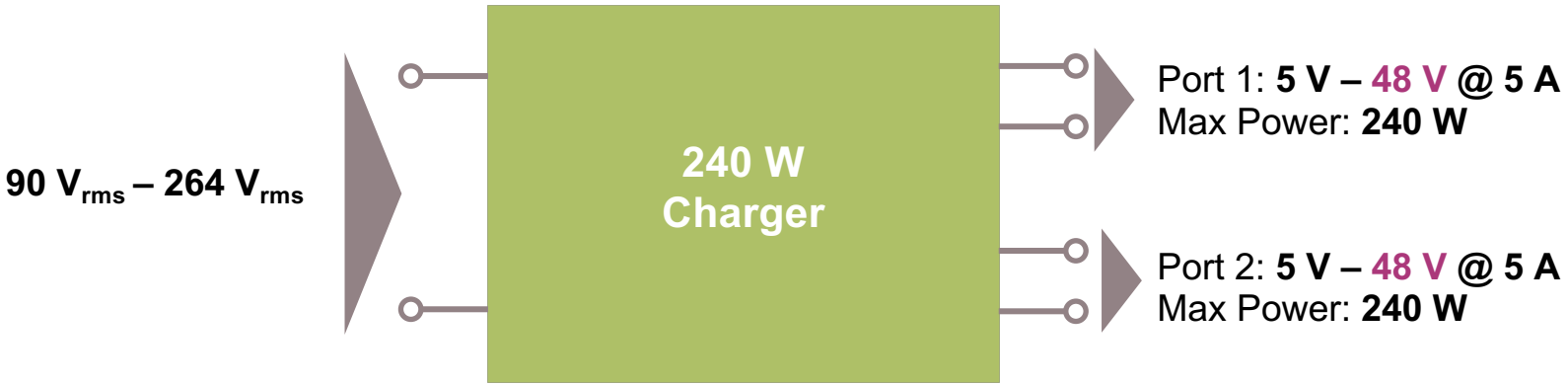
240 W USB-C charger with ultra-high power density and wide output voltage range

Kasper Matthias Joachim
Lead Principal Engineer Power Operated Systems
PCIM Europe 2022

Specifications of the 240 W ultra-high density charger generation

- State-of-the-art 65 W chargers soon no longer enough to charge all consumer devices
  → **Increase to future-proof 240 W**
- **Dual USB-C output ports** to support simulatenous charging of two mobile devices
- Increase of **output voltage to 48 V** (USB PD Rev. 3.1)



Challenges:
- 240 W power → PFC requirement
- Wide input & output voltage ranges
- Dual output
- 90 V_{rms} thermally most critical

Charger specifications become more similiar to other applications with 48 V and > 200 W like SmartTVs or AIO PCs!

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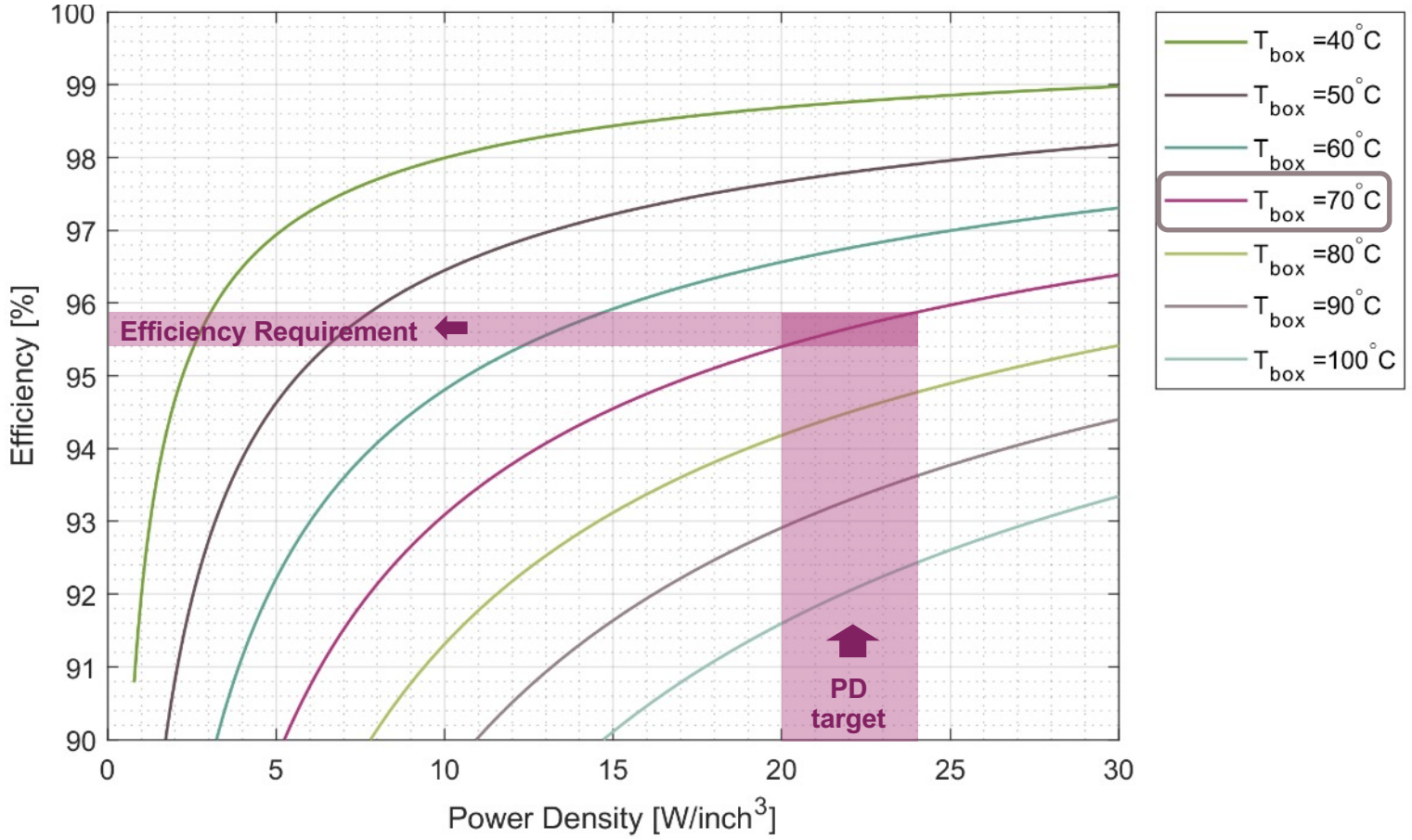
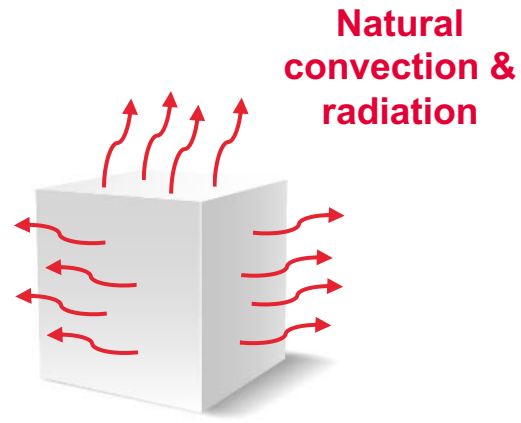
Efficiency & power density performance target for maximum case temperature

Increasing **power density** requires **higher efficiency** to keep **case temperature within limits**!





Cooling capability is proportional to surface area
→ Lower adapter volume requires lower losses!

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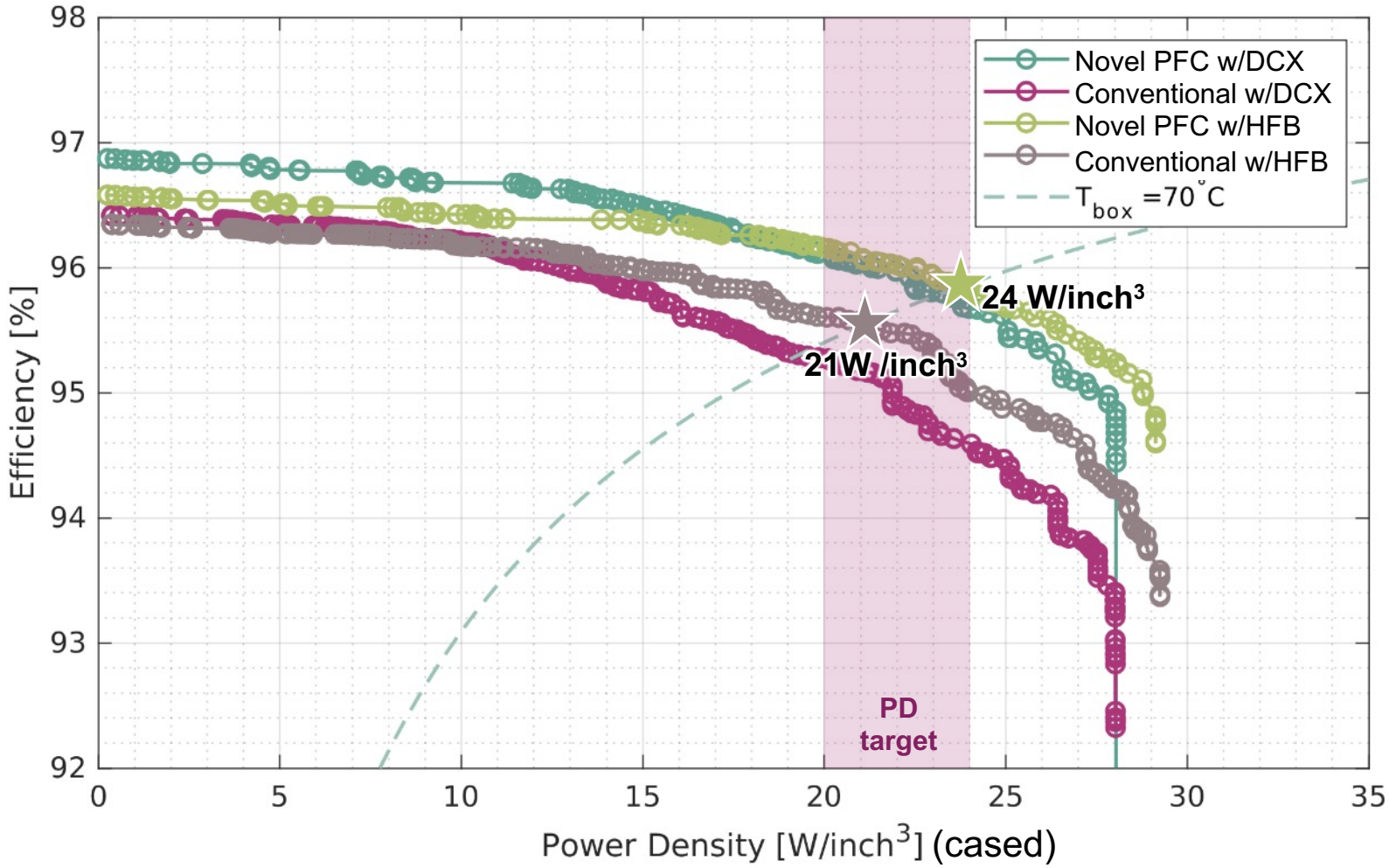
Pareto optimization of 4 remaining converter options for the most challenging operating point

Optimization results for **full load (240 W)** and low line **(90 V_{rms})**



- **Novel PFC**: Boost+Buck PFC with ~150 V output
- **Conventional PFC**: Totem-Pole PFC with ~400 V output
- **DCX**: unregulated series-resonant converter
- **HFB**: Hybrid Flyback

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Summary of optimization results

21 W/in^3

Conventional Solution (400 V DC link):
TP + HFB + 2x Buck

Why to use this solution:
- Straightforward solution
- Proven controllers
- Explore higher frequencies (within bounds of controllers)

Risks:
- Might miss target of 20 W/in^3
- Not going to extreme power densities
- Not learning about new topologies
- Missing chance to go to "new territory"

24 W/in^3

Novel Solution (160 V DC link):
Boost+Buck PFC + DCX or HFB + 2x Buck

Why to use this solution:
- Highest power density
- Learning about new topology
- Explore highest frequencies with proprietary control

Risks:
- Not fulfilling requirements:
  - Standby power; Harmonics/EMI; Surge; ESD; Safety test (i.e. Short circuit)
- Cost
  - High number of devices; Proprietary controller

Possibility to combine both solutions: **"Boost Follower" Totem-Pole** which is a conventional Totem-Pole that is operated with lower DC-link voltage depending on line voltage

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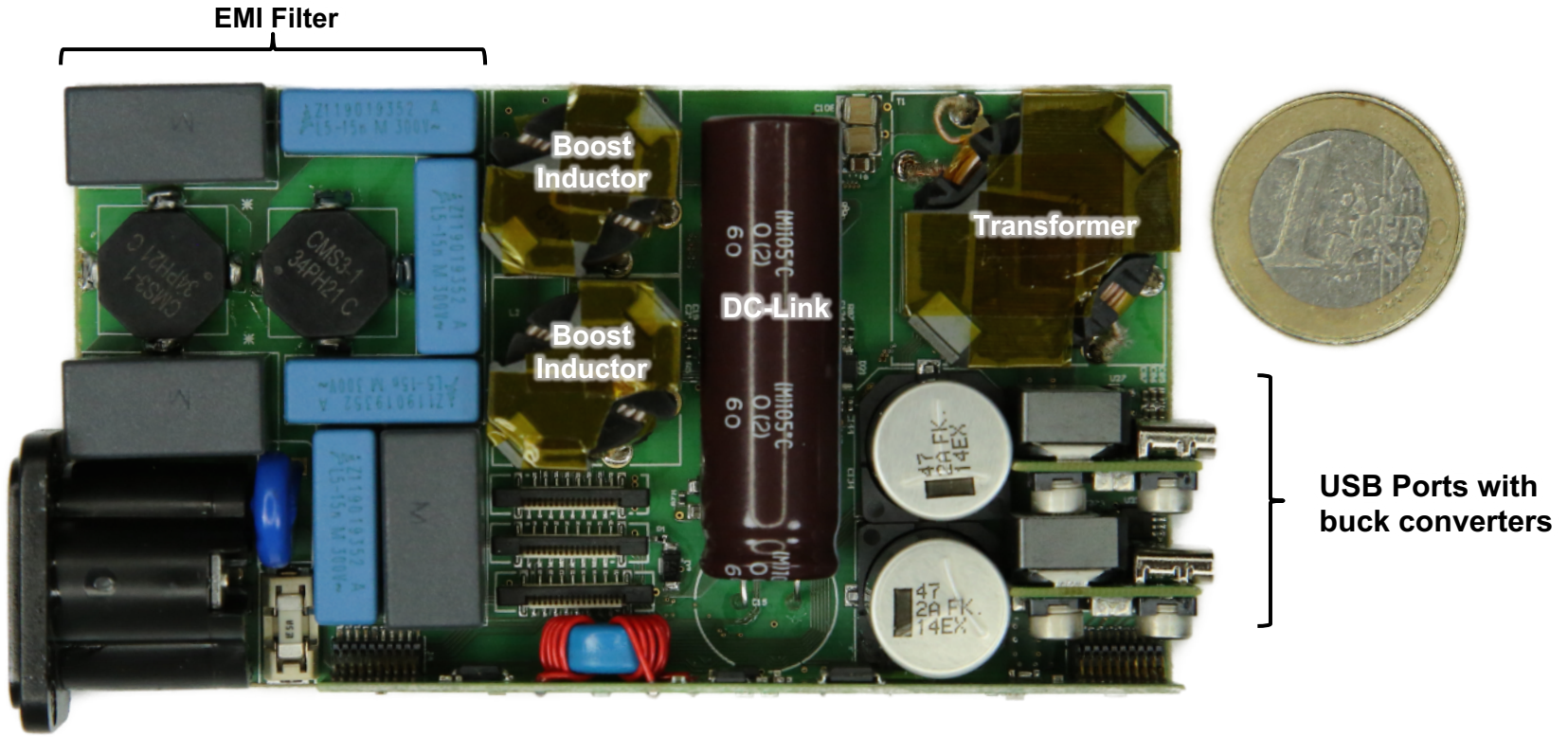
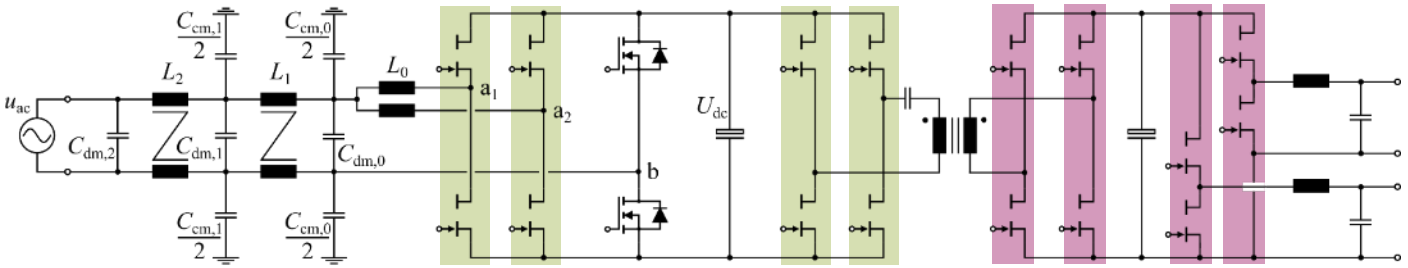
Hardware Demonstrator of Next-Gen 240W USB-C Charger



- **42 W/inch³** (uncased, 24W/inch³ cased)
- **113 g** (uncased)
- **95.3 % Eff** (240W, 90Vrms)

Dimensions W x L x H:
100mm x 55mm x 17mm
without case

Topology:
- **Interleaved Totem-Pole**
- **DCX**
- **ZVS Buck converter**



4x 600V 140mΩ$_{typ}$ Integrated GaN Half-bridges



4x 100V 2.5mΩ$_{typ}$ Discrete GaN Half-Bridges



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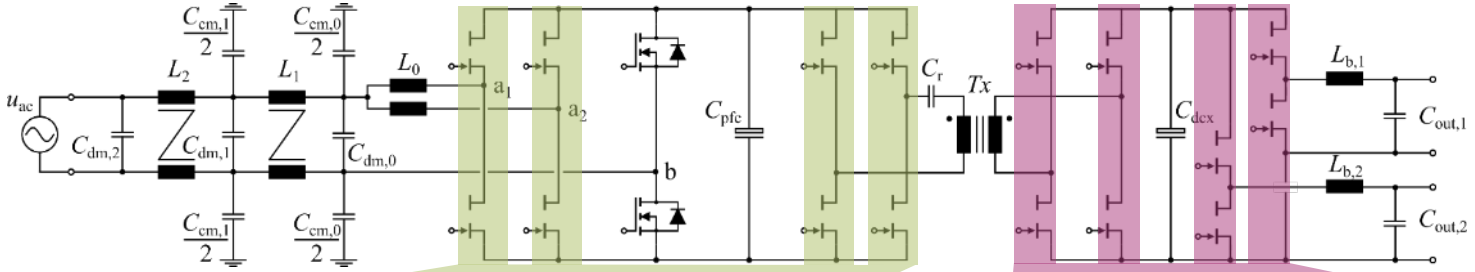
Infineon CoolGaN™ Solutions for 600 V and 100 V

Topology:
Interleaved Totem-pole & DCX & ZVS Buck converter



4x 600 V 140 mΩ$_{typ}$ Integrated GaN Half-Bridges

4x 100 V 2.5 mΩ$_{typ}$ Discrete GaN Half-Bridges



600 V CoolGaN™ GIT Integrated Power Stage (IPS)

- Isolated digital input with digital-in, power-out building block
- Application configurable switching behavior
- Fast, highly accurate, and stable timing
- Thermally enhanced 8x8 mm QFN-28 and 6x8 mm QFN-26 packages



100 V CoolGaN™ Schottky Gate (SG) HEMT

- Lower Q_{OSS} & more linear C_{OSS}
- Lower Q_G and no Q_{rr}
- 3x5 mm PQFN package with dual-sided cooling

\+  **TDI EiceDRIVER™ for SG GaN**

- Optimized driving strength – no gate resistors
- Featuring TDI & active Miller clamp
- 1.8x1.8 mm TSNP package

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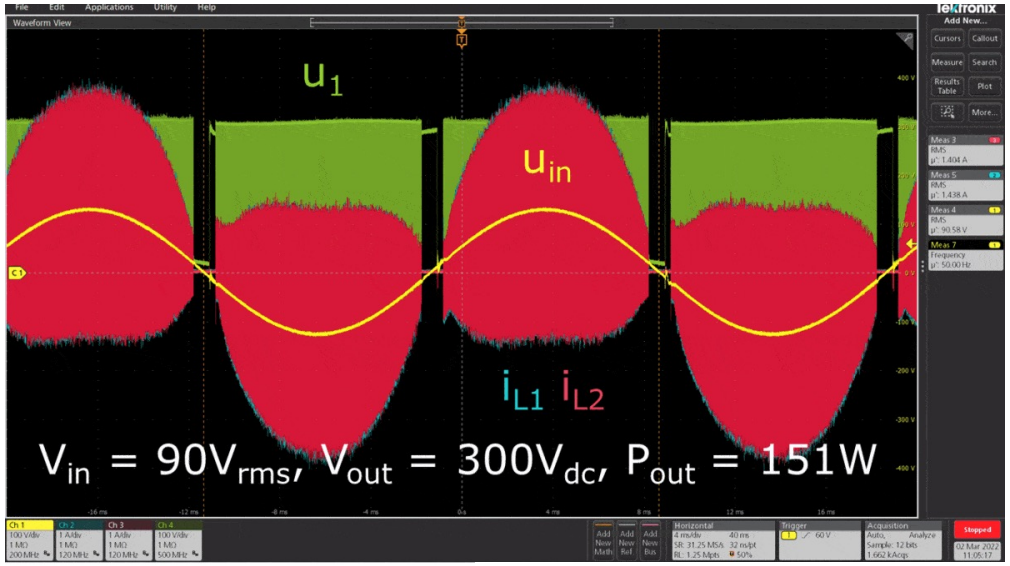
PFC Stage – Details and Measurement Results

97.9% @ 240W, 120V_{in}, 300V_{out}

ZVS Totem-pole PFC with 2x interleaving

- **Fixed f_{sw} = 400kHz CCM PFC**
- **Effective 800kHz for EMI Filter**
- **Large Δi_L** (L = 35 µH, Litz Wire) for **natural ZVS** → For All Voltage Ranges
- **Operating-Point-Dependent U_{dc} variation** to always achieve ZVS
- Easy-to-Implement **Avg. Current Control**

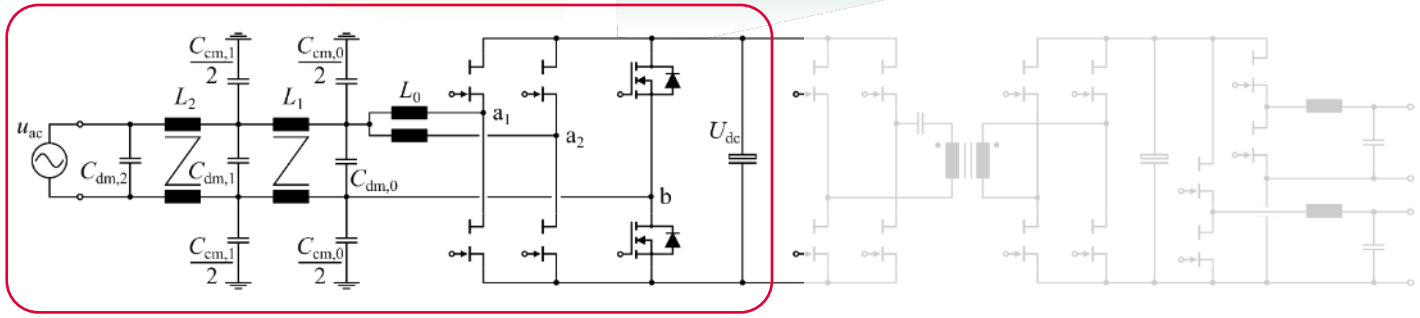


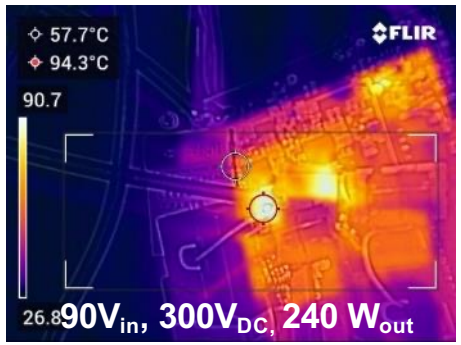
- **CoolGaN™ GIT IPS**
- **600 V 140mΩ$_{typ}$**

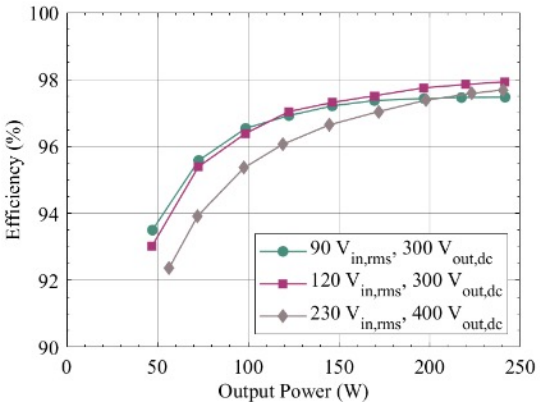


- **CoolMOS™ Si-SJ**
- **600V 48mΩ$_{typ}$**









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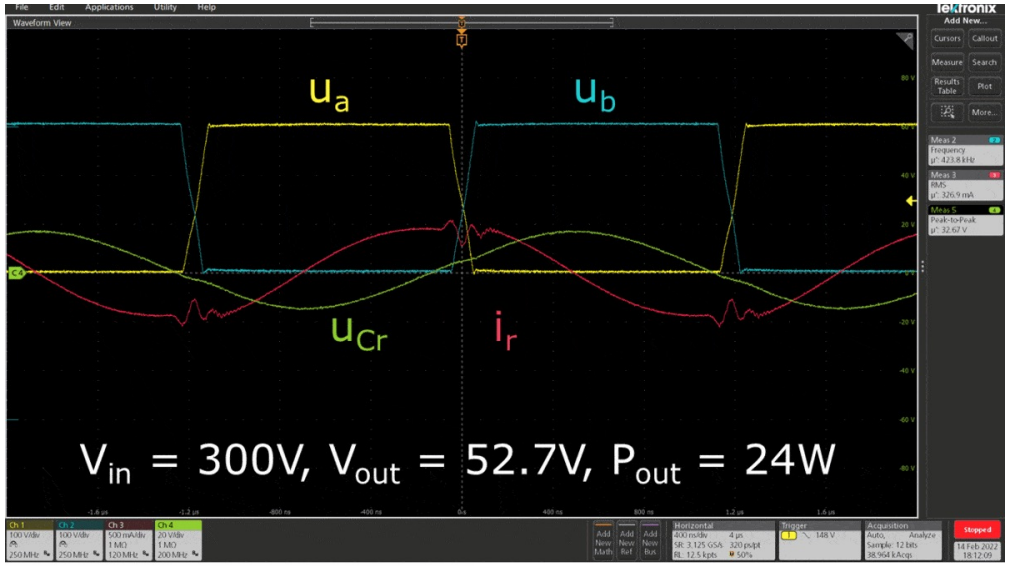
DCX stage details and measurement results

98.3% @ 240W, 300V$_{in}$, 52V$_{out}$

Unregulated DCX w/ Fixed Conversion Ratio (N_1:N_2 = 28:5 = 5.6)

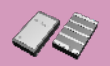
- f_{sw} = 425kHz → **Very High Dynamics**
- **Load independent ZVS** in **all operating points**
- **Small overall size** by **utilizing leakage inductance** (L_r = 12.6µH, Litz-Wire) of transformer **as resonance inductor**
- **Full-Bridge & Full-Bridge** configuration allows to start-up with discharged output with duty-cycle modulation

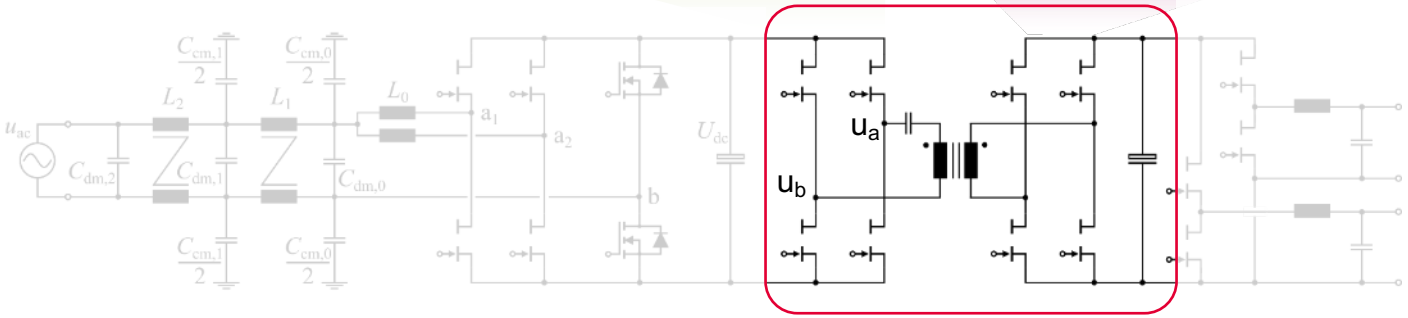


- CoolGaN™ GIT IPS
- 600 V 140mΩ$_{typ}$

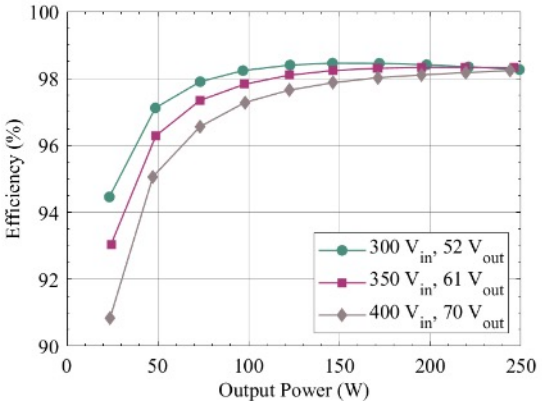


- CoolGaN™ SG
- 100V 2.5mΩ$_{typ}$









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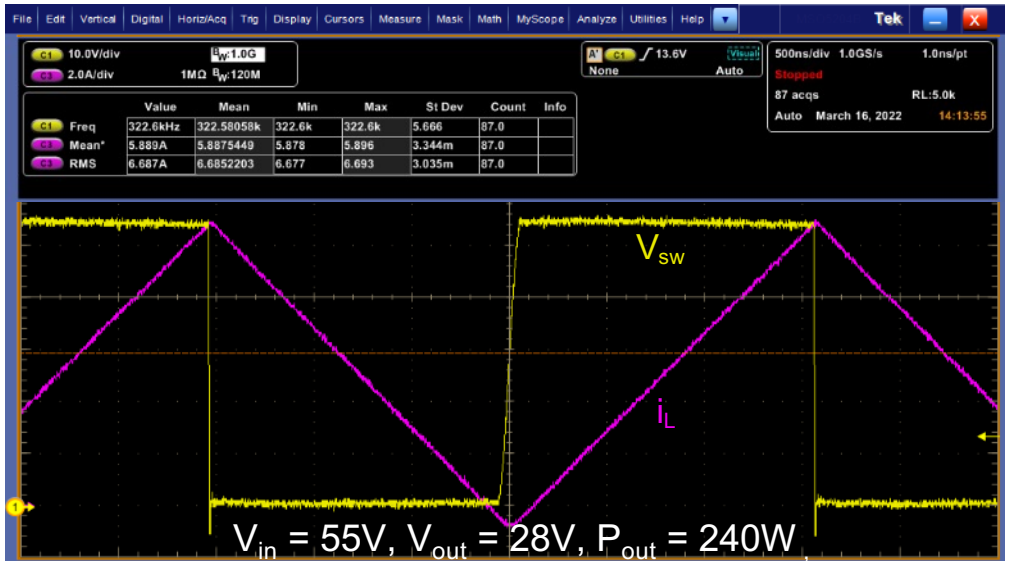
ZVS Buck Converter Stage

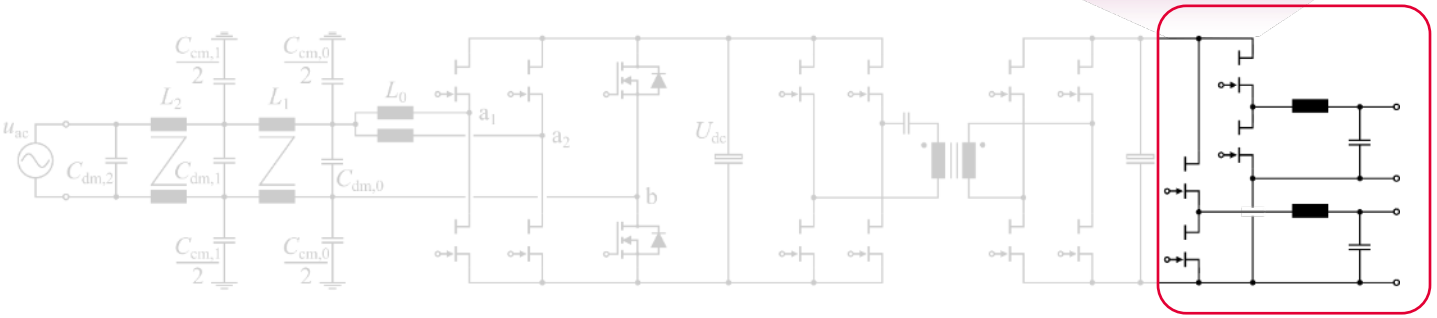
Full-ZVS Buck Stage

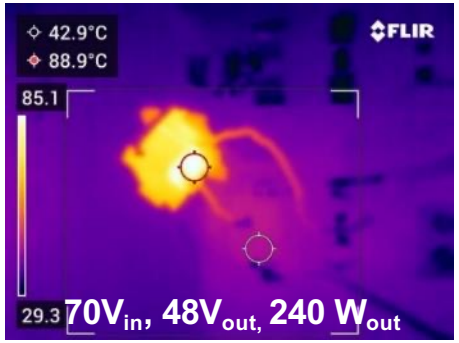
- **ZVS in All Operating Points**
- **Enabled by:**
  - **Variable frequency: f_{sw} = 120…420 kHz**
  - **Optimal Inductor Design** (L = 3.6 µH, Litz-Wire)

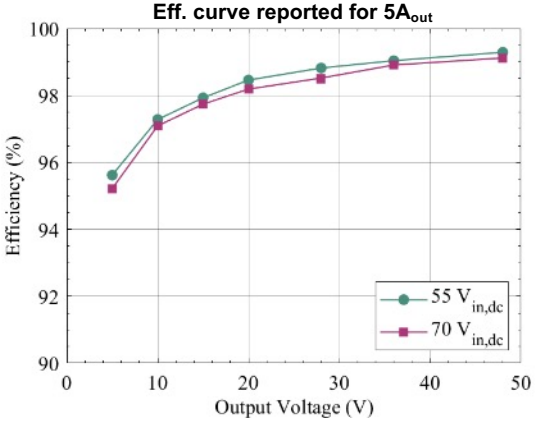
99.3% @ 240W, 55V_{in}, 48V_{out}



- **CoolGaN™ SG**
- **100V 2.5mΩtyp**







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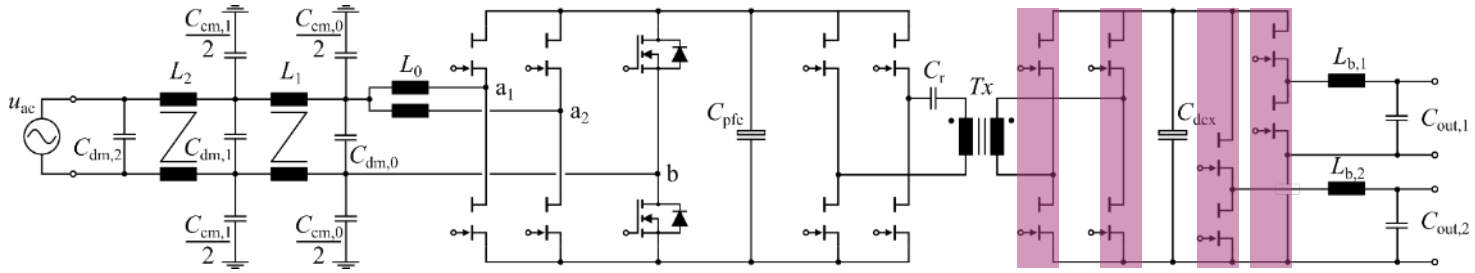
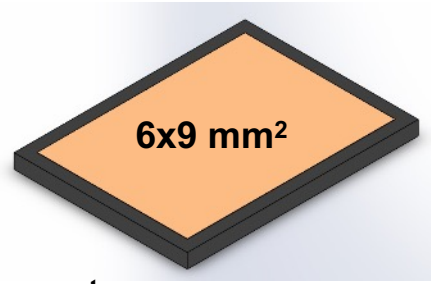
Outlook: 100 V CoolGaN™ Integrated Power Stage

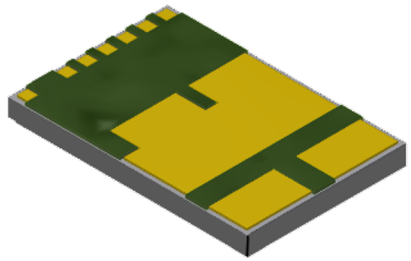


Size and BOM reduction with integrated 100 V power stages

- **Half-bridge** multi-chip module (MCM) in **6x9 mm laminate package:**
  - **2x 100 V 2.5 mΩ_{typ} CoolGaN™ HEMTs** in half-bridge configuration
  - **GaN-optimized half-bridge gate driver** with **regulated bootstrapping supply**
  - **ALL high-frequency capacitors included!** –PCB layout has no impact on switching performance or overshoot voltages,
    even on a single-layer PCB
- **Thermally optimized** package
  - Copious thermal microvias connecting to large PCB pads
  - Galvanically isolated top-side metal pad for easy heatsink attachment



Top view



Bottom view

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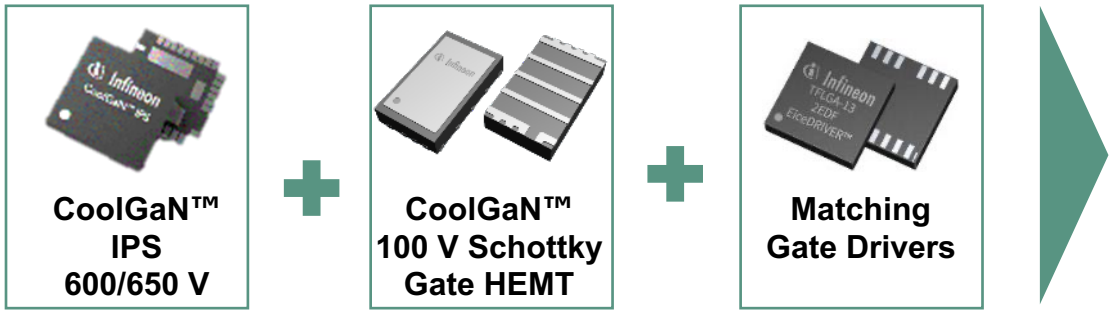
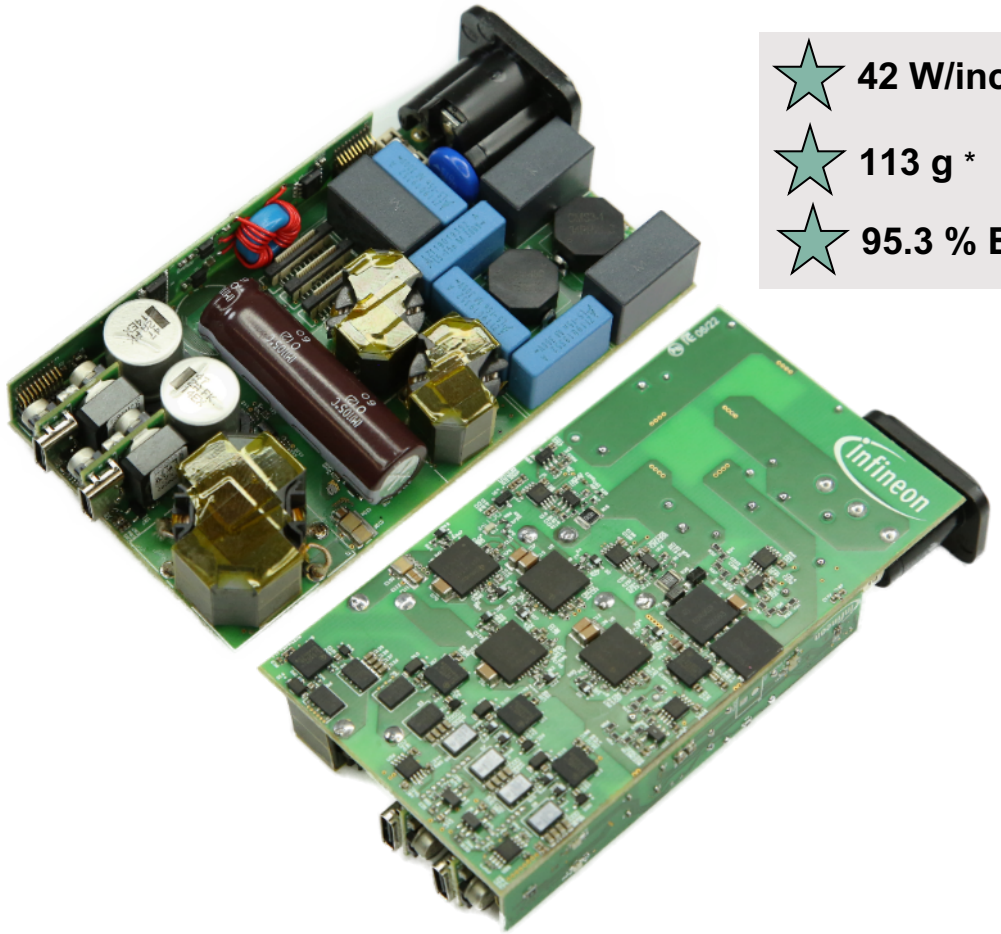
Conclusions

- **Unprecedented 240 W USB-C charger power density (42 W/inch³ & 113 g uncased, 24 W/inch³ cased)**
- Thoroughly **optimized system performance** due to **Infineon's comprehensive technology portfolio and system expertise**:
  - 600 V CoolGaN™ GIT Integrated Power Stage
  - 100 V CoolGaN™ Schottky Gate HEMTs
  - Matching gate drivers
  - Digital control with advanced modulation methods
  - Pareto multi-objective system optimization





42 W/inch³ *

113 g *

95.3 % Eff (240W, 90Vrms)

* Uncased

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