Forward Converters

Presented by

Xinbo Ruan

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

Aero-Power Sci-tech Center

Outlines

1. Introduction
2. Forward Converter with Reset Windings
3. Dual-Switch Forward Converter
4. Forward Converter with RCD Snubber
5. Forward Converter with Active Clamp Reset
6. Other Magnetic Reset Methods
7. Summary

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How to Select a Suitable dc/dc Converters

- Questions

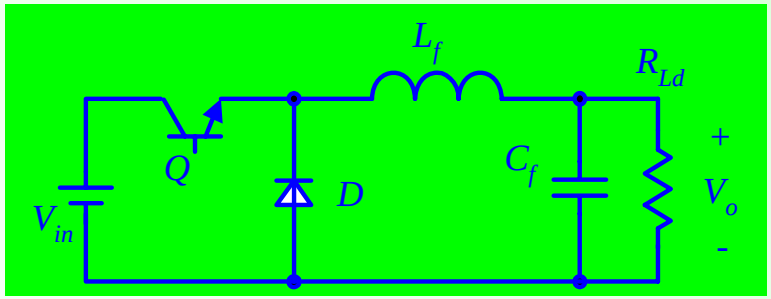
- Input: 60VDC;
- Output: 48VDC/10A;
- Switching frequency: 100kHz.

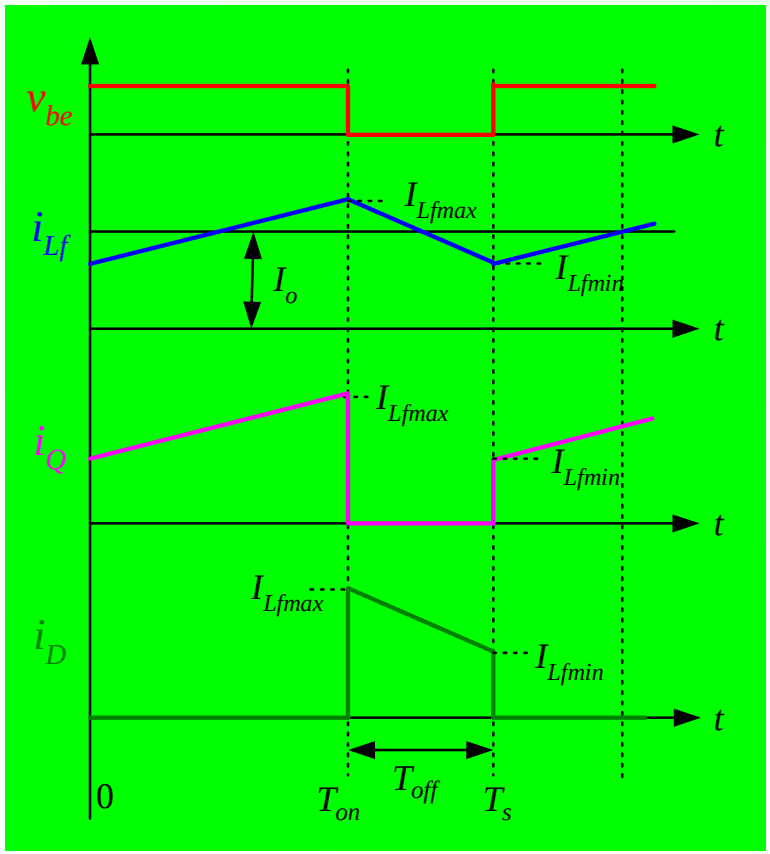
Please design a dc/dc converter, determine

1) the voltage and current stress on the power switch, and
2) the voltage and current stress on the the diode.

Given the ripple current of the filter inductance 20%I_{omax}.

Buck: 60Vin; 48V/10A output





$$V_o = L_f \frac{\Delta i_{Lf}}{T_{off}}$$

$20\%I_{omax} = 2$ A

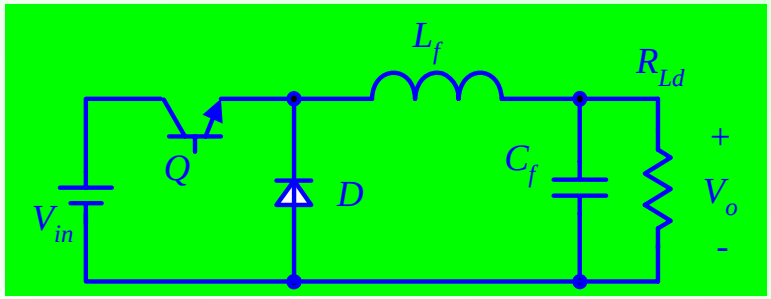
$D=V_o/V_{in}=0.8$

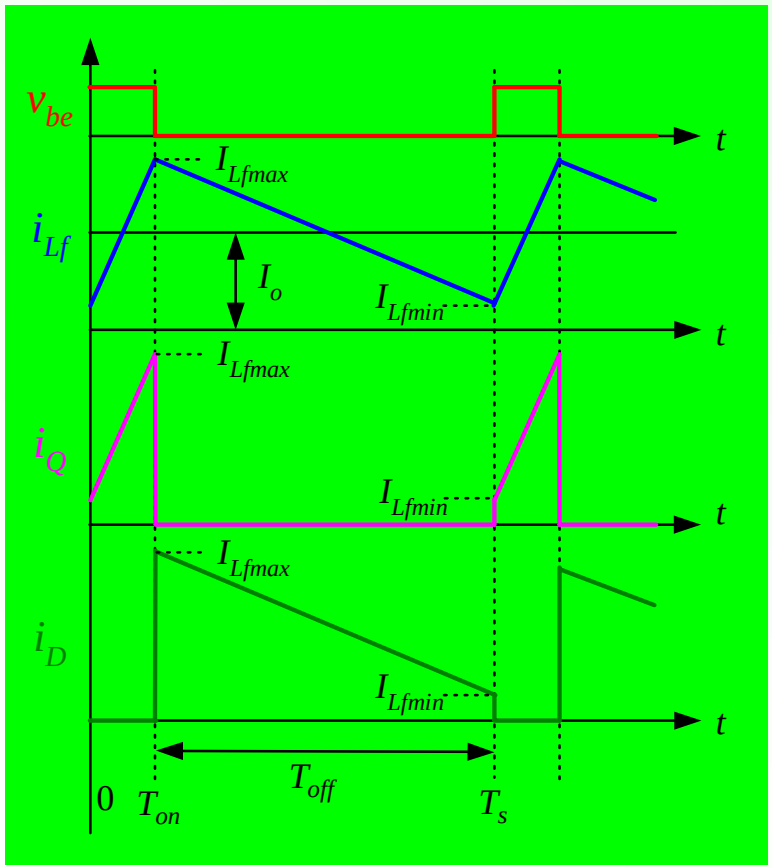
$T_{off}=(1-D)T_s=2\ \mu s$

$L_f = 48\ \mu H$

$$I_{Q\max} = I_{D\max} = I_{Lf\max} = 11A$$

Buck: 300Vin; 48Vout/10A





$$D=V_o/V_{in}=0.16$$

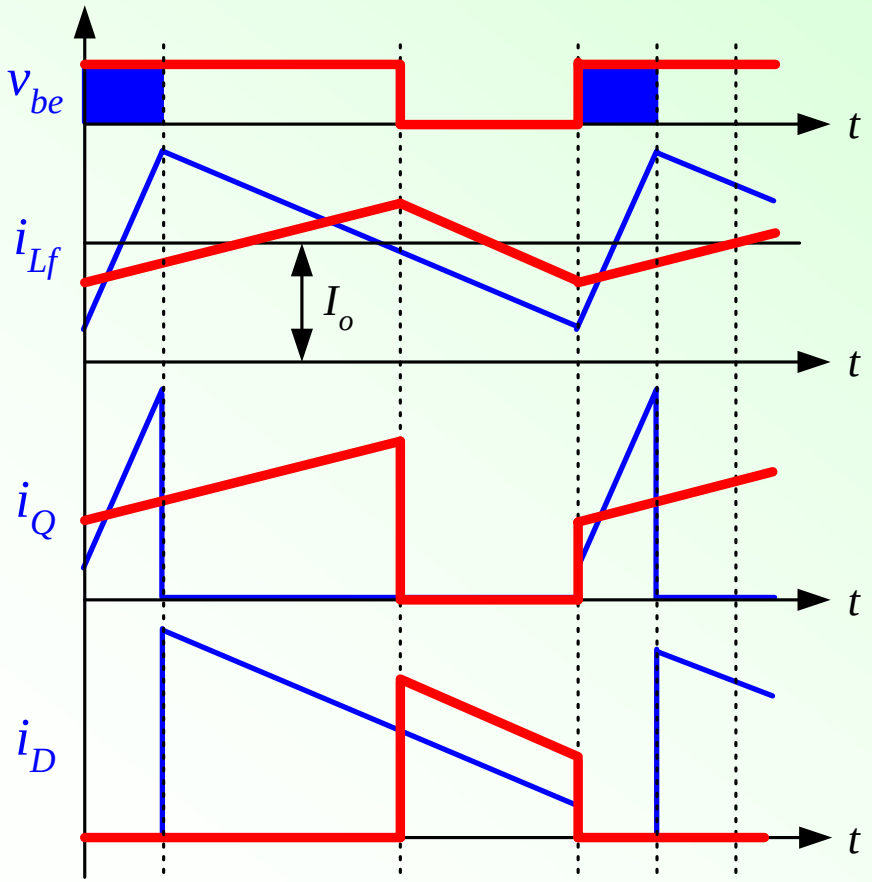
$$T_{off}=(1-D)T_s=8.4\ \mu s$$

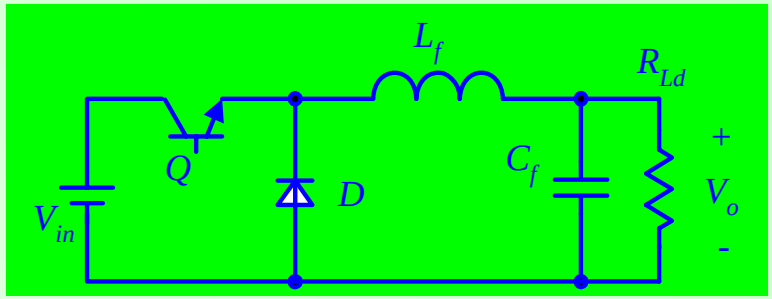
$$\Delta i_{Lf}=V_o T_{off}/L_f=8.4\ \text{A}$$

$$I_{Q\max}=I_{D\max}=I_{Lf\max}$$

$$=10+\frac{8.4}{2}=14.2\ \text{A}$$

Buck: Comparison of Different Input Voltage





Problems:

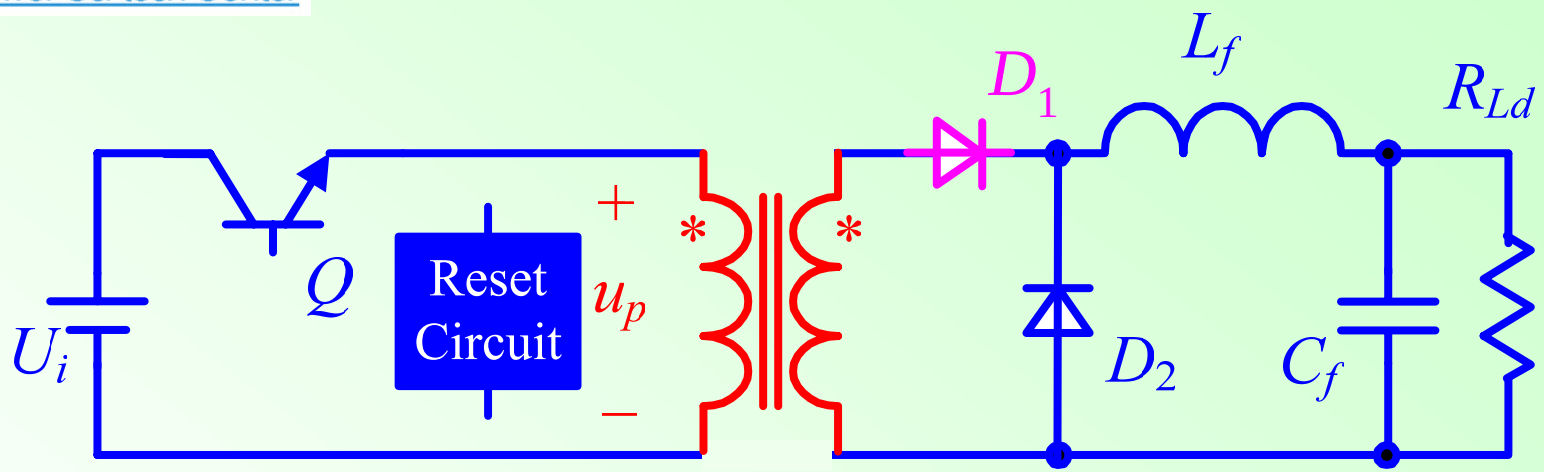
- ☹ *The current ripple becomes larger;*
- ☹ *The switching devices suffer high voltage;*
- ☹ *Duty cycle is too small.*
- ☹ *The input is not isolated with the output.*

?

Answer:

The input voltage is not so matched with the output voltage.

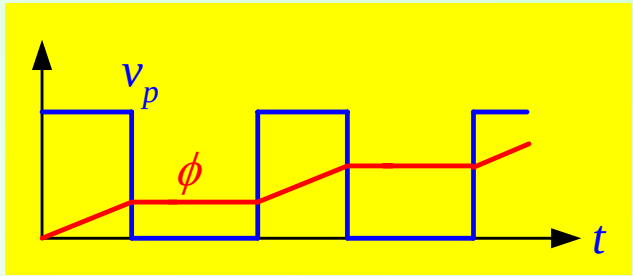
Derivation of Forward Converter

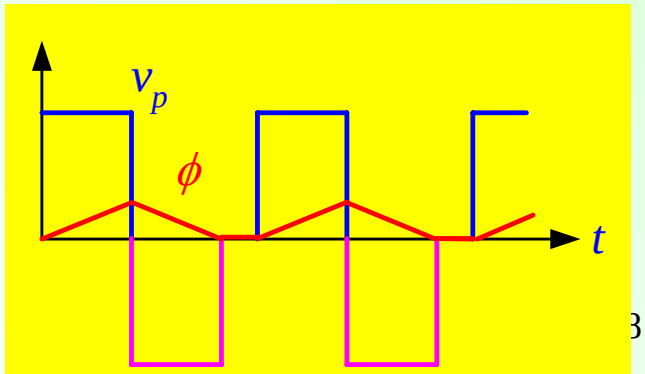


Step 1: Introduce a transformer;

Step 2: Magnetic Reset circuit;

Step 3: Introduce a rectifier diode.





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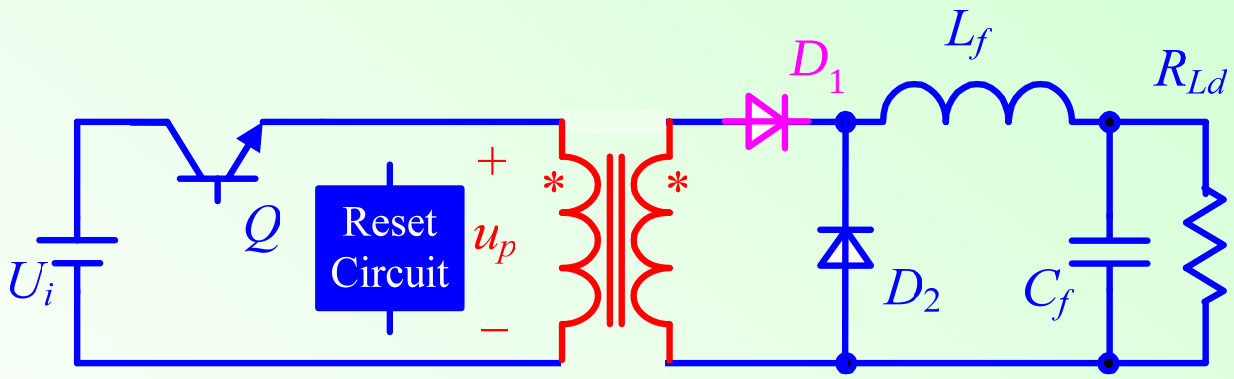
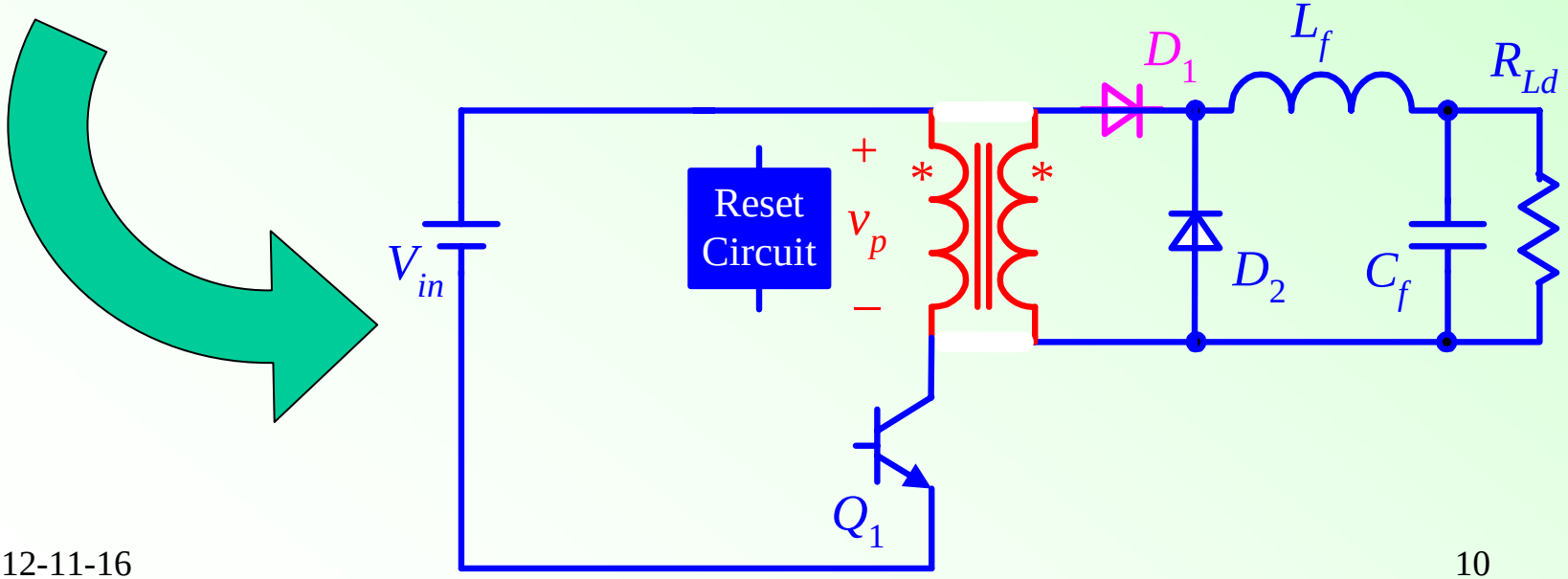
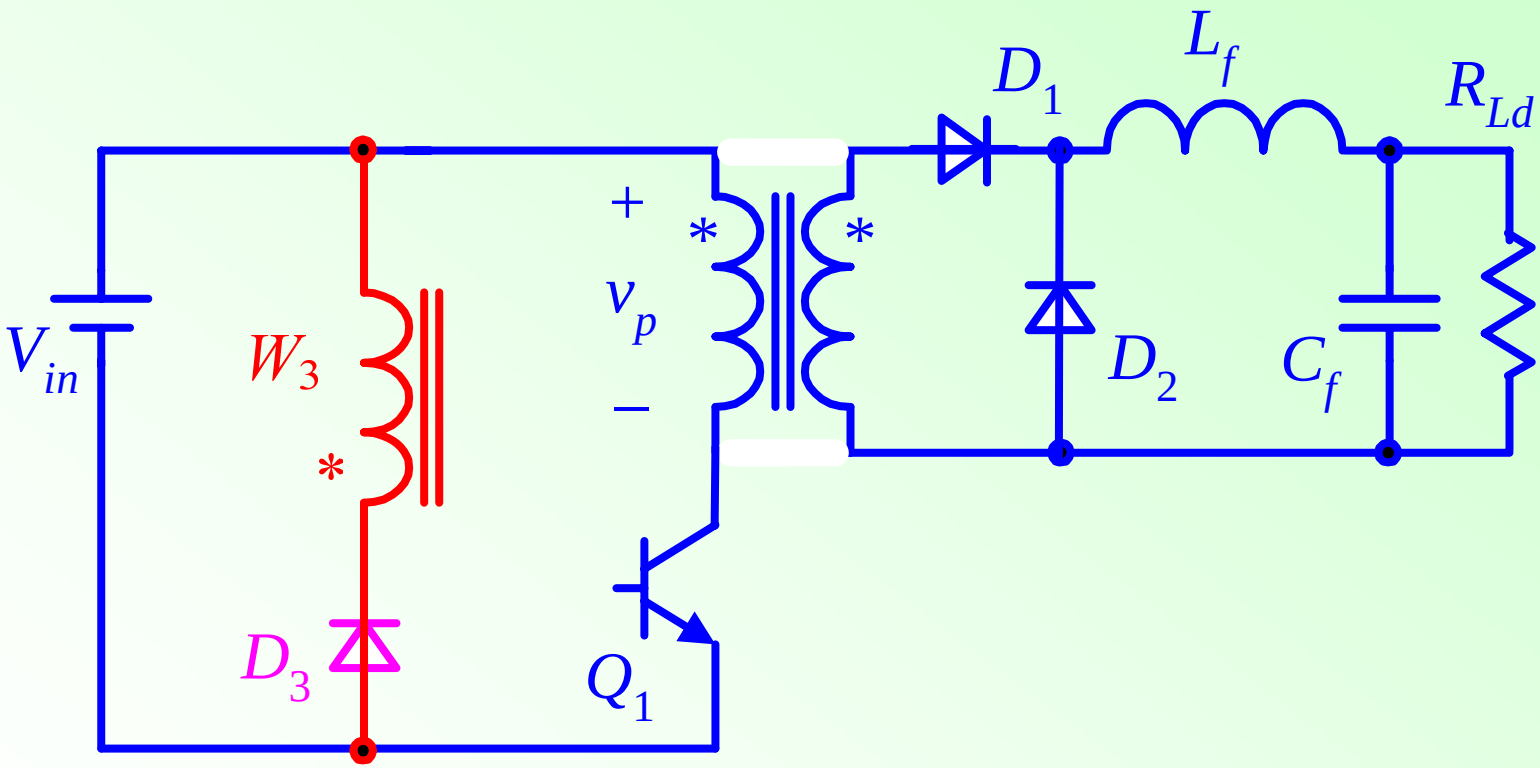
Another Form of Forward Converter

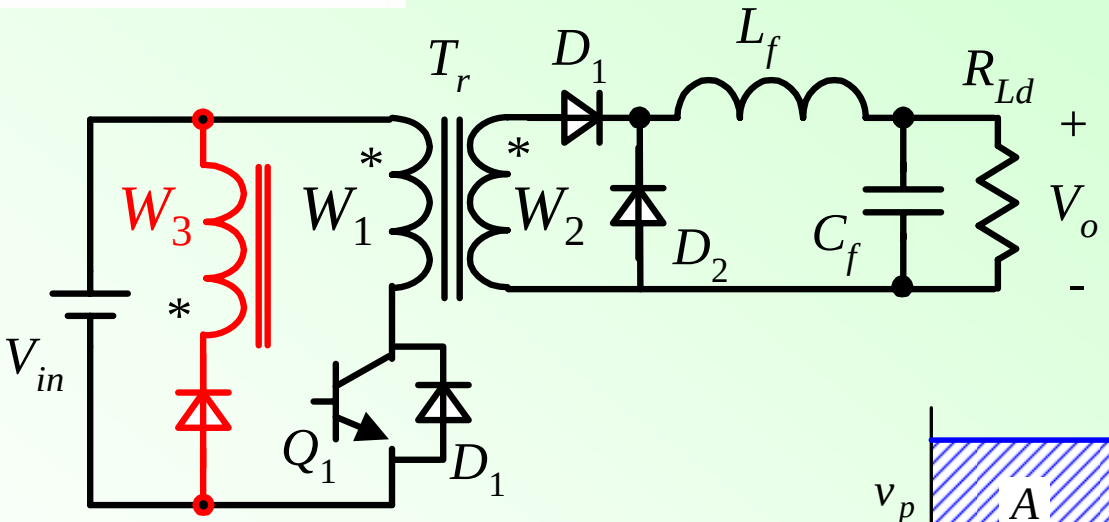




Basic Reset Method

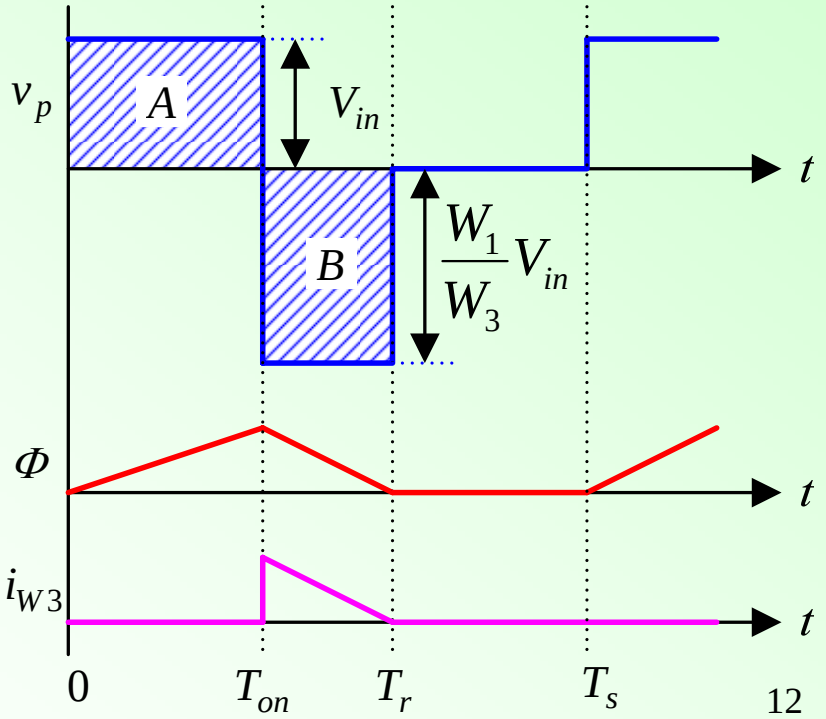


Forward Converters with Reset Winding



1. Duty cycle;
2. Voltage stress of Q_1.

W_3/W_1



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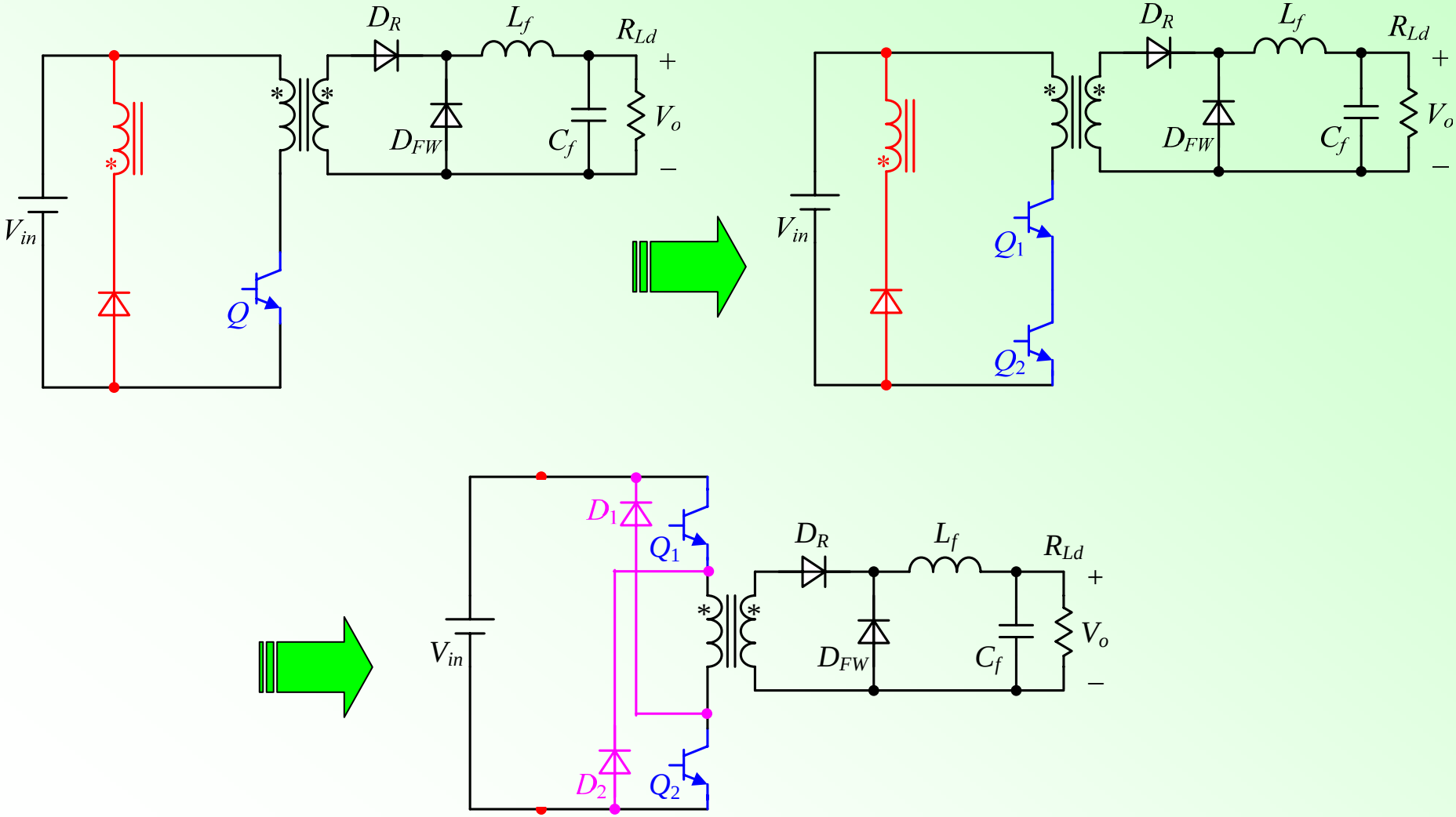
Dual-Switch Forward Converters



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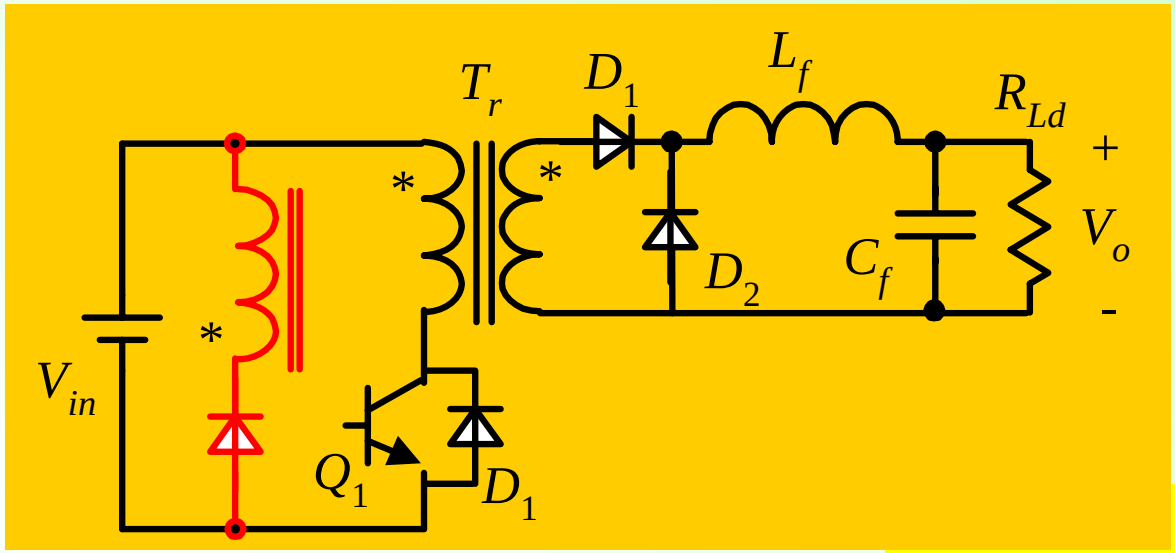
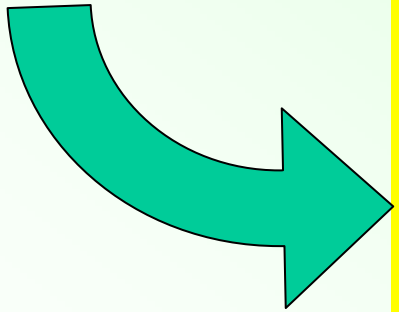
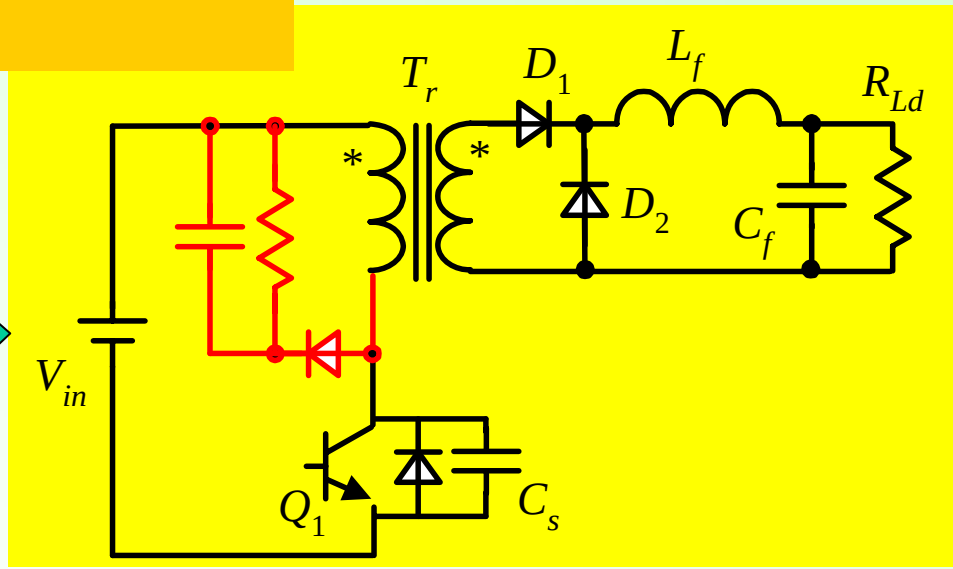
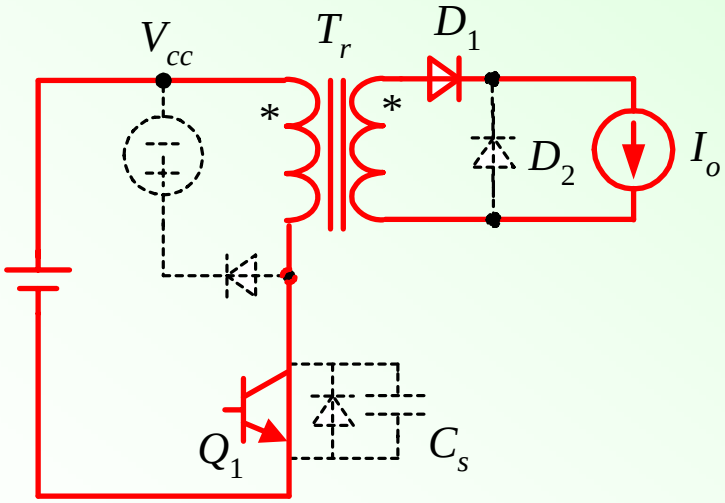
Forward Converters with RCD Snubber

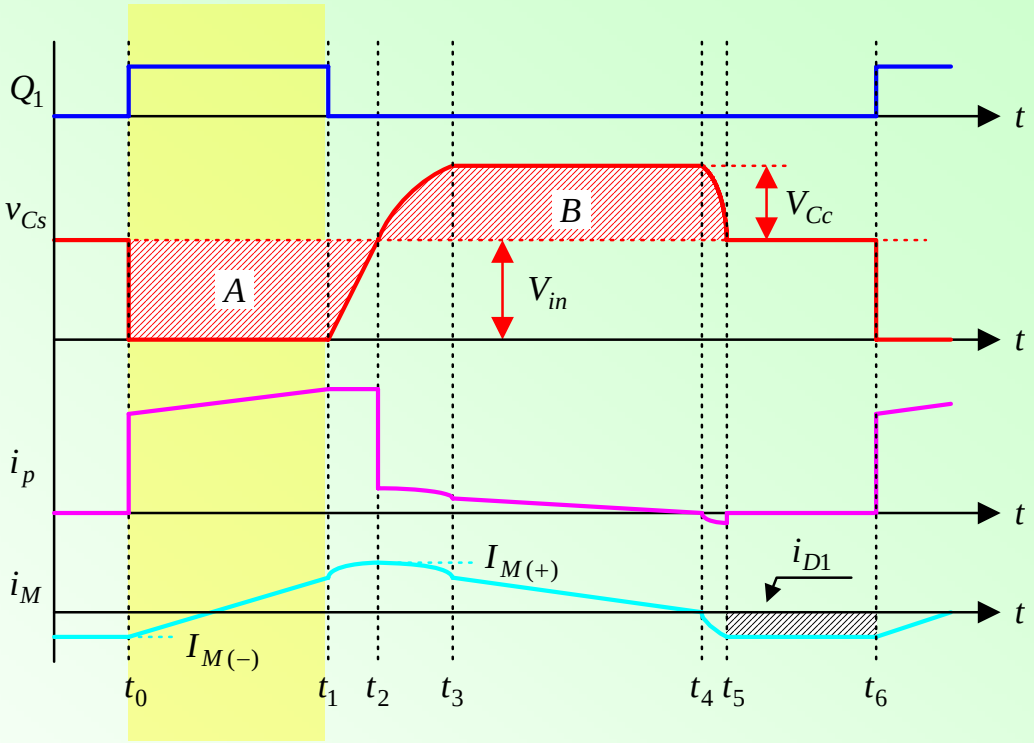




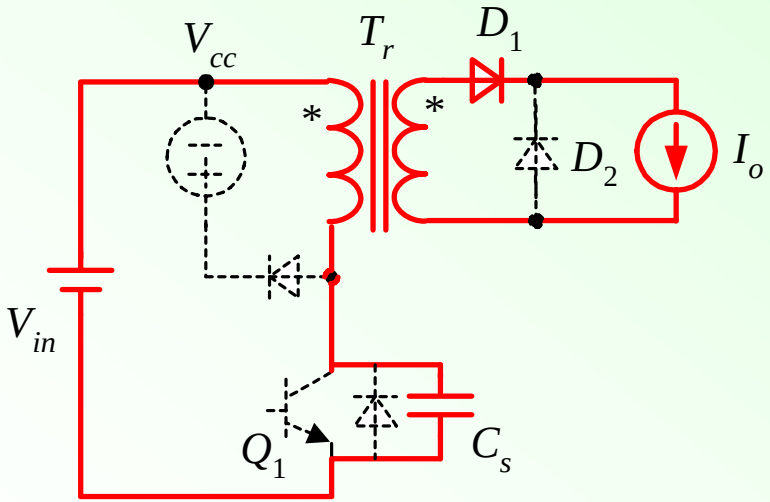


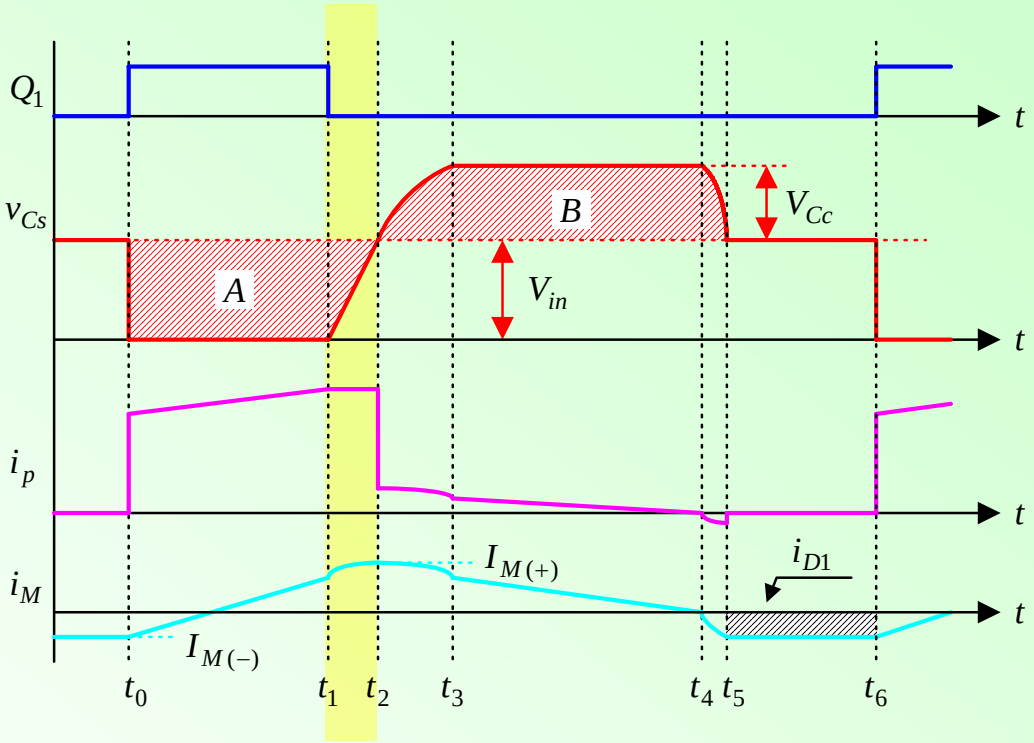
Operation Principle: [t_0 , t_1]



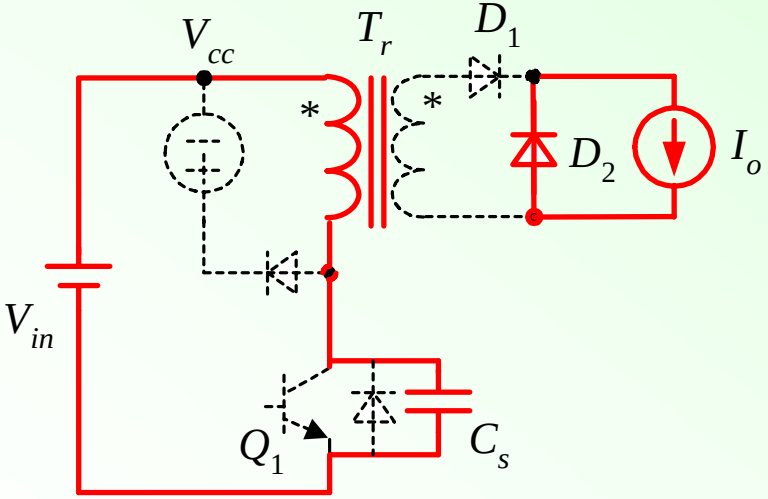


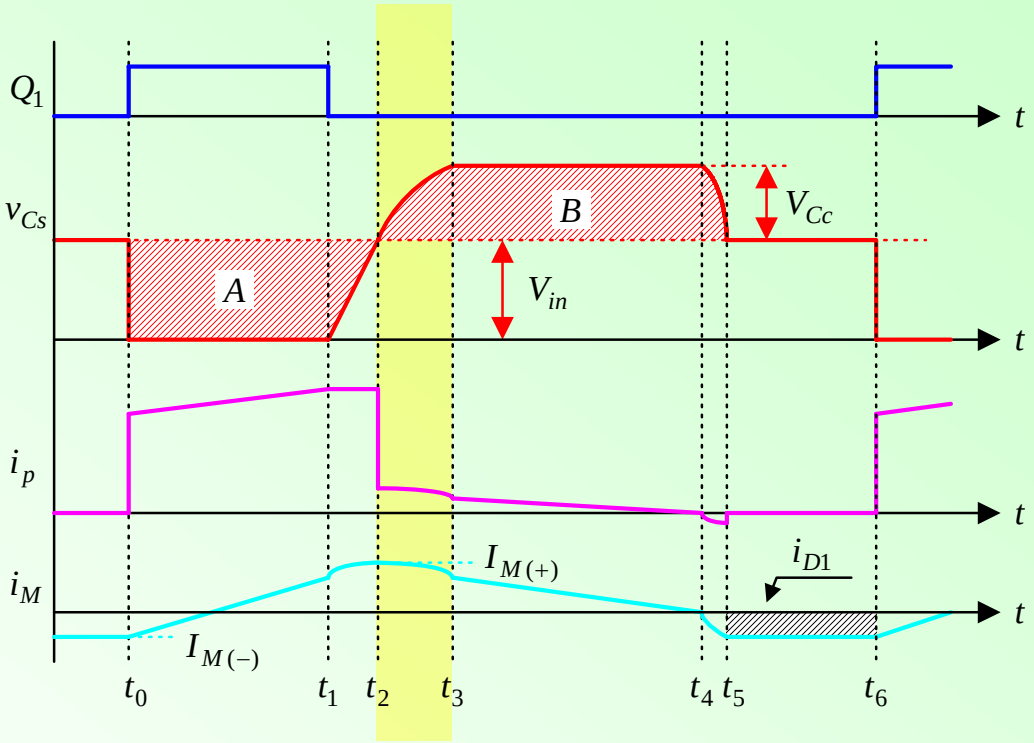
Operation Principle: [t_1 , t_2]



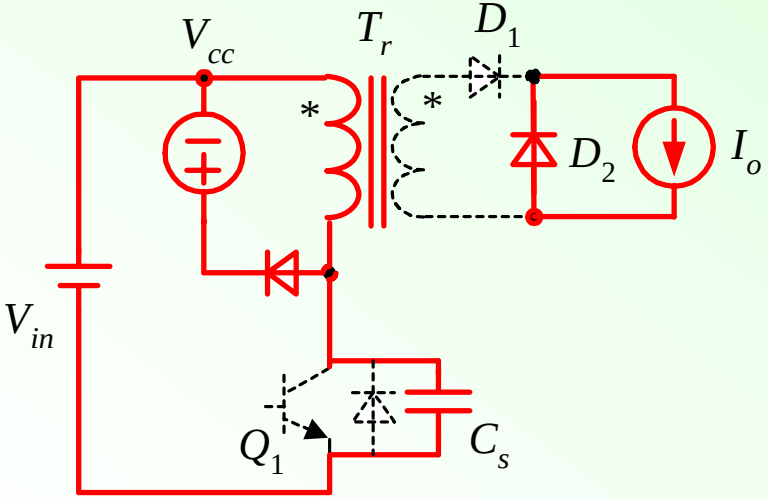


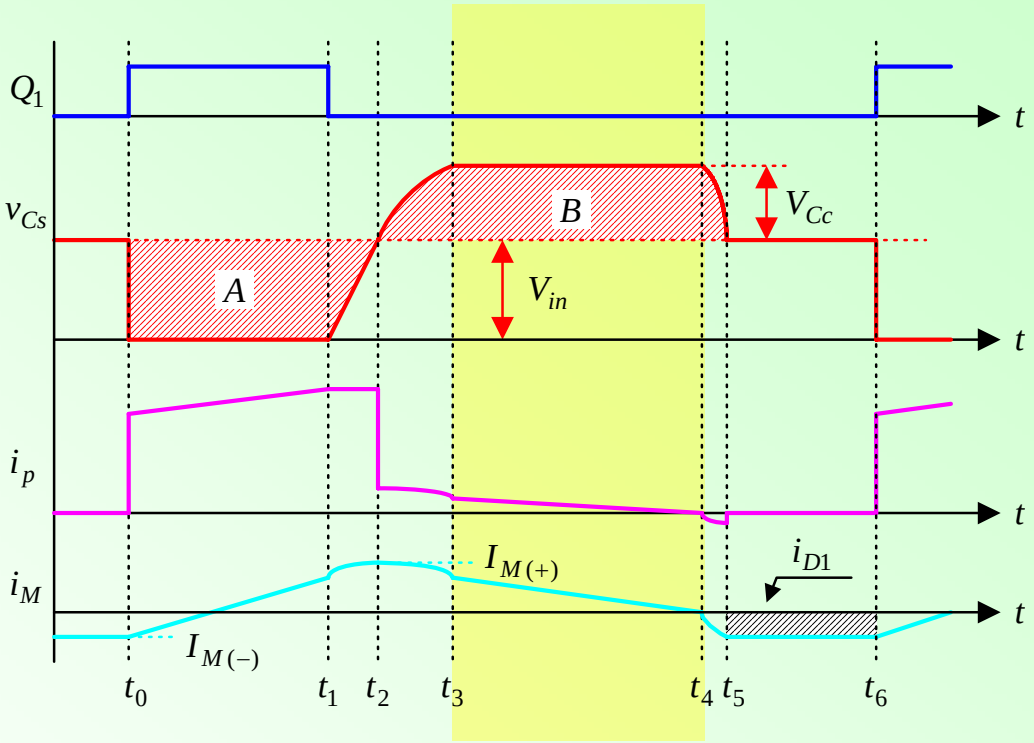
Operation Principle: [t_2 , t_3]



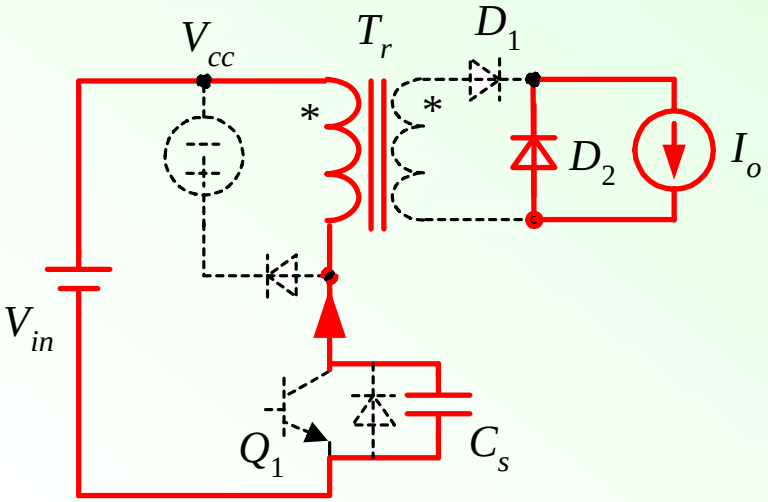


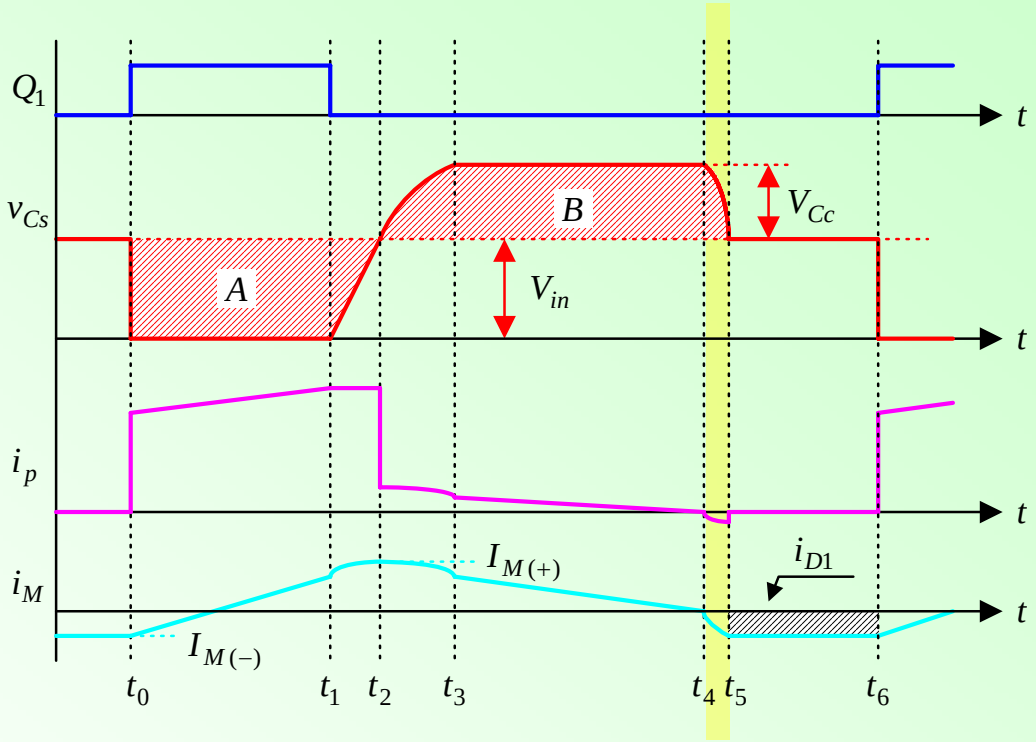
Operation Principle: [t_3 , t_4]



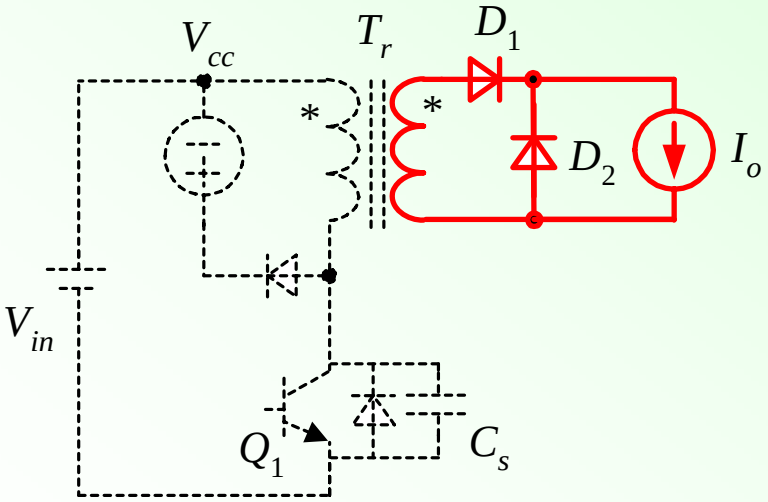


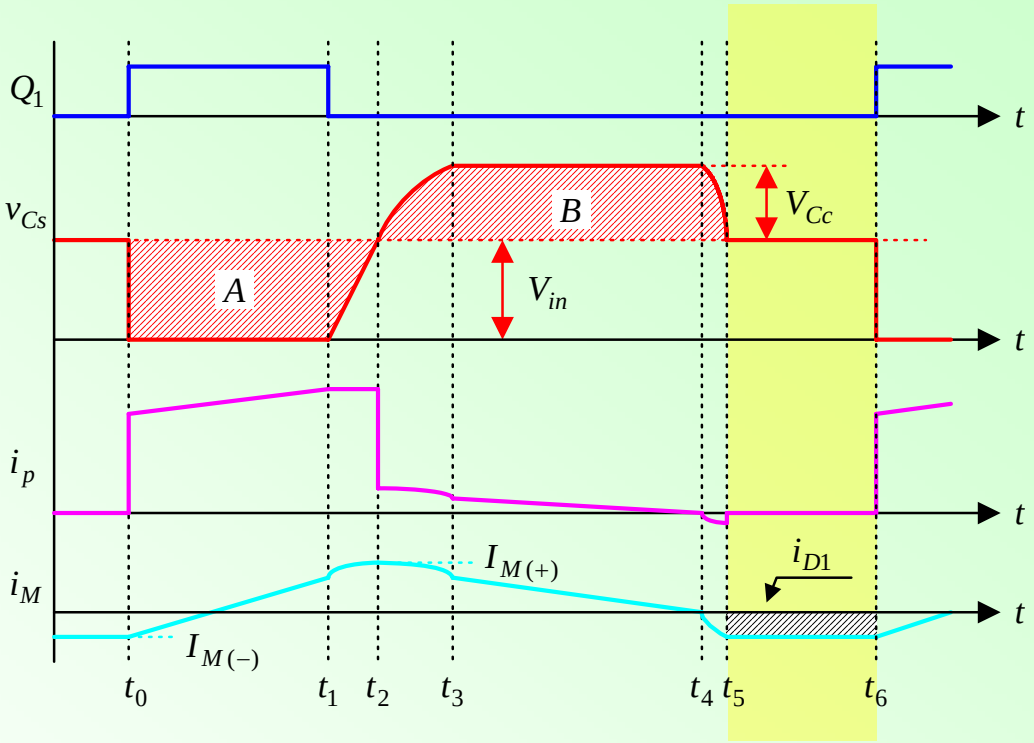
Operation Principle: [t_4 , t_5]



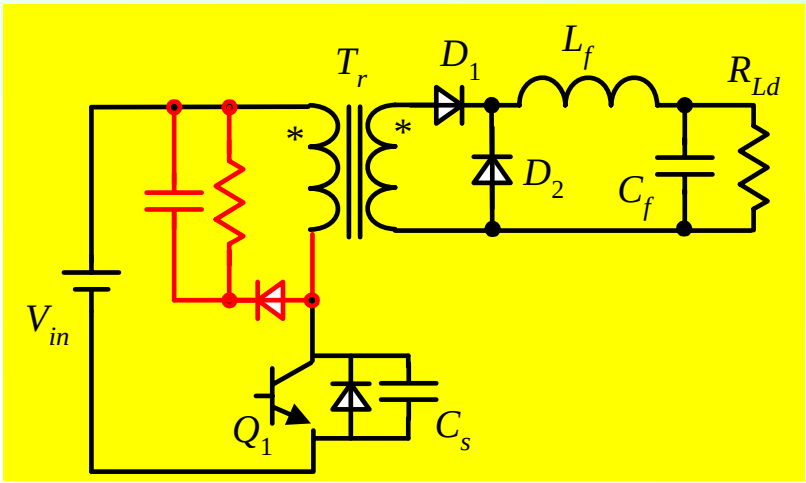


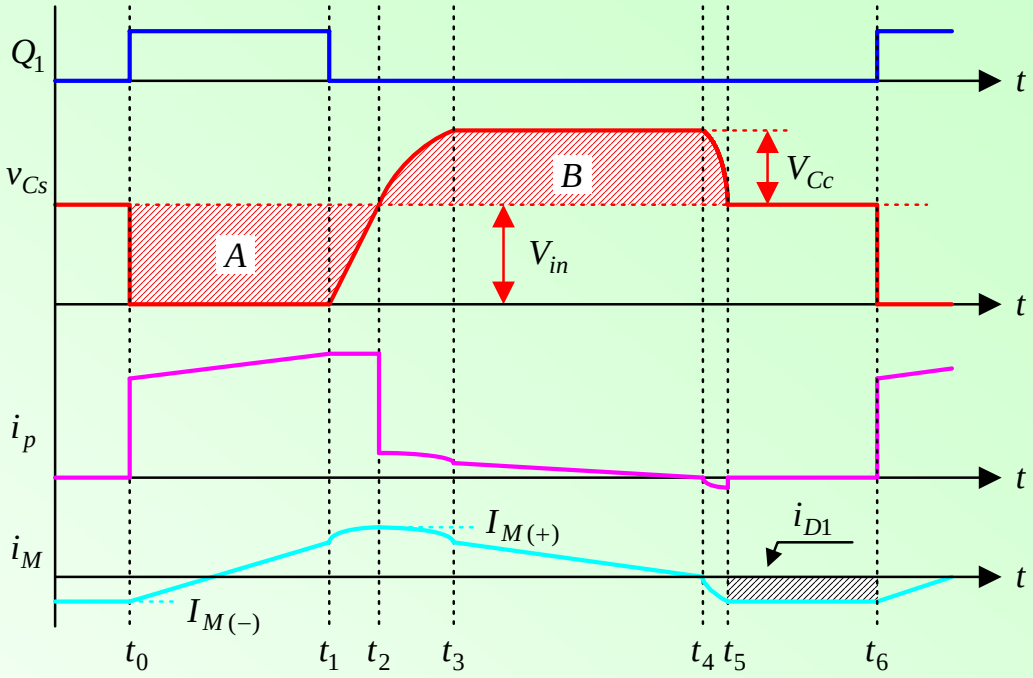
Operation Principle: [t_5 , t_6]





Parameters Design





1. V_{cc}

$$V_{cc\_\min} = \frac{V_{in} D_y}{1 - D_y} = \frac{K V_o}{1 - D_y}$$

$$V_{Q1} = V_{in} + V_{cc}$$

2. R_c

Magnetic Energy

- Stored by Junction capacitor
- Dissipated in the resistance

3. C_c

$$\Delta V_c \approx 5\% V_{cc}$$

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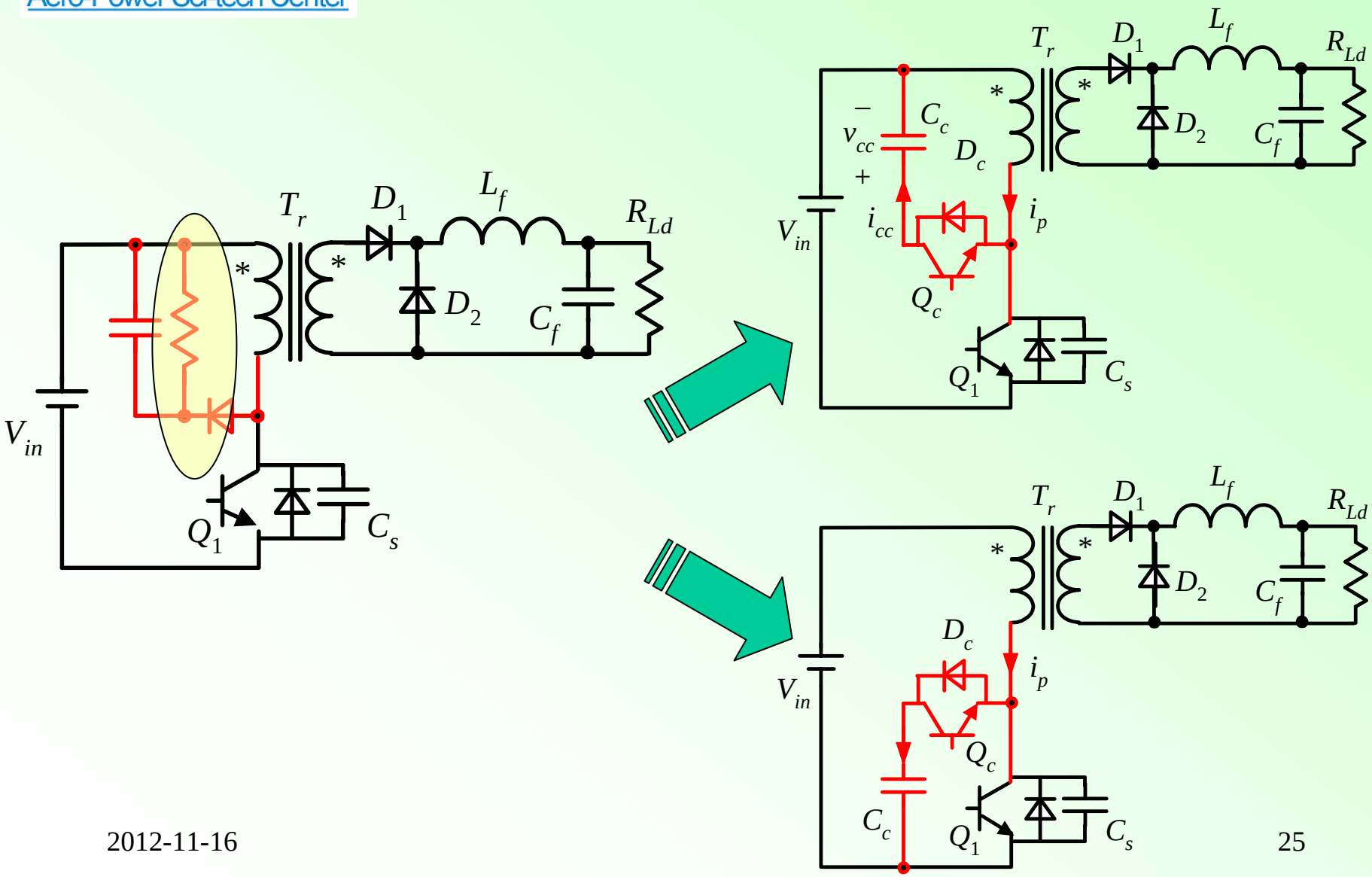
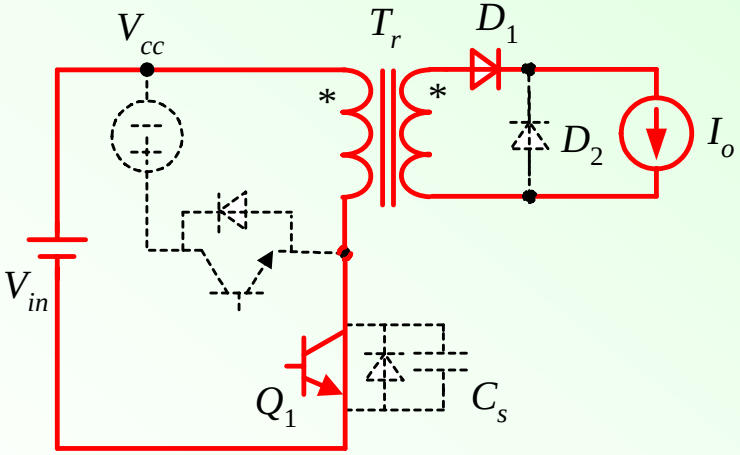
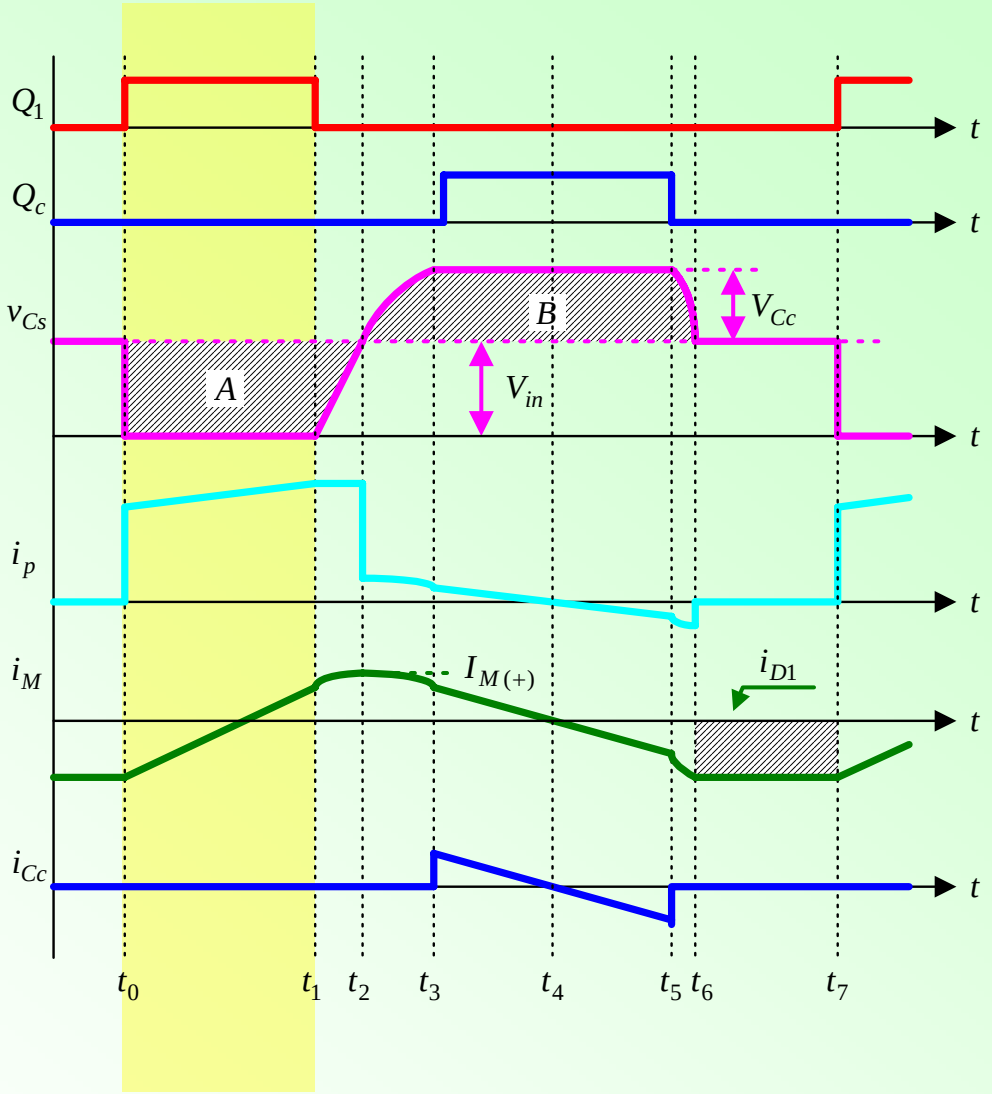
Active Clamp Forward Converter

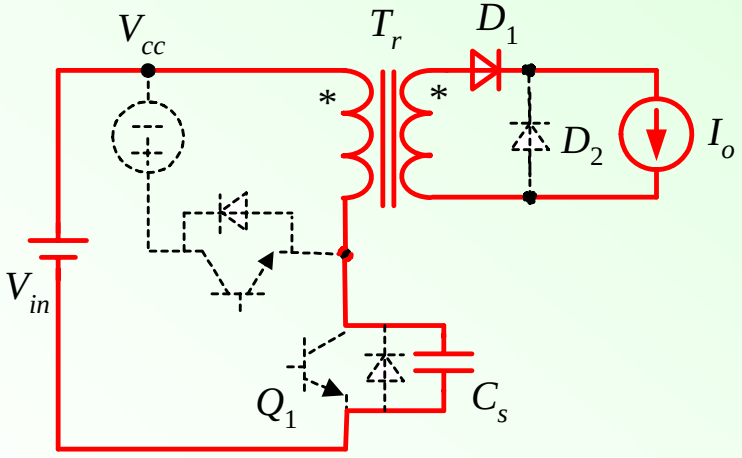


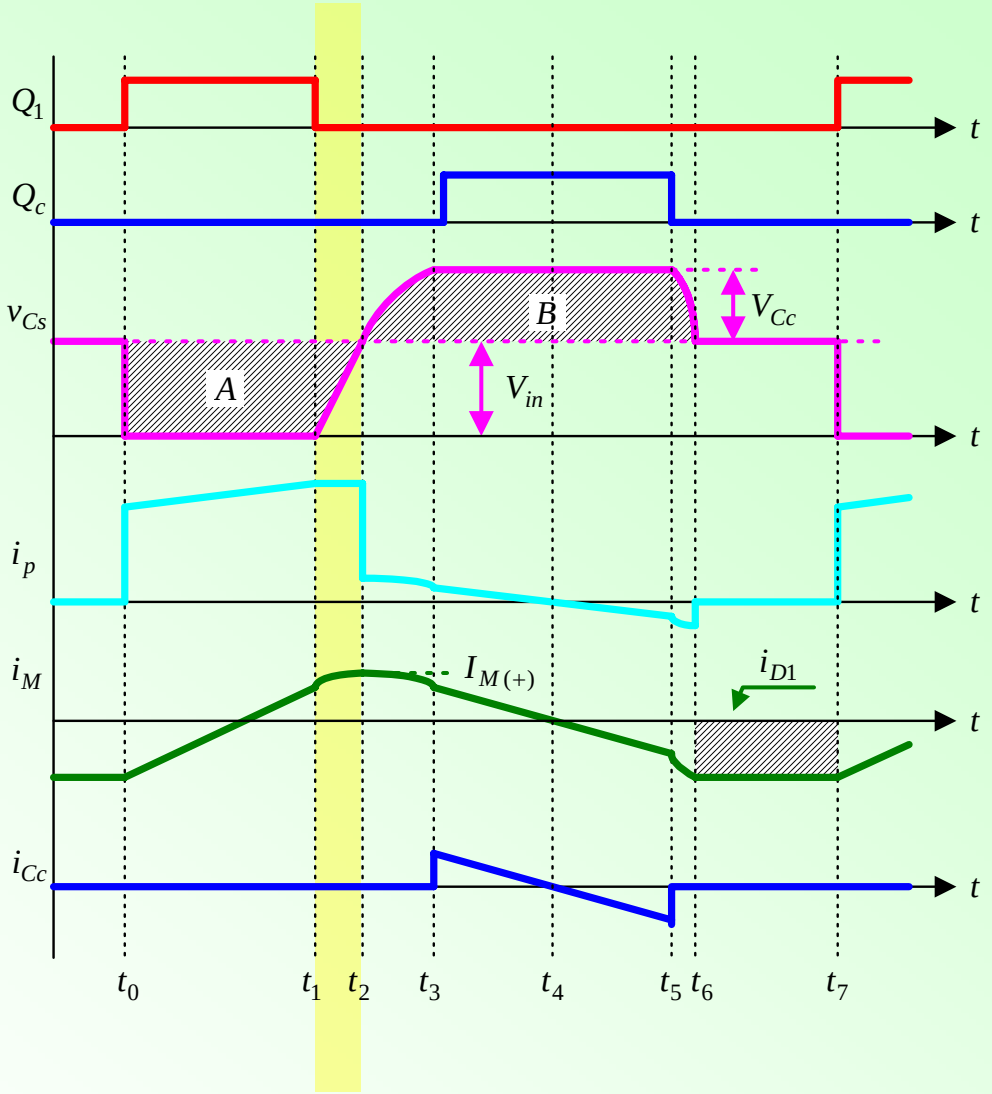
Operation Principle: [t_0 , t_1]



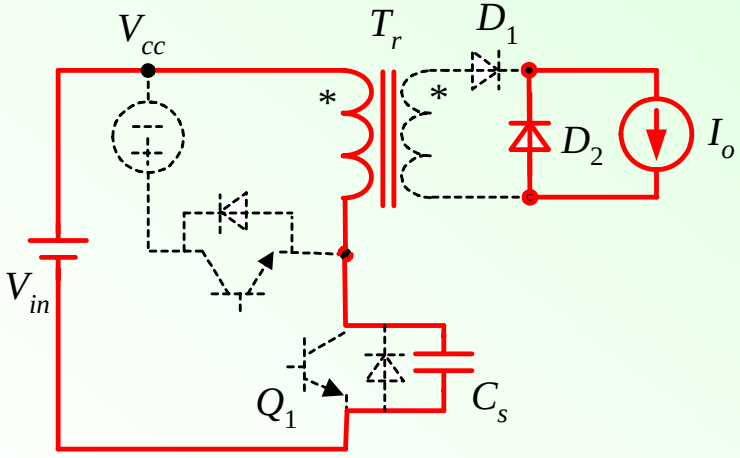


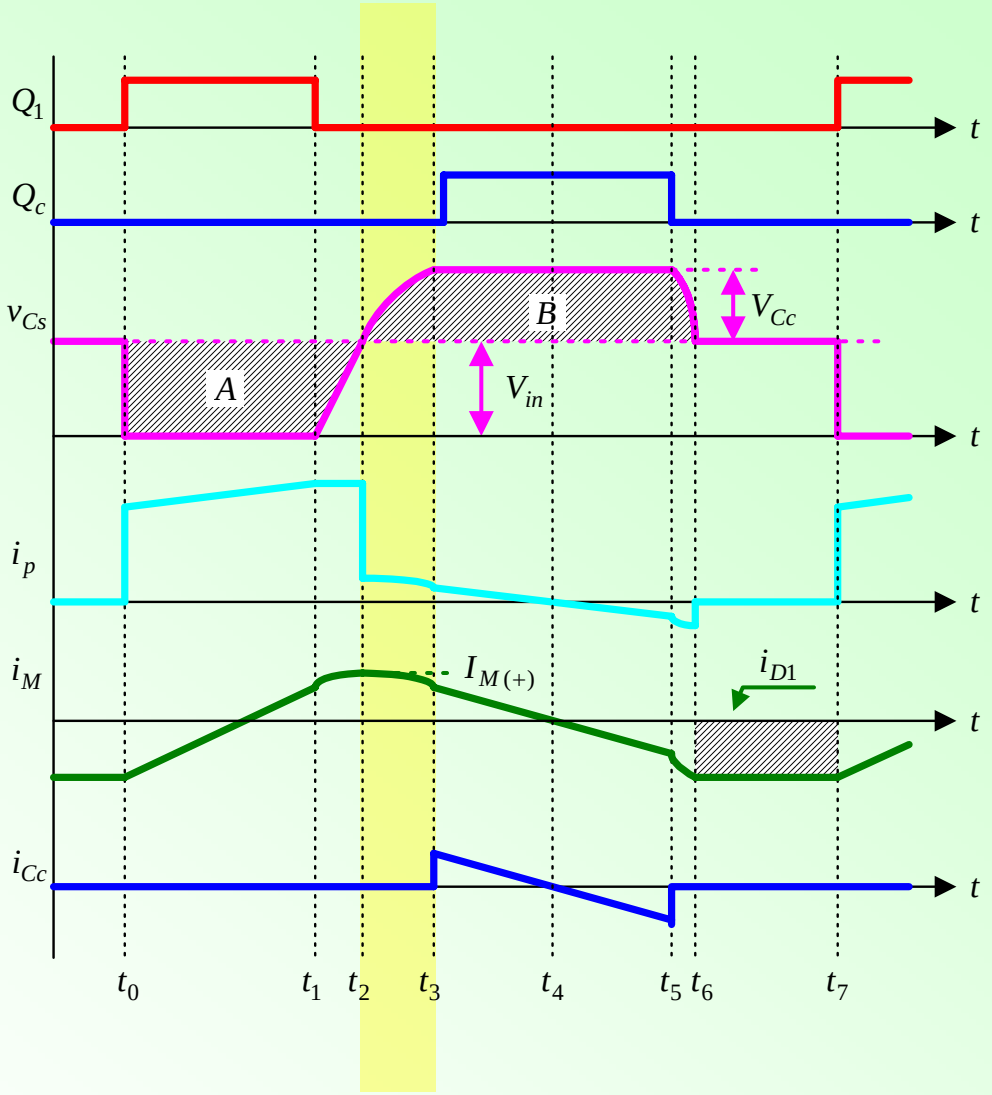
Operation Principle: [t_1 , t_2]



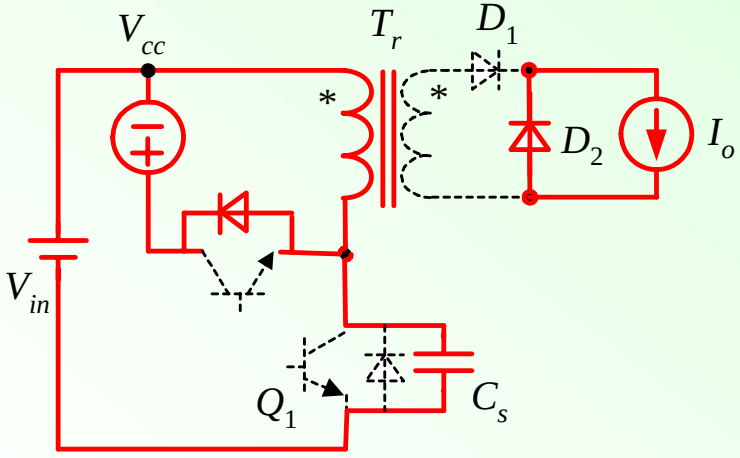


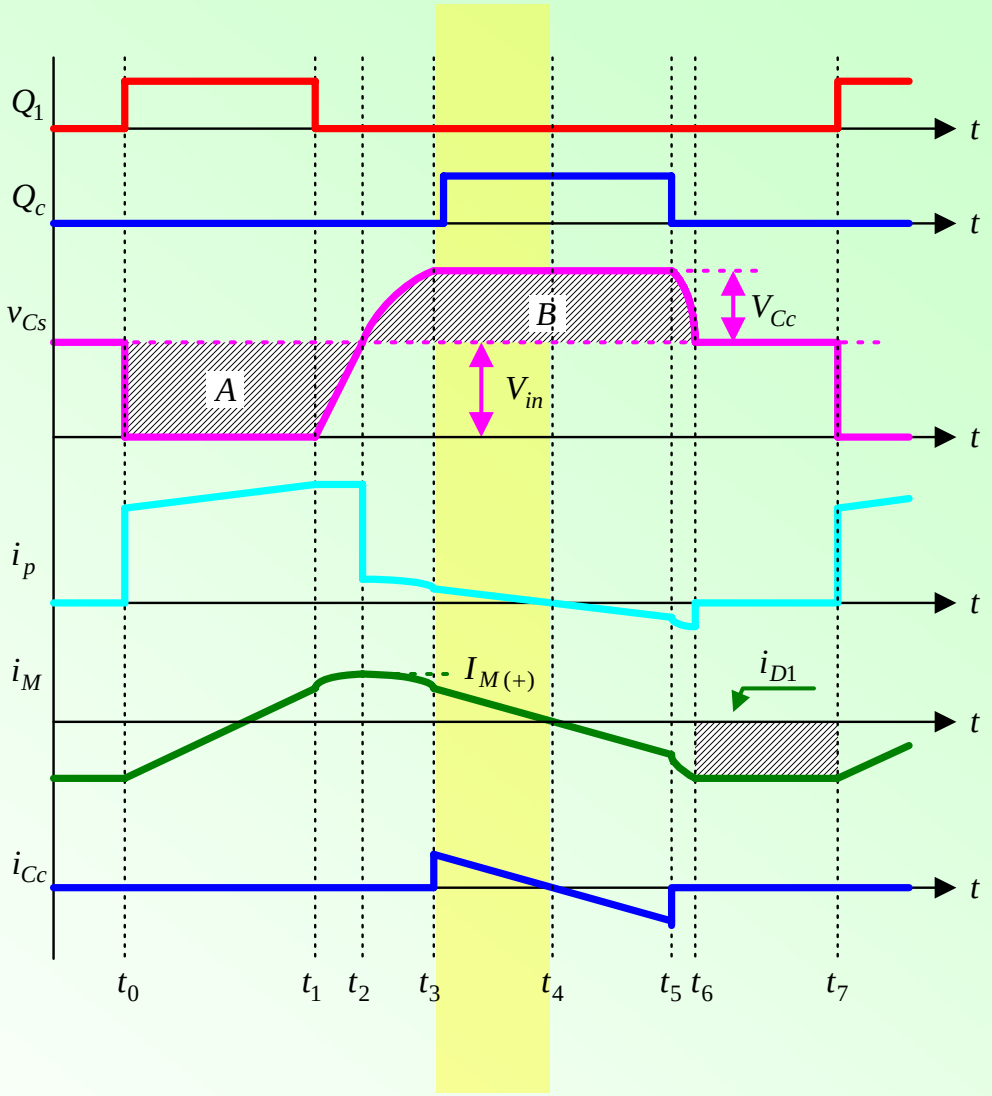
Operation Principle: [t_2 , t_3]



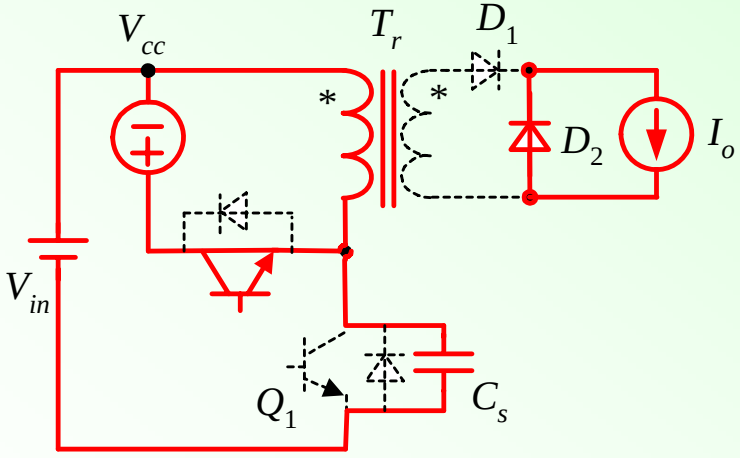


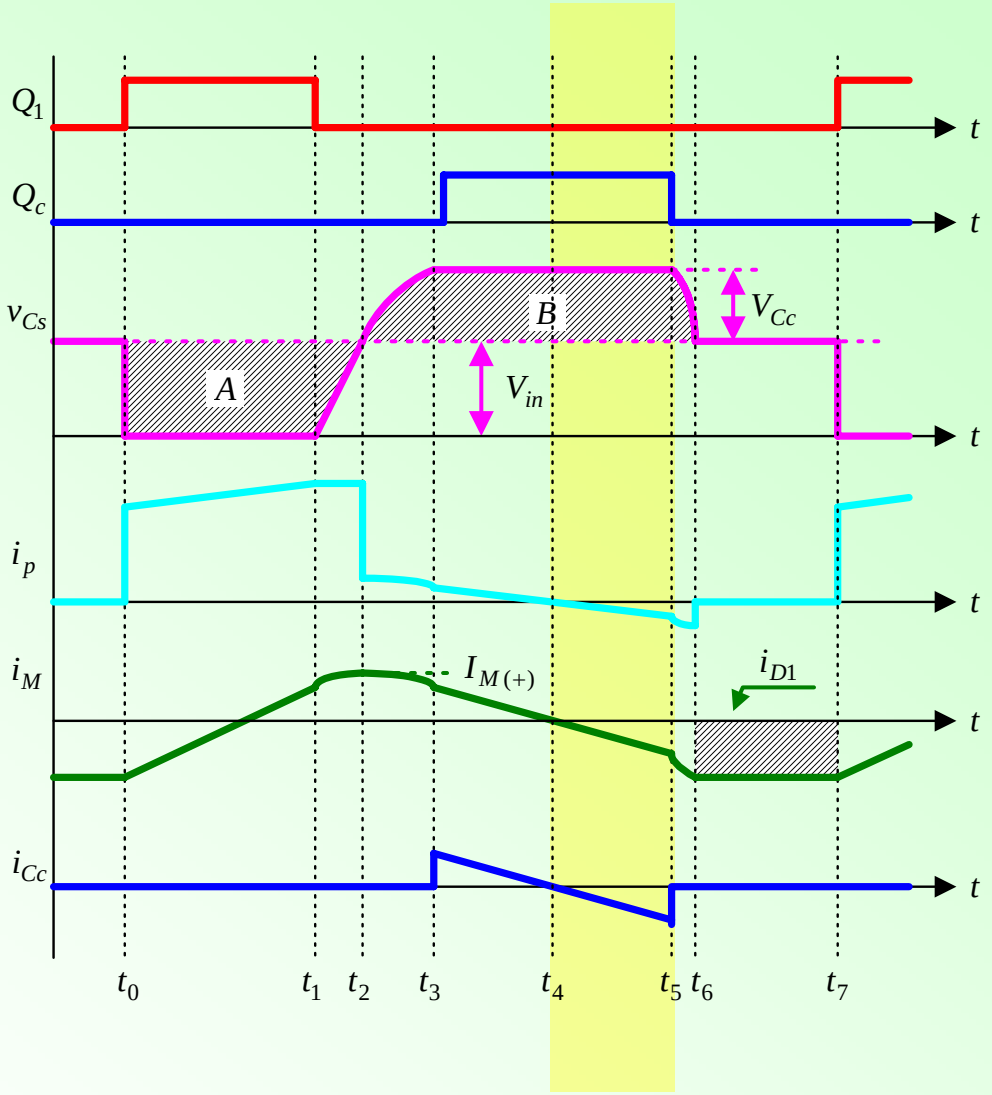
Operation Principle: [t_3 , t_4]



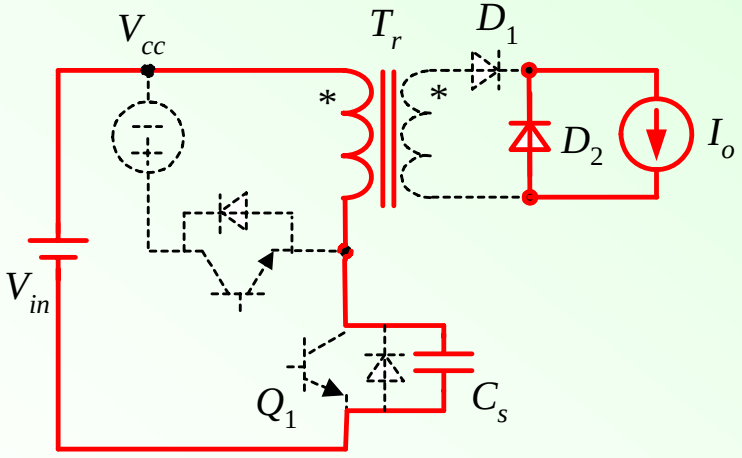


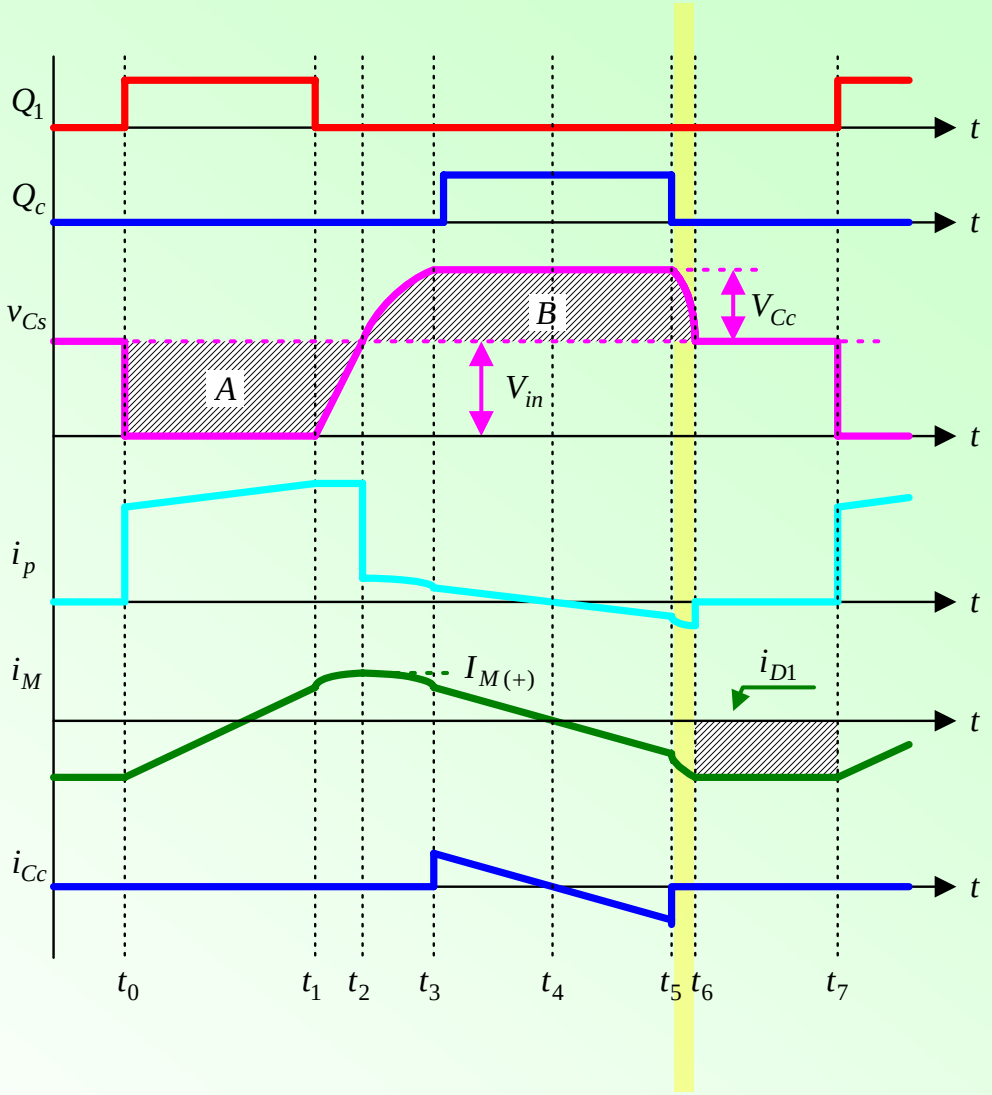
Operation Principle: [t_4 , t_5]



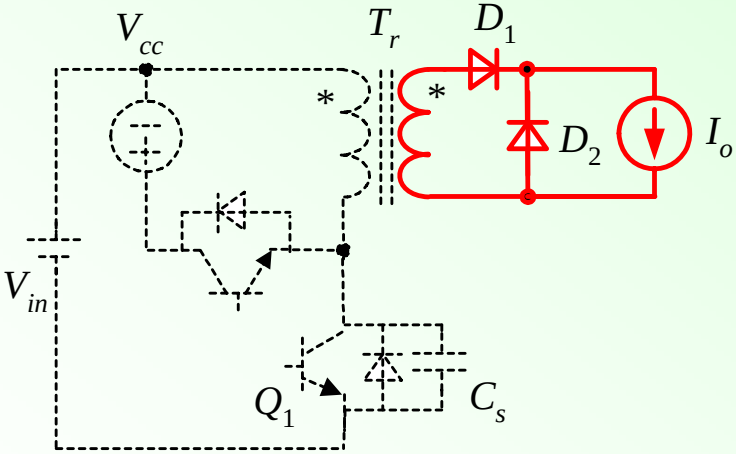


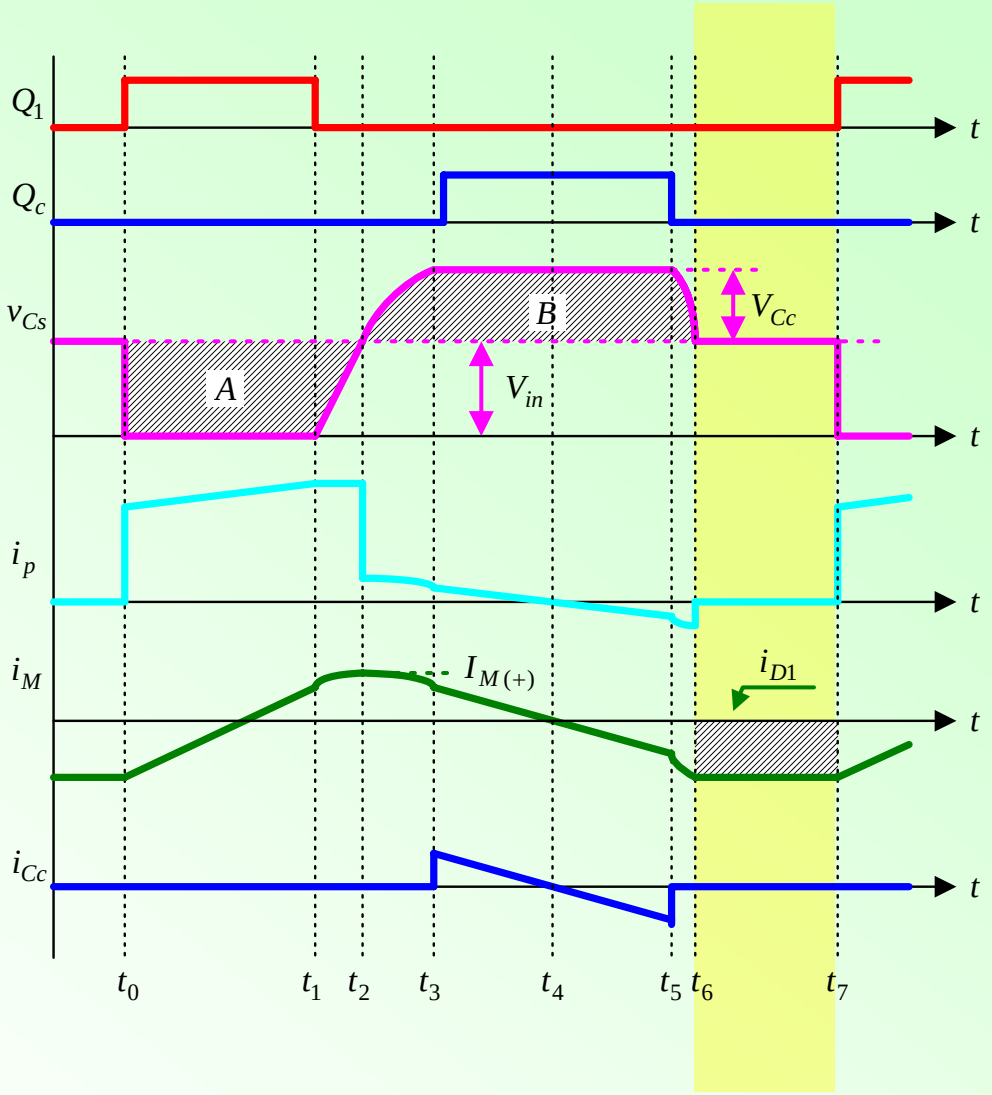
Operation Principle: [t_5 , t_6]





Operation Principle: [t_6 , t_7]





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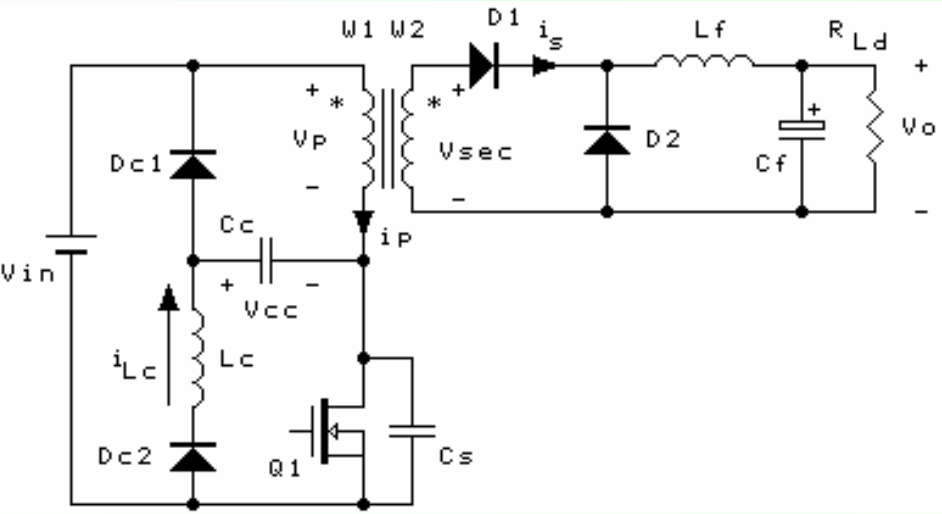
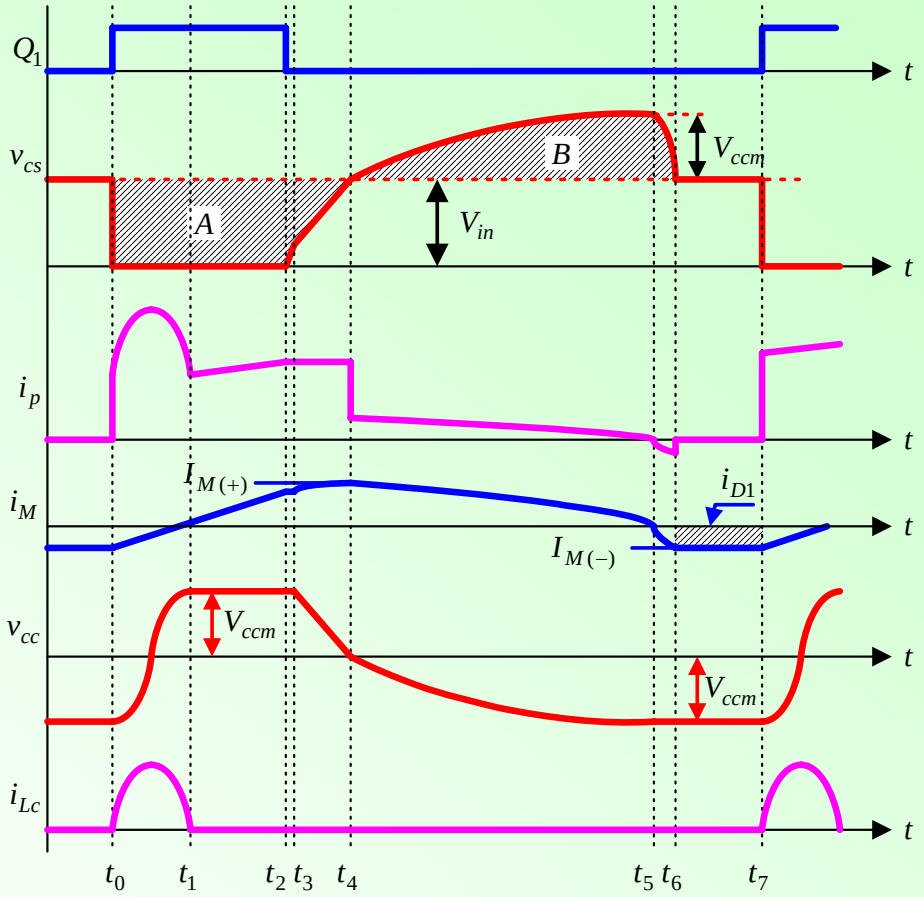
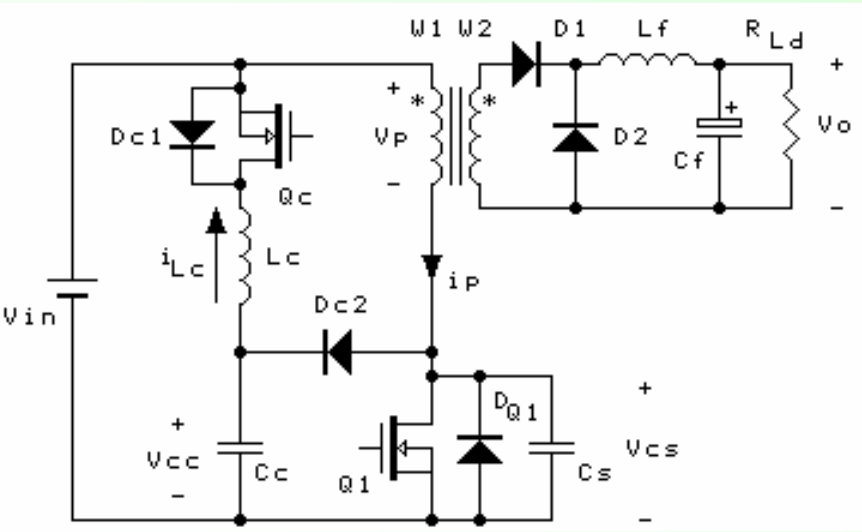
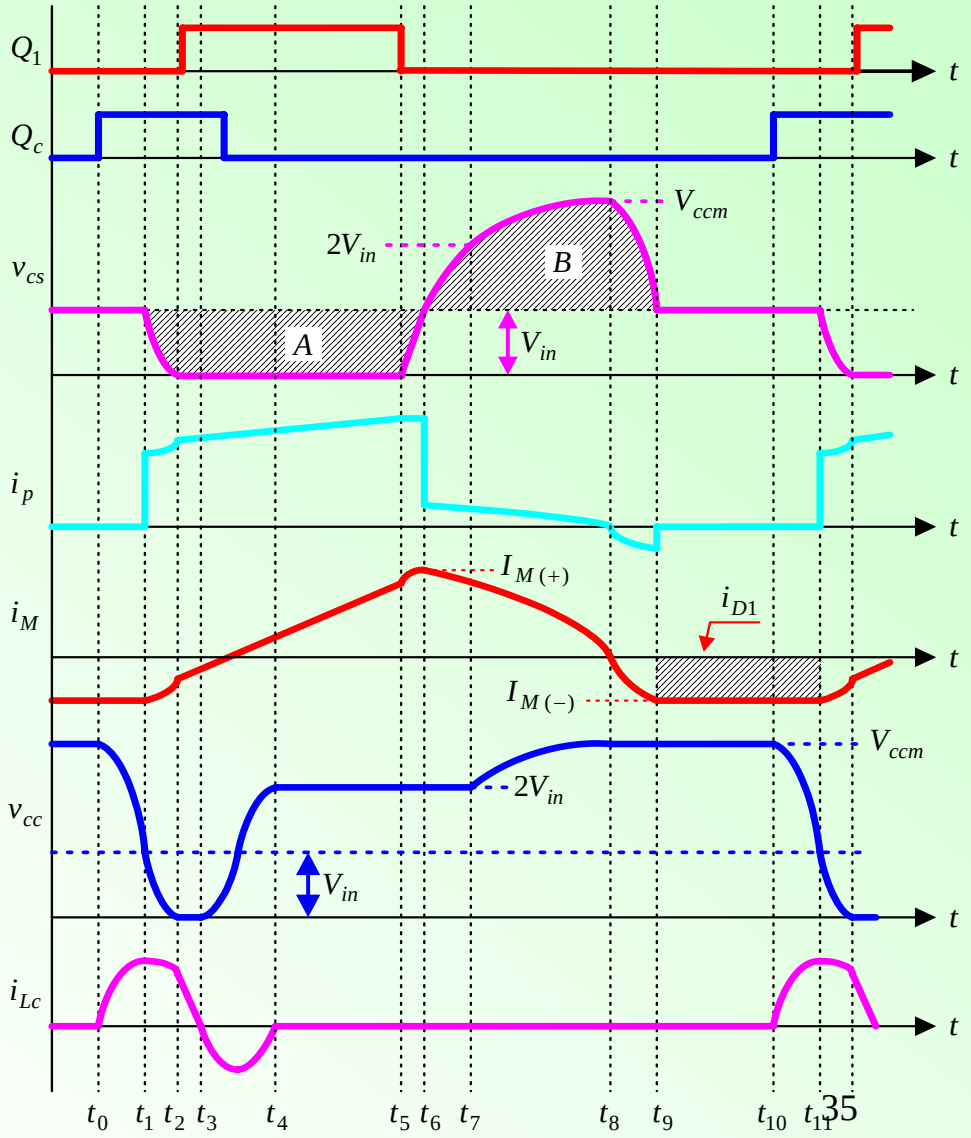
Forward Converters with LCD Snubber





Zero-Voltage-Transition Forward Converter





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Comparison of Reset Circuit

	Reset Winding	Dual-Switch	RCD Snubber	Active Clamp	LCD	ZVT
Topology	Simple	Simple	Very Simple	Simple	Not Simple	Not Simple
Voltage Stress of Main Switch	$2V_{inmax}$	V_{inmax}	$<2V_{inmax}$	$<2V_{inmax}$	$<2V_{inmax}$	$<2V_{inmax}$
Switching of Main Switch	Hard-Switching	Hard-Switching	Hard-Switching	Hard-Switching	Hard-Switching	**Zero-Voltage-Switching**
Magnetic Core	Unidirectional magnetization	Unidirectional magnetization	Unidirectional magnetization	Bidirectional magnetization	Unidirectional magnetization	Unidirectional magnetization
Duty Cycle	**< 0.5**	**< 0.5**	> 0.5	> 0.5	> 0.5	> 0.5
Efficiency	Not so high	high	low	High	Not so high	High
Input Voltage Range	Narrow	Narrow	Wide	Wide	Wide	Wide

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Thanks for your attention !

Questions? / Answer!