

Process control laboratory practice

Frequency analysis

Introduction

The main aim of process control is automation of a process. The control system consists of measuring devices, signal transferring elements, actuators, and elements performing the control logic. These elements are different according to how they respond to an input signal. The relation between the input and output signals flowing through an element can be characterized by the gain function of the element. Frequency analysis aims at determining the frequency response function, which is close relation to the gain function, of the element.

Frequency analysis

If an element is forced by a sinusoidal input, the response (output) will be a sinusoidal signal as well. However, the two signals differ in amplitude and phase, see Figure 1. During frequency analysis, these differences are recorded and analysed in order to obtain the frequency response function of the element or system investigated. Frequency analysis provides information useful in determining stability and controllability of the investigated element or system.

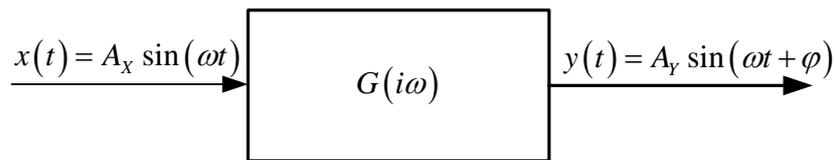


Figure 1. Sinusoidal input and response, as function of frequency ω .

$x(t)$	input signal
A	amplitude of the sine wave
ω	frequency of the sine wave
t	time
$G(i\omega)$	frequency response function of the element, i stands for imaginary unit
φ	phase angle

During frequency analysis, amplitude ratio (A_y/A_x) and phase angle (φ) are determined and investigated. Both parameters depend on the frequency of the input signal.

$$AR = \frac{A_y}{A_x} = f_1(\omega) \quad \text{and} \quad \varphi = f_2(\omega)$$

If the above written two functions, f_1 and f_2 , are measured at different ω frequencies, the graphical representations of the frequency response function can be visualized by plotting the results on the *Bode* and *Nyquist* diagrams.

Aims of the work

An aim of the work is determination of the frequency response functions (*Bode* and *Nyquist* diagrams) of a first order and a second order elements. Experiment is carried out by Matlab's SimuLink module. The investigated model is shown in Figure 2.

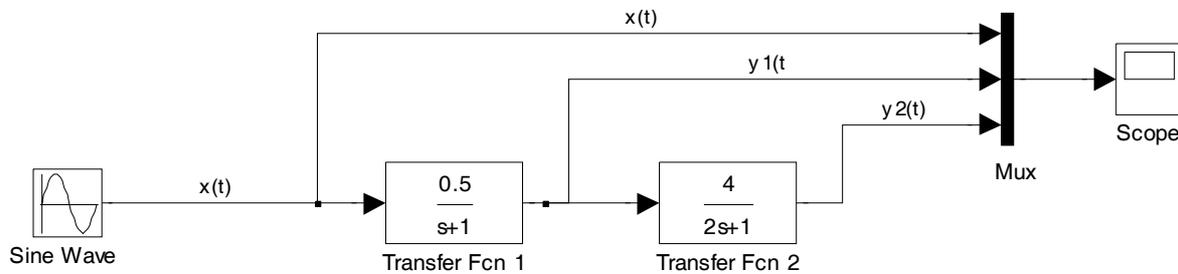


Figure 2. The investigated model

Sinusoidal input signal is generated by the *Sine wave* block that is forced through the two first order elements *Transfer Fcn 1* and 2. All signals (input and output signals) are collected in block called *Mux* (multiplex signal collector). Signals can be visualised by the block called *Scope*.

figure;plot(signal.time,signal.signals(1).values) is a further option to examine the signals, and is executed in Matlab's command window. **This command requires that *Scope's* data are stored in a variable named signal.** (Double click on scope, Parameters tab / Data history tab / Save data to workspace field:= signal.)

Building the model

For building the model shown in Figure 1, start Matlab from the desktop or start menu. (Some patience is required till the total boot of the program).

Type 'simulink' to the command window.

SimuLink is Matlab's module specially designed for dynamic modelling of complex systems.

Several (numerous) ready-to-use models, transfer functions are collected and assorted in SimuLink Library Browser. These models can be used to build up complex systems. *New model* can be launched in the *file* menu of the SimuLink Library Browser.

Models can be placed to the new model by drag-and-drop method.

Models can be connected by the mouse by connecting the in and out ports of the models by holding the mouse button.

Configure the model blocks

Sine wave: amplitude:= 2, frequency:= 1 rad/sec.

Parameters of the transfer function are shown in Figure 1.

Mux: number of inputs:= 3.

Scope: Parameters/Data history // Limit data history: remove tick from the tick box; // save data to workspace as signal.

Experiment

Set the frequency of the input signal. Run the model by clicking on the *play* button in the model window. Read the result diagrams to obtain the *amplitude ratios* $|G(i\omega)|$ (for the first and the second order element separately) and phase angles ($\varphi(\omega)$) both elements. Fill in the table on the handout.

Repeat these steps as many times as it is required in order to draw up the Bode and Nyquist diagrams of the two elements. Tips for input frequency values are given in the handout; however, these can be changed individually.

Plot your data on appended the log-log diagram (it is useful to use different colours for the two elements).

Hints

Result of a simulation is a diagram consisting of three sinus curves. One curve is for the input signal which can be recognized by the fact the amplitude of the input signal is known (it can be checked in the *Sine Wave* block). The other two curves are those of the first and second order elements.

Amplitude response is the ratio of the output and input signals' amplitudes.

Phase angle ($\varphi(\omega)$) can be determined from the time-lag (ΔT) and the periodical time (T_{per}) of the

output signal as follows: $\varphi = \frac{\Delta T}{T_{per}} \cdot 360^\circ$, see Figure 3.

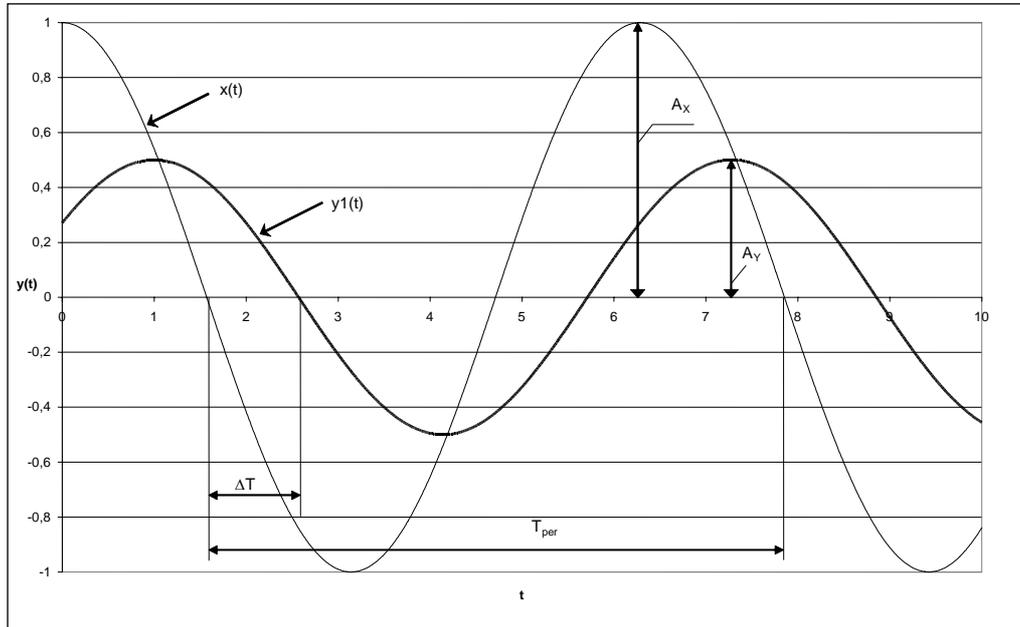


Figure 3. Determination of the phase angle.

Bode plot

