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Artificial Intelligence Augmented P(AI)ID Cycle-by-Cycle Controller for Automotive DC-DC Converter Applications Based on AURIX TC4x

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Infineon Technologies AG

Agenda

- Motivation
- Architecture of the P(AI)ID Controller
- Measurement Setup and Results

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Automotive On-Board Charger (OBC)

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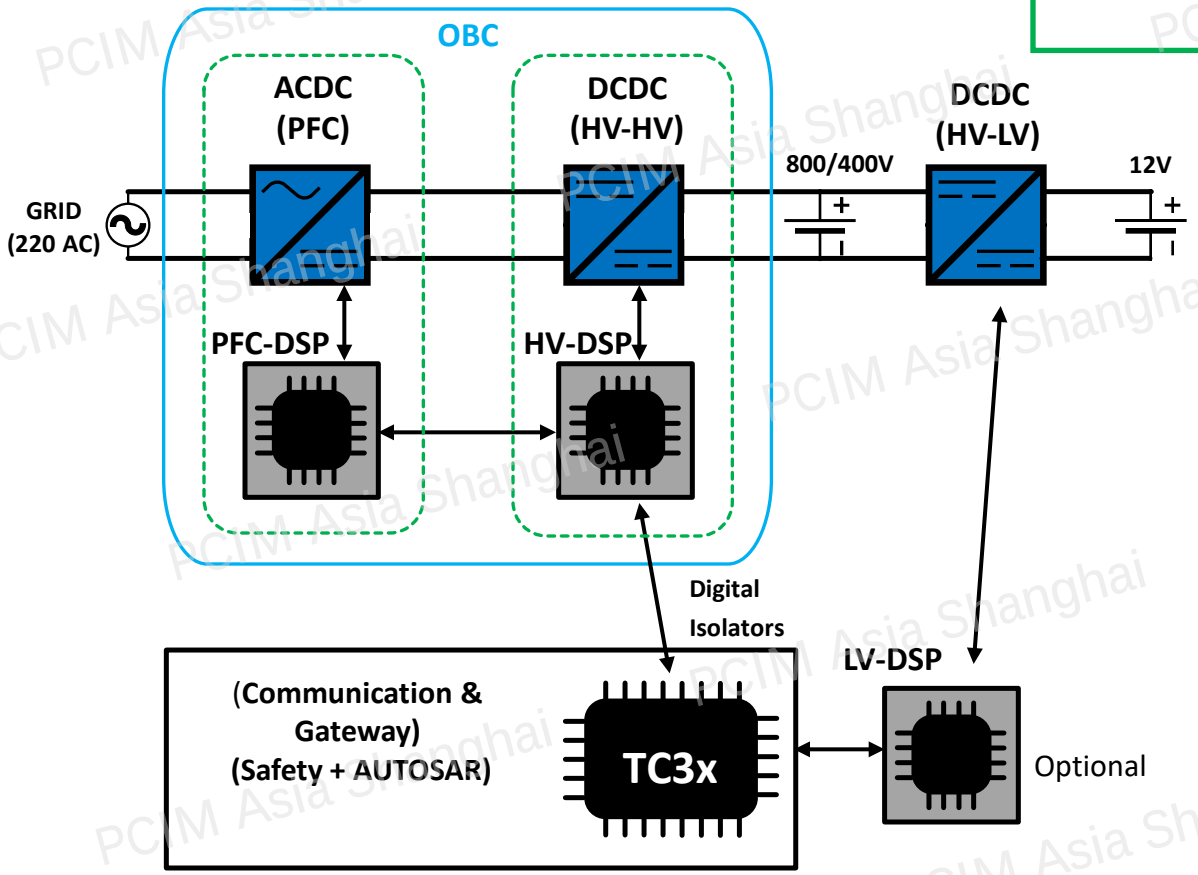
Today

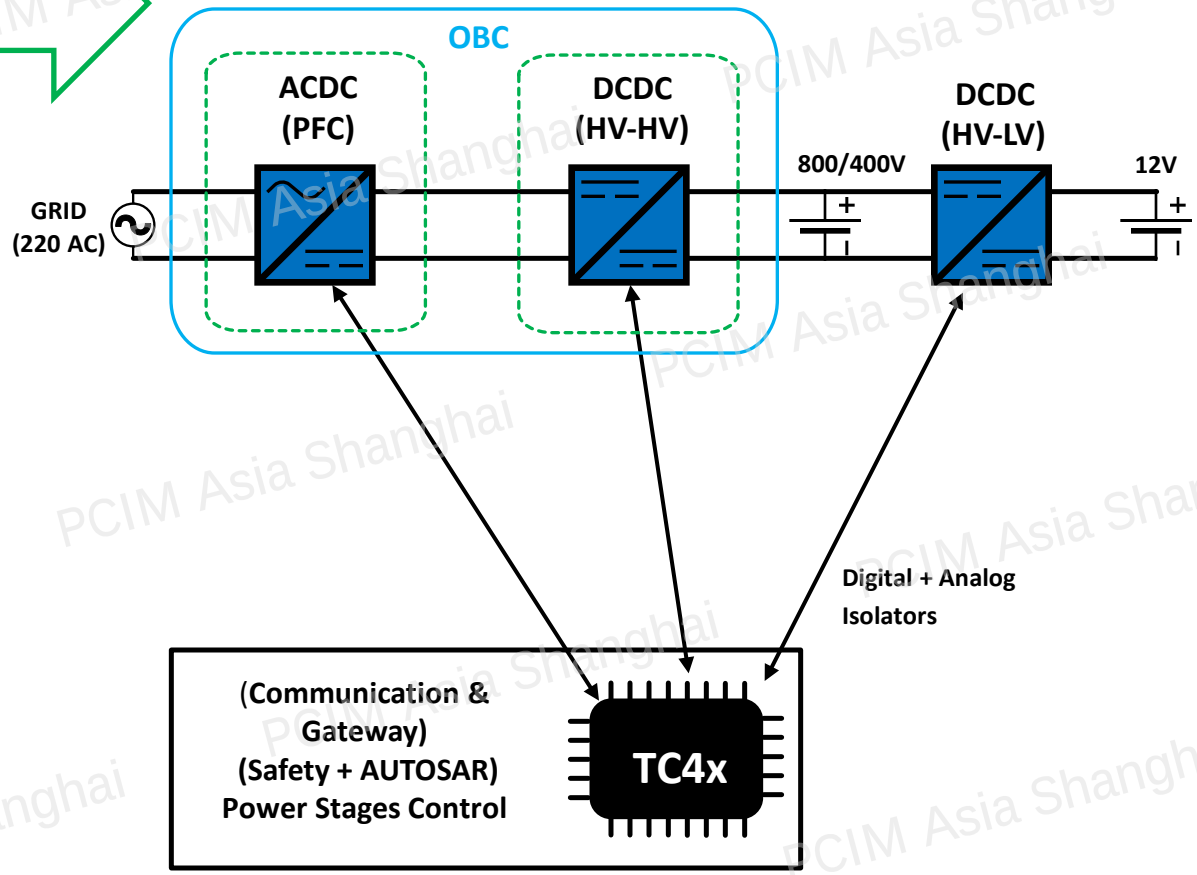
Dedicated DSPs are used to control the power stages

- No Safety
- No AUTOSAR

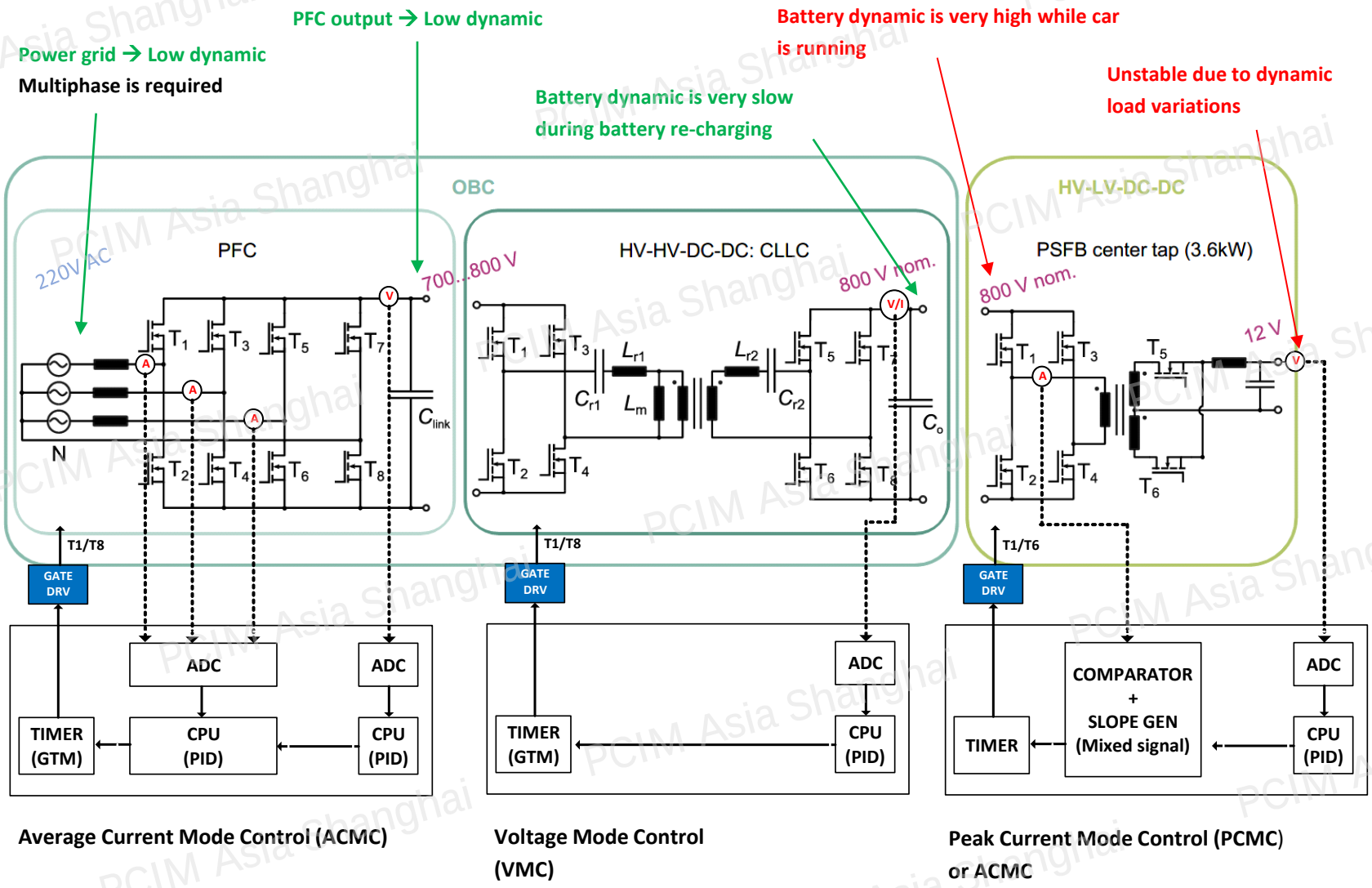


Future trend

«Single-MCU solution» with centralized architecture



Motivation for this Work



Average Current Mode Control (ACMC)

Voltage Mode Control (VMC)

Peak Current Mode Control (PCMC) or ACMC

	VMC	ACMC	PCMC
Dynamic input / load response	Bad	Good	Excellent
Inner loop design	-	Complex	Easy
Computation effort (e.g. CPU)	Low	High	Low
BoM costs (isolation)	Low	High	High
Comparator HW IP	No	No	Yes

Motivation is to improve the dynamic response but keeping all the good stuff from VMC

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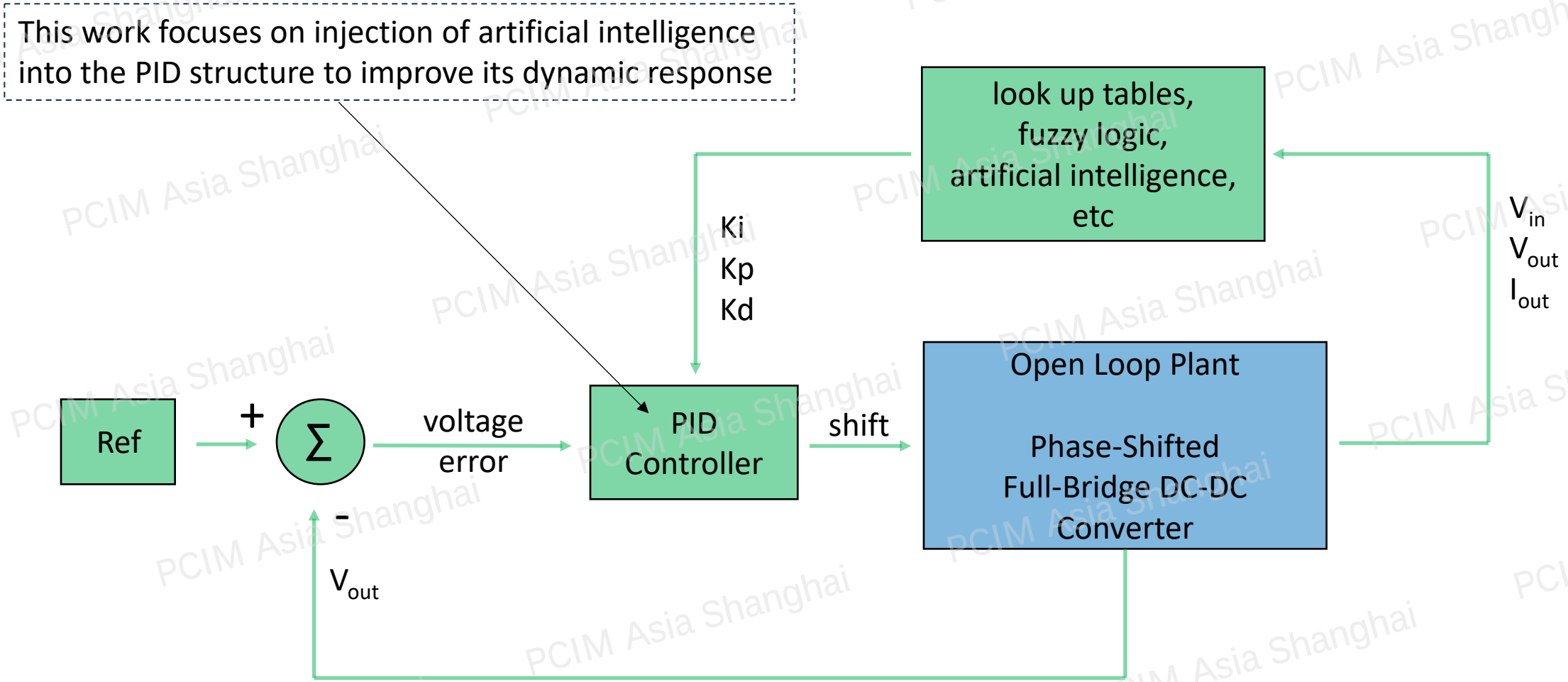
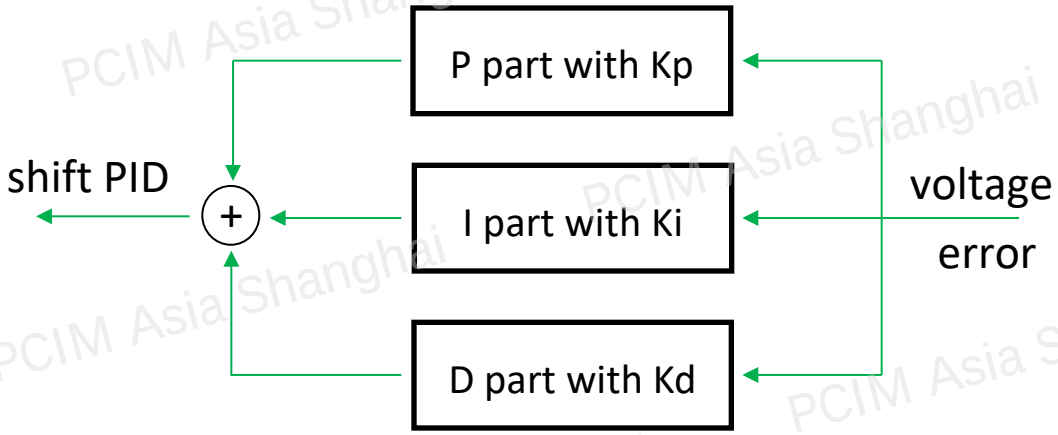
State of the Art PID Controller Approach

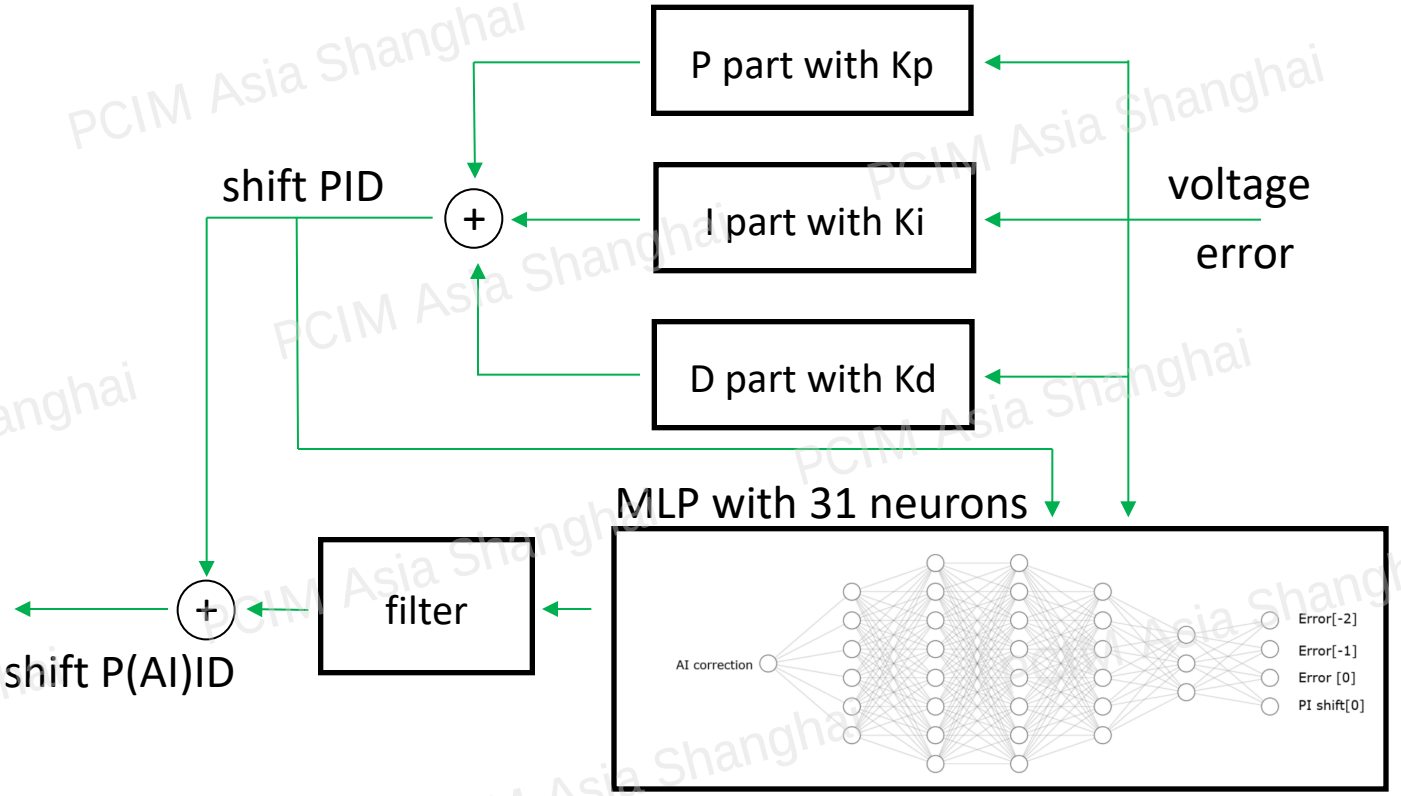


Proposed P(AI)ID Approach

State of the art PID controller



Proposed P(AI)ID controller



Adaption of Kx parameters for PID and P(AI)ID for optimal performance by another AI controller or look-up table approach (not focus of this work)

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Test Vehicle AURIX™ TC4x Power-Kit

Curious to see the test platform in action? → Visit our booth demonstrator

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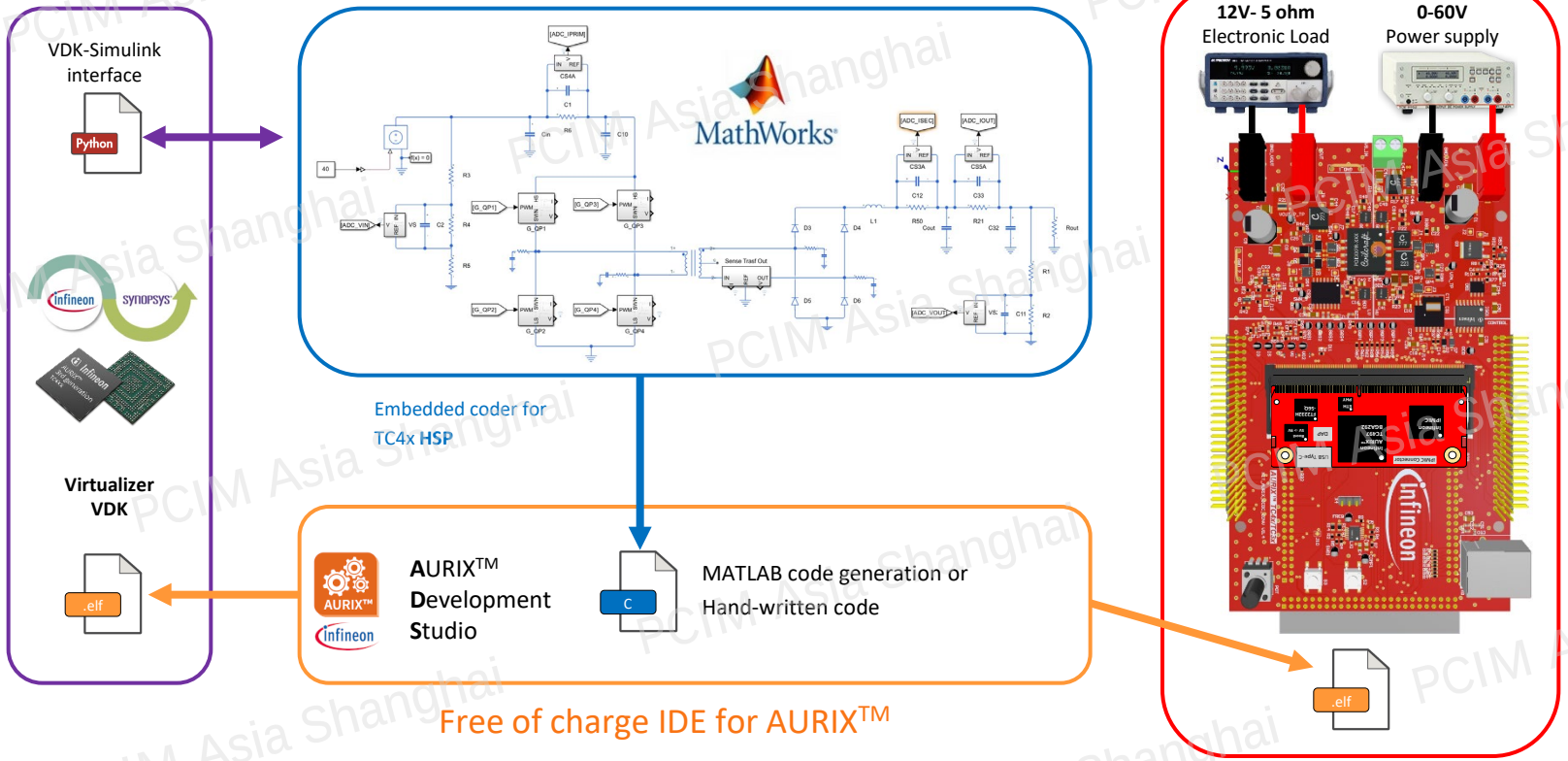
TC4x virtual prototype

High fidelity power stage model with control loop

Seamless deployment on real HW



Multi-topology support

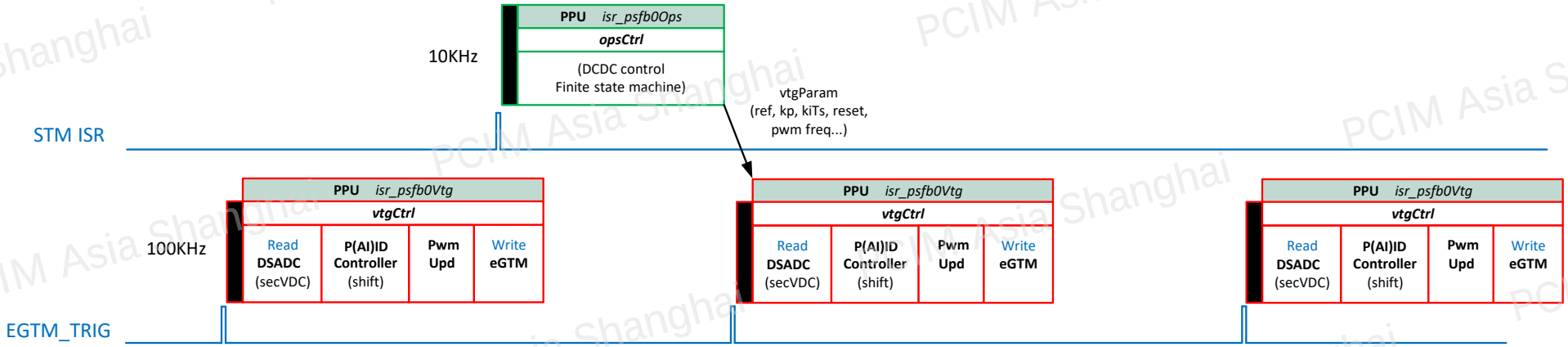
- **PSFB**
- LLC
- DAB
- Multichannel support (Parallel/Cascaded)

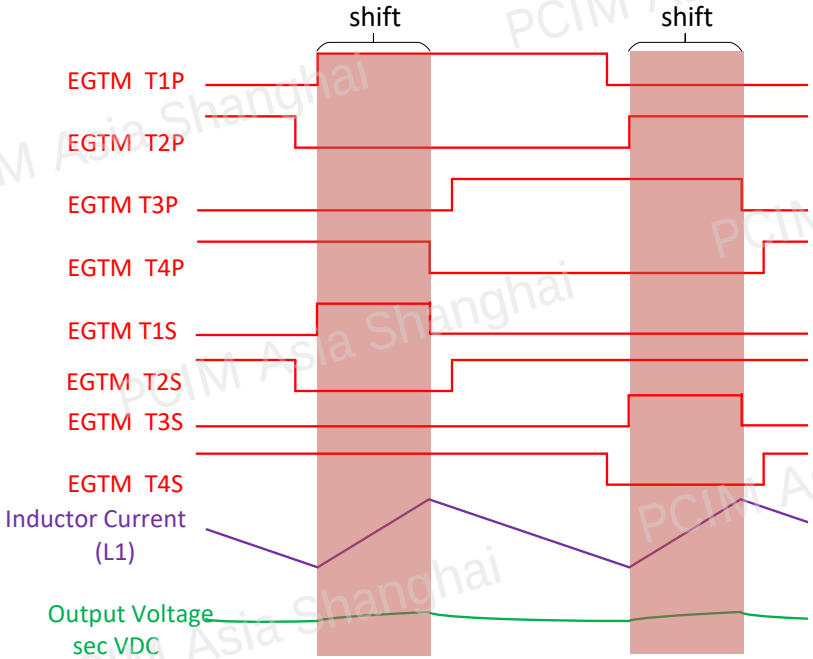
Supported control modes

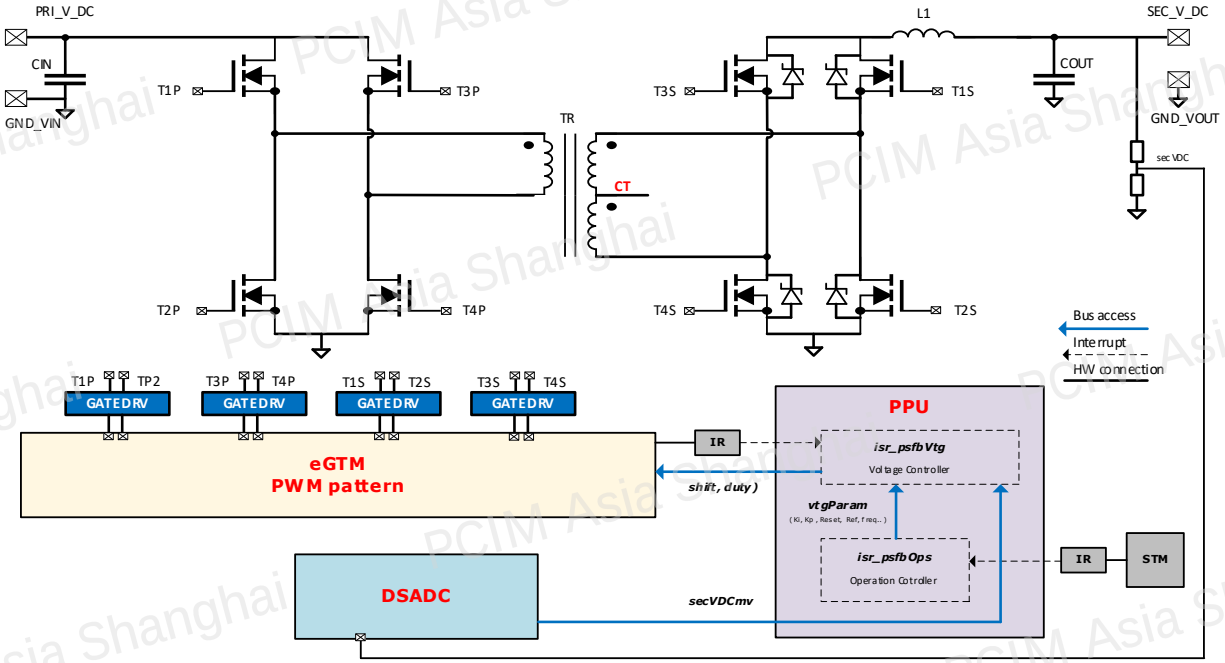
- **VMC (voltage mode)**
- ACMC (average current mode)
- PCMC (peak current mode)
- **AI-based controls**

- Vout/Vin < 60V
- Pout < 30W
- Overvoltage/Overcurrent protections

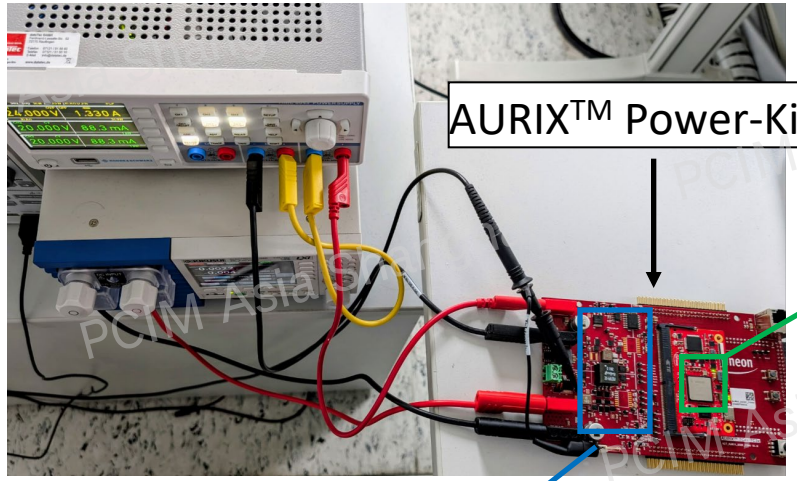
Phase-Shifted Full-Bridge DC-DC Converter







Measurement Setup



AURIX™ TC4x

PPU

Proposed P(AI)ID controller

P part with Kp

I part with Ki

D part with Kd

shift PID

voltage error

shift P(AI)ID

filter

AI correction

Error[-2]

Error[-1]

Error [0]

PI shift[0]

V_{target}

Timer (eGTM)

ADC (DSADC)

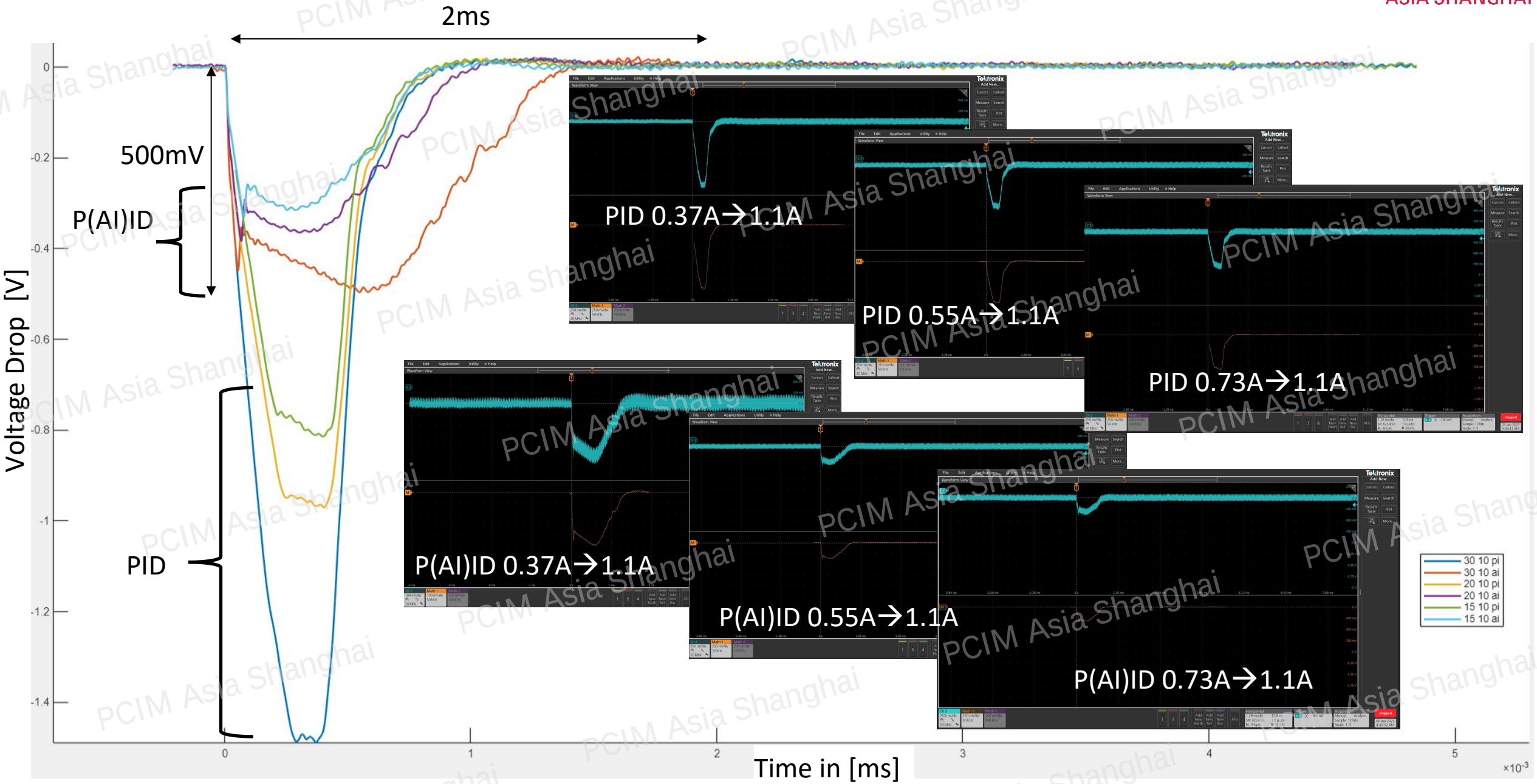
Plant (phase shifted full bridge)

V_{in} = 40V

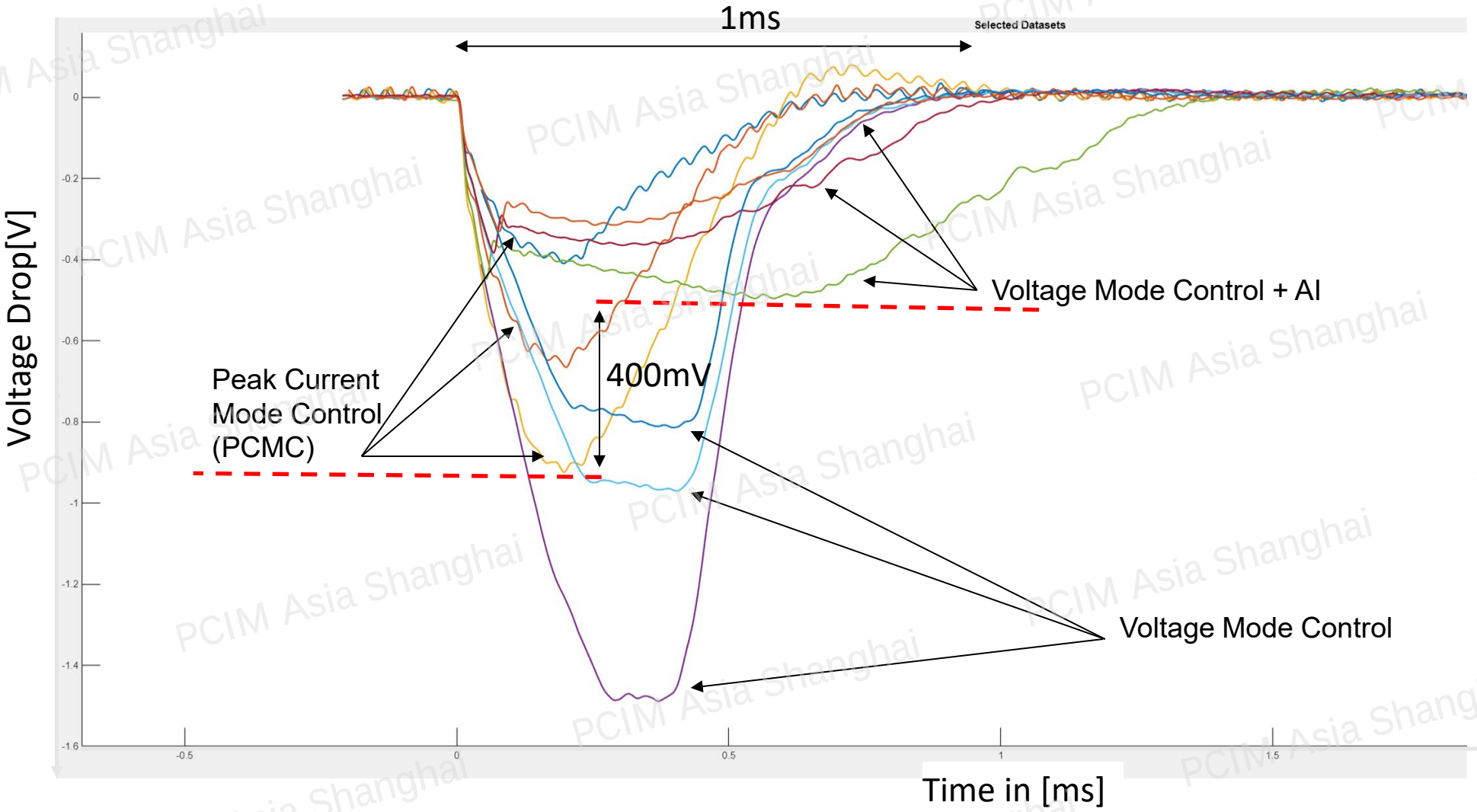
V_{out} = 11V

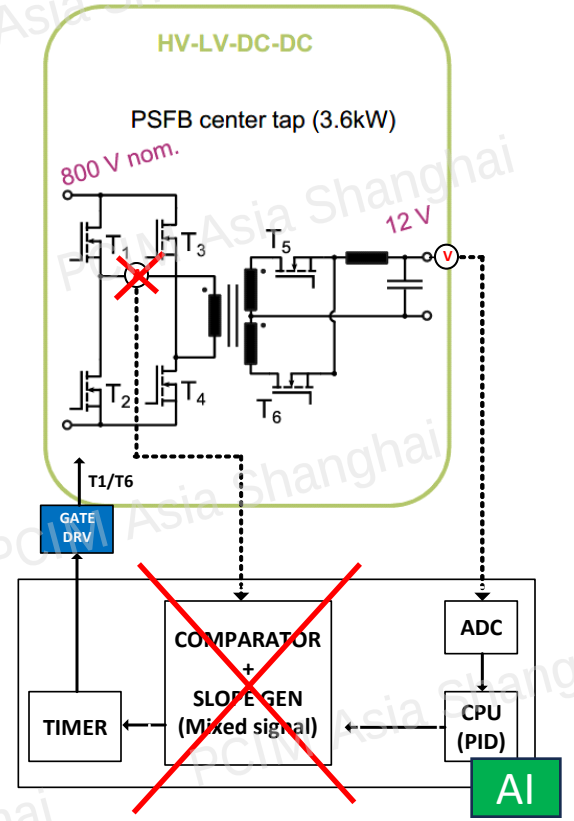
V_{ADC} = 2.75V

Measurements P(AI)ID vs PID



Measurements P(AI)ID vs Peak Current Mode





P(AI)ID Controller x2 better then best controller (PCMC) on the market at lower BoM and no comparator!

Summary

- The P(AI)ID controller approach enhances the dynamic response of the conventional PID controller

- Voltage mode controller using P(AI)ID reduces BoM cost (no current sensor) and the complexity (no comparator)

- P(AI)D has low compute and memory footprint of the MLP solution with 31 neurons

- The P(AI)ID controller is executed every 100kHz on Parallel Processing Unit (PPU) of AURIX™ TC4x microcontroller

- The P(AI)ID outperforms the PID by **3x** and peak current mode controller by **2x** in terms of dynamic response for the same cycle time and load step