Lab 1, Matlab Simulations

Jan Andersson and Leif Lindbäck

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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.

a) `sum(A)`

b) `diag(A)`

c) `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 $\mathbf{A}\mathbf{x} = \mathbf{B}$ 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.

a) Plot $x(t)$ for the time frame $0 \leq t \leq 5s$.

b) Plot in the same figure $x(t)$ when $T = 2s$.

c) Plot in the same figure $x(t)$ when $x(0) = -2$.

d) 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`.

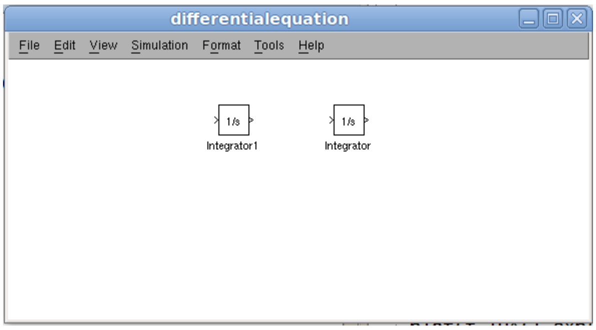

Figure 1: Simulink model with two integrators

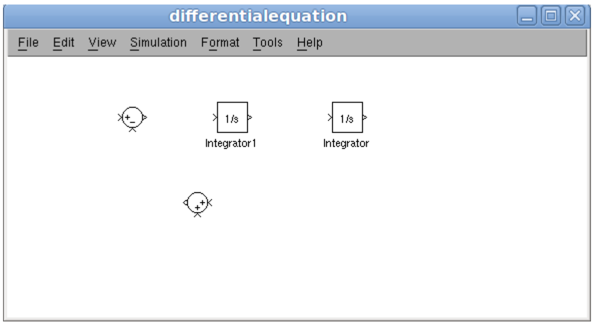

Figure 2: Simulink model with integrators and sums

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 `Continous` 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.

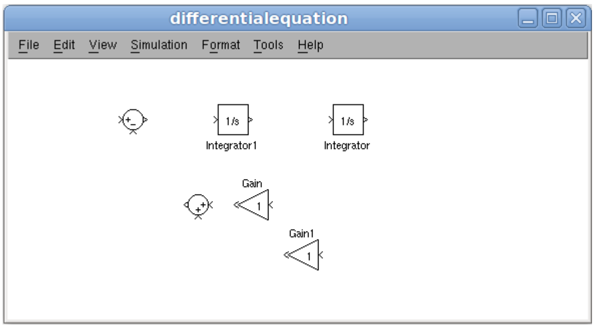

Figure 3: Simulink model with integrators, sums and gains

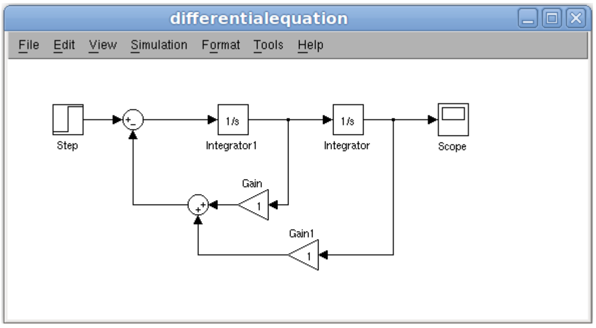

Figure 4: Complete Simulink model

5. Next, two `Gains` are placed on the work space, see Figure 3.
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?

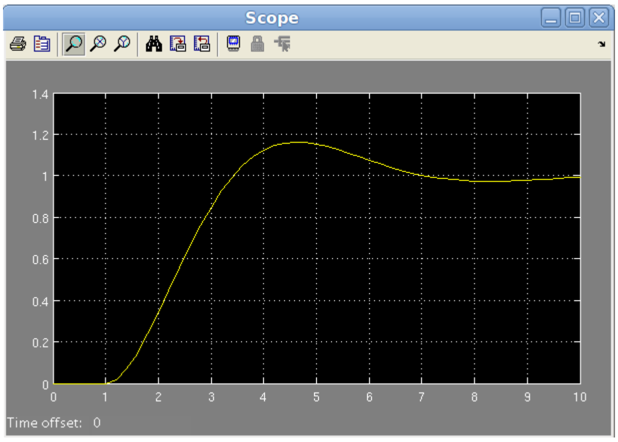

Figure 5: Simulation result

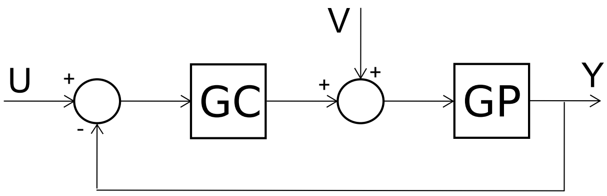

Figure 6: Feedback system used in task 4.1

b) Verify the answer by creating the same model using a `Transfer Fcn` block (from the `Continous` group) instead of `Integrators`, `Sums` and `Gains`. The `Transfer Fcn` 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.

a) Maximum gain, K_{max}, before the system starts to oscillate.

b) Steady-state error when $V = 0$, X is a unit step and K has the values $0, \frac{K_{max}}{4}, \frac{K_{max}}{2}, \frac{3K_{max}}{4}$.

c) Steady-state error when V is a unit step, $X = 0$ and K has the values $0, \frac{K_{max}}{4}, \frac{K_{max}}{2}, \frac{3K_{max}}{4}$.

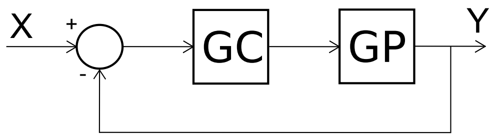

Figure 7: Feedback system used in task 4.3

Task 2

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

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 $G_S(s) = 1$.

a) Construct the system in Simulink.

b) Simulate a unit step input signal. Measure maximum overshoot, settling time and rise time. Also check control input.

c) Simulate a unit step disturbance. Again measure maximum overshoot, settling time, rise time and check control input.

d) What type of controller is used?