CNC Fact sheet

1) Dynamical Model

1.1) Mechanical & Electrical

$$G(s) = \frac{\frac{K}{LJ_{\text{tot}}}}{s^2 + \gamma s + \delta} \begin{bmatrix} \frac{1}{S}\frac{1}{r} \\ 1 \end{bmatrix} = \frac{g}{s^2 + \gamma s + \delta} \begin{bmatrix} \frac{1}{S}\frac{1}{r} \\ 1 \end{bmatrix} \quad 1.$$

Where $\gamma = \frac{\beta L + RJ}{J_{\text{tot}} L}$, $\delta = \frac{k^2 + \beta R}{J_{\text{tot}} L}$, $g = \frac{K}{J_{\text{tot}} L}$

1.2) First order approximation (only mechanical)

Voltage → Angular Speed transfer function: $G_\omega(s) = \frac{\mu}{\tau s + 1}$

Voltage → Shaft angle transfer function: $G_\theta(s) = \frac{1}{s}\frac{\mu}{\tau s + 1}$

1.2.a) Estimated parameters

	Motor 0	**Motor 1**
μ (DC Gain) $[\frac{\text{rad}}{s}\frac{1}{V}]$	-1.4479	-1.4684
τ (Time constant) [s]	0.0401	0.0409
$\frac{1}{\tau}$ (Pole of the mechanical system) [rad/s]	24.9218	24.4398

2) Joint space

$$\theta_{A1} \in \begin{bmatrix} -0.2967 \\ 0.5411 \end{bmatrix} \text{ rad} = \begin{bmatrix} -17° \\ 31° \end{bmatrix} \approx 48° \text{ peak peak} \quad 2.$$

$$\theta_{A2} \in \begin{bmatrix} -0.4712 \\ 0.4712 \end{bmatrix} \text{ rad} = \begin{bmatrix} -27° \\ 27° \end{bmatrix} \approx 52° \text{ peak peak} \quad 3.$$

3) Control

3.1) Frequency Based Design

- (Candidate) Control Bandwidth: 24 rad/s
- Phase Margin: 70° (balance between effort and overshoot)
- Control Scheme: PD

	Motor 0	**Motor 1**
Kp	-20.82	-20.604
Kd	-0.4158	-0.423
N	251	251
Rise Time [s]	0.0620	0.0620
Settling Time [s]	0.1880	0.1920
Overshoot [%]	5.6800	6.0723

4) MISC

- Conversion from encoder steps to radians:

$$\text{(angle in radians)} = \text{(encoder steps)} \times \frac{2\pi}{4096} = \text{(encoder steps)} \times \frac{\pi}{2048} \tag{4.}$$

- Hz to Rad/s and vice-versa:

$$\omega = 2\pi f$$
$$f = \frac{\omega}{2\pi} \tag{5.}$$

- Angular resolution:

  tick $= \frac{360°}{4096} = 0.087° \approx 0.09° \approx 0.1° = 0.0015$ rad

- .mat file row structure 1st, 2nd and 3rd labs

.mat Row	**Quantity**	**Unit**
1	time	s
2	Encoder 0	steps
3	Encoder 1	steps
4	Motor 0	V
5	Motor 1	V
6	ω Natural Frequency (only for looong test)	rad/s

- .mat file row structure 3rd lab with PLANT 🌴

muxer id	**.mat row**	**Name**	Unit	Description
1	2	ENC0 / Y0	rad	angular distance from rest position
2	3	ENC1 / Y1	rad	angular distance from rest position
3	4	U0	V	voltage requested by control law (copy of input signal)
4	5	U1	V	voltage requested by control law (copy of input signal)
5	6	U0_SAT	V	actual voltage provided to actuator after saturation (for anti-windup ?)
6	7	U1_SAT	V	actual voltage provided to actuator after saturation (for anti-windup?)
7	8	EC0	/	Error code for joint 0
8	9	EC1	/	Error code for joint 1

- .mat file row structure 4th lab with PLANT 🌴

muxer id	**.mat row**	**Name**	Unit	Description
1	2	ENC0 / Y0	rad	angular distance from rest position
2	3	ENC1 / Y1	rad	angular distance from rest position
3	4	U0	V	voltage requested by control law (copy of input signal)
4	5	U1	V	voltage requested by control law (copy of input signal)
5	6	U0_SAT	V	actual voltage provided to actuator after saturation (for anti-windup ?)
6	7	U1_SAT	V	actual voltage provided to actuator after saturation (for anti-windup?)
7	8	EC0	/	Error code for joint 0
8	9	EC1	/	Error code for joint 1
9	10	Y0_REF	rad	Setpoint motor 0
10	11	Y1_REF	rad	Setpoint motor 1
11	12	D0	V	Disturbance motor 0
12	13	D1	V	Disturbance motor 1

- .mat file row structure with observer

muxer id	**.mat row**	**Name**	Unit	Description
1	**2**	ENC0 / Y0	rad	angular distance from rest position
2	**3**	ENC1 / Y1	rad	angular distance from rest position
3	**4**	U0	V	voltage requested by control law (copy of input signal)
4	**5**	U1	V	voltage requested by control law (copy of input signal)
5	**6**	U0_SAT	V	actual voltage provided to actuator after saturation (for anti-windup ?)
6	**7**	U1_SAT	V	actual voltage provided to actuator after saturation (for anti-windup?)
7	**8**	EC0	/	Error code for joint 0
8	**9**	EC1	/	Error code for joint 1
9	**10**	Y0_REF	rad	Setpoint motor 0
10	**11**	Y1_REF	rad	Setpoint motor 1
11	**12**	D0	V	Disturbance motor 0
12	**13**	D1	V	Disturbance motor 1
13	**14**	LU, θ_0	rad	Lumberger Observer, angle
14	**15**	LU, ω_0	rad/s	LU, angular velocity
15	**16**	LU, d_0	V	LU, estimation of disturbance, to compare with D0 at row 12
16	**17**	LU, θ_1	rad	-
17	**18**	LU, ω_1	rad/s	-
18	**19**	LU, d_1	V	-
19	**20**	KF, θ_0	rad	-
20	**21**	KF, ω_0	rad/s	-
21	**22**	KF, d_0	V	-
22	**23**	KF, θ_1	rad	-
23	**24**	KF, ω_1	rad/s	-
24	**25**	KF, d_1	V	-