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| Research Article

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Study of Algebraic Statements Using Digital Technologies

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Abstract: This article is dedicated to the Electronics Workbench 5.12 system developed by Interactive Image Technologies. A distinctive feature of the system is the presence of control and measuring instruments, which, in terms of appearance and characteristics, closely resemble their industrial counterparts. The system is easy to learn and quite convenient to use.

Keywords: Negation, conjunction, disjuncts, Logic Converter.

1. Introduction.

The science of human thinking was created by the ancient Greek scholar Aristotle. He called it logic. Logic prescribed general rules by which a person should think, make inferences, and arrive at the truth. The German mathematician, G.W. Leibniz, brought logic closer to calculations. He had the idea to create a new science mathematical logic, in which logical concepts are represented by mathematical symbols. Only almost 200 years later, the English mathematician George Boole partially realized Leibniz's ideas. He created an unusual algebra for logical justifications and reasoning, in which logical statements were represented by special symbols, similar to how numbers are represented by letters in school algebra. It turned out that, by manipulating these symbols and logical connections, logical reasoning could be carried out using ordinary calculations.

2. Preliminaries

Research has shown that declarative sentences, which convey or describe some events, are most frequently encountered in human speech. These sentences are called statements.

A statement is a grammatically correct sentence, taken together with its expressed meaning (content), and it is either true or false.

The concept of a statement is one of the fundamental, key concepts in logic. As such, it does not allow for a precise definition equally applicable in different branches of logic. A statement is considered true if the description it provides corresponds to the real situation, and false if it does not. “Truth” and “falsehood” are called “truth values of statements.”

A statement is called simple if it does not include other statements as parts of itself. A statement is called complex if it is formed using logical connectives from other simpler statements. Let us consider the most important ways of constructing complex statements.

A negative statement consists of the original statement and a negation, usually expressed by words like "not" or "it is not true that." Thus, a negative statement is a complex statement: it includes another statement as a part of itself. Let us denote statements by letters A, B, C, etc. The full meaning of the concept of the negation of a statement is defined by the condition: if statement A is true, its negation is false, and if A is false, its negation is true.

For example, since the statement "1 is an integer positive number" is true, its negation "1 is not an integer positive number" is false, and since "1 is a prime number" is false, its negation "1 is not a prime number" is true.

The combination of two statements using the word "and" results in a complex statement called a conjunction. The statements combined in this way are called "conjuncts." For example, if the statements "Today is hot" and "Yesterday was cold" are combined in this way, the conjunction is "Today is hot and yesterday was cold."

A conjunction is true only when both of its constituent statements are true; if at least one of the conjuncts is false, then the entire conjunction is false.

The connection of two statements using the word "or" results in the disjunction of these statements. The statements that form a disjunction are called the "members of the disjunction." The word "or" in everyday language has two different meanings. Sometimes it means "one or the other, or both," and sometimes it means "one or the other, but not both together."

The first meaning of "or" is called non-exclusive. In this sense, the disjunction of two statements means that at least one of these statements is true, regardless of whether they are both true or not. In the second, exclusive, or strict sense, the disjunction of two statements asserts that one of the statements is true, and the other is false. A non-exclusive disjunction is true when at least one of its statements is true, and it is false only when both of its members are false. An exclusive disjunction is true when only one of its members is true, and it is false when both of its members are true or both are false. In logic and mathematics, the word "or" is almost always used in the non-exclusive sense.

3. **Main part**

In Boolean algebra, statements are considered not by their content or meaning, but only in relation to whether they are true or false. It is customary to denote: true as 1, and false as 0. Boolean showed that the simplest statements, connected by the logical operators: "AND", "OR", "NOT", form a compound statement, the truth or falsehood of which can be computed.

Negation is one of the simplest operations on sentences. Although a sentence in a natural language can be negated in many ways, we shall adopt a uniform procedure: placing a sign for negation, the symbol $\neg$, in front of the entire sentence. Thus, if A is a sentence, then $\neg$A denotes the negation of A. The truth-functional character of negation is made apparent in the following truth table:

A	$\neg A$
T	F
F	T

When AAA is true, $\neg$A is false; when A is false, $\neg$A is true. We use T and F to denote the truth values true and false.

Another common truth-functional operation is the conjunction: "and". The conjunction of sentences A and B will be designated by A∧B and has the following truth table:

A	B	$A \wedge B$
T	T	T
F	T	F
T	F	F
F	F	F

A∧B is true when and only when both A and B are true. A and B are called the conjuncts of A∧B. Note that there are four rows in the table, corresponding to the number of possible assignments of truth values to A and B.

In natural languages, there are two distinct uses of "or": the inclusive and the exclusive. According to the inclusive usage, "A or B" means "A or B or both," whereas according to the exclusive usage, the meaning is "A or B, but not both." We shall introduce a special symbol, ∨, for the inclusive connective. Its truth table is as follows:

A	B	$A \vee B$
T	T	T
F	T	T
T	F	T
F	F	F

Thus, A∨B is false when and only when both A and B are false. "A ∨ B" is called a disjunction, with the disjuncts A and B.

Scientific and technical design is fundamental to the development of science and technology. One of the directions is computer-aided schematic modeling of electronic devices. The use of integrated software systems for schematic modeling of analog and digital radio-electronic devices (Micro-Cap V, DesignLab 8.0, Aplac 7.0, System View 1.9, Circuit Maker 6.0, Electronics Workbench) allows solving the following tasks:

- ✓ Creation of a model for the basic electrical schematic of the device and its editing;
- ✓ Calculation of the operating modes of the model;
- ✓ Calculation of frequency characteristics and transient processes of the model;
- ✓ Conducting evaluation and analysis of the model;
- ✓ Expanding the component library;
- ✓ Presenting data in a form suitable for further work;
- ✓ Development of printed circuit boards;
- ✓ Preparation of scientific and technical documents, etc.

When you launch the integrated package **Electronics Workbench**, you will see a dialog box and an editing window (Figure 1). The editing window is filled with some components. The **Electronics Workbench** dialog box contains a menu field, a component library, and a ruler with control and measuring instruments located in the same field. The menu field is similar to many Windows applications.

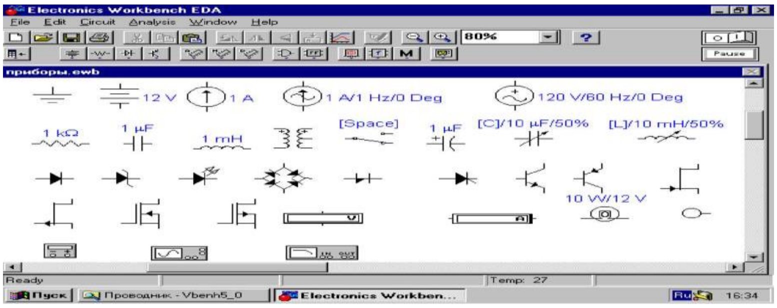

Figure. 1

Now, to solve the tasks, we will use the **Electronics Workbench** electronic laboratory software. For constructing logical circuits, the **Logic Gates** library (logical elements) provides the option to select logical elements. In **Figure 2**, you can see the list of available logical elements to choose from.

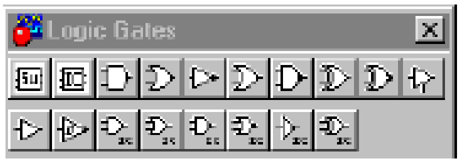

Figure. 2

Figure 3 shows the symbols used in **Electronics Workbench** for logical elements: conjunction - AND, disjunction - OR, negation - NOT, NAND (NOT AND), and NOR (NOT OR).

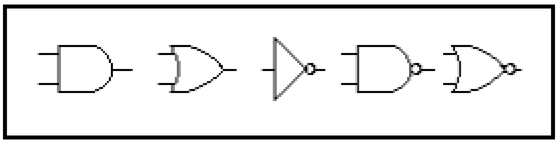

Figure. 3

In the Electronics Workbench electronic laboratory, there is a virtual device called the Logic Converter, which allows performing 6 logical transformations for a logical function with a number of variables ranging from 1 to 8:

- ✓ Representation of the truth table constructed from the logical elements of the circuit;
- ✓ Conversion of the truth table into a logical formula (Sums of Products Form, or SOP);
- ✓ Minimization of the SOP;
- ✓ Conversion of the formula into a truth table;
- ✓ Representation of the formula as a circuit in the logical basis of NAND (2-AND-NOT).

The Logic Converter is selected from the Instruments menu (Figure 4).

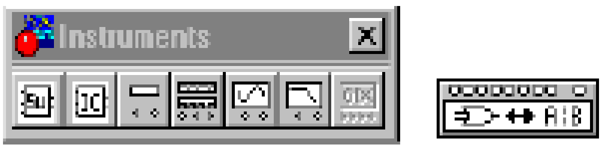

Figure. 4

Here is the description of the technology for analyzing logical circuits using the Logic Converter:

1. Assemble the logical circuit.

2. Connect the circuit under investigation to the Logic Converter (it has 8 inputs and one output, located on the right).
3. Open the Logic Converter by clicking the left mouse button on the converter icon. The Logic Converter menu appears on the screen (Figure 5).
4. To obtain the truth table, click.

5. To obtain the logical function (structural formula), click.

The Logic Converter can be used not only for analyzing logical devices but also for their synthesis. Here is the description of the technology for synthesizing a logical device based on the output combination using the Logic Converter (transformer):

1. Open the front panel of the Logic Converter (Figure 5).

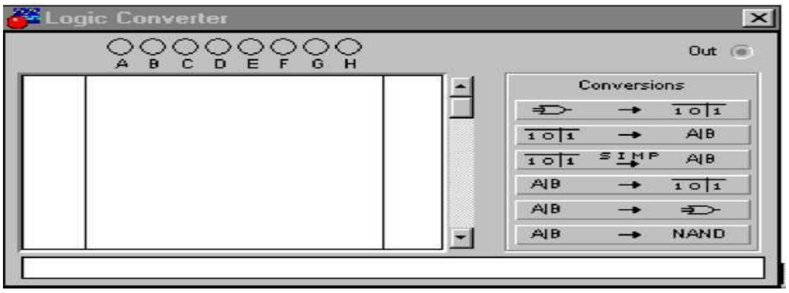

Figure. 5

1. Activate the terminal buttons A, B, ... H (starting from F) with the cursor, the number of which corresponds to the number of inputs of the synthesized device (the number of logical variables).
2. Make the necessary changes in the OUT column, and after pressing the buttons on the converter panel, you will obtain the result in the form of a circuit on the program's workspace and the logical function on the additional display.

Conclusions

1. The Logic Converter is a powerful tool that allows both the analysis and synthesis of logical circuits.
2. By using the Logic Converter, users can easily generate truth tables, logical functions, and circuit diagrams based on the provided logical expressions or output combinations.
3. The tool simplifies the process of logical circuit synthesis by allowing users to manipulate inputs and outputs through a simple interface, providing immediate feedback in the form of logical functions and circuit diagrams.
4. The ability to work with a variety of logical operations such as AND, OR, NOT, and combinations thereof, makes the Logic Converter an essential tool for both educational and practical applications in the field of digital electronics and circuit design.

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