2601/201
2602/201
2603/201
CONTROL SYSTEMS AND PROGRAMMABLE
LOGIC CONTROLLERS
Oct./Nov. 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;
Nichol's chart..

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.

SECTION A: CONTROL SYSTEMS

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

1. (a) With the aid of a canonical block diagram of a closed loop control system, derive the expression for:

   (i) closed loop transfer function;

   (ii) error ratio;

   (iii) primary feedback ratio.

(7 marks)

(b) **Figure 1** shows a block diagram of a control system.

   (i) Convert it to the equivalent signal flow graph;

   (ii) Using Mason's gain formula, determine the transfer function of the system.

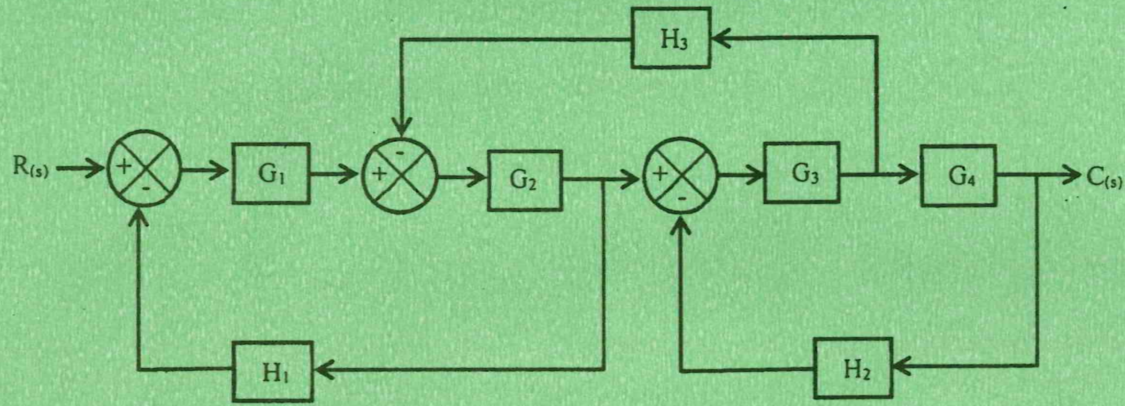


Fig. 1

(10 marks)

(c) Define each of the following terms as used in feedback control systems:

   (i) actuating signal;

2. (a) (i) State the Routh Hurwitz stability criterion.

(ii) A unity feedback open loop transfer function of a control system is given by;

$$G(s) = \frac{K}{S(S^2+S+1)(S+4)}.$$

(I) Determine the characteristic equation;

(II) Using Routh-Hurwitz stability analysis method, determine the range of K for which the system remains marginally stable.

(7 marks)

(b) State the poles and zeros of the transfer function expression given by:

$$G(s) = \frac{S^2-5S-6}{S^3(S+1+j)(S+1-j)}$$

(6 marks)

(c) **Figure 2** shows an electrical phase lead circuit diagram. Show that its transfer function is given by:

$$\frac{V_{out}(s)}{V_{in}(s)} = \frac{\alpha(1+S\tau)}{1+S\alpha\tau}$$

Where $\alpha = \frac{R_2}{R_1+R_2}$ $\quad ,\tau = R_1C$

(7 marks)

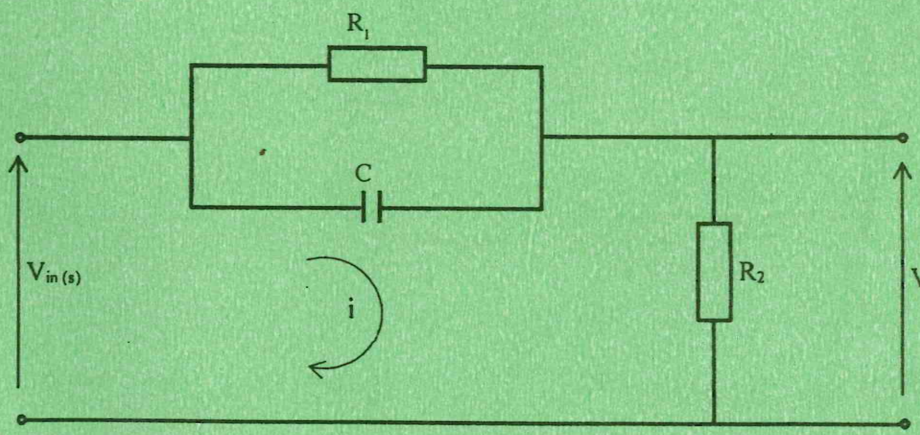


Fig. 2

3. (a) State the:

(i) **three** linear elements that are used in system simulation in analogue computing;

(ii) conditions for speeding up or slowing down a system; (5 marks)

(b) With the aid of an OP-amp based integrator circuit diagram, derive the expression for the output voltage, V_{out}.

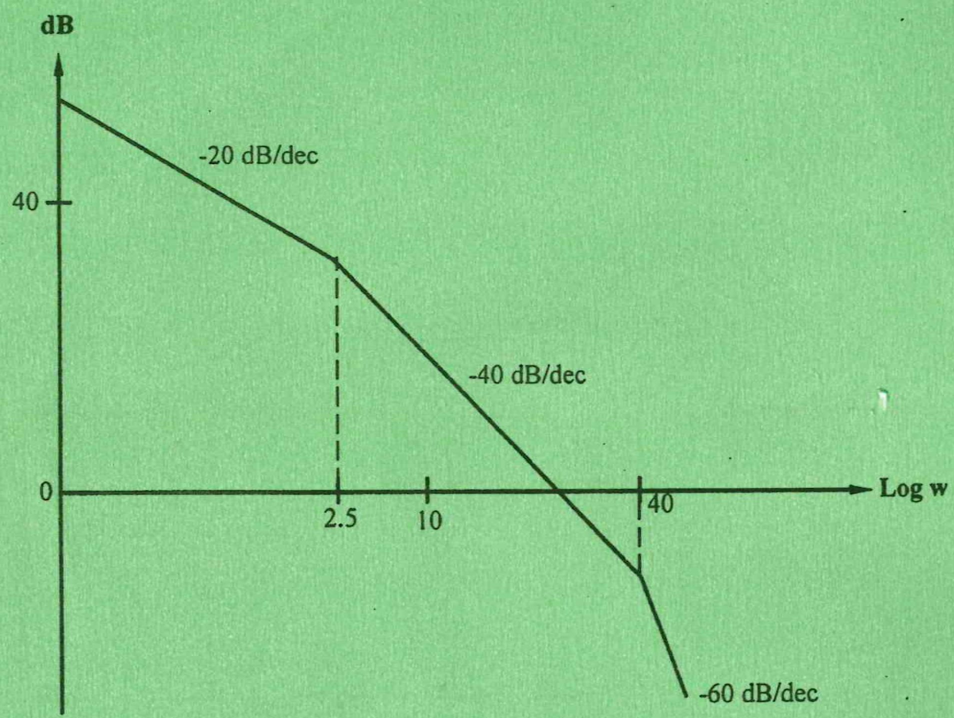
(6 marks)

(c) Obtain a scaled analogue computing flow diagram for the equation $2\ddot{x}+9\dot{x}+20x=35$.

Given that $x_{max}=5$, $\dot{x}_{max}=10$, $\ddot{x}_{max}=20$ and $\dot{x}_o=x_o=0$

(9 marks)

4. (a) **Figure 3** shows an asymptotic Bode plot of a control system. Determine its open loop transfer function. (8 marks)



(b) Table 1 shows the frequency response of an open loop control system.

Table 1

ω (rad/sec)	2	4	6	8	10	15	19
Gain(dB)	13.3	5.8	0.5	−3.7	−7.2	−13.9	−18.0
$< G(j\omega^{\circ})$	−114	−133	−147	−157	−164	−178	−186

(i) Plot the values on Nichol's chart;

(ii) From the plot in (i), obtain:

(I) gain margin;

(II) phase margin;

(III) gain crossover frequency;

(IV) phase crossover frequency.

(12 marks)

5. (a) A second order control system has the differential equation

$$3\frac{d^2\theta_0}{dt^2} + 6\frac{d\theta_0}{dt} + 12\theta_0 = 12\theta_i$$

Determine

(i) damping ratio;

(ii) percentage overshoot;

(iii) time taken to reach this overshoot.

(7 marks)

(b) (i) Draw a labelled response curve of a second order system when subjected to a unit step input.

(ii) Using the curve in (i) define each of the following:

(I) settling time;
(II) peak overshoot;
(III) delay time;
(IV) rise time. (8 marks)

(c) (i) State **two** applications of servomotors;

(ii) Draw a labelled diagram of a separately excited servo motor. (5 marks)

SECTION B: PROGRAMMABLE LOGIC CONTROLLERS

Answer any TWO questions from this section.

6. (a) (i) State **three** merits of industrial networks in a company.

(ii) Describe **three** features of each of the following types of communication networks:

(I) LAN;
(II) MAN;
(III) WAN. (12 marks)

(b) Describe the following data transmission modes:

(i) half duplex;

(ii) full duplex. (4 marks)

(c) Describe each of the following Highway Addressable Remote Transducer (HART) transmission modes.

(i) burst;

7. (a) Draw a labelled ladder diagram programming symbols for each of the following;

(i) timer;
(ii) counter;
(iii) output coil.

(3 marks)

(b) A digital control system has three inputs A, B and C and three outputs X, Y and Z. The relationship between the outputs and inputs is as follows:

- Output X indicates the absence of all the three inputs A, B and C
- Output Y indicates the presence of both inputs A and B
- Output Z indicates the presence of all inputs A, B and C

(i) Draw a truth table to represent these functions;
(ii) Write down the logic expressions for the output functions;
(iii) Draw the ladder diagram for the system.

(11 marks)

(c) Describe **three** preventive measures in the maintenance a PLC. (6 marks)

8. (a) (i) State **two** potential areas of applications of SCADA systems.

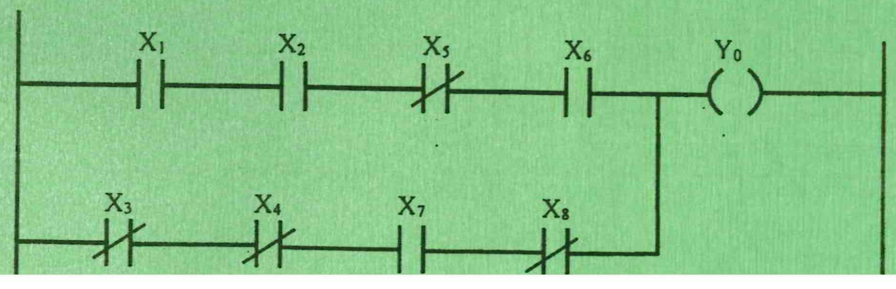
(ii) Describe **four** security counter measures used to secure networks in SCADA systems.

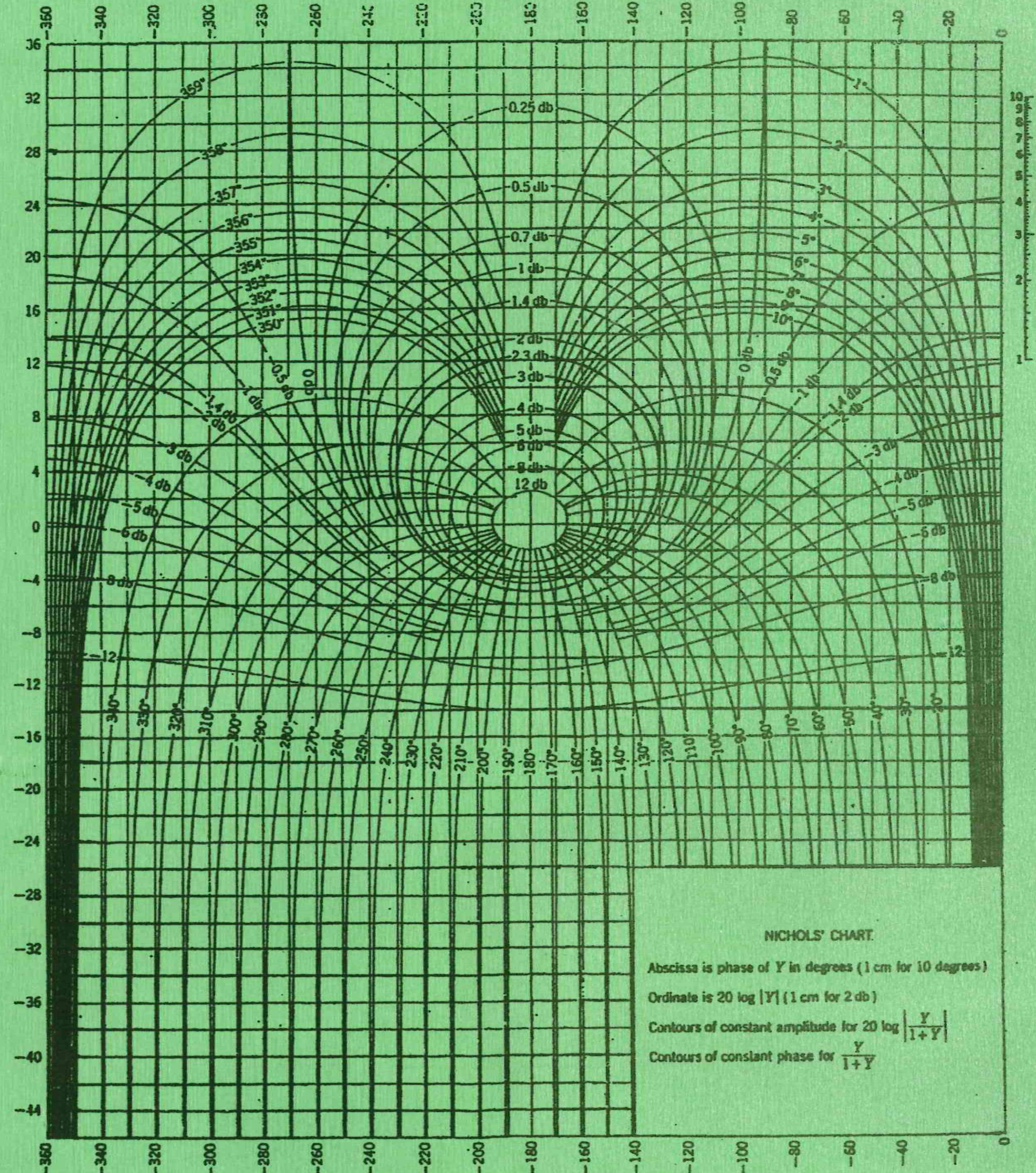
(10 marks)

(b) (i) Highlight any **four** checks involved while commissioning a PLC system.

(ii) **Figure 4** shows a ladder program of a machine control. Write its instruction listing.

(10 marks)





NICHOLS' CHART.

Abscissa is phase of Y in degrees (1 cm for 10 degrees)

Ordinate is $20 \log |Y|$ (1 cm for 2 db)

Contours of constant amplitude for $20 \log \left| \frac{Y}{1+Y} \right|$

Contours of constant phase for $\frac{Y}{1+Y}$