Regelalgorithmen im Zeitbereich

Beschreibung der Grundfunktionen als Differenzengleichungen für die Umsetzung in einen programmierbaren Rechner (SPS) mit diskretem Zeitverhalten.

$SP := 2^{10}$ Sampling Points

$\tau e := 8$ Zeitfenster [s]

$\Delta\tau := \dfrac{\tau e}{SP} = 7.813 \cdot 10^{-3}$ $\Delta\tau = 7.813 \cdot 10^{-3}$ Auflösung [s]

$\tau := 0 .. SP$ Laufvariable

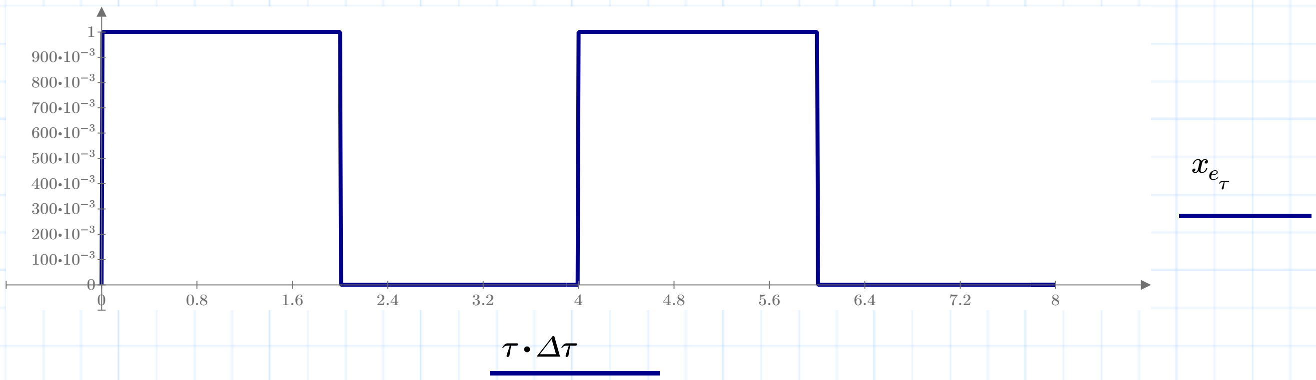
Schrittfunktion

$$
step(t, ts_1, te_1, ts_2, te_2) := \left\| \begin{array}{l} out \leftarrow 0 \\ \text{if } (t \geq ts_1) \wedge (t \leq te_1) \\ \quad \| \; out \leftarrow 1 \\ \text{else} \\ \quad \left\| \begin{array}{l} \text{if } (t \geq ts_2) \wedge (t \leq te_2) \\ \quad \| \; out \leftarrow 1 \\ \text{else} \\ \quad \| \; out \leftarrow 0 \end{array} \right. \\ \text{return } out \end{array} \right.
$$

$t_{s1} := 0 + \Delta\tau$ $t_{e1} := 2$ $t_{s2} := 4$ $t_{e2} := 6$

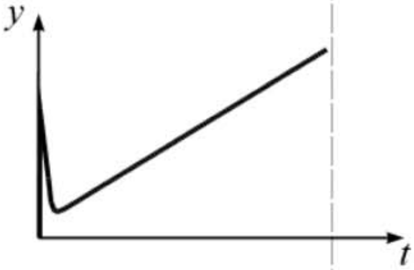
ToDo: Umsetzung mit Heavysidefunktion

$x_{e_\tau} := step(\tau \cdot \Delta\tau, t_{s1}, t_{e1}, t_{s2}, t_{e2})$



PID bzw. PIDT1

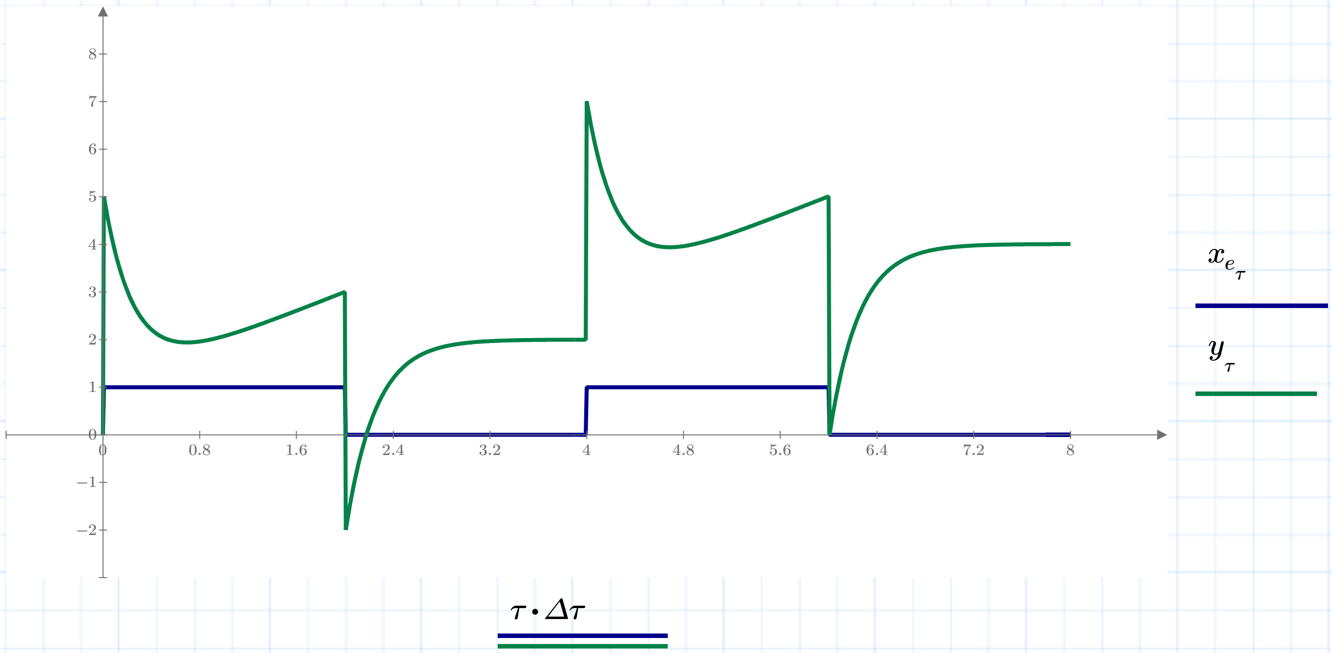
$$G(s) = K_R\left(1+\frac{1}{T_N s}+\frac{T_V s}{1+T_{Vz} s}\right)$$

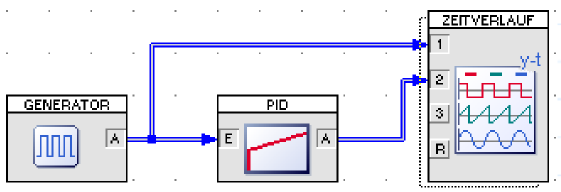


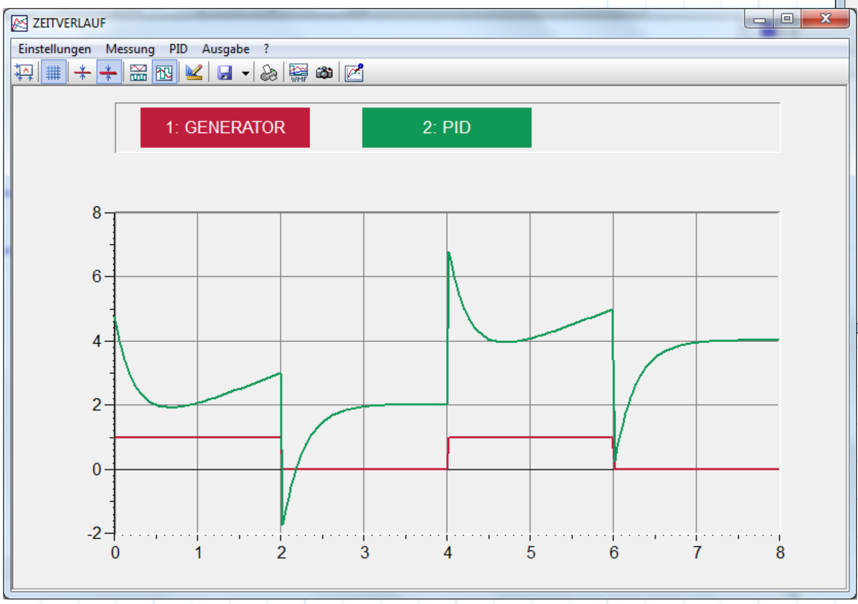
$$
\begin{array}{l}
PID\left(K_R, T_N, T_V, T_{Vz}, x\right) := \\
\quad \text{“Nullsetzen der Variablen”} \\
\quad proportional \leftarrow 0 \\
\quad integral \leftarrow 0 \\
\quad dx \leftarrow 0 \\
\quad dy \leftarrow 0 \\
\quad \text{for } n \in 0 \,..\, \text{rows}(x) \\
\quad\quad y_n \leftarrow 0 \\
\quad\quad differential_n \leftarrow 0 \\
\quad \text{“Bestimmung der Schrittantwort”} \\
\quad \text{for } n \in 1 \,..\, (\text{rows}(x)-1) \\
\quad\quad \text{“P–Anteil”} \\
\quad\quad proportional \leftarrow K_R \cdot x_n \\
\quad\quad \text{“I–Anteil”} \\
\quad\quad integral \leftarrow integral + \dfrac{K_R}{T_N} \cdot x_n \cdot \Delta\tau \\
\quad\quad \text{“DT1–Anteil”} \\
\quad\quad dx \leftarrow K_R \cdot T_V \cdot \left(x_{e_n} - x_{e_{n-1}}\right) \\
\quad\quad dy \leftarrow \dfrac{dx}{T_{Vz}} \\
\quad\quad differential_n \leftarrow differential_{n-1} - \dfrac{differential_{n-1}}{T_{Vz}} \cdot \Delta\tau + dy \\
\quad\quad \text{“Summation der Teilfaktoren”} \\
\quad\quad y_n \leftarrow proportional + integral + differential_n \\
\quad \text{return } y
\end{array}
$$

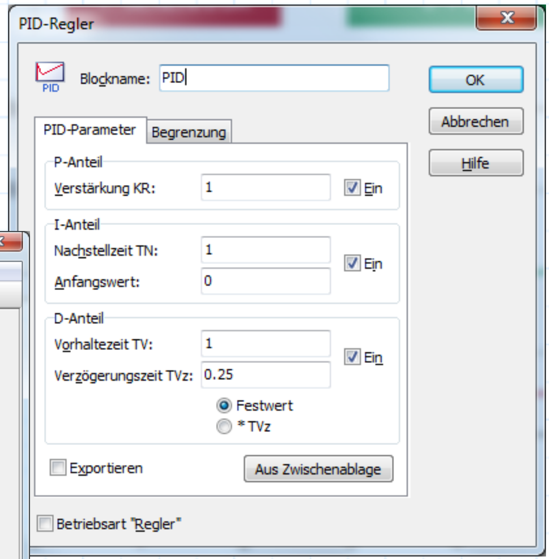
$K_R := 1.0$ $\quad T_N := 1$ $\quad T_V := 1$ $\quad T_{Vz} := 0.25$

$y := PID\left(K_R, T_N, T_V, T_{Vz}, x_e\right)$









Vorsteuerung

Koordinaten aus dem Kennlinienfeld => experimentelle Ermittlung

$$x_P := \begin{bmatrix} 0 \\ 10 \\ 20 \\ 30 \\ 40 \\ 50 \\ 60 \\ 70 \\ 80 \\ 90 \end{bmatrix} \qquad y_P := \begin{bmatrix} 9 \\ 31 \\ 44 \\ 55 \\ 65 \\ 72 \\ 79 \\ 83 \\ 87 \\ 90 \end{bmatrix}$$

$n := \text{length}(x_P) = 10$

$x_{Pmin} := min(x_P) = 0$ $\qquad y_{Pmin} := min(y_P) = 9$

$x_{Pmax} := \max(x_P) = 90$ $\qquad y_{Pmax} := \max(y_P) = 90$

```
linInt(x) := || y_int ← -1.0
             || m ← 0
             || q ← 0
             || i ← 0
             || if x ≤ x_Pmin
             ||   || y_int ← y_Pmin
             || else if x ≥ x_Pmax
             ||   || y_int ← y_Pmax
             || else
             ||   || while i < (n-1)
             ||   ||   || if (x > x_P[i]) ∧ (x ≤ x_P[i+1])
             ||   ||   ||   || m ← (y_P[i+1] - y_P[i]) / (x_P[i+1] - x_P[i])
             ||   ||   ||   || q ← y_P[i] - m·x_P[i]
             ||   ||   ||   || y_int ← m·x + q
             ||   ||   ||   || i ← n
             ||   ||   || i ← i + 1
             || return y_int
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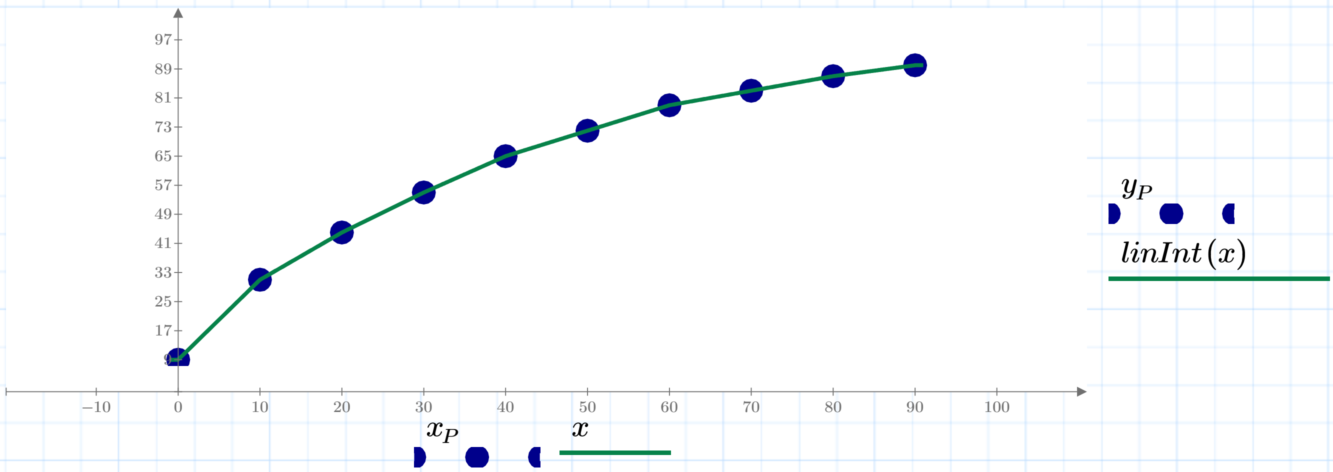
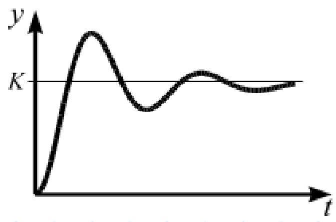
$x := x_{Pmin} - 1, x_{Pmin} - 0.9 .. x_{Pmax} + 1$



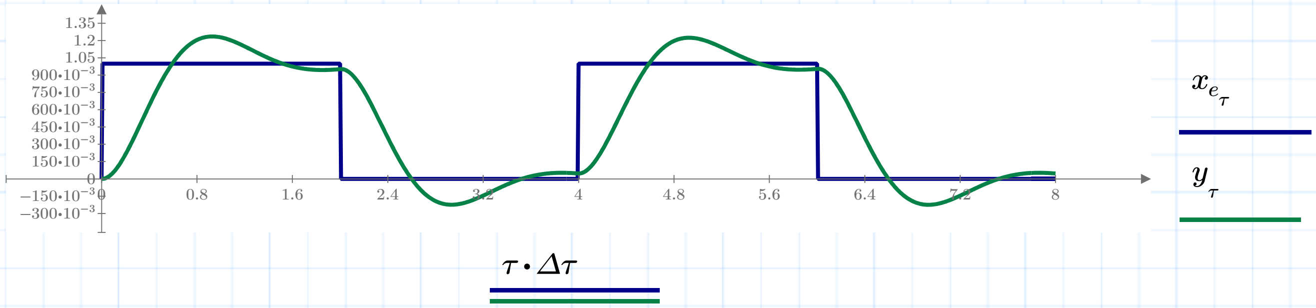
PT2

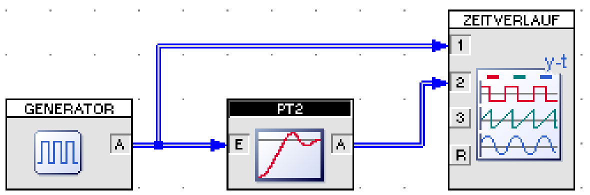
$$PT2(K,\zeta,\omega,x_e) := \begin{array}{|l} dx \leftarrow 0 \\ dy \leftarrow 0 \\ \text{for } n \in 0..\text{rows}(x_e) \\ \quad \begin{array}{|l} x_n \leftarrow 0 \\ y_n \leftarrow 0 \end{array} \\ \text{for } n \in 1..(\text{rows}(x_e)-1) \\ \quad \begin{array}{|l} dy \leftarrow \Delta\tau \cdot \omega \cdot x_{n-1} \\ dx \leftarrow \Delta\tau \cdot \omega \cdot \left(K \cdot x_{e_n} - y_{n-1} - 2 \cdot \zeta \cdot x_{n-1}\right) \\ x_n \leftarrow x_{n-1} + dx \\ y_n \leftarrow y_{n-1} + dy \end{array} \\ \text{return } y \end{array}$$

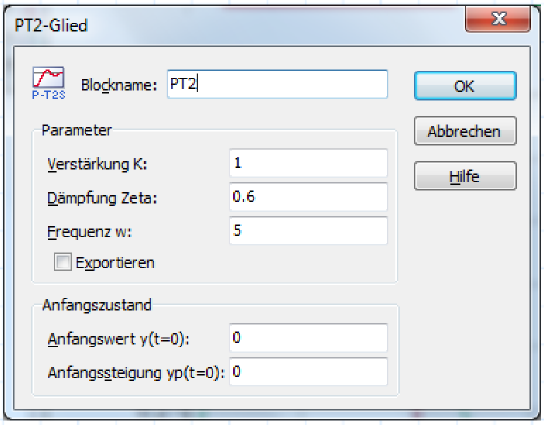
$$G(s) = \frac{K}{\left(\frac{s}{\omega}\right)^2 + 2\frac{\zeta}{\omega}s + 1}$$

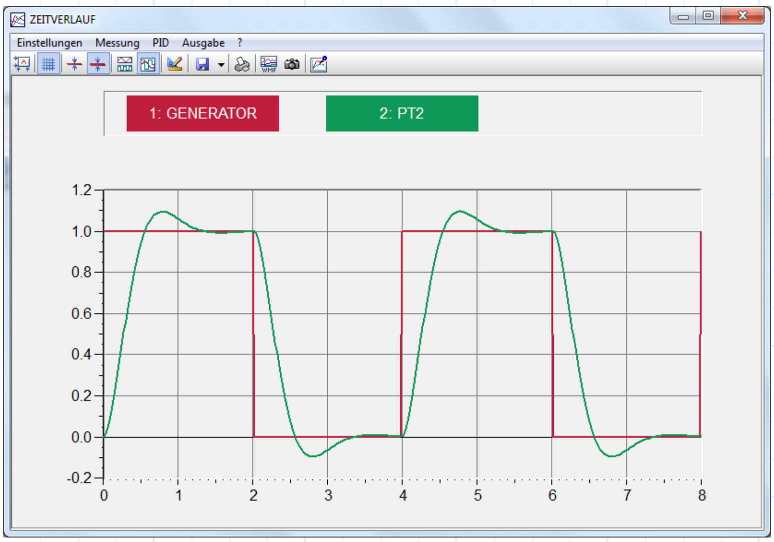


$K := 1$ $\zeta := 0.43$ $\omega := 3.72$ $y := PT2(K,\zeta,\omega,x_e)$









$$2 \cdot \frac{\zeta}{\omega} = 0.23118$$

$$\left(\frac{1}{\omega^2}\right) = 0.07226$$

Totzeit

$$TOTZEIT(K, T_t, x_e) := \left\| \begin{array}{l} n_t \leftarrow \text{floor}\left(\dfrac{T_t}{\Delta\tau}\right) \\ \text{for } n \in 0..\text{rows}(x_e) \\ \quad \| \; y_n \leftarrow 0 \\ \text{for } n \in n_t..(\text{rows}(x_e)-1) \\ \quad \| \; y_n \leftarrow K \cdot x_{e_{n-n_t}} \\ \text{return } y \end{array} \right.$$

$K := 0.5$ $T_t := 0.8$

$y := TOTZEIT(K, T_t, x_e)$