Inverter Manual

Documentation of

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Introduction

This manual will look at the setup and initialization procedure of a Bamocar D3 inverter (sometimes referred to as a *controller* or *servo amplifier*) for EMRAX 188 HV motors with a resolver as feedback system.

Our specific case scenario

The components used in our case are as follows:

- Motor: EMRAX 188 HV LC
- Resolver: Tamagawa TS2620N21E11
- Inverter: 890 Bamocar PG-D3-700-160 RS

Electrical wiring

There are two sets of connectors:

- Low voltage: X1, X7
- High Voltage: XB1, XB2, XB3, XB4, XB5

Low voltage

There are two low voltage data connectors on the device: X1 and X7.

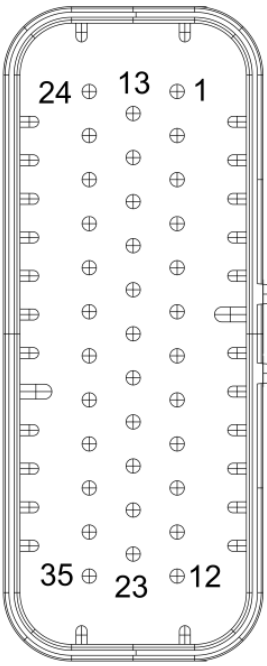
X1 connector

X1 is a 35-pin *Tyco 776164-1* connector.

The X1 connector handles the following:

- Auxiliary voltage
- Enable commands
- Digital I/O
- Analog I/O
- RS232
- CAN BUS

Connector pinouts are shown below.



X1

Connector X1 Control inputs/outputs		
1	PE2	
2	+24 V	Auxiliary voltage +
3	GND24	Auxiliarx voltage 0
4	nc	
5	nc	
6	+ AUS	Supply outputs
7	GNDE	GNDE Outputs
8	DOUT1	Digital output 1
9	DOUT2	Digital output 2
10	DOUT3	Digital output 3
11	BTB	Ready for operation
12	BTB	Ready for operation
13	GNDE	GNDE Inputs
14	FRG	Enable
15	END1	Limit switch 1
16	END2	Limit swich 2
17	DIN1	Digital input 1
18	DIN2	Digital input 2
19	RFE	Rotor Enable
20	AR1	Analog Input 1-
21	AIN1	Analog Input 1+
22	AR2	Analog Input 2-
23	AIN2	Analog Input 2+
RS232		
24	R1IN	RS232
25	T1OU	RS232
26	T2OU	RS232
27	R2IN	RS232
28	GND	Analog GND
Analog Output		
29	DAC1	Analog Output
30	GND	Analog GND
CAN-BUS		
31, 32	CAN H	
33, 34	CAN L	
35	CAN-GND	

2 +24 V Auxiliary voltage +

This pin must be connected to a power supply capable of providing +24V at 2A (±10% ripple), in order to power the inverter.
If the auxiliary voltage is less than 16V, even for short-term voltage drops, the error message *Hardware Fault 1* (Power Fault) is displayed and the internal PSU switches off, which causes temporary data saved in the RAM to be deleted and the digital speed and command torque values to be set to zero.

11, 12 BTB Ready for operation

It is a solid state relay contact (max 48V, 0.5A) for safety circuits, and it signals whether the inverter is ready for operation or not.
If the device is ready for operation the BTB relay contact is closed, otherwise the BTB relay is open, the 7-segment display will display an error message and the red fault LED will be lit.
It can also be read via software: state signal parameter state RDY (0x40 Bit 14) -> Ready BTB = logic 1.
In case of errors this safety circuit is separated by the relay and the RDY state is set to 0.
Further control units (e.g. BMS, VCU, etc.) may respond.

14 FRG Enable

Without the FRG/RUN enable the motor is electronically disabled (no PWM pulses are propagated).

Note: the FRG command must not be initiated before the auxiliary voltage and the power voltage have been switched on.

If the enable does not seem to be working while connected to NDrive via RS232, try enabling and disabling the *Dis* LED in the *Test* section

19 RFE Rotating Field Enable

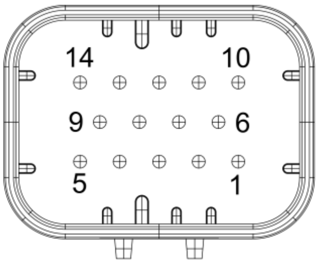
Allows the motor to rotate (rotation enable). If the rotating field is not enabled the output stage is additionally disabled (2nd disable channel).

When the input for the RFE is switched off the motor is torque free (no holding torque). Without mechanical brakes the motor may fail or move. In this case the motor cables are not voltage-free.

X7 connector

X7 is a 14-pin *Tyco 776273-1* connector.

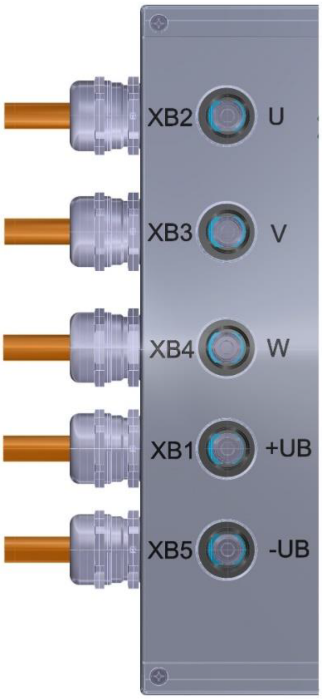
The X7 connector handles the feedback system, in our case a resolver, and the motor temperature probe. Connector pinouts are shown below.



X7

Connector X7	
Encoder plug - resolver	
1	
2	SIN1
3	COS2
4	REF1
5	
6	Temp GND
7	
8	
9	
10	
11	Temp. signal
12	REF2
13	COS1
14	SIN2

High voltage



XB2 U
U motor phase

XB3 V
V motor phase

XB4 W
W motor phase

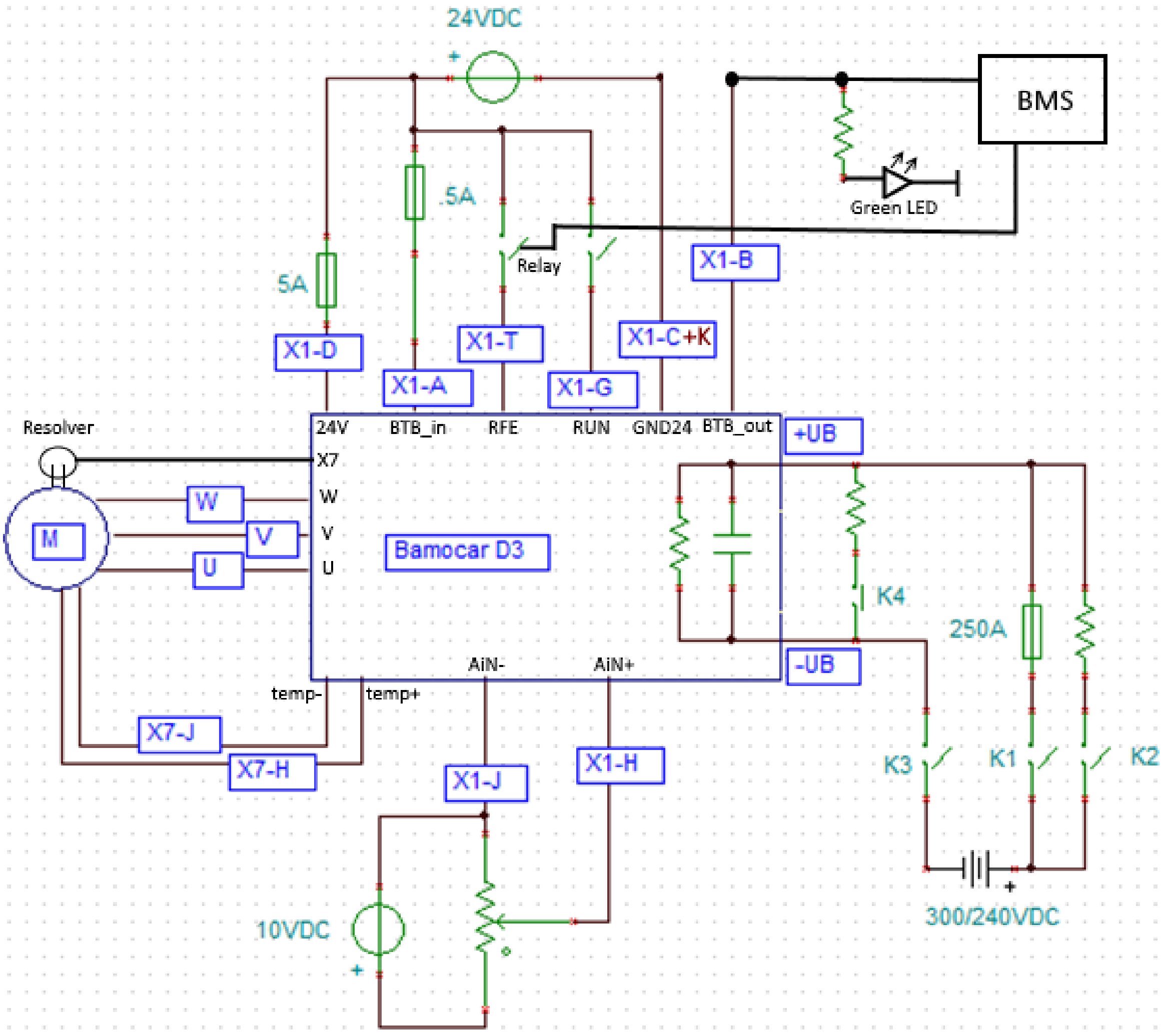
XB1 +UB
Positive battery voltage. The absolute maximum supply voltage is 740V, which must not be exceeded at any time, not even for short intervals.

XB5 -UB
Negative battery voltage

Attention:
The braking energy is fed to the battery, thus it must be able to absorb it.
If the battery is disconnected from the device during the braking process, high bus circuit voltages might occur.

Hardware setup

The schematic shown below is the connection scheme suggested by UniTek.



Notes:

- Important: DO NOT short BTB_in (X1-A) using 24 V with Ground via BTB_out (X1-B);
- The bleeder resistor at K4 and the K3 relay are optional;
- The safety circuit for BTB_in and BTB_out are optional. The BTB_out could also be connected to e.g. the main controller instead;
- The "Relay" at the X1-T circuit controlled by the BMS is a recommended safety logic. If it is required to disconnect the HV-DC (+UB, -UB) line during operation in an emergency situation, then it is important to disable the inverter beforehand. This is best done by disabling (cut) the RFE (enable) input using a relay;
- The Green LED is of course just an example of using the BTB output to indicate the ready state of the inverter.

NDrive

General information

NDrive is a software used to set-up and optimize UNITEK digital servo amplifiers (DS, DPC) and motor drives (BAMO-D, BAMOBIL-D, BAMOCAR-D).

Basic computer skills and fundamental knowledge of the Windows OS are required.

The NDrive software and the respective manual are available on CD or via the internet.

It is possible to use this software to communicate and change parameters of both the old inverters (Bamocar D3 700 400, used in Chimera Evoluzione) and the new inverters (Bamocar D3 700 160, used in Fenice).

Installation and connection

To download NDrive browse to this link and click on “NDrive2-Software.zip”.

Once the download is complete, unzip the file and open “NDrive v3xx.exe”.

Notes:

- The software is portable and no installation is required;
- The unzipped folder contains a “manuals” folder with many useful documents.

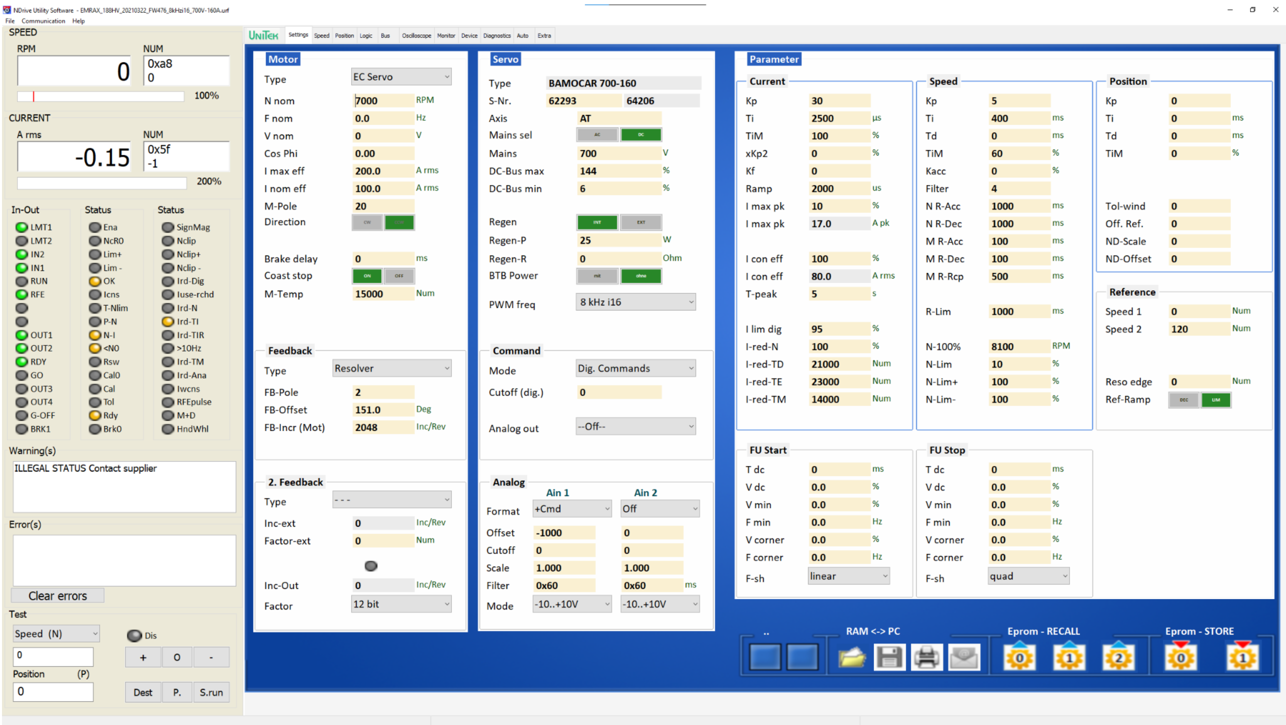
Now connect your PC to the inverter using the RS232 port on the X1 connector. If the PC doesn’t have a serial port use a RS232 to USB adapter.

Remember to plug and unplug the connecting cable only when the interface is disconnected.

After the physical connection, power on the inverter via the auxiliary voltage (turn on the LV battery), select the correct COM port (Communication -> COMx) and check that the baud rate is set to 115200. To find the correct COM port use Windows Device Manager.

Once the correct COM port is selected, the software will automatically read the parameters and registers saved on the inverter. If no connection is established, the parameters will show the corresponding register address.

Layout overview



The layout is composed of a status sidebar that allows the user to view the inverter's current state (speed, current, I/O, status, errors and test functions) and a main section which is divided in the following tabs:

- Settings: in this tab the user can set all the necessary parameters
- Speed: system overview for controlling speed/torque
- Position: system overview for controlling the position
- Logic: digital I/O setup
- Bus: CAN-Bus configuration
- Oscilloscope: parameter vs. time plot
- Monitor: a summarized view of the main parameters
- Device: register values
- Diagnostics: manual read/write of registers and debug tools
- Auto: motor auto-tune
- Extra: other registers and sensor readouts

Storing/Loading parameters

The memory management pane is placed on the bottom-right corner of the Settings tab.

When there is an active communication the parameters displayed on the screen are those currently active inside the RAM of the servo drive. By pressing the return key, the changed value is directly updated to the servo RAM.

Writing to EPROM
To permanently save the parameters on the Eprom click on ***Eprom - STORE 0 or 1***. Data will be written on the corresponding level of the Eprom.
Level 0 contains the current parameter record. Every time the auxiliary voltage is turned on, all parameters of the Eprom 0 are loaded onto the RAM.

Loading from EPROM
To load the parameters from another Eprom level click on ***Eprom - RECALL 0, 1 or 2***. The new data will be loaded onto the RAM and will be displayed on NDrive. If the new data is not saved on level 0, it will be lost upon shutdown and at the next power-up level 0 will be loaded.

The level 2 Eprom stores the default factory parameters and cannot be overwritten.

Saving/Loading register files
To save (load) a register file select *File -> Save* (*Load*) *registers* or click the *floppy disk* (*file*) symbol in the memory *RAM <-> PC* section.

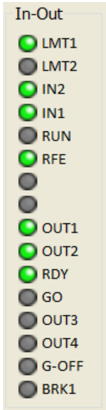
Working with .urf files when offline
Loading, changing, and saving of parameter files (.urf) while being in offline mode is possible by selecting *Communication → View File* in the menu bar. After selecting the .urf file all parameters are loaded onto NDrive and are ready to be analysed and changed.

To save the changes select *File → Load Registers* in the menu bar.

STATUS SIDEBAR

I/O

The LED indicators of the inputs are lit if the input voltage is >10V and for the outputs they are lit if the output voltage is positive.



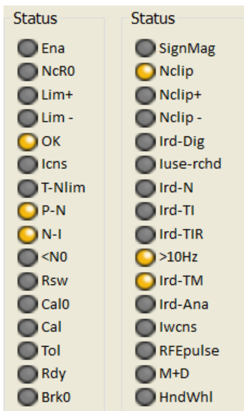
RUN **$0xD8_{\text{bit 4}}$**
If lit the hardware enable (FRG) is active.

RFE **$0xD8_{\text{bit 5}}$**
If lit the rotating field enable is active.

RDY **$0xD8_{\text{bit 10}}$**
If lit the device is ready for operation and the BTB contact is closed

OUT1 ÷ OUT4 **$0xD8_{\text{bits 8, 9, 12, 13}}$**
If lit the corresponding digital output, *Dout x*, is on

<IStatus



Ena **$0x40_{\text{bit 0}}$**
If lit both the hardware and the software *RUN* enables are active.

Lim+ **$0x40_{\text{bit } 2}$**
If lit the positive limit switch has tripped.

Lim+ **$0x40_{\text{bit } 3}$**
If lit the negative limit switch has tripped.

Icns **$0x40_{\text{bit } 5}$**
If lit the current limit is reduced to the continuous current limit

<N0 **$0x40_{\text{bit } 9}$**
If lit the actual speed is less than 0,1% (standstill).

SignMag **$0x40_{\text{bit } 16}$**
If lit, the direction of rotation is inverted (in the logic bus *N cmd Reverse* is Active Low)

Ird-Dig **$0x40_{\text{bit } 20}$**
If lit the current limit is reduced to the parameter value *I lim-dig* due to current derating being activated by the logic input (or via CAN-bus) *I limit (dig)*.

Iuse-rchd **$0x40_{\text{bit } 21}$**
If lit the current command value has reached the present maximum allowed current limit.

Ird-N **$0x40_{\text{bit } 22}$**
If lit current derating has been activated by *I-red-N*.

Ird-Ti **$0x40_{\text{bit } 23}$**
If lit the current reduction function, due to the IGBT temperature exceeding *I-red-TD* is active.

Ird-TiR **$0x40_{\text{bit } 24}$**
If lit the current reduction due to the IGBT temperature exceeding *I-red-TD* is active.

>10Hz **$0x40_{\text{bit } 25}$**
If lit, the current reduction function has been activated by the actual speed value, because the rotating field frequency is lower than 10 Hz.
If the rotating frequency is lower than 10 Hz the current limit must be reduced to the motor's allowed continuous current. This is important in order to protect the inverter from high currents.

At one's own risk this blocking protection can be deactivated by an automatic switch-over to a PWM frequency of 4 kHz:

- $0x5A_{\text{bit } 31}$ = 0 : blocking protection activated (current limit is reduced)
- $0x5A_{\text{bit } 31}$ = 1 : blocking protection deactivated (pulse frequency switched over to 4 kHz)

Ird-TM **$0x40_{\text{bit } 26}$**
The motor temperature *T-Motor* has exceeded the *I-red-TM* value and the current derating function has begun.

Errors

If an error is detected, it is sent to NDrive via the $0X8F_L$ register and the error information is displayed in the *Error(s)* field.

In case of an error the following occurs:

- The red fault LED on the side of the 7-segment display lights up;
- The error code is displayed on the 7-segment display;
- The BTB (ready) contact is opened;
- The software *BTB message* switches from *1* to *0*;
- The *RDY* state message extinguishes;
- The error message will remain even after turning off the enable input.

The error message is deleted only when the enable input is off and:

- The *Cancel errors* digital input is on;
- The Cancel errors command is sent via CAN or serial;
- In case of a positive edge from the enable input (FRG/RUN).

The following table shows the various error codes with their relative messages, descriptions and register addresses:

Display on the servo:	**Error message in NDrive:**	**Function:**	**ID address:** $0x8F_L$
	NOREPLY-No RS	RS232 interface not plugged in or disrupted	
0	BADPARAS	Defective parameter detected	Bit 0
1	POWER FAULT	Hardware fault	Bit 1
2	RFE	Faulty safety circuit (only active for RUN)	Bit 2
3	BUS TIMEOUT	CAN TimeOut time exceeded	Bit 3
4	FEEDBACK	Bad or faulty encoder signal	Bit 4
5	POWERVOLTAGE	No power supply voltage	Bit 5
6	MOTORTEMP	Motor temperature too high	Bit 6
7	DEVICETEMP	Device temperature too high	Bit 7
8	OVERVOLTAGE	Overvoltage > 1.8 x UN is reached	Bit 8
9	I_PEAK	Over-current or strongly oscillating current detected	Bit 9
A	RACEAWAY (*)	Racing (without command value, incorrect direction)	Bit 10
B	USER	User – error selection	Bit 11
C			Bit 12
D			Bit 13
E	HW_ERR	Current measuring fault	Bit 14
F	BALLAST*	Ballast circuit overload	Bit 15
Flashing decimal point		Active processor	
Dark decimal point		No auxiliary voltage or unit-internal hardware fault	

Warnings

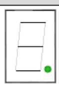
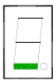
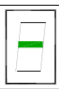
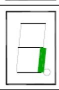
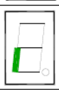
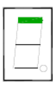
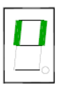
If a warning is detected, it is sent to NDrive via the $0X8F_H$ register and the error information is displayed in the *Warning(s)* field.

In case of a warning the red fault LED starts blinking and the 7-segment display alternately shows the warning status and the warning code.

The following table shows the various warning codes:

Display on the servo:	Warning message in NDrive:	Function:	ID address: $0x8F_H$
0	WARNING_0	Inconsistent device identification	Bit 16
1	ILLEGAL STATUS	Faulty RUN signal, EMI	Bit 17
2	WARNING_2	Inactive RFE signal (without RUN input active)	Bit 18
3			Bit 19
4			Bit 20
5	POWERVOLTAGE	Power supply voltage missing or too low	Bit 21
6	MOTORTEMP	Motor temperature > (I-red-TM or 93 % of M-Temp)	Bit 22
7	DEVICETEMP	Device temperature > 87 % of the limit	Bit 23
8	Vout_Sat	Limit of the existing voltage output reached	Bit 24
9	I_PEAK	Overcurrent 200 %	Bit 25
A	RACEWAY	Resolution range of the speed measuring exceeded	Bit 26
B			Bit 27
C			Bit 28
D			Bit 29
E			Bit 30
F	BALLAST*	Ballast circuit overload > 87 %	Bit 31

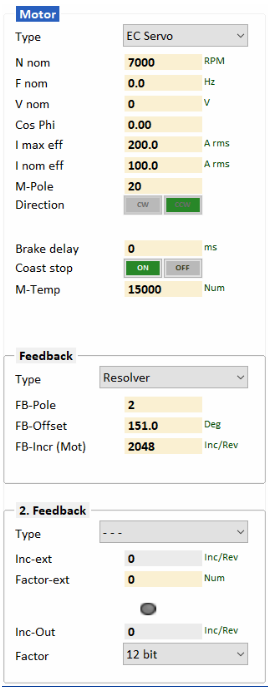
The following table shows the various status configurations:

Display: (7-segment LEDs)	Point/ segment:	Status:	Status in NDrive:
	flashing dark	Processor active Auxiliary voltage missing or inherent hardware failure	
	flashing bright dark	Starting state after reset (aux. voltage 24V off-on). The first enable stops the flashing display. Drive enabled Drive disabled (not enabled)	OK = 0 OK = 1, ENA = 1 OK = 1, ENA = 0
	bright	Speed zero (standstill signal)	NO = 1
	bright	Drive revolves clockwise, N currently positive	NO = 0
	bright	Drive revolves anti-clockwise, N currently negative	NO = 0
	flashing bright dark	Motor current reduced to continuous current Icns Motor current at max. current limit I_{max} Normal operation; Motor current within the current limits	Iwcns = 1 Iwcns = 0 Iwcns = 0
	bright for 0.1s	Left segment: A new command (value) was received from the BUS or RS232 Right segment: Digital input changed.	

SETTINGS

The current parameters have been set using a configuration file that has been sent to us by UniTek after a request from our side.
In this section the most relevant parameters and data inputs are explained.

Settings - Motor



Coast stop
If set to **OFF**, the drive decelerates in a controlled manner to a standstill before it is disabled. When the enable is turned off, the internal speed command value of *N cmd Ramp* is reduced to zero according to the *R-Lim* setting. The power section is disabled 50ms after the axis has come to a standstill or 50ms after the ramp-time (*R-Lim*) has elapsed. The power stage is disabled after 1.5s at the lastest. After this time the motor is free of torque

If set to **ON**, the power section is immediately disabled when the enable is turned off and the motor decelerates free of torque.

Beware that the maximum value for the *R-Lim* time is 1000ms (just 1s), and this could cause serious stress to the components.

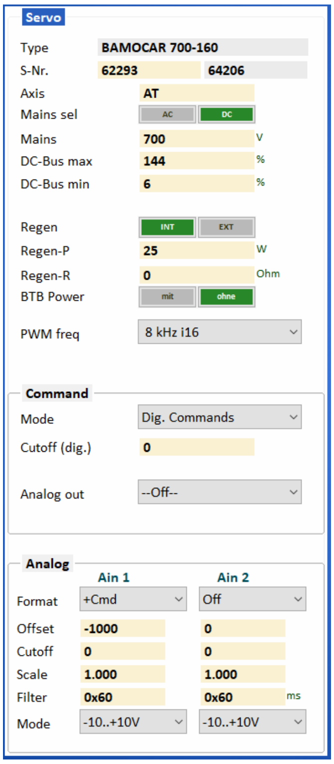
M-Temp
Switch-off point due to motor overheating.

If the motor temperature (*T-motor*) exceeds the set value of *M-Temp*:
- there will be a switch-off due to an error by the inverter
- the error 6 (MOTORTEMP) is displayed

If the motor temperature (*T-motor*) exceeds 87 % of the set value of *M-Temp*:
- the max current limit is reduced to the continuous current limit

- the *Ird-TM* ($0x40_{bit\ 26}$) LED is turned on in the *Status* pane
- the warning 6 (I-MOTORTEMP) is displayed

Settings - Servo



Direction of rotation

To reverse the direction of rotation it is possible to use a digital input or to switch the activation condition in the *logic* panel (AL/AH).

Settings - Parameter

Current

In this section the main parameters of the current section are explained.

Current

Kp	30	
Ti	2500	µs
TiM	100	%
xKp2	0	%
Kf	0	
Ramp	2000	us
I max pk	10	%
I max pk	17.0	A pk
I con eff	100	%
I con eff	80.0	A rms
T-peak	5	s
I lim dig	95	%
I-red-N	100	%
I-red-TD	21000	Num
I-red-TE	23000	Num
I-red-TM	14000	Num

Kp 0x1C

It indicates the proportional amplification factor of the PI feedback controller for the current control.

The current controller is a PI controller: $K_p \cdot (1 + \frac{1}{Ti \cdot s})$.

It can range from 0 to 200 Num and the value 33 corresponds to a 1.0 factor in amplification.
UniTek recommends setting the value between 10 and 40.

If *Kp* is set to the correct value the difference between the speed command value and the actual speed value is optimal (control error approx. < 5%) and the actual current value does not oscillate. Remaining errors can be eliminated by means of the integral adjustment.

If *Kp* is set too low, compensation error, bad dynamics and low-frequency vibrations will occur.
The difference between the speed command value (*Icmd (Ramp)*) and the actual current value (*Iactual*) is too large and the maximum torque is not reached at high speeds.

If *Kp* is set too high, strong motor noise and high-frequency vibrations will occur.
The actual current value overshoots the current command value.
Rough operation, and high-frequency motor noise.

Ti

It indicates the integral time constant of the PI feedback controller for the current control. It strongly depends on the value of *Kp*, these values must be evaluated and set together.

The current controller is a PI controller: $K_p \cdot (1 + \frac{1}{Ti \cdot s})$

It can range from 375 to 10000ms. UniTek recommends setting the value between 700 and 2500ms.

If *Ti* is set to too low, high frequency vibrations will occur and short current transient overshoots with high frequency oscillations will be visible on the oscilloscope. The motor will have a strong tendency to vibrate.

If *Ti* is set too high, the control error is nearly not compensated or it is compensated too slowly. Low frequency vibrations will occur and long current transient overshoots with low frequency oscillations will be visible on the oscilloscope.

TiM
Maximum value of the integral memory *Ti*. The value can range from 0 to 300%. UniTek recommends setting the value between 80 and 100%.

If *TiM* is set too low the requested speed is not reached with a high load, despite a sufficiently high current command value.

xKp2
Proportional amplification factor that multiplies *Kp* when the actual current is greater than the current limit *I lim inuse*.
The value can be 0 (deactivated) or it can range from 100 to 500%.
(If the feedback value is higher, the device will output less current -> it thinks it is providing too much current, hence the reduction).

UniTek recommends setting the value either to 0 (deactivated) or between 100 and 120%.

If *xKp2* is set too high there is a danger of current oscillation.

Kf
Proportional amplification factor for the feed-forward control to compensate for the operating delay in the controller. Activate only if demanded by the system.

The value can range from 0 to 167 Num. UniTek recommends setting the value either to 0 (deactivated) or between 10 and 50%.

If Kf is set too high there is a danger of current oscillation.

Ramp
Ramp time for the current command value. The value can range from 125 to 32000µs.
Note: the lower bound of the range depends on the PWM frequency.
UniTek recommends setting the value between 600 and 2500µs.

If *Ramp* is set too high there is a danger of long-wave speed oscillation (motor becomes unstable).

I max pk
Device peak current limit. The value can range from 0 to 100%.

I con eff
Device continuous current limit in A_{RMS}. The value can range from 0 to 100%.

T-peak
Maximum allowed time for the current to be above the continuous current limit (*I con eff*). The value can range from 1 to 40 seconds. The subsequent current reduction will last 5 times this amount.

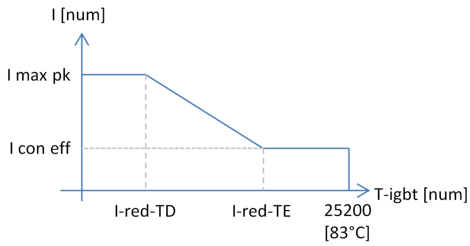
This setting is only active if *Ird-TI* (current derating due to the IGBT temperature exceeding *I-red-TD*) is not activated.

I limit (dig)
Current reduction limit that is considered when the logic input *I limit (dig.)* is activated (see digital I/O). The value can range from 0 to 100% and the reference is the maximum device peak current (*I max pk*).

I-red-N
Current reduction by means of the actual speed. The value can range from 0 to 100%.

I-red-TD
Triggering IGBT temperature for enabling current reduction (derating).
In case of an increasing IGBT temperature, the maximum current limit is linearly reduced until the IGBT temperature reaches the set target of *I-red-TE,* at which point the maximum current limit is set to the continuous current limit.

I-red-TE
Target IGBT temperature of the current reduction triggered by the IGBT temperature reaching *I-red-TD*. At *I-red-TE* the maximum current limit will be lowered to the continuous current limit.



- The maximum IGBT temperature is 25200 Num (approx. 83 °C);
- If 85% of the maximum IGBT temperature is reached, the warning 7 (DEVICETEMP) is set;
- If the maximum IGBT temperature is exceeded, an error switch-off from the inverter will occur and the error 7 (DEVICETEMP) will be displayed.

Note: The hardware power stage (IGBT) temperature monitoring works independently from the software setting.

The derating function is activated if the following conditions hold: (*I-red-TD* < *I-red-TE)* and (*I-red-TD* > 0).

The activation of the function is displayed as *Ird-TI* (0x40Bit 23) inside the Status field.

If this current derating function is triggered it is displayed as *Ird-TIR* (0x40Bit 24) inside the Status field.

Note: if there is a derating function activated because of the output stage temperature, the current limiting caused by *T-peak* (0xF0) is deactivated.

I-red-TM
Triggering value for enabling current reduction (derating) due to the motor temperature reaching the set threshold.
If the motor temperature (*T-Motor*) exceeds the *I-red-TM* value:

- The maximum current limit is linearly reduced to the continuous current limit from the triggering temperature *I-red-TM* to the switch-off temperature *M-Temp*
- The Ird-TM (0x40Bit 26) LED is lit in the Status field
- The warning 6 (I-MOTORTEMP) is displayed

Unit of measure: Num

Setting current control values

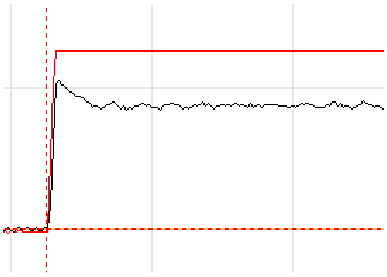
Kp

To set the correct *Kp* value follow this procedure:

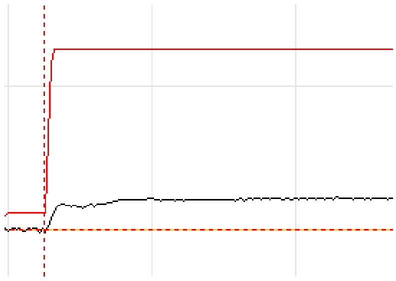
1. Remove the integral component (set TiM to 0%) to isolate the effects of Kp;
2. Set a fast speed ramp (N R-Acc = 10÷100ms)
3. Set the trigger on the NDrive oscilloscope to channel 1 (*N cmd (ramp)*), *Edge* to *Rise > Lev* and *Level* to 100;
4. Start the oscilloscope recording, send a speed command (e.g.: 10000), stop the motor and analyze the obtained waveform.

Note: set U/Div to 300 - 600 for the current readings.

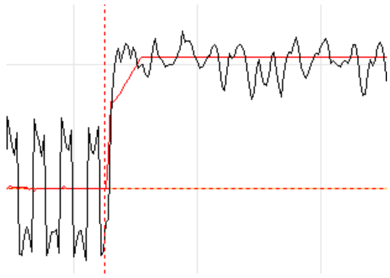
If *Kp* is set to the correct value the difference between the speed command value and the actual speed value is optimal (control error approx. < 5%) and the actual current value does not oscillate. Remaining errors can be eliminated by means of the integral adjustment.



If *Kp* is set too low, compensation error, bad dynamics and low-frequency vibrations will occur.
The difference between the speed command value (*Icmd (Ramp)*) and the actual current value (*Iactual*) is too large and the maximum torque is not reached at high speeds.



If *Kp* is set too high, strong motor noise and high-frequency vibrations will occur.
The actual current value overshoots the current command value.
Rough operation, and high-frequency motor noise.

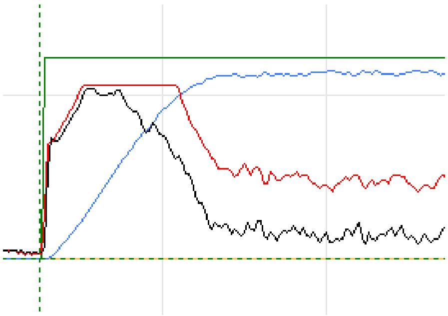


Ti and TiM

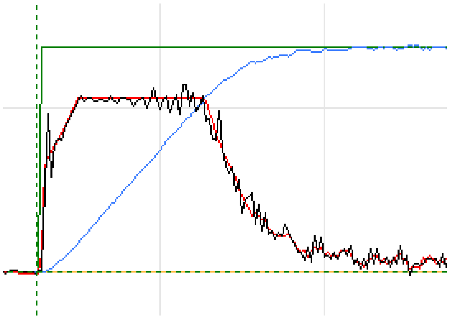
To set the correct *Ti* and *TiM* values follow this procedure:

1. Set *Kp* first;
2. Add the integral component back (set TiM ≠ 0% and Ti ≠ 0μs);
3. Set a fast speed ramp (N R-Acc = 10÷100ms)
4. Set the trigger on the NDrive oscilloscope to channel 1 (*N cmd (ramp)*), *Edge* to *Rise > Lev* and *Level* to 100;
5. Start the oscilloscope recording, send a speed command (e.g.: 10000), stop the motor and analyze the obtained waveform.

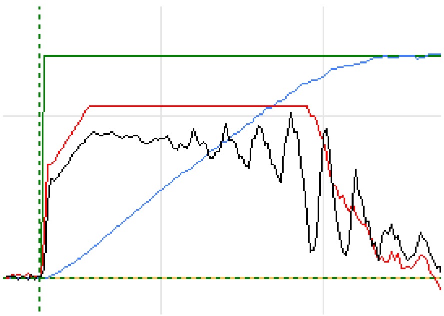
If TiM is set too low the requested speed (green) is not reached with a high load, despite a sufficiently high current command value (red). UniTek recommends setting the value between 80 and 100%.



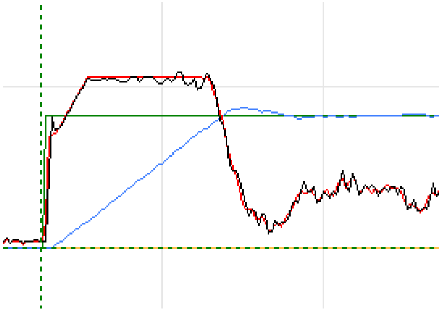
If *Ti* is set to too low, high frequency vibrations will occur and short current transient overshoots with high frequency oscillations will be visible on the oscilloscope. The motor will have a strong tendency to vibrate.



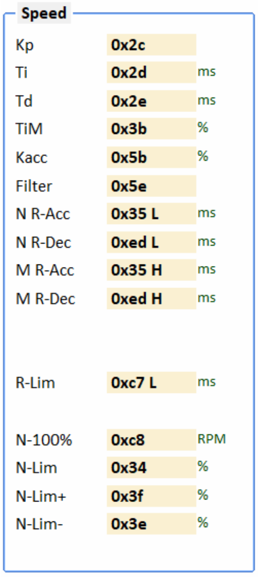
If *Ti* is set too high, the control error is nearly not compensated or it is compensated too slowly. Low frequency vibrations will occur and long current transient overshoots with low frequency oscillations will be visible on the oscilloscope.



If *Kp*, *Ti* and *TiM* are set correctly, the actual current will respond correctly to the requested current with no significant overshoots, delays or oscillations.



Speed



Kp 0x2C
It indicates the proportional amplification factor of the PID feedback controller for the speed control.

It can range from 0 to 200 Num and the value 33 corresponds to a 1.0 factor in amplification.
UniTek recommends setting the value between 5 and 50.

If *Kp* is set too low there will be a compensation error and bad dynamics and low frequency vibrations will occur.

If *Kp* is set too high, strong motor noise and high frequency vibrations will be present.

Ti 0x2D
It indicates the integral time constant of the PID feedback controller for the speed control. It strongly depends on the value of *Kp*, these values must be evaluated and set together.

It can range from 0 to 10000ms. UniTek recommends setting the value between 6 and 400ms.

If *Ti* is set to too low, high frequency vibrations will occur and the motor will have a strong tendency to vibrate.

If *Ti* is set too high, low frequency oscillations and large speed overshoots will occur and the motor will operate very weakly.

Td 0x2E
It indicates the derivative (differential) time constant of the PID feedback controller for the speed control. Activate only if demanded by the system.

The value can be either 0 (deactivated) or it can range from 0 to 100 ms. UniTek recommends setting the value either to 0 (deactivated) or between 6 and 20 ms.

If Td is set too high high frequency vibrations will occur and the motor will have a strong tendency to vibrate.

TiM **0x3B**
Maximum value of the integral memory *Ti*. The value can range from 0 to 100%. UniTek recommends setting the value between 20 and 60%.

If *TiM* is set too low the requested speed is not reached with a high load.

Kacc **0x5B**
Dynamic acceleration value directly to the current controller. Activate only if demanded by the system.

The value can range from 0 to 100%. UniTek recommends setting the value either to 0 (deactivated) or between 10 and 50%.

If *Kacc* is set too high there is a danger of current oscillations.

Filter **0x5E**
Filter for the actual speed value. The value can range from 0 (without filter) to 10 (max. filter effect).

If *Filter* is set too low, motor noise, high frequency vibrations will occur and the motor will have a strong tendency to vibrate.

If *Filter* is set too high, low frequency vibrations will occur.

N R-Acc **$0x35_L$**
Acceleration ramp for the speed and position command values. The parameter value always corresponds to the time needed to reach the reference value of *Nmax100%* from 0 RPM (not the time to reach the requested speed).

The value can range from 0 to 30000ms.

N R-Dec **$0xED_L$**
Braking/deceleration ramp for the speed and position command values. The parameter value always corresponds to the time needed to reach the reference value of *Nmax100%* from 0 RPM (not the time to reach the requested speed).

The value can range from 0 to 30000ms.

Set to <10ms for position control.

M R-Acc **$0x35_H$**
Current ramp for acceleration during torque control. The value can range from 0 to 4000ms.

This setting is only active in torque control mode and is ignored in speed control mode.
The reference value (the value that will be reached at the end of the ramp) is *I max pk*

M R-Dec **$0xED_H$**
Current ramp for deceleration during torque control. The value can range from 0 to 4000ms.
The reference value (the value that will be reached at the end of the ramp) is *I max pk*

M R-Rcp 0xC7$_H$

Current ramp for recuperation during torque control. The value can range from 0 to 4000ms.
The reference value (the value that will be reached at the end of the ramp) is *I max pk*

R-Lim 0xC7$_L$

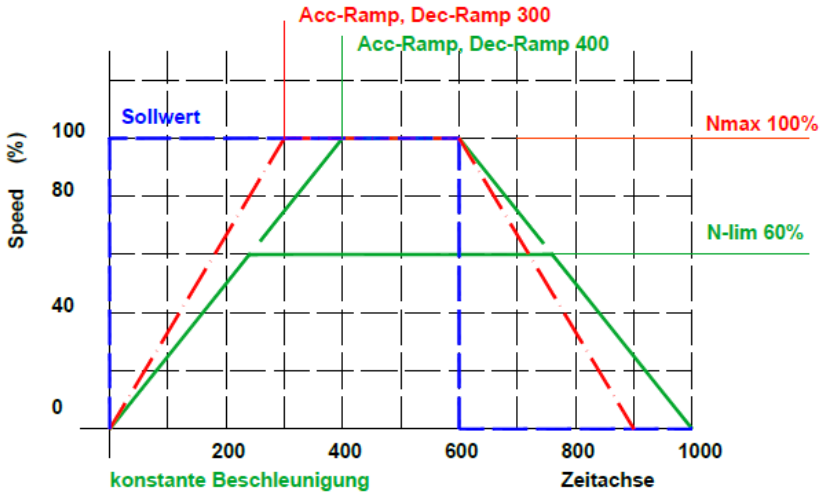
Minimum braking ramp in case of emergency stop or limit switch trigger. During speed control this setting is active only if the free coasting is deactivated.

The value can range from 0 to 1000ms.
The reference value for which the ramp is calculated is *Nmax100%*.

Nmax100% 0xC8

Physical reference value for the internal resolution of the speed to 16 Bit (±32767). The value can range from 100 to 50000 rpm.

Always set this value to the max. motor speed. If the speed needs to be limited to a lower value use *N-Lim*.



N-Lim 0x34

Speed limit for both the positive and negative rotation directions. The value can range from 0 to 100% and the reference value is *Nmax100%*.

For torque control (current presetting) with *N-Lim* < 100%, the torque speed control (Tempomat) is activated.

N-Lim+ 0x3F

Speed limit for the positive rotation direction. The value can range from 0 to 100% and the reference value is *Nmax100%*.
Only active if the *N clip(neg&pos)* logic input is set and activated.

Special function: it serves as the current limit for automatic recuperation during torque control.

N-Lim- 0x3E

Speed limit for the negative rotation direction. The value can range from 0 to 100% and the reference value is *Nmax100%*.
Only active if the *N clip(neg&pos)* logic input is set and activated.

Special function: it serves as the current limit for automatic recuperation during torque control.

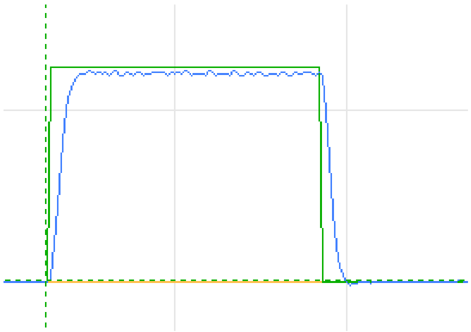
Setting speed control values

Kp

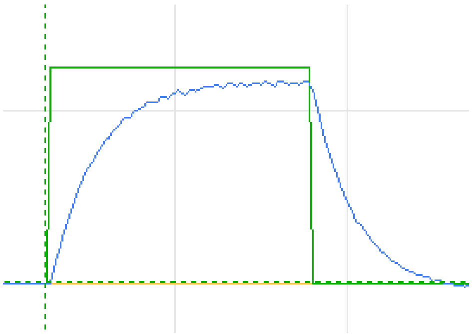
To set the correct *Kp* value follow this procedure:

5. Remove the integral component (set TiM to 0%) to isolate the effects of Kp;
6. Set the requested speed ramp (N R-Acc = 10÷10000ms)
7. Set the trigger on the NDrive oscilloscope to channel 1 (*N cmd (ramp)*), *Edge* to *Rise > Lev* and *Level* to 100;
8. Start the oscilloscope recording, send a speed command (e.g.: 1000), stop the motor and analyze the obtained waveform.

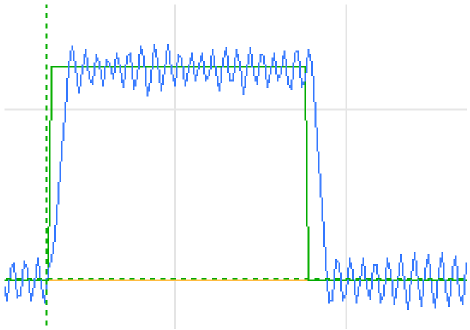
If *Kp* is set to the correct value the difference between the speed command value *N cmd (ramp)* and the actual speed value *N actual* is low (control error approx. < 5%) and the actual speed value does not oscillate. Remaining errors can be eliminated by means of the integral adjustment.



If *Kp* is set too low, the difference between the speed command value *N cmd (ramp)* and the actual speed value *N actual* is too large. The speed command value is not reached and the acceleration is too slow. The drive responds smoothly at changes in the command value and can be easily moved at standstill.



If *Kp* is set too high, the actual speed value significantly overshoots the speed command value. Rough operation, strong tendency to vibrate (also at standstill) and motor noise.

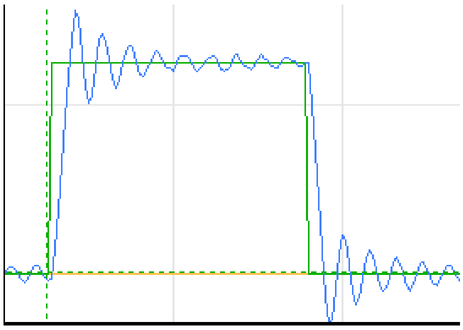


Ti and TiM

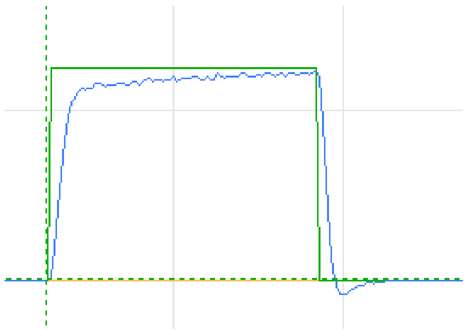
To set the correct *Ti* and *TiM* values follow this procedure:

6. Set *Kp* first;
7. Add the integral component back (set TiM ≠ 0%);
8. Set the requested speed ramp (N R-Acc = 10÷10000ms)
9. Set the trigger on the NDrive oscilloscope to channel 1 (*N cmd (ramp)*), *Edge* to *Rise > Lev* and *Level* to 100;
10. Start the oscilloscope recording, send a speed command (e.g.: 1000), stop the motor by turning off *FRG* and analyze the obtained waveform.

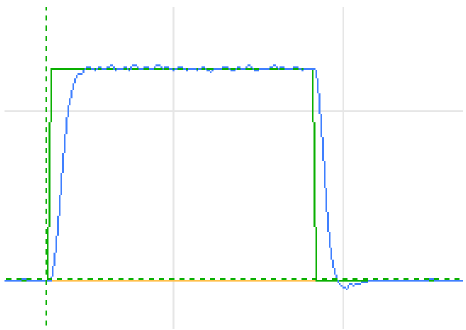
If *Ti* is set to too low, high and fast overshoots at the first command value step will occur and short-wave oscillations might be present.



If *Ti* is set too high, the control error is nearly not compensated or it is compensated too slowly. Long-wave vibrations are possible.



If *Kp* and *Ti* are set correctly, the actual speed will respond correctly to the requested current with no significant overshoots, delays or oscillations.



Note: to reduce the control error (overshoot) to a minimum, correct the *TiM* value. Set *TiM* as small as possible.

BUS

NBT
CAN transfer (baud) rate. See table below.

Transfer rate NBT	Setting value in NBT (0x73)	Max. cable length [m]
1000 kBaud	0x4002	20
625 kBaud	0x4014	70
500 kBaud	0x4025 (default)	70
250 kBaud	0x405C	100
125 kBaud	0x4325	100
100 kBaud	0x4425	100

Rx ID
CAN ID - receiving address

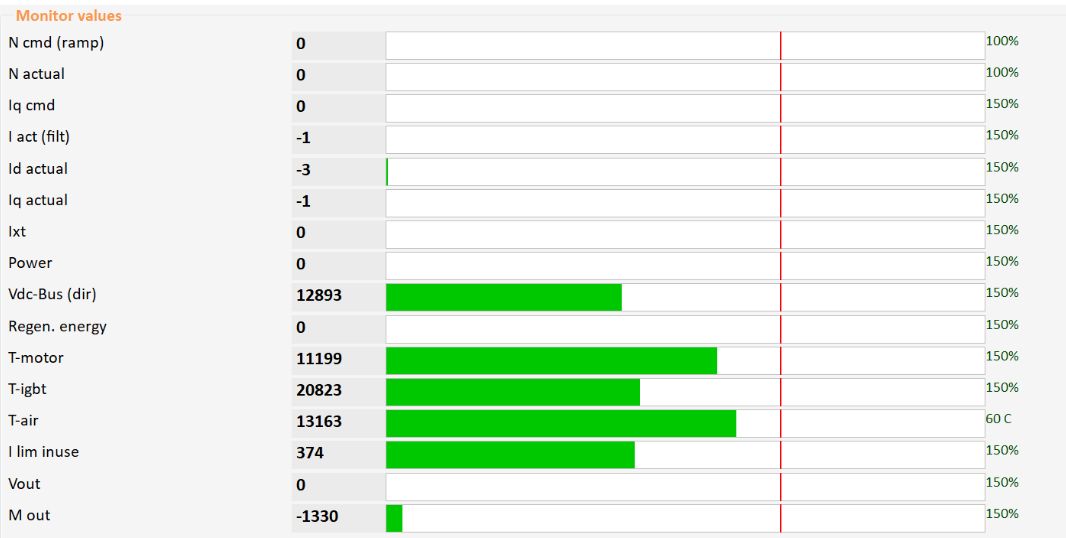
Tx ID
CAN ID - transmitting address

T-Out
CAN timeout time. The value can range from 0 to 60000ms

OSCILLOSCOPE

MONITOR

The monitor tab shows the real-time measured values of the following parameters.



N cmd (ramp)
Internal speed command evaluated after ramp and limit settings. The value can range from 0 to 32767 Num.

N actual 0x30
Actual speed value. The value can range from 0 to 32767 Num.

I cmd 0x26
Internal current command value. The value can range from 0 to 600 Num.

T-motor 0x49
Motor temperature. The value can range from 0 to 32767 Num.

T-igbt 0x4A
Output stage temperature. The value can range from 0 to 32767 Num.

T-air 0x4B
Air temperature in the motor. The value can range from 0 to 32767 Num.

I lim inuse 0x48
Present current limit. The value can range from 0 to 600 Num.

AUTO

Unit and registers conversions

To convert the numerical values from the inverter registers to real world values with measurement unit use these formulas.

Where:

- 0xC6 is the device's rated current (CurrentDevice) measured in [1/10 Arms] (tenths of amps) and it is a constant value that depends on the device.
  On the NDrive software: Device -> RegID Extra -> I device;
- 0xD9 is the device's numeric value that is read when a current that is 200% of the device's rated current 0xC6 is flowing. (essentially) It is the maximum value of the ADC and it is a constant value that depends on the device;
  On the NDrive software: Device -> RegID Extra -> I 200%;
- 0xXX is the numeric current value to convert.

Values examples:

- 0xc6=800
- 0xd9=1153

Current max vs current continuous

The max current is the RMS value the inverter can achieve for a short amount of time.

```
float Current_continuos = 1.0f / 10 * [reg 0xc6] // Arms

float Current_max = 1.5f * Current_continuos // Arms
```

Internal currents in the inverters

```
int16_t [reg 0xXX],[reg 0xc6],[reg 0xd9]

float <name 0xXX> =

      (1.0f / 5 * [reg 0xc6] / [reg 0xd9]) * [reg 0xXX] // Arms
```

Registers interested:

- 0x22 “Iq cmd ramp”
- 0x26 “Iq cmd”
- 0x27 “Iq actual”

Current command to inverter logic

```
int16_t [reg 0xXX],[reg 0xc6]

float <name 0xXX> =

      (1.5f / 10 * [reg 0xc6] / INT16_MAX) * [reg 0xXX] // Arms
```

Registers interested:

- 0x90 “M set (dig.)”

Note:

```
“1.5f / 10 * [reg 0xc6]” is the “Current_max”
```

Torque from current

```
float MOTOR_CURRENT_TORQUE_CONSTANT // Nm/Arms

float Current // Arms

float Torque = Current * MOTOR_CONSTANT // Nm
```

Current peak from Current RMS

The peak current of a sine is higher than the [RMS](RMS) value

```
float Current // Arms

float Current_peak = Current * sqrtf(2) // A
```

Initialization process

The following procedure has been suggested by UniTek directly, after a request from our side.
The symbols used reference the schematic in the *Hardware setup* section.

Power on Motor Controller

- Make sure that the switches of branches X1-T, and X1-G are all open.
- Turn on the power supply or power supplies that are being used to connect 24V to the motor controller through X1-D and X1-C

Connect Motor Controller to NDrive

- Once the 24V signal is identified as working correctly, load a version of NDrive on a computer and set the baud rate to the 115k value.
- Attach the serial port connector to the controller. Attach the serial port cable to the serial port to USB converter and connect the USB to the designated computer.
- Determine what COM port the USB is connected to and select that COM port on the NDrive software. (Check the Windows device manager to determine the COM port)
- Once the COM port is selected inside NDrive, identify that the NDrive software sees the controller.
- Successful connection will be indicated by the Firmware-Number at the bottom of NDrive (e.g. FW473)

Applying High Voltage to Controller

- Check that the switches in branches K1, K2, K3 are open
- Check that the switch in branch K4 is closed and has been closed for at least 15 seconds
    - If the switch is open, close the switch in branch K4 for at least 15 seconds
- Once the switch in branch K4 has been closed for at least 15 seconds, open the switch
- Close the switch in branch K3 (K3 is the main HV-DC supply switch)
- To initial Pre-Charge, close the switch in branch K2
- Using the N-Drive Software, determine when the DC-BUS is at least 90% of the total applied voltage (Check NDrive->Extra->Vdc-Bus (0xeb).
- For the initial phasing process, only a low HV-DC voltage (e.g. 40V) is required.
- Once the DC-BUS voltage is at least 90%, close the switch in branch K1
- Once the switch in branch K1 has been closed, open the switch in branch K2
- High voltage is now being supplied to the motor controller and the system is considered live and should be handled carefully and cautiously

Turn on enables

- Enabling motor controller and phasing process
    - With the 24V power supply already on, from section Power on Motor Controller the motor controller will already be on. This power supply will also supply power to X1-A, X1-G, and X1-T; these connections are initially off until they are switched on (steps below).
    - Once K1 has been enabled, switch on X1-T (RFE: Rotating field enable). Rotating field enable allows the motor to rotate

- Now we need to determine if the U,V,W connection are correct and we need to determine the feedback offset angle (Depending on your feedback system e.g. resolver) by using the Phasing process:
    1. Go to the connected NDrive.
    2. Set I max pk to 5% (Important)
    3. Set Speed 2 at Pos-Reference to 100
    4. Auto ~> Special functions ~> select [fn4] Phasing-Rotating
    5. Press START (The next step must be done before 10 s are over)
    6. Switch on X1-G (RUN: Run enable)
       (The drive Status-Map (0x40) inside N-Drive will activate Ena (Bit 0) to high and the output safety-circuit X1-B (BTB) will go high.
    7. The motor must then rotate 360° once in CW direction.
        - If the motor is not spinning or is rotating in CCW direction, then the motor phases (U, V, W) are not connected correctly
        - If the motor rotates less or more than 360°, then the motor pole configuration is wrong.
    8. Disable drive by switching X1-G (RUN) to off (NDrive will tell you)
    9. At FB-offset you will see the new offset angle. Write this new value into FB-Offset at the page settings and save to Eprom by pressing the Eprom-STORE 0 button.
- The motor controller is now ready to accept command signals.

Use and Configure Analogue Input and Test Motor

(If you intend to use digital commands from the start, just skip this section)

- After the phasing process the motor shouldn't be spinning (Because Ena = Off)
- Please leave the current settings at max. 10% for initial testing
    - Please set the motor currents only once to their nominal values and always use the current settings of the Bamocar device (below Parameter) for configurations
- Set inside NDrive the Command mode to Analog Torque (or Analog Speed), set the Format to Cmd+, set the Offset to -1000 and set Mode to 0..+10V
- Turn the potentiometer until the resistance between the between X1-H and the positive side of the 10V supply is at its maximum
- Turn on the 10V power supply that is connected to the potentiometer. The negative terminal of the potentiometer is connected to X1-J (AIN1-: Analog 1-) and the wiper is connected to X1-H (AIN1+: Analog 1+). This will supply Analog input 1 with a 0-10V signal that will act as the throttle for testing purposes.
- Inside NDrive go to the page Speed and on the top left you can see the Analog input
- Check if Ain scaled is below 0 if resistance is at its maximum.
  Now check if by changing the potentiometer the variable Ain scaled will change according to the potentiometer value. If a supply of 10V is used, the range should be between (0..32767)+Offset. (The calculation is Ain x scaled = (Ain in + Offset) * Scale)
- If all this is okay we can try to turn the motor.
- Set the potentiometer to 0. And check if Ain scaled is below 0
- Enable the motor controller by Switch on X1-G (RUN: Run enable)
- After all the status signals are okay, slowly turn the potentiometer and motor should be spinning in CW direction

- If the motor is not turning, crank the potentiometer back to its original position, Switch off X1-G (RUN: Run enable) and turn off the 10V supply. Then diagnose the problem.

Tip: Please read the manual "Information for Traction Applications.pdf" for proper analogue configuration and the use of recuperative breaking.

Use digital command Input and Test Motor

- After the phasing process the motor shouldn't be spinning (Because Ena = Off)
- Please leave the current settings at max. 10% for initial testing
    - Please set the motor currents only once to their nominal values and always use the current settings of the Bamocar device (below Parameter) for configurations
- Set inside NDrive the Command mode to Dig. Commands
- For initial Testing we recommend to
    - set the speed ramps to a slow value of 10000 ms (N R-Acc = N R-Dec = 10000 ms)
        - Make sure that the speed controller has the following default values:
            - Kp = 10; Ti = 400 ms; TiM = 60 %
    - To activate Coast stop = ON (Freier Auslauf).
- If all this is okay we can try to turn the motor.

Speed control:

- Enable the motor controller by Switch on X1-G (RUN: Run enable)
- At the bottom left of NDrive, Send a Speed N value of 1000 Num by pressing on (+). The motor should then spin.
    - Check the rotation speed at the top left of NDrive. The NUM 0xa8 value should match your desired speed of 1000 Num.
    - The rotation speed is calculated depending on the Nmax100% value.
        - Rpm = (Nmax100% * 1000) / 32767
- Press on (-) to send a negative speed request of 1000 and check again.
- Press on (0) to stop.

Torque control:

- Limit the maximum motor speed to 10 % (N lim = 10 %)
- Enable the motor controller by Switch on X1-G (RUN: Run enable)
- At the bottom left of NDrive, Send a Torque (Iq) value of 1000 Num by pressing on (+). The motor should then spin.
    - Check the rotation speed at the top left of NDrive. The NUM 0xa8 value should match the configured speed limit of 10 % (-> 3276 Num = 10 % of Nmax100%)
    - The rotation speed is calculated depending on the Nmax100% value.
        - Rpm = (Nmax100% * 1000) / 32767
- Press on (-) to send a negative torque request of 1000 and check again.
- Press on (0) to stop and the motor will run free until the inertia will stop the motor.

Read the manual BAMOCAR_FAQ.pdf for detailed explanation of proper torque control.

Important:

- Always make sure that you disable the drive (open RFE) before you disconnect the HV-DC (+UB, -UB) power connection at least 100ms before. This is extremely important, because the Bamocar will work as a step-up converter and will be destroyed if the energy during breaking cannot be consumed by the battery.
    - We recommend to link a relay at the RFE connection. If the BMS controller needs to separate the HV-DC (+UB, -UB) supply due to safety, it must open this relay beforehand.
- Always ensure proper shielding to the motor phases and especially to the resolver connection.

CAN-Bus Communication

Setup

To configure the device for CAN communication navigate to the Bus tab and set/check the baud rate (NBT) and the sending and transmitting addresses (*Rx ID*, *Tx ID*).

Default settings:

- Receiving address — *Rx ID* = 0x201
- Transmitting address — *Tx ID* = 0x181
- Baud rate — *NBT* = 4025 (500 kBaud)

Note: after changing any parameter in the CAN communication Bus tab, the inverter must be rebooted for the changes to take place. Before rebooting make sure to save the changes by clicking on STORE 0 (or 1).

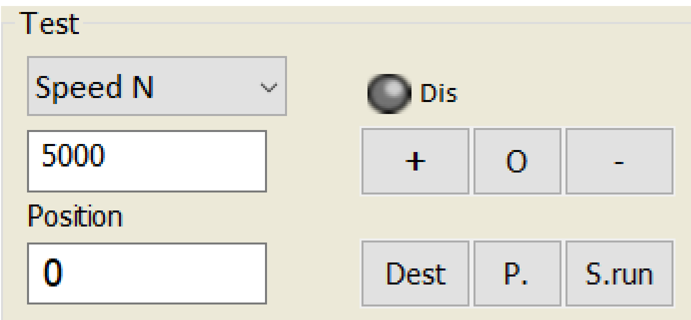
Enable/Disable via CAN-BUS/RS232

This is a special method to achieve an enable/disable state in case the hardware enable inputs are already set (the hardware enable function (FRG/RUN) and the safety input RFE are already switched on).

Disable
By means of the command ENABLE OFF (MODE-BIT 0x51Bit 2 = 1) the internal speed command value *N cmd (ramp)* is controlled to zero according to the ramp *R-Lim* adjusted in the parameter field ‘Speed’.

Enable
By means of the command NOT ENABLE OFF (MODE-BIT 0x51Bit 2 = 0) the servo drive is enabled without delay.

Software enable
Click on the *Dis* LED icon in the *Test* pane to switch between grey (software enable = ON) and red (software enable = OFF)



Enable sequence

1. First disable the servo by means of the command ENABLE OFF (MODE-BIT 0x51Bit 2 = 1).
2. Then disable the servo by means of the command NOT ENABLE OFF (MODE-BIT 0x51Bit 2 = 0).

   The servo drive is immediately enabled without any delay.
   → An enable is only possible in this order.
   → At the same time all saved errors are deleted.

Notes

Check PI and PID symptoms of bad setting once tested with load to confirm what was in the old report.

Check IO and Status conditions (on lit or on not lit)

Revision History

V1.0 XX/0X/20XX

- Initial release.