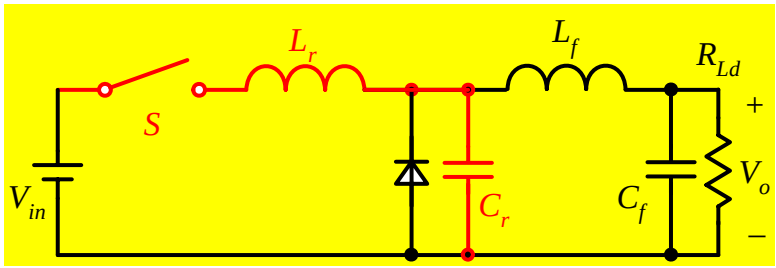
Multi-Resonant, ZVS PWM Converters and ZVT Converters

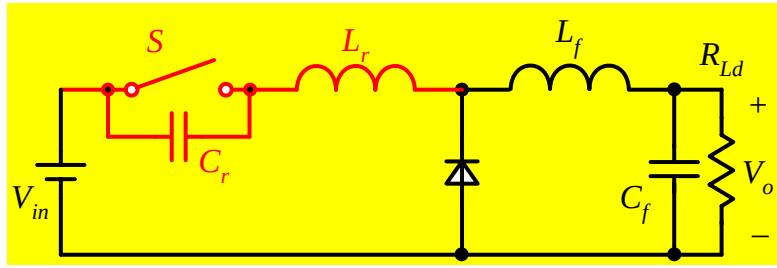
Presented by

Xinbo Ruan

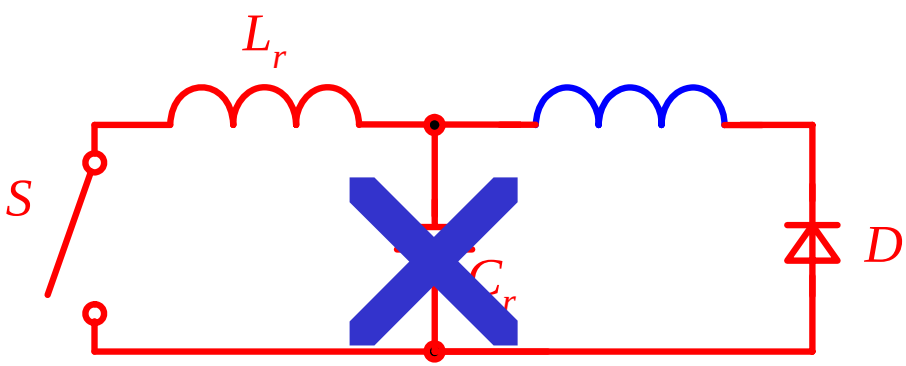
Aero-Power Sci-tech Center
Nanjing University of Aeronautics & Astronautics

Multi-Resonant Switch

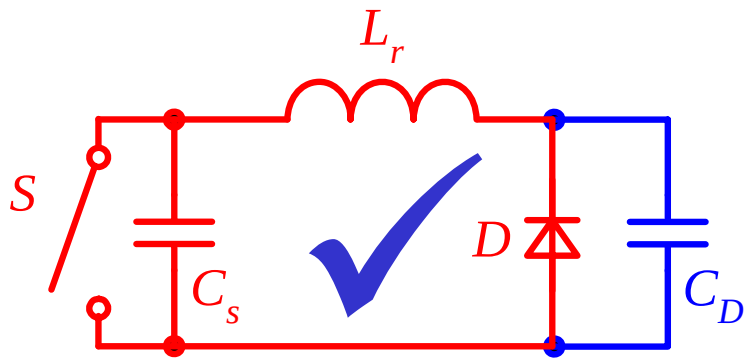




Short the capacitor and the voltage source;
Open the inductance.

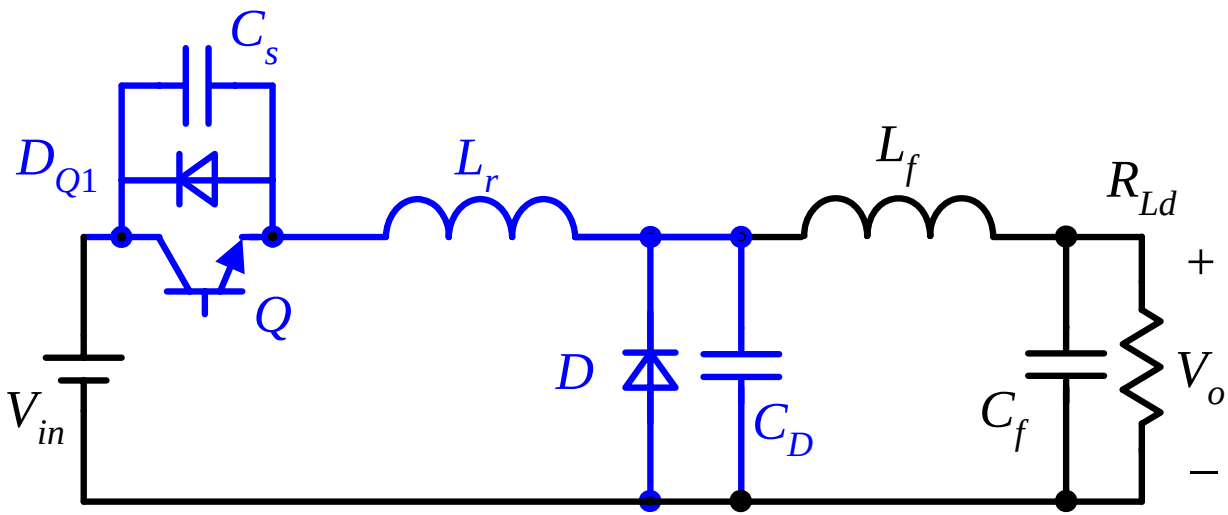


Zero-Current Multi-resonant switch

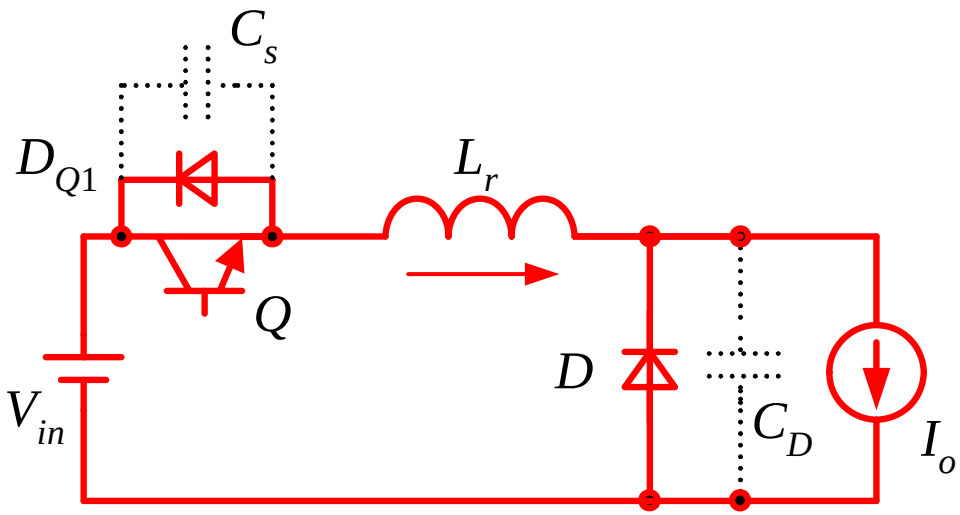


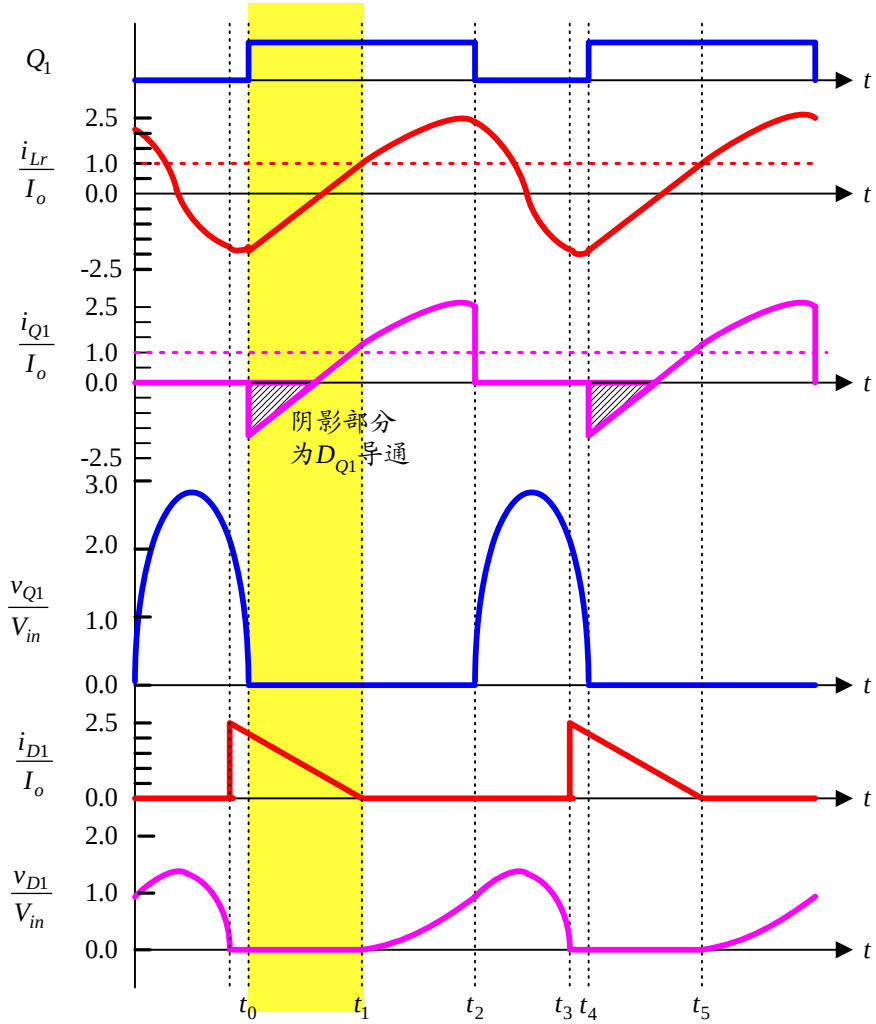
Zero-Voltage Multi-resonant switch

ZVS Buck MRC

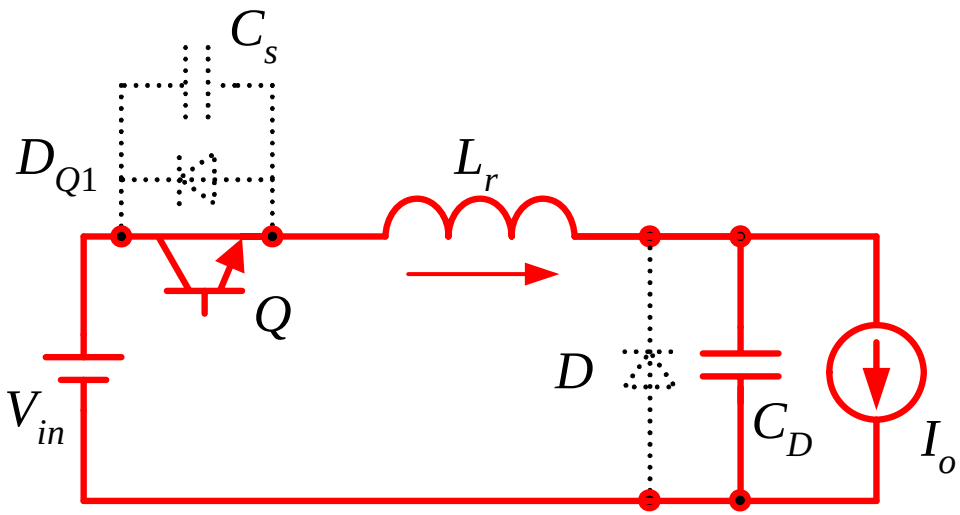


Operation Principle: Linear Charge Stage



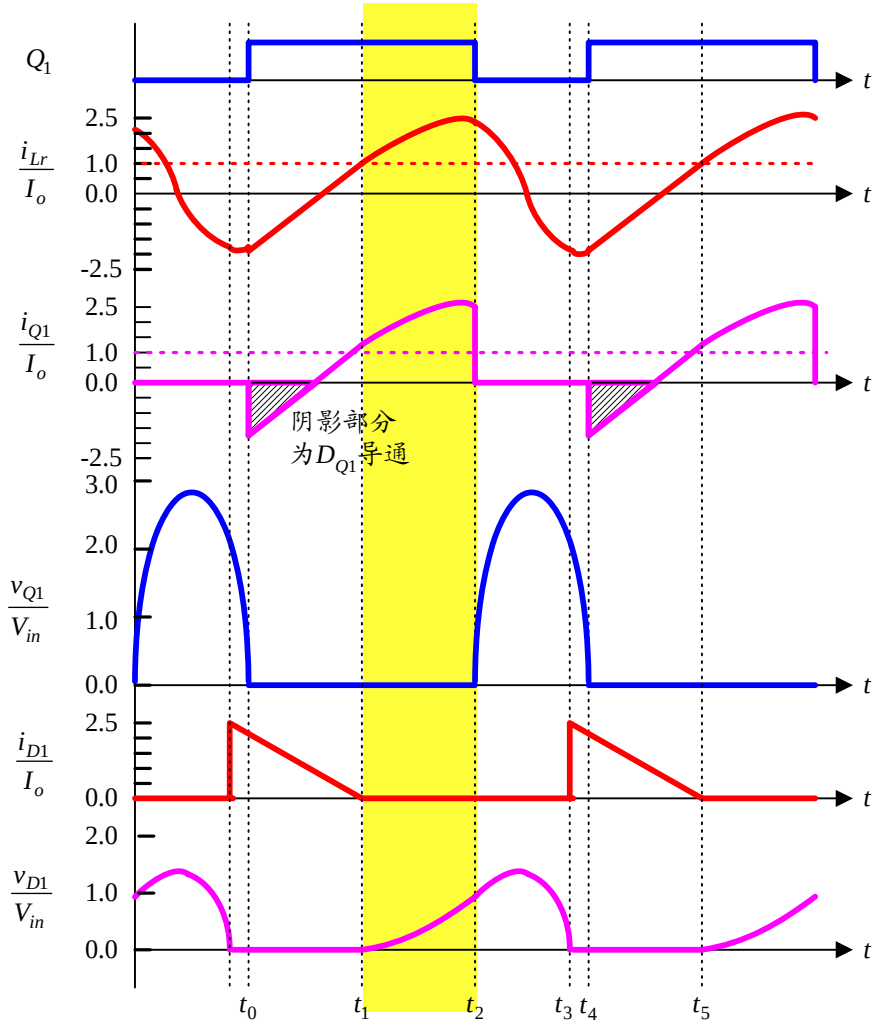


Operation Principle: Resonant Stage 1

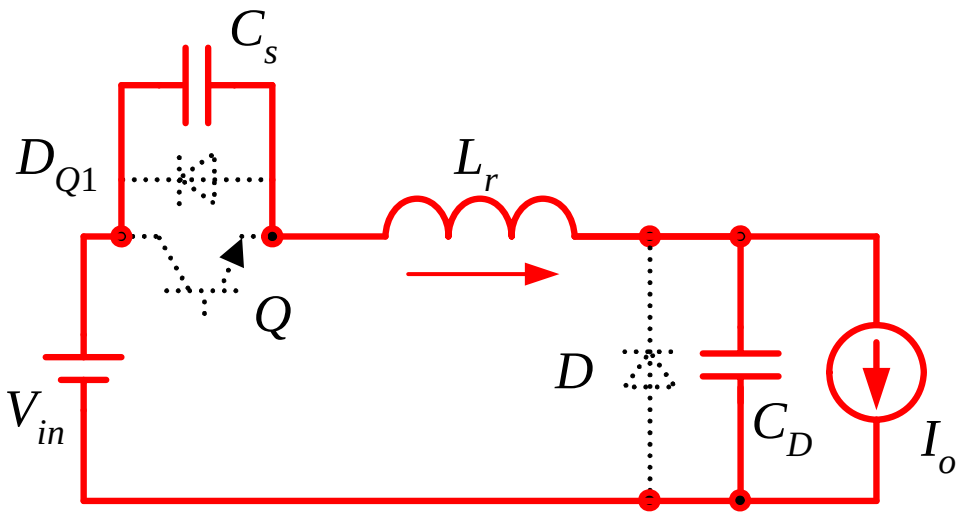


Resonant elements:

Lr and Cd

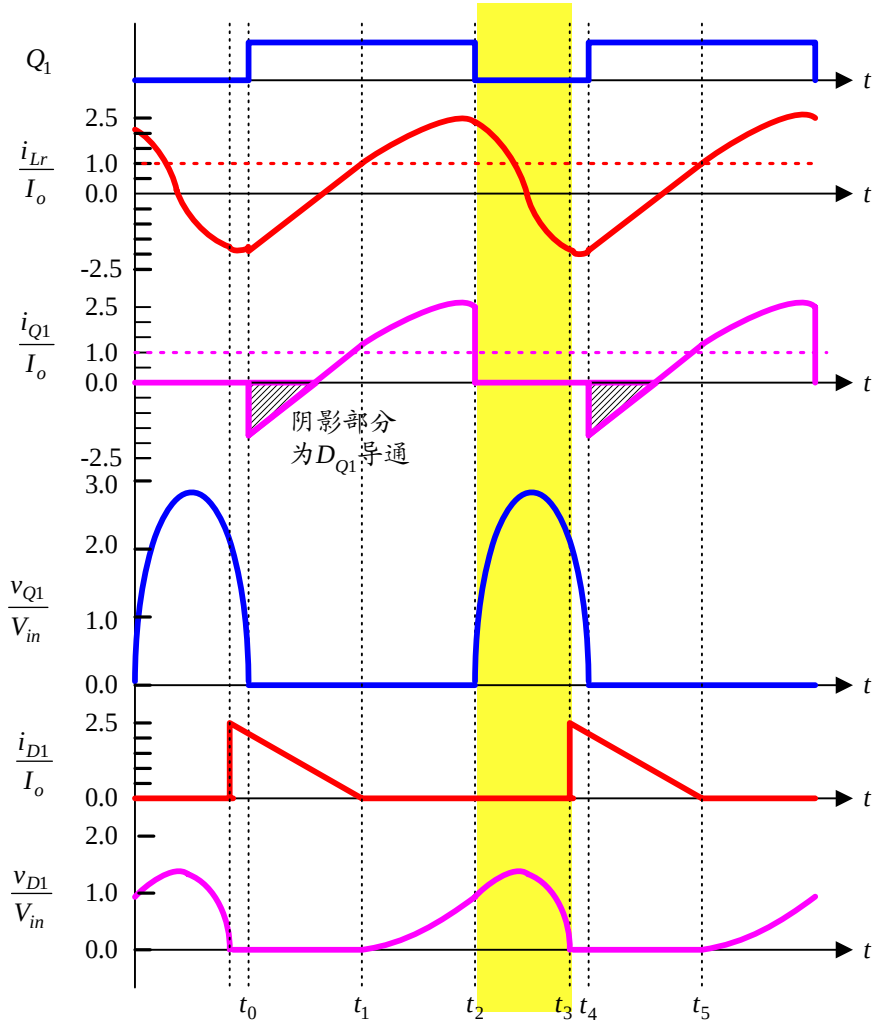


Operation Principle: Resonant Stage 2

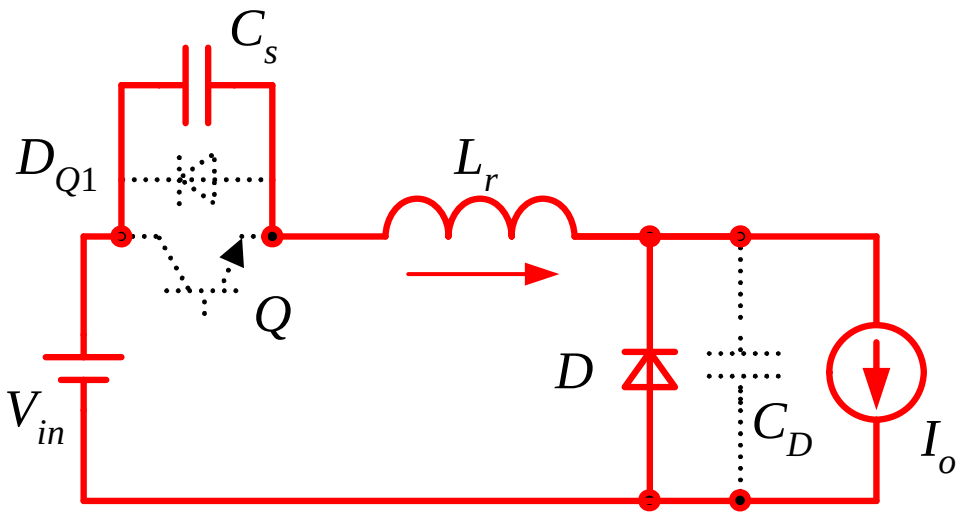


Resonant elements:

Lr, Cs and Cd

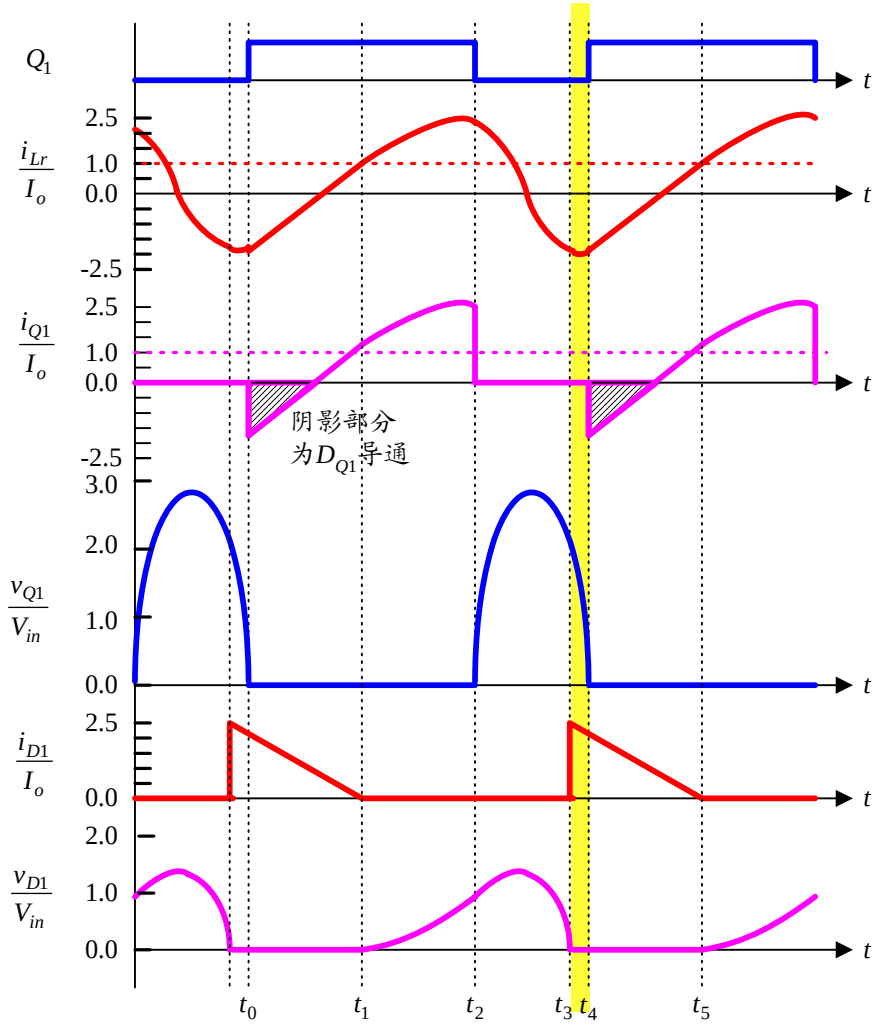


Operation Principle: Resonant Stage 3



Resonant elements:

Lr, and Cs



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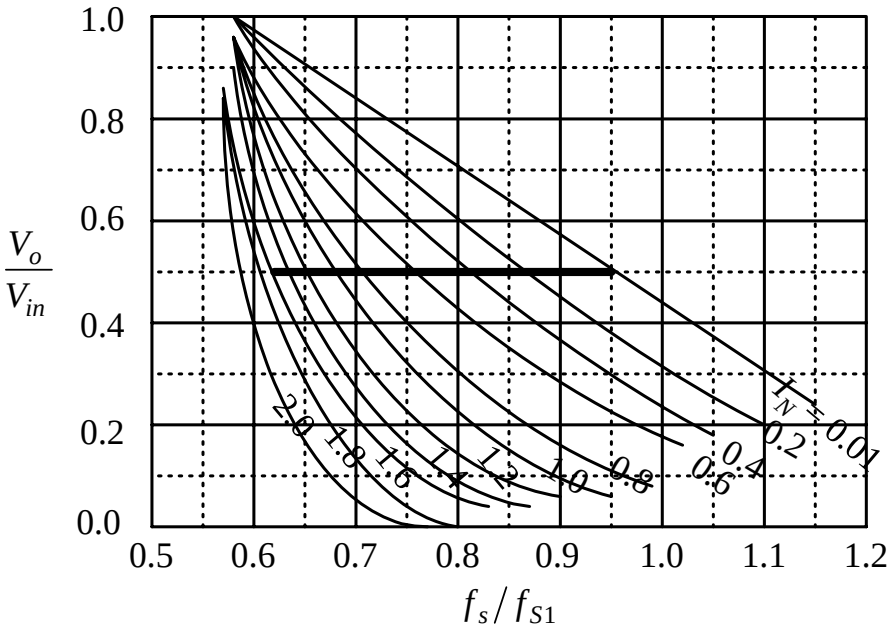
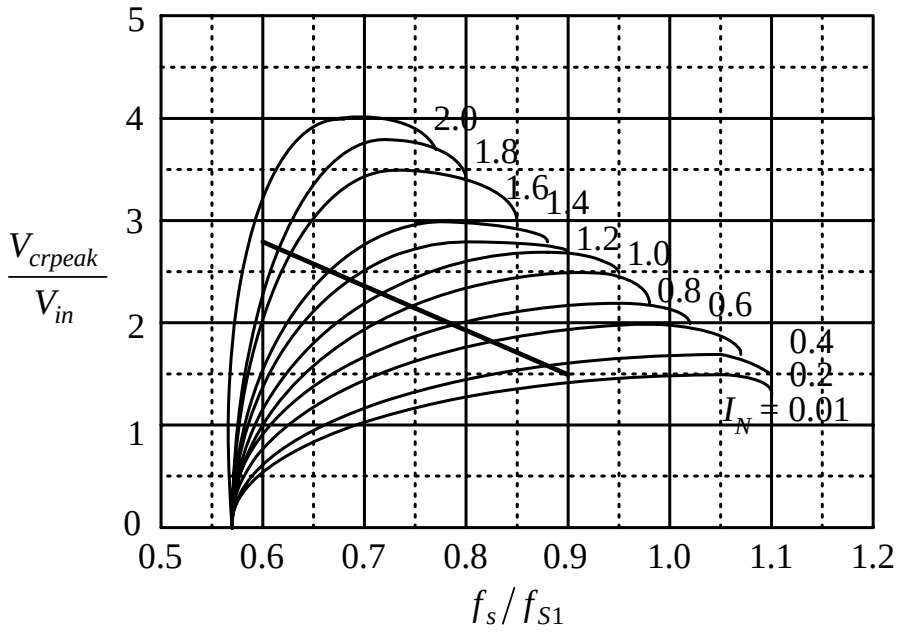
Voltage Conversion Ratio and Voltage Stress of the Switch



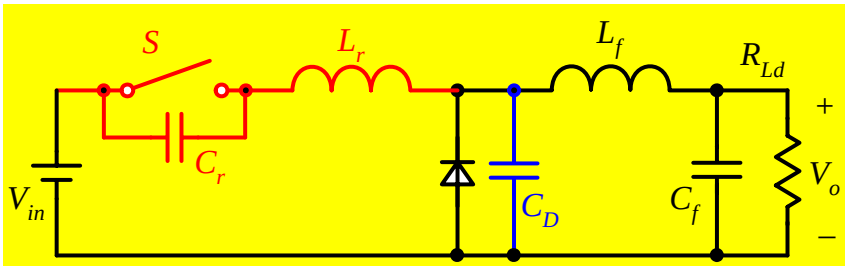
Voltage Conversion Ratio



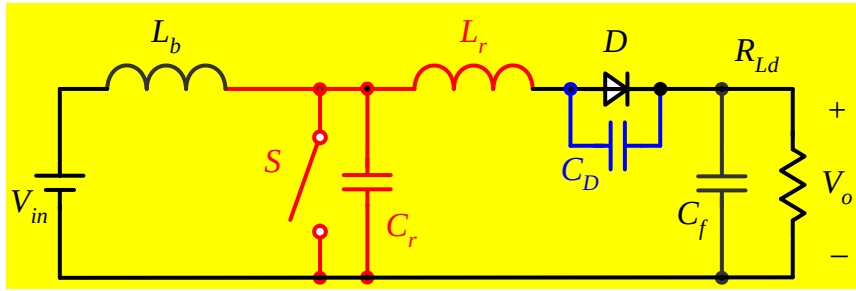
Voltage Stress of the Switch

$$I_N = \frac{I_o Z_S}{V_{in}}$$

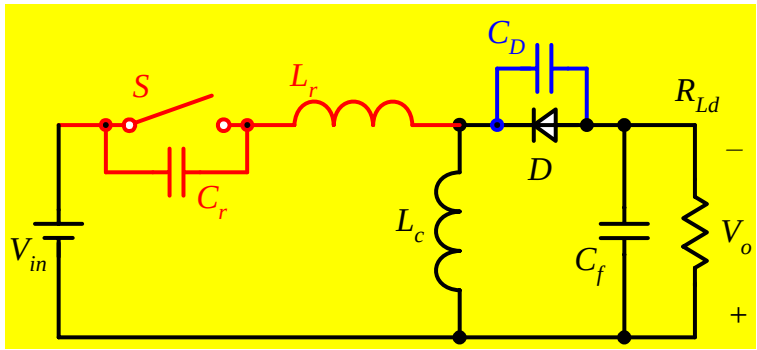
A Family of ZVS MRCs (1)



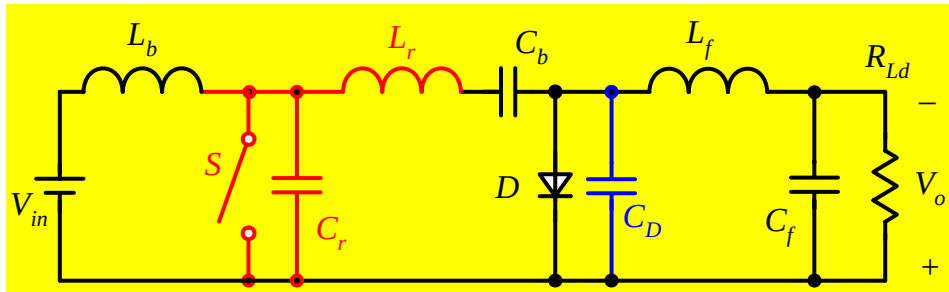
Buck



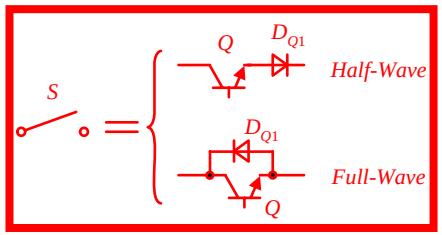
Boost



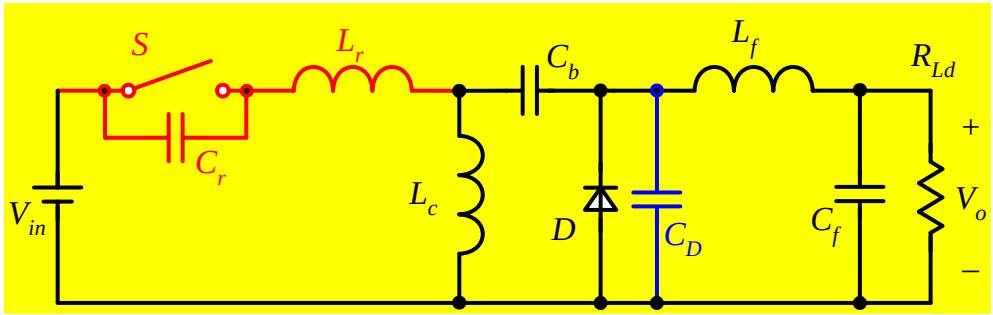
Buck-Boost



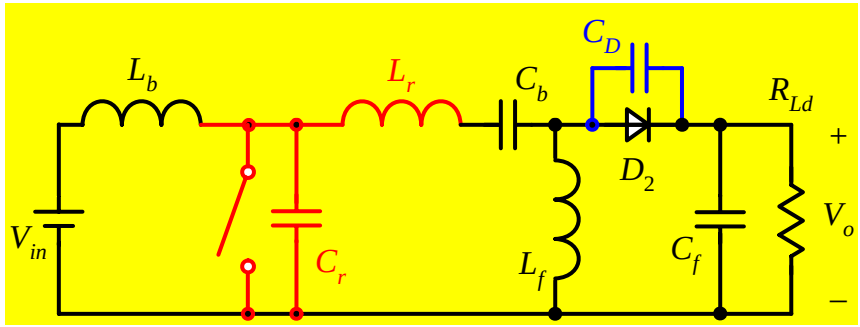
Cuk



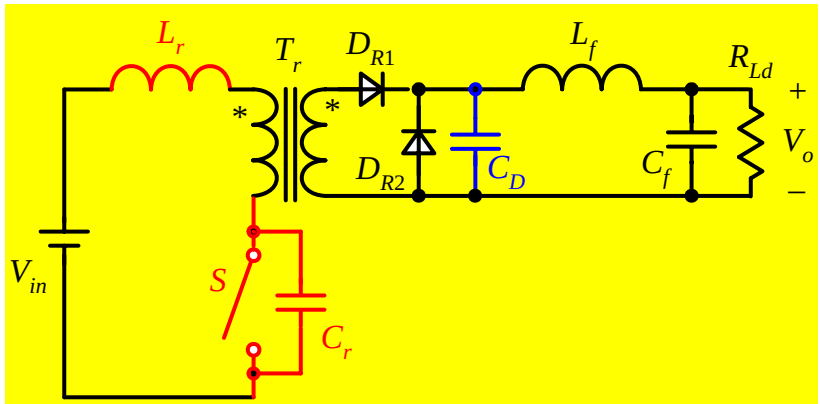
A Family of ZVS MRCs (2)



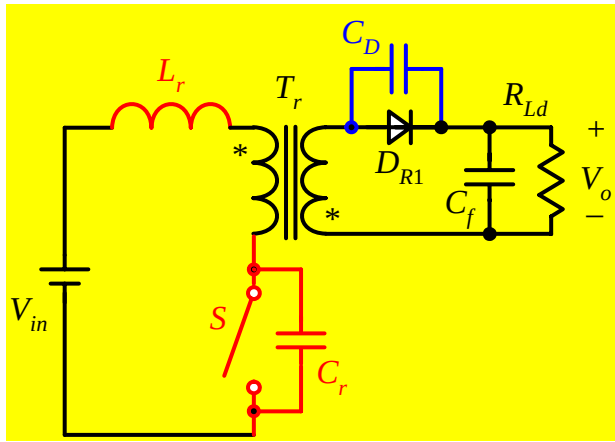
Zeta



Sepic

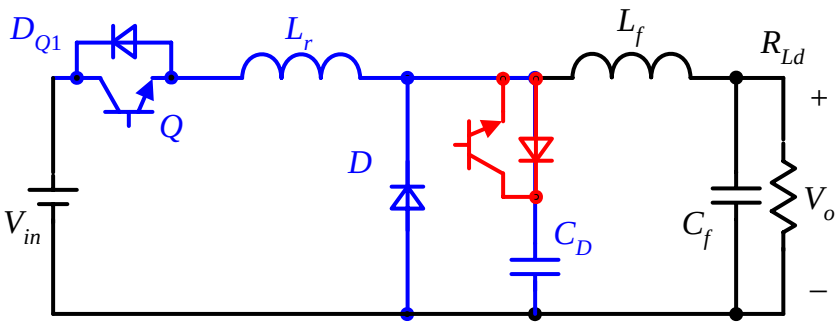


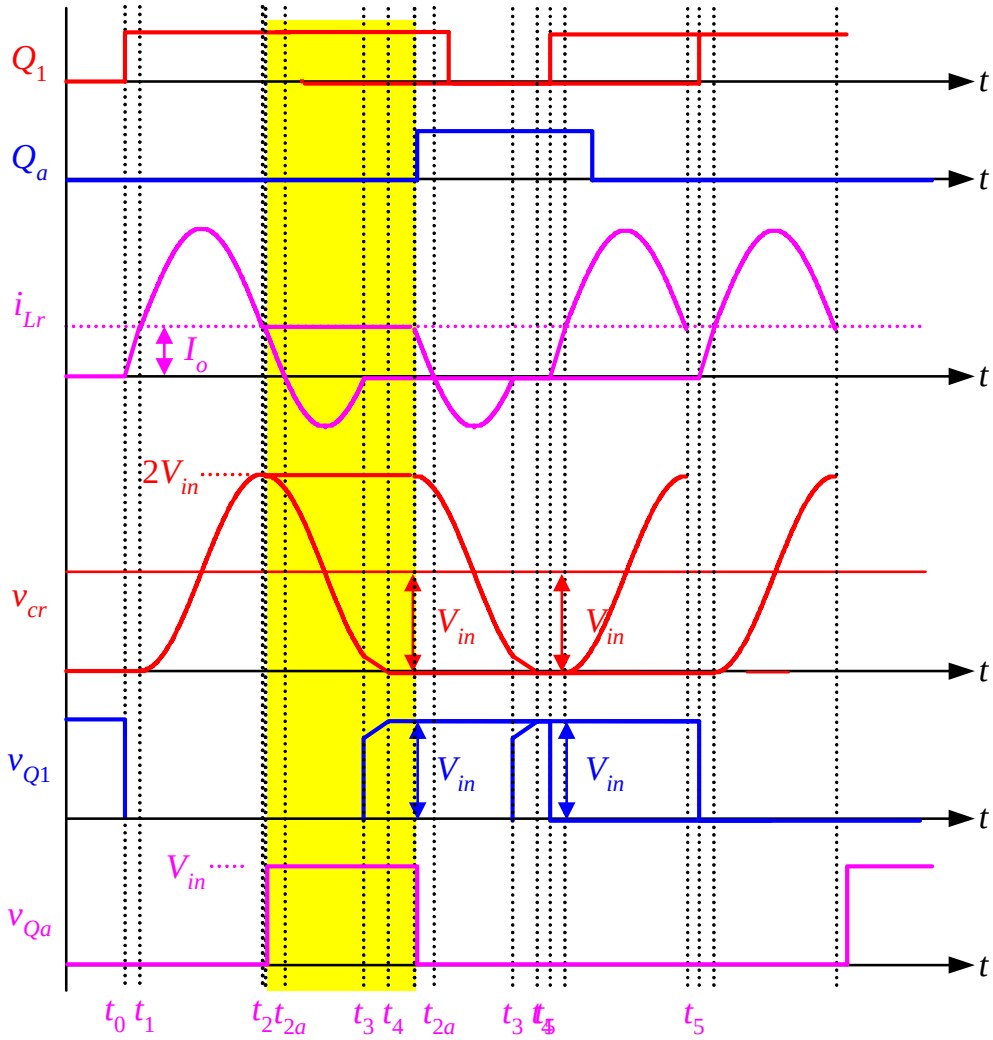
Forward



Flyback

ZCS PWM Buck Converter





A Family of ZCS PWM Converters (1)

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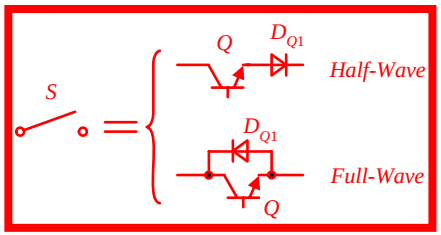
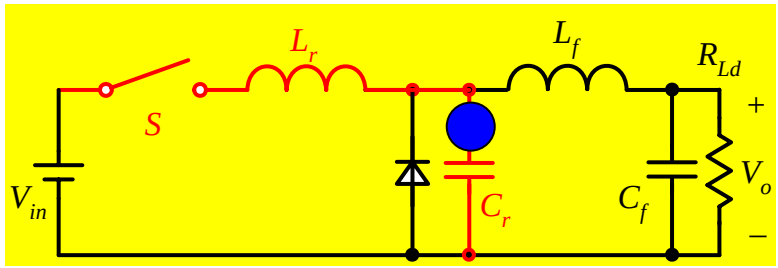
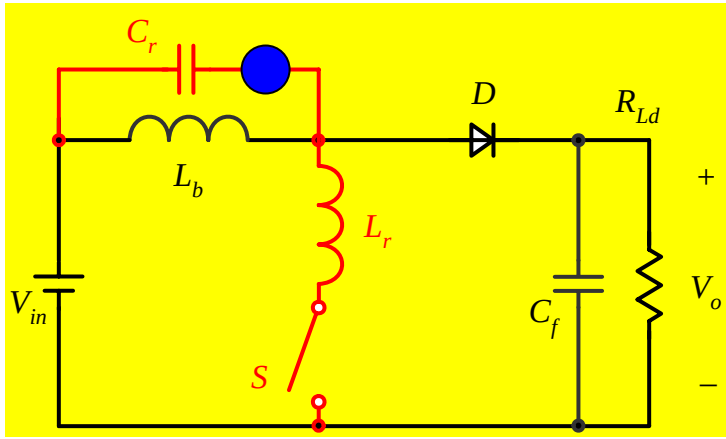
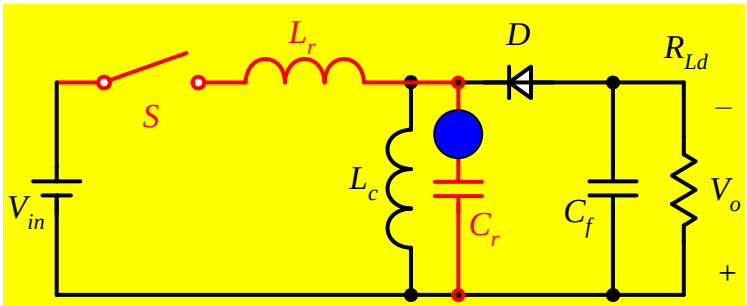




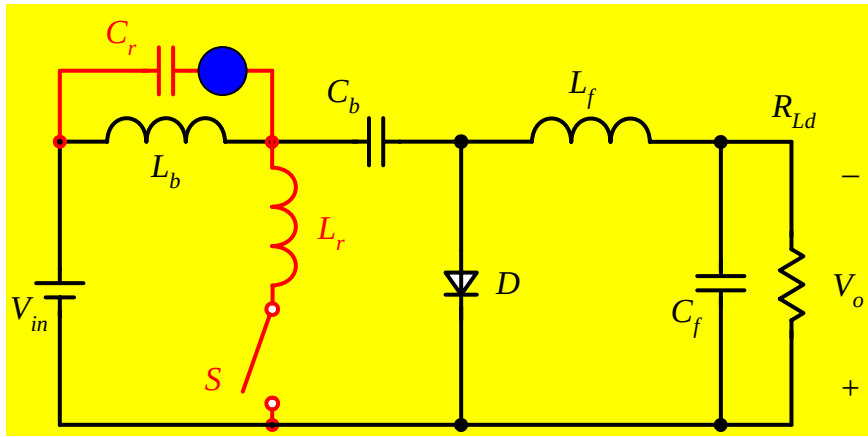
Buck



Boost

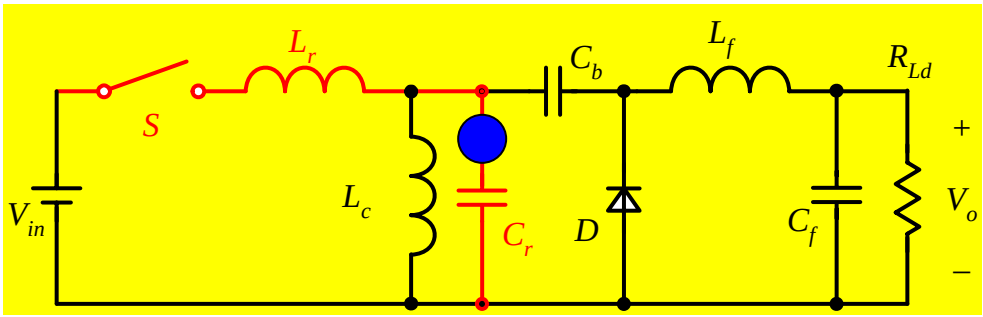


Buck-Boost

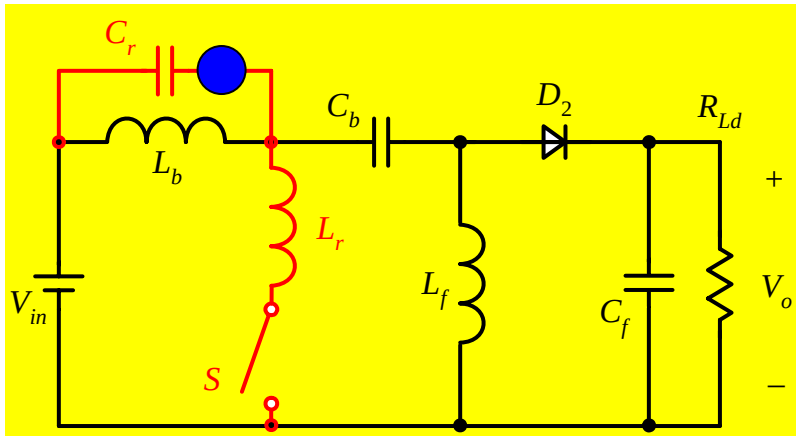


Cuk

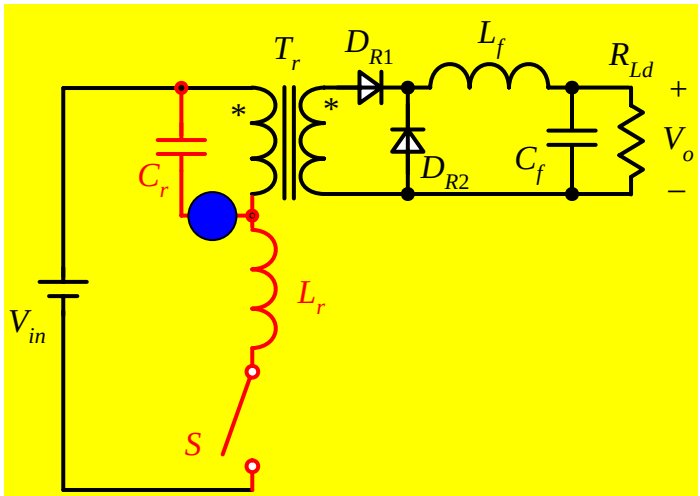
A Family of ZCS PWM Converters (2)



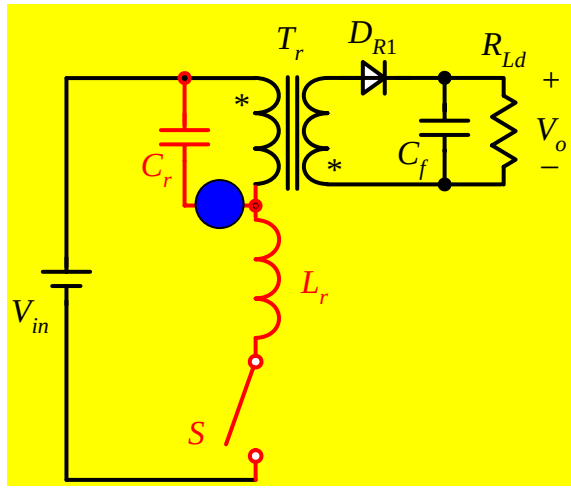
Zeta



Sepic

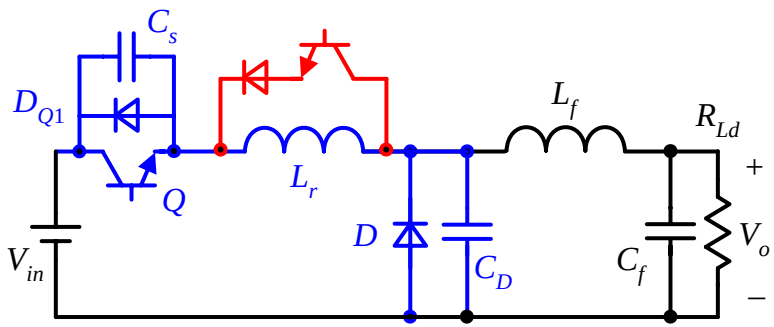


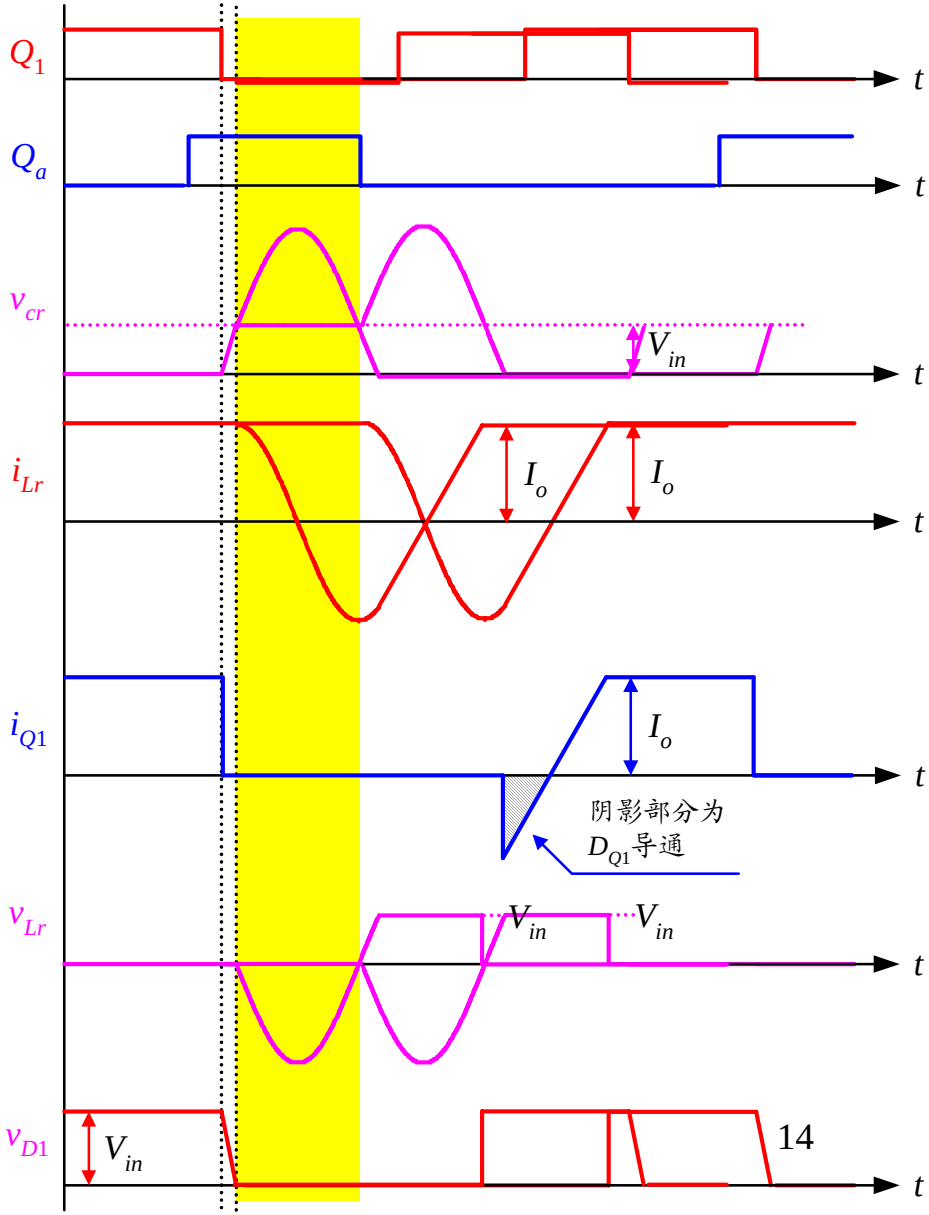
Forward



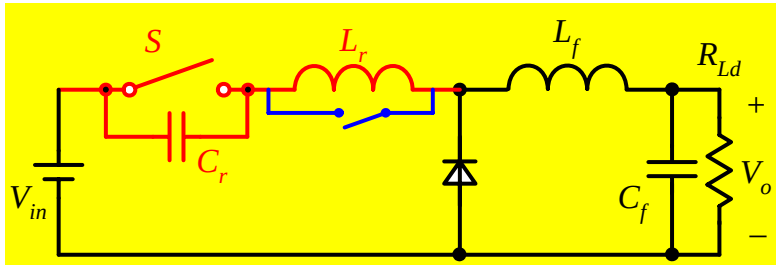
Flyback

ZVS PWM Buck Converter

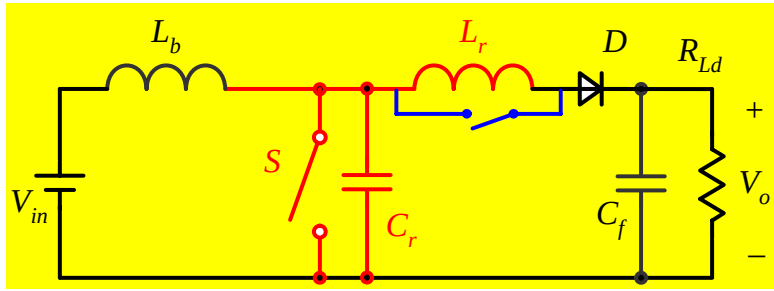




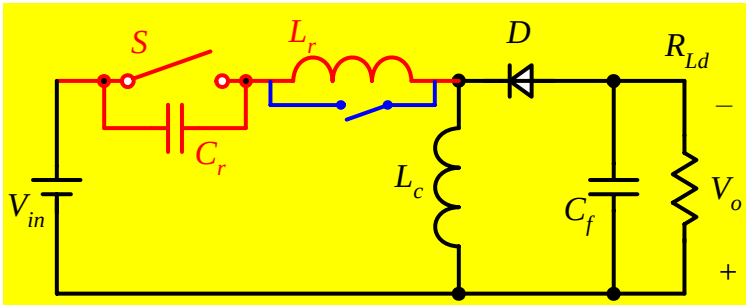
A Family of ZVS PWM Converters (1)



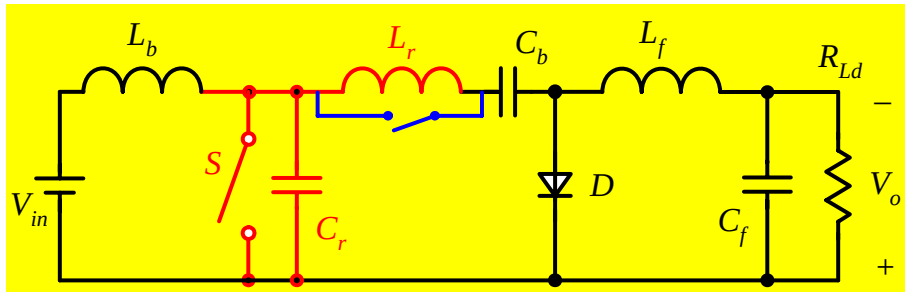
Buck



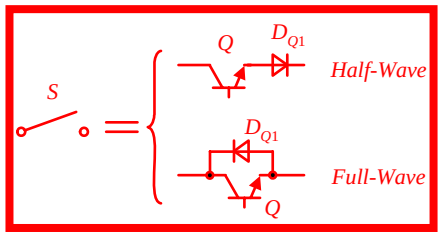
Boost



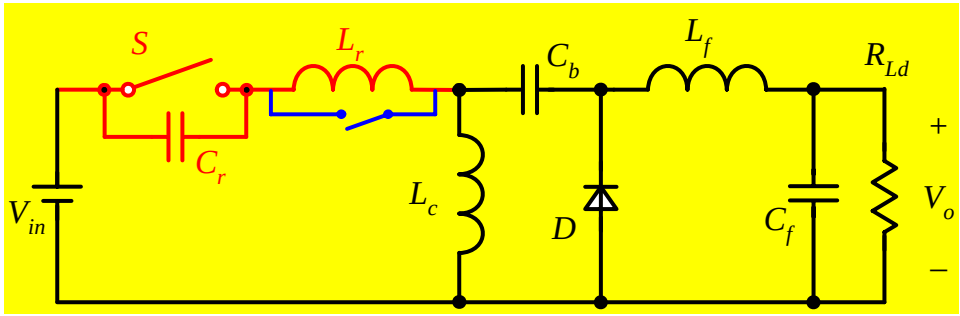
Buck-Boost



Cuk



A Family of ZVS PWM Converters (2)



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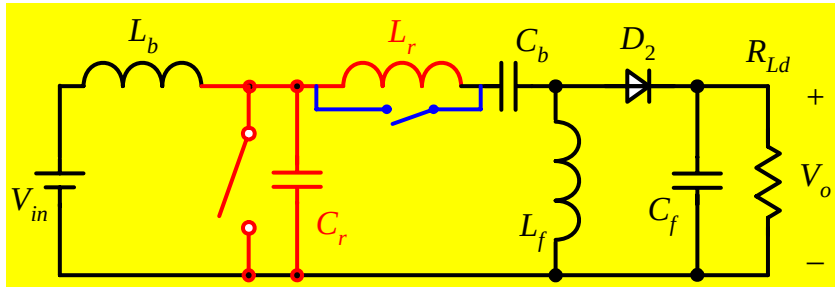
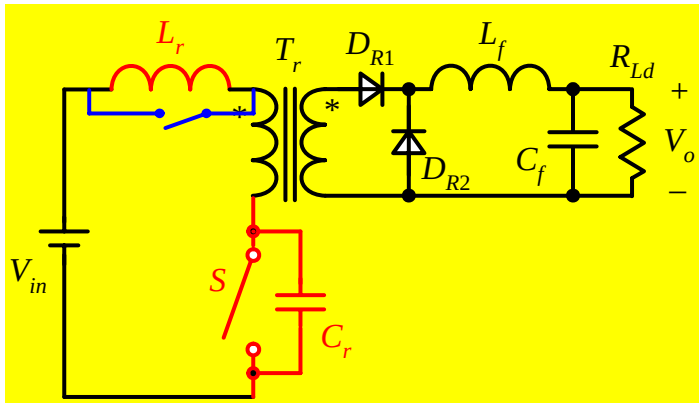
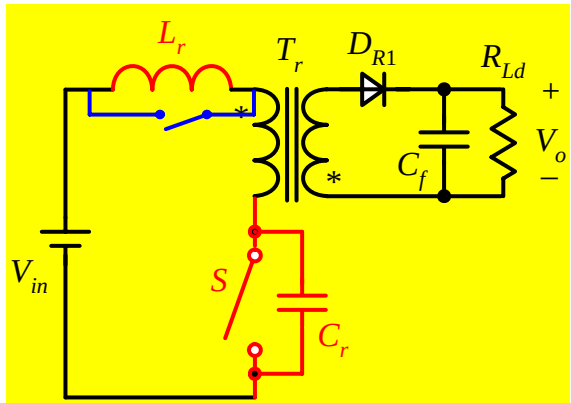


Sepic

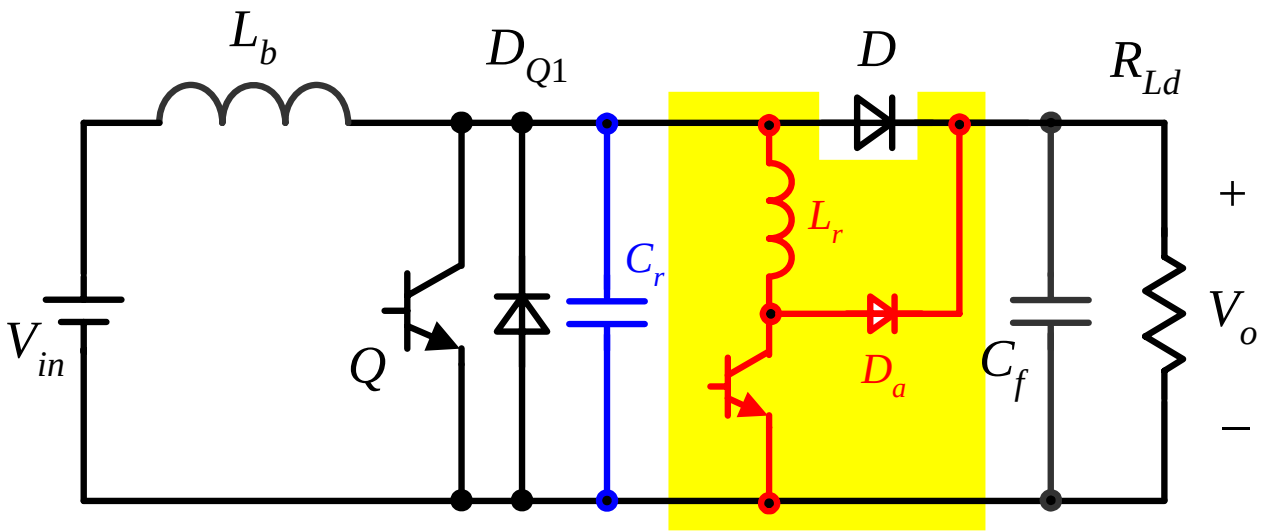


Forward

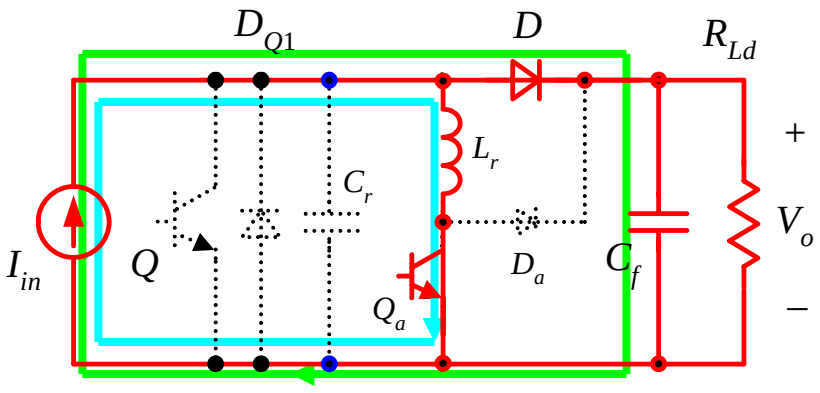


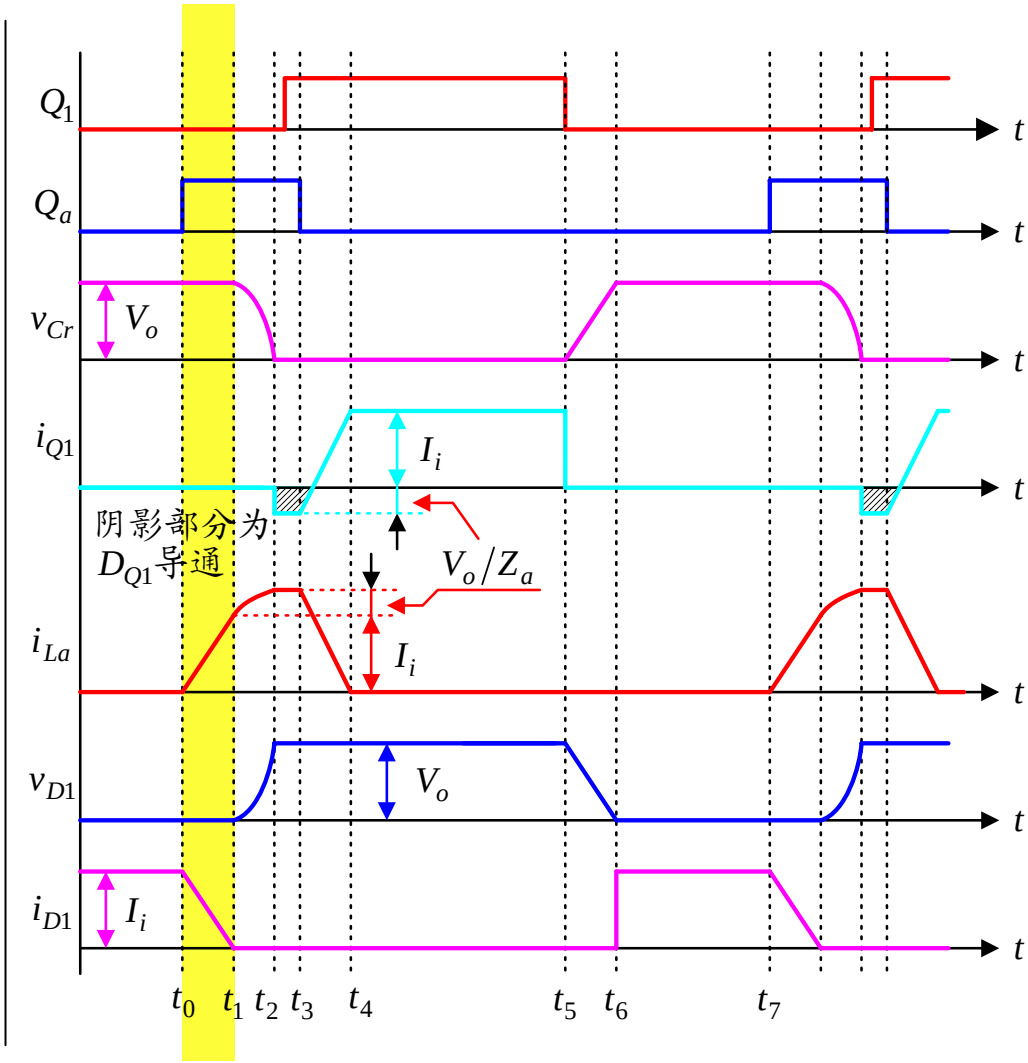
Flyback

Zero-Voltage-Transition Boost Converter

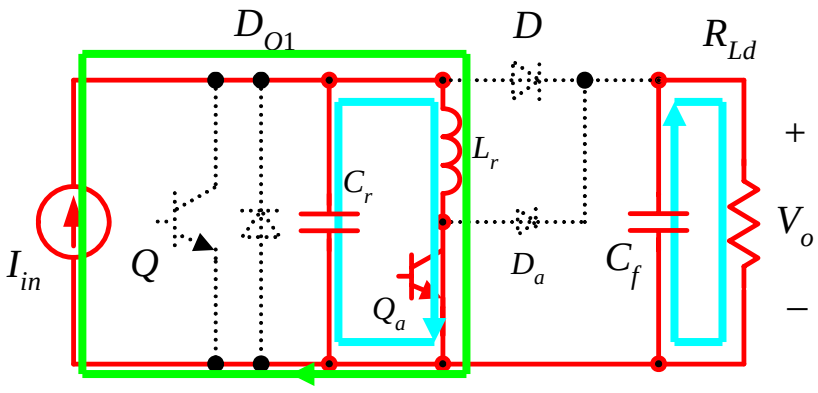


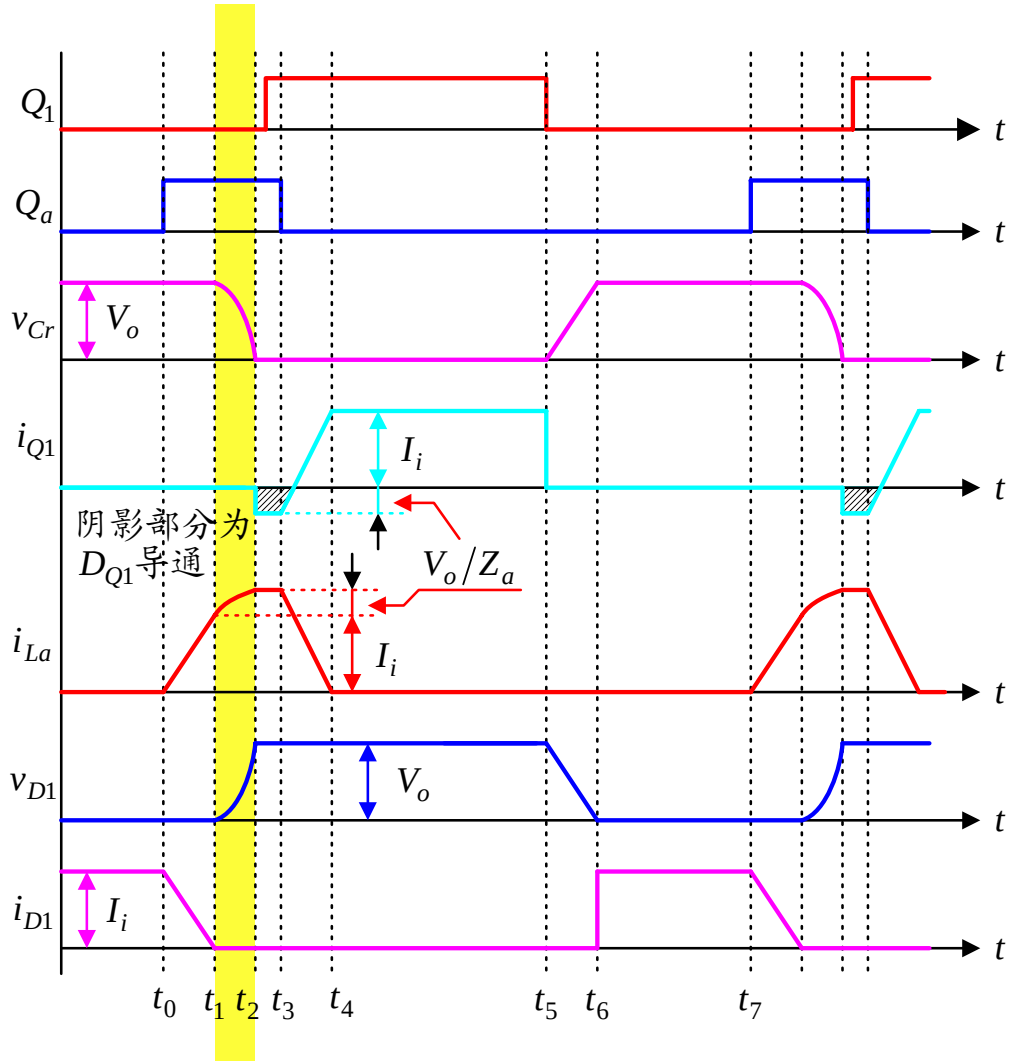
[t0, t1]


D_{Q1}
D
R_{Ld}
L_r
C_r
I_{in}
Q
D_a
C_f
Q_a
+
V_o
−

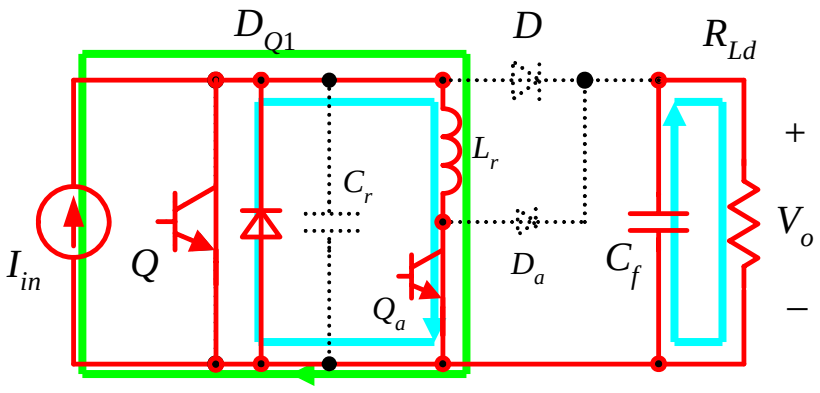

Q_1
Q_a
v_{Cr}
V_o
i_{Q1}
I_i
阴影部分为
D_{Q1}导通
V_o/Z_a
i_{La}
I_i
v_{D1}
V_o
i_{D1}
I_i
t
t_0 t_1 t_2 t_3 t_4 t_5 t_6 t_7

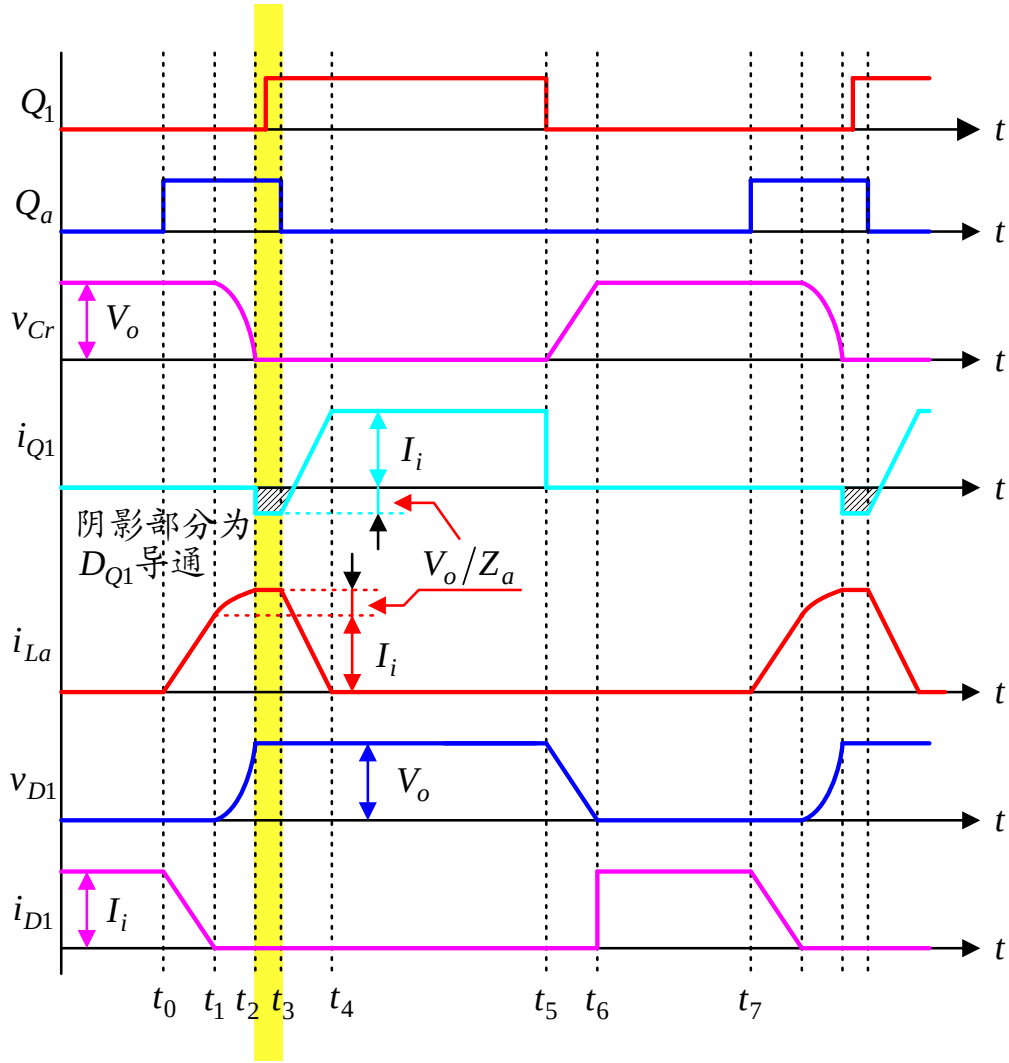
[t1, t2]


D_{O1}
D
R_{Ld}
L_r
C_r
I_{in}
Q
Q_a
D_a
C_f
+
V_o
−

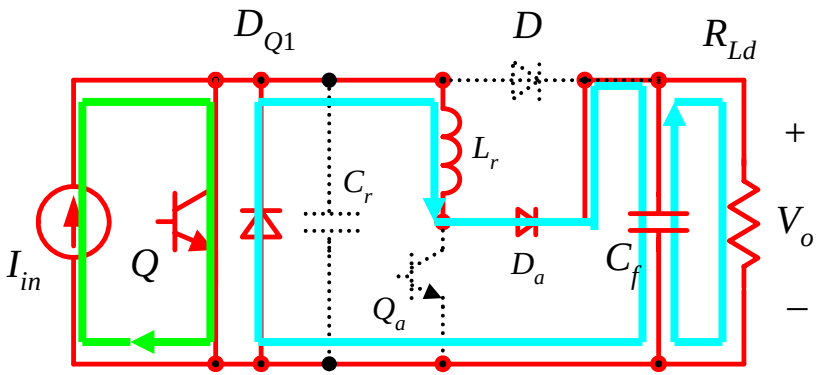

Q_1
Q_a
v_{Cr}
V_o
i_{Q1}
I_i
阴影部分为
D_{Q1}导通
V_o/Z_a
i_{La}
I_i
v_{D1}
V_o
i_{D1}
I_i
t
t_0 t_1 t_2 t_3 t_4 t_5 t_6 t_7

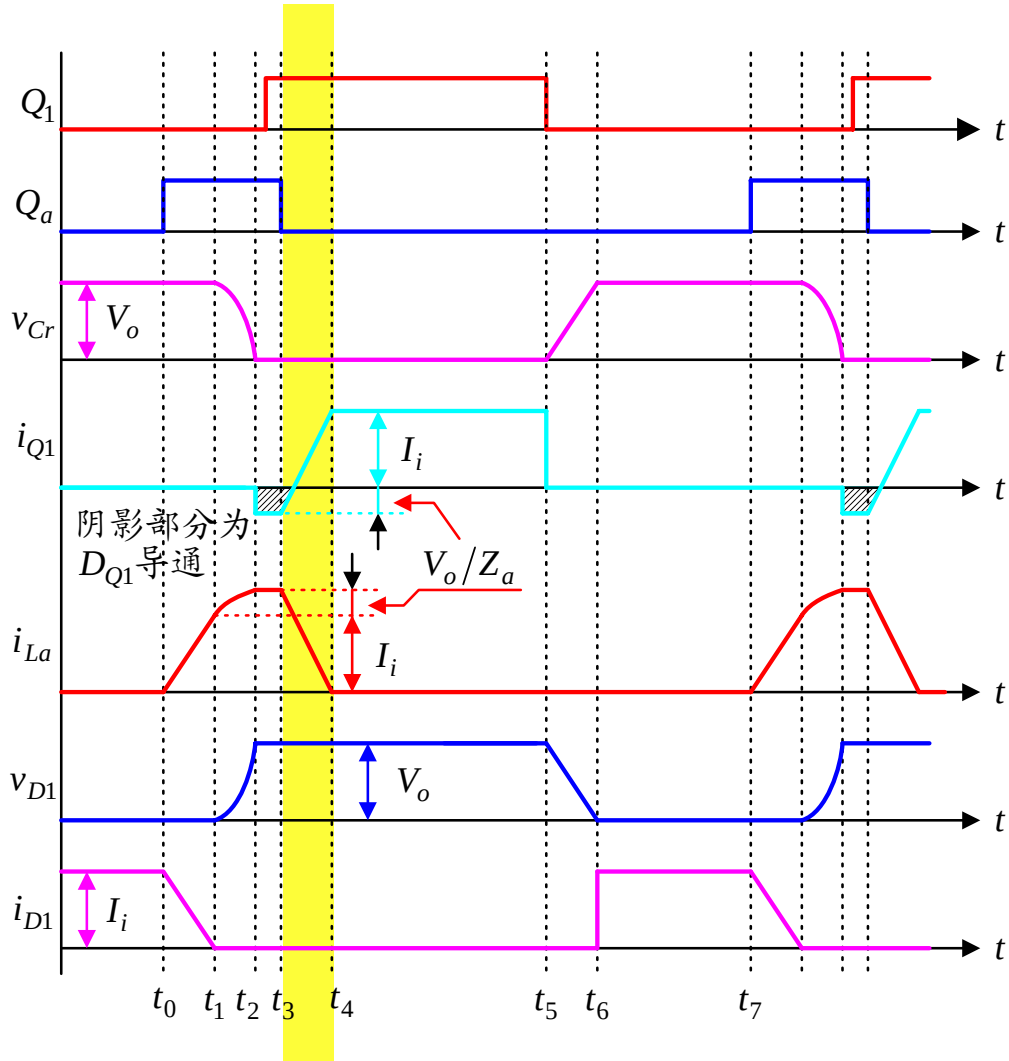
[t2, t3]


D_{Q1}
D
R_{Ld}
L_r
C_r
I_{in}
Q
Q_a
D_a
C_f
+
V_o
−

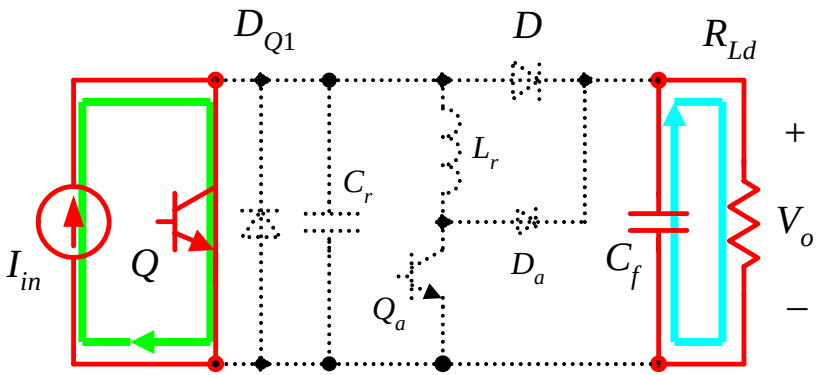

Q_1
Q_a
v_{Cr}
V_o
i_{Q1}
I_i
阴影部分为
D_{Q1}导通
V_o/Z_a
i_{La}
I_i
v_{D1}
V_o
i_{D1}
I_i
t
t_0 t_1 t_2 t_3 t_4 t_5 t_6 t_7

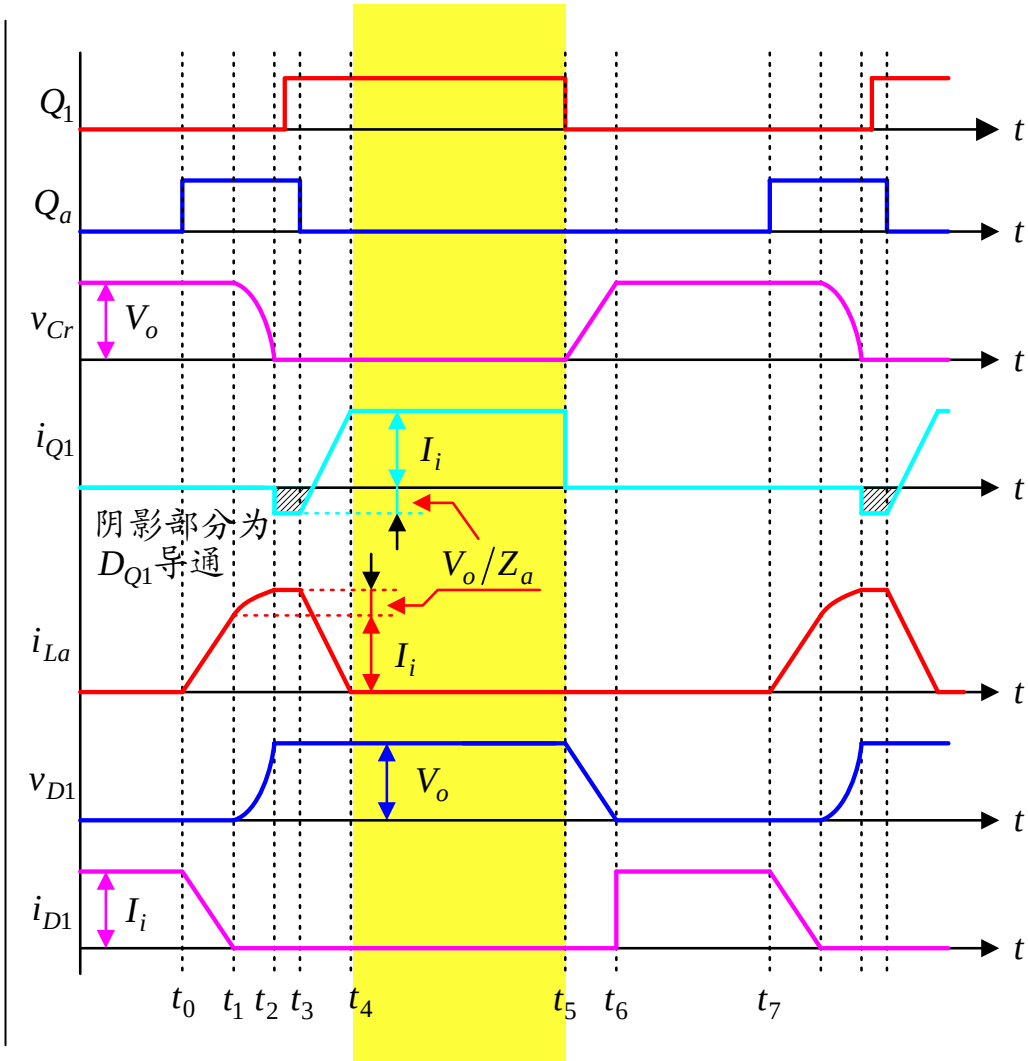
[t3, t4]


D_{Q1}
D
R_{Ld}
L_r
C_r
I_{in}
Q
D_a
C_f
V_o
+
−
Q_a

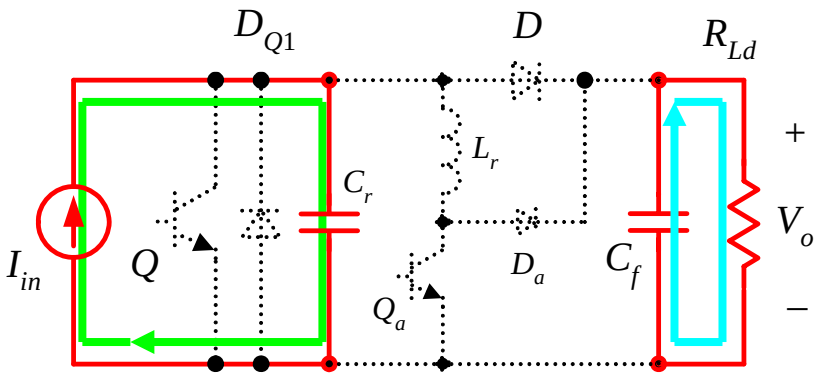

Q_1
Q_a
v_{Cr}
V_o
i_{Q1}
I_i
阴影部分为
D_{Q1}导通
V_o/Z_a
i_{La}
I_i
v_{D1}
V_o
i_{D1}
I_i
t
t_0 t_1 t_2 t_3 t_4 t_5 t_6 t_7

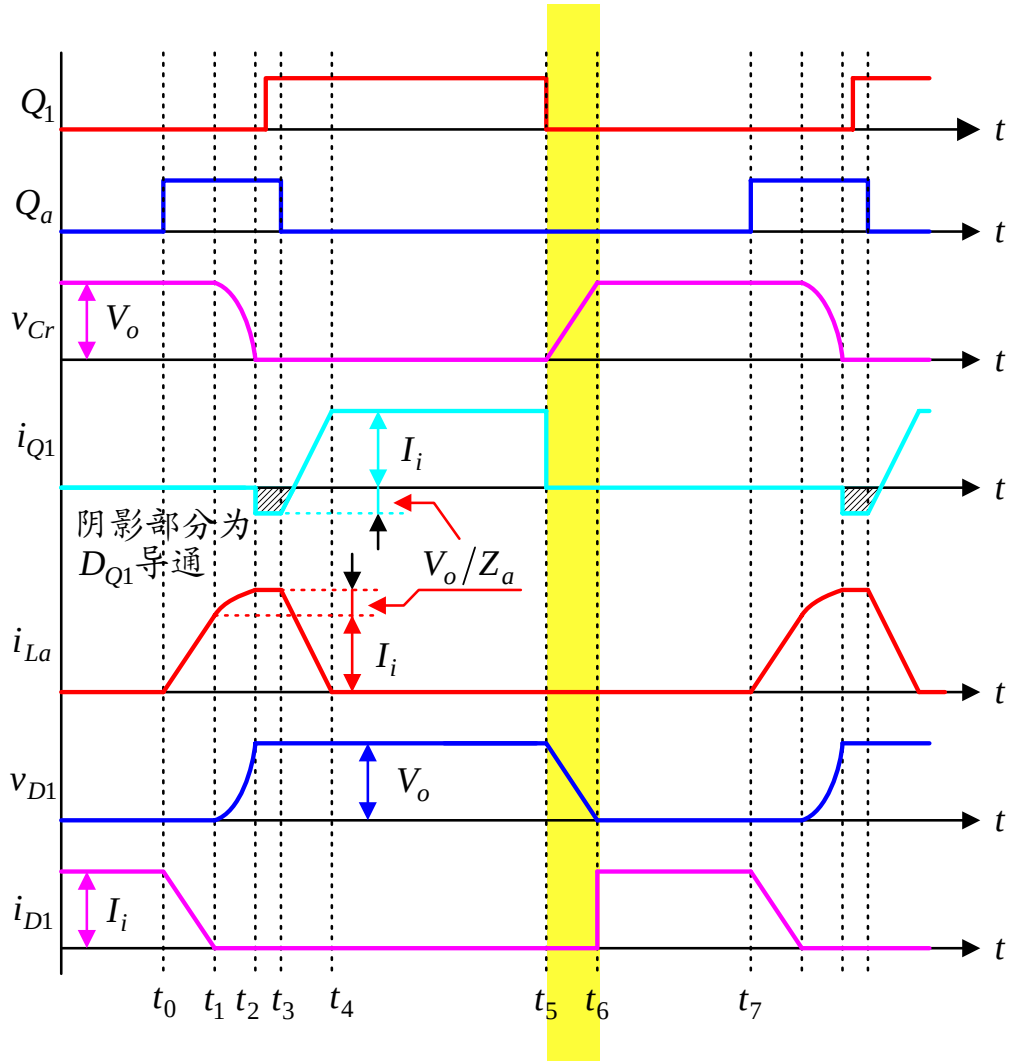
[t4, t5]


D_{Q1}
D
R_{Ld}
L_r
C_r
I_{in}
Q
Q_a
D_a
C_f
+
V_o
−

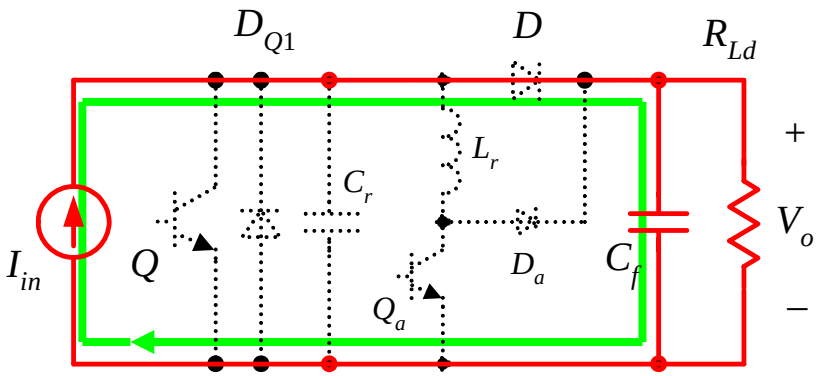

Q_1
Q_a
v_{Cr}
V_o
i_{Q1}
I_i
阴影部分为
D_{Q1}导通
V_o/Z_a
i_{La}
I_i
v_{D1}
V_o
i_{D1}
I_i
t
t_0 t_1 t_2 t_3 t_4 t_5 t_6 t_7

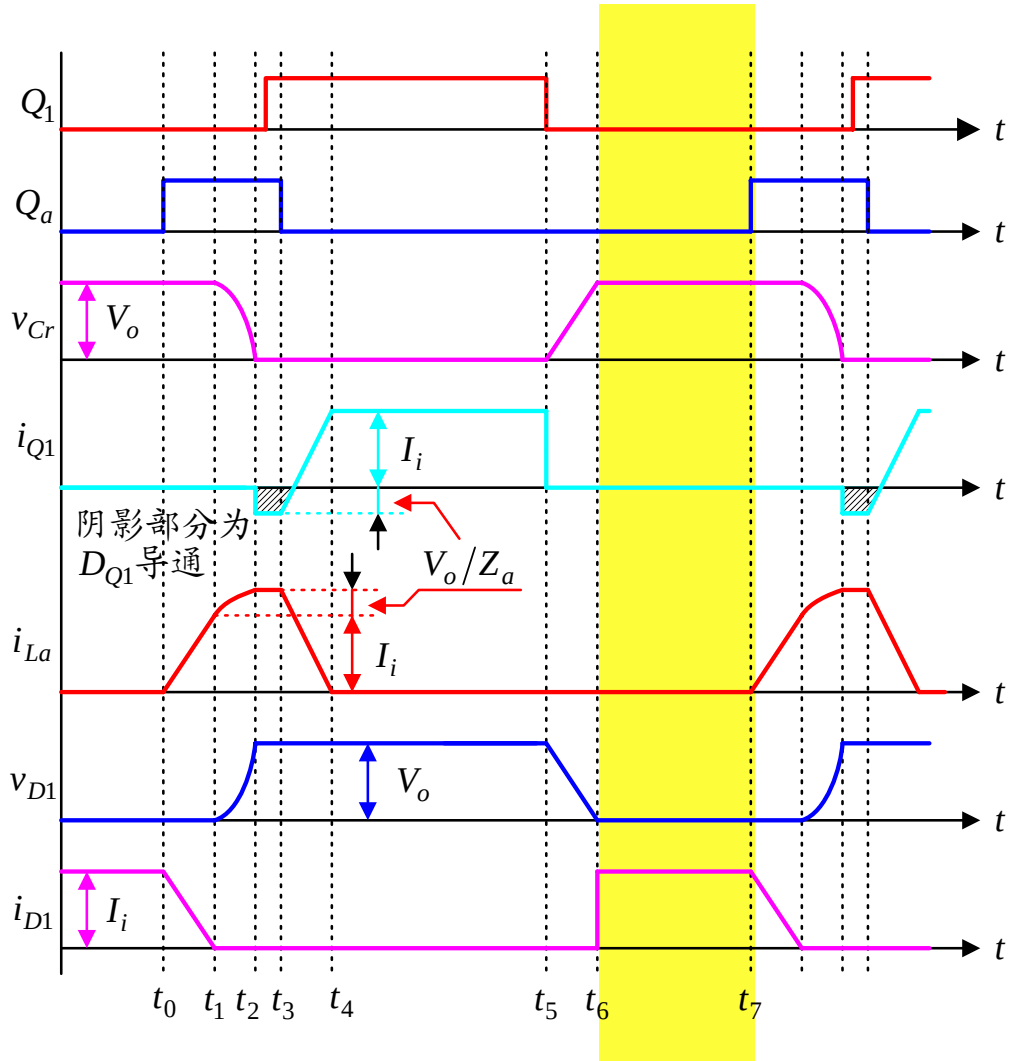
[t5, t6]


D_{Q1}
D
R_{Ld}
L_r
C_r
I_{in}
Q
Q_a
D_a
C_f
+
V_o
−

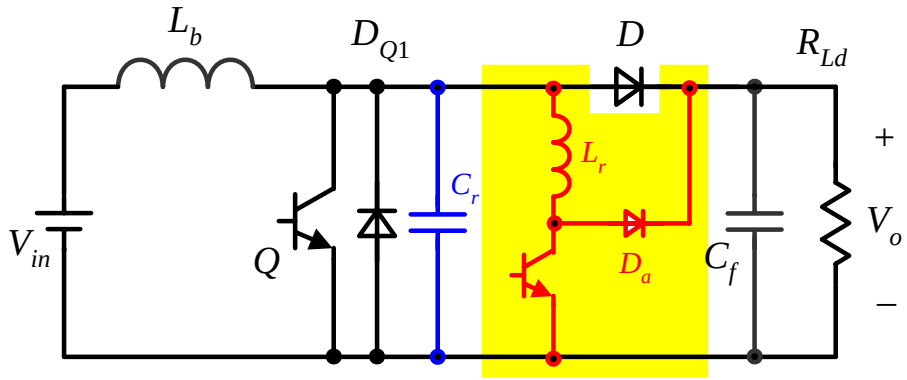

Q_1
Q_a
v_{Cr}
V_o
i_{Q1}
I_i
阴影部分为
D_{Q1}导通
V_o/Z_a
i_{La}
I_i
v_{D1}
V_o
i_{D1}
I_i
t
t_0 t_1 t_2 t_3 t_4 t_5 t_6 t_7

[t6, t7]


D_{Q1}
D
R_{Ld}
L_r
C_r
I_{in}
Q
D_a
C_f
V_o
+
−
Q_a


Q_1
Q_a
v_{Cr}
V_o
i_{Q1}
I_i
阴影部分为
D_{Q1}导通
V_o/Z_a
i_{La}
I_i
v_{D1}
V_o
i_{D1}
I_i
t
t_0 t_1 t_2 t_3 t_4 t_5 t_6 t_7

Merits and demerits of ZVT PWM Converters



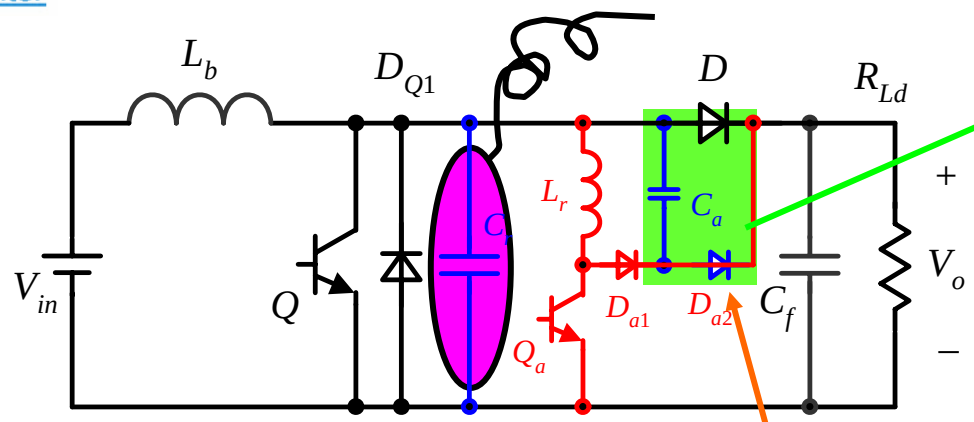
Advantages:

- ☺ ZVS achieved for Q1 and D1 under any load over the line range;
- ☺ The voltage stress and current stress of Q1 and D1 are the same as the basic converter;
- ☺ Qa is zero-current turn-on;
- ☺ The work time of the auxiliary circuit is very short, so the rms current is very small;
- ☺ PWM controlled.

Disadvantages:

- ☹ Hard turn-off for Qa, the turn-off loss is higher than the basic converter.

Improved ZVT PWM Converters



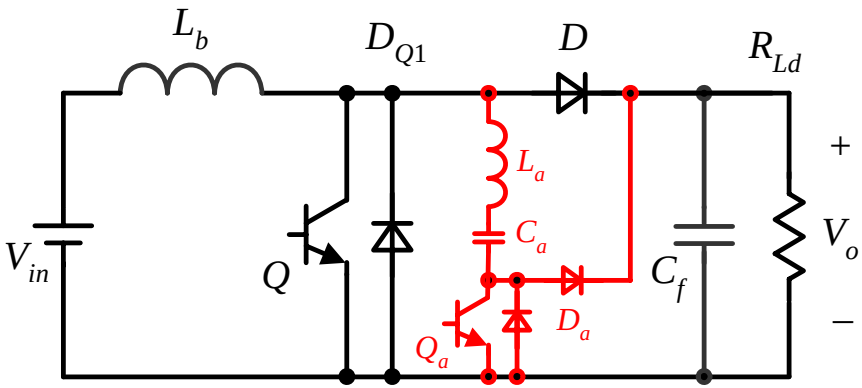
Advantages:

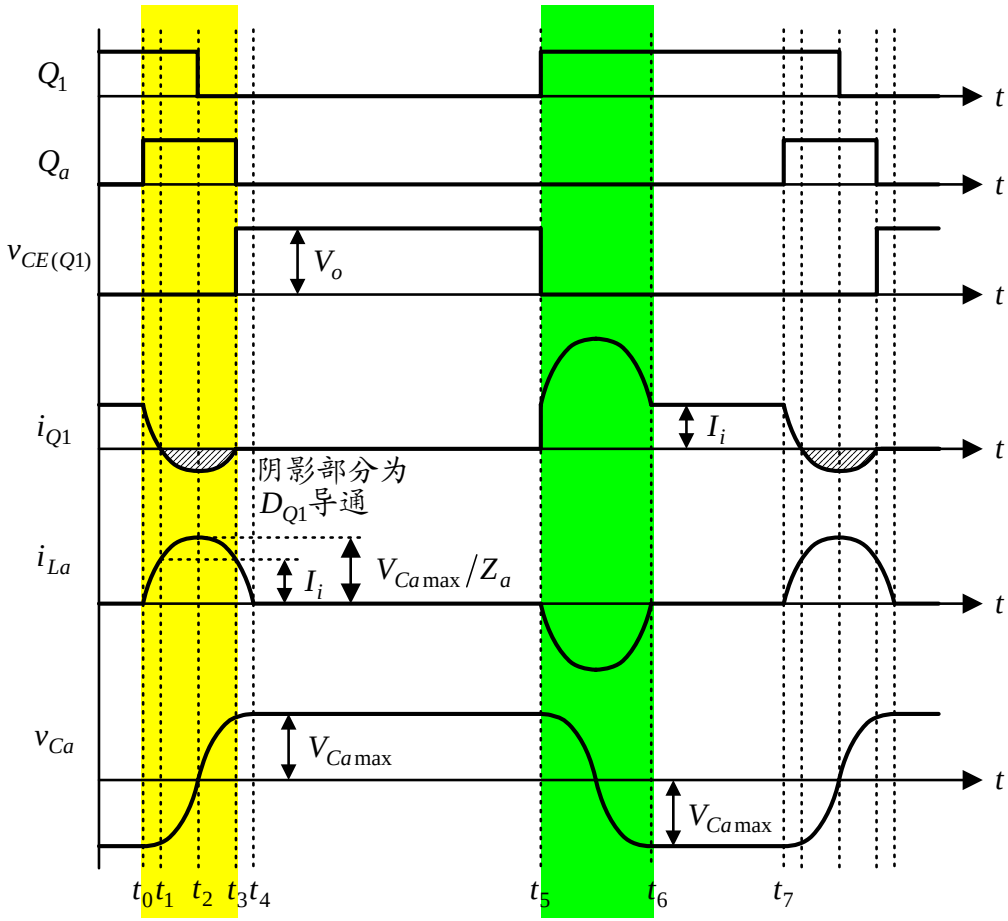
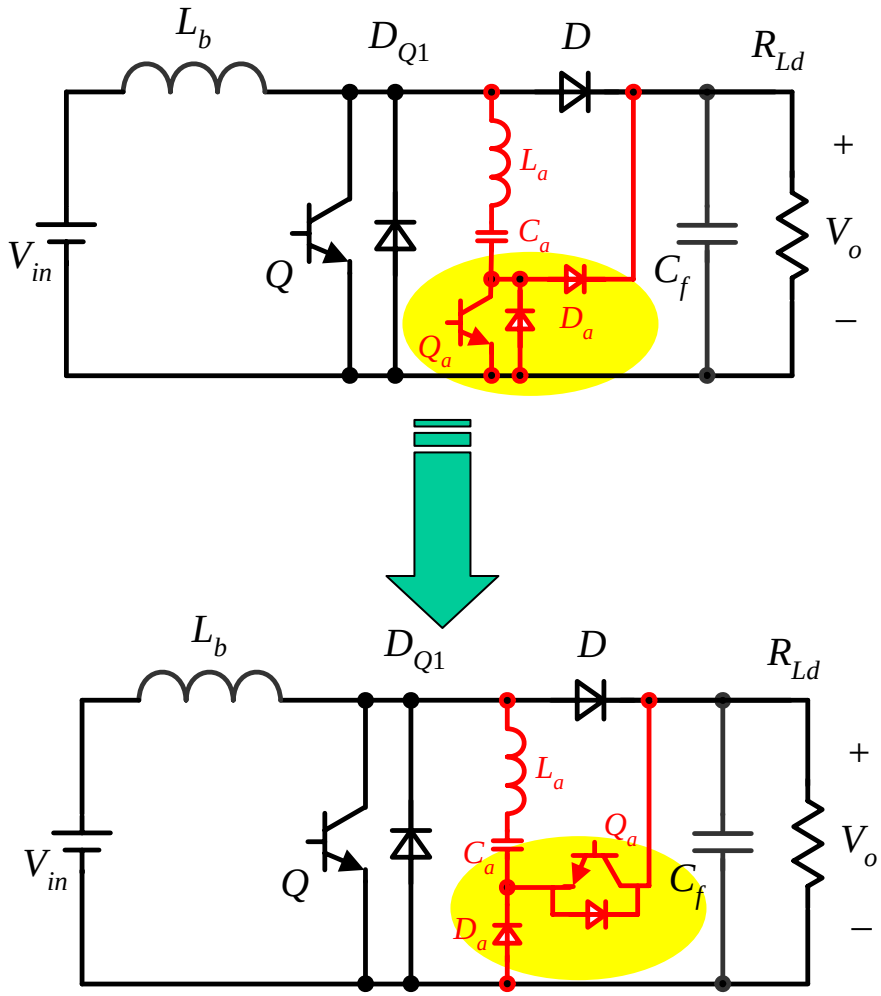
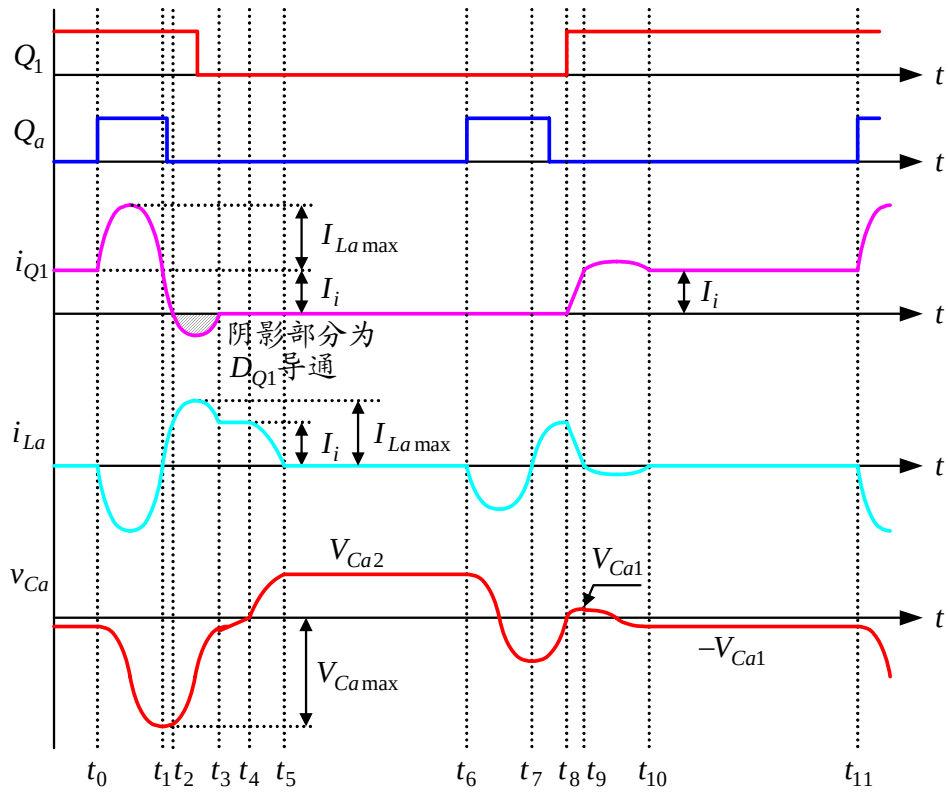
- ☺ ZVS achieved for Q1 and D1 under any load over the line range;
- ☺ The voltage stress and current stress of Q1 and D1 are the same as the basic converter;
- ☺ Qa is zero-current turn-on;
- ☺ The work time of the auxiliary circuit is very short, so the rms current is very small;
- ☺ PWM controlled.

Disadvantages:

- ☹ Hard turn-off for Qa, the turn-off loss is higher than the basic converter.

Zero-Current-Transition PWM Converter





Improved Zero-Current-Transition PWM Converter