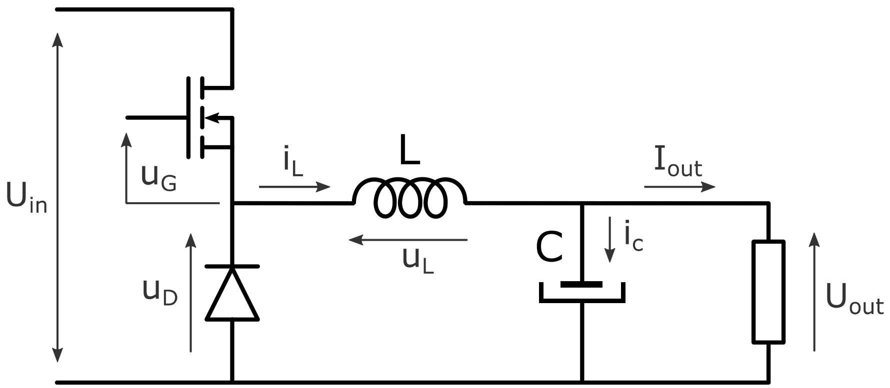
BUCK CONVERTER

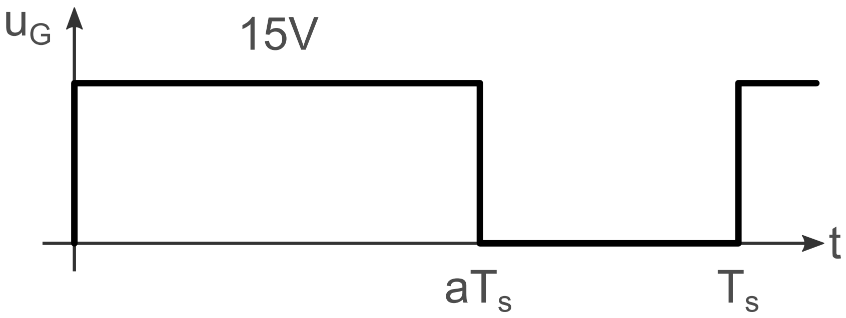
DC POWER SUPPLY

Buck converter – basic concepts

- The circuit:



- Modulation: Pulse width modulation (PWM)



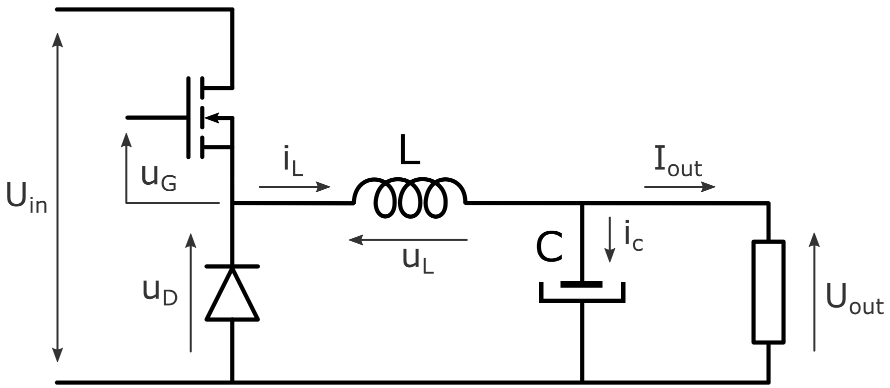
T_S – switching period

$f_S = 1/T_S$ – switching frequency

a – duty cycle

DC POWER SUPPLY

Assumptions and approximations



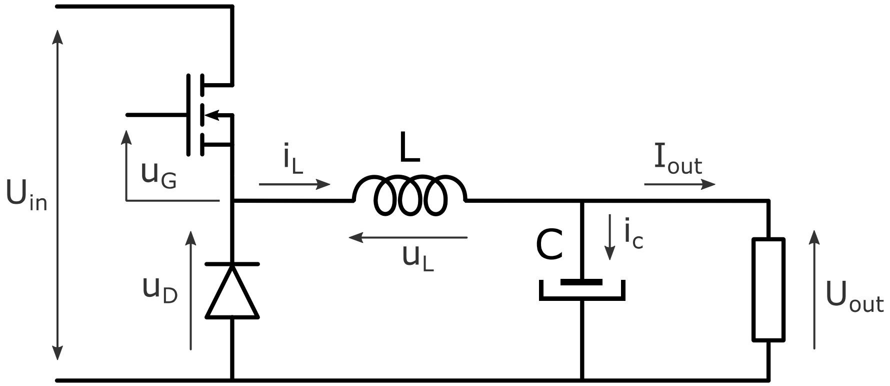
- Assumptions of importance DC power supply analysis:
  - Input voltage (U_{in}) oscillations can be neglected, within T_S period.
  - Output voltage (U_{out}) oscillations can be neglected while addressing other variables in the circuit ($\Delta U_{out} << U_{out}$).
  - Output current (I_{out}) oscillations can be neglected while addressing other variables in the circuit.

  - Parasitic elements (L,C) and neglected.
  - Resistances of the L and C are neglected.
  - Skin effect is not considered…

DC POWER SUPPLY

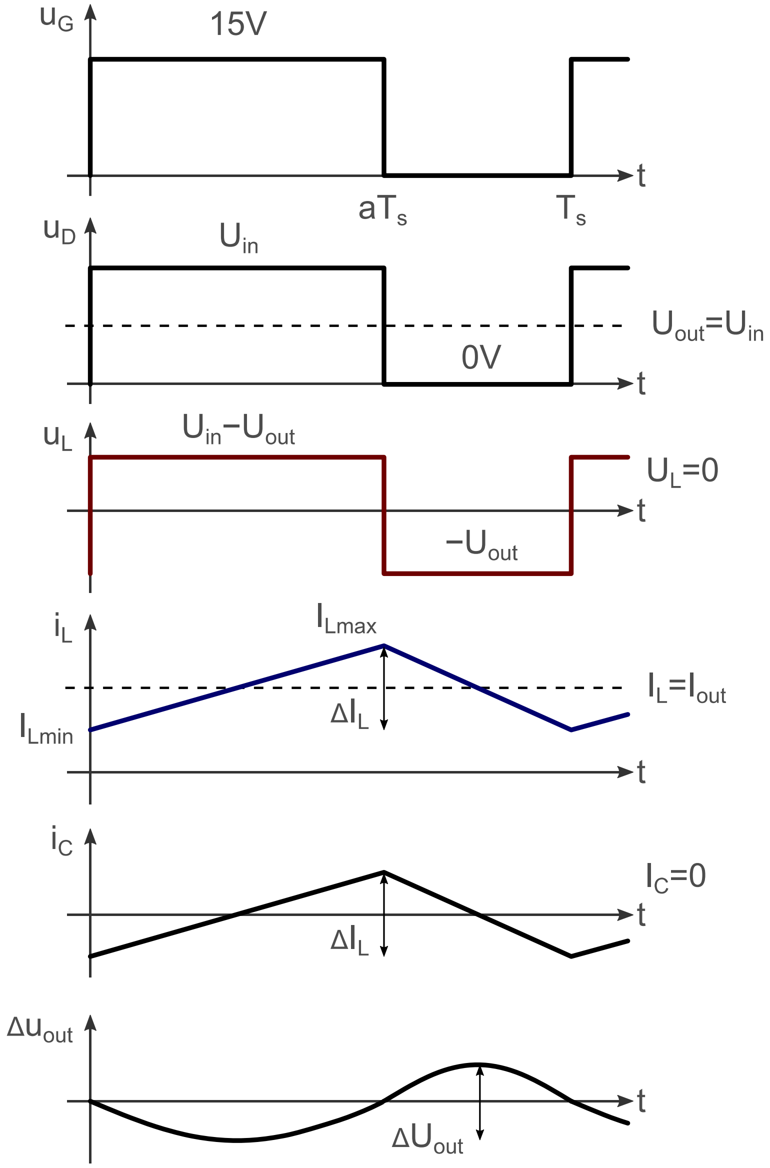
Assumptions and approximations

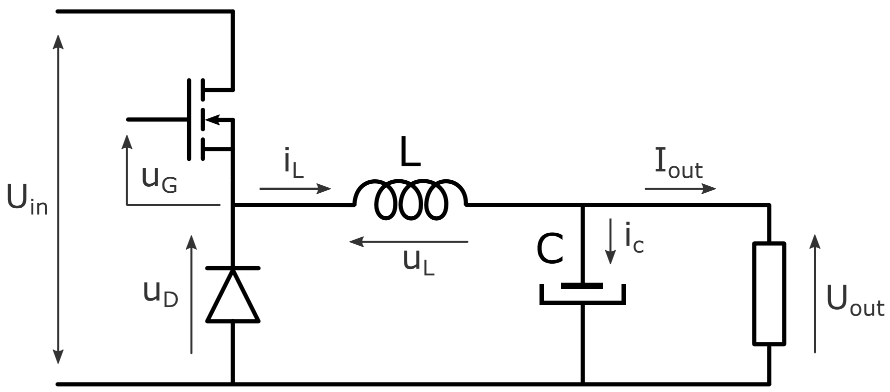
- Steady state:



DC POWER SUPPLY

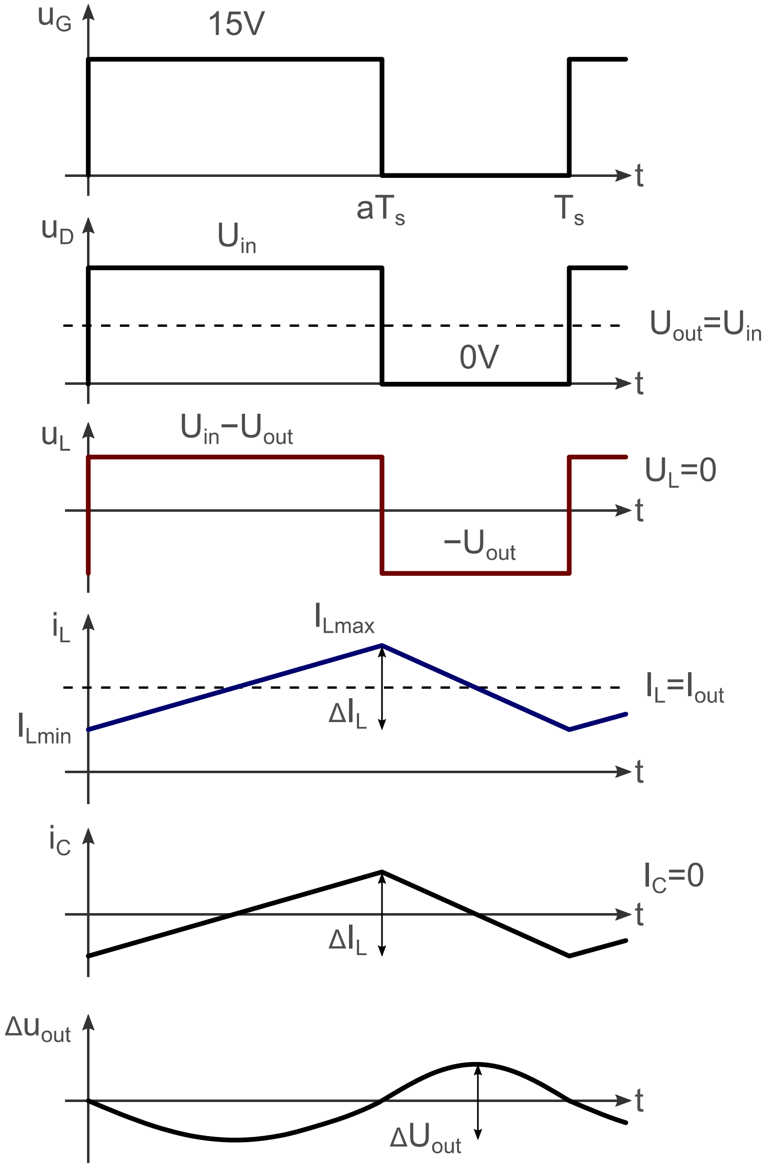
Buck - operation

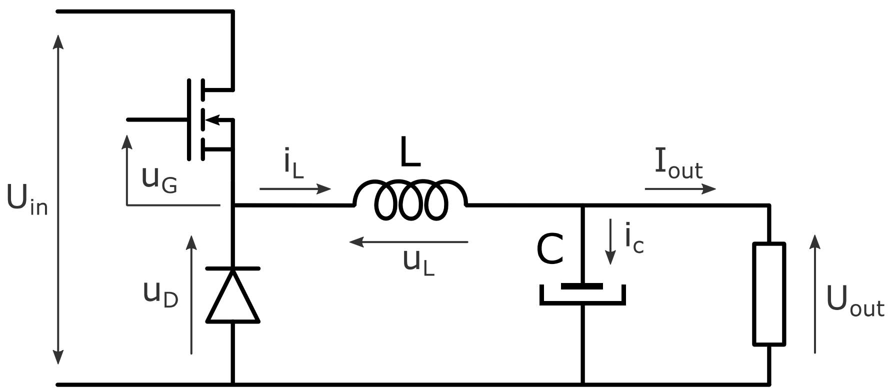




DC POWER SUPPLY

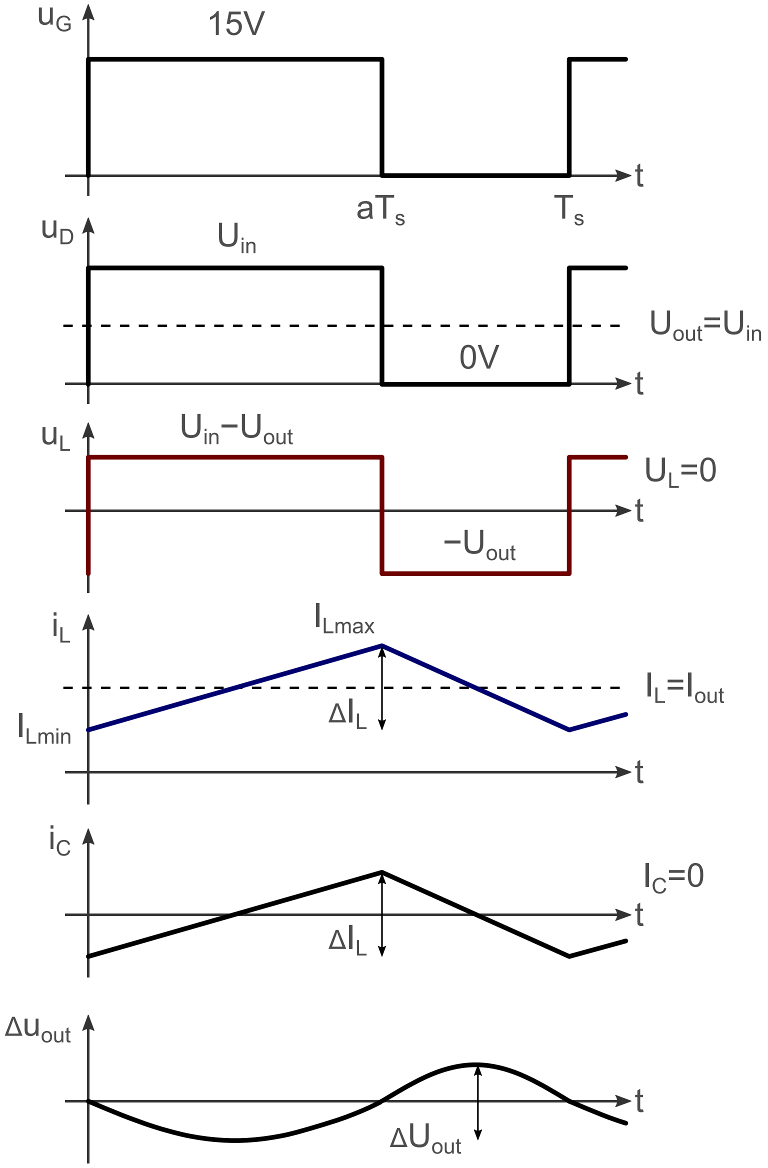
Buck - continuous conduction mode

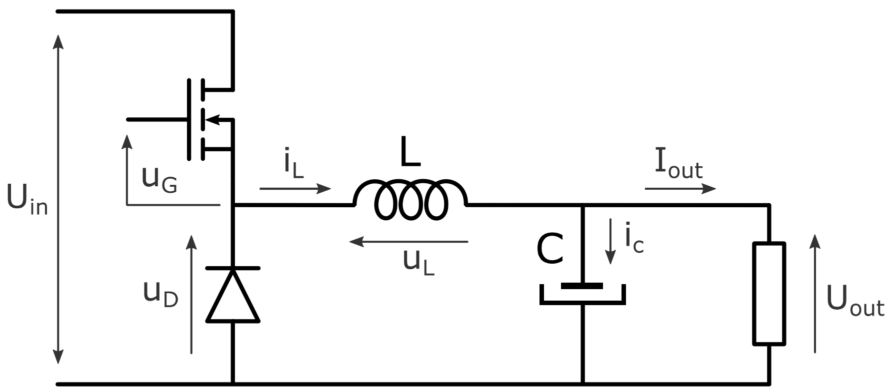




DC POWER SUPPLY

Buck - continuous conduction mode





- *Current "turns-ratio"*

$$P_{in} = P_{out}$$

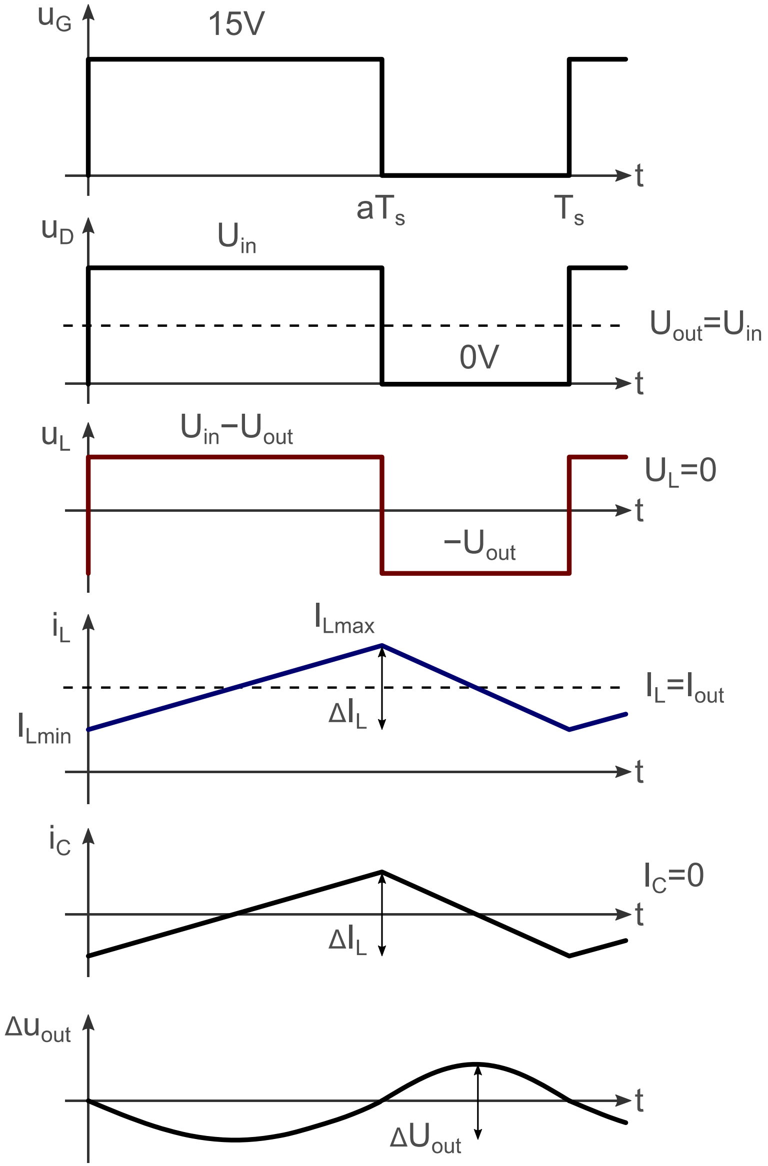
$$\Rightarrow U_{in} \cdot I_{in} = U_{out} \cdot I_{out}$$

$$\Rightarrow \frac{I_{out}}{I_{in}} = \frac{U_{in}}{U_{out}} = \frac{1}{a}$$

DC POWER SUPPLY

Buck - continuous conduction mode

Output filter (LC) design



- Inductance:

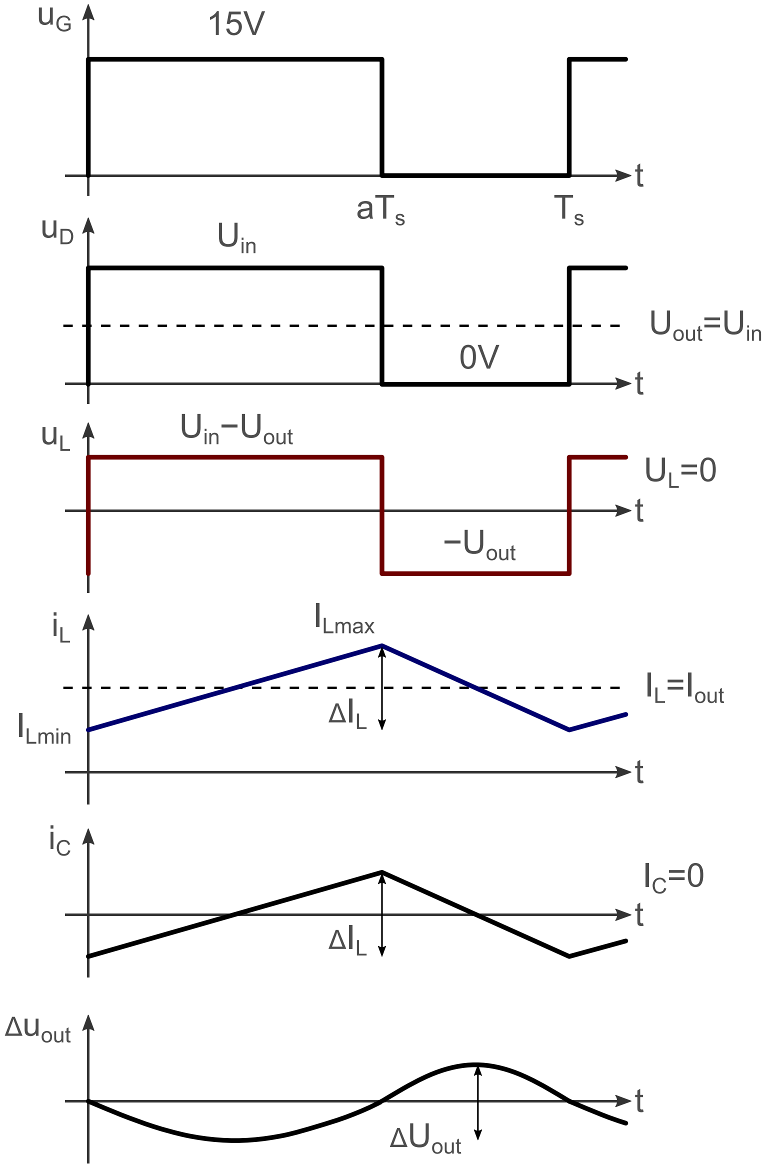
  Continuous conduction mode condition:

  $$I_L \geq \frac{\Delta I_L}{2}$$

DC POWER SUPPLY

Buck - continuous conduction mode

Output filter (LC) design



- Inductance:

  Continuous conduction mode condition:

$$I_{out} \geq \frac{1}{2} \cdot \frac{U_{out} \cdot (1-a)T_S}{L} \Rightarrow$$

$$L \geq \frac{U_{out} \cdot (1-a)T_S}{2 \cdot I_{out}}$$

Inductor choice:

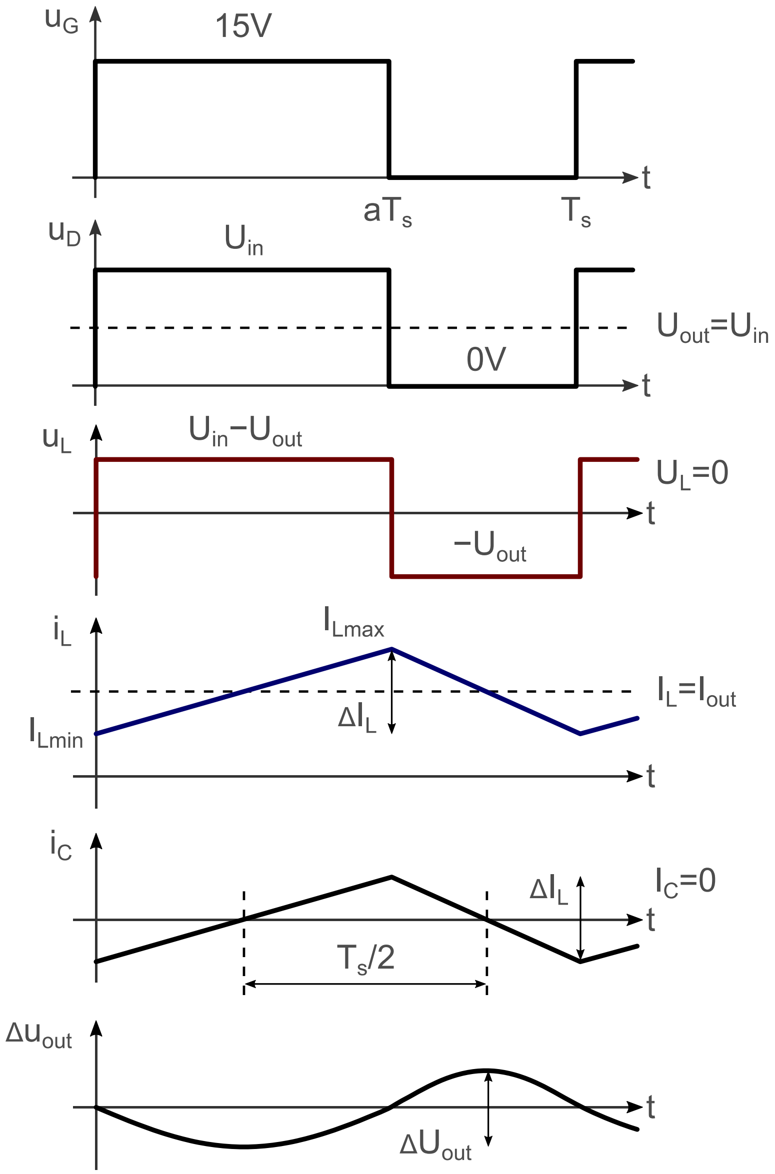
$$a = a_{min}, \quad I_{out} = I_{outmin}$$

$$\Rightarrow L \geq \frac{U_{out} \cdot T_S}{2 \cdot I_{outmin}} \cdot \left(1 - \frac{U_{out}}{U_{inmax}}\right)$$

DC POWER SUPPLY

Buck - continuous conduction mode

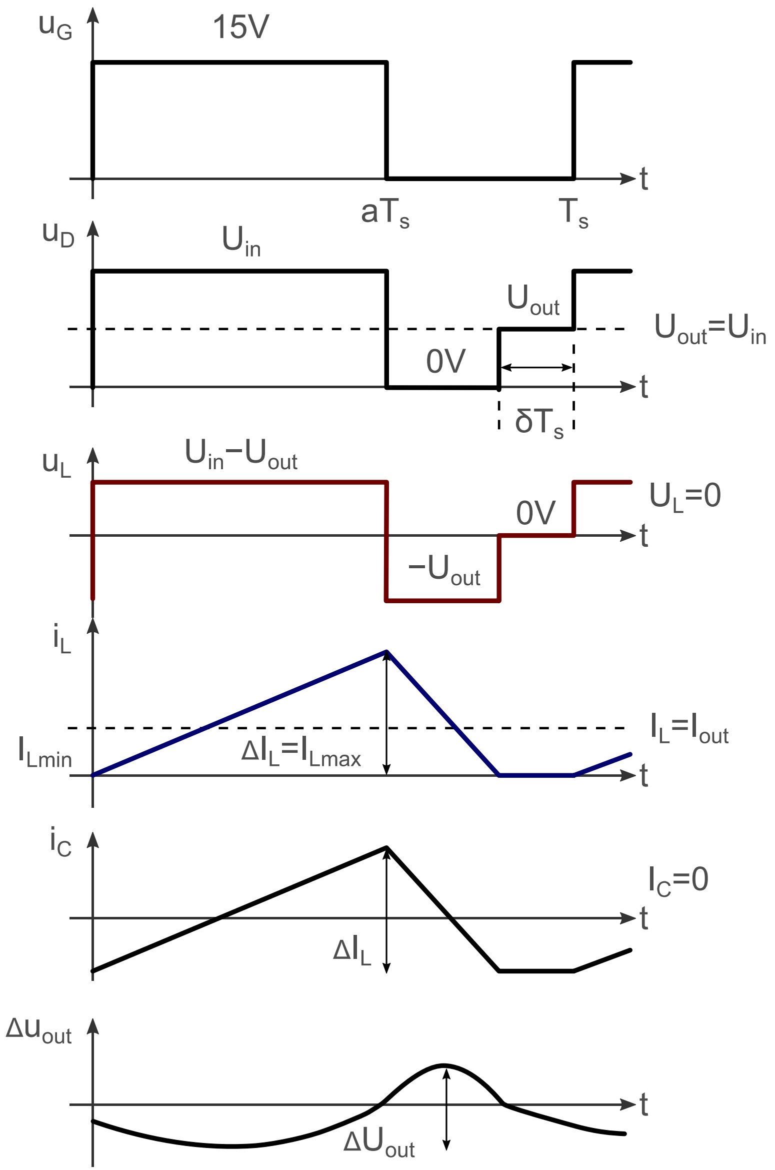
Output filter (LC) design

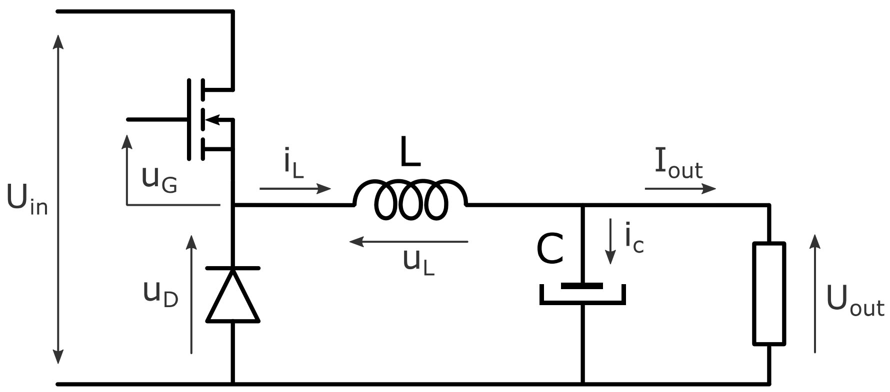


- Capacitance:

DC POWER SUPPLY

Buck - discontinuous conduction mode





- *Voltage "turns-ratio"*

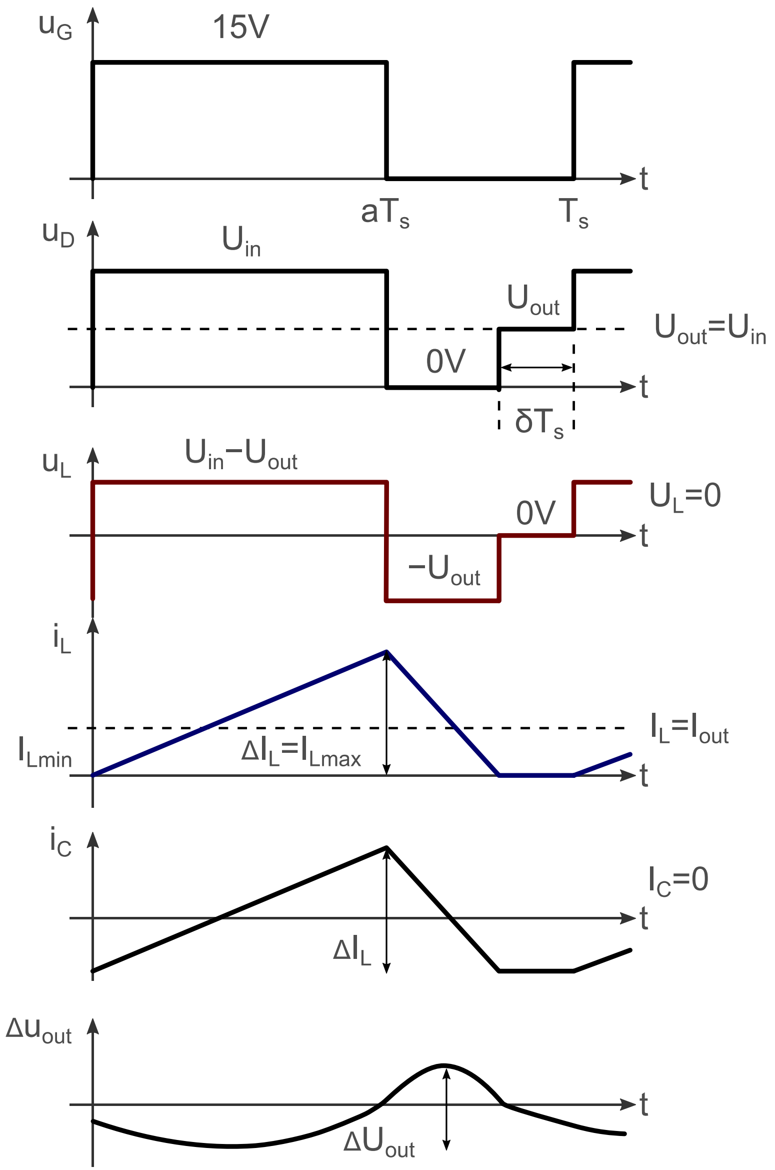
$$U_L = 0 \Rightarrow (U_{in} - U_{out}) \cdot aT_S = U_{out} \cdot (1 - a - \delta)T_S$$

$$\Rightarrow \frac{U_{out}}{U_{in}} = \frac{a}{1-\delta}$$

$$\Rightarrow \frac{I_{out}}{I_{in}} = \frac{U_{in}}{U_{out}} = \frac{1-\delta}{a}$$

DC POWER SUPPLY

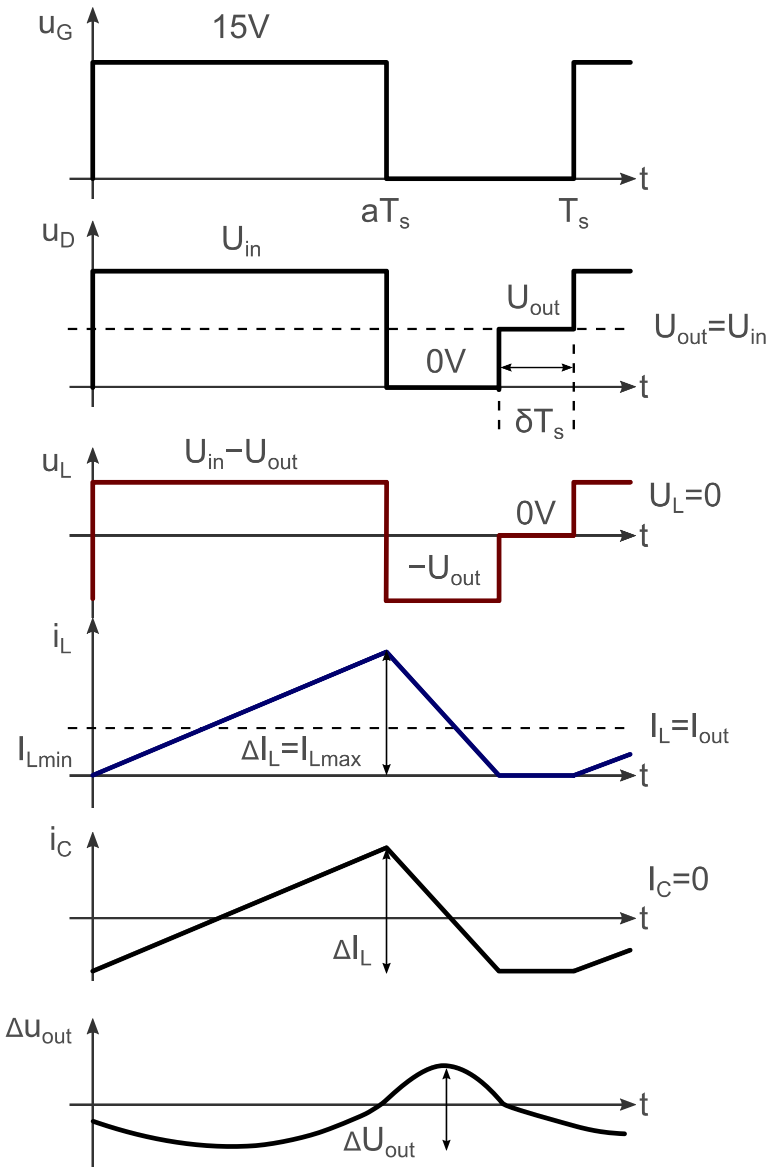
Buck - discontinuous conduction mode



- Duty cycle expression using known variables

DC POWER SUPPLY

Buck - discontinuous conduction mode



- Duty cycle expression using known variables

$$\frac{U_{out}}{U_{in}} = \frac{a}{1-\delta} \qquad (1)$$

$$I_{Lmax} = \frac{U_{out} \cdot (1-a-\delta)T_S}{L} \qquad (2)$$

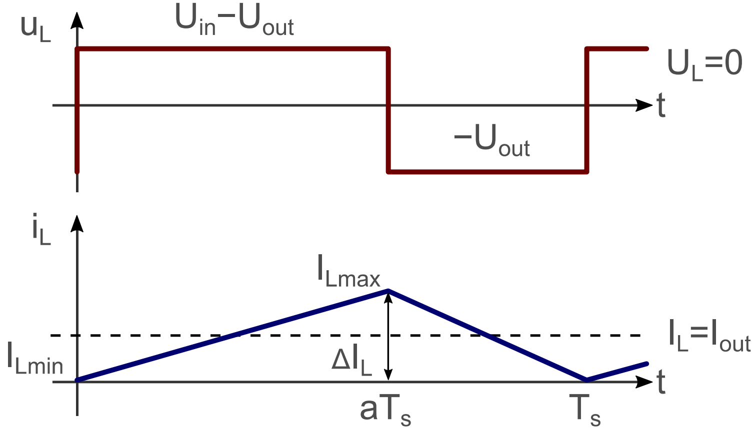
$$I_L = I_{out} = I_{Lmax} \cdot \frac{1-\delta}{2} \qquad (3)$$

$$\Rightarrow a^2 = \frac{2 \cdot L \cdot I_{out}}{T_S} \left(\frac{U_{out}}{U_{in}} \cdot \frac{1}{U_{in} - U_{out}}\right)$$

DC POWER SUPPLY

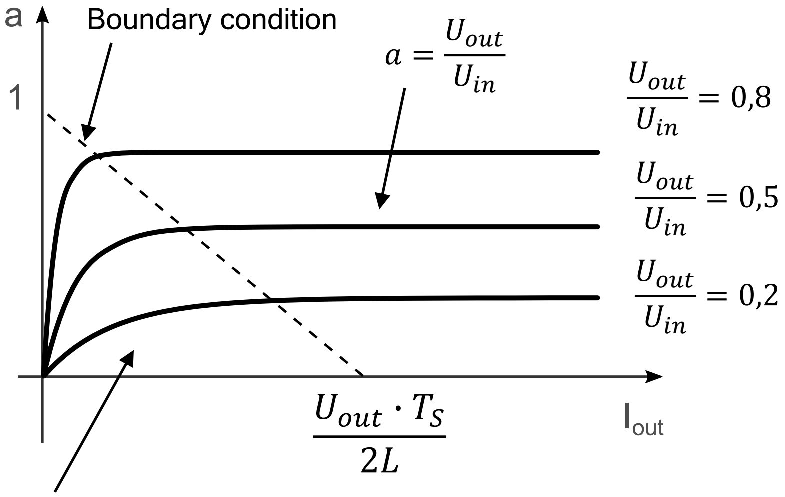
Buck – boundary operation

- Boundary condition:



$$I_{outb} = \frac{I_{Lmax}}{2} = \frac{U_{out} \cdot (1-a)T_S}{2L}$$

- Operating area:



$$a^2 = \frac{2 \cdot L \cdot I_{out}}{T_S} \left(\frac{U_{out}}{U_{in}} \cdot \frac{1}{U_{in} - U_{out}}\right)$$