ELEC 341 – Graded Assignments

Assignment A5
State-Space Representation

10 Marks

Learning Objectives

State-Space Representation
- Mechanical System
- Electro-Mechanical System
- Transmissions

State Transition Matrix

Matlab
- ss()
- inv()
- eye()
- padarray() % may be useful

A State-Space representation of the Mechanical Circuit in Assignment #3 allows you to compute positions and forces without an electrical equivalent.

*Derive a state-space representation of "Mechanical Circuit". Configure your matrices so a **UNIT** step applies **F0 = 1N**.*

Use the state vector $\bar{x}$ and output vector $\bar{y}$, exactly as shown.

All speeds in (m/s), all distances in (m), all forces in (N).

The state vector $\bar{x}$ contains ALL POSSIBLE states. If any 2 states are dependent, remove the one further to the right.

$\bar{x} = [v0\ \ v1\ \ v2\ \ v3\ \ d0\ \ d1\ \ d20\ \ d32]^T$ where: $d20 = d2 - d0$ $d32 = d3 - d2$

$\bar{y} = [d3\ \ fk1]^T$ where: *fk1 is a **separating** force (see Assignment 3)*

Q1 4 mark(s) State Matrices

Compute the **MECHANICAL A** & **B** state matrices.

- Q1.A (mixed) Matrix
- Q1.B (mixed) Matrix

Q2 1 mark(s) Output Matrices

Compute the **C** & **D** output matrices.

- Q2.C (mixed) Matrix
- Q2.D (mixed) Matrix

There are multiple ways to get a transfer function from a set of State-Space matrices. You can compute the state transition matrix, or use the 'ss' function.

Q3 1 mark(s) Distance TF

Compute the transfer function **G**.

G Input = F0 Output = d3

- Q3.G (rad/Vs) LTI

Q4 1 mark(s) Force TF

Compute the transfer function **G**.

G Input = F0 Output = fk1

- Q4.G (rad/Vs) LTI

***COW:** Use **step()** to see the response of each transfer function.*

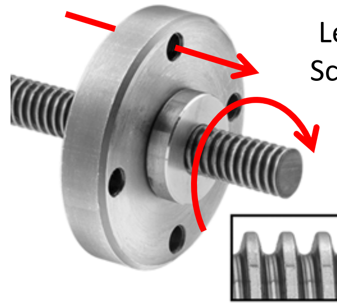
Compare them to what you got in Assignment #3.

Change your C&D matrices to check everything else you computed in Assignment #3.

Make sure you apply the same input force.

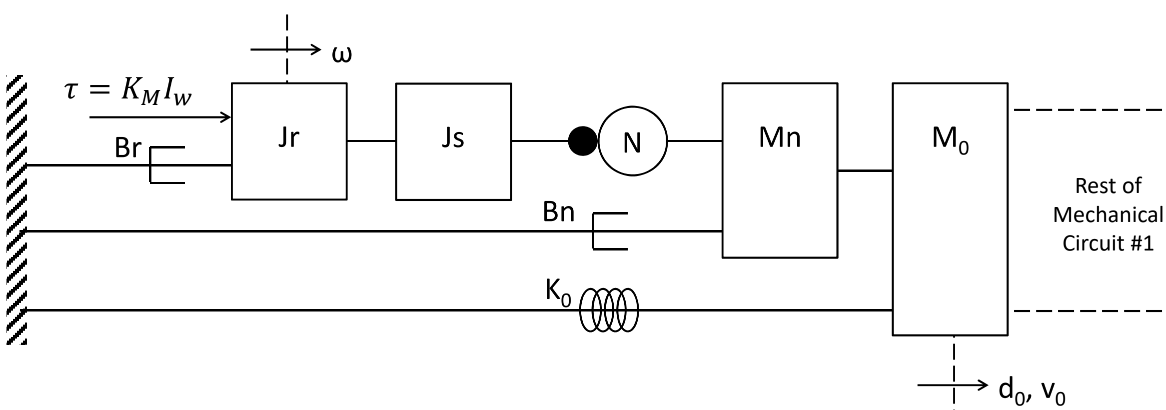
Replace F0 in Assignment #3 with a “Linear Actuator”. A linear actuator works just like a motor, but the motion is in a straight line. Hydraulic linear actuators are commonly used in excavators and other heavy equipment.

Another type of linear actuator is an electric motor with a rotary → linear transmission (like a lead-screw). When the motor turns the screw, the nut moves back & forth.



The applied force in the Mechanical Circuit in Assignment #3, is replaced with the Motor in Assignment #3 and a lead-screw with the following properties.

N	*= 5*	*(rev/m)*	*Transmission Ratio*
Js	*= #A x 20*	*(μNms²)*	*Screw Inertia*
Mn	*= #B / 2*	*(Kg)*	*Nut Mass*
Bn	*= #C / 2*	*(Ns/m)*	*Friction Between Screw & Nut*



Q5 2 mark(s) Actuated System

Modify the State-Space matrices to include the linear actuator in the State-Space model.
Configure your matrices so a **UNIT** step applies **Vin = 150V**.
Compute the transfer function G.

G	Input = Vin	Output = fk20
• Q5.G	(N/150V)	LTI

*Add gravity to **each** mass.* ***g = 9.81 (m/s^2)***

Assume the vertical direction is as depicted in Assignment #3.

Gravity may be modeled as an additional input to each mass.

The mass of the lead-screw nut is affected by gravity because it translates back and forth, but the inertia of the screw and motor are not, since they rotate.

Q6 2 mark(s) Gravity

Compute the transfer function **G**.
The unit-step response of **G** should show the effect of gravity only.

G	Input = gravity	Output = fk20
• Q6.G	(N/grav)	LTI

COW: *By the principle of super-position, adding the step responses of Q5.G and Q6.G gives the total response of the motor and gravity.*

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