Design and prototyping of a new SMPS for electrical vehicle

Arjan Hussein Fadhil[1], İsmail Topaloğlu[1]

[1]*Department of Electrical and Electronics, Faculty of Engineering, Çankırı Karatekin University, Çankırı, Turkey*

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Abstract

This project explains several well-known topologies (the basic building blocks) widely used to design and implement linear and switching power supplies. Each topology has common and unique characteristics, so an experienced designer can choose the most suitable topology for the intended application. The choice can be difficult, so it should take several times to establish a basic understanding of the characteristics. The correct initial selection will avoid sitting idly on a chassis that would not be the best for the application. In this work, some structures used in SMPS are described in detail, and each topology is described with specific mathematical equations for each component. The output of these structures was also shown. A comparison was made between the types of isolated and non-isolated topologies and the characterization of voltages and currents in each part of the design. In the end, the simulation was conducted using the Python language, and the practical results of the studied designs were presented and matched with the theoretical study.

Keywords: SMPS, topology, isolated SMPS

Introduction

SMPS is a system that provides this voltage by using semiconductor switching techniques instead of obtaining the required output voltages with the switched mode power supply standard methods (Allan et al. 2003; Alfarra et al. 2004; Alfarra et al. 2006). One of the critical points in the operation of SMPS is that it is a switched voltage regulator. The production and design of switching voltage regulators are much more complex and costly than linear voltage regulators. Output noise levels of the regulator are pretty high. In addition, the operating frequencies are much higher than the main frequency (Allan et al. 2004; Andersson-Skold and Simpson 2001). In addition to these disadvantages, the efficiency of the switching voltage regulators is relatively high and the output voltage of the linear voltage regulators should be higher than the input voltage. In contrast, the output value of the switching regulators can be smaller or larger than the input. Most DC power supplies contain a mains transformer, a half or full-branch rectifier, an electronic filter, and a voltage regulation circuit. This sequence of operation in a standard power supply is given below. A switched converter consists of a power switching step and a control circuit. The power switching stage provides the power conversion of the circuit's input voltage (Vin) (Liu and Jiang 2003; Bahreini et al. 2005). The most crucial advantage of SMPS is that it can convert at a very high efficiency compared to standard linear regulators. Moreover, this conversion is achieved by switching a transistor or MOSFET inside the circuit. Another important feature of SMPS power supplies is that they do not work as step-down converters like linear regulator converters. There are three types of SMPS (Canagaratna et al. 2006; Kostenidou et al. 2007). These are Buck Converters, Boost Converters, and step-down and step-up SMPSs. As their names suggest, these types are SMPSs that can provide input voltage and output voltage below that voltage. On the other hand, Amplifiers are SMPSs that can provide an output voltage at high voltage values at the input voltage (Maricq et al. 2010). This project aims to explain several well-known topologies that are widely used to design and implement a switching and linear power supply.

Results and discussion

In this section the simulation of some topologies (Buck, Buck-Boost, and the Flyback) will be presented and the result of simulation will be discussed.

Buck Converter simulation results

Using Python power electronics (Appendix A) to simulate the work of a buck converter as shown in Fig. 1 with PWM = 30%:

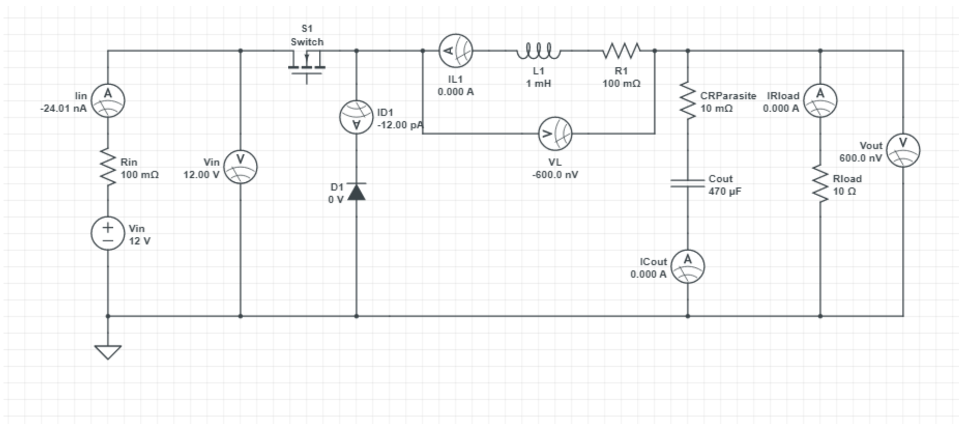

Figure 1: Buck converter circuit.

After setup the simulation (Appendix B) the the simulation results would be in the folder "C:\pythonpowerelectronics_simulation\Simulations\Buck_Converter" and the name of the file is "InputandOutputVoltages.png". Fig. 2 shows the output and input voltage for D=30%. The stability time 10ms with overshooting <55%.

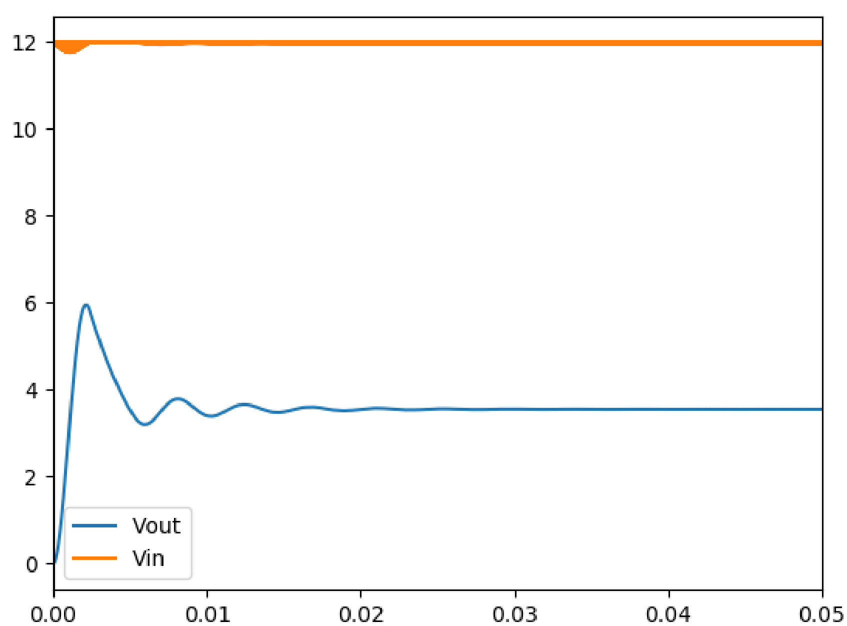

Figure 2: Buck converter simulated voltage.

The simulation results for the input current are shown in Fig. 3.

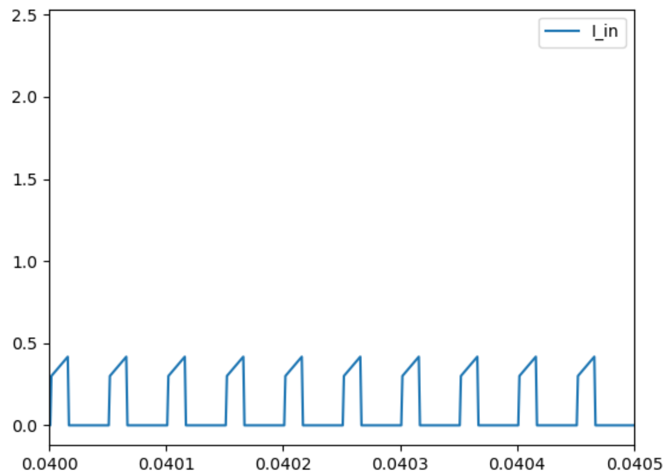

Figure 3: Buck converter simulated input current.

The simulation results for the inductor current are shown in Fig. 4.

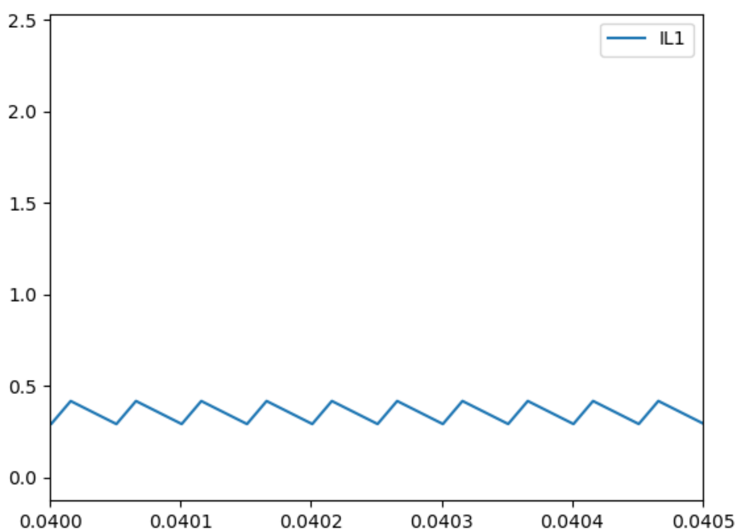

Figure 4: Buck converter simulated inductor current

The simulation results for the diode current are shown in Fig. 5.

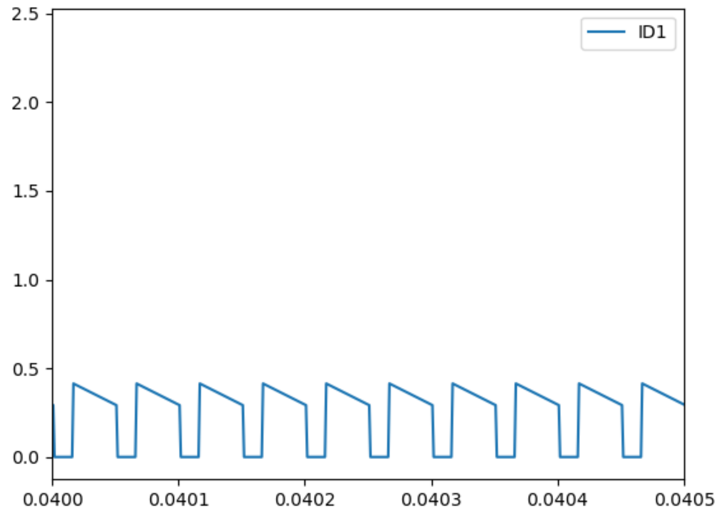

Figure 5: Buck converter simulated diode current

Conclusion

This study provided an overview of the most commonly used structures and showed the features of each. A comprehensive study of the most important types of isolated and non-isolated SMPS was presented. Mathematical relationships explain the shape and nature of the entire circuit's voltages and currents and each component. Python language was used to simulate the structures after explaining the working mechanism of each structure. The simulation results showed a perfect match with the theoretical relationships that determine the behavior of each SMPS.

Declarations

This study is part of a master's thesis.

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