I.-C. Benea-Chelmus

Electrotechique-II
MICRO-101: week 8

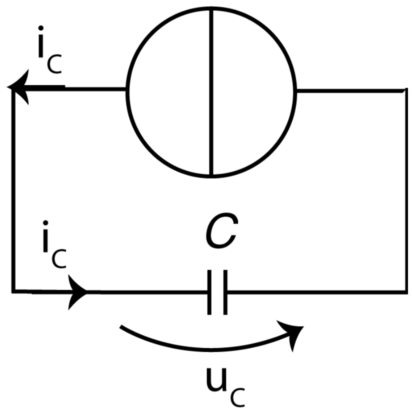
- What you have seen last time:
  - Time-dependent systems: Math recap (ch. 6.1), time-response of R and C (ch. 6.2.1 and 6.2.2) and RC circuits (ch. 6.3.1)

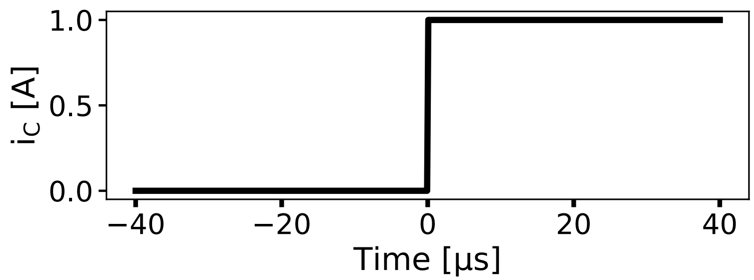
- Today:
  - Wrap up RC circuits (6.3.1)
  - Time-response of L (ch. 6.2.3.), RL circuits (ch. 6.3.2)

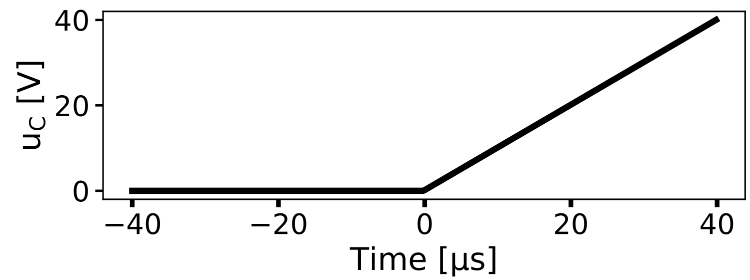
- Next time
  - Transient behavior with alternating voltages (ch. 6.4)
  - Solving of past exam (uploaded tomorrow to Moodle)

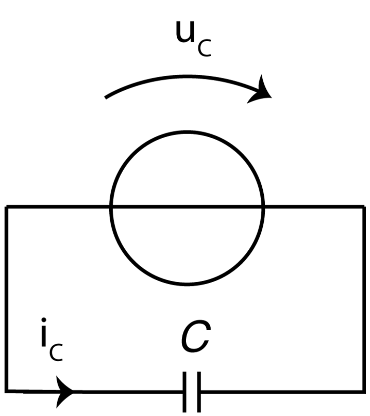
1-slide recap of last week

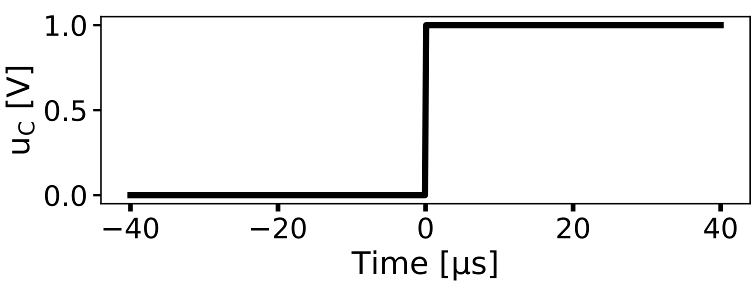
C-circuit (Ch. 6.2.3)

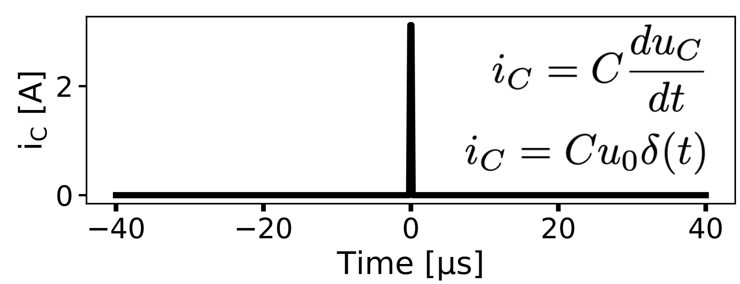












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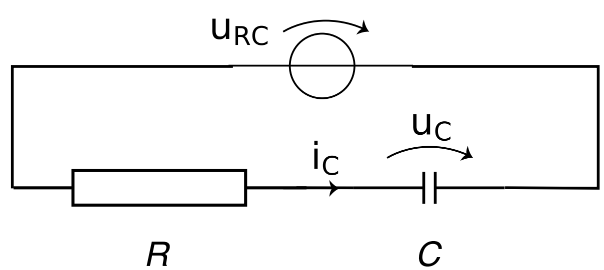
Today

RC circuit (Ch. 6.3.1): the current

- Rule 1: In real systems (with non-zero resistance) – the voltage across a capacitor can not change suddenly (no voltage jump)

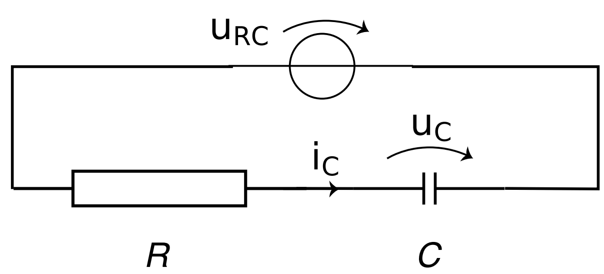


$$t < 0:$$
$$i_C = 0$$
$$u_C = 0$$

$$t \geq 0:$$
$$i_C = \frac{u_0}{R} e^{-\frac{t}{RC}}$$

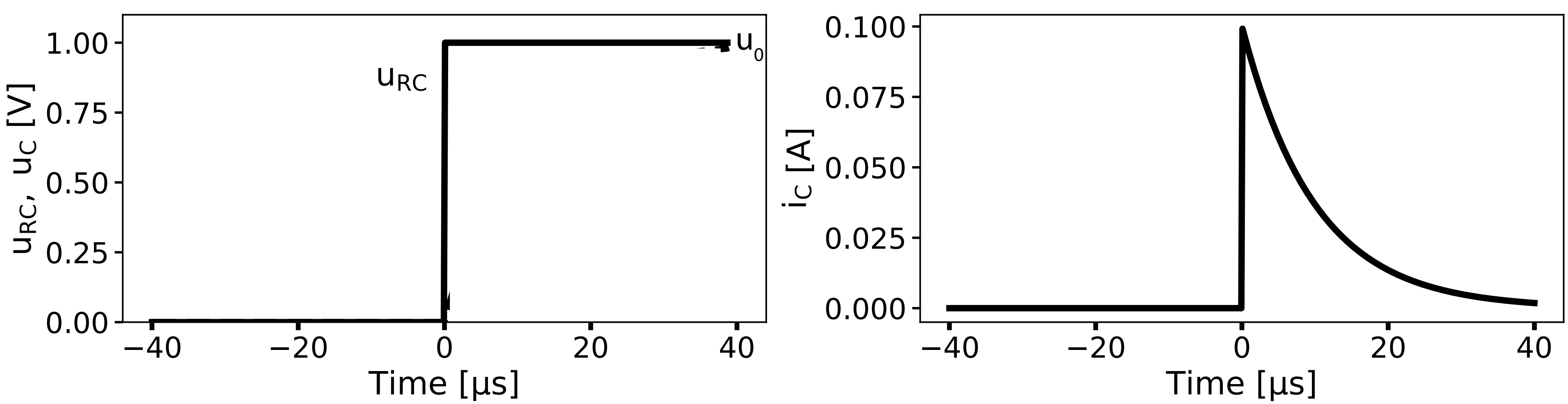
RC circuit (Ch. 6.3.1): the current

- Rule 1: In real systems (with non-zero resistance) – the voltage across a capacitor can not change suddenly (no voltage jump)



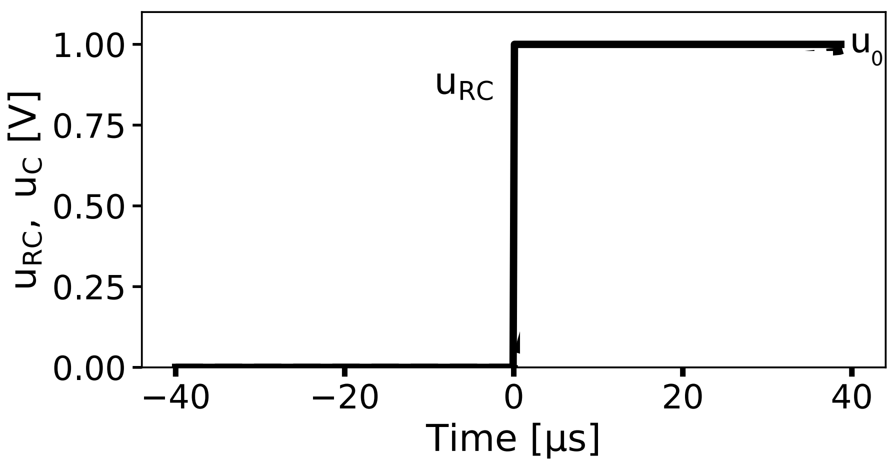
$$t \geq 0:$$

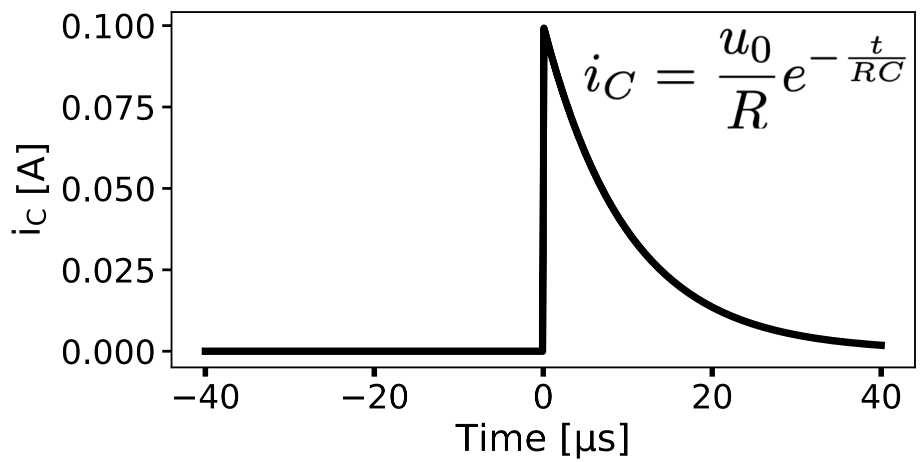
$$i_C = \frac{u_0}{R} e^{-\frac{t}{RC}}$$



RC circuit (Ch. 6.3.1): the current

- Rule 1: In real systems (with non-zero resistance) – the voltage across a capacitor can not change suddenly (no voltage jump)
- The current spikes to finite value at $t = 0$: $i_C(t = 0) = \frac{u_0}{R}$
- i_C then decays with characteristic time $\tau_{RC} = RC$.
- The smaller R, the shorter τ_{RC}, the higher $i_C(t = 0)$ → the more the system converges towards what we've seen for the C-circuit





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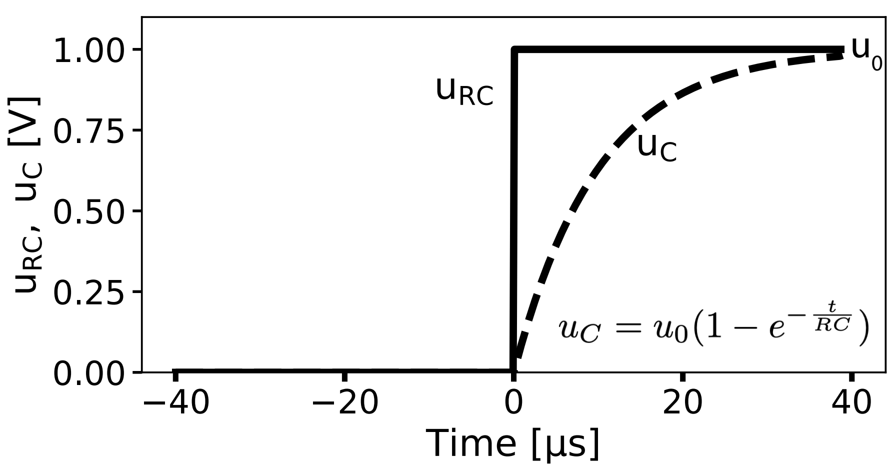
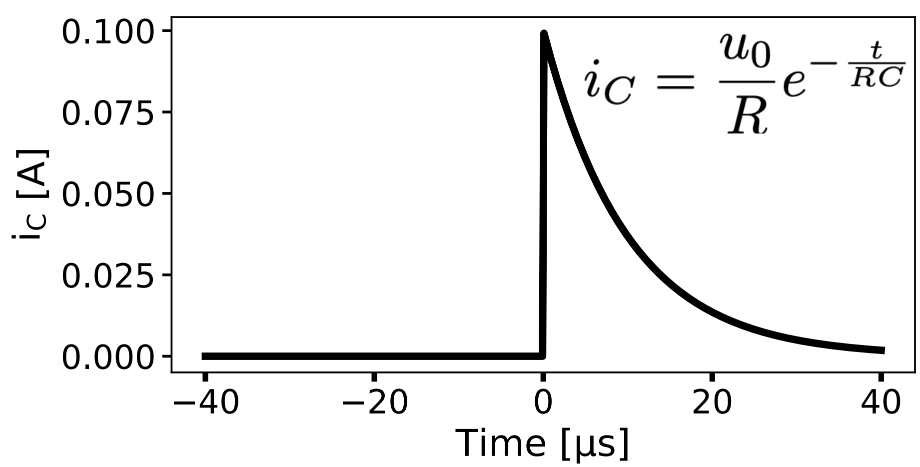
RC circuit (Ch. 6.3.1): the voltage

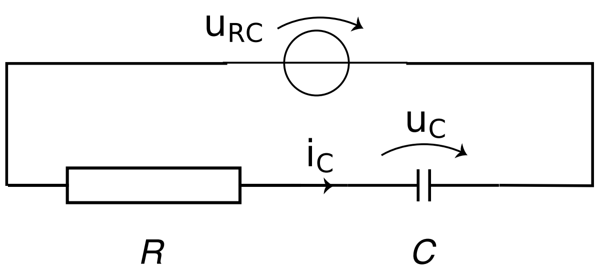
- Rule 1: In real systems (with non-zero resistance) – the voltage across a capacitor can not change suddenly (no voltage jump)
- No discontinuity in the voltage
- u_C then increases with τ_{RC} towards the value of the source.
- The smaller R, the shorter τ_{RC}, the faster u_C converges towards u_{RC} → what we've seen for the C-circuit





Overview RC circuit (Ch. 6.3.1)

- Guided example 1:



$t < 0:$

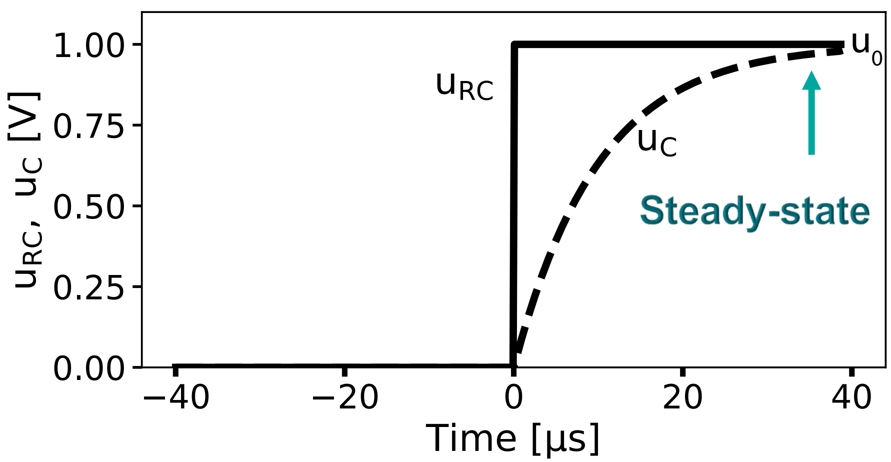
$$i_C = 0$$

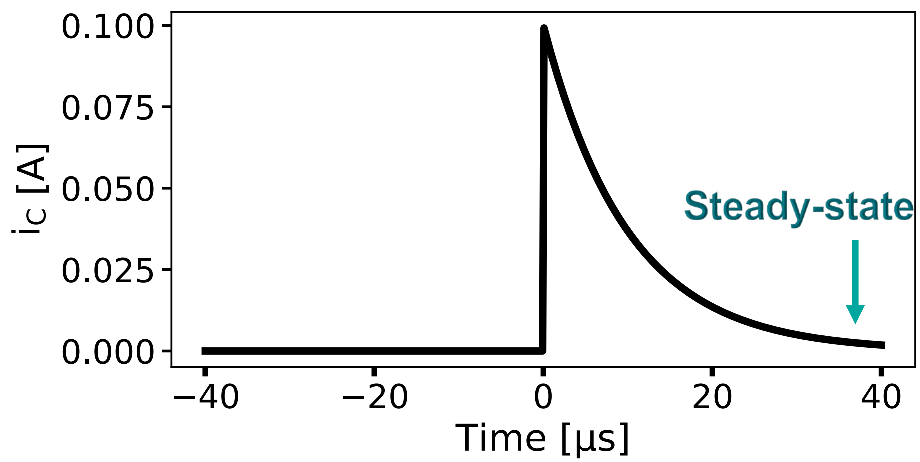
$$u_C = 0$$

$t \geq 0:$

$$i_C = \frac{u_0}{R} e^{-\frac{t}{RC}}$$

$$u_C = u_0 (1 - e^{-\frac{t}{RC}})$$

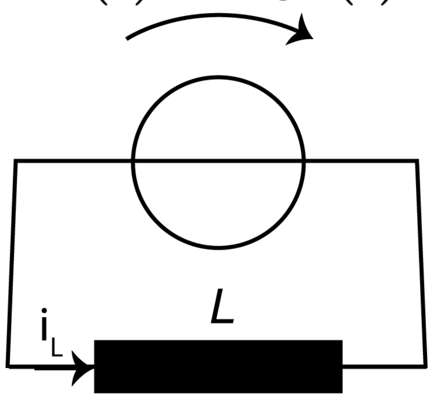




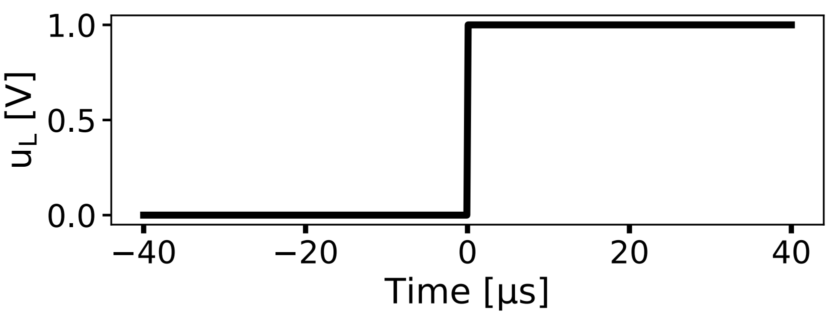
Time response of L (Ch. 6.2.3)

Voltage source connected

$$u_L(t) = u_0 h(t)$$



$$u_L(t) = L\frac{di_L}{dt}$$



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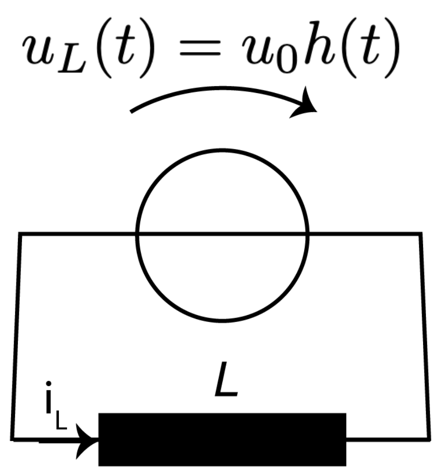
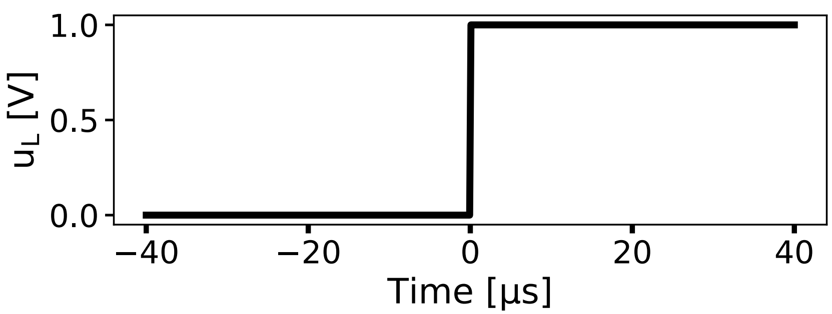
Time response of L (Ch. 6.2.3)

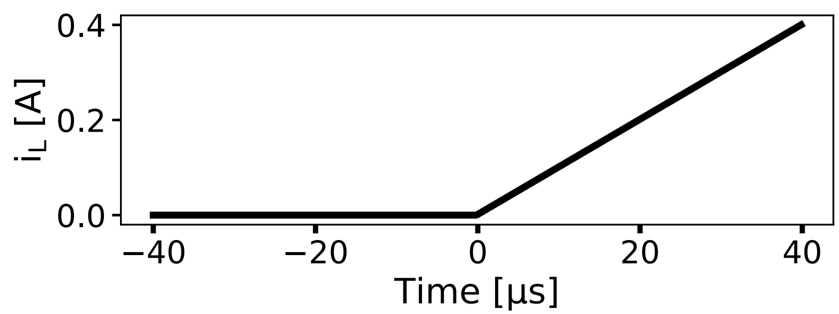
Voltage source connected



$$u_L(t) = L\frac{di_L}{dt}$$

Current does not react instantaneously to change in voltage:
It slowly ramps up until it reaches infinity.
For long times, the inductor behaves like a short.





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Time response of L (Ch. 6.2.3)

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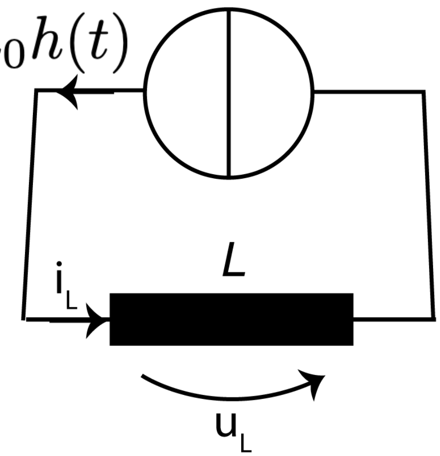
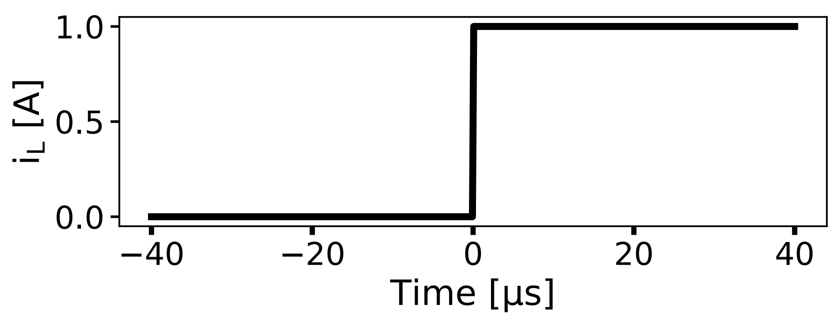
Current source connected

$$i_L(t) = u_0 h(t)$$



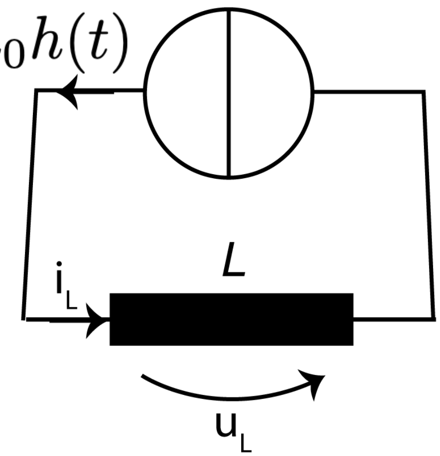
$$u_L(t) = L\frac{di_L}{dt}$$



Time response of L (Ch. 6.2.3)

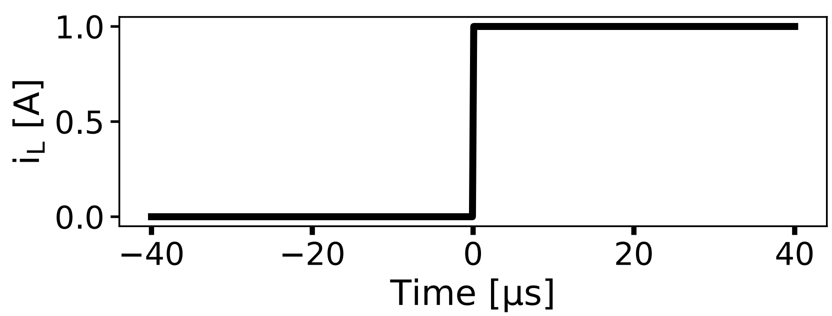
Current source connected

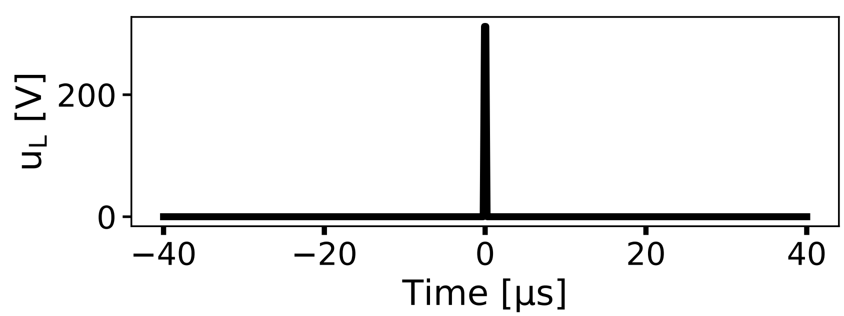
$$i_L(t) = u_0 h(t)$$



$$u_L(t) = L\frac{di_L}{dt}$$

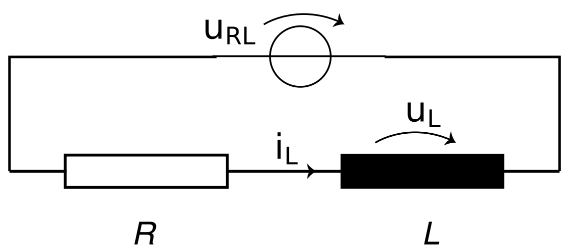
Voltage spikes in reaction to change in current, so that the current flowing across the inductor equalizes the one of the source.





RL circuit (Ch. 6.3.2)

- Guided example 2:



$$u_{RL} = u_0 h(t)$$

  - Boundary conditions:

(calculation at the blackboard)

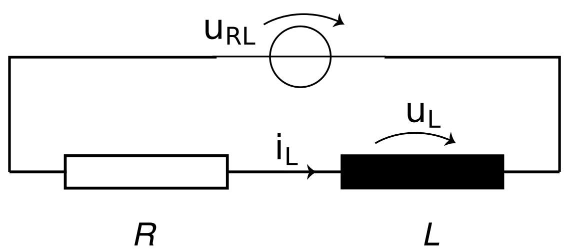
$$t < 0$$

$i_L = 0$ No current flowing through the circuit!

$u_L = 0$ No voltage drop across the inductor

RL circuit (Ch. 6.3.2)

- Rule 2: In real systems (with non-zero resistance) – the current flowing through an inductor can not change suddenly (no current jump)



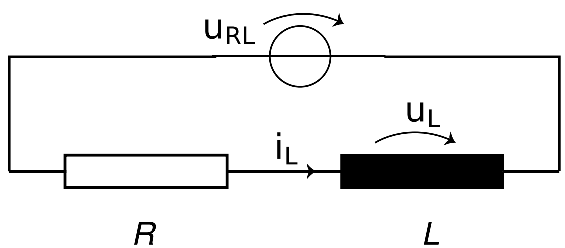
- Boundary conditions:

$$t < 0$$
$$i_L = 0$$
$$u_L = 0$$

$$t \geq 0$$
$$i_L = \frac{u_0}{R}(1 - e^{-\frac{tR}{L}})$$
$$u_L = L\frac{di_L}{dt} = u_0 e^{-\frac{tR}{L}}$$

RL circuit (Ch. 6.3.2)

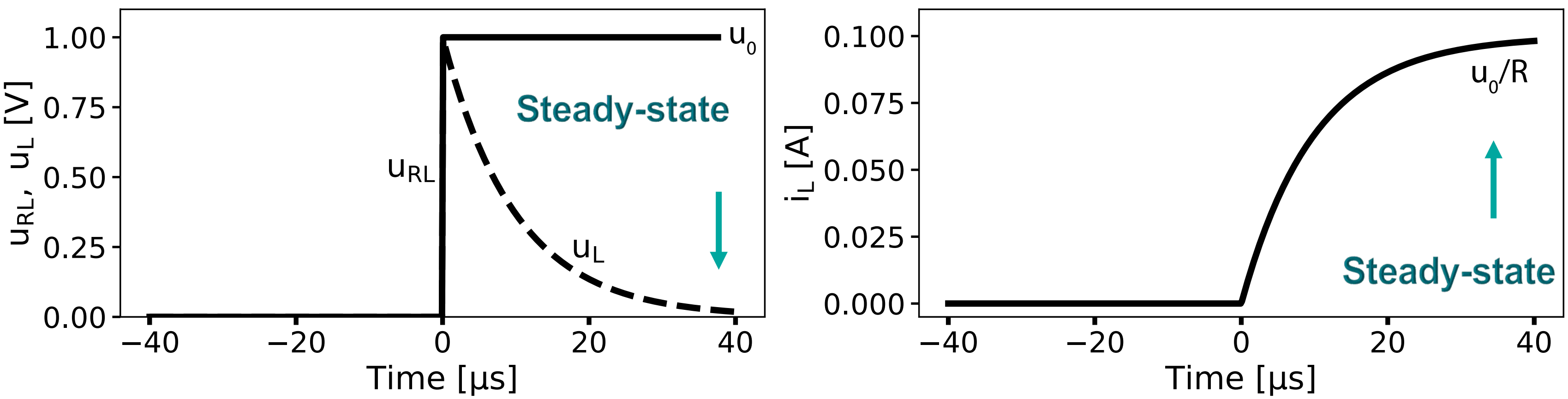
- Guided example 2:



$$t \geq 0$$

$$i_L = \frac{u_0}{R}(1 - e^{-\frac{tR}{L}})$$

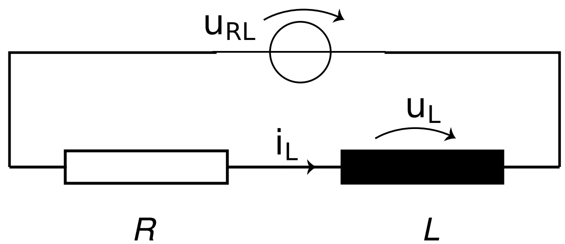
$$u_L = L\frac{di_L}{dt} = u_0 e^{-\frac{tR}{L}}$$



RL circuit (Ch. 6.3.2)

- Rule 2: In real systems (with non-zero resistance) – the current flowing through an inductor can not change suddenly (no current jump)

$$t \geq 0$$



$$i_L = \frac{u_0}{R}(1 - e^{-\frac{tR}{L}})$$

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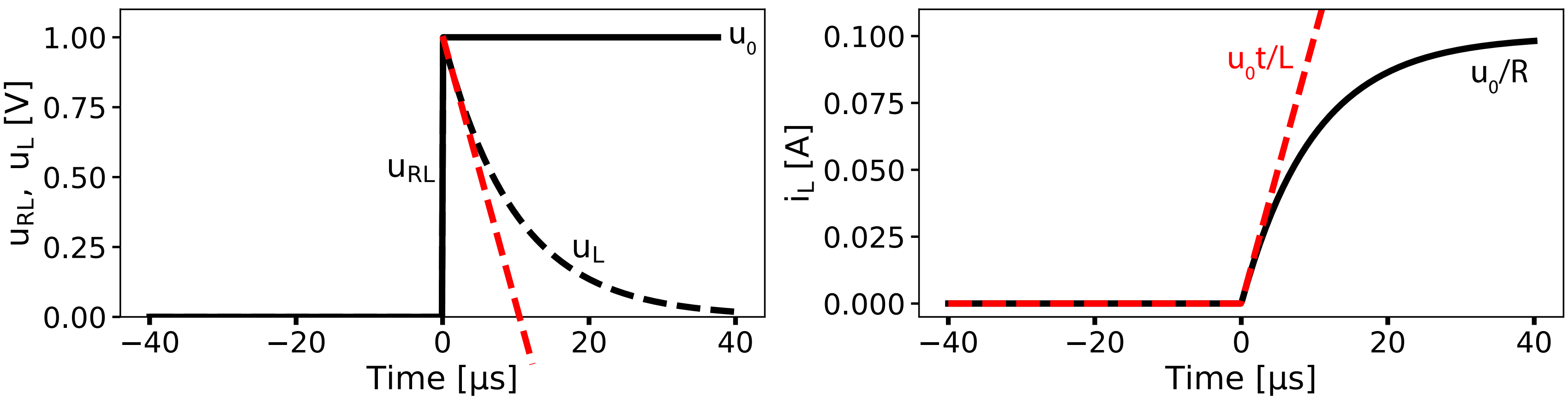
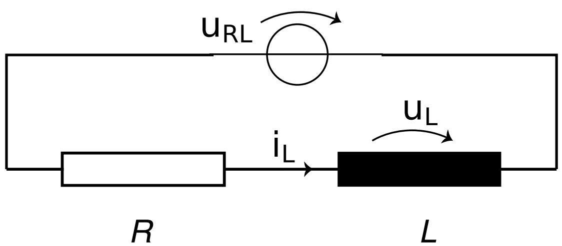


RL circuit (Ch. 6.3.2)

- Rule 2: In real systems (with non-zero resistance) – the current flowing through an inductor can not change suddenly (no current jump)



$$t \geq 0$$

$$i_L = \frac{u_0}{R}(1 - e^{-\frac{tR}{L}})$$

$$u_L = L\frac{di_L}{dt} = u_0 e^{-\frac{tR}{L}}$$

We find that the current ramps up with a characteristic time constant $\tau_{RL} = \frac{L}{R}$. The RL time constant can be reduced for example by decreasing L.

At t = 0, the voltage spikes to a value of $u_L\ (t = 0) = u_0$ after which it decreases again with the same slope as the current. We note that for L $\rightarrow$ 0 we find back the case of the resistor connected to a voltage source which is switched on.