ELEC 341 – Graded Assignments

Assignment A5
State-Space Representation

100 Marks

Required Files

Available on Canvas

- **e341-a5.pdf** *Assignment description (this document)*
- **a5Submit.p** *Grading script (**LATEST** version)*
- **e341-APE.pdf** *Instructions for submitting graded work (for reference)*

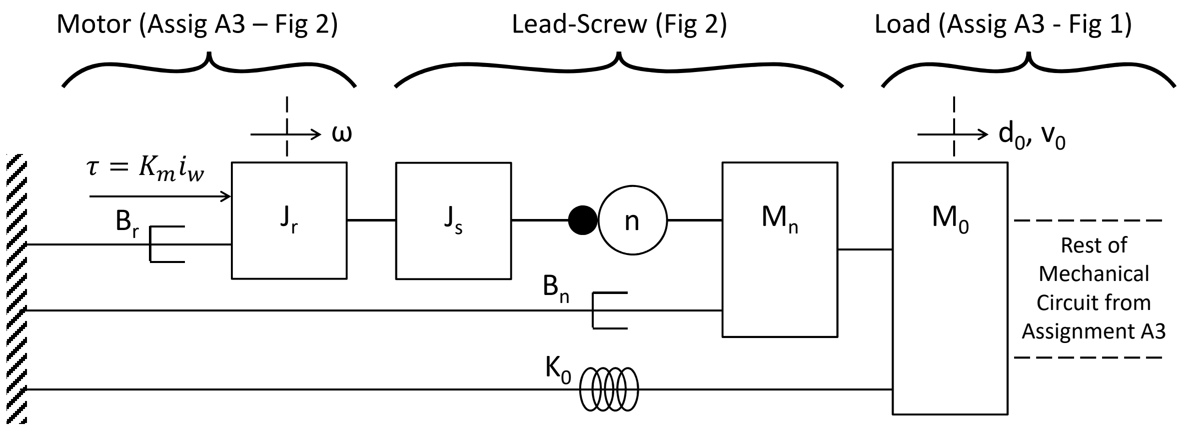
Topics

State Space
- state transition matrix

Output Matrices
- individual responses

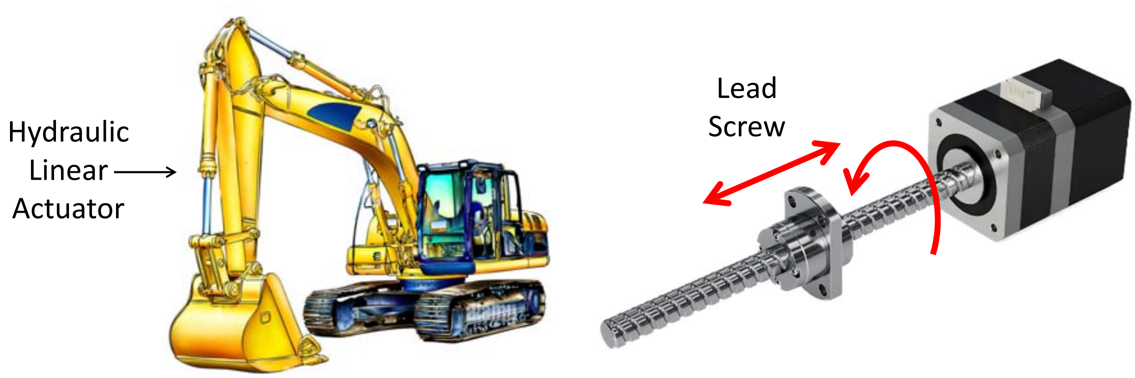
Total Response
- SIMO systems

Figure 1



Parameter	**Value**	**Physical Units**		**Parameter**	**Value**	**Physical Units**
J_s	#A x 20	µNms^2		M_n	#B / 2	Kg
n	5	rev/m		B_n	#C / 2	Ns/m

Figure 2



A linear actuator is 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). The motor turns the screw and the nut moves back & forth.

Develop a State-Space representation of **Figure 1** (from **Assig A3**).
Use the state $\bar{x}$ and output $\bar{y}$ vectors: $\bar{x} = [v_0\ \ v_1\ \ v_2\ \ v_3\ \ f_0\ \ f_1\ \ f_{20}\ \ f_{32}]^T$
Each distance **d** is in (m). $\bar{y} = [d_3\ \ f_{21}]^T$
Each speed **v** is in (m/s).
Each state force **f** is a spring **TENSION** force & f_{21} is a damper **TENSION** force, all in (N).
Find the **A&B** state matrices.

1. **20 mark(s) State-Space Matrices**
   - Q1.A (mixed) 8x8 Matrix
   - Q1.B (mixed) 8x1 Matrix

Develop **C&D** output matrices. Avoid the **'s'** operator so you can use the **ss()** function.
Find G_{d3}: $G_{d3} = d_3/F_0$
Find G_{f21}: $G_{f21} = f_{21}/F_0$

2. **20 mark(s) Outputs**
   - Q2.Gd3 (m/N) LTI
   - Q2.Gf21 (pure) LTI

COW: *Compare the step response of G_{d3} to what you got in **Assignment A3**.*
*Update your **C&D** matrices to check the rest of **Assignment A3**.*

Develop a State-Space representation of **Figure 1** (this **Assig A5**).
Use the state $\bar{x}$ and output $\bar{y}$ vectors: $\bar{x} = [v_0\ \ v_1\ \ v_2\ \ v_3\ \ f_0\ \ f_1\ \ f_{20}\ \ f_{32}\ \ i_w]^T$
Winding current i_w is in (A). $\bar{y} = [f_0\ \ f_1\ \ f_{20}\ \ f_{32}]^T$
Add gravity to each mass. $\bar{u} = [V_{in}\ \ g]^T$ **g = 9.81 (m/s²)**
Assume the vertical direction is as depicted in Assignment #3.
Find the **A&B** state matrices.

3. **20 mark(s) State-Space Matrices**
   - Q3.A (mixed) 9x9 Matrix
   - Q3.B (mixed) 9x2 Matrix

COW: *Gravity is modeled as an external force applied each mass.*
*It becomes a MISO system, which is why the **B** matrix has a second column.*
*Elements that rotate are **not affected** by gravity.*

Develop **C&D** output matrices. This is simple when all outputs are states.
Find the forced gain G_f: $G_f = f_{20}/V_{in}$
Find the gravitational gain G_g: $G_g = f_{20}/g$

4. **20 mark(s) Individual Gains**
   - Q4.Gf (pure) LTI
   - Q4.Gg (Ns²/m) LTI

Get the step response of each individual gain.
Use super-position to find the total response when: **V_{in} = 120V**
Find rise-time **T_r**.
Find peak-time **T_p**.
Find settle-time **T_s**.
Find final value **y_f**.
Find peak value **y_p**.
Find percentage overshoot **OS_y**.

5. 20 mark(s) Total Response

- Q5.Tr (s) Scalar
- Q5.Tp (s) Scalar
- Q5.Ts (s) Scalar
- Q5.yf (N) Scalar
- Q5.yp (N) Scalar
- Q5.OSy (%) Scalar

COW: *Peak value can be a negative number.*
It all depends on the sign of the final value.

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