The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 3 MODULE, AUTUMN SEMESTER 2021-2022

COMPUTER ENGINEERING AND MECHATRONICS

Time allowed 2 hours plus 30 minutes upload period

Open-book take-home examination

Answer ALL questions

<u>For Section A</u> *you must submit a single zip file of the computer programs that you wish to have marked for this open-book examination. This should be named in the format 'Student ID_MMME3085_Section A.zip'.*
At the top of each piece of code you write should be, in addition to any other, a comment statement indicating the question being undertaken and your candidate ID.

<u>For section B</u> *You must submit a single pdf document, produced in accordance with the guidelines provided on take-home examinations, that contains all of the work that you wish to have marked for this open-book examination. Your submission file should be named in the format* 'Student ID_MMME3085_Section B.pdf'*.*

Write your student ID number at the top of each page of your answers.

This work must be carried out and submitted as described on the Moodle page for this module. All work must be submitted via Moodle by the submission deadline.

Work submitted after the deadline will not be accepted without a valid EC.

No academic enquiries will be answered by staff and no amendments to papers will be issued during the examination. If you believe there is a misprint, note it in your submission but answer the question as written.

Contact your Module Teams Channel or SS-Assess-Eng@exmail.nottingham.ac.uk for support as indicated in your training.

Plagiarism, false authorship and collusion are serious academic offences as defined in the University's Academic Misconduct Policy and will be dealt with in accordance with the University's Academic Misconduct Procedures. By agreeing that you have completed the academic misconduct training accessible through the Moodle page you declare that work submitted is your own, that you understand the meaning of academic misconduct and that you have not engaged in it in the production of this work.

ADDITIONAL MATERIAL: MMME3085-E1 TemperatureData.txt

MMME3085-E1 Arduino Mega Pin Outputs.pdf

SECTION A

Answer this section by writing programs in the C language using the GCC compiler within CodeBlocks.

For both questions:

- Code should compile without warnings and use appropriate comments and variable definitions and names. [6]

1. The file ‘TemperatureData.txt’ provided contains pairs of time and temperature data, each on a separate line. The first line in the file gives the number of pairs of data in the file.

You are to develop a program that:

- Prompts the user to input the name of the data file.
- Reads the integer value at the beginning of the file.
- Allocates dynamic memory of the correct size to store the data from the file in an array of structures, each structure containing one set of time and temperature data.
- Reads the time and temperature data and populates the structure array with the data.
- Displays the data in tabulated format with a heading and the data displayed in columns 8 characters wide, left justified. The temperatures should be displayed with 2 decimal places of accuracy. Sample output is shown in Figure Q1.

```
Time/s  Temperature
0       12.34
1       13.57
2       14.36
```

Figure Q1 – Sample output for first three lines of data.

- Compiles without warnings and uses appropriate comments and variable definitions.

[23]

2. (a) Develop a function **external to main()** that calculates the kinetic energy of a moving car using the equation below.

$$KE = \frac{1}{2}mv^2$$

Where m = mass of the car, in kg.
v = velocity of the car, in m/s.
KE = kinetic energy, in joules.

The function should meet the following design criteria:

- The function is to return a value of 1 if the kinetic energy is calculated successfully.
- The function is to return a value of 0 if the mass is 0 or less.
- The mass and velocity can be non-integer values.
- Kinetic energy is to be returned via the argument list (using a suitable variable).

[12]

(b) Write a program (i.e. the main() function) to meet the following design criteria:

- The user should be prompted for input of mass and velocity.
- Use the function developed in (a) to calculate the kinetic energy of the car.
- The mass, velocity and kinetic energy (in kJ) are to be displayed with an appropriate message to 3DP of accuracy, including units.
- An error message should be displayed if the function returned a value of 0 (i.e. the mass was invalid).

The following data can be used to test your program:

Mass (kg)	Velocity (m/s)	Kinetic Energy (kJ)
1000	25	312.5
750	-22.2	184.82
-1000	25	Error

[9]

SECTION B

3. Figure Q3 shows the following components: (1) a DC motor, (2) a rotary potentiometer, (3) a dual H-bridge DC motor driver, (4) an 8-bit gray code encoder, (5) an Arduino Mega and (6) a 7-segment display. From these components, a feedback control system can be built to control the angular position (θ) of the DC motor shaft using the Arduino Mega as a microcontroller through the motor driver. The motor driver is a simple H-bridge with 5 inputs and 2 outputs for each motor. The inputs are Enable, Input-1(this enables clockwise rotation if it is High and input-2 is Low) and Input-2 (this enables counterclockwise rotation if it is High and input-1 is Low), supply voltage and the ground. The outputs of the motor driver are Motor + and Motor -. The actual motor shaft angular position (θ_a) is measured by the given encoder and it is used as a feedback signal. The output of the encoder is 8-bit parallel digital signal. The rotary potentiometer is used to generate a voltage (i.e., being used as a voltage divider) which is being used as an input that the controller will then interpret as the desired angular position of the motor shaft (θ_d). The range of the potentiometer resistance is 0-10kΩ. Furthermore, the system shows the actual angular position of the motor on a set of 7-segment displays as an integer number in degrees.

(a) Calculate the resolution of the angular position measurement of this system and the minimum required number of 7-segment displays? [3]

(b) Either by using schematic diagrams or text and the Arduino Mega pin outputs (provided with the exam and available on Moodle), show the following:

i) The connections between the DC motor driver pins, the Arduino pins, and the DC motor terminals. [3]

ii) The connections between the potentiometer and the Arduino pins. [2]

iii) The connections between the 7-segment display(s) and the Arduino pins. [5]

iv) The connection between the encoder outputs and the Arduino pins. [3]

(c) In 400 words, explain how to write a code to control the actual angular position $\theta_a$of the rotary shaft by using the Arduino according to the desired angle θ_d given by the rotary potentiometer and to show θ_a on the displays. Your explanation needs to include identification of the data to be sent to the Arduino ports/pins/registers and sequence of these data. Note: Do not write any code. No will be given for this. [13]

(d) If it is required to replace the DC motor and the encoder with a bi-polar stepper motor, use a schematic diagram to show the required connections between the stepper motor, the driver (i.e., the dual H-bridge), and the Arduino. [5]

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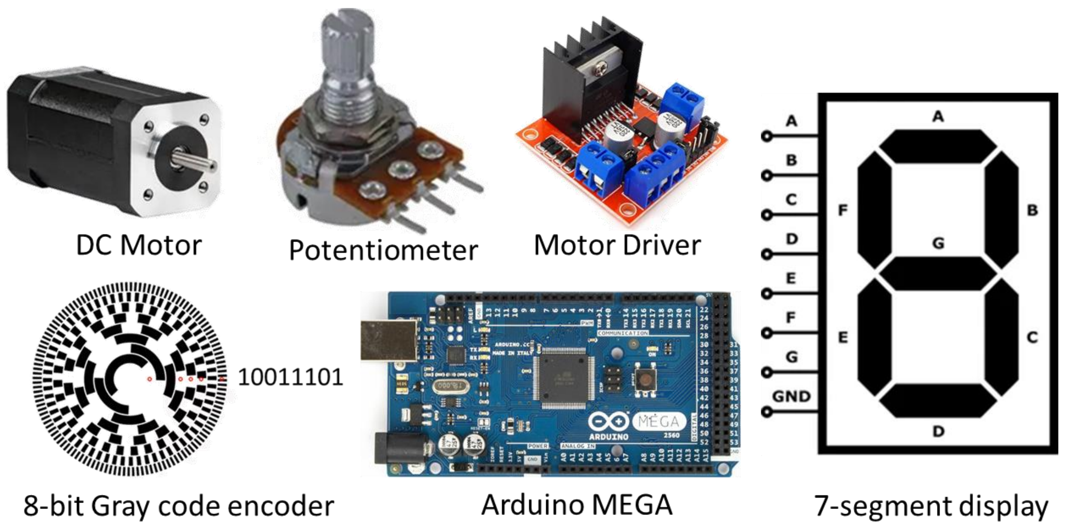

Figure Q3 A set of Mechatronics system to control DC motor with and Arduino.

[34]

4. Field programmable gate arrays (FPGAs) implement logic functions using configurable components called lookup tables (LUT). LUTs comprise of 1-bit memory cells and a set of multiplexers. The memory cells are programmable to hold either ‘0’ or ‘1’ and they are called static random-access memories (SRAM). A logic circuit is given on the left side of Figure Q4 and an LUT implementation is shown on the right side of the same figure.

(a) Using a schematic diagram, show how a set of multiplexers and SRAM can be used to implement LUT1. Your answer must show the connections between the inputs (U, V, X and Y), the SRAMs, the multiplexers, and the output F. [8]

(b) Determine the contents of the most significant and least significant two bits (i.e., the first two and last two bits marked with a question mark in the provided blank table below) of the SRAM for LUT1. [8]

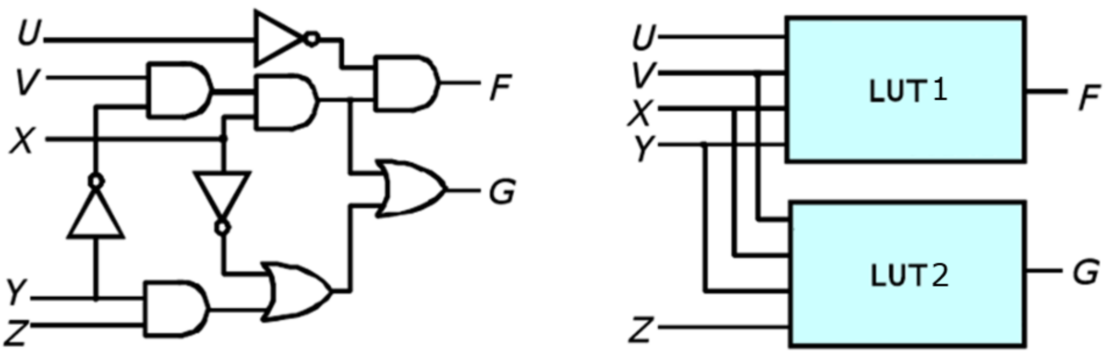

Figure Q4 a set of logic gates which can be represented by a LUT.

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Table 1 Blank table.

Inputs				Output
U	V	X	Y	F
				?
				?
				?
				?

[16]

END