COMPUTER SCIENCE TRIPOS Part IA – 2025 – Paper 2

2 Digital Electronics (ijw24)

(*a*) The state transition table of a synchronous finite state machine (FSM) is

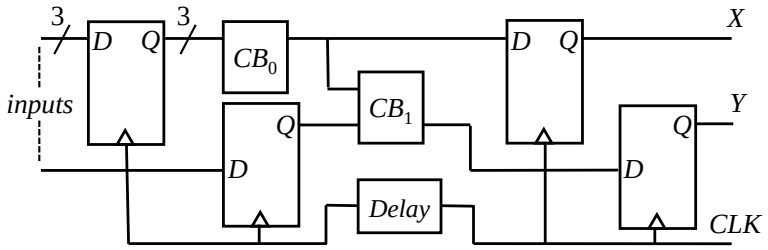
Current state	Next state				Output (Y)
	$X_1X_0 =$ 00	01	11	10	
S_0	S_0	S_1	S_1	S_1	0
S_1	S_0	S_0	S_2	S_2	1
S_2	S_0	S_0	S_3	S_0	1
S_3	S_0	S_0	S_0	S_0	1

(*i*) Assuming constant inputs over multiple clock cycles, determine the repeating bit sequence at Y for each of the four input combinations $X_1X_0 = \{00, 01, 11, 10\}$. The starting state does not matter. [4 marks]

(*ii*) Draw and label the state transition diagram for the FSM. [4 marks]

(*iii*) The FSM is to be implemented using two D-type flip-flops FF_1 and FF_0 having outputs Q_1 and Q_0 respectively. The state assignment is: $S_0[Q_1 = 0, Q_0 = 0]$, $S_1[Q_1 = 0, Q_0 = 1]$, $S_2[Q_1 = 1, Q_0 = 1]$ and $S_3[Q_1 = 1, Q_0 = 0]$. Determine the simplified equations necessary to generate the output Y and the flip-flop inputs D_1 and D_0. [5 marks]

(*b*) In the following schematic diagram, the *inputs* are connected to 4 D-type flip-flops (FFs) and CLK is the system clock. The outputs from 3 of the FFs are input to combinational logic block CB_0, and the output from the fourth FF is input to combinational logic block CB_1. The outputs from the combinational blocks are connected to two D-type FFs with outputs X and Y. For all FFs, the set-up time t_{su}= 50 ps, the hold time t_h= 60 ps, the propagation delay (clock-to-Q) t_{pc}= 80 ps and the minimum propagation delay (clock-to-Q) $t_{pc,min}$= 30 ps. For CB_0, the propagation delay t_{pd}= 80 ps and the minimum propagation delay $t_{pd,min}$= 50 ps. For CB_1, t_{pd}= 40 ps and $t_{pd,min}$= 25 ps. Unless stated otherwise, *Delay* has a propagation delay of t_{skew}= 0 ps.



(*i*) Determine the maximum clock frequency. [2 marks]

(*ii*) Determine if the FF hold time constraint is satisfied. [2 marks]

(*iii*) Now assume that t_{skew} = 20 ps. Determine the maximum clock speed, and whether the FF hold time constraint is now met. [3 marks]