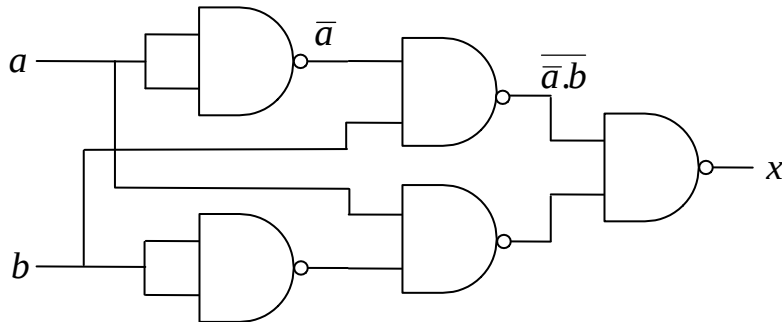


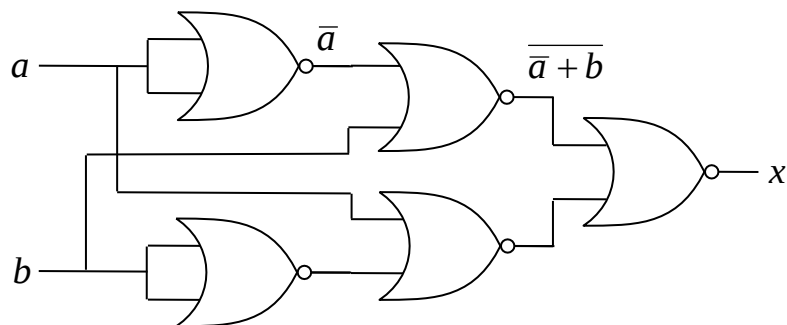
IA – Digital Electronics

Examples Paper 1 – Combinational Logic

1. Complete the truth tables for the following digital logic circuits.



a	b	$\bar{a}$	$\bar{a}.b$		x
0	0				
0	1				
1	0				
1	1				



a	b	$\bar{a}$	$\bar{a} + b$		x
0	0				
0	1				
1	0				
1	1				

2. Use Boolean algebra to prove the following identities:

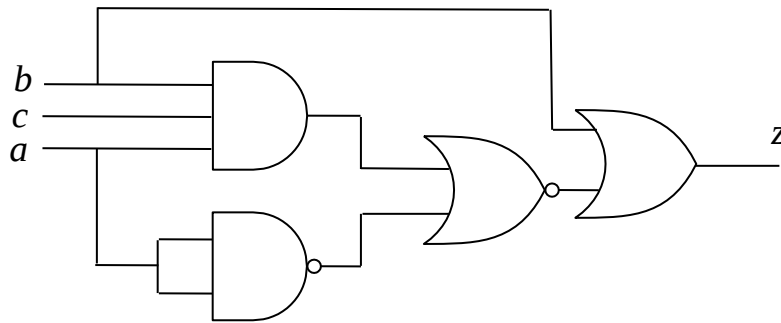
$$a.b.c + a.b.\bar{c} = a.b$$

$$a.(\bar{a} + b) = a.b$$

$$a.b + \bar{a}.c = (a + c).(\bar{a} + b)$$

$$(a + c).(a + d).(b + c).(b + d) = a.b + c.d$$

3. The following circuit does not make efficient use of logic gates. Write a Boolean expression for z , and hence show how z can be realised more efficiently.



4. A logic ‘voter’ circuit has 4 inputs a, b, c, d and one output v . The output is to be logic 1 if any 3 or all 4 inputs are at logic 1. Design a circuit using AND and OR gates to satisfy this requirement.

5. Devise circuits to solve question 4 if

- (a) NAND gates only;
- (b) NOR gates only are to be used.

6. Using a Karnaugh map, write simplified sum of products expressions for f and $\bar{f}$ where,

$$f = \bar{a}.\bar{d} + \bar{b}.\bar{c} + \bar{a}.b.\bar{c}.d$$

and $a.\bar{b}.c.\bar{d}$ is a don't care state.

7. A three variable function is given by:

$$f = a.\bar{b}.\bar{c} + a.\bar{b}.c + a.b.c$$

Find the simplest sum of products form for f using a Karnaugh map. Express f using:

- (a) NAND gates only;
- (b) NOR gates only. (Hint: try mapping $\bar{f}$ for fewest gates)

8. The function f in question 7 can be written in the form:

$$f = 100 + 101 + 111 = \sum(4,5,7)$$

Find the simplified sum of products and product of sums forms for the four variable function g where:

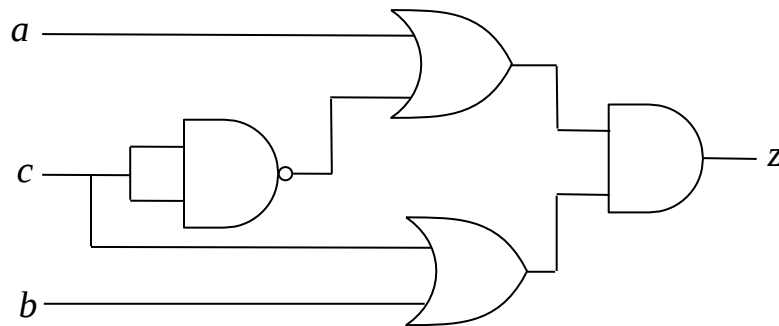
$$g = \sum(5,6,7,8)$$

and terms 10 to 15 inclusive are don't care states. Take $abcd$ to be the four variables, with a the most significant.

9. The months of the year are coded in binary with January represented by $A_3, A_2, A_1, A_0 = (0001)$ and December by (1100) . Find a simplified sum of products expression in terms of A_3, A_2, A_1, A_0 for the months without an r in their name.

Show that a simpler expression is obtained by changing the coding so January is represented by (0000) and December by (1011) .

10. Each gate in the following circuit has a propagation delay of τ seconds.



(a) Draw a timing diagram showing the output of each gate for $a = b = 0$; and c initially 0, switching to 1 for a time t ($t \gg \tau$), and then returning to 0. Hence show that a static hazard exists. Is it a static 1 or static 0 hazard?

(b) Write down a product of sums expression for Z from the circuit and use de Morgan's theorem to obtain a sum of products expression for $\bar{Z}$.

(c) Draw a Karnaugh map for $\bar{Z}$ and thus show how the hazard can be removed by adding one more OR gate to the circuit.

11. A 4 variable expression g has minterms $\sum(0,1,2,5,6,7,8,9,10,14)$. Take $ABCD$ to be the four input variables, with A the most significant bit. Use the Quine-McCluskey (Q-M) method to yield a simplified expression in the sum of products (SOP) form.

Relevant IA Paper 2 Tripos questions include:

Q1-2023, Q1-2022, Q1-2021, Q1-2020, Q1-2019, Q1-2018.