2201/304
2203/304
2204/304
CONTROL SYSTEMS
Oct./Nov. 2009
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

# DIPLOMA IN ELECTRONICS ENGINEERING
# DIPLOMA IN TELECOMMUNICATION ENGINEERING
# DIPLOMA IN ELECTRICAL ENGINEERING (POWER OPTION)

CONTROL SYSTEMS

**3 hours**

## INSTRUCTIONS TO CANDIDATES

*You should have the following for this examination:*
*Answer booklet;*
*Nyguist Chart;*
*Mathematical tables/Electronic calculator.*

*Answer any **FIVE** of the **EIGHT** questions in this paper.*
*All questions carry equal marks.*
*Maximum marks for each part of a question are as shown.*

**This paper consists of 8 printed pages.**

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

1. (a) (i) Draw a ladder diagram to carry out the following tasks:

- An output A occurs when input 1 occurs.
- Output B occurs when input 1 and input 3 occurs.
- Output C occurs when input 4 or input 5 occurs.

(ii) Outline the sequence of drilling using an automatic drilling machine. (8 marks)

(b) (i) State any **two** advantages of relays used for switching in programmable logic controller controlled systems.

(ii) With the aid of a circuit diagram, explain how time delay can be introduced in digital controlled processes. (5 marks)

(c) A door is controlled by four switches A, B, C,D. The door will open when either of the following conditions is satisfied.

1. all switches are open;
2. B and C are closed; A and D open;
3. any one switch is closed and the remaining three open;
4. A and D closed; and B and C open.

Assume switch closed = logic "1"
switch open = logic "0"

(i) Draw the truth table to represent the above information.

(ii) With the aid of Karnaugh map, obtain the minimal expression to implement the switching control. (7 marks)

2. (a) For a biological control system consisting of a human being reaching for an object; identify the following:

(i) input;

(ii) output;

(iii) comparison element. (3 marks)

(b) (i) Write the differential equation describing the dynamics of the system in figure 1.

(ii) Find the ratio $\frac{X_{2(s)}}{F_{(s)}}$

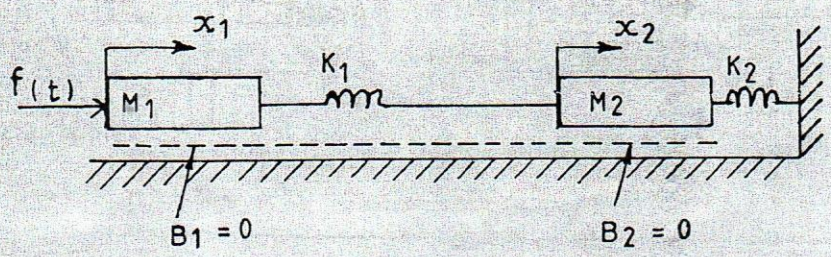


Figure 1

(9 marks)

(c) An R-L-C series circuit has the following parameters:
L = 2.0H, R = 100Ω and C = 20μF.

For the circuit determine:

(i) natural frequency, $W_n$;

(ii) damped frequency, $W_d$;

(iii) percentage overshoot. (8 marks)

3. (a) (i) State the input test signal that may be used for testing each of the following:

I: sudden change in displacement;
II: step change in velocity;
III: step change in acceleration.

(ii) Define each of the following as used in control systems:
I. rise time;
II. settling time. (5 marks)

(b) A second order system has characteristic equation $s^2 + 2s + 1 = 0$.
If unity feedback is used, determine for a unit step input:

(i) the expression for output response;

(ii) steady state errors. (10 marks)

(c) Figure 2 is a schematic diagram of an automatic shaft speed controller. Describe its operation.

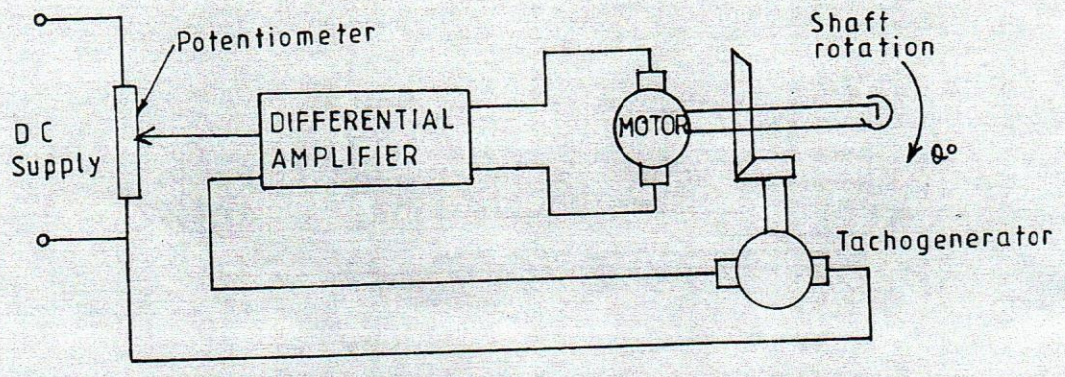


Figure 2

(5 marks)

4. (a) (i) For a system with transfer function; $G(s) = \frac{2(S+2)}{S(1+2S)(1+4S)}$

Determine the corner frequencies.

(ii) With the aid of a Bode plot sketch, explain the following:

I. phase margin;
II. grain margin;
III. grain cross over frequency;
IV. phase cross over frequency. (8 marks)

(b) For a unity feedback system having $G(s) = \frac{K}{s(s+1)}$,

Determine:

(i) position error coefficient, Kp;
(ii) velocity error coefficient, Kv;
(iii) acceleration error coefficient, Ka. (6 marks)

(c) State the effect of each of the following on a polar plot:
(i) addition of a non-zero pole to transfer function;
(ii) adding a zero to transfer function;
(iii) adding a pole at origin. (6 marks)

5. (a) Differentiate between:
   (i) physical system and mathematical model;
   (ii) block diagram and schematic diagram. (4 marks)

(b) Derive the transfer function of the circuit in figure 3.

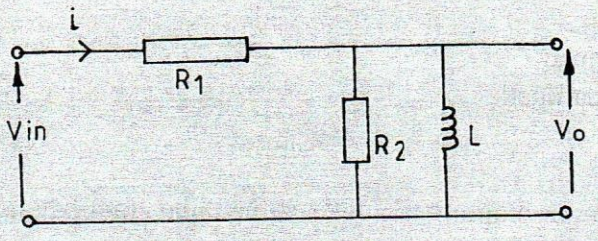


Figure 3

(5 marks)

(c) For the system of figure 4:
   (i) reduce to canonical form;
   (ii) determine the closed loop transfer function.

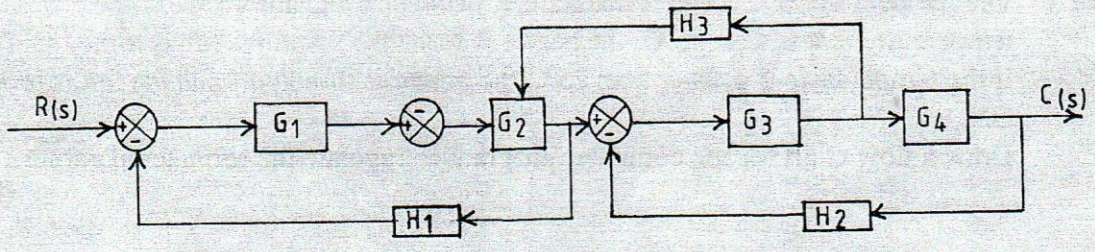


Figure 4

(11 marks)

6. (a) (i) List the steps followed when solving a differential equation using an analog computer.

(ii) List any **one** element used in analog computers under the following classifications:

I. linear element;
II. non-linear element;
III. control elements. (7 marks)

(b) With the aid of a suitable schematic diagram, explain the master potentiometer method of setting initial condition in analog computing. (5 marks)

(c) Draw a computer flow diagram to solve the following differential equation:

$$5\frac{d^3y}{dt^3} + \frac{20d^2y}{dt^2} + \frac{4dy}{dt} + 10y = 3e^{-2t}\sin 10t$$

(5 marks)

(d) Draw a labelled diagram to illustrate the following responses of a second order system to a step input:

(i) undamped;
(ii) under damped;
(iii) critically damped. (3 marks)

7. (a) (i) Draw a circuit diagram of a proportional plus integral electronic controller.

(ii) Derive the expression for the output for the circuit in a(i). (8 marks)

(b) A data logging system monitors 10 analog loops. It uses a computer which needs 100 instructions to address a multiplexer line, read in and process the data in that line. Each instruction requires $2\mu s$ and the ADC needs $20\mu s$ for conversion, while the multiplexer requires $10\mu s$ to select and capture the value of an input line. Determine the maximum sampling rate of each line. (6 marks)

(c) The temperature of a room is maintained between 15°C and 25°C. If the temperature is less than 15°C, the heater is turned ON and the fan is turned OFF. If the temperature is greater than 25°C the heater is turned off and the fan is turned ON.
Draw a flow chart for the computer program to regulate the room temperature. (6 marks)

8. (a) A unity feedback system has a closed loop response given by $\frac{G}{(1+G)}$
If G = x +jy:

(i) show that the closed loop N circles is given by

$$x^2 + x + y^2 - \frac{1}{N}y = 0$$

$$where\ N = \tan\alpha$$

$$and\ \alpha = \angle\frac{G}{1+G}$$

(ii) determine the centre of the circles;
(iii) calculate the radius of the circle if the phase angle is 30°C. (10 marks)

(b) The open-loop frequency response of a control system is given in table 1.

(i) plot the inverse Nyquist diagram.
(ii) determine from the plot:

I. peak resonant value;
II. resonant frequency at which (ii) (I) occurs. (10 marks)

Table 1

| W rad/sec | 1,0 | 1.5 | 2.0 | 3.0 | 5.0 | 10.0 |
|---|---|---|---|---|---|---|
| $\|G\|$ | 4.8 | 2.6 | 1.70 | 0.95 | 0.65 | 0.5 |
| $\phi$ deg | -110 | -122 | -126 | -135 | -142 | -145 |

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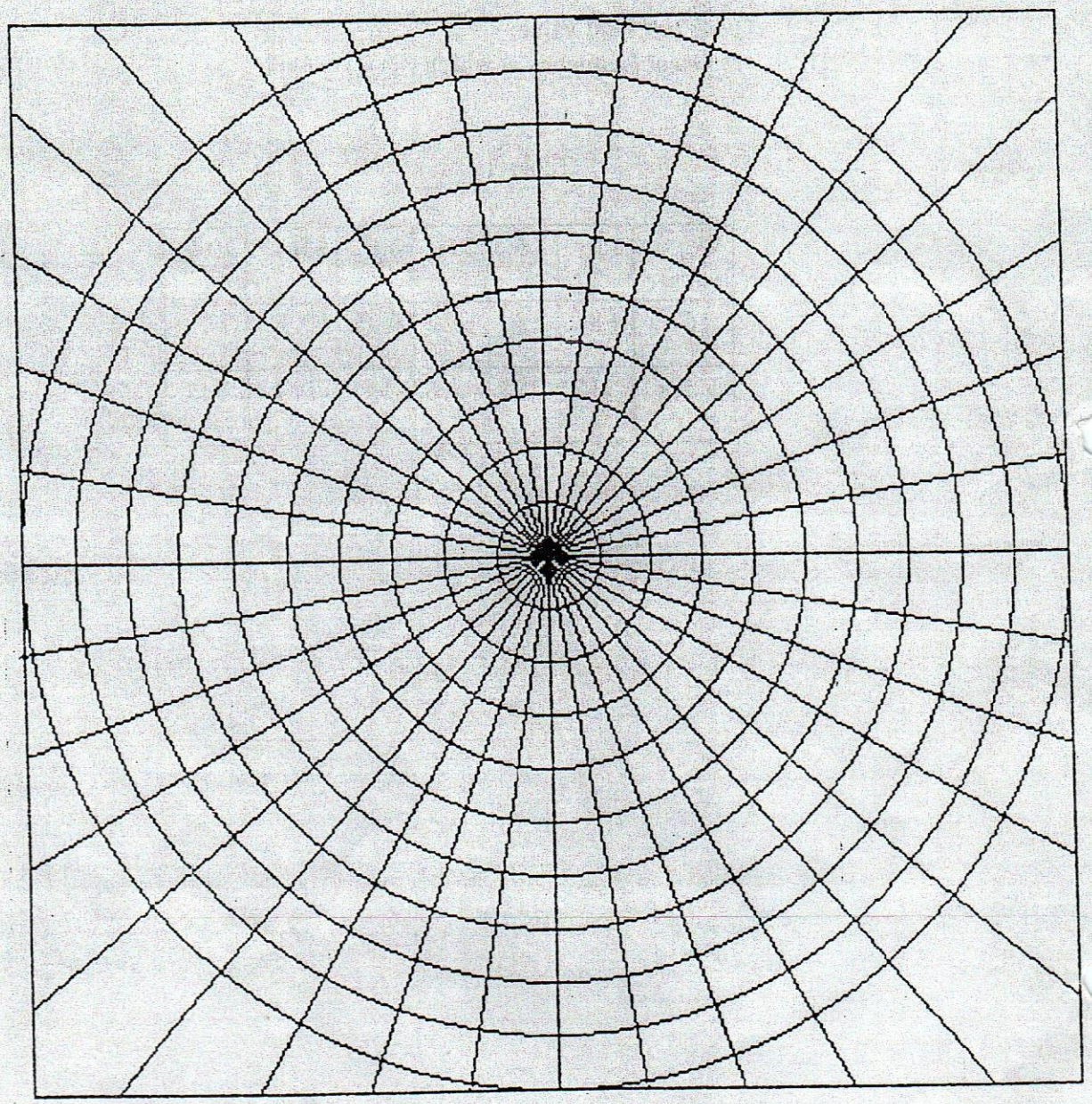

POLAR CURVE