Simulations in Mechatronic Design

Title of exercise	Ex. 4 – Modelling a stepping motor in MATLAB/Simulink environment			
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Group	1	No. of points		
Academic year	2023/2024		Σ	/7

1. Mathematical model of the stepping motor and the control system

$$M_e = -M_m \sin(\delta)\,,$$
$$\delta = Z_r[\gamma - \gamma_u(t)]$$

$$\gamma_u(t) = \gamma_{u0}\, E(1 + f_k t),$$

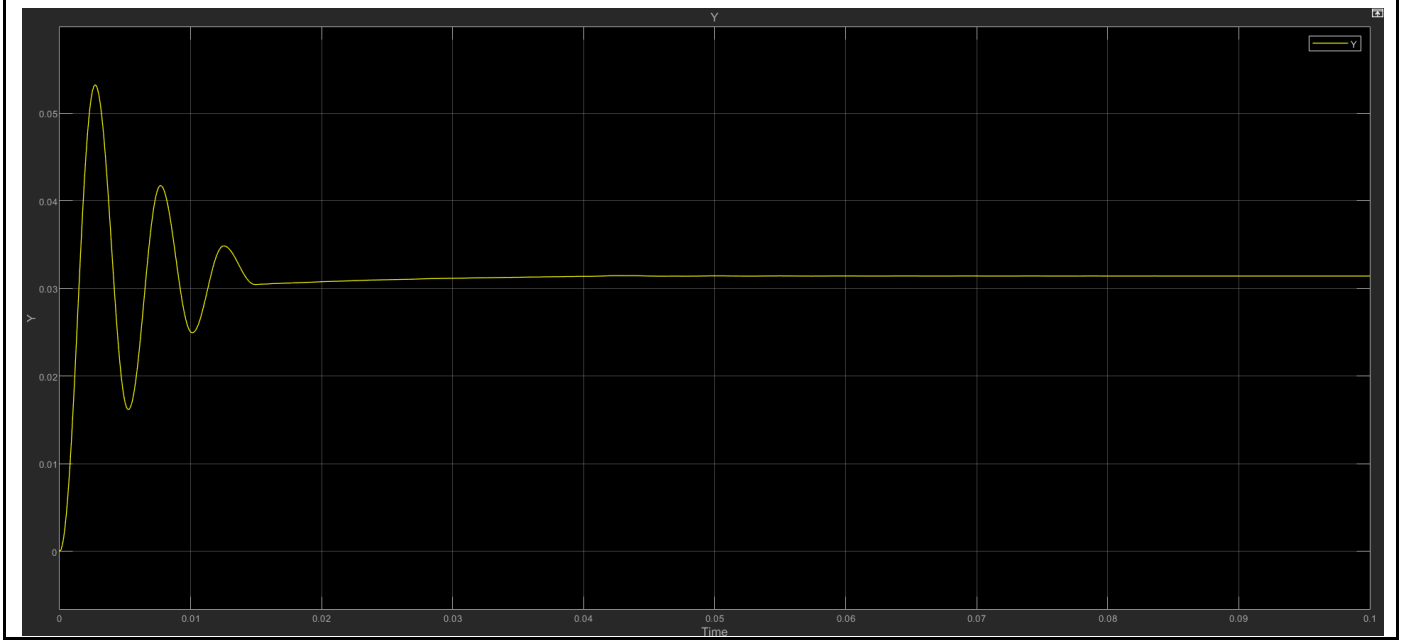
$$(J_s + J_{red})\frac{d^2\gamma}{dt^2} + D_m\frac{d\gamma}{dt} + (M_F + M_{Fred})\, sgn\left\{\frac{d\gamma}{dt}\right\} + M_{red} = M_e$$

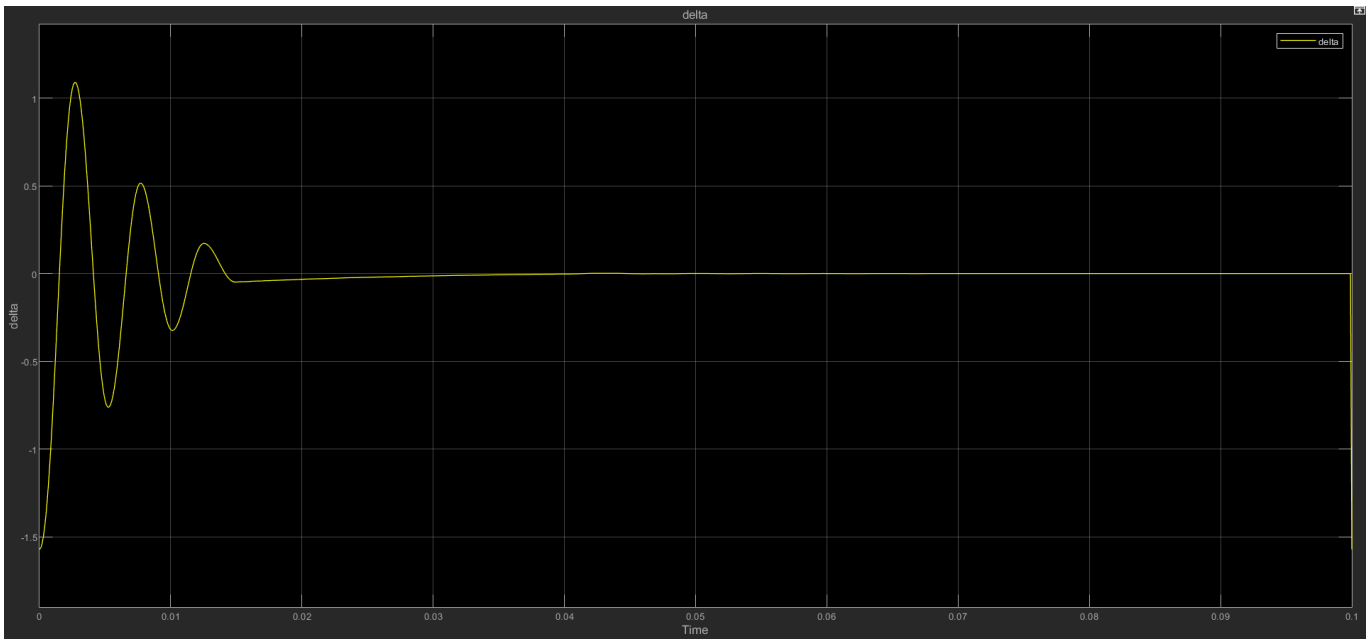
Symbol explanation

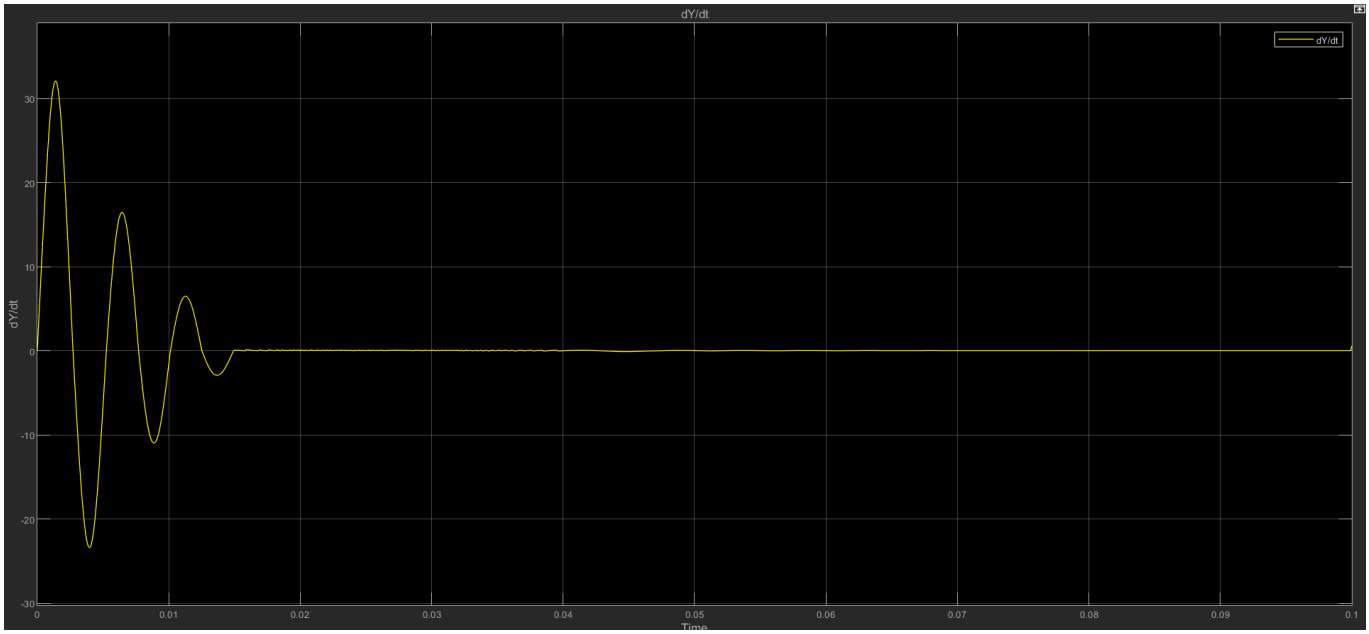
Symbol (and value)	Name of the quantity / parameter	Unit
Yuo	Basic step angle	degrees
fk	Constant commutation frequency	1/s
Zr	Number of the rotor teeth	1
Mm	Maximum torque	Nm
Me	Electromagnetic torque of the motor	
MF	Internal friction torque	N·m
MFred	Mechanical loads reduced to the motor shaft	Nmm
Dm	Damping factor	$N{\cdot}m\,/rad/$s

Symbol explanation		
Symbol (and value)	**Name of the quantity / parameter**	**Unit**
Mred	Mechanical loads reduced to the motor shaft	Nmm
Js	Mass moment of inertia of the rotor	Kg·m2
Y	rotor rotation angle	degrees
Jred	Mechanical loads reduced to the motor shaft	Nmm
delta	Incompatibility angle δ of the rotor	degrees
t	Time	s
E	Entier function (the integer part of the real number in parentheses)	1
Yu(t)	instantaneous position of stable equilibrium of the rotor	degrees

2. Graph of the step response of the unloaded motor



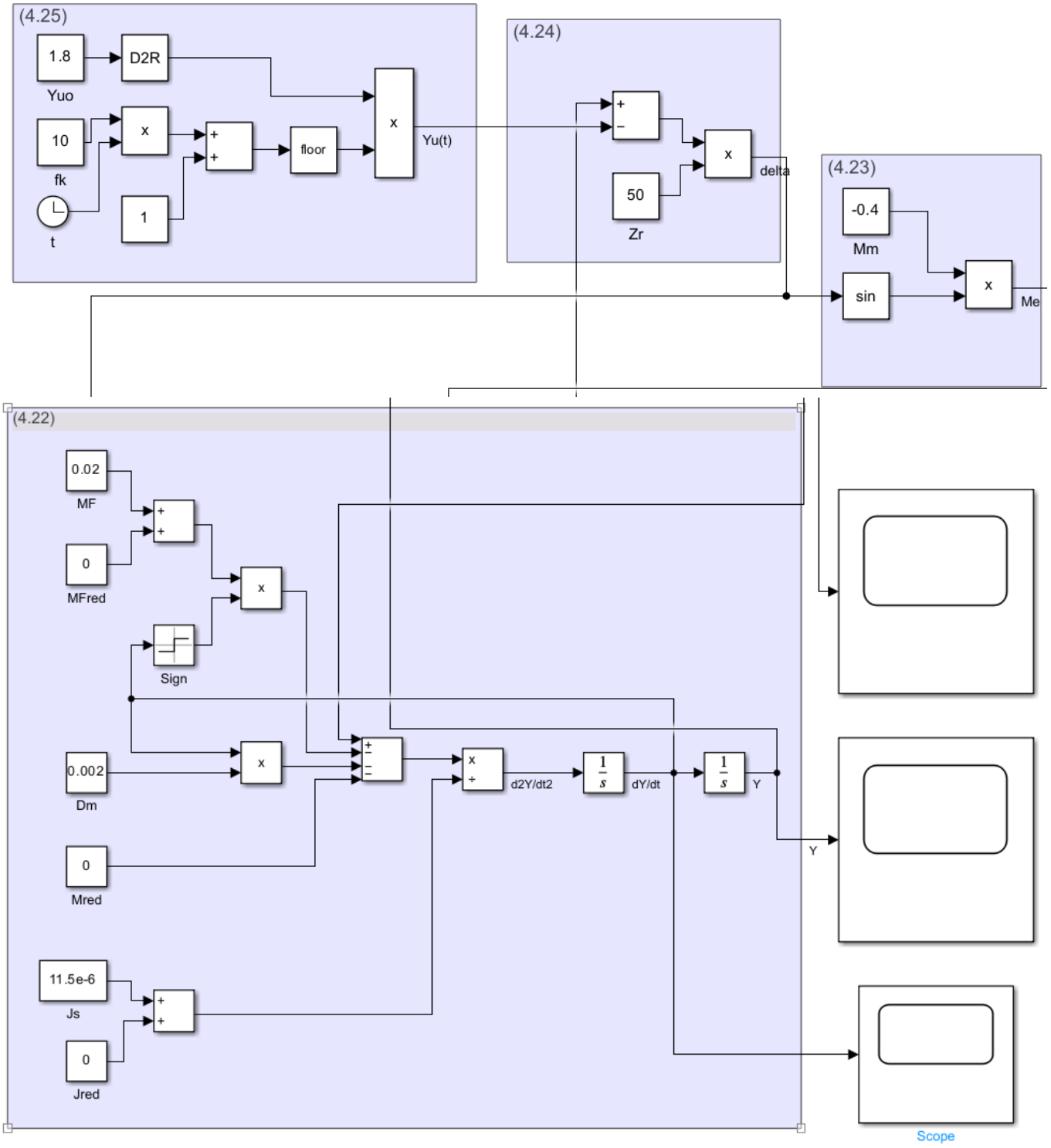




3. The results of determining the pull-in characteristic of the motor

L.p.	Loading torque M_{red}	Pull-in frequency f
1	**0.10**	**20**
2	**0.20**	**18**
3	**0.25**	**15**
4	**0.30**	**12**
5	**0.35**	**10**

4. A simulation model of the motor together with a model of the control system


(4.25)
1.8
D2R
Yuo
10
fk
t
1
floor
Yu(t)
(4.24)
50
Zr
delta
(4.23)
-0.4
Mm
sin
Me
(4.22)
0.02
MF
0
MFred
Sign
0.002
Dm
Mred
11.5e-6
Js
Jred
d2Y/dt2
dY/dt
Y
Scope