



英飞凌发布业界首款支持5~48V PD3.1 PFC+HFB二合一控制器XDP52221

钱家法

总监 技术支持
英飞凌大中华区电源与传感系统事业部



Infineon is a global leader in power systems and IoT

Global leader

in automotive, power management,
energy efficient technologies and IoT

~56,200

employees¹

Market position

Automotive

#1

TechInsights,
March 2023

Power

#1

Omdia,
October 2022

Microcontroller

#5

Omdia,
May 2023

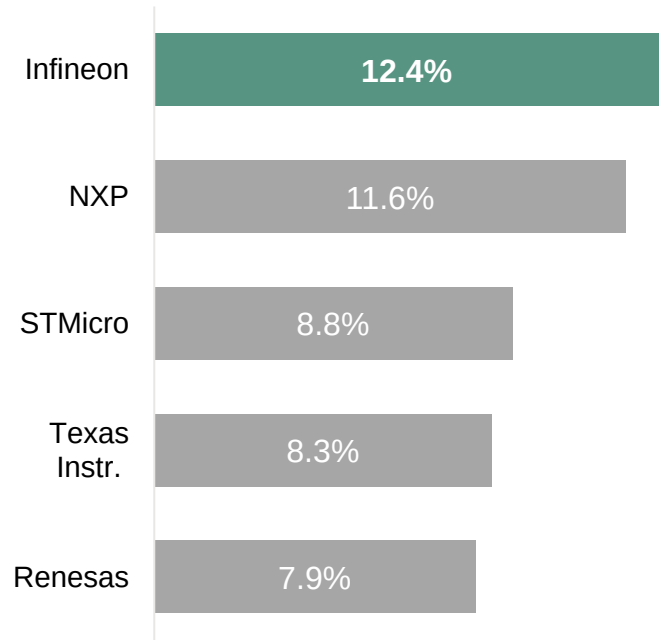
¹ As of 30 September 2022



Infineon is a top player in all target markets

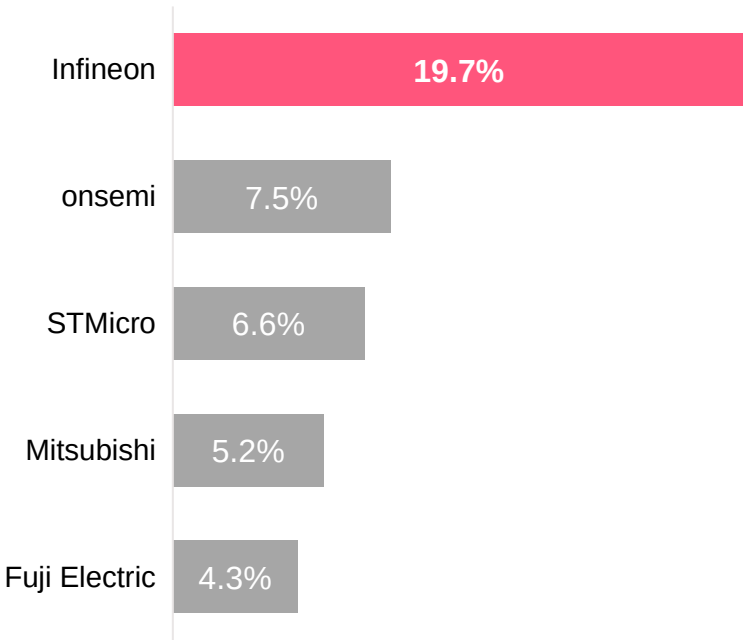
Automotive semiconductors¹

Total market in 2022: USD 59.4bn



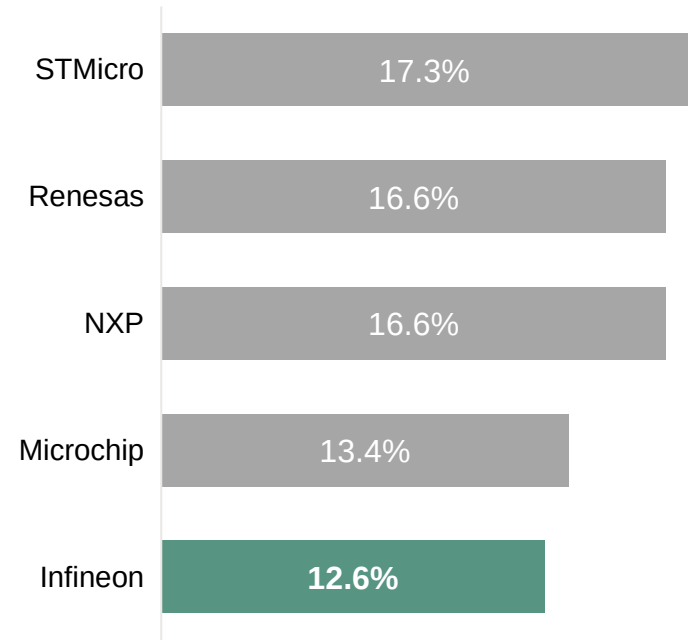
Power discretes and modules²

Total market in 2021: USD 27.5bn



Microcontroller³

Total market in 2022: USD 26.9bn



¹ TechInsights: Automotive Semiconductor Vendor Market Shares. March 2023. | ² Based on or includes research from Omdia: Power Semiconductor Market Share Database – 2021 – Final V2. October 2022. | ³ Based on or includes research from Omdia: Annual 2001-2022 Semiconductor Market Share Competitive Landscaping Tool – 1Q23. May 2023. Results are not an endorsement of Infineon Technologies AG. Any reliance on these results is at the third party's own risk.

XDPS2221

XDPS2222

USB-PD



Charger



SPR

EPR up to 28V

Adapter



SPR

EPR up to 48V

Non USB-PD



Battery charger



TV



Docking

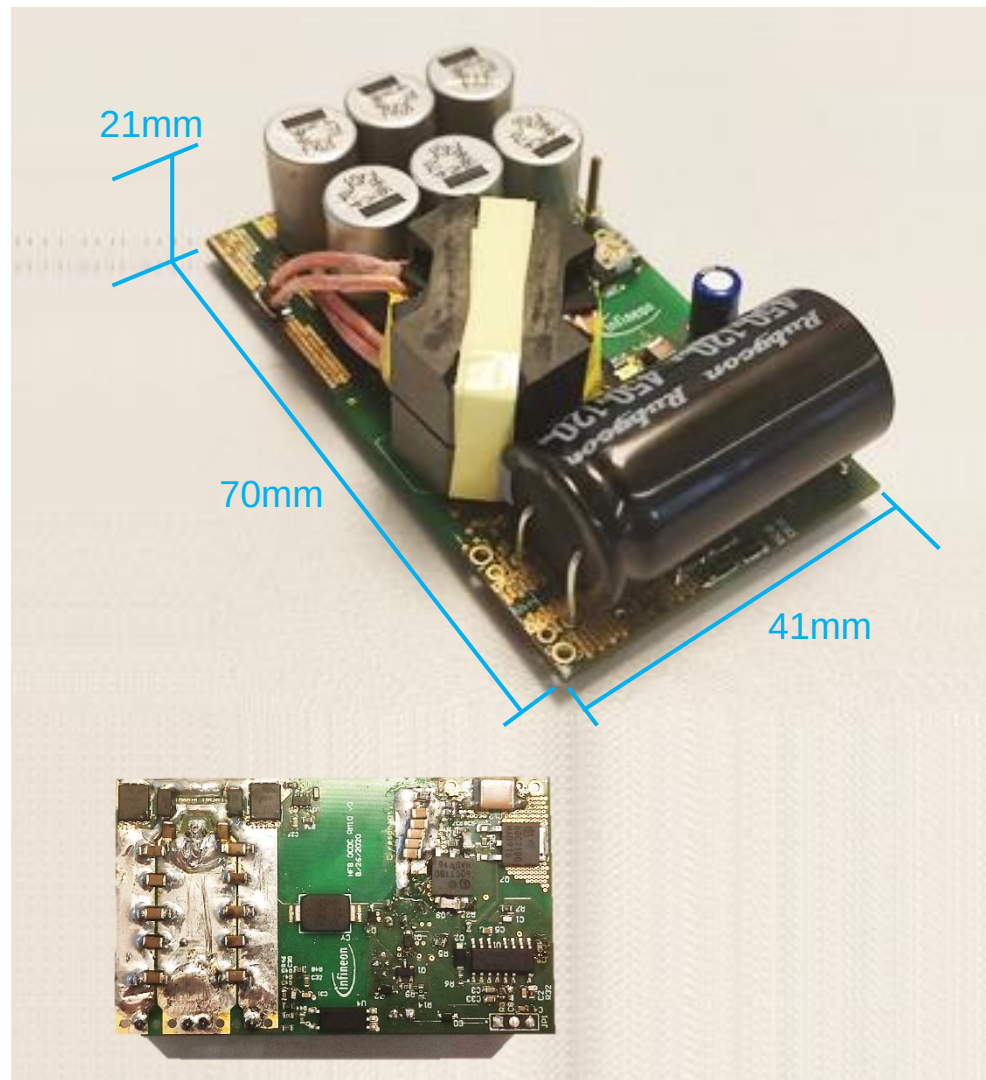


Gaming



- PFC级效率是进一步提升效率的瓶颈
- PD适配器的平均效率问题
- 5~48V超宽输出范围与效率存在矛盾
- PWM控制器驱动GaN的电路较复杂
- 主控制器与SR控制器的适配问题

240W HFB 控制器 XDPS2201 宽输出、峰值功率 DC/DC演示版



240w 5 ~ 24v

240W@5~24V/10A

300W@24V/12.5A, 10s

350W@24V/14.58A, 1s



4 w/cc

65 W/in³
70 x 41 x 21 mm³

97.6%

96.7% @12V/10A
97.6% @24V/10A

输入: 320-400V_{DC}

- HFB IC XDPS2201
- HFB GaN 2 x IPD60R180C7 (CoolMOS™)
- SR MOSFET BSC037N08NS5 (OptiMOSTM 5 power MOSFET)
- 变压器磁芯 RM10
- 母线电解电容 450V/120uF
- 输出电解电容 35V / 470uF

140W PFC+HFB 二合一控制器XDPS2221 PD3.1演示版



140w 5~28v

5 V / 3 A, 9 V / 3 A,
15 V / 5 A, 20 V / 5 A,
28 V / 5 A

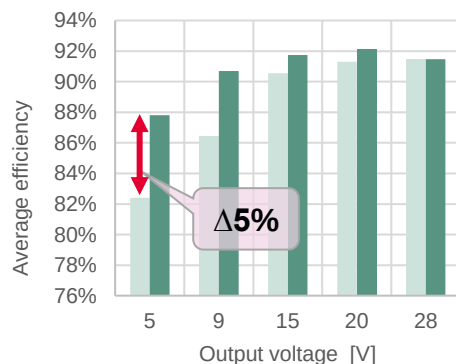
1.38 W/cc

22.7 W/in³
109.5 x 38.5 x 24.0 mm³

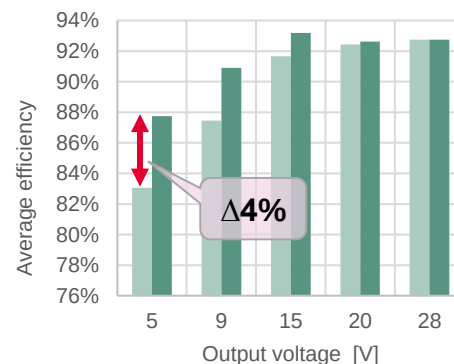
95% 峰值效率, 230Vac

4~5%↑ 平均效率提升
5Vo/230Vac~115Vac

平均效率 @115Vac



平均效率 @230Vac



- PFC+HFB IC
- PFC GaN
- HFB GaN

XDPS2221
IGLD60R190D1 (CoolGaN™)
2 x IGLD60R190D1 (CoolGaN™)

- SR MOSFET
- PD IC
- Output MOSFET

BSC040N10NS5 (OptiMOS™ 5 power MOSFET)
CYPD3175 (EZ-PD™ CCG3PA)
IRF7240

240W PFC+HFB 新一代二合一控制器 XDPS2222 PD3.1演示版



240w 5 ~ 48v

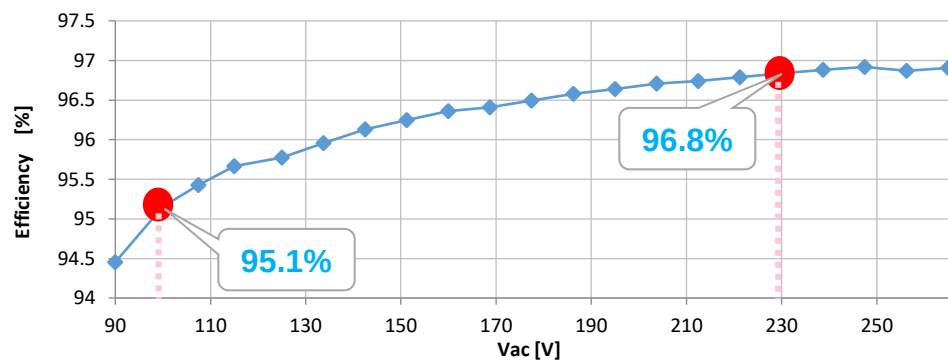
5 V / 3 A, 9 V / 3 A,
15 V / 5 A, 20 V / 5 A,
28 V / 5 A, 36 V / 5 A, 48 V / 5 A

2.7 w/cc

44 W/in³
110 x 40 x 20 mm³

95.1 ~ 96.8%

100Vac: 前级~ 97 % (有源桥), HFB: ~ 98 %
230Vac: 前级~ 98.8 %, HFB: ~ 98 %



- PFC+HFB IC
- Active Bridge
- PFC MOSFET
- HFB GaN

XDPS2222
4xIPL60R065P7 (CoolMOS™ 600 V)
IPL60R104C7 (CoolMOS™ 600 V)
2 x IGLD60R190D1 (CoolGaN™)

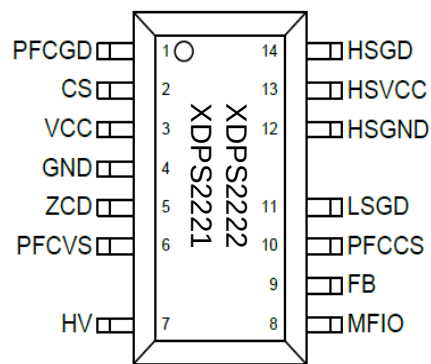
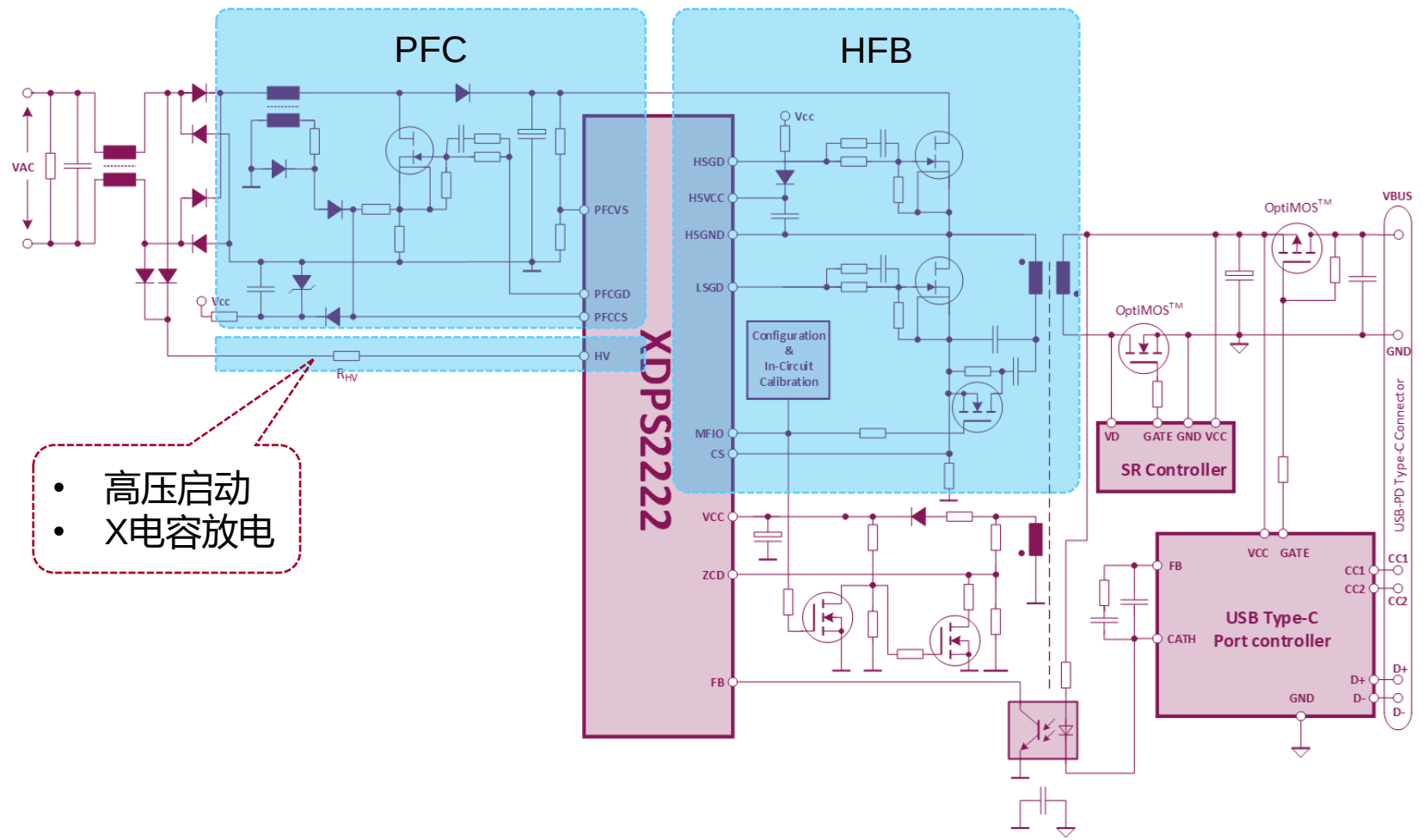
- SR MOSFET
- PD IC
- Output Switch

BSC074N15NS5 (OptiMOSTM 5 power MOSFET)
CYPD3175 (EZ-PD™ CCG3PA)
IPB110P06LM (p-channel power MOSFET)

XDP™ 数字电源 XDPS2222: PFC + HFB (Hybrid FlyBack) 二合一控制器



- 集成自适应PFC和软开关HFB
- 支持MOSFET/GaN应用
- 参数可配置，优化系统
- DSO-14 封装，与XDPS2221脚兼容
- 高压和低压单元宽安全爬电距离



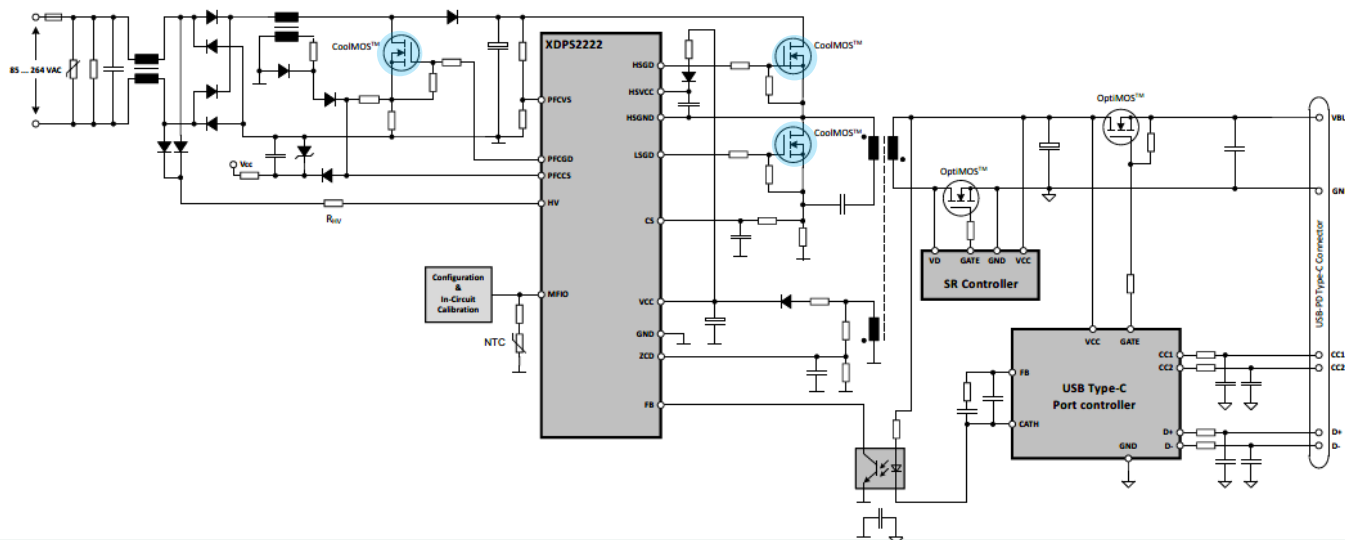
Hybrid FlyBack (HFB) = AHB Flyback

XDPS2222的几种应用形式 —— 搭配 MOSFET 或Infineon的GaN

■ 搭配MOSFET

- 无需外部驱动器
- 可搭配CoolMOS™ (C7,P7,P7S...)

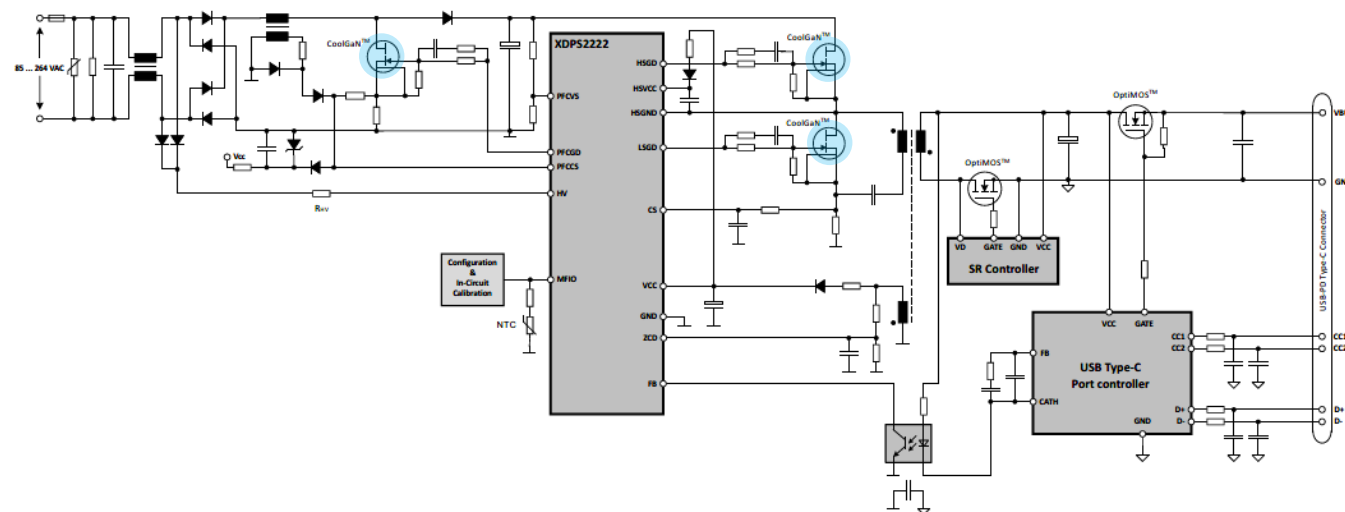
搭配 MOSFET



■ 搭配英飞凌电流型驱动的GaN

- 可搭配单管或半桥GaN
- 直接驱动，无需外部驱动器和限压电路

搭配英飞凌 GaN



XDPS2222的几种应用形式 —— 搭配Infineon的 SR+PD二合一控制器

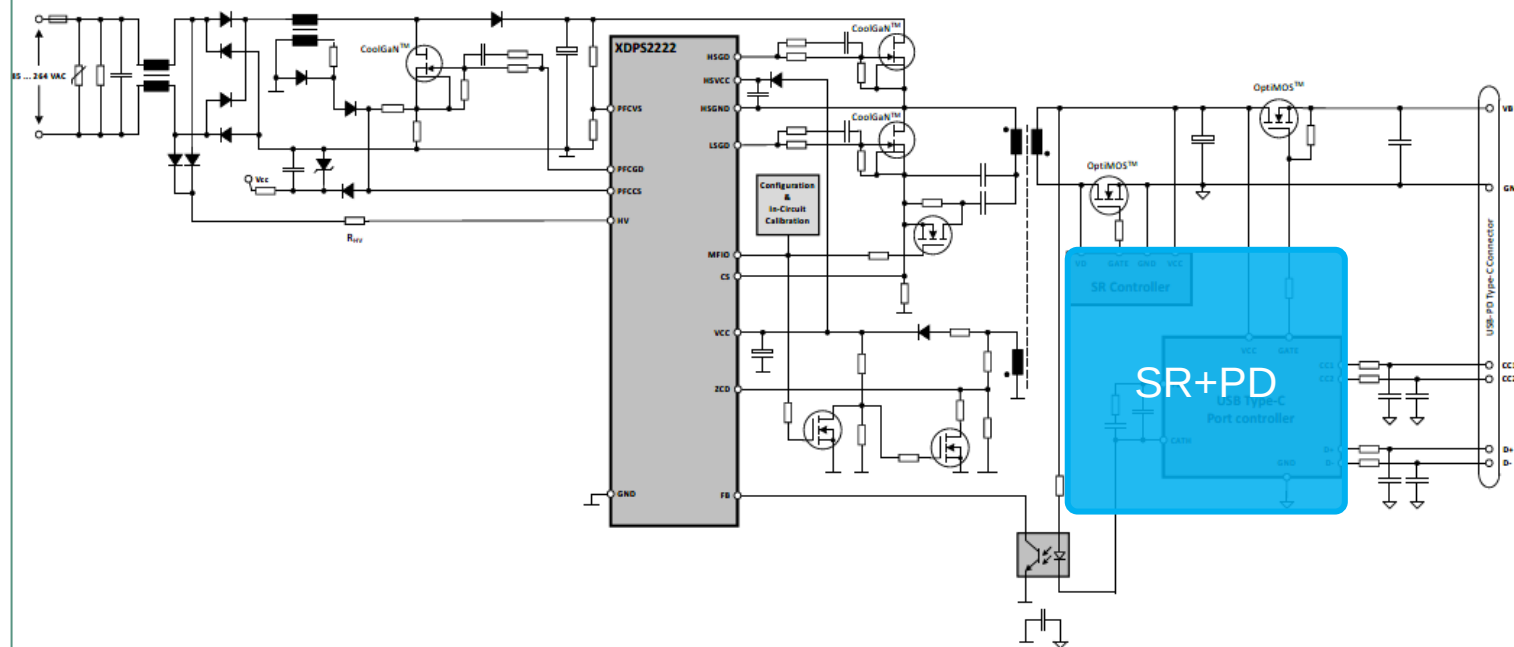
■ 简化次级电路

- SR+PD 二合一 (CYPAG2xx)
- 负载开关控制
- CYPAG2xx支持MV GaN

■ 与初级协同工作提高可靠性

- 与XDPS2221/2222 可灵活协同
- 减少SR与初级开关的误动作

与Infineon的 SR+PD二合一控制器 (CYPAG2xx) 搭配



XDPS2222的几种应用形式 —— 半桥谐振电容切换

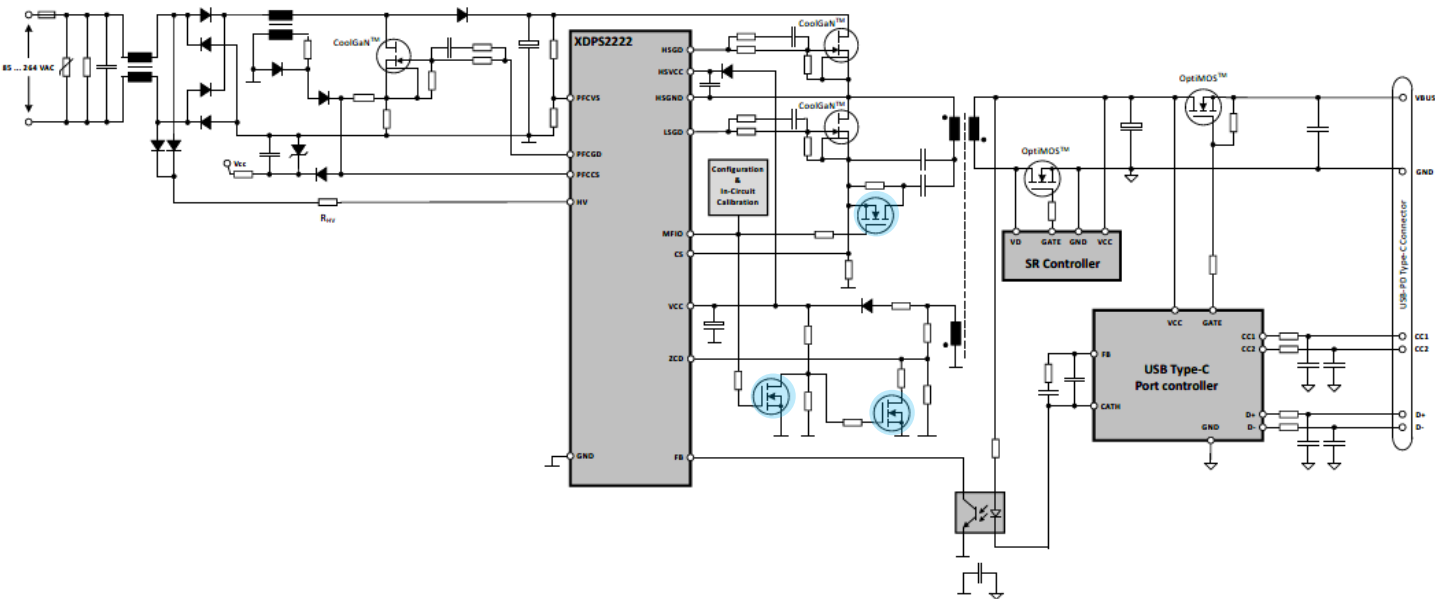
■ 半桥谐振电容切换

- 为高低不同的输出电压采用不同的谐振容容值，从而改变谐振槽路
- 减小低输出电压时的RMS电流，提高效率

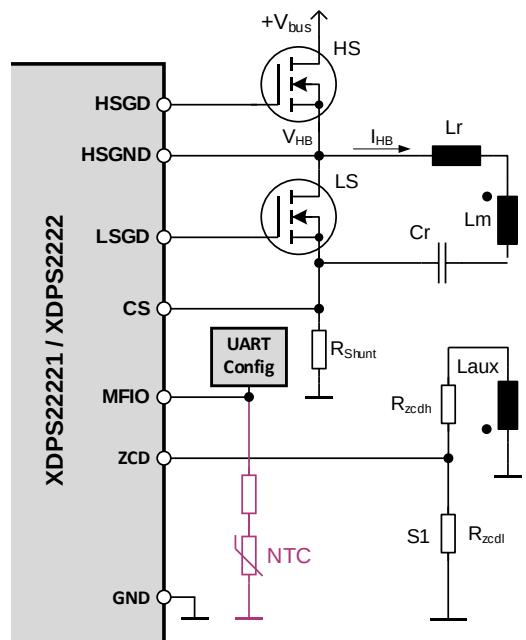
■ 切换ZCD分压比例

- 根据输出电压高低切换ZCD分压比例
- 提高ZCD电压分辨率

谐振电容切换

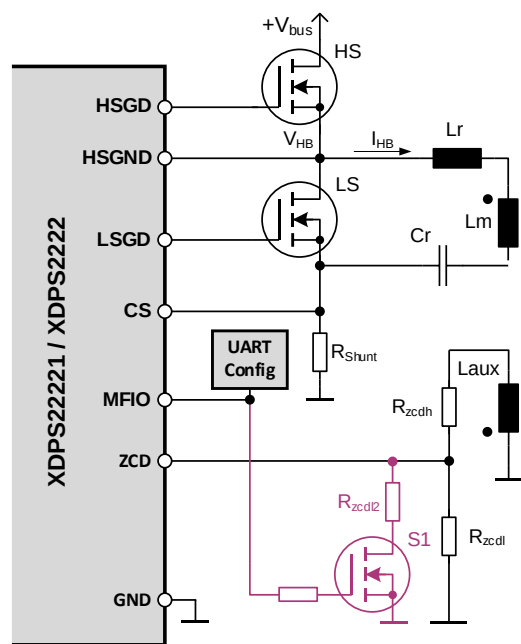


过温保护(XDPS2221 / XDPS2222)



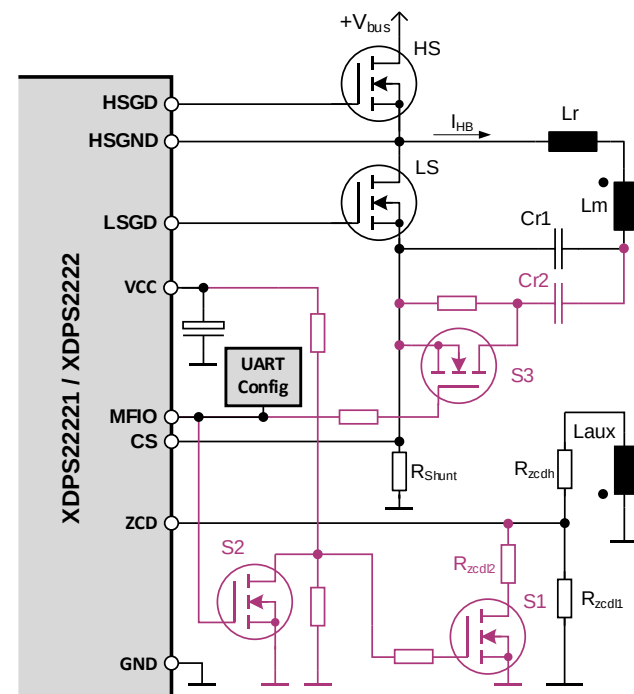
→ MFIO脚 使用NTC做外部过温保护

切换ZCD分压比(XDPS2222)



→ MFIO脚 根据输出电压高低切换ZCD分压比例
提高ZCD电压分辨率

谐振电容切换(XDPS2222)

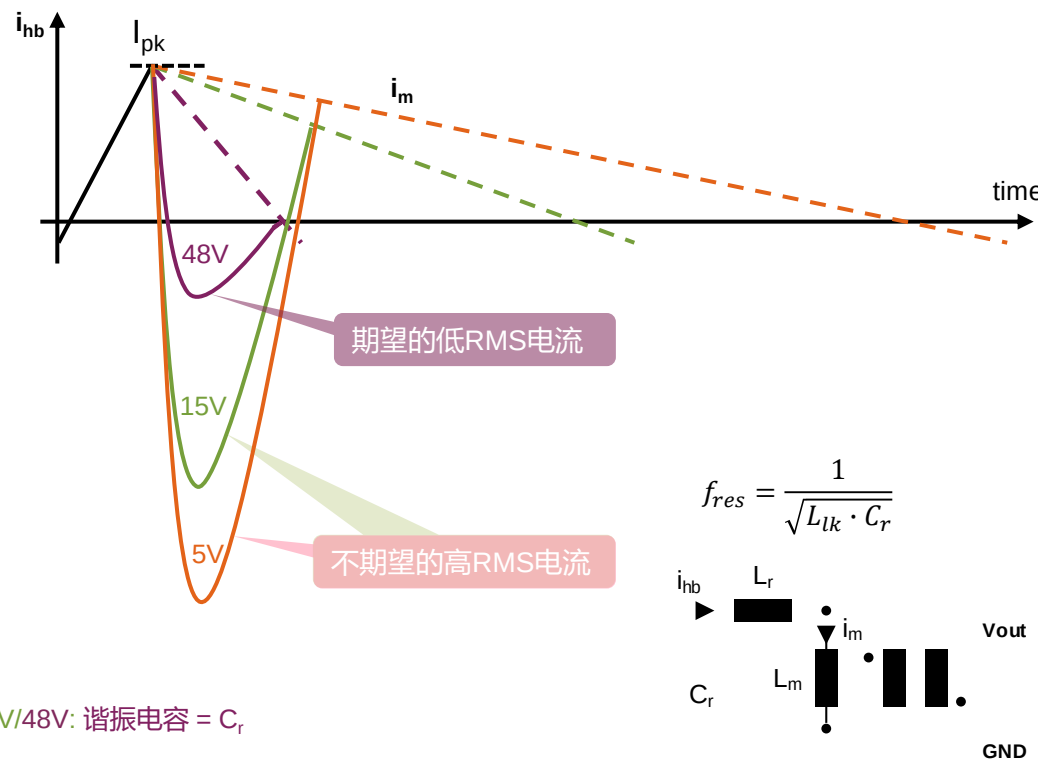


→ MFIO脚进一步根据输出电压切换谐振电容

不同输出电压下的混合反激电流波形

谐振槽路不变的电流波形

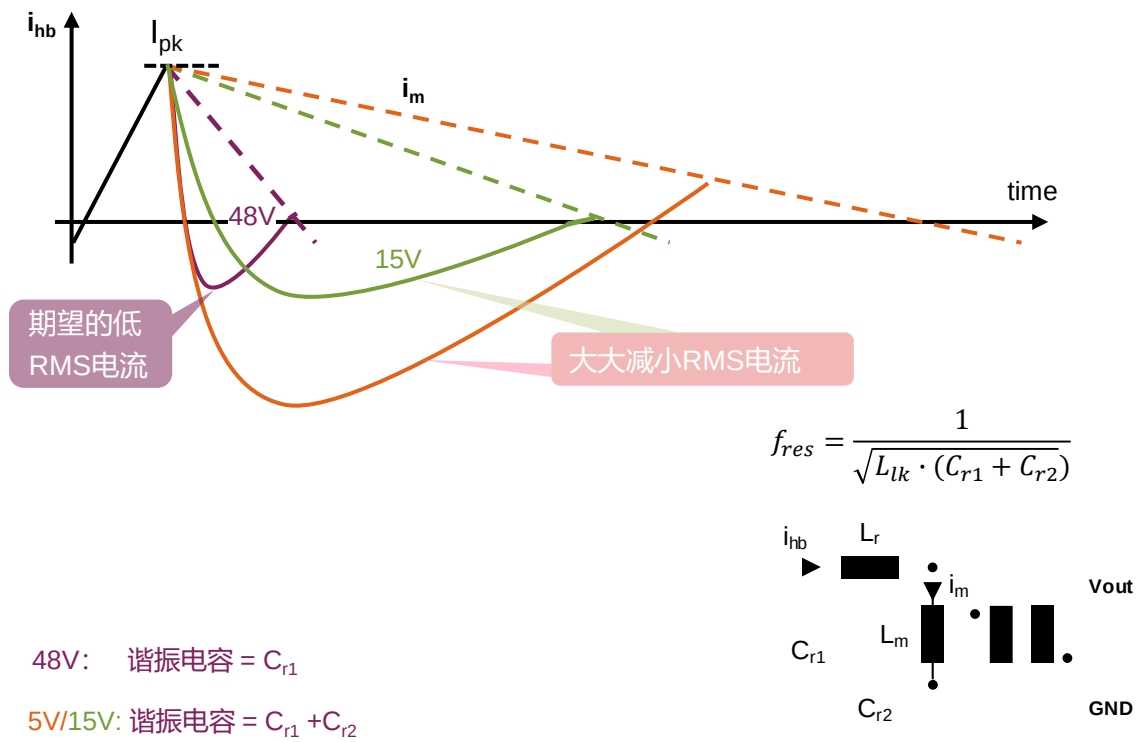
$$t_{demag} = \frac{I_{pk}}{V_{cr}} L_{mag} = \frac{I_{pk}}{NV_{out}} L_{mag}$$



→ 低输出电压下，变压器退磁时间长
低输出电压下，峰值谐振电流大，RMS电流大，低效率

谐振电容切换情形下的电流波形 (XDPS2222)

$$t_{demag} = \frac{I_{pk}}{V_{cr}} L_{mag} = \frac{I_{pk}}{NV_{out}} L_{mag}$$



→ 为高低不同的输出电压采用不同的谐振容容值
减小RMS电流，提高效率

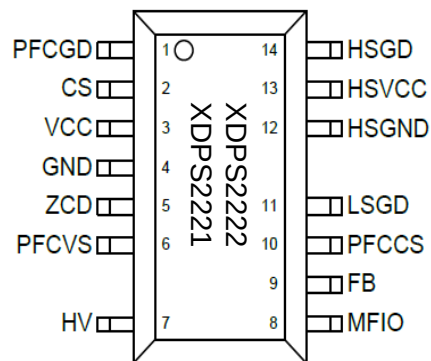
PFC+HFB 二合一控制器 XDPS2221/2222 —— 高集成，易设计

■ 能效提高单元

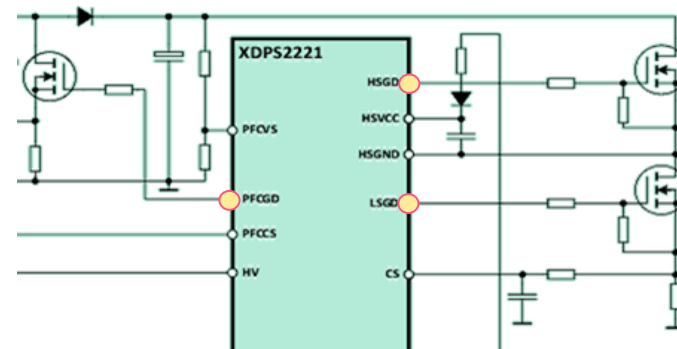
- 600 V 高压启动单元
- 有源 X电容放电功能

■ 集成 3 个开关驱动器

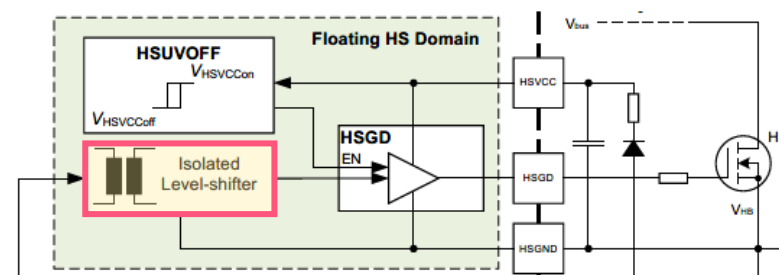
- PFC驱动+半桥驱动（低侧+高侧）
- **无磁芯变压器** 高侧驱动
 - 高耐压，抗干扰能力强，高可靠性
- **驱动电流可调**
 - 电流大小可调
 - 电流斜率可调，优化EMI



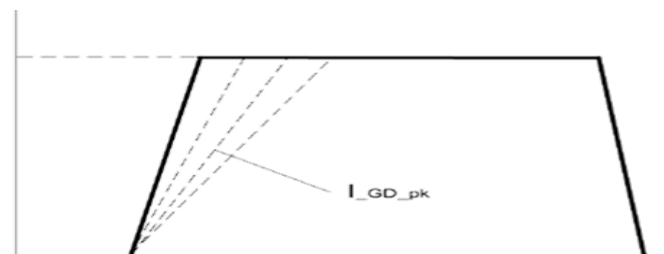
集成 3 个驱动



无磁芯变压器驱动



驱动电流可调



■ PFC多模式工作

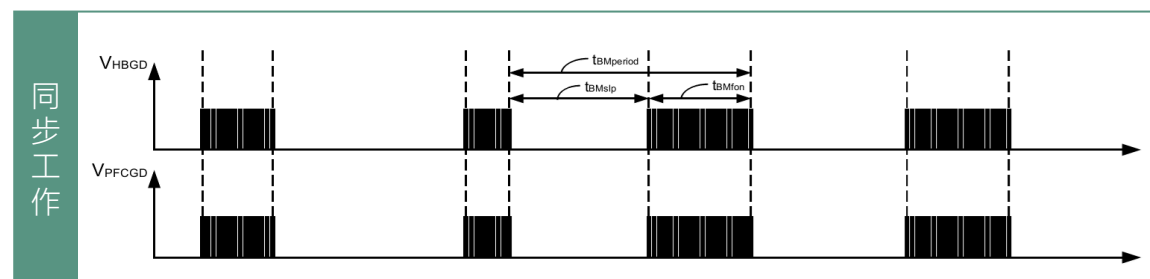
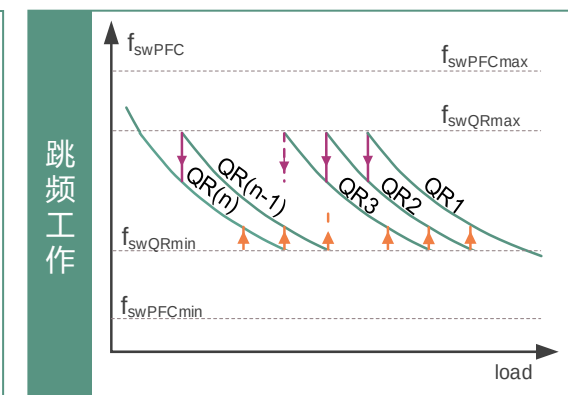
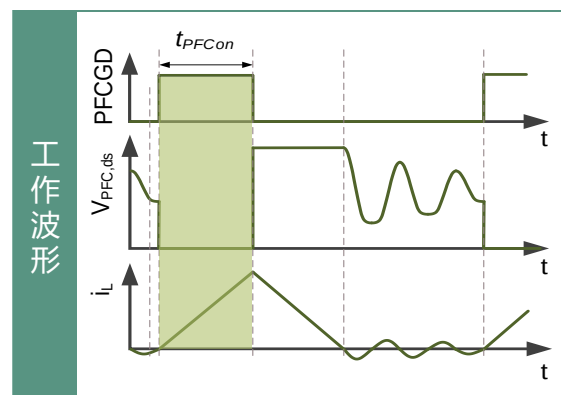
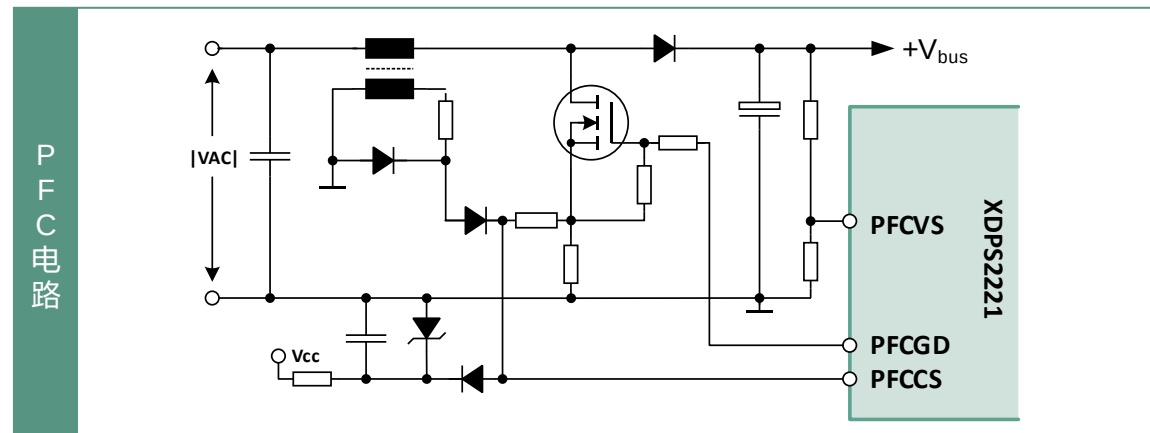
- 准谐振QR模式，谷底开通
- 最高频率限制，跳频工作
- 轻载间歇工作

■ 固定开通时间控制

■ 高PF值，低谐波畸变

■ 与后级HFB协同工作，同步间歇工作

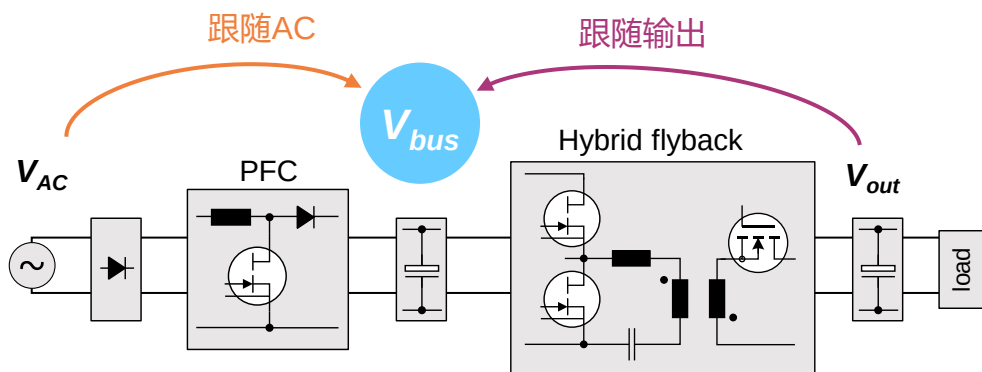
- 更好的待机效率
- 较小轻载或待机纹波电压
- 减小负载切换电压过冲



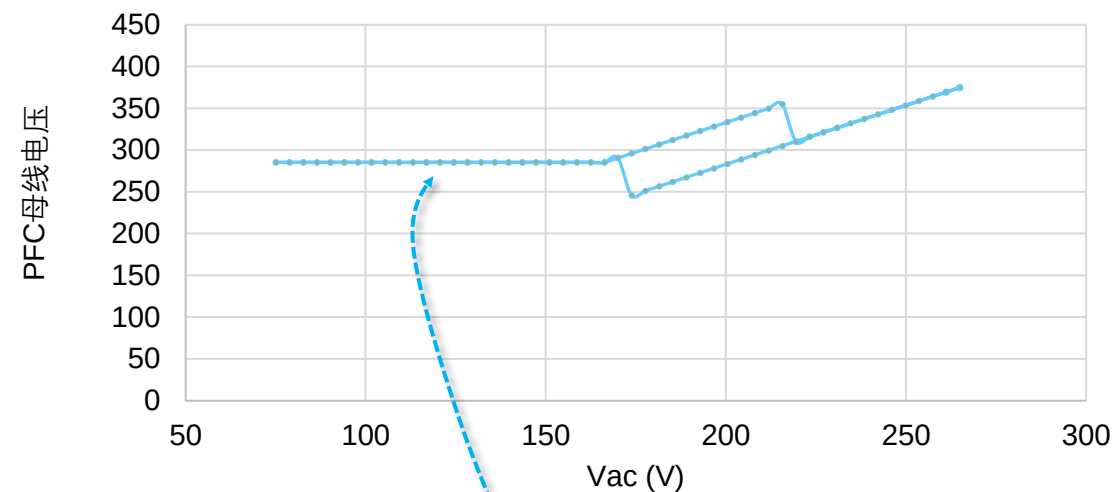
PFC母线电压自适应——提高平均效率

■ PFC母线电压根据不同条件改变

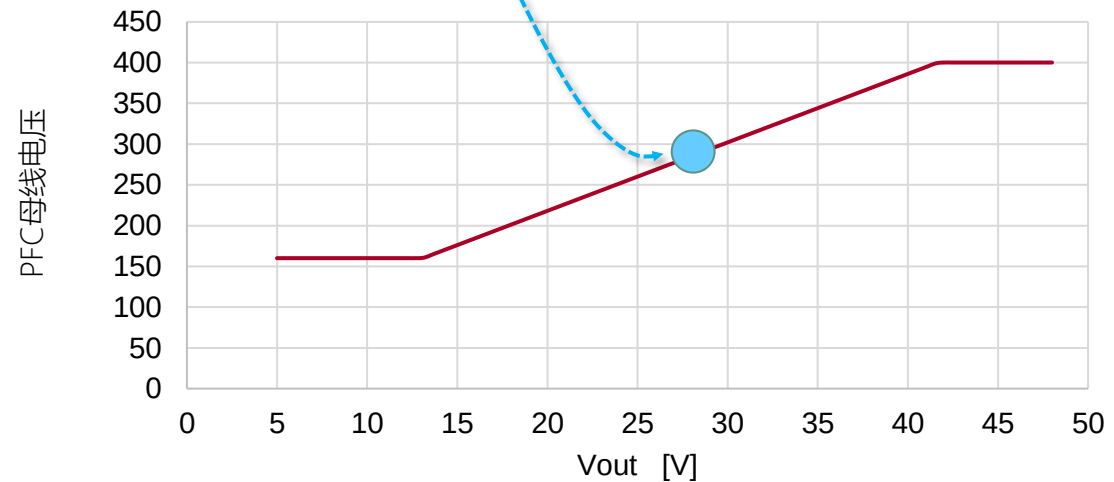
- 跟随输入电压，提高PFC级效率
- 跟随输出电压，维持HFB级增益和效率
- 切换条件可在配置文件中自定义



跟随输入电压



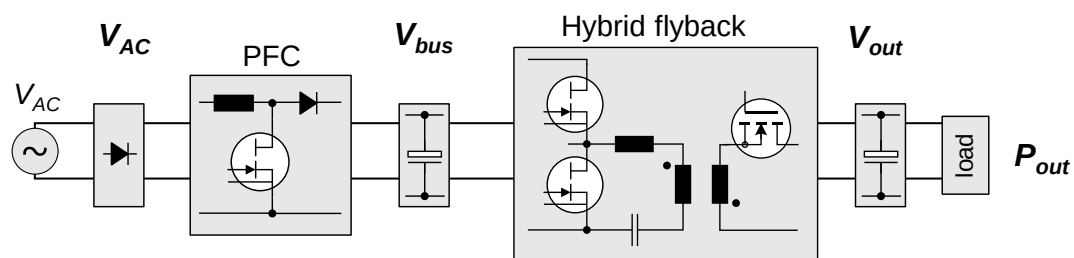
跟随输出电压



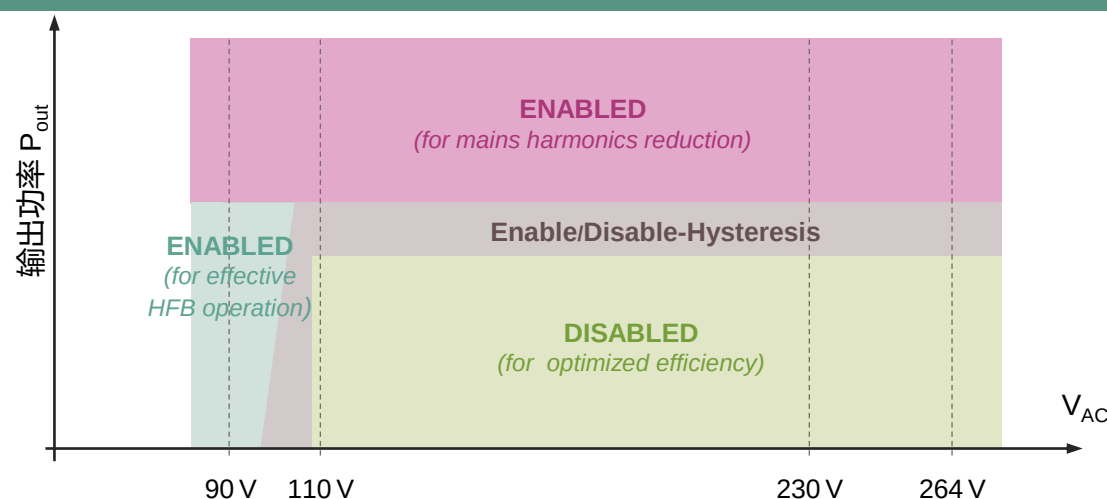
PFC自动启停 —— 提高轻载和待机性能

■ PFC根据不同的条件启停，提高轻载和待机性能

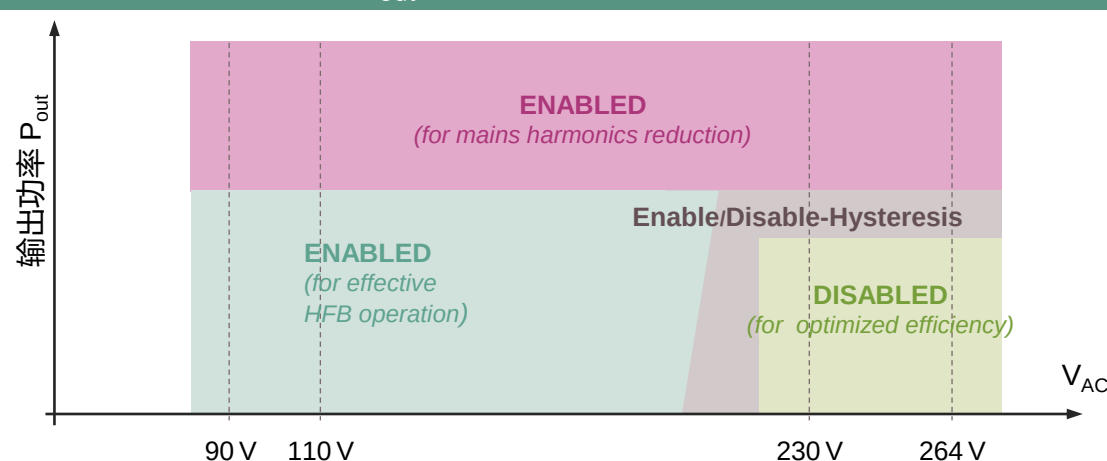
- HFB轻载间歇工作时睡眠/唤醒的状态
- 根据输出功率大小启停
- 根据输入AC电压和输出电压的不同组合启停
- 切换条件可在配置文件中自定义



低输出电压时(如: $V_{out} = 5.0\text{ V}$)



高输出电压时 (如: $V_{out} = 28.0\text{ V}$)



XDPS2221/XDPS2222的HFB混合反激控制

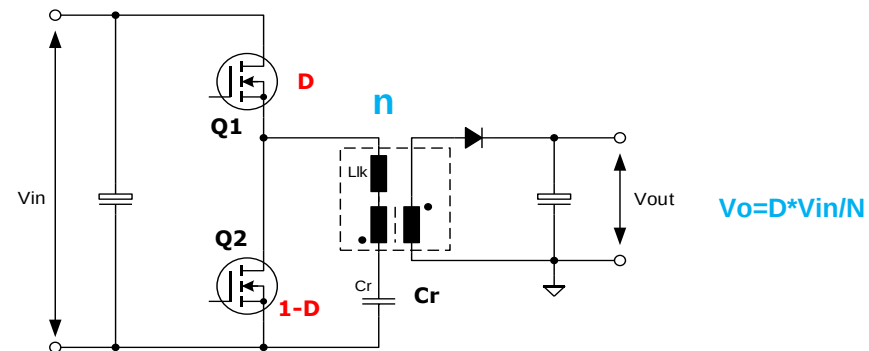
■ 拓扑优点

- 相比于传统反激, **变压器更小** (小一半或以上)
- 初级和次级的开关应力更低

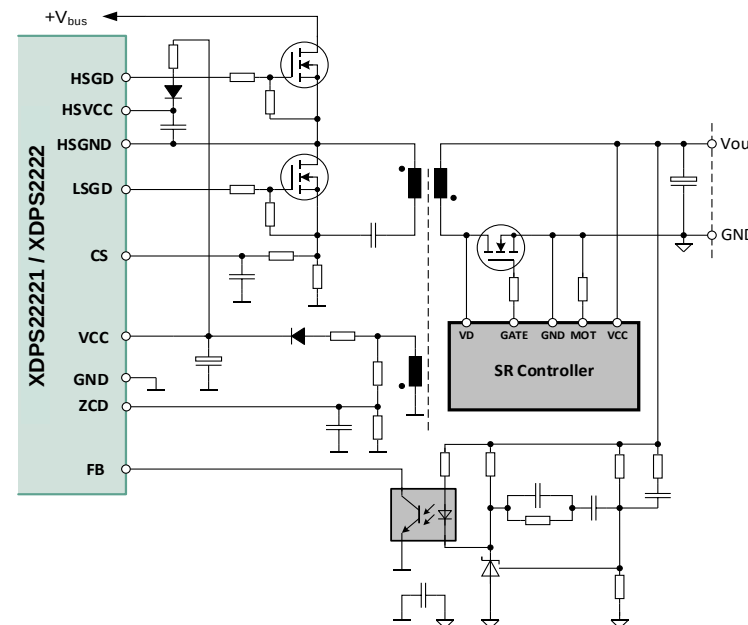
■ HFB混合反激控制

- 峰值电流模式控制
- 传递延时补偿
- 频率抖动改善EMI
- **全工况软开关工作**
- 独有ZVS脉冲插入技术实现轻载软开关

HFB 拓扑



HFB 混合反激电路



HFB混合反激拓扑减小变压器 (相比于 QR或ACF)

- ACF 变压器转移的功率

$$P_{m_ACF}=P_o$$

- HFB 变压器转移的功率

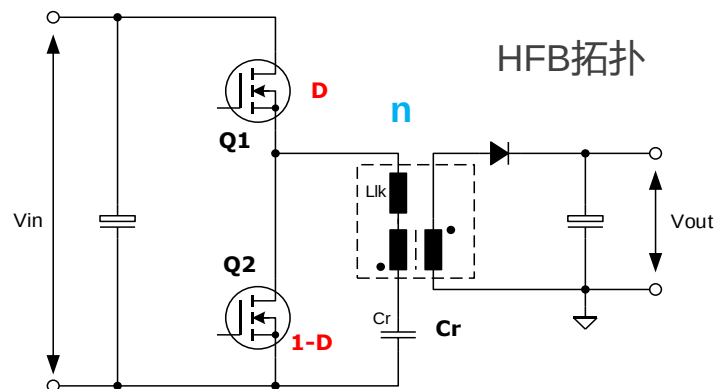
$$P_{m_HFB}=P_o * (1-D)$$

- HFB 谐振电容转移的功率

$$P_{c_HFB}=P_o * D$$

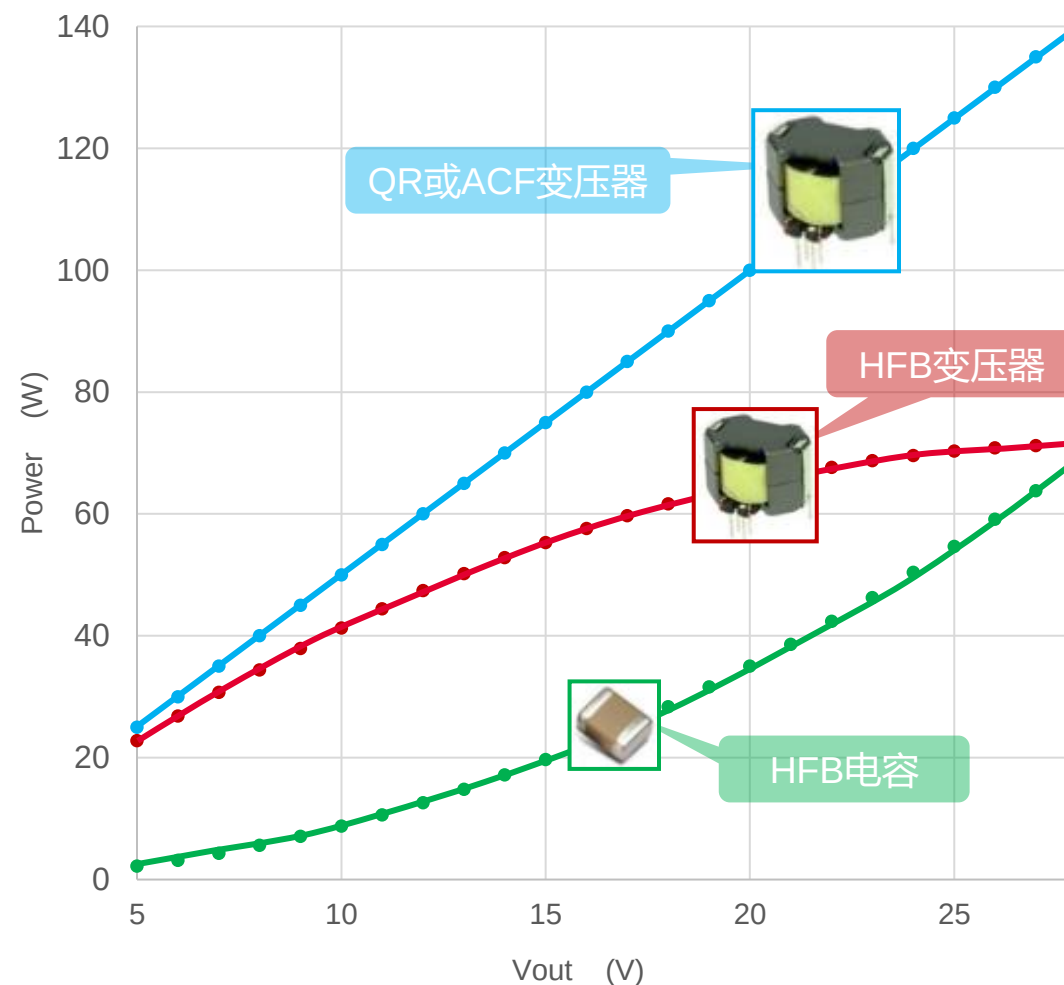
$$P_{m_HFB} + P_{c_HFB} = P_o$$

- HFB 在相同频率下，相同的变压器能传输更大的功率



*理想情况对比

固定母线电压下变压器储能对比 (临界工作模式)



HFB 的开关管具有更小的电压应力（相比于QR反激/ACF）

■ ACF (注：近似计算)

- 主开关管的电压应力较大，是输入电压加上反射电压：

$$V_{ds_Q} = V_{in} + n \cdot V_o$$

- 整流管的电压应力：

$$V_{ds_SR} = \frac{V_{ds_Q}}{n} = \frac{V_{in}}{n} + V_o$$

■ HFB

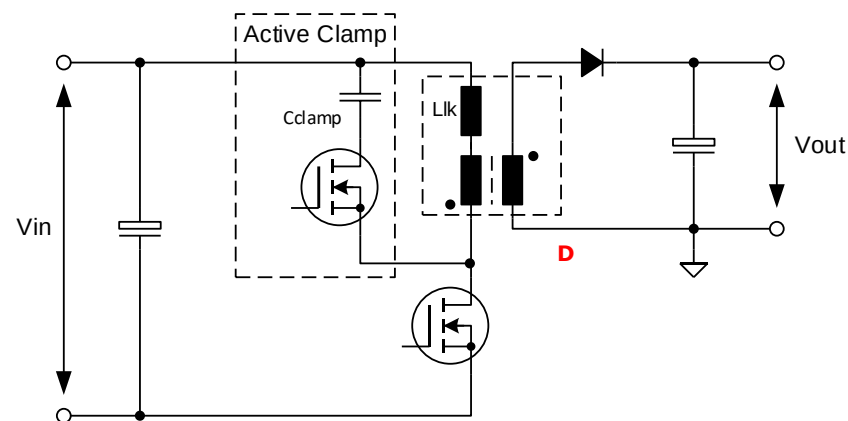
- 主开关管的电压应力较小，钳位到输入电压：

$$V_{ds_Q} = V_{in}$$

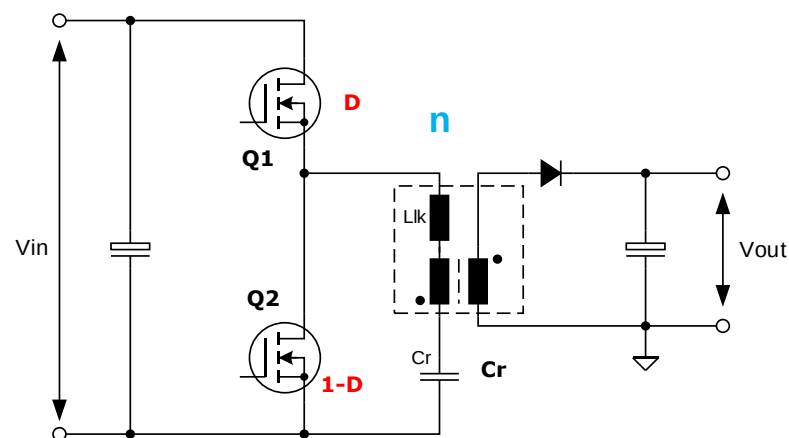
- 整流管的电压应力：

$$V_{ds_SR} = \frac{V_{ds_Q}}{n} = \frac{V_{in}}{n}$$

ACF有源钳位反激

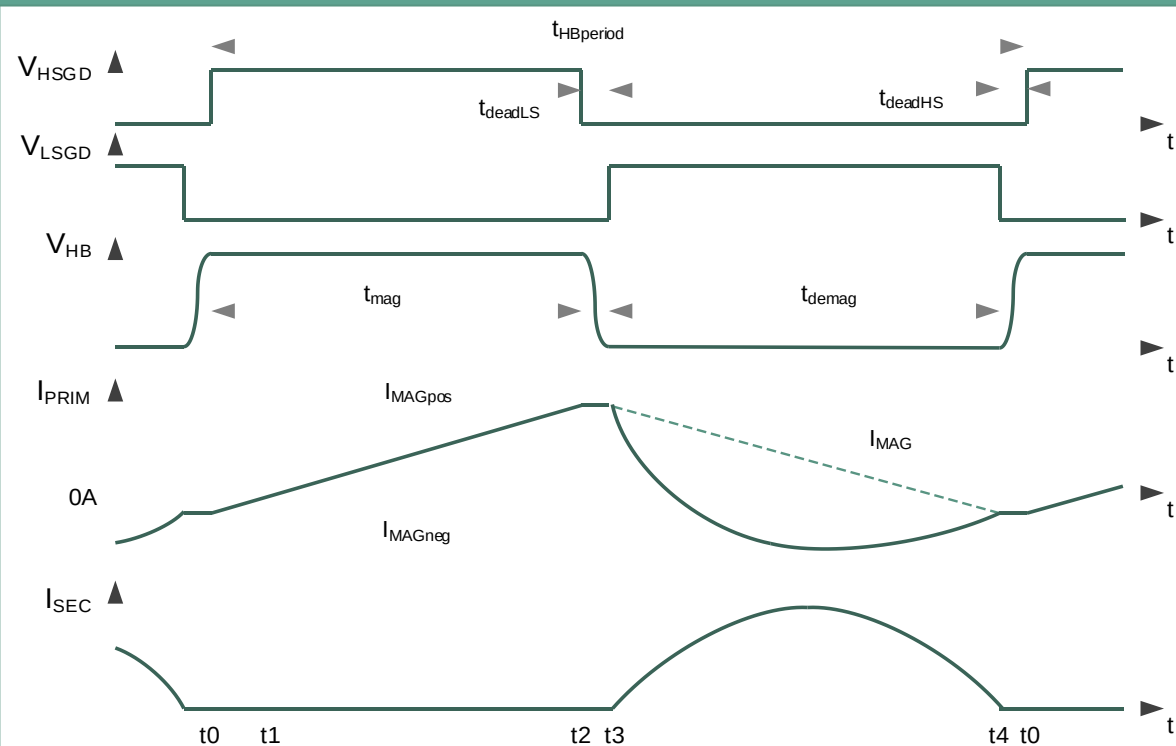


HFB混合反激



HFB不同模式的波形

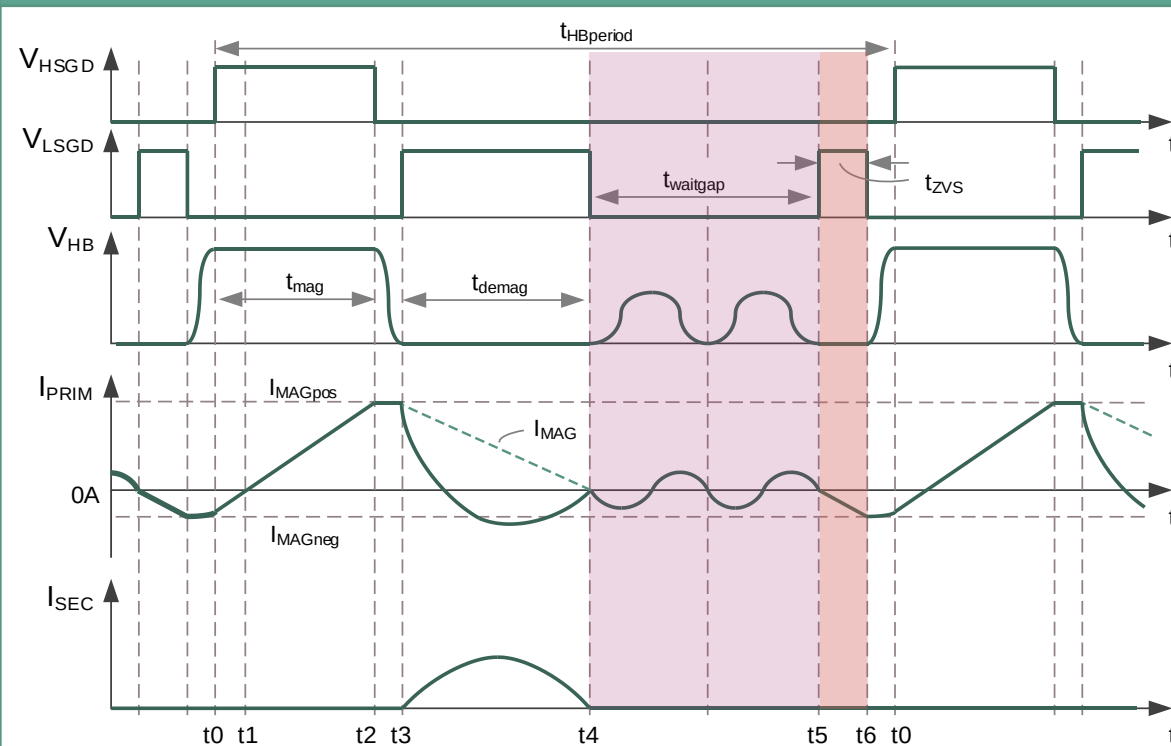
CRM 模式：重载条件下工作



$$I_{out} = \frac{N(I_{MAGpos} + I_{MAGneg})}{2}$$

$$F_{sw} = \frac{V_{cr}(V_{in} - V_{cr})}{I_p L_p V_{in}}$$

ZV-RVS模式：轻载条件，脉冲插入

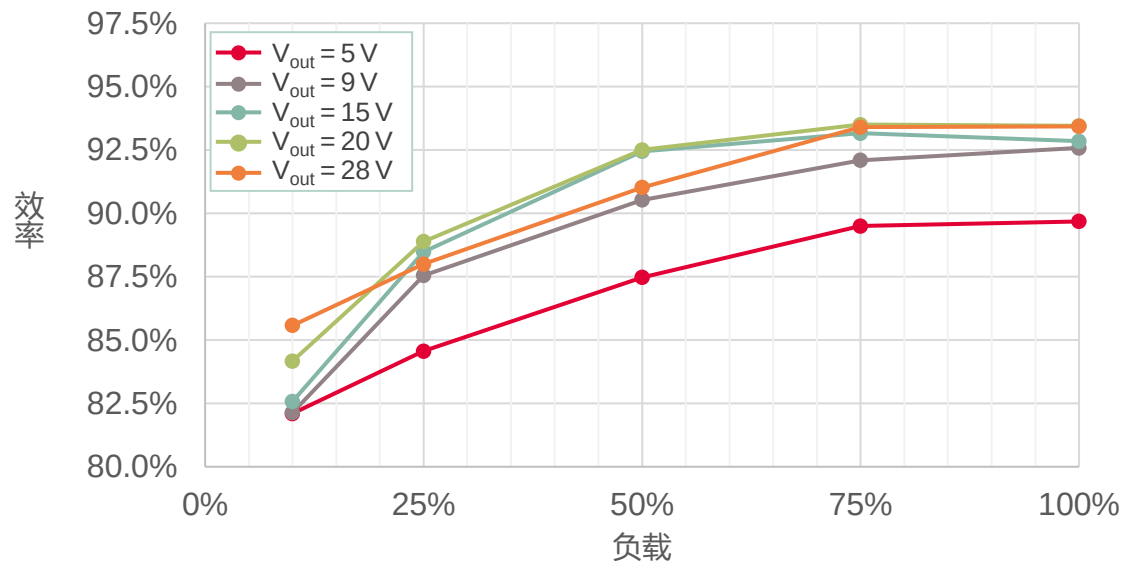


$$I_{out} = \frac{t_{HBperiod} - t_{waitgap}}{t_{HBperiod}} \frac{N(I_{MAGpos} + I_{MAGneg})}{2}$$

140W 演示版效率数据

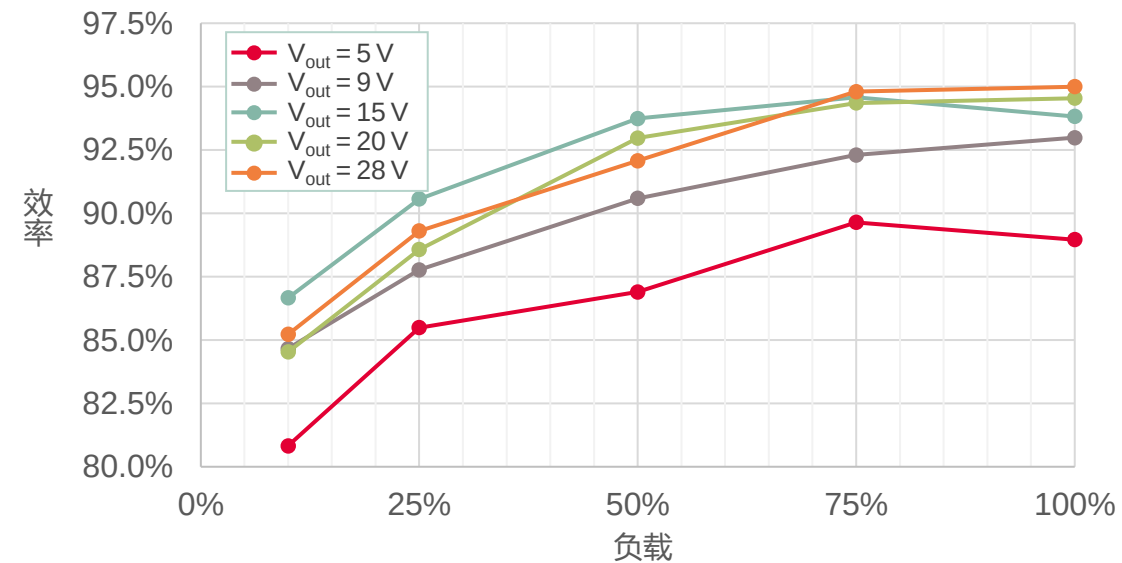


V_{AC} = 115V / 60 Hz



V _{out}	平均效率 (25%, 50%, 75%, 100%)	DoE level 6	CoC Tier 2	结果
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} = 230V / 50 Hz

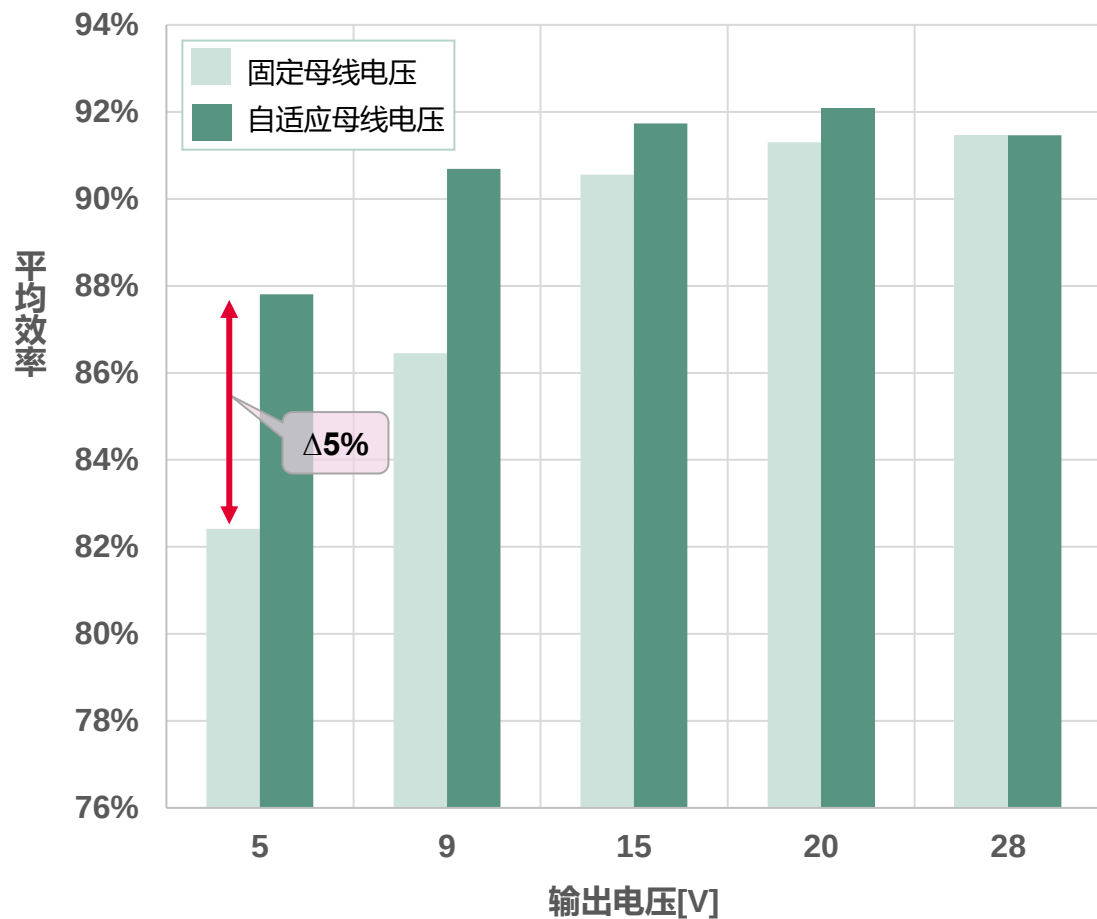


V _{out}	平均效率 (25%, 50%, 75%, 100%)	DoE level 6	CoC Tier 2	结果
5.0 V	87.63 %	81.39 %	81.84 %	PASS
9.0 V	90.85 %	87.73 %	88.85 %	PASS
15.0 V	93.09 %	88.0 %	89.0 %	PASS
20.0 V	92.33 %	88.0 %	89.0 %	PASS
28.0 V	92.51 %	88.0 %	89.0 %	PASS

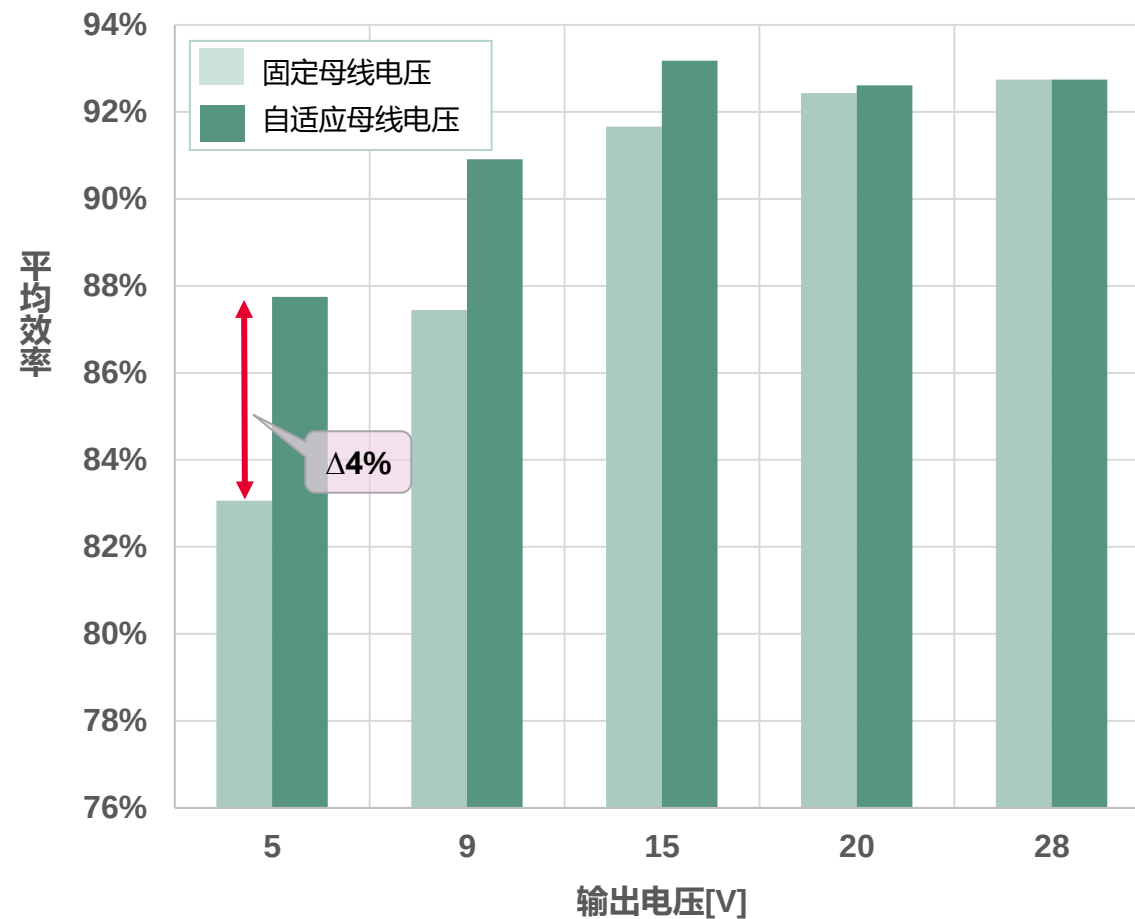
注：数据来自于140W XDPS2221 演示板

明显提升平均效率——可达 4~5%

$V_{AC} = 115\text{ V} / 60\text{ Hz}$



$V_{AC} = 230\text{ V} / 50\text{ Hz}$



注：数据来自于140W XDPS2221 演示板

- XDPS2221与XDPS2222引脚兼容
- 自适应PFC母线电压提升平均效率
- PFC自动启停提高待机及轻载性能
- HFB谐振电容切换功能轻松实现5~48V超宽输出范围
- 可以直接驱动英飞凌电流型GaN
- SR+PD二合一控制器（CYPAG2xx）可协同提高可靠性



Part of your life. Part of tomorrow.