2506/202
2507/202
ELECTRONICS AND CONTROL SYSTEMS
Oct./Nov. 2022
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN AERONAUTICAL ENGINEERING (AIRFRAMES AND ENGINES OPTION) (AVIONICS OPTION)

MODULE II

ELECTRONICS AND CONTROL SYSTEMS

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Answer booklet;
Mathematical tables/Non-programmable scientific calculator;
Log-linear graph paper;
Drawing instruments.
*This paper consists **EIGHT** questions in **TWO** sections; **A** and **B**.*
*Answer **THREE** questions from section **A** and **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 7 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: ELECTRONICS

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

1. (a) Minimise each of the following logic expressions using Boolean algebra:

(i) $f_1 = A\overline{C} + ABC + AC\overline{B}$

(ii) $f_2 = Wyz + xy + x\overline{z} + yz$

(iii) $f_3 = (w + x)(w + \overline{y})$ (7 marks)

(b) Convert each of the following:

(i) $(97.35)_{10}$ into binary (up to 5 binary points)

(ii) $(74.075)_{10}$ into octal (up to 4 octal points)

(iii) $(478.6)_{16}$ into octal. (8 marks)

159

(c) For a 2-to-4 decoder:

(i) draw the truth table;
(ii) draw the logic circuit diagram using NAND gates only. (5 marks)

2. (a) (i) Distinguish between intrinsic and extrinsic semiconductors.

(ii) For a common-emitter transistor configuration, show that the current gains are related by:

$$\alpha = \frac{\beta}{1 + \beta}$$ (6 marks)

(b) Figure 1 shows a common-emitter transistor amplifier, where $I_C = 100\mu A$, $\beta = 100,\ r_b = 0,\ r_0 = \infty, r_{in} = \frac{I_C(MA)}{26}$.

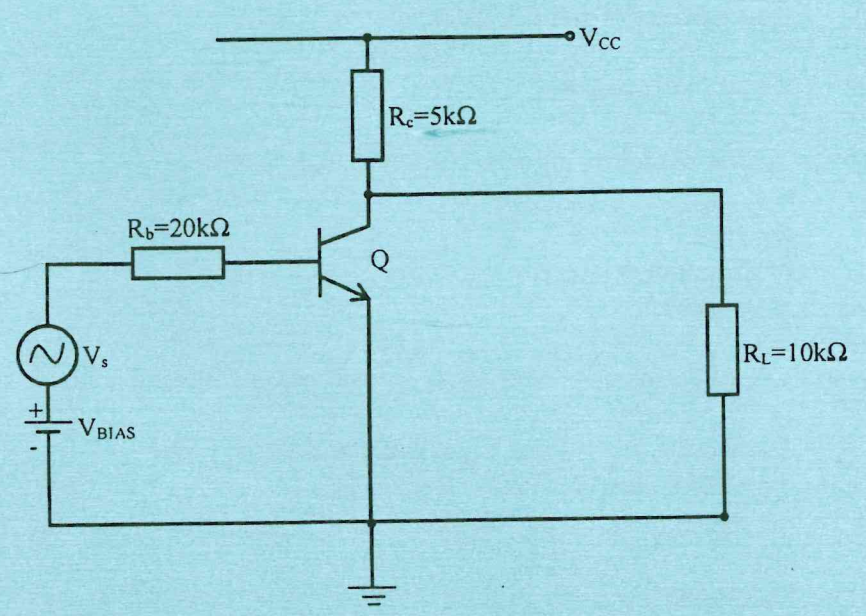

Fig. 1

(i) Draw the small signal equivalent circuit of the amplifier.

(ii) For the amplifier determine the:

I. input resistance;
II. output resistance;
III. voltage gain. (9 marks)

(c) With the aid of a voltage-current (V-I) characteristic curve, describe the operation of a silicon controlled rectifier (SCR). (5 marks)

3. (a) Draw the truth table for the following logic function:

$f = xy + \overline{x}\,\overline{z} + y\overline{z}$ (4 marks)

(b) Using a K-map, minimize the following Boolean expression:

$f(A,B,C,D) = \Sigma(1,3,7,9,12,13,14,15)$ (5marks)

(c) For each of the following expressions:

$f_1(A, B, C) = \Sigma(0,4,5,7)$
$f_2(w, x, y, z) = \Sigma(0,3,7,10,12,14,15)$

Implement each using:

(i) 3-to-8 decoders and OR-gates;

(ii) 8-to-1 multiplexers. (11 marks)

4. (a) Define each of the following with respect to logic gates:

(i) fan-in;
(ii) propagation delay;
(iii) noise margin. (3 marks)

(b) A family of logic gates operates under the following voltage thresholds,

$V_{0L} = 0.5\,V, V_{1L} = 1.6\,V, V_{0H} = 4.4V$ and $V_{1H} = 3.2V$.

(i) Sketch an input-output voltage transfer function for an inverter of the family.

(ii) Determine the:

I. highest voltage for the inverter for a logic 0 output;
II. highest voltage for the inverter for a logic 1 output. (7 marks)

159

(c) Draw a circuit diagram of a CMOS inverter gate and describe its operation. (7 marks)

(d) State **three** merits of CMOS gates. (3 marks)

5. (a) With respect to sinusoidal oscillators:

(i) define resonance;
(ii) state Barkhausen criterion. (3 marks)

(b) With aid of circuit diagram, describe the operation of a transistor-based colpitt oscillator. (7 marks)

(c) State **three** characteristics of an ideal OP-Amp. (3 marks)

(d) Figure 2 shows a circuit diagram of OP-Amp based system.

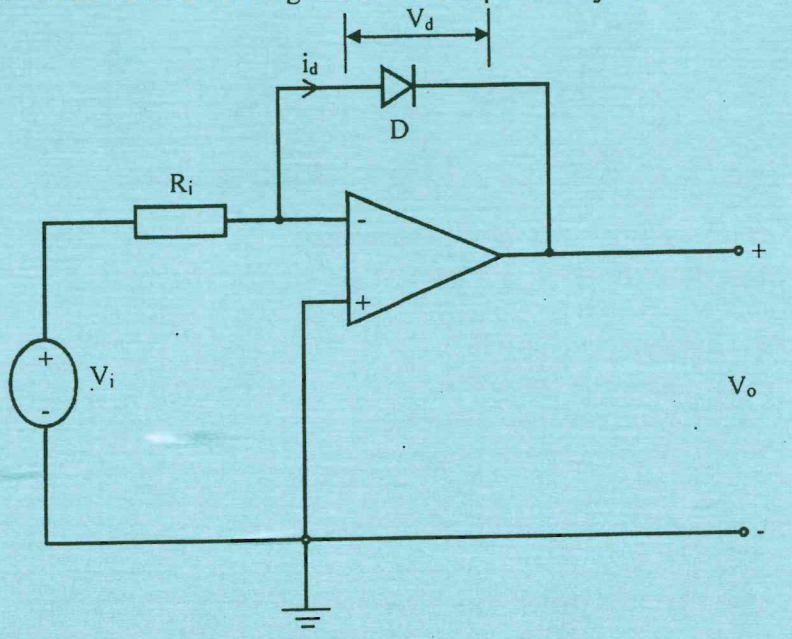

Fig. 2

(i) Derive the expression for Vo in terms of Vi and Ri.

(ii) Sketch the variation of Vo against Vi. (7 marks)

SECTION B: CONTROL SYSTEMS

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

6. (a) With aid of a diagram, explain the Nyguist stability criterion. (4 marks)

(b) Explain each of the following with respect to system stability:

(i) gain margin;
(ii) phase margin. (4 marks)

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

Table 1

ω (rad/s)	0.2	0.3	0.4	0.5	0.8	1.0	1.5	2	4	8	10	12
$\lvert G \rvert$ dB	20	18	14	12	8	4.5	0	-4	-16	-30	-36	-40
$< G°$	-95	-103	-105	-110	-120	-130	-145	-160	-195	-235	-245	-250

(i) Draw the Bode plot for the mechanism.
(ii) Determine from the plot the:

I. gain margins (GM);
II. phase margin (PM);
III. gain cross-over frequency;
IV. phase cross-over frequency.

(iii) Comment on the stability of the system. (12 marks)

7. (a) Define each of the following with respect to control systems:

(i) disturbance;
(ii) actuating signal. (2 marks)

159

(b) Figure 3 shows a block diagram of a control system.

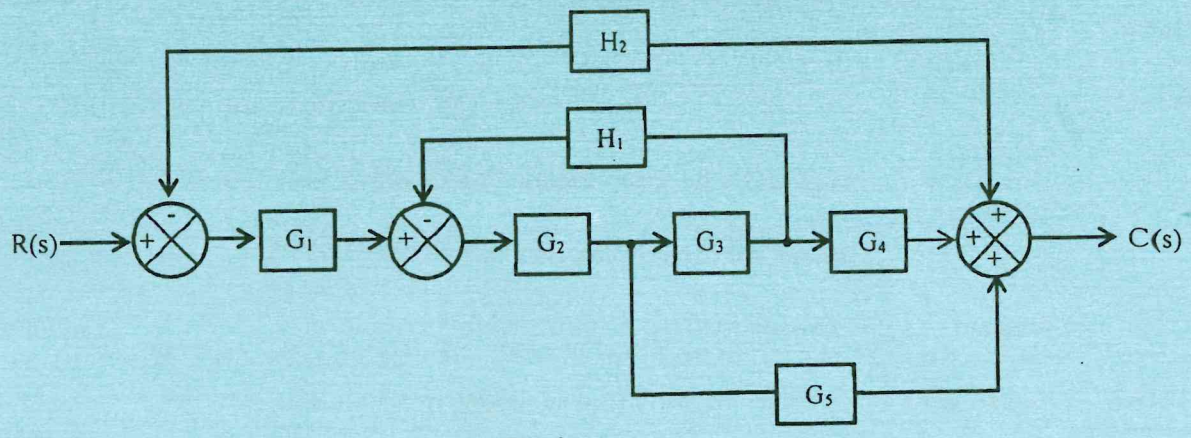

Fig. 3

(i) Draw a signal flow graph for the system.

(ii) Obtain the overall transfer function, C/R, of the system using Mason's gain formula. (10 marks)

(c) Figure 4 shows a block diagram of a unity feedback control system.

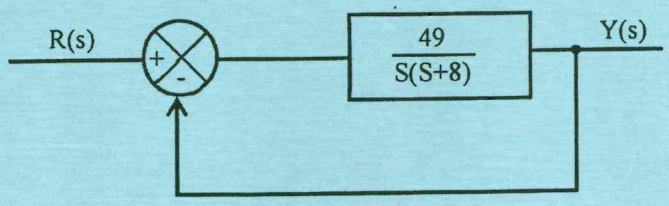

Fig. 4

Determine each of the following:

(i) natural frequency, ωn
(ii) damping ratio, ϵ
(iii) setting time (Ts), for 2% tolerance. (8 marks)

8. (a) State:

(i) **two** reasons for avoiding differentiation in analogue computing;
(ii) **three** reasons for time-scaling when solving computing problems using analogue computers. (5 marks)

159

(b) A control system is represented by the following simultaneous differential equations:

$$\ddot{y} - 6\dot{y} - x = 0$$
$$\ddot{x} + 2\dot{x} - 3\dot{y} + x = 5$$

Draw an analogue computer flow diagram to solve the equations. (8 marks)

(c) (i) Define each of the following with respect to stepper motors:

I. step-angle;
II. slewing.

(ii) State **three** reasons for the widespread use of stepper motors in control systems.

(iii) Sketch the typical static characteristics of a stepper motor showing the variation of the Torque (T) against step angle (θ). (7 marks)

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Candidate Name: _____ **Index No:** _____

Semi-log Graph Paper