

Overview and Properties of linear Blocks

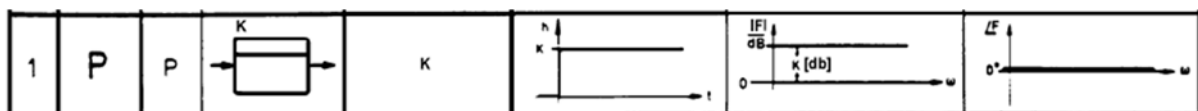
Supplement to Workbook page 16

Content

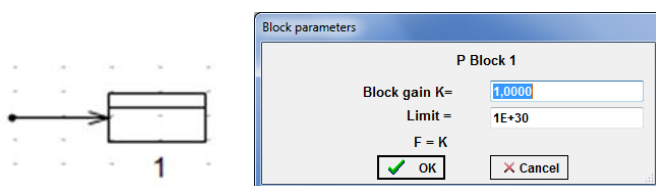
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You can switch the RegCSharp program to English text by using the US- flag button in the toolbar top left position.

3.7.1 P- Block

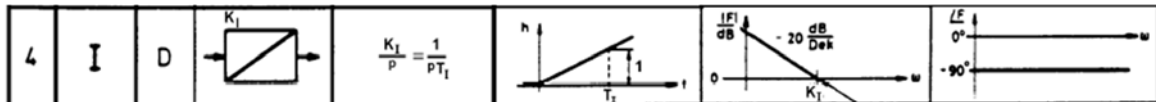


$$F(p)=K$$

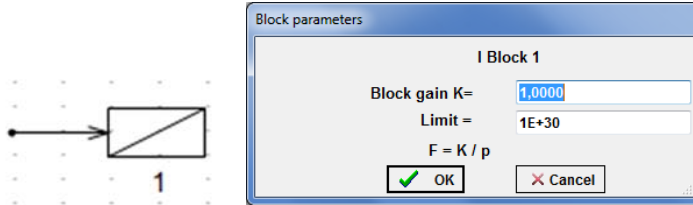


Step response, bode plot and polar plot are trivial.

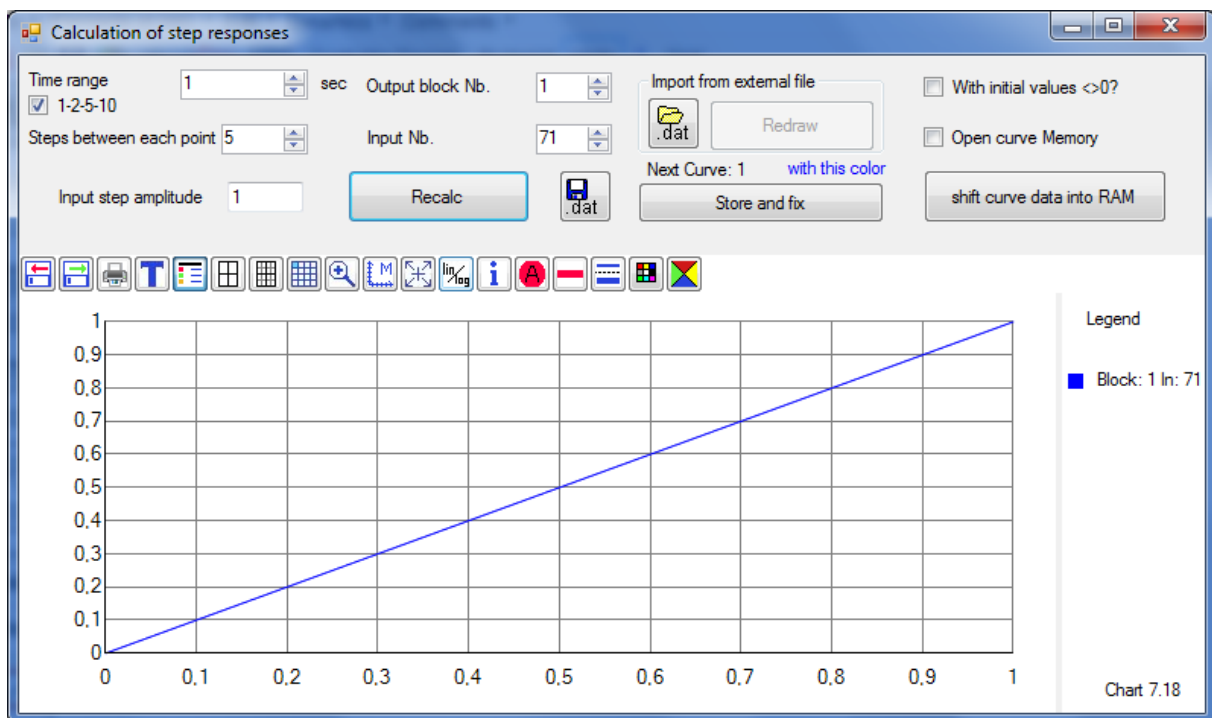
3.7.2 I-Block



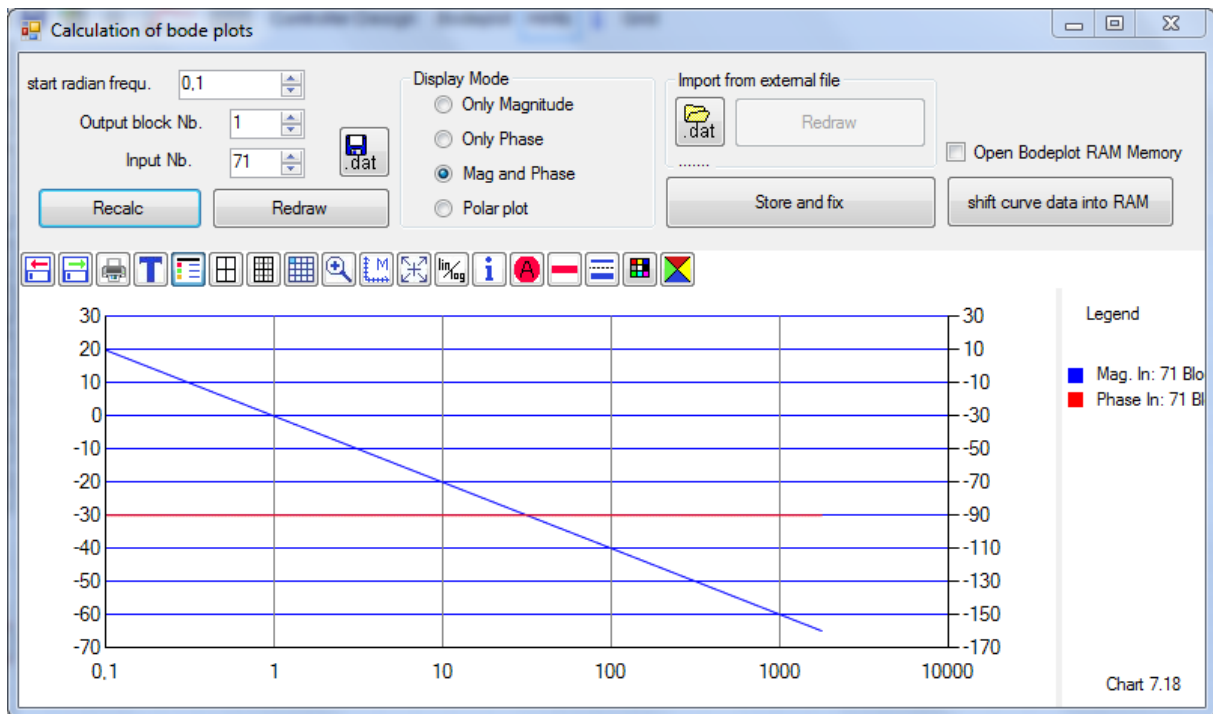
$$F(p) = K_I / p$$



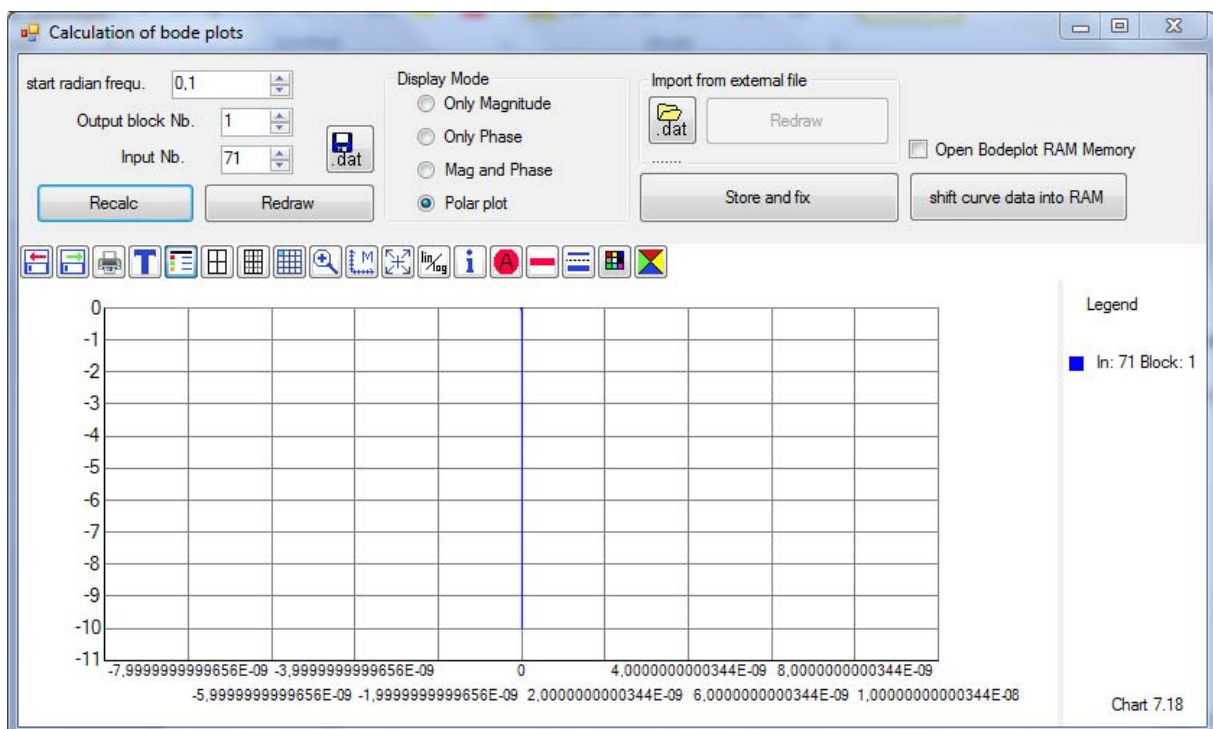
Step response I



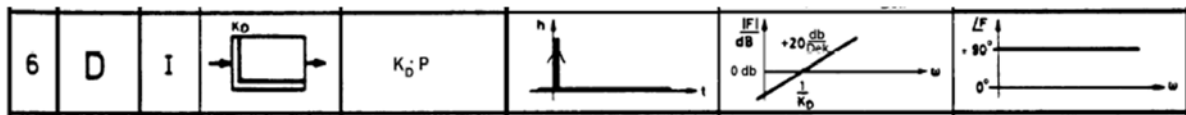
Bode plot I



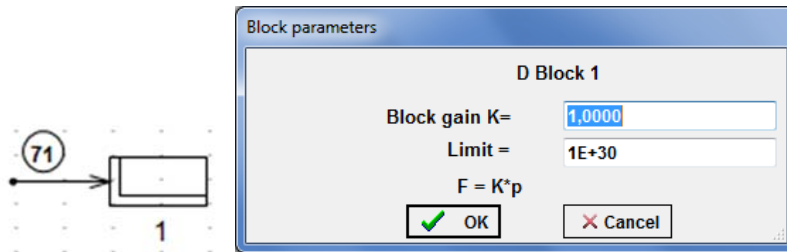
Polar plot I



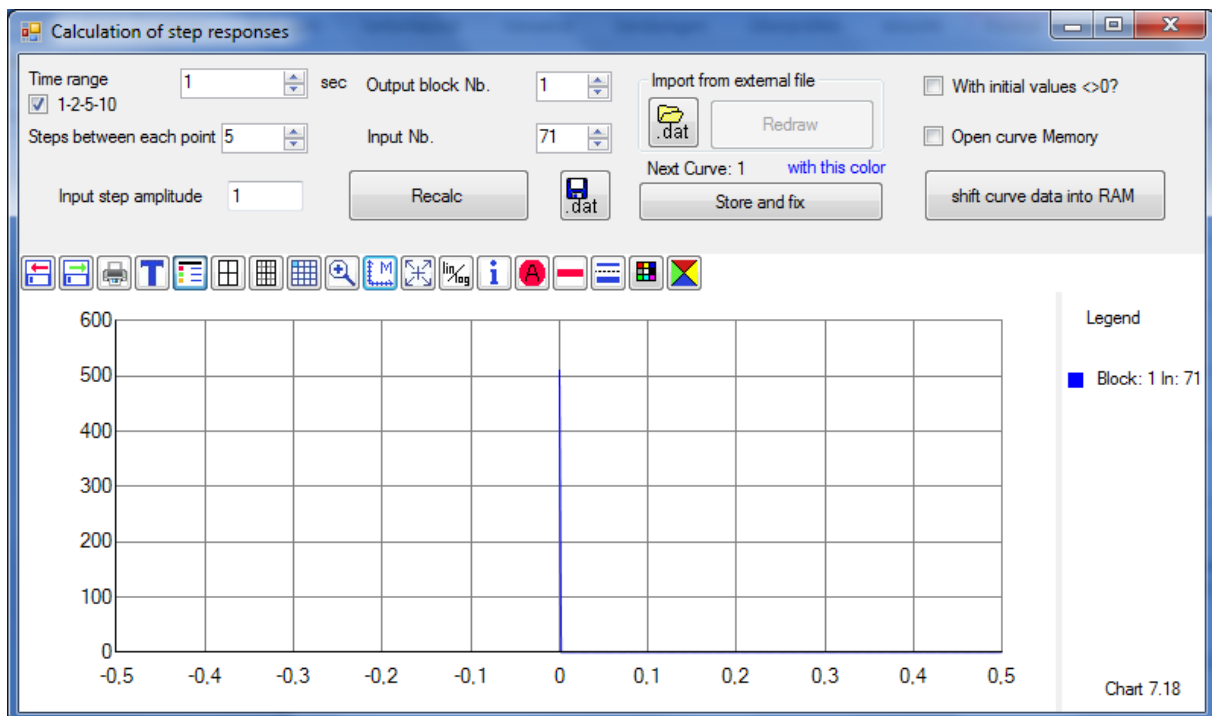
3.7.3 D-Block



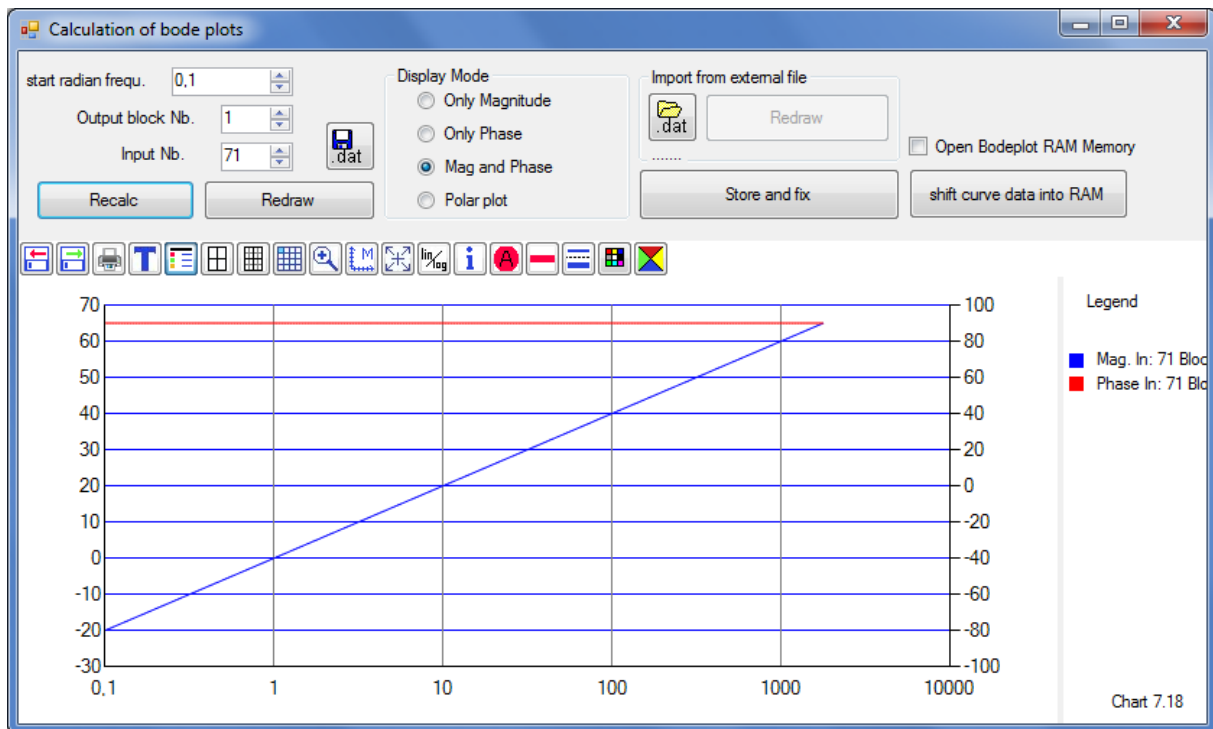
$$F(p) = K_D p$$



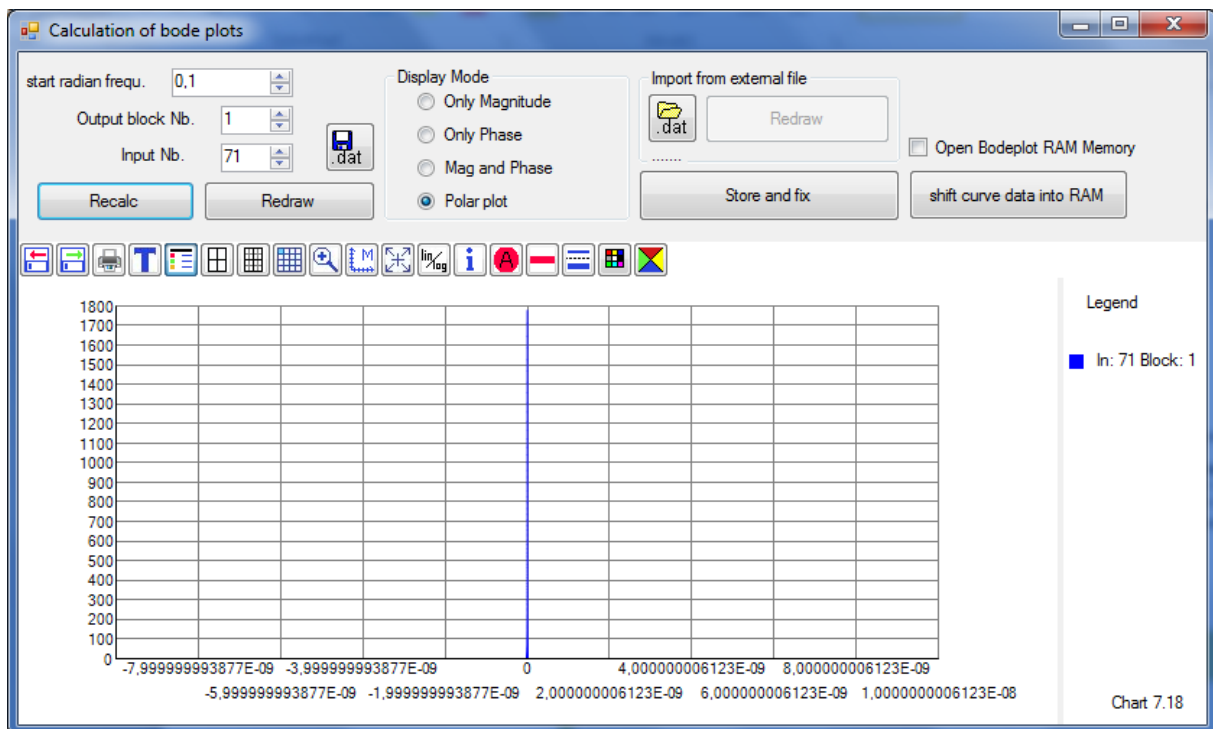
Step response(Dirac- impulse), displayed as pulse with limited width and height



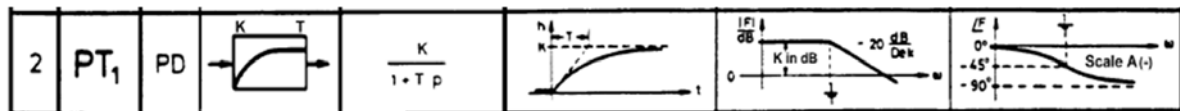
Bode plot D



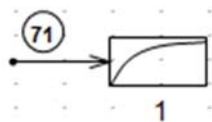
Polar plot D



3.7.4 PT1- Block



$$F(p) = \frac{K}{1 + pT}$$



Block parameters

PT1 Block 1

Block gain K= 1,0000

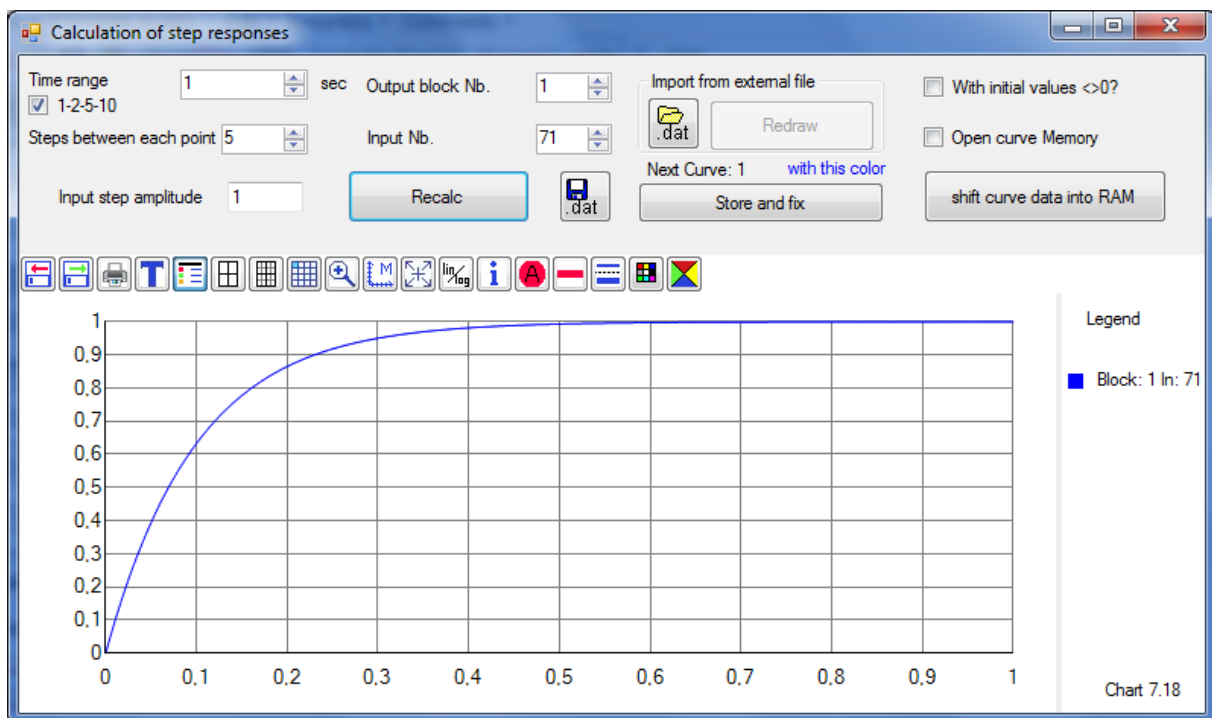
Time constant T= 0,1000

Limit = 1E+30

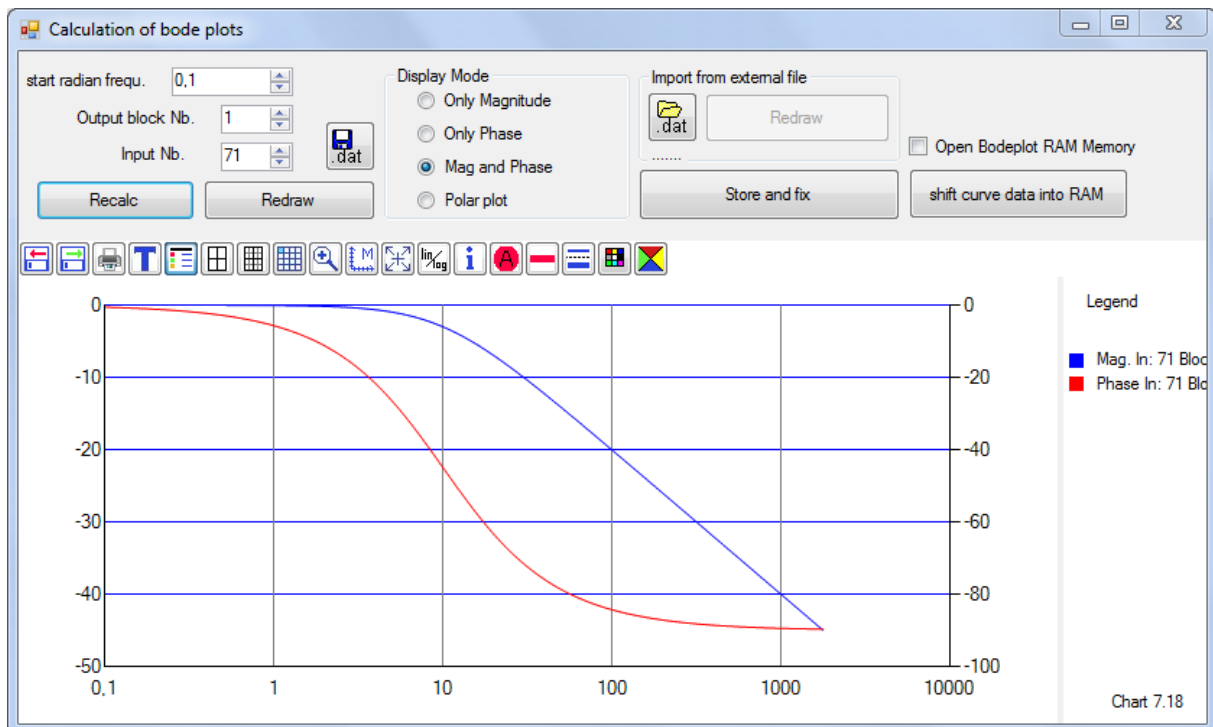
$F = K / (1 + p \cdot T)$

OK Cancel

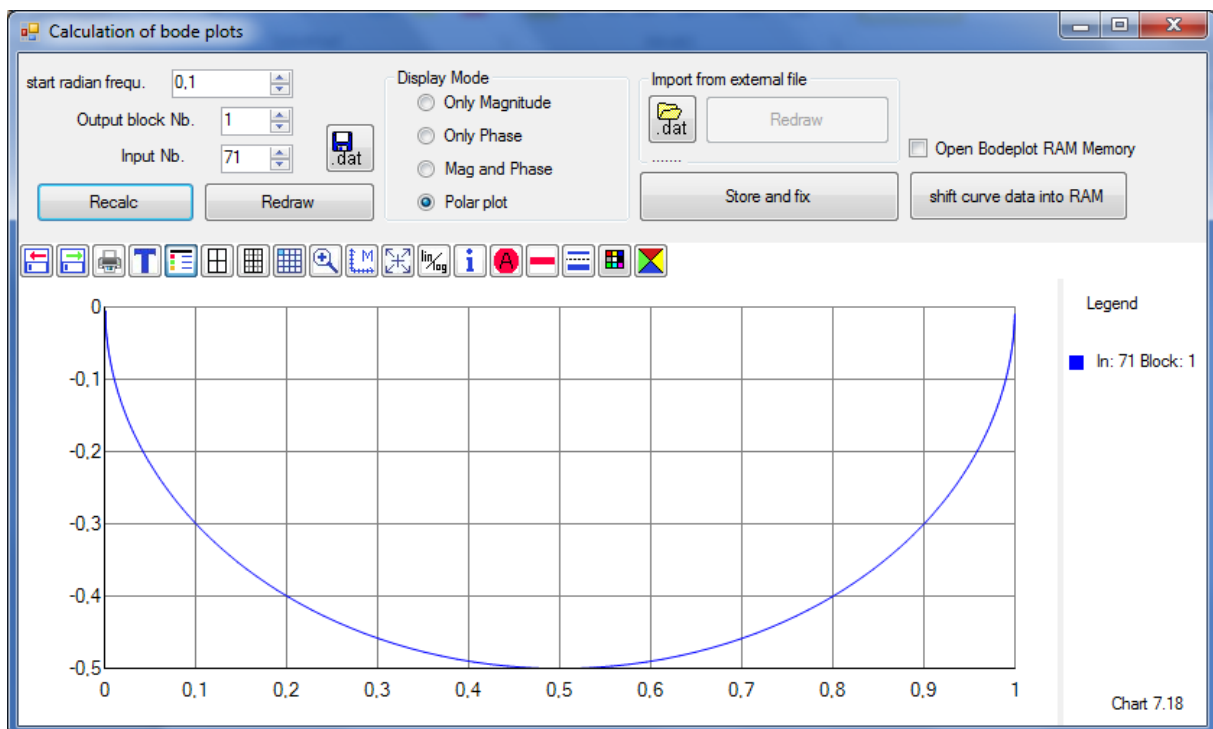
Step response PT1



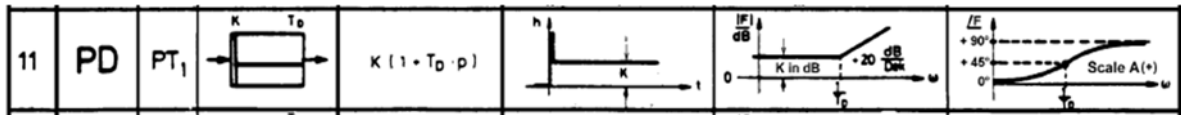
Bode plot PT1



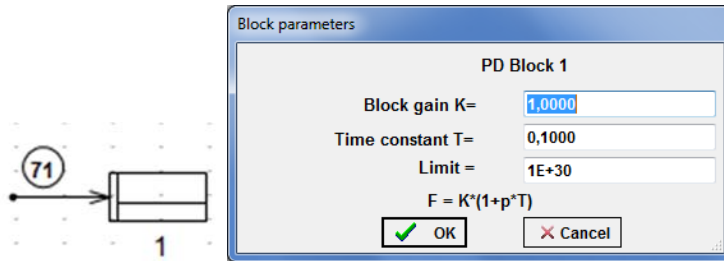
Polar plot PT1



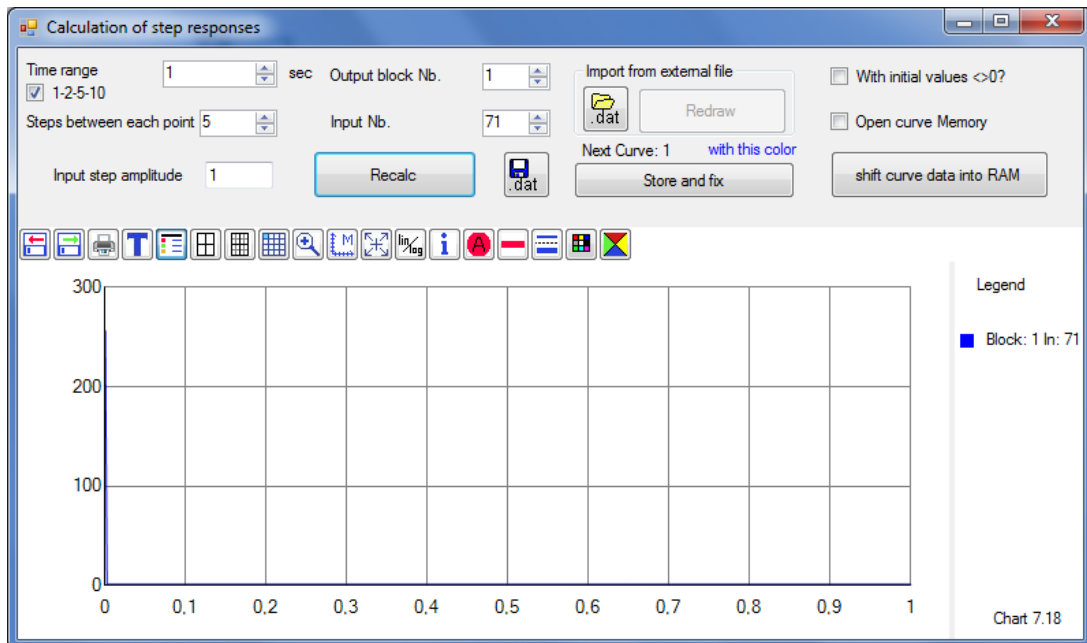
3.7.5 PD – Block



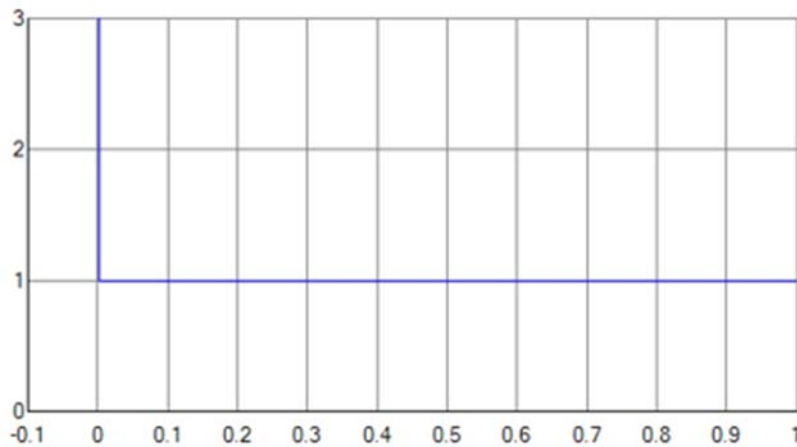
$$F(p) = 1 + T_D p$$



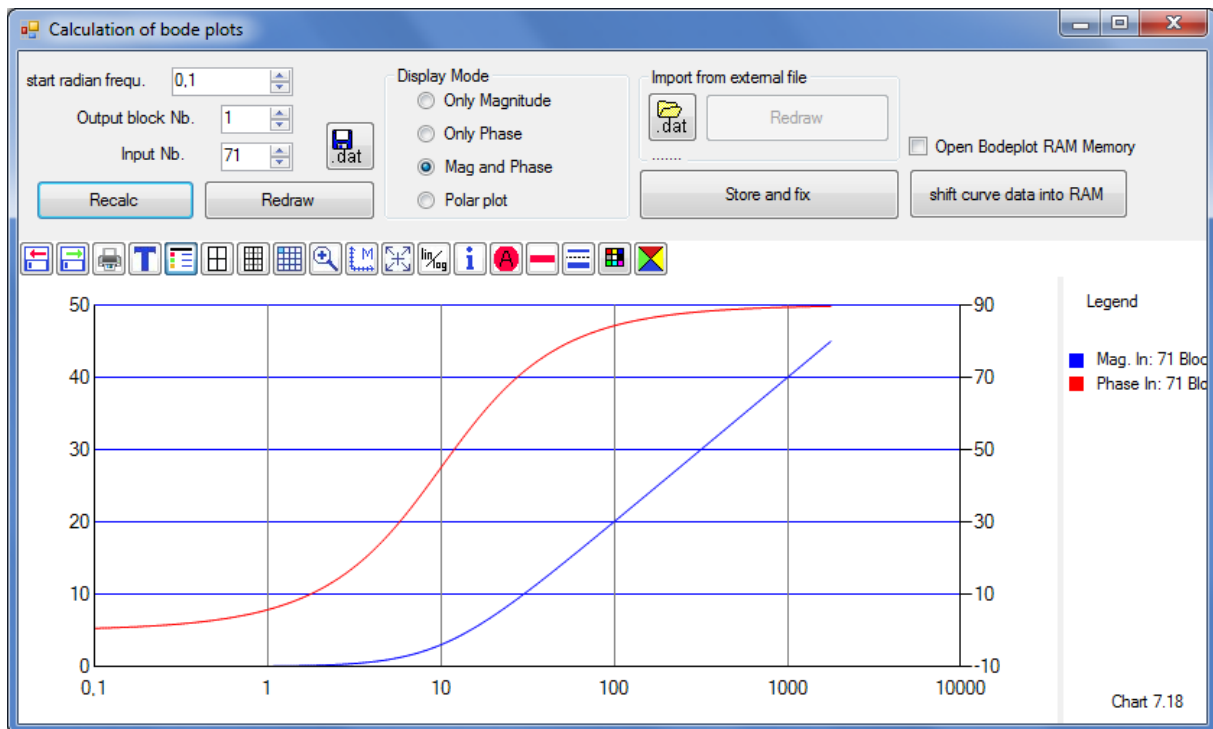
Step response (at beginning (t=0) again dirac impulse)



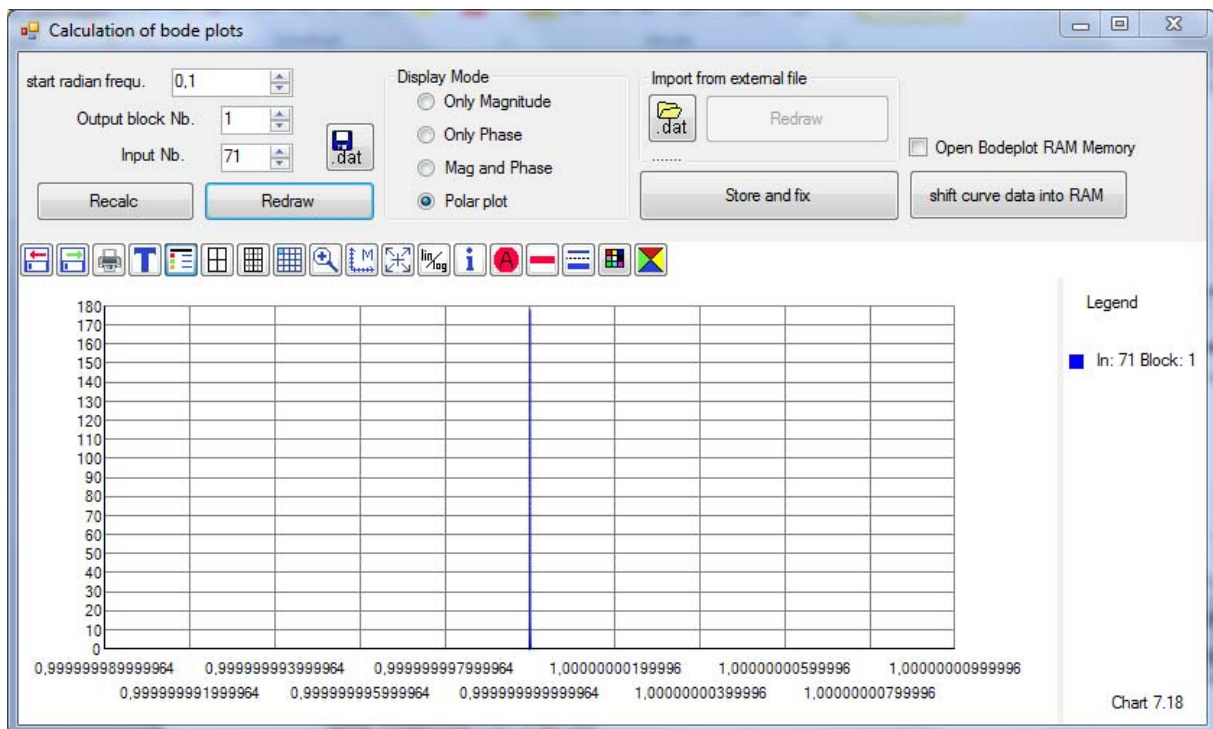
Other scaling:



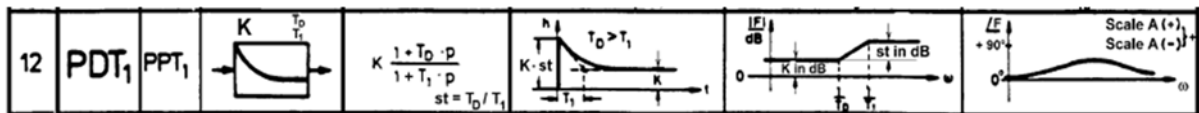
Bode plot PD



Polar plot PD

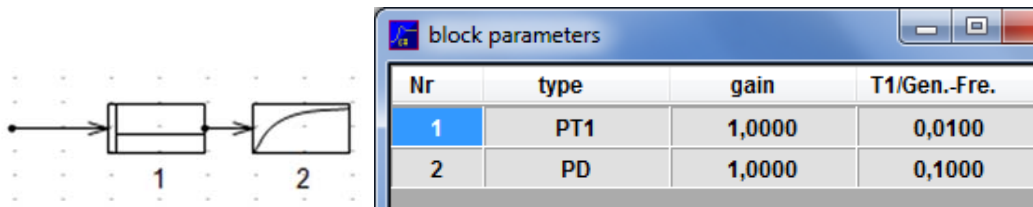


3.7.6 PDT1 – Block (series connection PD + PT1)

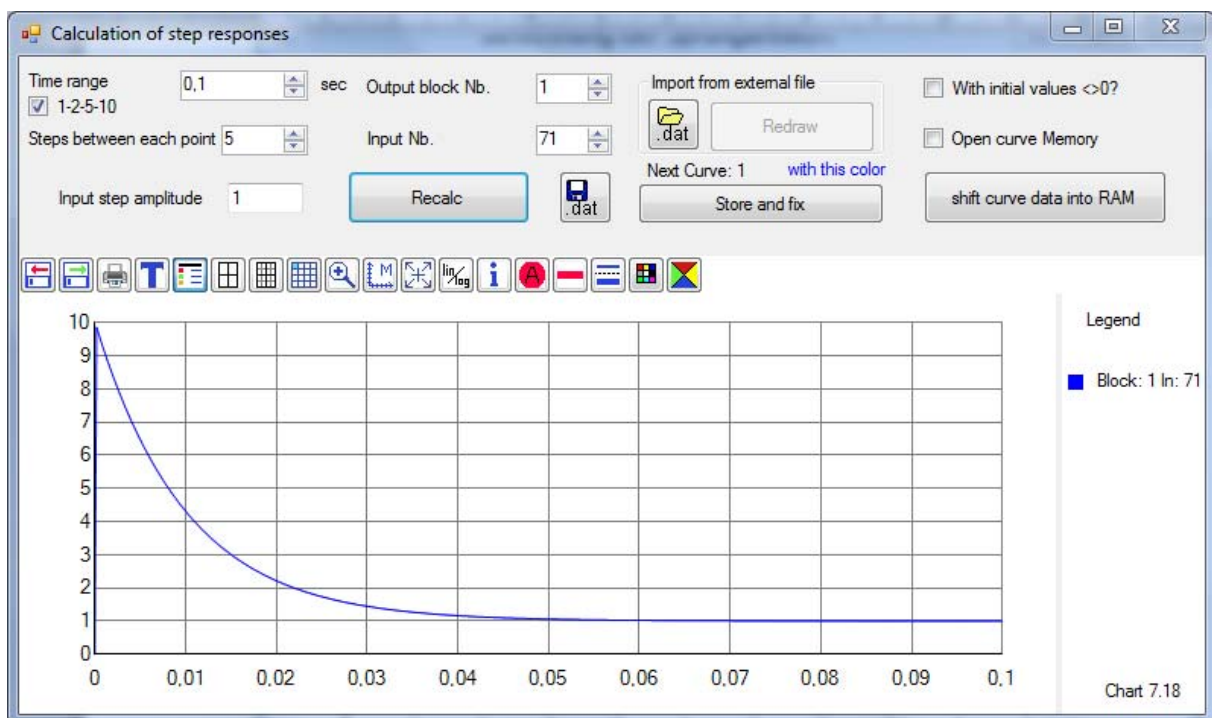


$$F(p) = K \frac{1 + pT_D}{1 + pT_1}$$

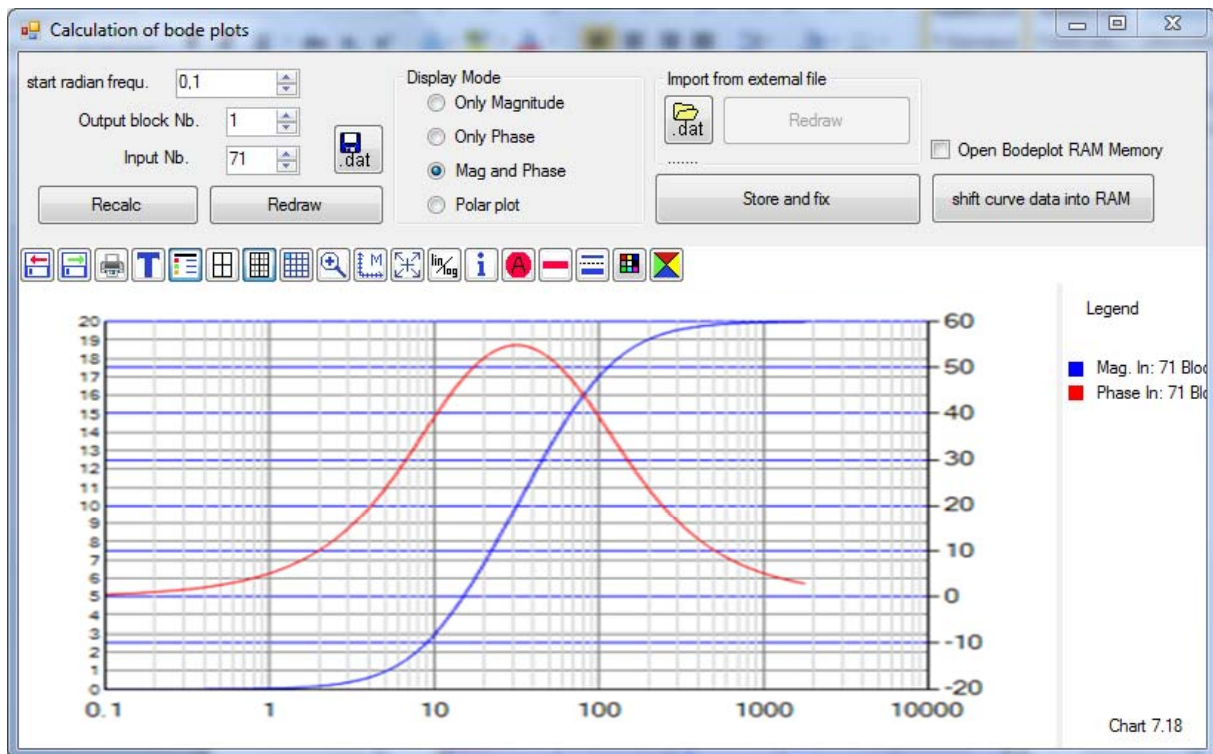
First $st=10$, preemphasis, also called lead-block



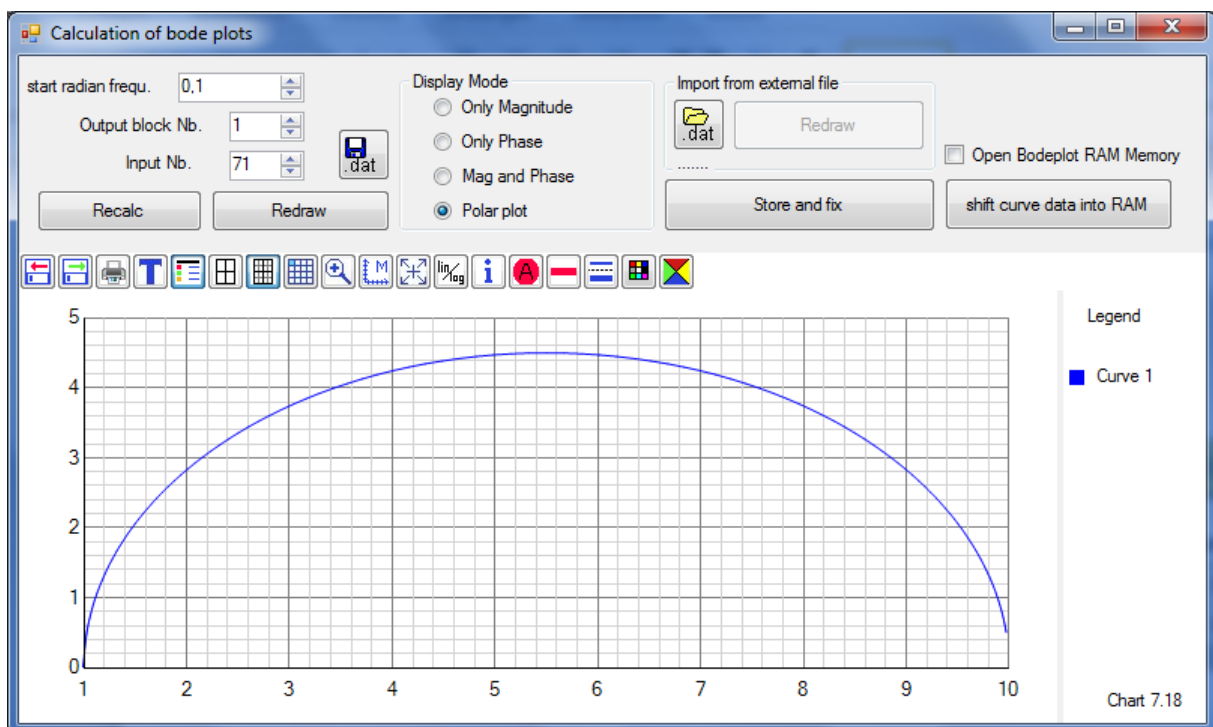
Step response PDT1 $st=10$



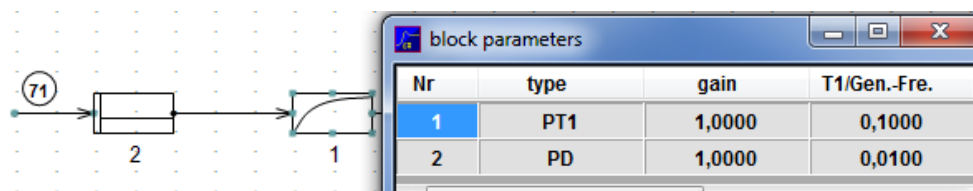
Bode plot PDT1 st=10



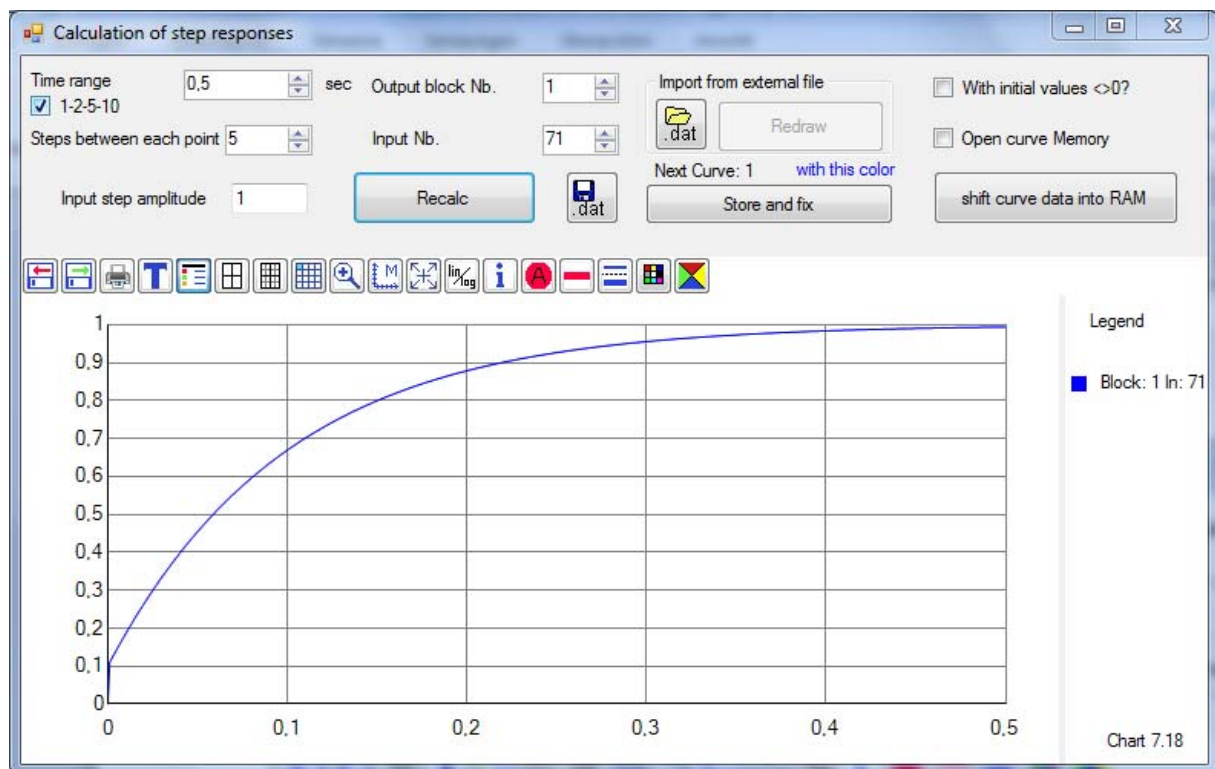
Polar plot PDT1, st=10



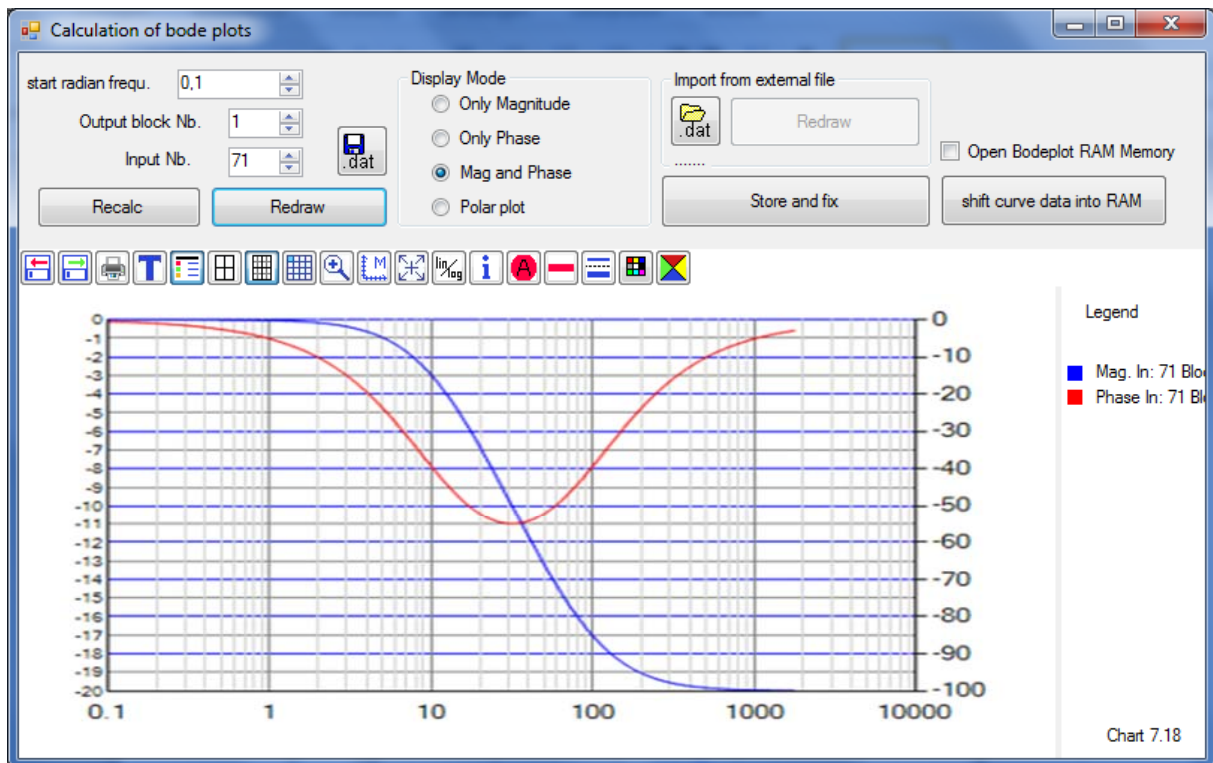
PDT1, now st=0.1 deemphasis, also called lag- block



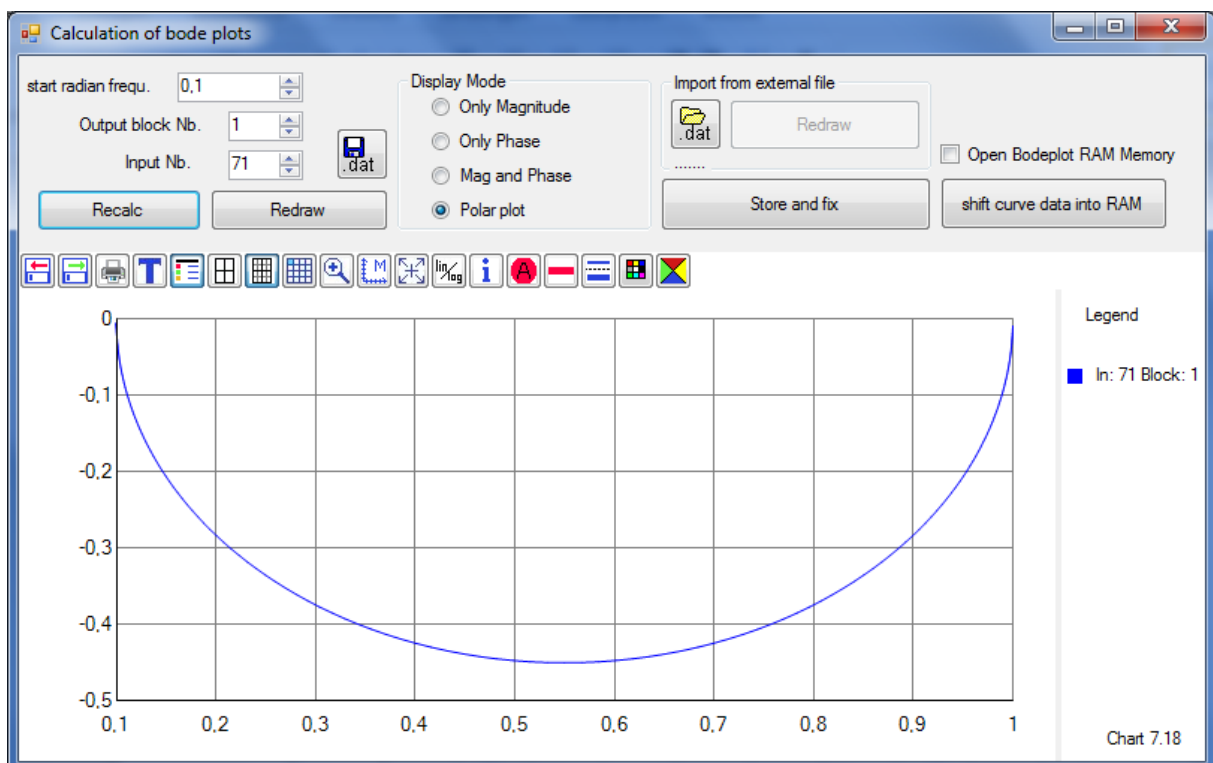
Step response PDT1, $st=0.1$



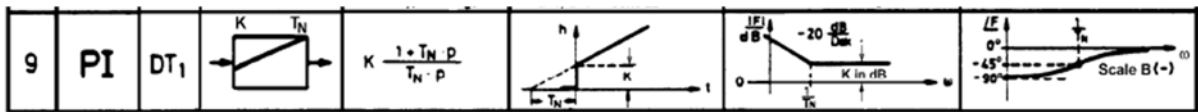
Bode plot PDT1, $st=0.1$



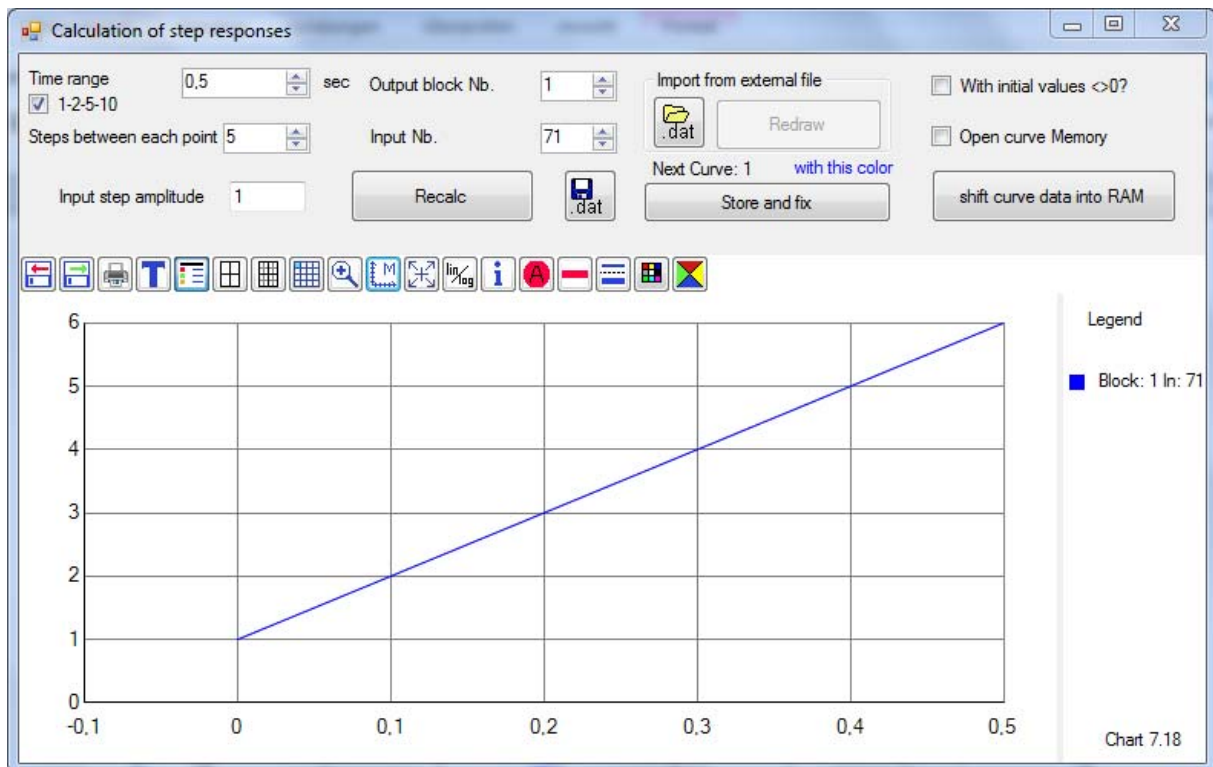
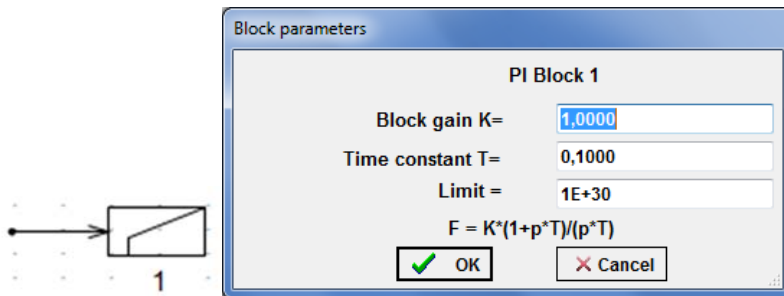
Polar plot PDT1, $st=0.1$



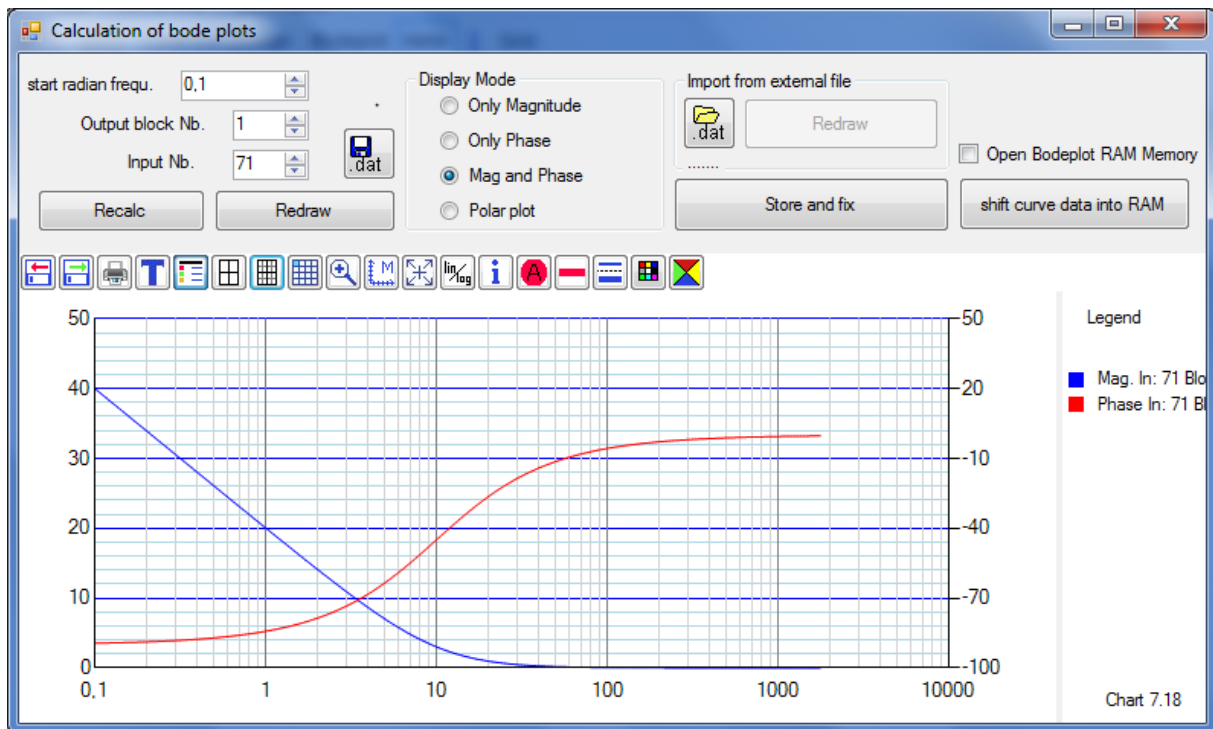
3.7.7 PI- Block, simple standard controller



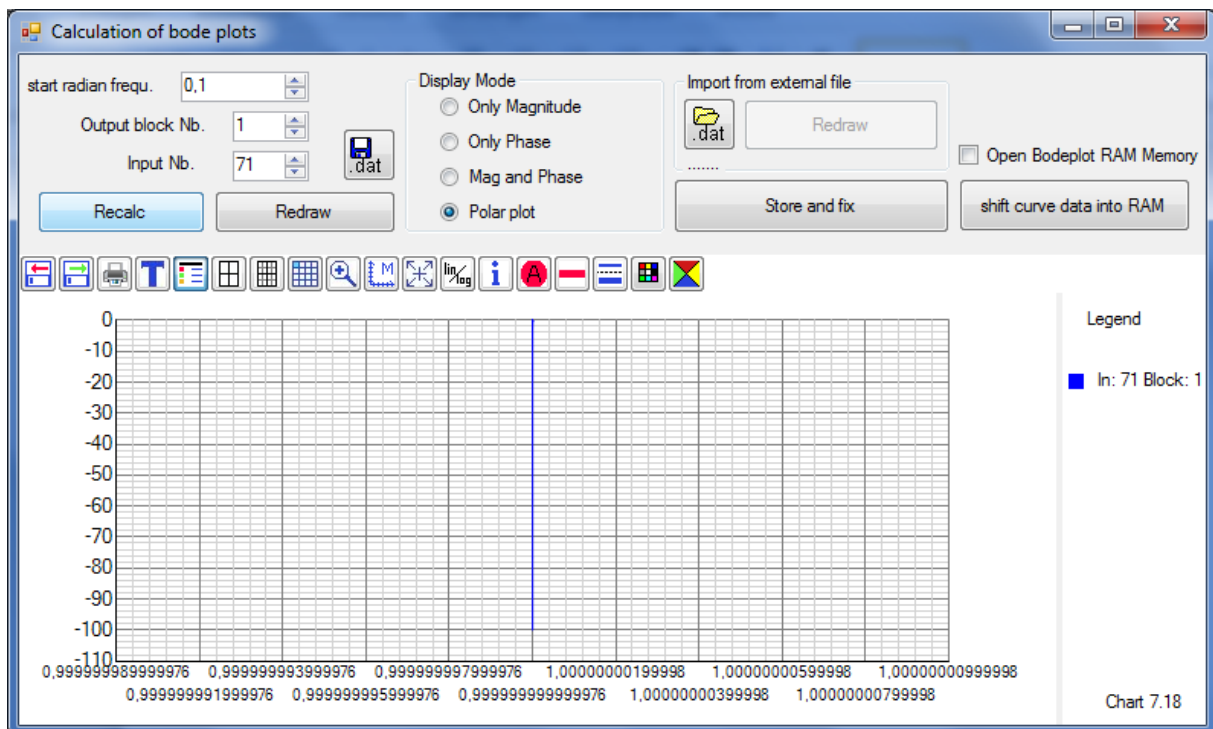
$$F(p) = K_R \frac{1 + pT_N}{pT_N}$$



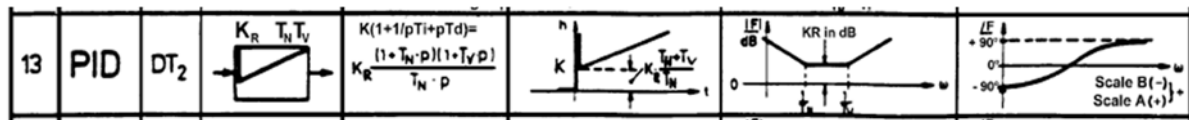
Bode plot PI



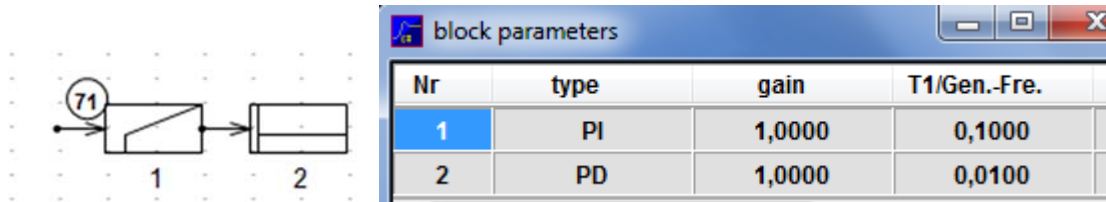
Polar plot PI



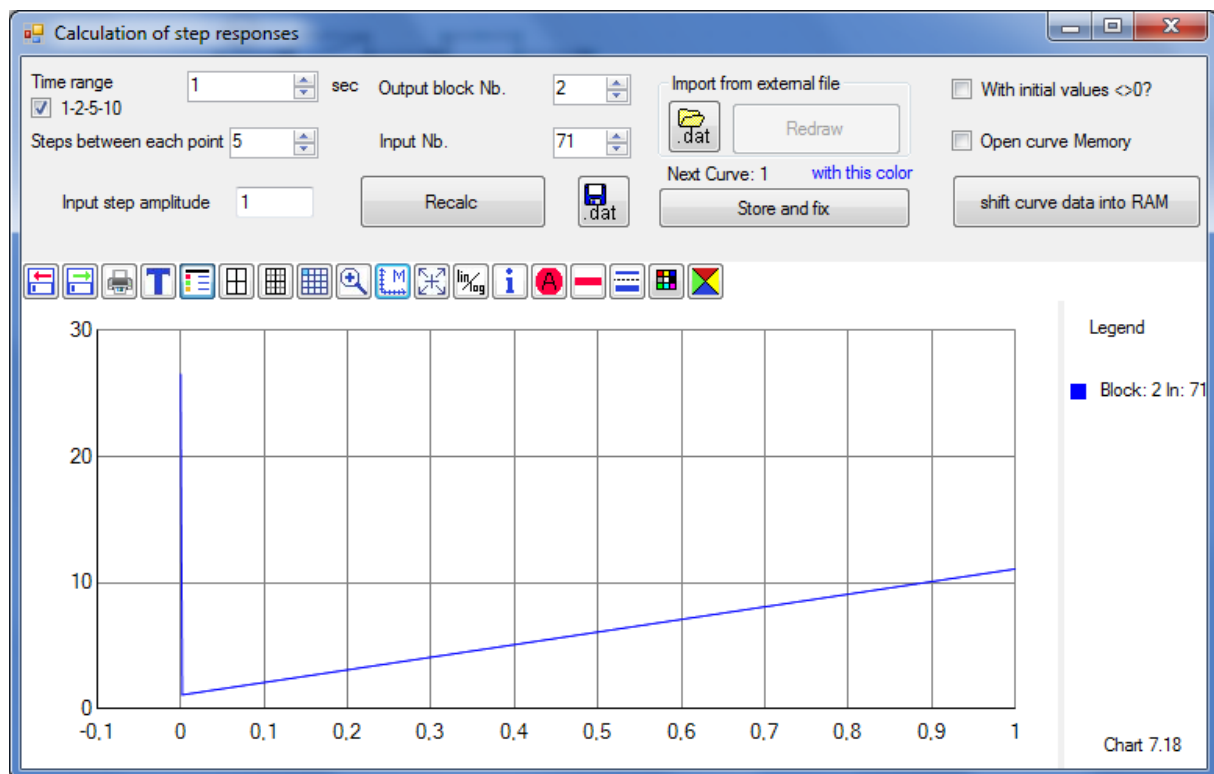
3.7.8 PID- Block (ideal, not realizable)



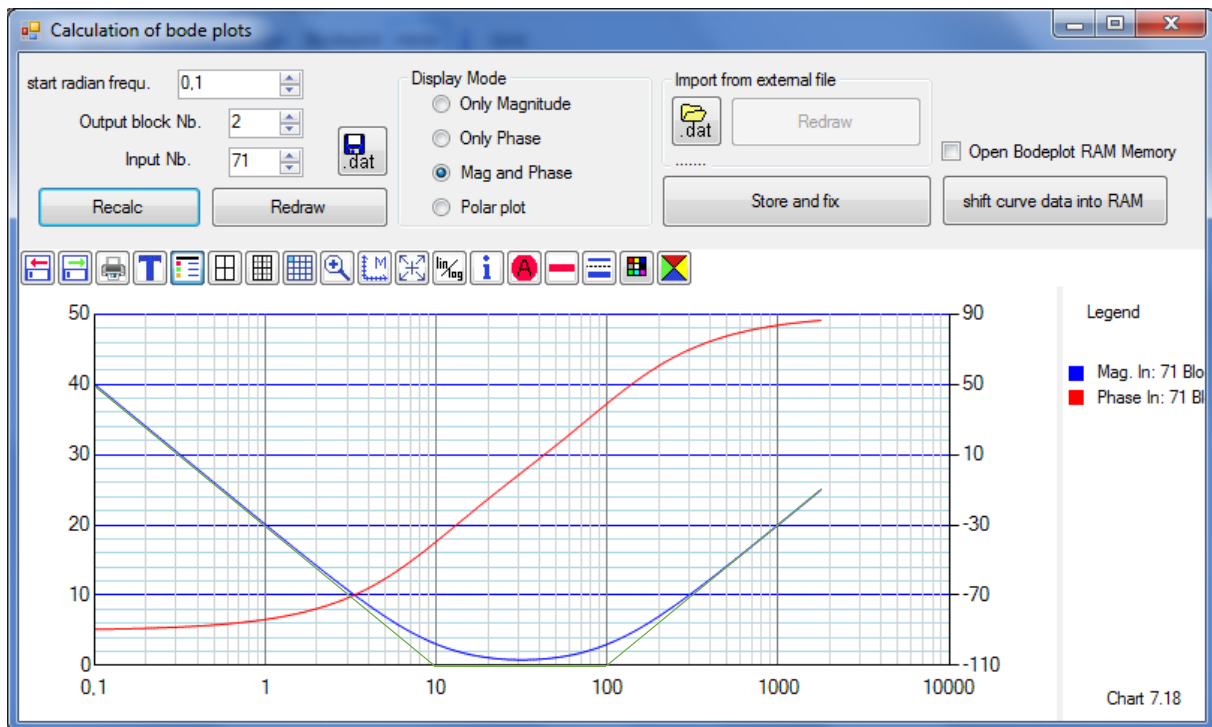
$F(p) = K_R \frac{(1+pT_N)(1+pT_V)}{pT_N}$, in RegCSharp not available, use series connection of PI +PD



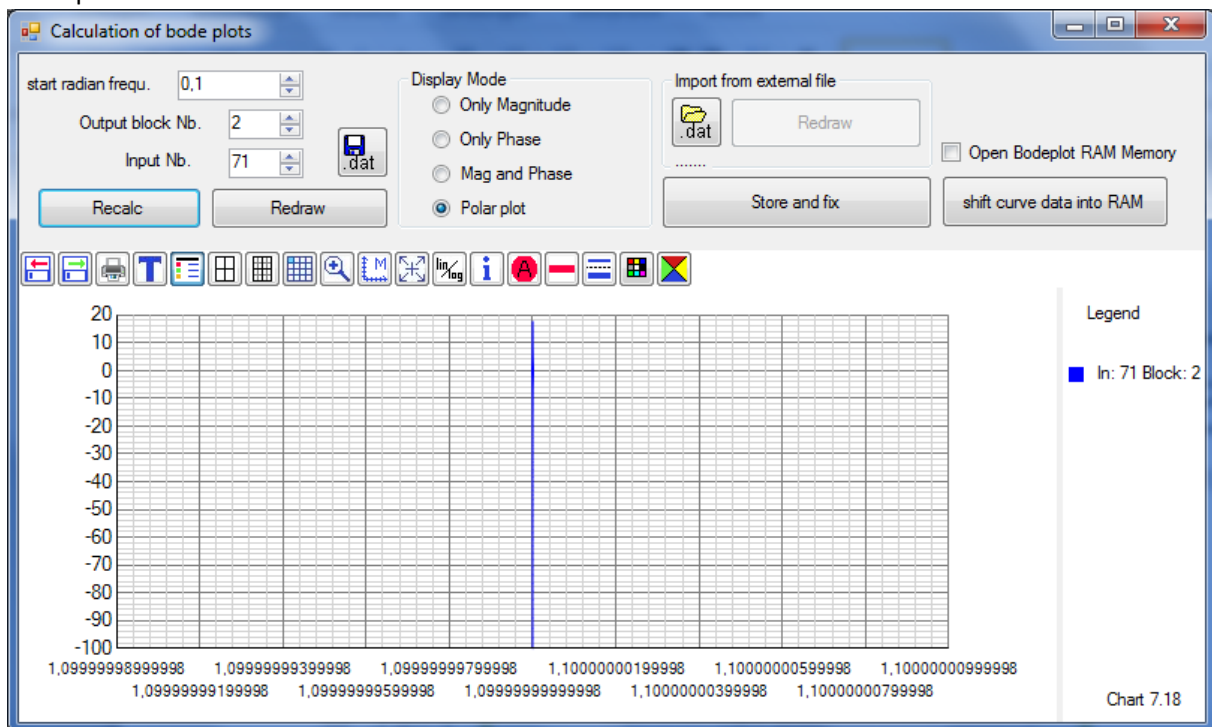
Step response with 5 calculation steps for each point. $T_N=0.1$, $T_V=0.01$, $K=1$



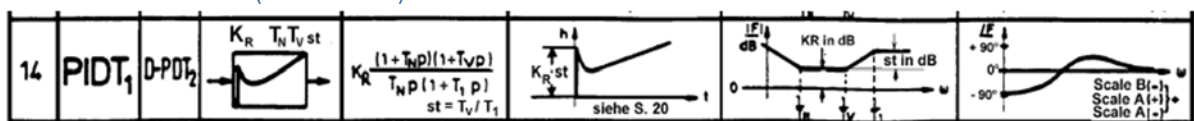
Bode plot PID, green lines are the asymptots



Polar plot

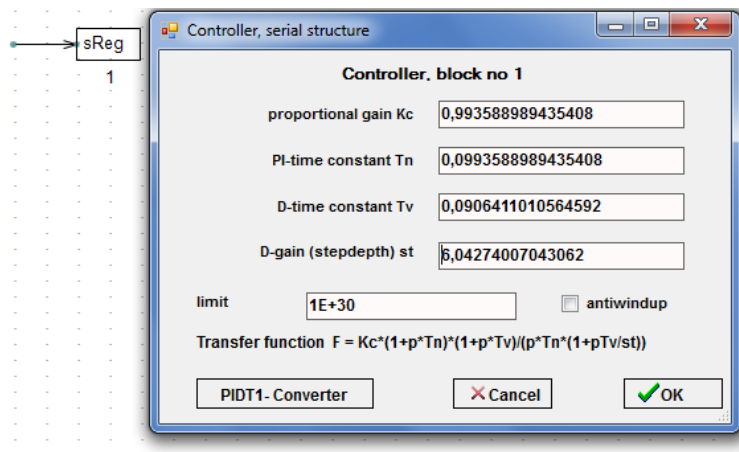


3.7.9 PIDT1- Block (realizable)



$$F(p) = K_R \frac{(1+pT_N)(1+pT_V)}{pT_N(1+pT_1)}, \text{ in RegCSharp available as block Reg / sReg, step depth } st=T_V/T_1.$$

Values from lecture example WB p. 20, $K=1.9$, $T_1=0.19$, $T_0=0.0474$, $T_1=0.015$



With PDT1- converter:

Calculation and conversion of PDT1-coefficients

Boide form

$$F(p) = K_R \frac{(1 + pT_N)(1 + pT_V)}{pT_N(1 + pT_1)}$$

KR 0,993588989435408 >>>

TN 0,0993588989435408 s

Tv 0,0906411010564592 s <<<

st 6,04274007043062 s

Parallel form

$$F(p) = K \frac{1 + 1/pT_I + pT_D}{1 + pT_1}$$

K 1,9 >>>

Ti 0,19 s

TD 0,0474 s <<<

T1 0,015 s

Wiki - P + I + DT1- Form

$$F(p) = K_a \left(1 + \frac{1}{pT_a} + \frac{pT_b}{1 + pT_1} \right)$$

Ka 1,75 >>>

Ta 0,175 s

Tb 0,0364628571428571 s <<<

T1 0,015 s

Digital controller

Sampling time T0 0,01 s

recursive algorithm:
 $y(n) = p1 \cdot y(n-1) + p2 \cdot y(n-2) + q0 \cdot x(n) + q1 \cdot x(n-1) + q2 \cdot x(n-2)$

p1 1,5 q0 4,9905

p2 -0,5 q1 -8,98100000000001

st effective 5,022700586 q2 4,0405

methods see paper
☐ I, simple PID Approach
☒ IV Trapezoidal Approach
☐ Antiwindup

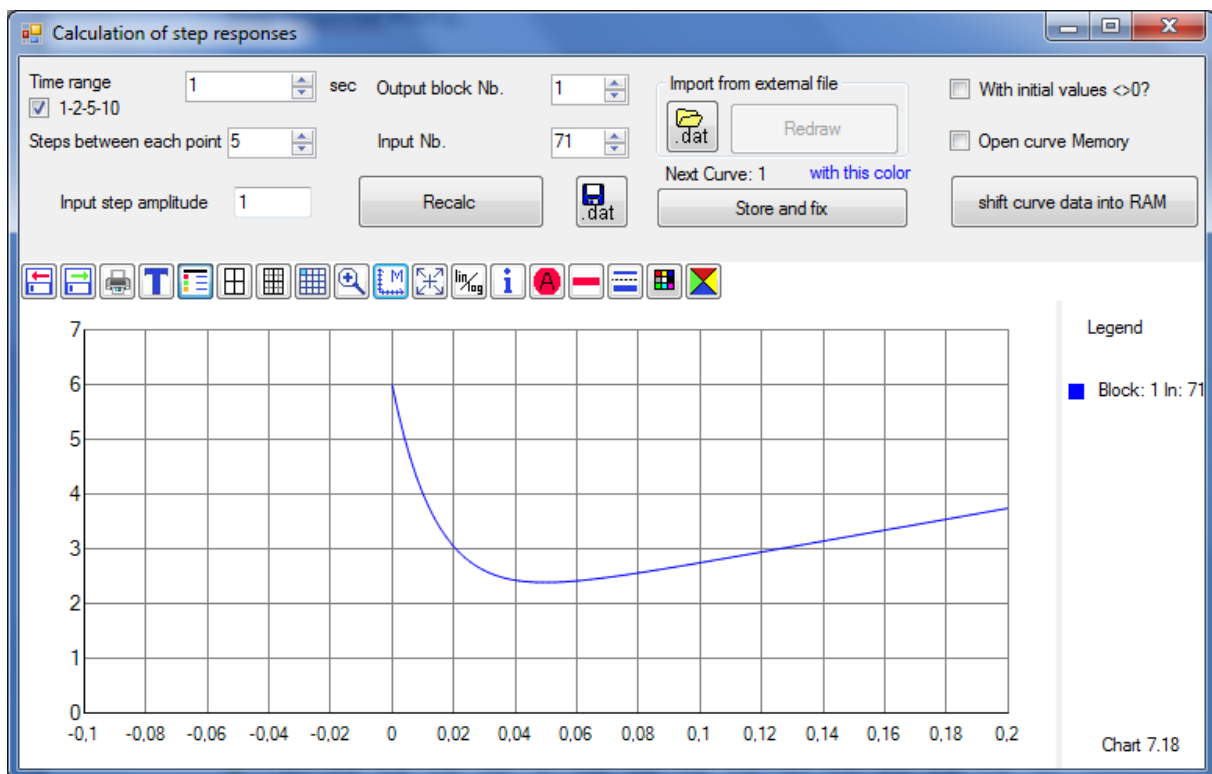
STO PDT1 Save ZK

RCL PDT1 RCL ZK

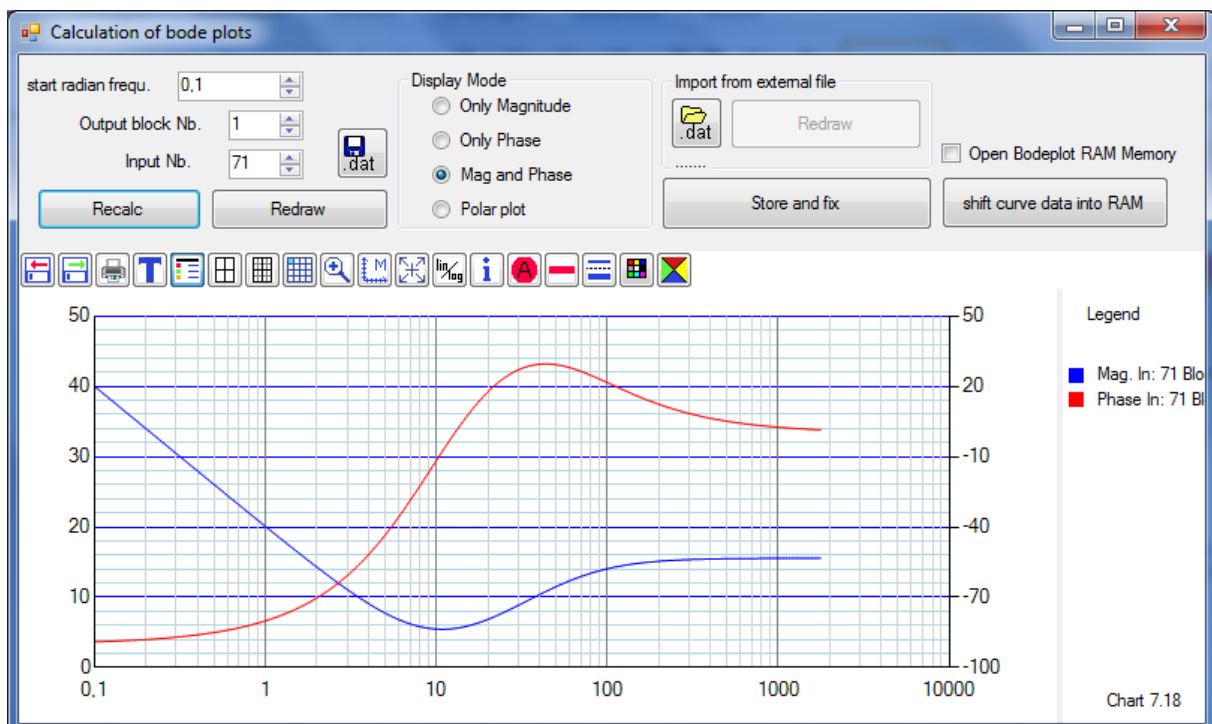
to report recalcula te

Copy Close

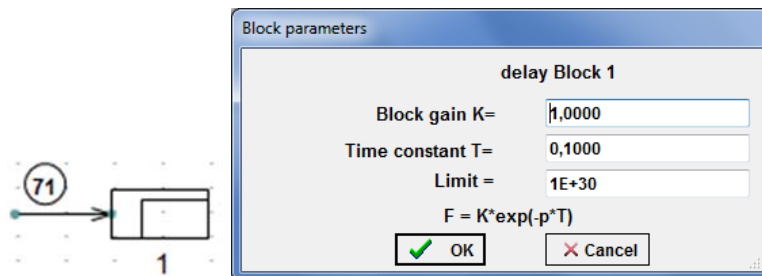
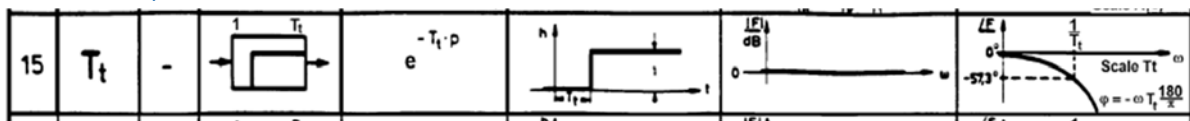
Step response PIDT1:



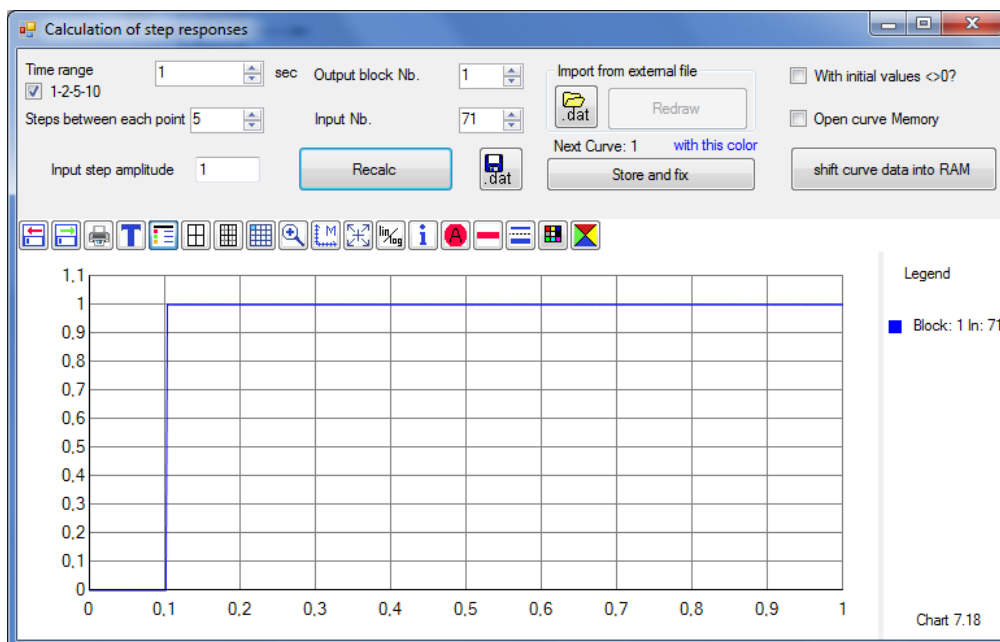
Bode plot PIDT1 (manually scaled)



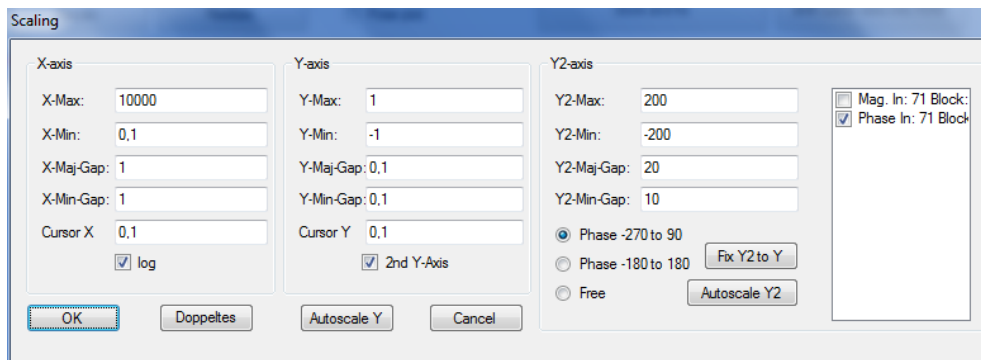
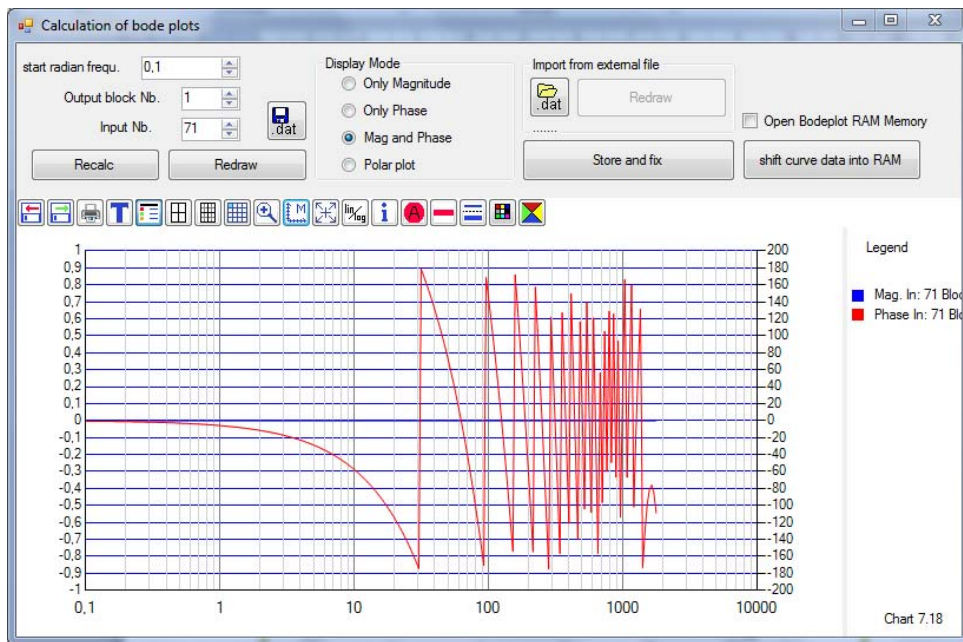
3.7.10 Delay time block



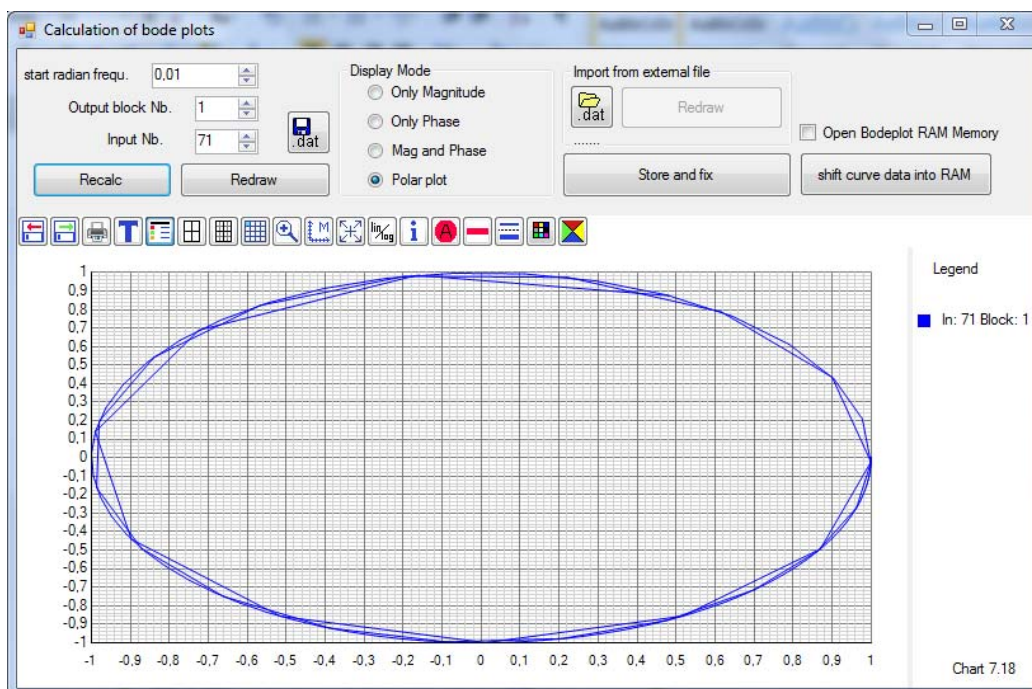
Step response of delay time block ($T_t=0.1$)



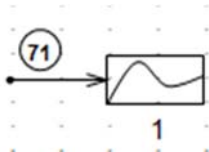
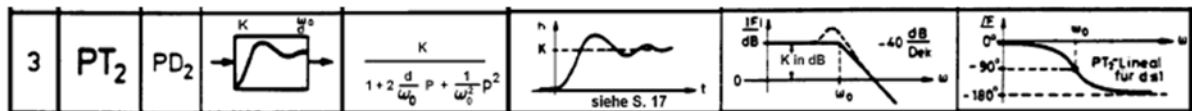
Bode plot delay time block (manually scaled)



Polar plot (is the unit circle, depending on number of points and position of delay time versus frequency scale not clearly round)



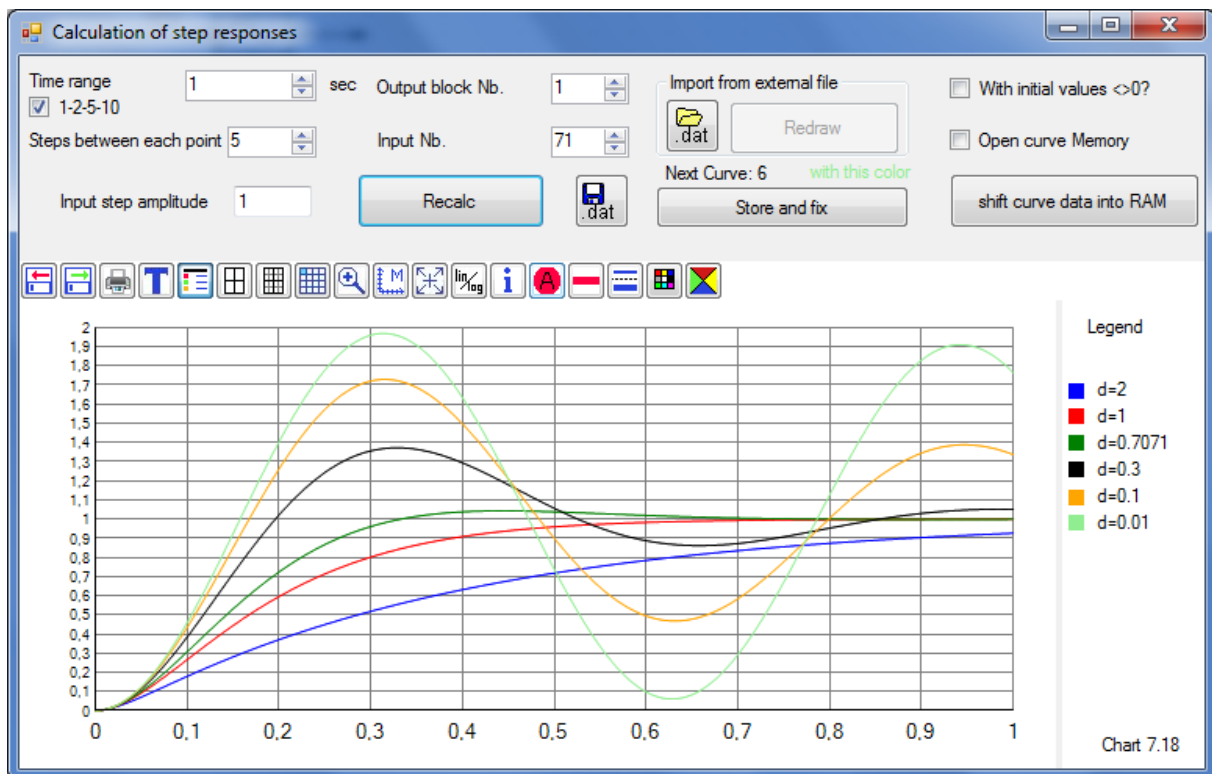
3.7.13 PT₂ (d<1) → 2PT₁ (d>=1)



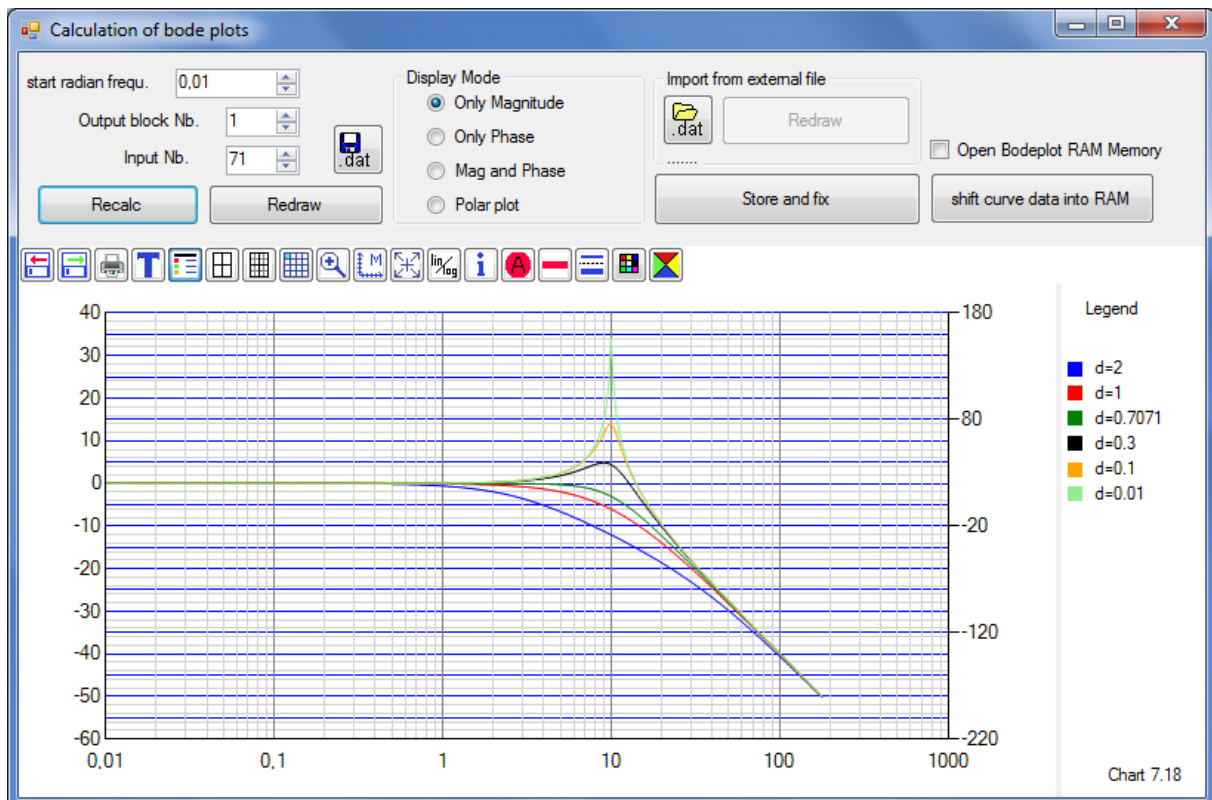
$$F(p) = \frac{K}{1 + \frac{2d}{\omega_0}p + \frac{1}{\omega_0^2}p^2} = \frac{K}{1 + 2dTp + T^2p^2}$$

In RegCSharp value input not ω_0 , but $T=1/\omega_0$. But there is an invert button. You can type in ω_0 use the button and you get T. Example: K=1, T=0.1, $\omega_0=10$.

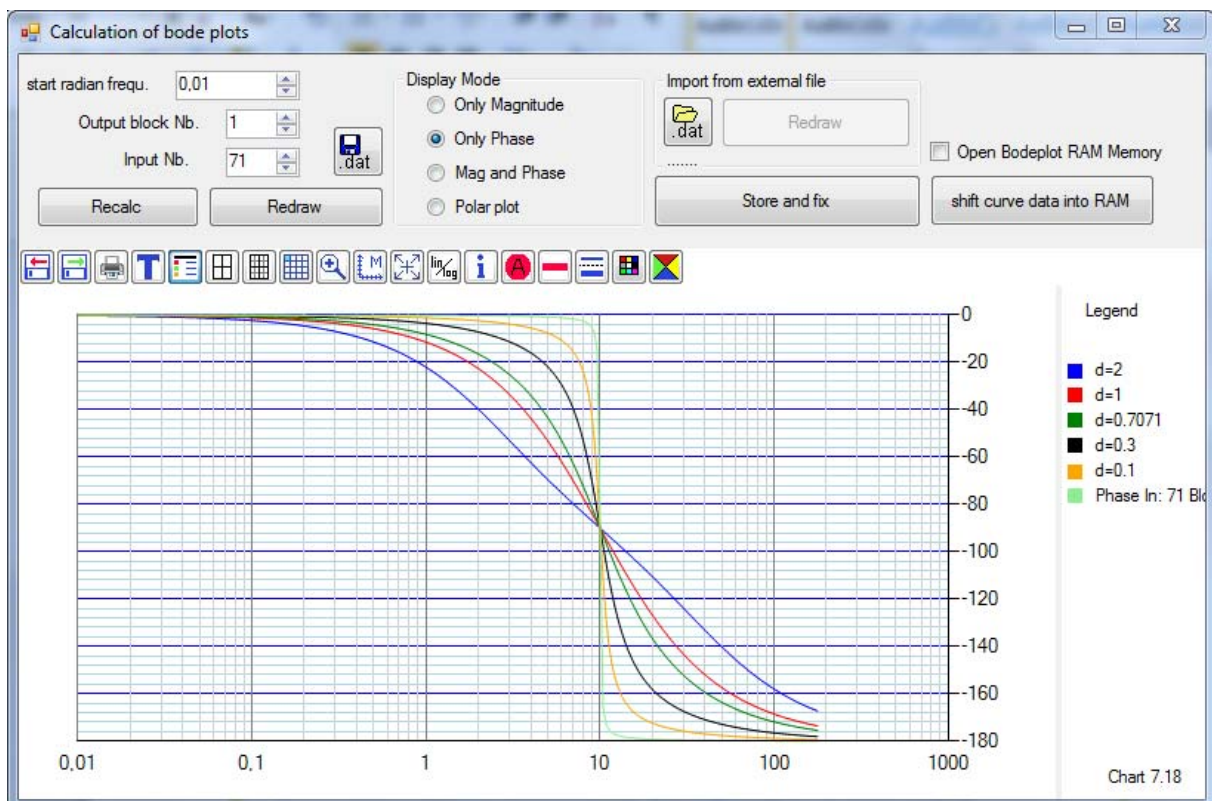
Step response PT₂ with different values of d:



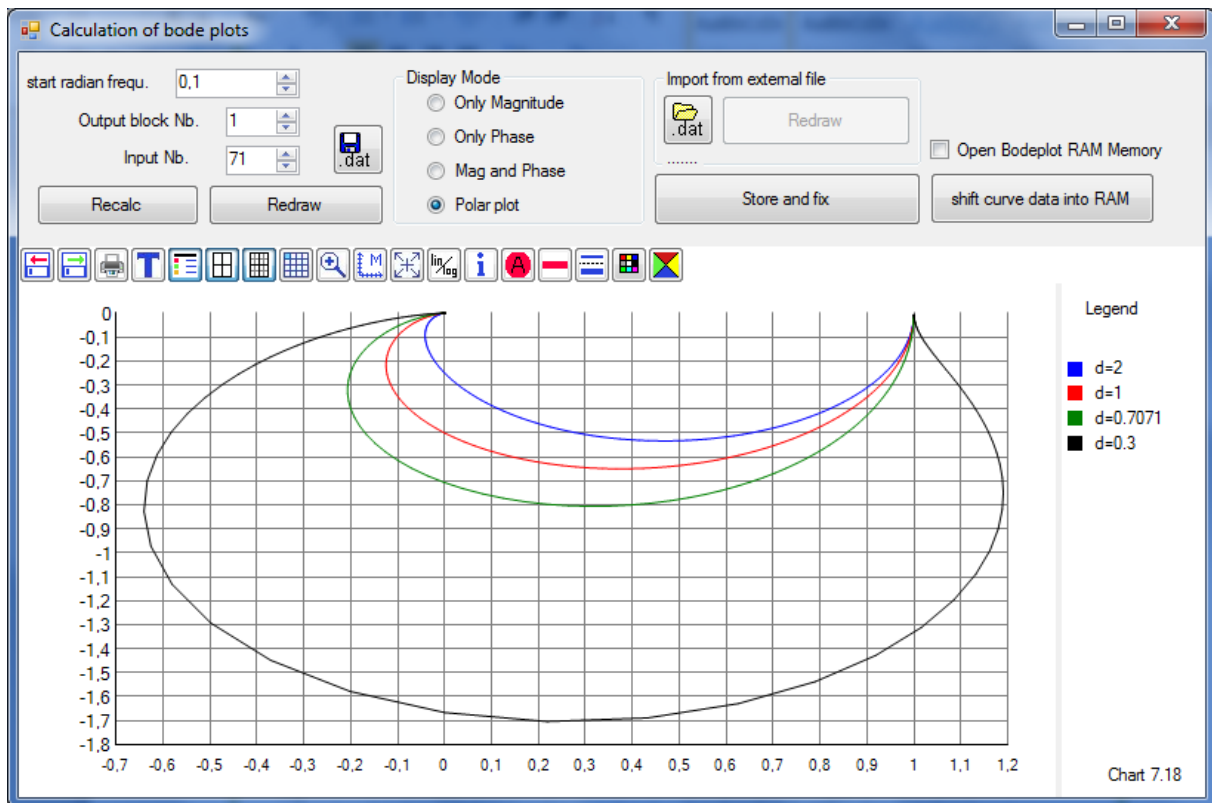
Bode plot magnitude curves PT₂ with different d -values:



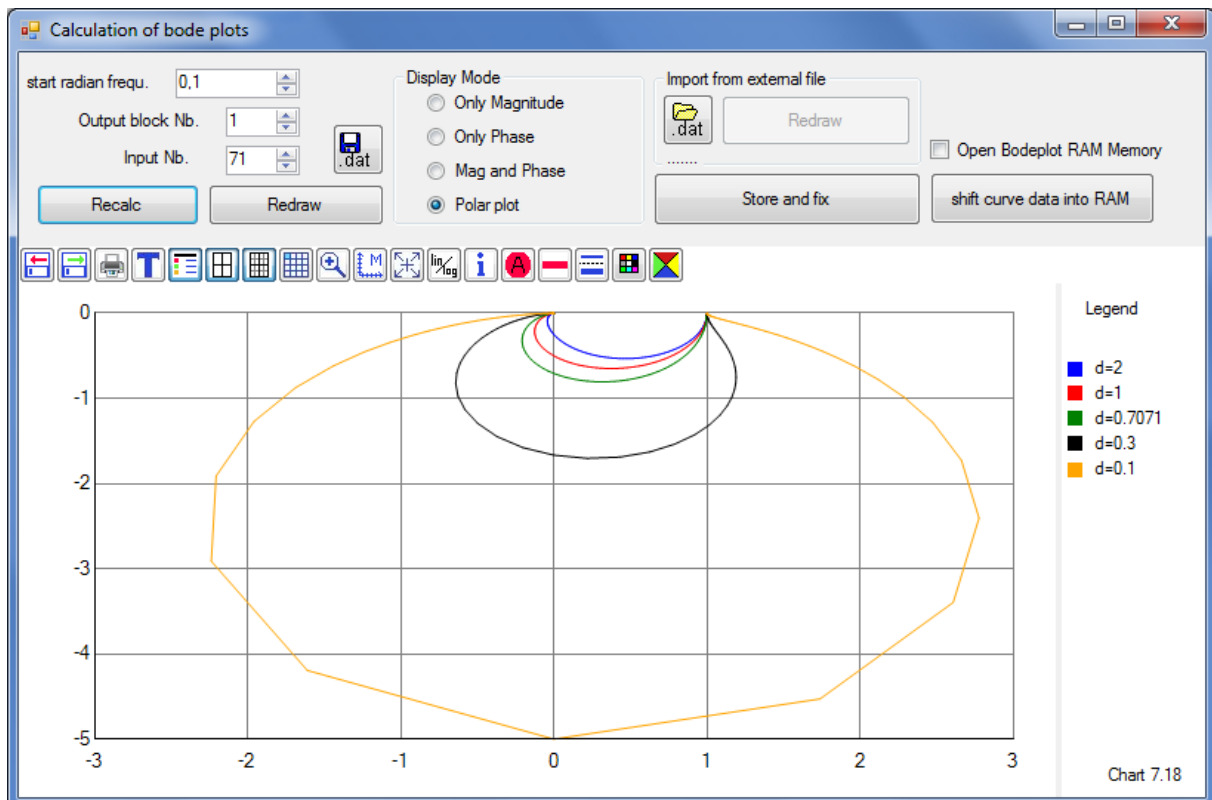
Phase curves PT2 with different d - values:



Polar plots of the PT2:

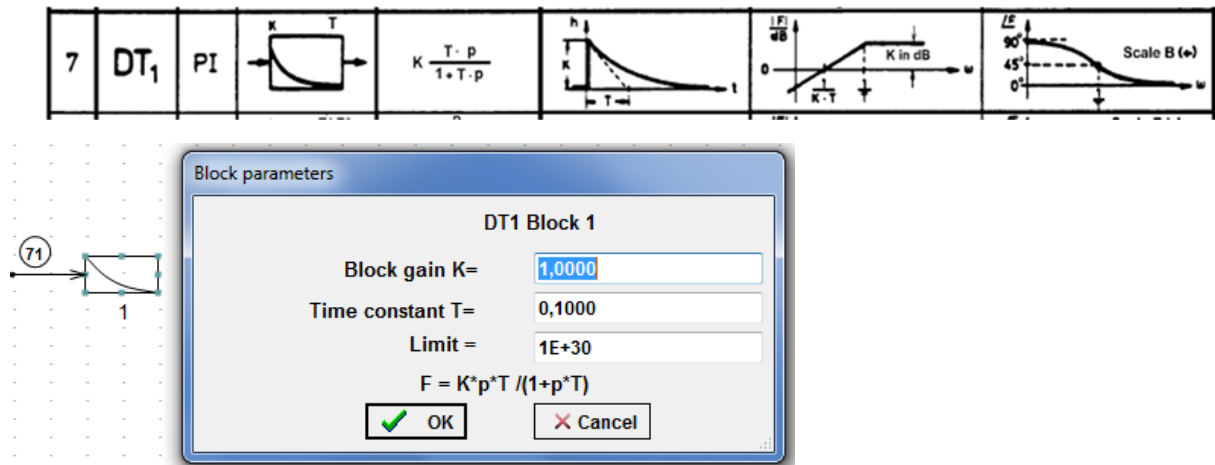


With $d=0.1$ added, at $d=0.01$ only one point is drawn so no picture:

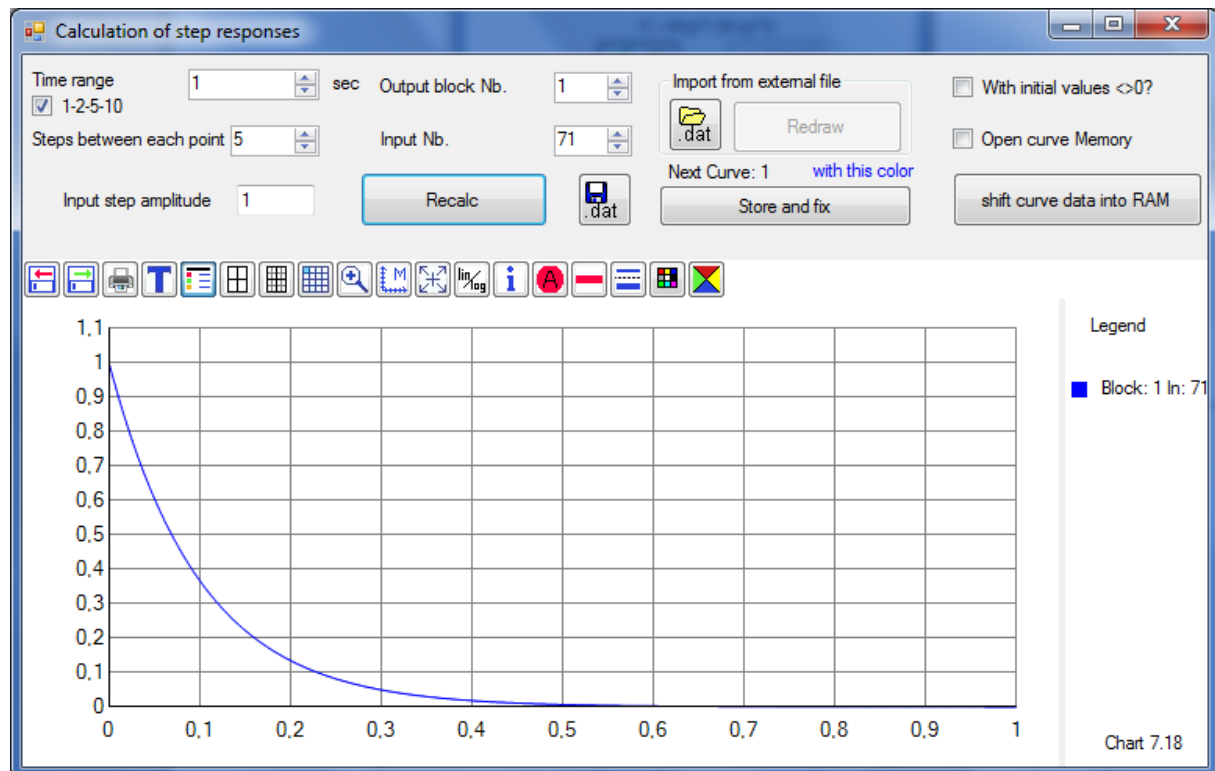


Is cancelled in lecture caused by limited time:

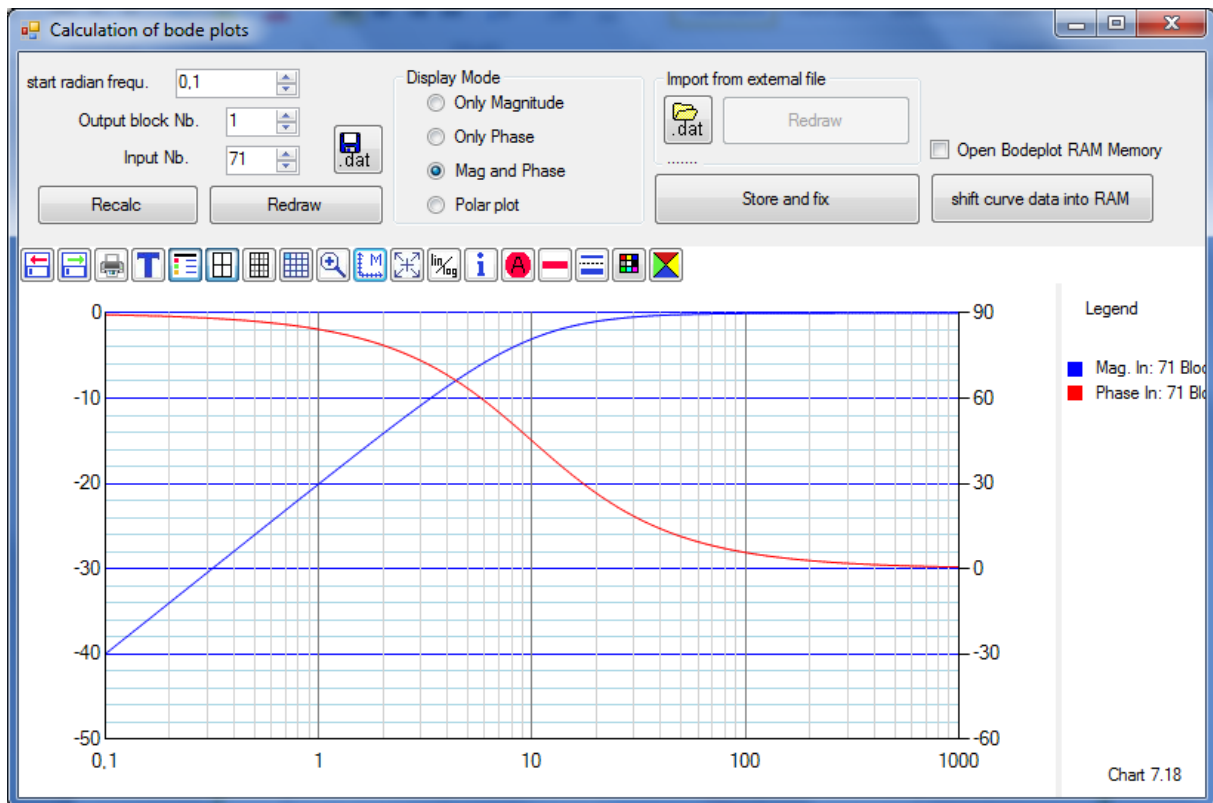
3.7.11 DT1



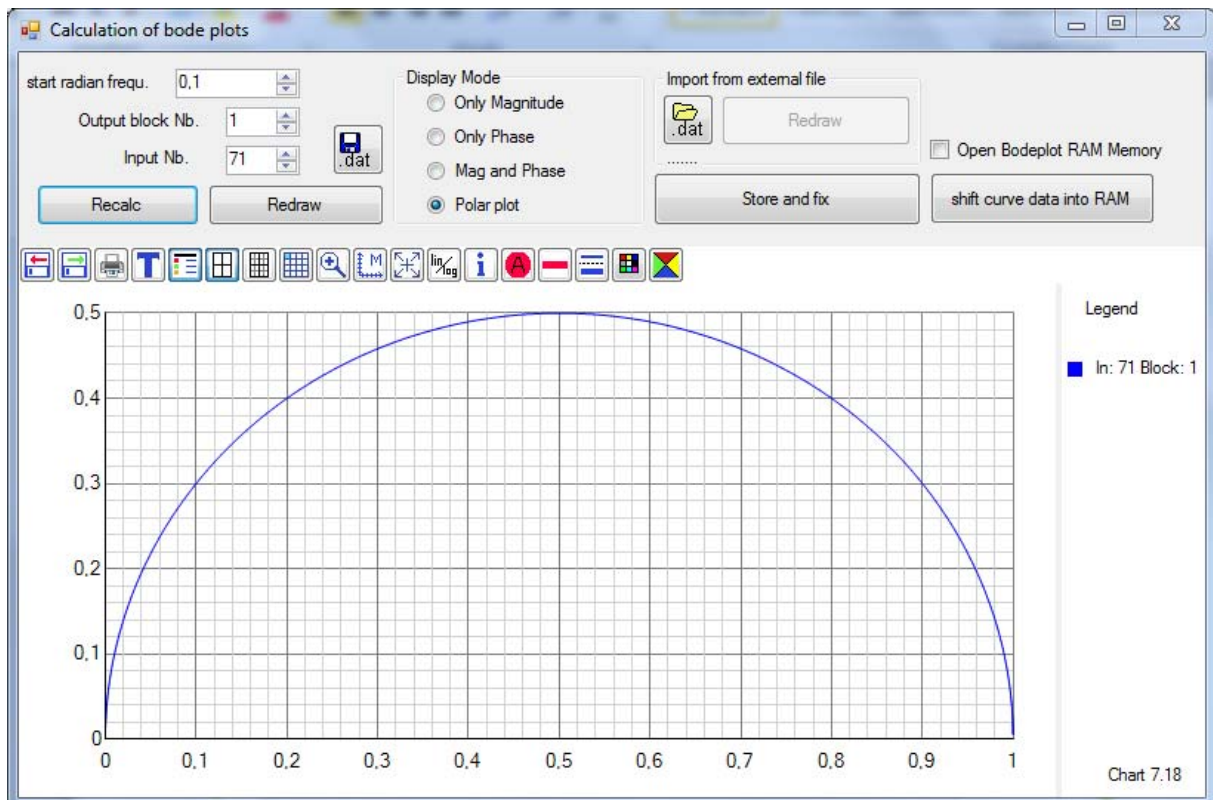
Step response DT1:



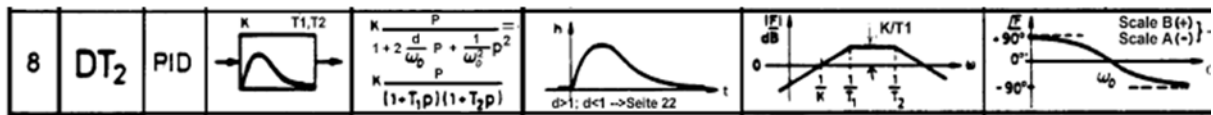
Bode plot DT1:



Polar plot DT1:

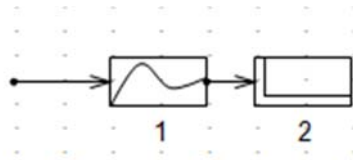


3.7.12 DT2

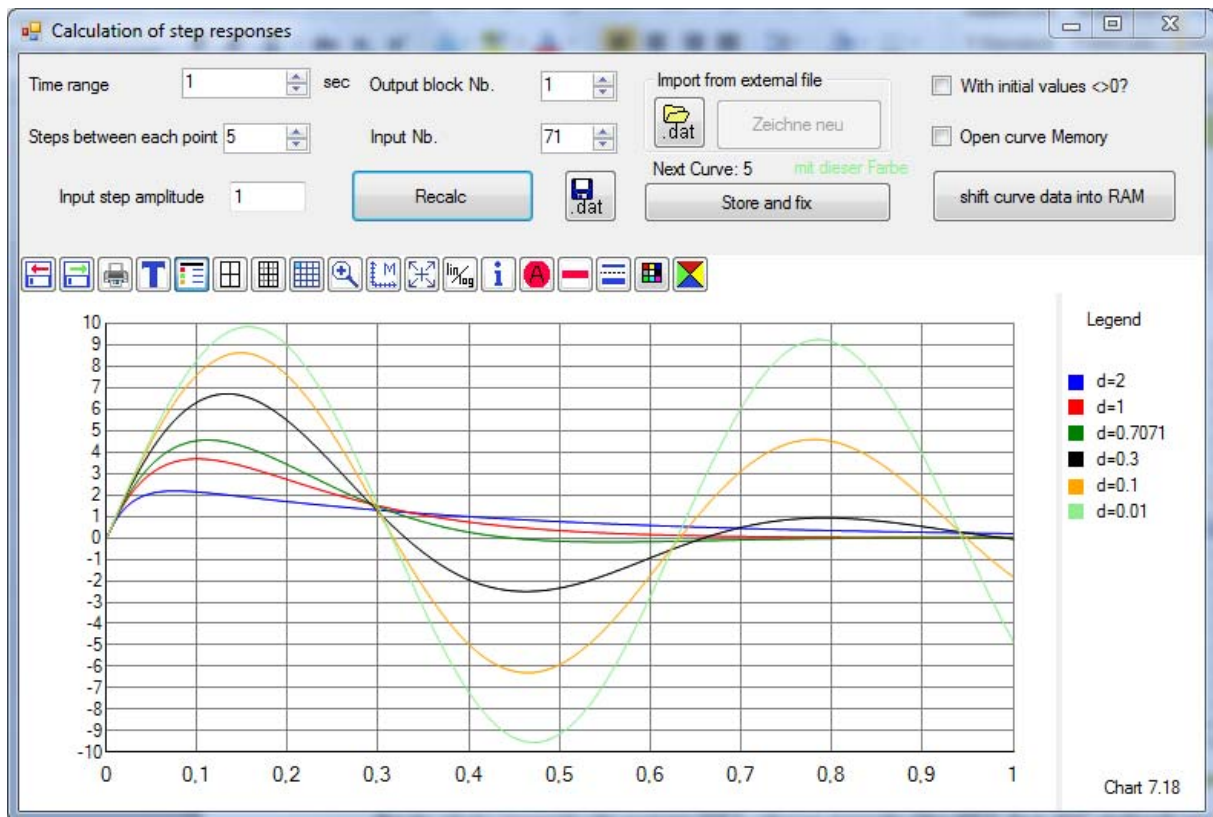


See also WB p 18-19. Example values: $K=1s$, $T=0.1$, $\omega_0=10$.

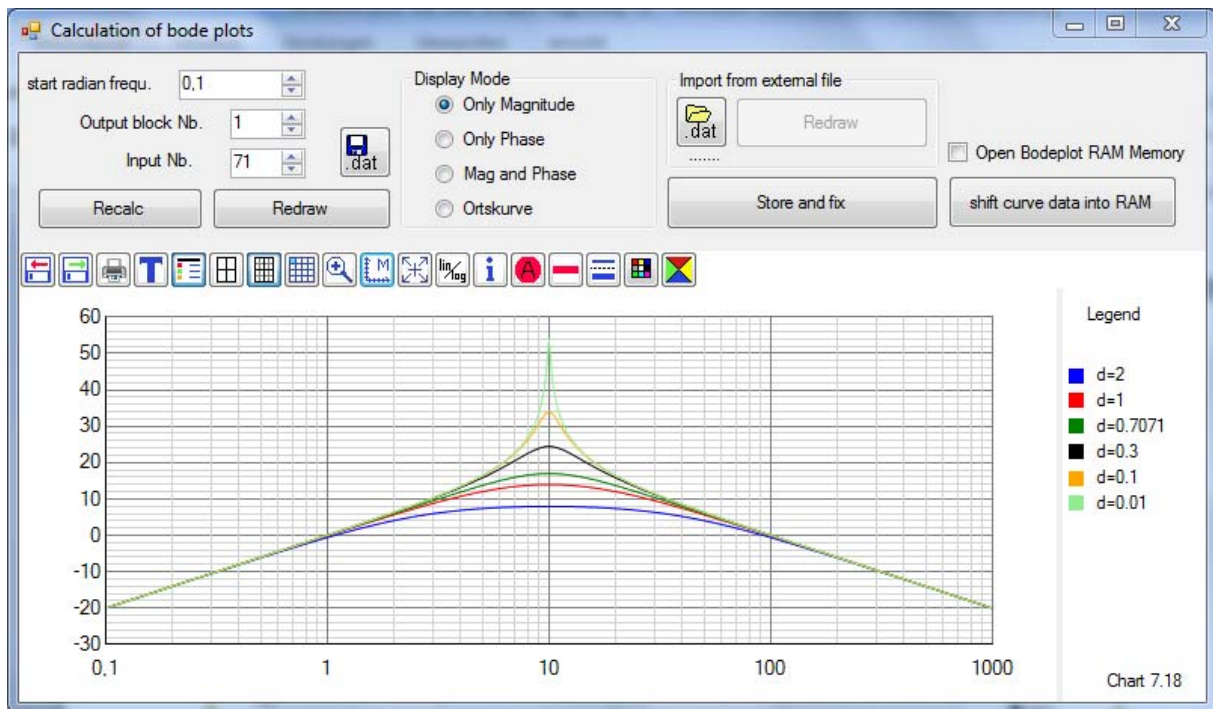
$$F(p) = \frac{U_2}{U_1} = \frac{Kp}{1 + \frac{2d}{\omega_0}p + \frac{1}{\omega_0^2}p^2}$$



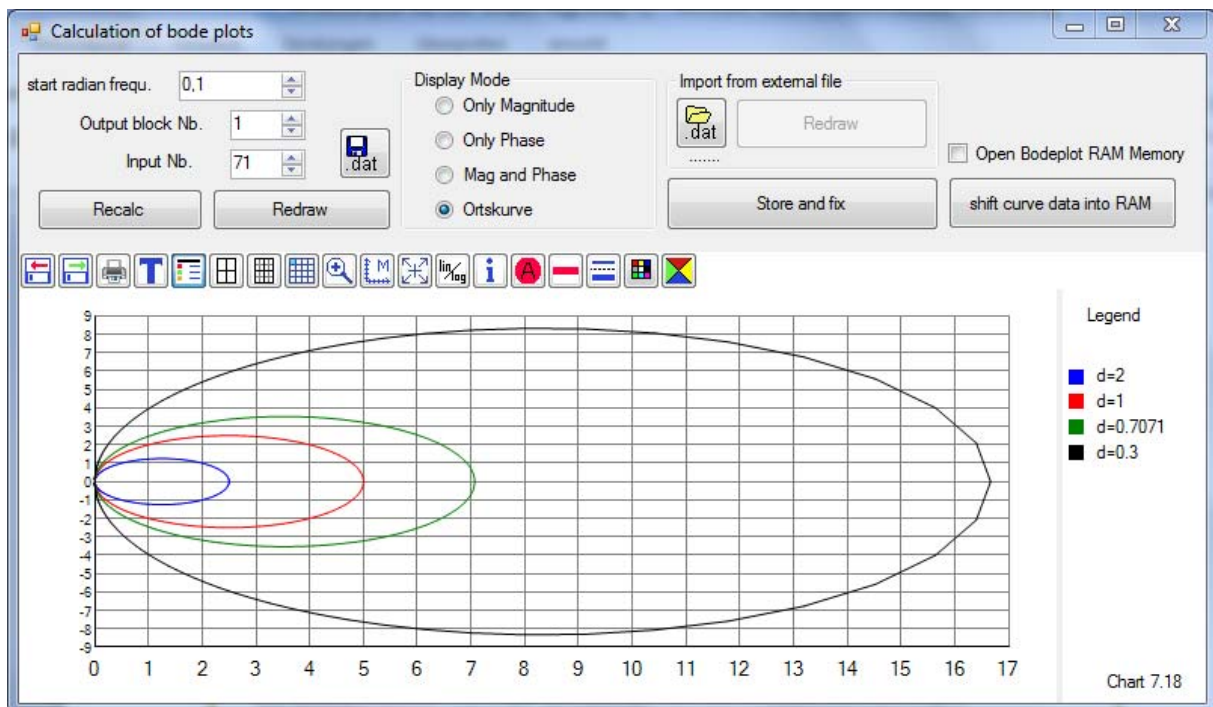
Step responses DT2,



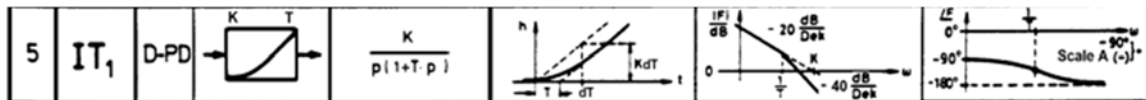
Bode plots magnitude curves DT2, phase exactly like PT2, but 90° shifted up to the top:



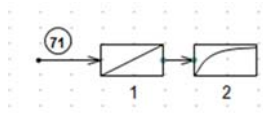
Polar plots DT2:



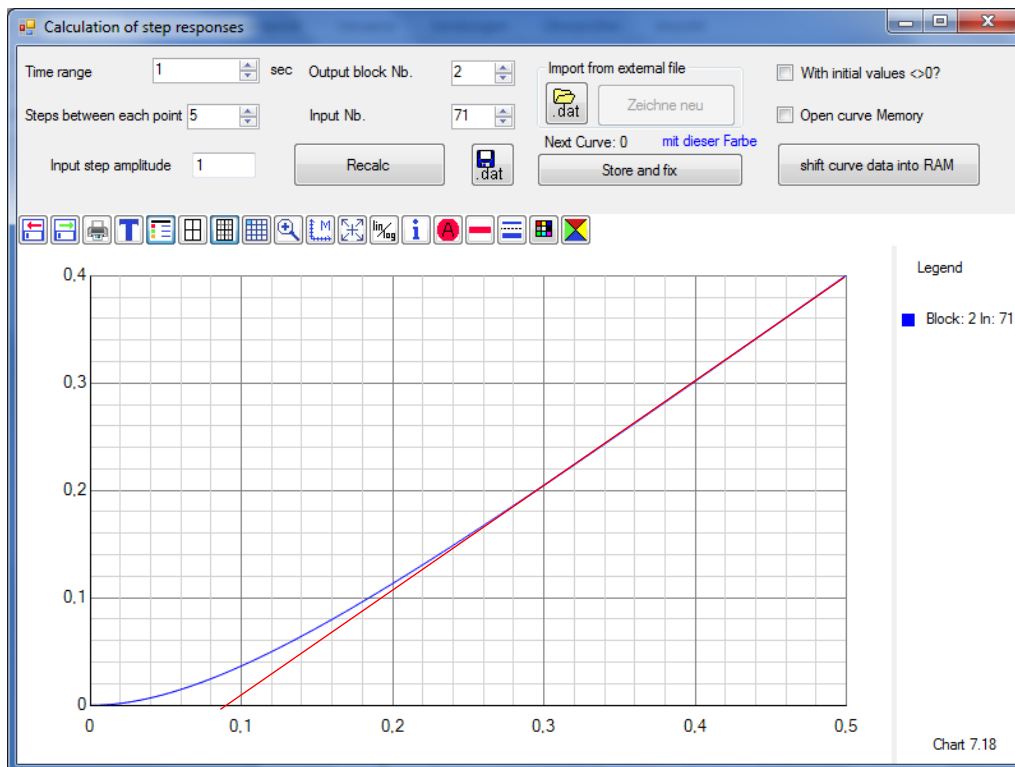
3.7.14 IT1



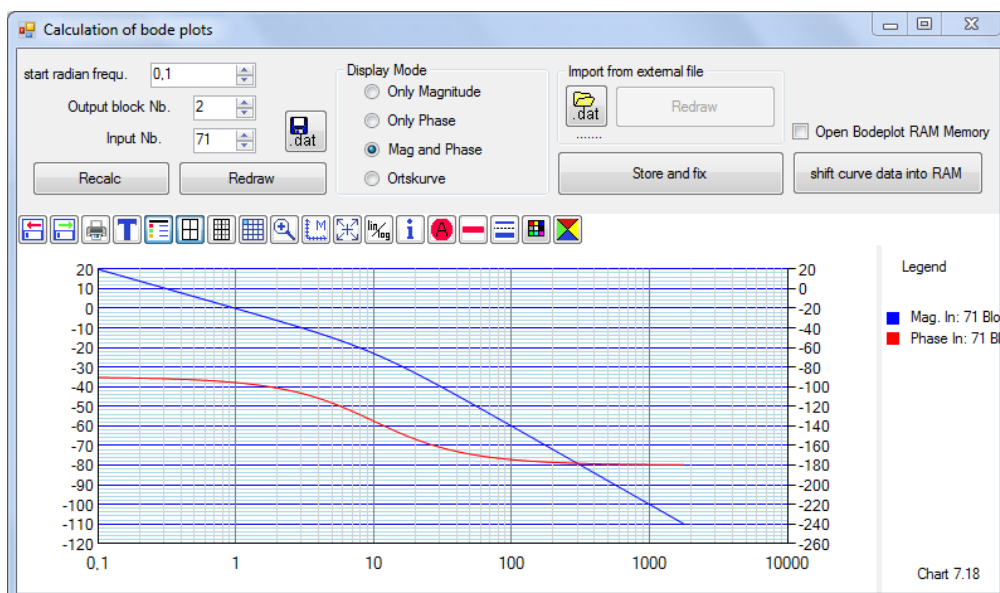
$$F(p) = \frac{K}{p(1+T \cdot p)}, \quad K=1, T=0.1.$$



Step response IT1, in red the tangent of the ramp

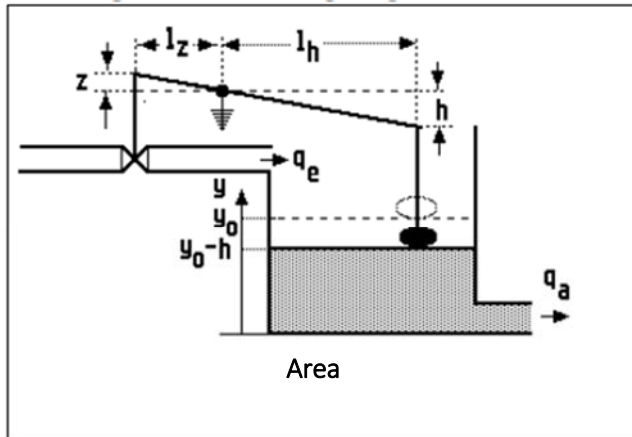


Bode plot IT1:



Examples from lecture with RegCSharp

Tank Level control



Formula:

$$q_e = C \cdot z$$

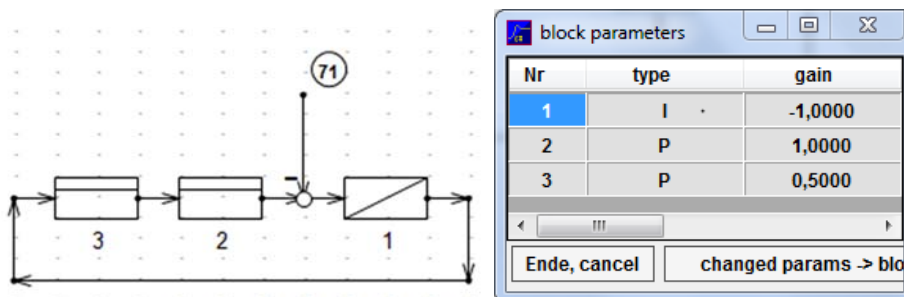
$$z / l_z = h / l_h$$

Volume:

$$A \cdot y = A(y_0 - h(t)) \quad \text{or}$$

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

file „taank level control.wln“



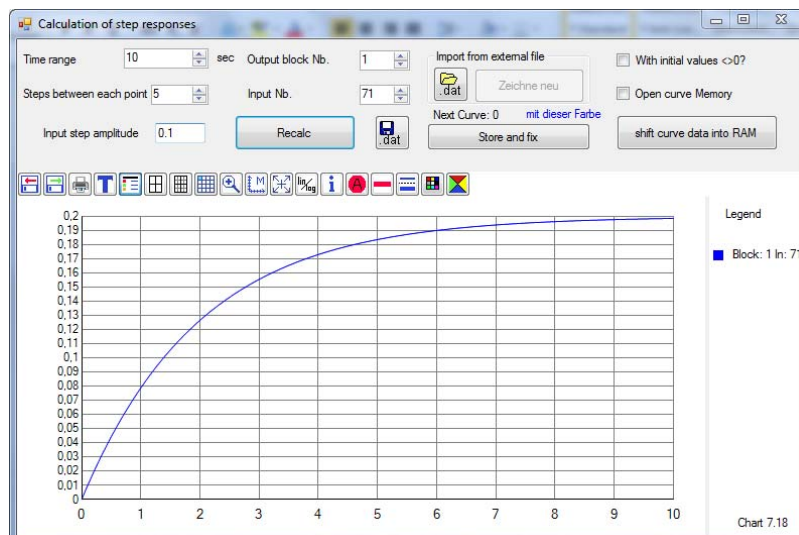
Input 71: Disturbance flow out, step with 10 l/min= 0.1 m³/min

Block 3 Controller lever with l_z=0.5m and l_h=1m, K=0.5

Block 2: Valve controlling the input flow with C= 1 m²/min

Block 1: Tank with base area A=1 m².

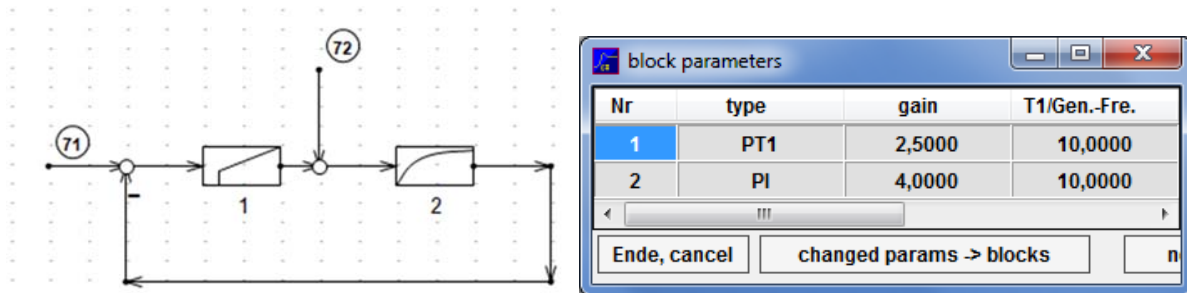
Resulting step response of the tank level (h=0 is equivalent to „filled“):



Project 1 Cruise control

Car PT1 with $K=100 \text{ km/h/KW}$, $T=10\text{s}$. Controller PI with $K_R=4\text{KW/h/km}$ and $T_N=10\text{s}$ (polcompensation).

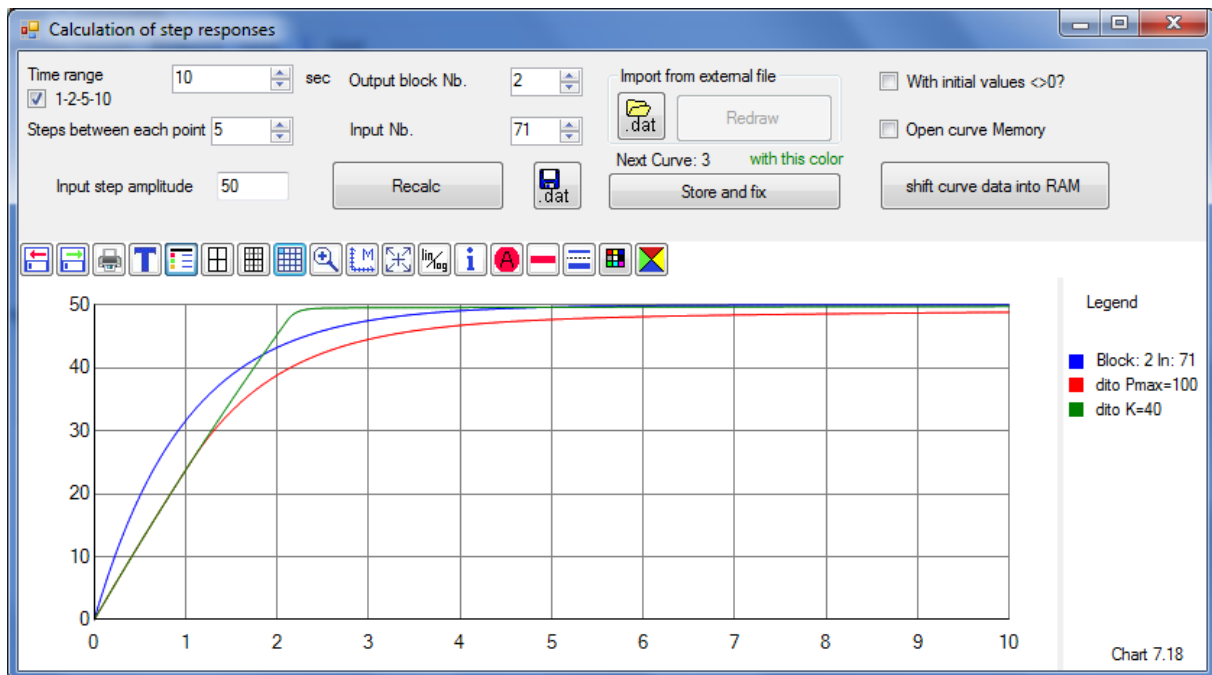
File „Tempomat.wln“.



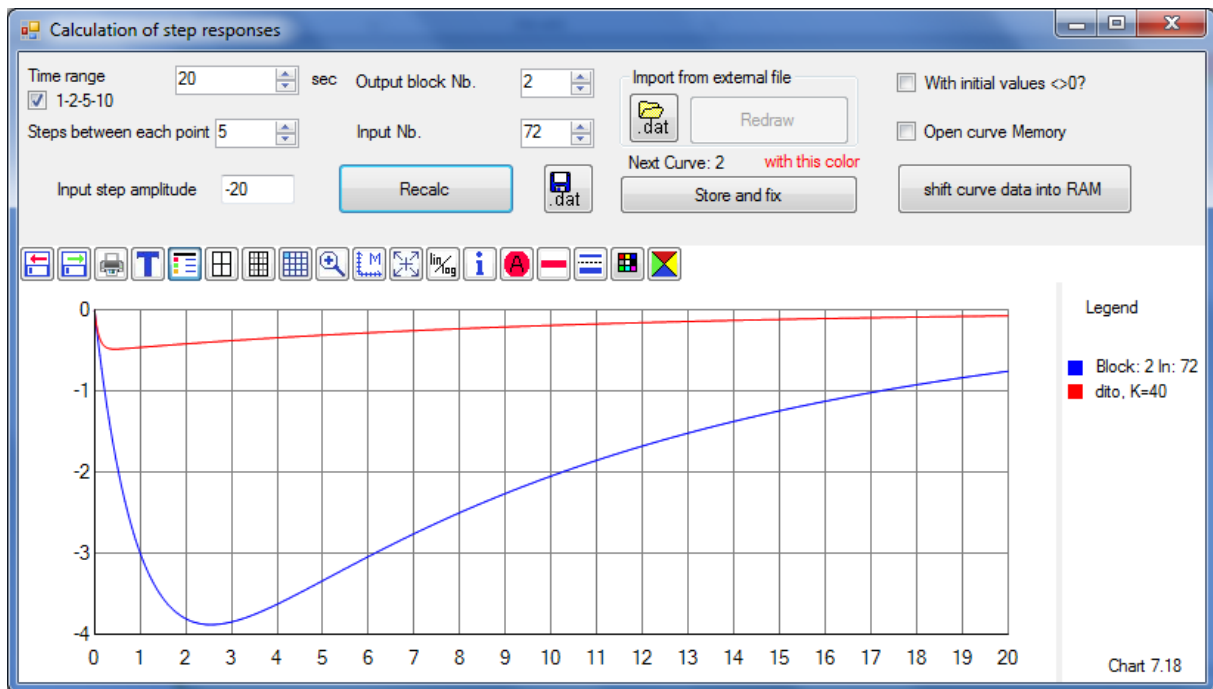
Input 71: Desired value speed in km/h

Input 72: fictive disturbance power in KW, negative value brakes (driving up a hill)

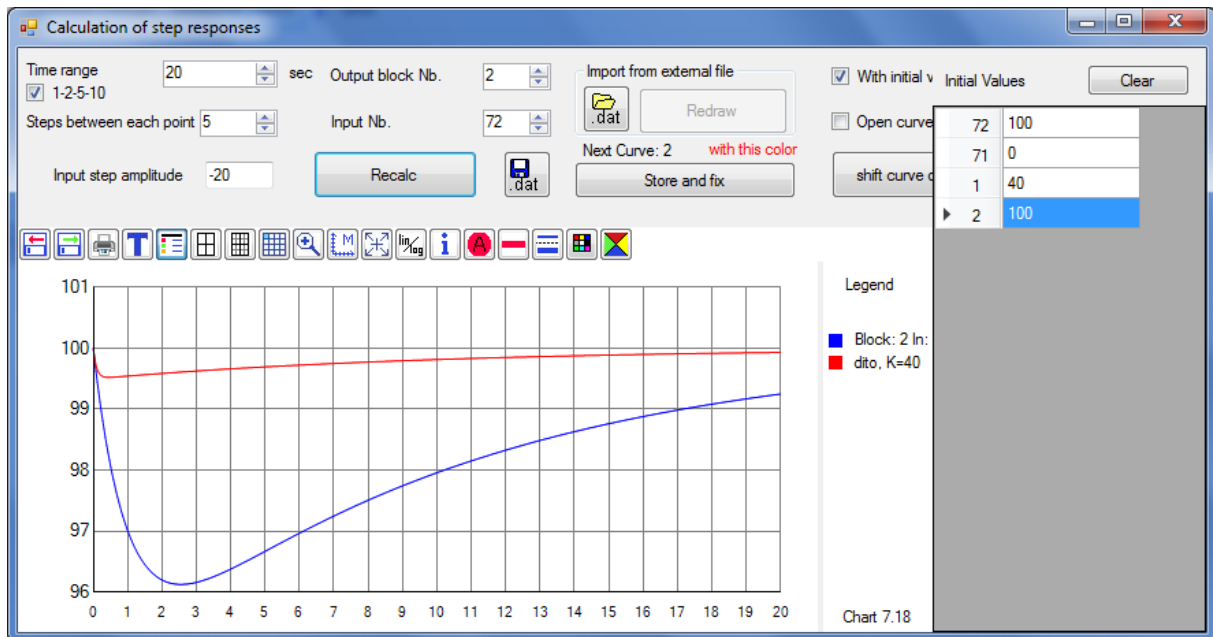
Reference step response from 0 to 50 km/h, 72 set to zero:



Disturbance behavior, step response of -20 KW:

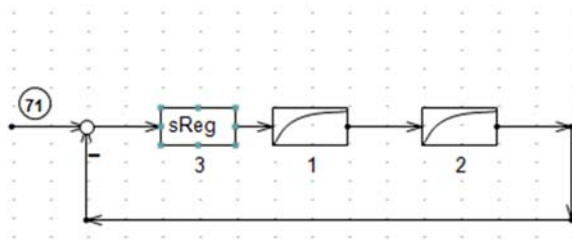


Same curves but now with starting values, disturbance happens at 100 km/h



Project 2: Temperature control

File: „Temperaturregelung Projekt 2.wln“

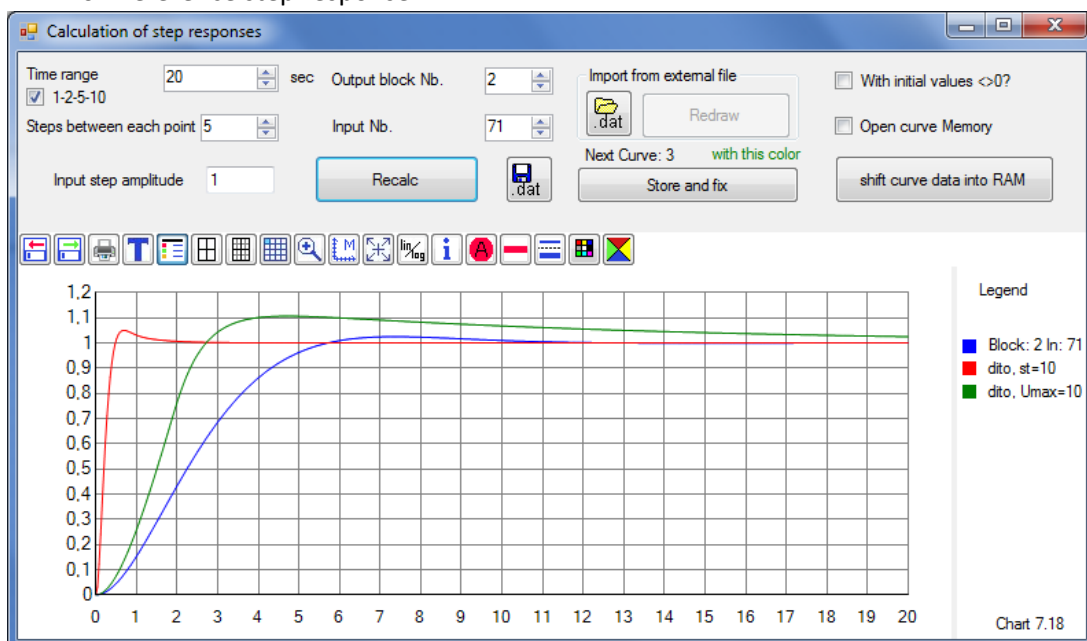


Nr	type	gain	T1/Gen.-Fre.
1	PT1	0,7300	10,0000
2	PT1	1,0000	1,0000
3	sController	5,9109	10,0000

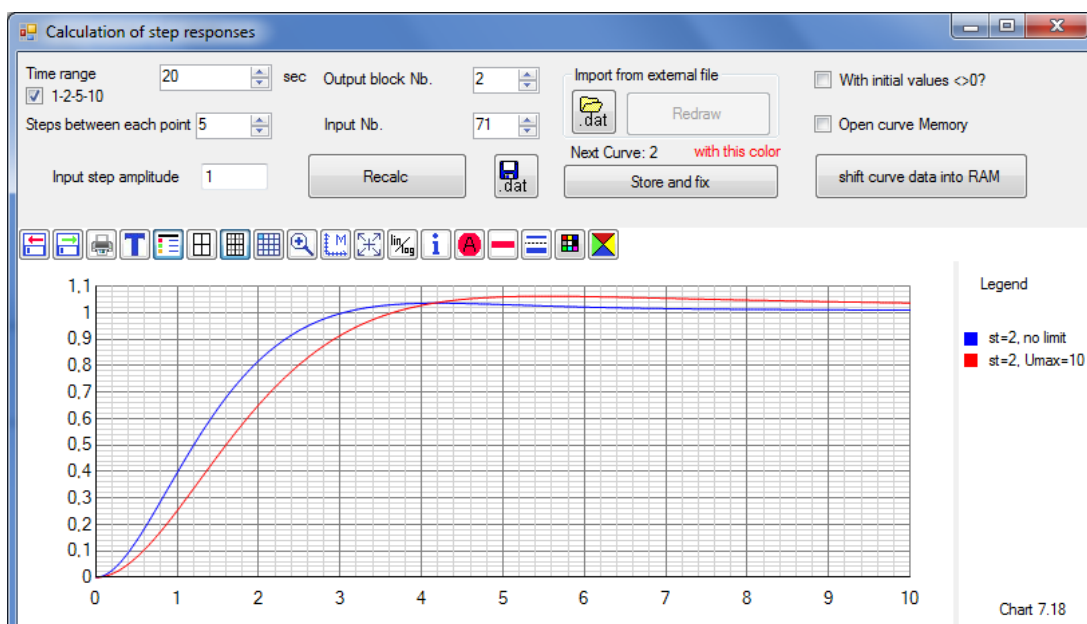
Buttons: Ende, cancel | changed params -> blocks | net

Controller designed with $d=0.7613$ (equivalent to $\ddot{u}=0.025$, $\Phi_R=68,18^\circ$) and polcompensation, $st=1$ (PI):

1V = 10° - reference step response:

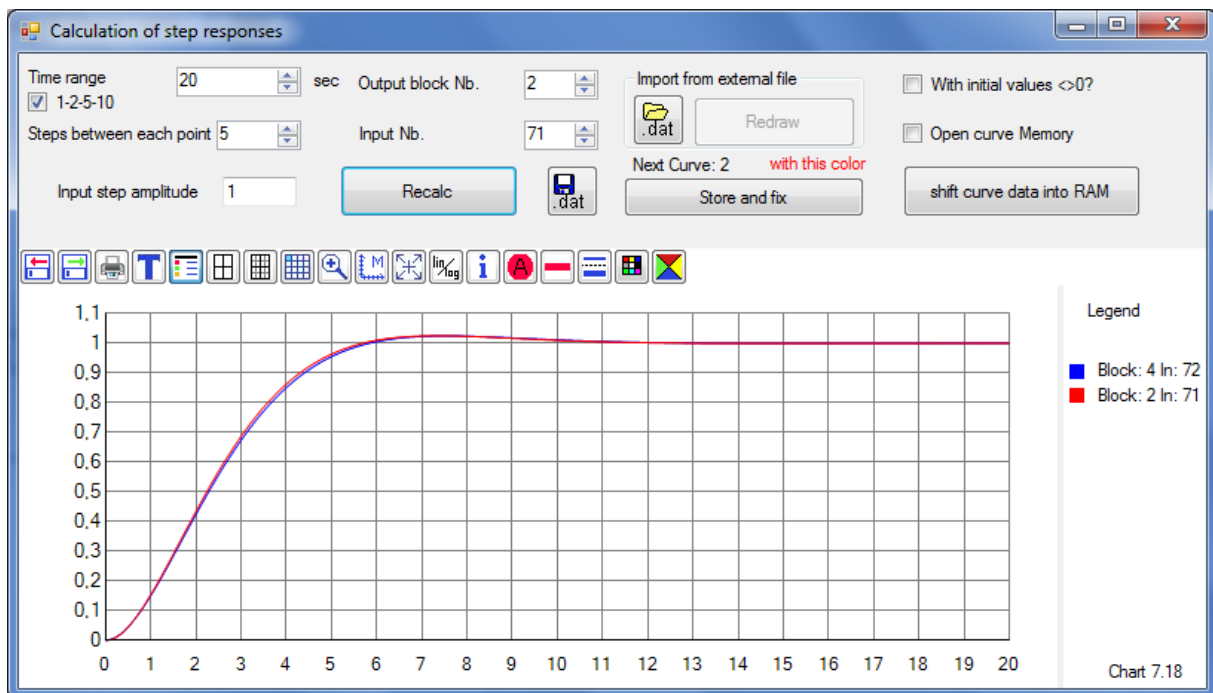
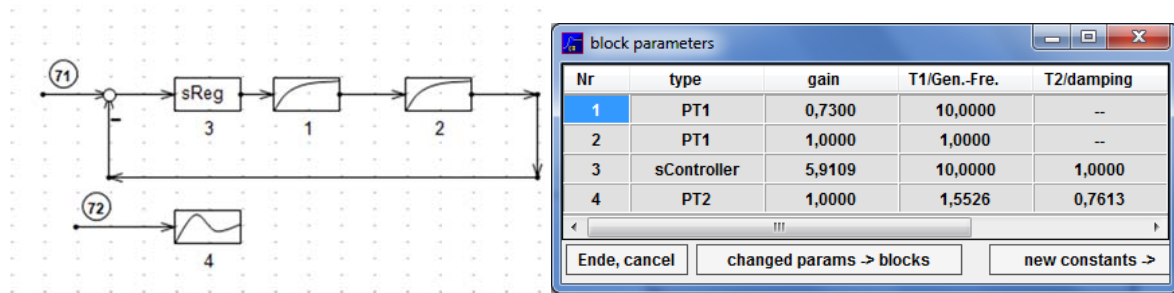


Design with compromise value $st=2$



Comparison with PT2

PT2: $K=1$, $\omega_0=0.65675$ 1/s, $T=1.5226$ s, $d=0.7613$



Curves of control loop and PT2 are identical.