

COMPUTER SCIENCE TRIPOS Part IA – 2022 – Paper 2

1 Digital Electronics (ijw24)

(a) Show using Boolean algebra

$$(i) \quad \overline{X} \cdot Y \oplus X \cdot \overline{Y} = \overline{X} \cdot Y + X \cdot \overline{Y}$$

$$(ii) \quad \overline{X} \cdot \overline{Y} \oplus X \cdot Y = \overline{X} \cdot \overline{Y} + X \cdot Y$$

[4 marks]

(b) Using the results in Part (a) or otherwise, express the four-variable function

$$F(A, B, C, D) = \overline{A} \cdot \overline{B} \cdot \overline{C} + \overline{A} \cdot \overline{C} \cdot \overline{D} + \overline{A} \cdot B \cdot C \cdot D + A \cdot B \cdot \overline{C} \cdot \overline{D} + A \cdot C \cdot \overline{D} + A \cdot \overline{B} \cdot C$$

as the Exclusive OR of three 2-variable AND terms, i.e., $F = X_1 \cdot X_2 \oplus X_3 \cdot X_4 \oplus X_5 \cdot X_6$ where each X_i is either one of the four variables or its complement.

[4 marks]

(c) (i) Simplify the four-variable function

$$G(A, B, C, D) = \sum(0, 2, 6, 7, 8, 9, 10, 13, 15)$$

using the Quine-McCluskey (Q-M) method. The numbers in the summation are the decimal representations of the minterms of G (where A represents the most-significant bit of the equivalent binary representation).

[9 marks]

(ii) How many equal-complexity solutions exist in total? Justify your answer.

[3 marks]

2 Digital Electronics (ijw24)

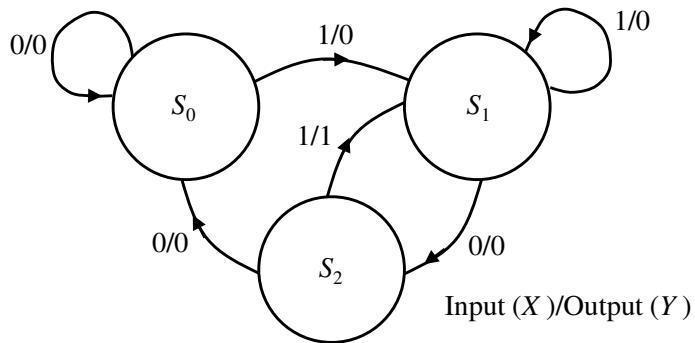
- (a) A (fictional) edge-triggered UV flip-flop has inputs U and V and output Q . Its state-transition table is given by:

Current state (Q)	Next state (Q')				
	$UV =$	00	01	10	11
0		0	1	0	1
1		0	0	0	1

(i) Draw the state-transition diagram for the Q output. [3 marks]

- (ii) For an implementation based on a D-type flip-flop, determine the simplified Boolean equation in sum-of-products form for the next-state (Q') logic. [2 marks]

- (b) Consider the following state machine:



- (i) Assuming that the machine starts in state S_0 and that the input data sequence at input (X) is appropriately synchronised with the state machine clock, determine the next-state and output sequences for the input sequence 0101011011011. What operation does the machine perform? [5 marks]

- (ii) For an implementation based on two D-type flip-flops (labelled A and B), determine simplified Boolean expressions for the next-state and output combinational logic, assuming the state assignment $S_0 = 00$, $S_1 = 01$ and $S_2 = 10$ is used, where a state is labelled $Q_A Q_B$ in terms of the flip-flop outputs. [4 marks]

- (iii) For an alternative one-hot implementation based on D-type flip-flops, determine expressions for the next-state and output logic. [4 marks]

- (iv) What feature, inherent in the proposed state-machine design, may give rise to problems at the output Y ? How might this be addressed? [2 marks]