From Battery Powered to Inductive Powered: The Wireless Mouse as a Design Example

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Principle inductive WPT

- Lenz law: A time-varying magnetic field leads to an induced voltage.
- Principle used in:
  - Transformers
  - Generators (e.g., dynamo cycling, power plants)
  - Electrical motors
  - Inductive charging of stand-alone electronic devices

Current commercial usage WPT

- Static receiver
- Non-flexible positioning
- E.g., Qi integrated in Ikea lamp[1] :

1: http://lifedsign.com/2015/03/ikea-draadloos-opladen-met-ikea-meubelen/ikea-homesmart-wireless-kabelloses-induktives-aufladen-smartphone-tablet-qi-7/

Reference configuration: Wireless Mouse

- Wireless mouse:
  - Device is moving constantly
  - Large working area
- Remove the battery's from a moving device
- Power the device inductively

Possible configurations

- Without battery constant power supply is required
  - Results in a defined working area

- Several possibilities
  - A single coil around the working area
  - A coil matrix covering the whole area
  - A single smaller coil with an energy buffer

Single transmitter coil

- Large transmitter coil around the entire area

- Advantages
  - Always magnetic field present
  - Easy to design
  - Simple driver circuitry

- Disadvantages
  - Low efficiency due to low coupling factor
  - Increased magnetic field on the entire work area

Coil matrix

- A matrix of small overlapping coils: Only one or a couple of coils in the transmitter array is active (detection mechanism)

- Advantages
  - Good efficiency due to the increased coupling
  - Device always in the presence of a magnetic field
  - Foreign object detection

- Disadvantages
  - Complex driver circuitry -> location of the receiver
  - Expensive coil structure

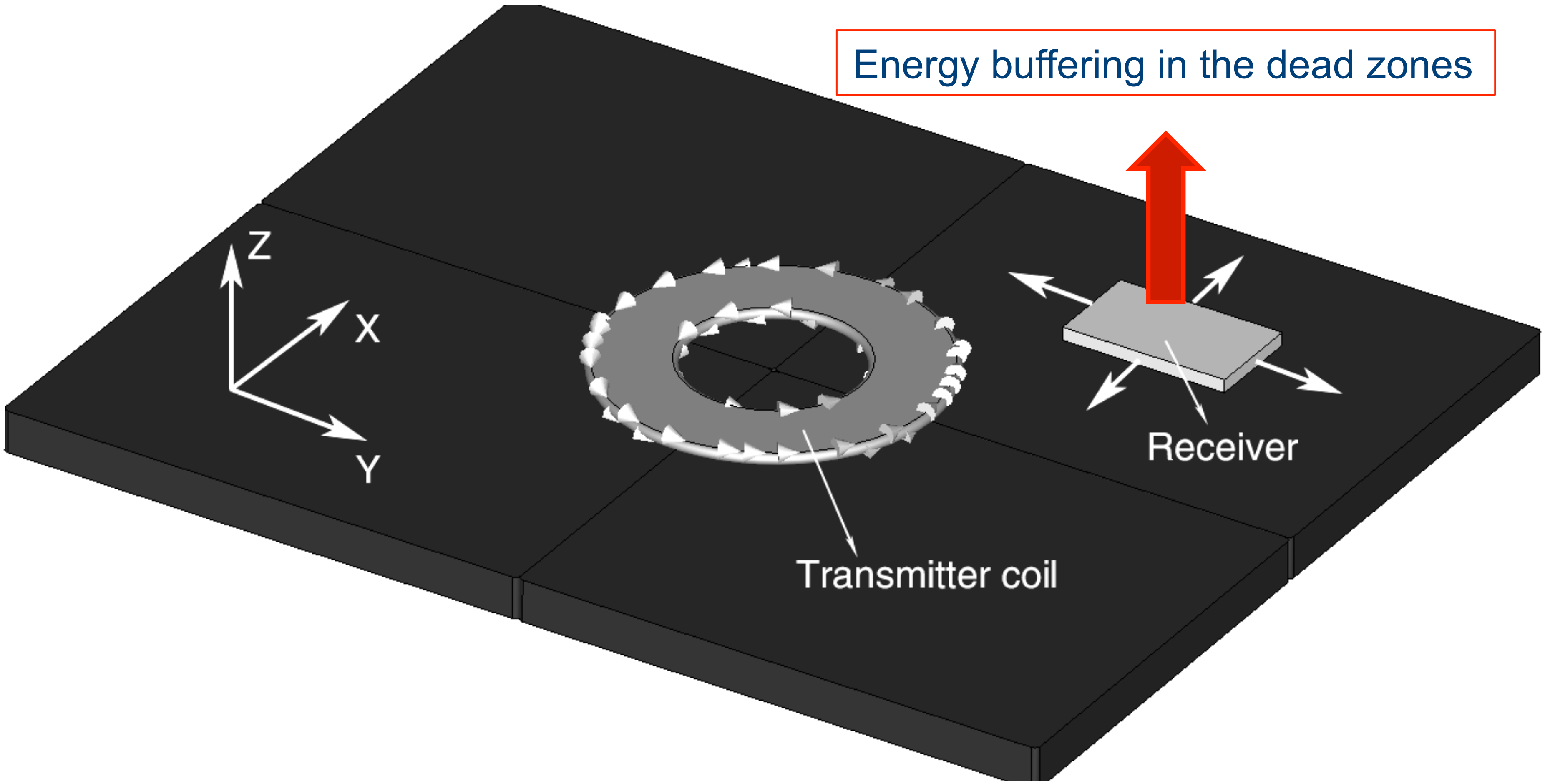
Smaller coil with energy buffer

- Small coil inside the working area
  - The device moves -> regularly coupled with the transmitter

- Disadvantages
  - Because of the “dead zones” energy buffering is required -> more driver complexity and dedicated communication protocol

- Advantages
  - Efficiency is high due to the high coupling and high power transfer during passage
  - Only increased magnetic field with good coupling

Setup


Energy buffering in the dead zones
Z
X
Y
Receiver
Transmitter coil

Energy buffer

- Supercapacitor or rechargeable battery

- Advantages supercapacitor
  - Charges quickly and efficiently
  - Many reload cycles possible

Supercap

- Disadvantage: Lower energy density (less important due to the regular recharge)

Coil design

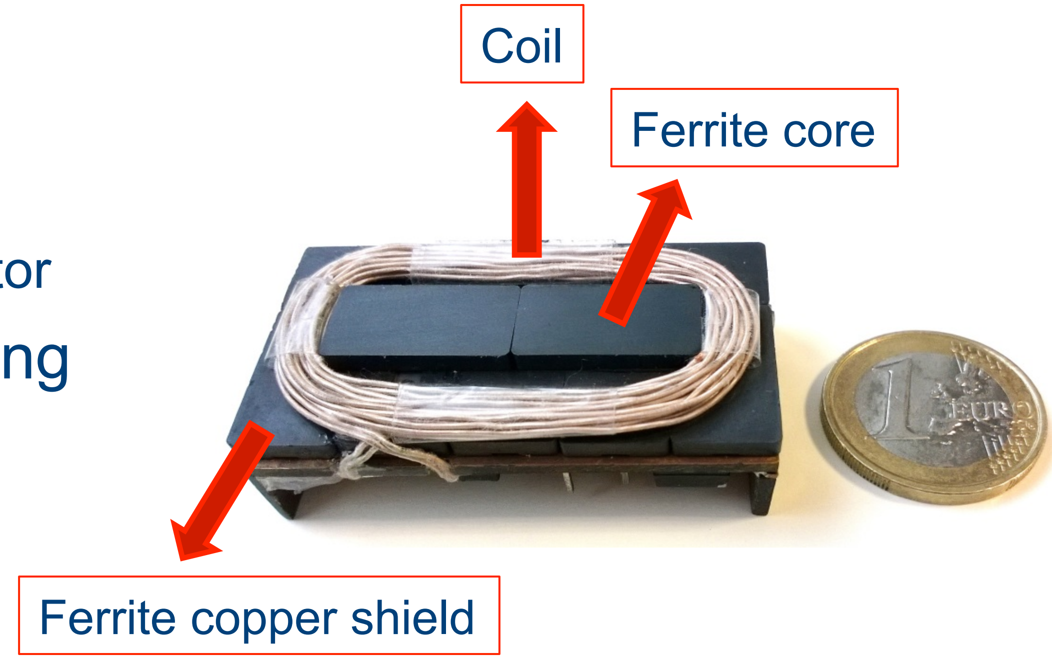
- Maximal efficiency is function of product coupling and quality factors.

$$\eta_{link,max} = \frac{k^2 Q_{T_x} Q_{R_x}}{\left(1 + \sqrt{1 + k^2 Q_{T_x} Q_{R_x}}\right)^2}$$

- Chosen frequency: 120 kHz.

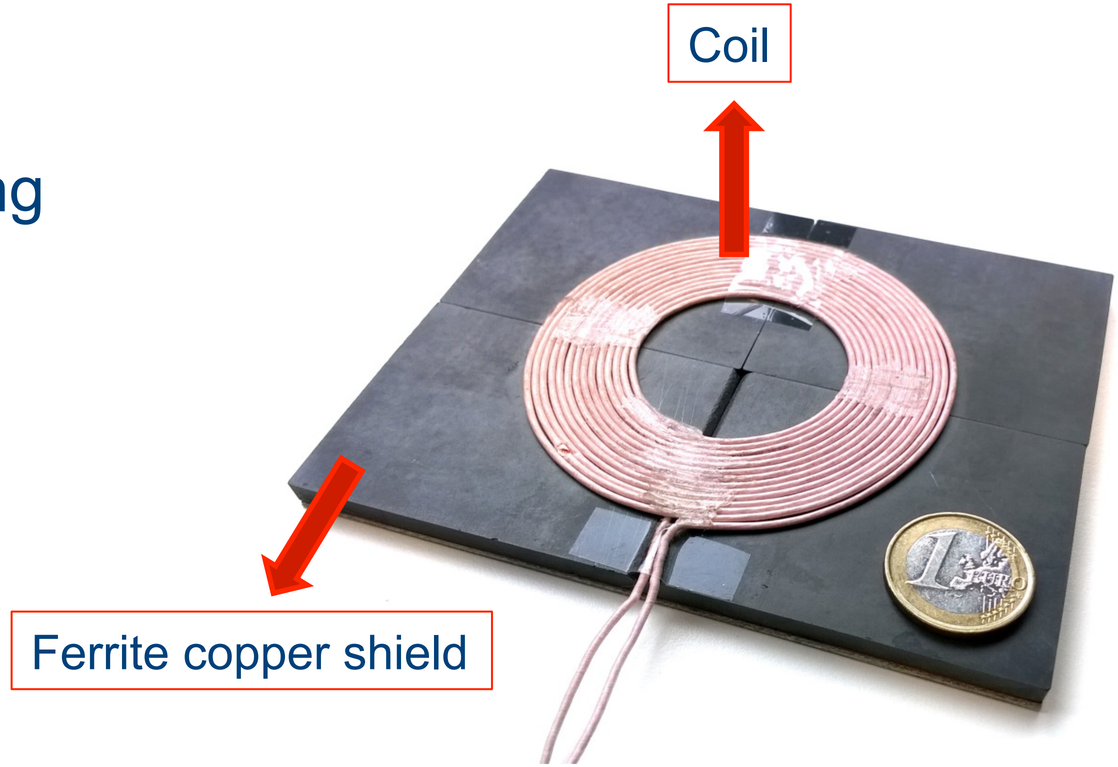
Receiver coil

- Boundary condition: Volume of 2 AA-batteries
- Implementation:
  - Litz wire
  - Ferrite core
    - Increases *Q*
    - Increases coupling factor
  - Ferrite copper shielding

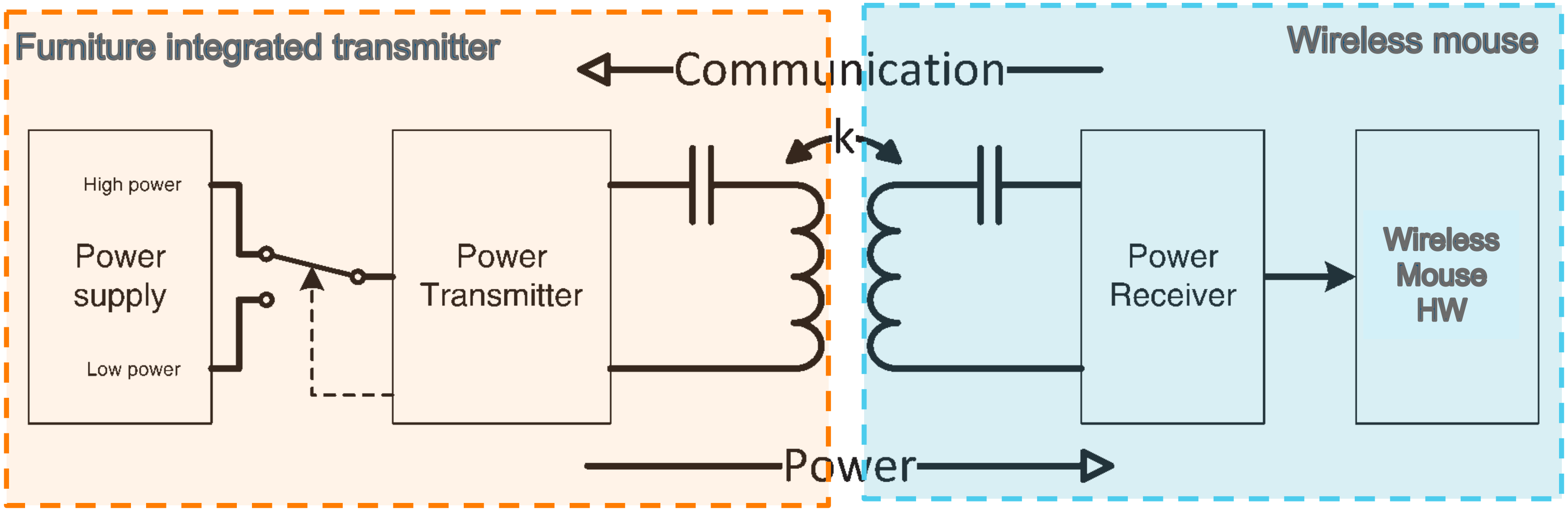


Transmitter coil

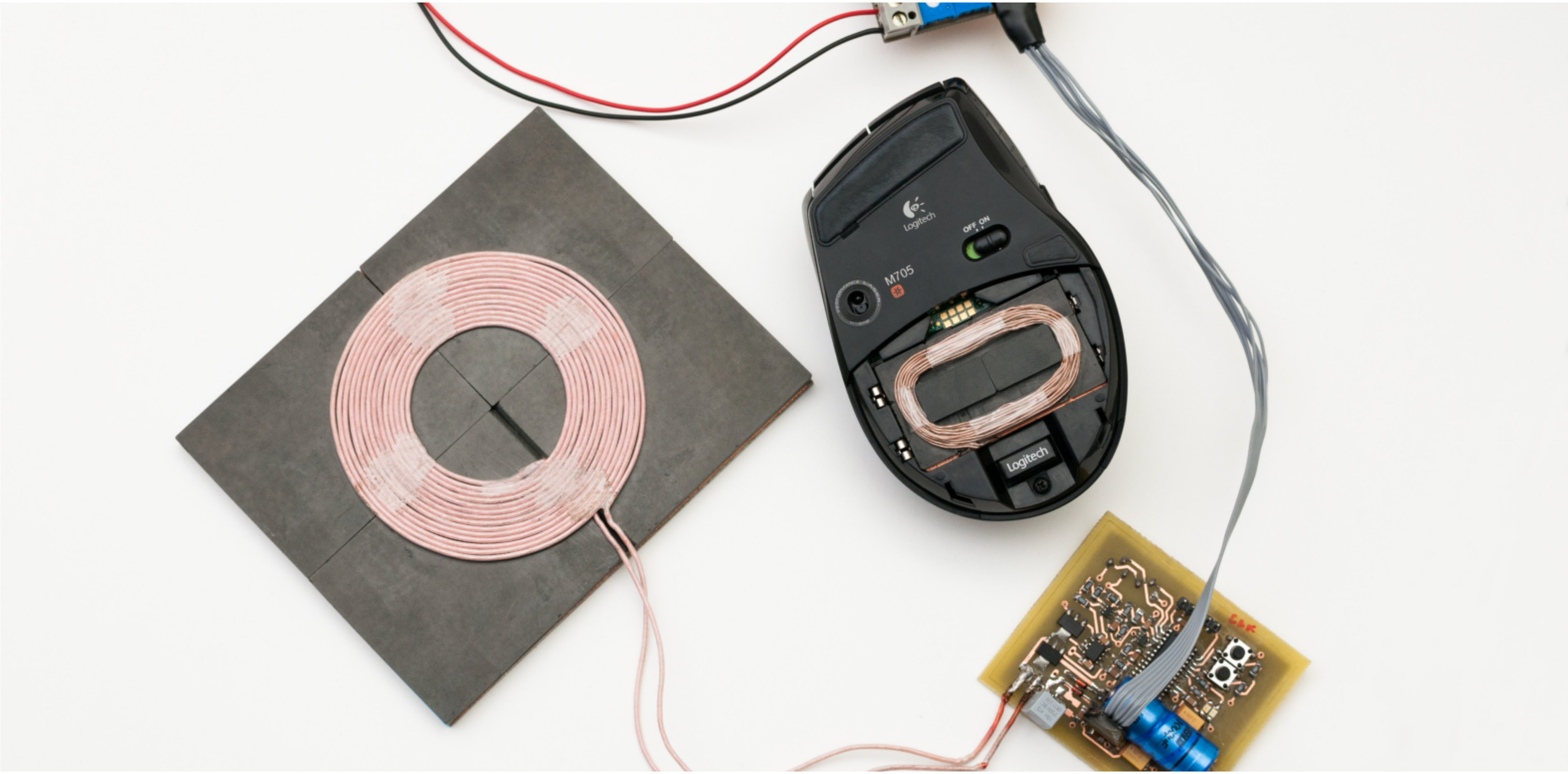
- “Pancake coil”: Reduce the total thickness in order to facilitate furniture integration
- Litz wire
- Ferrite copper shielding



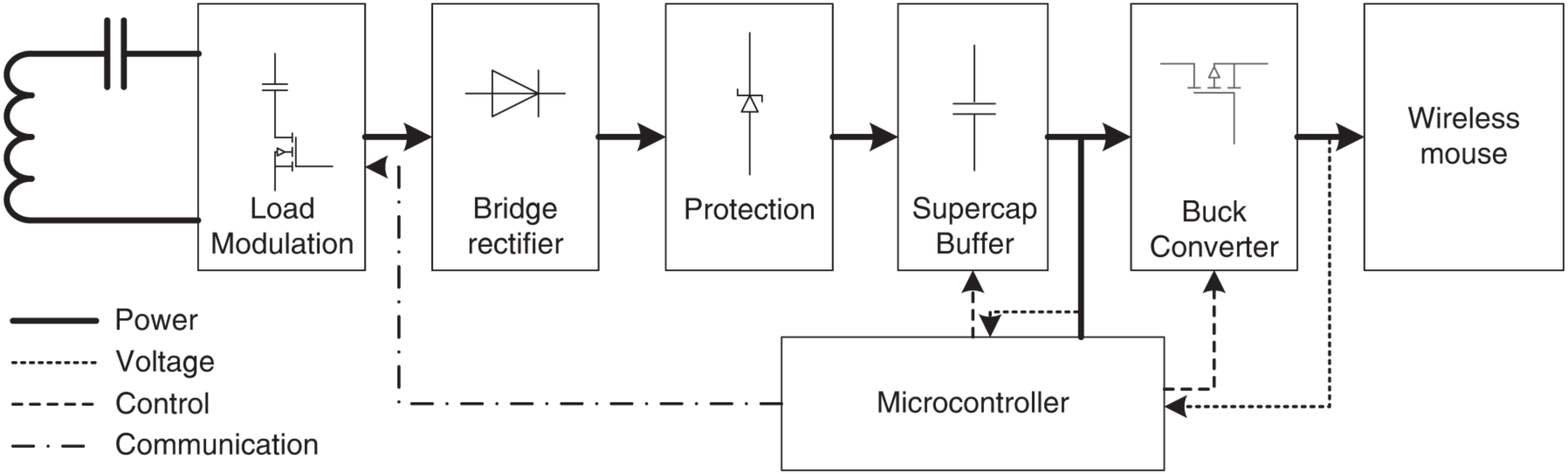
Total system



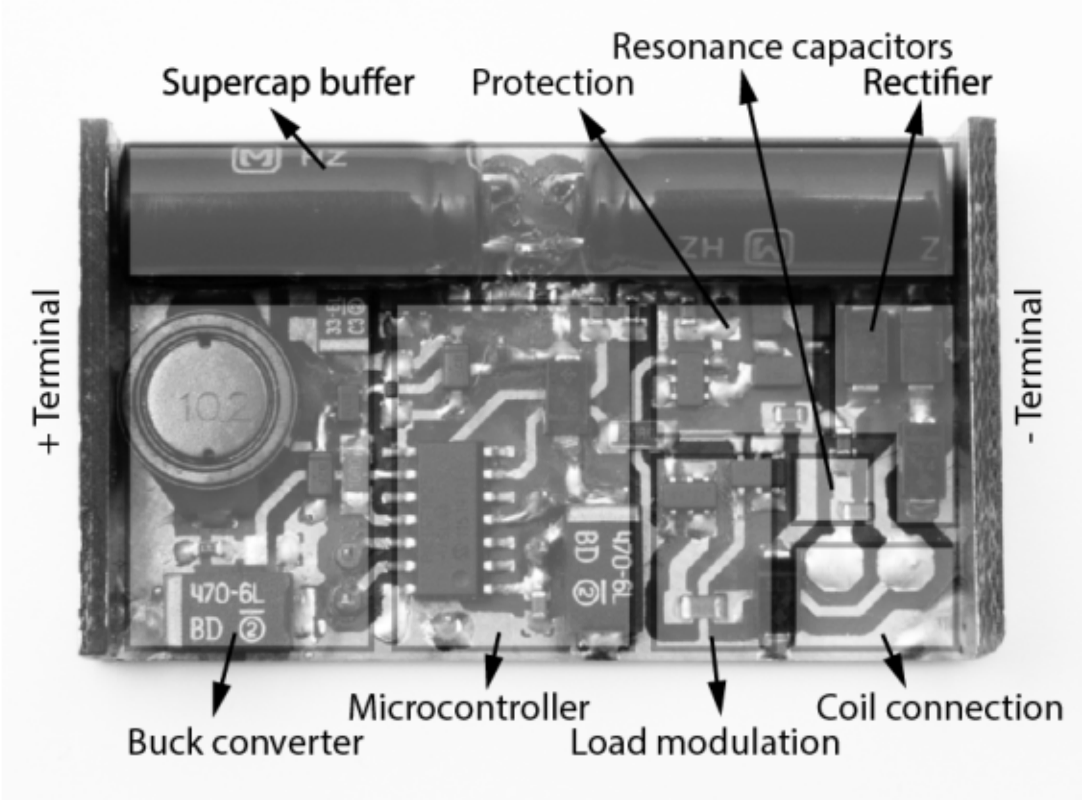
Total system



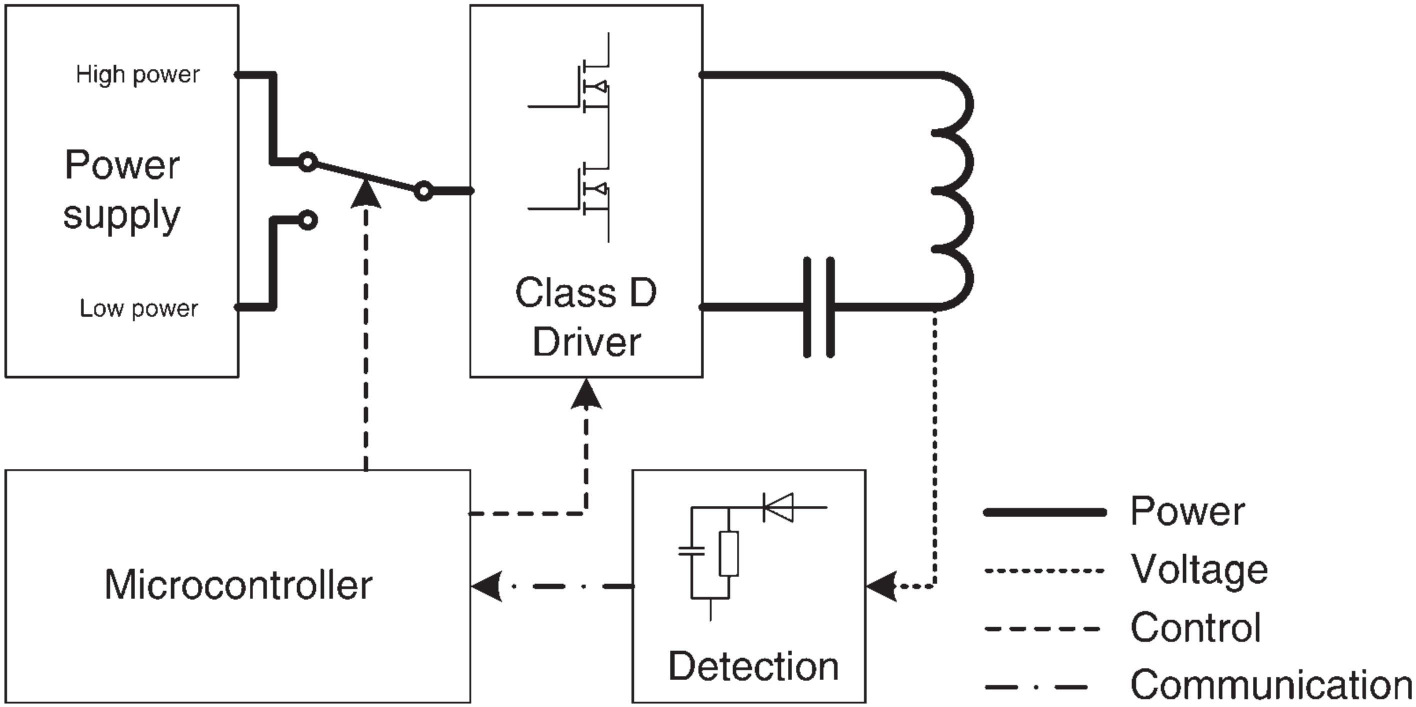
Power receiver



Power receiver



Power transmitter



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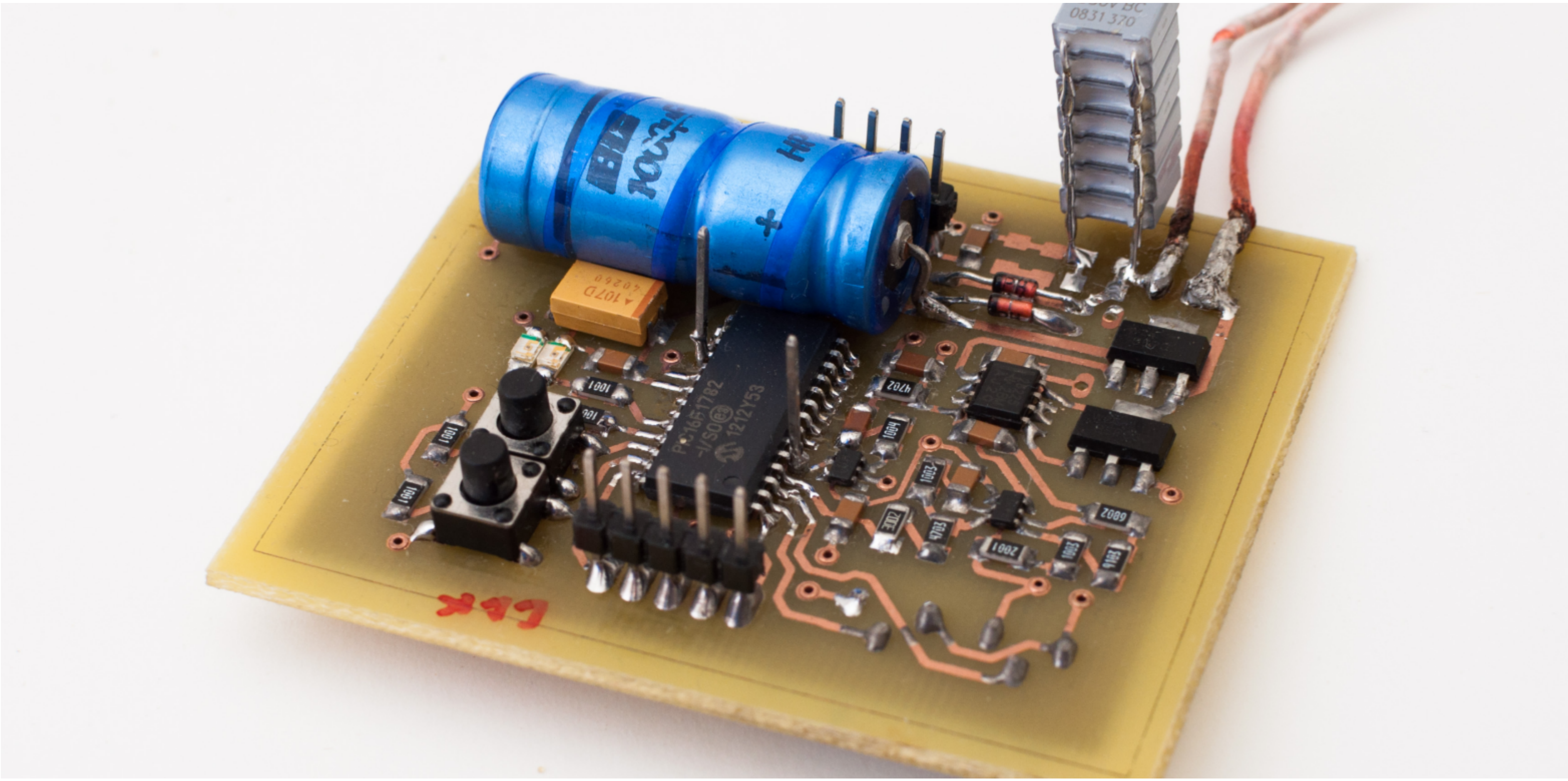
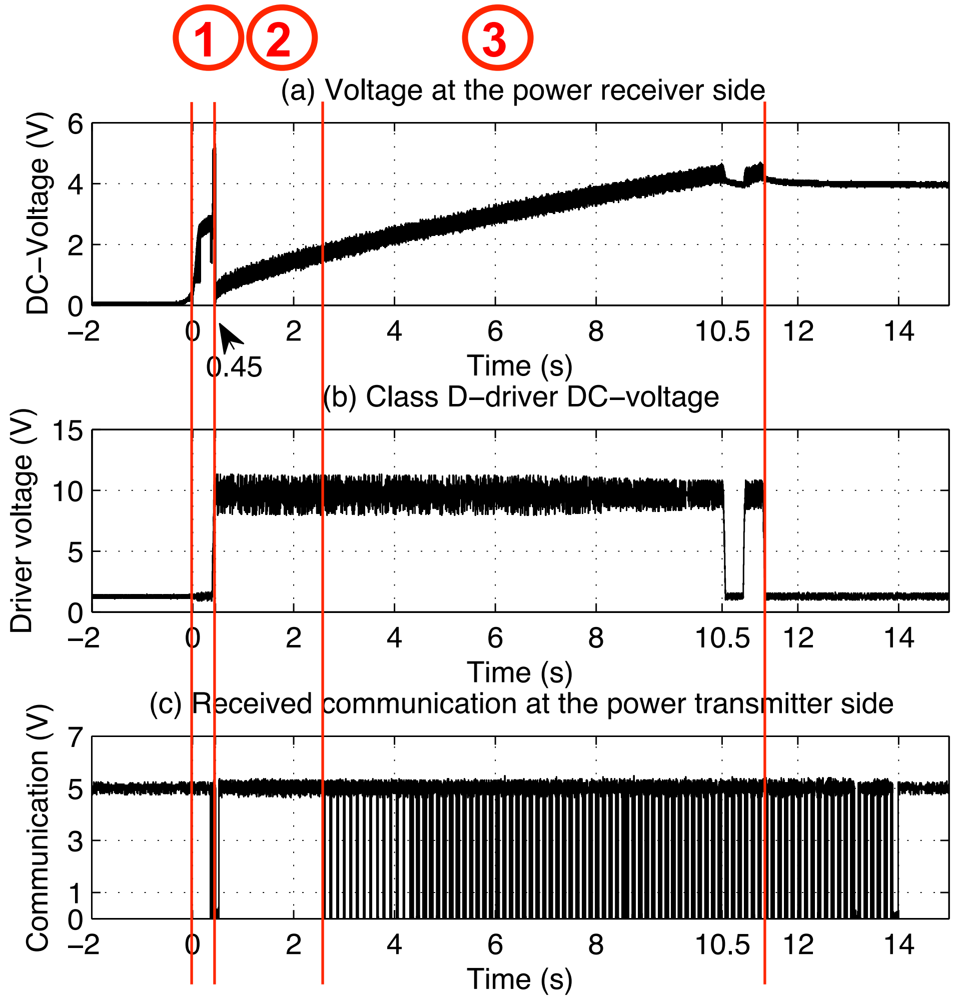
Power transmitter



Start-up of the device



1
- Receiver powers up
- Receiver asks high power
- Buffer activated

2
- Driver into high power
- Charging buffer
- Receiver MCU powered down

3
- Receiver MCU restarts
- Receiver sends buffer status
- Charging until buffer full

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Measurement results

- Average power consumption wireless mouse: 10 mW
- Goal: 15 minutes autonomy
- Maximum wireless power transfer: 4.2 W
- Capacity of the supercap: 1.65 F - 5 V

- Supercap charged in 10 s
- 18 minutes of working time
- Less than 1 % of the time over the transmitter guarantees correct functionality

Conclusion

- Working, realistic reference configuration for moving receivers over a larger working area:
  - Energy buffering
  - Dedicated communication protocol
  - Low duty cycle: Short loading time and high autonomy (1 %)

- Multiple transmitters can be combined to increase working area

Publications

- Conference paper: "Design of an Inductively Coupled Wireless Power System for Moving Receivers," *Wireless Power Transfer Conference (WPTC), 2014 IEEE* , pp.48-51, 8-9 May 2014 by Thoen, B.; Wielandt, S.; De Baere, J.; Goemaere, J.-P.; De Strycker, L.; Stevens, N.

- Journal paper: "Development of a Communication Scheme for Wireless Power Applications With Moving Receivers," *Microwave Theory and Techniques, IEEE Transactions on* , vol.63, no.3, pp.857,863, March 2015 by Thoen, B.; Stevens, N.