به نام خدا

دانشگاه تهران

دانشکده مهندسی برق و کامپیوتر

کنترل صنعتی

تمرین ۴

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تاریخ ارسال گزارش	

فهرست

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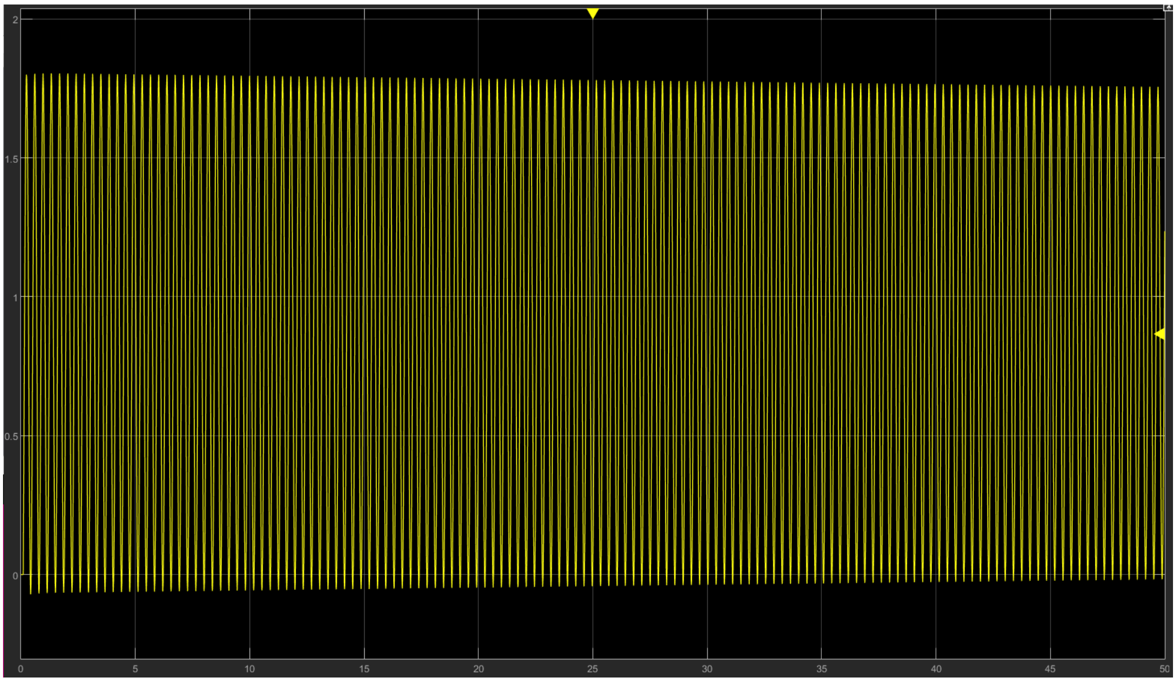
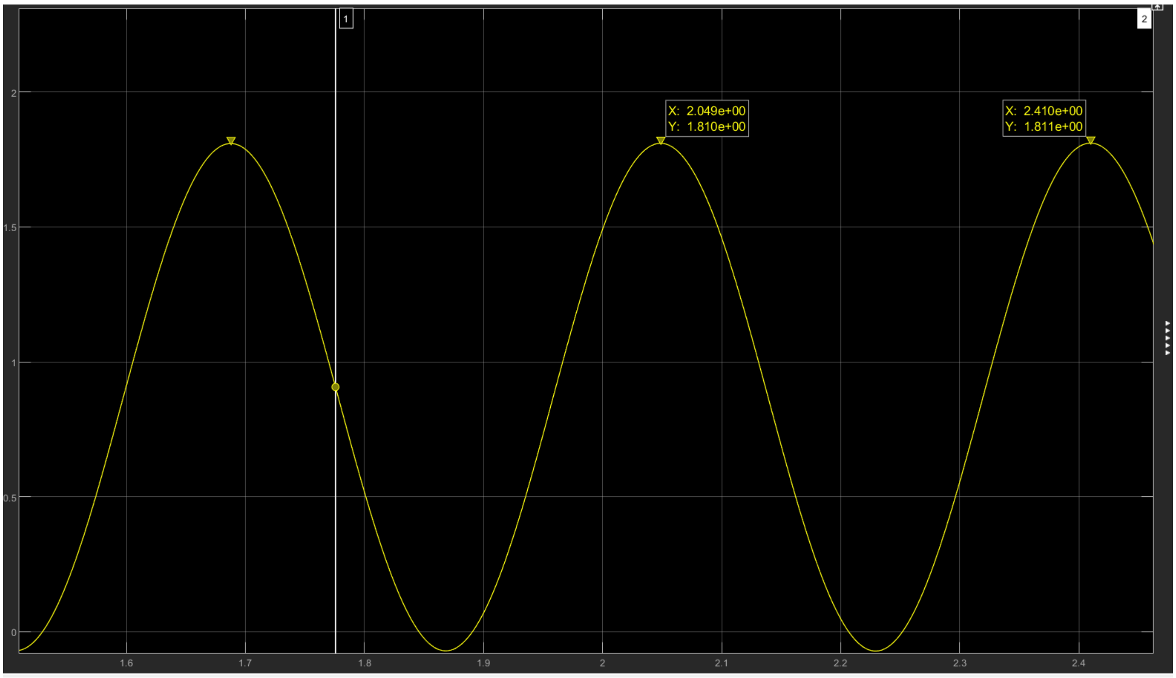
A

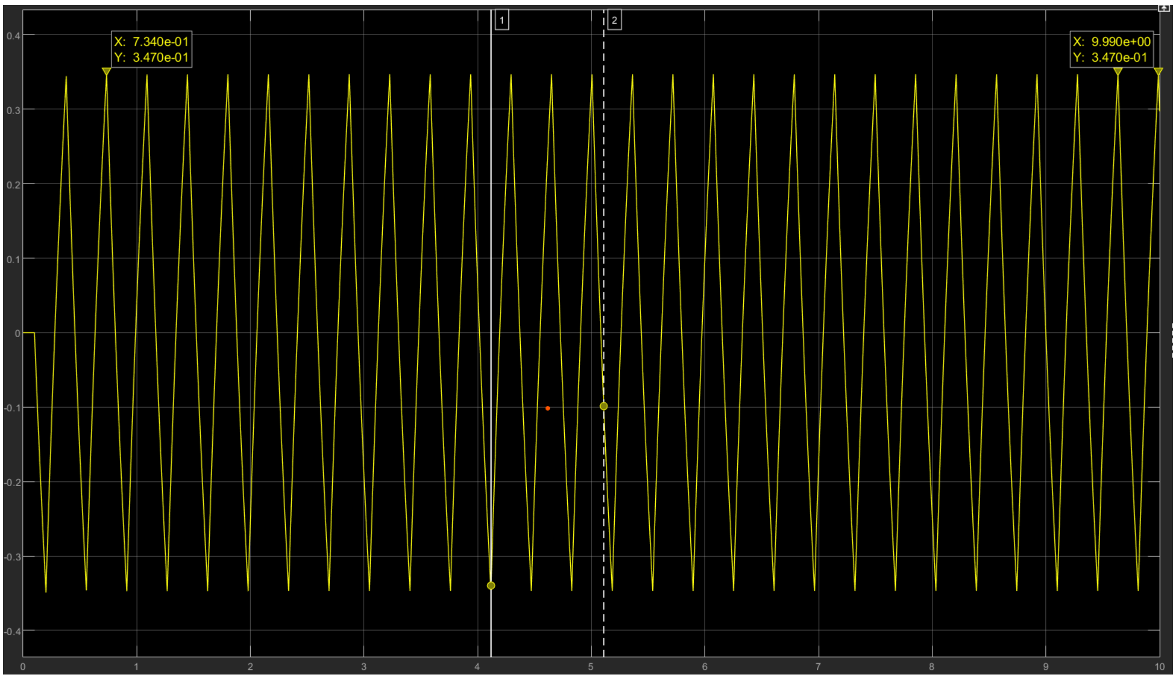
For findin K_u and $T_u$we try to increase the gain until it swining

The $K_u = 4.28$ and $T_u = 2.41 - 2.05 = 0.36$ $which$ $w_u = 2\frac{\pi}{0.36} = 17.4532$





B

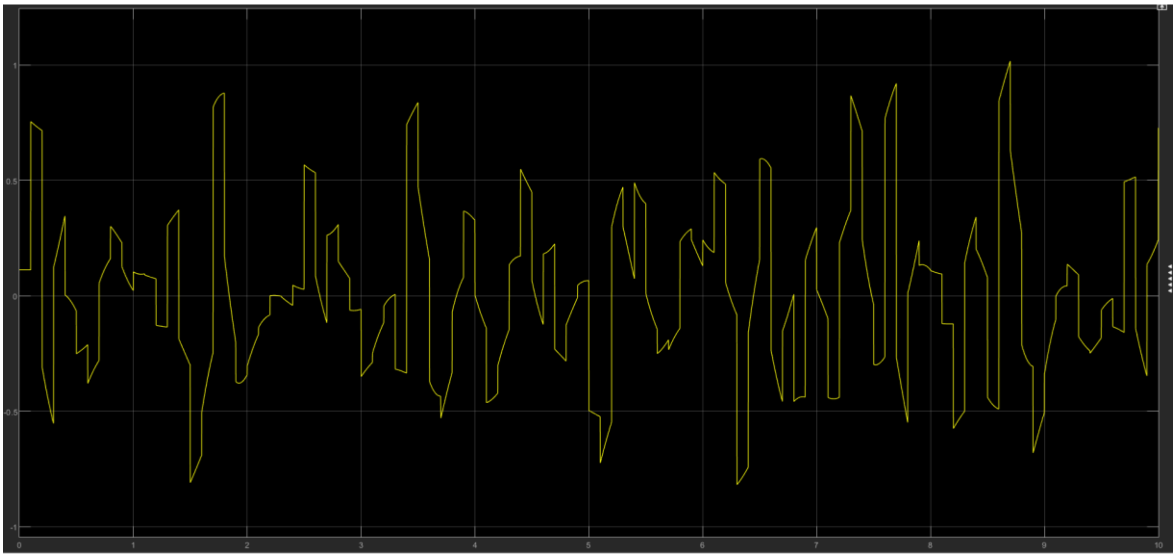


$$K_u = \frac{4d}{\pi a} = \frac{40}{\pi 3.47} = 3.67$$

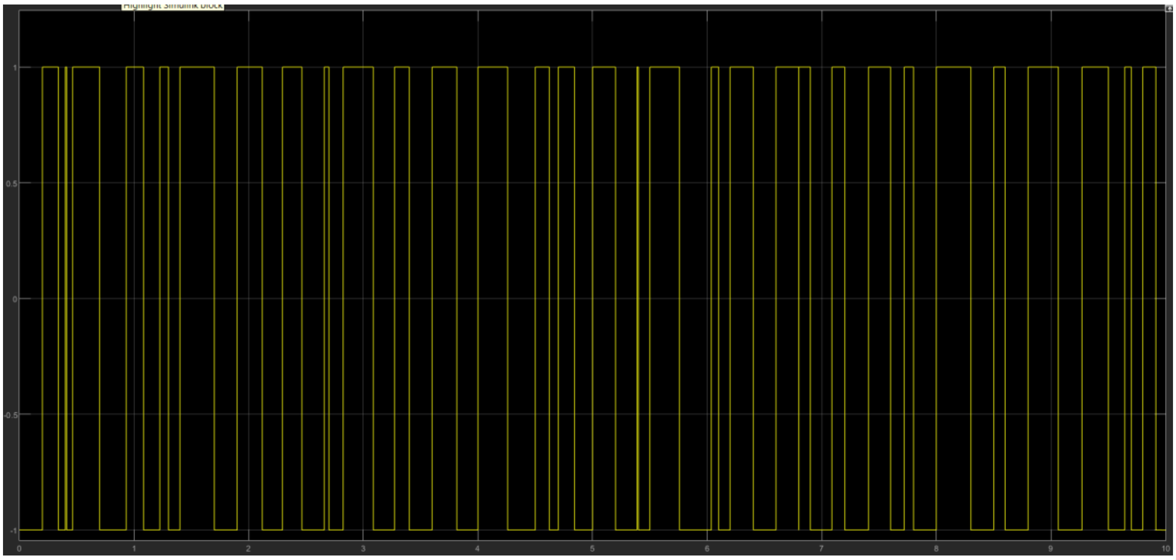
$$T_u = 0.361 \; w_u = 17.4$$

C

Output signal with noise without relay:

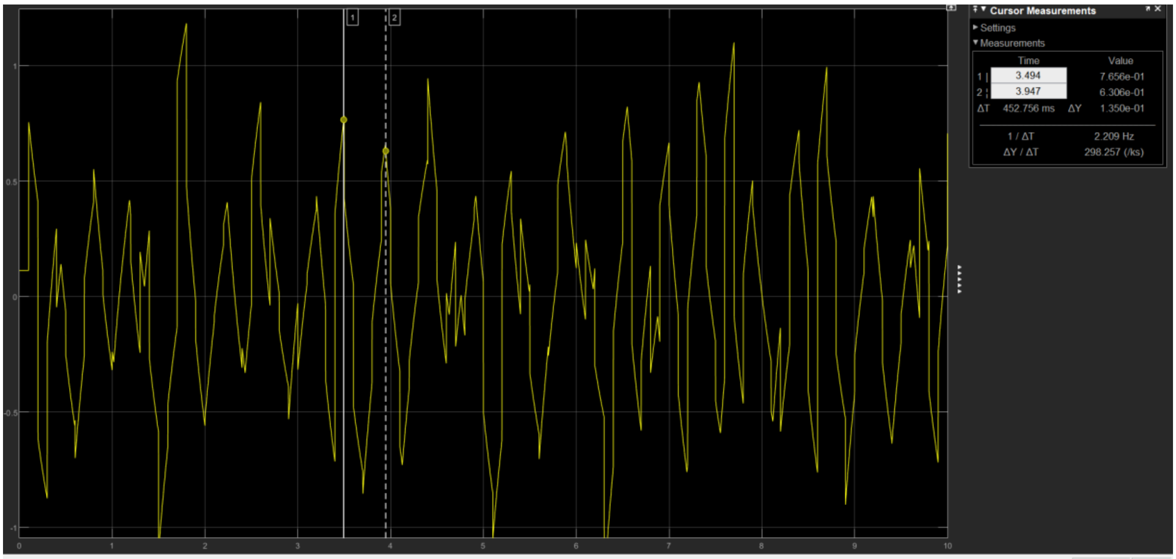


The control signal :



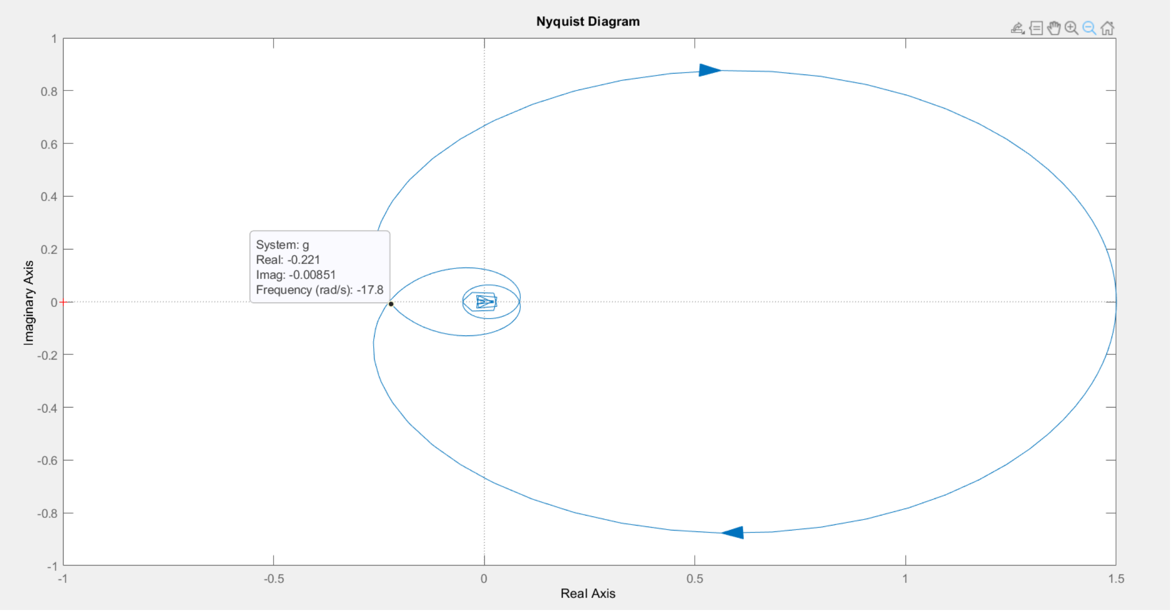
After changing relay:

The output:



$$T = 0.452 \; f = 2.2 \;\; w_u = 13.8 \; K_u = \frac{4d}{\pi(a^2 - \epsilon^2)^{0.5}} = \frac{4}{\pi(0.76^2 - 0.5^2)} = 3.886$$

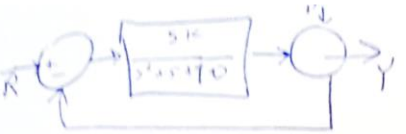
D



As can be seen, $w = 17.8$, $K_u = \frac{1}{0.221} = 4.5$

2

A



(الف

$R(s)=0 \Rightarrow Y=e$

$\frac{Y}{D}=\frac{1}{1+G}=\frac{s^2+s+10 \rightarrow C}{s^2+s+10+5K \rightarrow B}$

$K=K+\Delta K \Rightarrow \boxed{e+\Delta e = Y+\Delta Y = \frac{s^2+s+10}{s^2+s+10+5(K+\Delta K)} D}$

$S_K^Y = S_K^e$

$\Delta Y = \frac{s^2+s+10}{s^2+s+10+5(K+\Delta K)} D - Y$

$= \left(\underbrace{\frac{s^2+s+10}{s^2+s+10+5(K+\Delta K)}}_{A} - \underbrace{\frac{s^2+s+10}{s^2+s+10+5K}}_{B} \right) D$

$= \underbrace{(s^2+s+10)}_{C} \left(\frac{1}{A} - \frac{1}{B} \right) D = \frac{-5\Delta K\, C}{AB} D$

$= \frac{\Delta Y}{Y} \frac{K}{\Delta K} = \frac{\frac{-5\Delta K\, \cancel{CD}}{AB}}{\frac{\cancel{C}}{\cancel{B}}\cancel{D}} \times \frac{K}{\cancel{\Delta K}}$

$= \frac{-5K}{A} = \boxed{\frac{-5K}{s^2+s+10+5(K+\Delta K)}}$

$\ast$ جواب نهایی

B

ب) $D(s)=0$

$R(s)-Y(s)=e(s) \xRightarrow{\times \frac{1}{R(s)}} 1-\frac{Y}{R}=\frac{e}{R}$

$\frac{Y}{R}=\frac{G}{1+G}=\frac{\frac{5K}{s^2+s+10}}{\frac{s^2+s+10+5K}{s^2+s+10}}=\frac{5K}{s^2+s+10+5K}$

$\Rightarrow \boxed{\frac{s^2+s+10 \rightarrow C}{s^2+s+10+5K \rightarrow B}=\frac{e}{R}}$

$e+\Delta e = \frac{s^2+s+10}{s^2+s+10+5(K+\Delta K)} R \Rightarrow \Delta e = \frac{s^2+s+10}{s^2+s+10+5(K+\Delta K)} R - e$

$= \left(\underbrace{\frac{s^2+s+10}{s^2+s+10+5(K+\Delta K)}}_{A} - \underbrace{\frac{(s^2+s+10)}{s^2+s+10+5K}}_{B} \right) R$

$= CR \left(\frac{-5\Delta K}{AB} \right)$

$S_K^e = \frac{\Delta e}{e} \frac{K}{\Delta K}$

$= \frac{\frac{\cancel{CR}\, -5\cancel{\Delta K}}{A\cancel{B}}}{\frac{\cancel{C}}{\cancel{B}}\cancel{R}} \frac{K}{\cancel{\Delta K}} = \frac{-5K}{A} = \boxed{\frac{-5K}{s^2+s+10+5K}} \ast\ast$

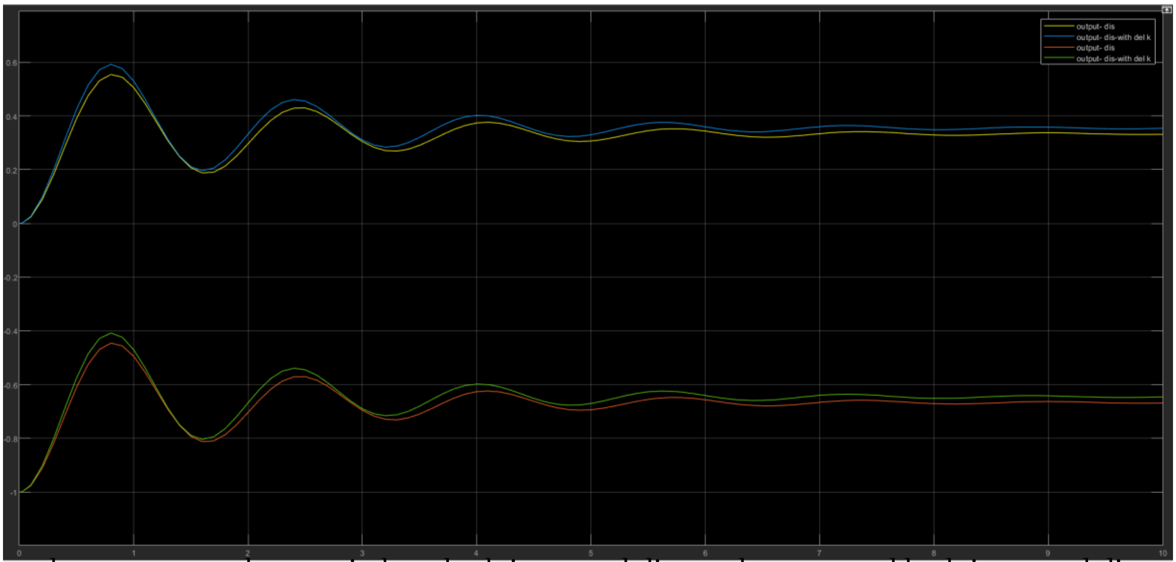
$\frac{\ast}{\ast\ast} \Longrightarrow \boxed{\ast = \ast\ast}$

C

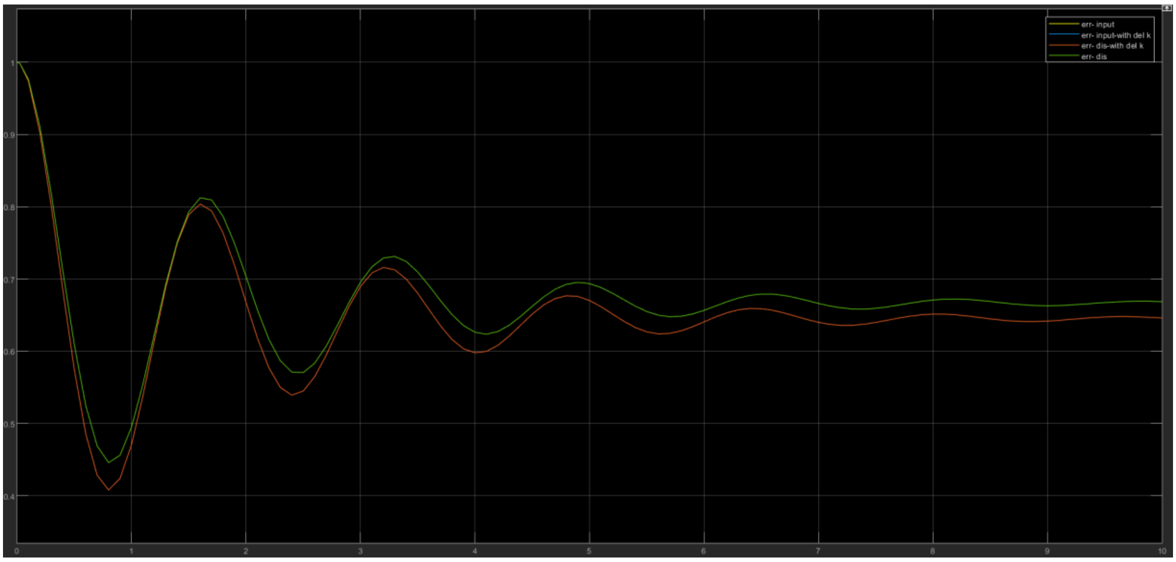
From seeing two previous part we find out that the sensitivity of k for both input and disturbance are the same and have the same effect on output.

For simulation we consider $\Delta K = 0.1$ and for disturbance we consider when it as -1 because when in it pass from feedback the value become 1.

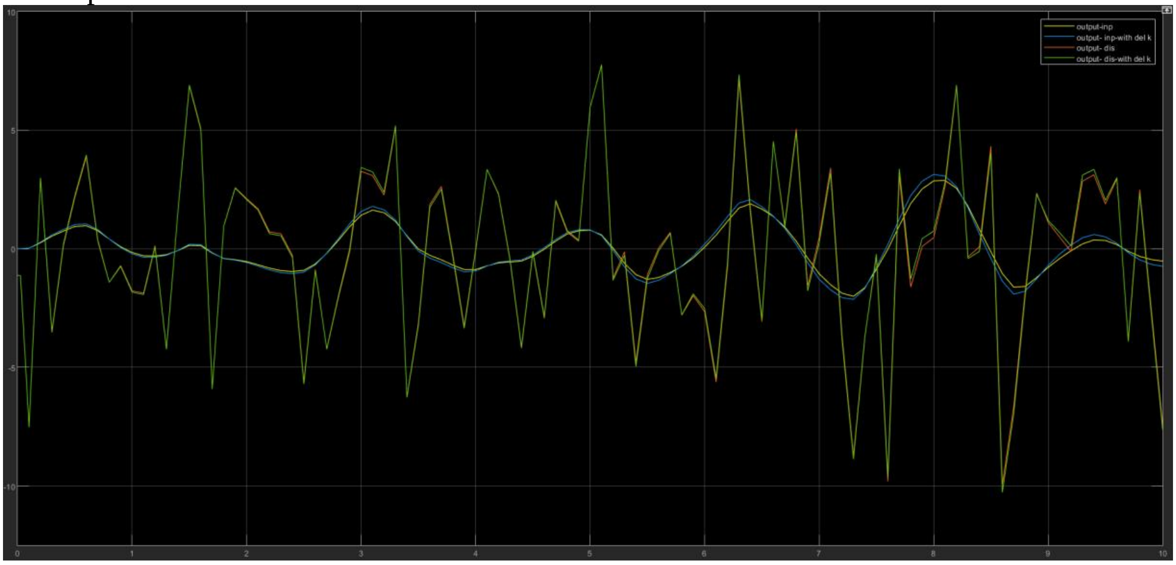
The outputs:



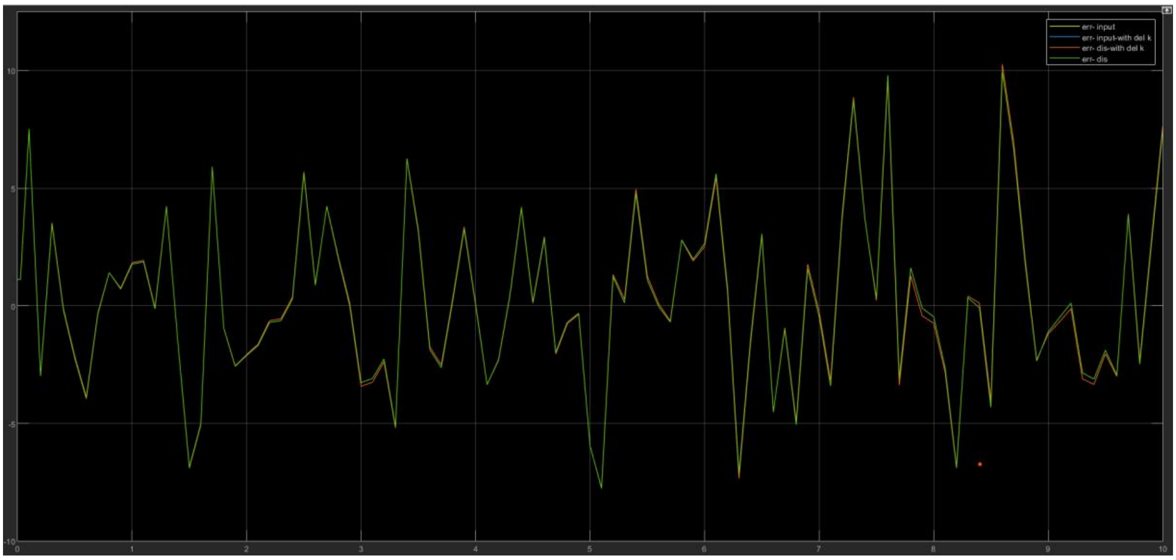
the error as can be seen in here both input and dis are the same and both input and dis with delta k are the same too.



output with white band noice:

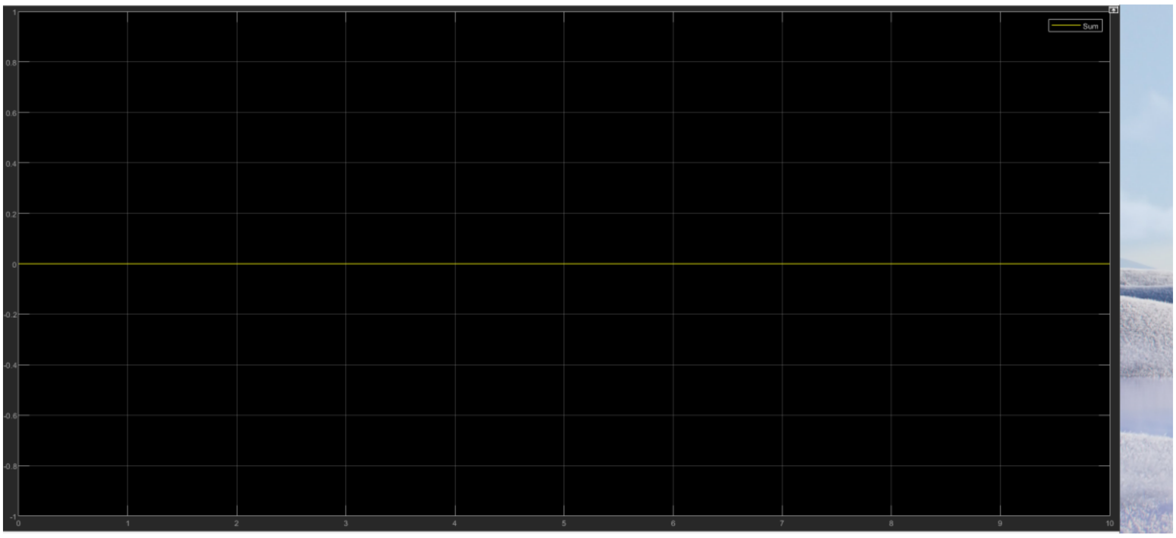


As before the sesivity is the same like before.



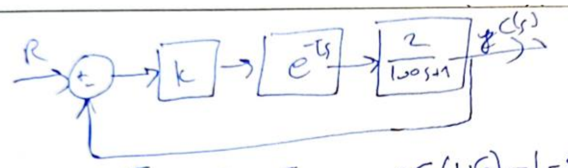
And finally as can be seen for S_k^y $when\ R = (0) and\ S'^y_k\ when\ D = (0)$

$$S_k^y - S'^y_k = 0$$



3

3)



$$G = \frac{2k\, e^{-\tau s}}{100s+1}$$

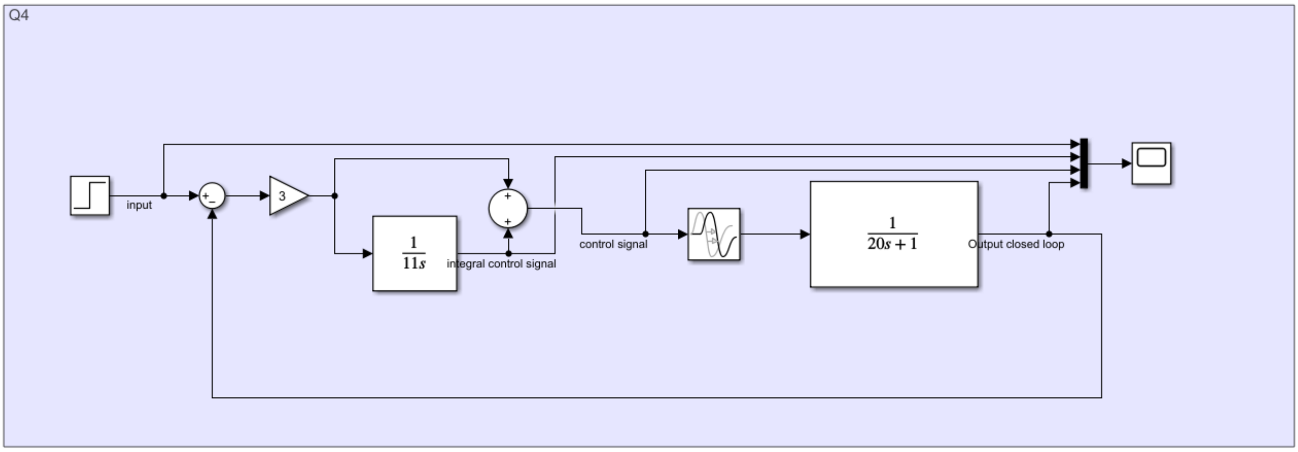
$T = \frac{C}{R} \Rightarrow S_{\tau}^{T} = \frac{\partial T}{\partial \tau} \cdot \frac{\tau}{T} = \frac{-sG(1+G) - (-s)G^2}{(1+G)^2} = \frac{\cancel{sG^2} - sG - \cancel{sG^2}}{(1+G)^2} = \boxed{\frac{-sG}{(1+G)^2}}$

$T = \frac{G}{1+G} =$

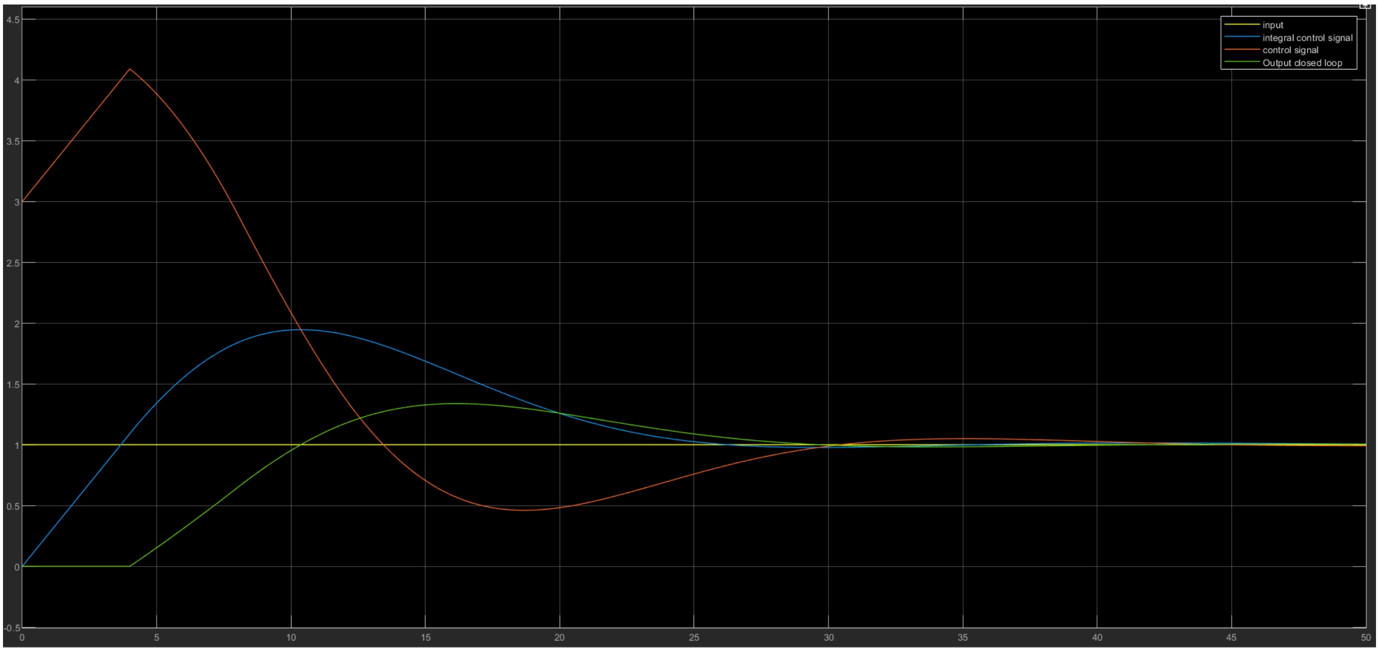
$$S_{\tau}^{T} = \frac{-s\cancel{G}}{(1+G)^{\cancel{2}}} \cdot \frac{\cancel{(1+G)}\tau}{\cancel{G}\ \cancel{T}} = \frac{-s\tau}{(1+G)} = \frac{-\tau s}{1 + \frac{2ke^{-\tau s}}{100s+1}} = \boxed{\frac{-\tau s(100s+1)}{100s+1+2ke^{-\tau s}}}$$

4

A



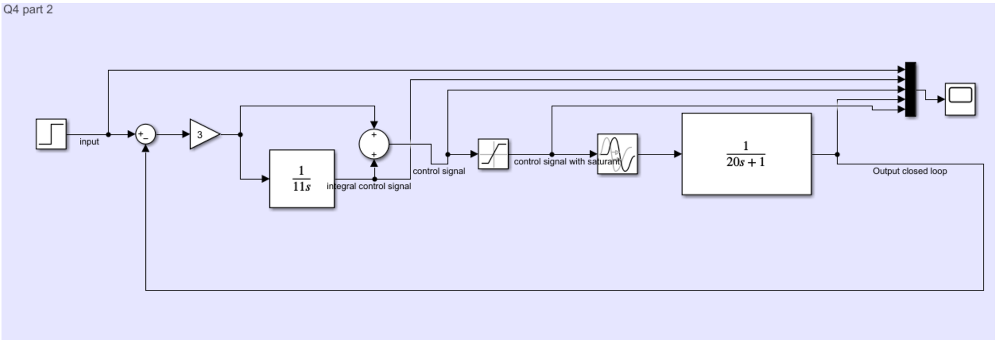
As wanted we have 3 + 1 signal :

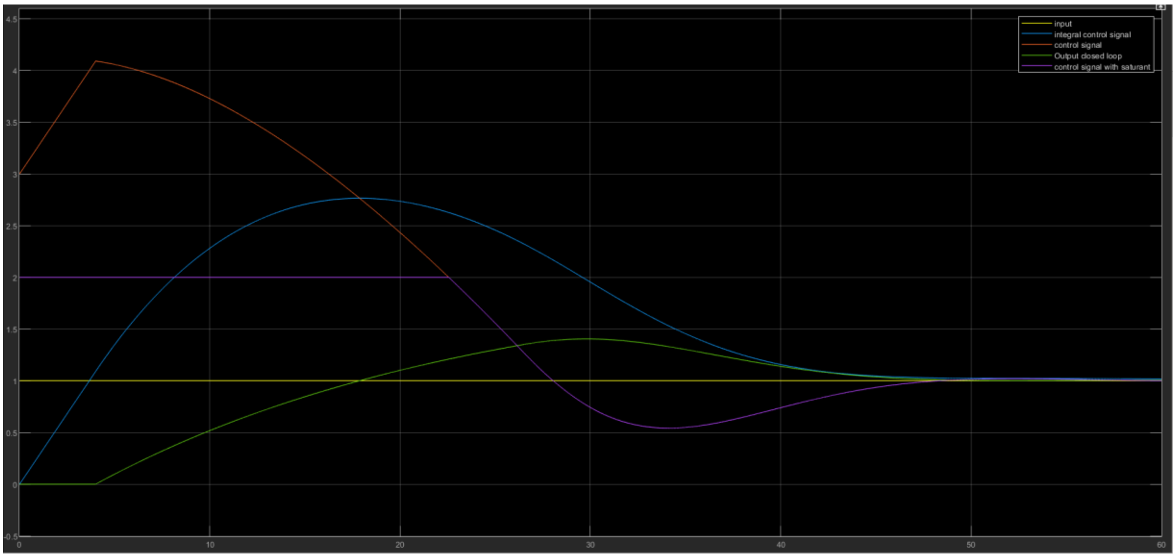


As you can see from the start, our signal controller starts from 3 because k sub p equals three, and the integral controller becomes more; after 4 seconds, the output starts to rise, so the error decreases, and the control signal decreases.

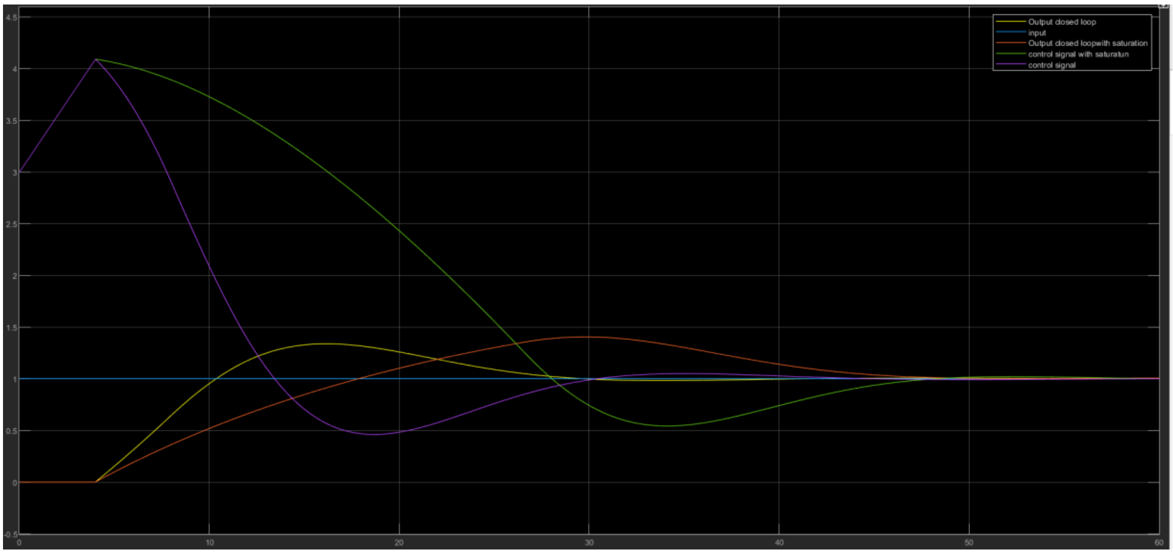
When the error becomes zero and the output is more than the input, the integral starts to decrease.

B



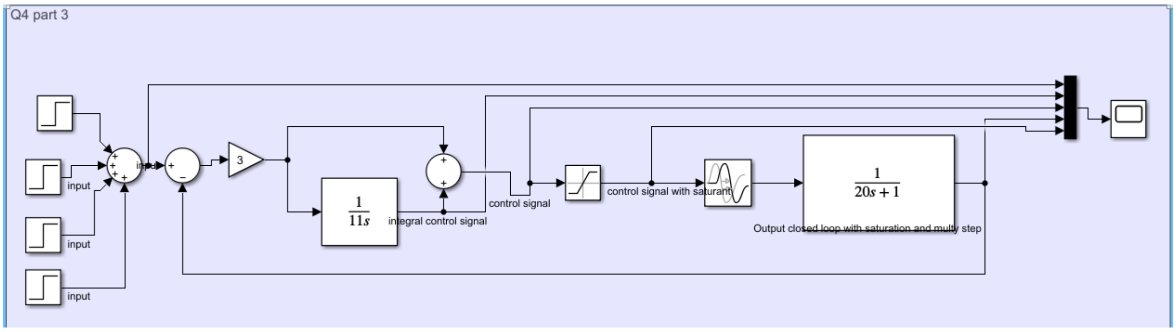


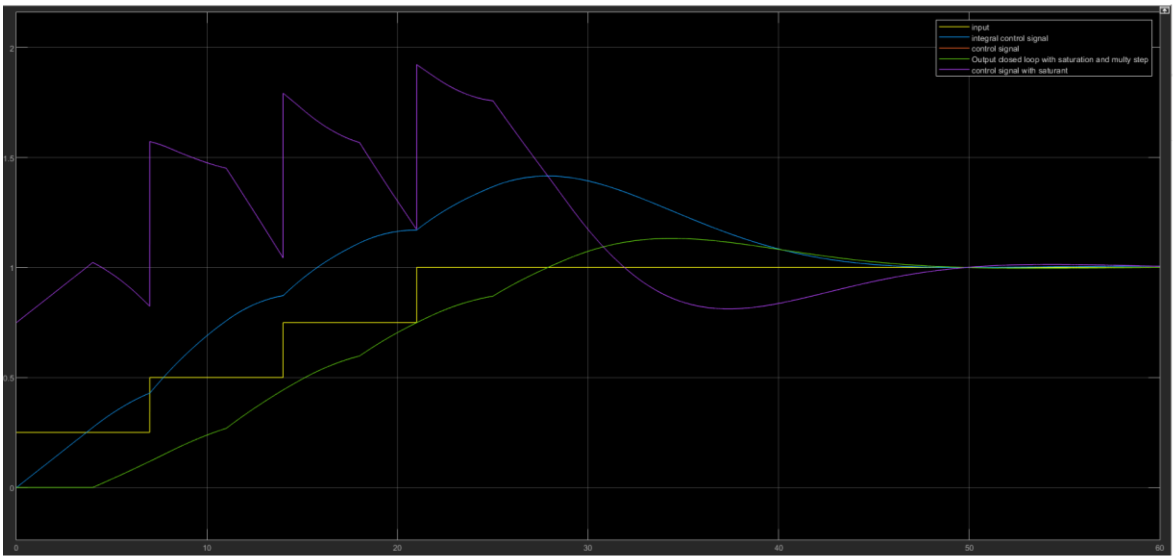
As we can see in this part and the previous part, In here cause of saturation, It takes more than 18 seconds to reach the input. (and in previous, the max of the integral control signal was about two, but here it is 2.75 (because of the error))



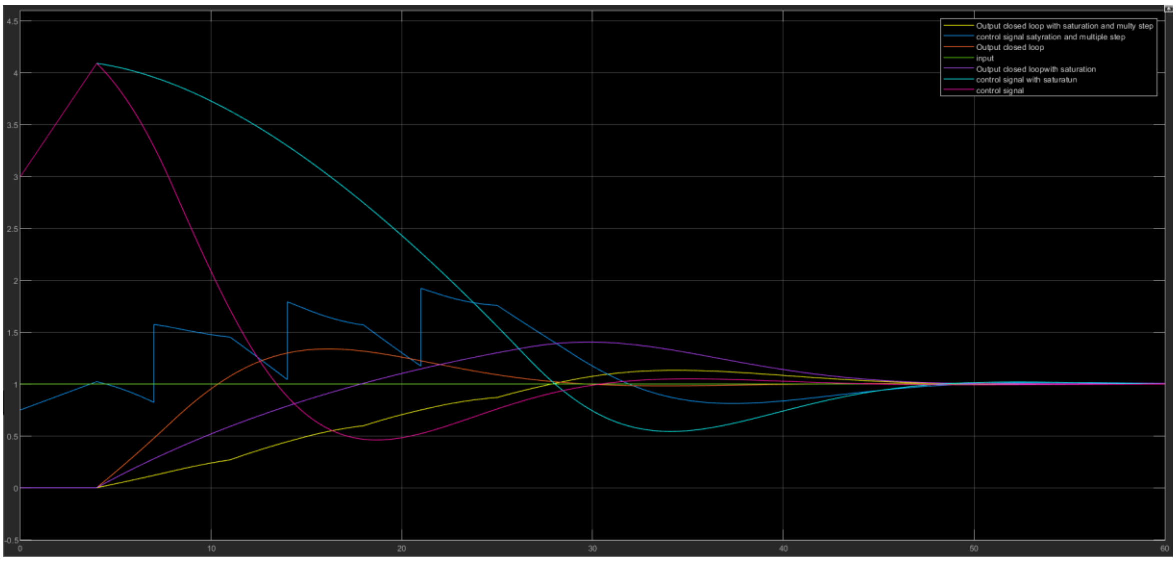
When it comes to comparison, we can easily see it takes more time for both the output signal and control signal to reach the input.

C



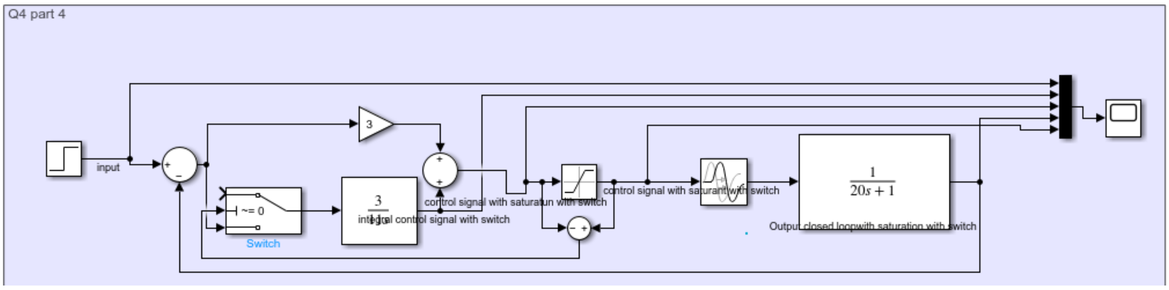


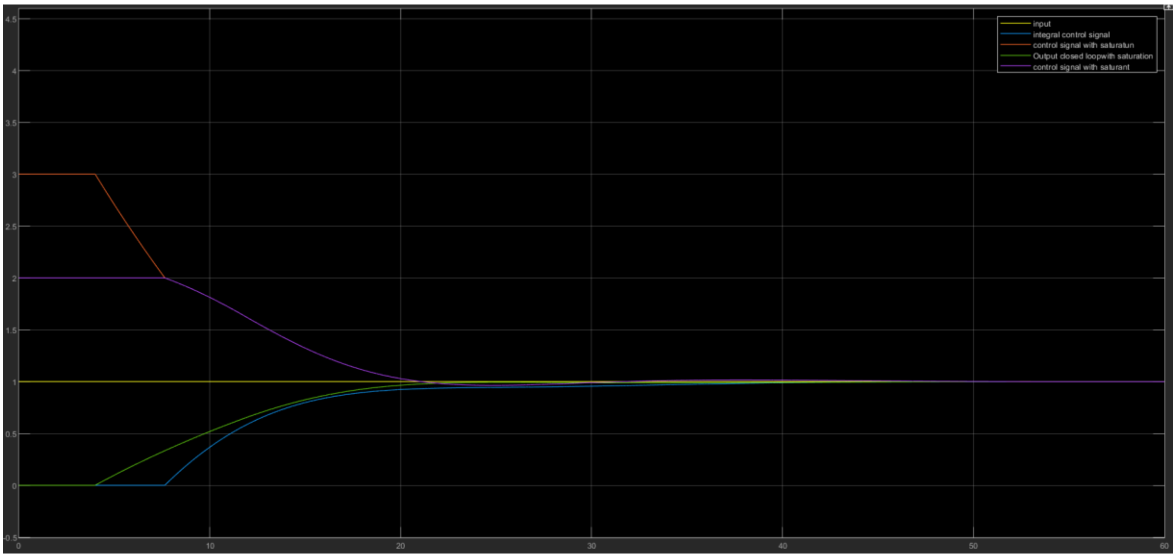
As shown in the picture, we divided it into four pieces, each one starting 7 seconds after the other.



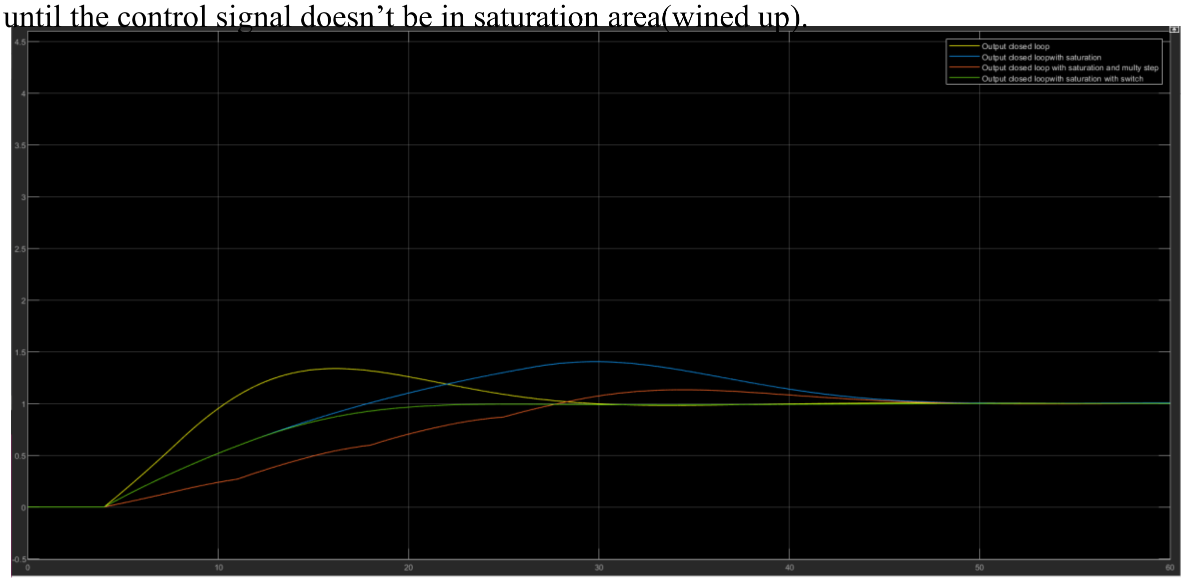
As we compare from the last part, it takes longer to reach the steady state. However, the positive point of this part is that the signal control didn't go to the saturation area.

D



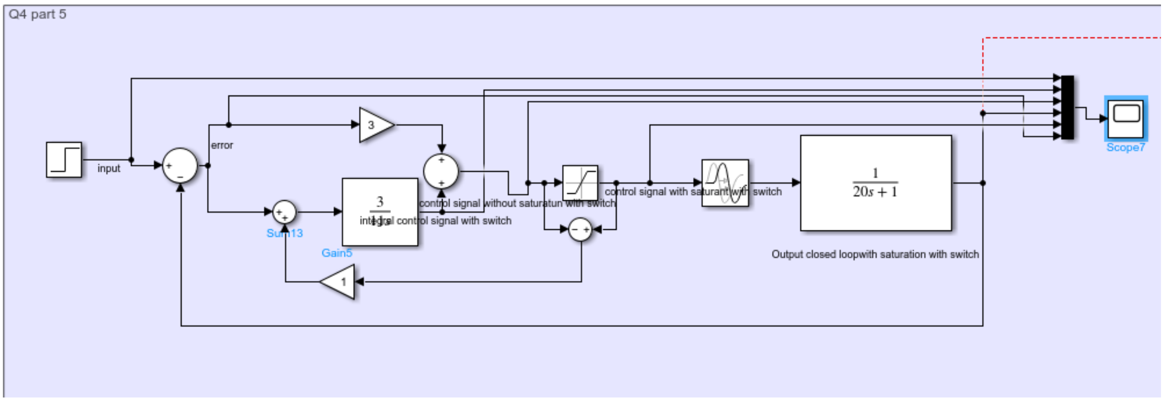


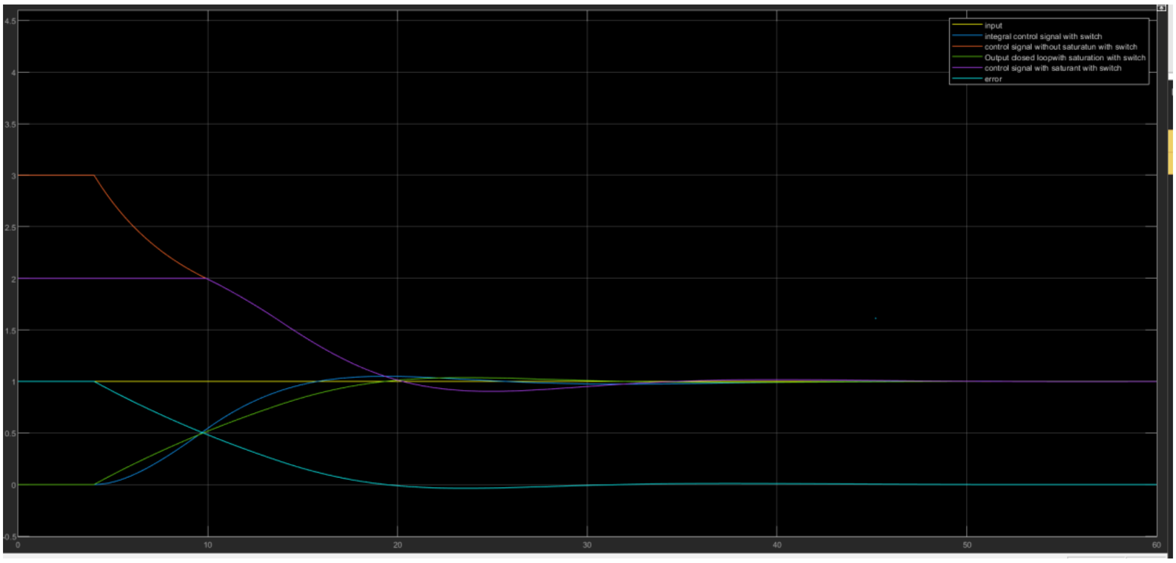
As the picture shows, it takes less time to reach a steady state, and we don’t Integral until the control signal doesn’t be in saturation area(wined up).



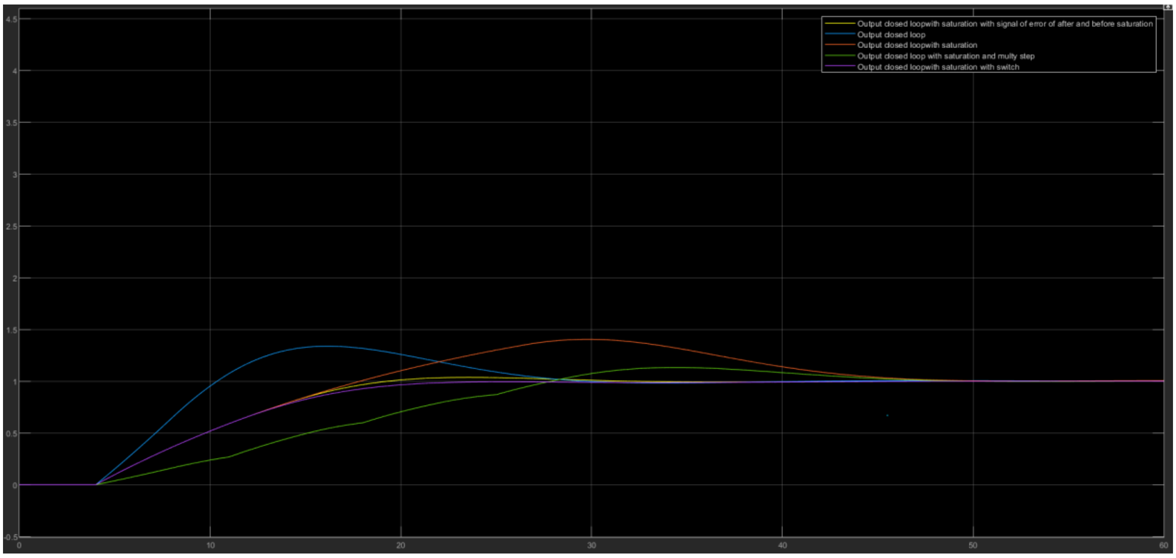
The system reach steady space sonner than other system but the problem in here is that the system is unlinear.

E





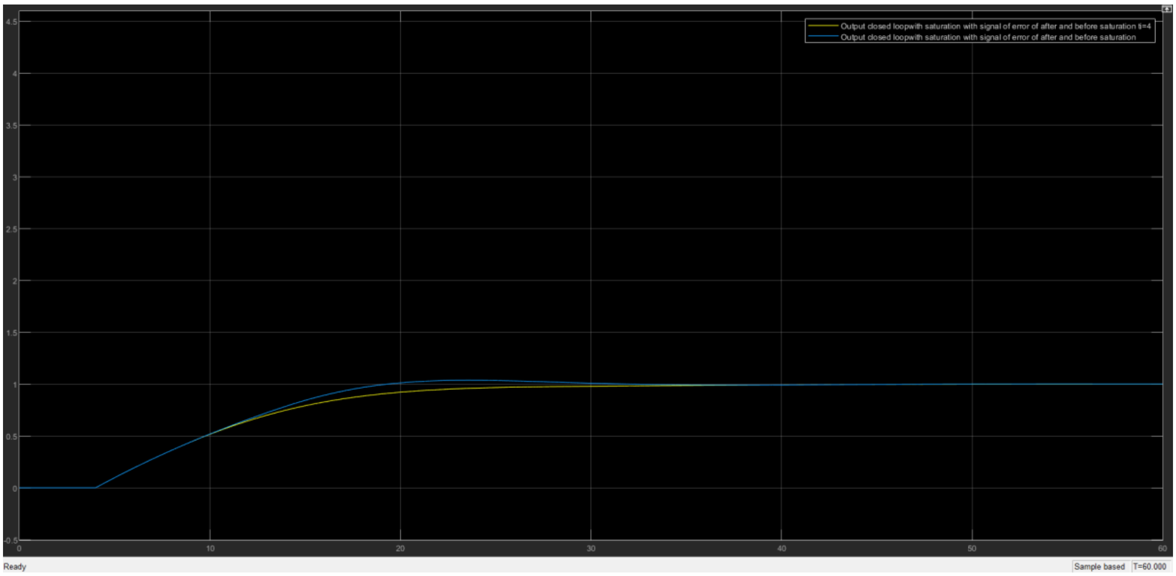
Now our system is linear and we can azalyze it.

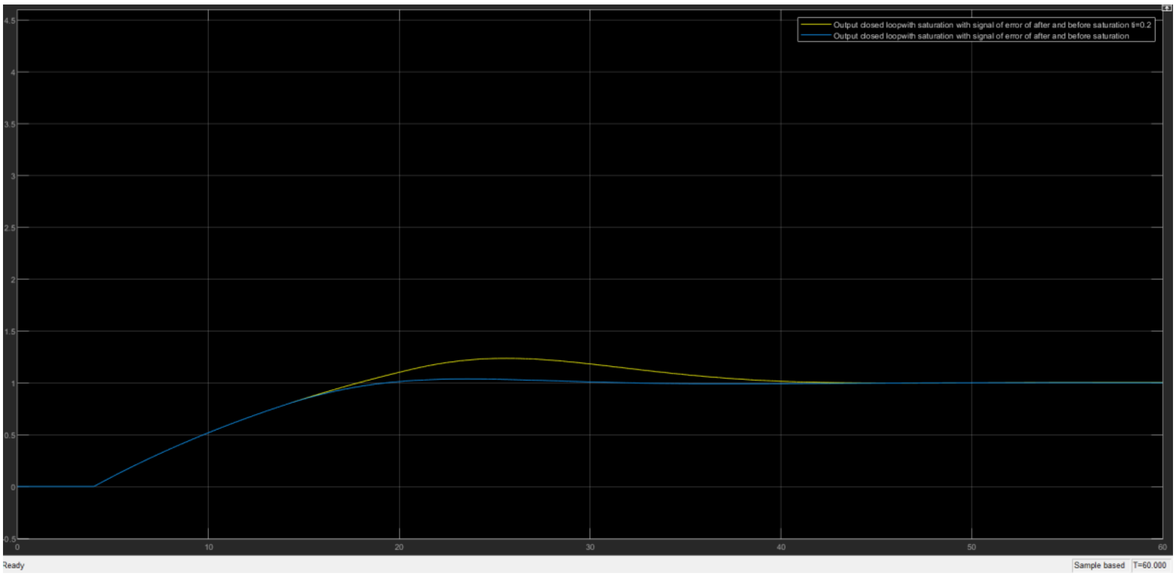


The system works as the same with previous system(a little better).

F

With decreasing T_{e2} the gain will be more so the gain of $integral\ block$ become zero faster than befor ane move smoother. But when T_{e2} increase the gain will be decrease so the the gain of $integral\ block$ takes more time become zero.

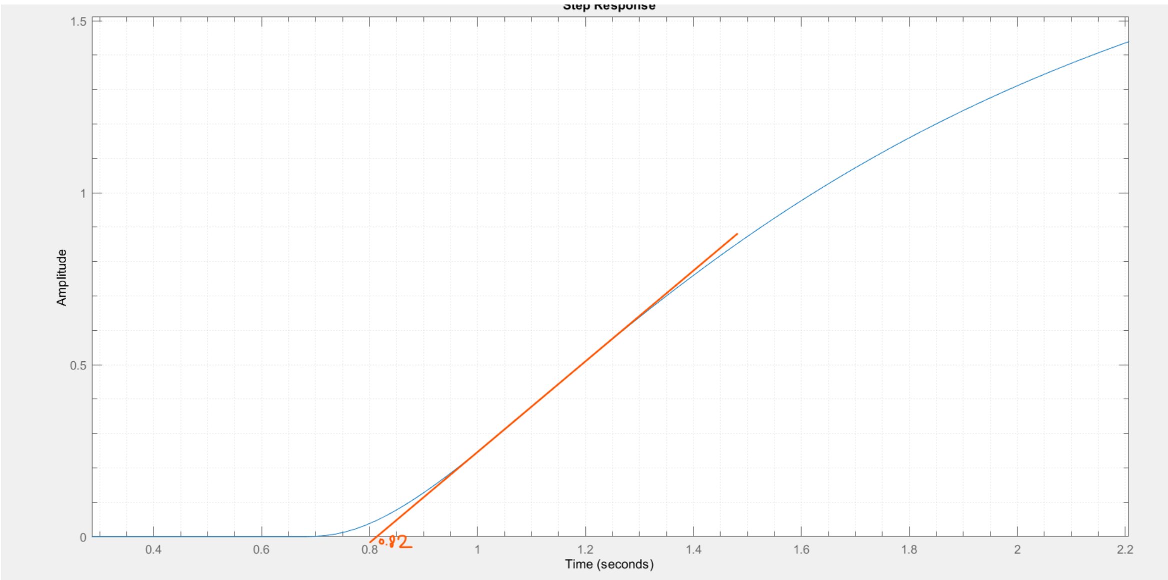




Q5

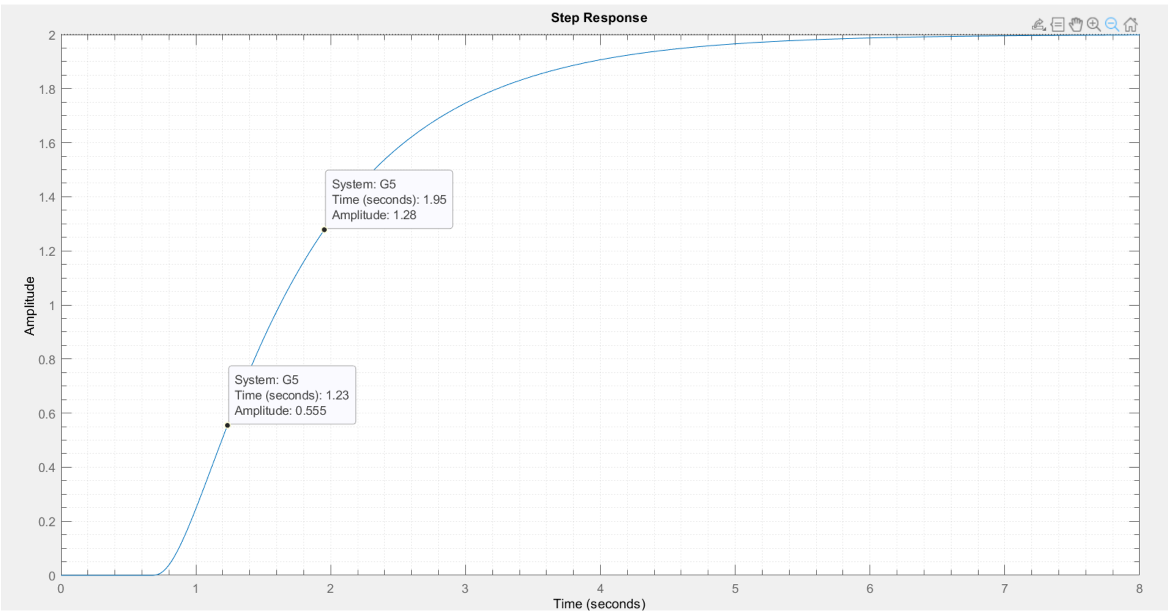
$$G(s)=\frac{2e^{-0.633s}}{(s+1)(0.2s+1)(0.04s+1)(0.008s+1)}$$

we must caculate a first order model:



$$\tau_d = 0.82$$

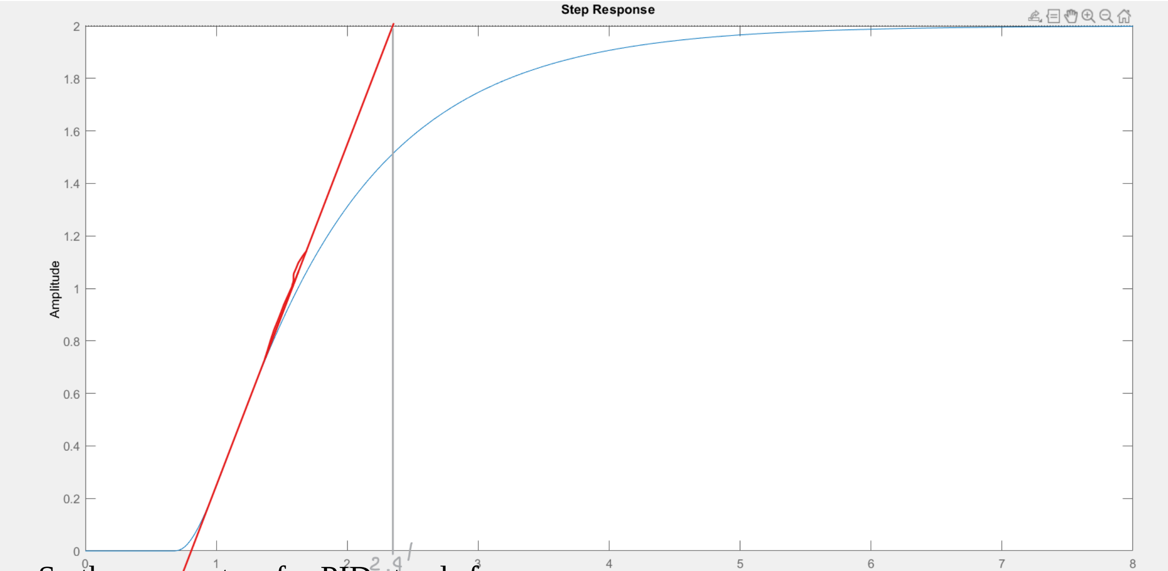
And then we use two point method to find τ :



And for $\tau = 1.5(1.95 - 1.23) = +1.08$ $And\ K = 2$ so $\alpha = 0.76$

$$G = \frac{2e^{-0.82s}}{1.08\ s+1}$$

Max slope:



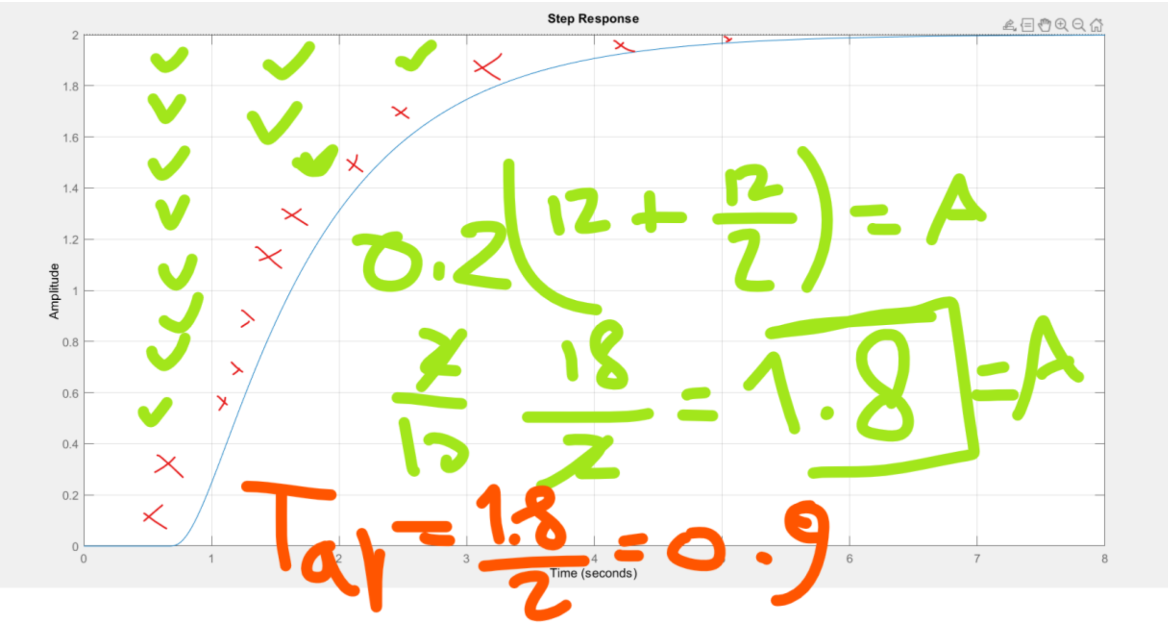
So the parameters for PID stands for :

$$G = \frac{2e^{-0.82s}}{(2.4-0.82)\ s+1}$$

One point

$$G = \frac{2e^{-0.82s}}{(1.95 - 0.82)\ s + 1}$$

ATR



$$G = \frac{2e^{-0.82s}}{(0.9)\,s + 1}$$

Now we caculate the error:

err_max_slope = 0.0012

err_one_point =   4.4576e-05

err_two_point = 4.3508e-05

err_ART = 4.7052e-04

Acording to the error the best model is two point model:

Which is:

$$G = \frac{2e^{-0.82s}}{1.08\ \mathrm{s}+1}$$

CC & CHR & ZN_open_loop:

For CC, we must use two point estimation model which is best one from the error

	kp	Ti	Td
P	$\frac{1}{k\alpha}$	—	—
PI	$\frac{۰٫۹}{k\alpha}$	۳٫۳Zd	—
PID	$\frac{۱٫۲}{k\alpha}$	۲Zd	۰٫۵Zd

ZN_open_loop

هدف ۱: حذف اغتشاش

OS%	0%			20%		
	k_p	T_i	T_d	k_p	T_i	T_d
P	$\frac{0.3}{k}\frac{\tau}{\tau_d}$ $\frac{1}{\alpha}$	—	—	$\frac{0.7}{k}\frac{\tau}{\tau_d}$	—	—
PI	$\frac{0.6}{k}\frac{\tau}{\tau_d}$	$4\tau_d$	—	$\frac{0.7}{k}\frac{\tau}{\tau_d}$	$2.3\tau_d$	—
PID	$\frac{0.95}{k}\frac{\tau}{\tau_d}$	$2.4\tau_d$	$0.42\tau_d$	$\frac{1.2}{k}\frac{\tau}{\tau_d}$	$2\tau_d$	$0.42\tau_d$

هدف ۲: ردیابی ورودی پله

OS%	0%			20%		
	k_p	T_i	T_d	k_p	T_i	T_d
P	$\frac{0.3}{k}\frac{\tau}{\tau_d}$	—	—	$\frac{0.7}{k}\frac{\tau}{\tau_d}$	—	—
PI	$\frac{0.35}{k}\frac{\tau}{\tau_d}$	1.2τ	—	$\frac{0.6}{k}\frac{\tau}{\tau_d}$	τ	—
PID	$\frac{0.6}{k}\frac{\tau}{\tau_d}$	τ	$0.5\tau_d$	$\frac{0.95}{k}\frac{\tau}{\tau_d}$	1.4τ	$0.47\tau_d$

تمرین: تحلیل کنید.

CHR

	k_p	T_i	T_d
P	$\frac{1}{k}\frac{\tau}{\tau_d}\left(1+\frac{3\tau_d}{\tau}\right)$	—	—
PI	$\frac{1}{k}\frac{\tau}{\tau_d}\left(\frac{9}{10}+\frac{\tau_d}{12\tau}\right)$	$\tau_d\frac{30+3\frac{\tau_d}{\tau}}{9+20\frac{\tau_d}{\tau}}$	—
PID	$\frac{1}{k}\frac{\tau}{\tau_d}\left(\frac{4}{3}+\frac{\tau_d}{4\tau}\right)$	$\tau_d\frac{32+6\tau_d/\tau}{13+8\frac{\tau_d}{\tau}}$	$\tau_d\frac{4}{11+2\frac{\tau_d}{\tau}}$
PD	$\frac{1}{k}\frac{\tau}{\tau_d}\left(\frac{5}{4}+\frac{\tau_d}{6\tau}\right)$	—	$\tau_d\frac{6-2\frac{\tau_d}{\tau}}{22+3\frac{\tau_d}{\tau}}$

CC

Result at the end!

Damped ocsillation

	k_p	T_i	T_d
P	۱,۱ k_{dmp}	—	—
PI	۱,۱ k_{dmp}	$\frac{T_{dmp}}{۲,۶}$	—
PID	۱,۱ k_{dmp}	$\frac{T_{dmp}}{۳,۶}$	$\frac{T_{dmp}}{۹}$

Which K_{dmp} $is\ equal\ to\ K_{gain} when \frac{e_1}{e_2}\ equals\ \ 4$

ZN_closed_loop

$K_u and\ t_u\ can\ find\ from\ increasing\ k\ until\ system\ swinging$

	k_p	T_i	T_d
P	۰٫۵ k_u		
PI	۰٫۴۵ k_u	$\frac{T_u}{۱٫۵}$	
PID	۰٫۶ k_u	$\frac{T_u}{۲}$	$\frac{T_u}{۸}$

process response

روش تنظیم بر اساس پاسخ فرآیند (process response)

گام ۱) $K_p = 0$, $T_d = 0$, $T_i = \infty$

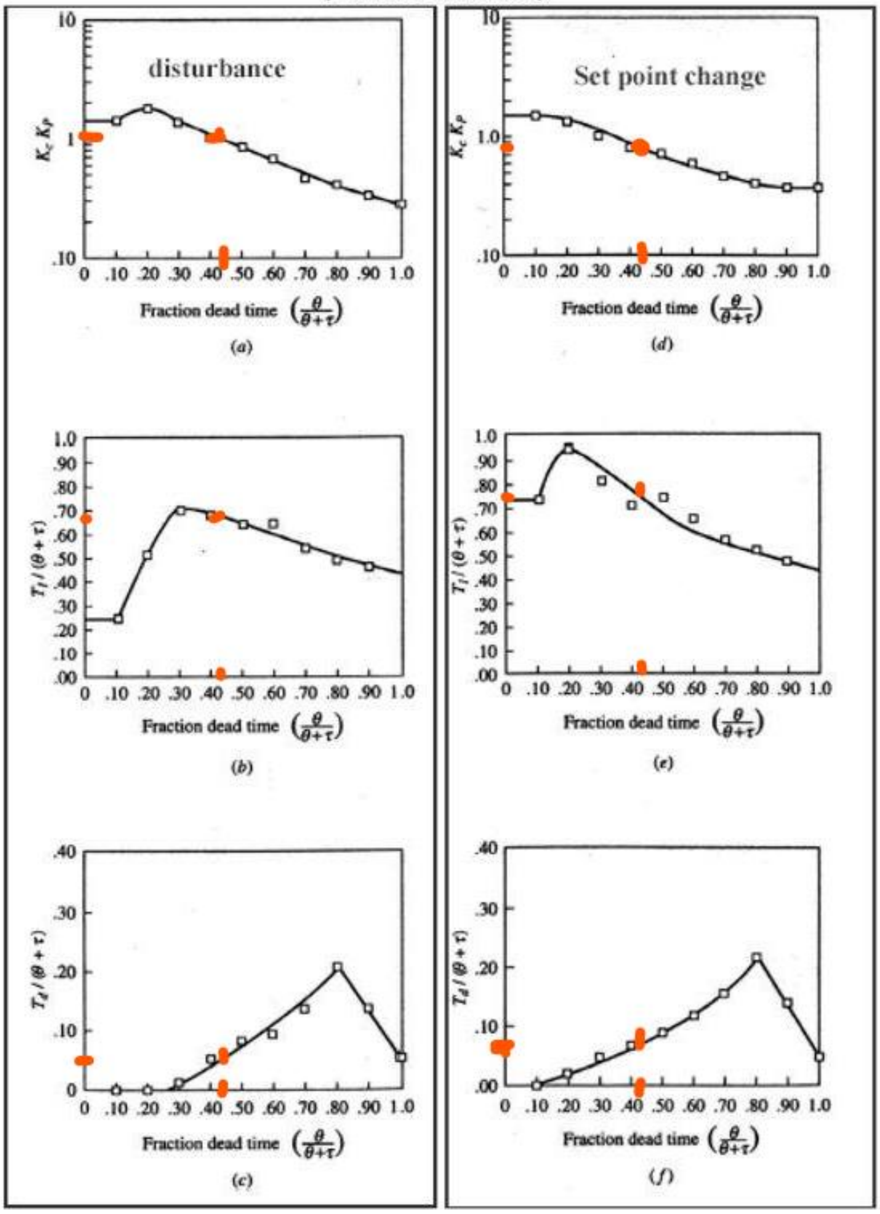
گام ۲) K_p را به تدریج زیاد می‌کنیم تا سیستم دچار نوسانات پایدار شود $\leftarrow K_u \leftarrow K_p = \frac{K_u}{2}$

گام ۳) با تنظیم $K_p = \frac{K_u}{2}$ در گام قبل مقدار T_i را به تدریج کاهش می‌دهیم تا سیستم دچار نوسانات پایدار شود $\leftarrow T_{iu} \leftarrow T_i = 3.3\,T_{iu}$

گام ۴) با تنظیم $K_p = \frac{K_u}{2}$, $T_i = 3.3\,T_{iu}$ ، T_d را به تدریج افزایش می‌دهیم تا سیستم دچار نوسانات پایدار شود $\leftarrow T_{du} \leftarrow T_d = 0.3\,T_{du}$

Ciancone Marline

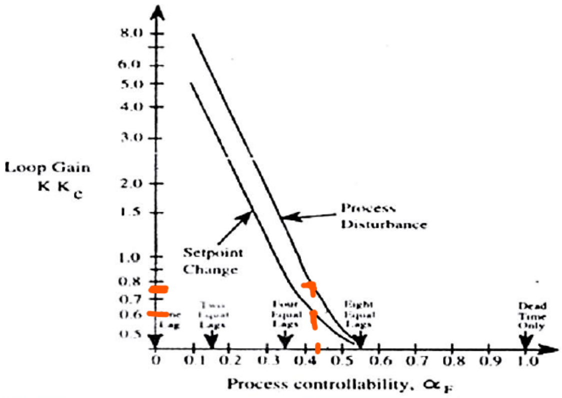
CIANCONE CORRELATIONS FOR DIMENSIONLESS TUNING CONSTANTS (PID ALGORITHM)

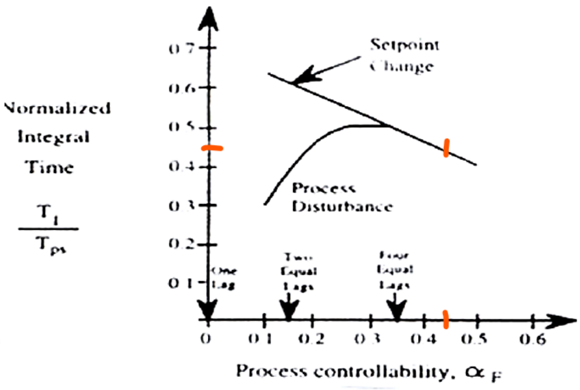


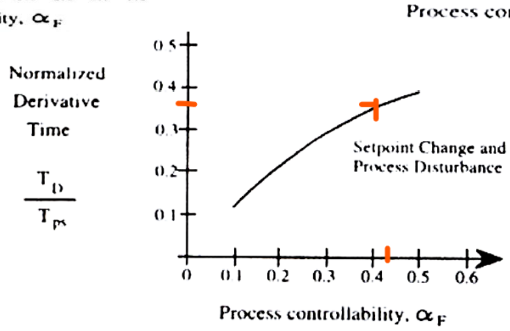
or disturbance response: (a) control system gain, (b) integral time, (c) derivative time.

or set point response: (d) control system gain, (e) integral time, (f) derivative time

Fertik







Which $\alpha_f = \frac{\tau_d}{\tau + \tau_d}$

method_name	kp	Ti	Td
ZN_open_loop	0.790	1.640	0.410
method_cc	1.003	1.572	0.262
CHR ref track 0%OS	0.395	1.080	0.410
CHR ref track 20%OS	0.626	1.512	0.385
CHR rem dis 0%OS	0.626	2.592	0.344
CHR rem dis 20%OS	0.790	2.160	0.344
Damped Ocsillation	0.858	0.850	0.340
ZN_close_loop	0.826	1.375	0.344
Fertik ref track	0.300	0.855	0.684
Fertik rem dis	0.365	0.855	0.684
Ciancone-Marline ref track	0.400	1.387	1.140
Ciancone-Marline rem dis	0.475	1.292	0.760
process response	0.688	2.145	0.285

From the table we can find out process response has the max amount of Ti and Damped Ocsillation has min value for it.

From the table we can find out method_cc has the max amount of kp and Fertik ref track has min value for it.

From the table we can find out Ciancone-Marline ref track has the max amount of Td and Fertik ref track has men value for it.

method_name	RiseTime	SettlingTime	Overshoot	Peak	PeakTime
ZN_open_loop	0.666	6.112	13.810	1.138	2.017
method_cc	0.525	7.343	47.259	1.473	1.991
CHR ref track 0%OS	1.445	6.823	9.188	1.092	4.210
CHR ref track 20%OS	0.876	5.180	4.102	1.041	4.101
CHR rem dis 0%OS	3.304	10.045	0.000	1.000	30.000
CHR rem dis 20%OS	0.709	5.732	7.897	1.079	2.011
Damped Ocsillation	0.527	5.495	66.669	1.667	2.156
ZN_close_loop	0.610	4.945	29.453	1.295	2.077
Fertik ref track	1.814	7.878	14.003	1.140	4.850
Fertik rem dis	1.457	9.891	18.258	1.183	4.234
Ciancone-Marline ref track	2.381	10.209	7.296	1.073	6.800
Ciancone-Marline rem dis	1.937	8.081	8.653	1.087	5.259
process response	0.851	6.650	1.323	1.013	2.164

From the info of the system we can figure it out that ZN_open_loop has the best rise time and try to track input very fast but CHR rem dis 0%OS works worst.
Also for settle time of the system ZN_close_loop have the best timing to stabilize itself with input but CHR rem dis 0%OS has the max time aong them.
And for last but not least for CHR rem dis 0%OS has no overshoot but Damped Ocsillation has the most time for it.
*we don’t have the information of the real model so sometimes some method don’t works correctly, like CHR ref track 0%OS method because it couldn’t make the overshoot to reach zero.

method_name	Sum_Abs_control_signal	Max_control_signal
ZN_open_loop	15.422	1.100
method_cc	15.549	1.415
CHR ref track 0%OS	15.257	0.635
CHR ref track 20%OS	15.336	0.893
CHR rem dis 0%OS	14.905	0.781
CHR rem dis 20%OS	15.257	1.025
Damped Ocsillation	15.693	1.514
ZN_close_loop	15.524	1.213
Fertik ref track	15.228	0.607
Fertik rem dis	15.355	0.648
Ciancone-Marline ref track	15.074	0.604
Ciancone-Marline rem dis	15.260	0.712
process response	15.161	0.895

Sum_Abs_control_signal : for method_cc has the max value among them maybe because it has the max kp and for that has the max overshoot
But CHR rem dis 0%OS has the min value and that can be a resion why it takes more time in rise time and settle time.

Max_control_signal :
Max: Damped Ocsillation , and because of that we can say we have the most overshoot in the system also must mention it has the most Ti so it takes more time to make to settle it.
Min: Ciancone-Marline ref track maybe we can say it has the maximum value of Td make it try make it less the control signal.

method_name	IE	IAE	ISE	ITAE
ZN_open_loop	1.038	1.407	1.075	1.474
method_cc	0.783	1.828	1.178	2.963
CHR ref track 0%OS	1.367	1.866	1.322	2.737
CHR ref track 20%OS	1.208	1.423	1.134	1.402
CHR rem dis 0%OS	2.071	2.071	1.229	4.864
CHR rem dis 20%OS	1.367	1.437	1.084	1.653
Damped Ocsillation	0.495	2.063	1.417	3.224
ZN_close_loop	0.833	1.514	1.105	1.650
Fertik ref track	1.425	2.285	1.480	4.693
Fertik rem dis	1.171	2.195	1.388	4.589
Ciancone-Marline ref track	1.734	2.309	1.471	4.828
Ciancone-Marline rem dis	1.360	1.946	1.286	3.381
process response	1.559	1.565	1.129	2.243

We can say when we don't have overshoot the IE and IAE must be equals.

Also we can say IAE is always bigger than IE and we can mention that the error of each method for when our output upper than the input signal can find out from this $\frac{\text{IAE}-\text{IE}}{2}$

Which means $\frac{\text{IAE}-\text{IE}}{2}$ was upper than input signal and $\frac{\text{IAE}-\text{IE}}{2}$ is belower than input signal.

So according what I said above we can say for Damped Ocsillation, it swing with bigger overshoot as can be seen in stepinfo table.

For ISE we can the method has the maxinmum value that has some condition

- First it takes more time to converge or has the min slope(kp).

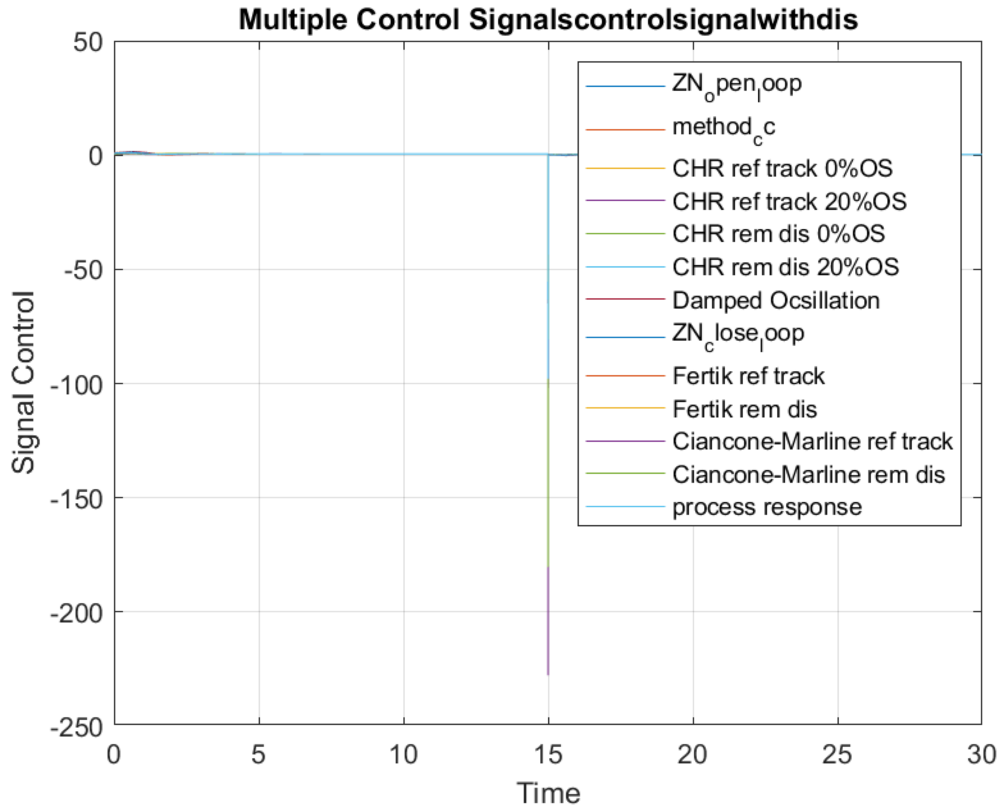
For ITAE , if takes more time to converge it has bigger amount that's why CHR rem dis 0%OS takes more time to settle and rise time amoung others.

method_name	IE_D	IAE_D	ISE_D	ITAE_D
ZN_open_loop	0.519	2.058	1.324	11.865
method_cc	0.392	2.700	1.455	17.417
CHR ref track 0%OS	0.683	2.767	1.638	17.529
CHR ref track 20%OS	0.604	2.091	1.401	12.030
CHR rem dis 0%OS	1.044	3.065	1.517	22.031
CHR rem dis 20%OS	0.684	2.139	1.340	13.047
Damped Ocsillation	0.248	3.025	1.740	19.096
ZN_close_loop	0.416	2.214	1.362	12.869
Fertik ref track	0.711	3.383	1.832	23.325
Fertik rem dis	0.585	3.237	1.714	22.312
Ciancone-Marline ref track	0.870	3.391	1.803	23.208
Ciancone-Marline rem dis	0.680	2.859	1.582	18.584
process response	0.781	2.339	1.398	15.008

In this table we collect both input error and dis error
according to them ZN_open_loop is the best one because it has the minimum error
But Fertik ref track has the most error and not good for disturbance.

We can say for the end it depens on our system and situation on how the system wants to work we can only choose one of them according to our needs.

The pictures of each model system is in the folder.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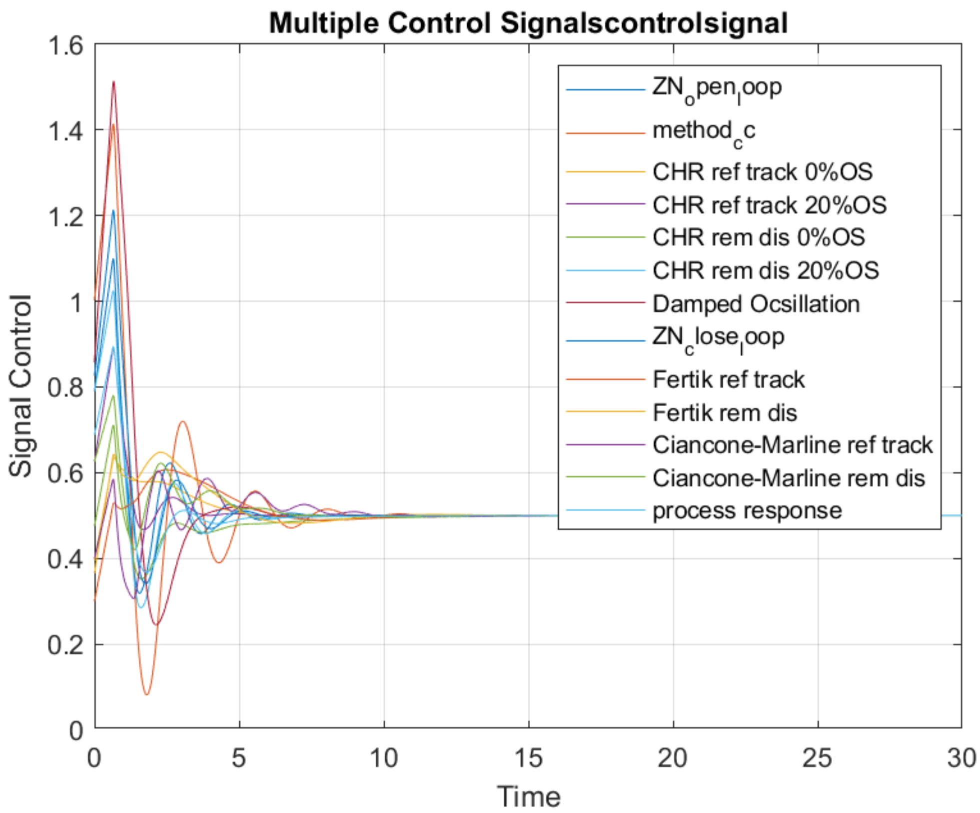
ZN_close_loop
Fertik ref track
Fertik rem dis
Ciancone-Marline ref track
Ciancone-Marline rem dis
process response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Fertik rem dis
Ciancone-Marline ref track
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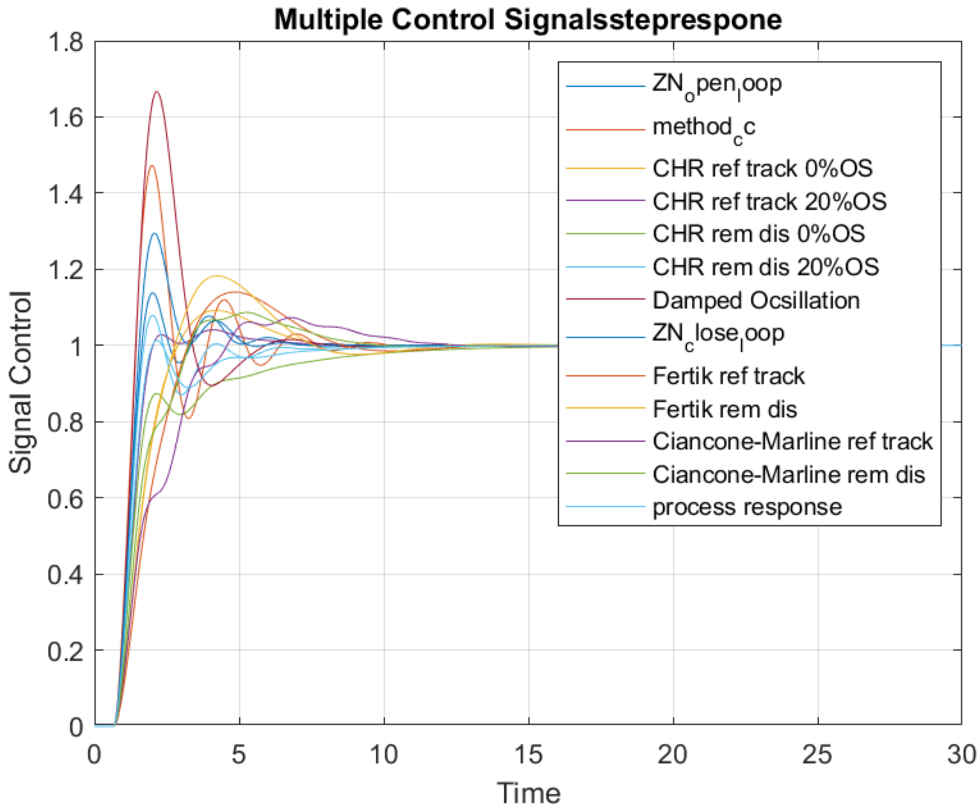
process response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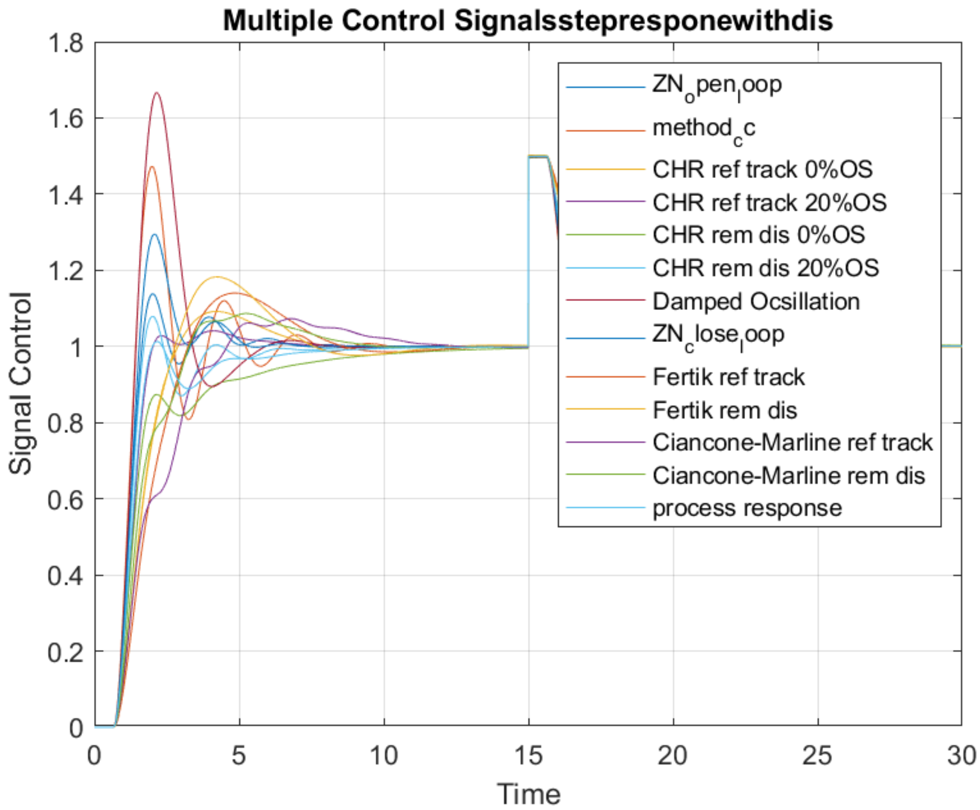
Fertik rem dis
Ciancone-Marline ref track
Ciancone-Marline rem dis
process response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