无电解电容的LED照明电源和驱动器

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报告内容

1. 概述
2. 无电解电容的LED照明AC/DC电源
3. 无电解电容的LED照明AC/DC驱动器
4. 结论

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电光源的发展过程

第一代：
白炽灯

第二代：
荧光灯

第三代：
高压纳灯

第四代：
LED

APSC
Aero-Power Sci-tech Center

LED的优点

☺ 效率高

传统的白炽灯: 12 – 24 lm / W;
LED: 25-200 lm / W.

可节能
80% - 90%

☺ 寿命长

大于100,000小时

☺ 绿色环保

是半导体发光器件，属于固态光源，无辐射，不会造成环境污染。

☺ 安全性好

是固体冷光源，采用环氧树脂封装，能承受机械冲击和震动，可安全触摸。

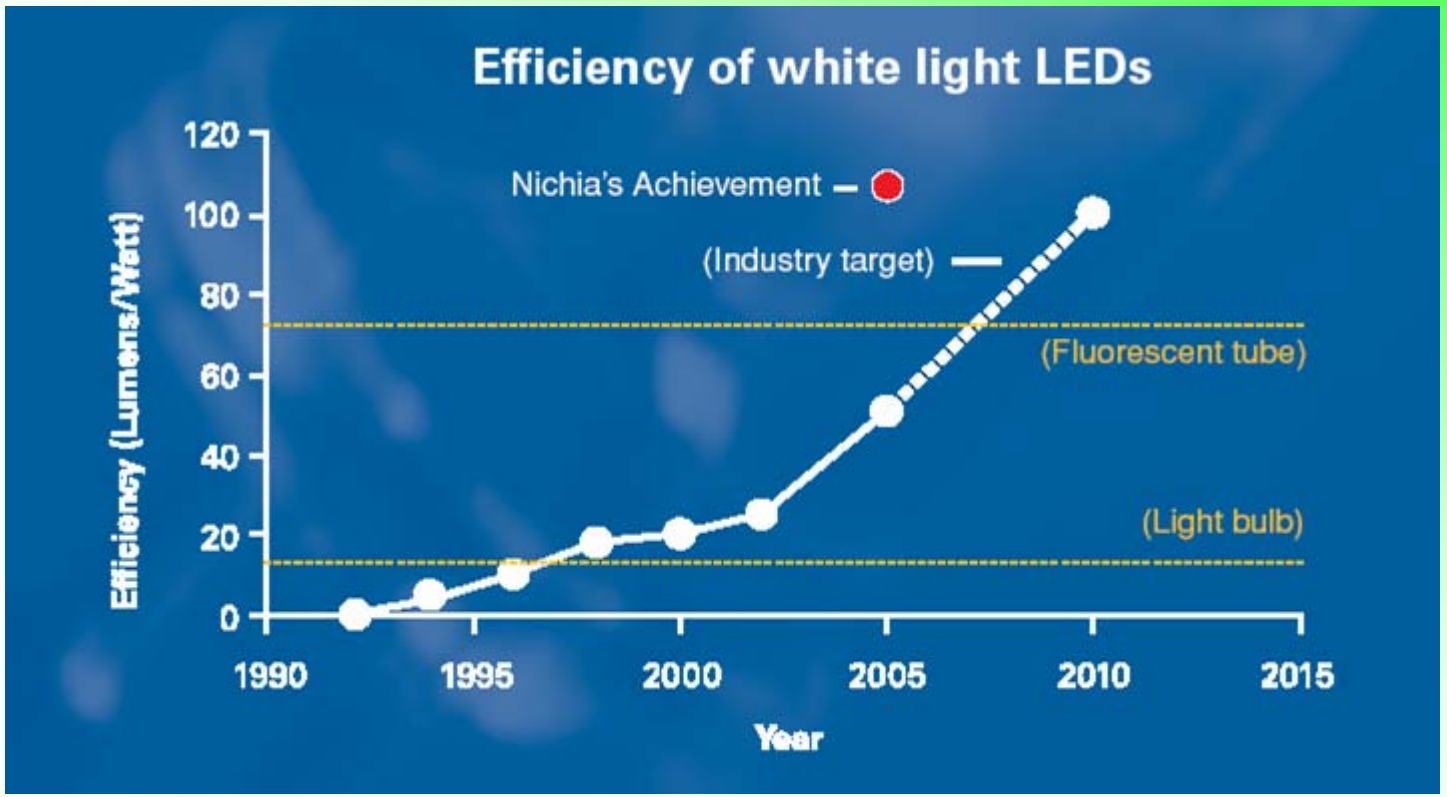
☺ 体积小

小型化、平面化、可设计性强；不受点线光源局限，可实现照明的随意布局。

☺ 色彩多

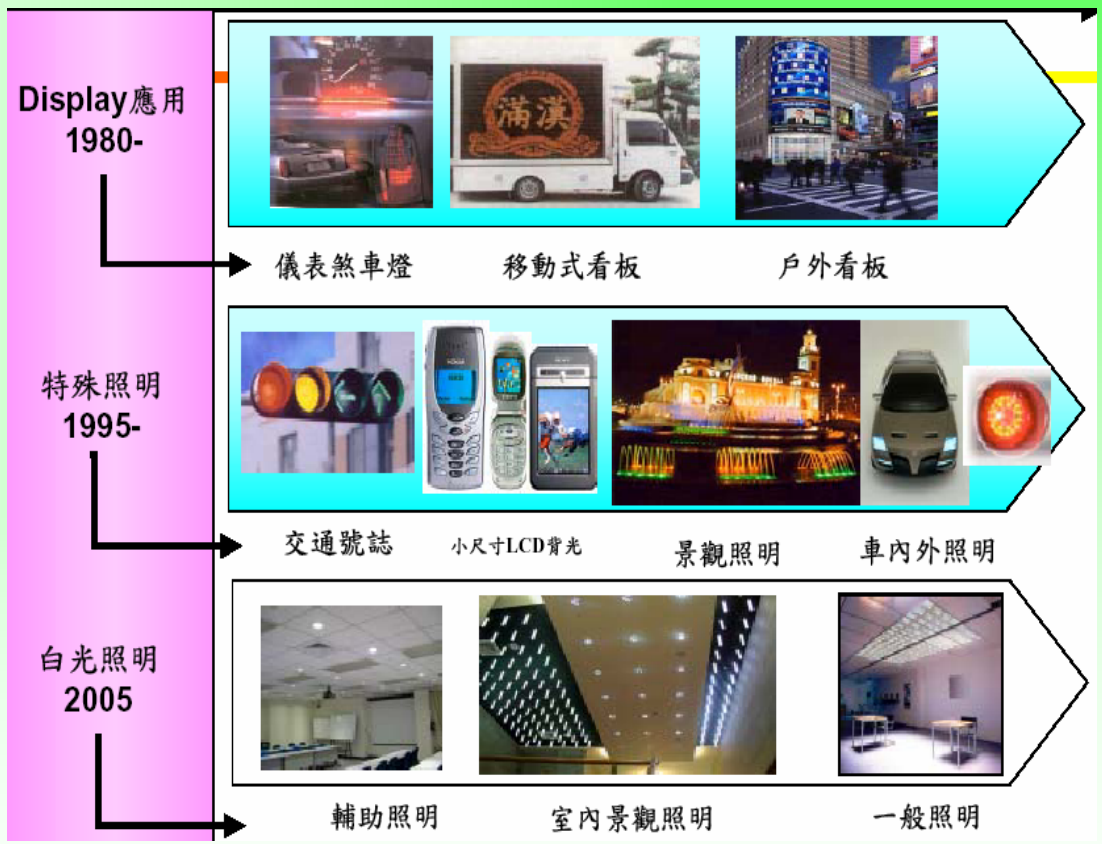
可以获得各种色彩 / 装饰灯

白光LED的效率

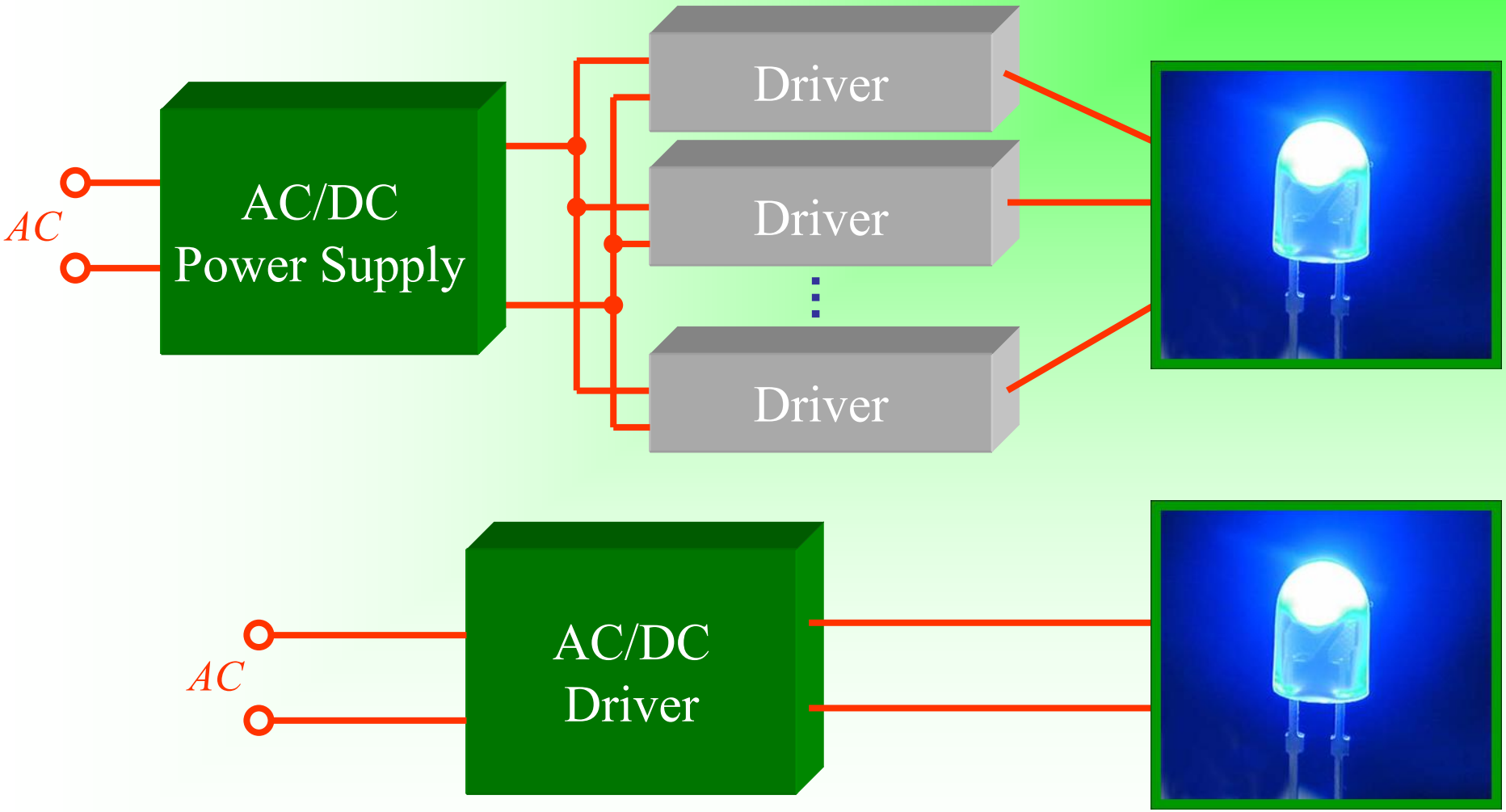

Efficiency of white light LEDs
Nichia's Achievement
(Industry target)
(Fluorescent tube)
(Light bulb)
Efficiency (Lumens/Watt)
120
100
80
60
40
20
0
1990
1995
2000
2005
2010
2015
Year

LED的应用

- 普通照明
- 装饰照明
- 交通信号指示
- 汽车内外照明
- LCD 背光源
- 特种照明
- 投影仪
- 光工业产品
- ……



关于LED照明中的研究内容



1. 概述

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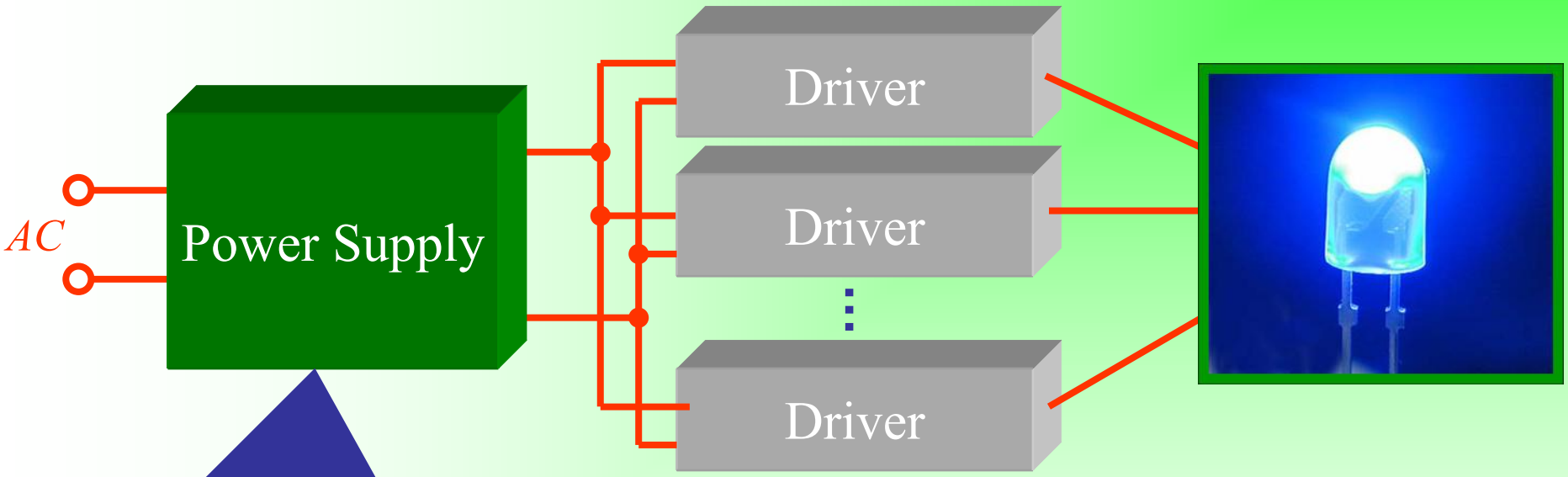
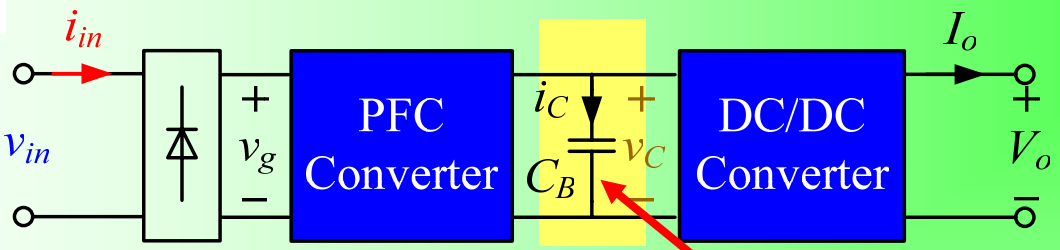
4. 结论

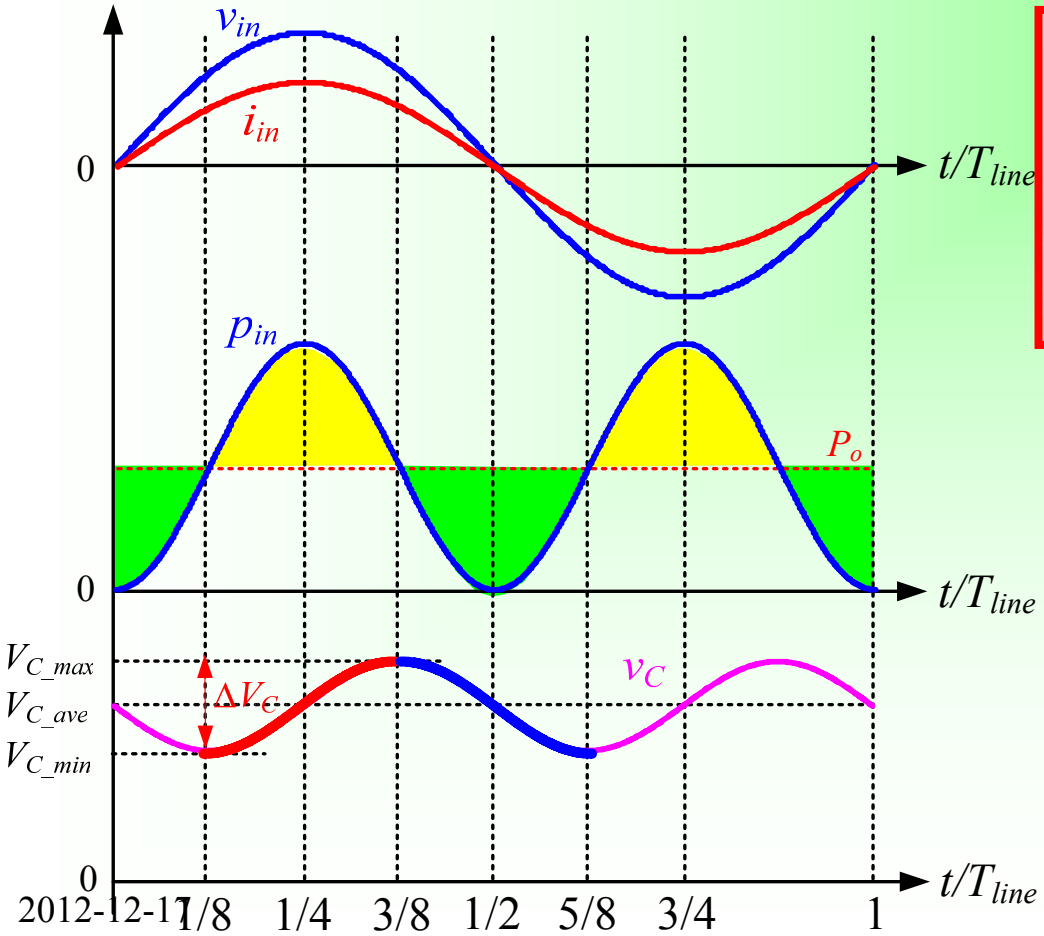
LED照明用AC/DC电源



- High input power factor (>0.9);
- Eliminate electrolytic capacitor to increase the lifetime;
- Low cost.

PFC变换器中的储能电容





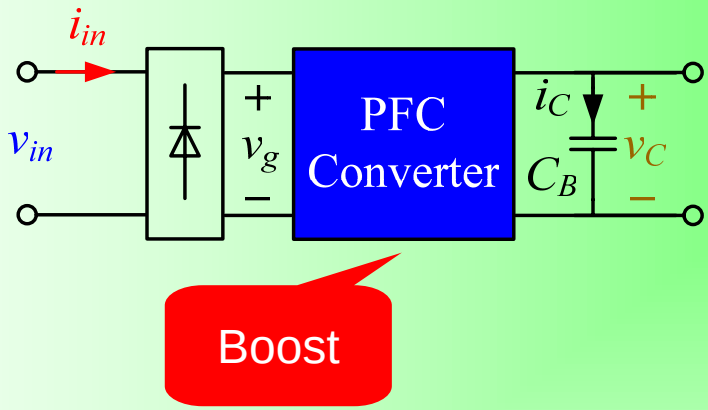
☹ 体积大;
☹ 寿命较短.

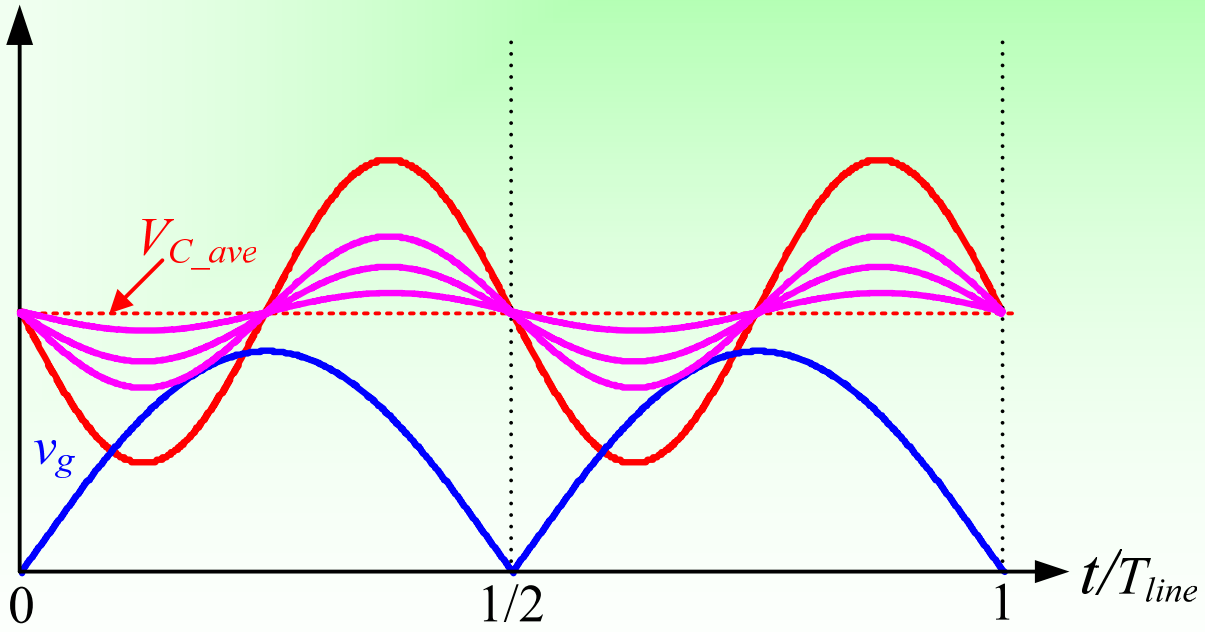
电解电容

☺ 体积小;
☺ 寿命长.

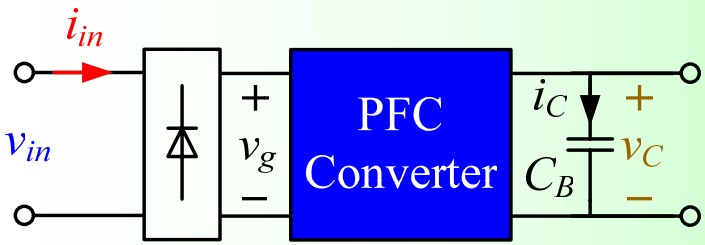
瓷片或薄膜电容

增大电压纹波以减小电容值

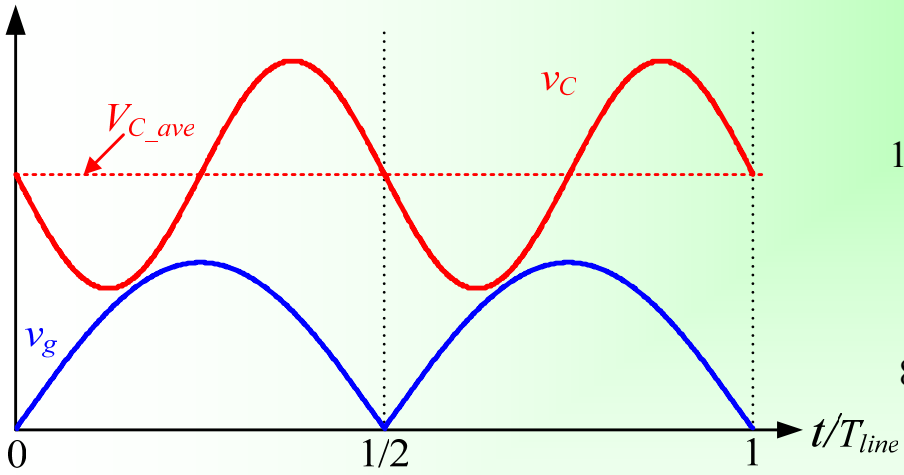




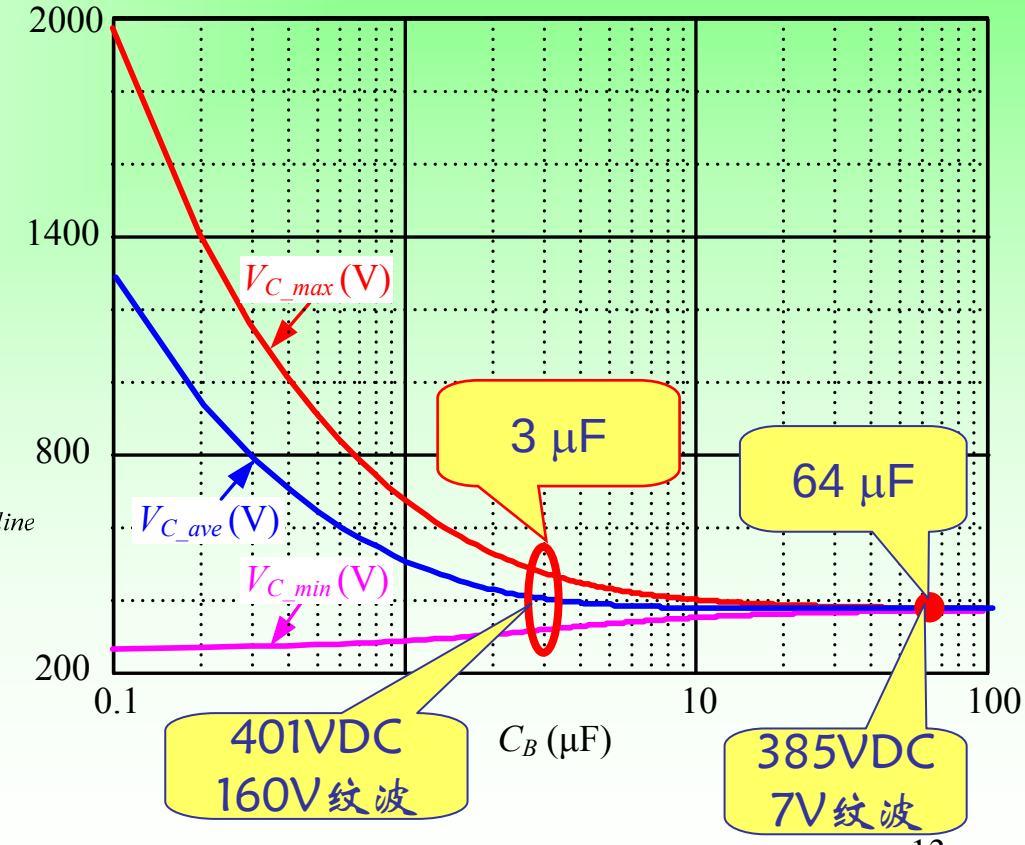
电压纹波与储能电容的关系



- 输入电压: 198 – 264 VAC;
- 输出功率: 60 W.



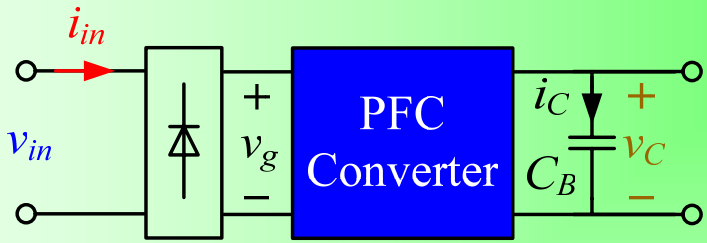
$v_C > v_g$



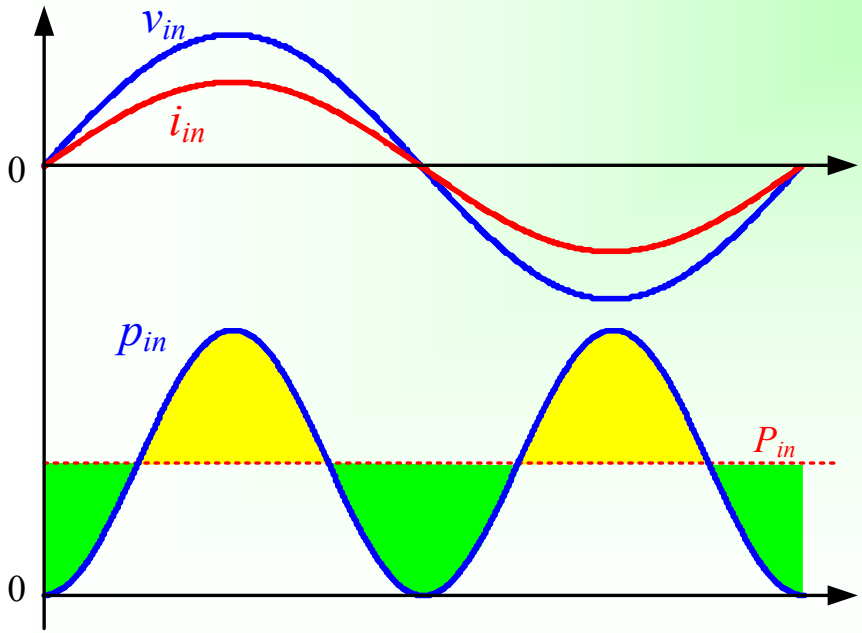
输入功率因数与输入功率脉动

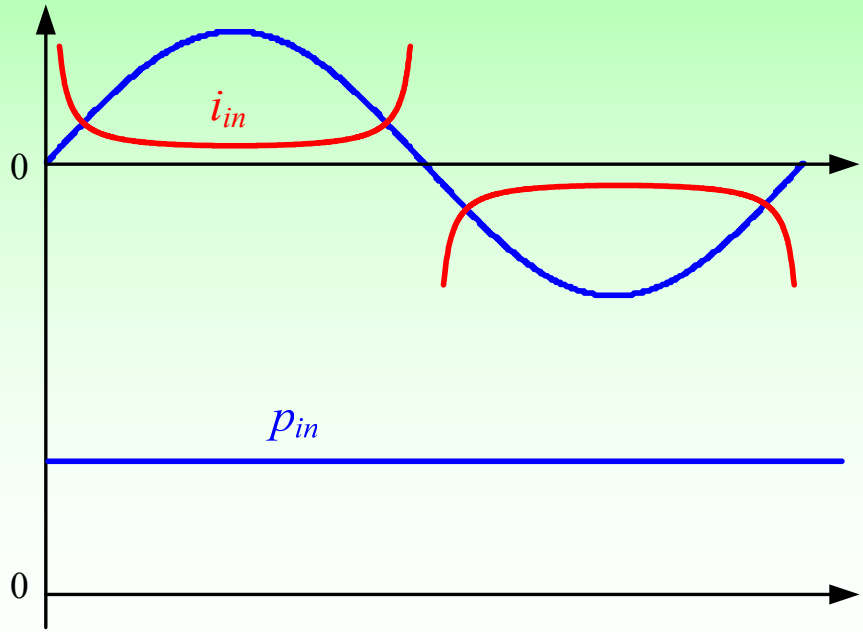
☺ PF=1.0

☹需要一个很大的储能电容.



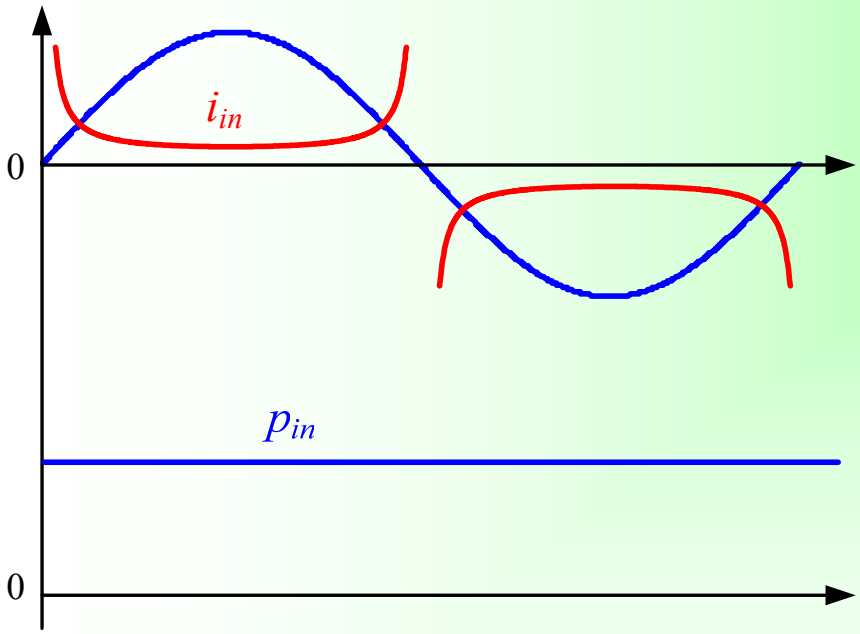
☺ 不需要储能电容

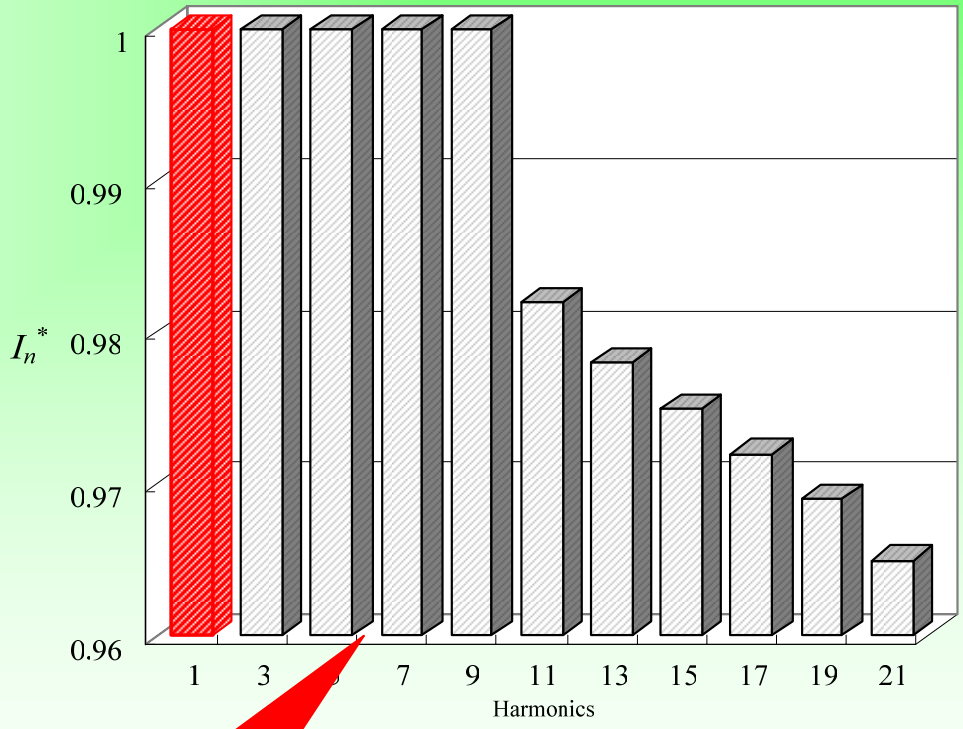




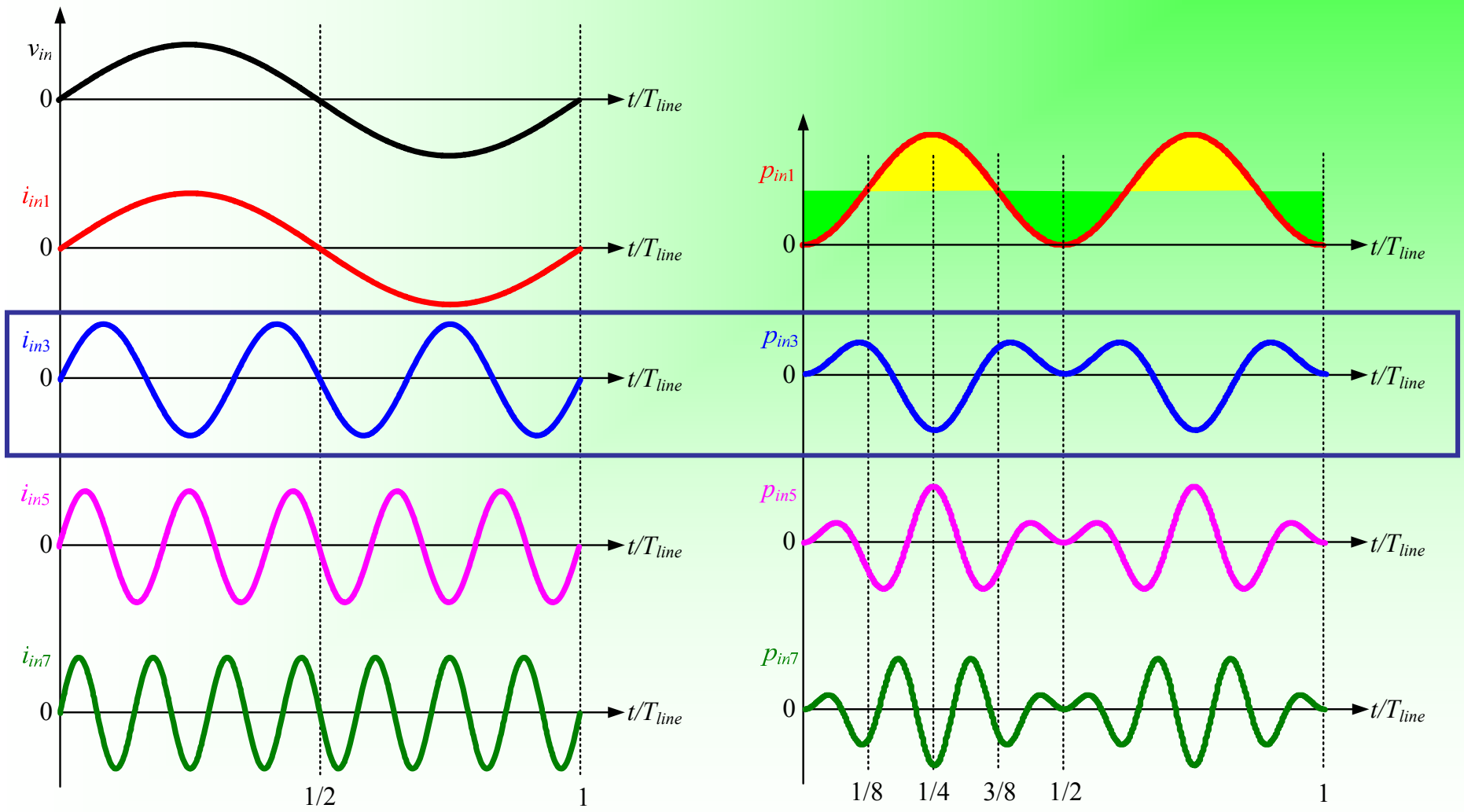
输入电流的谐波

☹ PF= 0


i_{in}
0
p_{in}
0

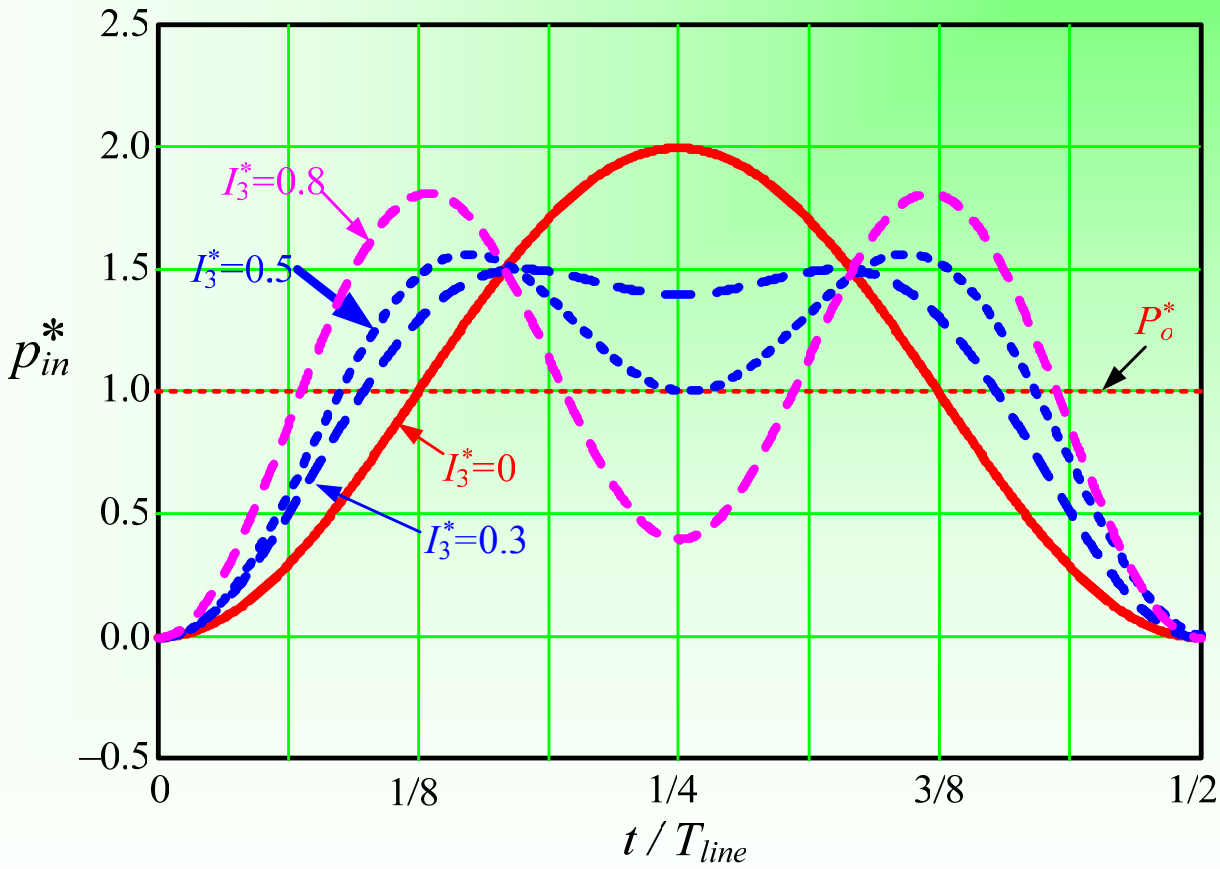

1
0.99
0.98
0.97
0.96
I_n^*
1
3
7
9
11
13
15
17
19
21
Harmonics
奇次谐波

奇次谐波电流对应的瞬时功率

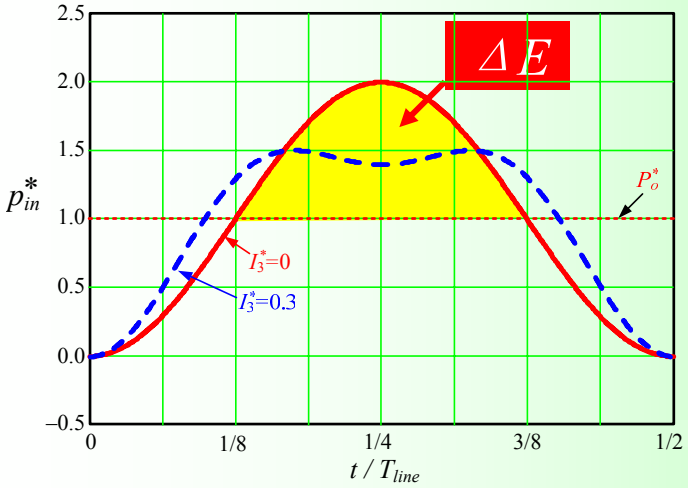


注入3次谐波后的瞬时输入功率

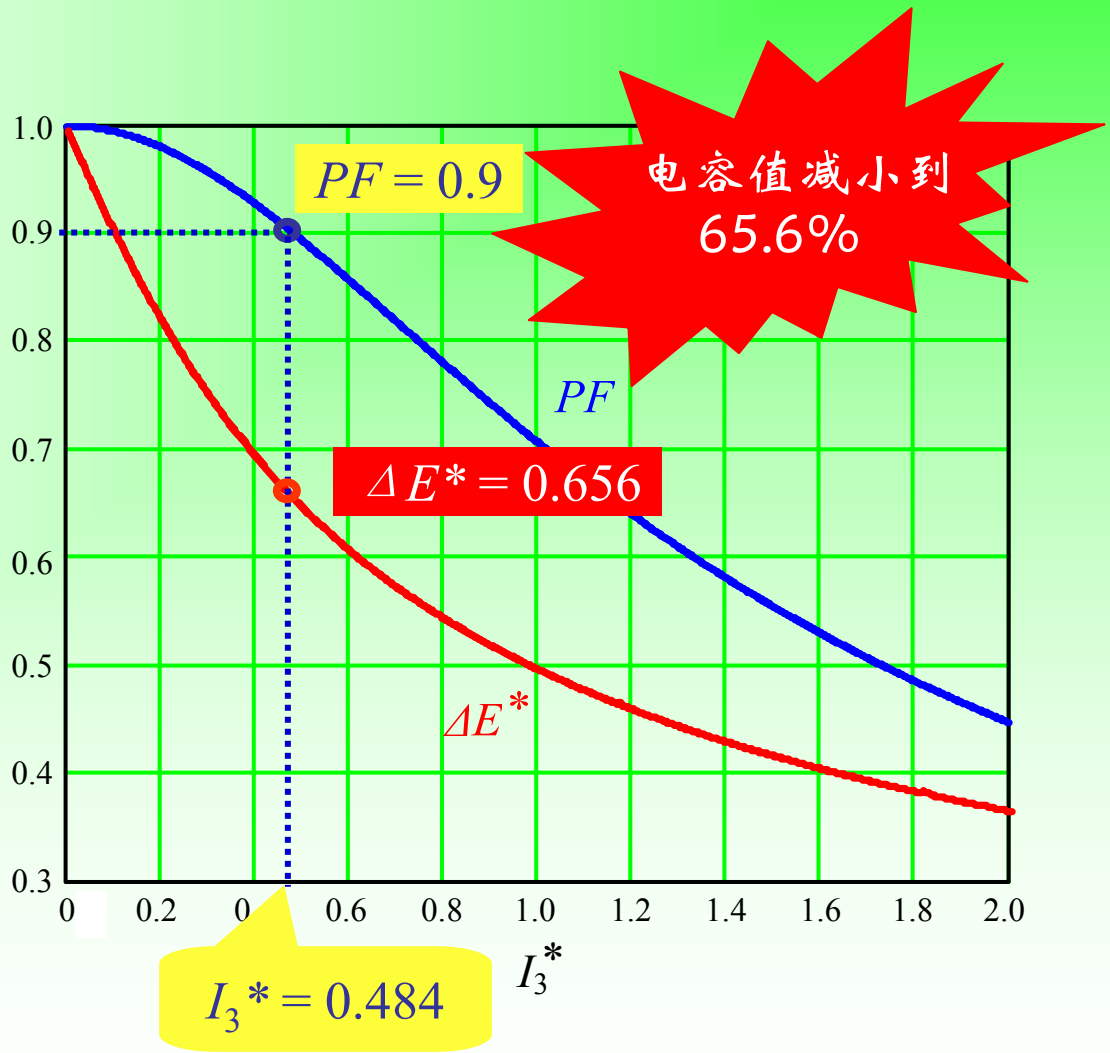
$$i_{in}(t) = I_1 \cdot \sin \omega t + I_3 \cdot \sin(3\omega t)$$



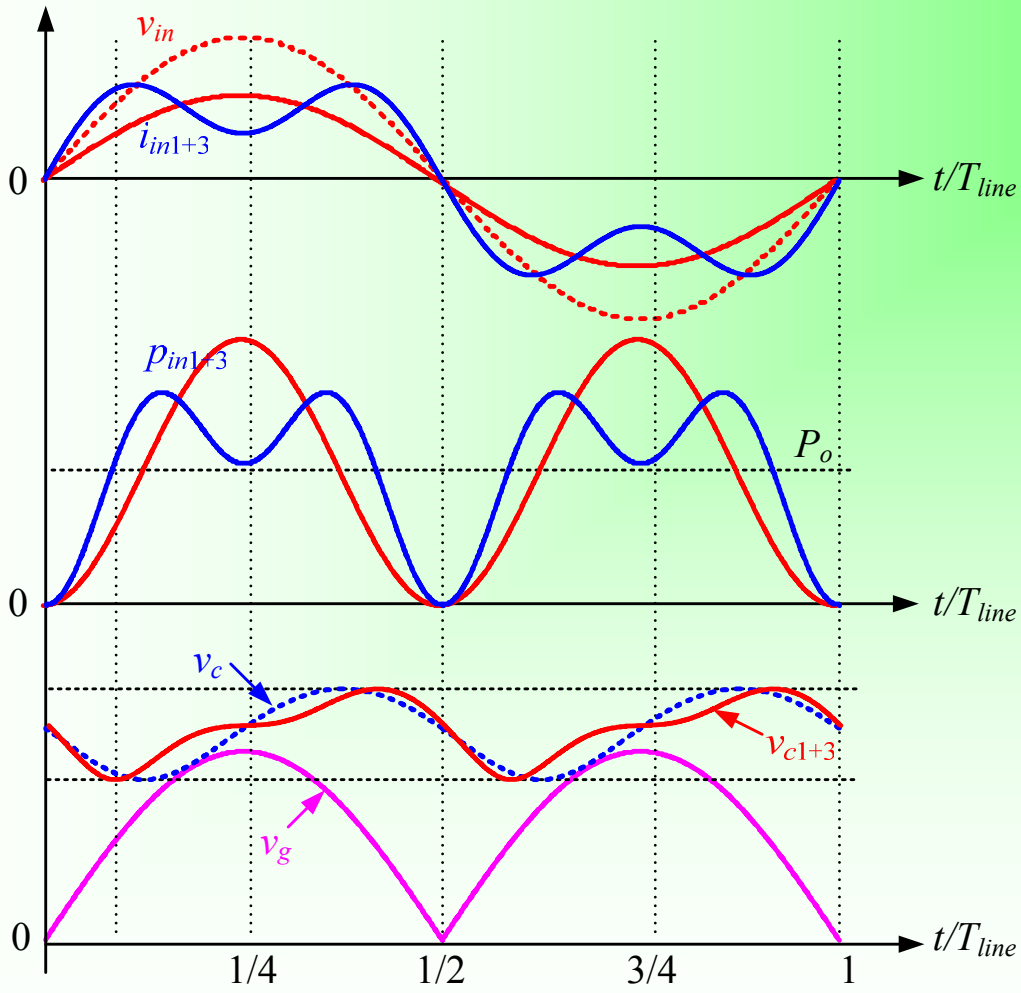
注入3次谐波后的输入功率因数与瞬时输入功率



$$PF = \frac{I_1}{\sqrt{I_1^2 + \left(I_3^* I_1\right)^2}} = \frac{1}{\sqrt{1 + \left(I_3^*\right)^2}}$$

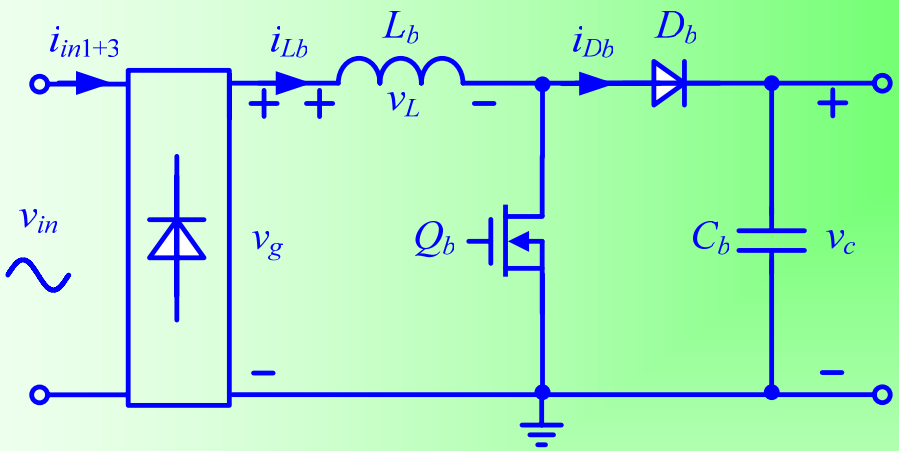


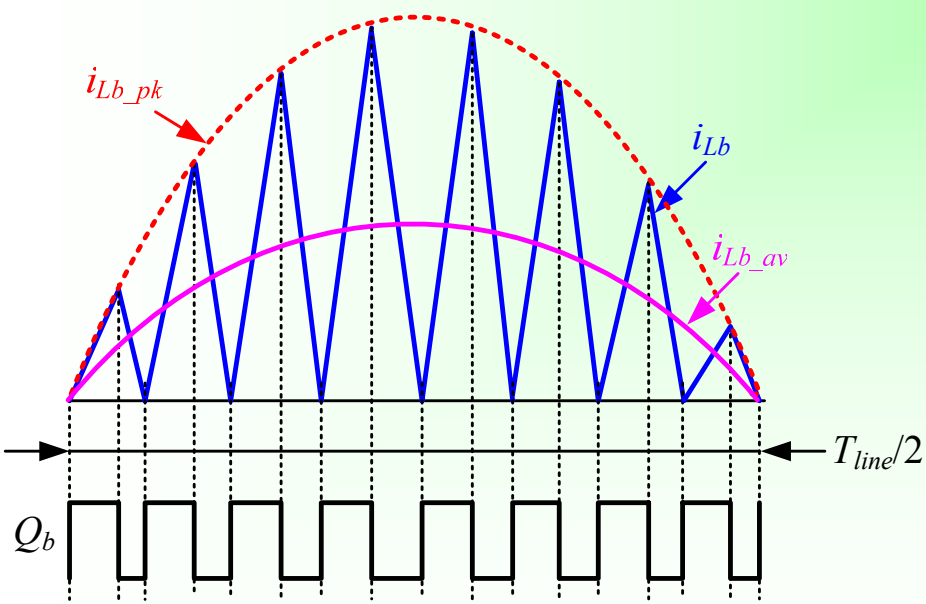
注入3次谐波后对输出电压脉动的影响

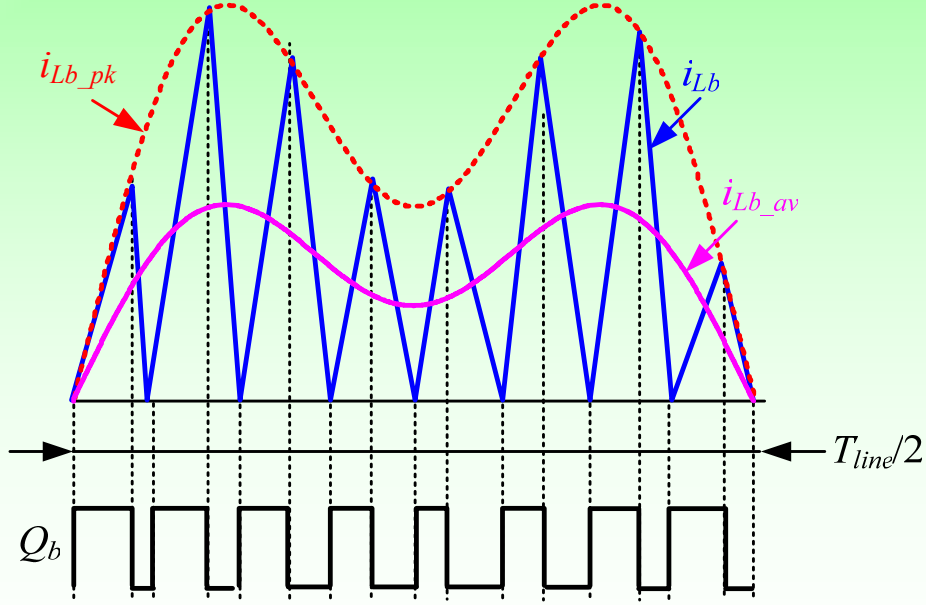


注入标幺值为0.484的三次谐波后，即使储能电容减小到65.6%，也不会影响Boost PFC变换器的正常工作。

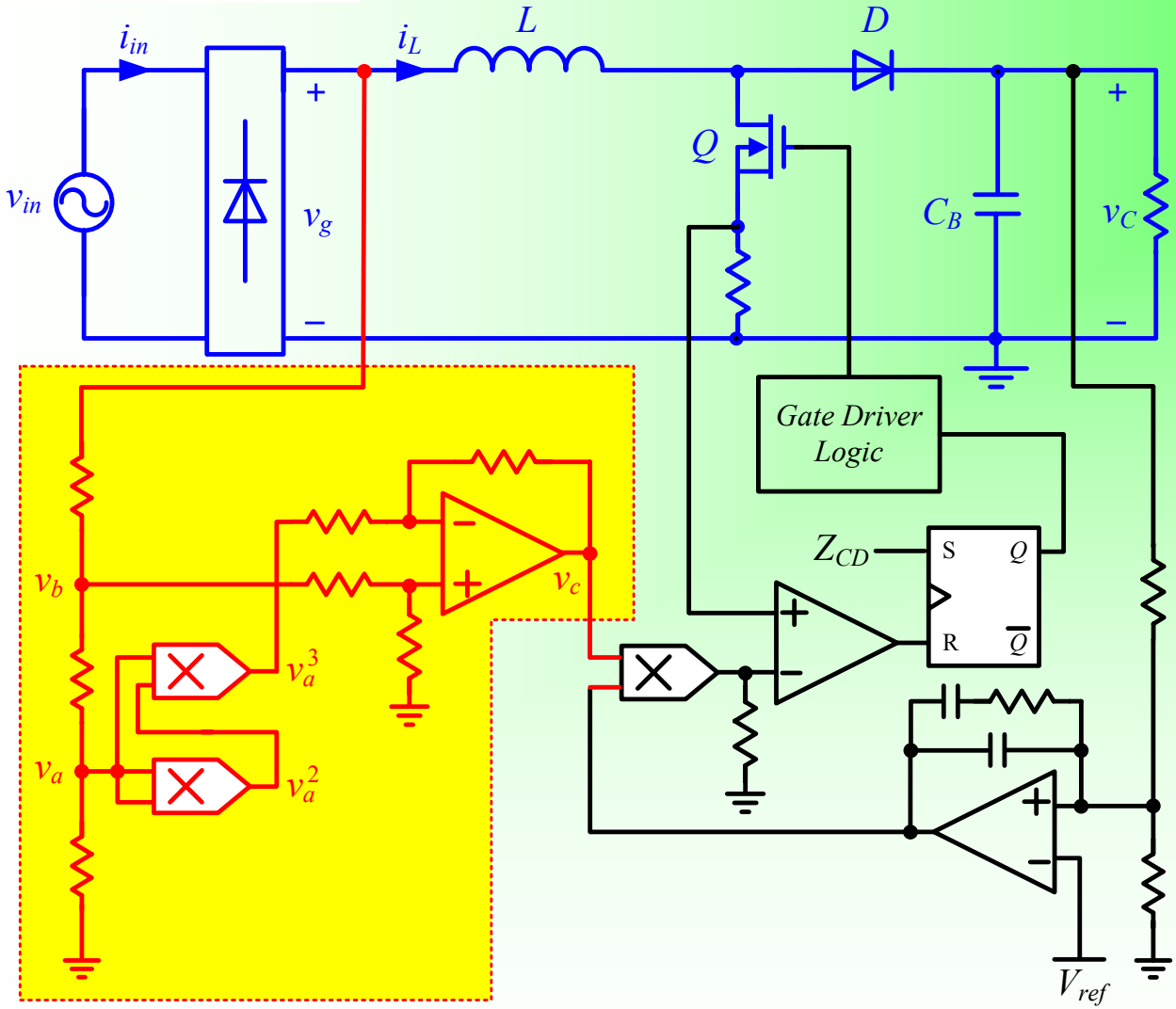
CRM Boost PFC变换器







Boost PFC变换器的电路实现

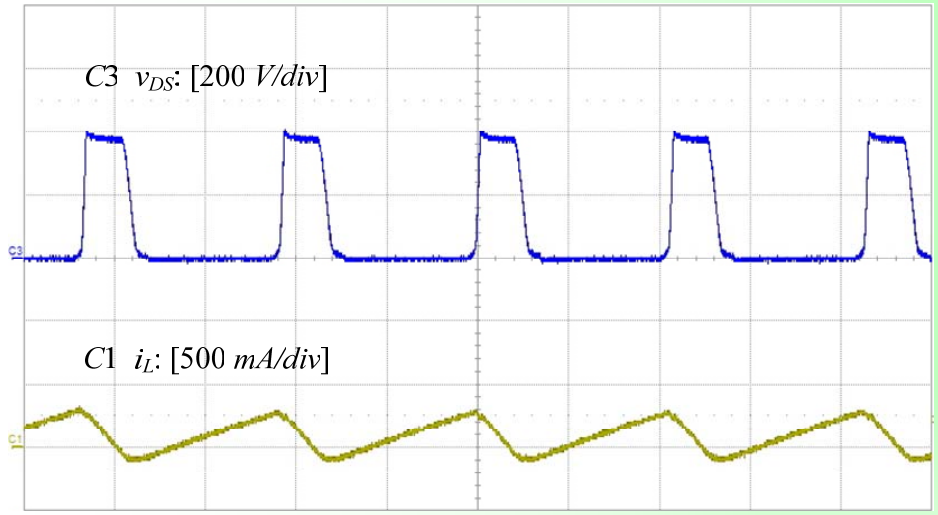


3rd harmonic current Injection reference generation circuit

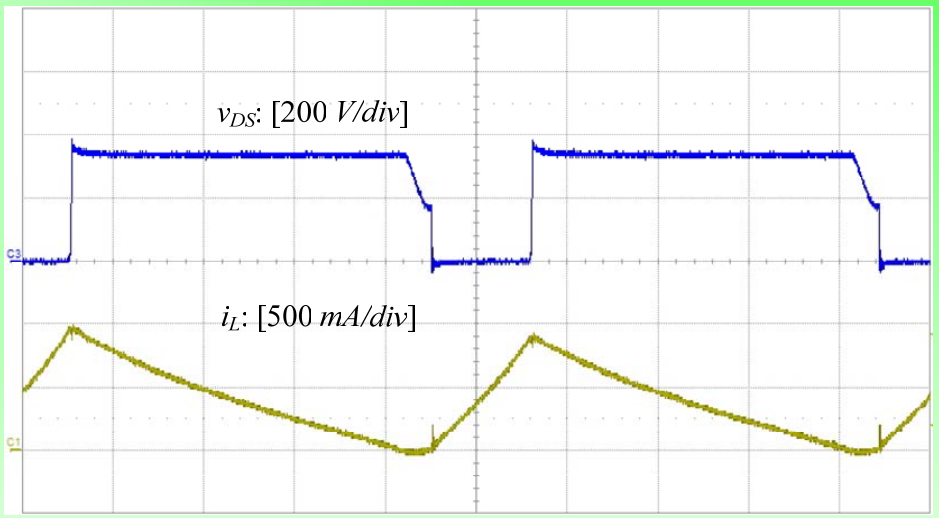
V_{in}: 198 – 264 VAC;
P_o: 60 W.

Q: FQPF4N60C
(600 V, 2.6 A)
D: MUR460
(600 V, 4 A)
L: 600 μH
C: 2 μF

实验结果



在输入电压的波谷附近

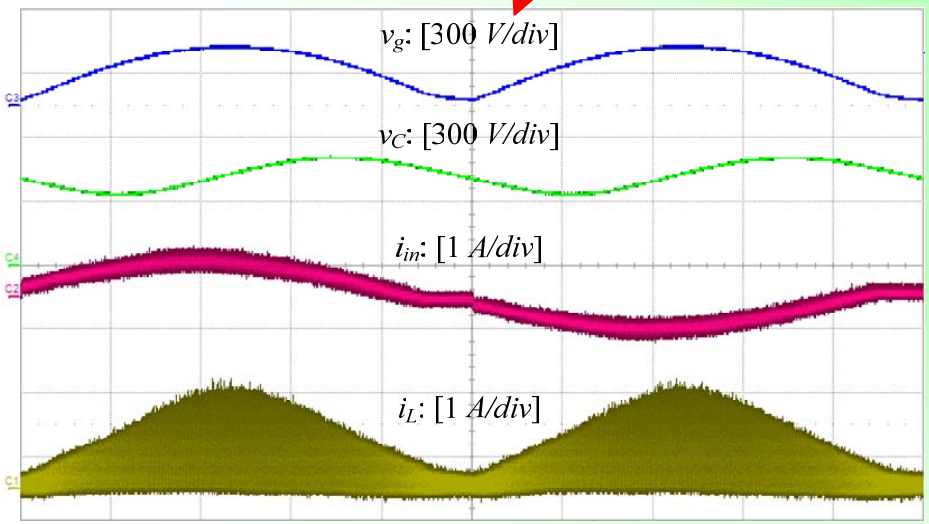


输入电压的波峰附近

实验结果

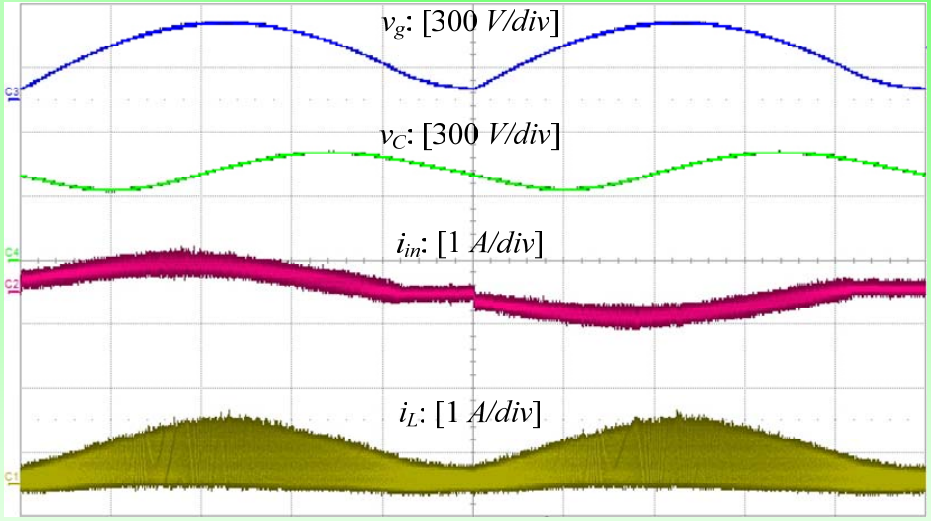
Cb=3μF

V_{c_av}= 424 V
$\triangle V$ = 180 V



Time: [2 *ms/div*]

输入198V



Time: [2 *ms/div*]

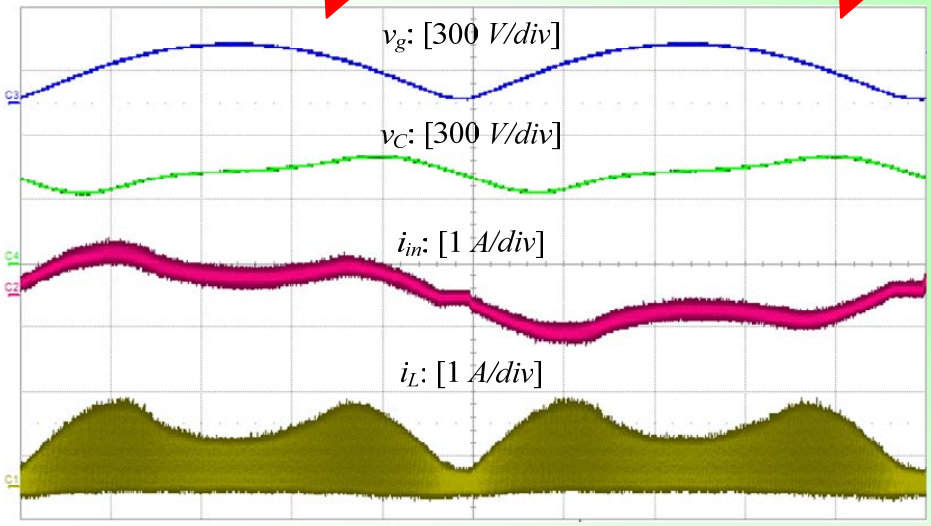
输入264V

加大储能电容电压纹波

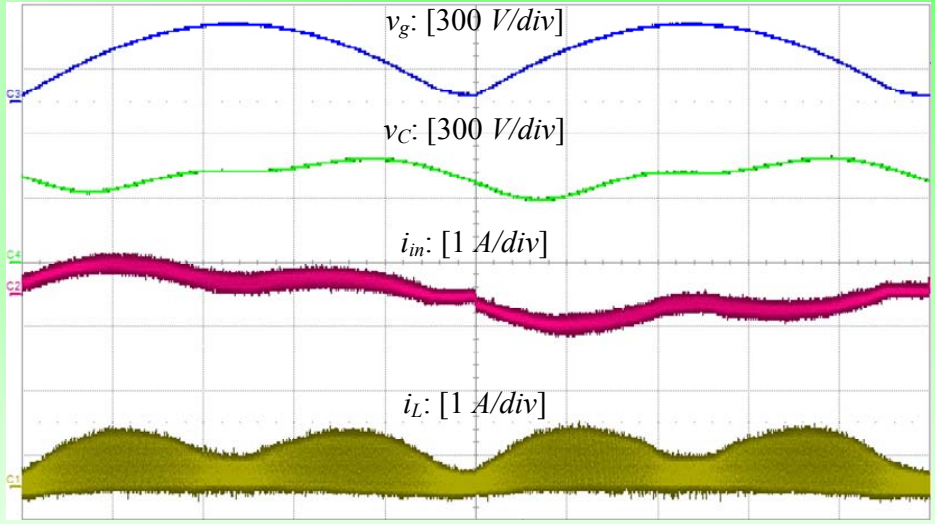
实验结果

Cb=3μF → Cb=2μF

V_{c_av}= 424 V
$\triangle V$ = 180 V



输入198V



输入264V

加大储能电容电压纹波，
同时注入三次谐波

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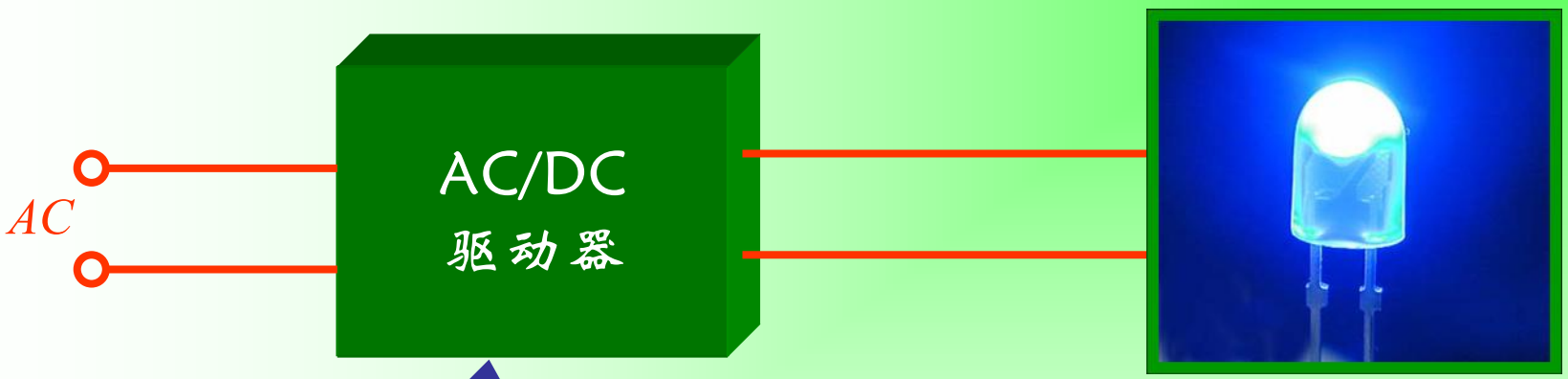
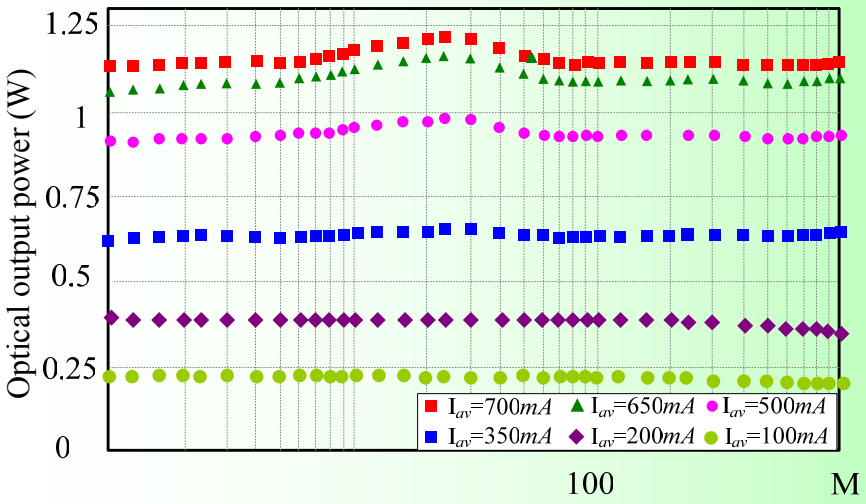
4. 结论

LED照明用AC/DC驱动器

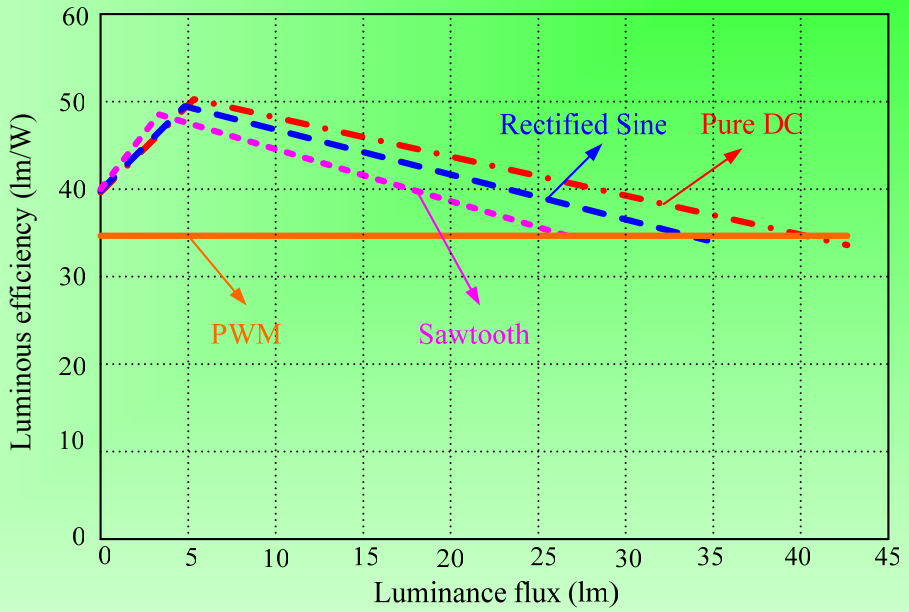


- High input power factor (>0.9);
- Eliminate electrolytic capacitor to increase the life time;
- Low cost.

脉动电流对LED输出光通量的影响



Source: Spiazzi G, et. al. Analysis of … for high brightness lighting emitting diodes. PESC, 2005



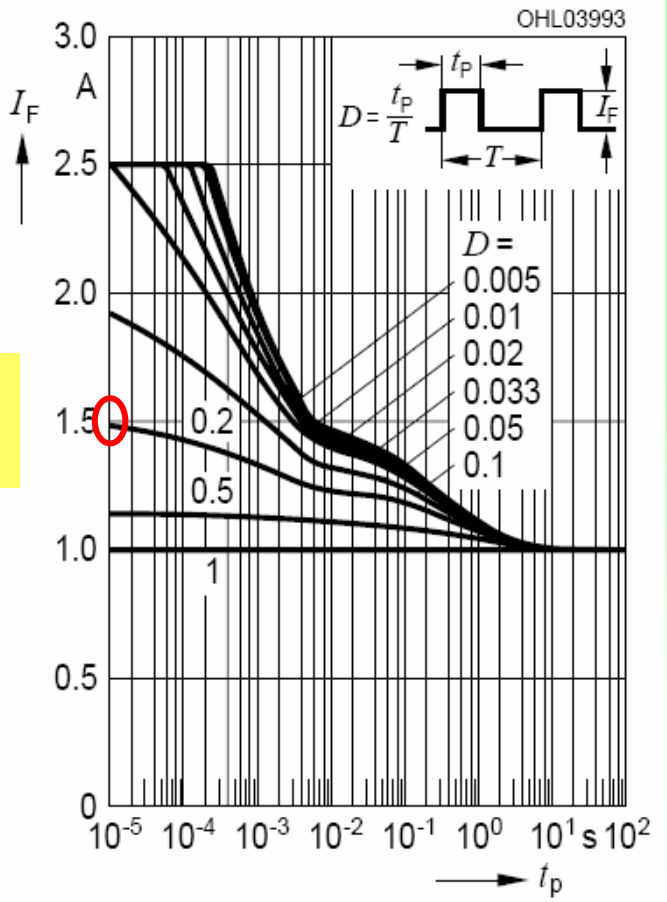
Source: Spiazzi G, et. al. Analysis of … for high brightness lighting emitting diodes. PESC, 2005

- LED的输出光通量只取决于平均驱动电流；
- 从输出功率的角度来看，可以采用脉动电流来驱动LED。

- 在LED输出光通量相等的条件下，直流驱动的发光效率最高，正弦半波与之效率相近，PWM驱动的LED光效最低。

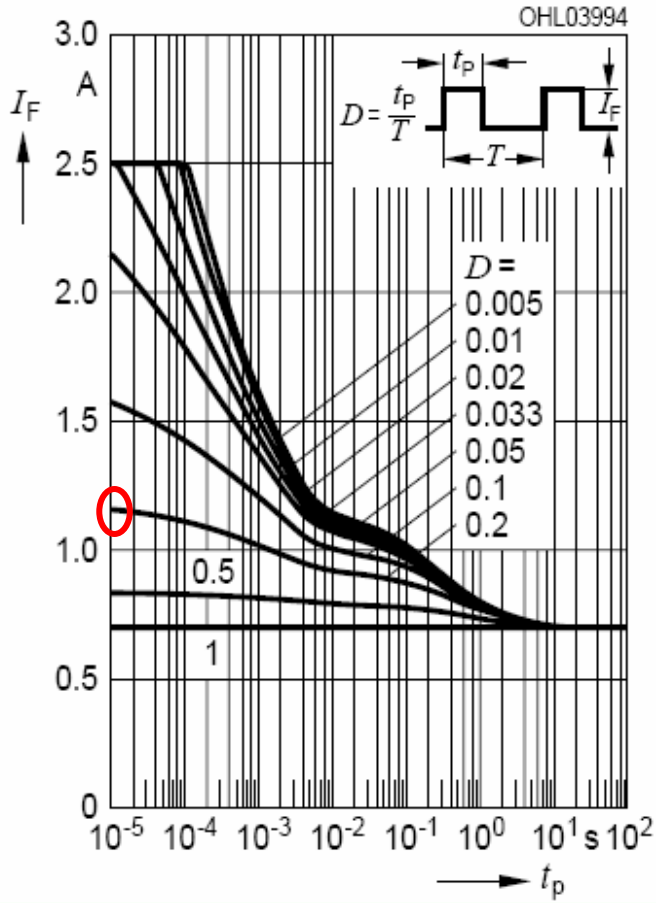
LED的最大电流

Permissible Pulse Handling Capability
Duty cycle D = parameter, T_S = 25 °C

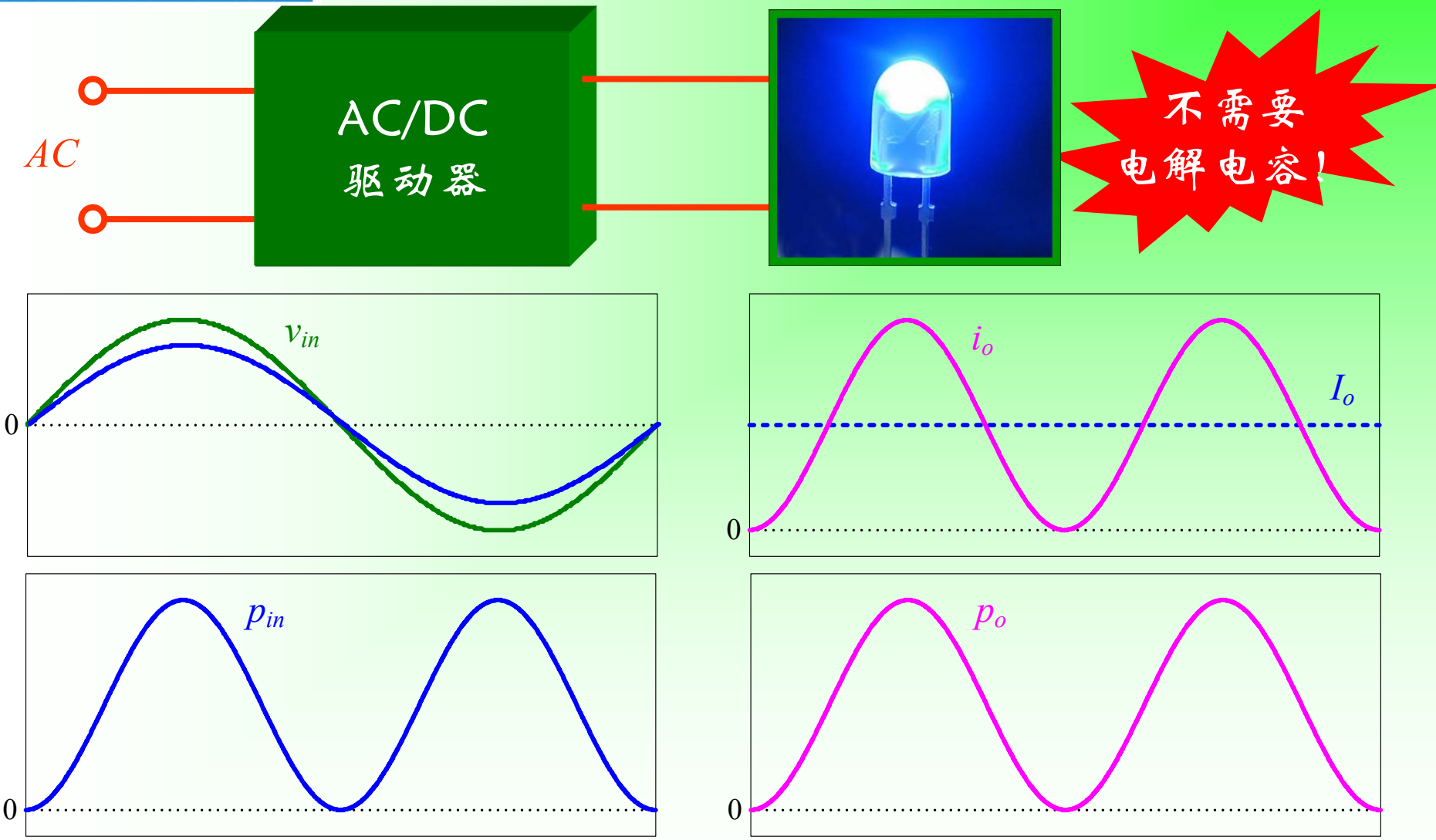


200 kHz,
D=0.2

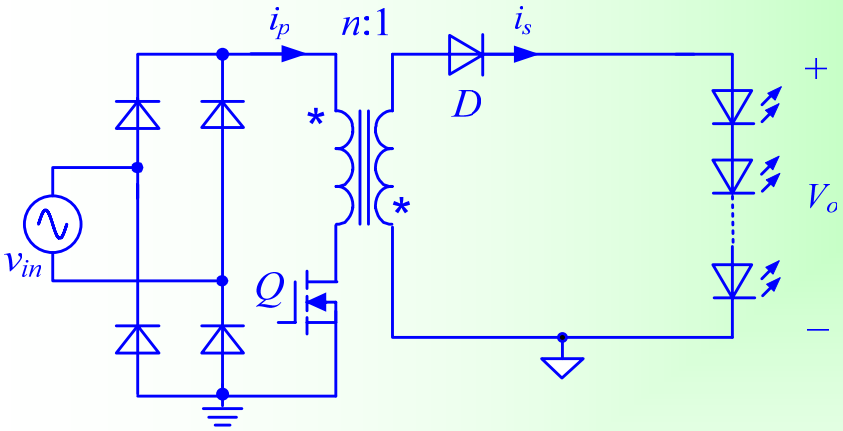
Permissible Pulse Handling Capability
Duty cycle D = parameter, T_S = 85 °C

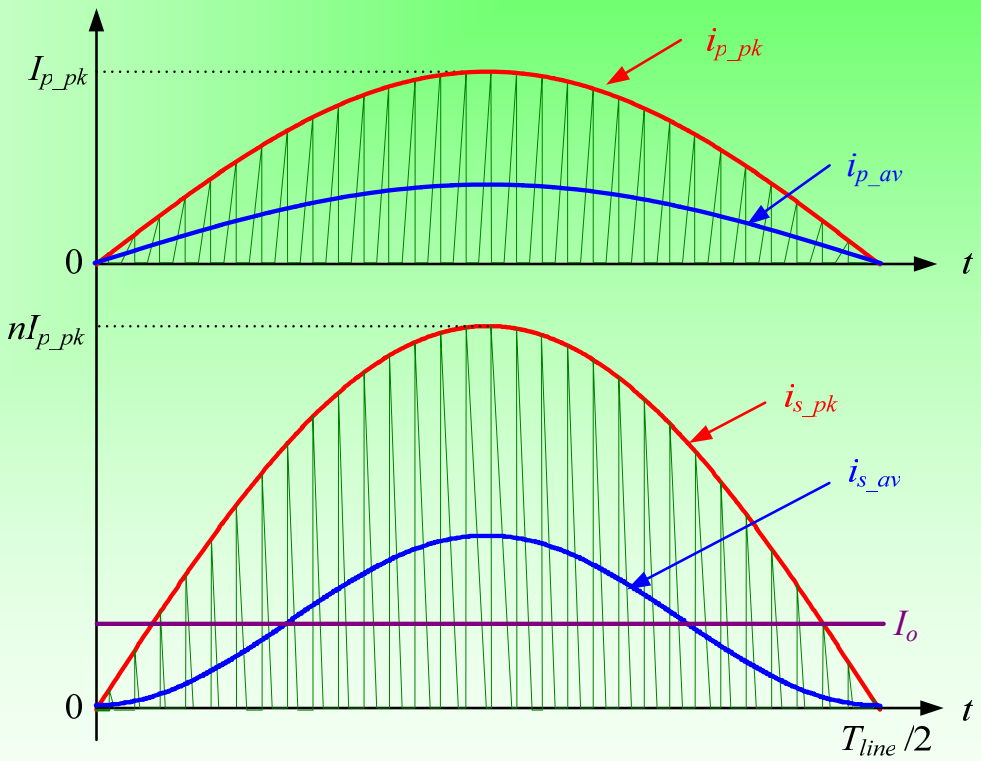


无电解电容的LED AC/DC驱动器

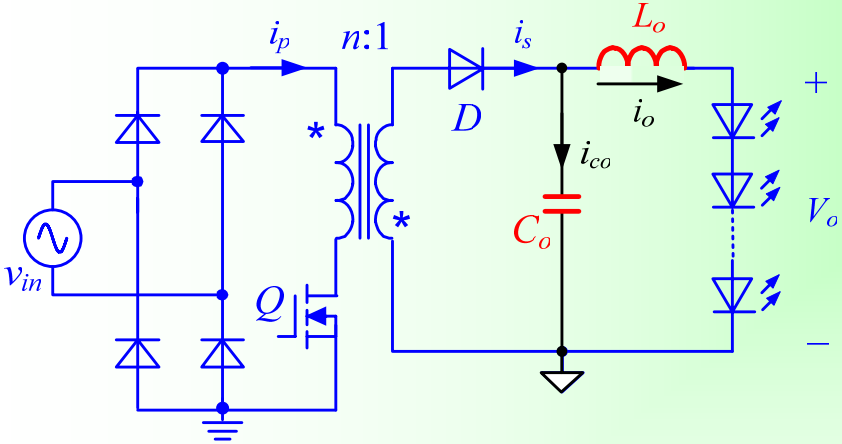


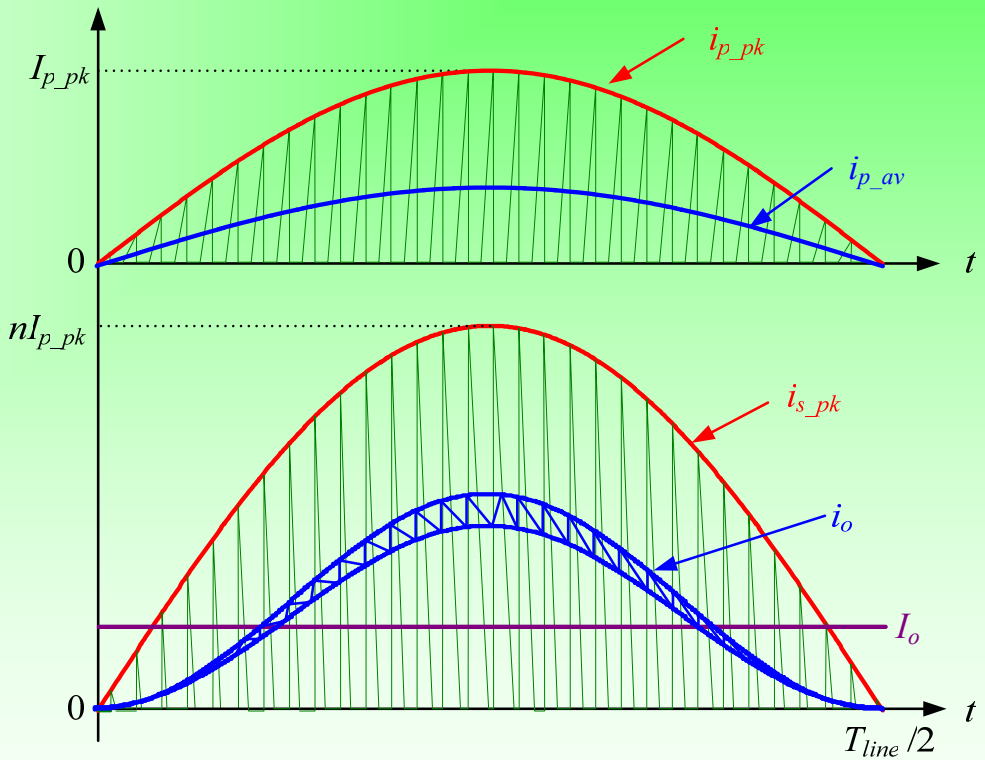
工作在DCM模式的Flyback变换器



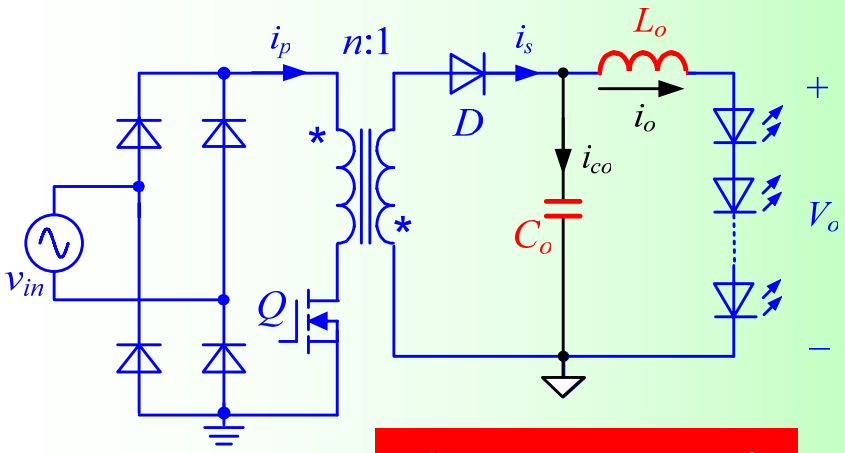


加入小的滤波器以减小输出电流纹波

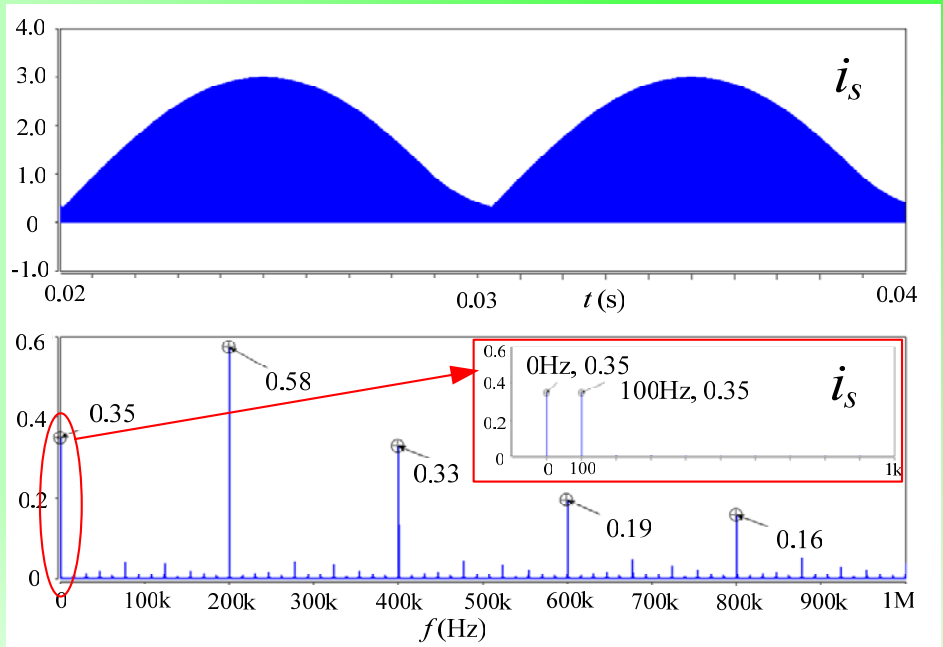


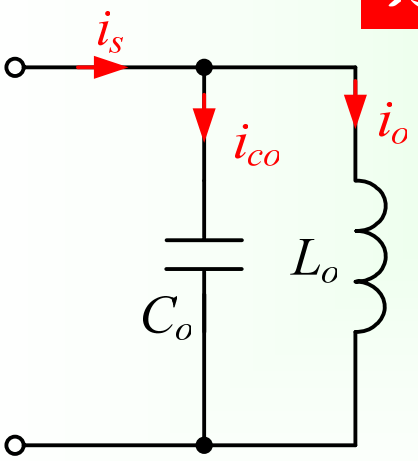


滤波器的设计



输出平均电流为0.35A





$$\zeta = \left|\frac{I_o(j\omega)}{I_s(j\omega)}\right| = \left|\frac{1}{1-\omega^2 L_o C_o}\right|$$

$\zeta = 0.05$

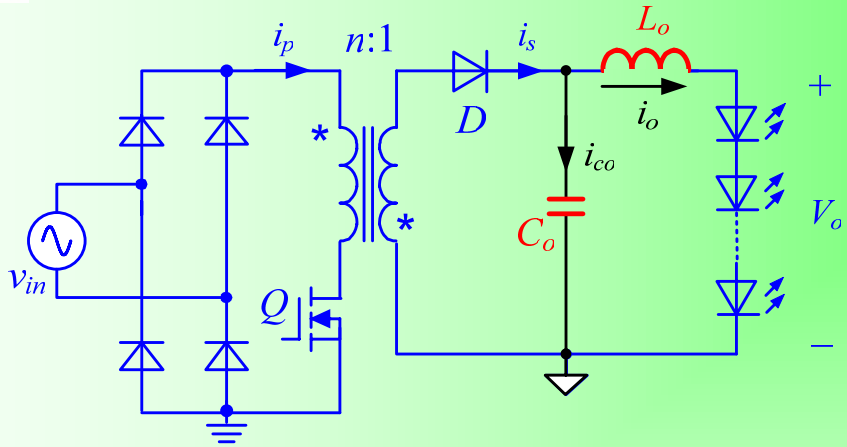
f_s=200kHz

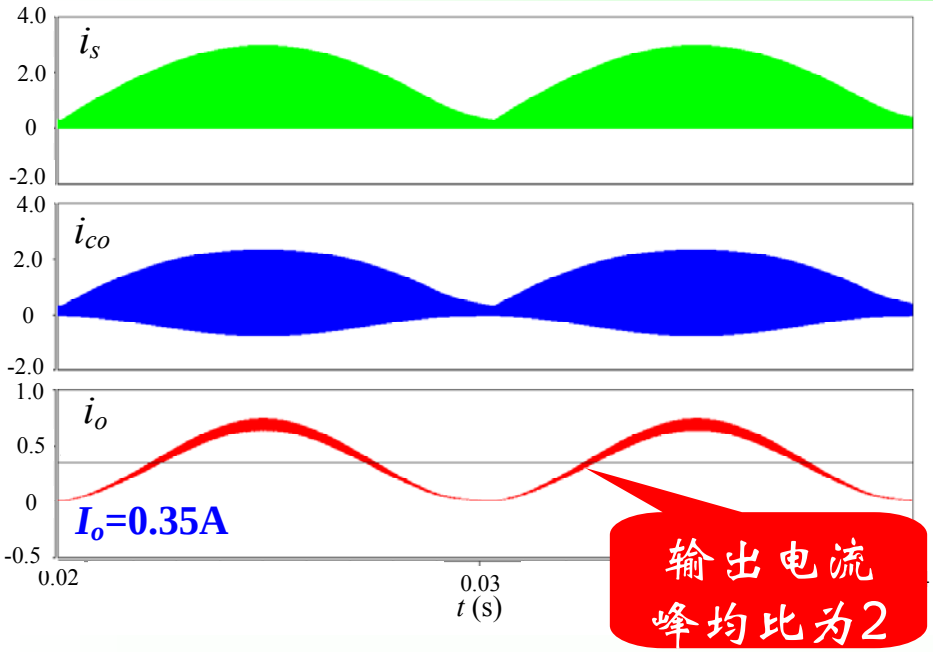
$$L_o \cdot C_o = 13.94\times10^{-12}$$

$$C_o = 0.47\ \mu\text{F}$$

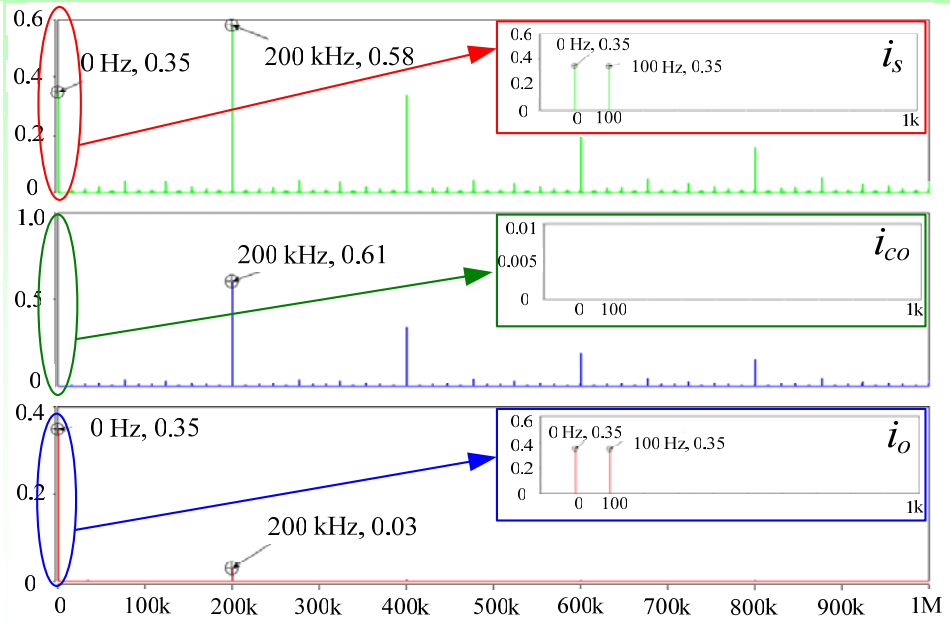
$$L_o = 30\ \mu\text{H}$$

加入滤波器后的仿真波形





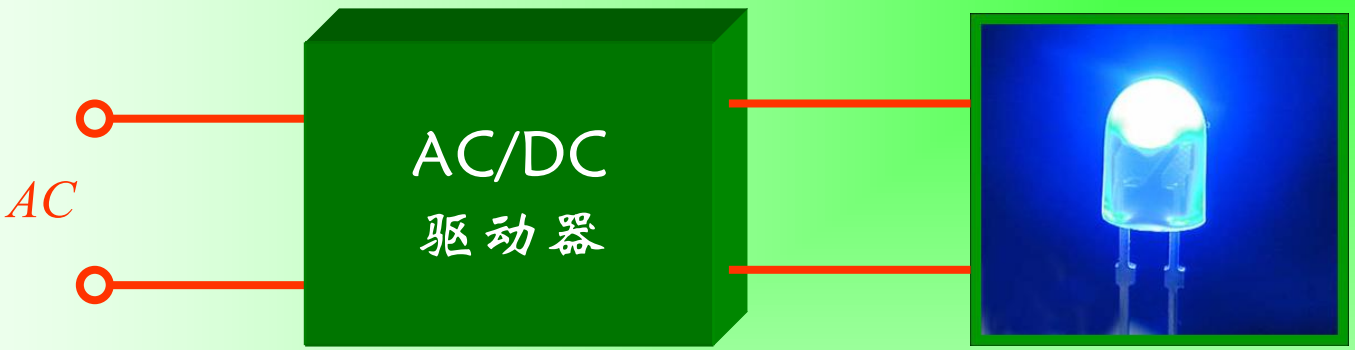
输出电流峰均比为2

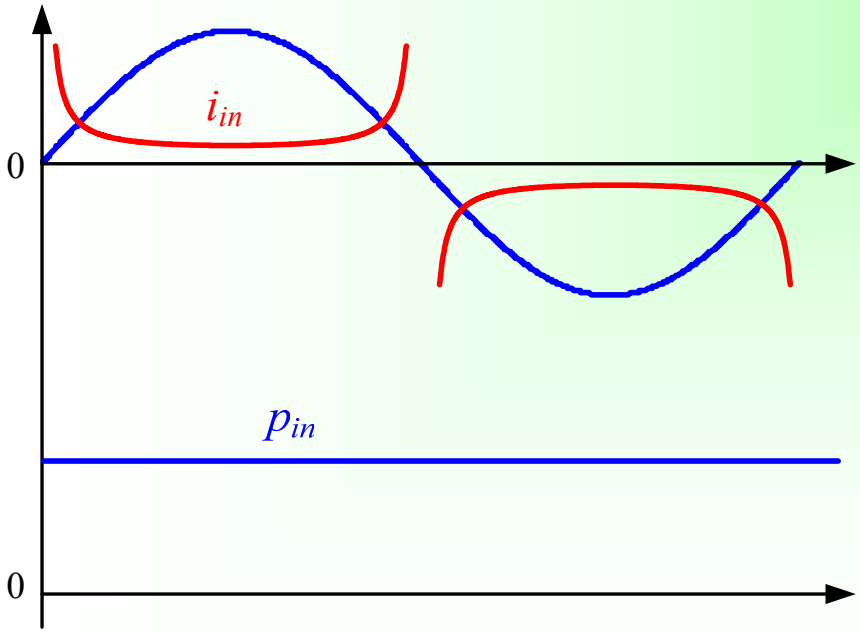


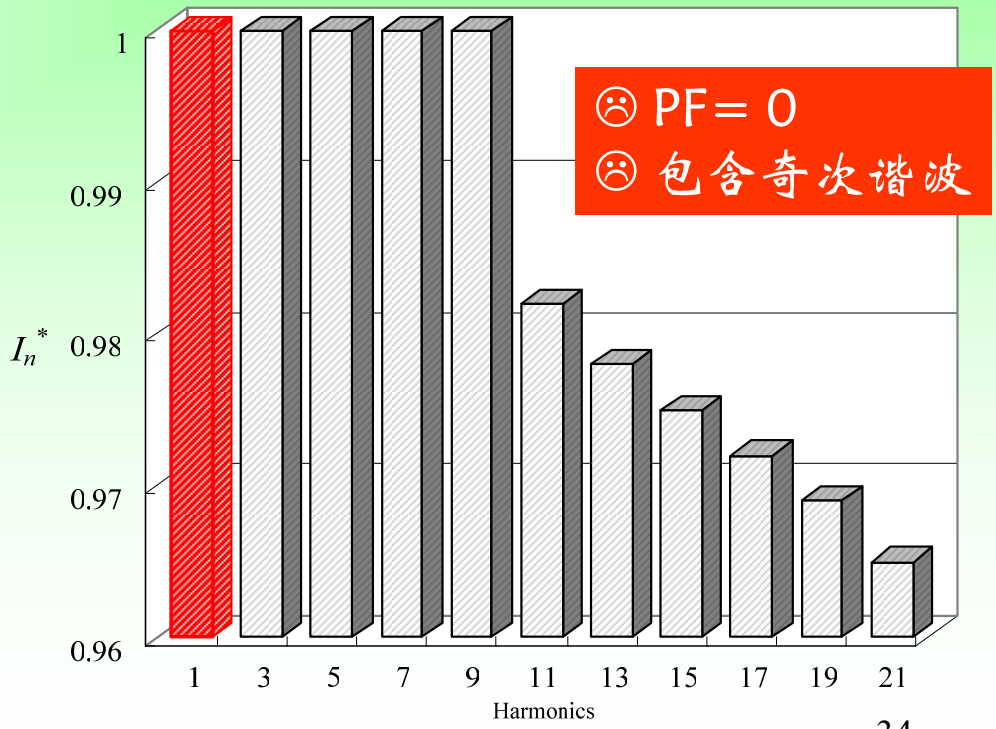
输出电流峰均比为1的输入电流谐波

输出电流峰均比最小为1

输出电流为直流电流







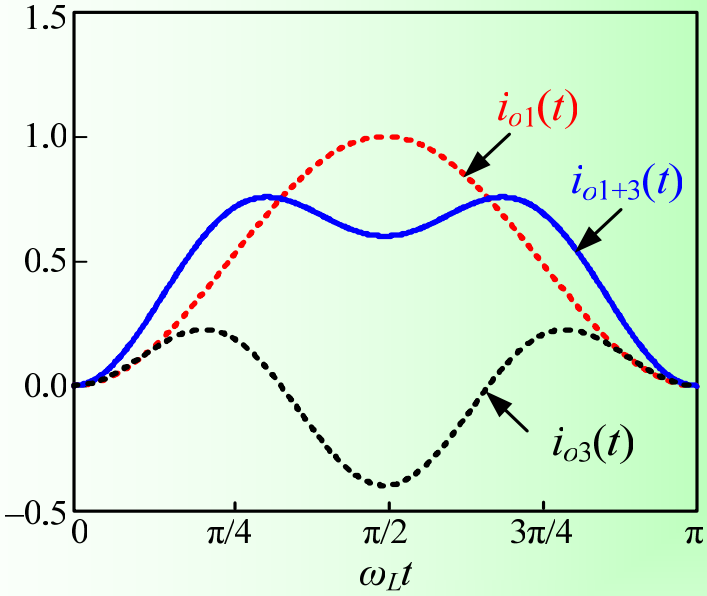
各次输入电流谐波对应的输出电流

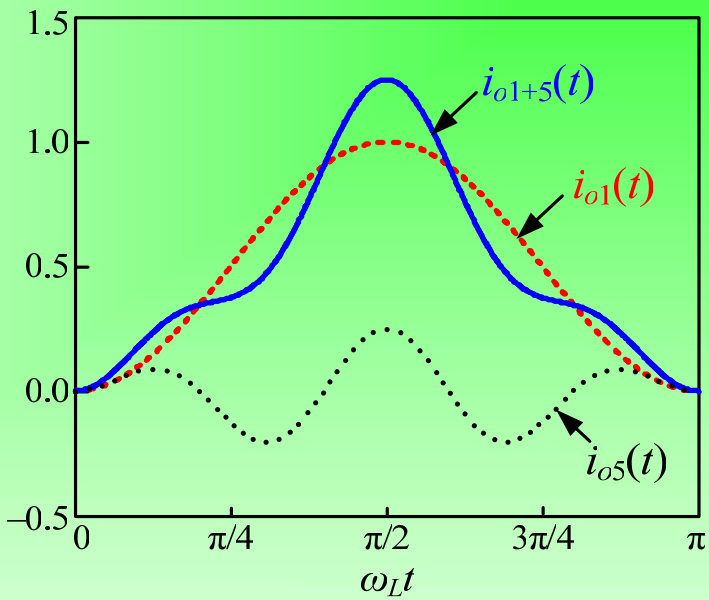
$$i_{o1} = \frac{v_{in} \cdot i_{in1}}{V_o} = \frac{(V_m \sin \omega_L t) \cdot (I_1 \sin \omega_L t)}{V_o} = \frac{V_m \cdot I_1}{V_o} \cdot \sin^2 \omega_L t$$

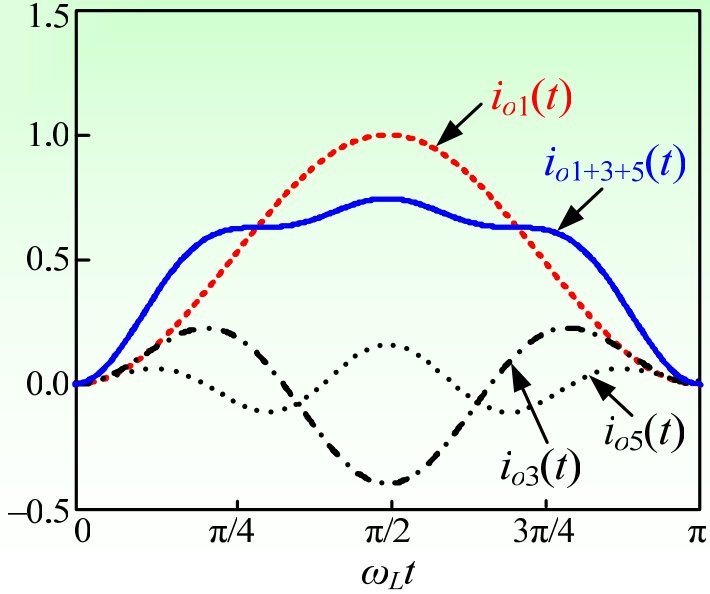
$$i_{o3} = \frac{v_{in} \cdot i_{in3}}{V_o} = \frac{(V_m \sin \omega_L t) \cdot (I_3^* \cdot I_1 \sin 3\omega_L t)}{V_o} = \frac{V_m \cdot I_3^* \cdot I_1}{V_o} \cdot \sin \omega_L t \cdot \sin 3\omega_L t$$

$$i_{o5} = \frac{v_{in} \cdot i_{in5}}{V_o} = \frac{(V_m \sin \omega_L t) \cdot (I_5^* \cdot I_1 \sin 5\omega_L t)}{V_o} = \frac{V_m \cdot I_5^* \cdot I_1}{V_o} \cdot \sin \omega_L t \cdot \sin 5\omega_L t$$

注入谐波后的输出电流


1.5
1.0
0.5
0.0
–0.5
0
π/4
π/2
3π/4
π
$\omega_L t$
$i_{o1}(t)$
$i_{o1+3}(t)$
$i_{o3}(t)$


1.5
1.0
0.5
0.0
–0.5
0
π/4
π/2
3π/4
π
$\omega_L t$
$i_{o1+5}(t)$
$i_{o1}(t)$
$i_{o5}(t)$

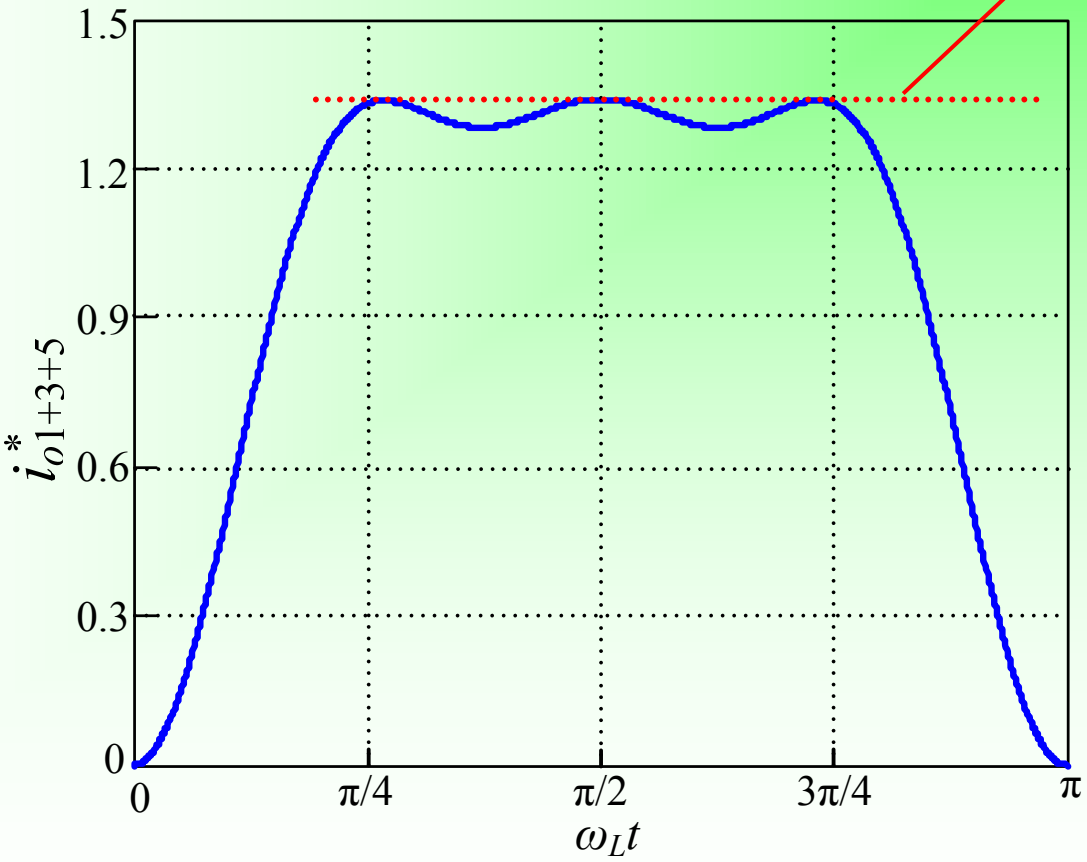

1.5
1.0
0.5
0.0
–0.5
0
π/4
π/2
3π/4
π
$\omega_L t$
$i_{o1}(t)$
$i_{o1+3+5}(t)$
$i_{o5}(t)$
$i_{o3}(t)$

注入3次和5次谐波后的最小输出电流峰均比

$I_3^* = 0.465$

$I_5^* = 0.135$

峰均比为 1.34



谐波注入的实现

半个工频周期内，占空比=D_{y0}

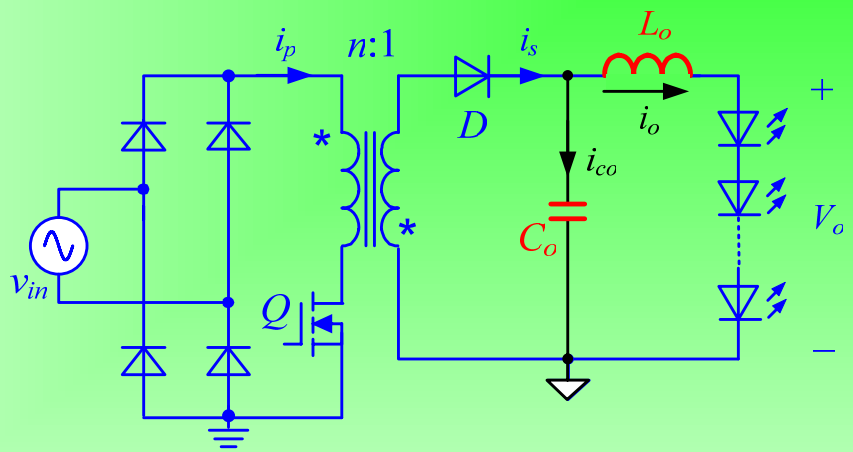
PF=1

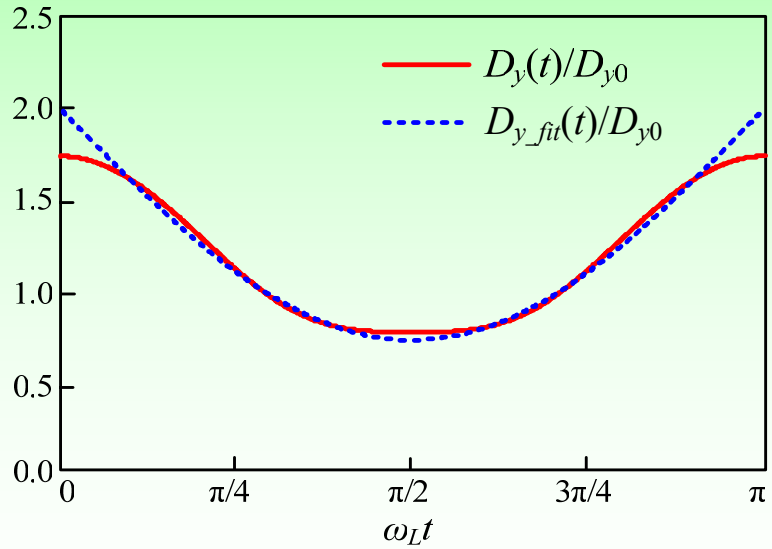
$$i_{in}(t)=I_1\left(\sin\omega_L t+I_3^*\cdot\sin 3\omega_L t+I_5^*\cdot\sin 5\omega_L t\right)$$

$$I_3^*=0.465,\quad I_5^*=0.135$$

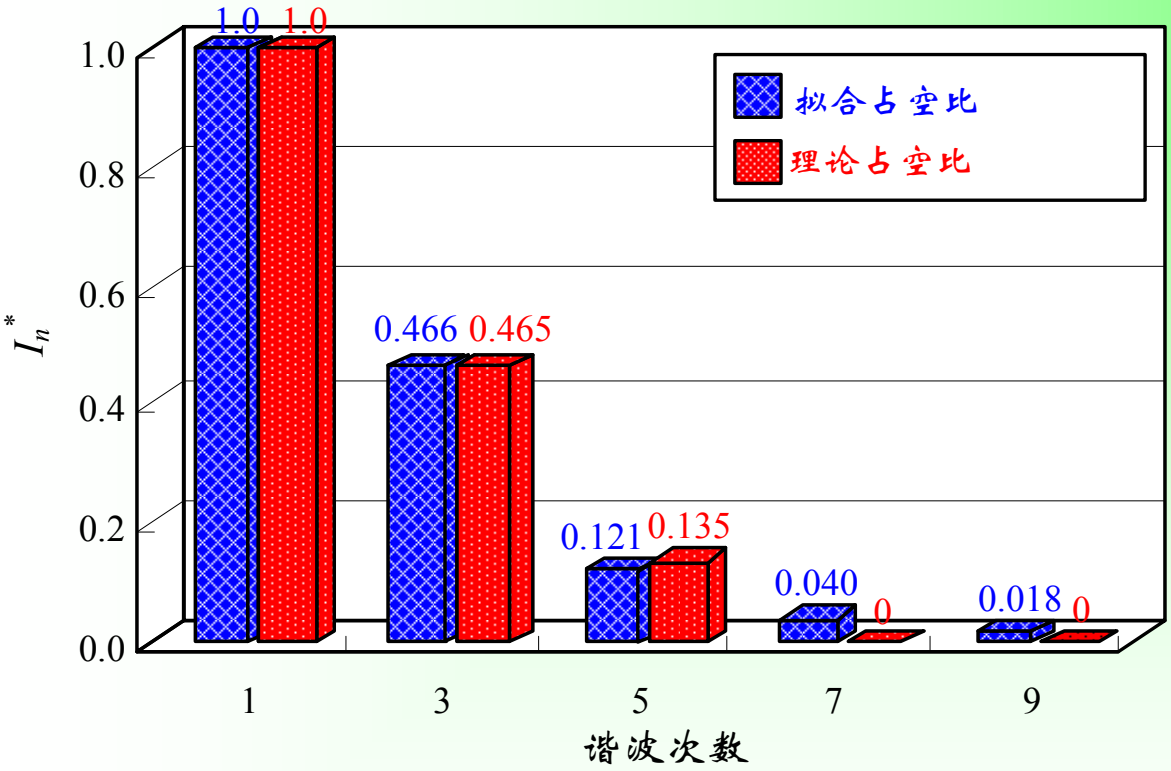
$$D_y(t)=D_{y0}\cdot\sqrt{2.16\sin^4\omega_L t-4.56\sin^2\omega_L t+3.07}$$

$$D_{y\_fit}(t)=D_{y0}\cdot 2.02\cdot\left(1-0.61\cdot\left|\sin\omega_L t\right|\right)$$



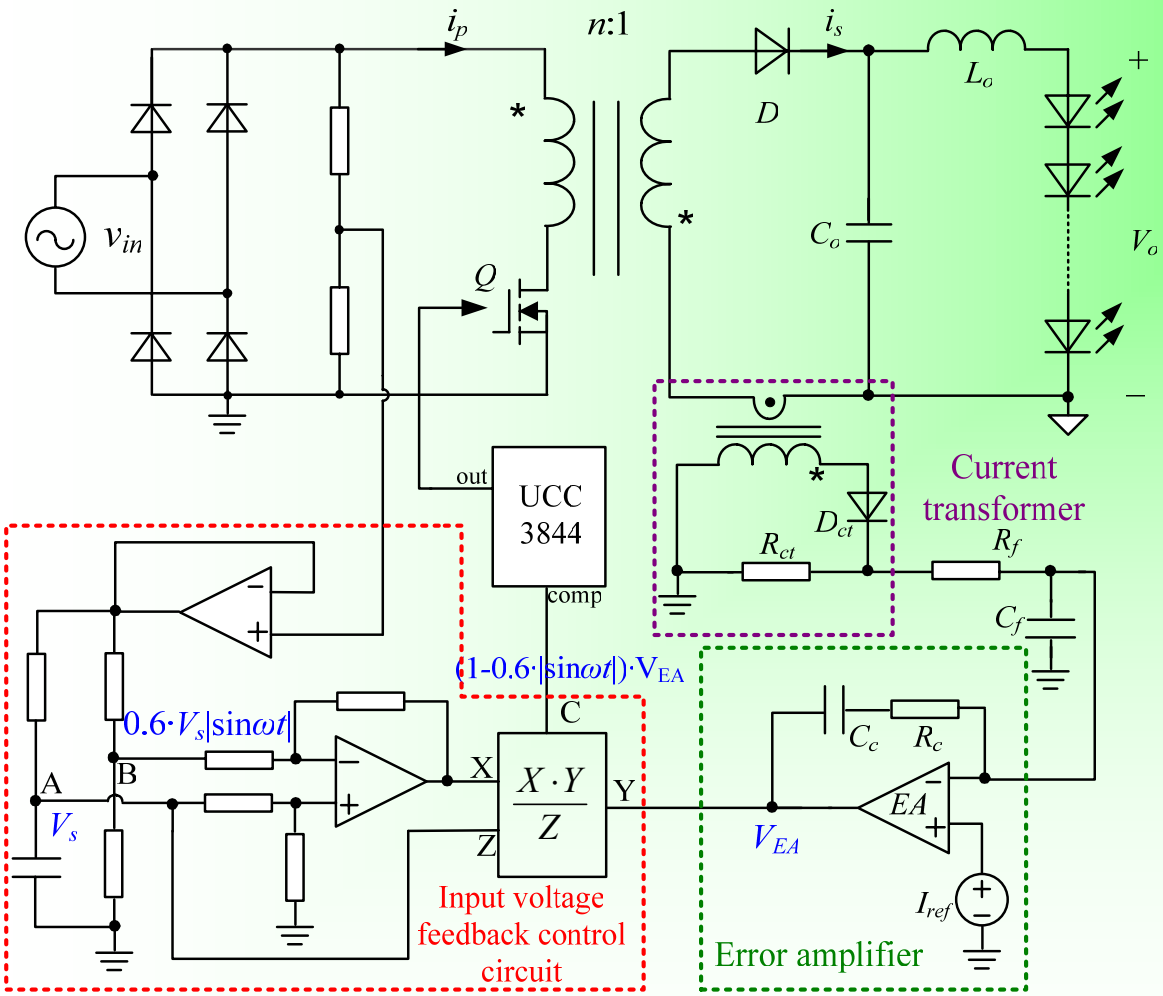


理论占空比与拟合占空比的对比



	理论占空比	拟合占空比
输出电流峰均比	1.34	1.38
输入功率因数	0.90	0.90

原理样机主要参数

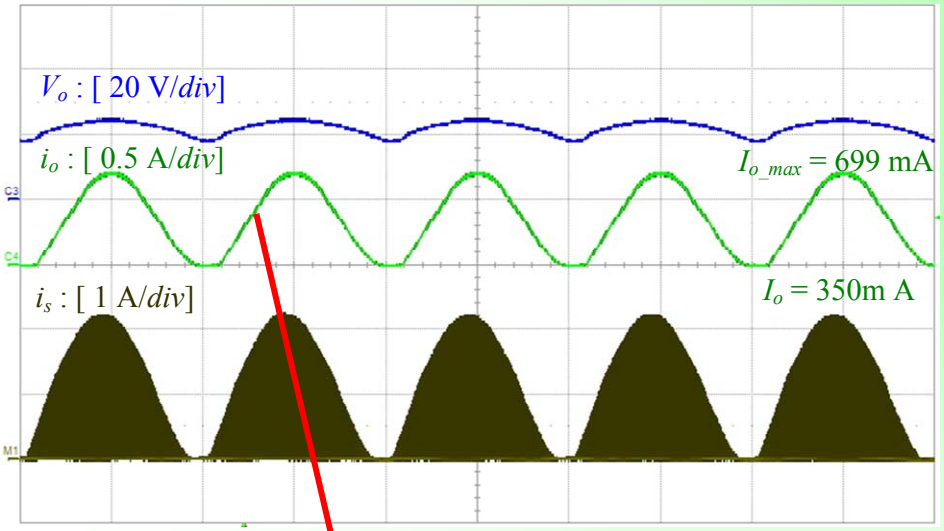


- 输入电压: 198-264 V
- 输出电流: 0.35 A
- 输出电压: 25 V

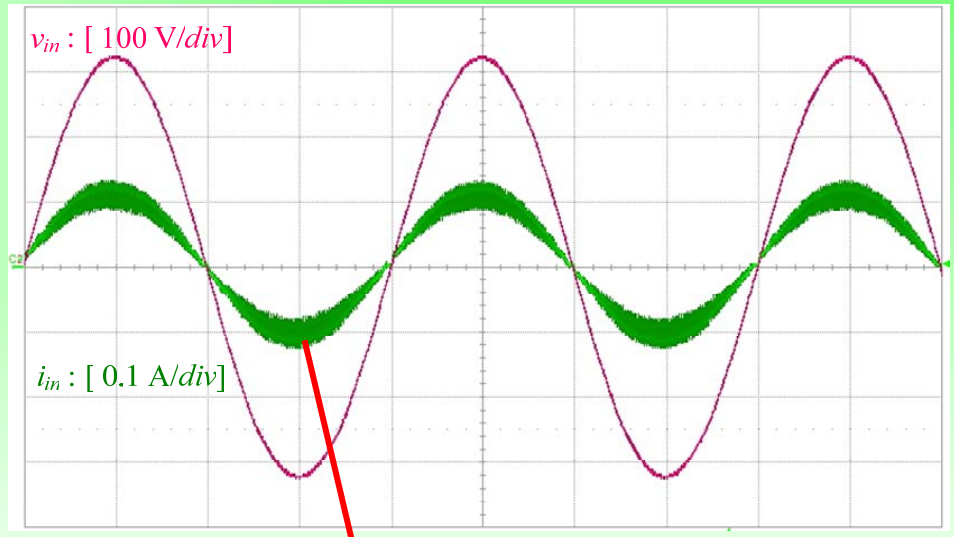
Q: FQD2N60 (600 V, 2.6 A)
D: RURD460 (600 V, 4 A)
L_p: 270 μH
n: 3
L_o: 30 μH
C_o: 0.47 μF

实验结果

未注入谐波电流

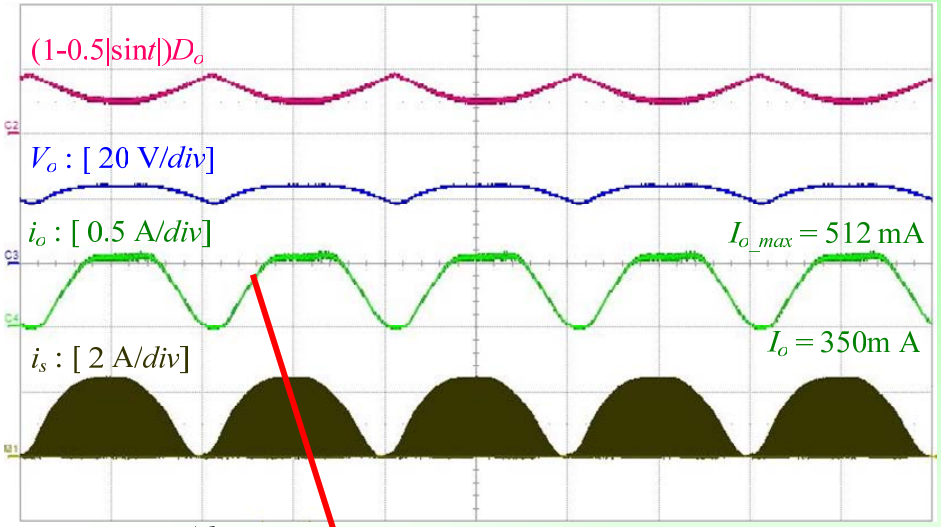


输出电流峰均比约为 2.

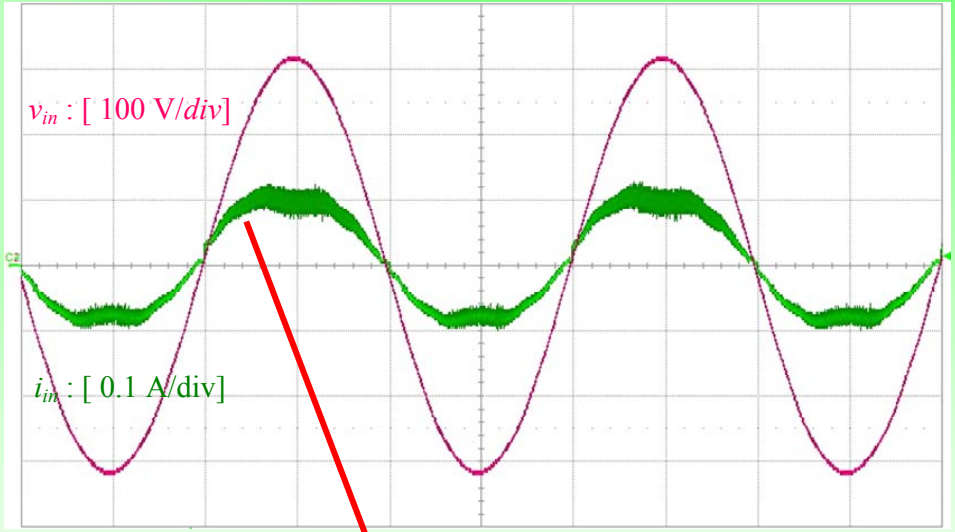


输入功率因数为 0.999.

注入谐波电流



输出电流峰均比约为1.4.



输入功率因数为0.91.

1. 概述
2. 无电解电容的LED照明AC/DC电源
3. 无电解电容的LED照明AC/DC驱动器
4. 结论

结论

针对LED照明的AC/DC电源，提出了去除电解电容的方法，以提高其使用寿命。

- 增大储能电容电压纹波以大大减小电容值，由此可以采用薄膜或瓷片电容来取代电解电容，由此可以提高AC/DC电源的使用寿命。
- 在输入电流中注入三次谐波，可以减小瞬时输入功率脉动，由此可以减小储能电容容量。当保证输入功率因数大于0.9时，储能电容容量可以减小到功率因数为1时的65.6%。

结论

提出了一种无电解电容的LED AC/DC驱动器。

- 根据LED可以采用脉动电流驱动的特点，提出了一种无电解电容的AC/DC驱动器，从而大大提高使用寿命。在输出侧增加一个小电感和一个小电容，可以大大减小驱动电流的脉动，以保证LED的安全工作。
- 提出在输入电流中注入3次和5次谐波的方法，在保证输入功率因数大于0.9的情况下，理论上可以将LED的驱动电流峰均比降低到1.34，这样可以保证LED的安全工作。
- 提出了一种简单的占空比拟合方法，它只需要检测输入电压，就可以实现3次和5次谐波的注入。

APSC
Aero-Power Sci-tech Center

Thank you for your attention!

Comments and Suggestions are Welcome!