MATLAB tutorial for mini project

Mohammad Najjarzadegan
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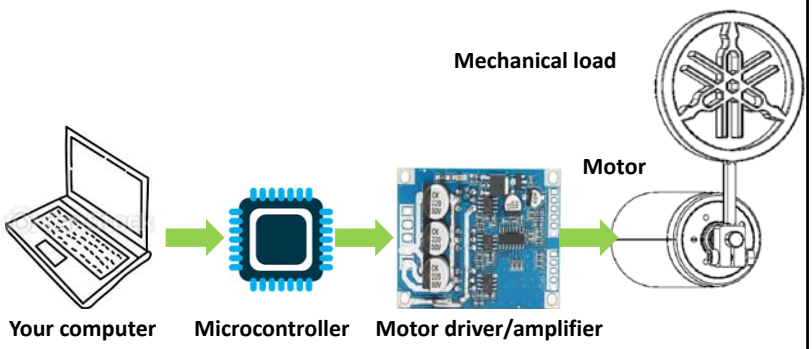
Outline

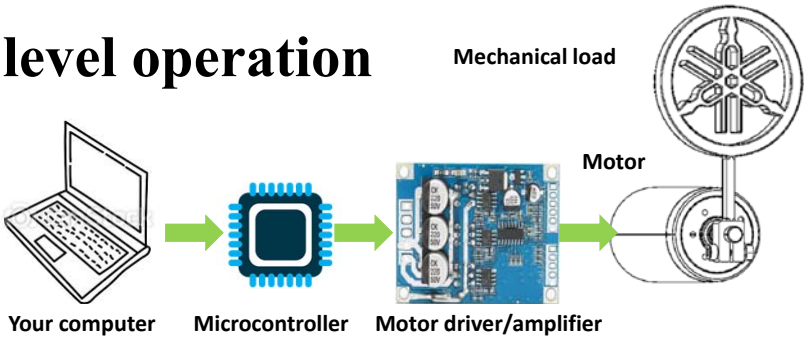
- **Mini project brief explanation**
- **System level operation**
- **Implementation in MATLAB**
- **Motor Modeling**
  - **For those who never worked with MATLAB/modeling**
  - **Overview for those who took ELEC 341**
- **Simulation in Simulink**

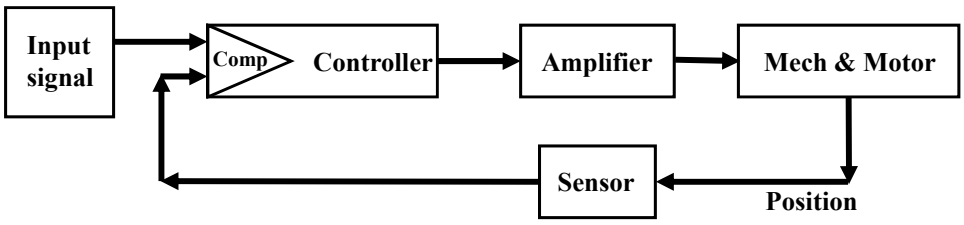
Mini project



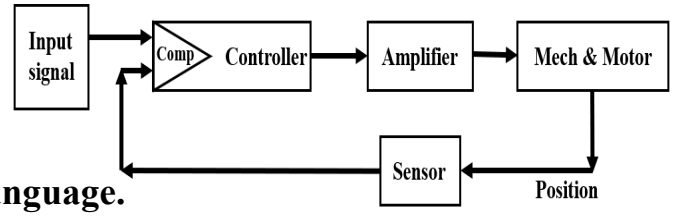
- **Computer**: MCU programming and command
- **MCU**: Digital controller
- **Driver/Amplifier**: Amplifies low voltage/current MCU signal
- **Motor**: Drives the mechanical load
- **Mechanical load**: Simply a pandelum

System level operation



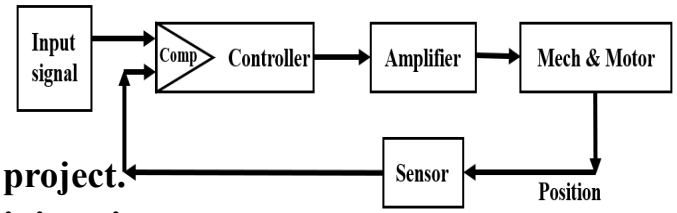


Matlab/Simulink



- Matlab is mathematical language.
- Only understands numbers, equations and mathematical operations.
- We need to model the physical units with mathematical blocks.

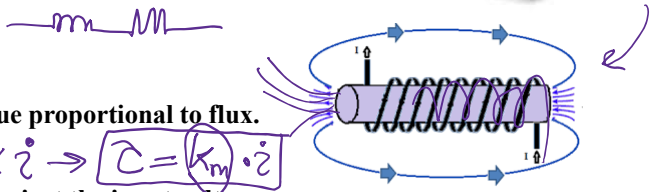
Modeling



- No Amplifier for the mini project.
- Sensor is Unity gain for mini project.
- Comparison is basically a subtraction.
- The controller is a P-controller, i.e. a constant gain .
- Input signal is a step-function from 0 to 90.
- Model Motor&Mech is the challenging part.

Motor modeling

- Motors have some windings in their rotor/stator.
- Winding produces magnetic field and acts as an inductor.
- The wires also have some resistance.

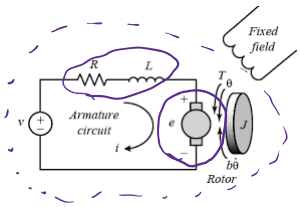


- Flux proportional to current and torque proportional to flux.

$$\tau \propto B \propto i \rightarrow \tau \propto i \rightarrow \tau = k_m \cdot i$$

- Back emf proportional to speed and against the input voltage.

$$e \propto \omega \rightarrow V_{b\text{-}emf} = k_a \cdot \omega$$



Motor modeling

$$J = J_{motor\ rotor} + J_{Load}$$

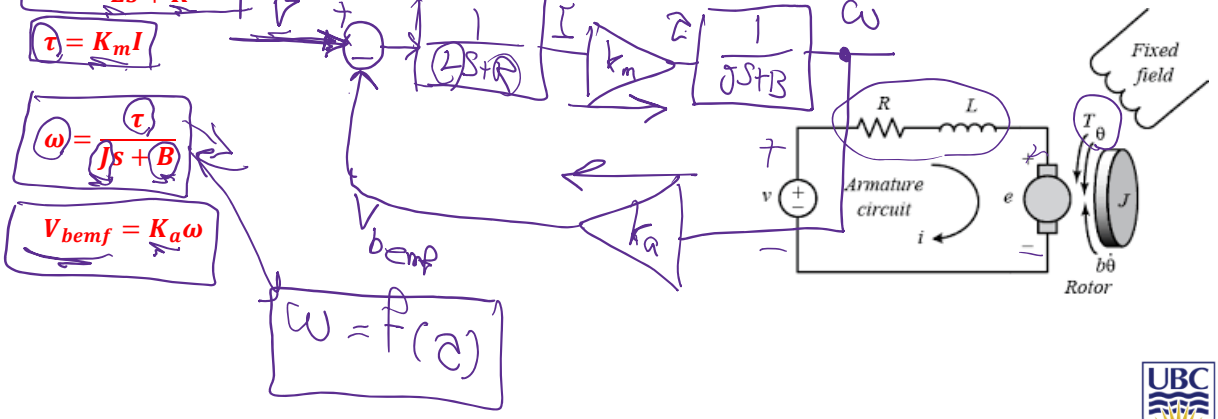
$$I = \frac{V - V_{bemf}}{Ls + R}$$

$$\tau = K_m I$$

$$\omega = \frac{\tau}{Js + B}$$

$$V_{bemf} = K_a \omega$$

$$\omega = f(\tau)$$



Datasheet

$1\ rpm = \frac{1\ Rotation}{minute} = \frac{2\pi\ (rad)}{60\ s} = \frac{\pi}{30}\ \left(\frac{rad}{s}\right)$

R
L
k_m
$1/k_a$

$k_m = k_a$

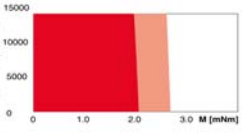
M 3:2

Motor Data								
1_ Nominal voltage	V	1.5	3	4.5	6	9	12	
2_ No load speed	rpm	11600	12200	12000	12200	12000	11300	1183
3_ No load current	mA	72.1	38.7	25.2	19.3	12.6	8.71	
4_ Nominal speed	rpm	9230	6930	7110	6640	6780	5980	626.2
5_ Nominal torque (max. continuous torque)	mNm	1.04	2.05	2.2	1.94	2.06	2.03	
6_ Nominal current (max. continuous current)	A	0.924	0.922	0.648	0.436	0.304	0.211	
7_ Stall torque	mNm	5.13	4.81	5.45	4.32	4.8	4.36	
8_ Stall current	A	4.23	2.09	1.55	0.937	0.682	0.439	
9_ Max. efficiency	%	75	75	77	74	75	74	
10_ Terminal resistance	Ω	0.355	1.44	2.9	6.4	13.2	27.3	
11_ Terminal inductance	mH	0.005	0.020	0.045	0.078	0.181	0.362	
12_ Torque constant	mNm/A	1.21	2.31	3.52	4.61	7.04	10.0	Km = Ka
13_ Speed constant	rpm/V	7870	4140	2710	2070	1360	960	
14_ Speed/torque gradient	rpm/mNm	2300	2590	2240	2880	2550	2640	
15_ Mechanical time constant	ms	3.68	3.67	3.54	3.58	3.56	3.59	
16_ Rotor inertia	gcm²	0.153	0.132	0.151	0.119	0.134	0.130	*10^(-7)

$kg \cdot m^2$

Thermal data		**Operating range**
17_ Thermal resistance housing-ambient	K/W	36.5
18_ Thermal resistance winding-housing	K/W	10.6
19_ Thermal time constant winding	s	3.94
20_ Thermal time constant motor	s	151
21_ Ambient temperature ball bearings	°C	-40...+85
Ambient temperature sleeve bearings	°C	-30...+85
22_ Max. winding temperature	°C	100
Mechanical data ball bearings		
23_ Max. speed	rpm	14300
24_ Axial play	mm	0...0.1
Preload	N	0.5
25_ Radial play	mm	0.015
26_ Max. axial load (dynamic)	N	0.5
27_ Max. force for press fits (static)	N	8.8
(static, shaft supported)	N	120
28_ Max. radial load [mm from flange]	N	1.5 [5]
Mechanical data sleeve bearings		
23_ Max. speed	rpm	14300
24_ Axial play	mm	0...0.15
Preload	N	0
25_ Radial play	mm	0.015
26_ Max. axial load (dynamic)	N	0.1
27_ Max. force for press fits (static)	N	30
(static, shaft supported)	N	120
28_ Max. radial load [mm from flange]	N	0.8 [5]
Other specifications		
29_ Number of pole pairs		1

n [rpm] Winding 4.5 V



Continuous operation
Continuous operation with reduced thermal resistance R_{th} 50%
Intermittent operation

maxon Modular System — Details on catalog page 32

maxon gear	Stages [opt.]	maxon sensor	maxon motor control
323_GPX 10 A	1–5	433_ENX 10 EASY	486_ESCON Module 24/2
		433_ENX 10 QUAD	486_ESCON 36/2 DC
		434_ENX 10 EASY XT	498_EPOS4 Mod./Comp. 24/1.5

Implementation in Simulink

- Input step function
- Constant gain
- Transfer function
- Subtraction
- Scope