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用户指南：

**FEBFAN9611_S01U300A
评估板**

FAN9611 300W交错式双BCM薄型PFC评估板

**飞兆特色产品
FAN9611**

**请将
有关此评估板的问题或评论提交至：
“全球支持中心”**

Fairchild Semiconductor.com

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本用户指南支持FAN9611 300W评估板，该评估板可用于交错临界导通模式功率因数校正电源。应与FAN9611数据手册、飞兆半导体应用指南 [AN-6086 - 采用FAN9611/FAN9612的交错式临界导通模式PFC设计依据](#)以及FAN9611/12 PFC基于Excel®的设计工具等配合使用。

1. 评估板概述

FAN9611系列的交错式双临界导通模式(BCM)、功率因数校正(PFC)控制器可控制两个并行连接的180°异相升压传动系统。交错式功能可将控制技术的最大实际功率电平从大约300W扩展至800W以上。与常用于更高功率电平的连续导通模式(CCM)技术不同，BCM可以实现升压二极管固有的零电流开关(不产生反向恢复损耗)，这样就允许在不牺牲效率的情况下采用成本较低的二极管。此外，输入和输出滤波器的体积更小了，这是因为传动系统间纹波电流的消除以及开关频率的有效增倍。

带峰值检测电路的高级线路前馈可在线路瞬变时最大程度减少输出电压变化。为了确保在轻负载条件下稳定运行并具有较少的开关损耗，最大开关频率固定在525kHz。在任何工作条件下都能保持同步。

保护功能有：输出过压保护、过流保护、反馈开路保护、欠压闭锁保护、掉电保护和冗余闭锁过压保护。FAN9611采用无铅16引脚小型集成电路(SO16)封装。

本FAN9611评估板使用4层印刷电路板(PCB)，针对300W (400V/0.75A)额定功率而设计。最大额定功率为350W，最大导通时间(MOT)功率限值设为360W。FEBFAN9611_S01U300A经过优化后能以小于18mm的薄型尺寸展现FAN9611器件所有效率和保护特性。

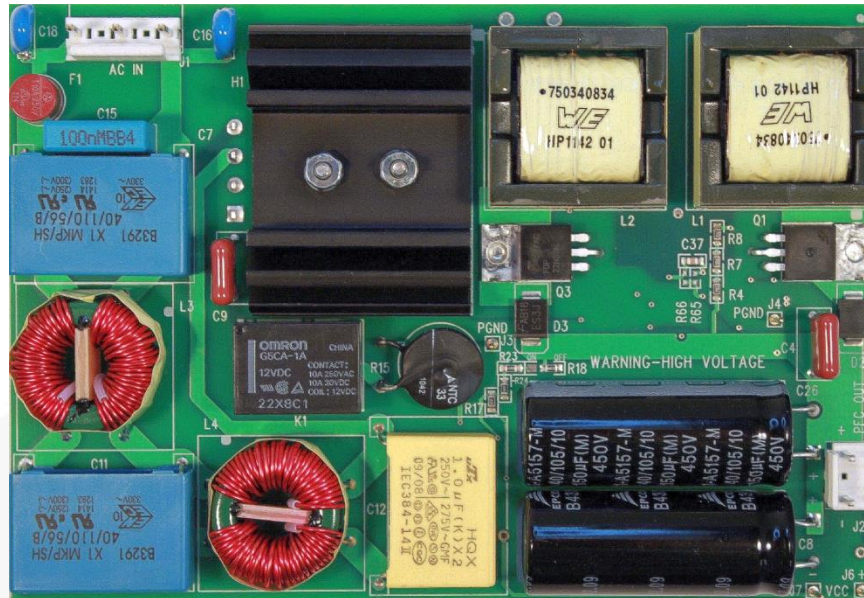


图 1. FEBFAN9611_S01U300A, 顶视图, 152mm x 105mm



图 2 FEBFAN9611_S01U300A, 侧视图 (薄型), 横截面积=18mm

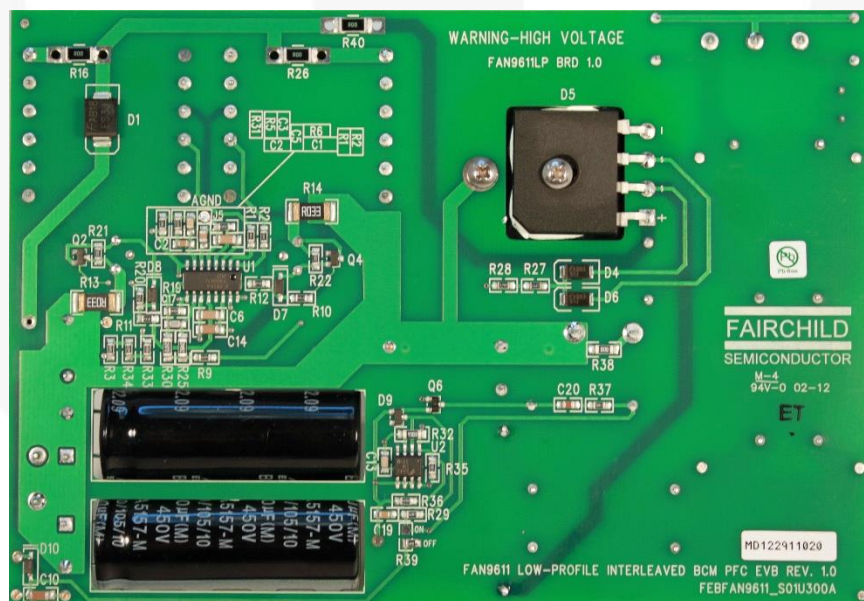


图 3 FEBFAN9611_S01U300A, 底视图, 152mm x 105mm

2. 主要功能

- 180° 异相同步
- 轻负载时的相位自动禁用
- 灌电流为1.8A、拉电流为1.0A的高电流栅极驱动器
- 可减少过冲的跨导(g_m)误差放大器
- 带(V_{IN}) 2前馈功能的电压模式控制
- 设有可编程软启动时间的闭环软启动, 可减少过冲
- 可避免音频噪声的最小重启定时器频率
- 最大开关频率箝位
- 带软恢复功能的欠压保护
- FB引脚提供非闭锁OVP(过压保护), OVP引脚提供次级级闭锁保护
- 开路反馈保护
- 针对每一相位都提供过流和功率限制保护
- 低启动电流: 80 μ A(典型值)
- 采用直流输入或50Hz至400Hz的交流输入

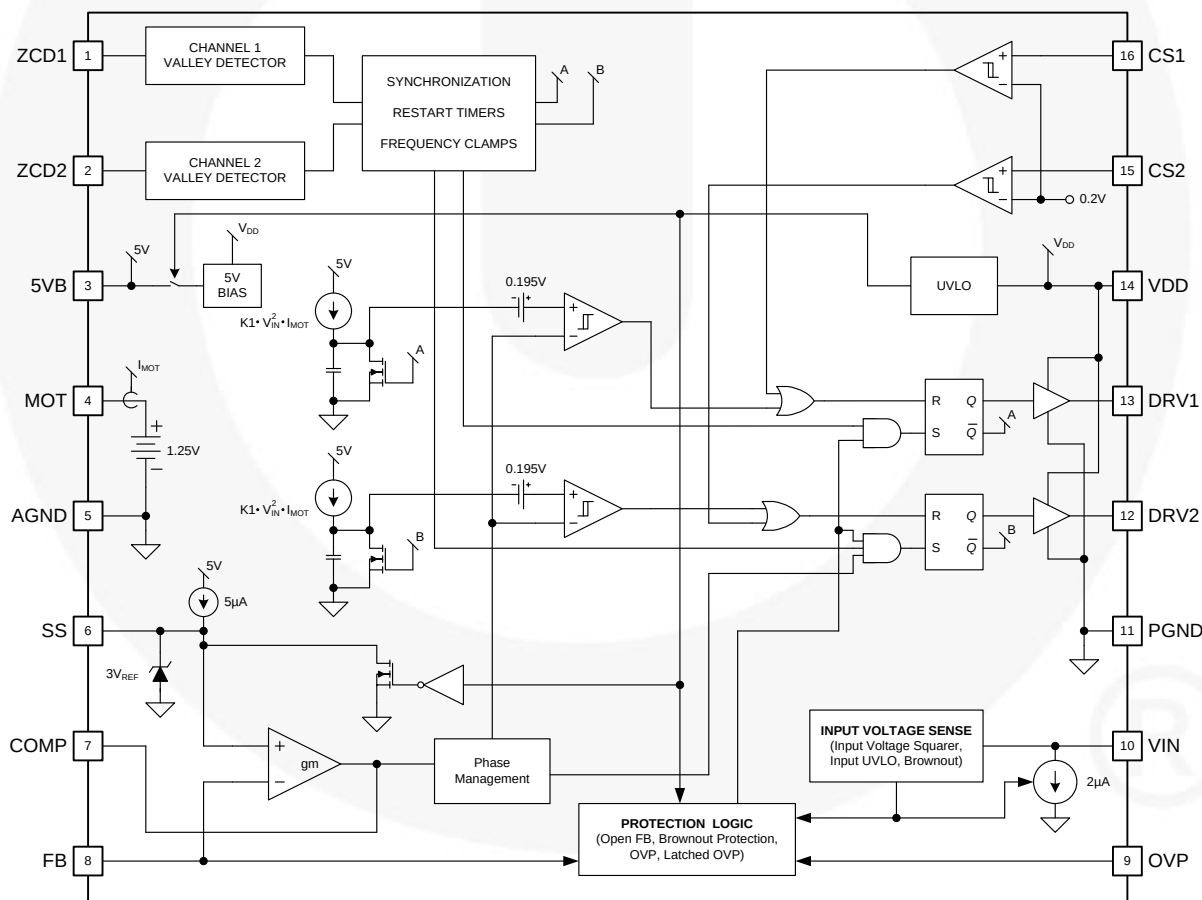


图 4 框图

3. 规格

该评估板设计和优化时针对的是表1中的条件：

表1. 电气和机械要求

	最小值	典型值	最大值
V_{IN_AC}	80V	120V	265V
$V_{IN_AC(ON)}$		90V	
$V_{IN_AC(OFF)}$		80V	
f_{VIN_AC}	50Hz	60Hz	65Hz
V_{OUT_PFC}	395V	400V	405V
$V_{OUT_PFC_RIPPLE}$		10V	11V
P_{OUT_PFC}		300W	350W
$P_{OUT_PFC(MOT_LIMIT)}$		360W	
f_{SW_PFC}	18kHz		300kHz
t_{HOLD_UP}	20ms		
t_{SOFT_START}		250ms	300ms
$t_{ON_OVERSHOOT}$			10V
$\eta_{PFC_120V} P_{OUT} > 30\% P_{OUT(TYP)}$		96%	96.5%
$\eta_{PFC_230V} P_{OUT} > 30\% P_{OUT(TYP)}$		95%	98%
PF_{120V}			0.991
PF_{230V}			0.980
机械与热性能			
高度			18mm
θ_{JC}			60°C

评估板内置保护功能的跳变点设置如下：

- 线路UVLO（掉电保护）跳变点设为80V_{AC}（10V_{AC}迟滞）。
- 每个MOSFET的逐脉冲限流设为6A。

工作电压为85V_{AC}时，将负载增大到360W并且同时对单个电感电流波形进行测量，即可观察到限流功能。最大功率限值设为额定输出功率的120%左右。工作电压在115V_{AC}以上时，将负载增大到360W以上，即可观察到功率限制功能。在功率限制情况下工作时，输出电压下降，COMP电压饱和，但交流线路电流仍然为正弦波形。对于高线路电压，相位管理功能允许在标称输出功率的18%左右进行切相/相位叠加（230V_{AC}）。该数值可通过修改MOT电阻（R6）而增加，如下列飞兆半导体应用指南中所述：[AN-6086 -采用FAN9611/FAN9612的交错式临界导通模式PFC的设计依据](#)。

4. 测试步骤

为FEBFAN9611_S01U300A供电给评估板前，作为 V_{DD5} 图的直流偏压、作为线路输入的交流电源电压以及作为输出的直流电气负载应连接评估板，如所示。

表2. 摘自FAN9611数据手册的规格

符号	参数	工作条件	最小值	典型值	最大值	单位
电源						
$I_{STARTUP}$	启动电源电流	$V_{DD} = V_{ON} = 0.2V$		80	110	μA
I_{DD}	工作电流	输出未转换		3.7	5.2	mA
I_{DD_DYN}	动态工作电流	$f_{SW} = 50kHz$; $C_{LOAD} = 2nF$		4	6	mA
V_{ON}	UVLO启动阈值	V_{DD} 增大	9.5	10.0	10.5	V
V_{OFF}	UVLO停止阈值电压	V_{DD} 减小	7.0	7.5	8.0	V
V_{HYS}	UVLO 滞环	$V_{ON} - V_{OFF}$		2.5		V

4.1. 安全预防措施

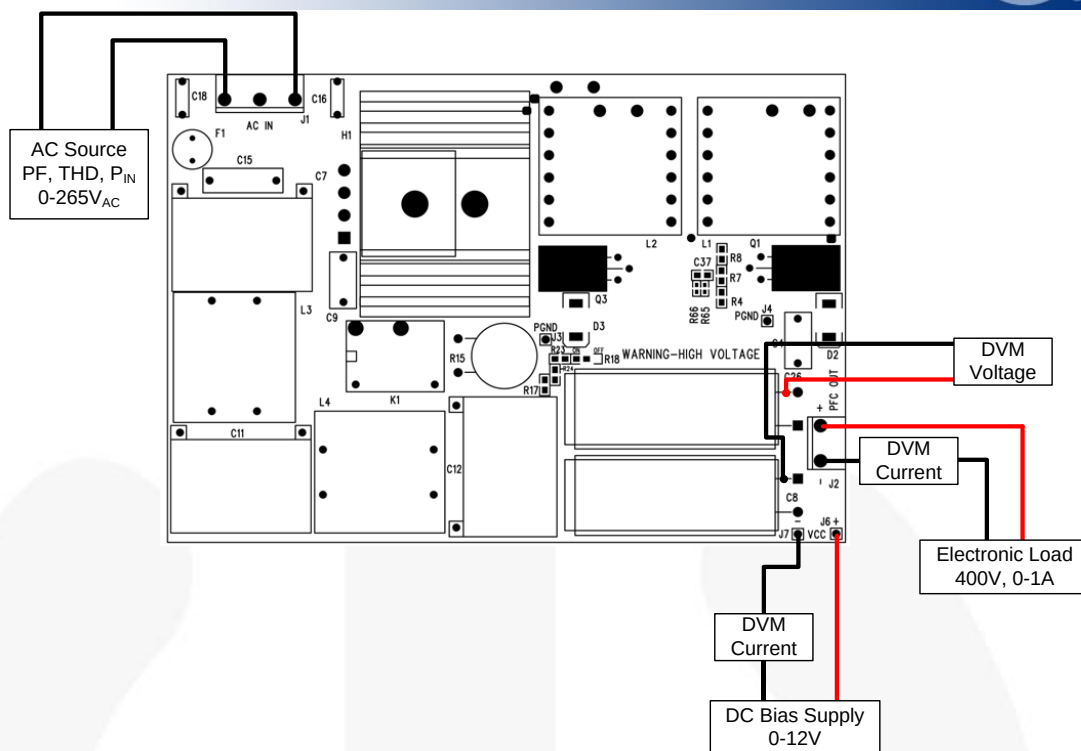


FEBFAN9611_S01U300A评估模块会产生致命电压，大容量输出电容可存储大量电荷。探测与处理模块时请格外仔细，并采取下列预防措施：

- 工作台表面应保持整洁，无任何导电材料。
- 开启开关接通交流电源时，需谨慎。
- 存在交流线路电压时，千万不可探测或移动DUT上的探针。
- 断开测试引脚时，确保输出电容已放电。一种方法是在直流输出负载导通的情况下断开交流电源。负载会对输出电容放电，然后模块便可安全断开连接。

上电步骤

1. 首先为控制芯片提供 V_{DD} 。电压应高于 10.5V（参见 V_{DD} 导通阈值电压规格，如表 2 所示）。
2. 连接交流电压 (90~265V_{AC}) 以启动 FAN9611 评估板。由于 FAN9611 具有掉电保护功能，任何小于最小交流线路电压设计值的输入电压都会触发掉电保护。交流输入电压高于 90V_{AC} 时，N9611_S01U300A 启动。
3. 改变负载电流 (0~0.75A)，检查工作状况
4. 检验输出电压是否在 395V_{DC}<V_{OUT}<405V_{DC} 范围内进行调节



5 图。建议的测试设置

本文中的所有效率数据均来源于 5 图中的测试设置，测试时直接在大输出电容端测量输出电压，而非通过输出连接器 (J2) 测量。

断电步骤

1. 确保电气负载设置为可从直流恒流源获取至少 100mA 电流。
2. 断开（关断）交流线路电压源
3. 断开（关断）12V 直流偏置电源
4. 最后断开（关断）直流电气负载，确保处理评估模块前，输出电容完全放电。

Connected by copper under U1
U1-5 to U1-11

FEBFAN9611_S01U300A · Rev. 0.0.1

6. 升压电感规格

Würth Electronics的750340834 (www.we-online.com)



- 磁芯: EFD30 ($A_e=69\text{mm}^2$)
- 骨架: EFD30
- 电感: $270\mu\text{H}$

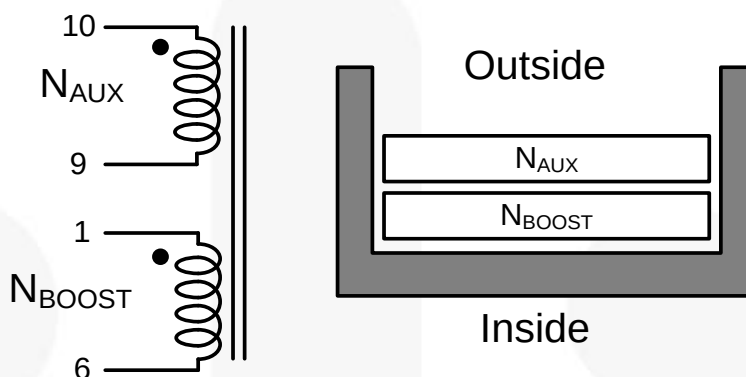


图 6. 评估板上的升压电感 (L1、L2)

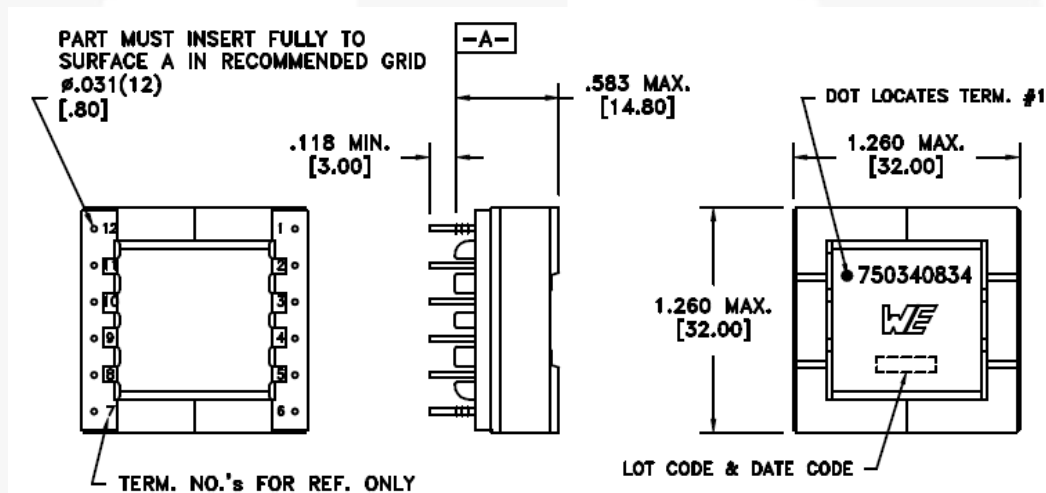


图 7. Würth 750340834 机械图纸

表3. 电感匝数规格

	引脚	匝数	绕线
N_{BOOST}	1 → 6	69 (3层)	30xAWG#38 Litz
绝缘带			
N_{AUX}	10 → 9	7	AWG#28
绝缘带			

7. 4层PCB和装配图

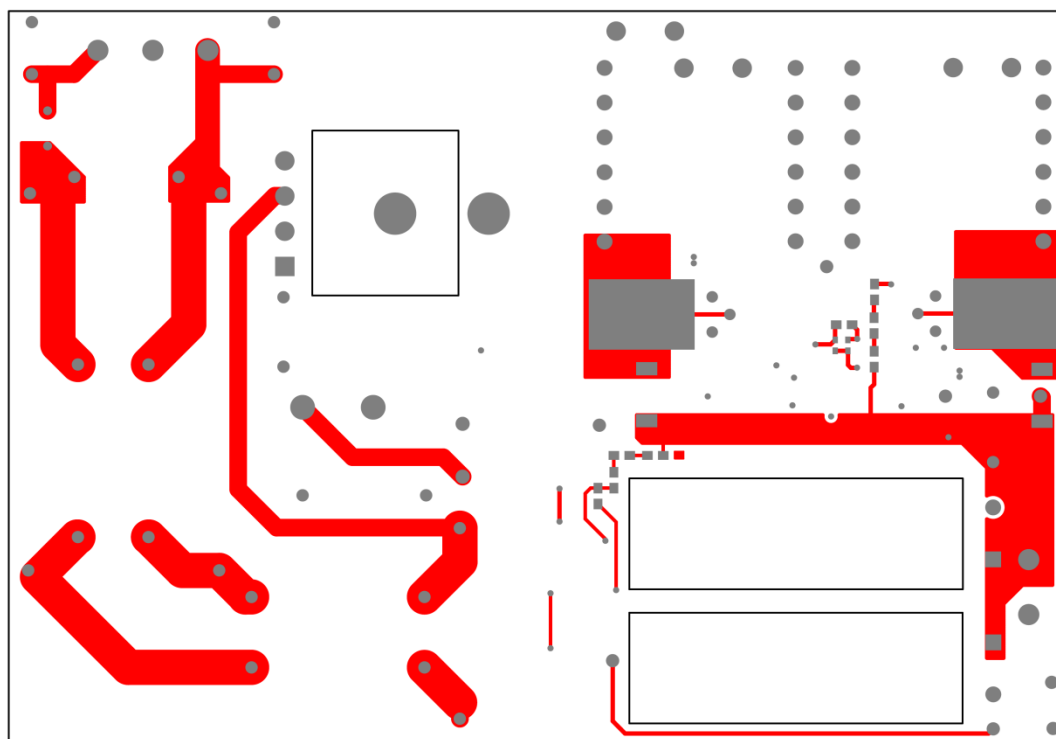


图8. 第1层 - 顶层

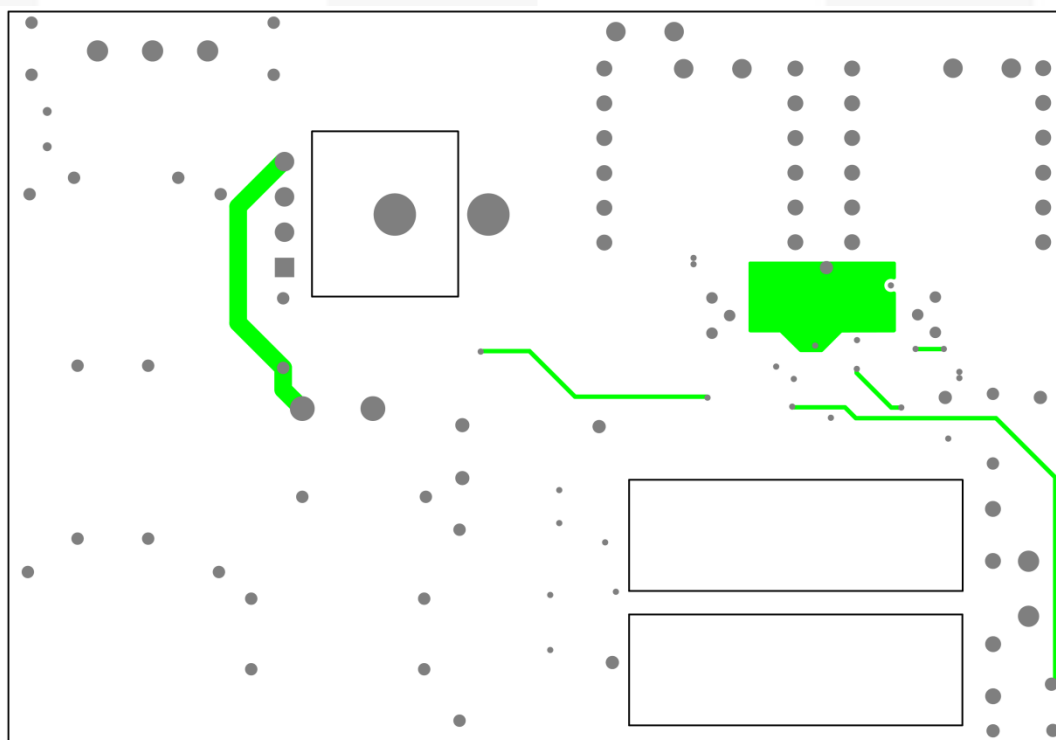


图9. 第2层 - 内部层

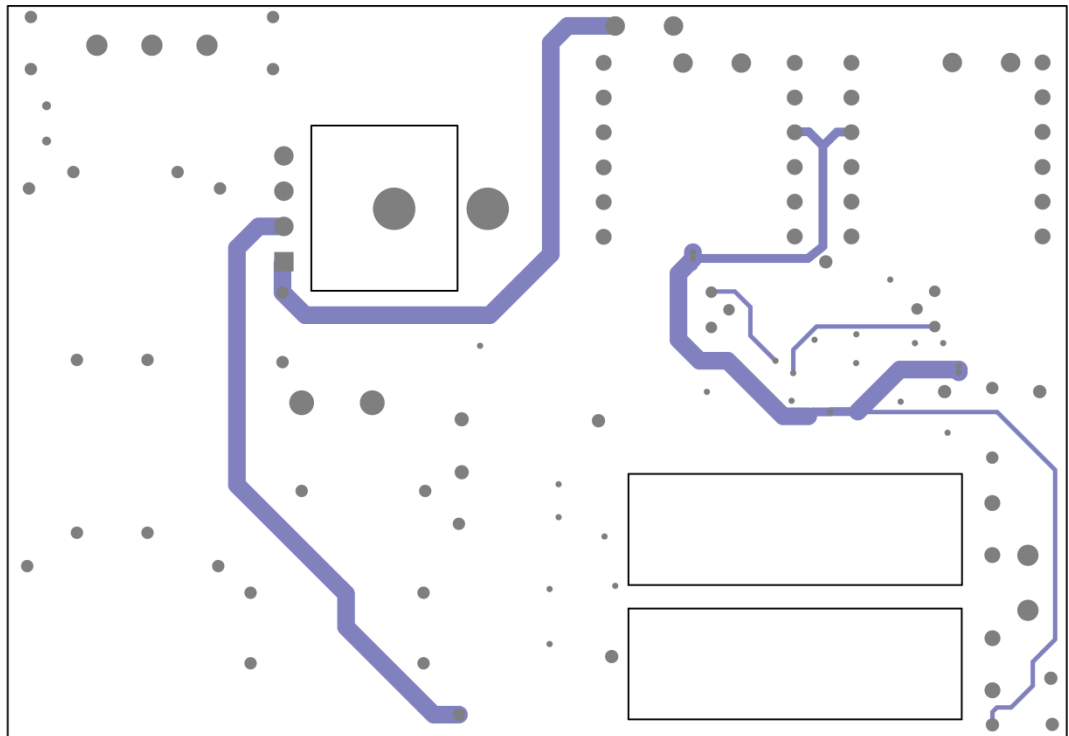


图 10。第 3 层 - 内部层

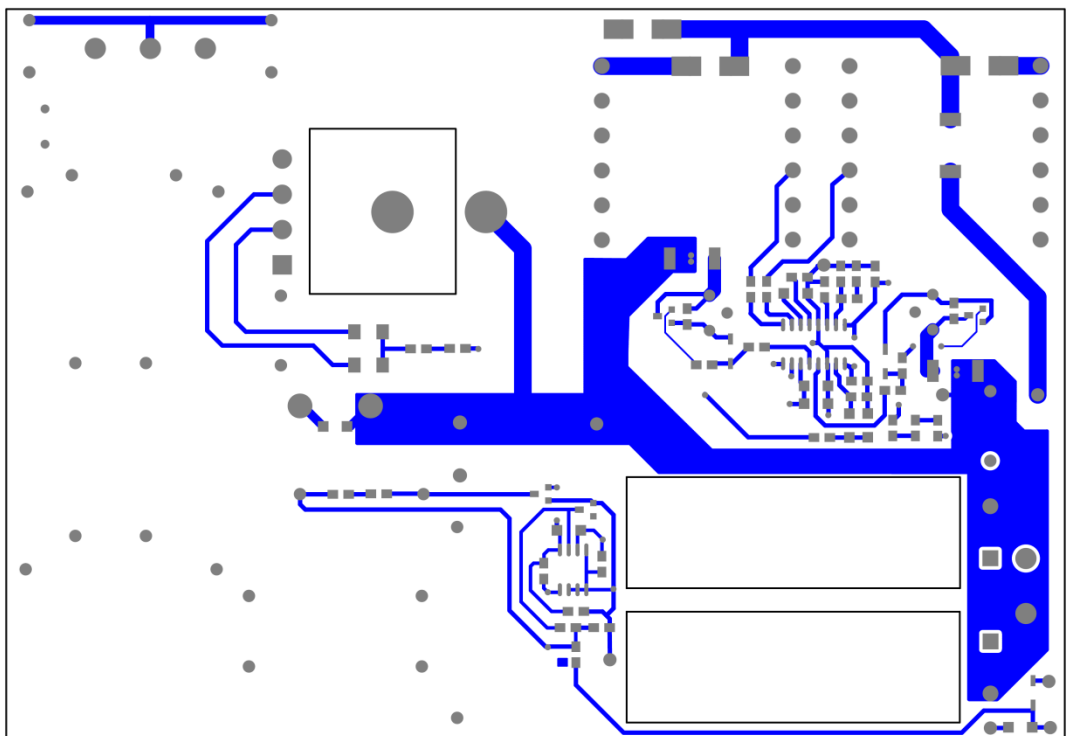


图 11。第 4 层 - 底层



8. 物料成本 (BOM)

项目	数量	标号	器件编号	数值	说明	生产厂商	封装
1	2	C1, C6		0.22 μ F	电容, SMD, 陶瓷, 25V, X7R	STD	1206
2	1	C2		390nF	电容, SMD, 陶瓷, 25V, X7R	STD	805
3	2	C3, C13		15nF	电容, SMD, 陶瓷, 25V, X7R	STD	805
4	2	C4, C9	ECW-F2W154JAQ	150nF	电容, 450V, 5%, 聚丙烯	Panasonic	通孔
5	1	C5		470nF	电容, SMD, 陶瓷, 25V, X7R	STD	805
6	2	C7, C11	B32914A3474	470nF	电容, 330VAC, 10%, 聚丙烯	EPCOS	通孔
7	2	C8, C26	B43041A5157M	150 μ F	电容, 铝, 电解	EPCOS	通孔
8	2	C10, C14		2.2 μ F	电容, SMD, 陶瓷, 25V, X7R	STD	1206
9	1	C12	B32914A3105K	1 μ F	电容, 330V _{AC} , 10%, 聚丙烯	Epcos	通孔
10	1	C15	PHE840MB6100MB05R17	0.1 μ F	电容, X型, 10%, 聚丙烯	KEMET	通孔
11	2	C16, C18	CS85-B2GA471KYNS	470pF	电容, 陶瓷, 250V _{AC} , 10%, Y5P,	TDK Corporation	通孔
12	1	C17		2.7nF	电容, SMD, 陶瓷, 25V, X7R	STD	805
13	1	C19		0.1 μ F	电容, SMD, 陶瓷, 25V, X7R	STD	805
14	1	C20		1 μ F	电容, SMD, 陶瓷, 50V, X5R	STD	805
15	1	C37		1nF	电容, SMD, 陶瓷, 25V, X7R	STD	805
16	3	D1-3	ES3J		二极管, 600V, 3A, 超快速恢复	飞兆半导体	SMC
17	2	D4, D6	S1J		二极管, 通用, 1A, 600V	飞兆半导体	SMA
18	1	D5	GBU6J		二极管, 桥式, 6A, 1000V	飞兆半导体	通孔
19	3	D7-8, D10	MBR0540		二极管, 肖特基, 40V, 500mA	飞兆半导体	SOD-123
20	1	D9	MMBZ5231B	5.1V	二极管, 齐纳, 5V, 350mW	飞兆半导体	SOT-23
21	1	F1	37421000410	10A	保险丝, 374系列, 5.08mm间距	Littlefuse	Radial
22	1	H1	7-345-2PP-BA		散热片, 薄型, T0-247	CTS	通孔
23	1	J1	1-1318301-3		连接头, 3引脚, 0.312间距	TE Connectivity	通孔
24	1	J2	1-1123724-2		连接头, 2引脚, 0.312间距	TYCO	通孔
25	5	J3-7	3103-2-00-21-00-00-08-0		测试引脚, 金, 40密尔,	密尔 (最大值)	通孔
26	1	K1	G5CA-1A DC12		继电器电源SPST-无10A 12VDC PCB	Omeron Electronics, Inc.	通孔
27	2	L1-2	750340834/NP1138-01	280 μ H	电感, 耦合	Würth	通孔
28	2	L3-4	750311795	9mH	共模扼流圈, 9mH	Würth	通孔
29	2	Q1, Q3	FDP22N50N		MOSFET, NCH, UniFET, 500V, 11.5A, 0.18 Ω	飞兆半导体	T0-220

接下页

30	2	Q2, Q4	ZXTP25020DFL		晶体管, PNP, 20V, 1.5A	Zetex	SOT-23
31	1	Q6	2N7002		MOSFET, NCH, 60V, 300mA	Philips	SOT-23
32	2	R1-2		46.4k Ω	RES, SMD, 1/8W	STD	805
33	6	R3, R18, R23-24 R33-34		665k Ω	RES, SMD, 1/8W	STD	805
34	3	R4, R7-8		340k Ω	RES, SMD, 1/8W	STD	805

项目	数量	标号	器件编号	数值	说明	生产厂商	封装
35	1	R5		68.1k Ω	RES, SMD, 1/8W	STD	805
36	1	R6		60.4k Ω	RES, SMD, 1/8W	STD	805
37	1	R9		422k Ω	RES, SMD, 1/8W	STD	805
38	2	R10, R20		47.5 Ω	RES, SMD, 1/8W	STD	805
39	2	R11-12		12 Ω	RES, SMD, 1/8W	STD	805
40	2	R13-14		0.033 Ω	RES, SMD, 1W	STD	2512
41	1	R15	B57237S0330M000	33 Ω	热敏电阻	Epcos Inc.	通孔
42	3	R16, R26, R40		0 Ω	RES, SMD, 1/2W	STD	2010
43	1	R17		45.3k Ω	RES, SMD, 1/8W	STD	805
44	1	R19		15.4k Ω	RES, SMD, 1/8W	STD	805
45	2	R21-22		10k Ω	RES, SMD, 1/8W	STD	805
46	1	R25		24.9k Ω	RES, SMD, 1/4W	STD	1206
47	2	R27-28		1.24M Ω	RES, SMD, 1/8W	STD	805
48	3	R29, R35-36		1.2k Ω	RES, SMD, 1/8W	STD	805
49	1	R30		23.7k Ω	RES, SMD, 1/4W	STD	1206
50	1	R31		7.68k Ω	RES, SMD, 1/8W	STD	805
51	1	R32		150k Ω	RES, SMD, 1/4W	STD	1206
52	1	R37		1k Ω	RES, SMD, 1/8W	STD	805
53	1	R38		0 Ω	RES, SMD, 1/4W	STD	1206
54	1	R39		0 Ω	RES, SMD, 1/8W	STD	805
55	2	R65-66		DNP	RES, SMD, 1/10W	STD	603
56	1	U1	FAN9611		交错式双BMC PFC控制器	飞兆半导体	S01C-16
57	1	U2	LM393M		双通道差分比较器	飞兆半导体	S01C-8
58	2	SC1, SC2	PMSSS 440 0050 PH		SCREW MACHINE PHIL 4-40X1/2 SS	STD	硬件
59	2	W1, W2	INT LWZ 004		WASHER LOCK INT T00TH #4 ZINC	STD	硬件
60	2	N1, N2	HNZ440		NUT HEX 4-40 ZINC PLATED	STD	硬件
61	1	PWB			4层, FR4, FAN9611薄型PWB - 修订版 1.0	飞兆半导体	PCB

注:

1. DNP = 不安装
2. STD = 标准组件

9. 浪涌电流限制

评估板集成浪涌电流限制电路，该电路由图14中高亮显示的元器件组成。

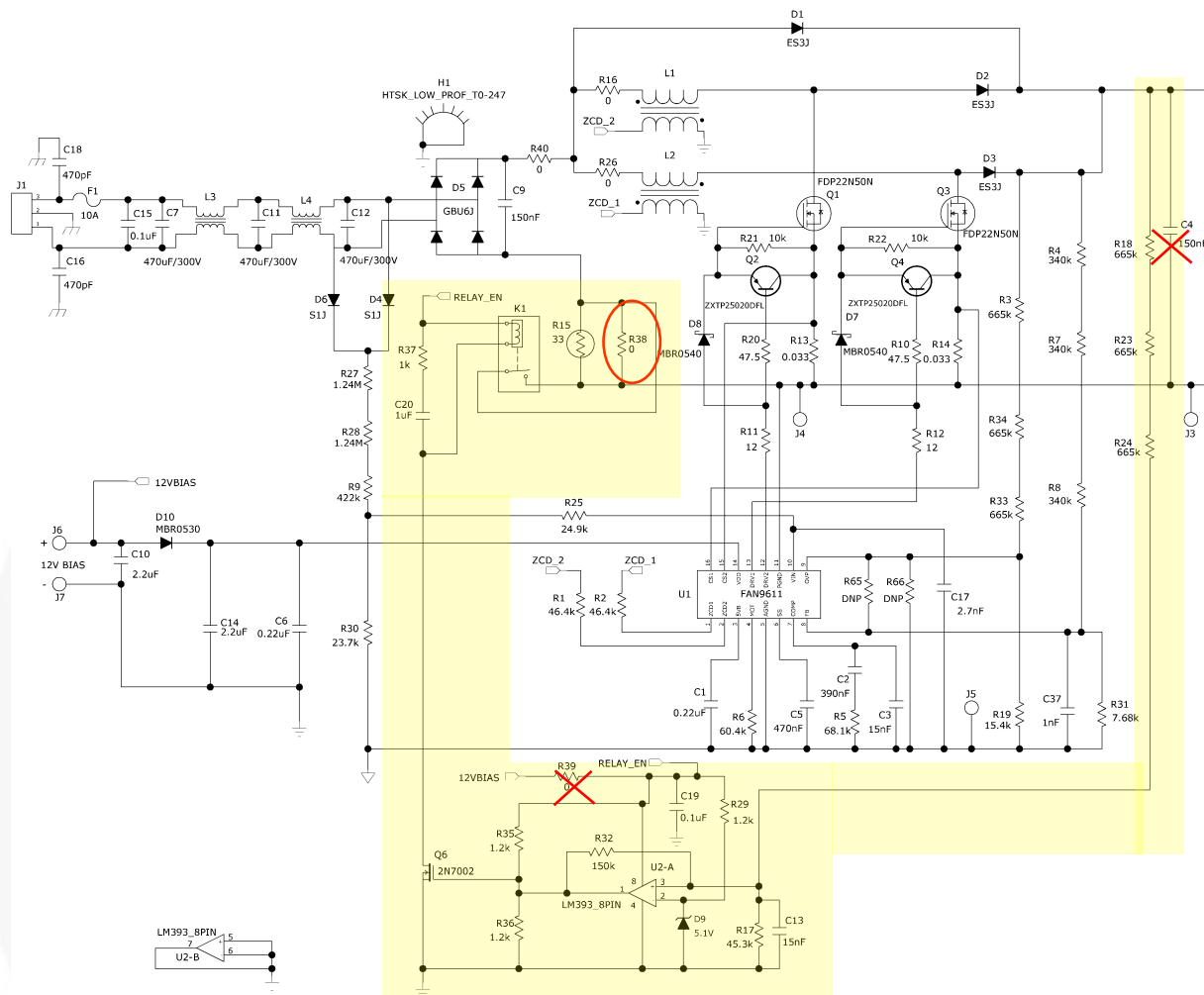


图 14. 浪涌电流限制电路

由于浪涌电流限制电路会对轻负载效率产生负面影响，并且并非所有离线应用都需使用，因此尽管评估板完全安装配置了浪涌电路，但默认禁用该电路，如图14所示。R18和R39安装在PCB上，且有意开路。如需使能并测试浪涌电流限制电路，可旋转R18和R39以完成正确的串联连接，如原理图所示。移除R38，以便允许33Ω

NTC热敏电阻 (R15) 在启动期间限制浪涌电流。移除R16、0Ω跳线并安装导线环路，然后连接R16

PCB焊盘位置处的通孔，即可测量输入电流。随后，电流探针便可连接导线环路。浪涌电流限制功能的效率如下文的15图中所示。

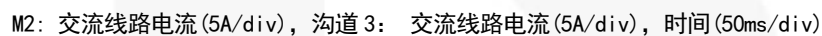


表4. 浪涌电流限制电路效率比较

输入线路电压	输出功率	峰值线路电流 (浪涌电路禁用)	峰值线路电流 (浪涌电路使能)	%浪涌电流 下降
$V_{IN}=115V_{AC}$	300W	22.50A _{PK}	8.45A _{PK}	62.40%
$V_{IN}=230V_{AC}$	300W	26.9A _{PK}	11.5A _{PK}	57.3%

10. 测试结果

10.1. 启动

图16和图17分别显示线路电压为115V_{AC}时空载和满载条件下的启动运行。由于是闭环软启动，空载启动和满载启动时几乎观察不到过冲。

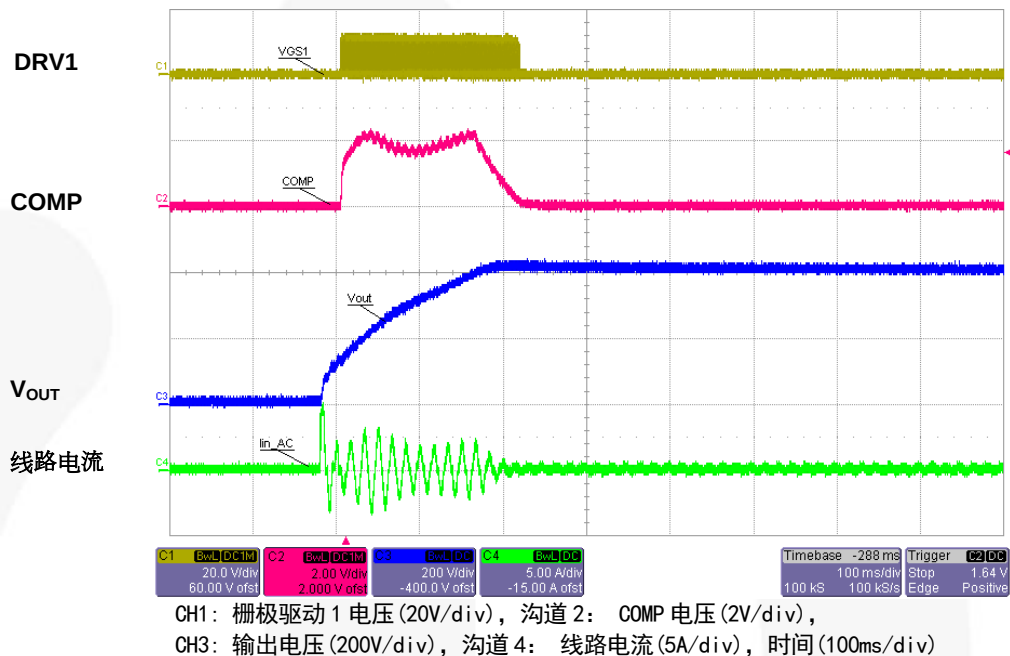


图 16. 115V_{AC}时的空载启动

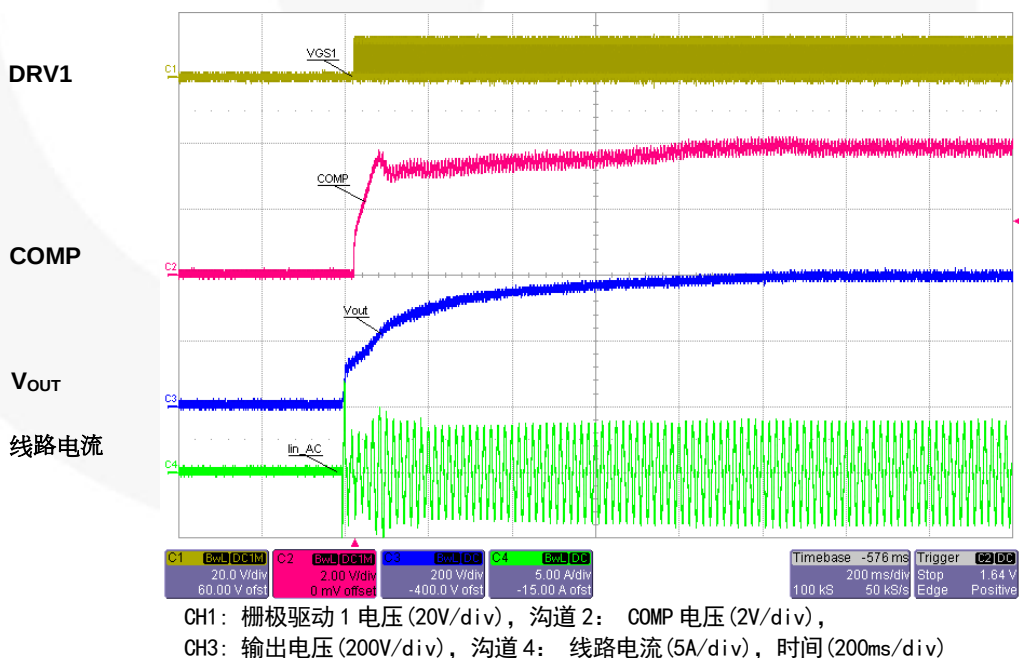


图 17. 115V_{AC}时的满载启动

图18和图19分别显示线路电压为230V_{AC}时空载和满载条件下的启动运行。由于是闭环软启动，空载启动和满载启动时几乎观察不到过冲。

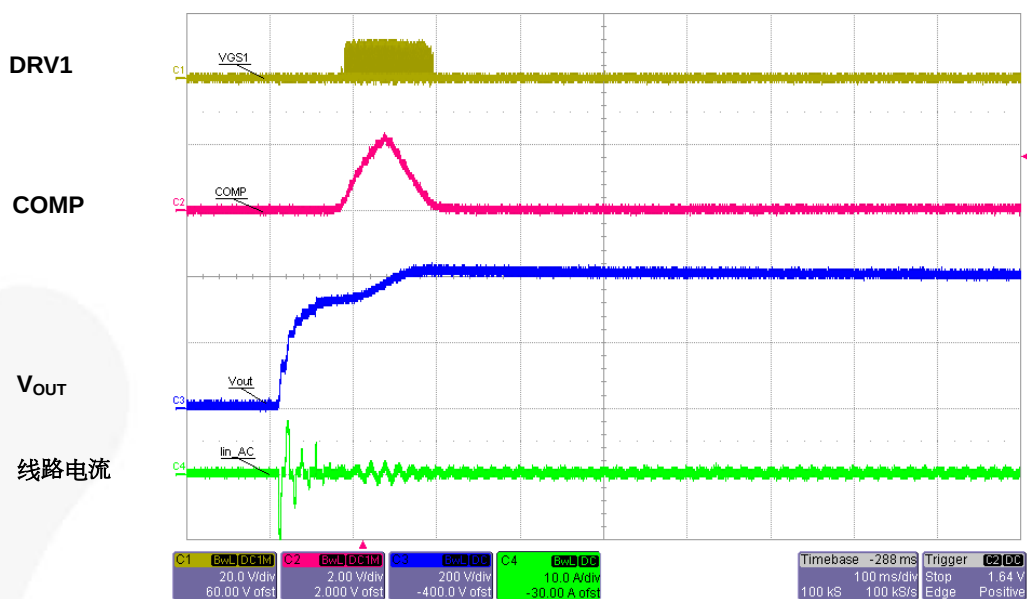


图 18. 230V_{AC}时的空载启动

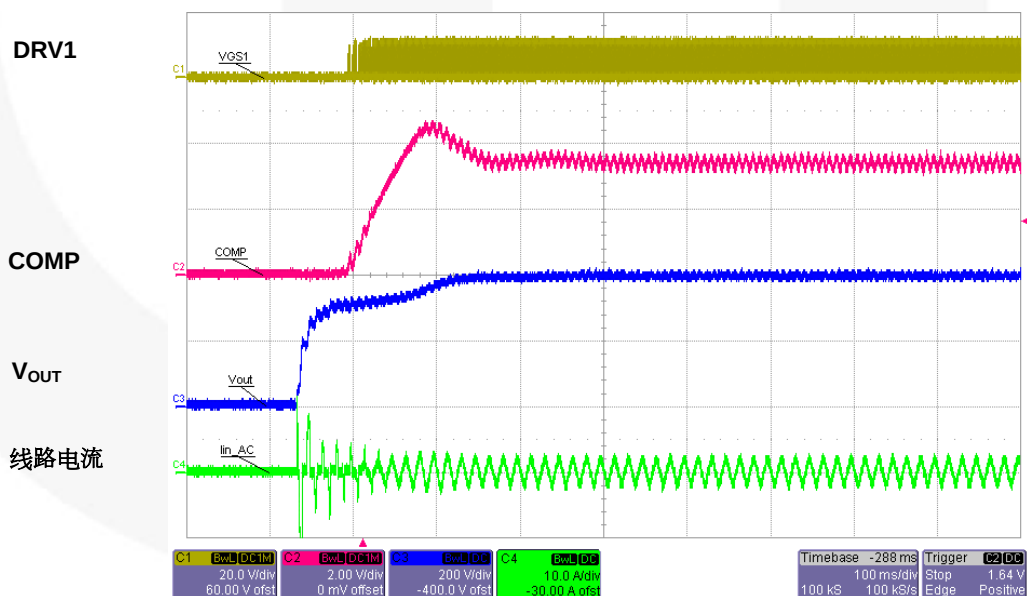


图 19. 230V_{AC}时的满载启动

10.2. 稳态工作

图20和图21分别显示线路电压为 $90V_{AC}$ 和 $230V_{AC}$ 时以及满载条件下两个电感的电流及两者之和。这两个电感的电流相加后，纹波电流相对较小，这是因为交错工作时纹波相消。

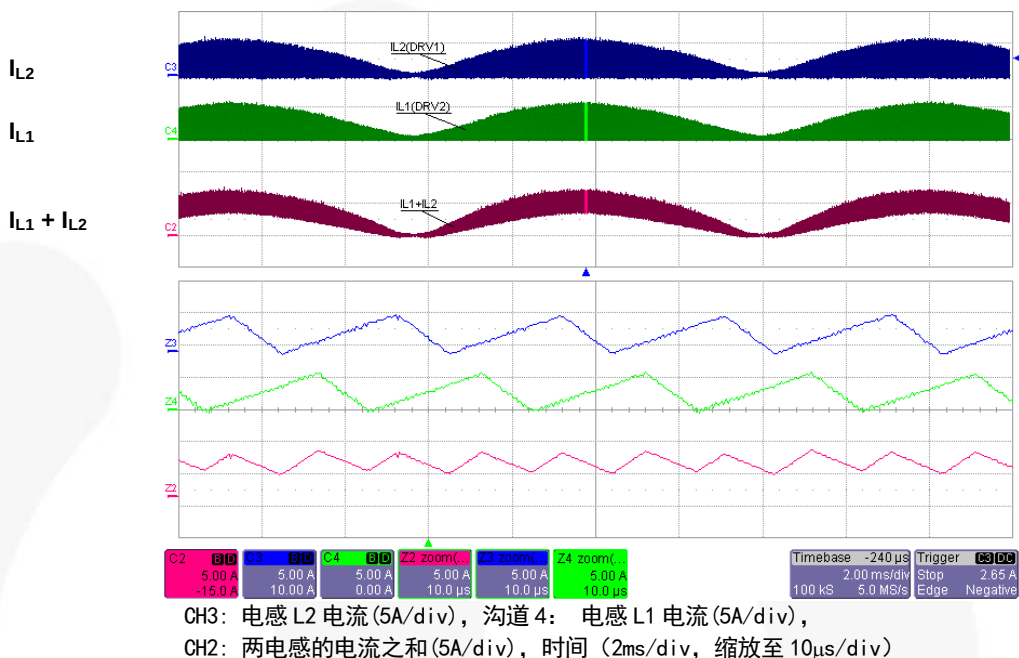


图 20. 满载和 $90V_{AC}$ 时的电感电流波形缩放

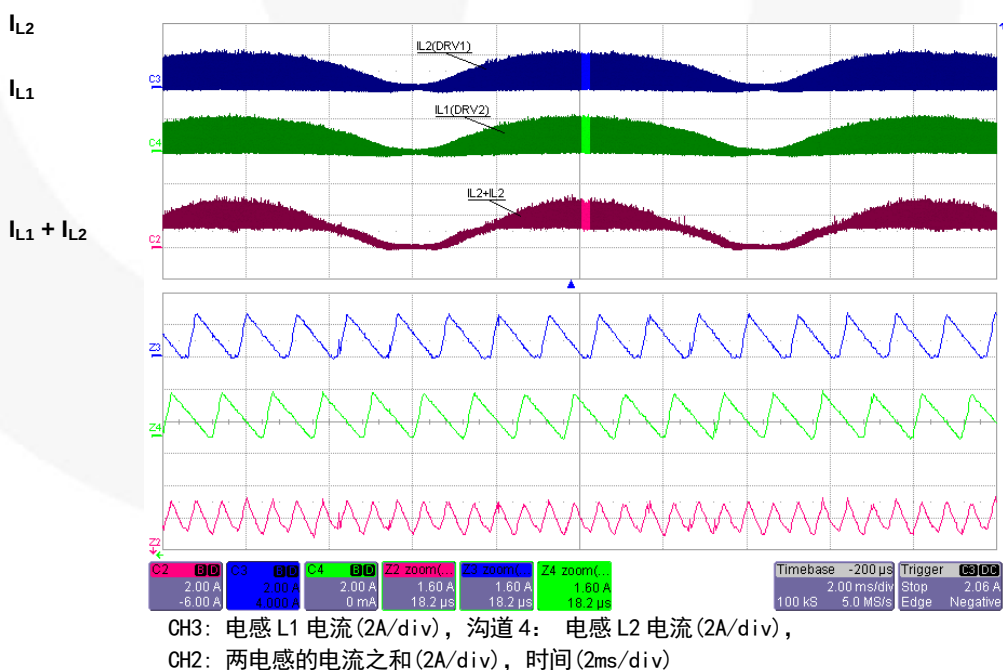


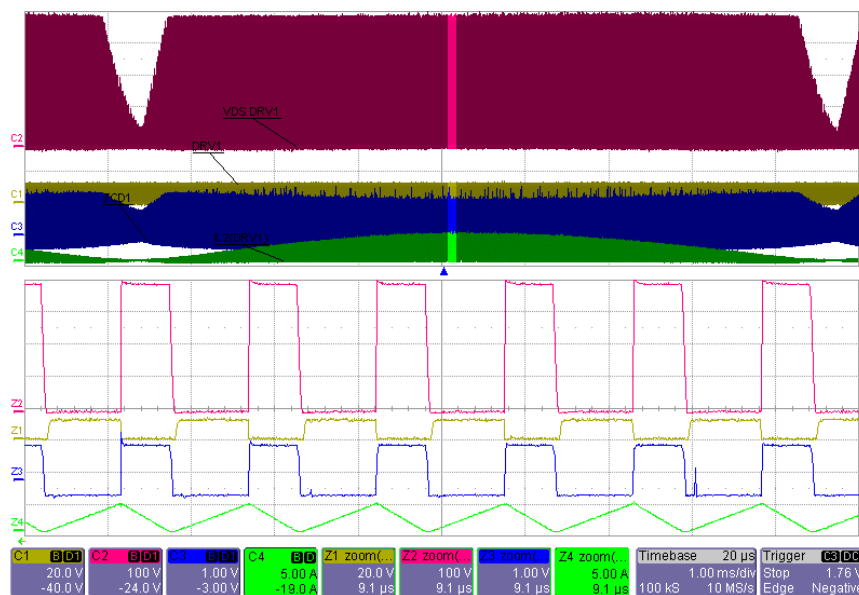
图 21. 满载和 $230V_{AC}$ 时的电感电流波形缩放

$V_{DS}(Q3)$

DRV1

ZCD1

I_{L2}



CH1: DRV1 (20V/div), CH2: VDS (Q3) (100V/div)

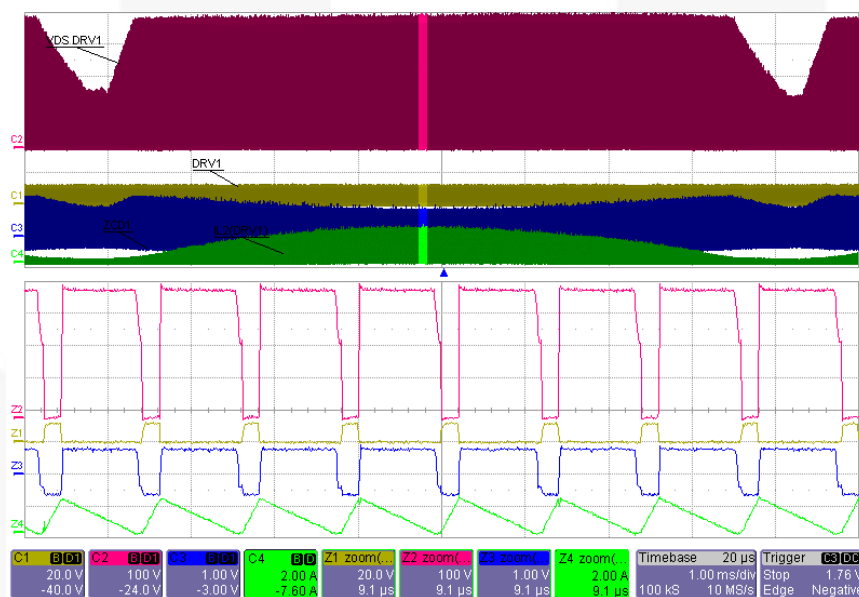
CH3: ZCD1 (1V/div), CH4: 电感 L2 电流 (5A/div)

图 22. 满载、115V_{ao}时的零电平谷底开关

$V_{DS}(Q3)$

DRV1

ZCD1



CH1: DRV1 (20V/div), CH2: VDS (Q3) (100V/div)

CH3: ZCD1 (1V/div), CH4: 电感 L2 电流 (5A/div)

图 23. 满载、230V_{ao}时的零电平谷底开关

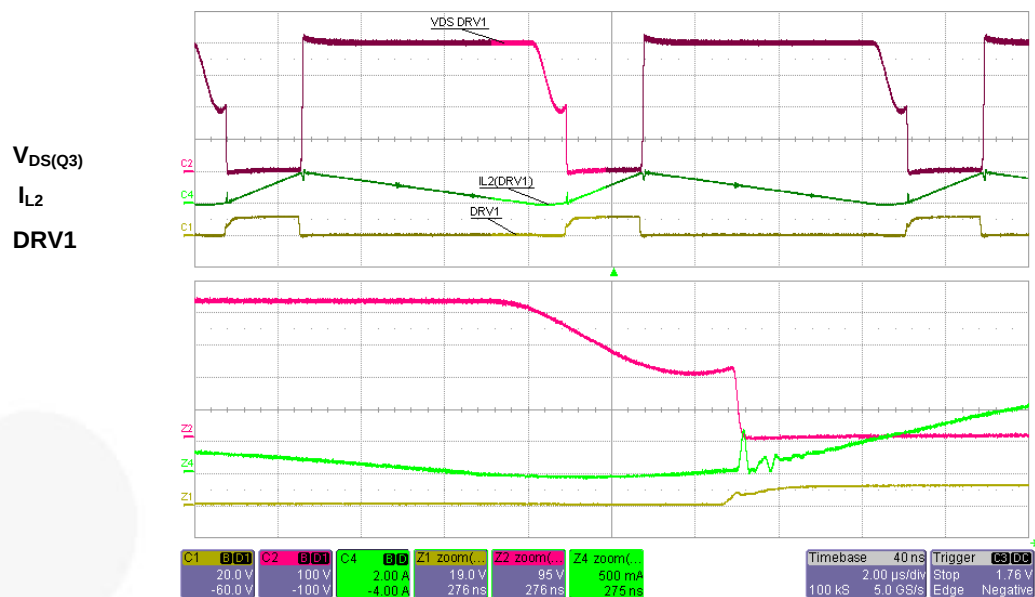


图 24。满载、230V_{ac}时的谷底开关缩放

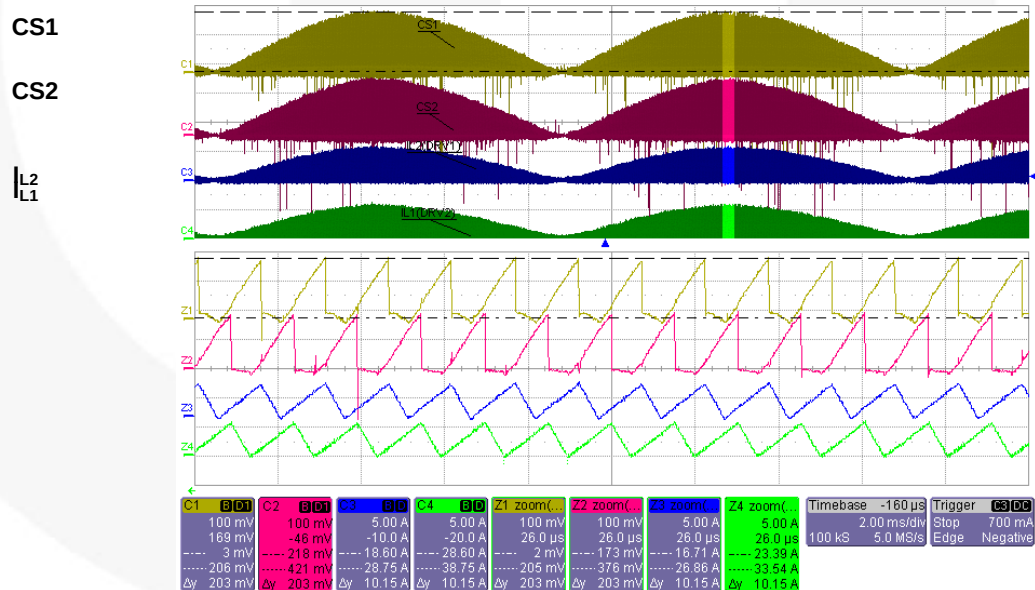
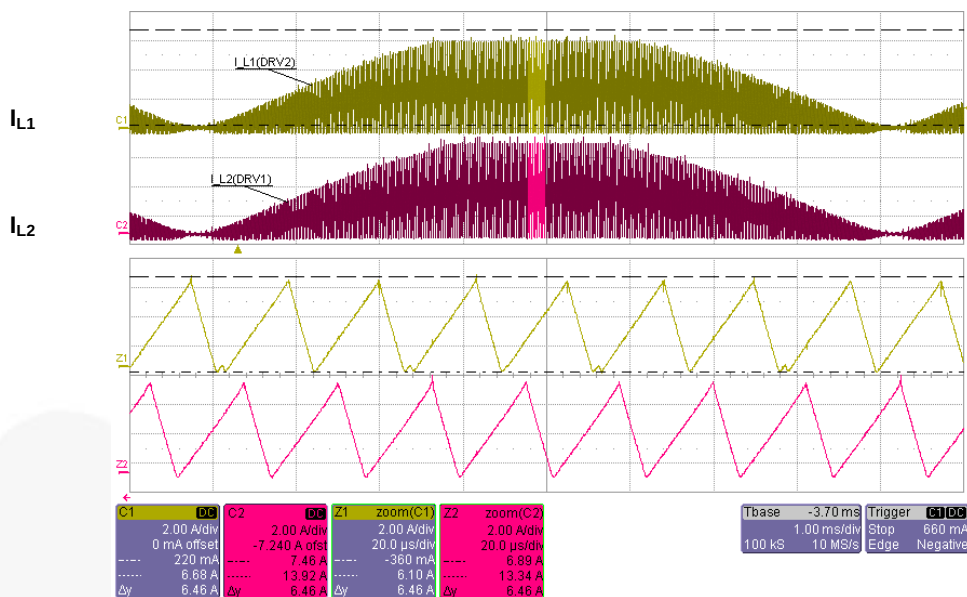
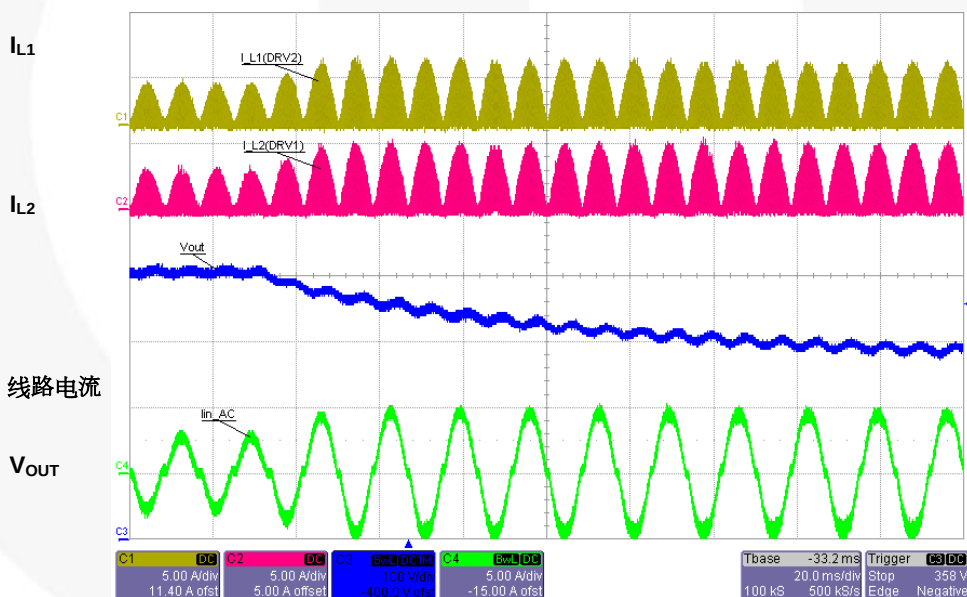


图 25。满载、90V_{ac}时的电流感测波形



CH1: 电感 L1 电流 (2A/div), 沟道 2: 电感 L2 电流 (2A/div)

图 26. 360W、85V_{AO}、过流工作条件下的电感电流波形

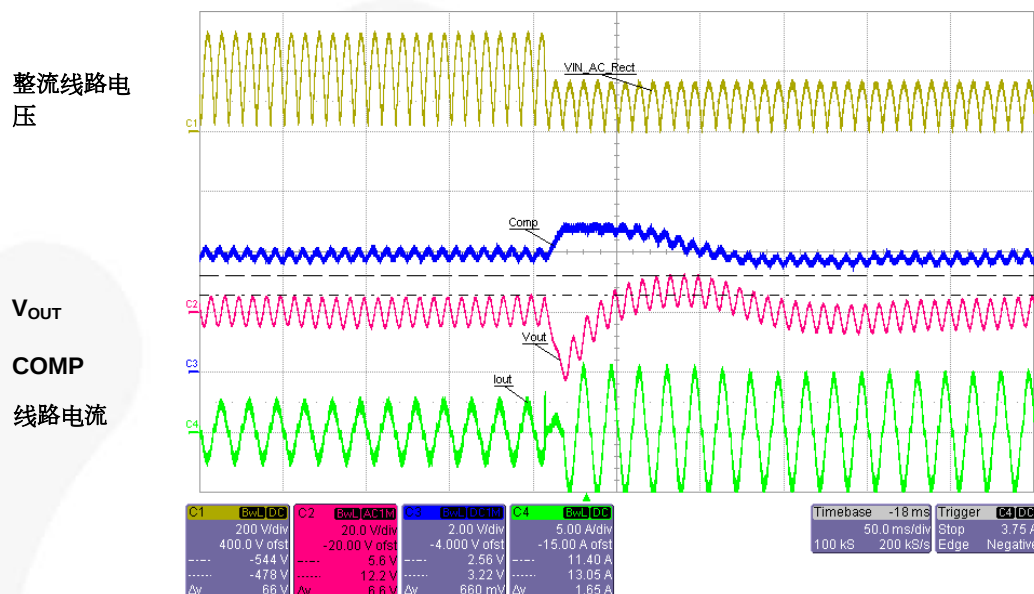


CH1: 电感 L1 电流 (5A/div), 沟道 2: 电感 L2 电流 (5A/div)
CH3: 输出电压 (100V/div), 沟道 4: 线路电流 (5A/div), 时间 (20ms/div)

图 27. MOT 功率限制, 0.5A 至 1.3A 负载瞬变, 115V_{AO}

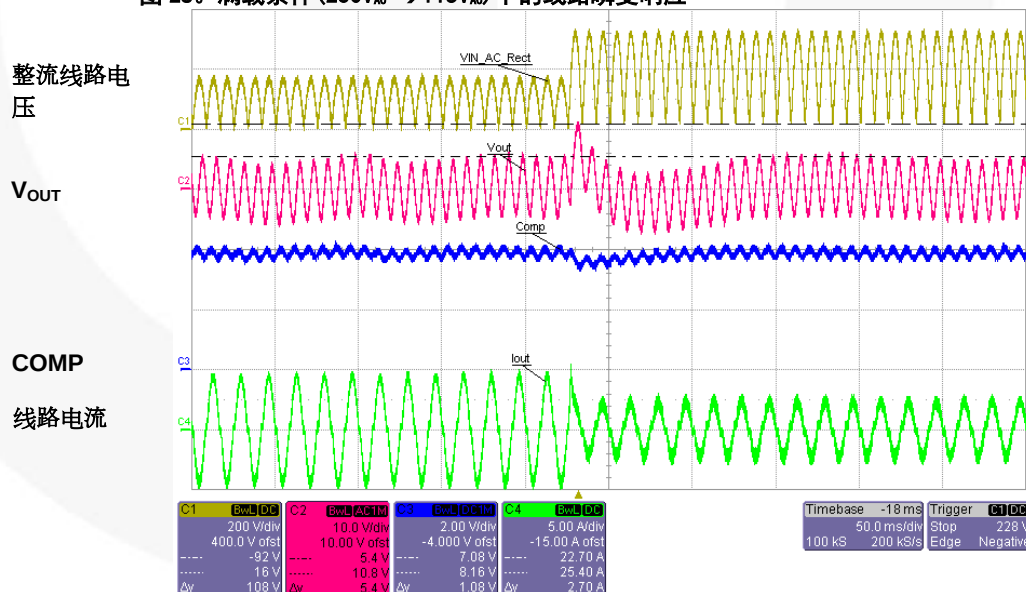
10.3. 线路瞬变

图28和图29显示的是线路瞬变操作以及线路前馈功能对输出电压的最小效应。线路电压从230V_{AC}变为115V_{AC}时，可观察到20V（标称输出电压的5%）左右的电压欠冲。线路电压从115V_{AC}变为230V_{AC}时，可观察到6V（标称输出电压的1.5%）左右的电压过冲。



CH1: 整流线路电压 (200V/div), 沟道 2: 输出电压 (20V/div, 交流),
沟道 3: COMP 电压 (2V/div), 沟道 4: 线路电流 (5A/div), 时间 (50ms/div)

图 28. 满载条件 (230V_{AC} → 115V_{AC}) 下的线路瞬变响应

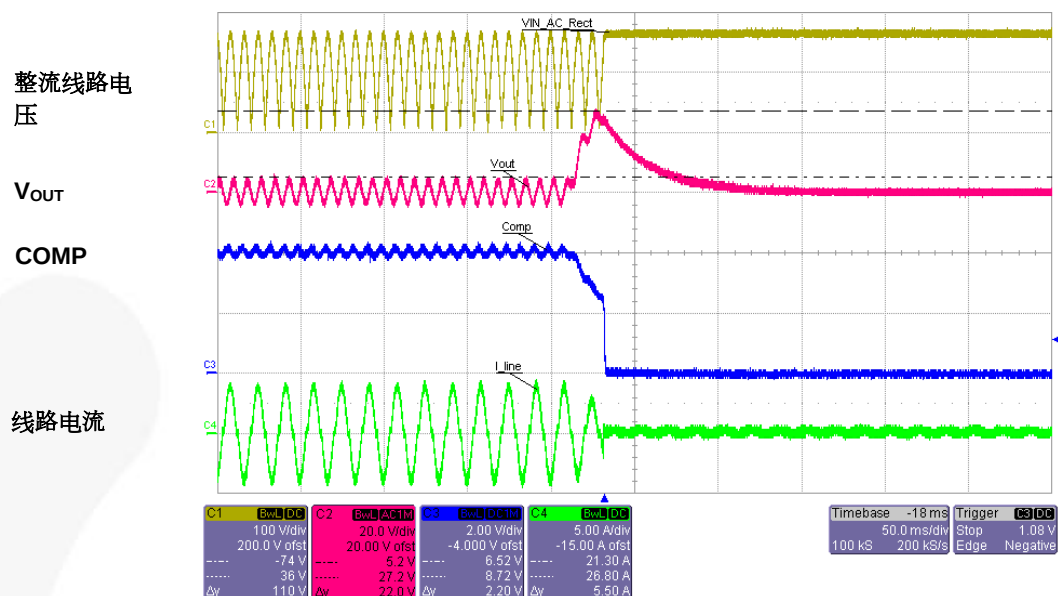


CH1: 整流线路电压 (200V/div), 沟道 2: 输出电压 (10V/div, 交流),
沟道 3: COMP 电压 (2V/div), 沟道 4: 线路电流 (5A/div), 时间 (50ms/div)

图 29. 满载条件 (115V_{AC} → 230V_{AC}) 下的线路瞬变响应

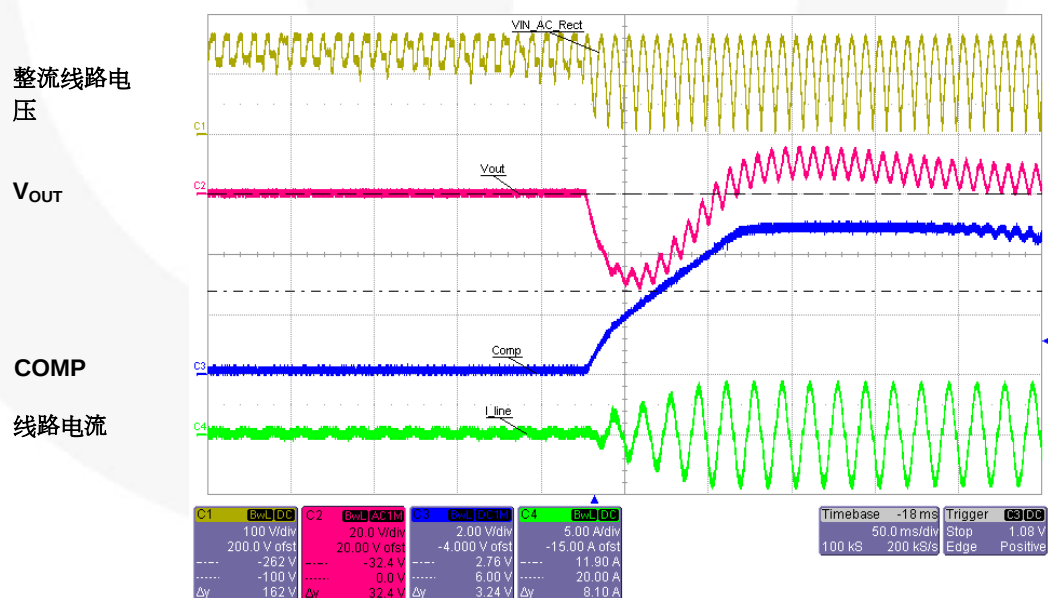
10.4. 负载瞬变

图30和图31显示的是负载瞬变操作。输出负载从100%变为0%时，可观察到20V（标称输出电压的5%）的过冲。输出负载从0%变为100%时，可观察到34V（标称输出电压的8.5%）的欠冲。



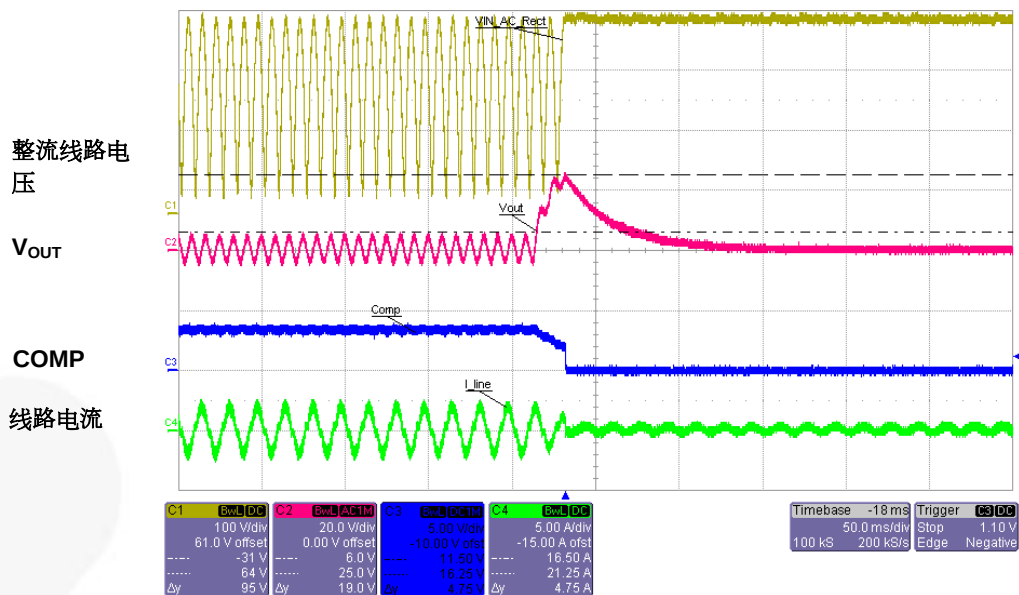
CH1: 整流线路电压(100V/div), 沟道 2: 输出电压 (20V/div, 交流),
CH3: COMP 电压(2V/div), 沟道 4: 线路电流 (5A/div), 时间 (50ms/div)

图 30。115V_{ac} (满载 → 空载) 时的负载瞬变响应



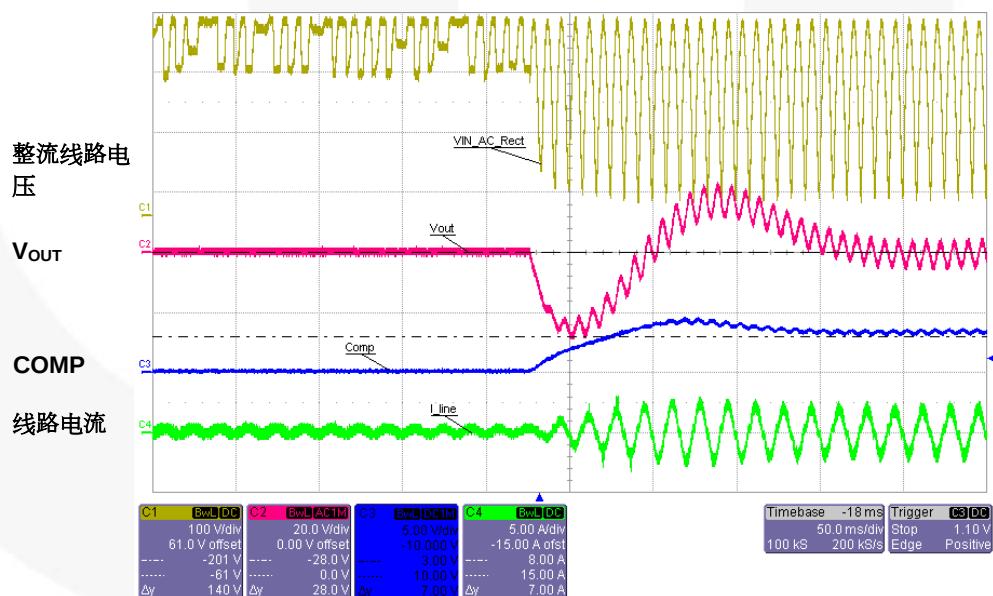
CH1: 整流线路电压(100V/div), 沟道 2: 输出电压 (20V/div, 交流),
CH3: COMP 电压(2V/div), 沟道 4: 线路电流 (5A/div), 时间 (50ms/div)

图 31。115V_{ac} (空载 → 满载) 时的负载瞬变响应



CH1: 整流线路电压(100V/div), 沟道 2: 输出电压 (20V/div, 交流),
CH3: COMP 电压(5V/div), 沟道 4: 线路电流 (5A/div), 时间 (50ms/div)

图 32. 230V_{AC} (满载 → 空载) 时的负载瞬变响应



CH1: 整流线路电压(100V/div), 沟道 2: 输出电压 (20V/div, 交流),
CH3: COMP 电压(5V/div), 沟道 4: 线路电流 (5A/div), 时间 (50ms/div)

图 33. 230V_{AC} (空载 → 满载) 时的负载瞬变响应

10.5. 掉电保护

图34显示的是线路电压缓慢增大时的启动运行 线路电压达到约90V_{AC}图35时，电源开启。显示的是线路电压缓慢减小时的关断运行 线路电压达到约80V_{AC}时，电源关断。

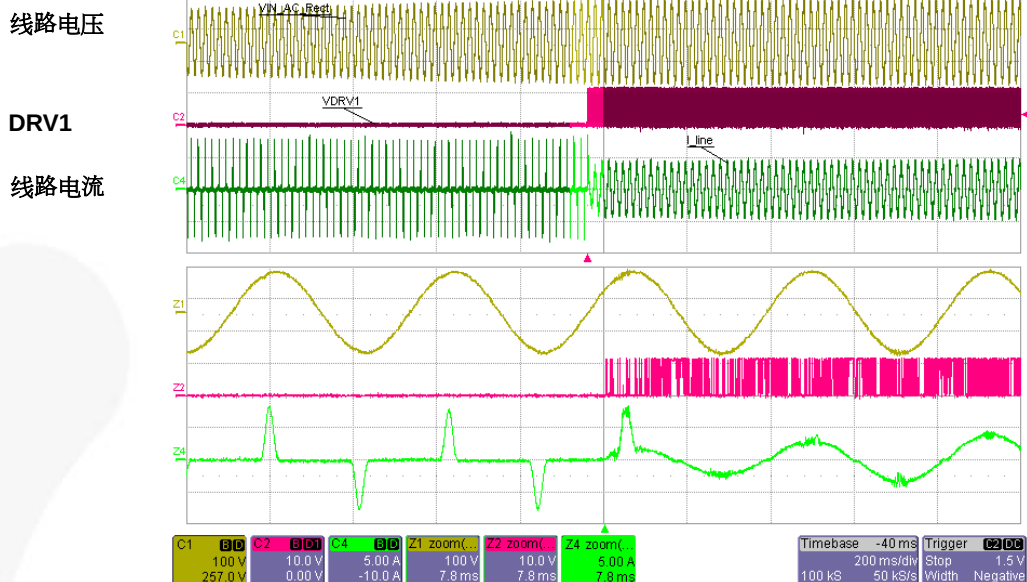


图 34. 缓慢增大线路电压的情况下启动

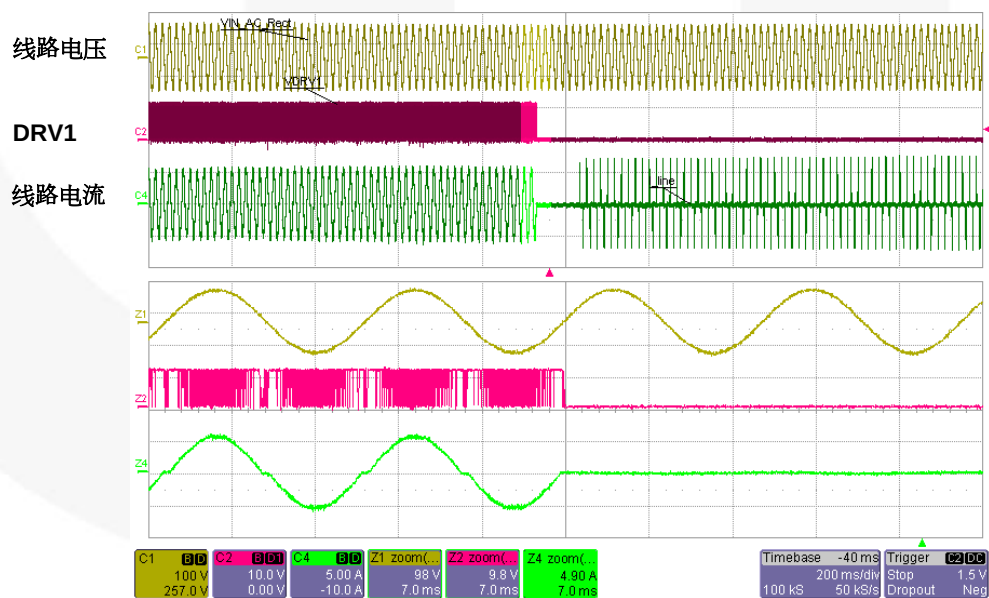
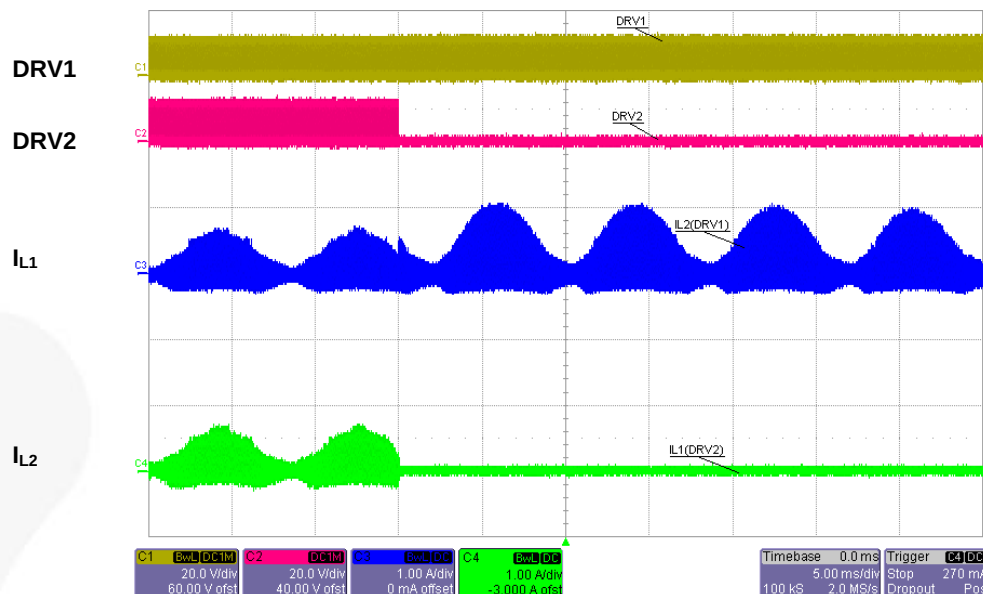


图 35. 缓慢减小线路电压的情况下关断

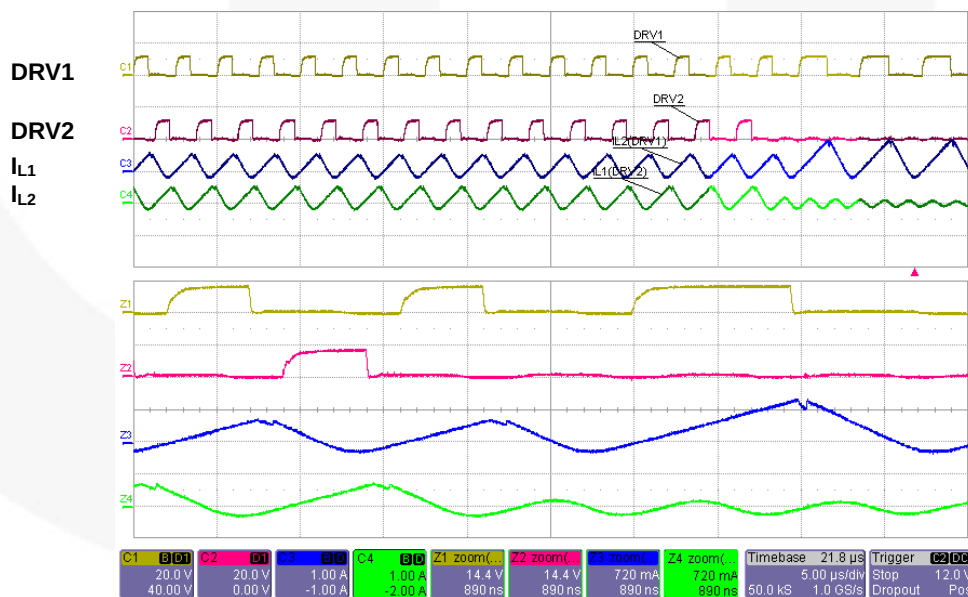
10. 6. 相位管理

图36和图37显示的是切相波形。如图所示，沟道1栅极驱动信号的占空比在通道2栅极驱动信号禁用时倍增，实现最少的线路电流干扰并确保平滑瞬变。



CH1: 栅极驱动 1 电压 (20V/div), 沟道 2: 栅极驱动 2 电压 (20V/div),
沟道 3: 电感 L1 电流 (1A/div), 沟道 4: 电感 L2 电流 (1A/div), 时间 (5ms/div)

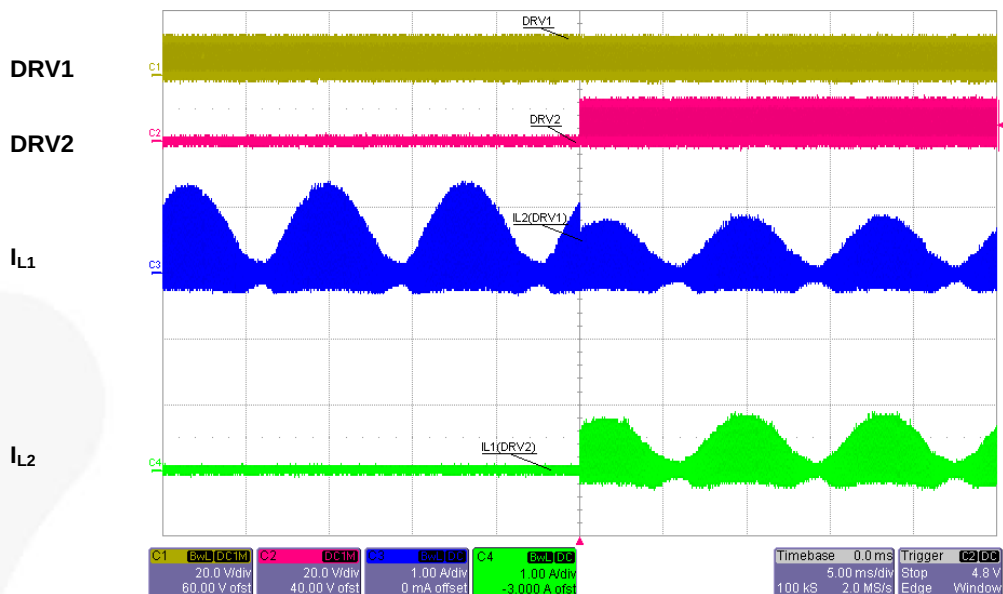
图 36. 切相操作



CH1: 栅极驱动 1 电压 (20V/div), 沟道 2: 栅极驱动 2 电压 (20V/div),
沟道 3: 电感 L1 电流 (1A/div), 沟道 4: 电感 L2 电流 (1A/div), 时间 (5μs/div)

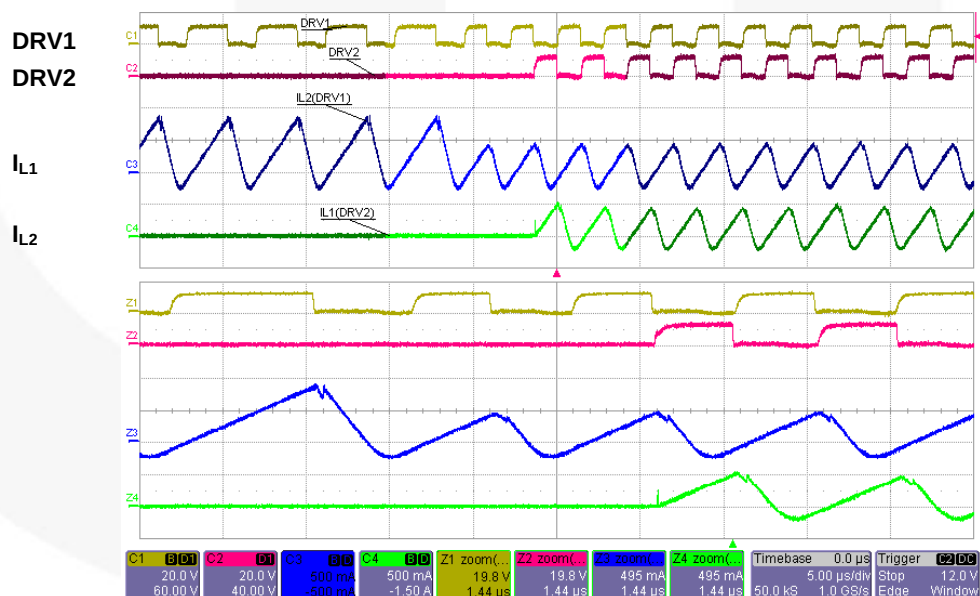
图 37. 切相操作 (时间线放大)

图38和图39显示的是相位叠加波形。如图所示，沟道1栅极驱动信号的占空比在通道2栅极驱动信号使能前减半，实现最少的线路电流干扰并确保平滑瞬变。在图39中，相位叠加操作时，略过栅极驱动2的第一个脉冲，确保瞬变时的180° 异相交错工作。



CH1: 栅极驱动 1 电压 (20V/div), 沟道 2: 栅极驱动 2 电压 (20V/div),
沟道 3: 电感 L1 电流 (1A/div), 沟道 4: 电感 L2 电流 (1A/div), 时间 (5ms/div)

图 38. 相位叠加操作



CH1: 栅极驱动 1 电压 (20V/div), 沟道 2: 栅极驱动 2 电压 (20V/div),
沟道 3: 电感 L1 电流 (1A/div), 沟道 4: 电感 L2 电流 (1A/div), 时间 (5µs/div)

图 39. 相位叠加操作 (时间线放大)

10.7. 效率

图40和41图显示 $R_{MOT}=60.4k\Omega$ 时（输入电压为 $115V_{AC}$ 和 $230V_{AC}$ ），测得的300W评估板的效率。测试评估板上的相位管理阈值约为标称输出功率的15%。增大MOT电阻可以上调阈值，获得更加理想的效率曲线。42图和43图显示的是通过将MOT电阻增大到 $120k\Omega$ 使阈值调节到30%从而实现轻负载效率的提高。

由于切相通过有效降低轻负载时的开关频率减少开关损耗，因此在开关损耗较高的 $230V_{AC}$ 线路上，效率能提高更多。 $115V_{AC}$ 线路上的效率相对提高较少，这是因为MOSFET以零电压开启，开关损耗忽略不计。效率测量包括EMI滤波器损耗、电缆损耗以及控制IC的功耗。

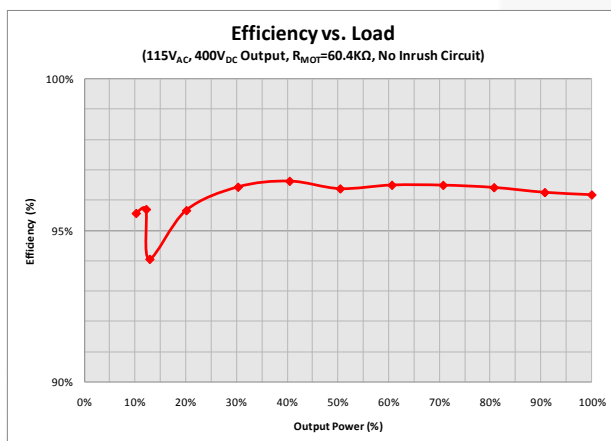
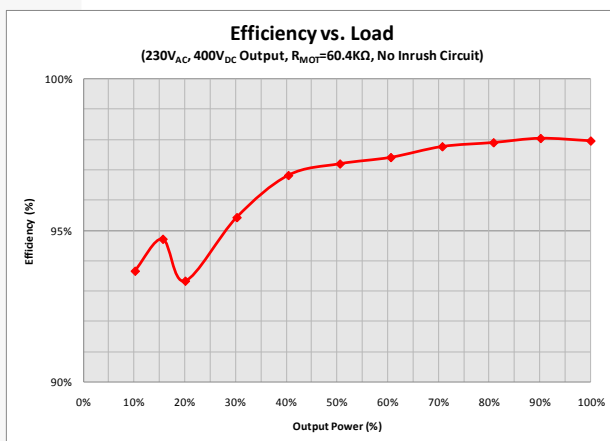
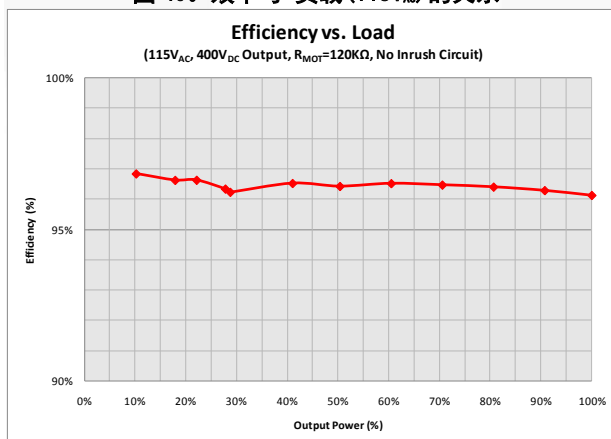


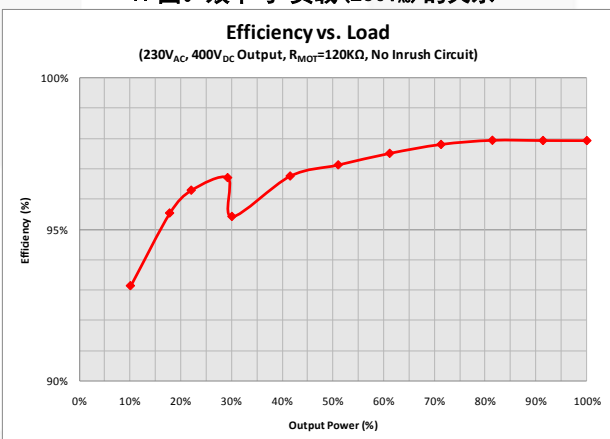
图 40. 效率与 负载 ($115V_{AC}$) 的关系



41 图. 效率与 负载 ($230V_{AC}$) 的关系

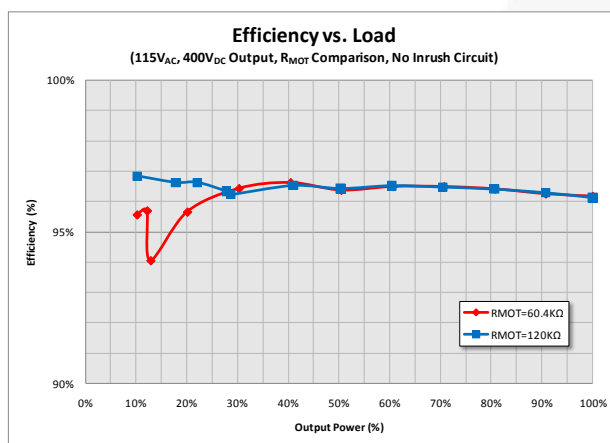


42 图. 效率与 负载 ($115V_{AC}$) 的关系

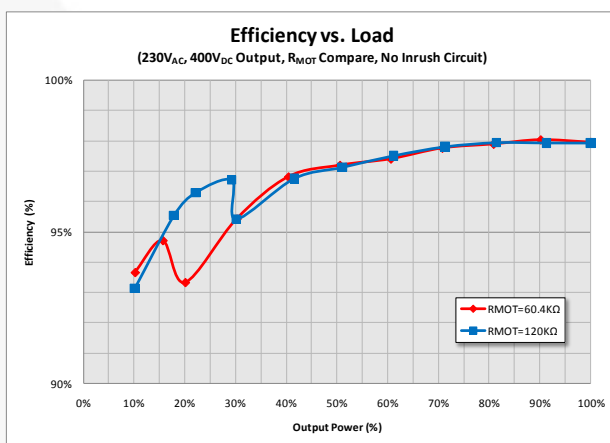


43 图. 效率与 负载 ($230V_{AC}$) 的关系

44 图和 45 图显示的是增加 MOT 电阻时，轻负载效率提高的直观比较。对于 $R_{MOT}=120k\Omega$ ，相位阈值从标称最大输出功率的 18%上调至大约 30%。不建议在标称最大输出功率的 50%附近调节相位阈值，因为每个独立的 BCM PFC 通道都针对处理负载所要求的总输出功率 50%（加上 20%裕量）而优化设计。



44 图。效率与 负载 (115V_{AC}) 的关系

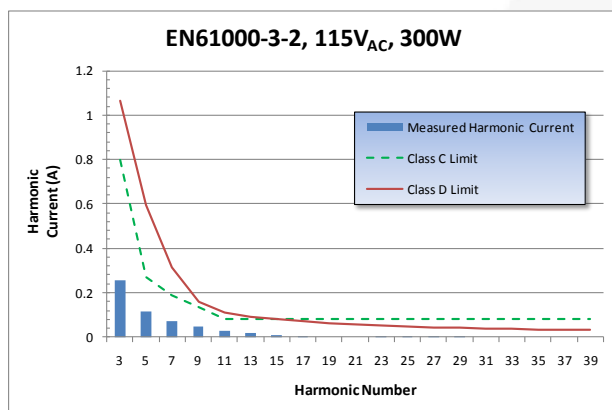


45 图。效率与 负载 (230V_{AC}) 的关系

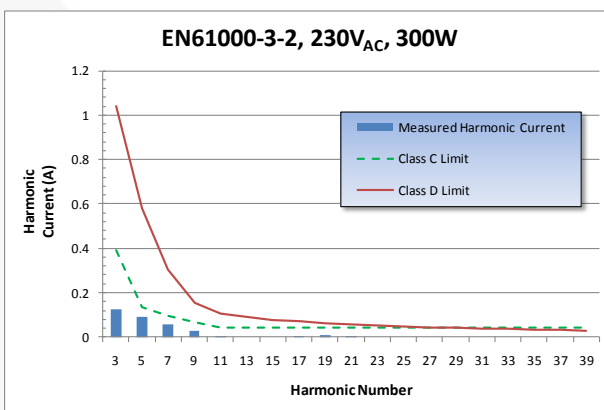
FEBFAN9611_S01U300A评估板配置有 $R_{MOT}=60.4k\Omega$ ，可将最大输出功率限值设为360W左右。由于采用高度优化的薄型横截面积设计，EFD30电感额定值并非针对每通道200W以上（总输出功率400W）而指定。MOT电阻增大到120k Ω 时，最大允许输出功率也随之增大到400W以上。为了完全保护功率级，可对FAN9611 COMP电压（引脚7）使用一个简单的分压器，并进行PNP箝位，详情参见图15中的[AN-6086](#)。

10. 8. 谐波失真和功率因数

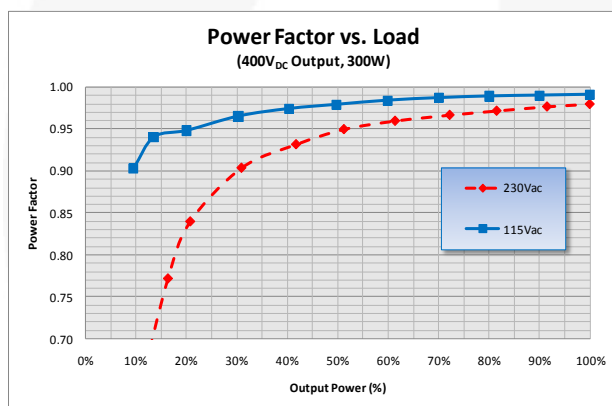
46图和47图分别采用EN61000 D类和C类规范比较输入电压为115V_{AC}和230V_{AC}时测得的谐波电流。D类适用于电视机和PC电源，C类适用于照明应用。从图中可以看出，两种规范均得到了满足，且裕量足够。



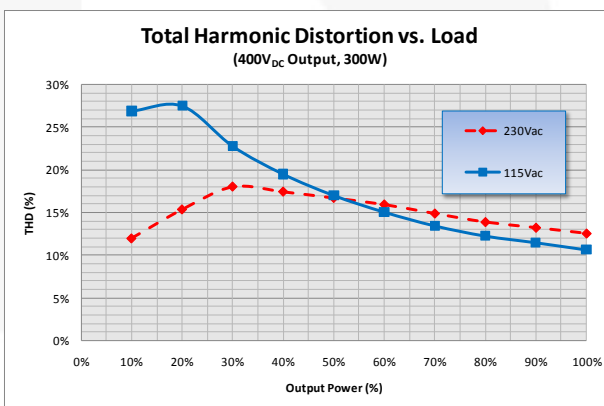
46 图。谐波电流，115V_{AC}



47 图。谐波电流，230V_{AC}



48 图。测得的功率因数



49 图。测得的总谐波失真

48图显示的是输入电压为115V_{AC}和230V_{AC}时测得的功率因数。从图中可以看出，高于0.95的高功率因数可在100%至50%负载处得到。49图显示的是输入电压为115V_{AC}和230V_{AC}时测得的总谐波失真。

10.9. EMI

EN55022 CISPR, B类

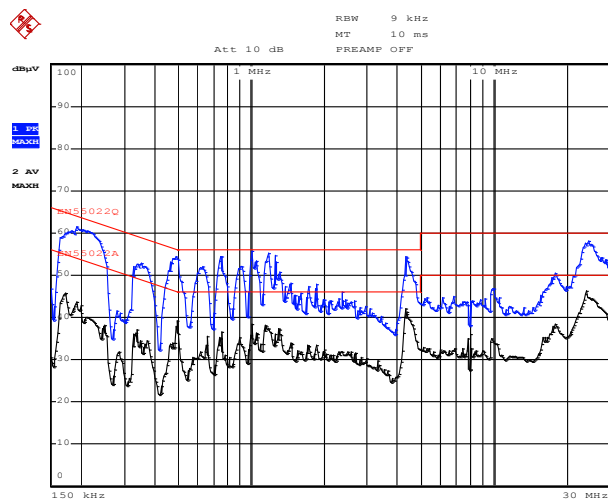


图 50. 115V_{AC}, 线路

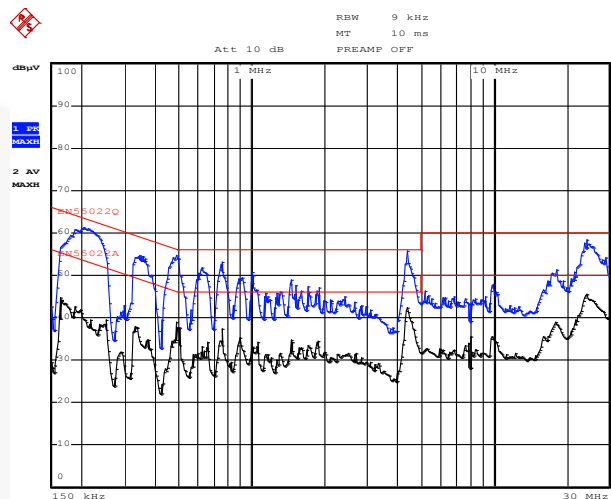


图 51. 115V_{AC}, 零线

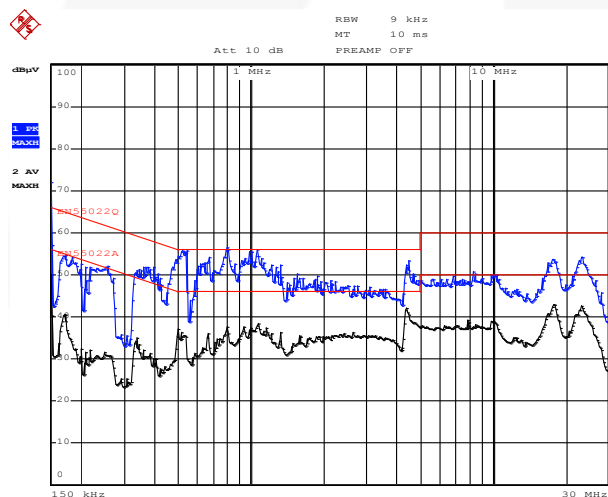


图 52. 230V_{AC}, 线路

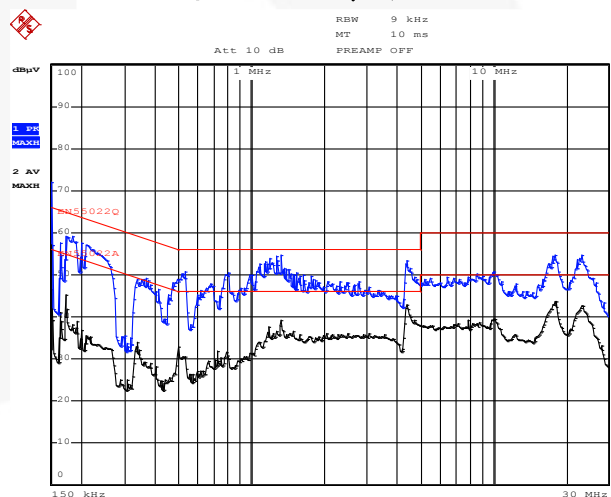


图 53. 230V_{AC}, 零线

11. 参考文献

- [1] [FAN9611 / FAN9612 — 交错式双 BCM PFC 控制器](#)
- [2] [AN-6086 – 采用 FAN9611 / FAN9612 的交错式临界导通模式 PFC 的设计依据](#)

12. 订购信息

可订购部件编号	说明
FEBFAN9611_S01U300A	FAN9611 300W评估板

13. 修订记录

日期	修订版	说明
2012 年 2 月	0.0.1	初始版

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