Ki Cordless kitchen

Power Transmitter & Reference Design

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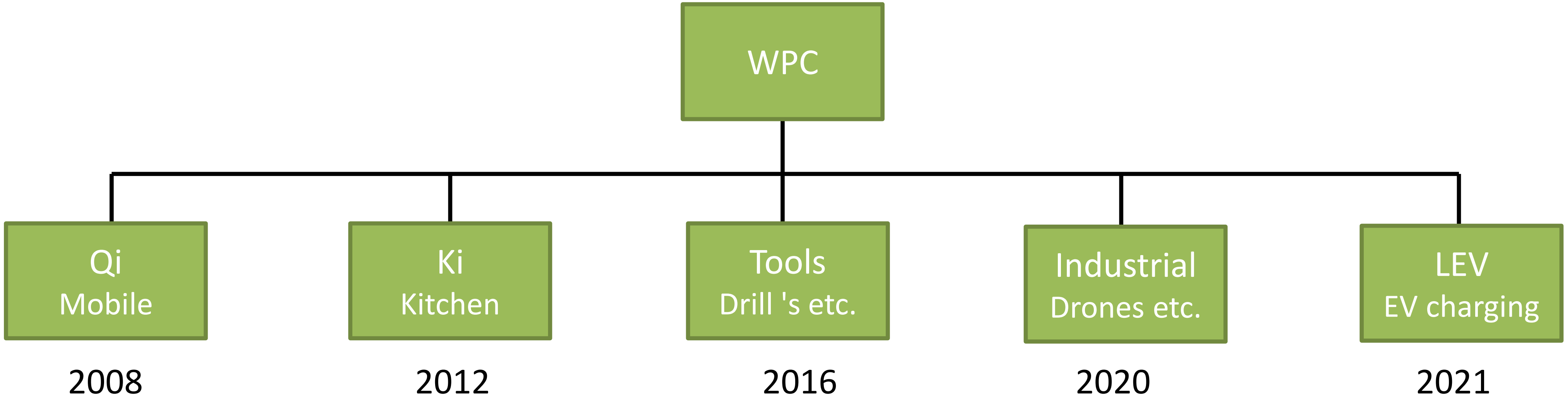
Introduction

WPC organization



The Wireless Power Consortium (WPC) consists of a group of companies that voluntarily explores the possibilities of global standardization of wireless power technology

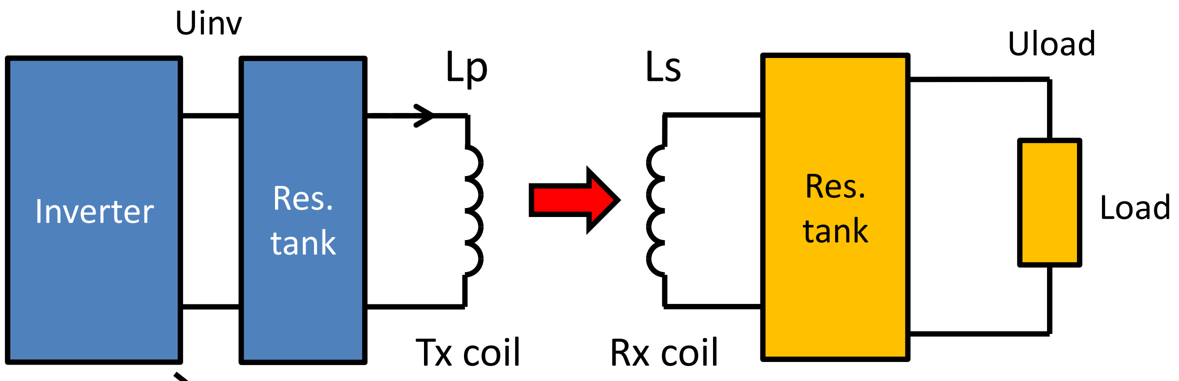
E.G.O., ST Micro Electronics, Midea, BSH, Philips, Group SEB (WMF), SEF, Electrolux,….

Introduction

Ki Cordless kitchen proposition

Ki power transmitter

Ki Cordless kitchen Appliance

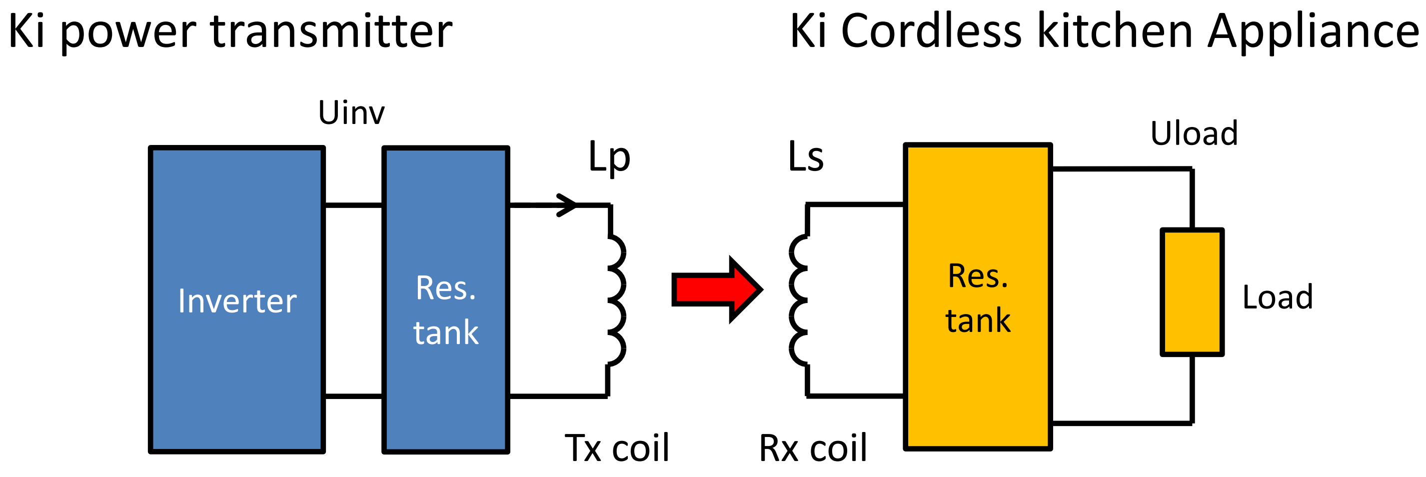


V1: Cooktop case

V2: Concealed case

Introduction

Ki specifications & boundaries



The Ki Standard should enable to power appliances:

- from 0 W to 2.2 kW
- At a frequency of 20 – 74 kHz
- At a maximum Coil – 2 – Coil distance of:
  - 1.5 cm for the hob case
  - 3.2 cm for the hidden case
- with an appliance footprint of 8 cm to 24 cm

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Introduction

Example re-worked kitchen appliance

HR7778
Food processor

800 Watt
220 - 240V AC / 50Hz

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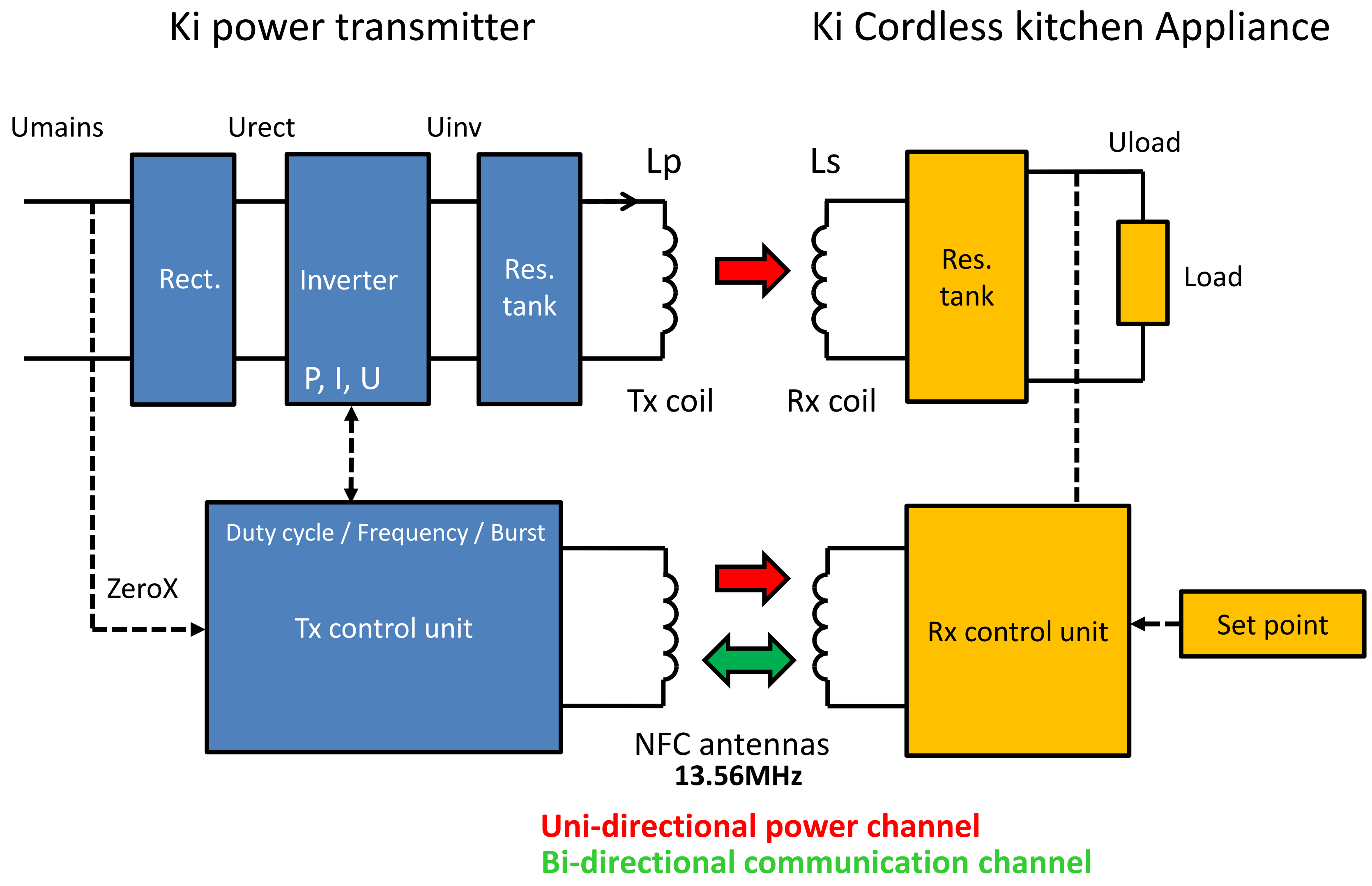
Ki Power chain in more detail

From AC to DC -> DC to AC



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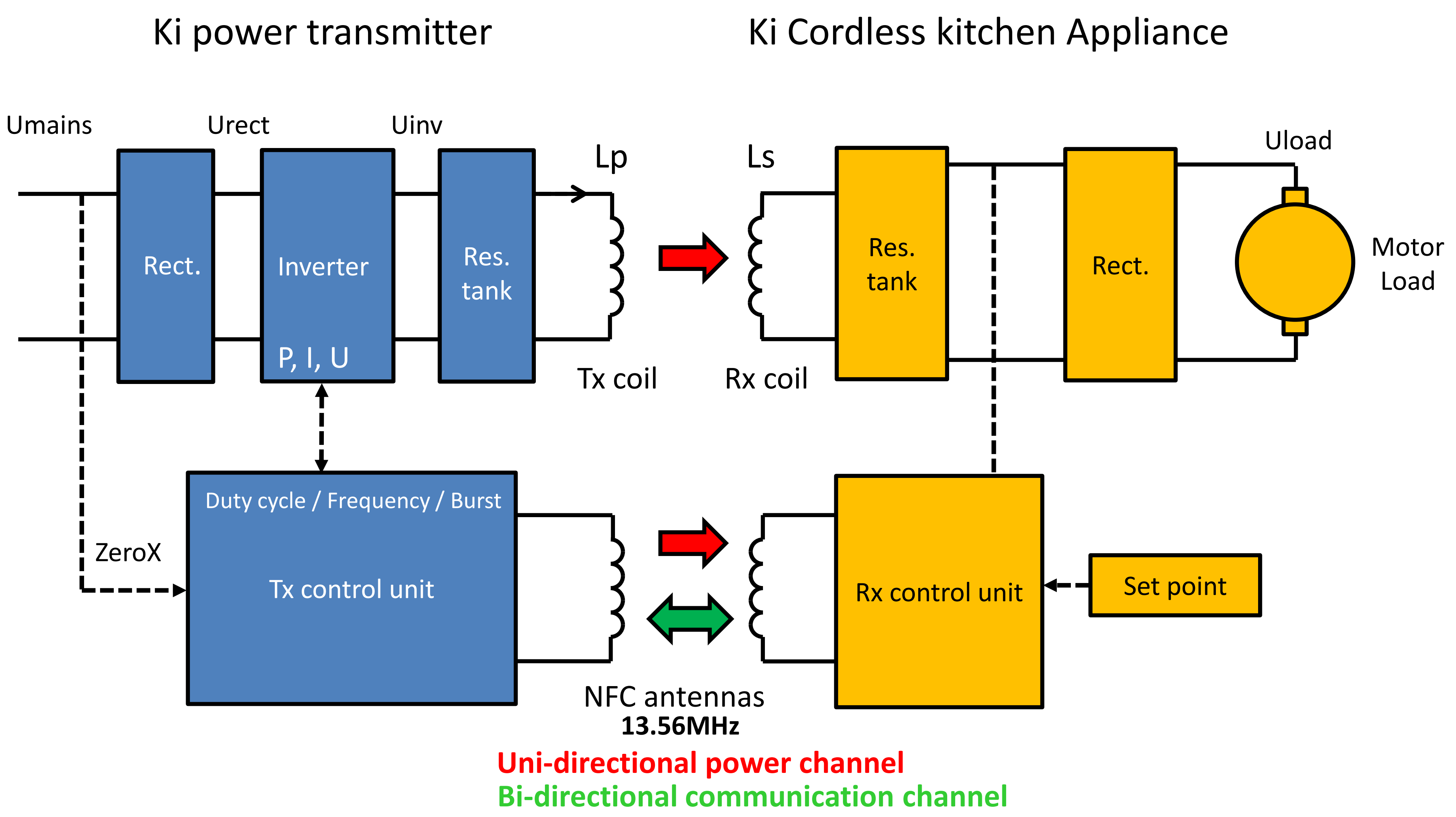
Ki Power chain in more detail

From AC to DC -> DC to AC -> AC to DC



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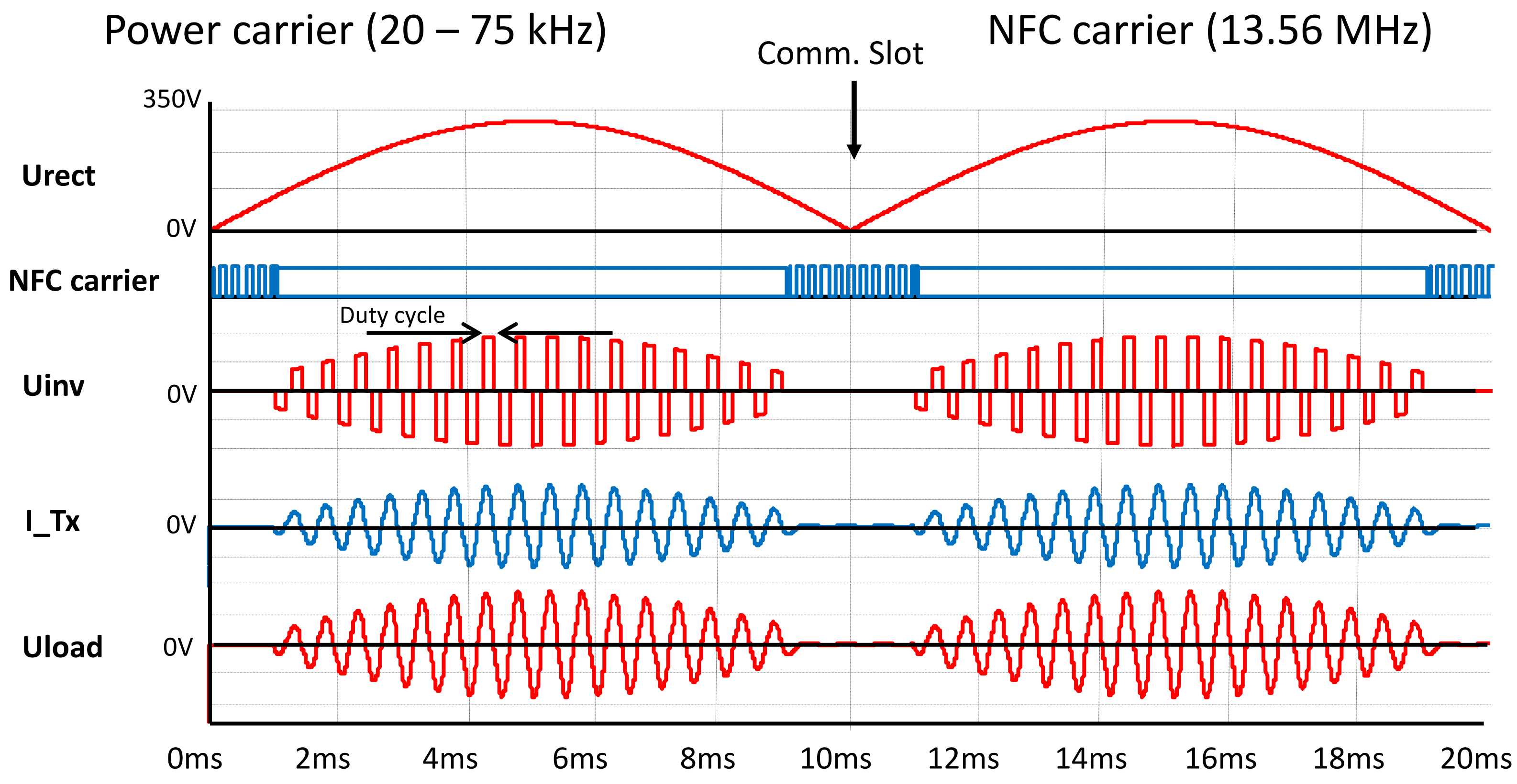
Ki Power chain in more detail

Transmitter & Receiver voltage & current wave forms



- Inverter output voltage Uac_HF is shaped according the rectified mains voltage
- Communication time-slot repeats typically **20 ms** (every other zero crossing)

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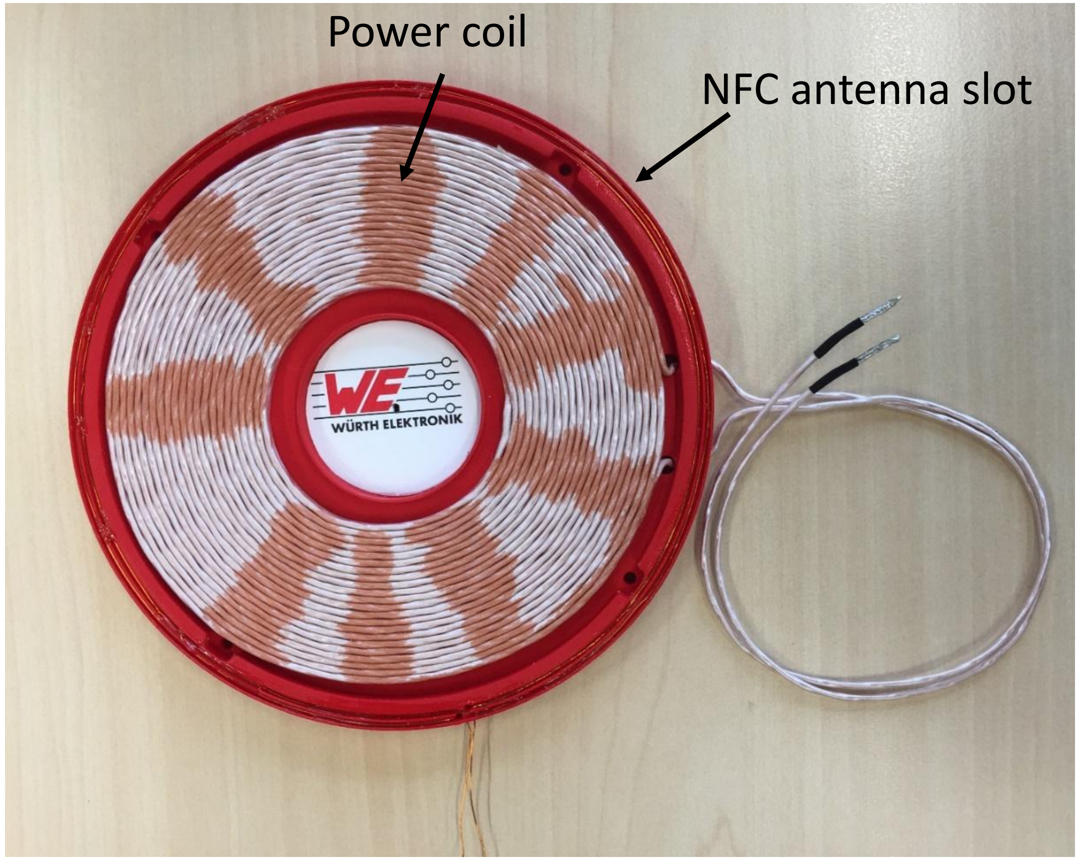
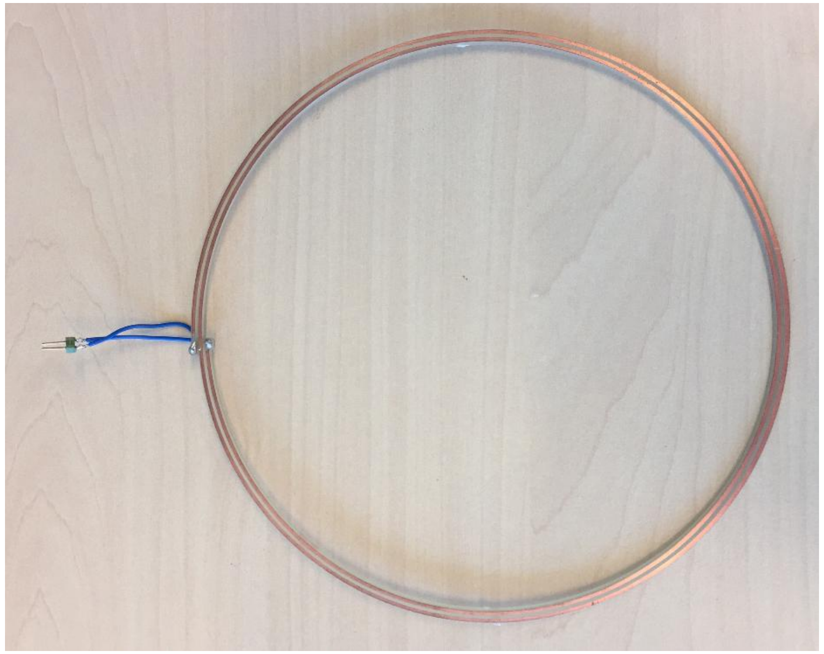
Ki Power chain in more detail

Receiver power coil & NFC antenna (example from Wurth)



NFC antenna



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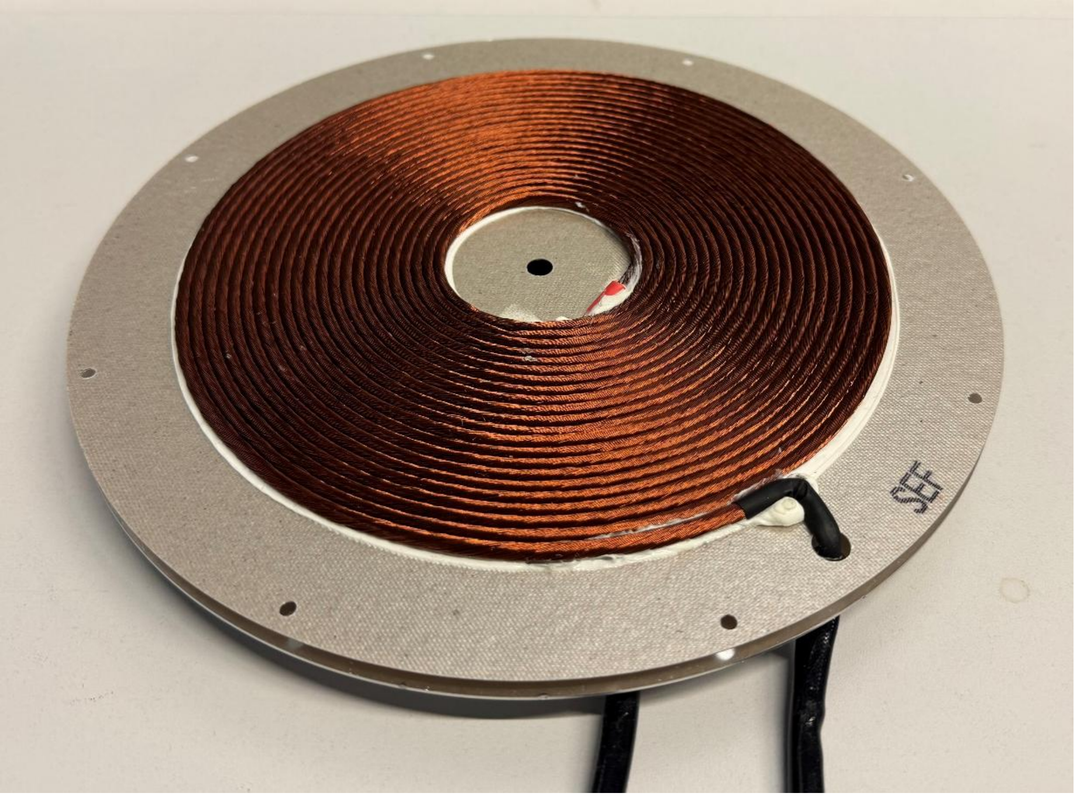
Ki Power chain in more detail

Transmitter power coil & NFC antenna (example from SEF)



With NFC antenna

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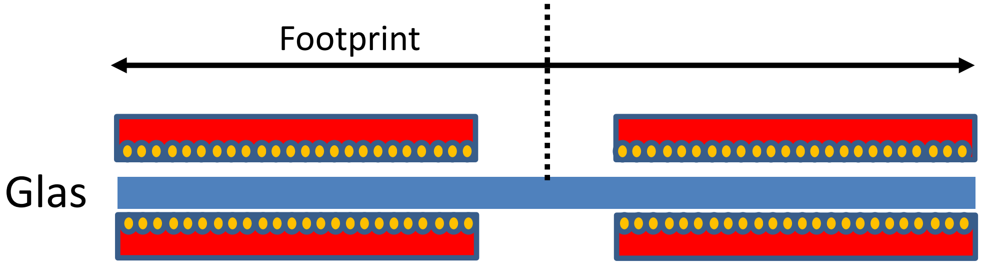
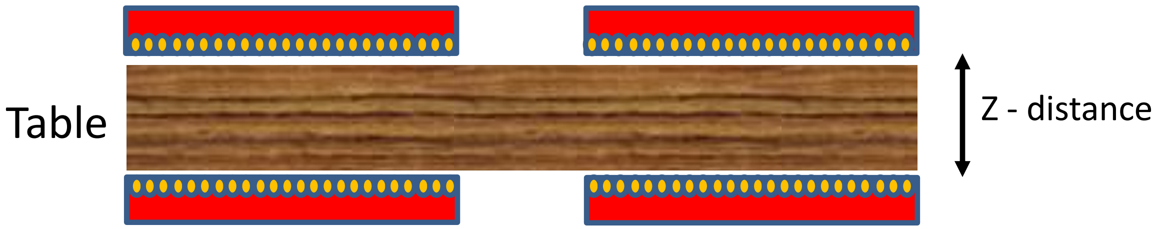
Ki Power chain in more detail

Z - distance vs. alignment vs. footprint



Cooktop case

Z – distance: 15mm max
K- factor range: 0.50 – 0.71



Concealed case

Z – distance: 32 mm max
K- factor range: 0.25 – 0.45

K-factor determined by:

- Z - distance
- Misalignment of the appliance
- Diameter of the Tx coil
- Footprint of the appliance

The Ki cordless appliance should be designed to operate on both platforms !

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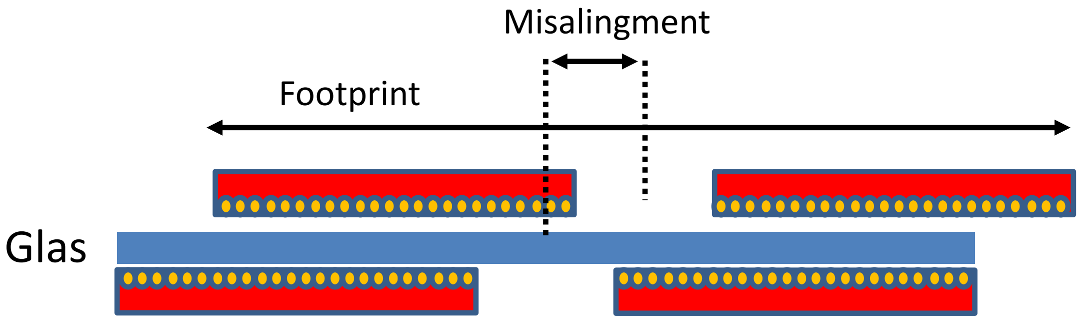
Ki Power chain in more detail

Z - distance vs. alignment vs. footprint



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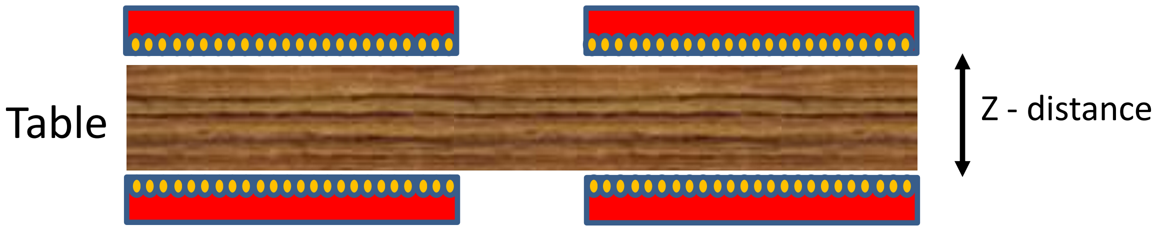

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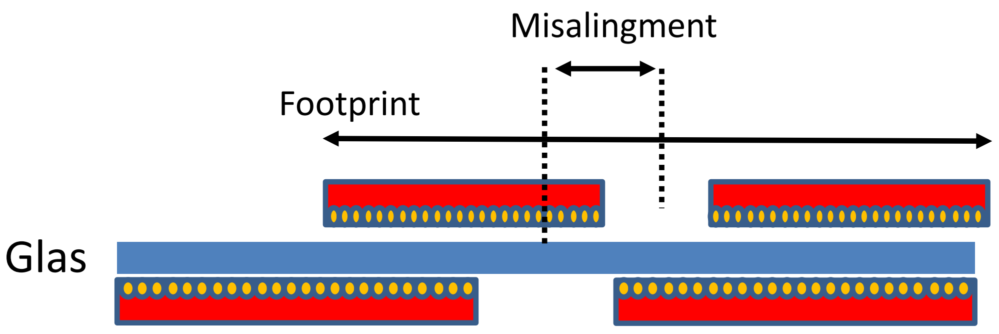
Ki Power chain in more detail

Z - distance vs. alignment vs. footprint



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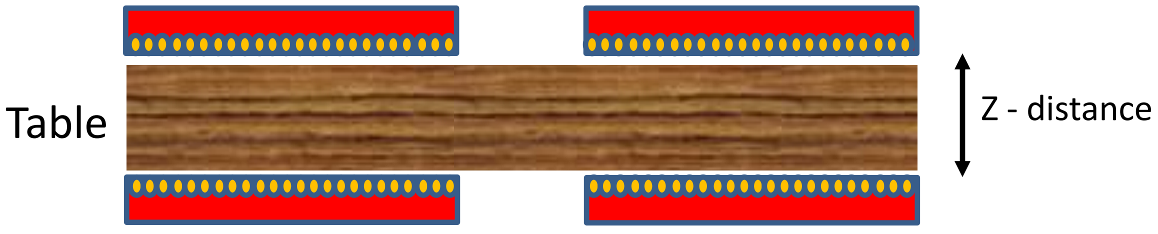

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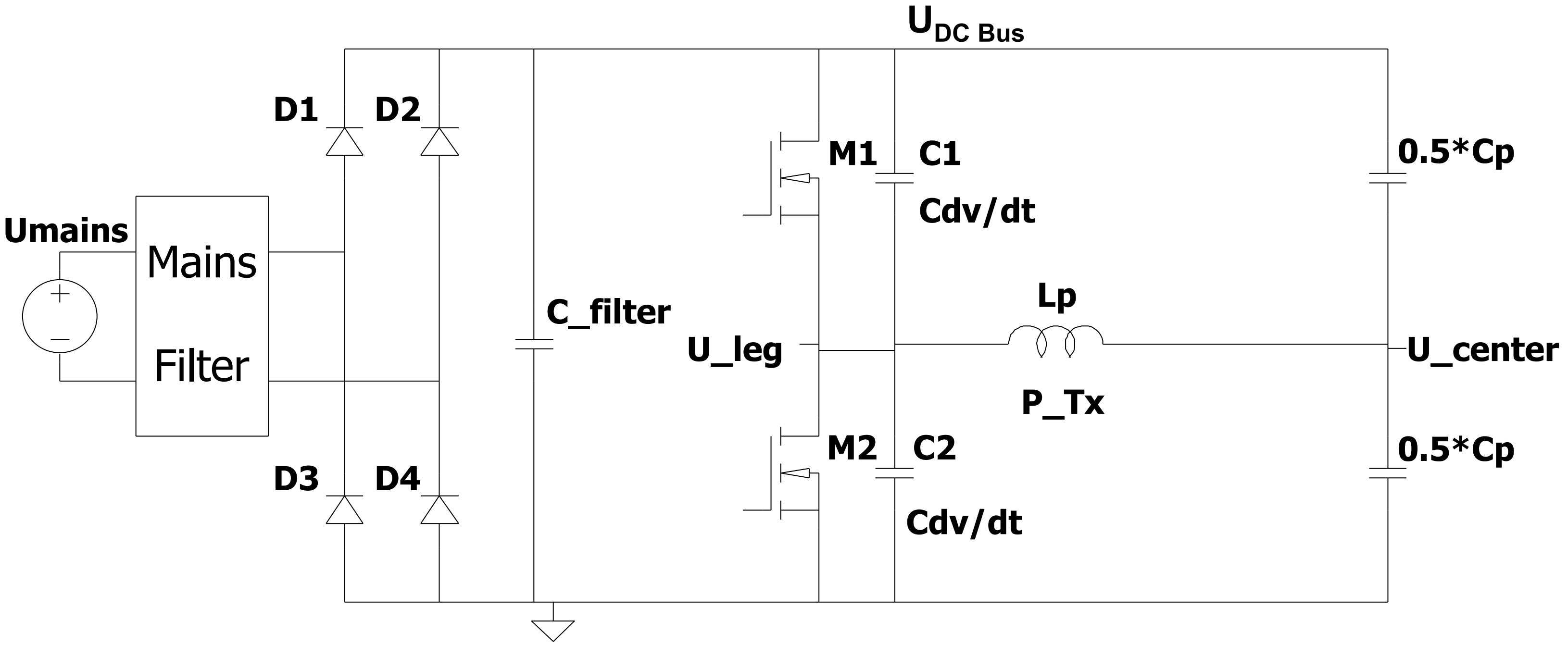
Ki Power chain in more detail

Transmitter implementation – Half bridge



Series resonant

Topology of choice was driven by Induction Hob industry

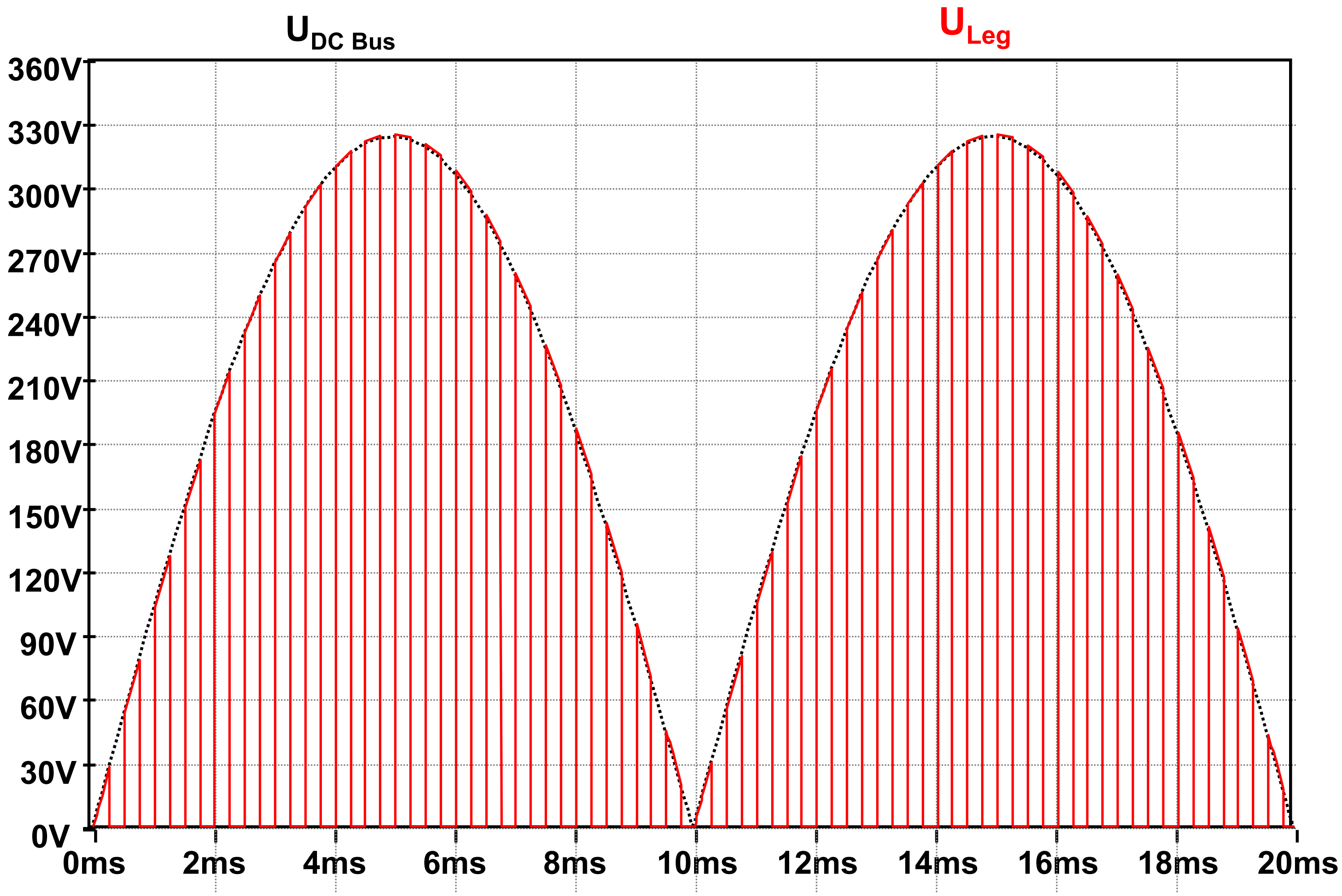
- Price vs. Complexity
- Near zero power transfer difficult but possible (Duty cycle, Frequency and Burst control)

But if you can do it with a Half bridge, you can also do it with a full bridge !!

- 110 V area's -> Full bridge

Ki Power chain in more detail

$U_{DC\ Bus}$ (dotted black) and U_{Leg} (solid red) for induction hobs

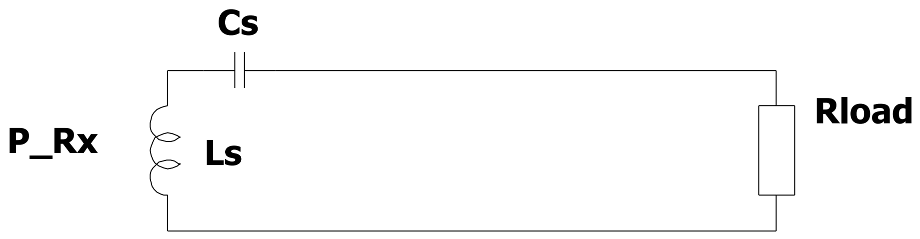


$F_{Operation}$ = 20 – 74 kHz

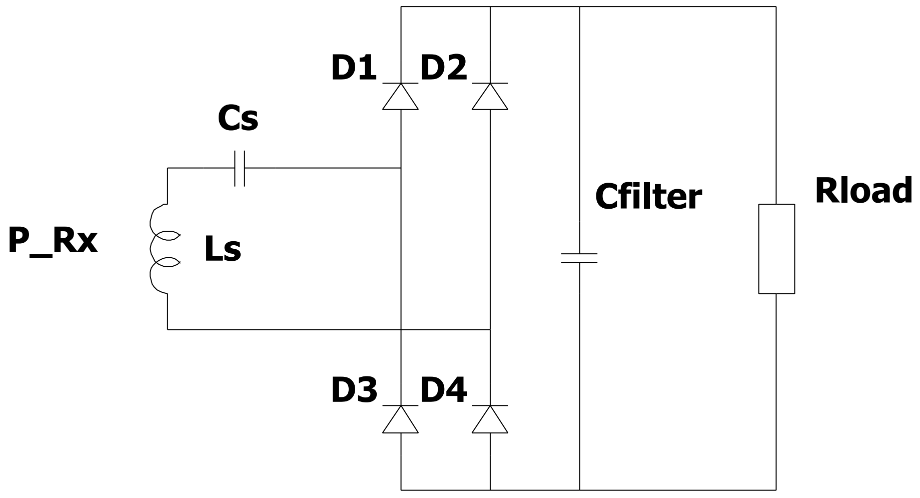
Duty Cycle = 0.2 – 0.5

Ki Power chain in more detail

Receiver implementations



- For simple appliances like water kettles, heating elements etc.



- For appliances with:
  - motors
  - both motors & heating element

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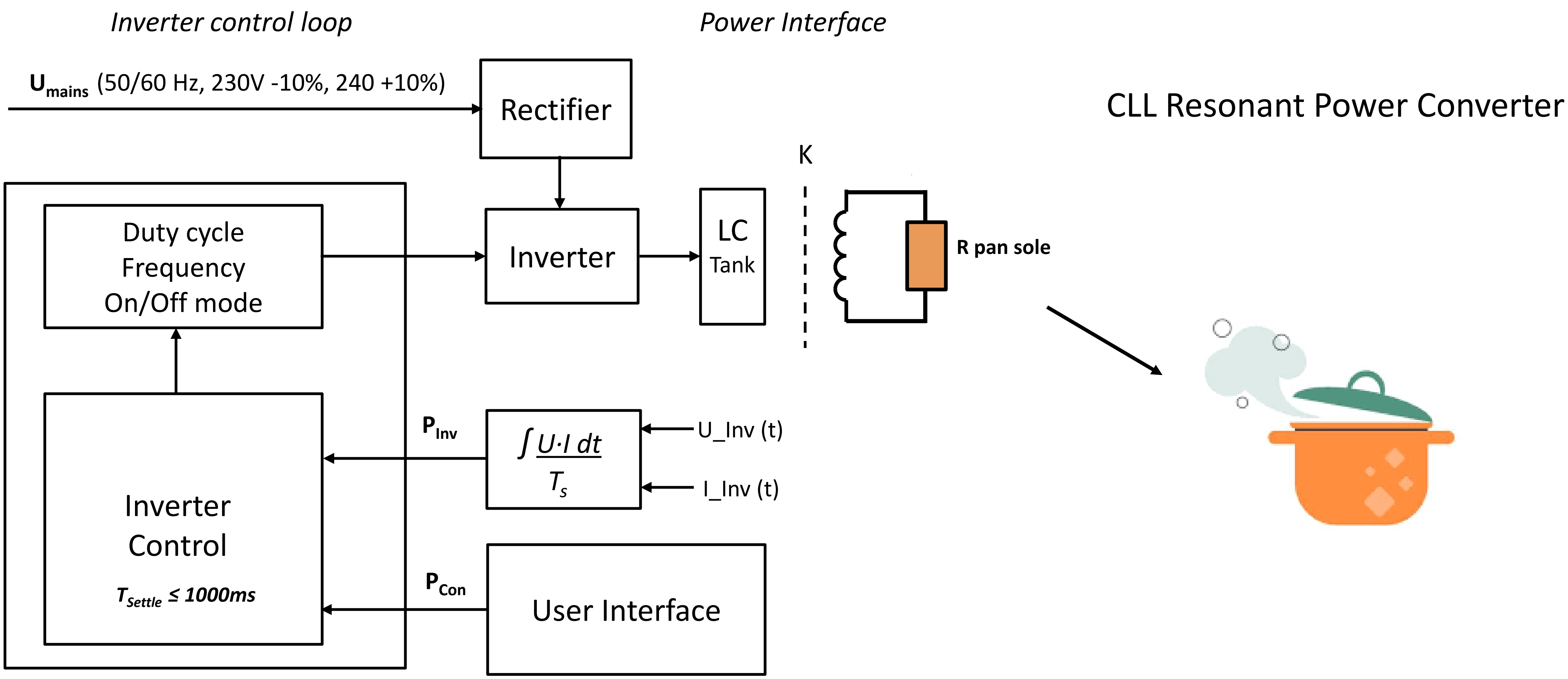
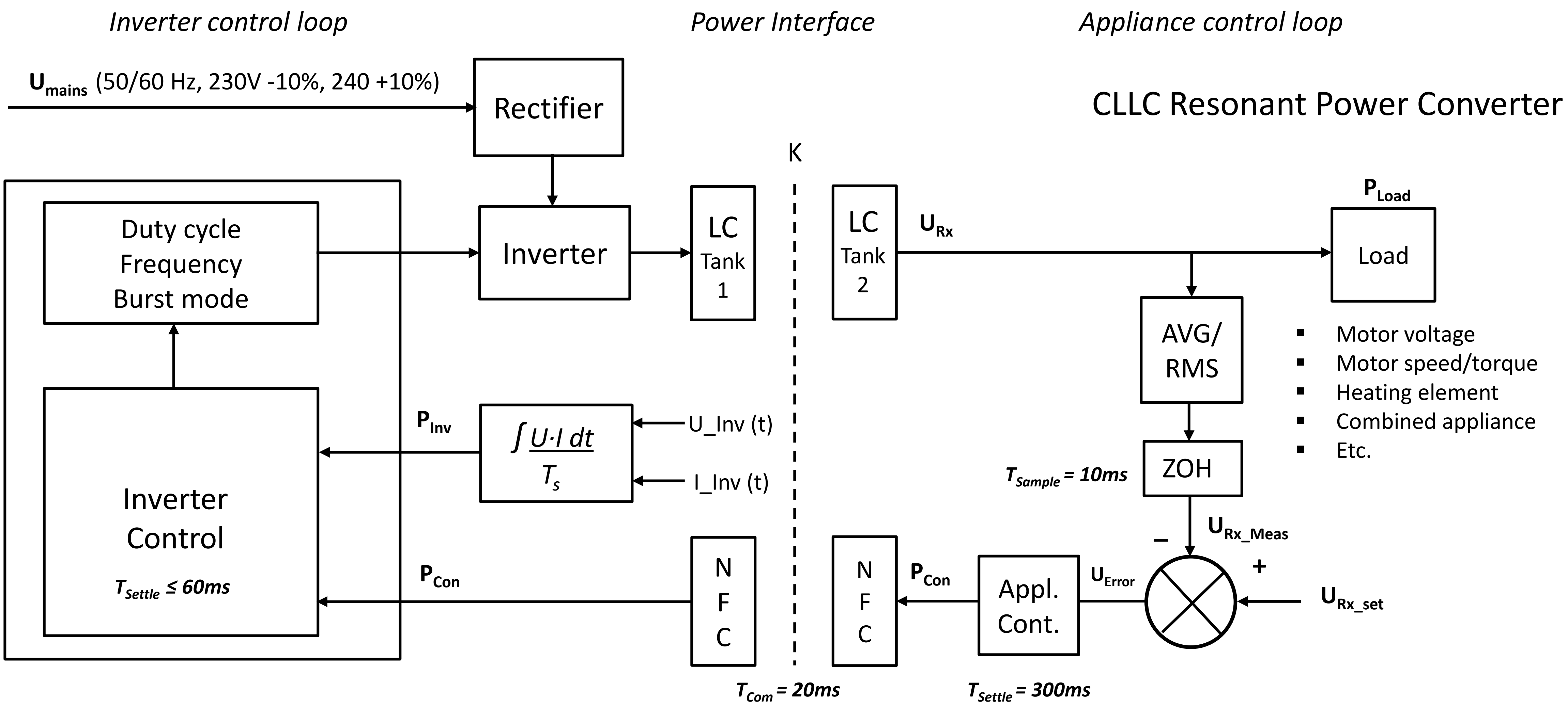
Power Control for general induction hobs

Single power control loop



Power Control for Ki cordless kitchen system

Inner power control loop + outer appliance control loop



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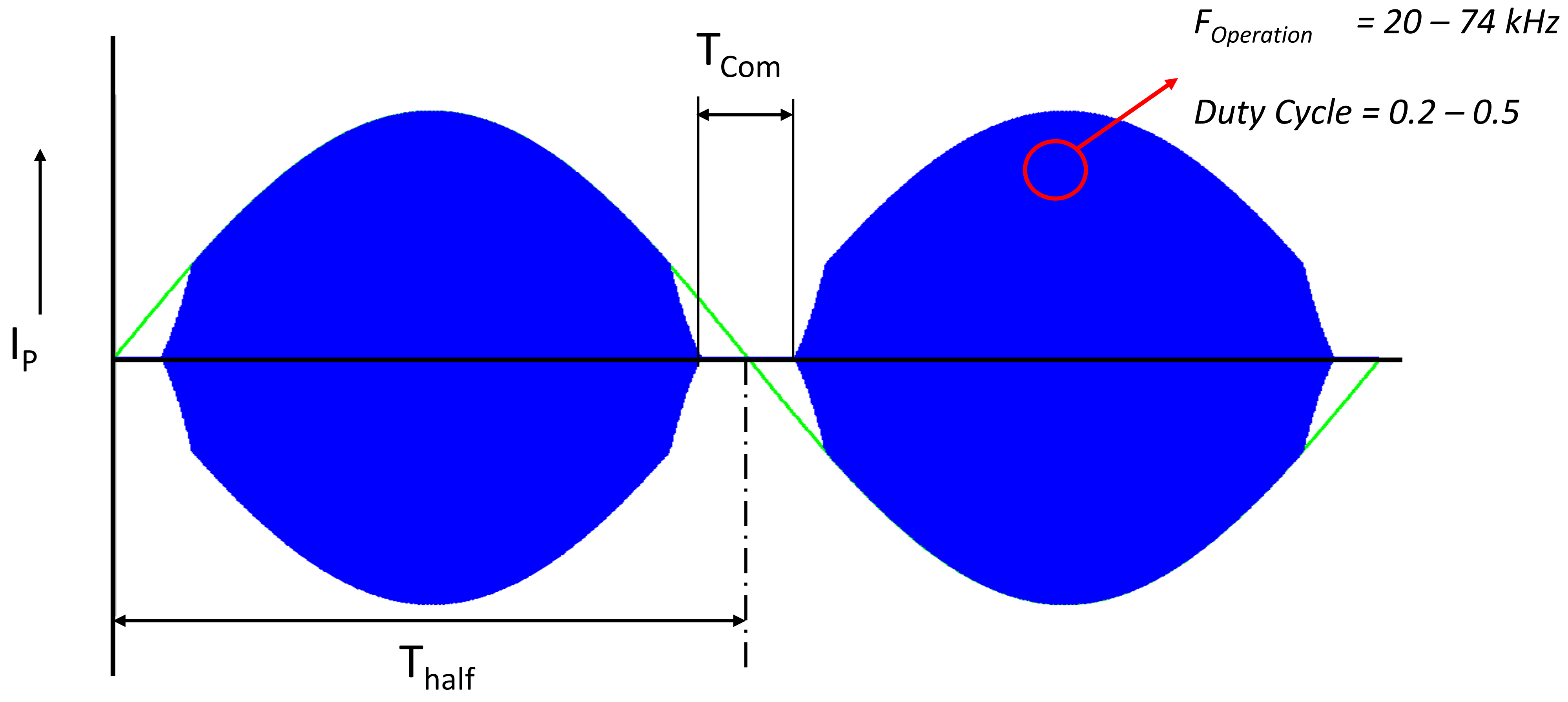
Power Control for Ki cordless kitchen system

For Pout > 50 W -> Duty Cycle & Frequency control



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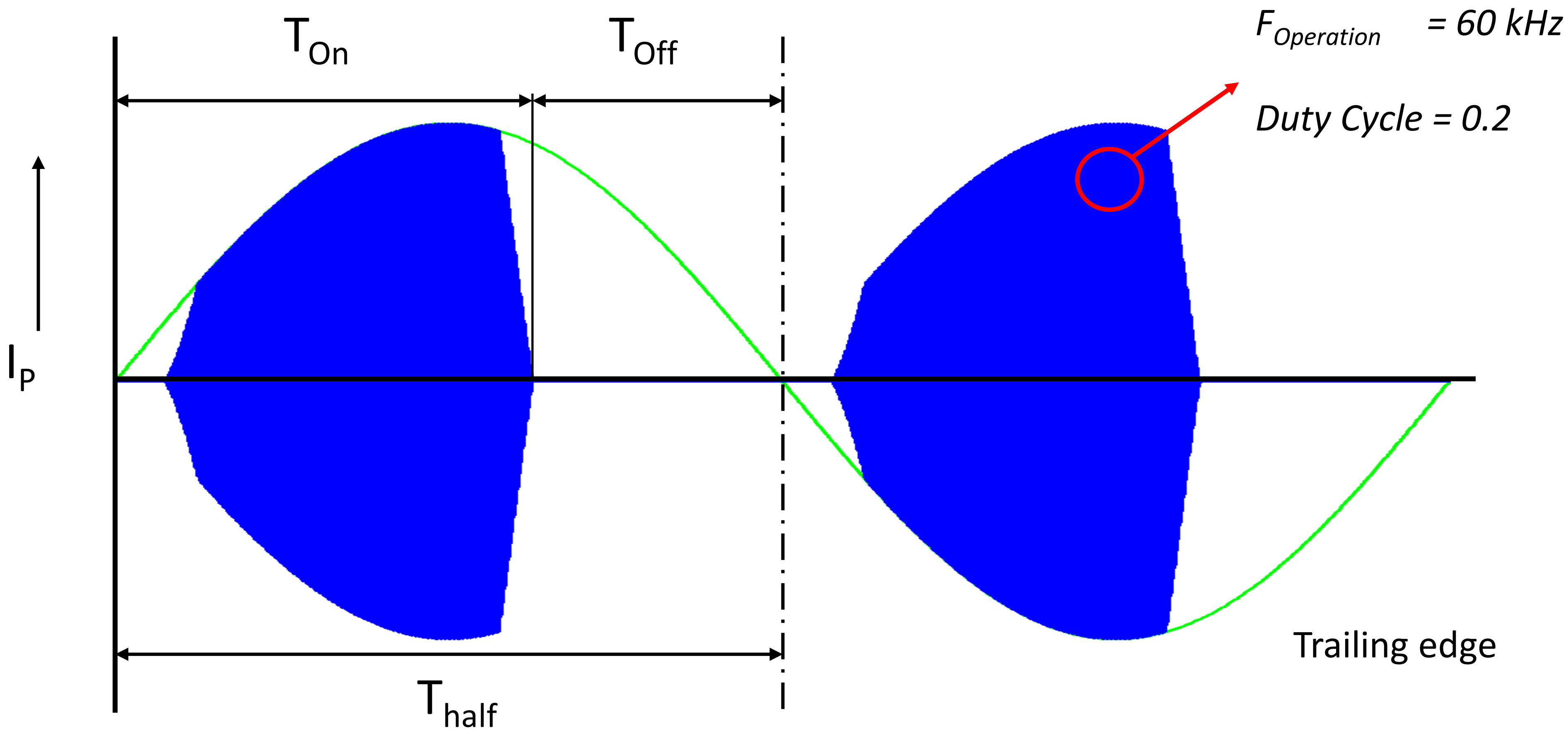
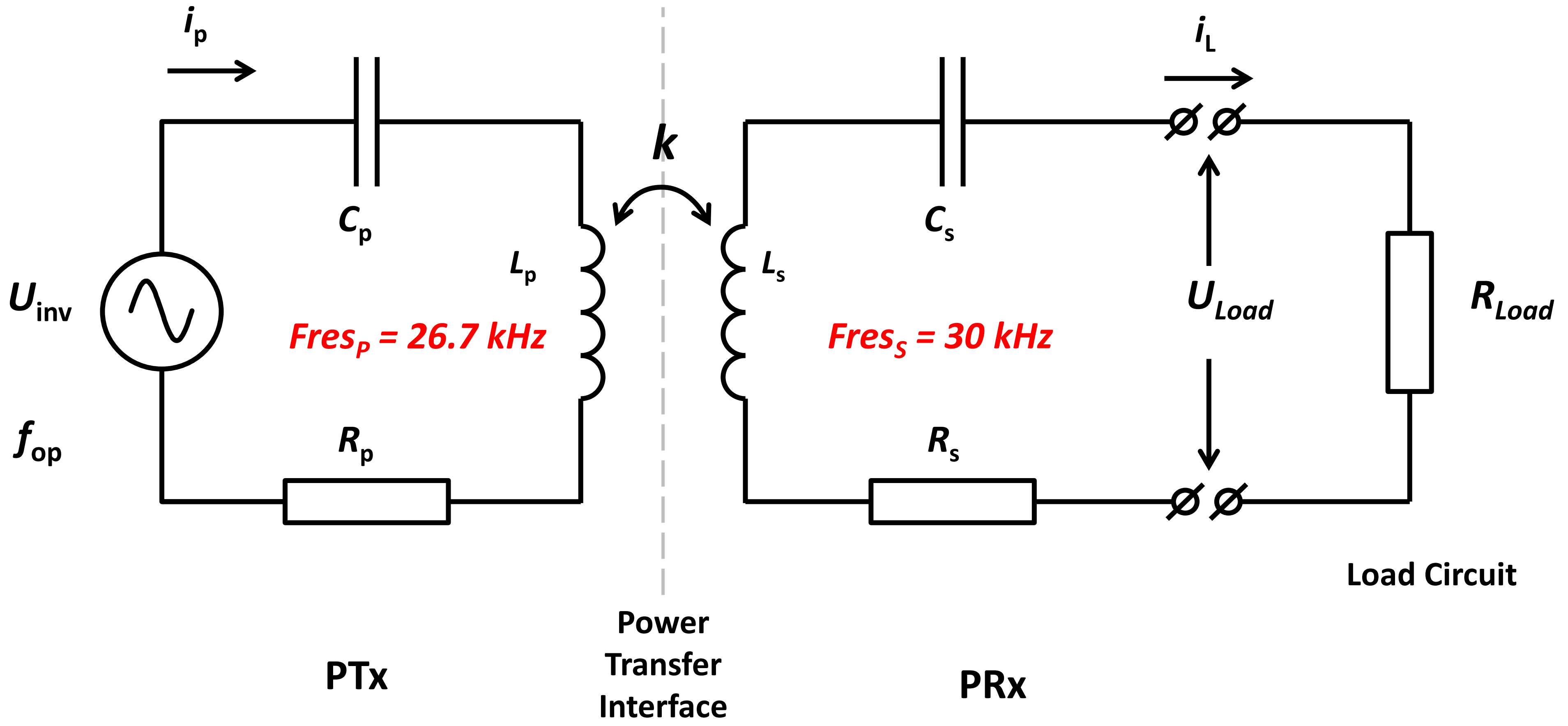
Power Control for Ki cordless kitchen system

For Pout < 50 W -> Burst Control @ fixed Frequency & Duty Cycle



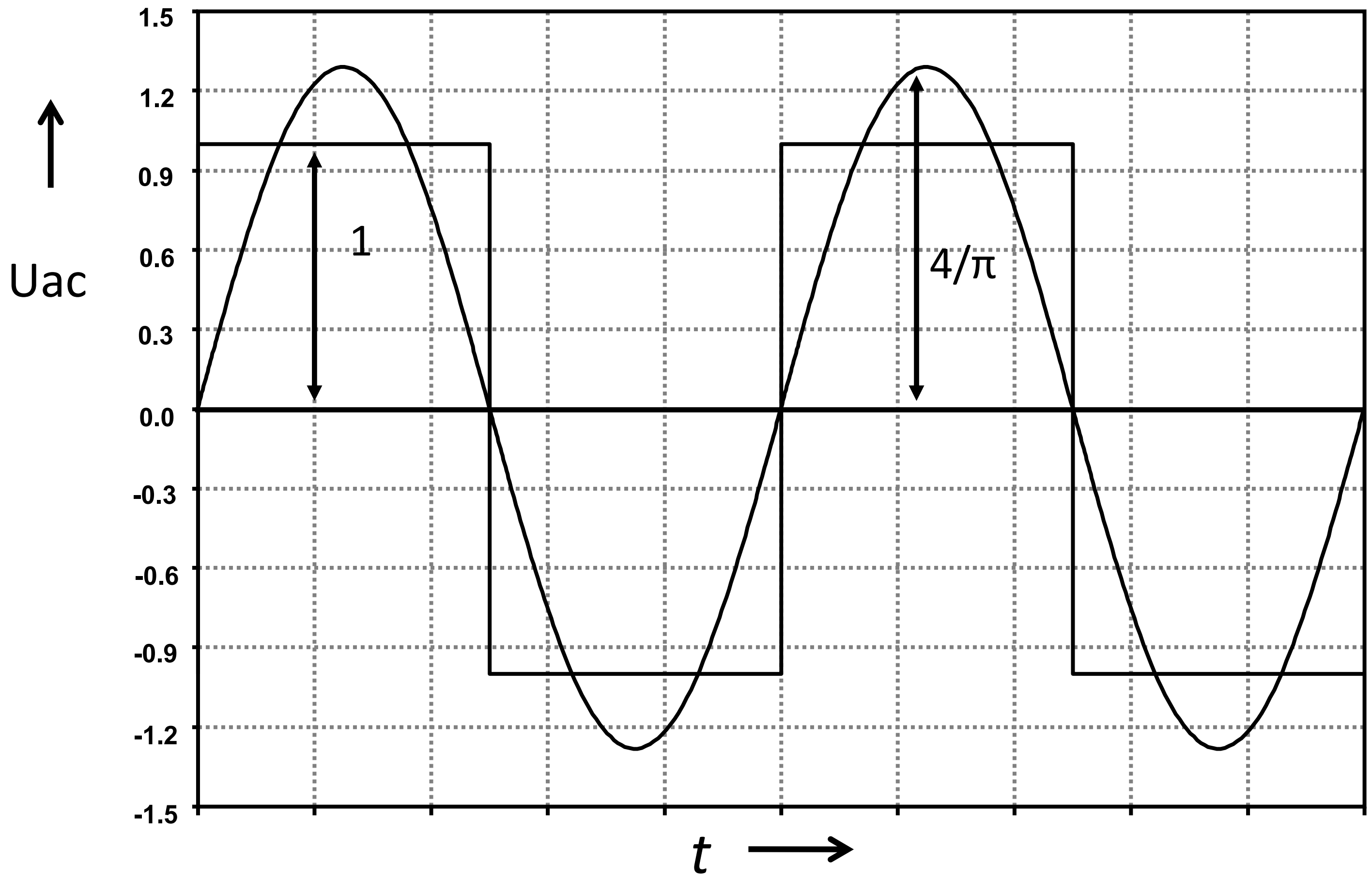
AC analysis

CLLC – network: Series CL in – Series LC out



AC analysis

First harmonic approximation (FHA)



First Harmonic Approximation (FHA) is a modelling technique used to analyze & design resonant power converters.

The assumption is that only the **first harmonic** of the square wave contributes to the power transfer

$$Uac_n(t) = \frac{4}{n \cdot \pi} \sin n\,\omega t$$

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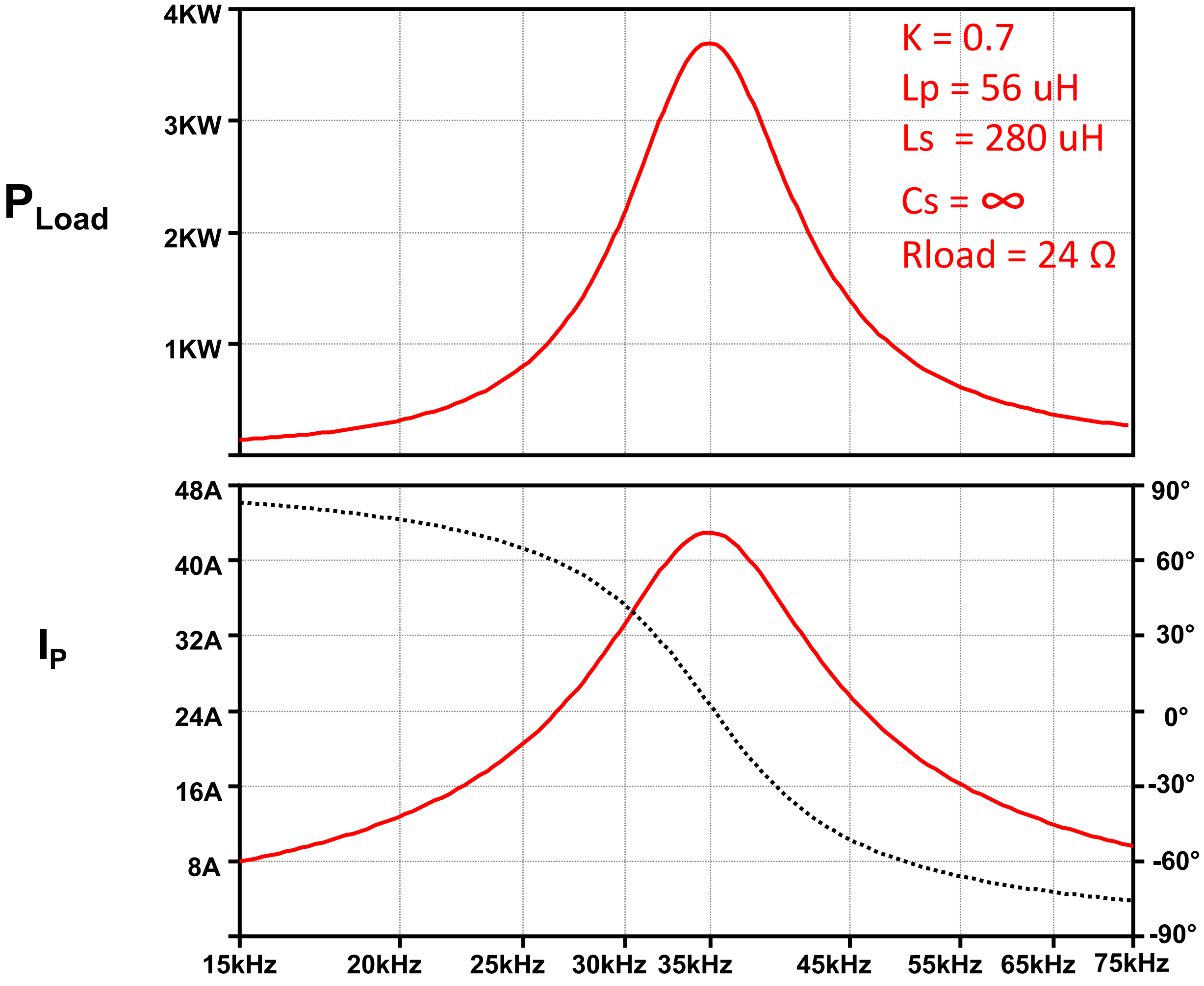
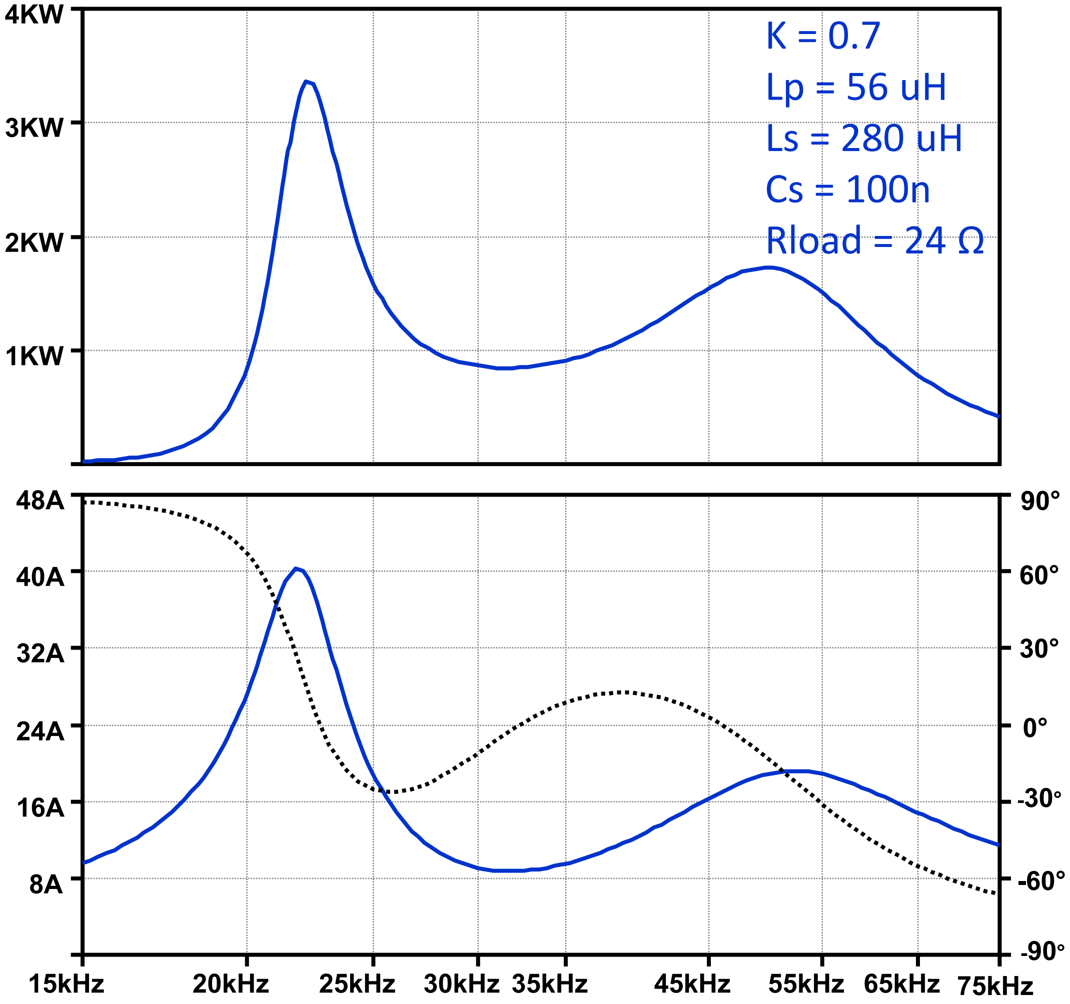
AC analysis

Bode plots General Induction hob vs. Ki cooktop case (CLL vs. CLLC)



General Induction Hob (CLL)



Ki cooktop system (CLLC)

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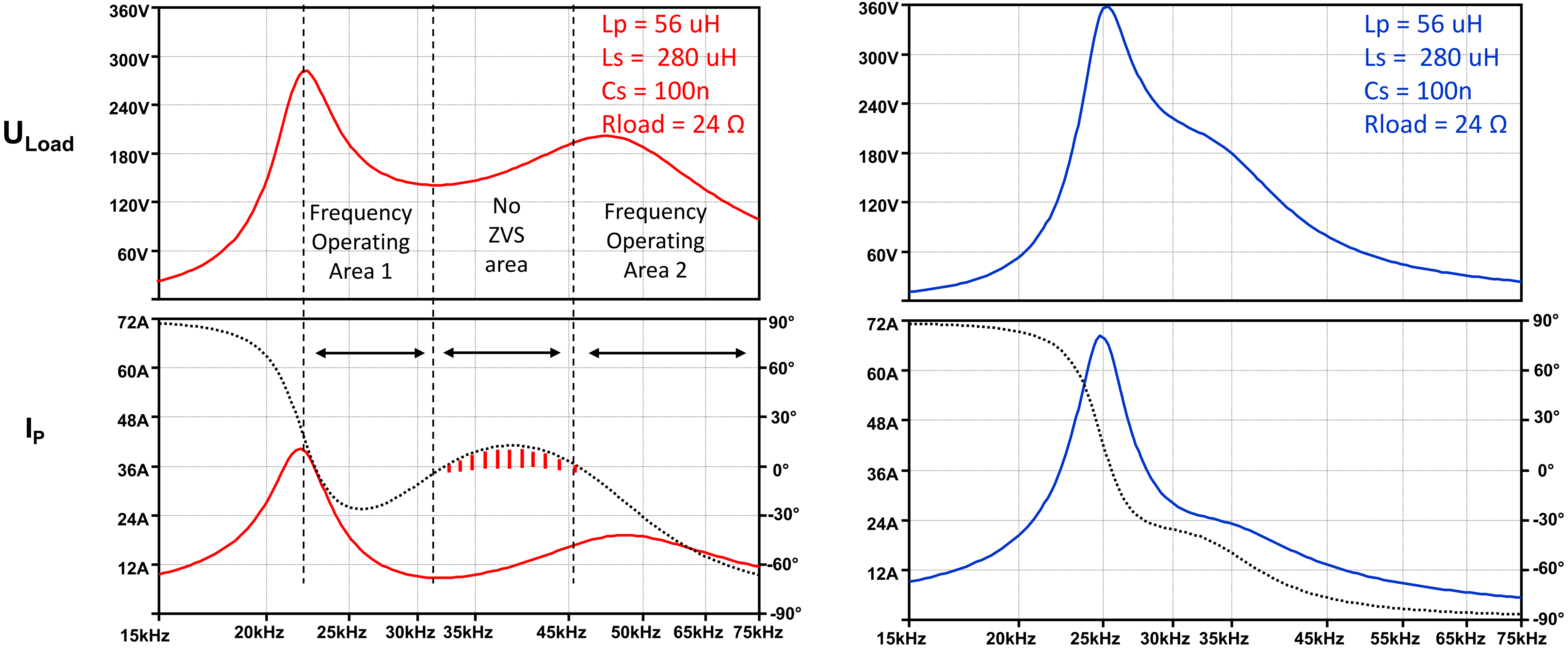
AC analysis

Bode plots Ki cooktop case vs. concealed case (K = 0.7 vs. K= 0.34)



Ki cooktop case (K=0.7)

Ki concealed case (K= 0.34)

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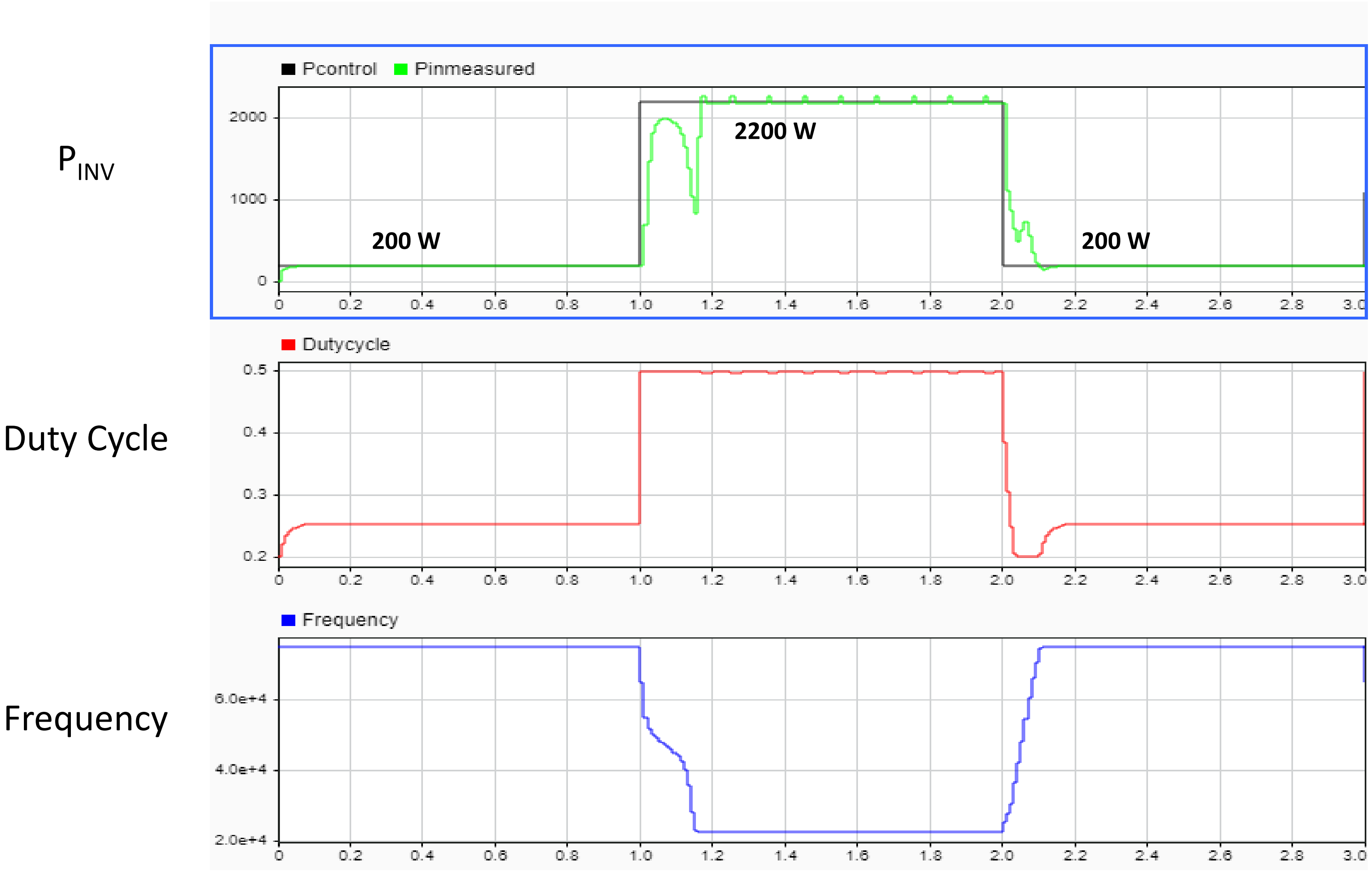
Power step response Ki cooktop case for K= 0.7



Conclusion

- In this presentation the proposition and basic operation principle of the Ki cordless kitchen system was discussed
- However, this presentation did not cover:
  - NFC system:
    - Communication protocol
    - Power harvesting
  - Control dynamics
  - Foreign Object Detection (FOD)
  - Global Safety, Radio & EMC regulations
  - Ki Test tools & Compliance program
  - Licensing programs
  - Reference designs
  - …..

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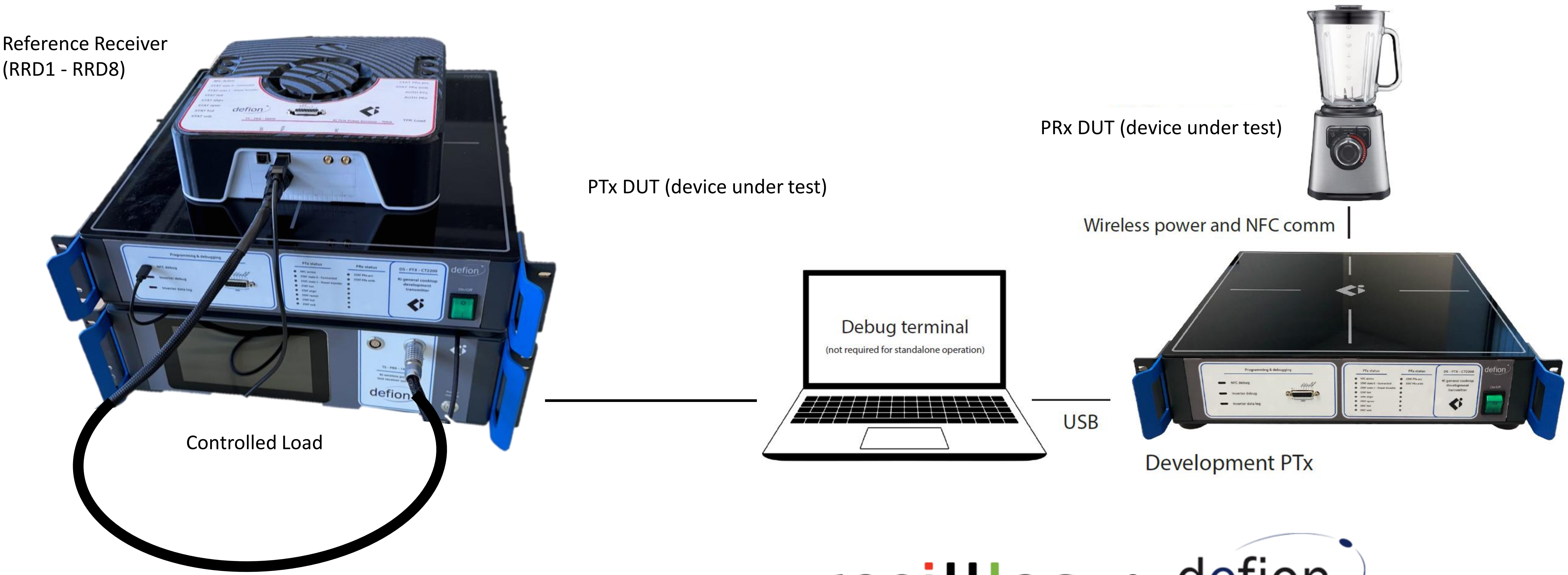
Supporting slides

Ki Devellopment tools

Development Receiver

Development Transmitter



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PTx coil parameters for half bridge inverters

Transmitter	Guaranteed Power [kW]	Z Coil-2-coil [mm]	fp nom [kHz]	Tx coil diameter [cm]	Lp [µH]
Cooktop case	2.20	12	26.8	18	56
Concealed case	2.20	32	30.0	21	60

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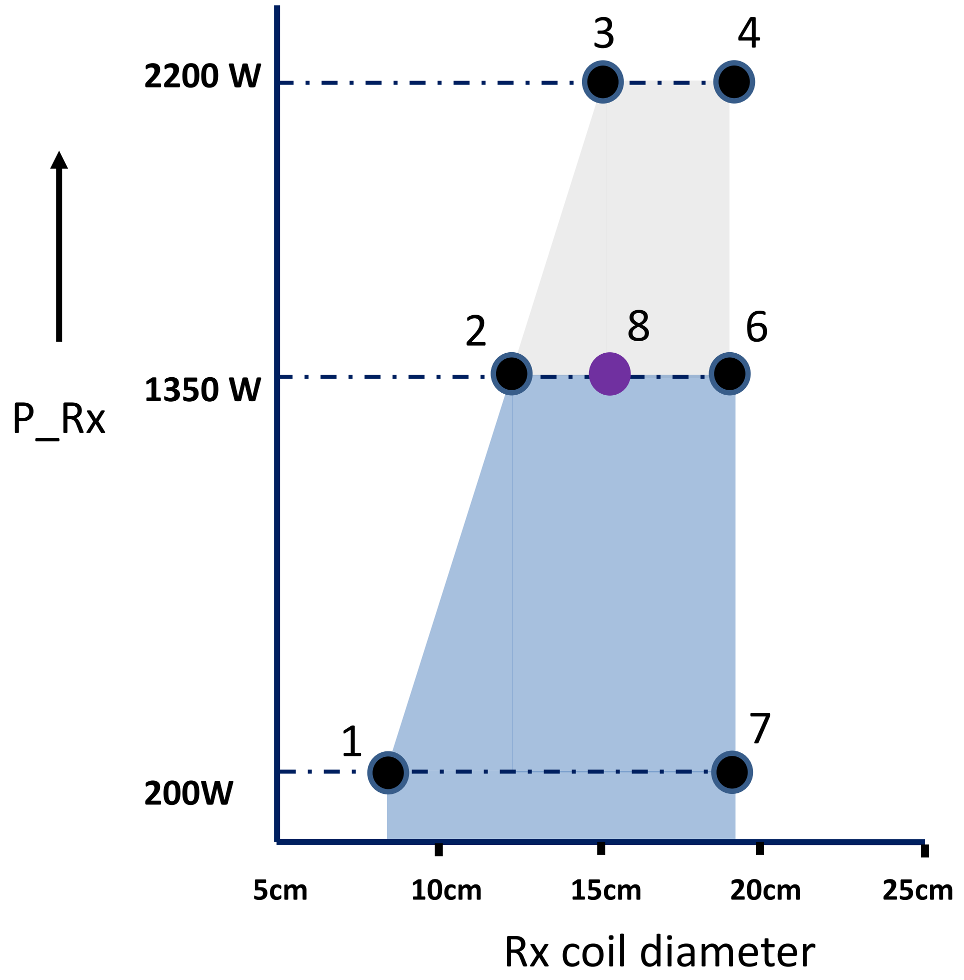
Ki Reference Receiver Designs (RRD’s)



Fres = 30 kHz

RRD #	P_Rx (W)	Ø (cm)	Ls (uH)	Uload (V)	Rload (Ohm)
1	200	8	390	115	66
2	1350	12	450	230	39
3	2200	15	280	230	24
4	2200	18	220	230	24
5					
6	1350	18	220	230	39
7	200	18	220	115	66
8	1350	15	280	230	39

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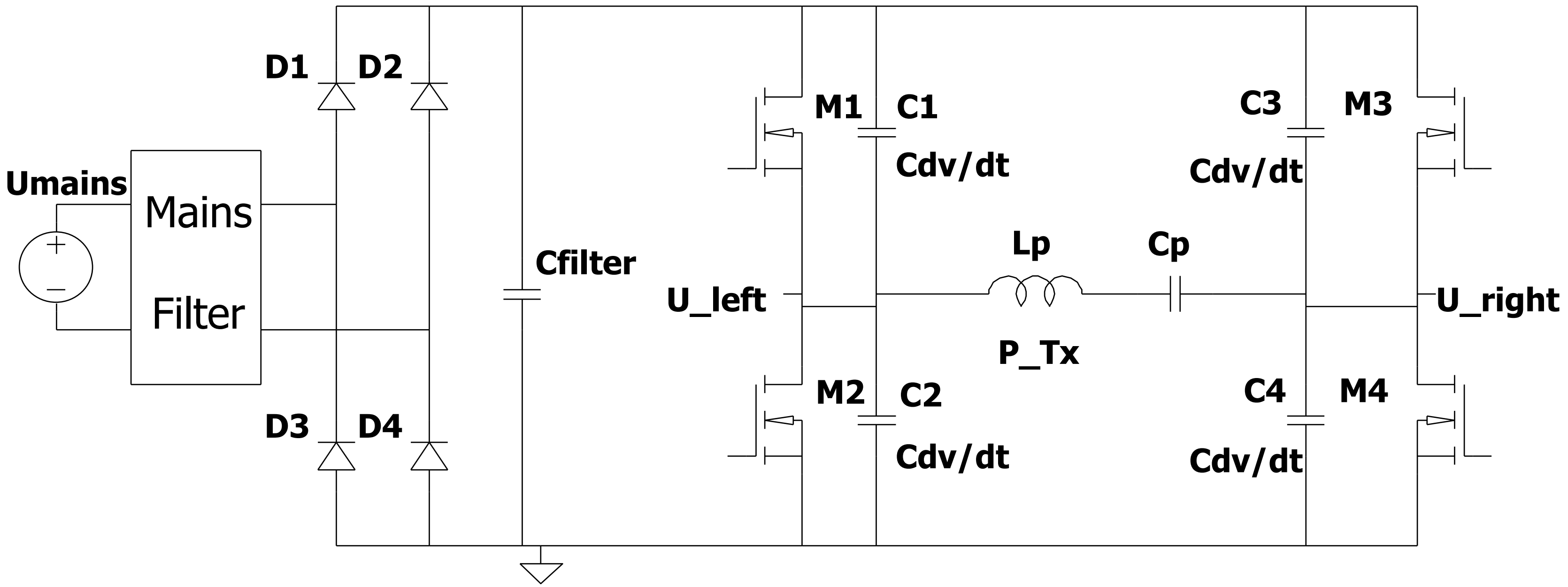
Ki Power chain in more detail

Transmitter implementation – Full bridge



Series resonant

Topology of choice for the engineers

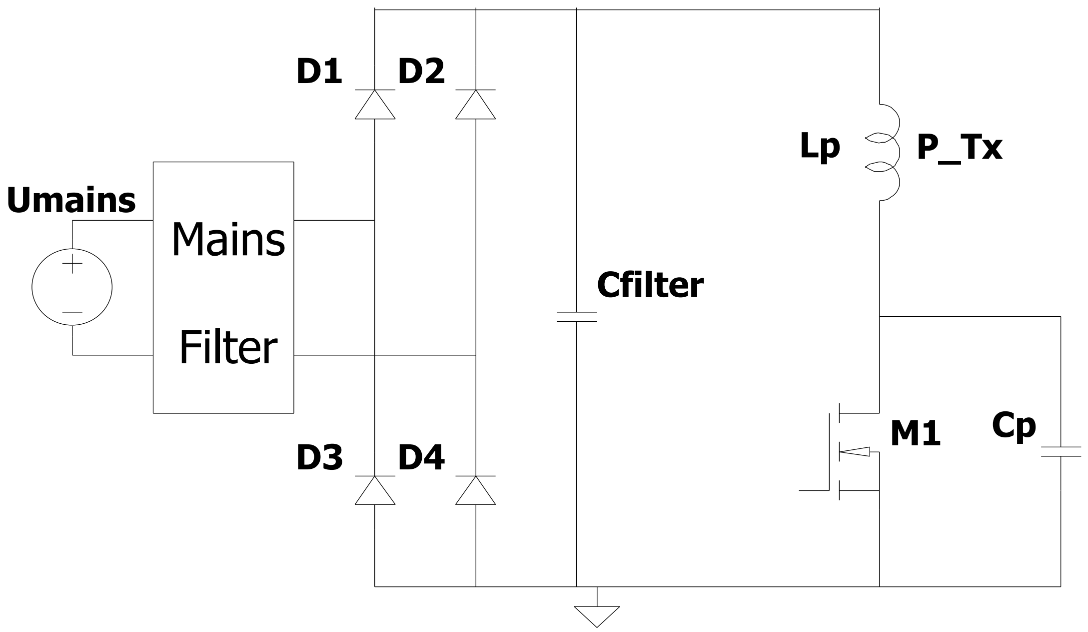
- Complexity vs. Flexibility
- Both near zero power transfer and high-power transfer possible

But…

- Price!
- Not in scope for “230V” region's

Ki Power chain in more detail

Transmitter implementation – Single switch



"Parallel" resonant

Topology of choice for the managers ☹

- Price vs. Complexity

But

- Optimized to provide high power, but in a small control window
- Near zero power transfer still a challenge, not proven yet

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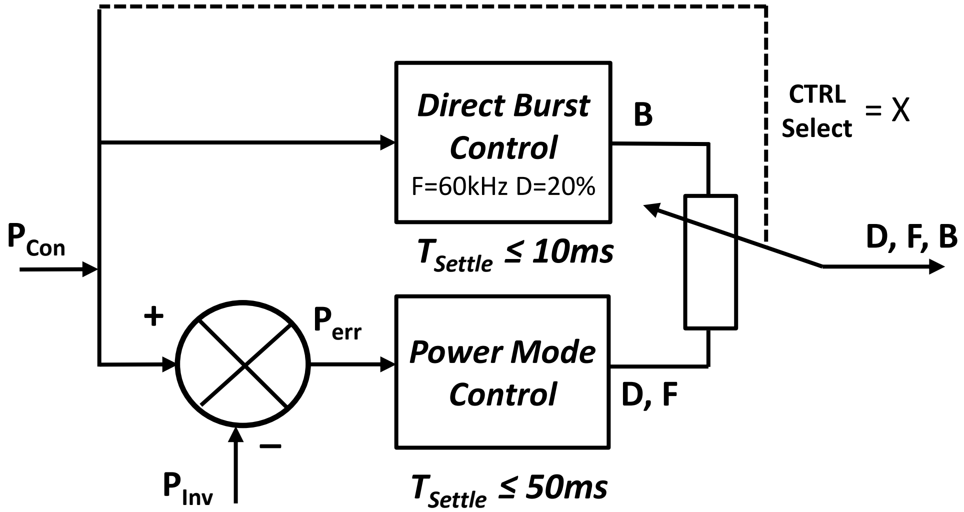
Power Control for Ki cordless kitchen system

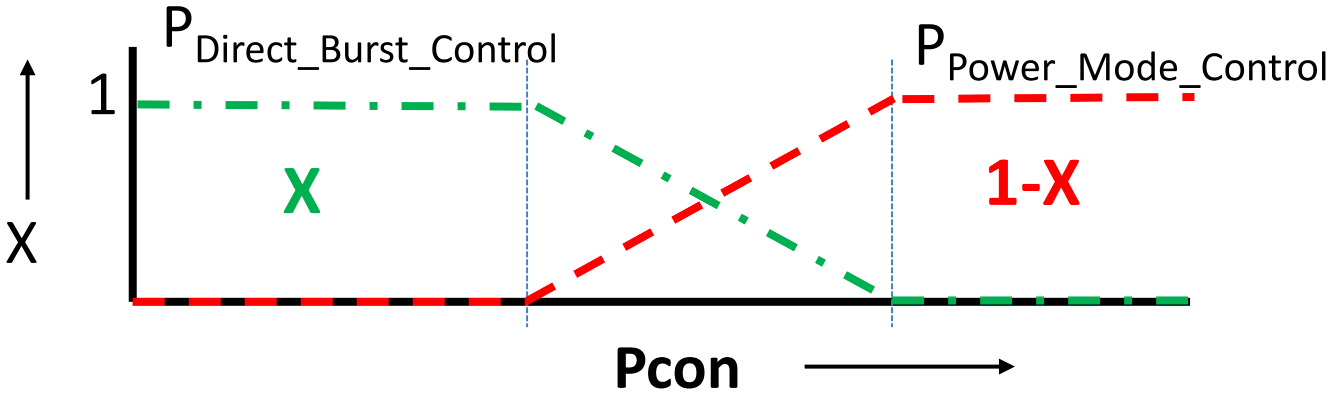
For Pout < 50 W -> Burst & Duty Cycle Control @ fixed frequency



$$B_{pwm} = B_{Direct\_Burst\_Control} * X + B_{Power\_Mode\_Control} * (1-X)$$

$$D_{pwm} = 20\% * X + D_{Power\_Mode\_Control} * (1-X)$$

$$F_{pwm} = 60kHz * X + F_{Power\_Mode\_Control} * (1-X)$$



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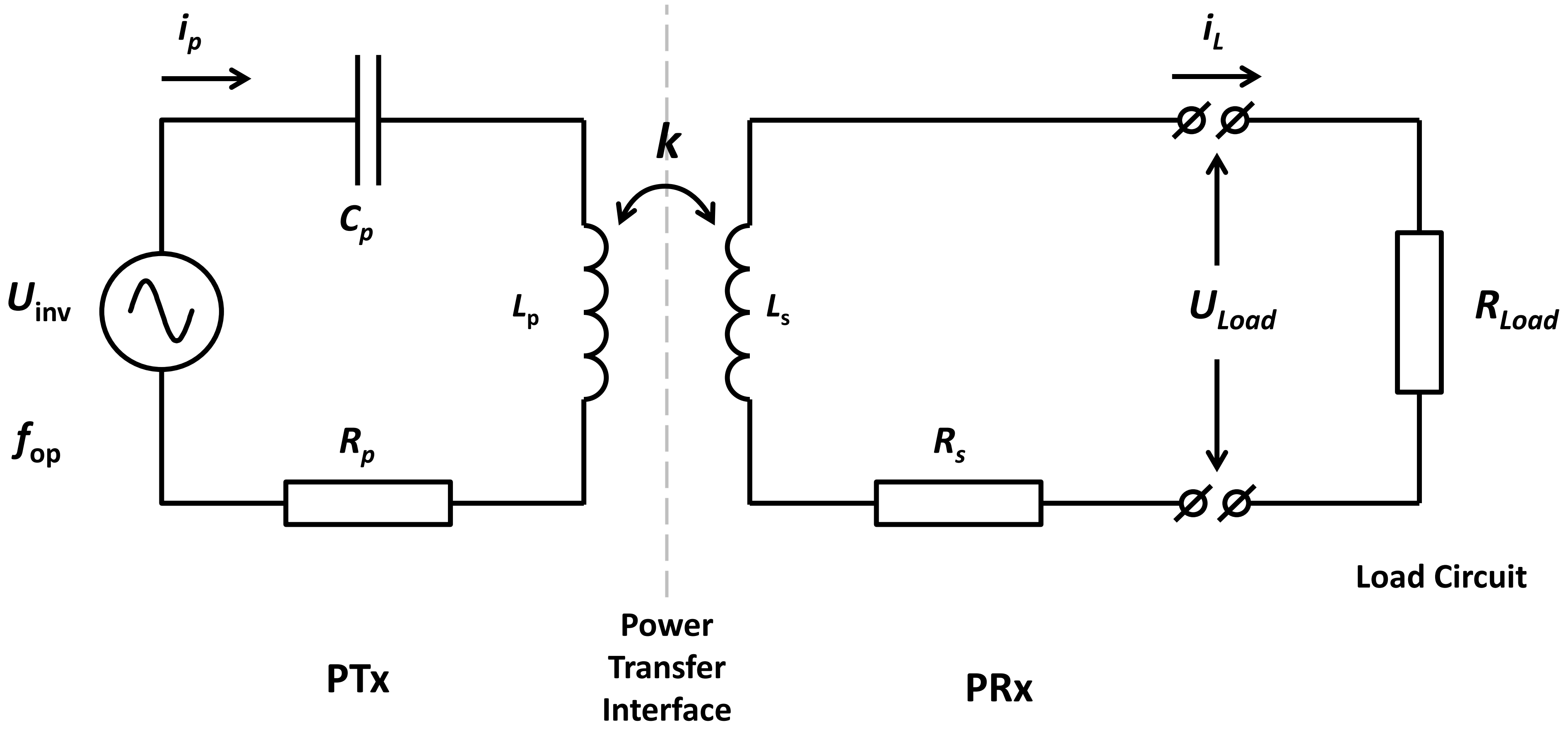
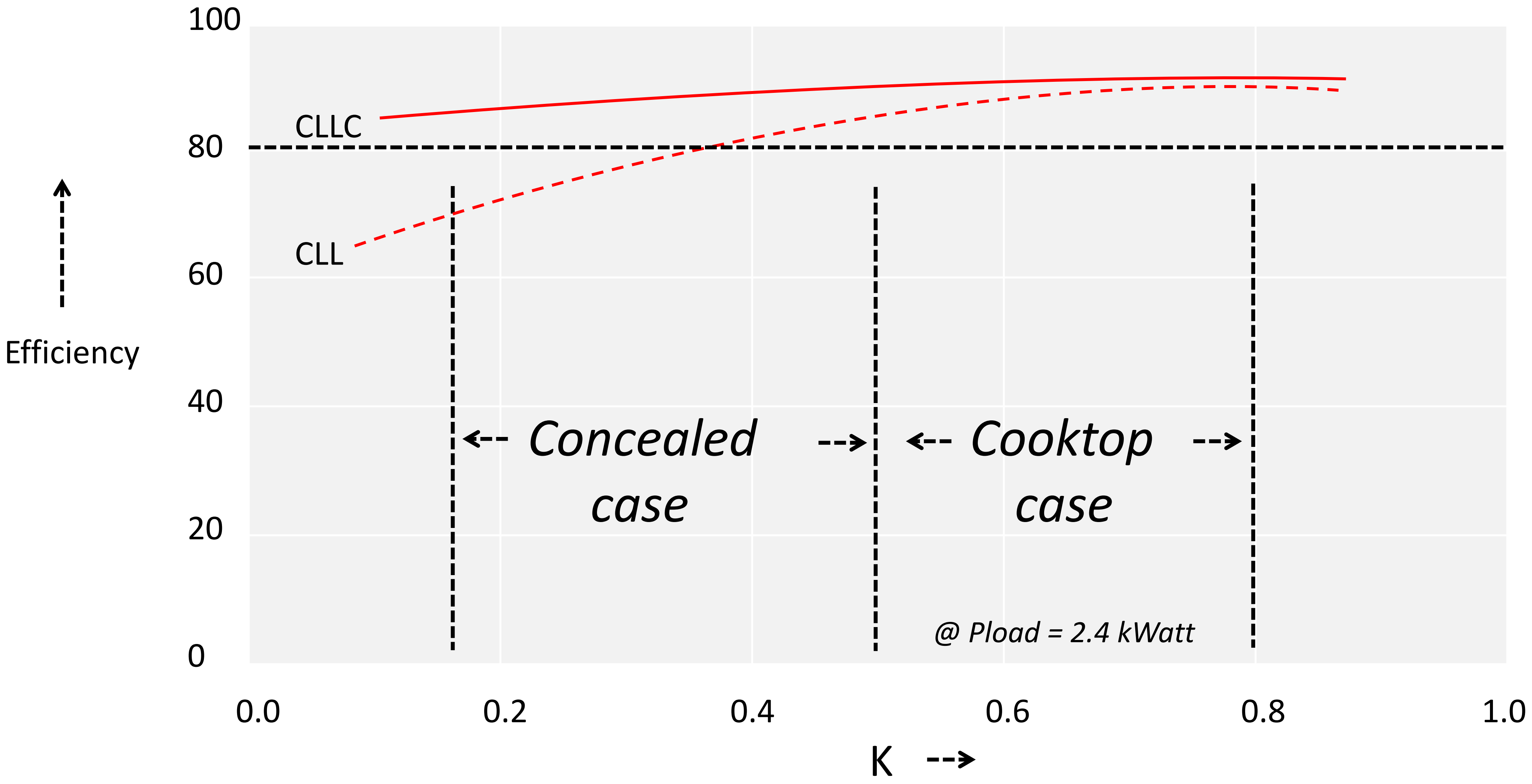
AC analysis

CLL – network: Series LC in – L out



AC analysis

CLL versus CLLC – network: Efficiency



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