Basisbausteine => Beschreibung im Zeitbereich

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

$SP := 2^{12}$ Sampling Points

$\tau e := 20$ Zeitfenster [s]

$\Delta\tau := \frac{\tau e}{SP} = 4.883 \cdot 10^{-3}$ Samplingtime[s]

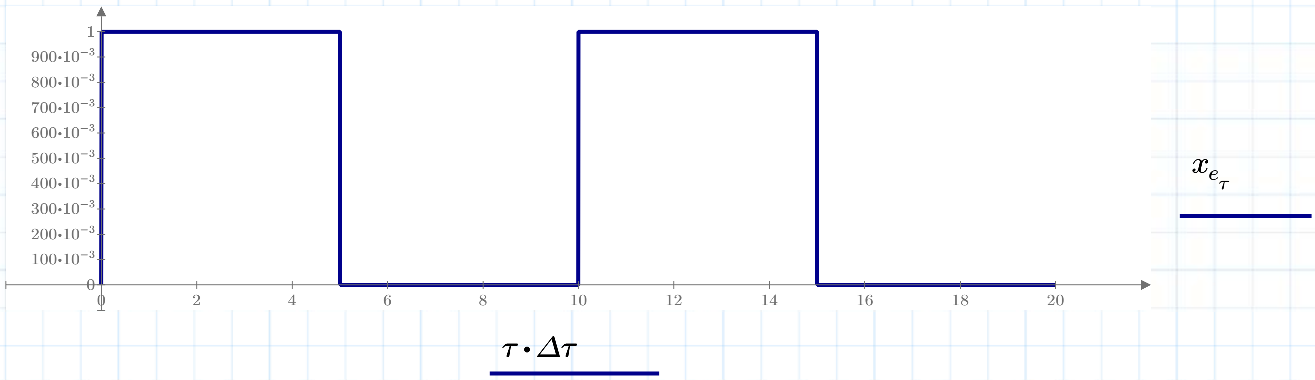
$\tau := 0 .. SP$ Laufvariable

Schrittfunktion

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

$t_{s1} := 0 + \Delta\tau$ $t_{e1} := 5$ $t_{s2} := 10$ $t_{e2} := 15$

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

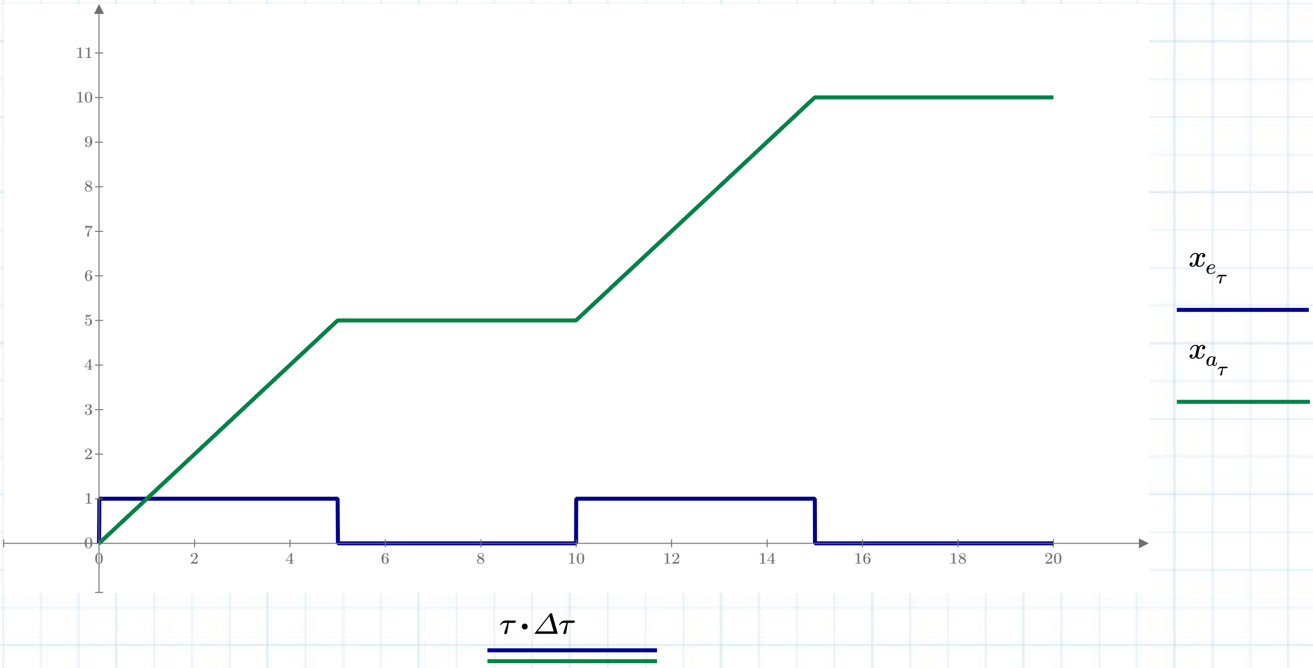


I

$$I\left(T_I, x_e\right) := \left\| \begin{array}{l} summe \leftarrow 0 \\ \text{for } n \in 0..\text{rows}\left(x_e\right) \\ \quad \left\| x_{a_n} \leftarrow 0 \right. \\ \text{for } n \in 1..\left(\text{rows}\left(x_e\right) - 1\right) \\ \quad \left\| \begin{array}{l} summe \leftarrow summe + \dfrac{1}{T_I} \cdot \left(x_{e_n} \cdot \Delta\tau\right) \\ x_{a_n} \leftarrow summe \end{array} \right. \\ \text{return } x_a \end{array} \right.$$

$T_I := 1$

$x_a := I\left(T_I, x_e\right)$

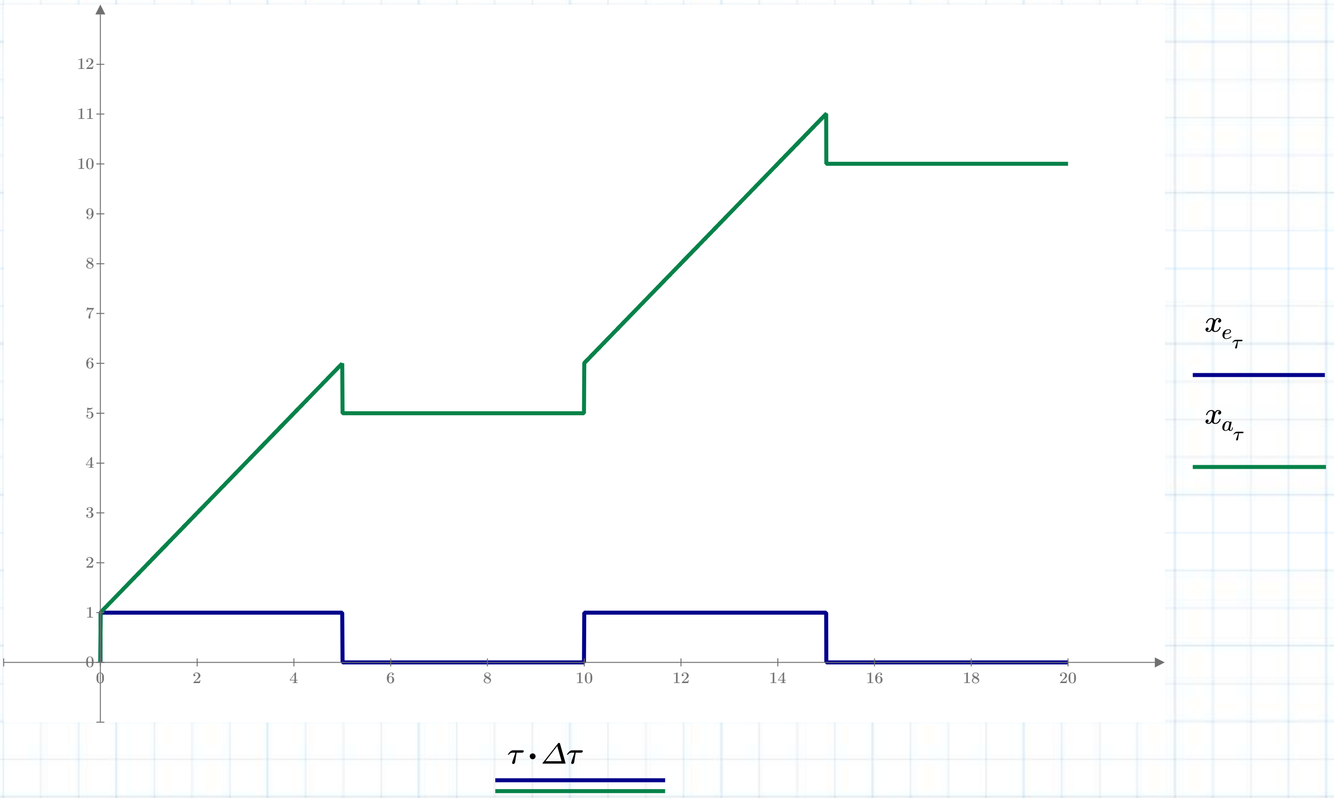


PI

$$PI(K_R, T_N, x_e) := \left\| \begin{array}{l} summe \leftarrow 0 \\ \text{for } n \in 0..\text{rows}(x_e) \\ \quad \left\| x_{a_n} \leftarrow 0 \right. \\ \text{for } n \in 1..(\text{rows}(x_e) - 1) \\ \quad \left\| \begin{array}{l} summe \leftarrow summe + \dfrac{K_R}{T_N} \cdot (x_{e_n} \cdot \Delta\tau) \\ x_{a_n} \leftarrow K_R \cdot x_{e_n} + summe \end{array} \right. \\ \text{return } x_a \end{array} \right.$$

$K_R := 1.0$ $\qquad$ $T_N := 1$

$x_a := PI(K_R, T_N, x_e)$

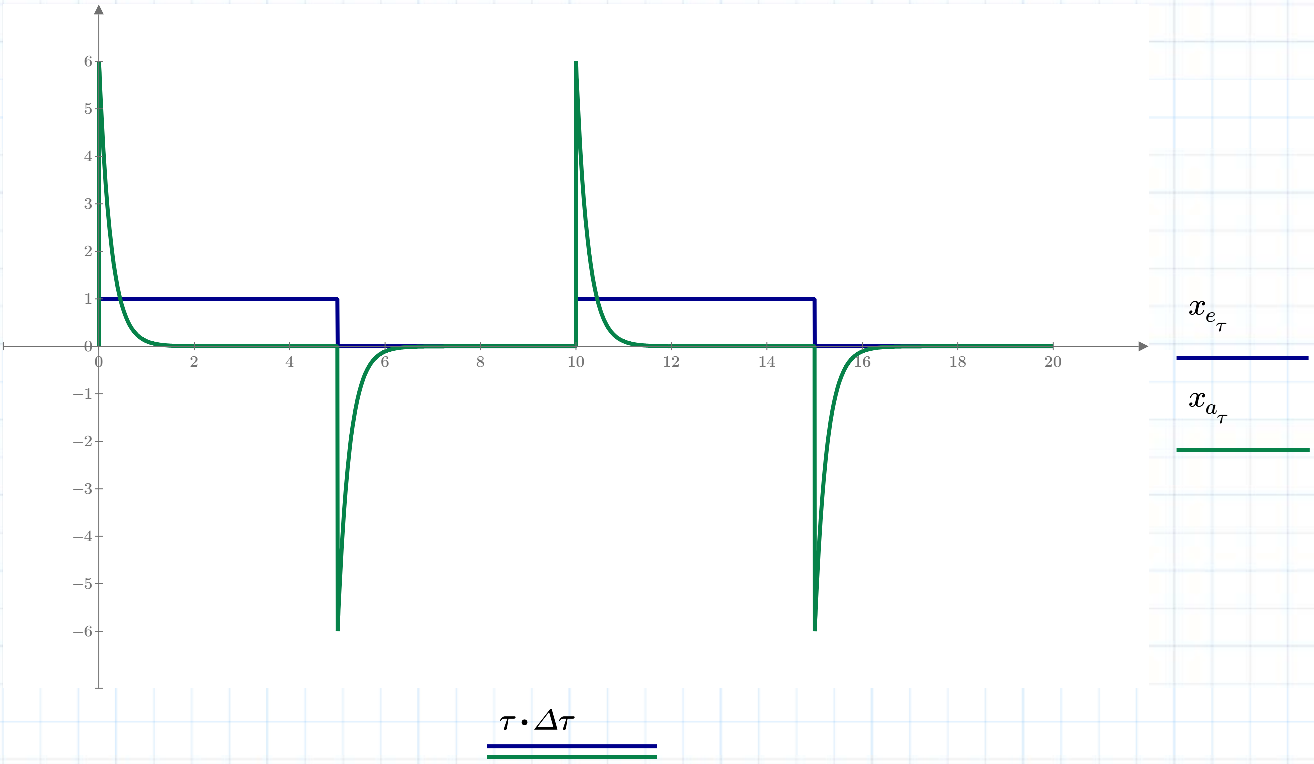


DT1

$$DT1\left(T_V, T_{Vz}, x_e\right) := \begin{array}{l} dx_a \leftarrow 0 \\ dx_e \leftarrow 0 \\ \text{for } n \in 0..\text{rows}(x_e) \\ \quad x_{a_n} \leftarrow 0 \\ \text{for } n \in 1..(\text{rows}(x_e)-1) \\ \quad dx_e \leftarrow \dfrac{T_V}{T_{Vz}} \cdot \left(x_{e_n} - x_{e_{n-1}}\right) \\ \quad dx_a \leftarrow \dfrac{x_{a_{n-1}}}{T_{Vz}} \cdot \Delta\tau \\ \quad x_{a_n} \leftarrow x_{a_{n-1}} + \left(dx_e - dx_a\right) \\ \text{return } x_a \end{array}$$

$T_V := 1.5$ $T_{Vz} := 0.25$

$x_a := DT1\left(T_V, T_{Vz}, x_e\right)$

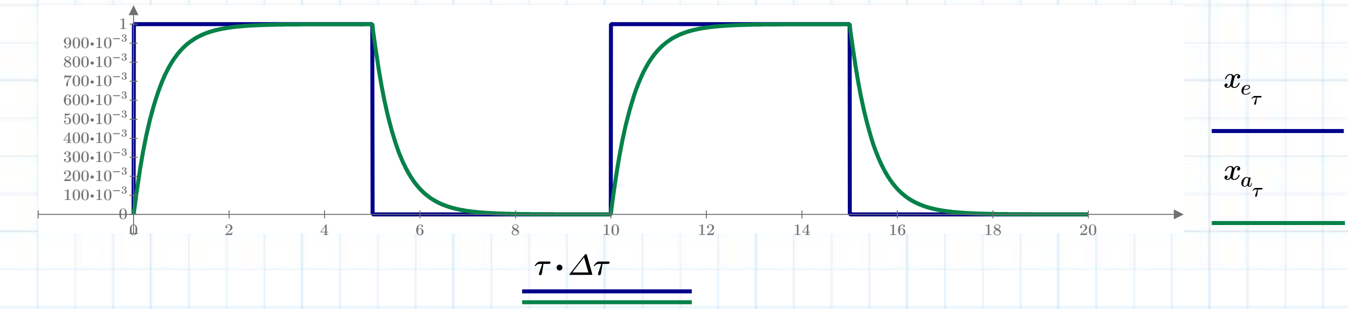


PT1

$$PT1\left(K_p, T_1, x_e\right) := \left\| \begin{array}{l} \text{for } n \in 0 \,..\, \text{rows}\left(x_e\right) \\ \quad \left\| \; x_{a_n} \leftarrow 0 \right. \\ \text{for } n \in 1 \,..\, \left(\text{rows}\left(x_e\right) - 1\right) \\ \quad \left\| \; x_{a_n} \leftarrow x_{a_{n-1}} + \dfrac{-x_{a_{n-1}} + K_p \cdot x_{e_n}}{T_1} \cdot \Delta\tau \right. \\ \text{return } x_a \end{array} \right.$$

$K_p := 1.0$ $\qquad$ $T_1 := 0.5$

$x_a := PT1\left(K_p, T_1, x_e\right)$



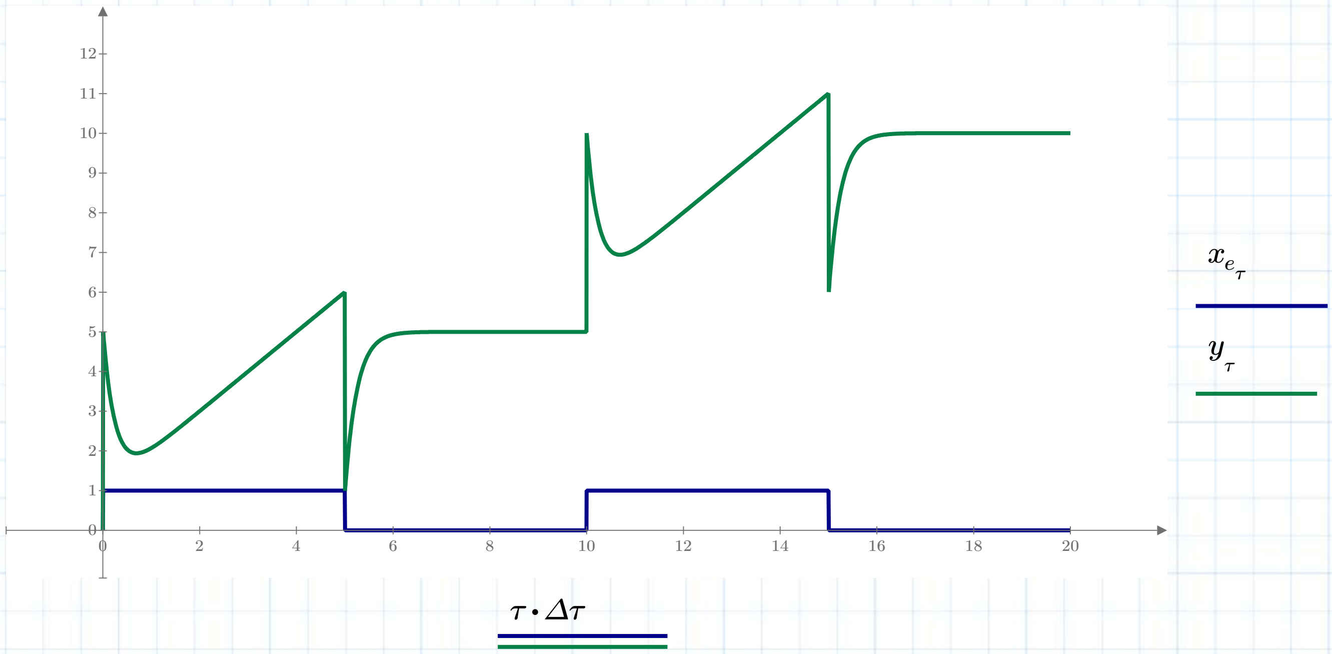
$$\omega_E := \frac{1}{T_1} = 2$$

PID

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

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

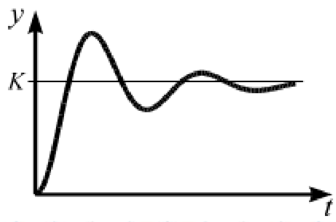
$y := PID\left(K_R, T_N, T_V, T_{Vz}, x_e\right)$



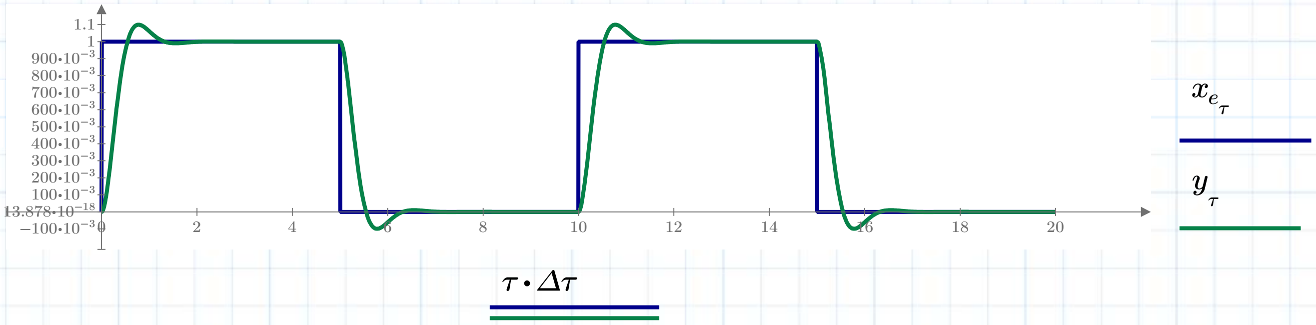
PT2s

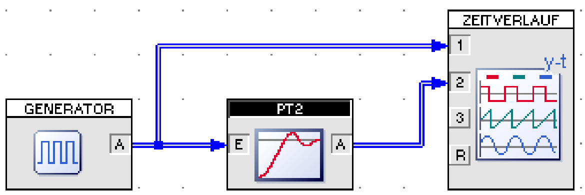
$$
PT2\left(K,\zeta,\omega,x_e\right):=\left|\begin{array}{l}
dx\leftarrow 0\\
dy\leftarrow 0\\
\text{for } n\in 0\,..\,\text{rows}\left(x_e\right)\\
\quad\left|\begin{array}{l} x_n\leftarrow 0\\ y_n\leftarrow 0\end{array}\right.\\
\text{for } n\in 1\,..\,\left(\text{rows}\left(x_e\right)-1\right)\\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

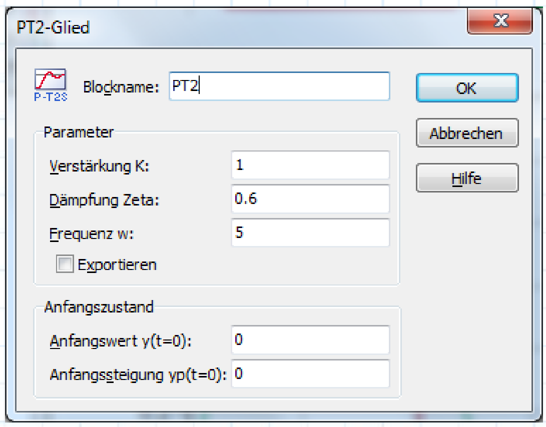
$$G(s)=\frac{K}{\left(\frac{s}{\omega}\right)^2+2\frac{\zeta}{\omega}s+1}$$

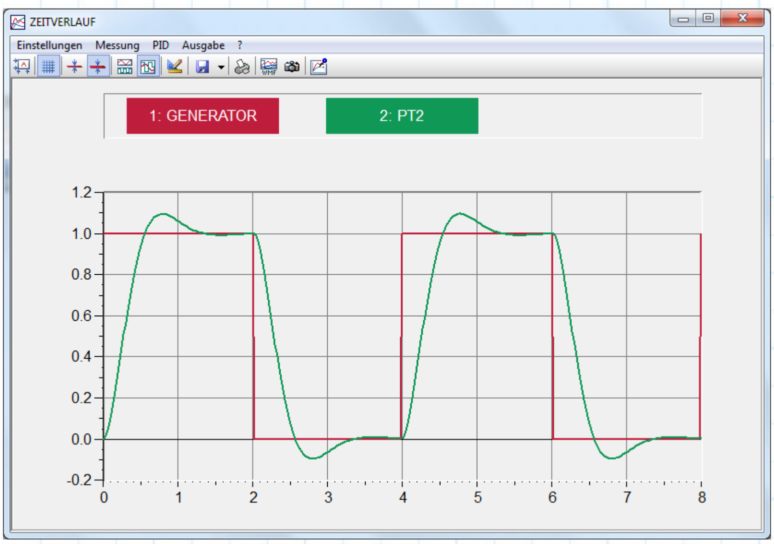


$K:=1$ $\zeta:=0.6$ $\omega:=5$ $y:=PT2\left(K,\zeta,\omega,x_e\right)$









$$2\cdot\frac{\zeta}{\omega}=0.24$$

$$\left(\frac{1}{\omega^2}\right)=0.04$$

PT2
Nicht schwingfähig abgeleitet aus dem PT2s Glied

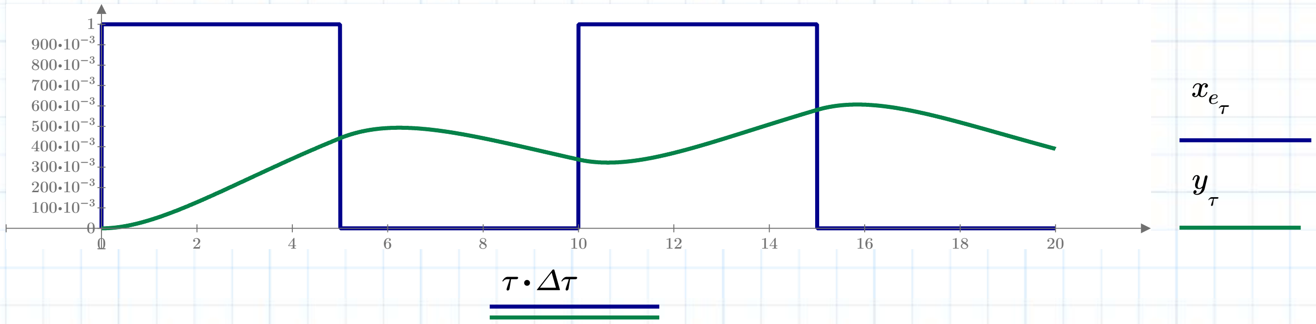
$K := 1$ $T_1 := 2$ $T_2 := 5$

$K := K$

$$\omega := \frac{1}{\sqrt{T_1 \cdot T_2}} = 316.228 \cdot 10^{-3}$$

$$\zeta := \frac{\omega \cdot (T_1 + T_2)}{2} = 1.107$$

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

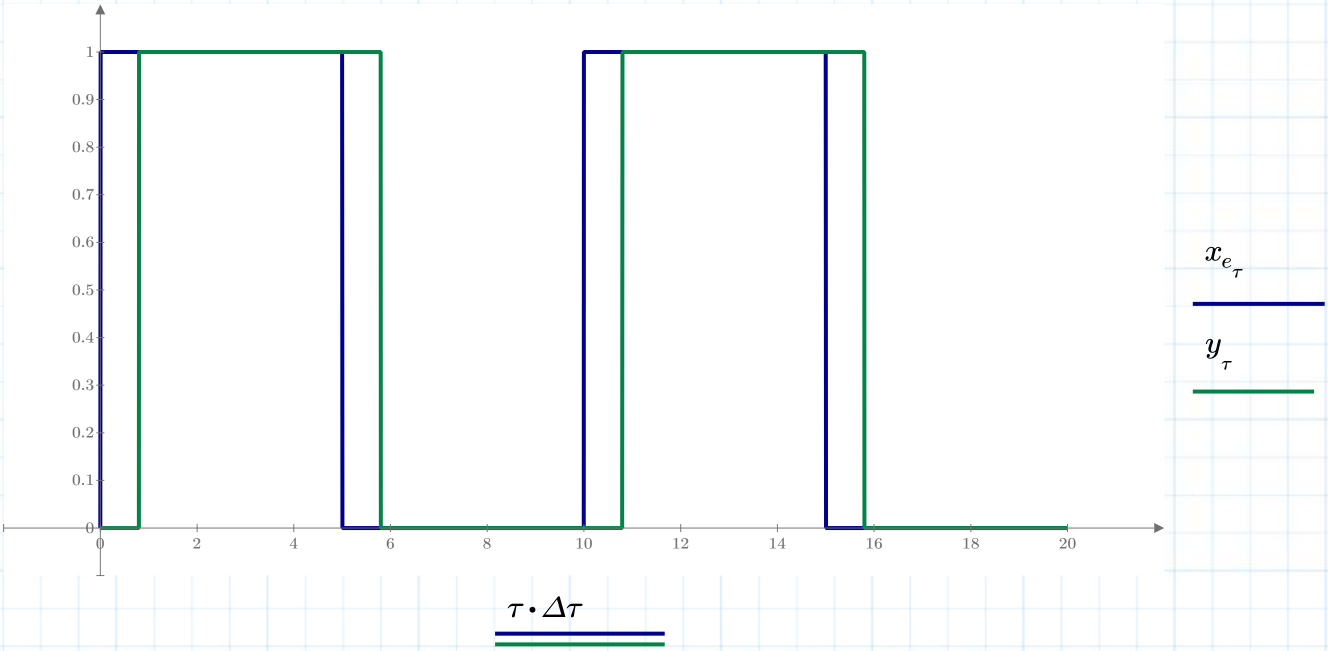


Totzeit

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

$K := 1$ $\quad$ $T_t := 0.8$

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



Vorsteuerung

Koordinaten aus dem Kennlinienfeld => experimentelle Ermittlung

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

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

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

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

$$
linInt(x) := \left\|
\begin{array}{l}
y_{int} \leftarrow -1.0 \\
m \leftarrow 0 \\
q \leftarrow 0 \\
i \leftarrow 0 \\
\text{if } x \le x_{Pmin} \\
\quad \| \; y_{int} \leftarrow y_{Pmin} \\
\text{else if } x \ge x_{Pmax} \\
\quad \| \; y_{int} \leftarrow y_{Pmax} \\
\text{else} \\
\quad \| \; \text{while } i < (n-1) \\
\quad \quad \| \; \text{if } \left(x > x_{P_i}\right) \wedge \left(x \le x_{P_{i+1}}\right) \\
\quad \quad \quad \| \; m \leftarrow \dfrac{y_{P_{i+1}} - y_{P_i}}{x_{P_{i+1}} - x_{P_i}} \\
\quad \quad \quad \| \; q \leftarrow y_{P_i} - m \cdot x_{P_i} \\
\quad \quad \quad \| \; y_{int} \leftarrow m \cdot x + q \\
\quad \quad \quad \| \; i \leftarrow n \\
\quad \quad \| \; i \leftarrow i + 1 \\
\text{return } y_{int}
\end{array}
\right.
$$

$x := x_{Pmin} - 1, x_{Pmin} - 0.9 .. x_{Pmax} + 1$