2601/201
2602/201
2603/201
CONTROL SYSTEMS AND PROGRAMMABLE LOGIC CONTROLLERS
March/April 2024
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;*
- *Polar curve;*
- *Bode plot.*

*This paper consists of **EIGHT** questions in **TWO** sections; **A** and **B**.*
*Answer **FIVE** questions by choosing **THREE** questions from section **A** and **TWO** questions from section **B** in the answer booklet provided.*
Maximum marks for each part of a question are as indicated.
Candidates should answer the questions in English.

This paper consists of 8 printed pages and 2 inserts.

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

Turn over

SECTION A: CONTROL SYSTEMS

*Answer any **THREE** questions from this section.*

1. (a) For each of the following, state whether it is an open loop or closed loop control system:

(i) Traffic lights control using fixed timers;

(ii) Radar servo systems;

(iii) Automatic washing machine;

(iv) Domestic central heating system maintained at 23°C.

(4 marks)

(b) Figure 1 shows a block diagram of a canonical control system. Derive its closed loop transfer function. (6 marks)

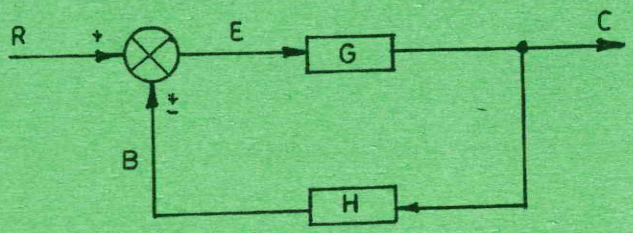

Fig. 1

(c) Figure 2 shows an electrical network. Show that $\frac{V_o(s)}{V_i(s)} = \frac{1}{\tau_1\tau_2 S^2 + \tau_1 S + 1}$

where $\tau_1 = 1/R$ and $\tau_2 = CR$

(10 marks)

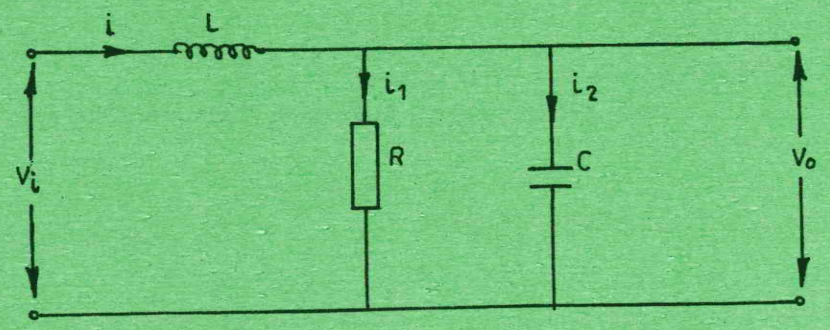

Fig. 2

2. (a) Figure 3 shows a circuit diagram of a servo-mechanism:

(i) Explain its operation.
(ii) Draw the equivalent labelled block diagram.

(9 marks)

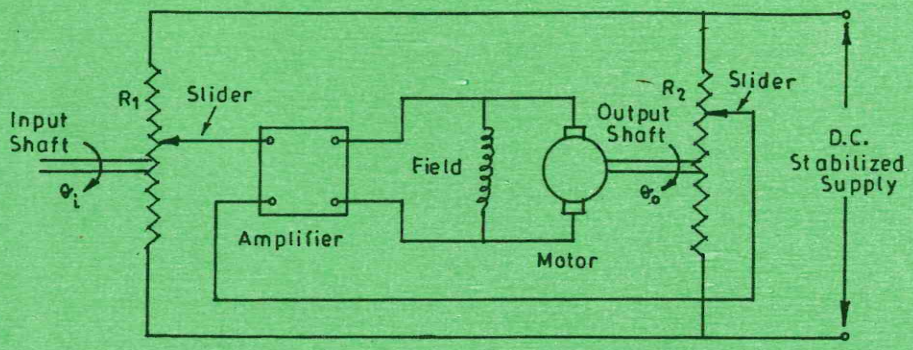

Fig. 3

(b) Figure 4 shows a block diagram of a control system. Determine its transfer function using block diagram reduction techniques. (8 marks)

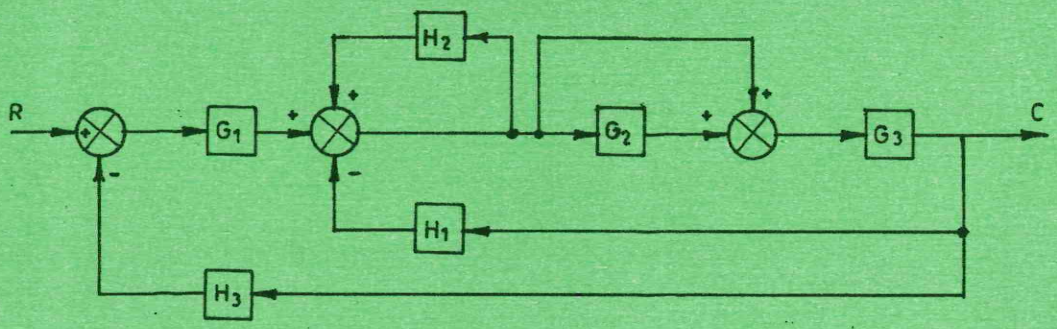

Fig. 4

(c) State **three** input test signals used in control systems. (3 marks)

3. (a) A feedback control system is described by the following transfer function

$$\frac{C_{(s)}}{R_{(s)}} = \frac{16}{S^2 + (4 + 16K)S + 16}$$

For a damping factor of 0.8, determine the:

(i) undamped natural frequency;
(ii) feedback transfer function K, value;
(iii) damped frequency;
(iv) percentage overshoot of the system.

(9 marks)

(b) The open-loop transfer function of a unity feedback system is given by:

$$G_{(s)} = \frac{200}{S(s+10)}$$

Determine each of the following static error constants:

(i) position error constant, K_p;
(ii) velocity error constant, K_v.

(4 marks)

(c) A control system is described by the characteristic equation:

$$S^4 + 4S^3 + 4S^2 + 3S + K = 0$$

Using the Routh-Hurwitz stability criterion, determine the range of values of K for stability. (7 marks)

4. (a) (i) Define an analog computer.

(ii) The following simultaneous differential equations describes a control system. Assuming a ± 10 V is available, obtain an analog computer flow diagram.

$$\frac{dy}{dt} - x = 9$$

$$\frac{dx}{dt} - y = 2$$

(8 marks)

(b) Table 1 shows the phase frequency details of a unity feedback control system whose open loop transfer function is

$$G_{(s)} = \frac{K}{s(1+s)(1+0.1s)}$$

Table 1

ω (rad/sec)	0	0.1	0.5	1	3	5	10
Phase angle	-90°	-96.3°	-119.4°	-140.7°	-178.3°	-195°	-219°

(i) Using asymptotes for the magnitude curve and details in table 1, draw the system Bode plot. Hint: let K = 1.

(ii) Determine the:

(I) gain margin;
(II) phase margin;
(III) Grain crossover frequency;
(IV) Phase crossover frequency;
(V) Stability.

(12 marks)

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

(ii) Table 2 shows the open-loop frequency response of a control system.

Table 2

ω (rad/sec)	3	3.5	4	5	7	10	20
$\|G\|$	9	6.6	5.2	3.2	1.6	0.7	0.11
$\phi°$	-164	-170	-175	-185	-200	-214	-238

Plot the Nyquist diagram and hence determine:

(I) phase margin;
(II) gain margin;
(III) With reason, whether the system is table or not.

(11 marks)

(b) (i) Explain how a stepper motor is used as a transducer.

(ii) A variable-reluctance stepper motor has 16 stator poles and 12 rotor teeth. Determine the:

(I) steps per revolution;
(II) step angle.

(6 marks)

(c) State **three** areas of applications of stepper motors. (3 marks)

SECTION B: PROGRAMMABLE LOGIC CONTROLLERS

*Answer any **TWO** questions from this section.*

6. (a) State **two** reasons why PLC is preferred to hardware control in factory automation. (2 marks)

(b) A PLC ROM chip stores 8192 words each 8 bits wide. Determine the:

(i) number of data bus lines;
(ii) number of address bus lines;
(iii) capacity in kilobytes.

(5 marks)

(c) Draw a ladder diagram for a system that makes lamp **L** to be ON when push button A is ON, or when either push button B or C are ON. (5 marks)

(d) Figure 5 shows a ladder diagram for a control system:

(i) Obtain its Boolean equation;
(ii) Simplify the equation in d(i);
(iii) Write down the instruction program list of the expression in d(ii).

(8 marks)

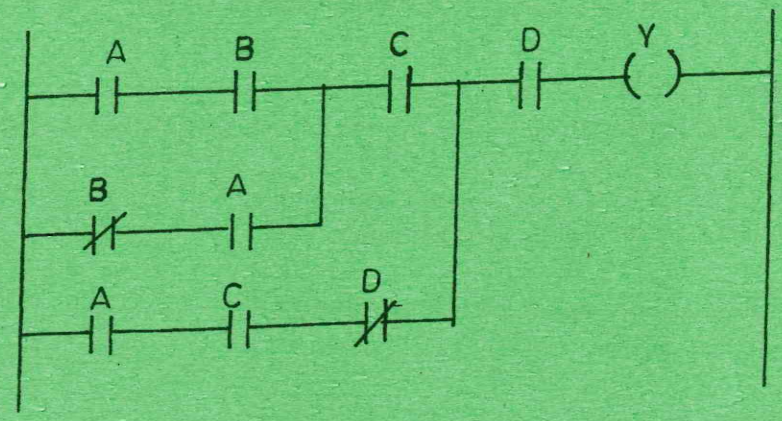

Fig. 5

7. (a) Figure 6 shows a wiring diagram for operating two motors M1 and M2.

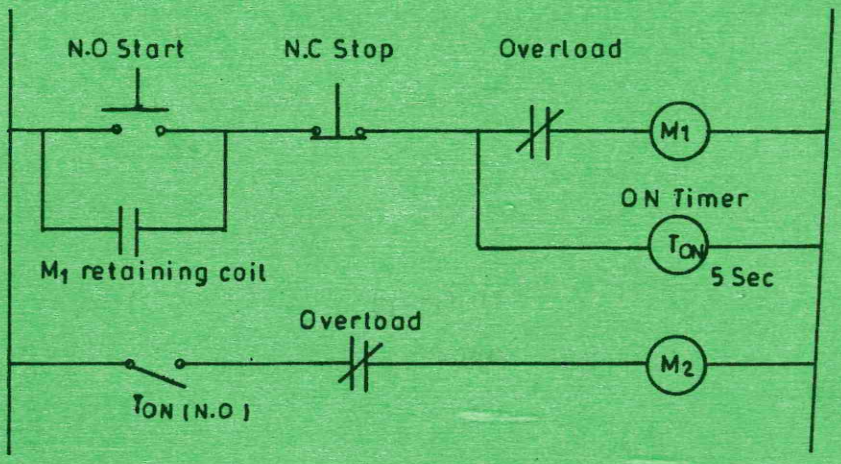

Fig. 6

(i) Explain what happens after each of the following scenarios:

(I) N.O start button is pressed;
(II) overload occurs for motor M1.

(ii) Write the equivalent instruction list for the system.

(9 marks)

(b) List **four** instances when calibration may be necessary on an instrument. (4 marks)

(c) (i) Explain the function of each of the following SCADA system software:

(I) central host computer application;
(II) RTU automation software.

(ii) State **three** areas of applications of SCADA systems.

(7 marks)

8. (a) Explain **three** core functions of a SCADA system. (6 marks)

(b) With an aid of a labelled diagram, describe the mesh LAN topology. (5 marks)

(c) Distinguish between peer-to-peer and client-server networking models highlighting **one** demerit for each. (4 marks)

(d) Draw a labelled constructional diagram of an optical fibre cable and state the function of each part. (5 marks)

THIS IS THE LAST PRINTED PAGE.