



iTMO

Lab 2 «Simulation components of dynamic 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.



Goals:

- Build the dynamic models of the DC motor in different forms: Simscape block, block diagram, transfer function, state space representation;
- Analyze the transient processes of DC motor;
- Draw bode plots.

Initial data

Initial data



R_a - armature resistance

L_a - armature inductance

Ψ_{rated} - rated flux

U_{rated} - rated voltage

T_{rated} - rated torque

J - inertia of the shaft

Task 1

a) Build the model of the DC-motor using:

- Simscape library
- block diagram
- transfer function
- state space model

$$\begin{cases} L_a \cdot \frac{di_a(t)}{dt} = U - R_a \cdot i_a(t) - \Psi \cdot \omega(t) \\ J \cdot \frac{d\omega(t)}{dt} = \Psi \cdot i_a(t) - T_L \end{cases}$$

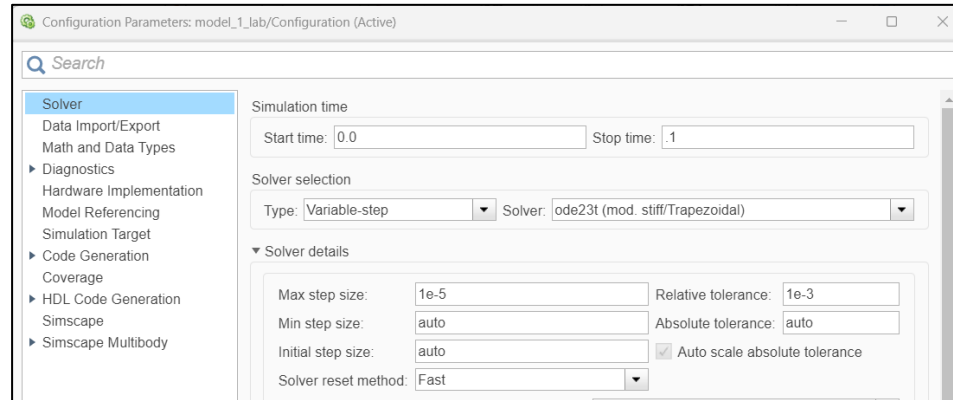
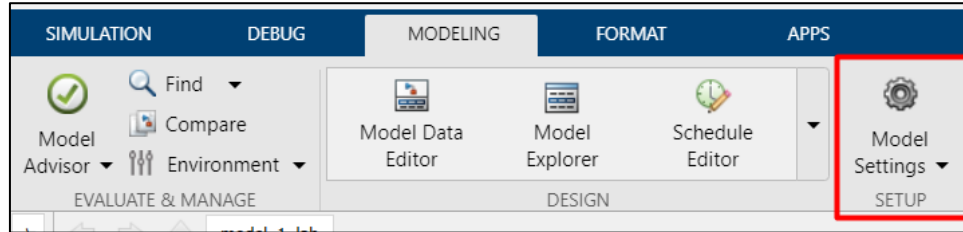
Create the script with initial data for your variant:



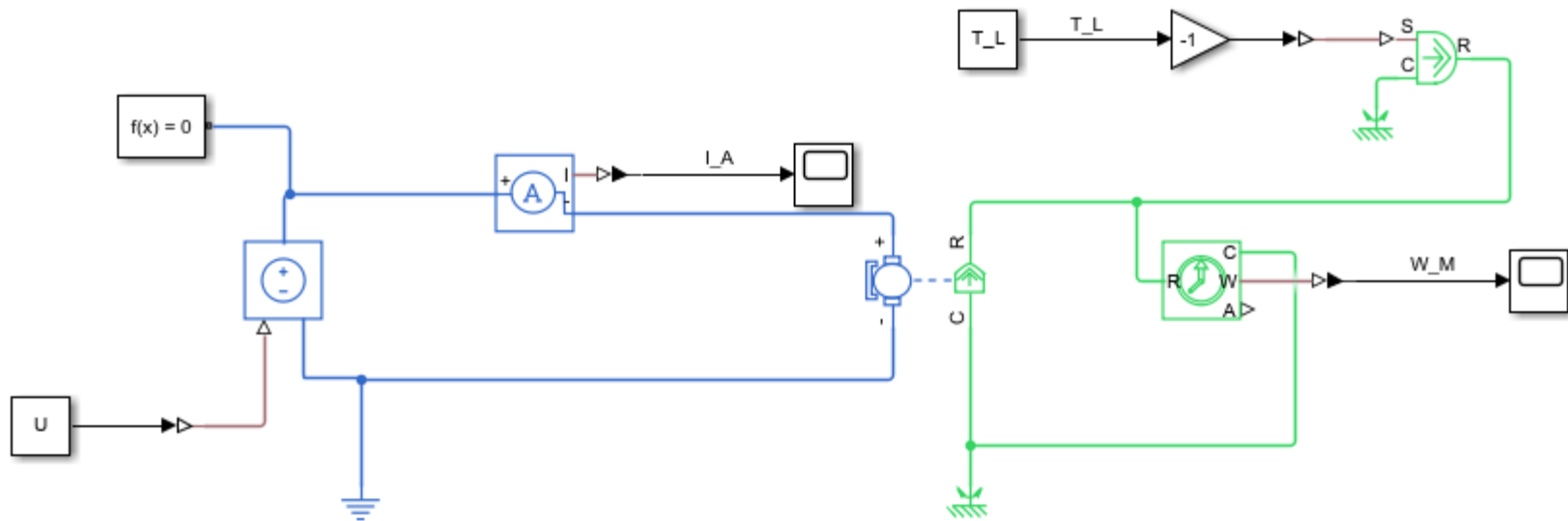
```
U Rated = 48;  
Ra = 0.1;  
La = 5e-4;  
psi = 0.2;  
J1 = 0.002;  
J2 = 0.02;  
J = J1;  
T Rated = 15;
```

Preliminary

Open new model, create new Simulink model, tune the solver:



Simscape model



Simscape model

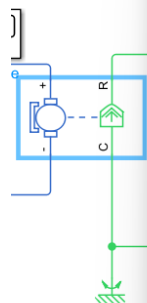
ITMO

Atomic Subsystem

Block Parameters: DC Motor

DC Motor ☒ Auto Apply

Settings	Description
NAME	VALUE
Modeling option	No thermal port
Selected part	<click to select>
▼ Electrical Torque	
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
▼ Mechanical	
Rotor inertia	J 0.002 kg*m^2
Rotor damping	0 N*m/(rad/s)
> Initial rotor speed	0 rpm
> Faults	



Simcape

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



Compound Motor



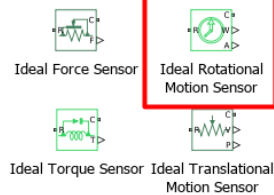
DC Motor

Simscape model

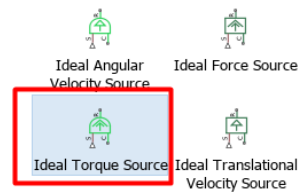
Foundation Library

- ▶ Electrical
- ▶ Gas
- ▶ Isothermal Liquid
- ▶ Magnetic
- ▼ Mechanical

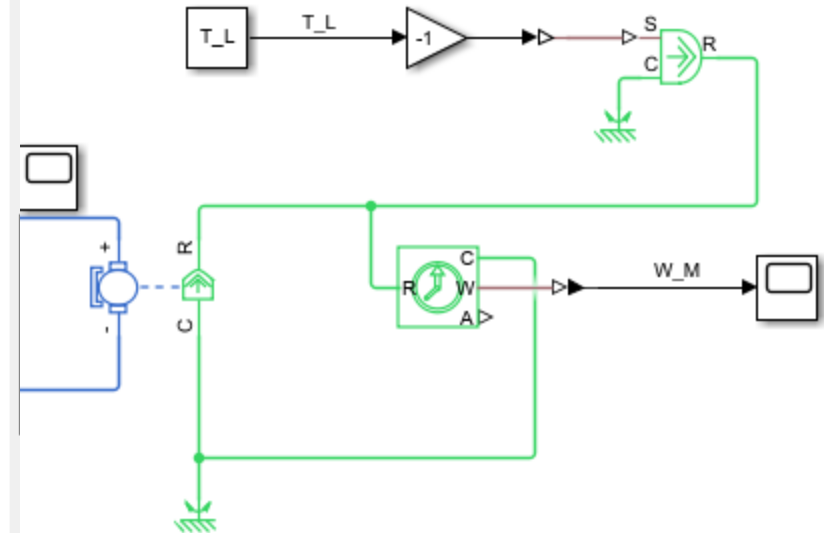
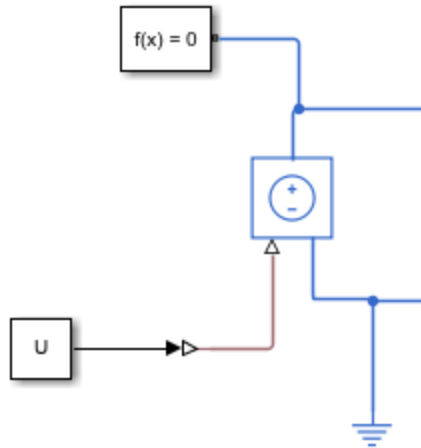
▼ Mechanical Sensors



▼ Mechanical Sources



- ▶ Mechanisms
- ▶ Multibody Interfaces
- ▼ Rotational Elements



Block diagram model

Build block diagram model based the dynamic model of DC motor:



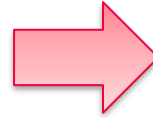
$$\begin{cases} L_a \cdot \frac{di_a(t)}{dt} = U - R_a \cdot i_a(t) - \Psi \cdot \omega(t) \\ J \cdot \frac{d\omega(t)}{dt} = \Psi \cdot i_a(t) - T_L \end{cases}$$

State space model

Calculate matrices of the state space model:



$$\begin{cases} L_a \cdot \frac{di_a(t)}{dt} = U - R_a \cdot i_a(t) - \Psi \cdot \omega(t) \\ J \cdot \frac{d\omega(t)}{dt} = \Psi \cdot i_a(t) - T_L \end{cases}$$



$$\begin{cases} \frac{d\mathbf{x}}{dt} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u} \\ y = \mathbf{C}\mathbf{x} + \mathbf{D}\mathbf{u} \end{cases}$$

State vector:

$$\mathbf{x} = \begin{bmatrix} i_a \\ \omega \end{bmatrix}$$

Control vector:

$$\mathbf{u} = \begin{bmatrix} U \\ T_L \end{bmatrix}$$

Output:

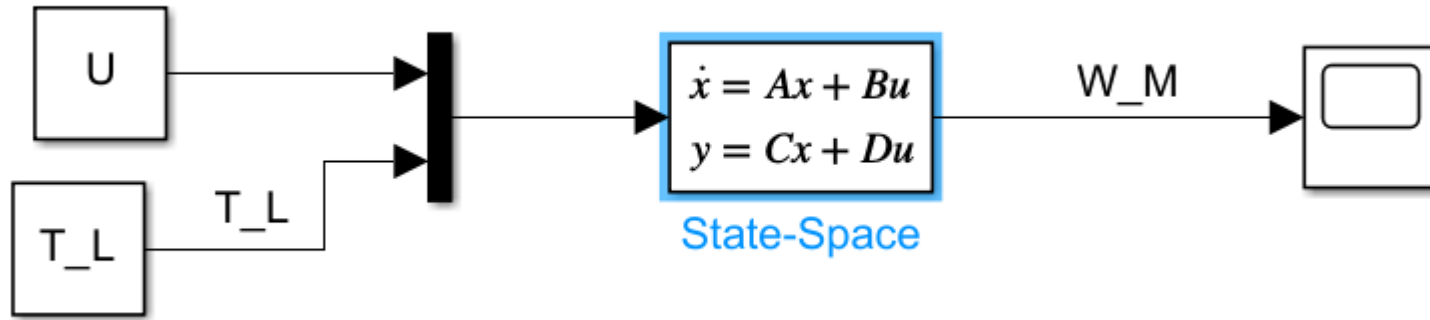
$$y = \omega$$

$A, B, C, D - ?$

Find state space matrices

State space model

To simulate state space model, use the follows block:



Transfer function

a) Calculate the transfer function from **voltage** to **speed**:

$$W_1(p) = \frac{\omega(s)}{U(s)}$$



b) Calculate the transfer function from **load torque** to **speed**:

$$W_2(p) = \frac{\omega(p)}{T_L(p)}$$

Simulation 1:

```
%% Simulation
```

```
U = U Rated;
```

```
TL = 0;
```

With **rated voltage** and **zero load torque**

Simulation 2:

```
%% Simulation
```

```
U = 0;
```

```
TL = TRated;
```

With **zero voltage** and **rated load torque**

Make sure that the speed ω measured from all the models built is the same!

Task 2



Consider the transfer function from **voltage** to **speed**:

$$W_1(p) = \frac{\omega(s)}{U(s)}$$

Using inverse Laplace transform, calculate the transient response function $\omega(t)$ for:

a) $U(t) = U_{rated}, \quad J = J_1$

b) $U(t) = U_{rated}, \quad J = J_2$

Answer the question which function is underdamped?

Task 2



If you want to draw in MATLAB some function $y(t)$ you can do it as follows:

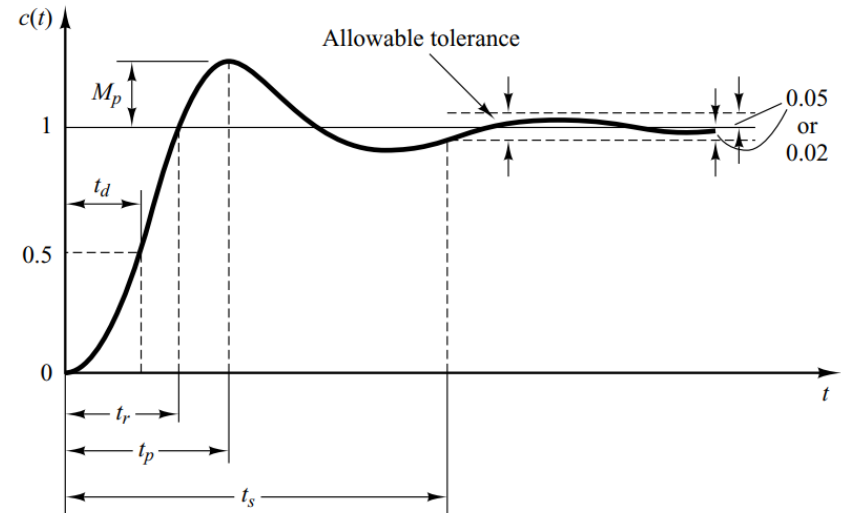
```
13 %%  
14 % Define time limits  
15 start_time = 0;  
16 stop_time = 0.5;  
17 % Define time step  
18 time_step = 0.001;  
19 % Define the array of times  
20 t = start_time:time_step:stop_time;  
21 % Define the function  
22 f_t = 1 - exp(-t./0.1); % here should be your own calculated time response  
23 % Draw the graph of f_t  
24 plot(t, f_t)  
25 grid on  
26  
27
```


Task 2

Draw calculated transient responses and find:



- **Rise time** from 10% to 90% of final value
- **Maximum (percent) overshoot**
- **Settling time** with 5% tolerance



Task 3

Draw bode plot for the underdamped DC-motor from the task 2.



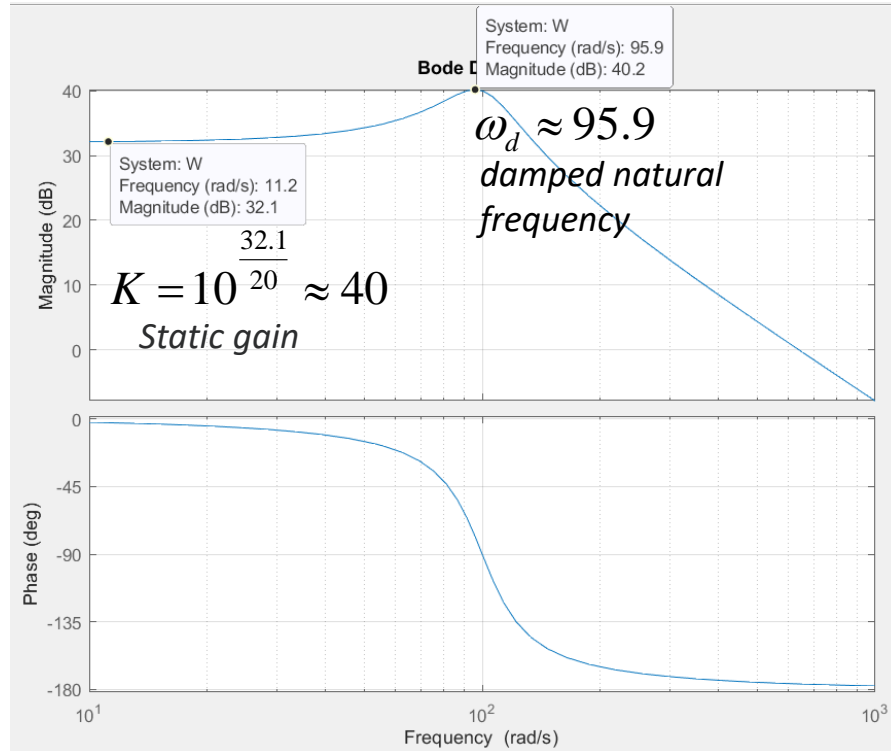
Calculate **static gain** and **damped natural frequency** of the dynamic system from bode plot.

The code to get bode plot for some transfer function:

```
27 %%  
28 K = 40;  
29 wn = 100;  
30 ksi = 0.2;  
31  
32 W = tf(K*wn^2, [1 2*ksi*wn wn^2]);  
33  
34 bode(W)  
35 grid on
```

Task 3

The bode plot:



Report content

1. Your name and HDU ID
2. Your variant and initial data
3. Simscape model of DC-motor
4. Block diagram model of DC-motor
5. Transfer functions of DC-motor
6. State space model of DC-motor
7. Simulation results for 2 cases
8. Calculation of transient response function based on transfer function of DC-motor for two values of inertia
9. Graphs of transient responses
10. Values of rise time, maximum overshoot and settling time
11. Bode plot of underdamped model of DC-motor
12. Values of the static gain and damped natural frequency calculated from Bode plots



Deadlines and penalties

7 points - max



Deadline 1: 2025/03/20 – missing the deadline gives you 1-point penalty

Deadline 2: 2025/04/03 – 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/67c86c2fd04688428d49a923/>



**THANK YOU
FOR YOUR TIME!**

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