

# Advanced Mechatronics System Design – MANU 2451

Final Exam (Semester 1, Year 2017)

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## Question 1 (3 Marks)

Assume you are a Mechatronics designer in a company which produces consumer appliances. You are asked to design an automated / robotic vacuum cleaner.

- Provide a rough sketch of the vacuum cleaner, along with the required sensors and actuators. You should label the sensors and actuators clearly in your sketch (1 Mark)
- Name one sensor which you would install on the vacuum cleaner, and explain the purpose of the sensor. (1 Mark)
- Name the type of motor which you would attach the wheels to, in order to move the vacuum cleaner around the floor. Justify the choice of the motor. (1 Mark).

## Question 2 (2 Marks)

One uses an ultrasonic range finder to determine the distance from the sensor and an object. The time duration between sending out a sound wave and receiving the reflected sound wave is 0.2 seconds.

- What is the distance between the sensor and the object? Assume the speed of sound in air is 345 m/s. Show your work out, not just the final answer. (2 Marks).

### Question 3 (6 Marks)

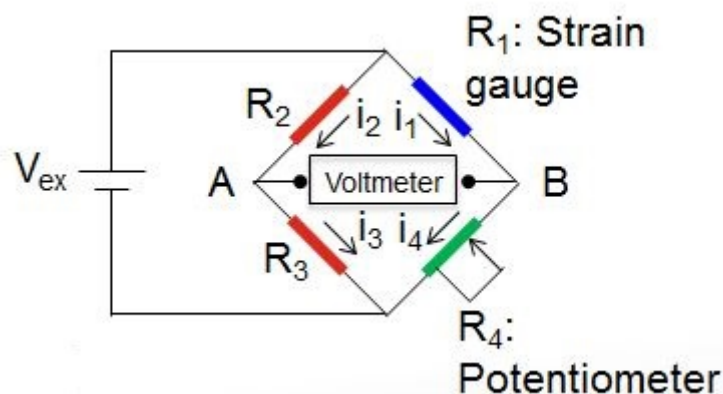
An encoder has 120 pulses per revolution.

- What is the best resolution of the encoder, assuming that it has only one channel? Show your work out, not just the final answer. (2 Marks)
- What is the best resolution of the encoder, if it has both Channel A and Channel B? Show your work out, not just the final answer. (2 Marks)
- Explain how you can determine the direction of rotation (clockwise or anticlockwise), if you use the encoder in the “x4 logic” mode. (2 Marks)

### Question 4 (6 Marks)

A strain gauge has a gauge factor of 2, and its original resistance (without being stretched or compressed) is 100 Ohms.

- The above strain gauge is connected in a quarter-bridge circuit, as shown in the following figure:



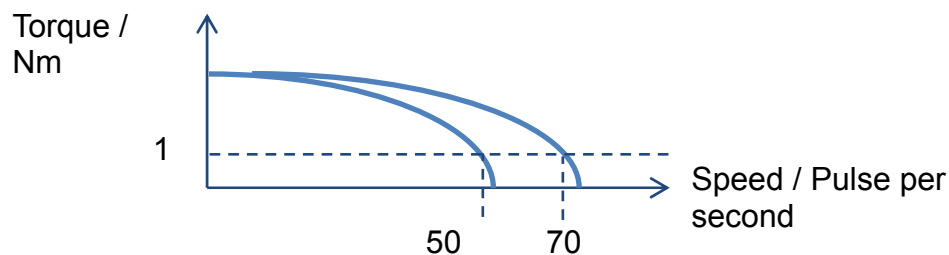
$R_2$  has a value of 20 Ohms and  $R_3$  has a value of 40 Ohms. A fixed load is applied, and the potentiometer  $R_4$  is tuned until the voltmeter shows 0V. At this point, the potentiometer  $R_4$  has a resistance of 202 Ohms.

What is the resistance of the strain gauge,  $R_1$ , at this moment? Show your work out, not just the final answer. (2 Marks)

- How much strain does the object, in which the strain gauge is attached, undergo? Show your work out, not just the final answer. (2 Marks)
- The strain gauge may give faulty measurements if there is a change in temperature. Provide a rough sketch on how this issue can be avoided, and explain how this works. (2 Marks)

### Question 5 (7 Marks)

- What is the main difference between a stepper motor and a brushless DC motor. (1 Mark)
- A stepper motor has 4 coils (A, B, A-bar and B-bar). The rotor is made of permanent magnet with one North pole and one South pole. Explain the working principle of this motor under the “2-Phase Full-Step Drive” operation. (2 Marks)
- The torque-speed curve of the stepper motor is shown in the following figure:



- If the motor is carrying a load of 1Nm, can it achieve the speed of 40 pulses per second instantly from rest? If no, what should be done to reach the speed of 40 pulses per second? (2 Marks)
- If the same motor is carrying a load of 1Nm, can it achieve the speed of 60 pulses per second instantly from rest? If no, what should be done to reach the speed of 60 pulses per second? (2 Marks)

### Question 6 (7 Marks)

- A permanent magnet DC motor has a stall torque of 1Nm, and a no-load speed of 200rpm. If the motor is required to run at 50 rpm, what is the maximum torque it could provide? Show your work out, not just the final answer. (2 Marks)
- Provide a “physical” sketch (not “circuitry”) of a series motor. (1 Mark)
- Provide a “physical sketch (not “circuitry”) of a shunt motor. (1 Mark)
- Which of the above (permanent magnet DC motor, series motor, shunt motor) can be used when given an alternating current? Explain why this particular motor can still work when given the alternating current. (3 Marks)

## Question 7 (5 Marks)

You have attached a speed sensor to a DC motor, and you would now like to design a controller to command the DC motor to rotate at a desired speed.

The controller is of type PID, with three parameters ( $K_p$ ,  $K_i$  and  $K_d$ ) to tune.

- a. Provide a sketch of the control loop. (2 Marks)
  - Just label the block for DC motor as “DC motor”, and there is no need to write the transfer function of the DC motor in this sketch.
  - However, please sketch out all individual components of the PID controller.
- b. Explain how you would tune the  $K_p$ ,  $K_i$  and  $K_d$  parameters. You can follow the following format: (3 Marks)
  - First, set all  $K_p$ ,  $K_i$  and  $K_d$  to zero.
  - Then, increase / decrease \_\_\_\_ until \_\_\_\_.
  - Next, increase / decrease \_\_\_\_ until \_\_\_\_.
  - Finally, increase / decrease \_\_\_\_ until \_\_\_\_.

## Question 8 (4 Marks)

- a. What is the meaning of “spontaneous polarization” in Piezo materials? (1 Mark)
- b. Explain why  $\text{SiO}_2$  (Quartz Crystal) does not exhibit spontaneous polarization. (1 Mark)
- c. A Piezoactuator stack has 100 Piezo elements. A voltage of 50V is applied to the surfaces of all the Piezo elements. The strain coefficient  $d_{33}$  has a value of 0.3 nm/V. How much is the stroke of the Piezoactuator stack? Show your work out, not just the final answer. (2 Marks)