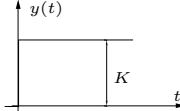
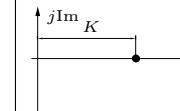
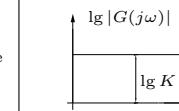
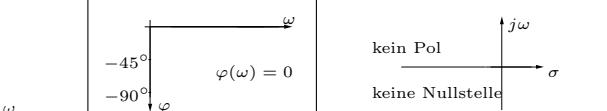
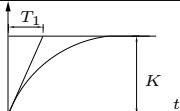
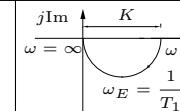
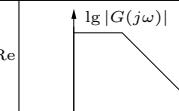
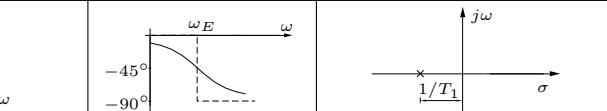
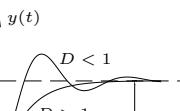
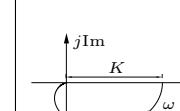
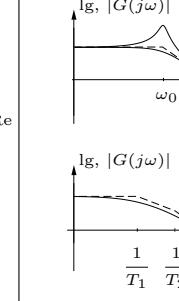
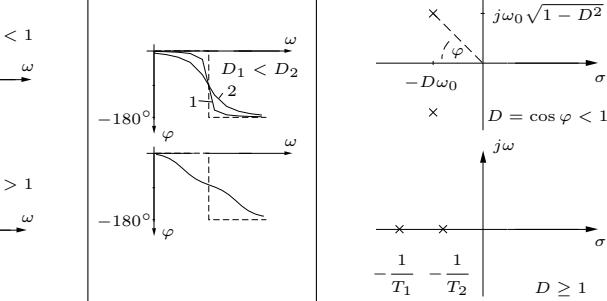
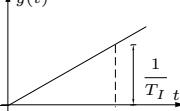
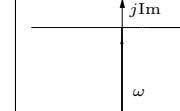
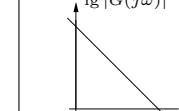
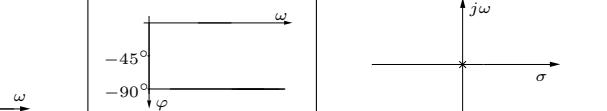
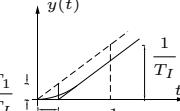
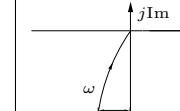
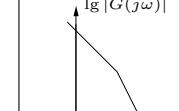
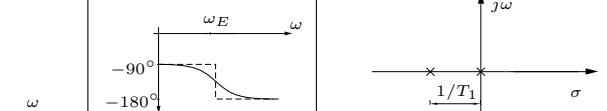
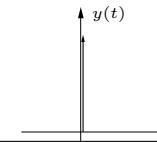
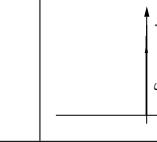
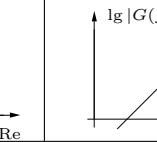
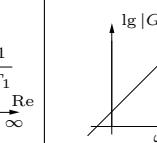
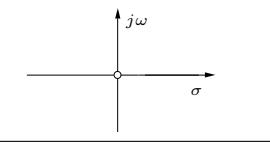
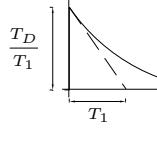
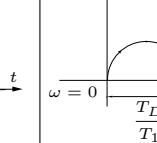
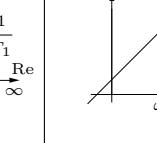
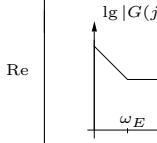
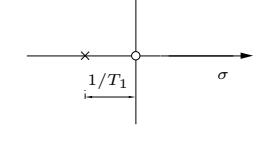
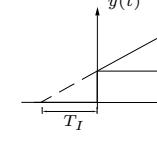
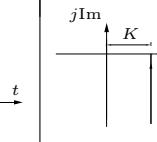
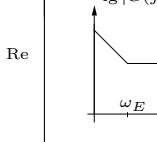
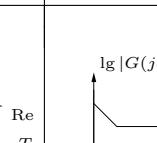
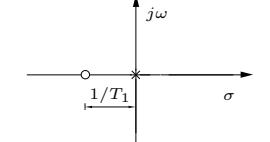
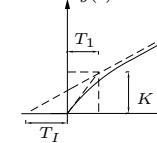
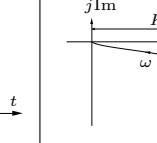
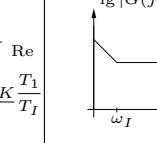
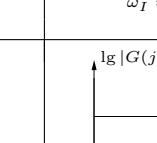
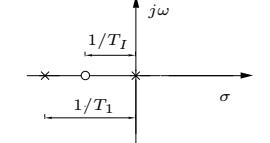
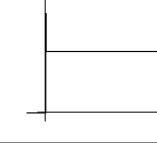
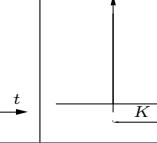
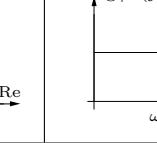
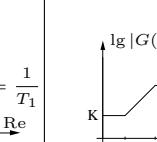
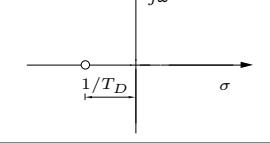
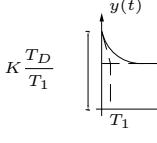
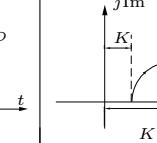
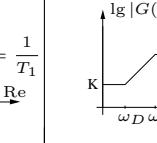
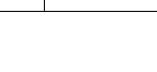
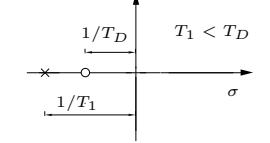
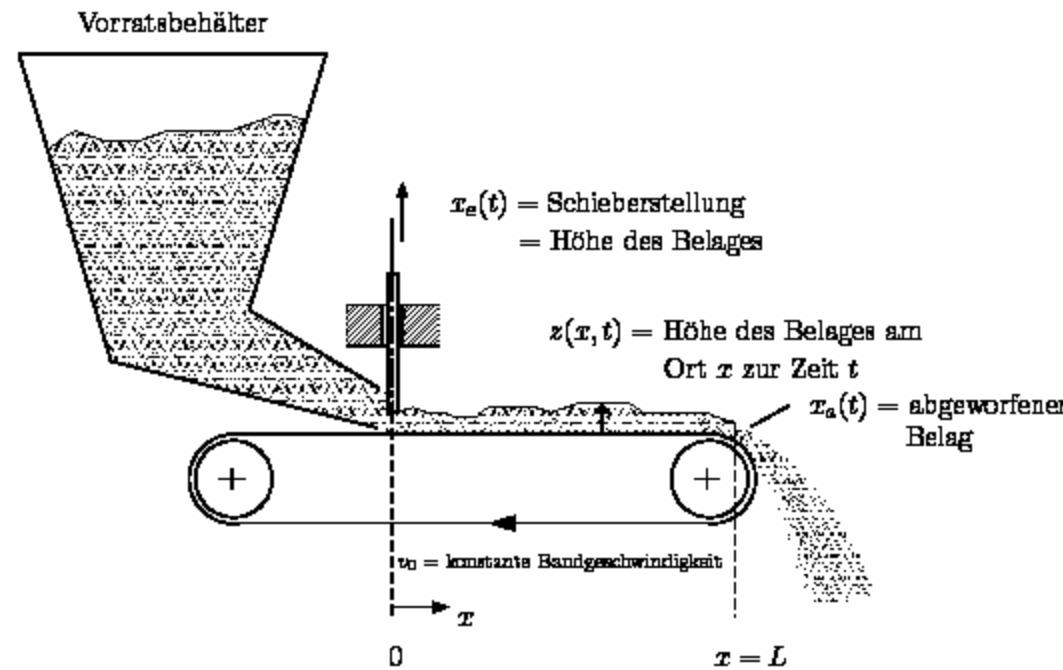


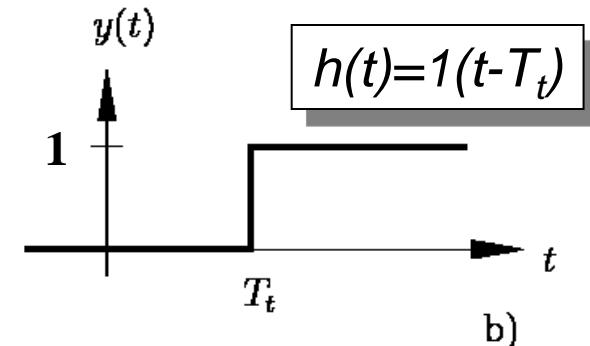
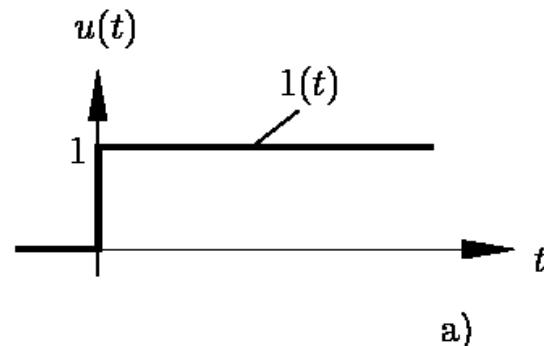
Tabelle 2.3: Verhalten der wichtigsten Regelkreisglieder

System	Zeitbereich Bildbereich	Übergangsfunktion	Ortskurve	Bode-Diagramm (Amplitudengang) (Phasengang)	s-Ebene
					$\times$ Pol $\circ$ Nullstelle
$P$	$y(t) = K u(t)$ $G(s) = K$				
$PT_1$	$T_1 \dot{y}(t) + y(t) = K u(t)$ $G(s) = K \frac{1}{1 + T_1 s}$				
$PT_2$	$\begin{aligned} \frac{1}{\omega_0^2} \ddot{y}(t) + \frac{2D}{\omega_0} \dot{y}(t) + y(t) \\ = K u(t) \end{aligned}$ $G(s) = K \frac{1}{\frac{1}{\omega_0^2} s^2 + \frac{2D}{\omega_0} s + 1}$ $D < 1$ : konjugiert komplexe Wurzeln der char. Gleichung $\lambda_{1,2} = -\omega_0(D \pm j\sqrt{1-D^2})$ $D \geq 1$ : reelle Wurzeln der char. Gleichung $\lambda_{1,2} = -\omega_0(D \pm \sqrt{D^2-1}) = -1/T_{1,2}$				
$I$	$y(t) = \frac{1}{T_I} \int u dt$ $G(s) = \frac{1}{T_I s}$				
$IT_1$	$T_1 \dot{y}(t) + y(t) = \frac{1}{T_I} \int u(t) dt$ $G(s) = \frac{1}{T_I s(1 + T_1 s)}$				

System	Zeitbereich Bildbereich	Übergangsfunktion	Ortskurve	Bode-Diagramm (Amplitudengang) (Phasengang)	s-Ebene x Pol o Nullstelle
$D$	$y(t) = T_D \frac{du}{dt}$ $G(s) = T_D s$			 	
$DT_1$	$T_1 \dot{y}(t) + y(t) = T_D \frac{du}{dt}$ $G(s) = T_D \frac{s}{1 + T_1 s}$			 	
$PI$	$y(t) = K \left[ u(t) + \frac{1}{T_I} \int u(t) dt \right]$ $G(s) = K \left[ 1 + \frac{1}{T_I s} \right]$			 	
$PIT_1$	$T_1 \dot{y}(t) + y(t) = K \left[ u(t) + \frac{1}{T_I} \int u dt \right]$ $G(s) = K \frac{1 + \frac{1}{T_I s}}{1 + T_1 s}$			 	
$PD$	$y(t) = K [u(t) + T_D \dot{u}(t)]$ $G(s) = K [1 + T_D s]$			 	
$PDT_1$	$T_1 \dot{y}(t) + y(t) = K [u(t) + T_D \dot{u}(t)]$ $G(s) = K \frac{1 + T_D s}{1 + T_1 s}$			 	



- Treten beim Transport von Masse, Energie und Information auf.
- Beschreibung durch partielle Differentialgleichungen
- Ausgangssignal ~ verzögerten Eingangssignal



**Frequenzgang:**

$$G(j\omega) = \frac{K}{1 + j\frac{2D}{\omega_0}\omega - \left(\frac{\omega}{\omega_0}\right)^2} = \frac{K\omega_0^2}{\omega_0^2 - \omega^2 + 2jD\omega_0\omega}$$

**Bodediagramm:**

K = 1

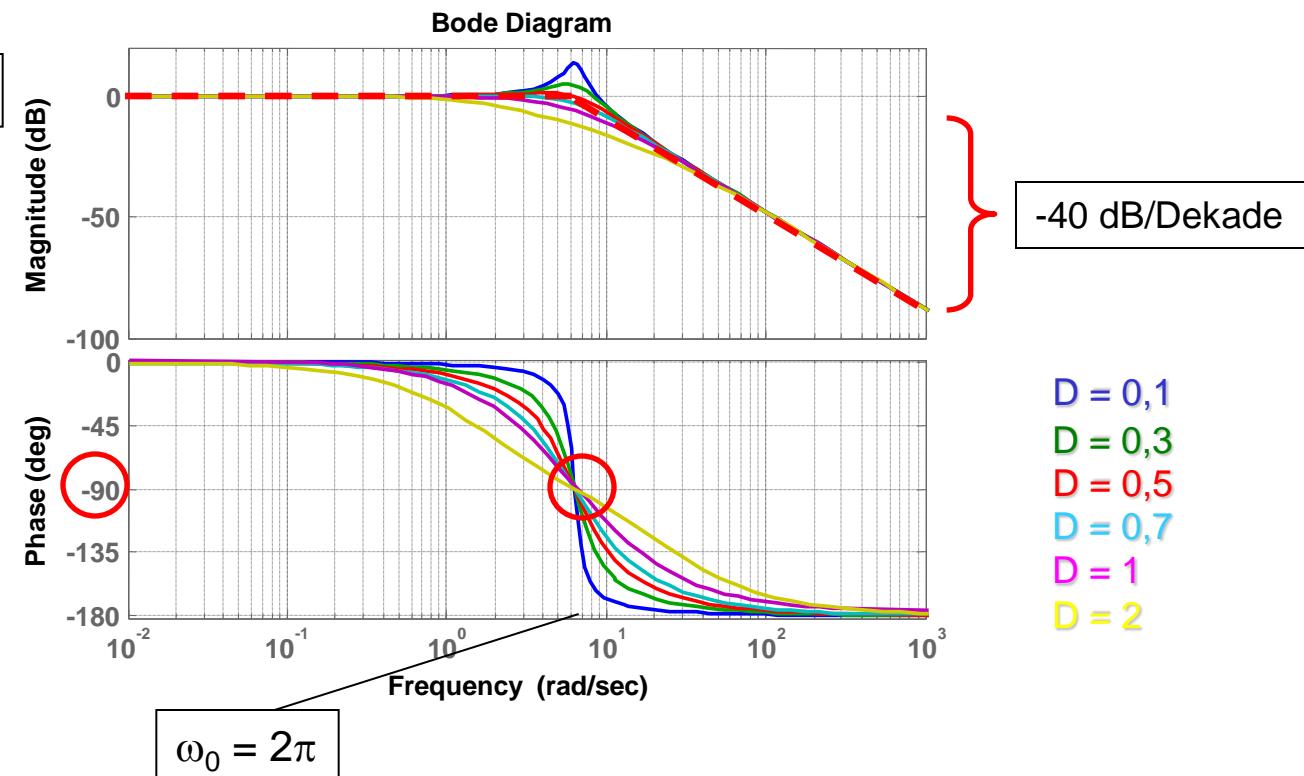
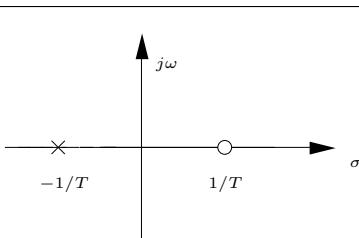
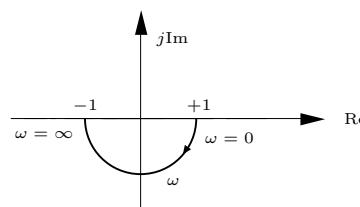
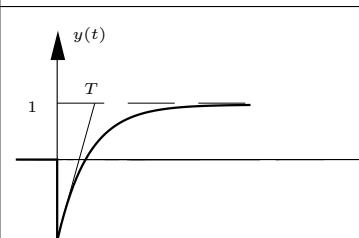
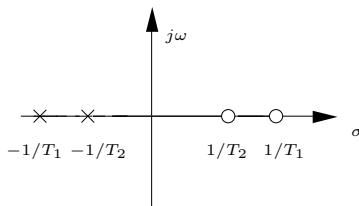
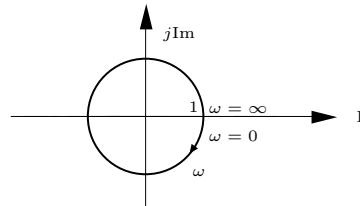
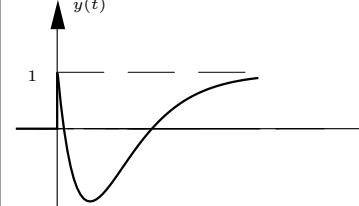
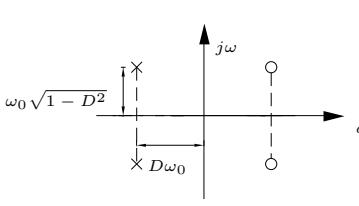
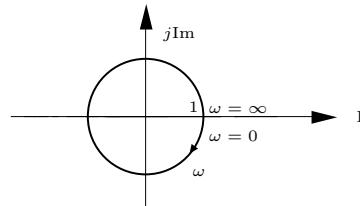
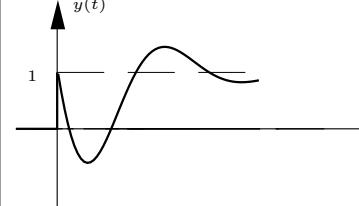
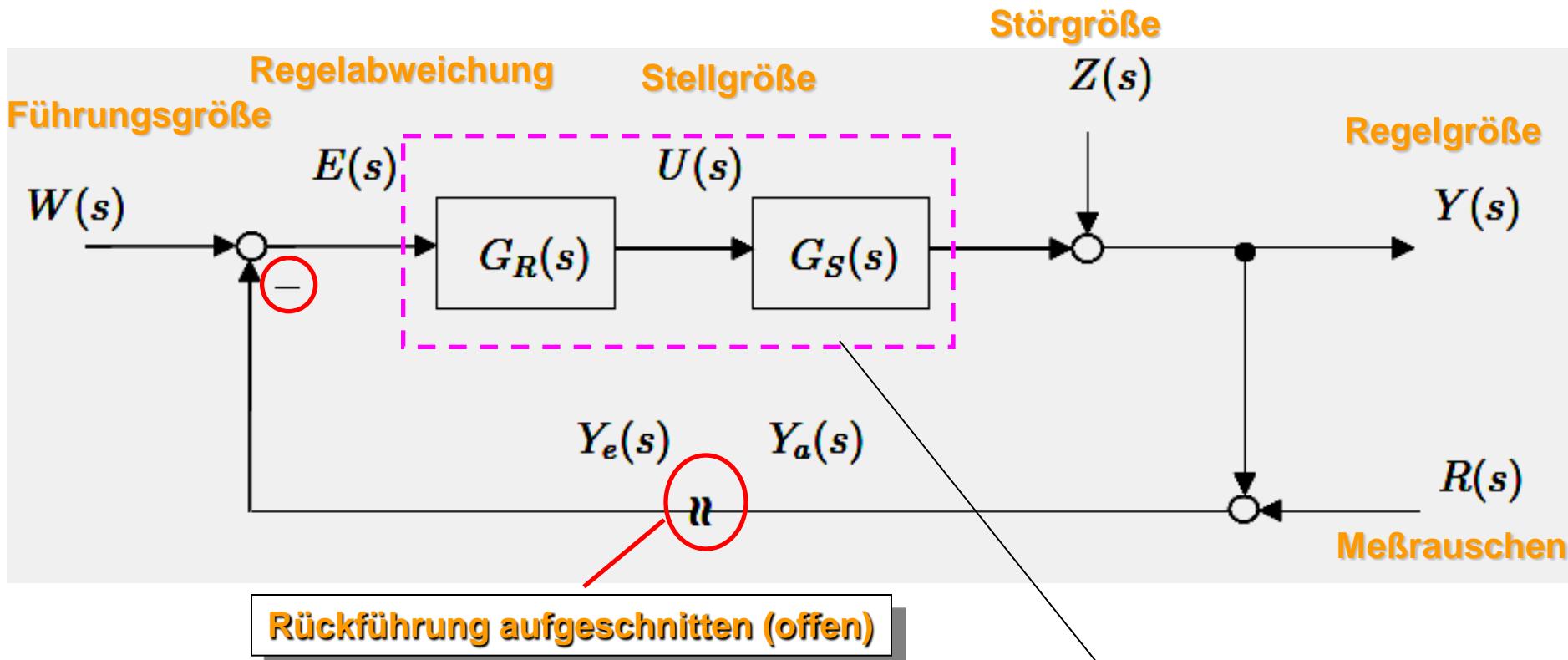


Tabelle 2.2: Allpaßsysteme

System	Übertragungsfunktion	s-Ebene	Ortskurve	Übergangsfunktion
Allpaß 1. Ordnung	$G(s) = \frac{1 - sT}{1 + sT}$			
Allpaß 2. Ordnung mit reellen Wurzeln	$G(s) = \frac{(1 - sT_1)(1 - sT_2)}{(1 + sT_1)(1 + sT_2)}$			
Allpaß 2. Ordnung mit komplexen Wurzeln	$G(s) = \frac{1 - \frac{2D}{\omega_0}s + \frac{s^2}{\omega_0^2}}{1 + \frac{2D}{\omega_0}s + \frac{s^2}{\omega_0^2}}$			



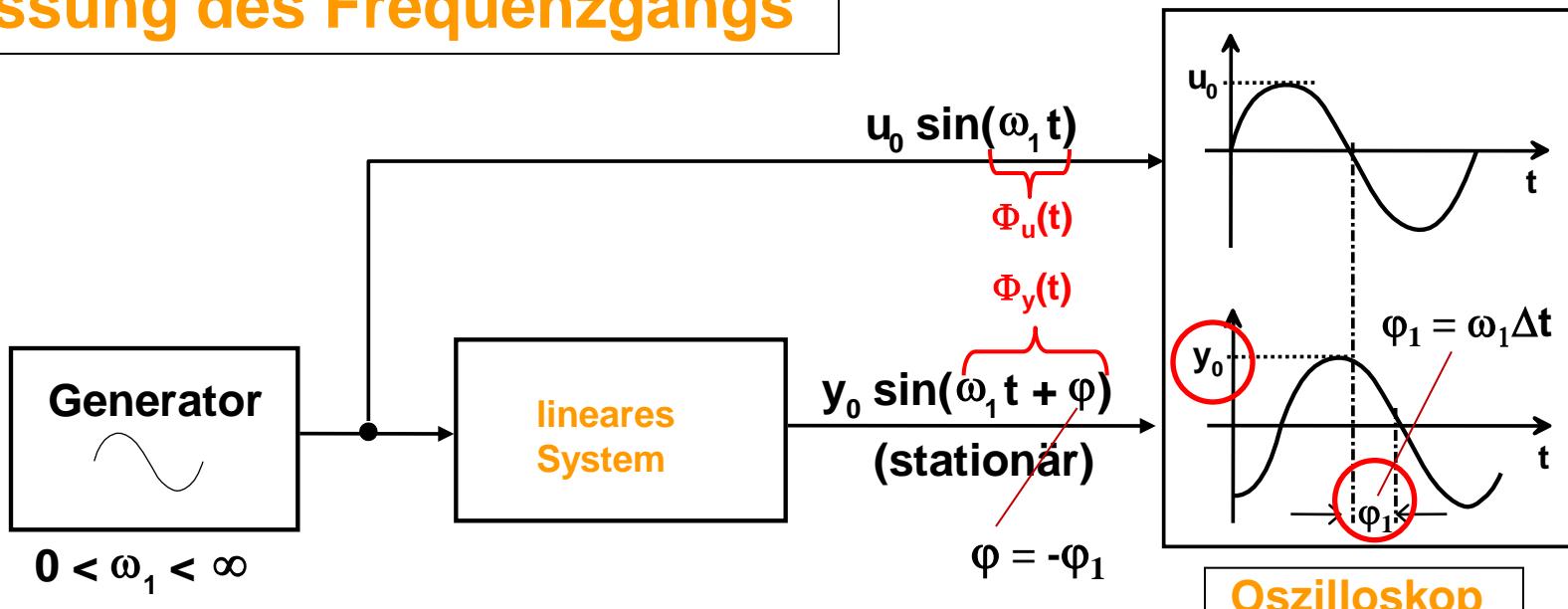
Übertragungsfunktion  $G_0(s)$  des **offenen** Regelkreises für  $Z(s)=W(s)=R(s)=0$ :

$$G_0(s) := G_R(s)G_S(s)$$

$$\Rightarrow Y_a(s) = -G_R(s)G_S(s)Y_e(s) = \textcircled{-}G_0(s)Y_e(s)$$



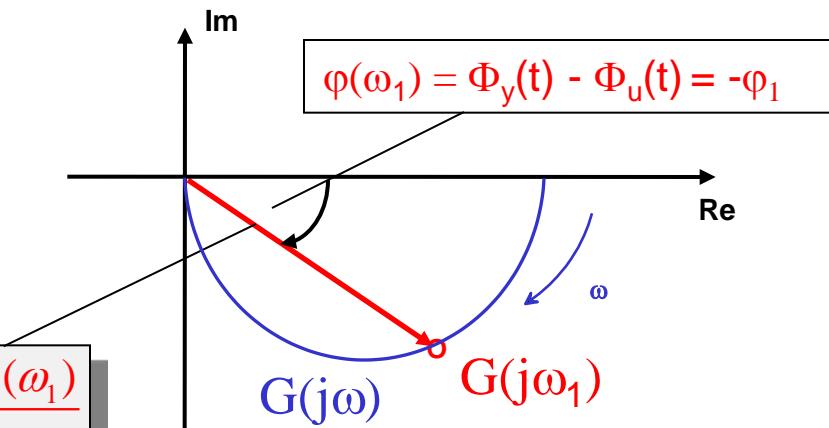
## Messung des Frequenzgangs



## Frequenzgang

$$G(j\omega_1) = \frac{y_0(\omega_1)}{u_0} e^{j\varphi(\omega_1)}$$

$$|G(\omega_1)| = \frac{y_0(\omega_1)}{u_0}$$

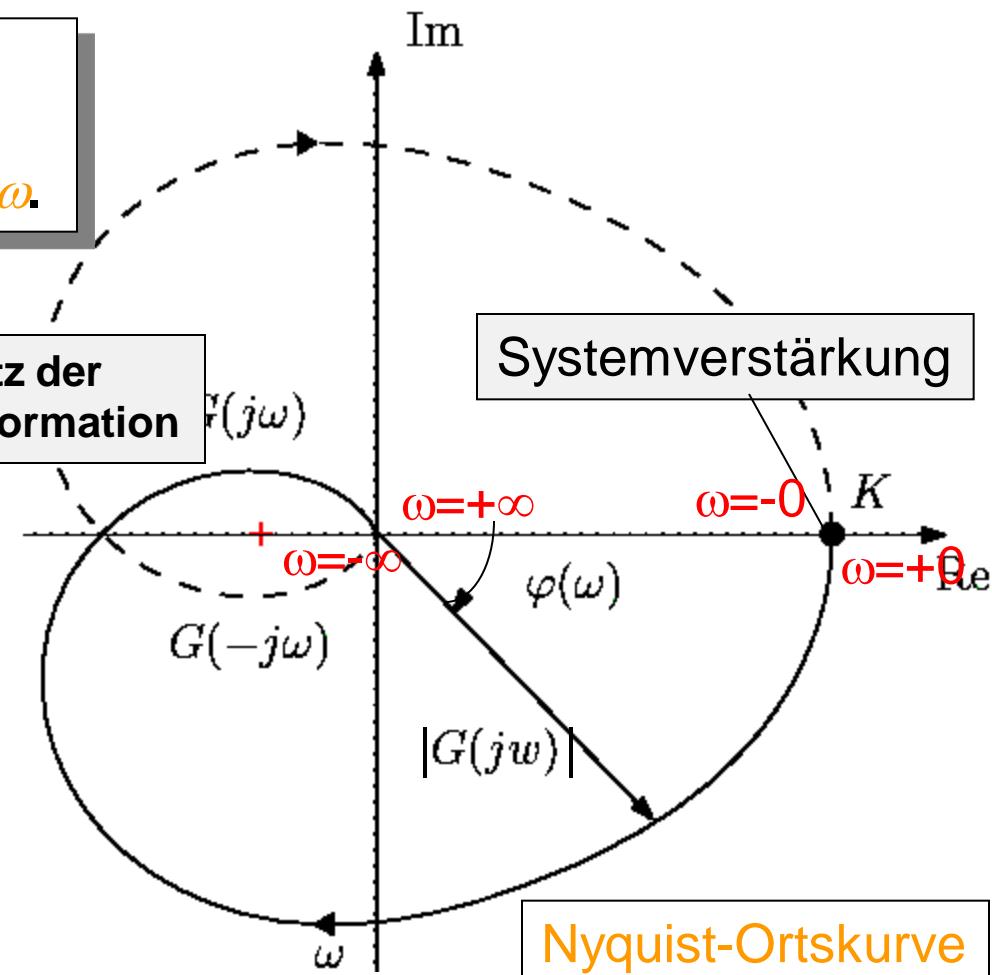


# Frequenzgang: Ortskurvendarstellung

Darstellung des Frequenzgangs  $G(j\omega)$  in der komplexen Ebene in Abhängigkeit von der Frequenz  $\omega$ .

$$\begin{aligned} K &= \lim_{t \rightarrow \infty} h(t) \\ &= \lim_{s \rightarrow 0} s \cdot H(s) \\ &= \lim_{s \rightarrow 0} s \cdot G(s) \cdot \frac{1}{s} \\ &= \lim_{j\omega \rightarrow 0} G(j\omega) \end{aligned}$$

Endwertsatz der Laplace-Transformation



Die vollständige Ortskurve von  $\omega \in [-\infty, \infty]$  ist stets symmetrisch zur reellen Achse

