Exam 7 Dec. 2015

Exam info and rules

1. Any material is allowed. This includes books, lecture slides/notes, internet sources, usb sticks, model answers for the weekly exercises etc.

2. No communication with other students is allowed. Therefore, you should not have any use for cell phones and thus they are forbidden. Also using any form of communication with the computers (chats, facebook, email, pastebin etc.) is forbidden and is monitored. Communication leads to automatic failed exam. You are not allowed to use your own laptop computers.

3. The course staff will help you with any technical problems related to Matlab, Simulink and in preparing the files to be submitted. The staff does not help you in building the models or the scripts or applying the Matlab functions.

4. You must report to course staff (with your student ID) in the computer class when leaving the exam. If you fail to do this, the exam will not be graded.

5. All the answers will be returned as .pdf files into the download boxes of "Assignment" type exercises in MyCourses. This is the same type as for example exercise 6.3. No Word documents. This way you will see before submitting what you are submitting so there should be no technical problems. Make sure before the exam that you know how to make a .pdf file for example from Word or whichever typing program you want to use.

6. In the exam, you have to return answers for three exercises. There are five exercises available. If you for some reason return more than three exercises, your grade will be calculated from the ones with the worst grades. Therefore, if you submit more than three exercises, make sure to mark clearly the exercises that you do not want to be graded. The assignments have unlimited attempts so you can revise an already submitted assignment by returning it again. Be 100 % sure that you have properly submitted the answers before leaving the exam.

7. The questions can be answered either in English or in Finnish.

8. 40 % of maximum points are required to pass the exam. The maximum grade for each exercise is 10 points.

9. Bathroom breaks are ok after asking for a permission. One student at a time.

Complete either Q1 or Q2. Not both.

Q1

Describe the structure and components of a generic mechatronic machine. How do they connect with each other and what kind of requirements do they usually have?

You can use examples, graphs and images.

Return the answer as .pdf file.

Q2

A factory needs an automation system for a bottling line.

Empty white plastic bottles are brought by the workers next to a conveyor line in cardboard boxes. The automation system should pick up the bottles from the boxes and lift them on the conveyor line. The lids of the boxes are already opened and the boxes are less than a meter away from the conveyor line. The bottles are transferred along the conveyor line to a spot where a liquid is injected into them. After that, a screw top is twisted on the bottles.

What kind of sensors and actuators does a production line such as this require? Choose appropriate actuators for gripping and moving the bottles from the boxes onto the conveyor, for driving the conveyor, and for mounting the screw top. Choose also suitable methods for guiding the actuators to the correct gripping and mounting positions and for checking that the operations were correctly executed.

It is not required, but you can use for example Powerpoint or even Paint to draw a schematic of the bottling line. Return your answer as .pdf file.

Complete two from Q3, Q4 and Q5.

Q3

An elevator drive system consists of a DC motor, a gear attached to it, cable drum and the elevator car itself.

Assume that the DC motor can produce a constant torque of 48 Nm during the lifting operation. Optimize the cable drum diameter with Simulink and Matlab so, that the elevator car travels a distance of 2m upwards as quickly as possible. You do not have to care about the velocity of the car when the 2 m distance is reached. Show your model, code, optimized drum diameter and plot the velocity of the car.

- Assume that the cable drum is a cylinder made of steel with a density of 7850 kg/m3̂. The cylinder is 40mm wide.

- The mass of the elevator car is 200 kg.

- The maximum rotating speed of the motor is 1600 rpm.

- The gear ratio of the gear is 18.3.

- The optimized drum diameter should be between 0...1m.

- Simulation time of 10s should be fine.

- You can try to restrict the maximum step size if there are some convergence problems.

Return a .pdf file with an image of your model, the answers and the plot. Return also your model file and the script(s).
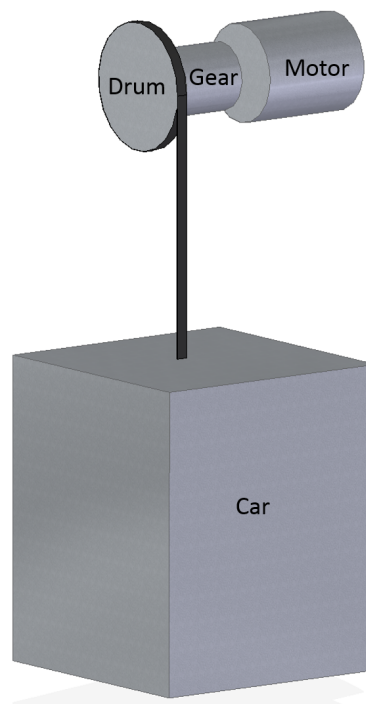
Q4

You have a positioning system where an electric motor rotates a ball screw which moves a slider. There is a gear box with a gear ratio of 10 between the motor and the ball screw. The pitch of the ball screw is 5 mm. The length of the slider's movement from end to end is 400 mm and the maximum velocity of the slider is 200 mm/s.

You need to design a position measurement system with the best possible resolution using the following components.

- Linear 0-10 kOhm (linear scale) potentiometer with a 500 mm stroke

- Rotary optical incremental encoder with 150 pulses (slots) per revolution

- Linear optical incremental encoder with 10 pulses (slots) per millimeter

- A microcontroller with the following properties:
  12-bit AD-converter with ground as the lower reference voltage and an input pin where an upper reference voltage can be supplied
  16-bit counters with PWM output
  General purpose input pins which can trigger interrupts from rising and falling edges
  The microcontroller can process up to 15000 input interrupts per second

How would you realize the measurement system (explain with words or diagrams, no microcontroller code required)? Calculate the resolution in micrometers for each method of utilizing these sensors (one sensor at a time), taking to account the limitations of the measurement system. What are the benefits and downsides of each sensor type.

Return your answer as .pdf. Include the equations in the .pdf in a readable format. A readable format is either made with equation editor or a Matlab script with very clearly named variables. If you are using matlab scripts, include also the script file.
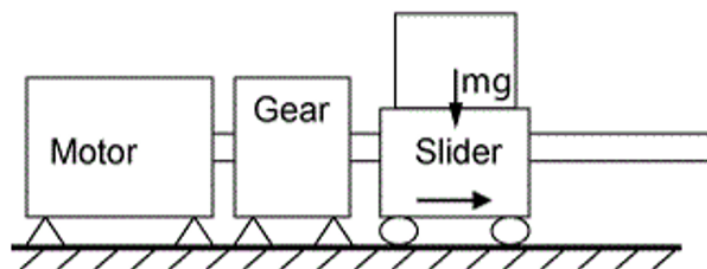
Q5

Input signal corrupted by noise is given in file noisydata.mat (available at the bottom of the page). Plot the fourier transformation of the signal (the interesting part) and analyze, which are the main frequency components of the original signal. Remove the high frequency noise, reconstruct the signal and plot the resulting signal on top of the original signal (in different colors, reconstructed on top).

What kind of an analog input filter and sampling frequency would you use when measuring this kind of a signal? Why?

- The sampling rate of the signal is 8 kHz.

- You can use for example 'load'-function for importing the data to the matlab workspace. You can also just drag the file on top of Matlab window to import it.

- In frequency domain, you should use a normalized x-axis to find out the real signal frequencies: F = ((0:1/NFFT:1-1/NFFT)*Fs).'; where NFFT stands for number of data points in the signal ("length" function) and Fs for the sampling rate of the signal.

- When plotting the signals in time domain, remember to define a proper x-axis for them. Otherwise the data may be plotted in a wrong way.

Return your answer in a .pdf file, with all the required plots. Include also the Matlab script file you used.