

2601/201

2602/201

2603/201

CONTROL SYSTEMS AND PROGRAMMABLE
LOGIC CONTROLLERS

June/ July 2019

Time: 3 hours



THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING
(POWER OPTION)

(TELECOMMUNICATION OPTION)

(INSTRUMENTATION OPTION)

MODULE II

CONTROL SYSTEMS AND PROGRAMMABLE LOGIC CONTROLLERS

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

Answer booklet;

Mathematical tables/Non-programmable Scientific calculator;

Drawing instruments;

Table of Laplace Transforms.

This paper consists of EIGHT questions in TWO sections; A and B.

Answer THREE questions from section A and TWO questions from section B in the answer booklet provided.

All questions carry equal marks.

Maximum marks for each part of a question are as indicated.

Candidates should answer the questions in English.

This paper consists of 9 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

SECTION A: CONTROL SYSTEMS

Answer **THREE** questions from this section.

1. (a) For each of the following control systems, state with a reason whether it is open or closed loop:
- a bread toaster;
 - a man walking on a road;
 - a photocell-controlled street lighting system.
- (6 marks)
- (b) (i) State the **three** types of forces that exist in translational control systems.
- (ii) Figure 1 shows a mass spring system.
- Derive the system equation if at equilibrium condition $M = 15 \text{ kg}$, $B = 40 \text{ N/M/sec}$ and $K = 10 \text{ N/M}$.
 - Derive the transfer function using Laplace transforms. (9 marks)

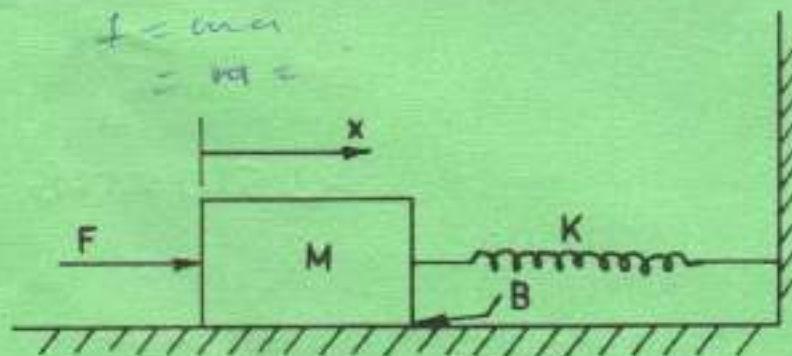


Fig.1

- (c) (i) With aid of a sketch, define an impulse function.
- (ii) Determine the transfer function of a system whose time response is $f(t) = e^{-2t}$. (5 marks)
2. (a) (i) State **two** reasons why mechanical system are usually studied using electrical analogy.

lead
types of forces
equilibrium
damping
friction

- (ii) Figure 2 shows a circuit diagram of an Op-amp based electrical network.

Assuming the Op-amp is ideal, determine its transfer function, $\frac{V_{out}(s)}{V_{in}(s)}$.

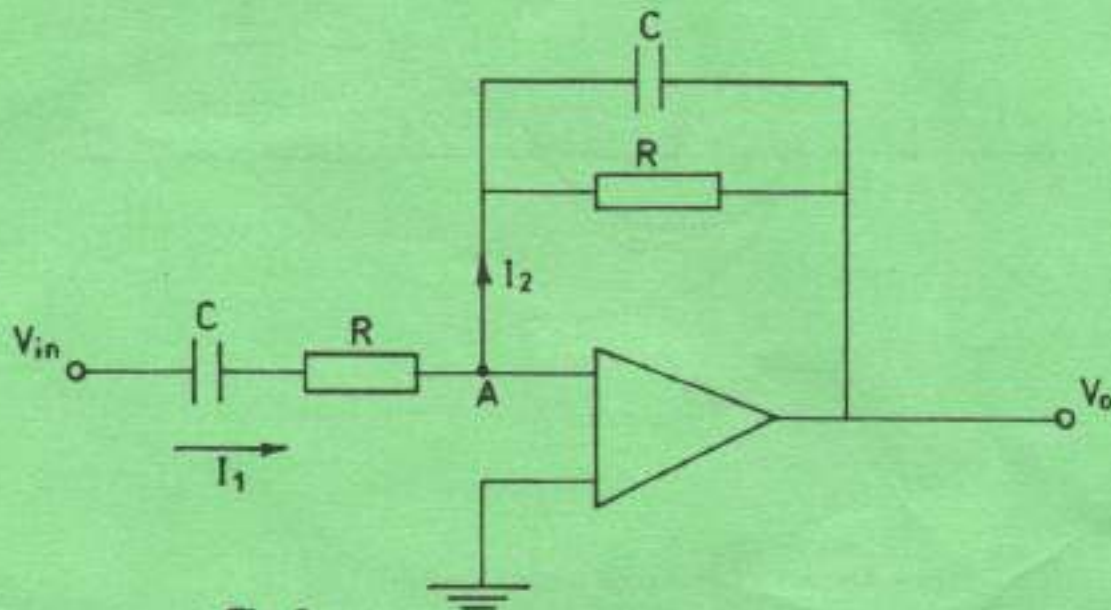


Fig. 2

(8 marks)

- (b) A control system has poles at $S_1 = -1$ and $S_2 = -2 \pm j$, zeros at $S_3 = -3 \pm j$. If the gain factor is 5:

- Draw the pole-zero plot;
- Write down the transfer function of the system;
- State with a reason whether the system is stable or not.

(6 marks)

- (c) A feedback control system has a characteristic equation given by:

$$S(S^2 + S + 1)(S + 4) + K = 0$$

Using the Routh-Hurwitz stability analysis method, determine the range of K for the system to remain stable.

(6 marks)

3. (a) (i) State two properties of signal flow graphs.
- (ii) Figure 3 shows a signal flow graph of a control system. Obtain its transfer function.

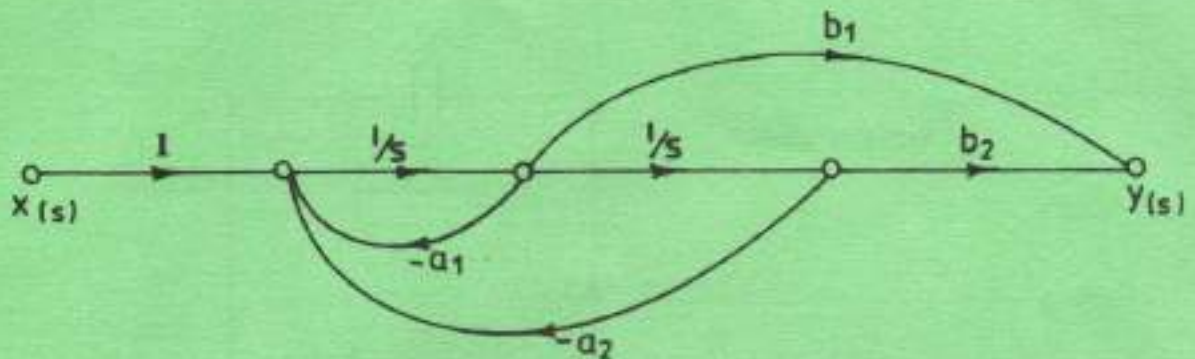


Fig.3

(10 marks)

- (b) Figure 4 shows a liquid level control system. Take:

q_i = inflow rate of the liquid in m^3/sec
 q_o = outflow rate of the liquid in m^3/sec
 h = height of the liquid in m
 R = resistance of the outlet pipe
 C = capacitance of the tank

Derive the expression for:

- (i) outflow, q_o
 (ii) rate of storage;
 (iii) overall transfer function of the system.

(6 marks)

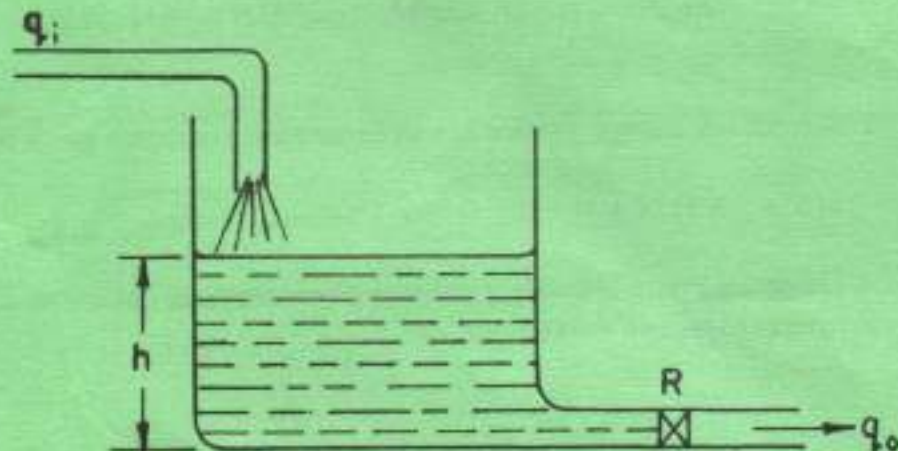


Fig. 4

(c) Explain the importance of each of the following with respect to analog computing:

- (i) time scaling;
- (ii) amplitude scaling. (4 marks)

4. (a) State:

- (i) two types of stepper motors;
- (ii) two advantages of D.C tachometers. (4 marks)

(b) A servomechanism is represented by the equation:

$$\frac{d^2\theta}{dt^2} + 10\frac{d\theta}{dt} = 150 E$$

Where $E = (r - \theta)$ is the actuating signal.

Determine the:

- (i) transfer function;
- (ii) undamped frequency of oscillations;
- (iii) damping ratio;
- (iv) damped frequency of oscillations. (9 marks)

(c) (i) Define steady-state error.

(ii) The open loop transfer function of a control system is given by:

$$G(s) = \frac{4}{s+1}$$

(I) State with reasons whether the system is a type 0, 1 or 2.

(II) Determine steady-state error when a unit step input is applied.

(7 marks)

5. (a) (i) State the Nyquist stability criterion.

(ii) A system's open-loop transfer function is given by:

$$G(s)H(s) = \frac{1}{s(1+2s)(1+s)}$$

(I) Show that the phase cross over frequency, $\omega = \frac{1}{\sqrt{2}}$ rad/sec.

(II) Determine the phase cross over magnitude.

(iii) Comment on the stability of the system in a (ii).

(12 marks)

- (b) Figure 5 shows an asymptotic Bode plot of a control system. Determine its transfer function.

(8 marks)

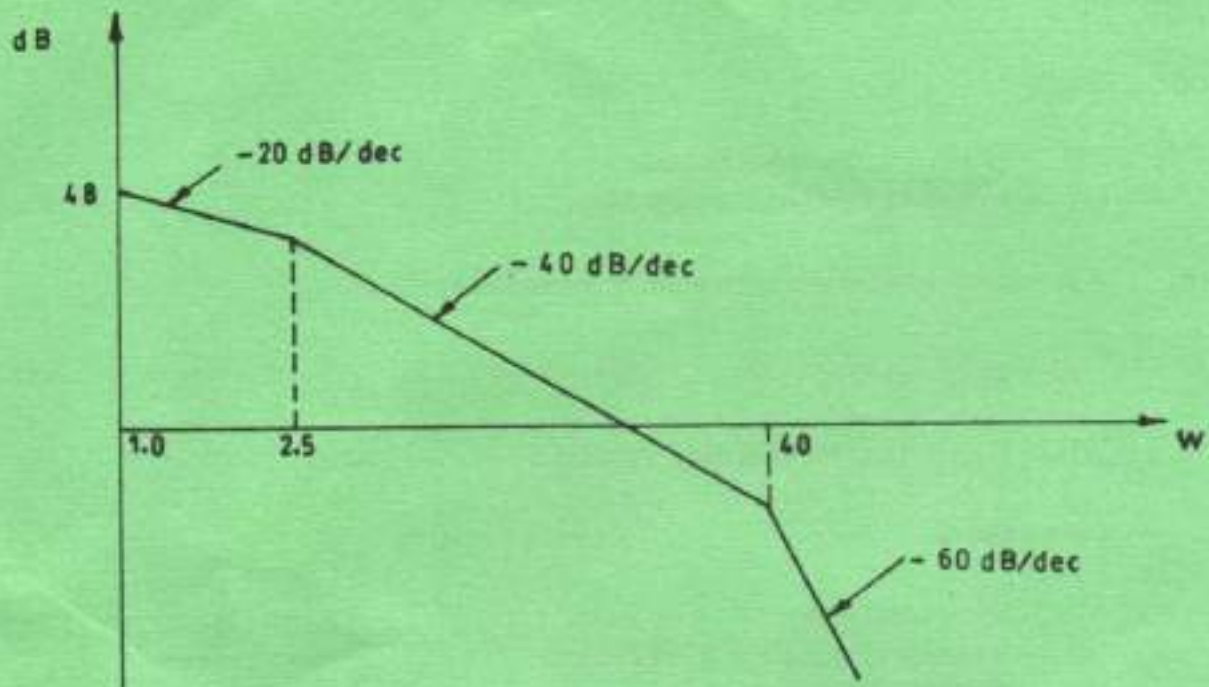


Fig.5

SECTION B: PROGRAMMABLE LOGIC CONTROLLERS

Answer *TWO* questions from this section.

- 6 (a) Describe each of the following sensors as used in programmable logic controllers (PLC):
- optical;
 - ultrasonic. (4 marks)
- (b) (i) A motor, M is controlled to run in forward and reverse directions by two buttons F and R respectively. The motor should not run when both buttons are pressed.
- Draw the ladder diagram for this control;
 - Write the equivalent instruction list program for the ladder diagram.

(ii) Figure 6 shows a ladder diagram of a control system. Describe the system operation.

(13 marks)

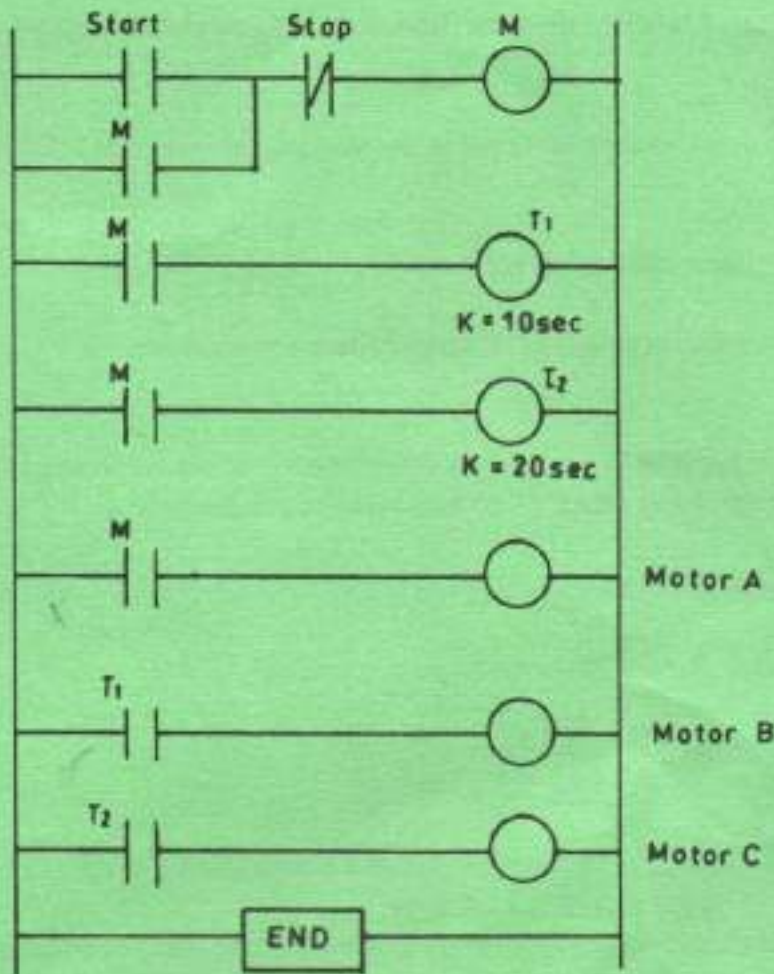


Fig. 6

(c) Define each of the following with respect to PLC memory:

- (i) Address;
- (ii) Random access;
- (iii) Solid State Drive (SSD).

(3 marks)

7. (a) (i) Define a SCADA system stating **two** potential areas of application.

(ii) Describe each of the following SCADA system communication media:

- (I) coaxial cable;
- (II) satellite;
- (III) fibre optic cable.

(9 marks)

(b) (i) SCADA software can be compromised either internally or externally. List **four** risks that the system could suffer after such attacks.

(ii) Draw a labelled diagram illustrating a SCADA network "ring of defences".

(9 marks)

(c) State **two** organisations involved in the standardization of SCADA systems.

(2 marks)

8. (a) (i) Define a calibration software.

(ii) Explain **three** merits of using calibration software.

(7 marks)

(b) With the aid of labelled diagrams, describe each of the following Highway Addressable Remote Transducer (HART) communication modes:

(i) point-to-point;

(ii) multi-drop.

(8 marks)

(c) State:

(i) **two** functions of Network Adaptor Cards (NAC) in data networks;

(ii) **three** parameters that two NACs must agree on to communicate.

(5 marks)

TABLE OF LAPLACE TRANSFORMS

| | <u>FUNCTION</u> F(t) | <u>TRANSFORM</u> $\int_0^\infty e^{-st} F(t) dt$ |
|-----|----------------------------------|------------------------------------------------------------------------------------|
| 1. | 1 | 1/s |
| 2. | e^{at} | 1/(s - a) |
| 3. | sin at | a/(s ² + a ²) |
| 4. | cos at | s/(s ² + a ²) |
| 5. | t | 1/s ² |
| 6. | t ⁿ (n a +ve integer) | n!/s ⁿ⁺¹ |
| 7. | sinh at | a/(s ² - a ²) |
| 8. | cosh at | s/(s ² - a ²) |
| 9. | t sin at | 2as/(s ² + a ²) ² |
| 10. | t cos at | (s ² - a ²)/(s ² + a ²) ² |
| 11. | $e^{-at} t^n$ | n!/(s + a) ⁿ⁺¹ |
| 12. | $e^{-at} \cos \omega t$ | (s + a)/[(s + a) ² + ω^2] |
| 13. | $e^{-at} \sin \omega t$ | ω /[(s + a) ² + ω^2] |
| 14. | $e^{-at} \cosh \omega t$ | (s + a)/[(s + a) ² - ω^2] |
| 15. | $e^{-at} \sinh \omega t$ | ω /[(s + a) ² - ω^2] |

Some Theorems used in Laplace Transforms.

1. If $f(s) = L\{F(t)\}$, then $f(s + a) = L\{e^{-at} F(t)\}$
2. $L\{dx/dt\} = sL\{x\} - x(0)$ (b) $L\{d^2x/dt^2\} = s^2L\{x\} - sx(0) - x'(0)$

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