2506/202
2507/202
ELECTRONICS AND CONTROL SYSTEMS
June/July 2023
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 8 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.

Turn over

SECTION A: ELECTRONICS

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

1. (a) Perform each of the following number system conversions:

   (i) $(827)_{10}$ into:

   (I) 8421 BCD;
   (II) 5211 BCD.

   (ii) $(629)_{10}$ into:

   (I) Octal;
   (II) Binary;
   (III) Hexadecimal.

   (10 marks)

   (b) Perform each of the following operations:

   (i) $$\begin{array}{r} (110011)_2 \\ \underline{\times (101101)_2} \end{array}$$

   (ii) $(17)_{10}$ - $(169)_{10}$ in two's complement using 9-bits. Leave the result in binary.

   (6 marks)

   (c) A half-subtractor consists of two inputs, A and B and two outputs D and Bo. Draw the truth table for the circuit. (4 marks)

2. (a) Define each of the following with respect to atomic structure of elements:

   (i) covalent bond;
   (ii) energy band.

   (2 marks)

   (b) With aid of an energy-level diagram, explain a p-type semiconductor. (5 marks)

   (c) A sample of silicon is made N-type by addition of pentavalent atoms at a rate of 1 atom per 8×10^6 silicon atoms. The intrinsic carrier concentration in silicon is, $n_i = 4\times10^{16}/m^3$ and the number of silicon atoms per unit volume is $22\times10^{28}/m^3$. Determine the:

   (i) concentration of donor atoms;
   (ii) concentration of electrons in the conduction band;
   (ii) concentration of holes in the valency band.

   (6 marks)

(d) (i) Draw the V-I characteristic curve of a unijunction transistor (UJT) and label the **three** distinct regions.

(ii) State **two** applications of UJT.

(7 marks)

3. (a) Define each of the following with respect to flip-flops:

(i) set-up time;
(ii) hold time.

(2 marks)

(b) (i) Draw the truth table for SR-flip flop.

(ii) Draw the logic circuit diagram of a JK-flip flip, made from SR-flip flop and gates.

(6 marks)

(c) For a modulo-12 Asynchronous up counter:

(i) Draw the counting sequence;
(ii) Determine the number of JK flip flops required;
(iii) Draw the schematic block diagram of the counter.

(9 marks)

(d) A 4K $\times$ 8 memory is made from 2K $\times$ 4 memory chips. Determine the:

(i) number of 2K $\times$ 4 chips required.
(ii) size of decoder required for the memory implementation.

(3 marks)

4. (a) Define each of the following with respect to PN-diode:

(i) Depletion region;
(ii) peak-inverse voltage (PIV).

(2 marks)

(b) Figure 1 shows a circuit diagram of a half-wave diode rectifier supplied from 220 V, 50 Hz through a step-down transformer of turns ratio 20:1. The load of resistor, $R_L = 500\ \Omega$.

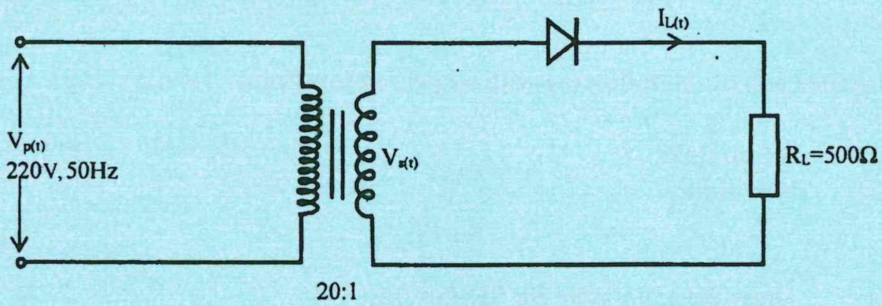

Fig. 1

Assuming the diode is ideal, determine the:

(i) dc voltage across the load;

(ii) average output load power;

(iii) PIV of the diode;

(iv) ripple factor.

(8 marks)

(c) State **two** limitations of half-wave rectifiers. (2 marks)

(d) (i) Draw the V-I characteristics of a TRIAC and explain its operation.

(ii) State **two** areas of application of TRIAC.

(8 marks)

5. (a) Define each of the following with respect to OP-Amps:

(i) slew rate;

(ii) input offset voltage;

(iii) common-mode rejection ratio.

(3 marks)

(b) Figure 2 shows a diagram of an OP-Amp based circuit.

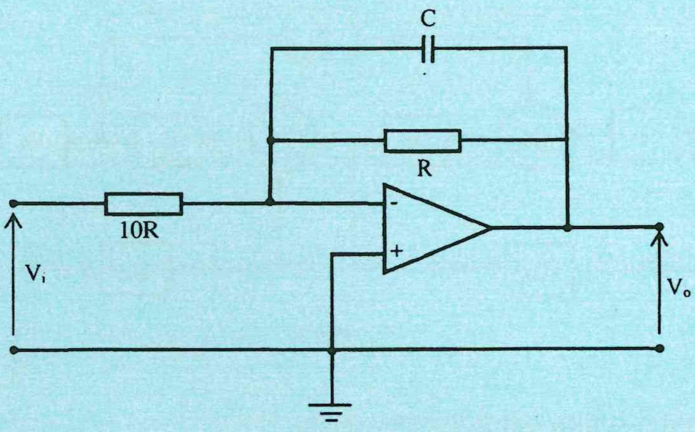

Fig. 2

(i) Derive the expression for the gain, $\frac{V_o}{V_i}$.

(ii) Sketch the variation of gain with frequency.

(7 marks)

(c) Draw a circuit diagram of a Colpitts oscillator and explain its operation. (6 marks)

(d) A Hartley Oscillator tank circuit has a capacitance of 150 pF. The inductances are $L_1 = 2000\ \mu H$ and $L_2 = 200\ \mu H$. Determine the:

(i) effective oscillator inductance;

(ii) frequency of oscillation.

(4 marks)

SECTION B: CONTROL SYSTEMS

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

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

(i) stimulus;

(ii) plant;

(iii) disturbance.

(3 marks)

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

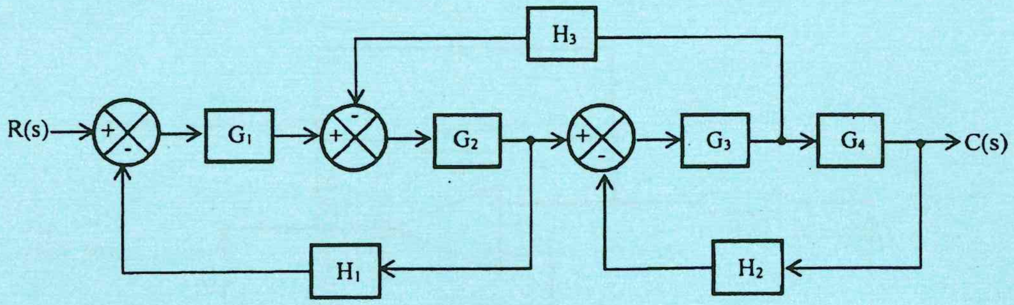

Fig. 3

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

(ii) Using Mason's gain formula, determine the transfer function, $\frac{C_{(s)}}{R_{(s)}}$.

(11 marks)

(c) Figure 4 shows a mass-spring system.

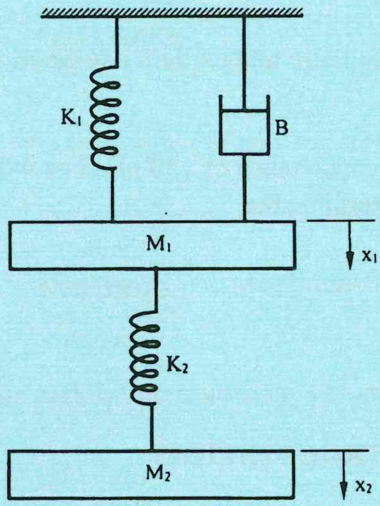

Fig. 4

(i) Write the differential equation to describe the system.

(ii) Draw a circuit diagram for the force-voltage analogy for the system.

(6 marks)

7. (a) (i) Describe the Routh-Hurwitz stability criterion.

(ii) The characteristic equation of a control system is given by:

$$D_{(s)} = 2s^3 + 6s^2 + 6s + K + 1 = 0.$$

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

(12 marks)

(b) A closed-loop servo system is represented by the differential equation:

$$\frac{d^2\theta}{dt^2} + 8\frac{d\theta}{dr} = 64e$$

where e is the displacement of the output shaft and r is the displacement of the input shaft. Where $e = r - \theta$. Determine the:

(i) undamped natural frequency;

(ii) percentage maximum overshoot for a step input.

(8 marks)

8. (a) Define each of the following with respect to control system stability:

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

(2 marks)

(b) An open-loop transfer function of a unity feedback control system is given by:

$$G(s) = \frac{80}{(2+s)(4+s)(10+s)}$$

(i) Determine the corner frequencies.

(ii) Table 1 shows the phase angles at selected frequencies.

Freq (ω) rad/s	0.1	0.5	1.0	2.0	4.0	5.0	8.0	9.0	20	50
Phase angle (°)	-4.87	-24.03	–	–82.9	–130	–146	–175	–	–226	–252

Determine the phase angles at frequencies $\omega =$ 1.0 and 9 rad/s respectively.

(iii) Plot the Bode diagram, using asymptotic approximations for gain.

(iv) From the Bode diagram, determine the phase margin of the system.

(12 marks)

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

$$\dot{y} + 4y + x = 3$$
$$\dot{x} + 3x - y = 7$$

Draw an analogue computer flow diagram for simulating the control system.

(6 marks)

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