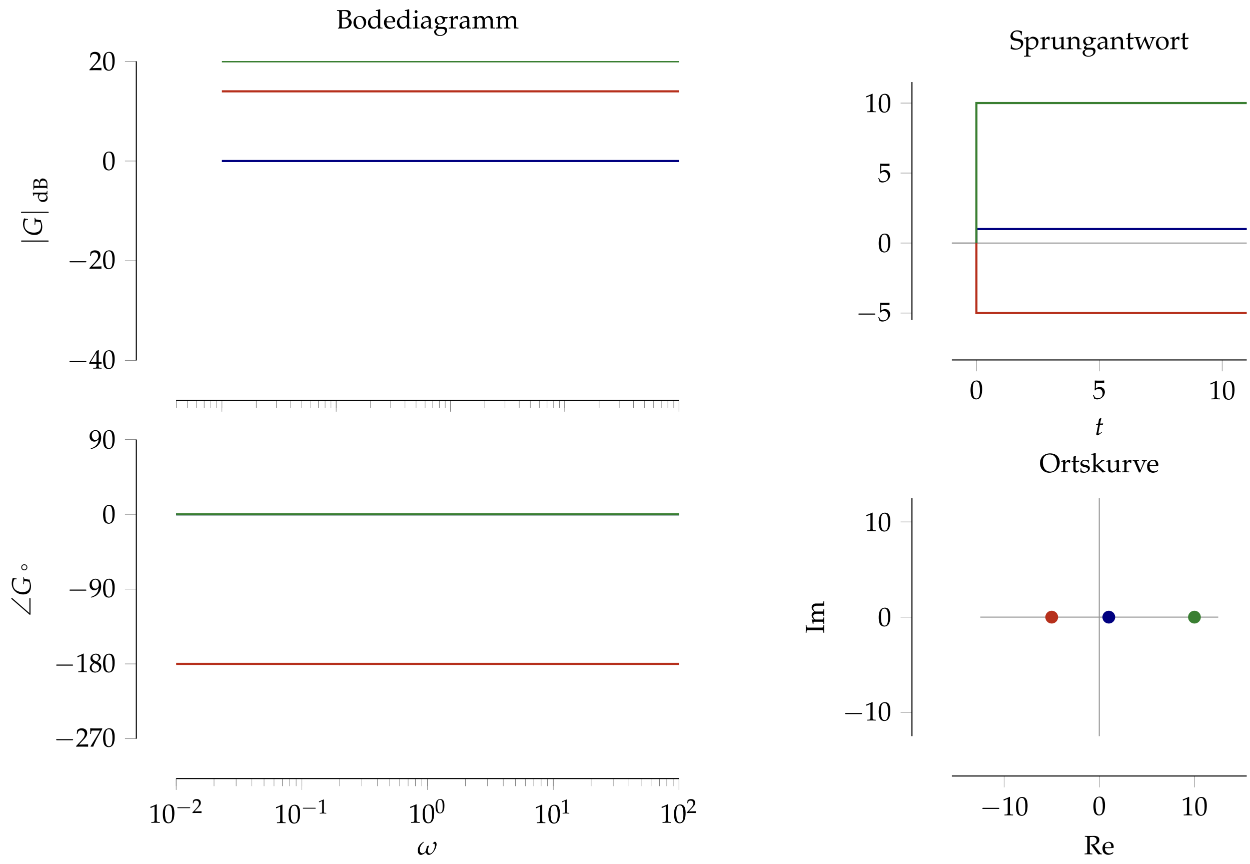
Konstanter Faktor : $y = ku$.

$G = k$ $\quad$ $k = -5 \quad k = 1 \quad k = 10$



Reeller Pol : $\dot{y} + ay = u$.

$$G = \frac{1}{s+a} \qquad \color{red}{a=-1} \quad \color{blue}{a=0} \quad \color{green}{a=+1}$$

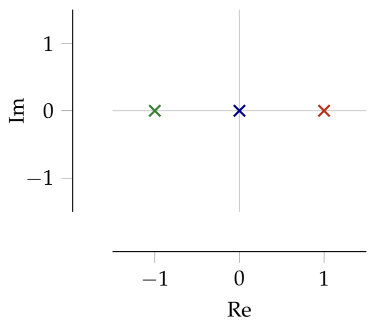
$$\omega_g = |a| \quad \Rightarrow \quad \angle G(j\omega_g) = -45/-135\,°$$

$$|G(j\omega_g)| = \frac{1}{\sqrt{2}} \approx -3\text{ dB}$$

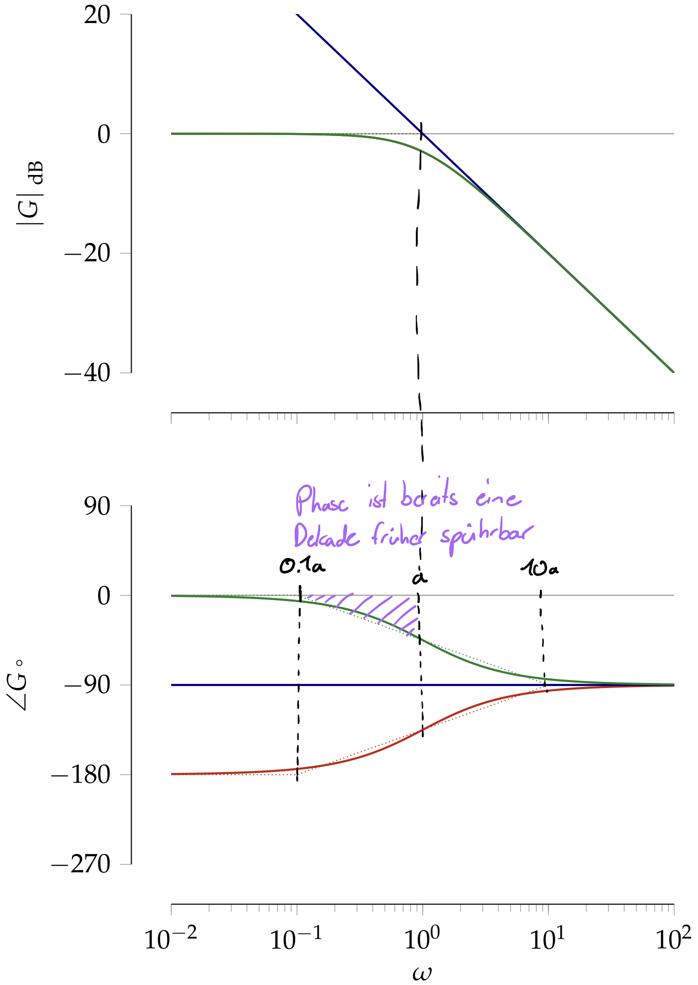
$$\omega \ll \omega_g \; : \quad |G| \approx \frac{1}{|a|}$$

$$\omega_g \ll \omega \; : \quad |G| \propto -20\ \text{dB/Dek.}$$

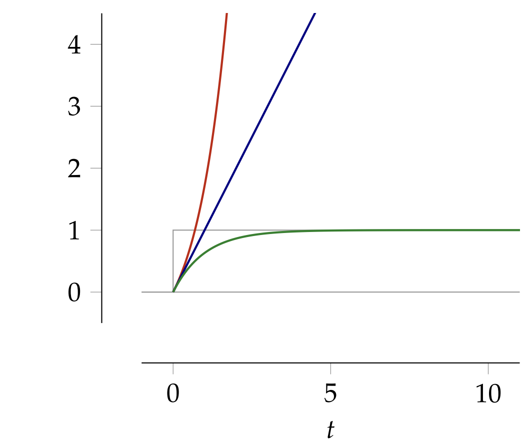
Pol-Nullstellenplan



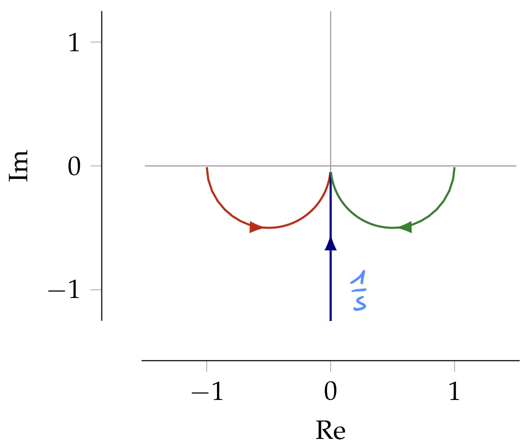
Bodediagramm



Sprungantwort



Ortskurve



Konjugiert komplexes Polpaar : $\ddot{y} + 2a\dot{y} + by = u$.

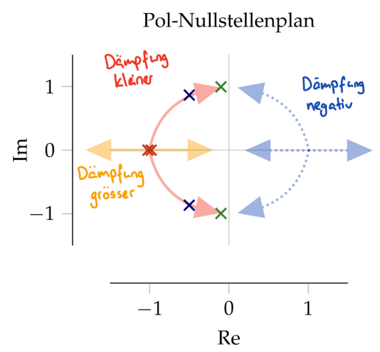
$$\frac{1}{s^2 + 2\zeta\omega_0 s + \omega_0^2} \qquad \omega_0 = 1 \quad \zeta = 1 \quad \zeta = 0.5 \quad \zeta = 0.1$$

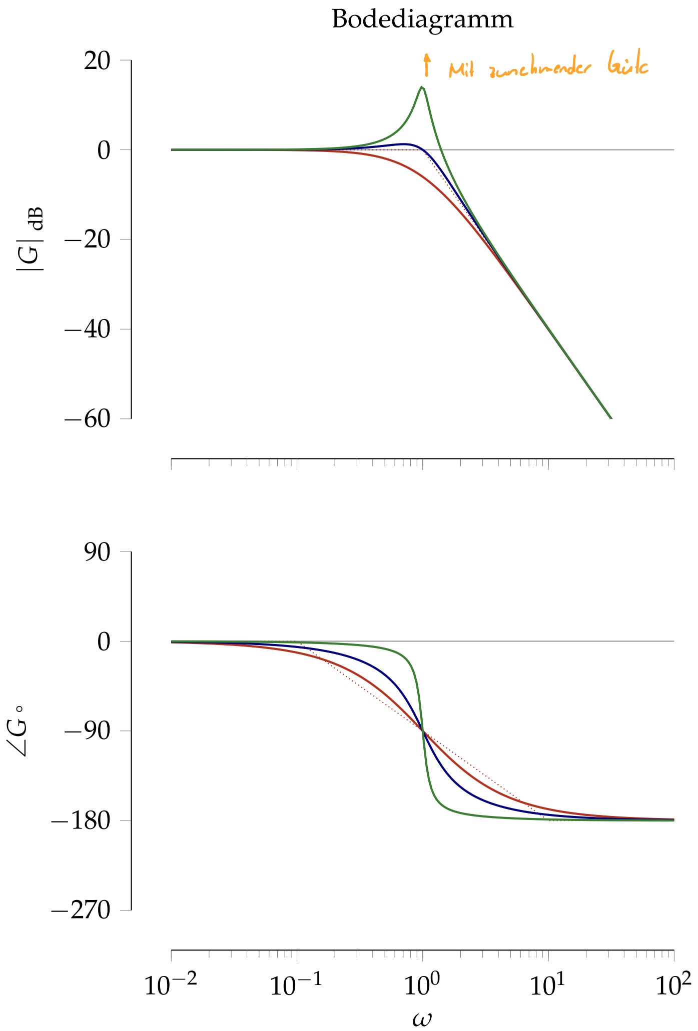
$\angle G(j\omega_0) = -90\,°$

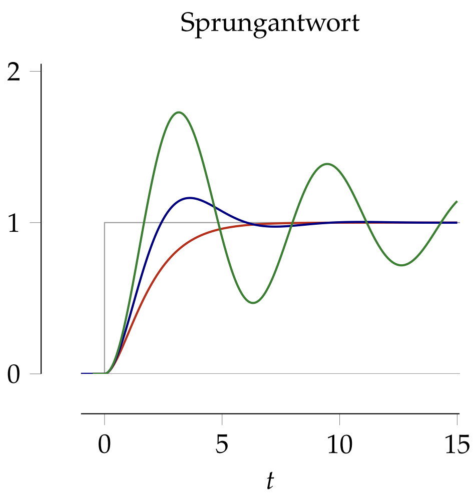
$\omega \ll \omega_0$: $|G| \approx 1/\omega_0^2$ → Konstante Dämpfung

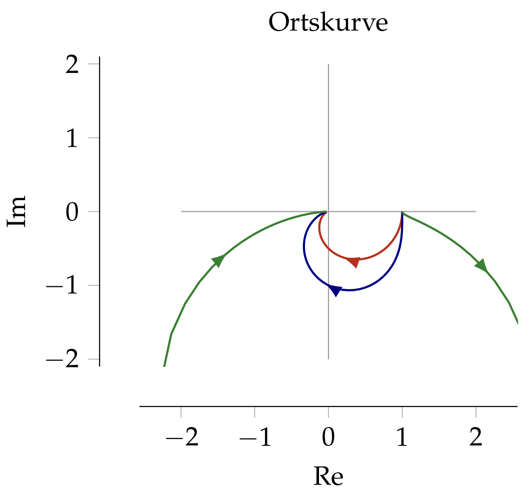
$\omega_0 \ll \omega$: $|G| \propto -40$ dB/Dek.

$M_p = e^{-\pi\zeta/\sqrt{1-\zeta^2}}$ relatives Überschiessen $\dfrac{\hat{h} - h_\infty}{h_\infty}$

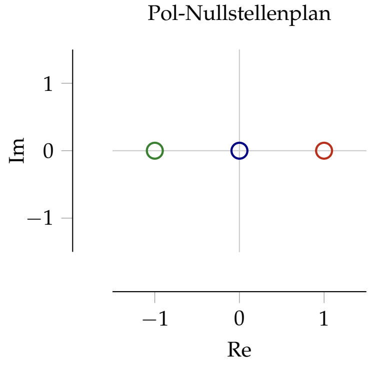








REELLE NULLSTELLE : $y = \dot{u} + au$.



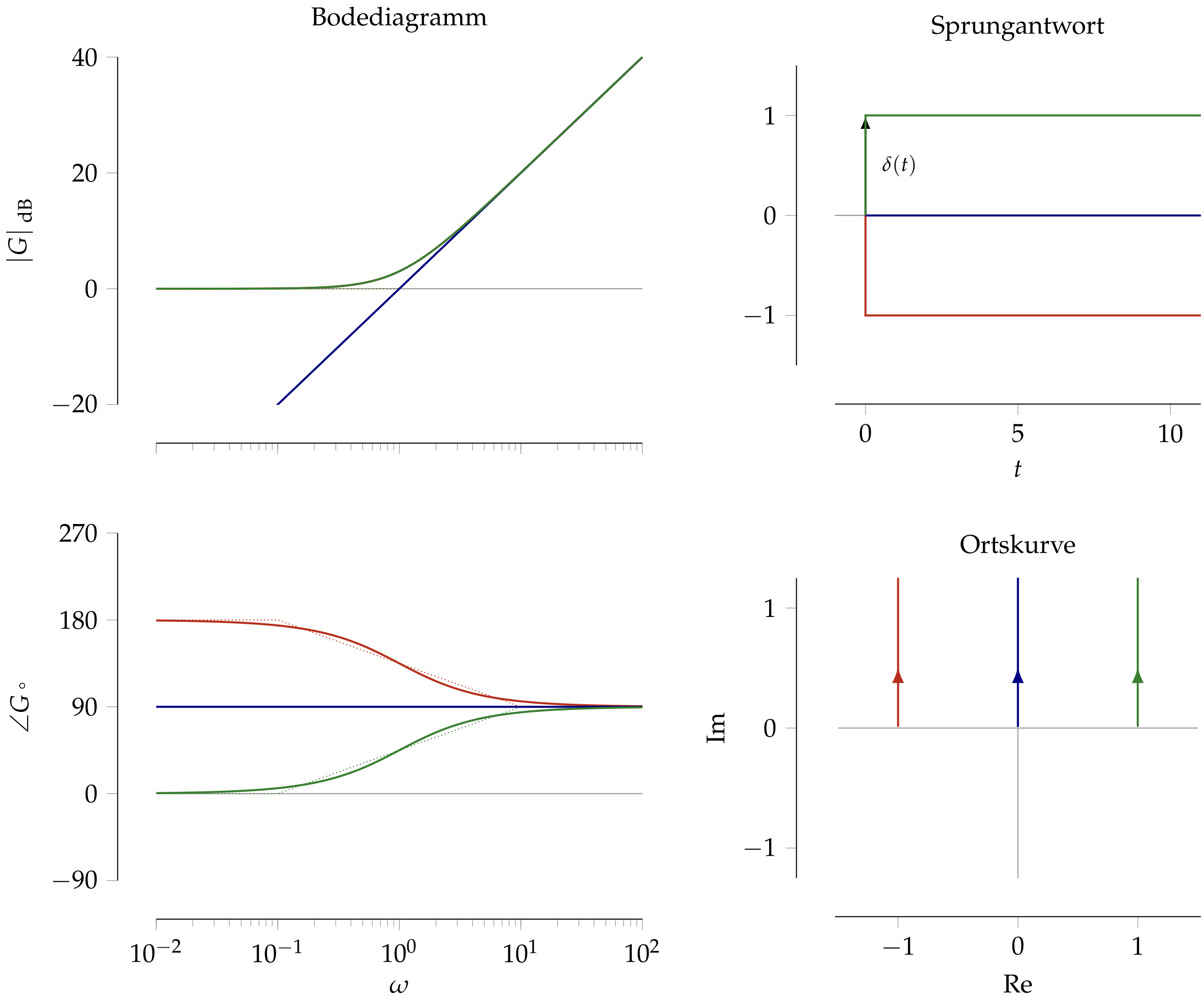
$G = s + a$ $\qquad$ $a = -1 \quad a = 0 \quad a = +1$

$\omega_g = |a| \quad \Rightarrow$ $\qquad$ $\angle G(j\omega_g) = +45/+135\,°$

$|G(j\omega_g)| = \sqrt{2} \approx +3\text{ dB}$

$\omega \ll \omega_g$: $\qquad$ $|G| \approx |a|$

$\omega_g \ll \omega$: $\qquad$ $|G| \propto +20\text{dB}/\text{Dek.}$ $\qquad \angle G \approx 90°$

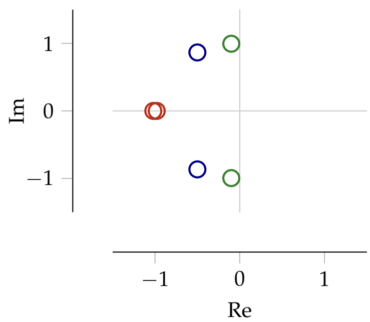


Konjugiert komplexes Nullstellenpaar : $y = \ddot{u} + a\dot{u} + bu$.

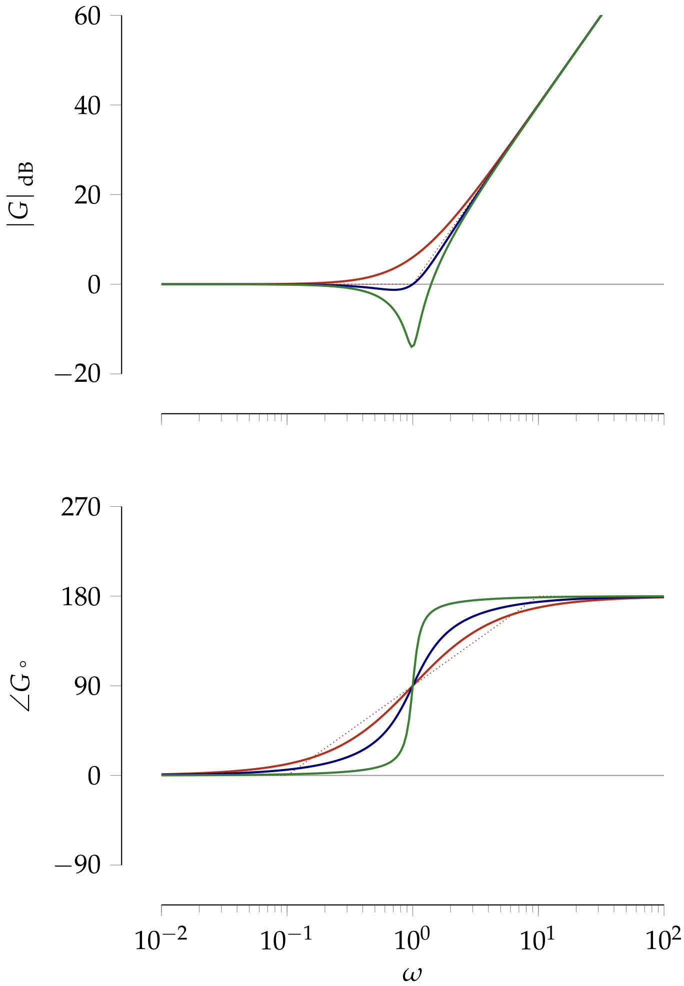
Nur theoretisch möglich

$s^2 + \underbrace{2\zeta\omega_0}_{a} s + \underbrace{\omega_0^2}_{b}$	$\omega_0 = 1$ $\zeta = 1$ $\zeta = 0.5$ $\zeta = 0.1$
	$\angle G(j\omega_0) = +90]\ °$
$\omega \ll \omega_0$:	$\lvert G\rvert \approx \omega_0^2$
$\omega_0 \ll \omega$:	$\lvert G\rvert \propto +40$ dB/Dek.

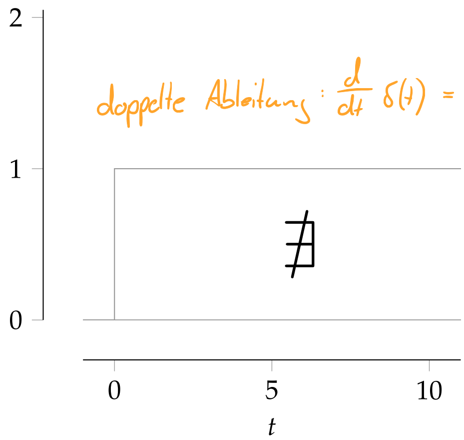
Pol-Nullstellenplan



Bodediagramm

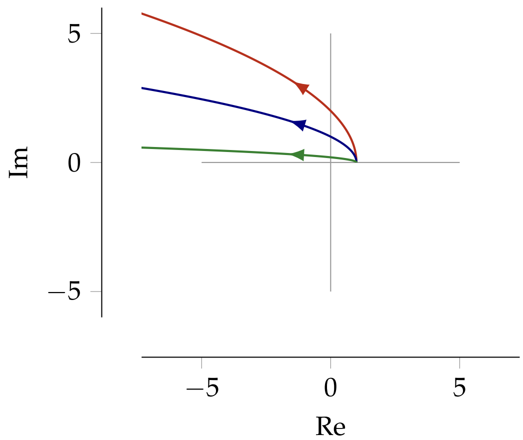


Sprungantwort



doppelte Ableitung : $\frac{d}{dt}\delta(t)$ = undef.!

Ortskurve



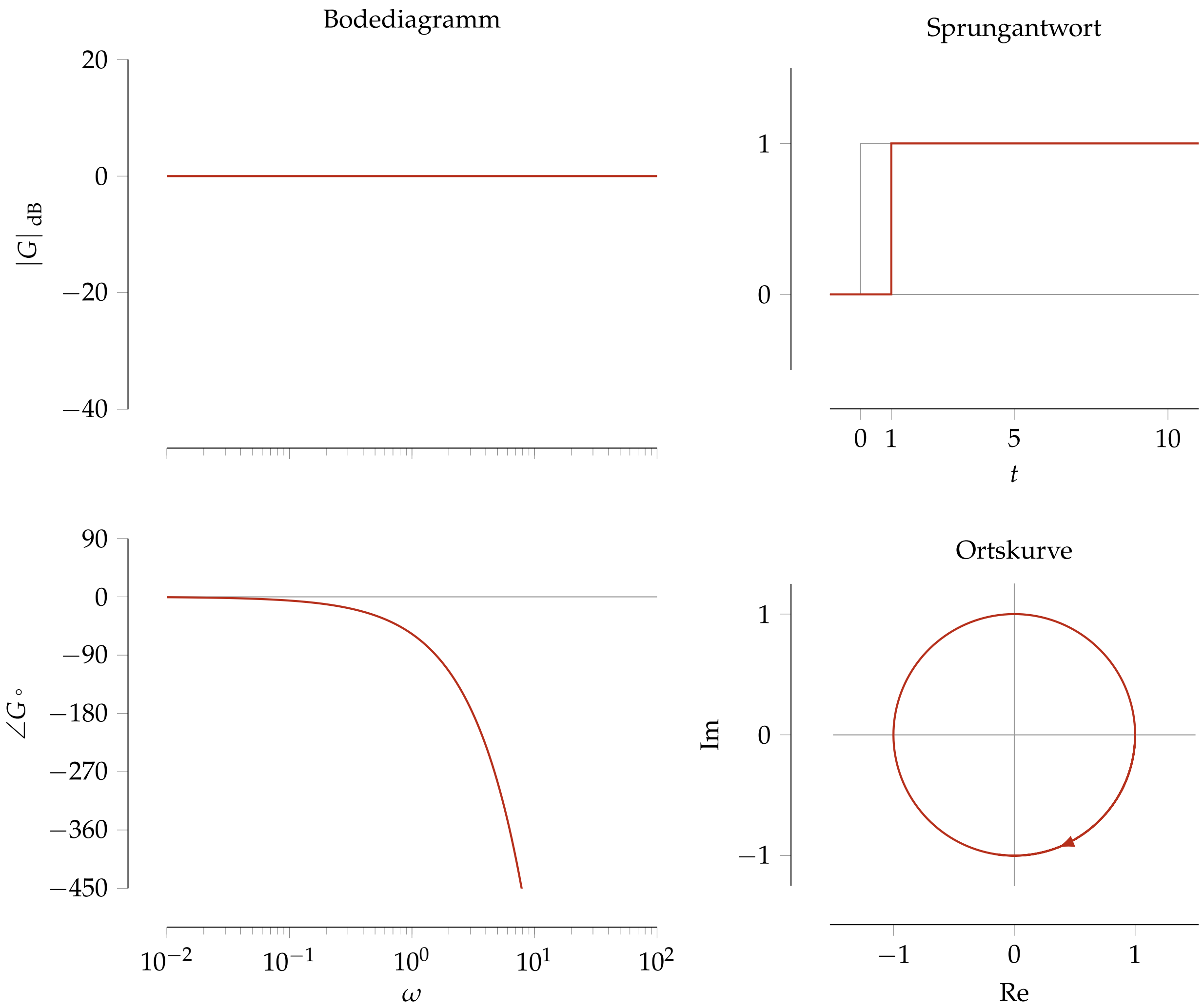
Totzeit, Verzögerung : $y(t) = u(t - \tau)$.

$G = e^{-s\tau} \quad \tau > 0$ $\qquad\qquad$ $\tau = 1$

$\angle G(j\omega) = -\omega\tau$

$|G| = 1 = 0$ dB

$$e^{-s\tau} = \frac{1}{\lim_{n\to\infty}(1 + s\frac{\tau}{n})^n}$$



Verkettung – Beispiel.

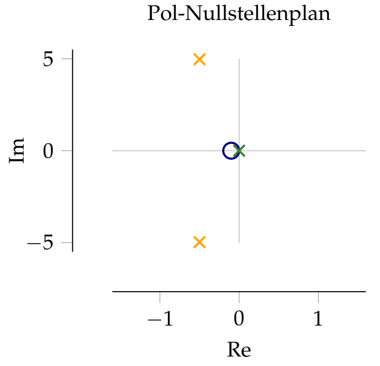
$$G = \frac{10s+1}{s^3+s^2+25s} = \underbrace{10}_{G_1} \cdot \underbrace{(s+0.1)}_{G_2} \cdot \underbrace{\frac{1}{s}}_{G_3} \cdot \underbrace{\frac{1}{s^2+s+25}}_{G_4}$$

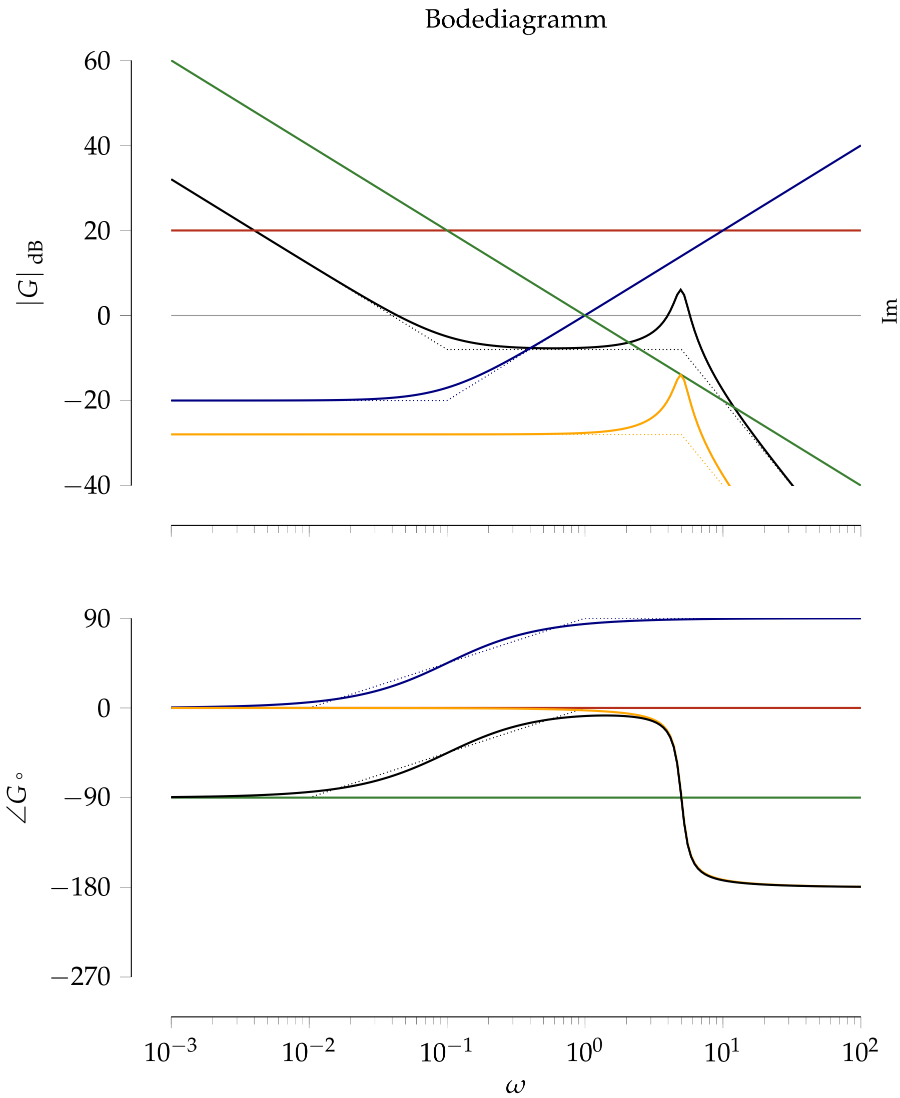
$$G_1 = 10$$

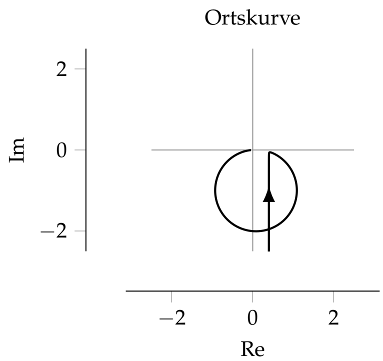
$$G_2 = (s+0.1)$$

$$G_3 = \frac{1}{s}$$

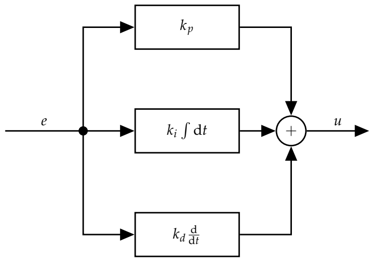
$$G_4 = \frac{1}{s^2+s+25} = \frac{1}{s^2+2\zeta\omega_0 s+\omega_0^2} \qquad \text{mit} \quad \omega_0 = 5\,, \ \ \zeta = 0.1$$







Addition – Beispiel PID.



$$u = k_p e + k_i \int_0^t e(\tau)\,\mathrm{d}\tau + k_d \frac{\mathrm{d}e}{\mathrm{d}t}$$
$$u = k_p e + k_i \frac{1}{s} e + k_d s e$$
$$G = \frac{u}{e} = k_p + k_i \frac{1}{s} + k_d s = \frac{k_p s + k_i + k_d s^2}{s} = k \frac{(1+sT_1)(1+sT_2)}{s}$$

Graphen für $k = 1, T_1 = 0.1, T_2 = 10$ sowie $k_p = 10.1, k_i = 1, k_d = 1$