UDC 538.9
DOI 10.36910/10.36910/6775-2313-5352-2025-26-02
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OPTICALLY SWITCHED LOGIC CIRCUITS

The development of information technologies at the present stage requires the development of new, more modern and more complex electronic equipment. Devices with controllable characteristics are being increasingly introduced. A separate direction of development of such devices is the development of circuits with the possibility of switching the circuit during operation without the need for its dismantling and reassembly. One of the possible ways to effectively solve this problem is the development of optically switched circuits. Optical switching provides a number of advantages over other switching methods, the main of which are the complete absence of electrical influence of the control circuit on the controlled circuit, the simplicity of the process of rapid reconfiguration of the circuit, as well as resistance to the influence of external electric and magnetic fields. This work shows the principle possibility of creating devices with optical switching of the circuit without the need to perform dismantling and assembly operations of this device. The paper presents the results of research on a logic circuit assembled on the basis of discrete electronic components, which can be optically switched as a logical 2AND-NOT element or as a logical 2OR-NOT element.
Keywords: *photoconductivity, commutation, semiconductors, optical control, logic circuits.*

Formulation of the problem. Modern society is largely dependent on the development of information technologies, which are actively penetrating all spheres of human activity. Such dependence requires constant updating and improvement of information technologies, which, in turn, leads to the need to improve their hardware base. An important direction for improving the hardware base is the development of devices with controllable characteristics. At the same time, much attention is paid to the development of technologies in which device reconfiguration is possible without their dismantling and reassembly. Today, a large number of methods are known for controlling the characteristics of electronic devices [1-6]:

- mechanical;
- electromechanical;
- electronic;
- magnetic;
- combined and etc.

In turn, they can be divided into two separate groups.

The first of these groups of methods is based on changing the properties of the active materials that make up the device, which can be implemented on the basis of magnetic, electrical or optical effects.

The second group of methods is based on changing the properties of the system by moving the parts of the system relative to each other.

The methods of the first group are characterized by a high level of internal losses, and their use at frequencies above 30…40 GHz is currently ineffective due to fundamental limitations in the millimeter wavelength range. The methods of the second group introduce a minimal level of losses into the microwave system and do not have fundamental limitations in the millimeter wave range. But, unfortunately, they have a relatively slow control speed and high control voltage.

Analysis of recent research and publications. Recently, much attention has been paid to optical methods for controlling the characteristics of electronic devices. This is due to a number of advantages of the optical control method: the complete absence of electrical influence of the control circuit on the controlled circuit, the simplicity of the process of rapid reconfiguration of the circuit, as well as resistance to the influence of external electric and magnetic fields.

For example, in article [7] a tunable all-optical microwave filter based on a photonic crystal cavity was experimentally demonstrated. In article [8] the microwave photonic filters with high rejection ratios and large tuning ranges of the central frequency and bandwidth were proposed and experimentally demonstrated. In one of our previous works, the possibility of transmitting information through conductive channels formed optically on the surface of a semiconductor material was demonstrated [9]. The possibility of implementing a microstrip microwave filter with optical control was also demonstrated [10]. However, the practical implementation of optically controlled devices requires additional research.

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Setting objectives. This work is a continuation of the authors' previous work and is devoted to investigating the possibility of practical implementation of optically controlled devices.

Presenting main material. As mentioned above, the purpose of the work is to investigate the possibility of changing the logical function of the circuit optically. For the experimental study, it was decided to implement a circuit on a single component basis that would allow switching the logical function AND-NOT to OR-NOT and vice versa optically.

In order to simplify the implementation of the experimental stand to demonstrate the principle of operation, common discrete components were used: 2N7002 field effect transistors and PFW2051 photoresistors. The circuit consists of three transistors and three photoresistors, which are irradiated at the appropriate moment.

Each photoresistor is a so-called model of the photoconductor path (Fig. 1). When resistor R_1 is illuminated and resistors R_2 and R_3 are not illuminated, we have a logical element 2AND-NOT (Fig. 2). If the resistor R_1 is not illuminated and the resistors R_2 and R_3 are illuminated, we have a logical element 2OR-NOT (Fig. 3).

The photoresistors were illuminated by a white light laser with a power of 5 mW from the distance of 2 cm and from the distance 0.8 cm.

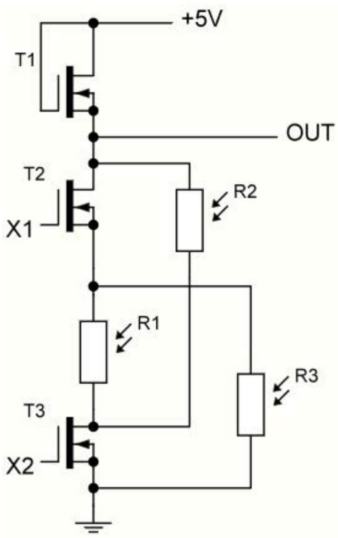

Figure1 – Schematic diagram of the test stand

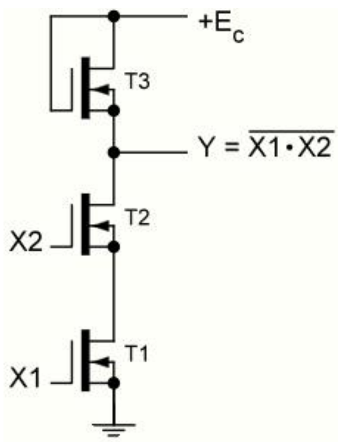

Figure 2 – Element 2 AND-NOT

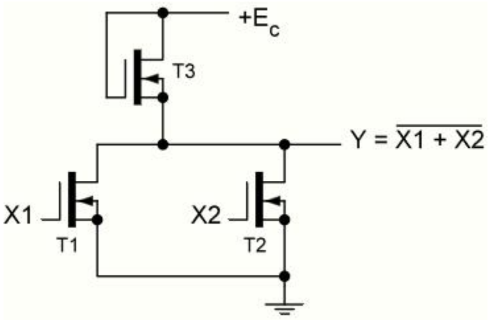

Figure 3 – Element 2 OR-NOT

The resistance of the photoresistor during illumination was 81 Ohm, and the dark resistance was 16 MΩ. When the distance between the laser and the surface of the photoresistor was reduced from 2 cm to 0.8 cm, the resistance was approximately 40 ohms.

Using a rectangular pulse generator, sequences of rectangular pulses were applied to the inputs X_1 and X_2, and the resulting signal was recorded from the output y. The high level of the input signals was 5 V and the low level was 0.2 V.

The input signals and the output signal were visualized using a multi-channel oscilloscope. The corresponding oscillograms are shown in Fig. 4 (element 2AND-NOT) and Fig. 5 (element 2OR-NOT).

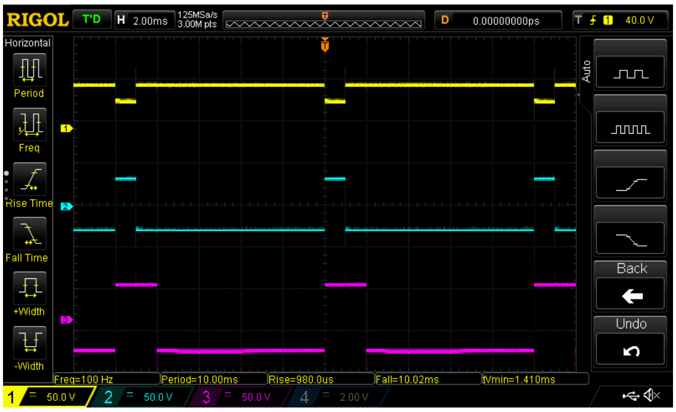

Figure 4 – Oscillograms for element 2AND-NOT: X1 – blue, X2 – violet, y – yellow

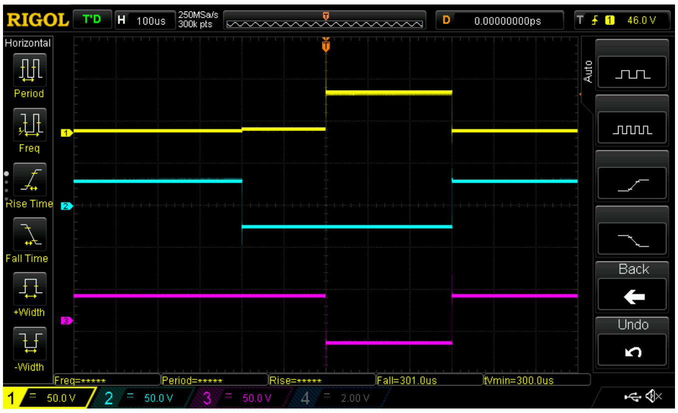

Figure 5 – Oscillograms for element 2OR-NOT: X1 – blue, X2 – violet, y – yellow

For comparison, truth tables for the considered circuits are provided (Tables 1, 2)

Table 1 – Truth table for logical element 2AND-NOT

X1	X2	Y
0	0	1
1	0	1
0	1	1
1	1	0

Table 2 – Truth table for logical element 2OR-NOT

X1	X2	Y
0	0	1
1	0	0
0	1	0
1	1	0

It should be noted that during the experiment it was found that the high-level voltage for the 2 AND-NOR circuit and the low-level voltage for the 2 OR-NOR circuit significantly depend on how many transistors, one or two, are in the open state, which is quite understandable from the point of view of the theory of electrical circuits. Thus, the high-level voltage for the 2 AND-NOR circuit was approximately 4.5 V when two transistors (T1 and T2) were in the closed state and approximately

3.2 V when only one of the transistors was in the closed state. Similarly, for the 2 OR-NOR circuit, the low-level voltage was 2.4 V with one open transistor and 1.4 V with two open transistors. However, this problem can be significantly reduced by using transistors with lower resistance in the open state, or by circuit means using a comparator.

Conclusions. Based on the obtained results, the following conclusions can be drawn:

– as a result of the work, it was possible to implement a circuit with the possibility of optical switching by setting active components as a logical element 2 AND-NOT or as a logical element 2 OR-NOT;

– the obtained results indicate the fundamental possibility of creating devices with the possibility of changing their function optically without the need to perform work on dismantling and re-assembling these devices;

– if necessary, the switching process can be controlled by a microcontroller according to a given program, which opens up a number of new opportunities for creating switched electronic devices for various purposes, which, in turn, will allow creating more complex electronic architectures necessary for high-speed computing and advanced telecommunications.

At the same time, as a result of the research, a number of problems were identified that need to be solved for the practical implementation of the above capabilities, which indicates the need for a number of additional studies.

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ЛОГІЧНІ СХЕМИ З ОПТИЧНОЮ КОМУТАЦІЄЮ

Розвиток інформаційних технологій на сучасному етапі вимагає розробки нової, більш сучасної та складнішої електронної техніки. Все частіше впроваджуються пристрої з керованими характеристиками. Окремим напрямком розвитку таких пристроїв є розробка схем з можливістю перемикання схеми під час роботи без необхідності її демонтажу та повторного монтажу. Подальший розвиток цього напряму вимагає принципово нового підходу до створення електронної техніки, а саме розробки нових технологій комутації електронних схем. Одним із можливих шляхів ефективного вирішення цієї проблеми є розробка схем з оптичною комутацією. Оптична комутація забезпечує ряд переваг перед іншими методами комутації, основними з яких є повна відсутність електричного впливу схеми керування на керовану схему, простота процесу швидкого переналаштування схеми, а також стійкість до впливу зовнішніх електричних і магнітних полів. У даній роботі показано принципову можливість створення пристроїв з оптичною комутацією схеми без необхідності виконання операцій демонтажу та повторного монтажу цього пристрою. У статті наведено результати дослідження логічної схеми, зібраної на основі дискретних електронних компонентів, яка може бути комутована оптичним шляхом як логічний елемент 2І-НІ або як логічний елемент 2АБО-НІ.

Ключові слова: *фотопровідність, комутація, напівпровідники, оптичний контроль, логічні схеми.*