2601/201
2602/201
2603/201
CONTROL SYSTEMS AND
PROGRAMMABLE LOGIC CONTROLLERS
Oct./Nov. 2021
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ELECTRICAL AND ELECTRONICS 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;
Drawing instruments;
Mathematical tables/non-programmable scientific calculator;
Loglinear paper.
*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.*
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 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.

Turn over

SECTION A: CONTROL SYSTEMS

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

1. (a) Define each of the following elements of a closed - loop system:

(i) correction element;
(ii) process element;
(iii) measurement element.

(3 marks)

(b) **Figure 1** shows a diagram of a control system. Derive the transfer function of the system; $\frac{X_{(s)}}{F_{(s)}}$. (6 marks)

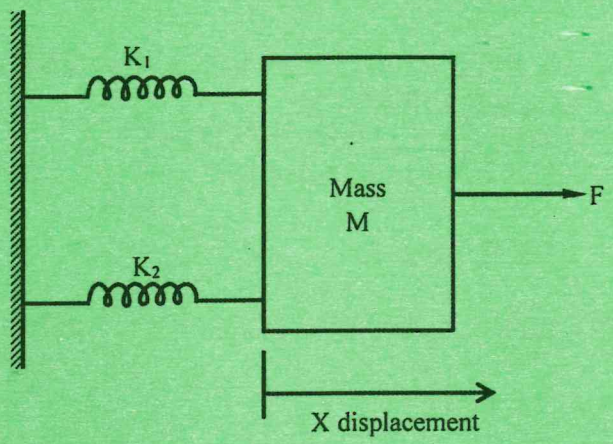


Fig. 1

(c) **Figure 2** shows a block diagram of a multi-input control system. Derive an equation relating the inputs $\theta_{i(s)}$, $\theta\delta_{1(s)}$, $\theta\delta_{2(s)}$ to output $\theta_{0(s)}$. (11 marks)

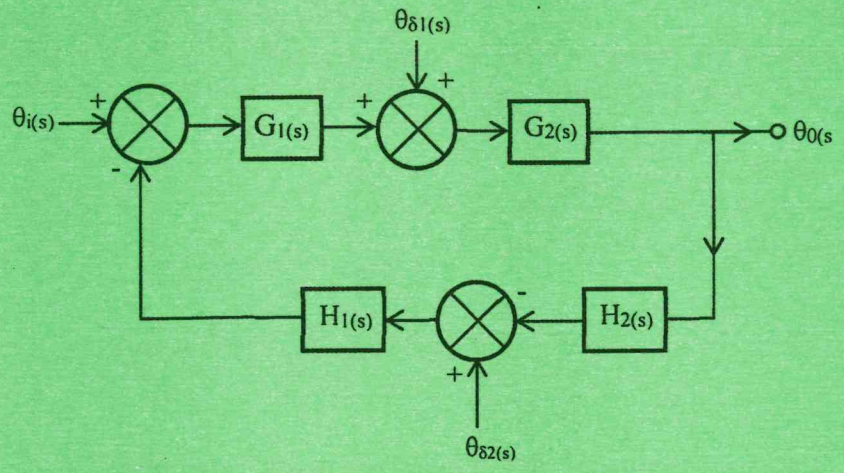


Fig. 2

2. (a) **Figure 3** shows an electrical network. Show that its transfer function is given by:

$$\frac{V_{0(s)}}{V_{i(s)}} = \frac{1}{T_1T_2S^2+T_1S+1} \text{ if } \frac{L}{R} = T_1 \text{ and } CR = T_2. \quad \text{(9 marks)}$$

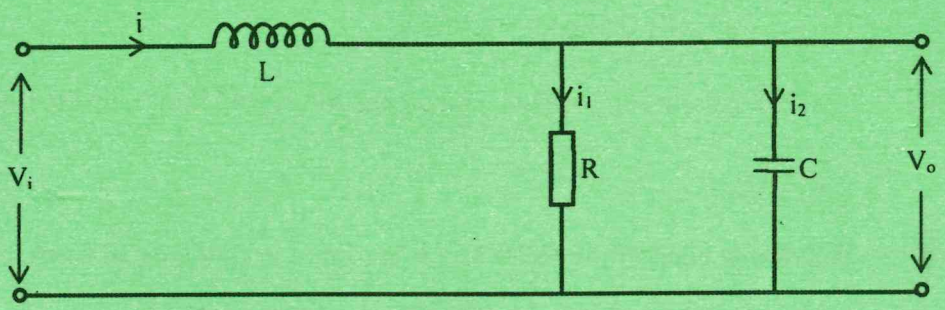


Fig. 3

(b) (i) Explain a signal flow graph;

(ii) **Figure 4** shows a signal flow graph of a control system. Using Mason's gain formula, determine its transfer function. (11 marks)

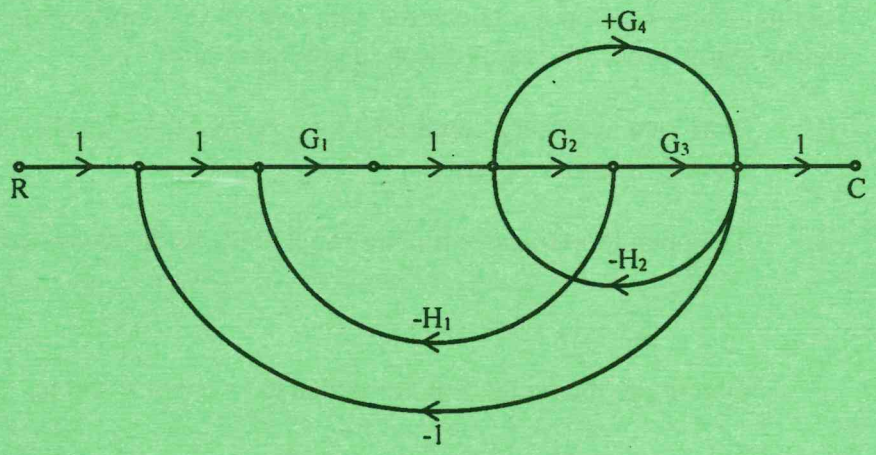


Fig. 4

3. (a) Define each of the following test input signals:

(i) step input;
(ii) ramp;
(iii) acceleration.

(3 marks)

(b) (i) On the same axis, sketch labelled response graphs of a second order system to a unit step input for each of the following damping:

(I) underdamped;
(II) overdamped;
(III) critically damped.

(ii) A servo system for position control has the closed loop transfer function:

$$\frac{6}{s^2+2s+6}$$

Determine each of the following if the input is suddenly moved:

(I) natural frequency;
(II) damping factor;
(III) time constant;
(IV) percentage overshoot;
(V) type of damping.

(13 marks)

(c) Distinguish between poles and zeros with respect to complex transfer functions stating significance of their position in pole-zero plot. (4 marks)

4. (a) (i) State **two** necessary conditions for a system to be stable with reference to Routh's stability criterion.

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

$$G_{(s)} = \frac{K}{(s^2+3s)(s^2+s+1)}$$

Determine the range of K for which the system is stable.

(11 marks)

(b) Obtain an analog computer flow diagram to solve the following second order simultaneous differential equations:

$$\ddot{x}+5\dot{x}+4x=5$$
$$\ddot{y}-6y-x=0$$

(7 marks)

(c) Define each of the following with respect to analog computers:

(i) time scaling;
(ii) amplitude scale factor.

(2 marks)

5. (a) A unity feedback control system is described by:

$$G_{(s)} = \frac{3}{s(1+0.05s)(1+0.2s)}$$

For $\omega(rad/\sec)$ values 0, 0.1, 0.5, 1, 5, 10 and 20.

(i) construct an asymptotic log-magnitude plot and an exact phase plot;

(ii) from the bode plot, determine the:

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

(14 marks)

(b) A control system has a loop gain $G_{(s)}H_{(s)} = \frac{50}{(s+2)(s+10)}$. If a step input of 5° is applied, determine the:

(i) steady state error;
(ii) error coefficient.

(6 marks)

SECTION B: INDUSTRIAL PROGRAMMABLE LOGIC CONTROLLERS

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

6. (a) (i) State **three** areas of applications of PLCs.

(ii) Explain the working of each of the following:

(I) inductive sensors for detection of metallic objects;
(II) ultrasonic sensors for measurement of object distance.

(9 marks)

(b) (i) Distinguish between logical and continuous PLC output and for each case, state an application area.

(ii) **Figure 5** shows an circuit diagram of a PLC output interface.

(I) identify the type of interface;
(II) state the function of components Q, R and S in the circuit.

(8 marks)

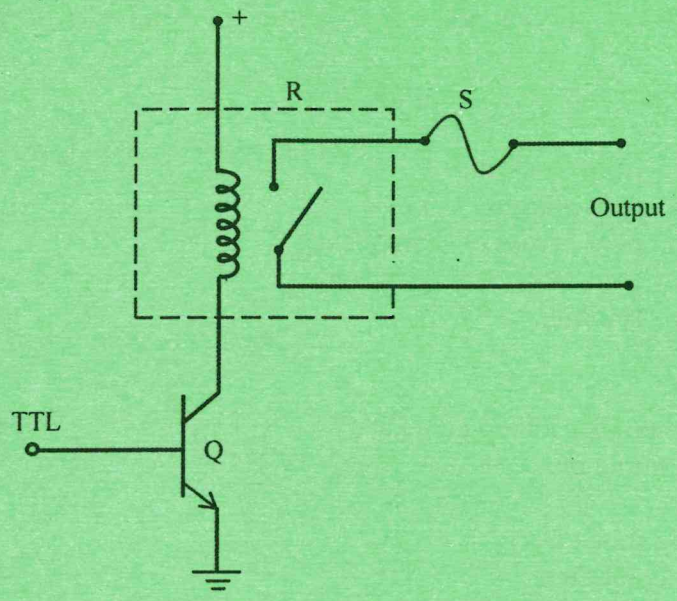


Fig. 5

(c) State **three** PLC programming devices. (3 marks)

7. (a) **Figure 6** shows a ladder diagram for a system controlling the cyclic movement of an engine piston. Write its equivalent instruction list. (12 marks)

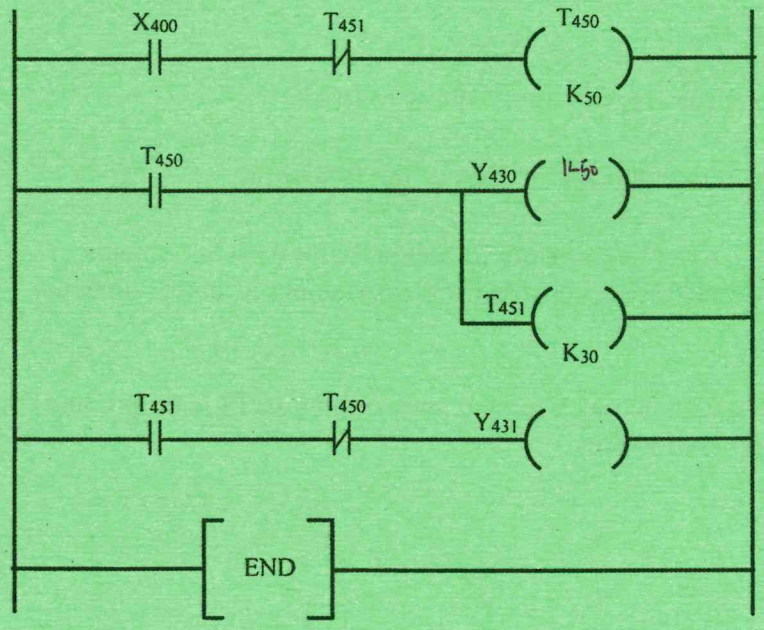


Fig. 6

(b) Explain the function of each of the following SCADA components:

(i) field data interface devices;
(ii) communications network;
(iii) central host computer;
(iv) operator workstations.

(8 marks)

8. (a) With an aid of labelled diagram, describe the operation of multi-drop mode Highway Addressable Remote Transducer (HART) network communication configuration.

(6 marks)

(b) (i) With reference to Twisted Pair (TP) cables, define each of the following and explain how each is minimized:

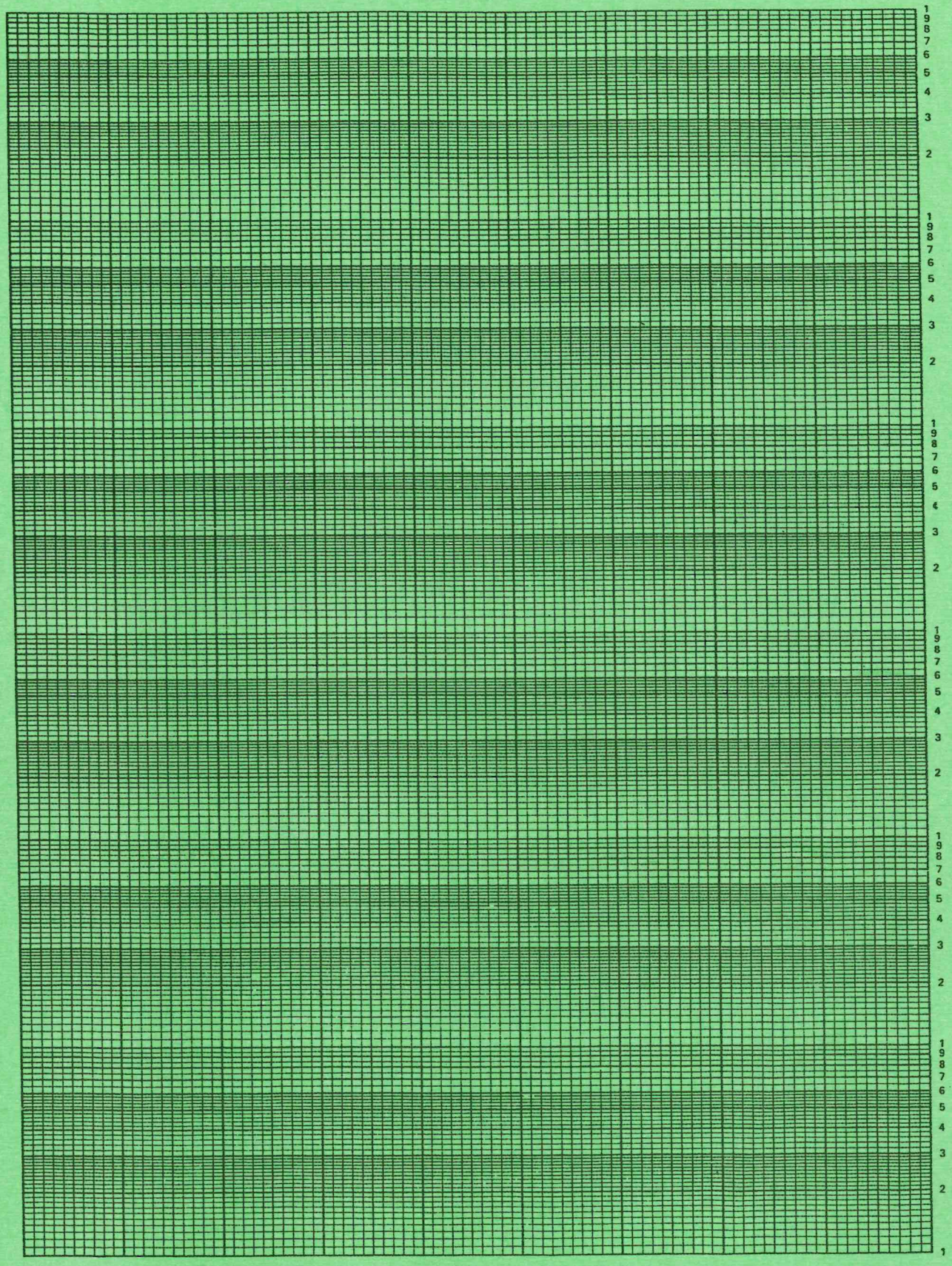
(I) cross talk;
(II) cancellation.

(ii) With the aid of a labelled diagram, explain ring topology data communication when networking industrial devices. (11 marks)

(c) Table 1 shows a partially filled TCP/IP layer model table. Redraw and complete the table. (3 marks)

Table 1

Layer	Functionality
4	
3	
2	Internet/Network
1	



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