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辅助电源方案

肖海斌

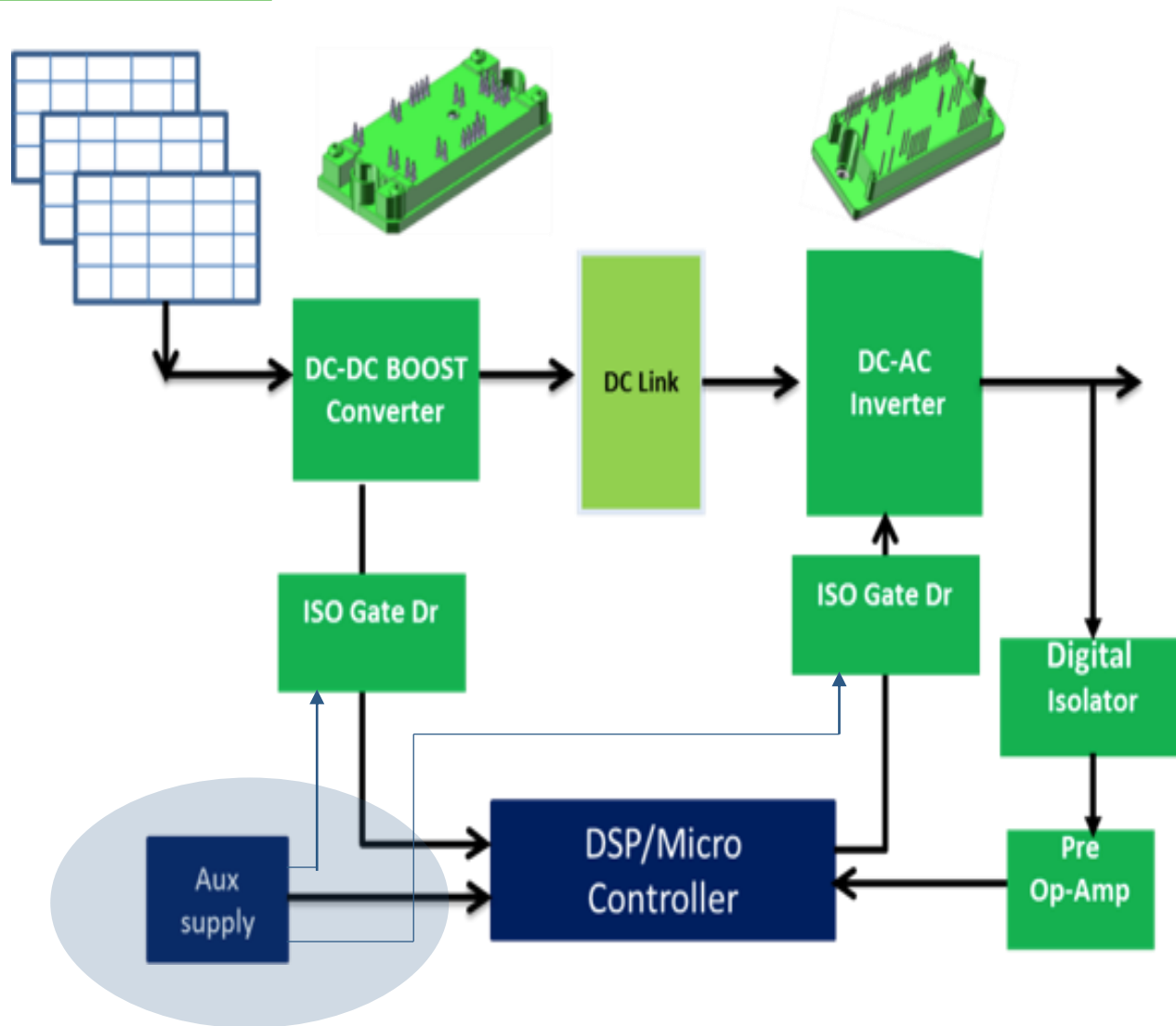
高级应用工程师

Public Information



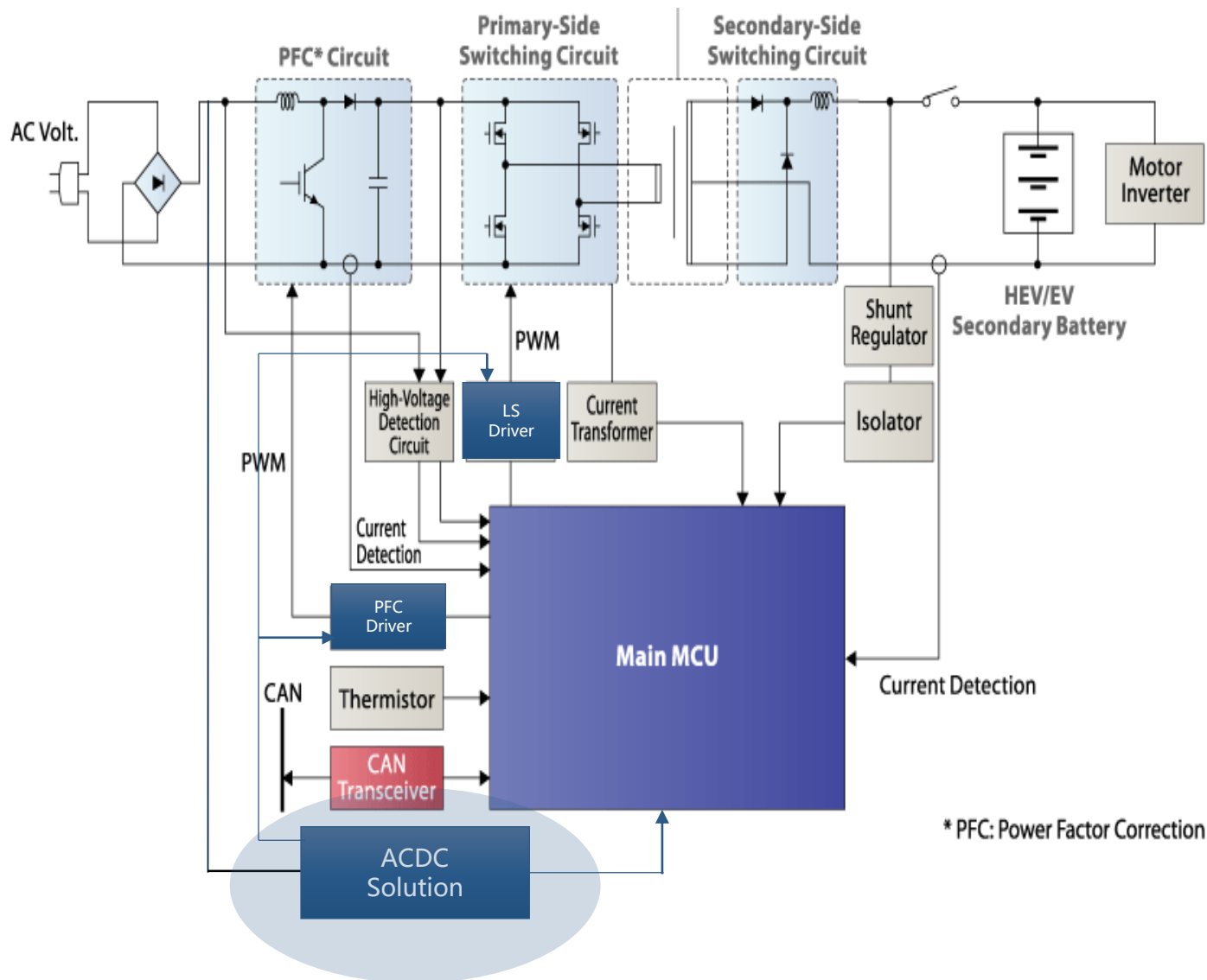
工业系统中的辅助电源

示例#1: 能源基础设施



工业系统中的辅助电源

示例#2: 电动汽车充电桩



电动汽车充电桩



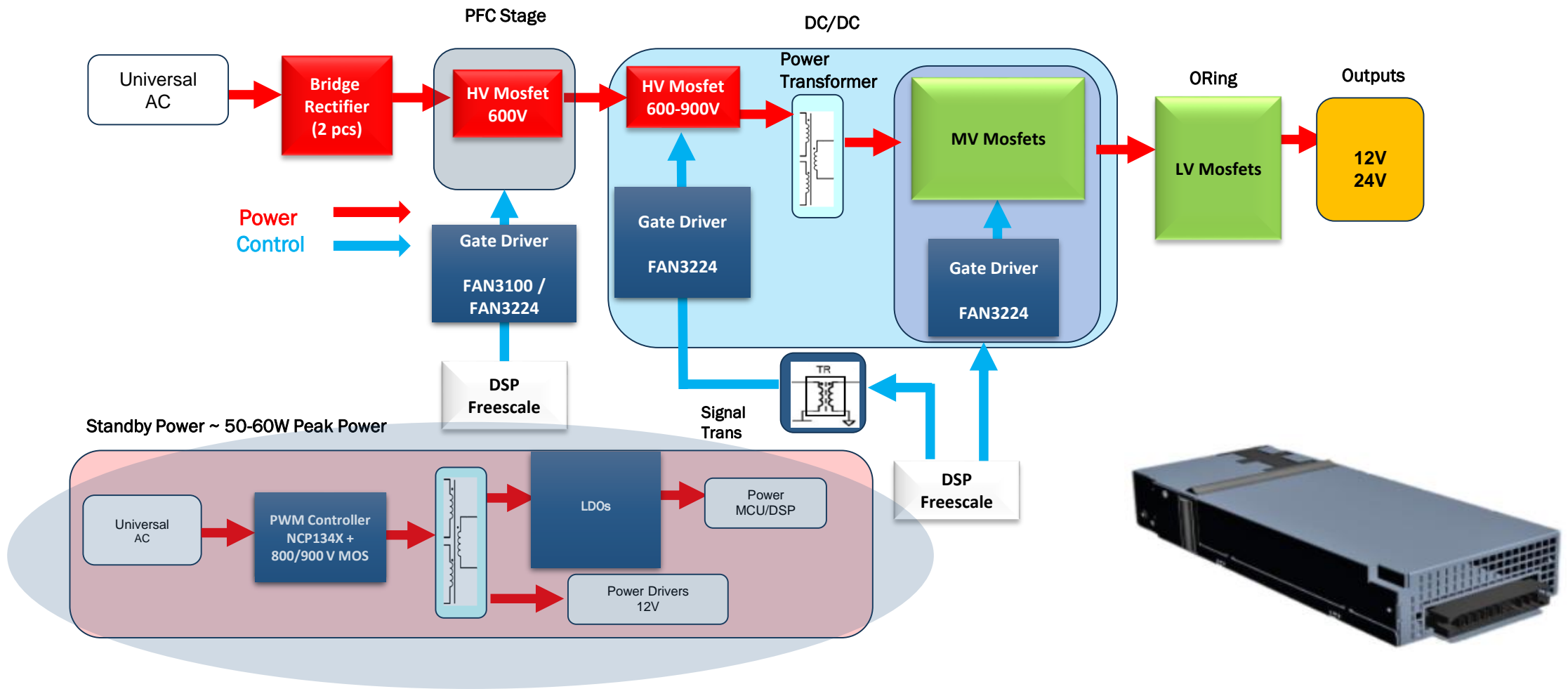
壁挂式

桩式



工业系统中的辅助电源

示例#3: 服务器电源



议程

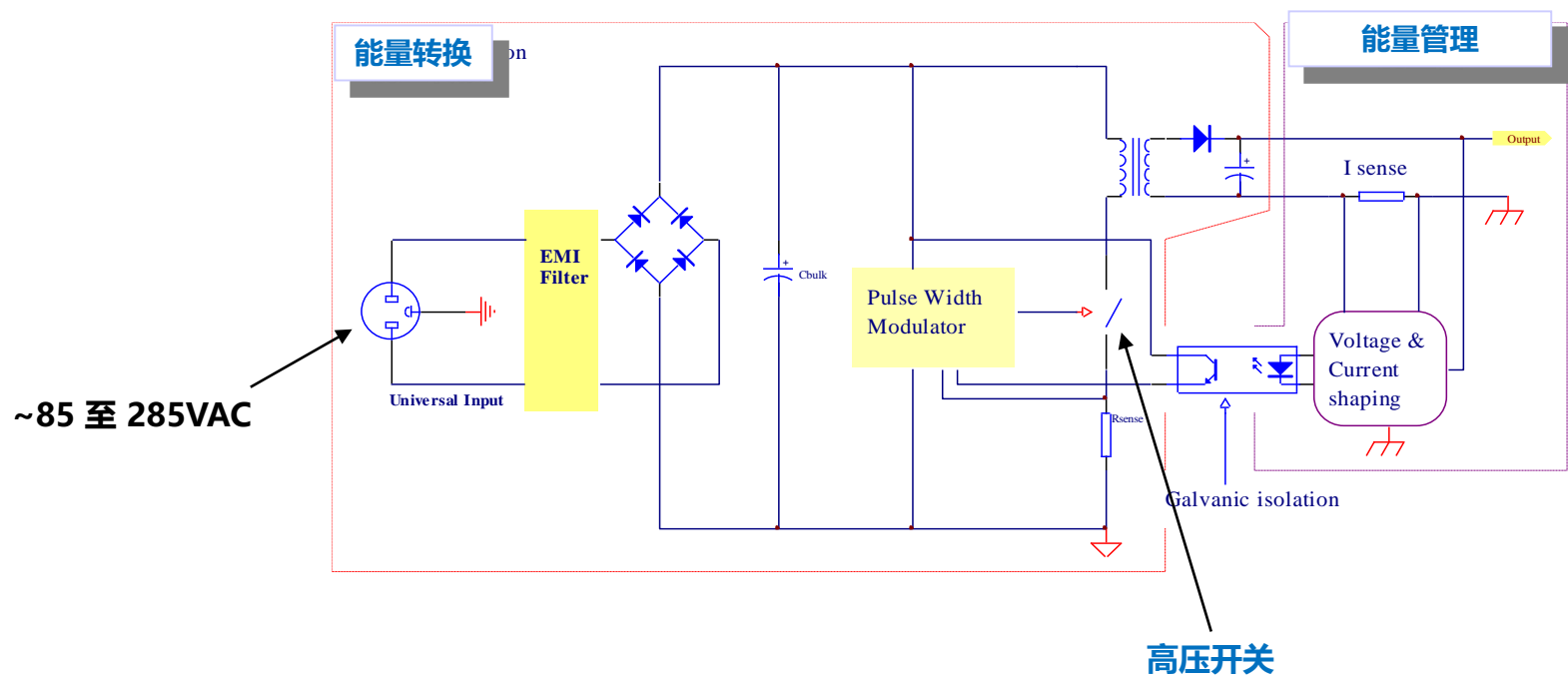
- **反激式转换器基础知识**
- **AC-DC 开关用于低功率辅助电源**
- **固定频率反激变压器设计**
- **准谐振(QR)反激实现高能效和高密度辅助电源**
- **QR反激式变压器设计**
- **超高密度辅助电源采用有源钳位反激**
- **反激式开关电源(SMPS)的PCB布局设计技巧**
- **总结**

反激式转换器基础知识

隔离反激拓扑作为辅助电源

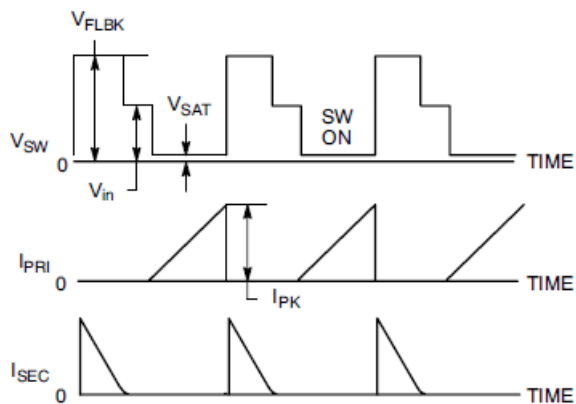
- 大多数辅助电源的输出功率水平小于60 W
- 隔离反激拓扑通常用于减少器件数和降低物料单(BOM)成本

典型的反激架构

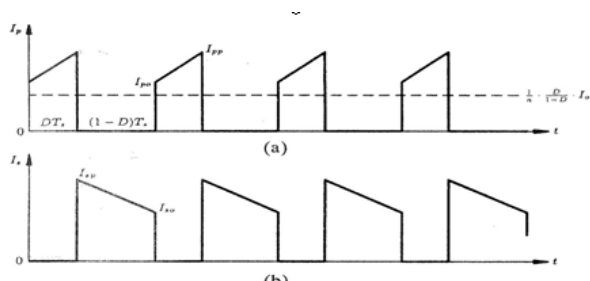


固定频率(Frequency Fixed)反激和准谐振(Quasi-Resonant)反激

固定频率

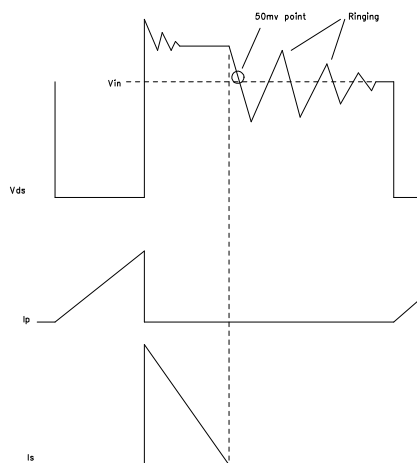


DCM

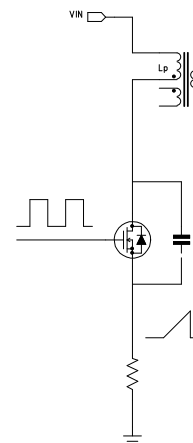


CCM

可变频率

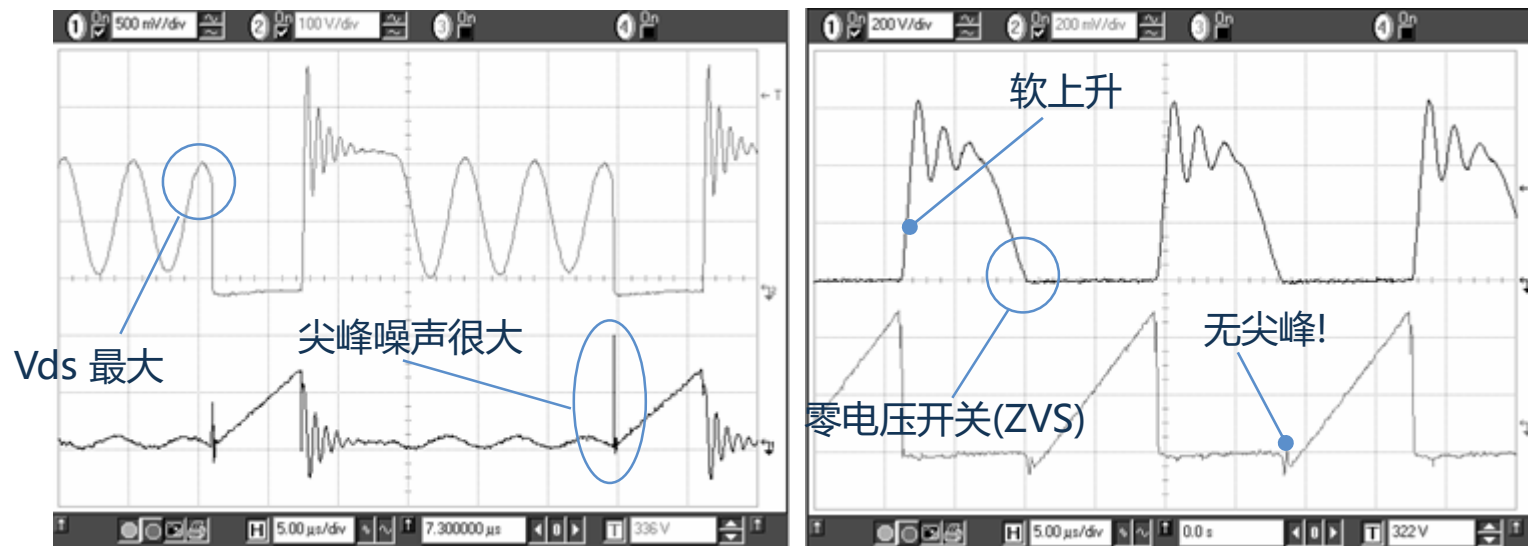


QR



频率反走(VCO)

硬开关和谷底开关模式



$$\text{Turn - on loss} = \frac{1}{2} C_{\text{Lump}} V_{\text{DS}}^2 f_{\text{SW}}$$

C_{Lump} = 功率MOSFET的 C_{OSS} + 总寄生电容

V_{DS} = 功率MOSFET在导通时的漏源电压

f_{SW} = 开关频率

对比CCM、DCM和QR

	连续导通模式 (CCM)	非连续导通模式 (DCM)	准谐振 (QR)
导通损耗	最低	最高	中高
转换/ 开关损耗	最高	中低	最低
内核损耗	最低	最高	中高
控制回路带宽	最低 + 斜坡补偿	更高带宽	更高带宽

DCM → 低功率, 低 F_{sw} ~ 60K - 130KHz

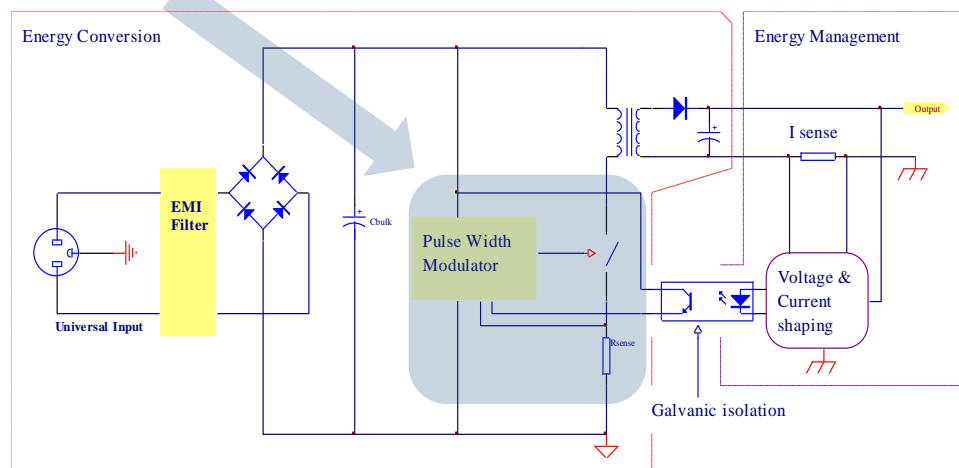
QR → 中低功率, 高 F_{sw} ~60K - 250KHz

CCM → 高功率, 低 F_{sw} ~ 60K - 130KHz

AC-DC开关或AC-DC控制器IC+外部 FET?

AC-DC 开关

AC-DC 控制器 + 外部 FET



~3W 至 30W

>20W

- 内置MOSFET → 高集成度
- 紧凑的尺寸
- 易于设计

但...

- 更低灵活性, 限制输出功率范围
- 热点在单个封装中/ 极受限的空间
→ 热管理问题

- 需要根据功率水平选择初级开关MOSFET
→ 更多器件数, 需要更大的PCB 占位

优势是:

- 更高灵活性, 主开关可实现非常宽的输出功率范围
- 更好的热管理, 因为分散了热点

AC-DC开关或低功率辅助电源



NCP107xA/B– 增强的700 V离线开关

价值定位

The NCP107xA/B products integrate a 700-V low $R_{DS(on)}$ N-channel MOSFET and enhanced protections set to easily design SMPS capable of delivering up to 25/30 watts of output power.

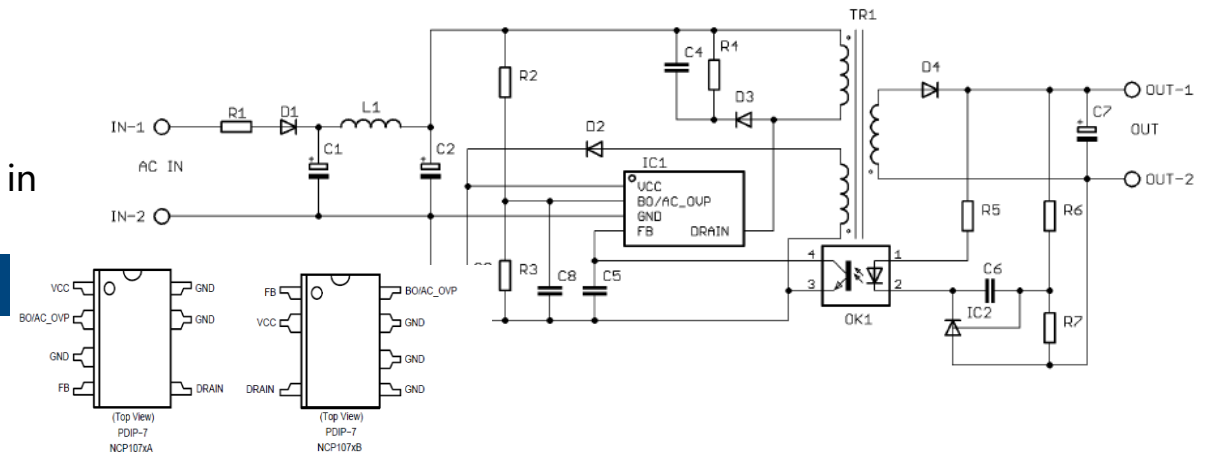
独特特性

- **RDS(on) 2.7 & 4.7/11-ohm typ**
- **Adj BO & AC line OVP**
- **Internal OPP**

优势

- Higher power capability & efficiency
- Improved protections & more robust designs
- Better output power regulation in wide mains

典型应用电路图



其它特性

- **No load Pstby < 50mW at 230Vac**
- Short circuit protection Independent of the aux. winding Frequency foldback and skip mode
- Soft start: 10 ms
- **Switching frequency: 65-100 kHz-130 kHz (B only)**
- **Frequency jittering**
- Over Voltage Protection – VCC pin

订购及封装

Product	$R_{DS(ON)}$	I_{PK}	230 Vrms $\pm 15\%$		85-265 Vrms	
			Adapter	Open Frame	Adapter	Open Frame
NCP1075uz	13.5 Ω	400 mA	8.5 W	14 W	6 W	10 W
NCP1076uz / NCP1077uz	4.8 Ω	800 mA	19 W	31 W	14 W	23 W
NCP1079uz	2.9 Ω	1050 mA	25 W	41 W	18 W	30 W

NCP107xPuzyG
 x = 5, 6, 7, 9 (power version)
 u = A, B pin out options
 z = A,B 2nd level OCP (Yes/No)
 y = A,B,C (Frequency option)

市场及应用

- Air-conditioning units
- White Goods
- **Aux PSU & E-Meters**



NCP107xB对比PI TNY27x/28x Xref

竞争对手 器件	RdsOn	电流限制	器件	RdsOn	电流限制
	典型值	典型值		典型值	典型值
	28	250 mA	NCP1070	22	250 mA
	19	275 mA	NCP1071	22	350 mA
	14	350 mA	NCP1075B	13.5	350 mA
	7.8	450 mA			
	5.2	550 mA	NCP1076B	4.8	650 mA
	3.9	650 mA	NCP1077B	4.8	800 mA
	2.6	750 mA	NCP1079B	2.7	1050 mA

器件	NCP1075/76/77/79B	竞争对手
电流模式或电压模式	电流	电流
拓扑	固定频率	门极振荡
	65 kHz +-10%	132 kHz ±6%
	100 kHz +- 10%	
130 kHz +- 10%		
待机模式	跳周期模式	跳周期模式
功率开关	RDS(on) (最大值 @ 25°C)	13.5至2.8 W
	峰值电流限值 (典型值)	28至2.7 W
	最大漏极电压	400 至 1,050 mA
	700 V	250至850 mA
		700 V TNY27x
		725 V TNY28x
频率抖动	√	√
频率反走	√	√
斜坡补偿	√ (固定)	N/A
动态自供电	√	√
上电与下电	可调 上电或下电	仅可调下电
AC 线路过压保护(OVP)	可调 AC 线路 OVP	无
OVP	新的 Vcc OVP 在18V时	√
最小高压启动限值	21V	50V
欠压锁定(UVLO)	6.4 至 8.4 V 典型值	2.4 V 典型值
短路保护不受辅助线圈影响	√ (53 ms 延迟关断, 420 ms 延迟恢复)	√ (64 ms 延迟关断, 2500 ms 延迟恢复)
次级端过流保护(OCP)	150% Ipeak & 3 pulses	无
过功率保护	通过 BO 引脚	无
软启动	10 ms	通过 CL 状态机
使能能力	√	√
热关断	150°C (典型值)	142°C (典型值)
封装	PDIP7	PDIP7 & GW

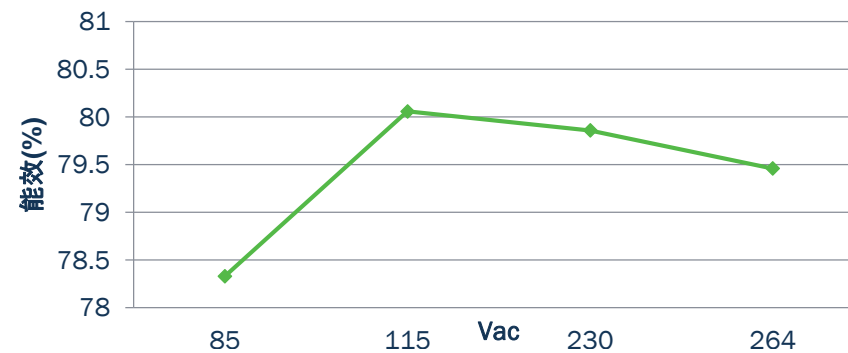


NCP1076B三路输出参考设计

描述	符号	最小值	类型	最大值	单位	测试条件
输入电压范围	Vin(最小值/最大值)	85		264	Vac	
输入电流	Irms			0.25	A	85 Vac和满载
额定输入频率	fin	50		60	Hz	
输入频率范围	Fin(最小值/最大值)	47		63	Hz	
浪涌电流	Irush			30	A	264 V和满载
满载能效	η	78			%	在板端测试, 85 V-264 Vac
输出电压和电流	Vout/Iout		12 V/0.8 A 15 V/0.1 A 5 V/0.3 A		V/A	85 Vac-264 Vac
额定输出功率	Pout		12.6		W	
纹波和噪声	Vripple			1% of output	mVp_p	85 Vac-264 Vac和空载到满载
上升时间	Rtime			50	mS	85 Vac-264 Vac和空载到满载
启动时间	Stime			100	mS	85 Vac-264 Vac和空载到满载
5 V和15 V交叉调节				+/-5	%	At 12 V/5 mA-0.8 A



满载能效



NCP10670/1/2 – 700 V 低功率开关

价值定位

The NCP10670/71/72 products integrate a 700 V MOSFET for cost effective isolated & non isolated switching power supply capable of delivering from 1 to 7 W. Protection features include a timer to detect an overload or a short-circuit event, Overvoltage Protection with auto-recovery.

独特特性

- 34 Ω & 12 Ω – 700 V FET
- Low $I_{dss}(Off)$ $\sim 1\mu A$ Typ.
- Skip Mode
- Direct FB connection

优势

- Tiny low power Buck
- Improved efficiency at no load and light load conditions
- Easy implementation of buck/buck-boost or flyback

其它特性

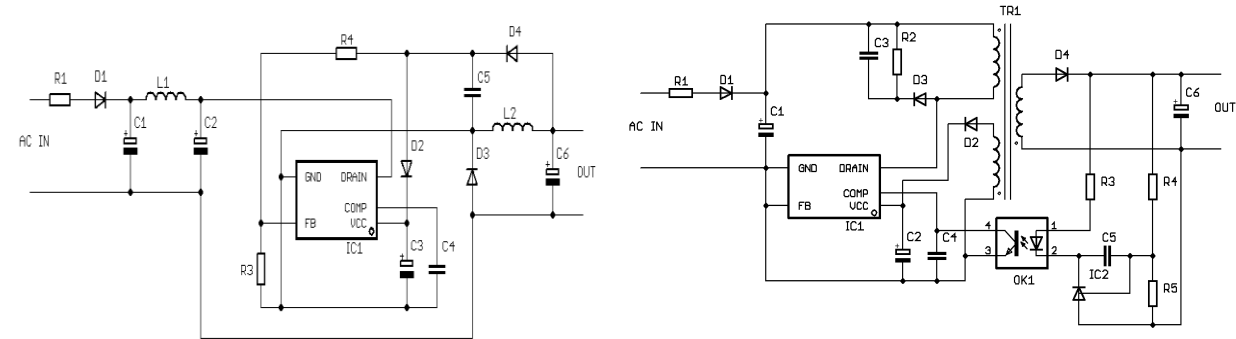
- Short circuit protection Independent of the aux. Winding
- I_{peak} 100/250 mA (NCP10670/71) or 780 mA (NCP10672)
- Soft start: 4 ms
- Internal switching frequency: 60 & 100 kHz
- Frequency jittering
- Wide Start-up voltage down to 22 Vdc

市场及应用

- Auxiliary Supply
- White Goods
- E-Meters



典型应用电路图

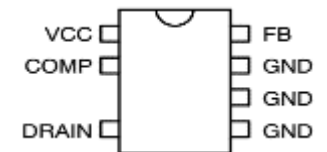


Product	$R_{DS(On)}$	$I_{PK(0)}$	230 Vac $\pm 15\%$		85 – 265 Vac	
			Adapter	OpenFrame	Adapter	OpenFrame
NCP10670 60 kHz	34 Ω	100 mA	1.1 W	2.7 W	0.6 W	1.5 W
NCP10671 60 kHz	34 Ω	250 mA	2.7 W	6.7 W	1.5 W	3.7 W
NCP10672 100 kHz	12 Ω	780 mA	6.2 W	15.5 W	3.3 W	7.8 W

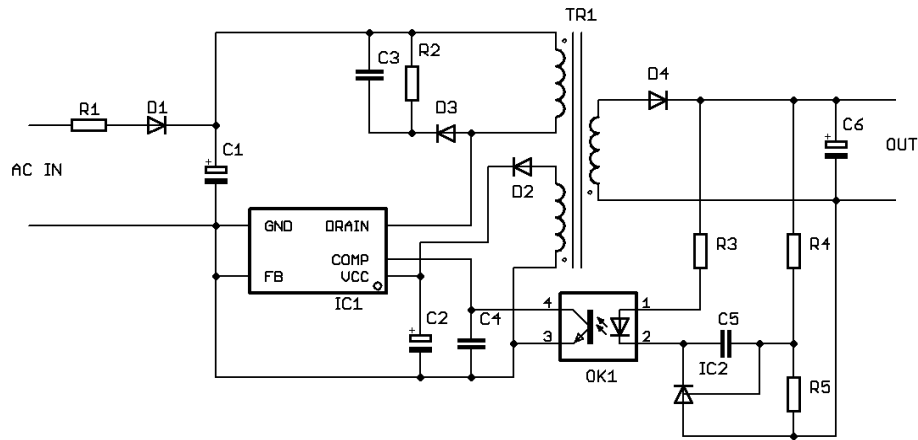
1. Informative values only, with $T_{amb} = 25^\circ C$, $T_{case} = 100^\circ C$, Self supply via Auxiliary winding and circuit mounted on minimum copper area as recommended.

封装信息

- NCP10670/1: 34 Ω 100/250 mA in SOIC-7
- NCP10672: 12 Ω 780 mA in SOIC-7

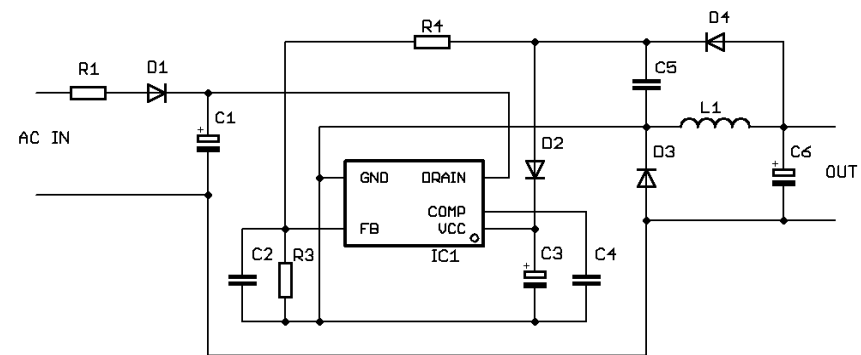
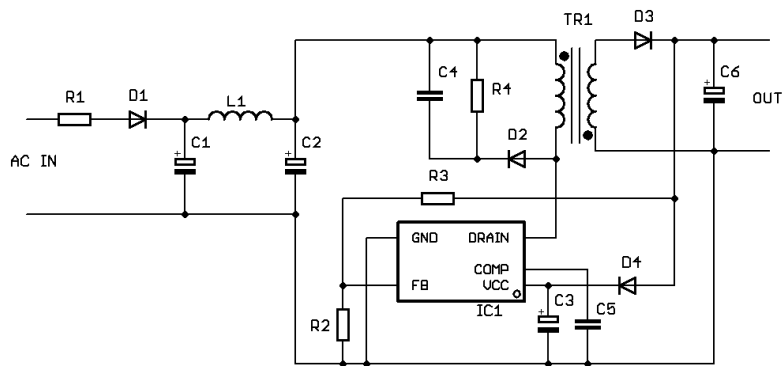


NCP1067X – 典型应用电路图



隔离应用

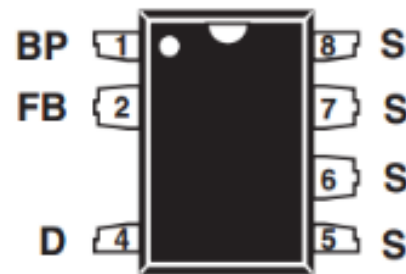
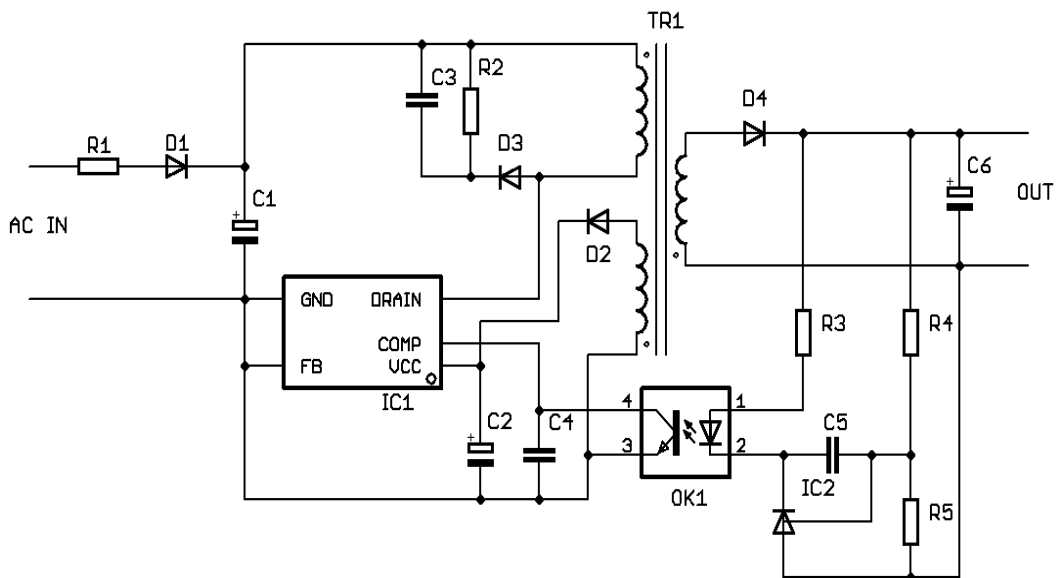
非隔离应用



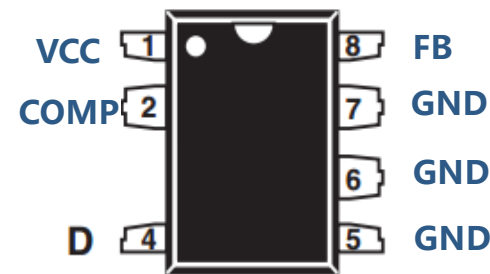
简单、紧凑的设计!

采用SOIC7封装，与LNK3xx 兼容

典型反激式



LNK302-306
LNK362-364
LNK562-564

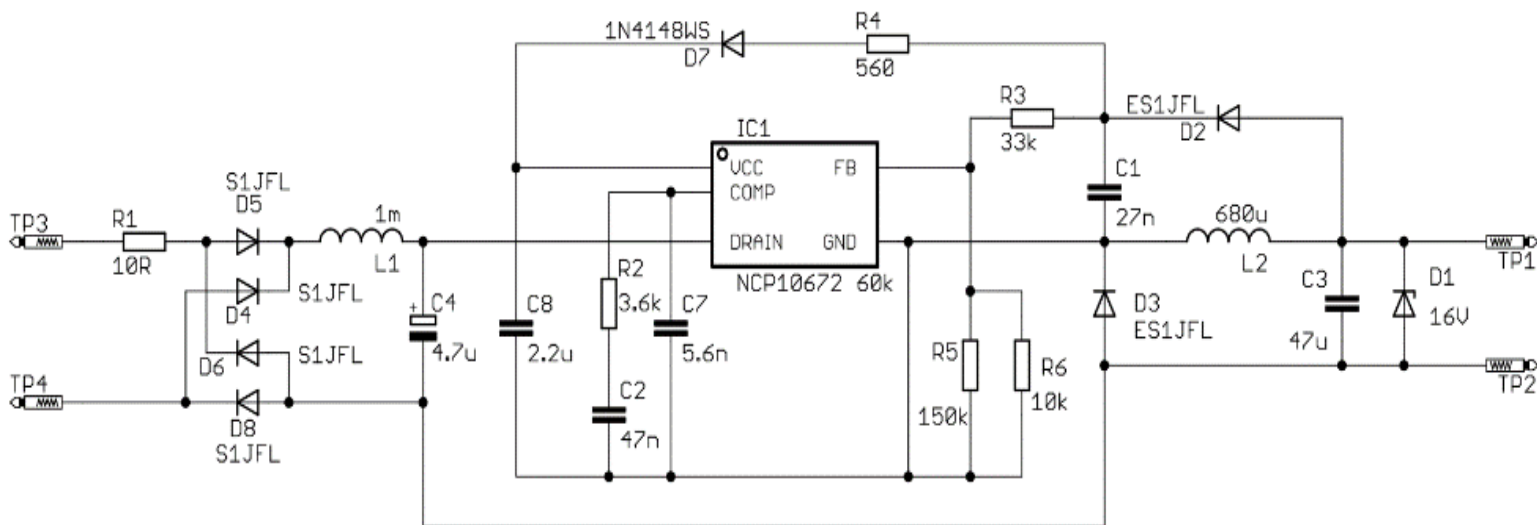


NCP10670/1
NCP10672

LNK3xx的FB引脚是
NCP1067x 的COMP引脚

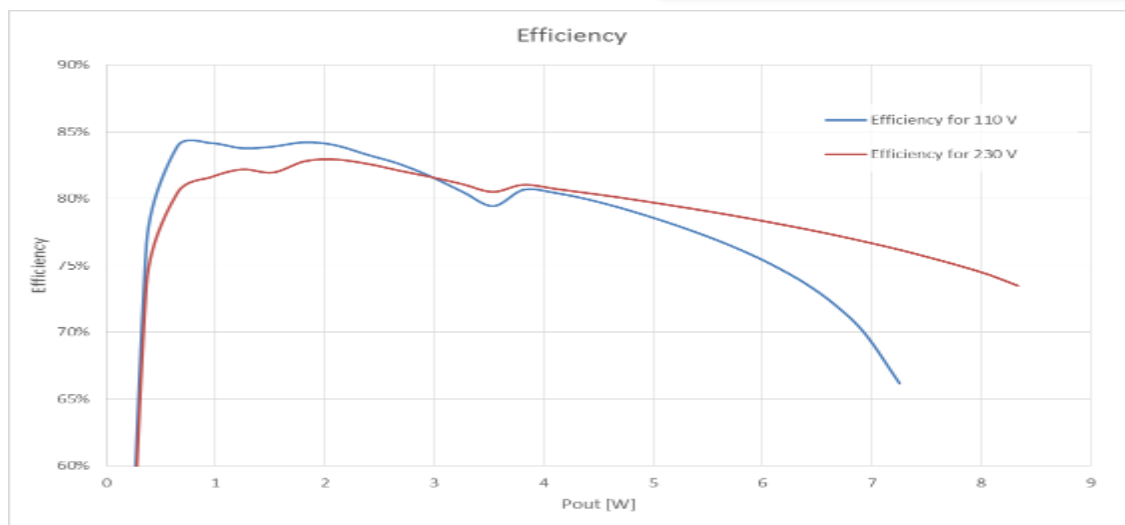
- 反激式中100 % 引脚对引脚
- 在降压应用中，需要将引脚2与引脚8反向连接

NCP10672 4 W降压演示板(15 V – 270 mA)

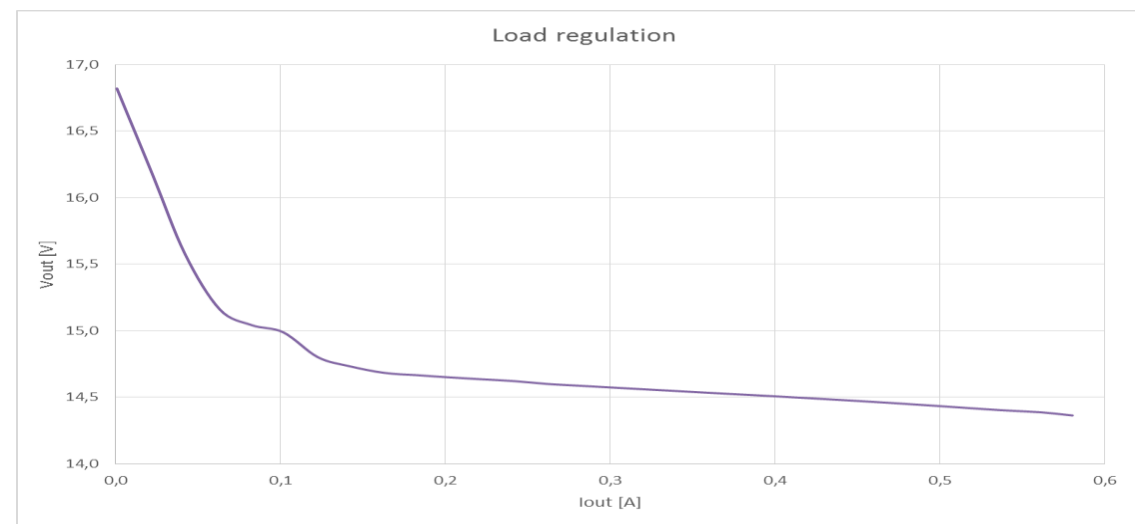


极小的板20 x 26 mm

能效达83% (2 W @ 230 Vac)



能效测量



负载稳压



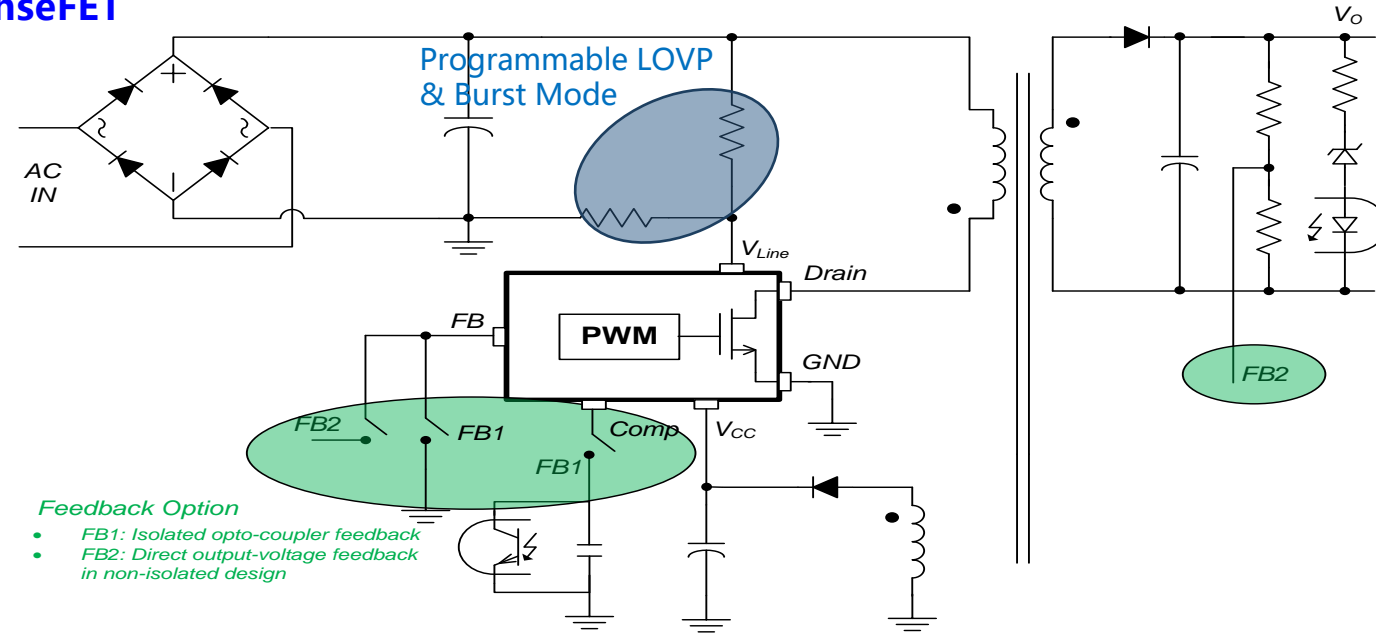
FSL5x8关键特性 – 集成SenseFET的高性能800 V离线开关

➤ 特性

- **Internal 800V Super-Junction II Rugged MOSFET with SenseFET Technology**
- Built-in HV current source for start up
- **Line compensation for maximum over load limiting**
- Soft-start for low electrical stress
- Peak current mode control with Built-in slope compensation
- Pulse-by-pulse current limit
- **Fine-tunable Burst Mode Operation**
- Frequency hopping for low EMI
- **8 / 4.6 ohm options**
- **Two FB Options for both Isolated & Non Isolated Config.**

➤ 高可靠性

- Brown In/Out Protection
- **Line Over Voltage Protection**
- V_{CC} Over Voltage Protection
- Over Load Protection
- **Abnormal Over Current Protection**
- Thermal Shutdown Protection
- V_{CC} Under-Voltage Lockout (UVLO)
- All protections are Auto Restart.
- Built-in 800ms restart time when fault occurs.



➤ 应用

- *While Goods*
- *Industrial auxiliary power supply, E-metering*
- *Consumer electronics (Chargers, Set-top-box, TVs)*

FSL5x8 选型表及建议的输出功率

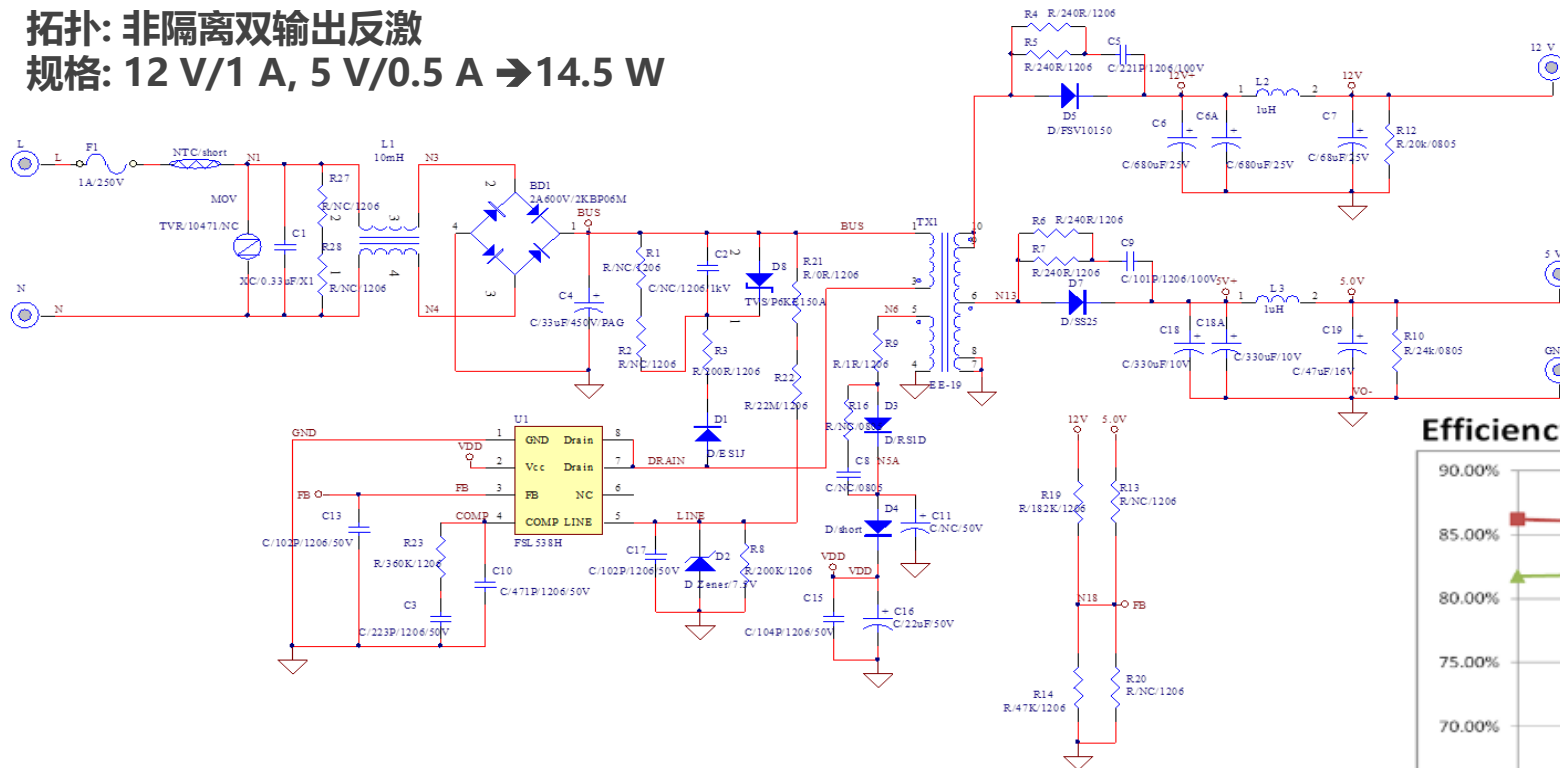
器件	封装	工作频率	电流限制(A)	最大 $R_{DS(ON)}$ (ohm)	230 VAC \pm 15%	85 ~ 265 VAC
FSL518H	DIP/LSOP	130 kHz	0.46	8.0	15 W	12 W
FSL538H	DIP/LSOP	130 kHz	0.66	4.6	21 W	17 W
FSL518A	DIP/LSOP	100 kHz	0.61	8.0	17 W	14 W
FSL538A	DIP/LSOP	100 kHz	0.86	4.6	25 W	20 W

1. The junction temperature can limit the maximum output power.
2. Maximum practical continuous power in an open-frame design at 50°C ambient.

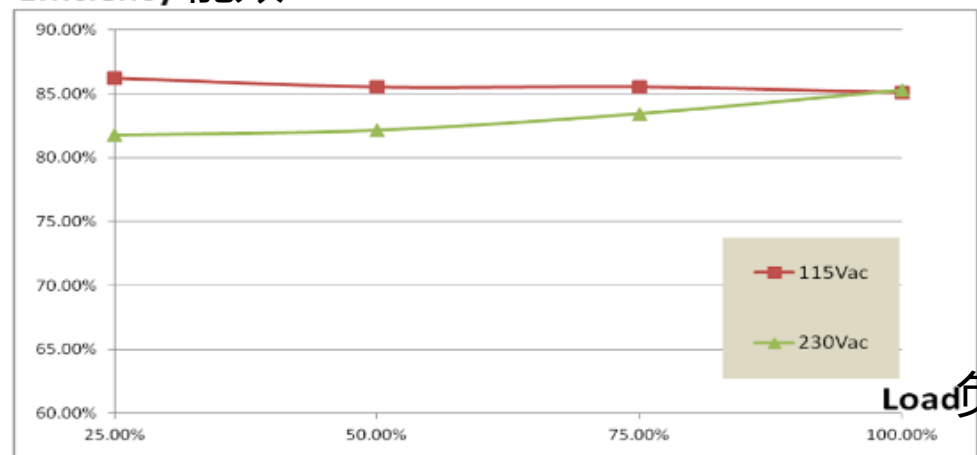
SOIC-7功率能力约6至10 W

FSL538H – 15 W非隔离反激演示板

拓扑: 非隔离双输出反激
规格: 12 V/1 A, 5 V/0.5 A → 14.5 W



Efficiency 能效



输入电压 [Vac]	25% 负载	50% 负载	75%负载	100%负载	平均能效
115 Vac	86.22%	85.52%	85.53%	85.05%	85.58%
230 Vac	81.75%	82.13%	83.43%	85.27%	83.15%

输入电压[Vac]	功耗 [mW]
115 Vac	23.73
230 Vac	41.66



固定频率反激变压器设计

Step 1: 输入输出参数

Vacmin: 最小输入交流电压

Vacmax: 最大输入交流电压

Vmin: 最小输入直流电压

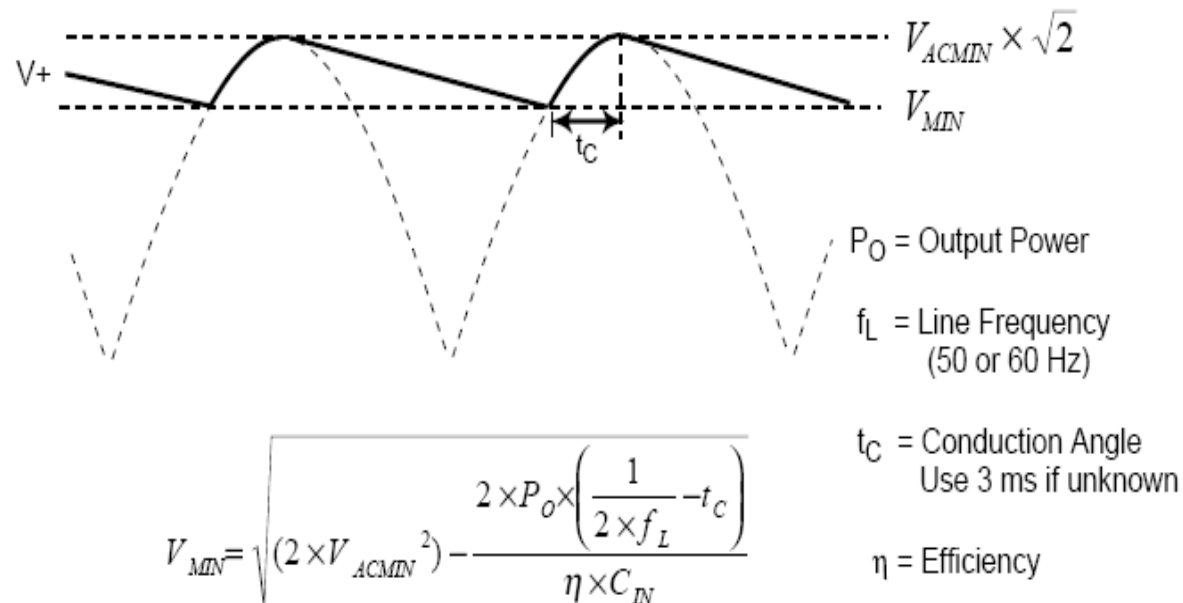
Vmax: 最大输入直流电压

Po: 输出功率

η: 电源效率

Fs: 开关频率

Step 2: 输入最小直流电压



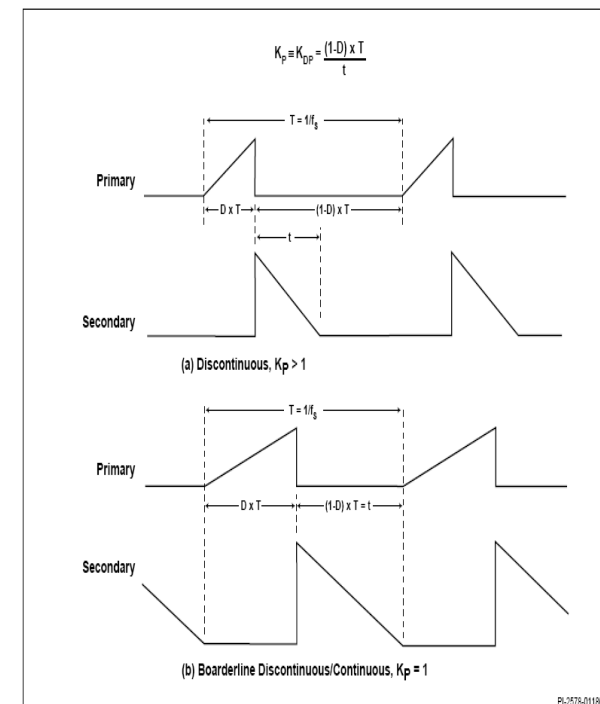
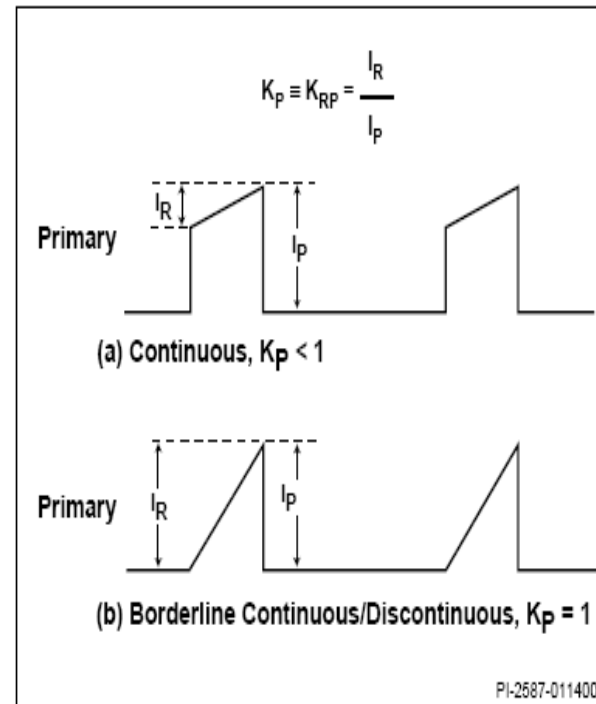
一般简单的设定: $V_{min} = 1.3 \times V_{acmin}$

Step 3: 反射电压Vor确定

根据MOSFET的耐压来设定反射电压Vor
 $V_{dcmax} + V_{or} + V_{peak} < \text{MOSFET耐压} * \text{裕量百分比}$

通常设定Vor=80 V-120 V

Step 4: Kp设定



• For $K_p \leq 1.0$, $K_p \equiv K_{RP}$, continuous mode

• For $K_p \geq 1.0$, $K_p \equiv K_{DP}$, discontinuous mode

Input (VAC)	K_p	
	Continuous Mode	Discontinuous Mode
Universal	0.4~1.0	≥ 1.0
230	0.6~1.0	≥ 1.0

Step 5: 最大占空比

- 计算Dmax

- Continuous mode

$$D_{MAX} = \frac{V_{OR}}{(V_{MIN} - V_{DS}) + V_{OR}}$$

- Discontinuous mode

$$D_{MAX} = \frac{V_{OR}}{K_P \times (V_{MIN} - V_{DS}) + V_{OR}}$$

Step 6: 计算最大初级电流

- 计算平均输入电流Iav

$$I_{AVG} = \frac{P_O}{\eta \times V_{MIN}}$$

- 计算初级峰值电流Ip

- Continuous mode ($K_p \leq 1.0$)

$$I_P = \frac{I_{AVG}}{\left(1 - \frac{K_P}{2}\right) \times D_{MAX}}$$

- Discontinuous mode ($K_p \geq 1.0$)

$$I_P = \frac{2 \times I_{AVG}}{D_{MAX}}$$

Step 7: 计算初级电流有效值

- Continuous mode

$$I_{RMS} = I_P \times \sqrt{D_{MAX} \times \left(\frac{K_P^2}{3} - K_P + 1 \right)}$$

- Discontinuous mode

$$I_{RMS} = \sqrt{D_{MAX} \times \frac{I_P^2}{3}}$$

Step 8: 计算Lp

- 计算主电感量Lp

Continuous mode

$$L_p = \frac{P_o}{\eta \times K_p \times \left(1 - \frac{K_p}{2} \right) \times I_p^2 \times F_s}$$

$$L_p = \frac{V_{min} \times D_{max}}{K_p \times I_p \times F_s}$$

Discontinuous mode

$$L_p = \frac{2 \times P_o}{\eta \times I_p^2 \times F_s}$$

$$L_p = \frac{V_{min} \times D_{max}}{I_p \times F_s}$$

Step 7: 计算初级电流有效值

- Continuous mode

$$I_{RMS} = I_P \times \sqrt{D_{MAX} \times \left(\frac{K_P^2}{3} - K_P + 1 \right)}$$

- Discontinuous mode

$$I_{RMS} = \sqrt{D_{MAX} \times \frac{I_P^2}{3}}$$

Step 8: 计算Lp

- 计算主电感量Lp

Continuous mode

$$L_p = \frac{P_o}{\eta \times K_p \times \left(1 - \frac{K_p}{2} \right) \times I_p^2 \times F_s}$$

$$L_p = \frac{V_{min} \times D_{max}}{K_p \times I_p \times F_s}$$

Discontinuous mode

$$L_p = \frac{2 \times P_o}{\eta \times I_p^2 \times F_s}$$

$$L_p = \frac{V_{min} \times D_{max}}{I_p \times F_s}$$

Step 9: 计算Np, Ns, Na

- 计算主边绕组圈数Np

$$N_p = \frac{L_p \times I_p}{\Delta B \times A_e}$$

- 计算输出和Vcc绕组圈数

$$N_s = \frac{N_p}{V_{or}} \times (V_o + V_d)$$

$$N_{Vc} = \frac{N_p}{V_{or}} \times (V_c + V_d)$$

ΔB - 最大工作磁通密度, 一般取0.15T - 0.25T

A_e - 磁芯的中心柱截面积

Step 10: 计算次级电流

- 计算次级整流管峰值

$$I_{SP} = I_P \times \frac{N_P}{N_S}$$

- 计算次级整流管有效值

Continuous mode

$$I_{SRMS} = I_{SP} \times \sqrt{(1 - D_{MAX}) \times \left(\frac{K_P^2}{3} - K_P + 1 \right)}$$

Discontinuous mode

$$I_{SRMS} = I_{SP} \times \sqrt{\frac{1 - D_{MAX}}{3 \times K_P}}$$

Flyback Transformer Design Spreadsheet

<https://www.onsemi.com/pub/Collateral/FLYBACK%20TRANSFORMER%20DESIGN%20TOOL.XLS>

准谐振反激实现高频和高密度辅助电源

NCP1342 – 高频准谐振反激控制器

- 高频准谐振反激控制器
- 高压启动集成X2放电和欠压检测功能
- 谷底锁定开关，运行达6个谷底
- 最小频率钳位和Quiet-Skip™模式以消除可闻噪声
- 跳周期模式下的电流消耗低，实现低待机功耗，在265 Vac时待机功耗 < 30 mW
- 频率抖动以改善EMI性能
- 具有最小峰值电流的频率反走
- 调制（MPCM）可以更快地减少开关操作以提高轻载能效

应用电路图

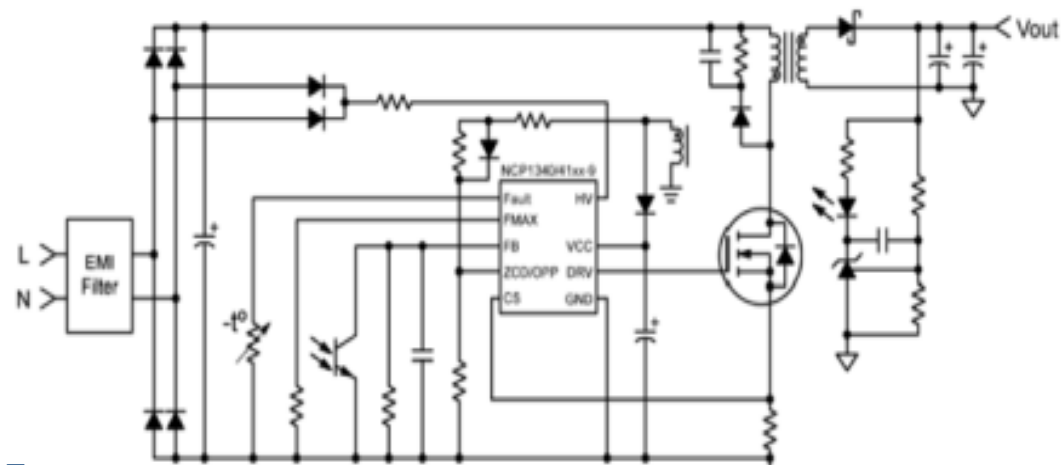
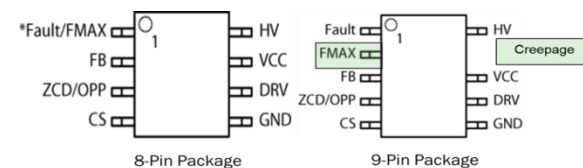
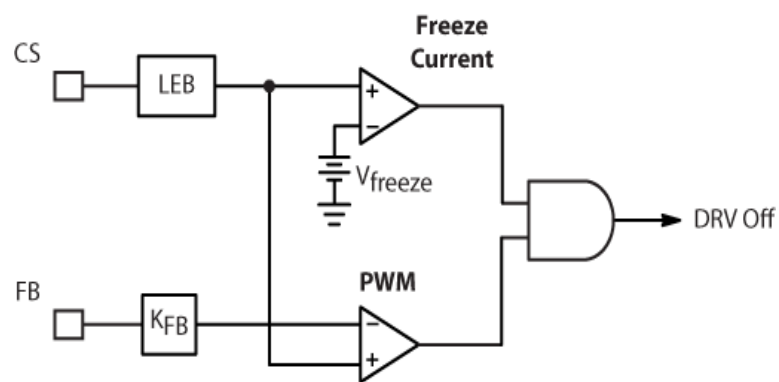


Figure 4: NCP1342xx-9/NCP1343xx-9 Typical Application Circuit

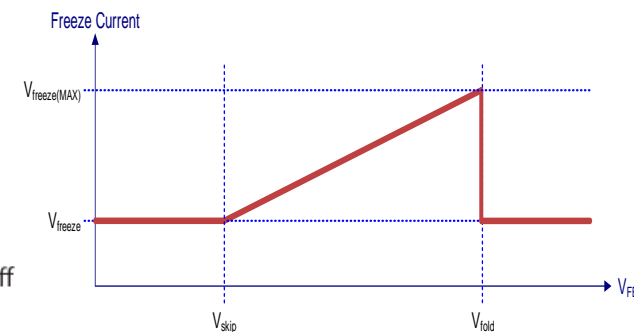
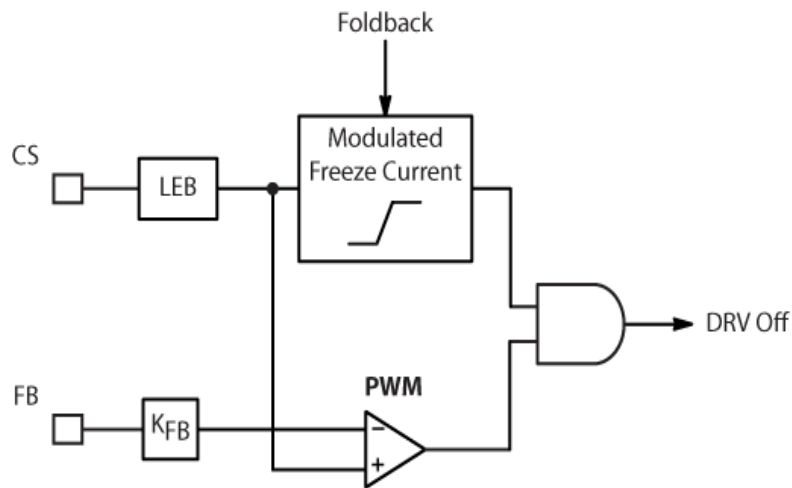


NCP1342调制的冻结电流

NCP1340

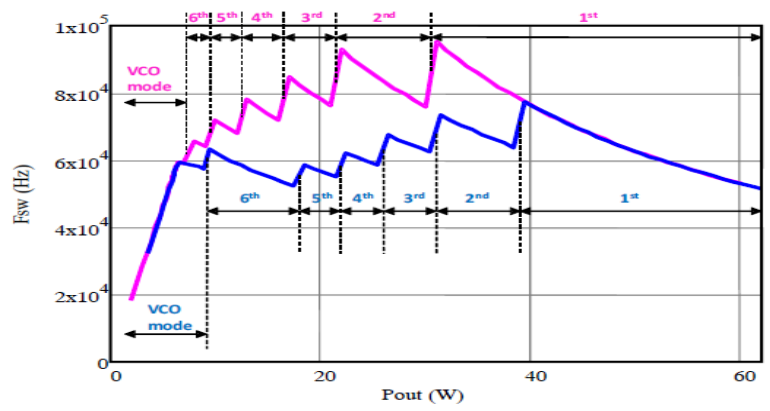


NCP1342



NCP1342 具有调制的冻结电流
→ 在高频设计中提升轻载能效

谷底开关运行6个谷底



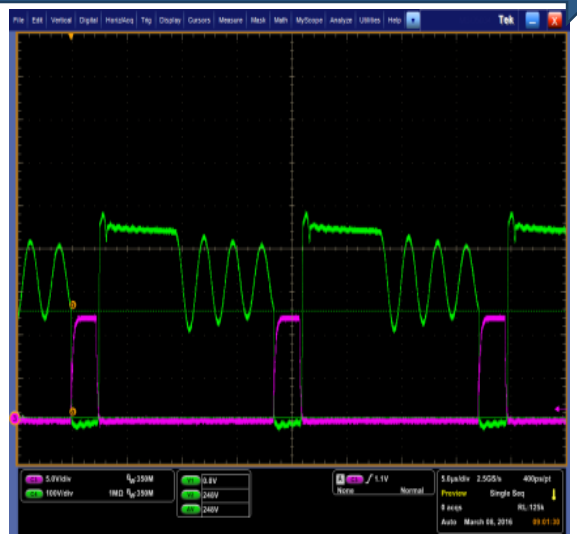
Valley Lockout Frequency vs. Output Power

满载

轻载



230 VAC, 1st Valley
Ch. 3 (Purple): DRV
Ch. 4 (Green): Drain Voltage



230 VAC, 4th Valley
Ch. 3 (Purple): DRV
Ch. 4 (Green): Drain Voltage



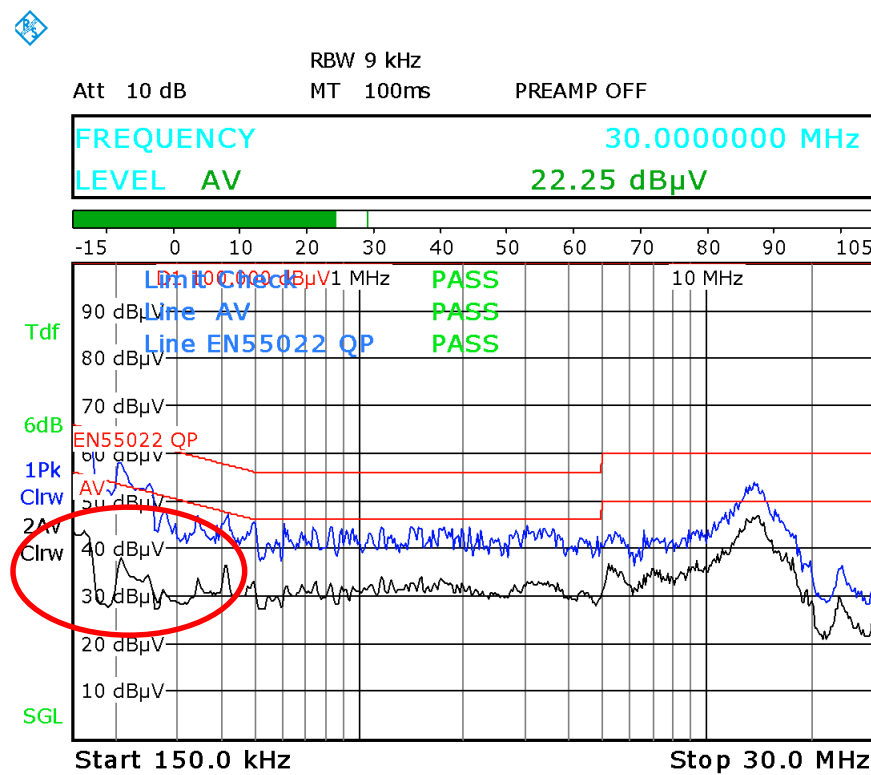
230 VAC, 6th Valley
Ch. 3 (Purple): DRV
Ch. 4 (Green): Drain Voltage



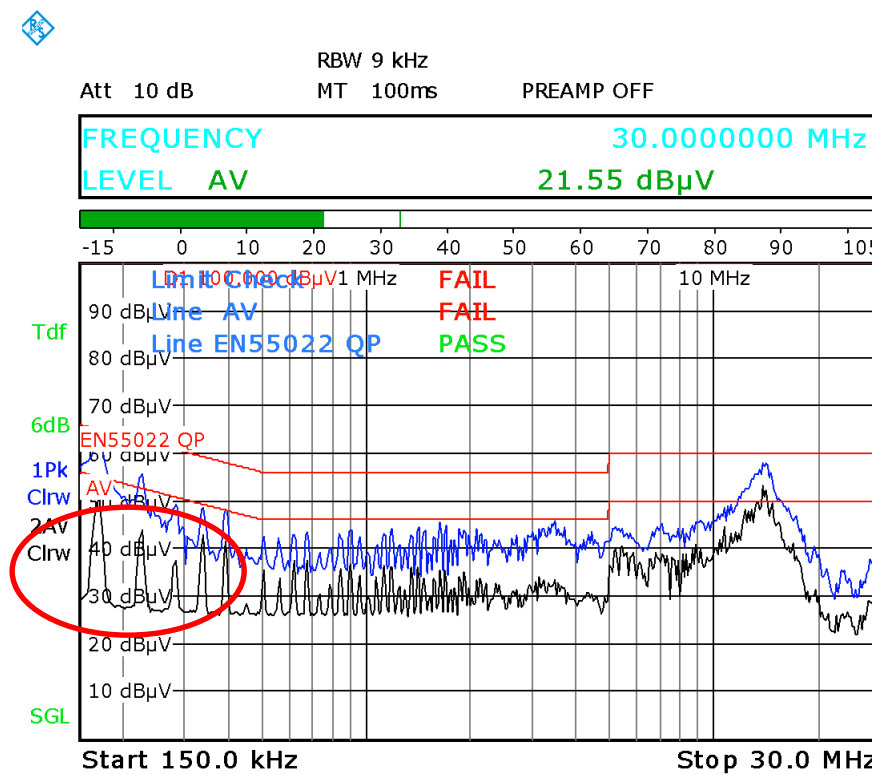
频率抖动EMI对比

- EMI 对比

- 左图显示了在230 Vac时具有抖动功能的板的EMI
- 右图显示了无抖动功能的板的EMI → 低频点的峰值约高5 dB



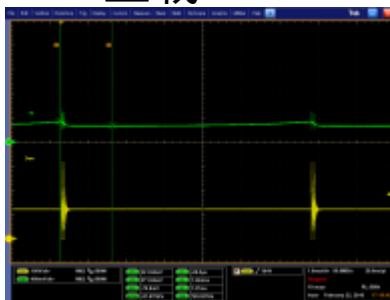
Date: 14.MAR.2016 14:15:51



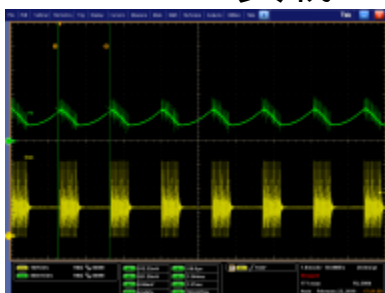
Date: 14.MAR.2016 10:30:46

跳周期模式采用Quiet-Skip技术

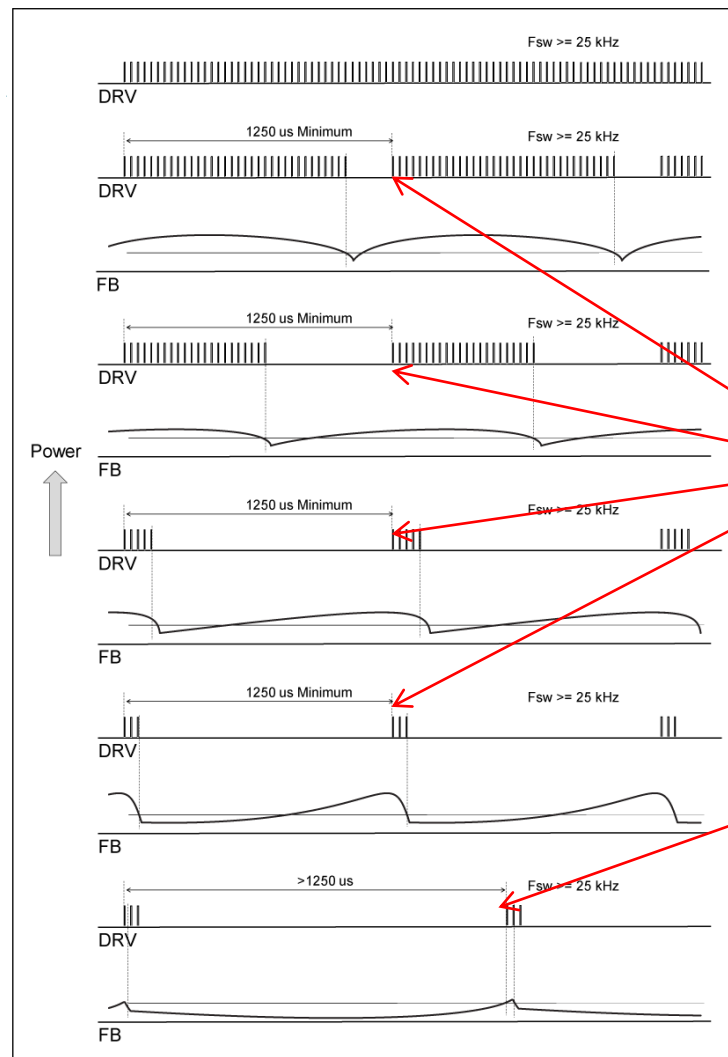
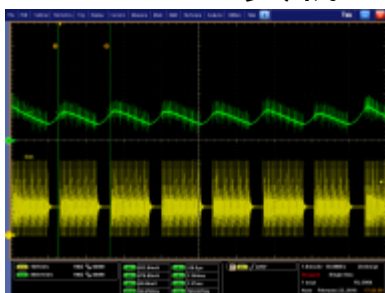
空载



100 mA负载



190 mA负载

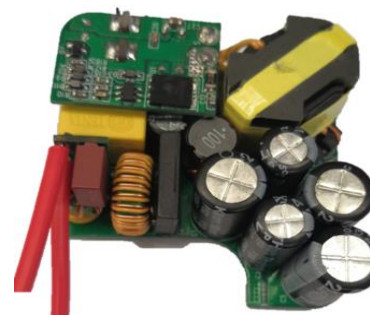


直到计时器超时
才开始脉冲周期

周期可能比计时器更长

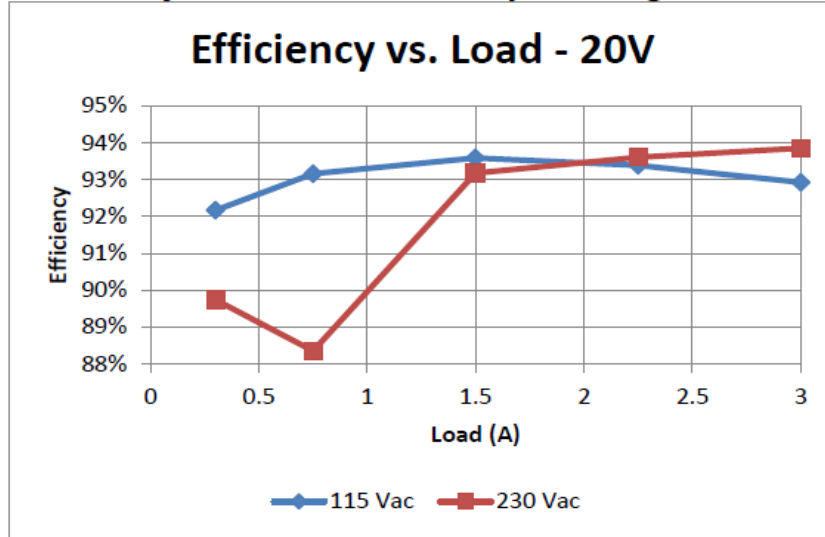
NCP1342高密度电源参考板摘要

功率	方案	供货情况	PPT /PDF 格式的测试报告
55W (3.3V-11V/5A) 新的!!	NCP1342 + NCP4306 + WT6633F	供货	有
30W PD Type C	NCP1342 + NCP4306 + WT6632F	供货	有
45W PD Type C	NCP1342 + NCP4306 + WT6632F	供货	有
65W PD Type C 新的!!	NCP1342 + NCP4306 + WT6632F	供货	有
90W PD Type C	NCP1622 + NCP1342 + WT6632F	供货	有

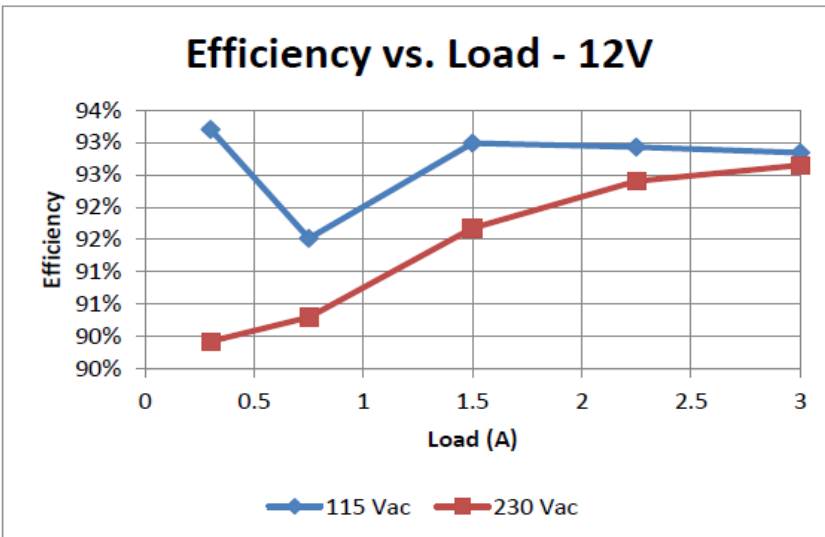


集成超级结FET的NCP1342 60 W演示的能效

Efficiency vs. Load Over Output Range



20V Output			
Input (Vac)	Load (%)	Efficiency (%)	Average (%)
115	100	92.9	93.3
	75	93.4	
	50	93.6	
	25	93.2	
	10	92.2	
230	100	93.9	92.2
	75	93.6	
	50	93.2	
	25	88.4	
	10	89.7	



12V Output			
Input (Vac)	Load (%)	Efficiency (%)	Average (%)
115	100	92.8	92.6
	75	92.9	
	50	93.0	
	25	91.5	
	10	93.2	
230	100	92.7	91.8
	75	92.4	
	50	91.7	
	25	90.3	
	10	89.9	

能效 92%+
集成 RM8 变压器及超
级结 FET



计算准谐振反激式变压器

Step 1: 匝数比计算

- 减小最大MOSFET BVdss:

$$V_{ds,max} = BV_{dss} (k_D) \rightarrow k_D: \text{derating factor}$$

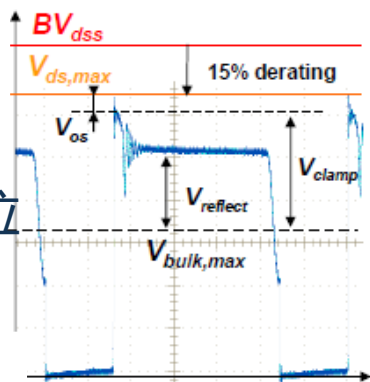
- 要获得最大体电压, 请选择钳位电压:

$$V_{clamp} = V_{ds,max} - V_{in,max} - (V_{os}) \rightarrow V_{os}: \text{diode overshoot}$$

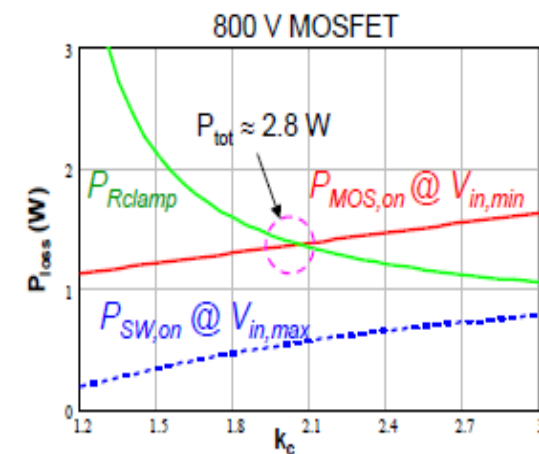
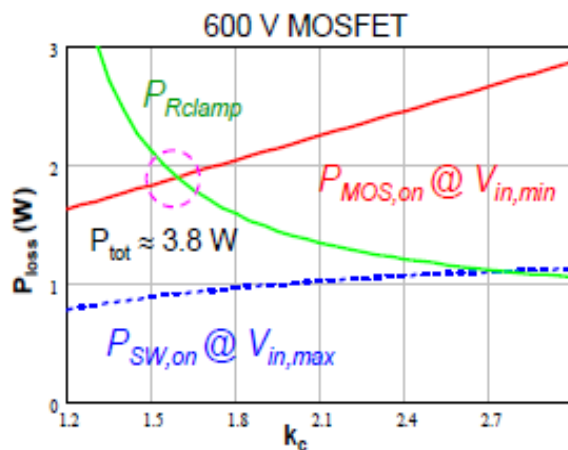
- 要获得最大体电压, 请选择钳位电压:

$$N_{ps} = \frac{N_s}{N_p} = \frac{k_c (V_{out} + V_f)}{V_{clamp}}$$

k_c : clamping coef.
 $k_c = V_{clamp} / V_{reflect}$



Step 2: 怎么选Kc



$$P_{Rclamp} = k_{leak} \frac{P_{out}}{\eta} \frac{k_c}{k_c - 1}$$

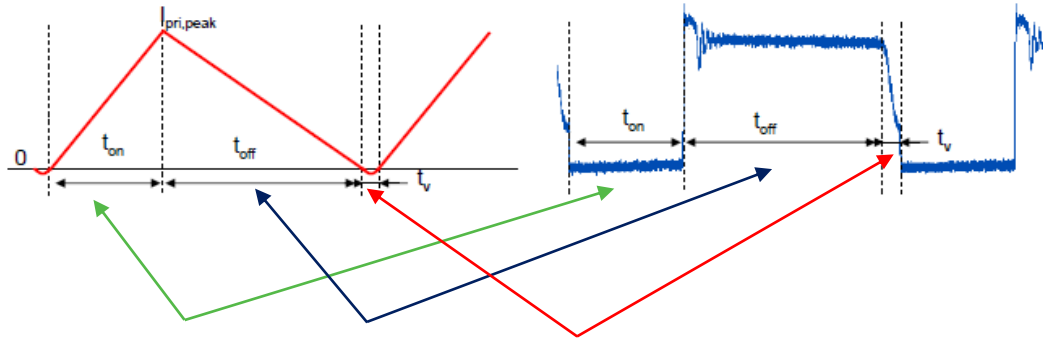
$$P_{MOS,on} = R_{dson} \frac{4P_{out}^2}{3\eta^2 V_{in,min}} \left(\frac{1}{V_{in,min}} + \frac{k_c}{BV_{dss} k_D - V_{in,max} - V_{os}} \right)$$

$$P_{sw,on} = \frac{1}{2} \left(V_{in,max} + \frac{BV_{dss} k_D - V_{in,max} - V_{os}}{k_c} \right)^2 C_{OSS} F_{sw,max}$$



Step 3: 初级端峰值电流和电感

DCM 模式: $P_{out} = \frac{1}{2} L_{pri} I_{pri,peak} F_{sw} \eta$



$$T_{sw} = \frac{I_{pri,peak} L_{pri}}{V_{in,min}} + \frac{I_{pri,peak} L_{pri} N_{ps}}{V_{out} + V_f} + \pi \sqrt{L_{pri} C_{lump}} \leftarrow C_{oss} \text{ contribution alone.}$$

$$I_{pri,peak} = 2 \frac{P_{out}}{\eta} \left(\frac{1}{V_{in,min}} + \frac{N_{ps}}{V_{out} + V_f} \right) + \pi \sqrt{\frac{2P_{out} C_{lump} F_{sw}}{\eta}}$$

$$L_{pri} = \frac{2P_{out}}{I_{pri,peak}^2 F_{sw} \eta}$$

选择适当的变压器铁心和铁损:

$$L_{pri} \times I_{pri, peak} = N_p \times B \times Ae$$

Step 4: RMS电流

- 计算最大Pout 和最小Vin时的最大占空比.

$$d_{max} = \frac{I_{pri,peak} L_{pri}}{V_{in,min}} F_{sw,min}$$

- 推导初级和次级RMS

$$I_{pri,rms} = I_{pri,peak} \sqrt{\frac{d_{max}}{3}}$$

$$I_{sec,rms} = \frac{I_{pri,peak}}{N_{ps}} \sqrt{\frac{1-d_{max}}{3}}$$

选择合适的电线并估算绕组损耗

高频QR设计Mathcad工具

<https://www.onsemi.cn/pub/Collateral/NCP1339%20DESIGN%20WORKSHEET%20-%20MATHCAD.ZIP>

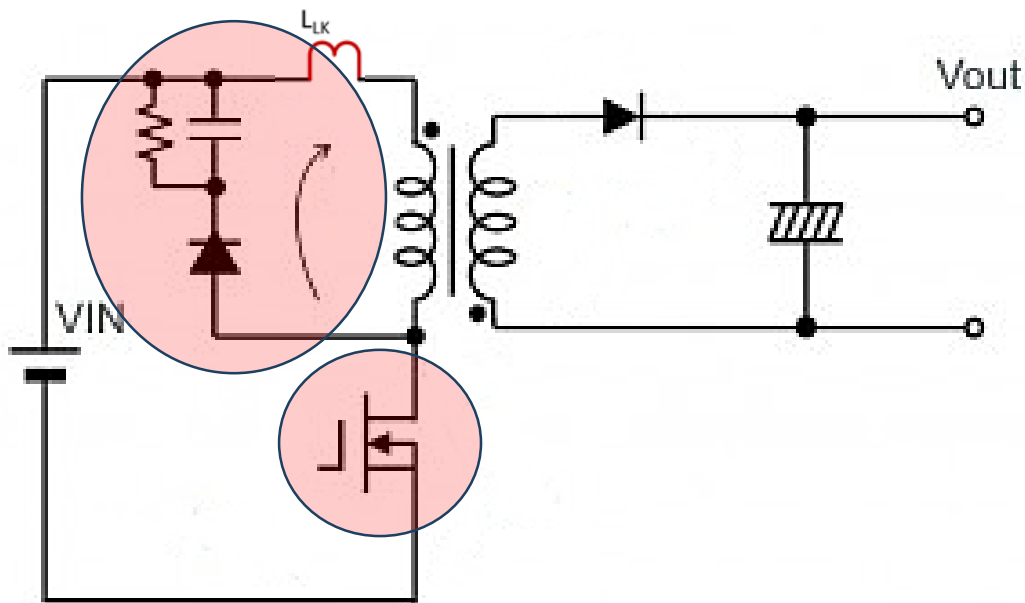


超高密度辅助电源采用有源钳位反激

为何采用有源钳位反激(ACF)?

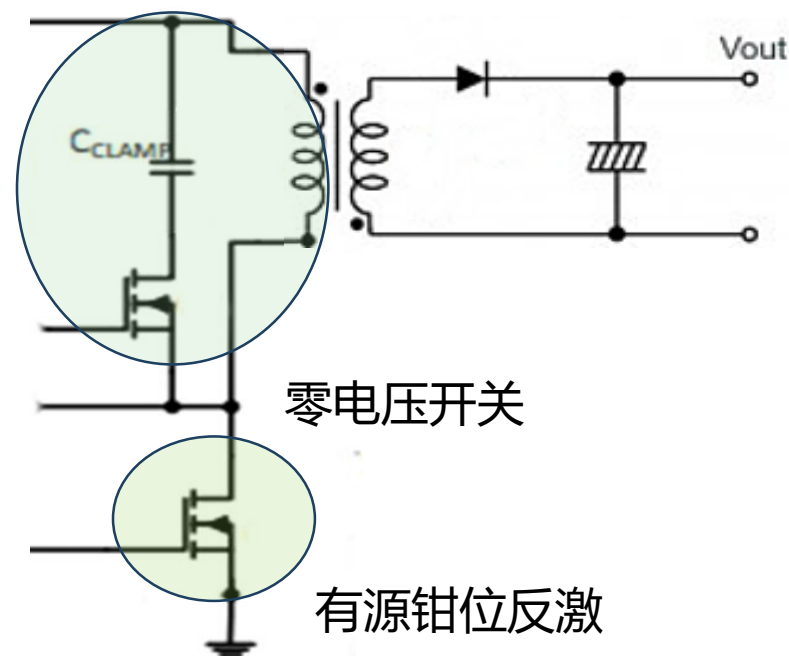
- 在传统的反激式中, 存储在变压器漏感中的能量通过缓冲电路消散, 其在较高频率下变得过高
- 开关损耗也随频率的增加变得非常明显

- ACF循环利用泄漏能量, 将泄漏能量存储在电容器中并将其传送到输出
- ACF实现零电压开关, 在FET两端的电压为零时进行开关, 从而消除了功率损耗
- **开关频率高达1 MHz**



具有RCD缓冲器的传统单端反激

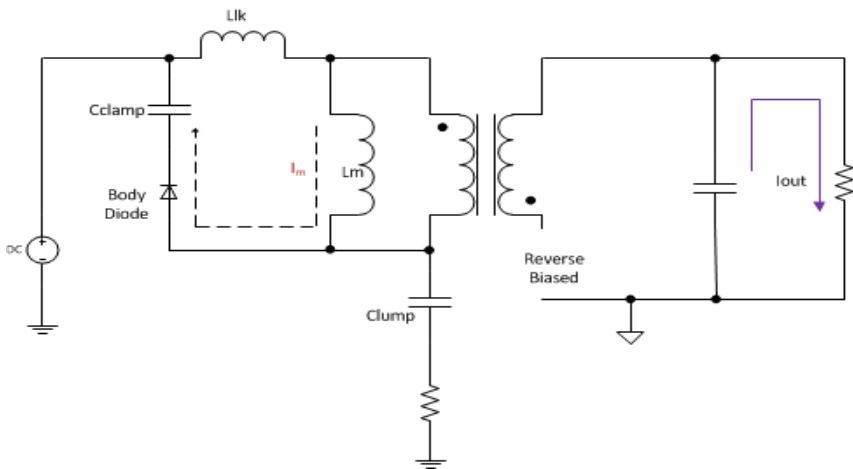
有源钳位



零电压开关

有源钳位反激

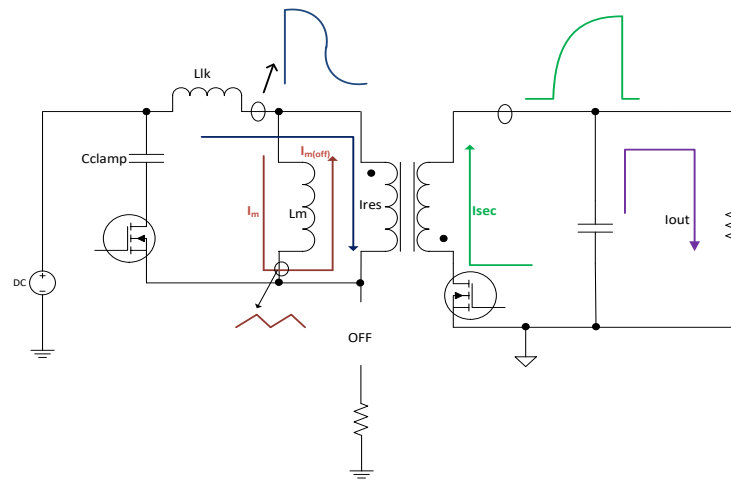
有源反激的关键工作状态



高边体二极管导通

- 当主FET关断，开关节点电压上升，正向偏置钳位FET的体二极管

$$T_{E_D} = \frac{C_{lump} * (V_{in} + V_{clamp})}{I_m}$$

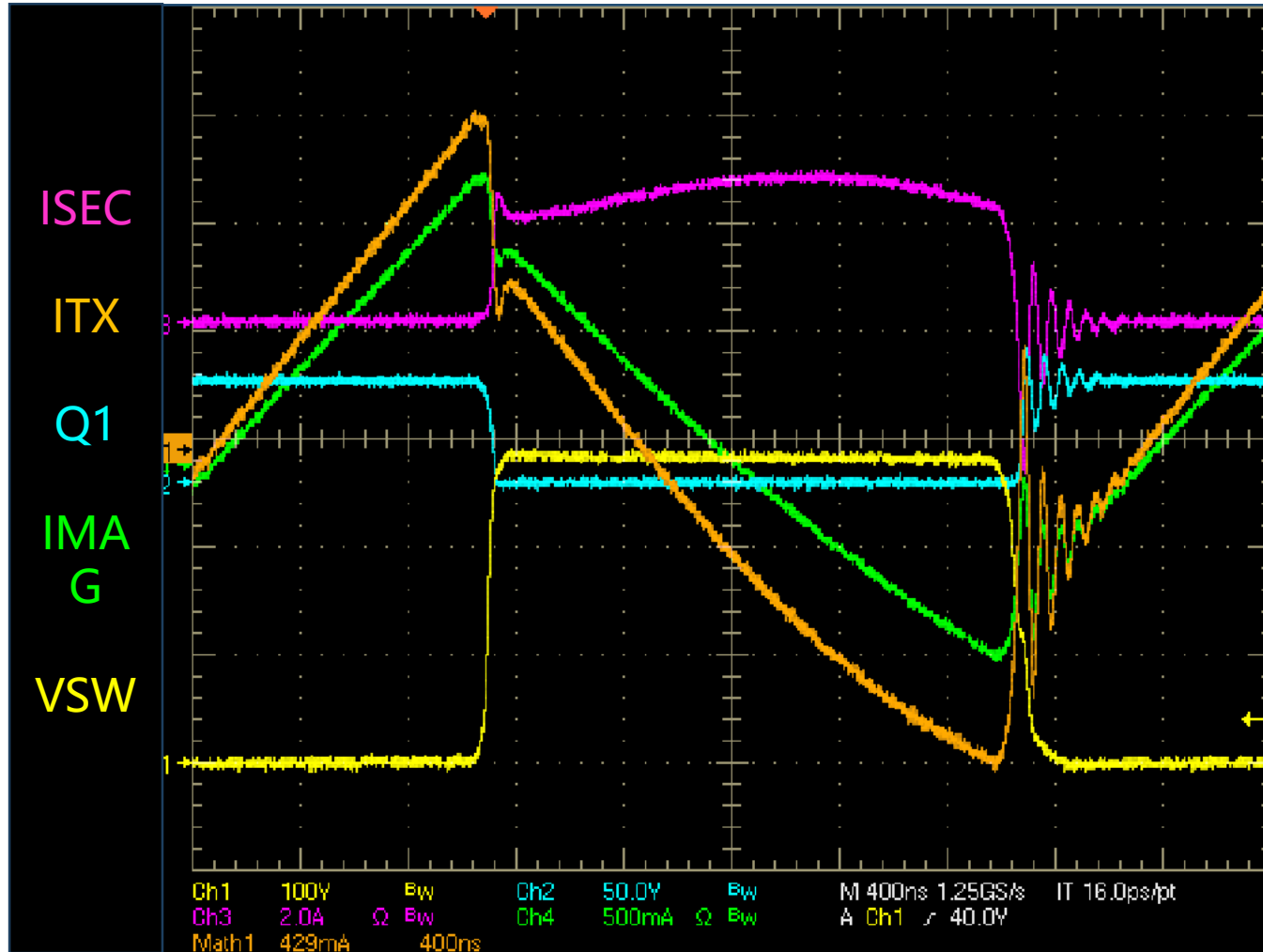


谐振电力传输

- 只要体二极管正向偏置，漏感就开始与钳位电容谐振。谐振频率由以下方程算得：

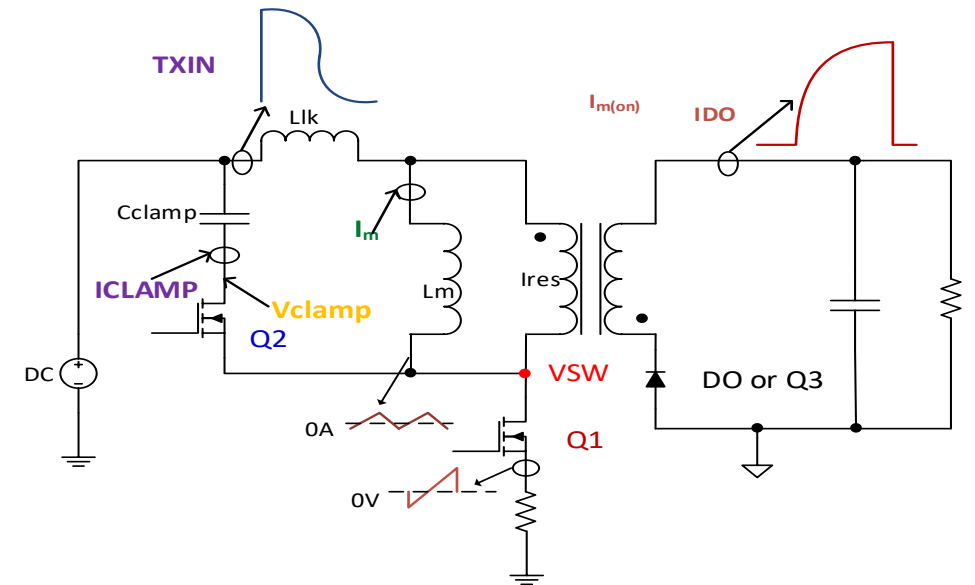
$$f_{Res} = \frac{1}{2 * \pi * \sqrt{L_{leak} * C_{clamp}}}$$

调整ACF开关周期



负励磁电流在导通事件发生前使大电容放电从而实现**零电压开关**

数学计算 $I_{pri} - n \cdot I_{secondary}$ 范围内的励磁电流



NCP1568有源钳位反激控制器关键特性

控制策略

- 自适应ZVS频率调制支持可变Vout模式
- 集成自适应死区时间
- 峰值电流模式控制

DCM 和轻载模式

- 可选过渡到DCM模式
- 初级端负载电流估算
- 频率折返，最低频率钳位为31 kHz
- Quiet skip消除可闻噪声
- 待机功耗 < 30mW

高压启动

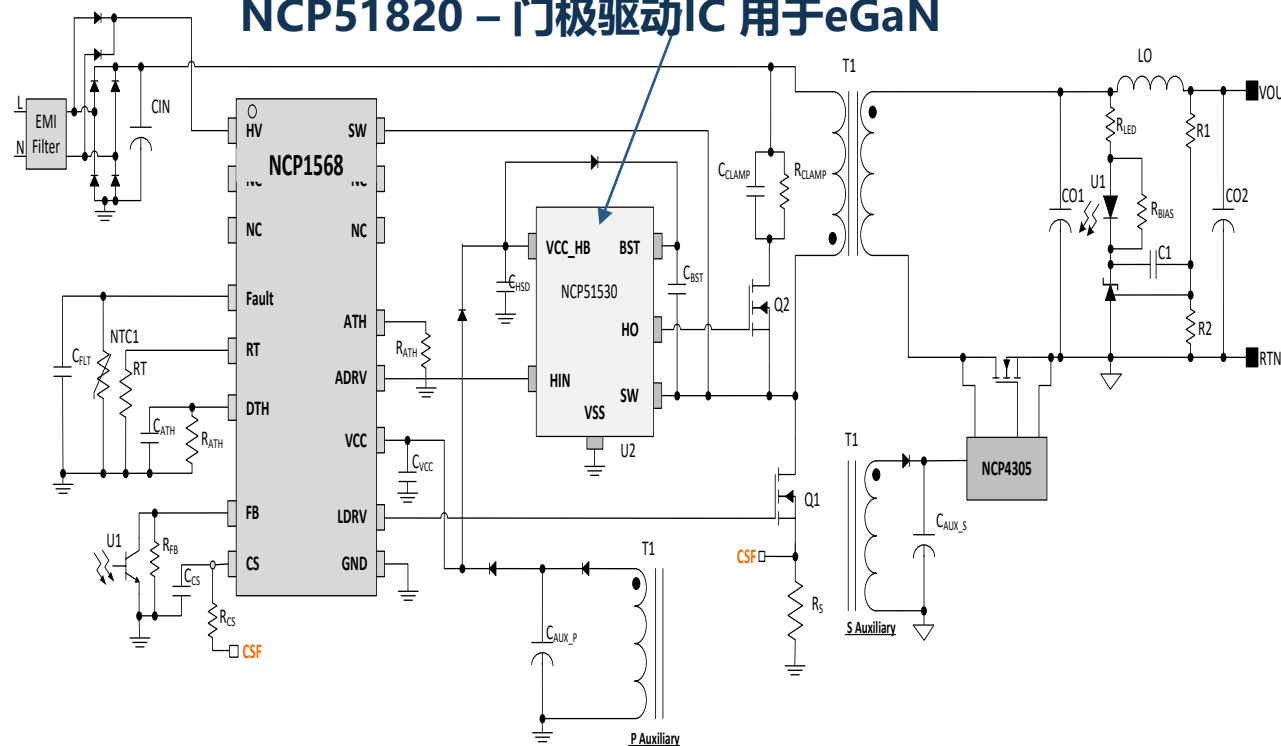
- 700 V 高压启动JFET
- 集成高压开关节点的检测，可实现最佳ZVS
- 内置欠压和X2放电

振荡器

- 从100 kHz到1 MHz的可编程频率
- 具有4个选项的内部软启动计时器
- 振荡器频率抖动降低EMI

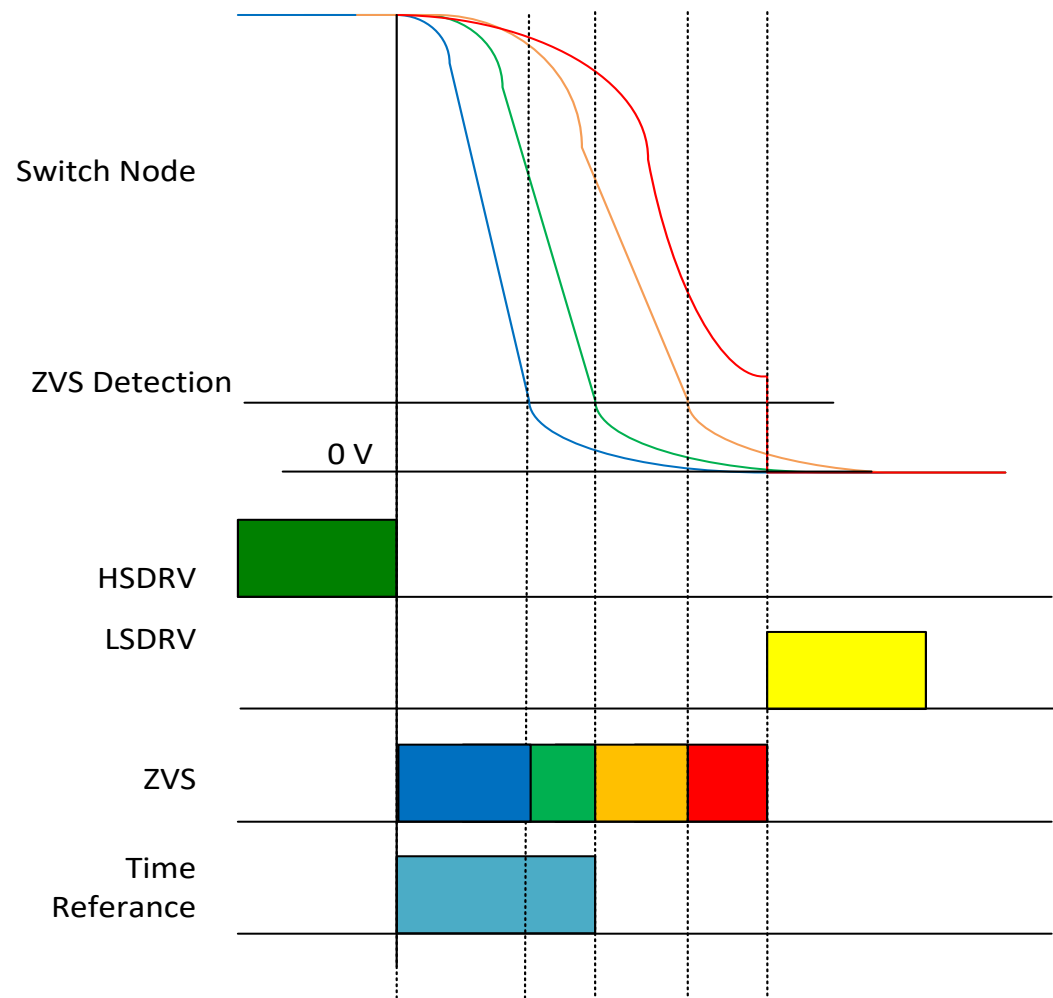
NCP51530 – 门极驱动IC 用于SuperFunction MOSFET

NCP51820 – 门极驱动IC 用于eGaN



**NCP1568, NCP51530 & NCP51820
现已发布!!**

开关节点进入ZVS频率调制



- **内部HV JEFT 监测开关节点.**
- 若ZVS发生时间比参考时间快, 则频率增加。
- 若ZVS发生时间比参考时间慢, 则频率减小。
- 此方法最大限度地减小为实现线路及负载ZVS所需的负循环电流
- 适用于超级结(SJ) FET 和 eGaN

基于自适应ZVS

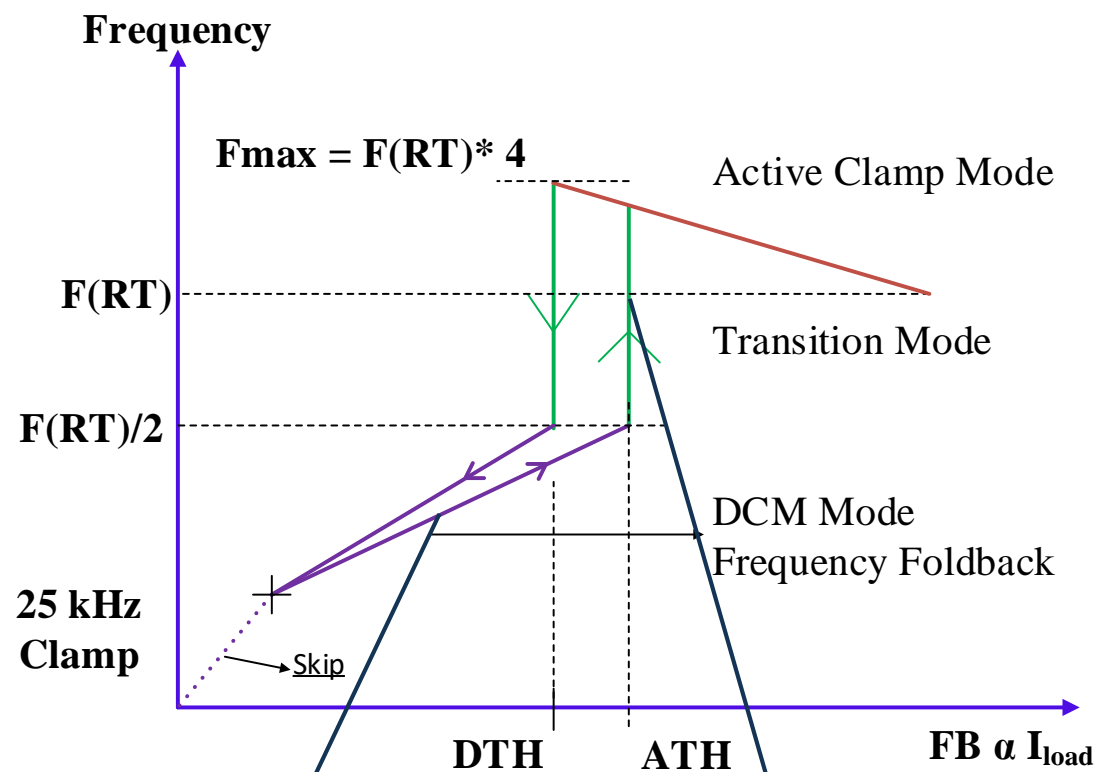
无自适应ZVS



自适应ZVS



轻载条件下过渡至DCM

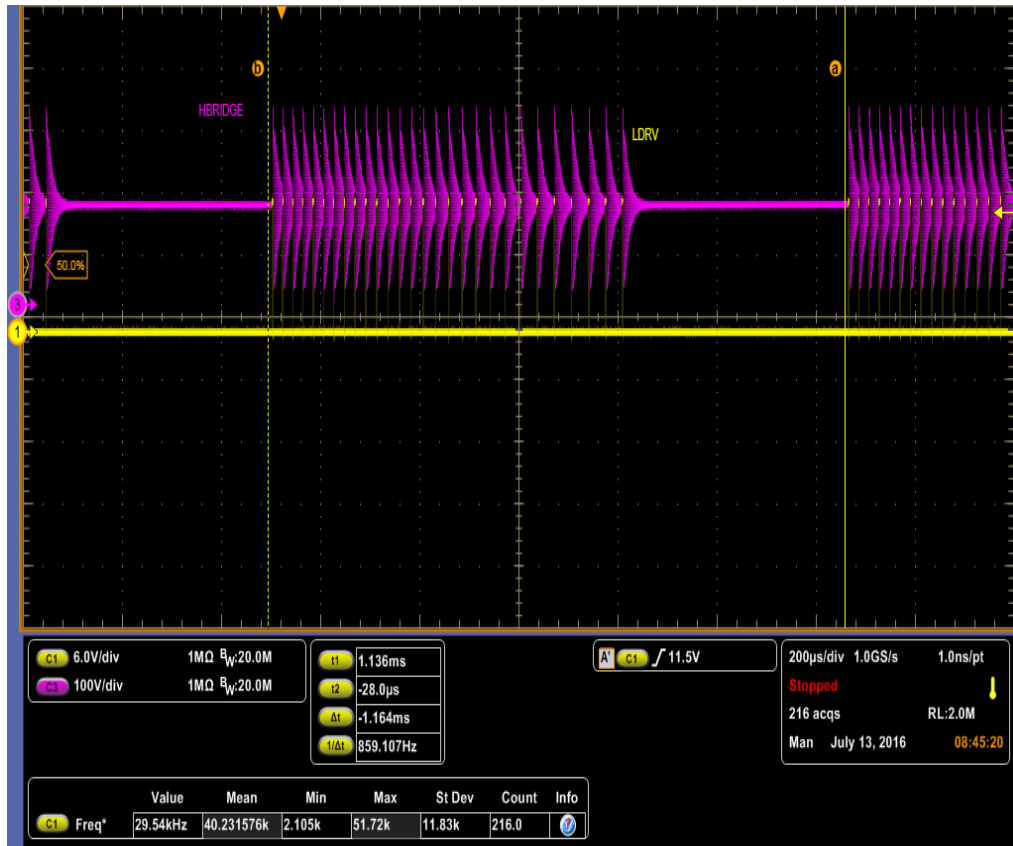


高边FET – 保持OFF

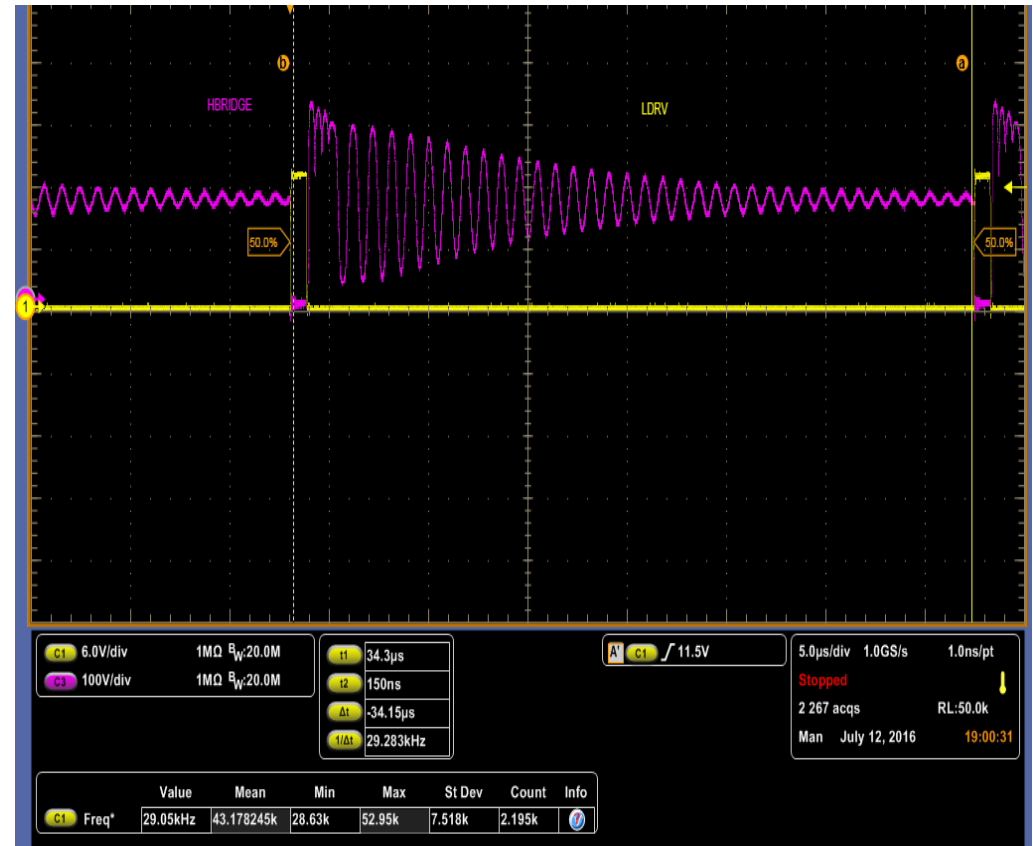
渐进钳位MOSFET前沿调制

- DCM 模式和跳周期模式的实施将使待机和系统能效符合严格的CoC Tier 2 法规

待机时安静的跳周期和频率钳位

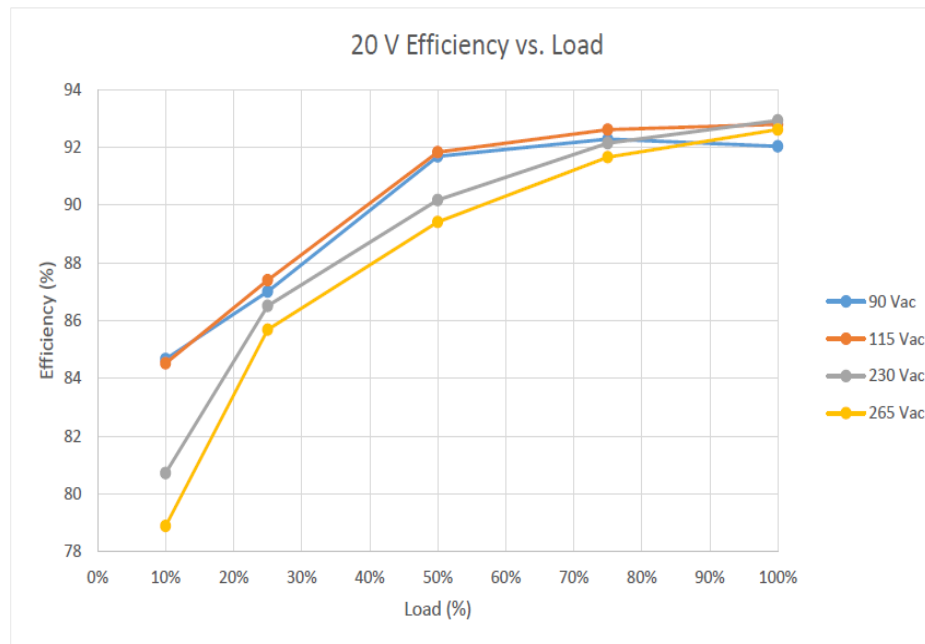
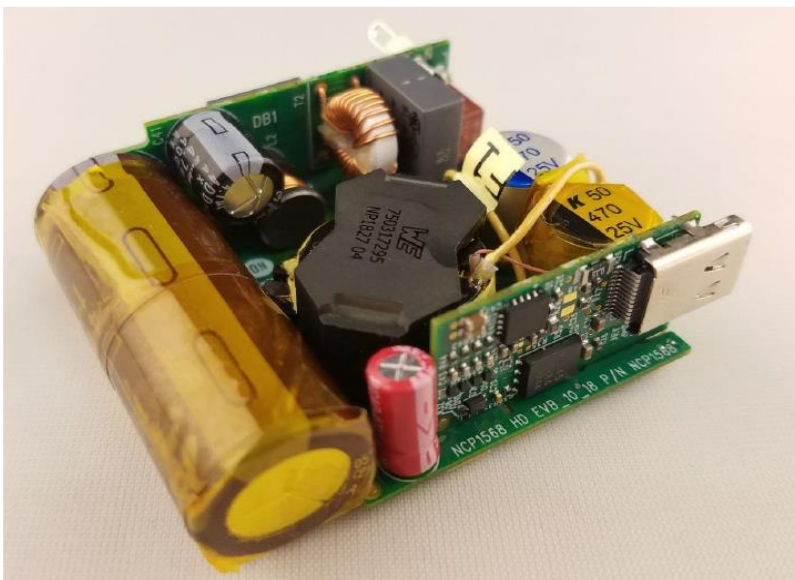


安静的跳周期，800 Hz 脉冲



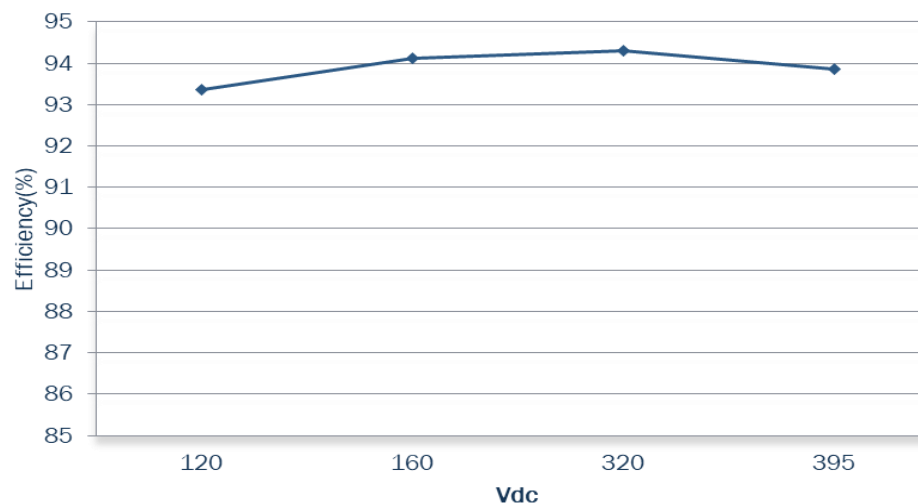
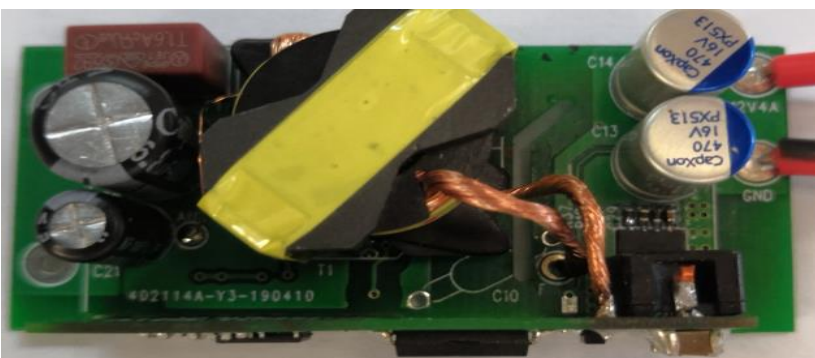
空载时~29 kHz 频率钳位

集成超级结FET的NCP1568演示的能效



通用 AC 输入:
90V~264Vac

在20V 时集成 RM8 变压器的能效: ~93%

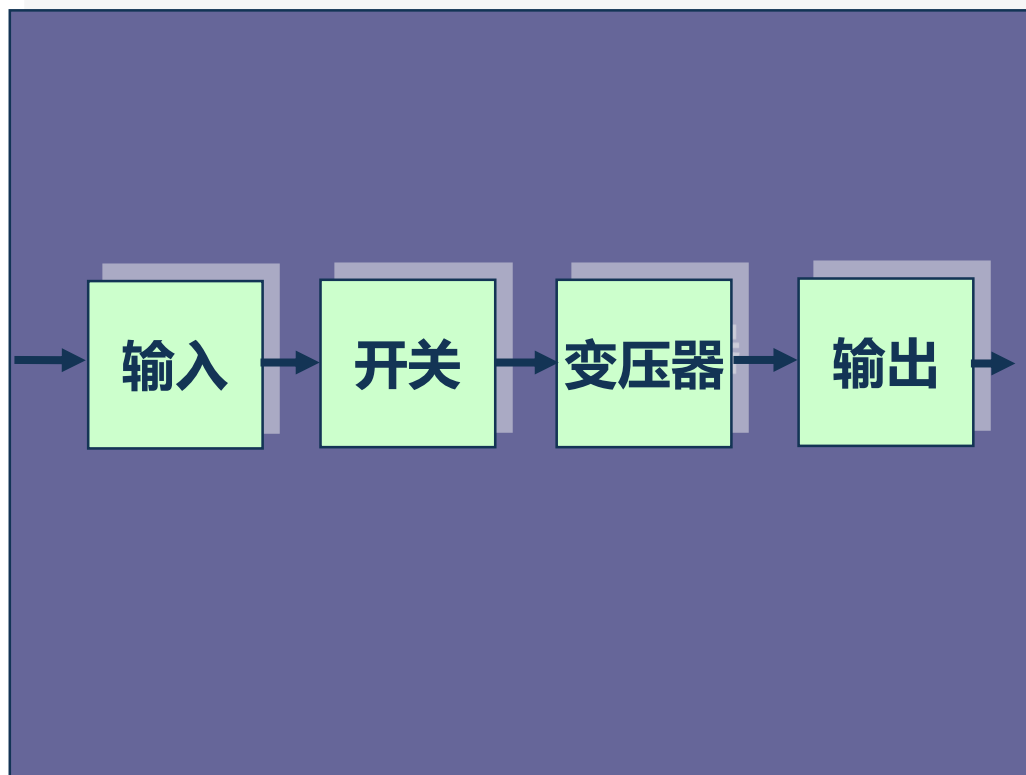


DC 输入: 120 – 400VDC

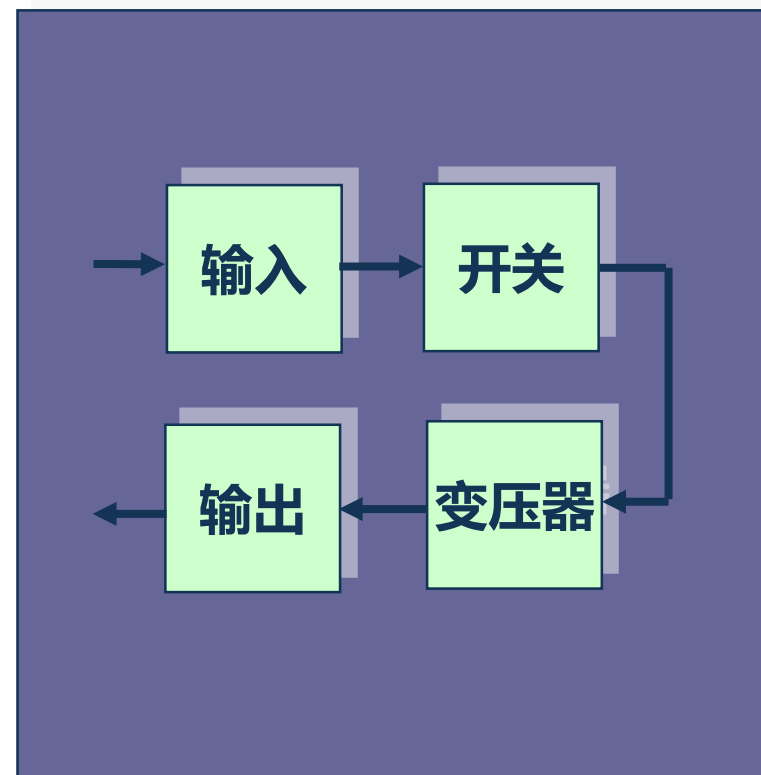
在12V时集成 RM7 变压器的能效: ~94%

开关电源(SMPS) PCB布板考量

元件布局

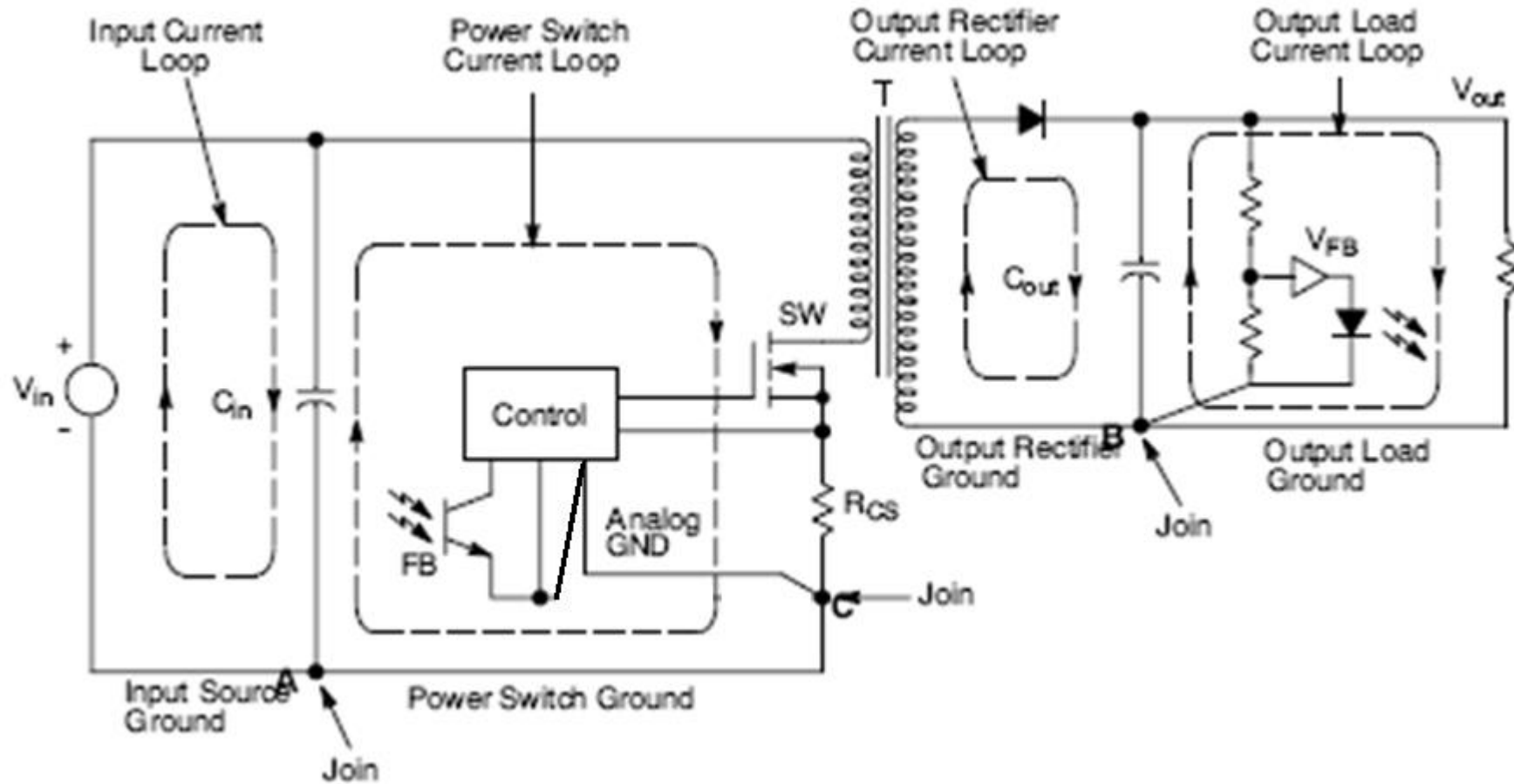


好

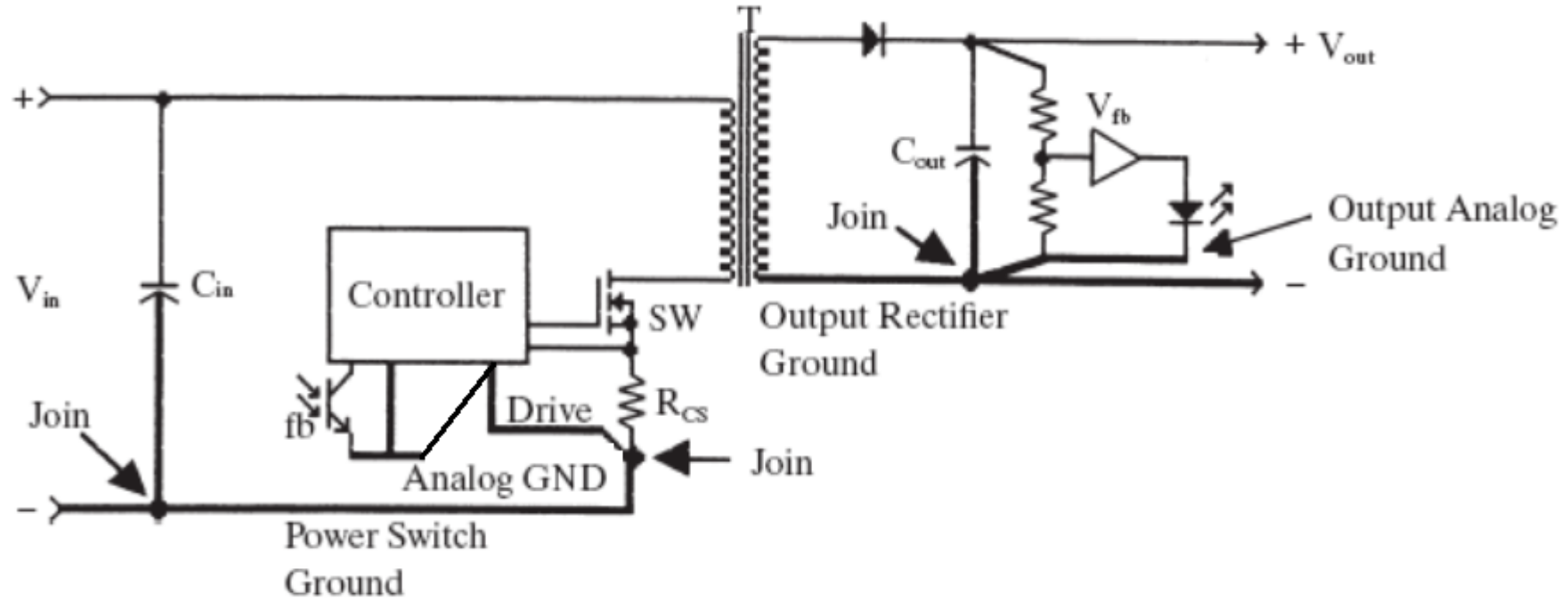


不好

反激电源走线

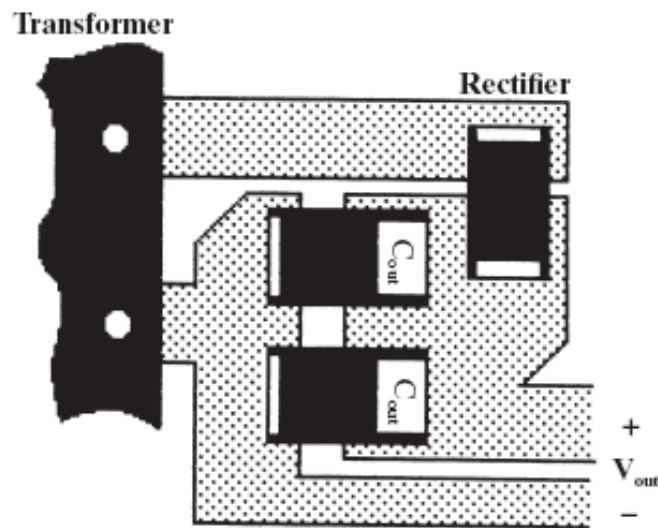
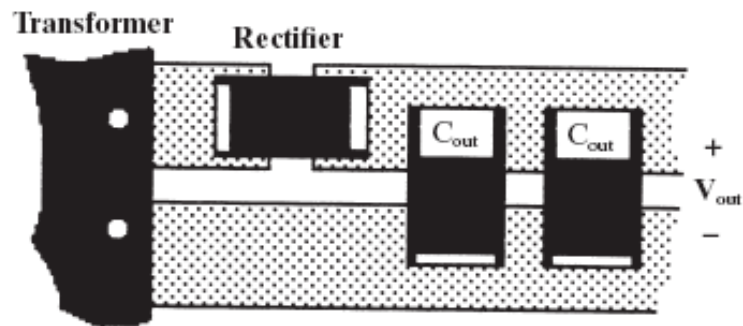


地线接法



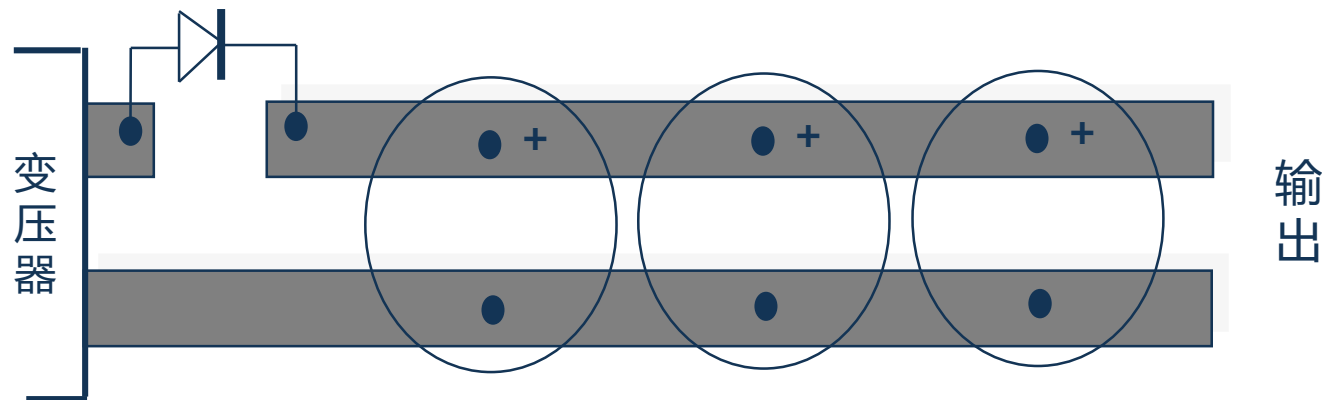
电容输出走线

贴片电容输出走线

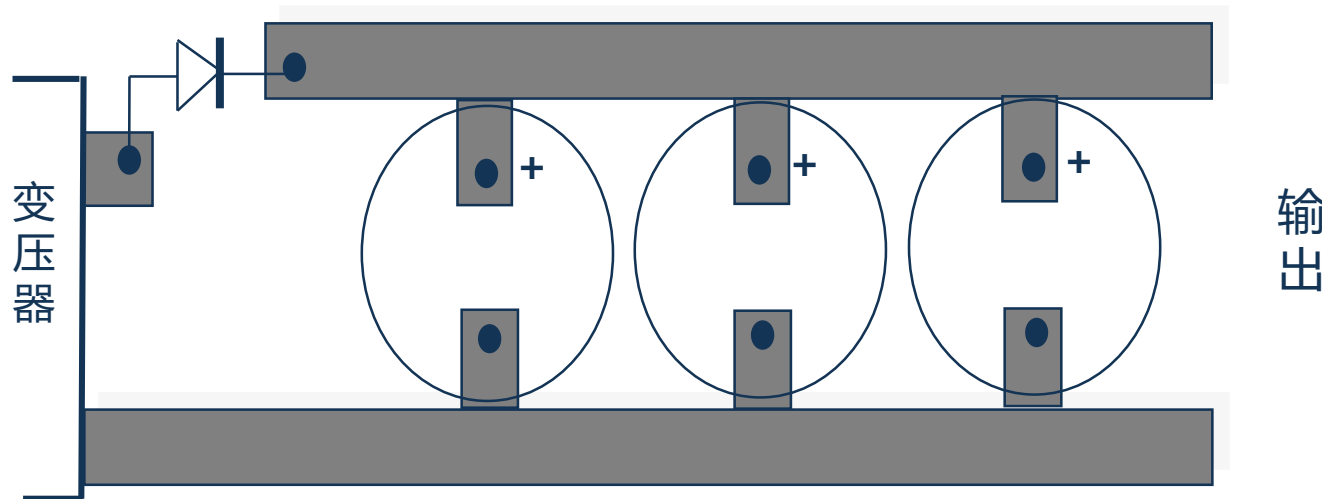


插件电容输出走线

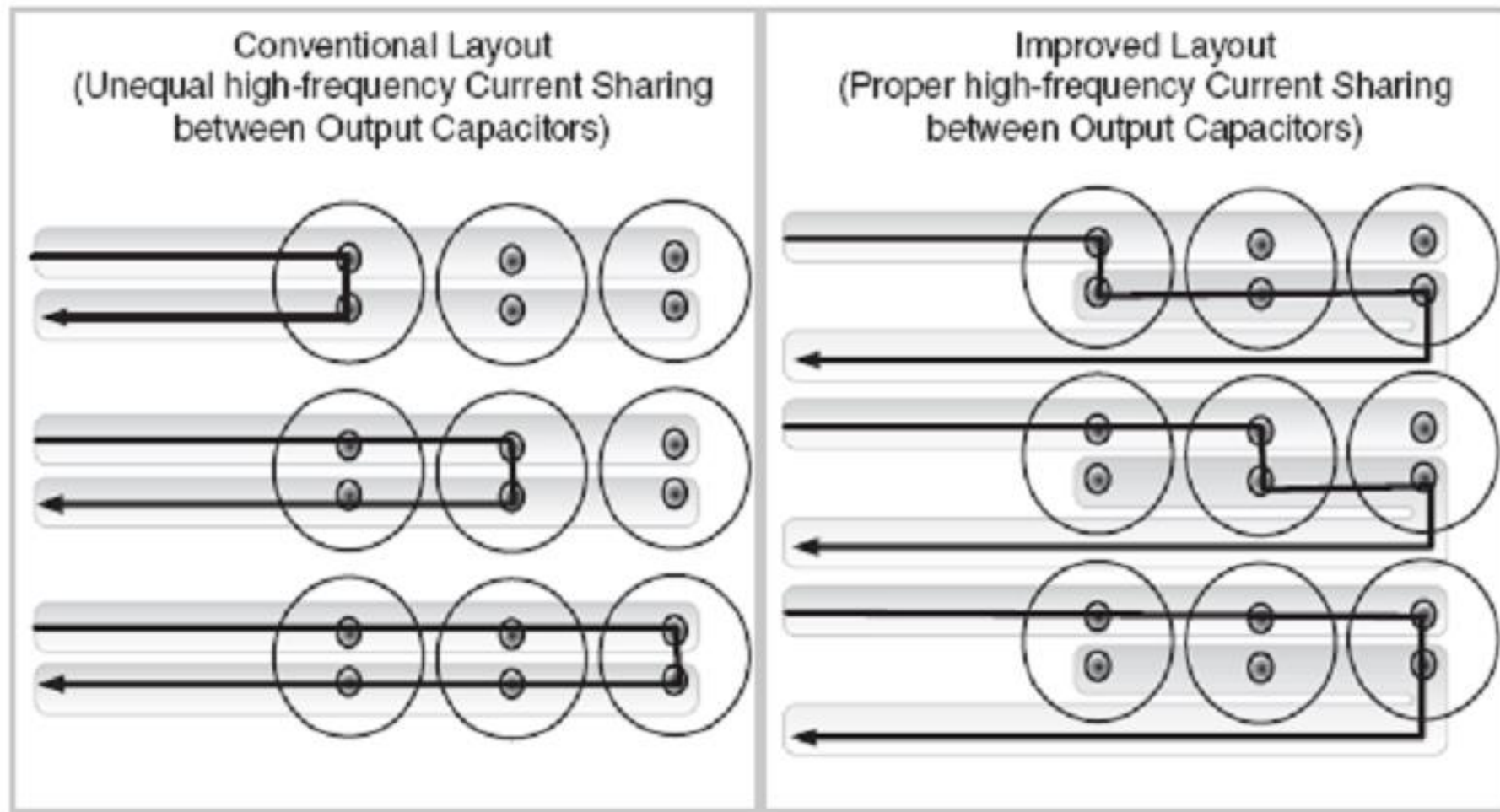
好



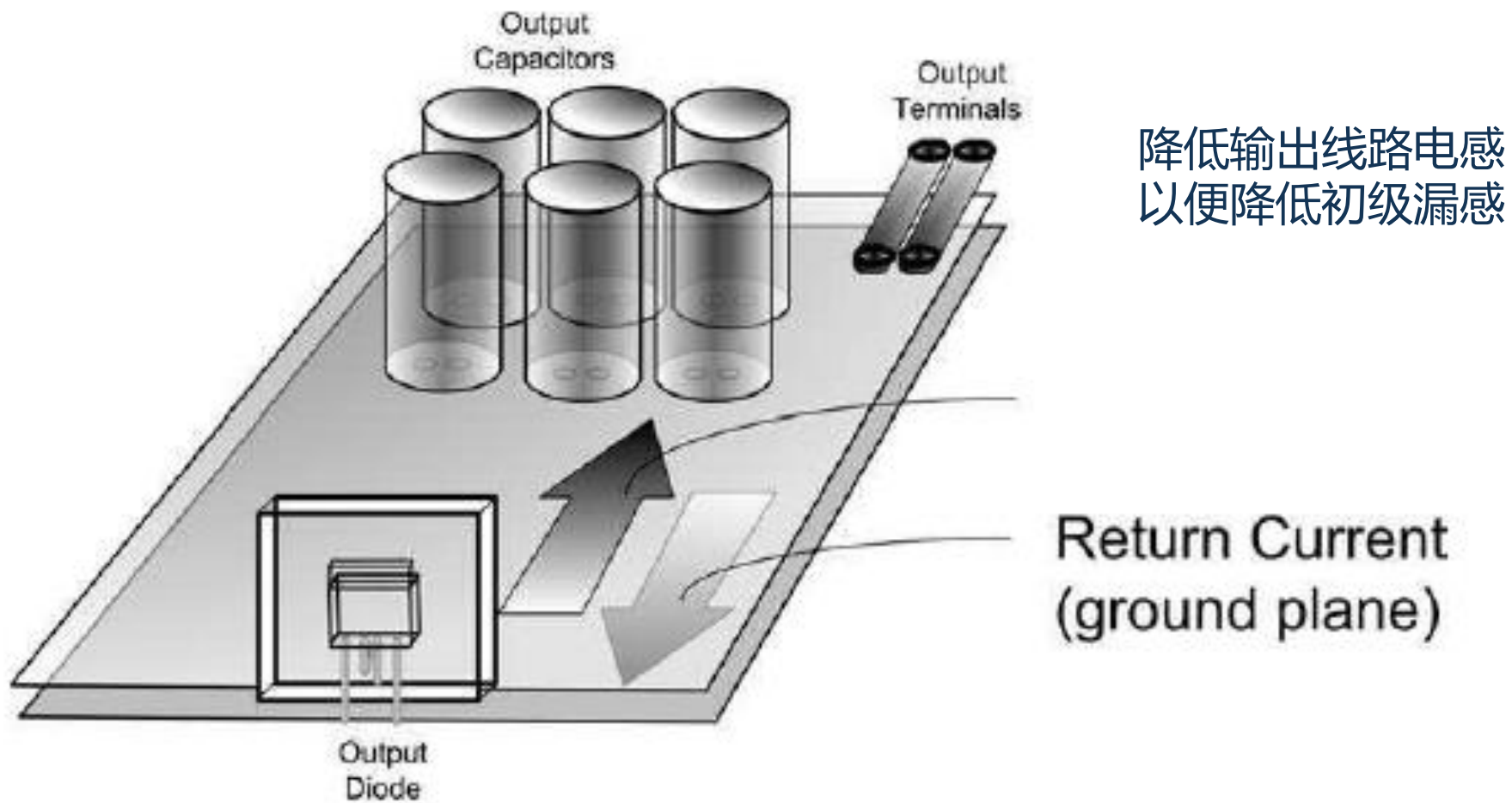
不好



改善电容的电流分配



大电流输出可用多层PCB



总结

- 反激转换器是最流行的辅助电源拓扑，因为它具有更少的器件数量和物料单(BOM)成本
- 对于小于30W的输出功率水平，内置高压MOSFET的AC - DC开关是易于设计和紧凑尺寸的首选方法。安森美半导体提供从3W到30W的广泛的AC - DC开关产品阵容。推出了新的AC - DC开关系列，包括NCP107x、NCP1067x和FSL5x8
- 对于 > 30W的输出功率水平，通常采用AC - DC控制器IC加外部MOSFET方法，以提供设计灵活性并简化热管理。为了提高功率密度和转换能效，安森美半导体提供采用NCP1342的高频准谐振(QR)反激方案和采用NCP1568的零电压开关(ZVS)有源钳位反激方案。突显了关键特性和优势
- 变压器设计是反激设计的关键。讲解了固定频率和QR反激变压器设计
- 交钥匙参考设计和设计电子表格工具有助于电源设计以减少开发工作量

谢谢大家!

专家答疑Q&A
