 1st floor, 'Anbau')

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Your MATLAB solution has to run from a main script called `main.m`. When running this script all the necessary results and plots should be clearly visible. Please send it to `fabiangirrbach@gmail.com`. State also your name and the names of your team members in the e-mail.

Exercise Task

Given a test system, estimate the Bode diagram characteristic of this system by analyzing the output to a multisine input. You can download the `unknown_system.p` test file from `http://www.syscop.de/teaching/ws2015/msi`. This MATLAB function accepts an $N \times 1$ input vector $u[\mathrm{V}]$ and a sampling time $T_s[\mathrm{s}]$, and returns an $N \times 1$ output vector as follows: `y = unknown_system(u,T_s)`. The system has a built-in safety: the amplitude of the input signal should be between $-10\mathrm{V}$ and $+10\mathrm{V}$.

1. Generate a periodic signal with a single frequency $f_1 = 1\,\mathrm{Hz}$, e.g. $u = \cos(2\pi f_1 t)\,\mathrm{V}, t \in [0, t_f]$. Apply the input to the test system and plot both the input and the output. What is the amplification (in dB) and the phase shift (in degrees) with respect to the input? (2 points)

2. Describe how you chose the sampling time in the previous question, and state the corresponding theorem. (2 points)

3. A "multisine" signal allows us to estimate amplification and phase shift for a bunch of different frequencies at the same time. Generate a few periods of the following multisine:

$$m(t) = A \sum_{k=0}^{N-1} \cos(2\pi k f_{\text{base}} t)\,\mathrm{V}, \quad t \in [0, t_f], \tag{1}$$

   for some amplitude A and $f_{\text{base}} = f_{\text{max}}/N$. Apply the multisine to the system. Plot the Bode diagram for this system in the frequency range $[0, 20]$ Hz. How did you do the averaging? *Hint: Do not forget to add units to your axes!* (2 points)

4. What A did you choose in the previous question as to not go over the safety bounds of the system? Why is this a problem? (2 points)

5. A solution to the problem mentioned in the previous question is to use random phases for the multisine signal. Such a signal is designed elegantly in the frequency domain. Generate a multisine signal in the frequency domain and compute the time domain signal using `ifft`. Use uniform random phases inside the interval $[0, 2\pi]\mathrm{rad}$. *Hint: A real-valued time domain signal is a complex conjugate symmetric signal in the frequency domain using the Fourier transform.* (2 points)

6. Apply the signal from the previous question to the test system and estimate the Bode diagram again. Compare with the Bode diagram from question 3. What is the advantage of using random phases? (2 points)

Note: It is important that you address all questions in words, either in the code as comments or on a seperate paper.

This sheet gives in total 12 points