EE324 Control Systems Lab

Problem Sheet 4

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1 Question 1

Part A Code:

```
s = poly(0, 's')
G = (1 / s^2) * (50 * s / (s^2 + s + 100)) * (s - 2)
C = G / (1 + G)
disp(C)
```

Part B Code:

```
s = poly(0, 's')
G1 = s * s + (1 / s)
C1 = G1 / (1 + G1)
G2 = C1 * (1 / s)
C2 = G2 / (1 + s * G2)
disp(C2)
```

Part C Code:

```
s = poly(0, ’s’)

G1 = 3 * s * (s / (1 + s))

G2 = 1 / (1 + s)

C2 = G2 / (1 + G2)

// x = r - c


// y = 2sx - 4c

// y = 2sr - c(2s+4)


// c = (G1x + y).C2

// c = (G1r - G1c + 2sr - c(2s+4)).C2

// c = G1C2r + 2sC2r - c(G1 + 2s +4)C2

C = (G1 * C2 + 2 * s * C2) / (1 + C2*(G1 + 2*s + 4))

disp(C)
```

Answers:

$$\frac{-100 + 50s}{-100 + 150s + s^2 + s^3} \qquad \frac{0.5 - 5.41082D\text{-}18s - 6.16791D\text{-}18s^2 + 0.5s^3}{s + 0.5s^2 - 1.23358D\text{-}17s^3 + s^4}$$

$$\frac{0.3333333s + 0.8333333s^2}{1 + 1.5s + s^2}$$

Figure 1: Answers to Part A, B, C

2 Question 2

I used the following code:

```
s = poly(0, 's')

function cl_tf_k = cltfk(K)

    // part a

    G = 10 / (s * (s + 2) * (s + 4))

    cl_tf_k = K * G / (1 + K * G)

endfunction


// part b

for k = 0:0.1:100

    tf = cltfk(k)

    poles = roots(tf.den)

    scatter(real(poles), imag(poles))

end


// part c

// my guess is k was around 5 when the poles cut the imaginary axis


// part d

tf = cltfk(5)

disp(routh_t(tf.den))

// the RH table has two sign changes, and the number causing the change is

// of the order of 10^-15
```

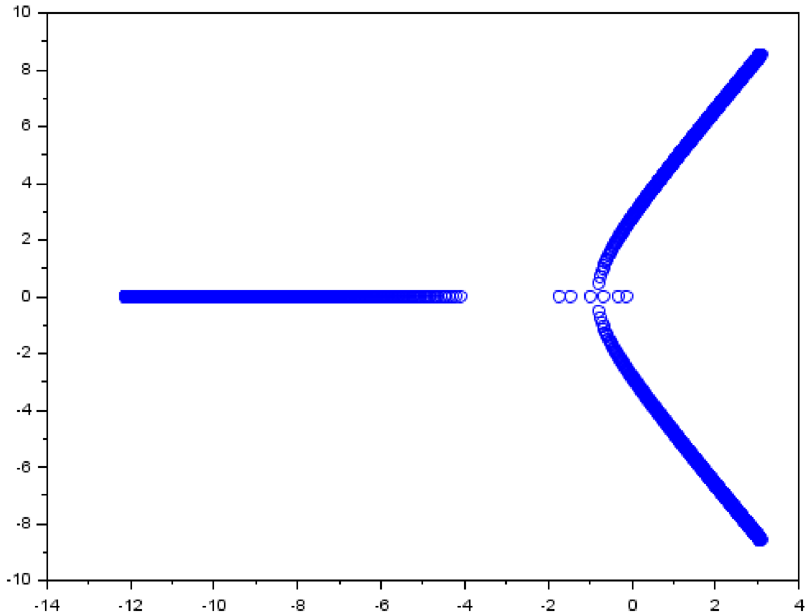

Figure 2: Plot of part B

1.	8.
6.	48.
-8.882D-15	0.
48.	0.

Figure 3: Routh Table of part D

3 Question 3

Code used:

```
s = poly(0, 's')


g =  s^5 + 3*s^4 + 5*s^3 + 4*s^2 + s + 3

disp(routh_t(g), "Part A")


g = s^5 + 6*s^3 + 5*s^2 + 8*s + 20

disp(routh_t(g), "Part B")


g = s^5 - 2*s^4 + 3*s^3- 6*s^2 + 2*s - 4

disp(routh_t(g), "Part C")


g = s^6 + s^5 - 6*s^4 + s^2 + s - 6

disp(routh_t(g), "Part D")
```

```
1                                 6              8
--                                --             --

1                                 1              1

eps                               5              20
----                              --             ---

 1                                1              1

-5 + 6eps                         -20 + 8eps     0
----------                        -----------    --

   eps                               eps         1
                   2
-25 + 50eps - 8eps                20             0
-------------------               ---            --

    -5 + 6eps                     1              1
                              2
-2.27374D-13 - 160eps - 64eps     0              0
------------------------------    --             --
                        2
     -25 + 50eps - 8eps           1              1

20                                0              0
---                               --             --

1                                 1              1
```

Part A

1.	5.	1.
3.	4.	3.
3.6666667	0.	0.
4.	3.	0.
-2.75	0.	0.
3.	0.	0.

Part D

```
1    -6   1    -6
--   ---  --   ---

1    1    1    1

1    0    1    0
--   --   --   --

1    1    1    1

-6   0    -6   0
---  --   ---  --

1    1    1    1

-24  0    0    0
---- --   --   --

1    1    1    1

eps  -6   0    0
---- ---  --   --

1    1    1    1

-144 0    0    0
---- --   --   --

eps  1    1    1

864  0    0    0
---- --   --   --

-144 1    1    1
```

Part C

1.	3.	2.
-2.	-6.	-4.
-8.	-12.	0.
-3.	-4.	0.
-1.333333333	0.	0.
-4.	0.	0.

Figure 4: Routh Tables

4 Question 4

Part A: We want a factor of p which has powers 4, 2, 0 only. Eg. s^4

Hence one such polynomial is: $\mathbf{s^6 + s^5 + s^4}$

Part B: Using similar logic, we get: $\mathbf{s^8 + s^7 + s^6 + s^5 + s^4}$

The s^6, s^5 rows have epsilon terms, but the s^3 row is purely zero throughout.

Part C: Let the s^3 row be 0 0.5 0 0

Hence the s^5 and s^4 rows can be 1 0 1 0, 2 0 1 0

This implies the s^6 row can be 1 3 1 2

The table will be:

1 2 1 1

1 0 1 0

2 0 1 0

0 0.5 0 0

Hence the polynomial is $\mathbf{s^6 + s^5 + 2s^4 + s^2 + s + 1}$