JURTEKSI (Jurnal Teknologi dan Sistem Informasi) ISSN 2407-1811 (Print)
Vol. IX No 2, Maret 2023, hlm. 207 - 214 ISSN 2550-0201 (Online)
DOI: https://doi.org/10.33330/jurteksi.v9i2.1957
Available online at http://jurnal.stmikroyal.ac.id/index.php/jurteksi

DESAIGN AND SIMULATION OF ADC CIRCUITS COMPILED BY IC ADC0804 AND IC ADC0809

Muhammad Amril[1], Panangian Mahadi Sihombing[2*], Sukarwoto[1]
[1]Telecommunication and Air Navigation Engineering, Politeknik Penerbangan Medan
[2]Electrical Engineering, Universitas Al-Azhar
email: mahadinababan@gmail.com

Abstract: Medan Aviation Polytechnic is one of the campuses under the ministry of transportation which has a major in telecommunication and air navigation engineering in Indonesia. Based on field surveys, an Analog to Digital Converter (ADC) practicum kit is needed to improve the ability of cadets. Based on this background, this study aims to design and simulate two ADC circuits, each of which is compiled by the integrated circuit (IC) ADC0804 and IC ADC0809 respectively. Three statistical formulas, namely mean error (ME), standard deviation error (SDE), and root mean square error (RMSE) are used to measure the performance of the two ADC circuits. Both ADC circuits are simulated using a Proteus 8.11 Simulator with 255 analog input voltages. Based on the result of the study, it is known that the ADC circuit compiled by IC ADC0809 is more accurate than the ADC circuit compiled by IC ADC0804. This is evidenced by a smaller error value, which is based on the simulation results of the ME, SDE, and RMSE values were 0.42_{10}, $0.34_{10,}$ and 0.51_{10}, respectively. And, based on the measurement results, it has ME, SDE, RMSE respectively, namely 0.85_{10}, 0.81_{10}, and 0.93_{10}.

Keywords: ADC; Proteus 8.11 Simulator; IC ADC0804; IC ADC0809; ME; SDE; RMSE

Abstrak: Politeknik Penerbangan Medan adalah salah satu kampus di bawah Kementerian Perhubungan yang memiliki jurusan teknik telekomunikasi dan navigasi udara di Indonesia. Berdasarkan survei di lapangan, kit praktikum konverter analog ke digital diperlukan untuk meningkatkan kemampuat taruna. Berdasarkan latar belakang tersebut, penelitian ini bertujuan merancang dan mensimulasi dua rangkaian ADC yang masing-masing disusun oleh IC ADC0804 dan IC ADC0809. Tiga formula statistik, yaitu *mean error* (ME), *standard deviation error* (SDE), and *root mean square error* (RMSE) digunakan untuk mengukur kinerja kedua rangkaian ADC tersebut. Kedua rangkaian ADC tersebut disimulasi menggunakan Simulator Proteus 8.11 dengan 255 tegangan masukan analog. Berdasarkan hasil penelitian diketahui bahwa rangkaian ADC yang disusun oleh IC ADC0809 lebih akurat dibandingkan dengan rangkaian ADC yang disusun oleh IC ADC0804. Hal tersebut dibuktikan dengan nilai kesalahan yang lebih kecil, yaitu berdasarkan hasil simulasi memiliki ME, SDE, RMSE masing-masing adalah $0{,}42_{10}$, $0{,}34_{10}$ dan $0{,}51_{10}$. Dan berdasarkan hasil pengukuran memiliki ME, SDE, dan RMSE masing-masing adalah $0{,}85_{10}$, $0{,}81_{10}$, dan $0{,}93_{10}$.

Kata kunci: ADC; Simulator Proteus 8.11; IC ADC0804; IC ADC0809; ME; SDE; RMSE

INTRODUCTION

Analog-to-digital converters are generally applied to convert analog signals from the output of a sensor (transducer – analog signals) into digital signals [1]. Furthermore, the digital signal is sent to a microprocessor or microcontroller for further processing. Microprocessors and sensors are the essential components that make up the internet of things (IoT) technology [2], [3]. IoT technology has great potential and capacity to make intelligent transportation systems (ITS) efficient, safe, intelligent, reliable, and sustainable [4]–[6]. This is because IoT technology can integrate vehicles with the internet network and other components that are related to the environment. These components can be public infrastructure, sensors, global navigation systems (GPS), pedestrians, and other vehicles. Thus, analog to digital converters implemented in ITS technology can improve traffic efficiency in the city center and the safety of road users [3], [7]. Based on this, the speed and accuracy of a converter to convert analog signals into digital signals can affect the performance of the ITS system [8]. In addition, the use of converters that suit your needs based on power usage, cost, and simple converter size (low profile) also needs to be considered to increase efficiency in the ITS system. Medan Aviation Polytechnic is one of the campuses under the ministry of transportation which has a major in telecommunication and air navigation engineering in Indonesia. Based on field surveys, an Analog to Digital Converter (ADC) practicum kit is needed to improve the ability of cadets.

This study aims to design and simulate two ADC circuits, each of which is compiled by the integrated circuit (IC) ADC0804 and IC ADC0809 respectively. This study also aims to determine the performance of the two ADC circuits. The performance includes a comparison of the degree of accuracy of the two converter circuits in converting analog signals to digital signals. Thus, it can be known which IC ADC is better at analog-to-digital conversion. Although it is already available in the market for embedded ADC systems in microcontrollers or microprocessors to make the system more compact, this study still analyzes the performance of ADC ICs that are not embedded in microcontrollers or microprocessors. This is due to the limitation of the number of analog pins contained in the microcontroller or processor. So additional circuits are needed to overcome the need for excess analog pins in a particular project [9], [10].

IC ADC0804 and IC ADC0809 are complementary metal–oxide–semiconductor (CMOS) technologies that apply the successive approximation method to convert analog signals into digital signals. The two ICs have been widely applied to various control systems because they have several advantages such as high speed, accuracy, and flexibility, as well as low power consumption [11]. To find out the performance of the two ADC circuits, two methods were used, namely, the simulation method using the Proteus 8.11 Simulator and the measurement method using the ADC circuits designed. Furthermore, the three results of the method are analyzed three using statistical formulas, namely the mean error (ME) and the standard deviation error (SDE), and the root mean square error (RMSE) [12].

There are several studies that have been done regarding analog to digital converter circuits. Yidong has applied the ADC0804 IC to the direct current (DC) source control system.

JURTEKSI (Jurnal Teknologi dan Sistem Informasi) ISSN 2407-1811 (Print)
Vol. IX No 2, Maret 2023, hlm. 207 - 214 ISSN 2550-0201 (Online)
DOI: https://doi.org/10.33330/jurteksi.v9i2.1957
Available online at http://jurnal.stmikroyal.ac.id/index.php/jurteksi

Based on the results of the study, the ADC0804 IC has high accuracy in converting analog signals into digital signals [13]. Sacko has researched the ADC0804 IC-based converter circuit with the result that the ADC0804 IC is sensitive to comparator shifts and linearity from the ADC thus affecting the performance of the IC. However, the study did not include data on the ADC0804 IC performance test sample [14]. Hongwu Jiang has developed a conventional ADC design for compute-in-memory (CIM) applications. The ADC design has a resolution of 6 bits while in this study it applies the ADC design with a resolution of 8 bits [15], [16]. Huiling has also researched the performance of the ADC0809 IC applied in voltage measurement systems. The results of the study stated that the ADC0809 IC has several advantages, namely being able to convert voltage accurately, a wide measurement range, and low power consumption. However, huiling research has not compared with the performance of the ADC0804 IC. Where both ICs are ADCs with a resolution of 8 bits[17].

METHOD

There are three methods carried out in this study to measure the performance of two ADC circuits. The three methods are the simulation method, measurement method, and calculation method. The ISIS Proteus 8.11 Simulator has been used in this study to simulate both ADC circuits. The simulator is widely applied in previous studies because it has high accuracy in simulating electronic circuits [18]–[20]. The simulation stage begins with designing the ADC circuits compiled by IC ADC0804 and IC ADC0809 respectively. The results of the design of both ADC circuits are shown in Image 1 and Image 2, respectively.

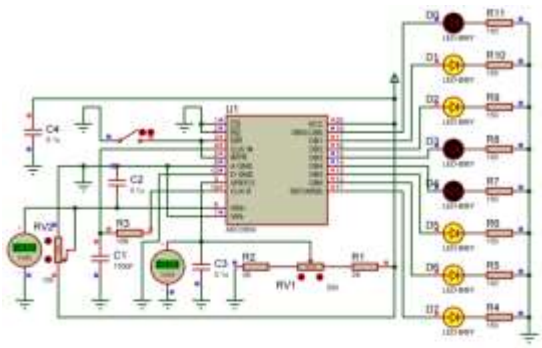

Image 1. ADC Circuit Compiled by IC ADC0804 on ISIS Proteus Simulator

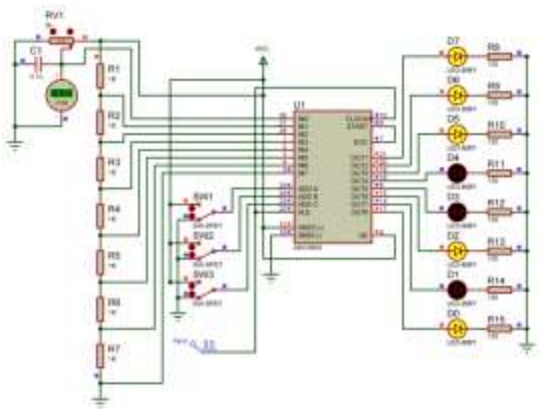

Image 2. ADC Circuit Compiled by IC ADC0809 on ISIS Proteus Simulator

The second stage is to determine the analog input in the form of direct current (DC) voltage. In this study, 255 analog input voltages were used. The voltage range is from 0.0 V – 5.0 V with an increase of 19,6 mV per stage. The range was chosen because it corresponds to the performance capacity of both of the IC ADC used. Meanwhile, an increase of 19,6 mV was chosen because it used an 8-bit resolution [11]. In addition, 19,6 mV has exceeded the limit of the minimum analog input voltage value that can be converted into a digital signal worth 1 least significant bit (LSB) [21], [22].

JURTEKSI (Jurnal Teknologi dan Sistem Informasi) ISSN 2407-1811 (Print)
Vol. IX No 2, Maret 2023, hlm. 207 - 214 ISSN 2550-0201 (Online)
DOI: https://doi.org/10.33330/jurteksi.v9i2.1957
Available online at http://jurnal.stmikroyal.ac.id/index.php/jurteksi

Based on Image 1, the analog input voltage is given via Pin 6 (Vin+), and the RV2 potentiometer is used to vary the magnitude of the given analog input voltage. Whereas in Image 2, the analog input voltage is given via Pin 20 (IN0) with the RV1 potentiometer acting as an analog input voltage regulator.

The last stage of the simulation method is to collect data from the conversion of analog signals to digital signals. Next, convert those digital signals into decimal numbers for easy analysis. The binary number of the conversion result is represented by the LED indicator.

Both simulated ADC circuits have been fabricated as shown in Image 3 and Image 4. Image 3 and Image 4 are ADC Circuit Compiled by IC ADC0804 and IC ADC0809 respectively.

Image 3. ADC Circuit Compiled by IC ADC0804 Base on Manufactured

A function generator is used as an external source to support both ADC circuits. Based on Image 3, an analog input voltage is given via Pin 6 and adjusted using Variable Resistor 2 (VR2). Furthermore, based on Image 4, Pin 26 is used as a pin to receive analog input voltage. The voltage is regulated by VR1.

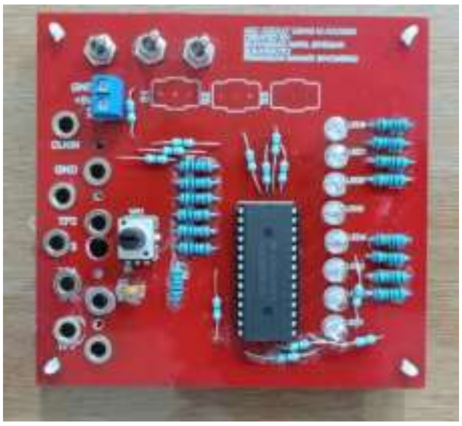

Image 4. ADC Circuit Compiled by IC ADC0809 Base on Manufactured

Similarly to the simulation method, the analog input voltage is measured using a digital multimeter and the digital output voltage is indicated by the LED indicator as a representation of binary numbers. Furthermore, the binary numbers are converted to decimal numbers to make them easier to analyze.

There are three types of research data in this study, namely research data based on calculations, simulations, and measurements. The data from the calculation of the conversion of analog signals into digital signals are used as a benchmark to determine the performance of the two converter circuits. To obtain the calculation result data, the calculation method that has been carried out in the study [11] is used.

The analysis stage is carried out by comparing the calculation result against the simulation result and the calculation result against the measurement result. Furthermore, three statistical formulas were used to analyze the two comparisons of research data. The three statistical formulas are mean error (ME), standard deviation error (SDE), and root mean square error (RMSE) which are shown in Formula (1), Formula (2), and Formula (3) respectively [11], [23].

$$\mathrm{ME} = \frac{1}{n} . \sum_{i=1}^{n} |D_{c.i} - D_{m.i}| \quad (1)$$

$$\mathrm{SDE} = \sqrt{\frac{1}{n} . \sum_{i=1}^{n} (|D_{c.i} - D_{m.i}| - \mathrm{ME})^2} \quad (2)$$

$$\mathrm{RMSE} = \sqrt{\frac{1}{n} . \sum_{i=1}^{n} |D_{c.i} - D_{m.i}|^2} \quad (3)$$

n is the number of data. $D_{c.i}$ is the calculation result. $D_{m.i}$ is the measurement or simulation result.

RESULT AND DISCUSSION

There are three research results data, namely calculation results data, simulation results data, and measurement results data. Image 1 is one of the simulation results of the converter circuit-based IC ADC0804 with an analog input voltage of 4.50 V. Based on Image 5, D0 is the least significant bit (LSB) while D7 is the most significant bit (MSB). So that it can be known that the output of digital signals in the form of binary numbers represented through led indicators is 11100110_2. Next, the binary numbers are converted into decimal numbers for easier analysis. Thus, the conversion of an analog input voltage of 4.50 V to 230_{10} was obtained. Image 2 is the simulation result of the converter circuit-based IC ADC0809 for an analog input voltage of 4.50 V. Based on Image 2, D7 is MSB and D0 is LSB. Thus, based on the figure obtained the conversion of 4.50 V is 11100101_2 or if converted to a decimal number is 229_{10}. Using the same method, 255 simulation data can be obtained for both ADC circuits. The analog input voltage starts from 0 mV – 5000 mV in increments of 19.6 mV.

The analog to digital conversion data based on calculation results is needed as a benchmark to determine the performance of converter circuits both based on simulation results and measurements. Formula 4 is used to calculate the conversion of one of the analog input voltages 4.50 V to a digital signal.

$$D_{calc.i} = \frac{V_{in.i}}{Q} \quad (4)$$

$$D_{c.4,50V} = \frac{4500\ \mathrm{mV}}{19{,}6\ \mathrm{mV}}$$

$$D_{c.4,50V} = 229{,}59 \approx 230$$

Dc.i is the result of analog to digital conversion in decimal units. Vin.i is analog input voltage (mV). For the above example, an analog input voltage is 4500 mV. Q is the quantization value obtained based on the full-scale analog input voltage and the number of bits of the ADC IC used. In this study, the full-scale analog input voltage used was 5.0 V and the resolution used was 8 bits. So the quantization value obtained is 19.6 mV. Based on the calculation results, 4.50 V was converted to 230_{10} [11]. Rounding of values has been performed on each decimal number data to make it easier to convert to binary numbers and led indicator representation.

Both manufactured ADC circuits are tested by providing analog input voltages. Based on one of the test results on the ADC circuit compiled by IC ADC0804, the 4.50V analog input voltage was converted to 11100111_2 (231_{10}). Meanwhile, in the ADC circuit compiled by IC ADC0809, the 4.50V analog input voltage is converted into 11100110_2 (230_{10}). Testing each of the two fabricated ADC circuits has been carried out in 255 experiments with an increase in the analog input voltage of 19.6 mV. Using Equation 1, Equation 2, and Equation 3, a comparison of the error results of each experiment for each ADC circuit is obtained as shown in Table 1.

ISSN 2407-1811 (Print)
ISSN 2550-0201 (Online)

Table 1. Comparison of ME, SDE, and RMSE of Each Experiment

No.	Results	Simulations		Measurements	
		IC ADC0804	IC ADC0809	IC ADC0804	IC ADC0809
1.	ME	0.63_{10}	0.42_{10}	0.94_{10}	0.85_{10}
2.	SDE	0.55_{10}	0.34_{10}	0.91_{10}	0.81_{10}
3.	RMSE	0.65_{10}	0.51_{10}	0.96_{10}	0.93_{10}

The data in Table 1 was obtained using the help of MatLab Software 2015b. Based on the table, it is known that the simulation results of the ADC circuit compiled by IC ADC0804 have ME, SDE, and RMSE respectively, namely 0.63_{10}, 0.55_{10}, and 0.65_{10}. While the results of the ADC circuit simulation compiled by the IC ADC0809 have a smaller error than the IC ADC0804 for each ME, SDE, and RMSE, namely 0.42_{10}, 034_{10}, and 0.51_{10}.

Based on Table 1, it is also known that the test results of the ADC series compiled by IC ADC0804 have ME, SDE, and RMSE respectively, namely 0.94_{10}, 0.91_{10}, and 0.96_{10}. These error values are greater when compared to the measurement results of the ADC circuit compiled by IC ADC0809. The measurement results of the ADC circuit compiled by IC ADC0809 have ME, SDE, and RMSE respectively, namely 0.85_{10}, 0.81_{10}, and 0.93_{10}.

Based on Table 1, it can be seen that the ME, SDE, and RMSE of the ADC circuit compiled by IC ADC0809 are smaller than the ADC circuit compiled by IC ADC0804. This happens for simulation results and measurement results. Thus, it can be known that the ADC circuit compiled by IC ADC0809 is more accurate than the ADC circuit compiled by IC ADC0809.

CONCLUSION

The converter circuit based on IC ADC0809 is more accurate for converting analog to digital than the converter circuit based on IC ADC0804. Based on the simulation results, the converter circuit based on IC ADC0809 has ME, SDE, and RMSE smaller than the converter circuit based on IC ADC0804. Based on the measurement results, the converter circuit based on IC ADC0809 also has a mean error and standard deviation error smaller than the converter circuit based on IC ADC0804.

ACKNOWLEDGMENTS

This research is fully supported by the Program of Research and Community Service 2022 Medan Aviation Polytechnic (Program Penelitian dan Pengabdian Masyarakat Politeknik Penerbangan Medan 2022).

BIBLIOGRAPHY

[1] G. Manganaro, “An Introduction to High Sample Rate Nyquist Analog-to-Digital Converters,” *IEEE Open J. Solid-State Circuits Soc.*, vol. 2, no. July, pp. 82–102, 2022, doi: 10.1109/ojsscs.2022.3212028.

[2] M. B. Mollah *et al.*, “Blockchain for the Internet of Vehicles

towards Intelligent Transportation Systems: A Survey," *IEEE Internet Things J.*, vol. 8, no. 6, pp. 4157–4185, 2021, doi: 10.1109/JIOT.2020.3028368.

[3] S. K. and A. K. S. S. Verma, S. Zeadally, "Intelligent and Secure Clustering in Wireless Sensor Network (WSN)-Based Intelligent Transportation Systems," *IEEE Trans. Intell. Transp. Syst.*, vol. 23, no. 8, pp. 13473–13481, 2022, doi: 10.1109/TITS.2021.3124730.

[4] F. Zhu, Y. Lv, Y. Chen, X. Wang, G. Xiong, and F. Y. Wang, "Parallel Transportation Systems: Toward IoT-Enabled Smart Urban Traffic Control and Management," *IEEE Trans. Intell. Transp. Syst.*, vol. 21, no. 10, pp. 4063–4071, 2020, doi: 10.1109/TITS.2019.2934991.

[5] P. M. Sihombing, H. A. Samosir, L. T. Hutabarat, M. W. Sitopu, J. Margolang, and J. Hidayat, "Microstrip antenna design using meander line technique for communication between pilot and air traffic controller in VHF A/G Band," *2020 4th Int. Conf. Electr. Telecommun. Comput. Eng. ELTICOM 2020 - Proc.*, pp. 111–114, 2020, doi: 10.1109/ELTICOM50775.2020.9230499.

[6] A. R. Abubar, Usman, M. W. Sitopu, P. M. Sihombing, J. Hidayat, and A. Sahputra, "Microstrip antenna design with left handed metamaterial (LHM) for automatic dependent surveillance broadcast (ADS-B)," *2020 4th Int. Conf. Electr. Telecommun. Comput. Eng. ELTICOM 2020 - Proc.*, pp. 103–106, 2020, doi: 10.1109/ELTICOM50775.2020.9230510.

[7] C. Chen, B. Liu, S. Wan, P. Qiao, and Q. Pei, "An Edge Traffic Flow Detection Scheme Based on Deep Learning in an Intelligent Transportation System," *IEEE Trans. Intell. Transp. Syst.*, vol. 22, no. 3, pp. 1840–1852, 2021, doi: 10.1109/TITS.2020.3025687.

[8] P. Neuhaus, N. Shlezinger, M. Dorpinghaus, Y. C. Eldar, and G. Fettweis, "Task-Based Analog-to-Digital Converters," *IEEE Trans. Signal Process.*, vol. 69, no. c, pp. 5403–5418, 2021, doi: 10.1109/TSP.2021.3095726.

[9] H. Richardo, P. S. Maria, and H. Mudia, "Alat Proteksi Kebakaran Rumah Menggunakan Wemos D1 Mini dengan Alarm dan Notifikasi Email dari Thinger.IO," *IJEERE*, vol. 2, no. 1, pp. 47–56, 2022.

[10] C. I. Cahyadi, K. Atmia, and P. M. Sihombing, "Simulasi dan Pengukuran Rangkaian Konverter Analog ke Digital Resolusi 8 Bit Berbasis IC ADC0804 dan IC ADC0809 Simulation and Measurement of 8 Bit Resolution Analog to Digital Converter Circuits Based on IC ADC0804 and IC ADC0809," *J. Ris. Sains dan Teknol.*, vol. 7, no. 1, pp. 83–91, 2023.

[11] P. M. Sihombing, R. A. Pratama, I. V. Sari, D. T. Lubis, Susilawati, and S. Novalianda, "Evaluasi Kinerja Modul Praktikum Pengkonversi Sinyal Analog ke Sinyal Digital Resolusi 8 Bit 1," *J. Inform. dan Peranc. Sist.*, vol. 4, no. 2, pp. 1–7, 2022.

[12] P. M. Sihombing, M. Pinem, and

S. I. Rezkika, “Analysis of the selection of propagation models from outside into the building at 1800 MHz and 2100 MHz,” *SinkrOn*, vol. 5, no. 2, pp. 239–250, 2021, doi: 10.33395/sinkron.v5i2.10871.

[13] Y. Du, “Design of High Precision and Wide Range Current Source Based on Microcontroller,” *Proc. 2018 2nd IEEE Adv. Inf. Manag. Commun. Electron. Autom. Control Conf. IMCEC 2018*, pp. 2521–2525, 2018, doi: 10.1109/IMCEC.2018.8469519.

[14] D. Sacko, A. Keita, and D. Traore, “Study and Simulation of an Analogical-to-Digital Converter 8 Bits,” *Int. J. New Technol. Res.*, vol. 4, no. 1, p. 263159, 2018.

[15] H. Jiang, W. Li, S. Huang, S. Cosemans, F. Catthoor, and S. Yu, “Analog-to-Digital Converter Design Exploration for Compute-in-Memory Accelerators,” *IEEE Des. Test*, vol. 39, no. 2, pp. 48–55, 2022, doi: 10.1109/MDAT.2021.3050715.

[16] J. H. Bang, W. J. Kim, and B. C. Ahn, “Two-Element Conformal Antenna for Multi-GNSS Reception,” *IEEE Antennas Wirel. Propag. Lett.*, vol. 16, no. c, pp. 796–799, 2017, doi: 10.1109/LAWP.2016.2604396.

[17] H. Jin and Z. Zhang, “Design and Simulation of Voltage Measurement System Based on ADC0809,” *For. Chem. Rev.*, pp. 314–323, 2022, doi: 10.17762/jfcr.vi.214.

[18] W. Hernandez, A. Mendez, V. Gonzalez-Posadas, J. L. Jimenez-Martin, and F. J. Arques-Orobon, “Current-to-Frequency Converter Based Photometer Circuit,” *IEEE Trans. Instrum. Meas.*, vol. 71, 2022, doi: 10.1109/TIM.2022.3144746.

[19] S. Shuvo, E. Hossain, T. Islam, A. Akib, S. Padmanaban, and M. Z. R. Khan, “Design and Hardware Implementation Considerations of Modified Multilevel Cascaded H-Bridge Inverter for Photovoltaic System,” *IEEE Access*, vol. 7, no. c, pp. 16504–16524, 2019, doi: 10.1109/ACCESS.2019.2894757.

[20] R. Ávila, A. Martínez, E. Barcenas, and A. J. Rangel, “Electronic Emulator Circuit to the Muscle Movement in Response to a Stimulus,” *IEEE Lat. Am. Trans.*, vol. 16, no. 4, pp. 1030–1035, 2018, doi: 10.1109/TLA.2018.8362133.

[21] T. Instruments, “ADC0808/ADC0809 8-Bit µP Compatible A/D Converters with 8-Channel Multiplexer,” 2013.

[22] T. Instruments, “8-Bit µP Compatible A/D Converters,” 2013.

[23] P. M. Sihombing, I. V. Sari, and J. Pratama, “Pengaruh Koridor Terhadap Rugi-Rugi Lintasan Gelombang Radio Di Dalam Gedung Kampus,” vol. 8, no. 2, pp. 132–144, 2022.