Realization of Boolean Algebra for a Biometric Wardrobe with CMOS Stick Monochrome Encoding

Joanna Grace V. David[1], Andrew Angel DR. Española[1], Ryan Rhay Vicerra[1], Ronnie Concepcion II[1], Joy Carpio[2]

Abstract

Logic gates are electronic components used to build digital circuits. In this project, it is significant to know the process involved in making the biometric wardrobe with its logic gate circuit mechanism and its equivalent Complementary metal-oxide-semiconductor (CMOS) circuit and stick diagram. The use of Multisim Simulation Software was maximized to design, simulate, and analyze the circuit. The electrical components used in the logic gates circuits were AND logic gate, NOT logic gate, inputs, and outputs. For the CMOS circuit, n-type, p-type transistors, ground, corresponding inputs, and outputs were used. Based on the gathered results, it was determined that the mechanism of the biometric wardrobe was analogous to the logic gates circuits, CMOS circuit, and stick diagram that were made. Furthermore, this project enhanced a regular wardrobe by installing a biometric scanner, an alarm, and a serial camera to pave the way to catch an intruder. As such, it is recommended to add features such as voice assistant and face recognition that will help the user conduct the system efficiently.

***Keywords*—logic gates, biometrics, wardrobe, alarm, serial camera**

[1]Department of Manufacturing Engineering and Management, De La Salle University, Manila, Philippines

[2]Systems Engineering Department, University of California - Berkeley, California, USA

joanna_david@dlsu.edu.ph[1], andrew_espanola@dlsu.edu.ph[1], ryan.vicerra@dlsu.edu.ph[1], ronnie.concepcion@dlsu.edu.ph[1], engrjoycarpio@berkeley.edu2

I. Introduction

Logic gates are electronic components that serve as the foundation for digital circuits. Logic gates initiate essential logical functions required by digital circuits, which is why most electronic devices nowadays contain it [1]. Logic gates are also small transistor circuits, basically a type of amplifier conducted in different forms within an integrated circuit. In addition, logic gates will make decisions based on a mix of digital signals from their inputs, which, as previously stated, will most likely have two inputs and one output. Another concept to comprehend is that logic gates are based mainly on Boolean algebra, which implies that each terminal is false or true, which are the two binary conditions [2].

Furthermore, a truth table is a practical approach to explain a logic gate's function to understand better how it operates. It displays the output states for every possible combination of input states, where truth tables typically utilize the symbols 0 (false) and 1 (true). On the other hand, Boolean statements can show the various operations of logic gates. Usually, the letters from the beginning of the alphabet, such as A, B, C, D, etc., are utilized to indicate inputs. In contrast, the letters from the second half of the alphabet, commonly X or Y / P or Q, indicate an output. These letters are used to label the various points in the circuit, which are connected by multiple Boolean symbols that explain how the gates operate logically [2].

Specifically, in this project, the researchers focused mainly on the significant properties of NOT gates and AND gates. The NOT logic gate has only one input and one output (Fig. 1). It is also known as an inverter because it switches the input signal and outputs the opposite signal [3]. It implies that when the input is 0 or low, the output would be its opposite which is 1 or active and vice versa. Table 1 depicts the NOT logic gate's equivalent truth table.

Furthermore, AND logic gate's application is multiplication (Fig. 2). As seen on Table 2, the input values (X and Y) should be multiplied to produce the output value (Z). Adding a NOT logic gate in a circuit uses very little power and is a straightforward interface when used in a circuit [4]. Consequently, Table 2 shows the corresponding truth table of the AND logic gate.

Table 1
NOT Logic Gate Truth Table

X	Y
0	1

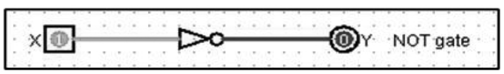

Fig. 1. NOT Logic Gate Circuit Simulation

Table 2
AND Logic Gate Truth Table

X	Y	Z
0	0	0
0	1	0
1	0	0

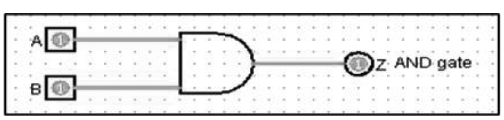

Fig. 2. AND Logic Gate Circuit Simulation

CMOS circuits are used in various digital electrical components, like microprocessors, batteries, and image sensors for digital cameras [5]. Additionally, it has a characteristic of an excellent noise margin and low power usage. When a single transistor from a pair of MOSFET transistors is turned off, the series arrangement consumes considerable power moving between the two states of ON and OFF. According to Elprocus [5], the additional feature of CMOS is it enables high-density integration of logic functions into an integrated device. As a result, CMOS has become the technology of choice for Very Large Scale Integration (VLSI) chips. To transform the logic gate into its equivalent CMOS transistor circuits, both p- and n-channel transistors are used. Additionally, p- and n- channel transistors, corresponding inputs, and outputs are used in the circuit.

Mobile and digital devices are part of our lives as we inhabit and progress in today's modern times. In using mobile and digital devices, the performance of logical functions was applied in operating the said devices. Moreover, some devices use digital control circuits which use logic gates such as AND, OR, NOT, NAND, NOR, XOR, and XNOR. These logic gates are used to generate directives in digital control circuits [3]. Thus, logic gates are used in a wide range of applications, mainly from small decision-making devices to large computers [6].

Safety and security are still of great national concern in the Philippines, with an estimated 41,300 crime incidents and theft as the most prevalent index crime [7] in December 2021. In fact, addressing criminality and safety is the number one priority of the country's administration. To complement these efforts, there is a growing need to advance security measures in safekeeping valuables in people's homes, hence, the innovation of a Biometric Wardrobe. This innovation aims to enhance a regular wardrobe by installing a biometric scanner, an alarm, and a serial camera. The biometric scanner provides exclusive access to the wardrobe while the serial camera is strategically placed to document attempts at security breaches. The alarm is an added feature to warn the owner regarding these unsolicited attempts. The alarm will not stop ringing unless the registered fingerprint is detected. With an enhanced Biometric Wardrobe, users can keep personal belongings with no uncertainties and simultaneously could maximize its use with its additional function to catch the intruder's information. Furthermore, to attain the goal of the enhancement of the Biometric Wardrobe, the objectives are as follows: (1)

Create a model with its corresponding logic gate circuit and CMOS circuit mechanism to secure a wardrobe that can be replicated inside many Filipino homes for better security of their valuables. (2)

Simulate the biometric wardrobe's constructed logic gate circuit mechanism and verify its functionality. (3)

Construct an equivalent truth table of the created logic gate circuit.

II. Review of Related Literature

In today's world, biometrics appears to be the new password, and it aids in the protection of one's personal belongings. By aiming for a low False Acceptance Rate (FAR), biometric systems limit the possibility of trial-and-error assaults. The FAR captures errors in which the systems accept illegitimate matches. Technology itself depends on the collection of fingerprints and often with light or dark powder. Moreover, four parameters, including accuracy, scale, security, and privacy, are used to determine the required essential performance in biometrics [8]. According to the study of [9], their system uses a smartphone, tablet, or other personal computing device to control the opening, unlock, and locking of enclosures such as bags, briefcases, lockers, cases, cabinets, automobiles, buildings, and residences, as well as indirect operational control. Specifically, the smartphone was able to maximize the use of biometric fingerprints as it has a unique locking and unlocking mechanism to control the usage of the device. With these features, thieves could be lessened, and safety would be prioritized. It could also be observed that as the technology behind biometrics improves, the range of biometrics features is getting wider and wider as the new technology arrives.

Alarm Systems, which alert the owner to suspicious activity in a specific location, is a modern means of detecting burglars. Based on the study of Ahmed *et al.* [10], a sound-activated burglar alarm circuit was built using a CMOS circuit, speaker circuit, transistor driver, and a flasher circuit. Similarly in this project, when the alarm was on, the speaker will also be on, and the LED light would also be flashed [10].

Logic gates are used in electrical circuits and correlate to real-life applications such as alarm systems, traffic light control systems, etc. According to the study of [11], the created anti-burglar alarm system and anti-fire security building with corresponding digital electronic circuits were highly effective in reducing the number of burglars and fires in the home or buildings. Additionally, the activation of the alarm for their created circuit also used a logic gate, specifically, the OR gate. Another application is based on the study of Jolani [12] that emphasized that if someone tries to lift their luggage while traveling by bus or train, the generated circuit will give a warning alarm to be aware of it. In that way, the circuit was able to maximize the use of the NAND logic gate.

Furthermore, logic gates are also widely used in different alarm system applications. Its mechanism is very efficient in creating a multi-function system design that mainly uses detection-like sensors. In a study conducted by Jeong [13], a bridge navigational watch alarm system was created wherein the concept of logic gates was integrated. The optimal function, which comprises three motion sensors linked to AND and OR logic gates, was implemented using a variety of sensors.

Logic gates are also used in the field of security; specifically, in the field of emerging technology like the keypad-lock security system. In a study conducted by Chen *et al.* [14], a keypad-lock security system was developed with a visible readout and an automatic reset mechanism; logic gates were one of the main features of integrating different functions. It uses series of logic circuits based on toehold-mediated strand displacement and three-way-DNA-junction architecture in creating the bio-computing keypad lock system. In the home security system field, a study conducted by Sumangala [15], wherein a security system with sensors has been established and developed to detect any security breach. In this study, the security system is mainly composed of logic gates implemented in the doors with the lock-key method. Also, the sensors send out the alert signal by a high-intensity buzzer if the input is false.

Moreover, logic gates are also applied in the field of banking security. In a study conducted by Ramyateja *et at.* [16], logic gates were utilized in biometric authentication using face recognition. It was integrated with the PCA algorithm using MATLAB Processing and login password-based authentication. This study shows that the use of logic gates has dramatically helped the structure of biometric-based authentication. The application of logic gates is also implemented in the finance industry. Specifically in the field of banking security. In a study of Mohan *et al.* [17], RF technology and biometric authenticity-based ATM security were created. This study simplified the circuit by incorporating logic gates in a single computer circuit chip.

Additionally, in a study conducted by Kang [18], logic circuits were applied and integrate in the field of fire security. The use of Boolean logic concepts and data sampling from the internet was heavily emphasized. Moreover, the circuit comprises three primary sensors: the gate, circuit, and medium-scale integrated chip. Specifically, the NAND gate was mostly applied in flame, smoke, and temperature sensor structures.

Logic gates are also applied in control system technology, specifically biometric access control system identification technology. According to a study Wang *et al.* [19], an extensively utilized biometric technology such as an access control system based on fingerprint recognition was built and integrated. In this study, the NOT gate was mostly used in rejecting invalid inputs and preventing security breaches.

In this study, the researchers could covert the logic gate circuit into CMOS circuits. According to the study of Kim *et al.* [20], a hardware-based authentication system with a CMOS image sensor was proposed for safeguarding customer information. It allows home products to have distinct features according to the fundamental characteristics of a CMOS image sensor (CIS) implanted in them. The said study aided the household in securing their personal belongings as it has device and biometric authentication built in the circuit.

III. Methodology

To further illustrate the biometric wardrobe, the researchers created a flowchart that will serve as a guide in creating its respective logic circuit (Fig. 3).

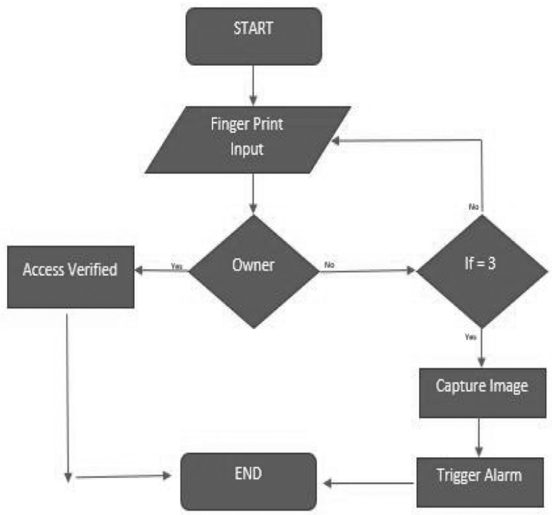

Fig. 3. Flowchart of the biometric wardrobe process

The process starts with the owner's fingerprint input. If the fingerprint input is true, then the wardrobe will be unlocked. However, if the fingerprint input is false, another try will be allowed. A total of three trials will be given, and if the fingerprint is still wrong up to the third trial, the serial camera and the alarm system will function. The owner's fingerprint will serve as the primary input of the biometric wardrobe. Whereas the access verification will serve as the output if the input is true, and the alarm system and serial camera will be the output if the fingerprint is false up to the third trial. The flowchart for the said process is presented below. Additionally, the researchers also created a CAD further to visualize the biometric wardrobe (Fig. 4).

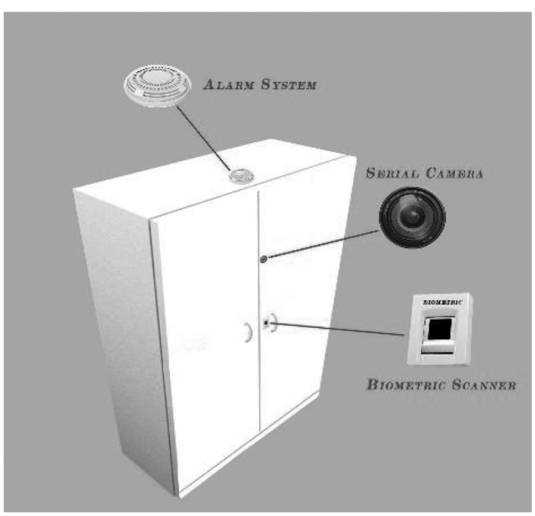

Fig. 4. CAD of the biometric wardrobe with its corresponding components

To further visualize and understand the mechanism of the biometric wardrobe, the researchers created its corresponding logic circuit. The Logisim application was used as the main medium in creating the circuit. As mentioned earlier, the owner's fingerprint serves as the main input of the entire process. There are two possible inputs namely true or false. If the input is true, then the output will be accessed and verified; if the input is false, it will undergo a second trial.

In the Logisim application, two inputs were created—one for true and the other one for false (Figure 5). The pin serves as the output indicator, which allows the lights to be on if the input is true and will be off if the input is false. Moreover, two logic gates were used in this part: the AND gate and the NOR gate. If the fingerprint is true in the first biometric input, then the access will be verified. And if the input is false, it will be denied using the NOT gate and will proceed to the second biometric input.

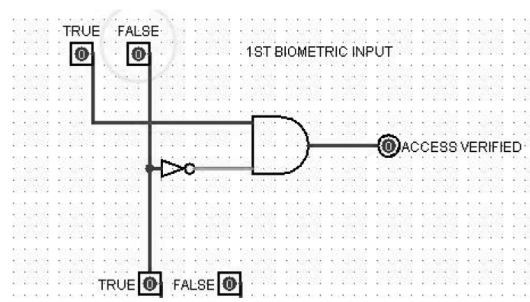

Fig. 5. Logic circuit for the first biometric input wherein the accessed was verified

After the false input in the first part is rejected by the NOT gate, it will proceed to the second part. In the second part of the process, two inputs were again created like in the first part—one for true input and one for false input. To be specific, the same mechanism was made in this part; the only difference is that the input is now the second biometric input. If the fingerprint is true, then the pin will light on, indicating that the access is verified, whereas if the fingerprint is false, it will again be rejected using the NOT gate and will proceed to the third part of the process. The diagram for this second part is in Fig. 6.

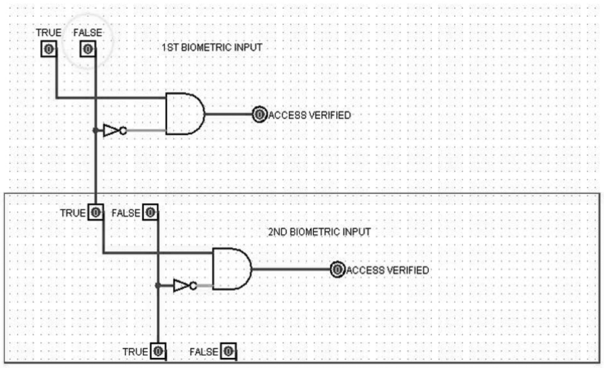

Fig. 6. Logic circuit for the second biometric input wherein the access was verified

Furthermore, if the input from the second biometric part is still false, it will proceed to the last part of the process. The same mechanism was again applied to the previous parts. However, in the third biometric input, if the fingerprint is still false, an alarm will be activated and the serial camera capturing the user's face to alert the owner. In other words, if the input in the third fingerprint trial is true, the access will be verified; however, if the output is still false, the security features of the biometric wardrobe will be activated, such as the alarm system and serial camera. The logic circuit for the third part and the entire process is presented below (Fig. 7).

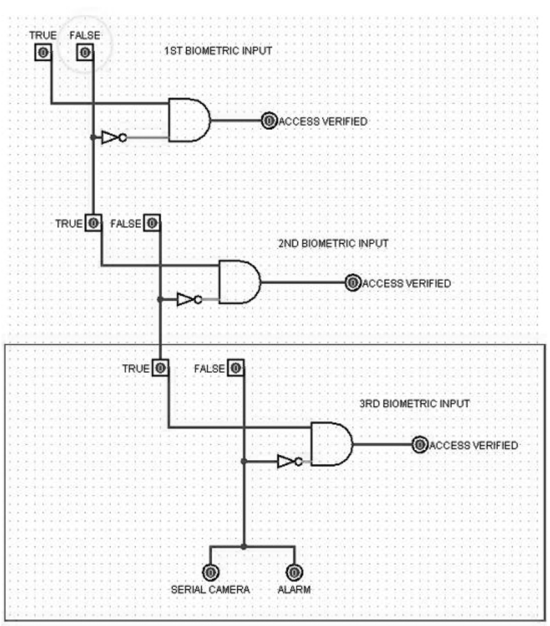

Fig. 7. Logic Circuit for the third biometric input wherein the access was verified

IV. Results and Discussion

This project provides understanding on the different operations of logic gates precisely the AND and OR logic gates. After the simulation of the mechanism of the biometric wardrobe using the Logisim Application, the data and results gathered are as follows:

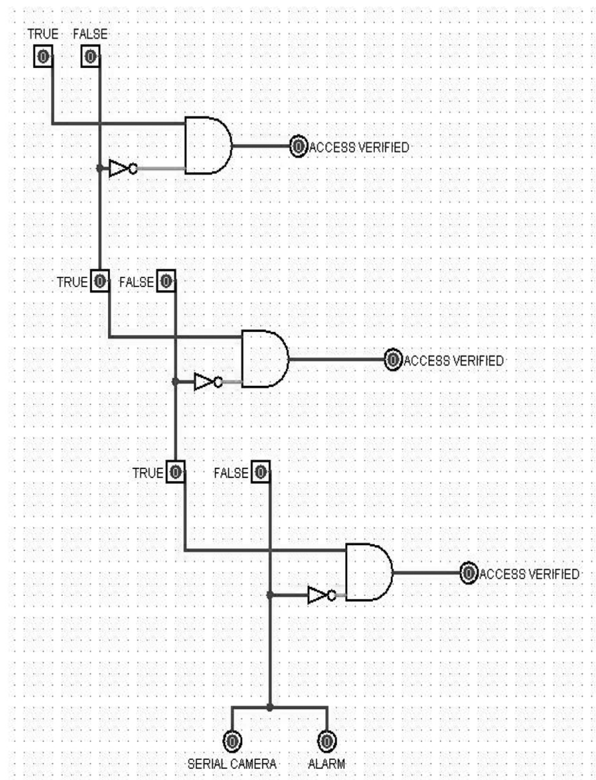

Fig. 8. Logic gate circuit mechanism of the biometric wardrobe

The diagram clearly presents the logic gate circuit mechanism of the biometric wardrobe. The circuit involved AND gate, NOT gate, and corresponding inputs and outputs. The AND gate and NOT gate enable the generation of decisions based on the combination of digital signals from its inputs and outputs. The inputs true and false were designated as the biometric scanner trials wherein the user can access the wardrobe if their biometric fingerprint is correct. The output - access verified was specified as the access verification, while the outputs - serial camera and alarm will only be activated when a certain condition is attained. Moreover, to analyze the circuit more, a truth table was made (Table 3.).

Table 3. Truth Table of The Biometric Wardrobe's Logic Gate Circuit Mechanism

Biometric Trial 1		Access Verified	Biometric Trial 2		Access Verified	Biometric Trial 3		Access Verified	Serial Camera and Alarm
True	False		True	False		True	False		
1	0	1	0	0	0	0	0	0	0
0	1	0	1	0	1	0	0	0	0
0	1	0	0	1	0	1	0	1	0
0	1	0	0	1	0	0	1	0	1

As presented in Table 3., the access to the wardrobe was verified since the input on the biometric fingerprint trial 1 is true or active (1). The bubble symbol on the NOT gate indicates negation, while the AND gate's application is multiplication. In this circuit, using the NOT and AND gate properties, the biometric access will only be verified if and only if the biometric fingerprint trial 1 is true or active (1). Additionally, the 1-value indicates that the circuit was able to produce a green light, and the biometric access was verified (Fig. 9). Hence, the user was able to access the wardrobe in this trial.

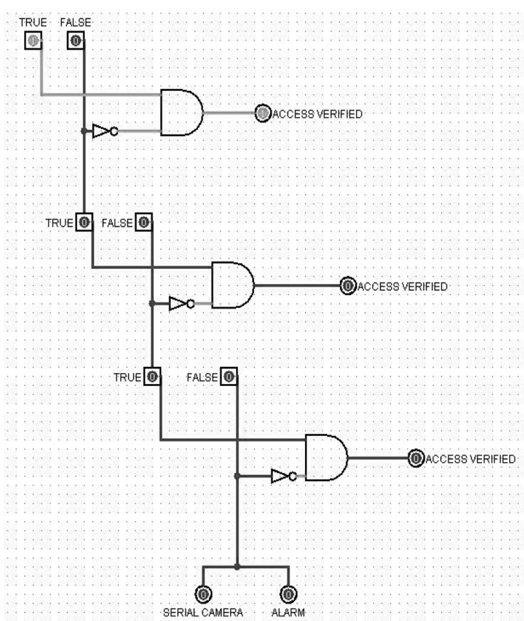

Fig. 9. First logic gate circuit mechanism of the biometric wardrobe

On the other hand, as seen in the third row of Table 3., the access to the wardrobe was not verified since the input on the biometric fingerprint trial 1 is false or low (0). The 0-value on the biometric fingerprint trial 1 indicates that the circuit was not able to produce a green light (Fig. 10.). In this case, the user would have to proceed to the biometric fingerprint trial 2 to re-access the verification. In the second trial, the wardrobe's access was verified since the biometric fingerprint trial 2 is true or active (1). Furthermore, the 1-value indicates that the circuit was able to produce a green light, and the biometric access was then verified (Fig. 10.). In this step, the biometric input for the first trial was denied. The device then proceeded to the second trial, in which, the biometric input was verified.

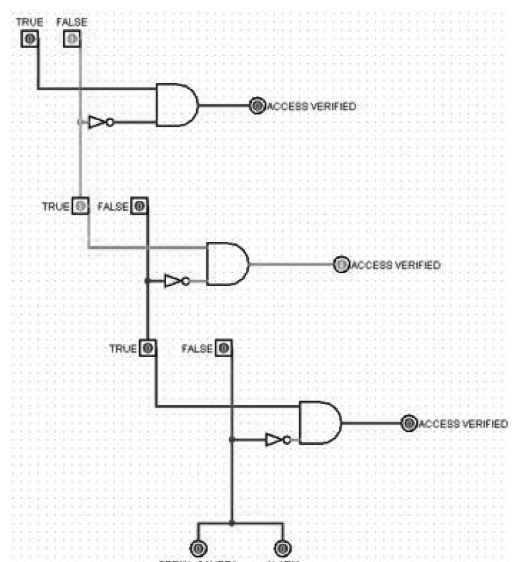

Fig. 10. Second logic gate circuit mechanism of the biometric wardrobe

In the fourth row of Table 3., the access to the wardrobe was not verified on the biometric fingerprint trials 1 and 2 because both inputs are false or low (0). In this case, the user would have to proceed to biometric fingerprint trial 3 to re-access the verification. In the third trial, the wardrobe's access was verified since the biometric fingerprint trial 3 is already true and active (1) (Fig. 11.). Moreover, the 1-value indicates that the circuit could produce a green light, and the biometric access was then verified on the third trial.

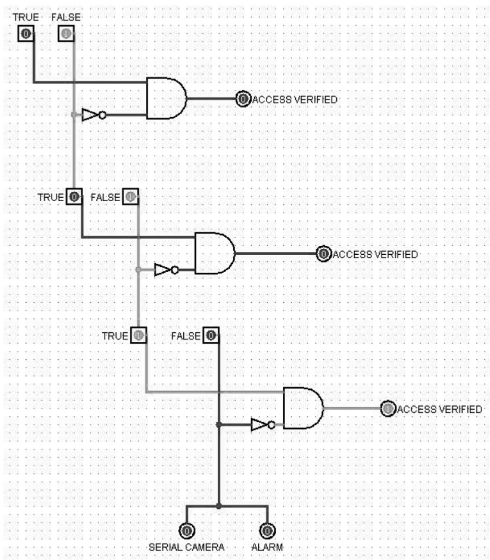

Fig. 11 - Third logic gate circuit mechanism of the biometric wardrobe

In the fifth row of Table 3, the access to the wardrobe was not verified on the biometric fingerprint trials 1, 2, and 3 because all the inputs are false or low (0). In this case, the outputs - serial camera and alarm will be true or active (1) since the maximum trial in accessing the wardrobe is three, and all the inputs in the biometric fingerprint trials are false. As seen in Fig. 12., the 1-value on the outputs - serial camera and alarm indicates that the circuit was able to produce a green light. This is because the mechanism of the biometric wardrobe states that whenever all the three trials are wrong and were maximized, the serial camera and the alarm will be triggered and on. Hence, it is inferred that the mechanism of the biometric wardrobe was analogous to the logic gates circuits that were made.

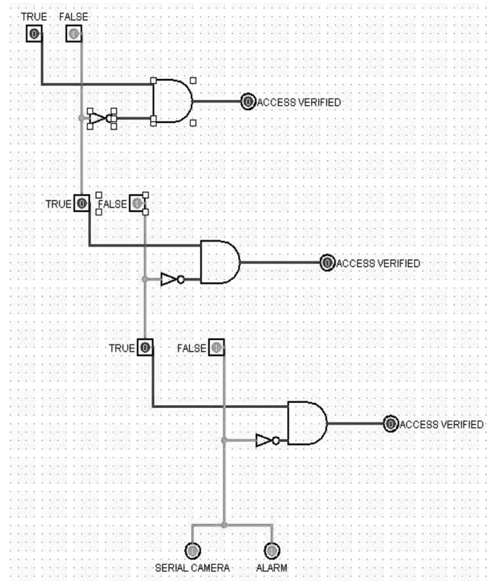

Fig. 12. Fourth logic gate circuit mechanism of the biometric wardrobe

This project also allowed a full comprehension on the conversion process of logic gate and circuit into equivalent CMOS transistor circuitry using the Logisim Application; the data and results gathered are as follows:

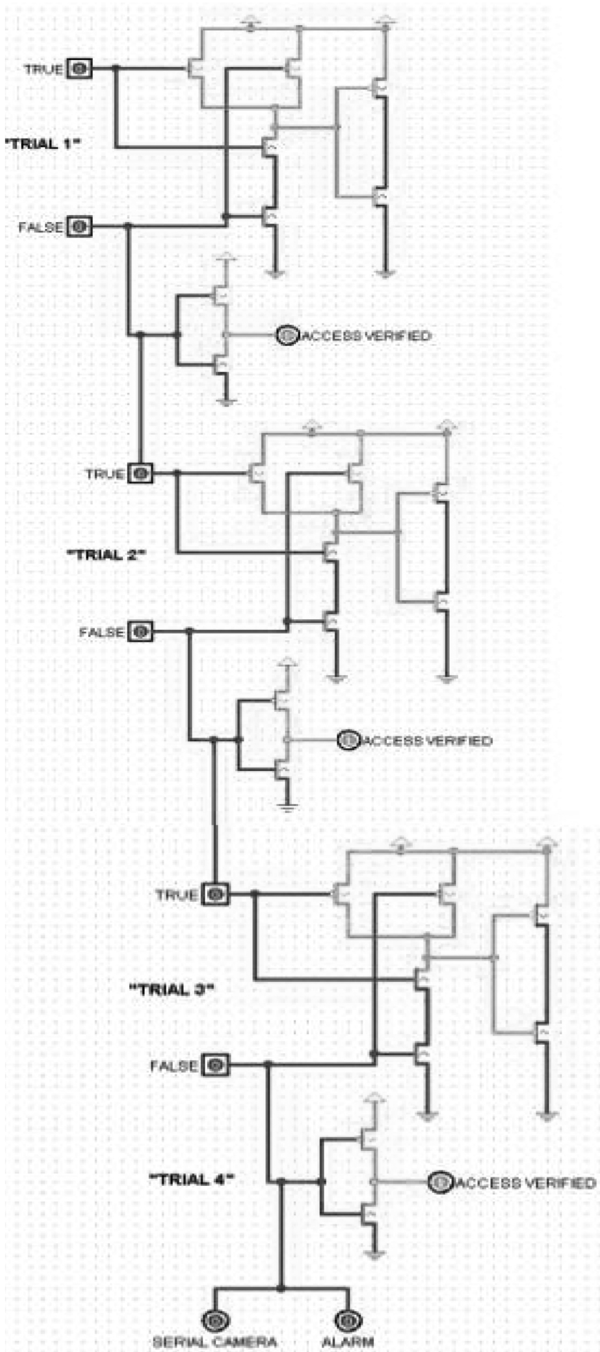

Fig. 13. Equivalent CMOS transistor circuit of the logic gate circuit

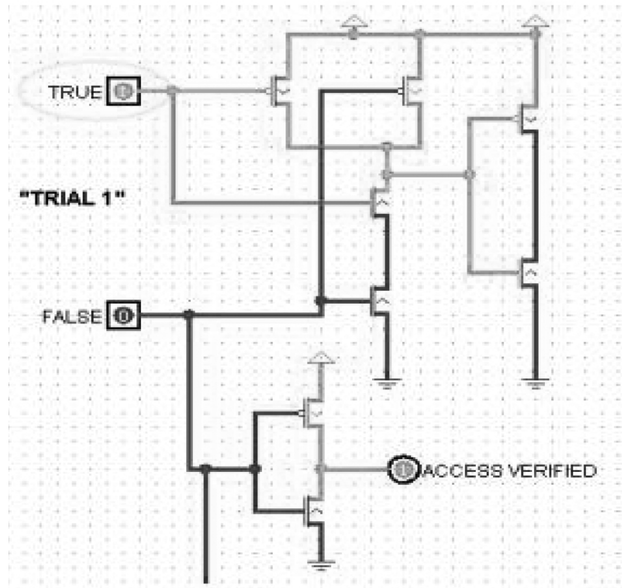

Fig. 14. CMOS transistor circuit wherein the access was verified in the first trial

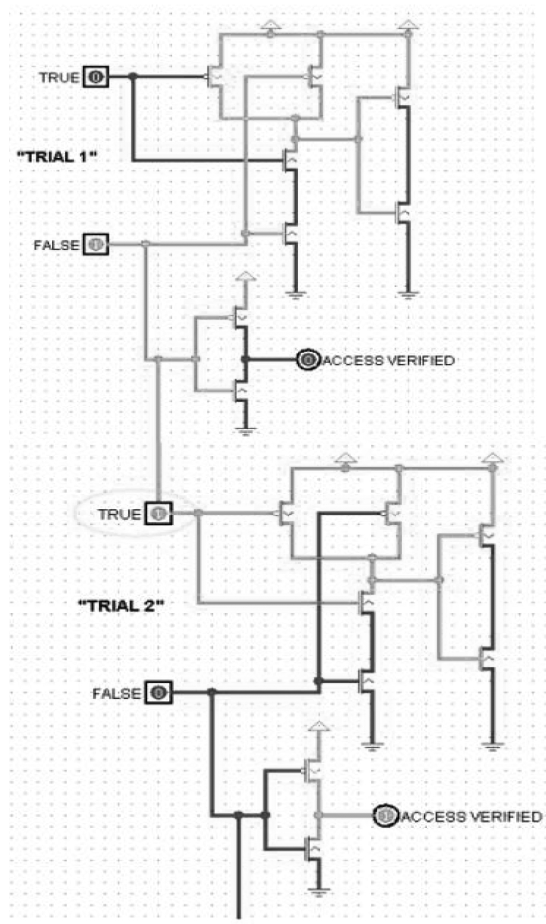

Fig. 15. CMOS transistor circuit wherein the access was verified in the second trial

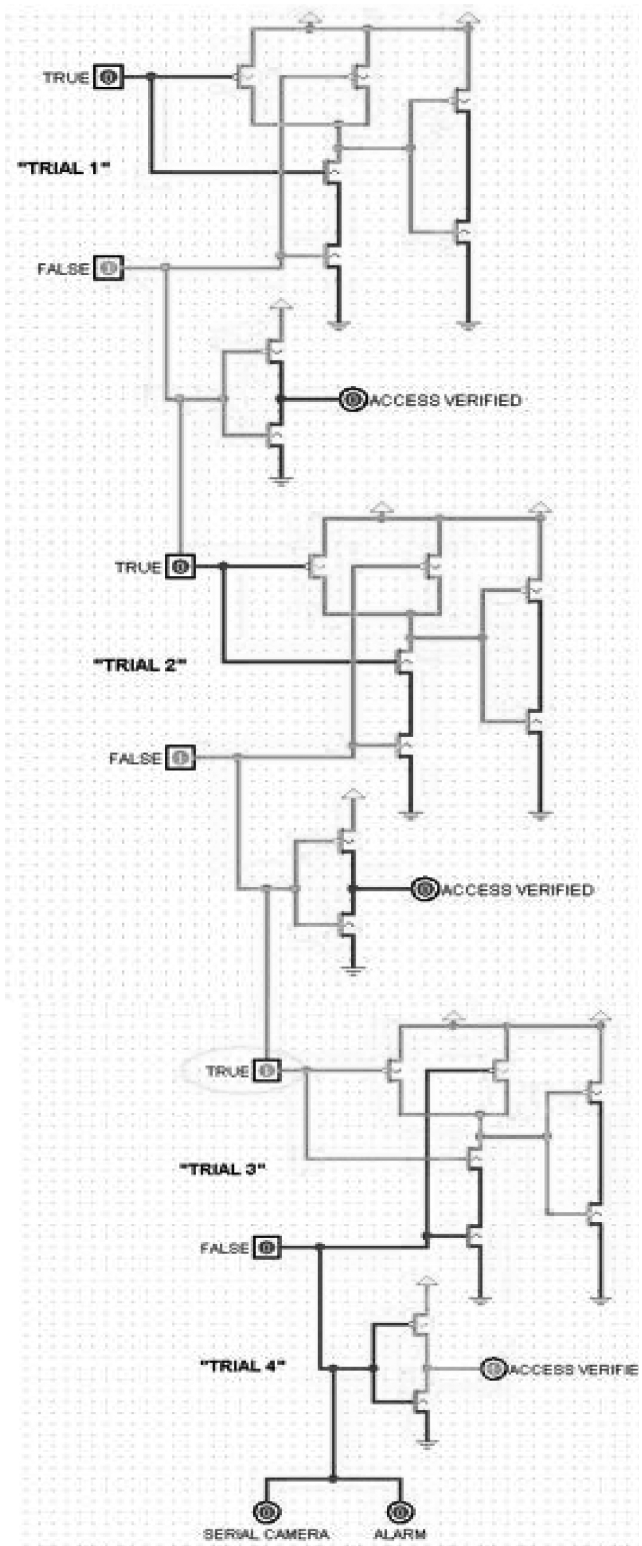

Fig. 16. CMOS transistor circuit wherein the access was verified in the third trial

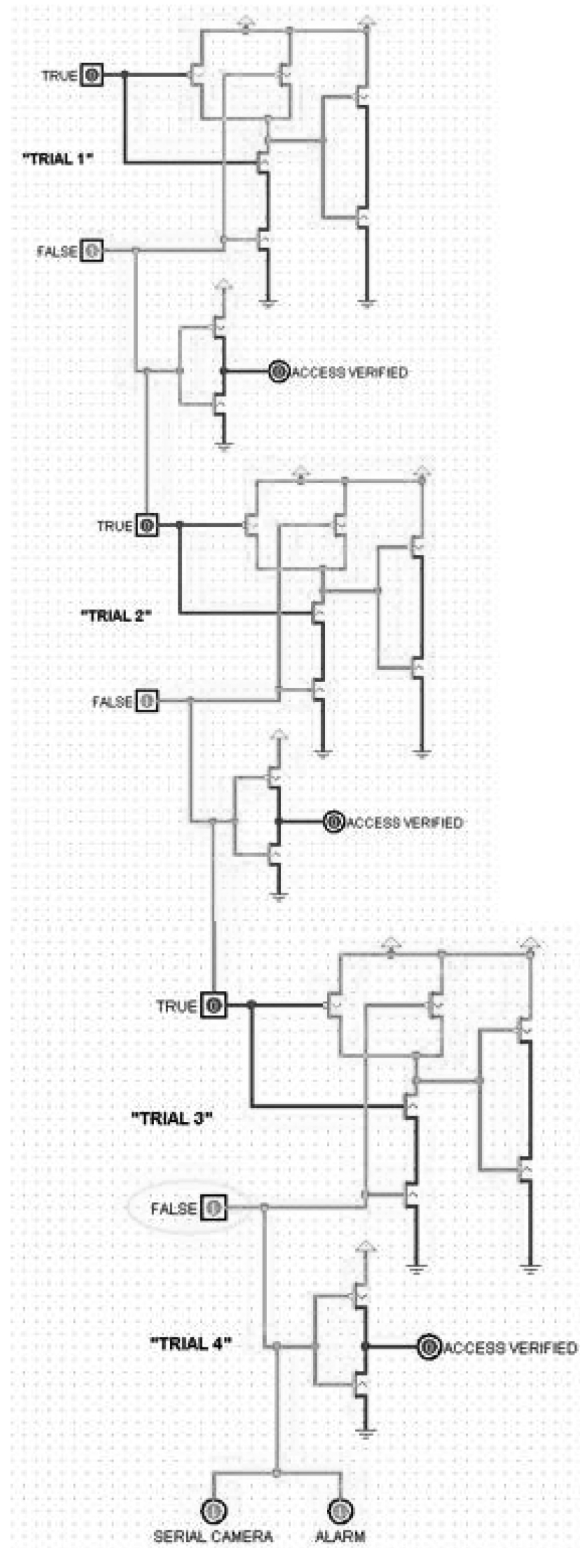

Fig. 17. Trial 4 of CMOS transistor circuit wherein the serial camera and alarm were accessed

The results showed each logic gate's equivalent CMOS transistor circuit, truth table, and stick diagram. In conducting the circuits, n-type, p-type transistors, ground, corresponding inputs, and outputs were used. The mechanism of the CMOS circuit corresponds to the results of the truth table on the logic gate circuits. Figures 14,15,16, and 17 shows the biometric fingerprint trials 1,2,3, and 4 respectively. Moreover, the CMOS transistor circuits presented above help to illustrate the implementation of logic gates of the biometric wardrobe. Further, AND logic gate and NOT logic gate applications were also used in making the CMOS circuit. Both of its applications would still be multiplication and negation consecutively for AND gate and NOT gate, even if it was recreated to CMOS transistor circuit.

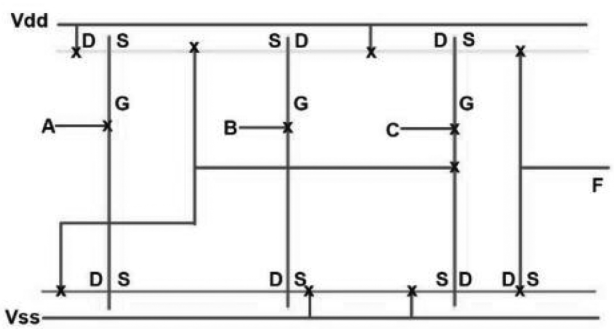

Fig. 18. Stick Diagram of CMOS Transistor Circuit

For the stick diagram, the various process layers, such as p-, n-diffusion, and polysilicon, are represented by colored lines. The process of conducting the stick diagram helped the students easily understand the circuit's components and parts with the use of colors, symbols, and labels.

Logic Function Simplification

A= Biometric Input 1
B = Biometric Input 2 F = Serial camera and alarm system
C = Biometric Input 3

F (output) = A'+B'+C'

The equation presented above represents the overall simplified logic function of the circuit; specifically, it describes the circuit if all the attempts or trials were utilized. The simplified function describes that if the input for the first biometric attempt is false, it will proceed to the second attempt, and further to the second and third attempt if the input is still false. Finally, suppose the biometric input is still false up to the third attempt, the serial camera and alarm system features of the biometric wardrobe will be activated.

Moreover, the findings obtained from the circuits demonstrate the vital role of Boolean algebra in electronic systems for consumer benefits. Additionally, in each trial, it is evident that an identical logic circuit was created since the user will have the same procedure in each trial. However, each trial was connected according to the input of the user. It means that the circuit was designed for both true and false and inputs, wherein there is a corresponding output for each input. The circuit also has a respective output when the trial limit is reached, which creates the final output for the logic circuit. In this innovation, it is apparent that the biometric wardrobe's logic circuit demonstrates the application of Boolean algebra in implementing security devices.

V. Conclusion

It can be seen that the study successfully created the logic circuit of the biometric wardrobe. Moreover, the equivalent CMOS circuit and stick diagram were also made to analyze the logic gate circuit further. The results showed that if the value of the first biometric input is true, then the access will be verified; and if the input is false, it will then go to the second and third biometric input. Moreover, the circuit successfully followed the number of trials or biometric input allowed before the security features activate, as stated in the methodology. Lastly, the biometric wardrobe's serial camera and alarm system activate accordingly if the biometric input is still false up to the third trial. On the other hand, the researchers recommend adding more features between the entire process's parts. Additional features such as voice assistant will help the user conduct the procedure easily. Also, a face detection feature will be a good integration into the biometric wardrobe. It will serve as an additional security alternative if the owner wants more control over the wardrobe. These recommendations require manipulation of the circuit generated from this study. Thus, using other features in the Logisim application is also recommended. Also, the study gave the researchers an in-depth understanding of the application of logic in creating innovations. The concept of logic gates was mainly applied and incorporated in generating the mechanism of the biometric wardrobe. The comprehensive application and integration of the topics learned from this course were successfully turned into a possible innovation that can be used to address rising issues of safety and security.

VI. Acknowledgment

The authors would like to thank the Intelligent Systems Laboratory and the Department of Manufacturing Engineering and Management of De La Salle University for all the support granted.

VII. References

[1] "Logic gate (AND, OR, XOR, NOT, NAND, NOR and XNOR)," TechTarget Contributor, Dec. 2020. https://whatis.techtarget.com/definition/logic-gate-AND-OR-XOR-NOT-NAND-NOR-and-XNOR#:~:text=A%20logic%20gate%20is%20a,are%20fundamental%20to%20digital%20circuits.&text=Most%20logic%20gates%20have%20two,are%20based%20on%20Boolean%20algebra. (accessed Jan. 26, 2022).

[2] E. Coates., "Boolean Statements," Learnabout Electronics, Dec. 2020. https://learnabout-electronics.org/Digital/dig21.php (accessed Jan. 26, 2022).

[3] ETechnoG., "Best application and uses of logic gates with practical examples," ETechnoG, Feb. 2019. https://www.etechnog.com/2019/04/application-uses-logic-gate.html (accessed March 1, 2022).

[4] Garg, B., & Kaur, S., "A review of logic gates and its applications," International Journal of Emerging Technologies and Innovative Research (www.jetir.org), 6(5), 124-129, May 2019. [Online]. Available: https://www.jetir.org/papers/JETIRCW06026.pdf (accessed March 1, 2022).

[5] Elprocus, What is a CMOS: Working principle & its applications, n.d. Available: https://www.elprocus.com/cmos-working-principle-and-applications/ (accessed Dec. 21, 2021).

[6] Chouhan, S., Chaudhary, S., Upadhay, T., Rupani, A., and Whig, P., "Comparative study of various gates based in different technologies," Int Rob Auto J., 3(1), 262-269, Sept. 2017. [Online]. Available: https://doi.org/10.15406/iratj.2017.03.00046 (accessed March 1, 2022).

[7] Statista Research Department, "Crime in the Philippines - statistics & facts," statista, Dec. 6, 2021. https://www.statista.com/topics/6994/crime-in-the-philippines/#dossierKeyfigures (accessed Jan. 26, 2022).

[8] Hamidi, H., "An approach to develop the smart health using Internet of Things and authentication based on biometric technology," ScienceDirect, Feb. 2019. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0167739X18313517 (accessed Feb, 7, 2022).

[9] S. D. Cabouli, R. J. Mos, C. V. Mueller, R. A. Lane, M. A. Schilling, and P. E. Catinella., "Smartphone controlled biometric and bluetooth enabled smart wallet system," IWallet Corporation, 2016. [Online]. Available: https://patents.google.com/patent/US20160098878A1/en (accessed Feb. 7, 2022).

[10] Ahmed, M. S., Mohamimed, A., Alah, G. "Development of a simple sound activated burglar alarm system," Leonardo Journal Sciences, 2006. [Online]. Available: https://www.researchgate.net/publication/26449169_Development_of_a_Simple_Sound_Activated_Burglar_Alarm_System (accessed Feb. 7, 2022).

[11] M.J. Jolani., "The anti-burglar alarm system and anti fire security building," Universitas Muhammadiyah Surakarta, 2017. [Online]. Available: http://eprints.ums.ac.id/54829/3/Journal%20Final%20Rev..pdf (accessed Jan. 27, 2022).

[12] Gupta, S., "Luggage Security Alarm System," July 1, 2014. [Online]. Available: https://www.eeweb.com/luggage-security-alarm-circuit/ (accessed Feb. 7, 2022).

[13] Jeong, T. G., & Bae, D. H. "A basic study on implementing optimal function of motion sensor for bridge navigational watch alarm system," Journal of Navigation and Port Research, 38(6), 645-653.2015. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/ange.201408334 (accessed Feb. 7, 2022).

[14] Chen, J., Zhou, S., & Wen, J. "Concatenated logic circuits based on a three-way DNA junction: a keypad-lock security system with visible readout and an automatic reset function," Angewandte Chemie, 127(2), 456-460. 2015. [Online]. Available: https://www.koreascience.or.kr/article/JAKO201403460492961.page (accessed Feb. 7, 2022).

[15] Sumangala, B. V., & Ram, K. B., "Design, development and performance study of L3-Home security system, Global Journal of Research in Engineering, 12(8-F), 2012. Available: https://www.engineeringresearch.org/index.php/GJRE/article/view/641/583 (accessed February 28, 2022)

[16] Ramyateja, S., & Srinivias, K. "Implementation of Enhanced Authentication Scheme for Secured Banking with Biometrics," 2015. [Online]. Available: http://ijsetr.com/uploads/263514IJSETR477-11.pdf (accessed Feb. 21,2022).

[17] Mohan, K., and Krishna S., "FPGA Implementation of RF Technology And Biometric Authentication Based ATM Security," International Journal of Engineering Trends and Technology (IJETT), 15(4), Sept 2014. [Online]. Available: https://nanopdf.com/download/fpga-implementation-of-rf-technology-and-biometric-authentication-based-atm-secu_pdf (accessed: February 28, 2022)

[18] Kang, S. "Analysis on the circuit design of fire alarm." In *Journal of Physics: Conference Series* (Vol. 1920, No. 1, p. 012022). IOP Publishing. 2015 Accessed https://iopscience.iop.org/article/10.1088/1742-6596/1920/1/012022/pdf (Feb. 21, 2022)

[19] Wang, H., Wang, Z., Sun, G., Zhang, L., Gao, Y., Zhang, Y., & Bi, C., "Design of a Biometric Access Control System Based on Fingerprint Identification Technology." In *Artificial Intelligence in China* (pp. 34-42). Springer, Singapore. 2021 Available: https://link.springer.com/chapter/10.1007/978-981-15-8599-9_5#citeas (accessed February 21, 2022).

[20] Kim, S., Lim, S., Shin, S., and Choi, J. "Biometrics for Electronic Eyes: System Authentication with Embedded CMOS Image Sensor," 2016. [Online]. Available: https://www.researchgate.net/publication/309469896_Biometrics_for_Electronic_Eyes_System_Authentication_with_Embedded_CMOS_Image_Sensor (accessed Feb. 7, 2022).