Buck Converter Design Report

This report outlines the design and analysis of a non-isolated buck converter that steps down an input voltage of 24V (with a 2% tolerance) to a 5V output. The design operates with a switching frequency of 43 kHz and aims to achieve an efficiency of at least 90%.

The schematic consists of the following key components-

1. Q2 (IRFZ44N): The switching MOSFET driven by a 43 kHz clock signal.
2. L1 (100 µH): The inductor that smooths the current to the load.
3. D3 (RBRSLAM60A): A Schottky diode that ensures current flow when the MOSFET is off.
4. C1 (22 µF): The input capacitor stabilizing the input voltage.
5. C3 (150 µF): The output capacitor that smooths the output voltage.
6. R4 (RL): The load resistor representing the output load.

Formulae Used-

Maximum Duty Cycle: $D = \dfrac{V_{OUT}}{V_{IN(\max)} \times \eta}$

$V_{OUT(ESR)} = ESR * \Delta I_L$

Buck Converter Design Specifications-

- Input Voltage (Vin): 24V ± 2% tolerance (23.52V to 24.48V)
- Output Voltage (Vout): 5V
- Max Input Current: 1A (24W input power)
- Max Output Current: 4.32A (considering 90% efficiency)
- Switching Frequency (f): 43 kHz
- Ripple Current (ΔIL): 20% of the output current (1.96A)
- Inductor Value (L): 90 µH (rounded to 100 µH standard value in the schematic)
- Expected Efficiency: At least 90%

Component Selection and Calculations-

1. Inductor (L1)

The inductor value is calculated based on the desired output voltage, input voltage, ripple current, and switching frequency. Using a switching frequency of 43 kHz and a ripple current of approximately 1.296A, the inductor value is calculated and selected as **100 µH.**

Model No:PCV-2-104-05

Inductor: 100 µH

Current Rating: At least 5A (calculated peak current of 4.97A)

$$\text{Inductor Ripple Current: } \Delta I_L = \frac{(V_{IN(max)} - V_{OUT}) \times D}{f_S \times L}$$

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{\Delta I_L \times f_S \times V_{IN}}$$

$$I_{MAXOUT} = I_{LIM(min)} - \frac{\Delta I_L}{2}$$

2. MOSFET (Q2)

A MOSFET is used as the switching element in the buck converter. The IRFZ44N is selected as the low-side N-channel MOSFET due to its high current rating and low RDS(on), which ensures minimal conduction losses.

MOSFET: IRFZ44N

Voltage Rating: 55V

Current Rating: 49A

3. Schottky Diode (D3)

The Schottky diode is used for freewheeling current during the off-state of the MOSFET. The RBRSLAM60A is selected for its low forward voltage drop and fast switching characteristics.

Diode: RBRSLAM60A

Voltage Rating: 60V

Current Rating: 5A

$$P_D = I_F * V_F$$

$$I_F = I_{OUT(max)} \times (1 - D)$$

4. <u>Input and Output Capacitors (C1 and C3)</u>

Capacitors are used to filter out voltage ripple at both the input and output sides of the converter. The input capacitor helps stabilize the input voltage and minimize high-frequency noise, while the output capacitor smooths the output voltage.

Input Capacitor (C1): 22 µF (ceramic capacitor) rated for 35V

Output Capacitor (C3):

150 µF (ceramic capacitor) rated for 50V

Model Number:GRM31CR60J157ME11

$$C_{OUT(min)} = \frac{\Delta I_L}{8 \times f_S \times \Delta V_{OUT}}$$

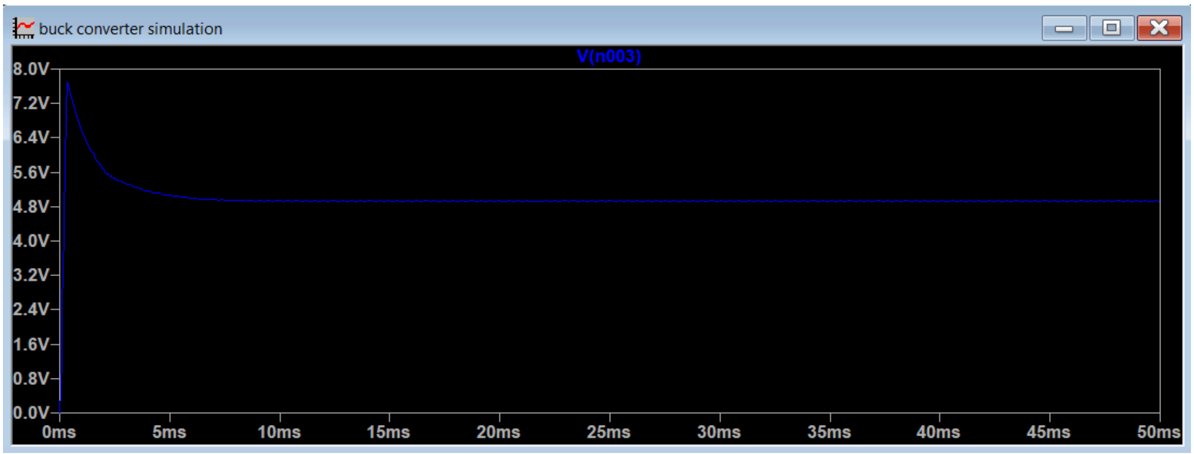
Conclusion-

Through careful selection and calculation of components, the design achieves the desired performance while adhering to practical limitations. This buck converter can be effectively utilized in a wide range of applications requiring reliable low-voltage DC output from a high-voltage DC input. Future improvements can involve optimizing the inductor value further to reduce ripple and improve efficiency even beyond the 90% target.

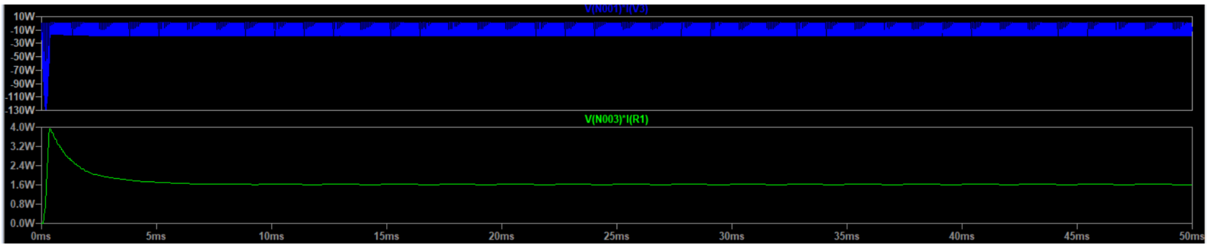
Simulation and Plots:-

Input Voltage-

Output Voltage-



Input and Output Power-



Current-