2506/202
2507/202
ELECTRONICS AND
CONTROL SYSTEMS
March/April 2024
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;
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.

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) (i) Define 'atomic number' with respect to semiconductors.

(ii) Figure 1 shows the energy band structure of a semiconductor.

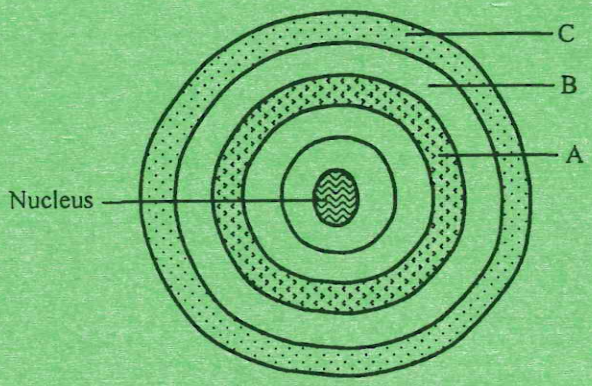

Fig. 1

Identify the bands labelled **A**, **B** and **C**. (4 marks)

(b) With aid of a construction diagram, describe the operation of N-channel, depletion MOSFET. (8 marks)

(c) Figure 2 shows a Junction Field Effect Transistor (JFET) with voltage divider bias. The drain voltage $V_D = 7V$.

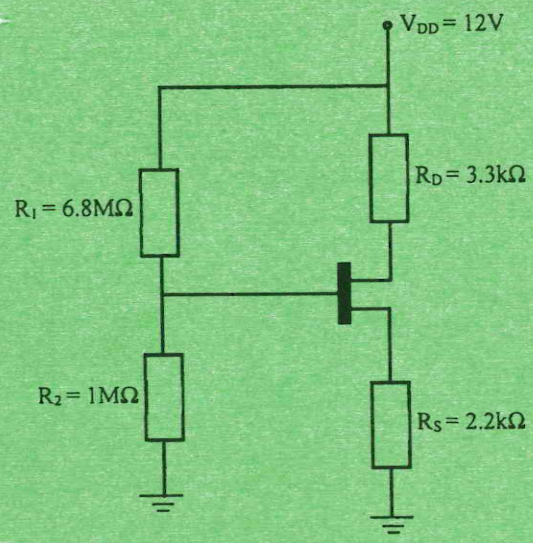

Fig. 2

Determine the:

(i) drain current, I_D;
(ii) source voltage, V_s;
(iii) gate voltage, V_G;
(iv) gate-to-source voltage, V_{GS}.

(8 marks)

2. (a) State **three** advantages of negative feedback in amplifiers. (3 marks)

(b) Figure 3 shows a single stage common emitter amplifier.

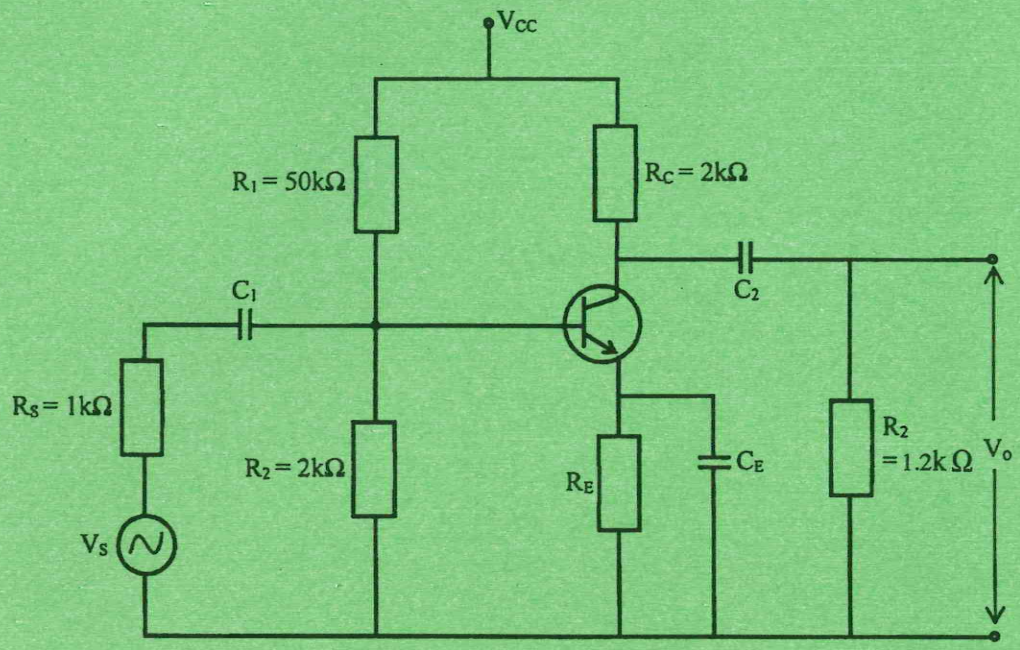

Fig. 3

Given that $h_{ie} = 1.1\ k\Omega$, $h_{oe} = 25\ \mu A/V$, $h_{fe} = 50$ and $h_{re} = 2.5 \times 10^{-4}$, determine the:

(i) input resistance, Ri;

(ii) overall current gain, Ais;

(iii) overall voltage gain, Avs.

(10 marks)

(c) With aid of a circuit diagram, explain the operation of a Hartley oscillator. (7 marks)

3. (a) (i) Define 'multi-vibrator' with respect to wave generators.

(ii) Distinguish between astable and monostable multi-vibrators.

(3 marks)

(b) (i) With aid of a circuit diagram, describe the operation of a negative clipper.

(ii) Draw the input and output waveforms of the circuit in b(i).

(7 marks)

(c) An op-amp has a differential gain of 80 dB and a common mode rejection ratio (CMRR) of 95 dB. The input voltages at the inverting and non-inverting inputs are $V_1 = 2\mu V$ and $V_2 = 1.6\mu V$ respectively.

Determine the:

(i) absolute differential gain;
(ii) differential output voltage;
(iii) common mode gain;
(iv) common mode output voltage.

(8 marks)

(d) Draw and label circuit diagram of a single phase half-wave controlled rectifier.

(2 marks)

4. (a) Convert the number $(82.25)_{10}$ to its equivalent:

(i) binary;
(ii) hexadecimal.

(6 marks)

(b) An aircraft warning lamp, L turns ON if the aircraft is airborne and either a seat belt is not buckled or a window is not closed.

Taking signals for:

- Lamp, L = 1 when it is ON
- Aircraft, A = 1 when it is airborne
- Seat belt, B = 1 when not buckled
- Window, C = 1 when not closed

(i) Draw a truth table for this operation;

(ii) Write down the simplified boolean expression;

(iii) Implement the boolean expression using logic gates.

(8 marks)

(c) (i) Draw the logic circuit of a half adder;

(ii) Write the truth-table of the circuit in c(i).

(6 marks)

5. (a) (i) Distinguish between 'fan in' and 'fan out' with respect to logic gates;

(ii) Draw a two-input NOR gate using resistor transistor logic (RTL).

(5 marks)

(b) Figure 4 shows a shift register implemented using D flip-flops.

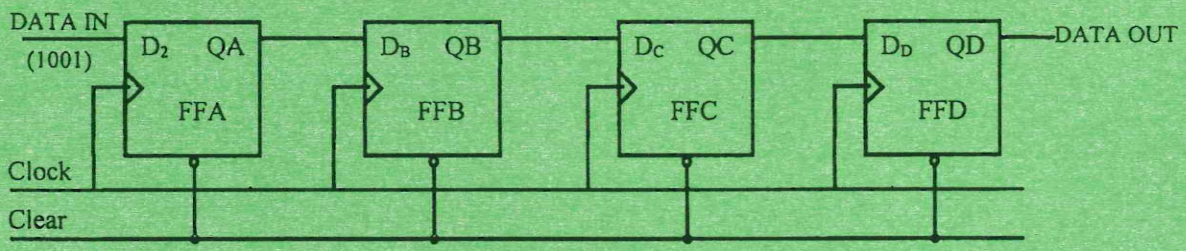

Fig. 4

(i) State the type of shift register represented;

(ii) Describe its operation;

(iii) Draw the timing waveforms for five clock cycles.

(9 marks)

(c) A ROM memory has a capacity of 16kB .

The internal architecture of the ROM uses a square matrix of cells.

Determine the:

(i) number of cells in each row;

(ii) total number of address inputs;

(iii) type of row decoder.

(6 marks)

SECTION B: CONTROL SYSTEMS

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

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

(i) transfer function;

(ii) controlled variable.

(2 marks)

(b) Figure 5 shows a block diagram of a closed-loop system.

(i) simplify the block diagram to its canonical form;

(ii) determine the closed loop transfer function $\frac{C_{(s)}}{R_{(s)}}$.

(8 marks)

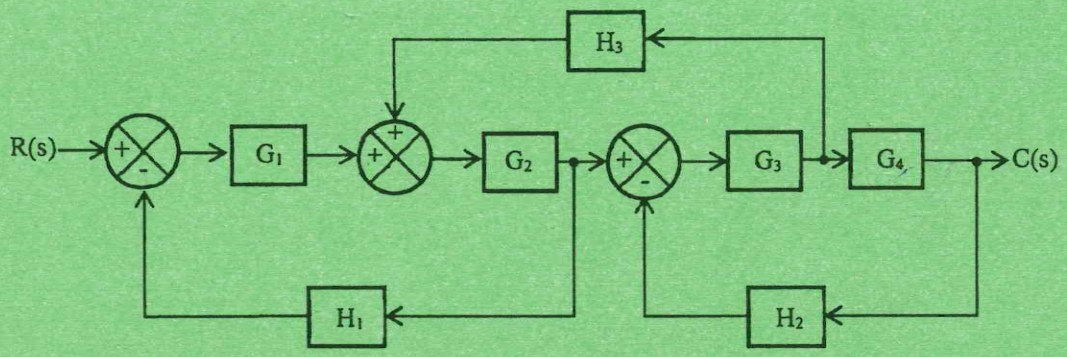

Fig. 5

(c) The unit step response of a closed loop control system is given by the expression:

$$\frac{C_{(s)}}{R_{(s)}} = \frac{36}{S^2 + 2S + 36}$$

Determine the:

(i) rise time;

(ii) peak time;

(iii) maximum overshoot;

(iv) settling time of within 2% of the final value.

(10 marks)

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

(i) poles;

(ii) zeros.

(2 marks)

(b) With aid of response curves, describe each of the following types of system stability:

(i) bounded input bounded output;

(ii) bounded input unbounded output.

(8 marks)

(c) The transfer function of a control system is given by the expression:

$$T.F = \frac{(s+1)(s-2)}{s(s-4)(s+5)(s+3)}$$

(i) Determine the system's poles and zeros;

(ii) Draw a pole-zero plot for the system;

(iii) From the plot in c(ii), determine the system stability.

(7 marks)

(d) With reference to Bode plot stability criterion, state the relationship between phase and gain crossover frequency for each of the following systems:

(i) stable;

(ii) marginally stable;

(iii) unstable.

(3 marks)

8. (a) (i) State **three** effects of phase lead compensation in a control system;

(ii) Draw a phase lag compensator network circuit. (6 marks)

(b) Describe micro-stepping with respect to stepper motors. (4 marks)

(c) A stepper motor has a step angle of 2.5°. Determine the:

(i) resolution;

(ii) number of steps required to make 25 revolutions;

(iii) shaft speed if the stepping frequency is 3600 pulses per second. (6 marks)

(d) Draw a schematic circuit diagram of a single phase a.c servomotor. (4 marks)

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