LAST NAME	
FIRST NAME	
MATRIKEL-NO.	

Problem 1

(2 points per subtask)

a) Describe the difference between closed-loop control and open-loop control by means of block diagrams.

b) What is a multivariable system?

c) What is the superposition principle and which basic dynamic property is caused through this?

d) Give the equation of the initial value theorem. What can be calculated with the initial value theorem?

e) Define mathematically:

   i) Pole of a transfer system,

   ii) Zero of a transfer system, and

   iii) Eigenvalue of a system.

Problem 2

(2 points per subtask)

a) For the description of SISO-Systems three different kinds of transfer behavior (proportional, differentiating, and integrating) can be distinguished. Give the related transfer function.

b) What is state stability of a system? Denote two methods for the analytical determination of stability.

c) A system with a PIT_3-transfer behavior is given. State the differential equation and the respective transfer function, which describes the transfer behavior.

d) The lateral dynamic of a vehicle can be described by a I-transfer behavior (parameter: $T_I = 1$). The related behavior of a driver can be described by

$$G_{Driver} = \frac{K}{1 + T_1 s} \cdot e^{-T_t s} \tag{2.1}$$

with $T_1 = 1$ s and $T_t = 1$ s. Sketch the bode plot of the open loop system with time delay. Is the system with $T_t = 0$ s stable? In which way the stability of the system changes with increasing time delay (e.g. intake of drugs or alcohol of the driver)?

e) A transfer system with PI-behavior is controlled by a system with PD-behavior. The feedback is positive. Determine the character (P, PI, PT_1...) of the disturbance transfer function, if the disturbance is assumed before the plant.

Problem 3

(15 points)

The control loop given in figure 3.1 with

$$F_\mathrm{S}(s) = \frac{1}{s^2 + 6s + 13}$$

has to be considered.

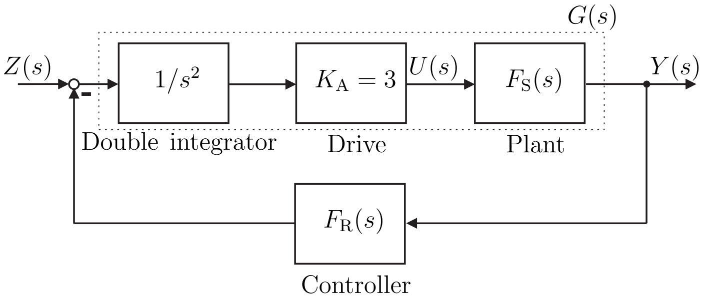

Figure 3.1: Block diagram of the closed-loop control loop

a) Firstly assume $F_\mathrm{R}(s)$ is a transfer element with P transfer behavior and amplification factor $K_\mathrm{P} > 0$. For sketching the root locus, calculate
- the corresponding transfer function $G(s)$ (cf. sketch) and
- its poles p_i and zeros p_{0i},
- the angles ϕ_i of the asymptotes and
- the root loci center s_Asymp,
- the intersection(s) with the imaginary axis $p_{\mathrm{Imag},i}$ and
- the corresponding value K_krit of the amplification factor

if possible.

b) Now sketch the root locus and use all the calculated values. Draw in all values clearly.

c) Also the velocity $\dot{y}(t)$ can be taken into account for control, i.e.

$$F_\mathrm{R}(s) = K_\mathrm{P}[1 + T_\mathrm{D}s] \ .$$

For a specific adjustment of the controller at the stability margin the closed loop system performs natural vibrations of $\omega = 2\,\mathrm{s}^{-1}$: Determine the used controller parameters T_D and K_P.

d) Sketch the root locus for the closed loop system with T_D from part c). Therefore do the same procedure as in part a) and b). Additionally calculate the **real** bifurcation points s_i. Use the phase condition to check if the calculated bifurcation points really belong to the root locus.
Hint: The rational roots of a polynom $f(x) = a_n x^n + \cdots + a_1 x + a_0$ with $a_i \in \mathbb{Z}$ are to be found among the fractions $\frac{a}{b}$ $(a, b \in \mathbb{Z})$, with a factor of a_0 and b factor of a_n.

Problem 4

(15 points)

The block diagram given in figure 4.1 has to be considered.

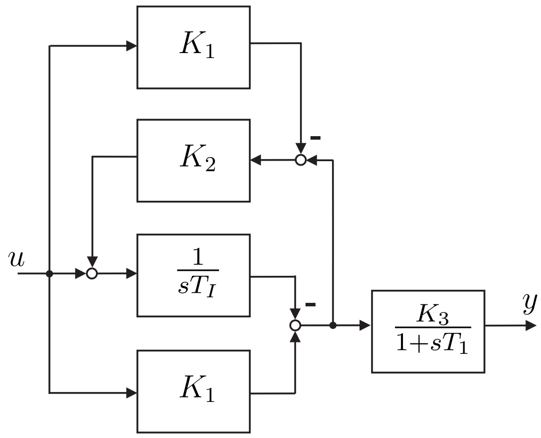

Figure 4.1: Block diagram

a) Calculate the transfer function $F(s) = \frac{Y(s)}{U(s)}$ and state it in the form

$$F(s) = A \cdot \frac{B - 1 + Cs}{(1 + sD)(E + sF)} \quad .$$

b) Use $K_1 = 1$ and $K_2 = 0.5$ for the system given in part a). Is it a phase minimum system? State reason.

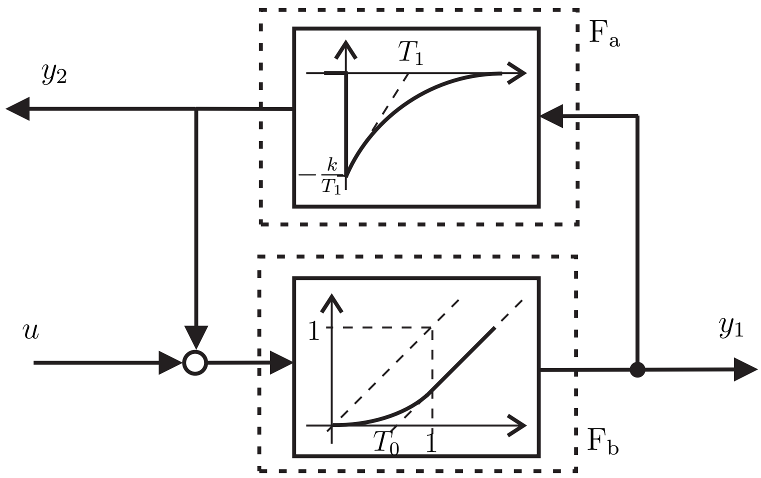

Figure 4.2: Block diagram

c) The system in figure 4.2 is given. Derive the transfer functions $F_a(s)$ and $F_b(s)$.

d) Derive the transfer functions $F_1(s) = \frac{Y_1(s)}{U(s)}$ and $F_2(s) = \frac{Y_2(s)}{U(s)}$.

e) Is the transfer behavior from u to y_1 asymptotically stable?

f) Assume $T_0 = T_1 = T$. For which real values of k has the transfer function $F_2(s)$ stable conjugated complex poles and for which does it have unstable poles?

Problem 5

(16 points)

a) The state space model of a system is given by

$$\begin{aligned}\dot{\boldsymbol{x}}(t) &= \begin{bmatrix} 4 & -2 \\ 5 & -3 \end{bmatrix} \boldsymbol{x}(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t), \\ y(t) &= \begin{bmatrix} 1 & 1 \end{bmatrix} \boldsymbol{x}(t).\end{aligned}$$

Calculate the eigenvalues of the system. ($\sqrt{2.25} = 1.5$)

b) The transfer function of the system in a) is

$$G_1(s) = \frac{1}{1+s}.$$

Is the system asymptotically stable? State reason!

Is the system I/O stable (BIBO)? State reason!

c) In Figure 3, the block diagram of a system of transfer elements is given.

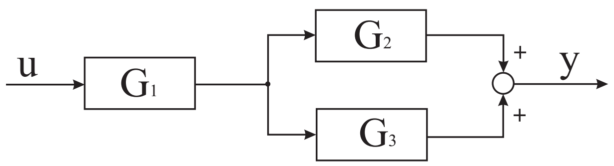

Figure 5.1: Block diagram

The transfer elements are

$$G_1(s) = \frac{1}{1+s}, \quad G_2(s) = \frac{2}{s+3}, \quad G_3(s) = \frac{2}{s-2}. \tag{5.1}$$

Set up the transfer function of the system. Determine the poles and zeros of the system. Is the system a minimum-phase system? State reason!

d) A P-transfer element with gain K_1 is taken as the controller for the system in c). Please determine the transfer function of the closed loop system with negative feedback according to the reference value. For which value of control gain K_1 is the closed-loop control asymptotically stable (use the Hurwitz-criterium)?

Use the transfer function (5.2)

$$G_s(s) = \frac{4s+2}{s^3 + 2s^2 - 5s - 6} \tag{5.2}$$

as the transfer function, if you could not find the one of the system in c).

Maximum achievable points:	**66**
Minimum percentage of points for the grade 1,0:	**95%**
Minimum percentage of points for the grade 4,0:	**50%**