# 多输入直流变换器
# ——电路拓扑和控制方法

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# 报告内容

- 研究背景
- 脉冲源单元
- 多输入变换器的生成和简化
- 单原边绕组隔离型多输入变换器
- 多输入变换器的控制方法
- 结论

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# 新能源的应用

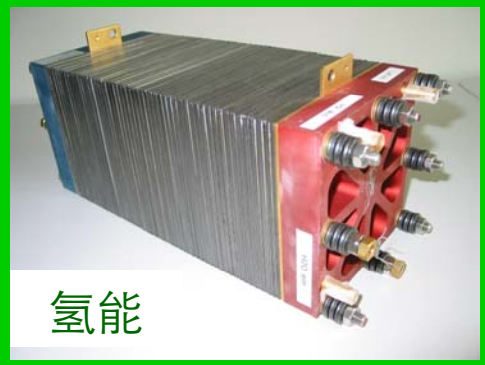
能源危机

环境污染

太阳能

风能

氢能



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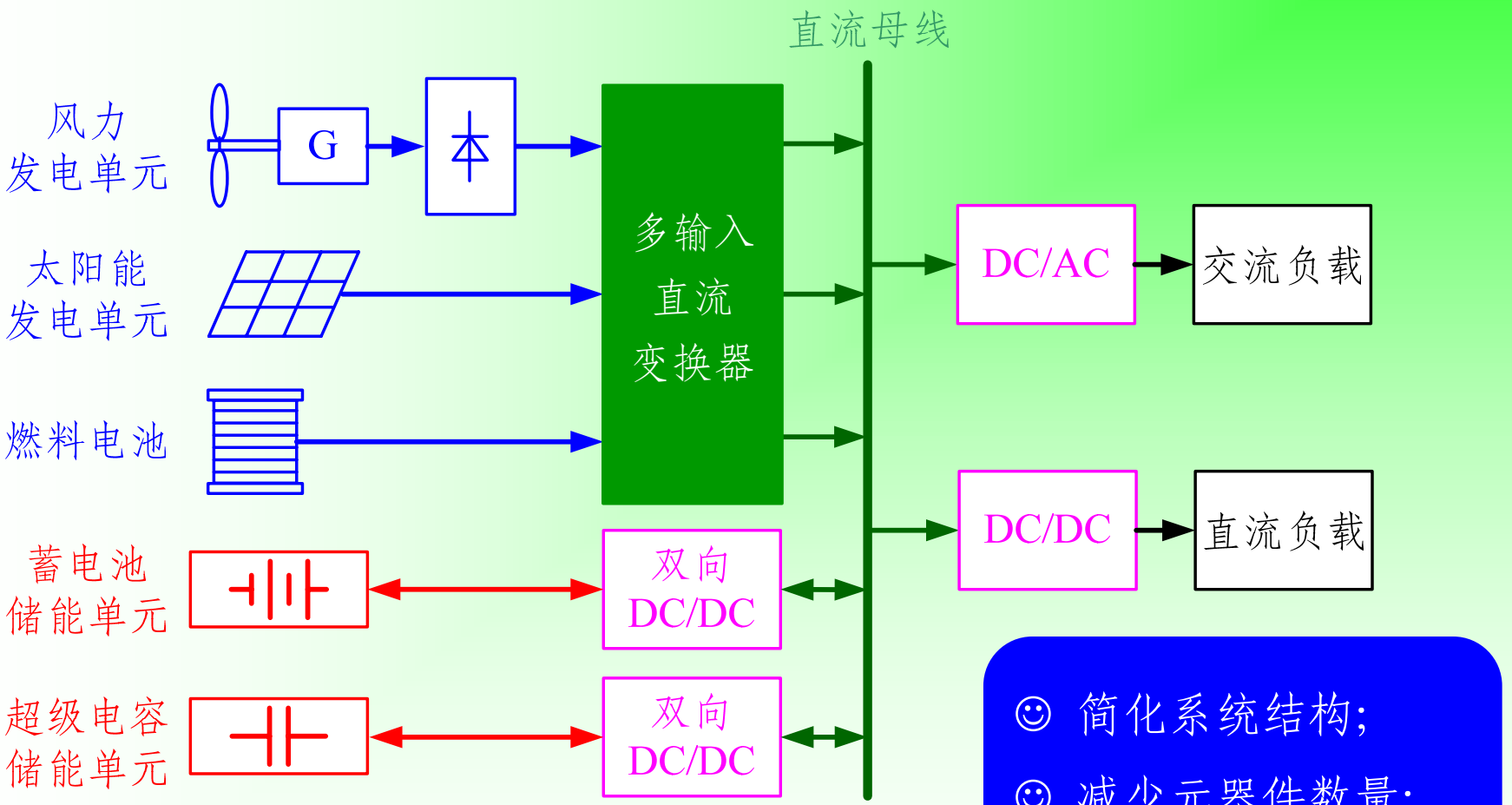
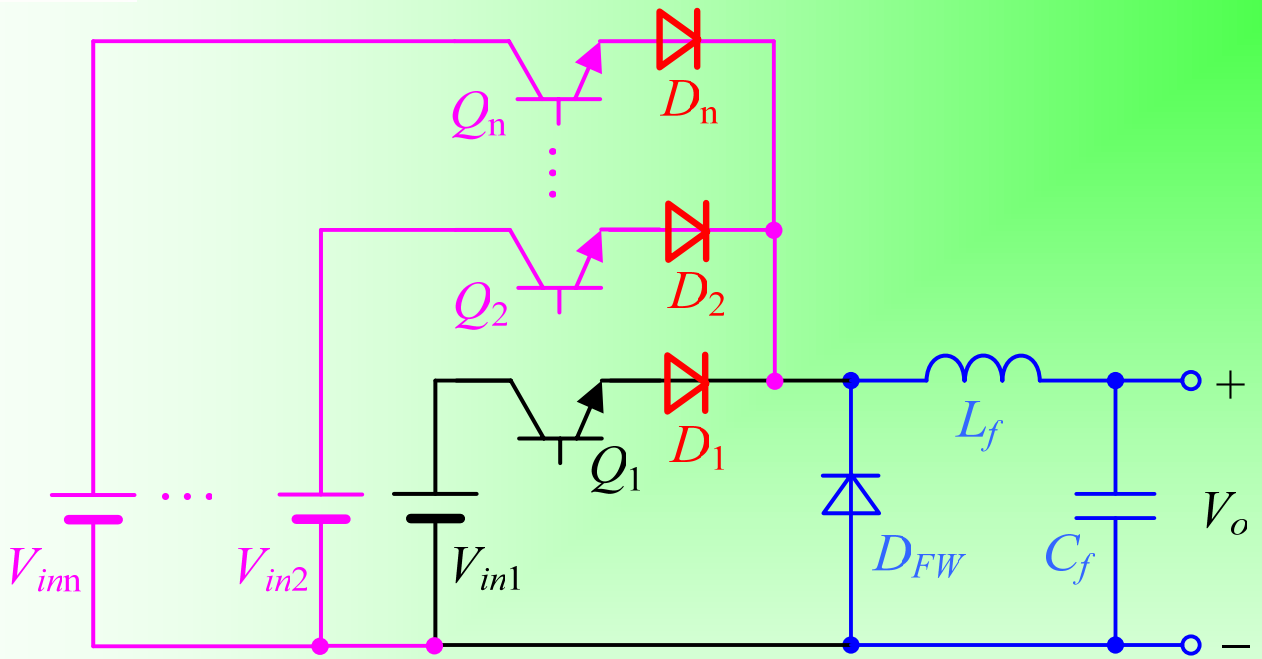
# 多种能源的联合供电




- ☺ 简化系统结构;
- ☺ 减少元器件数量;
- ☺ 降低成本。

# 分时供电的多输入Buck变换器



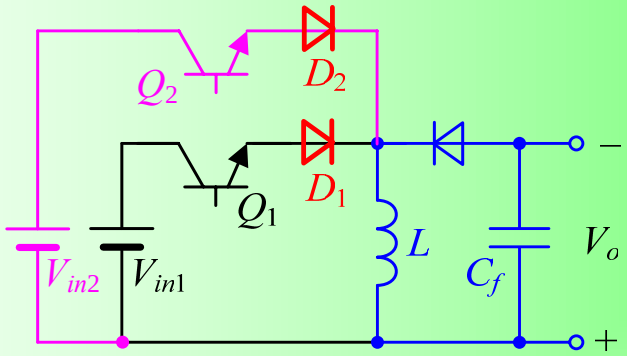

☺ 省去了n–1个输出滤波器和续流二极管。

☹ 各输入源只能分时供电。

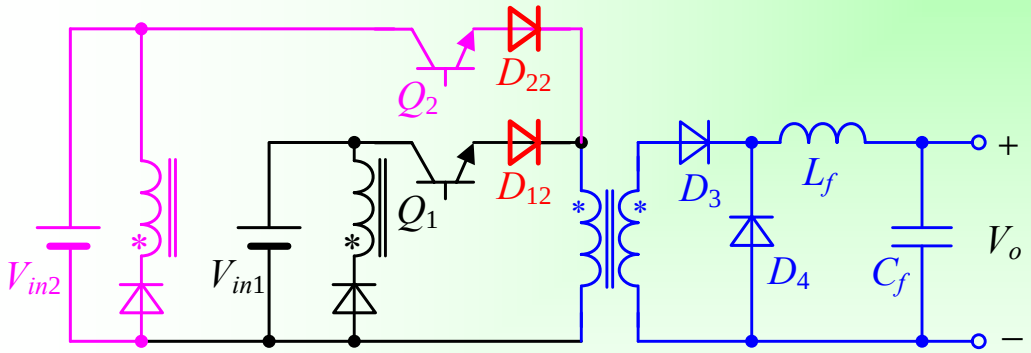
☹ 输出电压最高只能为各输入源的电压最大值。

[1] W. G. Imes and F. D. Rodriguez, “A two-input tri-state converter for spacecraft power conditioning,” in *Proc. AIAA IECEC*, 1994.

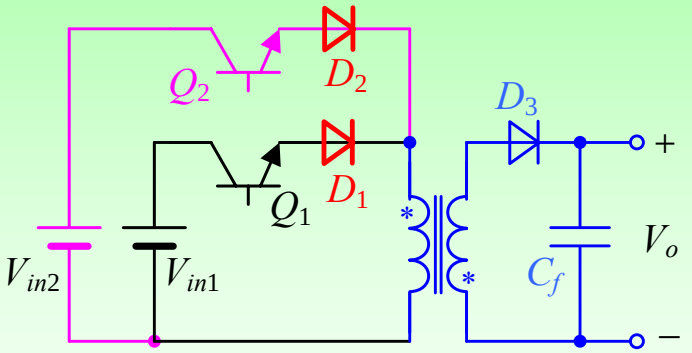
# 分时供电的多输入变换器




双输入Buck-Boost变换器[1]




双输入Forward变换器[2]

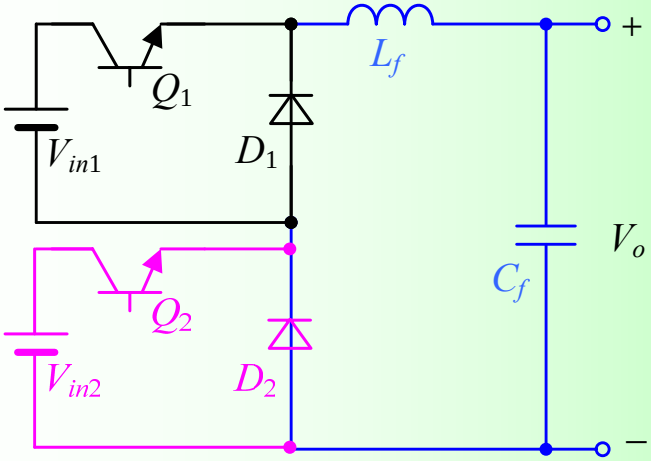



双输入Flyback变换器[2]

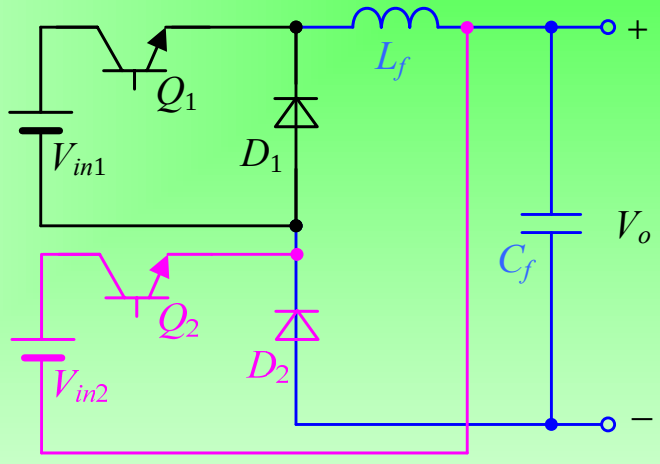
[1] B. G. Dobbs and P. L. Chapman, “A multiple-input dc-dc converter topology,” *IEEE Power Electron. Letter*, vol. 1, no. 1, Mar. 2003.

[2] H. Matsuo, W. Z. Lin, and F. Kurokawa, “Characteristics of the multiple-input dc-dc converter,” *IEEE Trans. Ind. Electron.*, vol. 51, no. 3, Jun. 2004.

# 同时供电的多输入变换器




双输入Buck变换器[1]



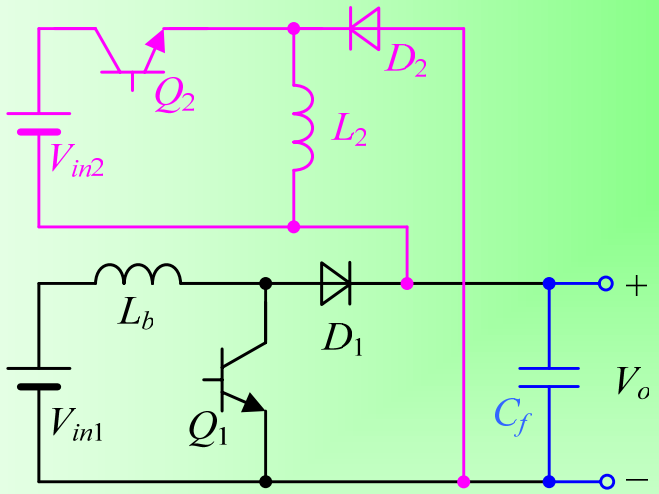

双输入Buck & Buck-Boost变换器[1]

☺ 省去了n–1个输出滤波器;

☺ 各输入源可以同时供电。

[1] Y. C. Liu and Y. M. Chen, “A Systematic approach to synthesizing multiple-input dc-dc converter,” *IEEE Trans. Power Electron.*, vol. 24, no. 1, Jan. 2009.

# 同时供电的多输入变换器




双输入Boost & Buck-Boost变换器

😐 实质上是多个单输入变换器在输出端并联，不能减少元器件数量。

Source: L. Solero, A. Lidozzi, and J. A. Pomilio, “Design of multiple-input DC-DC power converter for hybrid vehicles,” *IEEE Trans. Power Electron.,* vol. 20, no. 5, October 2005.

# 值得进一步研究的问题

- 除了已提出的多输入变换器，是否还有其他的多输入变换器？
- 目前已提出的多输入变换器之间，以及它们与本报告提出的其他多输入变换器之间存在什么样的关系？
- 为何有的多输入变换器只能分时供电，而有的可以同时供电？
- 如何控制多输入变换器？

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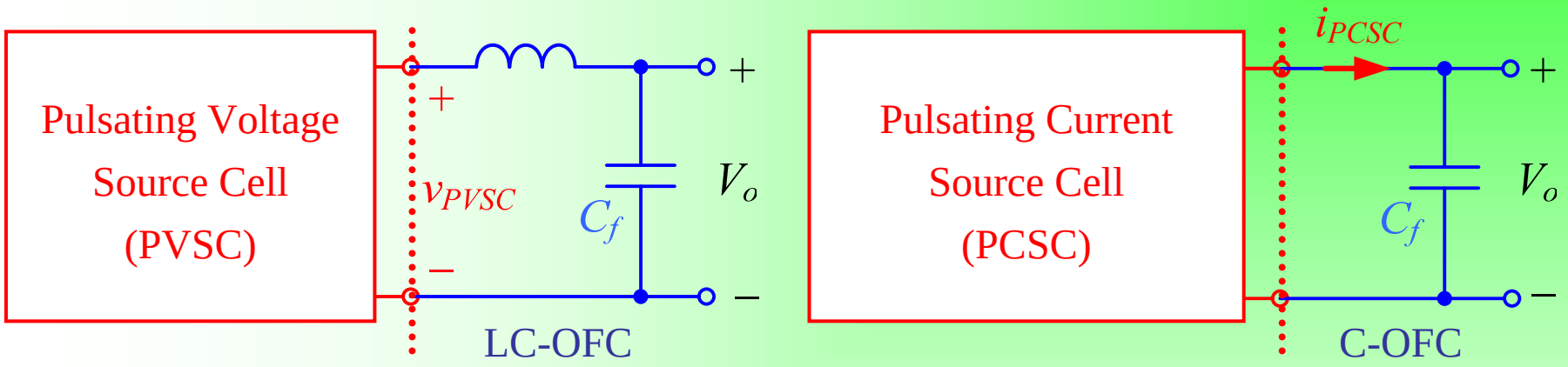
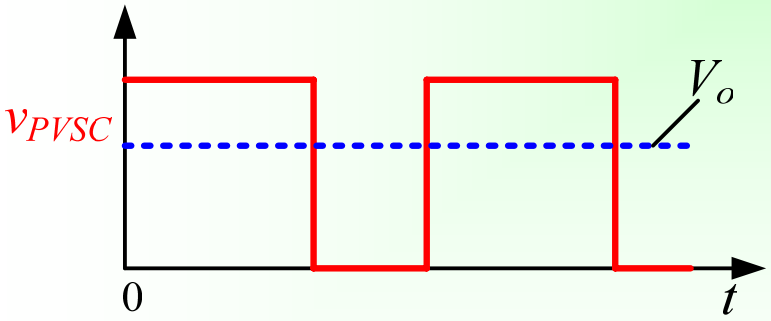
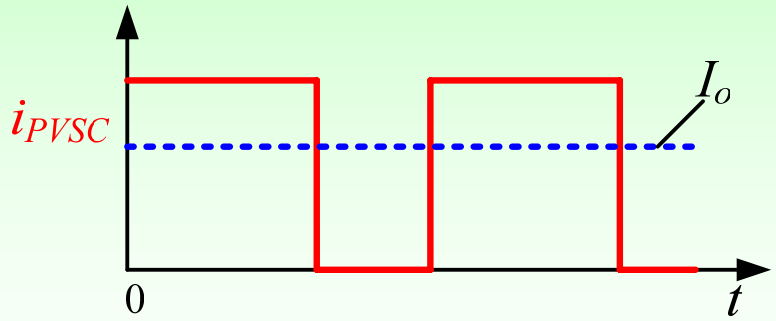
# 单输入直流变换器结构

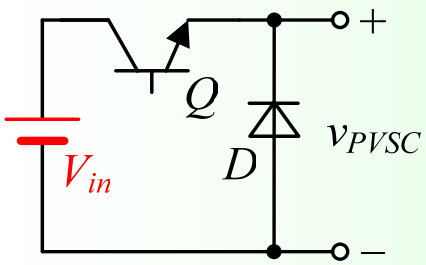



* OFC: Output Filter Cell

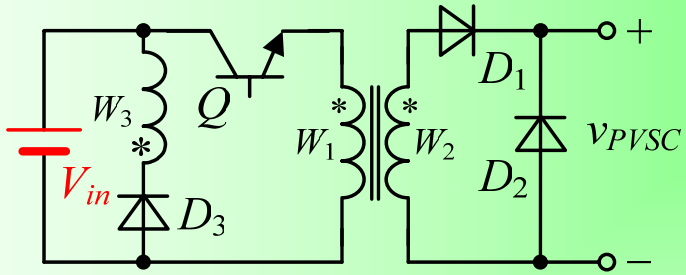


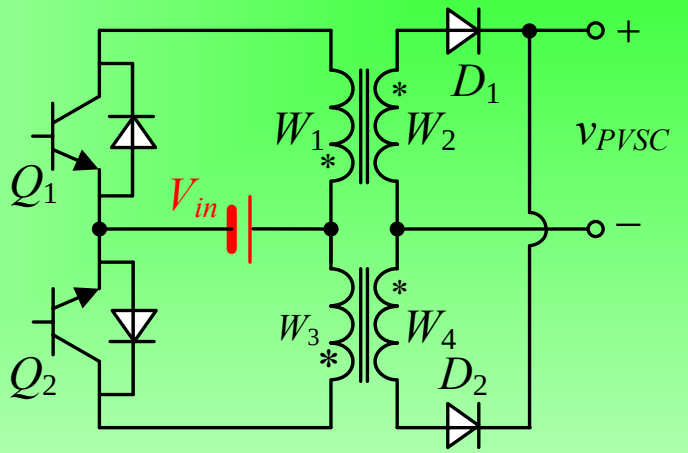
# 第I类基本PVSC： 电压源为独立电压源



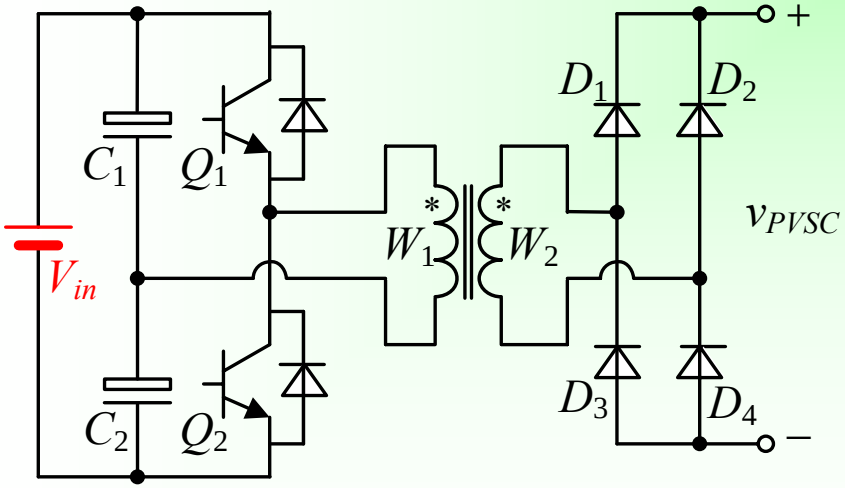

Buck PVSC



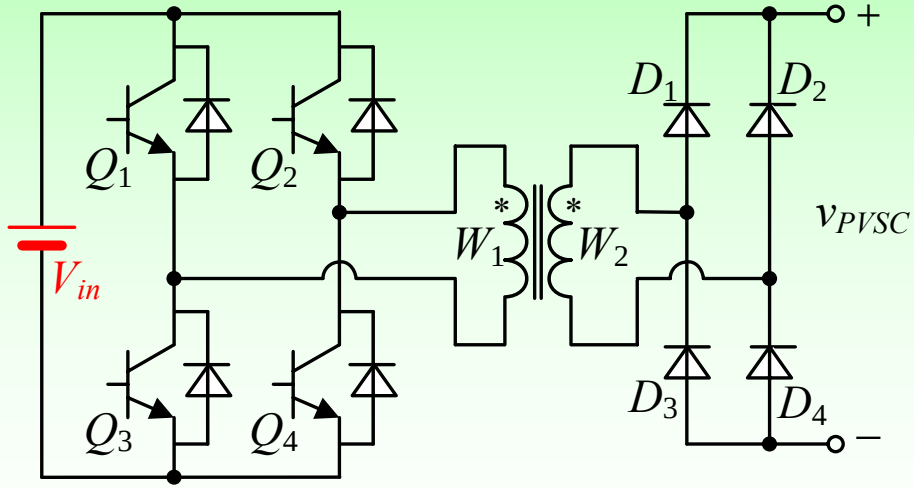

正激 PVSC




推挽 PVSC

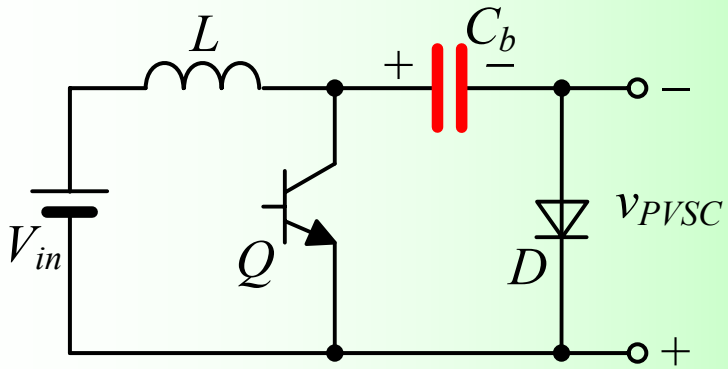



半桥 PVSC

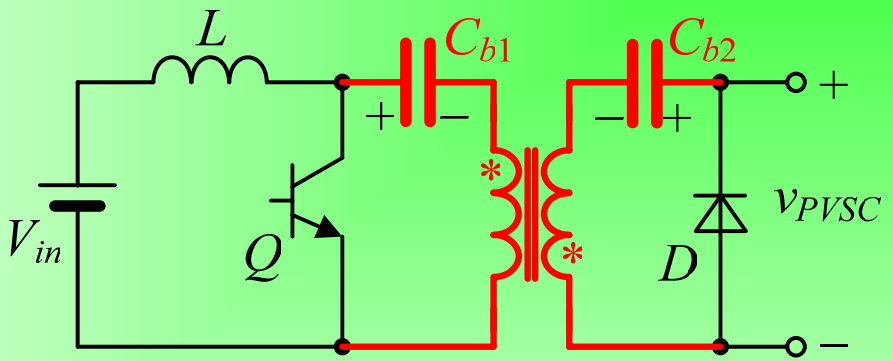



全桥 PVSC

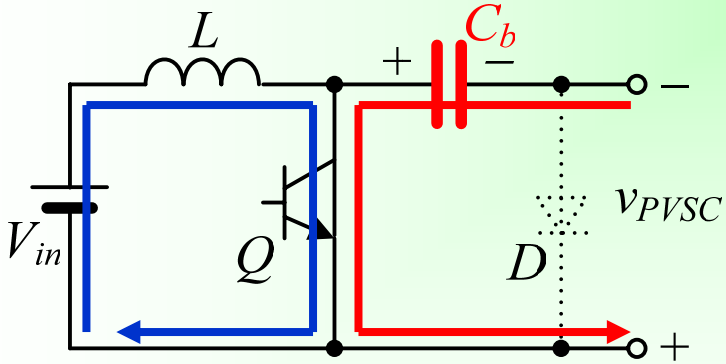
# 第II类基本PVSC：电压源为中间储能电压源



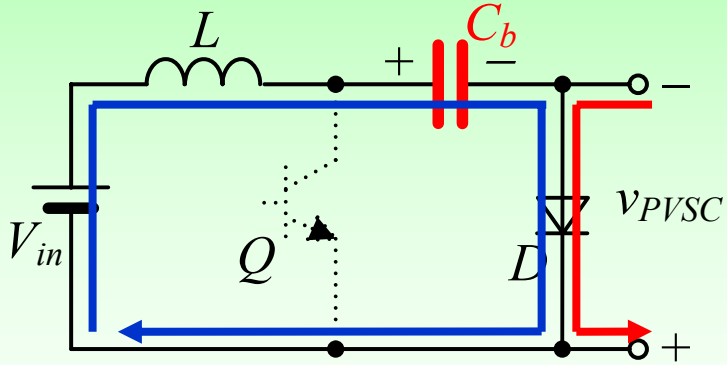

Cuk PVSC




隔离型Cuk PVSC

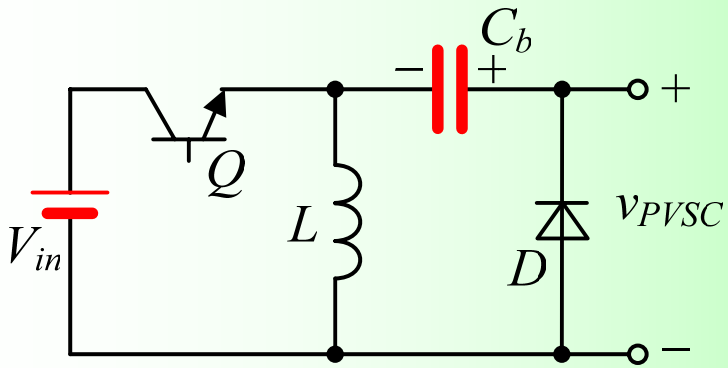



- $v_{PVSC} = V_{Cb}$。
- $V_{in}$给$L$储能。

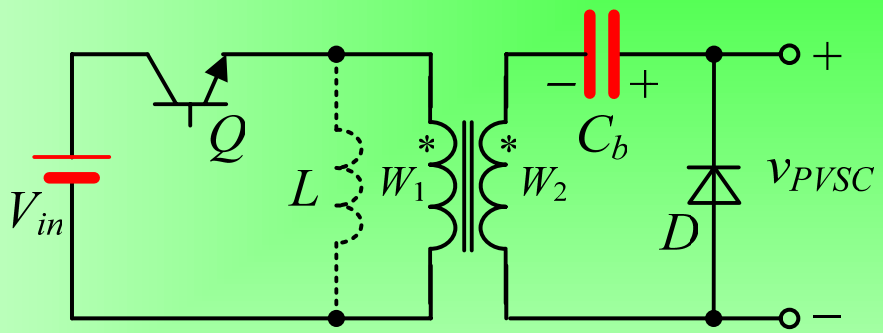



- $v_{PVSC} = 0$。
- $V_{in}$和$L$同时给$C_b$充电。

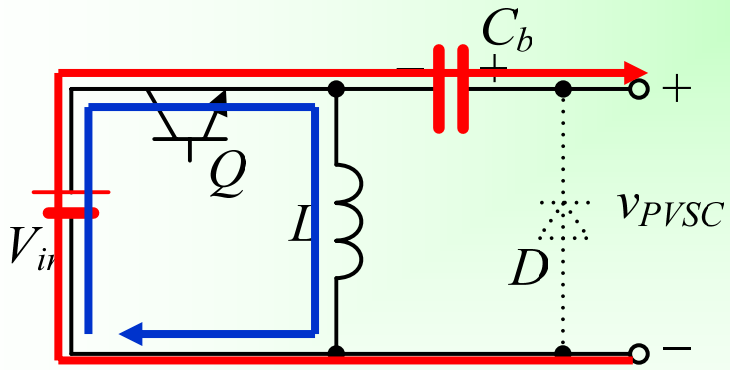
# 第III类基本PVSC：独立电压源与储能电压源之和



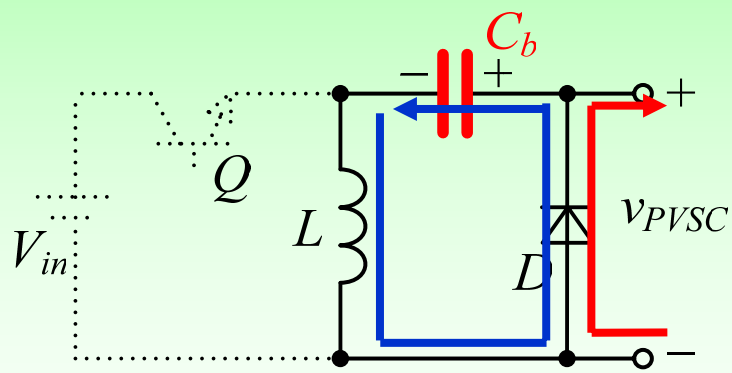

Zeta PVSC




隔离型Zeta PVSC

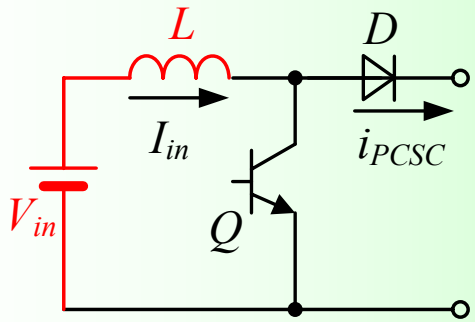



- $v_{PVSC} = V_{in} + V_{Cb}$。
- $V_{in}$给$L$储能。

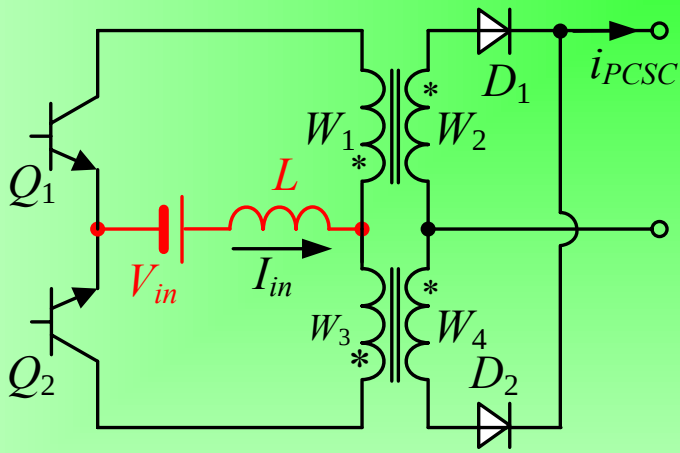



- $v_{PVSC} = 0$。
- $L$给$C_b$充电。

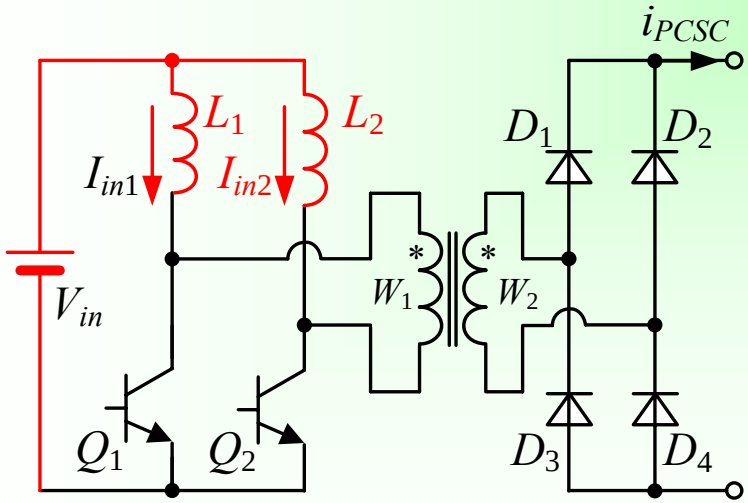
# 第I类基本PCSC：电流源为独立电流源



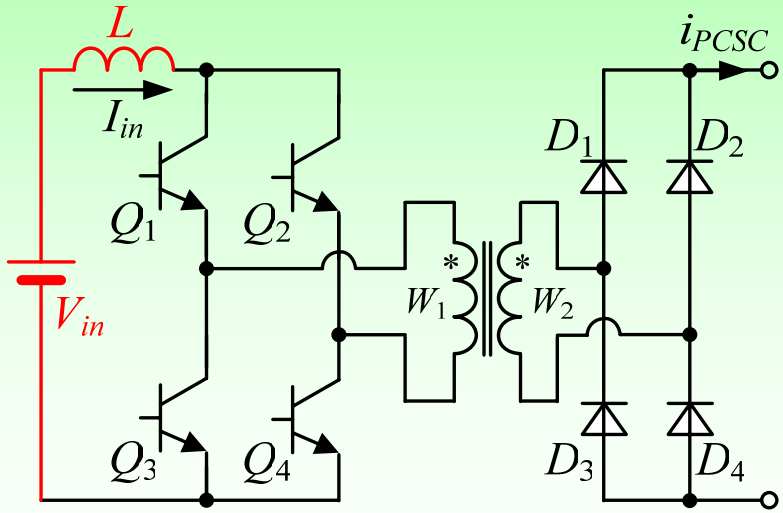

Boost PCSC




推挽 PCSC

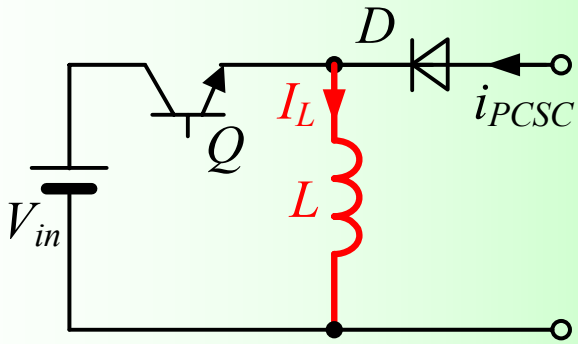



半桥 PCSC

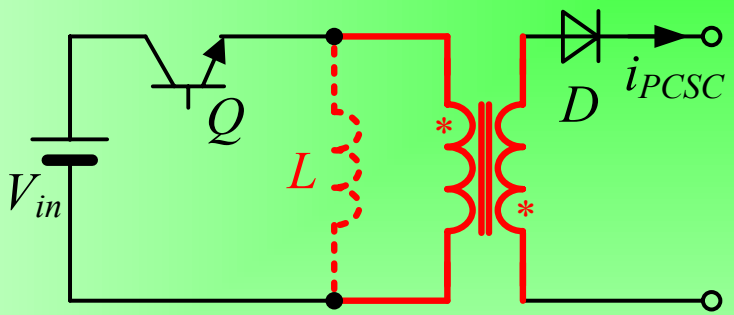



全桥 PCSC

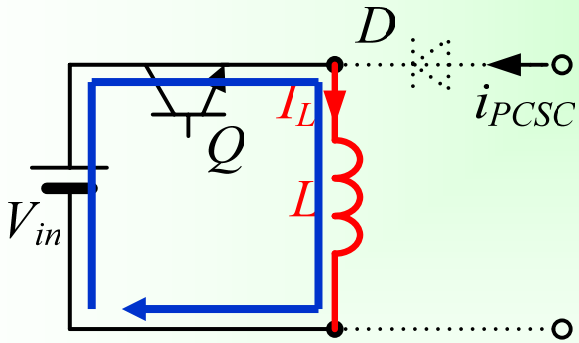
# 第II类基本PCSC：电流源为中间储能电流源



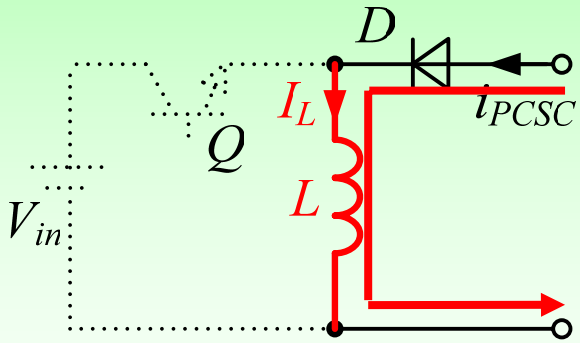

Buck-Boost PCSC




反激 PCSC

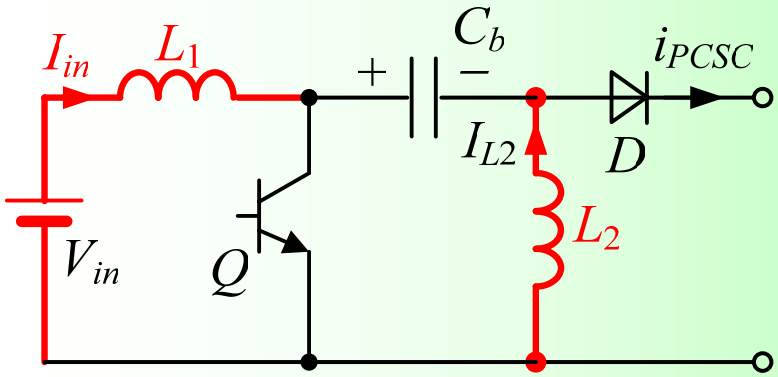



- $i_{PCSC}=0$。
- $V_{in}$给$L$储能。

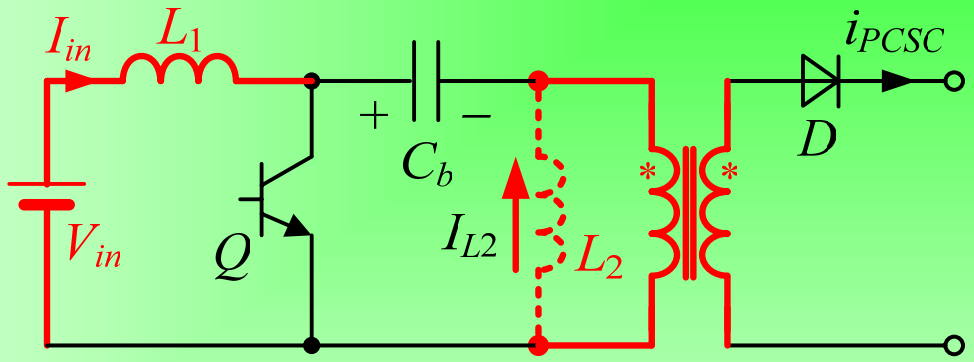



- $i_{PCSC}=i_L$。

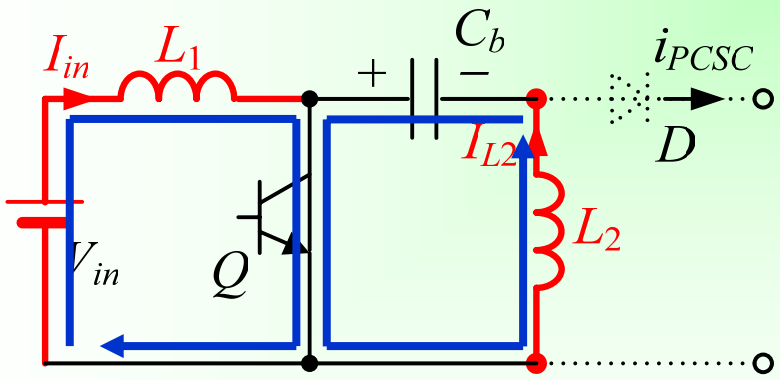
# 第III类基本PCSC：独立电流源与储能电流源之和



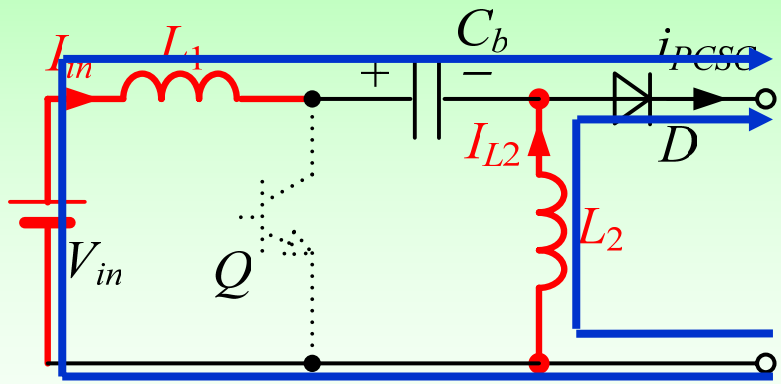

SEPIC PCSC




隔离型SEPIC PCSC

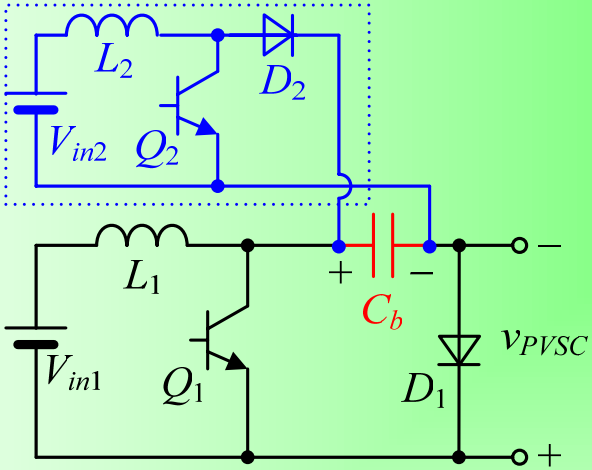



- $i_{PCSC}=0$。
- $V_{in}$给$L_1$储能；$C_b$给$L_2$储能。

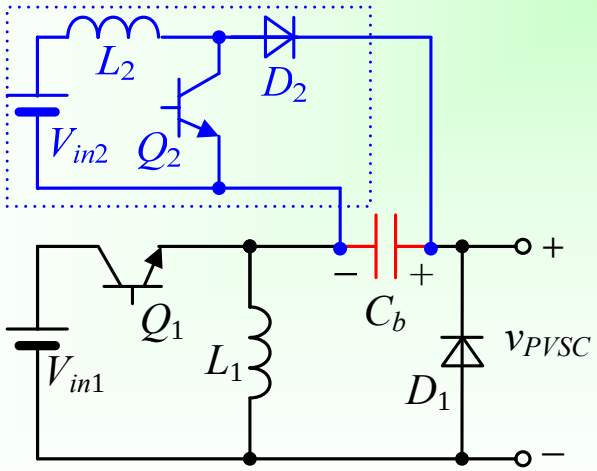



- $i_{PCSC}=i_{L1}+i_{L2}$。
- $V_{in}$和$L_1$同时给$C_b$充电。

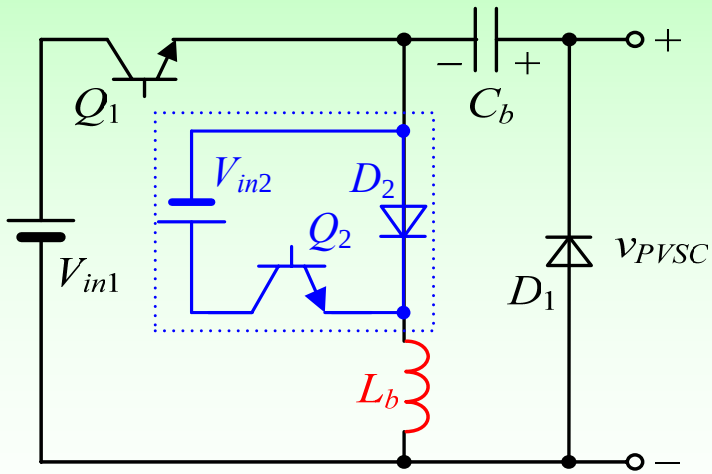
# 混合脉冲电压源单元 (Hybrid PVSC)




Boost PCSC + Cuk PVSC

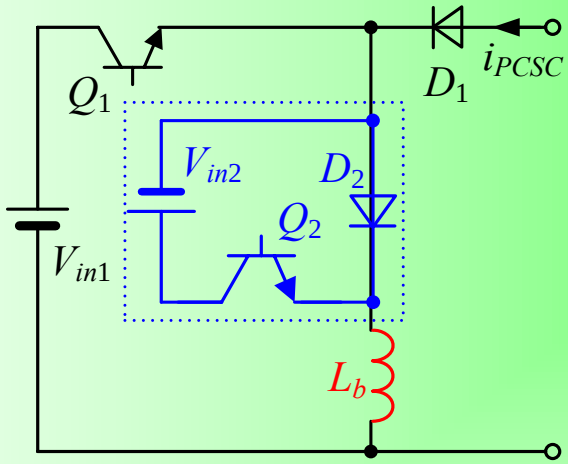



Boost PCSC + Zeta PVSC

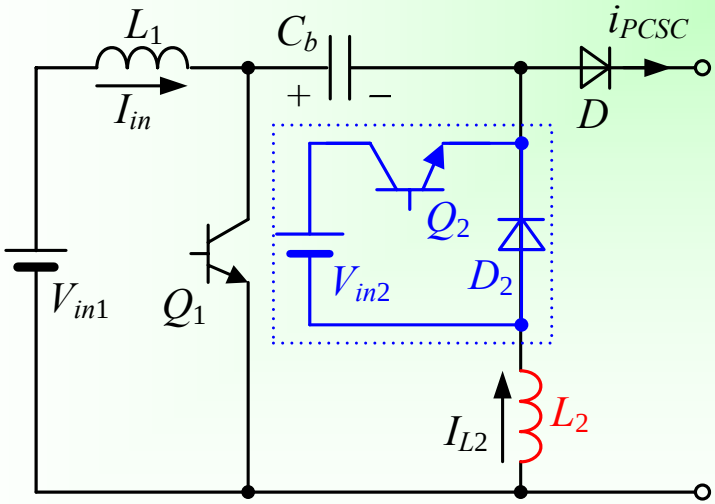



Buck PVSC + Zeta PVSC

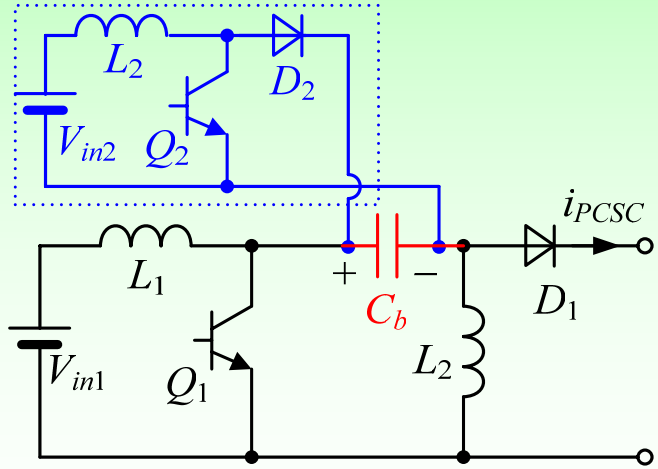
# 混合脉冲电流源单元 (Hybrid PCSC)




Buck PVSC + Buck-Boost PCSC




Buck PVSC + SEPIC PCSC




Boost PCSC + SEPIC PCSC

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- **多输入变换器的生成和简化**
- 单原边绕组隔离型多输入变换器
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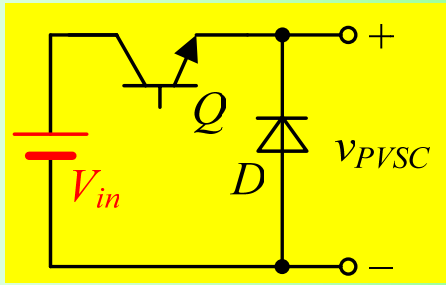
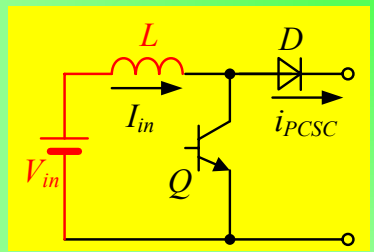
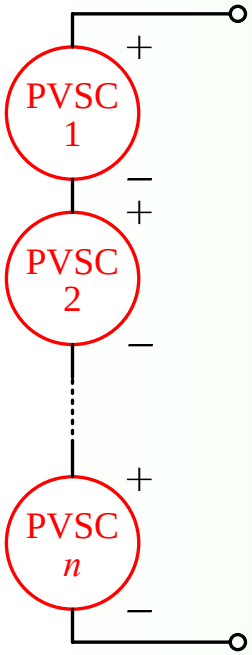
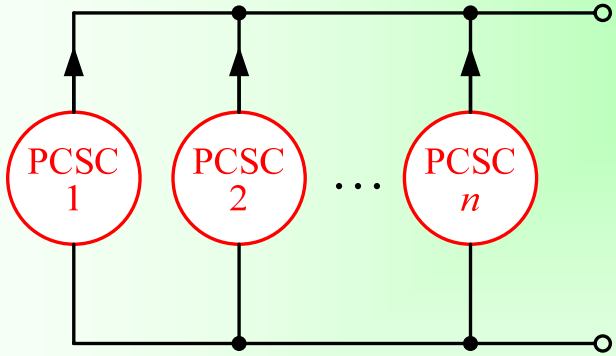
- 结论

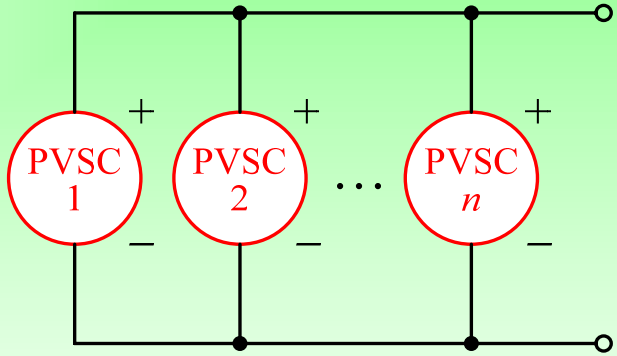
# 脉冲电源单元组合原则

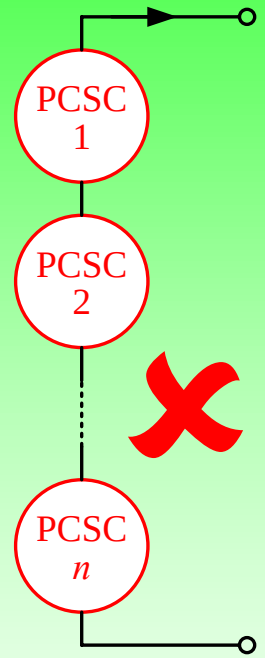


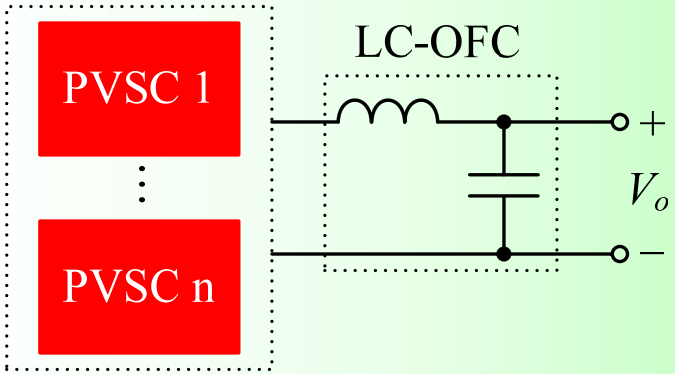

PVSC 串联　　PCSC 并联

各脉冲源单元可同时
供电或分时供电

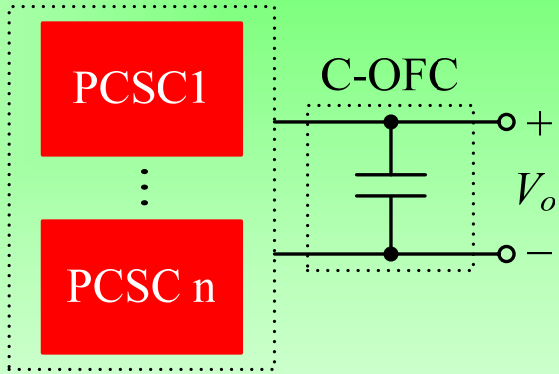
PVSC 并联　　PCSC 串联

只能分时供电

# 脉冲电源单元与输出滤波器单元的组合原则

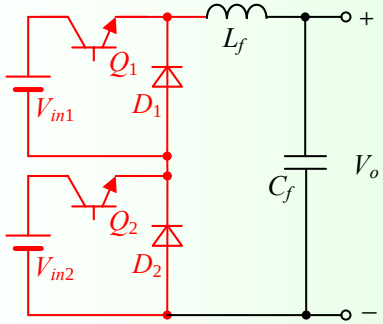



注意：该PVSC可以串联或并联

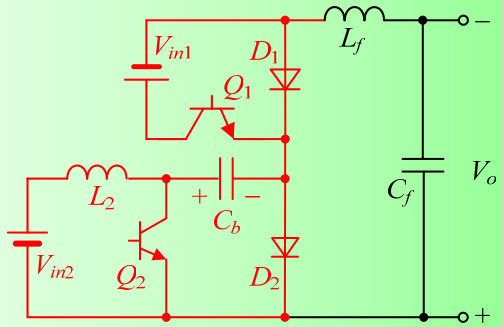



注意：该PCSC只能并联

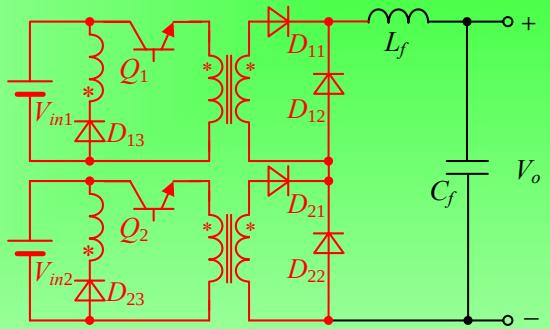
# 多输入直流变换器：多个基本的PVSC串联



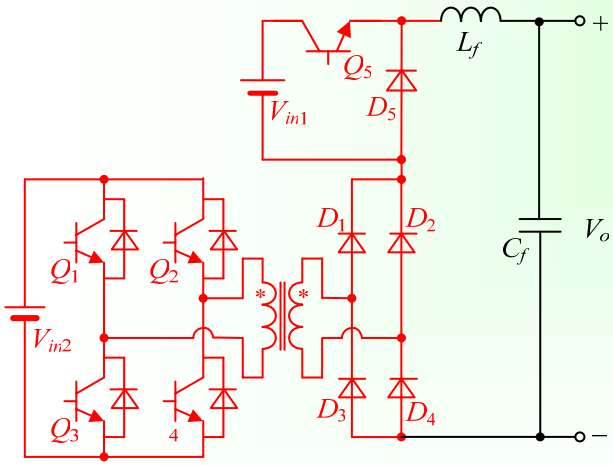

两个Buck PVSC



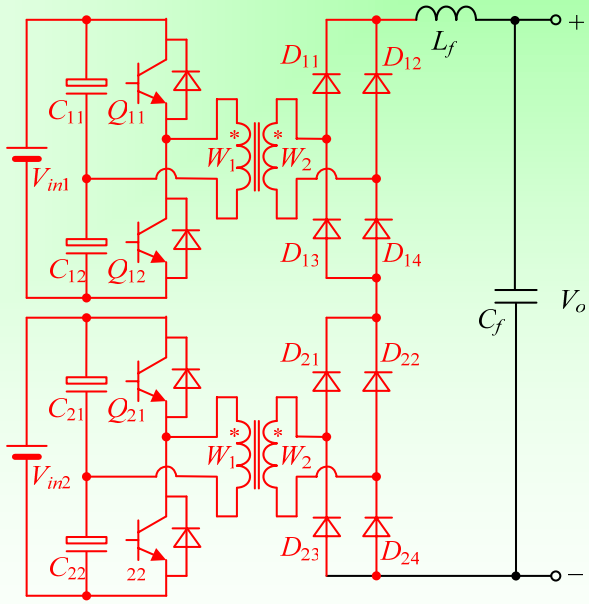

Buck & Cuk PVSC



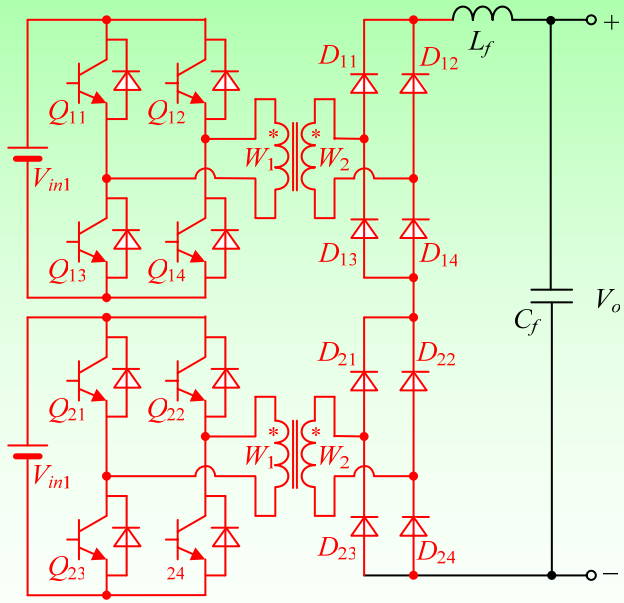

两个正激 PVSC




Buck & 全桥 PVSC

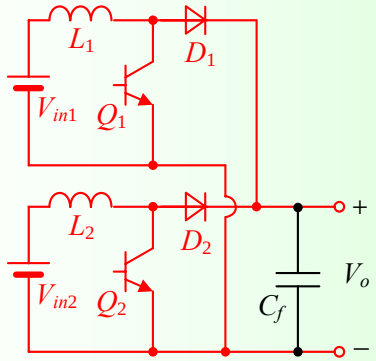



两个半桥 PVSC

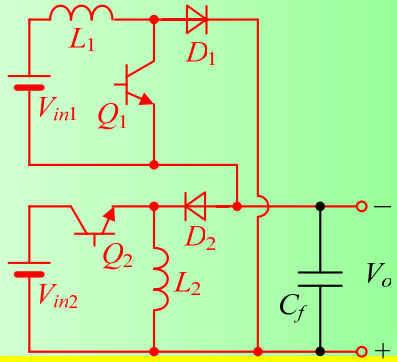



两个全桥 PVSC

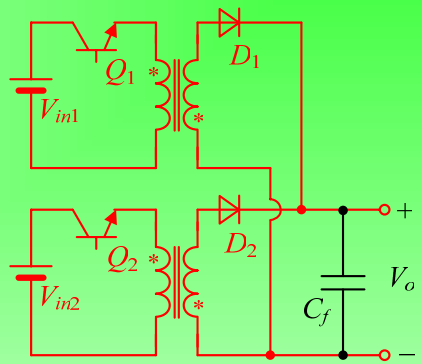
# 多输入直流变换器：多个基本的PCSC并联



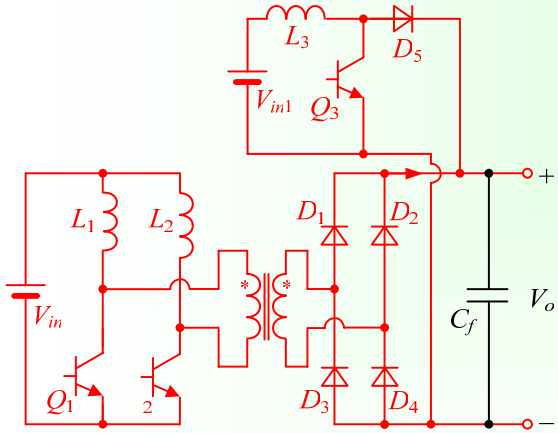

两个Boost PCSC



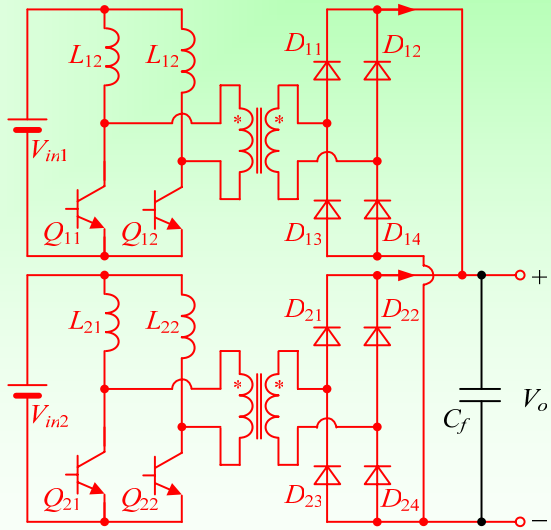

Boost & Buck-Boost PVSC



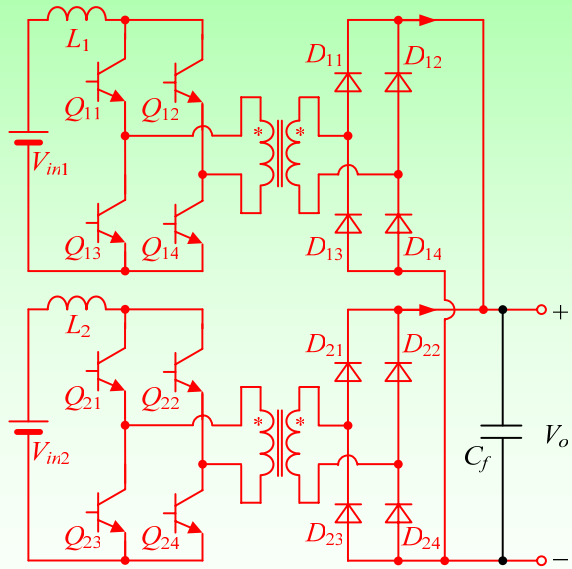

两个反激 PCSC




Boost & 半桥 PCSC

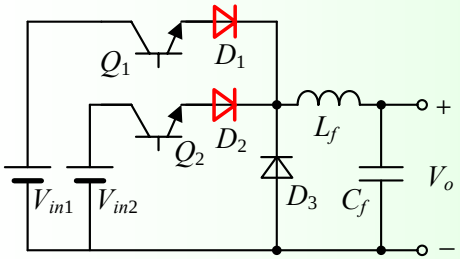



两个半桥 PCSC

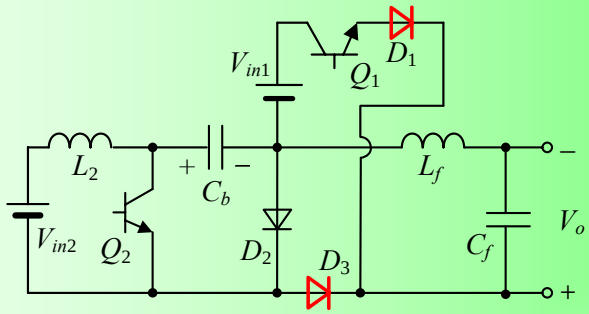



两个全桥 PCSC

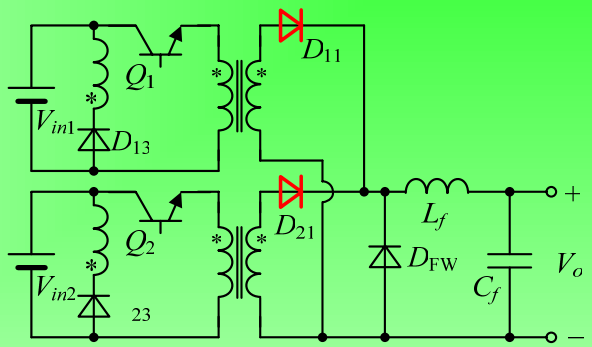
# 多输入直流变换器：多个基本的PVSC并联



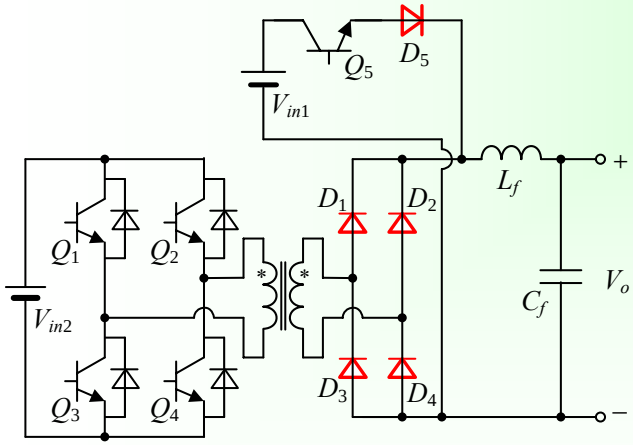

两个 Buck PVSC



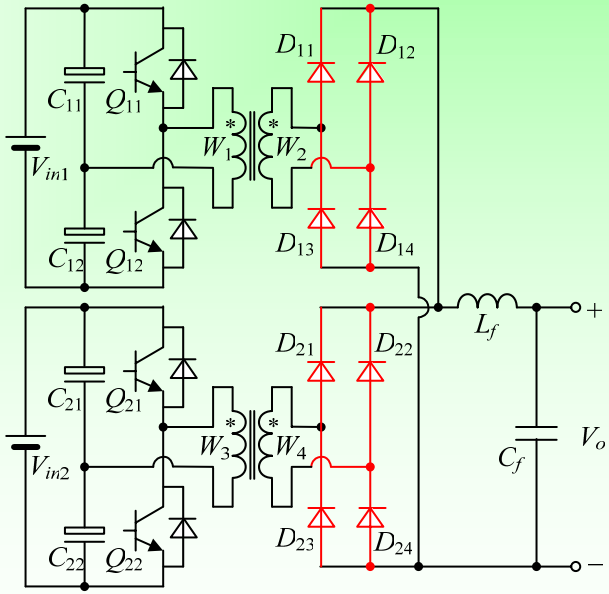

Buck & Cuk PVSC



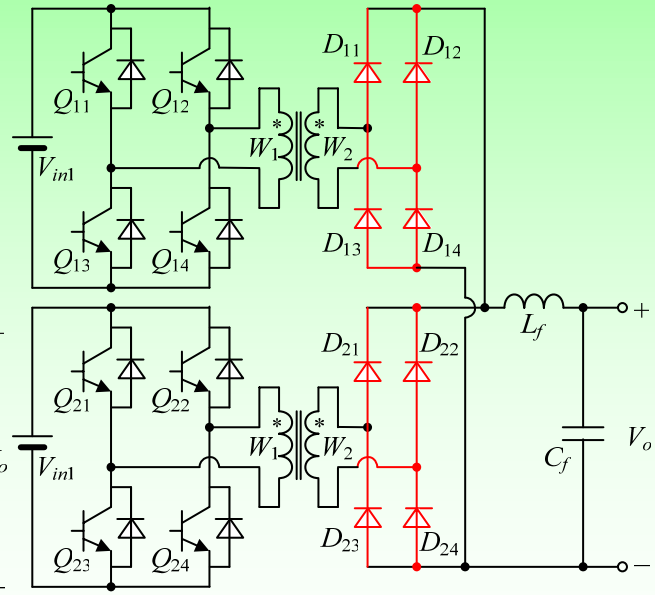

两个正激 PVSC




Buck & 全桥 PVSC

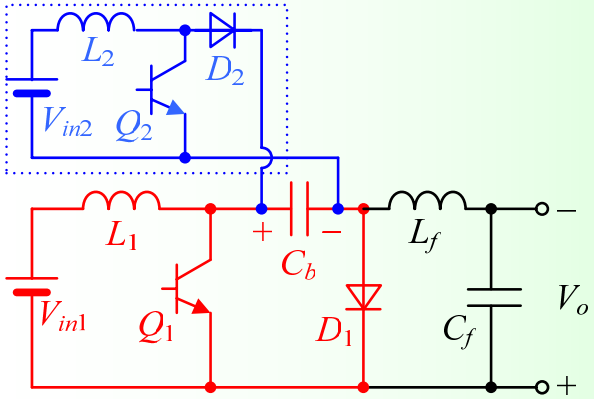



两个半桥 PVSC

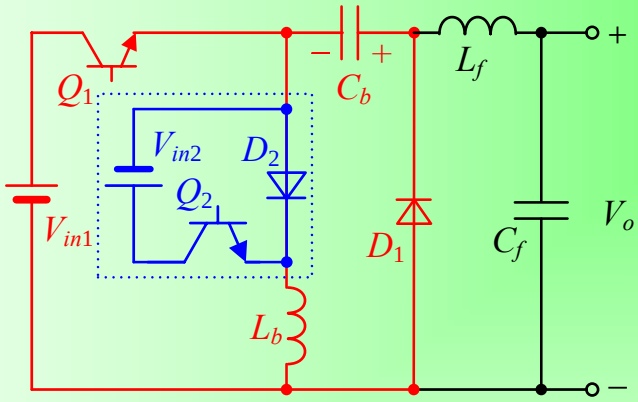



两个全桥 PVSC

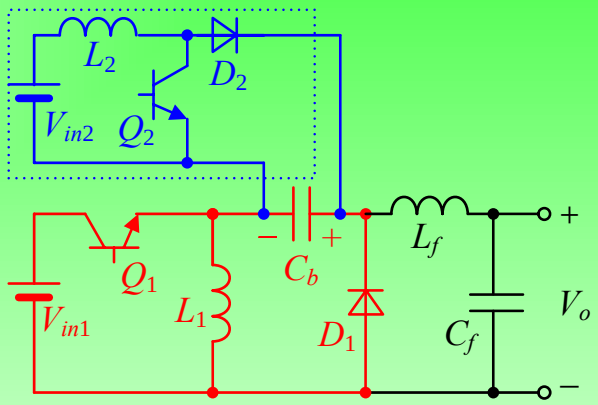
# 多输入直流变换器：单个混合PVSC



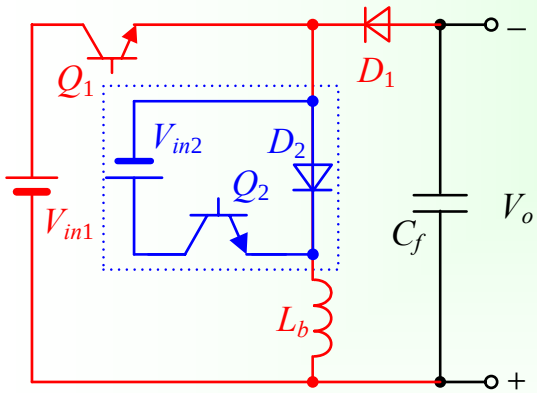

Boost & Cuk PVSC



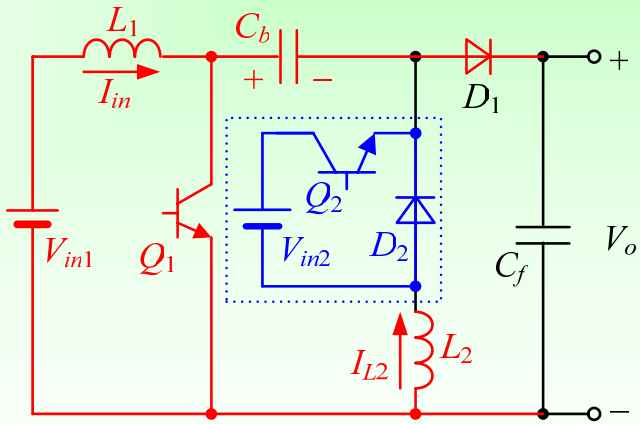

Buck & Zeta PVSC



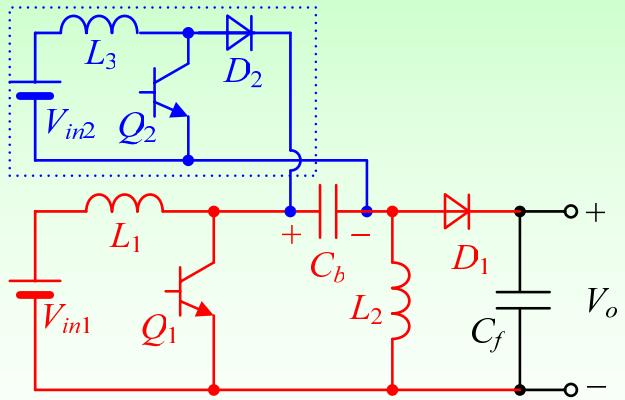

Boost & Zeta PVSC




Buck & Buck-Boost PVSC

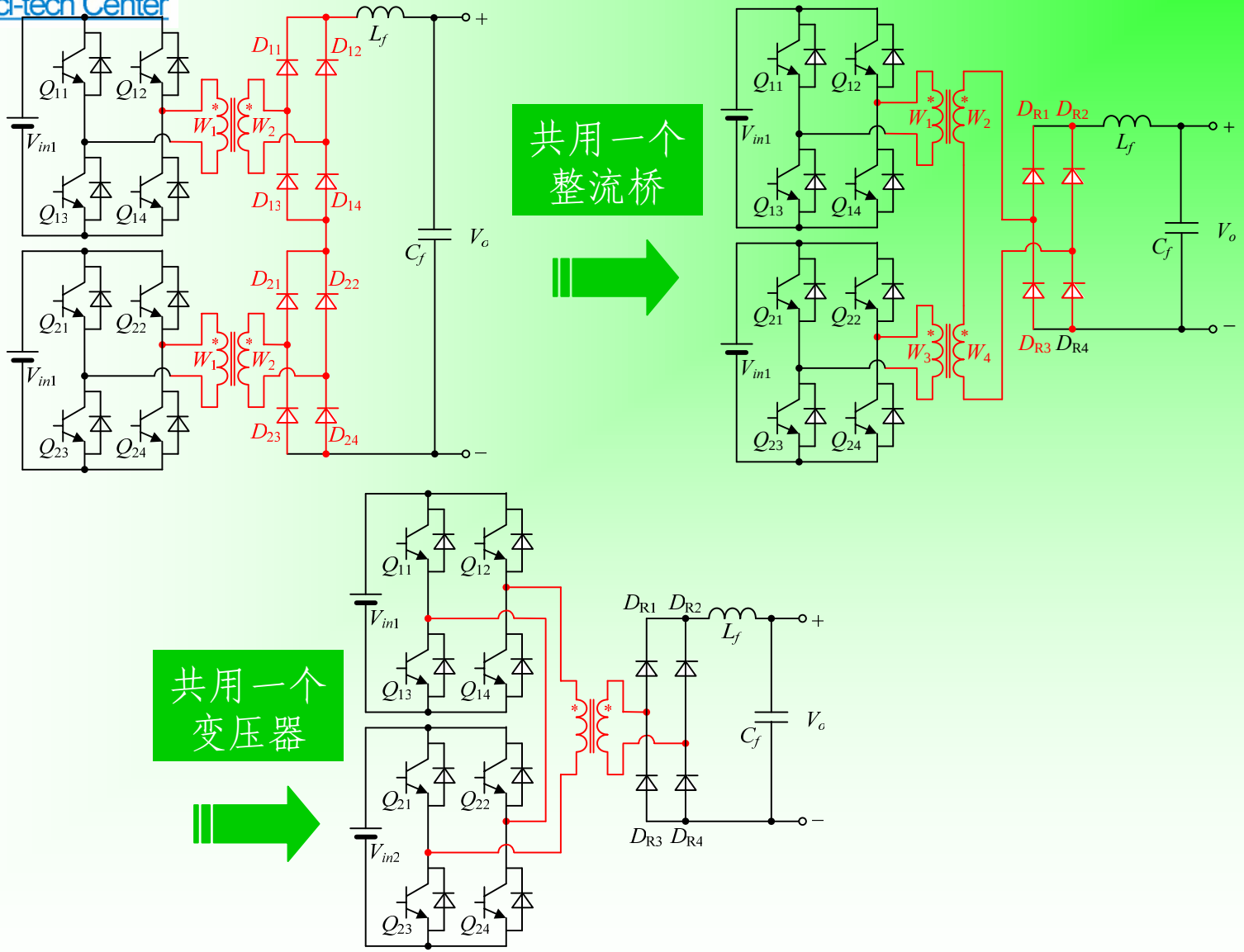



Buck & SEPIC PVSC

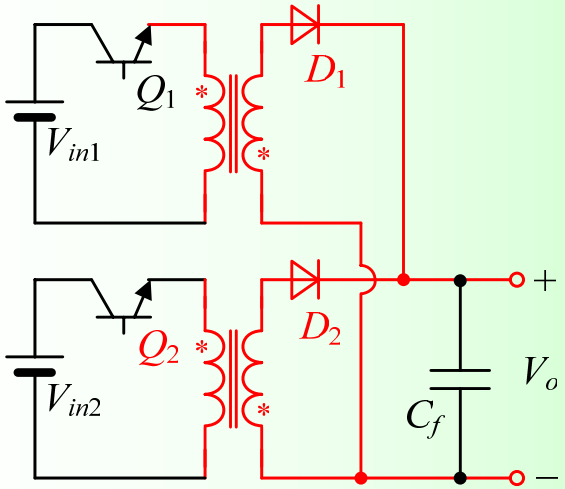


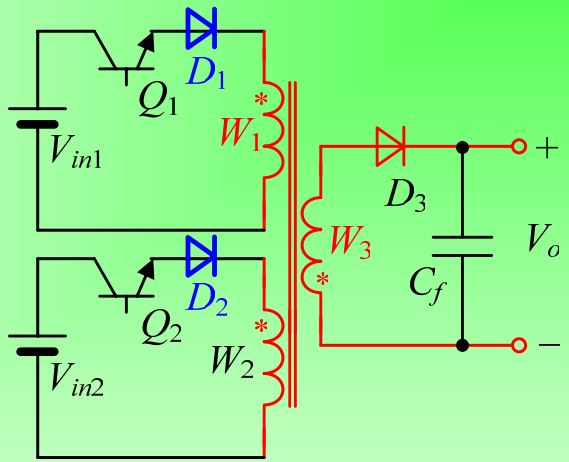

Boost & SEPIC PVSC

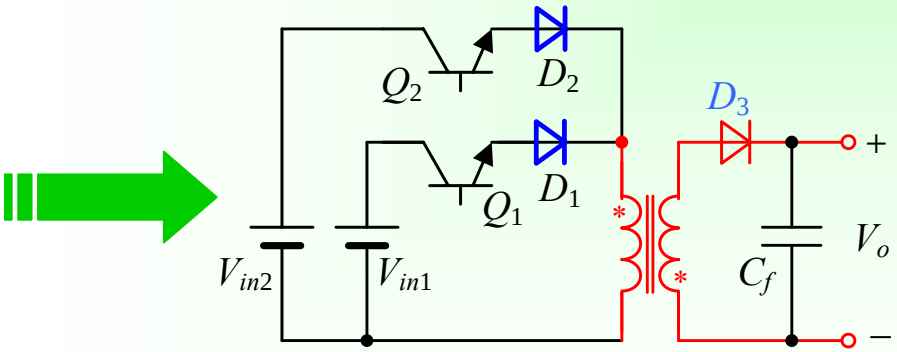
# 多全桥PVSC串联组合得到的MIC的简化

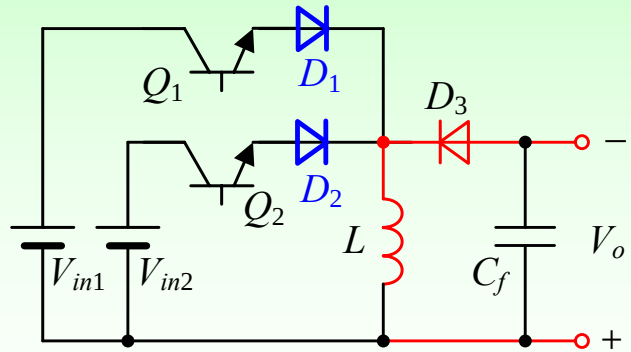


# 多反激PCSC并联组合得到的MIC的简化

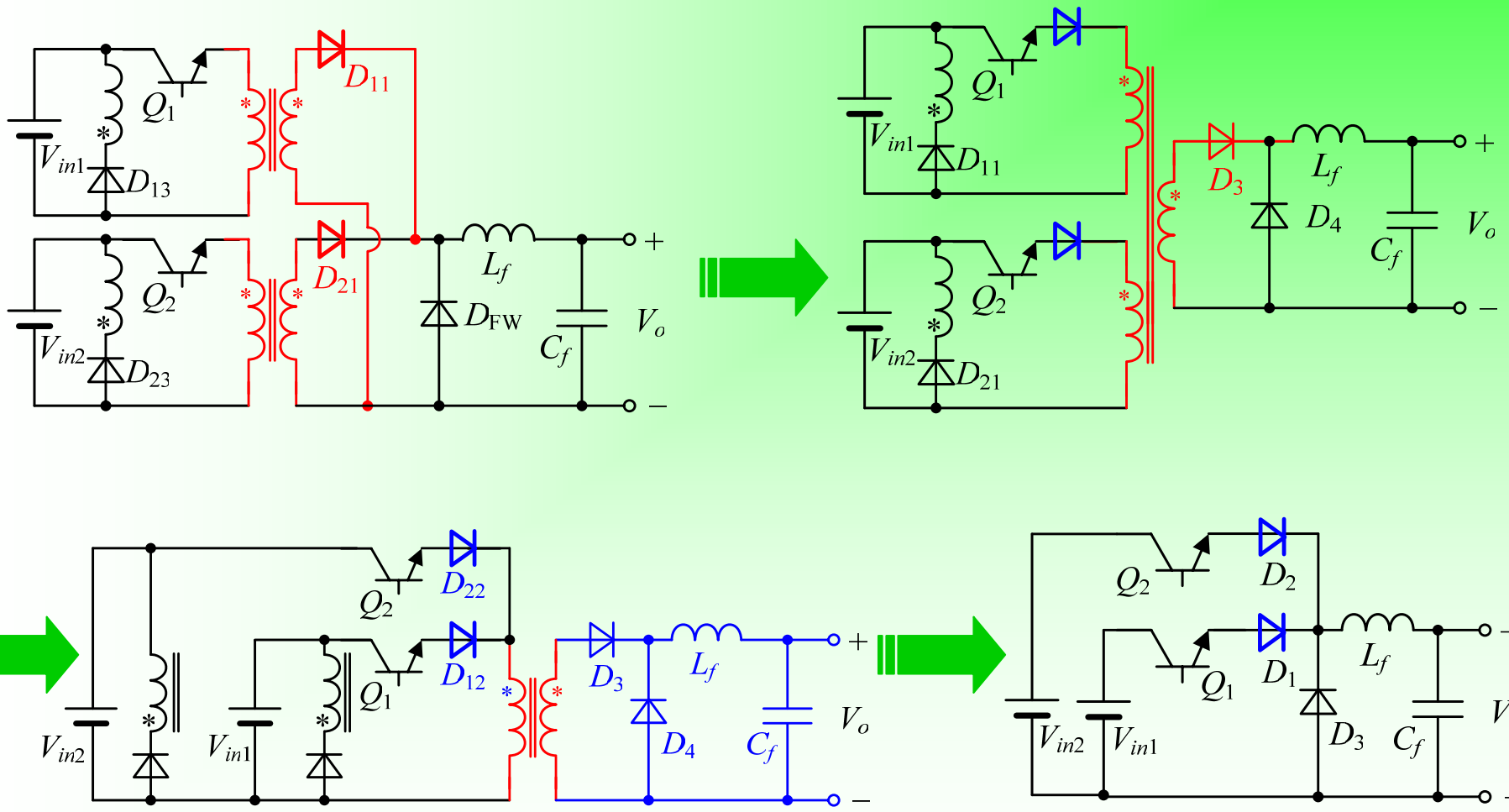


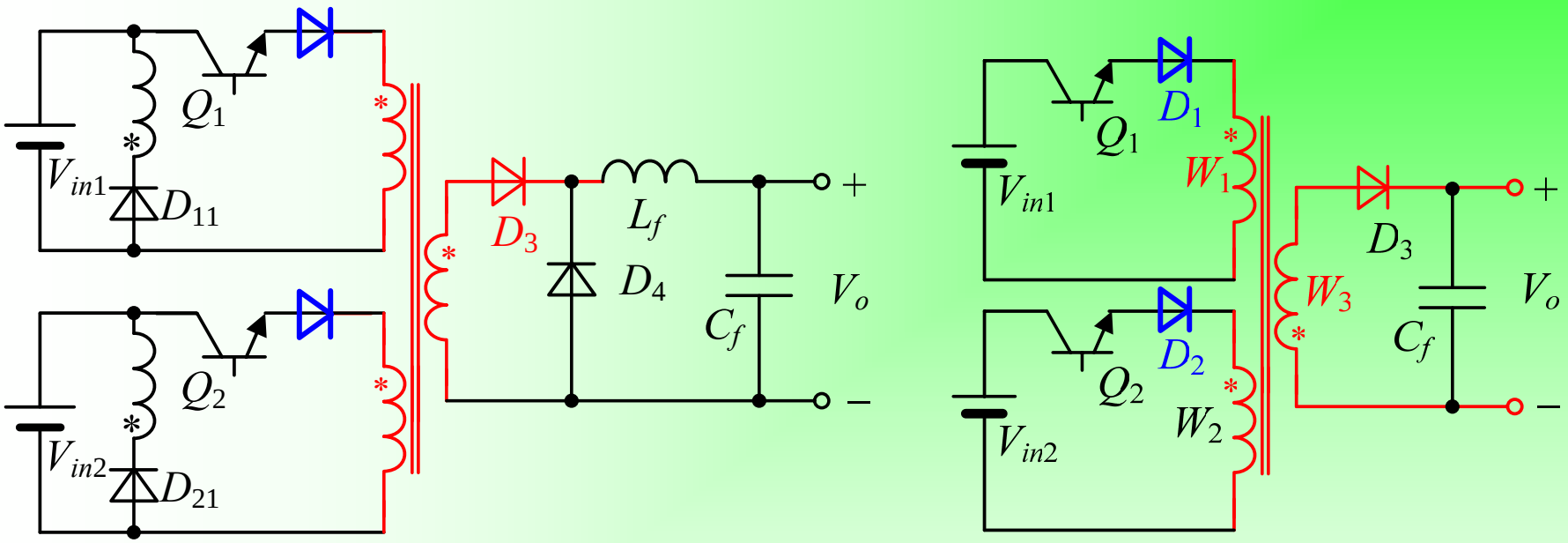
# 多正激PVSC并联组合得到的MIC的简化



# 报告内容

- 研究背景
- 脉冲源单元
- 多输入变换器的生成和简化
- **单原边绕组隔离型多输入变换器**
- 多输入变换器的控制方法
- 结论

# 隔离型多输入直流变换器的不足

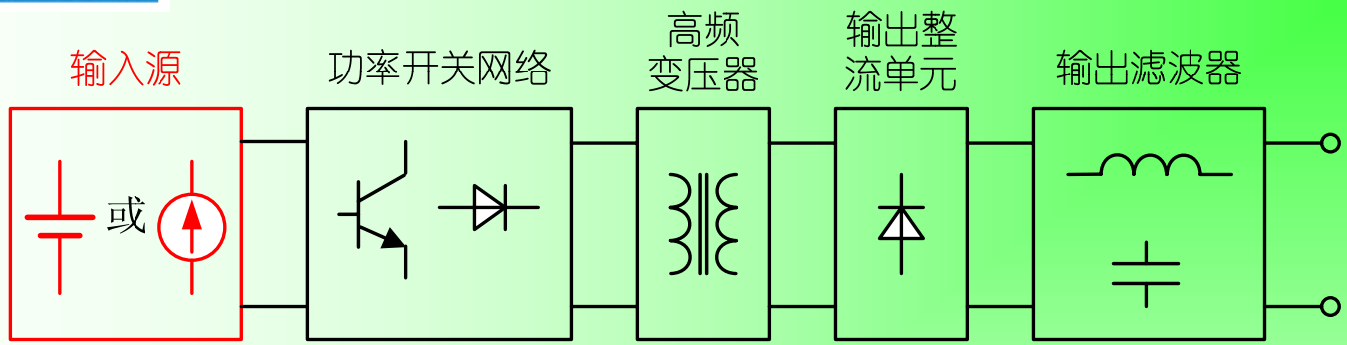


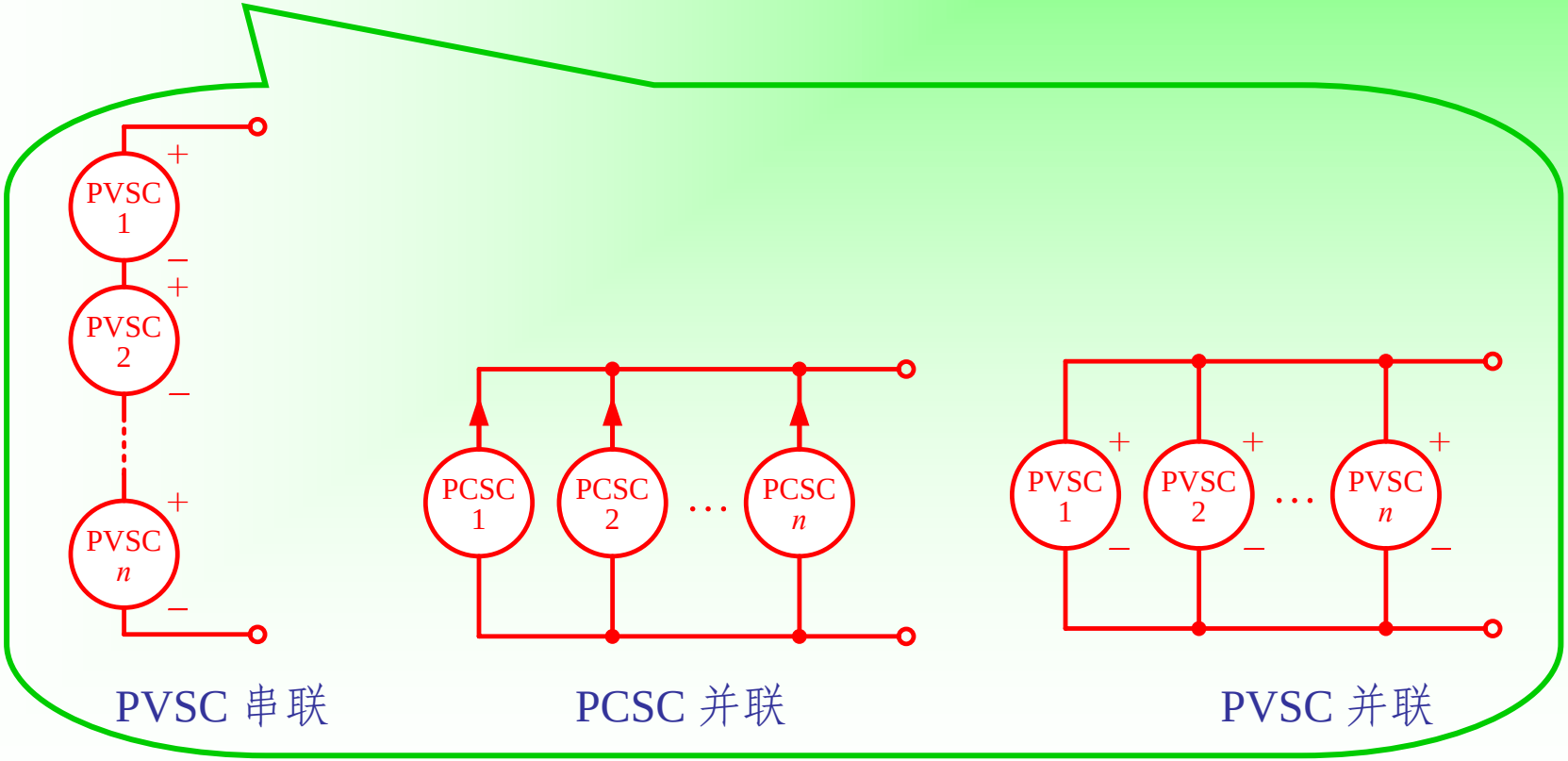

☹ 变压器结构复杂;

☹ 变压器漏感较大;

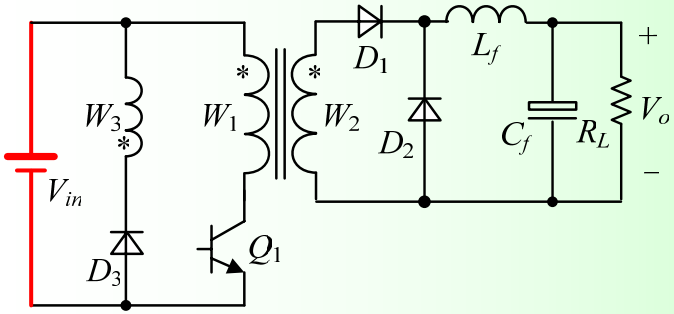
☹ 各输入源不能同时供电。

# 单原边绕组隔离型多输入直流变换器的基本推导思路

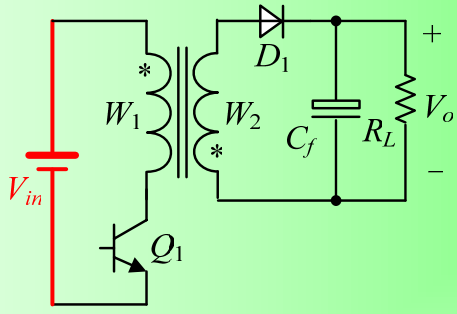


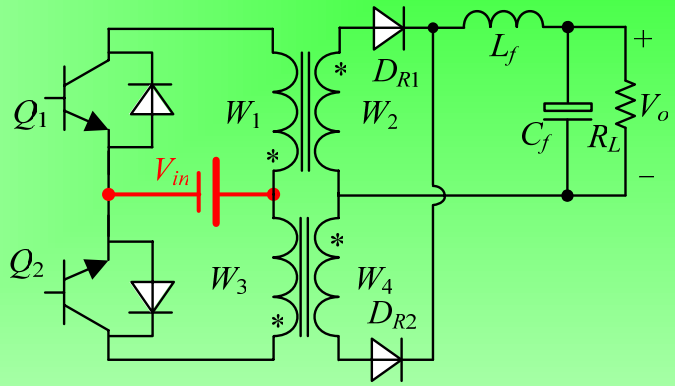
# 电压源型隔离型单输入直流变换器



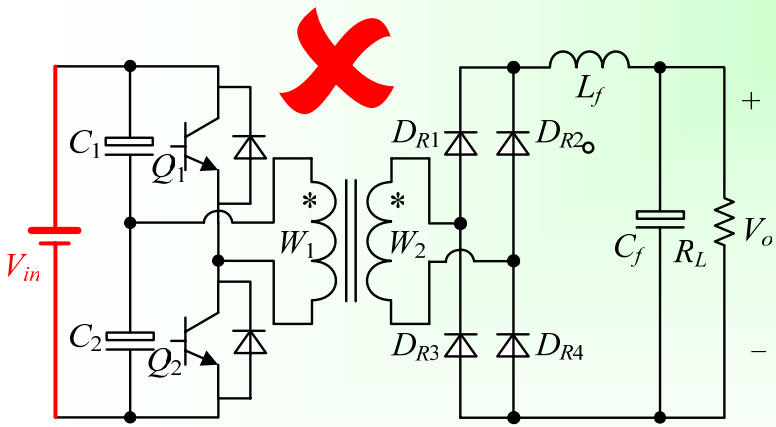

正激



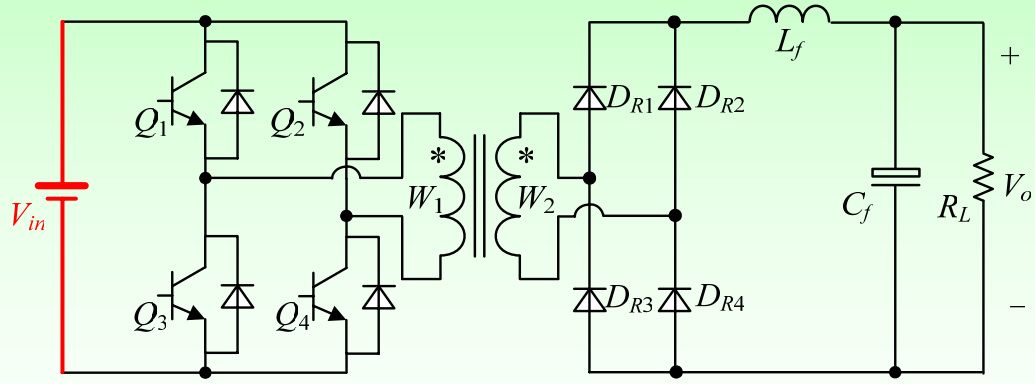

反激




推挽

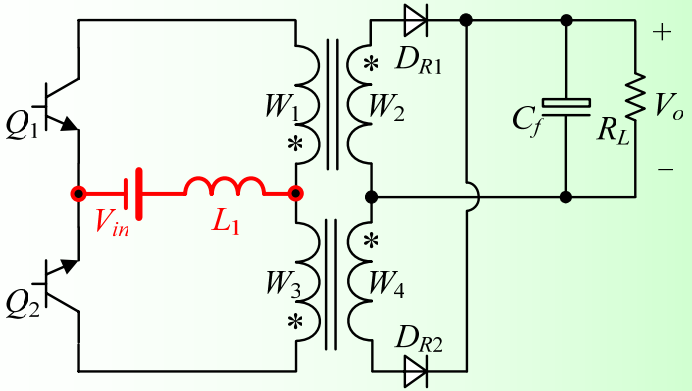



半桥




全桥

# 电流源型隔离型单输入直流变换器

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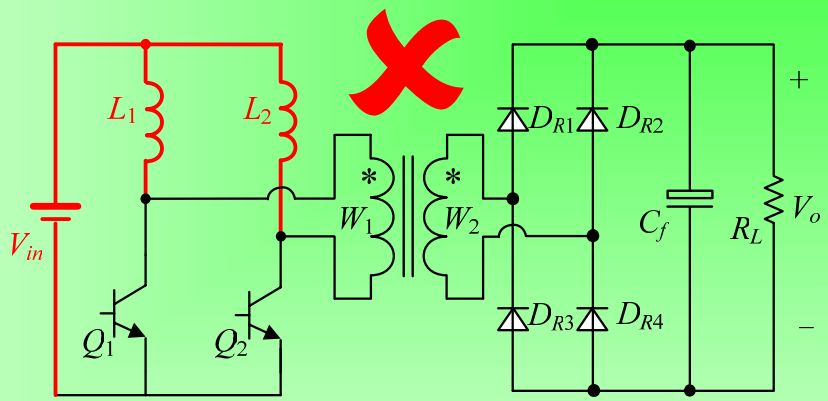


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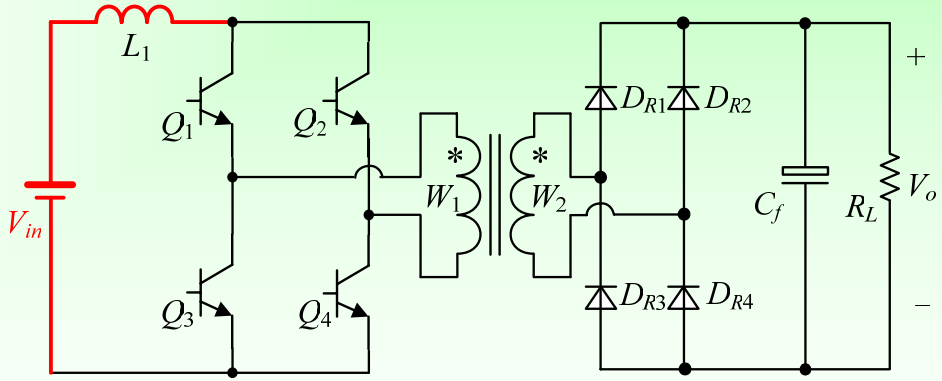
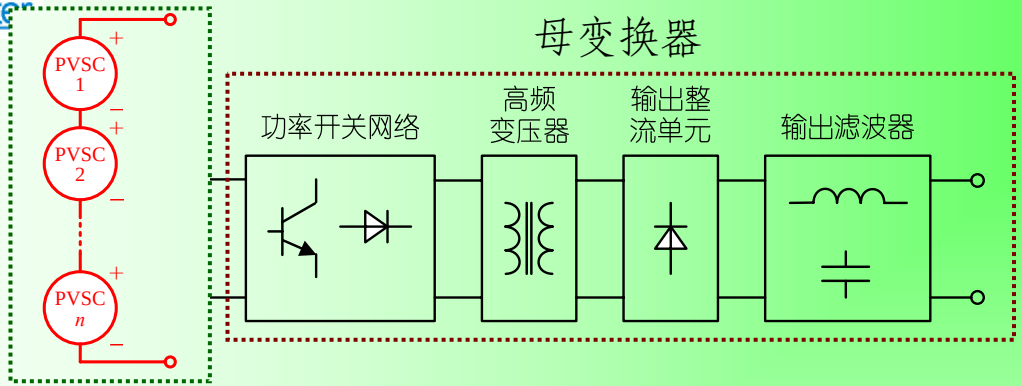
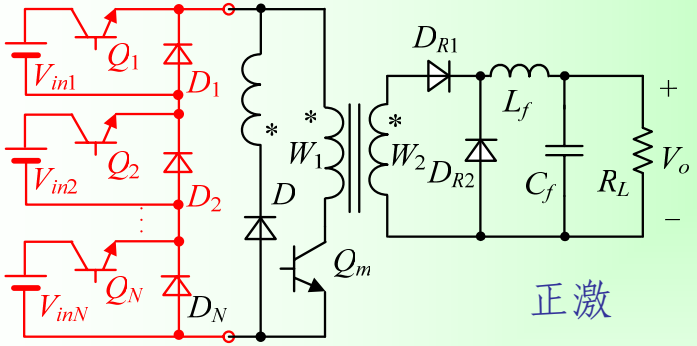


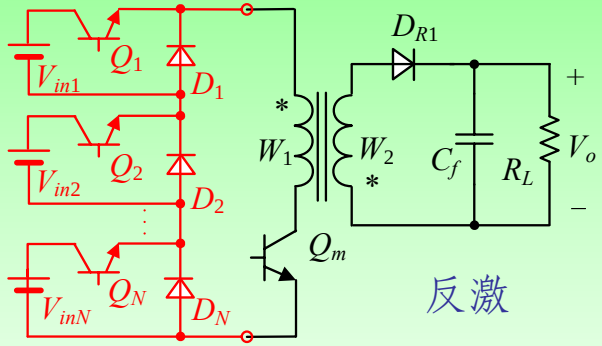

全桥

# 单原边绕组隔离型多输入直流变换器：PVSC串联

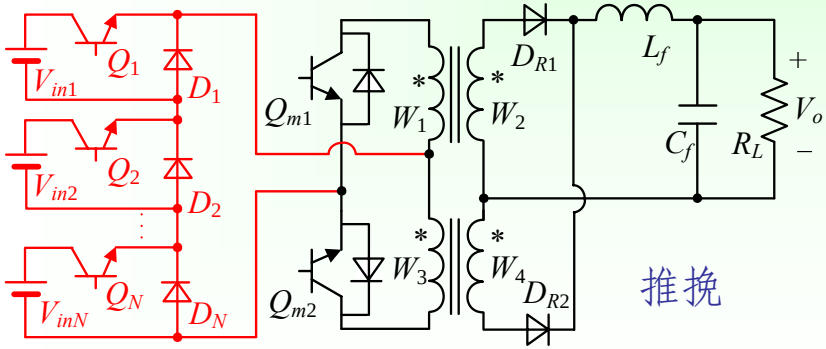


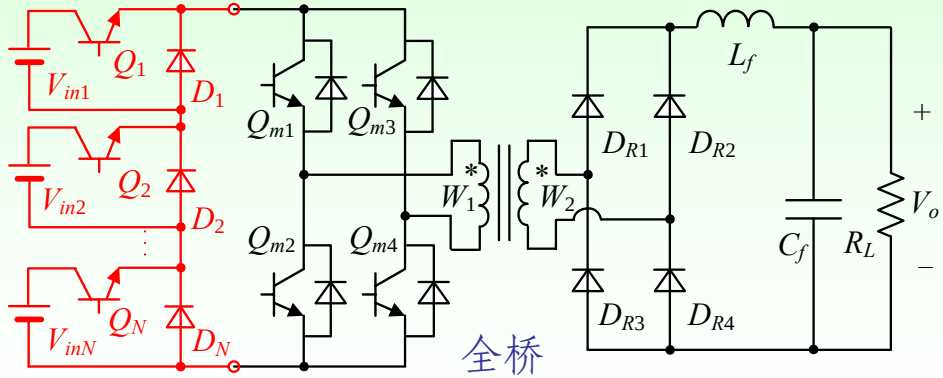

正激




反激

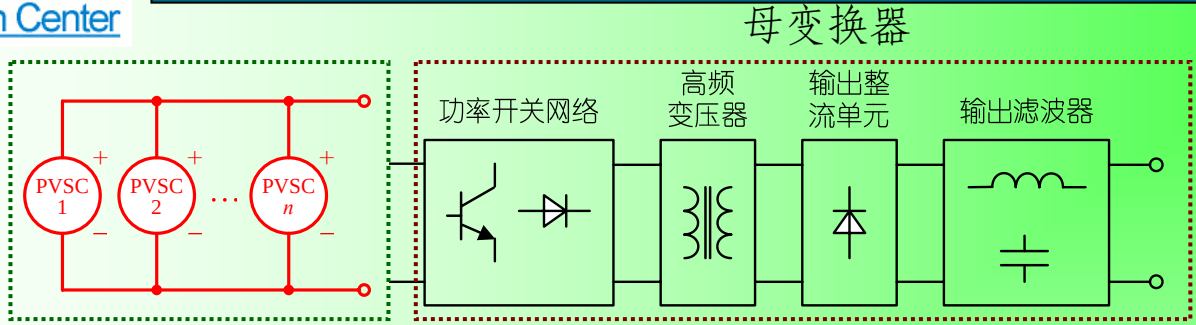


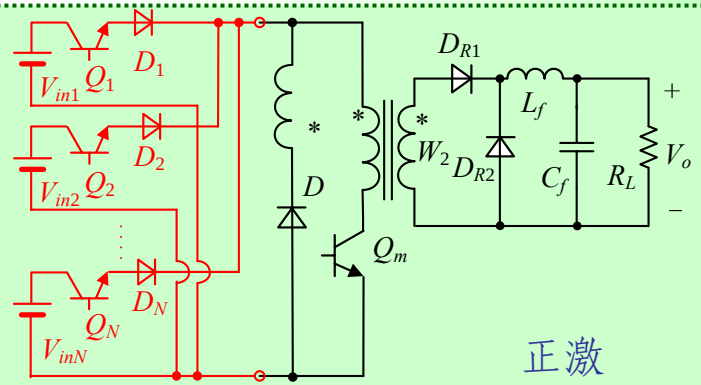

推挽

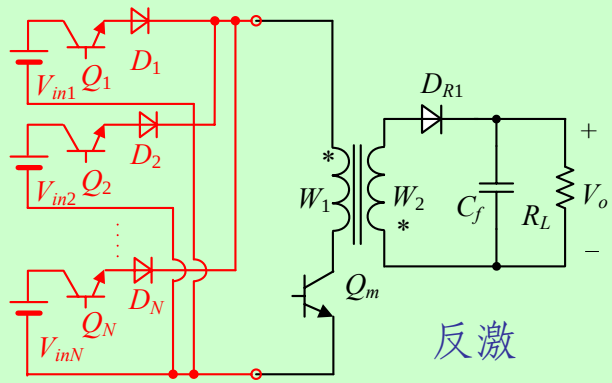


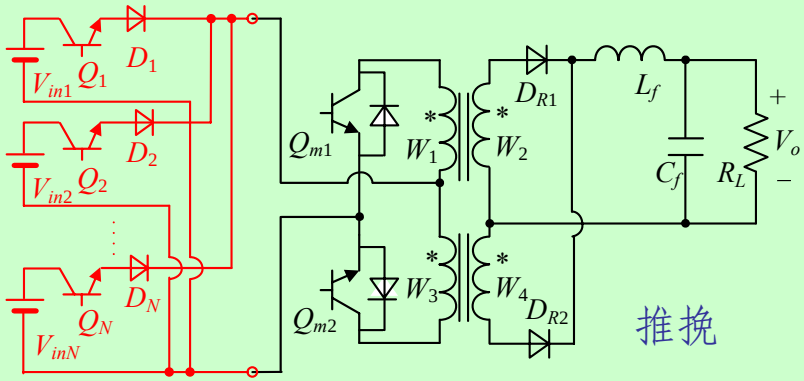

全桥

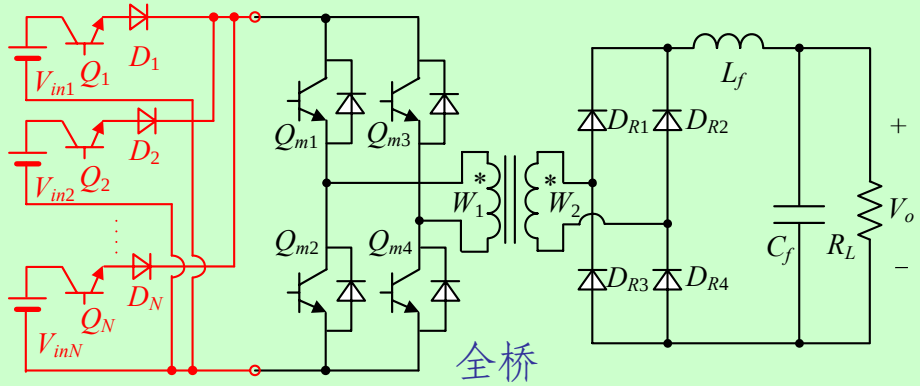
# 单原边绕组隔离型多输入直流变换器：PVSC并联



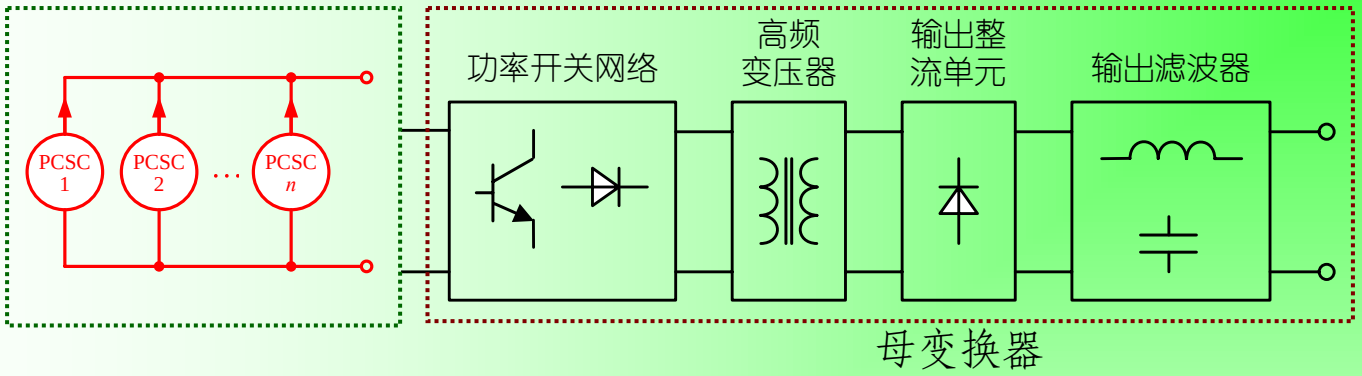



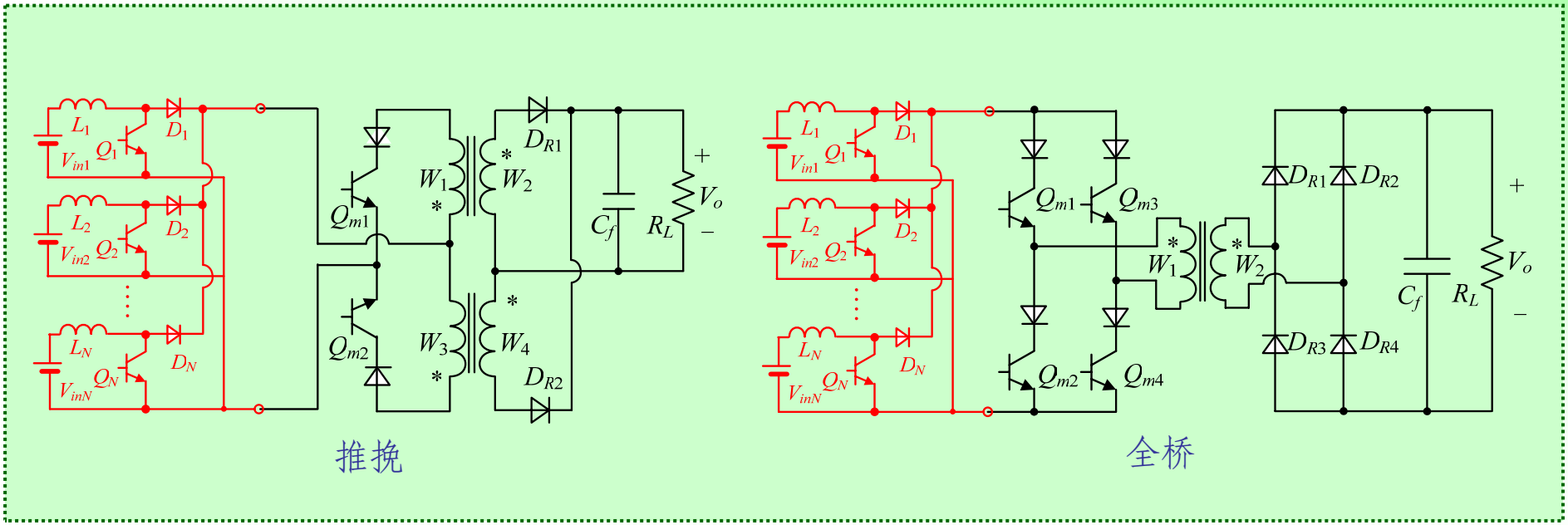



# 单原边绕组隔离型多输入直流变换器：PCSC并联

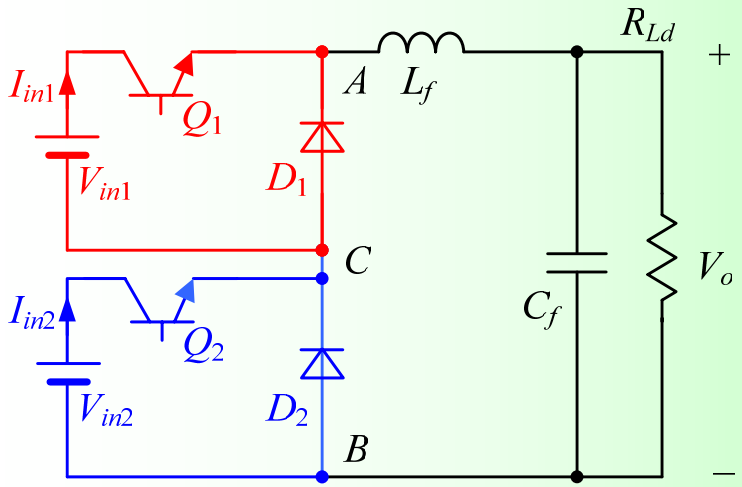


# 报告内容

- 研究背景
- 脉冲源单元
- 多输入变换器的生成和简化
- 单原边绕组隔离型多输入变换器
- **多输入变换器的控制方法**
- 结论

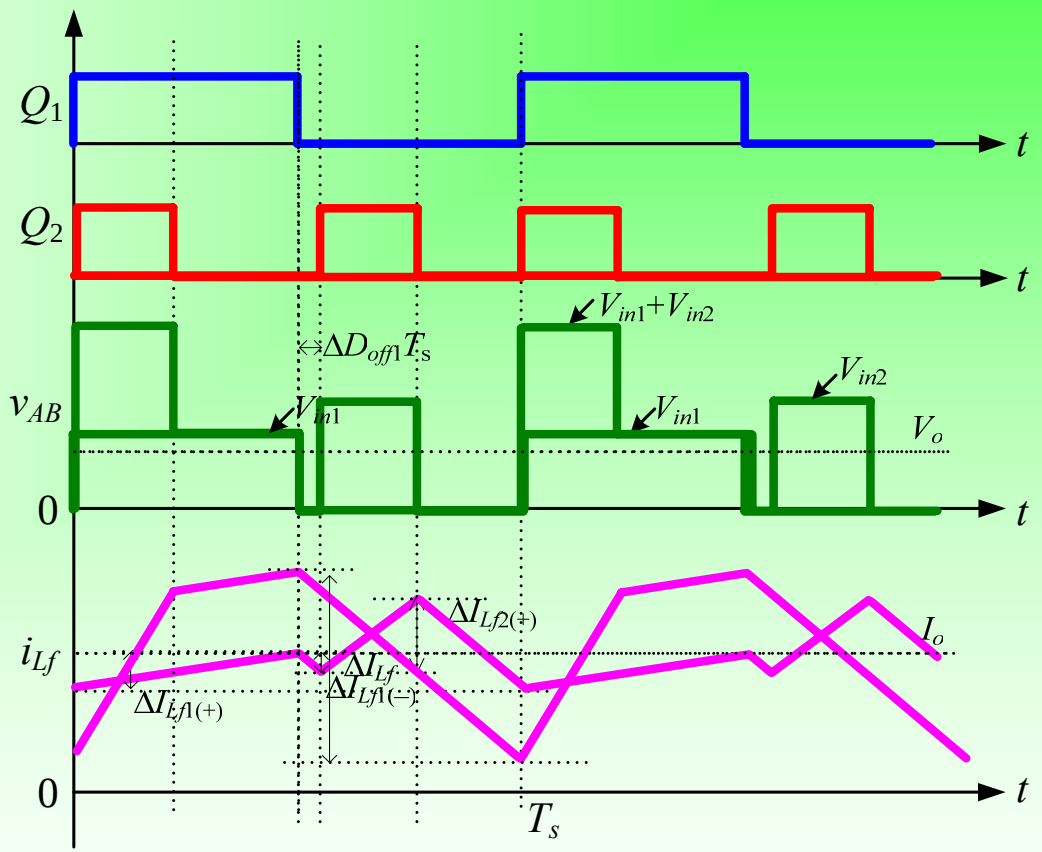
# 电感电流脉动与两个驱动信号相位差的关系




$$V_o = \bar{v}_{AB} = \bar{v}_{AC} + \bar{v}_{CB}$$
$$= V_{in1} \cdot D_{y1} + V_{in2} \cdot D_{y2}$$

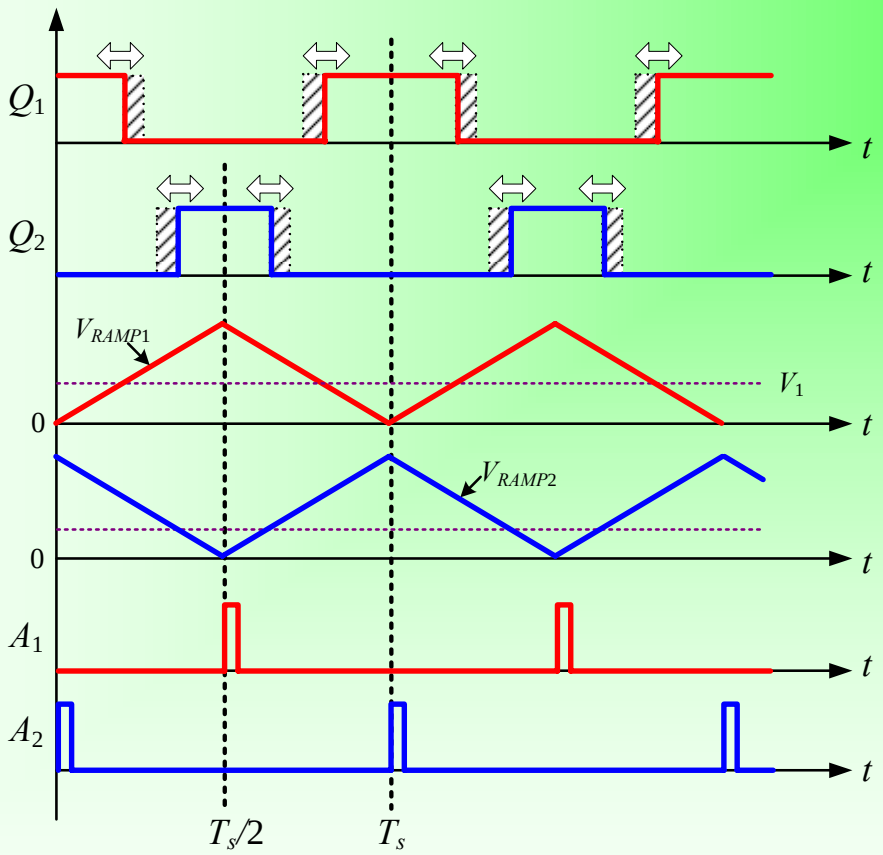
$$I_{in1} = D_{y1} \cdot I_o$$

$$I_{in2} = D_{y2} \cdot I_o$$



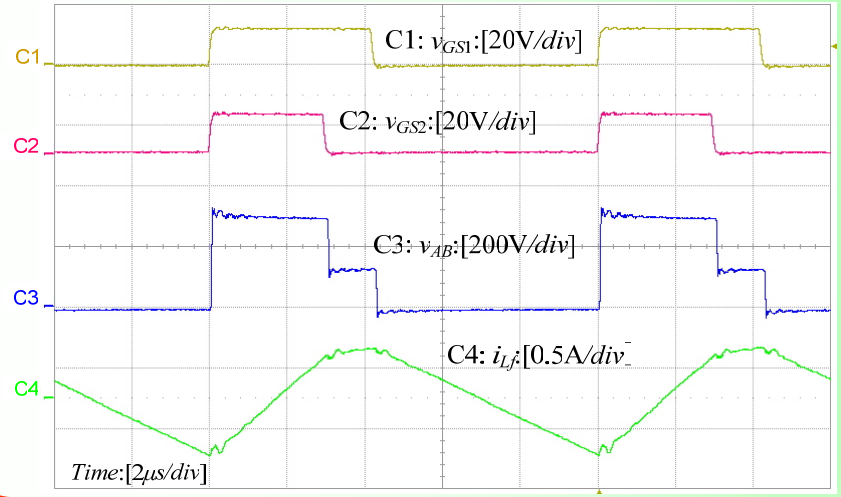

$$D_{y1}+D_{y2} \leqslant 1$$

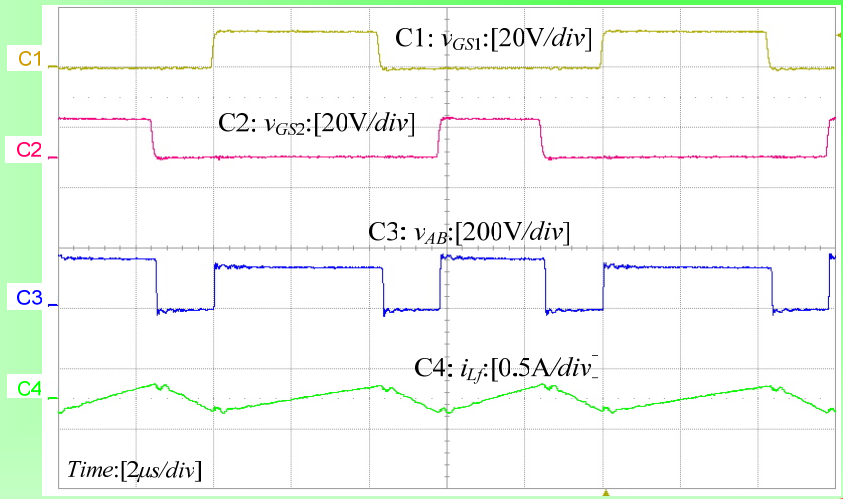
# 双输入Buck变换器：交错双沿调制方法

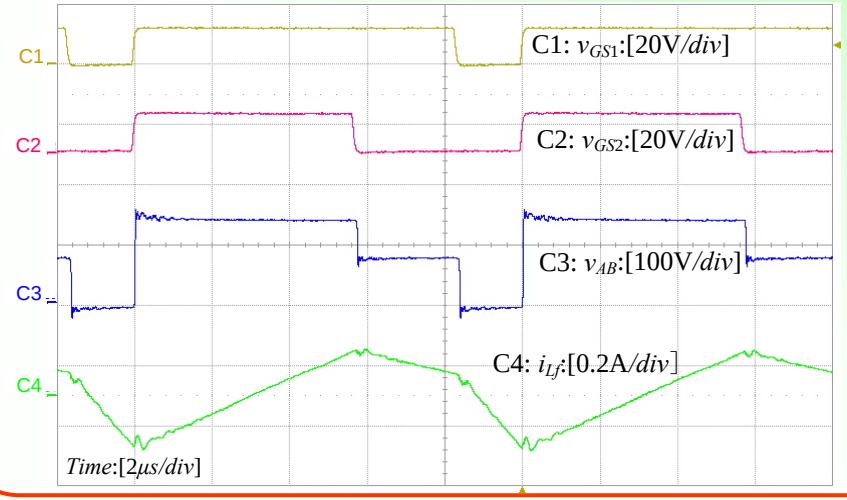


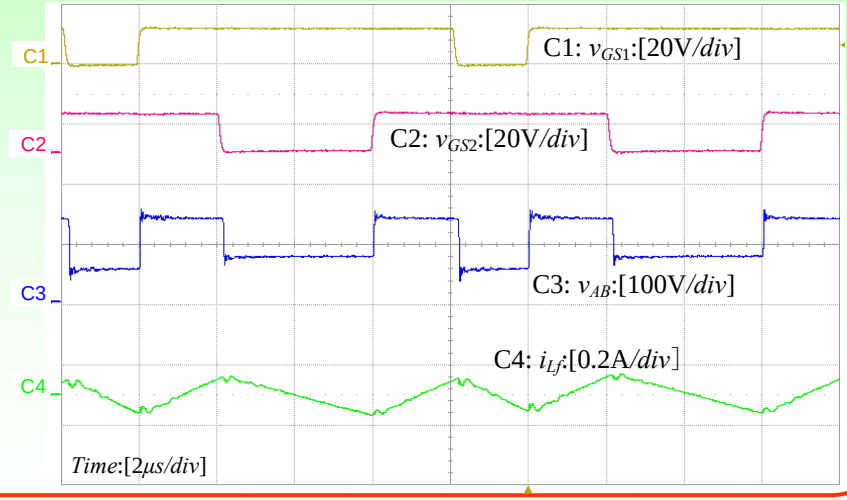

$$D_{y1}+D_{y2} \leqslant 1$$

# 交错双沿控制的实验验证

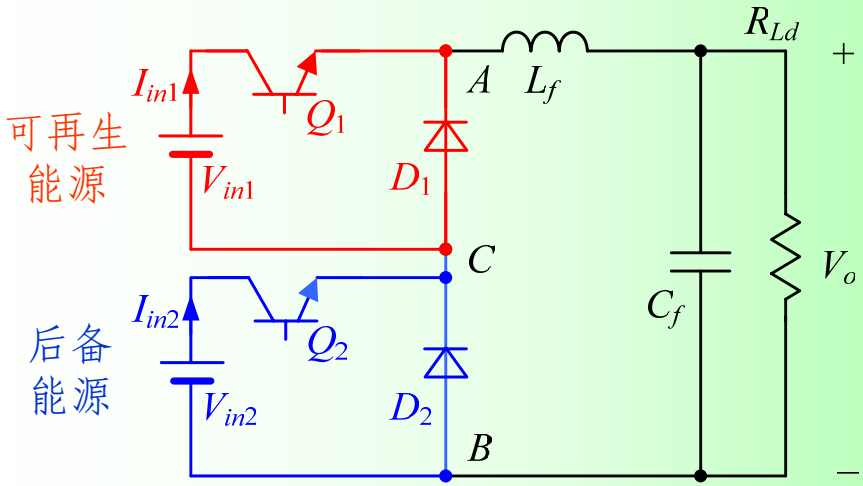


# 能量管理策略

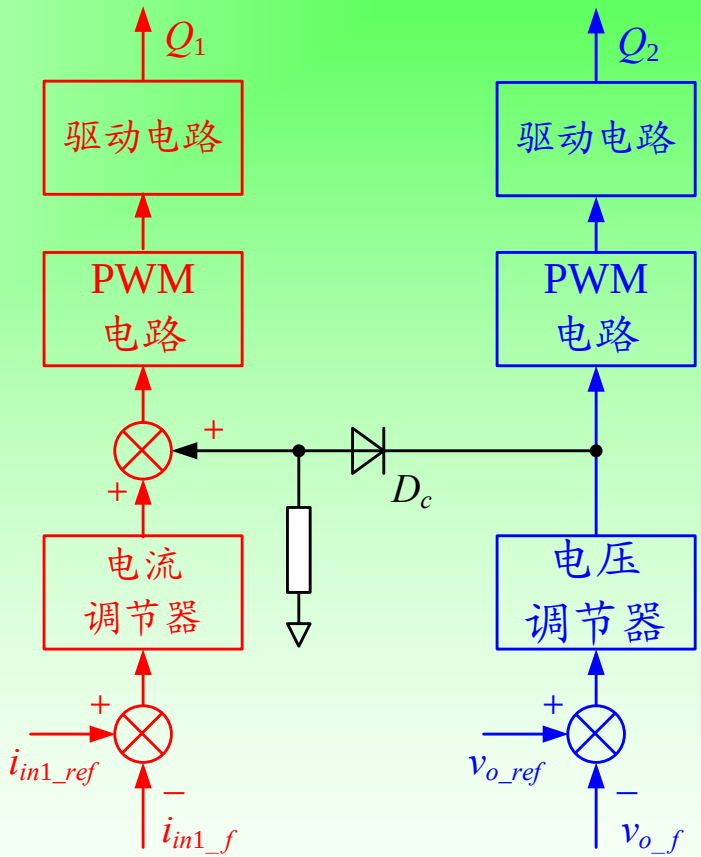



$$V_o = \bar{v}_{AB} = \bar{v}_{AC} + \bar{v}_{CB}$$
$$= V_{in1} \cdot D_{y1} + V_{in2} \cdot D_{y2}$$

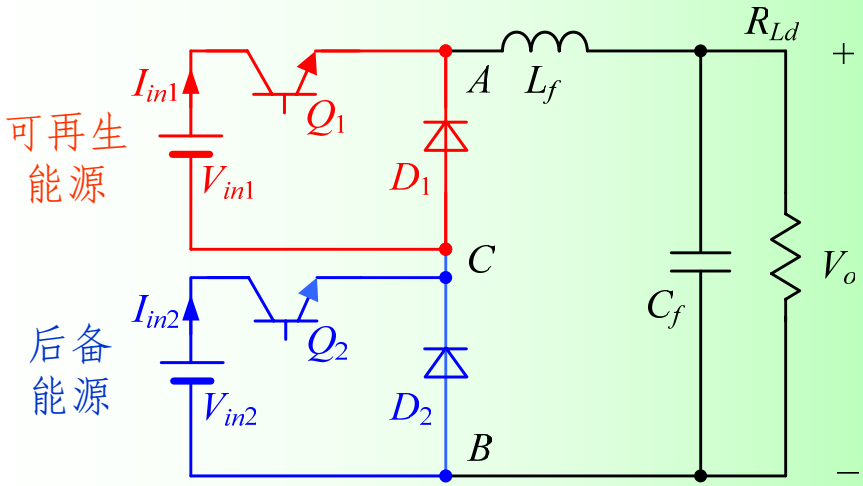
$$I_{in1} = D_{y1} \cdot I_o$$

$$I_{in2} = D_{y2} \cdot I_o$$

- 调节输出电压
- 实现能量分配

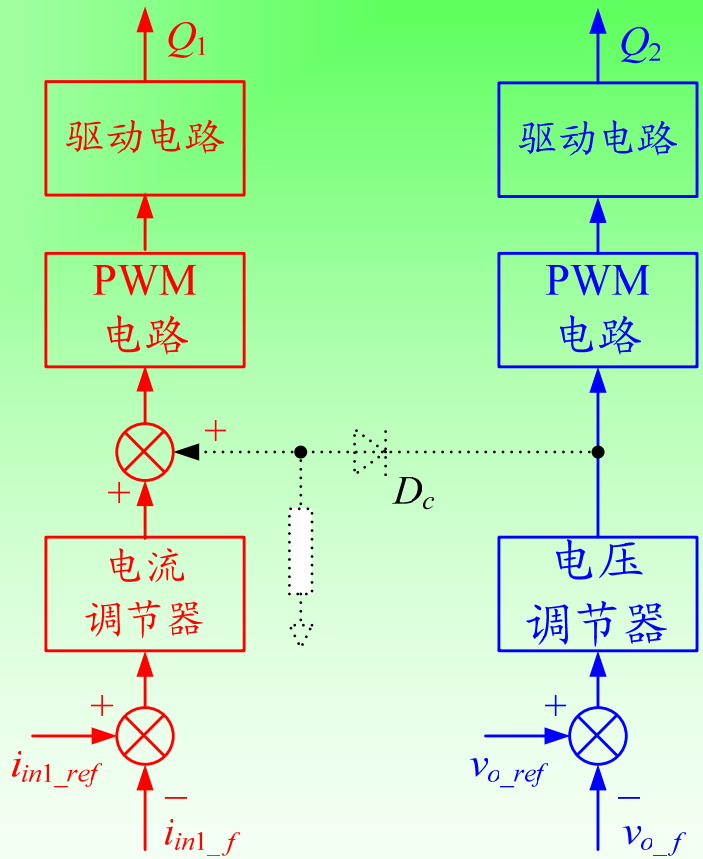


# 工作模式I：两个电源同时供电

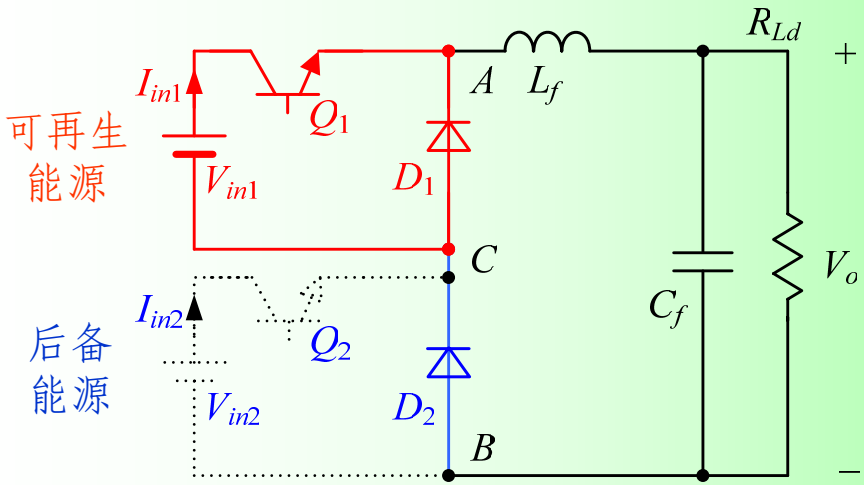


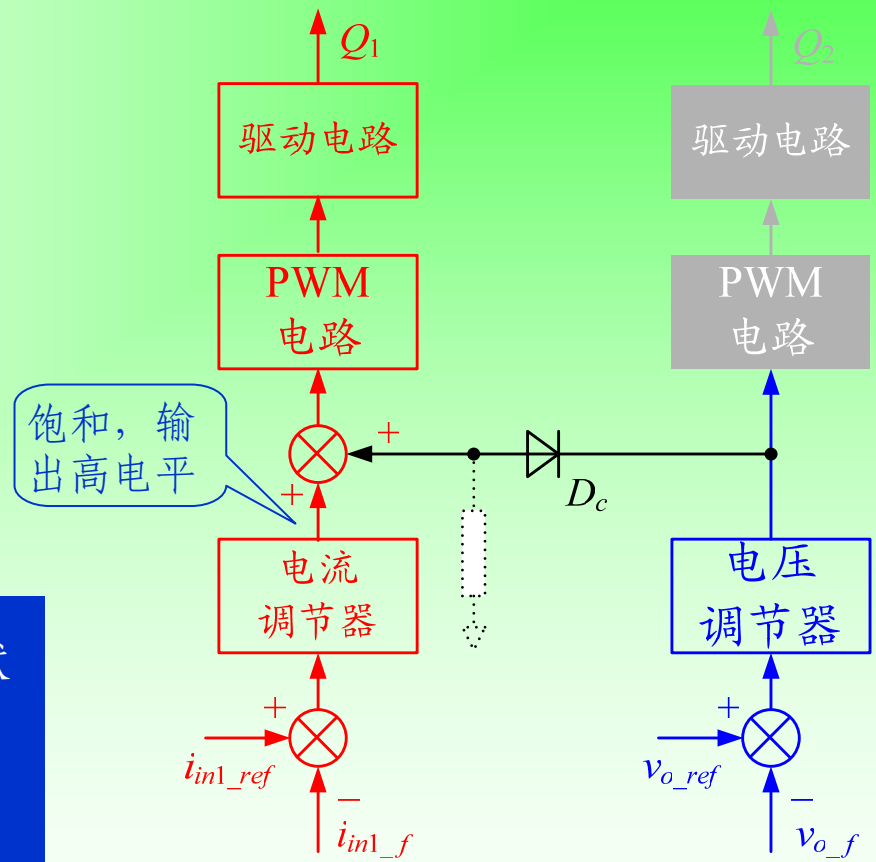

可再生能源的能量不足以提供负载功率

- 可再生能源发电单元工作在MPPT状态；
- 后备电源提供不足的负载功率。



# 工作模式II：1#电源供电

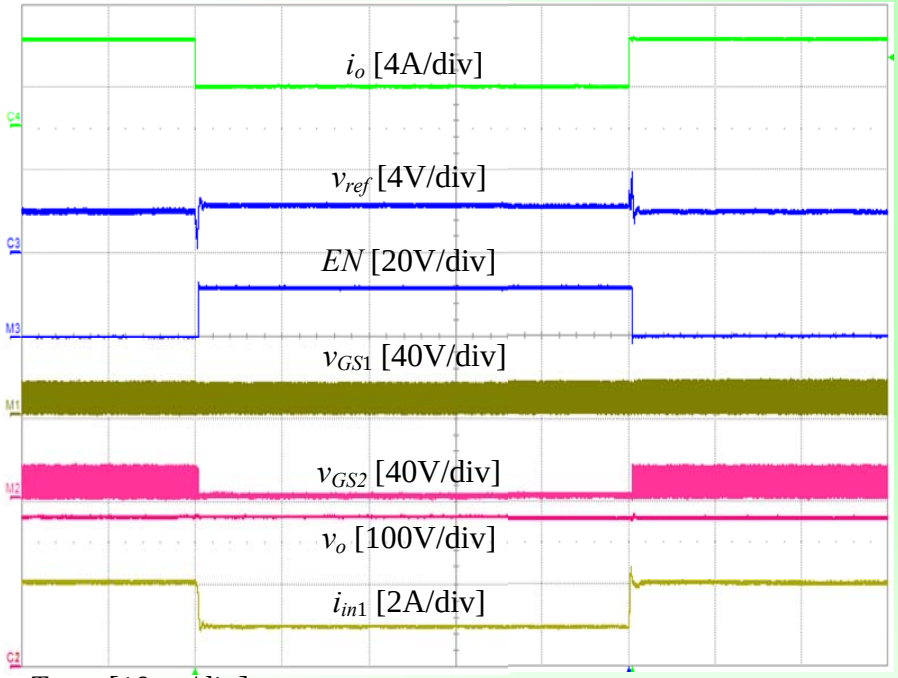


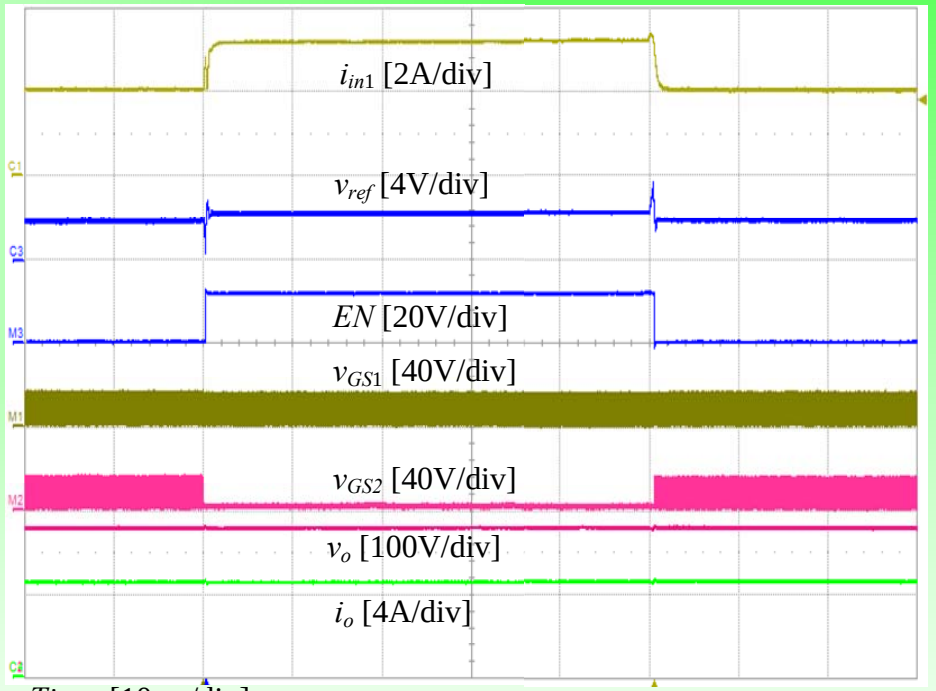

可再生能源的能量足以提供负载功率

- 可再生能源发电单元不再工作在MPPT状态，只提供负载所需的功率；
- 后备电源停止工作。

# 能量管理的实验验证




$P_{1max}$为500 W时，$P_o$在800W与400W之间跳变




$P_o$=800W时，$P_{1max}$在500 W和900 W之间跳变

# 报告内容

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- **结论**

# 结论

- 采用多输入直流变换器代替多个单输入直流变换器，可以简化系统结构，减少元器件数量，降低成本。
- 系统提出了脉冲源单元的概念，包括基本脉冲电压源、脉冲电流源、混合脉冲电压源和混合脉冲电流源。
- 提出了脉冲源单元的组合原则以及它们与输出滤波器的组合原则，由此推导出一系列多输入直流变换器，并将部分隔离型多输入直流变换器进行了简化。其中脉冲电压源串联和脉冲电流源并联生成的多输入直流变换器既可以分时工作也可以同时工作，而脉冲电压源并联生成的多输入直流变换器只能分时工作。
- 基于非隔离脉冲源，提出了一系列单原边绕组隔离型多输入直流变换器，简化了电路结构。
- 针对双输入Buck变换器，提出了交错双沿控制策略，使输出滤波电感电流脉动最小，由此可以减小滤波电感大小，提高动态响应速度。
- 针对双输入Buck变换器，给出了其能量管理策略及控制电路实现。

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谢谢!

请各位提出意见和建议!