High Power Fully Regulated Eighth-brick DC-DC Converter with GaN FETs

John Glaser, Johan Strydom, David Reusch

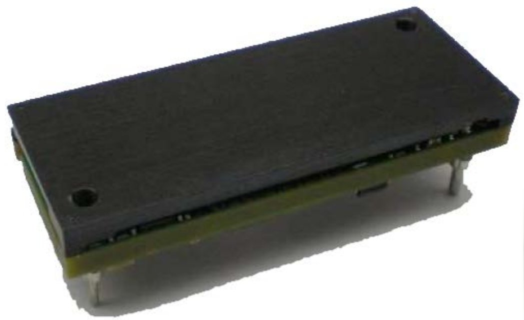
Efficient Power Conversion Corporation

Overview

- Existing eighth-brick technology
- Design goals
- Benefits of 4th-generation eGaN FETs
- Converter design
- Experimental results
- Potential Improvements
- Conclusion

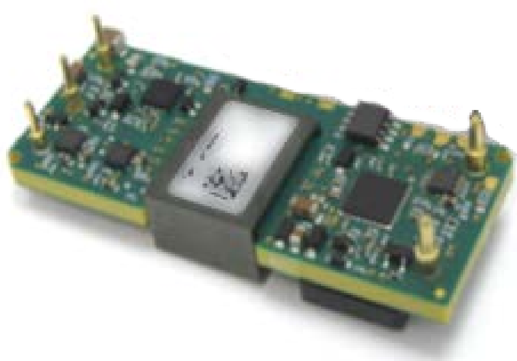
Some typical high-power *regulated* eighth-bricks

V_{in}	**38-55**
V_{out}	9.6
I_{out}	31
P_{out}	**300**
η_{max}	96.1%



V_{in}	**42-60**
V_{out}	12
I_{out}	25
P_{out}	**300**
η_{max}	96%

V_{in}	**40-60**
V_{out}	12
I_{out}	25
P_{out}	**300**
η_{max}	95.5



V_{in}	**45-55**
V_{out}	9.6
I_{out}	33
P_{out}	**320**
η_{max}	95.5%

eGaN FETs can boost power up to 500W and beyond!

Why GaN FETs?

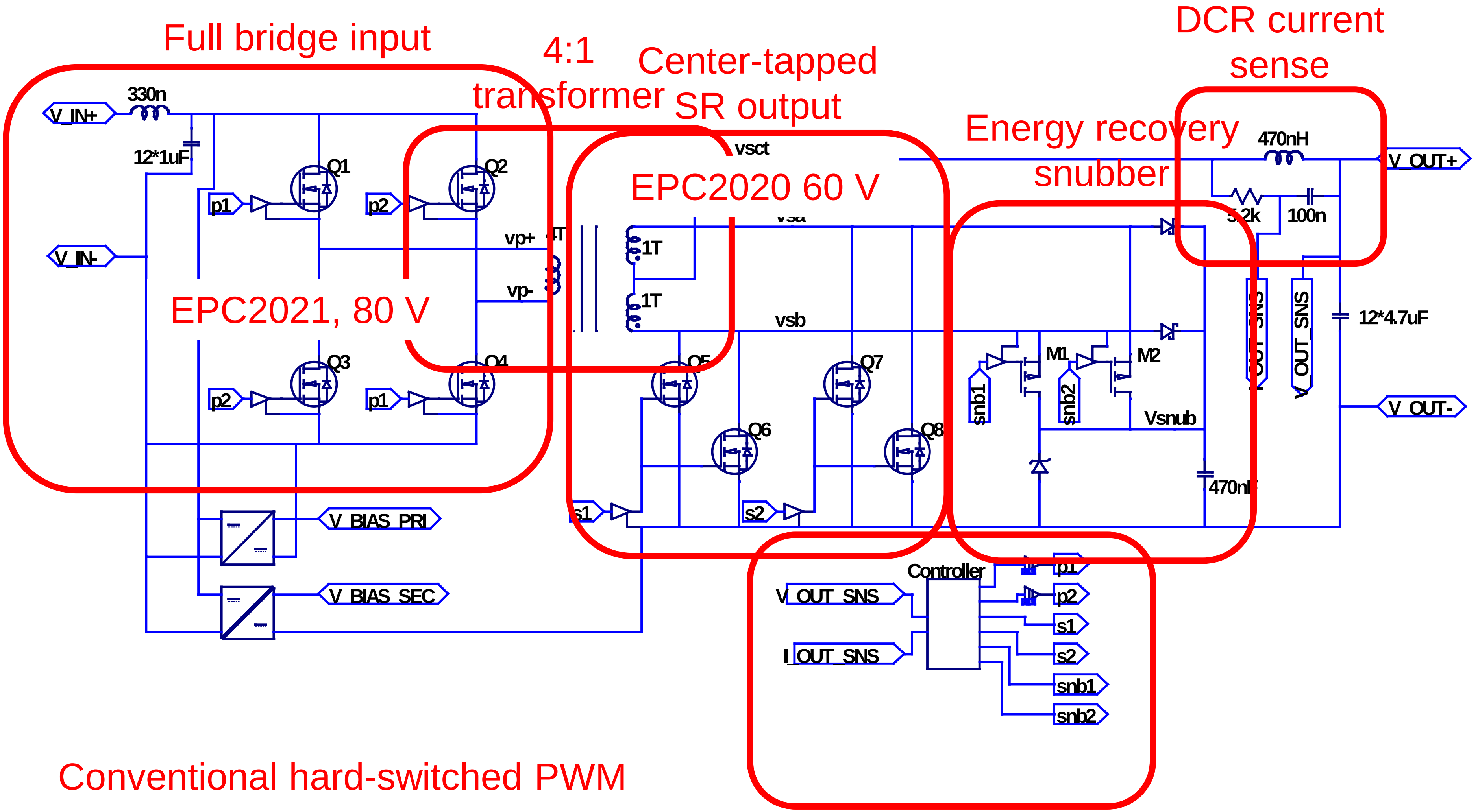
- Lowest switching loss
  - Fastest switching speed
  - Lowest charge, no reverse recovery ($Q_{rr} = 0$)
- Low $R_{DS(on)}$
  - Reduced conduction loss
- Simple gate drive
  - Normally off
  - 5V gate simplifies design
  - Low gate drive power

Prove the benefit of eGaN FETs with eighth-brick demonstration converter!

500 W Eighth-brick Specifications

- 500 W output at 12 V
- 48 V to 60 V input range (52 V nominal)
- Fully regulated
- Isolated
- > 96% efficient **at full load**
- DOSA-compliant footprint
- Off-the-shelf parts

Design Approach



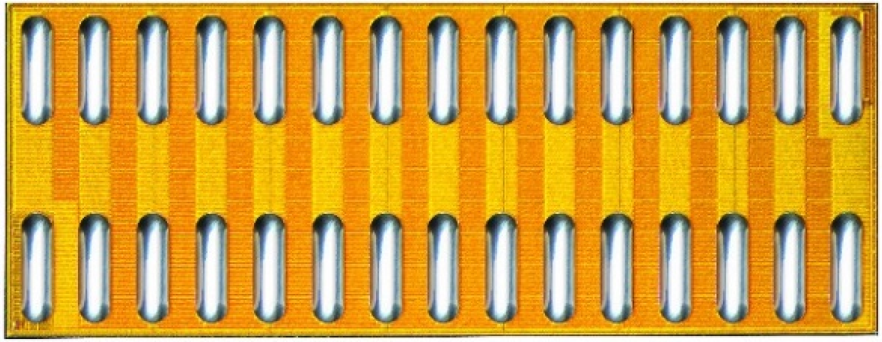
Conventional hard-switched PWM

300 kHz primary switching frequency

Large area eGaN FETs

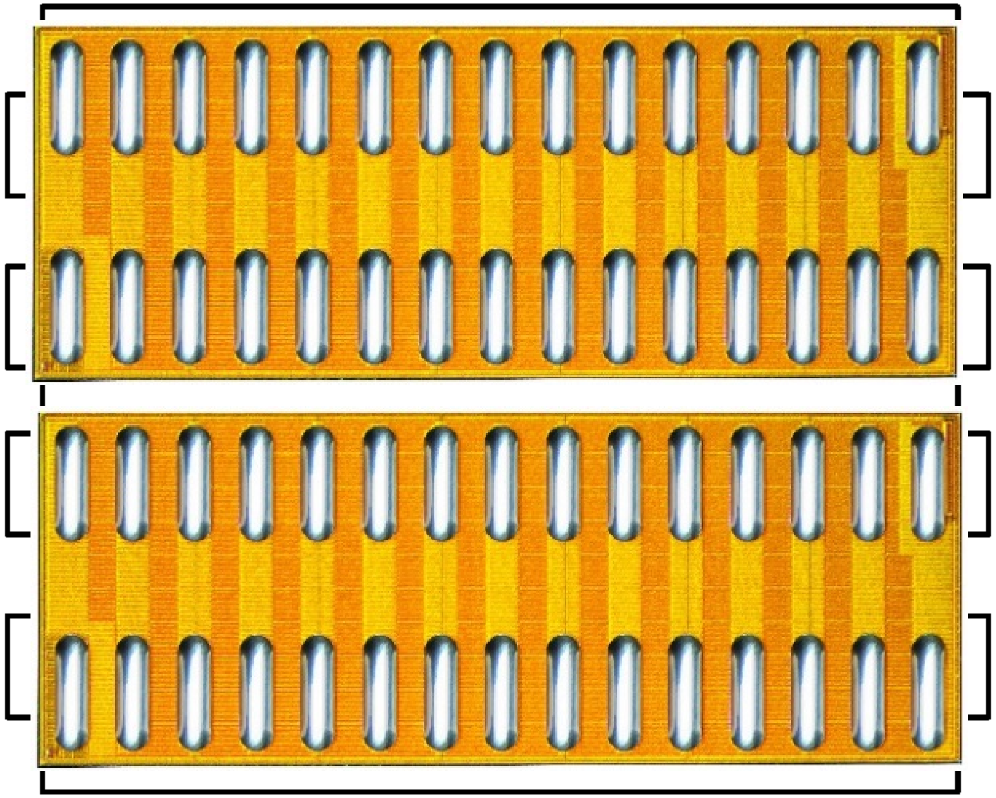
Fourth Gen eGaN FETs:

- Lowest $R_{DS(on)}$ per area
- Lowest charge per area
- Lowest parasitic inductance



Part	Max V_{DS} [V]	I_D [A]	Max $R_{DS(on)}$ [mΩ]
EPC2020	60 V	60 A	2.0
EPC2021	80 V	60 A	2.5
EPC2022	100 V	60 A	3.2
EPC2023	30 V	60 A	1.3
EPC2024	40 V	60 A	1.5

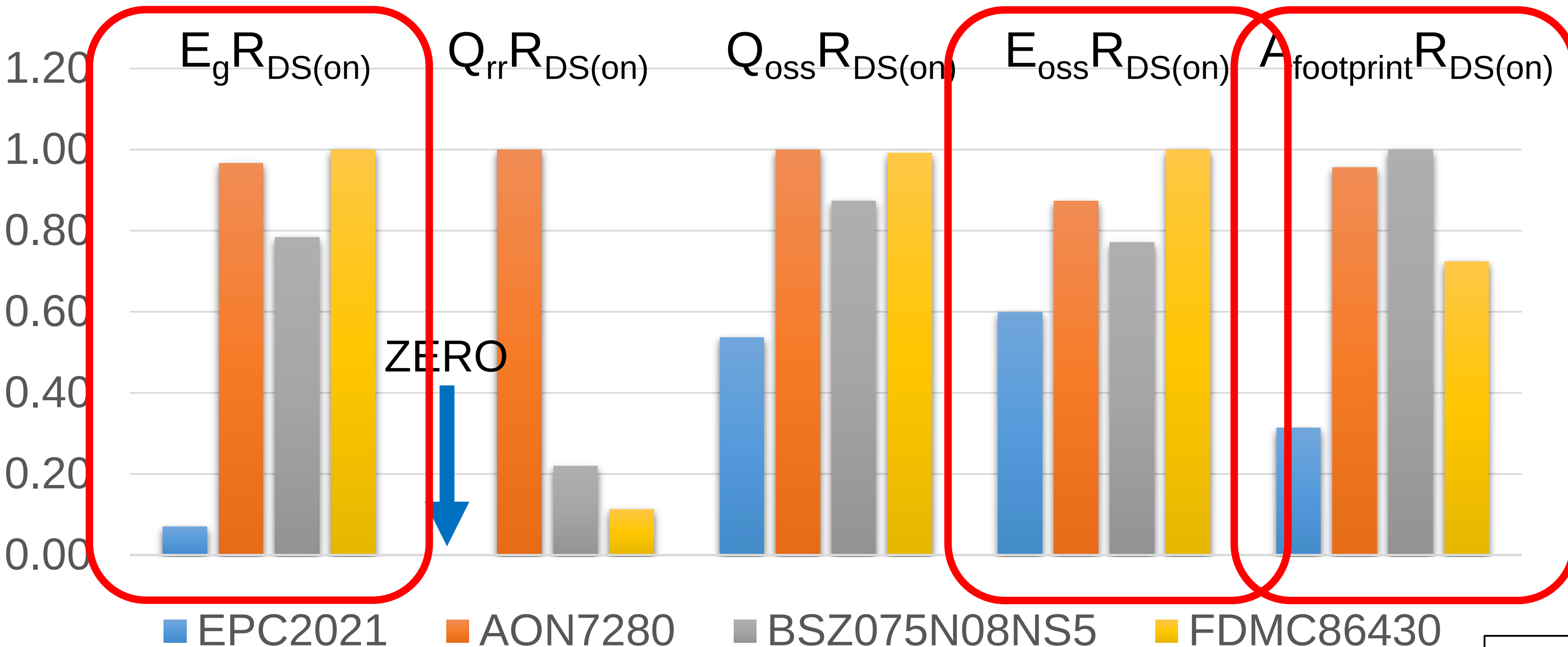
Don’t forget about size!



5X6 PQFN

80 V FOM Comparison

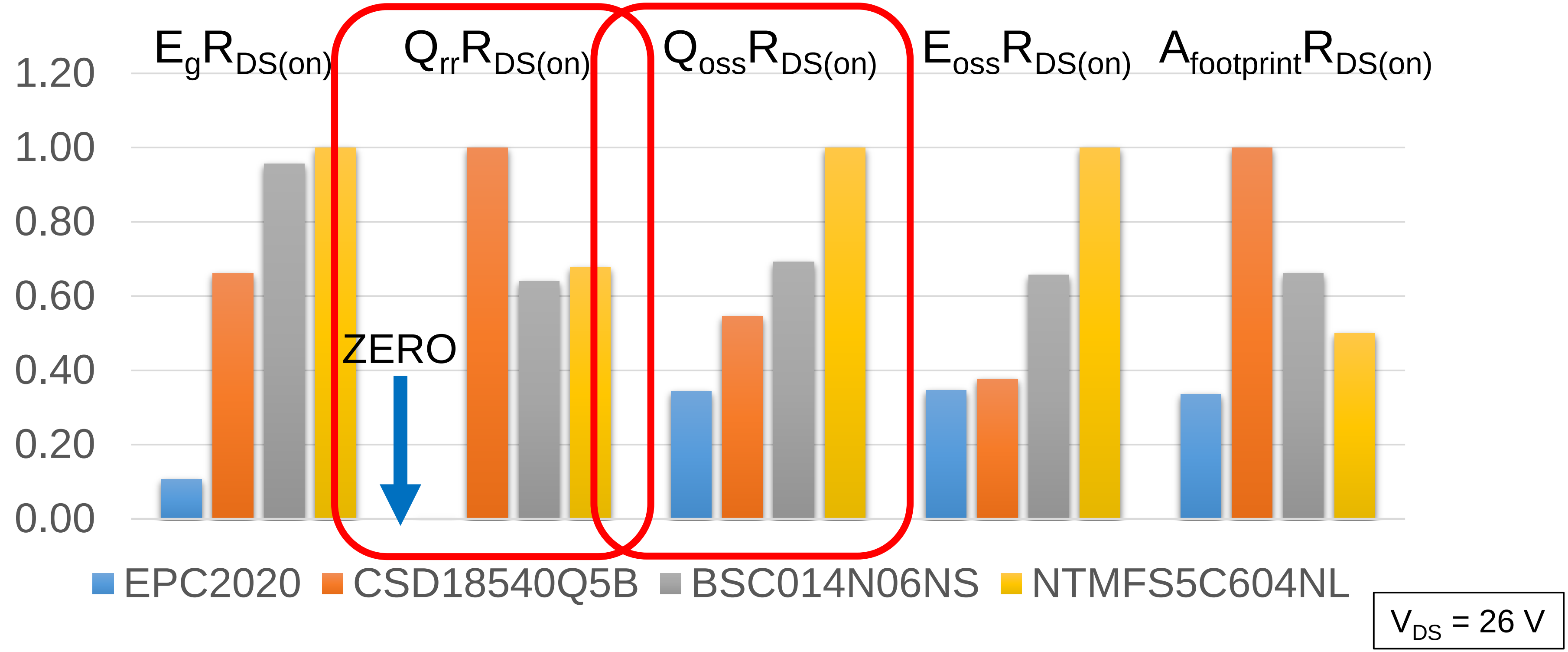
Part	$E_gR_{DS(on)}$ [nJ*mΩ]	$Q_{rr}R_{DS(on)}$ [nC*mΩ]	$Q_{oss}R_{DS(on)}$ [nC*mΩ]	$E_{oss}R_{DS(on)}$ [nJ*mΩ]	$A_{footprint}R_{DS(on)}$ [mm^2*mΩ]
EPC2021	135	0	123	2682	25.0
AON7280	1836 (13.6x)	1102	229 (1.9x)	3910 (1.5x)	76.3 (3.0x)
BSZ075N08NS5	1488 (11.0x)	242	200 (1.6x)	3453 (1.3x)	79.8 (3.2x)
FDMC86430	1900 (14.1x)	125	227 (1.8x)	4480 (1.7x)	57.8 (2.3x)



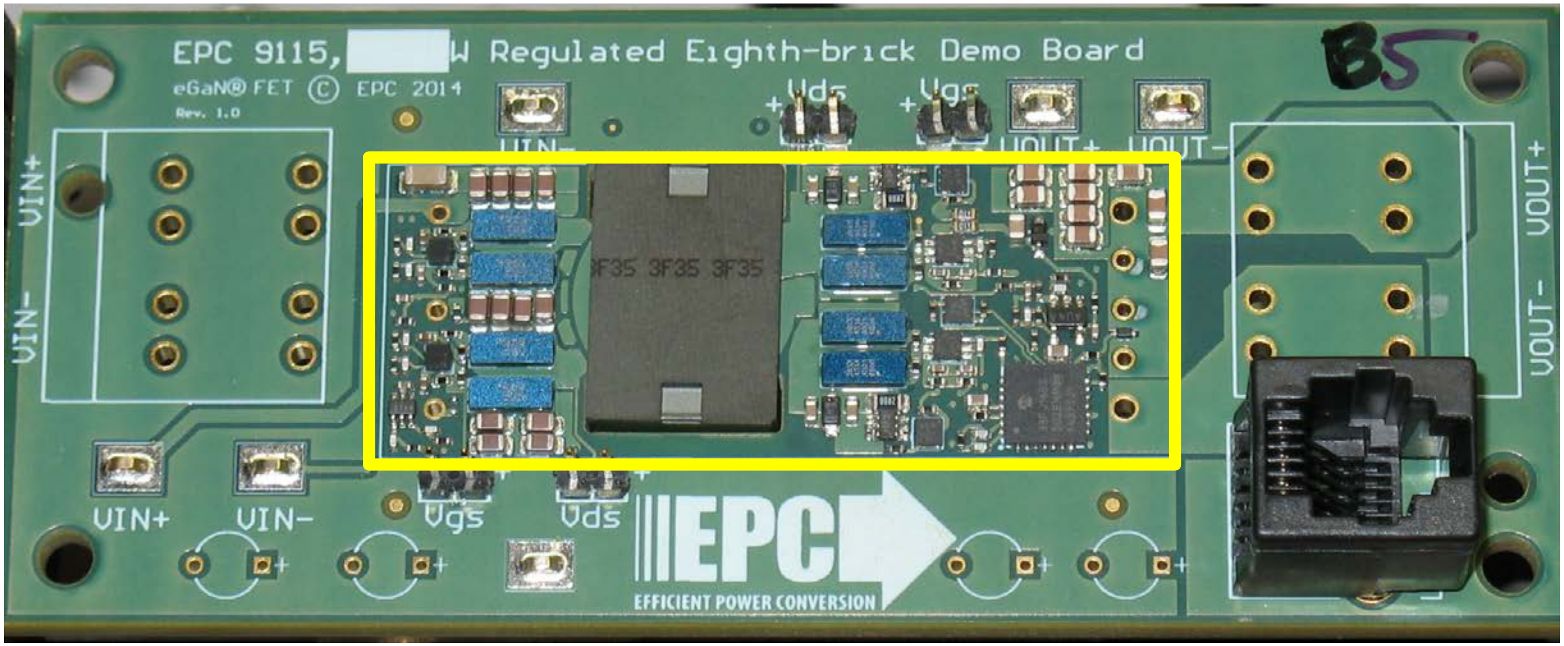
V_{DS} = 52 V

60 V FOM Comparison

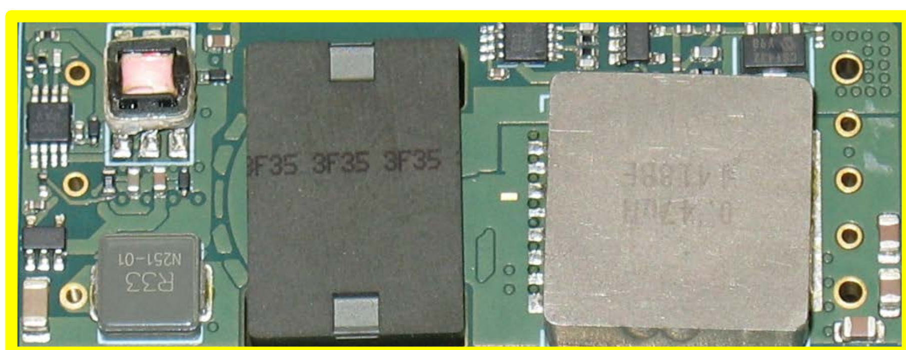
Part	$E_g R_{DS(on)}$ [nJ*mΩ]	$Q_{rr} R_{DS(on)}$ [nC*mΩ]	$Q_{oss} R_{DS(on)}$ [nC*mΩ]	$E_{oss} R_{DS(on)}$ [nJ*mΩ]	$A_{footprint} R_{DS(on)}$ [mm²*mΩ]
EPC2020	120	0	56	633	20.9
CSD18540Q5B	738 (6.2x)	261	89 (1.6x)	689 (1.1x)	62.2 (3.0x)
BSC014N06NS	1068 (8.9x)	167	113 (2.0x)	1199 (2.0x)	41.1 (2.0x)
NTMFS5C604NL	1116 (9.3x)	177	163 (2.7x)	1824 (2.7x)	31.1 (1.5x)



EPC9115 Demo Board Layout



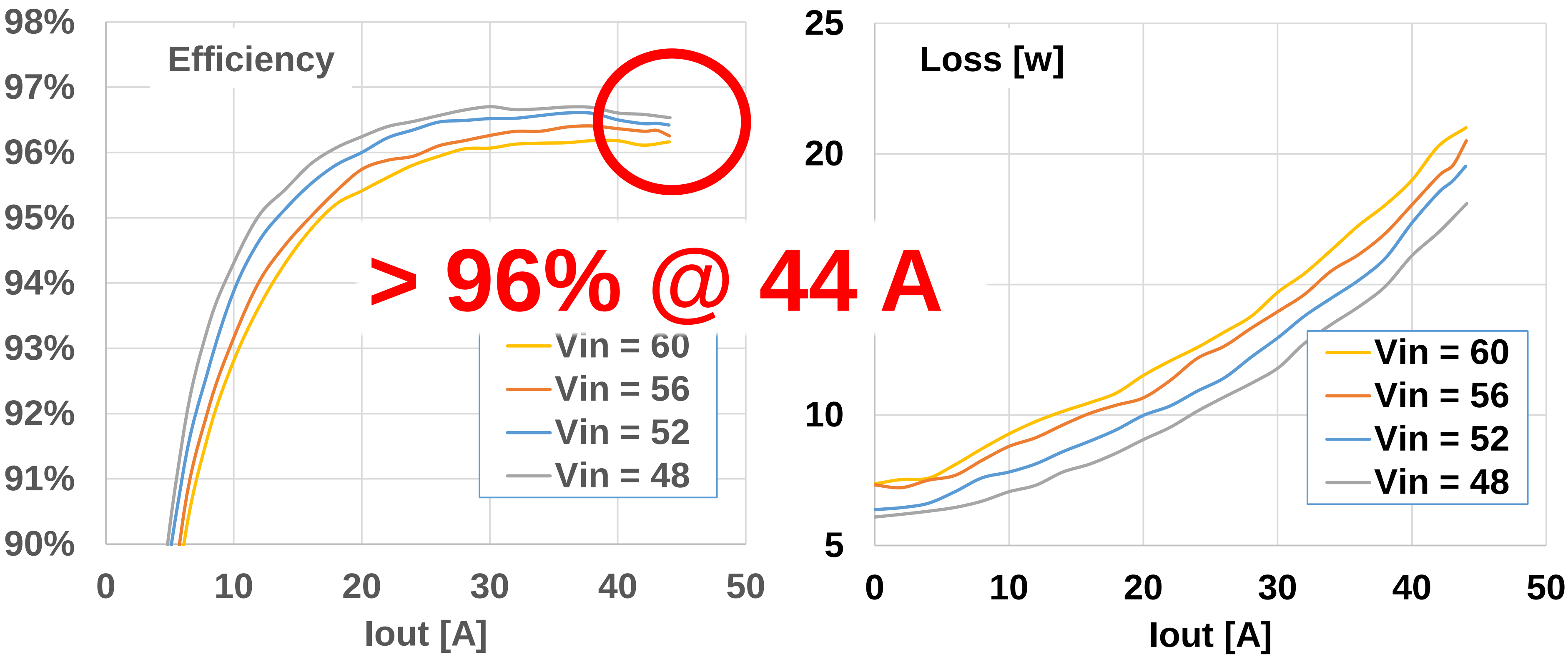
TOP and Bottom views



EPC9115 Performance Summary

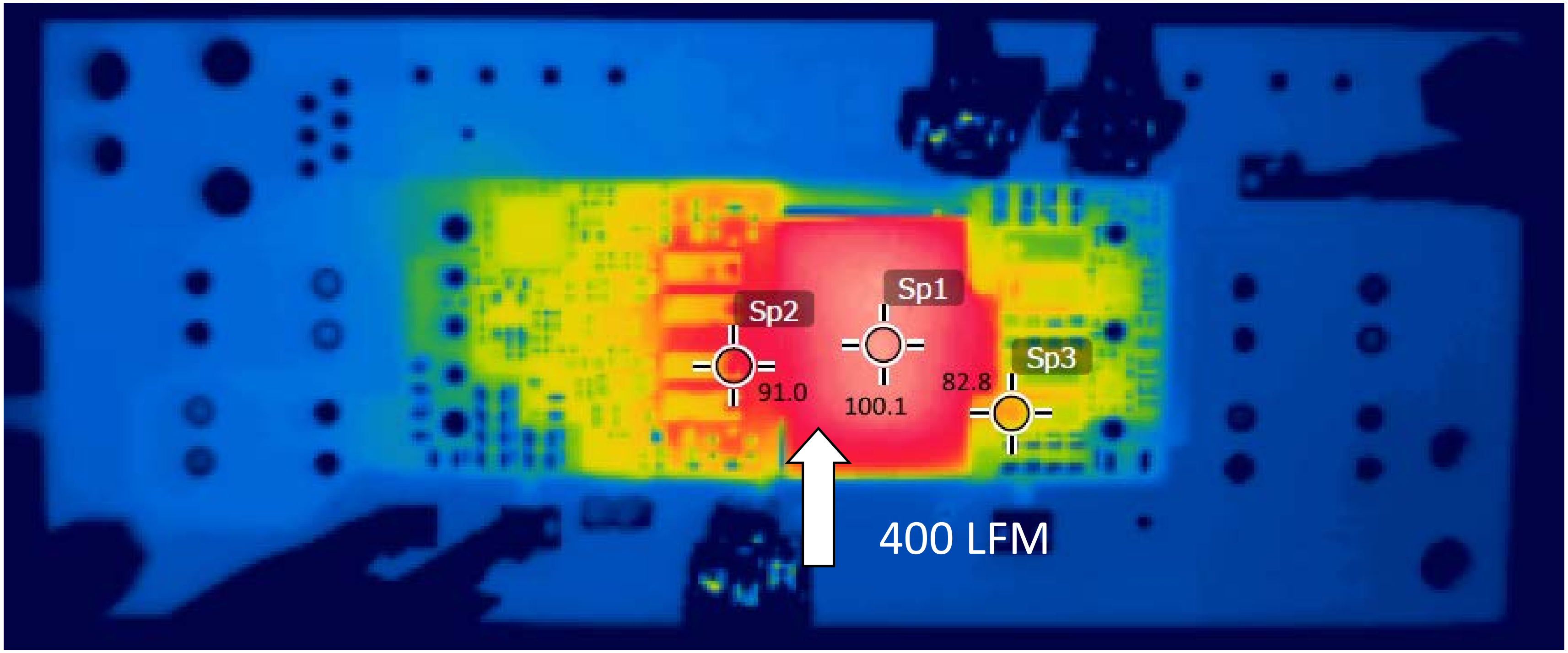
Parameter	Condition	Min	Typ	Max	Units
V_{IN}		48	52	60	V
V_{OUT}		11.4	12	12.1	V
I_{OUT}	~400 LFM, 25°C	0		42	A
f_{SW}	Primary side		300		kHz
Eff. (max)	V_{IN} = 48 V		96.7		%
Eff. (full load)	V_{IN} = 52 V		96.4		%

Typical Performance Curves



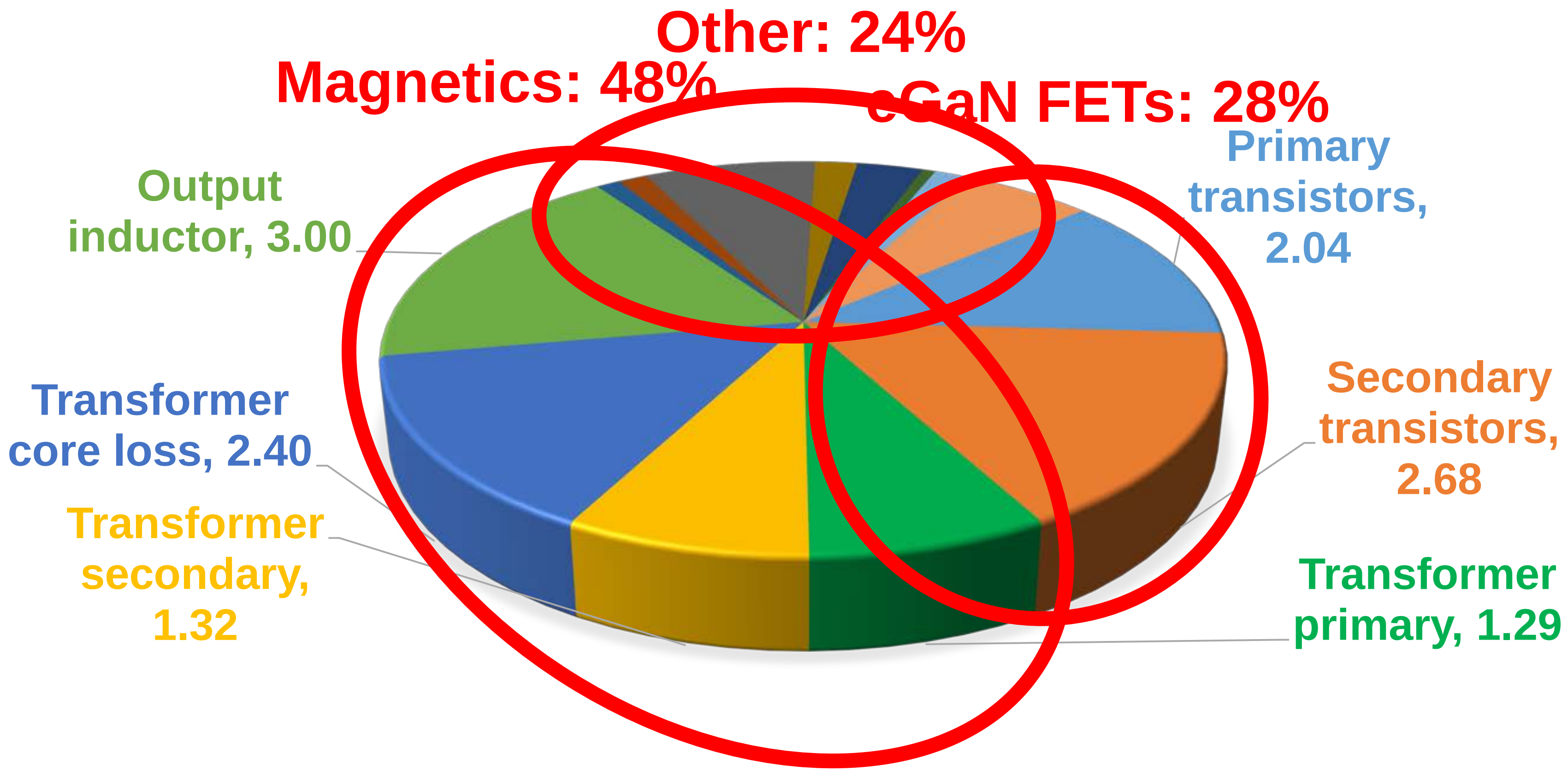
Operating conditions: 400 LFM (2 m/s) forced convection, ambient temperature 27°C, **thermal steady state**.

Nominal Thermal Image



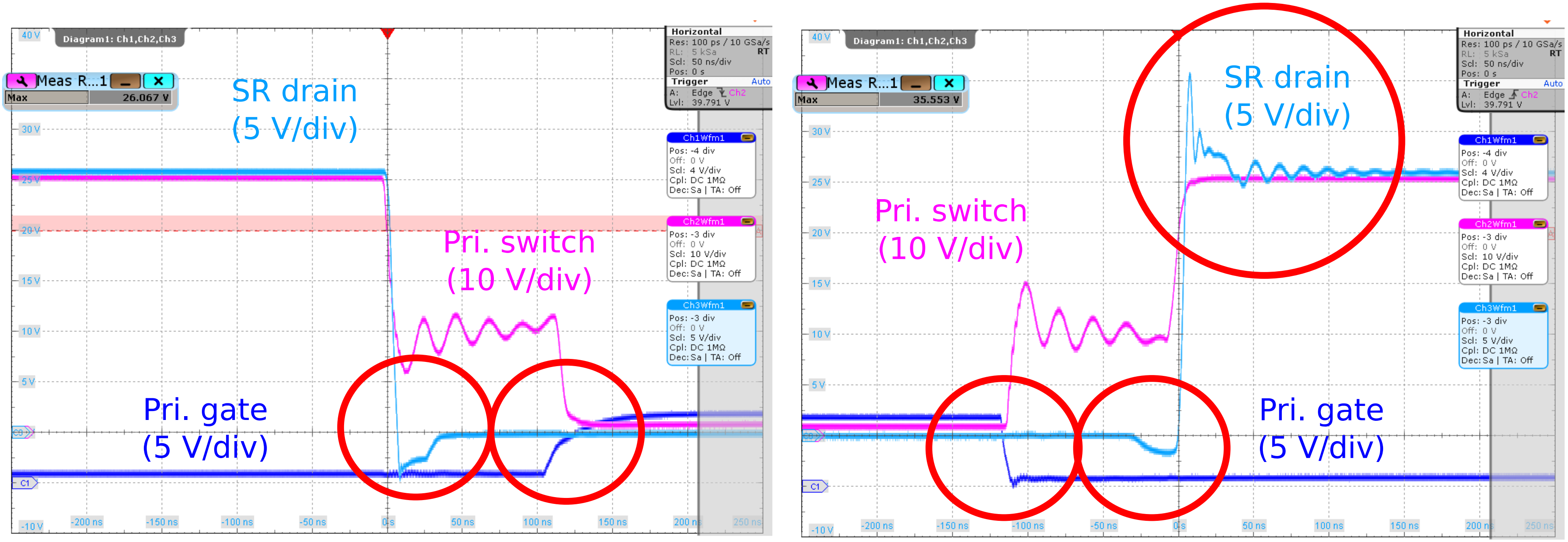
Operating conditions:400 LFM (2 m/s) forced convection, ambient temperature 27°C, **thermal steady state**.

Power loss breakdown (estimate)



Total: 16.6 W @ 100°C
Excludes: Vias, solder joints, traces

Switching transition waveforms



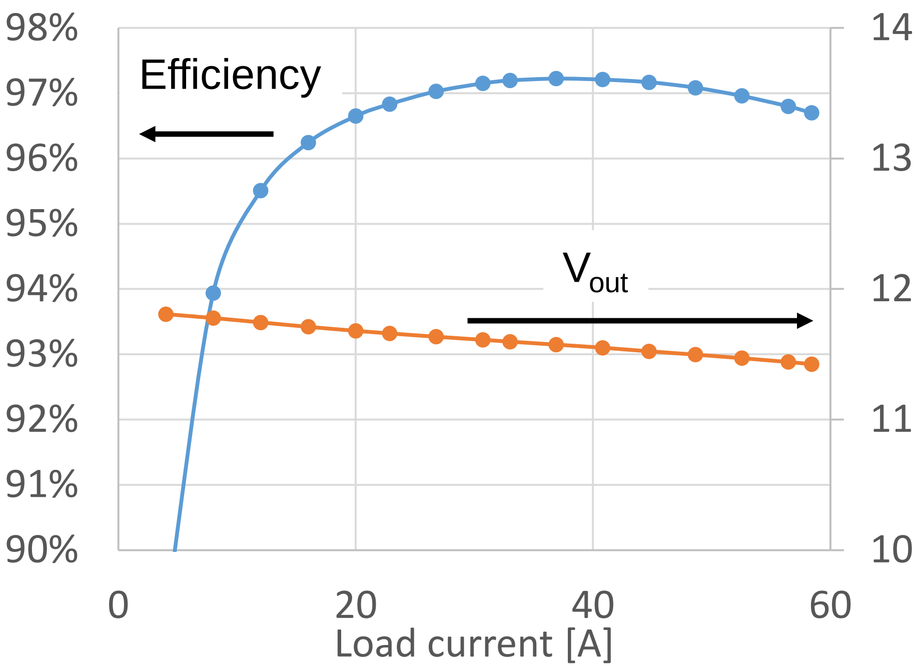
50 ns/div

$$V_{in} = 52\text{ V},\ V_{out} = 12\text{ V},\ I_{out} = 42\text{ A}$$

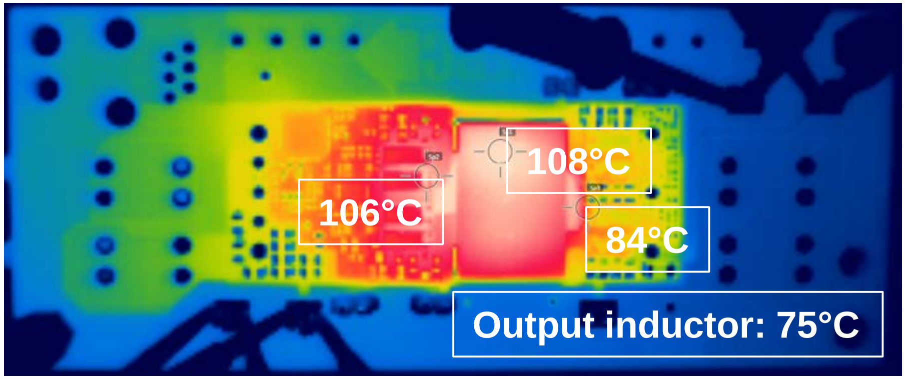
Ways to improve E-brick efficiency

- Improve bias supply (draws 1.3W, but bias load 0.6W)
- Add heat sink
- Optimize gate resistors
- Optimize dead time
- Use custom magnetics
- Optimize switching frequency

DCX performance with smaller inductor



48 V in, 58.4A out



667 W Output

Operating conditions: 400 LFM (2 m/s) forced convection,
ambient temperature 24°C, **thermal steady state**.

Changes from baseline design:

- Inductor: 470 nH, 0.9 mΩ → 210 nH, 0.3 mΩ
- D_{max}: 0.980 → 0.985 (Fixed)
- Deadtime: 25 ns → 15 ns

Summary
EPC9115 Eighth-Brick Converter

The power of a Quarter Brick…

in the footprint of an Eighth Brick

- Fully regulated, isolated converter hard-switched at 300 kHz
- 12 V, 42 A output with input range of 48-60 V
- Peak Efficiency: 96.7%
- Full Load Efficiency: 96.4% at 52 V

EPC
EFFICIENT POWER CONVERSION

The end of the road for silicon…..

is the beginning of the eGaN FET journey!