AY1516

Q4.

It is decided that Microchip TC77 digital temperature sensors (See Appendix A for datasheet) are suitable for the air-conditioning control system as described in Q3. An Arduino UNO MCU is used to interface with 2 units of TC77 temperature sensor (front seat and backseat).

a) Sketch a schematic diagram to show a possible connection between the MCU and two units of TC77 temperature sensors using SPI serial communication protocol.
(10 marks)

b) Does the TC77 temperature sensor support I^2C serial communication protocol?
(1 marks)

c) What is the temperature sensing resolution of the TC77 temperature sensor?
(2 marks)

d) How many bytes would be needed to hold a piece of temperature data in the MCU?
(2 marks)

e) What is the digital equivalent of temperature at 30°C? Express your answer in binary.
(4 marks)

f) Should the TC77 temperature sensor be configured to operate in Shutdown mode or Continuous Conversion mode? Explain your answer.
(3 marks)

g) What would be the content of the TC77 Configuration Register (CONFIG) if continuous conversion mode is used? Express of answer in hexadecimal.
(3 marks)

AY1718

Q2.
A mechatronics engineer wishes to develop an intelligent clothe iron that has the following features:

(i) When the iron is switched on, the user may select either “Manual” or “Auto” mode of operation.

(ii) In “Manual” mode, the iron performs like a typical consumer iron.
- The user may select “Low Heat” or “High Heat” operation for ironing.

(iii) In “Auto” mode, the iron has added intelligence in its operation.

- When the iron is in upright position, i.e. not ironing clothes, it is automatically set to “Low Heat”.
- When the iron is in horizontal position and in motion (i.e. the iron is in operation), it is automatically set to “High Heat”.
- When the iron is in horizontal position and not in motion for 10s, it is automatically set to “Low Heat”; and when it stays motionless for 20s, the heat level will be set to “Off” to prevent the hot iron from burning the clothe or ironing pad.

(ii) There is a user-select “Steam” function, which let out small amount of slightly pressurized steam from an array of holes on the iron surface.
- In “Auto” mode, the Steam function cannot be activated when the iron is in upright position.
- In “Manual” mode, it can be activated by the user at all time.

It is decided that an Arduino UNO MCU is to be used to control the intelligent iron. Sketch a schematic block diagram to show your design of the control system for this application. Indicate and describe clearly in your diagram all the mechatronic components (Arduino UNO MCU, sensors, actuators, I/O devices, interfacing devices, power sources, etc.) and their relationships. You may assume there is an onboard DC power supply, which can supply regulated 5V – 12VDC. Your answer need to specify only the component type, information on the make and model of components are not necessary.

(25 marks)

Q3.
A special ride in an amusement park is a merry-go-round (rotation about the vertical axis) with seats that would tumble ±360° about the horizontal axis. A ST LPY503AL dual axis gyroscope (refer to the Appendix for datasheet) is used with an Arduino UNO MCU to sense the two rotations.

a) Given that the vertical axis and horizontal axis rotations have maximum angular velocities of -0.45 rad/s and 1.00 rad/s respectively. Calculate the digitized value of the maximum angular velocities converted by the ADC of the MCU. Convert the answers to Hexadecimal. Assume the data is acquired at 25°C.

(8 marks)

b) What would the answers in (b) be if the data is acquired in deep winter at -25°C? Convert the answers to Hexadecimal.

(6 marks)

c) From the datasheet, adding an external lowpass filter to the interface circuit is recommended and an external highpass filter is optional. Do we need a highpass filter for this application? Briefly explain your answer.

(2 marks)

d) Sketch a schematic diagram to interface the gyroscope with an Arduino UNO MCU for this application.

(9 marks)

AY1819

Q2.
The NTU Student Union has proposed to launch a powered mobility device (PMD) sharing plan on campus. They have secured a sponsorship of a fleet of 50 PMDs which look similar to the one in Figure 1. The original controller of a PMD has only the following components:

- 1 x 100 Ah 12V battery
- 1 x 1.0 kW DC motor
- 1 x DC motor controller running on 12VDC
- 1 x throttle (potentiometer)
- 1 x mechanical brake activated manually by a lever, similar to that of a bicycle.

Figure 1A powered mobility device.

The NTU Student Union is seeking help from a mechatronics engineer to reengineer the controller to have the following functions:

- To power on the PMD with an APP via Bluetooth. The App only allows registered users to log on with a valid NTU ID.
- To limit the speed of the PMD to 10 km/h.
- To have a 5 inch TFT LCD as a user interface to display user information, speed and battery status.
- To have a LED headlight, controllable by a toggle switch.
- To have a LED taillight that lights up when the brake lever is depressed. The taillight will blink when the headlight is turned on; this Night mode does not affect the function of the taillight as a brake indicator.
- To have a horn, controllable by a pushbutton switch.

It is decided that an Arduino UNO MCU is to be used to control the PMD. Sketch a schematic block diagram to show your design of the control system for this application. Indicate and describe clearly in your diagram all the mechatronic components (Arduino UNO MCU, sensors, actuators, I/O devices, interfacing devices, power sources, etc.) and their relationships. You may make appropriate assumptions to add new components and/or reuse and modify old components of the original controller, but you need to state them clearly. Your answer need to specify only the component type, information on the make and model of components are not necessary.

(25 marks)

AY19/20

Q1)

As depicted in Figure 1, a thermocouple with a sensing resolution of 1.0°C senses the temperature of a chamber, T (°C) and outputs a voltage, V_T which ranges from 0.0 V – 5.0 V. The voltage output terminal is connected to an analog input pin of an Arduino UNO MCU and stored in a 16-bit integer named $D1$. The same terminal is also connected to another external ADC with 5-bit resolution. The digitized output is sent serially to a digital input pin of the Arduino UNO MCU and stored in a 8-bit integer named $D2$. LED1 and LED2 are associated with $D1$ and $D2$ respectively and will be turned on when the digitized T reaches a certain threshold. Assume that there is no noise in the signals.

(a) If T ranges from -10°C to 200°C, what is the scale factor of the thermocouple in term of mV/°C?

Look at the unit for hint (2 marks)

(b) For T = 100°C, answer the following questions:

(i) What are the digital equivalents of T for $D1$ and $D2$? Give your answers in Binary form.

(7 marks)

(ii) Will your valves for $D2$ be different if T = 99°C? Explain your answer.

(4 marks)

(c) With threshold temperature T_T set at 100°C, when T rises from 50°C to 120°C, which LED will be turned on first? Support your answer with calculations.

(9 marks)

(d) When T drops from 120°C back to 50°C, which LED will be turned off first? Explain your answer.

(3 marks)

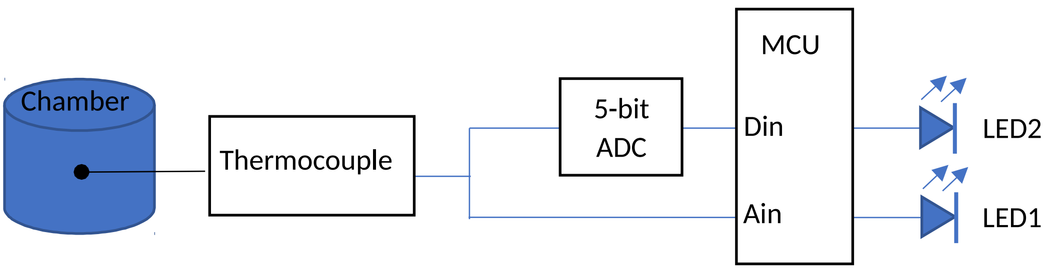

Figure 1: Thermocouple interface with MCU via 2 Analog-to-Digital Converters.

4. It has been decided that the Lightwave SF02 Laser Range Finder is to be used in the application described in Question 3. The datasheet is provided in Appendix A.

(a) Sketch a schematic diagram to show a possible interface of a pair of sensors with an Arduino UNO MCU using the Analog output mode.

(3 marks)

(b) The two Laser Range Finders are mounted 0.6m apart on the laser scanning device. Using the Lightwave Terminal Menu as shown on Page 10, Figure 14 of the datasheet to configure the sensors: Item a “Zero datum offset” is set to –0.3m, Item c “Analog 3.3V distance” is set to 20.0 m and Item d “Analog 0.0V distance” is set to 0.0 m.

(i) If both the sensors are tilted to the horizontal position, Sensor 1 outputs 2.5V and Sensor 2 outputs 1.5V, what is the measured width of the cave?

(7 marks)

(ii) What is the estimated maximum measured error in (i) with these settings?

(3 marks)

(c) The sensor also supports serial and digital interfaces.

(i) Sketch a schematic diagram to show a possible interface of a pair of sensors with an Arduino UNO MCU using the serial interface (Tx/Rx). You may also add words, if needed, to describe the connections or the necessary steps to set up the communications.

(6 marks)

(ii) Sketch a schematic diagram to show a possible interface of a pair of sensors with an Arduino UNO MCU using the digital interface (I2C). You may also add words, if needed, to describe the connections or the necessary steps to set up the communications.

(6 marks)

AY21/22

Q4

The datasheet of a mass flow meter – Renesas FS1012 is provided in Appendix A. The mass flow meter is interfaced with an Arduino UNO MCU for measurement data acquisition.

(a) Referring to Fig. 1 and Fig. 2 of the datasheet, describe the steps to calibrate out offset output voltage in the following signal conditioning implementations:

(i) Single-Ended Circuit

(6 marks)

(ii) Differential Circuit

(3 marks)

(b) For the applications as described in Questions 2 and 3,

- Orange Juice Vending Machine, as described in Question 2, the typical flowrate while filling a cup with freshly squeezed orange juice is 0.05 – 0.30 litre / min;
- Factory Chemical Consumption Monitoring System, as described in Question 3, the typical flowrates of both manufacturing lines range from 0 – 0.60 litre / min;

if only 1 model is to be selected for both cases, state and explain your recommendation.

(3 marks)

(c) For the model which you have recommended in Part (b), if Single-Ended Circuit is used with a gain of 50x, calculate the digitized value of zero flowrate measurement. Express your answer in hexadecimal.

Note: You may assume the Flow Curves on page 4-6 of the datasheet are based on calibrated (i.e. zero offset) values.

(6 marks)

(d) If higher sensing resolution is desirable, would you recommend setting the amplifier gain to 100x in the applications described in Part (c)? Explain your answer.

(4 marks)

(e) Would your answer in Part (c) be different in the Differential Circuit is used? Explain your answer.

(3 marks)