

2601/201

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**CONTROL SYSTEMS AND PROGRAMMABLE
LOGIC CONTROLLERS**

June/July 2020

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;

Drawing instruments;

Non-programmable scientific calculator;

Log linear 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.

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

Candidates should answer the questions in English.

This paper consists of 10 printed pages and 1 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.

- (a) (i) Define system modelling as used in control systems.
 (ii) Explain **three** reasons for system modelling of a physical system. (4 marks)
- (b) **Figure 1** shows a simple mechanical translational system. Determine its transfer function, $\frac{X(s)}{F(s)}$. (9 marks)

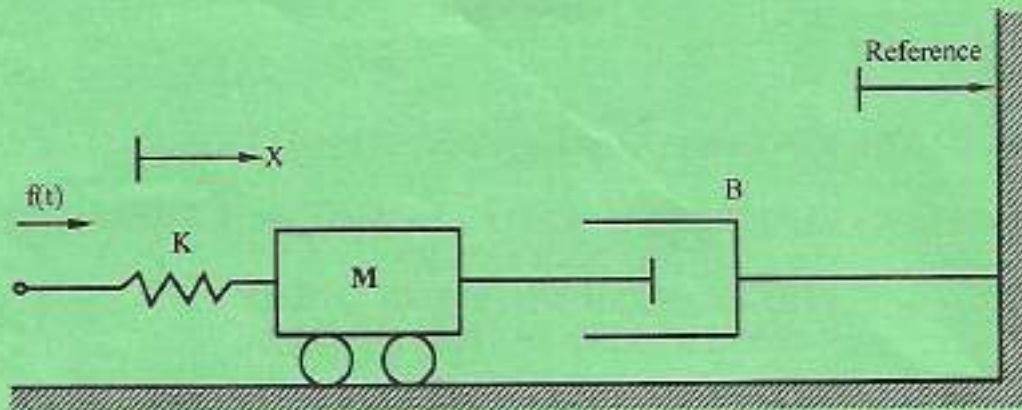


Fig. 1

- (c) **Figure 2** shows a block diagram of a control system. Derive each of the following:

- (i) closed loop transfer function;
 (ii) primary feedback ratio;
 (iii) error ratio.

(7 marks)

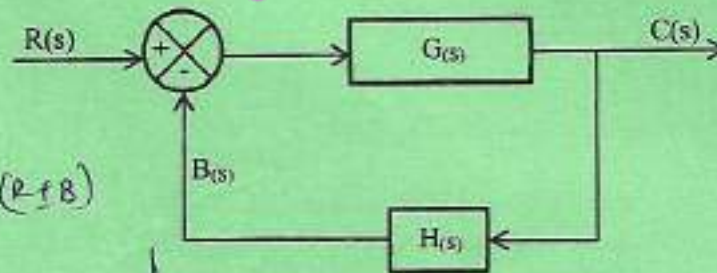


Fig. 2

Closed loop C/R

$$C_s = G_s E_s ; E_s = (R + B)$$

$$C_s = G(R + B)$$

$$C_s = G R + G B_s ; B_s = H C$$

$$C_s = G R + G H C$$

$$G(C - G H C) = G R$$

$$C/R = \frac{G}{1 - G H}$$

2601/201 $(1 - G H)$

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Primary feedback B/R

$$B = H C ; C = G E$$

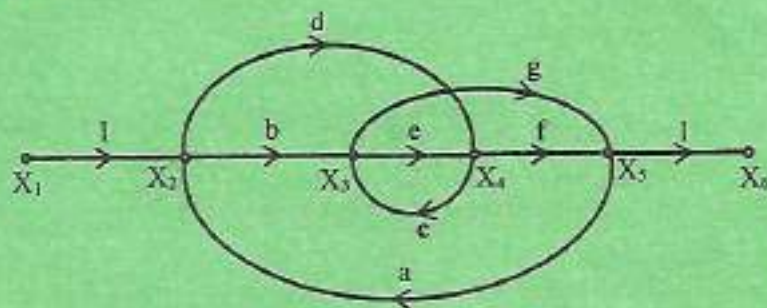
$$B_s = G H E ; E_s = (R + B)$$

$$B_s = G H (R + B)$$

$$\frac{B_s}{R} = \frac{G H}{1 - G H}$$

- 2 (a) Figure 3 shows a signal flow graph representing a control system. Determine the system gain. (10 marks)

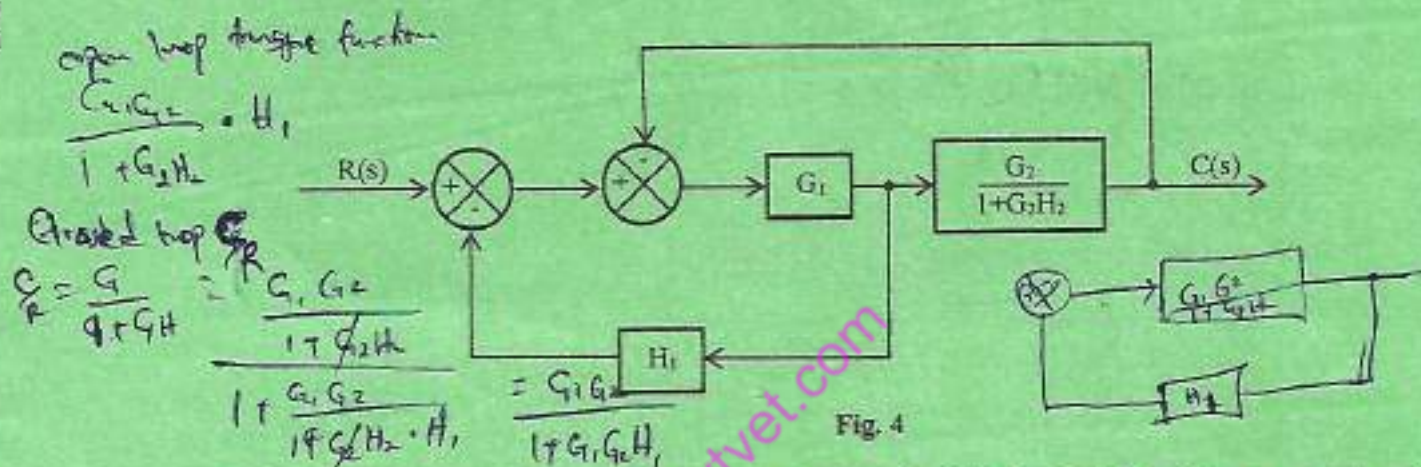
Individual loop
 $L_1 = -ec$
 $L_2 = eg$
 $L_3 = bd$
 $L_4 = -abef$



Forward path
 $P_1 = bed$
 $P_2 = bdf$
 $P_3 = eg$
 $P_4 = bedeg$

Fig. 3

- (b) Figure 4 shows a block diagram representation of a control system. Determine its transfer function using block diagram reduction technique. (7 marks)



- (c) The temperature range of a controlled system is 200 K to 330 K and has a set point of 285 K. Determine the percentage of span error when the temperature is 297 K. (3 marks)

3. (a) State three types of compensating networks. (3 marks)

Lead compensator - Lead lag compensator - Lag compensator.

- (b) An open loop control system is represented by the function

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

For a phase margin of 45° , determine the:

- (i) expression for the gain cross over frequency;
 (ii) the value of α . (9 marks)

- (c) Table 1 shows the phase angle - frequency values for a control system whose open loop transfer function is;

$$G(s) = \frac{10}{s(1+s)(1+0.02s)}$$

- (i) Using asymptotic approximation, sketch the bode diagram for the system.
 (ii) From the bode diagram, determine the:

- I. gain cross over frequency;
 II. phase cross over frequency;
 III. gain margin.

(8 marks)

Table 1

ω rads	0.2	0.5	1.0	3.0	5.0	10	50
Phase degrees (ϕ°)	-102	-117	-136	-165	-174	-186	-224

4. (a) Table 2 shows mechanical - electrical analogy for control system. Complete the table.
 (5 marks)

Table 2

Translational	Electrical	Rotational
Force (F)	Voltage (V)	
		Inertia (I)
Damper (B)		

- (b) A control system consists of a series RLC network:
 (i) draw the network;
 (ii) show that $V_{(s)} = BSQ_{(s)} + LS^2Q_{(s)} + \frac{Q_{(s)}}{C}$ where Q is the charge. (7 marks)
- (c) A servomechanism is represented by the equation

$$\frac{d^2\theta}{dt^2} + \frac{10d\theta}{dt} = 150(r - \theta)$$

Where r is the reference input and θ is the output shaft position. For the system, determine the:

- (i) undamped frequency;
 (ii) damping ratio;
 (iii) damped frequency.

(8 marks)

5. (a) With the aid of a labelled circuit diagram, explain the principle of operation of a phase sensitive rectifier. (9 marks)
- (b) State any **two** essential features of a servo mechanism. (2 marks)
- (c) **Figure 5** shows a schematic block diagram of position control system used to control the motion of a radar.
- (i) State the function(s) of each element used.
- (ii) Calculate the gear ratio needed for maximum acceleration if the inertia of the motor and load are 11 kg-m^2 and 363 kg-m^2 respectively. (6 marks)

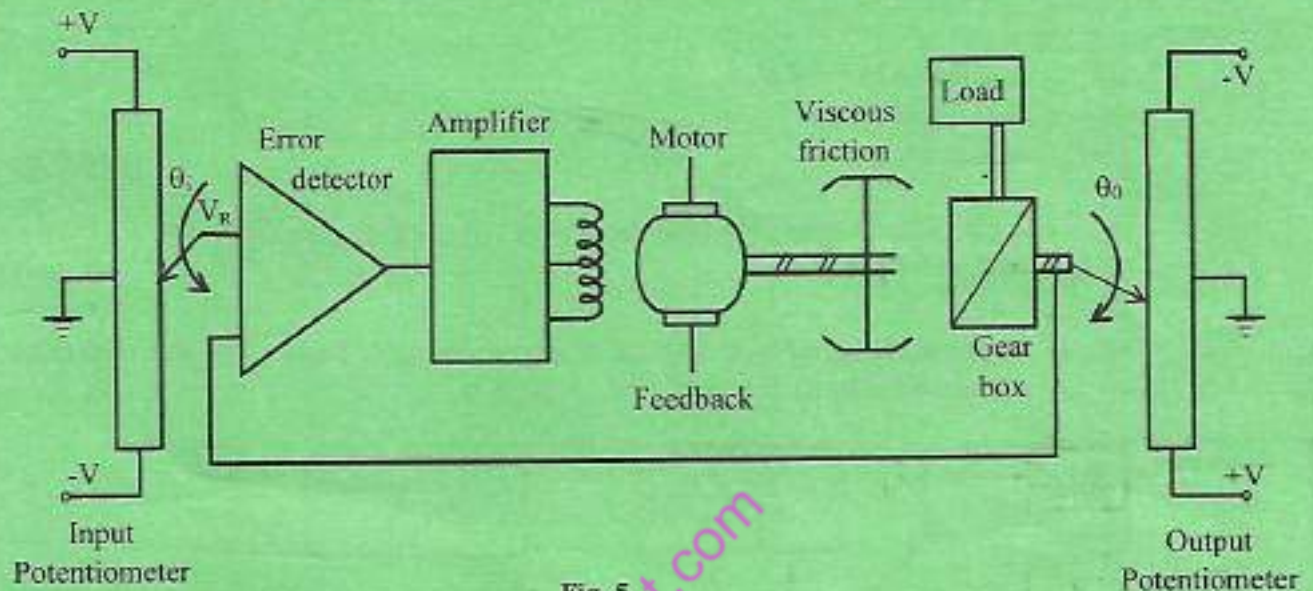


Fig. 5

- (d) Explain dead zone with respect to remote position control (R.P.C) systems. (3 marks)

SECTION B: PROGRAMMABLE LOGIC CONTROLLERS

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

- 6.
- (a) With the aid of a labelled block diagram, define each of the following data transmission modes:
- (i) half duplex;
 - (ii) full duplex.
- (6 marks)
- (b) With the aid of a labelled diagram, describe each of the following types of transmission media:
- (i) unshielded twisted pair;
 - (ii) coaxial cable;
 - (iii) optical fibre cable.
- (12 marks)
- (c) State **two** advantages of optical fibre cable over copper transmission cables.
- It is very cheap*
- (2 marks)

- 7.
- (a) (i) **Figure 6** shows a block diagram of a programmable logic controller. Describe the functions of each block.

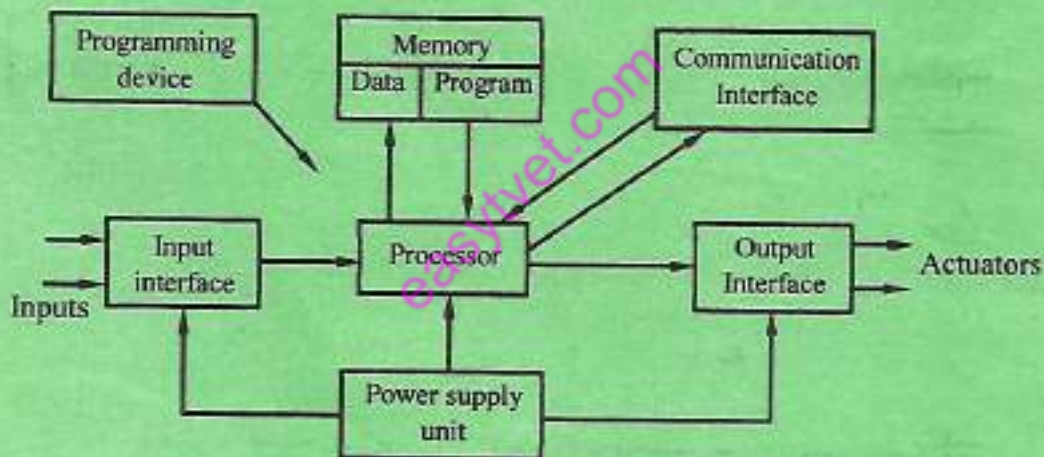
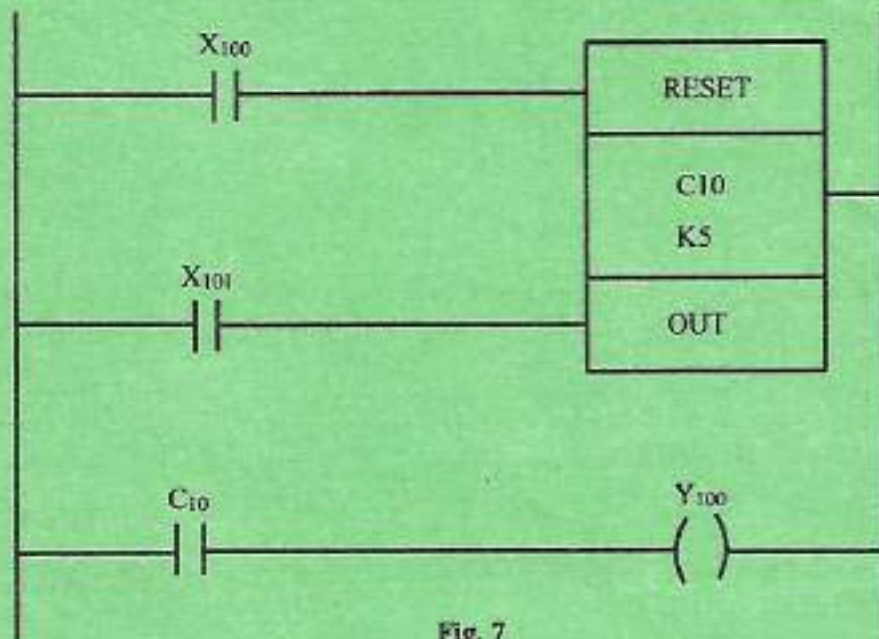


Fig. 6

- (ii) State **three** types of PLC output interfaces.
- (10 marks)

- (b) Figure 7 shows a ladder diagram for a PLC. Write down its equivalent instruction list program. (7 marks)



LD X100
LD X101

LD X100
OR X101
OR BLOCK
LD C10
OUT Y100

- (c) Draw a labelled circuit diagram of an opto-isolator used at the input terminal of a PLC. (3 marks)

8. (a) With the aid of a labelled diagram, describe each of the following types of SCADA systems:

- (i) centralized;
(ii) distributed. (8 marks)

- (b) Table 3 shows the functions of different layers of an open system interconnection (OSI) reference model. Identify the layers labelled A, B, C and D. (4 marks)

Table 3

Layers	Functions
A	It defines protocols responsible for sending data.
B	It defines the switching that routes data between system in the network.
C	Concerned with coding and transmission of information. It synchronizes data transfer.
D	It defines the protocols for sending and receiving information between two connected systems.

(c) Draw ladder logic program for each of the following Boolean functions:

(i) $X_1 = UV + \overline{U}V + UW$

(ii) $X_2 = U\overline{V}W + UVW$

(8 marks)

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