Sheet 4
Combinational Circuits (1)

Notes: [1] *Functions must be optimized.*
[2] *All unused combinations must be treated as don't care conditions.*
[3] *Unless mentioned use only (NOT – AND – OR) gates*

1. Design a combinational circuit with three inputs and one output. The output is equal to 1 when the binary value of the input is less than 3. Otherwise the output is 0.

2. Design a combinational circuit with four inputs and one output. The output is equal to 1 when the binary value of the input is greater than 10. Otherwise the output is 0.

3. Design a combinational circuit with three inputs, and three outputs. When the binary input is less than four, the binary output is one greater than the input. Otherwise the output is one less than the input.

4. Design a combinational circuit with three inputs and a number of outputs, the output is a number that equal to the double of the inputs.

5. Design a combinational circuit with three inputs and a number of outputs, the output is a number that equal to the square of the inputs.

6. Design a combinational circuit with three inputs and one output, this output is equal to 1 if the number is even else it is 0.

7. Design a combinational circuit that subtract 5 from a 4-bit binary number (input cannot take a value less than 5).

8. Design a combinational circuit building a 5-input majority function, this function generates 1 only if the input variables have more 1's than 0's.

9. Design a combinational circuit that adds one to a 4-bit binary number.

10. Design a combinational circuit that add two-bit binary numbers.

11. Design a combinational circuit that multiply two-bit binary numbers.

12. Design a combinational circuit that converts 4-bit gray code to a binary number:
    a) Using AND, OR, NOT gates. b) Using 2-input XOR gates only.

13. Design a combinational circuit with four inputs representing a decimal digit in BCD and four outputs that produce the 9's complement of the input digit.

14. Design a combinational circuit that generates the 2's complement of a 5-bit binary number.

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15. Design a combinational circuit that detects error in the representation of a decimal digit in BCD.
16. Design a combinational circuit with 4 inputs A, B, C and D and one output F where F=1 when A≠C and B=D.
17. Design the circuit of a 3-bits odd parity generator.
18. Design the circuit of a 4-bits even parity checker.
19. An integer number X is in the range 0 through 15. A circuit with four input lines is to generate Z=0 when the received integer is 5 or less, and Z=1 when the received integer is in the range 8 through 12, note that X cannot takes values other than the mentioned values. Design a combinational circuit to realize this function.
20. Design a combinational circuit that converts between the following codes (input code to output code):
    a. Excess-3 to BCD.
    b. BCD to 2421.
    c. 2421 to excess-3.
    d. Gray code to excess-3.
    e. BCD to gray code.
    f. BCD to 2 out of 5 (check the table).
    g. 2 out of 5 to BCD (check the table).

BCD	2 out of 5
0	00011
1	00101
2	00110
3	01001
4	01010
5	01100
6	10001
7	10010
8	10100
9	11000

21. A 5-bit creeping (or walking) code for the decimal digits is given. Design a minimal circuit which accepts a word W of this code, and produce 4 outputs ABCDE, according to the following:
    A=1 if W>5 B=1 if W≥5
    C=1 if W<5 D=1 if W≤5
    E=1 if W=5

Digit	Creeping code
0	00000
1	00001
2	00011
3	00111
4	01111
5	11111
6	11110
7	11100
8	11000
9	10000

22. Design a combinational circuit with three data inputs (D_2, D_1, D_0), two control inputs (C_2, C_1) and two outputs (R_1, R_0). The R_1, R_0 should be the remainder after dividing the unsigned binary number formed from D_2, D_1, D_0 by the unsigned binary number formed from C_1, C_2. (Note: Division by zero will never occur.).
23. A logic circuit has four inputs (I_3, I_2, I_1, I_0) and two outputs (O_1, O_0) At least one of the inputs is always asserted high. If a given input line has a logic 1 applied to it, the output signals will encode its index in binary. If two or more inputs are at logic 1, the output will

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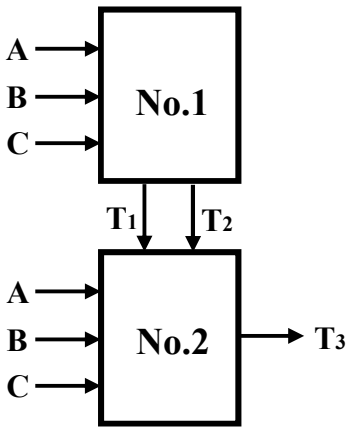
be set according to which input has the highest index ($I_0<I_1< I_2< I_3$). Design a combinational circuit that satisfies these specification.

24. A two terminal circuit is to be built on contacts from two groups of relays. Group 1 consists of two relays A and B. Group 2 consists of the relays X and Y. The circuit is to have 1 for either of the following conditions: When the number of operated relays in group 1 equals the number of operated relays in group 2, or when at least three of the four relays (regardless of group designation) are operated. For all other conditions the transmission is to be 0. Design a combinational circuit that satisfies these specification.

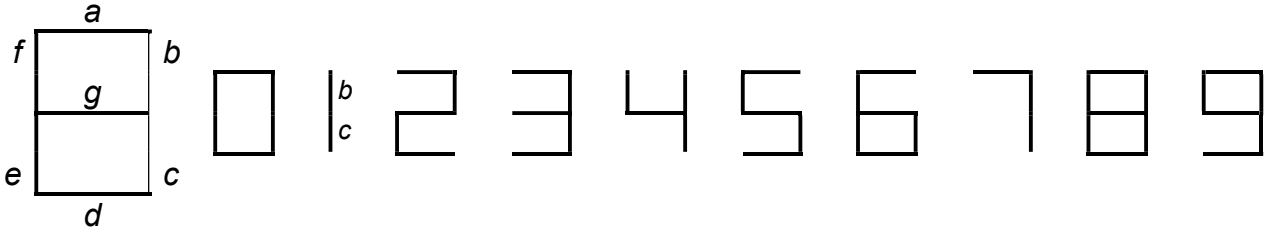
25. A circuit with three input signals x_3, x_2 and x_1 has four output signals terminals z_4, z_3, z_2 and z_2. Output z_1 is to be at the 1 (high) level only when all inputs are at the 0 (low) level; z_2 is to be high only when exactly one input is high; z_3 is to be high when any two, but not all the inputs are high. Finally z_4 is to be high when all three inputs are high. Design a combinational circuit for Z.

26. In the block diagram circuit No.1 is an electronic combinational switching circuit which realizes the functions T_1 and T_2 of the three variables A, B and C. Synthesis an electronic combinational circuit No.2 to realize T_3 as a function of T_1, T_2 and the three variables A, B and C. Then draw a logic diagram of T_3 using one 3-input XNORs.



$T_1(A,B,C) = \sum m\ (1,2,4,7)$
$T_2(A,B,C) = \sum m\ (0,3,5,6)$
$T_3(T_1, T_2, A, B, C) = \sum m\ (8,11,13,14,16,19,21,22)$

27. A BCD-to-seven-segment decoder is a combinational circuit that converts a decimal digit in BCD to an appropriate code for the selection of segments in a display indicator used for displaying the decimal digit in a familiar form. The seven outputs of the decoder (*a,b,c,d,e,f,g*) select the corresponding segments in the display as shown in the figure. The numeric designation chosen to represent the decimal digit as shown. Design the BCD-to-seven-segment decoder.



28. Repeat the previous problem but with adding the following pattern with numbers 10,11,12,13,14 and 15 respectively:

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29. Design a combinational circuit that will recognize the occurrence of three consecutive 1s in an eight-bit-parallel message.

30. Design a combinational circuit that compares two 4-bit numbers A and B to check if they are equal. The circuit has one output X, so that X=1 if A=B and X=0 if A≠B.

31. Design a combinational circuit that satisfies the following. Six relays are grouped into two groups, group 1 consisting of relays A, B and C, and group 2 consisting of relays X, Y and Z. A contact circuit on these relays is to transmit a ground to one of three output terminals, depending upon the relative numbers of relays operated in the two groups as follows:
    Terminal 1 is on when the number in group 1 is larger than the number in group 2.
    Terminal 2 is on when the number in group 1 equals the number in group 2.
    Terminal 3 is on when the number in group 1 is smaller than the number in group 2.

32. A five member committee requires a voting system. Each member sets his switch (1 for yes; 0 for no) and a master vote switch V is closed by the chairman (in addition to the five switches). The pass light P or fail light F indicates the outcome. When V is open, both lights must be off. Design a combinational circuit that satisfies these specification.

33. To fill a job opening, a company is looking for a man with the following qualifications:
    He must be an engineer with at least two years' experience as well as a politician.
    Or, he must be an engineer who is not in politics but has political influence.
    Or, he must be a politician and engineer but may or may not have any political influence.
    Or, he must be a politician with political influence.
    Design a combinational circuit to realize this problem.