AAE 364: Control Systems Analysis

HW 11

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School of Aeronautical and Astronautical

Purdue University

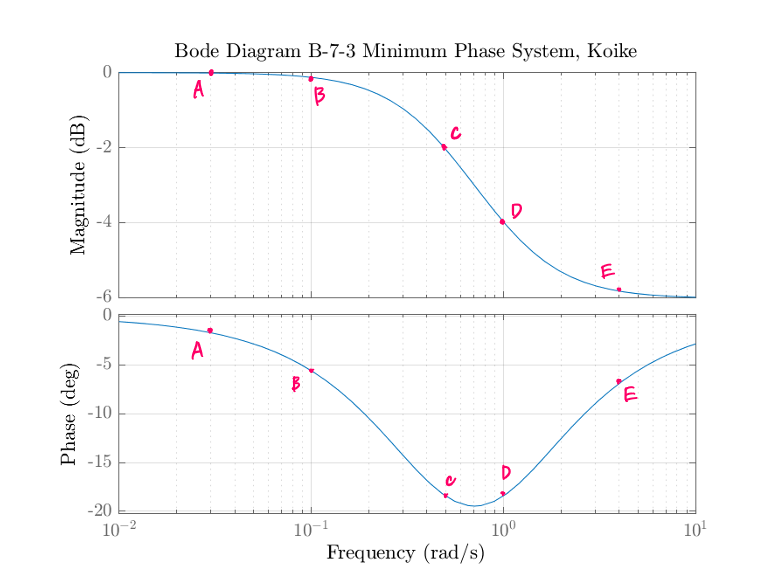
Tomoki Koike

Friday April 24th, 2020

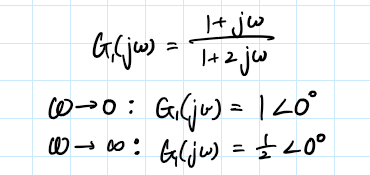


Minimum Phase System

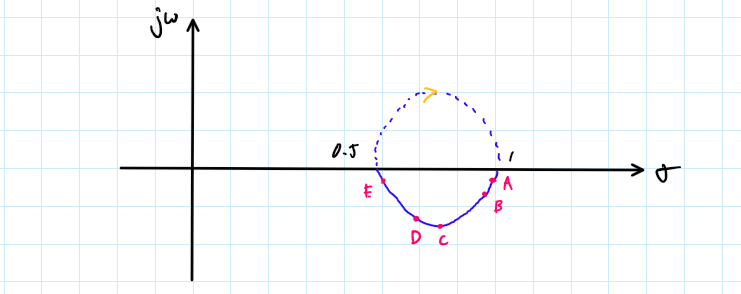
Bode Plot (from HW10)



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Point | [rad/s] | [deg] | [dB] | |G| |
| A | 0.02 | -1 | 0 | 1 |
| B | 0.1 | -6 | -0.15 | 0.9829 |
| C | 0.5 | -18 | -2 | 0.7943 |
| D | 1 | -19 | -4 | 0.6310 |
| E | 4 | -7 | -5.9 | 0.5129 |



Nyquist Plot Sketch



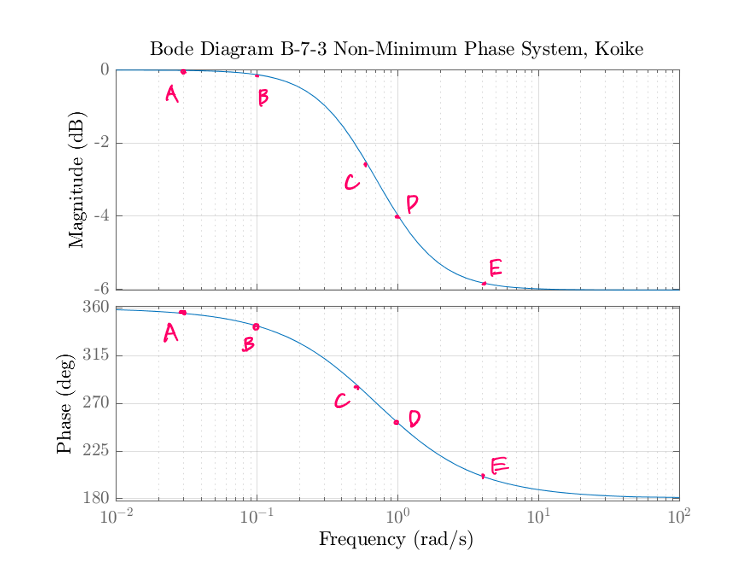
Nyquist Plot (MATLAB)

A close up of a map

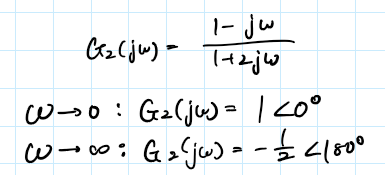
Description automatically generated

Non-Minimum Phase System

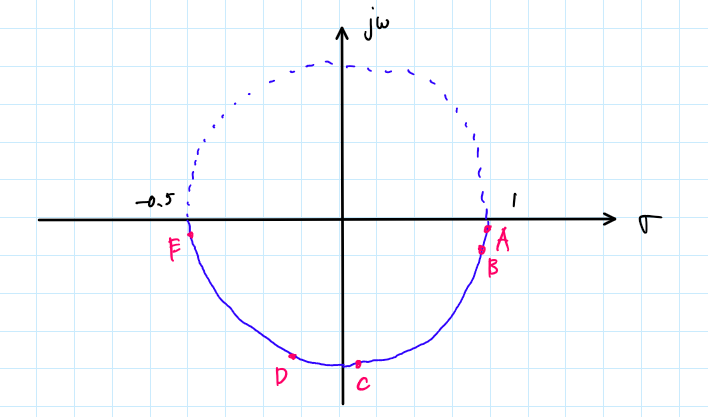
Bode Plot (from HW 10)



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Point | [rad/s] | [deg] | [dB] | |G| |
| A | 0.02 | 352 | 0 | 1 |
| B | 0.1 | 343 | -0.02 | 0.9988 |
| C | 0.5 | 281 | -2.5 | 0.7480 |
| D | 1 | 255 | -4 | 0.6310 |
| E | 4 | 198 | -5.9 | 0.5070 |



Nyquist Plot Sketch

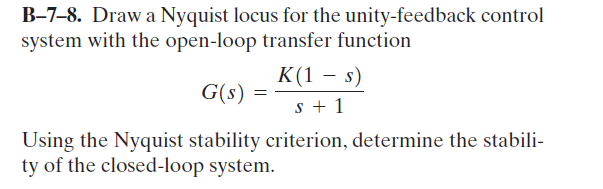




Nyquist Plot (MATLAB)

A close up of a map

Description automatically generated

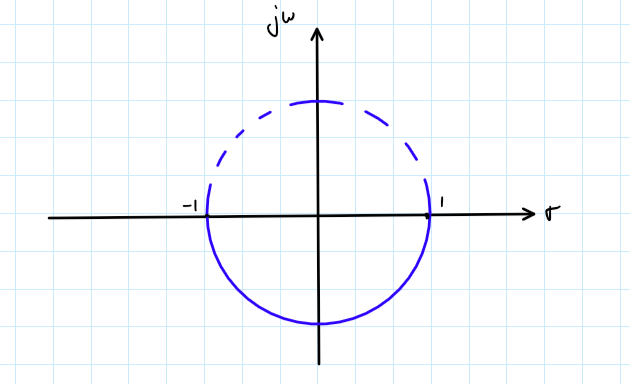


Bode Plot (from HW10)

A close up of text on a white background

Description automatically generated

Nyquist Plot Sketch

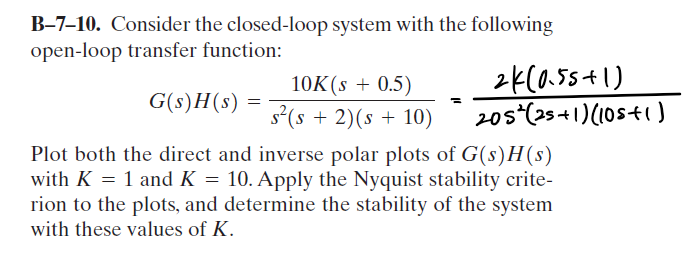




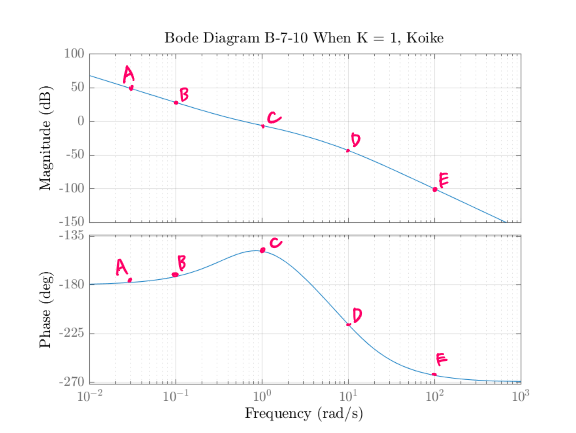
Nyquist Plot (MATLAB)

A close up of a map

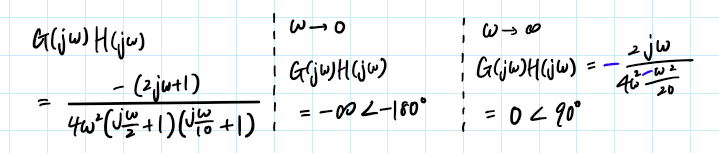
Description automatically generated



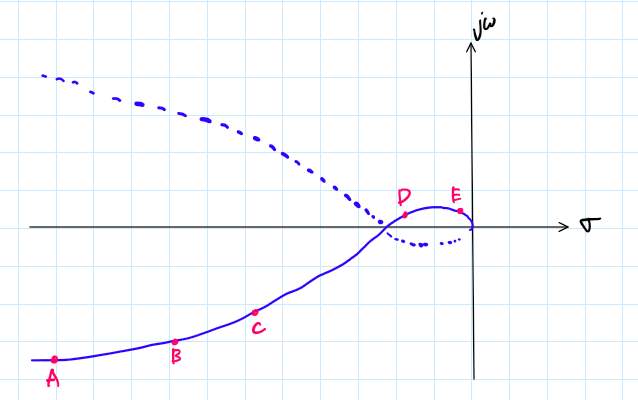
Bode Plot (from HW10)



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Point | [rad/s] | [deg] | [dB] | |G| |
| A | 0.02 | -178 | 55 | 562.3412 |
| B | 0.1 | -171 | 28 | 25.1189 |
| C | 1 | -150 | -7 | 0.4467 |
| D | 10 | -215 | -48 | 0.0004 |
| E | 100 | -261 | -100 | 0 |



Nyquist Plot Sketch

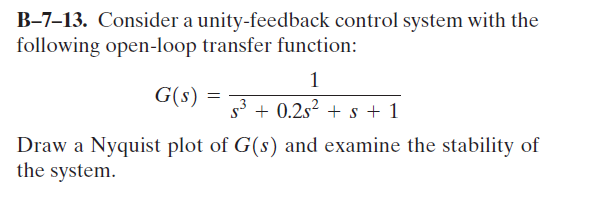




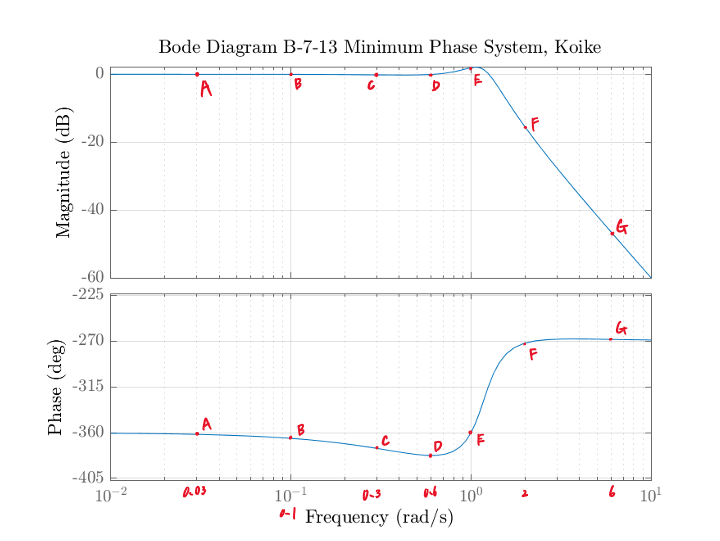
Nyquist Plot (MATLAB)

A close up of a map

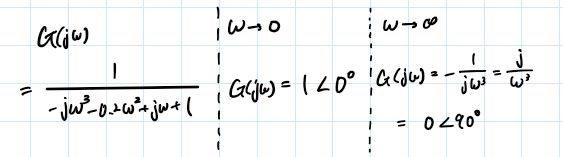
Description automatically generated



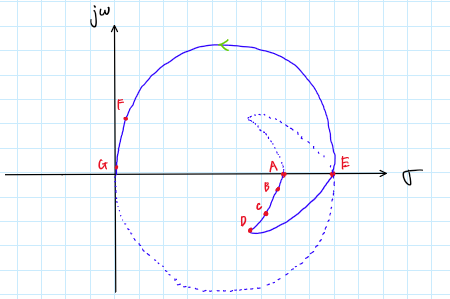
Bode Plot (from HW10)



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Point | [rad/s] | [deg] | [dB] | |G| |
| A | 0.03 | -360 | 0 | 1 |
| B | 0.1 | -364 | 0 | 1 |
| C | 0.3 | -375 | 0 | 1 |
| D | 0.6 | -382 | 0 | 1 |
| E | 1 | -360 | 2 | 1.2589 |
| F | 2 | -271 | -18 | 0.1259 |
| G | 6 | -270 | -46 | 0.00501 |



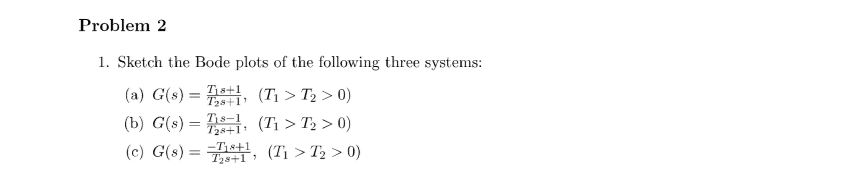
Nyquist Plot Sketch



Nyquist Plot (MATLAB)

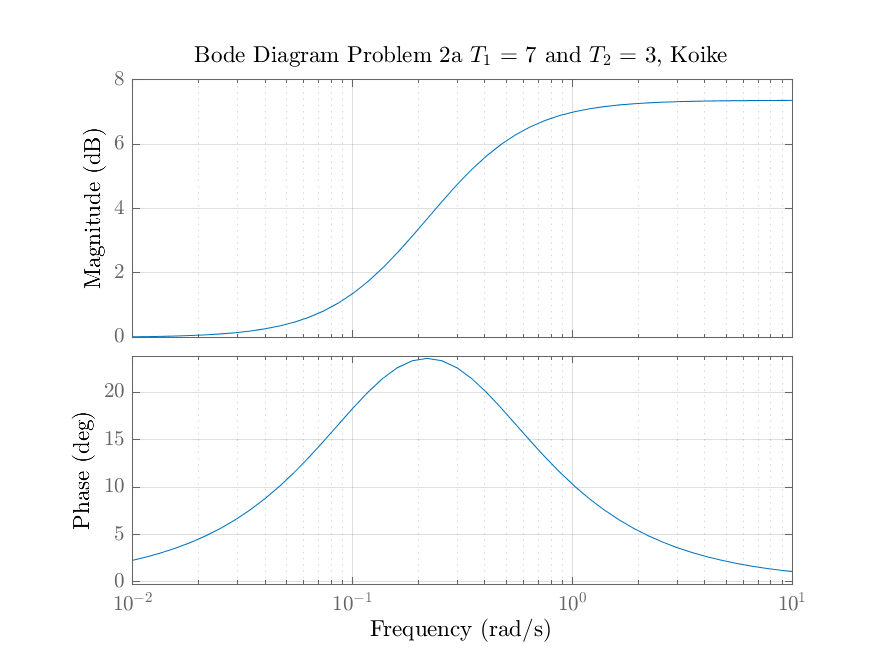
A close up of a map

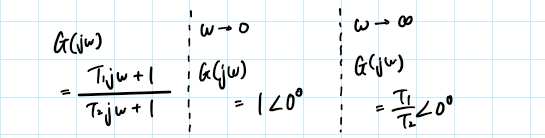
Description automatically generated



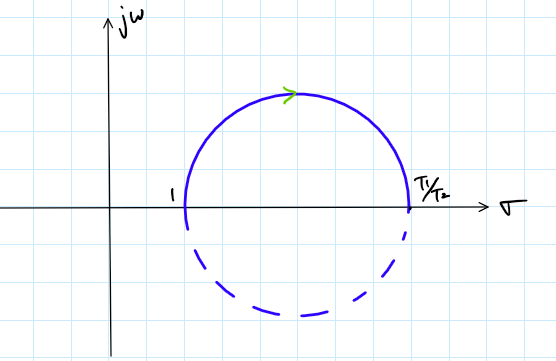
(a)

Bode Plot (from HW10)





Nyquist Plot Sketch



Nyquist Plot (MATLAB)

A close up of a map

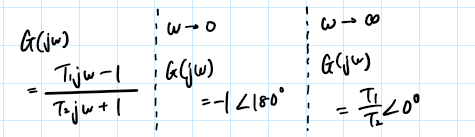
Description automatically generated

(b)

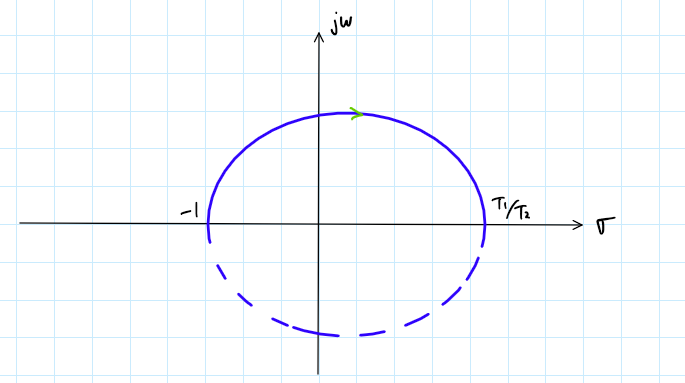
Bode Plot (from HW10)

A close up of a map

Description automatically generated



Nyquist Plot Sketch



Nyquist Plot (MATLAB)

A close up of a map

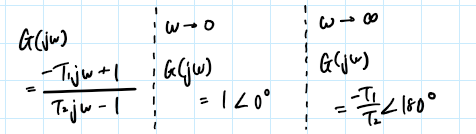
Description automatically generated

(c)

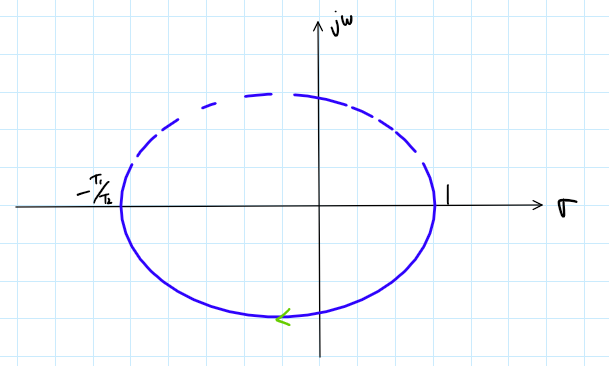
Bode Plot (from HW10)

A close up of a map

Description automatically generated



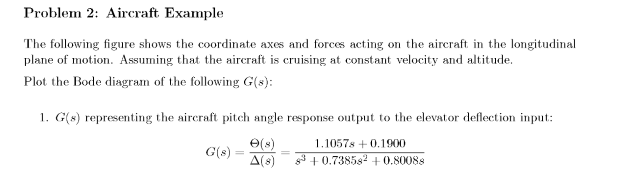
Nyquist Plot Sketch



Nyquist Plot (MATLAB)

A close up of a map

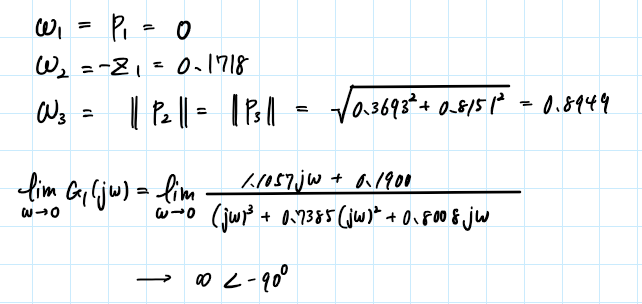
Description automatically generated



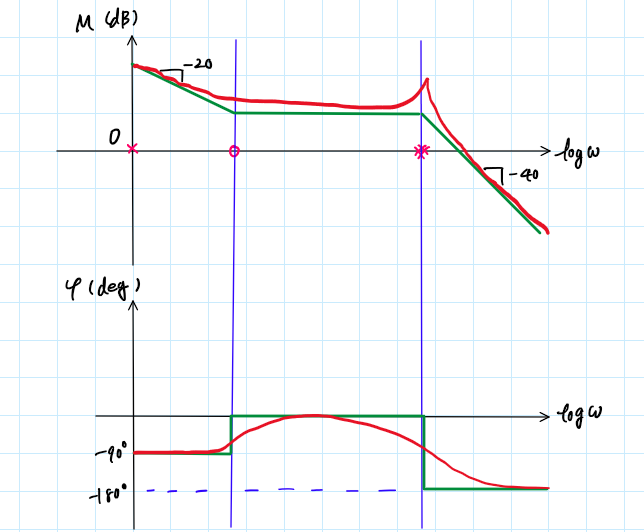
Poles and Zeros

|  |  |  |
| --- | --- | --- |
|  | Poles, | Zeros, |
| 1 | 0 + 0j | -0.1718 |
| 2 | -0.3693 + 0.8151j |  |
| 3 | -0.3693 - 0.8151j |  |

Corner Frequencies & Limits



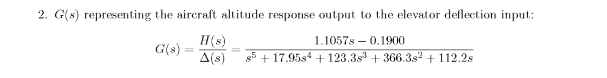
Bode Plot Sketch



Bode Plot (MATLAB)

A close up of a map

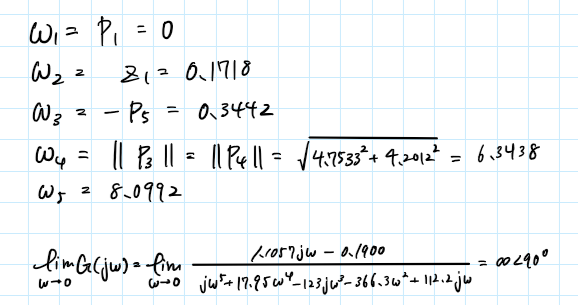
Description automatically generated



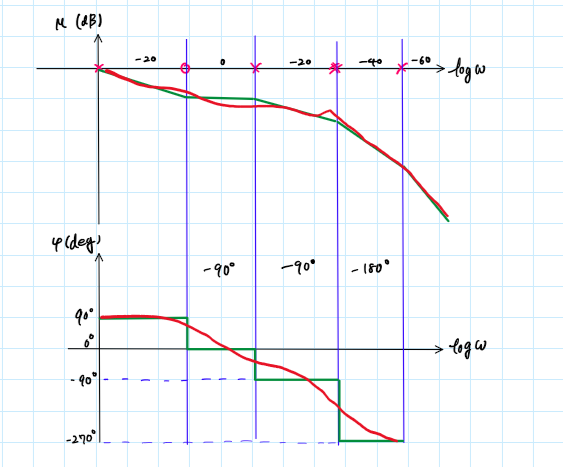
Poles and Zeros

|  |  |  |
| --- | --- | --- |
|  | Poles, | Zeros, |
| 1 | 0 + 0j | 0.1718 |
| 2 | -8.0992 |  |
| 3 | -4.7533 + 4.2012j |  |
| 4 | -4.7533 - 4.2012j |  |
| 5 | -0.3442 |  |

Corner Frequencies



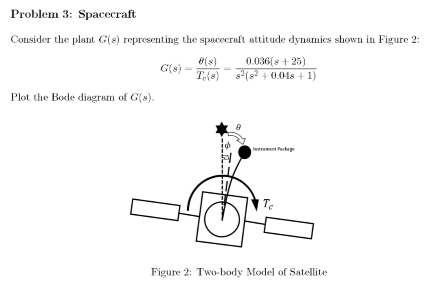
Bode Plot Sketch



Bode Plot (MATLAB)

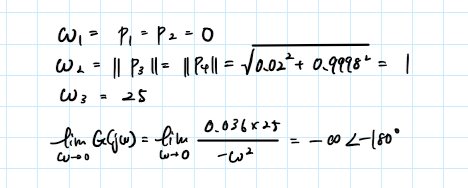
A close up of a map

Description automatically generated

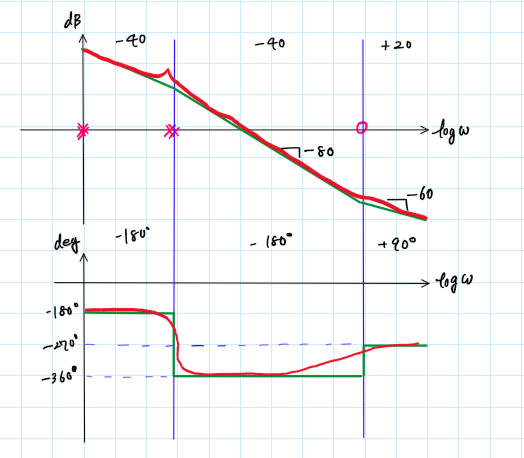


Poles and Zeros

|  |  |  |
| --- | --- | --- |
|  | Poles, | Zeros, |
| 1 | 0 + 0j | -25 |
| 2 | 0 + 0j |  |
| 3 | -0.02+0.9998j |  |
| 4 | -0.02-0.9998j |  |



Bode Plot Sketch



Bode Plot (MATLAB)

A close up of a map

Description automatically generated

Appendix

MATLAB CODE

**AAE 364 HW11**

clear all; close all; clc;

fdir = 'C:\Users\Tomo\Desktop\studies\2020-Spring\AAE364\matlab\matlab\_output\hw11';

set(groot, 'defaulttextinterpreter','latex');

set(groot, 'defaultAxesTickLabelInterpreter','latex');

set(groot, 'defaultLegendInterpreter','latex');

% Bode plot options

opts\_bd = bodeoptions('cstprefs');

opts\_bd.Title.Interpreter = "latex";

opts\_bd.XLabel.Interpreter = "Latex";

opts\_bd.YLabel.Interpreter = "Latex";

opts\_bd.Grid = 'on';

% Nyquist plot options

opts\_nq = nyquistoptions("cstprefs");

opts\_nq.Title.Interpreter = 'latex';

opts\_nq.XLabel.Interpreter = "Latex";

opts\_nq.YLabel.Interpreter = "Latex";

opts\_nq.Grid = 'on';

**B-7-3**

% Minimum Phase System

num = [1 1];

den = [2 1];

G = tf(num,den);

arr\_log = [0 -0.15 -2 -4 -5.8];

arr = 10.^(arr\_log/20);

% Nyquist Plot

fig = figure("Renderer","painters");

opts\_nq.Title.String = "Nyquist Diagram B-7-3 Minimum Phase System, Koike";

nyquistplot(G,opts\_nq);

axis equal;

saveas(fig,fullfile(fdir,"B-7-3\_min\_nyquist.png"));

% Non-minimum Phase System

num = [-1 1];

den = [2 1];

G = tf(num,den);

arr\_log = [0 -0.01 -2.5 -4 -5.9];

arr = 10.^(arr\_log/20);

% Nyquist Plot

fig = figure("Renderer","painters");

opts\_nq.Title.String = "Nyquist Diagram B-7-3 Non-Minimum Phase System, Koike";

nyquistplot(G,opts\_nq);

axis equal;

saveas(fig,fullfile(fdir,"B-7-3\_nonmin\_nyquist.png"));

**B-7-8**

K = 1;

num = K\*[-1 1];

den = [1 1];

G = tf(num,den);

% Bode Plot

fig = figure("Renderer","painters");

opts\_bd.Title.String = "Bode Diagram B-7-8 When K = 1, Koike";

bodeplot(G,opts\_bd);

saveas(fig,fullfile(fdir,"B-7-8\_bode\_K=1.png"));

% Nyquist Plot

fig = figure("Renderer","painters");

opts\_nq.Title.String = "Nyquist Diagram B-7-8 When K = 1, Koike";

nyquistplot(G,opts\_nq);

axis equal;

saveas(fig,fullfile(fdir,"B-7-8\_nyquist\_K=1.png"));

**B-7-10**

% Define the OL transfer function

num = 5\*[2 1];

den = conv(2\*[0.5 1 0 0],10\*[0.1 1]);

K = 1;

G = tf(K\*num,den);

% Bode Plot

fig = figure("Renderer","painters");

opts\_bd.Title.String = "Bode Diagram B-7-10 When K = 1, Koike";

bodeplot(G,opts\_bd);

saveas(fig,fullfile(fdir,"B-7-10\_bode\_K=1.png"));

arr\_log = [55 28 -7 -48 -100];

arr = 10.^(arr\_log/20);

% Nyquist Plot

fig = figure("Renderer","painters");

title\_txt = sprintf("Nyquist Diagram B-7-10 When K = 1, Koike");

opts\_nq.Title.String = title\_txt;

nyquistplot(G,opts\_nq);

xlim([-5.5 0])

file\_txt = sprintf("B-7-10\_nyquist\_K=1.png");

saveas(fig,fullfile(fdir,file\_txt));

**B-7-13**

% Define the transfer function

num = [0 1];

den = [1 0.2 1 1];

G = tf(num,den);

% Bode Plot

fig = figure("Renderer","painters");

opts\_bd.Title.String = "Bode Diagram B-7-13 Minimum Phase System, Koike";

bodeplot(G,opts\_bd);

saveas(fig,fullfile(fdir,"B-7-13\_bode.png"));

% Nyquist Plot

fig = figure("Renderer","painters");

opts\_nq.Title.String = "Nyquist Diagram B-7-13, Koike";

nyquistplot(G,opts\_nq);

saveas(fig,fullfile(fdir,"B-7-13\_nyquist.png"));

**P2**

% (a)

num = [7 1];

den = [3 1];

G = tf(num,den);

% Bode Plot

fig = figure("Renderer","painters");

opts\_bd.Title.String = "Bode Diagram Problem 2a $T\_1$ = 7 and $T\_2$ = 3, Koike";

bodeplot(G,opts\_bd);

saveas(fig,fullfile(fdir,"P2-a\_bode.png"));

% Nyquist Plot

fig = figure("Renderer","painters");

opts\_nq.Title.String = "Nyquist Diagram Problem 2a $T\_1$ = 7 and $T\_2$ = 3, Koike";

nyquistplot(G,opts\_nq);

saveas(fig,fullfile(fdir,"P2-a\_nyquist.png"));

% (b)

num = [7 -1];

den = [3 1];

G = tf(num,den);

% Bode Plot

fig = figure("Renderer","painters");

opts\_bd.Title.String = "Bode Diagram Problem 2b $T\_1$ = 7 and $T\_2$ = 3, Koike";

bodeplot(G,opts\_bd);

saveas(fig,fullfile(fdir,"P2-b\_bode.png"));

% Nyquist Plot

fig = figure("Renderer","painters");

opts\_nq.Title.String = "Nyquist Diagram Problem 2a $T\_1$ = 7 and $T\_2$ = 3, Koike";

nyquistplot(G,opts\_nq);

saveas(fig,fullfile(fdir,"P2-b\_nyquist.png"));

% (c)

num = [-7 1];

den = [3 1];

G = tf(num,den);

% Bode Plot

fig = figure("Renderer","painters");

opts\_bd.Title.String = "Bode Diagram Problem 2c $T\_1$ = -7 and $T\_2$ = 3, Koike";

bodeplot(G,opts\_bd);

saveas(fig,fullfile(fdir,"P2-c\_bode.png"));

% Nyquist Plot

fig = figure("Renderer","painters");

opts\_nq.Title.String = "Nyquist Diagram Problem 2a $T\_1$ = 7 and $T\_2$ = 3, Koike";

nyquistplot(G,opts\_nq);

saveas(fig,fullfile(fdir,"P2-c\_nyquist.png"));

**P3 Aircraft Example**

% 1

num = [1.1057 0.19];

den = [1 0.7385 0.8008 0];

G = tf(num,den);

pls = roots(den)

zrs = roots(num)

cornFreq = corner\_freq(num,den)

fig = figure("Renderer","painters");

opts\_bd.Title.String = "Aircraft Example Bode Diagram 1, Koike";

bodeplot(G,opts\_bd);

saveas(fig,fullfile(fdir,"P3-1\_bode.png"));

% 2

num = [1.1057 -0.19];

den = [1 17.95 123.3 366.3 112.2 0];

pls = roots(den)

zrs = roots(num)

cornFreq = corner\_freq(num,den)

G = tf(num,den);

fig = figure("Renderer","painters");

opts\_bd.Title.String = "Aircraft Example Bode Diagram 2, Koike";

bodeplot(G,opts\_bd);

saveas(fig,fullfile(fdir,"P3-2\_bode.png"));

**P4 Spacecraft Example**

num = 0.036\*[1 25];

den = [1 0.04 1 0 0];

pls = roots(den)

zrs = roots(num)

cornFreq = corner\_freq(num,den)

G = tf(num,den);

fig = figure("Renderer","painters");

opts\_bd.Title.String = "Spacecraft Example Bode Diagram 1, Koike";

bodeplot(G,opts\_bd);

saveas(fig,fullfile(fdir,"P4\_bode.png"));

function w\_i = corner\_freq(num,den)

%{

Function: corner\_freq()

Author: Tomoki Koike

Description: Computes the corner frequencies for a Bode Plot.

>>Inputs

num: the numerator of the open-loop transfer function

den: the denominator of the open-loop transfer function

Outputs<<

w\_i: the table with the corner frequencies for poles and zeros

%}

pls = roots(den);

zrs = roots(num);

cornP = unique(abs(pls));

cornZ = unique(abs(zrs));

if length(cornP) > length(cornZ)

cornZ = [cornZ; NaN([(length(cornP) - length(cornZ)), 1])];

else

cornP = [cornP; NaN([(length(cornZ) - length(cornP)), 1])];

end

w\_i = array2table([cornP, cornZ],"VariableNames",{'Poles','Zeros'});

end