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Battery Charger Control System Employing a Buck Converter with Visual Studio Interface

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ABSTRACT

This research develops a buck converter-based battery charger using the Constant Current Constant Voltage (CCCV) method to enhance reliability and prevent overcharging. A PI Controller is used to obtain the CC and CV parameters for system control. The charging process starts in Constant Current mode at 1.2 A until the battery voltage reaches 12.6 V, then switches to Constant Voltage mode, gradually decreasing the current to a cutoff at 0.07 A. A Visual Studio interface is employed to monitor the charging process, displaying graphs of current, voltage, and State of Charge. Testing with a 2800 mAh lithium-ion 18650 battery showed a charging duration of 2 hours and 43 minutes, with 73 minutes in Constant Current mode and 90 minutes in Constant Voltage mode. Real-time monitoring with the Visual Studio interface has provided an informative understanding of battery charging characteristics based on the CCCV method.

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1. INTRODUCTION

Charger is a device used to charge a battery or other electrically powered device. The battery charging process requires a current that is opposite to the battery's power output, causing a chemical reaction in the electrolyte that produces new chemical energy. Batteries in an electric power backup system must be able to accept energy recharge after their capacity is exhausted[1]. Continuous charging to a certain limit is necessary, but overcharging must be avoided because it can reduce battery life[2]. In order to avoid this problem, good charger performance is important to adjust battery charging, which can be achieved by the Constant Current (CC) Constant Voltage (CV) method. During the CC stage, the battery receives a constant current until the voltage reaches the maximum limit, then during the CV stage, the voltage is maintained while the current decreases until the battery is full[3]-[4]. This method prevents overcharging and maximizes charging efficiency[5]-[6].

Buck converter is a switching converter circuit that reduces the input voltage to a lower output voltage [7]-[9]. Buck converter settings can be done manually or automatically by adjusting the duty cycle or setpoint of the control system. An efficient controller is needed to regulate the MOSFET signal, so that stable output and fast response can be achieved [10][11]. PI controllers are often used to maintain the stability of the buck converter output. The combination of Proportional (P) and Integral (I) controllers can speed up the system response, eliminate offset, and create significant initial changes [12]-[14]. With these characteristics, buck converters are suitable as battery chargers because they are able to adjust the charging voltage and current according to the CC-CV method [15].

In this study, the author designed a battery charger using a buck converter integrated with a PI controller to analyze how constant voltage and current affect battery charging using the Constant Current Constant Voltage (CC-CV) method. Then the author also added a visual studio interface to observe real-time characteristic graphs of voltage, current and State of Charge on battery charging. This aims to provide intuitive information on battery charging using a buck converter in accordance with the provisions of the Constant Current Constant Voltage (CC-CV) method.

2. METHOD

In this study, the design of the battery charger uses a buck converter supplied with a voltage of 24 Volts and then reduced to 12.6 Volts. The battery used is an ICR18650 battery, LG-ABC21865 brand with a capacity of 2800 mAh which is arranged in series as many as 3 cells. Testing of this charger uses the Constant Current Constant Voltage (CC-CV) method with a constant current setting of 1.2 A and a constant voltage of 12.6 V. In an effort to obtain the constant current and voltage parameters, a PI controller is used which is integrated into the duty cycle setting so as to obtain the desired voltage and output current setpoints in the battery charging system. The complexity of the system can be seen in the image below.

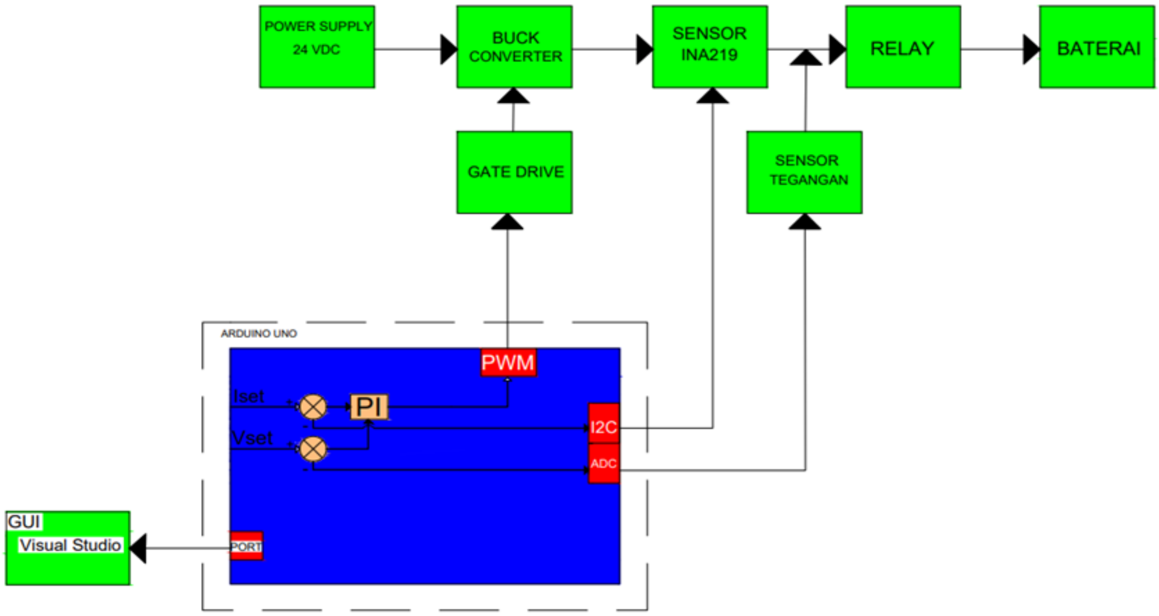


Figure 1. Diagram block of proposed system

The system starts by initializing the port used on the Arduino, then the system will measure the battery voltage, if the small battery voltage is equal to 12.6 V then charging starts from constant current mode. Then if the large battery voltage is equal to 12.6V then battery charging starts directly from constant voltage mode. After entering constant voltage charging, the current will decrease slowly until the system will automatically order the relay to cut off when the current reaches 0.05 A. After passing through these stages, the charging system is stopped and the battery is considered full. Figure 2 shows a flow diagram of the battery charger. The battery charger uses a buck converter with the specifications are Input Voltage 24 V, Output Voltage 12.6 V, Frequency 23 kHz, MOSFET IRFP 460, Schottky Diode SB540, Inductor 8.5 mH and capacitor 10 uF.

The switching component used is the MOSFET IRFP460 because it has a current capacity and can accommodate high switching frequencies. While the diode used is a Schottky SB540 type diode which has a low forward voltage drop and this type of diode also has a very fast recovery time. While the battery specifications used in the battery charger test are Capacity 2800 mAh, Nominal Voltage 3.72 V, Standard charge 0.5 C, Maximum Charge Voltage 4.30 V, Maximum Charge Current 1.0 A, Standard Discharge 0.2 A / 3.0 V, Maximum Discharge Current 0.5 A - 1.5 A, Weight Maximum 50.0 +/- 3.0 g, Operating Temperature -20 ℃ - 60 ℃ and Cell Voltage 3.7 - 3.9 V

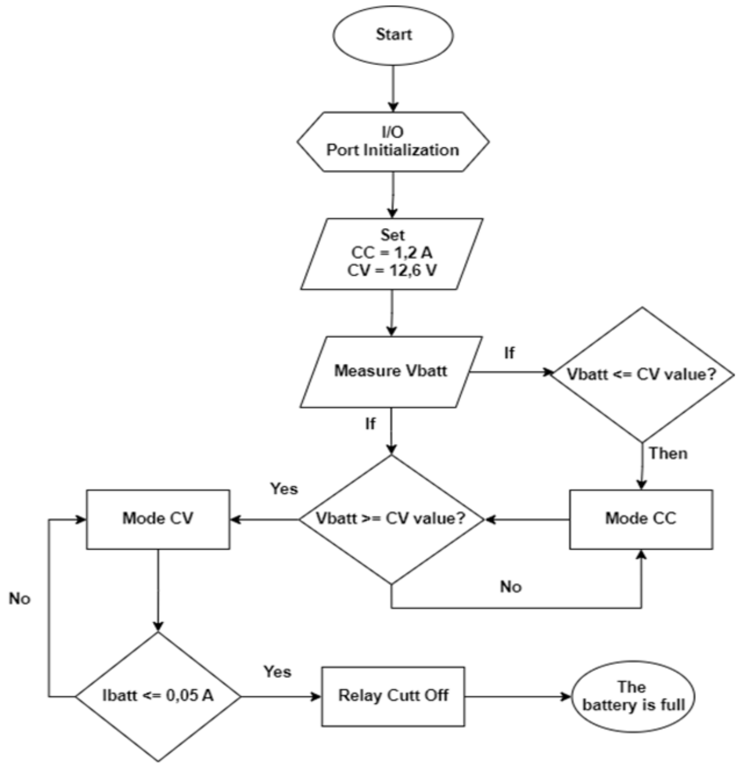


Figure 2. Flowchart of battery charger system

3. RESULTS AND DISCUSSION

Figure 3 shows the hardware used in this study as a battery charger using the Constant Current Constant Voltage (CC-CV) buck converter method.

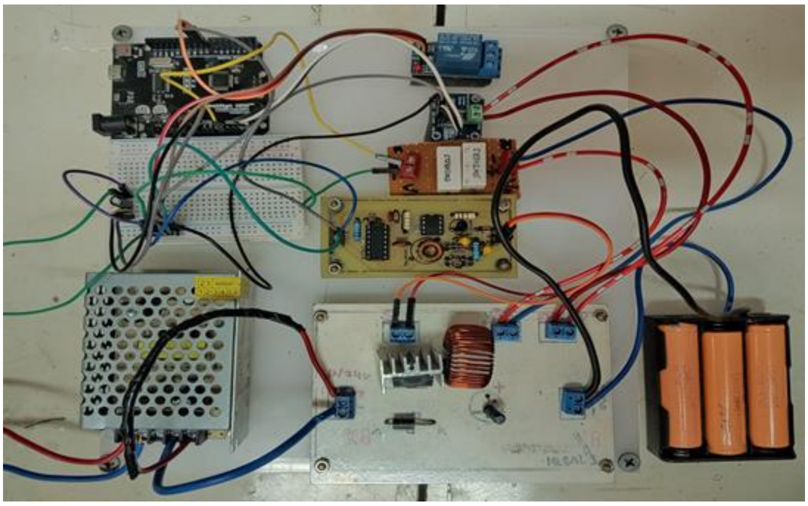
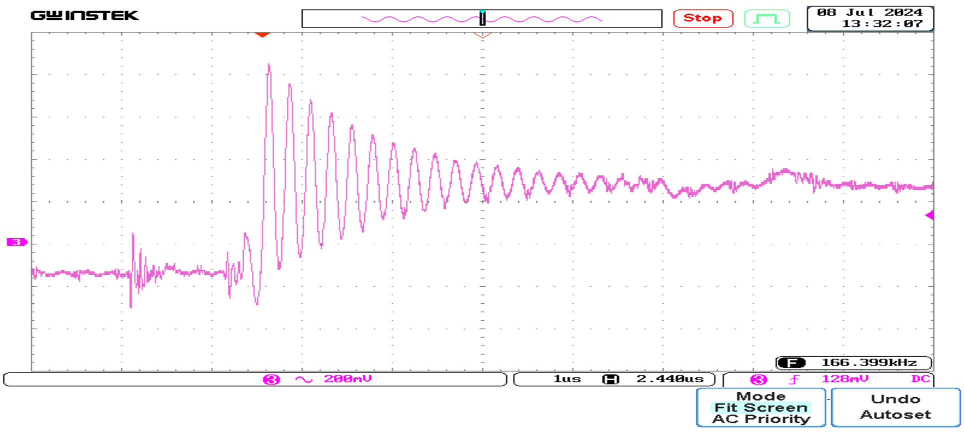
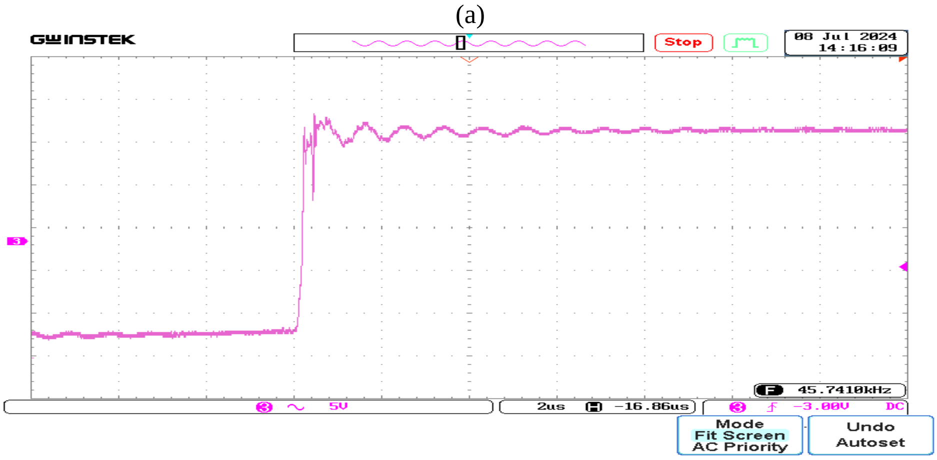


Figure 3. Hardware of battery charger system

The first experiment conducted was the buck converter test. This test is needed to verify the feasibility of the buck converter if used in the implementation of a battery charger using the constant current constant voltage method to work properly and ensure that the buck converter maintains energy efficiency during battery charging. The test was conducted by comparing the buck converter when without using control and using PI control. Figure 4 shows the results of the buck converter test.



(a)



(b)

Figure 4. Experimental results of buck converter, a) uncontrolled, b) PI controller

Next, battery charging testing is carried out. Testing is carried out by setting the PI setpoint for constant current to 1.2 A and the PI setpoint for Constant Voltage to 12.6 V. The battery voltage is discharged to 8.33 V, which if marked based on its SOC, the battery voltage is at 0%. The performance of this charging method is where the battery is charged with a constant current first until the battery voltage touches the constant voltage setpoint. After that, there is a transition from constant current to constant voltage maintaining the battery voltage until the current drops to the cut-off current of 50 - 70 mA according to the battery datasheet. Table 1 below describes the test data

Table 1. Experimental results of charger system

Time (m)	Ibatt (A)	Vbatt (V)	Vchrg (V)	SOC (%)
5	1,2	11,21	11,77	40
10	1,21	11,64	12,07	60
15	1,22	11,75	12,31	65
20	1,19	11,85	12,35	65
25	1,2	11,94	12,44	70
30	1,21	12,01	12,49	70
35	1,2	12,07	12,54	70
40	1,2	12,08	12,61	70
45	1,2	12,13	12,61	75
50	1,19	12,24	12,68	80
55	1,2	12,27	12,71	80
60	1,19	12,29	12,78	80
65	1,21	12,34	12,81	80

70	1,19	12,38	12,84	85
75	1,12	12,42	12,86	90
80	1,1	12,49	12,92	90
85	1,05	12,55	12,96	90
90	0,99	12,62	12,61	95
95	0,84	12,62	12,67	95
100	0,77	12,6	12,65	95
105	0,62	12,6	12,61	90
110	0,58	12,65	12,67	100
115	0,41	12,58	12,6	90
120	0,38	12,62	12,65	95
125	0,3	12,6	12,65	90
130	0,26	12,65	12,65	95
135	0,18	12,62	12,62	95
140	0,11	12,62	12,64	95
145	0,09	12,65	12,66	95
150	0,08	12,63	12,65	95
155	0,08	12,66	12,65	100
160	0,07	12,67	12,67	100
165	0,016	12,67	12,67	100

Based on the test results above, the data can be analyzed that the battery charging has been successfully carried out with a duration of 2 hours 43 minutes. Where the charging duration during the constant current cycle is 73 minutes and the charging duration during constant voltage is 90 minutes. It can be seen that even though the battery has been discharged to 8.33 V, at the beginning of charging, the battery voltage immediately jumps to 11.21 V. This is the initial response of the battery to catch up with its nominal voltage so that the battery does not run out of energy for too long, this is related to the difference in voltage between the converter and the battery because the requirement for charging the battery is the difference in electrical potential between the two. It can also be analyzed that the buck converter can make a good contribution to charging lithium ion batteries with the CCCV method.

Next, the battery charger interface test was carried out using Visual Studio. The real-time monitoring system test was carried out with the aim of finding out whether this system can display the parameters of the Lithium Ion battery while it is undergoing the charging process, especially providing a direct understanding of the CC-CV method through its characteristic graphs. Figure 5 is a test of the overall monitoring system using Microsoft Visual Studio.

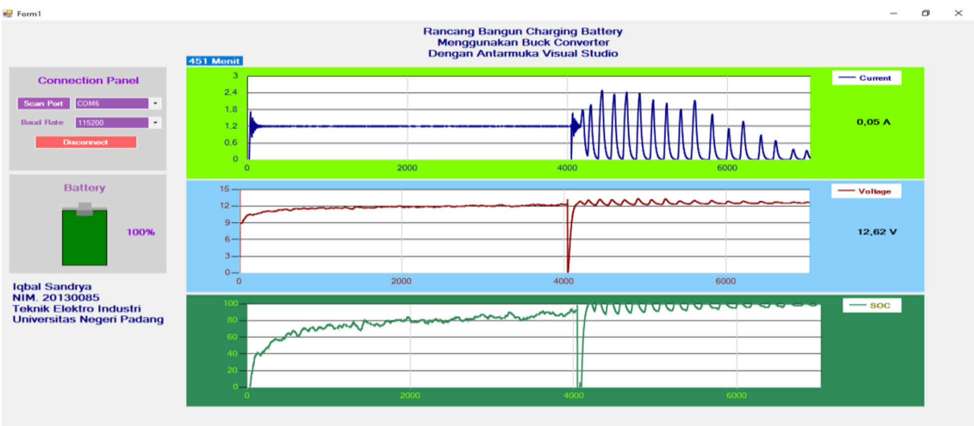


Figure 4. Overall Battery Charger Monitoring View

The monitoring display is created using the VisualBasic.NET programming language. The data sending interval from Arduino to Visual Basic is every 1 second with a data transfer rate of 115200 bps and limits 10800 data points displayed to each chart. The results of the data displayed are good enough to provide information when charging the battery using the CC-CV method even though the data received experiences a buffer overflow. The data received is piled up, resulting in a delay in reading the data to be displayed. The difference in the delay in the data received is 290 minutes, which is actually only 163 minutes of charging duration. However, this does not hinder the charging process and does not eliminate understanding of the CC-CV method. A more complete analysis can be seen in Figure 6.

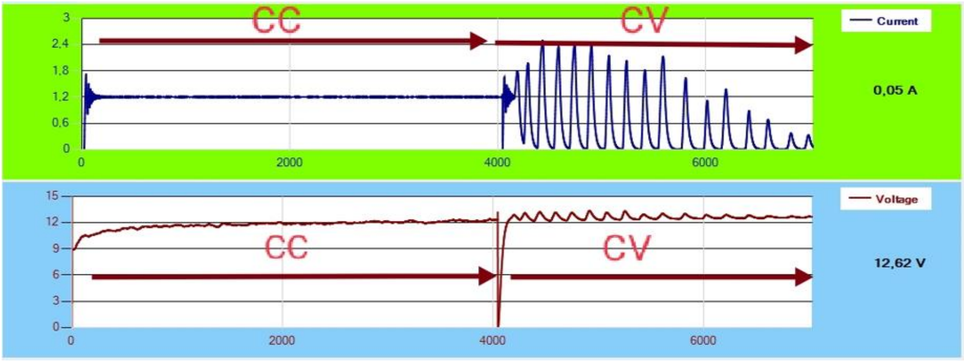


Figure 6. CC and CV graphs on the Monitoring Display

It can be seen that during the CC cycle the current parameter is kept stable at 1.2 A as the voltage slowly increases. During the transition, the current that was previously constant fluctuates because the PI controller switches to constant voltage mode. However, the fluctuation decreases when the voltage is constant at 12.62 V. Meanwhile, the state of charge analysis can be seen in Figure 7 below.

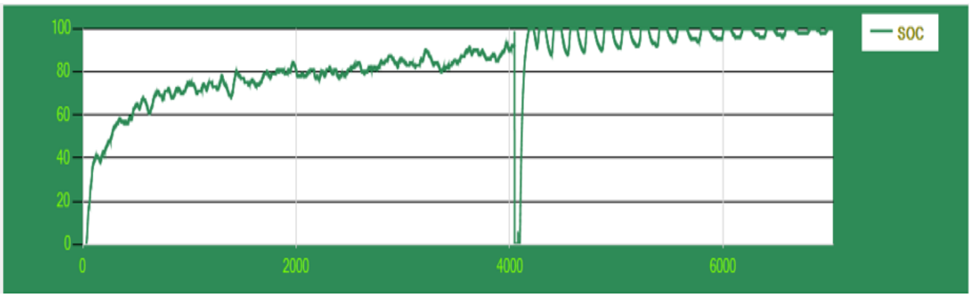


Figure 7. State of Charge graph on the Monitoring Display

State of Charge increases during charging and displays a fairly informative graph. The graph that increases significantly is during the CC cycle while during the CV cycle the SOC graph only increases slightly. For better information, see the battery status bar in Figure 8 below. Based on the test, the full battery status is at 100% calculated when the current is 0.05 A and the voltage is 12.62 V. The test results with the visual studio interface get good and intuitive results in monitoring the characteristics of current, voltage, and state of charge when charging the battery.

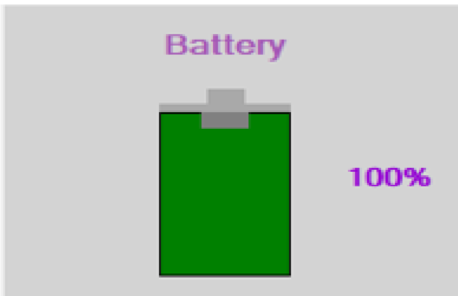


Figure 8. Battery Status Bar

4. CONCLUSION

This study discusses the test results which show that charging a 18650 lithium ion battery requires a total duration of 2 hours 43 minutes with a comparison of 73 minutes in Constant Current (CC) mode and 90 minutes in Constant Voltage (CV) mode and ends at a voltage of 12.67 V current 0.07 A. Monitoring the battery charging process using the Visual Studio interface has been successfully tested in real time displaying current, voltage and state of charge graphs. For further research, it is recommended to use other control systems such as Intelligent Control and hybrid and use the Internet of Things (IoT) in order to innovate and gain a broader understanding of the battery charging system.

REFERENCES

[1] I. Irianto, R. P. Eviningsih, F. D. Murdianto, and A. Muhyidin, "Optimization Improvement Using Pi Controller to Reach CCCV Method in Lead Acid Battery Load," *Kinet. Game Technol. Inf. Syst. Comput. Network, Comput. Electron. Control*, vol. 4, no. 4, 2022, doi: 10.22219/kinetik.v7i4.1496.

[2] M. Otong and M. Khudari, "Perancangan Sistem Charging Baterai Lithium-ion Mmenggunakan DC-DC Buck Converter Dengan Metode Constant Current-Constant Voltage," *J. Ilm. Setrum Artic. Press*, vol. 10, no. 1, pp. 144–154, 2021, doi: 10.36055/setrum.v10i1.11916.

[3] A. Nasir, "Design and Development of a Constant Current Constant Voltage Fast Battery Charger for Electric Vehicles," pp. 13–55, 2022, doi: 10.33422/4th.msetconf.2021.03.02.

[4] A. B. Khan and W. Choi, "Optimal Charge Pattern for the High-Performance Multistage Constant Current Charge Method for the Li-Ion Batteries," *IEEE Trans. Energy Convers.*, vol. 33, no. 3, pp. 1132–1140, 2018, doi: 10.1109/TEC.2018.2801381.

[5] F. Rahmatullah, "Desain dan Simulasi Battery Charger Metode CC-CV (Constant Current-Constant Voltage) dengan Kontrol Logika Fuzzy Menggunakan MATLAB," *Cyclotron*, vol. 4, no. 2, pp. 18–22, 2021, doi: 10.30651/cl.v4i2.8621.

[6] D. Lestari, A. N. Handayani, and N. M. Dwijayanti, "Buck Converter Output Voltage Control System Using Proportional Integral Differential Method on Solar Cell Battery Charging," *Front. Energy Syst. Power Eng.*, vol. 4, no. 2, p. 35, 2022, doi: 10.17977/um049v4i2p35-41.

[7] K. Muhammad Nur and Krismadinata, "Rancang Bangun Buck Konverter dengan Antarmuka Visual Studio," *MSI Trans. Educ.*, vol. 1, no. 2, pp. 41–50, 2020, doi: 10.46574/mted.v1i2.12.

[8] Asnil and I. Husnaini, "Analisis Riak Keluaran Buck Konverter," *Semin. Nas. FORTEI 2015*, no. May 2020, pp. 58–62, 2015.

[9] A. B. Pulungan and T. Ramadhani, "Buck Converter Sebagai Regulator Aliran Daya Pada Pengereman Regeneratif," *J. EECCIS*, vol. 12, no. 2, pp. 93–97, 2018.

[10] A. S. Samosir, T. Sutikno, and L. Mardiyah, "Simple formula for designing the PID controller of a DC-DC buck converter," *Int. J. Power Electron. Drive Syst.*, vol. 14, no. 1, pp. 327–336, 2023, doi: 10.11591/ijpeds.v14.i1.pp327-336.

[11] Z. Jamal, "Implementasi Kendali Pid Penalaan Ziegler-Nichols," *J. Inform.*, vol. 15, no. 1, pp. 81–88, 2015.

[12] M. Saputra, S. Djulihenanto, and I. Fadlika, "Implementasi Kendali Tegangan Lup Tertutup Buck Converter dengan ArduinoMega," *Elposys J. Sist. Kelistrikan*, vol. 8, no. 1, pp. 11–15, 2023, doi: 10.33795/elposys.v8i1.623.

[13] A. P. Utomo, A. T. N. Angga, D. S. A. Pambudi, and D. Priyambodo, "Battery Charger Design with PI Control Based on Arduino Uno R3," *Appl. Technol. Comput. Sci. J.*, vol. 4, no. 2, pp. 78–90, 2022, doi: 10.33086/atcsj.v4i2.2398.

[14] P. D. Lestari and Abdul Hadi, "Desain PI Controller menggunakan Ziegler Nichols Tuning pada Proses Nonlinier Multivariabel," *Semin. Nas. Teknol. Inf. Komun. dan Ind. 4*, pp. 439–446, 2012.

[15] B. W. A. Mahardika, T. Andromeda, and S. Sudjadi, "Perancangan Sistem Charging Baterai Menggunakan Dc-Dc Buck Converter Metode Constant Current (Cc) Dan Constant Voltage (Cv)," *Transient J. Ilm. Tek. Elektro*, vol. 9, no. 3, pp. 342–350, 2020, doi: 10.14710/transient.v9i3.342-350.