如何解决设计难点（第一部分）

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一站式电子技术宝库

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第一讲：电荷泵电路原理及使用注意事项

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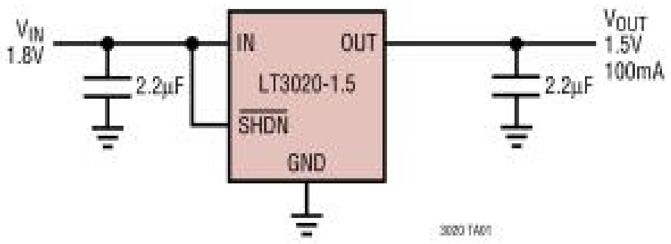
非隔离DC/DC变换器

LDO

（Linear Dropout Regulator）

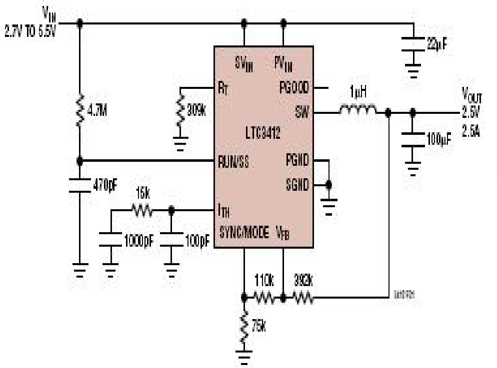
- 设计简单
- 低噪声
- 占板面积小
- 低效
- 只能降压
- 发热严重



开关变换器

（buck boost buck-boost）

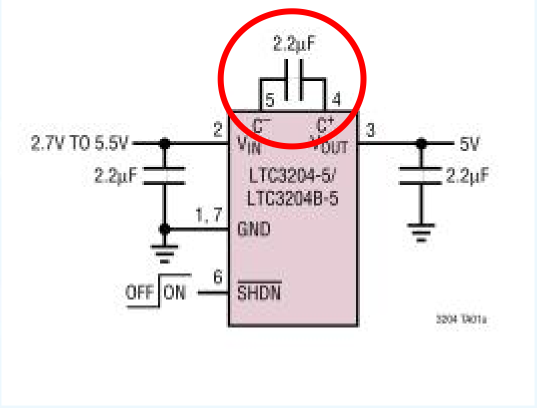
- 高效
- 大功率
- 可升压，可降压
- 需要电感
- 设计复杂
- 噪声



电荷泵

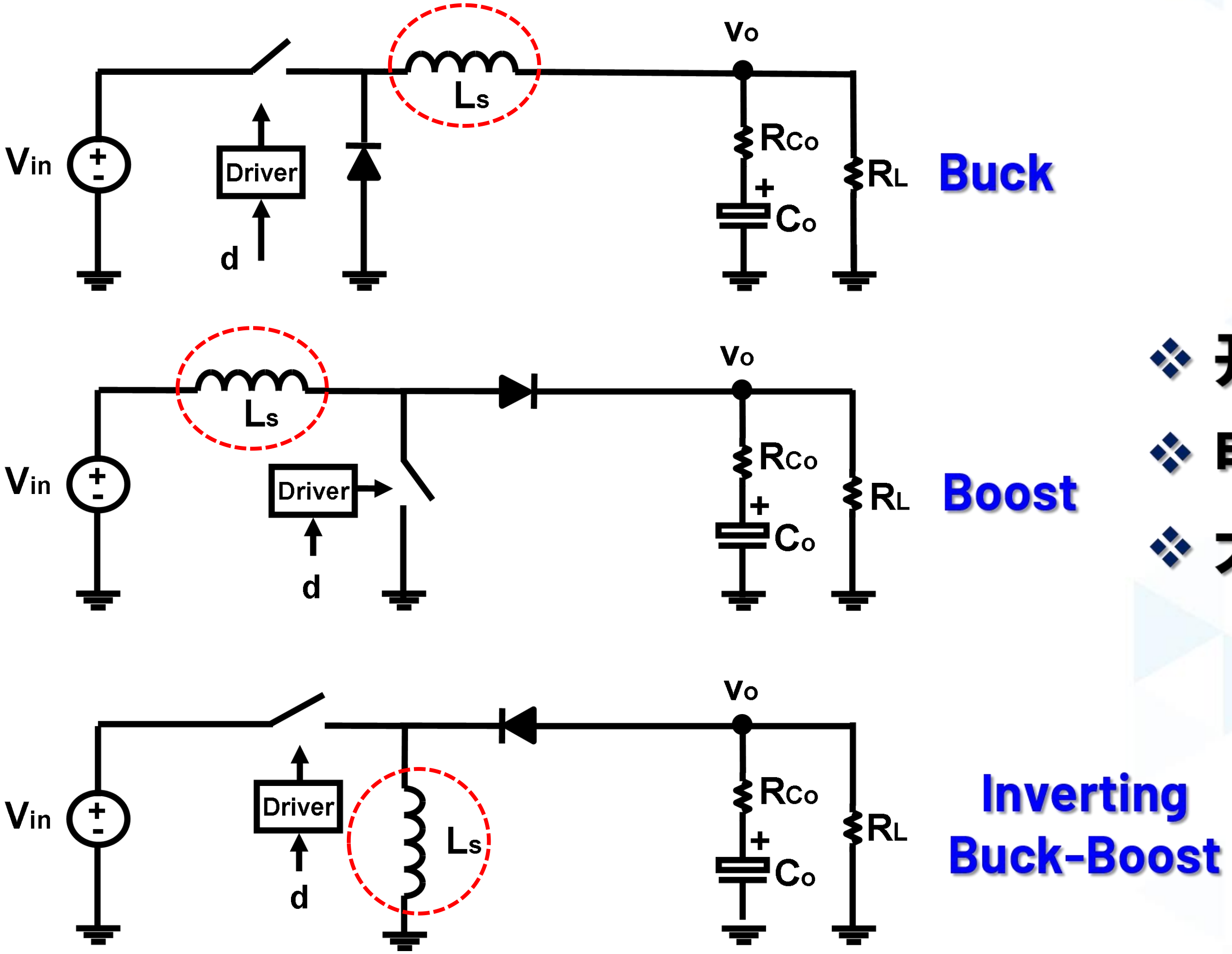
（switch CAP）

- 比LDO效率高
- 比开关变换器简单
- 比开关变换器小（没有电感）
- 电压可升可降
- 输出电流不大



传统非隔离开关变换器 vs 电荷泵

开关变换器



- **开关**
- **电容**
- **大电感**

⇨

- **开关**
- **电容**

电荷泵

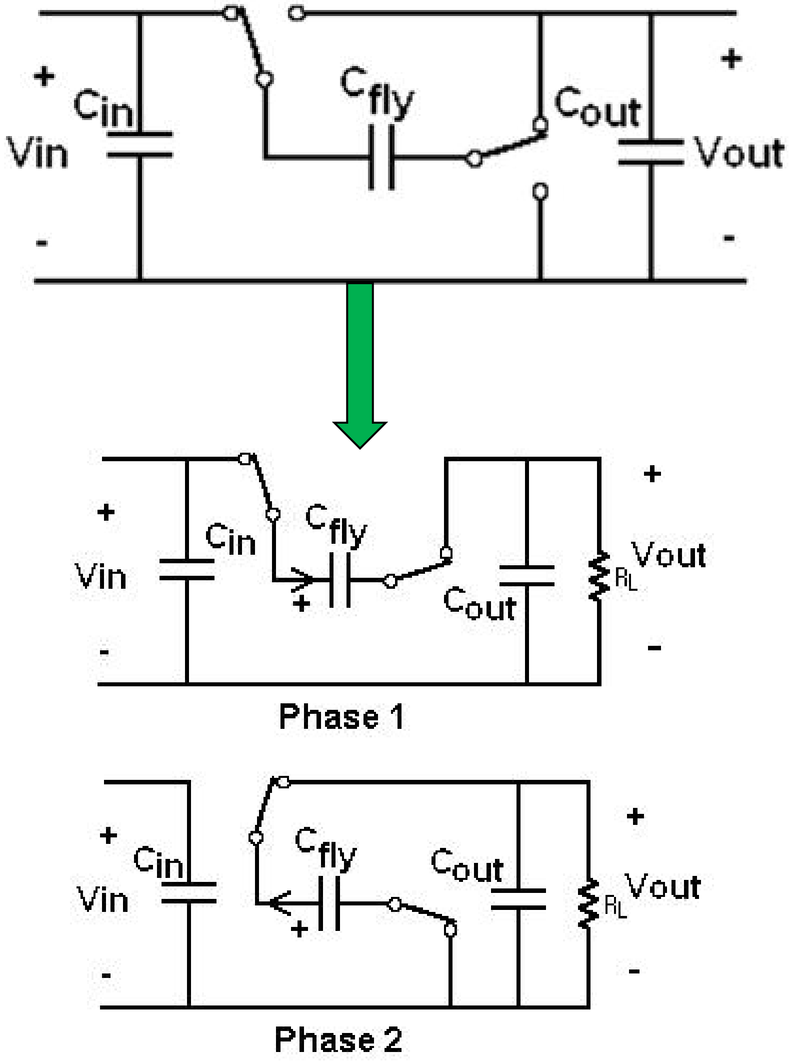
2： 1降压器

1： 2升压器

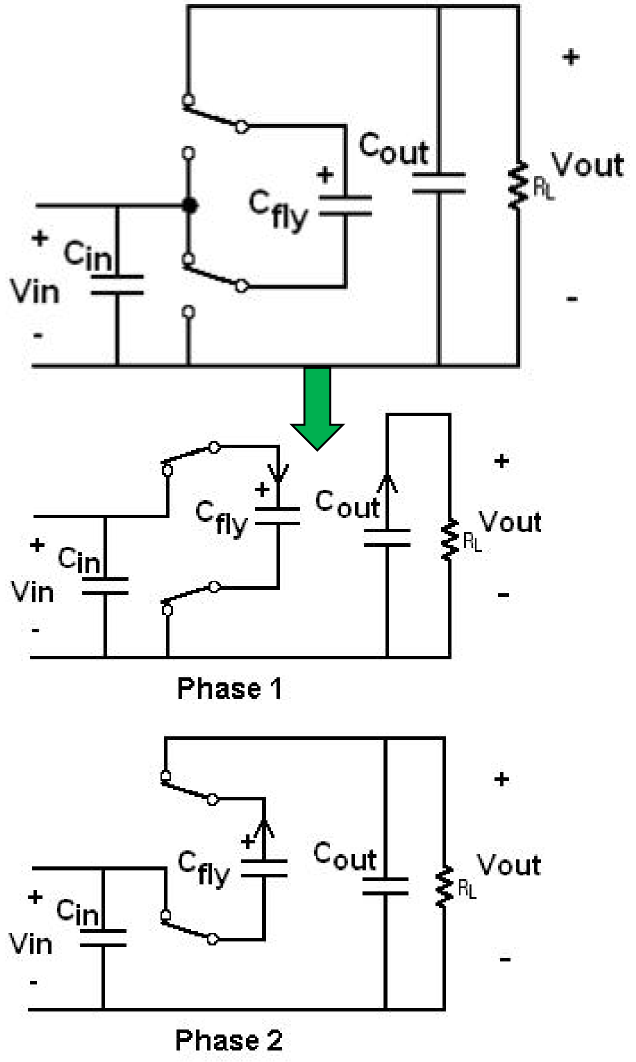
反压器

电荷泵基本电路

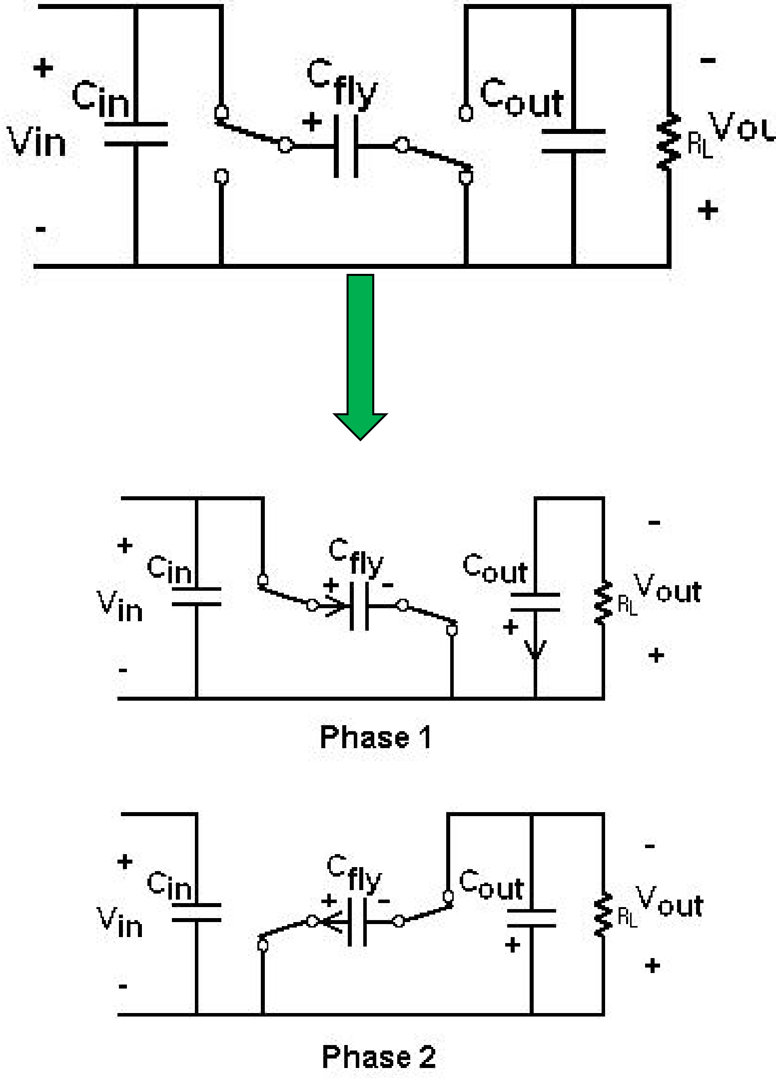
降压器(V_{out} ½V_{in})



倍压器(V_{out} 2*V_{in})



反相器(V_{out} -V_{in})



电荷泵扩展电路

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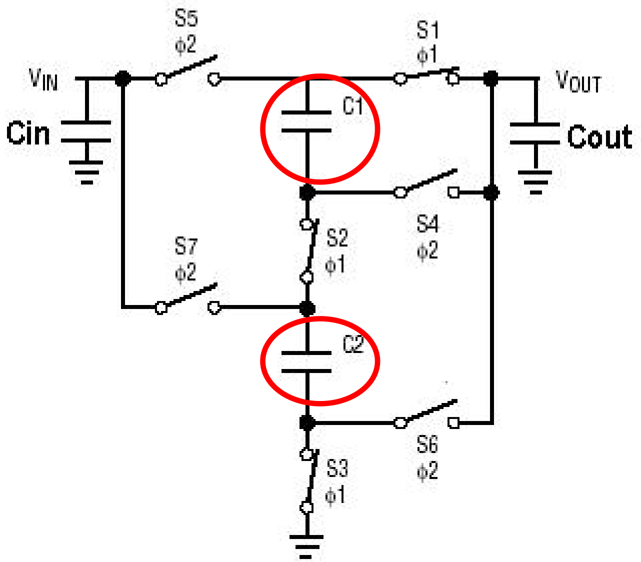
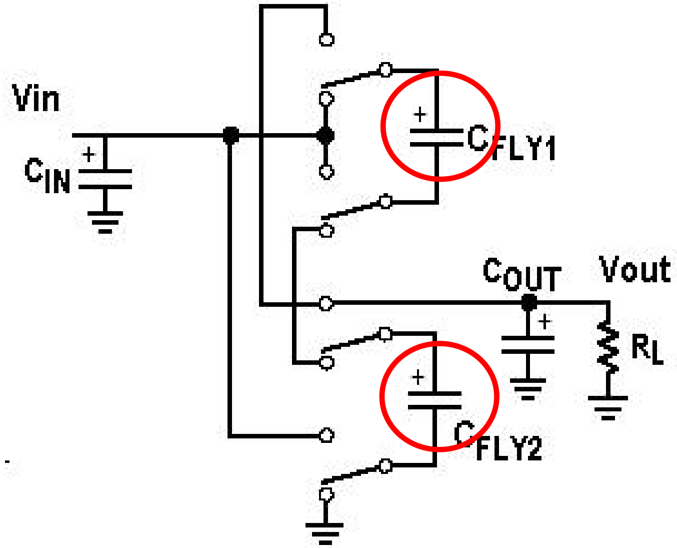
- 常规的电荷泵有1：2升压，2：1降压和1：-1反相；
- 当输入和输出不是以上的关系，怎么办?

V_{out} (2/3)V_{in}



V_{out} 1.5V_{in}

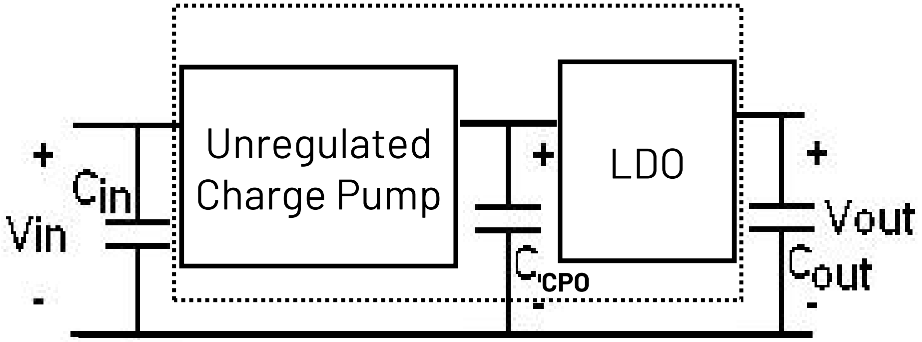


更多的飞跨电容和开关，可以产生更多的电压转换比！

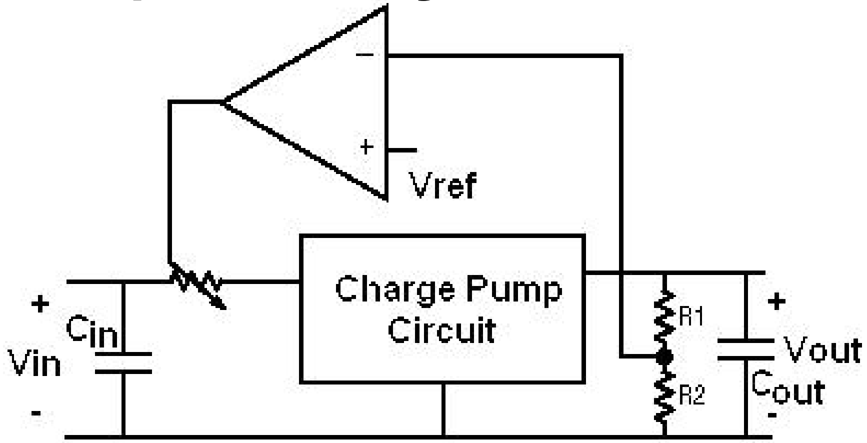
稳压电荷泵

- 当输入变化，如何得到一个稳定的输出？

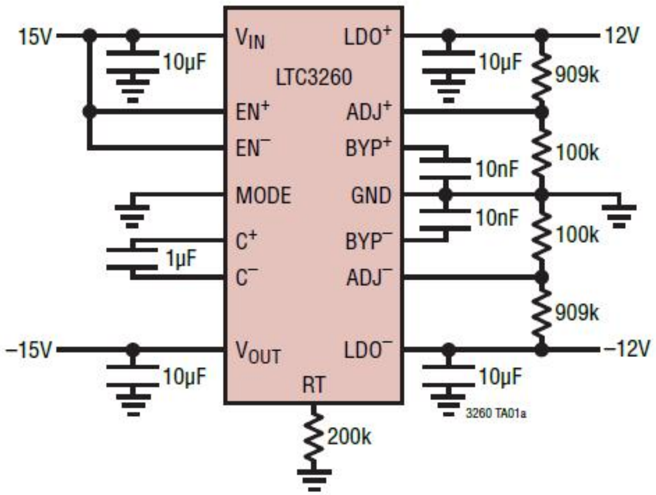
Charger pump + LDO

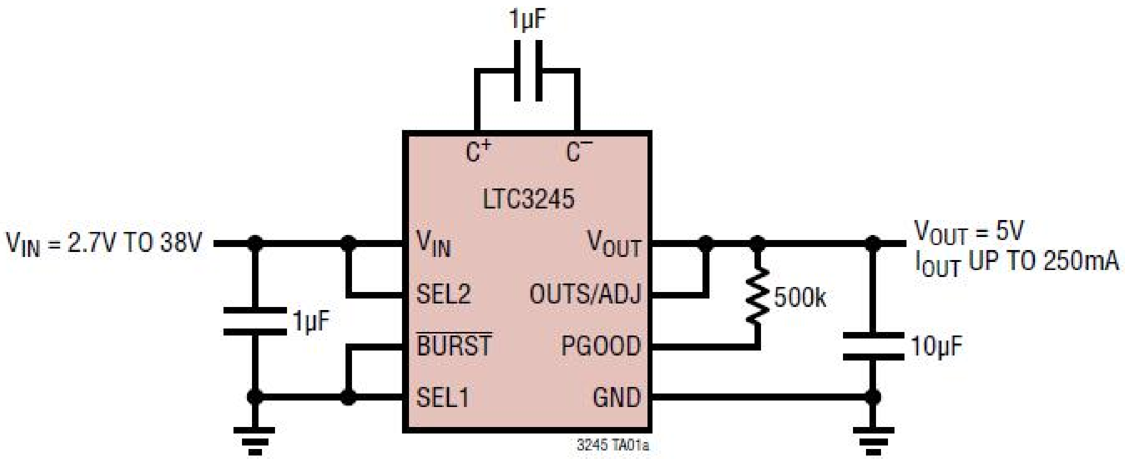


Input Pre-regulation



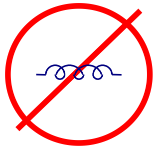
±12V Outputs from a Single 15V Input





DC/DC功率转换的技术对比

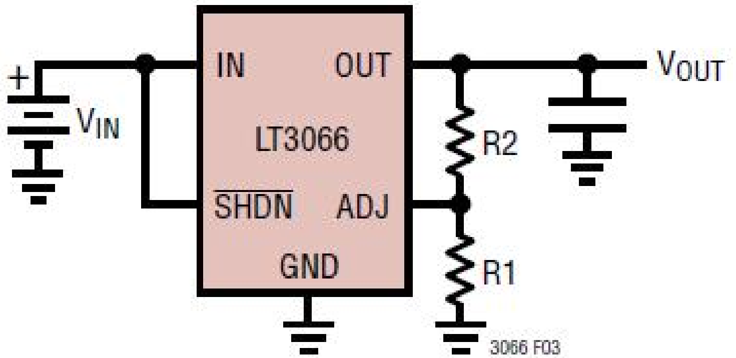
类型	线性调节器（LDO）	开关变换器(DC/DC)	
		电容型(电荷泵)	电感型
优点	• 低噪声 • 容易设计 • 低纹波 • 体积小 • EMI小	• 可升可降可负压 • 体积小 • 效率高 • EMI小	• 可升可降可负压 • 效率高
缺点	• 效率低 • 只能降压	• 只能提供中小功率	• 设计复杂 • 体积大 • EMI影响大
主要应用	• 手机等便携式设备 • AD/DA transceiver供电	• 小功率供电 • 运放负电源等	• 对纹波要求不高的负载 • LDO前级



实际应用对比

输入：2.7V-38V

输出：5V/0.25A



方案1：LDO

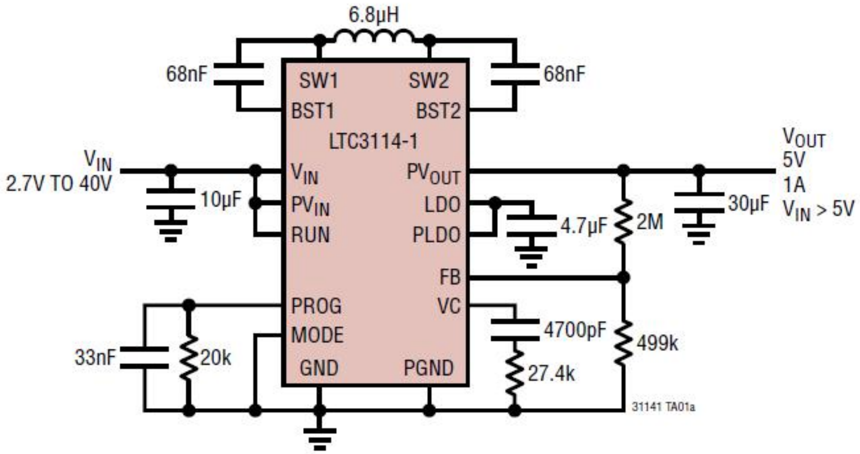
简单

低噪

输入5V以下，不稳压

输入12V时，效率只有41%

当Vin大于12V，发热严重



方案2：buck-boost

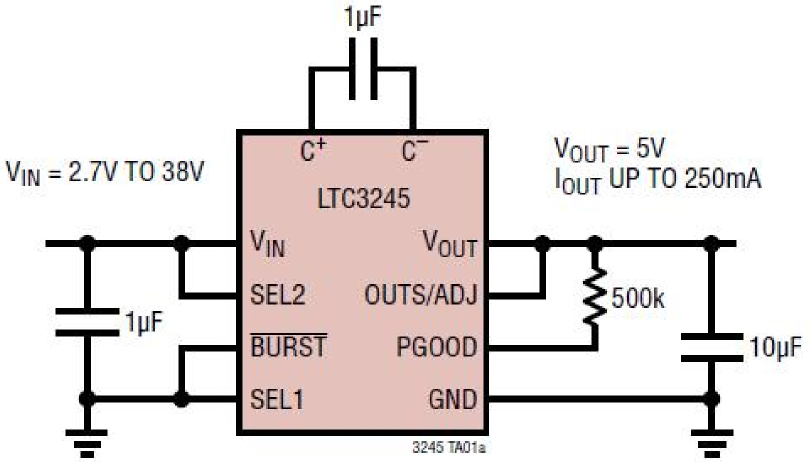
宽输入范围输出可以稳压

高效 91%@12V

电路复杂、设计周期长

噪声大

尺寸大



方案3：电荷泵

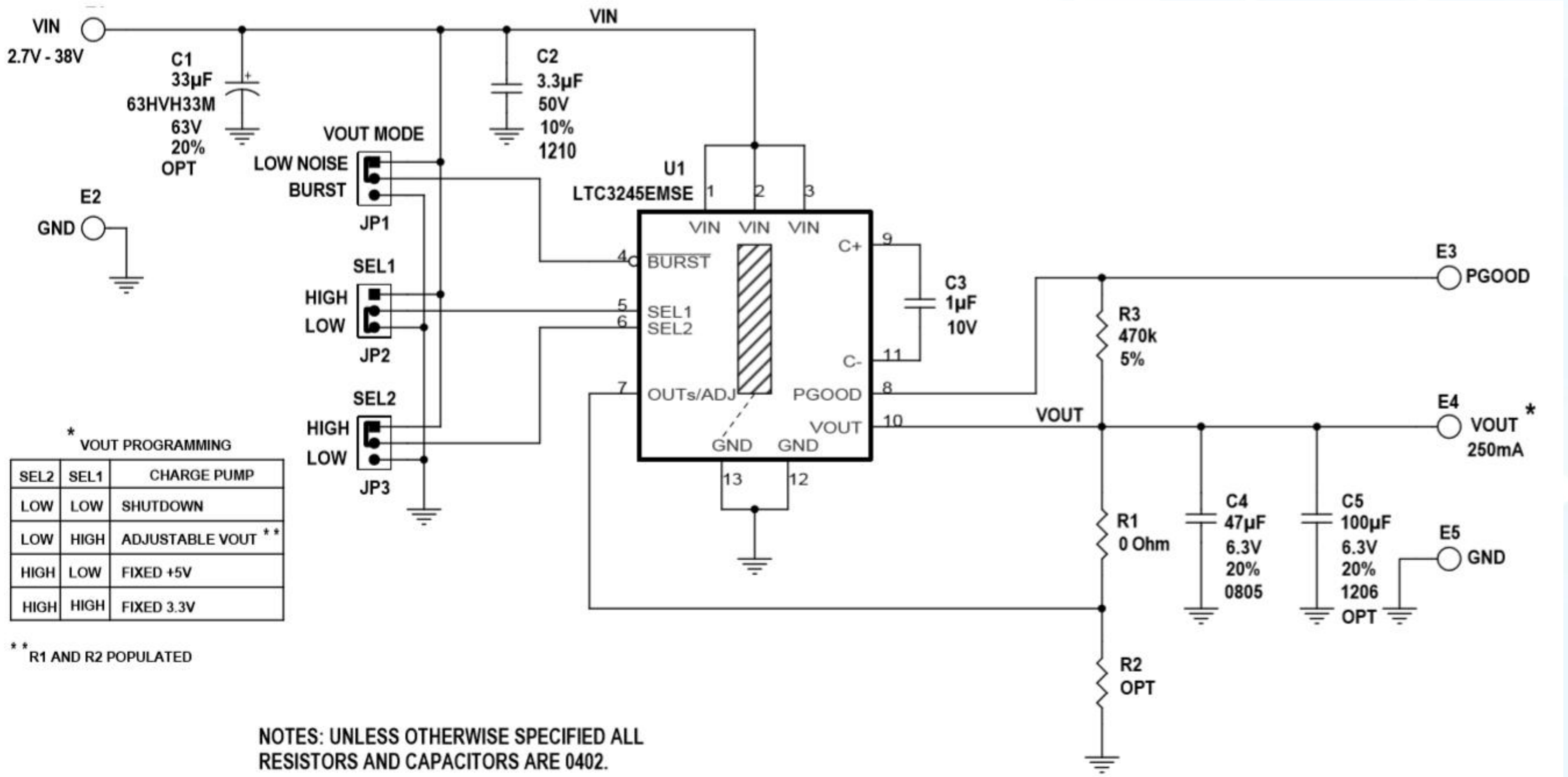
简单

宽输入范围输出可以稳压

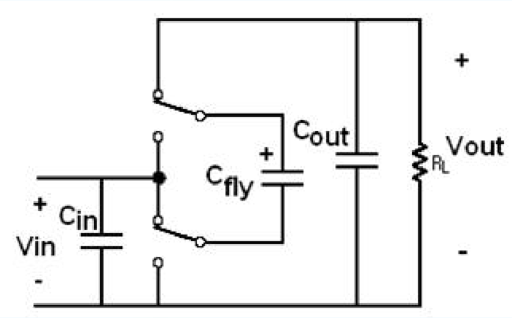
高效 81%@12V

噪声大于LDO

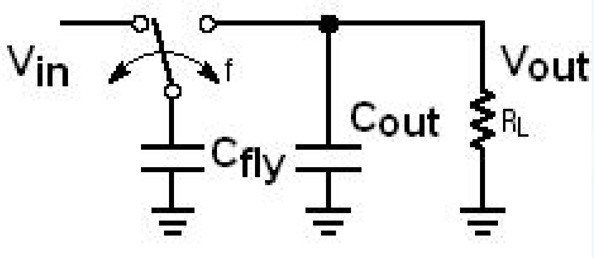
LTC3245评估板



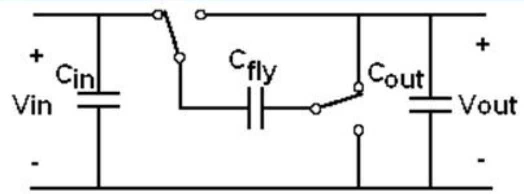
SEL2	SEL1	CHARGE PUMP
LOW	LOW	SHUTDOWN
LOW	HIGH	ADJUSTABLE VOUT * *
HIGH	LOW	FIXED +5V
HIGH	HIGH	FIXED 3.3V



Vin>2Vo 1:2 mode

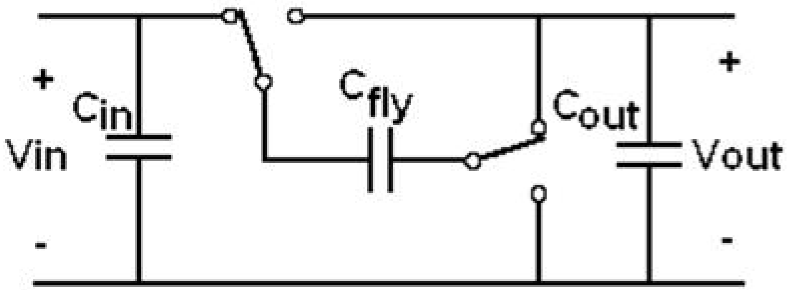


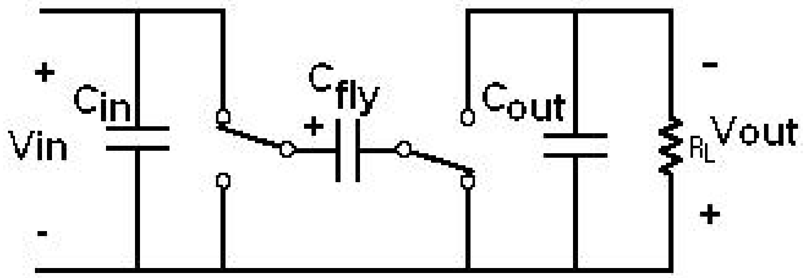
Vo<Vin<2Vo 1:1 mode



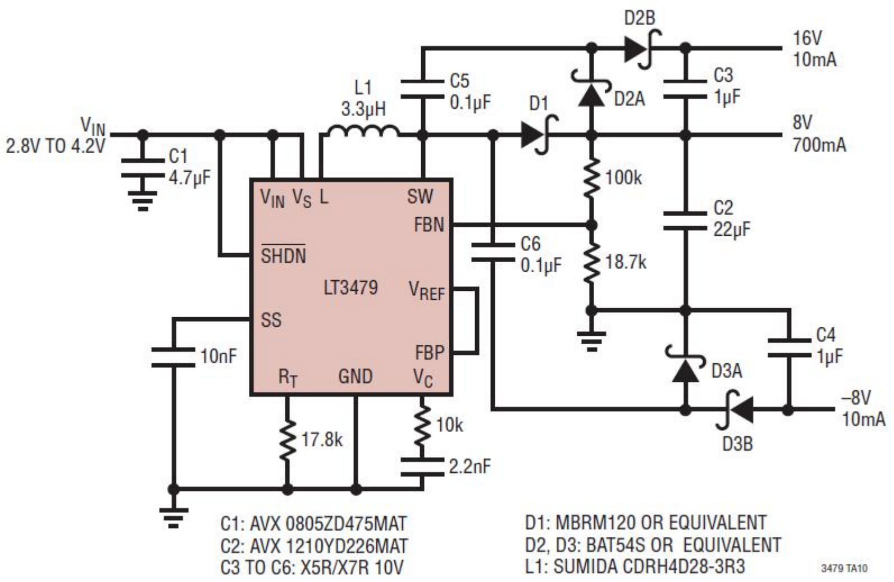
Vin<Vo 2:1 mode

电荷泵扩展应用1-boost电路倍压和反相

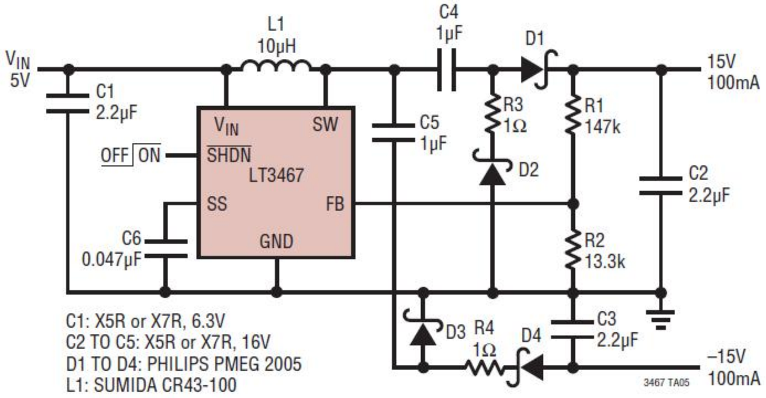




8V, 16V, –8V Triple Output Power Supply for TFTLCD Panels



±15V Dual Output Converter with Output Disconnect



电荷泵扩展应用2-高效高功率密度降压器

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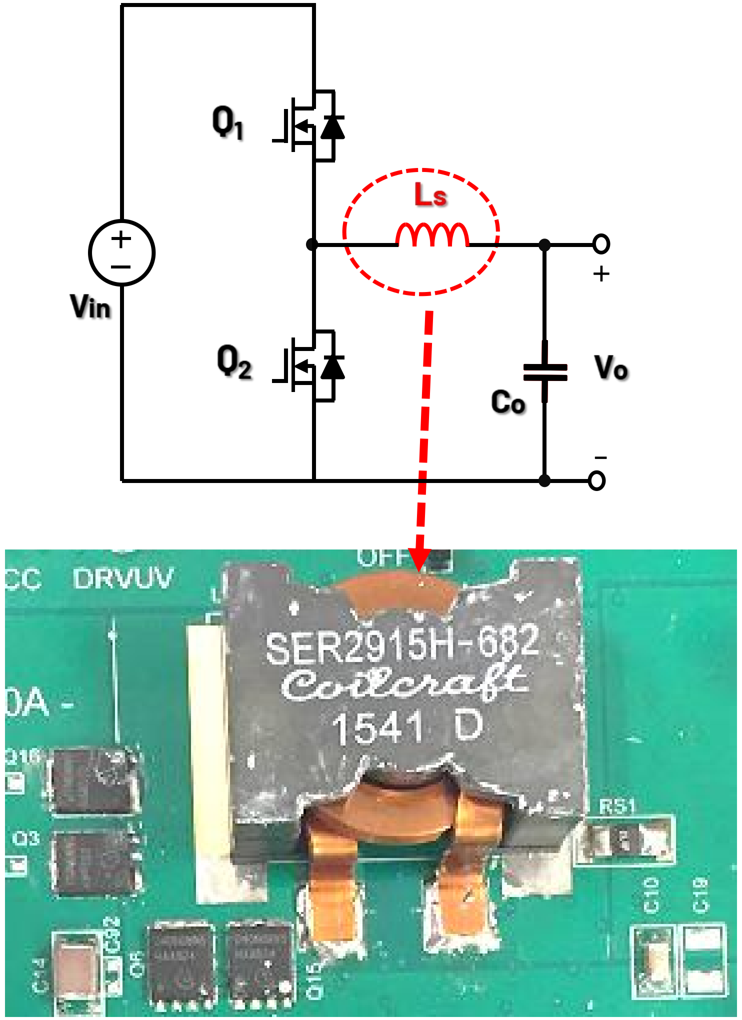
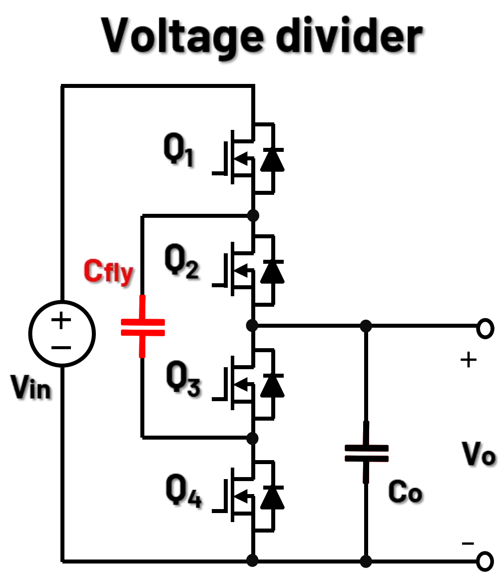
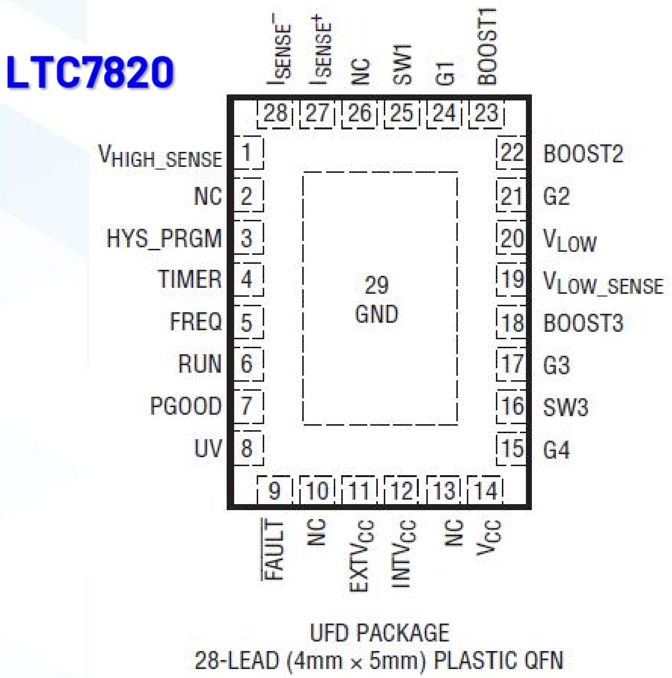


- 功率密度被大电感限制(尤其是高压输出)
- 提高功率密度? 增加频率? 增加开关损耗
- 效率和功率密度折中
- 如何突破限制? ?

电荷泵应用2-高效高功率密度降压器

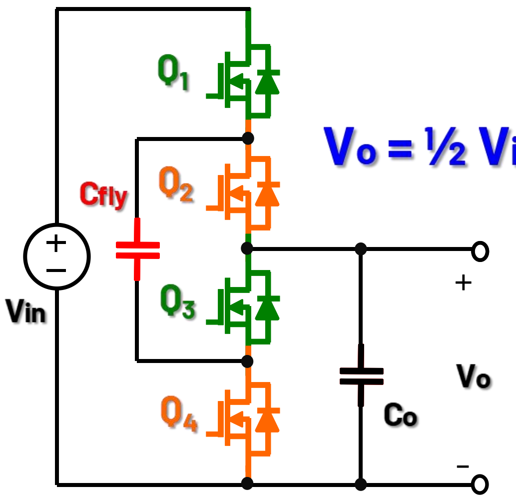




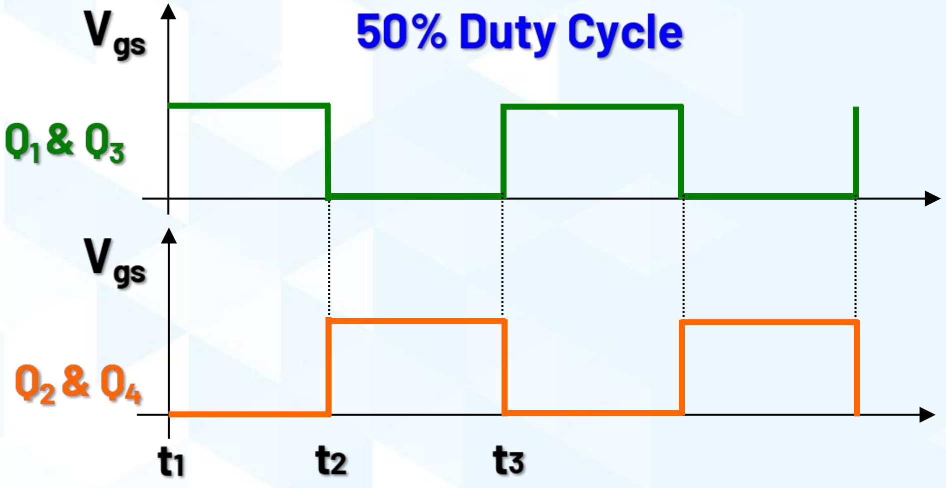
- High Efficiency
- High Density
- Low Profile

- Start up
- Gate driver
- OV/UV/OC Protection
- …

电荷泵应用2-高效高功率密度降压器

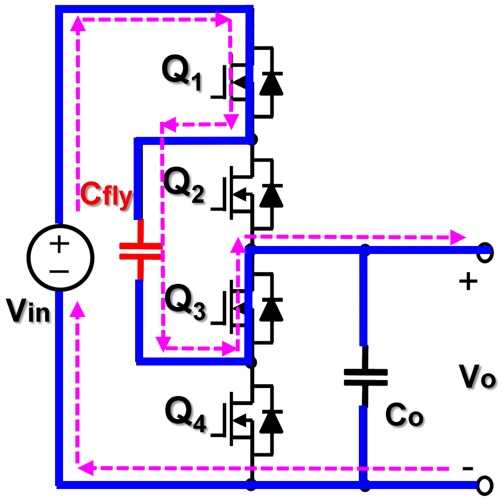


$V_o = \frac{1}{2} V_{in}$



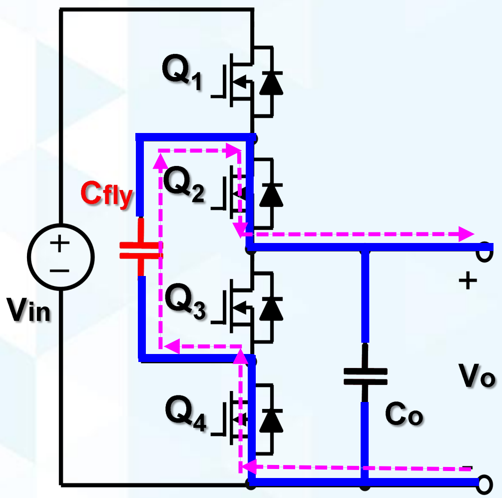
- t1 ~ t2

Mode I:



- t2 ~ t3

Mode II:



电荷泵应用3-高效高功率密度降压器
为什么输出电压=1/2 *Vin

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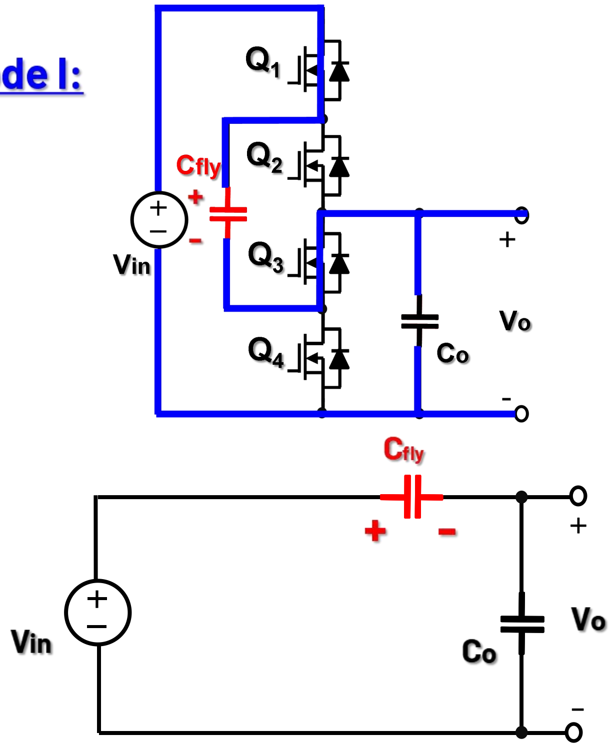
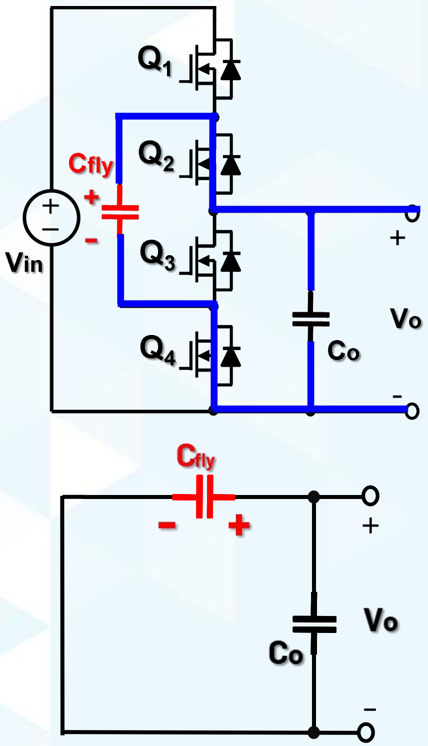
Mode I:



$V_{in} = V_{cfly} + V_o$

Mode II:

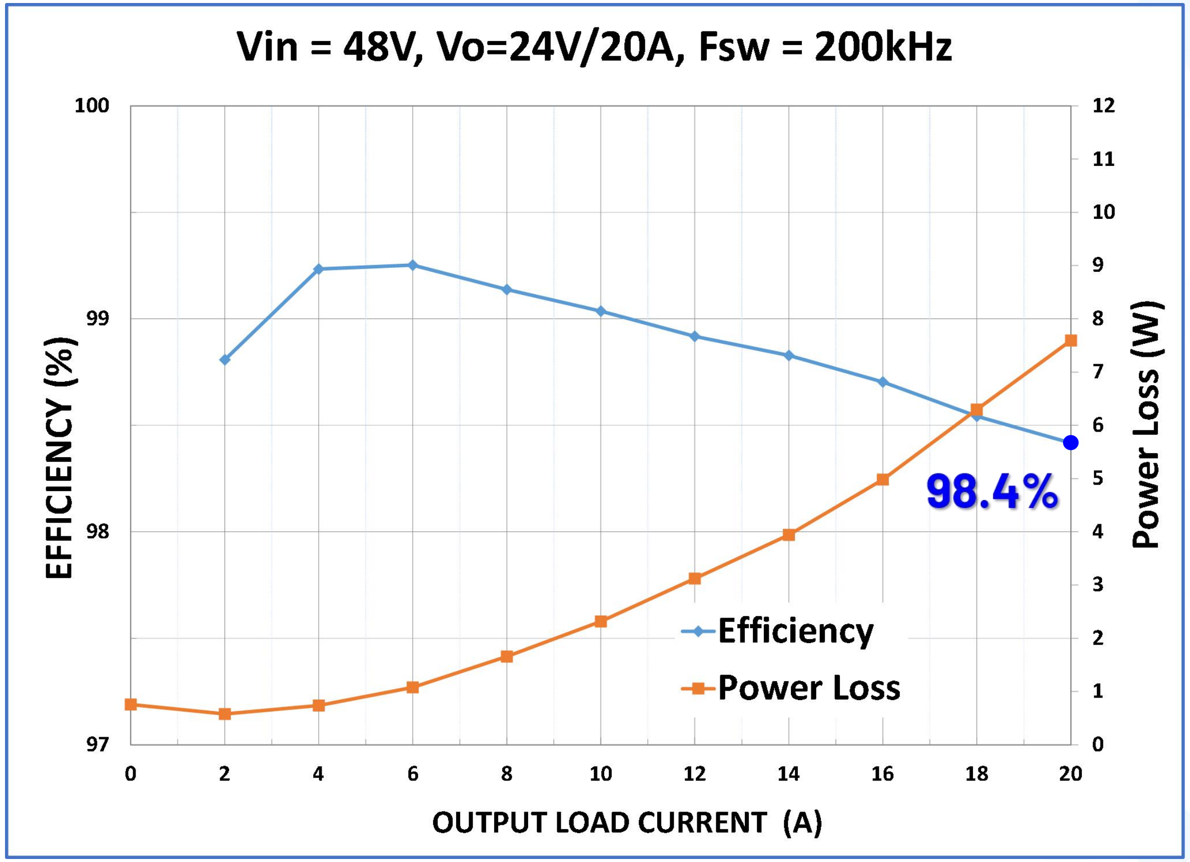


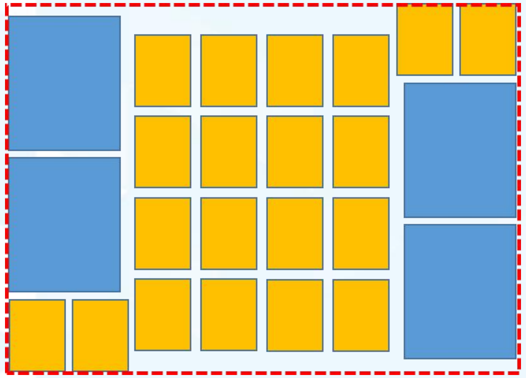
$V_{cfly} = V_o$

$V_o = V_{cfly} = ½ V_{in}$

电荷泵应用2-高效高功率密度降压器

V_{in} = 48V, V_o = 24V/20A, C_{fly} = 16x 10µF/50V/X7R/1210
Fsw = 200kHz, Q_1= BSC027N06LS5, Q_2 = Q_3 = Q_4 = BSC032N04LS





15mm x 13mm x 5mm

(0.59” x 0.51” x 0.2”)

Power density: 4000W/inch³

(800W/inch²)

电荷泵应用2-高效高功率密度降压器

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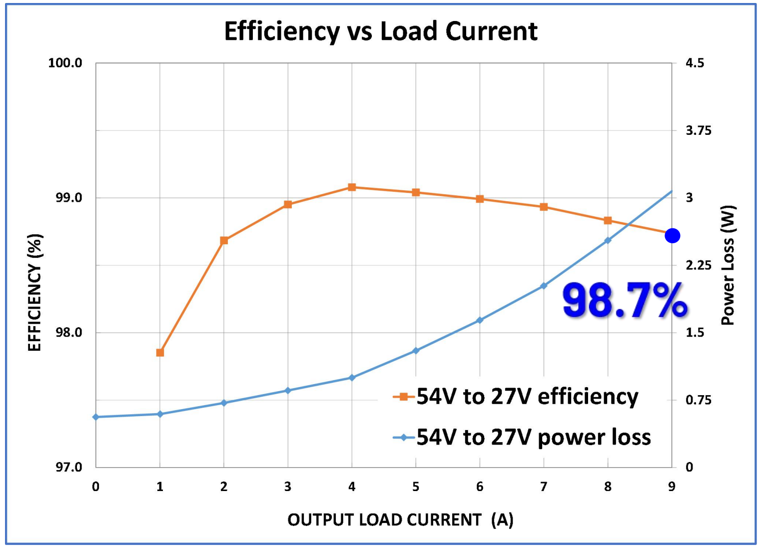
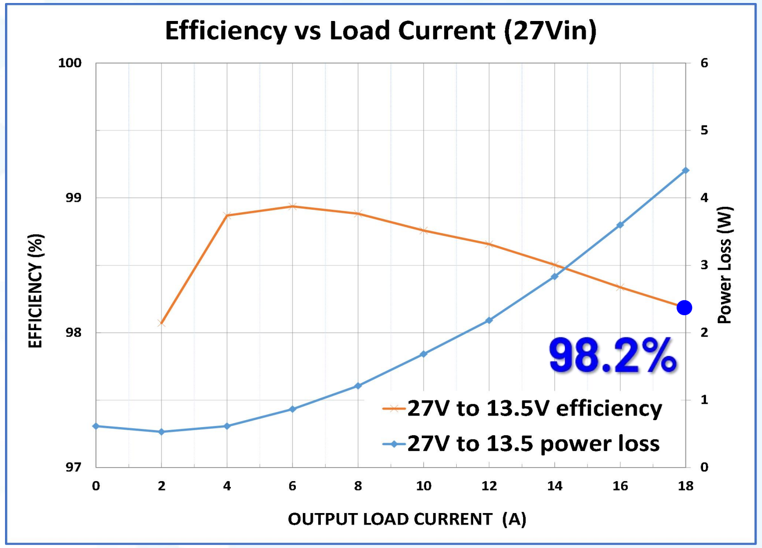
- **1st stage: 54V to 27V**

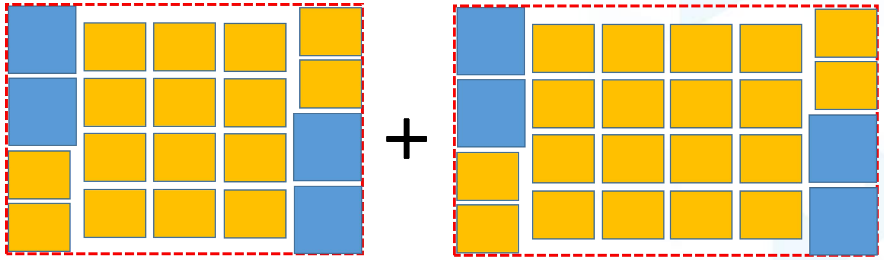
Cfly = 12x 10µF/50V/X7R/1210, Fsw = 200kHz
Q1= FDMC007N08LC, Q2 = Q3 = Q4 = BSZ097N04LSG



- **2nd stage: 27V to 13.5V**

Cfly = 16x 22µF/25V/X7R/1210, Fsw = 300kHz
Q1= BSZ025N04LS, Q2 = Q3 = Q4 = BSZ0500NSI





97% overall efficiency

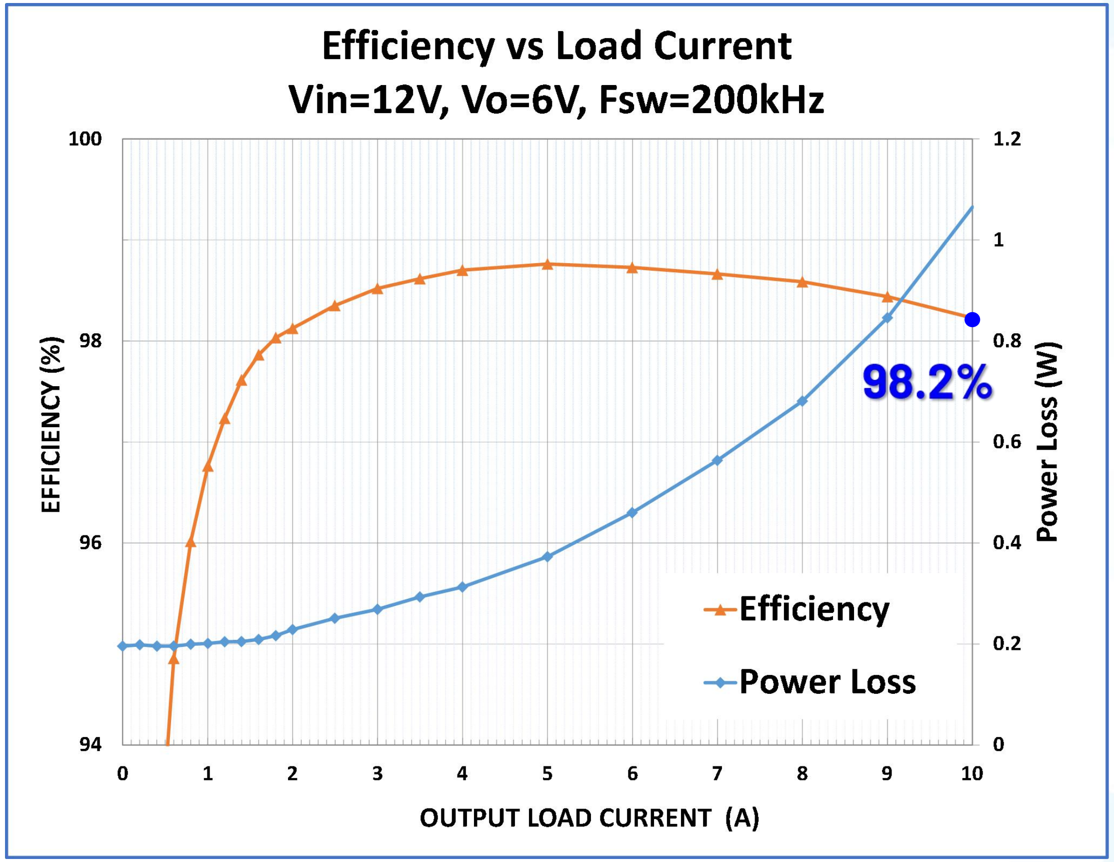
40.5mm x 13mm x 5mm

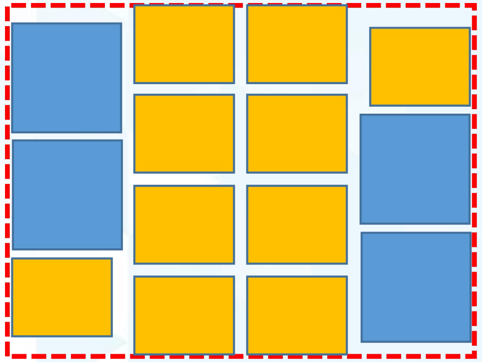
1.6" x 0.51" x 0.2"

Power density: 1500W/inch³
(300W/inch²)

电荷泵应用2-高效高功率密度降压器

V_{in} = 12V, V_o = 6V/5A, C_{fly} = 8x 47µF/16V/X7R/1210
Fsw = 200kHz, Q_1 = Q_2 = Q_3 = Q_4 = BSZ014NE2LS5IF





15mm x 11.2mm x 5mm

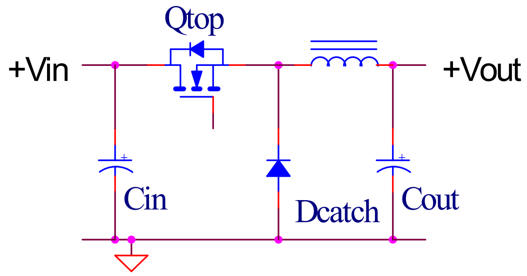
(0.59" x 0.44" x 0.2")

Power density: 1150W/inch³

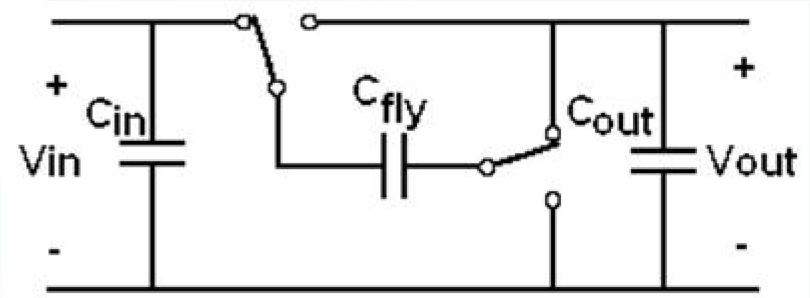
(230W/inch²)

电荷泵应用2-高效高功率密度降压器 储能元件对比

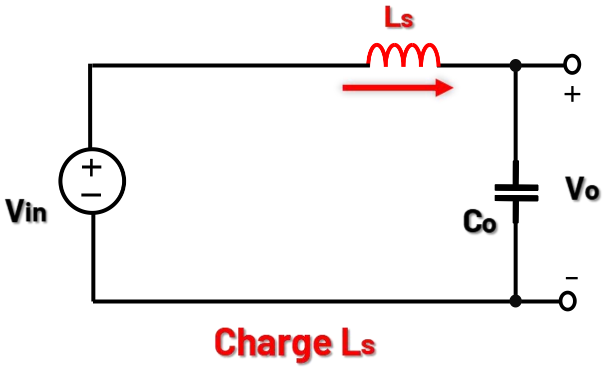
❖ 降压BUCK变换器



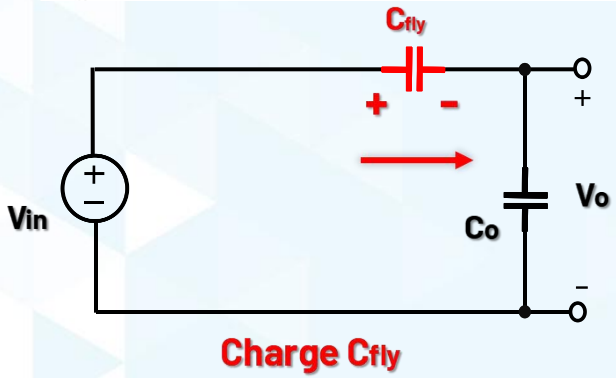
❖ 降压电荷泵



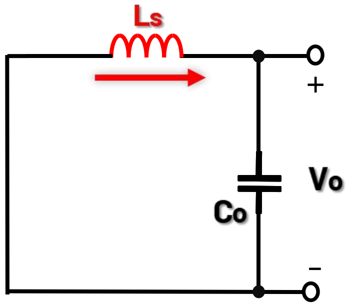
Mode I:



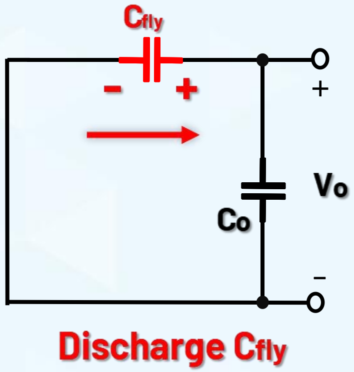
Mode I:



Mode II:



Mode II:



电荷泵应用2-高效高功率密度降压器
Cfly 电荷平衡

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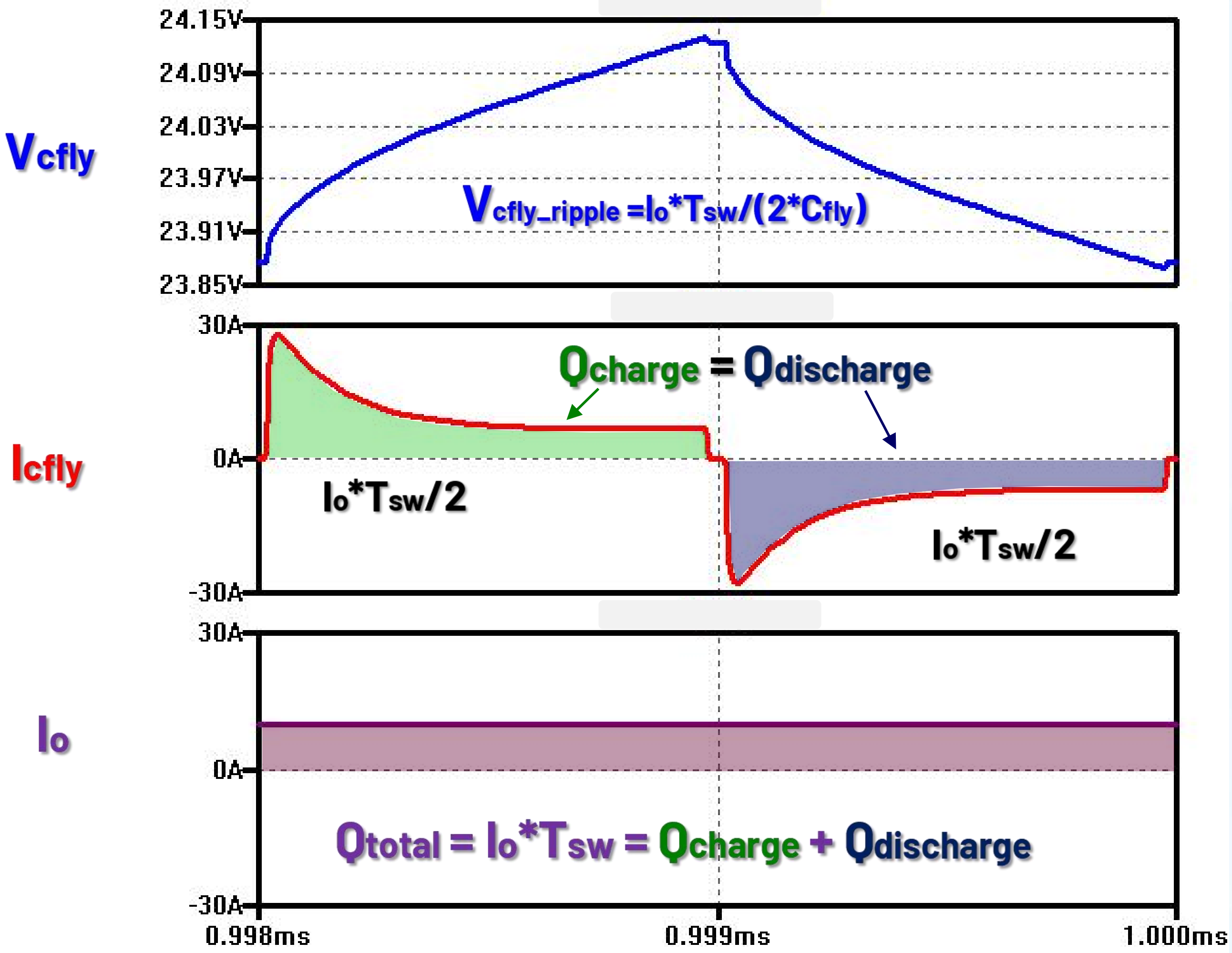
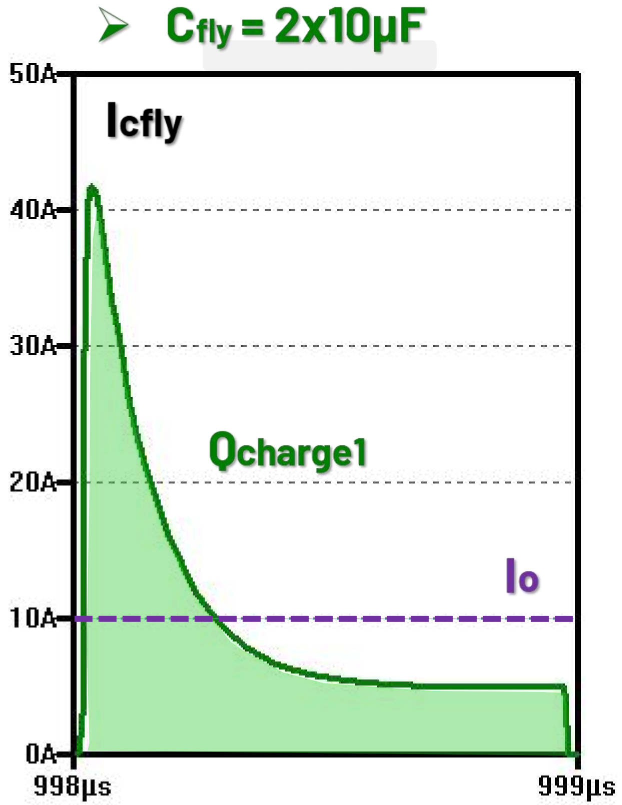
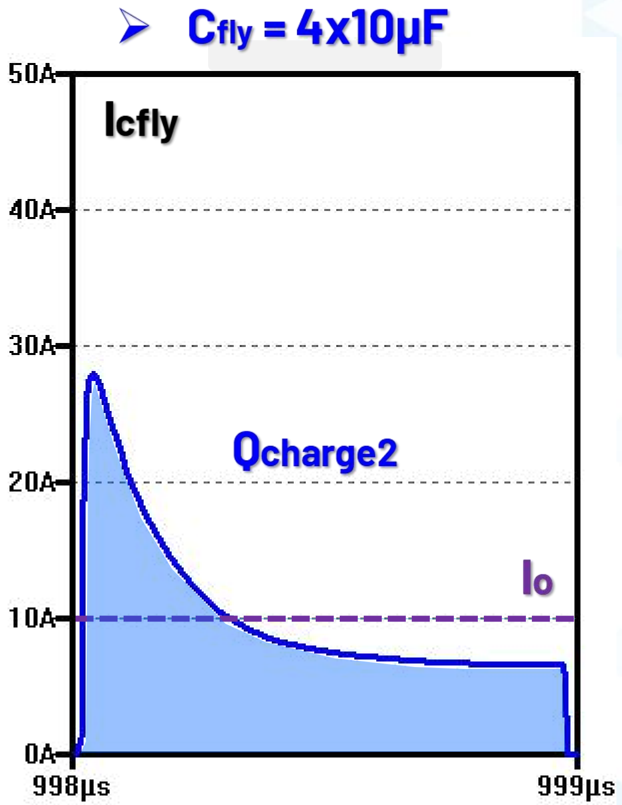
V_{in} = 48V, V_o = 24V/10A, C_o = 2x10µF, C_{fly} = 4x10µF, F_{sw} = 500kHz

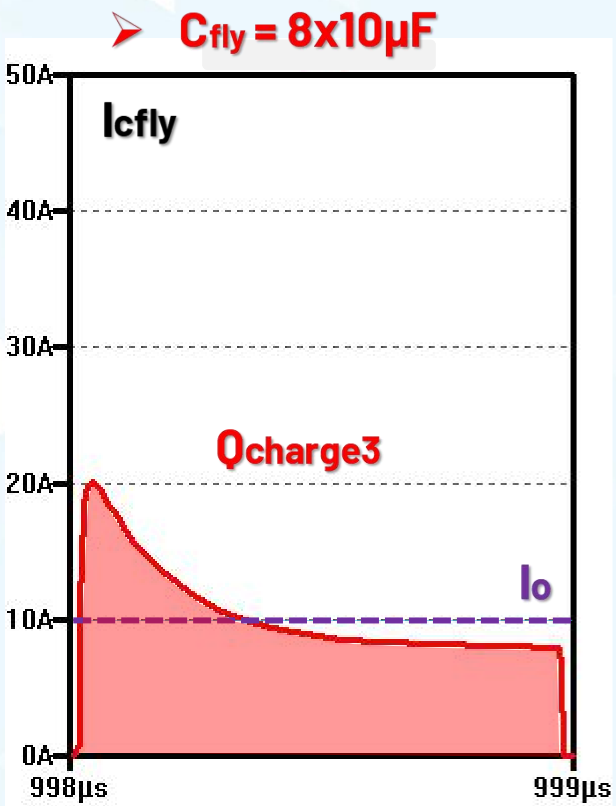


电荷泵应用2- C_{fly}对电流的影响

V_{in} = 48V, V_o = 24V/10A, C_o = 2x10μF, F_{sw} = 500kHz







$Q_{charge1} = Q_{charge2} = Q_{charge3} = I_o \cdot T_{sw}/2$

$I_{RMS1} > I_{RMS2} > I_{RMS3}$

第二讲：LED特性及驱动电路

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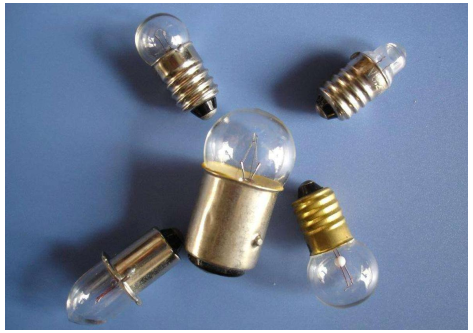
LED的基本原理及材料



爱迪生发明灯泡

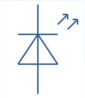
- **照明**
- **指示灯（微型灯泡）**
- **取暖灯（浴霸，红外灯）**
- **杀毒（紫外灯）**

传统灯泡的缺点：

- 体积大
- 寿命短（1000小时）
- 效率低（10%）

砷化镓二极管发红光，
磷化镓二极管发绿光，
碳化硅二极管发黄光，
氮化镓二极管发蓝光。

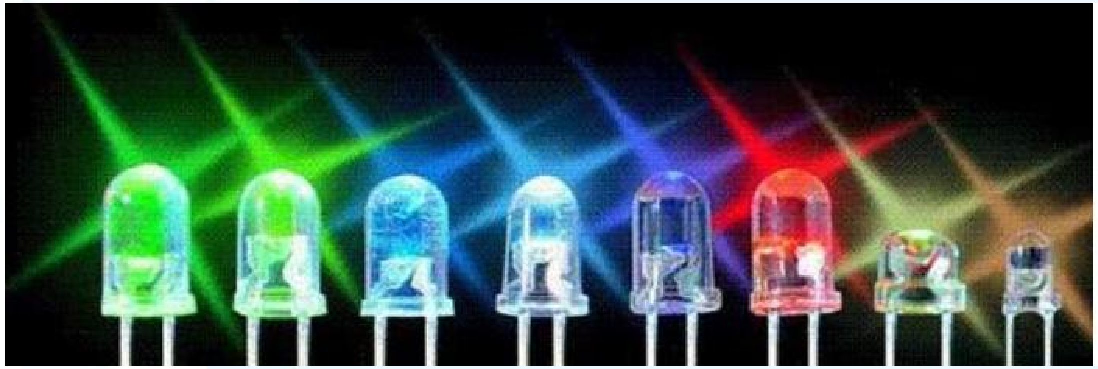
因化学性质又分
有机发光二极管OLED
无机发光二极管LED。



发光二极管简称为LED

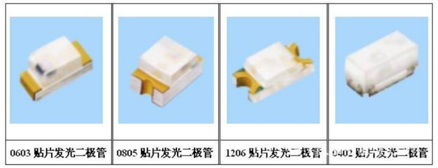
当电子与空穴复合时能辐射出可见光

由含镓（Ga）、砷（As）、磷（P）、氮（N）等的化合物制成。



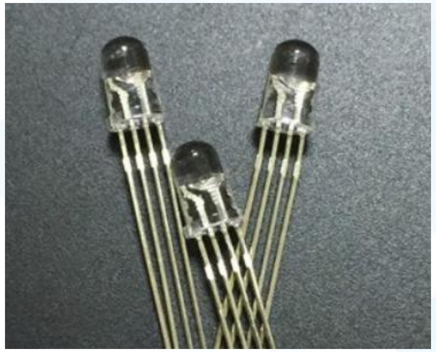
LED的种类

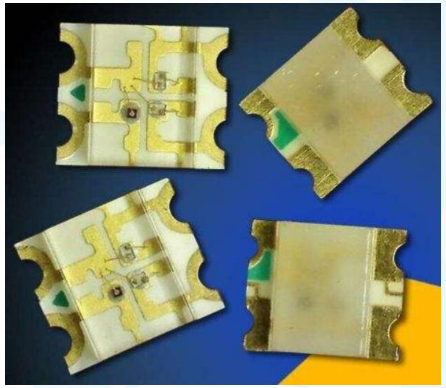
- 单色发光LED



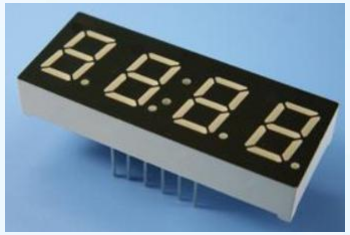
- 双色发光LED

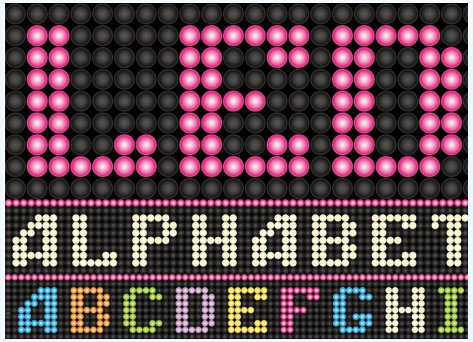
- 三色RGB发光LED



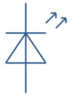


- 发光LED整列





LED工作特性及曲线



LED只能往一个方向导通（通电），
叫作正向偏置（正向偏压）。

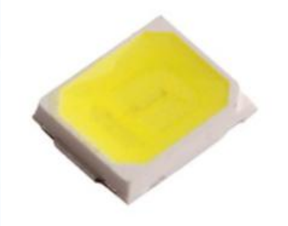
优点：
具有效率高（相比白炽灯）、
寿命长、
不易破损、
开关速度高、
高可靠性等传统光源不及的优点。

白光LED的发光效率，在近几年来已
经有明显的提升，
但在技术上，LED在光电转换效率
(有效照度对用电量的比值)上仍然低
于新型的荧光灯。

10%

电光转化效率低
寿命短
发热温度高
颜色单一
色温低

20.5%



起始成本高
显色性差
大功率LED效率低
恒流驱动
需专用驱动电路

30%

含汞等有害元素
不可调亮度
低电压无法启辉发光
紫外辐射
闪烁现象
启动较慢
稀土原料涨价
反复开关影响寿命
体积大。

LED工作特性及曲线

ANALOG DEVICES
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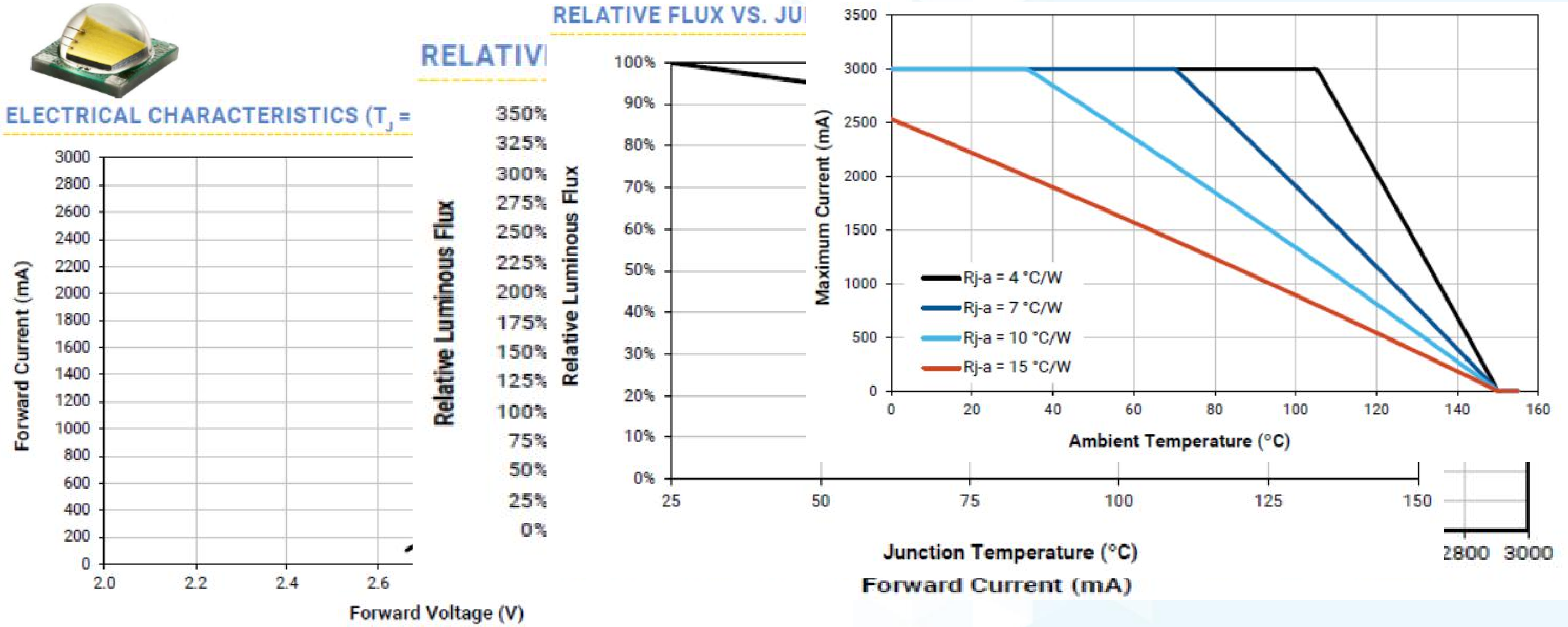
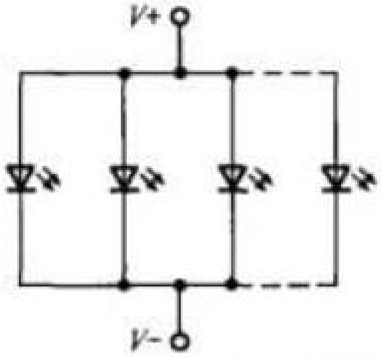
- LED像普通二极管一样，是一个PN结器件，具有单向导电性
- LED有门限电压，高于门限电压，LED才会导通发光
  - 肖特基二极管门限：0.3V-0.6V
  - 普通二极管门限：0.5V-0.7V
  - 普通LED门限：1.5V-3.5V
  - 白光LED门限：3V-4.2V
- LED的光通量与电流有关，但不成正比，增大到一定程度后，随电流增加的量变缓
- LED是温度敏感器件，结温升高时，光输出量减少，正向压降变低
- LED具有非线性的伏安特性曲线，流过LED的电流与LED两端电压不成正比
- LED一致性差，即使是同一批次生产的参数离散性也很大

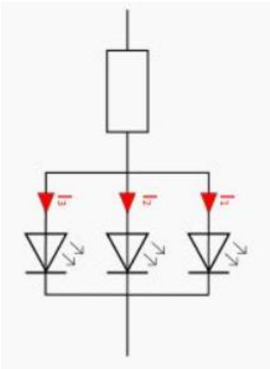
LED工作特性及曲线，安全问题

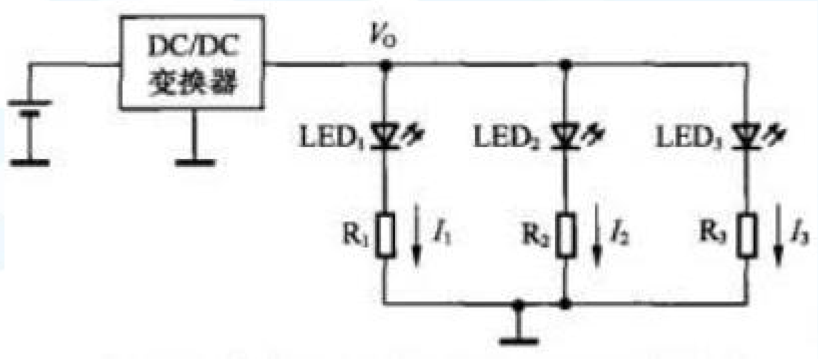
Cree® XLamp® XM-L LEDs

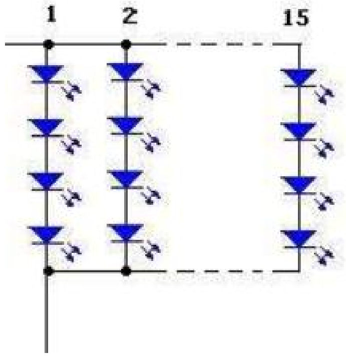


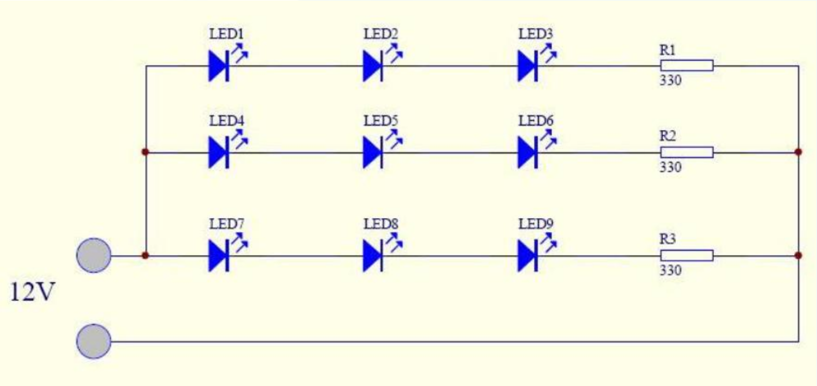
LED驱动方法


V+
V-




DC/DC
变换器
V0
LED1
LED2
LED3
R1
R2
R3
I1
I2
I3


1
2
15


LED1
LED2
LED3
R1
330
LED4
LED5
LED6
R2
330
LED7
LED8
LED9
R3
330
12V

为什么LED需要横流驱动芯片

- 发光强度与电流有关
- 伏安特性非线性
- 温度与正向压降成反比
- 稳定性
- 照度均匀性
- 驱动效率

典型的LED驱动电路

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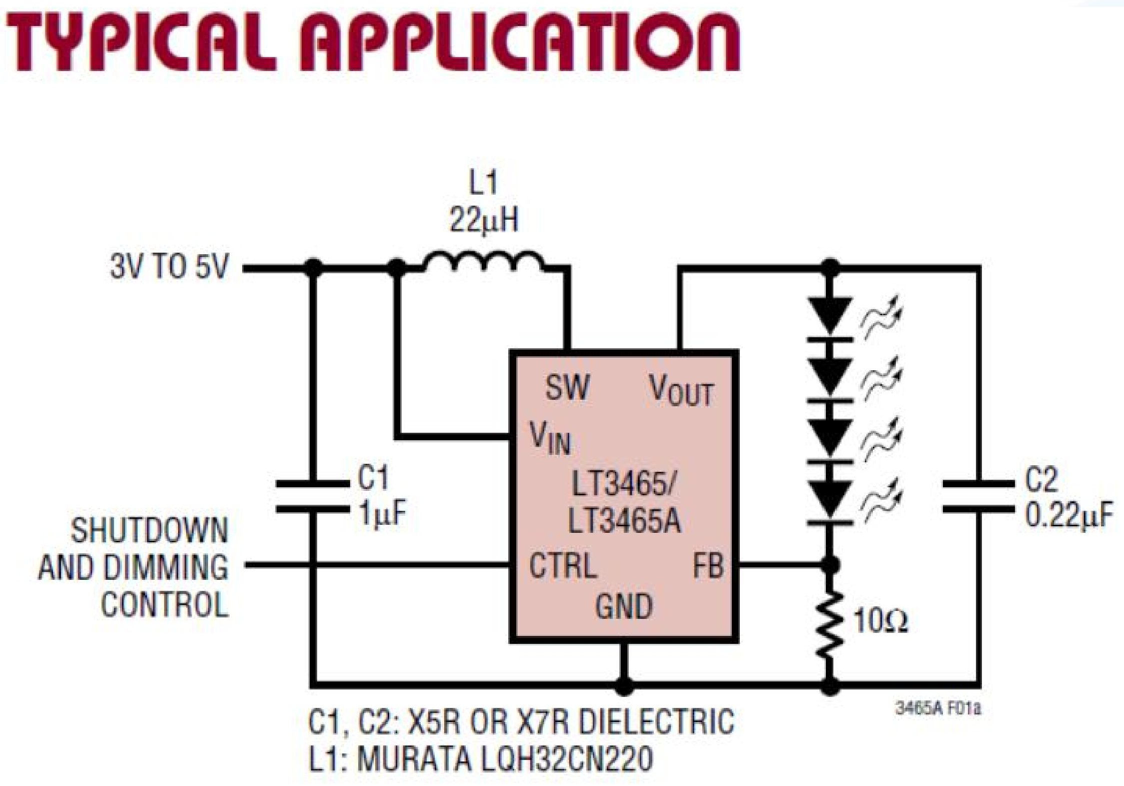
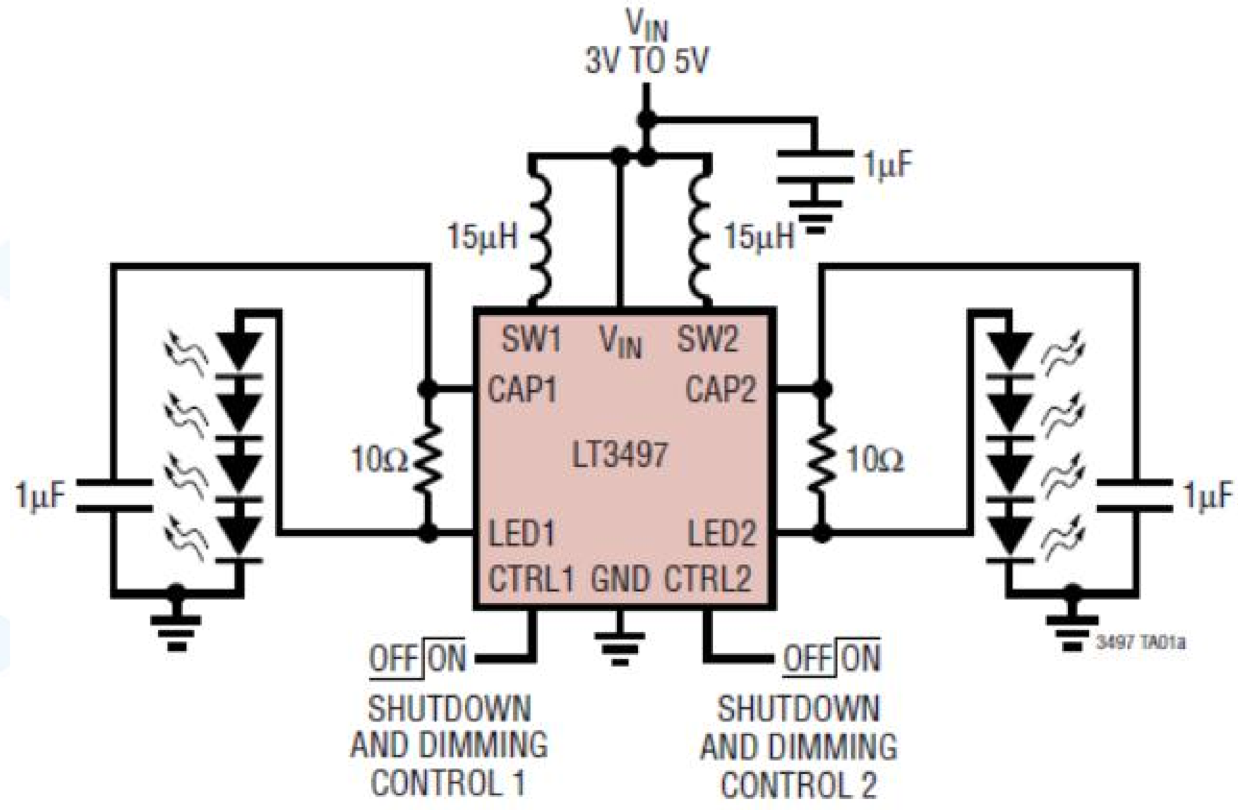


Figure 1. Li-Ion Powered Driver for Four White LEDs



实验对比：LED模拟调光与数字调光对比

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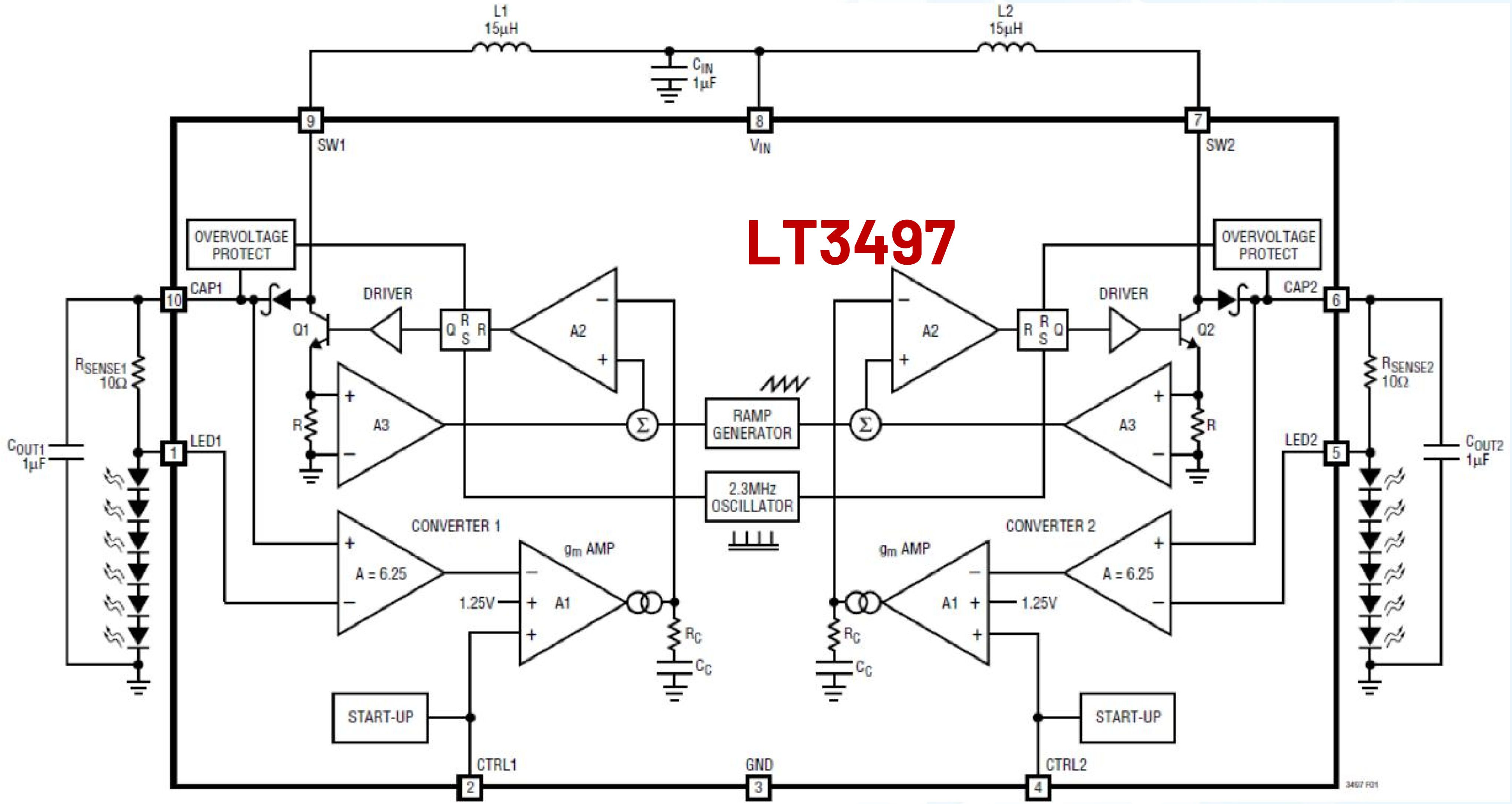


调光方法

DIMMING CONTROL

There are three different types of dimming control circuits. The LED current can be set by modulating the CTRL pin with a DC voltage, a filtered PWM signal or directly with a PWM signal.

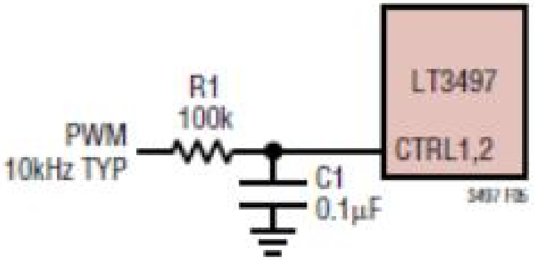
Using a DC Voltage

For some applications, the preferred method of brightness control is a variable DC voltage to adjust the LED current. The CTRL pin voltage can be modulated to set the dimming of the LED string. As the voltage on the CTRL pin increases from 0V to 1.5V, the LED current increases from 0 to I_{LED}. As the CTRL pin voltage increases beyond 1.5V, it has no effect on the LED current.

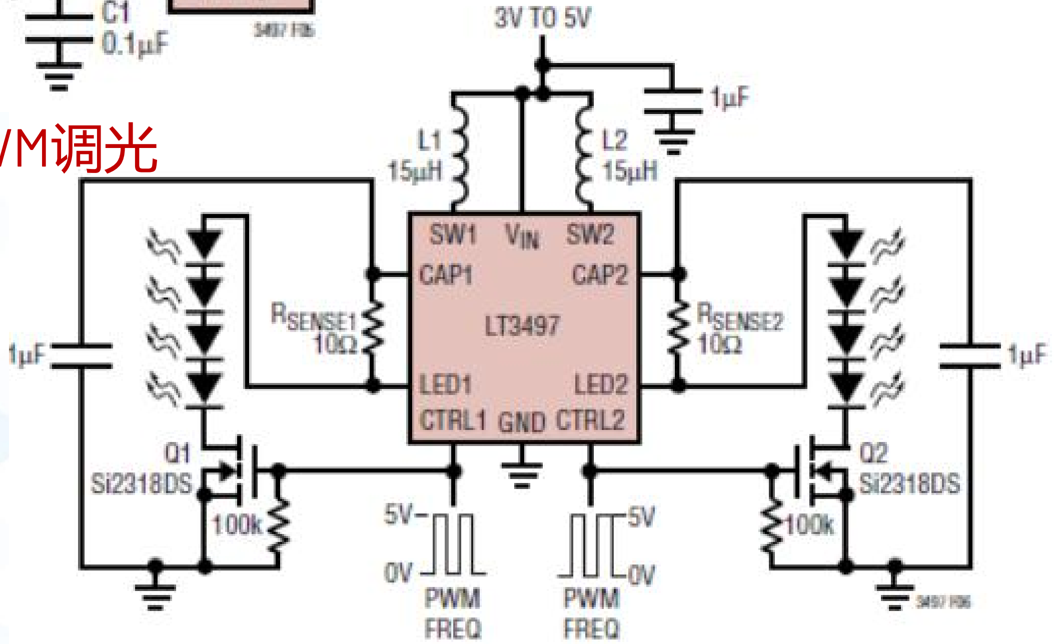
- 模拟调光（需要芯片支持,需要DAC）

Ctrl 0V to 1.5V，0mA-Iled

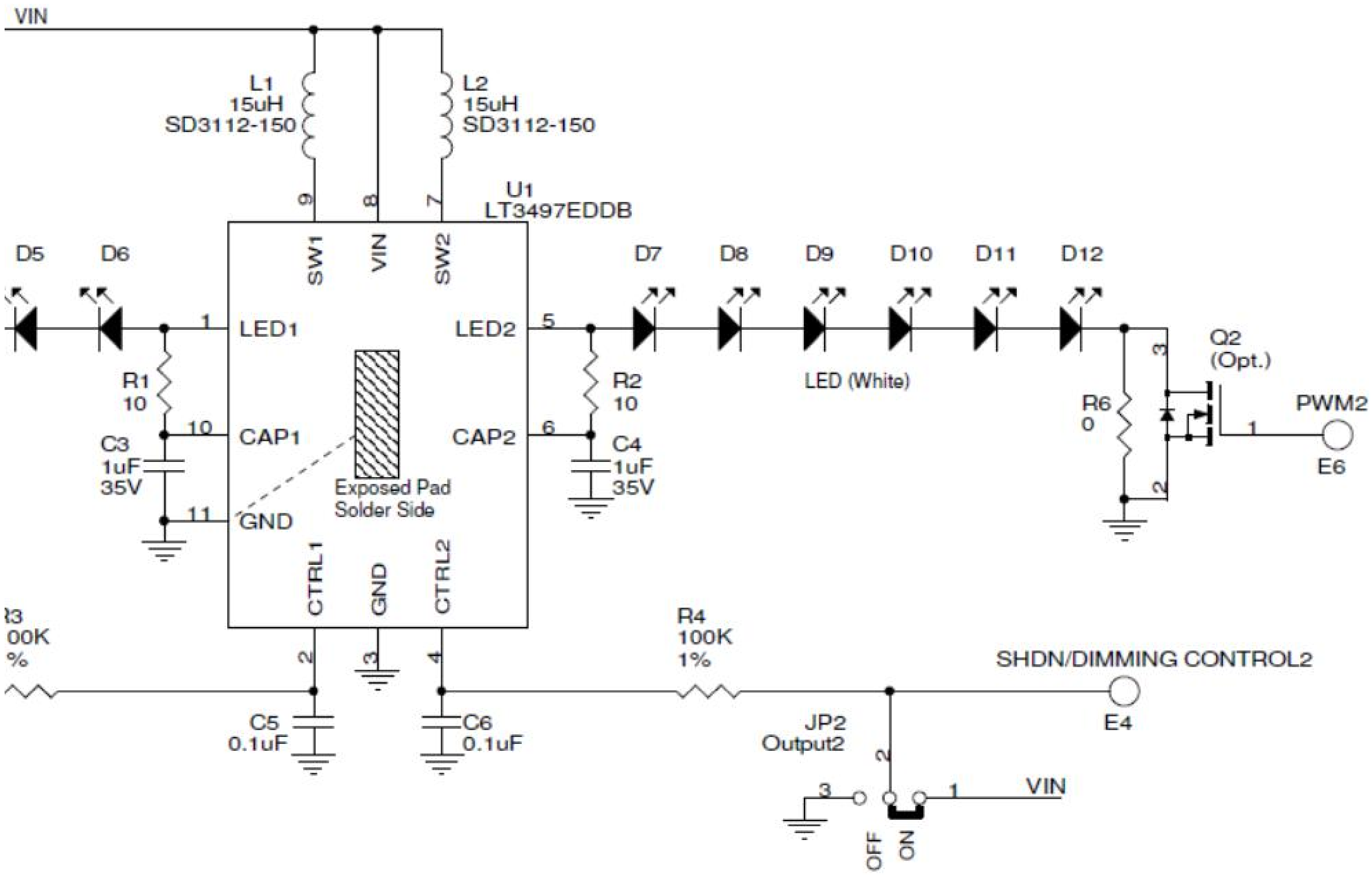
- 带滤波器的PWM调光（准模拟）

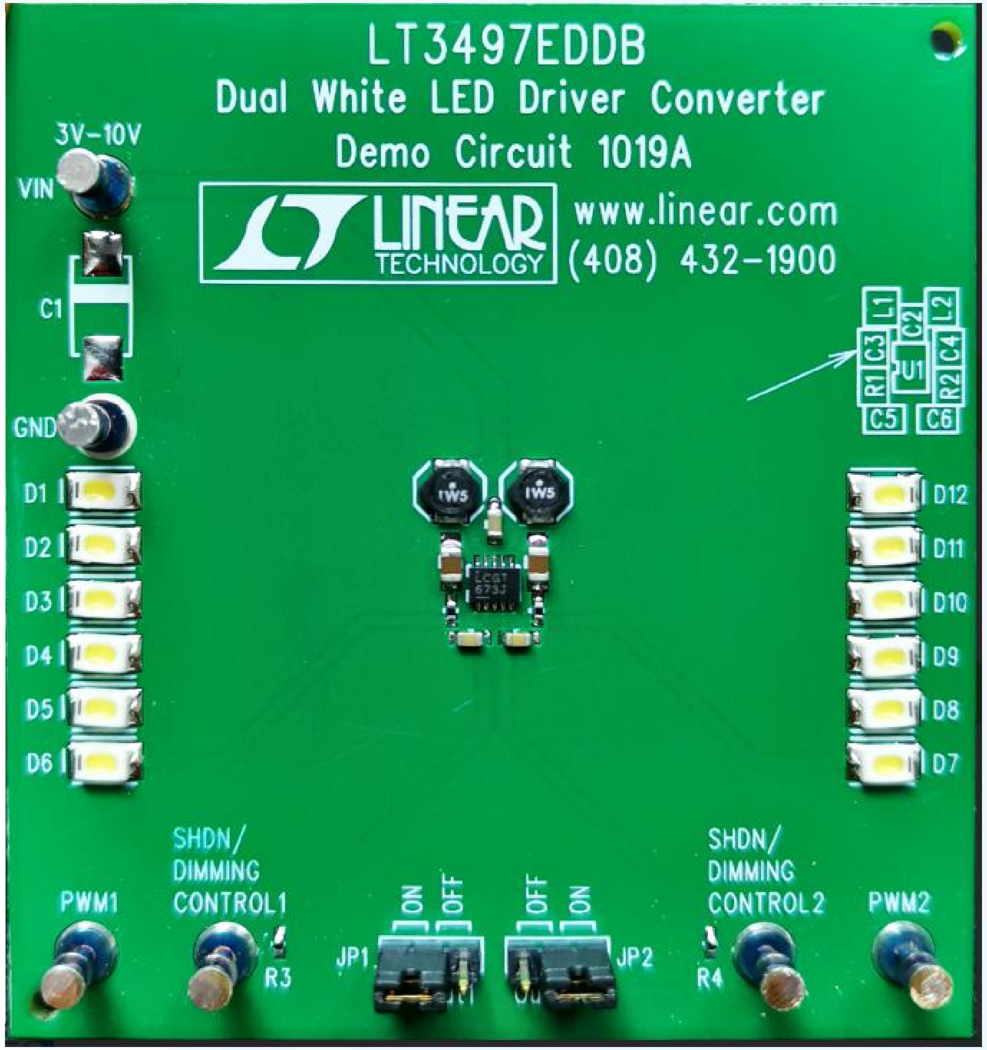


- 直接PWM调光



实验对比：LED驱动及调光





第三讲：浪涌特性及保护电路使用

微信扫描二维码

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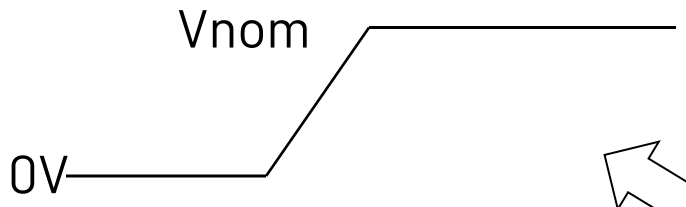
实际系统输入

理想系统输入

- ◆ 没有过冲
- ◆ 没有负压
- ◆ 稳定输入
- ◆ 没有短路

实际系统输入

- ◆ 存在过冲（Surge，lightning，谐振等）
- ◆ 存在反压（输入反接）
- ◆ 短路风险（输入电容，TVS等器件失效）



浪涌抑制

过压防护

过流防护

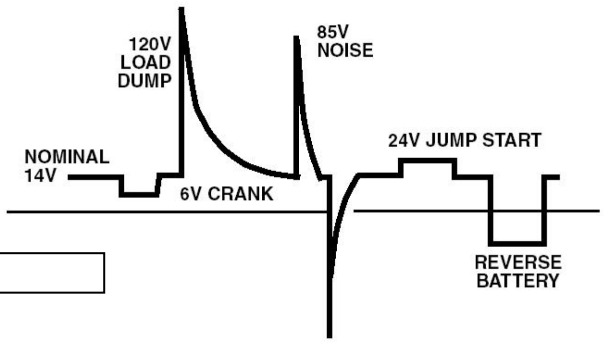
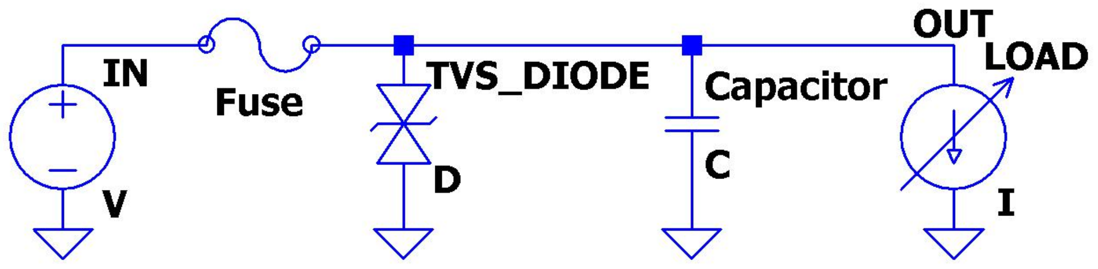
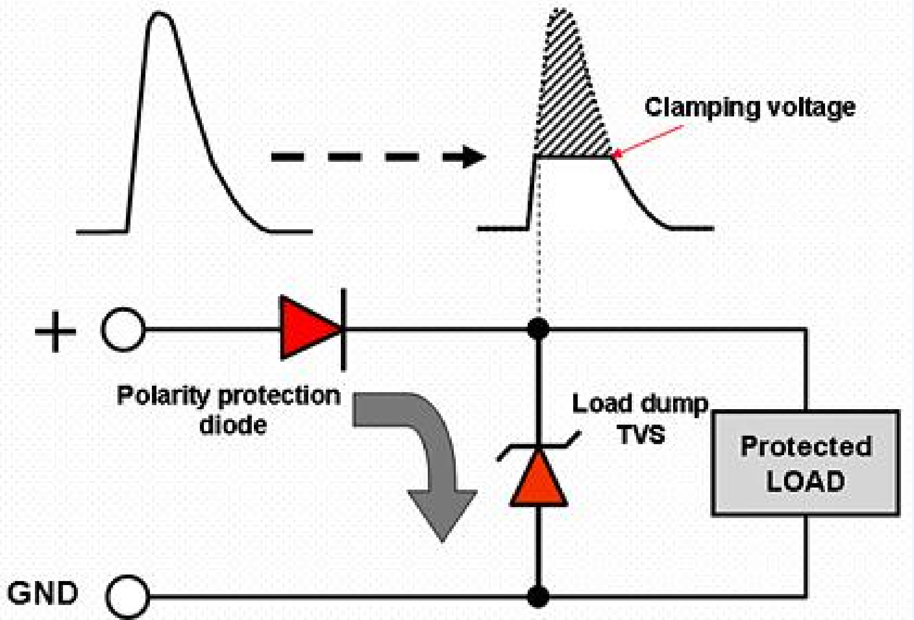


FIGURE 1. TYPICAL AUTOMOTIVE TRANSIENTS

传统的输入防护

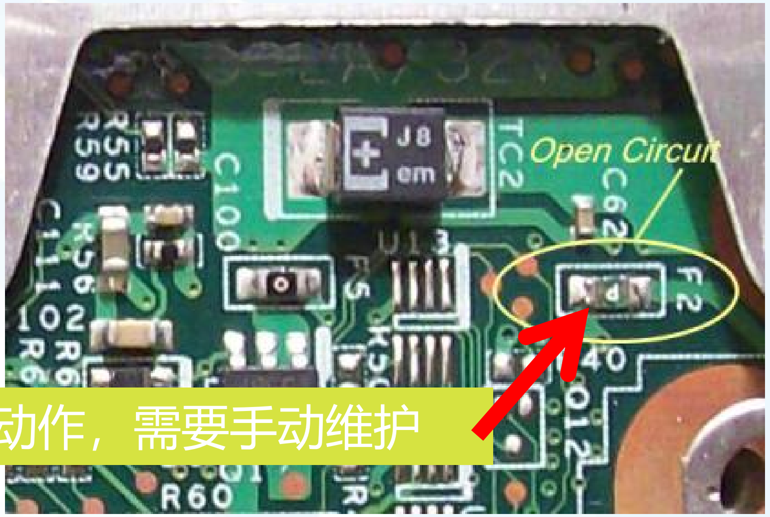
- 其中包含:
- TVS二极管
- 保险丝
- 电感，电容
- 串联二极管
- 缺点:
- 大尺寸
- 钳位效果差
- 不精确
- 防反二极管损耗大
- 过流不可恢复
- 不能有效处理长时间过压
- 输入斜率无法控制





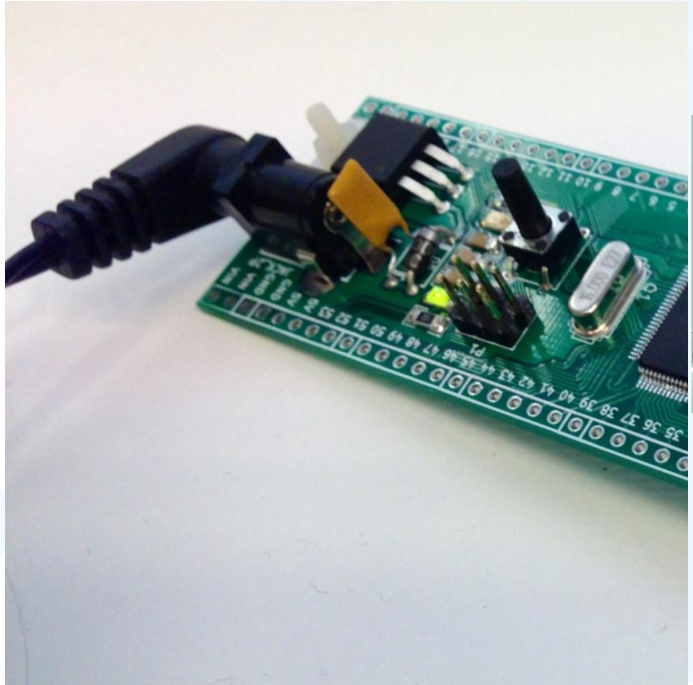
机械保险丝的问题

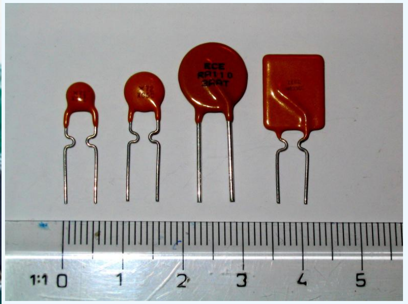
- 反应速度慢(秒级)
- 不准确,比较大的器件容差(±50%)
- 高阻抗
- 通常不可恢复
- 尺寸大



一旦动作，需要手动维护

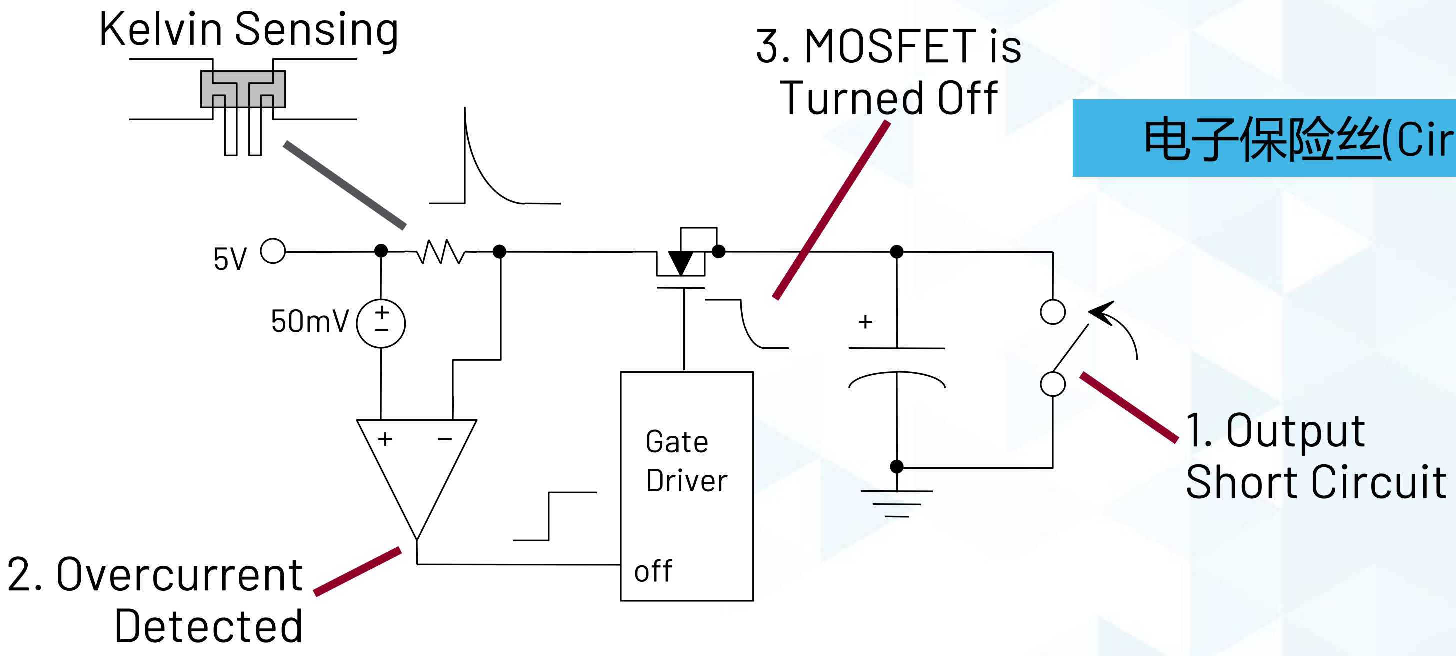
PTC 热敏电阻不需要维护，但是它不精确，尺寸大，且阻抗大





电子保险丝分立方案

- 过流检测，断开，恢复
- 分立方案缺点：复杂，尺寸大，精度取决于器件选择



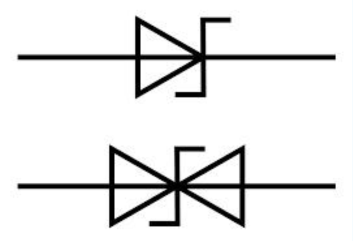
电子保险丝(Circuit Breaker)

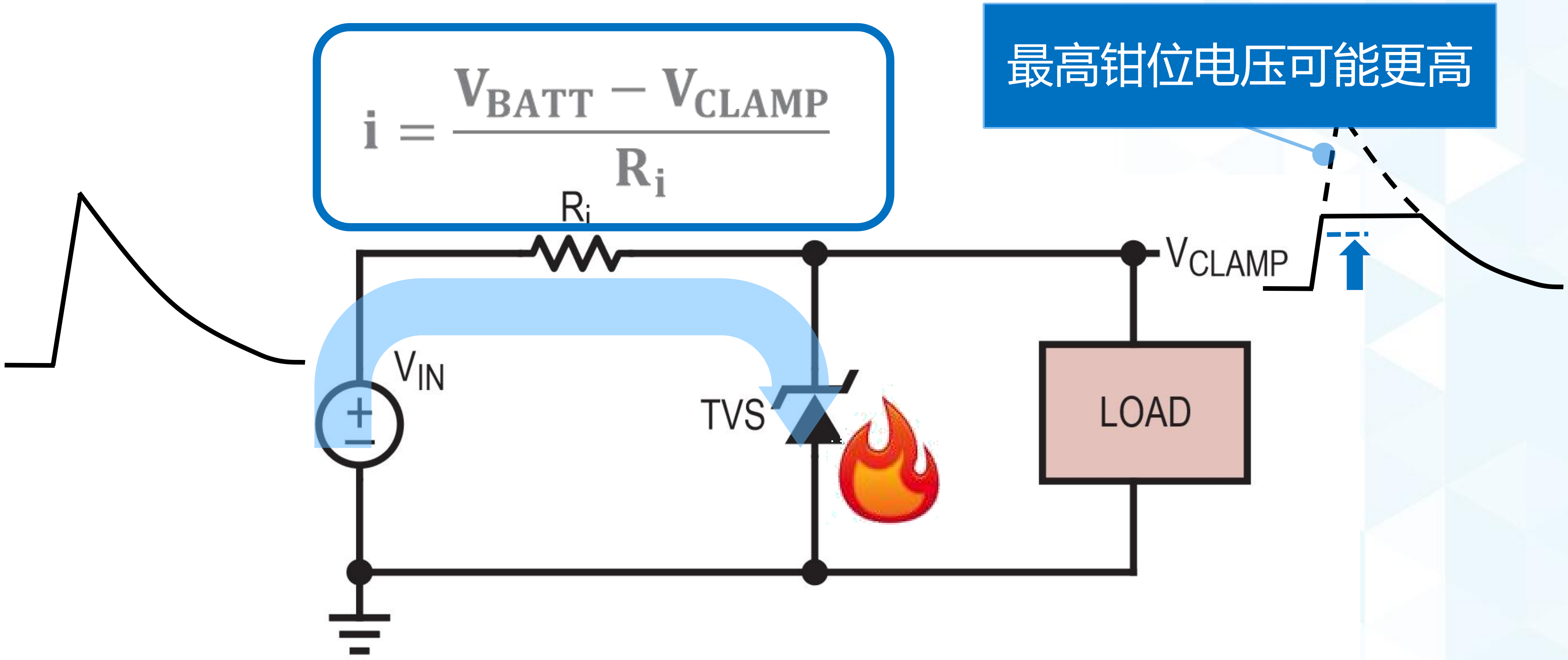
TVS二极管

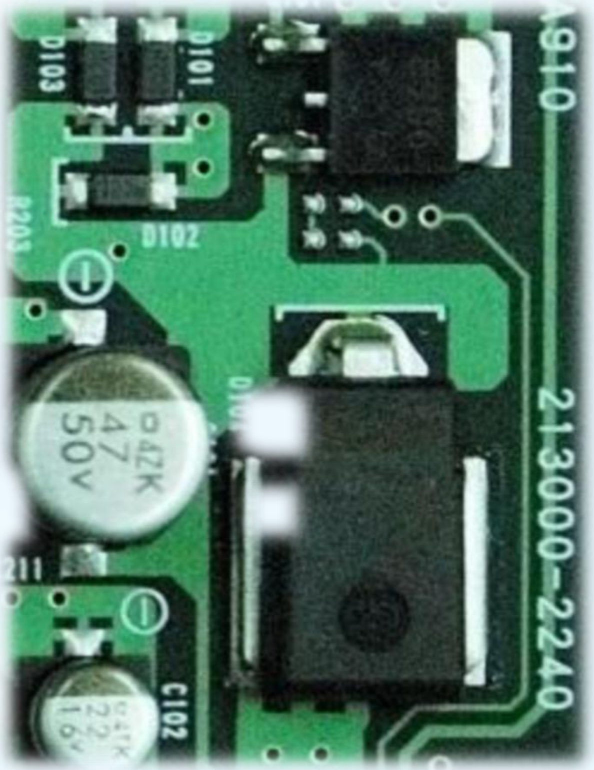
- TVS(Transient Voltage Suppressor）利用二极管的雪崩击穿特性
- 击穿电流

单向TVS

双向TVS







TVS关键参数

- Stand-off电压（大于稳态最高）
- 钳位电压(SMAJ28A 34.4V？）
- 允许功率(400W@10/1000us？）
  - 取决于温度
  - 取决于电压
  - 取决于脉冲
  - 取决于次数

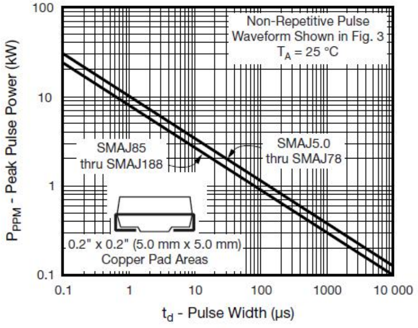


Fig. 1 - Peak Pulse Power Rating Curve

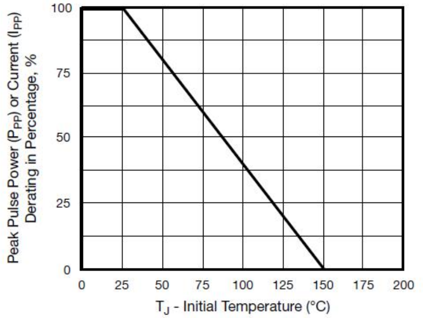


Fig. 2 - Pulse Power or Current vs. Initial Junction Temperature

ELECTRICAL CHARACTERISTICS (T_A = 25 °C unless otherwise noted)

DEVICE TYPE	DEVICE MARKING CODE		BREAKDOWN VOLTAGE V_{BR} AT I_T (1) (V)		TEST CURRENT I_T (mA)	STAND-OFF VOLTAGE V_{WM} (V)	MAXIMUM REVERSE LEAKAGE AT V_{WM} I_D (µA) (3)	MAXIMUM PEAK PULSE SURGE CURRENT I_{PPM} (A) (2)	MAXIMUM CLAMPING VOLTAGE AT I_{PPM} V_C (V)
	UNI	BI	MIN.	MAX.					
SMAJ20A	BV	XV	22.2	24.5	1.0	20	1.0	12.3	32.4
SMAJ22A	BX	XX	24.4	26.9	1.0	22	1.0	11.3	35.5
SMAJ24A	BZ	XZ	26.7	29.5	1.0	24	1.0	10.3	38.9
SMAJ26A	CE	YE	28.9	31.9	1.0	26	1.0	9.5	42.1
SMAJ28A	CG	YG	31.1	34.4	1.0	28	1.0	8.8	45.4
SMAJ30A	CK	YK	33.3	36.8	1.0	30	1.0	8.3	48.4
SMAJ33A	CM	YM	36.7	40.6	1.0	33	1.0	7.5	53.3

MAXIMUM RATINGS (T_A = 25 °C unless otherwise noted)

PARAMETER	SYMBOL	VALUE	UNIT
Peak pulse power dissipation with a 10/1000 µs waveform (1)(2) (fig. 1)	P_{PPM}	400	W
Peak pulse current with a waveform (1)	I_{PPM}	See next table	A
Peak forward surge current 8.3 ms single half sine-wave uni-directional only (2)	I_{FSM}	40	A
Operating junction and storage temperature range	T_J, T_{STG}	-55 to +150	°C

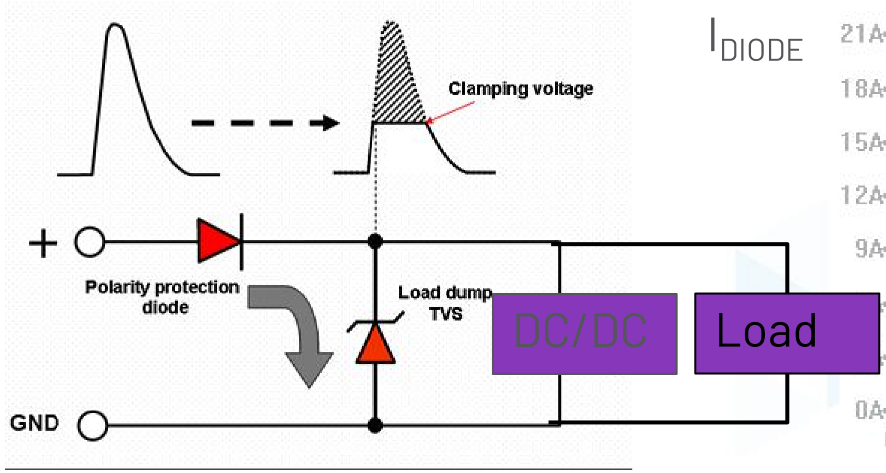
Notes

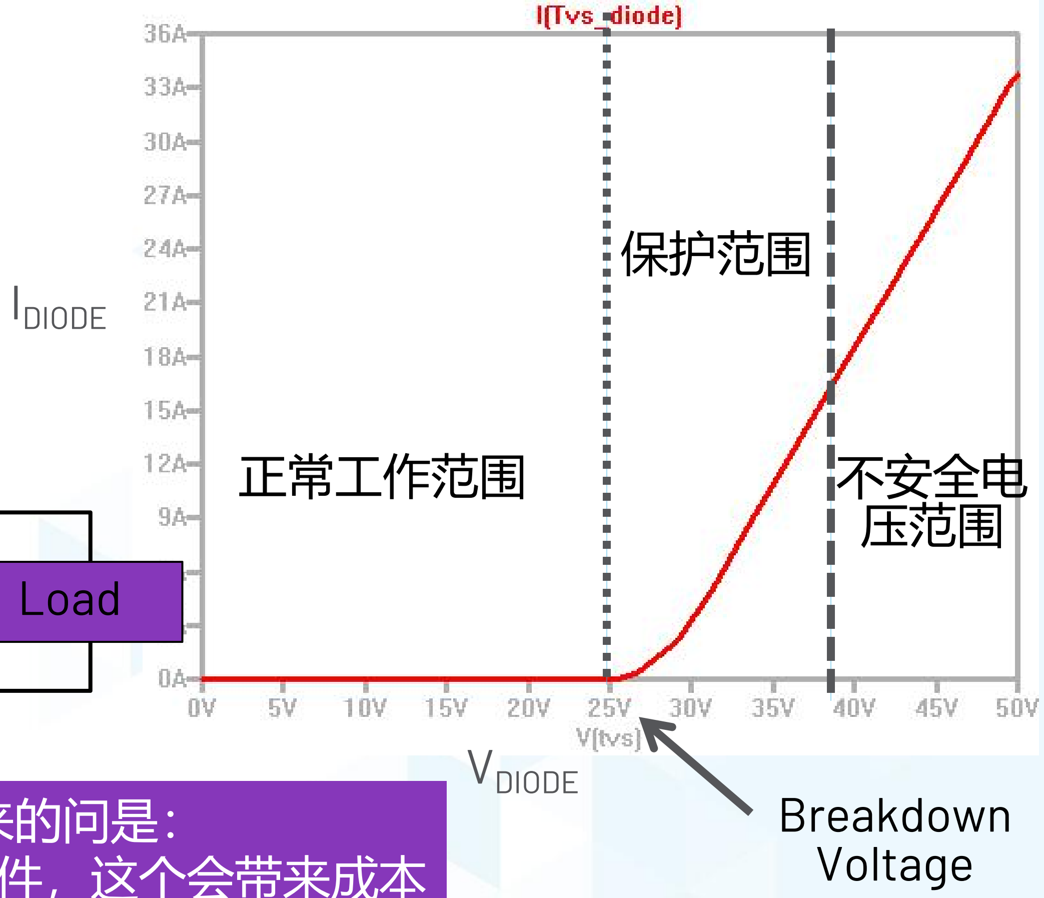
(1) Non-repetitive current pulse, per fig. 3 and derated above T_A = 25 °C per fig. 2. Rating is 300 W above 78 V

(2) Mounted on 0.2" x 0.2" (5.0 mm x 5.0 mm) copper pads to each terminal

TVS 问题

- 击穿点离散性较大(±20% tolerances)
- 击穿特性不陡
- 短路失效模式
- 较大尺寸

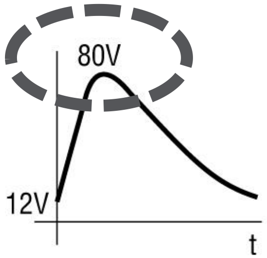




因为器件离散型和平坦击穿特性,带来的问是:
后级的DC/DC不得不选更高电压的器件，这个会带来成本的增加和效率的降低

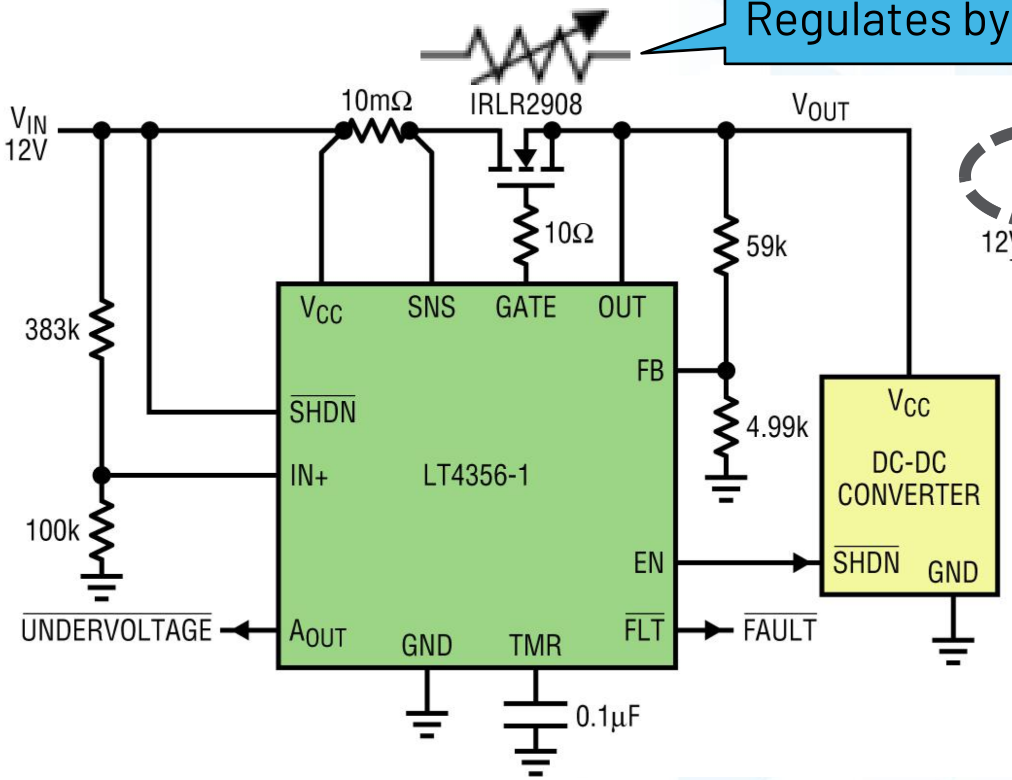
更好的输入防护

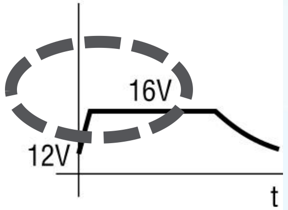
- 利用MOS管的线性区来钳位尖峰（类似LDO工作）
- 利用MOS管的可变电阻区来有效抑制电流，从而降低功率。
- 更多保护: 输入欠压，输入稳态过压，可恢复过流保护，理想二极管，斜率控制。。。。。。



No More Bulky Components!

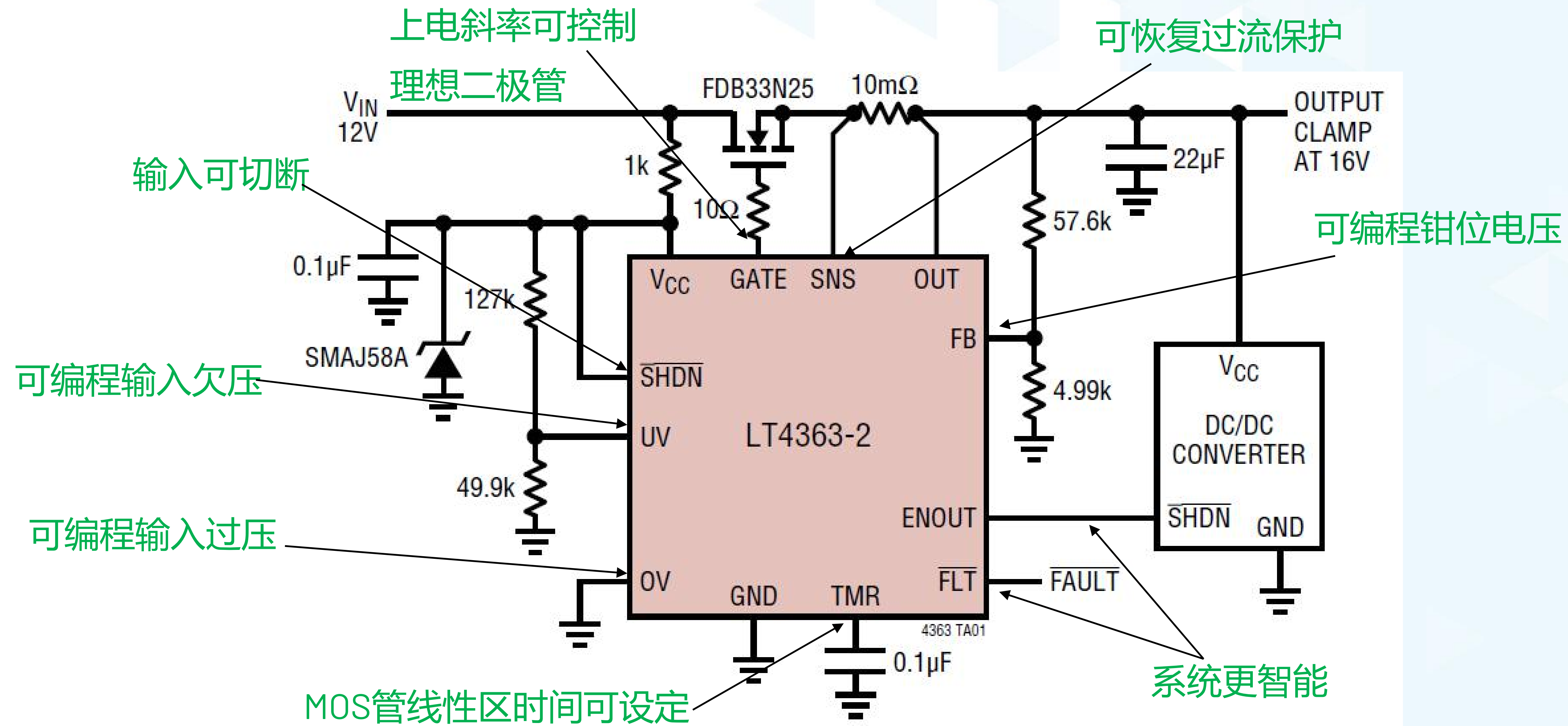
Regulates by dissipating heat





钳位电压是闭环控制的，精度高，可设定，减小后级DC/DC压力

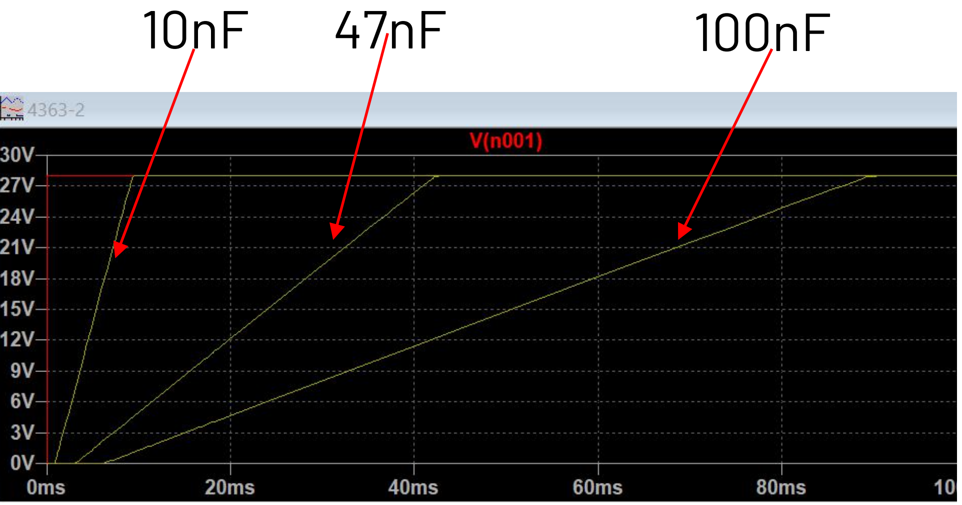
新防护电路的其它功能

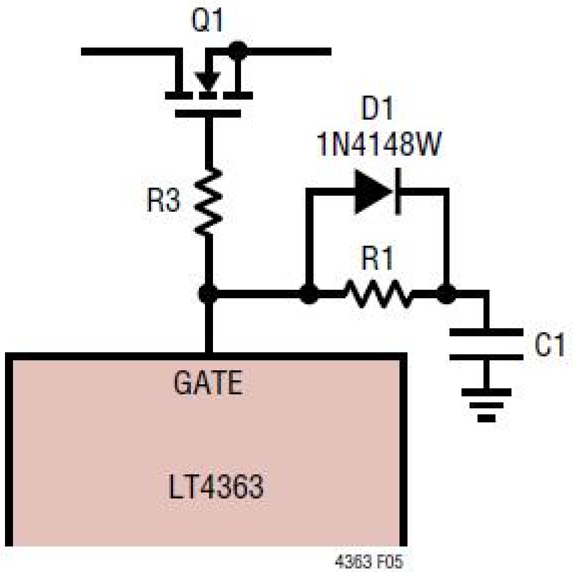


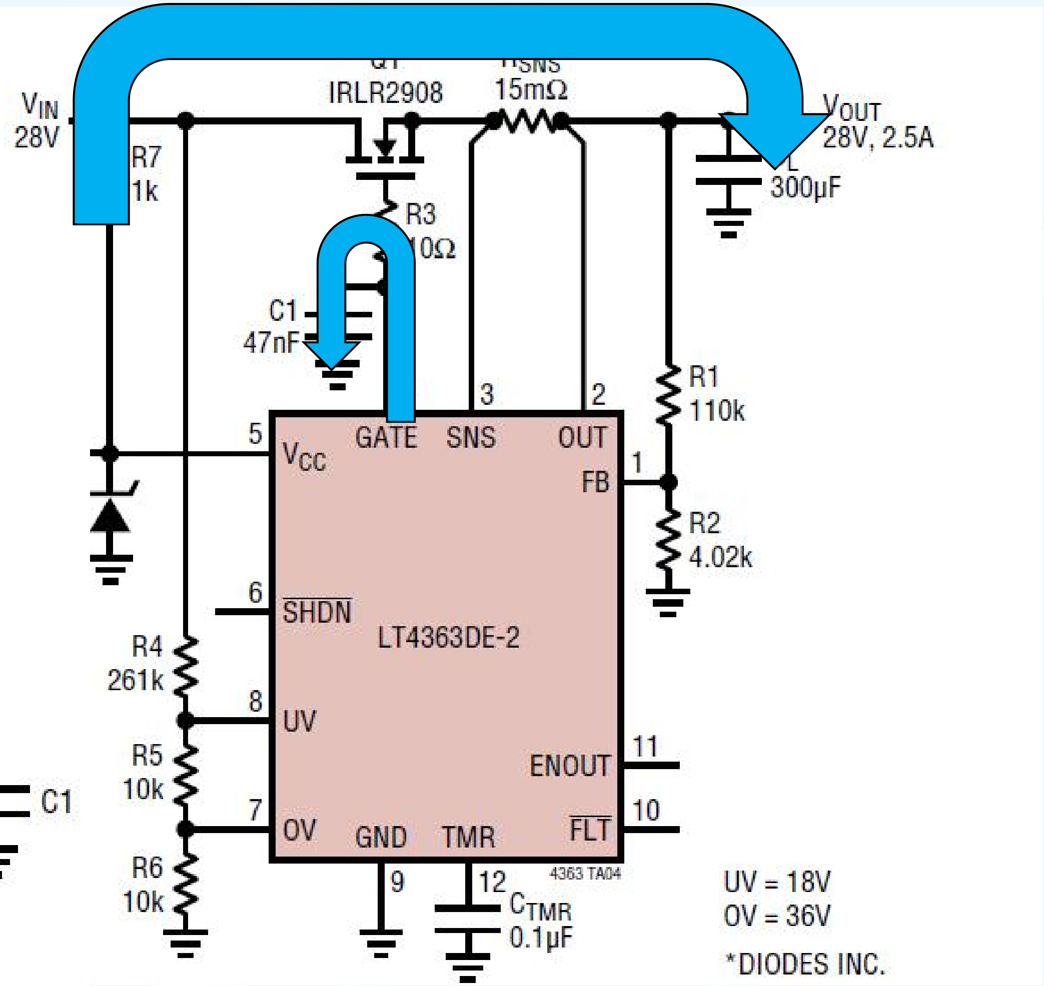
上电斜率可控制
理想二极管
可恢复过流保护
输入可切断
可编程钳位电压
可编程输入欠压
可编程输入过压
MOS管线性区时间可设定
系统更智能
VIN
12V
FDB33N25
10mΩ
OUTPUT
CLAMP
AT 16V
1k
22µF
10Ω
57.6k
0.1µF
127k
VCC
GATE
SNS
OUT
FB
SMAJ58A
SHDN
UV
LT4363-2
4.99k
VCC
DC/DC
CONVERTER
49.9k
ENOUT
SHDN
GND
OV
GND
TMR
FLT
FAULT
4363 TA01
0.1µF

如何控制输入上电斜率

- C1电容电压斜率=CL电容电压斜率
- GATE电流：30uA
- dv/dt=I/C1=30u/C1=Iinrush/CL
- 取不同的C1就得到不同的上电斜率
- 实际电路R1D1作用

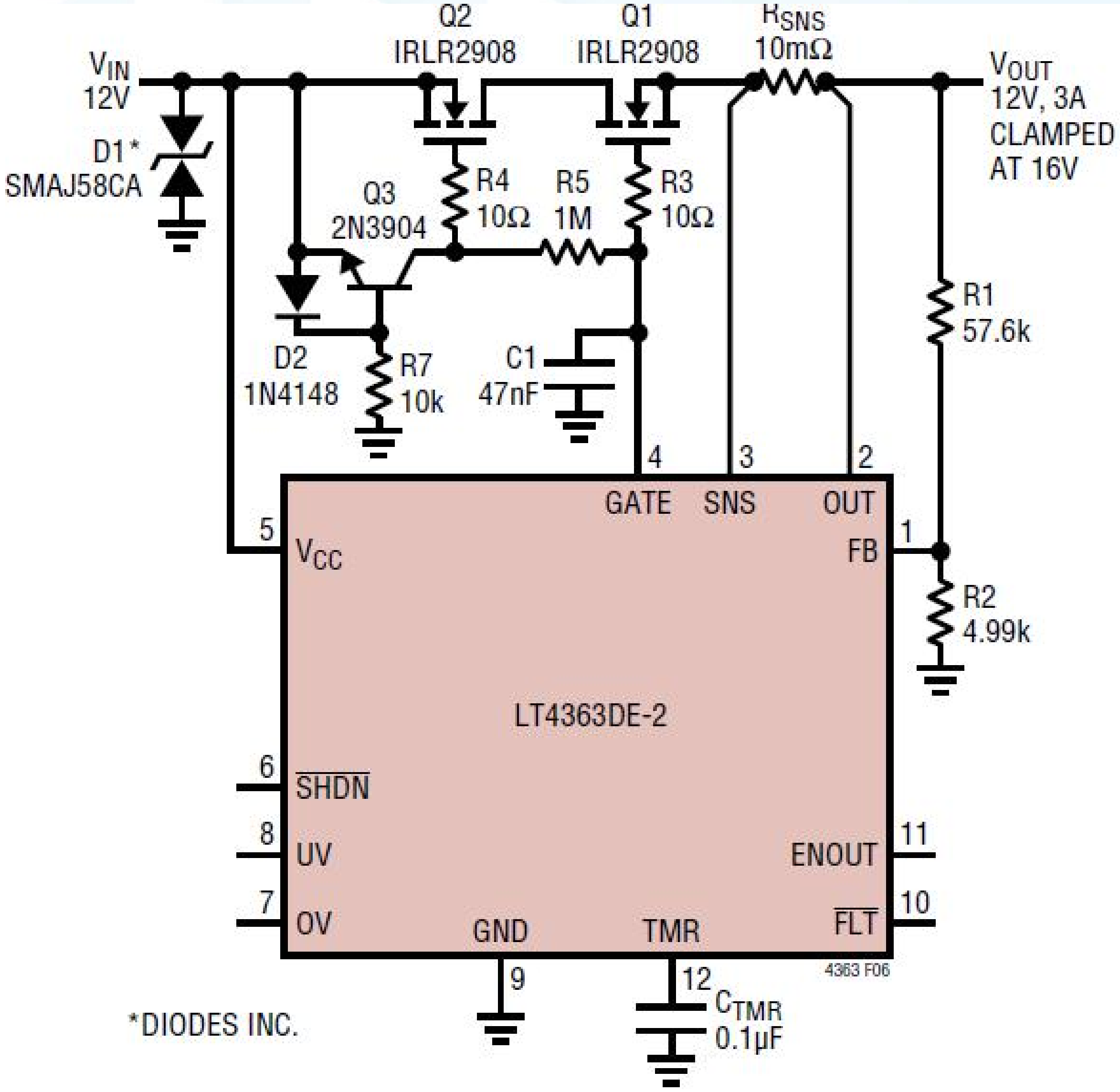




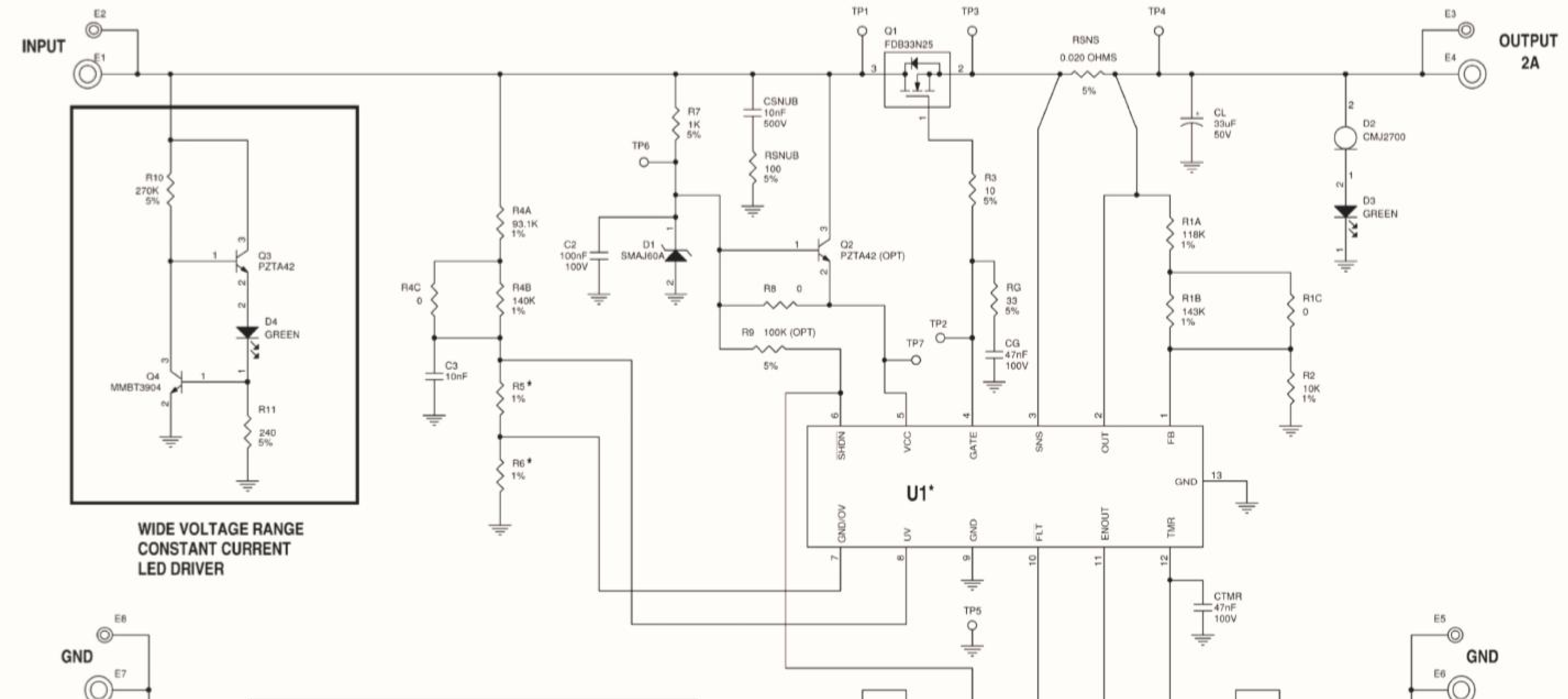


如何实现理想二极管

- 利用MOS管的沟道代替二极管
- 利用Q1的驱动信号驱动Q2
- 理解Q3，D2，R5的作用



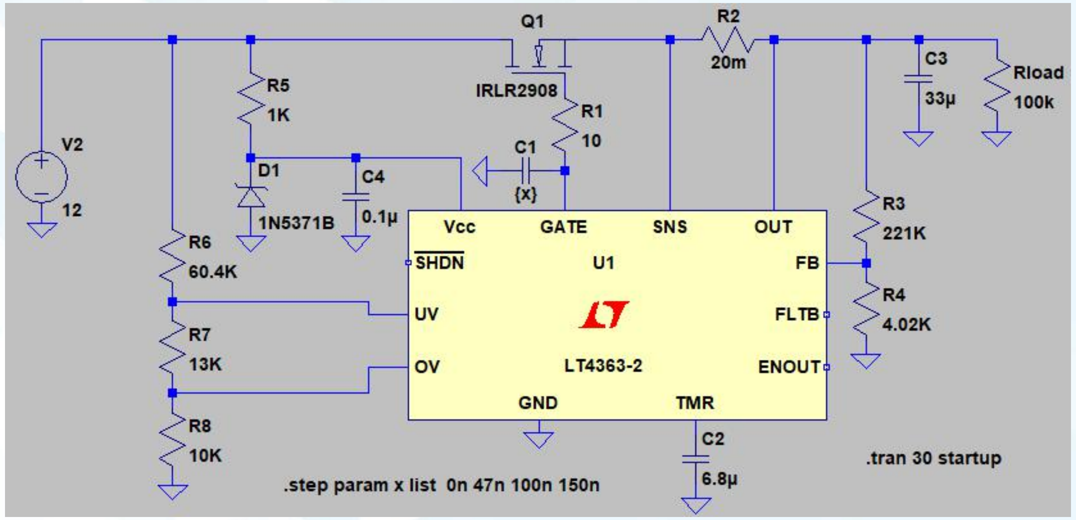
LT4363评估板

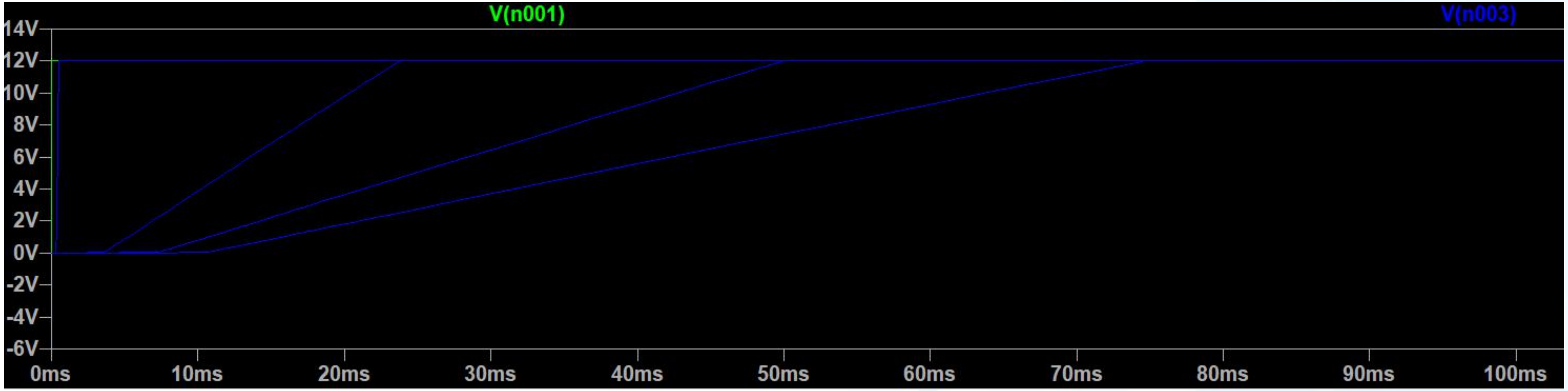


* ASSEMBLY OPTIONS					
ASS'Y TYPE	U1	PIN 7	BEHAVIOR	R5	R6
DC1935A-A	LT4363IDE-1	GND	LATCH OFF	28K	0 OHMS
DC1935A-B	LT4363IDE-2	OV	AUTO RETRY	18.2K	10K

LT4363评估板测试

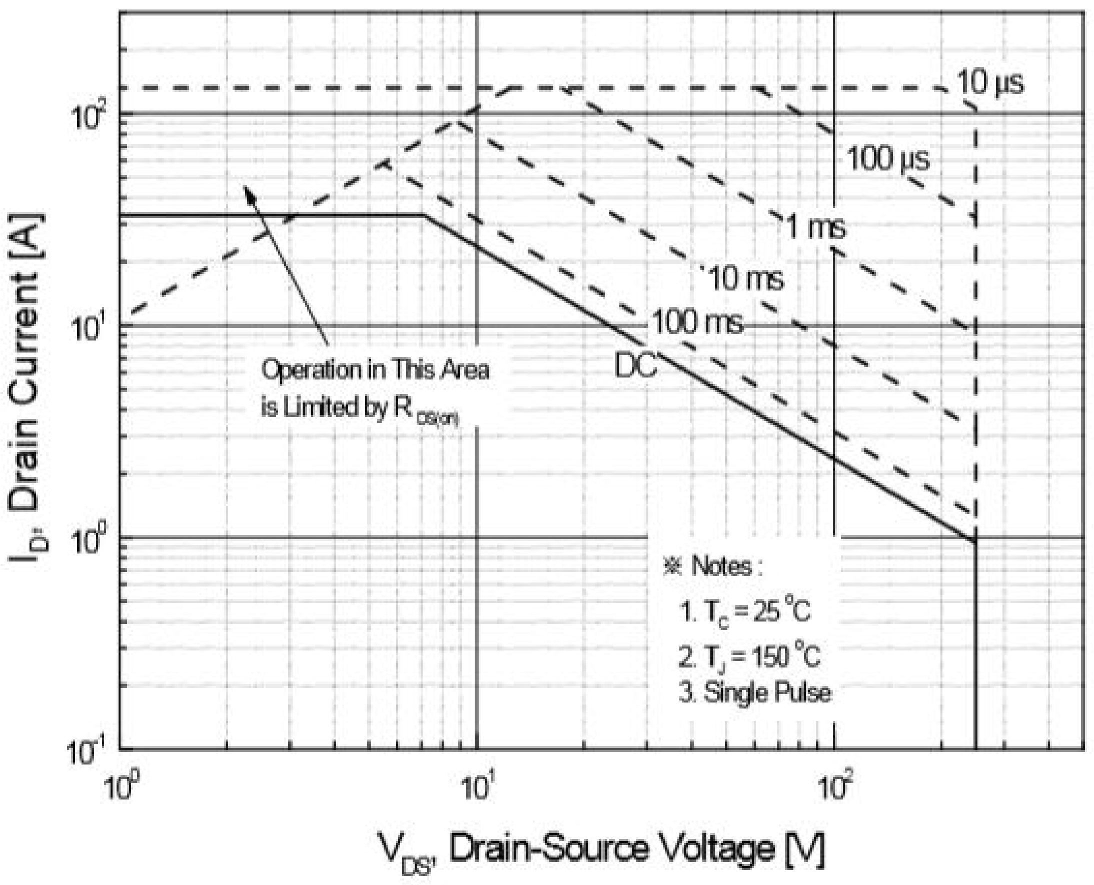
- 输出斜率控制（47nF 100nF 150nF）





LT4363评估板测试

- 各种保护测试
- MOSFET SOA 确认



FDB33N25 SOA

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