UNIVERSITY of TORONTO

WÜRTH ELEKTRONIK

Wide Input DC/DC Converters

03.10.2016 M.Haug

outline

- Introduction and motivation
- Comparison of prior art PoL topologies
- Novel flying capacitor based topology
- Experimental results
- Conclusion

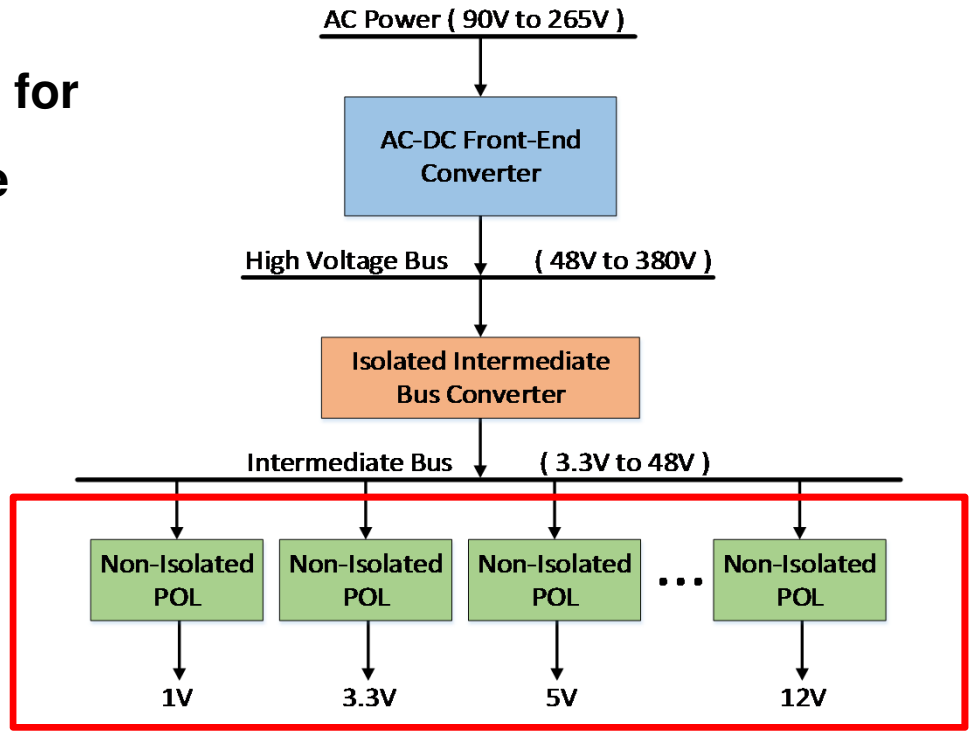
Introduction and motivation

Scope:

- **Non-isolated PoL DC/DC converters for intermediate bus power architecture**

Requirements:

- **High power efficiency**
- **Small solution size**
- **Good dynamic performance**



Intermediate bus power architecture for PoL applications

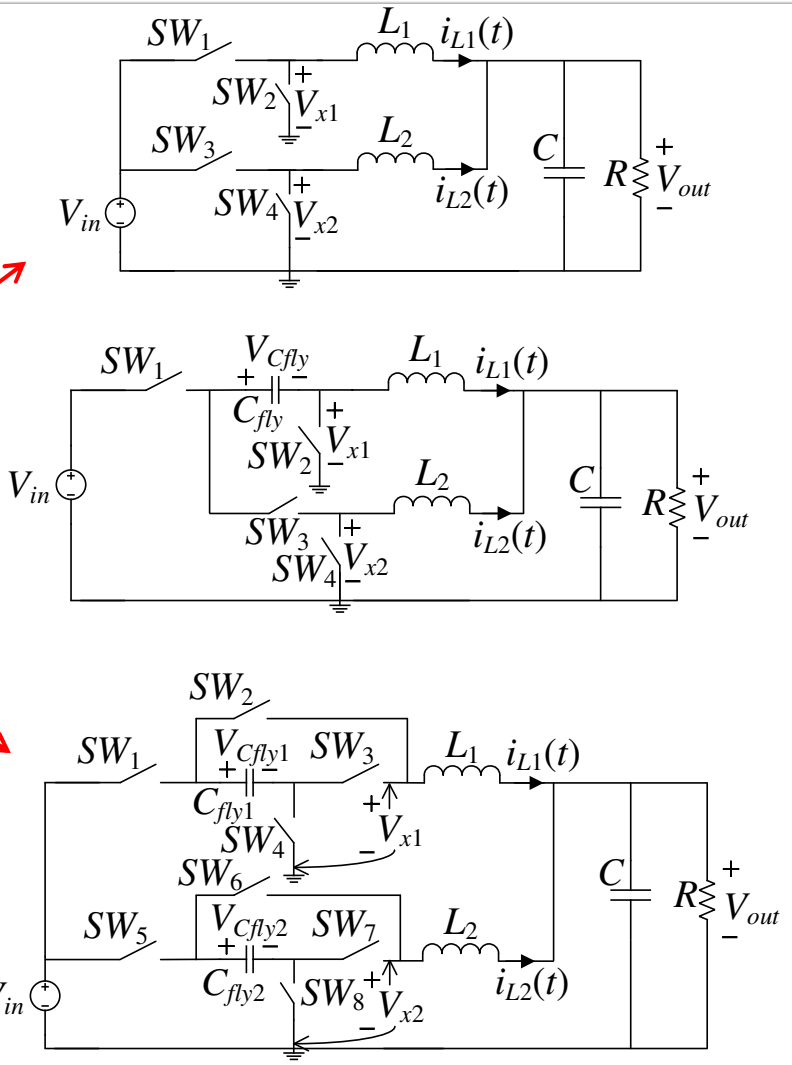
Common approach: dedicated PoL converter for each combination of Vin/Vout

Can we find a universal topology which can serve them all?

Comparison of prior art PoL topologies - I

Evaluated topologies:

- **2-Phase interleaved buck converter**
- **Double step-down buck converter**
- **2-phase 3-level buck converter**



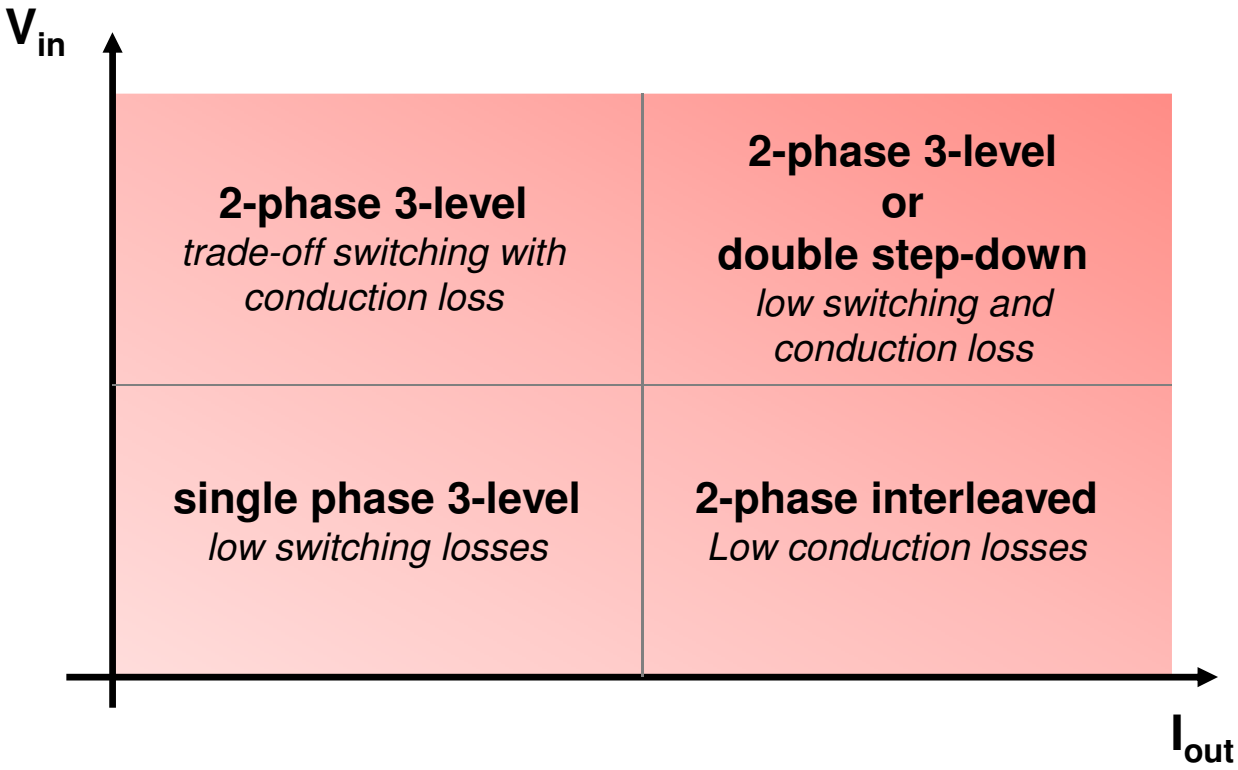
Prior art PoL topologies

Comparison of prior art PoL topologies II

topology	pros	cons
2-Phase interleaved buck	• wide range step down conversion • simple structure	• all 4 switches need to be rated to the full input voltage • large L at high V_{in} and conversion ratio close to 0.5
Double step-down buck	• good for high step-down ratios • 3 of 4 switches can be rated to $V_{in}/2$ • smaller L needed for same current ripple	• maximum conversion ratio: 0.25
2-phase 3-level buck	• smaller L needed for same current ripple • all switches can be rated to $V_{in}/2$	• more complex structure • higher number of switches (8)

Comparison of prior art PoL topologies III

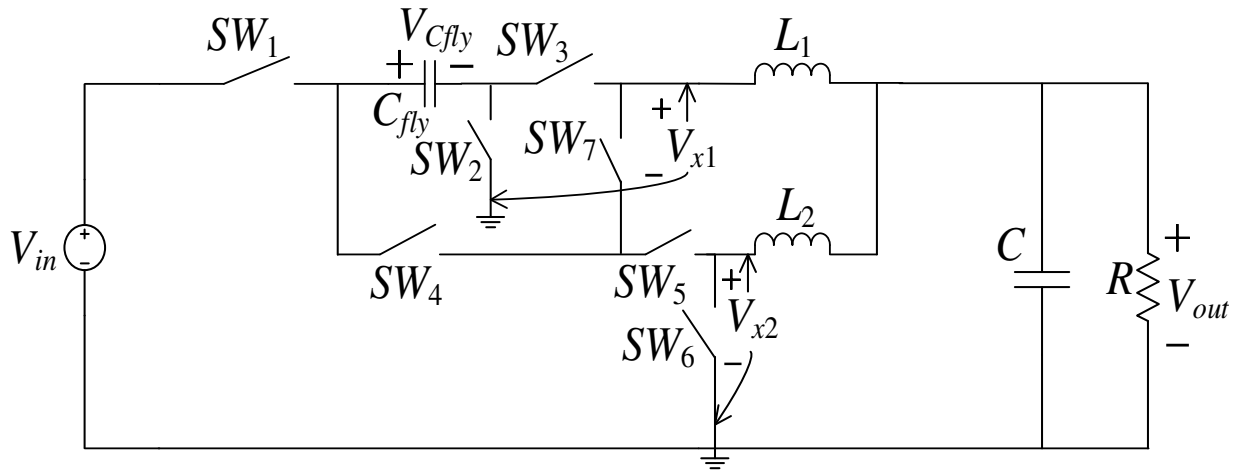
preferred topology depending on operating conditions



Can we find an universal approach which combines the advantages of these different topologies?

Novel flying capacitor based topology I

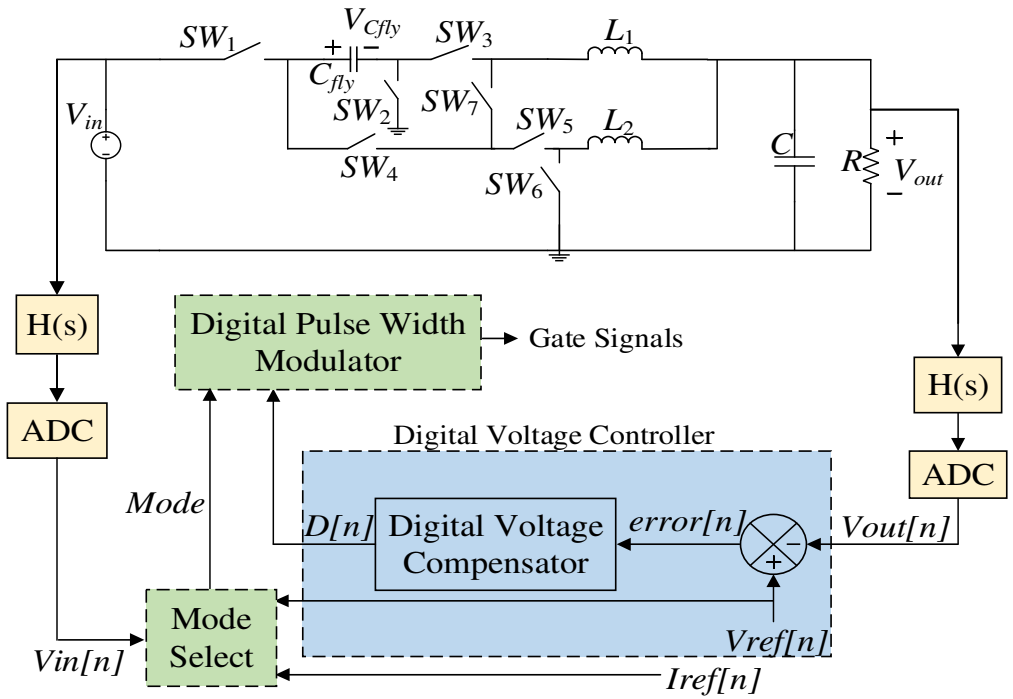
Novel 7-switch flying capacitor (7SFC) based multi-level buck converter



Combines following advantages:

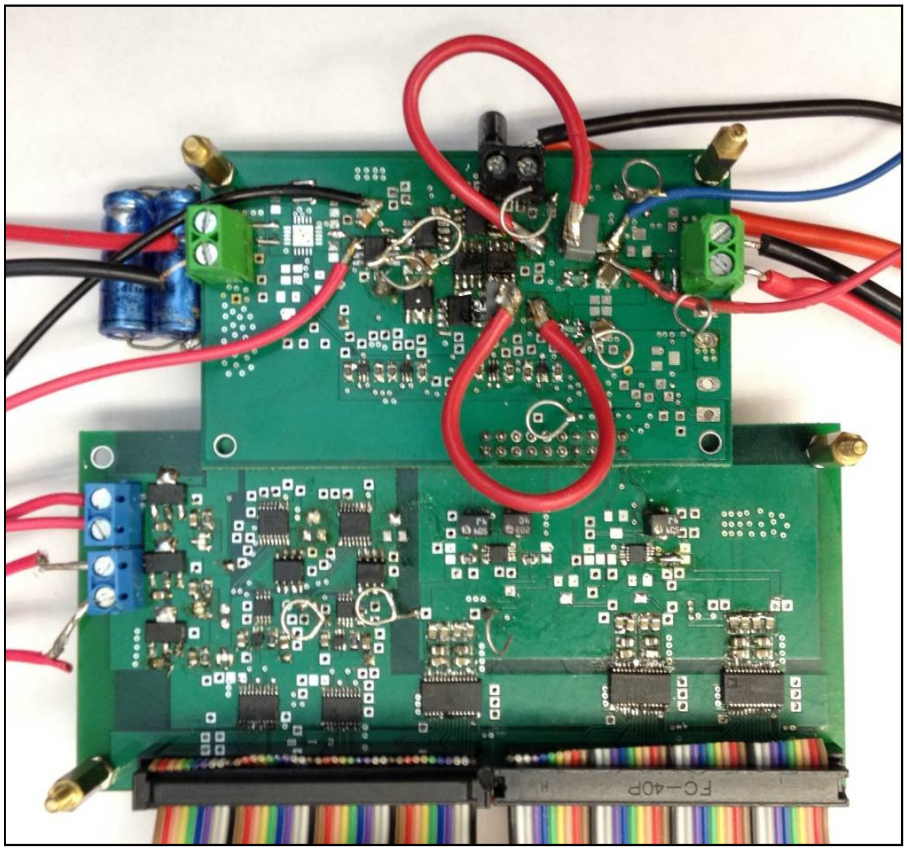
- **Wide conversion range of the interleaved buck**
- **High step-down advantages of double step down buck**
- **Reduced voltage ratings and switching voltages of the 3-level converter**

Novel flying capacitor based topology II



- **Digital controller to implement multiple modes of operation**
- **Mode select block determines operating mode based on V_{in}, V_{out}, I_{out}**

Experimental results – discrete prototype

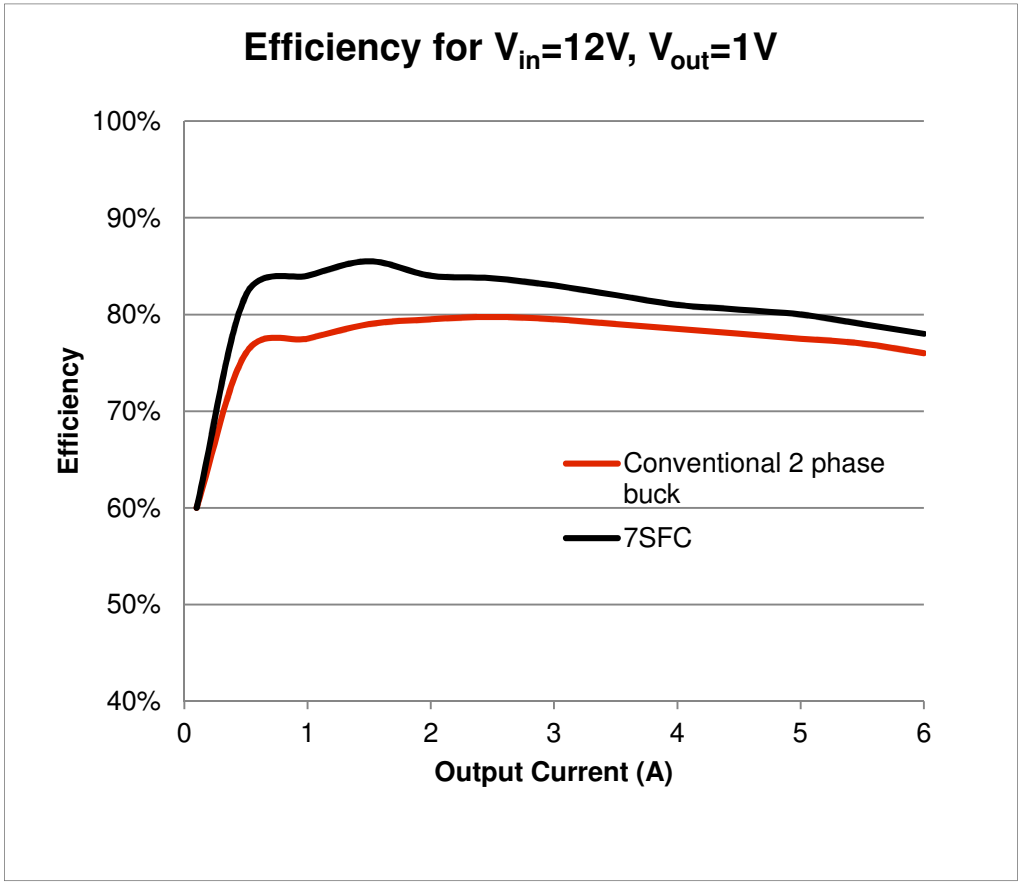


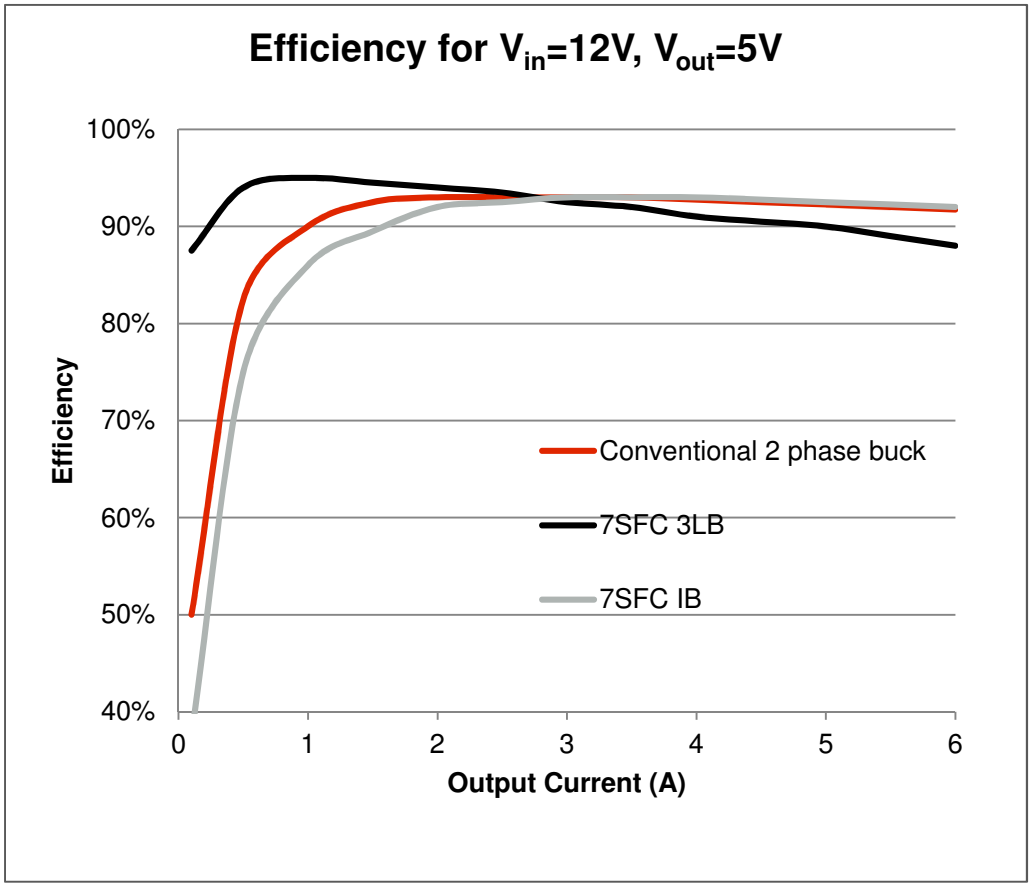
f_{SW} = 800kHz

$L_1 = L_2$ = 1µH (7SFC)

Discrete prototype of 7SFC topology (digital controller realized by FPGA)

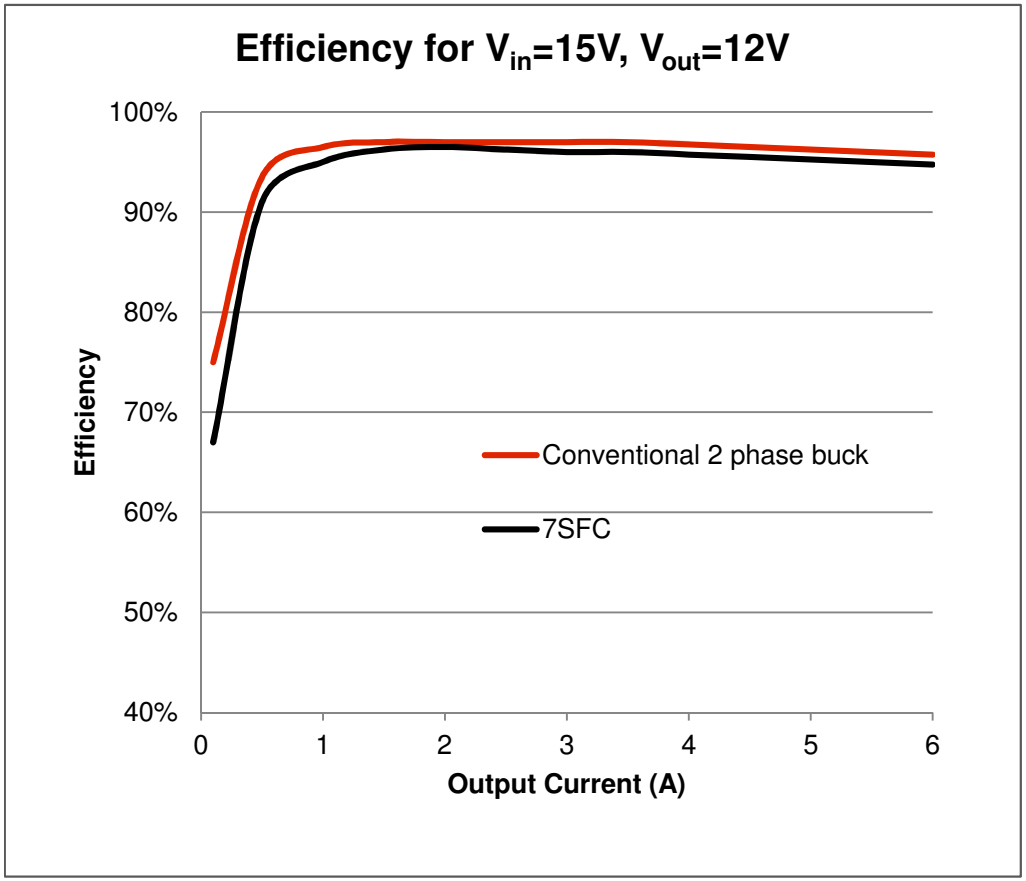
Experimental results – efficiency I

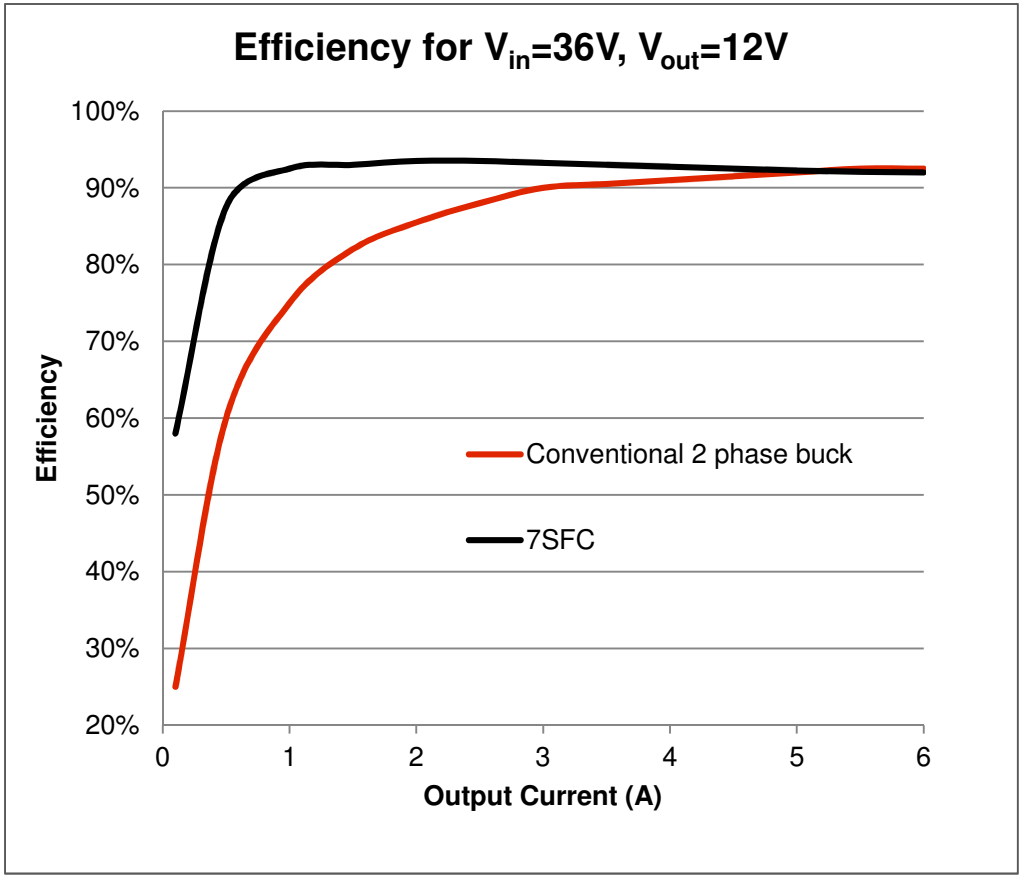




Experimental efficiency comparison between conventional 2-phase buck and 7SFC buck

Experimental results – efficiency II





Experimental efficiency comparison between conventional 2-phase buck and 7SFC buck

size comparison

	7SFC vs Conventional buck
inductance	-33%
output capacitance	-33%
silicon area [1)]	-56%

[1)] assumption: silicon area proportional to $V_{in,max}^2$

conclusion

Presented novel 7-switch flying capacitor multi level buck converter shows significant advantages in terms of power efficiency and size compared to conventional 2-phase interleaved buck thanks to:

- switch voltage reduction by $V_{in}/2$
- increased complexity together with operating-condition dependent changes of the switching sequence
- flying capacitor based approach
- reduced inductor and output capacitor requirement

acknowledgement

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