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Six Basic DC/DC Converters

Presented by

Xinbo Ruan

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

Power Converters

1. DC/DC
2. DC/AC
3. AC/DC
4. AC/AC

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DC-DC Converters

- Non-Isolated DC-DC Converter: single-switch, dual-switch, and four-switch

  ◎Single-switch: Buck, boost, buck-boost, Cuk, Zeta, and SEPIC;

  ◎Dual-switch: Dual-switch buck-boost;

  ◎Four-switch: Full-bridge converter.

- Isolated DC-DC Converter: Single-Switch, Dual-Switch, and Four-Switch

  ◎Single-switch: Forward, Flyback;

  ◎Dual-switch: Forward, Flyback;

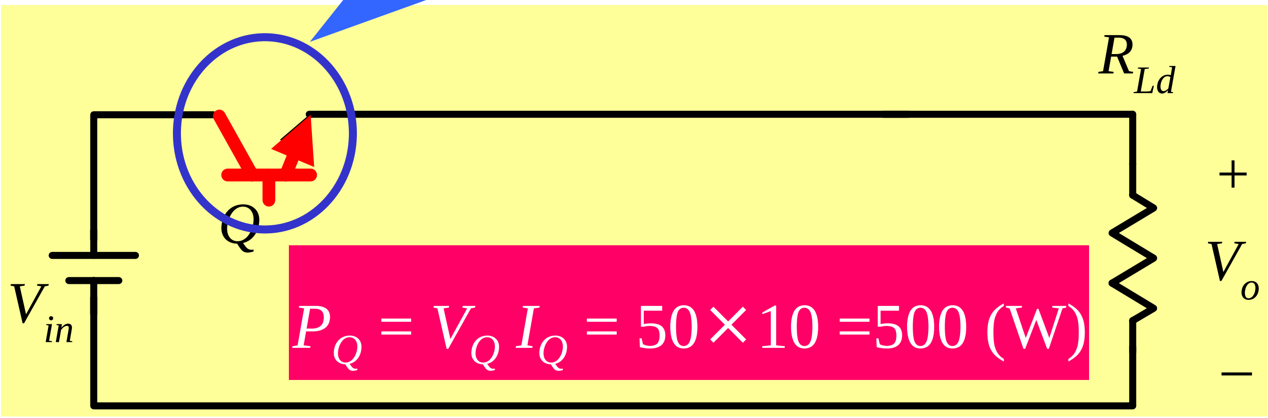
  ◎Four-switch: Full-bridge converter.

Linear DC Converter

Specifications:

- $V_{in} = 100$ V
- $V_o = 50$ V
- $I_o = 10$ A

$V_Q = 100 – 50 = 50$ (V)



$P_Q = V_Q\, I_Q = 50 \times 10 = 500$ (W)

Too ***Low*** Efficiency!!!

$\eta = V_o I_o / V_{in} I_o = V_o / V_{in}$

$= 50 / 100 = 50\%$

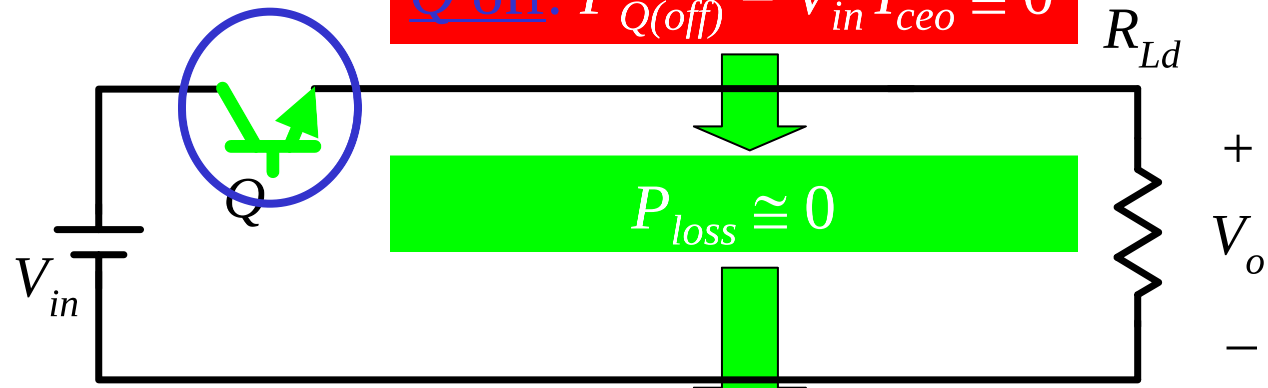
Switching-Mode DC Converter

Specifications:

- $V_{in} = 100$ V
- $V_o = 50$ V
- $I_o = 10$ A

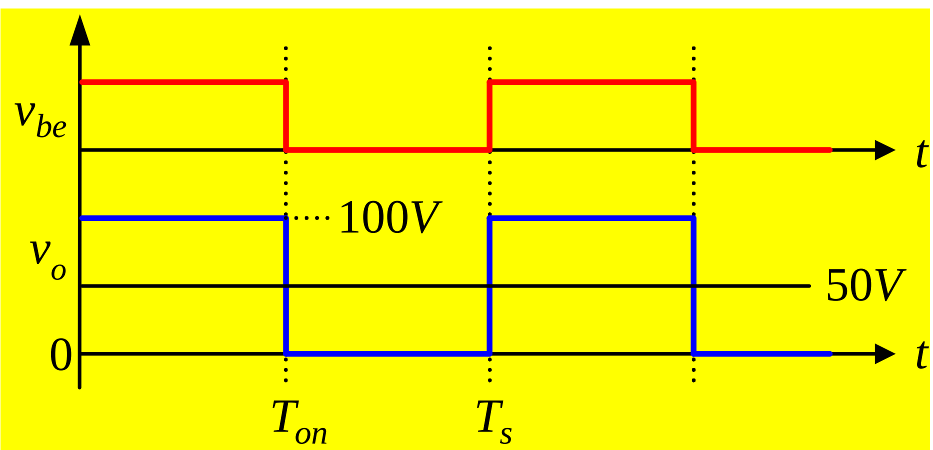
Q on: $P_{Q(on)} = V_{ces}\, I_o \cong 0$

Q off: $P_{Q(off)} = V_{in}\, I_{ceo} \cong 0$



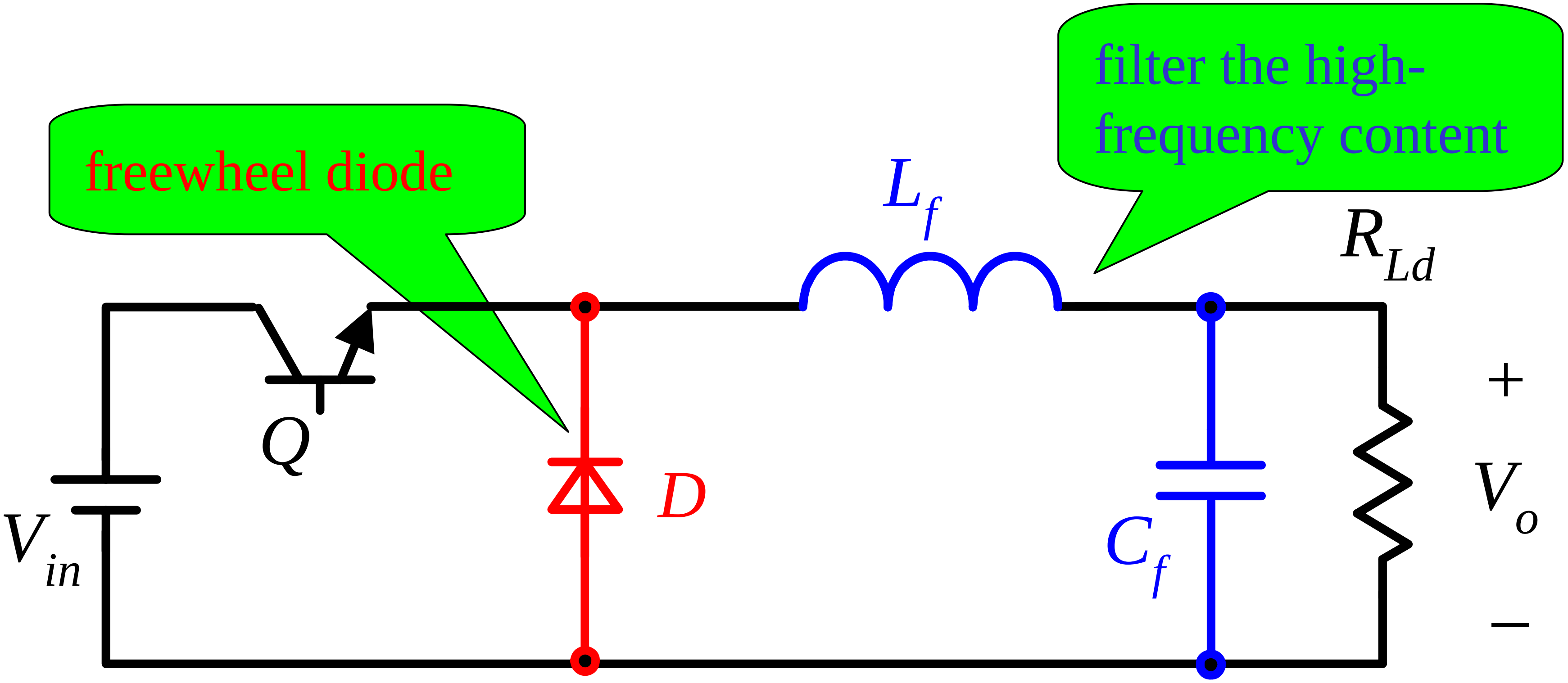
$P_{loss} \cong 0$

$\eta \cong 100\%$



High
Efficiency!!!

Derivation of Buck Converter



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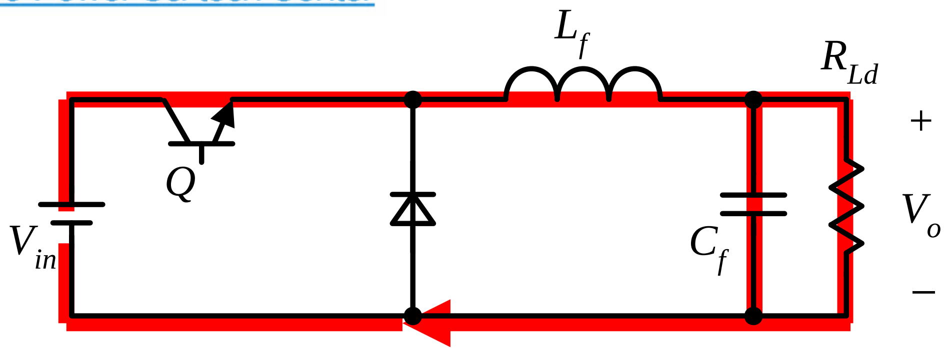
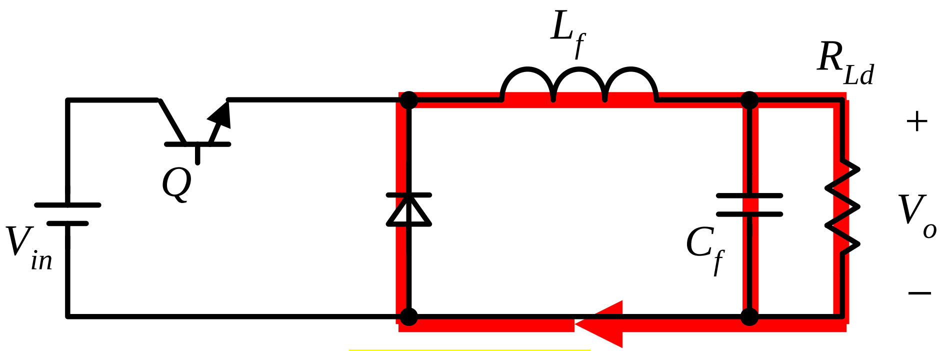
Operation Principle of Buck Converter: CCM

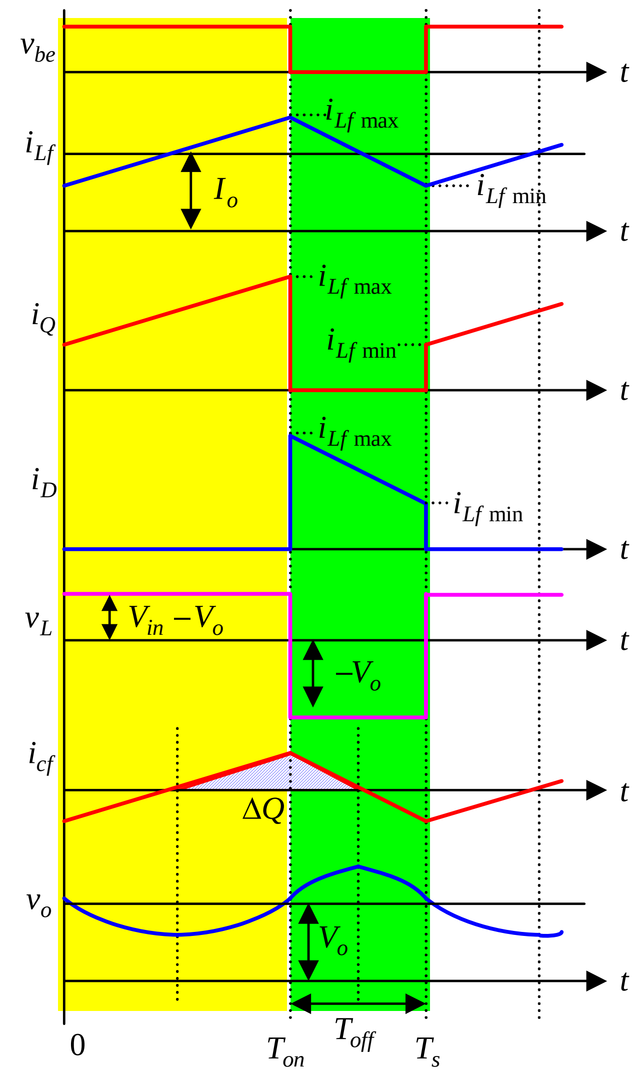


Q ON

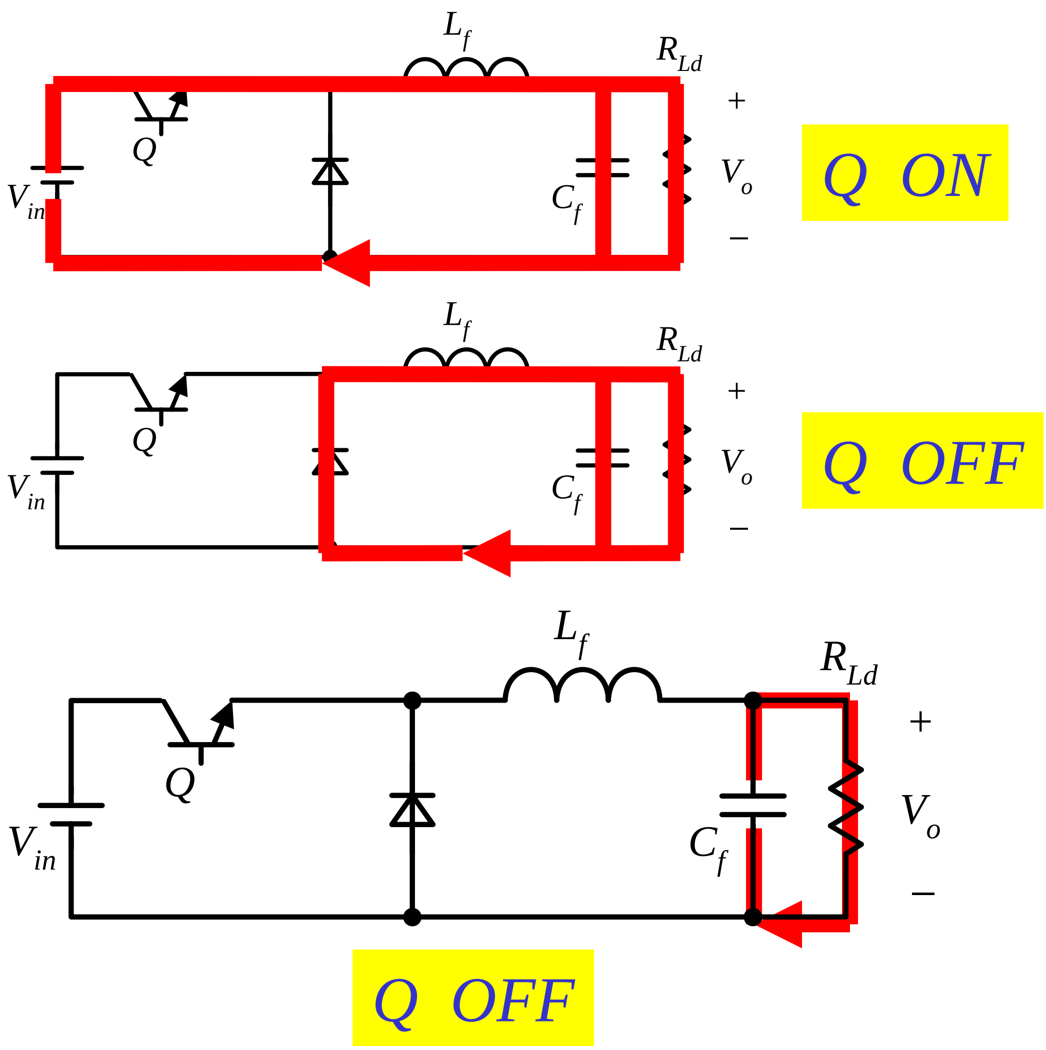


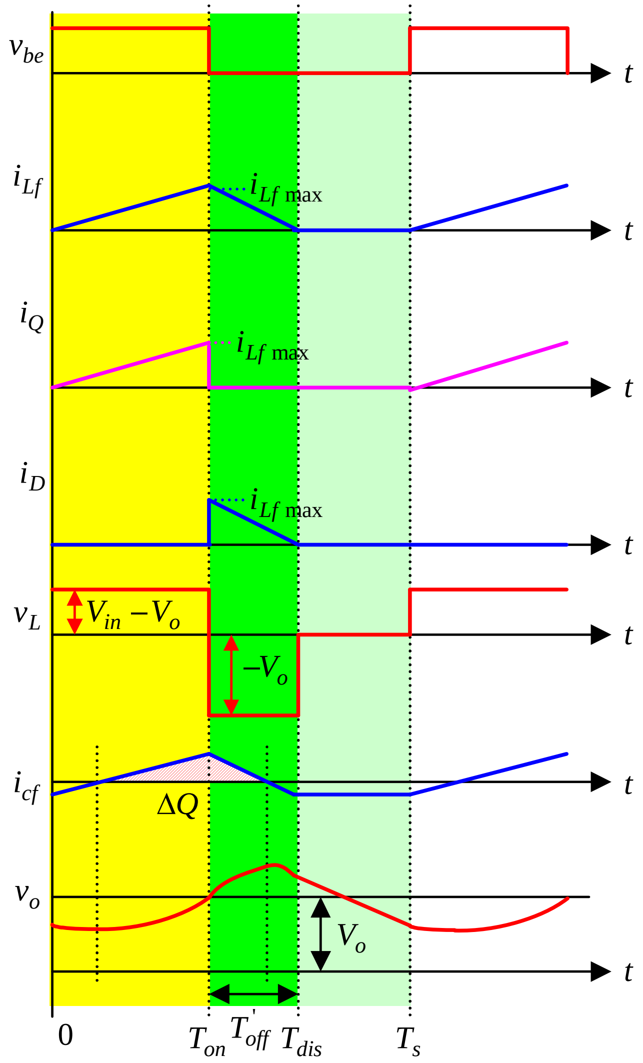
Q OFF

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

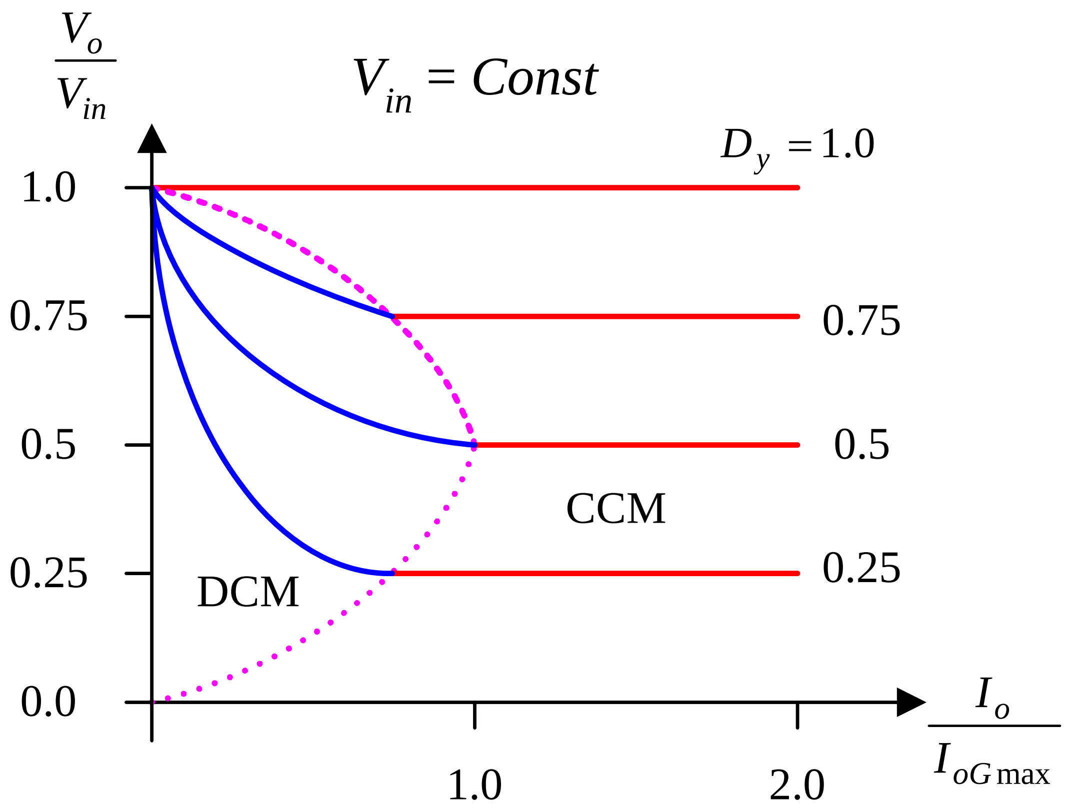


Operation Principle of Buck Converter: DCM

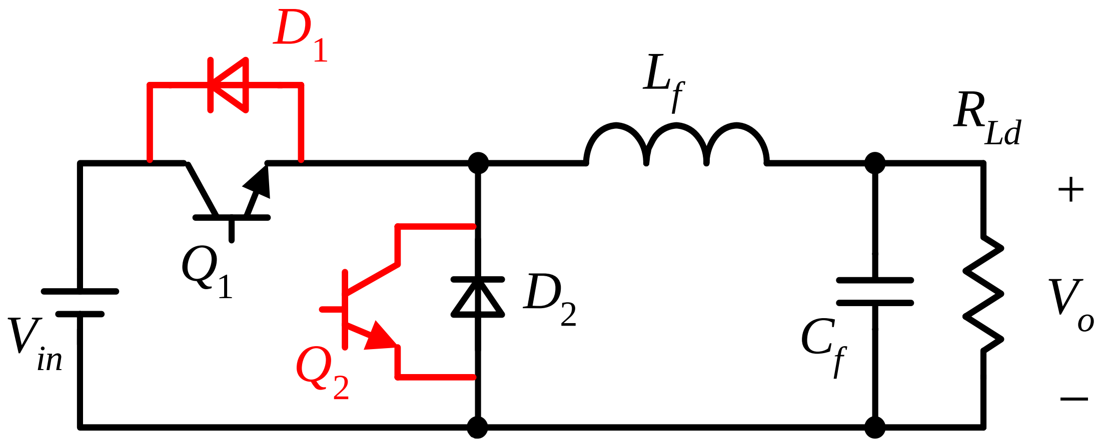




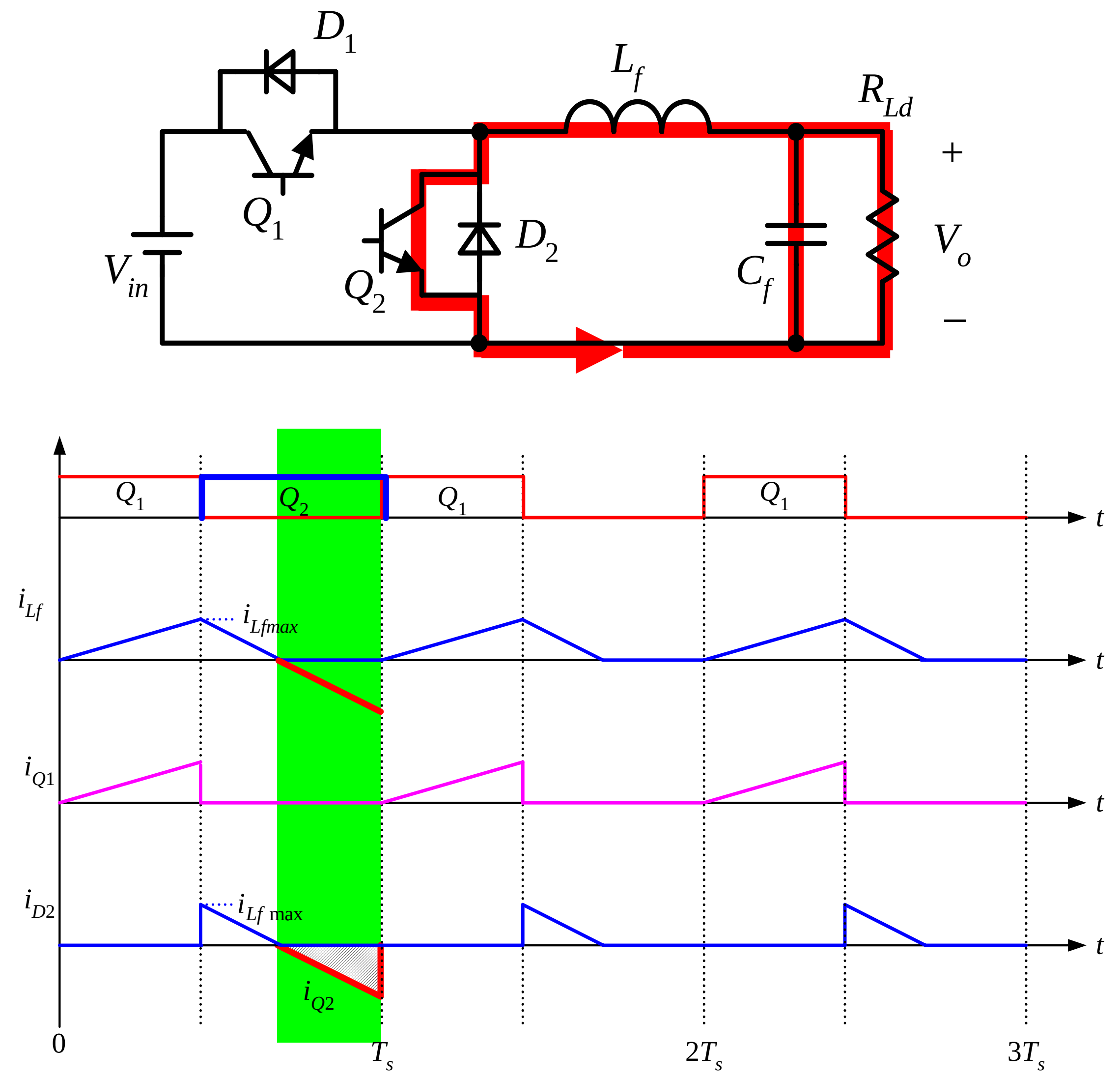
Voltage Conversion Ratio



Buck Converter with Bi-Direction Switches

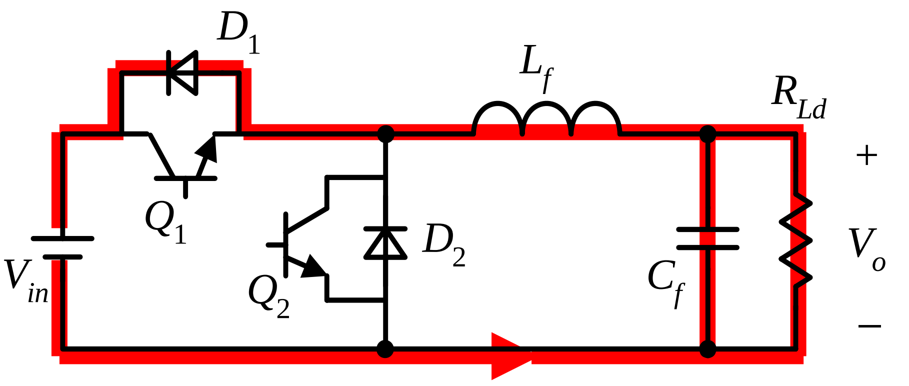


Buck Converter with Bi-Direction Switches

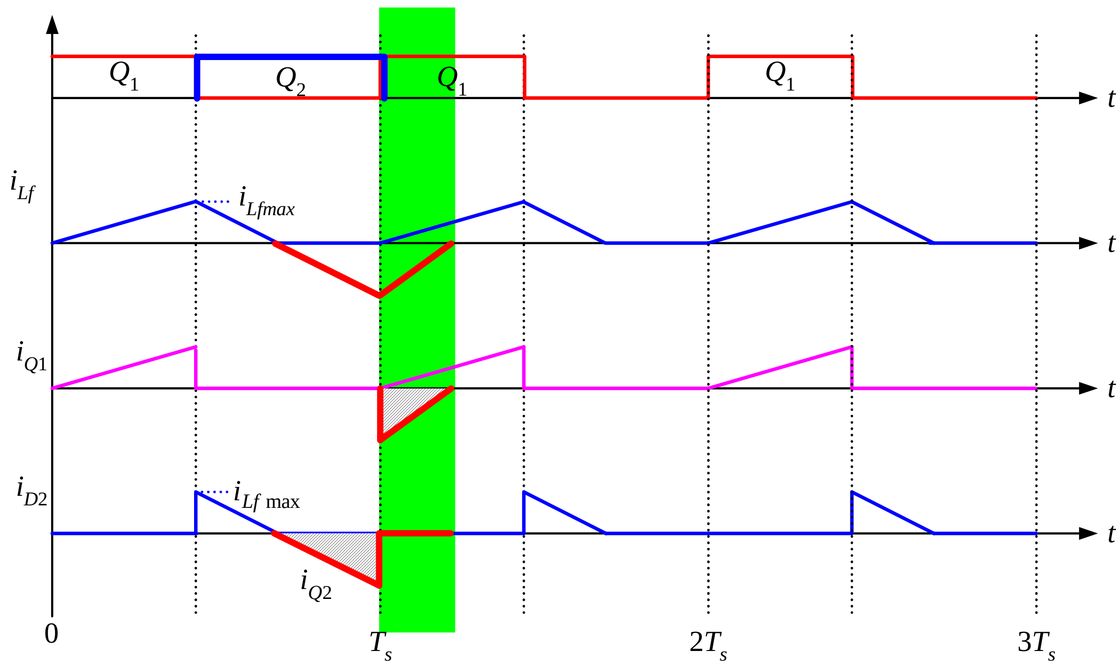


Q_1 OFF;
Q_2 ON.

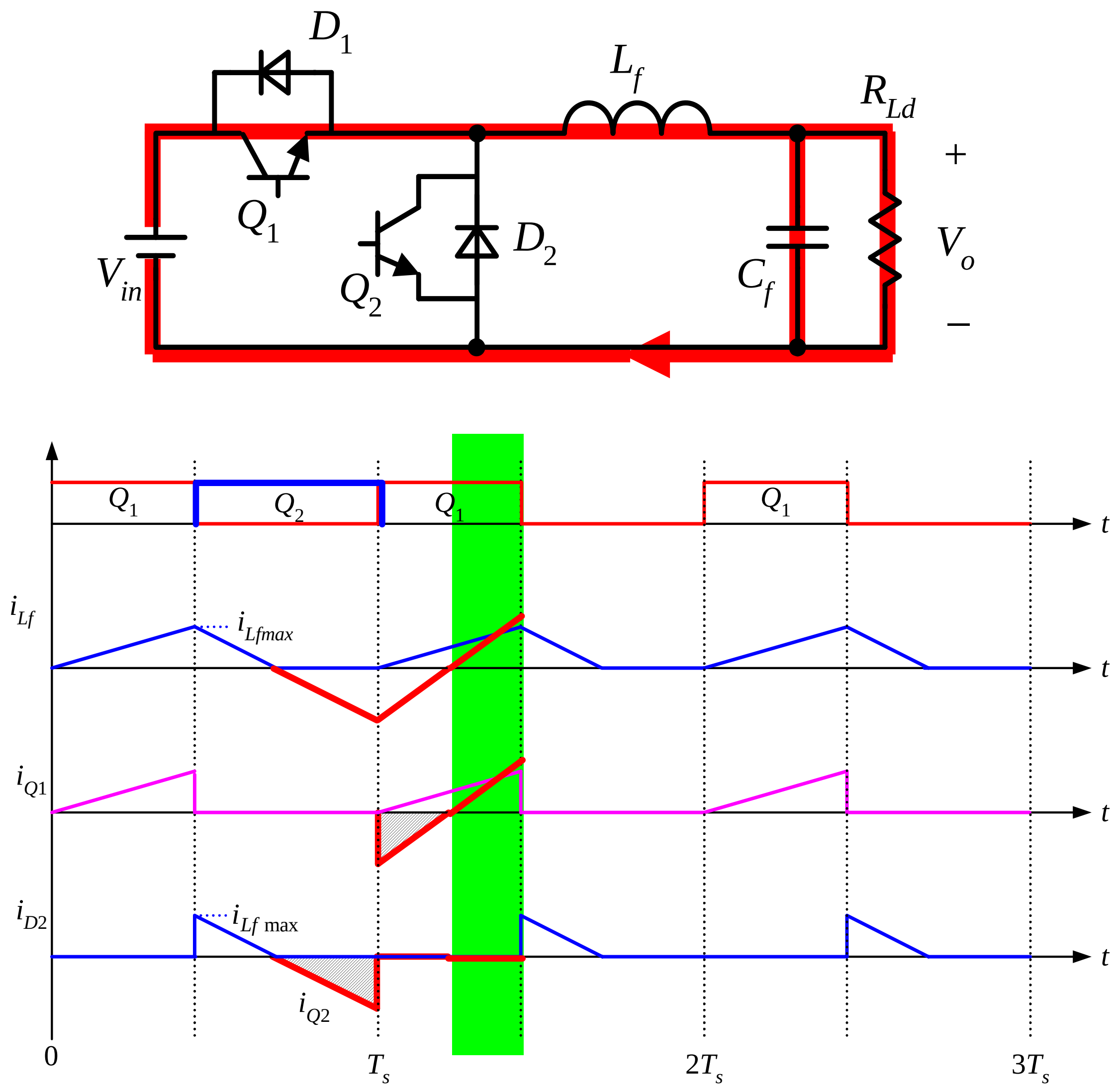
Buck Converter with Bi-Direction Switches



Q_1 ON
(D_1 Conduct);
Q_2 OFF.

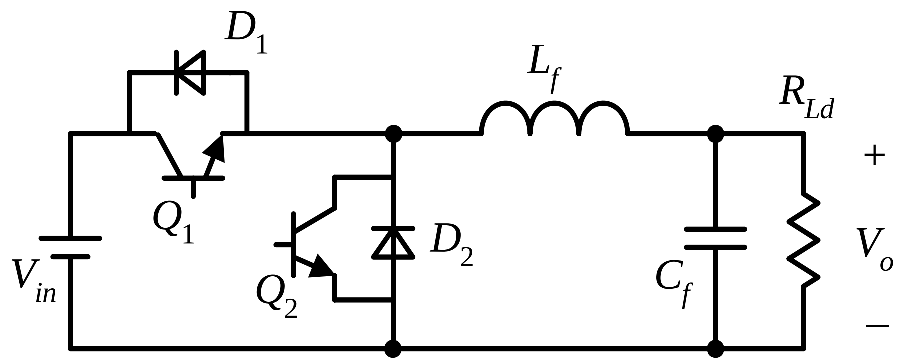


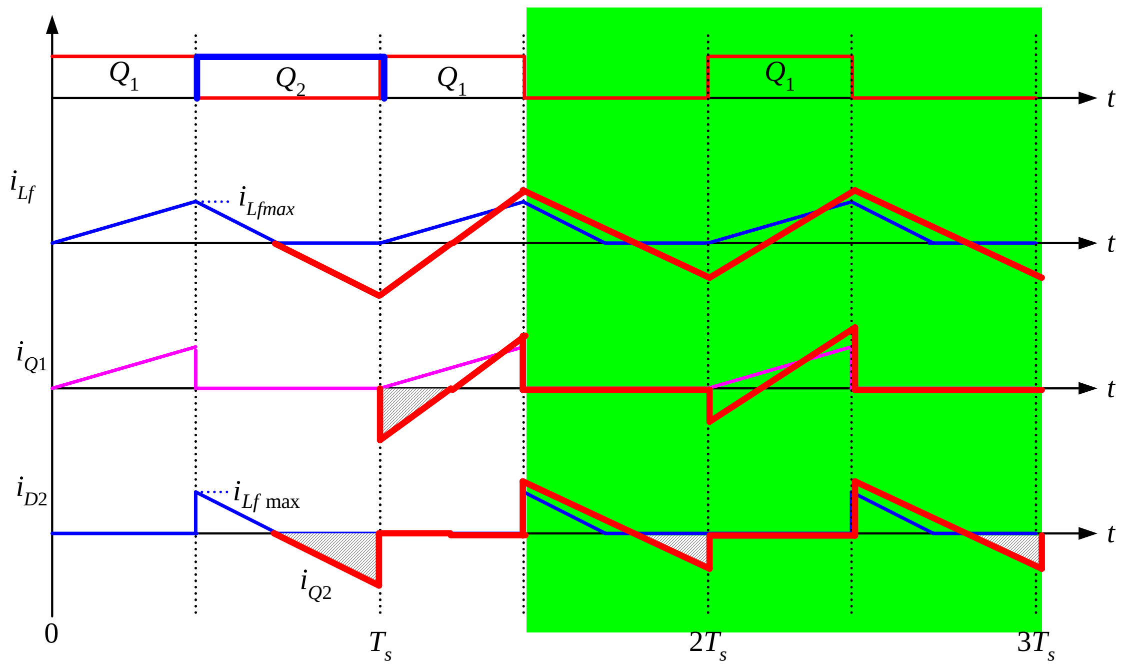
Buck Converter with Bi-Direction Switches



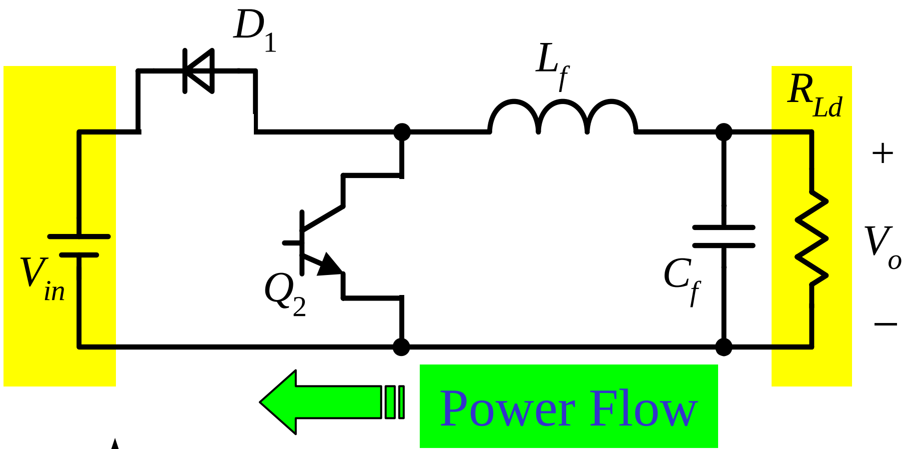
Q_1 *ON;*
Q_2 *OFF.*

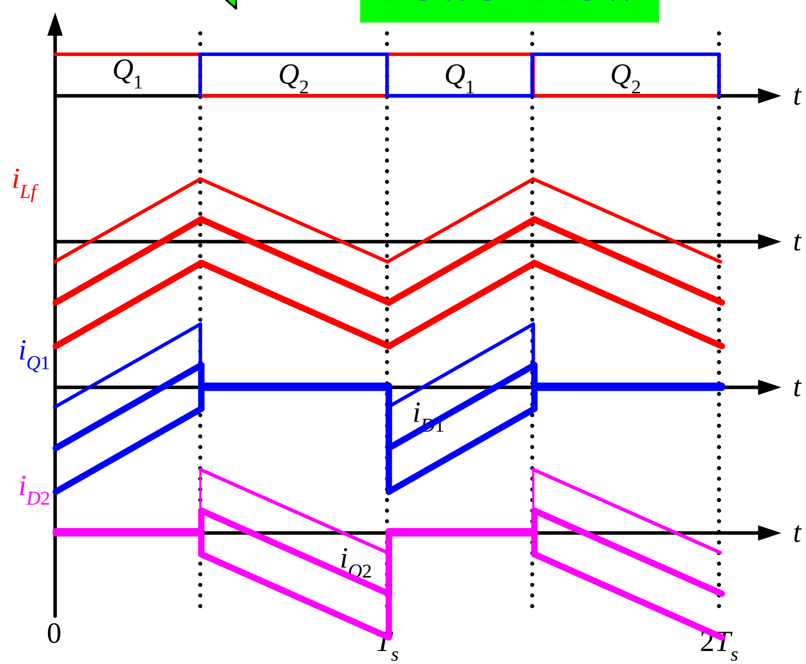
Buck Converter with Bi-Direction Switches

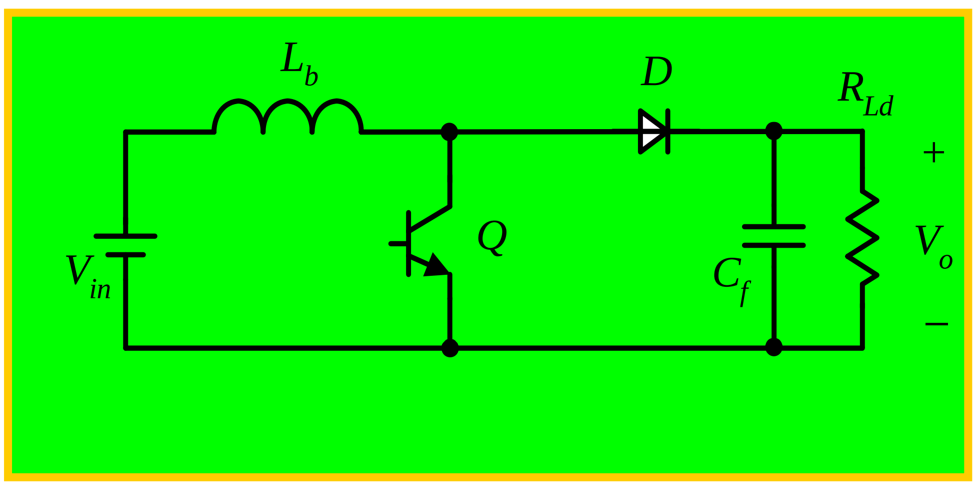




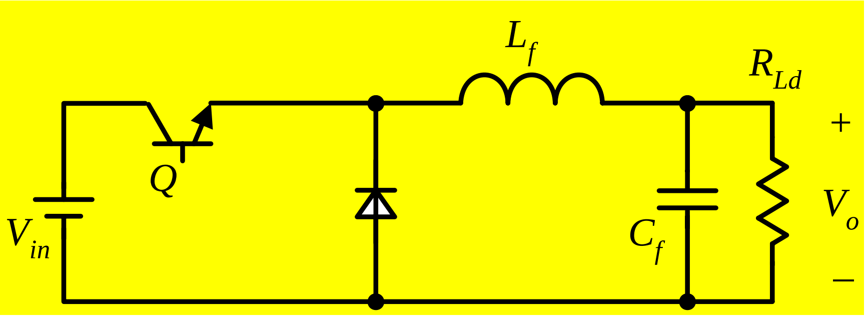
Buck Converter with Bi-Direction Switches





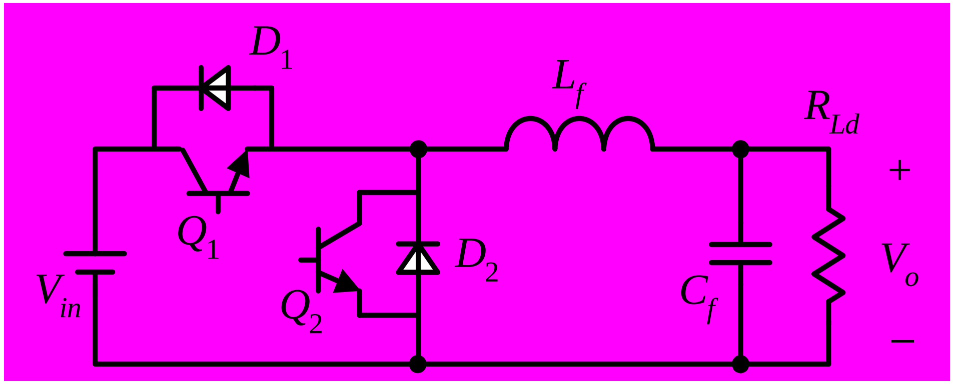


Voltage Conversion Ratio of Boost Converter



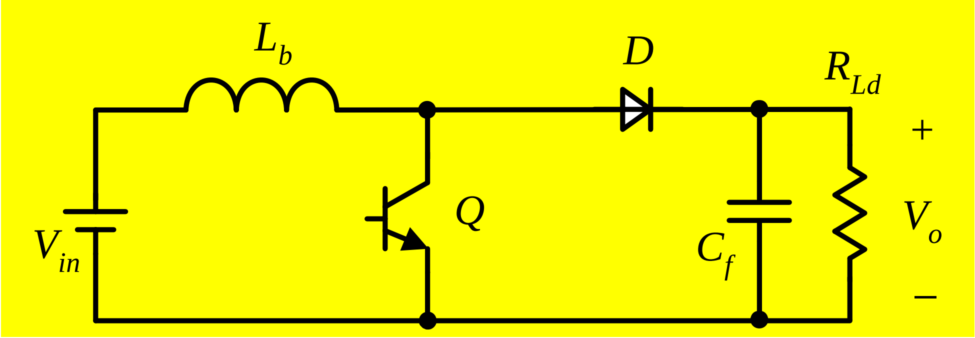
$$\frac{V_o}{V_{in}} = D$$

D is the duty cycle of Q_1



$$\frac{V_o}{V_{in}} = D$$

D is the duty cycle of Q_1



D is the duty cycle of Q_2

$$\frac{V_{in}}{V_o} = 1 - D$$

$$\boxed{\frac{V_o}{V_{in}} = \frac{1}{1-D}}$$

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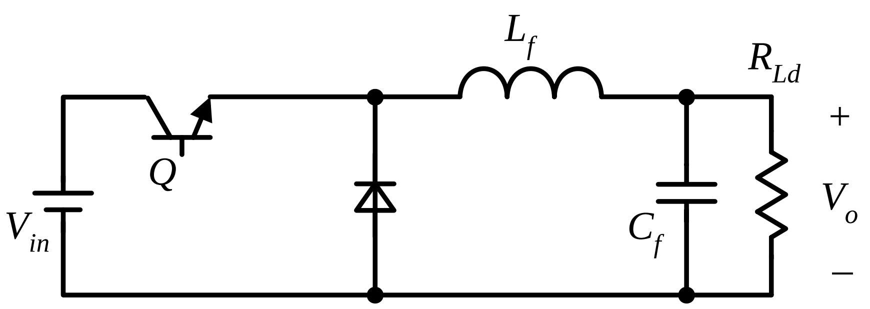
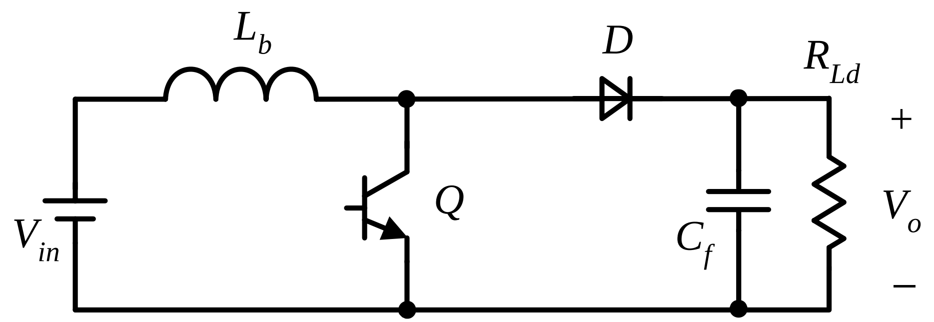
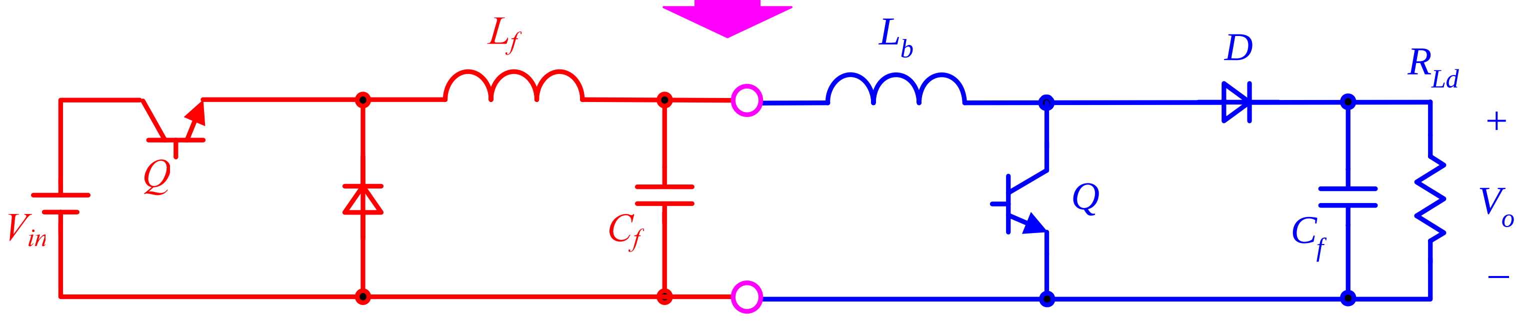
Why Buck-Boost Converter?





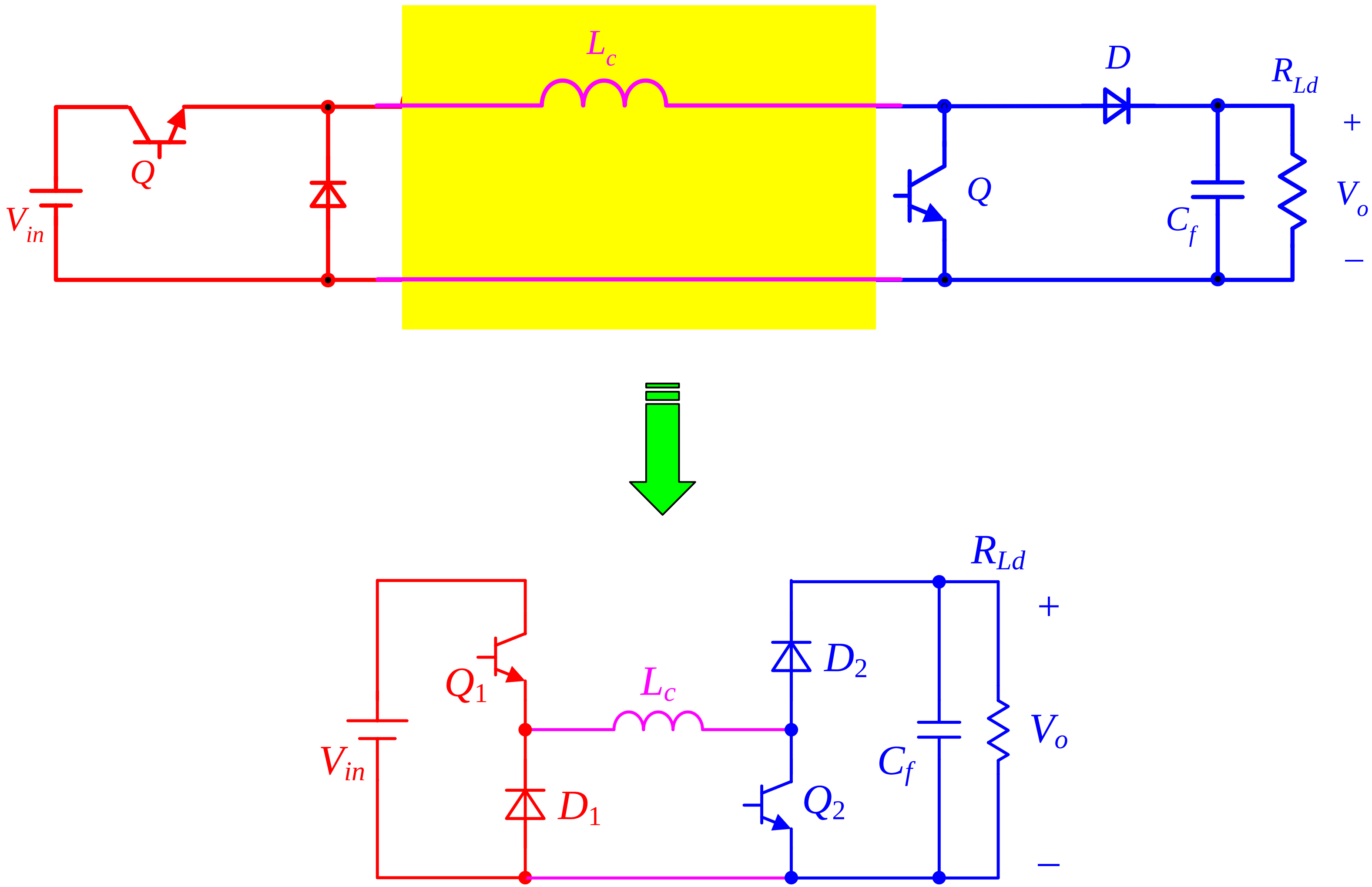
$V_o < V_{in}$

$V_o > V_{in}$

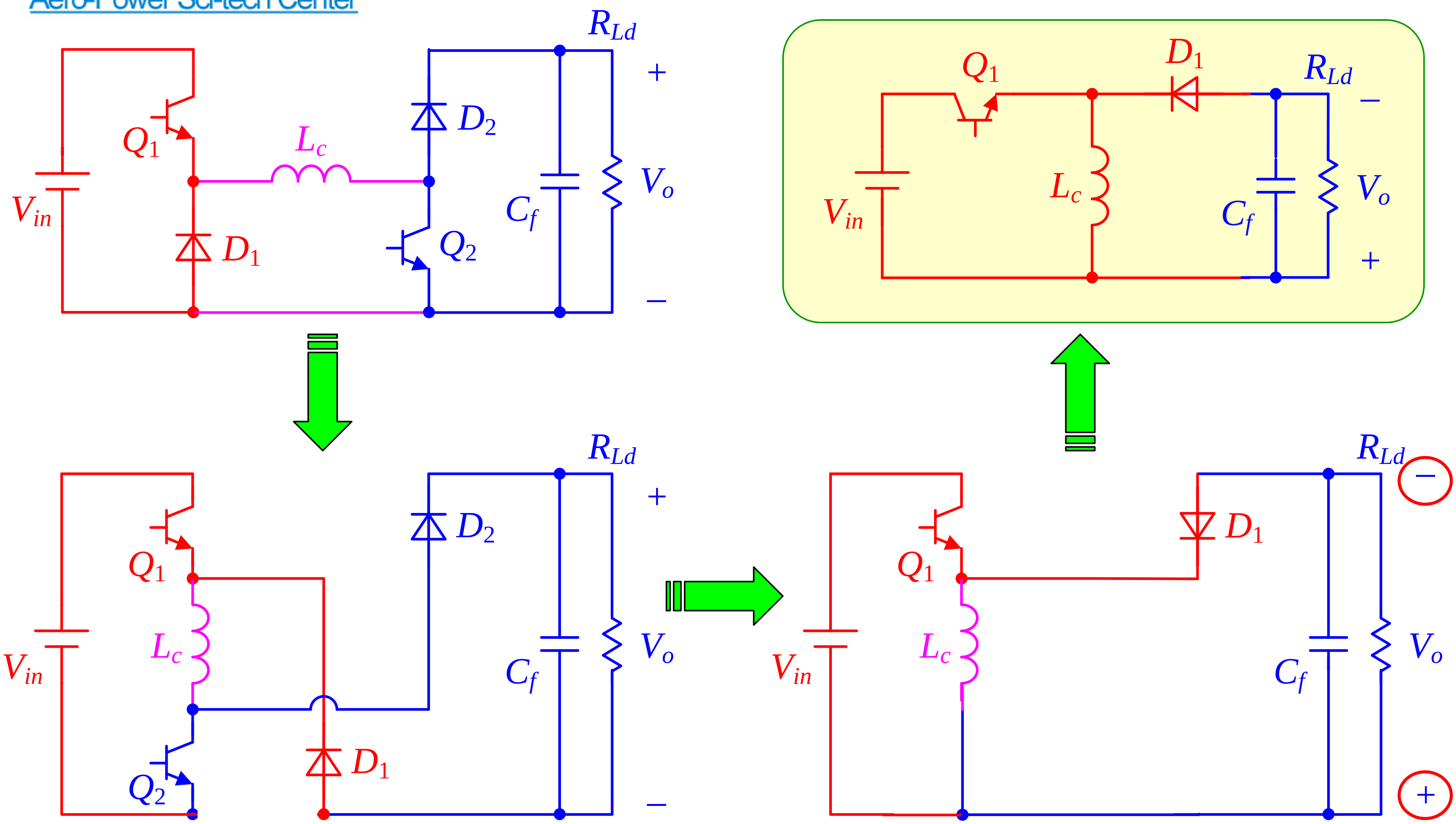


$$\frac{V_o}{V_{in}} = \frac{D_1}{1 - D_2}$$

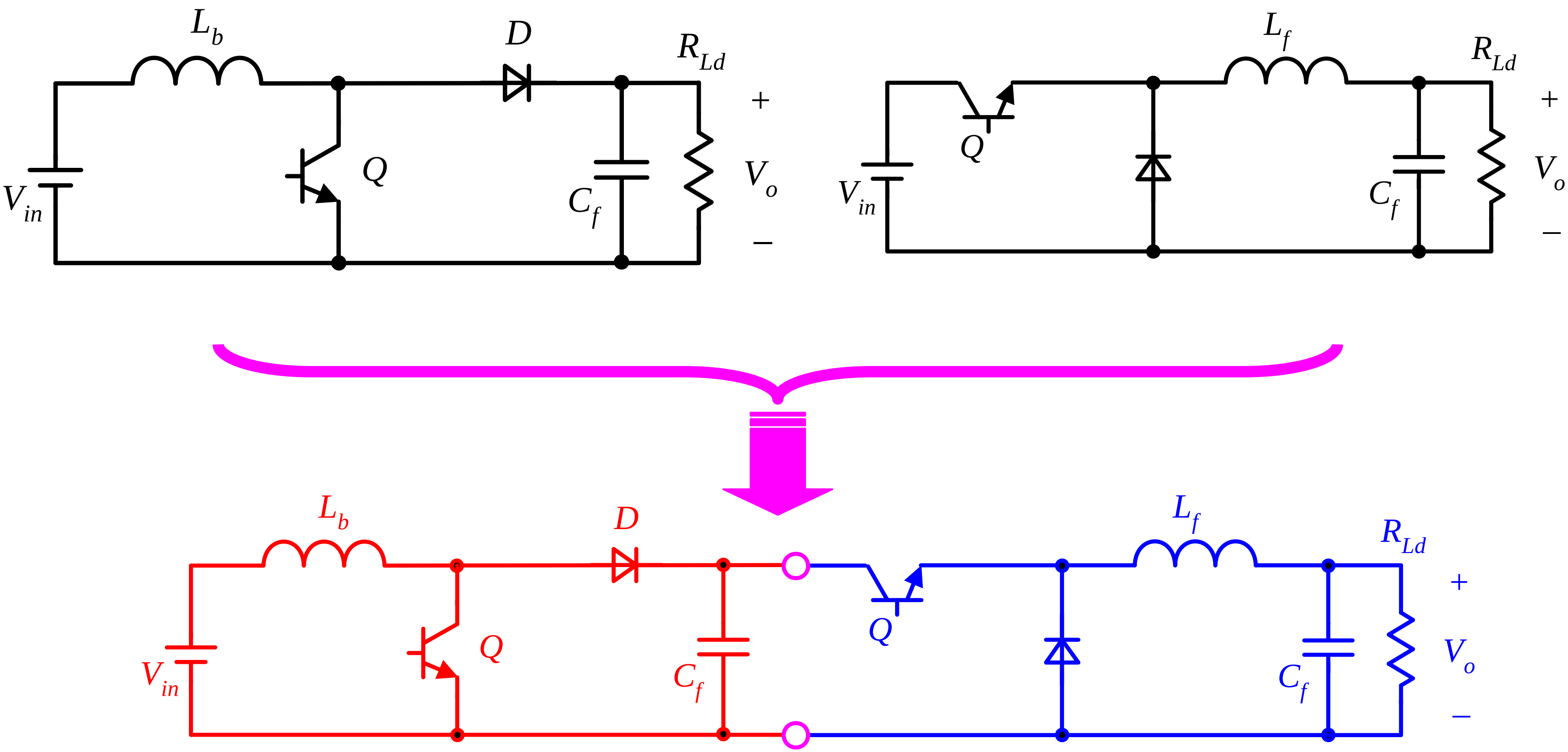
Simplification of Buck-Boost Converter (1)



Simplification of Buck-Boost Converter (2)

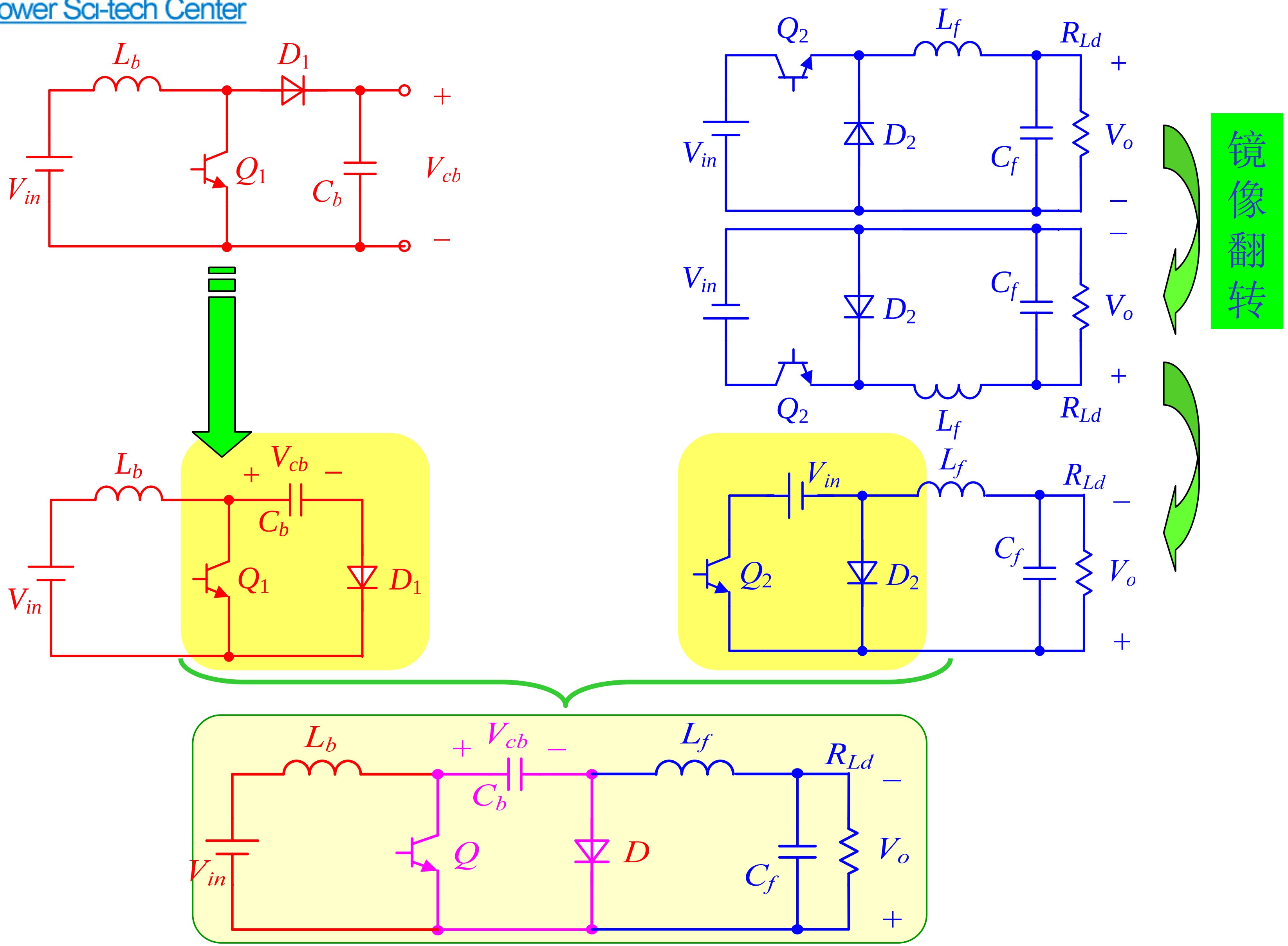


How to get Cuk?



$$\frac{V_o}{V_{in}} = \frac{D_1}{1 - D_2}$$

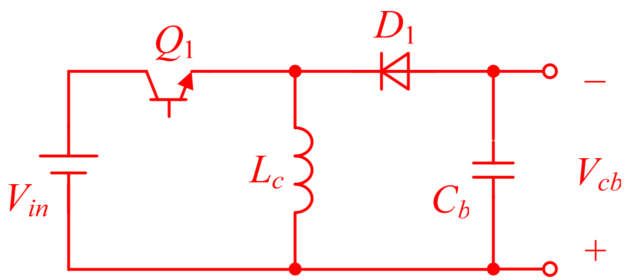
Derivation of Cuk



Derivation of Zeta

☹ Negative output voltage

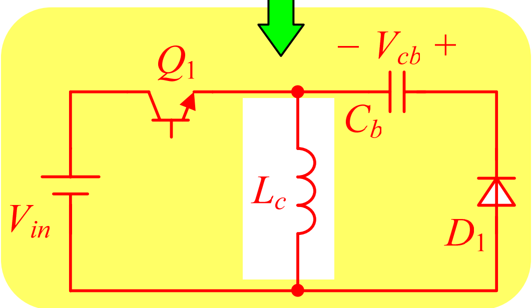
☝ Positive output voltage

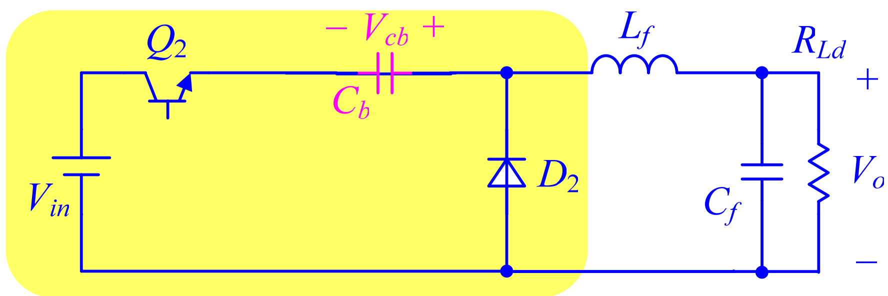


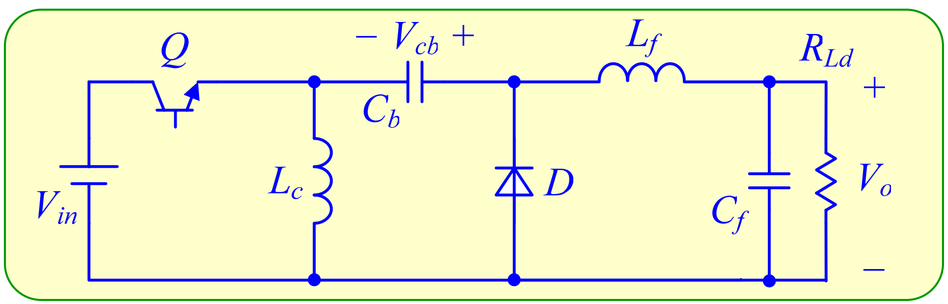
$$\frac{V_{cb}}{V_{in}} = \frac{D}{1-D}$$

$$V_o = \frac{D}{1-D}V_{in} = \left(1+\frac{D}{1-D}\right)DV_{in}$$

$$= D\left(V_{in} + \frac{D}{1-D}V_{in}\right)$$







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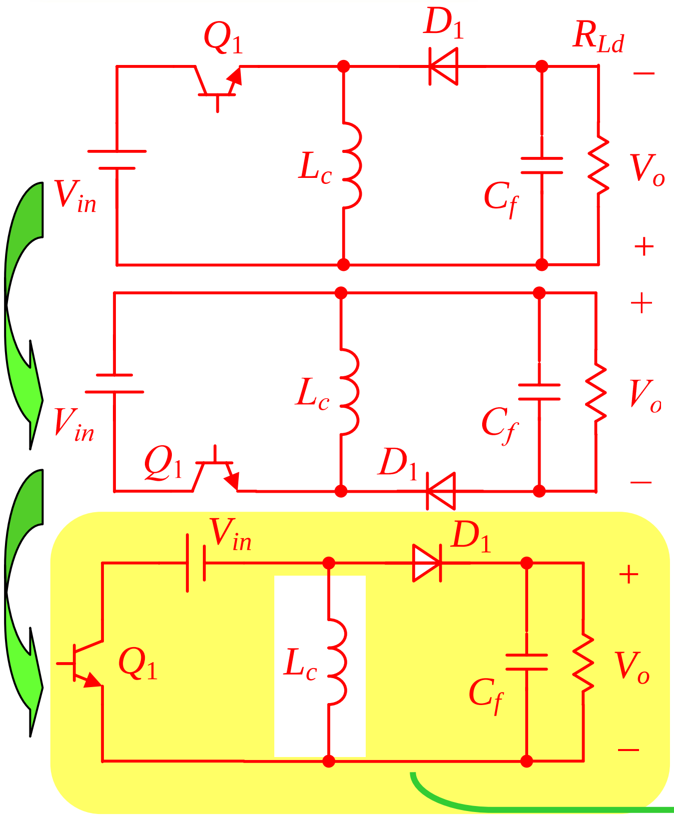
Derivation of SEPIC

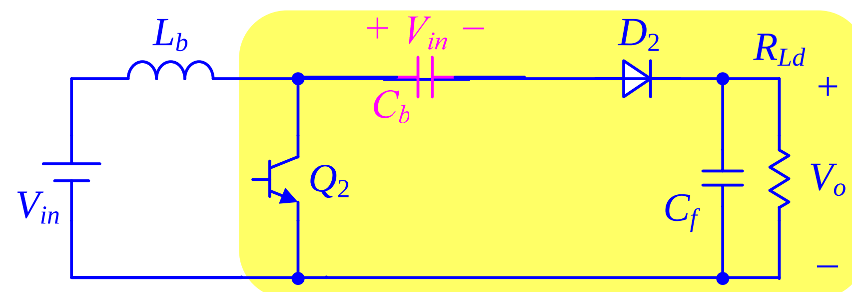


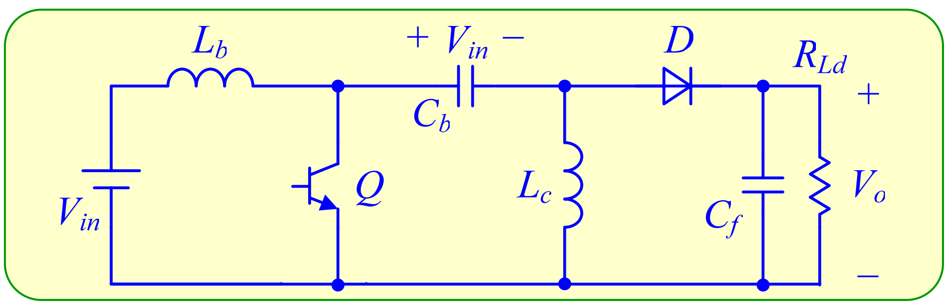
☹ Negative output voltage

$$\frac{V_{cb}}{V_{in}} = \frac{D}{1-D}$$

☝ Positive output voltage

$$V_o = \frac{D}{1-D}V_{in} = \frac{1}{1-D}V_{in} \boxed{-V_{in}}$$





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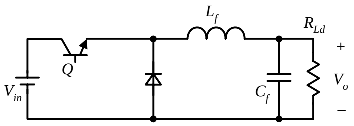
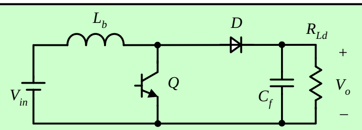
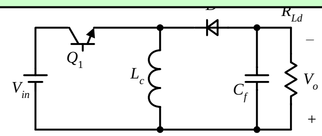
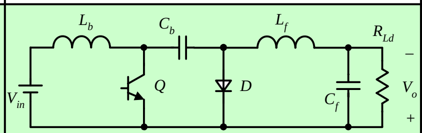
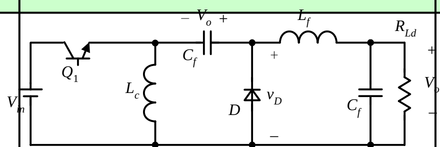
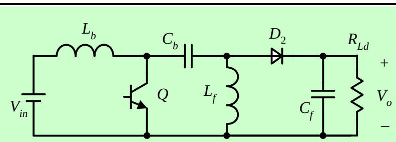
Comparison of the Six Converters

Converter	Topology	Voltage Conversion Ratio	Output Voltage Polarity	Input Current Ripple	Output Current Ripple	Configu-ration
Buck		$\frac{V_o}{V_{in}} = D$ $\downarrow$	+	Large	Small	Simple
Boost		$\frac{V_o}{V_{in}} = \frac{1}{1-D}$ $\uparrow$	+	Small	Large	Simple
Buck-Boost		$\frac{V_o}{V_{in}} = \frac{D}{1-D}$ $\downarrow\uparrow$	−	Large	Large	Simple
Cuk		$\frac{V_o}{V_{in}} = \frac{D}{1-D}$ $\downarrow\uparrow$	−	Small	Small	Complex
Zeta		$\frac{V_o}{V_{in}} = \frac{D}{1-D}$ $\downarrow\uparrow$	+	Large	Small	Complex
Sepic		$\frac{V_o}{V_{in}} = \frac{D}{1-D}$ $\downarrow\uparrow$	+	Small	Large	Complex

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Thanks for your attention !

Questions? / Answer!