Vol. 5, No. 5, May 2024
E-ISSN: 2723-6692
P-ISSN: 2723-6595
http://jiss.publikasiindonesia.id/

# Performance Investigation of Boost Converter Based on Fuzzy Logic Using Mamdani Rules

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**KEYWORDS**
Boost Converter; Investigation; PID; Fuzzy Logic; Simulink

**ABSTRACT**
Boost Converter is one type of DC converter that is often used for various purposes where the output voltage is equal to or higher than the input voltage. To get an output voltage higher than the input voltage commonly used by electrical and electronic equipment, a voltage increase is needed that can be varied as needed. One way to increase the voltage with a variable is to use the Boost Converter with Fuzzy Logic control. This research proposes a Boost Converter that can increase the variable direct voltage. Boost Converter proposed Fuzzy Logic using Mamdani's rules as a controller. Boost Converter is investigated on Open Jacks Boost Converter, Closed Loop Boost Converter and Boost Converter Fuzzy Logic Control Duty cycle on Boost converters using PID and Fuzzy Logic implemented using Simulink Matlab. The results of the investigation show that the Boost Converter designed in this study has worked well according to the purpose.



## 1. Introduction

Due to population growth and societal progress, the consumption of electrical energy is increasing, which leads to a decrease in the availability of fossil fuels. The use of power electronics converter technology in everyday life is increasing along with current technological advances; one example is the application of DC converters that utilize the Boost Converter technique. With this boost converter system, you can meet the requirements of variable output voltage sources by using non-insulating switching-type DC regulators (Hushaini et al., 2019; Setiawan & Yuhendri, 2020). You can set the output voltage value to be higher than the input voltage value.

A converter that raises the DC voltage is known as a boost converter. If the voltage requirement of an electronic device exceeds the available power supply voltage, then this circuit functions as a power source.

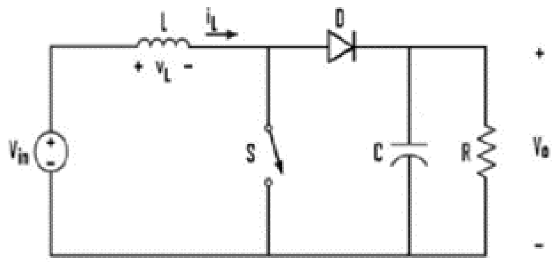



**Figure 1 Boost Converter**

Boost converter This research utilizes fuzzy logic control and several Pid control techniques (Harselina & Hendri, 2019).

PID control is often used and taught widely in university control systems courses. This is due to the closed-loop control mechanism on the system, which is easy to use and can be operated with other control mechanisms. There are three control methods in PID control systems: P (proportional), D (derivative), and I (integral). Each control approach has its pros and cons (Ali, 2004; Diaz et al., 2019; Li et al., 2006).

$$H_{(s)}=\frac{K_D S^2+K_p S+K_i}{S^3+K_D s^2+K_p S+K_i}$$

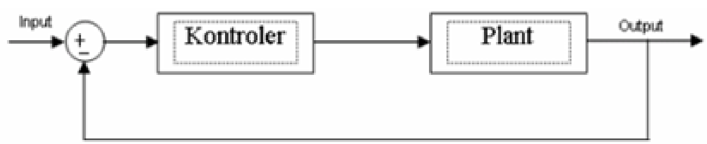



**Figure 2 Feedback control system block diagram**

Logic that has fuzzy value or similarities between right and wrong is called fuzzy logic. A value in fuzzy logic theory can be true and false at the same time (Jati et al., 2020). But the weight of a person's membership determines how much existence and guilt he has. The three main principles of fuzzy logic are fuzzification, rule base, and defuzzification (Nasution, 2012; Saelan, 2009).

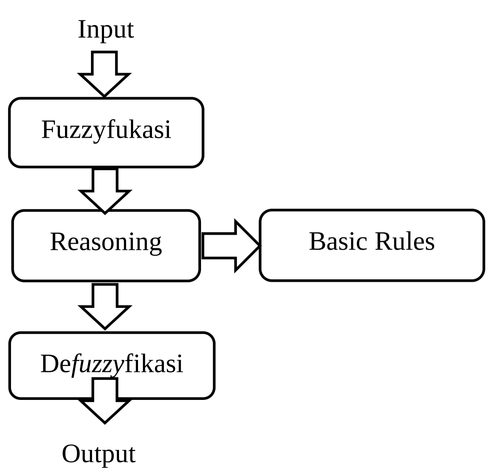


**Figure 3 Fuzzy Logic Controller system**

**Table 1 Rule Base Fuzzy**

| de\e | N | Z | P |
|---|---|---|---|
| **N** | N | N | Z |
| **Z** | N | Z | P |
| **P** | Z | P | P |

## 2. Materials and Methods

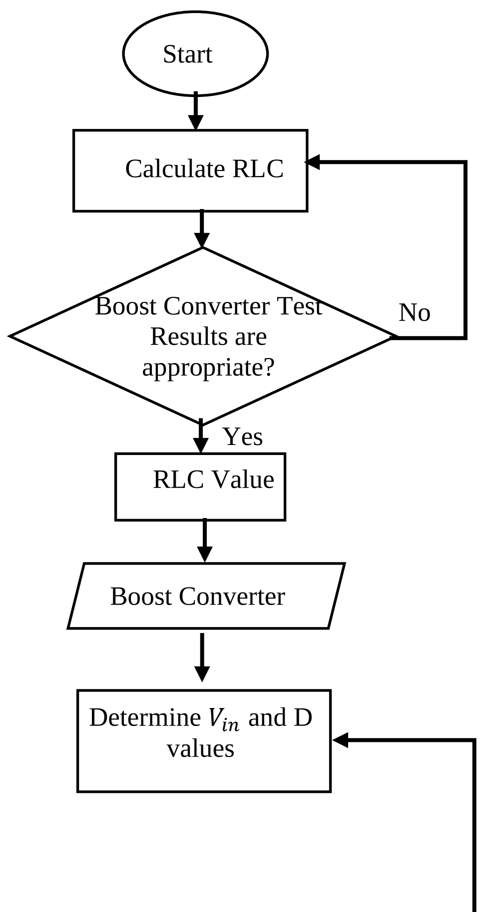
### Basic Research Framework

In this study to assess the effectiveness and efficiency of the output voltage of the Boost Converter with Different treatments. Open Jacks Boost Converter (Febrianto et al., 2018), Closed Jacks Boost Converter with Pid Control, and Fuzzy Logic Control Boost Converter. used Matlab/Simulink simulation ijing.

### Stages of Research

**a. *Boost Converter* System Design**

During this research process, it uses many stages. The stages of the process used are as follows.



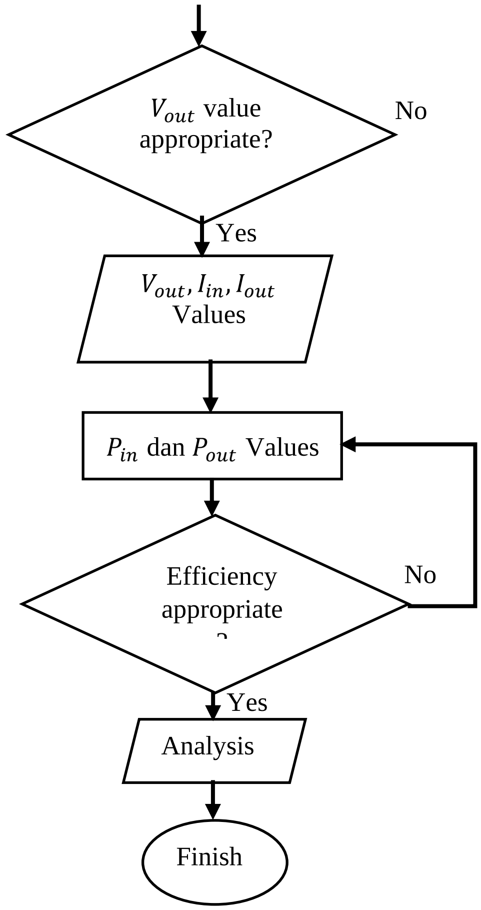



**Figure 4** ***Research Flowchart***

**Konverter Boost Design**

Specify the variables as follows before calculating the value of the component variable to be used:

*Duty cycle* = 5%-100%

Resistor (R) = 10 ohm

Inductor (L) = 10 μH

Kapasitor(C) = 100 μF

The next stage is to determine the input power (Pin), output power (Pout), and efficiency after receiving the results of the Simulink inquiry. You can use the following equation.

Determining the outgoing voltage (1)

$$V_{out} = \frac{V_{in}}{1-D}$$

Determine the inlet power (2)

$$P_{in} = V_{in}.I_{in}$$

Determine power out (3)

$$P_{out} = V_{out}.I_{out}$$

Determining Efficiency (4)

$$Efesiensi = \frac{P_{out}}{P_{in}} x100\%$$

## 3. Result and Discussion

The findings and analysis of many studies conducted using various methodologies on several series of Boost Converters are presented below.

a. Open Jacks Boost Converter

The circuit below is used for the simulation of the Open Loop Converter Boost circuit. It has a fixed input voltage of 12V, a duty cycle that ranges from 5% to 100%, a resistor (R) of 1 ohm, an inductor (L) of 10 μH, and a capacitor (C) of 100 μF (Nurcahyo et al., 2023).

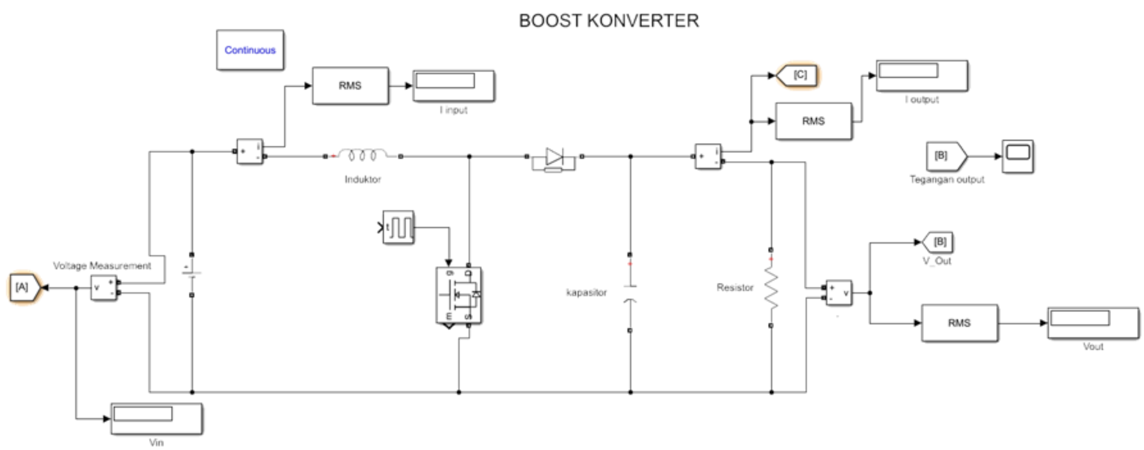


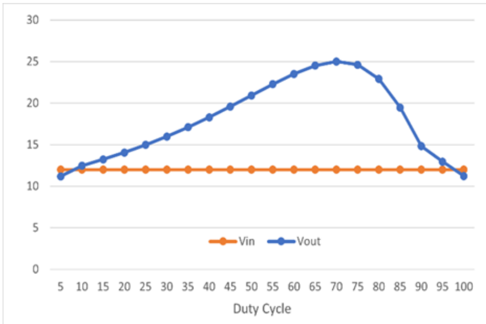

**Figure 5 Open Jack Boost Converter Series**

**Table 2 Data Boost Converter Open**

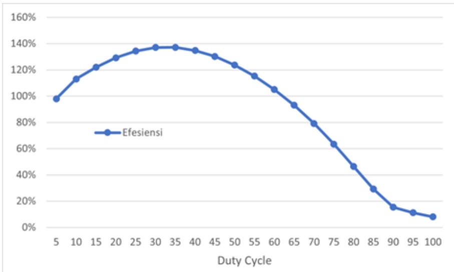
| No | Vin (V) | Iin (A) | D (%) | Vout (V) | Iout (A) | Pin (W) | Pout (W) | Efesiensi (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 11.22 | 5 | 11.19 | 11.79 | 134.64 | 131.93 | 97 |
| 2 | 12 | 11 | 10 | 12.47 | 12.47 | 137.52 | 155.501 | 113 |
| 3 | 12 | 11.94 | 15 | 13.22 | 13.22 | 143.28 | 174.768 | 121 |
| 4 | 12 | 12.73 | 20 | 14.05 | 14.05 | 152.76 | 197.403 | 129 |
| 5 | 12 | 13.9 | 25 | 14.97 | 14.97 | 166.8 | 224.101 | 134 |
| 6 | 12 | 15.53 | 30 | 15.98 | 15.98 | 186.36 | 255.36 | 137 |
| 7 | 12 | 17.75 | 35 | 17.09 | 17.09 | 213 | 292.068 | 137 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | 12 | 20.69 | 40 | 18.29 | 18.29 | 248.28 | 334.524 | 134 |
| 9 | 12 | 24.53 | 45 | 19.58 | 19.58 | 294.36 | 383.376 | 130 |
| 10 | 12 | 29.51 | 50 | 20.92 | 20.92 | 354.12 | 437.646 | 123 |
| 11 | 12 | 35.86 | 55 | 22.27 | 22.27 | 430.32 | 495.953 | 115 |
| 12 | 12 | 43.89 | 60 | 23.52 | 23.52 | 526.68 | 553.19 | 105 |
| 13 | 12 | 53.85 | 65 | 24.52 | 24.52 | 646.2 | 601.23 | 93 |
| 14 | 12 | 65.84 | 70 | 25.01 | 25.01 | 790.08 | 625.5 | 79 |
| 15 | 12 | 79.65 | 75 | 24.62 | 24.62 | 955.8 | 606.144 | 63 |
| 16 | 12 | 94.4 | 80 | 22.91 | 22.91 | 1132.8 | 524.868 | 46 |
| 17 | 12 | 108.3 | 85 | 19.47 | 19.47 | 1299.6 | 379.081 | 29 |
| 18 | 12 | 118.6 | 90 | 14.81 | 14.81 | 1423.2 | 219.336 | 15 |
| 19 | 12 | 125.3 | 95 | 12.96 | 12.96 | 1503.6 | 167.962 | 11 |
| 20 | 12 | 131.1 | 100 | 11.23 | 11.23 | 1573.2 | 126.113 | 8 |

Table 1 shows that the output voltage can be increased using the Boost Converter. However, efficiency figures and output voltage remain erratic based on the value of the duty cycle used. But in the end, the greatest efficiency produced was worth 137% (Arvianto et al., 2020; Nurwati et al., 2022).




**Graph 1: Vin and Vout compare to Duty cycle**




**Graph 2 Comparison D to Efficiency**

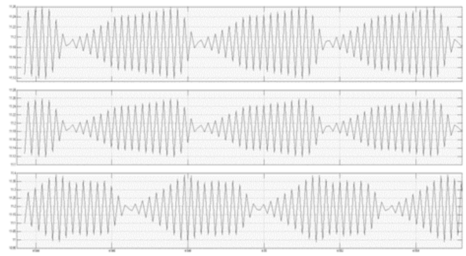


**Figure 6 Waveforms of Iout, Vout and Iin r Number Boost Converter Kalang Open**

b. Konverter Boost Kalang Tertutup dengan Kontrol PID

By providing a progressive increase in input voltage, simulation testing of the Closed Loop Boost Converter circuit with PID control was carried out. While resistors (R), capacitors (C), and inductors (L) all have the same value as in the previous circuit (Putri & Aswardi, 2020).

The value of the constant Kp is 0.01, the value of the constant Ki is 50, and the value of the constant Kd is 0. PID tuning is automatically performed using MATLAB software to determine the value of the PID constant.

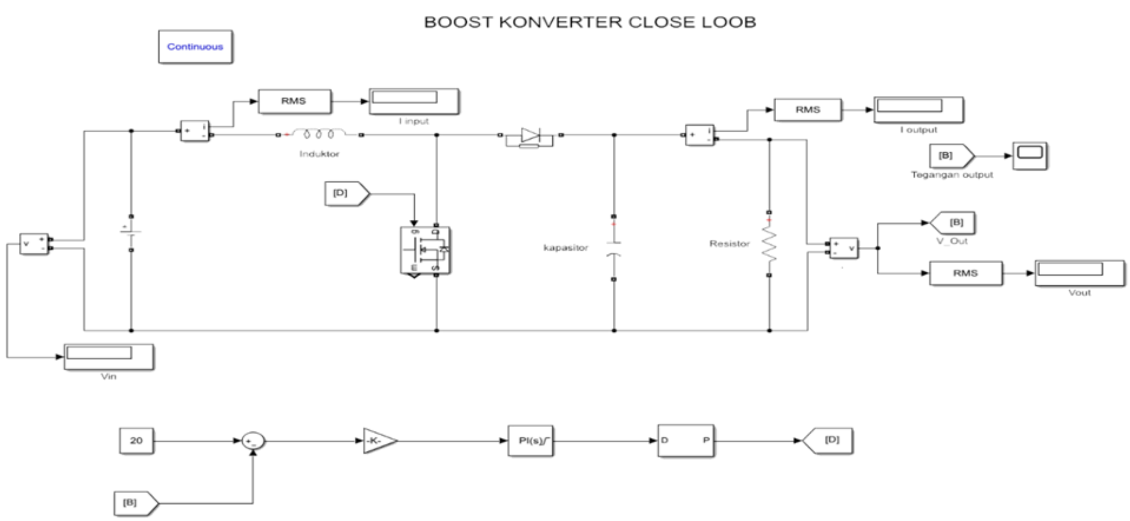



**Figure 6** ***Closed Range Boost Converter***

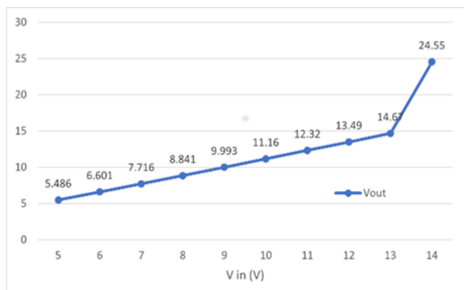
From the series above, the results of the investigation in table 1 are as follows

**Table 3** ***Data Boost Converter Open***

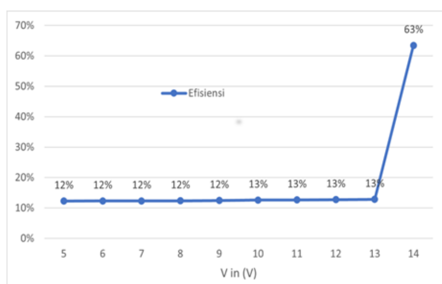
| No | Vin (V) | I in (A) | Vout (V) | I out (A) | P in (W) | P out (W) | Efisiensi (%) |
|---|---|---|---|---|---|---|---|
| 1 | 5 | 49.03 | 5.486 | 5.486 | 245.15 | 30.09 | 12 |
| 2 | 6 | 59.01 | 6.601 | 6.601 | 354.06 | 43.57 | 12 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | 7 | 68.99 | 7.716 | 7.716 | 482.93 | 59.53 | 12 |
| 4 | 8 | 78.98 | 8.841 | 8.841 | 631.84 | 78.16 | 12 |
| 5 | 9 | 88.95 | 9.993 | 9.993 | 800.55 | 99.86 | 12 |
| 6 | 10 | 98.93 | 11.16 | 11.16 | 989.3 | 124.54 | 13 |
| 7 | 11 | 108.9 | 12.32 | 12.32 | 1197.9 | 151.78 | 13 |
| 8 | 12 | 118.9 | 13.49 | 13.49 | 1426.8 | 181.98 | 13 |
| 9 | 13 | 128.9 | 14.67 | 14.67 | 1675.7 | 215.2 | 13 |
| 10 | 14 | 67.83 | 24.55 | 24.55 | 949.62 | 602.7 | 63 |

Table 3 illustrates that the Closed Snapper Boost Converter with PID control technique can produce a high-efficiency value of >63% and increase the applied voltage. In addition, when the input voltage rises, the output voltage value also rises (Putri & Aswardi, 2020).




**Graph 3 Vin to Vout Comparison**




**Graph 4 Vin to Efficiency Comparison**

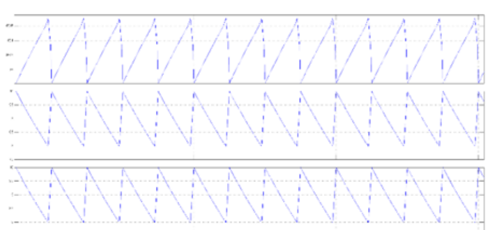


**Figure 7 Waveforms of Iin, Iout, and Vout of the sequence Boost Converter Closed Jacks**

c. Fuzzy Logic Control Boost Converter,

With a fixed input voltage of 5 volts and a gradually increased frequency, the Fuzzy Logic controlled Boost Converter circuit was simulated and tested. The values of resistors (R), inductors (L), and capacitors (C) used in this circuit are the same as the values in the previous circuit (Sirait & Matalata, 2018).

MATLAB control parameters for Fuzzy Logic systems are configured in such a way that enables optimal performance.

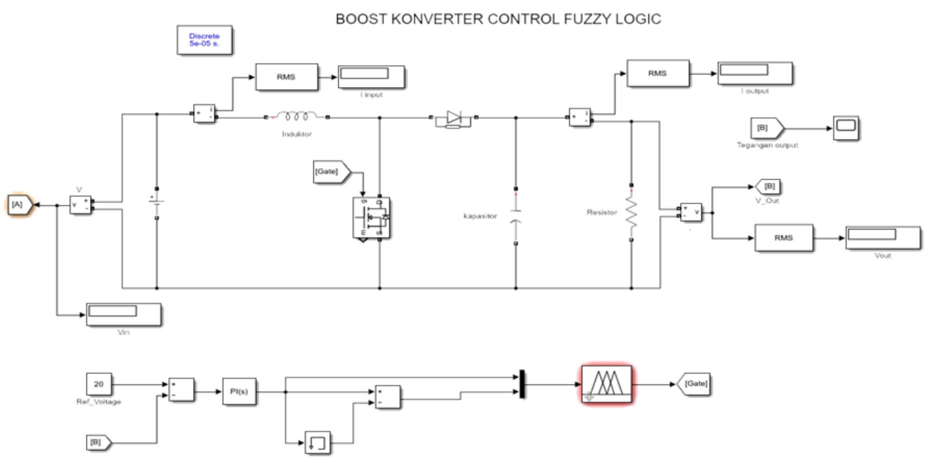


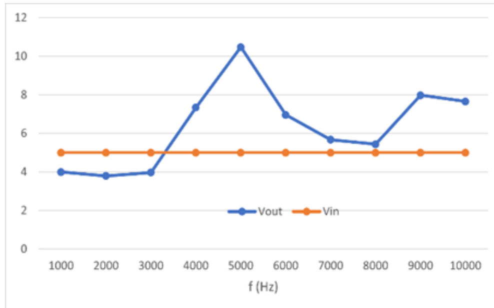

**Figure 7 Rangakaan Boost Converter Fuzzy Logic Control**

From the series above, the test results are obtained in the following table 4.

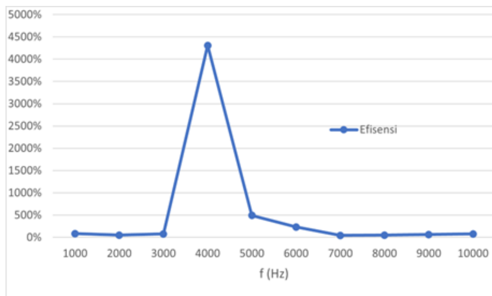
**Table 4 Fuzzy Logic Control Boost Converter test results**

| No | Frekuensi (Hz) | Vin (V) | Vout (V) | Iin (A) | Iout (A) | Pin (W) | Pout (W) | Efeisiensi (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 1000 | 5 | 3.994 | 3.82 | 3.99 | 19.1 | 15.93606 | 83 |
| 2 | 2000 | 5 | 3.799 | 5.53 | 3.71 | 27.65 | 14.09429 | 51 |
| 3 | 3000 | 5 | 3.975 | 4.11 | 3.97 | 20.55 | 15.78075 | 77 |
| 4 | 4000 | 5 | 7.337 | 0.25 | 7.34 | 1.25 | 53.85358 | 4308 |
| 5 | 5000 | 5 | 10.47 | 4.46 | 10.47 | 22.3 | 109.6209 | 492 |
| 6 | 6000 | 5 | 6.959 | 4.15 | 6.96 | 20.75 | 48.43464 | 233 |
| 7 | 7000 | 5 | 5.676 | 14.01 | 5.68 | 70.05 | 32.23968 | 46 |
| 8 | 8000 | 5 | 5.439 | 11.82 | 5.43 | 59.1 | 29.53377 | 50 |
| 9 | 9000 | 5 | 7.982 | 19.64 | 7.98 | 98.2 | 63.69636 | 65 |
| 10 | 10000 | 5 | 7.653 | 15.31 | 7.65 | 76.55 | 58.54545 | 76 |

Table 4 shows that the logic control fuzzy Boost Converter can increase the applied voltage and provide a relatively high-efficiency value, with a value of >83%. In addition, when the frequency rises, the output voltage value also rises. However, an error occurs when the frequency is set to 4000 Hz.




**Graph 3: Frequency comparison to Vin and Vout**




**Graph 4 Frequency to Efficiency Comparison**

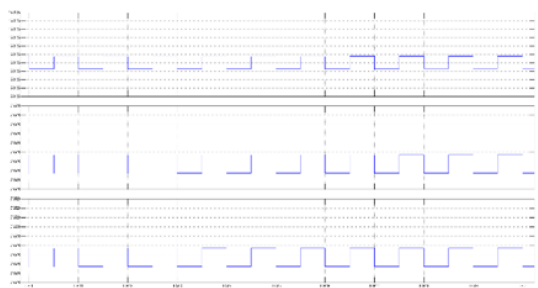


**Figure 1 Waveform of Fuzz Logic Control Boost Converter Circuit**

## 4. Conclusion

Open-loop Boost Converter Investigation The output voltage of a circuit with a fixed input voltage of 12 V and the Duty Cycle value gradually increases, the Outgoing Voltage increases as the Duty Cycle increases. This means that the final output voltage is determined by the Duty Cycle value. The Closed Snap Boost Converter with PID control technique can produce a high-efficiency value of >63% and increase the applied voltage. In addition, when the input voltage rises, the output voltage value also rises. The fuzzy logic control Boost Converter can increase the applied voltage and provide a relatively high-efficiency value, with a value of >83%. In addition, when the frequency rises, the output voltage value also rises. However, an error occurs when the frequency is set to 4000 Hz.

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