PHILIPS

www.philips.com

Ki cordless kitchen system

(Power) Control loop(s) aspects

Will Ettes
Philips TEG, Drachten, The Netherlands

Pascal Lebens, Tim Steunebrink, Jan Draak
Philips Research, Eindhoven, The Netherlands

10 -05 - 2019

innovation you

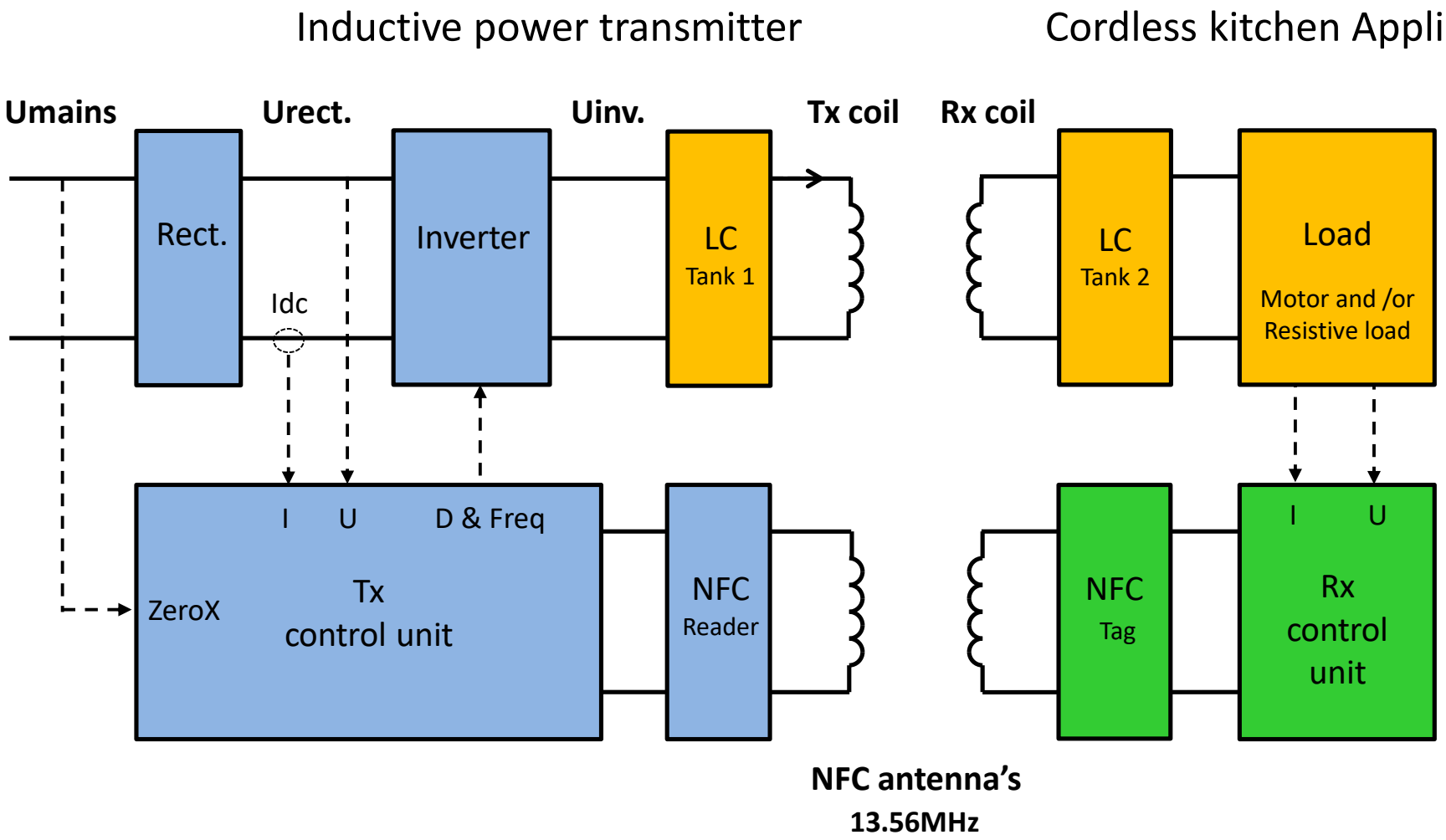
Contents of the presentation

- Introduction
- Ki system overview
- Power & Communication carrier waveforms for Ki
- Ki control loop for the hidden case (Philips)
- Induction hob system overview
- Existing Induction hob control loop
- Ki control loop for the hob case (option 1 & 2)
- Demo: Implementation Ki control loop for the hob case (option 1)
- Generic Ki control loop
- Conclusion & Proposal

Introduction

- With the aid of the control loop Receiver parameters can be controlled like Power, Current, Voltage or Speed and kept at a constant value
- To provide the end user the same user experience on each transmitter implementation, the dynamic behavior of the complete system must be well defined for all cases
- Especially for cordless appliances with a (DC) motor installed, the settling time must be sufficiently small and over- and undershoot of the motor speed must be avoided (audible noise)
- With this presentation typical implementation issues will be addressed which influence control loop behavior

Ki System overview

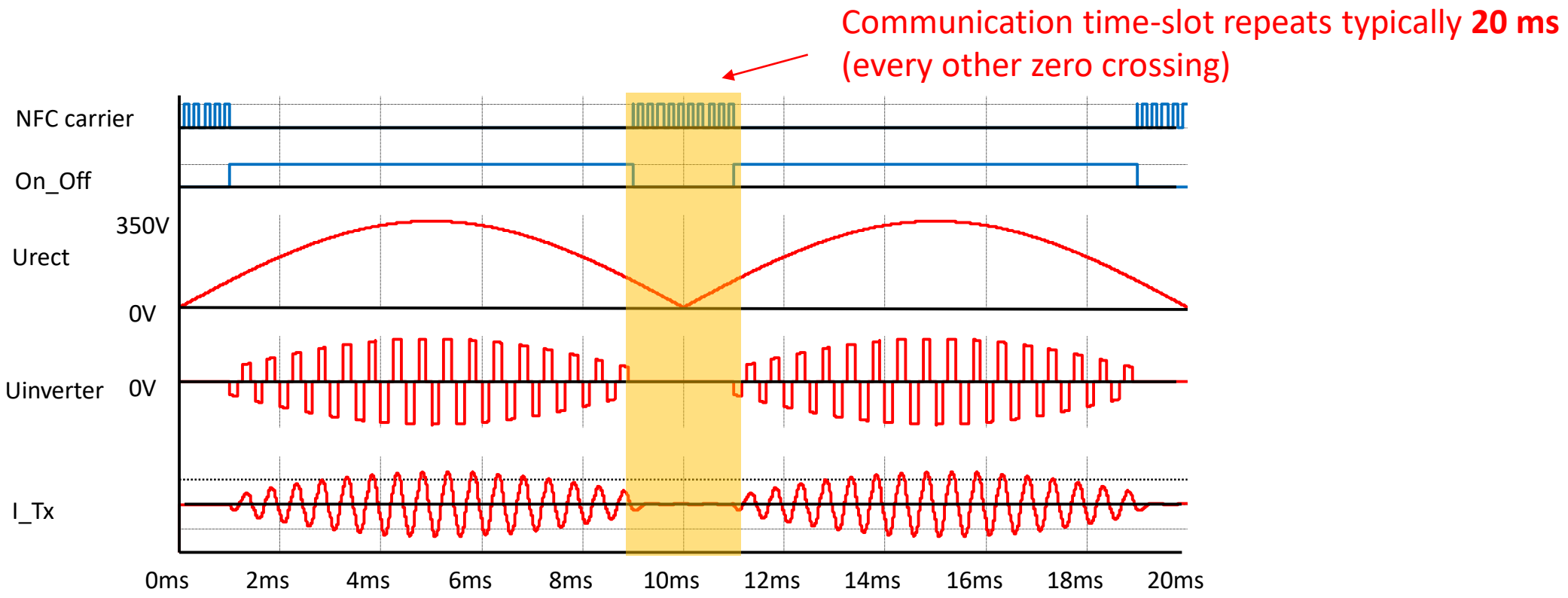


Bi-directional communication between transmitter and appliance

PHILIPS

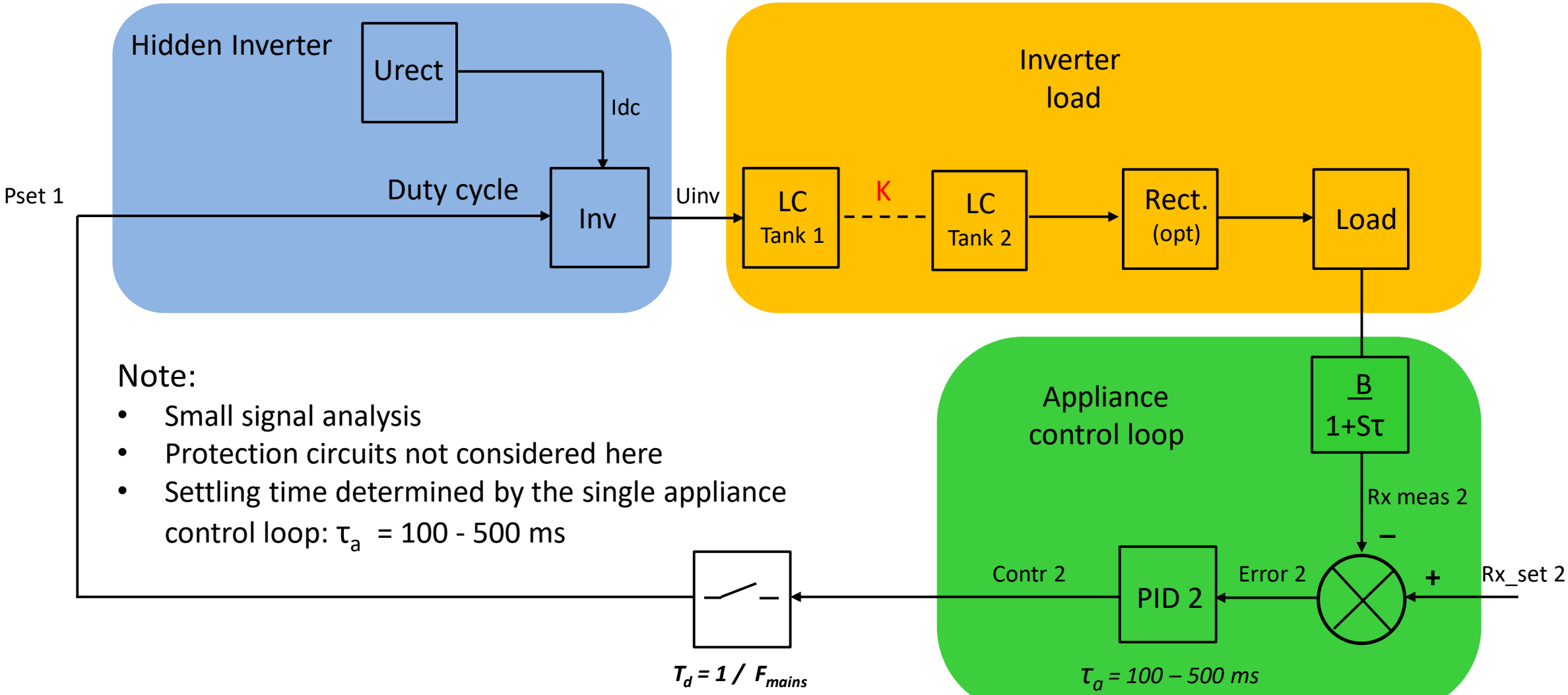
Power & Communication waveforms for Ki

- Power carrier (20 – 35 kHz)
- NFC carrier (13.56 MHz)
- 1.5 ms communication time-slot during zero crossings



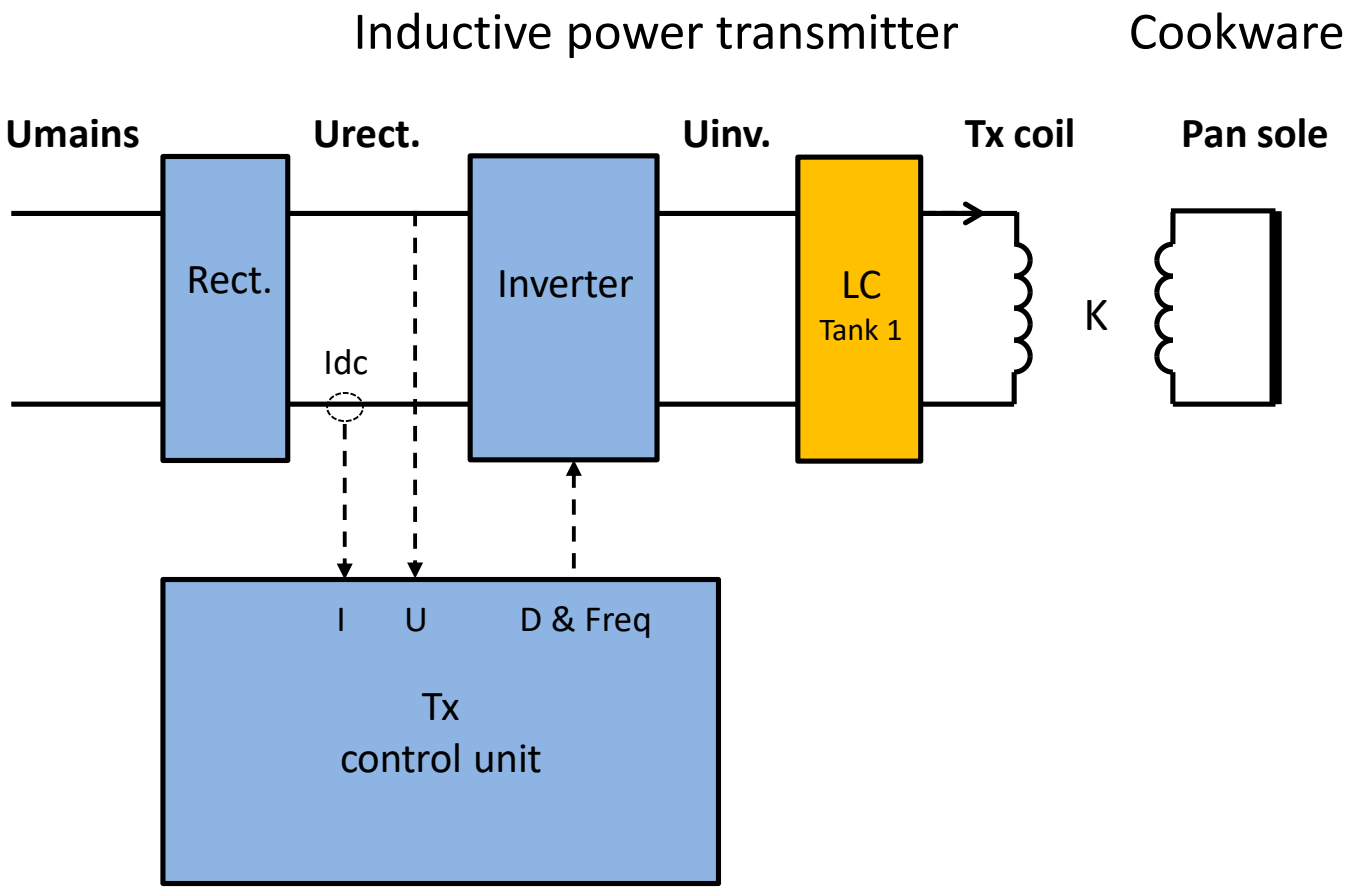
PHILIPS

Ki control loop for the hidden case (Philips)



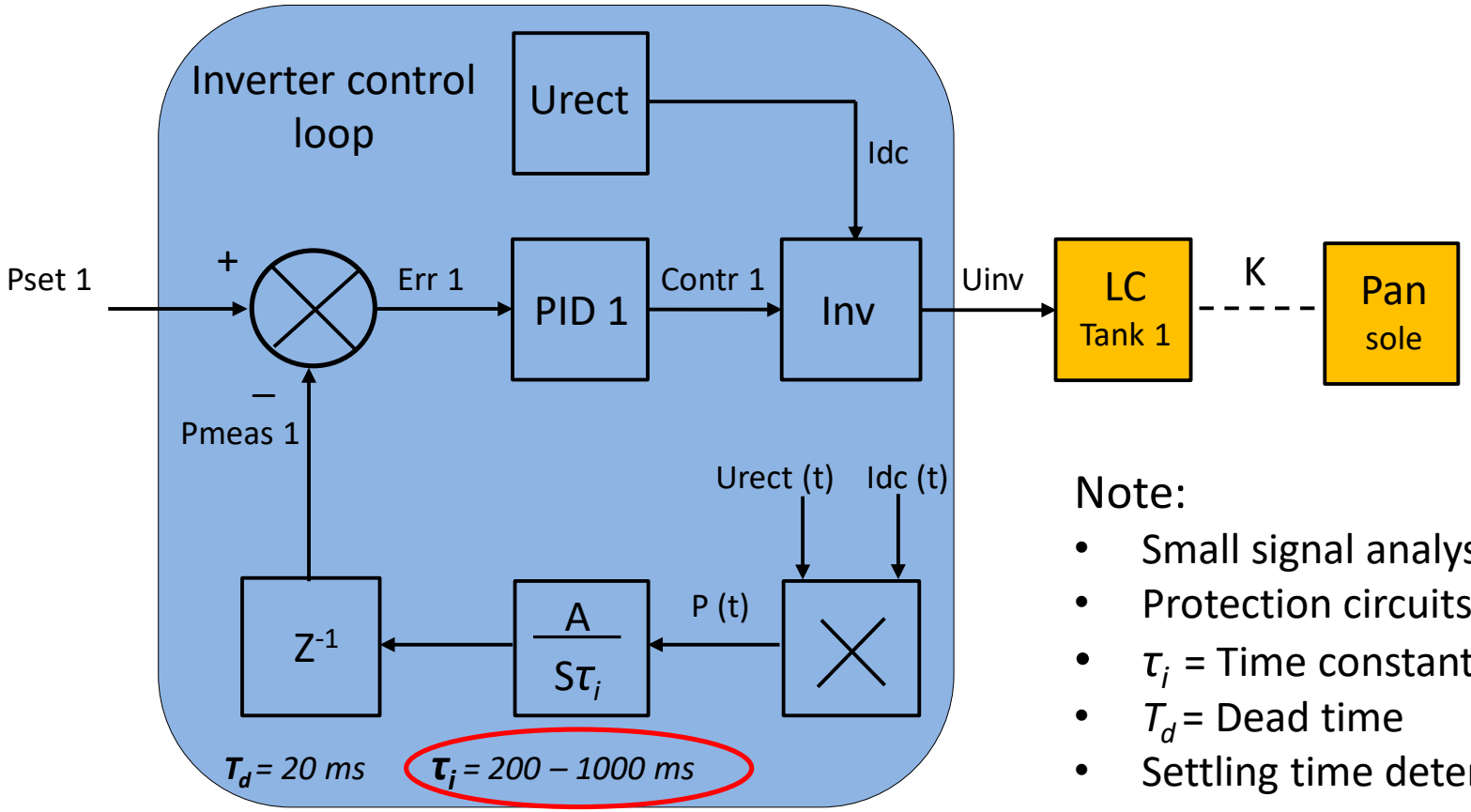
PHILIPS

Induction hob system overview



PHILIPS

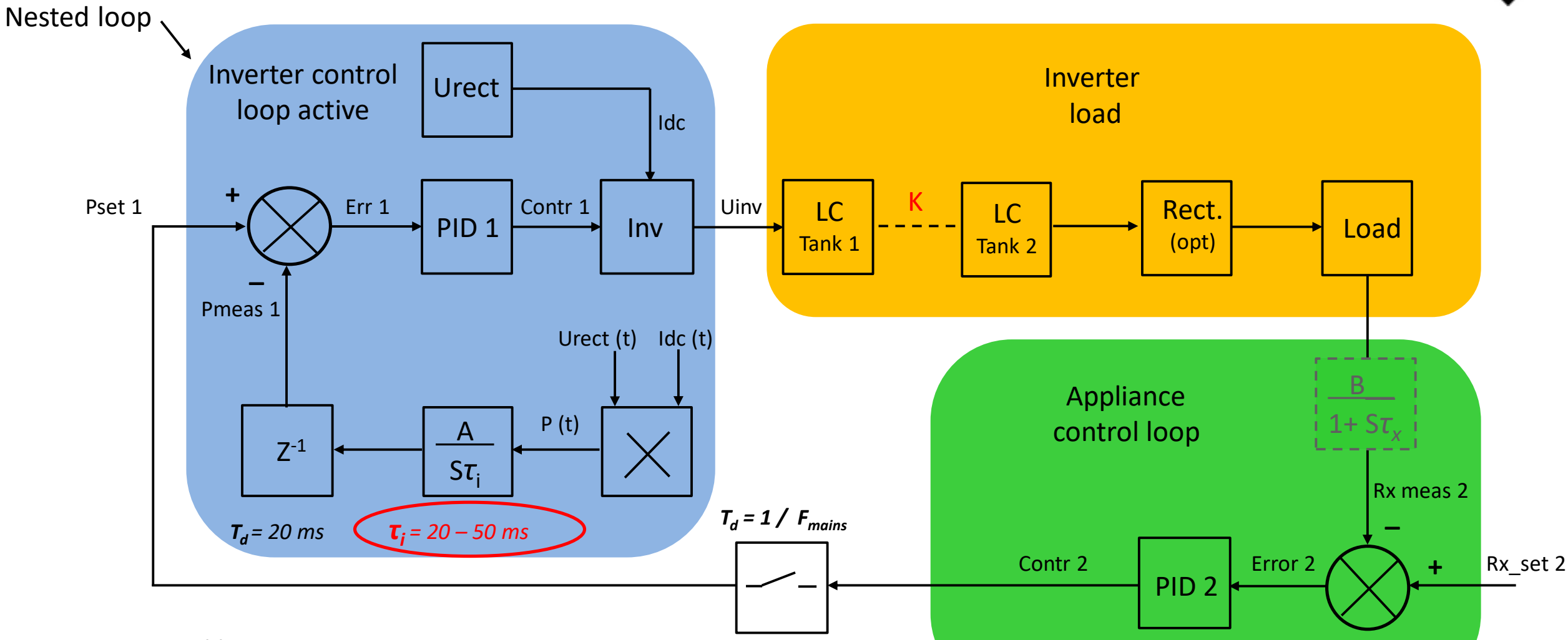
Existing Induction Hob control loop



Note:

- Small signal analysis
- Protection circuits not considered here
- τ_i = Time constant
- T_d = Dead time
- Settling time determined by the Power control loop: τ_i = 200 - 1000 ms

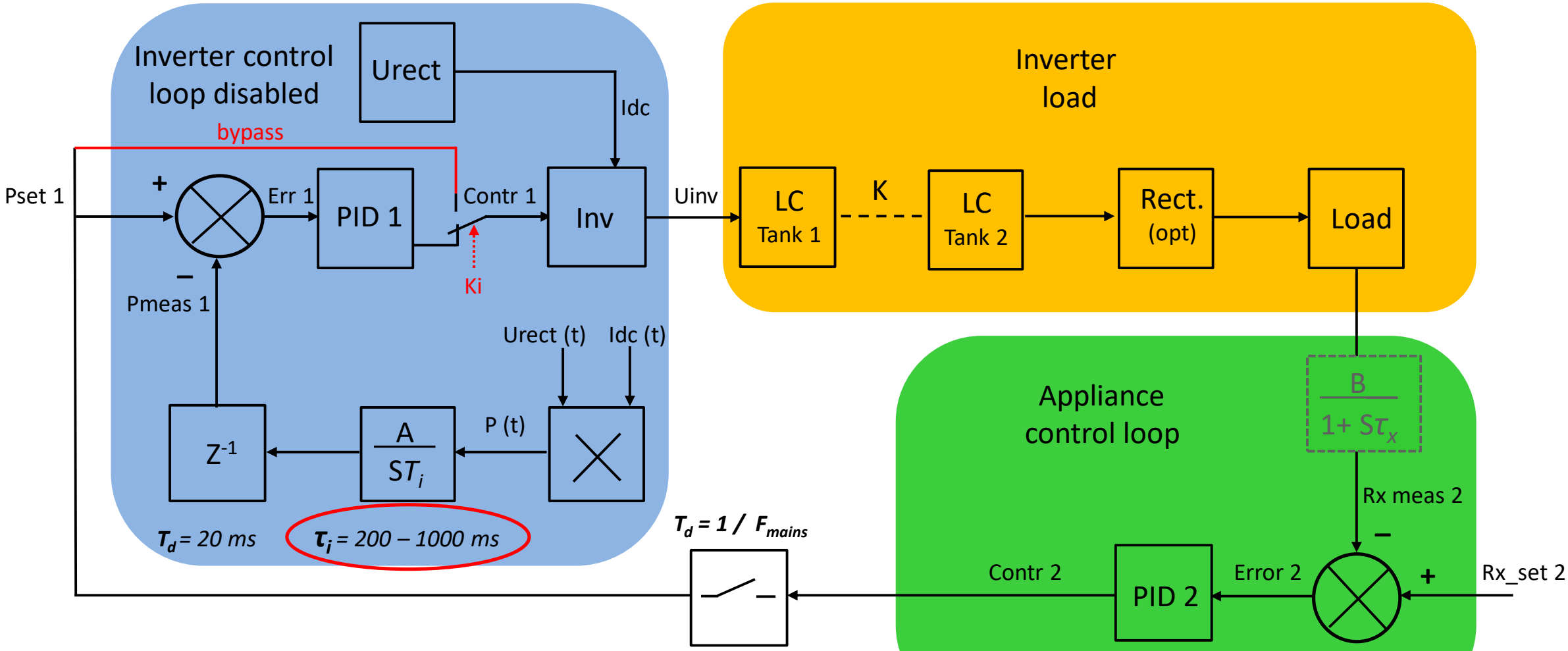
Ki Control loop for the hob case (option 1)



- Power control loop time constant: τ_i = 20 – 50 ms
- Settling time determined by outer appliance control loop: τ_a = 100 - 500 ms

PHILIPS

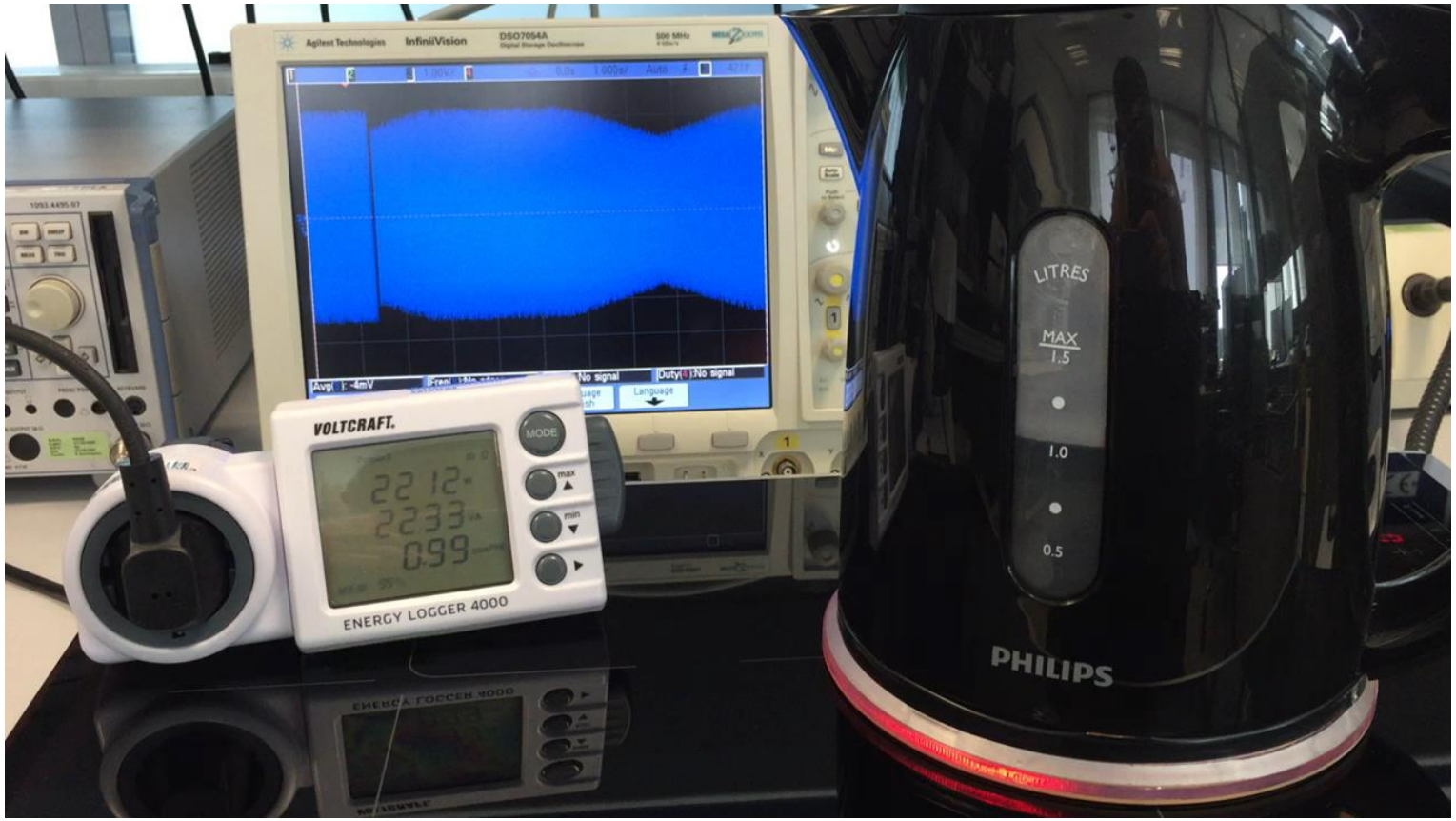
Ki Control loop for the hob case (option 2)



- Power control loop time constant: τ_i = 200 – 1000 ms
- Settling time determined by outer appliance control loop: τ_a = 100 - 500 ms

PHILIPS

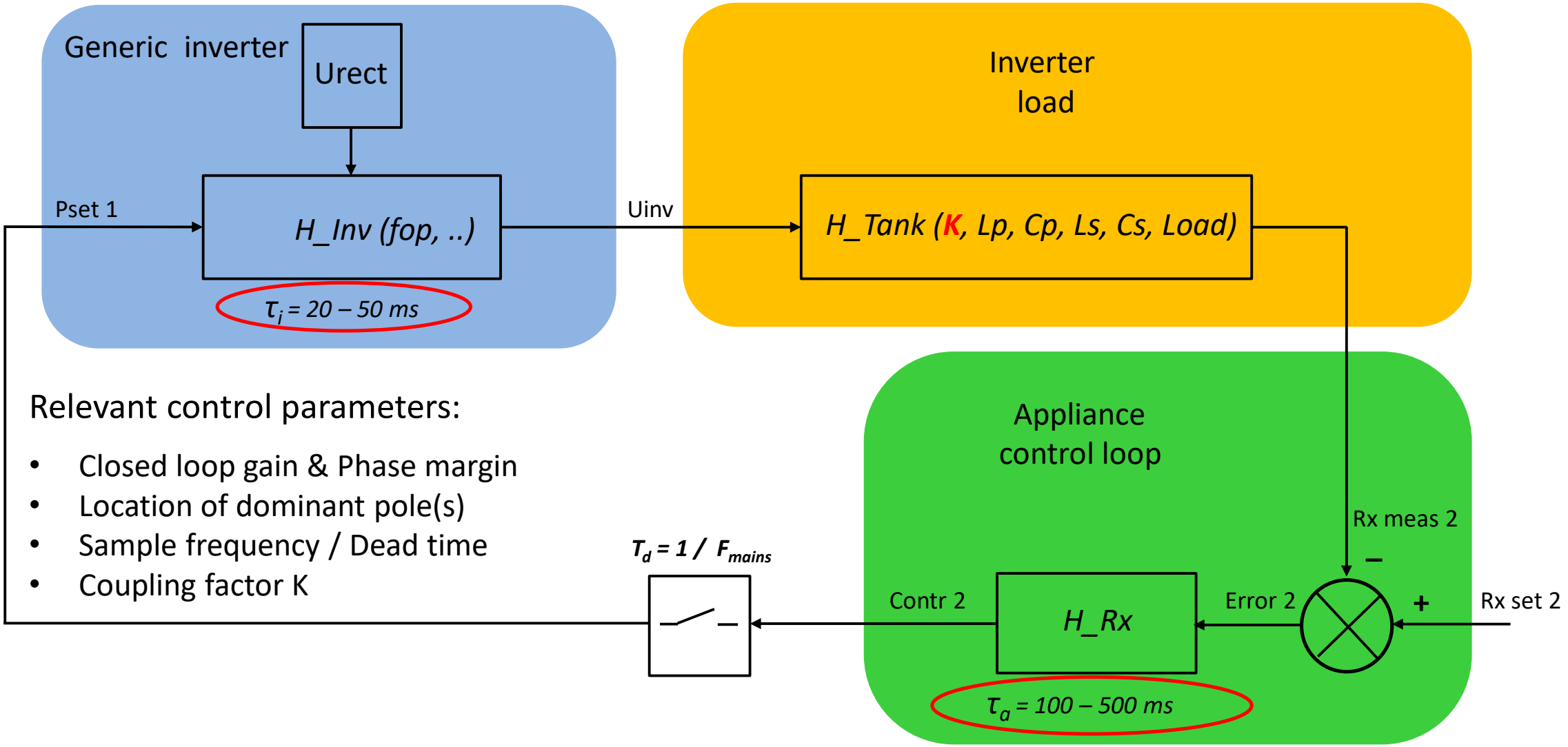
Implementation Control loop Ki hob case (option 1)



Demo: Modified induction hob with τ_i = 1000 ms

PHILIPS

Generic Ki Control loop



Relevant control parameters:

- Closed loop gain & Phase margin
- Location of dominant pole(s)
- Sample frequency / Dead time
- Coupling factor K

PHILIPS

Conclusion

- The control loop gain is determined by *H_Inv, H_Tank & H_Rx*
- The time constant τ_a should be a factor 5 to 10 larger than then τ_i

Proposal

- The **reference test** transmitter implementation shall have
  a. a time constant τ_i of 20 – 50 ms max. and a defined gain (option 2)
  b. a sample frequency / dead time of 50 Hz / 20 ms (@ F_{mains} = 50 Hz)
- If a dual function Ki induction hob transmitter detects a Ki appliance, the τ_i should be reduced such to make τ_a the dominant pole of the system
- The variance of the coupling factor *K* is a problem to be studied in more detail


PHILIPS