Stabilization of Output Voltage with Feedback Circuit and Filter on 2 Stages-Step Up Converter (24V to 312V DC)

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Abstract. Most DC voltage sources available produce low power whilst the supply needed for electrical devices is 220V AC The use of step up converter can be applied to several renewable energy sources that have relatively low output voltage. However, the output voltage of the DC-DC converter is often unstable due to the instability of the input voltage, the influence of the load, and the corrupted signal. To keep the output voltage of step up converter remains stable when given the load, this study implemented feedback circuit to adjust the duty cycle value, so that with the variation of the load, the output voltage remains stable. The designated 2 step step-up converter was able to amplify 24V DC input voltage to 312V DC. The output voltage was set at 312V DC to meet the AC voltage value of 220V based on DC-AC voltage conversion rules. The step up converter was tested with variations of input DC voltage, from 20V - 24V. The test results show that the converter with feedback circuit produces a more stable output voltage than the converter without feedback.

1. Introduction

The power supply system that works in switching mode has a much higher efficiency than a linear power supply system [1]. This power system is often called Switched Mode Power Supply (SMPS). SMPS is an electronic power supply consisting of a switching regulation provided as needed at the output voltage [2]. Basically a resource, including batteries, requires a dc-dc converter, either to raise or lower the voltage [3][4].

Battery is commonly used as a storage of electrical power, because a battery have a mechanism to store and repair output power, improve startup transitions, has dynamic characters and increase peak electric power [5]. The output voltage of the DC-DC converter is often unstable due to the instability of the input voltage [6], the influence of load [7], and the corrupted signal [8]. To keep the output voltage of the step up converter remain stable when given the load, some research has added a special technique of adding feedback circuits such as those done by M. Jamlay and W. M. Faizal. In his paper, M. Jamlay describes the DC-DC boost converter design to improve the efficiency of low-output renewable power by utilizing a combination of P and I controllers to control over steady state, fix settling time, and

stabilize the output converter voltage[7]. Meanwhile, to obtain the expected DC-DC converter specification expected, a careful calculation is required. B. Hauke in his application report describes how to perform calculations to obtain values of *step up converter components according to the specified specifications* [9]. H.Rudrigoez, et al adds a filter circuit to fix the corrupted signal before entering the ignition process [10].

Research on the development of DC-DC Converter by utilizing feedback circuit and various other techniques has been widely implemented to meet daily needs. Sanjib Chakraborty in his paper simulates how the effectiveness of the Photovoltaic (PV) output voltage becomes a residential power source. Output voltage from PV through Maximum Power Point (MPPT) becomes input for dual stage dc-dc bost converter [11]. The use of MPPT is intended to take maximum power before it is upgraded with step-up converter.

In the research, dual steps step up converter has been having been designed and implemented by using feedback circuit to maintain the stabilization of output voltage, and the addition of filter to repair the corrupted signal. The battery used in this study has a 24 Volt voltage source while the output voltage of 312 Volts. The output voltage is set to 312V DC because this value is equivalent to 220V AC voltage after converted. This equality is obtained with the equation 220V AC = $V_{maxDC}/\sqrt{2}$[12]. In the set up converter circuit, Atmega 16 is used as Pulse Width Modulation (PWM) signal generator, and IC IR2110 as a connector between control circuit and MOSFET. it is because IC IR2110, according to Yakoob [13], can lead control mosfet power N-Channel on high side configurations that operate up to 500V.

2. Methods

This paper discusses dual step step up converter from 24 volt voltage to 312 Volt DC using Atmega 16 as PWM signal generator and IC IR2110 as PWM signal driver circuit before step-up converter circuit ignition. The first step output was set to 80V. The first step of Step up converter circuit making is to do parameter calculation for each step.

2.1. The first Step

In system design, the parameter value of a component must be set so that the whole system can run well. In the first step, the Input voltage (V_{in}) of 20 Volt, Output voltage (V_{out}) of 80 Volt, Ripple voltage of 1%, and switching frequency (f_s) of 20 kHz were set.

The decision of initial specification of the design is done by several stages of calculation as follows [9]:

1. Determining the duty cycle value based on the equation

$$D = 1 - \frac{(V_{in} \times \eta)}{V_{out}}, \tag{1}$$

   With Vin = 20V, η = 80%, and Vout = 80V, to obtain D = 0.8.

2. Determining the maximum current based on the equation,

$$I_{sw\,(max)} = \frac{\Delta I_L}{V_{out}} + \frac{I_{out(max)}}{1-D}, \tag{2}$$

   With I_{sw}=4A, dan D=0.8, , thenI$_{out(max)}$ = 0.714A is obtained.

3. Determining the inductor value by first determiningΔI_L value based on the equation

$$\Delta I_L = (0.2\ to\ 0.4) \times I_{out(max)} \times \frac{V_{out}}{V_{in}}, \tag{3}$$

   with ripple current value 0.3 in 0.2-0.4 range, $I_{out(max)}$=0.714A, V_{out}=80V, andV_{in}=20V, to obtain ΔI_L value 0.857mH

   Determining L value is based on the following equation

$$L = \frac{V_{in} \times (V_{out} - V_{in})}{\Delta I_L \times f_s \times V_{out}}, \tag{4}$$

with V_{in}=20, V_{out}=80, ΔI_L=0.857,   and f_s=20kHz. the inductor value 933,4 was then obtainedμH.

4. Determining the capacitor using the equation

$$C_{out(min)} = \frac{I_{out(max)} \times D}{\Delta V_{out} \times fs}, \tag{5}$$

withI_{out}=0.714A, D=0.8,f_s=20kHz, and ΔV_{out}=3. the capacitor value 9.52 μF was obtained.

2.2. The second step
In the second step, *Input Voltage*(V_{in}) 80 -100 Volt, Output Voltage (V_{out}) 312 Volt, Voltage Ripple 1 % and Switching Frequency (f_s) 20 kHz were set. With those parameters, and the input obtained in the first step, and using the same equation as used in the first step, the following specifications were obtained in the second step: D=0.8, $I_{out(max)}$=0.128A, ΔI_L=0.15mH, L=21.3mH, dan C=51μF.

2.3. Feedback Circuit
a feedback circuit is required in order for the step-up converter output voltage to remain constant at the time of the load. The feedback circuit used in this step refers to the circuit reviewed by B. Hauke in [9], as shown in Figure 1.
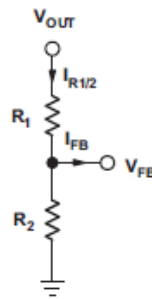

Figure 1. Feedback Circuit

R_1, R_2= resistive divider, V_{FB}= feedback voltage from the data sheet, $I_{R1/2}$= current through the resistive divider to GND, dan V_{out} = desired output voltage. To obtain R_1 and R_2 value, the following equation was applied

$$R_2 = \frac{V_{fb}}{R_1/2}, \tag{6}$$

$$R_1 = R_2 \times \left(\frac{V_{out}}{V_{FB}}\right). \tag{7}$$

From the analysis, using V_{out} =312 V, V_{fb} =2,5 V, R_1 = 560Ω dan R_2 = 68 kΩ were obtained

Meanwhile, in the step-up converter circuit designed, C filters are used to reduce the corrupt that occurs in the PWM signal before igniting the mosfet while the filter used is filter C.

3. Design Result
The design of a 2-step steps up converter circuit with the specified specifications and the calculated parameters is shown in Figure 2.
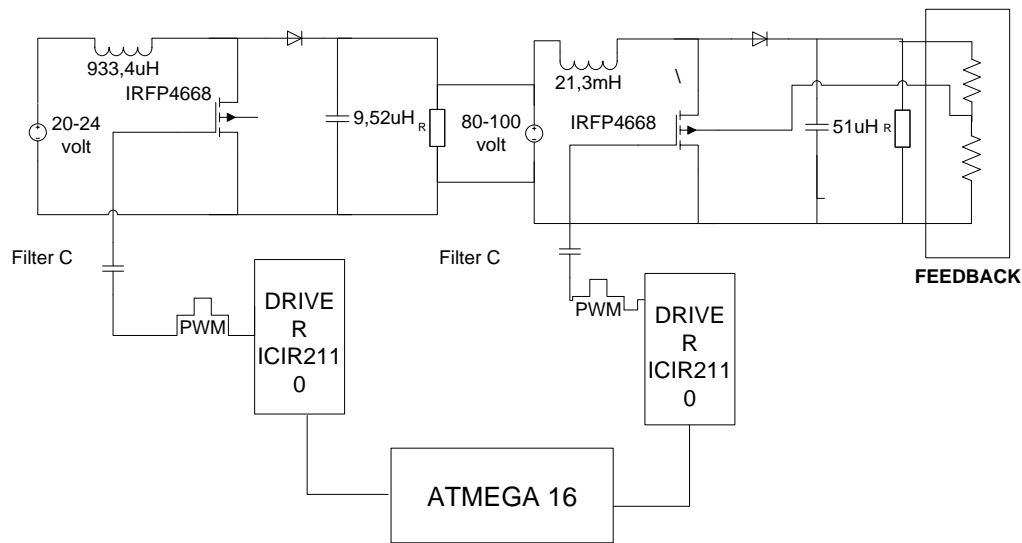
Figure 2. The design of 2 step step up converter

ATMEGA16 microcontroller as PWM signal generator, and IC IR2110 as driver circuit connecting control circuit with Mosfet IRF4668.

4. Test and Data Analysis

The test was then carried out to test the design. The test was done in the following variations:

1. Testing with feedback circuit and without feedback circuit with different load.
2. Testing with input voltage variation, where the input voltage converter was made with 20 - 24 Volt range, this done in order that the voltage on the battery will decrease.

Based on the input voltage variation test, the converter without the feedback resulted in unstable output voltage which is far from the set point 312V For instance, with a constant load of 10, and varied input voltage, the results were presented in Table 1.

Table 1. The effect of input voltage variation on output voltage in converter without feedback.

V_{in} (V)	Load (Watt)	I_{in} (A)	P_{in} (Watt)	V_{out} (V)	I_{out} (A)	P_{out} (kWatt)	Error (%)
20	10	5.210	100.73	264.77	0.0995	0.0258	15.13
22	10	5.695	125.38	281.55	0.1032	0.0274	9.75
24	10	6.253	140.12	304.68	0.2084	0.0337	2.34

On the other hand, for the converter with feedback circuit, stable output voltage was obtained in the 312V range As for example, With a constant load of 10, and the input voltage varies, the results obtained was shown in Table 2.

Table 2. The effect of input voltage variation toward out put voltage in converter with feedbac

V_{in} (V)	Load (Watt)	I_{in} (A)	P_{in} (Watt)	V_{out} (V)	I_{out} (A)	P_{out} (Watt)	Error (%)
20	10	6.248	2.87	312.42	0.1478	1.955	0.314
22	10	6.126	3.4	312.1	0.1512	1.962	0.032
24	10	6.084	3.61	311.68	0.1526	1.8489	0.102

There is a slight downward tren of V_{out} when the input voltage is increased, both in converter without feedback and with feedback. It is due to the fact that input voltage increase the current input that eventually cause heating on inductors. However, the V_{out} value for converter with feedback is more stable than the converter without feedback.

The test with load variations, While V_{in} was made constant, converter with feedback circuit produced relatively more stable output voltage than the converter without feedback circuit. The data of the test with load variations for converter without feedback circuit is presented in table 3, while te test for the converter with feedback circuit is shown in table 4.

Table 3. The data test with load variations for converter without feedback circuit

V_{in} (Volt)	Load (Watt)	I_{in} (Ampere)	P_{in} (Watt)	V_{out} (Volt)	I_{out} (Ampere)
22	0	2.0524	0.21	324.15	0.0373
22	5	4.6730	1.75	315.13	0.1755
22	10	5.6950	3.40	281.55	0.1032
22	15	12.859	4.88	185.45	2.3456

Table 4. Test Data with load variation for converter with feedback circuit

V_{in} (Volt)	Load (Watt)	I_{in} (Ampere)	P_{in} (Watt)	V_{out} (Volt)	I_{out} (Ampere)
22	0	3.0524	0.21	312.11	0.0163
22	5	4.6730	1.75	312.13	0.0768
22	10	6.1260	3.40	312.10	0.1512
22	15	7.8590	4.88	311.59	0.2187
22	20	8.7204	6.02	310.59	0.2743
22	25	9.9960	8.00	307.06	0.3594

Based on the table, the use of feedback as the PWM signal ignition control in Mofset was able to maintain the output voltage on the set point voltage. This is in contrast to the data generated without the use of feedback circuits, the voltage output was higher than the set point whent it has no load. in addition, when load was applied the output voltage dropped from the set point 312 Volt.

5. Conclusion
Based on the tests, it was confirmed that step up converter was able to strengthen input voltage from 20-24 volts to 312 Volt DC with load and input voltage variations. The average smallest error of voltage source variation occurs at an input voltage of 22V with an error of 0.032%. The use of feedback circuit on PWM signal ignition was proved able to maintain the output voltage when greater load was given.

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