Information
for special car applicatons

Short Manual for proper analogue or digital torque control in combination with interesting ride and safety features for car applications

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1 Analog Torque Control

1.1 Analog Torque Control in general

In traction applications it is preferred to use the electrical drive in torque control. This is a similar technic to the use of throttle position in combustion engines.

The setting inside "Command Mode" is used to configure the input command logic:
Analog Torque: Command via Analog Input → Torque-Control
⇨ Set Command Mode to "Analog Torque"

The internal ADC measurement has got a 12 bit resolution for the ±10 V input range.
The signal is then left-aligned creating a 16 Bit input range raw value of ±32767.

The final usage of the analogue input is the calculated (Ain x scaled) value which is defined by the settings of 'Offset', 'Cutoff' and 'Scale'. The 'Cutoff' defines a range (dead zone) where Ain x scaled is set to 0.
The calculation is defined by the formula: **Ain x scaled = (Ain x in + Offset) * Scale**

⇨ The Ain x scaled value is then the torque command for the inverter.
This is of course a current command which is proportional to the maximum inverter current (±32767 == ±I max pk at 100 %)

The 'Format' defines the command logic of the analogue input. While (+Cmd) will command a positive torque (speed) value in case of a positive Ain x scaled value, the (-Cmd) Format will command a negative torque (speed) value.

The 'Mode' selection will define which raw bipolar voltage input will be used. While a Mode select of [-10..+10V] will use even a negative voltage input, the Mode select of [0..+10 V] will only use the positive voltage input.

In case you only have a positive potentiometer supply, but require a bidirectional speed command (e.g. boat application), it is possible to modify the analogue input by setting a large offset, a cutoff in between, and adjusting of scale to cover a full command range. Bit 12 in ID-Address: 0xDC (0x10xx), can serve as enable (RUN) only possible with Analog Command < Cutoff (torque = 0).

Important to understand:
The parameter Nmax100% (ID: 0xC8) represents the resolution of the 16 Bit (±32767) actual speed value in relationship to the physical speed calculation. Always set this parameter to a rotation speed value above the motor nominal rotation speed.

By adjusting the setting of parameter "N-lim" (ID: 0x34) an activation for speed limitation in torque control mode can be activated. → "Torque-cruse-control"

N-lim = 100 %, no speed limitation
N-lim < 100 %, speed is limited to Nmax100% * N-lim (Torque-cruse-control activated)

With the usage of limited speed, the speed controller is active within the range of limitation. This means the parameters of the speed controller and the noise of speed actual signal are important in this operation range.

1.2 Analog Torque Control with automatic recuperation logic (Brake Car)

The theory of recuperative braking is actually very simple. As soon as the motor phase current (I_actual) and the motor phase voltage (SpeedActual) are of opposite sign, then recuperative energy will go back to the battery. This means that all you have to do is to send a negative torque command for generator torque and you will be recuperating current back to the battery ($P_{DC} \leftrightarrow P_{AC}$).

Using digital torque command the user has complete control whether the demanded torque will be a driving or a generator torque (recuperative braking) just by sending the desired torque value (M set (dig.)) using one of the digital communication interfaces (CAN, RS232).

Using analogue torque control the command logic for recuperation is more complicated.
Our software provides a function to let the inverter calculate a recuperative braking logic internally just by triggering the activation depending on the settings.

An analogue input is normally derived from an analogue throttle (potentiometer). The angle of the throttle is usually limited, the supply is normally unipolar and the zero position may be out of working range.

Diagram 1 gives an example of at which the working range of a throttle is between +1 V and 5 V.

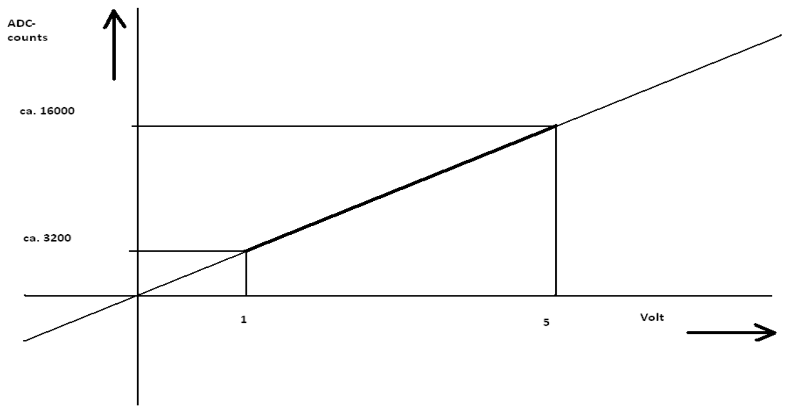


Diagram 1: Raw input signal
→ Ain x

Diagram 2 shows the modified analogue input by applying an offset of -4200, a cutoff of 400, and a scale factor of 2.500.

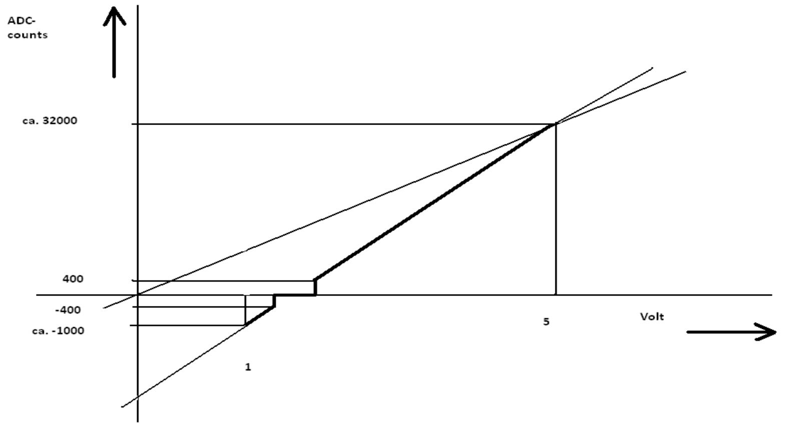


Diagram 2: Modified input signal
→ Ain x scaled

The positive values represent the range for driving torque. The scale factor is configured to reach the maximum possible output value. The offset create a negative value range which can be interpreted as the range where the internal recuperation logic will be triggered.
The result will be a vehicle with only one direction for moving. Backward movement has either to be performed manually or with the usage of a gear box. A more recent Firmware (≥ 471) makes it possible to change the sign of torque-command by triggering the input configuration “N cmd Reverse” (page Logic in NDrive).

Enable special function “recuperative braking logic” version 1:

→ set one digital input to the function “Brake Car”

→ **and** set Mode select to [-10..+10V] of the analogue input of the used throttle

Trigger of the special function “recuperative braking logic” (2 logics):

→ Logic 1: The Ain x scaled value is < 0

→ Logic 2: The configured input (e.g. Din1 = “Brake Car [Ax]” or “Brake Car #2 [Ax]”) is triggered

Calculation logic for the braking torque command:

→ Logic 1: Torque = -SpeedActual * Nlim+ (using parameter “Nlim+” (ID: 0x3F))

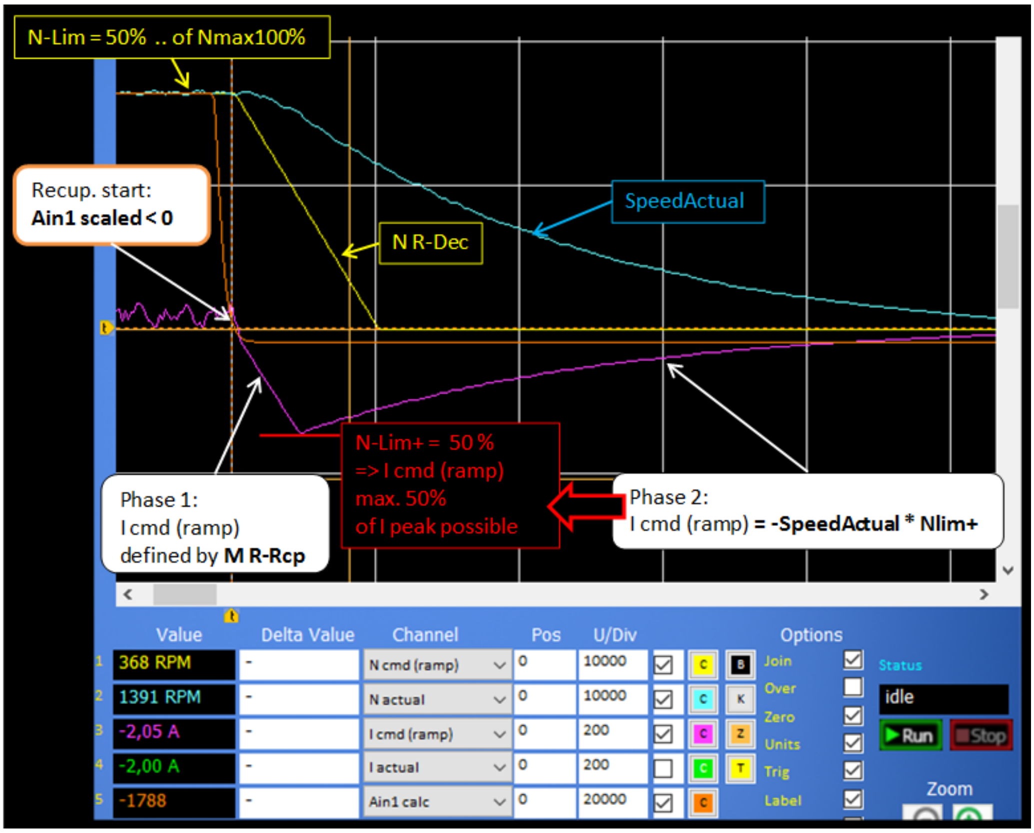
→ Logic 2: Torque = SpeedActual * Nlim- (using parameter “Nlim-“ (ID: 0x3E))

(Note: ‘Nlim+’ and ‘Nlim-’ represent the maximum possible current in % of I max peak = 100 %.
In case of a long “N R-Dec” Ramp, different responses will apply.)

The idea of Logic 1 is that if the throttle pedal is not pressed, the internal recuperation braking command will be activated.
The idea of Logic 2 is to connect the brake pedal to a switch (Digital Input) which will then activate the internal recuperation braking command. Meaning that different from Logic 1 the vehicle will be sailing, if the throttle pedal is not pressed.

Ramp generator for all analogue torque command values: (Firmware ≥ 476)

- M R-Acc → rate of increase of driving torque.
- M R-Dec → rate of decrease of driving torque.
- M R-Rcp → rate of increase of recuperative braking torque if either Logic 1 or 2 is activated.



Disable the “recuperative braking logic”: (without settings change)
Set one digital input to “recu-disab [Ax]”. If this input is triggered, it will force any recuperation torque to zero (e.g. in case of a full battery).

1.3 Analog Torque Control with automatic recuperation logic (Brake Car #2)

This calculation of the automatic recuperation logic is practically the same as in using the “Brake Car” setting except with one exception. This calculation logic allows the driver to modify the maximum possible torque command using the throttle position.

As shown in chapter 1.2 by modifying the analogue input value of the potentiometer with the offset settings it is possible to create a negative analogue input value. While for the “Brake Car” logic only a negative value is relevant, the “Brake Car #2” logic uses the percentage of the negative value in relationship to its maximum possible negative value to define the maximum possible recuperative braking torque. Meaning that if your throttle is only at 50 % of its possible negative position, the braking torque will also only be 50 % of the possible “N-Lim+” definition. If the negative throttle position is at 100 %, the calculation will be the same as if the “Brake Car” logic would be used.

Diagram 3 shows the same modified input signal from Diagram 2 but also showing the possible negative throttle positions relevant for the following braking calculations.

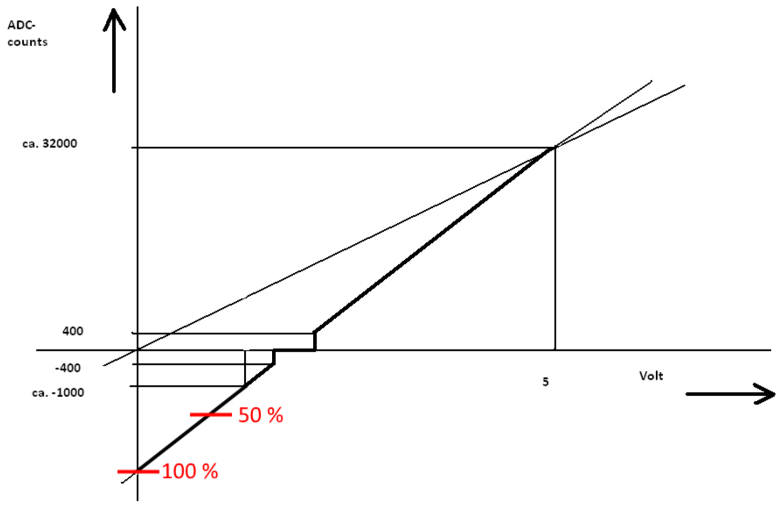


Diagram 3: Modified input signal
→ Ain x scaled for „Brake Car #2”

Enable special function “recuperative braking logic” Version 2:

→ set one digital input to the function “Brake Car #2”

→ **and** set Mode select to [-10..+10V] of the analogue input of the used throttle

Trigger of the special function “recuperative braking logic” (2 logics):

→ Logic 1: The Ain x scaled value is < 0

→ Logic 2: The configured input (e.g. Din1 = “Brake Car [Ax]” or “Brake Car #2 [Ax]”) is triggered

Calculation logic for the braking torque command:

→ Logic 1: Torque = -SpeedActual * Nlim+ * (percentage of negative Ain x scaled value)

→ Logic 2: Torque = SpeedActual * Nlim-

Note: The ramp generator calculation and the disable logic are the same as in chapter 1.2.

2 Digital Torque Control

2.1 Digital torque control in general

This chapter will only contain the digital torque control logics which can be relevant for car applications.

Switching between Speed-Control and Torque-Control is done automatically inside the drive when “Command Mode” is set to “Dig. Commands”.

Dig. Commands	Send request via CAN or RS232 to N set(dig.) ID: 0x31	→	Speed-Control
	Send request via CAN or RS232 to M set(dig.) ID: 0x90	→	Torque-Control

The general Torque control M set(dig.) (ID: 0x90) is of course not a torque command. It is a current command which has been scaled in order to be able to send a defined current value to set a desired torque value defined by the motor specifications.

Note: Please read the “BAMOCR_FAQ.pdf” manual on how to properly control a motors torque request.

Car_Mode_Config (0xCD) (Note: A lot of these functions are still under development)

Short symbol	Function	ID-Address
		REGID 0xCD
Car_Mode_Ena	Enable certain sensor related functions	Bit 0
DC_Current_Sens_Ena	Enable DC Bus current sensor (Only specific inverters)	Bit 1
I_DC_Limit_Ena	Enable DC Bus current limitation	Bit 2
TorqueVal_Init_Ena	Always start inverter using torque command	Bit 3
Dig_M_RcpRamp_Ena	Use M R-Rcp ramps	Bit 4
Reset_NRamp_AtNZero	Reset Speed Ramps if SpeedActual has a sign change	Bit 5
free_6	…	Bit 6
free_7	…	Bit 7
free_8	…	Bit 8
free_9	…	Bit 9
free_10	…	Bit 10
free_11	…	Bit 11
free_12	…	Bit 12
free_13	…	Bit 13
free_14	…	Bit 14
Dig_E_Brake_Act	Activate automatic recuperative braking logic	Bit 15
free_16	…	Bit 16..31

2.1.1 Digital torque control while enabling the inverter (FW ≥ 476)

If the “Command Mode” is set to “Dig. Commands” and the inverter is enabled (Ena = 1), the first automatic command request will always be a Speed-Control command with N set(dig.) = 0. Meaning that if the inverter is enabled while the motor is rotating, the inverter will try to ramp the motor to 0 rpm after enable. This can create high negative current spikes.

Only after the first torque command request (M set(dig.)) is received the inverter will change to Torque-Control. With the Bit 3 inside the parameter “Car_Mode_Config” (ID: 0xCD) it is possible to define if the enable mode should be Speed-Control or Torque-Control

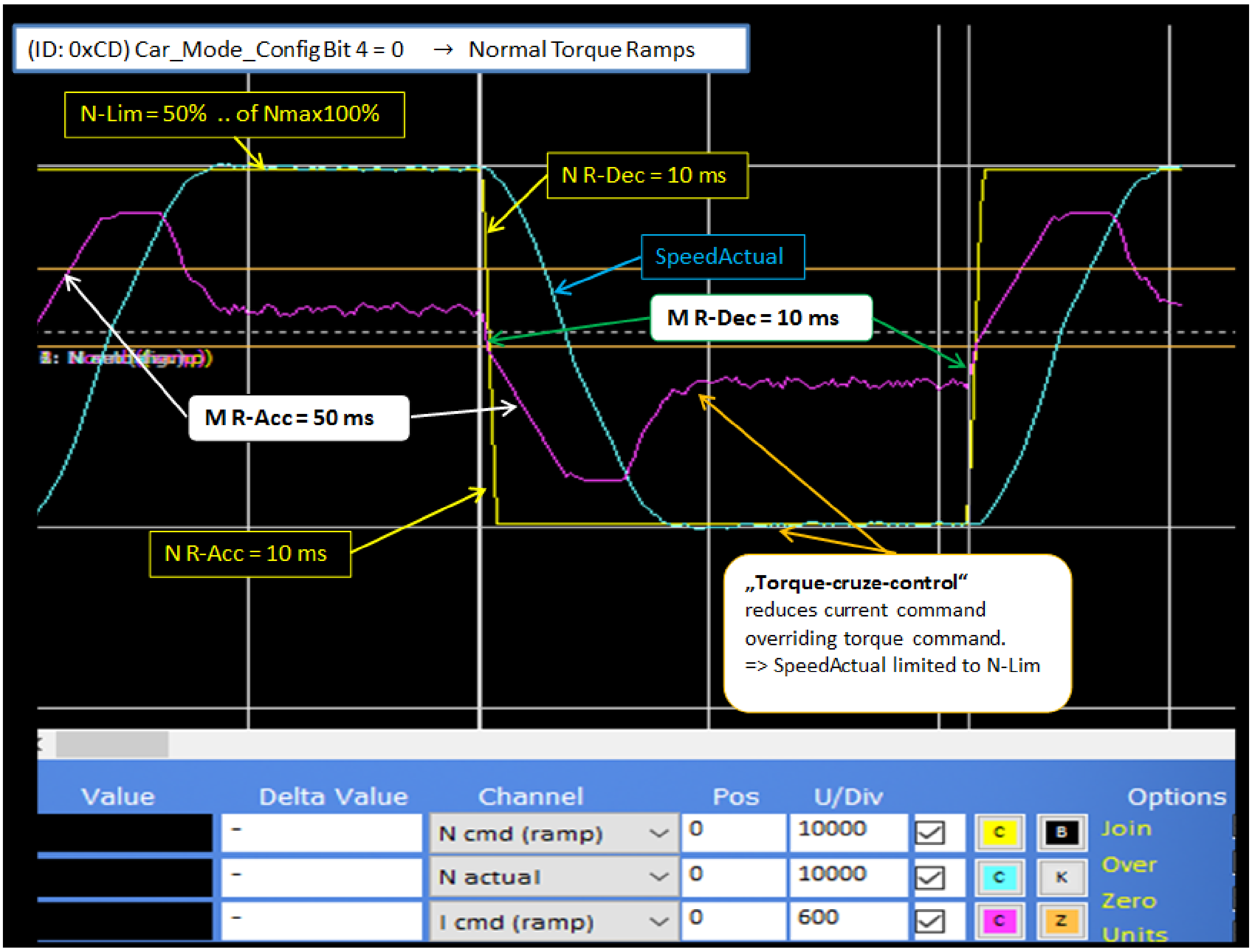
Car_Mode_Config.Bit.3 = 0 → Speed-Control after enable
Car_Mode_Config.Bit.3 = 1 → Torque-Control after enable

This means that with Car_Mode_Config.Bit.3 = 1, it is possible to enable the inverter to a running motor in Torque-Control mode without any braking or driving torque (M set(dig.) = 0).

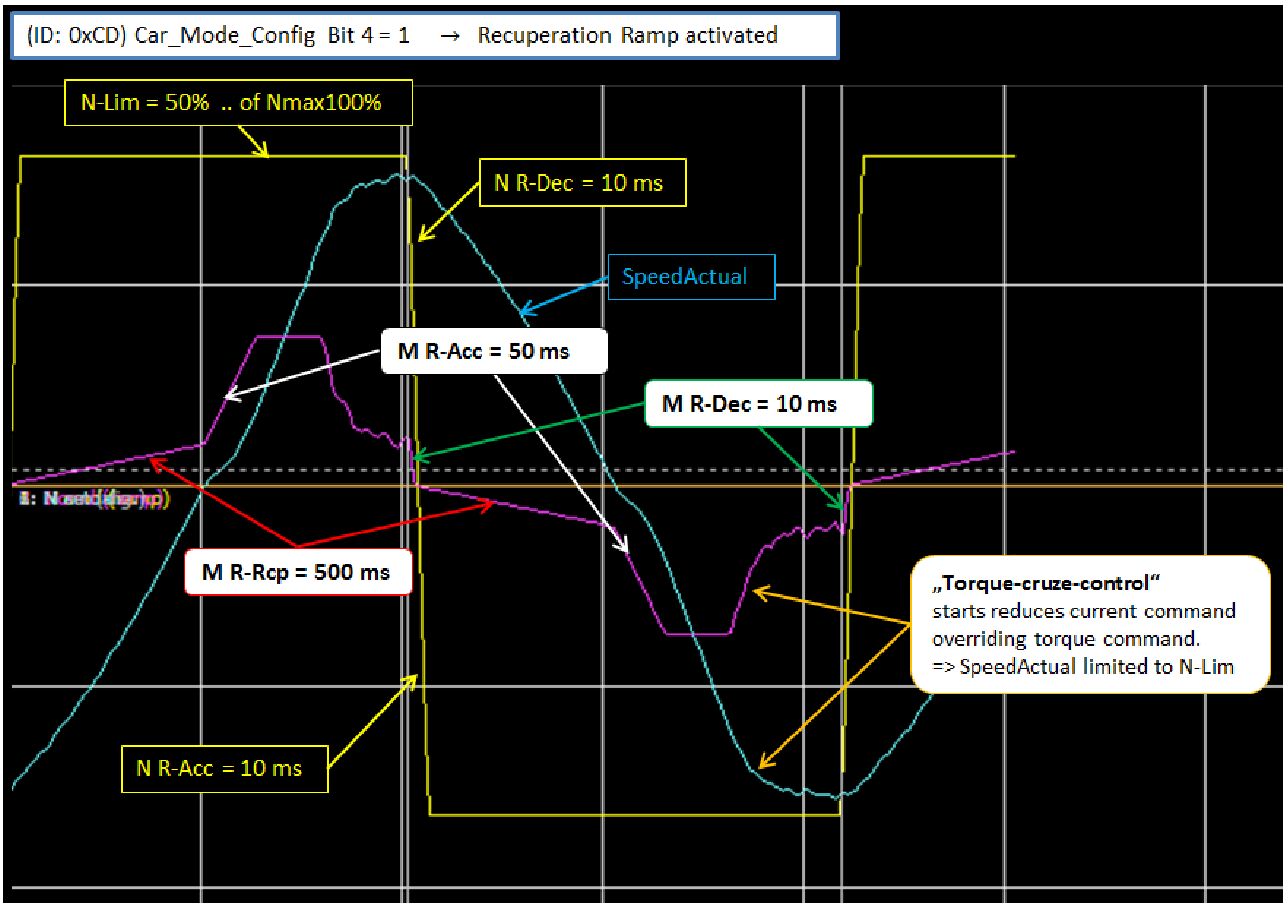
2.1.2 Digital torque control using recuperation ramps (M R-Rcp) (FW ≥ 476)

Since the release of the firmware 476 it is now possible to define the acceleration (M R-Acc), the deceleration (M R-Dec) and the recuperation ramps (M R-Rcp) individually. Beforehand, only the parameter M R-Dec defined all 3 ramp settings. It is also possible to define if the recuperation ramp should be used at all. This mainly depends on the HV battery. Not all HV batteries like a fast ramp for the recuperative current. With the Bit 4 inside the parameter “Car_Mode_Config” (ID: 0xCD) it is possible to define if the recuperation ramp should be used.

Car_Mode_Config.Bit.4 = 0 → Use “M R-Acc” (ID: 0x35-H)



Car_Mode_Config.Bit.4 = 1 → Use "M R-Rcp" (ID: 0xC7-H)



2.2 Digital Torque Control with automatic recuperation logic (Brake Car)

As explained in chapter 1.2, the theory of recuperative braking is actually very simple. As soon as the motor phase current (I_actual) and the motor phase voltage (SpeedActual) are of opposite sign, then recuperative energy will go back to the battery.
This means that all you have to do is to send a negative torque command for generator torque and you will be recuperating current back to the battery ($P_{DC} \leftrightarrow P_{AC}$).

Using digital torque command the user has complete control whether the demanded torque will be a driving or a generator torque (recuperative braking) just by sending the desired torque value (M set (dig.)) using one of the digital communication interfaces (CAN, RS232).

The downside of this technique is that the refresh rate for the calculation is limited to the same refresh rate as the communications interface (e.g. every 10 ms).
Our software provides a function to let the inverter calculate a recuperative braking logic internally just by triggering the activation depending on the settings. The logic is more or less the same as with the analogue logic except that the trigger command must also be a digital trigger.

Enable special function “recuperative braking logic”:
- → set one digital input to the function “Brake Car”
- → **and** set the usage of the digital recuperation ramps to active (Car_Mode_Config.Bit.4 = 1)

Trigger of the special function “recuperative braking logic” (2 logics)
- → Logic 1: Setting the activation Bit to 1 (Car_Mode_Config.Bit.15 = 1)
- → Logic 2: The configured input (e.g. Din1 = “Brake Car [Ax]”) is triggered

Calculation logic for the braking torque command:
- → Logic 1: Torque = -SpeedActual * Nlim+ (using parameter “Nlim+” (ID: 0x3F))
- → Logic 2: Torque = SpeedActual * Nlim- (using parameter “Nlim-“ (ID: 0x3E))

(Note: ‘Nlim+’ and ‘Nlim-’ represent the maximum possible current in % of I max peak = 100 %.
In case of long “N R-Dec” Ramps, different responses will apply.)

In case of Logic 1 as soon as the acceleration pedal is at recuperation point, set Bit.15=1, to activate recuperation and as soon as the acc. pedal starts accelerating, reset Bit.15=0, or no acceleration command will be accepted.

Ramp generator for all analogue torque command values: (Firmware ≥ 476)
- M R-Acc → rate of increase of driving torque.
- M R-Dec → rate of decrease of driving torque.
- M R-Rcp → rate of increase of recuperative braking torque if either Logic 1 or 2 is activated.

Disable the “recuperative braking logic”: (without settings change)
- Set one digital input to “recu-disab [Ax]”. If this input is triggered, it will force any recuperation torque to zero (e.g. in case of a full battery). This is then without settings change but with an extra input.

- Example of the digital recuperation logic with trigger logic 2: