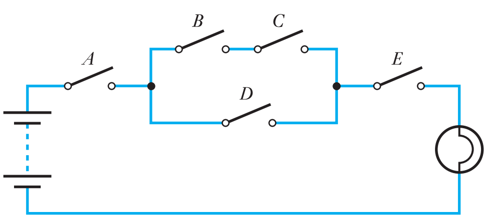
- In digital electronics, several number systems are used, the most common being decimal, binary, octal and hexadecimal.
- As binary numbers use only two digits, 0 and 1, arithmetic is simpler than it is for decimal numbers.
- Although simple binary code is the most frequently used option for representing numeric information, it is not the only method. In some applications, the use of other representations, such as Gray code, may be more appropriate.
- Codes are also used for non-numeric information, such as the ASCII code, which is used for alphanumeric data.
- Some coding techniques allow error detection and, in some cases, correction.

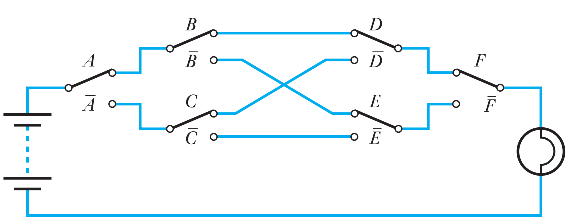
Exercises

23.1 Show how a power source, a lamp and a number of switches can be used to represent the following logical functions

$$L = A \cdot B \cdot C$$
$$L = A + B + C$$
$$L = (A \cdot B) + (C \cdot D)$$
$$L = A \oplus B$$

23.2 Derive expressions for the following arrangements using AND, OR and NOT operations.



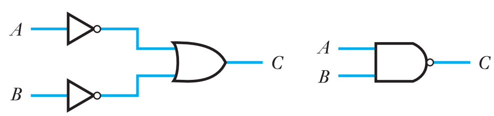


23.3 If the two circuits given in the previous exercise were described by truth tables, how many rows would each table require?

23.4 Sketch the truth table of a three-input NAND gate.

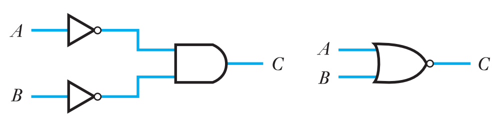
23.5 Sketch the truth table of a three-input NOR gate.

23.6 Show that the two circuits (a) and (b) below are equivalent by drawing truth tables for each circuit.



(a) (b)

23.7 Repeat the operations in Exercise 23.6 for the following circuits.



(a) (b)

23.8 Simulate the pairs of circuits in Exercises 23.6 and 23.7 and confirm that each pair produces the same output for every possible combination of the inputs.

23.9 List all the possible values of a Boolean constant.

23.10 List all the possible values of a Boolean variable.

23.11 What symbols are used in Boolean algebra to represent the functions AND, OR, NOT and Exclusive OR?

23.12 Write the function of a three-input NOR gate as a Boolean expression.

23.13 Given that A is a Boolean variable, evaluate and then simplify the following expressions: $A \cdot 1$; $A \cdot \bar{A}$; $1 + A$; $A + \bar{A}$; $1 \cdot 0$; $1 + 0$.

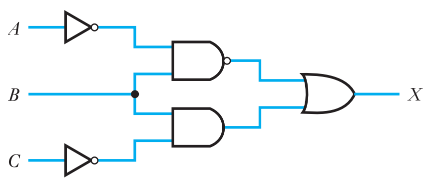
23.14 Exercises 23.6 and 23.7 illustrate fundamental laws of Boolean algebra. What is the name given to these laws?

23.15 What is the difference between combination and sequential logic?

23.16 Implement the following expressions using standard logic gates.

$$X = (\overline{A+B}) \cdot C$$
$$Y = A\overline{B}C + \overline{A}D + C\overline{D}$$
$$Z = \overline{(A \cdot B) + (\overline{C+D})}$$

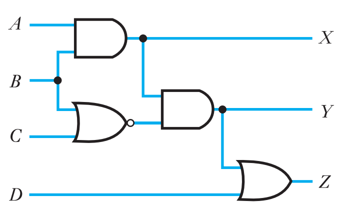
23.17 Derive a Boolean expression for the following circuit.



23.18 Design a logic circuit to take three inputs – A, B and C – and produce a single output X, such that X is true if, and only if, precisely two of its inputs are true.

23.19 Use circuit simulation to investigate your solution to Exercise 23.18 and hence demonstrate that it behaves as required.

23.20 Derive Boolean expressions to describe the operation of the following circuit. Minimise these expressions by means of algebraic manipulation and hence simplify the circuit.



23.21 Use Karnaugh maps to obtain minimised Boolean expressions for the following functions

$$X = \overline{A}\overline{B} + A\overline{B}\overline{C} + A\overline{B}C + ABC$$

$$Y = \overline{A}\overline{B}\overline{C} + \overline{A}B\overline{C}D + A\overline{C}\overline{D} + A\overline{C}D + A\overline{B}C\overline{D}$$

23.22 Use a Karnaugh map to obtain a minimised Boolean expression for the function described by the following truth table.

A	B	C	D	Z
0	0	0	0	1
0	0	0	1	0
0	0	1	0	X
0	0	1	1	0
0	1	0	0	1
0	1	0	1	X
0	1	1	0	1
0	1	1	1	1
1	0	0	0	X
1	0	0	1	0
1	0	1	0	1
1	0	1	1	0
1	1	0	0	0
1	1	0	1	1
1	1	1	0	0
1	1	1	1	X

23.23 Convert the following binary numbers into decimal: 1100, 110001, 10111, 1.011.

23.24 Convert the following decimal numbers into binary: 56, 132, 67, 5.625.

23.25 Convert the following hexadecimal numbers into decimal: A4C3, CB45, 87, 3FF.

23.26 Convert the following decimal numbers into hexadecimal: 52708, 726, 8900.

23.27 Convert $A4C7_{16}$ into binary.

23.28 Convert 10110010100101_2 into hexadecimal.

23.29 Perform the following binary arithmetic

$$\begin{array}{r} 10111 \\ \underline{+1001} \\ \underline{} \end{array} \quad \begin{array}{r} 110101 \\ \underline{-11010} \\ \underline{} \end{array} \quad \begin{array}{r} 1011 \\ \underline{\times 111} \\ \underline{} \end{array} \quad \begin{array}{r} 101010 \\ \underline{\div 110} \\ \underline{} \end{array}$$

23.30 Design a circuit to convert 3-bit Gray code numbers into simple binary.

23.31 Design an eight-input digital multiplexer along the lines of the circuit described in Example 23.28. The circuit should have eight data inputs, three line select inputs and a single output.

23.32 Simulate your solution to the previous exercise to confirm that the circuit functions as expected.

23.33 Design a four-output digital demultiplexer. The circuit should have one data input, four data outputs and two select inputs.

23.34 Simulate your solution to the previous exercise to confirm that the circuit functions as expected.