Advanced Mechatronics System Design – MANU 2451

Final Exam (Semester 1, Year 2018)

Question 1 (3 Marks)

Assume you are a Mechatronics designer in a company which produces consumer appliances. You are asked to design a 3D printer.

a. Provide a rough sketch of the 3D printer, along with the required sensors and actuators. You should label the sensors and actuators clearly in your sketch (1 Mark)

b. Name one sensor which you would install on the 3D printer, and explain the purpose of the sensor. (1 Mark)

c. Name the type of motor which you would use to move the printer head in its axis of motion. Justify the choice of the motor. (1 Mark).

Question 2 (7 Marks)

An infrared range sensor has the following Voltage – Distance curve:
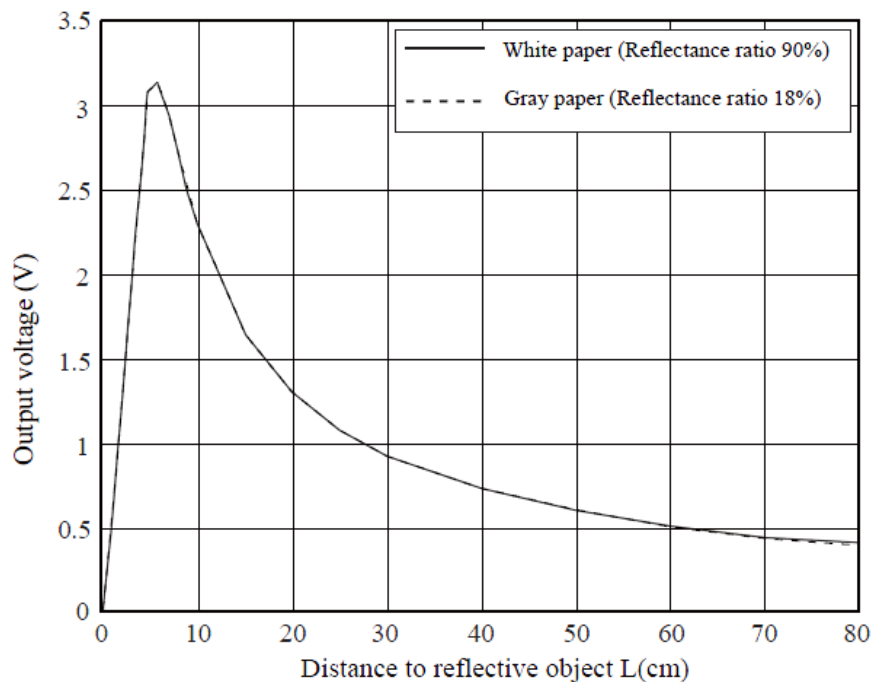
Please focus only on the solid line (White paper).

a. What are the TWO possible values of distance, when the sensor provides an output voltage of 1V? Note: The grids of the graph are not very fine, thus an approximate value within a ± 2 range from the exact answer is acceptable. (1 Mark)

b. In a few sentences, describe how you would make sure that you have only one distance value, instead of having the ambiguity of two possible values. You may use sketches to help explain your answer. (2 Marks)

c. Calibrate the IR range sensor for the range of 10cm to 60cm. In other words, find an equation relating the distance and the voltage. You should show the steps required to perform the calibration, as well as calculate and provide numerical values in the equation. (4 Marks)

    Note for C: When reading up the values of voltage from the graph, just give a rough but good estimate. It might affect the final numerical values in the equation but that is alright. What is more important is showing that you understand the steps of calibrating the IR sensor.

Question 3 (4 Marks)

a. Give two disadvantages of using a strain gauge in a quarter Wheatstone Bridge. (2 Marks)

b. How can you solve the two issues which you identified in part a? Justify your answer. (2 Marks)

Question 4 (6 Marks)

a. Explain the working principle of a solenoid. Use sketches to help with the explanation. (2 Marks)

b. What is a solenoid primarily used for? (1 Mark)

c. Explain the working principle of a voice coil actuator. Use sketches to help with the explanation. (2 Marks)

d. Give two advantages of the voice coil actuator. (1 Marks)

Question 5 (7 Marks)

a. Provide a sketch of the parts within a permanent magnet DC motor. You should label the parts clearly in your sketch. (2 Marks)

b. If the permanent magnet is replaced by electromagnet, what are the two types of motor which we can get? (1 Mark)

c. Explain the difference of the two types of motors which you stated in part b, in terms of the wire connection. (1 Mark)

d. Give one advantage for each of the electromagnet motors above. (1 Mark)

e. Give one disadvantage for each of the electromagnet motors above. (1 Mark)

f. Which of the two electromagnet motors can be powered using alternating current? (1 Mark)

Question 6 (7 Marks)

a. Provide a sketch of a one-axis positioning stage, which is actuated by a Piezo stack. You should label the parts clearly in your sketch. (2 Marks)

b. If d_{33} = 0.5 nm/V, and the Piezo stack consists of 100 Piezo elements, how much is the voltage needed to achieve a stroke of 10 micro meters? Show your work out, not just the final answer. (2 Marks)

c. Name two issues with Piezo actuators. (1 Mark)

d. The Piezo actuator has a lowly-damped structural mode, and the transfer function of the Piezo actuator is:

$$G = \frac{\omega^2}{s^2 + 2\xi_{small}\omega s + \omega^2}$$

How would you reduce the oscillations when the actuator is being actuated? Give not only the "name" of the solution but also a transfer function associated with it. (2 Marks)

Question 7 (6 Marks)

a. Name two signal conditioning processes which are often required before measurement of a signal. (1 Mark)

b. If the highest frequency component in a signal is expected to be 100 Hz, what is the minimum sampling frequency that your measurement device should have? Explain your answer, along with the name of the theorem which you use to arrive at this answer. (2 Marks)

c. A sensor provides an analog signal in the range of 0V to 0.2V. At the same time, the data acquisition (DAQ) device has an analog input range of 0 to 5V. Sketch a circuit which would help you make full use of the DAQ input range when using the sensor. You should label the circuit components clearly, and also provide sample values for the components. (3 Marks)