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# Project 4

a) I cannot tune only $K_p$ such that $\omega_{meas}$ tracks $\omega_{ref}$, or is close to tracking $\omega_{ref}$. This is because for $K_i = 0$, the system is in an algebraic loop. The transfer function has no poles so the system has no dynamics. The system tries to respond to any error by imediately tracking the output, which results in a negative error, which the system tries to track by throwing the motor into full reverse. This is not a 'true' algebraic loop because the system can only respond as fast as the sampling time, so after awhile, for low $K_p$ the system settles down, but not to the correct value, because

$$e_\omega = \frac{1}{1 + K_p^{\,rot} \cdot C_\omega}, \quad C_\omega \doteq 1 \;;\; K_p \approx 1$$

$$e_\omega \approx \frac{1}{1+1} = \frac{1}{2}$$, which is shown in figure 1

b) $K_p \neq 0$ is not necessary for the system to track the reference, as shown in Figure 2

$$\frac{C_\omega}{\omega_{ref}} = \frac{1}{1 + \frac{K_i C_\omega}{s}} = \frac{s}{s + K_i C_\omega}$$

for step reference, $$e_\omega(\infty) = \lim_{s \to 0} \frac{s}{s + K_i C_\omega} = 0$$

$K_p = 0$ and $K_i = 22$ allows the system to track the turning rate reference with only a little steady state noise. (figure 3)

c) $K_p^{vel}$ was tuned to be 20
$K_i^{vel}$ was tuned to be 700

Velocity Data shown in figure 4

d) I changed the script so that the $\omega$ reference was a function of $\cos(k/48.1)$ where 48.1 was determined by tuning. This produced a figure 8 trajectory shown in figure 5

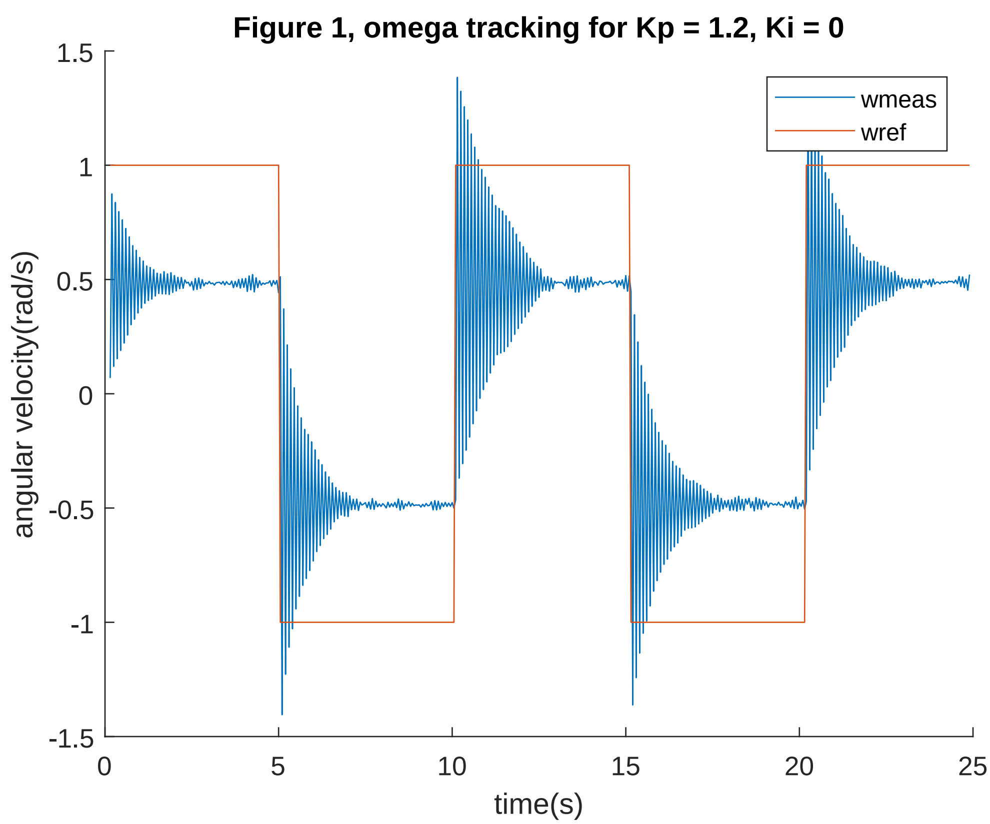
Figure 1, omega tracking for Kp = 1.2, Ki = 0
wmeas
wref
1.5
1
0.5
0
-0.5
-1
-1.5
0
5
10
15
20
25
angular velocity(rad/s)
time(s)

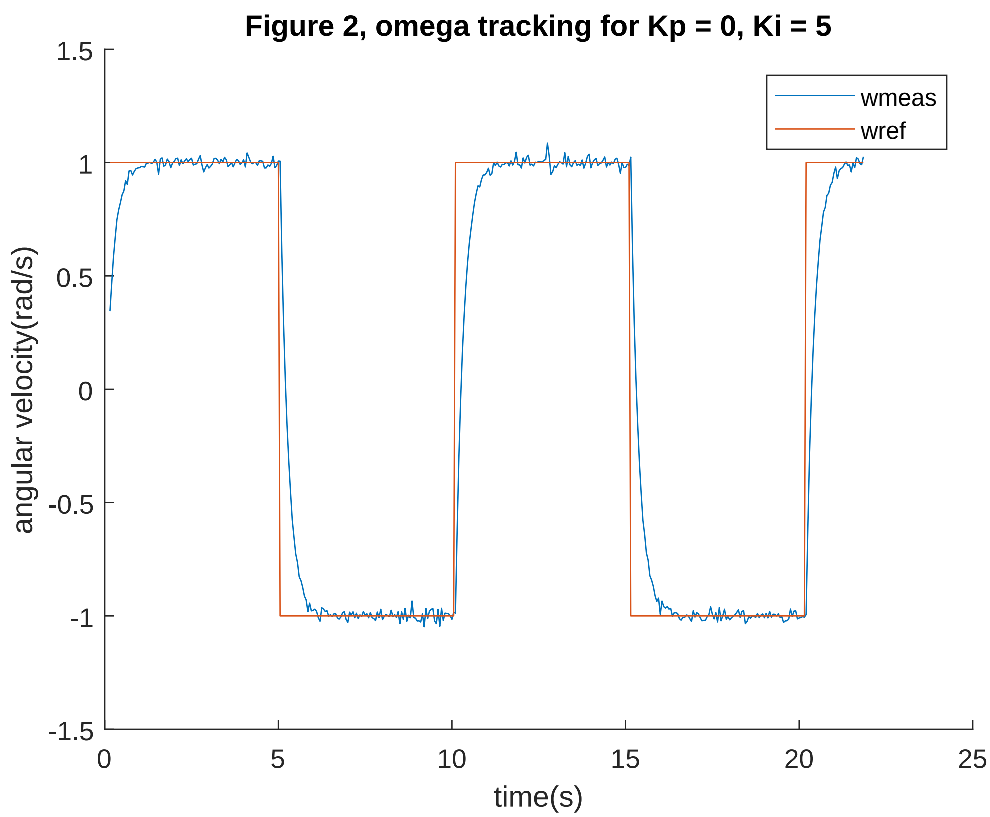
Figure 2, omega tracking for Kp = 0, Ki = 5
wmeas
wref
1.5
1
0.5
0
-0.5
-1
-1.5
angular velocity(rad/s)
0
5
10
15
20
25
time(s)

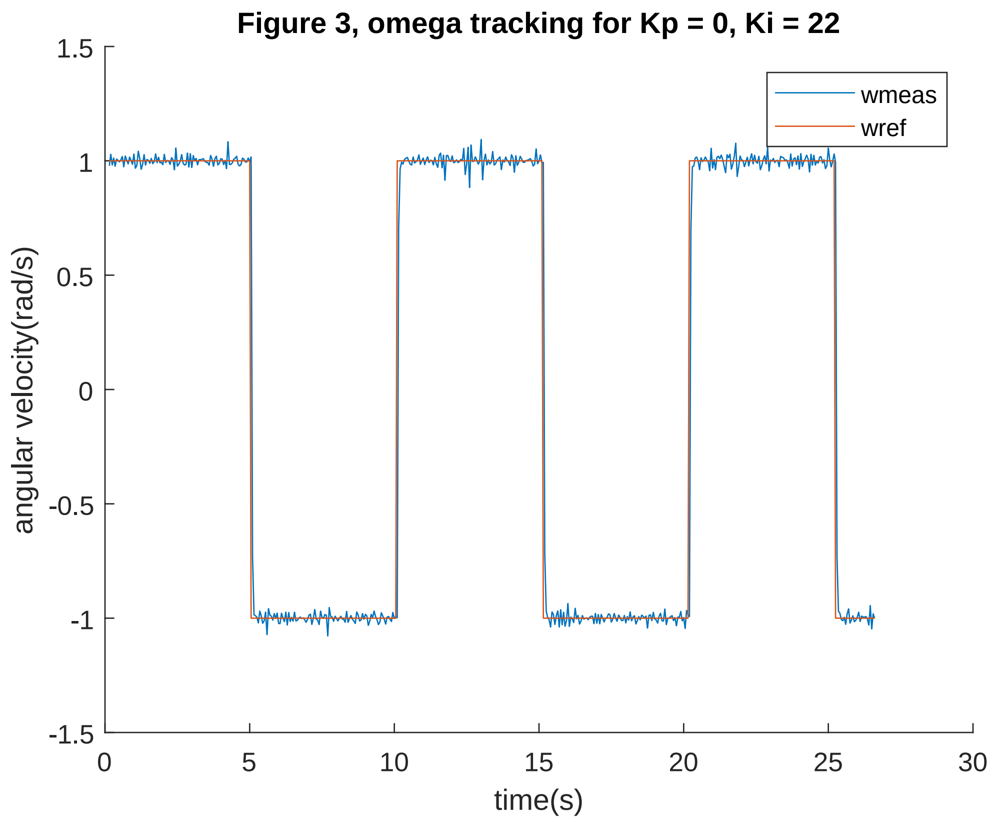
Figure 3, omega tracking for Kp = 0, Ki = 22
wmeas
wref
angular velocity(rad/s)
time(s)
1.5
1
0.5
0
-0.5
-1
-1.5
0
5
10
15
20
25
30

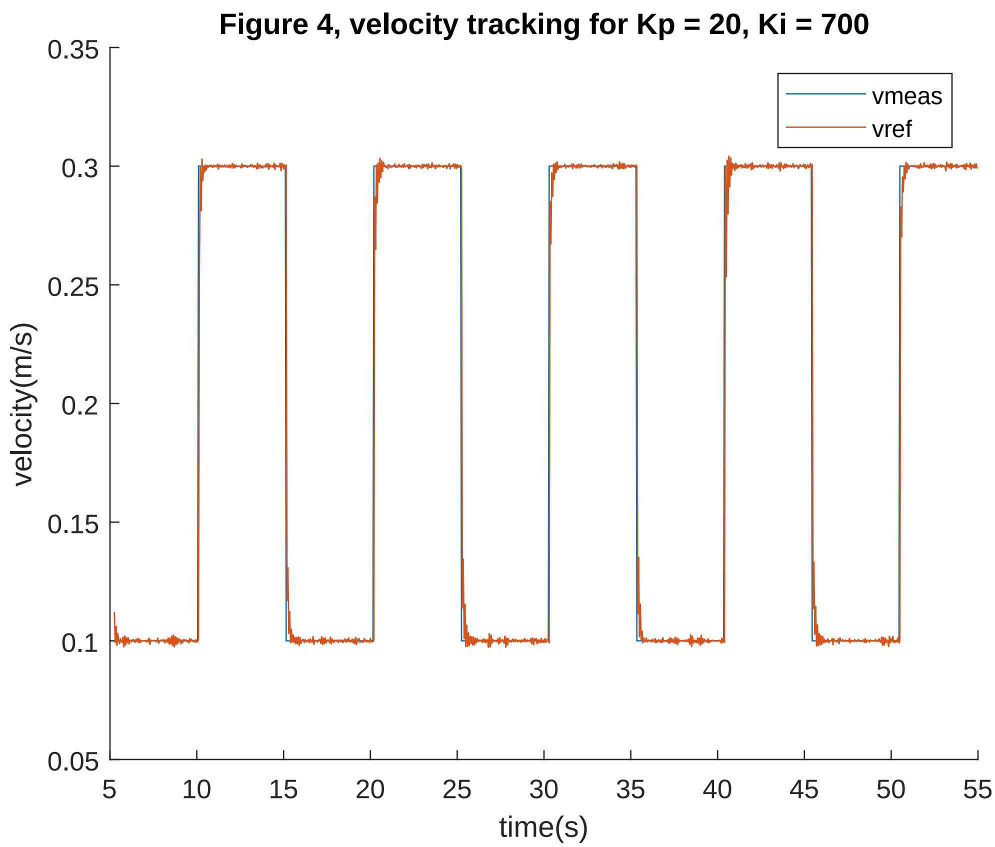

Figure 4, velocity tracking for Kp = 20, Ki = 700
vmeas
vref
velocity(m/s)
time(s)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
5
10
15
20
25
30
35
40
45
50
55

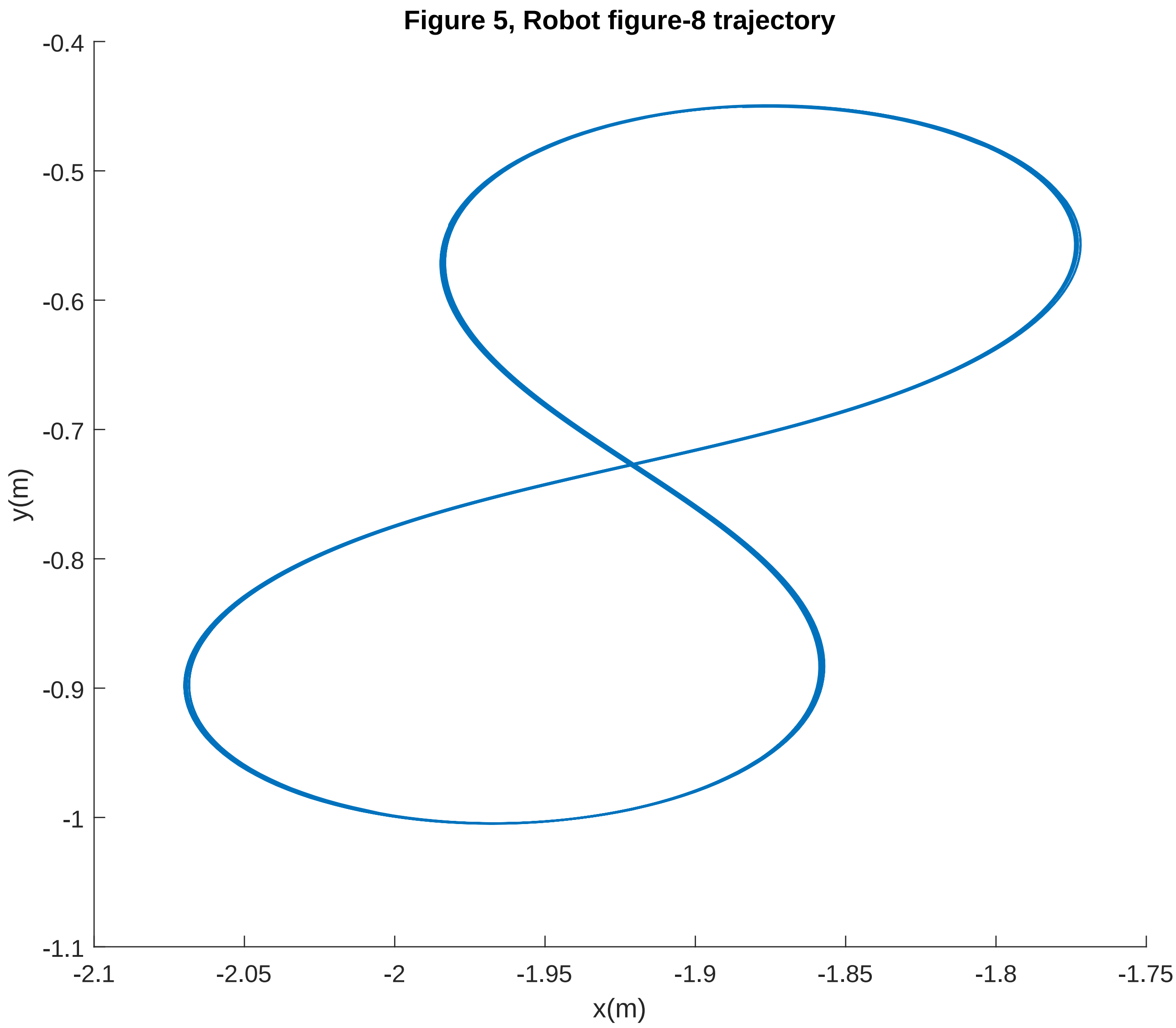

Figure 5, Robot figure-8 trajectory
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
y(m)
-2.1
-2.05
-2
-1.95
-1.9
-1.85
-1.8
-1.75
x(m)