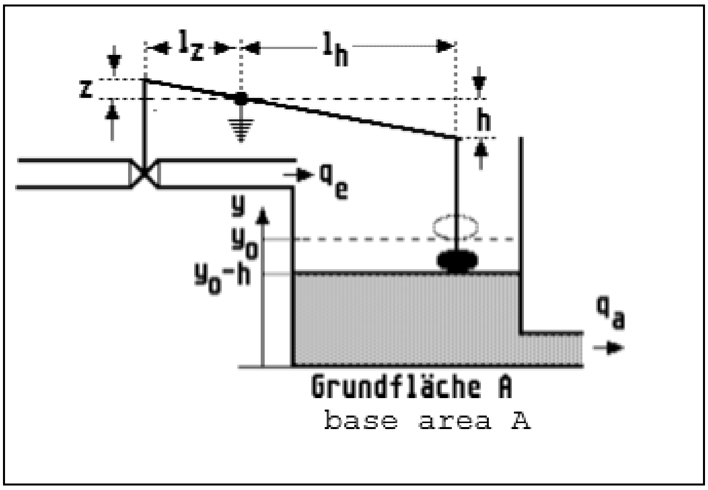
Examples with RegC#

tank level control.wln



The equations:

$q_e = C*z$ (Block 2)

$z / l_z = h / l_h$ are valid. (Block 3)

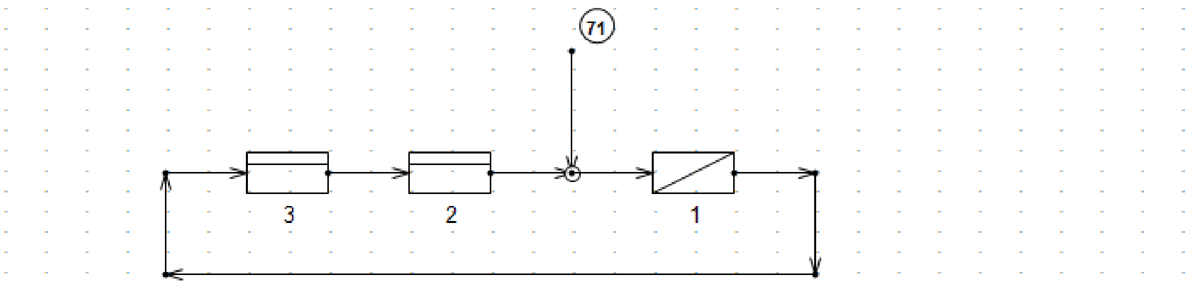
Content of the tank:

$A*y = A(y_0 - h(t))$ or

$$A*y = \int_0^t (q_e - q_a)dt + A*y_0$$ (Block 1)

q_e and q_a are the flow rates in l/min.

With C=10l/min/cm = 1 m²/min, l_z=0.5m, l_h=1m, A=1m² and a step function at q_a=0.1 m³/min lead to following plan:

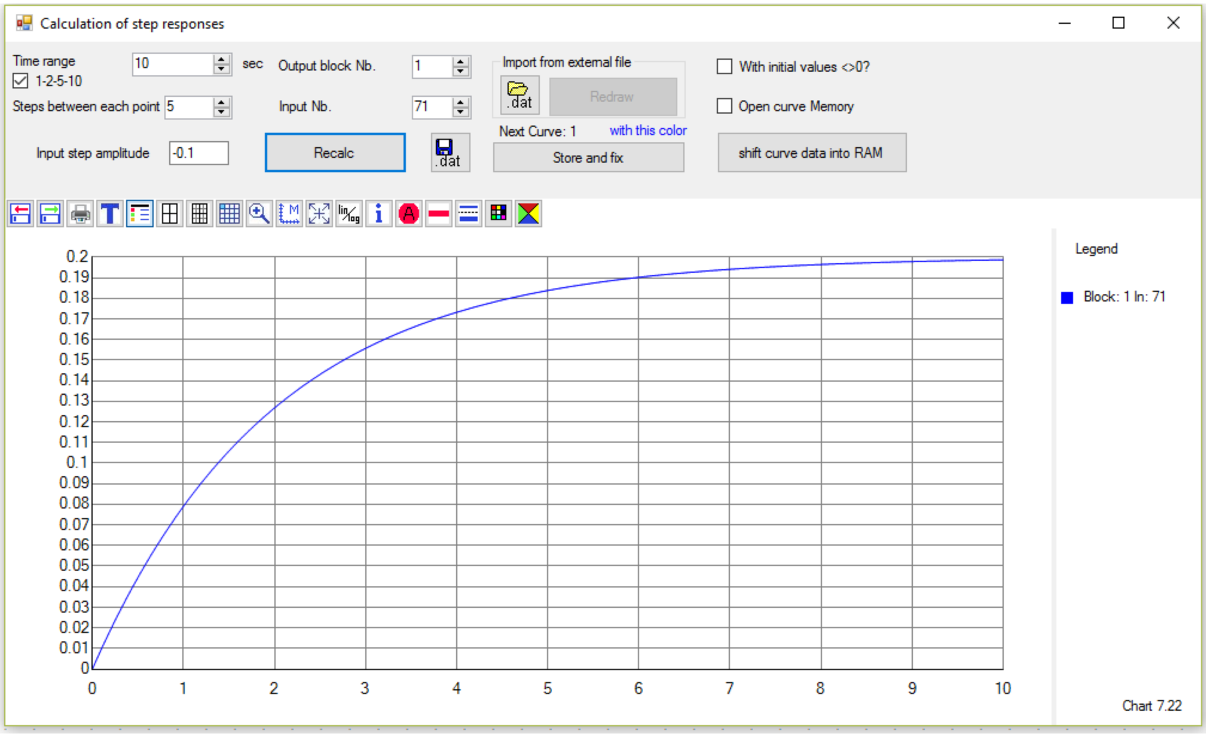


block parameters

Nr	type	gain	T1/Gen.-Fre.	T2/damping	limits	inputs
1	I	-1.0000	--	--	1E+30	2, 71
2	P	1.0000	--	--	1E+30	3
3	P	0.5000	--	--	1E+30	1

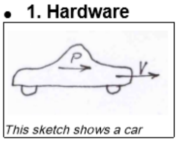
Ende, cancel | changed params -> blocks | new constants -> | Data into Report

q_a is a disturbance for the level. The disturbance step response with final control error of 0.2 m see next picture.



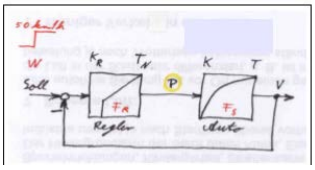
Cruise control project 1.wln

- **1. Hardware**

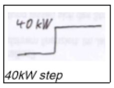


This sketch shows a car

- Speed Sensor: v → U_V with v is the speed
- Actuator: U_P → P with P is the power of the motor

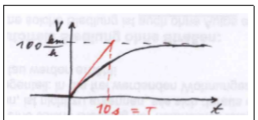


→ step function at input



40kW step

- We expect the **step response** look like that:

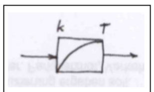


Step response of a PT1-block

Numerical example
(fits to an old VW-van)

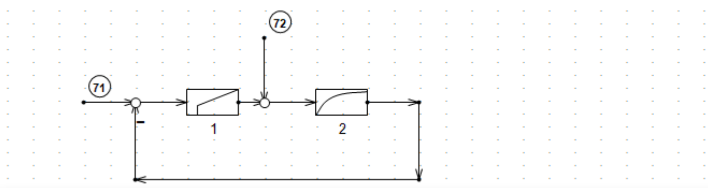
→ look at the table on page16

=> great similarity with a PT1 – block



Symbol of a PT1-block

- **K** extracted: $K = \frac{100\ km/h}{40\ kW} = 2{,}5\frac{km/h}{kW}$
- **T** extracted: $T = 10s$ → extracted with tangent method



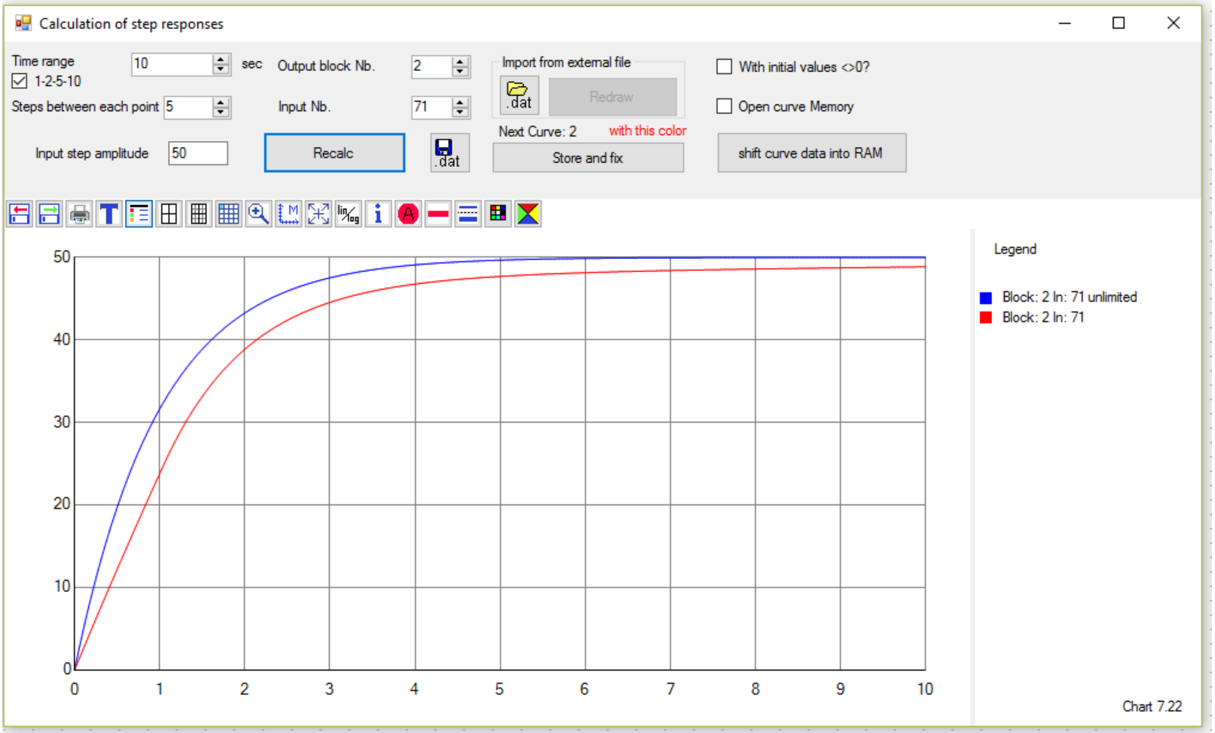
block parameters

Nr	type	gain	T1/Gen.-Fre.	T2/damping	limits	inputs
1	PI	4.0000	10.0000	--	1000	71, -2
2	PT1	2.5000	10.0000	--	1E+30	1, 72

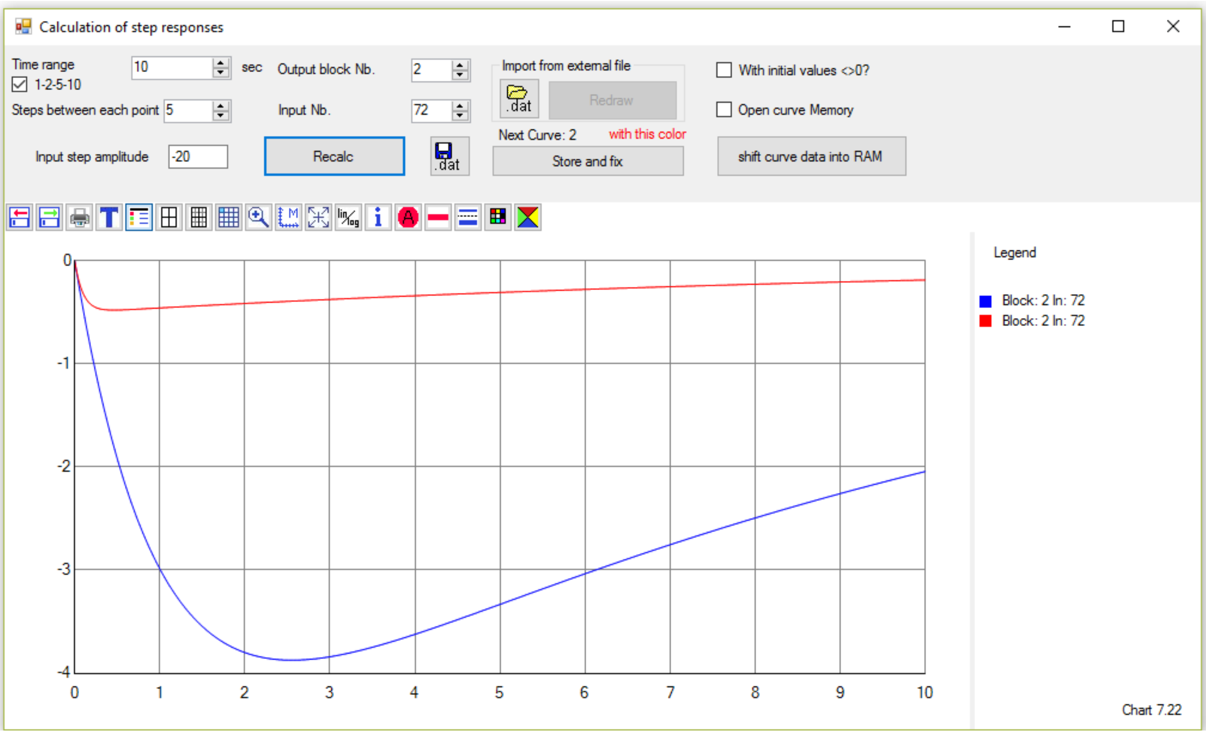
Ende, cancel | changed params -> blocks | new constants -> | Data into Report

Step at input 71 gives reference step response (response of speed of the car, if set value is switched from 0 to 50) and step at input 72 gives disturbance step response (if car is driving up a hill with fictive power reduction of 20 kW).

Reference step response (unlimited power (blue) and power limited to 100 kW(red)):

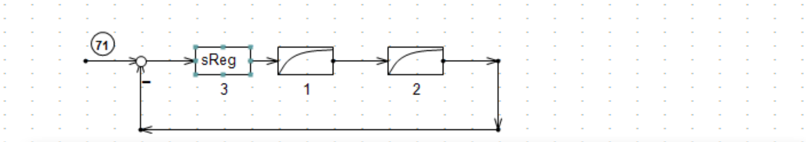


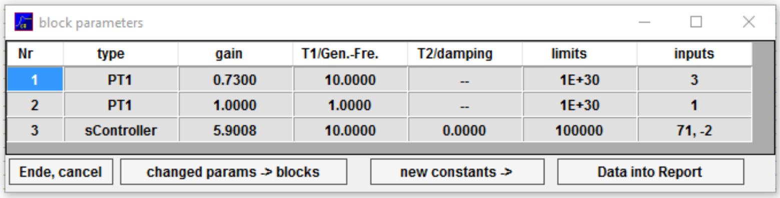
Disturbance step response of -20kw-Input at 72 (PI- gain K_c=4 (blue) and 40 (red):



Temperature control project 2.wln

First design of PI with phase margin 68,2° (equiv. to d= 0.7613 equiv. to overshoot ü=2.5%):





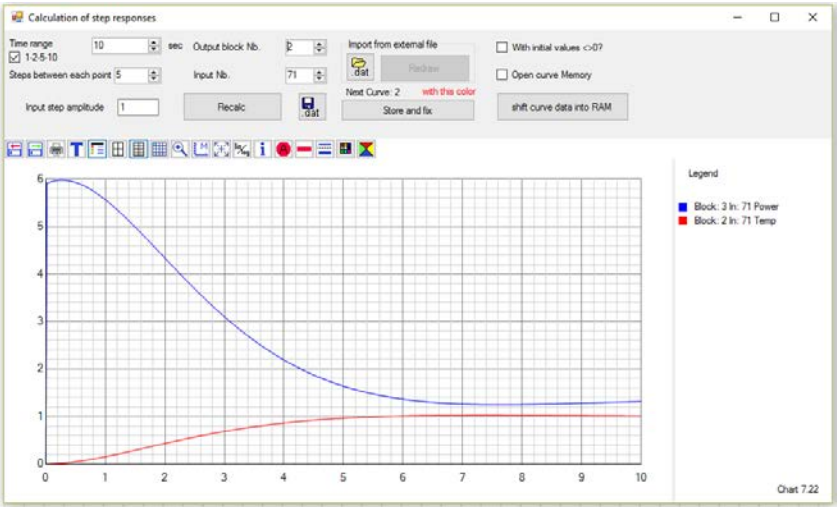
Nr	type	gain	T1/Gen.-Fre.	T2/damping	limits	inputs
1	PT1	0.7300	10.0000	--	1E+30	3
2	PT1	1.0000	1.0000	--	1E+30	1
3	sController	5.9008	10.0000	0.0000	100000	71, -2

Design:

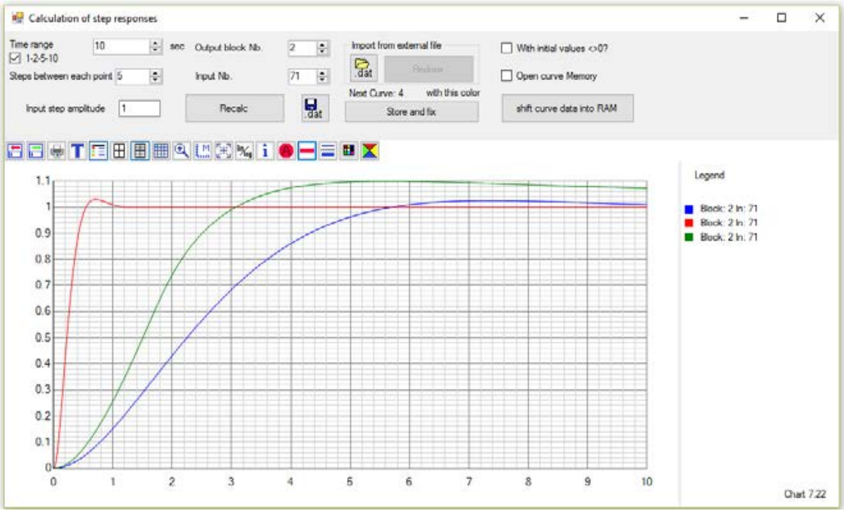
controller params, block no3

Controller type PI
phase margin 68.2 degree
cross over frequency omega_d: 0.4000
Controller gain Kc :5.9008
time constant TN : 10.0000
comment:

Unit step response of Temp and Power.

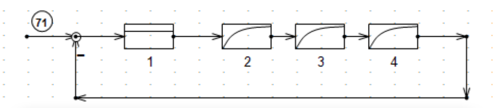


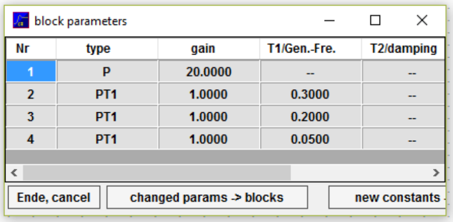
PIDT1 with st=10, T_n=1 and T_v=1, unlimited power (red) and limited power (green) and previous PI (blue). You see green curve with wind up effect. Phase margin always 68,2 °.



3PT1 with P-controller.wln

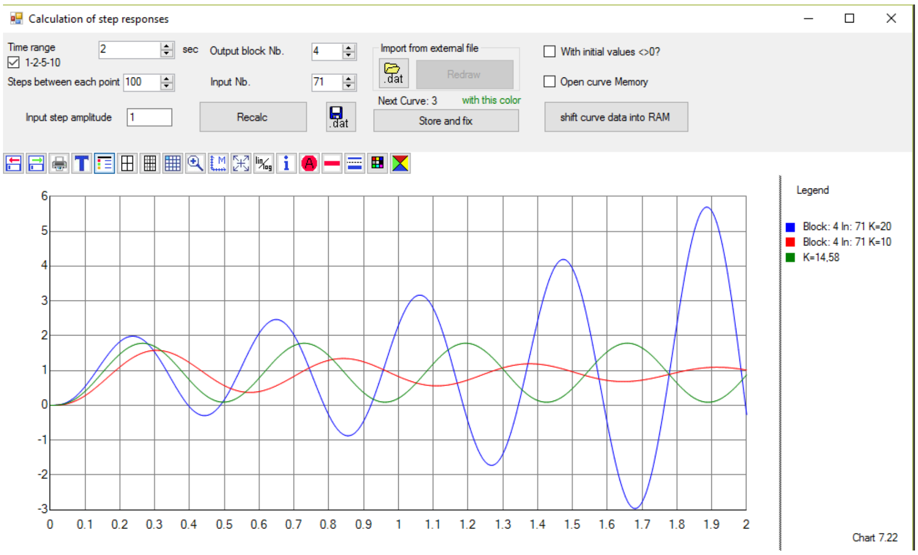
This example is used in my lecture to introduce stability problems. With K=10: stable. With K=20: unstable. With Hurwitz the calculation of border- value gives K=14.58.



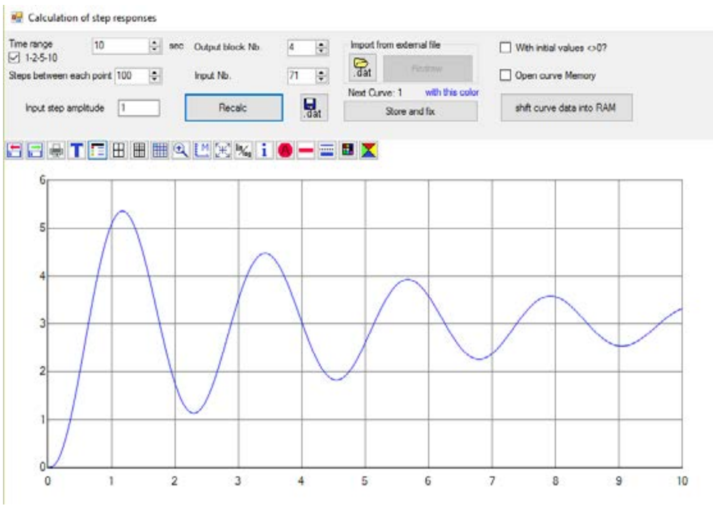

block parameters

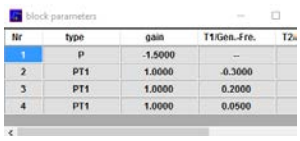
Nr	type	gain	T1/Gen.-Fre.	T2/damping
1	P	20.0000	--	--
2	PT1	1.0000	0.3000	--
3	PT1	1.0000	0.2000	--
4	PT1	1.0000	0.0500	--

Ende, cancel | changed params -> blocks | new constants



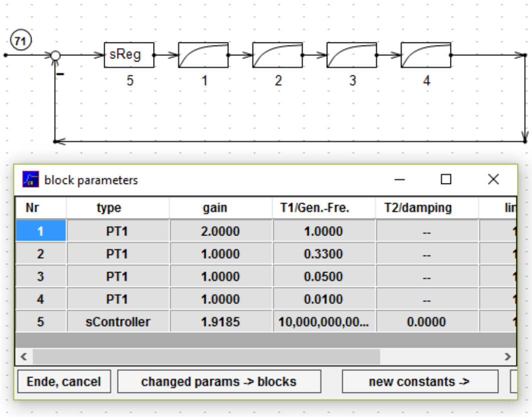
If Time constant of block 2 becomes negative, stability is with Hurwitz only possible in the range -2.083<K<-1. Step response is shown with K=-1.5.




block parameters

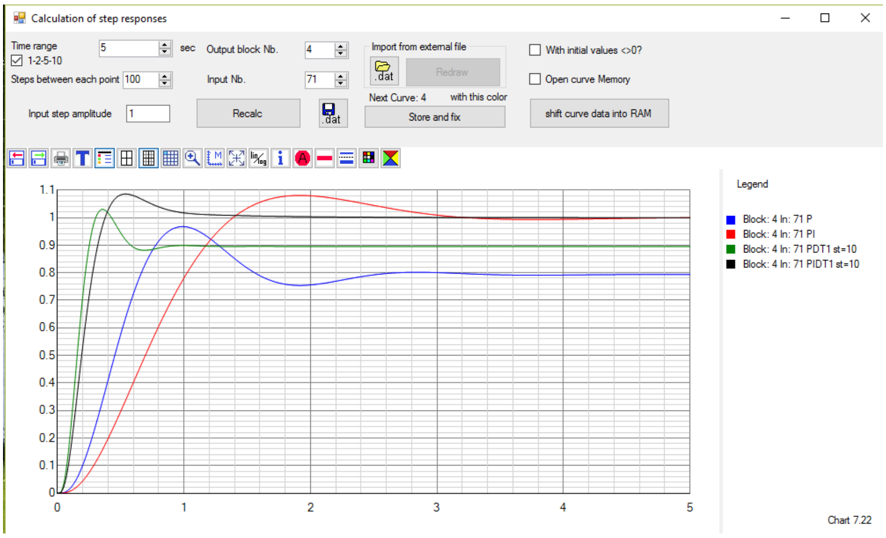
Nr	type	gain	T1/Gen.-Fre.
1	P	-1.5000	--
2	PT1	1.0000	-0.3000
3	PT1	1.0000	0.2000
4	PT1	1.0000	0.0500

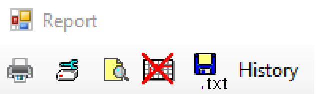
4PT1 with controller project 3.wln



Nr	type	gain	T1/Gen.-Fre.	T2/damping	lir
1	PT1	2.0000	1.0000	--	1
2	PT1	1.0000	0.3300	--	1
3	PT1	1.0000	0.0500	--	1
4	PT1	1.0000	0.0100	--	1
5	sController	1.9185	10,000,000,00...	0.0000	1

Now design of 4 controllers, polecompensation with -12 and -30 dB- method, DT1 with st=10, with unit reference step responses:





controller params, block no5

Controller type P
phase margin 60.0 degree
cross over frequency omega_d: 2.6712
Controller gain Kc :1.9185
comment:

controller params, block no5

Controller type PI
phase margin 60.0 degree
cross over frequency omega_d: 1.4228
Controller gain Kc :0.7883
time constant TN : 1.0013
comment:

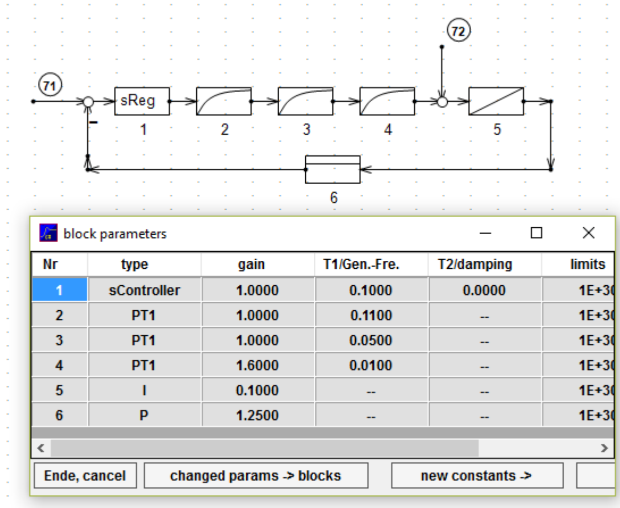
controller params, block no5

Controller type PDT1
phase margin 60.0 degree
cross over frequency omega_d: 7.1448
Controller gain Kc :4.2839
time constant Tv : 0.2971
step depth st (step of D-Part): 10.0000
comment:

controller params, block no5

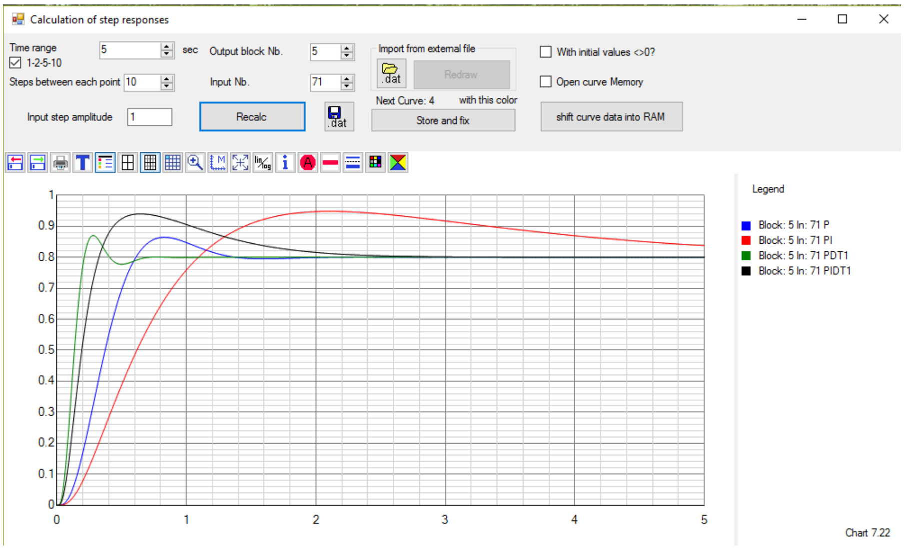
Controller type PIDT1
phase margin 60.0 degree
cross over frequency omega_d: 5.0397
Controller gain Kc :2.8166
time constant TN : 0.8621
time constant Tv : 0.2971
step depth st (step of D-Part): 10.0000
comment:

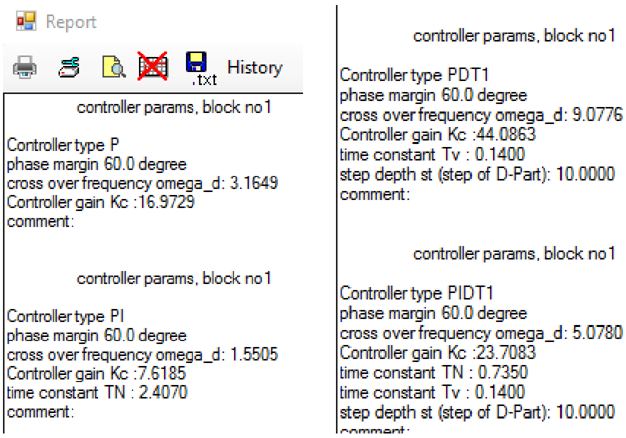
3PT1 and I with controller project 4.wln



Nr	type	gain	T1/Gen.-Fre.	T2/damping	limits
1	sController	1.0000	0.1000	0.0000	1E+3…
2	PT1	1.0000	0.1100	--	1E+3…
3	PT1	1.0000	0.0500	--	1E+3…
4	PT1	1.6000	0.0100	--	1E+3…
5	I	0.1000	--	--	1E+3…
6	P	1.2500	--	--	1E+3…

Four controllers, PI with sym Opt., polecompensation -30 dB- method, DT1 with st=10, with unit reference step responses:





controller params, block no1

Controller type P
phase margin 60.0 degree
cross over frequency omega_d: 3.1649
Controller gain Kc :16.9729
comment:

controller params, block no1

Controller type PI
phase margin 60.0 degree
cross over frequency omega_d: 1.5505
Controller gain Kc :7.6185
time constant TN : 2.4070
comment:

controller params, block no1

Controller type PDT1
phase margin 60.0 degree
cross over frequency omega_d: 9.0776
Controller gain Kc :44.0863
time constant Tv : 0.1400
step depth st (step of D-Part): 10.0000
comment:

controller params, block no1

Controller type PIDT1
phase margin 60.0 degree
cross over frequency omega_d: 5.0780
Controller gain Kc :23.7083
time constant TN : 0.7350
time constant Tv : 0.1400
step depth st (step of D-Part): 10.0000
comment: