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High Density USB-PD ZVS Flyback converter based on Secondary side control

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Agenda

1. Growing demand for USB-PD application: high power density improvement
2. Secondary side control Flyback-ZVS implementation and performance
3. Application results: secondary side control ZVS Flyback converter
4. Conclusion

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Growing demand for USB-PD application: high power density improvement

Evolution of USB PD power level

1996	2000	2008	2010	2014	2015	2018	2020	2021+
USB 1.1	USB 2.0	USB 3.0	BC 1.2	USB-C USB-PD USB 3.1	Thunderbolt3	USB 3.2	USB4 Thunderbolt4	USB-PD EPR

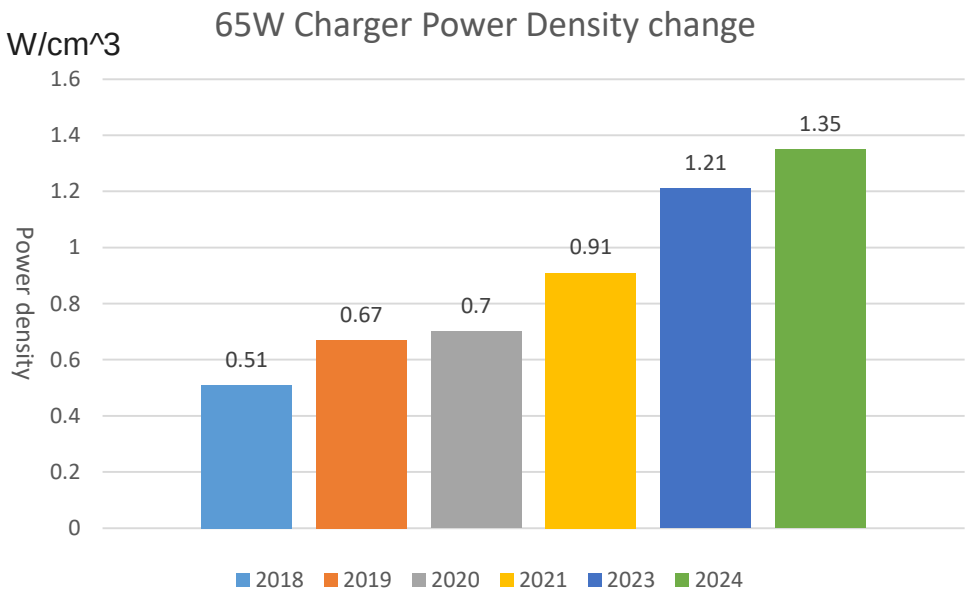
Power 2.5W → 4.5W → 7.5W → 100W → 240W

- PD power level become higher and higher, latest USB PD3.1 EPR standard, power delivery reach to **48V 5A**

PDP Rating (W)	5V Fixed	9V Fixed	15V Fixed	20V Fixed[9]	28V Fixed[3]	36V Fixed[3]	48V Fixed[3]	AVS[3, 7, 8]
100 < x ≤ 140	3A[5]	3A[5]	3A[5]	3A[1], 5A[2]	(PDP/28) A[3, 6]	NA[4]	NA[4]	(15V – PDP/5A): 5A (>PDP/5A – 28V): (PDP/AVS Voltage) A
140 < x ≤ 180	3A[5]	3A[5]	3A[5]	3A[1], 5A[2]	5A	(PDP/36)[6]	NA[4]	(15V – PDP/5A): 5A (>PDP/5A – 36V): (PDP/AVS Voltage) A
180 < x ≤ 240	3A[5]	3A[5]	3A[5]	3A[1], 5A[2]	5A	5[3]	PDP/48[3, 6]	(15V – PDP/5A): 5A (>PDP/5A – 48V): (PDP/AVS Voltage) A

Size evolution of USB PD 65W changer

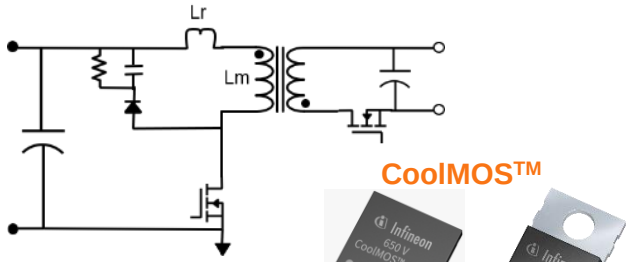
2018 2019 2020 2021 2023 2024



PD charger size become smaller and smaller to meet Small Form Factor and Portability.

65W charger power density change

Low-Frequency QR Flyback with Coolmos



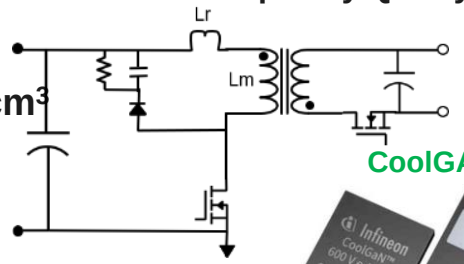
CoolMOS™

EZ-PD™ PAG1 + OptiMOS™

0.8 W/cm³

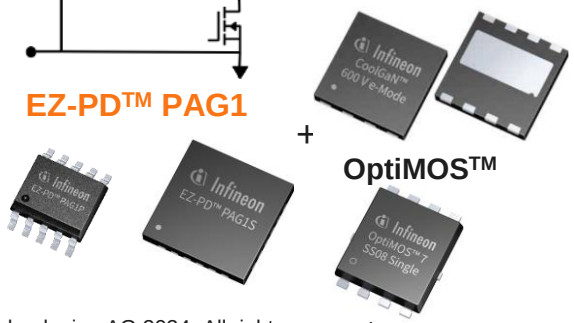
1.1 W/cm³

Medium -Frequency QR Flyback with GAN



CoolGAN™

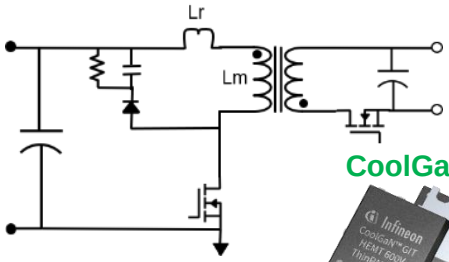
EZ-PD™ PAG1 + OptiMOS™



>1.4 W/cm³

Power Density

High-Frequency ZVS Flyback with GAN



CoolGaN™

EZ-PD™ PAG2 QR-ZVS + OptiMOS™

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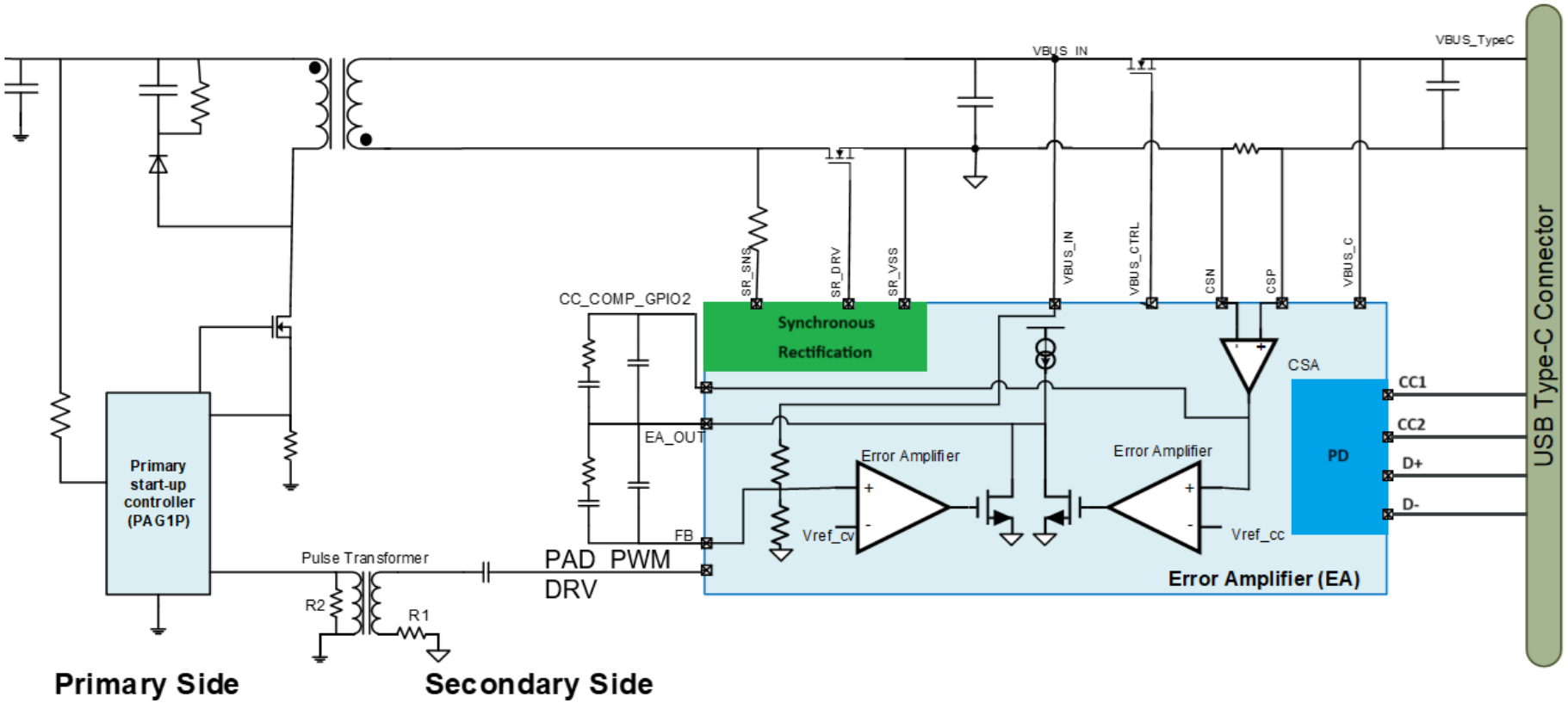
Secondary side control Flyback-ZVS implementation and performance

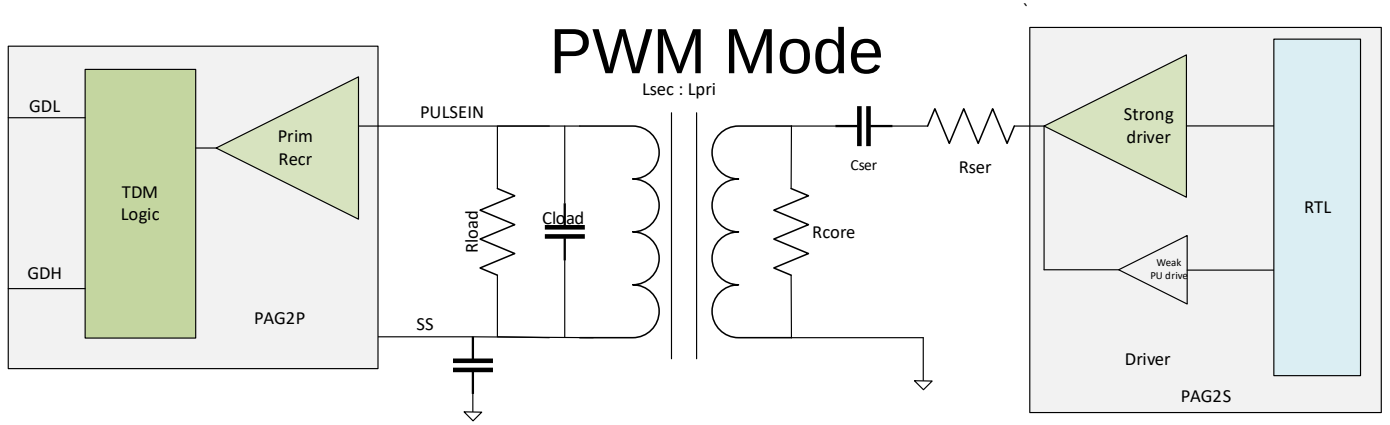
Architecture

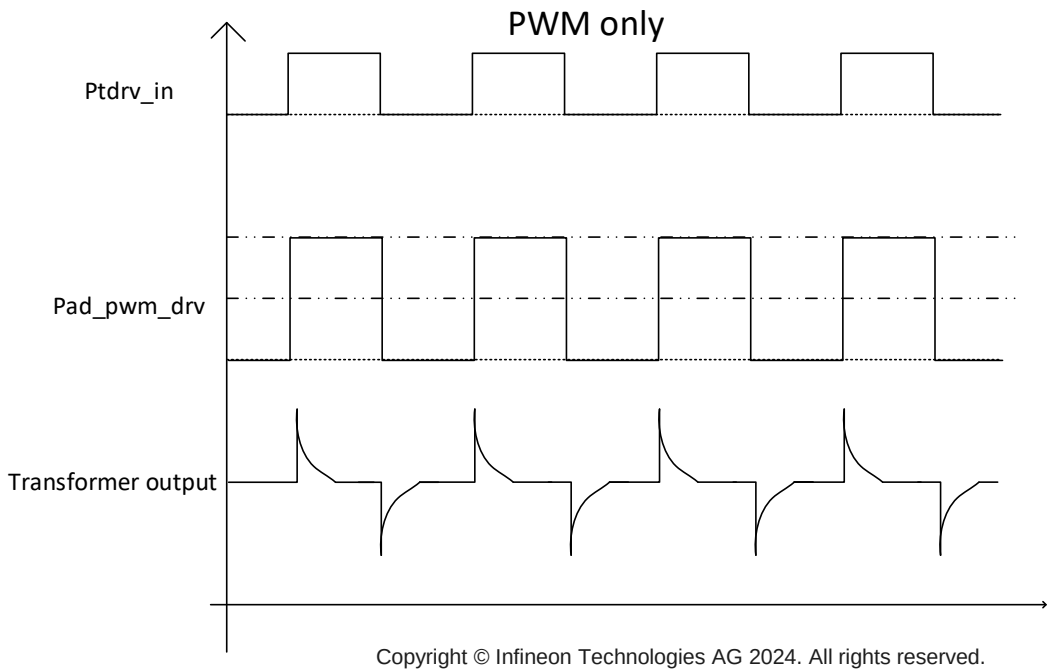
- Secondary side integrate SR control, USB-PD, CC/CV detection and PWM control.
- Secondary side regulates VBUS voltage or current during Constant Voltage (CV) or Constant Current (CC) mode.
- Increase/decrease the VBUS voltage in a power adapter. VBUS value can be adjusted from 3.3V to 21V in steps of 20mV and EPR from 22V to 28V in steps of 50mV or 100mV.
- Generate detection signals (cc_det, cv_det, cc_flag) to indicate that loop is in CV (or) CC mode. The CV and CC loop are independent of each other



PTDRV Application in PWM

- Secondary side PWM signal transfer to primary side with small Pulse transformer(PET).

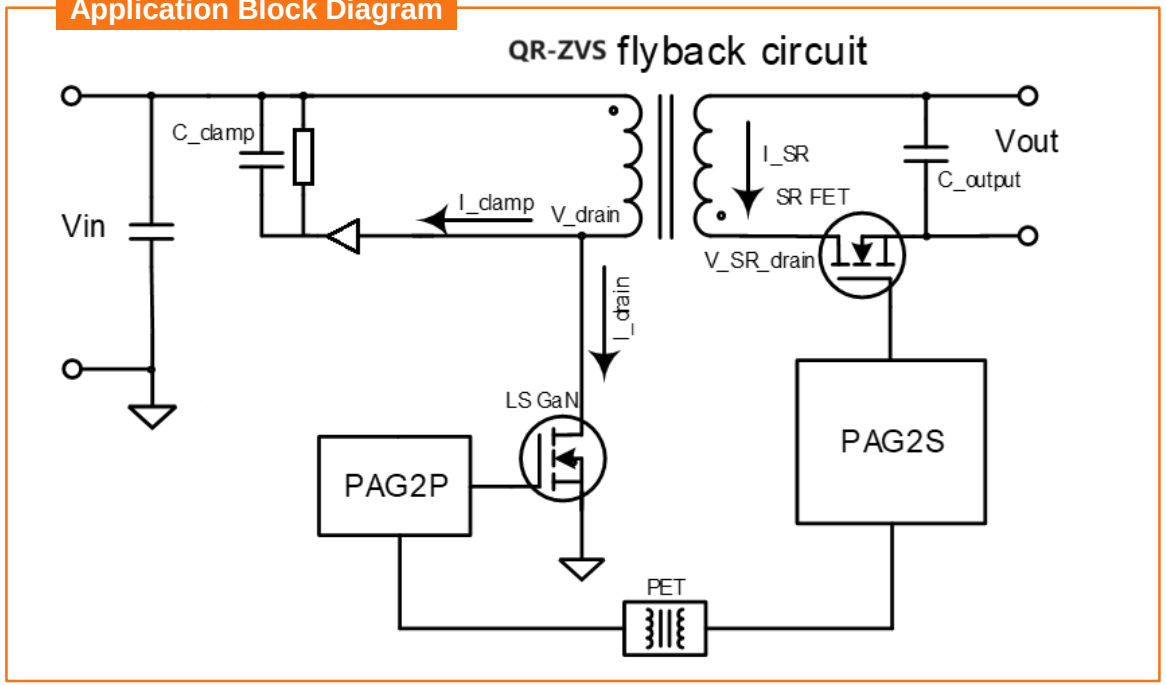


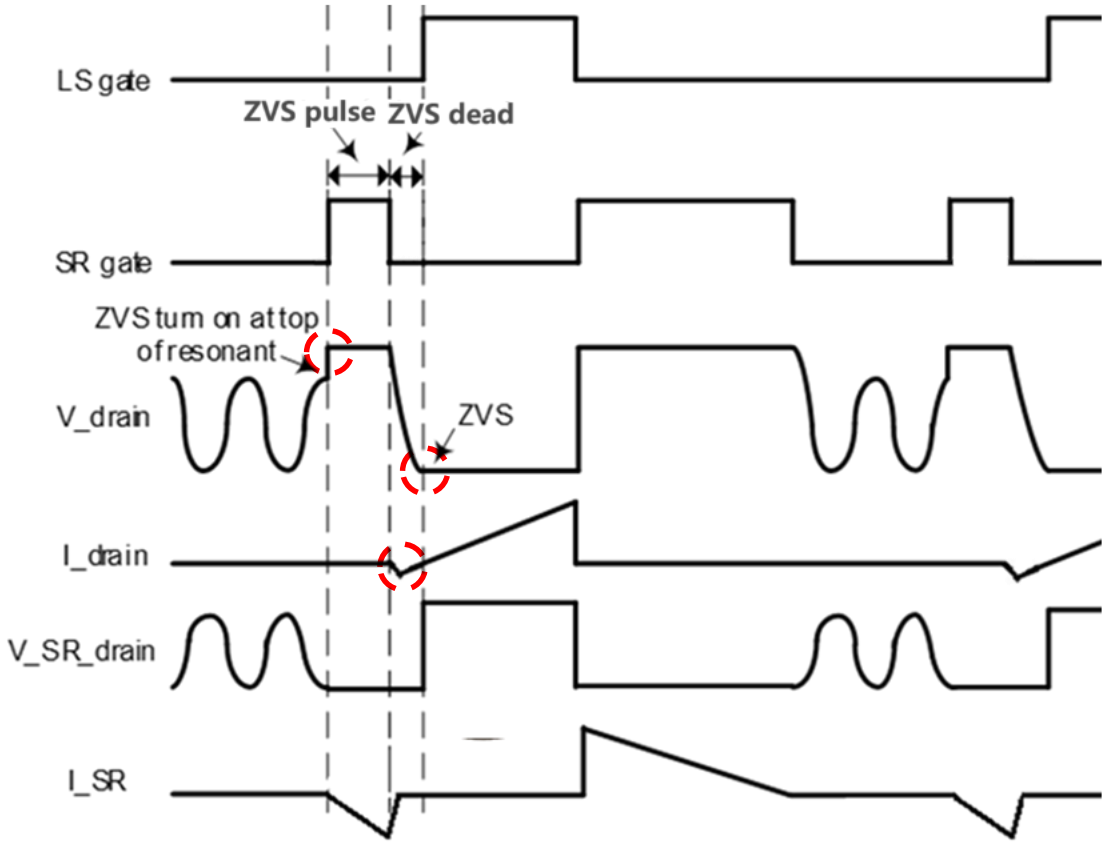


Quasi-Resonance with Zero-Voltage Switching

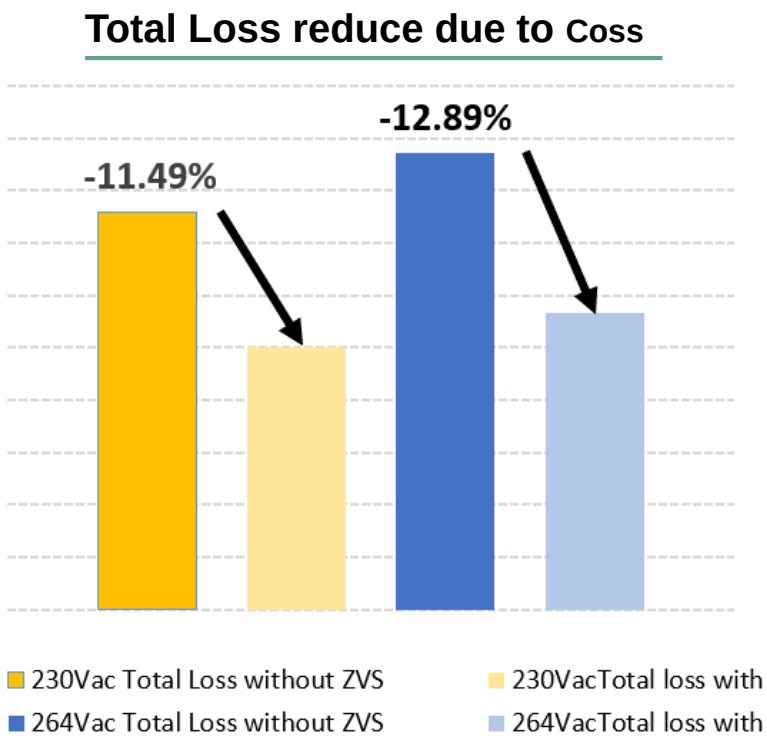
- Turning ON secondary FET before the primary FET turn on causes the transformer to reverse charge from the output. Hence secondary current is shown in negative direction
- As there is reverse energy present in the transformer, when the SR and primary FET are both off during deadtime, the transformer reverse energy discharges Coss of the primary FET to near zero - Hence the ZVS is achieved

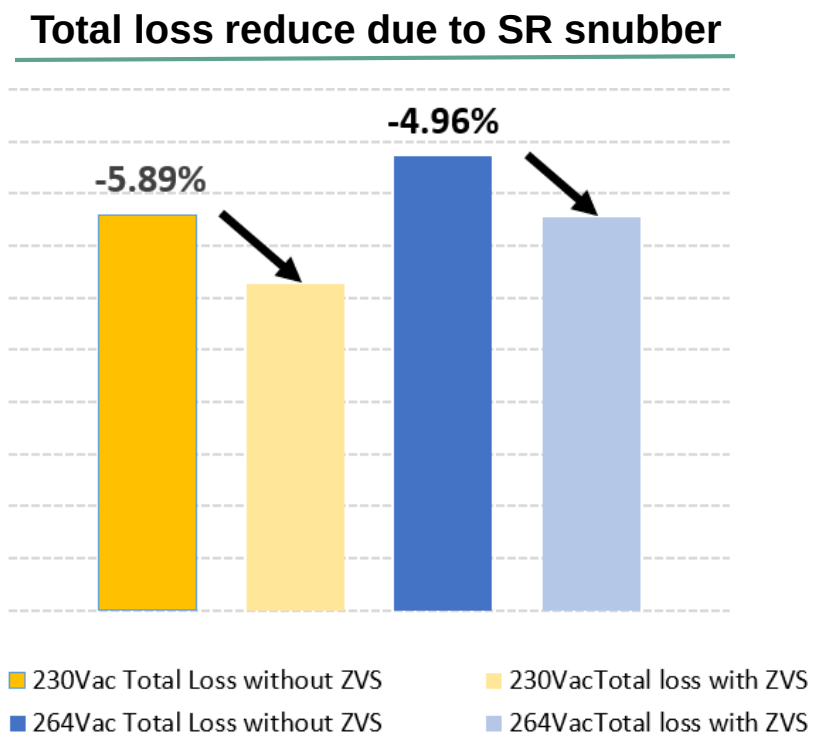
Application Block Diagram





Figures of merit: specific Coss and SR snubber loss, SR stress



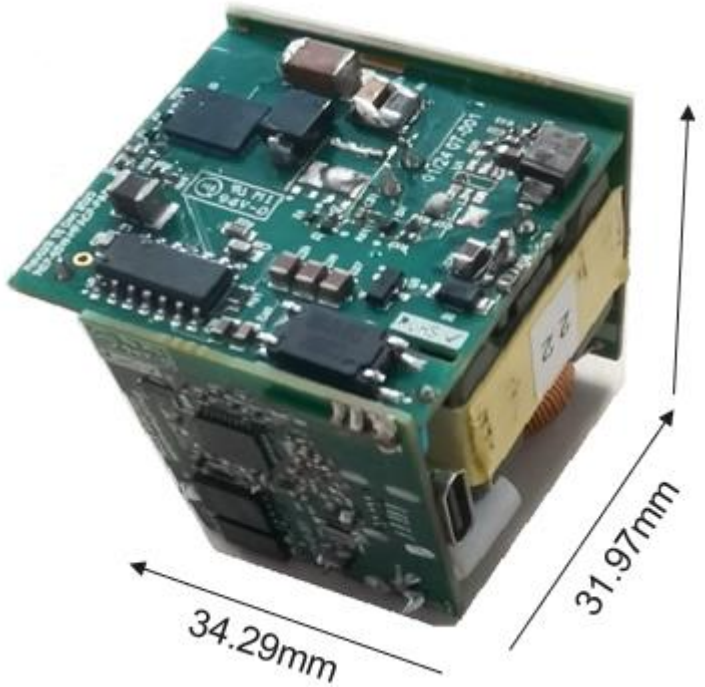


1，Secondary side Flayback ZVS improves ***efficiency*** due to Coss loss reduce and SR smubber loss reduce.

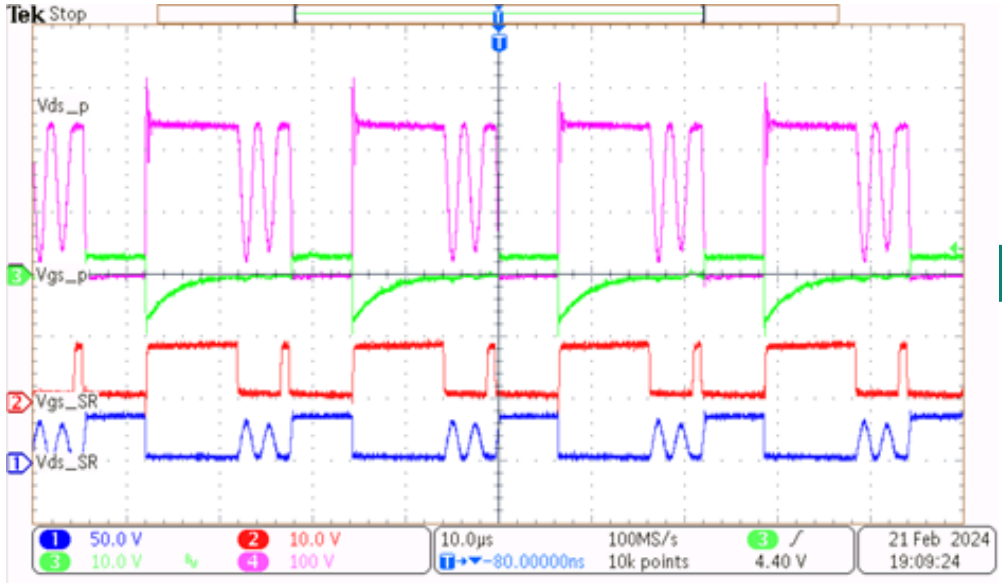
2，ZVS can decrease SR stress to use small SR snubber or remove

Application results: secondary side control ZVS Flyback converter

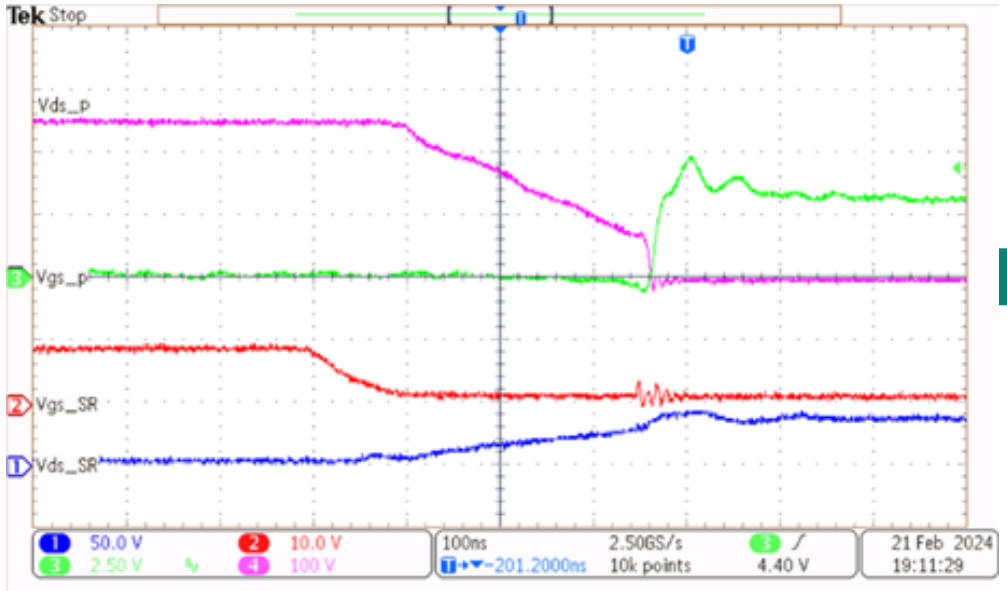
Basic QR-ZVS flyback operation



Power density:1.94W/cm^3 due to 200kHz high switching frequency



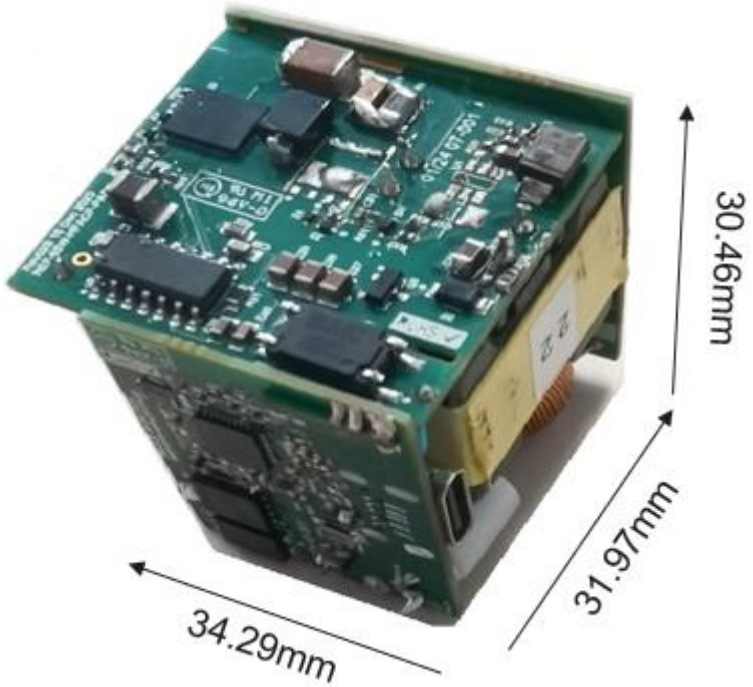
Before primary switch turn on, SR turn on for short interval to implement ZVS pulse.



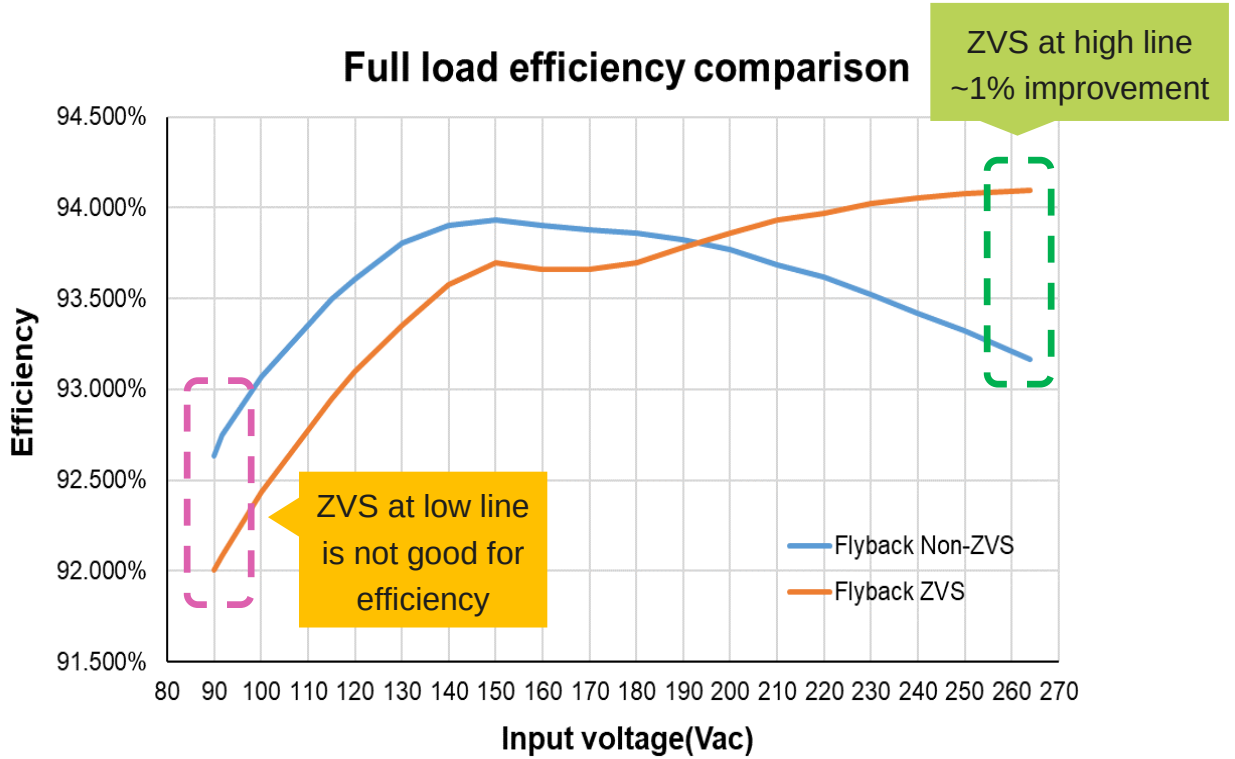
Coss of primary switch discharge to zero to realize ZVS before Primary gate turn on.

Secondary side-controlled ZVS Flyback Converter for 65W USB-PD

--Full load efficiency comparision between ZVS and Non-ZVS



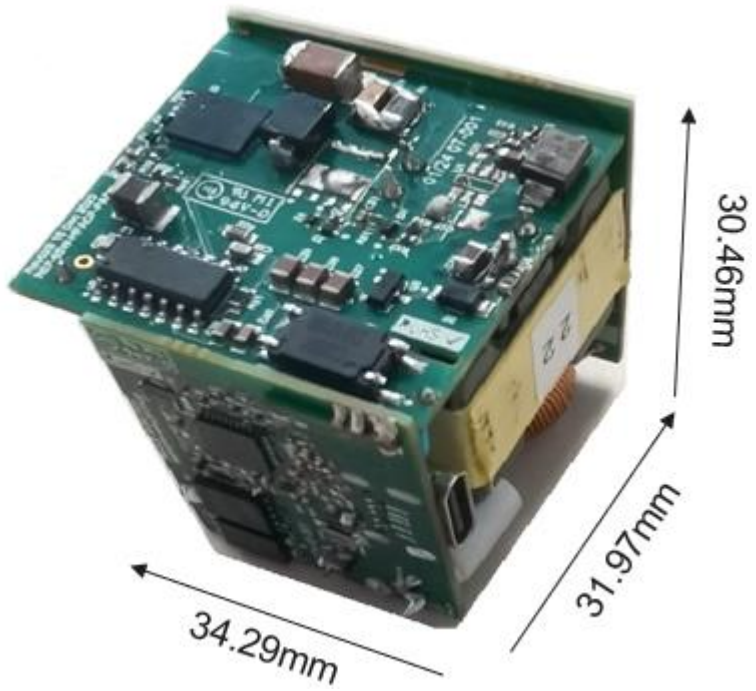
Power density:1.94W/cm^3 due to 200kHz high switching frequency



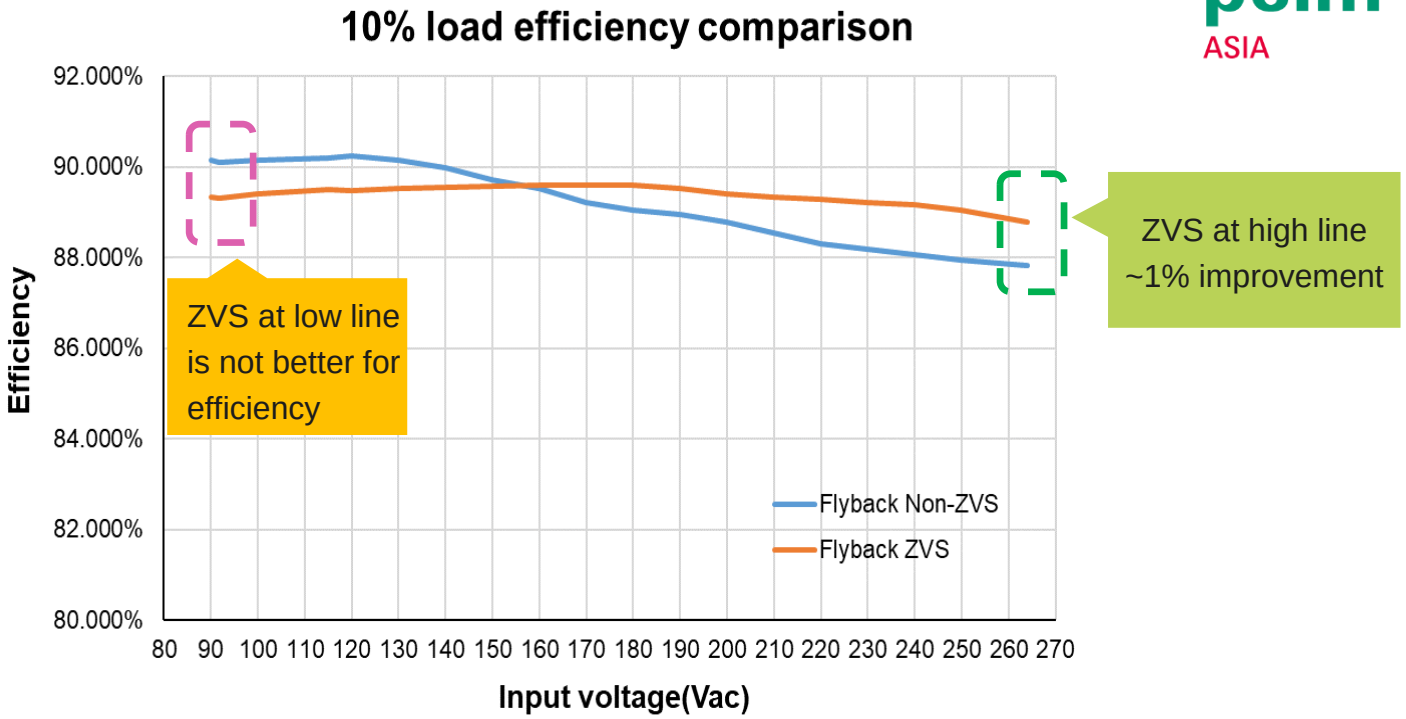
- Full load efficiency comparison between ZVS and Non ZVS of the prototype show ZVS at high line can improve efficiency obviously, ZVS at low line cannot bring improve.

Secondary side-controlled ZVS Flyback Converter for 65W USB-PD

--10% load efficiency comparision between ZVS and Non-ZVS



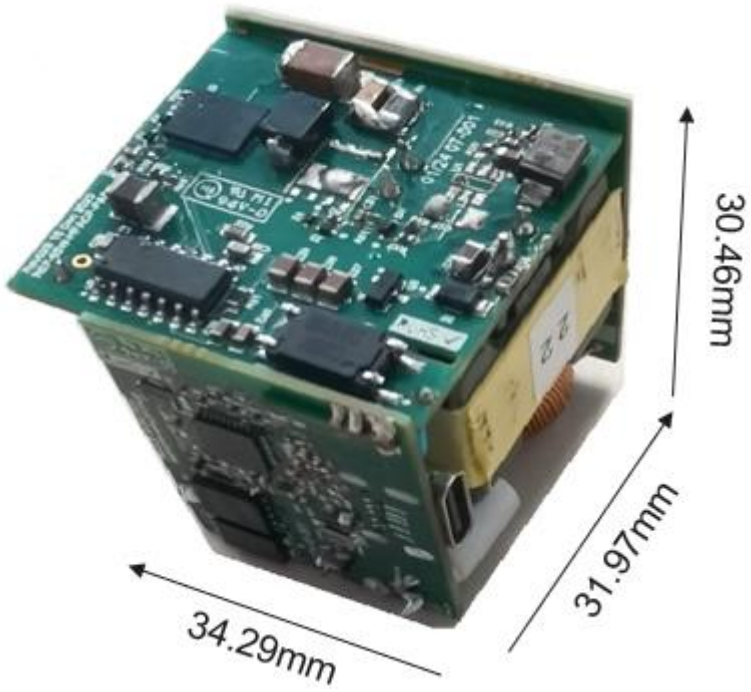
Power density:1.94W/cm^3 due to 200kHz high switching frequency



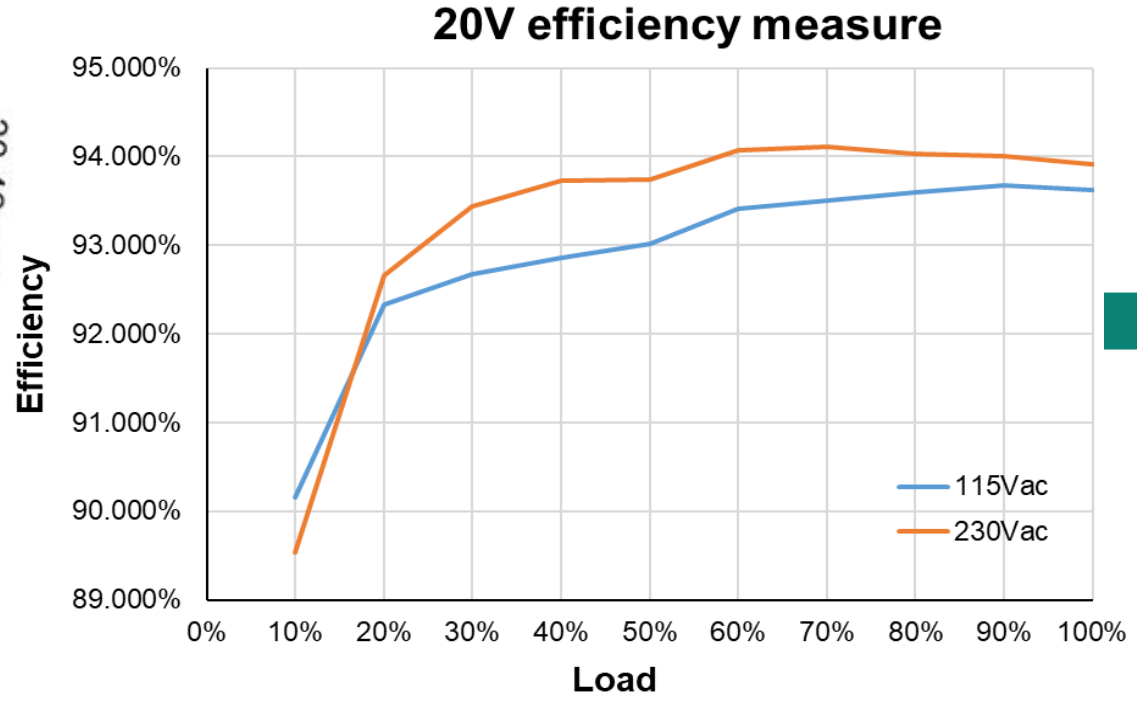
- 10% load efficiency comparison between ZVS and Non ZVS of the prototype also show ZVS at high line can improve efficiency, ZVS at low line cannot bring improvement.

Secondary side-controlled ZVS Flyback Converter for 65W USB-PD

--20V efficiency measure with ZVS at high line and disable ZVS at low line

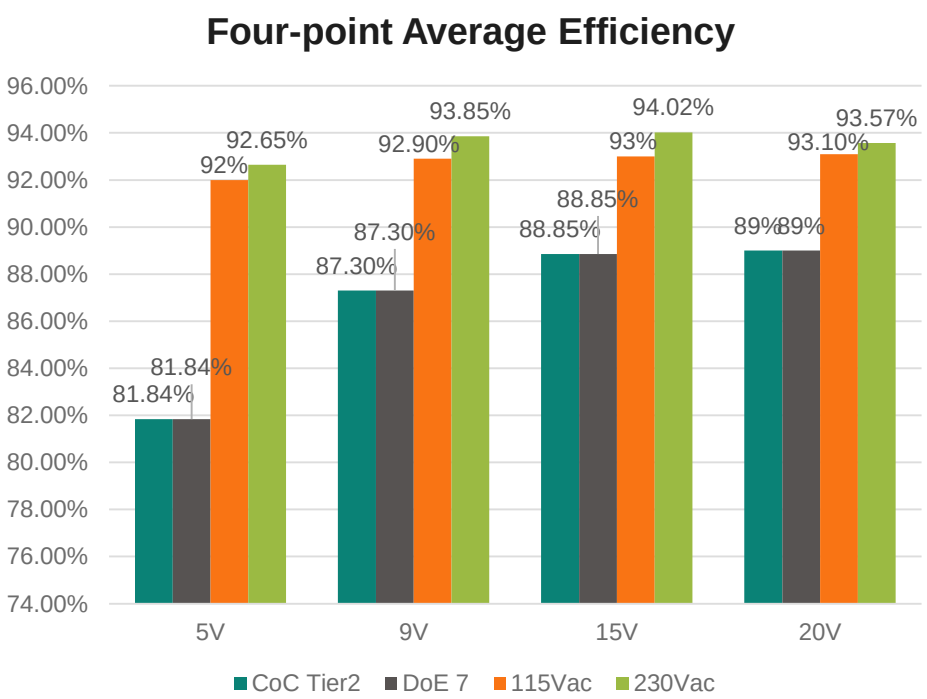


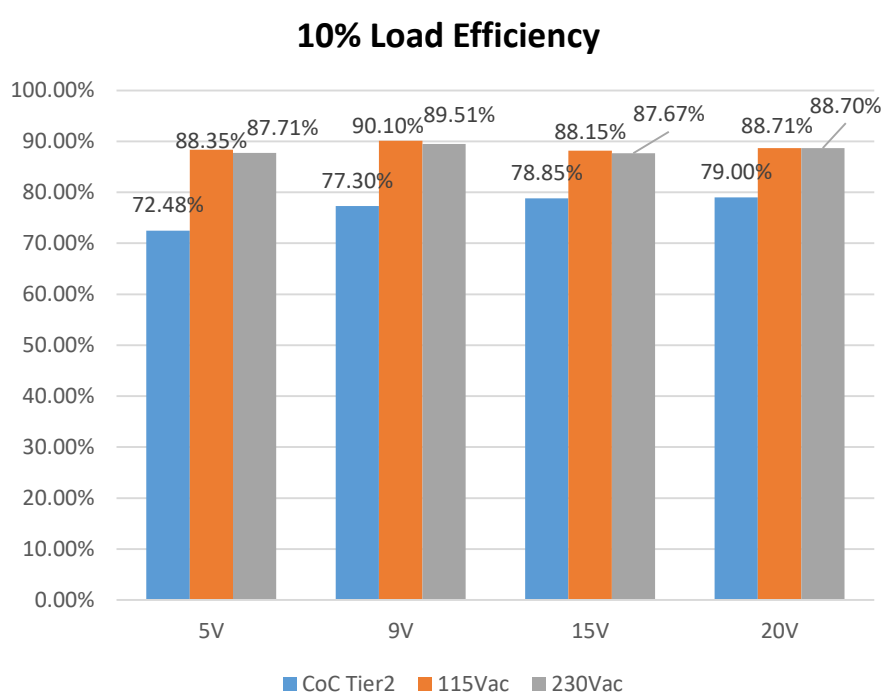
Power density:1.94W/cm^3 due to 200kHz high switching frequency

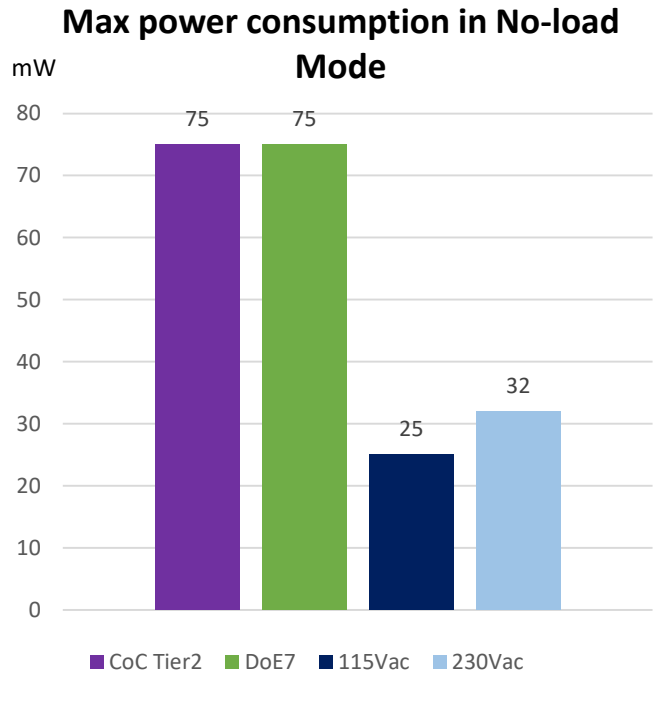


Firmware configuration enable ZVS at high line and disable ZVS at low line to improve efficiency at all range.

DoE VII and CoC Tier2 Compliance

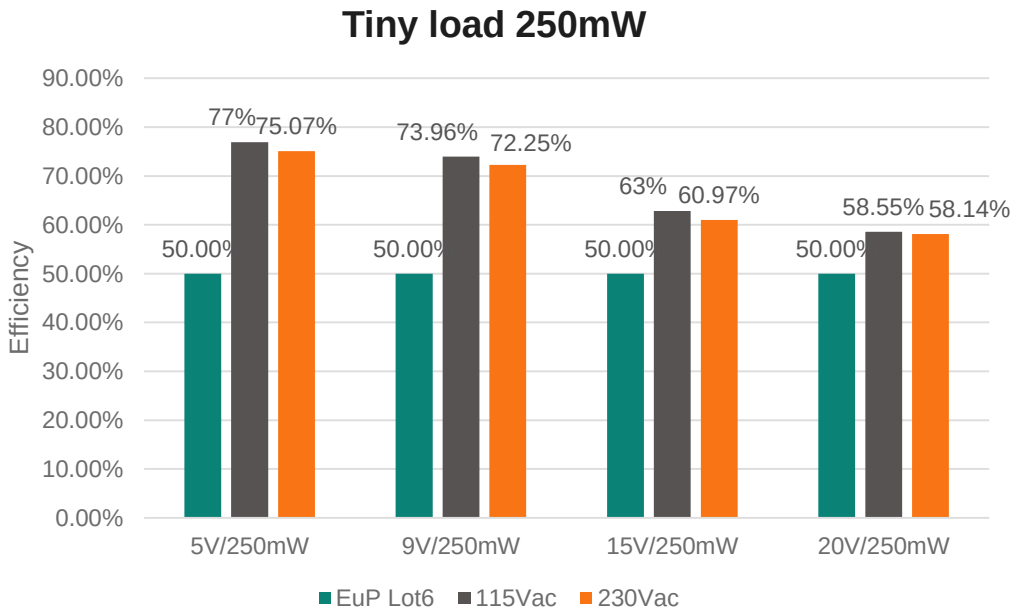


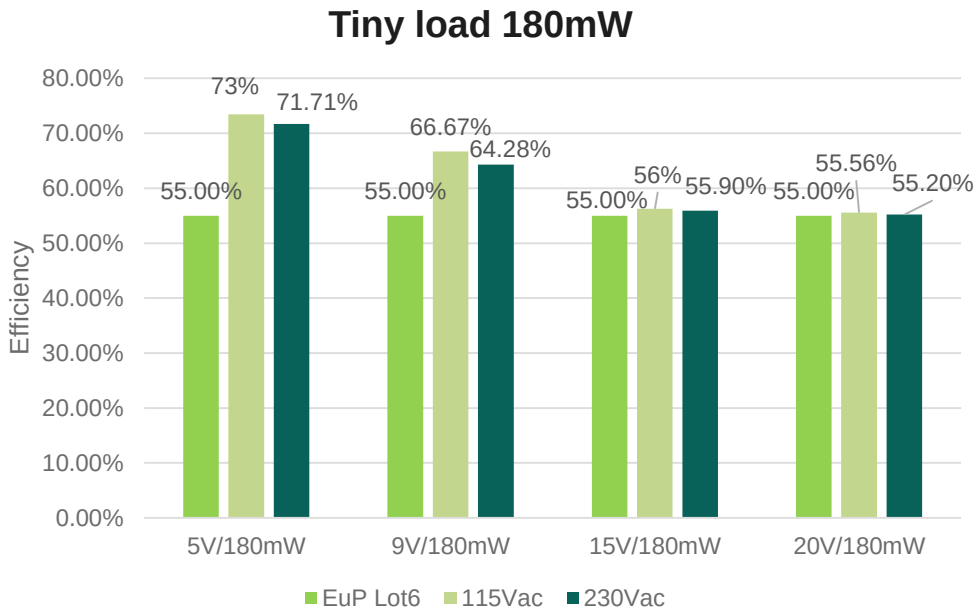




Disabling ZVS at low line and enabling ZVS at high line reach better four-point average efficiency,10% load efficiency and lower standby consumption.

Tiny Load Compliance (EuP Lot6)





Optimizing configurable system parameter dereases loss for tiny load and can meet EuP Lot6.

Conclusion

Conclusion

- A new ZVS flyback converter was developed with high Integration, better efficiency and thermal performance for Charger, Adapter and Wall outlet.
- The ZVS flyback converter can support high switching frequency performance and high efficiency without additional cost increase.
- Programmability can disable ZVS at low line and enable ZVS at high line for high efficiency at all AC input range.
- All programmable parameter like SR,PD,PWM can be optimized in secondary side for best performance.
- Efficiency measurements in targeted 65W USB-PD applications under ZVS and Non-ZVS conditions confirm the promises from the findings on the application level, with realized efficiency improvements of up to about 1 % at high line.


Infineon