



**iTMO**

# **Lab 3 «Simulation of mechanical systems»**

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# Objective and Goals

**Objective:** to study the basic principles of building mathematical models, modelling and analysis of electromechanical systems on the example of DC motor **with two-mass load with elastic joints**.



## Goals:

- Build the dynamic models of the DC motor with **two-mass load with elastic joints** in different forms: Simscape block, block diagram, transfer function, state space representation;
- Draw bode plots.
- Get data-driven model of DC motor with **two-mass load with elastic joints** by experimental frequency response function

# Initial data

## Initial data



$R_a$  - armature resistance

$k$  - torsional stiffness coefficient

$L_a$  - armature inductance

$b$  - damping coefficient

$\Psi_{rated}$  - rated flux

$J_L$  - inertia of the load

$U_{rated}$  - rated voltage

$J_M$  - inertia of the shaft

# Task 1

a) Build the model of the DC-motor **with two-mass load with elastic joints** using:

- Simscape library
- block diagram

- transfer functions:  $W_1(s) = \frac{\omega_M(s)}{U(s)}$   
 $W_2(s) = \frac{\omega_L(s)}{U(s)}$

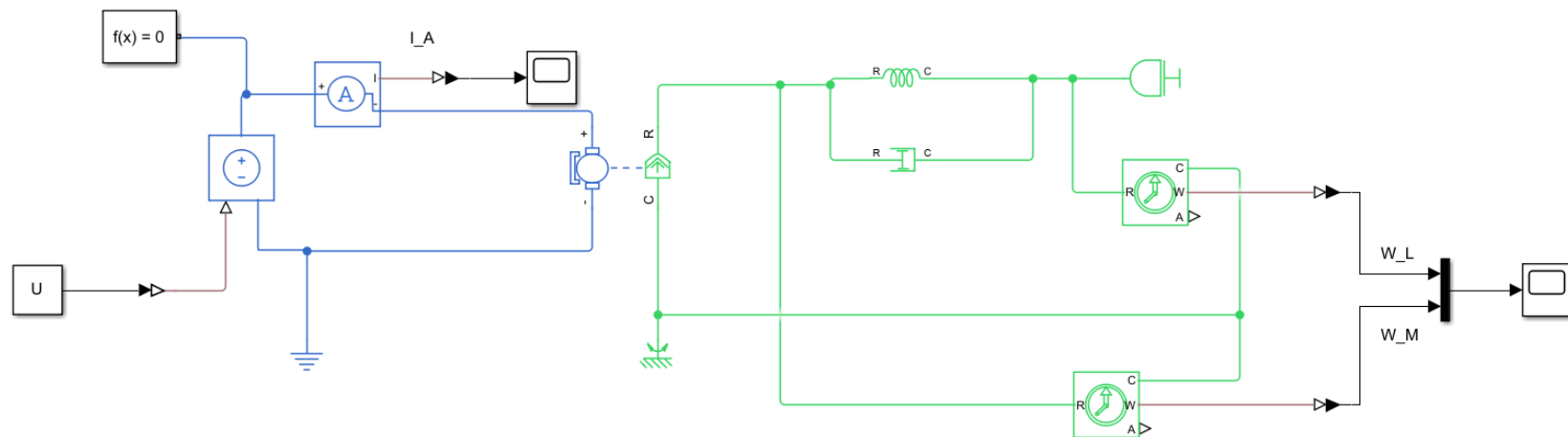
- state space model

$$\begin{cases} L_a \cdot \frac{di_a}{dt} = U - R_a \cdot i_a - \Psi \cdot \omega_M \\ J_M \cdot \frac{d\omega_M}{dt} = \Psi \cdot i_a - T_S - b(\omega_M - \omega_L) \\ J_L \cdot \frac{d\omega_L}{dt} = T_S + b(\omega_M - \omega_L) \\ \frac{dT_S}{dt} = k(\omega_M - \omega_L) \end{cases}$$

**Assume load torques equal to zero.**

**Simulate the models with the rated voltage. Draw graphs of the armature current, motor velocity, load velocity.**

# Simscape model



# Simscape model

ITMO

Block Parameters: DC Motor

DC Motor ☒ Auto Apply

Settings	Description
NAME	VALUE
Modeling option	No thermal port
Selected part	<click to select>
<b>Electrical Torque</b>	
Field type	Permanent magnet
Model parameterization	By equivalent circuit parameters
> Armature resistance	Ra 0.1 Ohm
Armature inductance	La 0.0005 H
Define back-emf or torque constant	Specify back-emf constant
> Back-emf constant	psi 0.2 V/(rad/s)
Rotor damping parameterization	By damping value
<b>Mechanical</b>	
Rotor inertia	J_M 0.02 kg*m^2
Rotor damping	0 N*m/(rad/s)
> Initial rotor speed	0 rpm
<b>Faults</b>	

## Simcape

- ▶ Foundation Library
- ▶ Utilities
- ▶ Battery
- ▶ Driveline
- ▼ Electrical
  - ▶ Connectors & References
  - ▶ Control
  - ▼ Electromechanical
    - ▶ Asynchronous
    - ▼ Brushed Motors

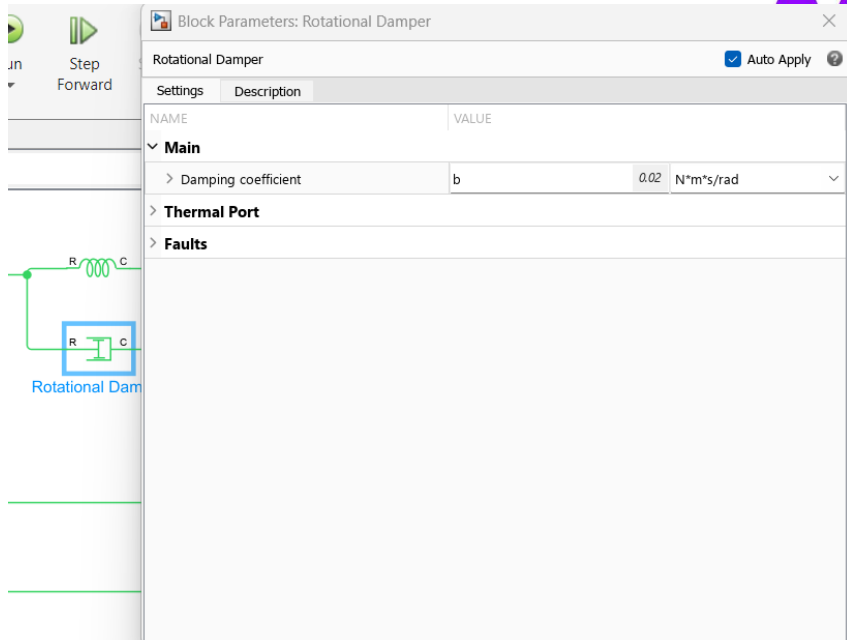
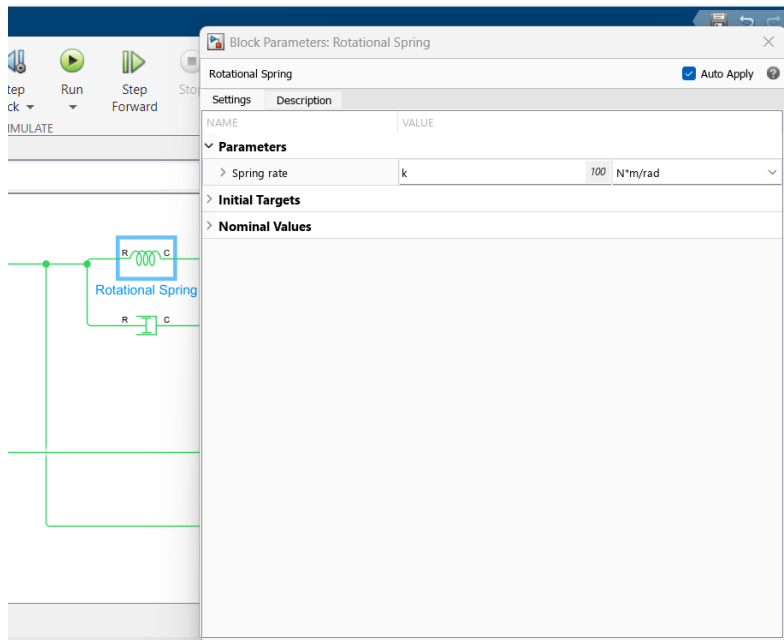


Compound Motor



DC Motor

# Simscape model



# Simscape model

Block Parameters: Inertia

Settings Description

NAME VALUE

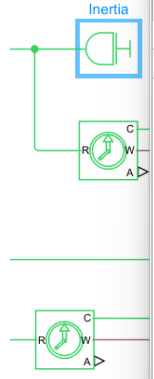
Parameters

> Inertia  $J_L$  0.04  $\text{kg}\cdot\text{m}^2$

Number of graphical ports 1

Initial Targets

Nominal Values

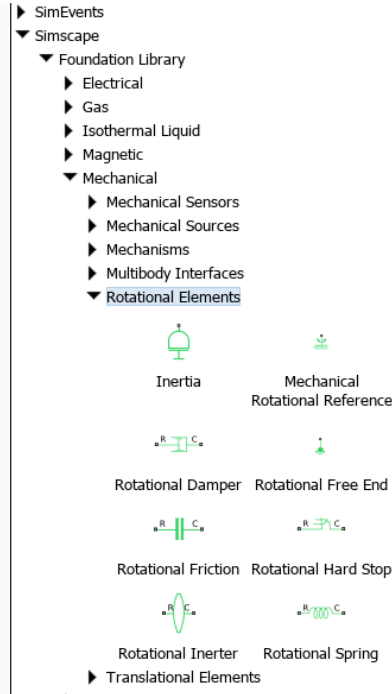


SimEvents

Simscape

Foundation Library

- Electrical
- Gas
- Isothermal Liquid
- Magnetic
- Mechanical
  - Mechanical Sensors
  - Mechanical Sources
  - Mechanisms
  - Multibody Interfaces
  - Rotational Elements
    - Inertia
    - Mechanical Rotational Reference
    - Rotational Damper
    - Rotational Free End
    - Rotational Friction
    - Rotational Hard Stop
    - Rotational Inerter
    - Rotational Spring
  - Translational Elements





## Task 2



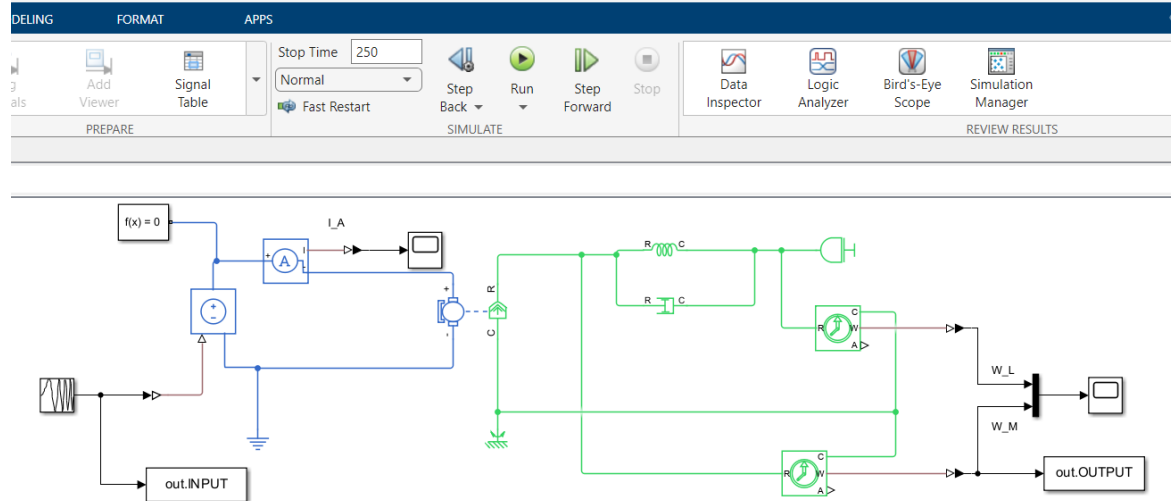
Draw bode plots for 2 transfer functions:

$$W_1(s) = \frac{\omega_M(s)}{U(s)} \quad W_2(s) = \frac{\omega_L(s)}{U(s)}$$

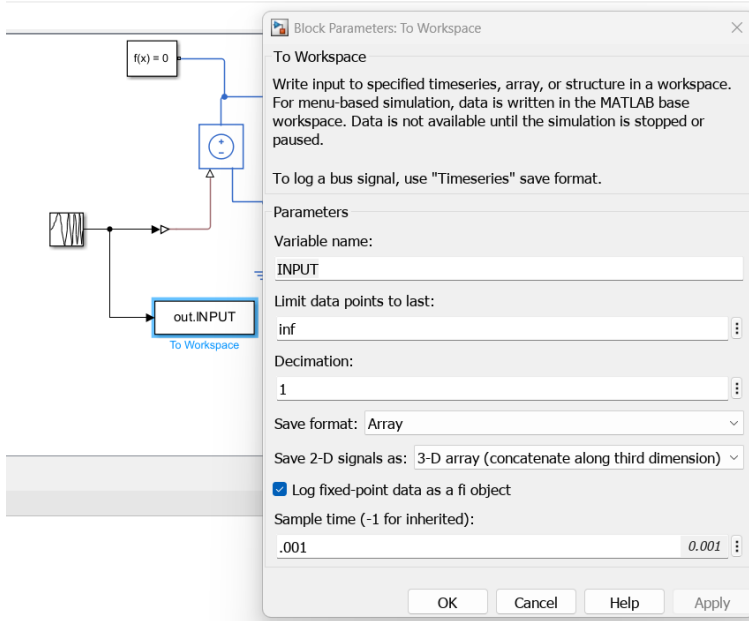
Find the resonant frequency of the mechanical subsystem from bode plot

## Task 3

a) Simulate the DC motor with 2-mass load with multi-harmonic input signal. Save the input data and velocity of the motor  $\omega_M$ .  
Simulation time: 250 s



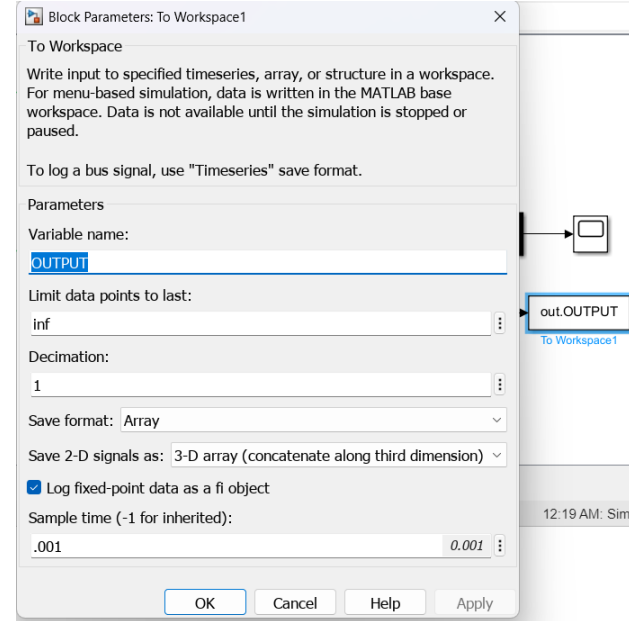
# Task 3



The screenshot shows a Simulink model with a sine wave input block, a summing junction, and a 'To Workspace' block labeled 'out.INPUT'. The 'Block Parameters: To Workspace' dialog box is open, showing the following settings:

- To Workspace**  
Write input to specified timeseries, array, or structure in a workspace. For menu-based simulation, data is written in the MATLAB base workspace. Data is not available until the simulation is stopped or paused.  
To log a bus signal, use "Timeseries" save format.
- Parameters**
  - Variable name:
  - Limit data points to last:
  - Decimation:
  - Save format:
  - Save 2-D signals as:
  - ☒ Log fixed-point data as a fi object
  - Sample time (-1 for inherited):

Buttons at the bottom: OK, Cancel, Help, Apply.

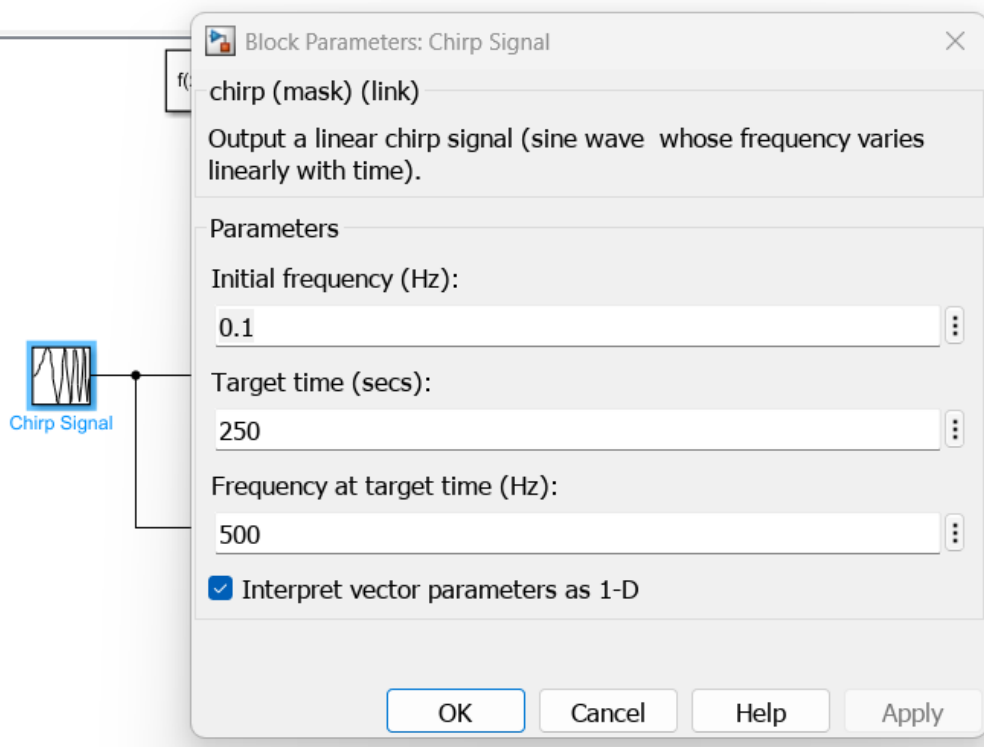


The screenshot shows a Simulink model with a 'To Workspace1' block labeled 'out.OUTPUT'. The 'Block Parameters: To Workspace1' dialog box is open, showing the following settings:

- To Workspace**  
Write input to specified timeseries, array, or structure in a workspace. For menu-based simulation, data is written in the MATLAB base workspace. Data is not available until the simulation is stopped or paused.  
To log a bus signal, use "Timeseries" save format.
- Parameters**
  - Variable name:
  - Limit data points to last:
  - Decimation:
  - Save format:
  - Save 2-D signals as:
  - ☒ Log fixed-point data as a fi object
  - Sample time (-1 for inherited):

Buttons at the bottom: OK, Cancel, Help, Apply.

## Task 3

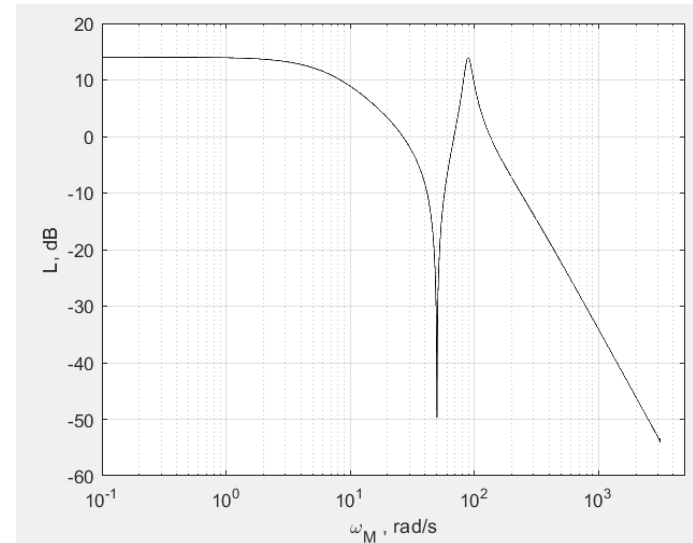


## Task 3

b) Find the frequency response function of the system from simulation data:



```
10 %%  
11 u = out.INPUT(:, 1);  
12 y = out.OUTPUT(:, 1);  
13 Ts = 1e-3;  
14 [txy, f] = tfestimate(u,y,[],[],[],(1 / Ts));  
15 om = 2 * pi * f;  
16 L = 20 * log10(abs(txy));  
17 figure();  
18 plot(om, L, '-k');  
19 xlim([0.1, 5000]);  
20 xlabel('\omega_M , rad/s')  
21 ylabel('L, dB')  
22 ax = gca;  
23 set(ax,'XScale','log')  
24 grid on  
25 hold all
```



## Task 3

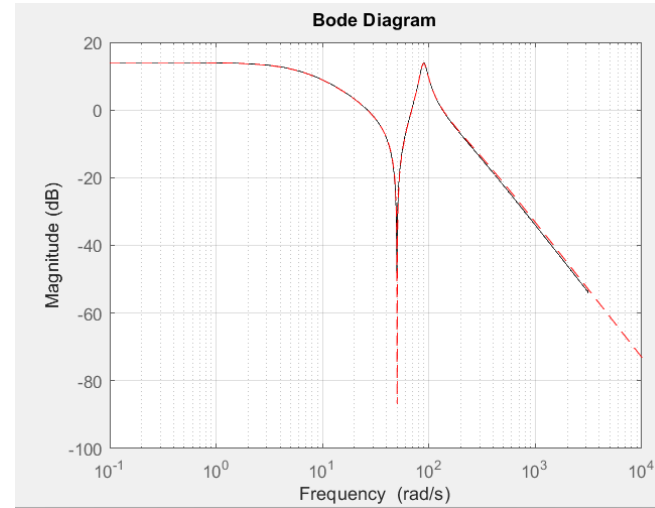
c) Identify the transfer function from FRF:



```
% Define number of poles and number of zeros
pole_num = 4;
zero_num = 2;

sys_fr = idfrd(txy,om,Ts);
id_freq_tf = tfest(sys_fr, pole_num, zero_num);
W_ident_1 = tf(id_freq_tf.num, id_freq_tf.den);

bodemag(W_ident_1, '--r');
grid on
```



d) Compare the identified transfer function with the original one  $W_1(s) = \frac{\omega_M(s)}{U(s)}$

# Report content

1. Your name and HDU ID
2. Your variant and initial data
3. Simscape model of DC-motor with two-mass load
4. Block diagram model of DC-motor with two-mass load
5. Transfer functions of DC-motor with two-mass load
6. State space model of DC-motor with two-mass load
7. Simulation results
8. Bode plots of transfer functions
9. Value of resonant frequency
10. Experimentally estimated frequency response function
11. Experimentally estimated transfer function
12. Comparison of estimated transfer function with original one



# Deadlines and penalties

## 7 points - max



Deadline 1: 2025/03/25 – missing the deadline gives you 1-point penalty

Deadline 2: 2025/04/08 – missing the deadline gives you 2-point penalty

Missing the Task 2 gives you 1-point penalty

Missing the Task 3 gives you 1-point penalty

The link for uploading your report:

<https://forms.yandex.ru/u/67cdcfcfd04688925ba8360e/>





**THANK YOU  
FOR YOUR TIME!**

**it's** **MO** *re than a*  
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