FRIWO

Motor-Control Experts

Application Guide

Motor Control Unit

Emerge 3000/6000

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4 List of abbreviations

AIN Analog Signal Input
GND Chassis Ground
MISO Master input - slave output
MOSI Master output - slave input
MPC4 *Connector Type*

5 Copyright

6 Safety Information, Terms of Use and Liaility Waiver

Warning!

Using the motor control unit referenced in this document can be dangerous. Please follow instructions it with extreme caution. Stop your application work if you encounter unexpected behavior.

Terms of use

The use of this program, further called "Enable-Tool", can be very dangerous, that means it can cause damage to personal and property.

Use it with extereme care and make sure that you have received instructions for use of it by qualified personnel.

With this software, you are able to influence or control a connectred electronic control system such as motor-controllers, battery-managament-units or other general electronic control devices. Your actions may result in serious personal injury or property damage. Therefore, you should only be using this software if you understand the possible consequences of the actions with this software and if you have been specifically trained to handle this software! Enable-Tool is currently under development and functionality might be subject to change without prior notice or arrangement.

Liability waiver

This is a liability waiver (further called “waiver”) which is made between the parties FRIWO Gerätebau GmbH ("Manufacturer") Von-Liebig-Strasse 11, 48346 Ostbevern and the user of Enable-Tool ("User"). For purposes of this waiver, the definitions of the parties shall be deemed to include any parent, subsidiary, affiliate of, or entity under common control with any entity constituting the parties consiting of Manufacturer and User.

1. Purpose

User desires to get access to the online-network infrastrucure of the Manufacturer to obtain a license to use Enable-Tool. User desires to use Enable-Tool to work with one or more electronic-control-units of Manufacturer. The parties acknowledge that advanced electronic-control-units are complex and proprietary devices that require special knowledge, skills and equipment to program and commission. User declares that he has all necessary special knowledge, skills and equipment to work with and apply to such devices.

2. No obligation

Keine der beiden Parteien ist aufgrund dieses Verzichts in irgendeiner Weise rechtlich verpflichtet. Die Durchführung des Verzichts hindert keine der Parteien daran, ihre unabhängige, kontinuierliche Entwicklung von Technologien, Produkten und anderen geschäftsbezogenen Forschungs- und Entwicklungsarbeiten fortzusetzen.

3. General

This waiver shall inure to the benefit of and be binding upon the parties and their successors and assigns, provided that the receiving Party may not assign all or a part of this waiver without the prior written consent of the Disclosing Party. If any provision of the waiver is held invalid or unenforceable by a court of competent jurisdiction, such invalidity or unenforceability will not effect any other provision of the waiver, which shall remain in effect.

4. Governing Law

This waiver shall be construed, and the obligations, rights and remedies of the parties hereunder shall be governed by the laws of and subject to the jurisdiction of Kornwestheim, Germany.

5. Entire waiver

This waiver constitutes the entire waiver between the parties with respect to the subject matter herein, and supersedes all prior oral or written waivers, arrangements, and understandings related thereto. This waiver may not be modified or amended except in writing signed by an authorized representative of each Party. WHEREOF, in consideration for the mutual promises contained herein, the parties have caused this waiver to be executed by their authorized representatives. FRIWO Gerätebau GmbH assumes no liability for loss of data, personal injury or damage of property caused by misuse of the program or by use of improper settings. In particular, we expressly point out that Emerge Engineering GmbH under no circumstances warranty / liability for data loss, personal injury or property damage resulting from the direct use of this software takes over.

7 General information

7.1 Usage

This document describes the functions of the FRIWO Gerätebau Motor-Control software and explains parameter settings to influence the behavior and function of the motor control.

To set the motor controls, you need a motor controller (e.g. Emerge 3000) and a Windows PC on which the FRIWO Enable Tool NG is installed.

Parameters on the motor control unit can be changed or measured during operation using the Enable-Tool software. A description of the Enable tool is provided separately.

7.2 Description of parameters and measured values

This document describes parameters and measured values that influence or make measurable the behavior of the software at runtime and assumes that you understand the Parameter names according to the following nomenclature:

The formation of variable names follows the following principle:

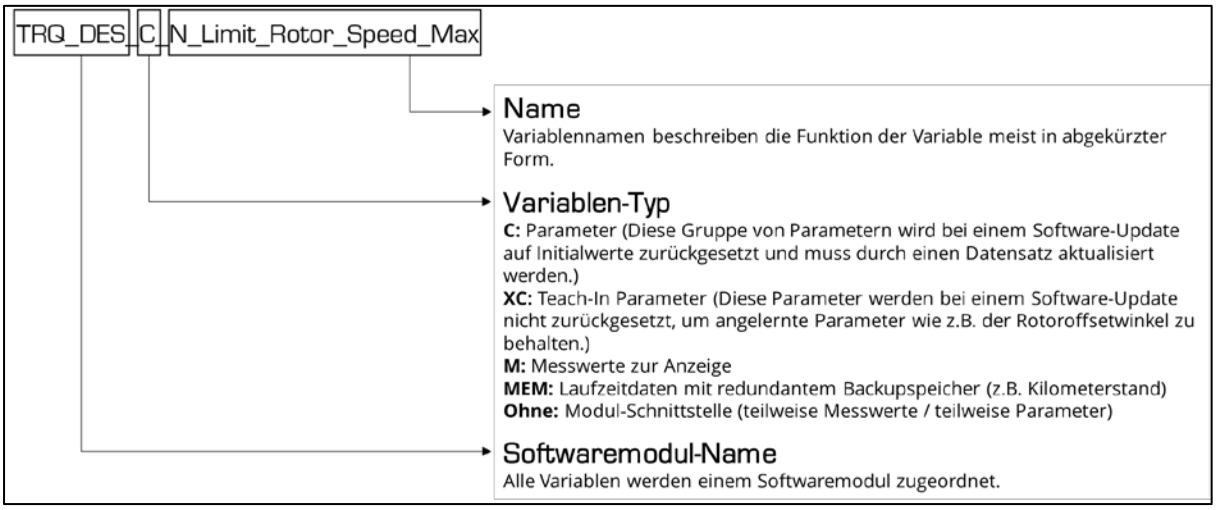


Figure 1: Variable education.

Variables can be adjusted or measured with the FRIWO Enable tool. Read the appropriate instructions before using the Enable tool. The view of the Enable tool is customer-specific configured and can vary depending on the application.

It is therefore possible that not all parameters and measured values described in this document are available to you.

7.3 Important notes on changing parameters

Changing parameters can have a negative effect on the behavior of the controller. Please observe the following notes when making adjustments:

- Start your application work only after you have read this document completely and understood how the parameters work.
- Change parameters in the smallest possible steps.
- Great importance was attached to your safety during the development of the Motor-Control software. Incorrect entries are usually intercepted and parameter changes are limited to safe values.
- However, a residual risk cannot be ruled out with certain changes. It is therefore recommended that you only change parameters during motor standstill. In addition, you should always use a USB isolator to protect your PC from possible overvoltages and to prevent ground loops in your laboratory or test bench.
- Some critical parameters are monitored by superimposed protective functions, so that only limited changes are possible during motor operation. Example: The flux-weakening current and the maximum motor current can only be increased during motor operation in the flux-weakening range. A reduction is only possible outside the flux-weakening range.
- Confirm the entry of the parameter values by pressing Enter. Save parameters by clicking on "Store Parameters". When restarting the motor control ("Restart ECU"), the stored parameters are retained. When resetting the motor control to the factory setting (SET_C_Reset_ECU_Parameter 23), the parameter settings made are lost, but not the statistical data (for example, mileage).

8 Procedure for setting up a drive unit

This shows you how to start up and adjust a motor with the Emerge 3000/6000 motor control unit. It is to be understood as a recipe: Go through it step by step. The first sub contains the necessary basic settings. After you have done this, the motor is trained and ready for operation. The second sub deals with the most important application-specific settings. With these you determine the driving style and ensure that the most important status values are displayed correctly. Finally, you will learn to record data during operation in order to make fine adjustments to the motor control on the basis of this data.

8.1 Required basic settings

The following steps are required for quick, initial setup a motor:

- Connect signal and power supply in accordance with the connection diagram. For a wiring diagram see "Electrical connections".
- Motor phases: Connect the motor to the motor control unit. Comply with markings (L1, L2, and L3) on the control unit.
- Connect the power supply. Comply with the marking (Battery +/Battery -) on the control unit.

  Attention: No reverse polarity protection! The logic part of the controller is supplied with 12V by an internal DCDC converter. This means that an additional power supply via the signal connector is not required.
- Motor sensor: Connect to hall sensor or resolver (Emerge resolver AS5048A).
- Connect control signals: Connect analogue signals (e.g. throttle grip signal, brake signal). Connect digital signals (e.g. brake signal, reverse gear signal, CAN bus).

Software:

- Establish connection between computer and motor control with the FRIWO Enable-Tool software via a USB interface. See the document: "Enable Tool Quick Start Guide", "Installation Guide Enable Tool".

Determine freedom from errors or correct existing errors: The error memory can be evaluated via the Enable tool or the CAN bus. See "Error diagnosis functions".

- Make basic settings: See the "Basic Settings".
- Perform automatic teach-in: See the "Automatic teach-in function".

8.2 Application-specific settings

Use the following steps to set the motor control for the intended use. The steps are sometimes optional if you do not want to use all the functions of the motor control.

8.2.1 Ride modes

The motor control supports four freely adjustable ride modes, which can be selected via the smartphone app. To define the behavior for the different ride modes, proceed as follows:

- Set the ride mode: For example, set the speed, power, speed limit, and regenerative braking intensity. You will find the corresponding parameters in the chapter entitled "Ride Modes".
- Set default ride mode: See "Setting the default ride mode".
- Change ride mode: You can switch between ride modes using a smartphone app, switch or CAN bus. See "Switching the Ride Mode".

8.2.2 Display

For the values in the Smartphone app display to be correct, a few parameters must be set. Proceed as follows:

- Speed: To calculate the vehicle speed, the wheel circumference must be set. See "Vehicle speed".
- Battery state of charge: Information about the battery used is required to calculate the state of charge and the remaining range. See "State of Charge (SOC)".
- Remaining range: To display the remaining range as accurately as possible, the typical consumption of the vehicle must be defined. See "Remaining range of coverage".

8.2.3 Fine tuning

After you have set up the motor control, taught the motor and made the most important application-specific settings, you can go to the fine adjustments. This application guide shows you the possibilities that the motor control offers and which you can use as required.

9 Basic settings

9.1 Restoring the factory settings

Before starting up, it may make sense to reset all parameters to the factory settings. To do this, set the parameter SET_C_Reset_ECU_Parameter to the value 23 and confirm with Enter. Statistical data (for example, the odometer) is not reset.

Restore Factory Settings		
Parameter name	**Description**	**Value**
SET_C_Reset_ECU_Parameters	Reset of all parameters to factory settings. The controller restarts automatically after resetting.	23

Table 1: Restore factory settings.

9.2 Motor-specific default settings

The following parameters must be set before using the automatic teach-in function.

Important motor parameters		
Parameter name	**Description**	**Value**
MO_C_Polepairs	Number of pole pairs	1 .. n
MO_C_Rotor_Position_Sensor_Type	Sensor Type: 0 = Hallsensor1 = Resolver AS5048A The change of the rotor position sensor only takes place after a restart of the control. Use "Store Parameters" to save your settings. The controller automatically restarts after saving.	0 .. 1

Table 2: Important motor parameters.

10 Automatic teach-in function

10.1 Preconditions for automatic teach-in function

To put a motor into operation, the controller must be ready for operation (see "State Manager".

Read these instructions completely before starting up.

Pay attention to your personal protection and observe the applicable standards and regulations.

Note that in this state the motor may start uncontrolled and can only be stopped by disconnecting the supply voltage.

Preconditions the automatic teach-in function	
Condition	**Description**
Motor shaft to rotate freely	The motor shaft should be able to rotate freely during the teach-in process. An additional inertial mass, e.g. wheel or gearbox, may negatively influence the teach-in process if the motor shaft oscillates strongly.
supply voltage	The power supply should be at least 15V and be able to supply sufficient current (min. 20A).
Hall sensors connected/resolver	The sensor of the motor must be connected to the controller.
Readiness for operation	The control must be ready for operation. This means that in the Enable tool the bar at the bottom of the screen turns green and the text "Connected in App-Mode" appears. An acoustic signal sounds as soon as the control is ready for operation.

Table 3: Preconditions the automatic teach-in function.

10.2 Run the teach-in function

During the teach-in process, a constant phase current is impressed into the motor and the motor is forcibly commutated. The rotor follows the impressed magnetic field. The teach-in process only takes a few seconds, but nevertheless ensure that your motor does not overheat due to the set phase current (default: 40A). If necessary, interrupt the power supply if the teach-in process takes unexpectedly long.

Note: The automatic teach-in process can be repeated as often as required without having to reset the parameters beforehand.

start teach-in function		
Step	**Instructions**	**Remarks**
Start automatic teach-in function	Set ROC_C_Start to 1.	The motor starts moving and starts abruptly several times. Teach-in was successful as soon as ROC_Result displays "Teach-in sucessful". If ROC_Result displays "Teach-in failed", the teach-in procedure was interrupted.

Table 4: Start teach-in function.

If the teach-in process has been interrupted, this may be due to insufficiently powerful supply voltage or faulty sensor signal, for example. The exact cause of the error can be found in the error memory. See "Structure of the error diagnosis function".

The direction of rotation during teach-in is in the future forward direction. If the motor should turn in the other direction, the direction of rotation must first be inverted and then the teaching process must be restarted.

Reversing the direction of rotation		
Step	**Instructions**	**Remarks**
Reverse direction of rotation	Set ROC_C_Desired_Direction to -1 (reverse to the previous direction of rotation). Then set ROC_Start to 1.	ROC_Result = teach-in sucessful. The teaching was successful. The motor is ready for operation.

Table 5: Reverse rotation.

Parameters of the teach-in function		
Step	**Instructions**	**Range**
ROC_C_Desired_Direction	With this parameter, the preferred direction of rotation can be set. The teach-in process must be performed again after changing this parameter.	1 = Forward/natural positive (default) -1 = down/course negative Whether the motor rotates forwards or backwards when the direction of rotation is positive depends on the assignment of the phases to the Hall sensors.
ROC_C_Current_Setpoint	Impressed motor current during the programming procedure. A higher motor current can be useful if the friction of the shaft is very high, or if the moving parts have an enormous inertia.	1 .. 500 A 45 (default)
ROC_C_Num_Mech_Revolutions	Number of mechanical revolutions during the programming procedure. The more turns, the more accurate the calculated rotor angular offset is.	1 .. 12 1 (default)

Table 6: Parameters of the teach-in function.

11 Fine tuning

11.1 Fundamentals of electrical acceleration and braking

The acceleration of the electric motor and energy recovery through regenerative braking (recuperation) of the electric motor is determined by the amount of motor current flowing in the motor. In field-oriented control, the motor current is divided into d-current and q-current, with q-current being responsible for torque generation and d-current for the strength of the magnetic flux in the motor.

- q-Current: Generates a magnetic field with an angle of 90° to the permanent magnetic field. The q current generates the torque in the motor. Positive q current accelerates the motor in the forward direction. Negative q-current decelerates the current from the forward direction or accelerates it in the reverse direction.
- d-current: Generates a magnetic field of 0° to the magnetic field of the permanent magnet and can therefore weaken or strengthen the magnetic field of the permanent magnet. Usually the d-current is used to weaken the magnetic field of the permanent magnet (flux-weakening). This reduces the induction voltage in the motor coils. This allows the motor to reach higher speeds because more q-current can flow into the motor due to the reduced counter-induction. See "Flux-weakening".

The q-current is usually based on the driver's desire to either accelerate or brake, but in some cases the driver's desire is limited to protect the motor and battery, or because the driving situation requires it.

11.1.1 The chain of action from the input signal to the control of the motor-current

This chapter describes how to generate the driver's desired torque (q-current setpoint) and the flux-weakening current (d-current setpoint) step by step from the signal input via signal processing up to the transfer of the setpoints to the current controller.

Define channels for input signals

The input signals for throttle, brake and reverse gear are transmitted to the motor control unit via one or more analog and/or digital channels (e.g. by means of a throttle grip, brake switch or CAN bus).

The channels for the input signals of the throttle, brake and reverse gear are defined by the following parameters.

Parameters for selection of the input signals		
Parameter name	**Function**	**Range of values**
APP_C_Ride_Mode_2_Throttle_Signal_Channel	Select input for "acceleration signal" (eg throttle/accelerator pedal). 1 = AIN1 2 = AIN2 3 = PWM @ DIN2 4 = CAN BUS 5 = USB	1 .. 55 (default)

APP_C_Ride_Mode_2_Brake_Signal_Channel	Select input for "braking signal". 1 = AIN1 2 = AIN2 3 PWM = @ = DIN2 4 CAN BUS 5 = USB 6 = DIN1 7 = DIN2	1 .. 75 (default)
APP_C_Ride_Mode_2_Reverse_Gear_Signal_Channel	Select input for "reverse gear signal". 1 = DIN1 2 = DIN2 3 = CAN-Bus 4 = USB	1 .. 44 (default)

Table 7: Parameters for selection of the input signals.

Conditioning input signals

The signals are processed by the motor controller, i.e. translated into relative control values between -100% and 100%.

The processed input signals of the driver are displayed in the following measured values.

Measured values of the selected input signal		
Parameter name	**Function**	**Range of values**
TRQ_DES_Driver_Throttle	Current value of the input signal for the acceleration	0 .. 100%
TRQ_DES_Driver_Brake	Current value of the input signal for the delay	0 .. 100%
TRQ_DES_Driver_Reverse_Gear	Current value of the input signal for the direction selection	0 = forward gear 1 = reverse gear

Table 8: Measured values of the selected input signal.

Processing of the driver's inputs

The conditioned input signals of the driver are then combined to a relative driver's desired torque. A value of 100% accelerates the motor strongly in forward direction, or decelerates the motor strongly when it is turning in reverse direction. A value of -100% slows the motor down strongly when it is turning in forward direction, or accelerates the motor strongly in reverse direction when reverse gear is selected. For more details, see "Processing of the driver's inputs".

Measured value for relative driver desired torque		
Parameter name	**Function**	**Range of values**
TRQ_DES_Trq_Req_Rel	Relatives driver's desired torque	-100 .. 100%

Table 9: Measured value for relative driver desired torque.

Limit torque request

Now the driver's desire is limited in order to comply with the system limits, see "Torque limitation (derating)". This applies to all adjustable system limits such as, for example:

- Battery current and voltage limits
- Speed limit in forward and reverse direction
- Temperature limit of the motor

In addition, there are other system limits that cannot be set by the user, for example:

- Temperature limit of the output stage
- Temperature limit of the microcontroller

The limited desired torque can be measured using the following measured value.

Measure of limited driver request torque		
Parameter name	**Function**	**Range of values**
TRQ_LIM_Setpoint_Rel	Limited driver's desired torque	-100 .. 100%

Table 10: Measure of limited driver request torque.

For further information on this topics, see "Torque limitation (derating)

".

Calculate setpoints for the current controller: q-current setpoint

Since the current controller operates with absolute values, the limited driver's desired torque must be converted from relative values to absolute values. For this purpose, the following calculation is performed:

By multiplying TRQ_LIM_Setpoint_Rel by the maximum motor current defined in Ride Mode APP_C_Ride_Mode_x_Max_Motor_Current or APP_C_Ride_Mode_0_Max_Regenerative_Motor_Current, the absolute q-current setpoint is generated in the physical unit Ampere. If necessary, the q-current setpoint is additionally limited by a speed dependency. See "q-current limitation via speed".

The final q-current setpoint can be measured via TRQ_STR_Iq_Setpoint.

A parallel flux-weakening controller automatically generates a d-current setpoint appropriate to the current speed and desired torque. See "Flux-weakening".

The q-current setpoint may be reduced by a d-current setpoint if necessary to request the d-current setpoint without exceeding the maximum motor current in total.

The d-current therefore has priority over the q-current. See "q-current and d-current setpoint formation".

The final d-current setpoint can be measured via TRQ_STR_Id_Setpoint.

Measured values for calculating the absolute driver request torque		
Parameter name	**Function**	**Range of values**
TRQ_LIM_Setpoint_Rel	Limited driver's desired torque = Limited relative q-current reference value	-100% .. 100%
APP_Ride_Mode_Max_Motor_Current	Ride mode dependent maximum motor power	0 .. 1000 A
APP_Ride_Mode_Max_Regenerative_Motor_Current	Ride mode dependent maximum regenerative motor current	0 .. 1000 A
TRQ_STR_Iq_Setpoint	= Final absolute driver request torque final absolute q-current reference value	-1000 .. 1000 A

Table 11: Measured values for calculating the absolute driver request torque.

Calculate setpoints for the current controller: d-current setpoint

The final driver's desired torque may be reduced in favor of flux-weakening in order not to exceed the maximum motor current. Depending on the current speed and torque requirement, a flux-weakening controller automatically generates a suitable d-current request. To request this d-current setpoint without exceeding the maximum motor current, the q-current and thus the final driver's desired torque must be reduced. The d-current request has priority over the q-current. See "q-current and d-current setpoint formation".

Measured value for the setpoint of the flux-weakening current		
Parameter name	**Function**	**Range of values**
TRQ_STR_Id_Setpoint	Final field attenuation = final d-current reference value	0 .. -1000 A

Table 12: Measured value for the setpoint of the flux-weakening current.

The q current setpoint and the d current setpoint are transferred to the current controller.

11.2 Input signals

11.2.1 Electrical connections

High-current terminals

Attention: The high current contacts are made of brass. The tightening torque must therefore not exceed 2.9Nm. We recommend a tightening torque of 2Nm. Only use washers and nuts made of copper or brass.

Connecting high-current screw terminals[1]		
L1	motor L1	Motor phase L1
L2	motor L2	Motor phase L1
(-)	battery -	Battery-
L3	motor L3	Motor phase L1
(+)	battery +	Battery + (Max. 65V)

Table 13: Connecting high-current screw terminals.

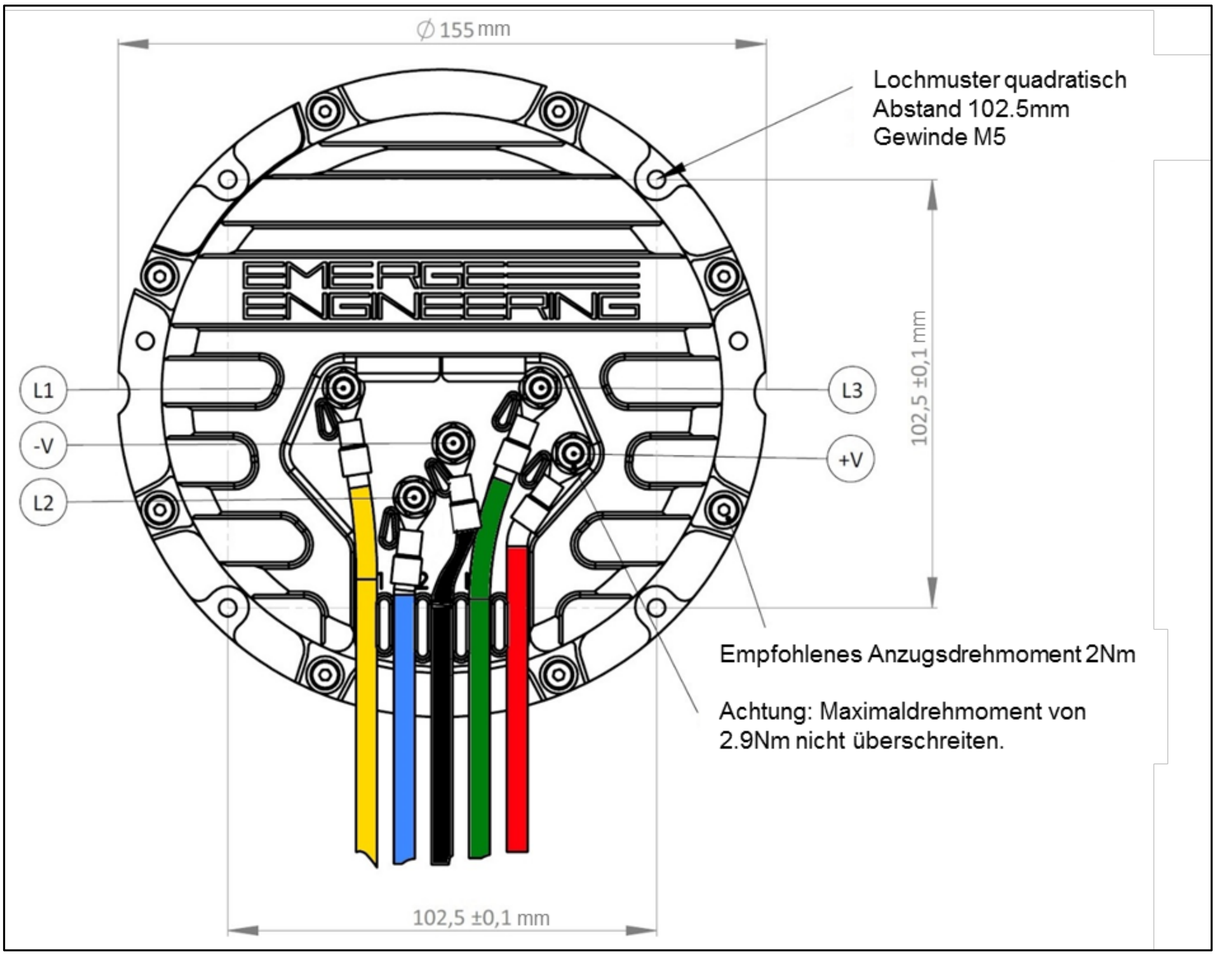


Figure 2: Wiring plan, high-current screw terminals.

[1] The name of the connection terminal is stamped into the housing.

Signal connector with hall sensors

Caution: Use the 5V supply voltage only for sensor supply. Do not connect any external voltage sources to the signal lines of the motor control unit.

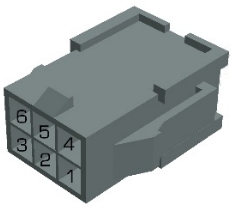
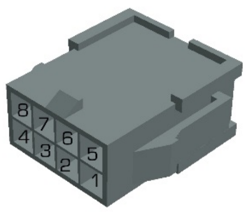
Installation signal cable (gray)[2] At standard configuration with Hall sensor			
Plug (control side)	**Contact/Color**	**Function**	**Additional information**
Analog signal connectors MPC4 Würth 64900421822 Pole 4 male 	1	NC	Not used
	2/Pink	5V	Supply voltage (max. 20 mA)
	3/Purple	AIN1	Analog signal 1 (for example, throttle/accelerator pedal)
	4/Brown	GND	Mass (not isolated/without Potentialrennung)
Motor sensor connector MPC4 Würth 64900621822 6 poles male 	1/Green	Hall L3	Hall sensor phase L3
	2 / Gray-Pink	Temp IN	Temperature sensor motor
	3/Red	5V	Supply voltage (max. 20 mA)
	4/Blue	Hall L2	Hall sensor phase L2
	5/Yellow	Hall L1	Hall sensor phase L1
	6/Black	GND	Mass (not isolated/without Potentialrennung)
Digital and analog signal connector MPC4 Würth 64900821822 8 poles male 	1/Yellow-Brown	DIN2	Digital signal 2
	2/White-Green	DIN1	Digital signal 1
	3/Red-Blue	5V	Supply voltage (max. 20 mA)
	4/gray	CAN low	125, 500,1000 kb/s
	5	NC	
	6/White-Yellow	AIN2	Analog signal 2 (for example brake)
	7/Brown-Green	GND	Mass (not isolated/without Potentialrennung)
	8/White	CAN high	125, 250, 500, 1000 kb/s

Table 14: Installation signal connection cable for standard configuration with Hall sensor.

[2] Warning: Unless otherwise noted, all inputs and outputs are not protected against short circuit, reverse voltage or voltages greater than + 5V hedged.

Signal connector with resolver

Caution: Use the 5V supply voltage only for sensor supply. Do not connect any external voltage sources to the signal lines of the motor control unit.

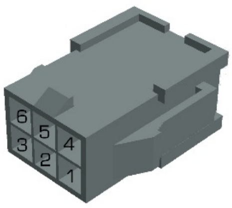
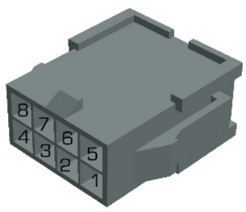
Installation signal cable (gray)[3] with extended resolver/encoder interface			
Plug (control side)	**Contact/Color**	**Function**	**Additional information**
Analog signal connectors MPC4 Würth 64900421822 Pole 4 male 	1	NC	Not used
	2/Pink	5V	Supply voltage (max. 20 mA)
	3/Purple	AIN1	Analog signal 1 (for example, throttle/accelerator pedal)
	4/Brown	GND	Mass (not isolated/without Potentialrennung)
Motor sensor connector MPC4 Würth 64900621822 6 poles male 	1/Green	Hall L3	Hall sensor phase L3
	2 / Gray-Pink	Temp IN	Temperature sensor motor
	3/Red	5V	Supply voltage (max. 20 mA)
	4/Blue	Hall L2	Hall sensor phase L2
	5/Yellow	Hall L1	Hall sensor phase L1
	6/black	GND	Mass (not isolated/without Potentialrennung)
Digital and analog signal connector MPC4 Würth 64900821822 8 poles male 	1/Yellow-Brown	CSn	resolver CS
	2/White-Green	MISO	resolver MISO
	3/Red-Blue	5V	Supply voltage (max. 20 mA)
	4/gray	CLK	resolver CLK
	5	NC	
	6/White-Yellow	AIN2	Analog signal 2 (for example brake)
	7/Brown-Green	GND	Mass (not isolated/without Potentialrennung)
	8/White	MOSI	resolver MOSI

Table 15: Installation signal connection cable with extended resolver/encoder interface.

[3] Warning: Unless otherwise noted, all inputs and outputs are not protected against short circuits, reverse voltages or voltages greater than +5V.

Mating connectors and contacts

These are the order numbers for contacts and housing on the side of the vehicle wiring harness:

- Crimp (female): Würth 64900713722DEC
- Pole housing 4 (female): 649 004 113 322 Würth
- Pole housing 6 (female): 649 006 113 322 Würth
- Pole housing 8 (female): 649 008 113 322 Würth

11.2.2 Input signal to throttle/accelerator pedal

The following list describes the different channels to get to an acceleration request.

Selection of signal input for acceleration		
Parameter name	**Function**	**Range of values**
APP_C_Ride_Mode_x_Throttle_Signal_Channel	Selection of the signal input to produce an acceleration. Each ride mode can define an individual signal.	= AIN1 = AIN2 = PWMI = CAN bus = USB
input AIN1	A relative torque between -100% and 100% can be requested via input AIN1. The special feature of input AIN1 is that, in addition to acceleration, braking can also be generated, similar to the motor brake in the internal combustion motor. See "Throttle mapping"	0 .. 100% (Mapping can be changed via Throttle mapping Table to -100% to 100%)
input AIN2 input PWMI	About AIN2 and PWMI relative torque between 0% and 100% can be obtained.	0 .. 100%
CAN bus	On the signal CAN_EXT_Torque_Request the torque can be set infinitely.	0 .. 100%
USB	Via parameter TRQ_DES_C_Test_Torque_Request the torque can be set infinitely.	0 .. 100%

Table 16: Selection of signal input for acceleration

11.2.3 Input signal for brake

The following list describes the different channels for get to a brake request:

Selection of signal input for deceleration (braking)		
Parameter name	**Function**	**Range of values**
APP_C_Ride_Mode_x_Brake_Signal_Channel	Selection of signal input to generate a braking. Each ride mode can define an individual signal.	1 = AIN1 2 = AIN2 3 = PWMI 4 = CAN bus 5 = USB 6 = DIN1 7 = DIN2
input AIN1 input PWMI	A relative torque between 0% and 100% can be requested via inputs AIN2 and PWMI.	0 .. 100%
input DIN1 input DIN2	Digital inputs generate a torque request of 100%.	0% (not operated) 100% (activated)
CAN bus	The signal CAN_EXT_Torque_Request can be used to steplessly set the torque.	-100 .. 0%
USB	Using the parameter TRQ_DES_C_Test_Torque_Request, the torque can be steplessly set.	-100 .. 0%

Table 17: Selection of signal input for deceleration (braking)

11.2.4 Input signal for driving direction selection

The following list describes the different ways to switch between forward and reverse gears

Selection of signal input for selecting the direction of travel		
Parameter name	**Function**	**Range of values**
APP_C_Ride_Mode_x_Reverse_Gear_Signal_Channel	Selection of the direction input	1 = DIN1 2 = DIN2 3 = CAN bus 4 = USB
input DIN1 input DIN2	the reverse gear can be selected via the digital input	0 = forward gear 1 = reverse gear
CAN bus	On the signal CAN_EXT_Reverse_Gear reverse may be selected	0 = forward gear 1 = reverse gear
USB	Via parameter TRQ_DES_C_Test_Reverse_Gear reverse may be selected	0 = forward gear 1 = reverse gear

Table 18: Selection of signal input for the selection of the direction of travel.

11.2.5 Calibration Analog Input AIN1

To calibrate the analog input, proceed as follows:

Procedure for calibrating AIN1		
step	**Description**	**Check**
Connect the throttle/accelerator pedal	Connect the control signal with the corresponding connector to the controller	
Start teach-in process	Set AIN1_C_Start_TeachIn to 1	The previous min/max values AIN1_XC_Max and AIN1_XC_Min are replaced by the new teach-in values.
Throttle up	Use the throttle/accelerator pedal twice over the entire range. Then hold for 1-2 seconds in the upper and lower end stop.	AIN1_Throttle shows the calibrated control value between 0 % and 100 % as soon as it is actuated for the second time.
Store parameters	Store parameters by clicking on "Store Parameters".	The motor controller restarts and saves the taught-in values for AIN1_XC_Max and AIN1_XC_Min

Table 19: Procedure for the calibration AIN1.

Throttle mapping

An alternative torque requirement can be assigned to the raw value of the acceleration signal via a conversion table. When the accelerator pedal is not pressed, a braking torque can be generated. In this way, the function of the motor brake, similar to that of an internal combustion motor, can be simulated.

Parameters for the relative torque request		
Parameter name	**Function**	**Range of values**
AIN1_C_Throttle_Mapping_0	Relative torque request with the accelerator pedal not pressed	-100 .. 100% -10% (default)
AIN1_C_Throttle_Mapping_10 .. AIN1_C_Throttle_Mapping_90	Relative torque request for intermediate positions of the accelerator pedal in 10% steps	-100 .. 100%
AIN1_C_Throttle_Mapping_100	Relative torque requirement with the accelerator pedal fully engaged	-100 .. 100%

Table 20: Parameters for the relative torque request.

More settings

The signal input can also be configured with the following settings

Parameters for analog input AIN1		
Parameter name	**Function**	**Range of values**
AIN1_C_Safe_Off_Zone	Inserts a virtual leeway at the lower end of the signal	00:01 .. 0.8
AIN1_C_Enable_Monitoring	Activate input monitoring. An error is triggered if the programmed min/max values are exceeded/underrun.	0 = monitoring inactive 1 = monitoring active
AIN1_C_F_Throttle_Max	Limit for monitoring function	0 .. 1
AIN1_C_F_Throttle_Min	Limit for monitoring function	0 .. 1
AIN1_F_Monitoring	Error when exceeding/falling below the semi-skilled Min/Max value	0/1
AIN1_C_Filter	PT1 filter for signal smoothing	0001 = very strong filtering 1 = no filtering
AIN1_C_Rate_Limit_Down	Limitation of the edge steepness during signal rise	-100000 .. 0%/100s
AIN1_C_Rate_Limit_Up	Limitation of the edge steepness at signal drop	0 .. 100 000%/100s
AIN1_C_s_Invert_Raw_Signal	Reversing the direction of action of the input. After the conversion a new calibration must be performed.	0 = rising voltage increases the signal value 1 = fall in voltage increases the signal value

Table 21: Parameters for analog input AIN1.

11.2.6 Calibration Analog Input AIN2

To calibrate the analog input, proceed as follows:

Procedure for calibrating AIN2		
Step	**Description**	**Check**
Connect brake pedal/brake contact switch	Connect the control signal with the corresponding connector to the controller	
Start teach-in process	Set AIN2_C_Start_TeachIn to 1	The previous min/max values AIN2_XC_Max and AIN2_XC_Min are replaced by the new teach-in values.
Apply the brake	Apply the brake twice over the entire range. Then hold for 1-2 seconds in the upper and lower end stop.	AIN2_Throttle shows the calibrated control value between 0 % and 100 % as soon as it is actuated for the second time.
Store parameters	Store parameters by clicking on "Store Parameters".	The motor controller restarts and saves the taught-in values for AIN2_XC_Max and AIN2_XC_Min

Table 22: Procedure for the calibration AIN2.

More settings

The signal input can also be configured with the following settings

Parameters for analog input AIN2		
Parameter name	**Function**	**Range of values**
AIN2_C_Safe_Off_Zone	Inserts a virtual leeway at the lower end of the signal	00:01 .. 0.8
AIN2_C_Enable_Monitoring	Activate input monitoring. An error is triggered if the programmed min/max values are exceeded/underrun.	0 = monitoring inactive 1 = monitoring active
AIN2_C_F_Throttle_Max	Limit for monitoring function	0 .. 1
AIN2_C_F_Throttle_Min	Limit for monitoring function	0 .. 1
AIN2_F_Monitoring	Error when exceeding/falling below the semi-skilled Min/Max value	0/1
AIN2_C_Filter	PT1 filter for signal smoothing	0001 = very strong filtering 1 = no filtering
AIN2_C_Rate_Limit_Down	Limitation of the edge steepness during signal rise	-100000 .. 0%/100s
AIN2_C_Rate_Limit_Up	Limitation of the edge steepness at signal drop	0 .. 100 000%/100s
AIN2_C_s_Invert_Raw_Signal	Reversing the direction of action of the input. After the conversion a new calibration must be performed.	0 = rising voltage increases the signal value 1 = fall in voltage increases the signal value

Table 23: Parameters for analog input AIN2.

11.2.7 Calibration of the PWM input (PWMI)

To calibrate the PWM input, proceed as follows:

Procedure for calibrating the PWM signal input		
Step	**Description**	**Check**
Connect a PWM signal	Connect the control signal with the corresponding connector to the controller	
Start teach-in process	Set PWMI_C_Start_TeachIn to 1	The previous min/max values PWMI _XC_Max and PWMI _XC_Min are replaced by the new teach-in values.
Apply the brake	Engage the PWM-signal over its full range twice. Then hold for 1-2 seconds in the upper and lower end stop.	PWMI _Throttle shows the calibrated control value between 0 % and 100 % as soon as it is actuated for the second time.
Store parameters	Store parameters by clicking on "Store Parameters".	The motor controller restarts and saves the taught-in values for PWMI _XC_Max and PWMI _XC_Min

Table 24: Procedure for the calibration of the PWM signal input.

More settings

The signal input can also be configured with the following settings

Parameters for the PWM input PWMI		
Parameter name	**Function**	**Range of values**
PWMI_C_Safe_Off_Zone	Inserts a virtual leeway at the lower end of the signal	00:01 .. 0.8
PWMI _C_Enable_Monitoring	Activate input monitoring. An error is triggered if the programmed min/max values are exceeded/underrun.	0 = monitoring inactive 1 = monitoring active
PWMI _C_F_Throttle_Max	Limit for monitoring function	0 .. 1
PWMI _C_F_Throttle_Min	Limit for monitoring function	0 .. 1
PWMI _F_Monitoring	Error when exceeding/falling below the semi-skilled Min/Max value	0/1
PWMI _C_Filter	PT1 filter for signal smoothing	0001 = very strong filtering 1 = no filtering
PWMI _C_Rate_Limit_Down	Limitation of the edge steepness during signal rise	-100000 .. 0%/100s
PWMI _C_Rate_Limit_Up	Limitation of the edge steepness at signal drop	0 .. 100 000%/100s
PWMI _C_s_Invert_Raw_Signal	Reversing the direction of action of the input. After the conversion a new calibration must be performed.	0 = rising voltage increases the signal value 1 = fall in voltage increases the signal value

Table 25: Parameters for the PWM input PWMI.

11.2.8 Digital input DIN1

To use the digital input, proceed as follows:

Procedure for calibrating DIN1		
Step	**Description**	**Check**
Connect a digital signal, for example a push button or switch	connect control signal with the appropriate connector to the controller	
Set NC/NO contact or effective direction	DIN_C_DIN1_Logic_Level must be set to 1 for an NC contact. For make contacts, the value remains at 0	
Check signal	The measured value DIN_DIN1_Signal shows the current state of the signal	When the button is pressed, the measured value DIN_DIN1_Signal must change from 0 to 1
Store	Store parameters by clicking on "Store Parameters".	The motor controller restarts and stores the set values

Table 26: Procedure for the calibration DIN1.

11.2.9 Digital input DIN2

To use the digital input, proceed as follows:

Procedure for calibrating DIN2		
Step	**Description**	**Check**
Connecting the digital signal, for example push button	connect control signal with the appropriate connector to the controller	
Set NC/NO contact or effective direction	DIN_C_DIN2_Logic_Level must be set to 1 for an NC contact. For make contacts, the value remains at 0	
Check signal	The measured value DIN_DIN2_Signal shows the current state of the signal	When the button is pressed, the measured value DIN_DIN2_Signal must change from 0 to 1
Store	Store parameters by clicking on "Store Parameters".	The motor controller restarts and stores the set values

Table 27: Procedure for the calibration DIN2.

11.2.10 CAN-Bus Control

Information on control via CAN bus can be found under "CAN bus communication".

11.2.11 USB control

The Enable-Tool interface is controlled via the following parameters:

Parameters for control via USB		
Parameter name	**Function**	**Range of values**
TRQ_DES_C_Test_Torque_Request	Set torque setpoint	-100 .. 100%
TRQ_DES_C_Test_Reverse_Gear	Set reverse gear	0 = forward gear 1 = reverse gear

Table 28: Parameters for control via USB.

11.3 Processing of the driver's inputs

11.3.1 Combinations of accelerator, brake and reverse gear

The input signals of the driver are combined in the driver request conditioning to a relative driver request torque, measurable via TRQ_DES_Trq_Req_Rel.

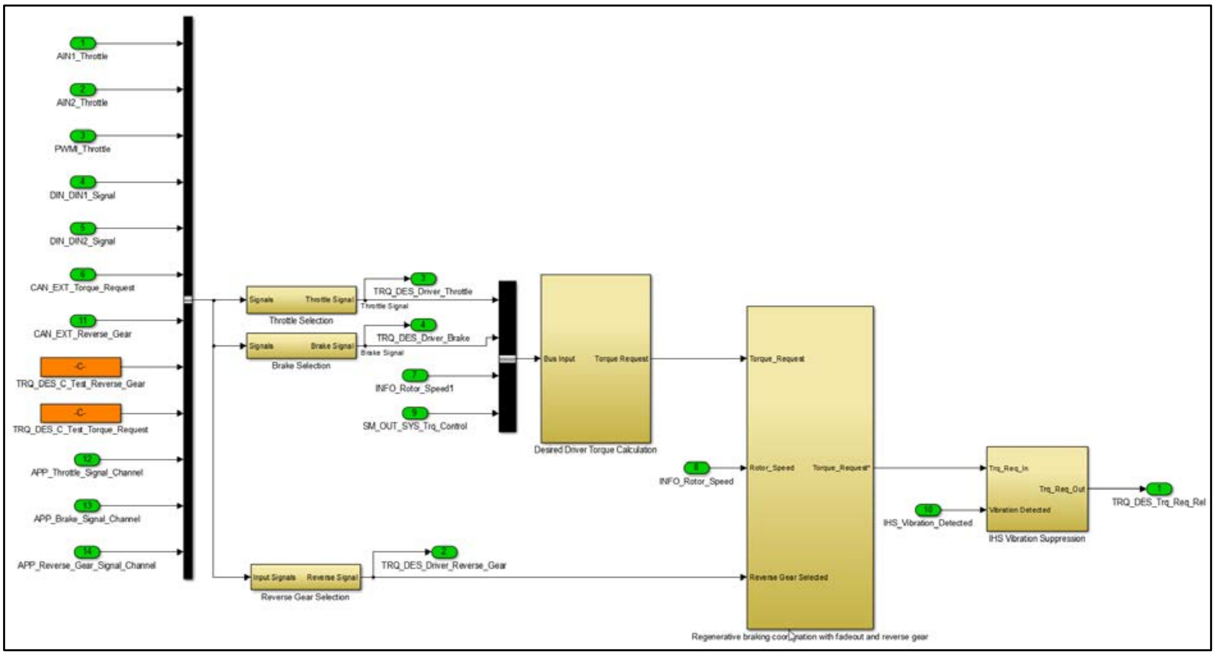


Figure 3: Function model driver request processing (TRQ_DES)

A value of 100% accelerates the motor strongly in forward direction, or brakes the motor strongly when it is turning in reverse direction. A value of -100% slows the motor down strongly when it is turning in forward direction, or accelerates the motor strongly in reverse direction when reverse gear is selected.

When combining throttle, brake and reverse gear, there are not only a multitude of input combinations and different sequences by the driver, but also a number of situations in which the vehicle can find itself.

The following table shows the behavior of the motor control unit during operation

Driving conditions and vehicle reaction with simultaneous actuation of throttle and brake						
The driver operates...			**The vehicle...**			**Resulting characteristic**
brake	**throttle**	**Rev. gear**	**moves vw.**	**Stands**	**moves rw.**	
Actuated	-	irrelevant	-	Yes	-	At standstill, the brake signal generates no torque. Relative torque requirement in the range: 0
Operated first	Operated after	irrelevant	-	Yes	-	The brake was applied first, then the gas. The vehicle starts up against the brake (hill start assistance). Relative torque requirement: 0 % .. 100 %
Operated after	Operated first	irrelevant	-	Yes	-	The gas was actuated first, then the brake. The brake overrides the gas and reduces the torque to 0 %. Relative torque requirement: 0

Actuated	irrelevant	irrelevant	Yes	-	Yes	When the brake is actuated, regenerative braking takes place, which is faded out towards standstill. If the vehicle brakes to a standstill, the gas must first be reduced before starting again. Relative torque requirement: 0
-	actuated	-	-	Yes	-	The vehicle accelerates from standstill in forward direction Relative torque requirement: 0 .. 100 %
-	actuated	actuated	-	Yes	-	The vehicle accelerates from standstill in reverse direction. Relative torque requirement: -100 .. 0 %
actuated	-	-	-	-	Yes	The vehicle is moving straight backwards, at the same time the forward gear is selected. This is typical for starting off on a mountain, for example. The brake slows down the vehicle. Relative torque requirement: 0 .. 100 %
-	actuated	-	-	-	Yes	The vehicle is moving straight backwards, at the same time the forward gear is selected. This is typical for starting off on a mountain, for example. The direction of action of the gas signal is already set to the forward direction, i.e. the more the driver accelerates, the more the vehicle slows down the reverse drive. When the vehicle comes to a standstill, it accelerates forward. Relative torque requirement: 0 .. 100 %
actuated	-	actuated	Yes	-	-	The vehicle is moving forward while reverse gear is selected. The vehicle can be slowed down by the brake. Relative torque requirement: -100 .. 0 %
-	actuated	actuated	Yes	-	-	The vehicle is moving forward while reverse gear is selected. The direction of action of the gas signal is reversed, i.e. the more the driver accelerates, the more the vehicle slows down. When the vehicle comes to a standstill, it accelerates backwards in the new desired direction. Relative torque requirement: -100 .. 0 %

Table 29: Driving conditions and vehicle reaction with simultaneous actuation of throttle and brake.

11.3.2 Hill start and panic assistance

The motor control unit has a hill start aid to support the hill start process. On slopes, there is often the problem that a forward movement is desired, but that when the mechanical brake is actuated, the brake contact is also actuated, which causes the acceleration signal to be cut.

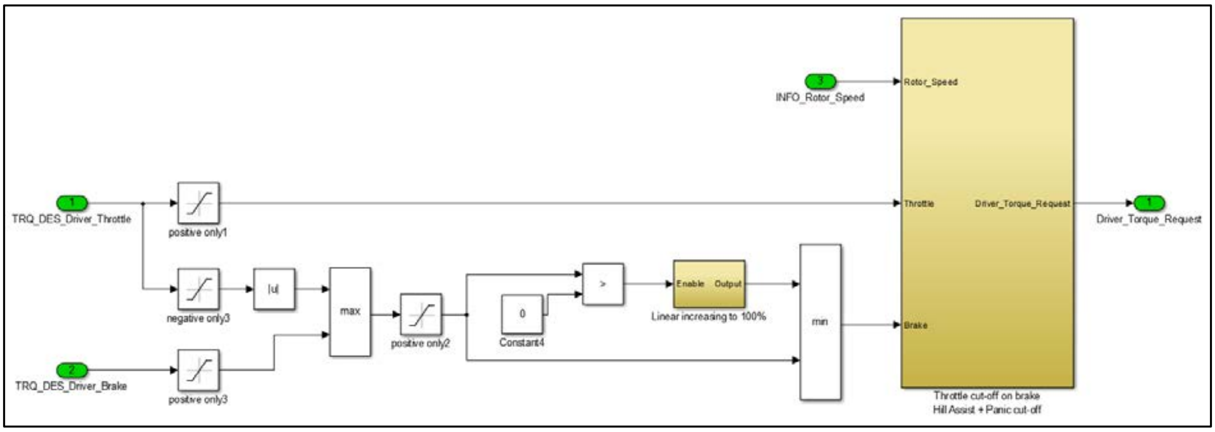


Figure 4: Function model throttle cut-off handler in the driver's desired torque calculation (TRQ_DES)

The starting assistance enables the simultaneous use of accelerator and brake in the low speed range. At the same time the vehicle can be prevented from rolling backwards via the mechanical brake while a torque is generated via the motor to move the vehicle forward. When the brake is released, the vehicle starts moving without rolling back.

This function is maintained up to an adjustable maximum speed, at the latest when the speed limit is reached the mechanical brake should be released completely, otherwise there is an electrical braking, if necessary until standstill (panic detection).

Furthermore, the maximum time for simultaneous use of accelerator and brake can be limited to prevent excessive wear.

parameter traction		
Parameter name	**Function**	**Range of values**
TRQ_DES_C_ThrottleBrakeComb_Cut_Time	Maximum time in milliseconds for the simultaneous use of the accelerator and brake	0 .. 100000
TRQ_DES_C_ThrottleBrakeComb_Max_Speed	Speed limit for the simultaneous use of the accelerator and brake.	0 .. 2000/s

Table 30: Parameter traction.

11.3.3 Fade-out function for regenerative braking

The fade-out function reduces the braking torque around standstill. The speed TRQ_DES_C_Brake_Torque_Fade_Out_Speed defines a speed range around standstill in which the maximum braking torque is reduced to 0. Outside this range, the maximum braking torque then increases above the speed. The slope of the slope can be defined with TRQ_DES_C_Brake_Torque_Fade_Out_Gain.

Parameters for the suppression of recuperation near standstill		
Parameter name	**Function**	**Range of values**
TRQ_DES_C_Reverse_Gear_Max_Torque	Torque limiter in reverse gear	0 .. 100%
TRQ_DES_C_Brake_Torque_Fade_Out_Speed	Speed range around standstill in which the braking torque is reduced to zero in both directions of travel.	0 .. 2000/s
TRQ_DES_C_Brake_Torque_Fade_Out_Gain	Determination of the slope with which the maximum braking torque increases above the speed.	0 .. 2000/s

Table 31: Parameters for the suppression of recuperation near standstill.

The following chart shows the limitation of the maximum relative braking torque in the forward direction with the following settings:

- TRQ_DES_C_Brake_Torque_Fade_Out_Gain = 50%/s
- TRQ_DES_C_Brake_Torque_Fade_Out_Speed = 0.5/s

The driver's braking request is limited to those shown in the chart value.

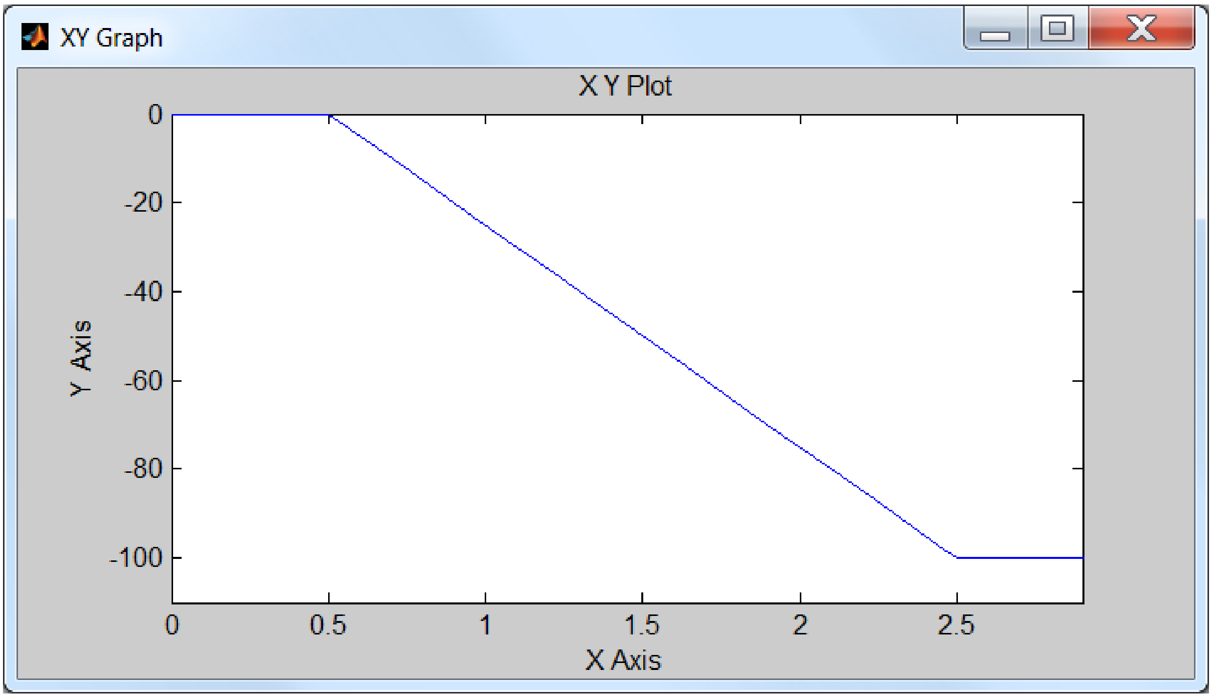


Figure 5: Driver's braking request.

11.3.4 Reverse gear

The torque in reverse gear can be adjusted by using the following parameters:

Parameters for the reverse gear		
Parameter name	**function**	**Range of values**
TRQ_DES_C_Reverse_Gear_Max_Torque	Torque limitation in reverse gear	0 .. 100%

Table 32: Parameters for the reverse gear.

11.4 Torque limitation (derating)

11.4.1 Basic function

During operation, it is more the rule than the exception that the acceleration required by the driver is constantly limited by the torque limitation.

The torque limiter is a controller function that reduces the relative desired torque as soon as an operating limit is exceeded or is about to be exceeded. The operating limits set in ride mode serve as the setpoint for torque limitation.

11.4.2 Derating information

The motor control informs the user via the USB interface and the CAN bus via derating bits that the current motor torque is reduced due to an operating limit. The following table provides information on the derating bits.

Overview derating bits		
Derating bit	**Description**	**Range of values**
TRQ_LIM_Derating_Active	General info: The torque is currently restricted	0/1
TRQ_LIM_Derating_Max_Positive_Current	Limitation of the acceleration power due to the current AC or DC current limit. The following parameters have influence on this bit: APP_C_Ride_Mode_x_Max_DC_Current APP_C_Ride_Mode_xMax_Motor_Current CAN_BMS_Max_Discharge	0/1
TRQ_LIM_Derating_Max_Negative_Current	Limitation of the braking power due to the battery charging current. The following parameters have influence on this bit: APP_C_Ride_Mode_x_Max_Regenerative_DC_Current APP_C_Ride_Mode_x_Max_Regenerative_Motor_Current CAN_BMS_Max_Charge	0/1
TRQ_LIM_Derating_DC_Link_Voltage_Min	Limitation of the acceleration power due to the lower battery voltage limit. The following parameters have influence on this bit: APP_C_Ride_Mode_x_Voltage_Limit_Low CAN_BMS_Min_Voltage CAN_BMS_Min_Voltage	0/1
TRQ_LIM_Derating_DC_Link_Voltage_Max	Limitation of the braking power due to the upper battery voltage limit. The following parameters have influence on this bit: APP_C_Ride_Mode_x_Max_Regenerative_DC_Current APP_C_Ride_Mode_x_Max_Regenerative_Motor_Current CAN_BMS_Max_Charge	0/1

TRQ_LIM_Derating_Rotor_Speed	Limitation of the acceleration power by the speed limit. The following parameters have influence on this bit: APP_C_Ride_Mode_x_Speed_Limit APP_C_Ride_Mode_x_Speed_Limit_Reverse	0/1
TRQ_LIM_Derating_Temp_FET	Limitation of acceleration or braking power due to high temperature of the output stage.	0/1
TRQ_LIM_Derating_Temp_MCU	Limitation of acceleration or braking power due to high microcontroller temperature.	0/1
TRQ_LIM_Derating_Temp_Motor	Limitation of acceleration or braking power due to high motor temperature. The following parameters have influence on this bit: TRQ_LIM_C_Temp_MO_Max TRQ_LIM_C_Temp_MO_Min	0/1

Table 33: Overview derating bits.

11.4.3 Controller setting

Speed control

The speed controller can be adapted with the following parameters. Setting the controller requires basic knowledge of control engineering. The motor controller can also brake generatively to control the maximum speed.

Parameters for setting the speed controller		
Parameter name	**function**	**Range of values**
TRQ_LIM_C_Rotor_Speed_Limit_Controller_P_Gain	P-component	0..1000%/s
TRQ_LIM_C_Rotor_Speed_Limit_Controller_I_Gain	I component	0..1000%/s ^ 2
TRQ_LIM_C_Rotor_Speed_Limit_Controller_D_Gain	D component	0..1000%
TRQ_LIM_C_Rotor_Speed_Limit_Allow_Regenerative_Braking	Activating the counter-braking. The controller may request negative torque to actively slow down the vehicle if the speed is exceeded.	0 = The desired torque is controlled only down to 0. 1 = The desired torque may be negative.

Table 34: Parameter for setting the speed controller.

NOTE: An alternative to the active control of the speed limits, the reduction of the maximum motor current to the rotational speed so that the vehicle when it reaches the desired speed, the motor current is withdrawn. The speed regulation is therefore usually very harmonious, however, does not have the ability to counter-braking. See "q-current limit as a function of speed".

Current limiting controller

The current limiting controller can be adjusted with the following parameters. Setting the controller requires basic knowledge of control engineering.

Parameters for setting the current limit regulator		
Parameter name	**function**	**Range of values**
TRQ_LIM_C_Curr_Lim_Pos_Controller_P_Gain	P component of the current limiting controller for the positive current (from the battery)	0 .. 1
TRQ_LIM_C_Curr_Lim_Pos_Controller_I_Gain	I-component of the current limiting controller for the positive current (from the battery)	0 .. 1
TRQ_LIM_C_Curr_Lim_Pos_Controller_D_Gain	D component of the current limiting controller for the positive current (from the battery)	0 .. 1
TRQ_LIM_C_Curr_Lim_Neg_Controller_P_Gain	P component of the current limiting controller for the regenerative current	0 .. 1
TRQ_LIM_C_Curr_Lim_Neg_Controller_I_Gain	I-component of the current limiting controller for the regenerative current	0 .. 1
TRQ_LIM_C_Curr_Lim_Neg_Controller_D_Gain	D component of the current limiting controller for the regenerative current	0 .. 1

Table 35: Parameter for setting the current limit controller.

11.4.4 q-Current limit as a function of speed

The relative driver's desired torque can be limited to a speed-dependent q current maximum value via a table. A separate characteristic curve with 10 points each is available for each ride mode. The grid points on the axis of the table can be changed to cover the speed range relevant for the drive. When changing the grid points, make sure that the values of the axis are strictly monotonously increasing.

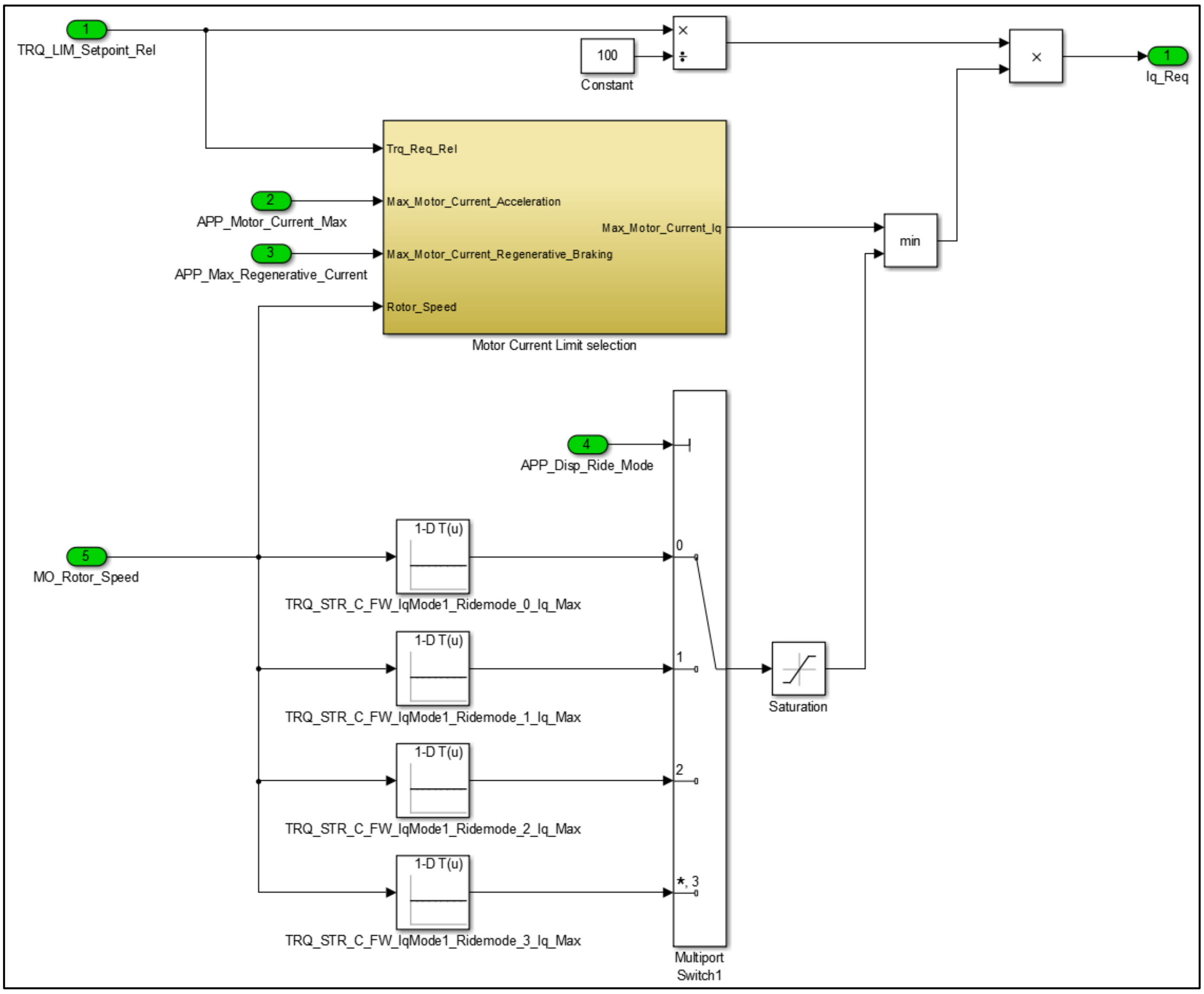


Figure 6: Function model of the q-current limit as a function of speed.

Parameter List for setting a max. Phase current in dependence on the rotational speed		
Parameter name	**Function**	**Range of values**
TRQ_STR_C_FW_IqMode1_Ridemode_0_Iq_Max_axis_P0 .. P9	Mechanical speed axis (1/s). The axis is the same for all tables. The supporting points must be set strictly monotonously increasing. An EEPROM error is triggered if the nodes have not been defined correctly.	-2000 .. 2000 1/s
LUT_TRQ_STR_C_FW_IqMode1_Ridemode_0_Iq_Max_Table_P0 .. P9	q current maximum values for Ride-Mode 0	0 .. 1000 A
LUT_TRQ_STR_C_FW_IqMode1_Ridemode_1_Iq_Max_Table_P0 .. P9	q-current maximum values for Ride Mode 1	0 .. 1000 A
LUT_TRQ_STR_C_FW_IqMode1_Ridemode_2_Iq_Max_Table_P0 .. P9	q-current maximum values for Ride Mode 2	0 .. 1000 A

LUT_TRQ_STR_C_FW_IqMode1_Ridemode_3_Iq_Max_Table_P0 .. P9	q-current maximum values for Ride Mode 3	0 .. 1000 A

Table 36: Parameter list to set a max. Phase current as a function of the speed.

Depending on the direction of travel and the relative driver's preference, the q-current setpoint required in the table is limited to the maximum positive motor current set in ride mode or the maximum regenerative braking motor current.

Speed limit

By reducing the maximum motor current as a function of the speed, the motor current can be reduced to zero when the desired final speed is reached. The control is therefore very harmonious but does not have the ability to counter-braking. See also the chapter entitled "Speed Control".

11.5 Control of d-current and q-current

The field-oriented PI current controller for d-current and q-current can be set via parameters below. Setting these constants requires knowledge of control technology and the function of field-oriented current control.

P component and I component can each be set in three definable speed ranges. In the factory settings, both speed thresholds are zero, so that the parameters for high speed are always decisive.

Parameter to determine the speed ranges		
Parameter name	**Function**	**Range of values**
	For electrical speeds lower than FOC_C_Id_Curr_Control_Speed_Thresh_Mid "Slow-parameter" apply	
FOC_C_Id_Curr_Control_Speed_Thresh_Mid	For electrical speeds greater than or equal FOC_C_Id_Curr_Control_Speed_Thresh_Mid the "Mid-parameter" apply	0 .. 2400 /
FOC_C_Id_Curr_Control_Speed_Thresh_High	For electrical speeds greater than or equal FOC_C_Id_Curr_Control_Speed_Thresh_High the "high-parameter" apply	0 .. 2400 /

Table 37: Parameter to determine the speed ranges.

Parameters for the current controller		
Parameter name	**Function**	**Range of values**
FOC_C_Id_Curr_Control_I	I-component for Id controller at high speed	0 .. 1 V/65µs
FOC_C_Id_Curr_Control_I_Mid	I-component for Id controller at medium speed	0 .. 1 V/65µs
FOC_C_Id_Curr_Control_I_Slow	I-component for Id controller at low speed	0 .. 1 V/65µs
FOC_C_Id_Curr_Control_P	P component for Id controller at high speed	0 .. 1 V/65µs
FOC_C_Id_Curr_Control_P_Mid	P component for Id controller at medium speed	0 .. 1 V/65µs
FOC_C_Id_Curr_Control_P_Slow	P component for Id controller at low speed	0 .. 1 V/65µs
FOC_C_Iq_Curr_Control_I	I-component Iq for control at high speed	0 .. 1 V/65µs

FOC_C_Iq_Curr_Control_I_Mid	I-component Iq for control at medium speed	0 .. 1 V/65µs
FOC_C_Iq_Curr_Control_I_Slow	I-component Iq of control at low speed	0 .. 1 V/65µs
FOC_C_Iq_Curr_Control_P	P-component Iq for control at high speed	0 .. 1 V/65µs
FOC_C_Iq_Curr_Control_P_Mid	P component for Iq controller at medium speed	0 .. 1 V/65µs
FOC_C_Iq_Curr_Control_P_Slow	P-component Iq for control at low speed	0 .. 1 V/65µs

Table 38: Parameters for the current controller.

Readings for the generated voltage commands		
Parameter name	**Function**	**Range of values**
FOC_OUT_Vsd	Target voltage in the d-axis	-500 .. 500 V
FOC_OUT_Vsq	Target voltage in the q-axis	-500 .. 500 V
FOC_OUT_Magnitude_Induction	Total control factor as a vector addition	-1000 .. 1000 V

Table 39: Values for the generated nominal voltages.

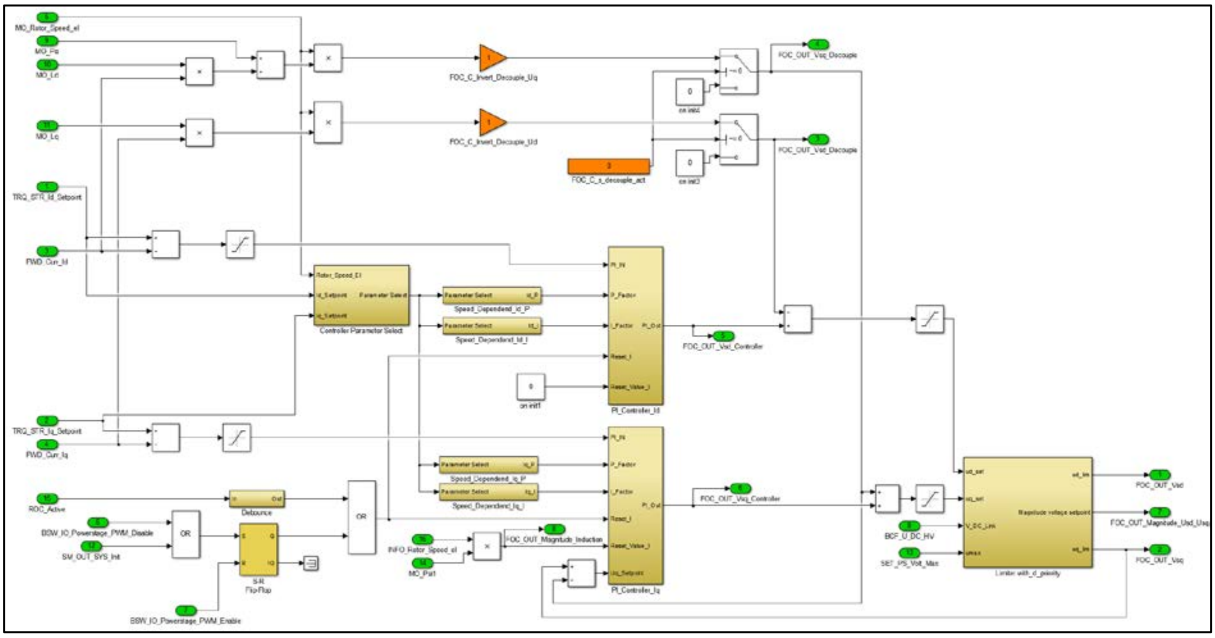


Figure 7: Function model of field-oriented current regulator

11.5.1 Decoupling network

The decoupling network can be activated to increase the control dynamics. Make sure that the motor parameters are fully set before activation.

parameter		
Parameter name	**Function**	**Range of values**
FOC_C_s_decouple_act	Activation of the decoupling network	0..1

11.6 Ride mode settings

The motor control offers four adjustable ride modes which can also be switched while driving via the smartphone app, a button or CAN bus. The ride modes are used to define the driving behavior of the vehicle and adapt it to your application by defining the system limits (current, voltage, speed, input signals).

11.6.1 Actual system limits

The system limits applicable during operation are composed of the ride mode-dependent settings and the boost settings (see "Boost function").""). To check which system limits are currenly in effect, you can view the measured values from the table below.

Note: After resetting to factory settings, the motor control automatically starts in ride mode 2 and you should start setting the parameters of ride mode 2 to see the effect of your settings on the readings below.

Reading actual system limits		
Parameter name	**Function**	**Range of values**
APP_Disp_Ride_Mode	Currently selected Ride mode	0 .. 3
APP_Throttle_Signal_Channel	Selected control signal for acceleration	1 .. 5
APP_Brake_Signal_Channel	Selected control signal to the brakes	1 .. 7
APP_Reverse_Gear_Signal_Channel	Selected control signal for selecting the reverse gear,	1 .. 4
APP_DC_Current_Max	Current limit for the discharge (of the battery)	0 .. 500 A
APP_Regenerative_DC_Current_Max	Current limit for the charging current (in the battery)	-500 .. 0 A
APP_Motor_Current_Max	Current limit for the motor current (d-q current + current)	0 .. 500 A
APP_Max_Regenerative_Motor_Current	Current limit for the motor current when recuperation (d-q current + current)	0 .. 500 A
APP_Flux_Weakening_Current_Max	Current limit for the d-current (flux-weakening)	-100 .. 0 A
APP_DC_Voltage_Limit_High	Current limit for charging voltage	0 .. 500 V
APP_DC_Voltage_Limit_Low	Current limit for discharge voltage	0 .. 500 V
APP_P_EL_Max	Current limit for the electric power	0 .. 100 000 W
APP_Speed_Limit	Current limit for motor speed in the forward direction	0 .. 2400 /
APP_Reverse_Gear_Speed_Limit	Current limit for motor speed in the reverse direction	0 .. 2400 /

Table 40: Reading actual system limits.

11.6.2 Ride mode parameters

The following settings can be made separately for each ride mode. The parameters are available separately for each ride mode. The parameters for ride mode 2 are described here, as this is automatically selected after resetting to factory settings.

Ride mode-dependent parameters		
Parameter name	**Function**	**Range of values**
APP_C_Ride_Mode_2_Throttle_Signal_Channel	Select input for "acceleration signal" (eg throttle/accelerator pedal). 1 = AIN1 2 = AIN2 3 = PWM @ DIN2 4 = CAN BUS 5 = USB	1 .. 55 (default)
APP_C_Ride_Mode_2_Brake_Signal_Channel	Select input for "braking signal". 1 = AIN1 2 = AIN2 3 = PWM @ DIN2 4 CAN BUS 5 = USB 6 = DIN1 7 = DIN2	1 .. 75 (default)
APP_C_Ride_Mode_2_Reverse_Gear_Signal_Channel	Select input for "reverse gear signal". 1 = DIN1 2 = DIN2 3 = CAN Bus 4 USB	1 .. 4 4 (default)
APP_C_Ride_Mode_2_Max_DC_Current	Limitation of the maximum battery current (DC) and thus the electrical acceleration power.	0 .. 500 A 10 A (default)
APP_C_Ride_Mode_2_Max_Regenerative_DC_Current	Limitation of the maximum recuperation current (DC) and thus the electrical braking power or charging power.	-500 .. 0 A -10 A (default)
APP_C_Ride_Mode_2_Max_Motor_Current	Limitation of the maximum motor current (phase current) (AC) and thus of the torque during acceleration.	0 .. 500 A 25 A (default)
APP_C_Ride_Mode_2_Max_Regenerative_Motor_Current	Limitation of the maximum motor current (phase current) (AC) during recuperation braking and thus of the torque during braking.	0 .. 500 A25 A (default)
APP_C_Ride_Mode_2_Max_Flux_Weakening_Current	Limitation of the maximum flux-weakening current (AC) and thus the possible overspeed.	-150 .. 0 A -5 A (default)
APP_C_Ride_Mode_2_Max_Power_El	Limitation of maximum electrical power (product of U*I).	0 .. 10000 W 10000 W (default)

APP_C_Ride_Mode_2_Speed_Limit	Limitation of the maximum motor speed and thus the vehicle speed in forward direction.	0 .. 2000/s 2000/s (default)
APP_C_Ride_Mode_2_Speed_Limit_Reverse	Limitation of the maximum motor speed and thus the vehicle speed in reverse direction.	0 .. 2000/s 2000/s (default)
APP_C_Ride_Mode_2_Voltage_Limit_High	Upper charging voltage limit to limit the recuperation current when the battery is full.	14 .. 500 V 60 V (default)
APP_C_Ride_Mode_2_Voltage_Limit_Low	Lower discharge voltage limit to limit the acceleration power when the battery is empty.	10 .. 500 V 12 V (default)

Table 41: Ride mode-dependent parameters.

11.6.3 Set default ride mode

The standard ride mode determines which ride mode is selected after starting the motor control or after a reset.

Parameters for standard ride mode		
Parameter name	**Function**	**Range of values**
APP_C_Default_Ride_Mode	Standard ride mode. The standard ride mode can be set as follows: 0 = Ride Mode 0 1 = Ride mode 1 2 = Ride Mode 2 (default) 3 = Ride Mode 3	0 .. 3 2 (default)
APP_C_Ride_Mode_Restore_Mode	Ride mode at startup. When starting the motor control or after a reset (for example, ignition on) the control is in the standard drive mode or can automatically switch to a different ride mode, depending on the settings: 0 = Start in the standard ride mode (APP_C_Default_Ride_Mode) 1 = The Ride mode last used is selected 2 = Start in standard ride mode. However, when the Smartphone Connectivity is activated, the system switches to the last selected ride mode. However, this only works as long as no Secure_Access_Mode is set or as soon as the password has been entered correctly. See "Password protect Smartphone Connectivity ".	0 .. 20 (default)

Table 42: Parameters for standard ride mode.

11.6.4 Toggle ride mode

The ride modes can be switched either via the smartphone app (Smartphone Connectivity), via switches (DIN1/DIN2) or via the CAN bus. The switchover can be made at any time, even while the motor is rotating. Certain parameters may be changed over with a delay if this is necessary for safe operation of the drive.

Via smartphone app

If you want to change the ride mode via the smartphone app, you must first install the app. See "Smartphone App". Then all ride modes can be selected in the app under Settings/Drive Mode Settings.

Via button or switch

Connect the push-button or switch to the motor control as shown in the wiring diagram. For this purpose, use the control signal inputs DIN1 or DIN2 See "Input signals" for connection diagram".

Via CAN bus

The specification of the corresponding CAN bus signal "MC_Ride_Mode" can be found in the chapter "Received Messages".

11.6.5 Password protect Smartphone Connectivity

You have the possibility to protect the Smartphone Connectivity and the switching of the ride mode with a password. If enabled, the smartphone app will prompt you to enter a password before you can switch ride mode. The password is requested only once per ignition cycle, i.e. after a short loss of the connection the password does not have to be entered again.

Settings for smartphone connection		
Parameter name	**Function**	**Range of values**
BLE_C_Secure_Access_Mode	Access to the ride mode switch in the smartphone app can be blocked by a password. There are three modes for this: 0 = no password (default) 1 = Default password (created from the last 4 digits of the serial number of the motor control +1) 2 = personal password (number with max. 9 digits)	0 .. 20 (default)
BLE_Default_Secure_Access_Passcode	This metric shows you the default password.	6-digit number (The last six digits of the serial number of the motor control +1)
BLE_C_Personalized_Secure_Access_Passcode	Here you can set personal password.	Number with max. 9 digits 911 (default)

Table 43: Settings for smartphone connection.

11.6.6 Boost function

Using the boost function, DC current (power), torque, flux-weakening and the final speed can be increased for a limited period of time. The boost function increases the system limits of the respective ride mode by an additional, adjustable amount. The extended system limits only apply if the boost function is requested via an external input (or permanently) and if the boost memory is sufficiently full.

Extended system limits

The parameters for the boost function extend the current system limits. Each ride mode provides the following boost parameters to extend the current system limits. The boost parameters for Ride-Mode 2 are described here as an example.

Parameters for extended Boost limits		
Parameter name	**Function**	**Range of values**
APP_C_Ride_Mode_2_Boost_DC_Current	Increasing the battery current for higher electric power	0 .. 1000 A
APP_C_Ride_Mode_2_Boost_Flux_Weakening_Current	Increasing the flux-weakening current to achieve higher speeds and more power in the high speed range (AC)	-100 .. 0 A
APP_C_Ride_Mode_2_Boost_Motor_Current	Increasing the motor phase current during acceleration for more torque.	0 .. 1000 A
APP_C_Ride_Mode_2_Boost_Speed_Limit	Increasing the motor speed and the vehicle speed	0 .. 2400 /

Table 44: Parameters for extended boost limits.

The active system limits result from the sum of the ride mode-dependent system limits and the extended boost limits. See "Actual system limits".

Boost charge

The extended boost limits only become active if the boost is sufficiently charged, i.e. the boost must contain a certain amount of charge which can be discharged again at the next full load acceleration. The unit of the boost is amp seconds (As).

Status of the boost function		
Parameter name	**Function**	**Range of values**
APP_Disp_Boost_Avail_As	boost memory	Ampere-second
APP_Disp_Boost_Avail_Rel	Boost memory relative to the upper limit	0 .. 100%
APP_Disp_Boost_Info	Displays the status of the boost function	1 = Boost function available 2 = boost charge ready to use 4 = Boost Fully Charged 8 = Extended boost limits activated 16 = Boost charge which cancled 32 = Cool down after boost 64 = Collecting boost charge 128 = Depleting boost charge 256 = Boost depleted

Table 45: Status of the boost function.

Boost charging

When the current control is activated, the boost memory can be charged with a start value so that the extended system limits can be used right from the start. The boost is recharged either by accumulation of recuperation energy or continuously over time.

Any negative DC current (charging current) is multiplied by the charging rate (APP_C_Boost_Regen_Charge_Ratio) and summed up.

- Example 1 - Charging rate 1:

  A driver brakes for 4 seconds and generates a charging current of -15 A. The boost memory is loaded to 60As during this braking.

- Example 2 - Charging rate 100:

  A driver brakes for 4 seconds and generates a charging current of -15 A. The boost memory is loaded to 6000 Ace during this braking. Charging is relatively strong. With this setting, the boost memory can be strongly charged even during the shortest of braking operations.

- Example 3 - Charging rate 0.25:

  A driver brakes for 4 seconds and generates a charging current of -15 A. The boost memory is charged to 15 Ace during this braking. Charging is relatively weak. With this setting it can be achieved that the boost is sufficiently charged e.g. only with every third braking from 45 km/h.

A constant charging rate of the boost is adjustable via APP_C_Boost_Charge_Over_Time.

Parameters of the boost function for charging and activating		
Parameter name	**Function**	**Range of values**
APP_C_Boost_Max_Charge	Maximum upper limit for the charging of the memory Boost	0 .. 4000000000 As
APP_C_Boost_Initial_Boost	Start value for the boost memory after ignition-on (after starting the software by power supply)	0 .. 4000000000 As
APP_C_Boost_Regen_Charge_Curr_Min	Minimum recuperation current for charging the boost memory	-1000 .. 0 A
APP_C_Boost_Regen_Charge_Ratio	Charging rate	0 .. 1000000 A
APP_C_Boost_Entry_Motor_Current	A motor current above this limit discharges the boost memory	0 .. 500 A
APP_C_Boost_Activation_Min_Available_Rel	Relative minimum amount of boost in the boost memory to enable the extended boost limits	0 .. 100%

Table 46: Parameters of the boost function for charging and activation.

Cool down function

The boost function can be disabled for a certain time after the boost accumulator has been completely emptied. This may help to protect the motor from overheating.

Cooldown parameters of the boost function		
Parameter name	**Function**	**Range of values**
APP_C_Boost_Cool_Down_Threshold	Cool-down phase after the boost was completely consumed	1000 .. 4000000000 ms

Table 47: Cooldown parameters of the boost function.

Caution: The protection function does not provide guaranteed protection against overheating. For example, a motor that is already hot can again be loaded with boost just by an ignition change, provided a start value for the boost memory has been defined. Furthermore, the driver can "avoid" the cool-down phase if the driver does not completely empty the boost.

Manual boost

The extended system limits are automatically activated in the factory settings, but the extended system limits can also be activated manually.

Manual activation of the boost function		
Parameter name	**Function**	**Range of values**
APP_C_Boost_Input_Select	The activation of the extended boost limits can be controlled by different inputs	0 = Boost limits via Trq_Req_Raw (torque request) 1 = via SP1 2 = via SP2 3 = via CAN

Table 48: Manual activation of the boost function.

11.7 Display features

The following section describes the settings required for displaying in the smartphone app and for sending signals on the CAN bus.

11.7.1 Vehicle speed

To calculate the vehicle speed, the mechanical motor speed is multiplied by the set wheel circumference.

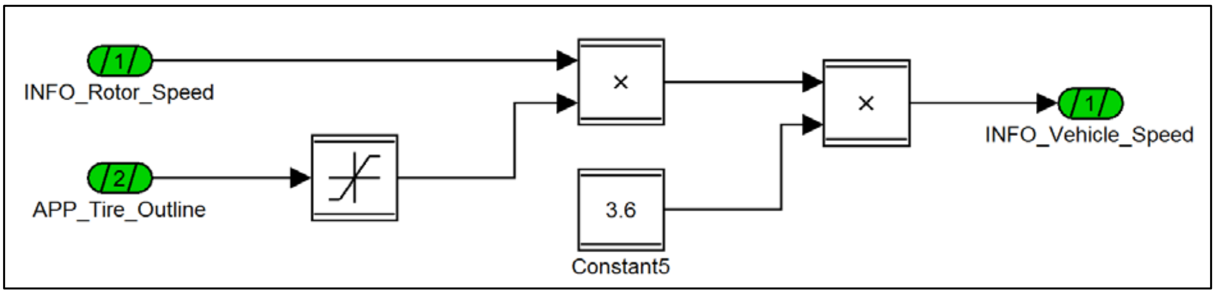


Figure 8: Function model to calculate the vehicle speed.

Measured values of the vehicle speed display		
Parameter name	**Function**	**Unit of values**
INFO_Rotor_Speed	mechanical speed	In revolutions per second
APP_Tire_Outline	Tyre circumference or distance travelled per mechanical revolution	in meters
INFO_Vehicle_Speed	Measured value for speed display	In kilometers per hour

Table 49: Measured values of the vehicle speed display.

For the correct calculation of the vehicle speed, the wheel circumference must be specified using the following parameter.

Parameters of the vehicle speed display		
Parameter name	**Function**	**Unit of values**
APP_C_Tire_Outline	Setting the wheel circumference	in meters

Table 50: Parameter for setting the vehicle speed display.

11.7.2 State of Charge (SOC)

The motor controller needs the information about the current SOC of the battery to calculate the remaining range and for display in the smartphone app. The motor controller typically receives this information via the CAN bus. If you use a battery without CAN bus, the motor controller can estimate the SOC from the measured battery voltage.

Switching between CAN bus and internal estimation is automatic. If the SOC is not received via the CAN bus, the internal estimation takes place automatically.

Measured values for state of charge (SOC)		
Parameter name	**Function**	**Unit of values**
SOC_State_of_Charge	Current SOC estimate	In percent
SOC_Remaining_Wh	remaining energy	In watt hours
SOC_Remaining_Capacity	capacity remaining	In mAh

Table 51: Measured values to state of charge (SOC).

The following parameters are used to adjust the SOC estimation:

Parameters for estimating the state of charge (SOC)		
Parameter name	**Function**	**Range of values**
SOC_C_Battery_Num_Serial_Cells	Serial number of cells in the cell assembly of the battery.	1 .. 12014 (default)
SOC_C_Battery_Capacity_Ah	Nominal capacity of the entire battery pack.	0 .. 100000 AH10 Ah (default)

Table 52: Parameters for estimating the state of charge (SOC).

Cell voltage-SOC characteristic

The estimation of the SOC is based on a cell voltage SOC characteristic. You can adjust the factory implemented characteristic (Samsung INR 18650 29E) to the cell chemistry used if necessary to increase the accuracy of the estimate.

Parameters of the cell voltage-SOC characteristic		
Parameter name	**Function**	**Range of values**
LUT_SOC_C_Cellvoltage_to_SOC_Lut_axis_P0 LUT_SOC_C_Cellvoltage_to_SOC_Lut_axis_P20	Axis of the lookup table from minimum cell voltage to maximum cell voltage	0 .. 5 V
LUT_SOC_C_Cellvoltage_to_SOC_Lut_Table_P0 LUT_SOC_C_Cellvoltage_to_SOC_Lut_Table_P20	Lookup table values from 0% SOC to 100% SOC.	0 .. 100%

Table 53: Parameter of the cell voltage-SOC characteristic.

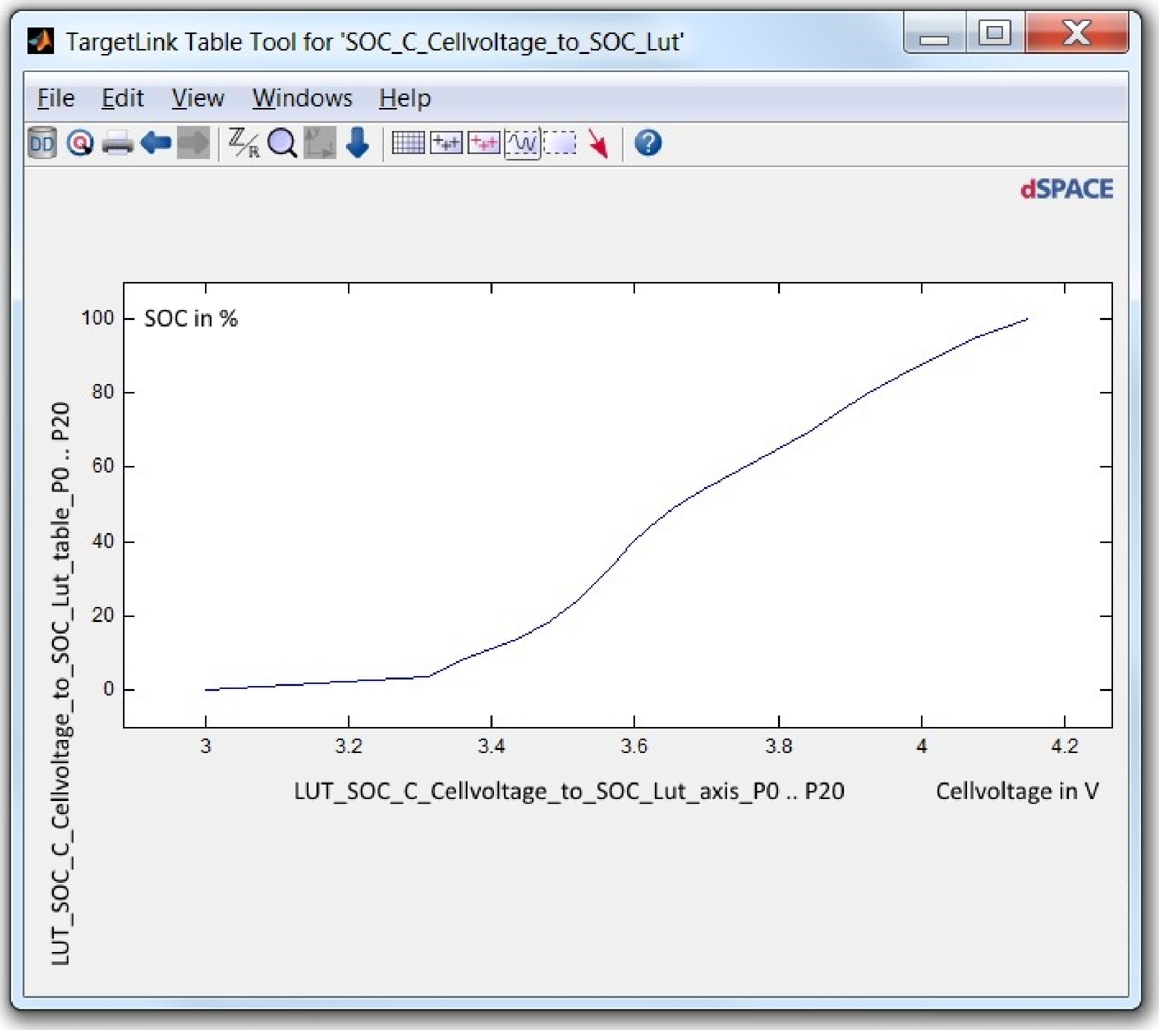


Figure 9: Cell voltage-SOC characteristic.

Attention: The values of the axis must be strictly monotonously increasing. Use all grid points on the axis and distribute the cell voltage only in the range from 0% SOC to 100% SOC. If you do not have enough measured values, calculate intermediate values yourself. In case of faulty settings, the controller outputs an EEPROM error in the error handler. Reset the controller to the factory settings for an example of a correct table setting.

11.7.3 Remaining range

The motor controller has a function for calculating the remaining range of a vehicle on the basis of past and current energy consumption. The energy currently available in the storage tank serves as the basis for calculation.

Display calculated remaining range		
Parameter name	**Function**	**Unit of values**
INFO_Remaining_Distance	Restreichweite.Wird used via CAN bus for display on the screen and Smartphone Connectivity for display in the smartphone app.	in kilometers

Table 54: Display the calculated remaining range.

The settings for the remaining range calculation are made after you have already set all other settings of your vehicle, since every change in power, torque and recuperation influences the fuel consumption of the vehicle.

The settings should be made in the following order:

- Reset the energy meter for consumption measurement
- Drive as many representative kilometers as possible in each ride mode. This means that your test track should be representative for later customer-oriented use.
- Suggestion: Choose a standard round with 50% city tour, 30% overland, 10% uphill, 10% downhill. Repeat this lap in each ride mode for at least one full battery charge per ride mode. This gives you meaningful consumption readings.
- Enter the measured average consumption as the standard consumption for each ride mode.
- The remaining range of coverage is now calculated on the basis of your determined typical average consumption and the measured consumption.

Parameters and measured values for setting the remaining range calculation		
Parameter name	**Function**	**Range of values**
INFO_C_Reset_Consumption	With this parameter the reset of the energy meter can be requested. The energy counter can also be reset from the smartphone. To do this, press the "Reset" button repeatedly for approx. 5 seconds (press 10 times within 5 seconds)	0/1
INFO_M_Meas_Consumption_Ride_Mode_0	This reading shows the actual measured consumption in watt-hours per kilometer (Wh/km) in ride mode 0	In Watt hours per kilometer
INFO_M_Meas_Consumption_Ride_Mode_1	This reading shows the actual measured consumption in watt-hours per kilometer (Wh/km) in ride mode 1	In Watt hours per kilometer
INFO_M_Meas_Consumption_Ride_Mode_2	This reading shows the actual measured consumption in watt-hours per kilometer (Wh/km) in ride mode 2	In Watt hours per kilometer
INFO_M_Meas_Consumption_Ride_Mode_3	This reading shows the actual measured consumption in watt-hours per kilometer (Wh/km) in ride mode 3	In Watt hours per kilometer
INFO_M_Meas_Consumption_Average	This reading displays the measured consumption in watt-hours per kilometre (Wh/km) as the average value from all ride modes, whereby the distance travelled in each ride mode influences the percentage composition of the consumption value.	In Watt hours per kilometer
INFO_C_Typical_Consumption_Ride_Mode_0	This parameter is used to set the typical consumption of the vehicle in ride mode 0.	0 .. 10 000 Wh/km
INFO_C_Typical_Consumption_Ride_Mode_1	This parameter is used to set the typical consumption of the vehicle in ride mode 1.	0 .. 10 000 Wh/km
INFO_C_Typical_Consumption_Ride_Mode_2	This parameter is used to set the typical consumption of the vehicle in ride mode 2.	0 .. 10 000 Wh/km
INFO_C_Typical_Consumption_Ride_Mode_3	This parameter is used to set the typical consumption of the vehicle in ride mode 3.	0 .. 10 000 Wh/km

INFO_C_Remaining_Distance_Reserve	Determination of a reserve that is deducted from the calculated remaining range value.	0 .. 10000 km
INFO_C_Remaining_Distance_Max	Defining a meaningful upper limit for the displayed range of coverage. If the calculated remaining range of coverage exceeds this value,"---" is displayed.	0 .. 10000 km

Table 55: Parameters and measured values for setting the remaining range calculation.

Adaptive remaining range

The calculation of the remaining range is adaptive in relation to the SOC of the battery.

If the battery is fully charged, only the typical consumption in the respective ride mode is used to calculate the remaining range. This has the following advantages:

- The remaining range display can be set exactly by the vehicle manufacturer.
- Deviations in a fleet of vehicles are minimized.
- Display of a typical range independent of the previous driver of the vehicle.

For a half discharged battery, the typical consumption and the actual consumption from the respective ride mode are included to 50% each in the remaining range calculation. With a largely discharged battery below 10% SOC, only the actually measured consumption in the respective ride mode is included in the remaining range calculation.

In addition, the average consumption from all modes can be combined with the average consumption from all modes via a mix ratio.

Setting the adaptive remaining range via the mix ratio of the average consumption		
Parameter name	**Function**	**Range of values**
SYS_INFO_C_Typical_Consumption_Mix_Ratio	Determination of a mixture of the measured consumption per ride mode and the average consumption from all ride modes. Example: 0 = 100% of the measured consumption of a certain ride mode is used for calculating the remaining range. The display can vary greatly between modes, especially when the battery is flat, when the measured consumption becomes particularly relevant. 1 = 100% of the average consumption from all modes is used. The display fluctuates only slightly when the ride mode is switched, but is also less adaptive. The factory setting for the mixture is 0.5.	0 .. 1 0.5 (default)
SYS_INFO_Consumption_Mixed	Measured value for mixed consumption. The emptier the battery, the greater the proportion of this consumption value compared to typical consumption.	

Table 56: Setting the adaptive remaining range via the mix ratio of the average consumption.

11.7.4 Measured values current, voltage, power consumption, time

The following measurements are helpful for the fine tuning:

Measured values for current, voltage, energy, consumption, time		
Parameter name	**Function**	**Range of values**
INFO_Remaining_Distance	Calculated remaining range	in kilometers
INFO_Consumption_Mixed	Average consumption	In Watt hours per kilometer
INFO_Consumption_Act	Current consumption	In Watt hours per kilometer
INFO_Consumption_Ave_Trip	Consumption since trip reset	In Watt hours per kilometer
INFO_Rotor_Speed	Motor speed (mechanical)	In revolutions per second
INFO_Rotor_Speed_el	Motor speed (electric)	In revolutions per second
INFO_Vehicle_Speed	Vehicle speed	In kilometers per hour
INFO_Vehicle_Speed_Average	Average speed	in volts
INFO_Voltage_DC_Link	DC link voltage	in volts
INFO_DC_Current	Battery current	in amperes
INFO_Motor_Current	Motor current	in amperes
INFO_Motor_Current_Id	d-current	in amperes
INFO_Motor_Current_Iq	q-current	in amperes
INFO_Power_El	Electrical power	in watts
INFO_Temp_BMS	Temperature of the BMS output stage	In degrees Celsius
INFO_Temp_Cells	Temperature of the battery cells	In degrees Celsius
INFO_Average_Power_Trip	Average power since trip reset	in watts
INFO_Phase_Voltage_Rel	Relative phase voltage relative to the current dc link voltage	0 .. 1
INFO_Flux_Angle	Flux-angle as the ratio of d-and q-voltage voltage	in degrees
INFO_Time_Driving_Since_Reset	Driving time in this ignition cycle	in seconds
INFO_Time_Driving_Trip	Driving time since trip reset	in seconds
INFO_Time_Driving_Total	Driving time (lifetime)	in seconds
INFO_Time_PowerOn_Since_Reset	Time in this ignition cycle	in seconds
INFO_Time_PowerOn_Total	Lifetime	in seconds
INFO_ODO_Trip_Kilometers	Mileage since trip reset	in kilometers
INFO_ODO_Total_Kilometers	Mileage (lifetime)	in kilometers
INFO_Ah_Neg	Electricity meters for recovered electricity	In ampere-hours
INFO_Ah_Pos	Electricity meters for consumed electricity	In ampere-hours

Table 57: Measured values for current, voltage, energy, consumption, time.

11.8 CAN bus communication

11.8.1 General Settings

CAN bus settings		
Parameter name	**Function**	**Range of values**
CAN_C_Baudrate_Select	baud rate	1 = 125kb/s 2 = 500kb/s 3 = 1000kb/s

Table 58: CAN bus settings.

11.8.2 Received messages

EXT_Torque_Control_01 (0x111)

The motor control can be remote controlled via the message EXT_Torque_Control_01 with ID 0x111. The control unit checks the reception of the message at intervals of 1 ms. There is no fixed cycle time in which the message is expected. Typical cycle times are 1 ms - 100 ms. A receive timeout is detected after 250 ms, unless otherwise set. The byte arrangement corresponds to the Intel format.

Structure of the message EXT_Torque_Control_01 (0x111)						
signal name	**function**	**start bit**	**length**	**value type**	**factor**	**Range of values**
MC_Alive_Counter	message count	0	4	unsigned	1	0 .. 15
MC_State_Request	mode request	8th	1	unsigned	1	0 .. 1
MC_Ride_Mode	Ride mode selection	16	2	unsigned	1	0 .. 3
MC_ROC_Start	Start automatic Motoranlernvorgang	18	1	unsigned	1	0 .. 1
MC_Boost_Enable	Enable advanced system limits	19	1	unsigned	1	0 .. 1
MC_Reverse_Gear	Reverse selection	20	1	unsigned	1	0 .. 1
MC_Torque_Setpoint	Torque requirement	32	16	signed	0.00390625	-100 .. 100%
MC_Rotor_Speed_Max	Speed limit for forward and reverse directions	48	16	signed	0.03125	0 .. 1000/s

Table 59: Structure of the message EXT_Torque_Control_01 (0x111)

EXT_Immo_Control_01 (0x1B6)

The motor control can be remote controlled via the message EXT_Immo_Control_01 with ID 0x1B6. The message is expected with a cycle time of 1000 ms to 100 ms. The byte arrangement corresponds to the Intel format.

Structure of the message EXT_Immo_Control_01 (0x1B6)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
Immo_Unlock_Request	Unlock code immobilizer	0	32	unsigned	1	0 .. 4294967295

Table 60: Structure of the message EXT_Immo_Control_01 (0x1B6).

BMS_Info_02 (0x172)

Via the message BMS_Info_02 with ID 0x172, the motor control unit can receive information on the battery charge status. The message is expected with a cycle time of 1000 ms. The byte arrangement corresponds to the Intel format.

Structure of the message BMS_Info_02 (0x172)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
BMS_State	BMS status	0	16	unsigned	1	0 .. 65535
BMS_SOC	SOC	16	8th	unsigned	1	0 .. 100%
BMS_State_of_Health	Aging state (SOH)	24	8th	unsigned	1	0 .. 100%
BMS_Remaining_Capacity	capacity remaining	32	16	unsigned	1	0 .. 65535 mAh
BMS_Fullcharge_Capacity	Capacity at 100% SOC	19	1	unsigned	1	0 .. 65535 mAh

Table 61: Structure of the message BMS_Info_02 (0x172).

BMS_Info_08 (0x178)

Via message BMS_Info_08 with ID 0x178, the motor control can receive information on the system limits of the battery. The message is expected with a cycle time of 10 ms. The byte arrangement corresponds to the Intel format.

Structure of the message BMS_Info_08 (0x178)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
BMS_08_BZ	message count	0	4	unsigned	1	0 .. 15
BMS_Max_Charge	Maximum permissible charging current	8th	16	signed	0.015625	-500 .. 500 A
BMS_Max_Discharge	Maximum permissible discharge	24	16	signed	0.015625	-500 .. 500 A
BMS_Max_Voltage	Charge voltage	40	8th	unsigned	1	0 .. 255 V
BMS_Min_Voltage	discharge voltage	48	8th	unsigned	1	0 .. 255 V
BMS_Pending_HV_Shutdown	Announcement 48V shutdown in 2 sec.	57	1	unsigned	1	0/1
BMS_Pending_Bordnet_Shutdown	Announcement 12V shutdown in 2 sec.	58	1	unsigned	1	0/1
CAN_BMS_PushButton_ShortPress_Detected	short button press detected	59	1	Unsigned	1	0 / 1
CAN_BMS_PushButton_LongPress_Detected	long button press detected	60	1	Unsigned	1	0 / 1
CAN_BMS_PushButton_SuperLongPress_Detected	super long button press detected	61	1	Unsigned	1	0 / 1

CAN_BMS_PushButton_SuperLongPress_Ongoing	ongoging button press detected	62	1	Unsigned	1	0 / 1

Table 62: Structure of the message BMS_Info_08 (0x178).

11.8.3 Sent messages

MC_APP_01 (0x1F0)

The message is sent with a cycle time of 100 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_APP_01 (0x1F0)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
APP_V_Ref	vehicle speed	0	16	signed	0.01	-327.68 .. 327.67 km/h
Ride_Mode	ride mode	16	2	unsigned	1	0 .. 3

Table 63: Structure of the message MC_APP_01 (0x1F0).

MC_APP_02 (0x1F1)

The message is sent with a cycle time of 100 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_APP_02 (0x1F1)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
APP_Remaining_Distance	Residual range	0	16	unsigned	1	0 .. 65535 km
APP_SOC	SOC	16	8th	unsigned	1	0 .. 100%
APP_Total_Distance	mileage	24	24	unsigned	1	0 .. 16777216 km
APP_Trip_Distance	Trip Mileage	48	16	unsigned	1	0 .. 65535 km

Table 64: Structure of the message MC_APP_02 (0x1F1).

MC_Boost_01 (0x1F4)

The message is sent with a cycle time of 100 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_Boost_01 (0x1F4)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
Boost_Info	Bit 0 = Boost available Bit 1 = usable Boost Bit 2 = Boost fully charged Bit 3 = Advanced System limits active Bit 4 = Boost aborted Bit 5 = Boost shortly not avail. Bit 6 = Boost is charged Bit 7 = Boost is discharged	0	8th	unsigned	1	0 .. 255
Boost_Available_Rel	Relative state of charge boost memory	8th	8th	unsigned	1	0 .. 100%
Boost_Available_Abs_As	Absolute state of charge boost	16	16	unsigned	1	0 .. 65535 As

	memory					

Table 65: Structure of the message MC_Boost_01 (0x1F4).

MC_Current_01 (0x1BA)

The message is sent with a cycle time of 10 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_Current_01 (0x1BA)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
Iq_Current	q-current	0	16	signed	0.01	-327.68 327.67 .. A
Id_Current	d flow	16	16	signed	0.01	-327.68 327.67 .. A
DC_Current	DC	32	16	signed	0.01	-327.68 327.67 .. A
DC_Voltage	DC voltage	48	16	unsigned	0.01	0 .. 655.35 V

Table 66: Structure of the message MC_Current_01 (0x1BA).

MC_Energy_01 (0x1F2)

The message is sent with a cycle time of 100 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_Energy_01 (0x1F2)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
Consumption_Average	Average consumption	0	16	unsigned	0.01	0 .. 65535 Wh/km
Total_Ah_Used	Verbauchte amount of energy	16	24	unsigned	0.1	0 .. 1,677,721 Ah
Total_Ah_Regen	Recuperated energy quantity	40	24	unsigned	0.1	0 .. 1,677,721 Ah

Table 67: Structure of the message MC_Energy_01 (0x1F2).

MC_Errorflags_01 (0x1BC)

The message is sent with a cycle time of 100 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_Errorflags_01 (0x1BC)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
ERR_E_Hardware_Init	See Construction fault diagnosis function	0	1	unsigned	1	0/1
ERR_E_Powerstage_Monitoring	See Construction fault diagnosis function	1	1	unsigned	1	0/1
ERR_E_I_Max_DC	See Construction fault diagnosis function	2	1	unsigned	1	0/1

ERR_E_U_HV_Min	See Construction fault diagnosis function	3	1	unsigned	1	0/1
ERR_E_U_HV_Max	See Construction fault diagnosis function	4	1	unsigned	1	0/1
ERR_E_FET_Temp_Max	See Construction fault diagnosis function	5	1	unsigned	1	0/1
ERR_E_Throttle_Monitoring	See Construction fault diagnosis function	6	1	unsigned	1	0/1
ERR_E_Block_Det	See Construction fault diagnosis function	7	1	unsigned	1	0/1
ERR_E_AWD	See Construction fault diagnosis function	8th	1	unsigned	1	0/1
ERR_E_Motor_Sensor	See Construction fault diagnosis function	9	1	unsigned	1	0/1
ERR_E_Current_Sensor	See Construction fault diagnosis function	10	1	unsigned	1	0/1
ERR_E_Rotor_Speed_Limit	See Construction fault diagnosis function	11	1	unsigned	1	0/1
ERR_E_Current_Setpoint_Mon	See Construction fault diagnosis function	12	1	unsigned	1	0/1
ERR_E_Rotor_Offset_Calibration	See Construction fault diagnosis function	13	1	unsigned	1	0/1
ERR_E_EEPROM	See Construction fault diagnosis function	14	1	unsigned	1	0/1
ERR_E_CAN_Timeout	See Construction fault diagnosis function	15	1	unsigned	1	0/1
ERR_E_BMS_Trig_HV_Off	See Construction fault diagnosis function	16	1	unsigned	1	0/1
ERR_E_I_Max_AC	See Construction fault diagnosis function	17	1	unsigned	1	0/1

ERR_E_HW_Var_Code	See Construction fault diagnosis function	18	1	unsigned	1	0/1
ERR_E_Flux_Angle	See Construction fault diagnosis function	19	1	unsigned	1	0/1
ERR_E_Temp_MCU_Max	See Construction fault diagnosis function	20	1	unsigned	1	0/1
ERR_E_CAN_MC	See Construction fault diagnosis function	21	1	unsigned	1	0/1
ERR_E_Brake_Monitoring	See Construction fault diagnosis function	22	1	unsigned	1	0/1
ERR_E_Phase_Connection	See Construction fault diagnosis function	23	1	unsigned	1	0/1
ERR_E_U_LV_Min	See Construction fault diagnosis function	24	1	unsigned	1	0/1
ERR_E_Temp_Motor_Max	See Construction fault diagnosis function	25	1	unsigned	1	0/1
ERR_E_Temp_Aux_Max	See Construction fault diagnosis function	26	1	unsigned	1	0/1
Previous_Hardware_Init	See Construction fault diagnosis function	32	1	unsigned	1	0/1
Previous_Powerstage_Monitoring	See Construction fault diagnosis function	33	1	unsigned	1	0/1
Previous_I_Max_DC	See Construction fault diagnosis function	34	1	unsigned	1	0/1
Previous_U_HV_Min	See Construction fault diagnosis function	35	1	unsigned	1	0/1
Previous_U_HV_Max	See Construction fault diagnosis function	36	1	unsigned	1	0/1
Previous_FET_Temp_Max	See Construction fault diagnosis function	37	1	unsigned	1	0/1
Previous_Throttle_Monitoring	See Construction fault diagnosis function	38	1	unsigned	1	0/1

Previous_Block_Det	See Construction fault diagnosis function	39	1	unsigned	1	0/1
Previous_AWD	See Construction fault diagnosis function	40	1	unsigned	1	0/1
Previous_Motor_Sensor	See Construction fault diagnosis function	41	1	unsigned	1	0/1
Previous_Current_Sensor	See Construction fault diagnosis function	42	1	unsigned	1	0/1
Previous_Rotor_Speed_Limit	See Construction fault diagnosis function	43	1	unsigned	1	0/1
Previous_Current_Setpoint_Mon	See Construction fault diagnosis function	44	1	unsigned	1	0/1
Previous_Rotor_Offset_Calib	See Construction fault diagnosis function	45	1	unsigned	1	0/1
Previous_EEPROM	See Construction fault diagnosis function	46	1	unsigned	1	0/1
Previous_CAN_Timeout	See Construction fault diagnosis function	47	1	unsigned	1	0/1
Previous_BMS_Trig_HV_Off	See Construction fault diagnosis function	48	1	unsigned	1	0/1
Previous_I_Max_AC	See Construction fault diagnosis function	49	1	unsigned	1	0/1
Previous_HW_Var_Code	See Construction fault diagnosis function	50	1	unsigned	1	0/1
Previous_Flux_Angle	See Construction fault diagnosis function	51	1	unsigned	1	0/1
Previous_Temp_MCU_Max	See Construction fault diagnosis function	52	1	unsigned	1	0/1
Previous_CAN_MC	See Construction fault diagnosis function	53	1	unsigned	1	0/1
Previous_Brake_Monitoring	See Construction fault diagnosis	54	1	unsigned	1	0/1

	function					
Previous_Phase_Connection	See Construction fault diagnosis function	55	1	unsigned	1	0/1
Previous_U_LV_Min	See Construction fault diagnosis function	56	1	unsigned	1	0/1
Previous_Temp_Motor_Max	See Construction fault diagnosis function	57	1	unsigned	1	0/1
Previous_Temp_Aux_Max	See Construction fault diagnosis function	58	1	unsigned	1	0/1

Table 68: Structure of the message MC_Errorflags_01 (0x1BC).

MC_Grid_ICS (0x90)

The message is sent with a cycle time of 10 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_Grid_ICS (0x90)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
ICS_BZ	message count	0	8th	unsigned	1	0 .. 255
ICS_Grid_Current	Measured current consumer	8th	16	signed	0.03125	-1000 .. 1000 A
ICS_Grid_Voltage	Measured voltage across the load	23	14	unsigned	0.015625	0 .. 128 V
ICS_Charge_Plug_Detection	Not implemented	38	2	unsigned	1	0 .. 3
ICS_Sensor_State	Not implemented	40	4	signed	1	0 .. 3
ICS_Sensor_Type	Not implemented	44	4	signed	1	0 .. 15
ICS_TEMP_Sensor	Not implemented	48	8th	unsigned	1 Offset -30	-30 .. 200 ° C
ICS_TEMP_Charge_Plug	Not implemented	56	8th	unsigned	1 Offset -30	-30 .. 200 ° C

Table 69: Structure of the message MC_Grid_ICS (0x90).

MC_Prod_Data_01 (0x601)

The message is sent with a cycle time of 1000 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_Prod_Data_01 (0x601)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
Prod_SW_Version	software version	0	32	unsigned	1	0 .. 4294967295
Prod_SW_Revision	software revision	32	32	unsigned	1	0 .. 4294967295

Table 70: Structure of the message MC_Prod_Data_01 (0x601).

MC_Prod_Data_02 (0x602)

The message is sent with a cycle time of 1000 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_Prod_Data_02 (0x602)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
Prod_Dataset_UserID	Record Creator User ID	0	16	unsigned	1	0 .. 65535
Prod_Dataset_yyMMddHHmm	Record Creator Date code	16	32	unsigned	1	0 .. 4294967295
Prod_Dataset_ssff	Record Creator Date code	48	16	unsigned	1	0 .. 65535

Table 71: Structure of the message MC_Prod_Data_02 (0x602).

MC_Prod_Data_03 (0x603)

The message is sent with a cycle time of 1000 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_Prod_Data_03 (0x603)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
Prod_Info_1	production code	0	32	unsigned	1	0 .. 4294967295

Table 72: Structure of the message MC_Prod_Data_03 (0x603).

MC_Prod_Data_04 (0x604)

The message is sent with a cycle time of 1000 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_Prod_Data_04 (0x604)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
Prod_HW_ID1	Hardware ID	0	32	unsigned	1	0 .. 4294967295
Prod_HW_ID2	Hardware ID	32	32	unsigned	1	0 .. 4294967295

Table 73: Structure of the message MC_Prod_Data_04 (0x604).

MC_State_01 (0x2B9)

The message is sent with a cycle time of 10 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_State_01 (0x2B9)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
Rotor_Speed	Motor speed	0	16	signed	0.025	-819.2 .. 819 175 1/s
Motor_Current	motor current	16	16	signed	0.01	-327.68 327.67 .. A
State_Active	State of the current	32	1	unsigned	1	0/1

	regulation					
Error_Active	Error has occurred	33	1	unsigned	1	0/1
Derating_Active	Current limitation active	34	1	unsigned	1	0/1
ROC_Ongoing	Motor runs teaching	35	1	unsigned	1	0/1
ROC_Successful	Engine successfully trained	36	1	unsigned	1	0/1
Internal_State_Request	Software internal request for activation of the current regulation	37	1	unsigned	1	0/1
Ride_Mode	ride mode	38	2	unsigned	1	0 .. 3
Derating_Temp_MCU	See Derating information	48	1	unsigned	1	0/1
Derating_Curr_DC_Pos	See Derating information	49	1	unsigned	1	0/1
Derating_Curr_DC_Neg	See Derating information	50	1	unsigned	1	0/1
Derating_DC_Link_Voltage_Max	See Derating information	51	1	unsigned	1	0/1
Derating_DC_Link_Voltage_Min	See Derating information	52	1	unsigned	1	0/1
Derating_Temp_Motor	See Derating information	53	1	unsigned	1	0/1
Derating_Temp_Powerstage	See Derating information	54	1	unsigned	1	0/1
Derating_Rotor_Speed	See Derating information	55	1	unsigned	1	0/1

Table 74: Structure of the message MC_State_01 (0x2B9).

MC_Temperature_01 (0x1BD)

The message is sent with a cycle time of 500 ms. The byte arrangement corresponds to the Intel format.

Structure of the message MC_Temperature_01 (0x1BD)						
Signal name	**Function**	**Start bit**	**Length**	**Value type**	**Factor**	**Range of values**
Temp_Powerstage_Max	Power unit temperature	0	16	signed	1	-32768 .. 32767 ° C
Temp_Motor	motor temperature	16	16	signed	1	-50 .. 250 ° C
Temp_MCU	Microcontroller temperature	32	16	signed	1	-50 .. 250 ° C

Table 75: Structure of the message MC_Temperature_01 (0x1BD).

11.8.4 Definition of CAN message ID

The identifiers of the described CAN messages can be defined via the following parameters. To reduce the bus load, the sending of a message can be deactivated.

Parameters to determine CAN IDs message		
Signal name	**Function**	**Start bit**
CAN_C_ID_90	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_111	Identifier for this message as a decimal	1 .. 2047: Sets the ID of the message
CAN_C_ID_160	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_171	Identifier for this message as a decimal	1 .. 2047: Sets the ID of the message
CAN_C_ID_172	Identifier for this message as a decimal	1 .. 2047: Sets the ID of the message
CAN_C_ID_176	Identifier for this message as a decimal	1 .. 2047: Sets the ID of the message
CAN_C_ID_178	Identifier for this message as a decimal	1 .. 2047: Sets the ID of the message
CAN_C_ID_1B6_RX	Identifier for this message as a decimal	1 .. 2047: Sets the ID of the message
CAN_C_ID_1B6_TX	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_1BA	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_1BC	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_1BD	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_1F0	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_1F1	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_1F2	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_1F4	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_206	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_207	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_209	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_2B9	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_305	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_306	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message

CAN_C_ID_310	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_521	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_601	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_602	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_603	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message
CAN_C_ID_604	Identifier for this message as a decimal	0: Disables sending the message 1 .. 2047: Sets the ID of the message

Table 76: Parameter to determine CAN message IDs.

11.9 Smartphone App

The display of the smartphone app is comparable to the instrument cluster of a vehicle. It displays all data relevant to driving. However, it also has other functions. For example, you can switch the ride mode via the smartphone app or save your driving data in a log file.

11.9.1 Install smartphone app

How to find the smartphone app:

- Apple/App Store: "eBike app" developers FRIWO Gerätebau GmbH.
- Google/Play Store: "Emerge EV app (eBike App)", developers FRIWO Gerätebau GmbH.

Alternatively you can find a link on our website: www.emerge-motorering.de

11.9.2 Activate Smartphone Connectivity

The Smartphone Connectivity can be manually deactivated by the following parameters or activated depending on the operational readiness.

Enable Smartphone connection and disable		
Parameter name	**Function**	**Range of values**
BLE_C_s_Enable_BLE	The Smartphone Connectivity can be activated/deactivated. 0 = 1 = Smartphone Connectivity is not activated Smartphone Connectivity is enabled (default) 2 = Smartphone Connectivity is only activated when the motor controller is operable and has been unlocked via the CAN bus.	0 .. 21 (default)

Table 77: Enable Smartphone connection on and off.

11.10 Flux-weakening

Flux-weakening is a special operating range in which the motor can be accelerated to many times its natural idling speed.

The flux-weakening is generally used to:

- Increase performance in the high speed range.
- Increase the natural idling speed of the motor.
- Increase the efficiency of hybrid synchronous motors in the base speed range. For example, by the Maximum-Torque-Per-Ampere (MTPA) strategy. This is not described in this document.

The following problems may occur when using field attenuation:

- Over speed can cause the motor to burst, tires to burst or other mechanical damage to the drive.
- When the current control is deactivated in the over speed range, sudden overvoltage occurs, as the motor can generate a multiple of its natural induction voltage at the motor phases. See "Active short-circuit of the power unit in the event of a fault".
- The motor can overheat and demagnetize

Check with the motor manufacturer for the permissible or recommended strength of the flux-weakening.

11.10.1 Automatic flux-weakening function

The motor control offers the possibility to increase the speed limit and the performance in the high speed range. The user must set an upper limit for the d-current for each ride mode.

Parameters for setting the maximum flux-weakening current		
Parameter name	**Function**	**Range of values**
APP_C_Ride_Mode_x_Max_Flux_Weakening_Current	Maximum flux-weakening current. Oriented on the thermal performance of the motor and the maximum permissible speed of the drive.	-150 .. 0 A -5 A (default)

Table 78: Parameters for setting the maximum flux-weakening current.

Use the following settings to protect your drive from electrical and mechanical damage:

Parameters for setting protection functions against overvoltage in flux-weakening		
Parameter name	**Function**	**Range of values**
ERR_C_Rotor_Speed_Limit	Set a speed limit. In unexpected exceeding the power unit is deactivated	0 .. 2000 1/s 2000 1/s (default)
SET_C_PS_Error_Reaction	Activate the active short circuit to protect the power unit against overvoltage	0/1

Table 79: Parameters for setting protection functions against overvoltage in flux-weakening.

11.10.2 Phase voltage reserve controller

The d-current setpoint for the field-oriented current controller is determined by a superimposed phase voltage reserve controller. This controls the required amount of d-current so that the relative phase voltage does not exceed an adjustable limit value. Thus q-current can always flow. If no q current is requested, the d current is automatically reduced. The reset of the d-current is additionally delayed by a rate limiter, so that no sudden voltage jumps at the output stage occur.

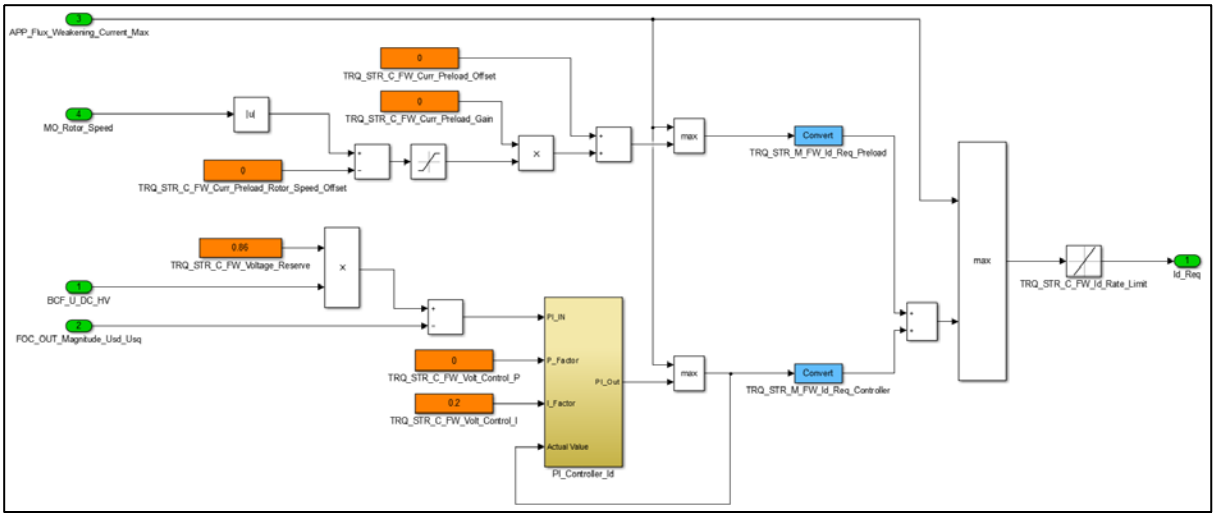


Figure 10: Function model of the phase voltage reserve controller.

Phase voltage reserve regulator with preload		
Parameter name	**Function**	**Range of values**
TRQ_STR_C_FW_Voltage_Reserve	Setpoint for the relative phase voltage reserve	0 .. 1 1/V
TRQ_STR_C_FW_Volt_Control_I	I component of the phase voltage reserve regulator	0 .. 1
TRQ_STR_C_FW_Volt_Control_P	P-component of the phase voltage reserve regulator	0 .. 100
TRQ_STR_M_FW_Id_Req_Controller	Measured value for the generated d-current command value from the phase voltage reserve controller	in amperes
TRQ_STR_C_FW_Curr_Preload_Gain	Gain factor of the preload function	-100 .. 0 1/s
TRQ_STR_C_FW_Curr_Preload_Offset	Offset of the preload function	-10 .. 0 1/s
TRQ_STR_C_FW_Curr_Preload_Rotor_Speed_Offset	Offset for the motor speed to shift the preload characteristic in the x direction to higher speeds	0 .. 2000 1/s
TRQ_STR_M_FW_Id_Req_Preload	Measured value of the generated d-current Setpoint from the feedforward control	in amperes
TRQ_STR_C_FW_Id_Rate_Limit_Down	Rate limit for entry into flux-weakening (increase of flux-weakening)	-100000 .. 1 A/s
TRQ_STR_C_FW_Id_Rate_Limit_Up	Rate limit for exit out of flux-weakening (decrease of flux-weakening)	1 .. 100 000 A/s

TRQ_STR_Id_Setpoint	q-current reference value for handover to the current regulator	-1000 .. 1000 A

Table 80: Phase voltage reserve regulator with preload.

11.10.3 q-current and d-current setpoint calculation

The d-current setpoint, which was calculated by the phase voltage reserve controller, is usually set by the field-oriented current controller. However, it may be necessary to reduce the q-current setpoint so as not to exceed the total motor current. The d-current has priority over the q-current requirement. The reduction of the q current setpoint is symmetrical and is based on the maximum permissible motor current.

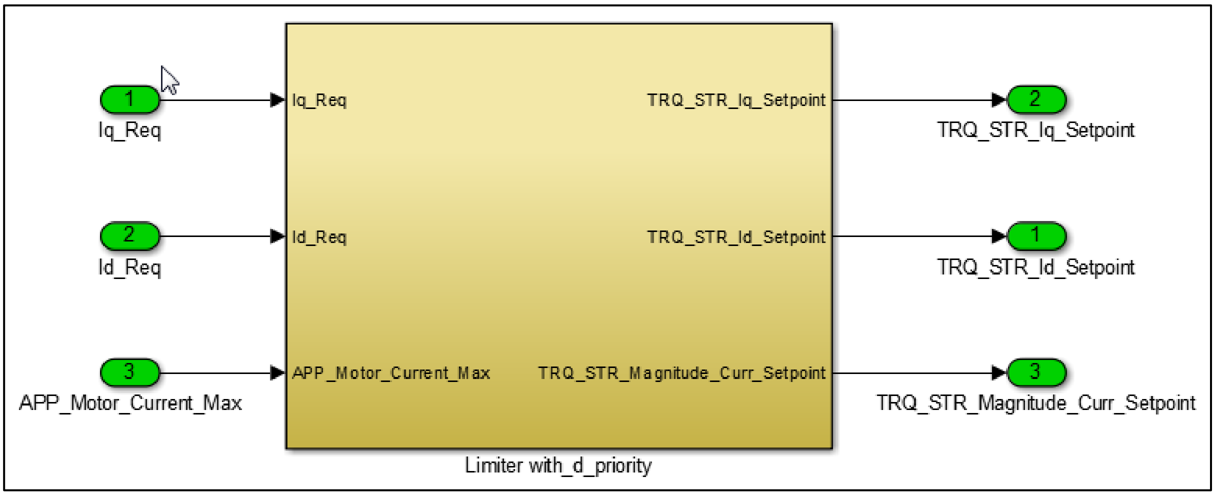


Figure 11: Function model of the q-current limitation via d-current priority

12 Behavior at startup

As soon as the supply voltage is activated, the motor control software starts checking the memory contents in the flash memory. All stored settings are protected against possible errors and changes by a checksum.

Communication via CAN bus and the smartphone app is operational within approx. 250 ms after startup. However, the output stage is initially inactive, i.e. current control is not activated. The transition to active current control is controlled by a state machine.

12.1 State Manager

The State Manager monitors the transition from the inactive state to the active state of the controller with active current control. An acoustic signal similar to the sound of a bell signals the activation of current control (for volume control of the activation sound, see "Activation sound.

Prerequisites for activating current control

Before current control is activated, the following conditions must be met.

Prerequisites for activating current control		
Parameter name	**Function**	**Range of values**
SM_PE_Mode_Req_Int	This measured value shows the internal software request for activation of the power unit. The measured value must indicate 1, otherwise either the manual request for activating the current control (SET_C_PS_Mode_Request) or the activation via the immobilizer is missing (see APP_C_Activation_Mode). After resetting the factory settings, the current control is automatically activated as soon as the other conditions are fulfilled.	1
MO_Rotor_Speed <SM_C_RPM_Enable_Treshold	The current motor speed must be below the activation threshold.	-
TRQ_DES_Trq_Req_Raw <SM_C_TRQ_Enable_Treshold	The user requested torque must be below the activation threshold.	-
SM_Throttle_Signal_Check_Okay	Throttle signal check completed (if enabled)	1
SM_Brake_Signal_Check_Okay	Check brake signal complete (if enabled)	1
ERR_Errorcode	There must be no active faults in the system.	-

Table 81: Prerequisites for activating current control.

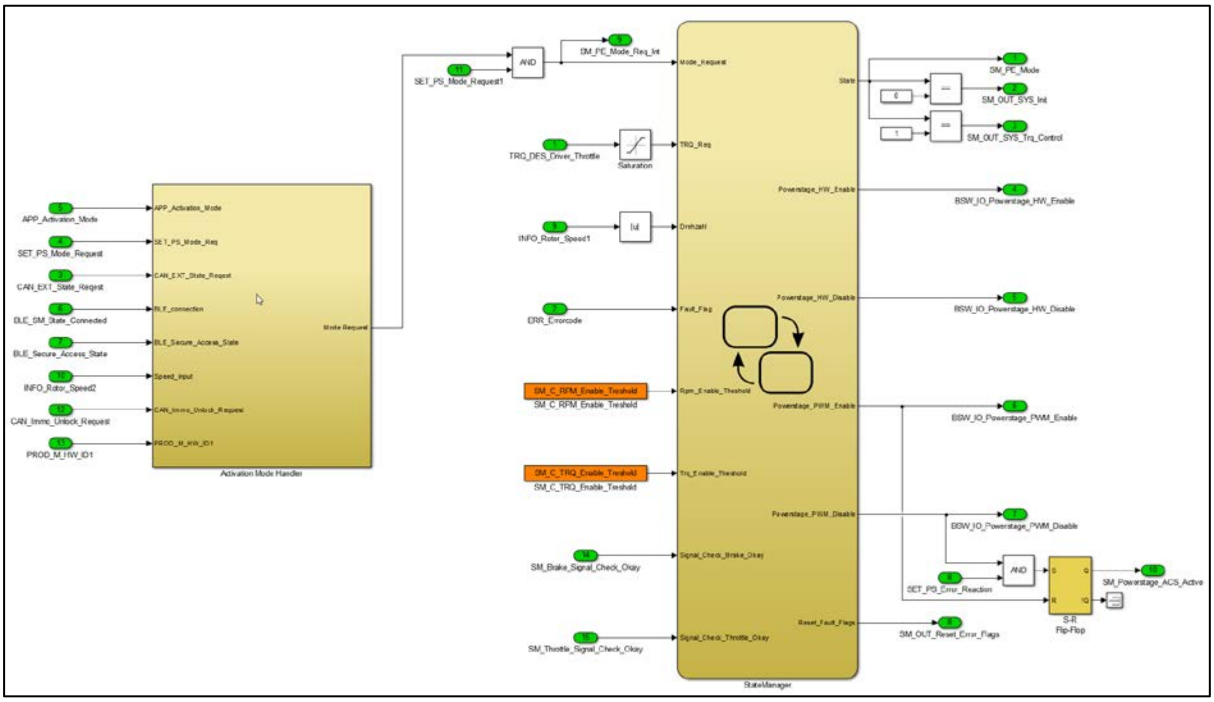


Figure 12: Function model of the State Manager

If an error is detected during a drive cycle, or if current control is deactivated via SET_C_PS_Mode_Request, the state manager deactivates current control and the error handler generates an entry in the error memory when an error is present.

When deactivating the current control, two variants can be selected:

- All MOSFETs of the power unit become high-impedance. This makes the motor phases "free floating", i.e. the motor can be turned without resistance. The engine can generate a dangerous overvoltage if it is driven at a speed above the idle speed (e.g. by driving in the flux-weakening range).
- All low-side MOSFETs are low impedance. This short-circuits the motor phases. The motor shaft is braked by the short-circuit current. The resulting induction voltage is short-circuited. This setting is recommended when using flux-weakening when over speed cannot be excluded.

Further details See "Active short-circuit of the output stage in the event of a fault".

12.1.1 Activation sound

As soon as the current control is active and the motor is ready for operation, an acoustic signal sounds. You can adjust the volume of this sound as follows.

Parameter activation Sound		
Parameter name	**Function**	**Range of values**
APP_C_Startup_Sound_Volume	Volume of the activation sound (acoustic signal when the vehicle is ready to drive).	0 .. 100% 50% (default)
APP_C_Startup_Sound_Replay_Speed	Playback speed of the sound. Changes the pitch of the sound.	0:01 .. 10 1 (default)

Table 82: Parameter activation sound.

12.1.2 Remote control via CAN bus/smartphone app

Various variants are available for activating/deactivating current control via the CAN bus or the smartphone app. The specification of the corresponding CAN bus signal "MC_State_Request", "Immo_Unlock_Request" or “BMS_Info_08” can be found in the chapter "Received Messages".

Parameters for selecting the activation of the torque control from different sources		
Parameter name	**Function**	**Range of values**
APP_C_Activation_Mode	0 = Manual control via SET_C_PS_Mode_Request, usually via USB 1 = Control via message 0x111 2 = Control via message 0x1B6 3 = Control via the smartphone app (after password verification) 4 = Control via message 0x1B6 in combination with meassage 0x111 5 = Control via message 0x178 from the battery (CAN_ BMS_PushButton_SupperLong_Press_Ongoing)	0 .. 3 0 (default)

Table 83: Parameters for selecting the activation of the torque control from various sources.

Separate control of the vehicle becomes operative and the power source

The motor controller can be controlled separately from the power source via the CAN bus. It is therefore possible to activate only the power source but leave the standby mode deactivated.

Two CAN-Bus messages (0x111 and 0x1B6) are necessary in order to generate an operative vehicle. These messages have different control mechanism, message 0x1B6 controls the current source and message 0x111 the vehicle readiness.

For this variant, the parameter "APP_C_Activation_Mode" must be set to the value "4". In addition, the activation method of the current source must be changed with the parameter "SM_C_BMS_Control_Mode". For this purpose, this parameter must be set to the value "3" so that the power source can be separately controlled without disturbing or influencing the driving readiness of the vehicle.

Parameters to select the activation of the power source from different sources		
Parameter name	**Function**	**Range of values**
SM_BMS_Control_Mode	0 = Manual activation of power source 1 = Power source always activated 2 = Power source activation with driving readiness 3 = Power source activation via message 0x1B6	0 .. 3 0 (default)

12.1.3 Activation of current control with the motor in motion

In some applications it is necessary to activate current control while the motor is in motion to ensure maximum availability of the drive.

To keep the current transient during the connection of the output stage as low as possible, the integral parts of the d-current controller and the q-current controller are pre-loaded with a voltage matching the motor speed, so that the output stage is activated exactly at the operating point of the current controller.

Ensure the following:

- To check activation with the motor rotating, start step by step, initially at low speeds. First test the activation of the output stage at low speeds.
- When activating the control, first check the current transient at low speeds and without active torque requirement, i.e. the motor should switch over to the active current control with as little load transients as possible.
- Use the automatic flux-linkage estimation described below.
- Adjust the automatic estimate manually so that the current transient during activation is as low as possible.

Automatic estimation of flux-linkage

The motor control provides a function for estimating the flux-linkage. Allow the motor to idle for a few seconds, i.e. without load and at maximum speed, and then reduce the torque requirement to 0% so that the motor can run down without load. The flux-weakening must be deactivated for this test, i.e. the maximum permissible flux-weakening current should be 0 A.

The measured value for the flux-linkage can be read via INFO_Motor_Psi_Estim. This value can then be used as the value for MO_C_Psi.

Parameters for the activation of the current regulation for a motor in motion		
Parameter name	**Function**	**Range of values**
SM_C_RPM_Enable_Treshold	Maximum motor speed (1/s) at the transition to the control. Start with low values!	0 .. 2000 1/s 1 1/s (default)
SM_C_TRQ_Enable_Treshold	Maximum torque request of the driver at transition to control. Increase the value if current control can also be activated under load.	0 .. 100% 0% (default)
INFO_Motor_Psi_Estim	Measured value for the estimated flux-linkage	0.00001 .. Vs 0999
MO_C_Psi	Flux-linkage of the motor. Calculation: = MO_Psi induction voltage/electrical speed	0.00001 .. Vs 0999 0.1 Vs (default)

Table 84: Parameters for the activation of the current regulation for a motor in motion.

12.1.4 Two-stage activation of the output stage

Before the transition to active current control, the throttle & brake signal can be checked.

This function serves to implement the rules from 2018 L1E approval regulations within the EU. Accordingly, a L1E vehicle requires a two-stage activation to become operative.

- Switch Ignition on first
- Then tap the brake

With the following parameters of the signal check can be parameterized:

Parameters for setting the two-stage activation for the throttle signal		
Parameter name	**Function**	**Range of values**
SM_C_Check_Throttle_Enable	Turns the throttle signal test on/off.	0/1 1 (default)
SM_C_Check_Throttle_Upper_Range_Enable	Switches the extended acceleration signal check on/off. When activated, the system also checks whether the acceleration signal can also be above SM_C_C_Check_Throttle_Threshold_High. This means that the driver must first press the accelerator pedal for 200ms, then release the accelerator pedal for 200ms to activate the control.	0/10 (default)
SM_C_Check_Throttle_Threshold_Low	Lower threshold value. The acceleration signal must be below this threshold for 200ms to activate.	0 .. 100% 0% (default)
SM_C_Check_Throttle_Threshold_High	Upper threshold value. The acceleration signal must first be above this threshold for 200ms and then below the threshold SM_C_C_Check_Throttle_Threshold_Low for 200ms. Only relevant if SM_C_C_Check_Throttle_Upper_Range_Enable is activated.	0 .. 100% 5% (default)

Table 85: Parameters for setting the two-stage activation for the throttle signal.

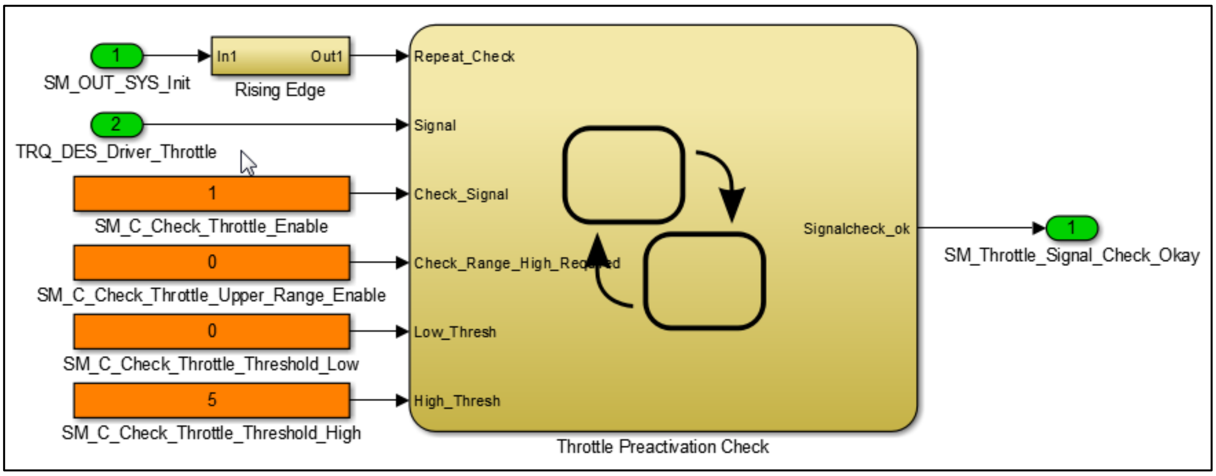


Figure 13: Function model for the throttle signal-Check

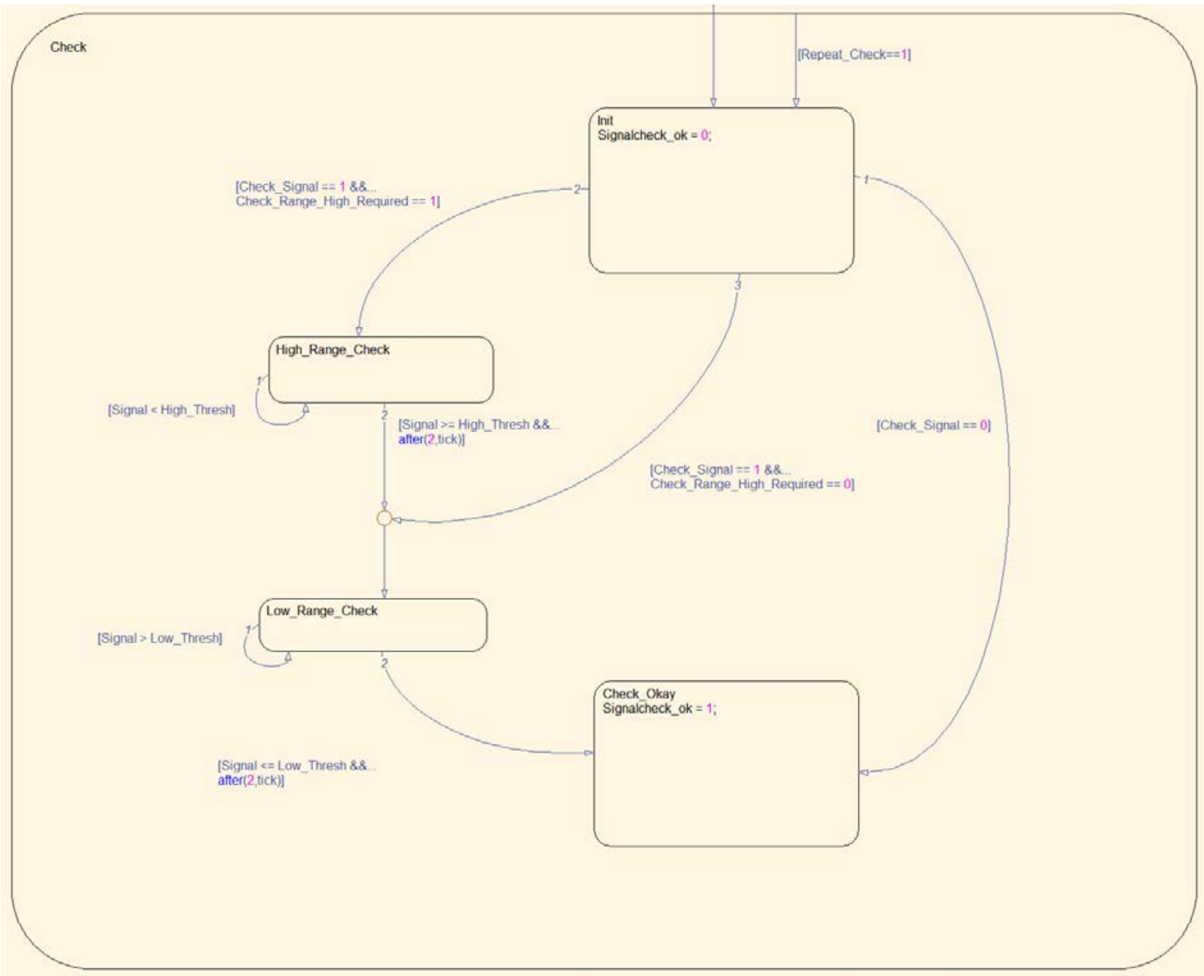


Figure 14: State machine model for the throttle signal check.

Parameters for setting the two-step activation of the brake signal		
Parameter name	**Function**	**Range of values**
SM_C_Check_Brake_Enable	Turns the brake signal test on/off.	0/1 1 (default)
SM_C_Check_Brake_Lower_Range_Enable	Switches the extended brake signal test on/off. When activated, it is also checked whether the brake signal can also be below SM_C_C_Check_ Brake _Threshold_Low. This means that the driver does not have to apply the brake for 200ms first, then confirm for 200ms. to activate the control.	0/11 (default)
SM_C_Check_ Brake _Threshold_Low	Lower threshold value. The brake signal must be below this threshold for 200ms to activate.	0 .. 100% 5% (default)
SM_C_Check_ Brake _Threshold_High	Upper threshold. For activation, the brake signal must first be above this threshold for 200ms and then below the threshold SM_C_C_Check_ Brake _Threshold_Low for 200ms. Only relevant if SM_C_C_Check_ Brake _Lower_Range_Enable is activated.	0 .. 100% 10% (default)

Table 86: Parameters for setting the two-step activation of the brake signal.

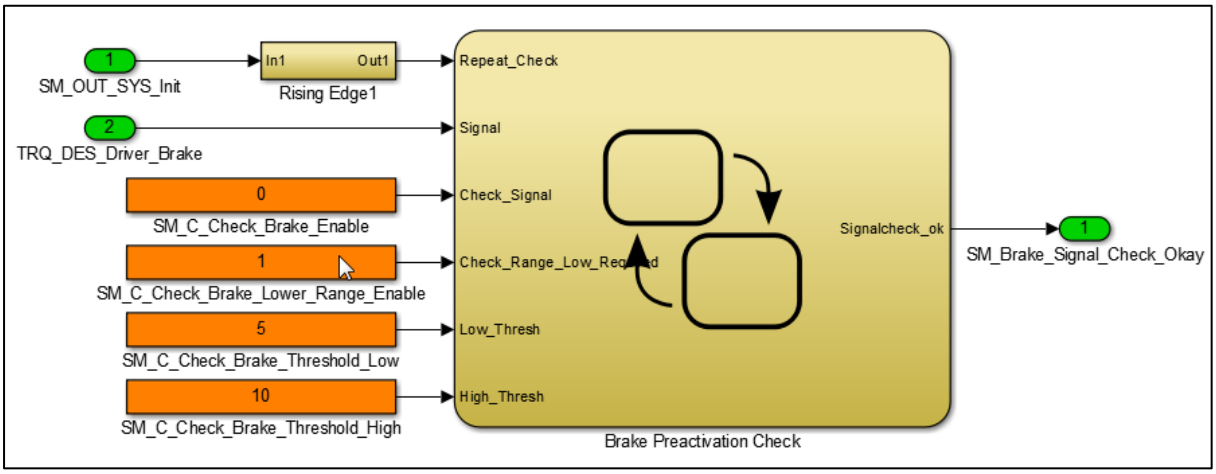


Figure 15: Function model for the brake signal check

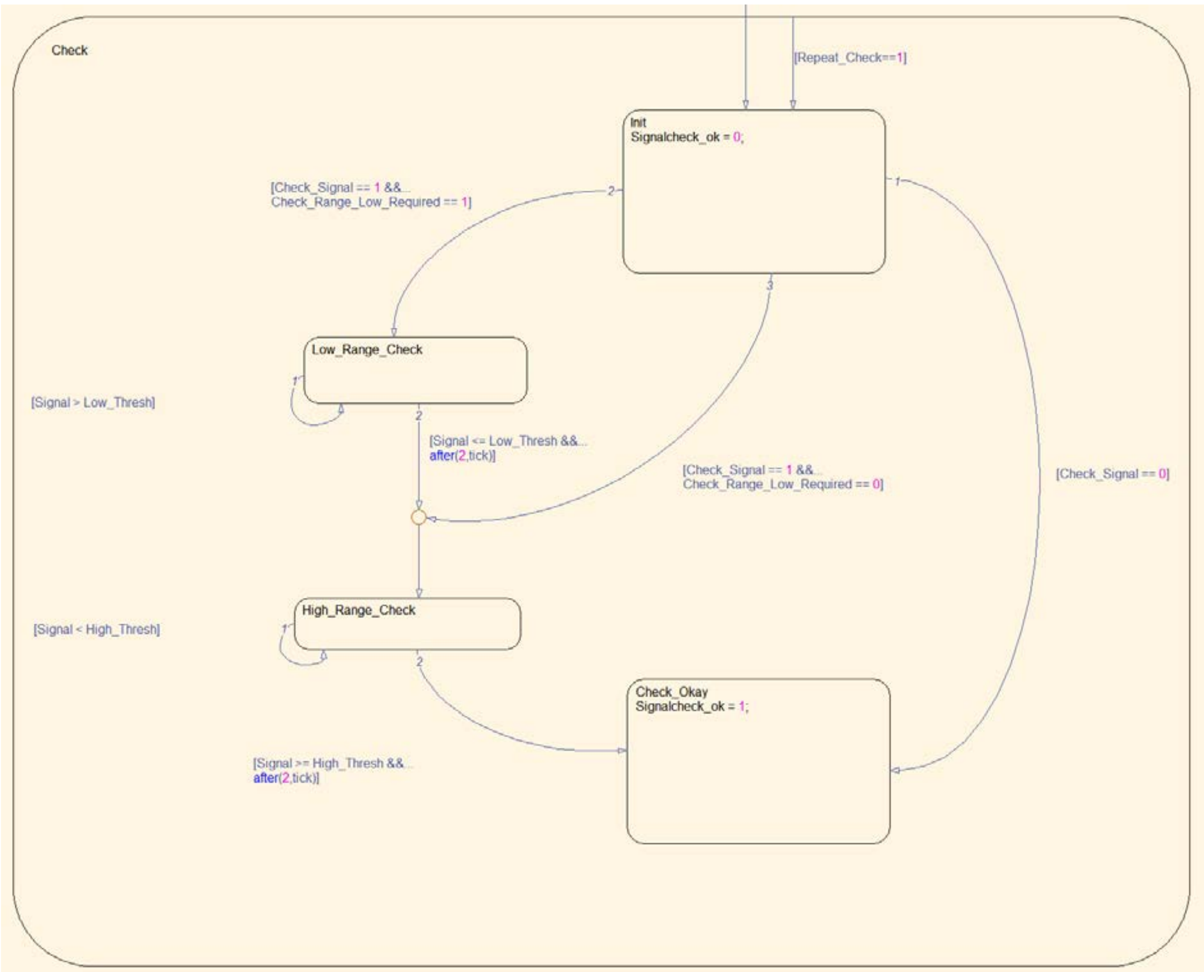


Figure 16: State machine model for the brake signal check.

13 Error Handling

13.1 Construction fault diagnosis function

Construction fault diagnosis function

The motor control software monitors the entire system of motor, motor control unit and battery during operation to detect hardware and software errors. The error monitoring is modularly structured and consists of individual error diagnosis functions. Each error diagnosis features at least the following parameters:

- Enable bit: For activating or deactivating the error diagnosis
- Level 1 Debouncing: To delay the warning bit
- Level 2 Debouncing: To delay the error bit

Each error diagnosis module has the following output signals:

- Warning bit: Does not lead directly to the deactivation of the output stage. Some functions react to the warning bit and ignore signal values for which there is a warning bit. For example, if the signal range for the acceleration signal is exceeded, the torque requirement is briefly reduced to zero, but electrical braking is still possible.
- Error bit: This leads to the deactivation of the current control and to an entry in the error memory.
- Error counter: Counts the number of times that the error has occurred

As soon as an error bit is set, the current control is deactivated by the state manager and the output stage is brought into the preconfigured states “free floating” or “active short circuit braking”. See "Active short-circuit of the output stage in the event of a fault".

Note on using the factory settings

In the factory settings, the error monitoring is set very tolerantly, so that you are interrupted as rarely as possible by safety shutdowns at the beginning of your work with this motor control unit. If a fault is detected, the state manager deactivates the power unit with a safety shutdown. See "State Manager".

Tolerant settings during error handling can result in the motor control, motor or battery not being adequately protected against overload or overvoltage, so you should use the setting options of the error diagnosis functions described below to provide the best possible protection for the entire system.

13.2 Error diagnosis functions

The following section describes the individual error diagnoses and explains the options.

ERR_E_I_Max_DC

Description of the diagnostic function	
Purpose of the diagnostic function	Monitoring of the maximum permissible battery current.
How is the fault diagnosed (technical description)	By monitoring the current measured value of the battery current.
possible causes	The ride mode settings for maximum battery power exceed the fault detection limit. Poorly adjusted current regulator.
Reaction when an error is detected	Deactivation of the output stage
Critical error (transition to the current control requires ignition Reset)	Yes (ignition reset required)

Table 87: Description of the diagnostic function ERR_E_I_Max_DC.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_I_Max_DC	Maximum battery current	0 .. 1000 A
ERR_C_I_Max_DC_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_I_Max_DC_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 88: Parameters of diagnostic function ERR_E_I_Max_DC.

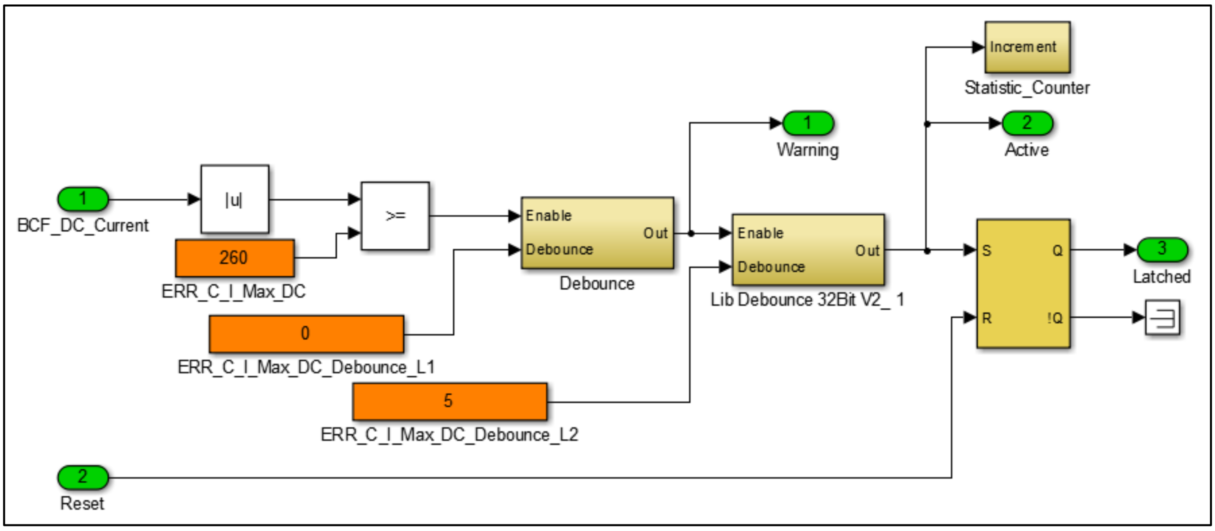


Figure 17: Function model for fault diagnosis for over-current (DC)

ERR_E_I_Max_AC

Description of the diagnostic function	
Purpose of the diagnostic function	Monitoring of the maximum permissible motor current.
How is the fault diagnosed (technical description)	By monitoring the current measured value of the motor current.
possible causes	Your ride mode settings for the maximum engine current exceed the fault detection limit. Poorly adjusted current regulator.
Reaction when an error is detected	Deactivation of the output stage
Critical error (transition to the current control requires ignition Reset)	No

Table 89: Description of the diagnostic function ERR_E_I_Max_AC.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_I_Max_AC	Maximum motor current	0 .. 380 A
ERR_C_I_Max_AC_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_I_Max_AC_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 90: Parameters of diagnostic function ERR_E_I_Max_AC.

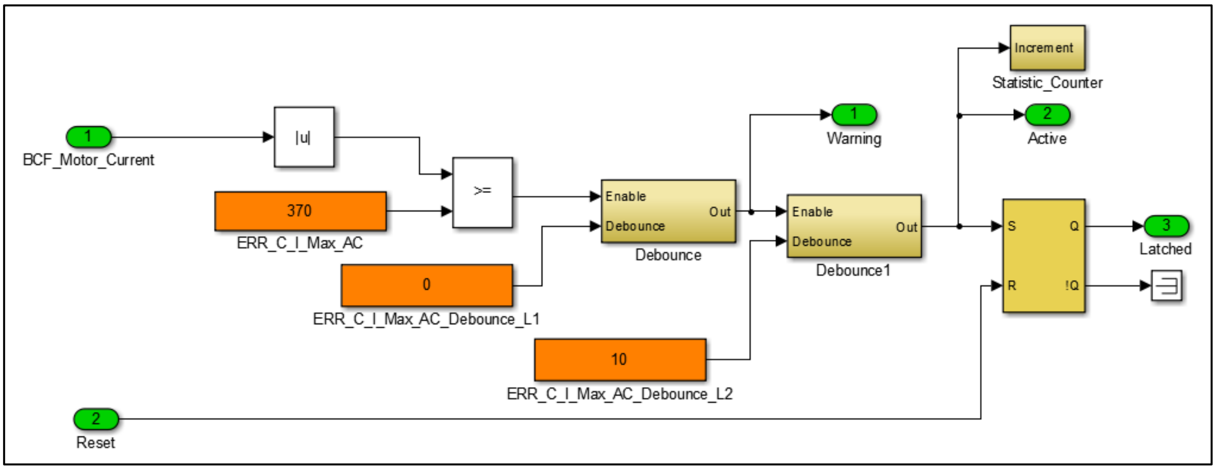


Figure 18: Function model for fault diagnosis for over-current (AC)

ERR_E_U_HV_Max (overvoltage)

Description of the diagnostic function	
Purpose of the diagnostic function	Detection of overvoltage on the DC link of the motor control unit.
How is the fault diagnosed (technical description)	The voltage is measured at the DC link capacitors and compared with the set maximum value.
possible causes	The supply voltage is too high. The voltage in the DC link has increased due to energy recovery, but the generated current could not flow back to the battery. The connection to the battery is interrupted or a diode blocks the current from flowing back.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 91: Description of the diagnostic function ERR_E_U_HV_Max.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_U_HV_Max	Maximum voltage	0 .. 65 V
ERR_C_U_HV_Max_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_U_HV_Max_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 92: Parameters of diagnostic function ERR_E_U_HV_Max.

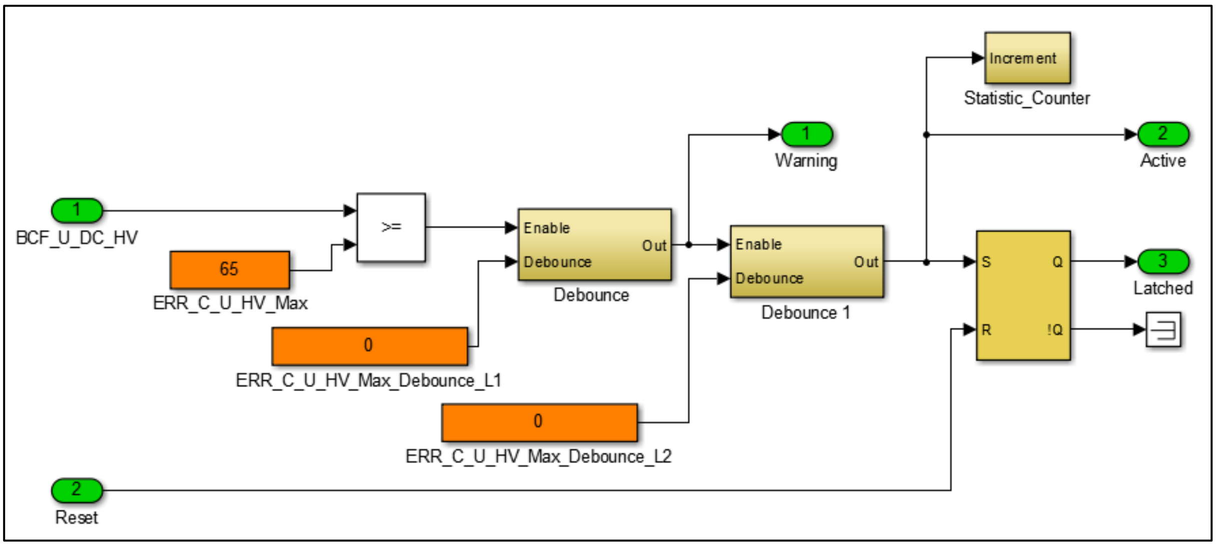


Figure 19: Function model for fault diagnosis for over voltage (DC)

ERR_E_U_HV_Min (low voltage)

Description of the diagnostic function	
Purpose of the diagnostic function	Detection of undervoltage on the DC link of the motor control unit
How is the fault diagnosed (technical description)	The voltage is measured at the DC link capacitors and compared with the set minimum value.
possible causes	The supply voltage is too low. The connection to the battery is interrupted.
Reaction when an error is detected	Deactivation of the output stage
Critical error (transition to the current control requires ignition Reset)	No

Table 93: Description of the diagnostic function ERR_E_U_HV_Min.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_U_HV_Min	Minimum permissable voltage	12 .. 65 V
ERR_C_U_HV_Min_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_U_HV_Min_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 94: Parameters of diagnostic function ERR_E_U_HV_Min.

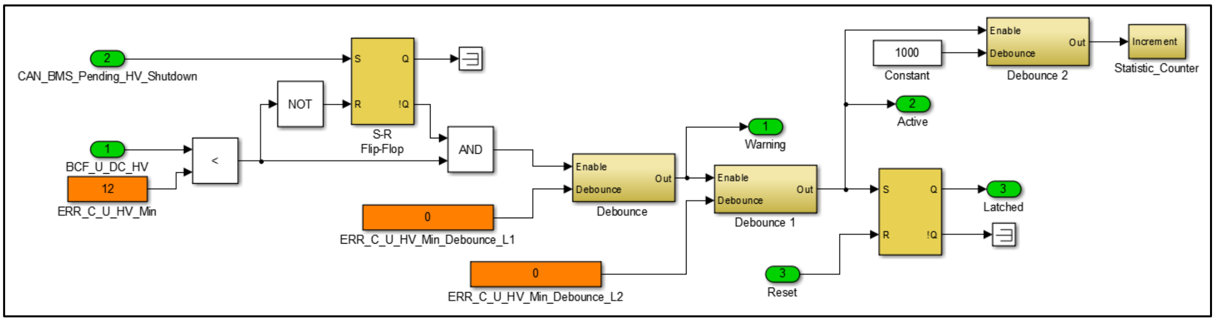


Figure 20: Function model for fault diagnosis for low voltage (DC)

ERR_E_U_LV_Min (low voltage internal 12V supply)

Description of the diagnostic function	
Purpose of the diagnostic function	Monitoring low voltage for the internal power supply
How is the fault diagnosed (technical description)	The voltage is measured by the internal 12V DCDC converter and compared with a minimum value.
possible causes	The 5V sensor supply is overloaded. The internal 12V-DCDC converter is damaged (the control unit is defective).
Reaction when an error is detected	Deactivation of the output stage
Critical error (transition to the current control requires ignition Reset)	No

Table 95: Description of the diagnostic function ERR_E_U_LV_Min.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_U_LV_Min	Lower limit for the internal supply voltage	0 .. 12 V
ERR_C_U_LV_Min_U_HV_Thresh	Lower limit of the battery voltage to avoid multiple errors.	0 .. 15 V
ERR_C_U_LV_Min_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_U_LV_Min_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 96: Parameters of diagnostic function ERR_E_U_LV_Min.

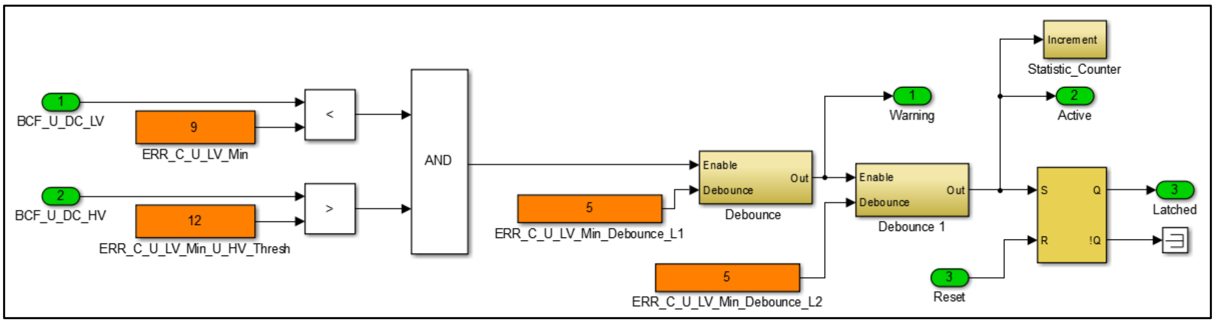


Figure 21: Function model for fault diagnosis for low voltage (internal supply voltage)

ERR_E_AWD (short-term over- & under voltage)

Description of the diagnostic function	
Purpose of the diagnostic function	Protection of the power electronics against very dynamic overvoltages and undervoltages. In the event of undervoltage, the storage of current travel data and fault memory in the flash memory is triggered.
How is the fault diagnosed (technical description)	A hardware-side interrupt with very high priority can deactivate the output stage without the help of the control software to avoid damage to the hardware.
possible causes	Undervoltage or overvoltage on the DC link of the motor control unit. This error occurs when the permissible operating voltage limits are exceeded.
Reaction when an error is detected	Deactivation of the output stage
Critical error (transition to the current control requires ignition Reset)	No

Table 97: Description of the diagnostic function ERR_E_AWD.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
BSW_C_AWD_High_Threshold_Voltage	Overvoltage limit. 70V (default) The parameter is possibly not to change available	0 .. 160 V V 70 (default)
BSW_C_AWD_Low_Threshold_Voltage	Undervoltage limit. 20V (default) The parameter is possibly not to change available	7 .. 160 V 20 V (default)

Table 98: Parameters of diagnostic function ERR_E_AWD.

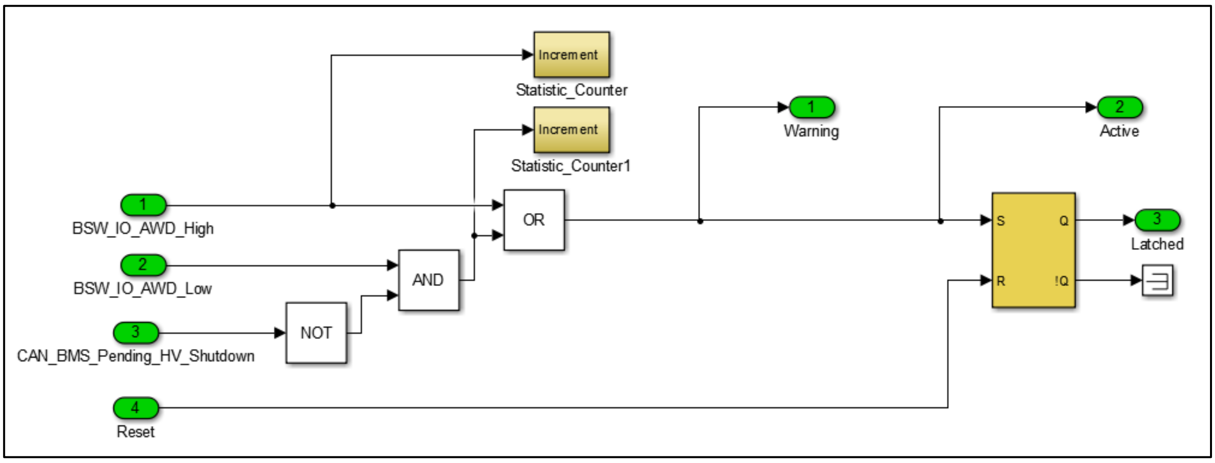


Figure 22: Function model for fault diagnosis for dynamic Sub & Surge

ERR_E_Block_Det (blocking)

Description of the diagnostic function	
Protection of the drive against overheating by blocking the motor while maintaining a high motor current.	Protection of the drive against overheating by blocking the motor while maintaining a high motor current.
How is the fault diagnosed (technical description)	A two-stage detection of the blocking via the motor current takes place. The first stage detects moderately high current at low motor speed and delays the tripping of the fault for a relatively long time. The second stage is used to detect very high currents and delays the tripping of the fault only for a short time.
possible causes	The driver blocks the drive The vehicle is too heavy to accelerate fast enough
Reaction when an error is detected	Deactivation of the output stage
Critical error (transition to the current control requires ignition Reset)	No

Table 99: Description of the diagnostic function ERR_E_Block_Det.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Block_Det_Current	Motor current limit for the first monitoring stage	0 .. 1000 A
ERR_C_Block_Det_Current_L2	Motor current limit for the second monitoring stage	0 .. 1000 A
ERR_C_Block_Det_Debounce_L1	Delay of tripping for the first monitoring stage	0 .. 10000 ms
ERR_C_Block_Det_Debounce_L2	Delaying the tripping for the second monitoring stage	0 .. 10000 ms
ERR_C_Block_Det_Speed	Speed limit for both stages. A blockage of the actuator is detected below the set speed	0 .. 2000 1/s

Table 100: ERR_E_Block_Det parameters of the diagnostic function.

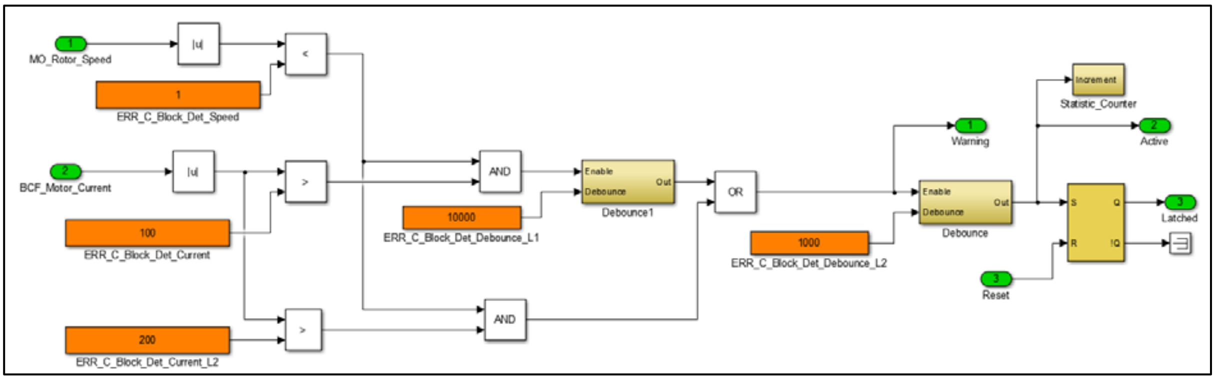


Figure 23: Function model to diagnose the blocking detection

ERR_E_Throttle_Monitoring (acceleration signal error)

Description of the diagnostic function	
Purpose of the diagnostic function	Detection of exceeding the signal range of the acceleration signal. Detection of loose contact or short circuit of the input signal against ground or supply voltage.
How is the fault diagnosed (technical description)	For the input signals AIN1, AIN2 and PWMI, the raw signal value is monitored. The range of values is relative to the calibrated signal range from 0 to 100 %. When controlled via CAN bus, an excess of 100 % torque demand is monitored.
possible causes	Poor calibration. Calibration values are too close to the error threshold. Loose contact on the signal input. Short circuit to ground or supply voltage. Strong electrical interference on the signal path (e.g. EMC). Control value on the CAN bus of over 100 %.
Reaction when an error is detected	When the warning bit is triggered, the relative torque generated by the input is set to zero. When the error bit is triggered, the output stage is deactivated.
Critical error (transition to the current control requires ignition Reset)	Yes (ignition reset required)

Table 101: Description of the diagnostic function ERR_E_Throttle_Monitoring.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Throttle_Monitoring_Enable	Enable use of fault diagnosis function	0/1
ERR_C_Throttle_Monitoring_Min_Raw_Value	Lower threshold for the raw value of the torque demand	0 .. 100%
ERR_C_Throttle_Monitoring_Max_Raw_Value	Upper threshold for the raw value of the torque demand	0 .. 100%
ERR_C_Throttle_Monitoring_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Throttle_Monitoring_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 102: Parameters of diagnostic function ERR_E_Throttle_Monitoring.

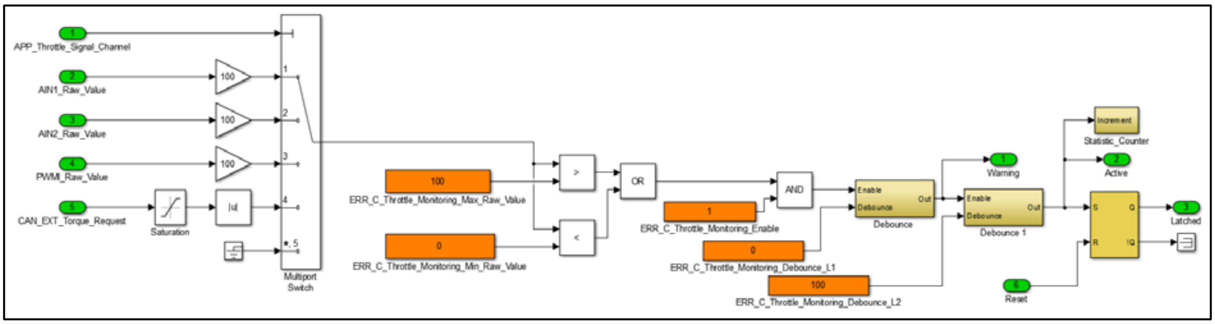


Figure 24: Function model for fault diagnosis of the acceleration signal monitoring

ERR_E_Brake_Monitoring (brake signal error)

Description of the diagnostic function	
Purpose of the diagnostic function	Detection of exceeding the signal range of the brake signal Detection of loose contact or short circuit of the input signal against ground or supply voltage.
How is the fault diagnosed (technical description)	For the input signals AIN1, AIN2 and PWMI, the raw signal value is monitored. The range of values is relative to the calibrated signal range from 0 to 100 %. When controlled via CAN bus, a torque below -100 % is monitored.
possible causes	Poor calibration. Calibration values are too close to the error threshold. Loose contact on the signal input. Short circuit to ground or supply voltage. Strong electrical interference on the signal path (e.g. EMC). Control value via CAN bus is below -100 %.
Reaction when an error is detected	Upon triggering of the warning bits, the relative torque produced by the input is set to zero The triggering of the error bits, the deactivation of the power unit is carried out
Critical error (transition to the current control requires ignition Reset)	Yes (ignition reset required)

Table 103: Description of the diagnostic function ERR_E_Brake_Monitoring.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Brake_Monitoring_Enable	Enable use of fault diagnosis function	0/1
ERR_C_Brake_Monitoring_Min_Raw_Value	Lower threshold for the raw value of the torque demand	0 .. 100%
ERR_C_Brake_Monitoring_Max_Raw_Value	Upper threshold for the raw value of the torque demand	0 .. 100%
ERR_C_Brake_Monitoring_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Brake_Monitoring_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 104: Parameters of diagnostic function ERR_E_Brake_Monitoring.

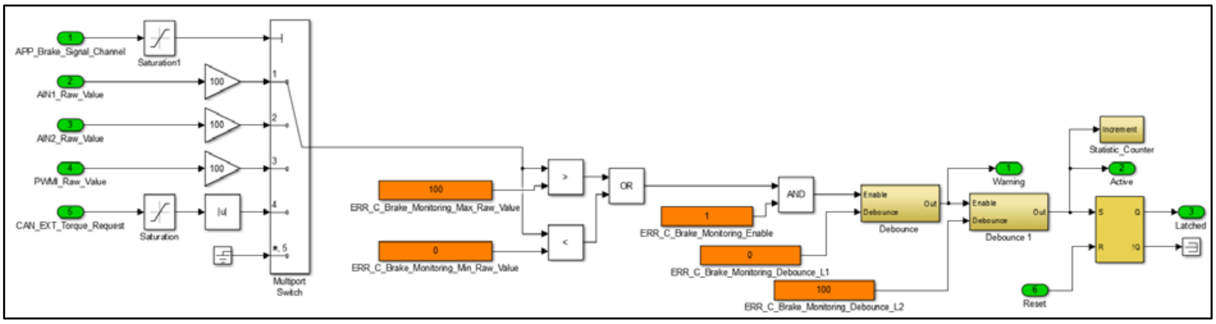


Figure 25: Function model for fault diagnosis of the braking signal monitoring

ERR_E_CAN_Timeout (CAN Timeout)

Description of the diagnostic function	
Purpose of the diagnostic function	Timeout detection for the message EXT_Torque_Control_01.
How is the fault diagnosed (technical description)	The time interval between the reception of CAN messages is monitored.
possible causes	The CAN bus is not connected correctly. The baud rate is set incorrectly. The station doesn't send the message. The message is not received often enough. The message has an invalid DLC.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 105: Description of the diagnostic function ERR_E_CAN_Timeout.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_CAN_Timeout_Enable	Enable use of fault monitoring	0/1

Table 106: Parameters of diagnostic function ERR_E_CAN_Timeout.

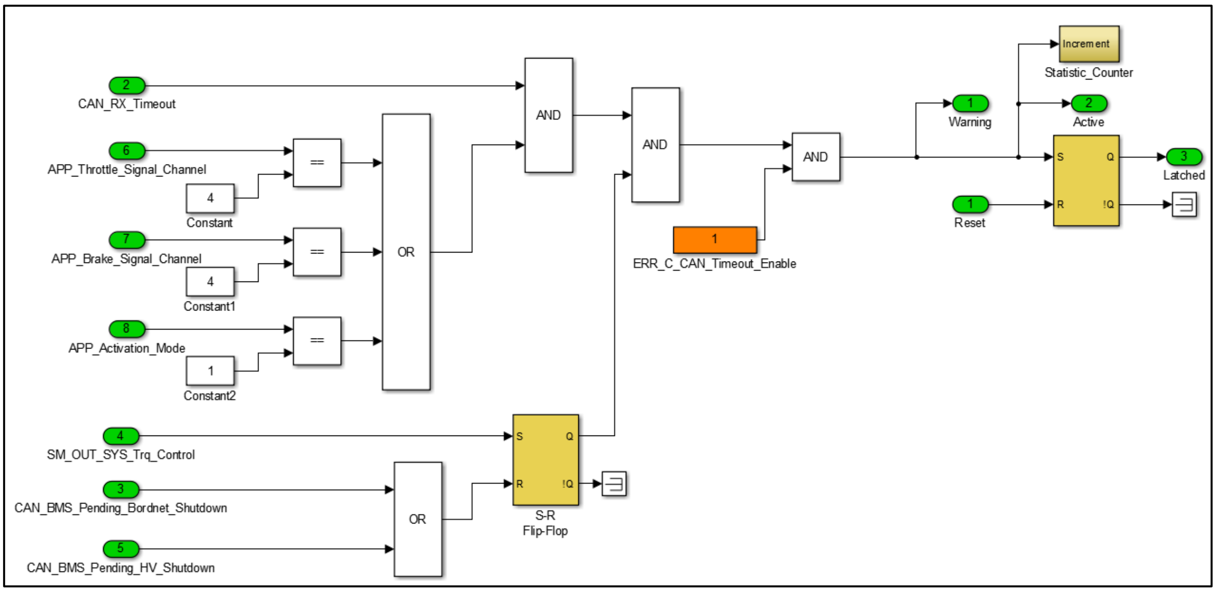


Figure 26: Function model to diagnose a CAN Timeout

ERR_E_CAN_MC (CAN message monitoring)

Description of the diagnostic function	
Purpose of the diagnostic function	Monitoring of the CAN message EXT_Torque_Control_01. Detection of reception gaps. Detection of static/frozen values.
How is the fault diagnosed (technical description)	The CAN signal CAN_EXT_Alive_Counter is evaluated with each received CAN message and the distance between the last two received values is compared. An error is triggered if a distance in the message counter distance is exceeded or not reached.
possible causes	CAN_EXT_Alive_Counter returns only static values The message EXT_Torque_Control_01 is received incompletely
Reaction when an error is detected	Deactivation of the output stage
Critical error (transition to the current control requires ignition Reset)	No

Table 107: Description of the diagnostic function ERR_E_CAN_MC.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_CAN_MC_Enable	Enable use of fault monitoring	0/1
ERR_C_CAN_MC_Threshold	Upper limit for the distance between two alive counter values	1 .. 15

Table 108: Parameters of diagnostic function ERR_E_CAN_MC.

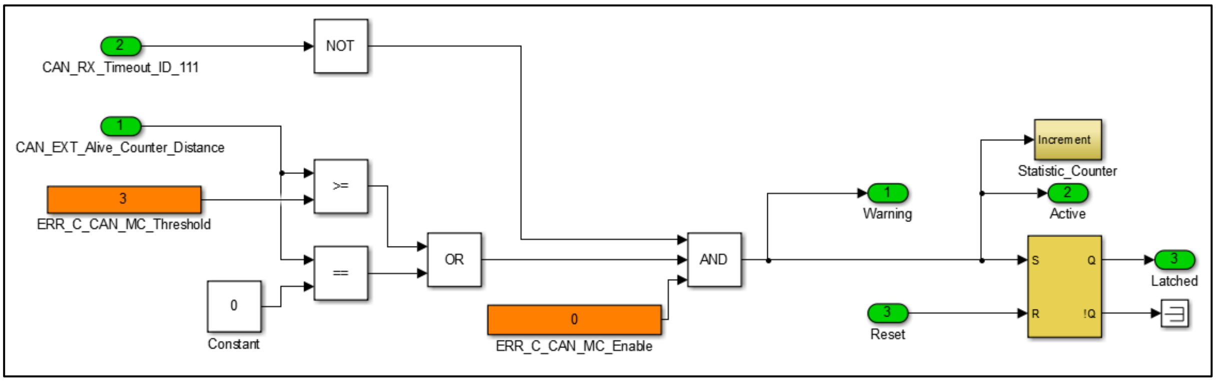


Figure 27: Function model for fault diagnosis of a CAN message count error

ERR_E_EEPROM (memory issue)

Description of the diagnostic function	
Purpose of the diagnostic function	Detection of a non-parameterized motor control unit. Detection of invalid data record. Detection of errors in the flash memory. Detection of memory errors.
How is the fault diagnosed (technical description)	immediately after a software update as long as no record was written. for invalid data or incorrect checksum. with incorrectly set axes of Tables.
possible causes	It was still not transmit a snapshot to the controller. Since the current data status was not saved ie "Store Parameters" has not yet been carried out.
Reaction when an error is detected	Deactivation of the output stage
Critical error (transition to the current control requires ignition Reset)	No

Table 109: Description of the diagnostic function ERR_E_EEPROM.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
There are no parameters for this function		

Table 110: Parameters of diagnostic function ERR_E_EEPROM.

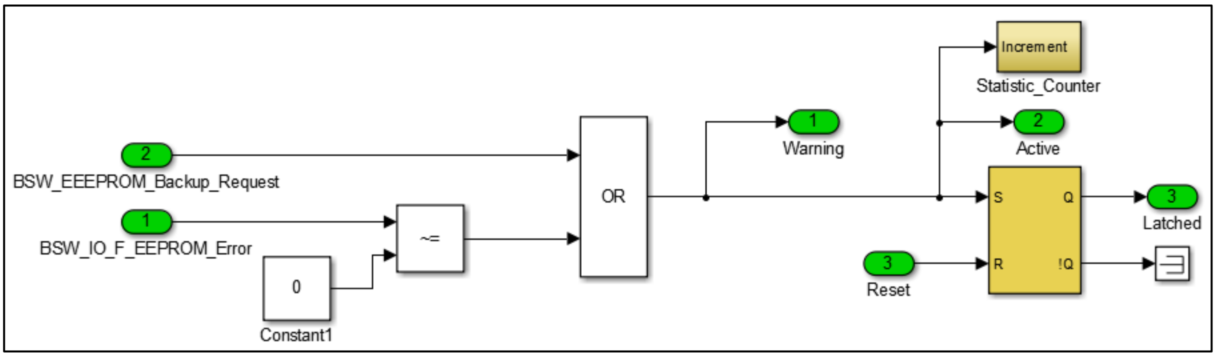


Figure 28: Function model for fault diagnosis of an EEPROM problem

ERR_E_Rotor_Speed_Limit

Description of the diagnostic function	
Purpose of the diagnostic function	Overspeed detection
How is the fault diagnosed (technical description)	By monitoring the mechanical and electrical motor speed. The error is triggered as soon as one of the two limits is exceeded.
possible causes	The motor speed exceeds the set maximum value.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 111: Description of the diagnostic function ERR_E_Rotor_Speed_Limit.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Rotor_Speed_Limit	Maximum value as a mechanical speed limit	0 .. 2400 1/s
ERR_C_Rotor_Speed_Limit_el	Maximum value as an electrical speed limit	0 .. 2400 1/s
ERR_C_Rotor_Speed_Limit_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Rotor_Speed_Limit_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 112: Parameters of diagnostic function ERR_E_Rotor_Speed_Limit.

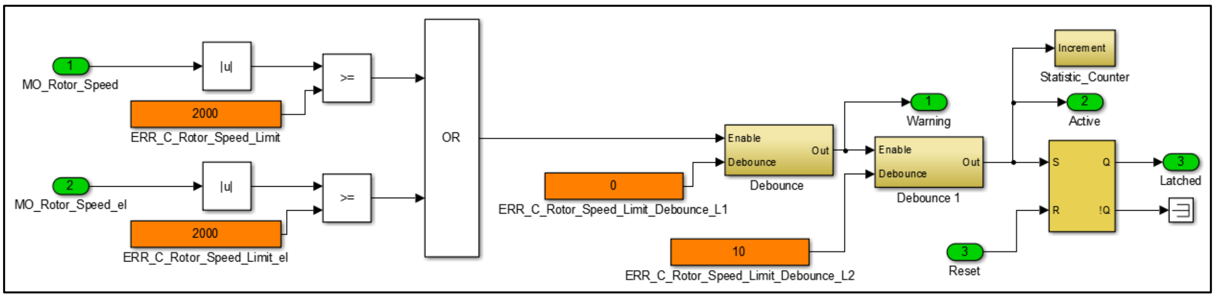


Figure 29: Function model for fault diagnosis of over speed

ERR_E_Motor_Sensor

Description of the diagnostic function	
Purpose of the diagnostic function	Detection of faults in the motor sensor signal.
How is the fault diagnosed (technical description)	For hall sensors: by monitoring the signal levels at the inputs for hall sensors 1 to 3. by monitoring the pulse pattern. With resolver: By monitoring the signal failure. By monitoring the distance between two measured values of the resolver
possible causes	Faulty wiring. Mechanical problem with the sensor. Strong electrical interference on the sensor signal (EMC). Insufficient supply voltage of the sensor.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 113: Description of the diagnostic function ERR_E_Motor_Sensor.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Motor_Sensor_Enable	Enable use of fault monitoring	0/1
ERR_C_Motor_Sensor_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Motor_Sensor_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 114: Parameters of diagnostic function ERR_E_Motor_Sensor.

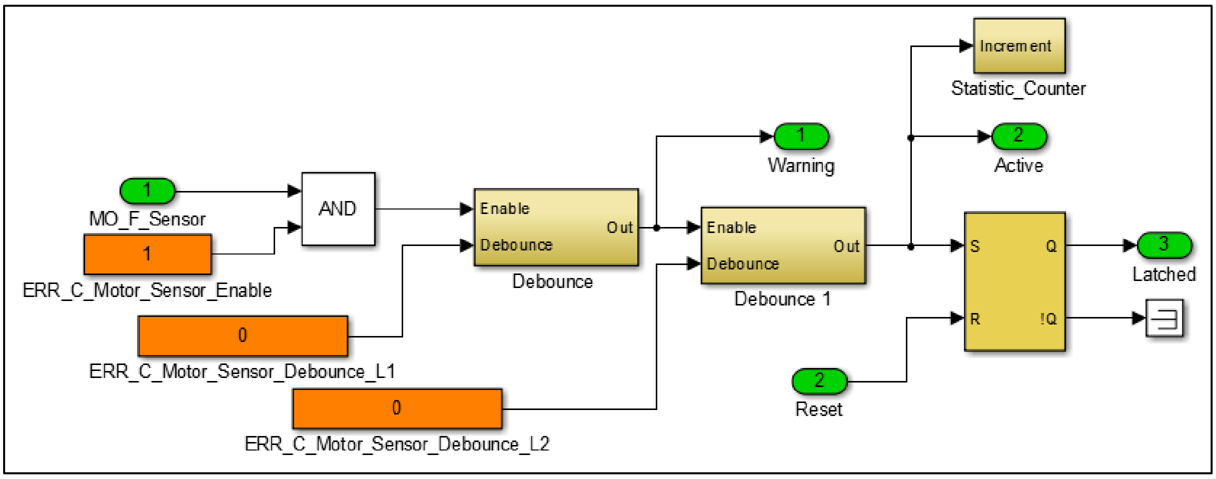


Figure 30: Function model for fault diagnosis of motor sensor problems

ERR_E_FET_Temp_Max (temperature power unit)

Description of the diagnostic function	
Purpose of the diagnostic function	Overtemperature detection on the output stage. Detection of high temperature gradients.
How is the fault diagnosed (technical description)	By monitoring the temperature value TEMP_FET_Max. By monitoring the temperature gradient TEMP_FET_Gradient.
possible causes	Severe overload of the power unit. Insufficient cooling of one or more areas of the power section.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 115: Description of the diagnostic function ERR_E_FET_Temp_Max.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Temp_FET_Max	Maximum temperature MOSFET	-50 .. 200 ° C
ERR_C_Temp_FET_Gradient_Max	maximum temperature gradient	0.1 .. 50 ° C
ERR_C_Temp_FET_Max_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Temp_FET_Max_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 116: Parameters of diagnostic function ERR_E_FET_Temp_Max.

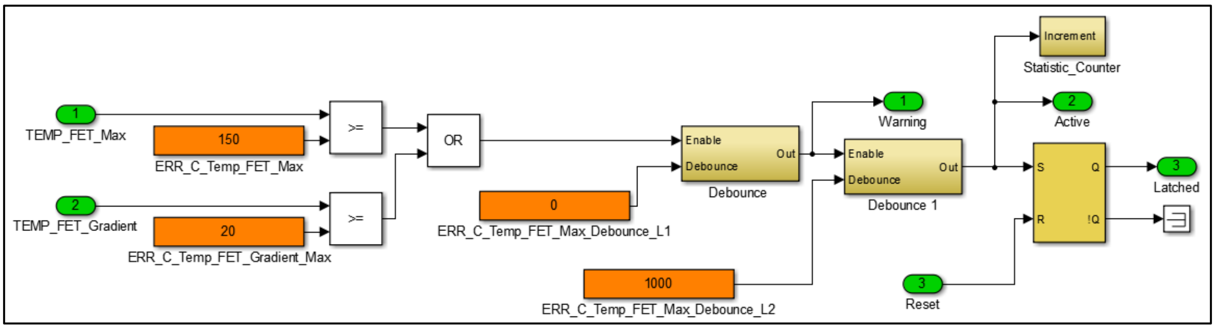


Figure 31: Function model for fault diagnosis of over temperature (FET)

ERR_E_Temp_Aux_Max (temperature auxiliary input)

Description of the diagnostic function	
Purpose of the diagnostic function	Overtemperature detection at the aux input.
How is the fault diagnosed (technical description)	By monitoring the temperature value TEMP_Aux.
possible causes	Signal error at the input. Actual high temperature. Incorrectly adjusted sensor type.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 117: Description of the diagnostic function ERR_E_Temp_Aux_Max.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Temp_Aux_Max	Enable use of fault monitoring	-50 .. 500 ° C
ERR_C_Temp_Aux_Max_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Temp_Aux_Max_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 118: Parameters of diagnostic function ERR_E_Temp_Aux_Max.

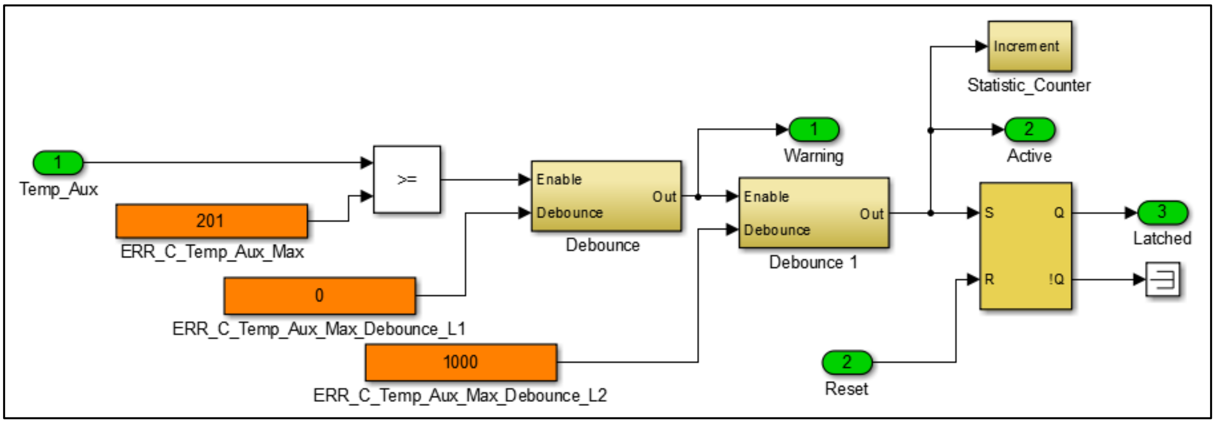


Figure 32: Function model for fault diagnosis of over temperature (Aux)

ERR_E_Temp_MCU_Max (temperature microcontroller)

Description of the diagnostic function	
Purpose of the diagnostic function	Overtemperature detection on the microcontroller.
How is the fault diagnosed (technical description)	By monitoring the temperature value TEMP_MCU.
possible causes	High temperature at the power section or in the motor control unit housing.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 119: Description of the diagnostic function ERR_E_Temp_MCU_Max.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Temp_MCU_Max_V1	Maximum temperature Emerge 3000	0 .. 100 ° C
ERR_C_Temp_MCU_Max_V2	Maximum temperature Emerge 6000	0 .. 125 ° C
ERR_C_Temp_MCU_Max_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Temp_MCU_Max_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 120: Parameters of diagnostic function ERR_E_Temp_MCU_Max.

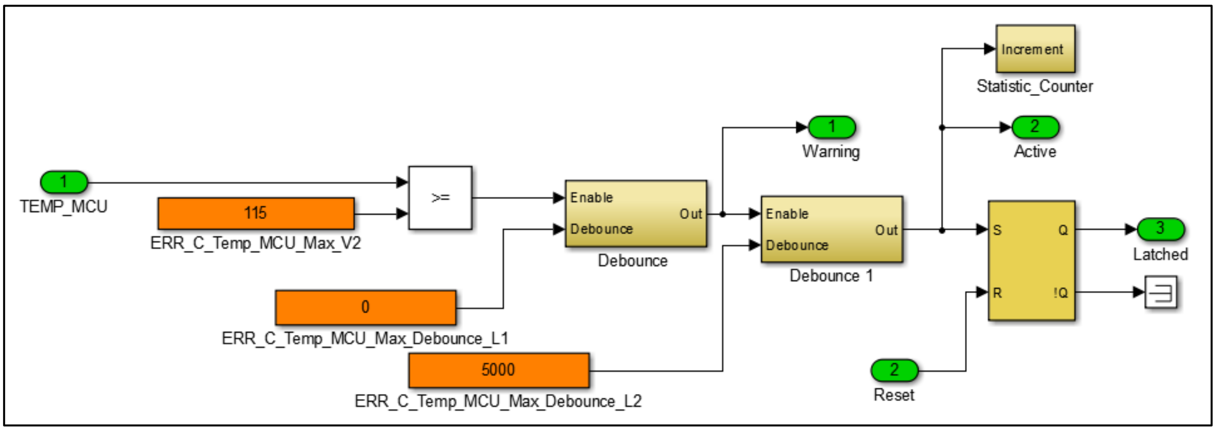


Figure 33: Function model for fault diagnosis of over temperature (Microcontroller)

ERR_E_Temp_Motor_Max (motor temperature)

Description of the diagnostic function	
Purpose of the diagnostic function	Overtemperature detection at the motor temperature input.
How is the fault diagnosed (technical description)	By monitoring the temperature value TEMP_Motor.
possible causes	Signal error at the input. Actual high temperature. Incorrectly adjusted sensor type.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 121: Description of the diagnostic function ERR_E_Temp_Motor_Max.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Temp_Motor_Max	Enable use of fault monitoring	-50 .. 500 ° C
ERR_C_Temp_Motor_Max_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Temp_Motor_Max_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 122: Parameters of diagnostic function ERR_E_Temp_Motor_Max.

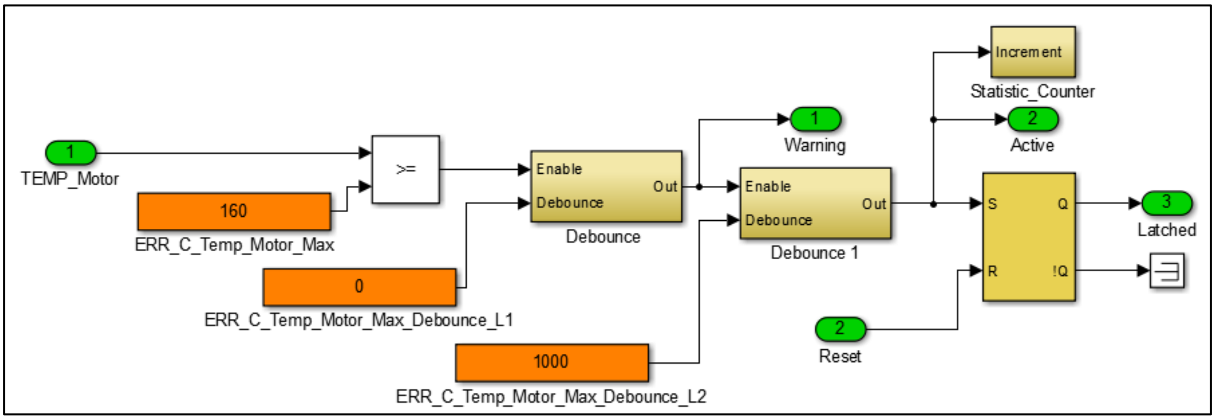


Figure 34: Function model for fault diagnosis of over temperature (Engine)

ERR_E_HW_Var_Code

Description of the diagnostic function	
Purpose of the diagnostic function	Checking the compatibility of software and hardware.
How is the fault diagnosed (technical description)	An encoding of the hardware informs the software about the type status of the hardware. If the software is not compatible with the hardware, an error is triggered.
possible causes	The software cannot run on the hardware used. The software or data set does not match your hardware. The wrong software was flashed onto the controller.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 123: Description of the diagnostic function ERR_E_HW_Var_Code.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
There are no parameters for this function		

Table 124: Parameters of diagnostic function ERR_E_HW_Var_Code.

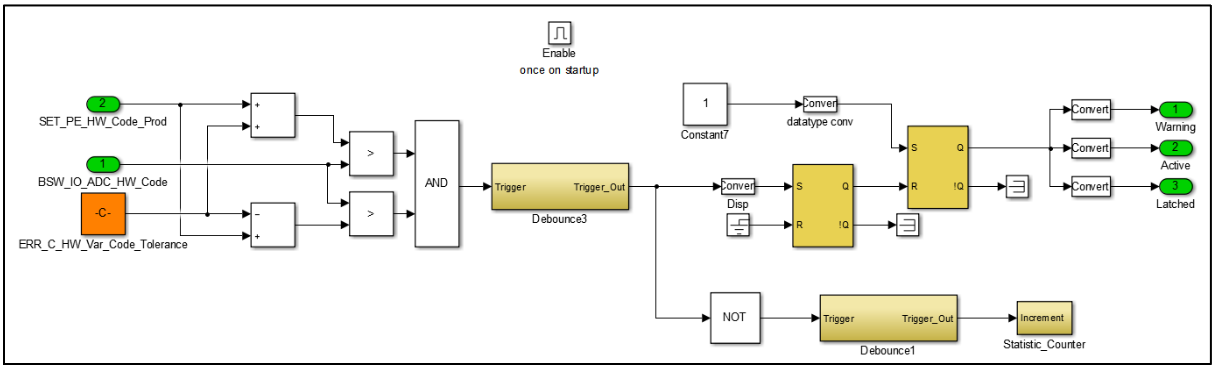


Figure 35: Function model for fault diagnosis of incompatibility of hardware and software

ERR_E_Current_Setpoint_Monitoring (torque monitoring)

Description of the diagnostic function	
Purpose of the diagnostic function	Detection of deviating motor current in comparison to the driver's request
How is the fault diagnosed (technical description)	The motor current INFO_Motor_Current_Iq is compared with the driver request TRQ_STR_Iq_Setpoint. The error is triggered if the deviation exceeds a tolerance limit.
possible causes	Incorrectly set current controller. Defective motor or output stage.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	Yes (ignition reset required).

Table 125: Description of the diagnostic function ERR_E_Current_Setpoint_Monitoring.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Current_Setpoint_Monitoring_Enable	Enable use of fault monitoring	0/1
ERR_C_Current_Setpoint_Monitoring_Thresh	Tolerance limit of the motor current deviation from the driver's request	0 .. 100 A
ERR_C_Current_Setpoint_Monitoring_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Current_Setpoint_Monitoring_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 126: Parameters of diagnostic function ERR_E_Current_Setpoint_Monitoring.

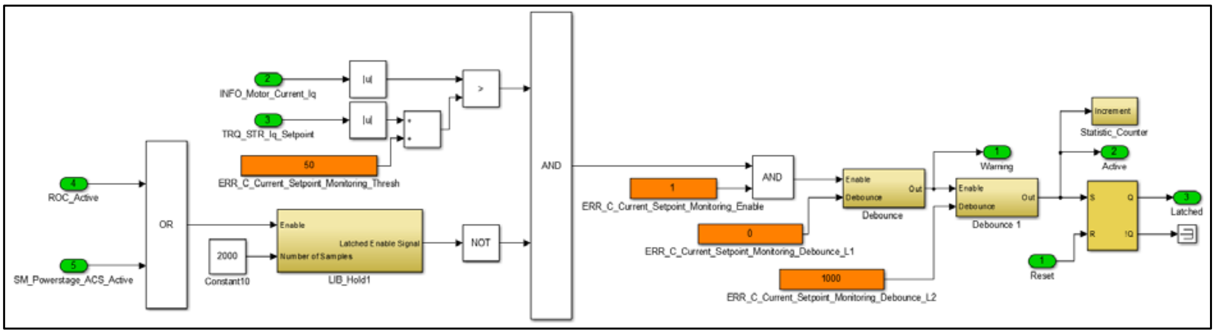


Figure 36: Function model for fault diagnosis of the driver's desired torque monitoring

ERR_E_Current_Sensor (current sensor)

Description of the diagnostic function	
Purpose of the diagnostic function	Detection of a faulty current sensor.
How is the fault diagnosed (technical description)	Before each transition to current control, the average value of the sensor signals is determined. This must be within a valid range.
possible causes	When rolling out in the active short-circuit, the activation of the current control was requested. The power supply is too low. Sensor fault/power section fault.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 127: Description of the diagnostic function ERR_E_Current_Sensor.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Current_Sensor_Enable	Enable use of fault monitoring	0/1
ERR_C_Current_Sensor_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Current_Sensor_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 128: Parameters of diagnostic function ERR_E_Current_Sensor.

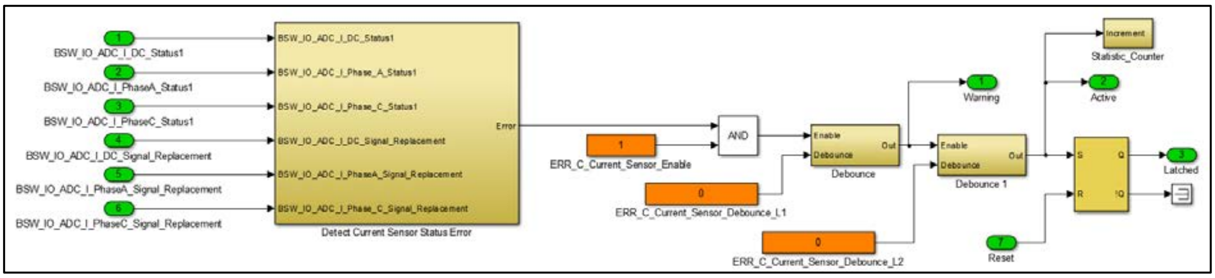


Figure 37: Function model for fault diagnosis of a current sensor error

ERR_E_Flux_Angle

Description of the diagnostic function	
Purpose of the diagnostic function	Magnetic flux angle monitoring
How is the fault diagnosed (technical description)	By calculating the angle INFO_Flux_Angle between the two control values for the phase voltages FOC_OUT_Vsq and FOC_OUT_Vsd. The angle may only deviate by an adjustable value of 90° (optimum). The diagnosis is only active for: Motor speed > 10 1/s (electrical speed). INFO_Phase_Voltage_Rel > 80 % (high phase voltage). TRQ_STR_Id_Setpoint == 0 (not in the flux-weakening range).
possible causes	Incorrectly adjusted rotor angle offset. Motor has not been properly taught-in. The magnetic properties of the motor are special
Reaction when an error is detected	Deactivation of the output stage
Critical error (transition to the current control requires ignition Reset)	No

Table 129: Description of the diagnostic function ERR_E_Flux_Angle.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Flux_Angle_Enable	Enable use of fault monitoring	0/1
ERR_C_Flux_Angle_Diff_Max	Maximum deviation from the 90 ° optimum	0 .. 90 °
ERR_C_Flux_Angle_Debounce_L1	Warning delay of bits	1 .. 10000 ms
ERR_C_Flux_Angle_Debounce_L2	Delaying the error bits	1 .. 10000 ms

Table 130: Parameters of diagnostic function ERR_E_Flux_Angle.

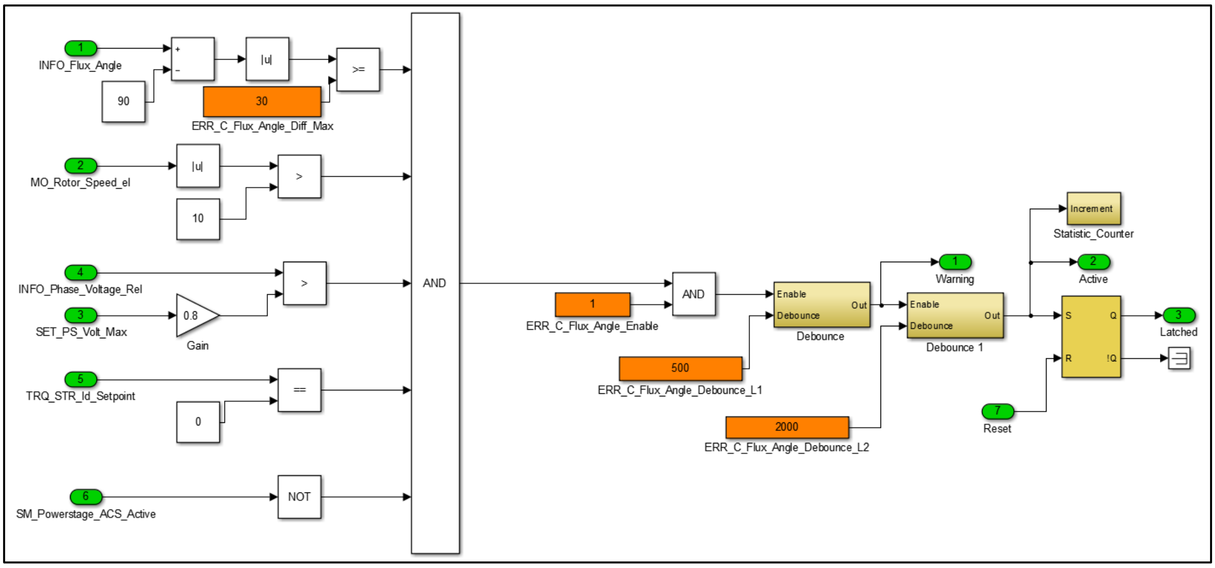


Figure 38: Function model for fault diagnosis of the flux-angle monitoring

ERR_E_Phase_Connection

Description of the diagnostic function	
Purpose of the diagnostic function	Detection of unconnected motor phase lines. Detection of faults in the output stage.
How is the fault diagnosed (technical description)	The output voltage of the output stage is plausibility checked against the current flow on the motor phases.
possible causes	Missing electrical connection of the motor phases. Incorrect diagnosis (software error) with incorrect settings or very special applications . Defective power section.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 131: Description of the diagnostic function ERR_E_Phase_Connection.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Phase_Connection_Enable	Enable use of fault monitoring	0/1
ERR_C_Phase_Connection_Act_Debounce	Time delay after the transition in the current control	0 .. 60000 ms
ERR_C_Phase_Connection_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Phase_Connection_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 132: Parameters of diagnostic function ERR_E_Phase_Connection.

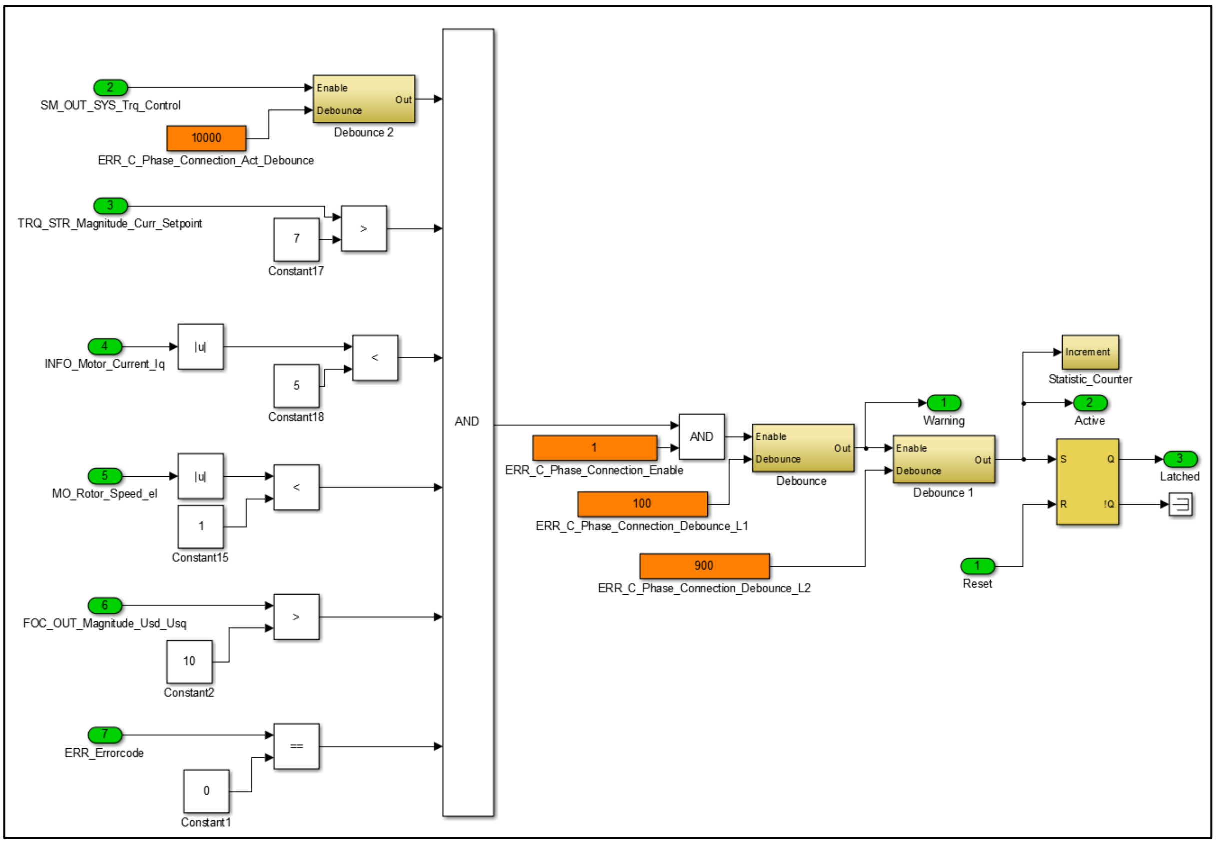


Figure 39: Function model for fault diagnosis of motor phase connection

ERR_E_Rotor_Offset_Calibration

Description of the diagnostic function	
Purpose of the diagnostic function	Deactivation of current control if the motor has not been correctly taught-in
How is the fault diagnosed (technical description)	By evaluating the error signal of the rotor offset calibration (ROC) function
possible causes	The teach-in process was not successfully completed or aborted by the user
Reaction when an error is detected	Deactivation of the output stage
Critical error (transition to the current control requires ignition Reset)	No

Table 133: Description of the diagnostic function ERR_E_Rotor_Offset_Calibration.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Rotor_Offset_Calibration_Enable	Enable use of fault monitoring	0/1
ERR_C_Rotor_Offset_Calibration_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Rotor_Offset_Calibration_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 134: Parameters of diagnostic function ERR_E_Rotor_Offset_Calibration.

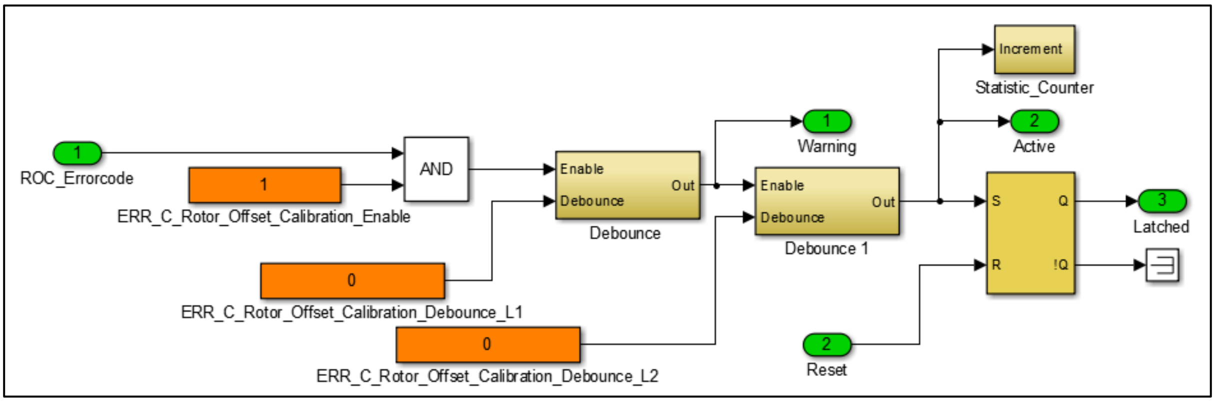


Figure 40: Function model for fault diagnosis of the automatic rotor offset angle teach-in function

ERR_E_Powerstage_Monitoring

Description of the diagnostic function	
Purpose of the diagnostic function	Evaluation of the error bits of the output stages.
How is the fault diagnosed (technical description)	By evaluating the error bits of the output stages.
possible causes	The error on the driver module of the power amplifiers has been set.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	Yes (ignition reset required).

Table 135: Description of the diagnostic function ERR_E_Powerstage_Monitoring.

Parameters of the diagnostic function		
Parameter name	**Function**	**Range of values**
ERR_C_Powerstage_Monitoring_Enable	Enable use of fault monitoring	0/1
ERR_C_Powerstage_Monitoring_Debounce_L1	Warning delay of bits	0 .. 10000 ms
ERR_C_Powerstage_Monitoring_Debounce_L2	Delaying the error bits	0 .. 10000 ms

Table 136: Parameters of diagnostic function ERR_E_Powerstage_Monitoring.

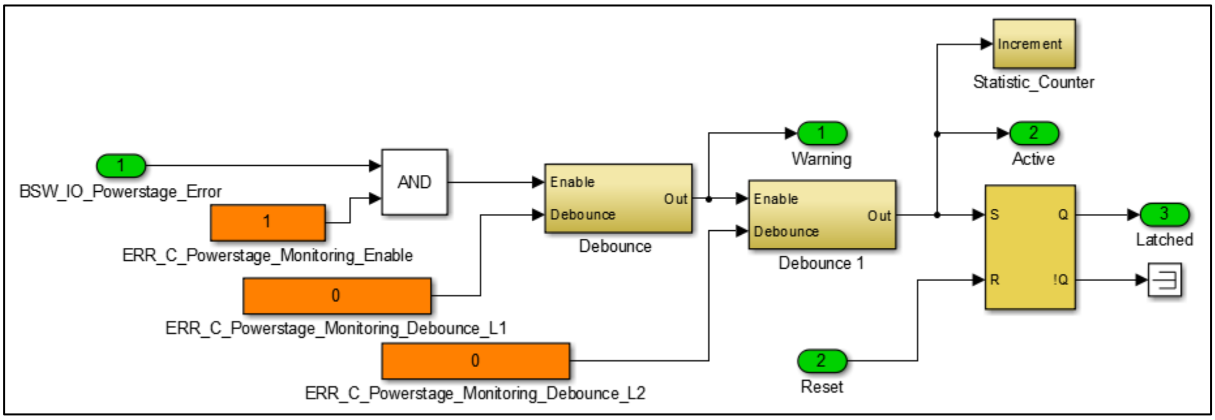


Figure 41: Function model for fault diagnosis of the power stage

ERR_E_Immobilizer (Immobilizer)

Description of the diagnostic function	
Purpose of the diagnostic function	Activation of the motor control unit or deactivation of the motor control unit by the immobilizer function.
How is the fault diagnosed (technical description)	The details on the function of the immobiliser are not disclosed to the public.
possible causes	The details on the function of the immobiliser are not disclosed to the public.
Reaction when an error is detected	Deactivation of the output stage.
Critical error (transition to the current control requires ignition Reset)	No

Table 137: Description of the diagnostic function ERR_E_Immobilizer.

13.3 Error memory

The fault memory records the last nine error codes and the associated mileage.

Error memory/Trace Memory	
ERR_MEM_Trace_0_Errorcode	Latest error code in the error memory
ERR_MEM_Trace_0_ODO	Mileage at the last occurrence of the error
ERR_MEM_Trace_1_Errorcode	...
ERR_MEM_Trace_1_ODO	...
ERR_MEM_Trace_2_Errorcode	...
ERR_MEM_Trace_2_ODO	...
ERR_MEM_Trace_3_Errorcode	...
ERR_MEM_Trace_3_ODO	...
ERR_MEM_Trace_4_Errorcode	...
ERR_MEM_Trace_4_ODO	...
ERR_MEM_Trace_5_Errorcode	...
ERR_MEM_Trace_5_ODO	...
ERR_MEM_Trace_6_Errorcode	...
ERR_MEM_Trace_6_ODO	...
ERR_MEM_Trace_7_Errorcode	...
ERR_MEM_Trace_7_ODO	...
ERR_MEM_Trace_8_Errorcode	Oldest error code in the error memory
ERR_MEM_Trace_8_ODO	Mileage at oldest error

Table 138: Error memory/Trace Memory.

Attention: Errors that occur together within a very short time are listed separated by commas. The sequence for multiple errors does not correspond to the sequence of events!

13.4 Active short-circuit of the output stage in case of failure

When the current control is deactivated in the event of a fault, the output stage can have two states.

- All MOSFET transistors of the power section become high-impedance: this makes the motor phases "free floating", i.e. the motor shaft can be moved without resistance, but the motor can generate an overvoltage if it is driven externally.
- All low-side MOSFET are low impedance: this short-circuits the motor phases using the low-side MOSFET transistors. The motor shaft is slowed down by the short-circuit current. The resulting induction voltage is short-circuited. No overvoltage can occur, but there is a braking torque, which can lead to instability of the vehicle depending on the driving condition.

Parameters for the use of the active shorting		
Parameter name	**Function**	**Range of values**
SET_C_PS_Error_Reaction	0 = motor phases floating in error or setpoint Mode 0 1 = Motor phases in short circuit (all low-side FET are conductive)	0/1

Table 139: Parameters for the use of the active short circuit.

Note: Please note the following warnings:

- The active short circuit can generate a strong braking torque on the motor, thereby contributing to the instability of the vehicle.
- The active short circuit is not suitable for use as a brake.
- The occurring short-circuit current can overheat or destroy the output stage if the motor is driven for a longer period despite an active short-circuit.
- The active short circuit can only be maintained with an active supply voltage (> 12V).
- Dangerous overvoltages can occur during operation in the flux-weakening range if hardware or software deactivate the output stage or if the hardware is damaged.
- In the event of a defect in the output stage, the function of the active short circuit may be limited or even harmful.
- Observe the maximum dielectric strength of each component, which could be damaged by overvoltage (BMS, motor control DCDC converter, etc.).

14 Versioning

Versioning of this document		
Version	**Date**	**Remarks**
V2.5 (EN)	20180704	Manual translation to english using DeepL translation.

Table 140: Versioning of this document.