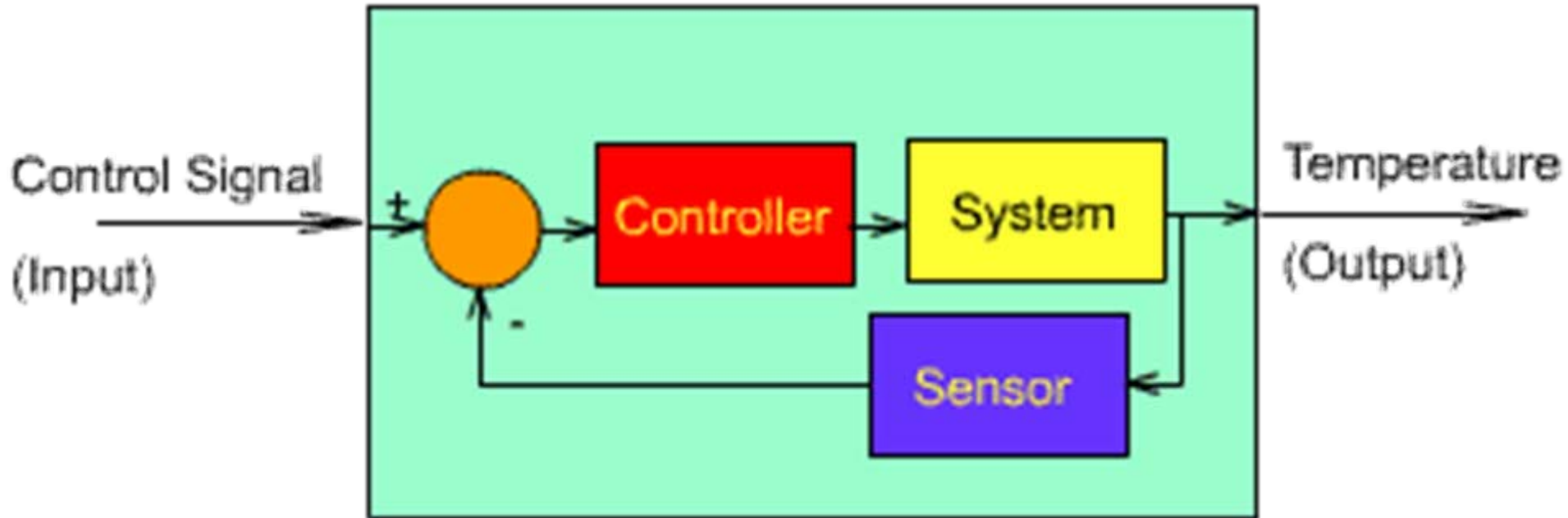


Exploring Classical Control



Vorgehen bei der Systemanalyse

1. Modellierung eines Systems
2. Untersuchung der Linearität, evtl. Linearisierung
3. Überführung in ein Ein-Ausgabe System (State Space)
4. Experimentelle Ermittlung des Sin-Erregungsverhaltens
5. Konstruktion der Ortskurve des Frequenzganges (Nyquist)
6. Ermittlung der Pole der Übertragungsfunktion
7. Aussagen über die Stabilität des Systems

Das Vorgehen kann **analytisch** über die Differentialgleichung bzw. die Kenntnis der einzelnen Übertragungsglieder oder **experimentell** durch Messungen am System erfolgen.

$$\begin{array}{cc|c} -1 & -1 & 1 \\ 1 & 0 & 0 \\ \hline 0 & 1 & 0 \end{array}$$

system K = 1
 root-locus K' = 1
 u = Sine\output
 y = C1\state
 x [1] = I1\state
 x [2] = C1\state
 \dot{x} [1] = I1\p.e
 \dot{x} [2] = C1\p.f

$\dot{x} = A x + B u$
 $y = C x + D u$

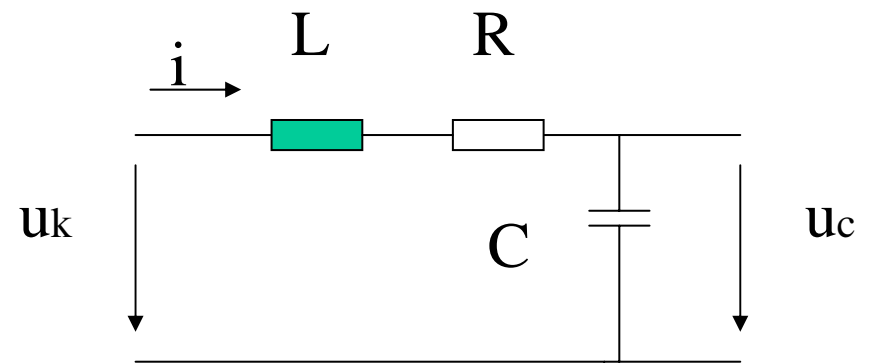
Symbolic linear description :

$A =$
 $\begin{pmatrix} -R1/L & -1/L \\ 1.0 & 0.0 \end{pmatrix}$
 $\begin{pmatrix} 1.0 & 0.0 \end{pmatrix}$

$B = 1.0$
 0.0

$C = 0.0 \ 1.0$

$D = 0.0$

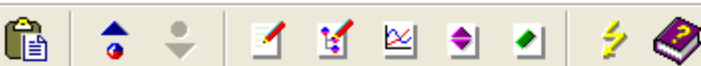


$$L \frac{di}{dt} + Ri + u_c = u_k$$

$$C \frac{du_c}{dt} = i$$

$$\Rightarrow LC u_c'' + RC u_c' + u_c = u_k$$

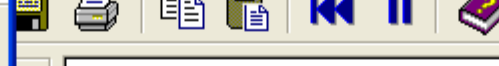
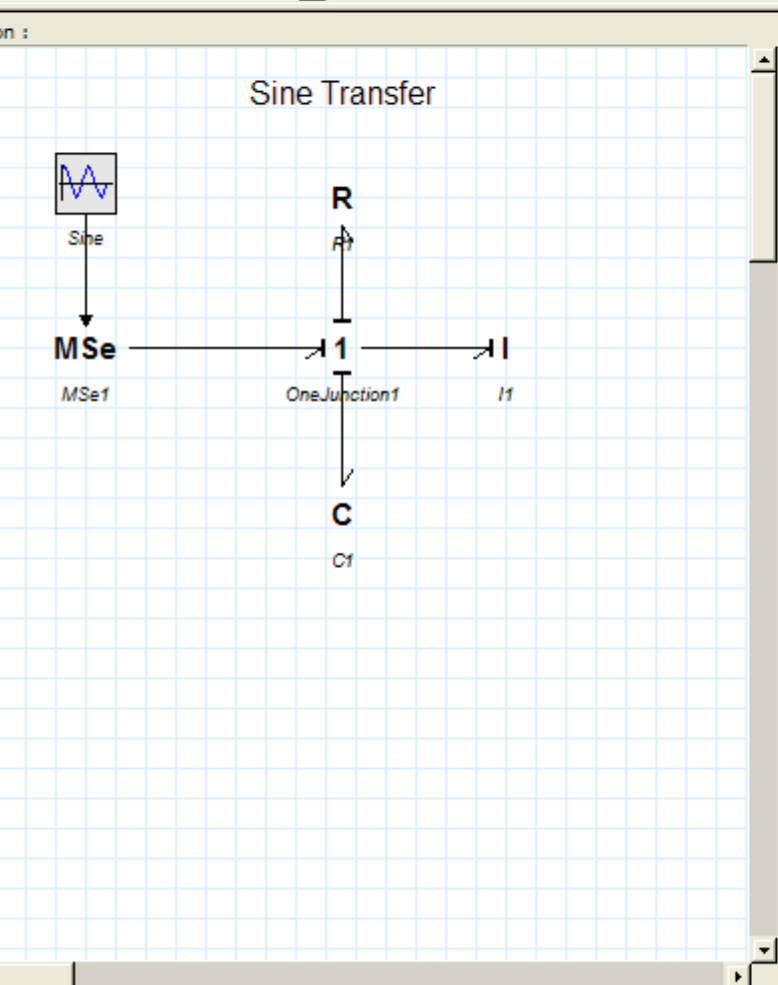
$$\begin{bmatrix} i' \\ u_c' \end{bmatrix} = \begin{bmatrix} -R/L & -1/L \\ 1/C & 0 \end{bmatrix} \begin{bmatrix} i \\ u_c \end{bmatrix} + \begin{bmatrix} 1/L \\ 0 \end{bmatrix}$$



Icon :

del

name



1

$$s^2 + 1 \quad s + 1$$

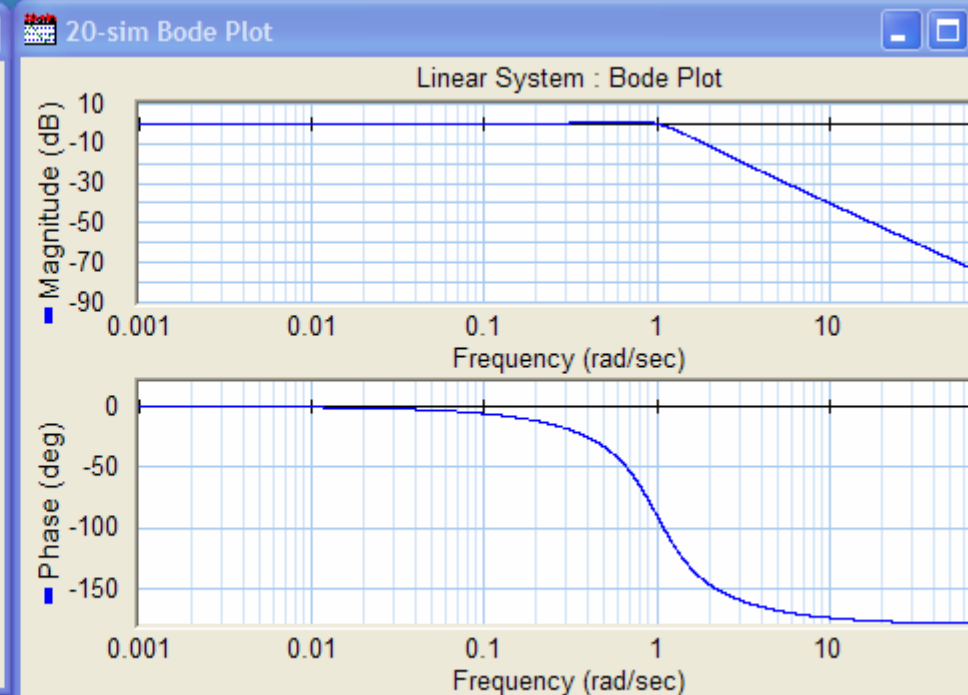
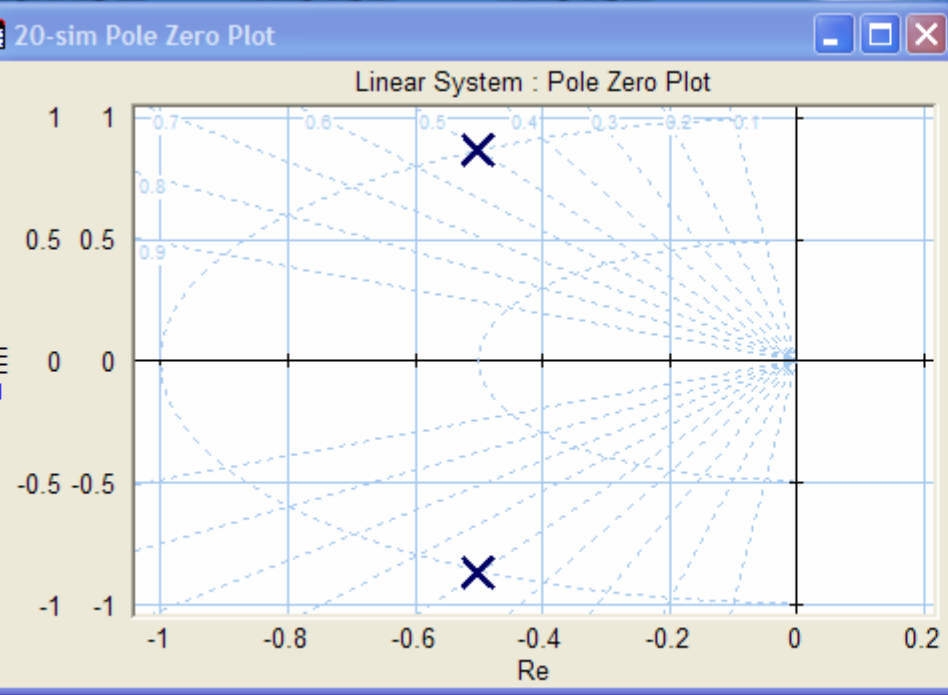
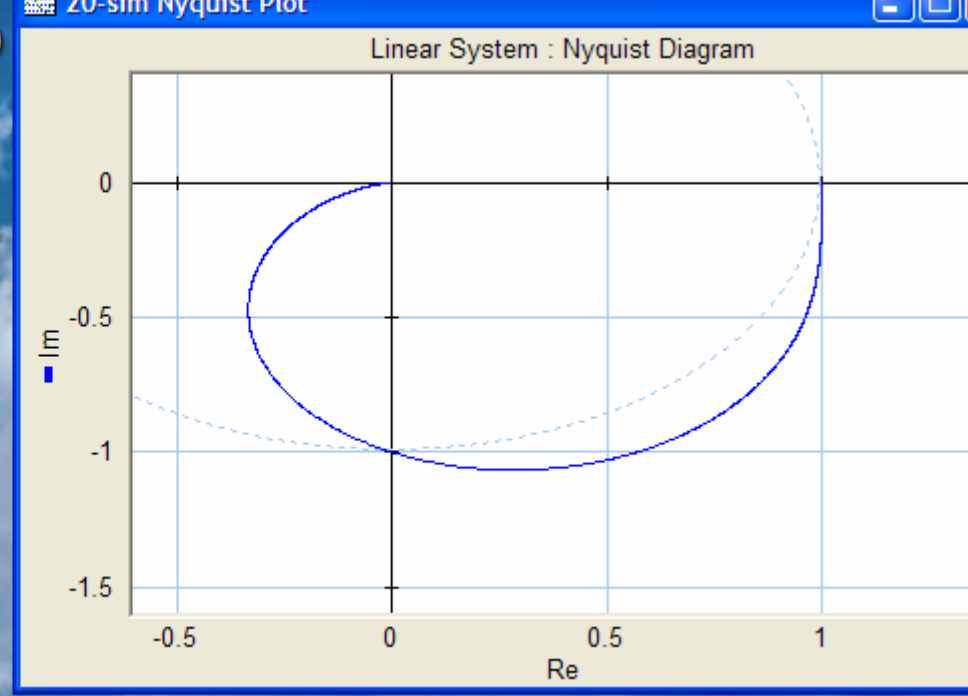
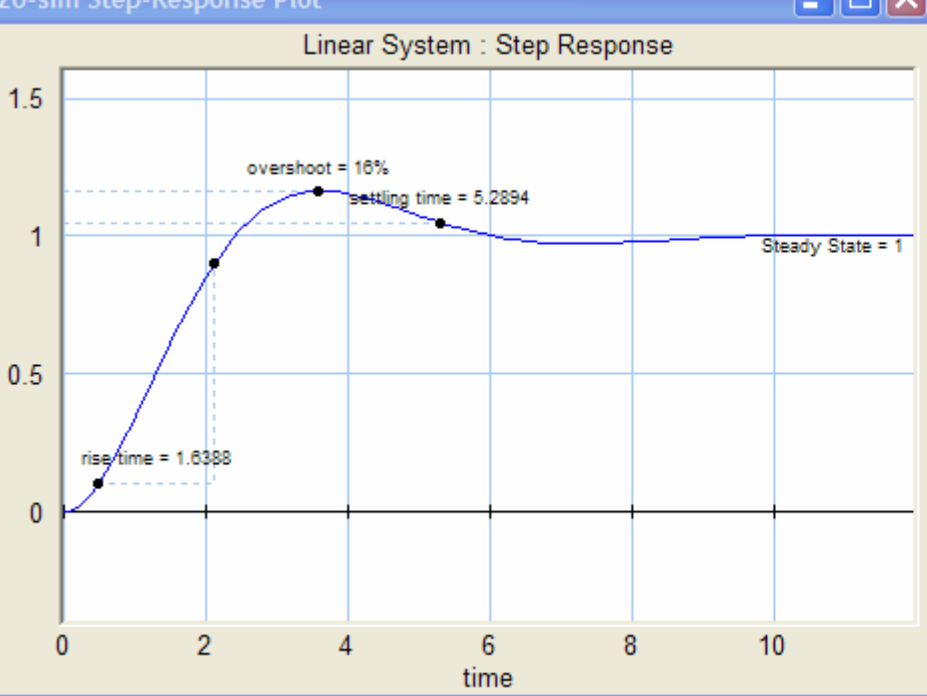
system K = 1

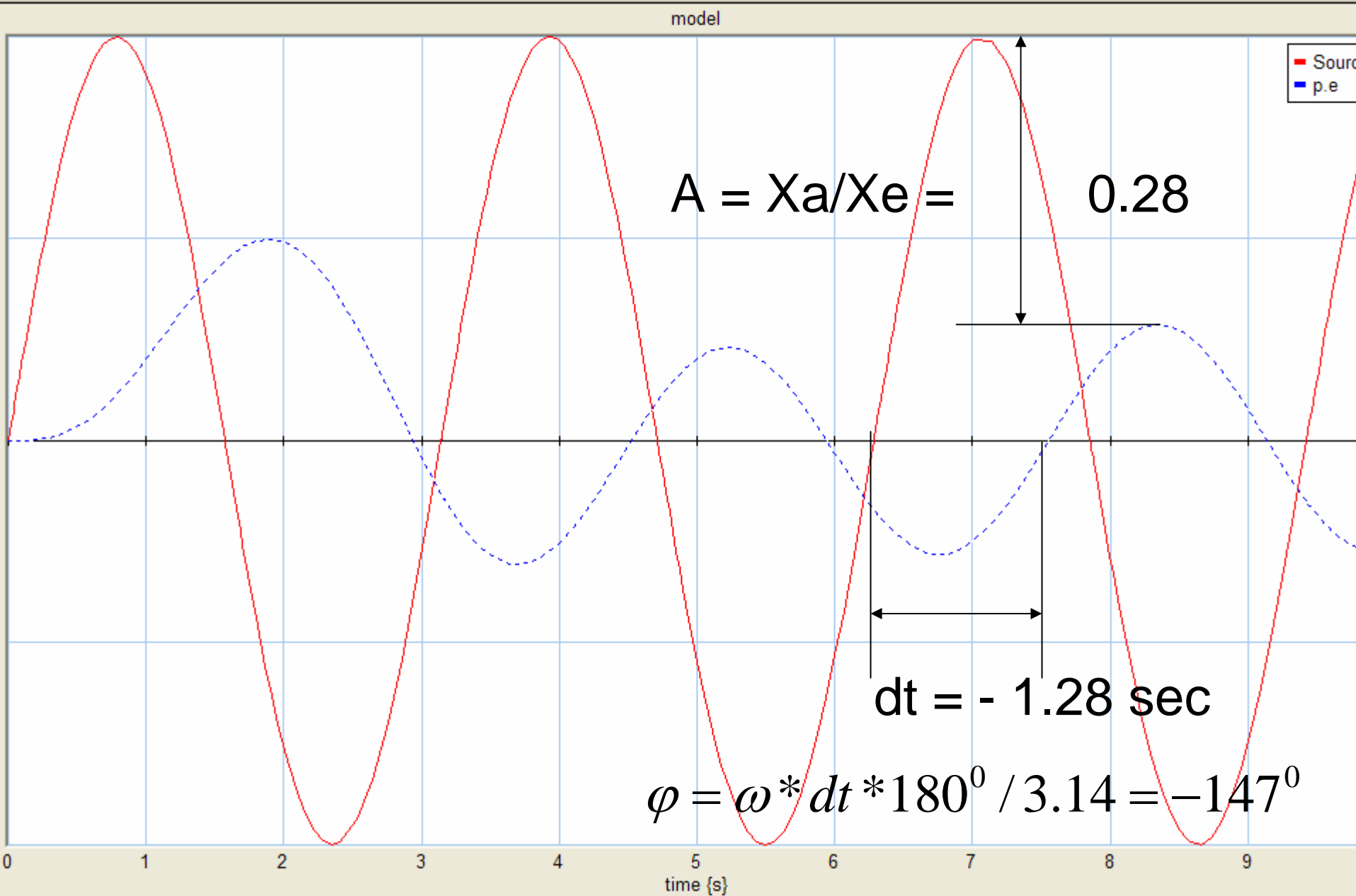
root-locus K' = 1

u = Sine\output

y = C1\state

Y = $\frac{\text{numerator}}{\text{denominator}}$ X





Ortskurve des Frequenzganges

$$X_a \sin((\omega - \varphi) * t) = G * X_e \sin(\omega * t)$$

$$\text{Amplitudengang } A(\omega) = X_a / X_e$$

$$\text{Phasengang } \varphi(\omega)$$

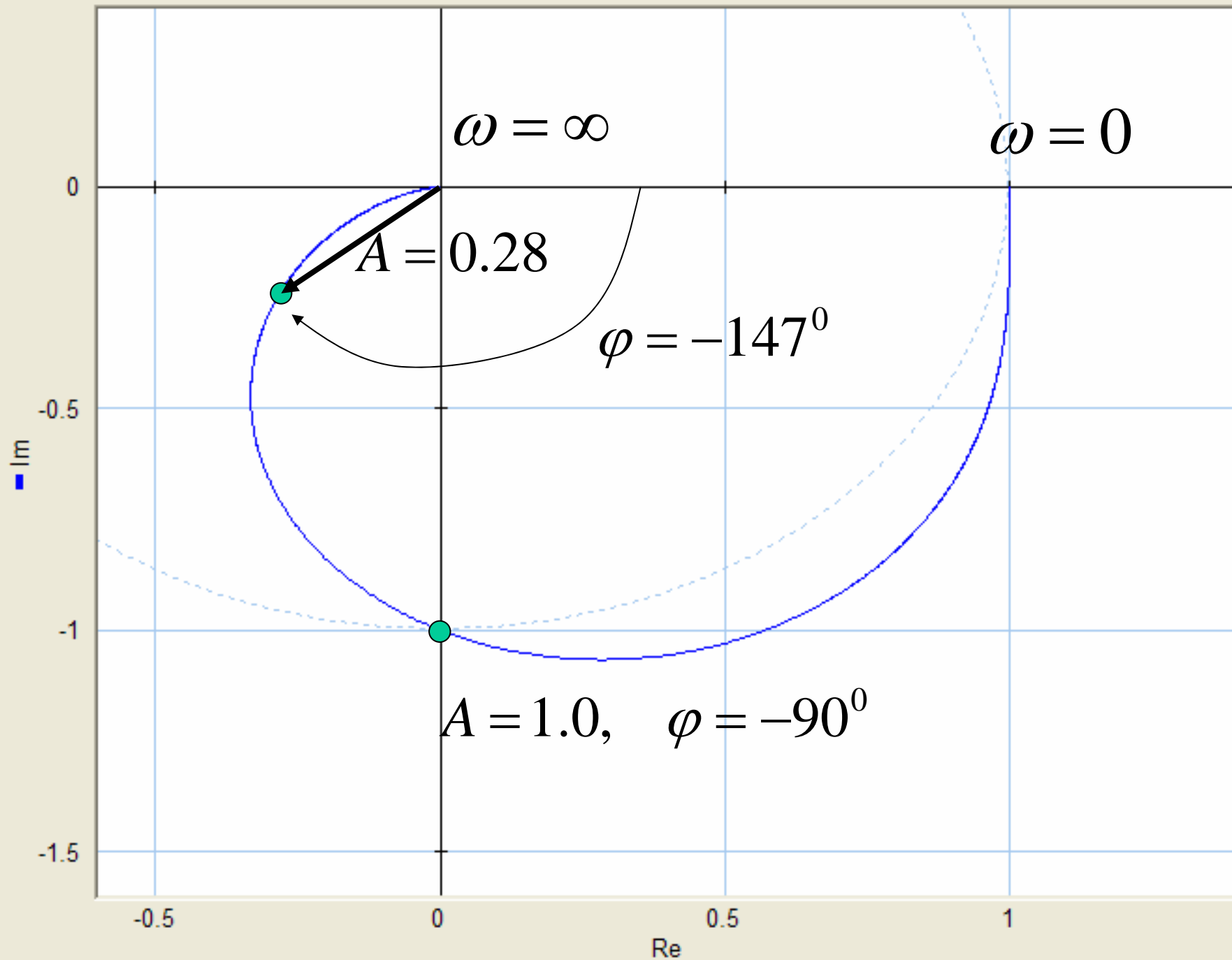
$$\text{LogAmplitudengang } A_{db} = 20 * \log(A)$$

Beispiel

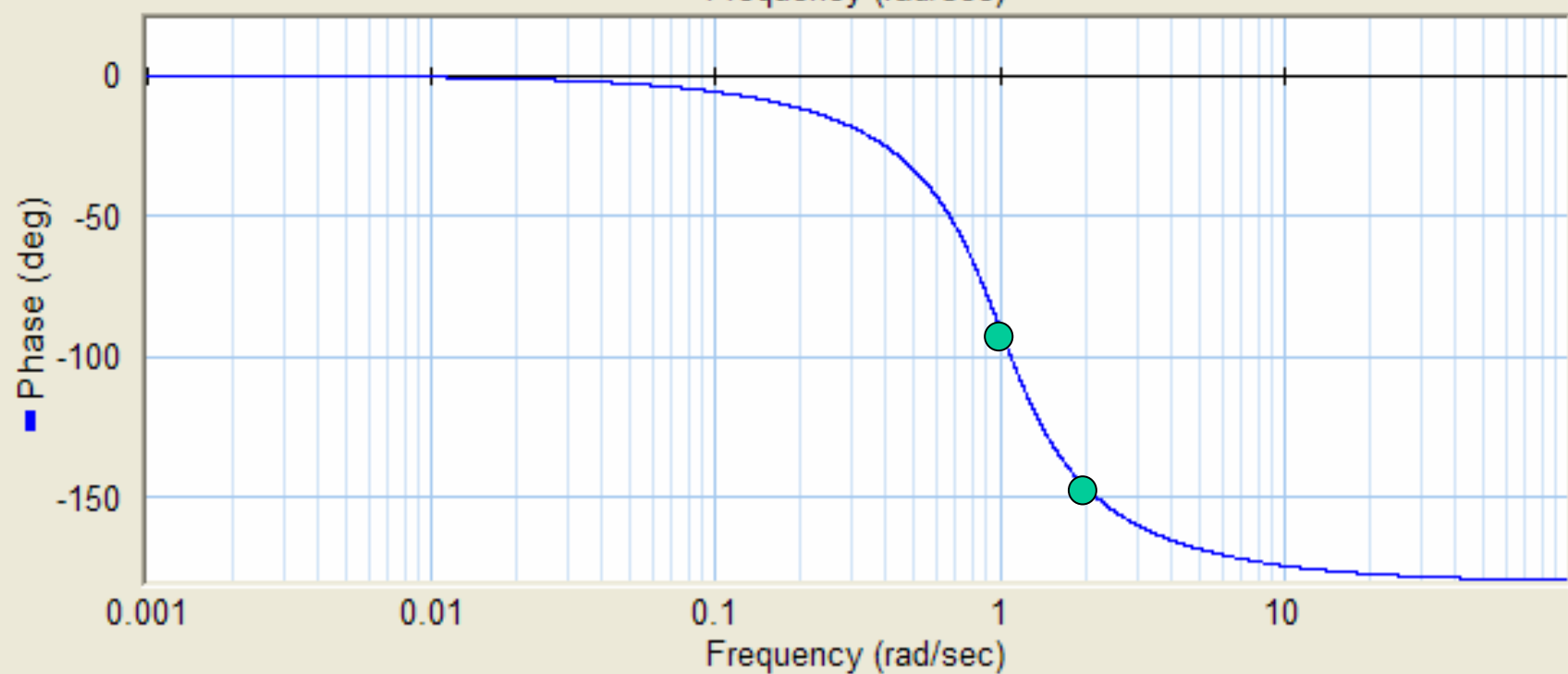
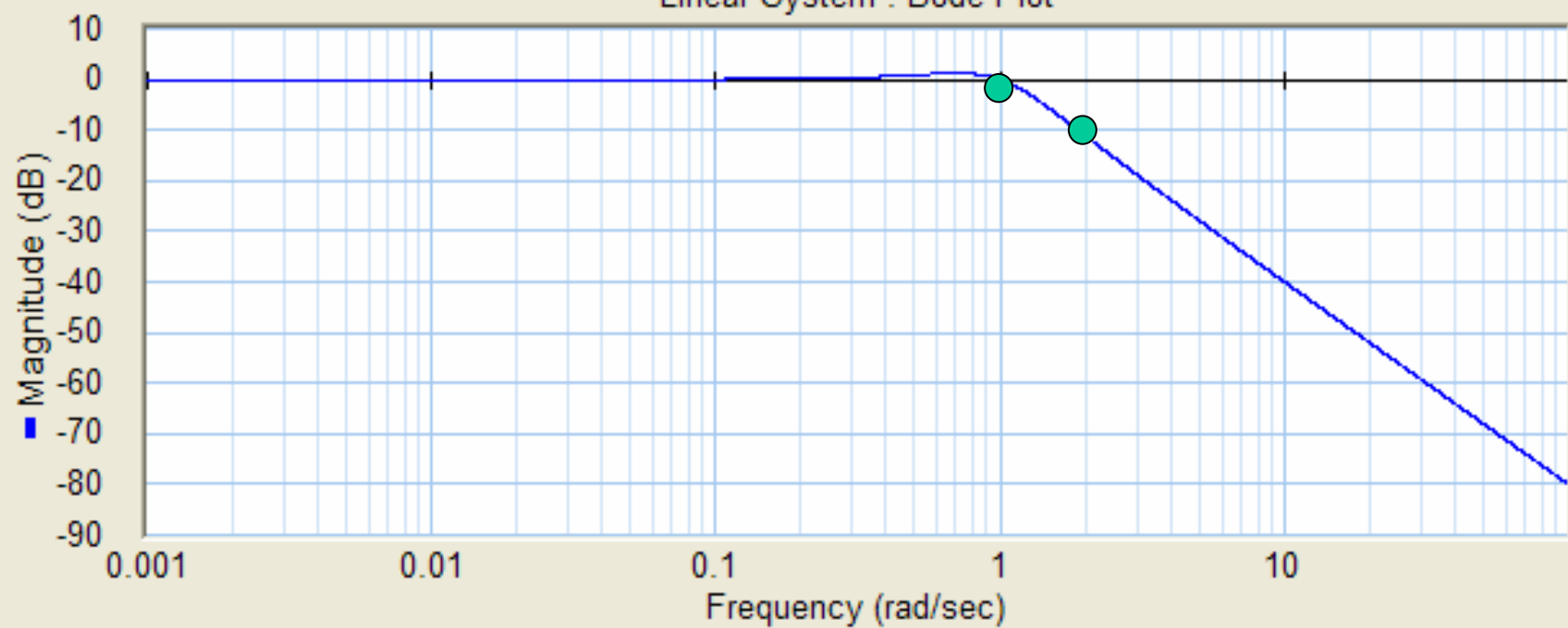
$$A = 0.28 \Rightarrow \log(0.28) = -0.553$$

$$A_{db} = 20 \log(A) = -11.06$$

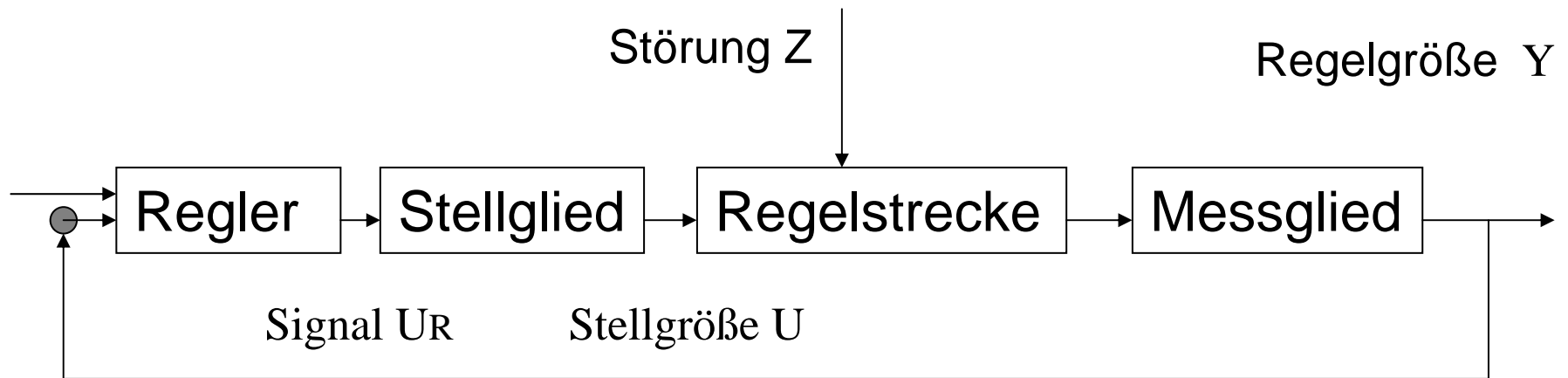
Linear System : Nyquist Diagram



Linear System : Bode Plot



Verhalten linearer Regelkreise



$$Y(s) = \frac{G_{SZ}}{(1 + G_R * G_{SU})} * Z(s) + \frac{G_R * G_{SU}}{(1 + G_R * G_{SU})} * W(s)$$

G_{SZ} = Übertragungsfunktion für Störverhalten

G_{SU} = Übertragungsfunktion für Stellverhalten

G_R = Übertragungsfunktion für Reglerverhalten

Verhalten des offenen Regelkreises

$$R(s) = \frac{1}{(1 + G_R * G_{SU})} = \textit{dynamischer Regelfaktor}$$

$$G_R * G_{SU} = G_0$$

Übertragungsfunktion des offenen Regelkreises



$$G_{\text{offen}}(s) = \frac{X_a(s)}{X_e(s)} = - G_R * G_{SU} = - G_0$$

Verstärkung des offenen Regelkreises

Das Verhalten des offenen Regelkreises lässt sich oft beschreiben durch

$$G_0(s) = \frac{K_0}{s^k} * \frac{1 + \beta_1 s + \dots \beta_m s^m}{1 + \alpha_1 s + \dots \alpha_{n-k} s^{n-k}} e^{-Ts}$$

$K_0 = K_R * K_S = \text{Verstärkung des offenen Regelkreises}$

$k = 0$ Proportionales Verhalten, P-Verhalten

$k = 1$ Integrales Verhalten, I-Verhalten

$k = 2$ doppelt-integrales, I2-Verhalten

Stabilität linearer Regelkreise

Aus der Nyquist-Kurve des offenen Regelkreises läßt sich die Stabilität des geschlossenen Regelkreises erkennen.

Dazu aber mehr Hintergrundwissen :

Classical Control Systems

E. J. Mastascusa, Bucknell University, Lewisburg, PA, USA

<http://www.facstaff.bucknell.edu/mastascu/>

Exploring
Classical
Control
Systems
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E. J. Mastascusa

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Games & Interesting Simulations/Problems

Games - A few control systems games. Play them with your friends. High score wins.

- ♦ **Manual Control**
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