

Research Migration Project

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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 steps down a DC input voltage to a lower regulated DC output using a switching MOSFET, a freewheeling diode, and an LC output filter. When the MOSFET is ON, the inductor is energized from the source; when it turns OFF, the freewheeling diode provides a path for the inductor current, maintaining continuous current flow to the load.

The choice of freewheeling diode significantly affects converter performance. A standard silicon (Si) PN-junction diode (e.g., MUR860) exhibits reverse recovery — stored minority-carrier charge that produces a brief reverse current spike when the diode turns off. This spike causes additional switching stress and current overshoot in the MOSFET at turn-on. A Silicon Carbide (SiC) Schottky diode (e.g., CSD04060) is a majority-carrier device with negligible reverse recovery (transit time, $TT \approx 0$), resulting in a clean turn-off transition, reduced switching losses, lower peak overshoot, and faster settling time.

This work reproduces the simulation study of the reference paper by modelling an open-loop buck converter in eSim (KiCad + Ngspice) and comparing converter behaviour with a Si diode model against a SiC diode model under identical operating conditions.

Simulation parameters used:

- Input voltage (V_{in}): 40 V
- Switching frequency: 10 kHz
- Duty cycle: 75%
- Inductor (L): 500 μ H
- Capacitor (C): 690 μ F
- Load resistor (R): 5 Ω
- MOSFET: IRF510 (n-channel)
- Diode models compared: Si – MUR860; SiC – CSD04060 (custom SPICE model, $TT = 0$)

Circuit Diagram:

The circuit was implemented in eSim's schematic editor as an open loop buck converter: DC source $\rightarrow$ MOSFET switch $\rightarrow$ freewheeling diode $\rightarrow$ LC filter $\rightarrow$ resistive load. A PULSE voltage source emulates the microcontroller-generated PWM gate signal (10 kHz, 75% duty cycle).

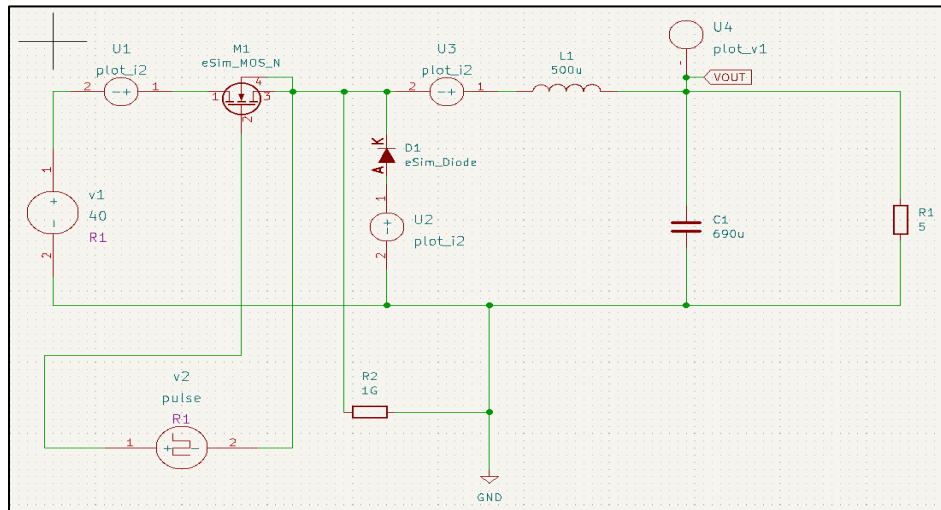


Fig. 1: Circuit schematic of the open loop buck converter

Results / Output:

The output voltage and inductor current were observed over the full transient (0–50 ms) to confirm correct startup and steady-state settling.

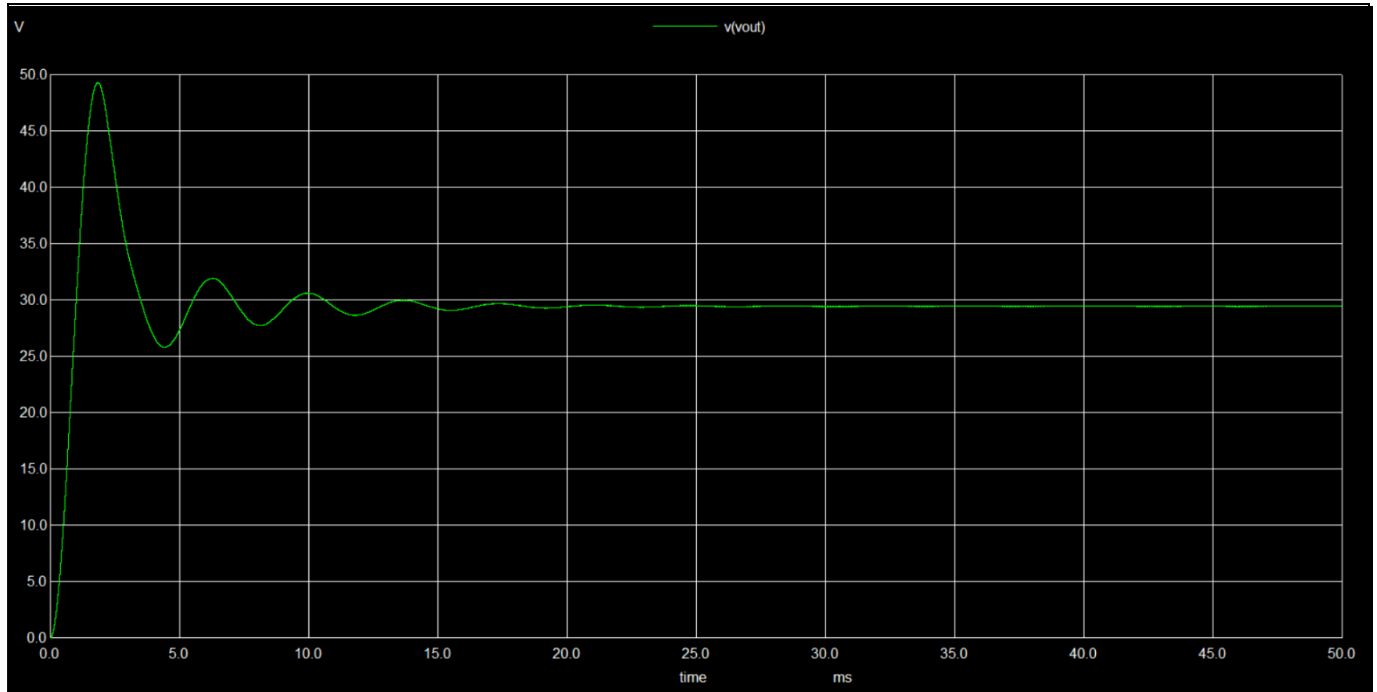


Fig. 2: Output voltage settling to steady state ($\sim 29\text{--}30\text{ V}$, close to ideal $V_{in} \times D = 30\text{ V}$)

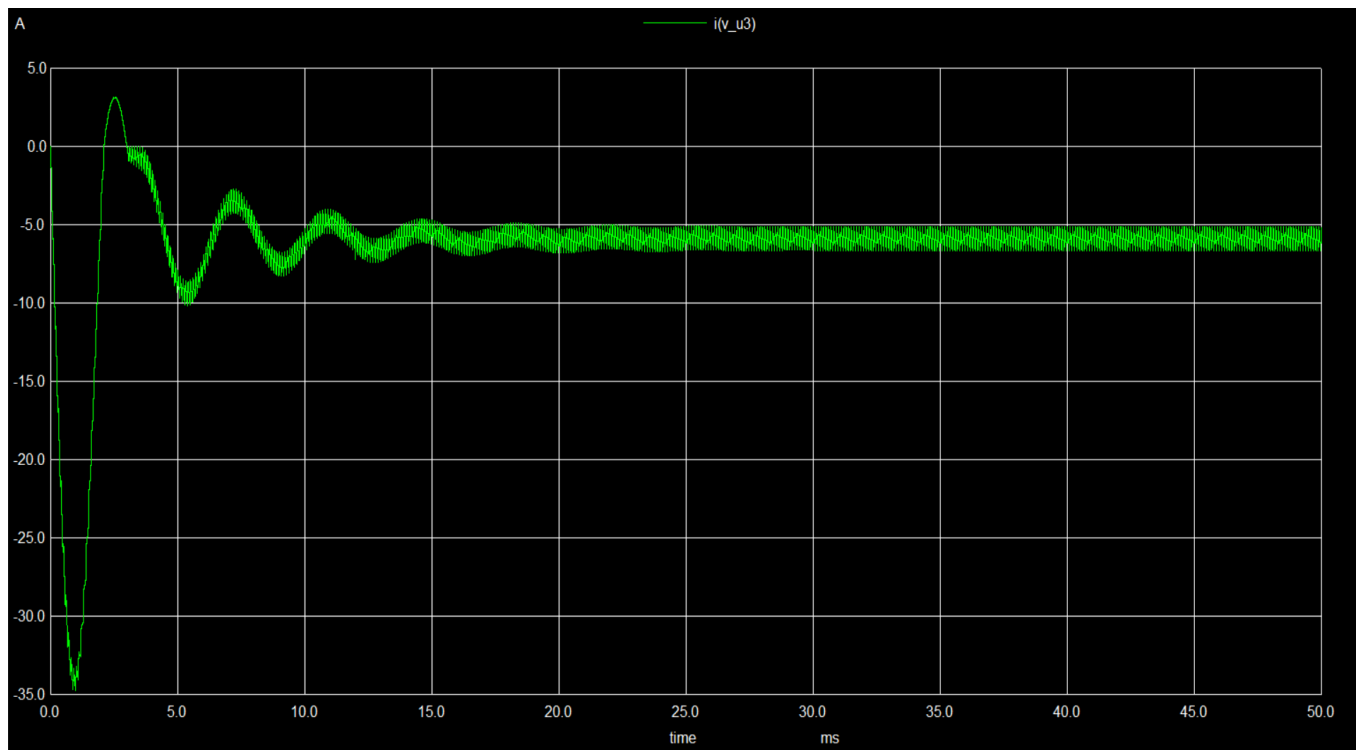


Fig. 3: Inductor current settling to steady-state ripple band ($\sim 6\text{ A}$ avg, matching V_{out}/R)

Diode Reverse Recovery — Si vs. SiC (Zoomed Steady State):

To observe true per-cycle behaviour, the diode current was zoomed into a narrow steady-state window (e.g., 40.00–40.30 ms, ~3 switching cycles), for both diode models.

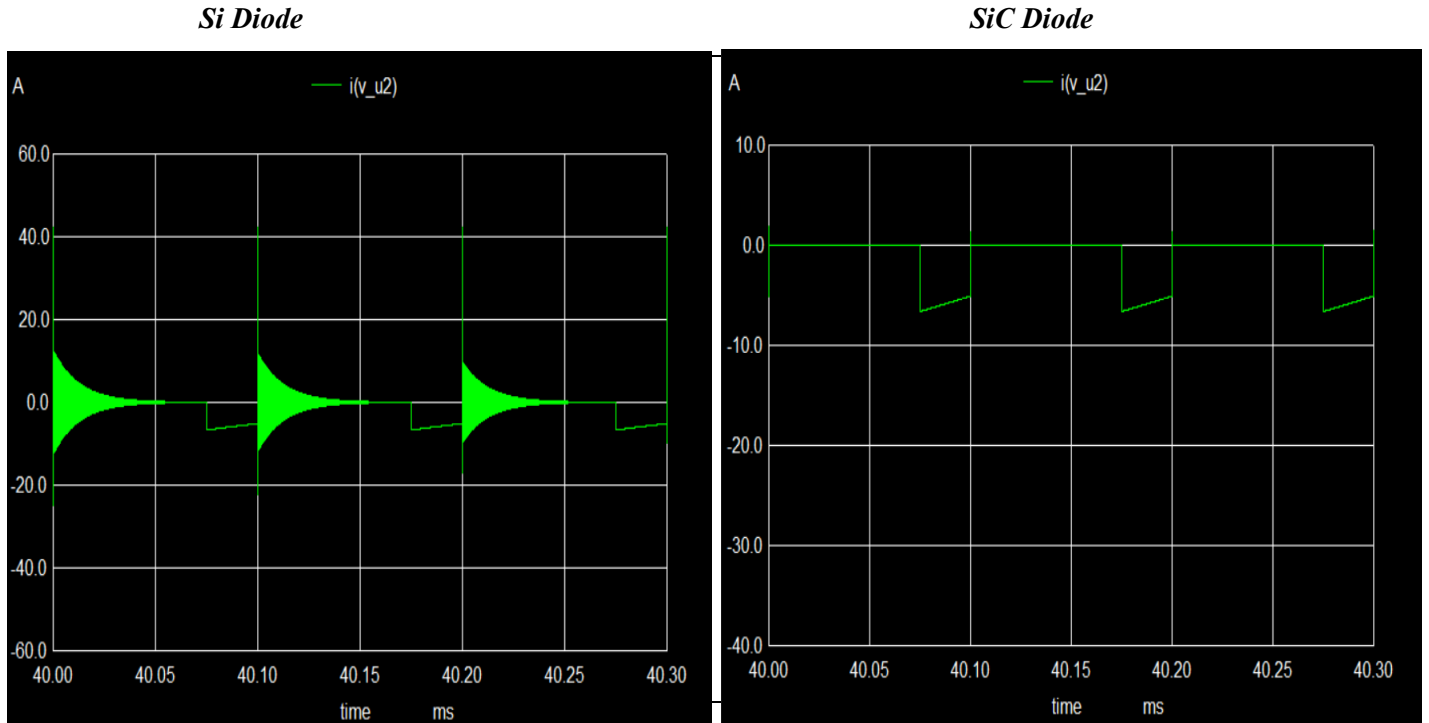


Fig. 4: Diode current comparison — Si diode shows a reverse-recovery current spike at turn-off; SiC diode shows a clean edge with no recovery spike

MOSFET Turn-On Current — Si vs. SiC (Zoomed Steady State):

The MOSFET-side current was similarly zoomed to observe the turn-on current spike induced by diode reverse recovery.

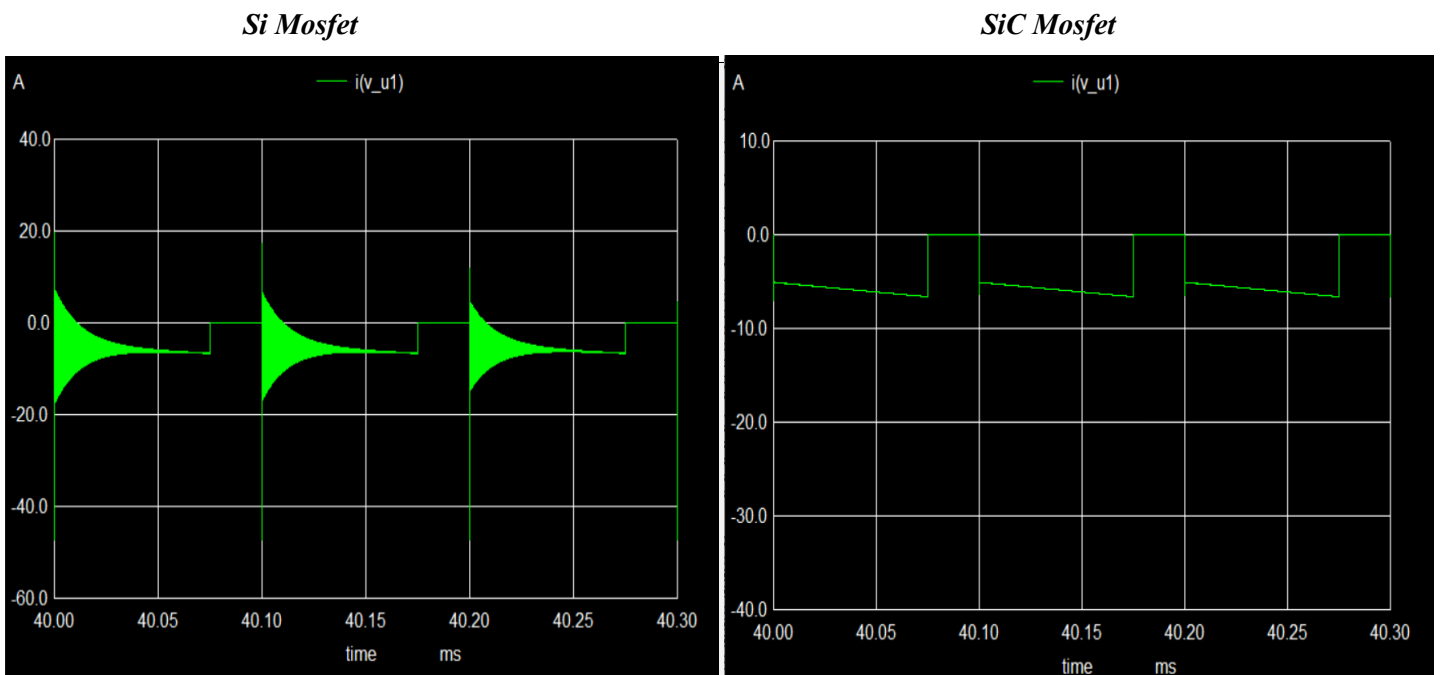


Fig. 5: MOSFET turn-on current comparison — Si diode causes a pronounced current spike due to reverse recovery; SiC diode results in a much smaller, cleaner turn-on transition

Quantitative Comparison:

Turn-on settling time and peak current overshoot were measured from the zoomed diode-current waveform at a single switching transition, for each diode:

	Turn-on Time (Settling Time)	Peak Current Overshoot
Si Diode (MUR860)	50 μ s	42 A
SiC Diode (CSD04060)	< 1 μ s	2.0 A

Table I: Settling time and peak overshoot comparison

Note: SPICE diode models used are approximate and simplified; the reported reverse-recovery magnitude and settling time reflect the specific SPICE parameters used (TT , RS , N , CJO) rather than exact manufacturer datasheet values, and are intended to illustrate relative Si vs. SiC behaviour rather than absolute hardware measurements.

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.