UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: September 2023

Module Number: ME4210 **Module Name: Analog and Digital Electronics**

[Three Hours]

[Answer **all questions**, each question carries **12 marks**]

This paper contains **5 questions** on 5 **pages**.
Clearly state any assumptions that you may make.
In order to get **full marks**, make sure to use standard notations and SI units, where appropriate.

Q1. (a) Analog to Digital Conversion (ADC) plays a major role in the context of analog electronics.

Explain the necessity of ADC in electronic circuits and main steps followed during the process of converting analog signals to digital format.

[2.0 Marks]

(b) Using neat sketches, briefly describe the non-inverting and inverting op-amp configurations.

[3.0 Marks]

(c) Suppose you have been asked to design an audio mixer for adding together individual waveforms or sounds from three different source channels (vocal, drum, and guitar) before sending them to an audio recorder.

Sketch the circuit diagram that you are going to propose for the above requirement using a summing amplifier.

[3.0 Marks]

(d) Briefly describe the importance of including Voltage to Current Converters in control systems when transmitting signals over long distances.

[2.0 Marks]

(e) Multiplexing is a technique used to combine and send multiple data streams over a single medium. Using a sketch, briefly explain the operation of a 4-to-1 multiplexer.

[2.0 Marks]

Q2. (a) Using neat sketches, briefly describe the four (4) types of analog filters, categorized by the range of frequencies they allow to pass.

[2.0 Marks]

(b) Briefly explain the difference between active and passive filters.

[2.0 Marks]

(c) Assume you are an engineer who has been assigned to design a condition monitoring system for bridge structures. For this application, you will employ vibration sensors equipped with a transmitter installed along the bridge structure to monitor and record its vibration levels over a specified period. The transmitted frequency levels, intended for the analysis of the structural condition of the bridge must remain below 170 Hz.

Design a non-inverting active low-pass filter circuit, as depicted in **Figure Q2(c)**, with the following specifications:

A gain of 10 at low frequencies, a high-frequency cut-off (corner frequency) of 170 Hz, and an input impedance of 10 kΩ.

(i) Calculate all the resistor and capacitor values of the filter circuit.

(ii) Draw the frequency response curve of the filter.

[8.0 Marks]

Q3 (a) Briefly explain why Programmable Logic Controllers (PLCs) are preferred over microcontrollers when it comes to industrial applications.

[2.0 Marks]

(b) List **four (04)** advantages of PLCs compared to conventional relay control systems.

[2.0 Marks]

(c) Suppose you are tasked with controlling a CNC lathe machine using a PLC. The layout of the main components of the CNC lathe machine is shown in **Figure Q3(c)**, and the control system is expected to perform the following functions:

- The 'Main Motor' of the CNC spindle needs to be controlled using a Single Switch (detent type).
- The main motor bearing needs to be continuously lubricated using the 'Lubrication Pump' while in operation.
- After switching off the main motor, it takes approximately 30 seconds for it to slow down and reach to complete stop. During this period, lubrication for the main motor bearings should continue.
- An 'Alarm' will be activated to alert the operator if the lubrication level falls below a predetermined value or if the lubrication flow is

interrupted for any reason. In such cases, the main motor will be automatically stopped until the issue is resolved.

- A 'Liquid Level Sensor' (LLS) is used to sense the lubricant level and a 'Flow Sensor' (FS) is used to detect the status of the lubrication pump.
- During machine operation, a 'Green Indicator' bulb should illuminate, and it should turn off once all the components are completely stopped.
- The fully automated system is to be activated using a Master Switch.

Draw the input/output mapping table and develop a ladder logic program for the above application.

[8.0 Marks]

Q4 (a) Briefly explain the main difference between Finite Impulse Response filters and Infinite Impulse Response filters.

[1.0 Marks]

(b) Consider the digital filter given by the following difference equation.
$y[n]=3x[n]-5x[n-3]+y[n-1]-4y[n-2]$

(i) Explain the meaning of the term $[n-1]$.

(ii) Construct the transfer function (z^{-1} transform) for the given difference equation.

(iii) Construct the direct form 1 signal flow graph to the given difference equation using z^{-1} blocks for delays.

(iv) Transform the constructed signal flow graph for the above question, to a direct form 2 signal flow graph using z^{-1} blocks for delays.

[8.0 Marks]

(c) Consider the digital filter given by the following difference equation.
$y[n]=3x[n]-5x[n-1]+2x[n-3]-4x[n-5]$

Derive the frequency response of the filter.

[3.0 Marks]

Q5 (a) Draw the T-type flip-flop with correctly marked pins and write down its characteristic equation.

[1.0 Marks]

(b) Briefly explain the operation of a D-type flip-flop.

[2.0 Marks]

(c) You are asked to design a control system of a remote control robot. Here, the

control system gets the inputs from the sensors and user commands, and moves the robot accordingly. Given below are the inputs and outputs of the controller.

Inputs and status:

1. Forward obstacle sensor
   '1' if there is an obstacle at the front and '0' if there are no obstacles at the front
2. Backward obstacle sensor
   '1' if there is an obstacle at the back and '0' if there are no obstacles at the back
3. User remote control forward push button
   '1' if the user needs the robot to go forward and '0' if the user does not need the robot to go forward
4. User remote control backward push button
   '1' if the user needs the robot to go backwards and '0' if the user does not need the robot to go backwards
5. User remote control brake push button
   '1' if the user needs the robot to stop and '0' if the user does not need the robot to stop

Outputs:

1. Forward motor
   '1' robot goes forward and '0' robot does not go forward
2. Backward motor
   '1' robot goes backwards and '0' robot does not go backwards

Notes:

1. When the user presses an input push button, the input value is '1'. When the user let go of the push button, the input value is '0'.
2. To stop the robot, make both outputs to '0'.

Given below is the operation of the control system.

- The control system should memorise the user input even if the user let go of the push button.
- The main control system will move or stop the robot according to the memorised user input.
- If there are obstacles in the moving direction of the robot, the robot will stop till the obstacles move away.
- After the obstacles move away, the controller commands to move the robot according to the memorised user input.
- If the memorised user input is to brake or stop the robot, the controller will stop the robot regardless of the presence of obstacles.
- The user can decide to change the moving direction or to stop the robot at any time.

Assumption

The user will push only one button at a given time.

(i) Construct the state diagram.

(ii) Comment whether the state reduction is possible or not.

(iii) Assign values to states using binary numbers (State assignment).

(iv) Construct the state table using D-type flip-flops.

[9.0 Marks]

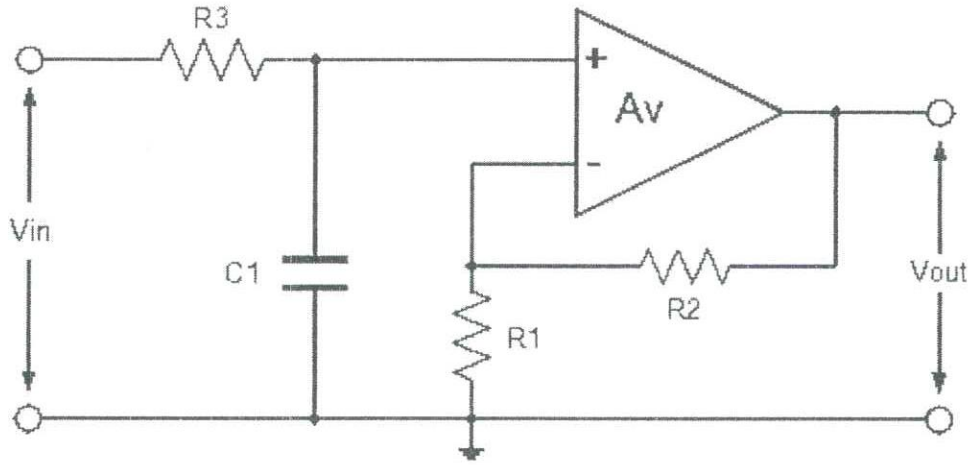

Figure Q2(c) - Circuit diagram of non-inverting active low-pass filter

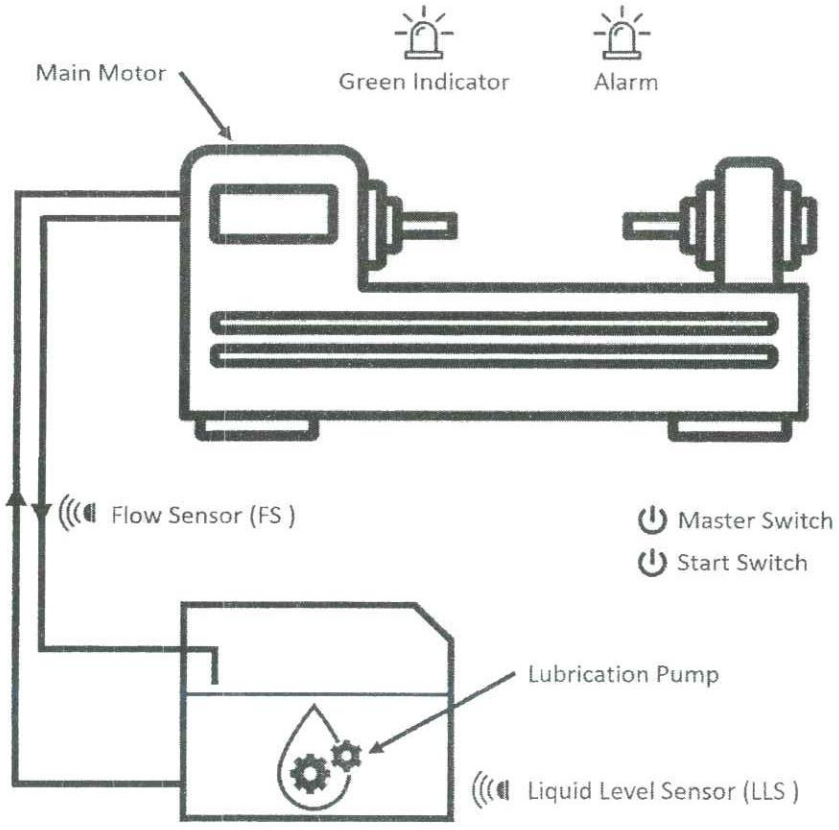

Figure Q3(c) - Main components of the CNC lathe machine

End of the paper.