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

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

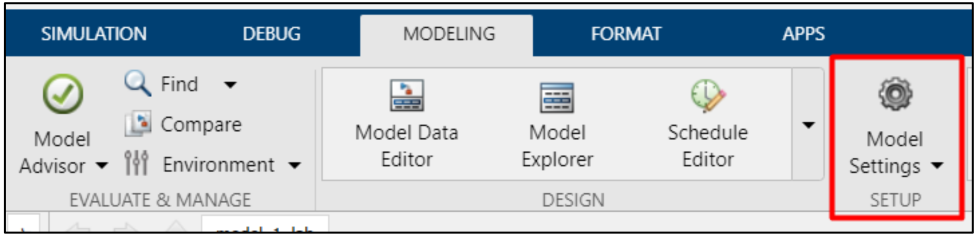
Preliminary

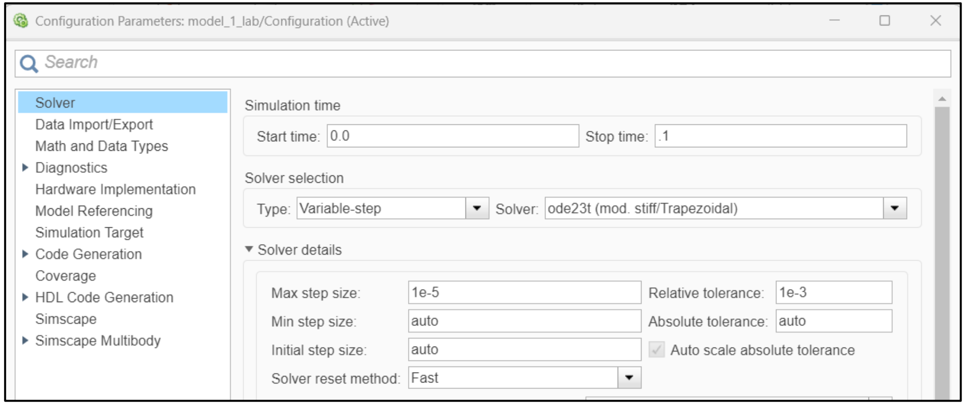
Create the script with initial data for your variant:

```
U_rated = 48;
Ra = 0.1;
La = 5e-4;
psi = 0.2;
J1 = 0.002;
J2 = 0.02;
J = J1;
T_rated = 15;
```

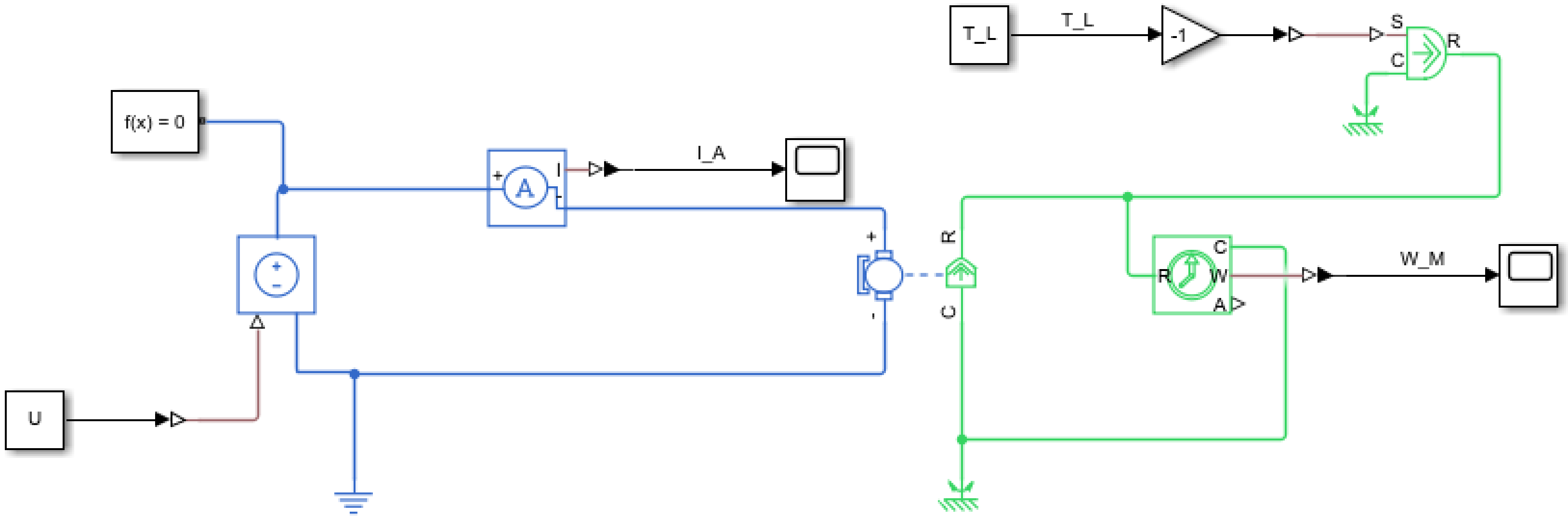
Preliminary

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

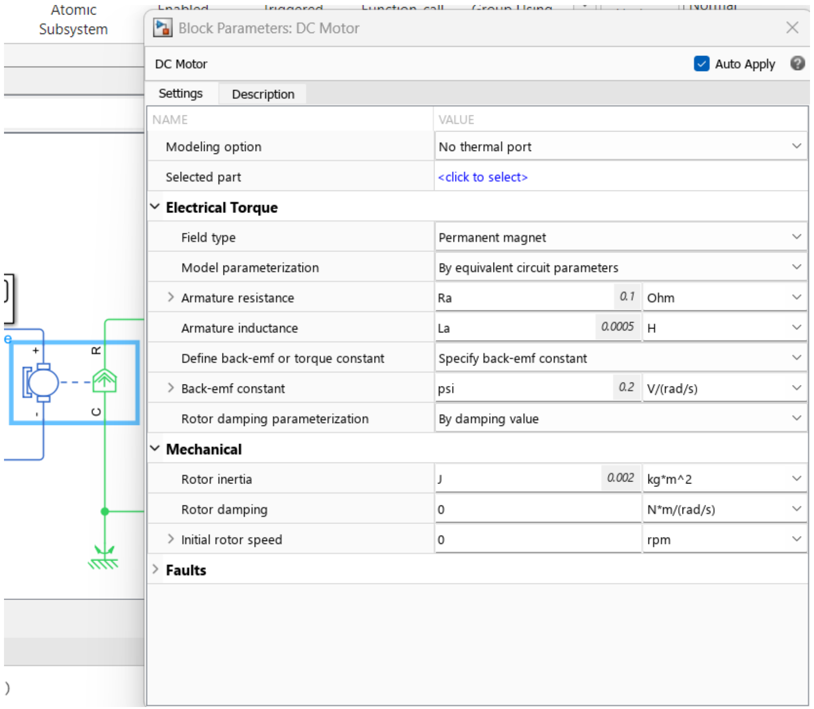


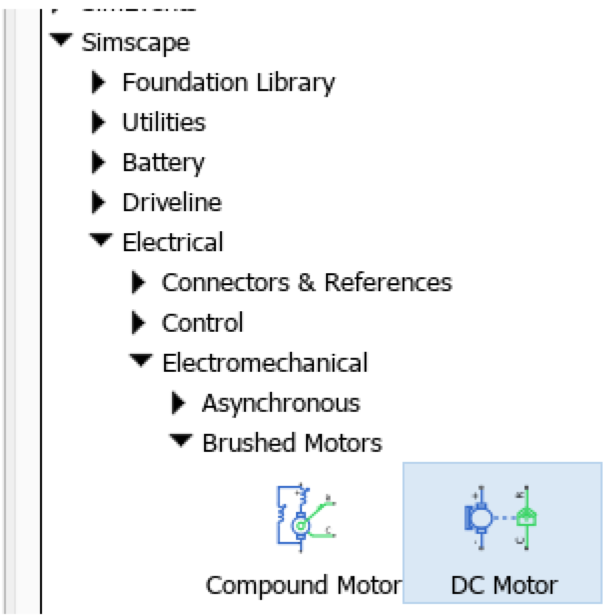


Simscape model

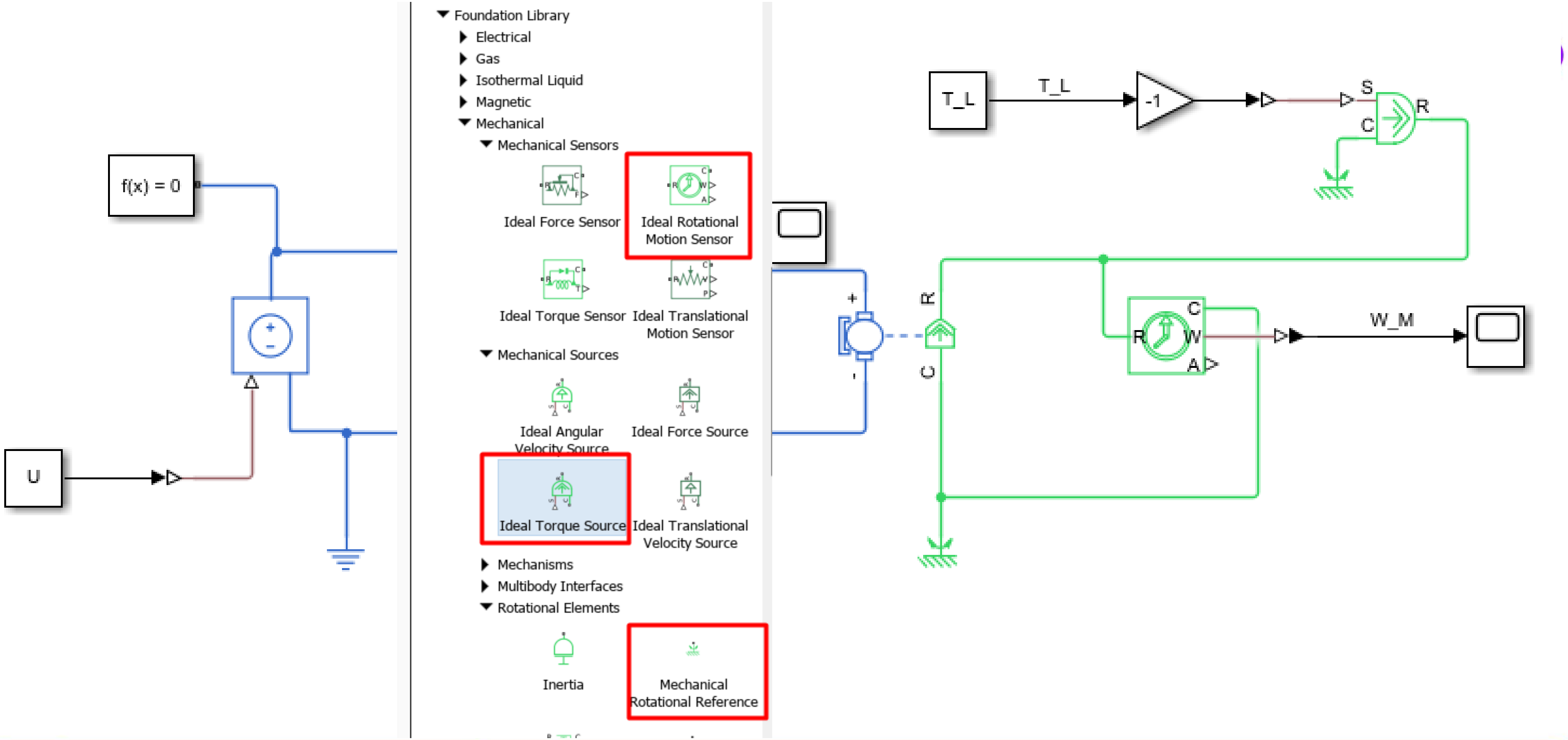


Simscape model





Simscape model



Block diagram model

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

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

State space model

Calculate matrices of the state space model:

$$\begin{cases} L_a \cdot \dfrac{di_a(t)}{dt} = U - R_a \cdot i_a(t) - \Psi \cdot \omega(t) \\ J \cdot \dfrac{d\omega(t)}{dt} = \Psi \cdot i_a(t) - T_L \end{cases} \Rightarrow \begin{cases} \dfrac{d\mathbf{x}}{dt} = \mathbf{Ax} + \mathbf{Bu} \\ y = \mathbf{Cx} + \mathbf{Du} \end{cases}$$

State vector:

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

Control vector:

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

Output:

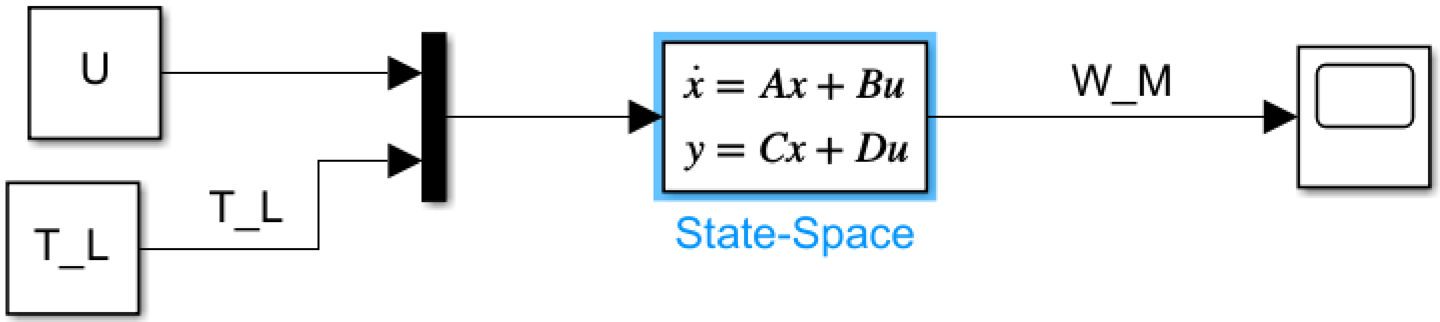
$$y = \omega$$

$$A, B, C, D - ?$$

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

Simulation 1:

```
%% Simulation
U = U_rated;
T_L = 0;
```

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

Simulation 2:

```
%% Simulation
U = 0;
T_L = T_rated;
```

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

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

Task 2

<u>Consider the transfer function from voltage to speed:</u>

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

<u>Using inverse Laplace transform, calculate the transient response function ω(t) for:</u>

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

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

Answer the question which function is ***underdamped?***

Task 2

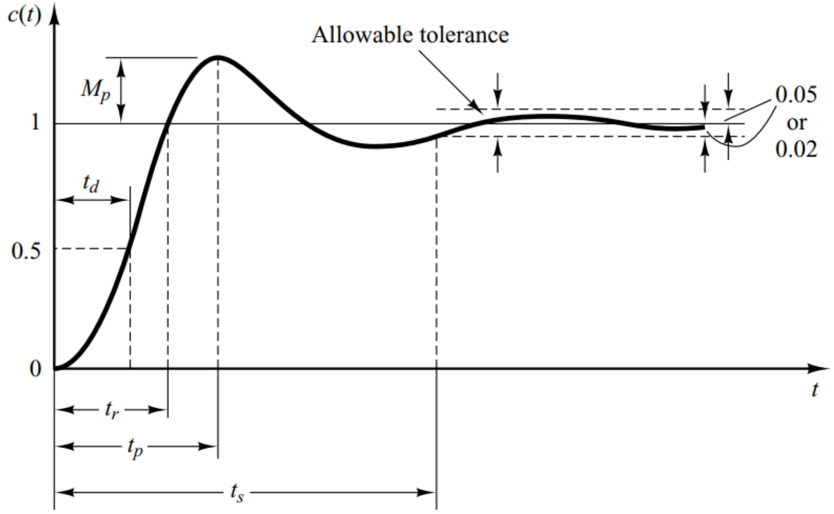
If you want to draw in MATLAB some function y(t) you can do it as follows:

```
%%
% Define time limits
start_time = 0;
stop_time = 0.5;
% Define time step
time_step = 0.001;
% Define the array of times
t = start_time:time_step:stop_time;
% Define the function
f_t = 1 - exp(-t./0.1); % here should be your own calculated time response
% Draw the graph of f_t
plot(t, f_t)
grid on
```

Task 2

<u>Draw calculated transient responses and find:</u>

- **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:

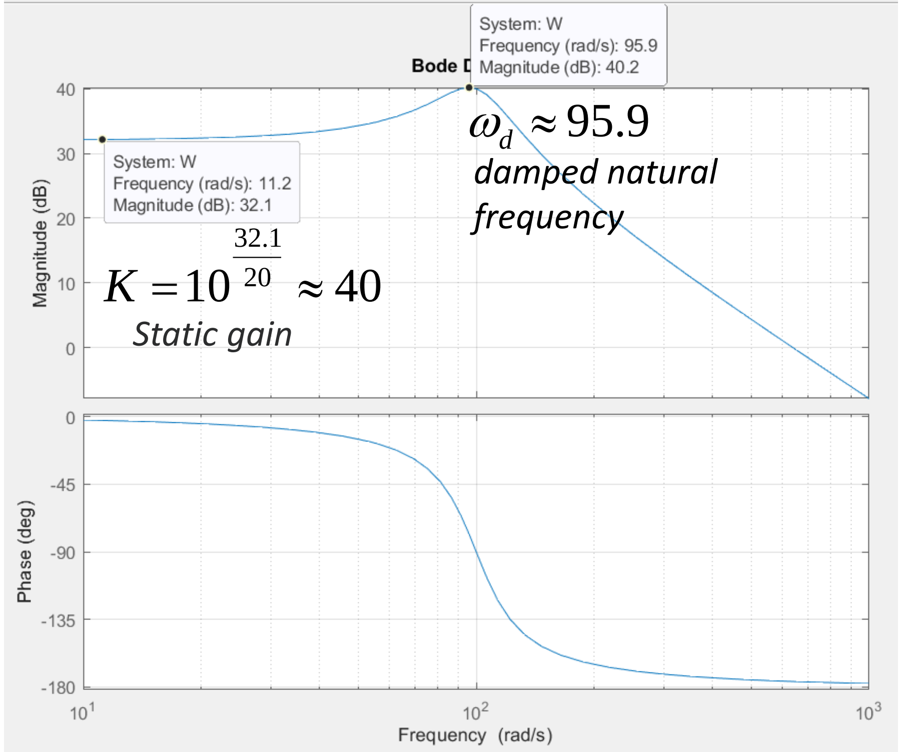
```
%%
K = 40;
wn = 100;
ksi = 0.2;

W = tf(K*wn^2, [1 2*ksi*wn wn^2]);

bode(W)
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!

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