Addisionele gegewens/*Additional information*

$$\Phi(t) = e^{\mathbf{A}t} = Laplace^{-1}\left\{[s\mathbf{I}-\mathbf{A}]^{-1}\right\} \qquad \Delta_{OL}(s) = |s\mathbf{I}-\mathbf{A}| = s^n + \alpha_1 s^{n-1} + \ldots + \alpha_{n-1}s + \alpha_n$$

$$\mathbf{x}(t) = \Phi(t)\mathbf{x}(0) + \int_0^t \Phi(t-\tau)\mathbf{b}\,u(\tau)\,d\tau \qquad \mathbf{X}(s) = \Phi(s)\mathbf{x}(0) + \Phi(s)\mathbf{b}\,\mathbf{U}(s)$$

$$e^{-at} \Leftrightarrow \frac{1}{s+a} \qquad t\,e^{-at} \Leftrightarrow \frac{1}{(s+a)^2}$$

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \qquad \mathbf{A}^{-1} = \frac{kof[\mathbf{A}]^T}{|\mathbf{A}|} = \frac{adj[\mathbf{A}]}{|\mathbf{A}|}$$

$$kof[\mathbf{A}] = \begin{bmatrix} a_{22}a_{33} - a_{23}a_{32} & a_{23}a_{31} - a_{21}a_{33} & a_{21}a_{32} - a_{22}a_{31} \\ a_{13}a_{32} - a_{12}a_{33} & a_{11}a_{33} - a_{13}a_{31} & a_{11}a_{32} - a_{12}a_{31} \\ a_{12}a_{23} - a_{13}a_{22} & a_{13}a_{21} - a_{11}a_{23} & a_{11}a_{22} - a_{12}a_{21} \end{bmatrix}$$

$$|\mathbf{A}| = a_{11}(a_{22}a_{33} - a_{23}a_{32}) - a_{12}(a_{21}a_{33} - a_{23}a_{31}) + a_{13}(a_{21}a_{32} - a_{22}a_{31})$$

$$G(s) = \mathbf{c}(s\mathbf{I} - \mathbf{A})^{-1}\mathbf{b} + d$$

Tydgebied ontwerp/*Time domain design*:

$$t_r \approx \frac{1.8}{\omega_n}, \quad t_p = \frac{\pi}{\omega_d}, \quad 1\%t_s = \frac{4.7}{\zeta\omega_n}, \quad 2\%t_s = \frac{4}{\zeta\omega_n}, \quad s = -\sigma \pm j\omega_d = -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2}$$

$$e^{j\omega T} = \cos\omega T + j\sin\omega T, \qquad z = e^{sT}, \qquad G_{ho}G(z) = \frac{z-1}{z} Z\left\{\frac{G(s)}{s}\right\}$$

$$K_p = \lim_{z\to 1} D(z)G_{ho}G(z), \quad K_v = \frac{1}{T}\lim_{z\to 1}(z-1)D(z)G_{ho}G(z), \quad K_a = \frac{1}{T^2}\lim_{z\to 1}(z-1)^2 D(z)G_{ho}G(z)$$

$$e_{ss} = \frac{1}{1+K_p}, \quad e_{ss} = \frac{1}{K_v}, \quad e_{ss} = \frac{1}{K_a}$$

Z-Transform:

$$F(z) = \sum_{k=-\infty}^{\infty} f(k)z^{-k}, \quad f(k+1) = zF(z) - z\,f(0), \quad f(k-1) = z^{-1}F(z), \quad \lim_{k\to\infty} f(k) = \lim_{z\to 1}(z-1)F(z)$$

Bilineêre Transformasie/*Bilinear Transformation:*

$$s = \frac{2}{T}\left(\frac{z-1}{z+1}\right)$$

Truwaartsverskil metode/*Backward difference:*

$$s = \frac{1}{T}\left(\frac{z-1}{z}\right), \quad \frac{1}{s} = T\frac{z}{z-1}$$

$F(s)$	$f(kT)$	$F(z)$
$\frac{1}{s}$	$1(kT)$	$\frac{z}{z-1}$
$\frac{1}{s+a}$	e^{-akT}	$\frac{z}{z-e^{-aT}}$
$\frac{a}{s(s+a)}$	$1-e^{-akT}$	$\frac{z(1-e^{-aT})}{(z-1)(z-e^{-aT})}$
$\frac{1}{s^2}$	kT	$\frac{Tz}{(z-1)^2}$

Tabelle met Z-transforms/*Tables of Z-transforms*

$F(s)$	$f(t);\ t \geq 0$	$f(kT)/f(k)$ $k = 0, 1, 2, \ldots$	$F(z)$
—	—	Unit step $\mu(k)$	$\frac{z}{z-1}$
—	—	a^k	$\frac{z}{z-a}$
—	—	k	$\frac{z}{(z-1)^2}$
—	—	k^2	$\frac{z(z+1)}{(z-1)^3}$
—	—	$k\,a^k$	$\frac{az}{(z-a)^2}$
—	—	$a^k \sin \Omega k$	$\frac{(a\sin\Omega)z}{z^2-(2a\cos\Omega)z+a^2}$
—	—	$a^k \cos \Omega k$	$\frac{z^2-(a\cos\Omega)z}{z^2-(2a\cos\Omega)z+a^2}$

Laplace transform $F(s)e^{-\Delta Ts};\ 0 \leq \Delta < 1$	*z-transform* $\mathscr{Z}[F(s)e^{-\Delta Ts}];\ m = 1 - \Delta$
$\frac{e^{-\Delta Ts}}{s}$	$\frac{1}{z-1}$
$\frac{e^{-\Delta Ts}}{s^2}$	$\frac{mT}{z-1}+\frac{T}{(z-1)^2}$
$\frac{2e^{-\Delta Ts}}{s^3}$	$T^2\left[\frac{m^2z^2+(2m-2m^2+1)z+(m-1)^2}{(z-1)^3}\right]$
$\frac{e^{-\Delta Ts}}{s+a}$	$\frac{e^{-amT}}{z-e^{-aT}}$
$\frac{e^{-\Delta Ts}}{(s+a)(s+b)}$	$\frac{1}{(b-a)}\left[\frac{e^{-amT}}{z-e^{-aT}}-\frac{e^{-bmT}}{z-e^{-bT}}\right]$
$\frac{ae^{-\Delta Ts}}{s(s+a)}$	$\frac{(1-e^{-amT})z+(e^{-amT}-e^{-aT})}{(z-1)(z-e^{-aT})}$
$\frac{ae^{-\Delta Ts}}{s^2(s+a)}$	$\frac{T}{(z-1)^2}+\frac{amT-1}{a(z-1)}+\frac{e^{-amT}}{a(z-e^{-aT})}$