EME172 Discussion 4

(1) Frequency Domain Analysis

```
int bode(class CPlot *plot, array double mag[&],
                            array double phase[&],
                            array double wout[&],
                            /* double w[&]
                               or
                               double wmin, double wmax */);
```

- Create the Bode frequency response of a system
- *plot* Pointer to an existing object of class CPlot
- *mag* Array of reference containing the magnitudes of the frequency response at the frequencies in array *wout*
- *phase* Array of reference containing the phases of the frequency response at the frequencies in array *wout*
- *wout* Array of reference containing the output frequencies
- *w* Array of reference containing the user-defined frequencies
- *wmin* and *wmax* Two double values specifying the frequency interval

Example 1: Create the Bode Plot for a System

Create the Bode plot for the following system.

$$H(s) = \frac{1}{(s+1)(s+2)(s+3)}$$

Program:

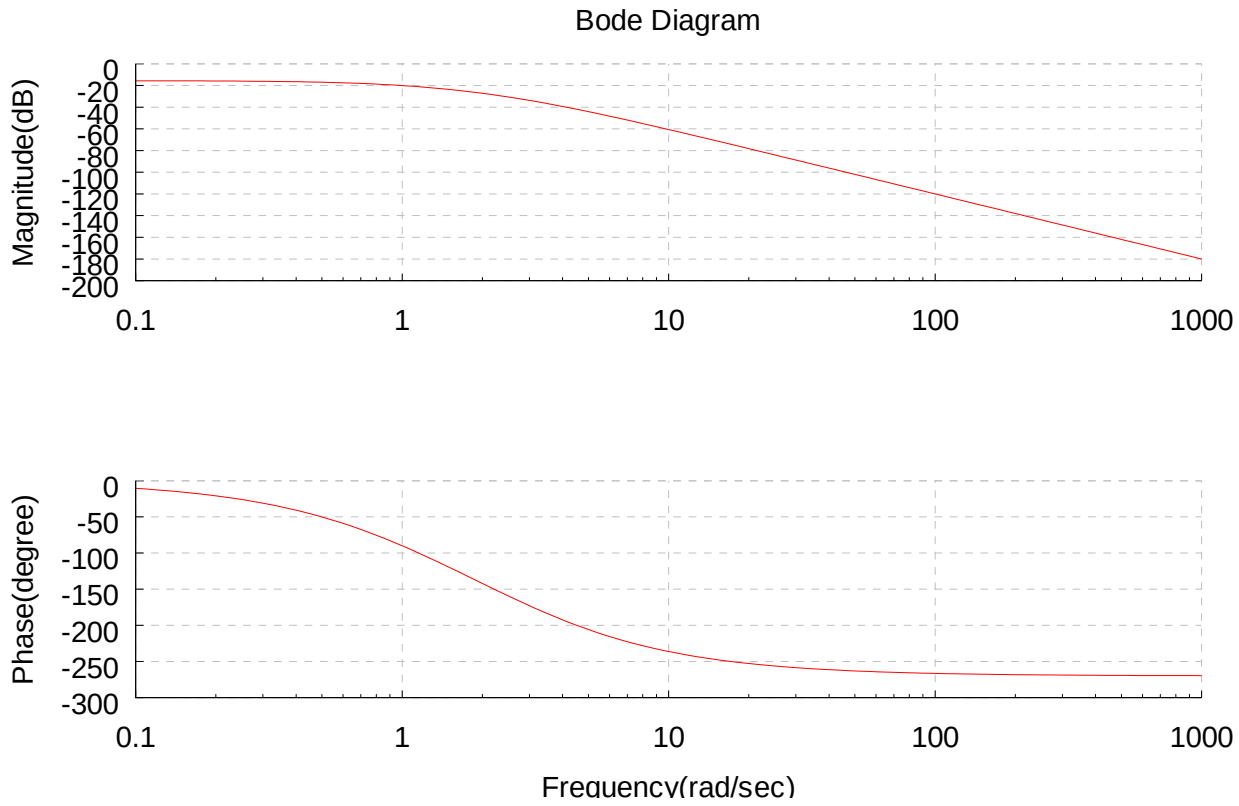
```
/* example1.ch */
#include <control.h>

int main() {
    double k = 1;
    array double complex p[3] = {complex(-1, 0),
                                 complex(-2, 0),
                                 complex(-3, 0)};
    CControl sys;
    CPlot plot;

    sys.model("zpk", NULL, p, k);
    sys.grid(1);
    sys.bode(&plot, NULL, NULL, NULL);

    return 0;
}
```

Output:


Bode Diagram
Magnitude(dB)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
0.1
1
10
100
1000
Phase(degree)
0
-50
-100
-150
-200
-250
-300
0.1
1
10
100
1000
Frequency(rad/sec)

(2) Root Locus Design

```
int rlocus(class CPlot *plot, array double &r,
                              array double &kout,
                              /* array double &k */);
```

- Compute and plot the root locus of a system
- *plot* Pointer to an existing object of class CPlot
- *r* Array of reference containing the roots corresponding to the gains in array *kout*
- *kout* Array of reference containing the output gains
- *k* Array of reference containing the user-defined gains

```
int rlocfind(array double &k, array double &poles,
                              /* array double complex p[:] */);
```

- Find the gains that make the closed-loop system poles move to the user-defined poles as close as possible
- *k* Array of reference containing the output gains
- *poles* Array of reference containing the closed-loop system poles corresponding to the gains in array k
- *p* Array of reference containing the user-specified poles

```
int sgrid(int flag, /* array double z[:], array double w[:] */);
```

- Generate an s-plane grid for constant damping factors and natural frequencies.
- *flag* Integer to turn on/off the sgrid.
- *z* Computational array containing damping factors at which the grid lines are plotted.
- *w* Computational array containing natural frequencies at which the grid lines are plotted.

```
CControl *feedback(CControl *sys2, /* array int feedin[:],
                                      array int feedout[:],
                                      int sign */);
```

- Feedback connection of two LTI models.
- *sys2* Pointer to the class **CControl** representing the system to be connected in the feedback path
- *feedin* One-dimensional computational array containing indices specifying which inputs are involved in the feedback loop. For SISO systems, the default value is {1}.
- *feedout* One-dimensional computational array containing indices specifying which outputs are involved in the feedback loop. For SISO systems, the default value is {1}.
- *sign* Integer indicating every element of input is a positive feedback or a negative one. The default value is −1, denoting a negative feedback.

Example 2: Create the Root Locus for a System

Create the root locus for the following system. The grid line is plotted at $\zeta = 0.4$.

$$H(s) = \frac{1}{(s+1)(s+2)(s+3)}$$

Program:

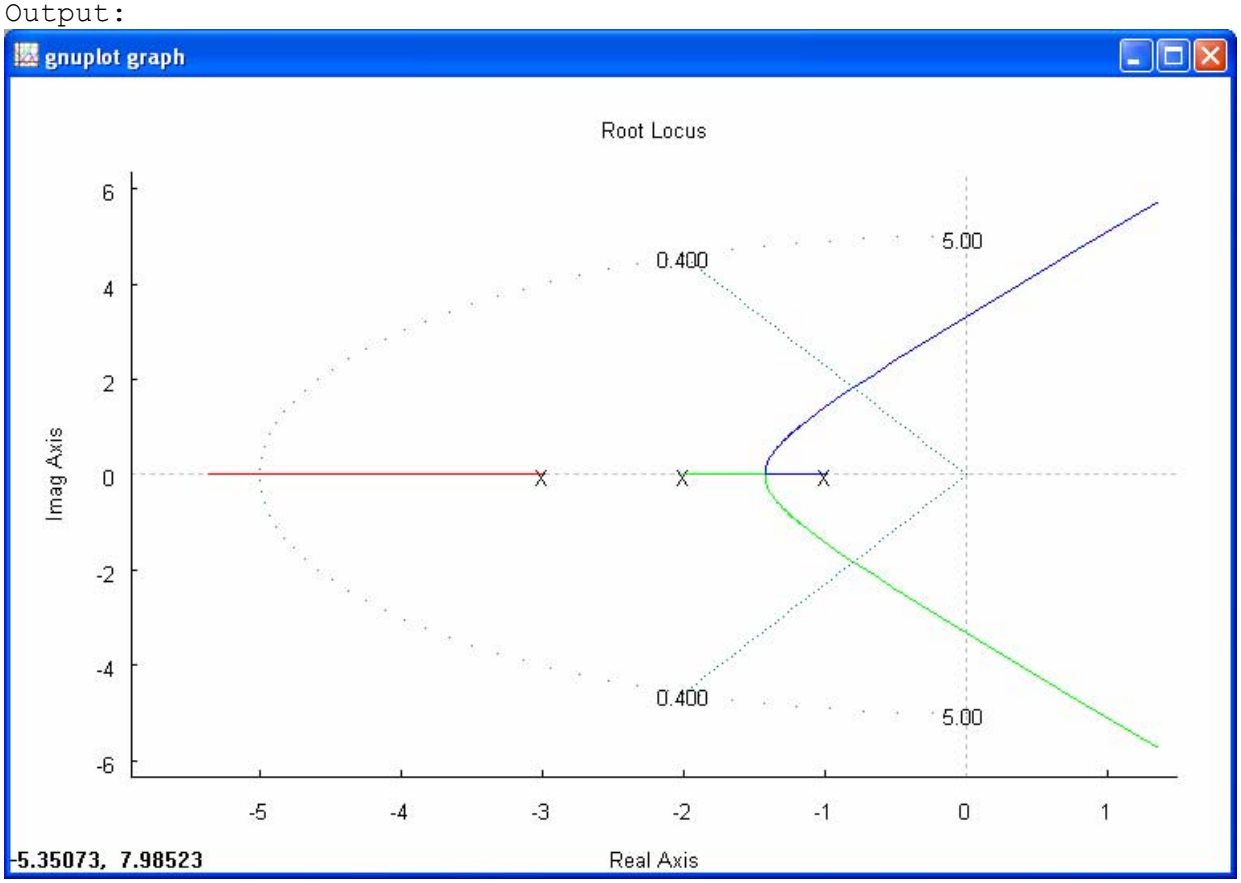
```
/* example2.ch */
#include <control.h>

int main() {
    double k = 1;
    array double complex p[3] = {complex(-1, 0),
                                 complex(-2, 0),
                                 complex(-3, 0)};
    array double zeta[1] = {0.4};
    array double omega[1] = {5};
    CControl sys;
    CPlot plot;

    sys.model("zpk", NULL, p, k);
    sys.sgrid(1, zeta, omega);
    sys.rlocus(&plot, NULL, NULL);

    return 0;
}
```

Output:



Example 3: Find the Gain Corresponding to the Pole Selected from the Root Locus

For the system below, find the gain corresponding to the pole, -0.8 + j1.84, which locates at the intersection of the root locus and the grid ($\zeta = 0.4$) as shown above.

$$H(s) = \frac{1}{(s+1)(s+2)(s+3)}$$

Program:

```
/* example3.ch */
#include <control.h>

int main() {
    double k = 1;
    array double complex p[3] = {complex(-1, 0),
                                 complex(-2, 0),
                                 complex(-3, 0)};

    // selected pole from the root locus
    array double complex spole[1] = {complex(-0.8, 1.84)};

    // output closed-loop poles
    array double complex clpole[3];

    // output gain
    array double gain[1];

    CControl sys;

    sys.model("zpk", NULL, p, k);
    sys.rlocfind(gain, clpole, spole);
    printf("gain: %f\n", gain);
    printf("closed-loop poles: %f\n", clpole);

    return 0;
}
```

Output:

```
gain: 11.660785

closed-loop poles: complex(-4.414452,0.000000) complex(-0.792774,1.836351)
complex(-0.792774,-1.836351)
```

Example 4: Find the Step Response of a Closed-Loop System

Find the step response for a unity feedback system with a plant as shown below.

$$H(s) = \frac{11.66}{(s+1)(s+2)(s+3)}$$

Program:

```
/* example4.ch */
#include <control.h>

int main() {
    double k = 11.66;
    array double complex p[3] = {complex(-1, 0),
                                 complex(-2, 0),
                                 complex(-3, 0)};
    array double num[1] = {1};
    array double den[1] = {1};
    double tf = 20;

    CControl sys1, sys2, *sys3;
    CPlot plot;

    sys1.model("zpk", NULL, p, k);
    sys2.model("tf", num, den);
    sys3 = sys1.feedback(&sys2);
    sys3->grid(1);
    sys3->step(&plot, NULL, NULL, NULL, tf);

    return 0;
}
```

Output: