

Development of boost converter training kit as a practical tool in power electronics course

Junaidi Akbar¹, Krismadinata^{2*}, Ahyanuardi², Asnil²

¹ Technology and Vocational Education, Faculty of Engineering, Universitas Negeri Padang
Jl. Prof. Dr. Hamka Kampus UNP Air Tawar Padang, Indonesia-25131

² Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang
Jl. Prof. Dr. Hamka Kampus UNP Air Tawar Padang, Indonesia-25131

* Corresponding author: krisma@ft.unp.ac.id

Abstract

Abstract - In the power electronics learning process, apart from theory, it is also necessary to carry out practicum learning to improve the competence of students, so that the learning process runs well, learning is held in the laboratory using a training kit. Practical training kit is very important in the educational process, especially at the level of vocational education at the diploma level. Its existence is very much needed to improve the competence of students and make it easier for teaching staff to carry out the teaching and learning process, especially for practicum activities. The aim of this research is to produce a boost converter practicum training kit, where the parameters are close to the values calculated in theory and simulation. The method used is the experimental method in which the boost converter theory study is designed, made and tested. The test results show that the value of voltage, current and output power shows an average error presentation of less than 10% and the efficiency of the Boost Converter an average of 74% - 95%. The boost converter training kit can be produced well, so that it can be used as a support in power electronics practicum, especially on DC - DC Converter material.

Keywords: Training Kit, Boost Converter, Experimental, Power Electronics Practicum

I. Introduction

In the development of science in the field of technology that develops quite quickly and often competes, we are demanded not to be left behind, currently every company is trying to develop technology with various competitive human resource capabilities to advance and not be left behind. Therefore, a good practicum that supports the availability of teaching aids is a solution to the problem of less competitive human resources [1]. A nation's progress depends on quality human resources (HR), in order to achieve the quality of human resources, the fulcrum of a country lies in education. Education will be a core tool in supporting the advancement of quality human resources in a positive direction. Schools and Universities become processors of an education in the learning process. Along with technological advances, the industrial world cooperates with universities. In this regard, there is a need for vocational education to improve the competence of students. The practicum training kit is an important instrument in the learning process, especially for vocational education. Considering that this vocational education focuses on learning in practical activities with the division of 70% practice and 30% theory [2]. So that training kits are needed to support students' understanding of practicum material studied in higher education. In addition, it is hoped that the training kit can improve the quality of the learning process [3].

In power electronics practicum activities carried out in renewable energy laboratories, in practice simulations using the Power Simulator (PSIM) or Proteus program. Meanwhile, in direct practicum, the tools used are in the form of a circuit board or breadboard and electronic components which must then be assembled on a breadboard. In the absence of special equipment, every time students do a practicum, they must assemble a circuit from the beginning first and after completion it must be immediately dismantled because the boards and components used are tools with the electrical engineering department which of course are used by students from other classes. In the absence of special equipment, of course, it is difficult for educators to handle and supervise practical activities. Every time the practicum

educators must go back and forth to see the results of the series made by students, whether it is correct or not. This is important because if the circuit is wrong, the consequences will be fatal, for example a burned or overheating component can cause the breadboard to melt. The practicum time is also used too much just to check and justify the circuit made by students, so that the practicum which should aim to observe the performance of the circuit and data collection is not achieved.

Padang State University is one of the universities in the implementation of vocational education programs. Along with the facts above, the existence of a training kit is very much needed in supporting the understanding of course learning. Especially the Power Electronics course which is a subject in the field of science and skills. Basically, there is no training kit for this practicum and students only perform simulations at every practicum meeting at the Renewable Energy Laboratory.

Several studies have been carried out related to the Boost Converter training kit, such as Agus Samuel Marpaung, a dc power supply is connected to the trainer input, the duty cycle is 20-100% regulated by a potentiometer, electronic components are in the box, then students assemble their own , for testing a trainer kit with an input supply of 5 Vdc and an output of 2-12 Vdc [4]. Sunu Wakhid Rinawan, testing the trainer kit with a power supply of 15 Vdc and 20 Vdc, to determine the duty cycle settings, a practicum was carried out first and the components were located on top of the box [5]. From several explanations, research still takes a lot of time to take practical tools such as measuring instruments and installing circuits, then the mock-up model of the arrangement is too complicated and the duty cycle controller uses an analog circuit.

The training kit for the power electronics practicum course that will be made consists of several circuits, one of which is a boost converter circuit. The training kit will be designed to follow the practical table in the Renewable Energy laboratory, to read the input and output voltage and current values using a digital measuring instrument located in the training kit to save time, then there is a 16X2 LCD interface to see the frequency and magnitude of the duty cycle, circuit The power boost converter has been installed according to the theory of power electronics, and the training kit is also equipped with a controller chip so that further development can be carried out such as interfaces via a PC or the internet. The end of the goal achieved in this research is to produce a power electronics practicum boost converter training kit for D3 Electrical Engineering and D4 Industrial Electrical Engineering students at Padang State University with parameter values that are close to theoretical calculations.

In the working circuit, the boost converter is a direct electric power conversion device that produces a higher output than the input [6]. Periodically the switch will work to open and close that's how the boost converter works. So that the output voltage of the boost converter is greater than the input, a switching component is used to adjust the size of the duty cycle. Some examples of switching components that can be used are IGBT, thyristor, MOSFET (Metal Oxide Semiconductor Field Effect Transistor), etc. The basic form of a boost converter consists of only a few components such as a direct input (DC) source, an inductor, a diode, a capacitor and a resistor. The following basic circuit form of the boost converter is shown in Figure 1.

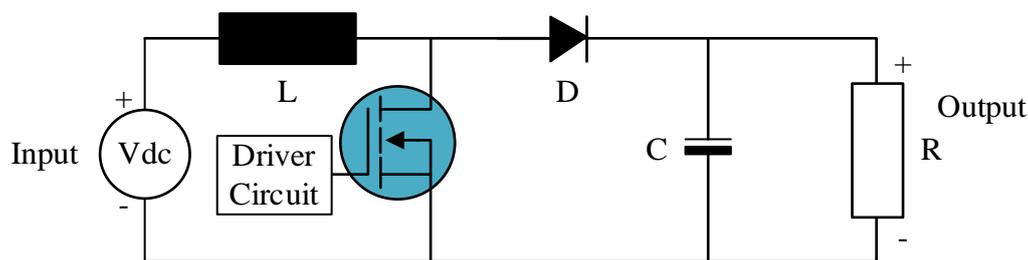


Figure 1. Boost Converter Circuit

The system works into two modes, while the first mode is the mosfet as an on switch, then the dc input voltage is the same as the voltage on the inductance. So the diode will be in a pre-voltage reverse state. The inductor component will start to store in the form of magnetic energy. The capacitor will work to supply energy to the load [7]. In the on state it can be seen in Figure 2

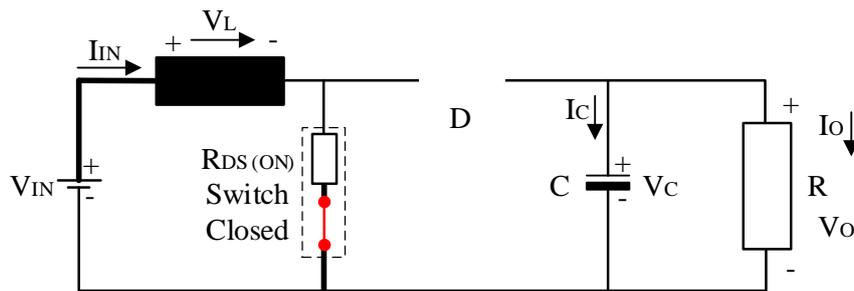


Figure 2. Circuit conditions ON boost converter

In the second mode, the mosfet acts as an off switch. Then the diode is in a state of pre-voltage forward or forward. So that the energy stored in the inductor will be flowed through a diode to fill the capacitor and supply the load. In the off state, it can be seen in Figure 3.

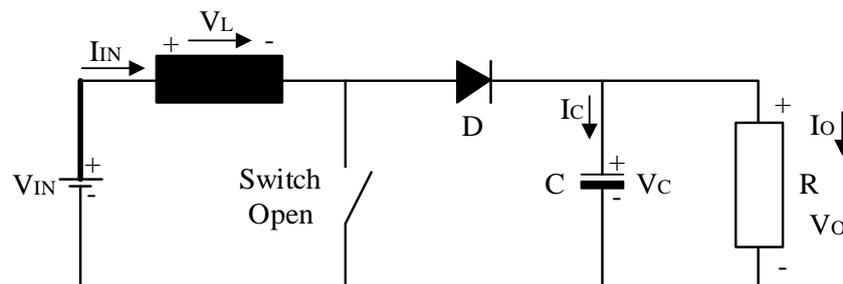


Figure 3. Circuit conditions OFF boost converter

If the current in the inductor becomes constant, then the equation obtained is:

$$\frac{V_{in}.DT}{L} + \frac{(V_{in}-V_o)(1-D)T}{L} = 0 \tag{Equ. 1}$$

$$V_{in} \times D = (V_o - V_{in}) \times (1-D) \tag{Equ. 2}$$

$$\frac{V_o}{V_{in}} = \frac{1}{(1-D)} \tag{Equ. 3}$$

Where, V_o is the output voltage generated from the boost converter circuit, V_{in} is the dc input voltage supplied to the boost converter circuit and D is the regulator of the width of the pulse to the scaling.

In the inductor part used is a solenoid inductor made of copper wire, then wrapped around a ferrite core [8][9]. The calculation of inductance can be seen in equation 4.

$$L_{min} = \frac{D_{min} (1-D_{min})^2 \cdot R_{max}}{2 \cdot f_{min}} \tag{Equ. 4}$$

Where, L_{min} is the minimum value of the inductor, D_{min} is the minimum value of the duty cycle, R_{max} is the maximum value of the resistor, f_{min} is the value of Switching Frequency. In the capacitor section which will function as a filter to limit the output voltage ripple of the boost converter circuit. So that the calculation of the capacitor can be seen in equation 5.

$$C_{min} = \frac{D_{max}}{\%V_r \cdot R_{min} \cdot f_{min}} \tag{Equ. 5}$$

Where, C_{min} is the minimum value of the capacitor, D_{max} is the maximum value of the duty cycle, $\%V_r$ is the tolerance value of the Ripple Capacitor, R_{min} is the minimum value of the resistor.

The next component to determine is the resistor. The value of the resistance used in the boost converter circuit is determined using the calculations in equation 6.

$$R = \frac{V_o}{I_o} \tag{Equ. 6}$$

Where, R is the resistor value, Vo is the output voltage value, Io is the output current value. In the boost converter efficiency section, you can find the input power supply (Pin) and output power (Pout) using equation 7.

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \tag{Equ. 7}$$

Where, η is Efficiency, Pout is output power, Pin is input power.

II. Method

a. Research Methods

The type of research used in this research is quantitative research with experimental methods. The experimental method is carried out by designing, manufacturing and testing tools carried out at the Renewable Energy Laboratory. Experimental research methods can be interpreted as research methods used to find the effect of certain treatments on others under controlled conditions [10].

b. Block Diagram

The block diagram of the boost converter training kit that will be made in general can be seen in Figure 4.

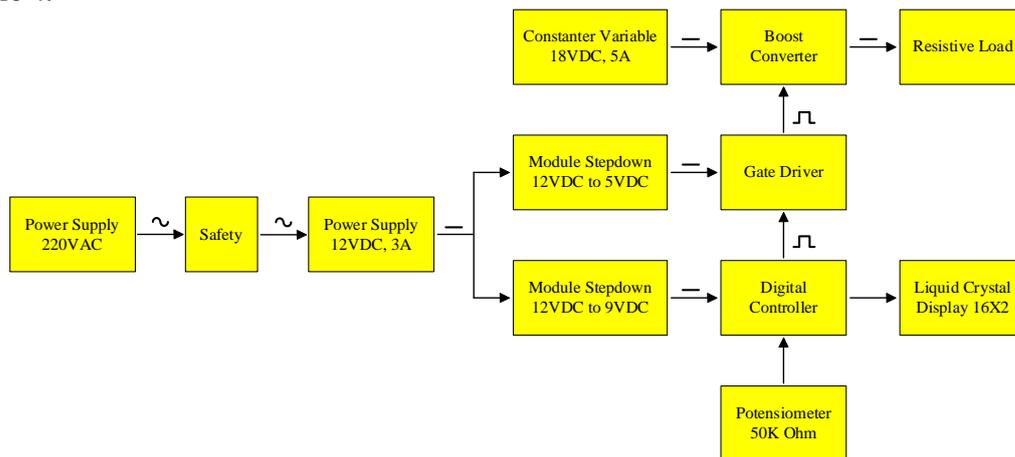


Figure 4. Boost Converter Training Kit Block Diagram

c. Parameter Testing Flowchart

The flow chart of this research is presented in Figure 5.

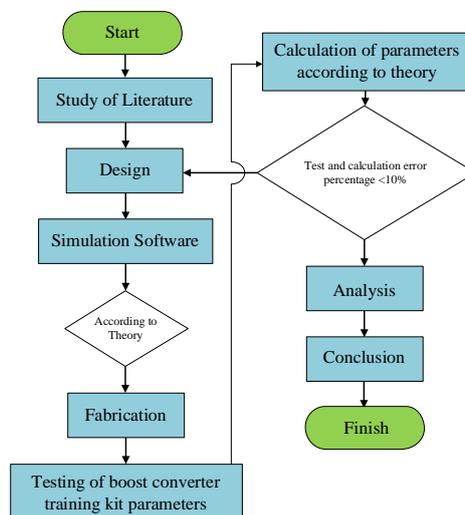


Figure 5. Parameter Testing Flowchart

III. Results and Discussion

a. Design

This stage, it is to determine the appropriate design for the power electronics practicum, especially on the topic of DC - DC Converter, and determine the value of the circuit making up the training kit in accordance with the theory. The design of the training kit can be seen in Figure 6.

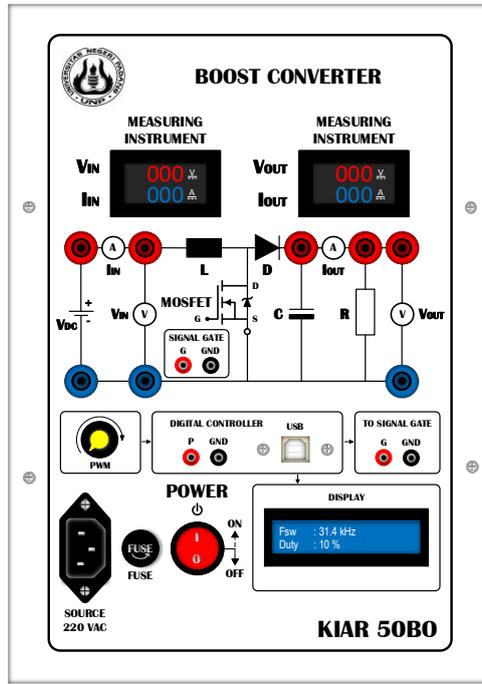


Figure 6. Design of the boost converter training kit

The overall component specifications for the boost converter training kit have been calculated according to theory, which can be seen in table 1.

Table 1. Specifications of boost converter training kit

Parameter	Nilai
Input Voltage (Vin)	0 - 18,6 V
Trigger Frequency (f)	31,4 KHz
Duty Cycle (%)	10-50%
Load Resistance (Ohm)	100 Ω
MOSFET	IRFP460
Diode	MUR460
Inductor	26 mH
Capacitor	100 uF / 250 V

b. Software Simulation Results

The simulation results are used to verify the design results. This verification aims to test the results of the design in accordance with the components used, so as to minimize errors in planning and fabrication. Simulation using proteus software, as for the boost circuit in the simulation can be seen in Figure 7.

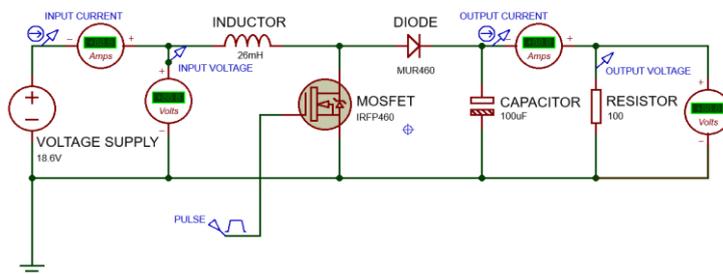


Figure 7. Boost Converter Simulation Circuit

The input and output current waveforms with a duty cycle of 10% - 50% are shown in Figure 8.

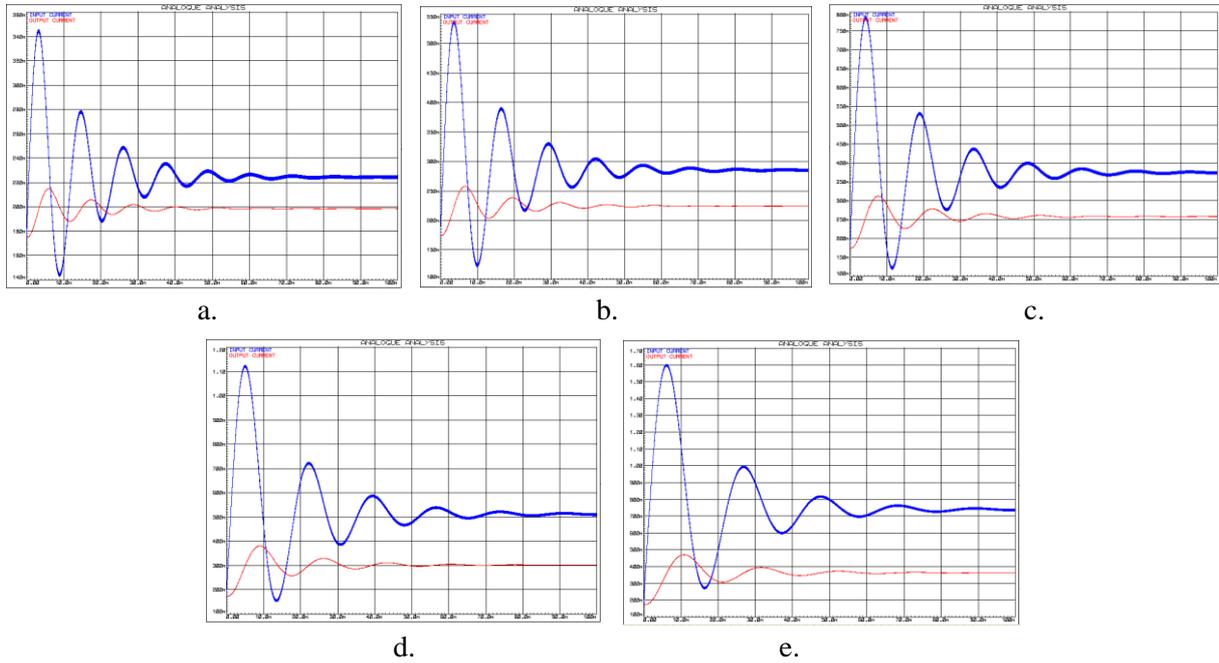


Figure 8a. 10% duty cycle current, b. 20% duty cycle current, c. 30% duty cycle current, d. 40% duty cycle current, e. 50% duty cycle current

The input and output voltage waveforms with a duty cycle of 10% - 50% are shown in Figure 9.

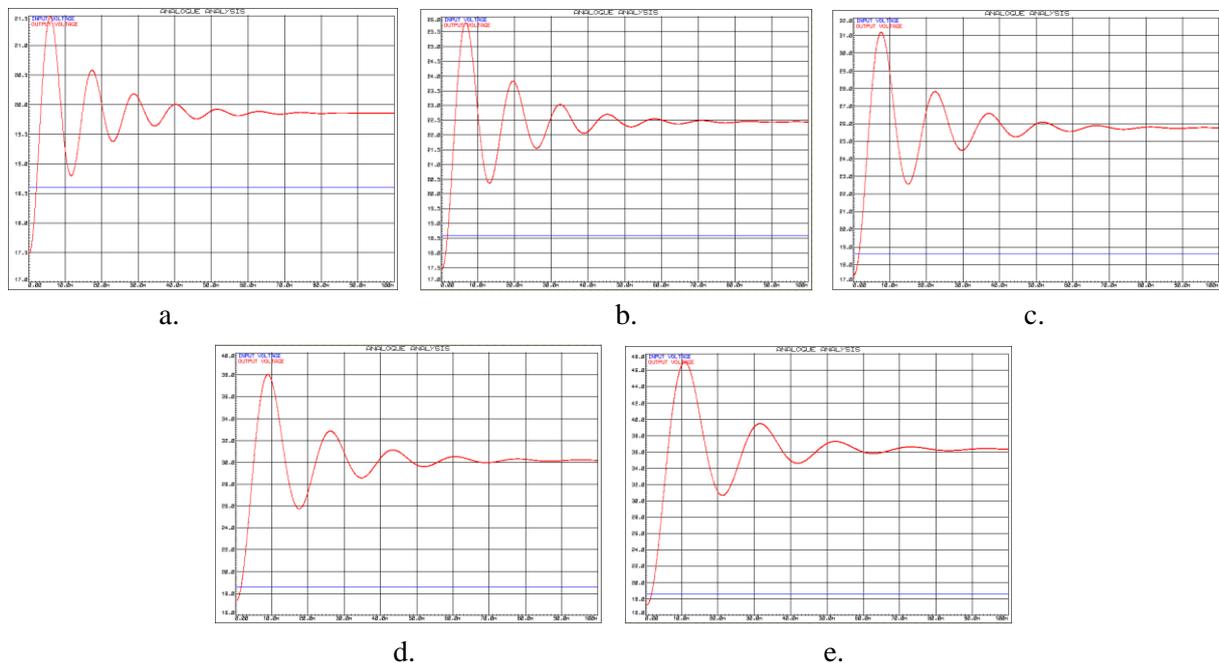


Figure 9a. 10% duty cycle voltage, b. 20% duty cycle voltage, c. 30% duty cycle voltage, d. Voltage duty cycle 40%, e. 50% duty cycle voltage

c. Boost Converter Training Kit Fabrication Results

The results of the fabrication of the design are presented in Figure 10.

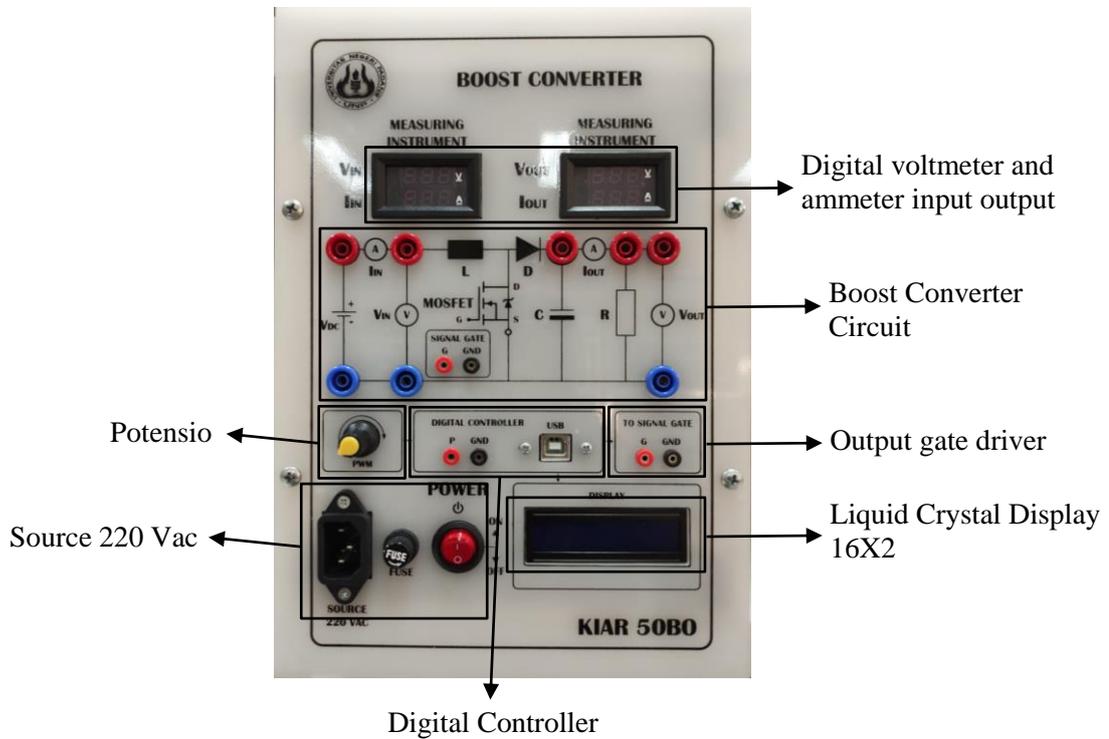


Figure 10. Fabrication Results of Boost Converter Training Kits Design

d. Boost Converter Training Kit Test Results

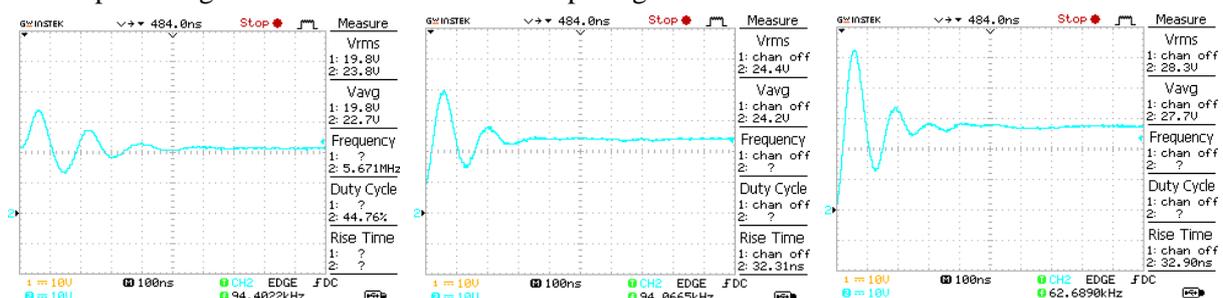
Testing of the boost converter training kits is carried out with an input voltage of 18.6 Vdc with a duty cycle of 10% - 50%, using a resistive load of 100 . The results are presented in table 2.

Table 2. Test results of input and output boost converter training kit

Frequency (KHz)	Resistive Load (Ohm)	Duty Cycle (%)	V input (Volt)	I input (Ampere)	P input (Watt)	V output (Volt)	I output (Ampere)	P output (Watt)	η (%)
31,4	100	10	18,61	0,224	4,11	19,93	0,196	3,91	95
		20	18,58	0,298	5,54	22,15	0,219	4,85	86
		30	18,58	0,401	7,45	25,59	0,253	6,48	86
		40	18,58	0,576	10,70	30,15	0,294	8,87	82
		50	18,58	0,881	16,37	35,87	0,357	12,81	78

Information : V : Voltage, I : Current, P : Power, η : Efficiency

Figure 11 shows the boost converter output signal, based on observations using an oscilloscope. The output voltage waveform is close to the output signal like a simulated reference.



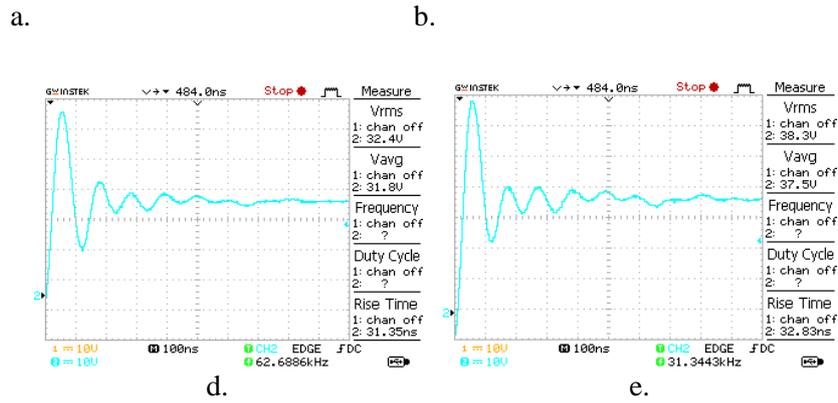


Figure. 11a. 10% duty cycle output signal, b. Output signal duty cycle 20%,, c. 30% duty cycle output signal, d. Output signal duty cycle 40%, e. 50% duty cycle output signal

The following testing of the boost converter training kit as a whole can be seen in Figure 12.

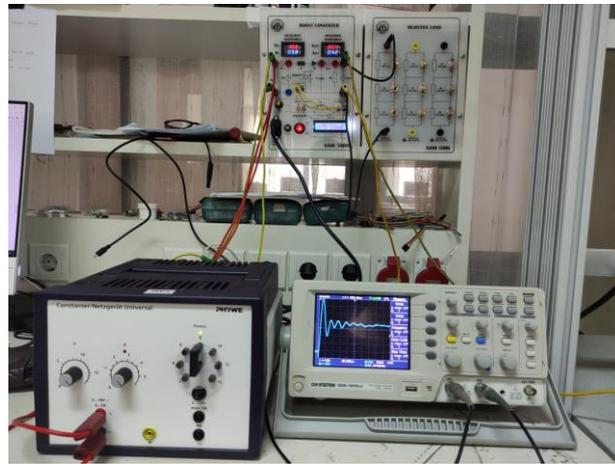


Figure 12. Overall Testing of the Boost Converter Training Kit

e. Analysis and Discussion

The analysis used in this study is to compare the theory, simulation and testing of the boost converter training kit. Besides, it will be seen how the effect of the duty cycle on the output current, voltage and efficiency. Table 3 presents the results of the comparison of theoretical output voltage calculations, simulation results and test results.

Table 3. Comparison of output voltage

Frequency (KHz)	Resistive Load (Ohm)	V input (Volt)	Duty Cycle (%)	V output (Volt)			Error percentage (%)	
				Te	Si	Pe	TP	SP
31,4	100	18,6	10	20,6	20,1	19,9	3,4	1
			20	23,2	22,5	22,1	4,74	1,78
			30	26,5	25,7	25,6	3,4	0,4
			40	31	30,2	30,1	2,9	0,33
			50	37,2	36,4	35,9	3,5	1,38

Information : Te : Theory, Si : Simulation, Pe : Testing, TP : Percentage of test error against theory, SP : Percentage of Test Error on simulation

Table 4 presents the results of the comparison of theoretical output current calculations, simulation results and test results.

Table 4. Comparison of output current

Frequency (KHz)	Resistive Load (Ohm)	V input (Volt)	Duty Cycle (%)	I output (Ampere)			Error percentage (%)	
				Te	Si	Pe	TP	SP
31,4	100	18,6	10	0,206	0,198	0,196	4,85	1,01
			20	0,232	0,225	0,219	5,6	2,67
			30	0,265	0,257	0,253	4,52	1,55
			40	0,31	0,301	0,294	5,16	2,32
			50	0,372	0,363	0,357	4,03	1,65

Table 5 presents the results of the comparison of theoretical output power calculations, simulation results and test results.

Table 5. Comparison of output power

Frequency (KHz)	Resistive Load (Ohm)	V input (Volt)	Duty Cycle (%)	P output (Watt)			Error percentage (%)	
				Te	Si	Pe	TP	SP
31,4	100	18,6	10	4,24	3,98	3,91	7,78	1,76
			20	5,38	5,06	4,85	9,85	4,15
			30	7,02	6,6	6,48	7,69	1,81
			40	9,61	9,09	8,87	7,7	2,42
			50	13,83	13,21	12,81	7,37	3,02

Figure 13 shows a comparison graph in the form of output voltage, output current, output power and boost converter efficiency in theory, simulation and testing.

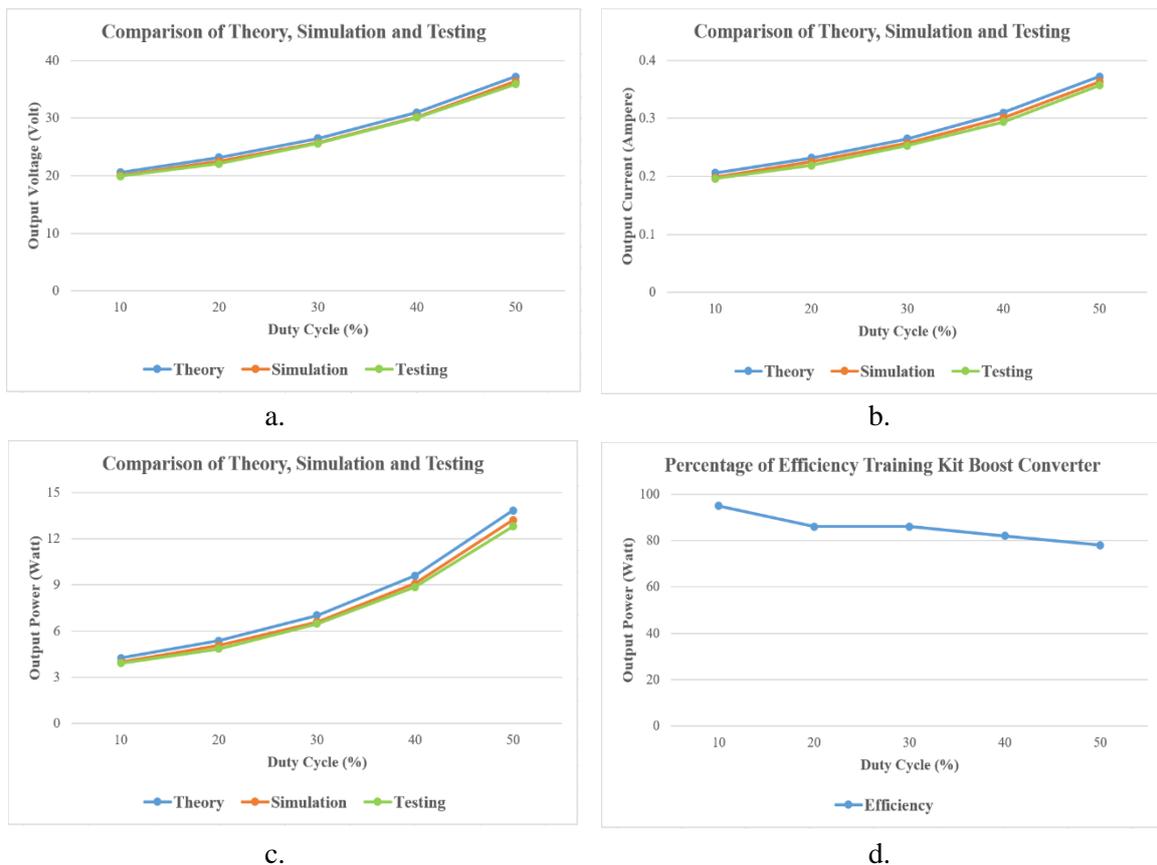


Figure. 13a. Output voltage graph, b. Output current graph, c. Output power graph, d. Efficiency boost converter training kit kit

IV. Conclusion

The boost converter training kit has been successfully created and can be used to increase the output voltage with different loads. The larger the duty cycle, the greater the boost converter output voltage. In addition, the average error of calculation and testing is <10%. The efficiency of the Boost Converter is on average 78% - 95%. It can be concluded that the training kit can be produced properly. With these results, the boost converter training kit can be used as a support in power electronics practicum, especially in the DC – DC Converter material.

References

- [1] Krismadinata K, Anwar A, Akbar J, Pengembangan Training Kit Pada Mata Pelajaran Mengoperasikan Sistem Kendali Elektronik, *Jurnal Pendidikan Teknologi dan Kejuruan*, 2021; 18(1) : 89-98.
- [2] Aditya P, Pengembangan Dan Implementasi Media Pembelajaran Trainer Kit Sensor Ultrasonik Pada Mata Diklat Praktik Sensor Dan Transduser Di SMKN 2 Depok Sleman, Yogyakarta, *Doctoral dissertation*, 2012.
- [3] Kristanto D. R., Ansori A., Pengembangan Media Pembelajaran Praktikum Kelistrikan Body Otomotif Untuk Meningkatkan Kualitas Pembelajaran Mahasiswa D3 Teknik Mesin UNESA, *Jurnal Pendidikan Teknik Mesin*, 2013; 1(3) : 40-49 .
- [4] Marpaung A. S., Boost Converter Pada Elektronika Daya, Batam, *Proyek Akhir*, 2017.
- [5] Rinawan S. W., Pengembangan Trainer sebagai Alat Praktikum Pengujian Rangkaian Pembangkit PWM, Buck Converter, Boost Converter dan Buck-Boost Converter pada Mata Pelajaran Penerapan Rangkaian Elektronika di Kelas XI SMK Muhammadiyah 1 Bantul, Yogyakarta, *Skripsi*, 2018.
- [6] Badri S, Krismadinata K, Design of Boost Converter Integrated with Graphical User Interface, *Journal of Mechanical Electrical and Industrial Engineering*, 2020; 2(1) : 31-42.
- [7] Afarulrazi A. B., Wahyu M. U., Taufik T., Aizam S., Yonis M., Design of Analog to Digital Converter for DC to DC Boost Converter with Constant Output Voltage,” in *The 3rd International Conference on Computer Engineering and Mathematical Sciences (ICCEMS 2014)*, 2015, pp. 800–804.
- [8] Bakar A. A., Gani A. F. H. A., Ridzuan H. A. M., A. Ponniran, Wahyu M. U., Amran M. A. N. Design and Analysis of 2-in-1 DC / DC Converter Trainer with Reduced Number of Components. *Universal Journal of Electrical and Electronic Engineering*. 2019; 6(5B): 17-25.
- [9] Assyidiq M. A., Winardi B., Andromeda T. Perancangan Boost Converter menggunakan Voltage Feedback pada Panel Surya. *Transient*, 2017; 6 (3): 1-7.
- [10] Sugiyono. Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif, dan R & D). Bandung: Alfabeta, 2010.