Faculty of Technology - University of Ruhuna

Bachelor of Engineering Technology Honours

Level 4 (Semester 1) End-Semester Examination, December 2020

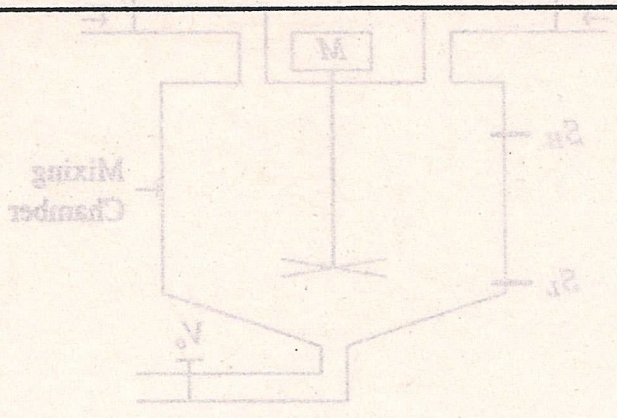
Academic year 2020/2021

Course Unit: ENT4113 - Mechatronics

Duration: 3 hours

Instructions to the candidate.

- Answer all **Five (05)** questions.
- This paper contains 5 questions in 6 pages.
- Calculators are allowed to use.



Q1.

a) Using a switch as an example, explain the two configurations: **NO - Normally Open** and **NC - Normally Closed.**

(01 marks)

b) What type of a switch should you use as an emergency stop, justify your answer.

(01 marks)

c) Using **timing diagrams**, explain the following instructions used in ladder diagrams.

i. SR

ii. TON - Timer On Delay

iii. TOF - Timer Off Delay

(03 marks)

d) You are given a task to automate a mixing machine. Two liquids are required be mixed using a mixing chamber. There are two valves named V_a and V_b to control two fluid inlets. Agitating motor M, is at the top to agitate the liquid inside. To take the fluid out, valve V_o should be opened.

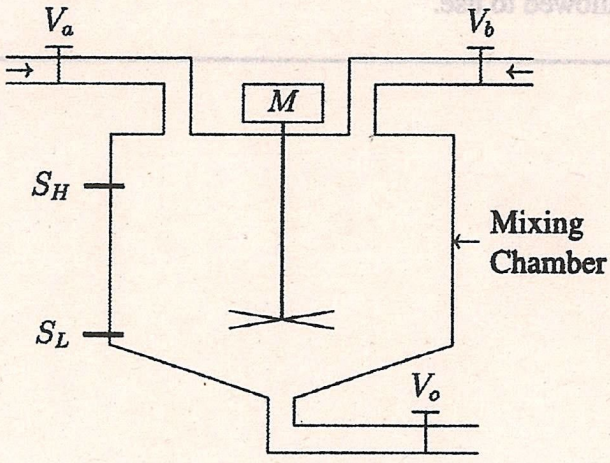


Figure 1: Mixing machine

e) When a $START$ button (NO type) is pressed, the valves V_a and V_b should be opened until the mixer is filled. That indicates by the level switch S_H (ON). The valves V_a, V_b should be closed when fluid level reaches to upper level (S_H ON).

i. Draw the ladder diagram to open the valves V_a, V_b, and to close the valve V_o when $START$ is pressed.

(03 marks)

ii. When fluid level reaches level S_H, the agitating motor M should start running for 60 s, and stop. Then the valve V_o should be opened to liquid to go out. Draw the ladder diagram.

(02 marks)

Q2.

a) Shown below is the transfer function of a mechanical system,

$$F(s) = \frac{s+4}{(s+1)(s+2)(s+3)}$$

i. Find the zeros and poles of this system.

ii. Plot the zero-pole map of the system.

iii. Comment on the stability of the system.

(05 marks)

b) A physical system is governed by following equation, where $y(t)$ is the output and $u(t)$ is the input.

$$\dot{y}(t) + 2y(t) = u(t)$$

i. Find the transfer function of the above system. Take initial conditions are as zero.

ii. Find the impulse response of the system using inverse Laplace transformation.

(05 marks)

$f(t)$	$F(s)$
$f'(t)$	$sF(s) - f(0)$
$f''(t)$	$s^2F(s) - sf(0) - f'(0)$
e^{-at}	$\frac{1}{s+a}$
$\frac{1}{s^n}$	$\frac{1}{(n-1)!}t^{n-1}$

Table 1: Laplace transforms

Q3. Figure 2 shows a Lifting Robot. A thread is attached to a pully of radius $r = 10\ cm$, which is connected to a mass m at the other end. The wheel is driven by a motor M_r. The robot should rotate the motor M_r in the counter-clockwise direction to lift the mass m up.

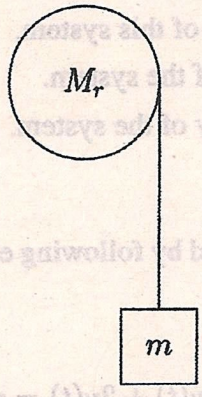


Figure 2: Lifting robot

a) Assume that you want to keep a still mass, Find
   i. the tension of the thread and,
   ii. the torque required to keep the mass still.

(02 marks)

b) What should be the torque required to accelerate the mass at, a m/s^2 towards the wheel.

(02 marks)

c) If the mass attached, $m = 2\ kg$ to accelerate upwards at 10 m/s^2, (take gravitational acceleration, $g = 9.8\ m/s^2$), Find
   i. the tension on thread and,
   ii. the torque required by motor.

(02 marks)

d) You are given the task to measure the RPM of the motor. Explain the steps.

(02 marks)

e) Explain how the motion of the motor to be controlled using the RPM measurements. Draw the control block diagram.

(02 marks)

Q4. A Current Transformer CT is connected as in Figure 3 to measure current I_w, though a wire W. The CT produce $0 - 10\ mA$ current output. When the current though the wire is 30 A, CT will produce 10 mA through the loop. The output of the CT is attached to an Analog To Digital converter (ADC) pin of a micro-controller using 100 Ω resistor.

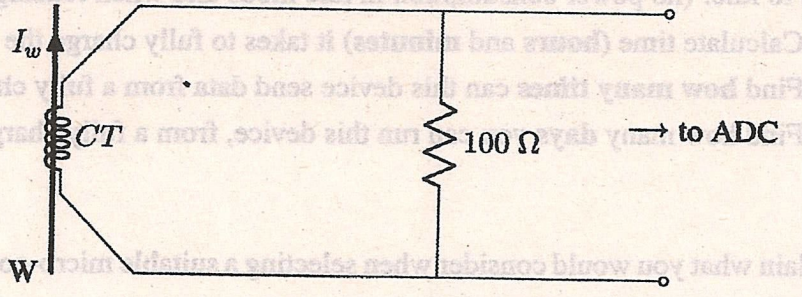


Figure 3: Current measurement using CT

i. Find the voltage across the 100 Ω resistor, when current I_w is 5 A.

ii. If ADC has 12-bit resolution and it can measure up to 1 V, find the minimum voltage (> 0) that can be measured using the ADC.

iii. Find the minimum current value on wire W, that you can measure using this ADC.

iv. Assume that the ADC is not faulty and you are getting ADC reading as 0 V. Explain a possible reason for this.

(08 marks)

a) You are given a proximity switch that produce an AC 230 V when turned on and 0 V when off. Using clear sketches and components, explain how would you interface it to a micro-controller's digital pin that operates using 3.3 V.

(02 marks)

Q5. You are given a task to create a wearable smart device to monitor health of an elderly patient. It should read status of the patient every **hour** and send this data to a server.

a) The device has a battery with a capacity of 2540 mAh. The battery charger can provide 2032 mA at its maximum. Each time the device sends data, it consumes 8 mAh, and goes to idle. (no power consumption in idle mode and when reading data).

i. Calculate time (**hours** and **minutes**) it takes to fully charge the battery.

ii. Find **how many times** can this device send data from a fully charged battery.

iii. Find how many **days** you can run this device, from a fully charged battery.

(03 marks)

b) Explain what you would consider when selecting a suitable micro-controller and sensors to design a wearable health monitoring system.

(02 marks)

c) Provide a diagram using clear sketches, protocols, and all the components needed to monitor patient's information remotely over internet.

(03 marks)

d) Motion of the patient should be measured using a sensor. A sick patient will have limited movements.

i. Propose a suitable sensor you would use to measure patient's motion.

ii. Explain how you would monitor motion of the patient's motion using the above sensor.

(02 marks)