Electrotechique-II
MICRO-101: week 7

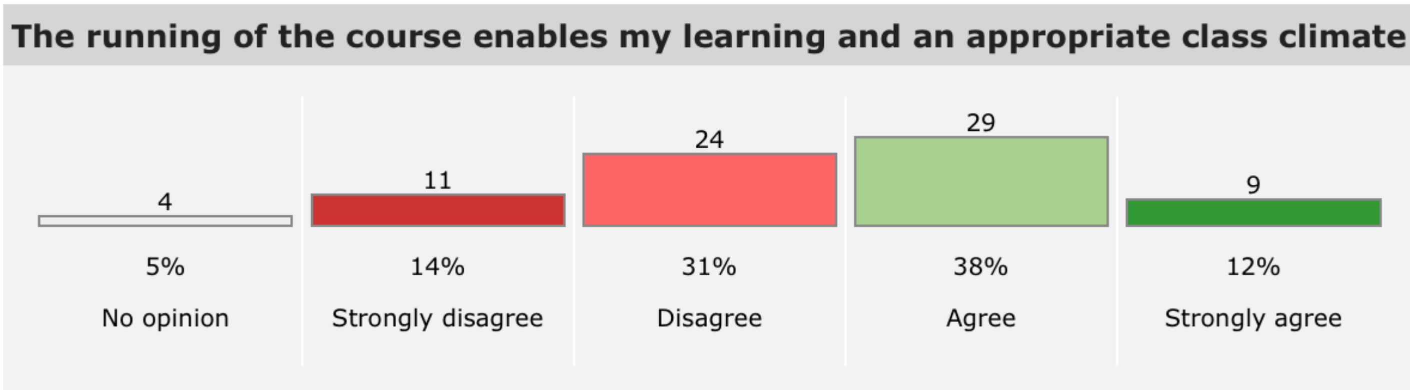
I.-C. Benea-Chelmus

- What you have seen last time:
  - Time-dependency of power in Δ- network (ch. 5.3. in the script)
  - Unbalanced three-phase systems (ch. 5.4. in the script)

- Today:
  - Discussion of preliminary evaluations
  - 1-slide summary of last week
  - 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)

- Next time
  - Time-response of L (ch. 6.2.3.), RL circuits (ch. 6.3.2)

Evaluation results



Comments (apart from the positives – nice class, nice teacher, interesting content, very good written notes):

See next page.

Comments and action items

1. Some students mention that the class is too repetitive, too much time spent on recap and too little on other difficult concepts (6 x) leading to difficulties to follow the red line of the class (8x).
   - Action 1: Adapted structure: Overview slide/ 1-slide summary of last time/ new topic
   - Action 2: Slides are incorporated to avoid wasting time. Link to chapter in written notes given.

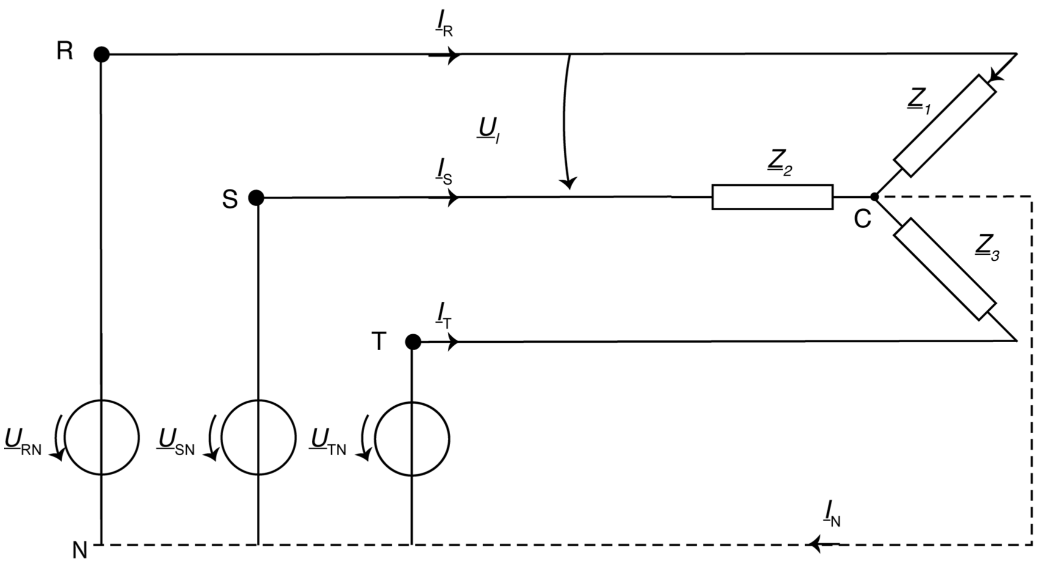
2. Students feel there is a disconnect between exercises and class. Some find the solutions difficult to follow and ask for more examples during class (10 x).
   - Action 1: More examples during class.
   - Action 2: paid student assistantship position to rework all solutions in May & June to improve clarity (send me an email at cristina.benea@epfl.ch).
   - Note: some exercises are on-purpose difficult to solve and ask concepts you saw only little in class (such as week 3, exercise 2) as part of deliberate, guided failure learning strategy.

3. Students find that there is too much noise during class (microphone issues) and especially during the exercise class (9 x).
   - Action 1: Need a noise check responsible to confirm each lecture.
   - Action 2: Adapted format for exercise class:
   - 10 mins solving on your own – then 5-10 mins explanation by TA – then solving in groups.

1-slide recap of last week

I.-C. Benea-Chelmus

Unbalanced Y-network (ch. 5.4.)



- Two distinct scenarios:
  - Neutral line connected

$$\underline{I}_N = \underline{I}_R + \underline{I}_S + \underline{I}_T \tag{5.4.4}$$

Current in the neutral compensates for the imbalance of the current in the three lines (see script ch 5.4).

  - Neutral line not connected

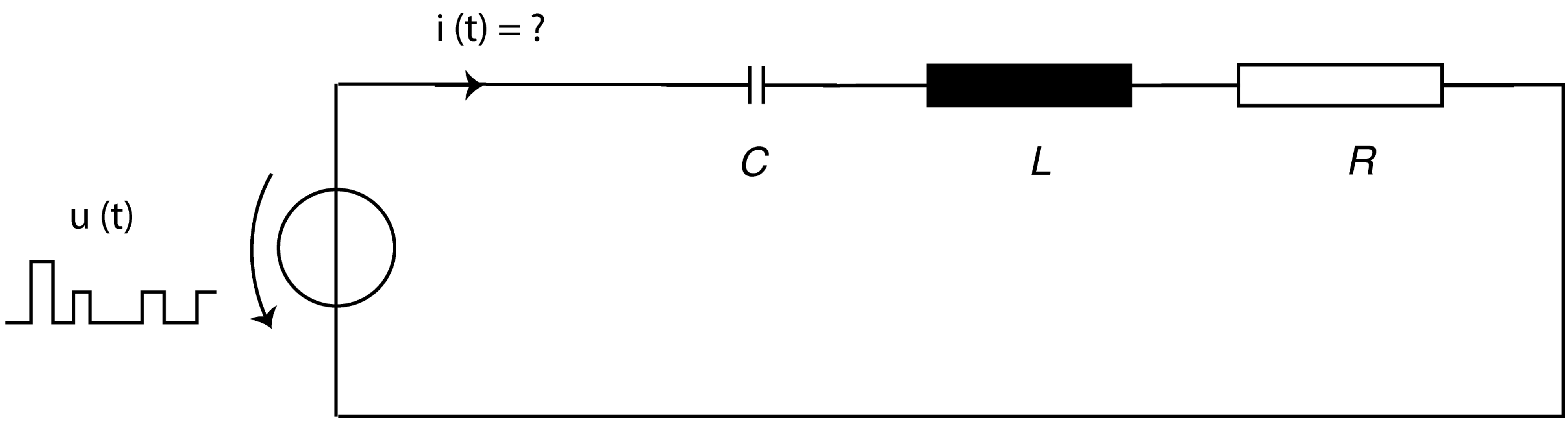
$$\underline{I}_R + \underline{I}_S + \underline{I}_T = 0 \tag{5.4.9}$$

Current is balanced out across the various lines (see script ch 5.4).

Today

Ch 6: Time-dependent electrical circuits

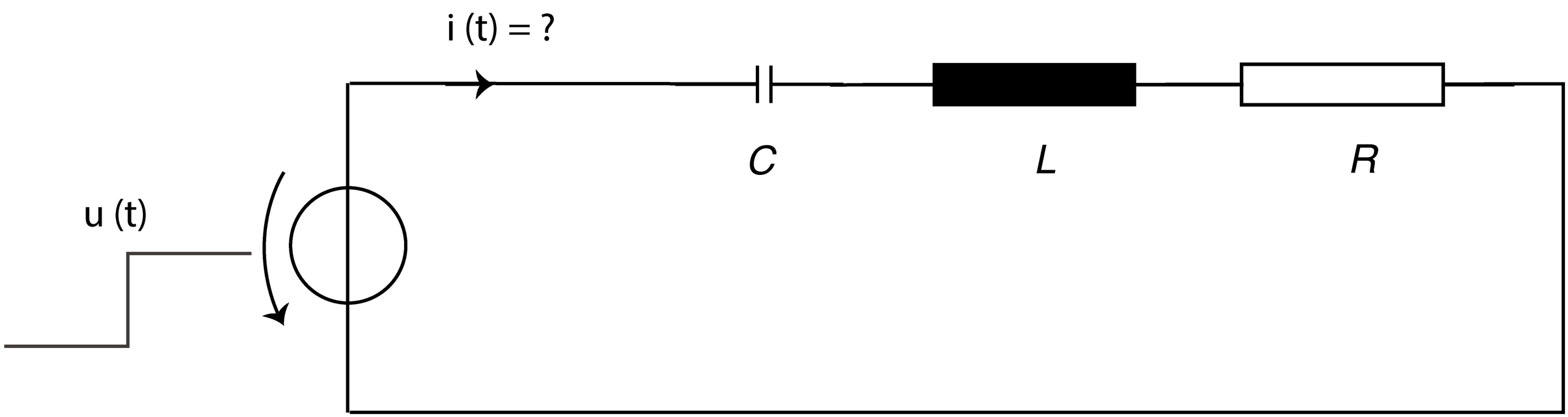
I.-C. Benea-Chelmus



What do you remember about response of capacitors/inductors to sudden changes in voltage/current?

Ch 6: Time-dependent electrical circuits

I.-C. Benea-Chelmus



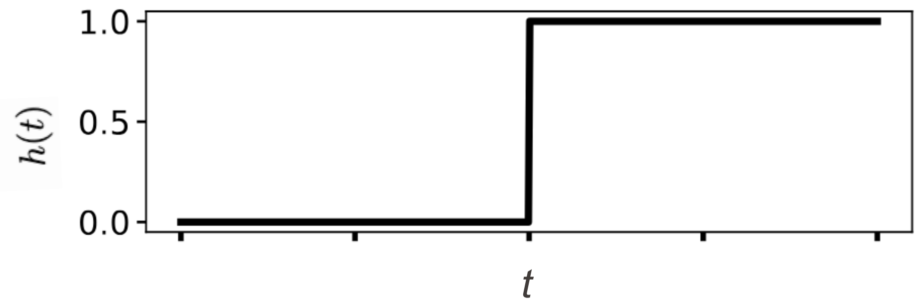
Most basic time-dependent system: switch-on/switch-off:

1. Dynamic behavior right after t>0
2. Steady state at t >> characteristic time scales (we'll find out in a moment!)

Math recap (Ch. 6.1.)

- Step function (Heaviside function)

$$h(t) = \begin{cases} 0, & t < 0 \\ 1, & t \geq 0 \end{cases}$$



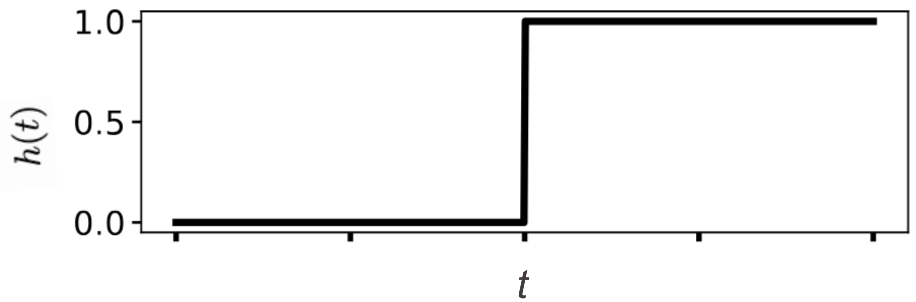
Exercise:

1. describe jump from 0 to u_0 at $t = 0$ using $h(t)$ (switch-on)
2. describe jump from u_0 to 0 at $t = 0$ using $h(t)$ (switch-off)

Math recap (Ch. 6.1.)

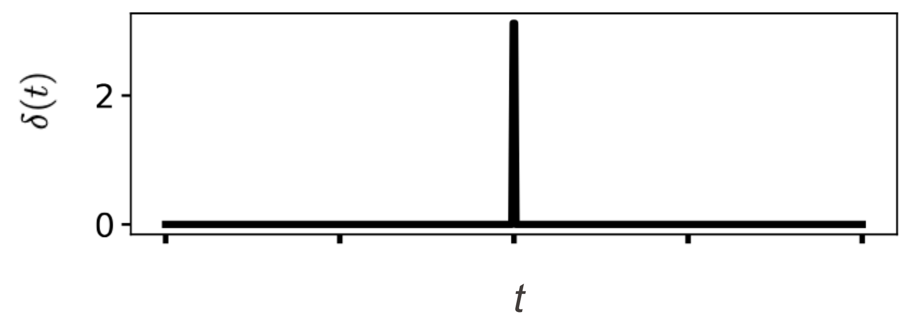
- Step function (Heaviside function)

$$h(t) = \begin{cases} 0, & t < 0 \\ 1, & t \geq 0 \end{cases}$$



- Delta function

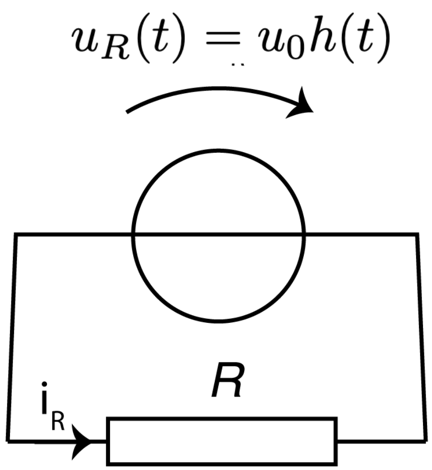
$$\delta(t) = \begin{cases} \infty, & t = 0 \\ 0, & elsewhere \end{cases}$$

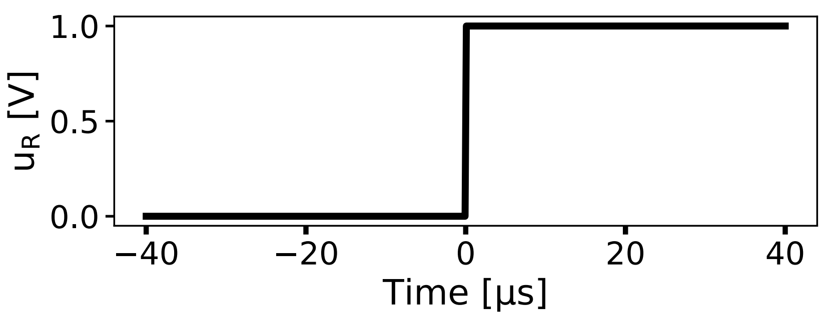


$$\frac{dh}{dt} = \delta(t) \quad \text{since} \quad \frac{dh}{dt}|_{t=0} = \infty, \; 0 \; elsewhere$$

Time response of R (Ch. 6.2.1)

Voltage source connected

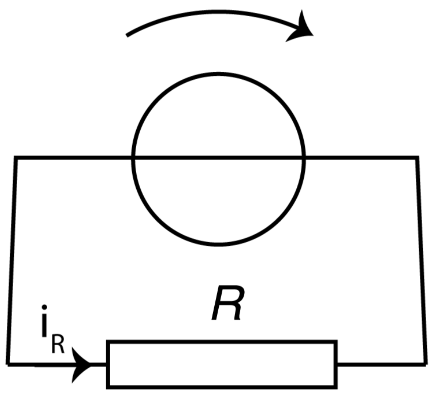




Time response of R (Ch. 6.2.1)

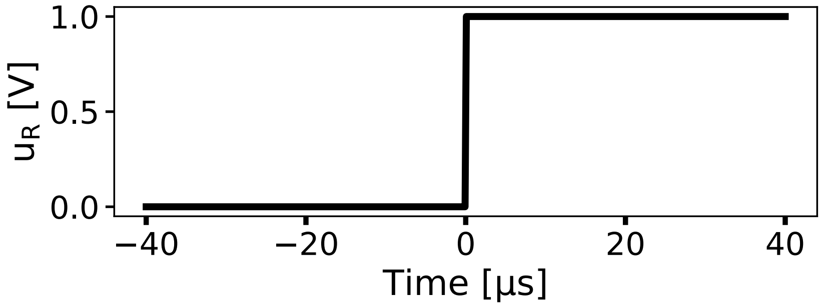
Voltage source connected

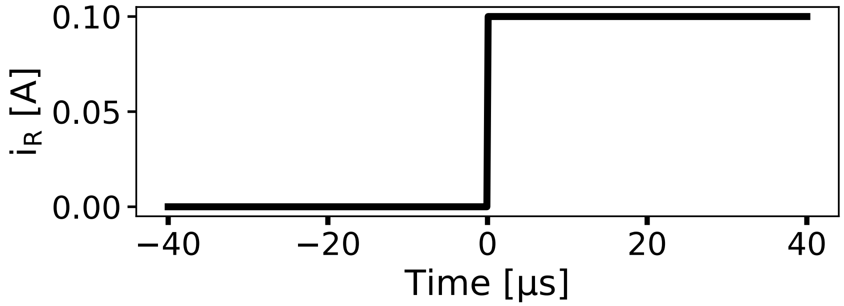
$$u_R(t) = u_0 h(t)$$



$$i_R = \frac{u_R}{R} = \frac{u_0}{R} h(t)$$

Current follows applied voltage.

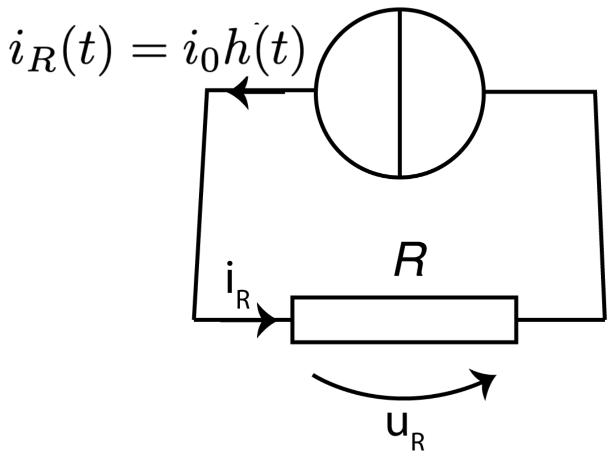


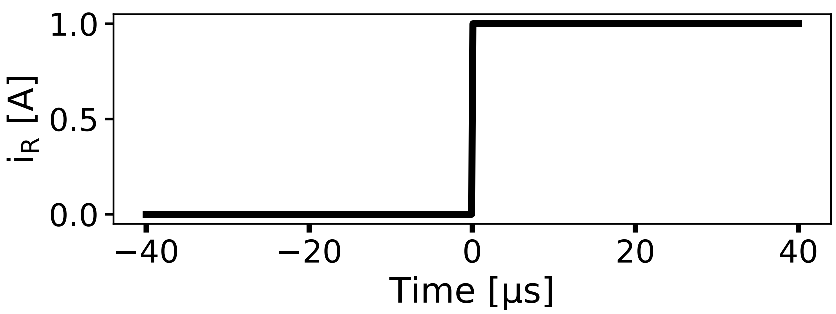


$R = 10\ \Omega$, $C = 1\ \mu\mathrm{F}$, $L = 0.1\ mH$, $u_0 = 1\ V$ and $i_0 = 1\ A$.

Time response of R (Ch. 6.2.1)

Current source connected

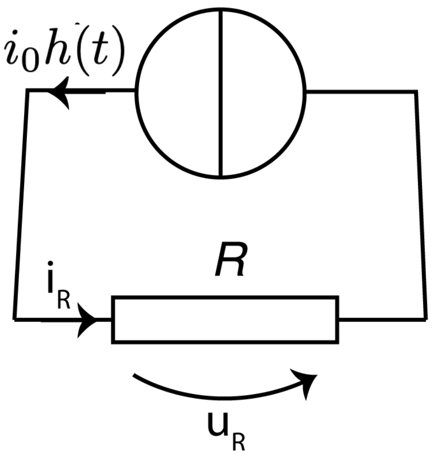




Time response of R (Ch. 6.2.1)

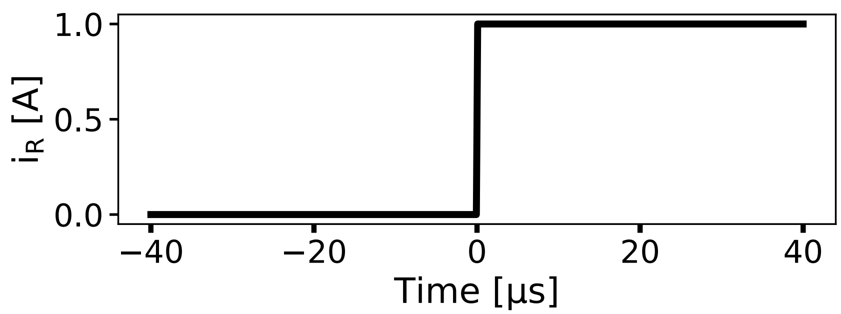
Current source connected

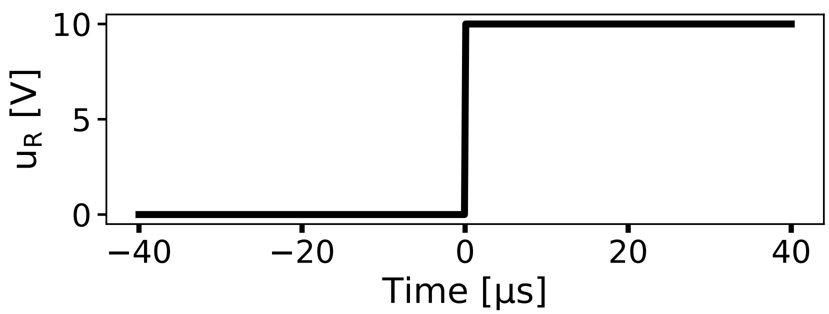
$$i_R(t) = i_0 h(t)$$



$$u_R = i_R R = i_0 R h(t)$$

Voltage follows applied current.





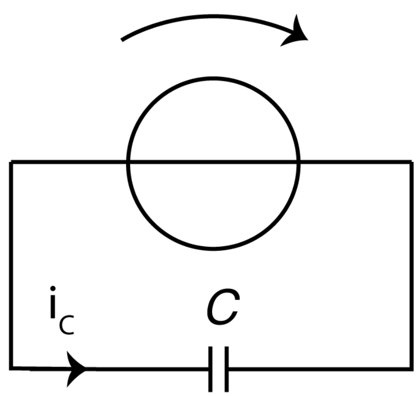
I.-C. Benea-Chelmus

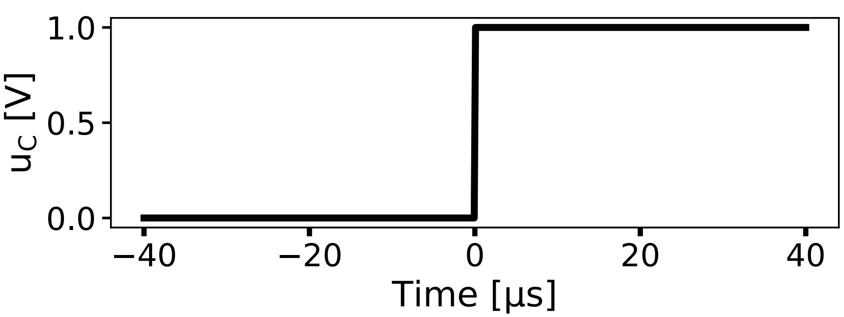
Time response of C (Ch. 6.2.2)

I.-C. Benea-Chelmus

Voltage source connected

$$u_C(t) = u_0 h(t)$$

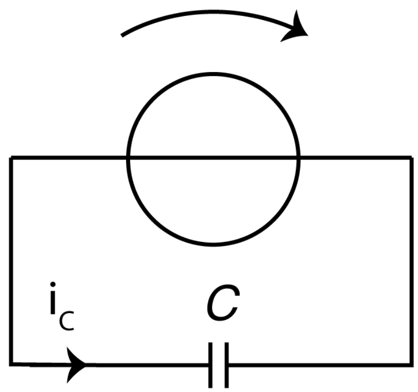




Time response of C (Ch. 6.2.2)

Voltage source connected

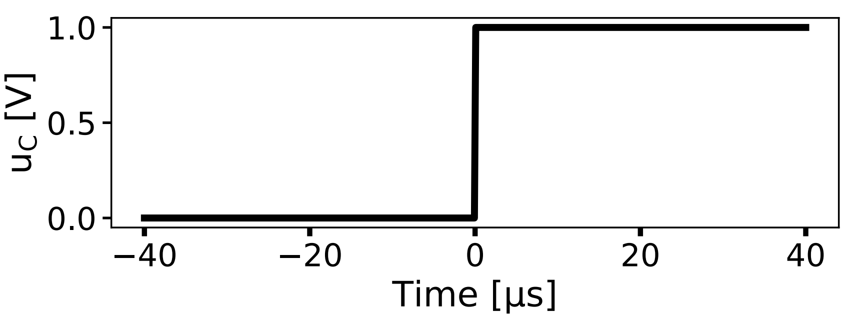
$$u_C(t) = u_0 h(t)$$

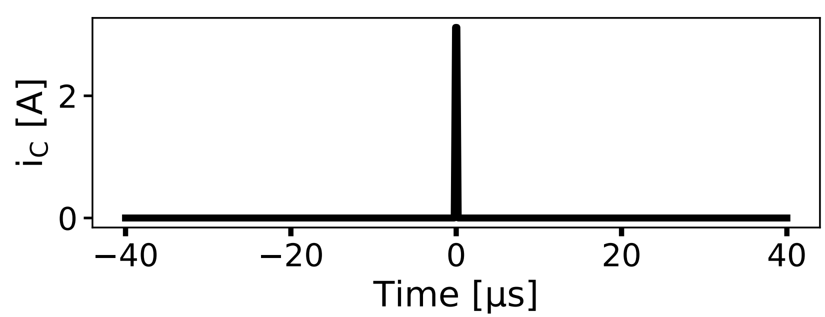


$$i_C = C\frac{du_C}{dt}$$

$$i_C = Cu_0\delta(t)$$

Current spikes in reaction to change in voltage, so that the voltage across the capacitor equalizes the one of the source.

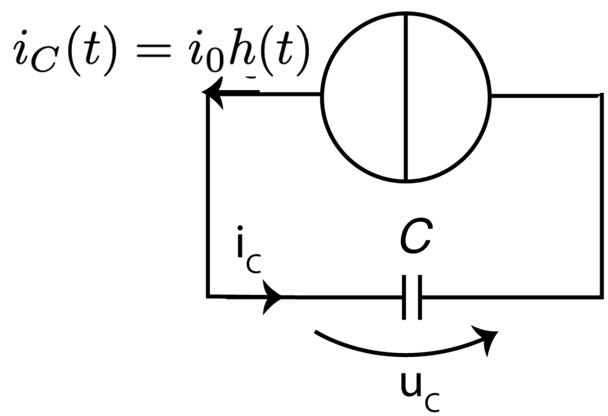




I.-C. Benea-Chelmus

Time response of C (Ch. 6.2.2)

Current source connected



$$i_C = C\frac{du_C}{dt}$$

$$u_C(t_2) - u_C(t_1) = \frac{1}{C}\int_{t_1}^{t_2} i_C dt' = \frac{i_0}{C}\int_{t_1}^{t_2} h(t')dt'$$

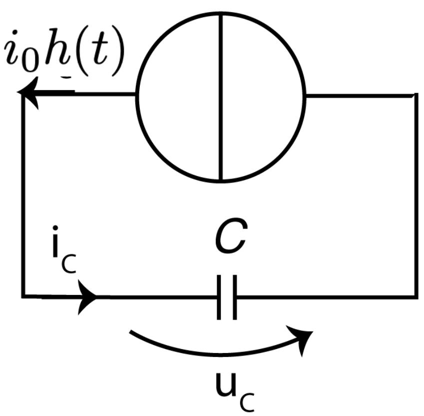
(Calculation at the blackboard)

Time response of C (Ch. 6.2.2)

I.-C. Benea-Chelmus

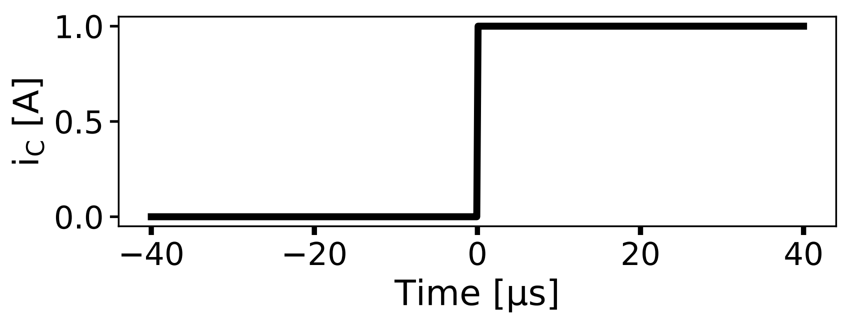
Current source connected

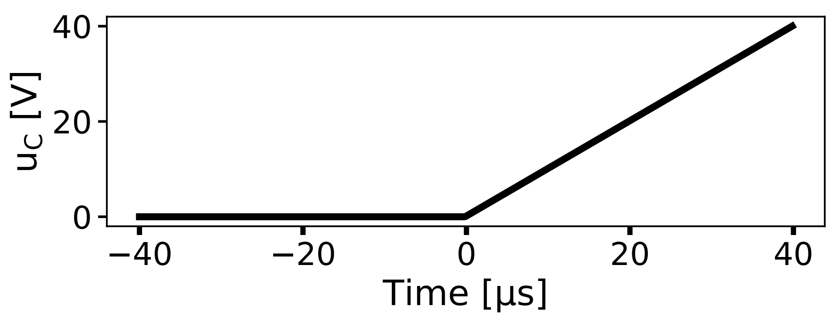
$i_C(t) = i_0 h(t)$



$$u_C = \begin{cases} 0, & t < 0 \\ \frac{i_0}{C} t, & t \geq 0 \end{cases}$$

Voltage does not react instantaneously to change in current: It slowly ramps up until it reaches infinity because current source delivers infinitely many electrons.



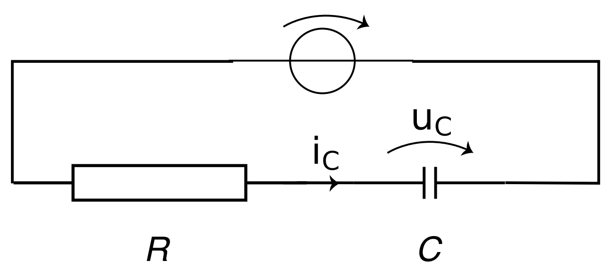


Real circuits: RC circuit (Ch. 6.3.1)

I.-C. Benea-Chelmus

- Guided example 1:

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



$$i_C = C \frac{du_C}{dt}$$

Boundary conditions:

(calculation at the blackboard)

$$t < 0 :$$

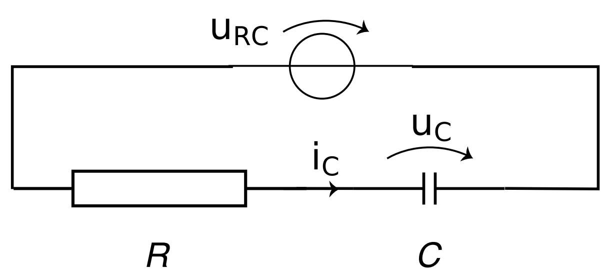
$$i_C = 0$$ No current flowing !

$$u_C = 0$$ Capacitor not charged!

Real circuits: RC circuit (Ch. 6.3.1)

I.-C. Benea-Chelmus

- Guided example 1:

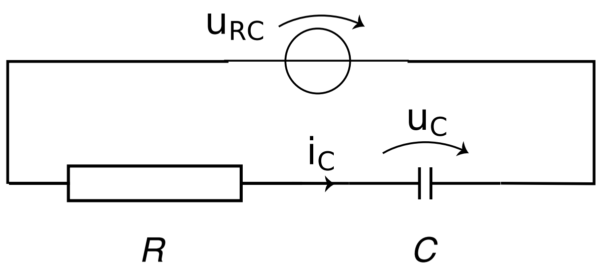


$$t < 0:$$
$$i_C = 0$$
$$u_C = 0$$

$$t \geq 0:$$
$$i_C = \frac{u_0}{R} e^{-\frac{t}{RC}}$$
$$u_C = u_0 (1 - e^{-\frac{t}{RC}})$$

Real circuits: RC circuit (Ch. 6.3.1)

- Guided example 1:



$t < 0:$

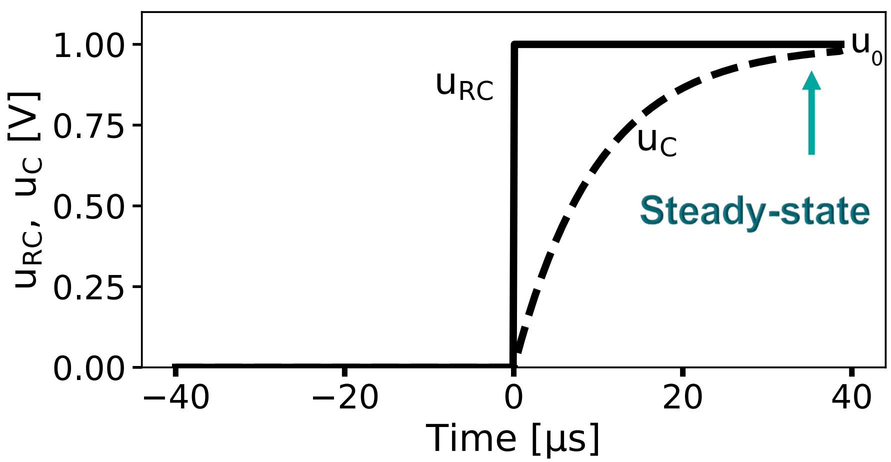
$$i_C = 0$$

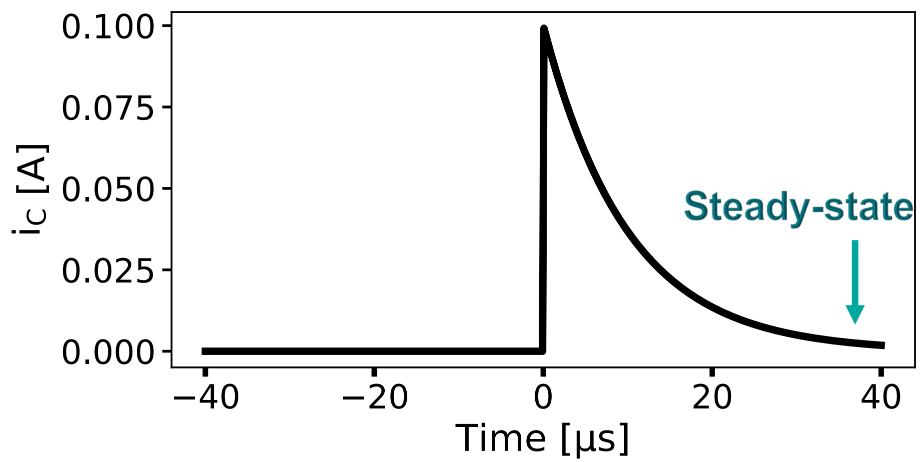
$$u_C = 0$$

$t \geq 0:$

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

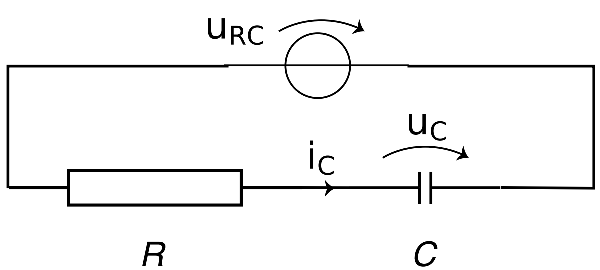
$$u_C = u_0 (1 - e^{-\frac{t}{RC}})$$





Real circuits: RC circuit (Ch. 6.3.1)

- Guided example 1:



$$t \geq 0:$$

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

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

We find that the capacitor loads up to the voltage of the source with a characteristic time constant $\tau_{RC} = RC$. This is the so-called RC time constant. The RC time constant can be reduced for example by decreasing R. The shorter the RC time constant τ_{RC} , the steeper the slope and the closer will u_c follow the source u_{RC} .

At the same time, we notice that at t = 0, the current spikes to a value of $i_{RC}\,(t = 0) = \frac{u_0}{R}$ after which it decreases again with the same slope as the voltage. We note that for R → 0 we find back the case of the capacitor connected to a voltage source which is switched on.