

AS-74. 3123 Model-based control systems
Exam 11. 12. 2014

The final grade is determined when the examination and the mandatory project assignment have been accepted. The (not mandatory) homework problems constitute one problem in the exam (the 5th problem).

4 problems.

1. Consider the multivariable 2 degrees-of-freedom control configuration shown in Fig. 1.

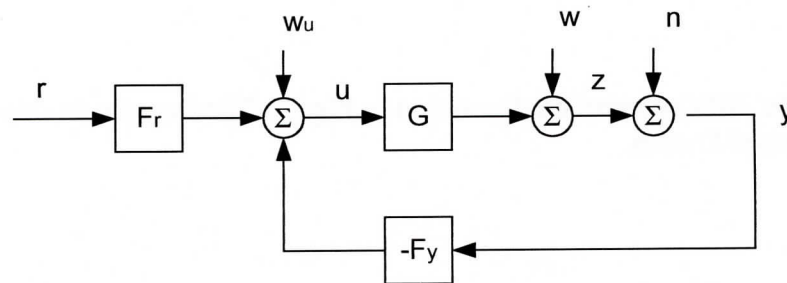


Fig. 1.

- a. Write expressions for the output variables z , $e = r - z$ and u as functions of the input variables r , w , n and w_u (Laplace domain).
- b. Define the *loop gain function*, *sensitivity* and *complementary sensitivity functions* and the *closed-loop transfer function*. Present and prove the relationship between the two sensitivity functions.

2. a. Let A and B be such matrices that the products AB and BA are both defined. Prove

$$A(I + BA)^{-1} = (I + AB)^{-1} A$$

This rule has a special name. What is it?

b. Explain shortly the concept *principle of optimality*?

c. What does *robust stability* mean? Explain and prove the following condition for robust stability (Hint: Using the Small gain theorem is one way, geometrical analysis an other)

$$\|\Delta_G T\|_\infty < 1$$

3.

- a. Explain shortly and present the necessary formulas also, what is *singular value decomposition* and *singular values*? If the transfer function of a MIMO system is $G(s)$, what do the singular values mean in terms of system characteristics? What are the control implications?
- b. Let a dynamic transfer function matrix be given as a *Matlab* object G . Explain the meaning of the following Matlab commands

```
G1 = minreal(ss(G));  
sigma(G1)
```

4. Consider the SISO control configuration in Fig. 2. The transfer function of the process is assumed known.

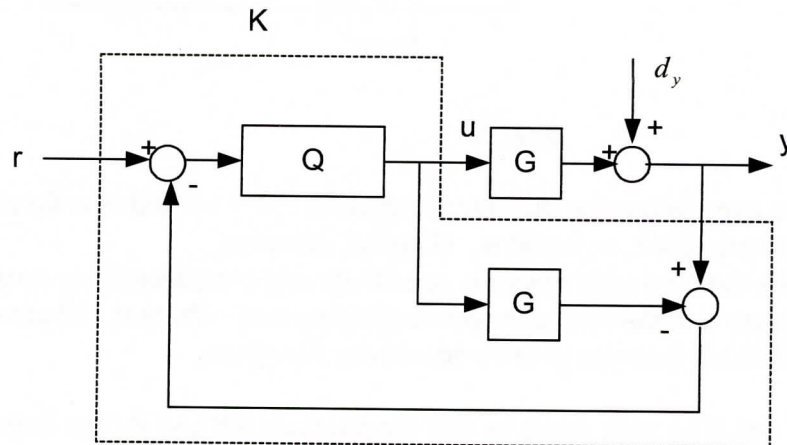


Fig. 2.

- a. What is the name of this control configuration? Describe its idea shortly, using the necessary formulas also.
- b. Let $G(s) = G_1(s)e^{-sT}$, where T is the constant delay of the process. Establish the connection of the above control structure to the so-called *Smith-predictor*? What is the idea of the Smith predictor? How is Q chosen then?