International Institute of Information Technology, Hyderabad
(Deemed to be University)

EC2.101 – Digital Systems and Microcontrollers – Monsoon 2019-20
End Semester Examination

Max. Time: 3 Hr **Date: 20th September 2019** **Max. Marks: 72**

Numbers in square brackets [x] after a statement show the marks for that question.

Q1. In base-10, you can determine the divisibility of a number by 3 or 9 simply by adding up all the digits in the number; if the results are divisible by 3 or 9, then the numbers are divisible by 3 or 9, respectively. What is the smallest base n such that we can do the same trick for all the numbers from 2 to 6? In other words, what is the smallest integer $n > 1$ such that for any number written in base n, we can determine the divisibility by all integers m, $(2 \leq m \leq 6)$, by adding up all the digits of the number and, if the result divides by m, we conclude that the original number is divisible by m?

[12 marks]

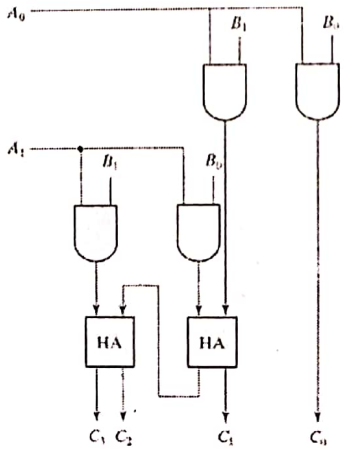
Q2. There are four independent logic variables A, B, C and D. We are tasked with making a Boolean function and a circuit that outputs logic-1 when *either* one or more of the following conditions is/are *explicitly* met (in cases not explicitly described by the statements, it will be considered as an unmet condition):

i. When A is true, B is true
ii. When B is true, either A is true, or C and D are both false
iii. When either C is true or A and B are both false, D is true
iv. If B is false when either C or D (or both) are true, then A is true, and either C is false, or D is true

In case *all the conditions* are unmet, the function outputs a zero. Make a truth-table, k-map, simplified logical expression and logic circuit (sum of products) for this function.

[12 marks]

Q3. We know we can make a 2-bit x 2-bit multiplier using some AND gates and half adders as shown in the figure.



Make an optimized version of this circuit using the truth-table and k-map method in sum of products form, using NAND implementation wherever suitable [8]. Calculate the number of transistors needed to implement the circuit in both cases and compare [4]. (Hint: assume the 2-input XOR gate is made using four 2-input NAND gates)

[8+4 = 12 marks]

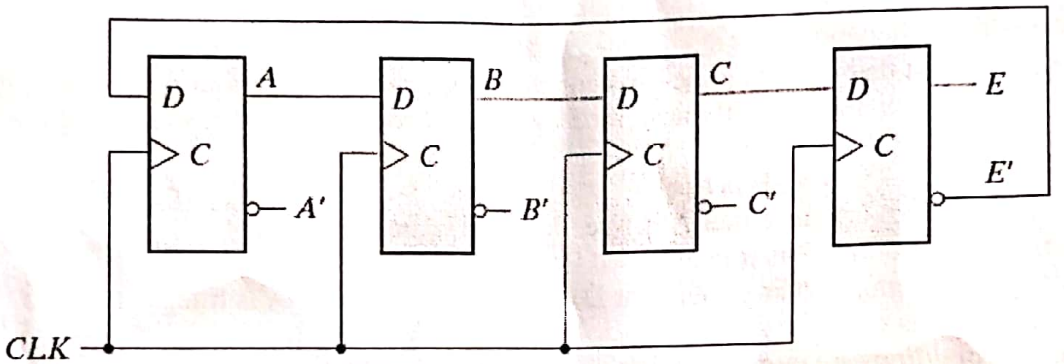
Q4. In a comparator circuit for two 4-bit inputs A and B, the outputs are (A>B), (A<B) and (A=B). Write the Boolean expressions for these outputs [4]. Prove using Boolean algebra, that only one of them can be logic-1 at a given time [8].

[4+8 = 12 marks]

Q5. Let us design a sequential circuit that is looking for two ones in a bit stream (not necessarily consecutive). The circuit will reset if it finds three *consecutive* zeros. The circuit outputs logic-1 when it has found two ones (consecutive or non-consecutive), in all other cases, it outputs zero. Make the state diagram, truth-table and circuit using D flip-flops.

[12 marks]

Q6. What is the behaviour of the following circuit if clock pulses are applied from a reset state (when all FFs are at zero) [4]? Draw the complete state diagram for the 16 distinct states (including starting in any other state) [4]. In general, if there are k flip-flops in this chain and any arbitrary starting state is chosen, how many clock cycles does it take to *make sure* we return to the original state [4]?



[4+4+4 = 12 marks]