2601/201
2602/201
2603/201
CONTROL SYSTEMS AND PROGRAMMABLE
LOGIC CONTROLLERS
June/July 2023
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;
Non-programmable scientific calculator;
Drawing instruments;
Polar curve.
This paper consists of EIGHT questions in TWO sections; A and B.
Answer any THREE questions from section A and any 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 one insert.
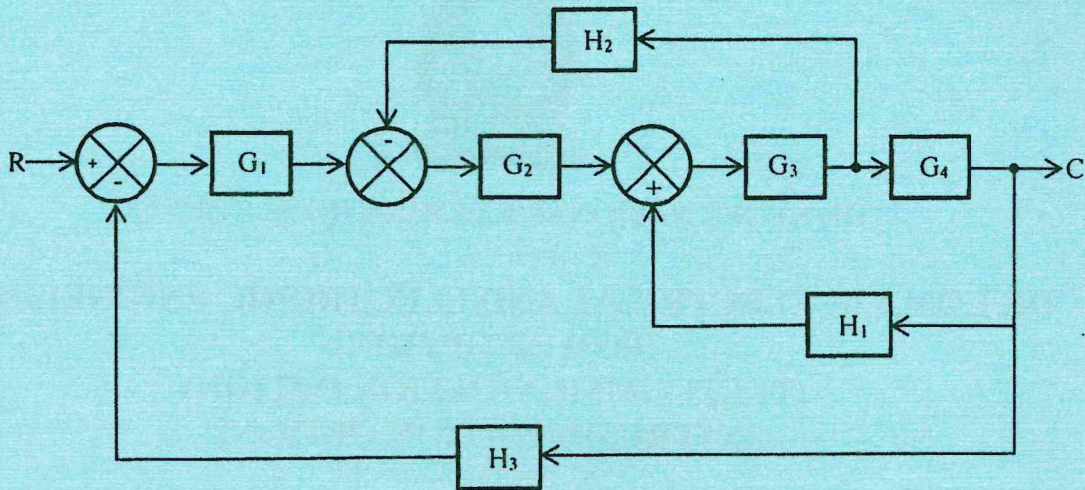
Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.
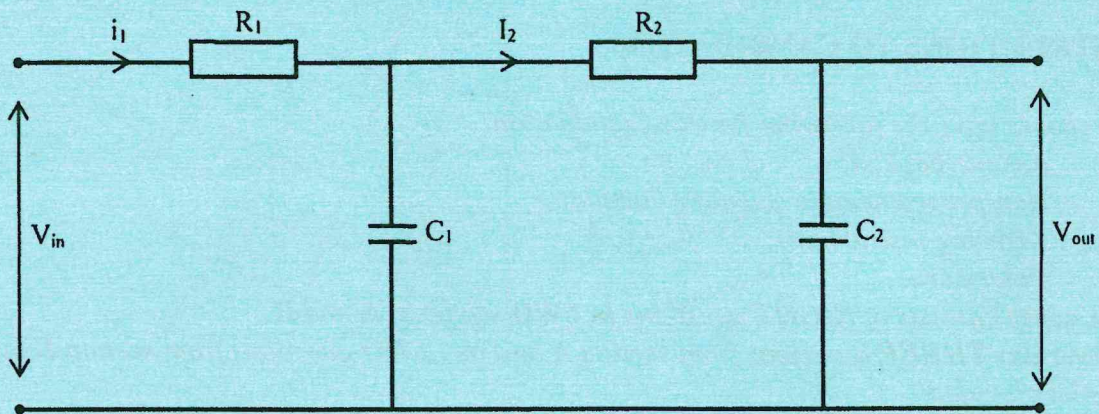
SECTION A: CONTROL SYSTEMS

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

1.　(a)　**Figure 1** shows a closed loop control system. Using block diagram manipulation determine the transfer function.　(10 marks)

Fig. 1

(b)　**Figure 2** shows an electrical network. Determine it's transfer function $\dfrac{V_{out}(t)}{V_{in}(t)}$.

(10 marks)

Fig. 2

2. (a) Write down the equivalent Force-current electrical analogy for each of the following mechanical quantities:

     (i)   velocity;
     (ii)   spring constant;
     (iii)   mass.

(3 marks)

(b) A servomechanism is represented by the equation $\dfrac{d^2\theta}{dt^2} + 10\dfrac{d\theta}{dt} = 150E$.

Where, $E = (r - \theta)$, r is the reference input and θ is the output shaft position. For the system, determine the:

     (i)   undamped natural frequency;
     (ii)   damping ratio;
     (iii)   damped frequency of oscillations.

(8 marks)

(c) **Figure 3** is a unity feedback control system. Show that the damping factor is given by
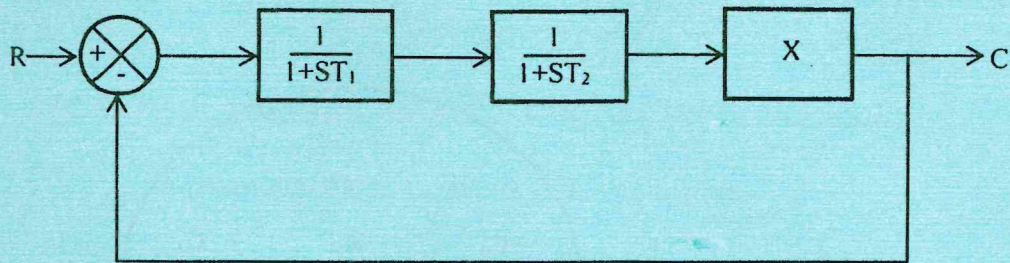$$\frac{T_1 + T_2}{\sqrt[2]{(1+x)T_1 T_2}}.$$

(9 marks)

Fig. 3

3. (a) (i) Draw a three-input OP-AMP based electronic summer.

     (ii) Derive the expression for output voltage for the summer in (a)(i).

(7 marks)

(b) State **three** factors that affect the accuracy of an analogue computer simulation.

(3 marks)

(c) The charge q on a capacitor in RLC circuit is given by $100 = 5\dfrac{dq}{dt} + \dfrac{1}{10^3}\dfrac{d^2q}{dt^2} + \dfrac{10^6}{50}q$.
Given that $q = \dfrac{dq}{dt} = 0$ at $t = 0$ and the scaled variables are $|q|_{max} = 10^{-2}$ units and $\left|\dfrac{dq}{dt}\right|_{max} = 25$ units. Employing time scaling such that "computer time" is 5000 times "real time" derive a time scaled flow diagram.

(10 marks)

4.   (a)   State the Nyquist stability criterion.   (2 marks)

       (b)   Table 1 shows the open loop frequency response of a servo mechanism.

Table 1

W(rad/sec)	2	3	4	5	6	8	10	30
Gain	2.8	1.9	1.3	0.9	0.68	0.4	0.26	0.12
Phase angle (°)	−120	−130	−140	−149	−157	−170	−180	−200

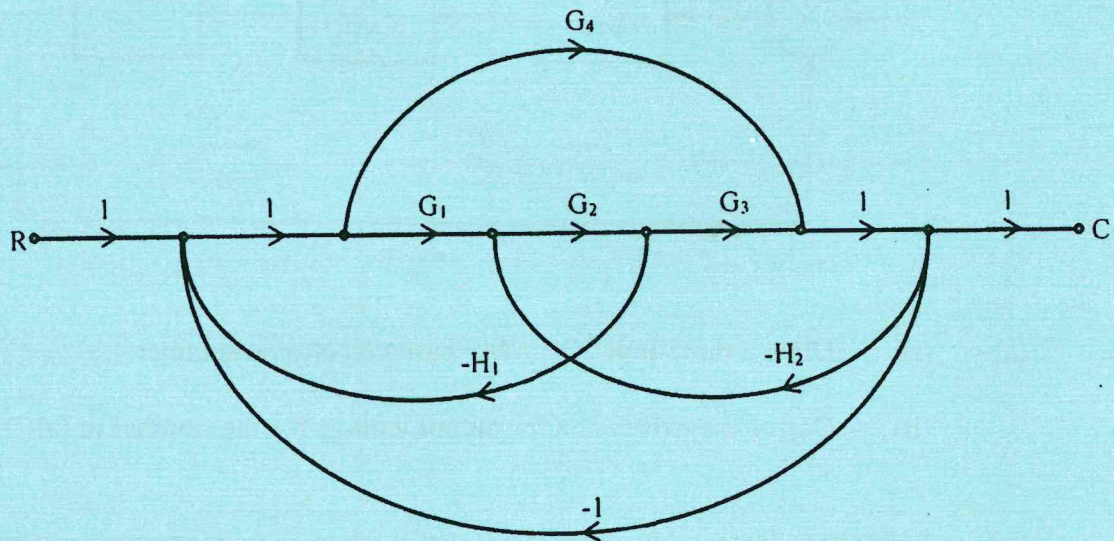   (i)   Construct it's polar plot.

           (ii)   Determine the:

                (I)   gain margin;
                (II)   phase margin;
                (III)   phase cross over frequency;
                (IV)   phase crossover frequency;
                (V)   stability.

                                                              (8 marks)

       (c)   **Figure 4** shows a signal flow graph. Using Mason's gain formular, determine the closed loop transfer function.

Fig. 4

                                                           (10 marks)

5. (a) State **three** advantages of bode plots over nyquist stability diagrams.

(3 marks)

(b) A negative unity feedback system has an open-loop transfer function of:

$$G(s) = \frac{k}{s^4 + 2s^3 + 6s^2 + 10s}.$$

(i) Determine the characteristic equation of the system;

(ii) Use Routh Hurwitz method to determine the range of values of k for which the system is stable;

(iii) Given that $k = 5$, calculate the value of the oscillating frequency for self oscillations.

(9 marks)

(c) A stepper motor wired for a four sequence is fed from a pulse train of 500 Hz frequency. The number of rotor teeth is 180. Determine:

(i) the steps per revolution;
(ii) step angle;
(iii) rotor speed (revolutions per minutes) in radians per seconds.

(8 marks)

SECTION B: PROGRAMMABLE LOGIC CONTROLLERS

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

6. (a) (i) State **three** factors that make programmable logic controllers more suitable for industrial control over convectional computers.

(ii) List **four** contents of documentation guide for PLC installation.

(7 marks)

(b) Describe each of the following PLC programming language citing an example in each case:

(i) structured text;
(ii) sequential function chart.

(6 marks)

(c)   **Figure 5** shows a ladder diagram program of a PLC. Translate the ladder program into it's instruction list program.
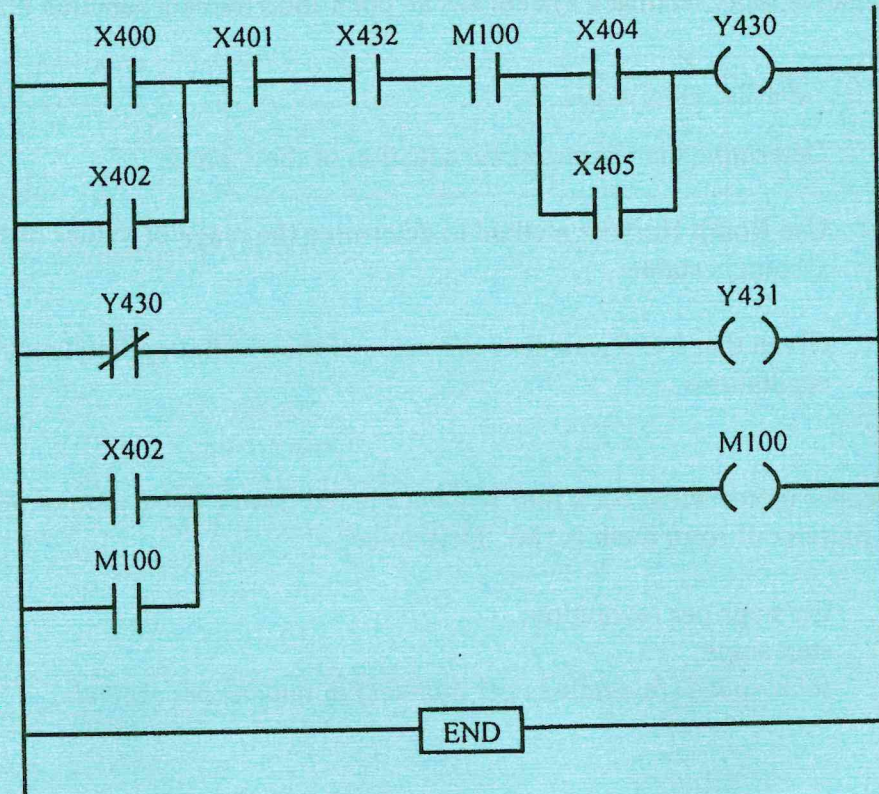(7 marks)

Fig. 5

7.   (a)   (i)   State **three** main elements of a SCADA system.

(ii)   Differentiate between logging and archiving as used in SCADA systems.
(7 marks)

(b)   With the aid of a labelled block diagram, describe the operation of a distributed SCADA system.
(7 marks)

(c)   State **three**:

(i)   merits of calibration software;
(ii)   parameters that two network adaptor cards (NACs) must agree on during data transfer.
(6 marks)

8. (a) With the aid of labelled diagram, describe parts of a coaxial cable used in an industrial network. (6 marks)

(b) Describe the functions of three networking hardware devices that are used to implement a computer network. (6 marks)

(c) A digital control system has two inputs A and B and two outputs X and Y. The relationship between the outputs and inputs is as follows:

- output Y indicates presence or absence of both inputs;
- output X indicates presence of either inputs.

(i) Draw a truth table to represent these functions;
(ii) Write down the Boolean expressions for the functions in (c)(i);
(iii) Draw the ladder diagram for the system. (8 marks)
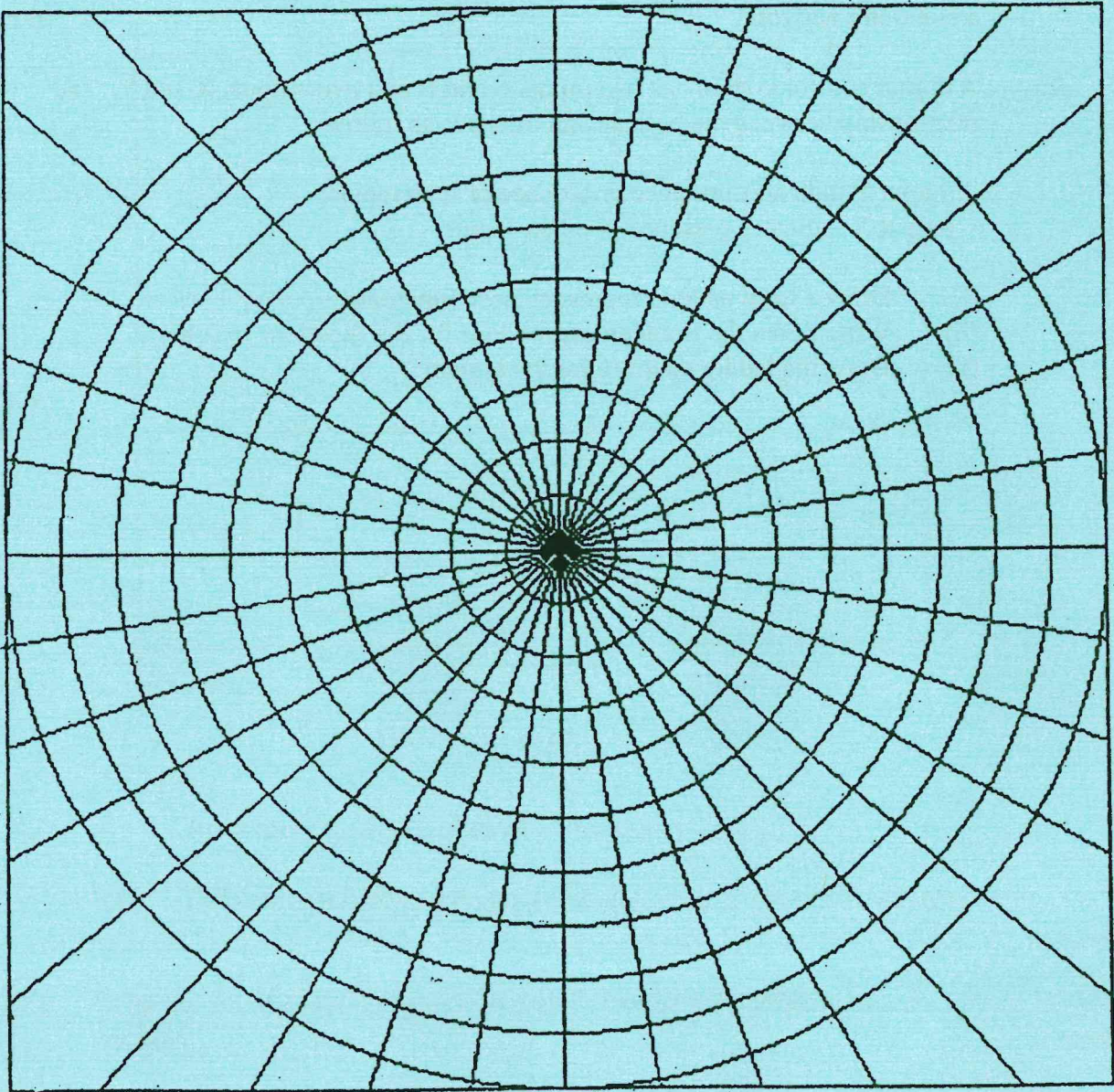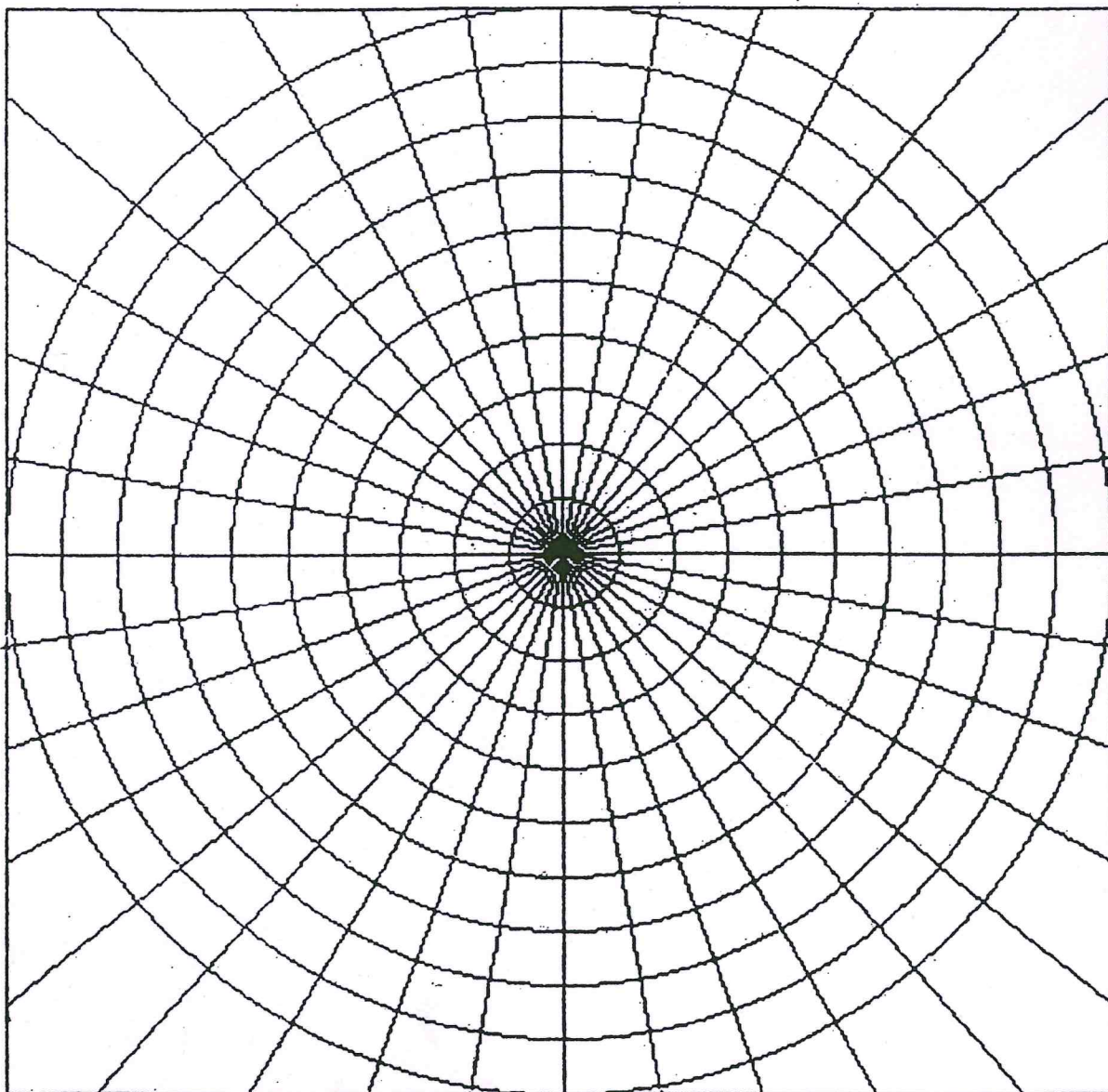
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