

如何拥有系统化开发能力（第一部分）

课程回放：

请微信扫描二维码，
获取课程观看链接



AHEAD OF WHAT'S POSSIBLE™

ADI 智库

一站式电子技术宝库

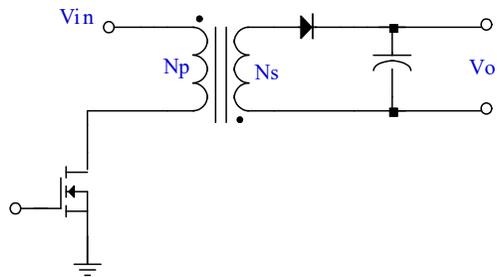
第一讲：板级中等 功率隔离电源设计



微信扫描二维码
获取课程观看链接

隔离电源两大类

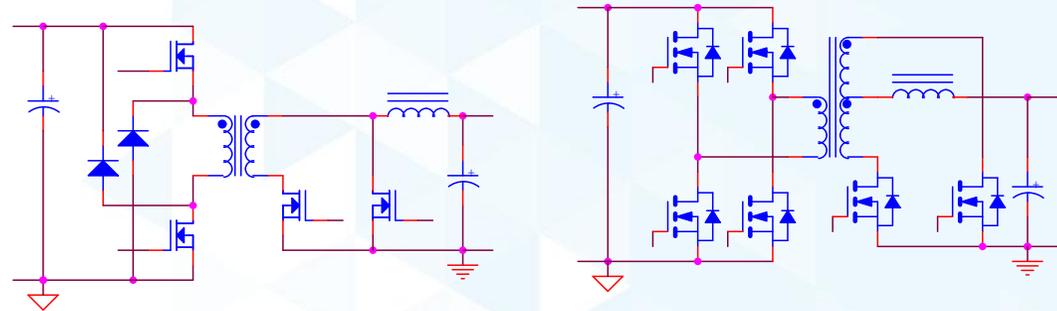
反激类 (开关开
通存储能量)



反激变换器

简单
低成本
高电压电流应力
小功率

正激类 (开关开
通传递能量)

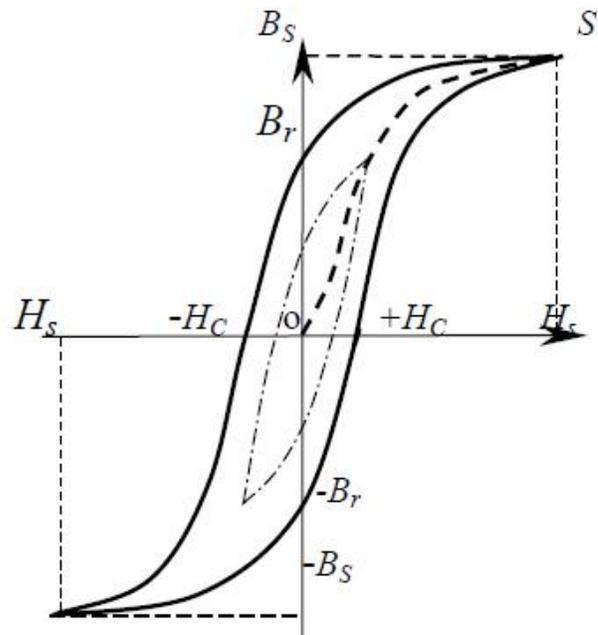


双管正激变换器

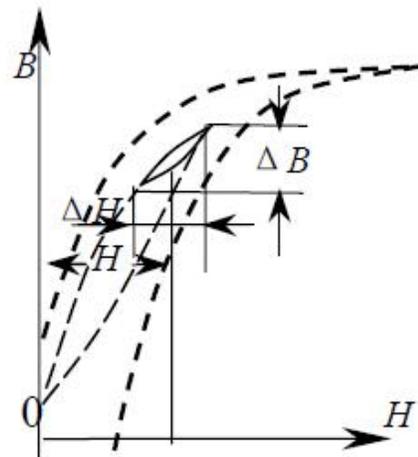
全桥变换器

复杂
高成本
低电压电流应力
中大功率

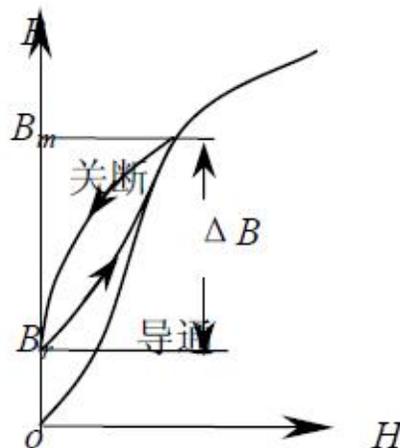
变压器磁芯工作状态



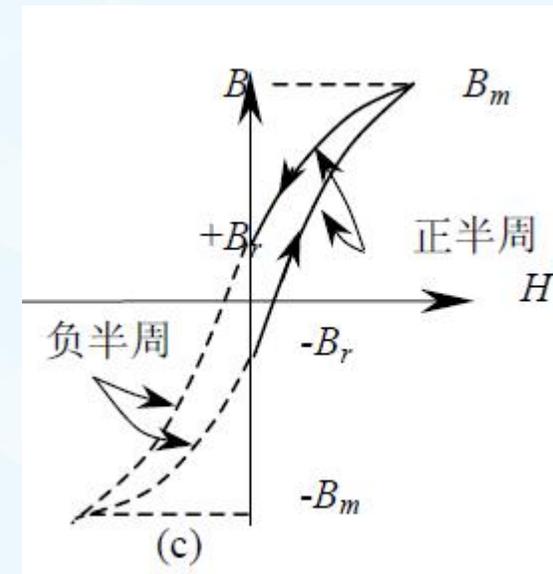
磁芯的磁滞回线



反激变换器

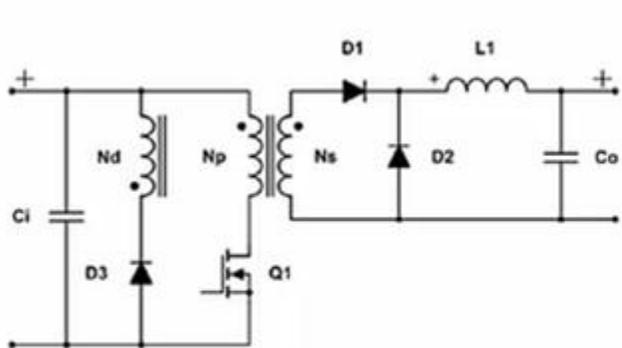


正激变换器

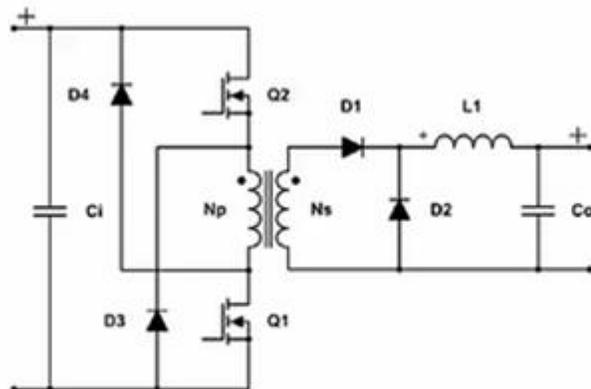


桥式变换器

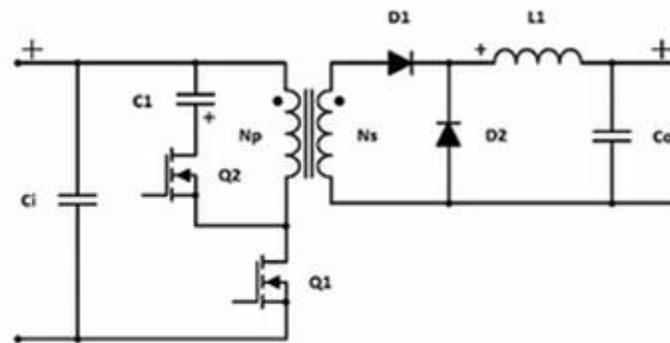
正激变换器种类



单管正激



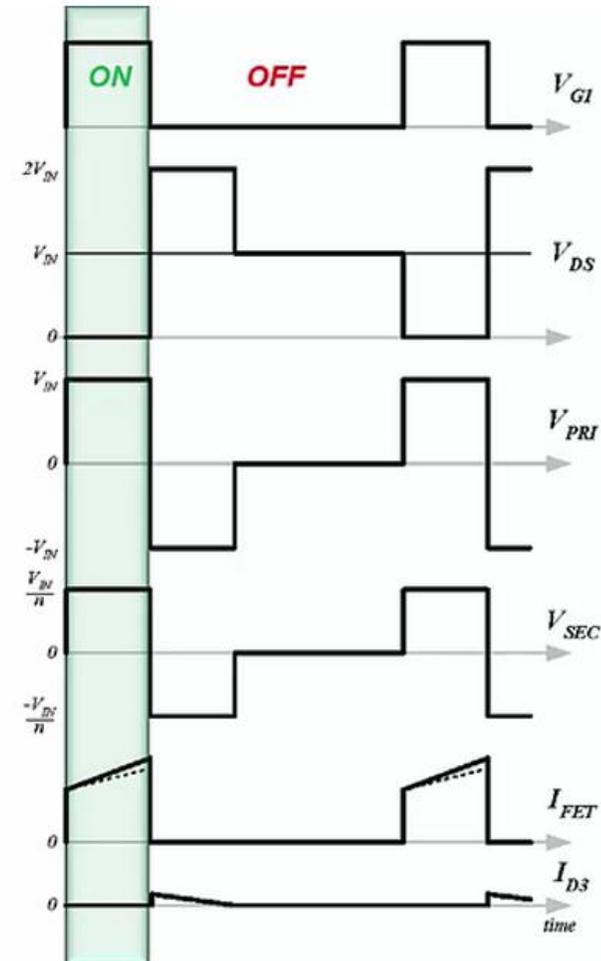
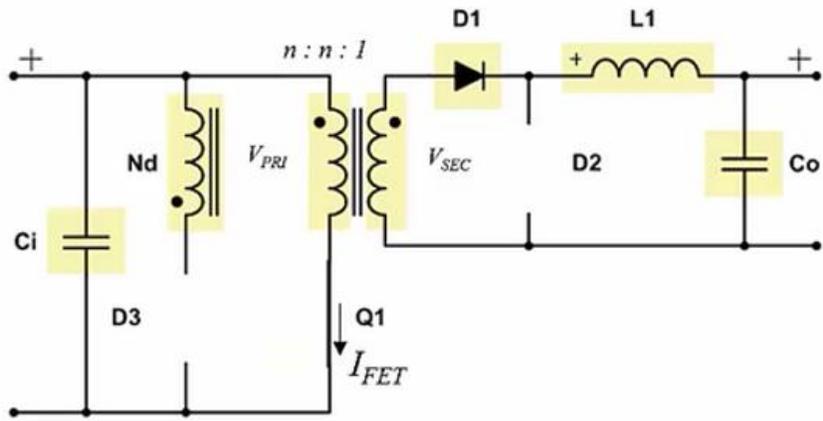
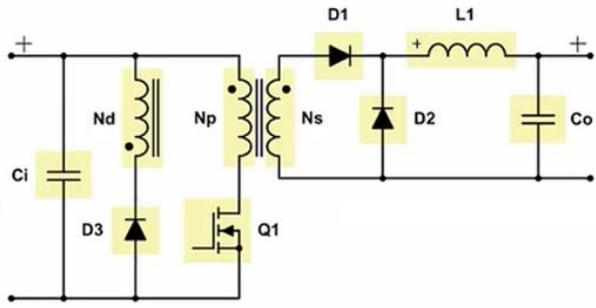
双管正激



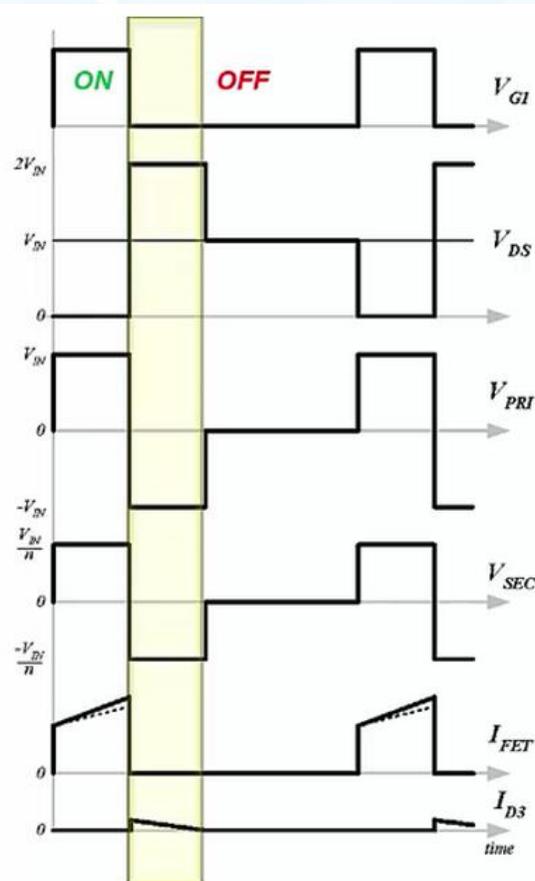
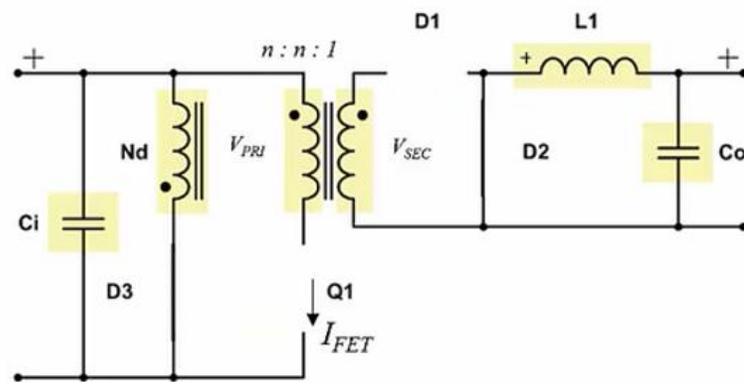
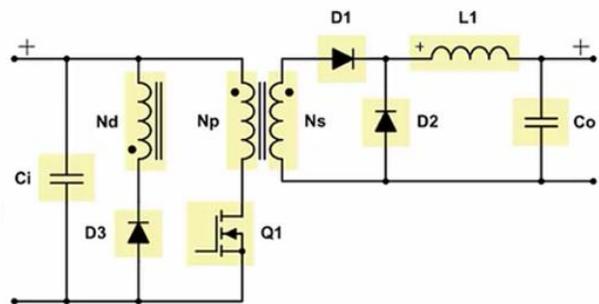
有源钳位正激

	单管正激	双管正激	有源钳位
开关管数量	1	2	2
开关管耐压	$2 \times V_{in}$	V_{in}	$V_{in}/(1-D)$
Q2管电流	N/A	I_p	I_{mag}
是否要吸收	需要	不需要	不需要
50%占空比限制	有限制	有限制	无限制

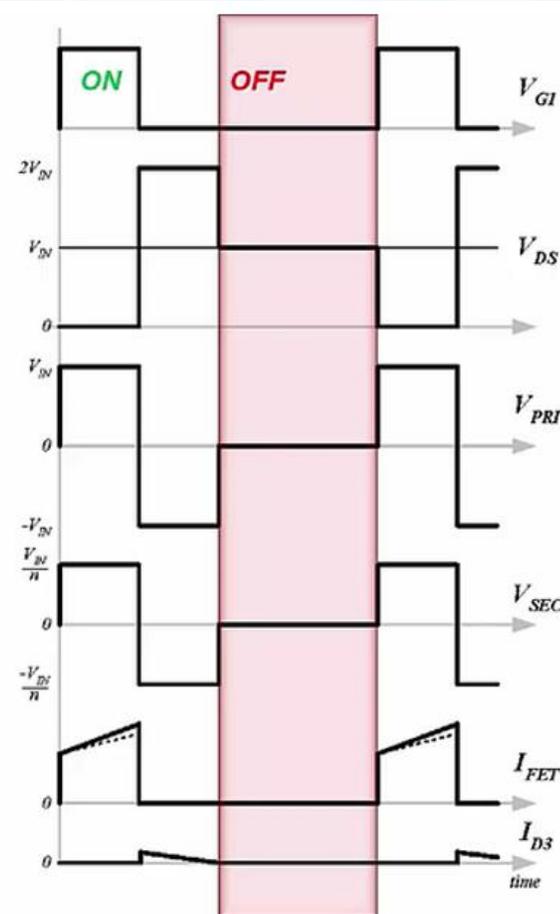
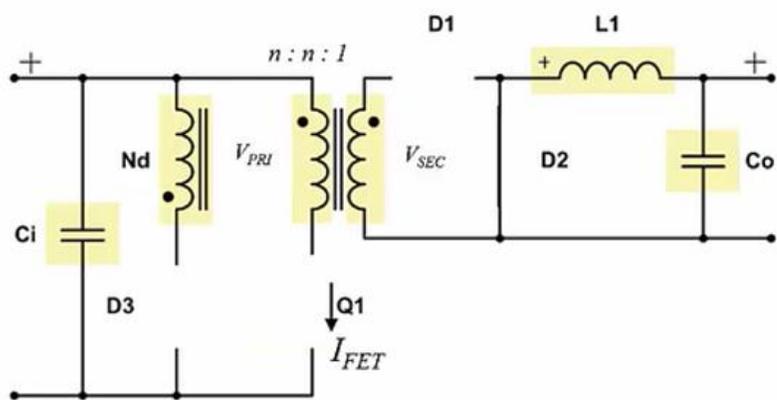
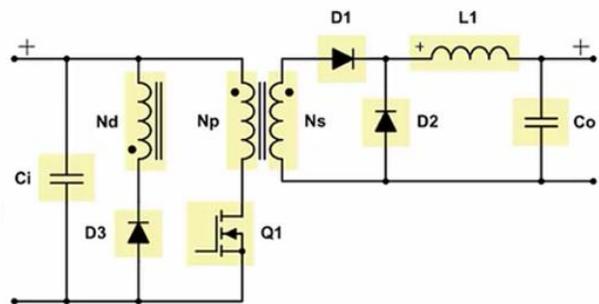
单管正激变换器



单管正激变换器

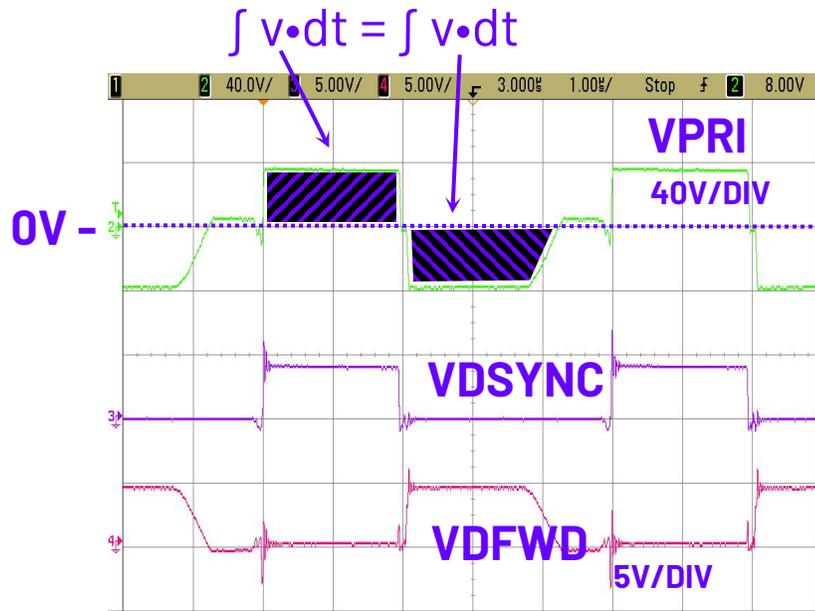
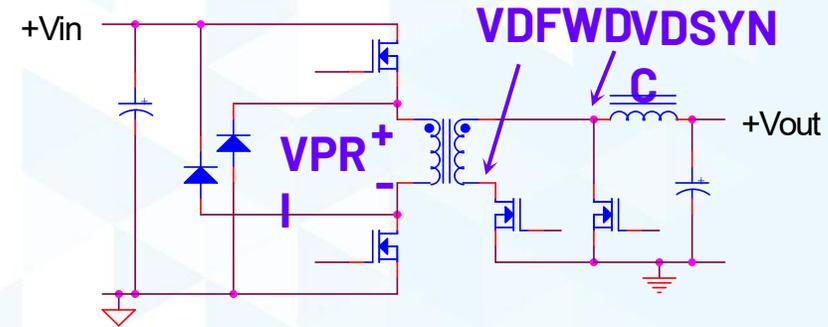


单管正激变换器

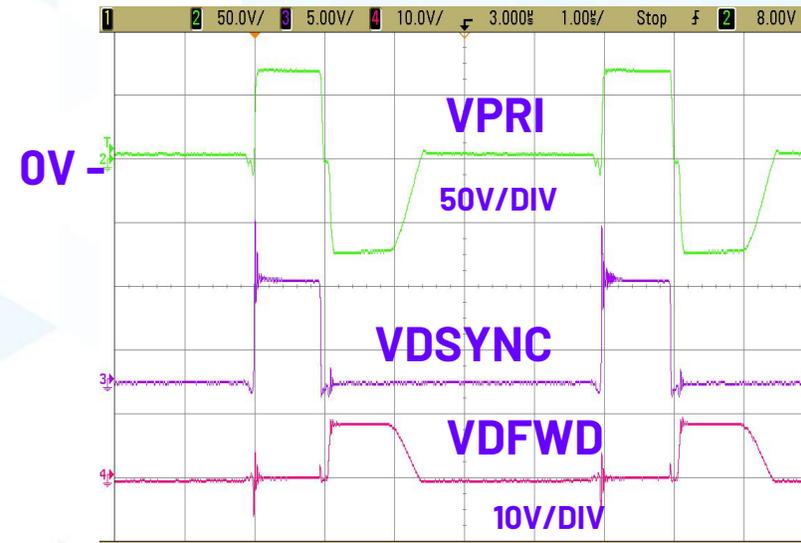


双管正激变换器

- ▶ 双管正激提供最简单的变压器复位方式
- ▶ 双管正极最大占空比必须小于50%



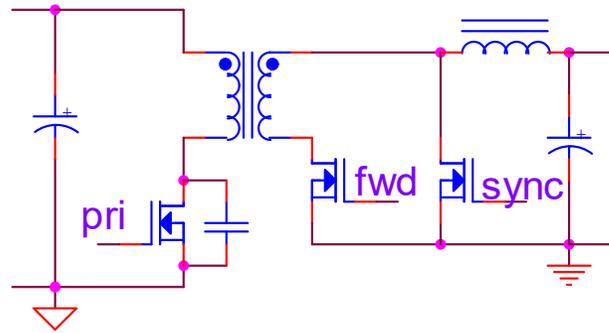
开关波形(36Vin to 1.5V/10A)



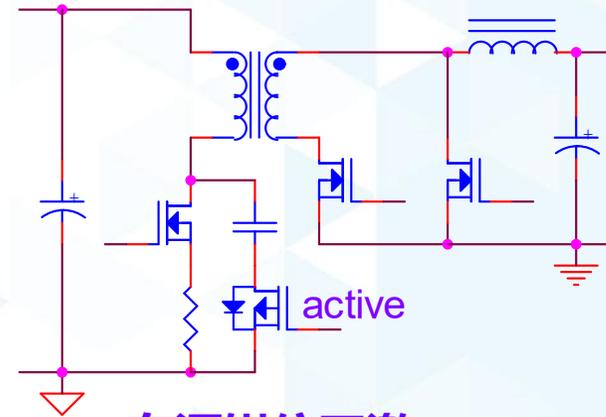
开关波形(72Vin to 1.5V/10A)

谐振复位和有源钳位正激变换器

- ▶ 采用不同的方式抑制漏感能量和变压器复位
- 谐振复位使用小电容.
- 有源钳位使用更大的电容和额外的开关.

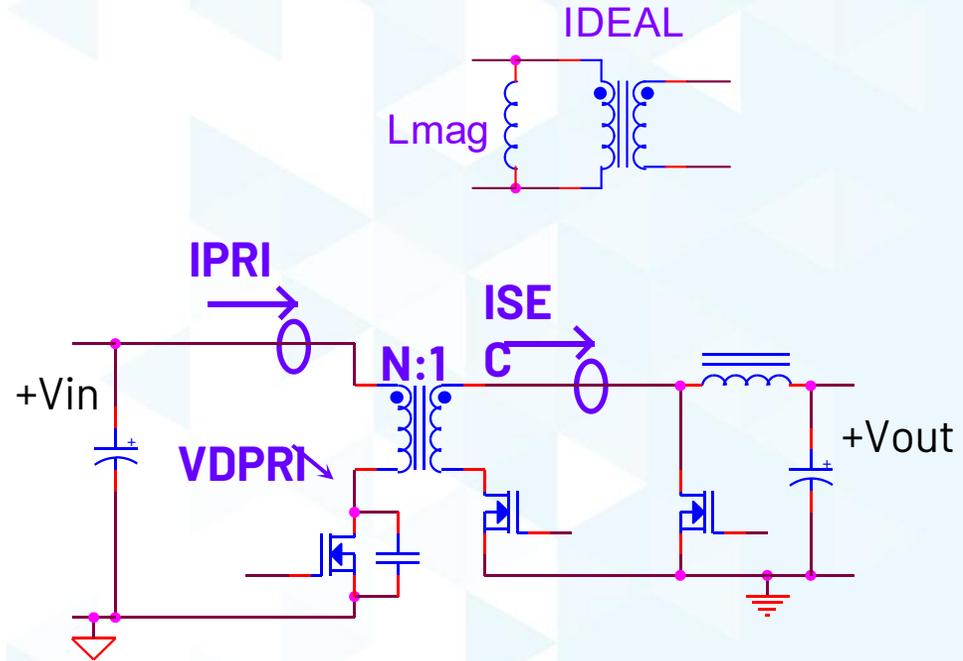
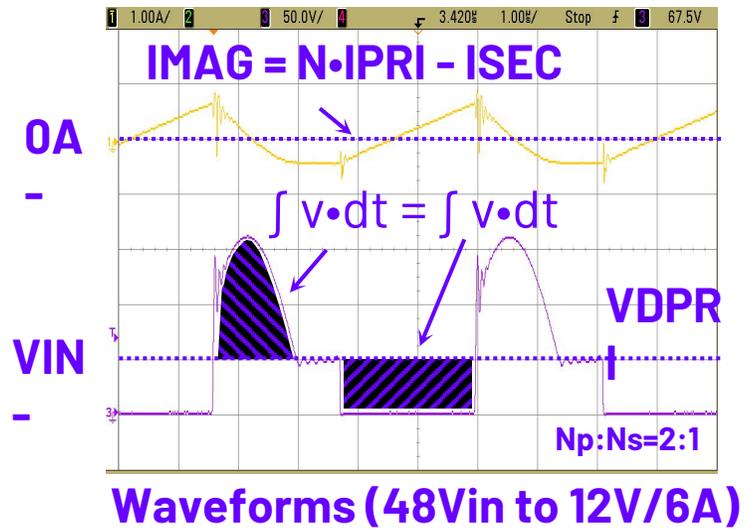


谐振复位正激

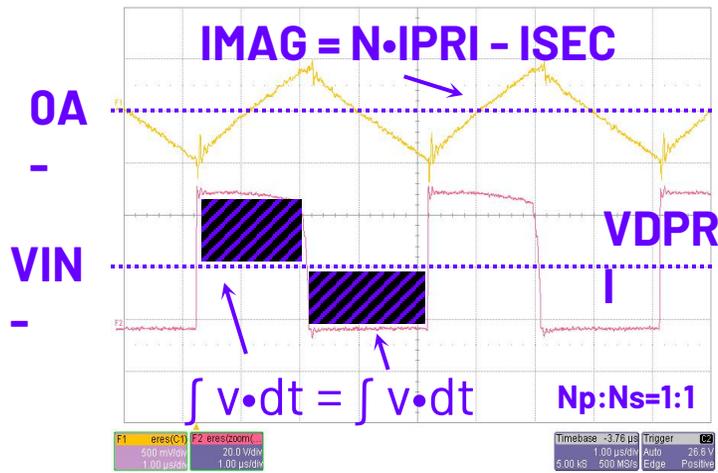


有源钳位正激

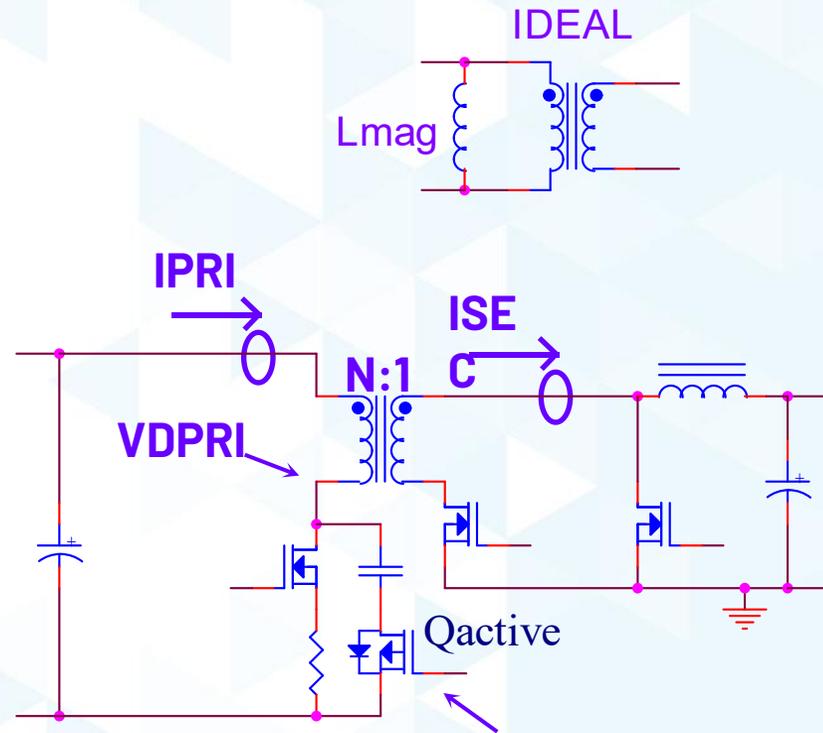
谐振复位正激变压器复位



有源钳位正激变压器复位



Waveforms (24Vin to 12V/6A)



Active FET is on when Pri FET is off.

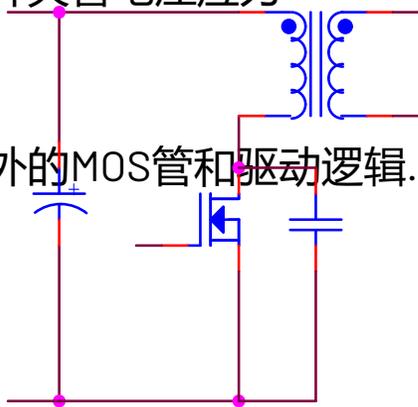
有源钳位正激

▶ 优点

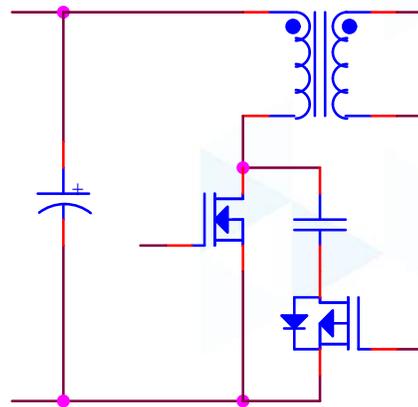
- 较低的原边开关管电压应力
- 更高的效率

▶ 缺点

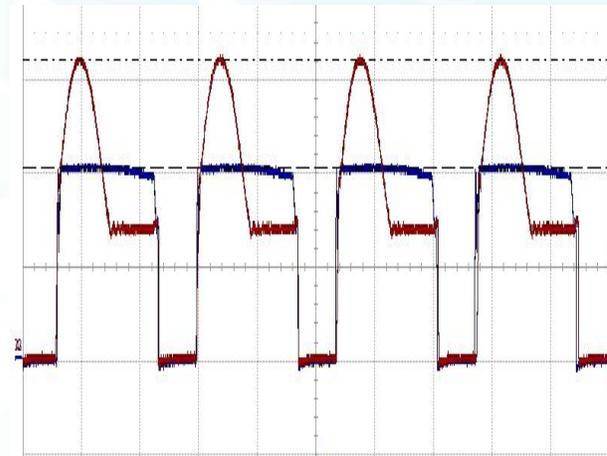
- 需要一个额外的MOS管和驱动逻辑.



谐振复位正激



有源钳位正激



谐振复位(160V_{PK})和有源钳位
(100V_{PK}) MOS漏极稳态波形

正激变压器设计流程

	Parameter/Equation	Value	Unit	Comment
1.确定频率和 ΔB	$F_s/\Delta B$	50-300/0.1-0.3	KHZ/Tesla	取决于频率和散热条件
2.确定 V_{inmin} 和 D_{max}	V_{inmin}/D_{max}	<0.5		根据磁芯复位机制
3.计算变压器匝比	$N_{ps} < \frac{V_{inmin} * D_{max}}{V_{out}}$			根据最大占空比限制, 结果尽量取整方便后面匝数选择
4.选择合适的磁芯	$AP = A_e * A_w = \frac{99 * P_o}{\Delta B * f_s}$		cm^2	根据经验选一个差不多大小尺寸或面积乘积法
5.计算线圈匝数	$N_p = \frac{V_{in} * D * T}{\Delta B * A_e}$ $N_s = N_p / NPS$			取整数匝
6.选择线径	$I_p = I_o * \sqrt{D} / N_{ps}$ $I_s = I_o * \sqrt{D}$			取4A-6A/mm ² 需要考虑集肤效应
7.确认窗口面积是否够绕				

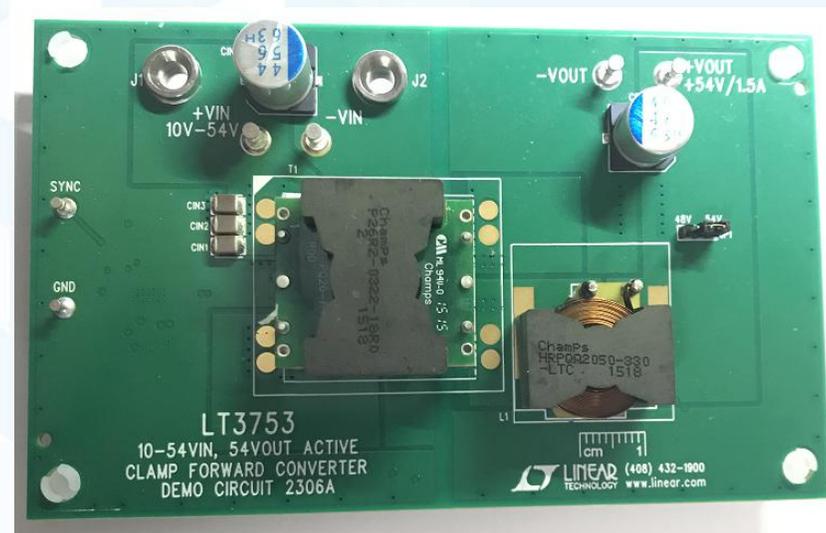
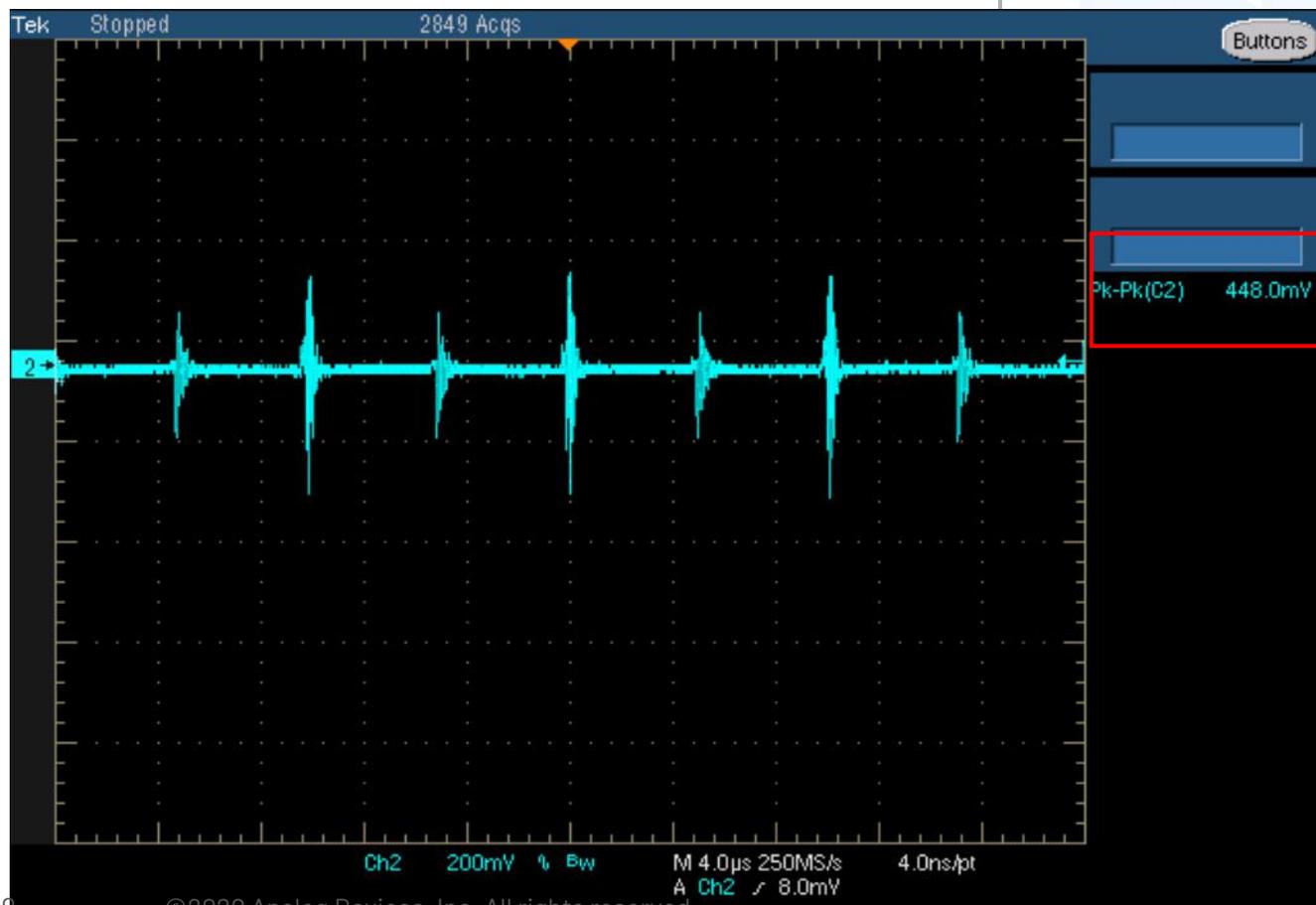
隔离电源纹波噪声优化实例

- ▶ 输入 DC 48V (40V-60V)
- ▶ 输出 DC 54V/2A (峰值) 54V/1A (稳态) 隔离2KV 纹波噪声低于10mV

10mV 纹波噪声对于隔离的高压输出是非常有设计的挑战!

LT3753 EVM 测试结果

测试条件:48V 输入, 54V/2A 输出



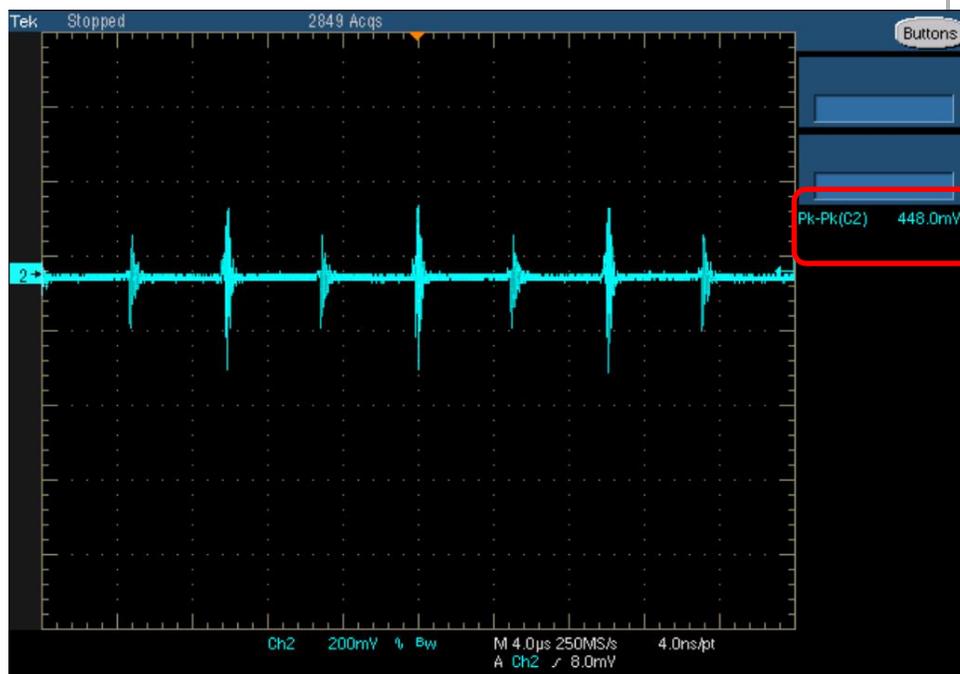
448mV 远高于10mV!!!

如何满足如此严格的要求?

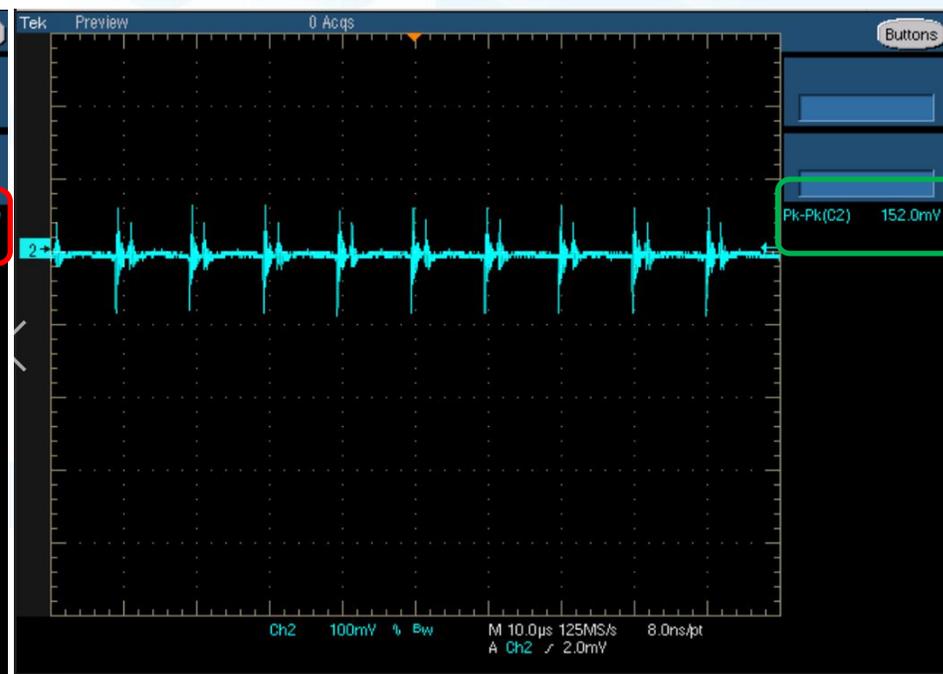
- 减小输出纹波
 - 增大滤波.
 - 但是加大输出电感（加倍），输出的纹波噪声非但没有减小，反而变大!
- 为什么?
 - 高频下电感不再是电感
 - 更大的寄生参数
- 而且更大的输出滤波还会带来:
 - 更高的成本
 - 更大的占板面积
 - 更差的动态
- 如何满足如此严格的要求?
 - 必须分析噪声产生机理
 - 源头抑制

YCAP 效果对比

越大的Y电容越能衰减来自原边Q1的噪声,但越大的Y电容会带来原副边漏电流的问题。
所以Y电容必须控制在一定范围,进一步减小只能将变压器分布电容减小。



2.2nF YCAP



4.4nF YCAP

448mV vs 152mV

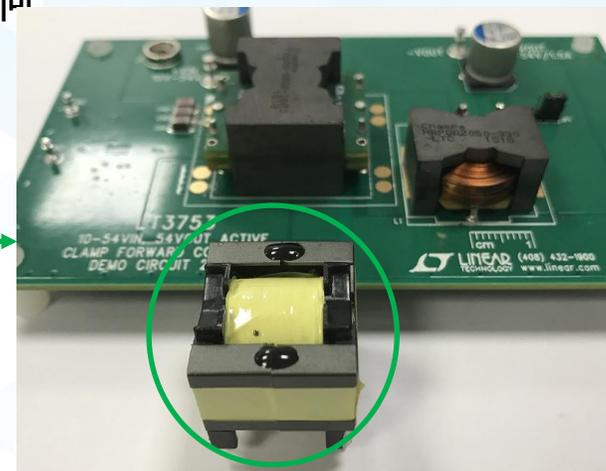
变压器优化

平面变压器拥有较大的初次级寄生电容，且原变压器变比不优化
针对该应用，变压器有两个优化方向：

1. 变压器变比：减小匝比，减小副边开关点电压尖峰
2. 变压器初次级寄生电容：减小原边尖峰对副边的影响



减小变压器匝比
减小初次级电容



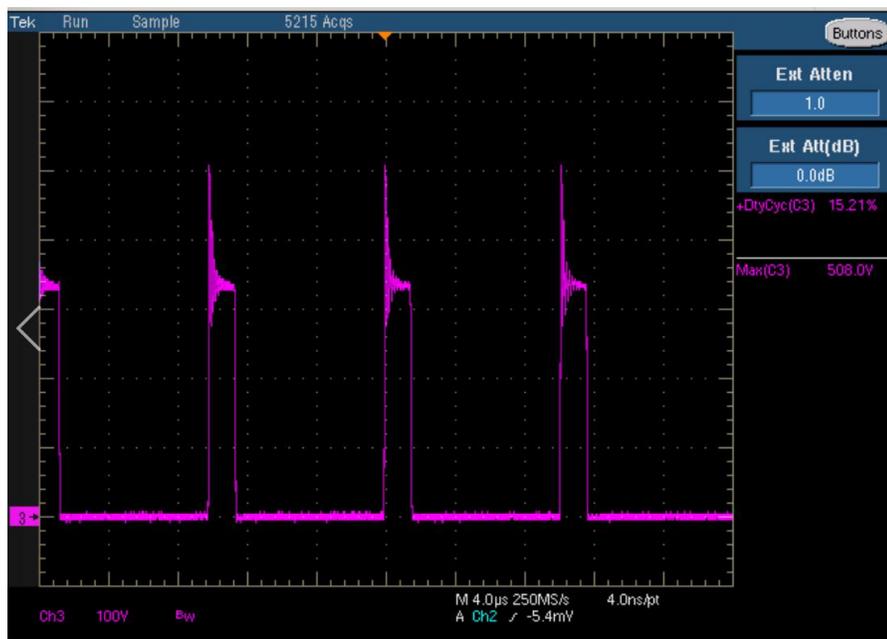
SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{IN}	Input Supply Range		10 40		54	V
V_{OUT}	Output Voltage		53	54	55	V
I_{OUT}	Maximum Output Current, Continuous		1.5			A

正激变压器设计流程

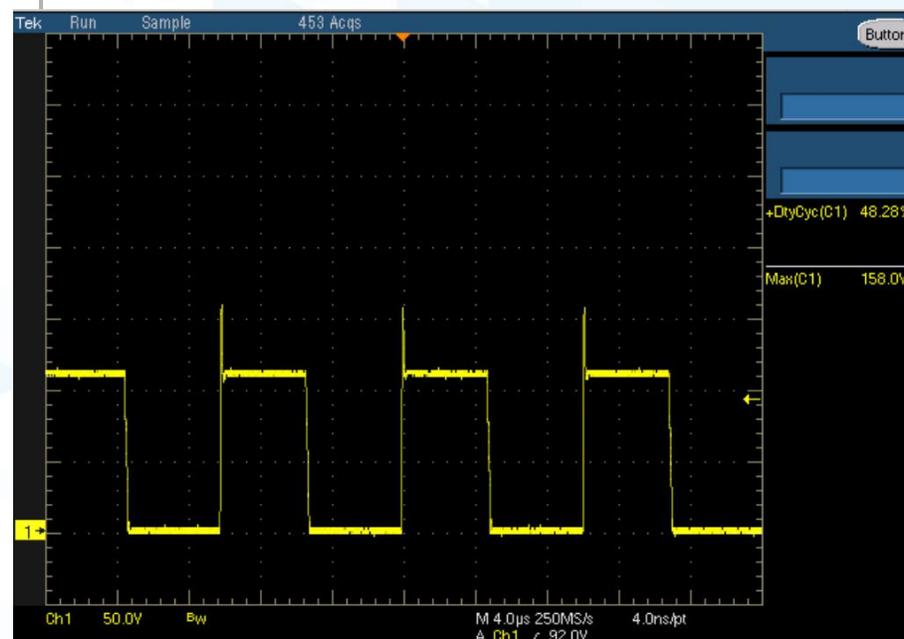
	Parameter/Equation	Value	Unit	Comment
1.确定频率和 ΔB	$F_s/\Delta B$	100/0.3	KHZ/Tesla	取决于频率和散热条件
2.确定 V_{inmin} 和 D_{max}	$40/0.7$	0.7		有源钳位可以支持>0.5的占空比
3.计算变压器匝比	$N_{ps} < \frac{40 \cdot 0.7}{60} = 0.467$	0.4		根据最大占空比限制, 结果尽量取整方便后面匝数选择
4.选择合适的磁芯	$AP = A_e \cdot A_w = \frac{99 \cdot P_o}{\Delta B \cdot f_s}$	1.21	cm ²	根据经验选择PQ2620磁芯
5.计算线圈匝数	$N_p = \frac{V_{in} \cdot D \cdot T}{\Delta B \cdot A_e} = \frac{40 \cdot 0.7 \cdot 10\mu}{0.3 \cdot 1.21} = 8T$ $N_s = N_p / NPS = 20T$			取整数匝
6.选择线径	$I_p = 1 \cdot \sqrt{0.5} / 0.4 = 1.8$ $I_s = 1 \cdot \sqrt{0.5} = 0.7$	取0.3mm ² 线 取0.11mm ² 线		取6A/mm ² 电流密度 需要考虑集肤效应

变压器效果对比

原来的变压器变比是1:7, 在SW节点造成高达508V的电压噪声;
原来的变压器是平面变压器, 耦合比较好, 原副边寄生电容为1nF;
新的变压器变比是1:2.5, SW节点的噪声电压变为158V;
新的变压器采用普通变压器, 寄生电容为0.4nF。



原来变压器



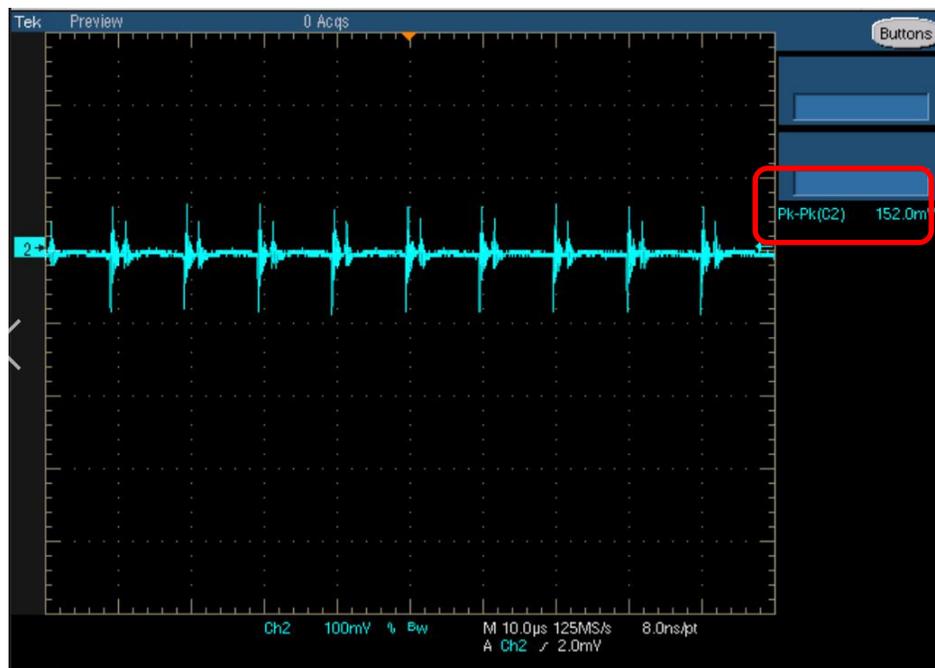
新变压器

508V vs 158V

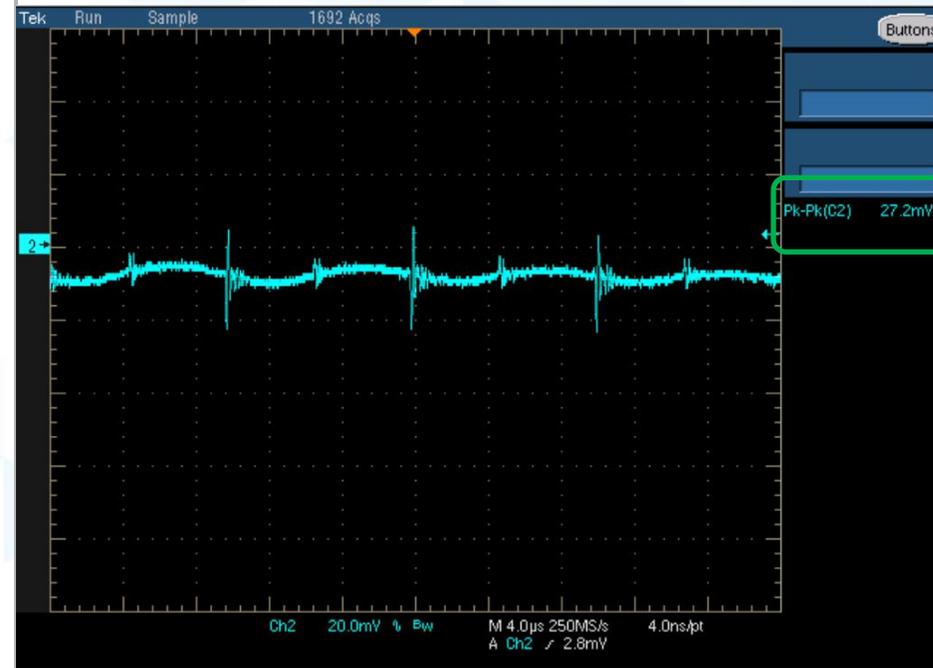
1nF vs 0.4nF

变压器效果对比

通过变压器优化，没有额外的成本增加，带来纹波的显著减小！



原来变压器/4.4nF YCAP

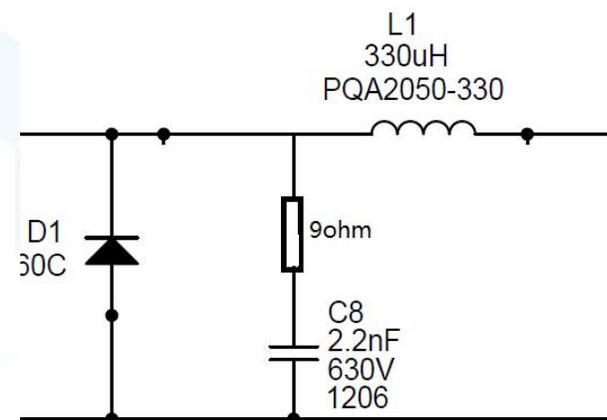
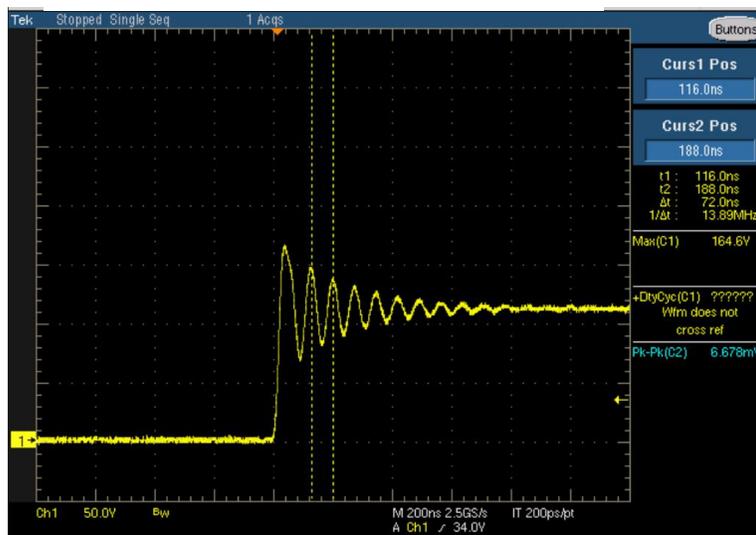
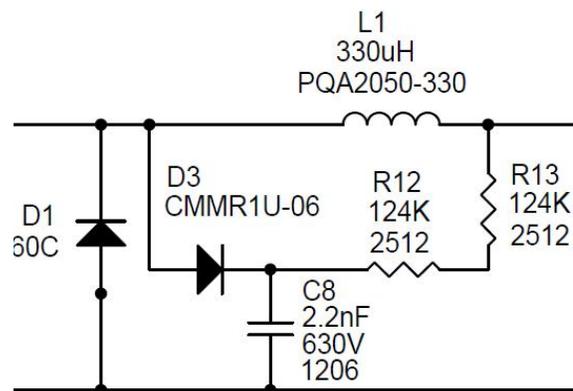


新变压器/4.4nF YCAP

152mV vs 27.2mV

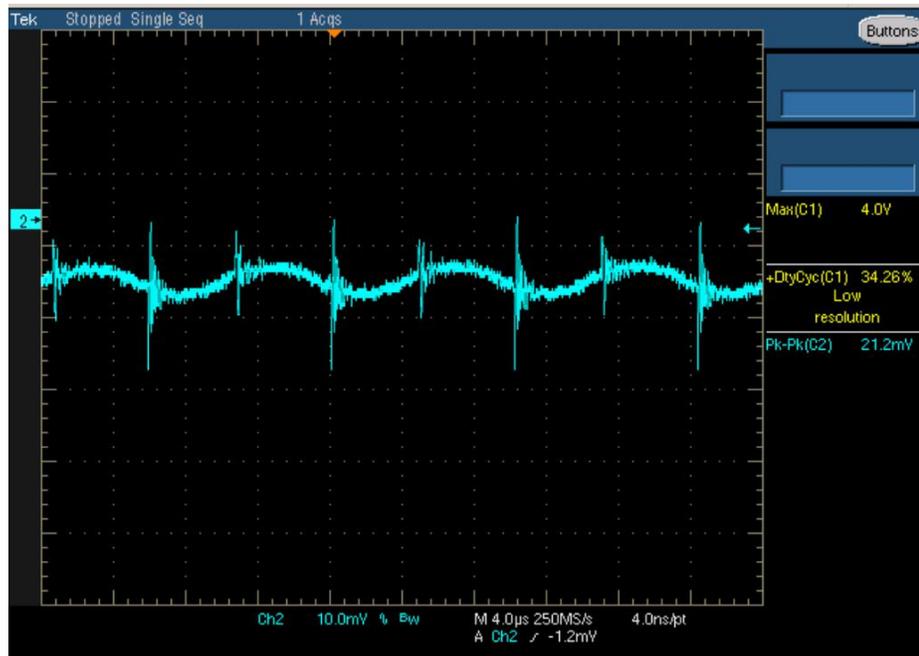
吸收电路对比

EVM采用高效的RCD吸收，大的电阻为了提高效率，但阻尼效果不好，因此有更多的震荡在SW节点。采用新的RC吸收，9ohm电阻大大阻尼了震荡。

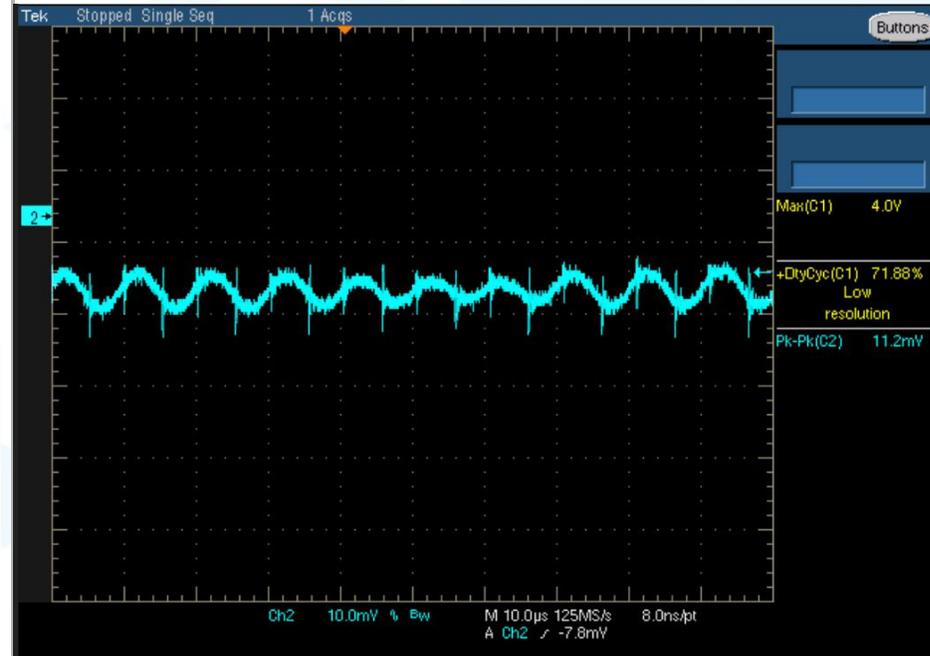


吸收电路对噪声的影响

随着吸收电路的改变，SW节点的震荡被大大阻尼，输出纹波上的噪声也相应变小。



原先Snubber



新Snubber

21.2mV vs

11.2mV

第二讲：理想二极管 Ideal Diode



微信扫描二维码
获取课程观看链接

二极管

二极管 (Diode)

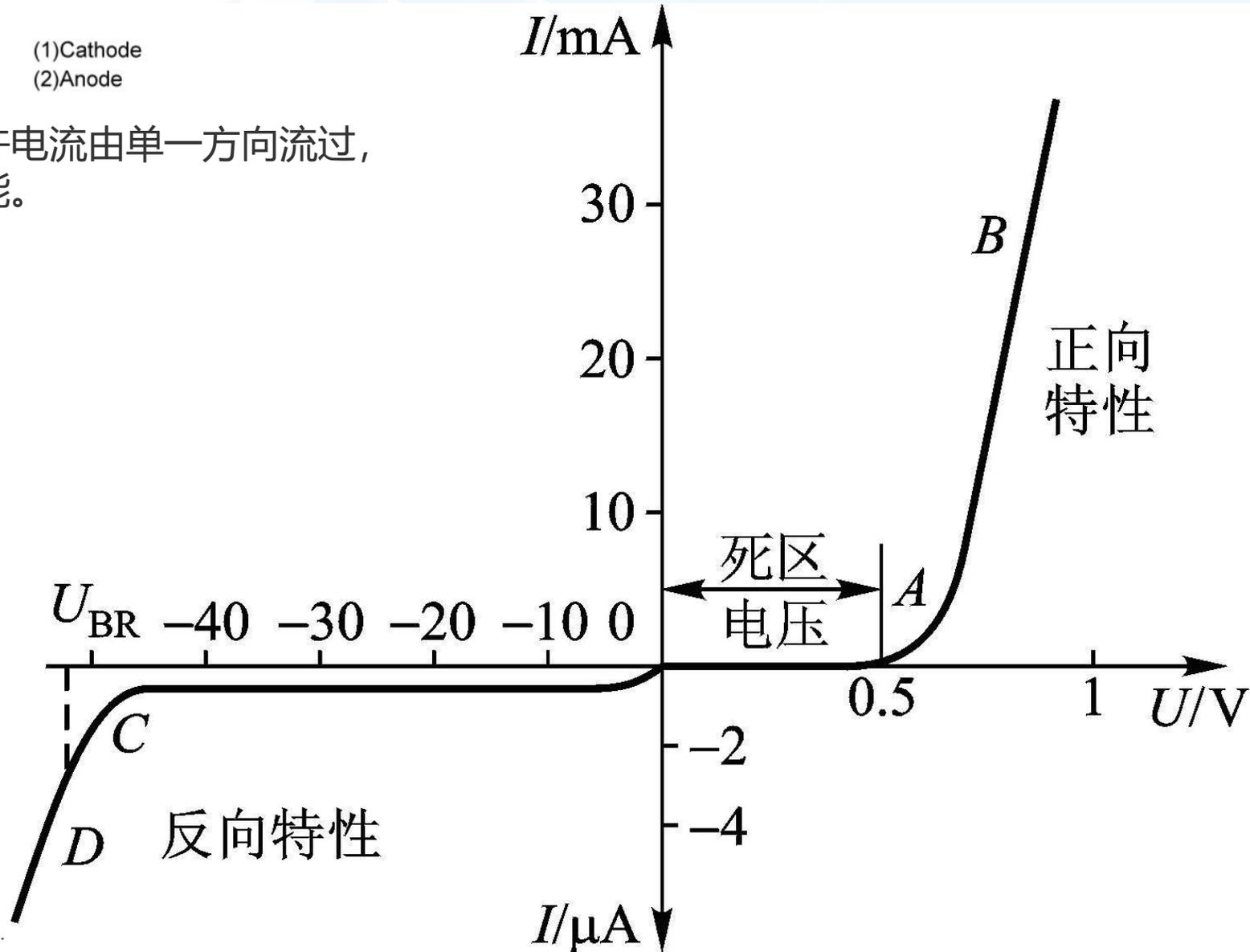


(1) Cathode
(2) Anode

一种具有两个电极的电子元件，只允许电流由单一方向流过，最常见的应用是发光、整流或防反功能。

- 检波二极管
- 整流二极管
- 稳压二极管
- 开关二极管
- 隔离二极管
- 肖特基二极管
- 发光二极管
- 硅功率开关二极管

-
-
-



二极管的主要极限参数

1、最高反向工作电压

加在二极管两端的反向电压高到一定值时，会将管子击穿，失去单向导电能力。为了保证使用安全，规定了最高反向工作电压值。例如，1N4001二极管反向耐压为50V，1N4007反向耐压为1000V。

2、最大整流电流

是指二极管长期连续工作时，允许通过的最大正向平均电流值。在规定散热条件下，二极管使用中不要超过二极管最大整流电流值。例如，常用的1N4001 - 4007型二极管的额定正向工作电流为1A。

3、结温

器件能正常工作的温度范围。

例如1N4001的工作温度范围为-65°C-175°C

1N4001, 1N4002, 1N4003, 1N4004, 1N4005, 1N4006, 1N4007

MAXIMUM RATINGS

Rating	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
†Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
†Non-Repetitive Peak Reverse Voltage (halfwave, single phase, 60 Hz)	V_{RSM}	60	120	240	480	720	1000	1200	V
†RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
†Average Rectified Forward Current (single phase, resistive load, 60 Hz, $T_A = 75^\circ\text{C}$)	I_O	1.0							A
†Non-Repetitive Peak Surge Current (surge applied at rated load conditions)	I_{FSM}	30 (for 1 cycle)							A
Operating and Storage Junction Temperature Range	T_J T_{stg}	-65 to +175							°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

†Indicates JEDEC Registered Data

二极管的主要工作参数

1、正向工作电压（与电流及测试条件有关）

当加在二极管两端的正向电压很小时，二极管仍然不能导通，流过二极管的正向电流十分微弱。只有当正向电压达到某一数值（这一数值称为“门坎电压”，又称“死区电压”，以后，二极管才能真正导通。导通后二极管两端的电压基本上保持不变，称为二极管的“正向压降”。

2、反向电流

当加在二极管两端的电压为反向电压时，二极管中几乎没有电流流过，此时二极管处于截止状态，这种连接方式，称为反向偏置。二极管处于反向偏置时，仍然会有微弱的反向电流流过二极管，称为漏电流。当二极管两端的反向电压增大到某一数值，反向电流会急剧增大，二极管将失去单向导电特性，这种状态称为二极管的击穿。

3、结电容

二极管与PN结一样，其结电容由势垒电容组成。所以PN结结电容的大小影响单向导电性及工作上限频率。

ELECTRICAL CHARACTERISTICS† 1N4001, 1N4002, 1N4003, 1N4004, 1N4005, 1N4006, 1N4007

Rating	Symbol	Typ	Max	Unit
Maximum Instantaneous Forward Voltage Drop, ($i_F = 1.0$ Amp, $T_J = 25^\circ\text{C}$)	V_F	0.93	1.1	V
Maximum Full-Cycle Average Forward Voltage Drop, ($I_O = 1.0$ Amp, $T_L = 75^\circ\text{C}$, 1 inch leads)	$V_{F(AV)}$	–	0.8	V
Maximum Reverse Current (rated DC voltage) ($T_J = 25^\circ\text{C}$) ($T_J = 100^\circ\text{C}$)	I_R	0.05 1.0	10 50	μA
Maximum Full-Cycle Average Reverse Current, ($I_O = 1.0$ Amp, $T_L = 75^\circ\text{C}$, 1 inch leads)	$I_{R(AV)}$	–	30	μA

THERMAL CHARACTERISTICS (Note 1)

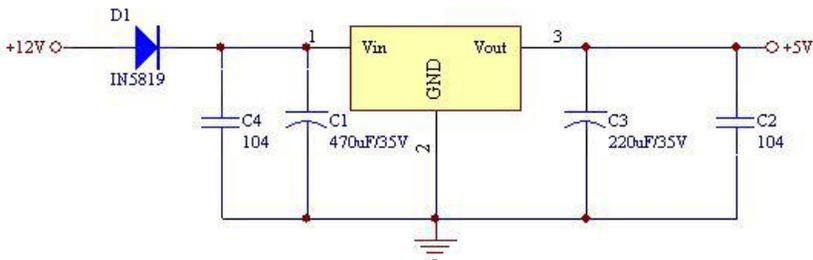
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction-to-Ambient	$R_{\theta JA}$	80	$^\circ\text{C/W}$

ELECTRICAL CHARACTERISTICS ($T_L = 25^\circ\text{C}$ unless otherwise noted) (Note 1)

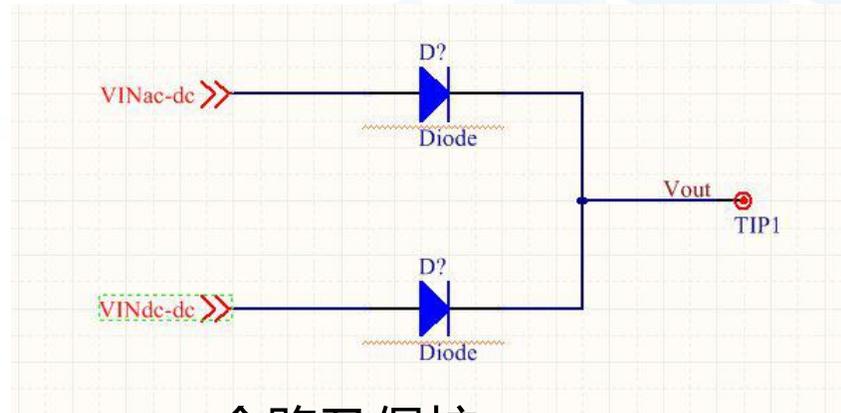
Characteristic	Symbol	1N5817	1N5818	1N5819	Unit
Maximum Instantaneous Forward Voltage (Note 2) ($i_F = 0.1$ A) ($i_F = 1.0$ A) ($i_F = 3.0$ A)	V_F	0.32 0.45 0.75	0.33 0.55 0.875	0.34 0.6 0.9	V
Maximum Instantaneous Reverse Current @ Rated dc Voltage (Note 2) ($T_L = 25^\circ\text{C}$) ($T_L = 100^\circ\text{C}$)	I_R	1.0 10	1.0 10	1.0 10	mA

1. Lead Temperature reference is cathode lead 1/32 in from case.
2. Pulse Test: Pulse Width = 300 μs , Duty Cycle = 2.0%.

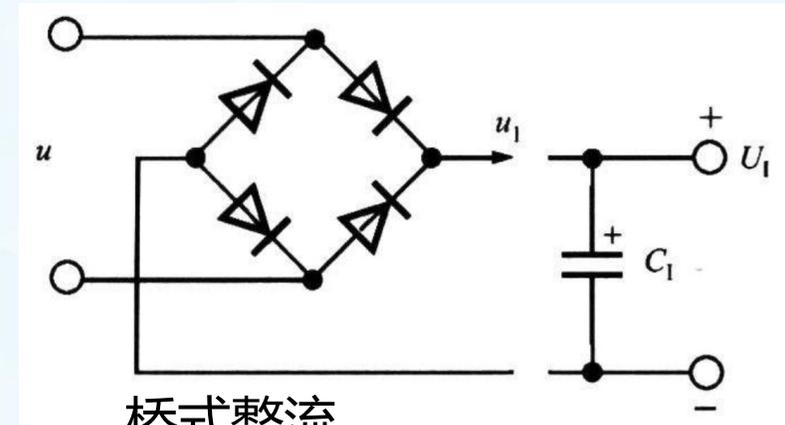
最常见的大电流二极管应用



单向保护



合路及保护



桥式整流

THERMAL CHARACTERISTICS (Note 1)

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction-to-Ambient	$R_{\theta JA}$	80	$^{\circ}\text{C/W}$

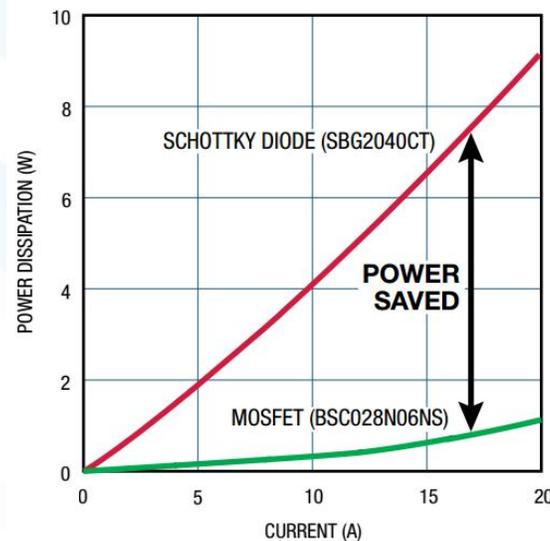
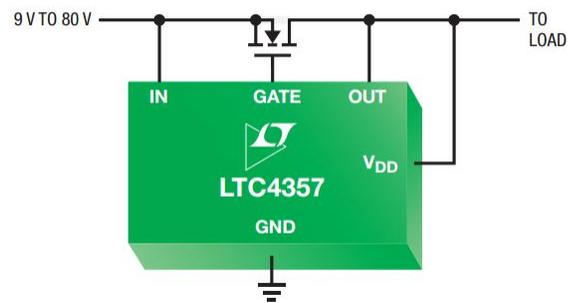
$$\text{Power loss} = V_d * I_d$$

$$\text{e.g.: } PL = 0.4 * 4A = 1.6W$$

理想二极管控制电路

Ideal Diode Controller

- ▶ Connects highest voltage supply to output
- ▶ Low forward turn-on voltage (< 50 mV)
- ▶ Controls external N-channel or P-channel MOSFETs
- ▶ Linear regulation of MOSFET forward voltage drop
- ▶ Conserves voltage and power over Schottky diodes
- ▶ Minimizes or eliminates heat sinks
- ▶ Works as high side load switch with back-to-back MOSFETs
- ▶ Blocks reversed inputs from load

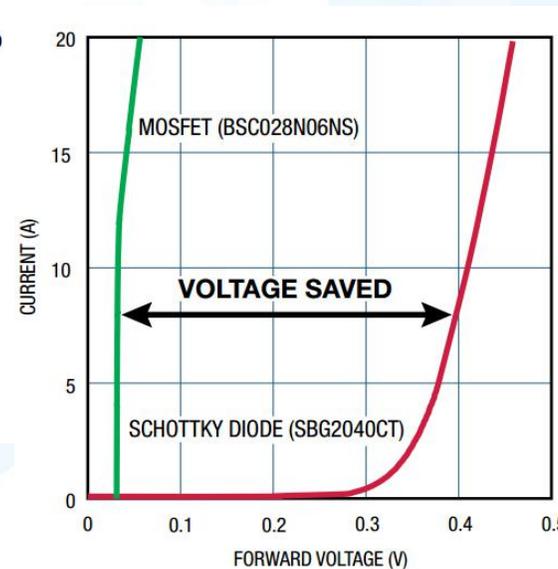
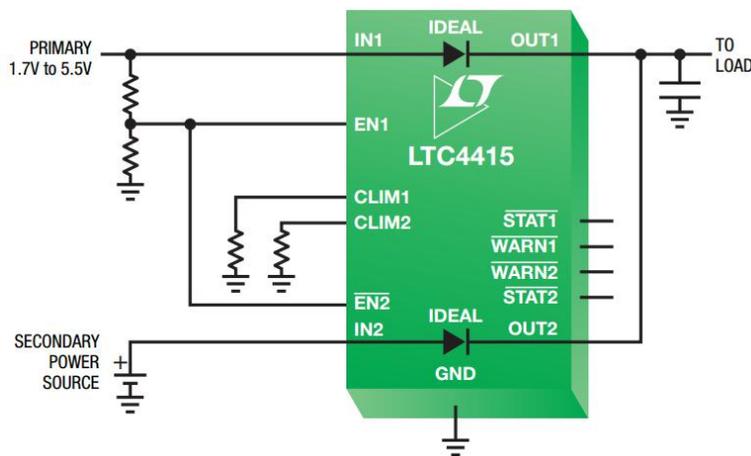


▶ 低功率损耗

▶ 无需散热

Ideal Diode

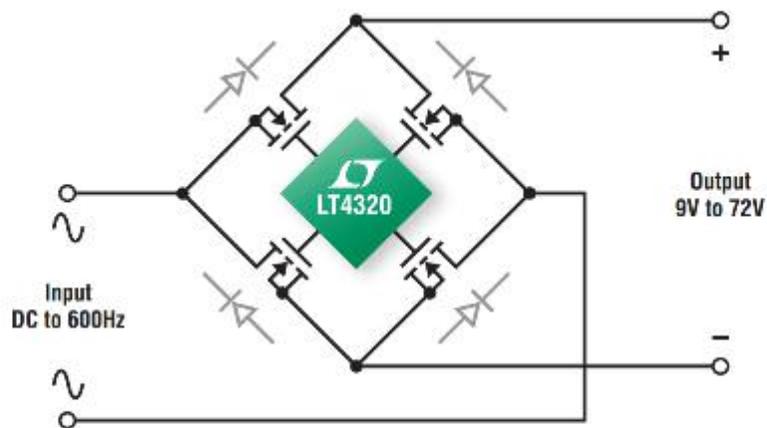
- ▶ Internal power MOSFET for compact solution footprint
- ▶ Load currents up to 5 A
- ▶ Low reverse leakage current (< 1 μ A at 25°C, < 10 μ A at 125°C)



▶ 高可靠性

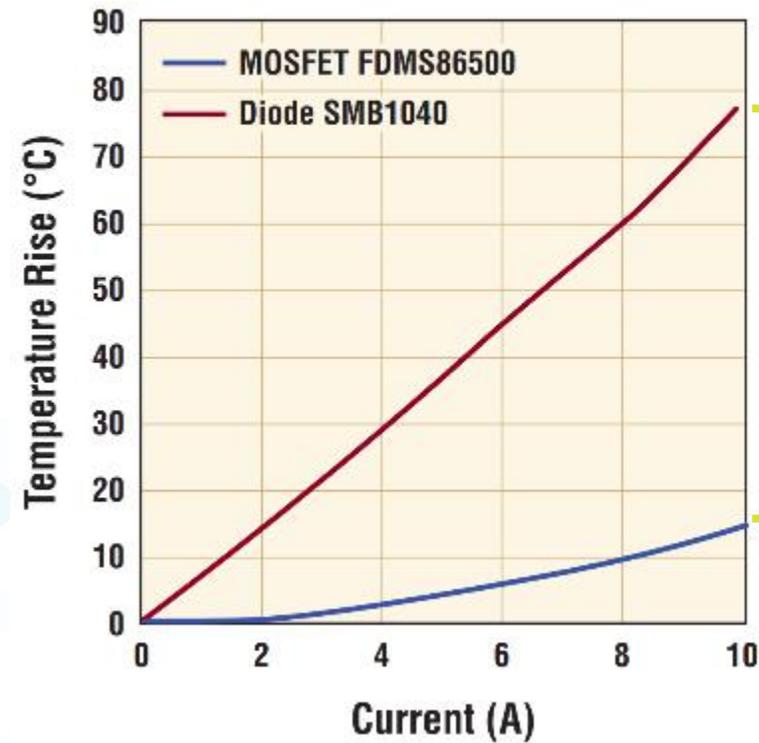
▶ 高效率

Ideal Diode Bridge



Active Diode Bridge Controller Minimizes Voltage Drop & Heat Sinking Requirements

Temperature Rise vs Load Current



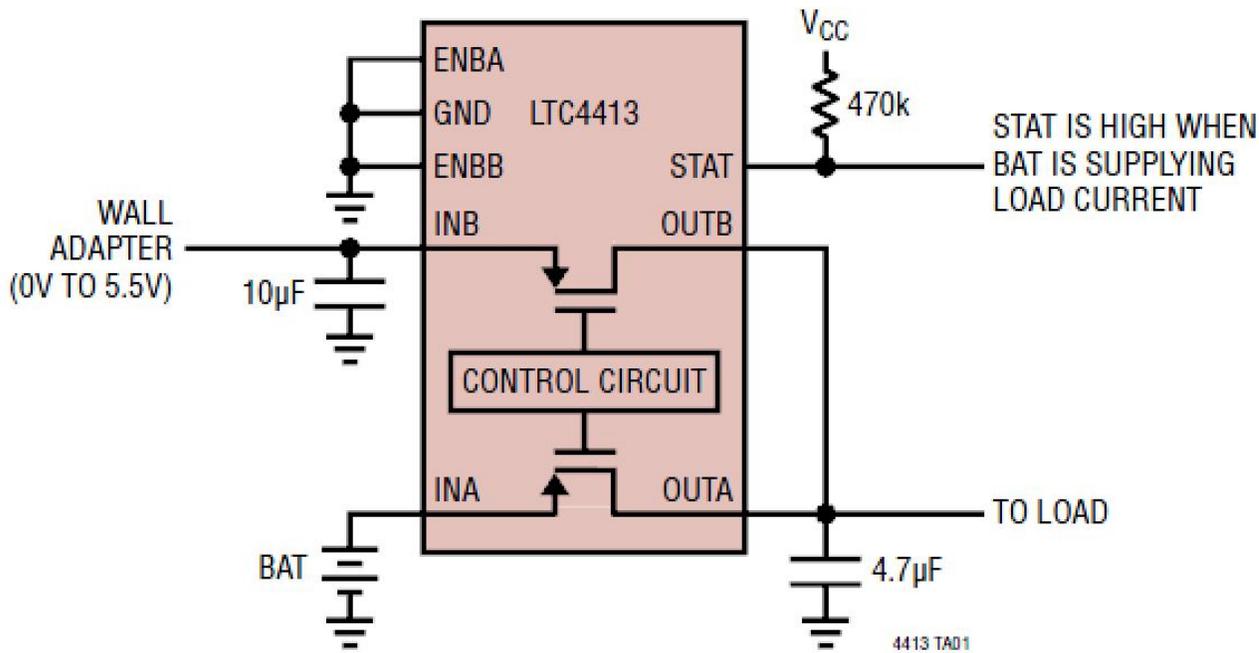
▶ 低功率损耗

▶ 无需散热

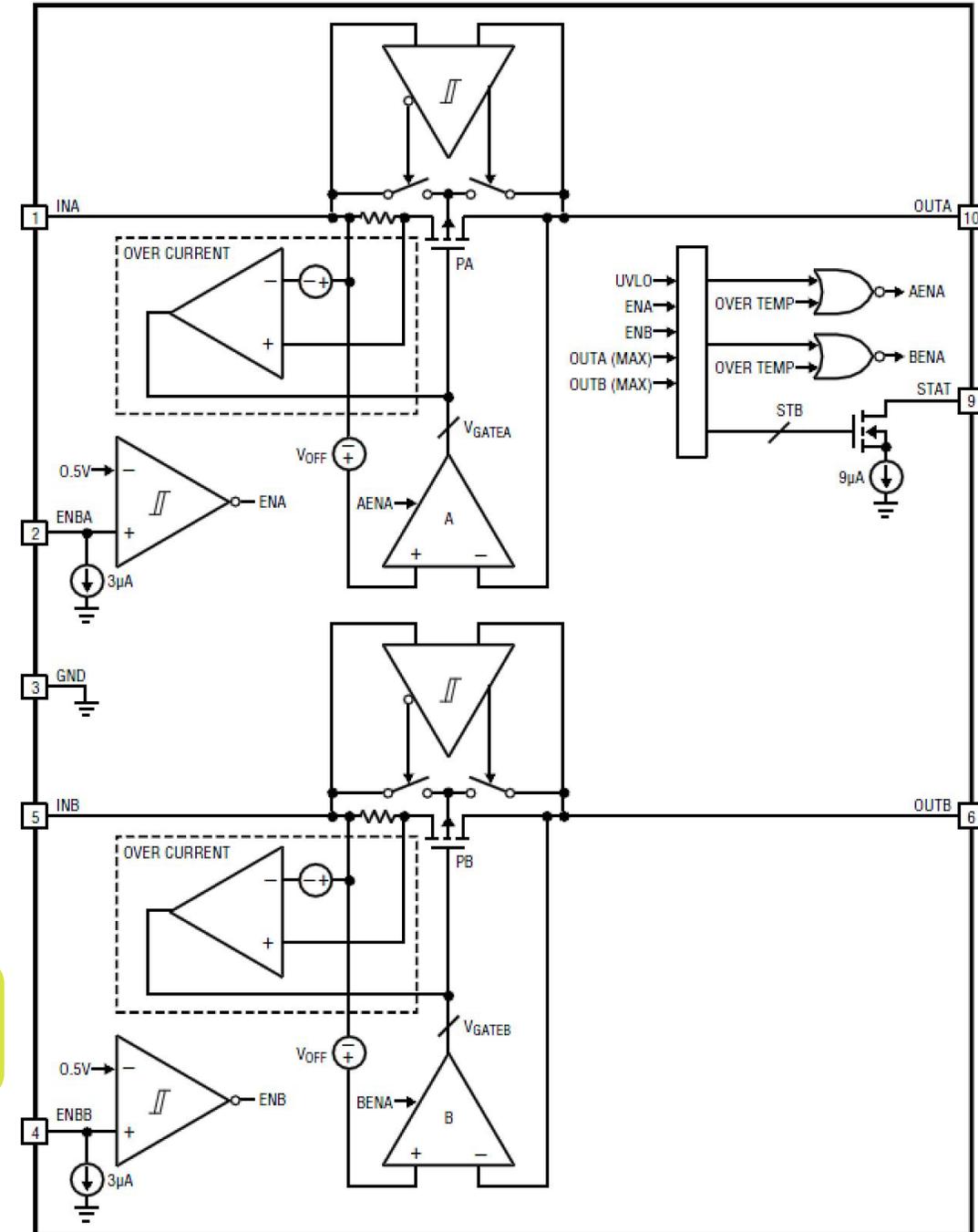
▶ 高可靠性

▶ 高效率

基本工作原理

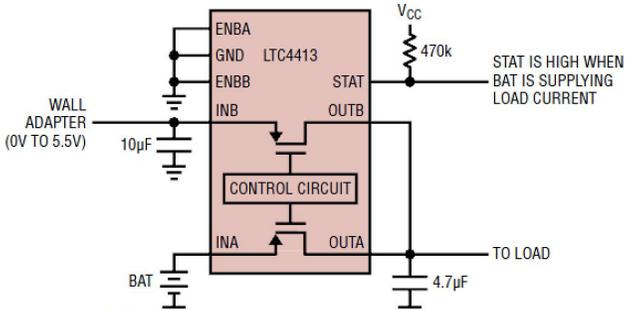


BLOCK DIAGRAM



ELECTRICAL CHARACTERISTICS The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. (Notes 2, 6)

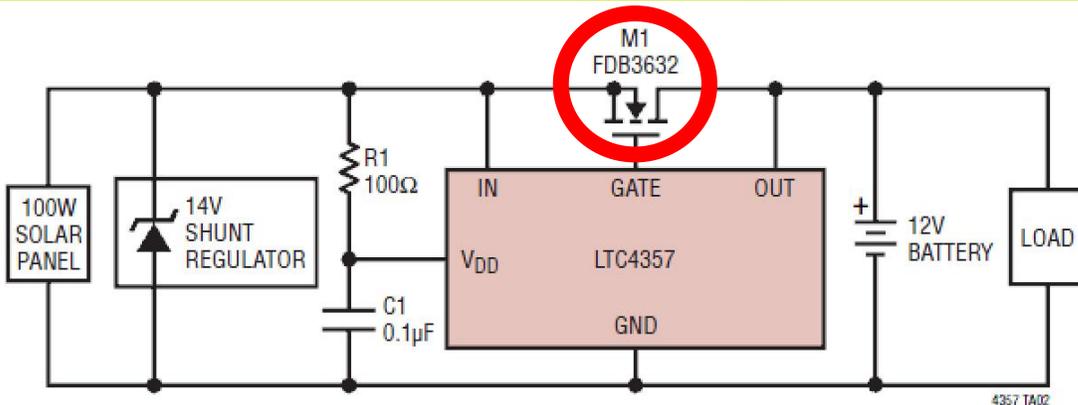
SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
I_{LEAK}	V_{INA} or V_{INB} Current When V_{OUTA} or V_{OUTB} Supplies Power	$V_{IN} = 0V, V_{OUT} = 5.5V$	-1		1	μA
V_{RTO}	Reverse Turn-Off Voltage ($V_{OUT} - V_{IN}$)	$V_{IN} = 3.6V$	-5		10	mV
V_{FWD}	Forward Voltage Drop ($V_{IN} - V_{OUT}$)	$V_{IN} = 3.6V$	●	28	38	mV
R_{FWD}	On-Resistance, R_{FWD} Regulation (Measured as $\Delta V/\Delta I$)	$V_{IN} = 3.6V, I_{OUT} = -100\text{mA}$ to -500mA (Note 5)		100	140	$\text{m}\Omega$
R_{ON}	On-Resistance, R_{ON} Regulation (Measured as $V/\Delta I$)	$V_{IN} = 3.6V, I_{OUT} = -1.0A$ (Note 5)		140	200	$\text{m}\Omega$



ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. (Notes 2, 6)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
I_{LEAK}	V_{INA} or V_{INB} Current When V_{OUTA} or V_{OUTB} Supplies Power	$V_{IN} = 0\text{V}$, $V_{OUT} = 5.5\text{V}$	-1		1	μA
V_{RTO}	Reverse Turn-Off Voltage ($V_{OUT} - V_{IN}$)	$V_{IN} = 3.6\text{V}$	-5		10	mV
V_{FWD}	Forward Voltage Drop ($V_{IN} - V_{OUT}$) at $I_{OUT} = 1\text{mA}$	$V_{IN} = 3.6\text{V}$	●	28	38	mV
R_{FWD}	On-Resistance, R_{FWD} Regulation (Measured as $\Delta V/\Delta I$)	$V_{IN} = 3.6\text{V}$, $I_{OUT} = -100\text{mA}$ to -500mA (Note 5)		100	140	$\text{m}\Omega$
R_{ON}	On-Resistance, R_{ON} Regulation (Measured as V/I at $I_M = 1\text{A}$)	$V_{IN} = 3.6\text{V}$, $I_{OUT} = -1.0\text{A}$ (Note 5)		140	200	$\text{m}\Omega$



MOSFET Maximum Ratings $T_C = 25^\circ\text{C}$ unless otherwise noted

Symbol	Parameter	FDH3632 / FDP3632 / FDB3632	Unit
V_{DSS}	Drain to Source Voltage	100	V
V_{GS}	Gate to Source Voltage	± 20	V
I_D	Drain Current		
	Continuous ($T_C < 111^\circ\text{C}$, $V_{GS} = 10\text{V}$)	80	A
	Continuous ($T_{amb} = 25^\circ\text{C}$, $V_{GS} = 10\text{V}$, $R_{\theta JA} = 43^\circ\text{C/W}$)	12	A
	Pulsed	Figure 4	A
E_{AS}	Single Pulse Avalanche Energy (Note 1)	337	mJ
P_D	Power dissipation	310	W
	Derate above 25°C	2.07	$\text{W}/^\circ\text{C}$
T_J, T_{STG}	Operating and Storage Temperature	-55 to 175	$^\circ\text{C}$

Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance Junction to Case, Max. TO-220, D ² -PAK, TO-247	0.48	$^\circ\text{C/W}$
$R_{\theta JA}$	Thermal Resistance Junction to Ambient, Max. TO-220 (Note 2)	62	$^\circ\text{C/W}$
$R_{\theta JA}$	Thermal Resistance Junction to Ambient D ² -PAK, Max. 1in ² copper pad area	43	$^\circ\text{C/W}$
$R_{\theta JA}$	Thermal Resistance Junction to Ambient, Max. TO-247 (Note 2)	30	$^\circ\text{C/W}$

Electrical Characteristics $T_C = 25^\circ\text{C}$ unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Typ	Max	Units	
Off Characteristics							
B_{VDSS}	Drain to Source Breakdown Voltage	$I_D = 250\mu\text{A}$, $V_{GS} = 0\text{V}$	100	-	-	V	
I_{DSS}	Zero Gate Voltage Drain Current	$V_{DS} = 80\text{V}$ $V_{GS} = 0\text{V}$	$T_C = 150^\circ\text{C}$	-	-	1	μA
				-	-	250	
I_{GSS}	Gate to Source Leakage Current	$V_{GS} = \pm 20\text{V}$	-	-	± 100	nA	

On Characteristics

$V_{GS(TH)}$	Gate to Source Threshold Voltage	$V_{GS} = V_{DS}$, $I_D = 250\mu\text{A}$	2	-	4	V
$r_{DS(ON)}$	Drain to Source On Resistance	$I_D = 80\text{A}$, $V_{GS} = 10\text{V}$	-	0.0075	0.009	Ω
		$I_D = 40\text{A}$, $V_{GS} = 6\text{V}$,	-	0.009	0.015	
		$I_D = 80\text{A}$, $V_{GS} = 10\text{V}$, $T_C = 175^\circ\text{C}$	-	0.018	0.022	

对比与测试



NRVTSS5100E, NRVTSAF5100E

MAXIMUM RATINGS

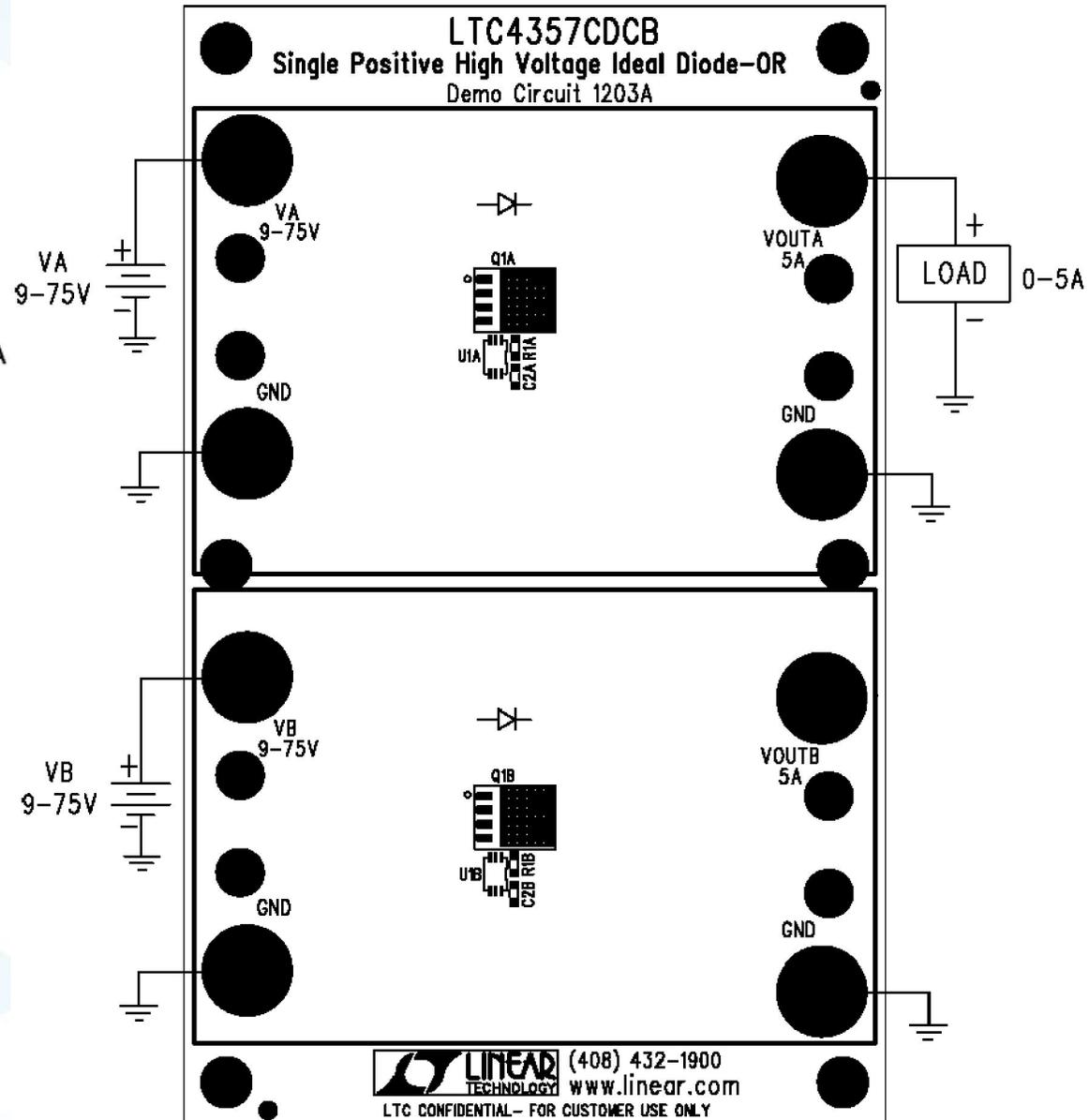
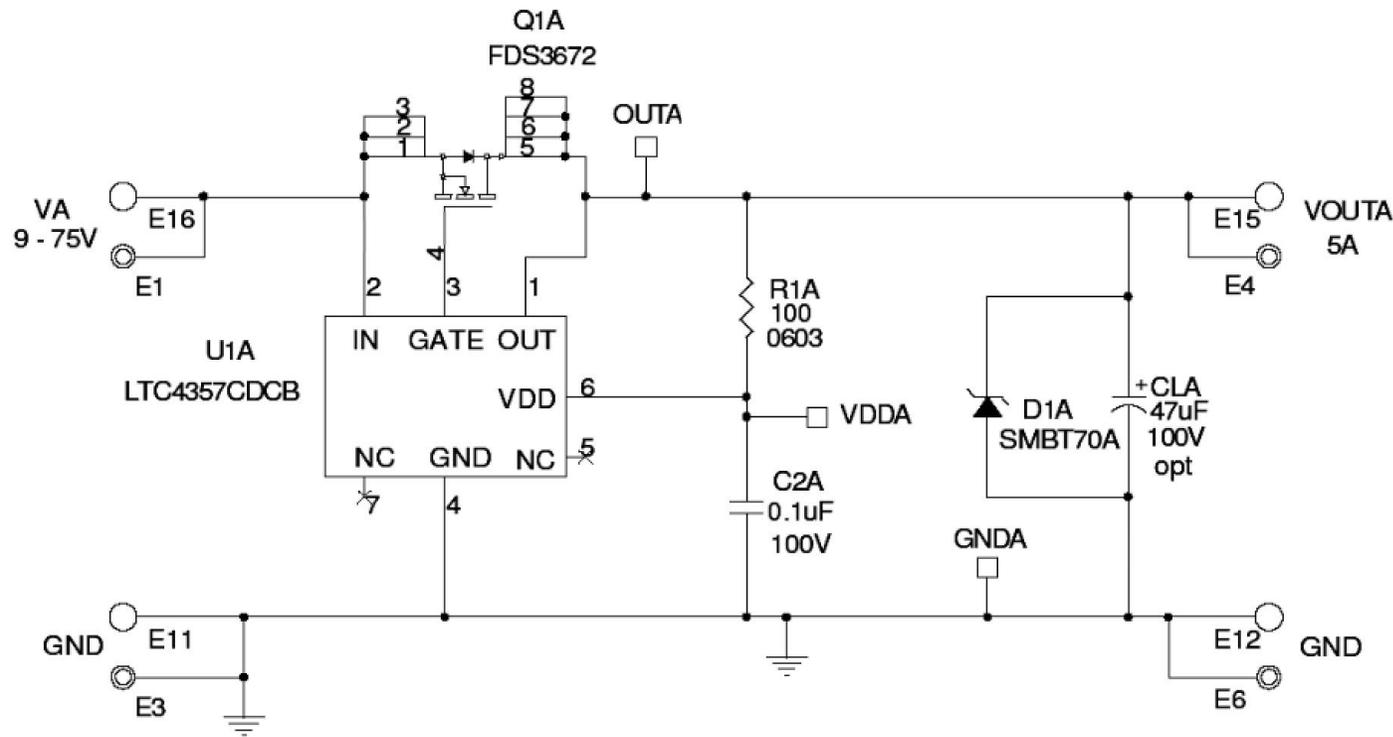
Rating	Symbol	Value	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	100	V
Average Rectified Forward Current ($T_L = 100^\circ\text{C}$)	$I_{F(AV)}$	5.0	A
Peak Repetitive Forward Current, (Square Wave, 20 kHz, $T_L = 83^\circ\text{C}$)	I_{FRM}	10	A
Non-Repetitive Peak Surge Current (Surge Applied at Rated Load Conditions Halfwave, Single Phase, 60 Hz)	I_{FSM}	50	A
Storage Temperature Range	T_{stg}	-65 to +175	$^\circ\text{C}$
Operating Junction Temperature	T_J	-55 to +175	$^\circ\text{C}$

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Typ	Max	Unit
Instantaneous Forward Voltage (Note 2) ($i_F = 3.0\text{ A}$, $T_J = 25^\circ\text{C}$) ($i_F = 5.0\text{ A}$, $T_J = 25^\circ\text{C}$) ($i_F = 3.0\text{ A}$, $T_J = 125^\circ\text{C}$) ($i_F = 5.0\text{ A}$, $T_J = 125^\circ\text{C}$)	V_F	0.56 0.65 0.50 0.56	- 0.69 - 0.62	V
Reverse Current (Note 2) (Rated dc Voltage, $T_J = 25^\circ\text{C}$) (Rated dc Voltage, $T_J = 125^\circ\text{C}$)	i_R	2.6 2.2	9 5	μA mA
Diode Capacitance (Rated dc Voltage, $T_J = 25^\circ\text{C}$, $f = 1\text{ MHz}$)	C_d	54.4		pF

Characteristics	Symbol	SS54	Unit
Maximum Recurrent Peak Reverse Voltage	V_{RRM}	40	V
Maximum RMS Voltage	V_{RMS}	28	
Maximum DC Blocking Voltage	V_{DC}	40	
Maximum Average Forward Rectified Current 0.375" (9.5 mm) Lead Lengths at $T_L = 95^\circ\text{C}$	$I_{(AV)}$	5	A
Peak Forward Surge Current 8.3 ms Single Half Sine-wave Super Imposed on Rated Load (JEDEC Method)	I_{FSM}	150	
Maximum Forward Voltage at 5 A dc	V_F	0.55	V
Maximum DC Reverse Current at $T_J = 25^\circ\text{C}$ Rated DC Blocking Voltage at $T_J = 100^\circ\text{C}$	I_R	1 50	mA
Typical Junction Capacitance (Note 1)	C_J	500	
Typical Thermal Resistance (Note 2)	$R_{\theta JA}$	15	$^\circ\text{C}/\text{W}$
Operating Temperature Range	T_J	-55 to +125	$^\circ\text{C}$
Storage Temperature Range	T_{STG}	-55 to +150	

对比与测试

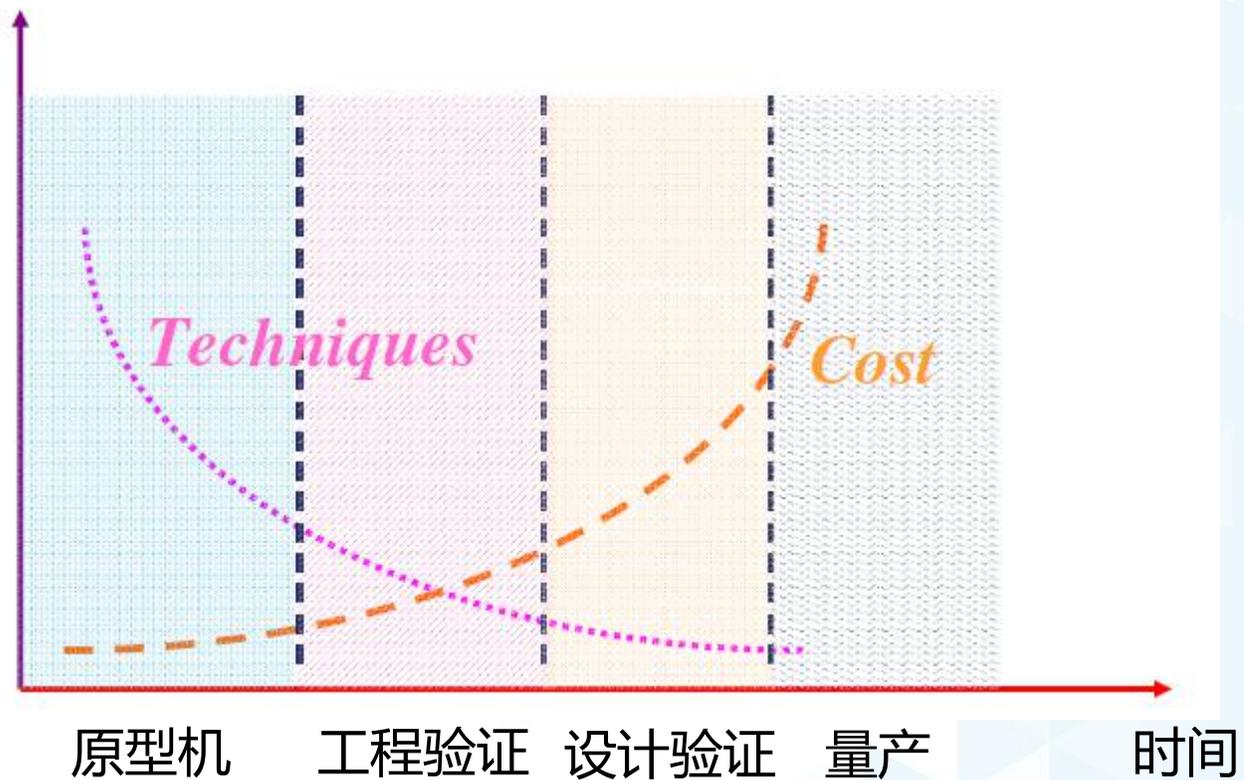


第三讲：EMC基础 介绍

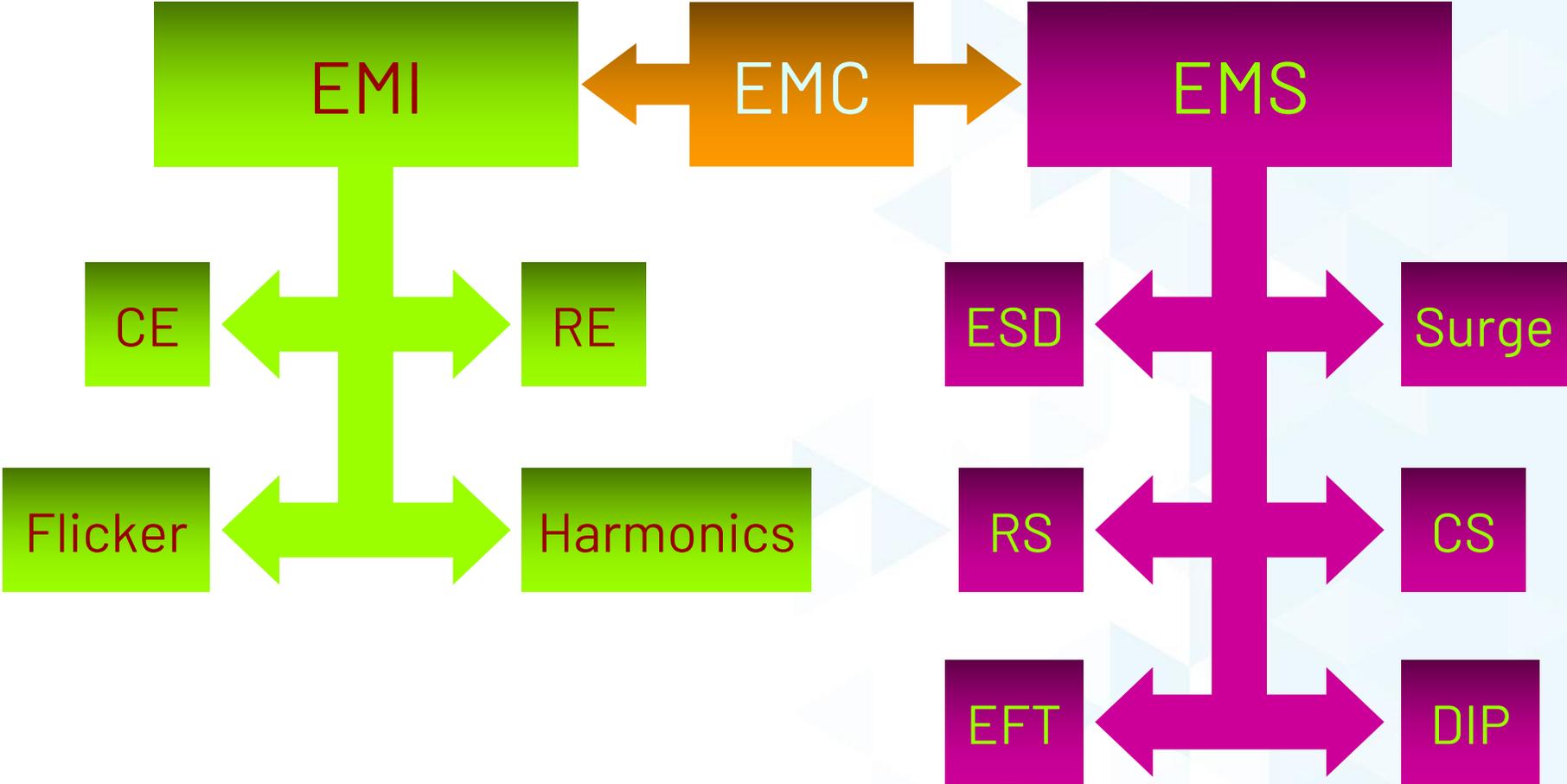


微信扫描二维码
获取课程观看链接

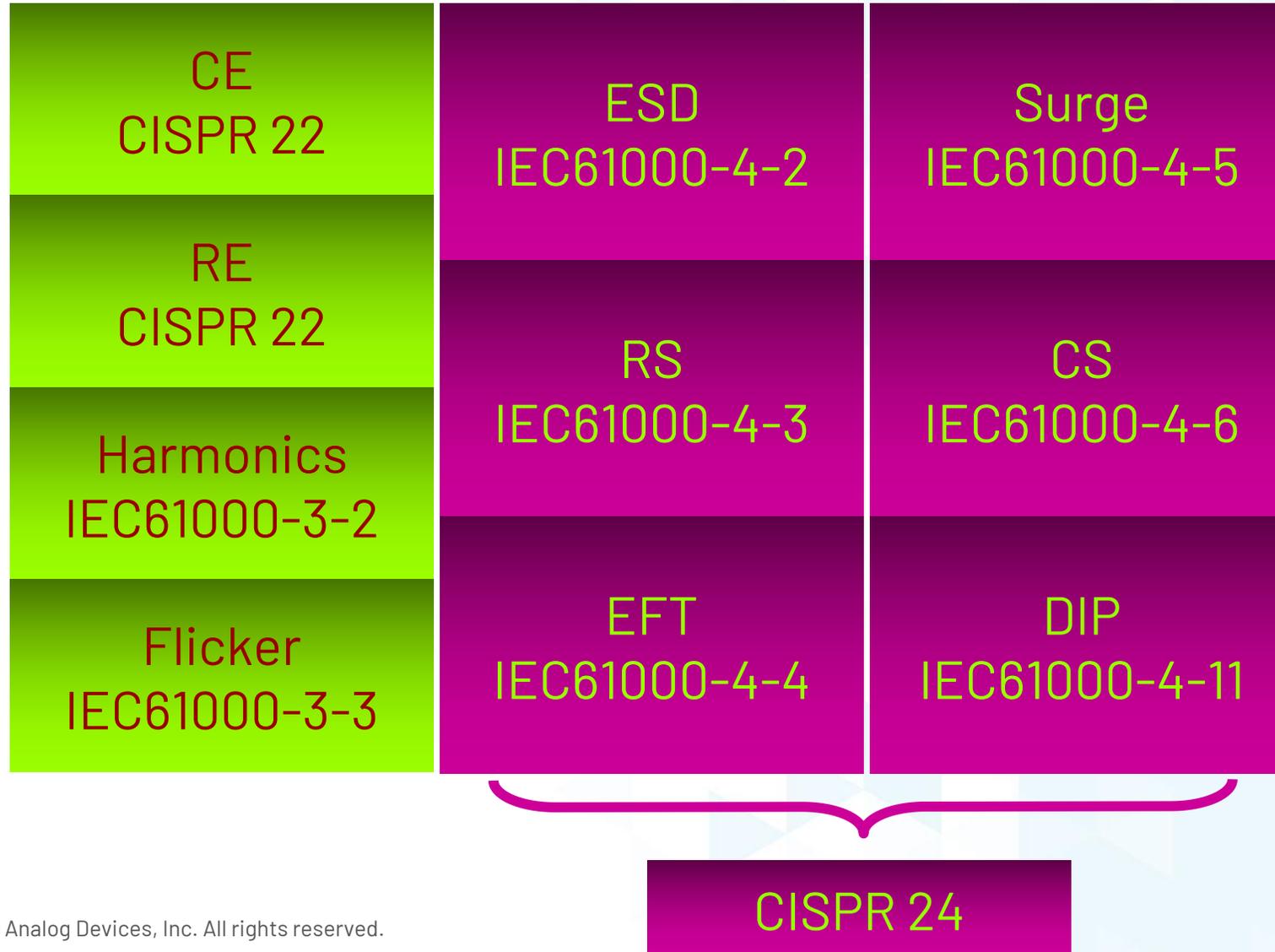
EMC技术手段、成本 vs 时间



电源产品常用EMC测试



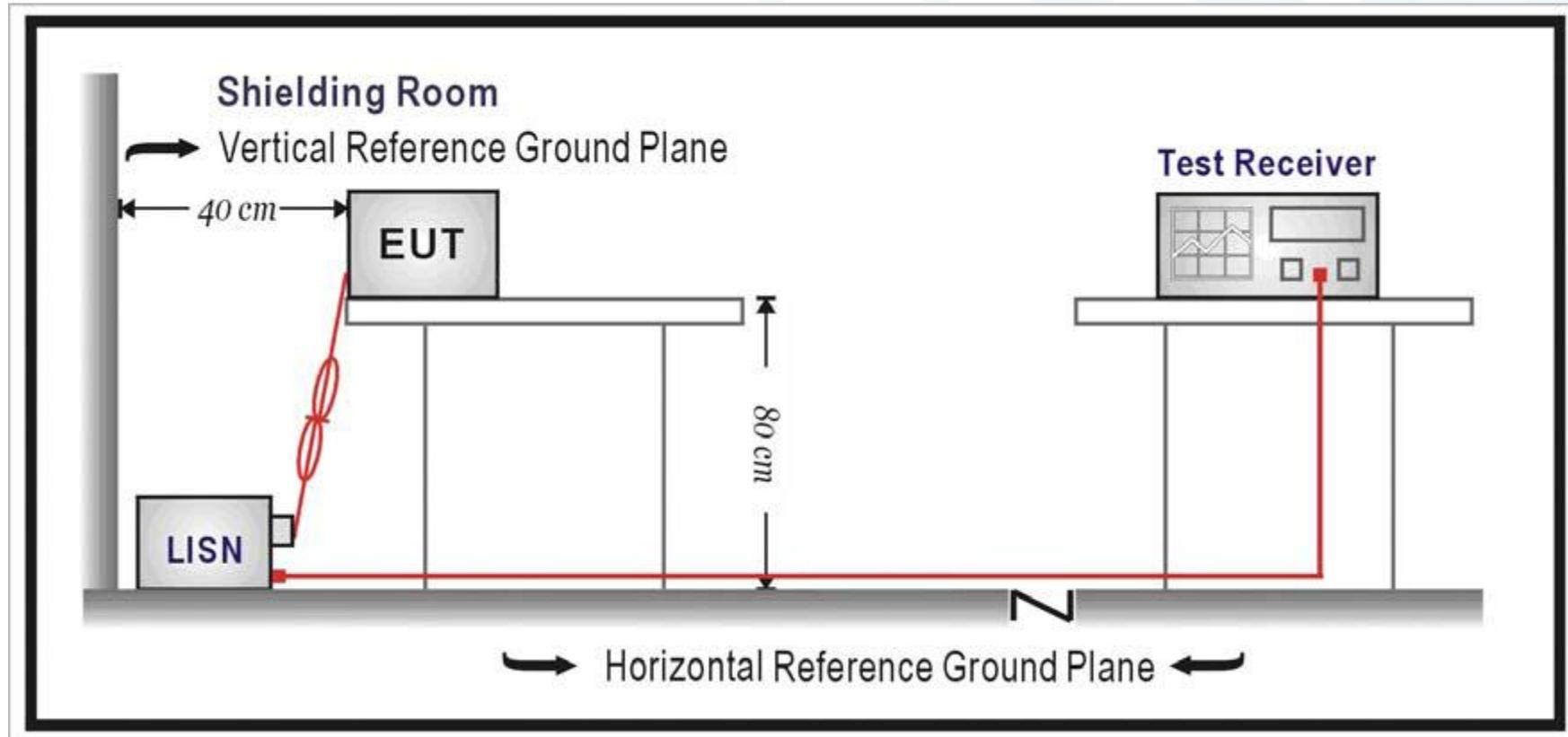
对应标准



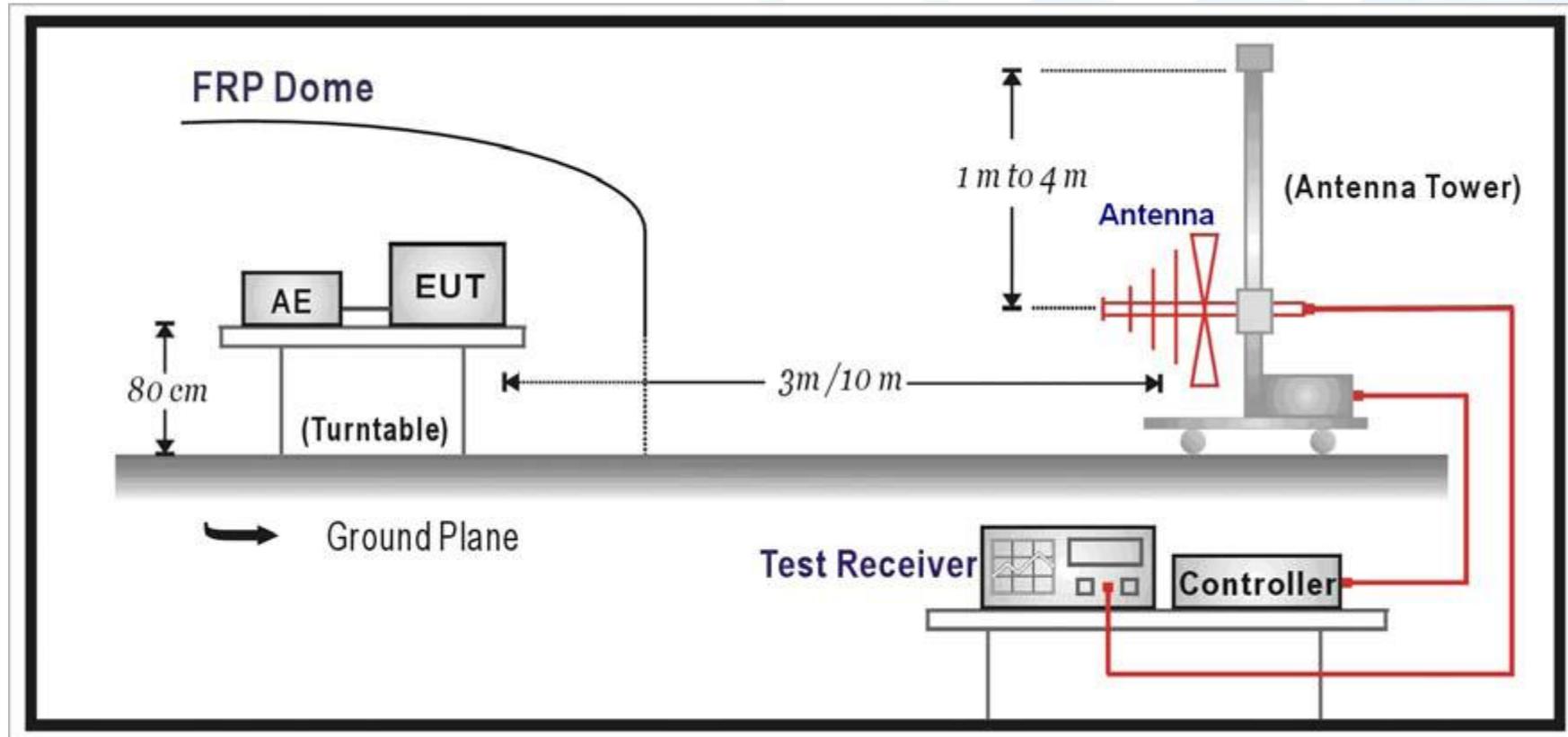
EMI发射类标准分类

应用	中国国标	欧盟标准	国际标准
工业医疗	GB4824	EN55011	CISPR11
音视频设备	GB13837/6	EN55013	CISPR13
家用设备	GB4343	EN55014	CISPR14
电气照明	GB17743	EN55015	CISPR15
信息技术	GB9254	EN55022	CISPR22
汽车电子	GB18655	EN55025	CISPR25

传导发射setup



辐射发射setup

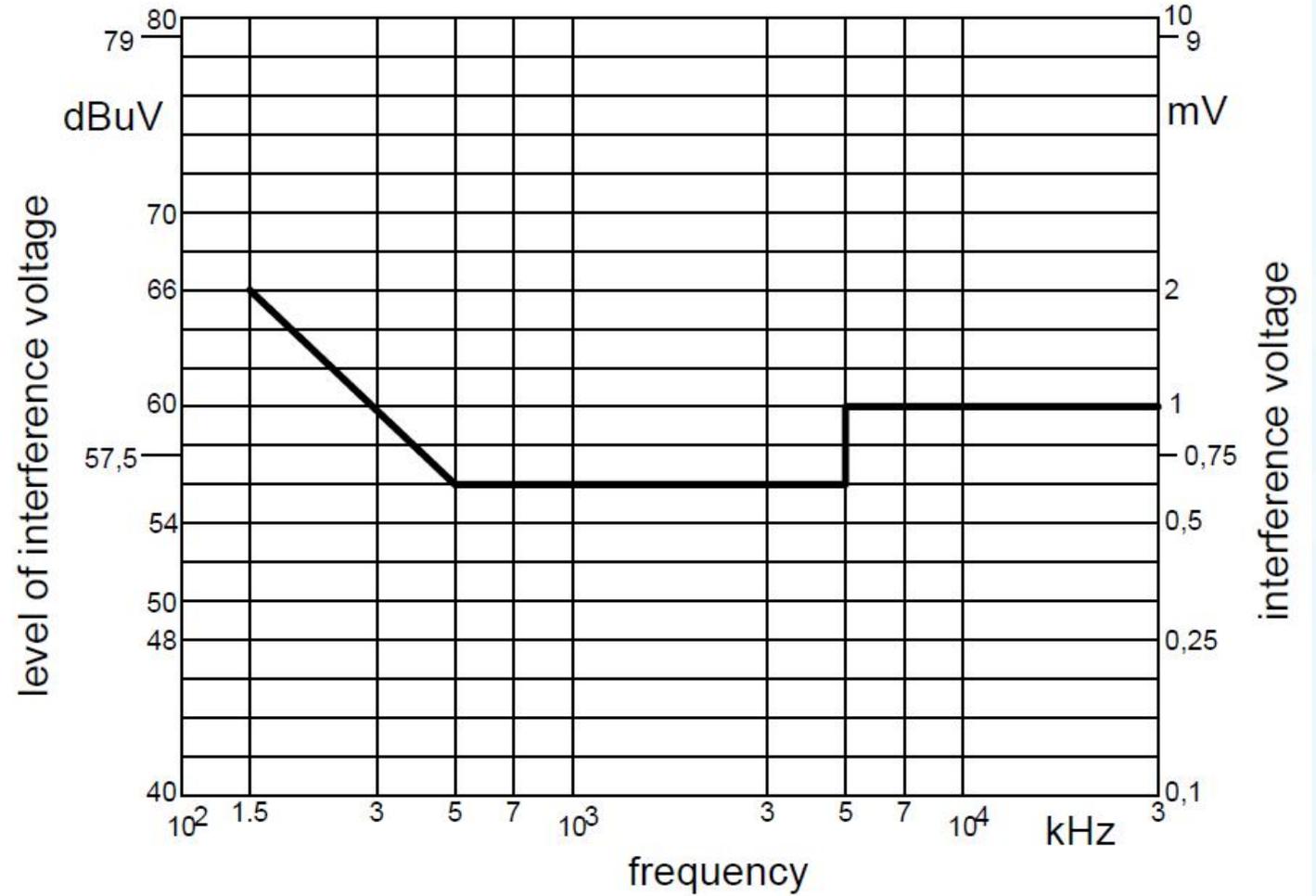


限值单位

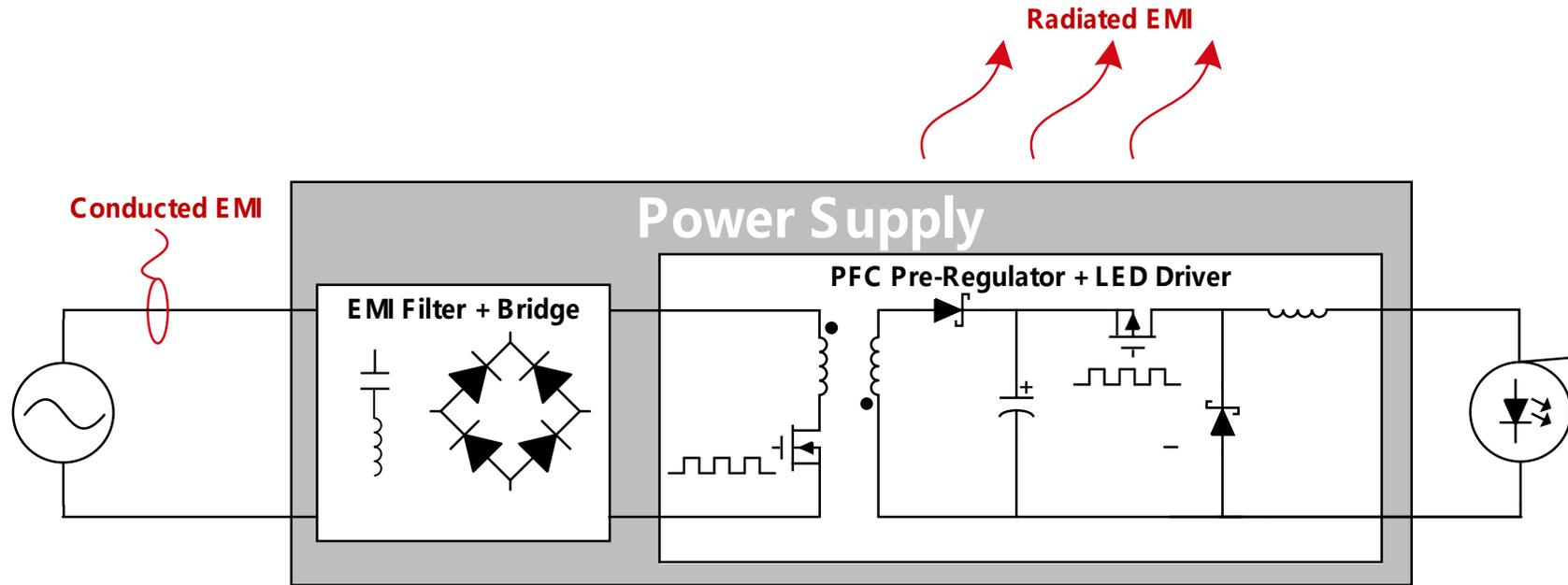
dBuV mV

$dBuV = 20 \log(V/V_{ref})$ $V_{ref} = 1\mu V$

40dBuV = 100uV



为什么需要EMI滤波器?

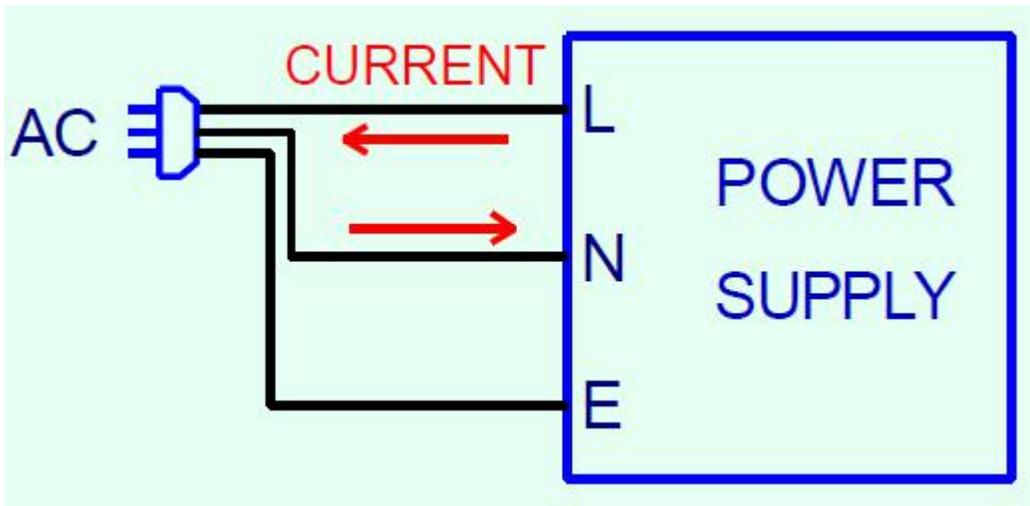


标准限制了电源产生的EMI

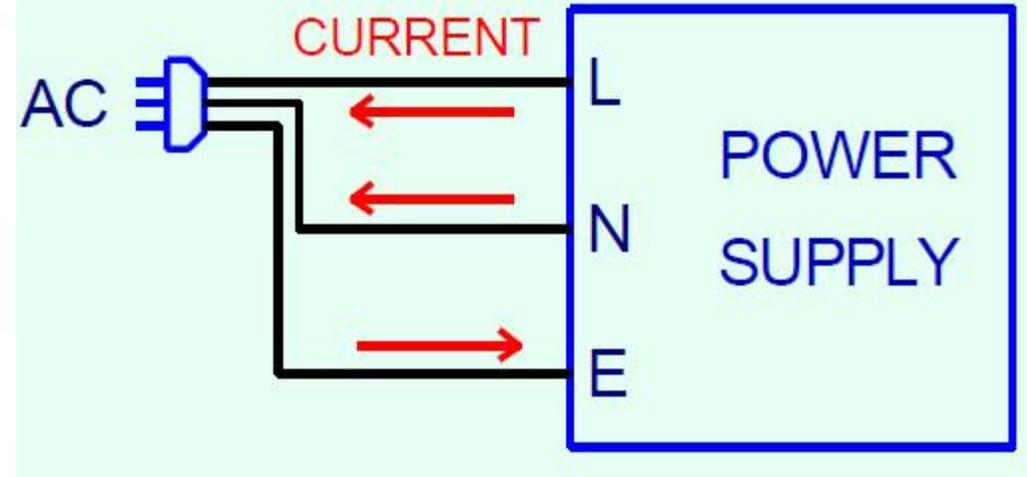
- 传导是通过输入线 需要滤波器衰减
- 辐射是通过空间 EMI滤波器没有帮助

传导干扰分类

- 差模干扰
 - 电流在正负线上，大小相等方向相反
 - 低中频段

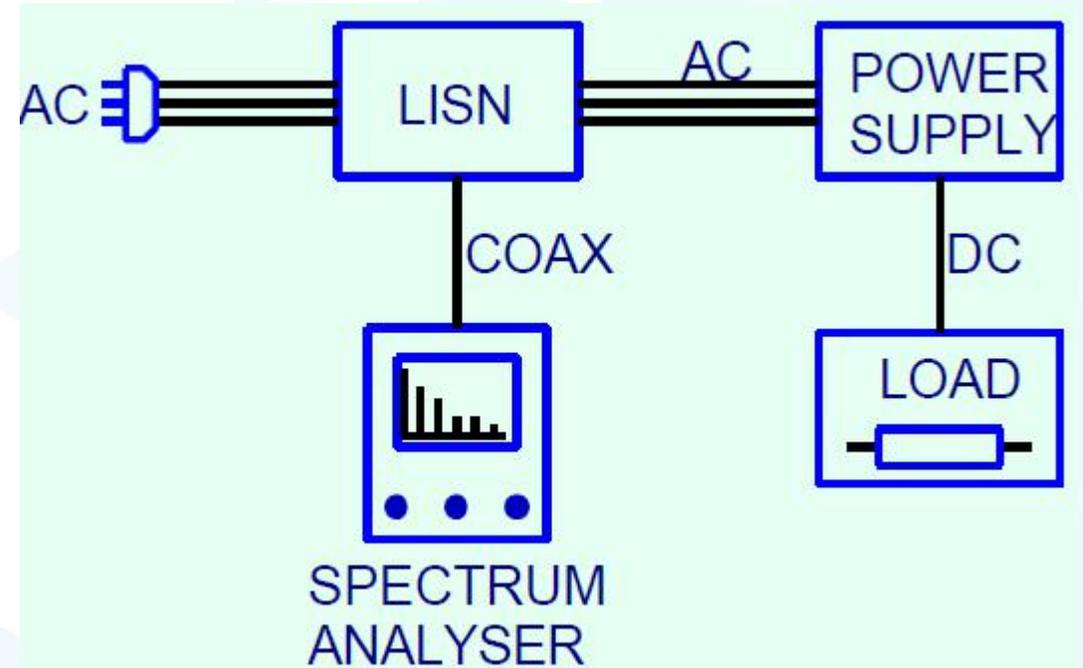


- 共模干扰
 - 电流在正负线上电流方向相同
 - 需要借助于地线回流
 - 中高频段



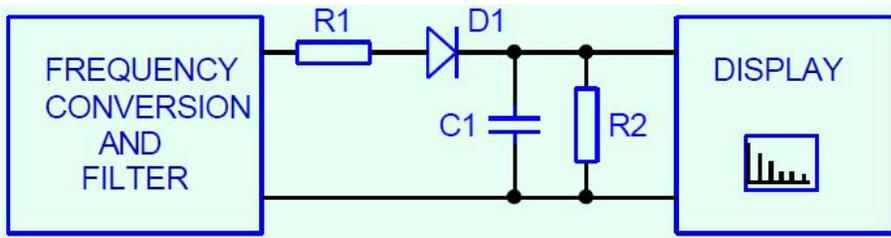
传导测试SETUP

- LISN(线路阻抗稳定网络)
- SPECTRUM Analysis (频谱分析仪)
- Power supply (EUT/DUT)-待测设备
- LOAD-考虑纯电阻负载

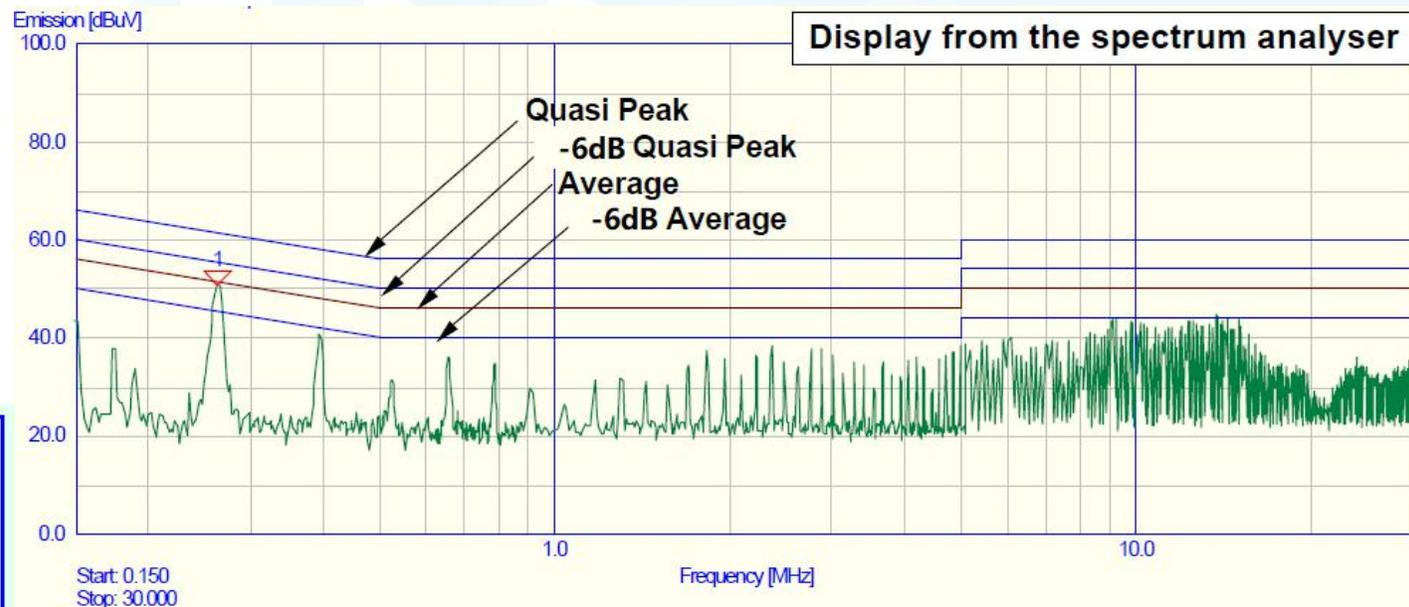
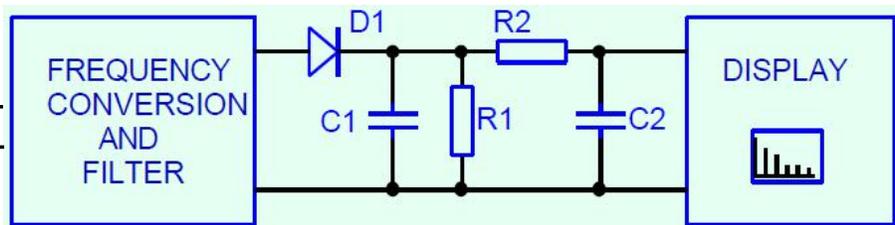


传导EMI如何被测量?

准峰值



平均值



CISPR22 CLASSB 传导限值 (准峰值, 平均值)

LISN

150KHZ下的阻抗

1uF: 1.06ohm

50uH: 47ohm

100nF: 10.6ohm

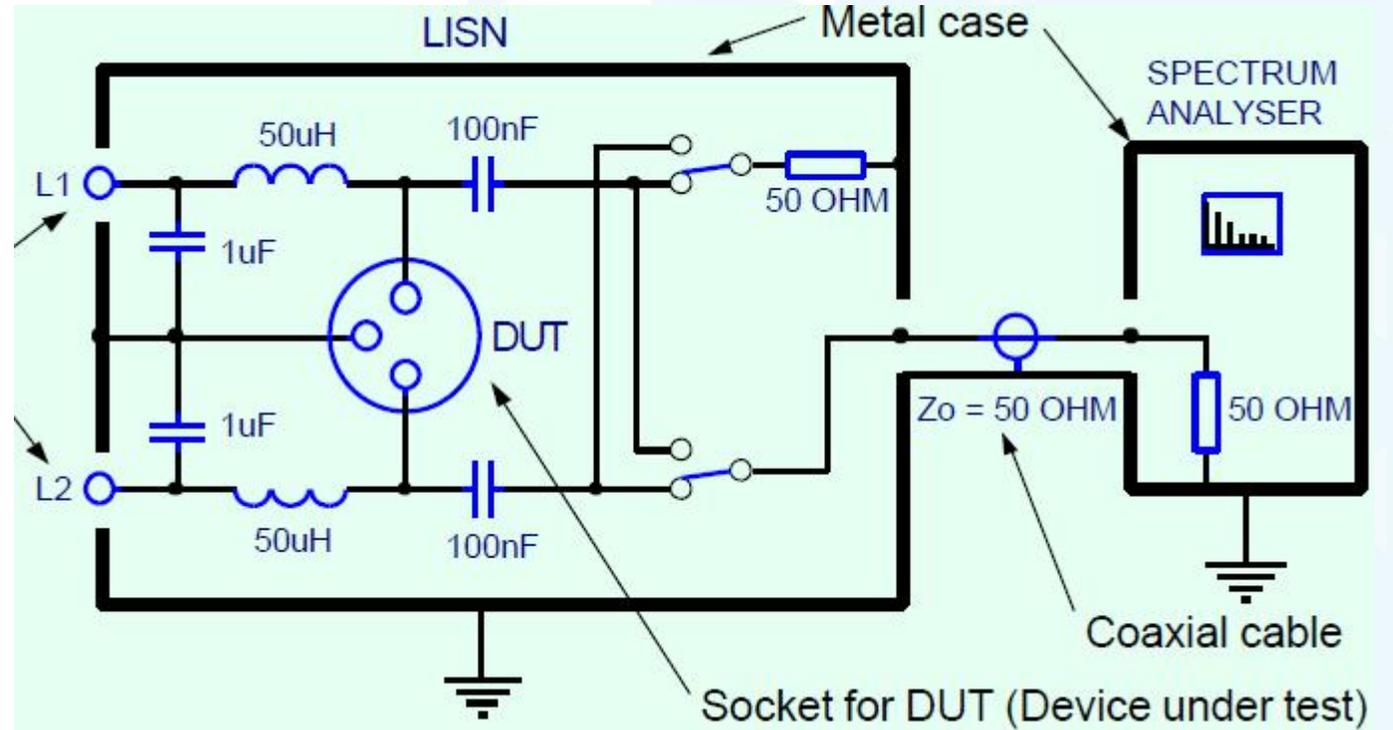
1.5MHZ下的阻抗

1uF: 0.106ohm

50uH: 470ohm

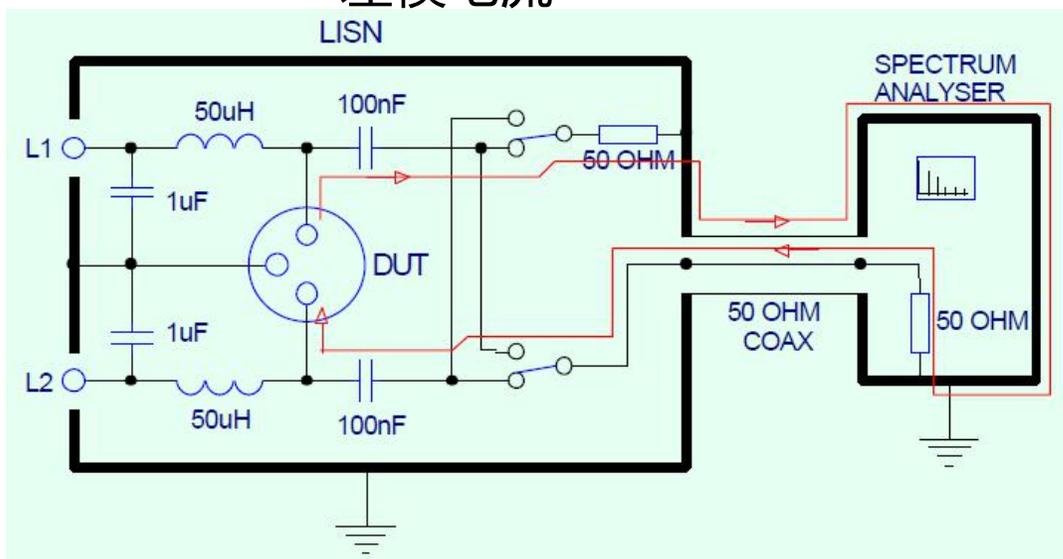
100nF: 1.06ohm

高频时, 50ohm测量阻抗占主导



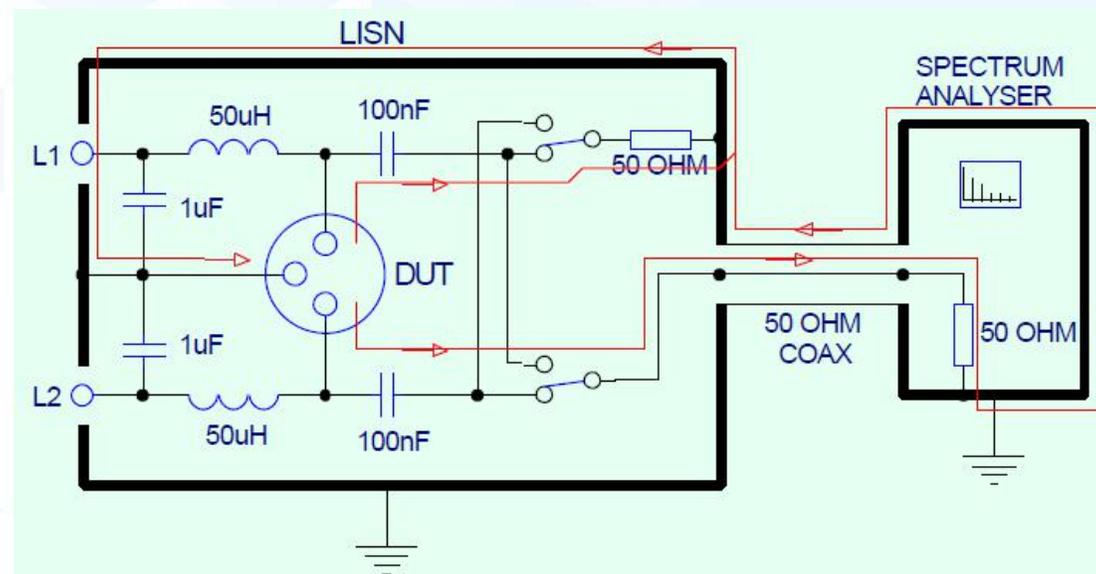
传导EMI如何被测量?

差模电流



总的线路阻抗是100欧姆 (50+50)

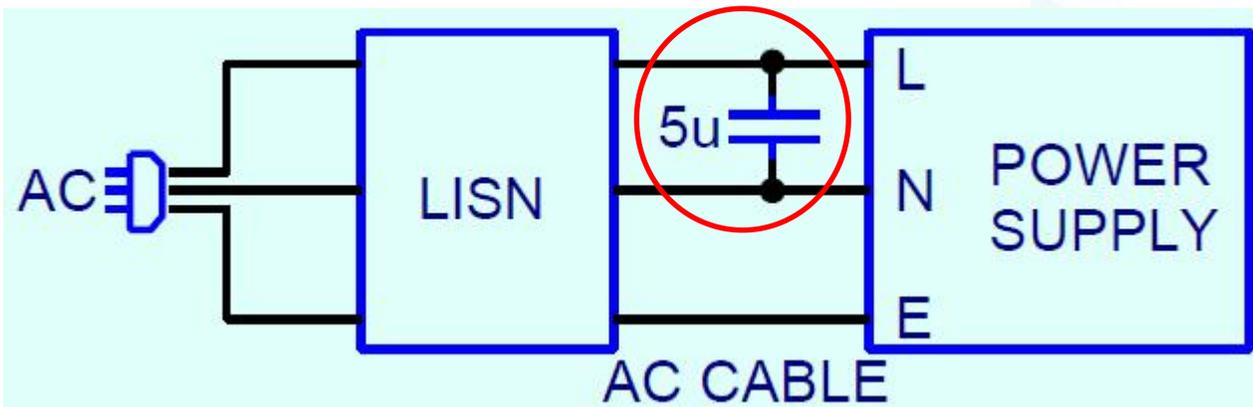
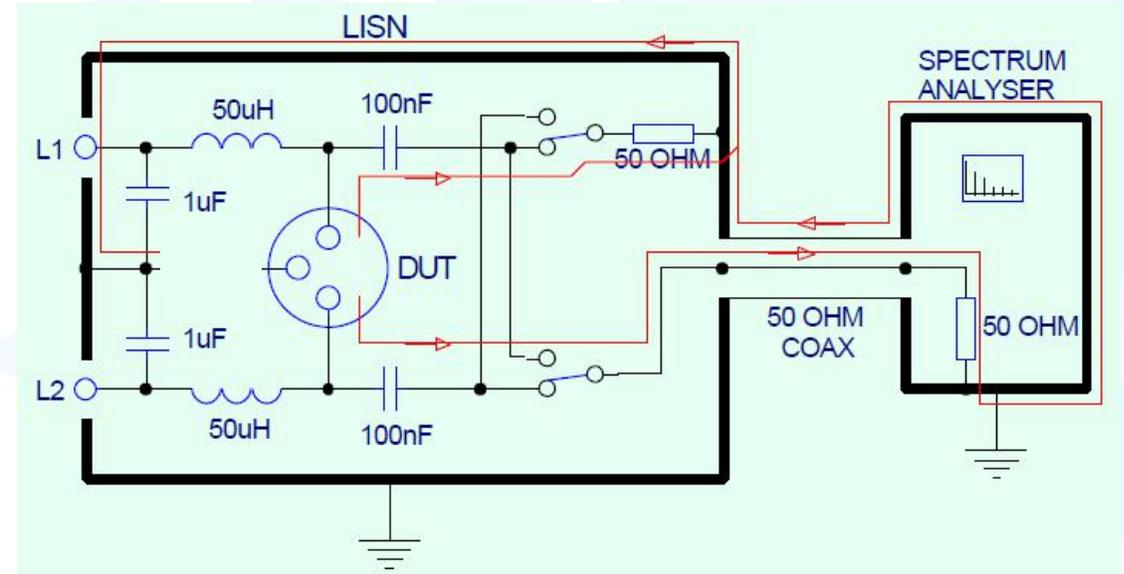
共模电流



总的线路阻抗是25欧姆 (50//50)

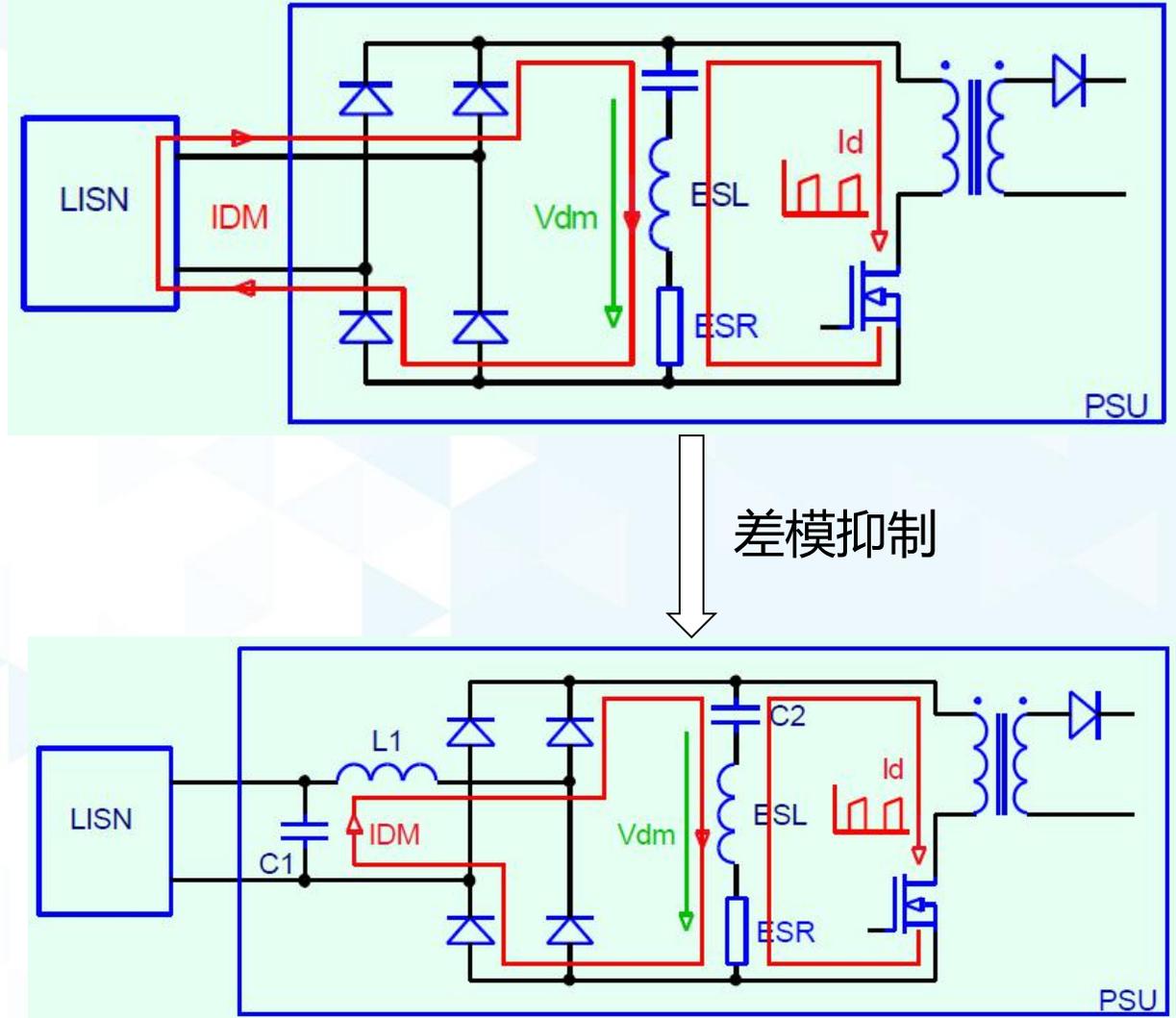
差共模区分

- 当传导发射超限值时，经常会被问到的问题：
是差模超标还是共模超标？
- 如何区分？
 - 断开地线，断开共模的回路；
 - 在输入端口外加大的X电容。



小功率差模路径传输

- ▶ 差模电流的形成
 - ▶ V_{dm} 取决于 ESL 和 ESR di/dt
 - ▶ 回路阻抗很低，主要是 100 欧姆
-
- ▶ L1C1 构成低通滤波
 - ▶ L1 通常几十到几百 μH ，或者是共模电感的漏感
 - ▶ C1 通常是 0.1 μF 到 1 μF (低 ESR、ESL)

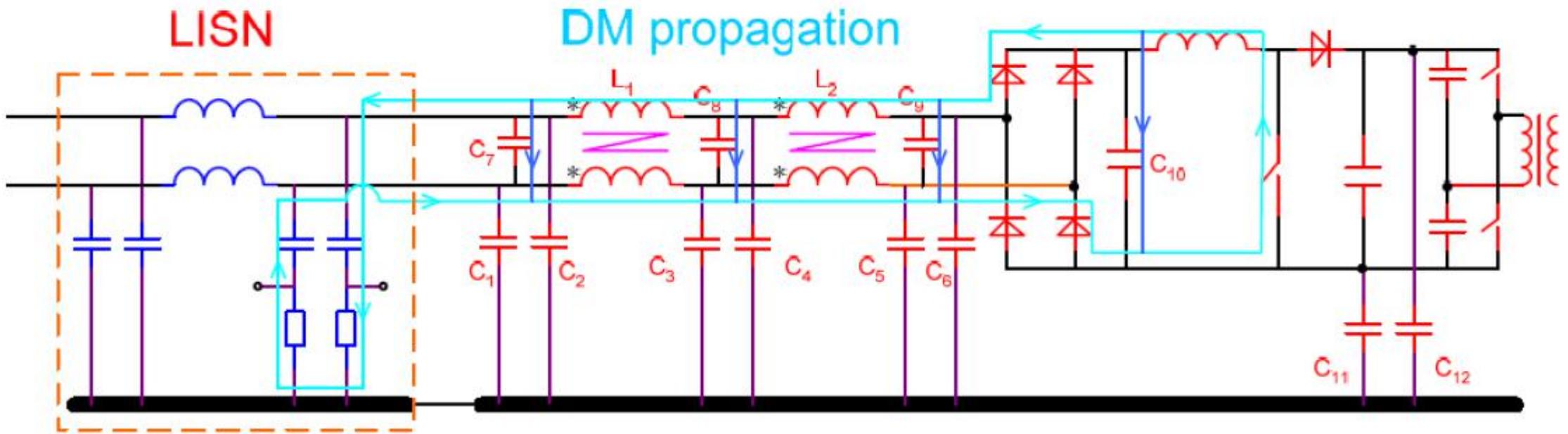


大功率差模路径传输

噪声源：纹波电流

传输路径：正负线之间

如何抑制：差模电感、差模电容



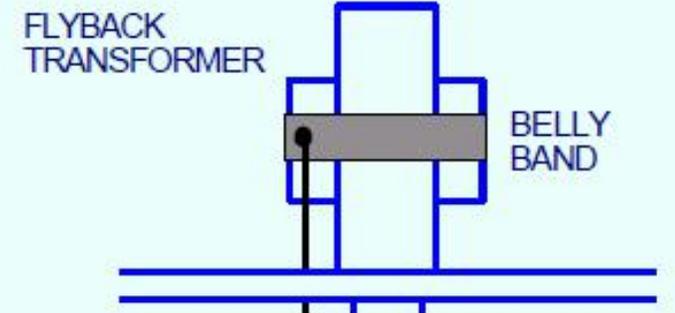
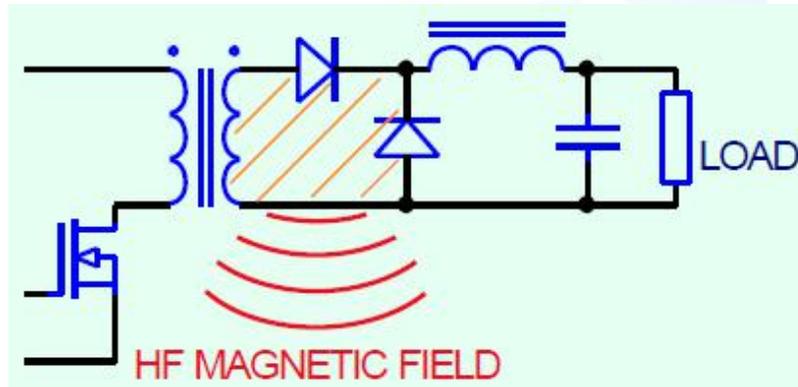
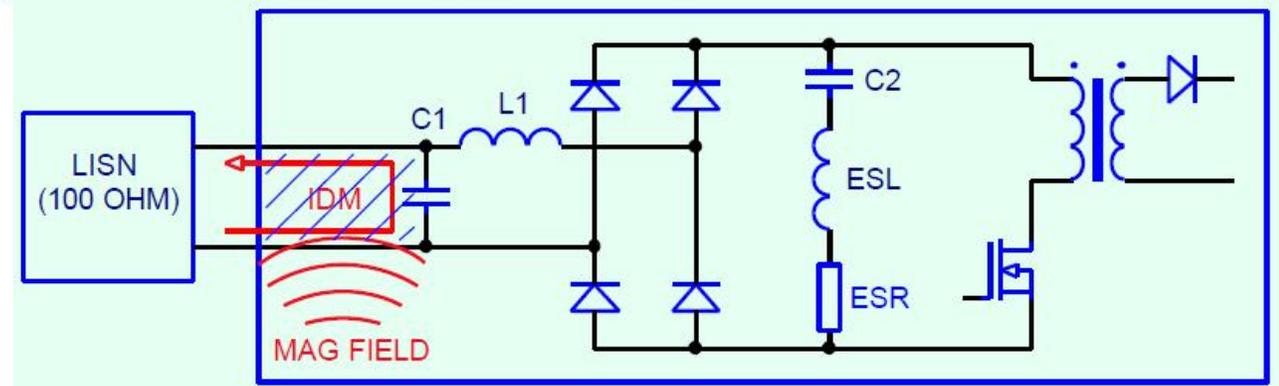
差模滤波器干扰

➤ 当差模超出限值 加大LC滤波
加大电容C, 没什么效果, 再加大, 甚至变差!

➤ 什么原因? 不是差模超标?

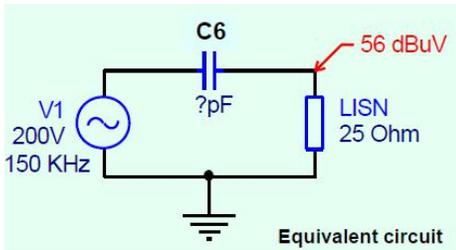
- 空间磁场干扰
- 反激变压器漏磁
- 高频电流环

C1尽可能靠近输入口;
用双绞线至插座;
将C1放入屏蔽腔。



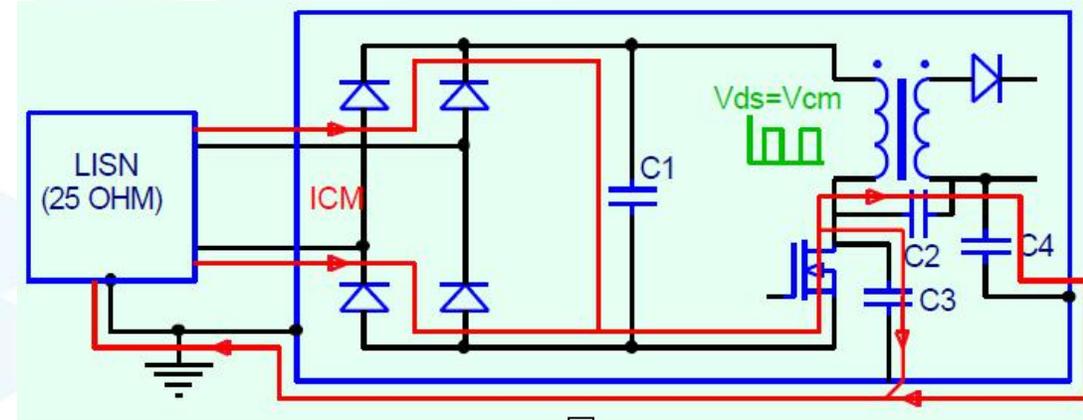
小功率共模路径传输

- ▶ 共模电流的形成 (高dv/dt)
- ▶ 漏极到安全地的寄生电容 (C3,C2)
- ▶ 只要很小的寄生电容就会超标。

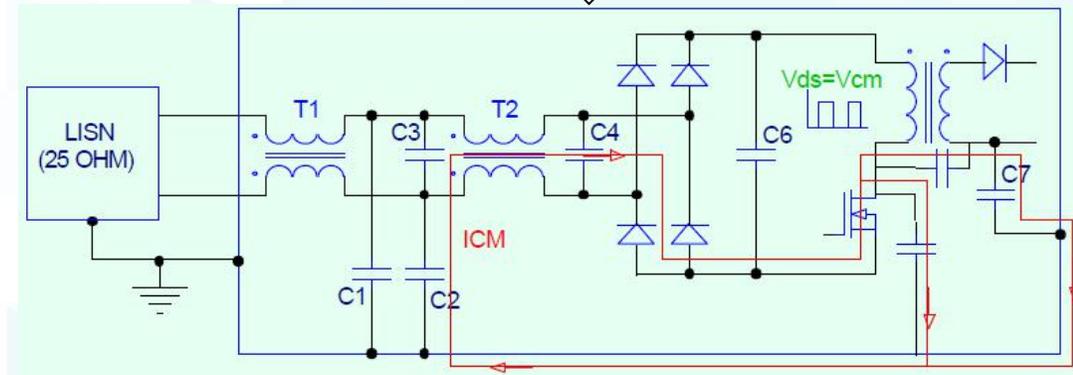


仅仅
0.067pF!!!!

- ▶ T2C1C2构成低通滤波
- ▶ C1C2受漏电流限制 (1nF到4.7nF)
- ▶ T1T2通常1mH到10mH



共模抑制

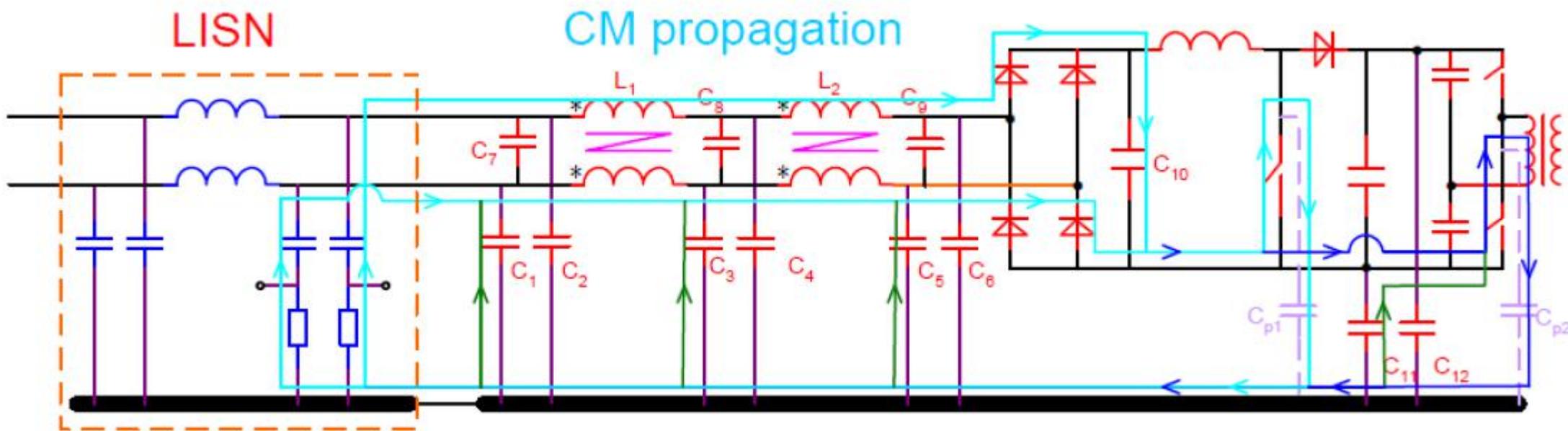


大功率共模路径传输

噪声源：开关节点的高dv/dt

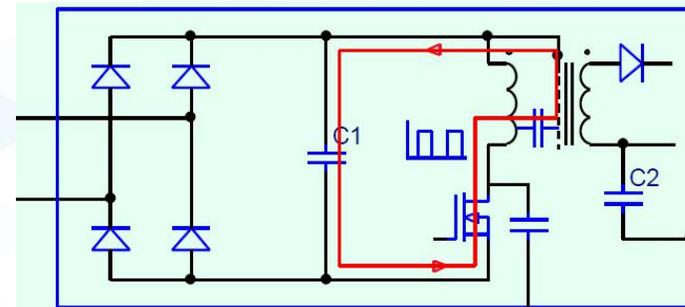
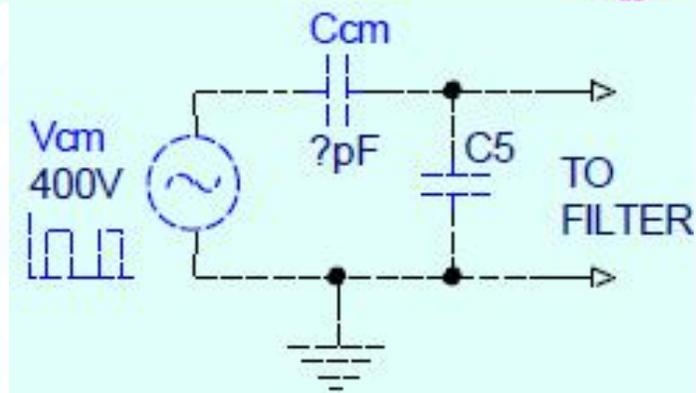
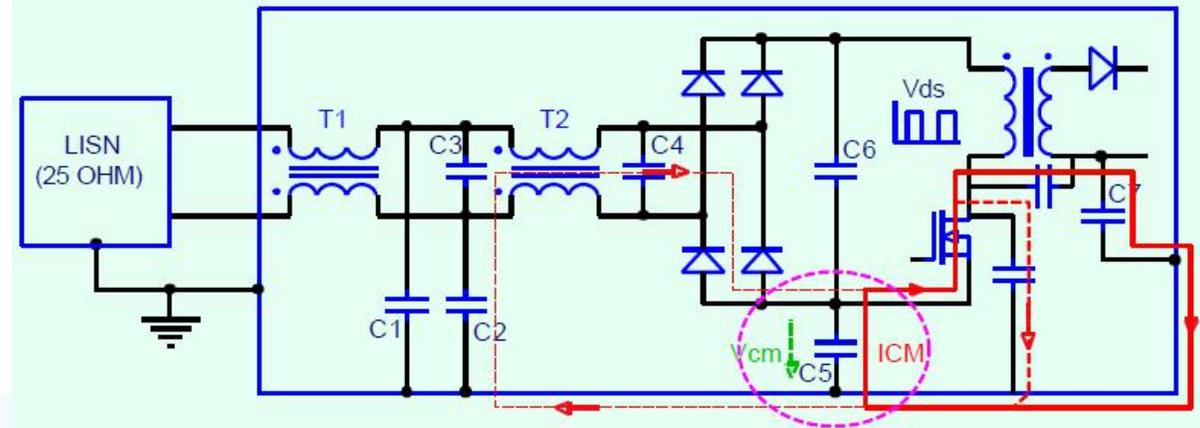
传输路径：正负线和PE（保护地，机壳）之间

如何抑制：共模电感、共模电容

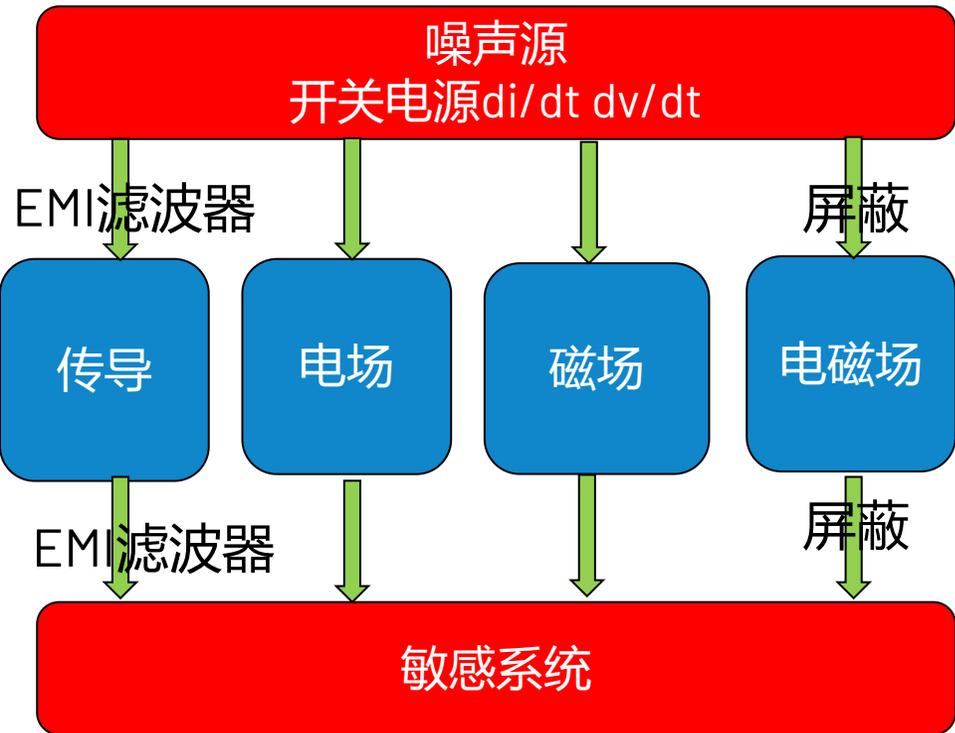


共模抑制

- ▶ 增加电容C5
- ▶ C5提供最直接的共模电流返回路径
- ▶ C5和漏级到壳的寄生电容构成分压网络
- ▶ C5为寄生电容的10倍，共模变成原来的1/10.
- ▶ 减小漏极到壳的寄生电容C_{cm}
- ▶ 将散热器接静点
- ▶ 散热器不能接壳
- ▶ 减小漏极PCB走线到壳的寄生电容
- ▶ 减小变压器原副边寄生电容



EMI问题考虑



找出重要的EMI干扰源

找出关键路径

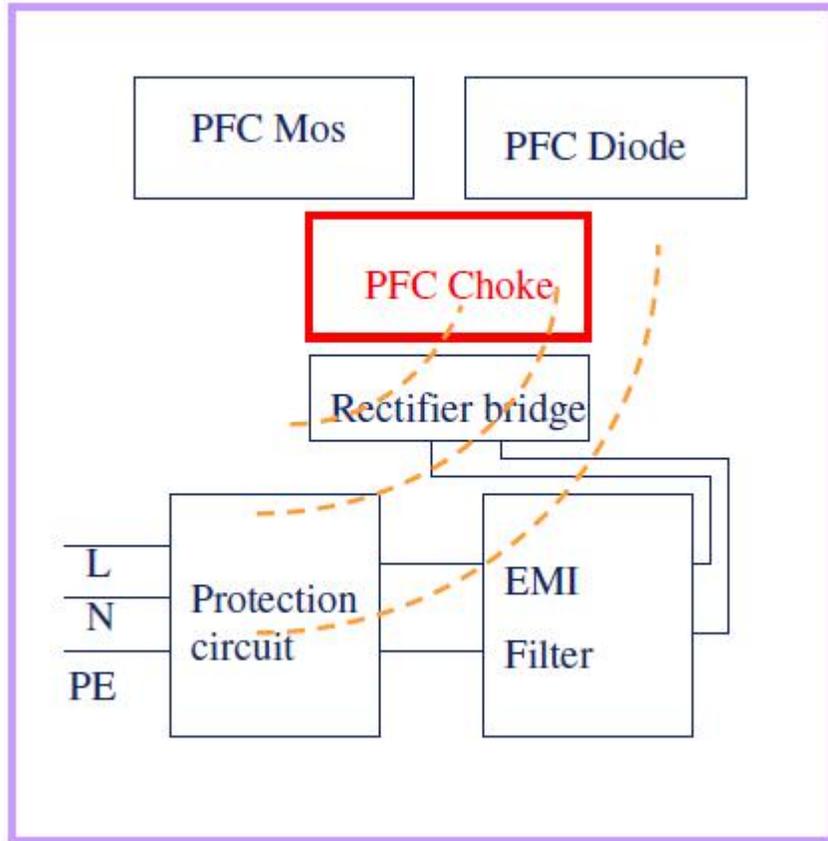
寻找合适的IC和优化PCB布局

增加EMI滤波器、吸收电路、屏蔽等

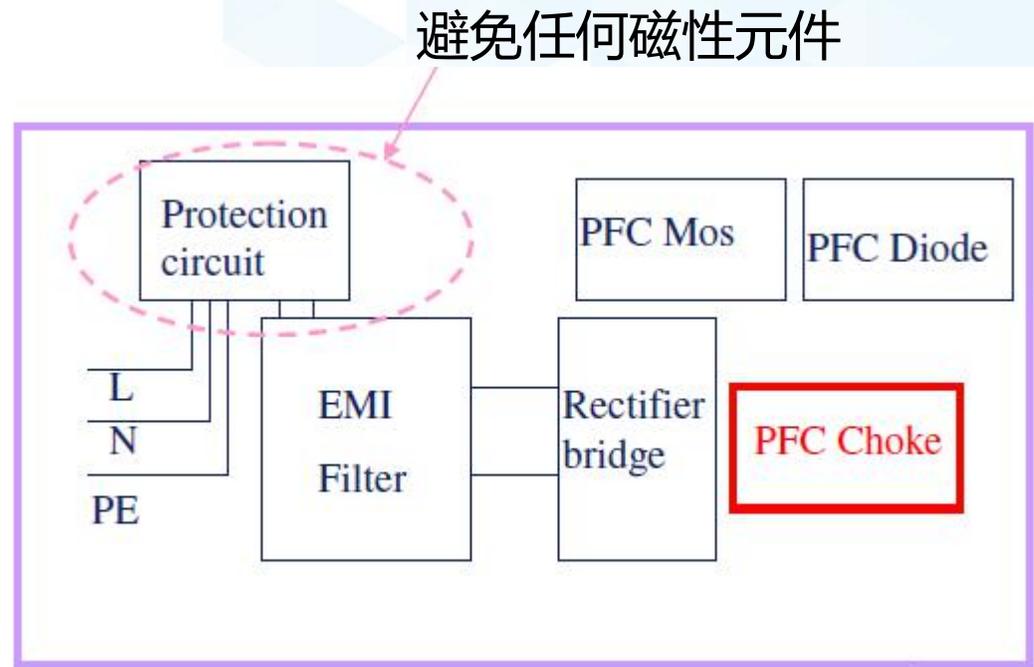
常见EMI处理对策

- ▶ MOS管slew rate控制 (门极驱动电阻、漏源极snubber)
- ▶ MOS管二极管电流斜率控制 (磁珠)
- ▶ 减小磁场天线效应 (找出 di/dt 环并减小、变压器加腰带)
- ▶ 减小电场辐射 (找出 dv/dt 并找出寄生耦合电容并减小、变压器做屏蔽、Y电容等)
- ▶ 滤波器 (差模filter、共模filter、高频磁珠)
- ▶ 采用抖频技术

开关电源器件布局



错误



正确

开关电源EMC设计检查清单

序号	检查内容
1	充分考虑PCB layout, 元器件放置要顺着功率流方向
2	EMI滤波器要尽可能靠着输入端口
3	让PFC电感、变压器等磁性元件尽量远离输入端口和EMI滤波器
4	优先放置关键元件和关键PCB走线
5	找出高di/dt环路并减小, 考虑放置高频瓷片电容
6	找出高dv/dt节点并减小该节点对地寄生电容
7	减小X、Y电容走线寄生电感
8	在开关节点和开关二极管两端预留吸收电路
9	所有MOS管驱动预留驱动电阻
10	所有散热器接静点

关于ADI智库

ADI智库是ADI公司面向中国工程师打造的一站式资源分享平台，除了汇聚ADI官网的海量技术资料、视频外，还有大量首发的、免费的培训课程、视频直播等。九大领域、十项技术，加入ADI智库，您可以尽情的浏览收藏、下载相关资源。此外，您还可一键报名线上线下会议活动，更有参会提醒等贴心服务。





微信扫描二维码，获取《如何解决设计难点（第一部分）》观看链接

