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Smart Charging & Power Management Zeta Converter Topology Based on Microcontroller

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Abstract— *The use of renewable energy systems requires a large investment in devices that generate and control the energy produced. One of them is the charging system for energy storage in the battery. The use of reliable and easy-to-use devices is a solution for the convenience of ordinary users and various levels of society. Collecting data using observation methods and experimental methods to get results that are efficient and in accordance with the wishes. The efficiency of the tool is directly affected by the type of circuit and the design process of the circuit. The charging system uses a DC converter with a Zeta topology which is a non-inverting 4 cycle DC converter. Zeta Converter was chosen because it has a higher efficiency than other types of converters and has less output waveform. A high-frequency PWM switching system is used using an Arduino microcontroller with the hope of shrinking the components used to produce a compact, efficient, and reliable tool. The converter produces a DC voltage output which has a higher charging voltage value than the battery voltage. This converter can work with both VRLA and Lithium battery types. The input voltage range of the circuit is a minimum of 7 volts and a maximum of 23 volts.*

Keywords— *Charging, Zeta Converter, Non-Inverting Converter, Arduino, PWM.*

I. Introduction

Today's, power plant with renewable energy is an energy source solution that continues to be developed. The use of fossil energy as an energy source is increasingly having a negative impact on the existing ecosystem[1]. The use of renewable energy sources allows a reduction in pollution levels in the surrounding environment.

One that has been widely developed is a small-scale self-contained hydroelectric power plant. Many supporting equipment for an independent renewable energy generator have also been developed[2], starting from inverters, charger controllers, and so on. However, there is not yet a device that can regulate the process of charging the battery with a smart system[3] so that it makes the battery more durable and free from the risk of damage in the short term.

Therefore, from the problems above, the author intends to make a final project "Smart Charging & Power Management Zeta Converter Topology Based on Micro control". The converter and control system on the device will use the Arduino Nano. Zeta Converter topology was chosen with the aim of getting good efficiency. The Zeta Converter is a four-cycle DC-DC converter like the SEPIC converter. The smart charging system is regulated by limiting the charging voltage to 1 volt higher than the detected battery voltage. The manufacture of charging and power management devices will be used in renewable energy self-generating systems.

It is hoped that this final project will provide additional knowledge to readers and especially writers in designing a device that provides convenience in the installation of a battery charging system to increase the lifespan of a battery.

II. Methodology

A. Design Converter

The device design is using Zeta Converter topology, the switching frequency is set at 62.5 KHz frequency. The microcontroller used is Arduino Nano as a PWM controller and Arduino UNO as a controller of the power management system.

To detect the current from the input and output current sensor is used ACS712[4]. While the voltage value will be measured with a voltage divider circuit (Voltage Divider) which is adjusted to the voltage value to be measured. By using a 16x2 LCD, the parameters of the input and output currents and voltages will be displayed.

Design of ZETA CONVERTER
Parameter :
- V input = 10V – 25V
- V output = 14,6 Volt
- Pout = 100 Watt
- Frequency = 62500 Hz
- Ripple output = 10mV
- Ripple input = 1%
- Ripple C1 = 1%
- Max Temp = 70 degrees Celsius

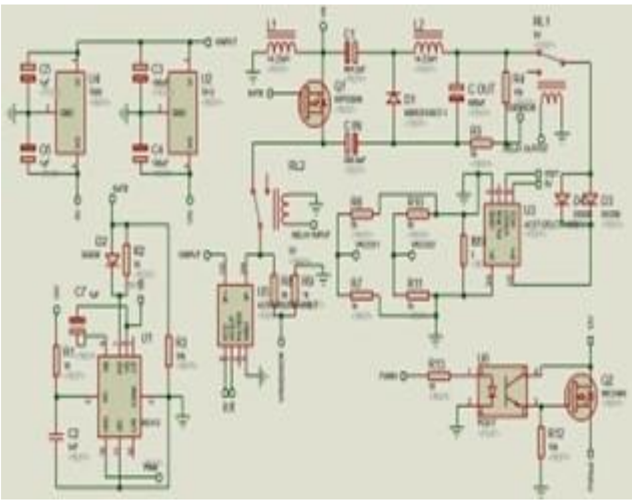

Fig. 1. Converter circuit schematic.

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B. *Inductor Manufacture*

The inductor is made with a 5cm outer diameter core and a 2.5cm inner diameter core[5]. In the manufacture of the inductor, the value is not exactly the same as the calculation. However, a value greater than the calculation is taken to meet the predetermined Lmin value.

Fig. 2. Inductor Measurement 1.

C. *PCB Manufacture*

The screen-printing process is carried out using the transfer paper method[6], after the image is transferred to the paper, it is followed by the dissolving process using liquid ferric chloride[7].

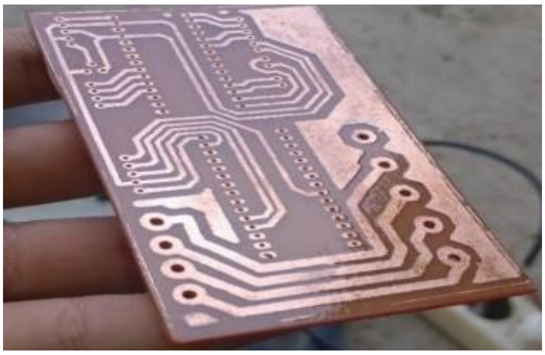
Fig. 3. PCB Manufacture.


Fig. 4. Components already assembled on PCB.

III. Result

A. *Generator Test*

Testing the generator with the rotation simulation method using an electric motor to get the desired RPM value, the generator specification used is DC 24V 5A MAX. The test results are as follows:

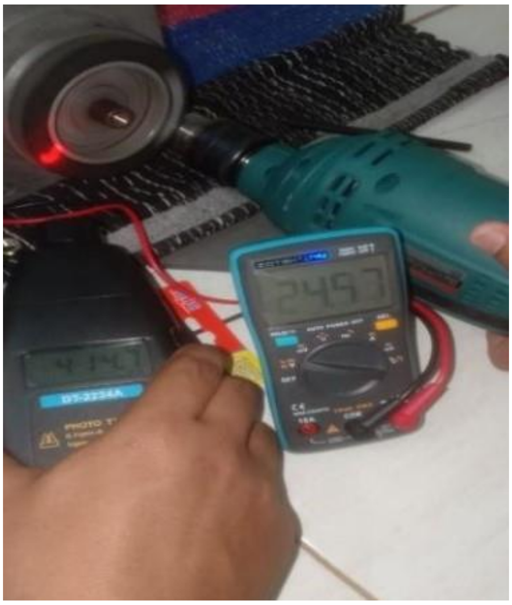
Fig. 5. Generator RPM Test.

TABLE 1. Generator test result table

No	RPM	Vout
1.	134,8 RPM	7,97 Volt
2.	199 RPM	11,73 Volt
3.	261,4 RPM	15,01 Volt
4.	313 RPM	18,62 Volt
5.	324,5 RPM	19,23 Volt
6.	414,7 RPM	24,57 Volt

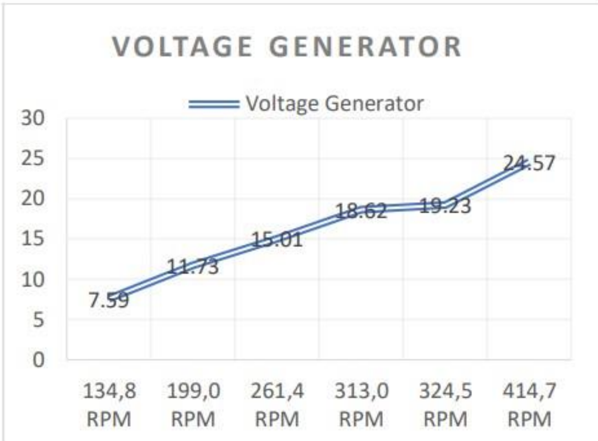

Fig. 6. Graph of generator output against RPM.

From the data above, the generator's working ranger is 12 volts to 24 volts with a generator rotation of 200 - 415 RPM. Based on these data, the working range of the converter is designed between a minimum source of 10V to a maximum of 25V. with a maximum voltage of 24 volts assuming the generator can flow a current of 5 A, the maximum output power is 120 Watts. So we need a converter with a current power rating in accordance with the generator specifications.

B. *Converter Out Test*

In this test, measurements will be made using an

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oscilloscope, the data to be analysed is the waveform of the output converter. The test result data are as follows:

Test Conditions

1. The generator source is replaced with power supply rate 3A MAX.
2. Load Battery 2Ah 12.6V Lithium
3. Ambient temp = ± 26 ºC 4. Capacitor Output 1000 μF

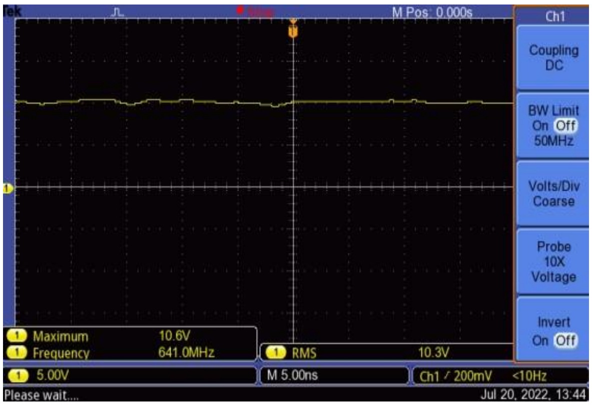

Fig. 7. Pure DC electric oscilloscope measurement sample.

Picture 7 is the result of pure DC wave measurements measured from a VRLA type battery with a voltage rating of 12 volts. Measurements were made with a 5 VOLT/DIV scale setting

Fig. 8. Converter output waveform measurement.

Picture 8 shows the results by measuring the converter output to the battery load during charging conditions. From Picture 7 and Picture 8, the measurement results are obtained in the form of a difference in waveform between pure DC and DC converter output, this is certainly contrary to the principle of DC current which has straight waves without valleys or hills (red mark). On the Oscilloscope the maximum voltage is twice the RMS voltage (green sign), this condition will certainly reduce the working efficiency of the converter. The peak to peak voltage (blue mark) also has a value of 2 times the maximum voltage which means that the converter output has a negative cycle at its output.

This can be caused by the use of an output filter capacitor that is too small so that it cannot compensate for the existing voltage drop. Next, the output filter capacitor will be replaced from 1000uF to 4700uF. The test results are as follows:

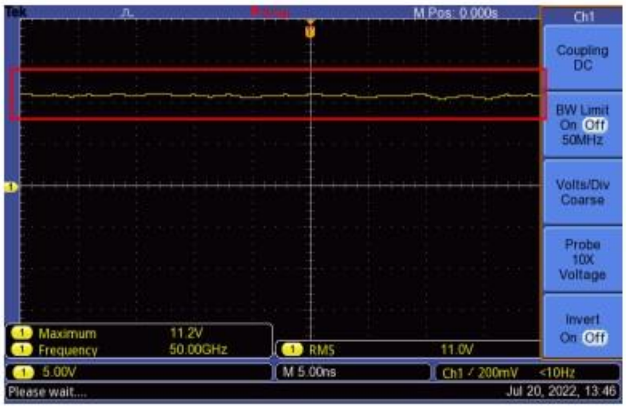

Fig. 9. Converter output waveform measurement after filter capacitor change to 4700uF

It can be seen in Picture 12 that the shape of the output waveform has improved (red mark). The shape of the ripple at the output is reduced due to the use of a capacitor with a larger value. The difference between the maximum value and the RMS has decreased quite drastically (green mark) which originally had a difference of ± 12V to only ± 2V, this gives the effect of increasing the value of the RMS Vout.

C. Charging Test dan Power Management

In this test, data is taken from the simulation of the filling process. Measurements are carried out with several test parameters with the aim of obtaining data on the overall work of the device that can be analyzed. The measurement data are as follows:

Test Conditions

1. The generator source is replaced with power supply rate 3A MAX.
2. Load battery 2Ah 12.6V Lithium
3. Ambient temp = ± 26 ºC
4. Standby current = 262 mA (fan on) = 100 mA (fan off)
5. Battery voltage before charging = 10 V The test takes data with parameters such as input voltage, output voltage, input current, output current, duty cycle, and efficiency. The measurement data are presented in table 2 as follows:

TABLE 2. Table of 2Ah lithium battery charging test results

Time	Vinput	Voutput	Iinput	ΣIOutput	$\Delta Vaccu$	Duty Cycle	Efficiency
1 minute	20.00 V	13.28 V	1.26 A	1.16 + 0.26 A	12.44 V	22.6 %	75 %
10 minutes	20.00 V	13.22 V	0.69 A	0.68 + 0.10 A	12.46 V	17.1 %	75 %
30 minutes	20.00 V	13.26 V	0.62 A	0.23 + 0.1 A	12.49 V	10.5 %	35 %
60 minutes	20.00 V	13.20 V	0.29 A	0.07 + 0.10 A	12.47 V	8.26 %	38 %
120 minutes	20.00 V	13.21 V	0.27 A	0.03 + 0.10 A	12.54 V	7.88 %	24,4 %

Information

- Vinput: The source voltage of the power supply
- Voutput: Battery charging voltage
- Iinput: Incoming consumption flow into the converter
- Time: Time interval from charging to measurement
- ΣIOutput: Sum of output current and current standby converter consumption

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- Duty Cycle: The duty cycle value of the Microcontroller
- Efficiency: ratio of input power and power Network outputs.

In table 2 there is a change in the current value at each test interval. This is the effect of the power management setting which regulates the charging voltage above the battery voltage of ±1 Volt so that the amount of current flowing will also be adjusted. The power management system also keeps the battery voltage at the upper limit of the charging voltage, which is 12.6.

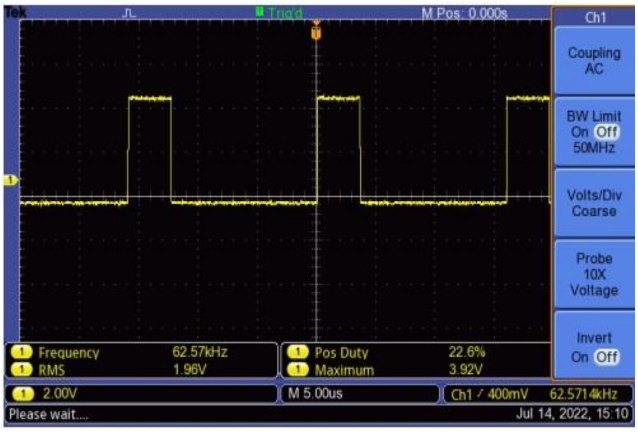

Fig. 10. Duty cycle measurement 1 minute battery charge

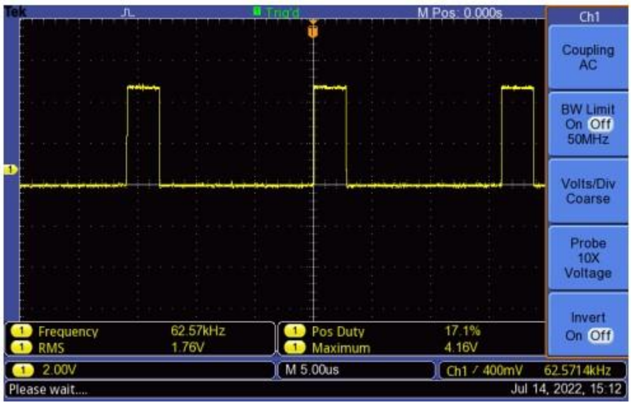

Fig. 11. Duty cycle measurement 10minute battery charge

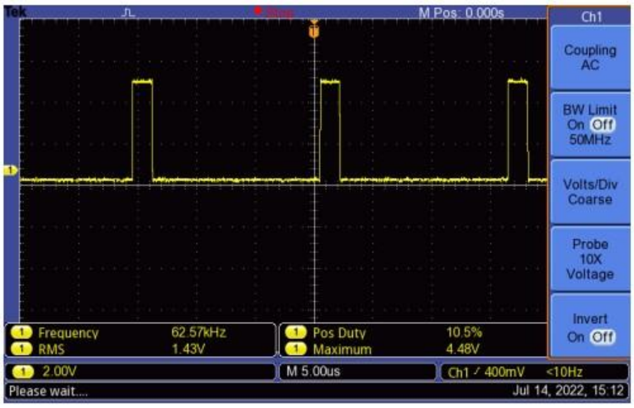

Fig. 12. Duty cycle measurement 30minute battery charge

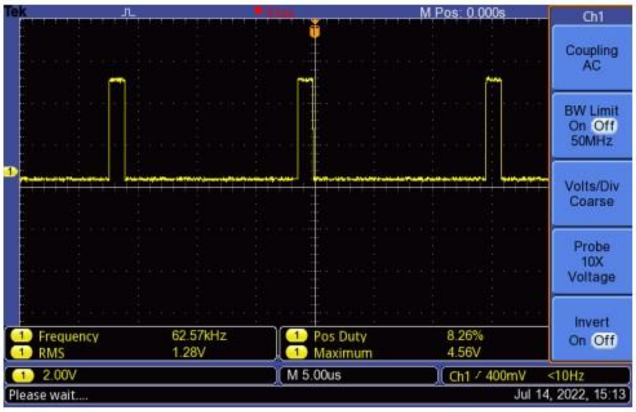

Fig. 13. Duty cycle measurement 60minute battery charge

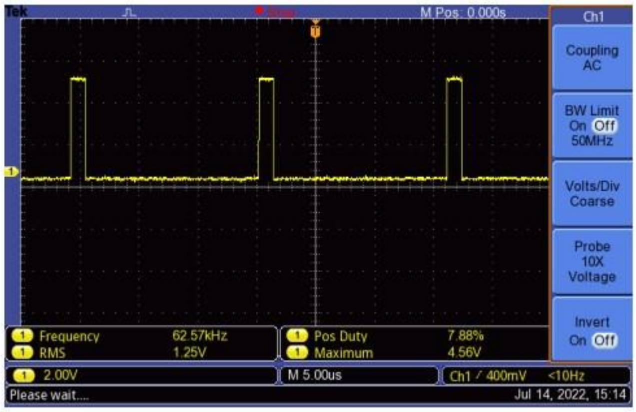

Fig. 14. Duty cycle measurement 120minute battery charge

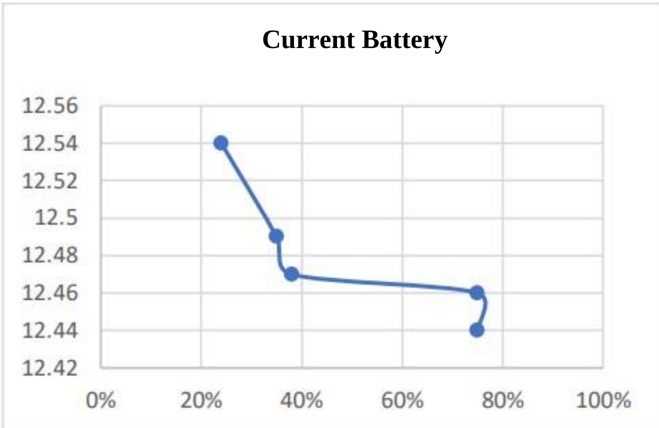

Fig. 15. Comparison graph of duty cycle(X) and battery voltage(Y)

From figure 15, the change in Duty Cycle decreases as the battery voltage increases to near the full voltage of the lithium battery. The closer to the value of the full battery voltage of 12.6 Volts, the Duty Cycle will be lowered so as to protect the battery from the risk of over voltage and over current, this system will also reduce the current so as to keep the battery from overheating because the charging current is not lowered when the battery is near full. Compensation from this system will certainly reduce the charging speed when the battery is full.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

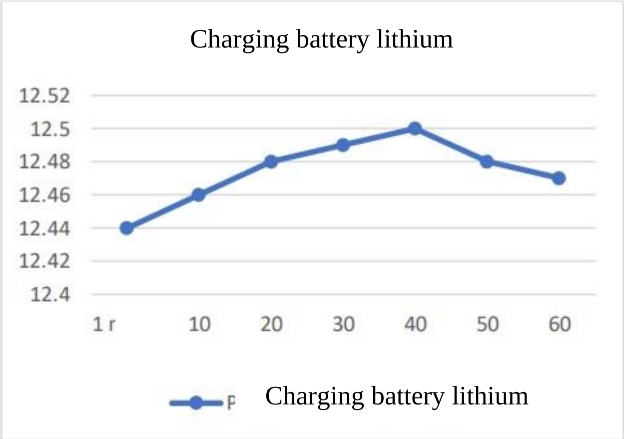

Fig. 16. Comparison graph of charging duration(X) and battery life(Y)

It can be seen in picture 16 that the increase in the value of the battery voltage in 10minute intervals occurs in the first 40 minutes, then the system will decrease the duty cycle which automatically lowers the battery charging voltage and current.

D. *Final Test with Voltage Source from Pico Hydro Turbine Screw Power Plant*

In this test, the data taken is field data with conditions that are not ideal and are influenced by environmental conditions. Measurements were made with test parameters that represent the entire working system of the device supplied from the Pico Hydro generator source. The test data are as follows:


Fig. 17. Parameter measurement process in field testing


Fig. 18. Measurement of the generator output voltage to the converter

In this test, data are taken in the form of input voltage, output voltage, input current, output current, duty cycle, and battery voltage. The measuring instrument used is multi meter

TABLE 3. VRLA 12Ah battery charging test results table

	Vinput	Voutput	Iinput	ΣIOutput	$\Delta Vaccu$	Duty Cycle	Efficiency
1.	11,42 V	15,28 V	0,56 A	0,34 A	14,78 V	19,0 %	81 %
2.	21,74 V	15,26 V	0,31 A	0,38 A	14,62 V	12,8 %	86 %
3.	17,87 V	15,26 V	0,62 A	0,61 A	14,79 V	18,3 %	84 %
4.	21,56 V	15,34 V	0,36 A	0,40 A	14,86 V	12,5 %	79 %
5.	23,38 V	15,42 V	0,32 A	0,33 A	14,96 V	9,2 %	67 %
6.	23,27 V	15,50 V	0,29 A	0,37 A	14,97 V	11,8 %	85 %
7.	7.50 V	16,03 V	1,48 A	0,59 A	15,39 V	40,9 %	85 %
Average Efficiency							81 %

Information:
- Vinput: The source voltage of the power supply
- Voutput: Battery charging voltage
- Iinput: Incoming consumption flow into the converter
- ΣIOutput: Sum of output current and current standby converter consumption
- Duty Cycle: The duty cycle value of the Microcontroller
- Efficiency: Ratio of input power and power Network outputs.

In table 3 the highest efficiency is at the input voltage condition of 21.74 volts and the lowest efficiency is at the input condition of 23.38 volts. From the seven test samples, it can be concluded that the conversion efficiency is directly affected by the amount of the duty cycle. A duty cycle that is too small will result in the work cycle of the converter not running normally so that it affects the efficiency value.

This can be overcome by limiting the value of the duty cycle at the upper and lower limits of the saturation point so that the switching process will be maintained. However, this method will reduce the input voltage range of the converter which will eliminate the ability of the tool to convert input voltages that have a large difference to the set point voltage.

IV. CONCLUSIONS

The conclusions of this study are as follows:

A. The working range of the converter needs to be determined based on the voltage source that will be used to get the optimal duty cycle in the circuit.

B. The power management system works by keeping the charging voltage value above the battery voltage and below the full battery voltage (12.6 volts for the lithium type or 14.6 volts for the VRLA type).

C. Zeta Converter topology has an average efficiency of up to 81% in the VRLA battery charging process with a Pico-hydro generator source.

D. In laboratory testing, the maximum circuit efficiency is 75% when the lithium battery is charging.

E. The Zeta Converter circuit with the configuration discussed above can perform normal voltage conversion with input voltages ranging from 7 volts to 23 volts in field tests with a pico-hydro generator source.

F. In testing with a pico-hydro generator, a duty cycle below 9% will drastically reduce efficiency.

Dimas Nur Prakoso, Budi Triyono, and MH. Ramdhani Ismar, "Smart Charging & Power Management Zeta Converter Topology Based on Microcontroller," *International Research Journal of Advanced Engineering and Science*, Volume 7, Issue 3, pp. 279-284, 2022.

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