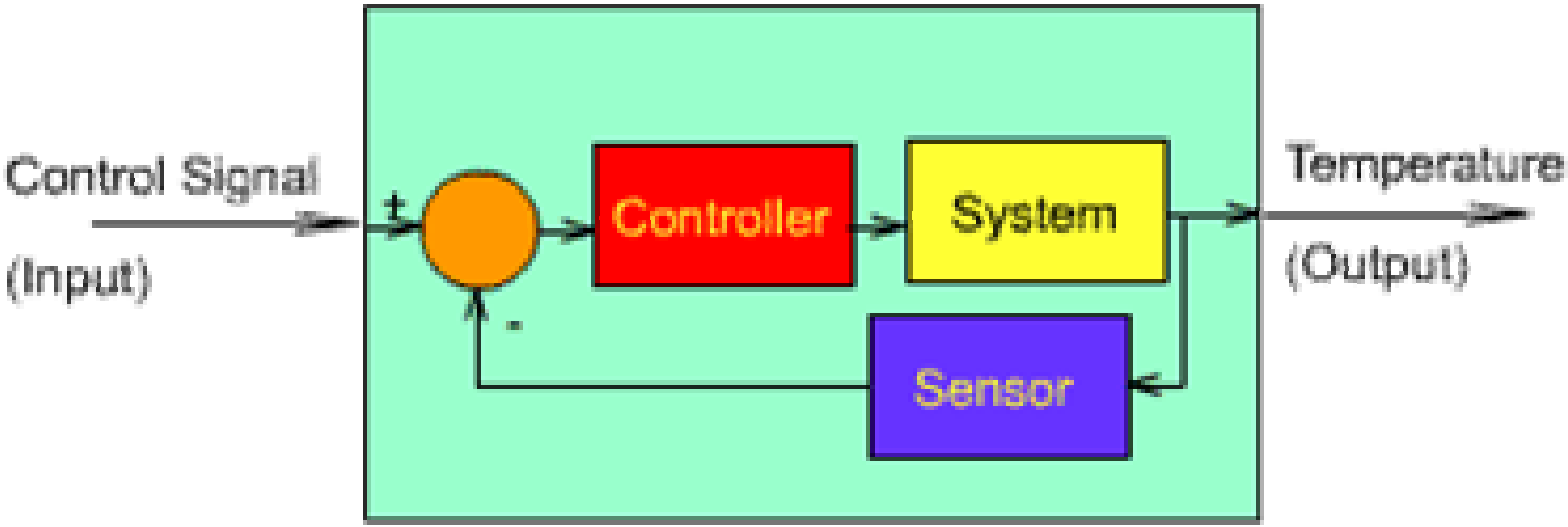
Exploring Classical Control



Nach E. J. Mastascusa, 2006

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.

-1	-1	1
1	0	0
0	1	0

system K = 1
root-locus K' = 1
u = Sine\output
y = C1\state
x [1] = l1\state
x [2] = C1\state
$\dot{x}$ [1] = l1\p.e
$\dot{x}$ [2] = C1\p.f

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

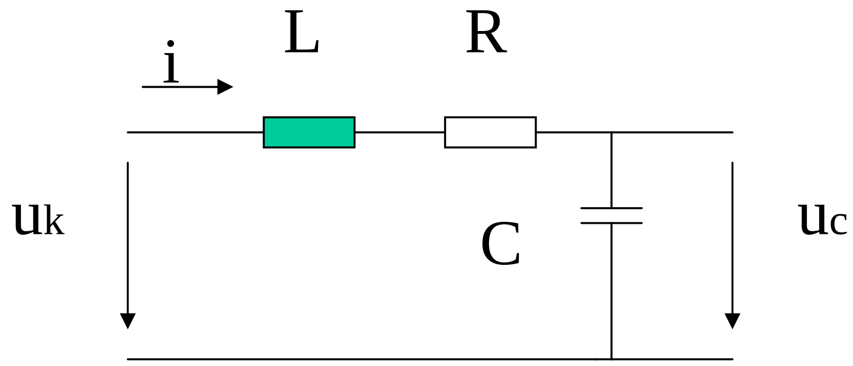
Symbolic linear description :

A =
-(R1\r / l1\i) -(1.0 / C1\c)
1.0 / l1\i 0.0

B = 1.0
0.0

C = 0.0 1.0

D = 0.0

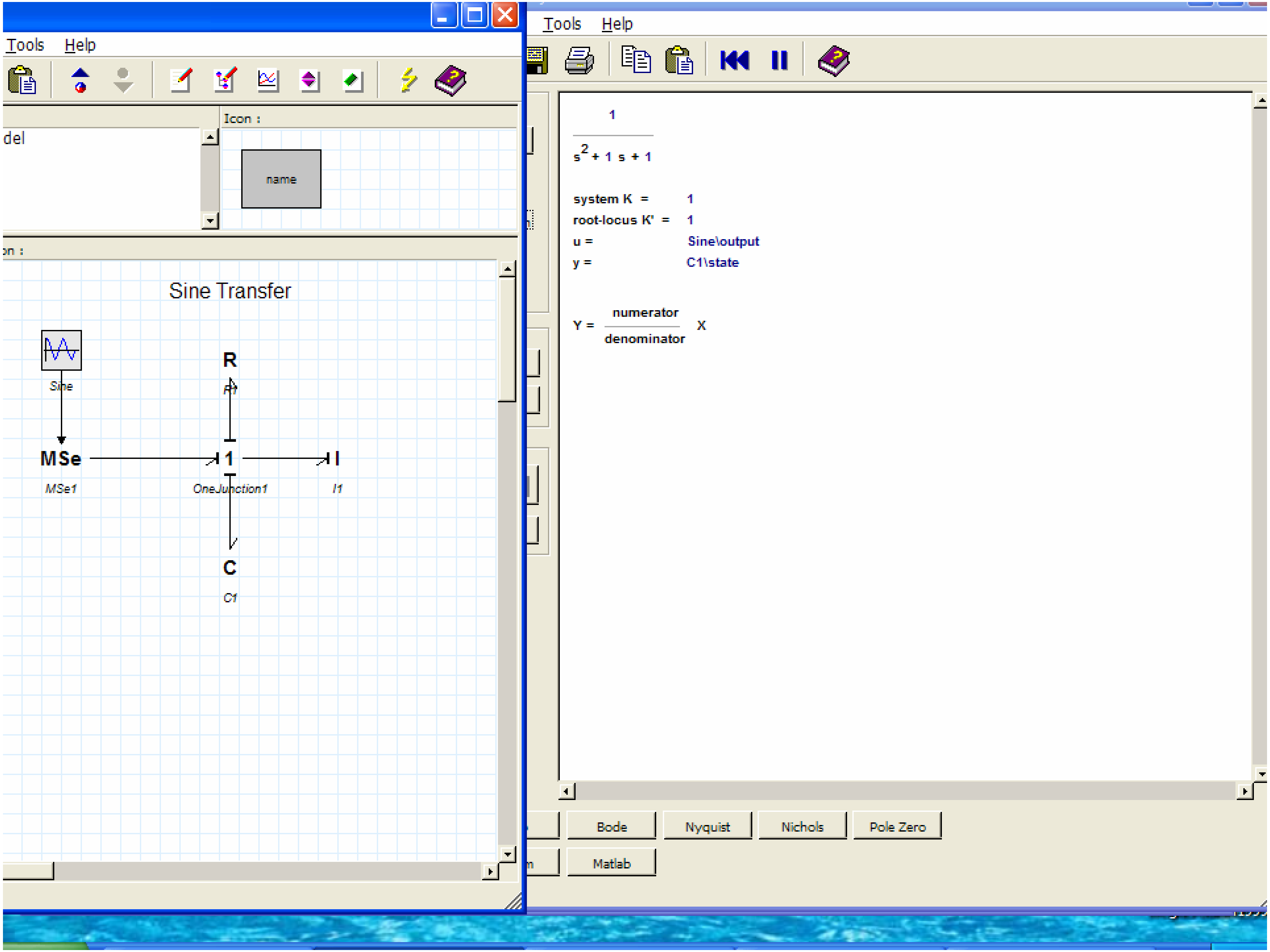


L di/dt + Ri + uc = uk

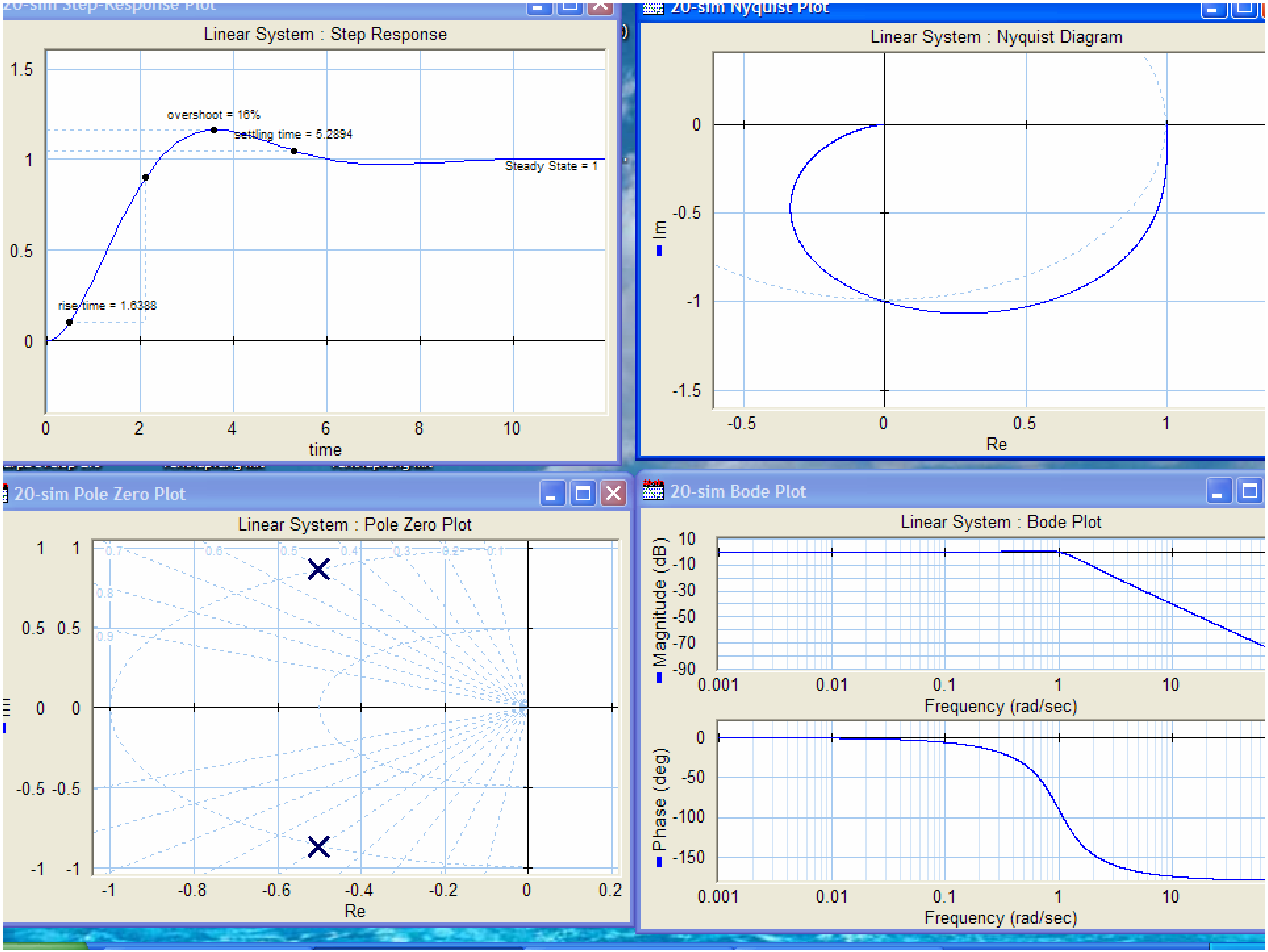
C duc/dt = i

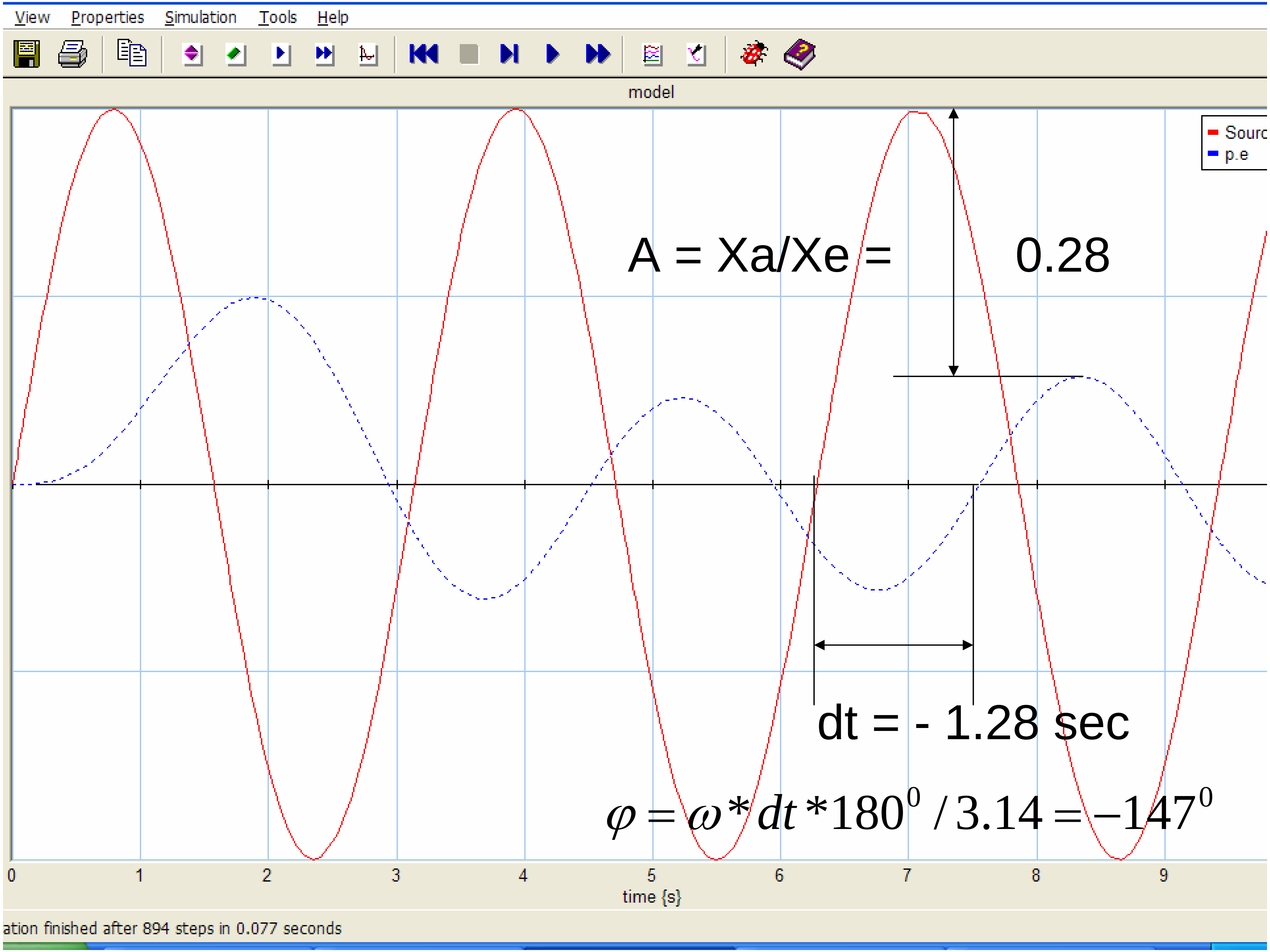
⇒LC uc“ + RC uc‘ + uc = uk

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



Tools
Help
del
Icon :
name
Sine Transfer
Sine
R
R1
MSe
1
I
MSe1
OneJunction1
I1
C
C1
1
s^2 + 1 s + 1
system K =
1
root-locus K' =
1
u =
Sine\output
y =
C1\state
Y =
numerator
denominator
X
Bode
Nyquist
Nichols
Pole Zero
Matlab


20-sim Step-Response Plot
Linear System : Step Response
overshoot = 16%
settling time = 5.2894
Steady State = 1
rise time = 1.6388
1.5
1
0.5
0
0
2
4
6
8
10
time
20-sim Nyquist Plot
Linear System : Nyquist Diagram
0
-0.5
-1
-1.5
Im
-0.5
0
0.5
1
Re
20-sim Pole Zero Plot
Linear System : Pole Zero Plot
1 1
0.5 0.5
0 0
-0.5 -0.5
-1 -1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
Re
20-sim Bode Plot
Linear System : Bode Plot
Magnitude (dB)
10
-10
-30
-50
-70
-90
0.001
0.01
0.1
1
10
Frequency (rad/sec)
Phase (deg)
0
-50
-100
-150
0.001
0.01
0.1
1
10
Frequency (rad/sec)


View Properties Simulation Tools Help
model
Sourc
p.e
A = Xa/Xe = 0.28
dt = - 1.28 sec
$\varphi = \omega * dt * 180^0 / 3.14 = -147^0$
0
1
2
3
4
5
6
7
8
9
time {s}
ation finished after 894 steps in 0.077 seconds

Ortskurve des Frequenzganges

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

$$Amplitudengang \; A(\omega) = X_a / X_e$$

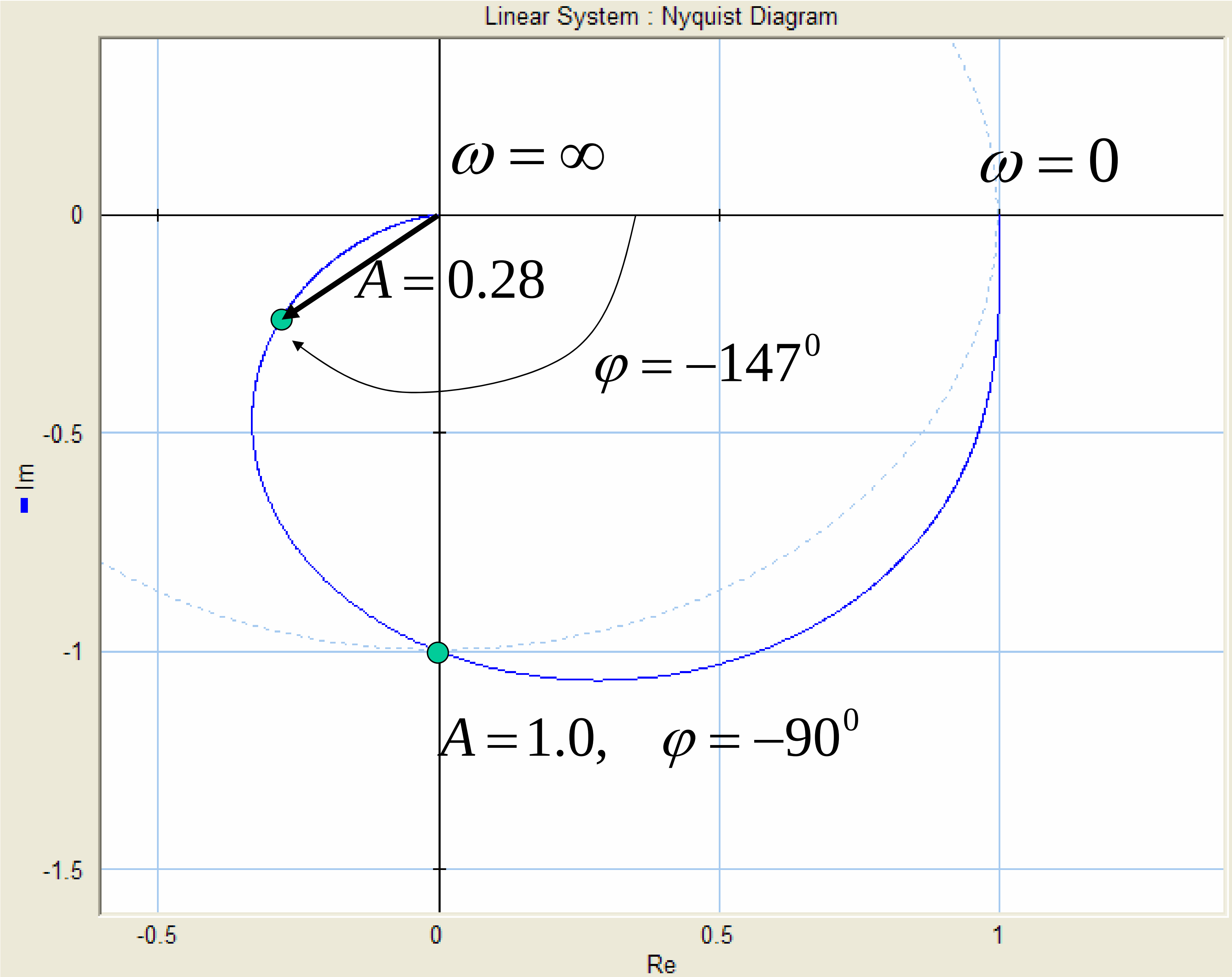
$$Phasengang \quad \varphi(\omega)$$

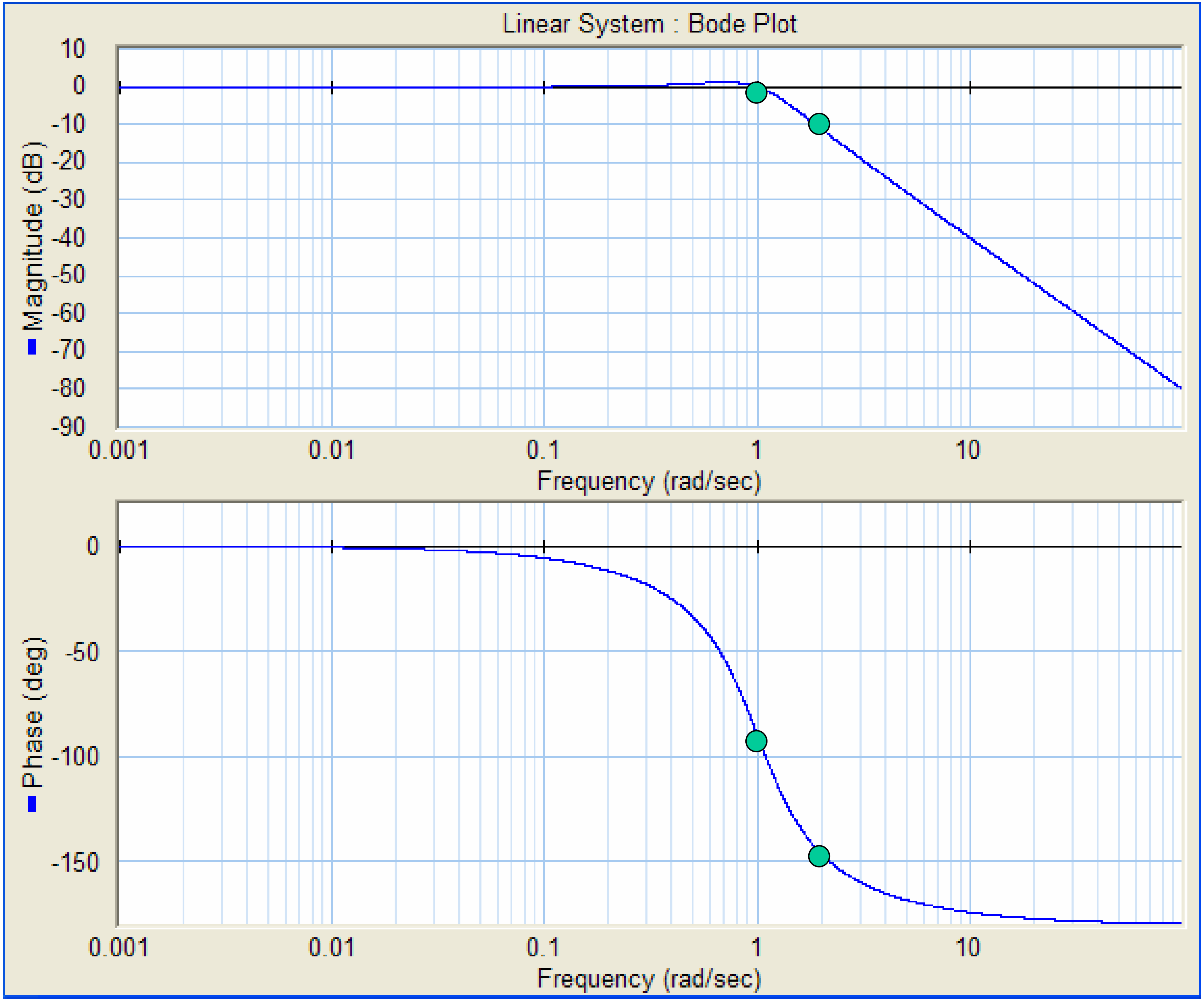
$$LogAmplitudengang \; A_{db} = 20 * \log(A)$$

$$Beispiel$$

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

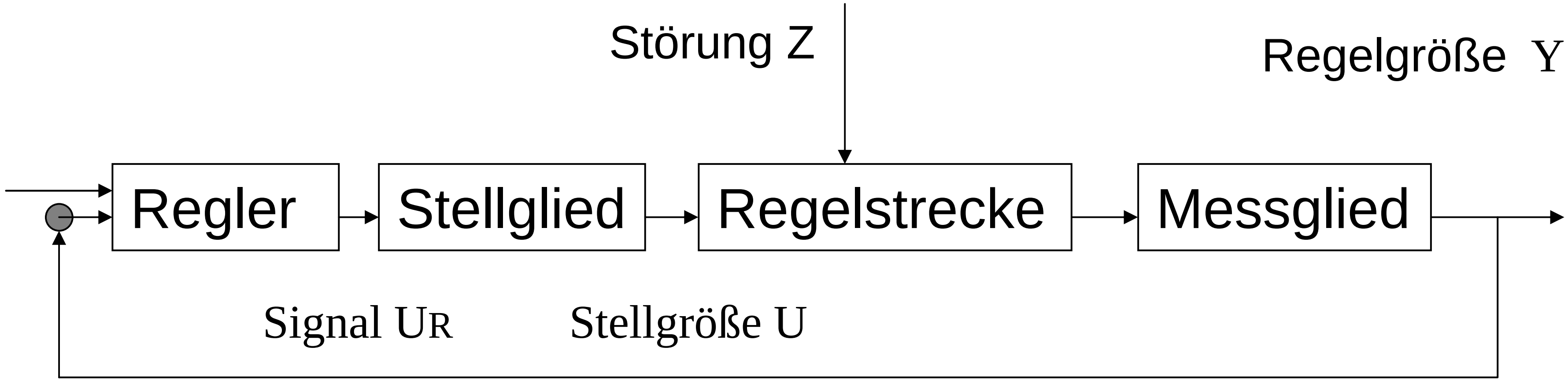
$$A_{db} = 20 \log(A) = -11.06$$


Linear System : Nyquist Diagram
$\omega = \infty$
$\omega = 0$
0
-0.5
-1
-1.5
Im
$A = 0.28$
$\varphi = -147^0$
$A = 1.0, \quad \varphi = -90^0$
-0.5
0
0.5
1
Re



Linear System : Bode Plot
Magnitude (dB)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0.001
0.01
0.1
1
10
Frequency (rad/sec)
Phase (deg)
0
-50
-100
-150
0.001
0.01
0.1
1
10
Frequency (rad/sec)

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

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

Verstärkung des offenen Regelkreises

Das Verhalten des offenen Regelkreises
lässt sich oft beschreiben durch

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

$K_0 = K_R * K_S =$ *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

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Games & Interesting Simulations/Problems

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

- Manual Control
  - First Order System
  - Second Order System
  - A Better Second Order System

Interesting Simulations/Problems

- Aircraft
  - A second order model
  - A third order model
- Submarines
  - Problem 1