



Lab 1, Matlab Simulations

IE1304 Control Theory

1 Introduction

Matlab is installed on the lab computers. You can also install Matlab on your own computer by downloading it from KTH ProgDist, see <http://progdist.ug.kth.se/public/>. Unfortunately only *Matlab*, *Simulink* and *Symbolic Toolbox* are included. The important toolboxes *Control Systems Toolbox* and *Signal Processing Toolbox* are no longer included.

1.1 Some useful Matlab commands

- Define the vectors x and y .
`x = [0 1 2 3 4 5 6 7 8 9]`
`y = [5 7 4 3 2 4 6 6 5 6]`
- Draw the graph $y = y(x)$.
`plot(x,y)`
- Show help for the `plot` command.
`help plot`
- Define the vectors t and u containing values in the range 0 to 10 with the interval 0.1 and values in the range 0 to 20 with the interval 0.2
`t=0:0.1:10`
`u=0:0.2:20`
- Multiply the elements with the same indexes in t and u . Note the dot before the multiplication which instructs Matlab to do the multiplication element by element instead of performing a matrix multiplication.
`v = t.*u`
- Draw the graphs $e^{-0.1} * t$ and $v(t)$ in the same figure.
`plot(t,exp(-0.1)*t,t,v)`
- Create a vector containing elements 3, 4 and 5 from the vector t .
`t1 = t(3:5)`



- Ending an instruction with a semicolon means that its result is not displayed.
`t1 = t(3:5);`
- Define the matrix **A**.
`A=[1 2; 3 4]`
- Transpose the matrix **A** and store the result in **B**.
`B= A'`
- Multiply the matrices **A** and **B**.
`C = A * B`
- Invert the matrix **C**.
`D = inv(C)`

2 Preparation tasks for Matlab, to be solved BEFORE the lab

Task 1

Read the basic parts of the Matlab introduction. You can find it in Matlab under the menu `Help -> Product Help`, choose `MATLAB` in the tree to the left. Tutorials can be found under `Getting Started` and `MATLAB Demos`.

Also read chapter 24, *Simulering av reglersystem med Matlab och Simulink*, in the course book.

Task 2

$$\mathbf{A} = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$$

Given the matrix **A** above, examine what the following Matlab commands do.

- `sum(A)`
- `diag(A)`
- `A(1:2,2)`

**Task 3**

Use the following matrices

$$\mathbf{A} = \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix} \text{ and } \mathbf{B} = \begin{bmatrix} 8 \\ 6 \end{bmatrix}$$

and solve the equation system $\mathbf{Ax} = \mathbf{B}$ using the operator `\`.
You can get help with the Matlab command `help \`.

Task 4

Which symbol is used for imaginary numbers in Matlab?

Task 5

What is the meaning of `NaN`?

Task 6

How is π written in Matlab?

Task 7

The differential equation

$$T \frac{dx}{dt} + x = u, \quad \begin{cases} T = \text{time constant} \\ u = 0, t < 0 \\ u = u, t \geq 0 \end{cases}$$

has the solution $x(t) = x(0)e^{-\frac{t}{T}} + u(1 - e^{-\frac{t}{T}})$. Choose $T = 1s, u = 10, x(0) = 0$ and perform the following tasks in Matlab.

- Plot $x(t)$ for the time frame $0 \leq t \leq 5s$.
- Plot in the same figure $x(t)$ when $T = 2s$.
- Plot in the same figure $x(t)$ when $x(0) = -2$.
- Plot in the same figure $x(t)$ when $u = 5$.

You can get help by looking at the Matlab help text for the instructions `plot` and `hold`.

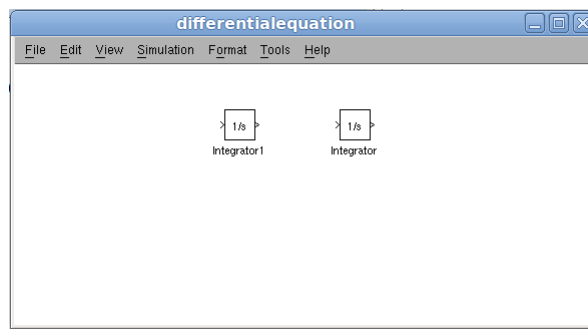


Figure 1: Simulink model with two integrators

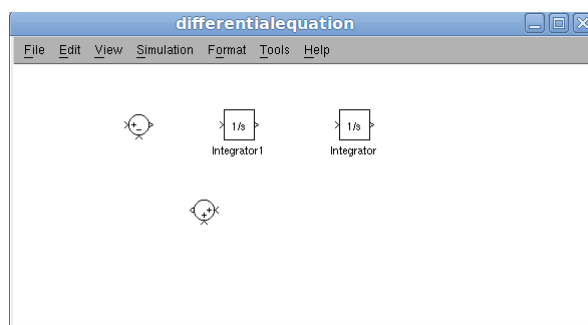


Figure 2: Simulink model with integrators and sums

3 Preparation tasks for Simulink, to be solved BEFORE the lab

Task 1

Simulate a differential equation in Simulink using the guide below.

1. Type `simulink` at the Matlab command prompt, Simulink Library Browser is opened.
2. Create a new model.
3. Choose the group **Continuous** in the tree to the left and drag two **Integrators** to it, see Figure 1.
4. Choose the group **Commonly used blocks** in the tree to the left and drag two **Sums** to the work space, see Figure 2. Double clicking on a **Sum** block opens the **Function Block Parameters** window where the Sums can be configured.
5. Next, two **Gains** are placed on the work space, see Figure 3.

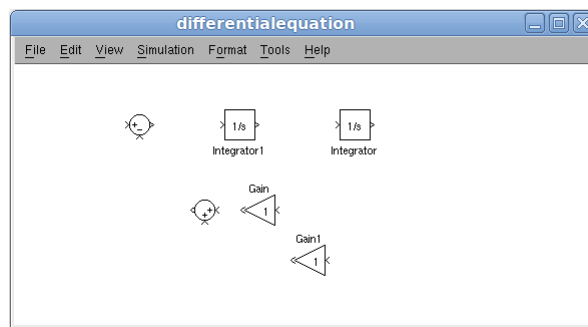


Figure 3: Simulink model with integrators, sums and gains

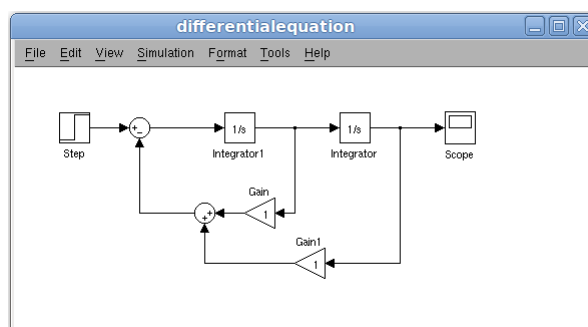


Figure 4: Complete Simulink model

6. Finally, add a **Step** from the **Sources** group and a **Scope** from the **Sinks** group and connect the blocks, see Figure 4. The **Step** will be our input signal and the **Scope** will enable us to watch the output.
7. Now it is time for the simulation. The simulation parameters can be adjusted in the **Configuration Parameters** window which is opened when you choose **Simulation -> Configuration Parameters** in the menu. In this case, there is no need to change any parameters.
8. Start the simulation by choosing **Simulation -> Start** in the menu and double click on the **Scope** to display the result. To zoom the curve properly, right click on it and choose **Autoscale**. The result should look like Figure 5.

Task 2

- a) Which differential equation did we simulate in the previous task?
- b) Verify the answer by creating the same model using a **Transfer Fcn** block (from the **Continuous** group) instead of **Integrators**, **Sums** and **Gains**. The **Transfer Fcn**

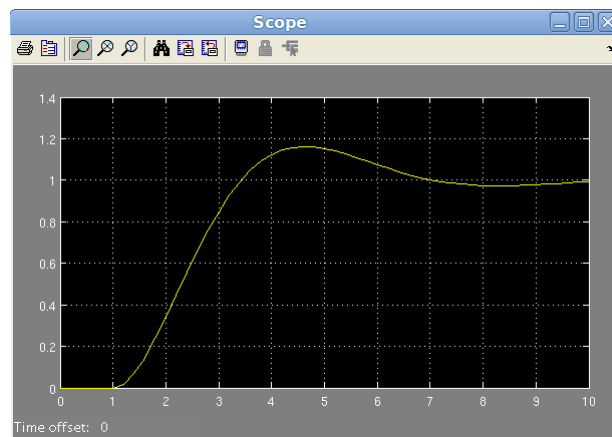


Figure 5: Simulation result

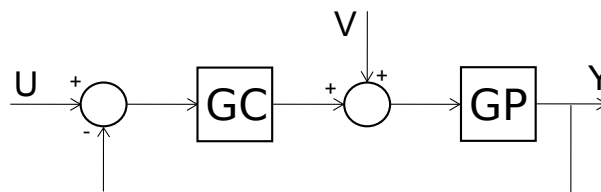


Figure 6: Feedback system used in task 4.1

should describe the Laplace transform of the differential equation.

4 Lab tasks, to be solved at the lab

Task 1

Use Simulink to simulate the system depicted in Figure 6, let $GC = K$, $GP = \frac{1}{s^3+3s^2+3s+1}$. Decide the following by simulating in Simulink.

- Maximum gain, K_{max} , before the system starts to oscillate.
- Steady-state error when $V = 0$, U is a unit step and K has the values 0 , $\frac{K_{max}}{4}$, $\frac{K_{max}}{2}$, $\frac{3K_{max}}{4}$.
- Steady-state error when V is a unit step, $U = 0$ and K has the values 0 , $\frac{K_{max}}{4}$, $\frac{K_{max}}{2}$, $\frac{3K_{max}}{4}$.

Task 2

Do the same as in the previous task, but set $GC = \frac{K}{s}$.

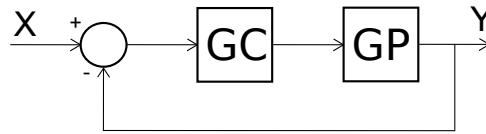


Figure 7: Feedback system used in task 4.3

Task 3

Use Matlab to draw the Bode diagram for the system depicted in Figure 7 with $GC = 2.5$ and $GP = \frac{e^{-s}}{1+2.5s}$ and decide if the system is stable. If so, decide the phase margin, Φ_m , and the amplitude margin A_m . The delay can be modeled in matlab by specifying GP as `GP=tf(1,[2.5 1], 'InputDelay',1)`.

Task 4

A heater process has the transfer function $G_P(s) = \frac{1}{(1+3s)^2}$. It is regulated by a controller with transfer function $G_C(s) = 3(1 + \frac{1}{2s})$. The sensor used to feed back the output signal has the transfer function $G_S(s) = 1$.

- Construct the system in Simulink.
- Simulate a unit step input signal. Measure maximum overshoot, settling time and rise time. Also check control input.
- Simulate a unit step disturbance. Again measure maximum overshoot, settling time, rise time and check control input.
- What type of controller is used?