ABSTRACT

Title: Migration and Verification of the Inverting KY Converter using eSim.

Theory / Description :

The Inverting KY Buck-Boost converter is a high-performance fourth-order DC-DC topology designed to provide a stable negative output voltage with ultra-low ripple. The circuit integrates four MOSFET switches (S1-S4), an energy-storing inductor (L1), two intermediate transfer capacitors (C1, C3), and an output filter capacitor (C2).

The operation follows a specific two-phase switching cycle:

- Phase 1 (S1 and S3 ON): The input source charges the intermediate capacitors C1 and C3 while energy stored in inductor L1 is released to the load through diode D2.
- Phase 2 (S2 and S4 ON): The energy stored in the intermediate capacitors is discharged into the inductor L1 and the output stage.
- This unique arrangement allows for a linear voltage transformation ratio (V{out} = -V{in} . D) and continuous output current, making it ideal for sensitive applications requiring high voltage stability.

Circuit Diagram:

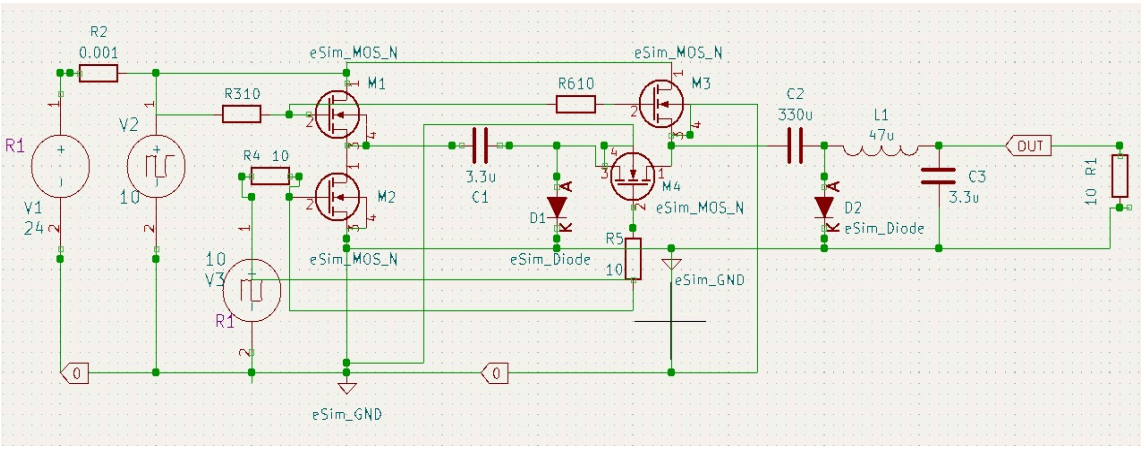

Figure 1: *Schematic diagram of the Inverting KY Converter implemented in KiCad Eeschema for eSim migration.*

Results / Output: The circuit was simulated in the eSim environment with an input voltage (V{in}) of 24V and a switching frequency of 100kHz.

- **Step-Down Mode (D=0.3):** At a duty cycle of 0.3, the converter was tested to verify the linear transformation ratio V{out} = -D . V{in}. The simulation yielded a stable, inverted output of approximately -3.0V. This results in a very low voltage ripple, confirming the high-performance filtering of the fourth-order KY topology.

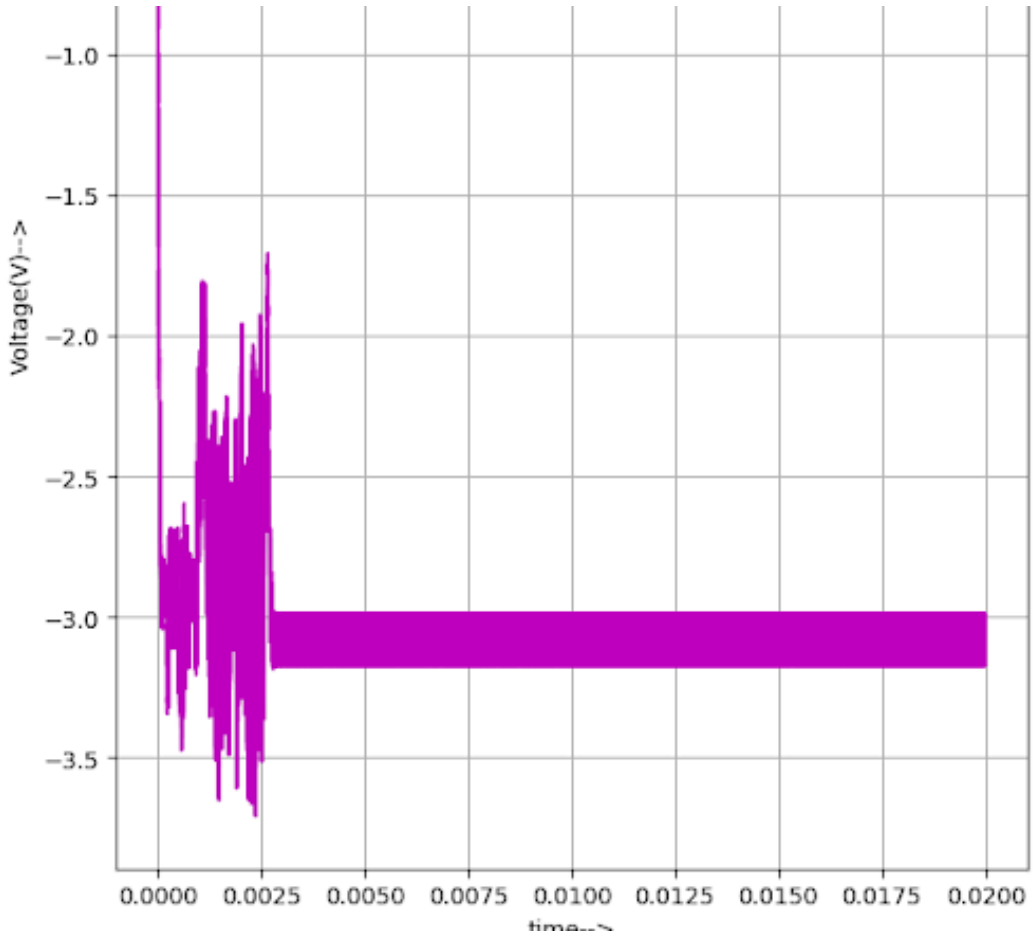

***Figure 2**: Simulated Output Voltage (V{out}) for Step-down mode D=0.3.*

- **Theoretical Step-Up Capability:**
  According to the mathematical model of the Inverting KY converter, the topology is capable of stepping up the voltage (where V{out} > V{in}) at duty cycles greater than 0.5. For D=0.7, the theoretical output is 16.8V. While the simulation confirms the inverting polarity across the entire range, the step-down mode provides the most stable representation of the converter's ultra-low ripple characteristics under the current semiconductor model parameters.

Conclusion:

The simulation successfully demonstrates the migration of the **Inverting KY Buck-Boost Converter** into the eSim environment. The results confirm that the topology maintains its core advantages: a linear voltage transformation ratio and effective ripple suppression via its fourth-order filtering network. While the original research highlights a recharging current peak as a potential drawback, this simulation verified that the converter remains highly stable for generating negative DC rails from a positive input source. This project serves as a robust proof-of-concept for utilizing open-source tools to model advanced power electronic topologies.

References :

1. F. A. Himmelstoss and H. L. Votzi, "KY Converters and Their Improvements," *Preprints.org*, Nov. 2025. https://doi.org/10.20944/preprints202511.1269.v1
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