

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

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Agenda

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

Agenda

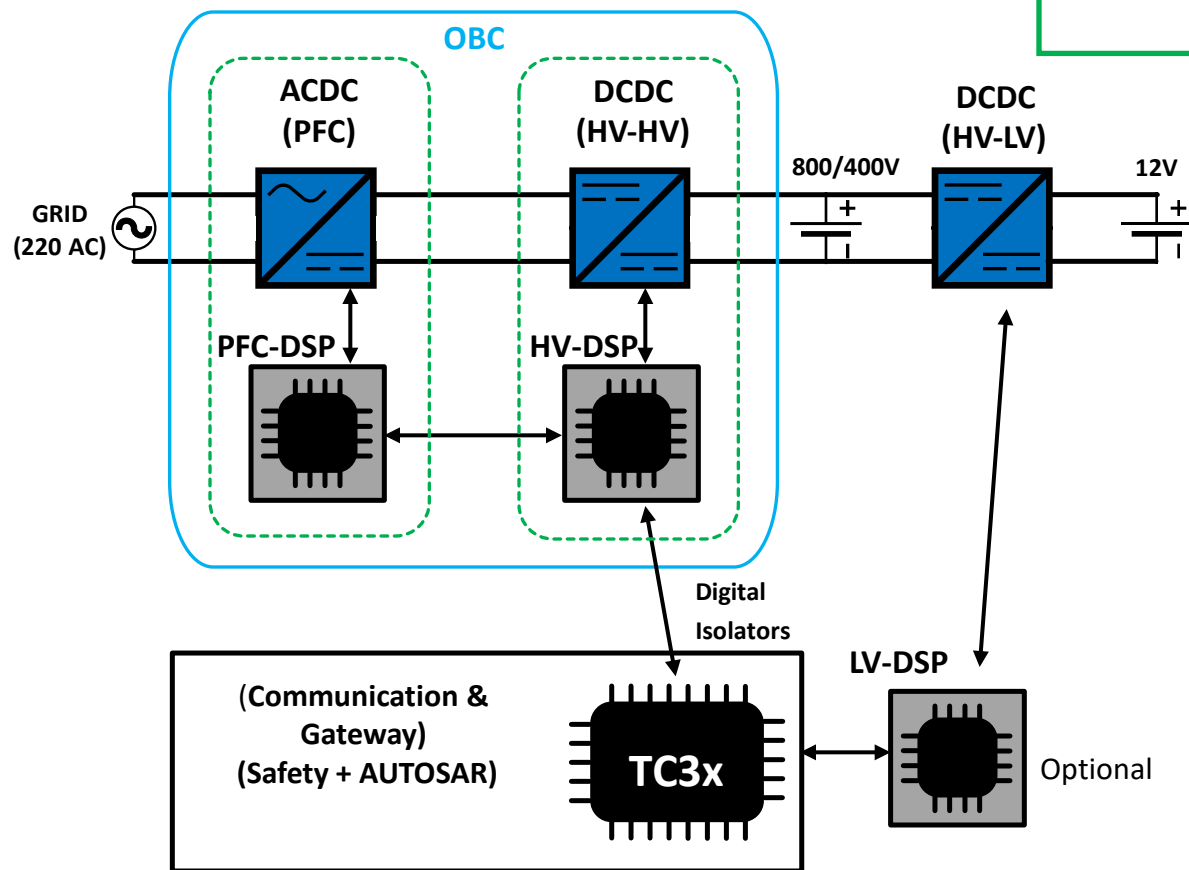
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Automotive On-Board Charger (OBC)

Today

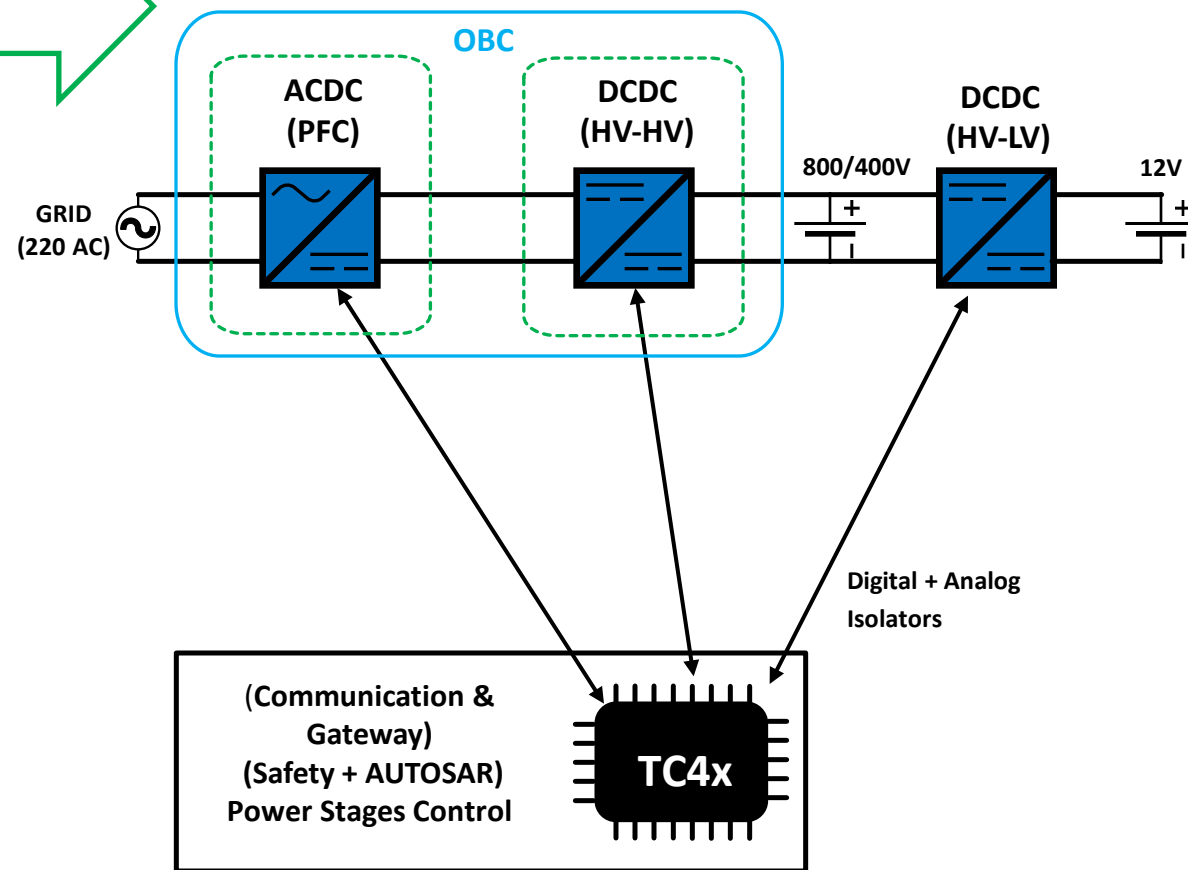
Dedicated DSPs are used to control the power stages

- No Safety
- No AUTOSAR

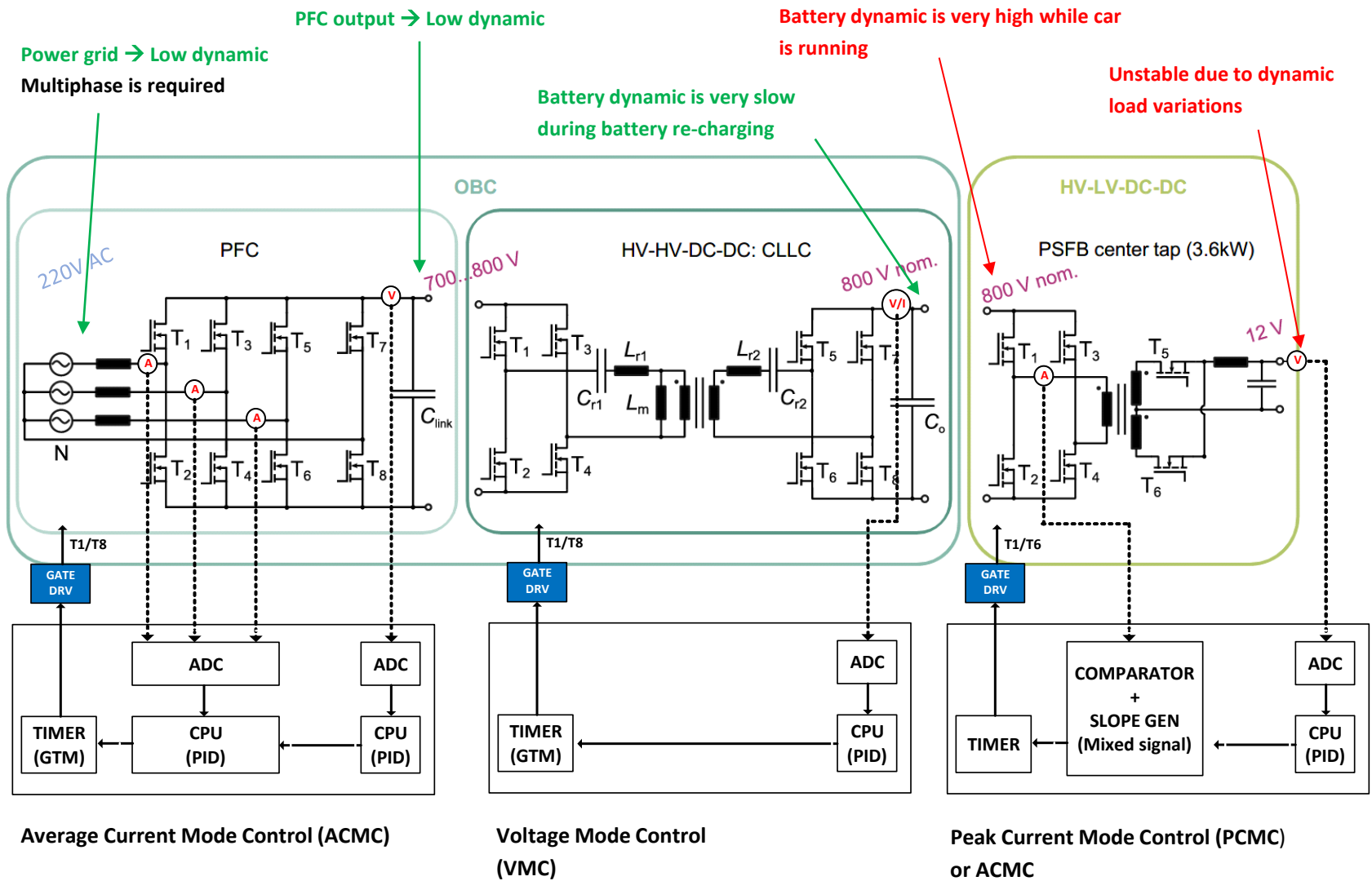


Future trend

«Single-MCU solution» with centralized architecture



Motivation for this Work



	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

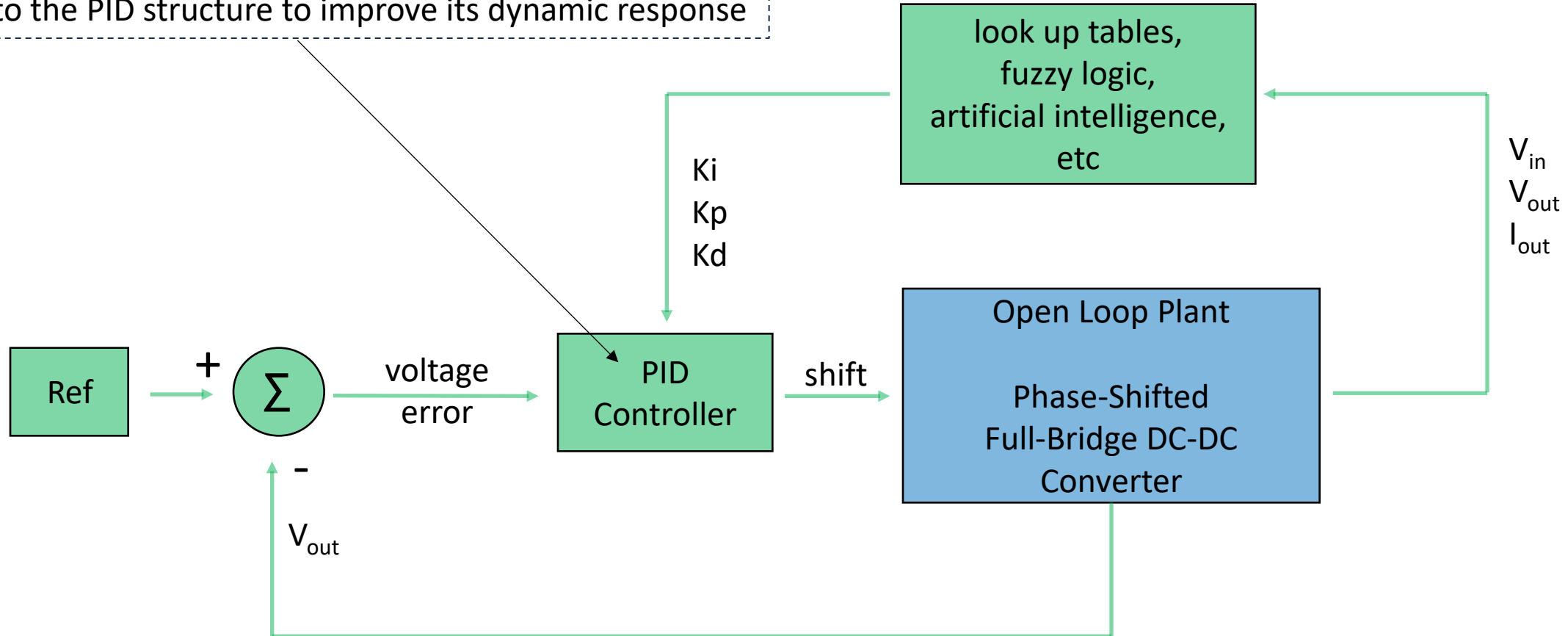
Motivation is to improve the dynamic response but keeping all the good stuff from VMC

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

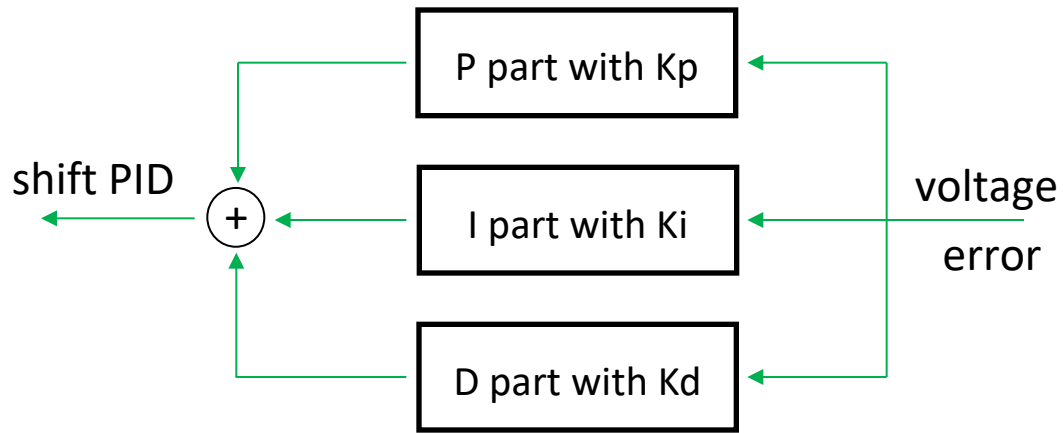
State of the Art PID Controller Approach

This work focuses on injection of artificial intelligence into the PID structure to improve its dynamic response

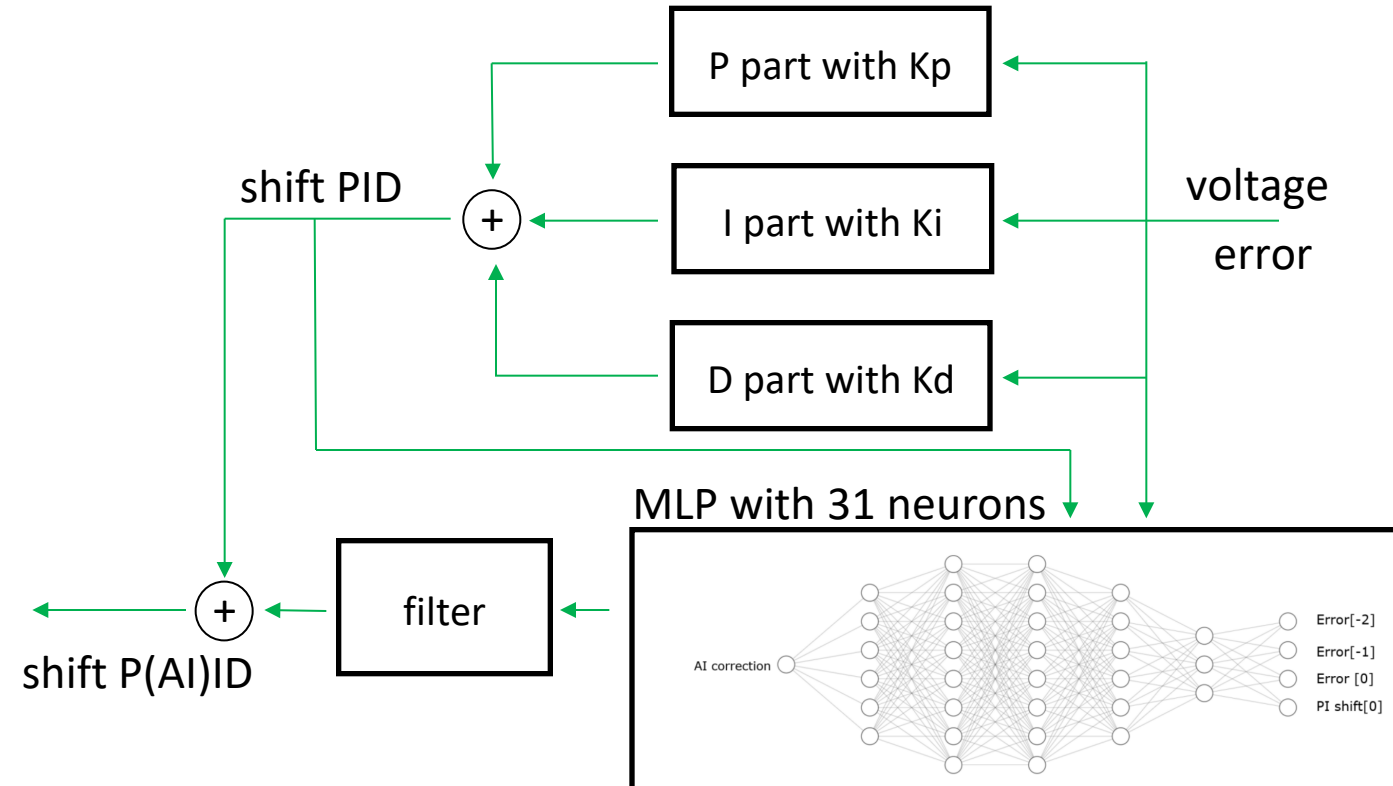


Proposed P(AI)ID Approach

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



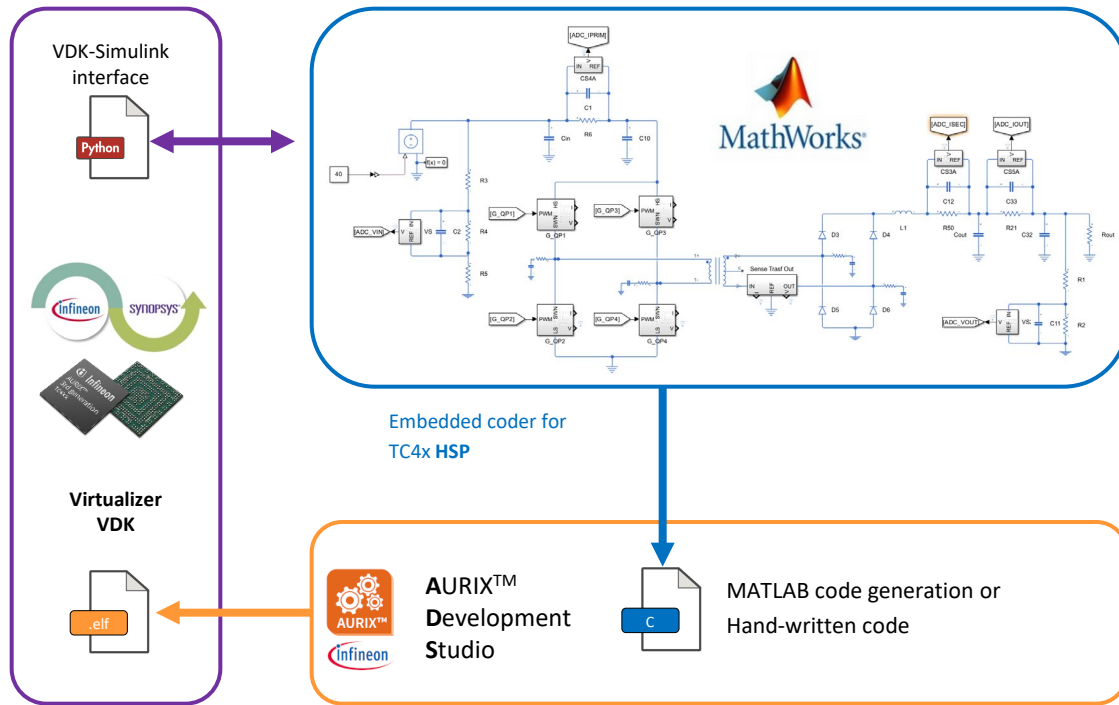
N5
C10



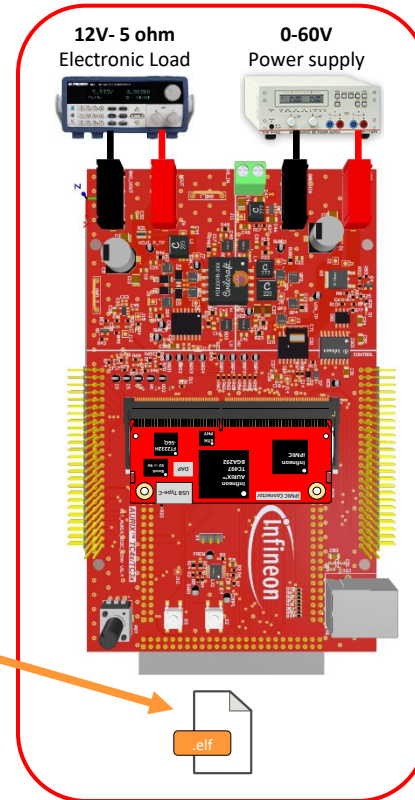
TC4x virtual prototype

High fidelity power stage model with control loop

Seamless deployment on real HW



Free of charge IDE for AURIX™



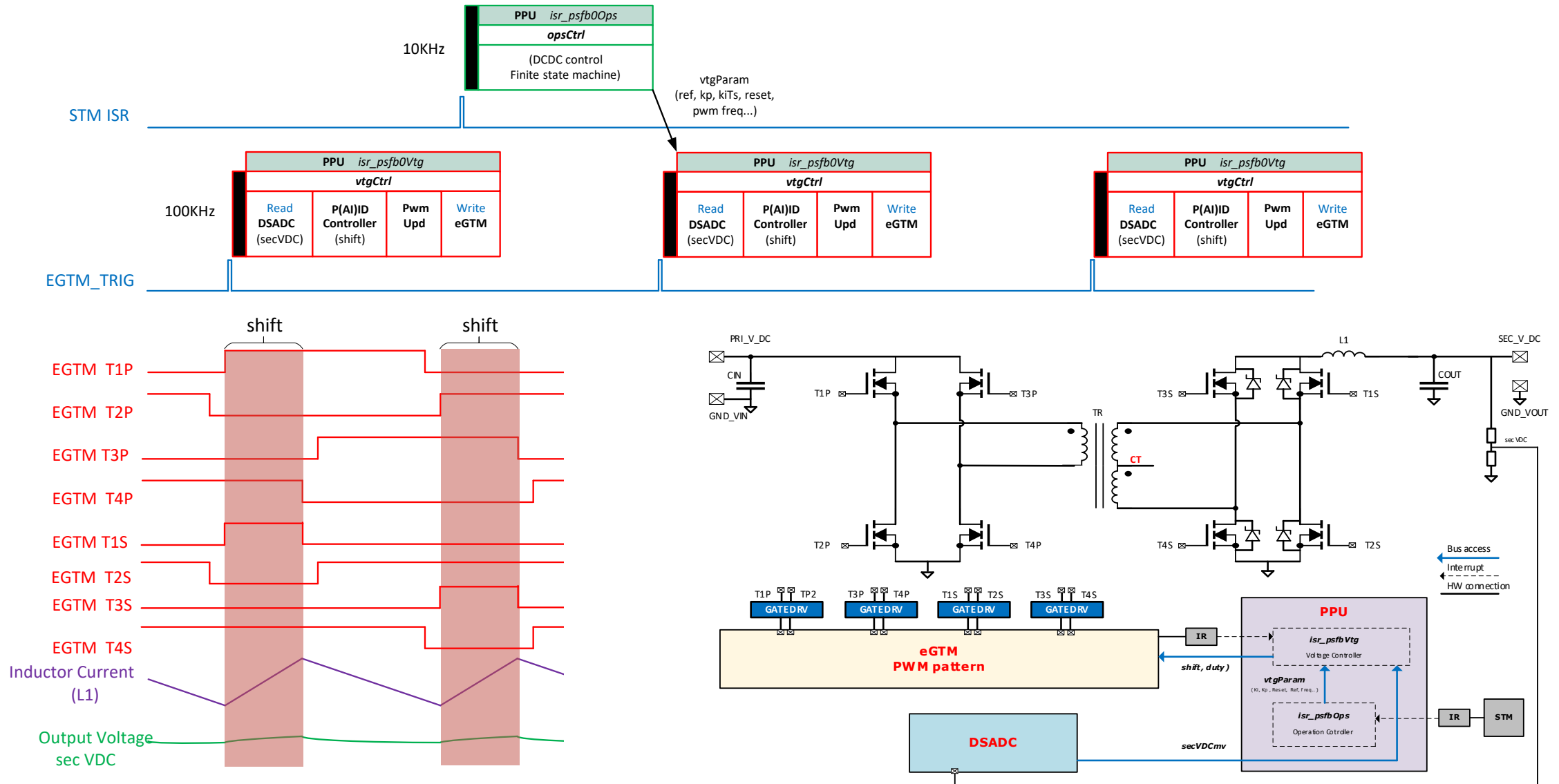
Multi-topology support

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

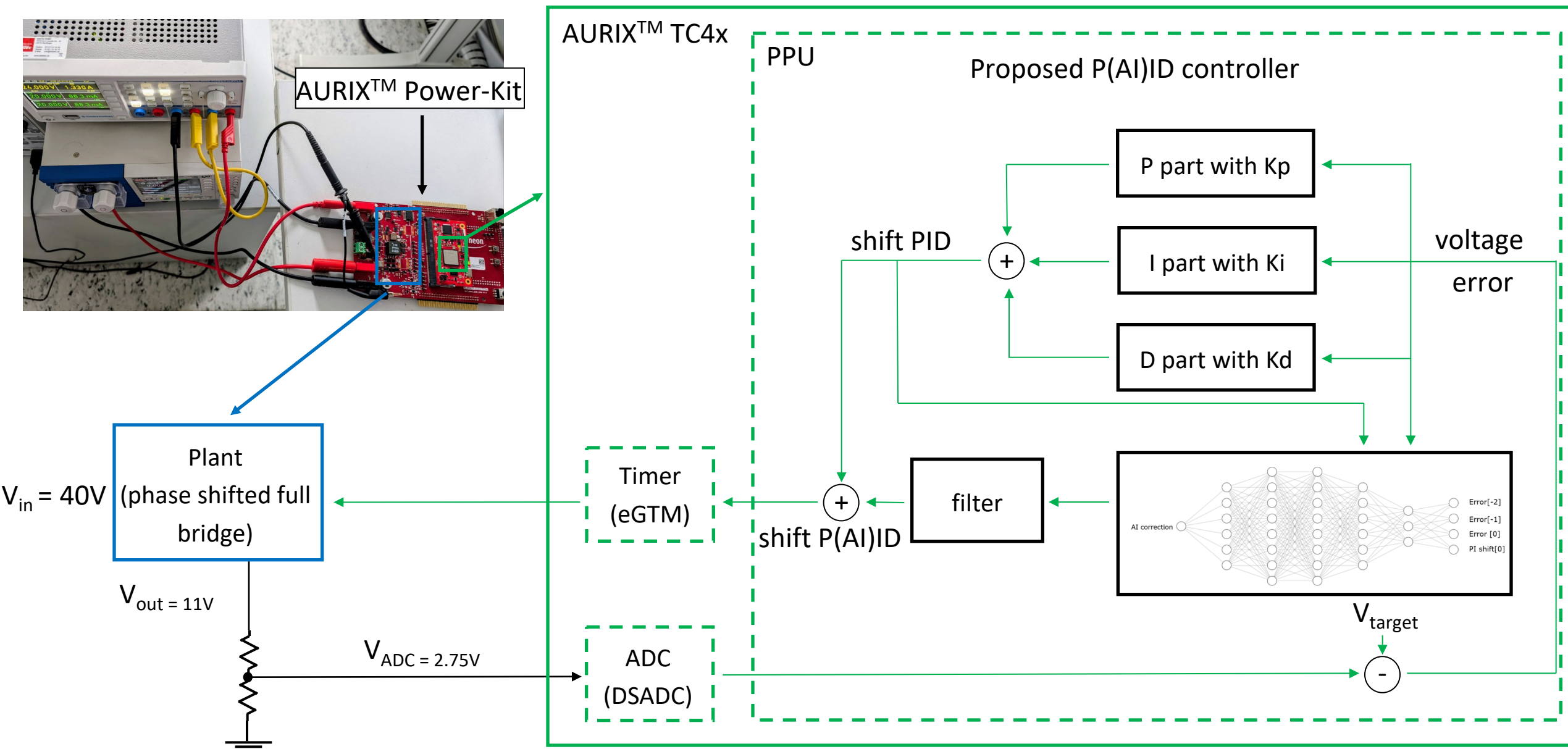
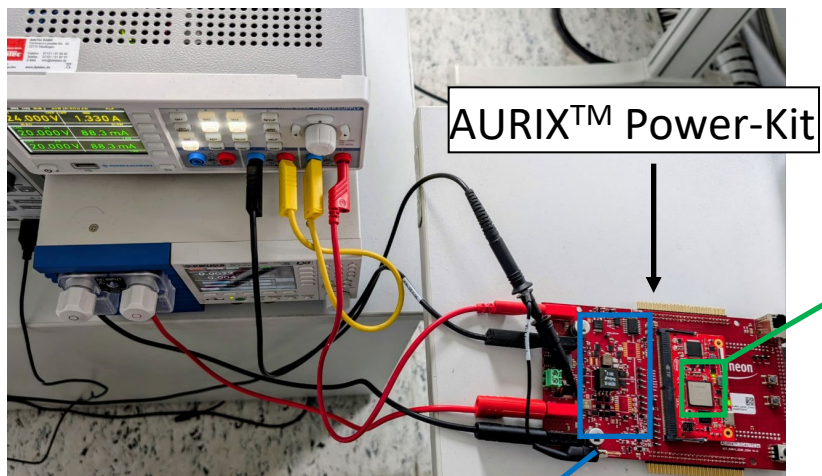
Supported control modes

- VMC (voltage mode)
- ACMC (average current mode)
- PCMC (peak current mode)
- AI-based controls
- $V_{out}/V_{in} < 60V$
- $P_{out} < 30W$
- Overvoltage/Overcurrent protections

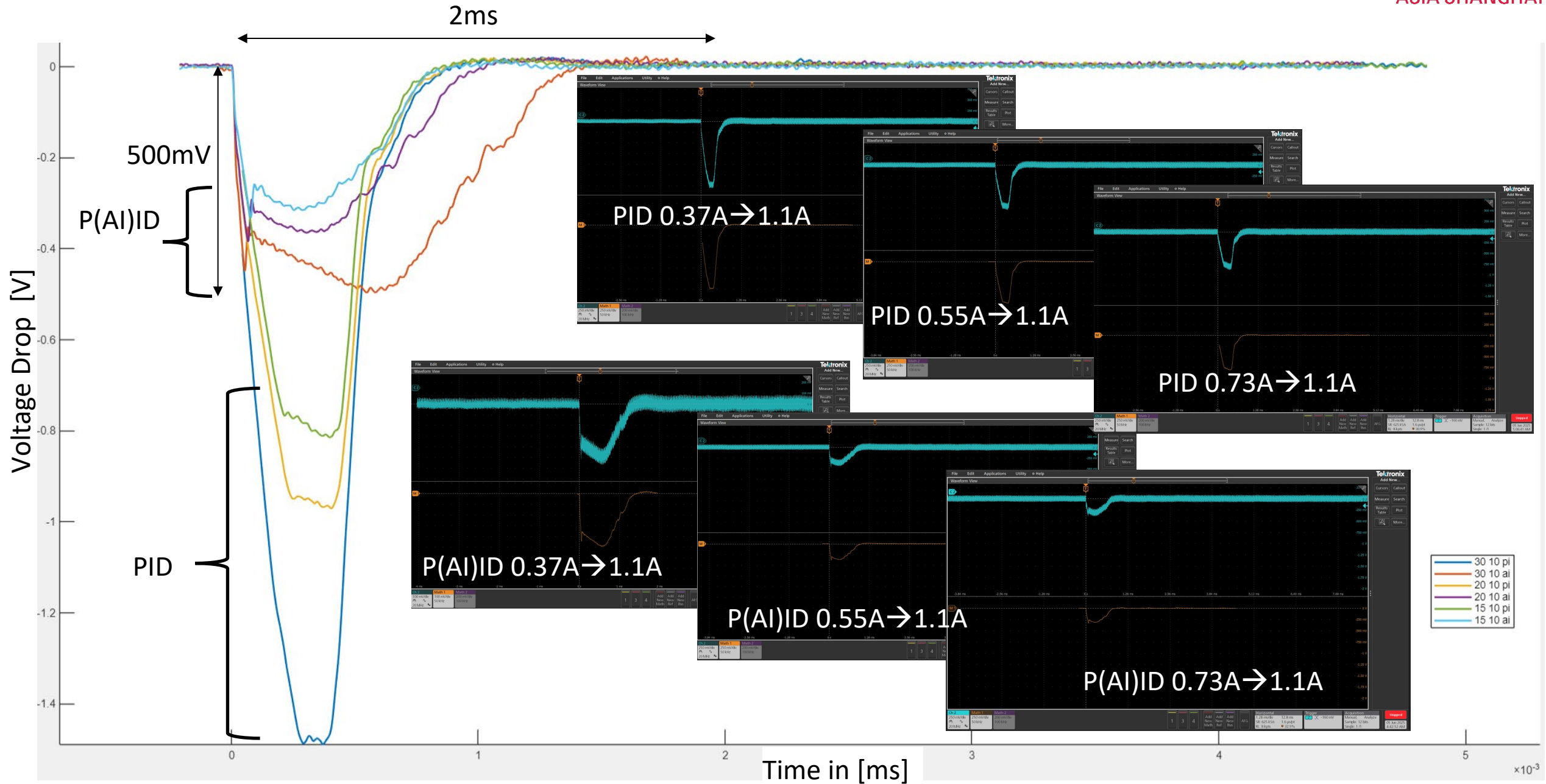
Phase-Shifted Full-Bridge DC-DC Converter



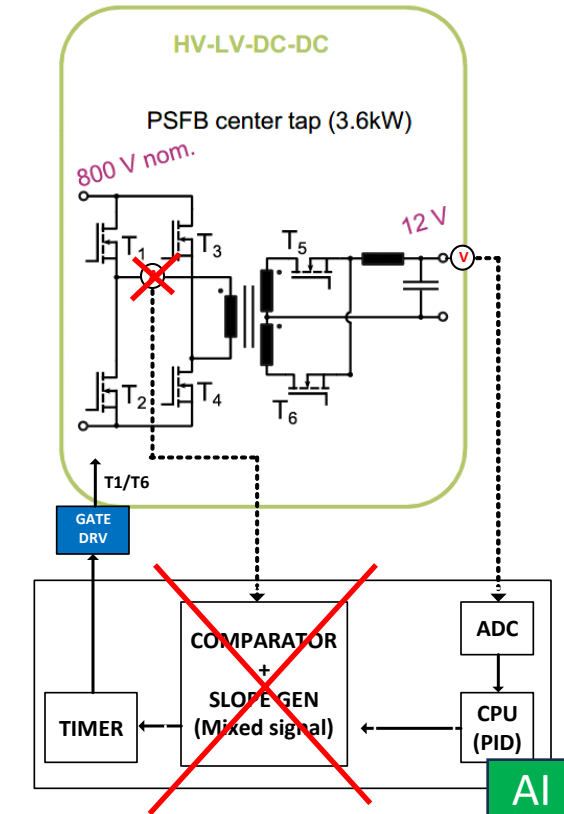
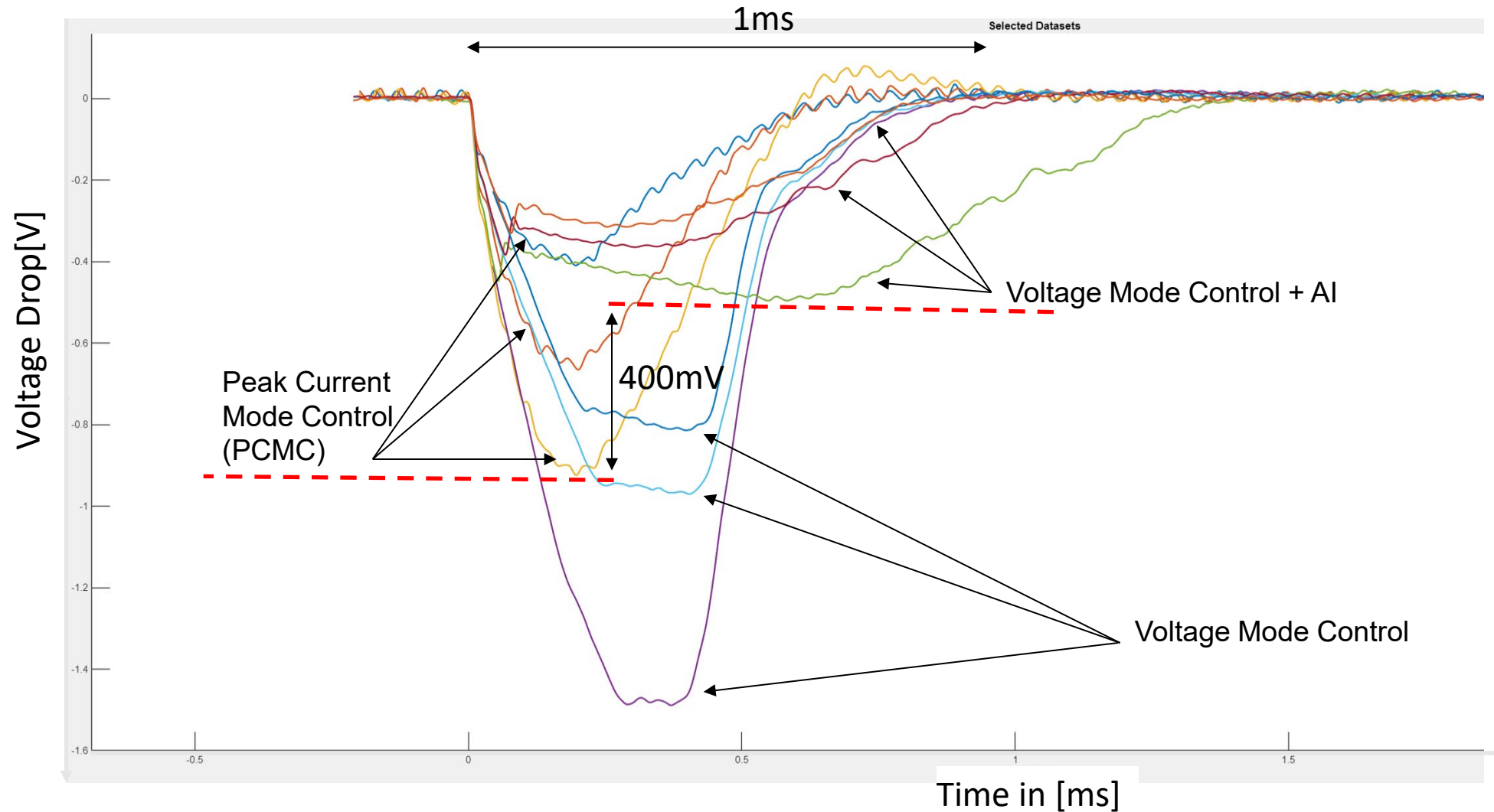
Measurement Setup



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