



ANKARA UNIVERSITY
Engineering Faculty
Department of Electrical and Electronics Engineering

Experiment-5

EEE 360 Control Lab

STABILITY
OF
LINEAR FEEDBACK SYSTEMS

Objectives of the Experiment:

- Learn basics of LabVIEW on stability analysis
- Construct feedback control systems on Labview environment and providing a readily accessible method for computing the poles of the characteristic equation.
- Understand the impact of the position of the pole.
- Learn the Simulation window and related topics of LabVIEW

1.Preliminary Study:

1.Please read experimental study section to understand what you are going to do in the experiment.

2.Research on related topics in computer programs like Matlab or Scilab. Prepare yourself for the next questions and experiment. Learn and read related documents to understand the experiment.

3. Utilizing the Routh–Hurwitz criterion, determine the stability of the following polynomials. Determine the number of roots, if any, in the righthand plane. If it is adjustable, determine the range of K that results in a stable system.

(a) $s^2 + 5s + 2 = 0$

(b) $s^3 + 4s^2 + 8s + 4 = 0$

(c) $s^3 + 2s^2 - 6s + 20 = 0$

(d) $s^4 + s^3 + 2s^2 + 12s + 10 = 0$

(e) $s^4 + s^3 + 3s^2 + 2s + K = 0$

(f) $s^5 + s^4 + 2s^3 + s + 6 = 0$

(g) $s^5 + s^4 + 2s^3 + s^2 + s + K = 0$

4. Determine the relative stability of the systems with the following characteristic equations (1) by shifting the axis in the s-plane and using the Routh–Hurwitz criterion, and (2) by determining the location of the complex roots in the s-plane:

(a) $s^3 + 5s^2 + 6s + 2 = 0.$

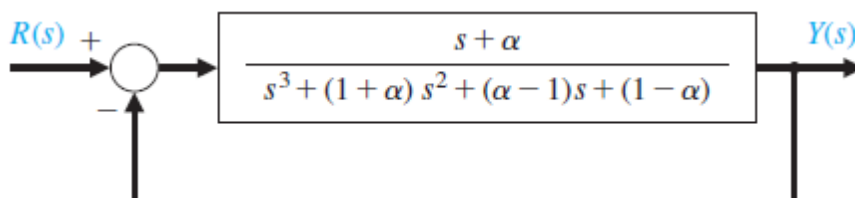
(b) $s^4 + 9s^3 + 30s^2 + 42s + 20 = 0.$

(c) $s^3 + 20s^2 + 100s + 200 = 0.$

5. A feedback control system has a characteristic Equation. Determine whether the system is stable and determine the values of the roots.

$$s^6 + 2s^5 + 13s^4 + 16s^3 + 56s^2 + 32s + 80 = 0.$$

6. A control system is shown in Figure. We want the system to be stable and the steady-state error for a unit step input to be less than or equal to 0.05. (a) Determine the range of α that satisfies the error requirement. (b) Determine the range of α that satisfies the stability requirement. (c) Select an α that meets both requirements.

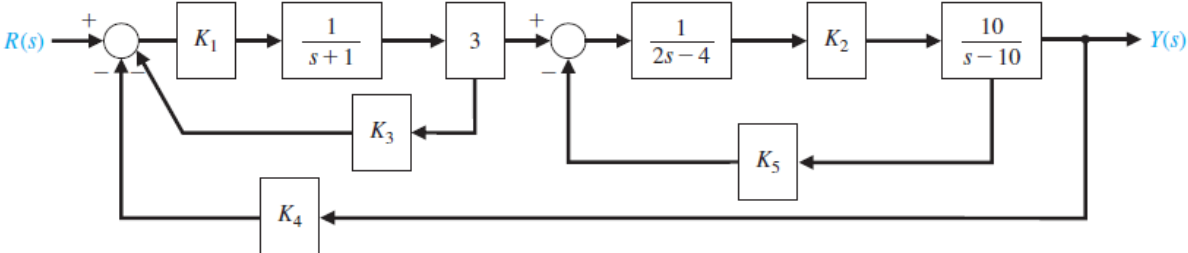


7. Consider the closed-loop system in Figure. Suppose that all gains are positive, that is, $K_1 > 0$, $K_2 > 0$, $K_3 > 0$, $K_4 > 0$, and $K_5 > 0$.

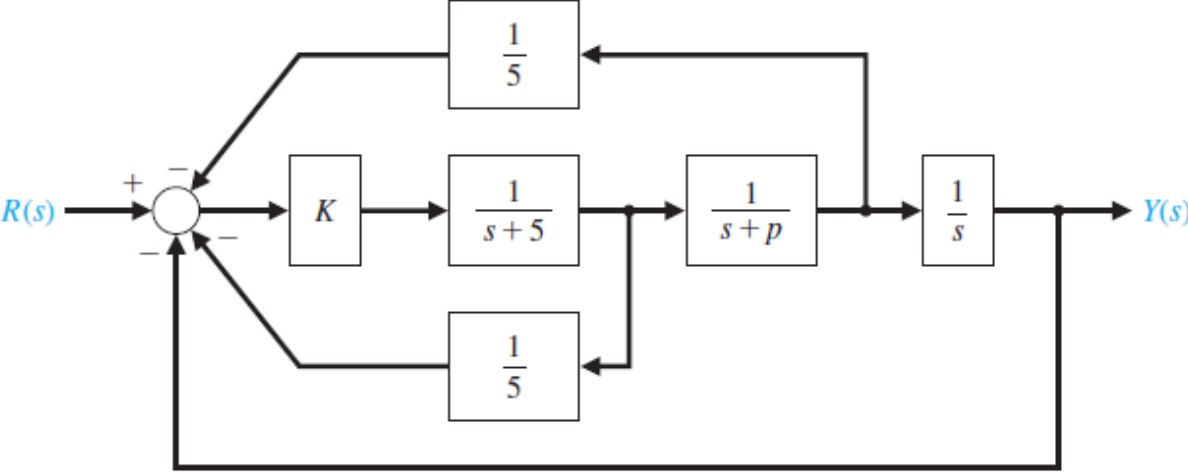
(a) Determine the closed-loop transfer function $T(s) = Y(s)/R(s)$.

(b) Obtain the conditions on selecting the gains K_1 , K_2 , K_3 , K_4 , and K_5 , so that the closed-loop system is guaranteed to be stable.

(c) Using the results of part (b), select values of the five gains so that the closed-loop system is stable, and plot the unit step response.



8. The control of the spark ignition of an automotive engine requires constant performance over a wide range of parameters. The control system is shown in Figure, with a controller gain K to be selected. The parameter p is equal to 2 for many autos but can equal zero for those with high performance. Select a gain K that will result in a stable system for both values of p .



2.Experimental Study:

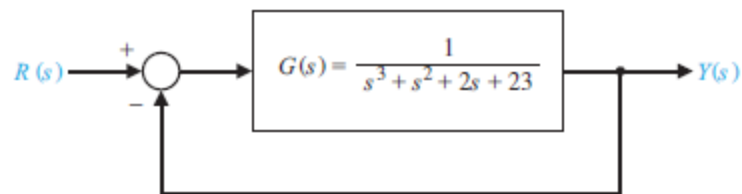
This section is given in two parts. The application in the first part (Repeat the Steps) is expected to be repeated by the student and to find the same result obtained. Thus, the student understands the subject and learns how to use it. In the second part (Do it Yourself), the jobs to be done are listed, but they are not explained how to do them. He solves and fills in the datasheet using the information (s)he learned in the first part and what he did in the preliminary study.

Look at the previous experiment's documents. Be sure you learn every step at the previous experiments. You may need the information from the previous experiment.

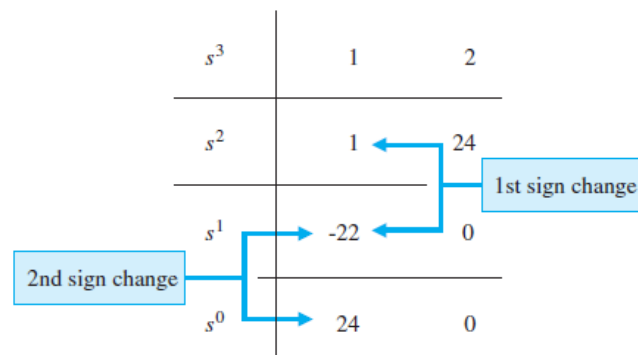
2.1. Repeat the Steps

Consider the characteristic equation and the corresponding closed loop system.

$$q(s) = s^3 + s^2 + 2s + 24 = 0$$

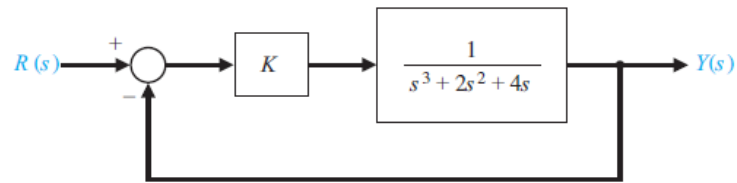


The two sign changes in the first column indicate that there are two roots of the characteristic polynomial in the right half-plane; hence the closed-loop system is unstable.

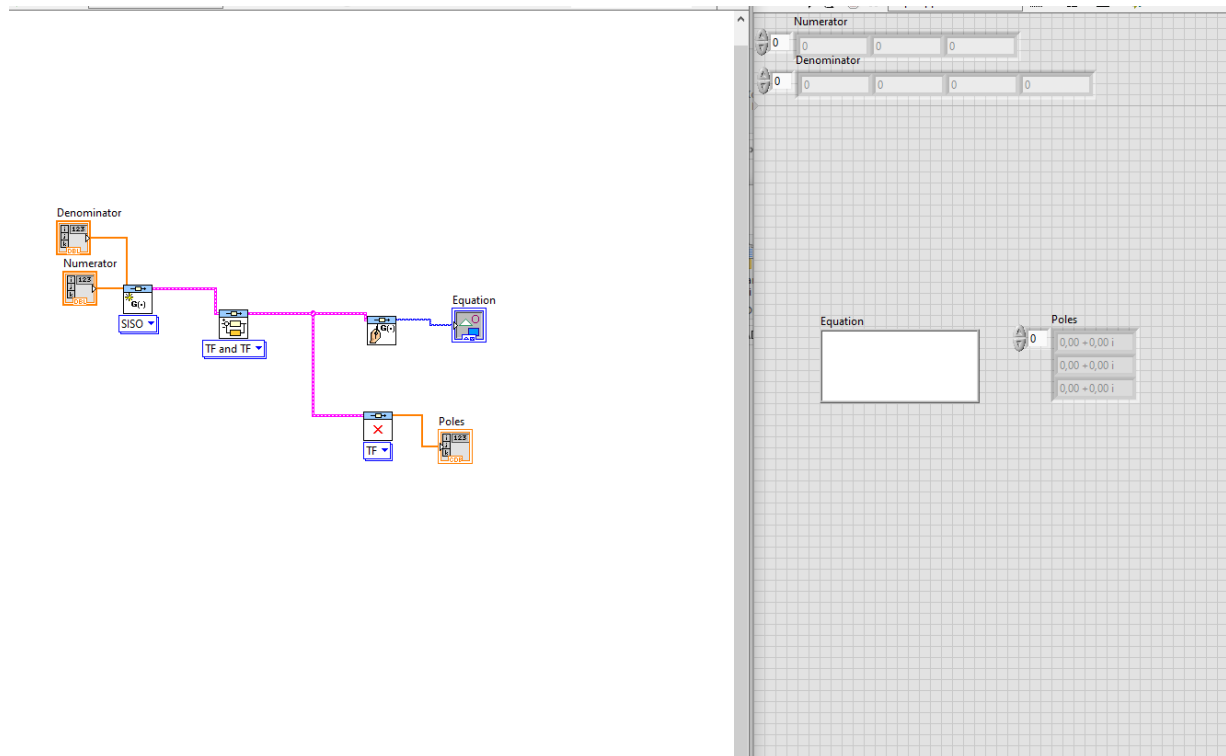


Using LabVIEW, we can verify the Routh–Hurwitz result by directly computing the roots of the characteristic equation using the CD Poles function. Recall that the CD Poles function computes the system poles. Whenever the characteristic equation is a function of a single parameter, the Routh–Hurwitz method can be utilized to determine the range of values that the parameter may take while maintaining stability. Consider the closed-loop feedback system in Fig. The characteristic equation is

$$q(s) = s^3 + 2s^2 + 4s + K = 0.$$



Construct the following block diagram and Front panel by using the previous knowledge from the previous experiments. You can observe the roots of the system given above.

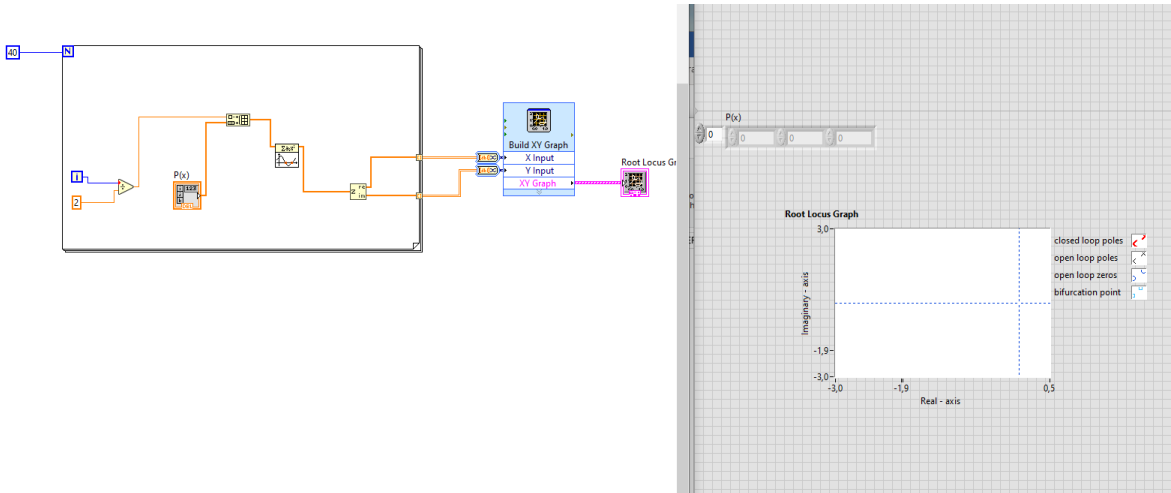


The associated Routh array is given by

$$\begin{array}{c|cc}
 s^3 & 1 & 4 \\
 s^2 & 2 & K \\
 s & \frac{8-K}{2} & 0 \\
 1 & K & .
 \end{array}
 \quad
 \begin{array}{l}
 8 - K > 0 \Rightarrow K < 8, \\
 K > 0 \Rightarrow K > 0.
 \end{array}$$

We can use LabVIEW to verify this result graphically. As shown in Fig, we establish a vector of values for K at which we wish to compute the roots of the characteristic equation. Then using the Polynomial Roots function, we calculate and plot the roots of the characteristic equation, as shown in Fig. As K increases, the roots of the characteristic equation move toward the right half-plane as the gain tends toward K = 8, and eventually into the right half plane when K > 8.

Now, construct the following block diagram and Front panel and obtain the position of the poles on s-plane.



2.2. Do it Yourself!

1. For all the problems in pre-work (questions 3-8). Make the LabVIEW codes by using the idea at “repeat the steps” part. Send LabVIEW files and report the roots and compare your results with the analytical results on the preliminary work.

Report:

1. Please answer all the questions give in experimental study.
2. The closed-loop characteristic equation is

$$q(s) = s^4 + 8s^3 + 17s^2 + (K + 10)s + aK = 0.$$

Use the Routh-Hurwitz to find range of K for stability.

3. (LabVIEW) The closed-loop transfer function

$$T(s) = \frac{70s + 42}{s^4 + 8s^3 + 17s^2 + 80s + 42}.$$