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DESIGN AND IMPLEMENTATION OF LOGIC AND GATES IN INTERNET OF THINGS (IOT) BASED SYSTEMS

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ABSTRACT

In this study, a web-based "AND gate experiment platform" was designed using the ESP8266-based nodemcu, a popular component of the Internet of Things (IOT) and a key component of automation systems over the Internet and networks in recent years. The two-input AND gate is selected as one of the fundamental gates in digital electronics. This web-based platform, which provides interactive simulations and visual demonstrations of the AND gate's operation in classroom or laboratory environments, particularly in physics, electrical and electronics, and computer science departments, allows multiple users to connect to the nodemcu and practice simultaneously. Since the nodemcu is used in this study, the software connects the nodemcu to the local network via a modem and receives a fixed IP address. This allows each user connected to the IP address to individually simulate the operation of the AND gate through their web browser. Furthermore, by adjusting the modem settings, each user accessing the IP address over the internet can individually simulate the operation of the AND gate in their own web browser. The input and output values on the platform will be those of the last user performing the operation. This makes the platform also suitable for distance learning.

Keywords: AND gate, nodemcu, 74574, ESP8266, IOT, Shift register.

1 INTRODUCTION

Today, it is crucial to test the theoretical knowledge taught in electronics-related vocational education experimentally in a classroom or laboratory environment [1-3]. Because concepts such as electronics, computers, and the internet are intertwined in many professional fields, experimental applications of these concepts have also been conducted in the education

of related fields [4],[5]. Naturally, owing to the wide student population, the understanding levels of different educational fields will vary for various reasons. Therefore, the subject should be approached in its simplest form and the most effective and cost-effective techniques used today [6].

Logic gates are the fundamental elements of digital systems with one or more inputs and a single output. Without this, data transmission, processing and storage are difficult. The operating principles of logic gates are implemented in various devices, even though they may not be aware of them owing to technological advancements. These electronic circuits, which have input, output, processing, and recording capabilities compatible with binary number systems, are used in almost every field of daily life, especially in industry, military, space technologies, communications and similar fields. Examples of these circuits include computers, clocks, televisions, telephones, medical devices, and all types of electronic automation and control circuits, particularly those using microprocessors and microcontrollers [7].

There are seven basic logic gates, NAND and NOR gates are known as universal gates. These logic gates are AND, OR, XOR, NOT, XNOR, NOR and NAND gates. Logic gates have inputs in a binary format, and all have at least to inputs, except for the NOT gate. Only the NOT gate had one input and one output. Similarly, the outputs of all logic gates are in a binary format and have a single output. The truth tables provide all possible input and output values according to the characteristics of the relevant gate. In the table, "0" indicates a low logic level and "1" indicates a high logic level [8-12].

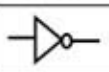
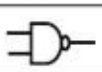
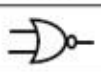
Gate Name		NOT		AND	OR	NAND	NOR	XOR	XNOR
Gate Symbol									
Inputs		Boolean Expression Outputs							
A	B	$\overline{A}$	$\overline{B}$	A·B	A+B	$\overline{A \cdot B}$	$\overline{A + B}$	A⊕B	$\overline{A \oplus B}$
0	0	1	1	0	0	1	1	0	1
0	1	1	0	0	1	1	0	1	0
1	0	0	1	0	1	1	0	1	0
1	1	0	0	1	1	0	0	0	1

Figure 1. Logic Gates, Their Symbols and Truth Demonstrations.

Figure 1 summarizes logic gates, their symbols, and truth demonstrations [13].

Ease of internet access and advancements in hardware and software technologies have enabled the development and proliferation of web-based applications. The advantages of web-based applications include remote access, free use via a web server without time or location

restrictions, multiple simultaneous connections, ability to handle many desired operations with software and the lack of additional hardware requirements for applications to run. Therefore, they can be used as alternatives for educational applications [14].

A microcontroller can be defined as a programmable computer that contains a central processing unit (CPU), random access memory (RAM), a specific type of memory (ROM/PROM/EPROM/EEPROM), and input/output (I/O) ports on a single integrated circuit. The impact of microcontrollers on our lives is significant and cannot be ignored. Unlike general-purpose computers, microcontrollers are specialized in performing specific tasks and are designed to run only a single application [15]. Therefore, they can emulate (or act like) various logic devices depending on the program loaded, paving the way for new designs [16]. There are many types of microcontrollers. The ESP8266 microcontroller stands out with its Wi-Fi feature and can be used as a web server. Data can be transferred to the internet via a web page using the ESP8266 module, and data from the internet can be received from the ESP8266 module. This allows all real-time information to be shared online in the applications where the module is used. This also means that the input and output pins can be controlled over the web [17].

In this study, the Nodemcu V3 ESP12-e development board, based on the ESP8266 microcontroller, was used to develop the AND gate Experiment Set. Owing to its structural features, it can connect to the internet, operate as a web server by obtaining an IP address on the network, and its inputs and outputs can be easily controlled using software. It is a low-cost, easy-to-access development board. Despite its versatility, the number of physical inputs and outputs that can be used was limited. Various techniques are used to increase the number of input and output ports on microcontrollers. One of these is the use of shift registers to increase input/output capacity [18]. Therefore, the 74574 integrated circuit, serial input and parallel output registers can be used to display the input and output values of the AND gate.

Because the main stages in the development of microcontroller systems are the hardware and software stages, the materials and methods used are reviewed under two main headings in the remainder of this article. First, the circuit was constructed using nodemcu and other electronic components. Then, the software and its operation, including a flow diagram, will be discussed, and the construction of the "Logic Gate Experiment Set" circuit will be explained. The constructed circuit was then run, and the results were examined.

Recognizing that the primary stages in the development of microcontroller systems involve both hardware and software components, the subsequent sections of this article will explore the materials and methods employed within these two main categories. Initially, the circuit will be assembled using nodemcu in conjunction with other electronic components.

Following this, the software and its functionality, including a flow diagram, will be analyzed, and the construction of the "Logic Gate Experiment Set" circuit will be elucidated. After assembly, the circuit was operated, and the results were thoroughly examined.

2 MATERIAL AND METHODS

2.1 Logic AND Gate Experiment Set Hardware

Logic gates are used according to the design for operating digital electronic circuits. These gates are usually encased in plastic or epoxy sheaths and manufactured as integrated circuits. The truth table of an example 7408 integrated circuit containing four two-input and gates is shown in Figure 1. A and B represent the inputs, and C represents the output. Pin 14, designated as VCC, represents the supply voltage (5V), and pin 7, designated as GND, represents ground (chassis). Logic circuits are operated using a binary number system. A logic "0" indicates no input current or voltage, while a logic "1" indicates that it is present. In these 78 series integrated circuits, a logic "0" represents 0 volts and a logic "1" represents 5 volts. In other words, if an LED diode is connected to the output through a resistor, the LED diode is off at logic "0" and on logic "1." Examining the truth table, the output is definitely "0" when any input is 0, and the output is "1" when all inputs are 1. And this rule is the same no matter how many entrances there are [1].

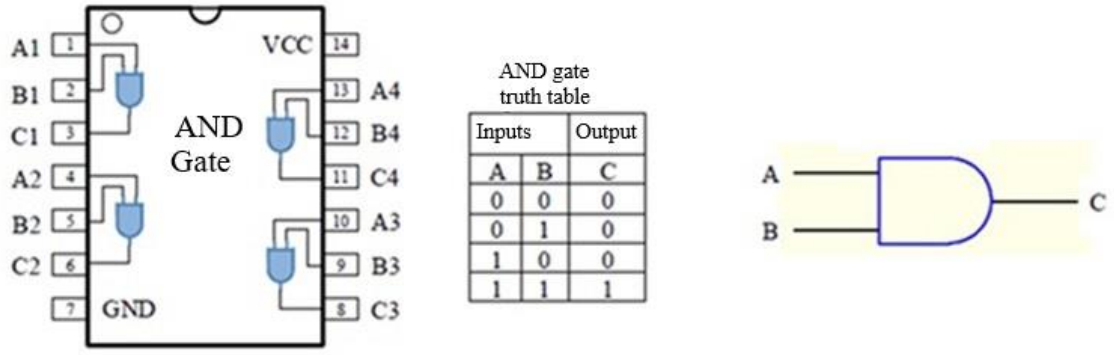


Figure 2. AND Gate Schematic Representation, Truth Table and Symbol [1].

In the circuit, a nodemcu microcontroller was used to simulate the operation of the AND gate, whereas a 74HC574 integrated circuit, resistors and LED diodes were used to create the shift register. A laptop connected to a local network was used to monitor the system's operation. Alternatively, a device with a web browser, such as a tablet, phone or computer could be used.

Figure 3 shows the circuit diagram drawn using Proteus. While 11 pins of the nodemcu can be used as input/output, only six of them can be used safely owing to special circumstances. Using others requires a more complex circuit structure and software. Therefore, if we want to use a nodemcu directly as a gate, we can have at most two 2-input and 1-output gates. To achieve this, we used a 74574 integrated circuit containing eight D-type flip-flops and two shift registers. Considering the physical usability of the circuit and the experimental set with eight gates in the design, the number of inputs was determined to be 8 x 2 = 16, and the number of outputs was determined to be 8 x 1 = 8. In this case, two 74HC574 ICs were used as inputs and one 74574 IC was used for outputs, creating an 8-bit shift register. Both registers are designed as serial and inputs. Pin D1 of the nodemcu was used as the data input of the 16-bit shift register representing the inputs, and pin D2 was used as the clock pin to shift the input data. Similarly, pin D5 of the nodemcu was used as the data input of the 8-bit shift register representing the outputs, and pin D6 was used as the clock pin to shift the output data. Thus, the input data are loaded into the registers with a 16-bit clock pulse, and output data are loaded into the registers with an 8-bit clock pulse. The input and output values were displayed using LEDs connected to the outputs of each register. In the experimental set, the AND gate symbols were drawn, and LEDs representing the input and output values were connected to the inputs of the symbols to show the outputs based on the input values. When the AND gate is checked against the truth table, the results are obtained as if the gate is present even though the elements constituting the gate are physically absent. Figure 4 shows that the appearances in the software and experimental set are identical. Although the LED diodes at the output of the AND gates in the experimental set appear to be reverse-connected visually, because the AND gates are hypothetical, the diode terminals are hidden below the symbols and are not visible. As in the circuit diagram, the (-) terminals of all diodes are connected to the chassis.

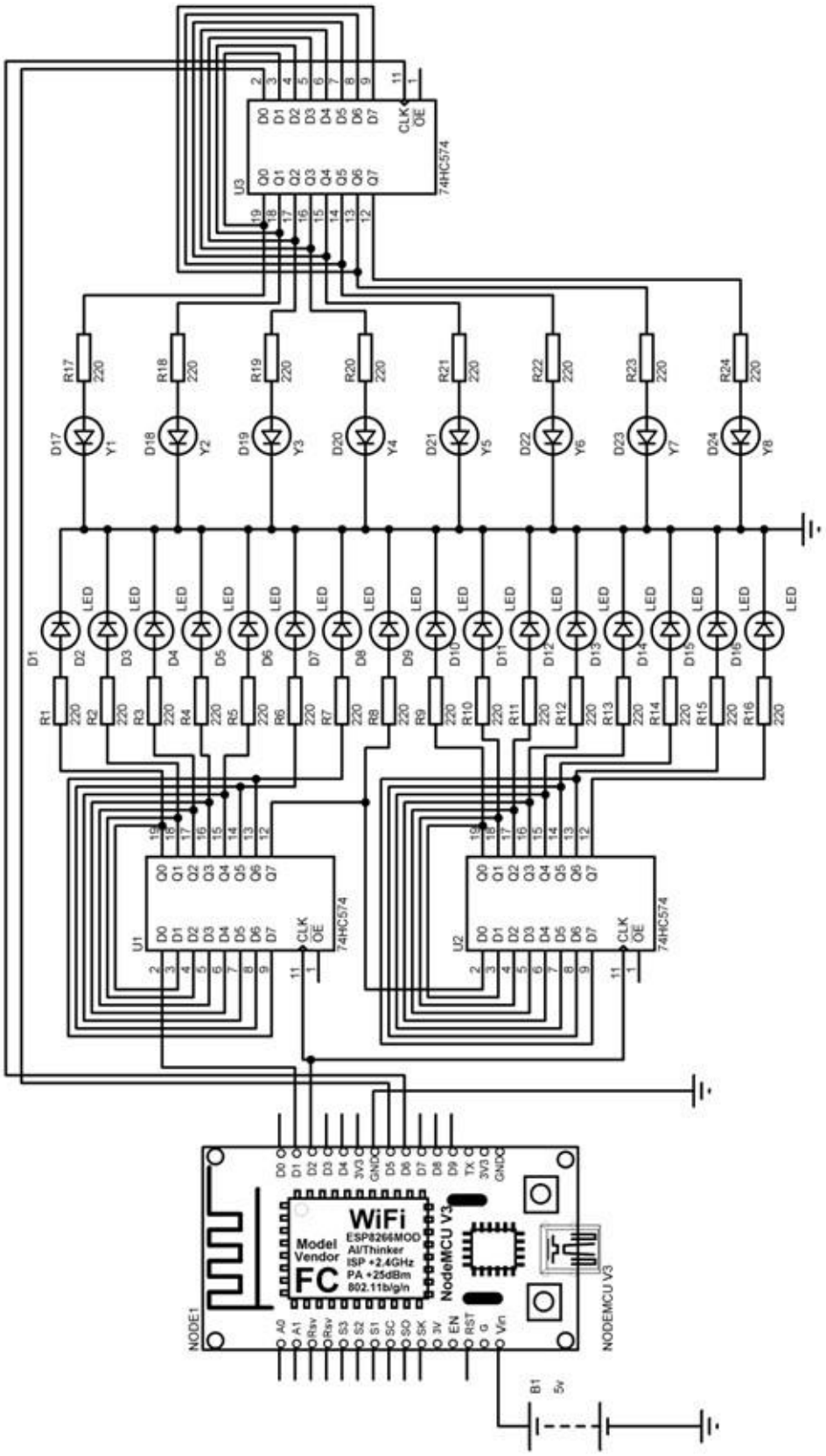


Figure 3. AND Gate Experiment Set circuit diagram.

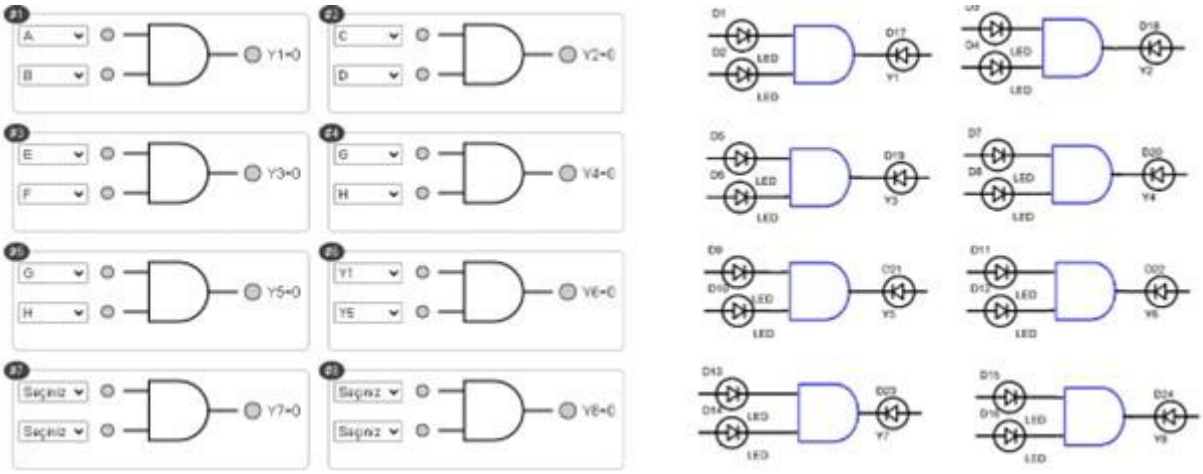


Figure 4. The view in the software and the view on the experimental set.

Although the implemented circuit has 8 gates, it can simulate gates represented by 100s using the same logic. After designing and drawing the circuit using Proteus, it was installed on two breadboards. Nodemcu was installed on the first breadboard, and a 16-bit register representing the inputs and an 8-bit register representing the outputs, made with 74HC574, was installed on the second breadboard to create the circuit.

2.2 Logic AND Gate Experiment Set Software

The software is an integral part of the microcontroller. Regardless of the hardware circuit design, coding in the appropriate language and loading it onto the microcontroller are essential for the microcontroller to perform the desired operations. Because nodemcu is an ESP8266-based microcontroller, the primary programming language was Lua. However, the Arduino programming language was used because it has a broader scope and supports nodemcu programming with customizations. Arduino is a user-friendly, open-source electronic prototyping platform. Offering microcontroller-based hardware and easy-to-program software, Arduino is used in a wide range of applications, from education to industrial applications [19].

The Arduino compiler was downloaded from the relevant website and installed on a Windows computer. The libraries necessary for nodemcu's operation were installed and configured. Nodemcu was connected to the computer via a micro USB cable, and the compiled version of the program was ready to be loaded. After all the settings were completed, the program was written and loaded onto the microcontroller. Figure 5 shows a flowchart of the written program.

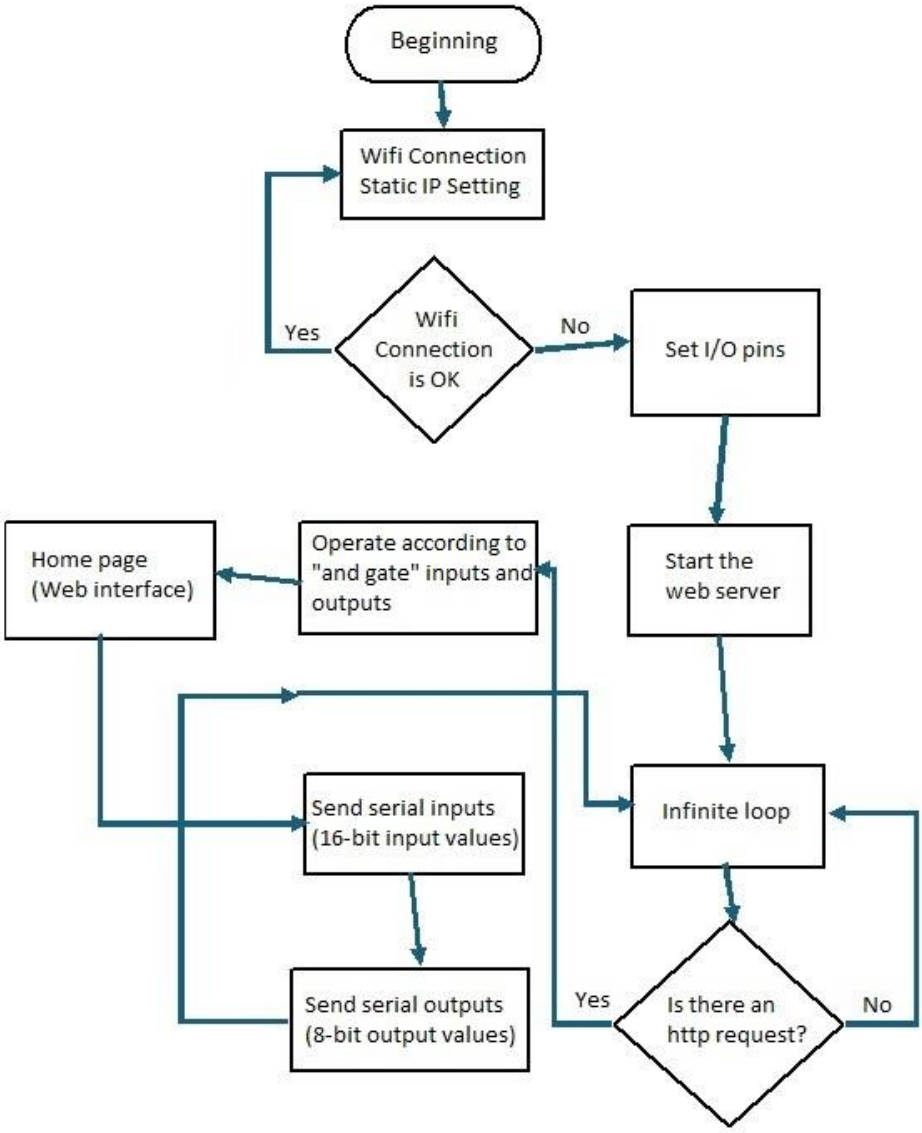


Figure 5. Flow chart of the program loaded into the microcontroller.

3 RESULTS AND DISCUSSION

"Select" and the LEDs at the input and output of all ports in the test set are off. The desired input variable was selected from the relevant DropDown box. If desired, the input variables displayed in the list and selected can be increased or decreased from the menu on the left side. The output variables were fixed, as shown on the screen. The output variables are optional in the DropDown box. By clicking on the input variables, a value of 0 can be changed to 1, and a value of 1 to 0. The Y output variables take values based on the output of the AND gate and cannot be changed otherwise. When the inputs of the gate symbols on the screen are selected and the input values are selected, the LED at the symbol's input turns gray if 0 and red if 1. When the AND gate operates according to the truth table, the output turns gray if 0 and red

if 1. Each time an operation is performed on the browser screen, a request is sent simultaneously to the web page (Figure 6). To display the gate input and output values on the test set, nodemcu sends the 16-bit input values first, followed by the 8-bit output values.

Thus, the AND gate operations observed on the screen were also visible on the test set. All users connected to the network could connect to the test set and conduct individual experiments on the browser. The final user's values were displayed on the test set.

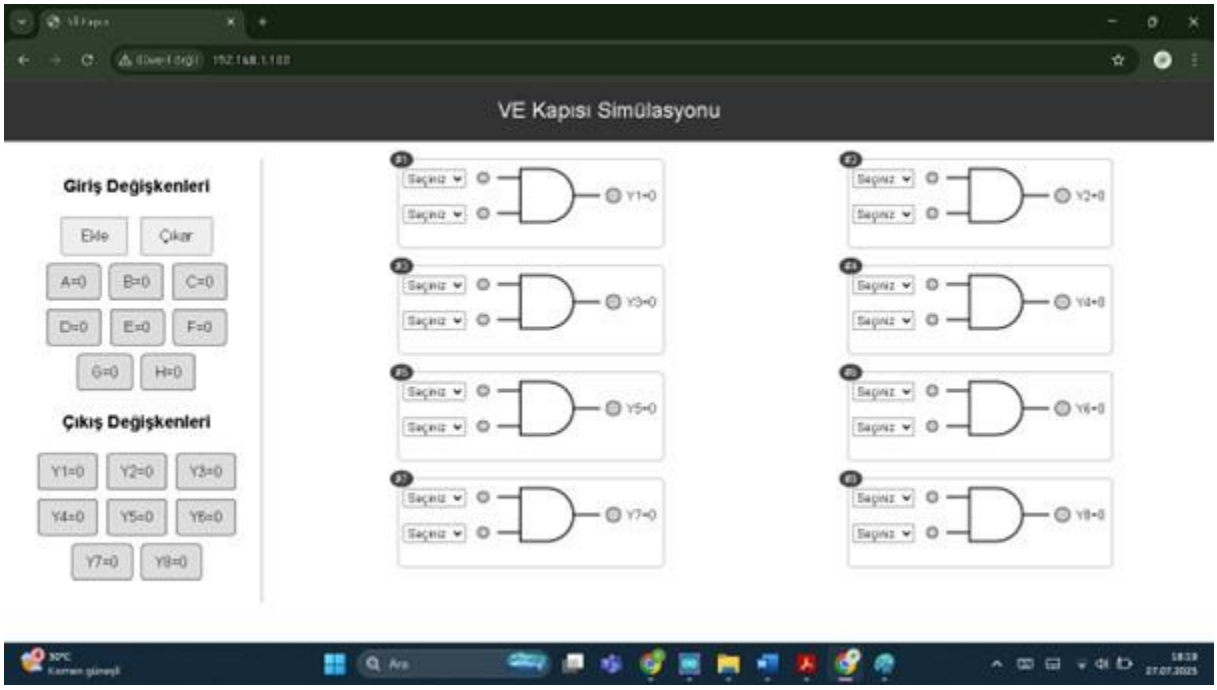


Figure 6. Web page screenshot.

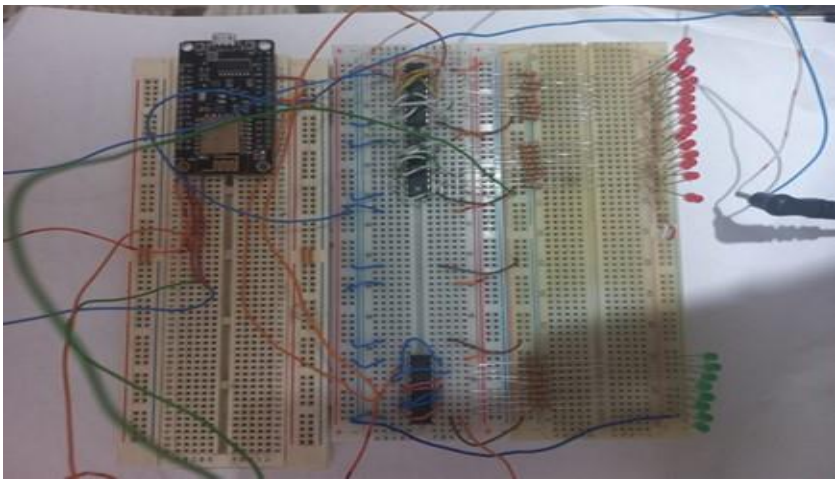


Figure 7. Circuit built on breadboard.

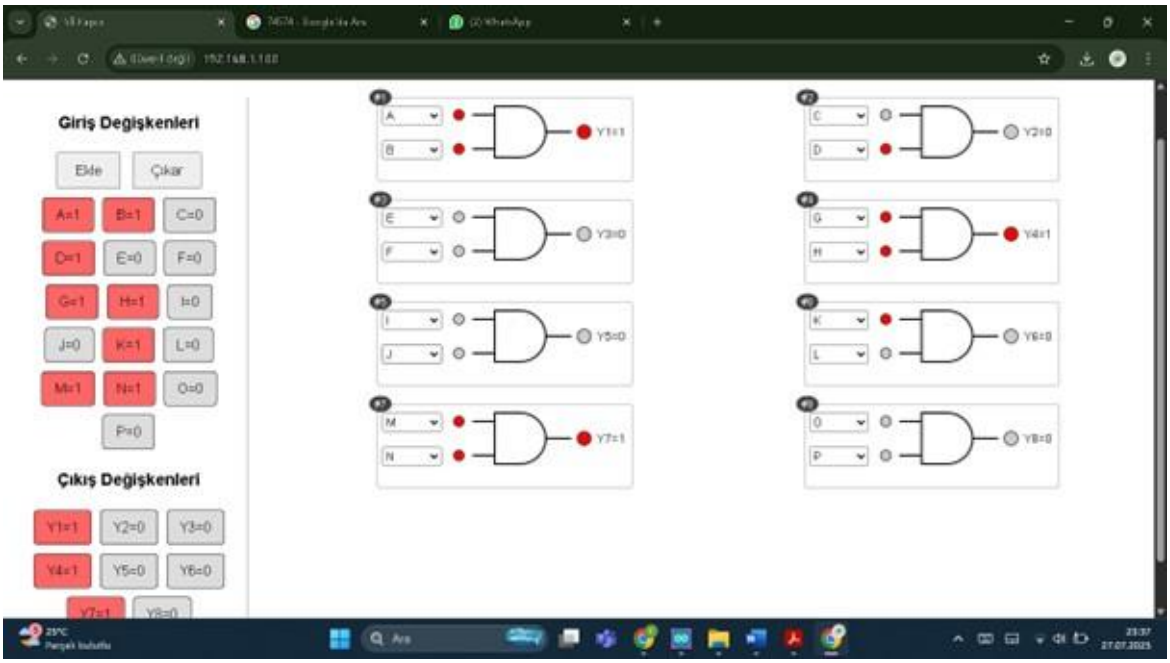


Figure 8. Values of the outputs depending on the inputs on the web page.

4 CONCLUSION

The circuit was built and tested on a breadboard. In the tests, the circuit functioned as intended. The values displayed on the web page were found to be identical on the test set. Figure 7 shows the circuit built on the breadboard, and Figure 8 shows the output values depending on the inputs on the web page as examples. As can be seen, the buttons for the input and output variables are gray when logic is 0 and red when logic is 1.

Logic gates are a crucial concept in digital electronics education. Therefore, as in every field of electronics, understanding the operation of these gates requires hands-on experience in a laboratory setting. The sheer variety of experimental materials, especially in crowded classrooms and environments, leads to time loss, cost loss, malfunctions and other problems. Considering that there are only seven logic gates, and each can have more than two inputs, it's clear how confusing it can be for beginners. In this circuit we designed using nodemcu, we simulated 20 two-input gates and their corresponding gates on the web page and demonstrated them on the experimental set. When a smart board is connected to nodemcu in a classroom, the input and output values for 20 gates can be selected and modified on the web page, which can be demonstrated on the experimental set. Students can also connect to nodemcu with their own mobile phones and simulate the operation independently. With further design, it's possible to significantly increase the number of gates and implement other gate designs. In addition, because nodes can communicate with each other via Wi-Fi, it is possible to design a dynamic

circuit by adding a different port to each node and establishing a wireless connection. We believe that our circuit can be used to develop new teaching techniques in digital electronics laboratories in physics, electrical, electronics, and computer science departments.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

Artificial Intelligence (AI) Contribution Statement

This manuscript was entirely written, edited, analyzed, and prepared without the assistance of any artificial intelligence (AI) tools. All content, including text, data analysis, and figures, was solely generated by the authors.

REFERENCES

[1] S. Çınar, "Integrated Test Circuit Design for Logic Circuit Laboratories," *Gazi University Journal of Science Part C Design and Technology,* vol. 7, pp. 165-174, 2019, doi: 10.29109/gujsc.449163.

[2] C. S. Lee, J. H. Su, K. E. Lin, J. H. Chang and G. H. Lin, "A project-based laboratory for learning embedded system design with industry support," *IEEE Transactions on Education*, vol. *53*, pp. 173-181, 2009,

[3] L. A. Ajao, J. Agajo, J. G. Kolo, M. A. Adegboye and Y. Yusuf, "Learning of embedded system design, simulation and implementation: a technical approach,"*American Journal of Embedded Systems and Applications*, *vol*. 3, pp. 35-42, 2016, doi: 10.11648/j.ajesa.20150303.12.

[4] K. Krismadinata, I. Husnaini, A. Asnil, R. Lapisa, and H.S. Mulya, "Development of Digital Electronics Lab Kit for Vocational Education," *5th Vocational Education International Conference (VEIC-5 2023),* Atlantis Press, 2024, doi: 10.2991/978-2-38476-198-2_144.

[5] W.G. Ecton and S.M. Dougherty, "Heterogeneity in high school career and technical education outcomes,"*Educational Evaluation and Policy Analysis,* vol. 45, pp. 157-181, 2023, doi: 10.26300/4jwf-wb39.

[6] N. Goyibova., N. Muslimov, G. Sabirova, N. Kadirova, and B. Samatova, "Differentiation approach in education: Tailoring instruction for diverse learner needs," *MethodsX,* vol. 14, pp. 103163, 2025, doi:10.1016/j.mex.2025.103163.

[7] Y. Raghuvanshi, "Modelling Logic Gates in Python," *International Journal for Multidisciplinary Research*, vol. 4, 2022, doi: 10.36948/ijfmr.2022.v04i05.043.

[8] P. Dumka, "Building Logic Gate Circuits in Python," *Mathematics and Computer Science: Contemporary Developments*, vol. 5, pp. 104-115, 2024, doi: 10.9734/bpi/mcscd/v5/2500.

[9] R. L. Boylestad, " Electronic devices and circuit theory," *Pearson Education India*, 2009

[10] K. W. Martin, "Digital integrated circuit design, " *No Title*, 2000.

[11] B. Borowik, M. Karpinskyy, V. Lahno and O. Petrov, " Basic logical functions and gates. Logic Design.In" *Theory of Digital Automata*, vol. 63, pp. 51–73, 2013, doi:10.1007/978-94-007-5228-3_6

[12] V. S. Popov, ,"Equivalence of logical operations and other operations in Python programming language," In *2023 5th International Youth Conference on Radio Electronics, Electrical and Power Engineering (REEPE)*, IEEE, Moscow, Russian Federation, March vol. 5, pp. 1-6, 2023, doi: 10.1109/REEPE57272.2023.10086928.

[13] R.T. Rasheed, and S.K.C. Olajumoke," The Use of Truth Table, Logical Reasoning and Logic Gate in Teaching and Learning Process", *International Journal of Latest Technology in Engineering, Management & Applied Science*, vol. 13, pp. 1-12, 2024, doi: 10.51583/IJLTEMAS.2024.130601.

[14] S. Sazak, "PHP Tabanly Application Development Method for Logic Circuits Course," *Technological Applied Sciences*, vol. 6, pp. 24-29, 2011, S. Sazak, "PHP Tabanly Application Development Method for Logic Circuits Course," *Technological Applied Sciences*, vol. 6, pp. 24-29, 2011, doi: 10.12739/10.12739.

[15] A. Hussain, M. Hammad, K. Hafeez, and T. Zainab, "Programming a microcontroller," *Int. J. Comput. Appl.,* vol. 155, pp. 21-26, 2016, doi: 10.5120/ijca2016912310.

[16] G.O. Uzedhe, H.C. Inyiama, C.C. Udeze, and E.S. Mbonu, "Microcontroller Based Real-Time Emulator for Logic Gate and Structured Logic Devices," *International Journal of Science and Technology,* vol. 2, pp. 639-647, 2013.

[17] F. Başçiftçi, and K.A. Gündüz, "A Research on Internet of Things Compatible Microcontrollers," *Selçuk University Journal of Social and Technical Research*, vol.18, pp.66-76, 2019.

[18] R.K. Mishra, M. Pitale, and G. Singh, "Expanding I/O Pins of Microcontroller by Cascading Shift Registers," *In TENCON 2024-2024 IEEE Region 10 Conference (TENCON)*, pp. 1105-1108, 2024, doi: 10.1109/TENCON61640.2024.10902701.

[19] “Arduino Genu ino” [Online]. Available at: https://www.arduino.cc. [Accessed: 26-Jul-2025].