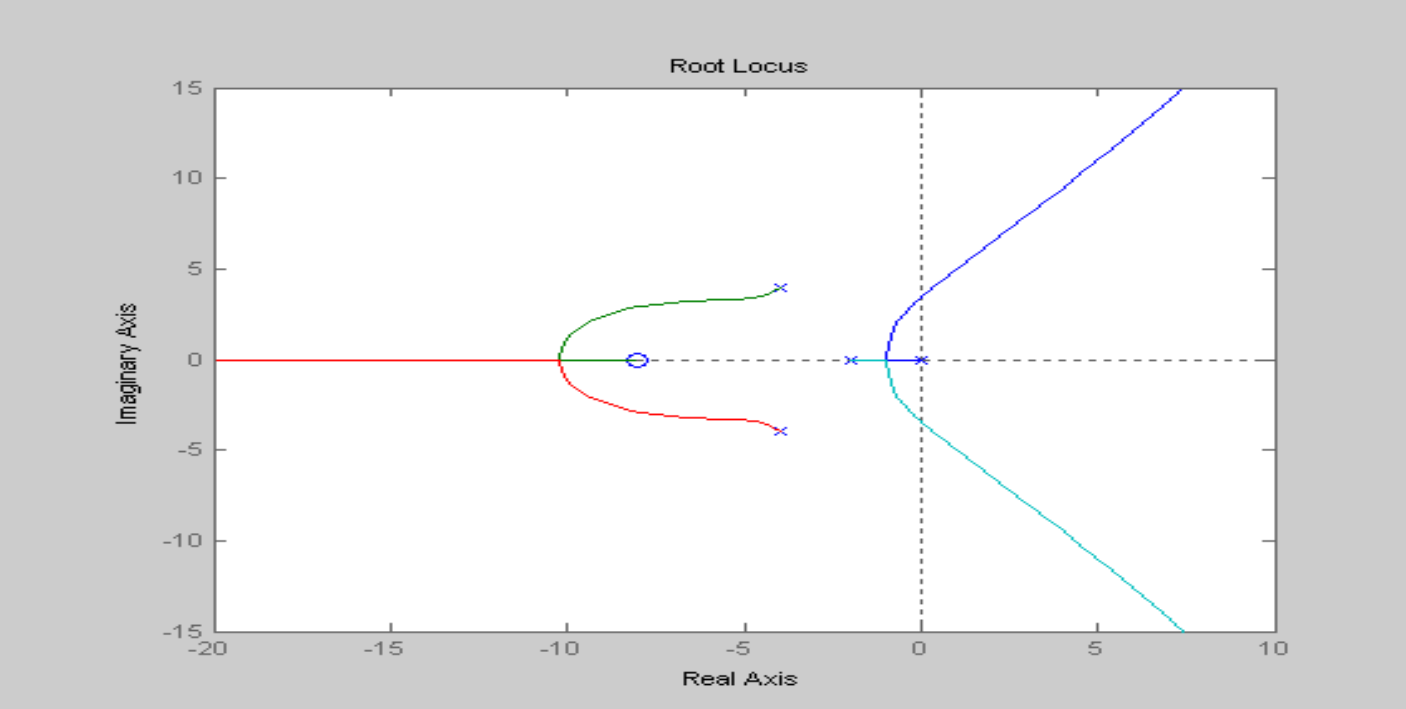
Frequency Domain Analysis and Design

Root Locus

```
>> rlocus(tf([1 8], conv(conv([1 0],[1 2]),[1 8 32])))
```



Frequency Response: Bode and Nyquist Plots

- Typically, the analysis and design of a control system requires an examination of its frequency response over a range of frequencies of interest.

- The MATLAB Control System Toolbox provides functions to generate two of the most common frequency response plots: Bode Plot (bode command) and Nyquist Plot (nyquist command).

Control System Toolbox

Frequency Response: Bode Plot

Problem

- Given the LTI system

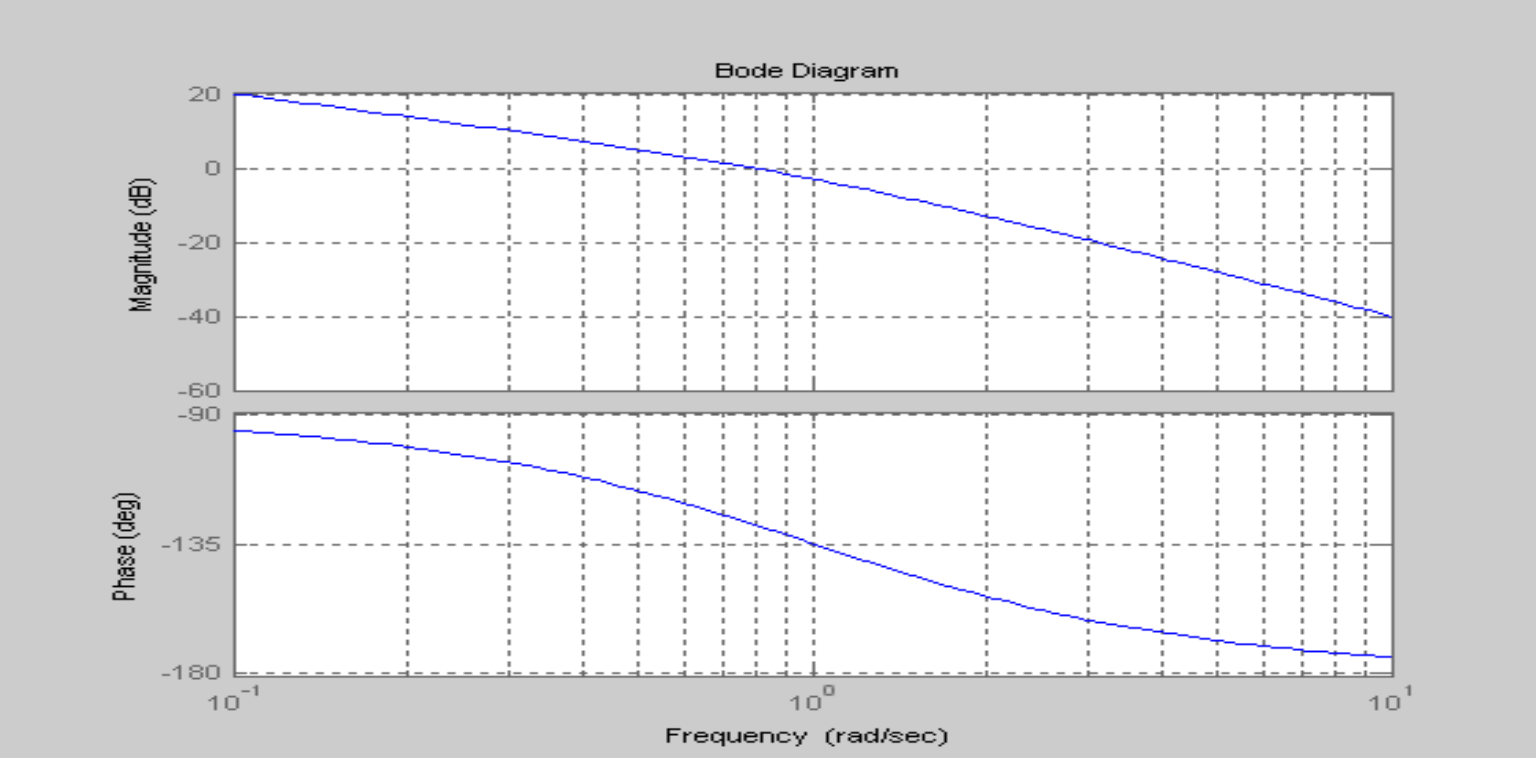
$$G(s) = \frac{1}{s(s+1)}$$

Draw the Bode diagram for 100 values of frequency in the interval $[10^{-1} \quad 10]$

Control System Toolbox

Frequency Response: Bode Plot

```
>>bode(tf(1, [1 1 0]), logspace(-1,1,100));
```



Control System Toolbox

Frequency Response: Nyquist Plot

- The loop gain Transfer function *G(s)*
- The **gain margin** is defined as the multiplicative amount that the magnitude of *G(s)* can be increased before the closed loop system goes unstable
- **Phase margin** is defined as the amount of additional phase lag that can be associated with *G(s)* before the closed-loop system goes unstable

Control System Toolbox

Frequency Response: Nyquist Plot

Problem

Given the LTI system

Draw the bode and nyquist plots for 100 values of frequencies in the interval $\left[10^{-4} \quad 10^{3}\right.$. In addition, find the gain and phase margins.

$$G(s) = \frac{1280s + 640}{s^4 + 24.2s^3 + 1604.81s^2 + 320.24s + 16}$$

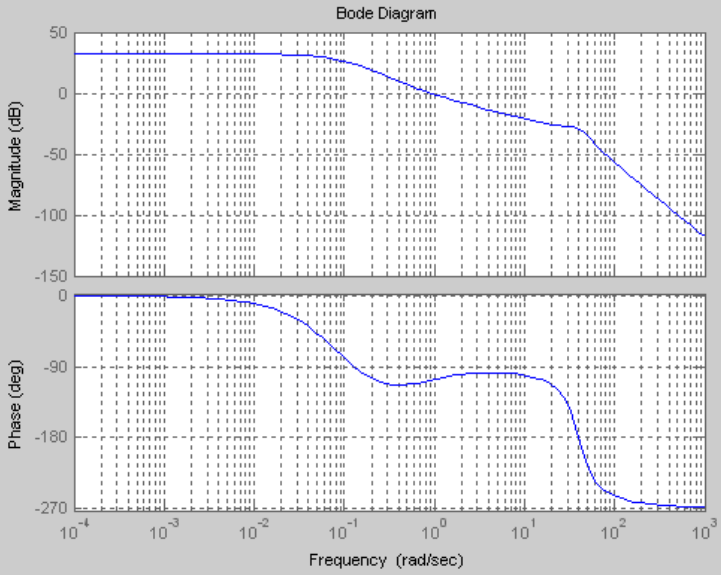
Control System Toolbox

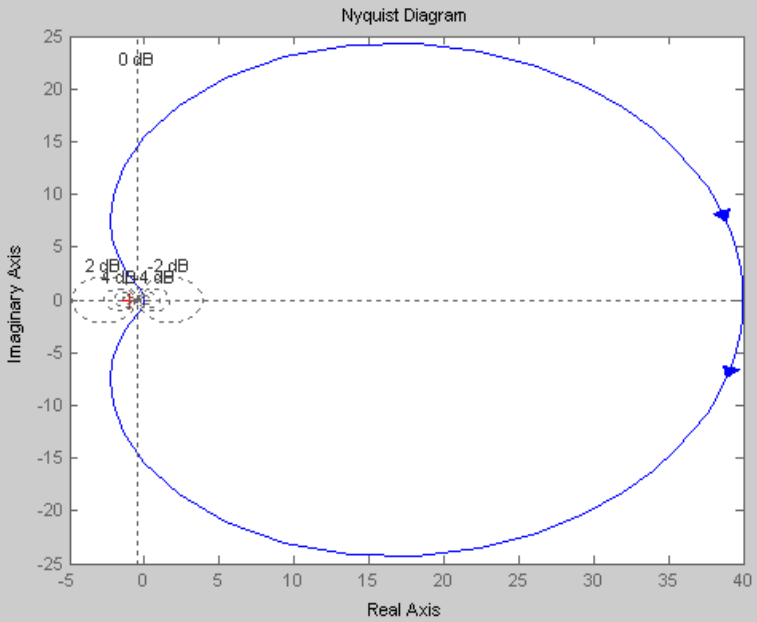
Frequency Response: Nyquist Plot

```
w=logspace(-4,3,100);
sys=tf([1280 640], [1 24.2 1604.81 320.24 16]);
bode(sys,w)
[Gm,Pm,Wcg,Wcp]=margin(sys)
%Nyquist plot
figure
nyquist(sys,w)
```

Control System Toolbox

Frequency Response: Nyquist Plot





The values of gain and phase margin and corresponding frequencies are

Gm = 29.8637 Pm = 72.8960 Wcg = 39.9099 Wcp = 0.9036

Frequency Response Plots

bode - Bode diagrams of the frequency response.
bodemag - Bode magnitude diagram only.
sigma - Singular value frequency plot.
Nyquist - Nyquist plot.
nichols - Nichols plot.
margin - Gain and phase margins.
allmargin - All crossover frequencies and related gain/phase margins.
freqresp - Frequency response over a frequency grid.
evalfr - Evaluate frequency response at given frequency.
interp - Interpolates frequency response data.

Control System Toolbox

Design: Pole Placement

- place - MIMO pole placement.
- acker - SISO pole placement.
- estim - Form estimator given estimator gain.
- reg - Form regulator given state-feedback and estimator gains.

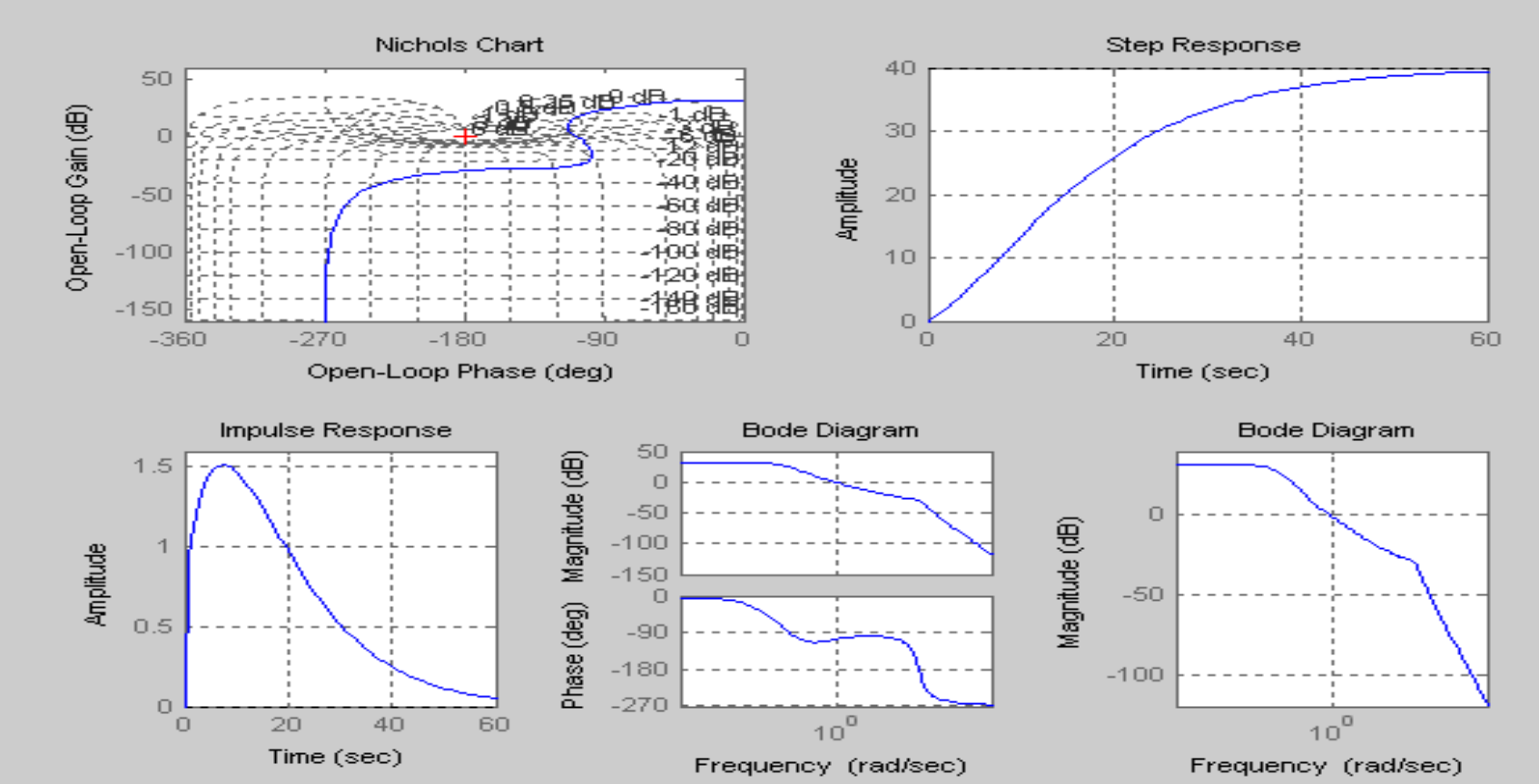
Control System Toolbox

Design : LQR/LQG design

- lqr, dlqr - Linear-quadratic (LQ) state-feedback regulator.
- lqry - LQ regulator with output weighting.
- lqrd - Discrete LQ regulator for continuous plant.
- kalman - Kalman estimator.
- kalmd - Discrete Kalman estimator for continuous plant.
- lqgreg - Form LQG regulator given LQ gain and
- Kalman estimator.
- augstate - Augment output by appending states.

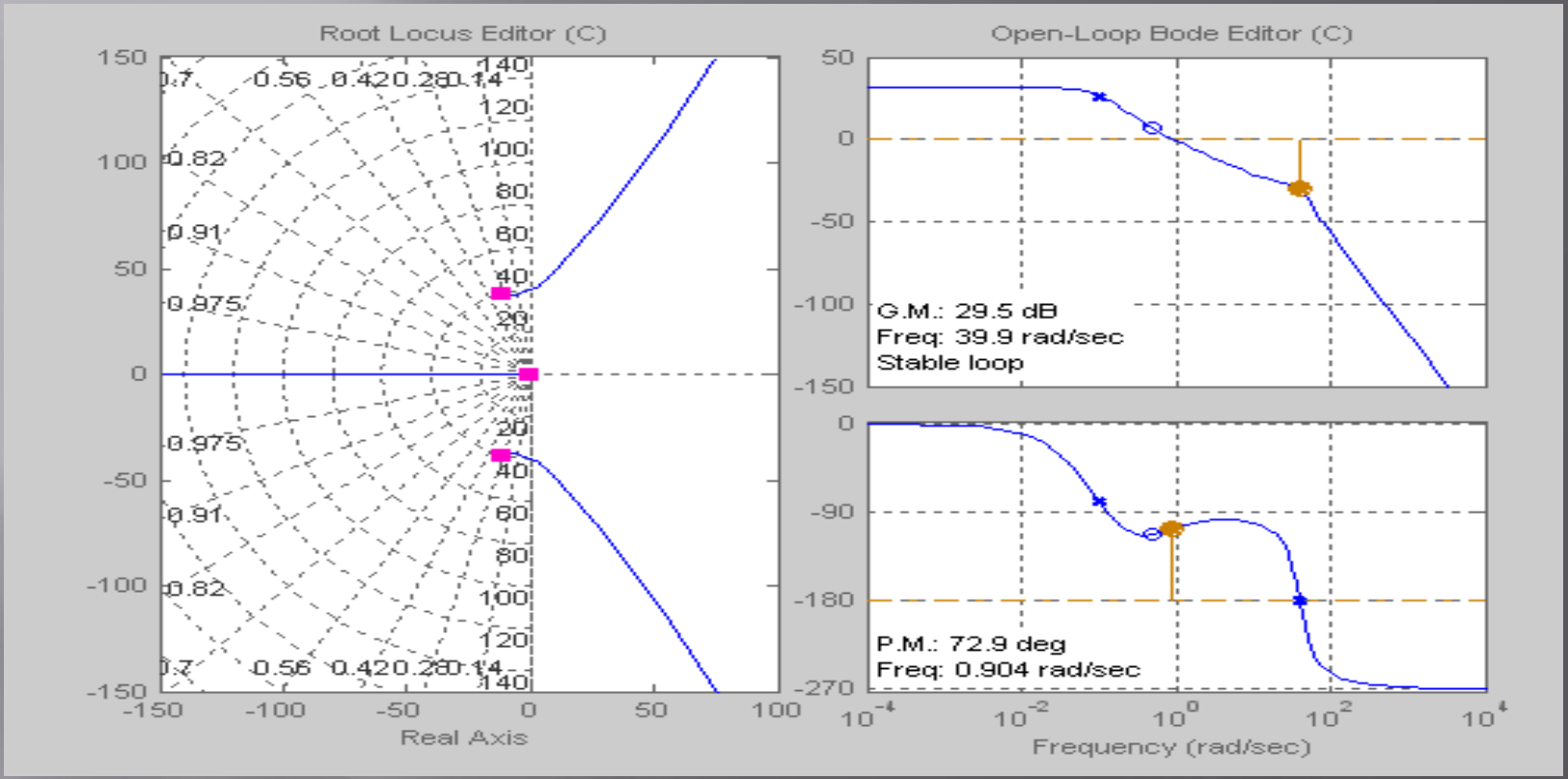
Control System Toolbox

Analysis Tool: ltiview



File->Import to import system from Matlab workspace

Control System Toolbox
Design Tool: sisotool



Design with root locus, Bode, and Nichols plots of the open-loop system.
Cannot handle continuous models with time delay.

M-File Example

```
%Define the transfer function of a plant
G=tf([4 3],[1 6 5])

%Get data from the transfer function
[n,d]=tfdata(G,'v')

[p,z,k]=zpkdata(G,'v')

[a,b,c,d]=ssdata(G)

%Check the controllability and observability of the system
ro=rank(obsv(a,c))
rc=rank(ctrb(a,b))

%find the eigenvalues of the system
damp(a)

%multiply the transfer function with another transfer
        function
T=series(G,zpk([-1],[-10 -2j +2j],5))

%plot the poles and zeros of the new system
iopzmap(T)

%find the bandwidth of the new system
wb=bandwidth(T)

%plot the step response
step(T)

%plot the rootlocus
rlocus(T)

%obtain the bode plots
bode(T)
margin(T)

%use the LTI viewer
ltiview({'step';'bode';'nyquist'},T)

%start the SISO tool
sisotool(T)
```