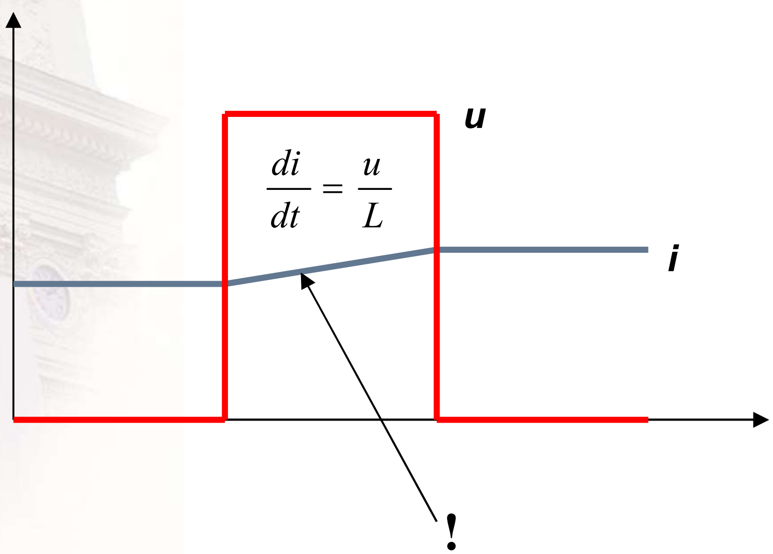
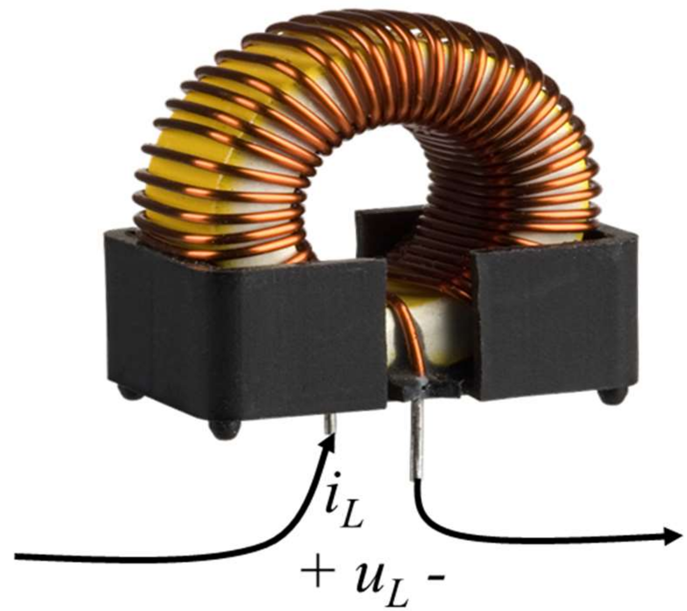
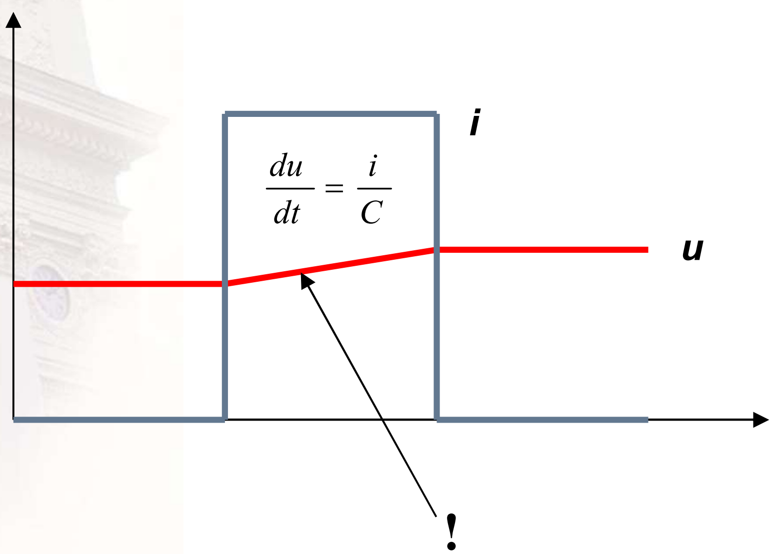
Lecture 2 – Bridges, switches and snubbers

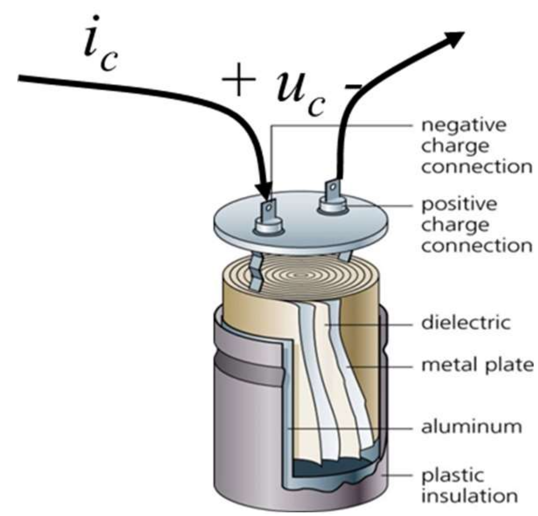
Summary
An inductance keeps a current ”constant”





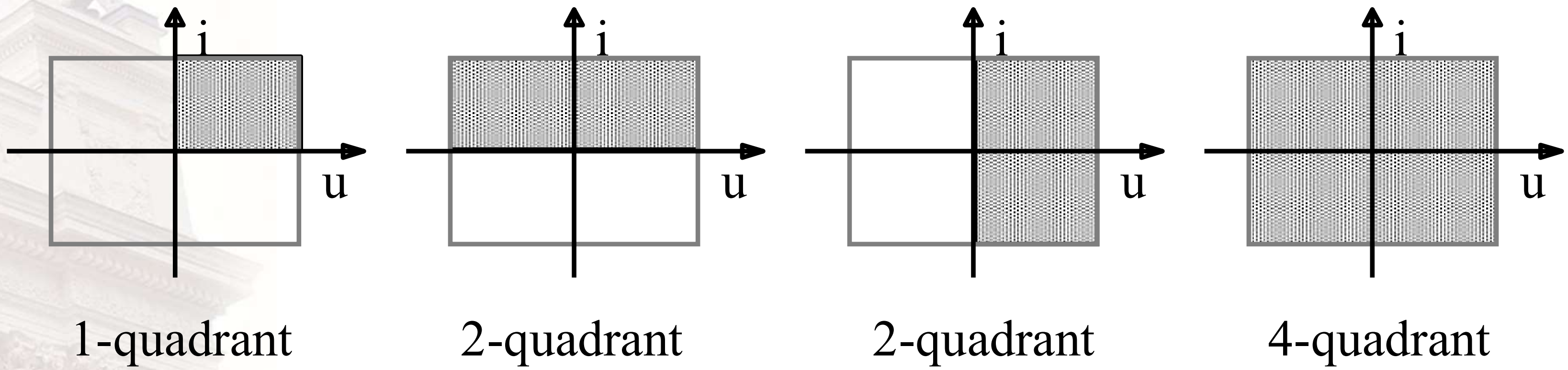
Summary
A capacitance keeps a voltage ”constant”



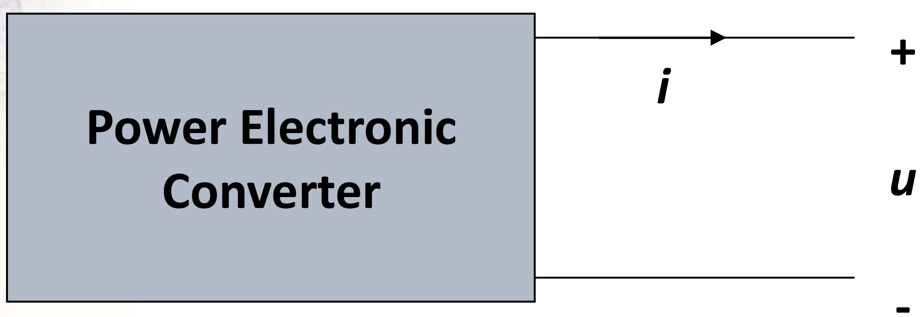


Some fundamental topologies

Quadrants

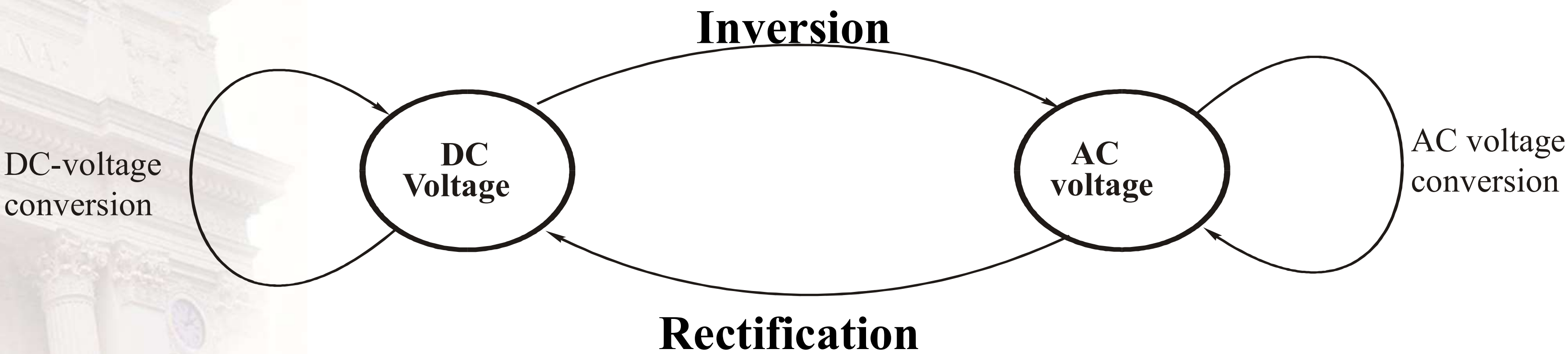


i
u
1-quadrant
i
u
2-quadrant
i
u
2-quadrant
i
u
4-quadrant

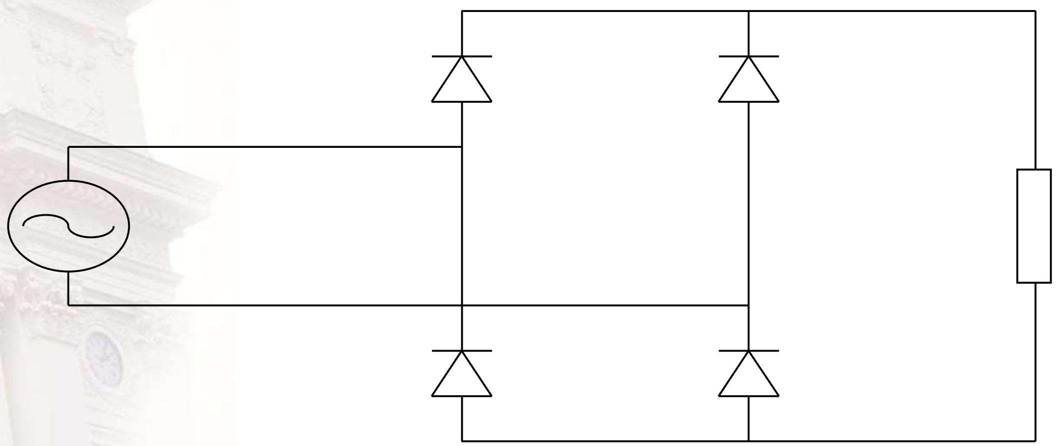


Power Electronic Converter
i
+
u
-

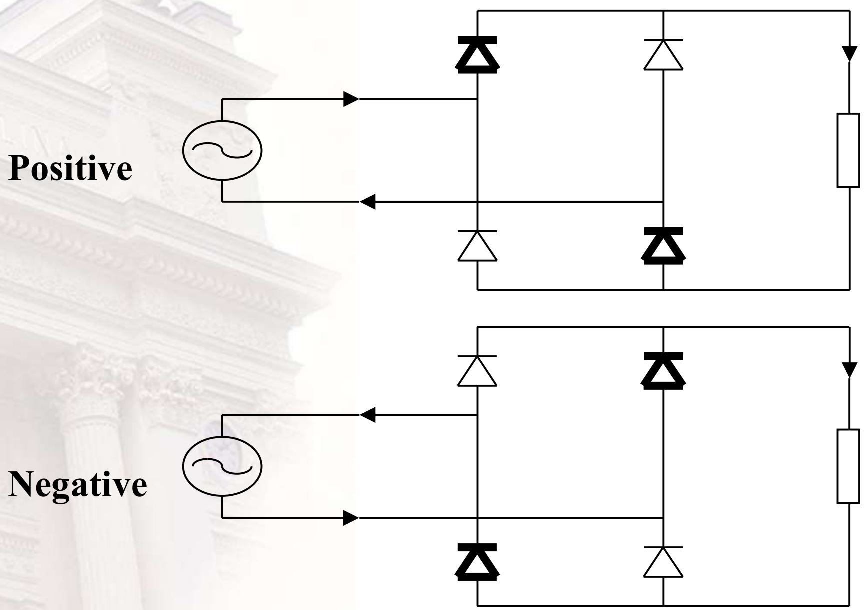
Classification

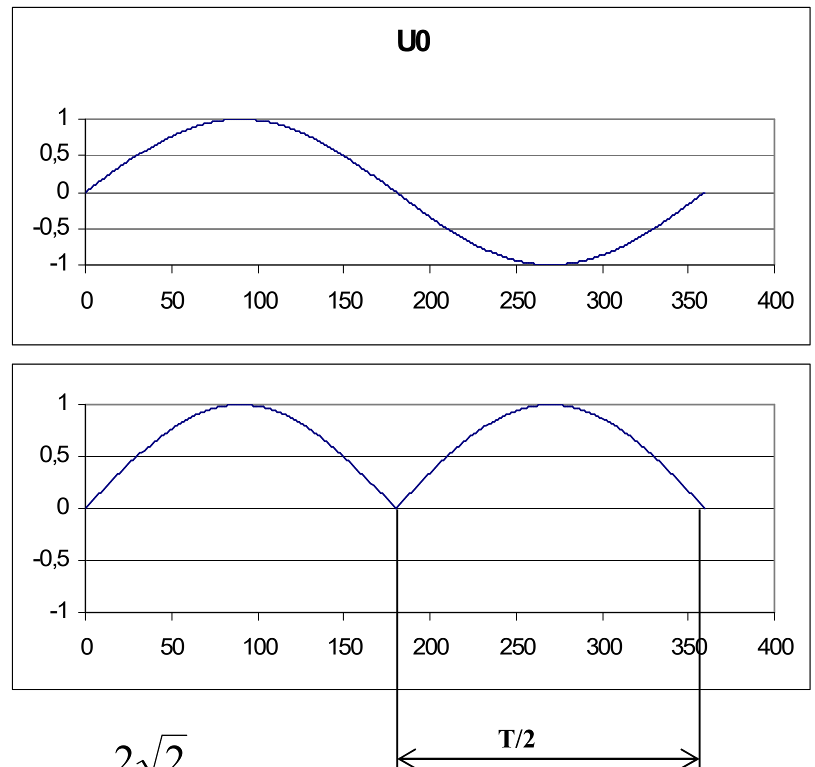


Single phase diode rectifier ideal



Single phase diode rectifier ideal





$$V_{dc} = \frac{1}{T/2} \int_{T/2} \hat{e}_{LN} \cos(\omega t) dt = 2 \frac{\hat{e}_{LN}}{2\pi} \int_{-\pi/2}^{\pi/2} \cos(\omega t) d(\omega t) = \frac{2}{\pi} \hat{e}_{LN} = \frac{2\sqrt{2}}{\pi} E_{LN}$$

Diode rectifier with capacitive DC link

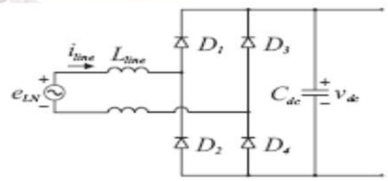


Figure 1.1: A single-phase diode rectifier with a capacitive DC link.

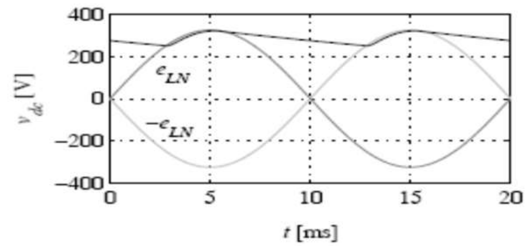


Figure 1.2: Line-to-neutral voltage and DC side voltage for a single-phase diode rectifier with a capacitive DC link.

$$V_{dc} = \frac{1}{T/2}\int_{T/2} \hat{e}_{LN} \cos(\omega t)\,dt = 2\frac{\hat{e}_{LN}}{2\pi}\int_{-\pi/2}^{\pi/2}\cos(\omega t)\,d(\omega t) = \frac{2}{\pi}\hat{e}_{LN} = \frac{2\sqrt{2}}{\pi}E_{LN}$$

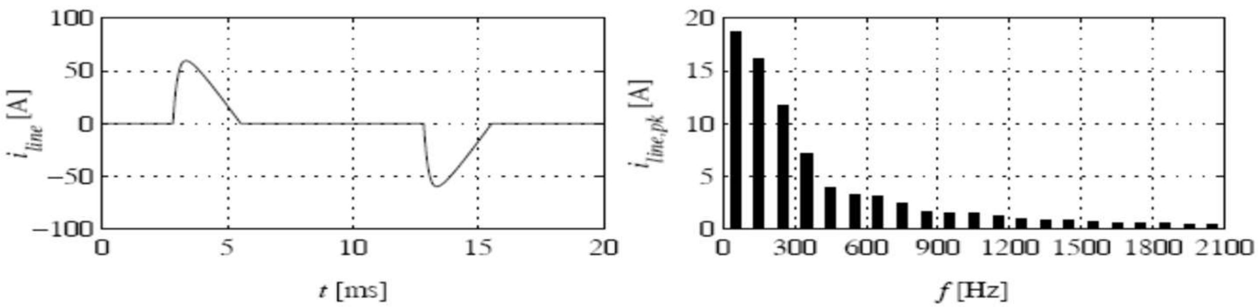


Figure 1.3: Line current (left) and its frequency spectrum (right), for a single-phase diode rectifier with a capacitive DC link.

The Buck Converter (Step-Down Converter)

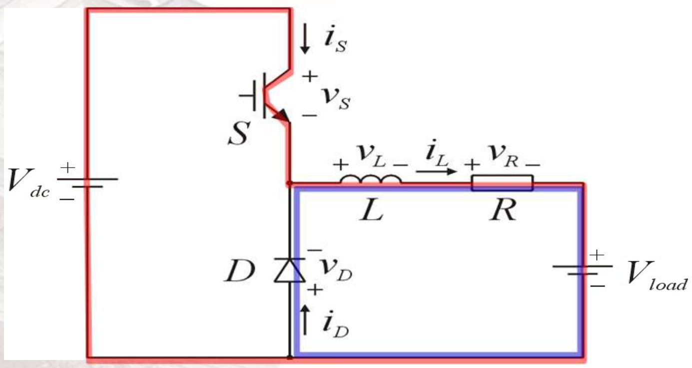


Figure 1.16: Buck converter.

***S* "on"**

$$V_{dc} - V_{load} = v_L = L\frac{di_L}{dt} \Rightarrow \Delta i_L = \frac{V_{dc} - V_{load}}{L} \cdot DT_{sw}$$

***S* "off"**

$$-V_{load} = v_L = L\frac{di_L}{dt} \Rightarrow \Delta i_L = -\frac{V_{load}}{L} \cdot (1 - D)T_{sw}$$

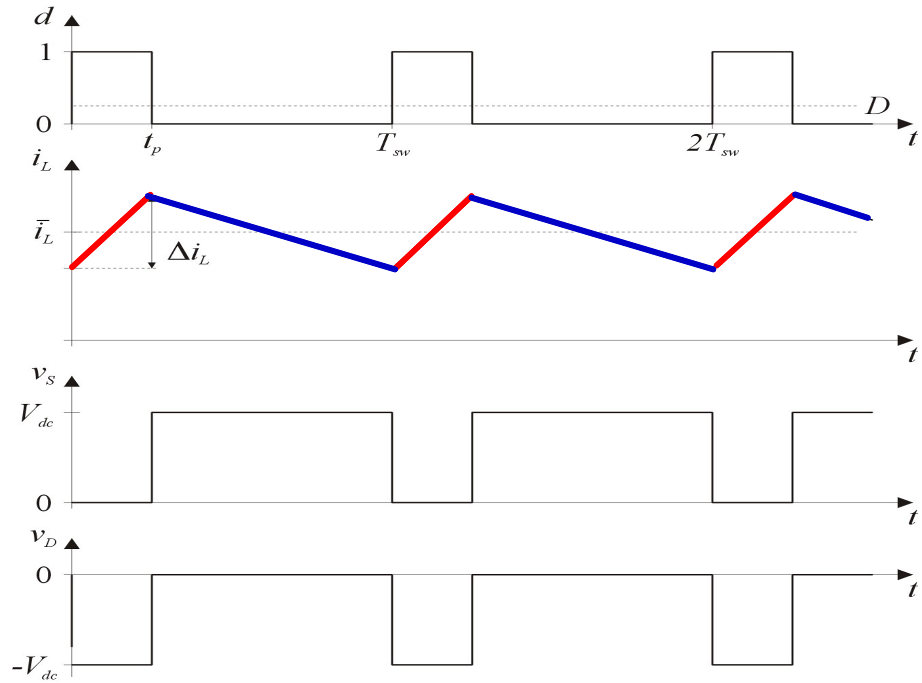


Figure 1.17: Ideal waveforms of the Buck converter.

The Boost Converter (Step-Up Converter)

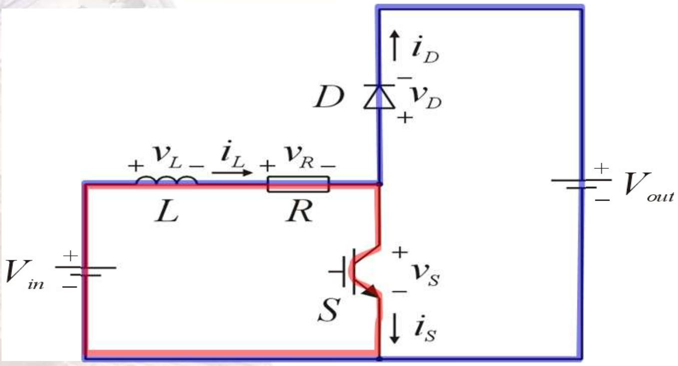


Figure 1.18: Boost converter.

***S* "on"**

$$L\frac{di_L}{dt} = v_L = V_{in} - v_S \approx V_{in} \quad \Rightarrow \quad \Delta i_L = \frac{V_{in}}{L} \cdot DT_{sw}$$

***S* "off"**

$$L\frac{di_L}{dt} = v_L = V_{in} - v_D - V_{out} \approx V_{in} - V_{out} \quad \Rightarrow$$

$$\Delta i_L = \frac{V_{in} - V_{out}}{L} \cdot (1 - D)T_{sw}$$

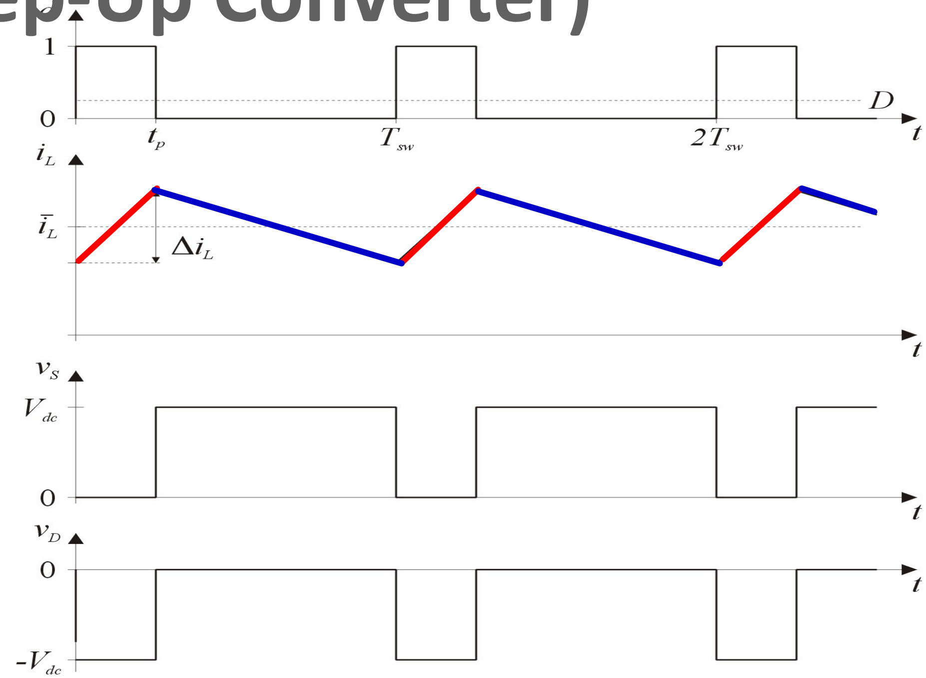


Figure 1.17: Ideal waveforms of the Boost converter. Replace V_{dc} and V_{load} of the Buck converter with V_{out} and V_{in}

The Buck-Boost Converter (Half-Bridge)

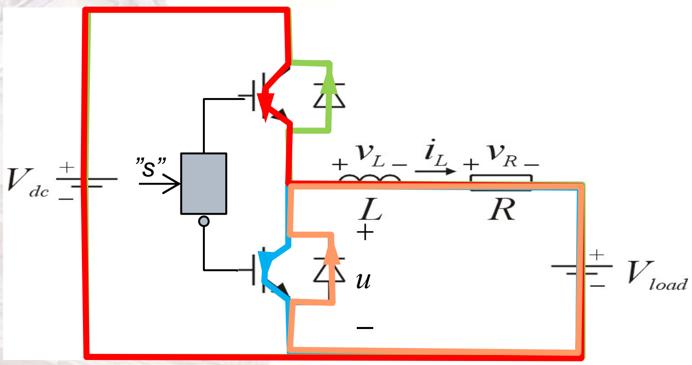
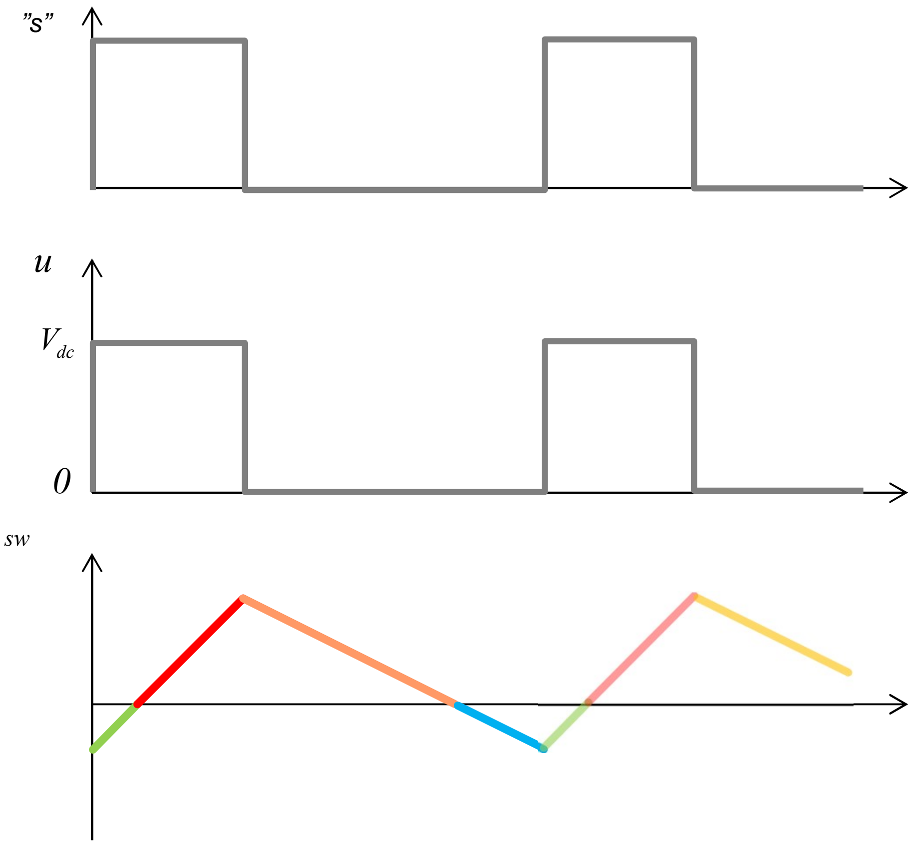


Figure 1.19: Buck-boost converter.



***s* "on"**

$$V_{dc} - V_{load} = v_L = L\frac{di_L}{dt} \Rightarrow \Delta i_L = \frac{V_{dc} - V_{load}}{L} \cdot DT_{sw}$$

***s* "off"**

$$-V_{load} = v_L = L\frac{di_L}{dt} \Rightarrow \Delta i_L = -\frac{V_{load}}{L} \cdot (1 - D)T_{sw}$$

The Flyback Converter

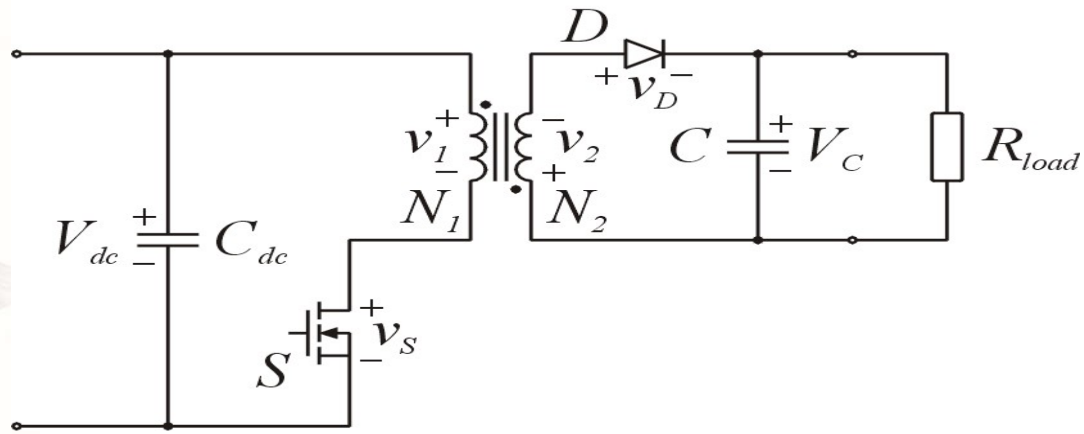
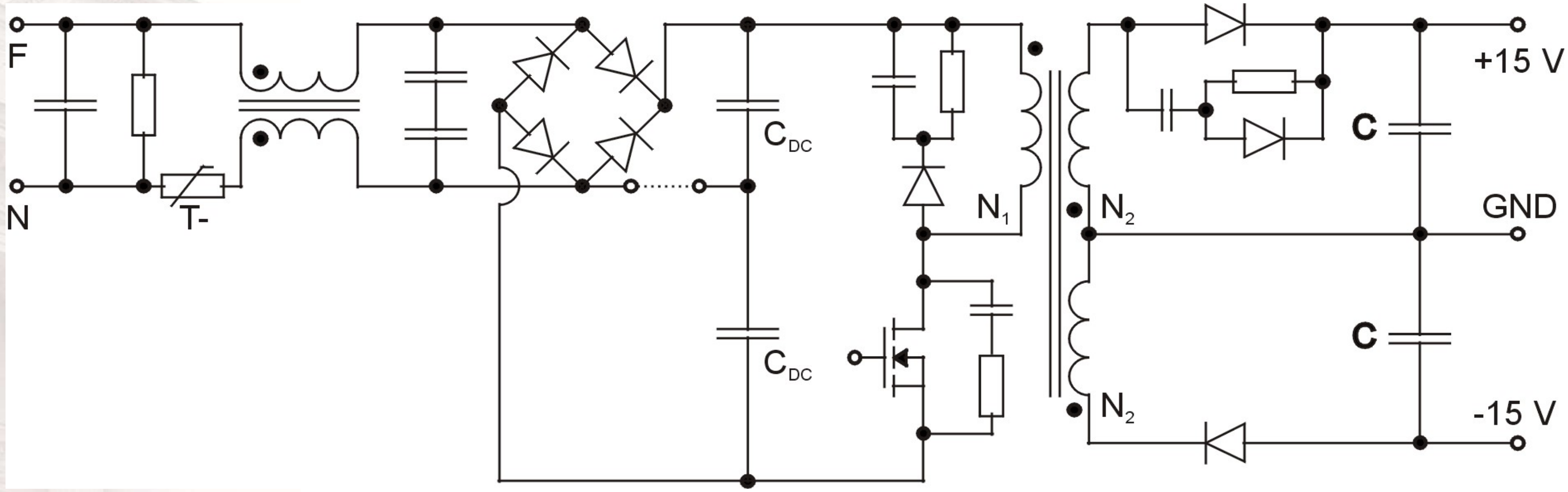


Figure 1.23: Principal schematic of a flyback converter. Only the devices needed to understand the operation are included.

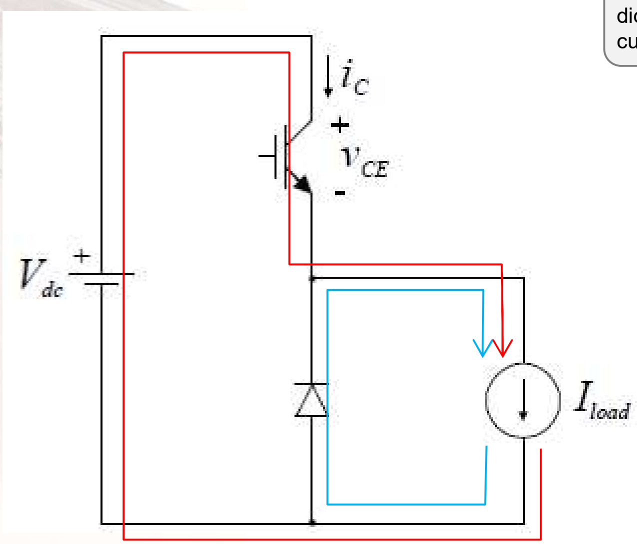
The Laboratory Flyback Converter

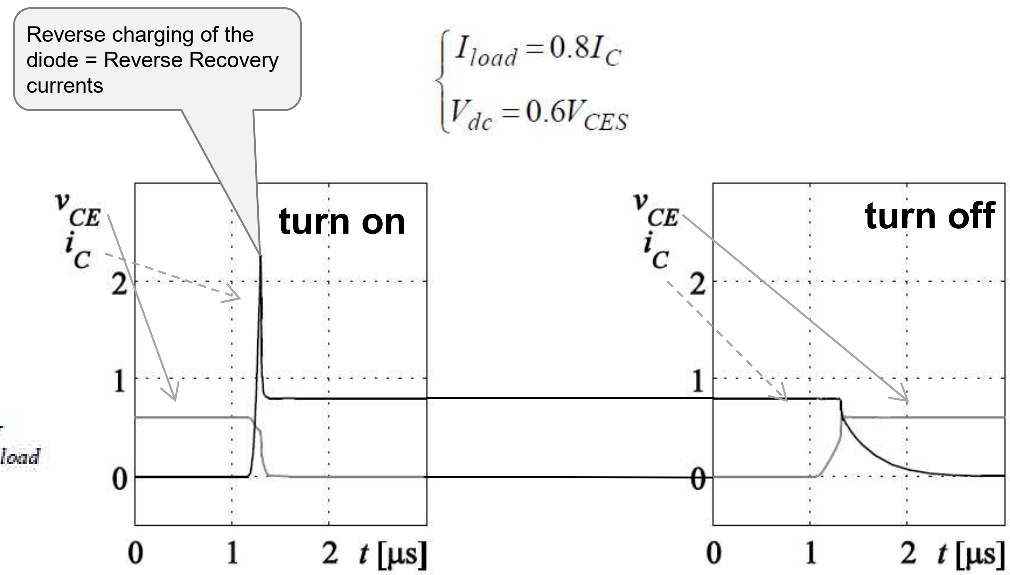


Flyback converter with input filter, inrush current limitation, diode rectifier, dc link capacitors, power MOSFET, transformer, output filter and three snubber circuits. The controller circuits are not included in the circuit.

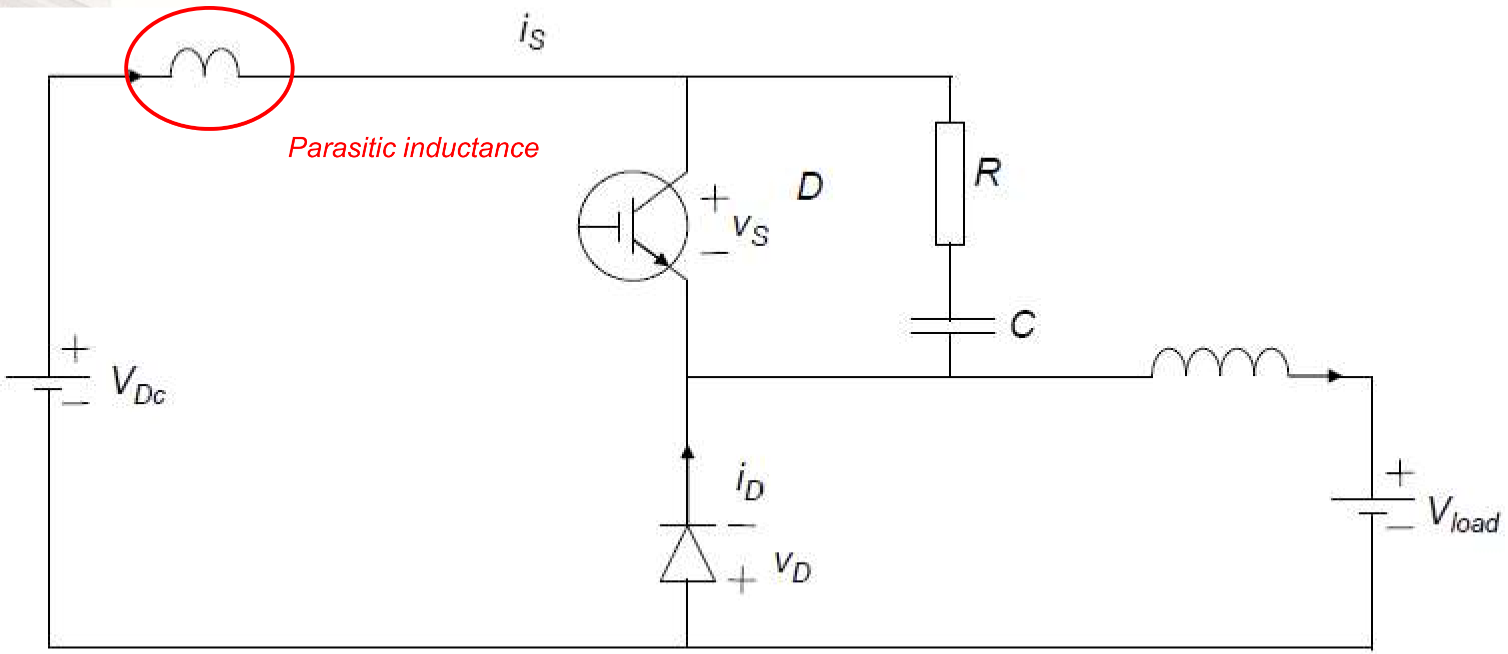
Switching dynamics 1

- Note:
  - the ”reverse recovery currents” in the diode at turn on
  - the simultaneous voltage and current when switching – high ”switching losses”

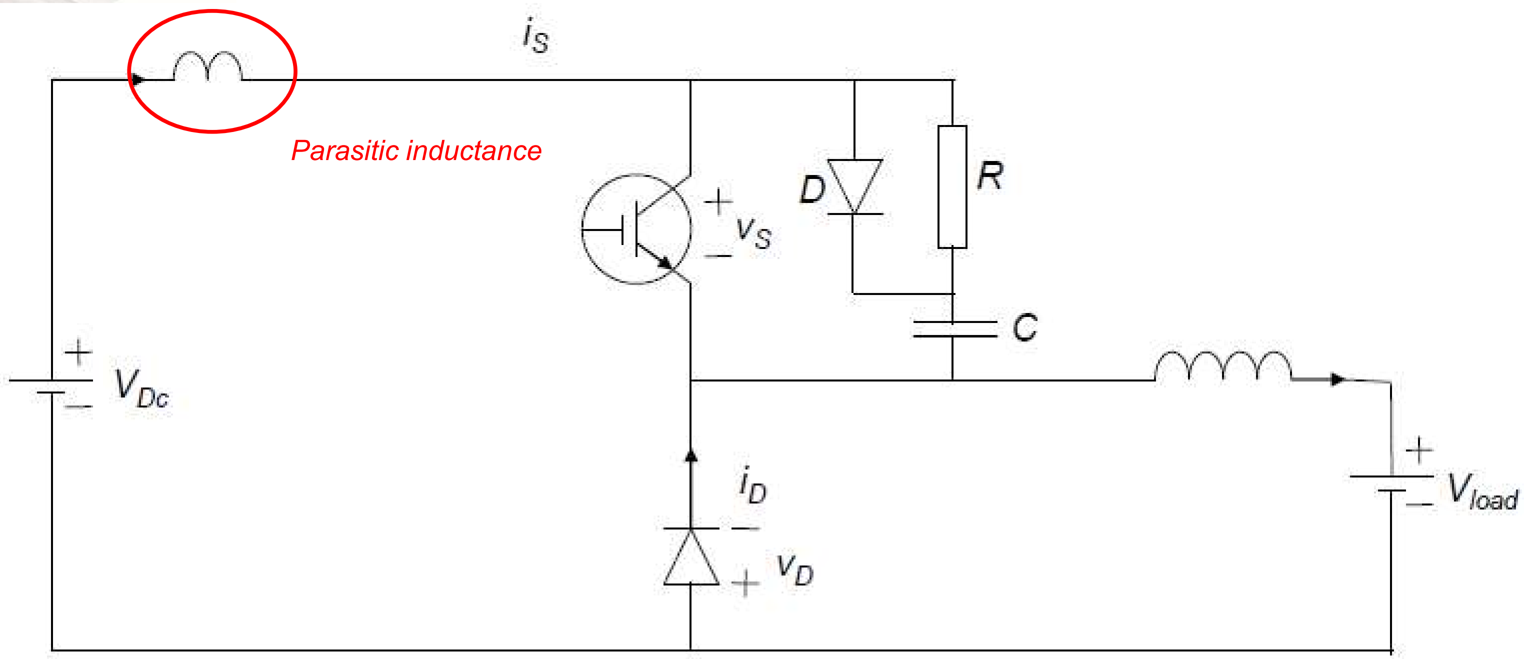




RC charge-discharge snubber

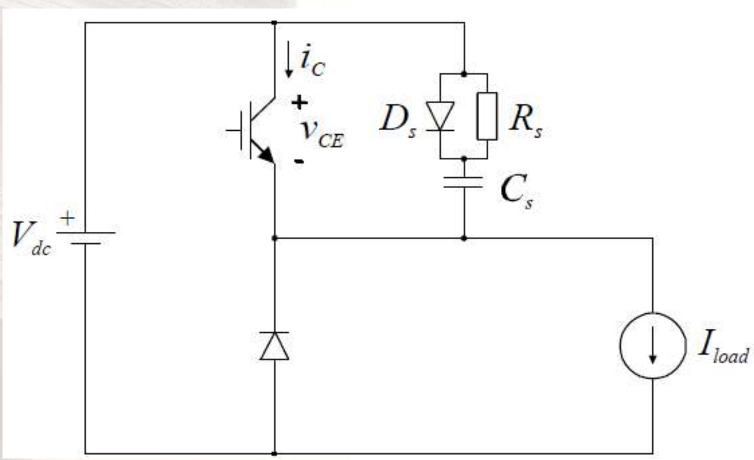


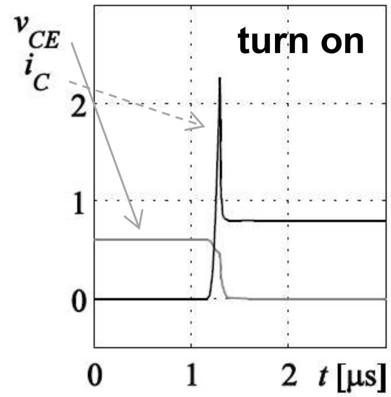
RCD charge-discharge snubber



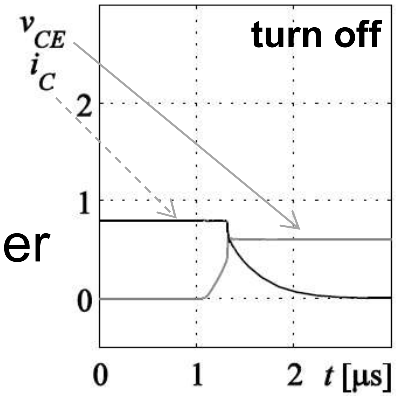
Switching dynamics

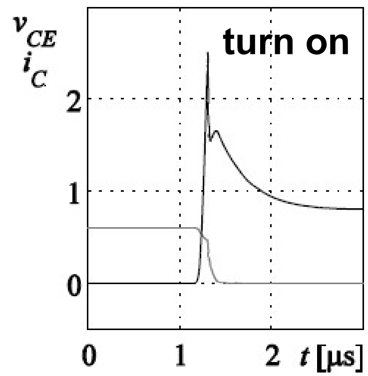
$$\begin{cases} I_{load} = 0.8 I_C \\ V_{dc} = 0.6 V_{CES} \end{cases}$$



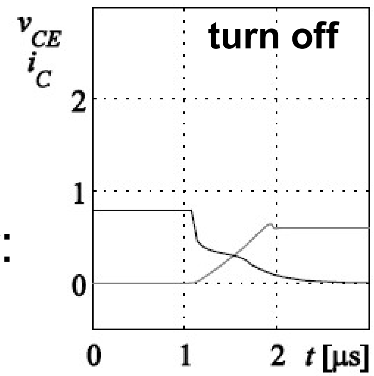


No snubber





RCD snubber:



That's all folks...