CS2102 02 Digital Logic Design Midterm 1 (13:20-15:10pm, March 23rd)

Name: _____ **ID:** _____ **(Return this with your answer sheet)**

Truth or False (33%):

(Write down T or F. You don't need to give the reason.)

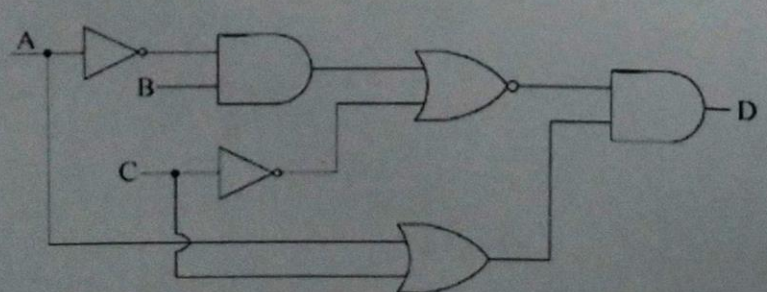
1. T Each K-map defines a unique truth table which defines a combinational logic function (circuit).
2. T Let $f(c,b,a) = \sum m(0,1,4,6)$. Then $f(c,b,a) + \prod M(2,3,5,7) = 1$.
3. T Synchronous sequential logic uses a clock as a timing reference to trigger storage devices.
4. T The sum-of-minterms form is also the sum-of-products form.
5. F According to the duality principle, $0 \vee x = x$ and $1 \vee x = 1$ are dual to each other.
6. F The digital circuit is designed such that $V_{OL} < V_{IL}$ and $V_{OH} < V_{IH}$. The noise margins, $V_{NML} = V_{IL} - V_{OL}$ and $V_{NMH} = V_{IH} - V_{OH}$, reflect the ability of the circuit to resist the input noise.
7. F The axioms of Boolean algebra can be proved from others.
8. T Sampling and quantization can be used to digitize analog signals. Sampling technique is to measure analog signals at the discrete time; quantization technique is to convert the continuous quantities of the analog signals into discrete values.
9. T A Boolean function can possibly have no essential prime implicant.
10. F Combinational circuits may generate hazards (or glitches) at the outputs only due to the noise added to the circuits.
11. F The Boolean property, $(x \vee y) \wedge (x \vee \overline{y}) = x$, is called the combining property.

Distributive
Absorption

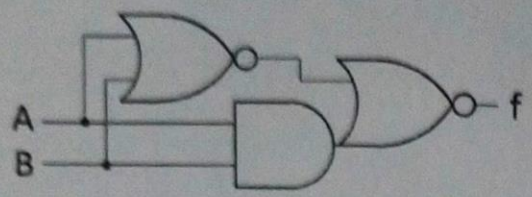
Answer the following questions: (75%)

(Write down your intermediate results with the final answer to get the scores.)

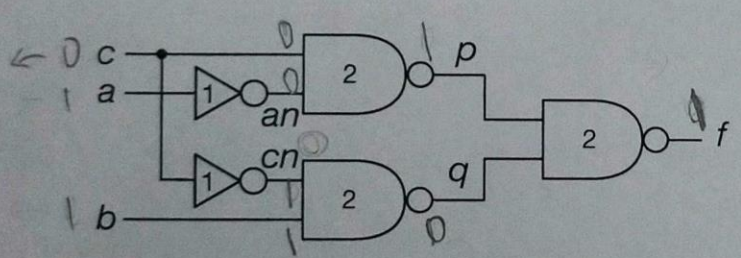
1. (5%) **[Noise Margin]** A logic family has signal levels of $V_0 = 0V$, $V_1 = 1.5V$, $V_{min} = -0.25V$, $V_{max} = 1.68V$, $V_{OL} = 0.25V$, and $V_{OH} = 1.2V$. How do you define V_{IL} and V_{IH} such that the noise less than $0.3V$ can be tolerated?
2. (15%) **[Boolean Algebra and Logic]**
   (a) (10%) Derive the Boolean function of D in the following logic circuit. Reduce it to the simplified **product-of-sums** form.
   (b) (5%) Draw the result of (a) using a logic diagram of **nMOS** and **pMOS** transistors.
   Hint: Each AND gate has 6 transistors and each OR gate has 6 transistors. NOT gate has 2 transistors. Assume that the true input and its complement are both available as primary inputs (for example, you can use a or $\overline{a}$ as the inputs of this circuit.

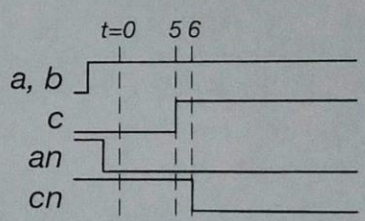


3. (5%) **[DeMorgan's]** Derive the **sum-of-minterms** form for the output f in the following logic circuit:



4. (15%) **[K-Map]** Consider the Boolean function $f(d,c,b,a) = \sum m(0,1,2,3,5,7,8,10,12,14)$.
   (a) (5%) List all the prime implicants.
   (b) (5%) List all the essential prime implicants.
   (c) (5%) List all the possible simplified functions of f in the **sum-of-products** form.
5. (10%) **[Don't-Care]** Simplify the Boolean function with don't-care conditions, $f(d,c,b,a) = \sum m(2,7,10,11) + D(0,3,5,6,14)$. Assume that ONLY true inputs are available (for example, you can use a as an input, and add a NOT gate to produce $\overline{a}$.). For the logic diagram with AND, OR, and inverter (NOT) gates, which one between the simplified AND-OR and simplified OR-AND circuits is better in terms of the number of gates in the circuit (that is, the fewer gates the better)?
6. (10%) **[Hazard]**
   (a) (5%) Fix the hazard (if any) that may occur in the following circuit. You should state what to do and draw the final result.
   (b) (5%) What kind of hazard (if any) may occur? State your reason. Hint: the timing diagram is for you to recall the discussion in the lecture.





Static 1 hazard
static 1 hazard

7. (15%) **[Design]** Design a comparator of two 2-bit integers, $n_1 = \{d,c\}$ and $n_2 = \{b,a\}$. The output of the comparator is 1 when $n_1 \geq n_2$.
   (a) (5%) List the truth table of the comparator.
   (b) (5%) List the simplified **product-of-sums** form.
   (c) (5%) Draw the logic diagram of the comparator by using the NOR-NOR circuit. Assume that the true input and its complement are both available as primary inputs

Good Luck and Happy Midterm Exam!!

If you have too much time left, there is a joke for you:

A professor was giving the first midterm exam one day to his students. Once the test was over, the students all handed the tests back in. The professor noticed that one of the students had attached a $1,000 bill to his test with a note saying
"Ten dollars per point!"

The next class the professor handed the tests back out. This student got back his test, an envelope with $490 change, and a note saying "Thanks!"