ASCENT

Setting up a Mechatronic System

4th Training in Rio de Janeiro, BRA

6th-9th of May 2019

Thomas Lechner

Co-funded by the Erasmus+ Programme of the European Union

Agenda

- Implementing a new ECU
  - Introduction
  - Input- and Output-Signals
  - Hardware and Software Setup
  - Programming a ECU with Simulink
  - Controller Setup with Ziegler-Nichols
  - Live Demo via Skype

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Choosing the ECU

Interfaces

- Speed Controller
  - Motor Speed (Input)
  - DC-Motor terminal voltage (Output)
- Position Controller
  - Rotor position (Input)
  - Motor speed and **direction** (Output → desired value for speed controller)
- DC-Motor load torque
  - Estimated via DC-Motor current

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Choosing the ECU

Interfaces

- Communication between ECU and environment
  - CAN-Interface
- ECU application
  - Can Calibration Protocol (CCP)

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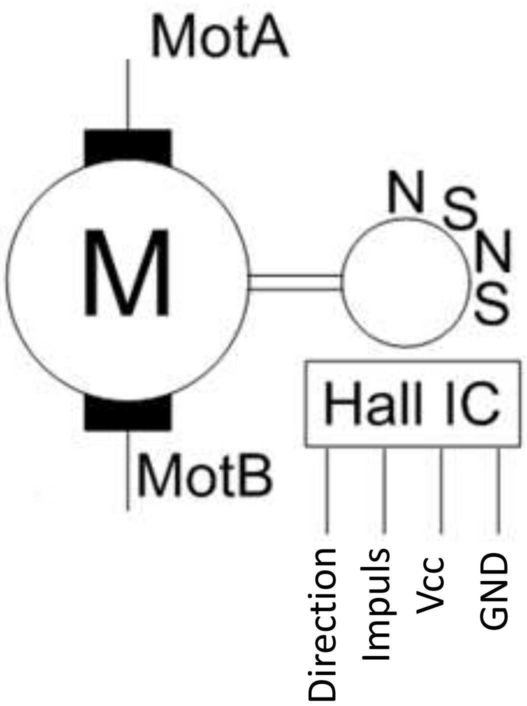
Choosing the ECU

Speed Measurement

- **DC-Motor → 10 Magnets**
  - Hall-Sensor measures
  - Rotor position (Input)
  - Motor speed and **direction** (Output → desired value for speed controller)
- **DC-Motor load torque**
  - Estimated via DC-Motor current



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Choosing the ECU – Speed Measurement

$\tau \approx 1.3\text{ ms} \rightarrow n \approx 2308\text{ RPM}$

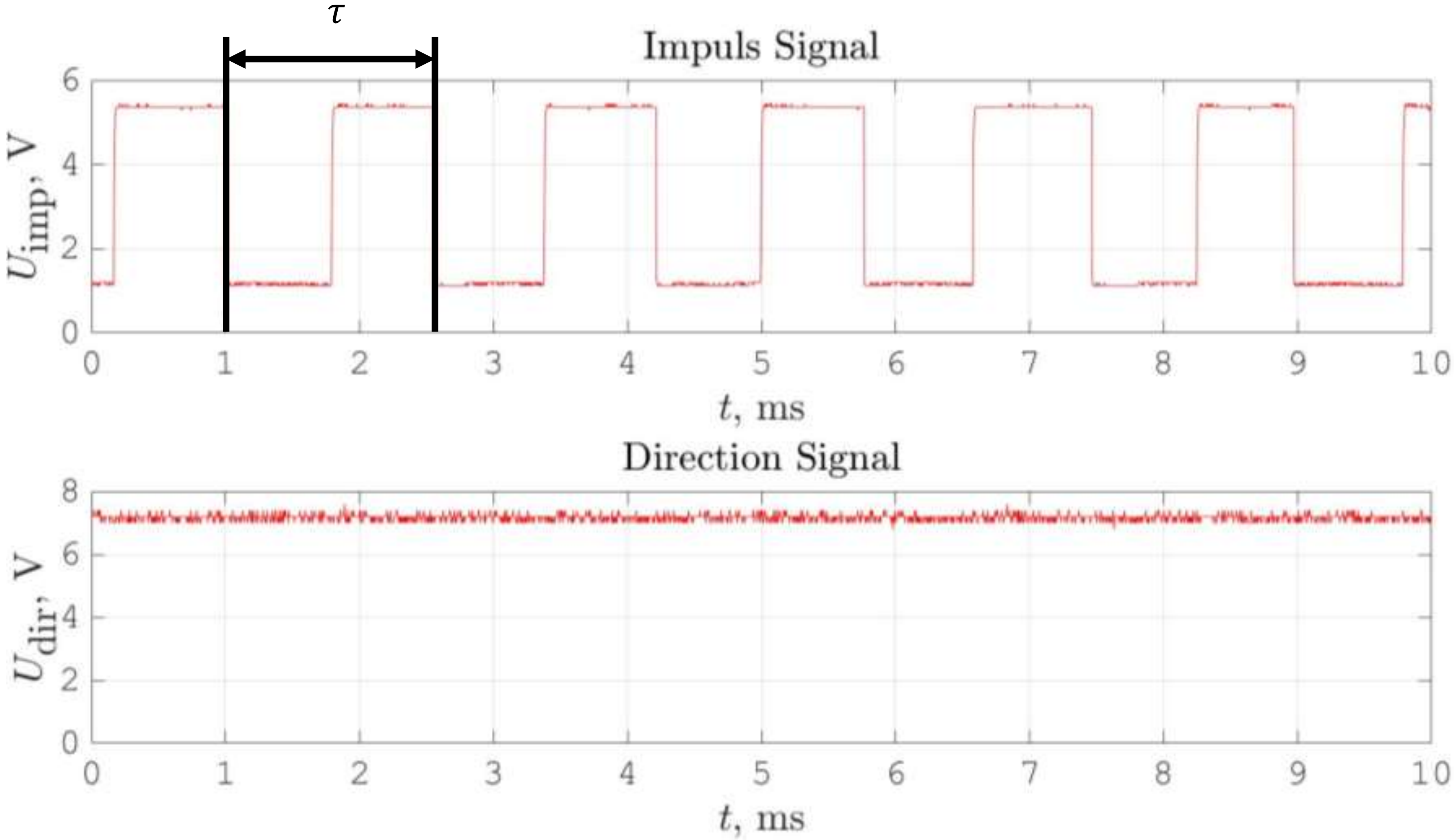
Speed measurement with timer input:

$$f = \frac{1}{\tau}$$

f ... Frequency in Hz
τ ... Period time in s
f → Measurement value

$$n = \frac{f}{N} \cdot 60$$

n ... engine speed in RPM
N ... Number of increments per revolution. In our case, N=20.



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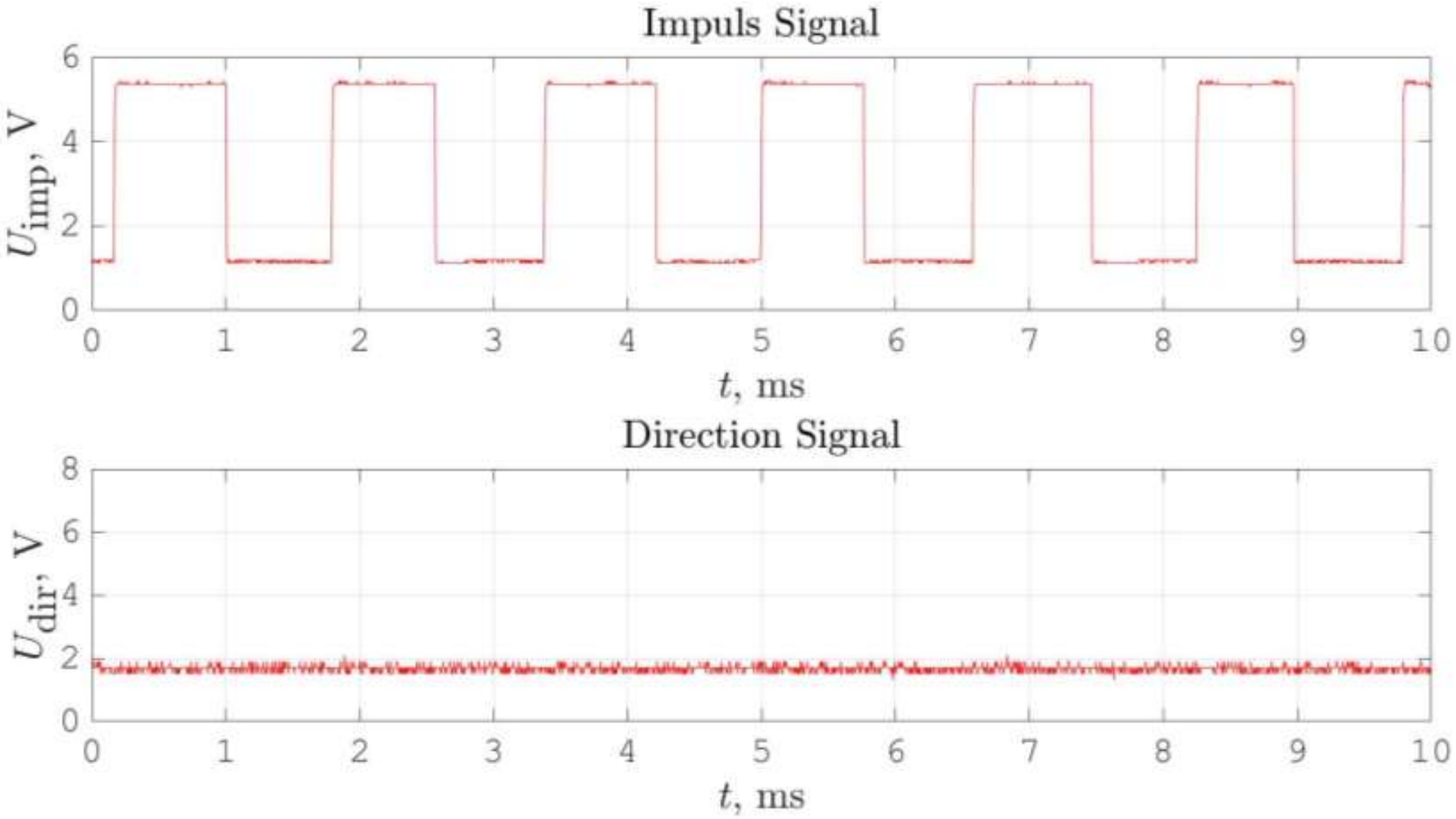
Choosing the ECU – Direction Measurement

Direction measurement with a digital input:

$U_{dir} \cong 1.9\ \mathrm{V} \rightarrow$ logical 0

$U_{dir} \cong 5.5\ \mathrm{V} \rightarrow$ logical 1

Direction of rotation:
1 → clockwise
0 → counterclockwise



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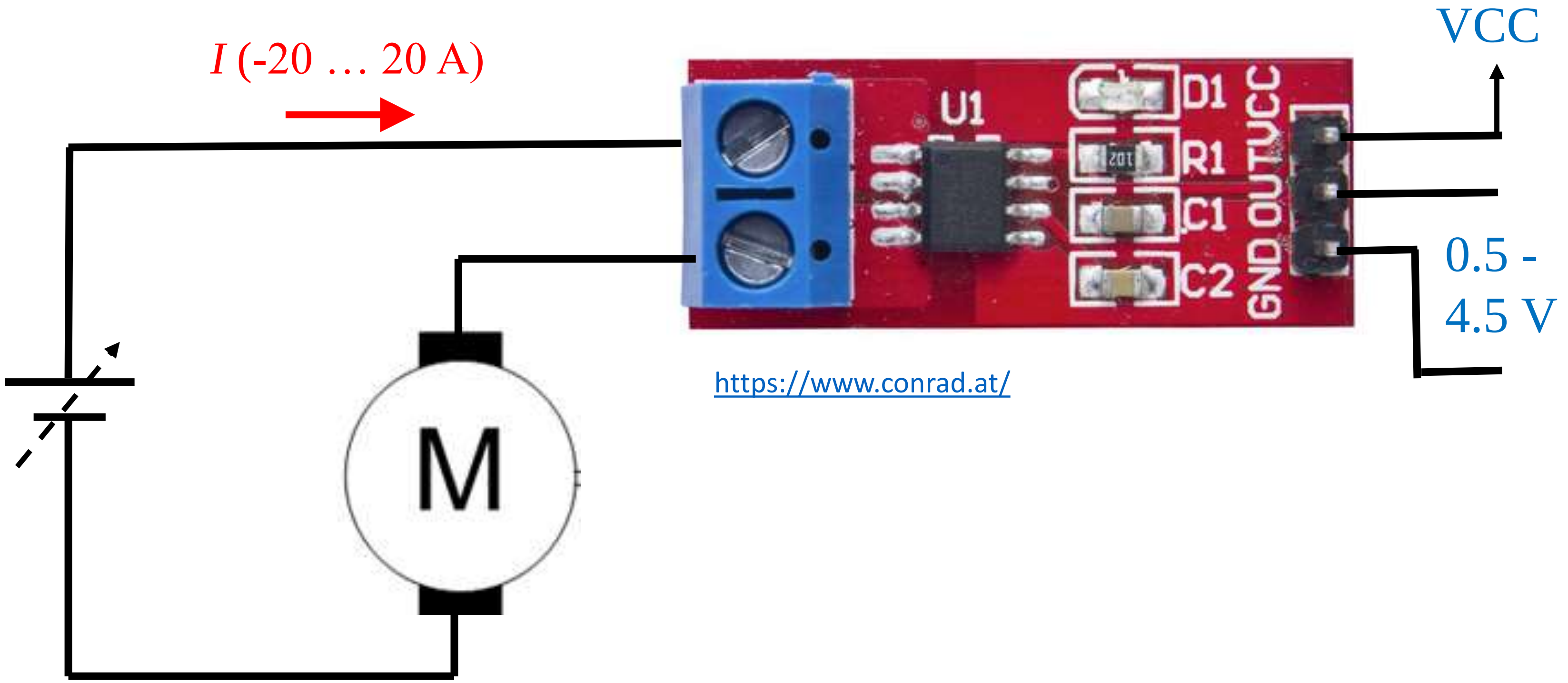
Choosing the ECU-Electrical Current Measurement

Current Measurement with a Hall-Sensor:

Supply Voltage (VCC) → 5 V

-20 A → 0.5 V
0 A → 2.5 V
20 A → 4.5 V

For DAQ → Analog Input



https://www.conrad.at/

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Choosing the ECU – DC-Motor connection

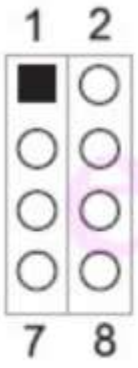
PWM modulated Voltage

H-Bridge

DC-Motor terminal voltage

- The voltage must be variable to change the motor-speed
- The voltage must change the polarity to change the direction
- Maximum (minimum) DC-motor current is ±12 A

http://www.hessmer.org/blog/2013/12/28/ibt-2-h-bridge-with-arduino



1、	RPWM	:Forward level or PWM signal input, active high
2、	LPWM	:Inversion level or PWM signal input, active high
3、	R_EN	:Forward drive enable input , high enable , low close
4、	L_EN	:Reverse drive enable input , high enable , low close
5、	R_IS	:Forward drive −side current alarm output
6、	L_IS	:Reverse drive −side current alarm output
7、	VCC	:+5 V power input,connected to the microcontroller 5V power supply
8、	GND	:Signal common ground terminal

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ECU - Input/Output Overview

	Quantity	Range	Description
CAN	>= 1	500 kBaud	- ECU flashing - Communication with environment, dynamic measurement …
Sensor Supply	1	5 V	- Current transducer - H-Bridge
Sensor Supply	1	10 V	- DC-Motor speed/position sensor
Voltage out 5 V	1	0 - 5 V	- H-Bridge → PWM enable
PWM out	2	10 kHz, 0 – 100 %, 0 – 5 V	- DC-Motor direction clockwise - DC-Motor direction counter clockwise
Timer in	1	2000 Hz	- DC-Motor speed
Digital in	1	1.9 V → logical 0 5.5 V → logical 1	- DC-Motor direction
Analog in	1	5 V	- Current transducer
Counter in	1	1.9 V → logical 0 5.5 V → logical 1	- DC-Motor position

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ECU – Required Performance

Performance Requirement

- Minimum cycle time: 2 ms
  - This is an empirical value, estimated according to the expertise we have with a similar application. The cycle time influences the controller performance.
- Automatic software-generation out of Simulink
  - State of the art method. (language C is not longer part of our curriculum)
- Calibration via XCP or CCP
  - State of the art method for development, parameter setting, debugging …
- Calculation with Floating Points (single, double, …)
  - Knowledge about Integer-Arithmetic is not so important for an system engineer.

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ECU – Our Choice

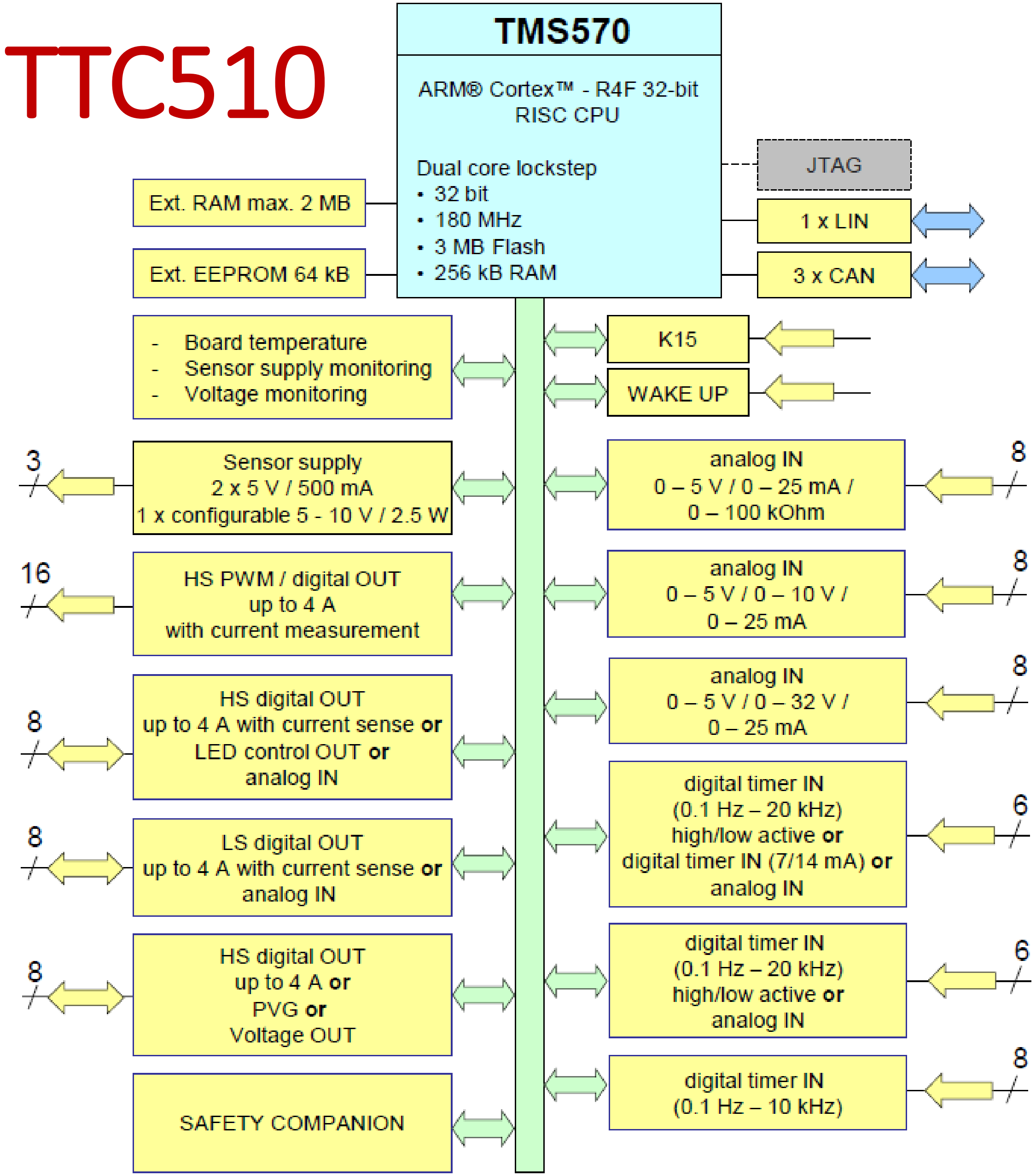
HY-TTC 510 from TT-Tech

Key Benefits:

- 32 bit dual-core CPU with 180MHz
- Floating-point unit
- 12 Bit ADC
- PWM-Outputs
- Digital in an Outputs
- CAN, CCP ....

https://www.ttcontrol.com

Description TTC510



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ECU – Target-performance comparison

	Quantity	Range	Possible with HY TTC 510?
CAN	~2	500 kBaud	- Yes (3 CAN-Interfaces available)
Sensor Supply	1	5 V	- Yes (2 x 5 V supply on board)
Sensor Supply	1	10 V	- Yes (1 x programmable between 5 V an 10 V)
Voltage out 5 V	1	0 - 5 V	- Yes
PWM out	2	10 kHz 0 – 100 % 0 – 5 V	- No (maximum 1 kHz) - Yes - Yes/No →Voltage level must be adapted (voltage divider)
Timer in	1	2000 Hz	- Yes (maximum 20 kHz)
Digital in	1	1.9 V → logical 0 5.5 V → logical 1	- Yes
Analog in	1	5 V	- Yes
Counter in	1	1.9 V → logical 0 5.5 V → logical 1	- Yes (for Simulink, a Workaround is necessary)

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ECU – Target-performance comparison

- Minimum cycle time: 2 ms
  - OK. The cycle time can be adjusted in discreet steps. The minimum value is 1 ms.
- Automatic Software generation out of Simulink
  - OK. A Simulink-Library is included in the scope of delivery. A basic description, for correct solver settings is available.
- Calibration via XCP or CCP
  - OK. CCP is supported in the polling mode.
- Calculation with Floating Points (single, double, …)
  - OK. The µP has a FPU on board.

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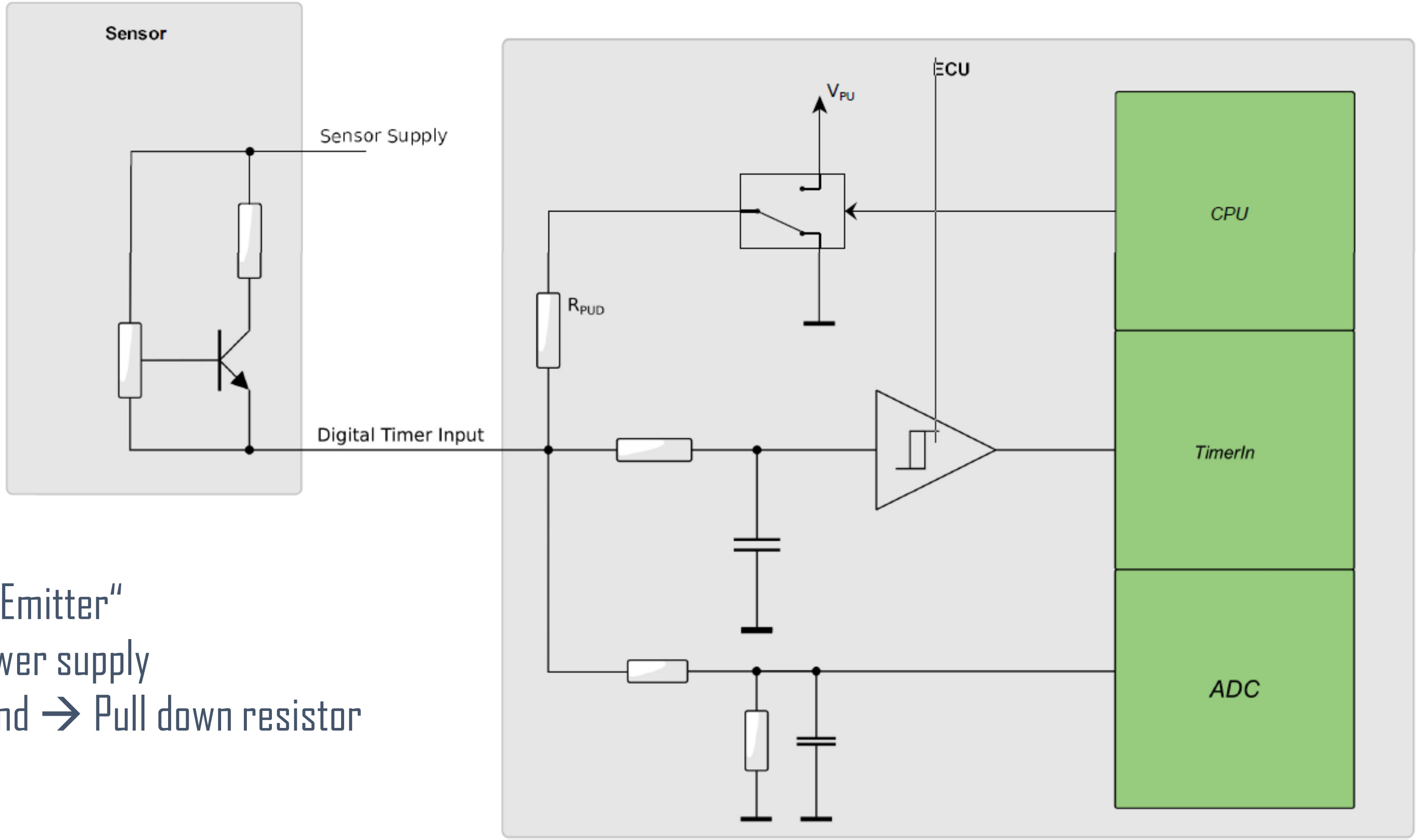
ECU – Circuit diagram of Input's



Sensor output is „Open Emitter"

- External sensor power supply
- Connection to ground → Pull down resistor

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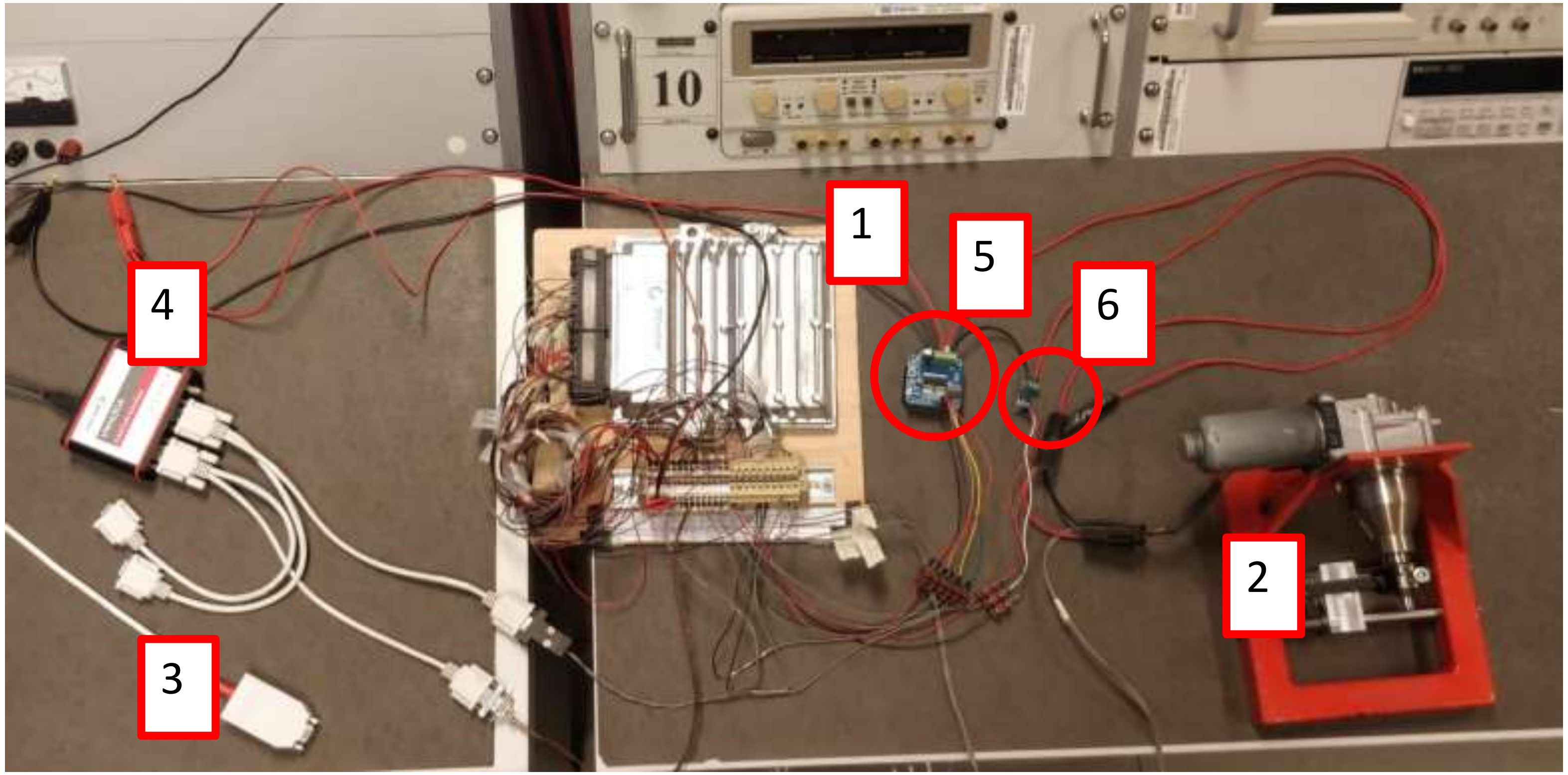
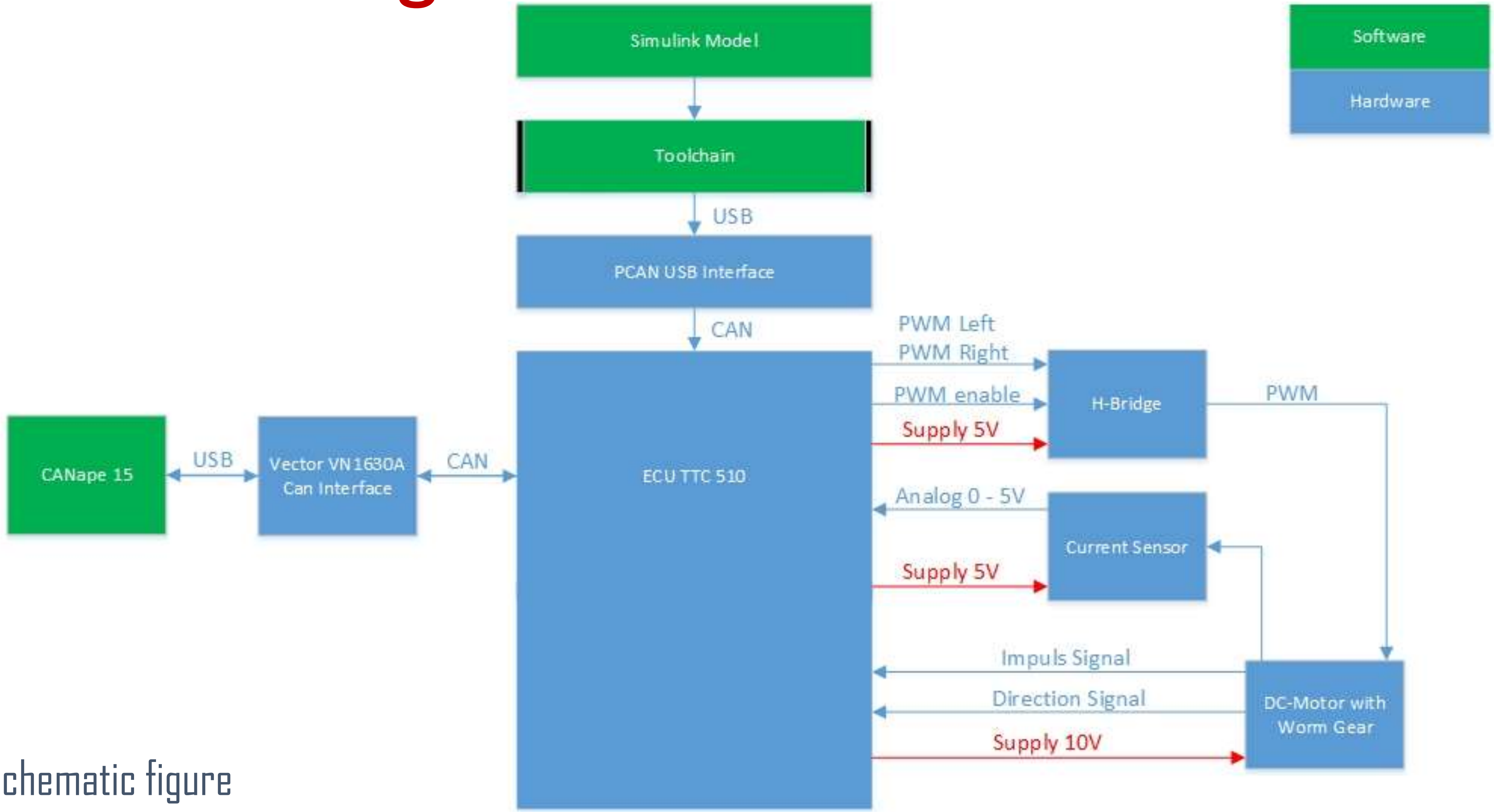
System overview

1) ECU HY-TTC 510
2) Device under Test (DUT)
3) PCAN-USB Interface for flashing
4) Vector VN1630 USB to CAN Interface for application (CCP) and measurement
5) H-Bridge
6) Current transducer

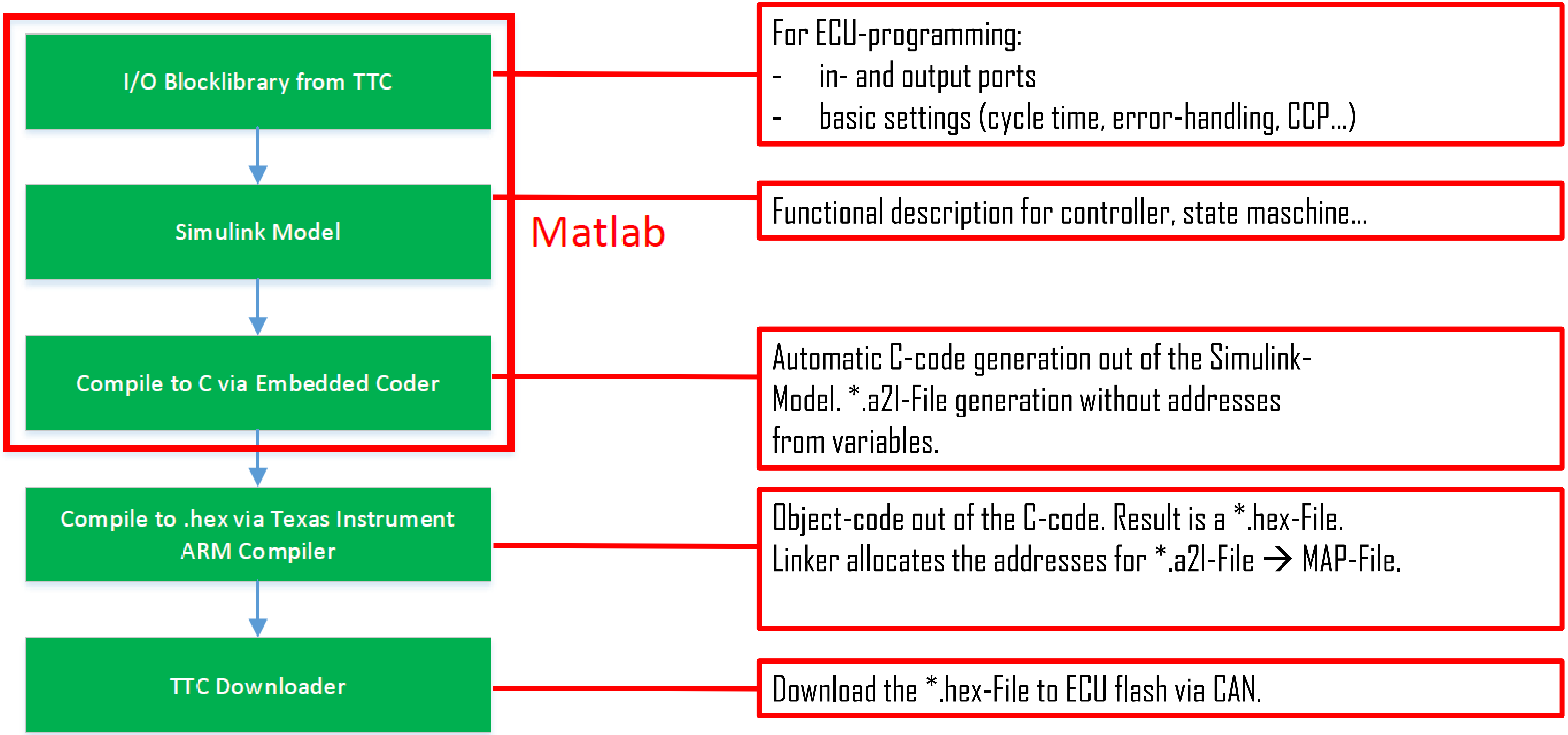


System block diagram

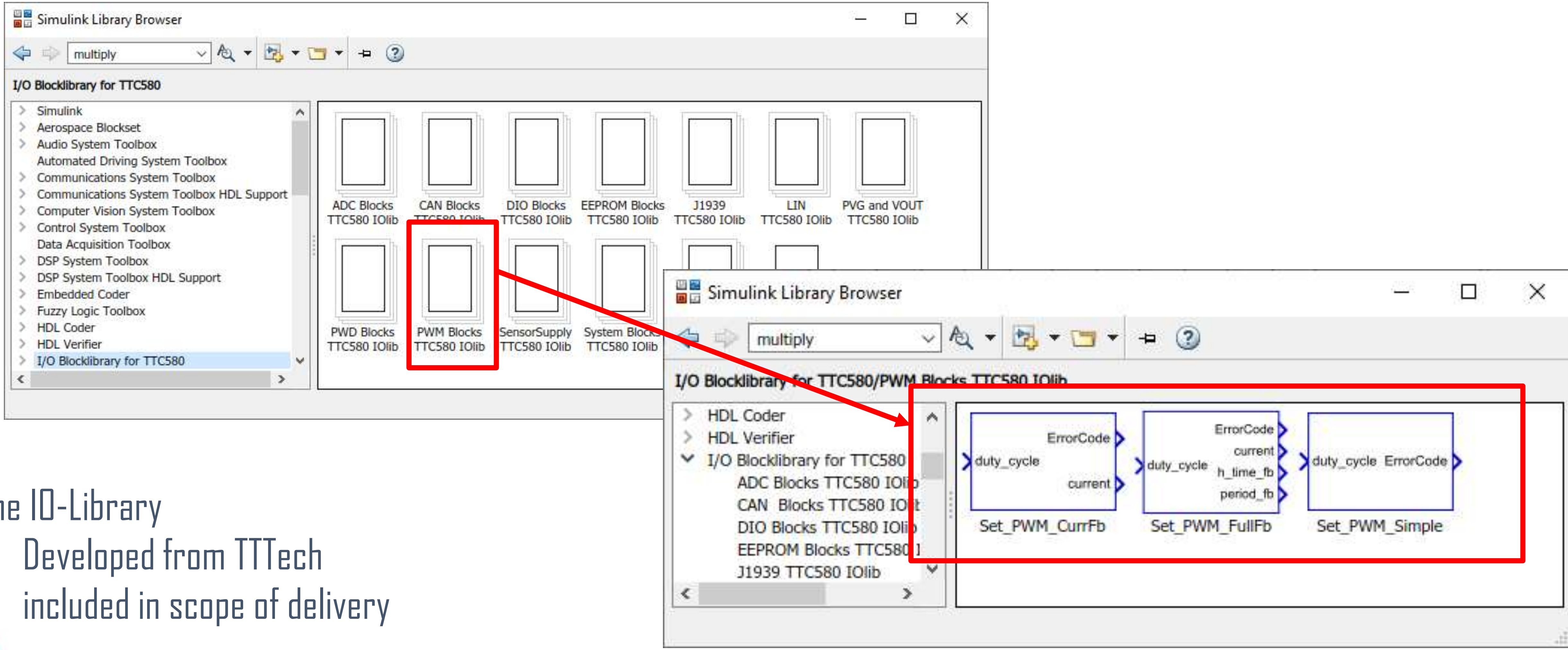


Schematic figure

Tool chain description



TTC IO-Library



The IO-Library

- Developed from TTTech
- included in scope of delivery

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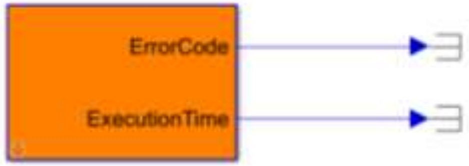
A simple Simulink example

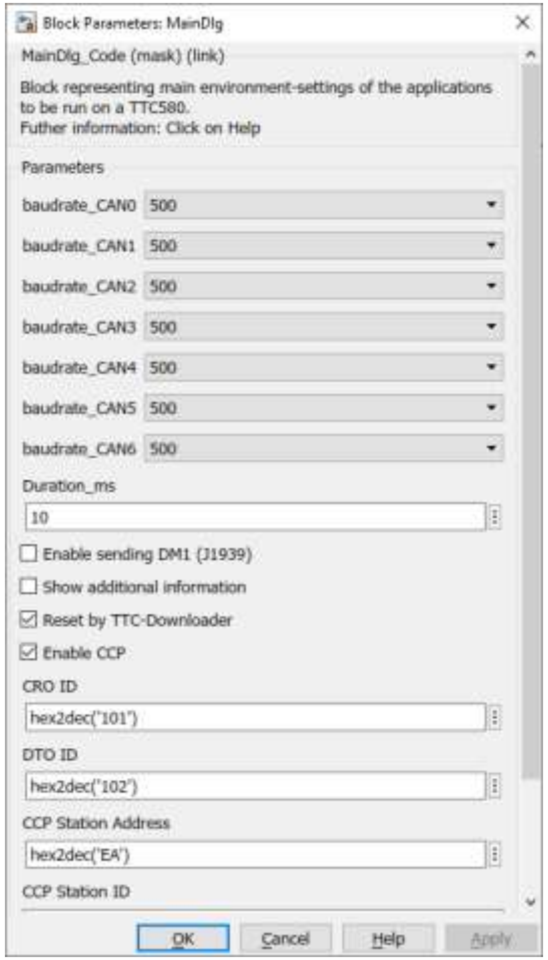
Change PWM ratio as a function of a voltage signal

Global Settings for the ECU → Block *MainDlg*

Setup for:

- CAN Baudrate (max. 1000 kHz)
- Cycle (Duration) time
- CCP Addresses





Power outputs must be enabled

- Block *Power_Enable*
  - 0 → disable
  - 1 → enable
  - Data type: Boolean

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A simple Simulink example

Change PWM ratio as a function of a voltage signal

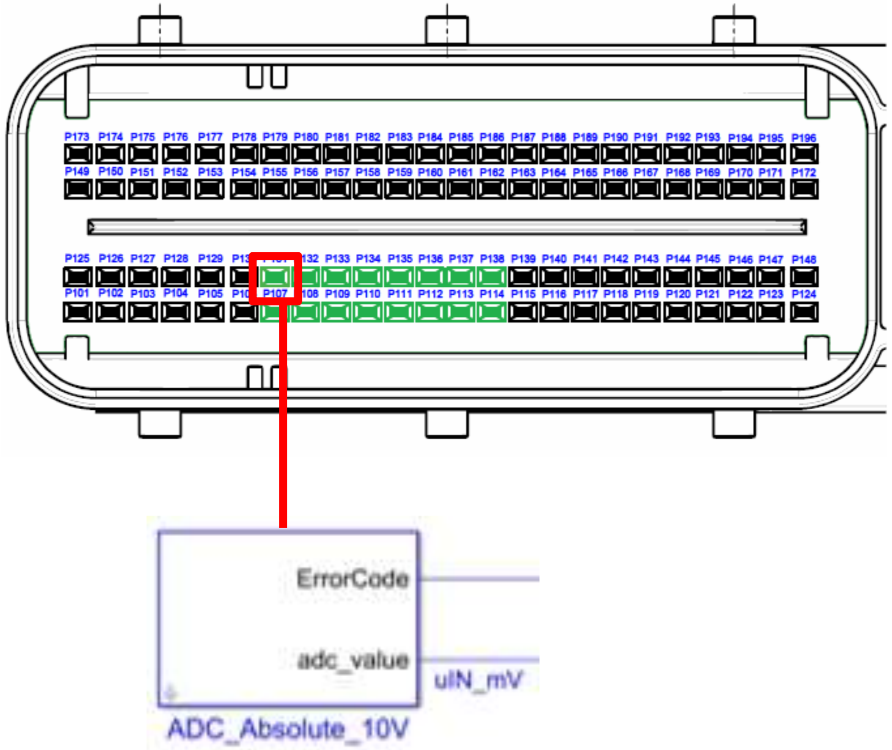
Input: Voltage Signal

Choosing an Analog-Input port→ Block
ADC_Absolute_10V

Choose the input port that fits to the conector pinning:

Pin 131 is connected → IO_ADC_09

For more infos see *[1] 4.10 Analog Input 2 Modes*



Pin No.	Function 1	Function 2	SW-define
P107	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_08
P131	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_09
P108	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_10
P132	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_11
P109	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_12

A simple Simulink example

Change PWM ratio as a function of a voltage signal

Output: PWM-Siganl

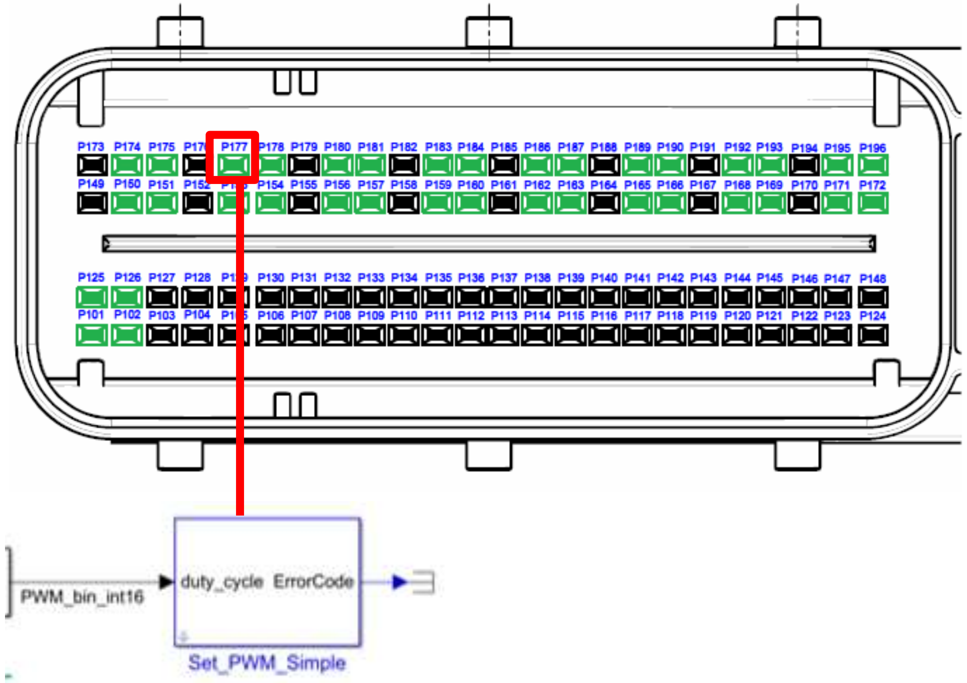
Choosing a PWM output port→ Block

ADC_Absolute_10V

Choose the input port that fits to the conector pinning:

Pin 177 is connected → IO_PWM_01

For more infos see *[1] 4.12 High-Side PWM Outputs*



Pin No.	Function	SW-define	Ext./Second. Shut-off	Power stage
P153	High-Side PWM Output	IO_PWM_00	A	a
P177	High-Side PWM Output	IO_PWM_01	A	a
P156	High-Side PWM Output	IO_PWM_02	A	b
P180	High-Side PWM Output	IO_PWM_03	A	b
P159	High-Side PWM Output	IO_PWM_04	A	c
P183	High-Side PWM Output	IO_PWM_05	A	c
P186	High-Side PWM Output	IO_PWM_06	A	d

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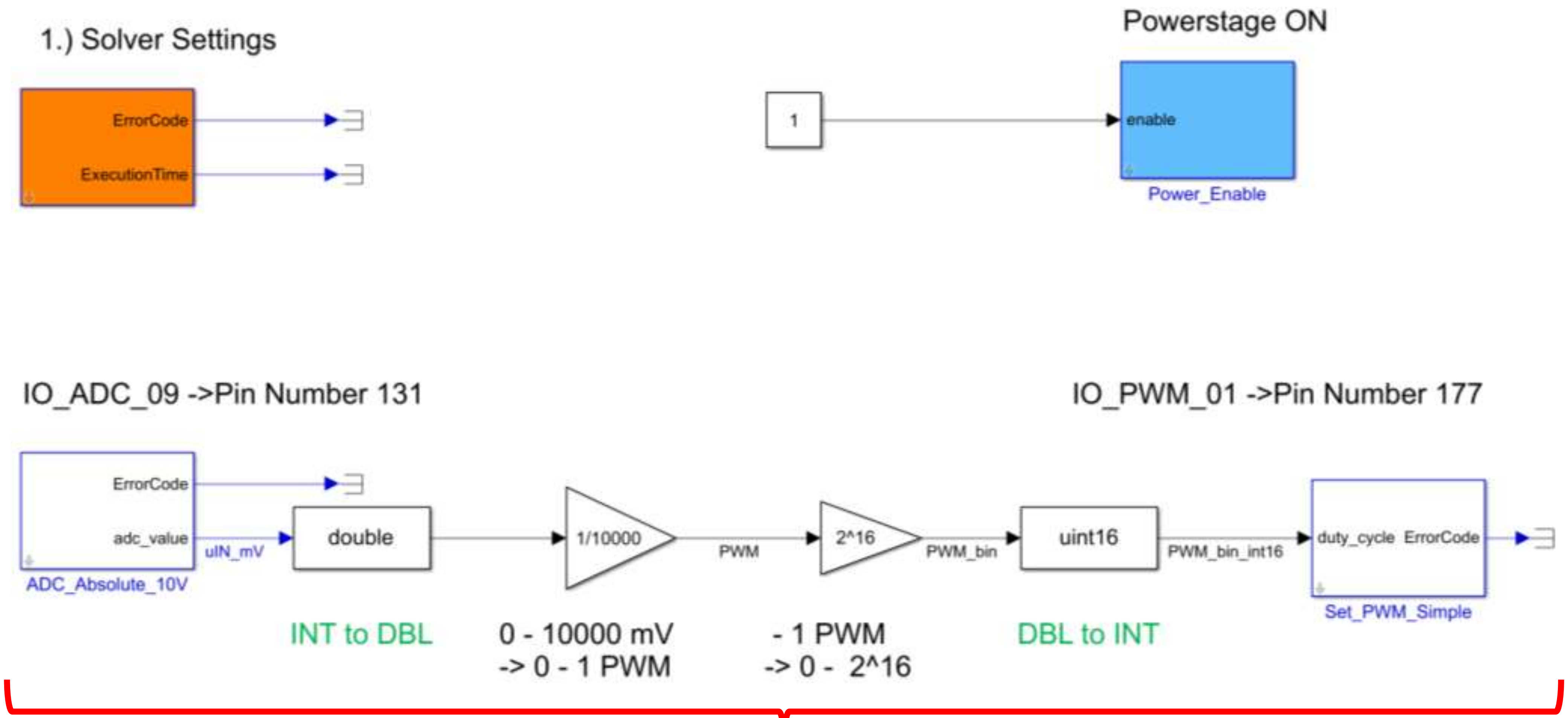
A simple Simulink example

Change PWM ratio as a function of a voltage signal



build → C-Code generation

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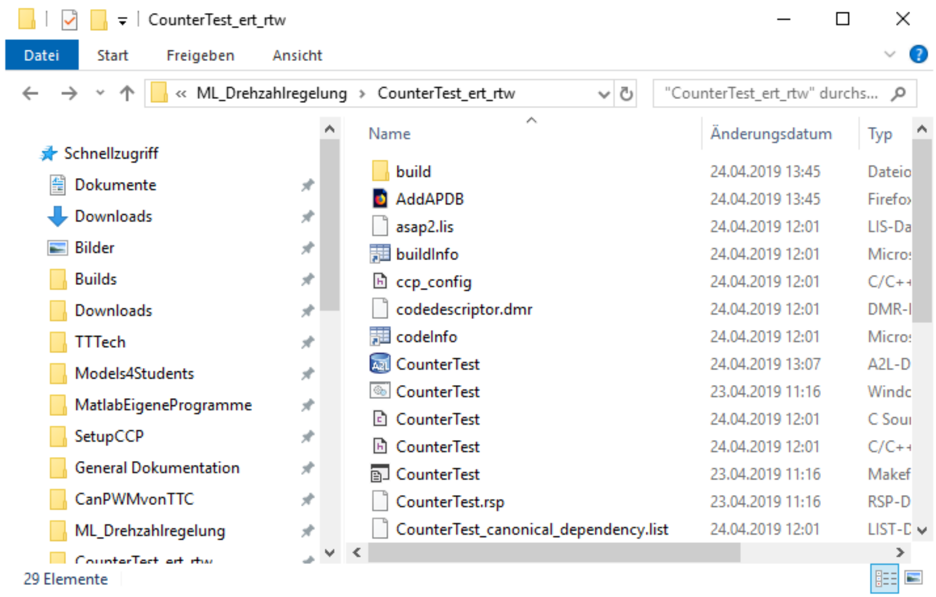
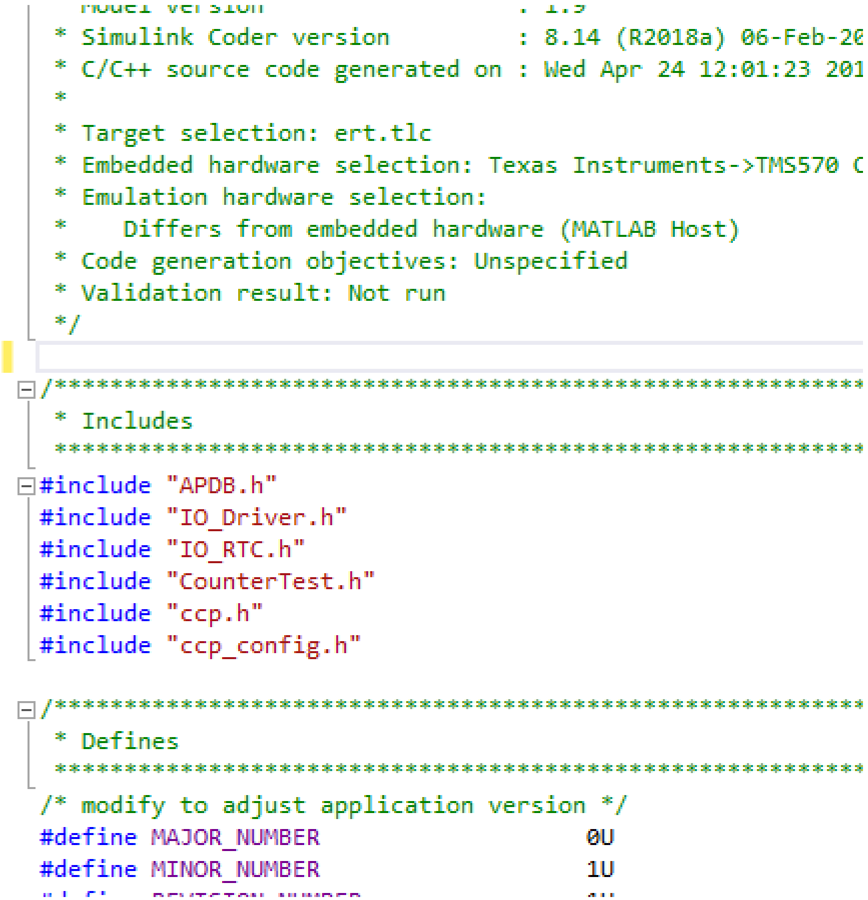
Embedded Coder

Embedded Coder:
https://mathworks.com/products/embedded-coder.html
The correct Simulink solver settings must be set before compiling the model.





make → object files (*.hex)
TI Code Composer Studio:
http://processors.wiki.ti.com/index.php/Download_CCS

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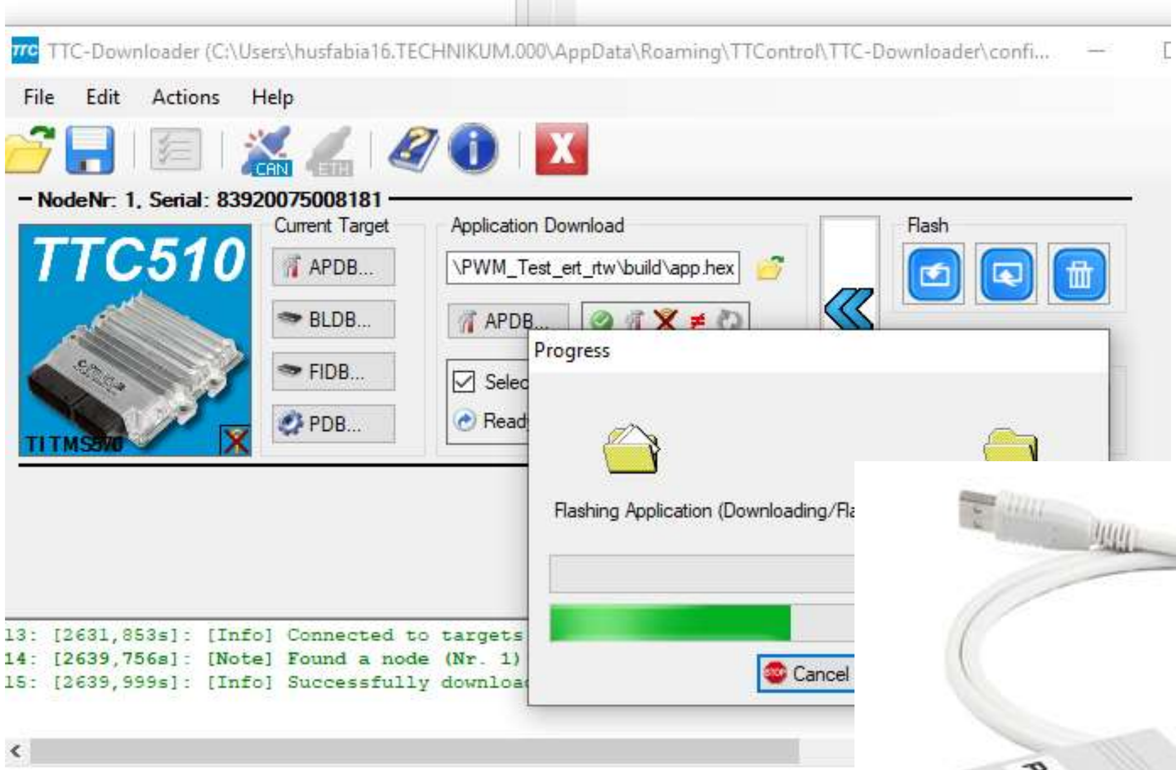
TTC-Downloader

Flashing the ECU:

- Upload the *.hex-File from the PC to the ECU
- Physical Connection between PC and ECU → CAN
- Download Software → TTC-Downloader (included in scope of delivery)
- For CAN-Connection → USB to CAN-Interface PCAN from Peak-System



https://www.peak-system.com

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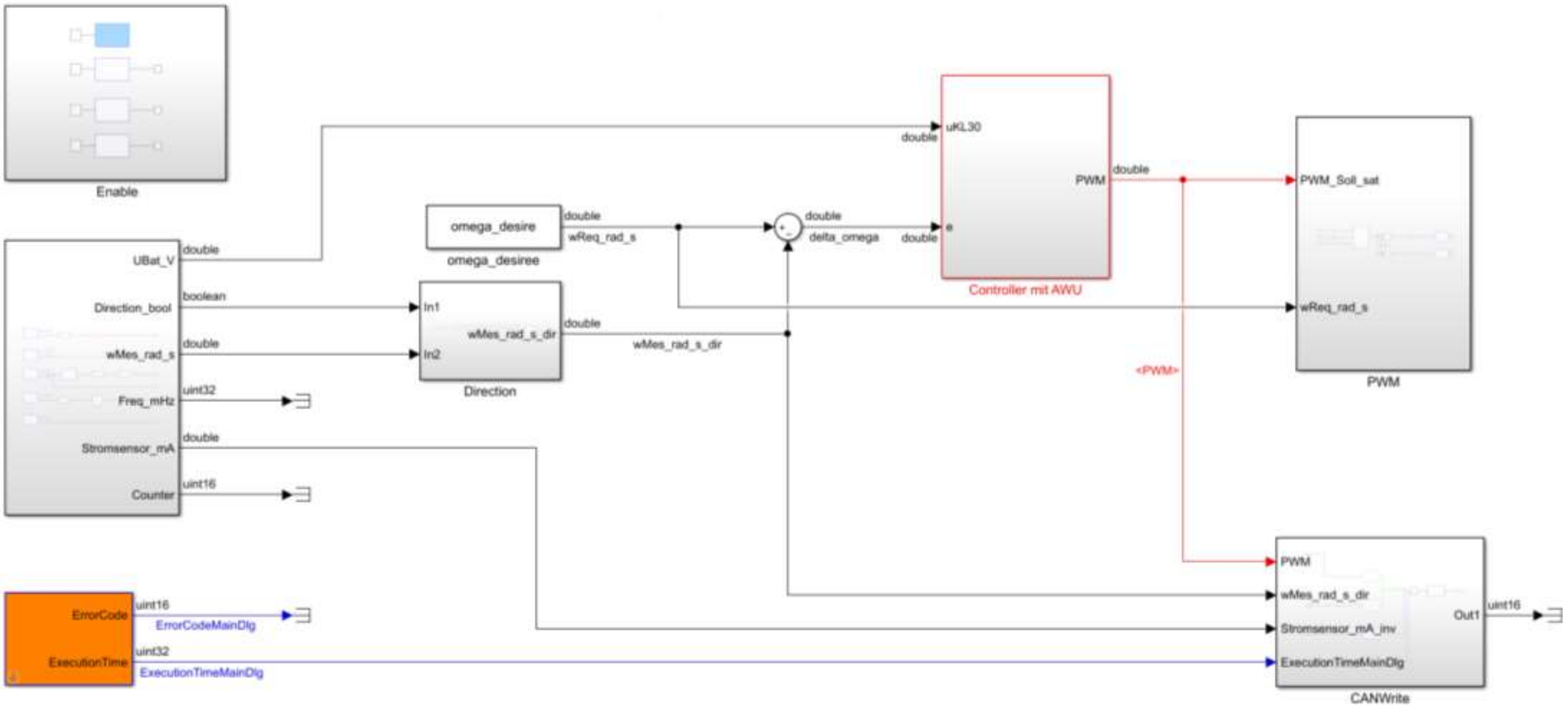
Speed Controller



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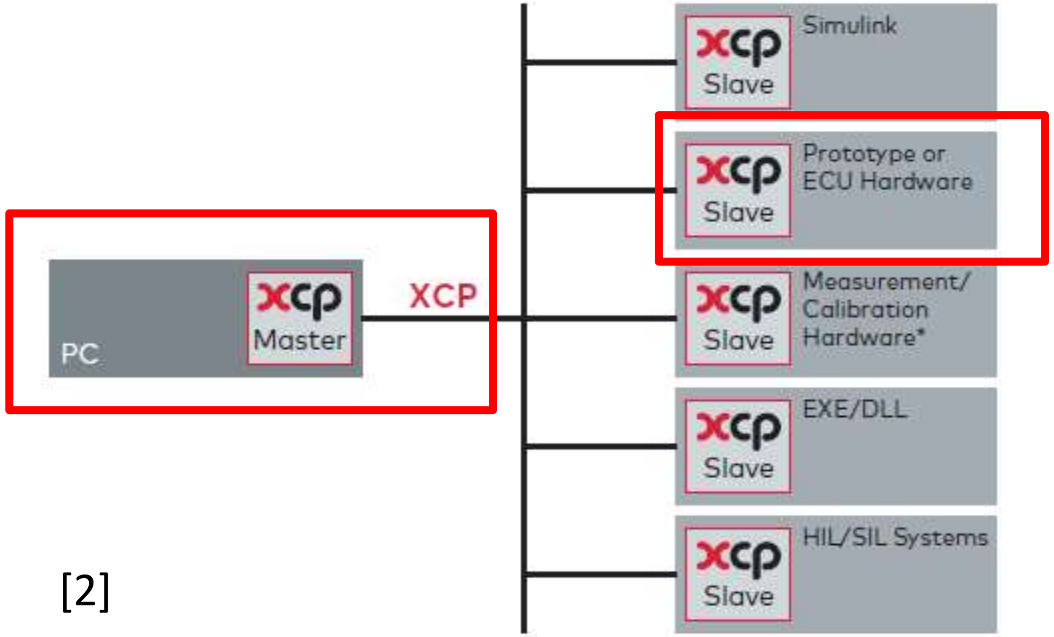
ECU-Calibration with CCP

Host PC with CANape



ECU HY-TTC 510

[2]

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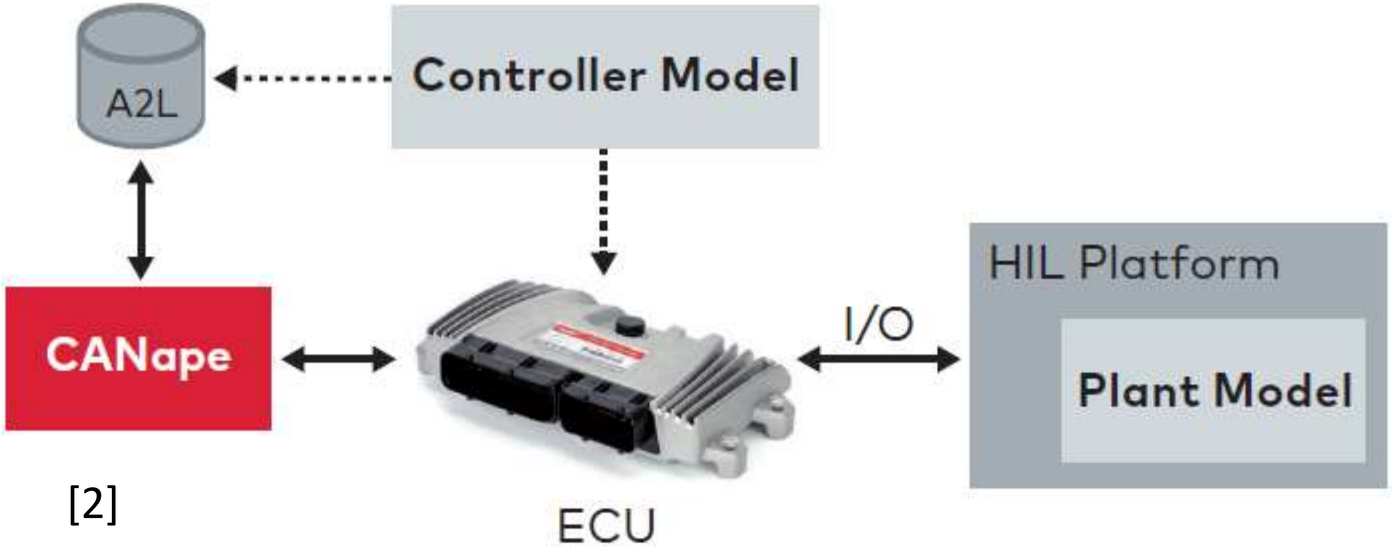
ECU-Calibration with CCP

Schematic figure of the calibration concept
- Calibration Software CANape from Vector Informatics - https://www.vector.com/int/en/
- Connection CANape <-> ECU with VN1630 CAN Interface
- A2L-File generated by Simulink Embedded Coder and TI ARM Compiler
- Controller Model from Simulink



[2]

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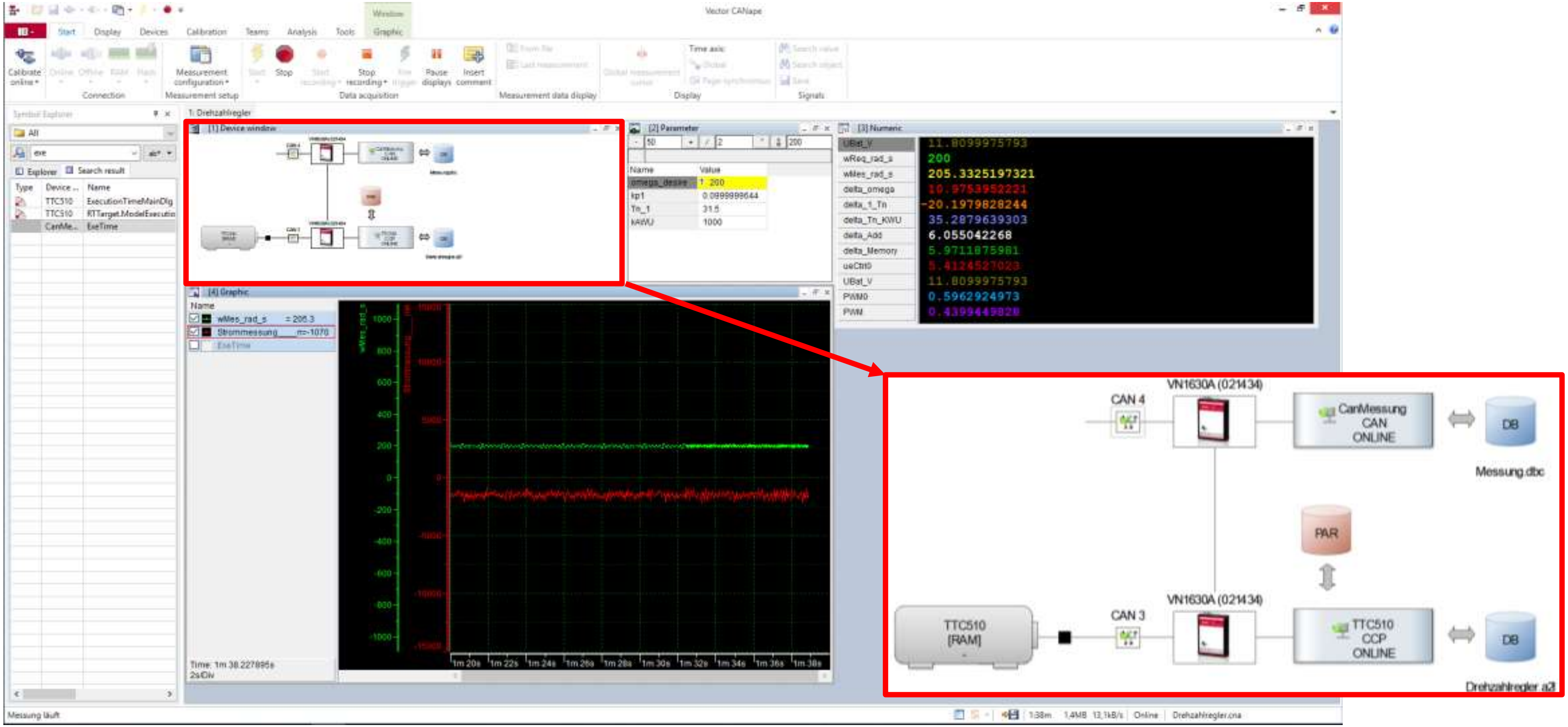
CANape Example

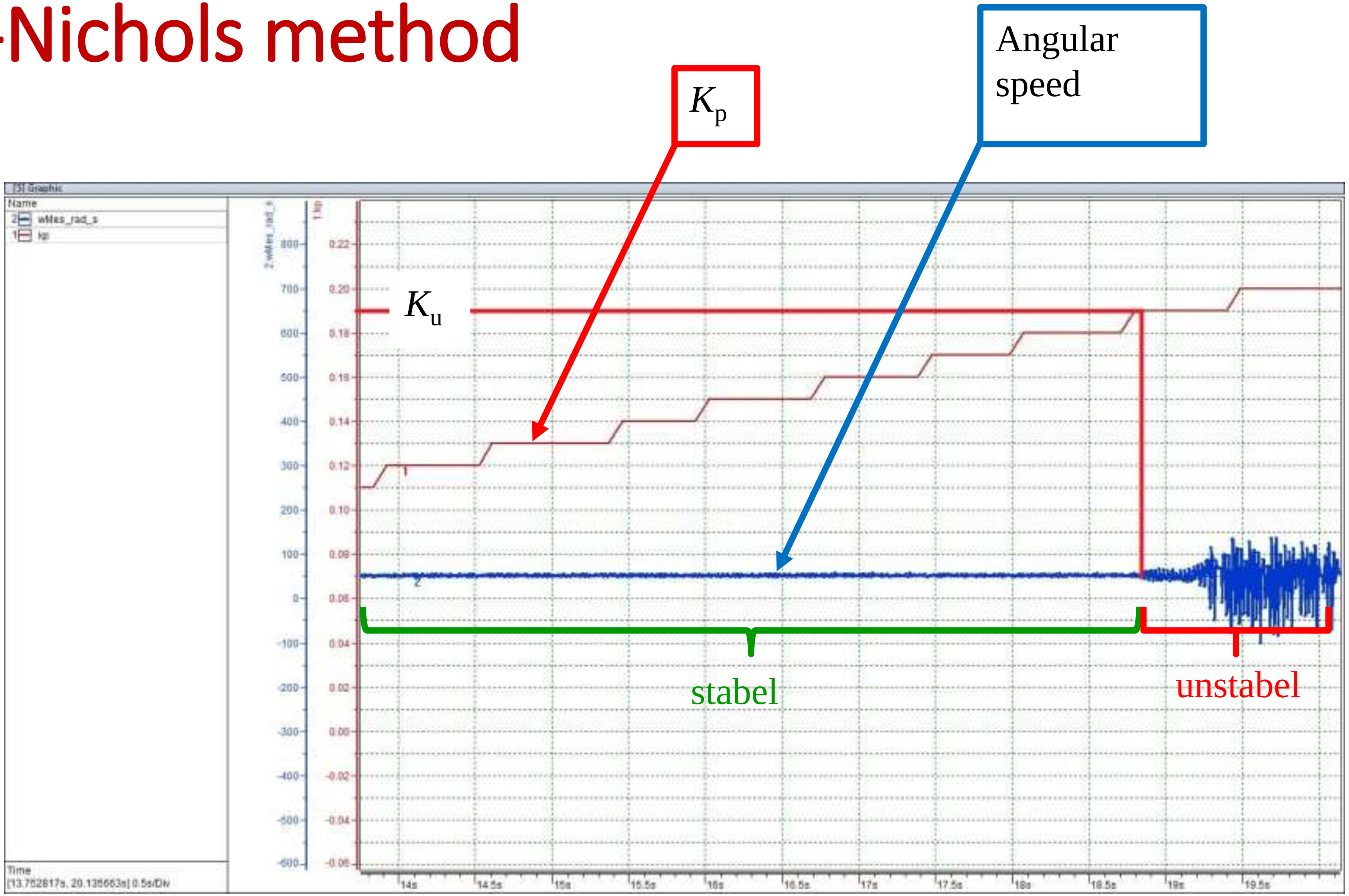


The Ziegler-Nichols method

Setup for the speed controller (PI)

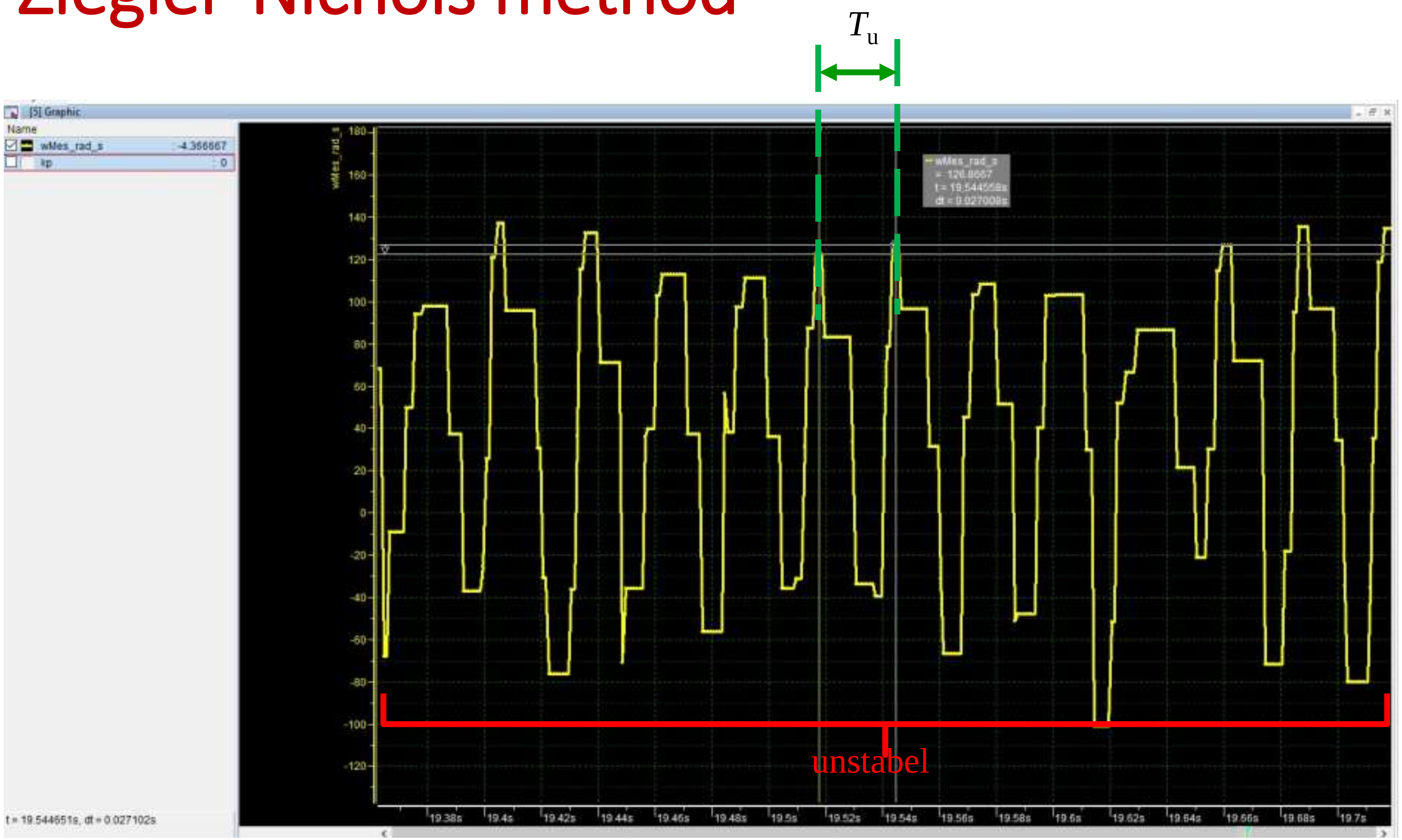
- Goal: Find optimal values for K_p and T_n
- Increasing K_p to the ultimate gain K_u.
- Adjustment via CCP out of CANape
- PI-controller →

$$K_p = 0.45\ K_u.$$



The Ziegler-Nichols method

$T_i = 0.8\ T_u$

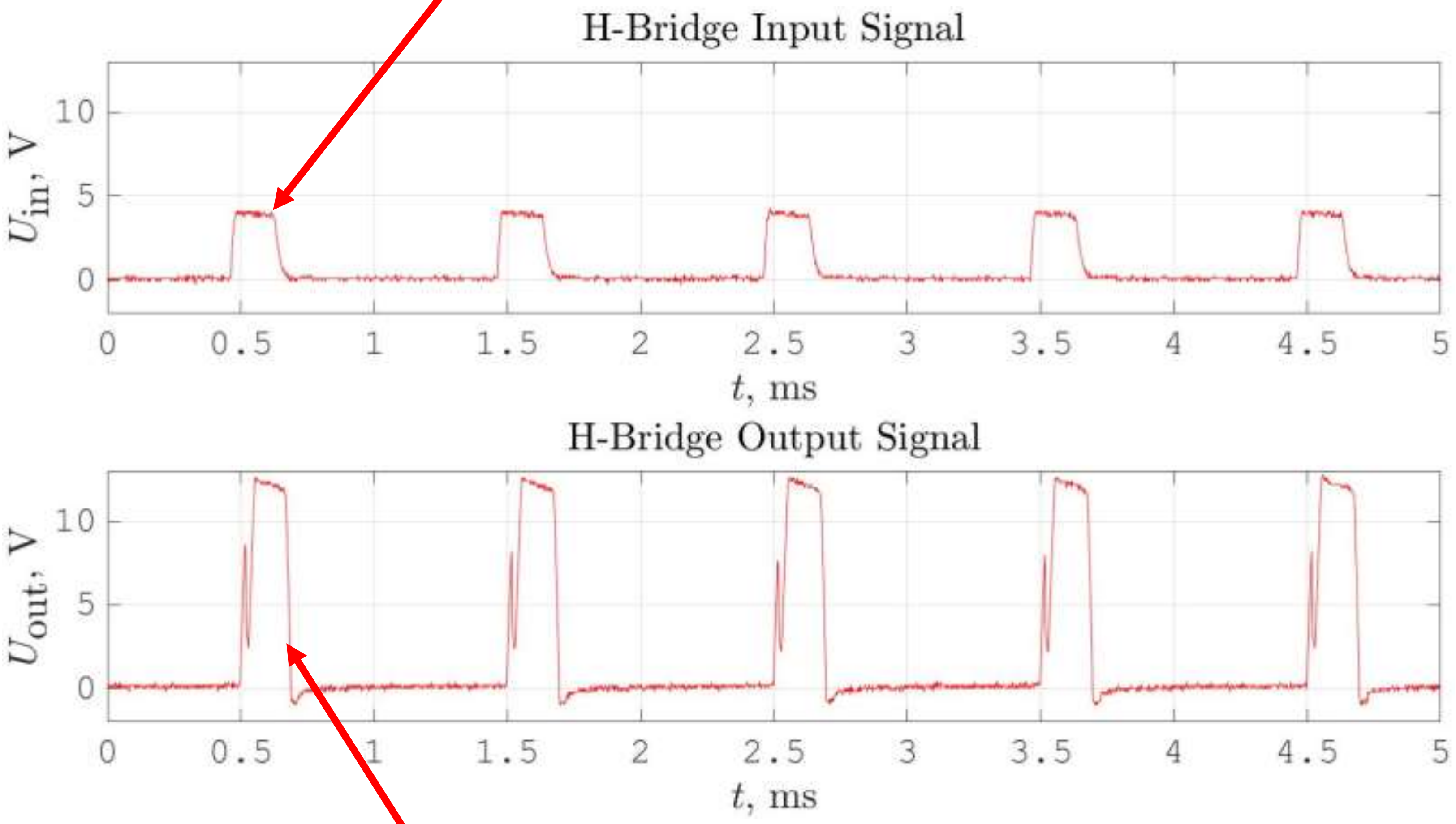


ECU – adjust the DC motor speed

The TTC510-ECU has no H-Bridge included.

- External device must be used
- The ECU controls the H-Bridge with a PWM-Signal
- Maximum PWM-frequency from ECU is 1 kHz → Problem: structure-borne sound

PWM-Singnal out from the ECU



Output Voltage from the H-Bridge to DC-Motor

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References

[1] TT Control GmbH: *HY-TTC 500 System Manual Programmable ECU for Sensor-Actuator Management Product Version 01.04;* 28 June 2017
[2] Andreas Patzer | Rainer Zaiser: XCP – The Standard Protocol for ECU Development; Vector Informatik GmbH - Stuttgart, Germany (Free download)

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Setting up a Mechatronic System

4th Training in Rio de Janeiro, BRA

6th-9th of May 2019

Thomas Lechner