Research Migration Project

https://esim.fossee.in/research-migration-project

The Research Migration Project is an initiative of FOSSEE, IIT Bombay that promotes the use of eSim for reproducing published research circuits originally implemented using proprietary simulation tools. The objective is to migrate these validated designs to eSim to build an open source resource database.

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Title of the circuit: Performance Evaluation of an Open-Loop Buck Converter with Si and SiC Diodes

Theory/Description: A buck converter is a DC-DC converter used to reduce a higher DC voltage to a lower DC voltage. It mainly consists of a MOSFET switch, diode, inductor and capacitor. When the MOSFET is ON, energy is supplied to the inductor and load. When the MOSFET is OFF, the inductor current continues through the freewheeling diode. The capacitor helps in reducing the ripple in the output voltage.

The switching performance of the buck converter also depends on the reverse recovery characteristics of the diode. In a conventional silicon diode, reverse recovery current flows when the diode changes from the conducting state to the blocking state. This current can cause a current spike in the MOSFET during turn-on and can increase switching losses.

A SiC diode has very low reverse recovery current compared to a conventional silicon diode. Because of this, it can reduce the switching current spike and losses in the converter. The paper compares the performance of MUR860 silicon diode and CSD04060 SiC diode for this reason.

In this project, I will reproduce the buck converter presented in the research paper "Performance Evaluation of Buck Converter with SiC Diode" using eSim. The circuit will be tested using the main simulation conditions given in the paper, with an input voltage of 40 V and a duty cycle of 75%. The MUR860 silicon diode and CSD04060 SiC diode will be used separately for comparison. The inductor current, output voltage, MOSFET drain current during turn-on and diode reverse recovery current will be observed and compared. The original paper reports an output voltage of approximately 29.6 V for a 40 V input and 75% duty cycle. It also shows a large reduction in the MOSFET transient current and reverse recovery current when the CSD04060 SiC diode is used instead of the MUR860 diode.

Reason to reproduce with eSim: The main reason for reproducing this circuit in eSim is to migrate a circuit that was originally simulated using PSpice and Proteus to an open-source simulation environment. The original paper used PSpice and Proteus for its simulation.

The circuit is suitable for eSim because it contains basic power electronics components such as a MOSFET, diode, inductor, capacitor and load. The MUR860 and CSD04060 diode models can be used for comparing the switching behaviour of the two diodes.
In the original simulation, an ATmega32 microcontroller was used to generate the PWM pulses, with a 4 V set point and 5 V reference to obtain a 75% duty cycle. In the eSim reproduction, a fixed pulse source with a 75% duty cycle will be used instead of the microcontroller. This will keep the required duty cycle the same while making the circuit simpler to reproduce in eSim.

Expected Outcome: **The eSim simulation is expected to produce an output voltage close to 29.6 V for an input voltage of 40 V and a duty cycle of 75%, similar to the result reported in the paper. The inductor current is expected to show a ripple similar to the waveform given in the paper. When the MUR860 silicon diode is used, a larger transient current spike is expected in the MOSFET during turn-on because of the reverse recovery current of the diode. When the MUR860 is replaced by the CSD04060 SiC diode, the reverse recovery current is expected to be much smaller, which should reduce the MOSFET turn-on current spike. The reverse recovery current waveforms of both diodes will be observed and compared. The results will then be compared with the simulation results reported in the original paper.**

Circuit Diagram(s): **The figure shows the basic buck converter circuit used in the reference paper. It consists of an n-channel MOSFET, freewheeling diode, inductor, output capacitor and load. The original circuit uses a microcontroller to generate PWM pulses for controlling the MOSFET. For the proposed eSim reproduction, the microcontroller based PWM generation will be replaced by a fixed 75% duty-cycle pulse source and the MUR860 and CSD04060 diodes will be used separately to compare their switching behaviour.**

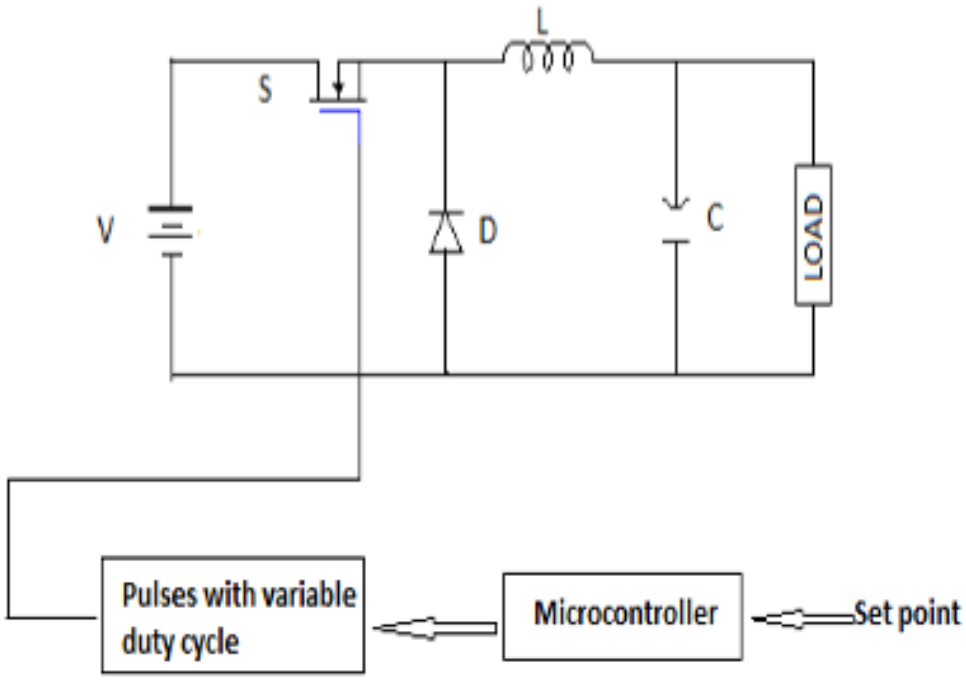
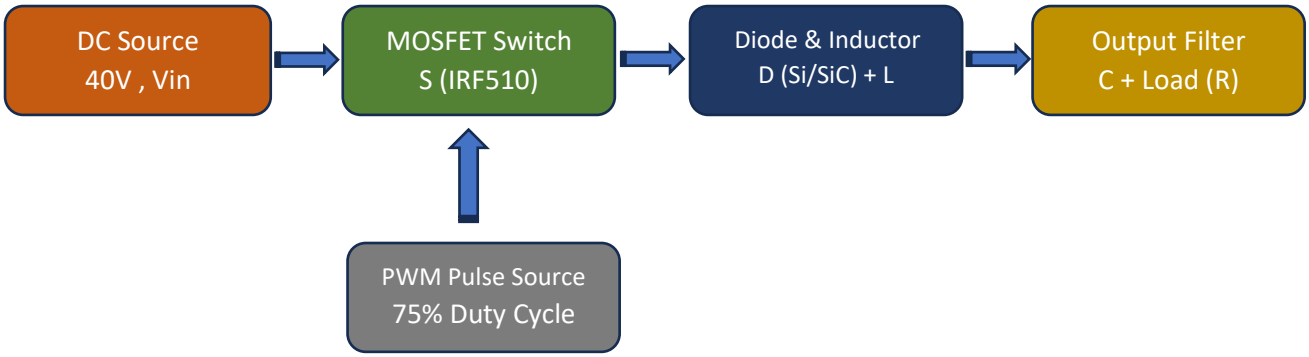


Fig: Schematic of the set-point controlled buck converter used in the reference paper.

Block Diagram (s): The block diagram shows the basic flow of the proposed buck converter. A 40 V DC source is connected to the MOSFET switching stage, followed by the diode and inductor and then the output filter consisting of the capacitor and load. A fixed 75% duty-cycle pulse source will be used to control the MOSFET in the eSim reproduction.



Expected Results: For an input voltage of 40 V and a duty cycle of 75%, the output voltage is expected to be approximately 29.6 V. The inductor current is expected to show a ripple similar to the result given in the paper.
The MOSFET drain current is expected to show a larger transient spike when the MUR860 silicon diode is used. When the CSD04060 SiC diode is used, this spike is expected to be considerably lower because of its lower reverse recovery current. Similarly, the reverse recovery current of the MUR860 is expected to be larger than that of the CSD04060. These results will be compared with the simulation waveforms reported in the original research paper.
The main aim will be to check whether the switching behaviour reported in the original paper can be reproduced using eSim.

Research Paper/Journal/etc.:

Title : Performance Evaluation of Buck Converter with SiC Diode
Authors : Naman Dwivedi, Akash Verma, Dipta Ghosh, Rajendra Pratap, Vineeta Agarwal
Link : https://ieeexplore.ieee.org/document/6129732

Source/Reference(s):

- eSim User Manual, Version 2.5, FOSSEE, IIT Bombay.
- MUR860 Silicon Fast Recovery Rectifier Datasheet, ON Semiconductor.
- CSD04060 Silicon Carbide Schottky Diode Datasheet, Wolfspeed/Cree.
- IRF510 MOSFET Datasheet.
- N. Dwivedi, A. Verma, D. Ghosh, R. Pratap and V. Agarwal, “Performance Evaluation of Buck Converter with SiC Diode.”