Optimized Rad-Hard DC/DC Converters for HEP Applications

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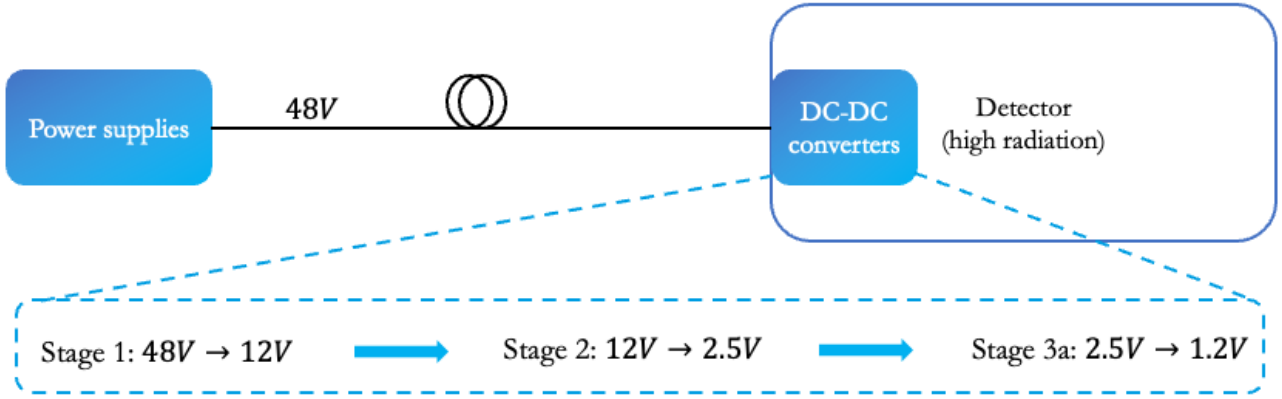
This R&D has been made possible thanks to the CERN EP- R&D funding WP5.4.

Introduction

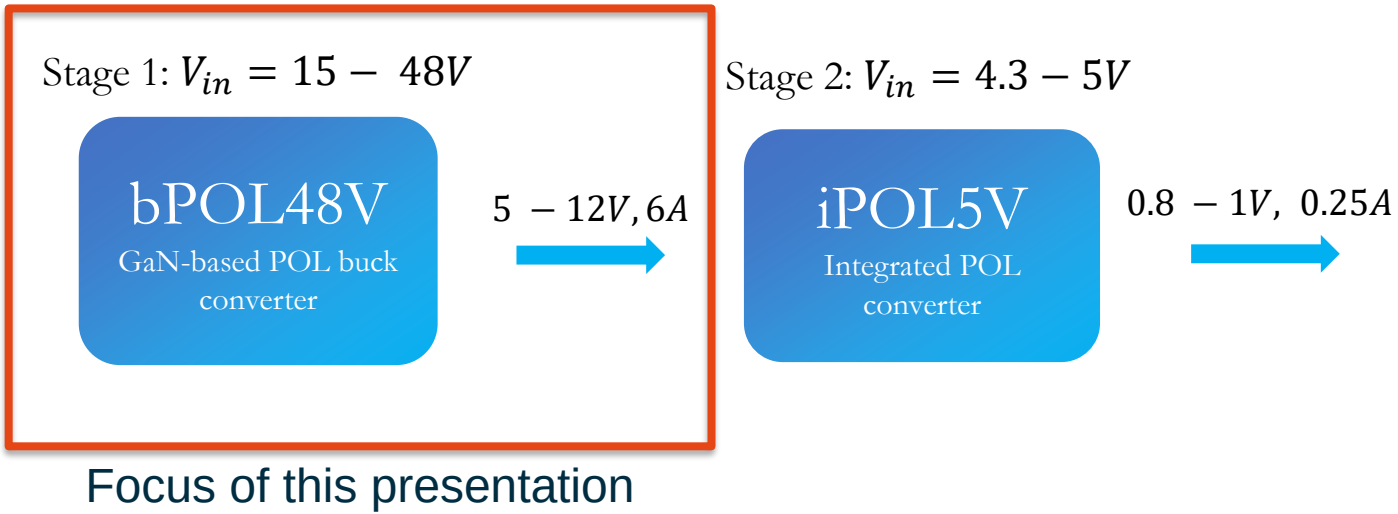
On-detector DC-DC converters are utilized to minimize the losses in the distribution lines and reduce material requirements.



Introduction

Development of novel and efficient powering schemes:

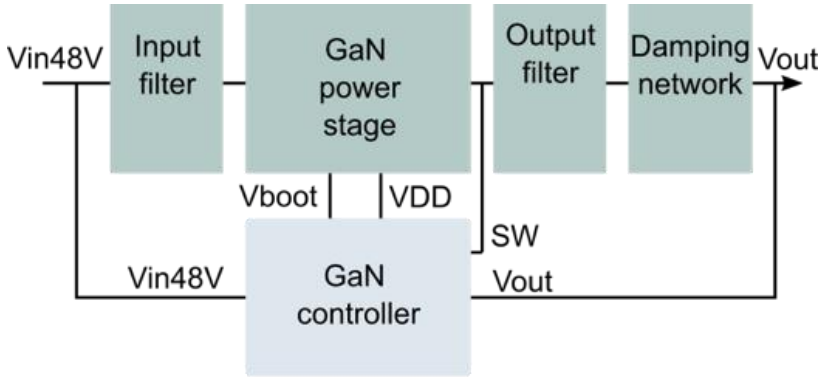
- Increasing power demand
- Reduction in size and weight of cabling, power supplies and cooling



bPOL48V

bPOL48V:

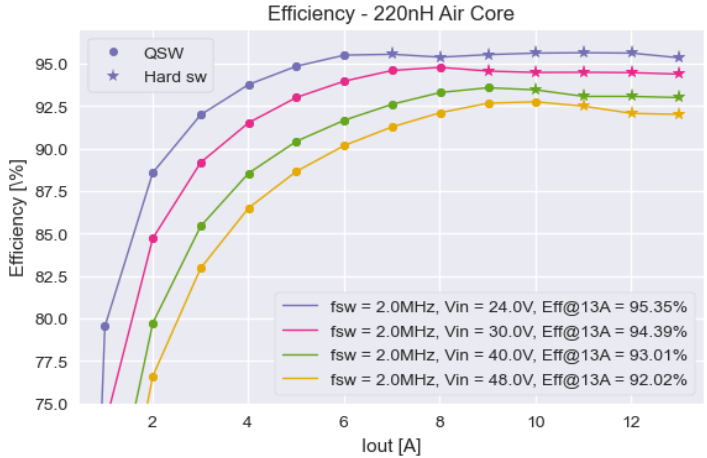
- GaN_Controller: Custom CERN ASIC
- EPC2152: Integrated GaN power stage
- Input filter
- Output filter



Preceding bPOL48V Design

High-Current Module:

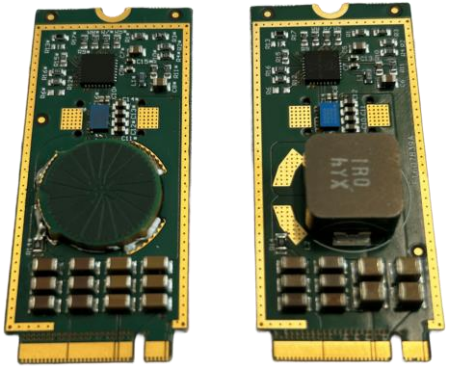
- Input voltage: 48 V
- Output voltage: 12 V
- Output current: 12 A
- Volume: 56899 mm^2

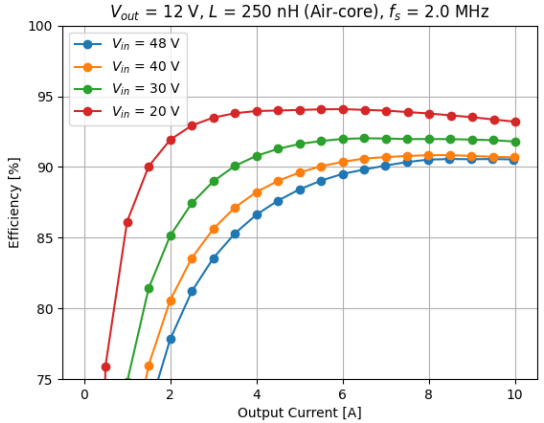


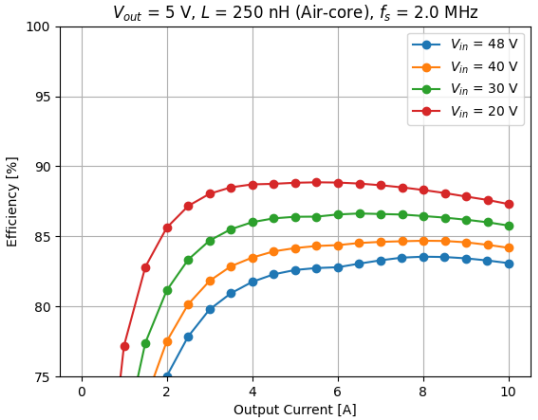
Compact bPOL48V Module

High-Current Module:

- Input voltage: 48 V
- Output voltage: 5 - 12 V
- Output current: 10 A
- Volume: 3960 mm^2

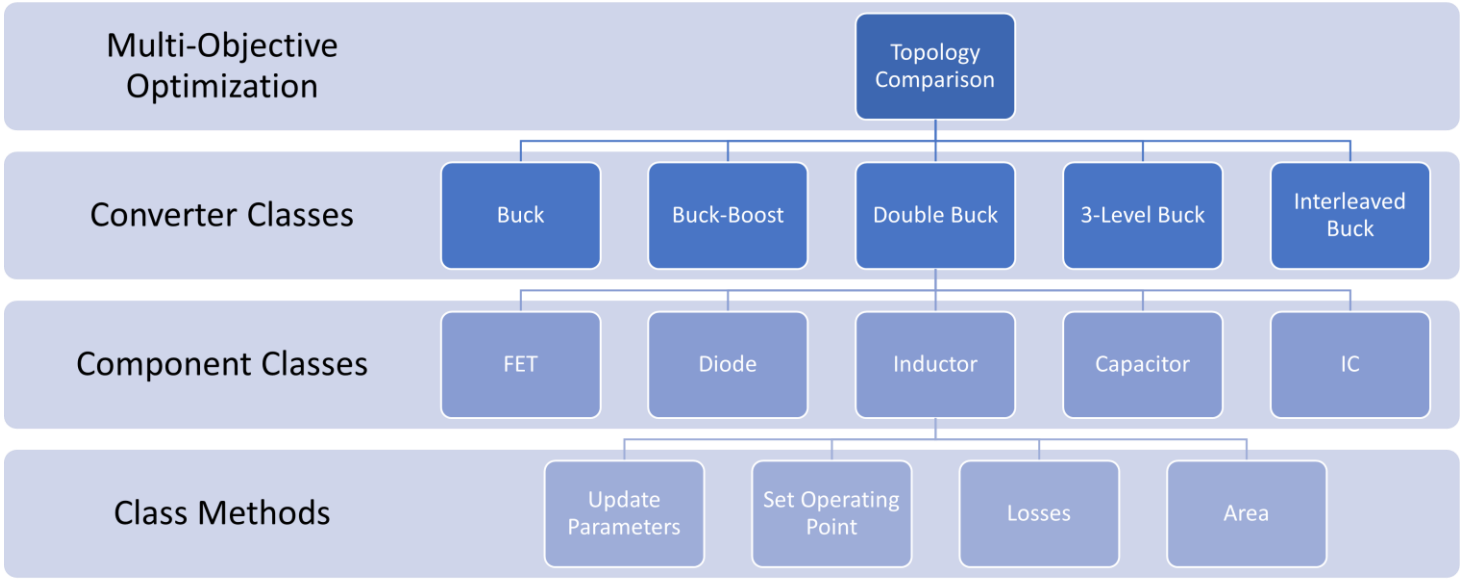






Available for purchase and as reference design!

Optimization Framework



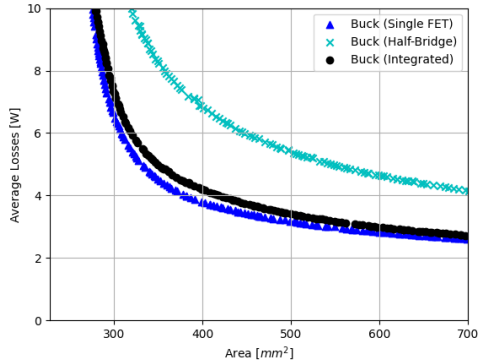
Optimization Framework

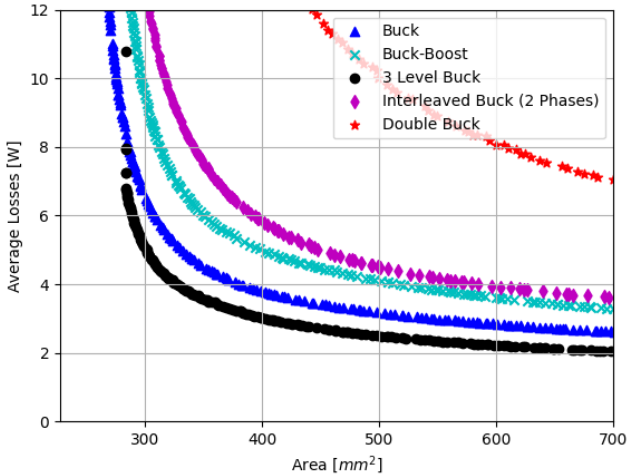
- Component classes: FET, Diodes, Diodes, Capacitors, ICs
  - Attributes: Parameters, operating conditions
  - Methods: Losses, occupied area
- Converter classes:
  - Attributes: Input voltage, output voltage, output power
  - Methods: Operating conditions, sizing capacitors
- Multi-Objective Optimization:
  - Input variables: Devices, switching frequency, inductance, capacitance
  - Minimization: Losses, occupied area (pareto front)

Optimization Framework: Results

High-Current Module:

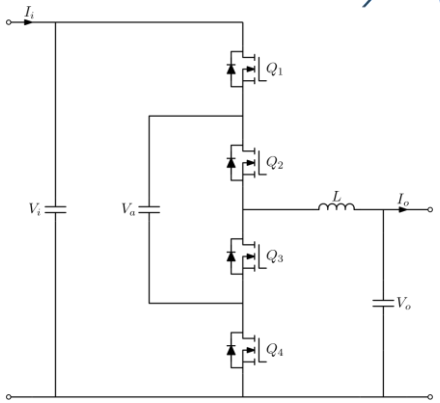
- Input voltage: 48 V
- Output voltage: 5 V
- Output current: 10 A
- Voltage ripple: 1%

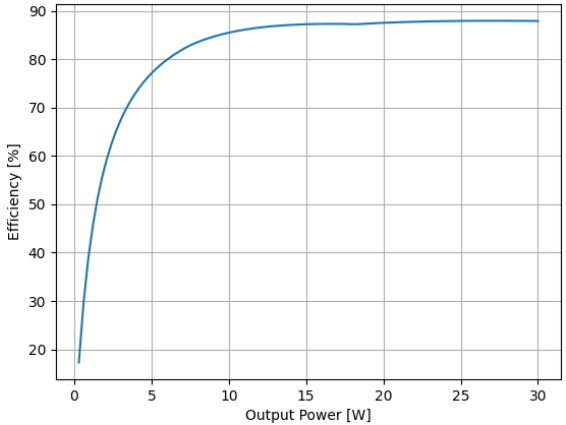


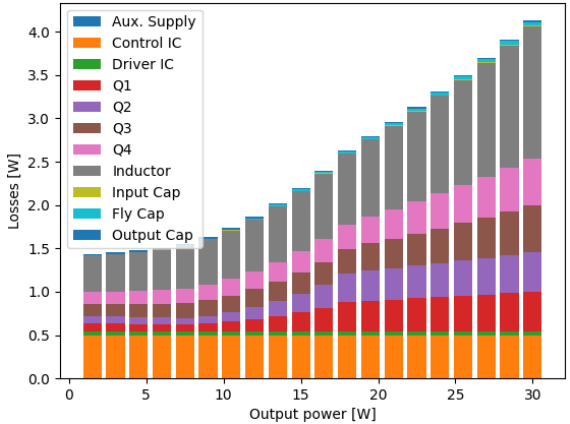


Optimization Framework: 3-Level

- f_s = 1.3 MHz
- L = 211 nH
- Area = 225 mm^2
- High side: EPC2214
- Low Side: EPC7002

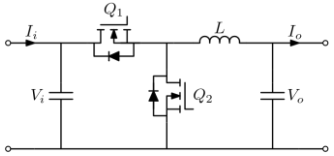




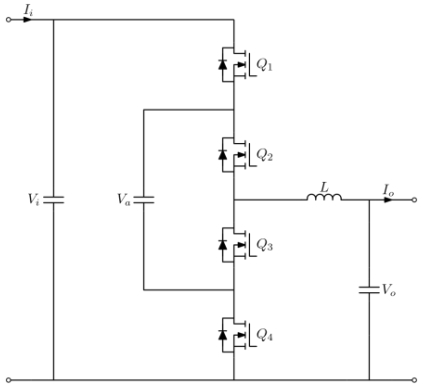


Experimental Verification: Topologies

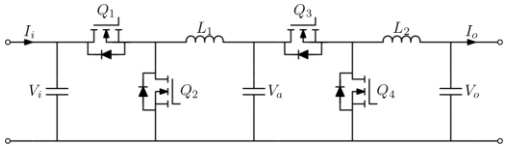
- Buck



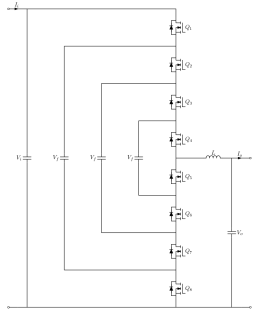
- 3-Level Buck



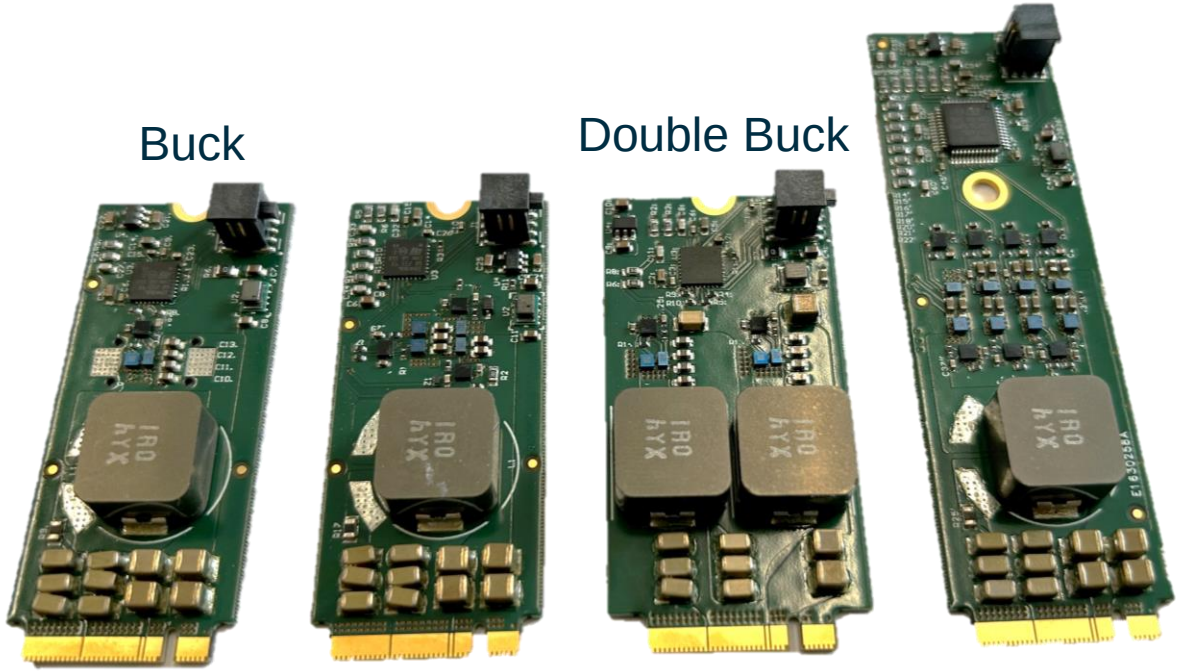
- Double Buck



- 5-Level Buck

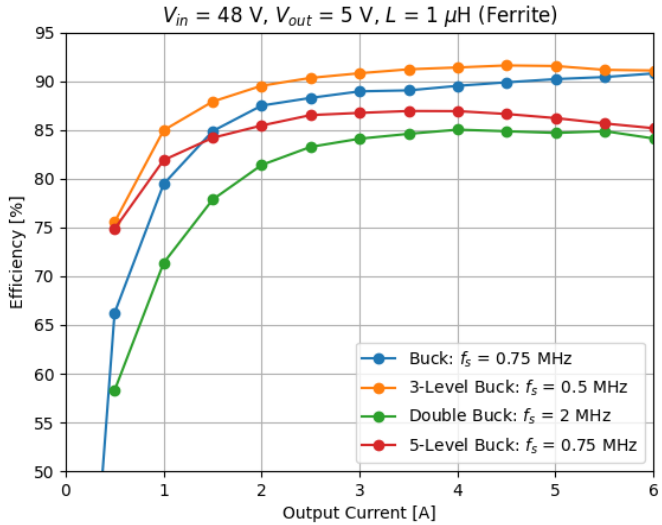


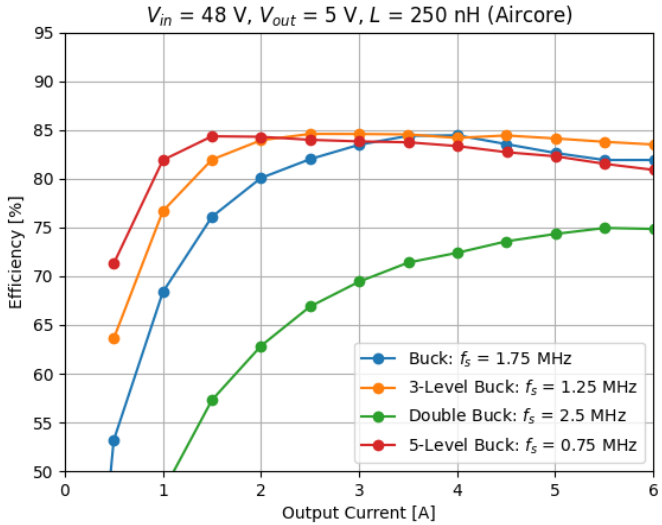
Experimental Verification: Prototypes



All prototypes are designed with an STM32 microcontroller, commercial GaN switches, and commercial drivers.

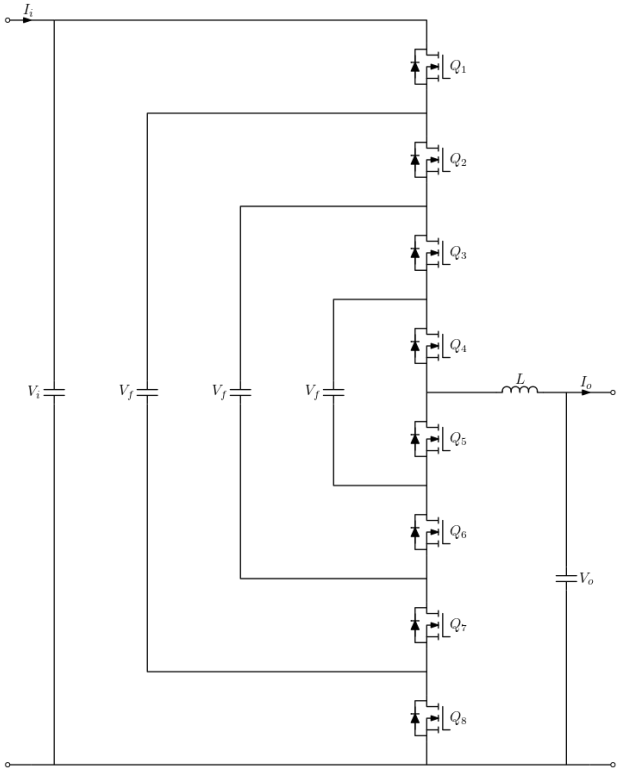
Experimental Verification: Results



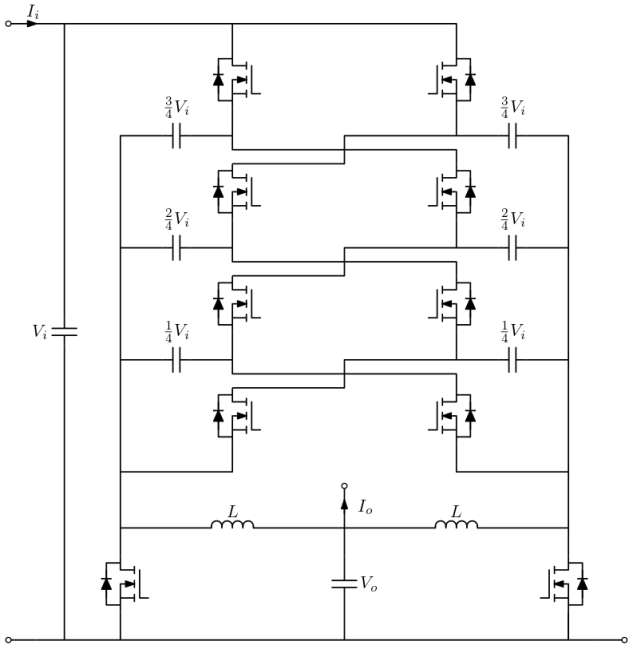


Each prototype's switching frequency was individually optimized.

Experimental Verification: 48 V to 1 V

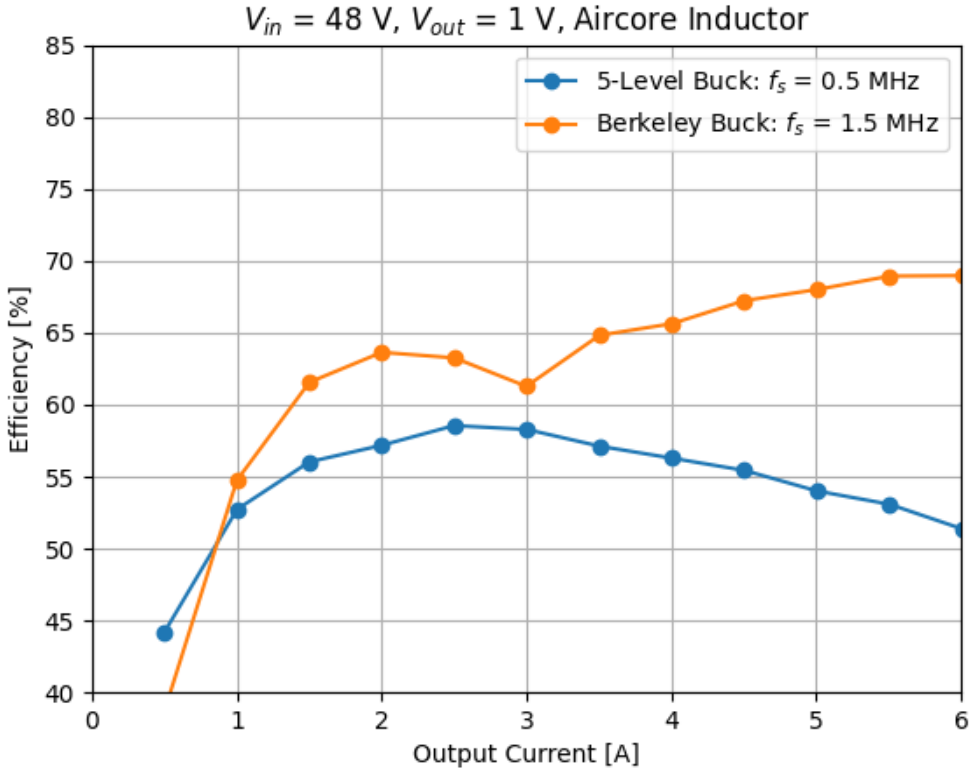


5-Level Buck



Berkeley Buck

Experimental Verification: 48 V to 1 V



Very preliminary results!

Conclusions

- Two volume optimized bPOL48V module were presented
  - PCB Inductor Module: Up to 95% efficiency in 3960 mm^2
  - Ferromagnetic Module: Up to 97% efficiency in 9240 mm^2
  - Available for purchase or as reference design
- An optimization framework was developed
  - Multi-objective minimization of losses and area
  - Comparison of power electronic conversion topologies
- Prototypes were built and tested
  - 3-Level Buck converters show promise from 48 V to 5 V
  - Berkeley Buck converters show promise from 48 V to 1V

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