Driving gi**GaN**tic performance

Industry's first PFC + hybrid flyback combo IC



Markus Schmid, Product Definition Engineer
electronica 2022

Moving to a USB-C powered world



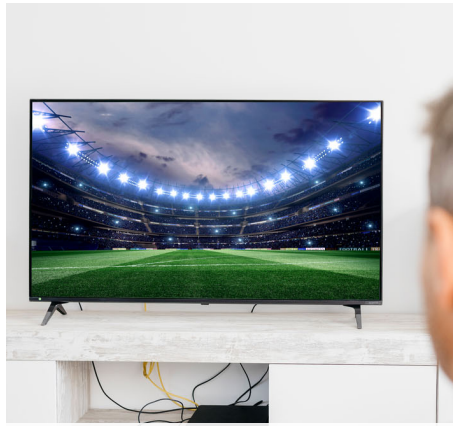
Mobile PCs and tablets



Smartphones



USB-C chargers & power adapters











Next: Consumer products

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USB Power Delivery Extended Power Range (USB-PD EPR)

"USB has evolved **from a data interface** capable of supplying limited power to **a primary provider of power** with a data interface."

Power range	Available current and voltages	PDP range	Notes
Standard Power Range (SPR)	3 A: 5 V, 9 V, 15 V, 20 V 5 A: 20 V	15 W – 60 W >60 W – 100 W	
Extended Power Range (EPR)	3 A: 5 V, 9 V, 15 V, 20 V 5 A: 20 V 5 A: 28 V, 36 V, 48 V	15 W – 60 W >60 W – 100 W >100 W – 240 W	Requires entry into EPR mode

from: Universal Serial Bus Power Delivery Specification, Rev. 3.1, Version 1.5, July 2022





→ **USB-PD EPR power supplies to support wide output voltage and high power**

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Key drivers for the charger market evolution

High power

Peak power capability to fast charge bigger and bigger batteries fast

Small form factor

Makes it easier to travel from A to B

Unification

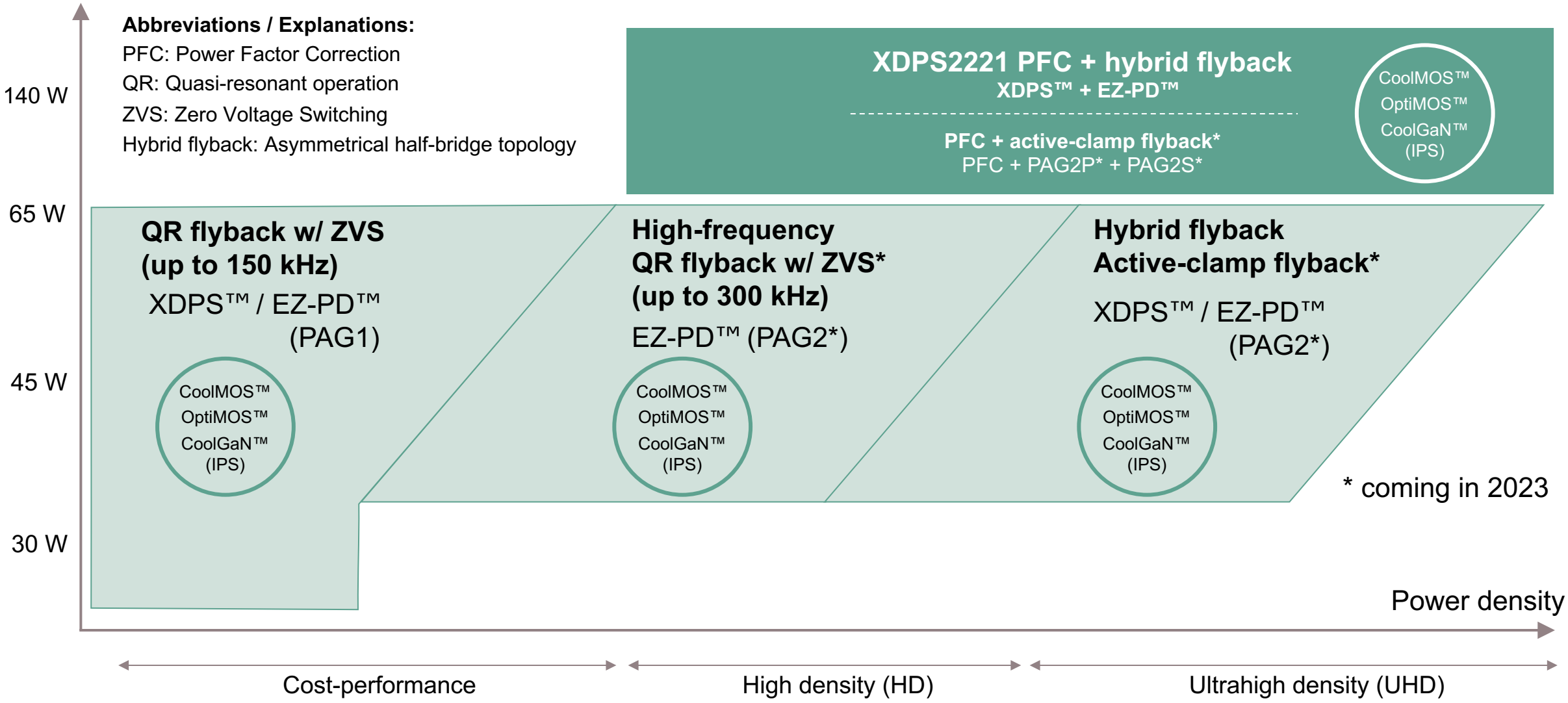
One charger for all electronic devices

Low cost

Overall BOM cost is sensitive in consumer oriented applications

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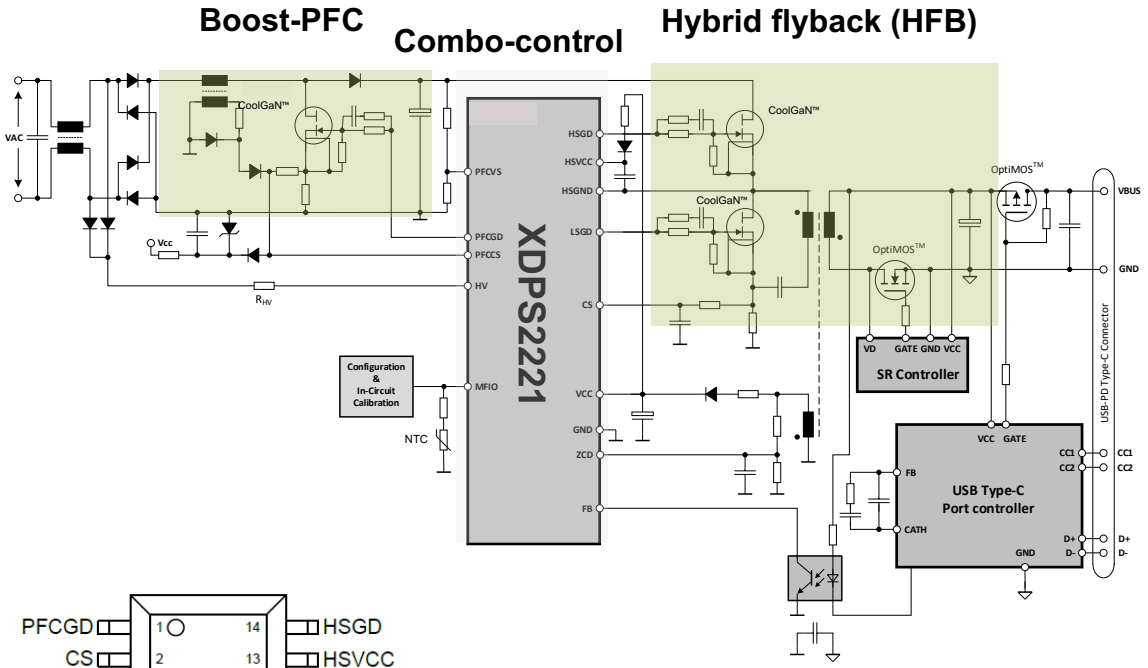
Positioning of Infineon's system solutions

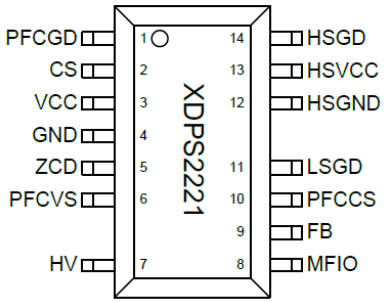


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XDP™ digital power XDPS2221 key features at a glance

Typical application





Inherent HFB topology advantages

- Low voltage stress on primary and secondary switches
- Small transformer by resonant energy transfer

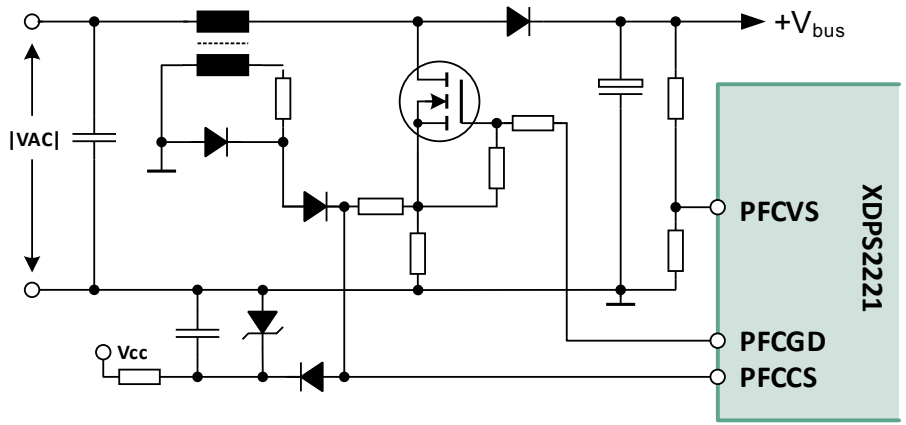
Key features

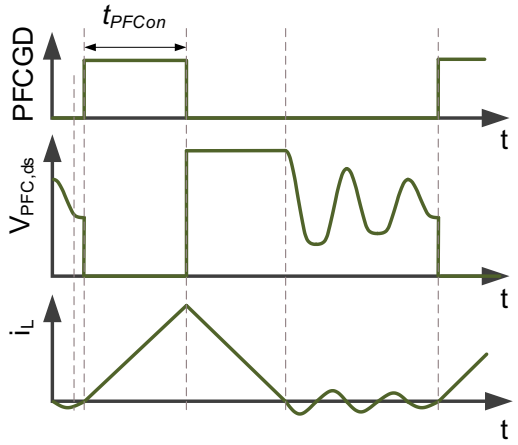
- **600 V high voltage start-up cell** for fast VCC charging and certified **active X-capacitor discharge**
- Novel **ZVS hybrid flyback topology** (asymmetrical half-bridge) for **ultra-high system efficiency**
- **HFB peak current control** for robust and fast control
- **HFB ZVS operation** of high-side and low-side switch (with **ZVS pulse insertion in DCM**)
- **PFC QRM multimode** operation for improved efficiency
- **Harmonized PFC and hybrid flyback control**
- **Burst mode operation** control for lowest stand-by power
- **Integrated gate drivers** supporting GaN switches
- **Configurability** for protections and system performance
- DSO-14 (150mil) package

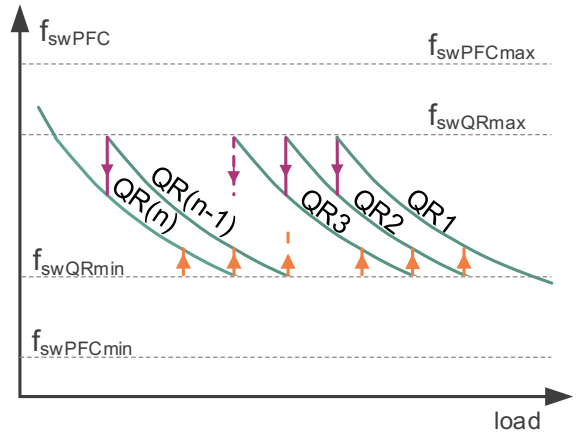
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PFC control

PFC control







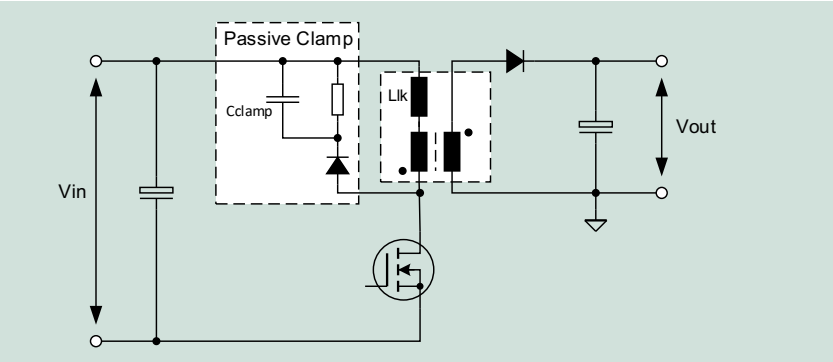
PFC control features

- **PFC multimode operation**
  - Quasi-resonant operation (critical conduction mode with valley switching)
  - Maximum frequency limitation with valley skipping
  - Pulse skipping in light-load conditions
- **Integrated PFC gate driver**
- **On-time correction** for **high power-factor** and **low harmonic distortion** even in part and light load
- **Harmonized PFC and hybrid flyback control**

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DC-DC topology comparison

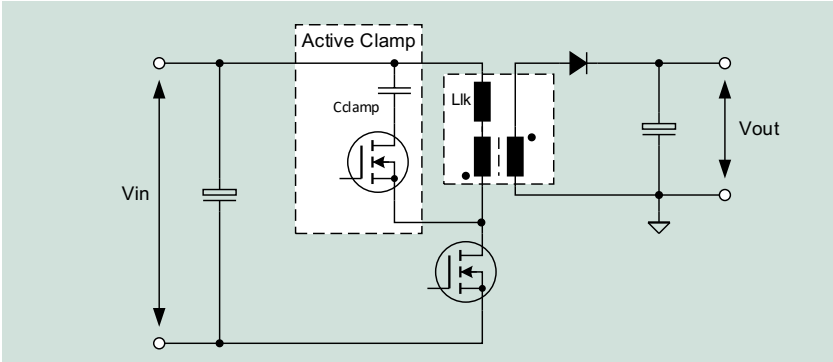
Conventional flyback with snubber



› Recycling the **leakage energy for** ZVS

› But: all energy stored in transformer

Active clamp flyback

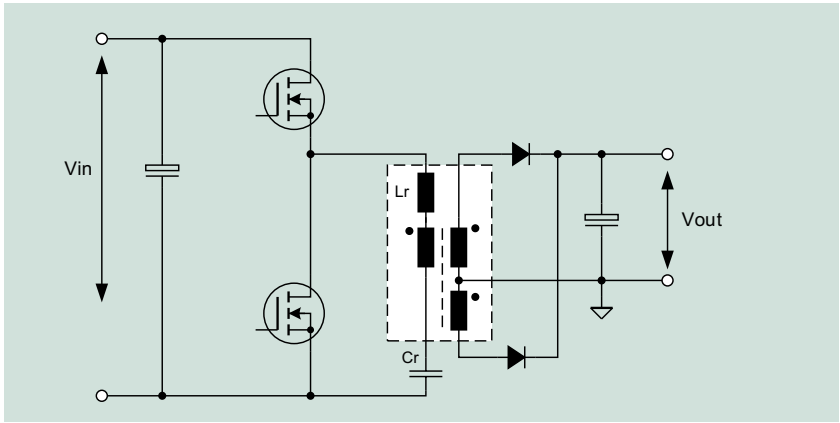


› Using flyback principle with time separated energy storage and transmission phase

› Reduced magnetic energy for **transformer size reduction**

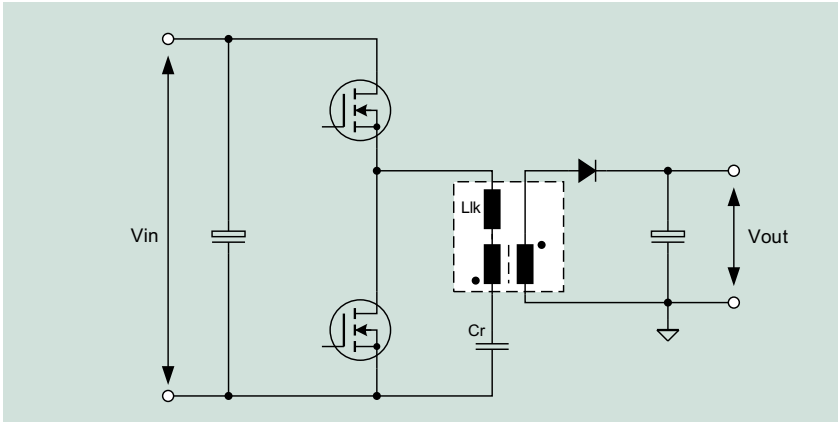
› **Lower breakdown voltage** requirement of **output rectifier**

LLC (Forward resonant half-bridge)



› Using resonant energy storage for **substantial energy transmission** and ZVS

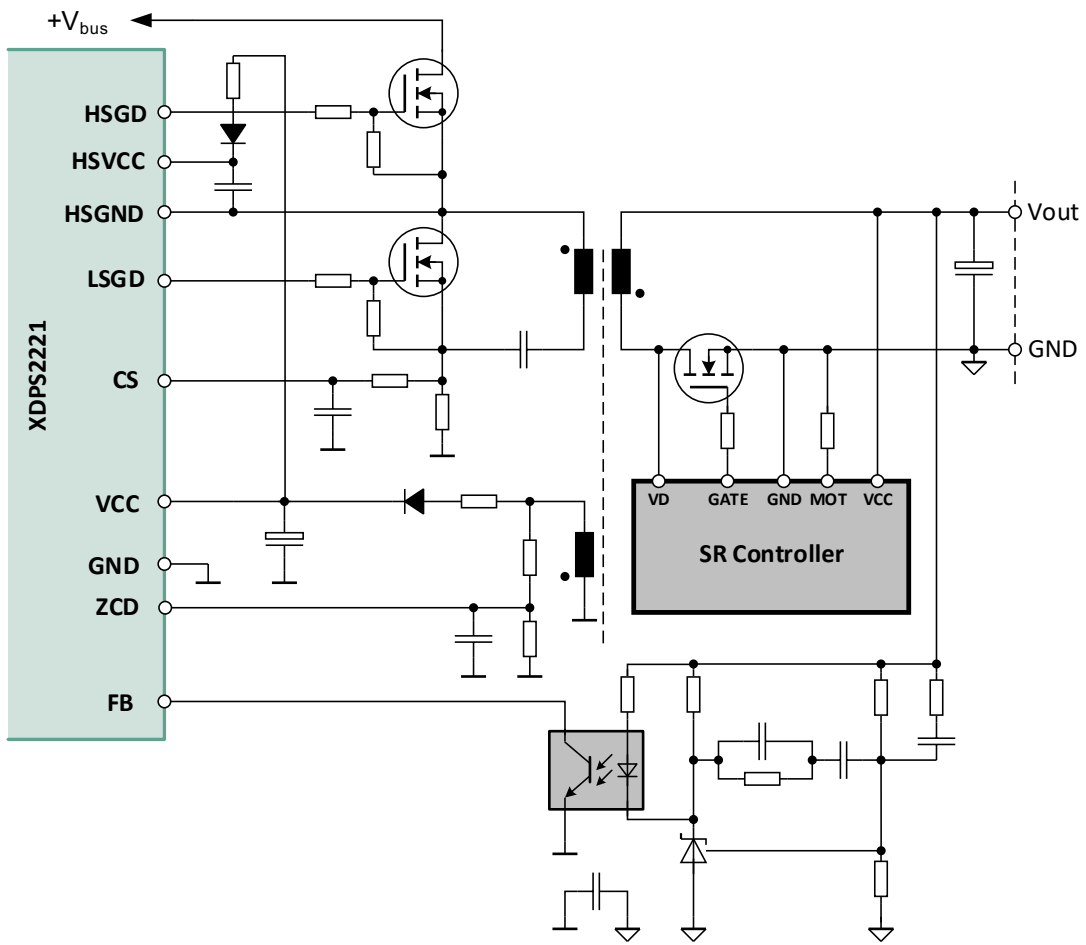
Hybrid flyback



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Hybrid flyback control

Hybrid flyback control



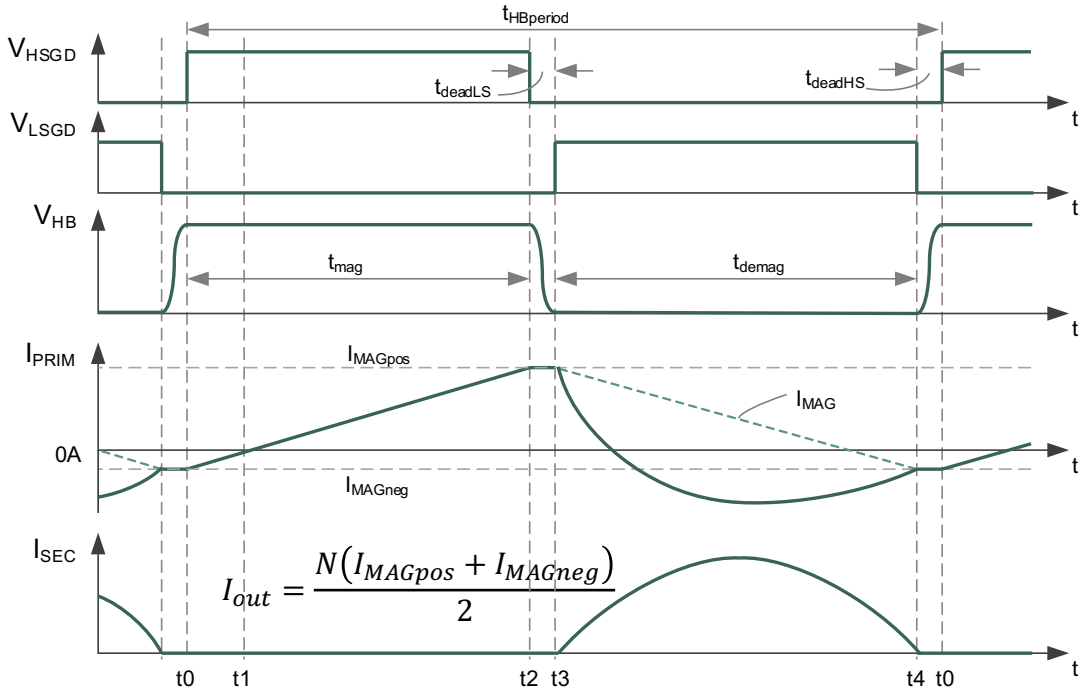
Hybrid flyback control features

- **Peak current mode control for robust and fast output regulation**
- **Propagation delay compensation**
- **Switching frequency jitter for EMI noise rejection**
- **ZVS operation incl. body-diode cross conduction prevention** under all conditions
  - ZVS-pulse insertion in ZV-RVS mode
  - I_{magneg}-ctrl for keeping ZVS for wide V_{BUS} voltage range
  - Dedicated start-up control
- **Valley control for improved light load efficiency**

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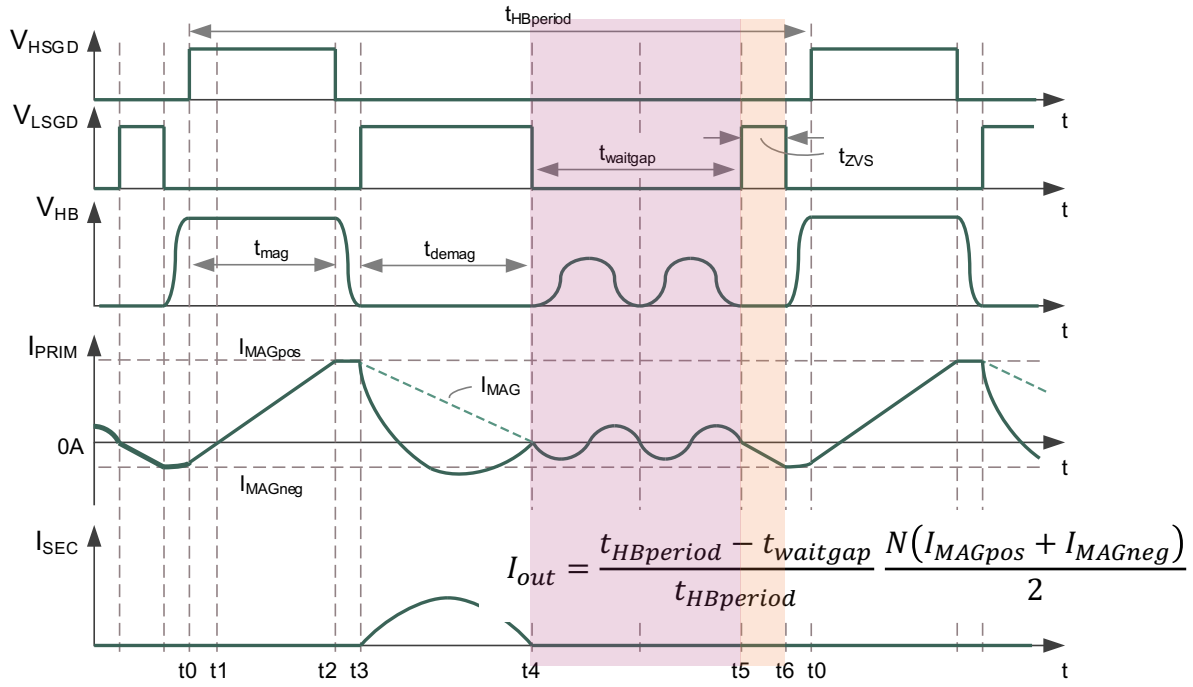
Waveforms of different operation modes

CRM – Mode



→ **CRM operation in full and part load**

ZV-RVS – Mode with waitgap and ZVS-pulse insertion

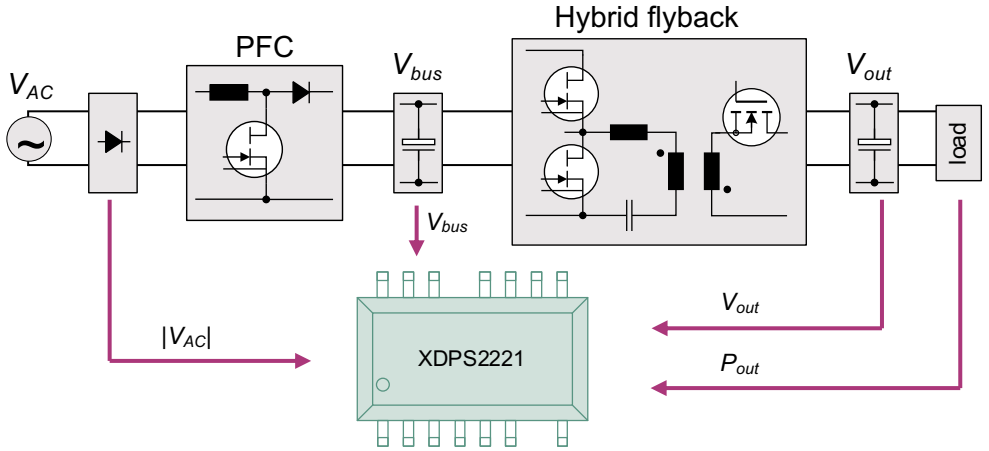


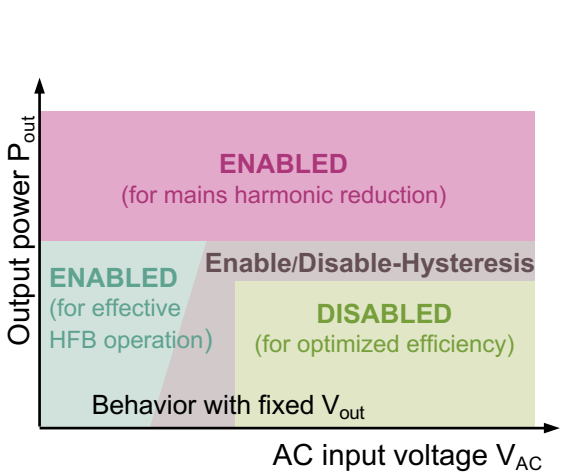
→ **ZV-RVS (DCM) – mode with ZVS pulse insertion for increased part and light load efficiency**

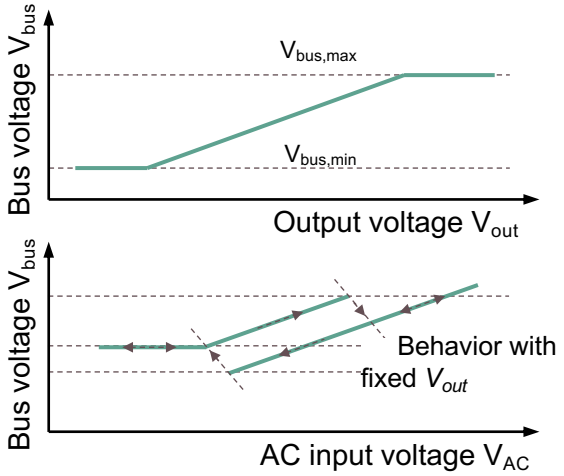
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Combo control functions

Combo control







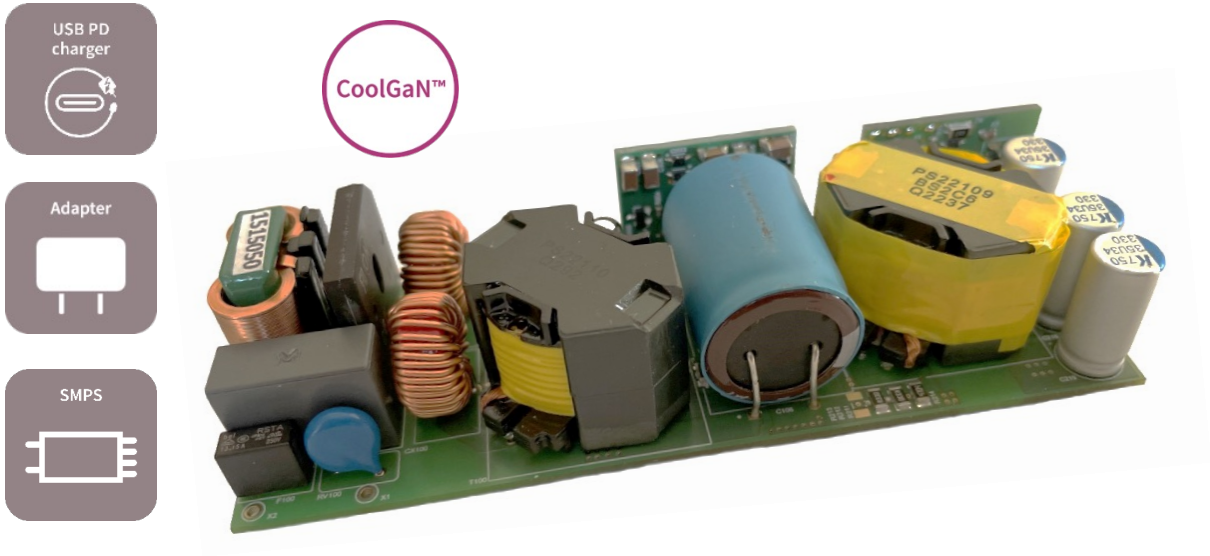
Combo control features

- **PFC enable/disable** control depending on load, AC input and output voltage
- **Adaptive PFC bus voltage** depending on AC input and output voltage
- **Synchronized PFC and hybrid flyback burst mode** operation for **high light-load efficiency** and **low** standby power consumption
- **High level of integration** for ease of system design and low system BOM

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140 W form-factor reference design with industry-benchmark power density using XDP™ XDPS2221, EZ-PD™ CCG3PA and CoolGaN™

140 W USB-PD



Technical details

Parameter	Value
Input voltage	90 – 264 $V_{AC,rms}$
Output voltage / current	5 V / 3 A, 9 V / 3 A, 15 V / 5 A, 20 V / 5 A, 28 V / 5 A
Max. nominal power	140 W
Peak efficiency	95%
Dimensions (uncased)	109.5 x 38.5 x 24.0 mm³
Power density (uncased)	22.7 W/in³ 1.38 W/cm³

Infineon components	
Primary PWM controller	XDPS2221 (XDP™ digital power)
PFC switch	IGLD60R190D1 (CoolGaN™)
PWM switch	2 x IGLD60R190D1 (CoolGaN™)
PD IC	CYPD3175 with additional circuitry (EZ-PDTM CCG3PA)
Secondary SR MOSFET	BSC04N10NS5 (OptiMOS™ 5 power MOSFET)
Output switch	IRF7240

Features

- USB-C single-port solution with USB-PD 3.1 for **5 V – 28 V output range**
- Small form factor system design
- CrCM PFC + hybrid flyback topology
- USB-PD controller EZ-PD™ CCG3PA with programming flexibility
- Compliance to DOE Level VI, CoC Tier 2

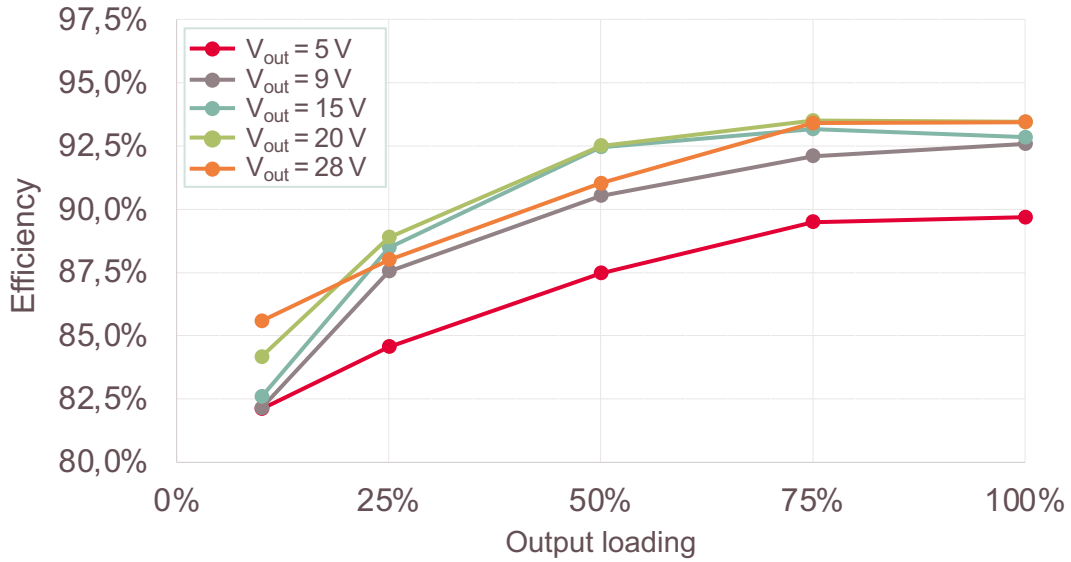
Benefits

- USB-PD compliant up to 140 W
- Industry-benchmark power density
- Very high efficiency over the whole output voltage and load range
- High forward integration for lowest system BOM
- Best performance and highly flexible syste parameterization

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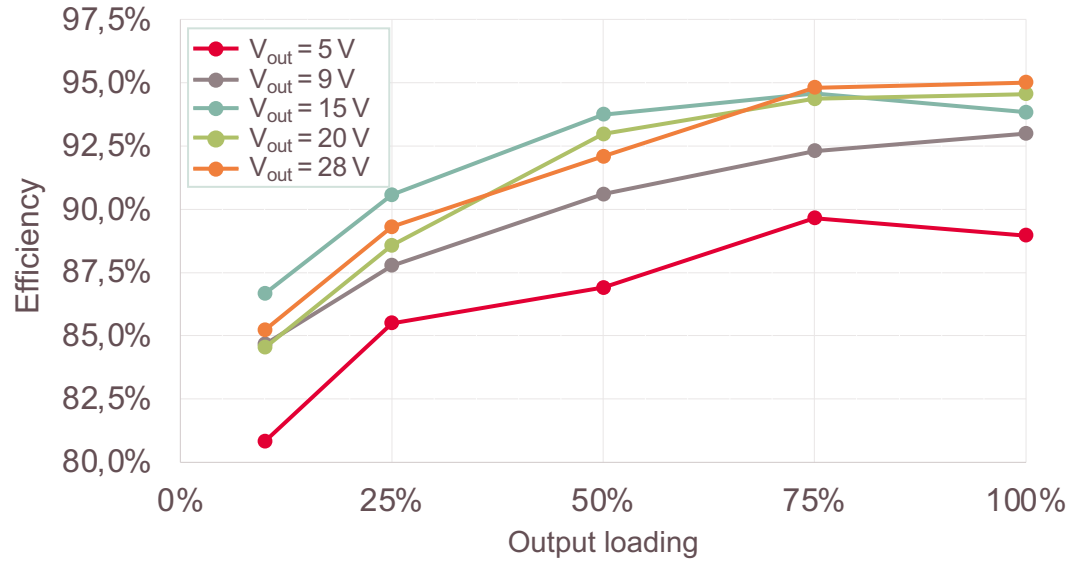
140 W form-factor reference design efficiency measurements (measured at USB-C connector)

V_{AC} = 115 V / 60 Hz



V_{out}	Avg. efficiency (25%, 50%, 75%, 100%)	DoE level 6 limit	CoC Tier 2 limit	Result
5.0 V	87.75 %	81.39 %	81.84 %	PASS
9.0 V	90.91 %	87.73 %	88.85 %	PASS
15.0 V	93.18 %	88.0 %	89.0 %	PASS
20.0 V	92.91 %	88.0 %	89.0 %	PASS
28.0 V	92.80 %	88.0 %	89.0 %	PASS

V_{AC} = 230 V / 50 Hz



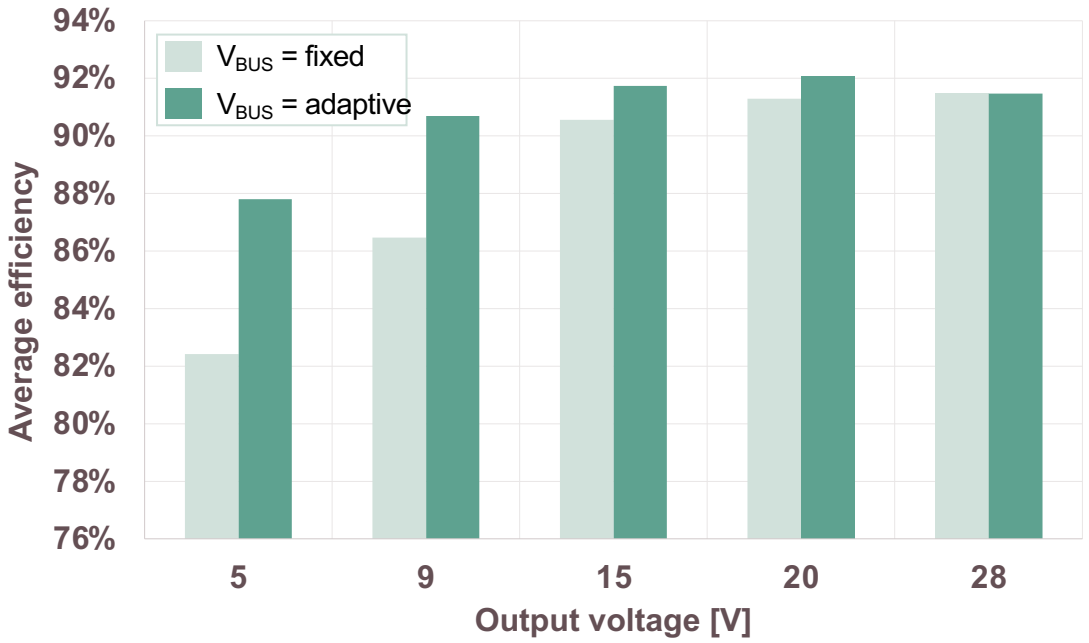
V_{out}	Avg. efficiency (25%, 50%, 75%, 100%)	DoE level 6 limit	CoC Tier 2 limit	Result
5.0 V	87.63 %	81.39 %	81.84 %	PASS
9.0 V	90.85 %	87.73 %	88.85 %	PASS
15.0 V	93.09 %	88.0 %	89.0 %	PASS
20.0 V	92.33 %	88.0 %	89.0 %	PASS
28.0 V	92.51 %	88.0 %	89.0 %	PASS

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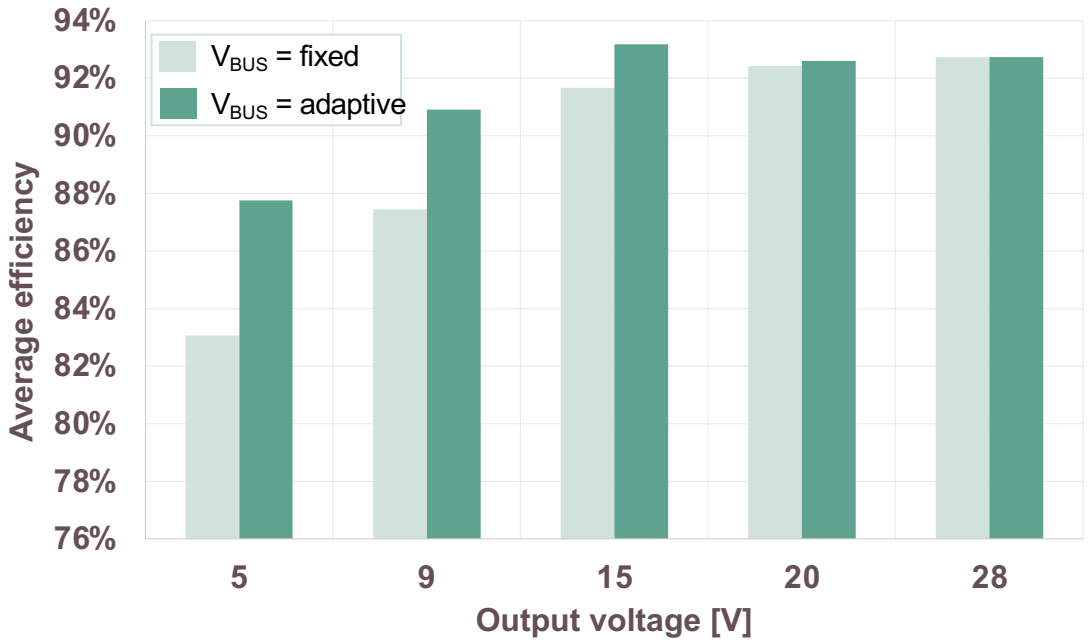
Harmonized combo control

Average efficiency measurement with adaptive bus voltage target level

V_{AC} = 115 V / 60 Hz



V_{AC} = 230 V / 50 Hz



→ **Adaptive bus voltage target level can greatly improve average efficiency in case of low output voltages**

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140 W form-factor reference design exemplary results

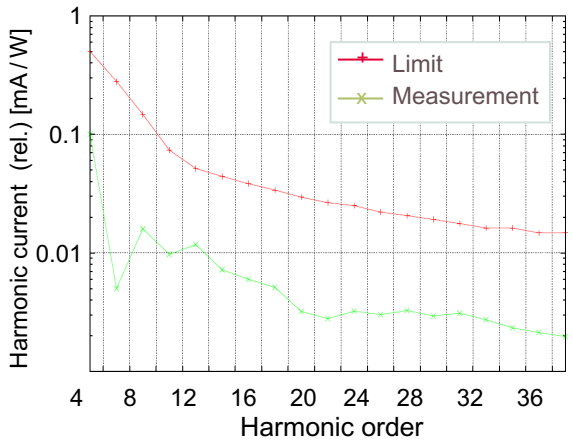
Standby power consumption

Test condition	V_{AC} = 115 V / 60 Hz	V_{AC} = 230 V / 50 Hz
5.0 V, cable unplugged	33 mW	49 mW

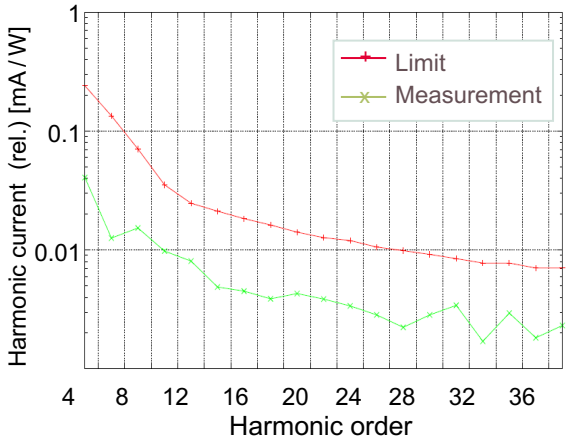


AC input current harmonics and power factor

V_{AC} = 230 V / 50 Hz, P_{out} = 140 W



V_{AC} = 230 V / 50 Hz, P_{in} = 73 W



Power factor

Power level	V_{AC} = 115 V / 60 Hz	V_{AC} = 230 V / 50 Hz
P_{out} = 140 W	0.993	0.965
P_{in} = 73 W	0.988	0.927

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