mDrive User Manual

Release 3.1.0

LLC STELM

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CONTENTS:

CHAPTER

ONE

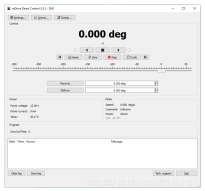
ABOUT

1.1 General information

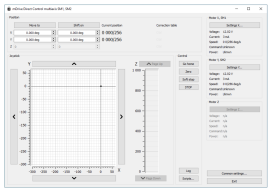
Fig. 1.1: Three-axis mDrive controller

We offer an inexpensive and ultra-compact servo-drive with USB and Ethernet interfaces for stepper and BLDC motors with external power supply.

Forget about cumbersome and expensive servo-drives! All you need is a stepper or BLDC motor, a controller, an USB/Ethernet cable and any stabilized external power supply. Forget about active coolers as well. With modern controller design even simple and inexpensive stages can be utilized to achieve high speed and precision. The controller is great at driving stepper and BLDC motors with a rated winding current of up to 3 A. Controller works with stepper motors with no feedback as well as with ones equipped with encoders in feedback loop, including linear encoders on the stages. USB/Ethernet connector provides easy communication and work with computer. Several controllers can be connected to one computer via USB/Ethernet ports. The controller is fully compatible with the majority of operating systems, e.g., Windows, Mac OS X, Linux, etc.



mDrive Direct Control main window (Single Axis mode)


mDrive Direct Control main window (Multi Axis mode)

All the necessary software including all configuration files (profiles in .cfg format) are supplied with the controller. It allows you to start working with it the controller right out of the box, according to "plug-and-play" principle. Therefore, all you need is to open your controller in the mDrive direct control software, download the .cfg file for your stage and click "Apply". Your controller is now fully configured! Enter the move commands and the controller will execute them.

1.2 Benefits

1.2.1 Main benefits

- *Compact and powerful!* The controller's dimensions are 155 x 112 x 59 mm including all connectors. The device is adapted to all stepper motors with rated winding current of up to 3 A.
- *It does remember all!* Do not worry about saving the current position on the computer: the controller does it itself using its own nonvolatile memory that works even after a sudden power cut.
- It works with peripherals! It supports a *quadrature encoder*, *magnetic brake*, a *joystick*, *limit switches*, a zero position sensor.
- *Built-in zero calibration!* Using the *limit switches*, the *revolution sensor*, the *external signal* or their combination, the zero calibration is performed by a single *command*!

1.2.2 All benefits

- Really powerful! The controller is great at driving stepper and BLDC motors with a rated winding current of up to 3 A.
- Choose your interface! Both USB and Ethernet are built-in and ready to use.
- Really fast! Up to 15,000 steps per second for any microstep mode!
- Precise! The microstep modes: full step, 1/2, 1/256 of the step on all the speeds.
- *It does remember all!* Do not worry about saving the current position on the computer: the controller does it itself using its own nonvolatile memory that works even after a sudden power cut.
- It works with peripherals! It supports a *quadrature encoder*, *magnetic brake*, a *joystick*, *limit switches*, a zero position sensor. Additional stabilized output for peripherals (5 V, 500 mA) is available.

- *Built-in zero calibration!* Using the *limit switches*, the *revolution sensor*, the *external signal* or their combination, the zero calibration is performed by a single *command*!
- Stand-alone! Would you like to work in the stand-alone mode? Just go ahead! An external *joystick*, a *keypad* or their combination is supported.
- *Energy conserving!* Programmable current reduction in the motor windings in the hold mode with 1% accuracy.
- Silent! Smooth movement at lower speeds and no extra noise at higher speeds.
- Protected! An ESD protection on all pins of external connectors and additional short circuit protection for the motor windings.
- *Attentive!* It controls the temperature of the processor and the power driver as well as both currents and voltages for the power supply and USB.
- Modern! The firmware in the nonvolatile memory of the controller *can be updated* via USB interface.
- Controlling and controllable! The built-in *synch input and output* allow to start the rotation to desired position by the incoming external signal and/or to transmit the outgoing signal after the desired position is reached. The *analog common input* and the *digital common input/output* are built in as well.
- Comprehensible! The *status LED* displays the power supply and the controller's state. For convenience of use both signals doubled at the external LEDs as well as the state of the limit switches.
- It works with all computers! All the supplied software is compatible with *Windows* (XP SP3 - 11), *Linux*, *Mac OS for intel*, including 64-bit versions and Apple Silicon (via Rosetta 2).
- Examples for programming languages! Controllers are supplied with cross-platform library and examples which allow rapid development using C++, C#, Python.
- *Full-featured interface!* The mDrive Direct Control user interface is supplied with the controller. It allows to easily control all the functions and features of the device without any programming.
- *Unique scripting language!* A scripting language is integrated into mDrive Direct Control software. It allows easy setting the sequence of actions, including cycles and branches, without compilation or learning any programming language.
- *Stepper motor close-loop control algorithm are ready!* Motion is smoother and faster than ever with innovation encoder based close-loop on mDrive motor controllers. No hidden catch, no stall or hitch, just free move!

1.3 Table of specifications

Number of axes	1 - 3
Power supply system	unified for all 3 axes
Synchronization supply system	internal (common to all axes, for the possibility of creating a connected motion along the trajectory) and external (individual for each axis)
Supported engine types	bipolar stepper, BLDC
Supply voltage range	12 - 48 V
Rated current in the winding of the stepper motor/BLDC	up to 3 A
Number of digital inputs/outputs	3 inputs, 1 output (EXTIO)
Possibility to set the voltage of the output signals according to the user's purposes	from 5 to 24 V for EXTIO, SYNC, EMBRAKE outputs (depends on the voltage applied to EXT REF SUPPLY)
Step modes	full-step, 1/2, 1/256
Maximum speed	up to 15 000 full steps per second

Continued on next page

Table 1.1 – continued from previous page

Compatibility with OS types	Windows (XP SP3, Vista, 7, 8, 10, 11), Linux, Mac OS for intel, including 64-bit versions and Apple Silicon (using Rosetta 2)
A user-friendly graphical interface	mDrive Direct Control
Programming language support, availability of examples	the controller comes with a cross-platform library and examples that allow you to quickly start programming using C/C++, C#, Python
Connecting to a PC	via USB or Ethernet
Controller dimensions	155 x 112 x 59 mm

Controller weights:

One-axis controller	533 g
Two-axis controller	603 g
Three-axis controller	669 g

Note: The controller's working voltage range is 12 V to 48 V DC. The voltage limits are 12 V and 50 V DC. If the voltage exceeds 50 V, the controller is guaranteed to fail. If the voltage falls below 12 V, the controller turns off.

1.4 Specifications

1.4.1 Motor requirements

- Motor type: bipolar stepper motor, BLDC motor.
- Rated winding current: minimum 100 mA.
- Rated winding voltage: minimum 2 V.

1.4.2 Electric specifications of the controller

- Power supply modes: external power supply.
- Current in each winding of the stepper motor, BLDC motor: up to 3 A.
- Maximum encoder pulse frequency: 200 kHz for single-ended and 5MHz for differential encoder.
- Stabilized 5 V DC output (the power supply for encoder and other peripherals): 500 mA maximum output current, 5% or better output voltage stability.
- ESD-protection on all pins of the output connectors (e.g., DVI-I, USB type B or power jack).
- Winding-to-ground short circuit protection.
- Winding-to-winding short circuit protection.
- Motor hot-swapping protection.
- Wrong power polarity protection (no more than 1 sec).
- Voltage overload protection (no more than 1 sec).
- External power supply current limitation.
- Motor rotation speed limitation.
- Programmable full winding current with 10mA precision.

- Programmable winding current decrease with 1% precision for the hold mode.
- For earth conditions, the temperature range of the controller is from +5 °C to +75 °C.

Note: The controller was not tested in a vacuum. Most likely, the controller will work in a vacuum, but it is important how the heat will be removed from the body.

1.4.3 Rotation control features

- Microstep modes: full-step, 1/2, 1/256.
- Noiseless at low speeds.
- Minimum speed is 1/256 of the full step per second.
- Maximum speed is up to 15 000 full steps per second for all microstep modes.
- Minimum shift is 1/256 of the step.
- Maximum shift is 2,147,483,647 full steps for all microstep modes.
- Smooth start/stop mode.
- 40-bit position counter (32 bits for full step and 8 bits for microstep).
- Motion modes: left/right move, move to point, shift on delta, continuous speed, acceleration and deceleration ramps, backlash compensation mode, automatic home position calibration mode.

1.4.4 Additional firmware features

- Automatic HOME calibration at firmware level.
- The nonvolatile memory used for saving/downloading the controller settings.
- Software update via USB interface.
- Automatic position saving according to step counter and encoder with power-off protection.

1.4.5 Additional features available via DVI-I connector

- Processing the signals from one or two limit switches; software configurable.
- The “step loss” detection and position recovery using either a revolution sensor or a quadrature encoder (if the stage supports this feature).
- The position detection using a quadrature encoder. The x4 mode.
- The stepper motor control using master quadrature encoder mode, providing the maximum speed without any step loss.
- Synchronization input: once the pulse is received via this pin, the controller starts rotating the motor to predetermined position or by predetermined shift value. The triggering mode, the polarity and duration of the pulse are adjustable by user. Specifications: TTL 3.3 V.
- Synchronization output: emit pulse to this pin if rotation is started or finished, or predetermined user-defined shift value is reached. The triggering mode, the polarity and duration of the pulse are adjustable by user. Specifications: TTL 3.3 V.
- Outputs for connecting control buttons (“right”, “left”). Once the button is pressed, the rotation in corresponding direction starts and the speed increases gradually according to acceleration and other settings. Specifications: TTL 3.3 V.

- Joystick pin allowing operation with various joysticks with the voltage range no more than 0–3 V.
- Magnetic brake control pin providing control to magnetic brake mounted on the motor shaft. Specifications: TTL 3.3 V, 5 mA.
- Common analog input pin allowing operation with signals within 0–3 V range. Reading frequency is 1 kHz. The configuration is programmable.
- Common digital input/output pin. 1 kHz update frequency, software configurable. Specifications: TTL 3.3 V, 5 mA.
- Digital "Power" and "Status" pins duplicate the status LED and designed for direct connection of LEDs. Specifications: TTL 3.3 V, 2 mA.
- External driver control interface allowing to control any type of external driver using three signals: enable, direction, clock.
- Multiaxis systems development. Up to 3 axes can be placed in the mDrive housing. To combine more than 3 axes, use a standard external USB hub or an Eternet connection (there are 2 Ethernet ports on the drive case). On the PC multi axis system is presented as a set of virtual serial ports or connected Ethernet devices according to the number of connected axes.

1.4.6 Programming the controller

- Controllers are supplied with cross-platform library and examples which allow rapid development using C++, C#, .NET, Delphi, Visual Basic, Xcode, Python, Matlab, Java, LabWindows and LabVIEW.
- The mDrive Direct Control user interface is supplied with the controller, which integrates a scripting language, an EcmaScript language dialect. With it, you can easily set sequences of actions, including loops and conditional transitions, without compiling and mastering any programming language. But if you don't want to program, then mDrive Direct Control makes it easy to control all the functions of the device without any programming.

Attention: The programming guide can be found on our second site libximc.xisupport.com or you can download a PDF version of it

CHAPTER

TWO

SAFETY INSTRUCTIONS

Power supply and grounding requirements. Connection to controller

General requirements for a systems in box (*single-axis*, *multi-axis* and three-axis) are listed below.

During operation, current consumption will vary depending upon how the controller is being used. Our controllers are calibrated to the rated current of the motors they are to be used with. Due to Pulse Width Modulation (PWM) our controllers consume less current than the rated current of motors. However, to avoid problems during worst case scenarios, we recommend selecting a power supply with a max current not less than the rated current of motors that will be connected to the controller. In case of multi-axis controllers you will need to sum the current of all controllers connected to the power supply. **Our controllers require a voltage of 12 - 48 V. Recommended power supply parameters: 24 V; 2.5 A**

Important: Either the power supply unit should be plugged to grounded 220 V AC socket (a three-wire connection scheme). Make sure that the minus electrode of your power supply unit is grounded. Non-compliance with this rule may lead to the decrease in controller stability and noise resistance.

Typical connection diagram for a controller:

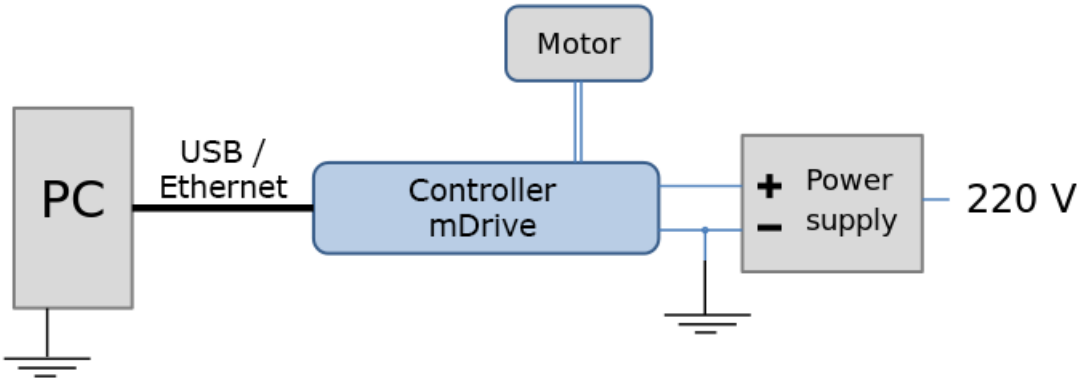


Fig. 2.1: Controller grounded via minus electrode of power cable connection diagram

Warning: Power supply unit should be able to supply sufficient current to rotate the motor. As an absolute minimum it should be able to supply

$$I_{power.min} = \frac{2 * I_{motor} * U_{motor}}{U_{power}}$$

where $I_{power.min}$ is the minimum working current of power supply unit, I_{motor} is the operating current in the winding, U_{power} is power supply unit stabilized voltage, and U_{motor} is rated operating voltage of the motor. It is recommended to use a power supply unit with operating current equal to $I_{power} \geq 2 * I_{power.min}$. The U_{power} voltage should be greater than U_{motor}. The higher the voltage, the faster rotation speed could be reached.

One can use power consumption of power supply unit to calculate minimum requirements instead. An absolute minimum of power is:

$$W_{power.min} = I_{power.min} * U_{power} = 2 * I_{motor} * U_{motor}$$

For example, for motor with operating winding current of 1 A and operating voltage of 5 V (with 5 W rated power consumption), the operating voltage of power supply unit may be chosen at 20 V with the output power of at least 10 W (the maximum operating current of power supply unit is at least 0.5 A).

Important: It is strictly forbidden to touch the *controller board* without any antistatic equipment. We recommend you to use antistatic wrist strap. **You should not exceed maximum allowed voltage of 48 V**. If voltage goes over allowed value at more than 2 volts, it can immediately and irreversibly damage the controller.

CHAPTER

THREE

QUICK START GUIDE

This guide describes the operation of controller for the multi-axis and one-axis systems, basic parameters configuration and getting started with the mDrive Direct Control software for Windows 10.

Attention: For a quick start with the controller, see the *Overview and getting started*. The programming guide can be found on our second site libximc.xisupport.com or you can download a PDF version of it.

- *Overview and getting started* - a brief description of the beginning of work with the controller mDrive. It is also considered quick mDrive Direct Control setup and lists all necessary equipment.
- *Example of a motor connection* - connection of stepper motor Nanotec ST5918L3008-B with encoder CUI INC AMT112S-V to mDrive controller. It is described how to make your own cable, guided by the specification on the engine and explanation of the specification is given.
- *Manual profile setting* - setting of working profile for mDrive Direct Control. Overview of the main features.
- *Calculation of the nominal current* - setting of amplitude of nominal current for stepper motors.

3.1 Overview and getting started

Attention: This manual is universal for all mDrive controllers

3.1.1 Introduction

This manual describes the controller installation procedures and getting started with mDrive Direct Control software for Windows 10. The installation on other OSs is described in *mDrive Direct Control installation* chapter. The detailed controller specifications are described in *Specifications* chapter. For developing your own applications, please read the *Programming guide* chapter and download the programming software package from the software chapter.

3.1.2 Requirements

For successful installation you will need:

- **PC with USB/Ethernet port**

- **Software** All necessary software to work with the controller can be downloaded from software page.
- **USB Type-A - USB Type-B cable / Ethernet cable**

- **mDrive** (one-axis) controller

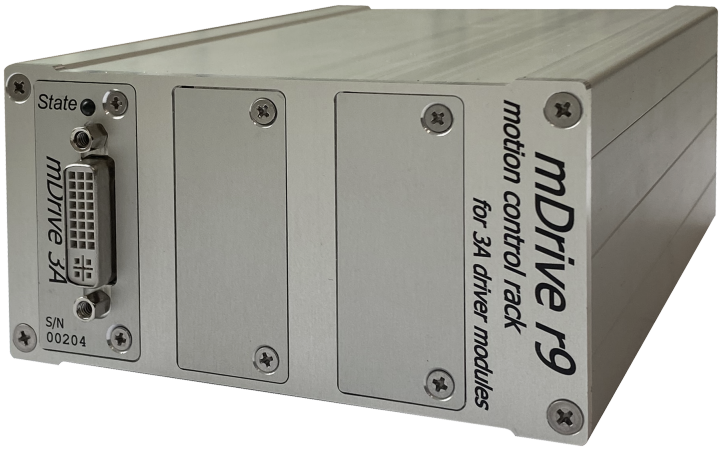


Fig. 3.1: One-Axis mDrive Controller

- **Stage or motor**

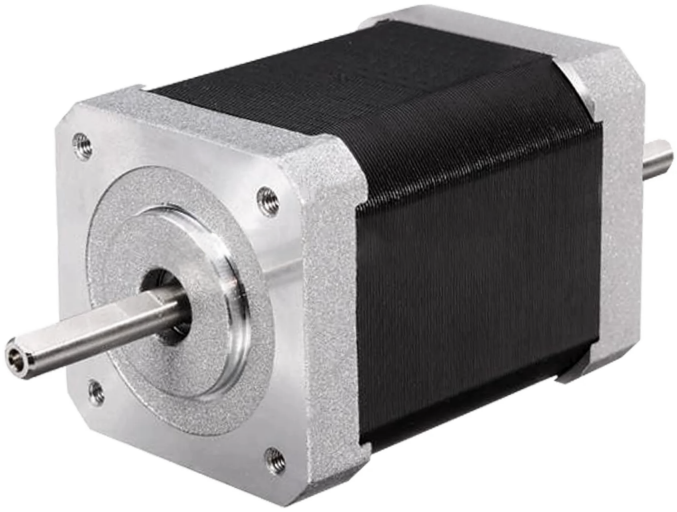


Fig. 3.2: The stepper motor

The stepper motor used in the operations is shown at the figure. The detailed motor requirements are described in *Specifications* chapter. If you use your own cables for connecting the motor/stage to the controller, please refer to *stage connection scheme* and *the controller's output connector scheme*. For motor/stage with limited movement range, two *limit switches* must be used: SW1 and SW2. These pins are used to determine the movement limits.

- **Power supply**

- Please use the 12-48 V DC stabilized power supply. Too high voltage may damage the controller. For more information please read the *Safety instructions* chapter. The power supply unit must provide the current enough for sustainable rotation of the motor.
- Grounding of the controller occurs through the "ground" of the power supply. For more information please read the *Safety instructions* chapter.
- Make sure that the controller lays on the insulating surface.

3.1.3 Software installation and startup procedures

You can download the software here. The installer file name is "mdrive_direct_control-<version_name>.exe". It automatically detects whether it is running on 32-bit or 64-bit version of Windows and installs the appropriate version of mDrive Direct Control. Launch the installation program, the installation window will appear. (Software versions may differ from each other).

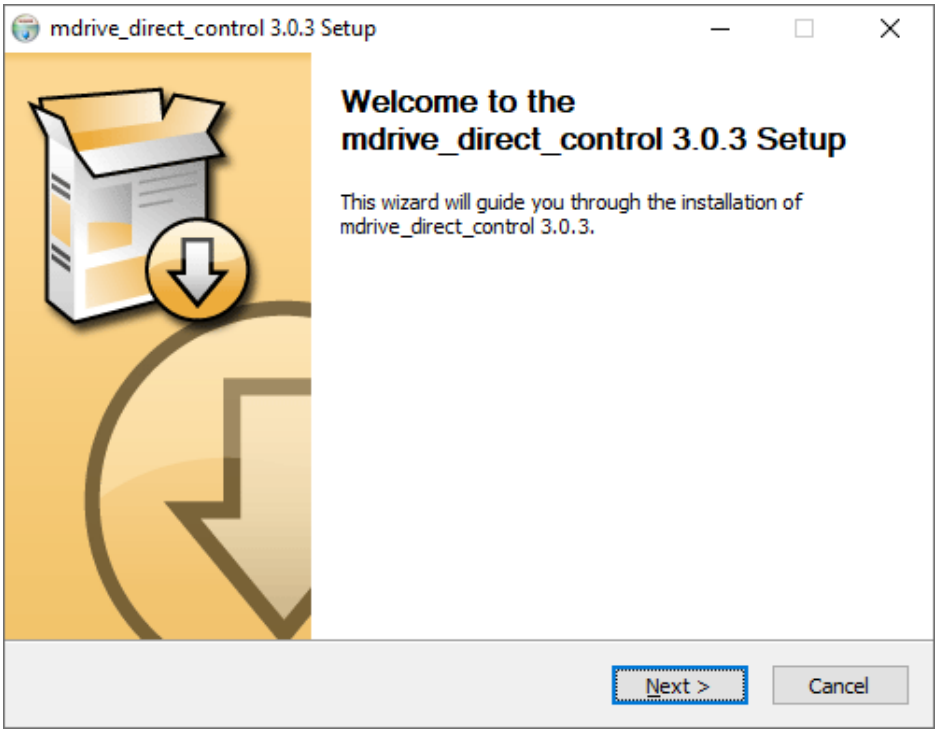


Fig. 3.3: mDrive Direct Control main installation window

Press “Next>” button and follow the instructions on screen. All the necessary software including all drivers, packages and programs will be installed automatically. After installation is finished, the mDrive Direct Control software starts by default and the following window will open:

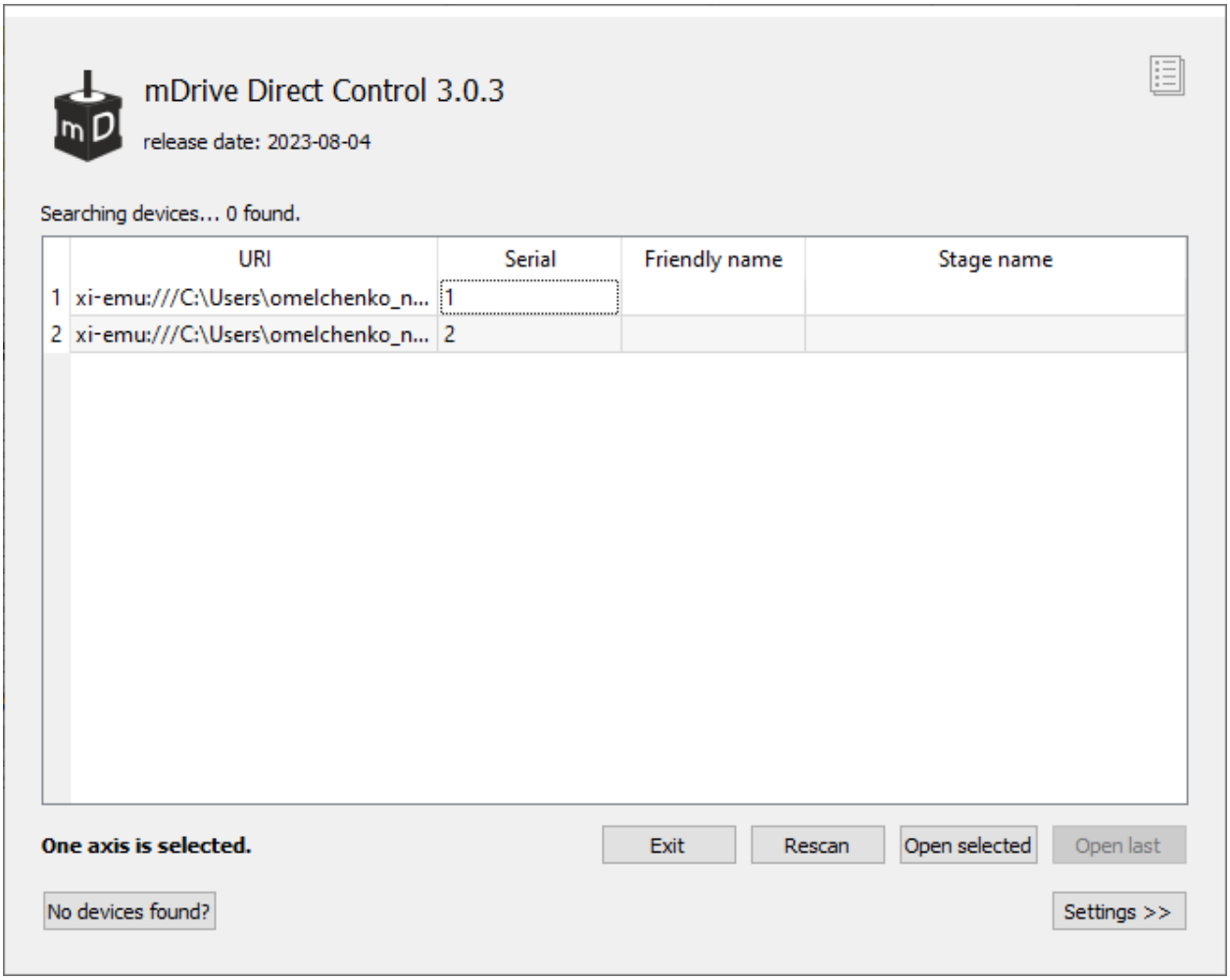


Fig. 3.4: mDrive Ditect Control “Virtual controllers found” dialogue window

Don’t press any buttons. Connect the stage to the controller. Connect the stabilized power supply unit to the controller. Ground the controller or power supply unit. Connect the controller to your PC using the USB Type-A to USB Type-B cable or Ethernet cable.

The LED indicator at the controller board will start *flashing*. The New Hardware Wizard starts working after the first connection of the controller to PC. Please wait until Windows detects a new device and installs all necessary drivers for it.

If the automatic driver installation has failed, please select “No, not this time” in the window being opened and press “Next>” button. Select “Install from a list or specific location (Advanced)” in the next window and press “Next>” again. Browse the software disk supplied with controller and find the **.inf* file there or in the **C:\Program Files\mdrive_direct_control\driver** folder and wait until installation is completed.

Go back to mDrive Direct Control “Virtual controllers found” dialog window and press “Rescan” button. If this window was closed, please reopen mDrive Direct Control software. The dialog window will open again.

3.1.4 Getting started with mDrive Direct Control software

mDrive Direct Control is a user-friendly graphic interface designed for control, diagnostics and adjustment of motors. It can also be used for easy installation and save/restore of parameters for any type of motors. This chapter describes the startup procedures with mDrive Direct Control software. For complete information please refer to *mDrive Direct Control application User's guide* chapter.

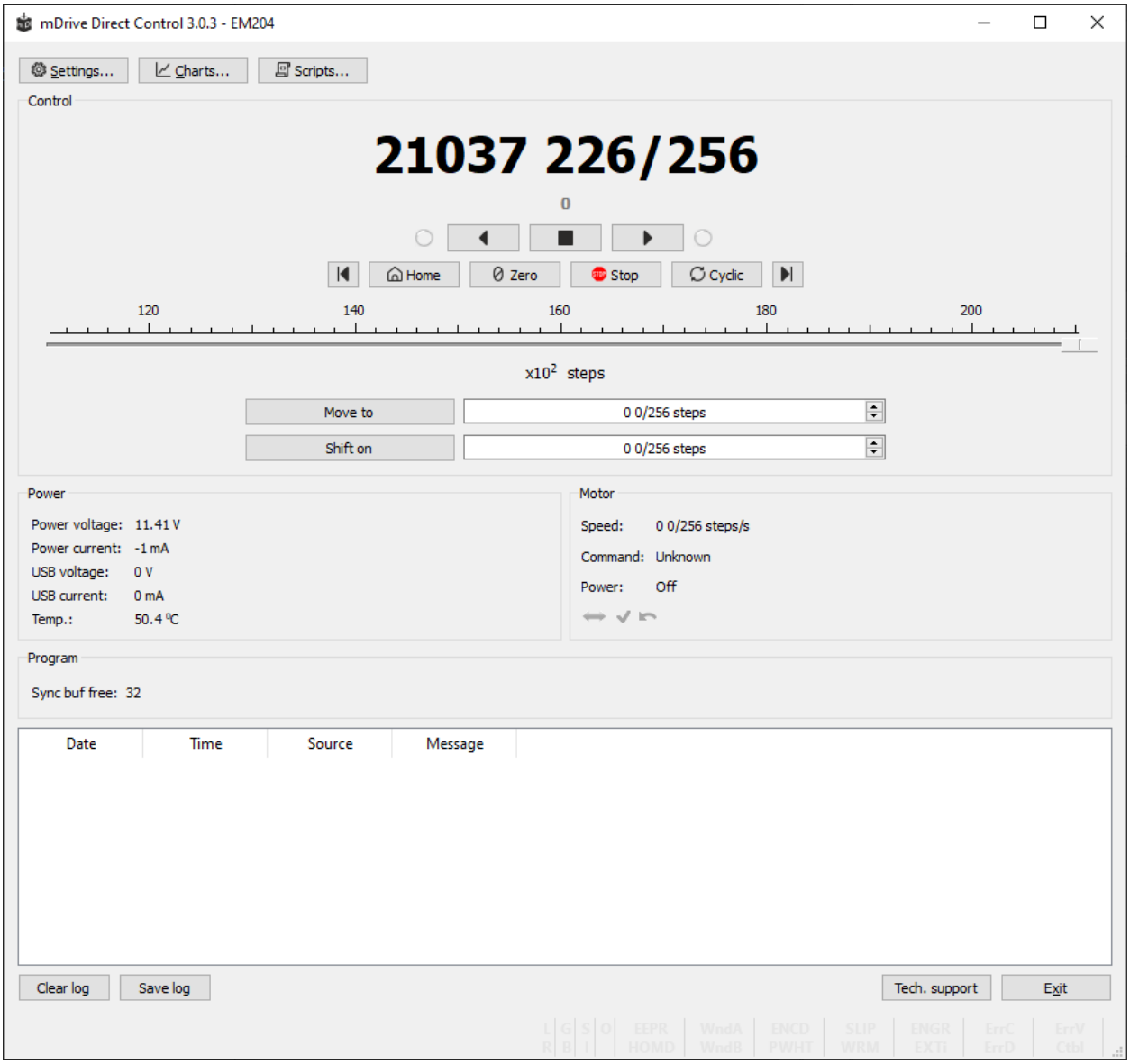


Fig. 3.5: mDrive Direct Control main window

Open "Settings…", then press "Load setting from file…" and select the configuration file for your stage from the opened **C:\Program Files\mdrive_direct_control\profiles** folder. The values applicable for your stage will automatically fill all the fields of "Settings…" menu. If the necessary file isn't found, please leave your request at our technical support website.

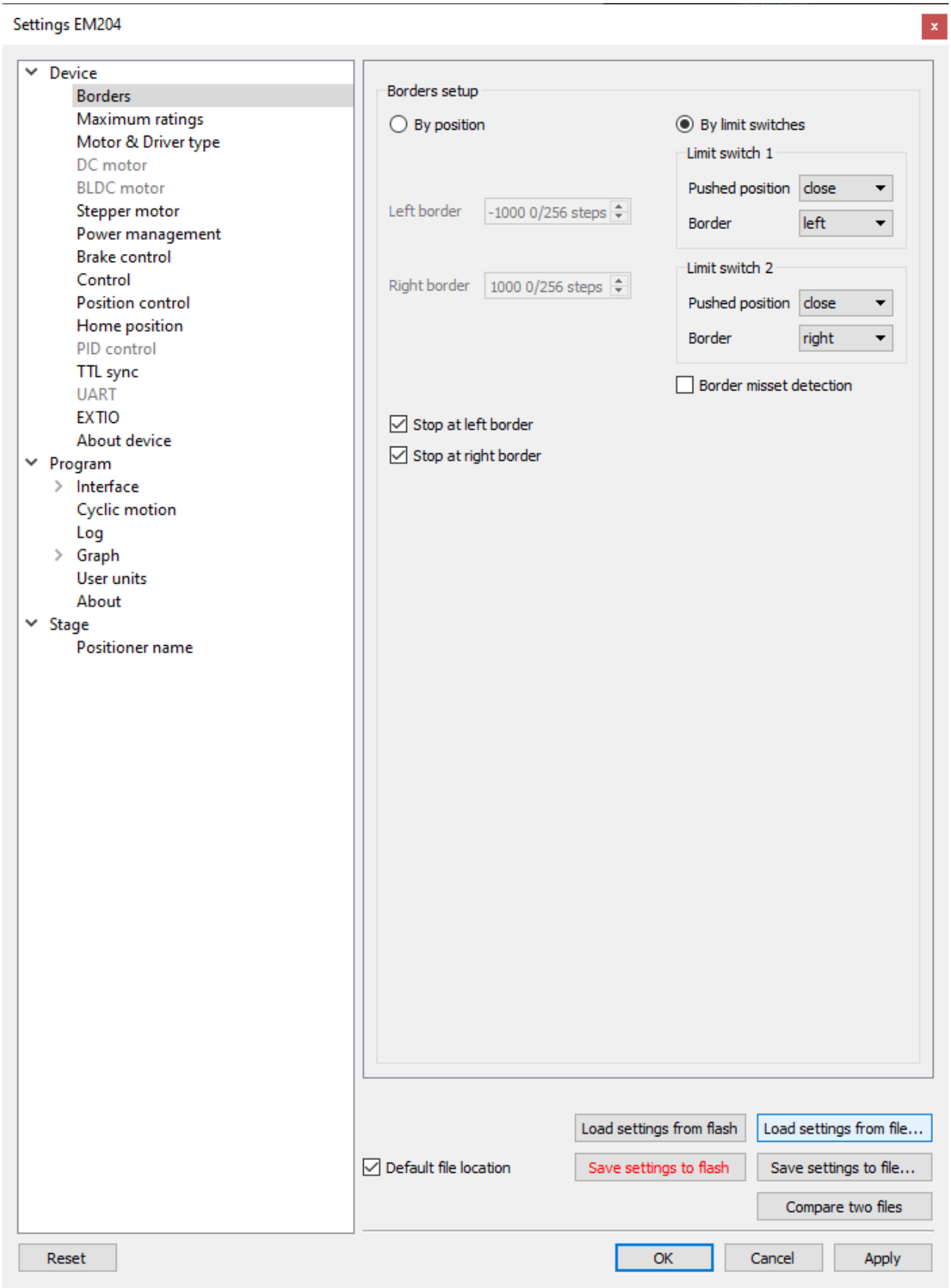


Fig. 3.6: mDrive Direct Control, the Settings menu window

Warning: For the controller to work with motors it is required to properly set up:

- *working current*,
- *displacement limits and limit switches*,
- *critical parameters*,
- *limiters*,
- *power supply mode*.

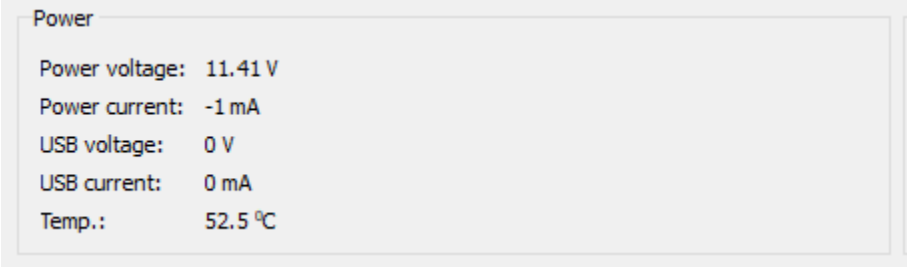
If you decide to configure your controller by yourself, please check these parameters carefully!

Congratulations, your controller is ready for operation!

3.1.5 Functional test

Check if the controller is configured properly by pressing left or right button in the central row of mDrive Direct Control main window control buttons. The stage has to start moving. Use the central "soft stop" button to stop the rotation.

Please pay attention to the power supply parameters of the controller in the *Power* section. There you can see the power voltage, working current and temperature of the controller.



If mDrive Direct Control main window is shaded red when the movement was supposed to start, that means that protection was activated and controller entered the *ALARM* state. This may be caused by incorrect settings, wrong connection of the stage or controller malfunction. For detailed information please read the *Critical parameters* chapter.

3.1.6 Control from user applications

For convenient control of the mDrive controller, you can use the *mDrive Direct Control software*. However, if you need to control the mDrive from your own application, you may do so by using libximc library. *Programming guide* has several examples in *C*, *C#*, *Python* programming languages. If all you need is to automate a small number of control steps, then instead of a standalone program you may find it easier to use mDrive Direct Control *scripting language*.

3.2 Example of a motor connection

- *General case*

3.2.1 General case

To connect a motor to the controller please refer to *stage connector*, and use the scheme of stage connection:

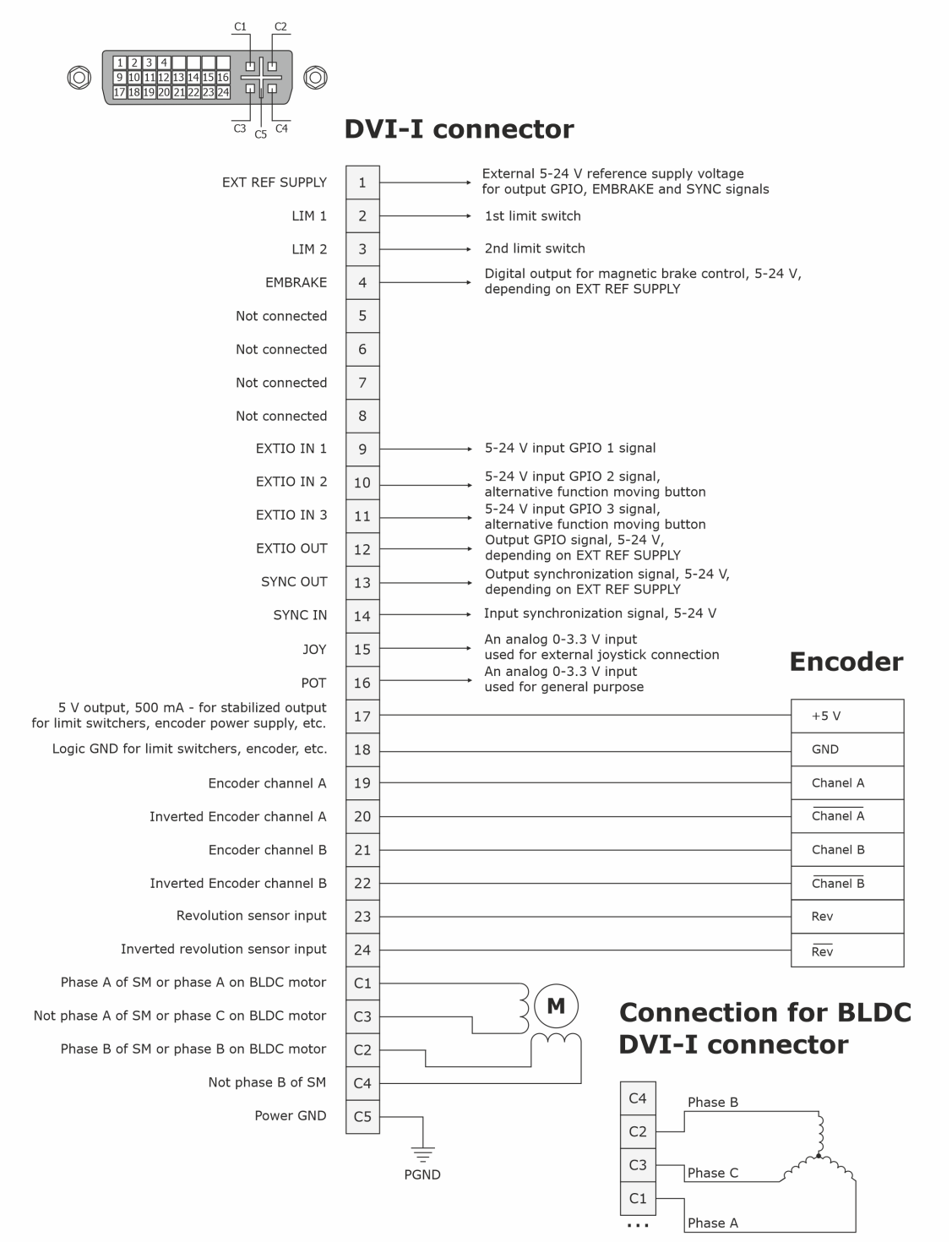


Fig. 3.7: General diagram of stage and encoder connection using DVI-I connector

Note: If A and B encoder channels work in open drain mode, some extra pull-up of encoder outputs to 5V power voltage using the resistors may be required at high rotation speeds in order to provide the maximum signal transmission

speed (see *Operation with encoders*).

3.2.2 Example

Consider the connection of the two-phase stepper motor Nanotec ST5918L3008-B with encoder CUI INC AMT112S-V to controller mDrive.

3.2.2.1 Preparation

To get started, we need:

- Motor;
- Encoder;
- *Pinout of DVI-I connector* for mDrive;
- Motor datasheet ;
- Encoder datasheet ;
- Soldering equipment: soldering-iron, wires, flux, solder, nippers, heat shrink tubes of different sizes;
- Screws M2.5x6 for fixing the encoder;
- Hot melt glue;
- DVI-I cover + connector (male) and wires for cable manufacturing;

3.2.2.2 Connecting the motor and encoder to the controller

- Before you begin, assemble the encoder in accordance with the appropriate instructions.

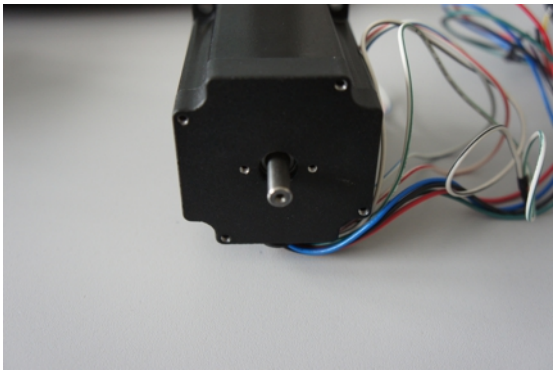


Fig. 3.8: The motor without encoder. Note 2 holes M2.5 to which is usually attached an encoder

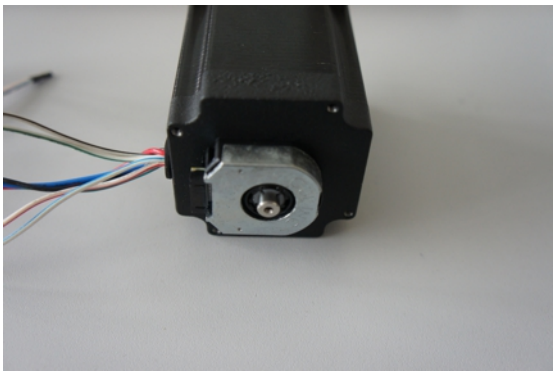


Fig. 3.9: Motor with attached encoder

- In the engine specification, find the wiring diagram (for Nanotec ST5918L3008-B it is at the bottom right in the specification):

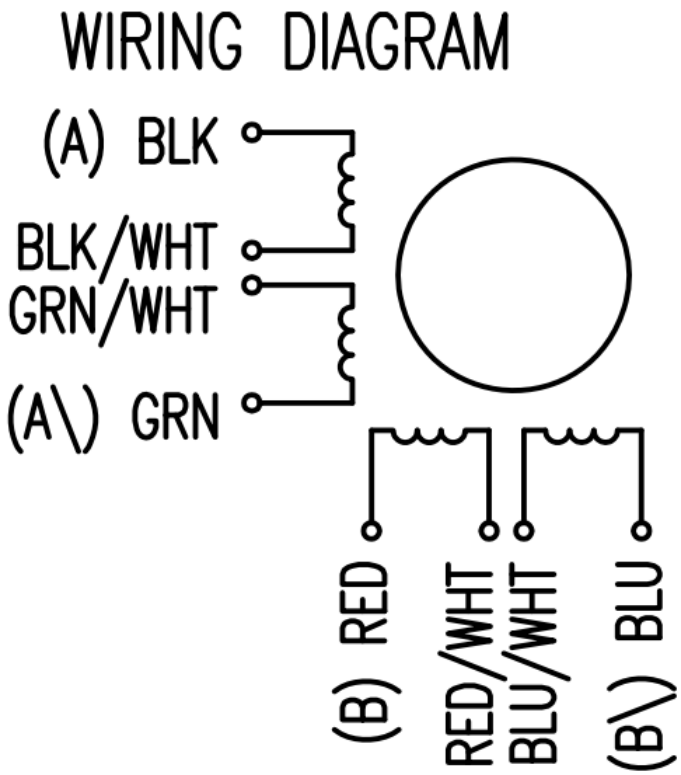


Fig. 3.10: Motor contacts

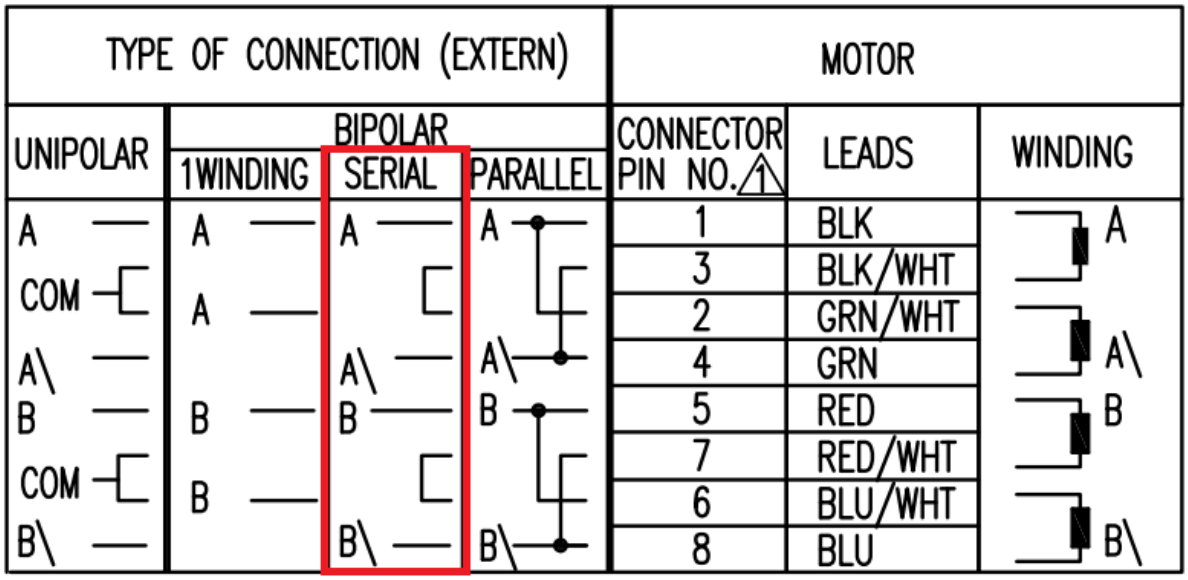
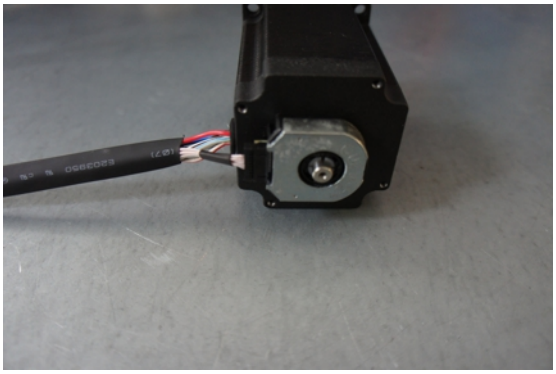


Fig. 3.11: Connection type

– There exist serial and parallel winding connection and each type allows to obtain various characteristics for the motor. We will connect the windings in series (red frame on the picture). To do this, wires having two colors BLK/WHT and GRN/WHT, as well as RED/WHT and BLU/WHT must be connected to each

other in pairs. Next, you need to put in accordance *A*, *not A*, *B*, *not B* pins of controller to contacts of motor windings ST5918L3008-B: black, green, red, blue. One winding is a connection of *A* and *not A* or *B* and *not B*. After the connection between a two-color wire, you will get that one winding of the motor is black - green connection, other is red - blue. Therefore, matching contacts will be the follows: black - *A*, green - *not A*, red - *B*, blue - *not B*. It can be seen in the picture above *"Connection type"*.

– To connect encoder, open its datasheet and find 5 contacts on encoder connector: *A+* (channel *A*), *B+* (channel *B*, shifted relative to *A* by 90 degrees), *Z+* (rev counter), *5V*, *GND*. They should be taken from the encoder as 5 separate wires and put together with the wires from the motor as they then go to a connector. CUI INC AMT112S-V encoder has 18 pin input, therefore it is needed to make a cable with the same connector on the end to output necessary signals:



Encoder contacts A+, B+, Z+, 5V and GND corresponds to 19, 21, 23, 17, 18 pins of *DVI-I male connector* respectively.

For convenience, use the next tables (the number in parentheses indicates pin on the corresponding connector):

Encoder pin	**DVI-I pin**
A+ (10)	Encoder A (19)
B+ (8)	Encoder B (21)
Z+ (12)	Revolution sensor input (23)
5V (6)	Output 5V, 100 mA (17)
GND (4)	Logical ground (18)

Motor pin	**DVI-I pin**
A (BLK)	phase *A* (C4)
not A (GRN)	phase *not A* (C3)
B (RED)	phase *B* (C2)
not B (BLU)	phase *not B* (C1)

- Solder the above contacts to DVI-I male connector:

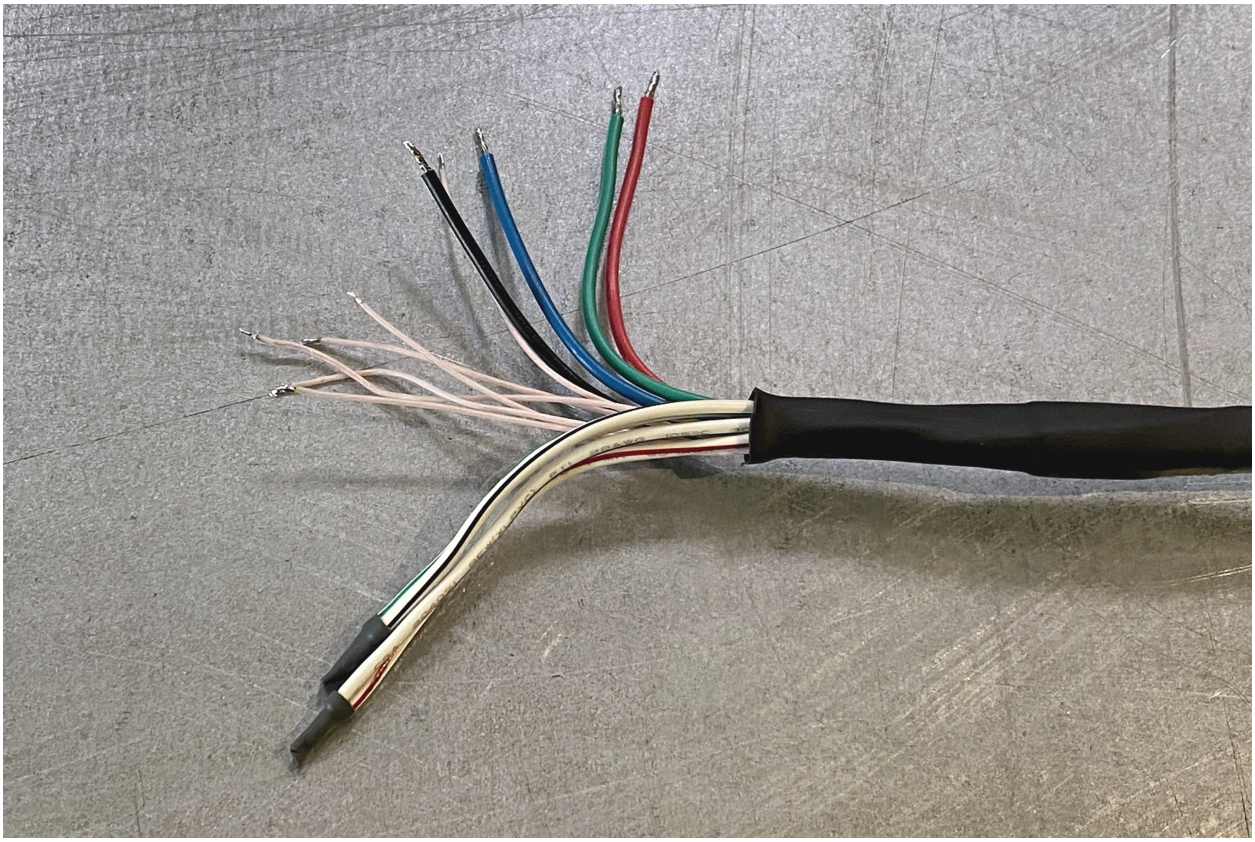


Fig. 3.12: The wires from the motor and encoder in a heat shrink tube.

Note the presence of small heat-shrinkable tubes for wires going to the motor windings (BLK, GRN, RED and BLU), as well as two-colored wires joined together (BLK/WHT and GRN/WHT, RED/WHT and BLU/WHT). The thin wires are an encoder contacts (5 pcs).

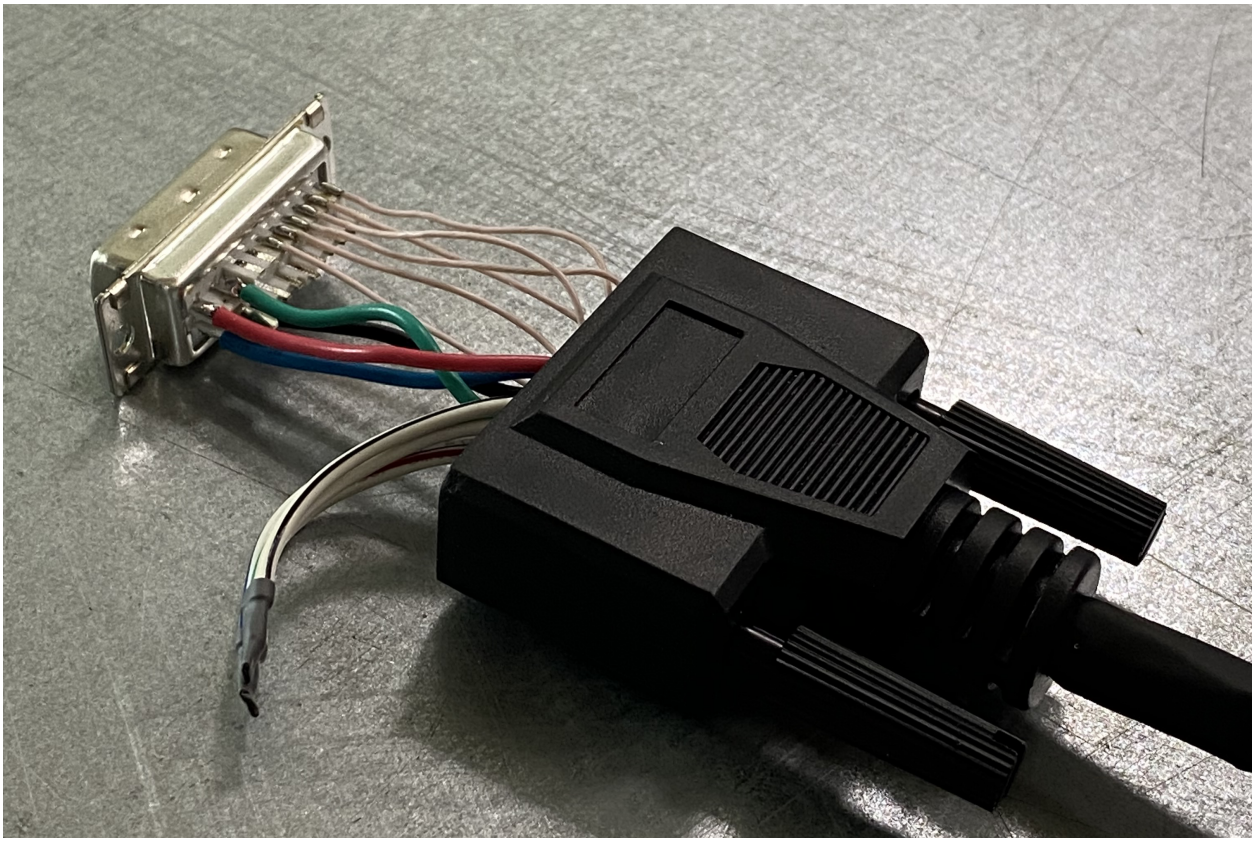
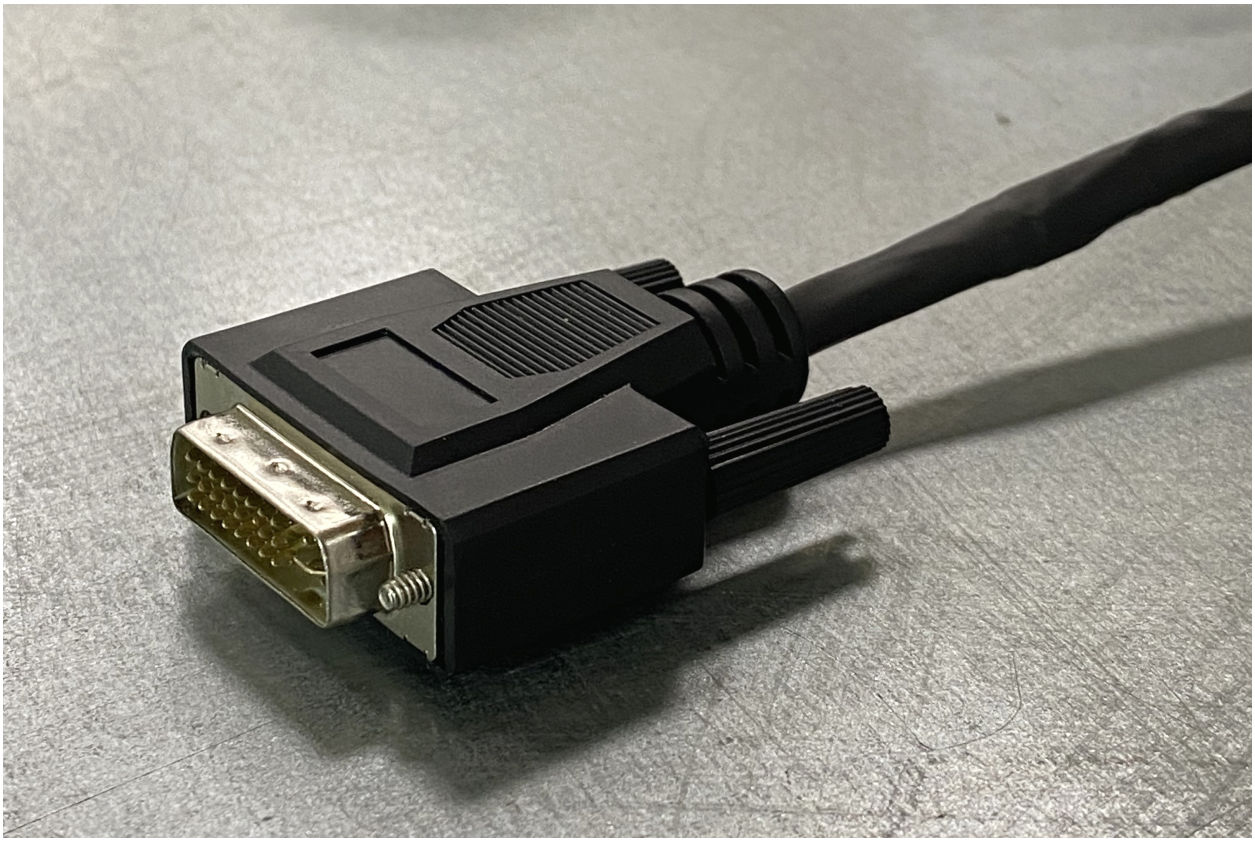


Fig. 3.13: Ready cable from the motor with the DVI-I connector on its end

Recommendation: use heat shrink tubes of a small diameter (2-3 mm) while soldering contacts to DVI-I connector, and large diameter to skip through them all the wires coming from the motor and encoder. Put them before soldering.

- Apply hot melt glue adhesive to the finished contact part and tighten the cable with the DVI-I connector tightly inside the cover.



- Now you can connect it to mDrive.

Description and profile settings are given in the next chapter *Manual profile setting*.

3.3 Manual profile setting

3.3.1 Introduction

All necessary parameters are set after motor connection (see *Example of a motor connection* where the Nanotec ST5918L3008-B motor connection is described). There we will consider the setting of the profile for **Nanotec ST5918L3008-B** stepper motor.

3.3.2 Getting started

- Install and run mDrive Direct Control (see *Overview and getting started*).
- Load the profile with default settings. To do this, open **Settings -> Load setting from file...** and select xilabdefault.cfg file from mDrive Direct Control folder.

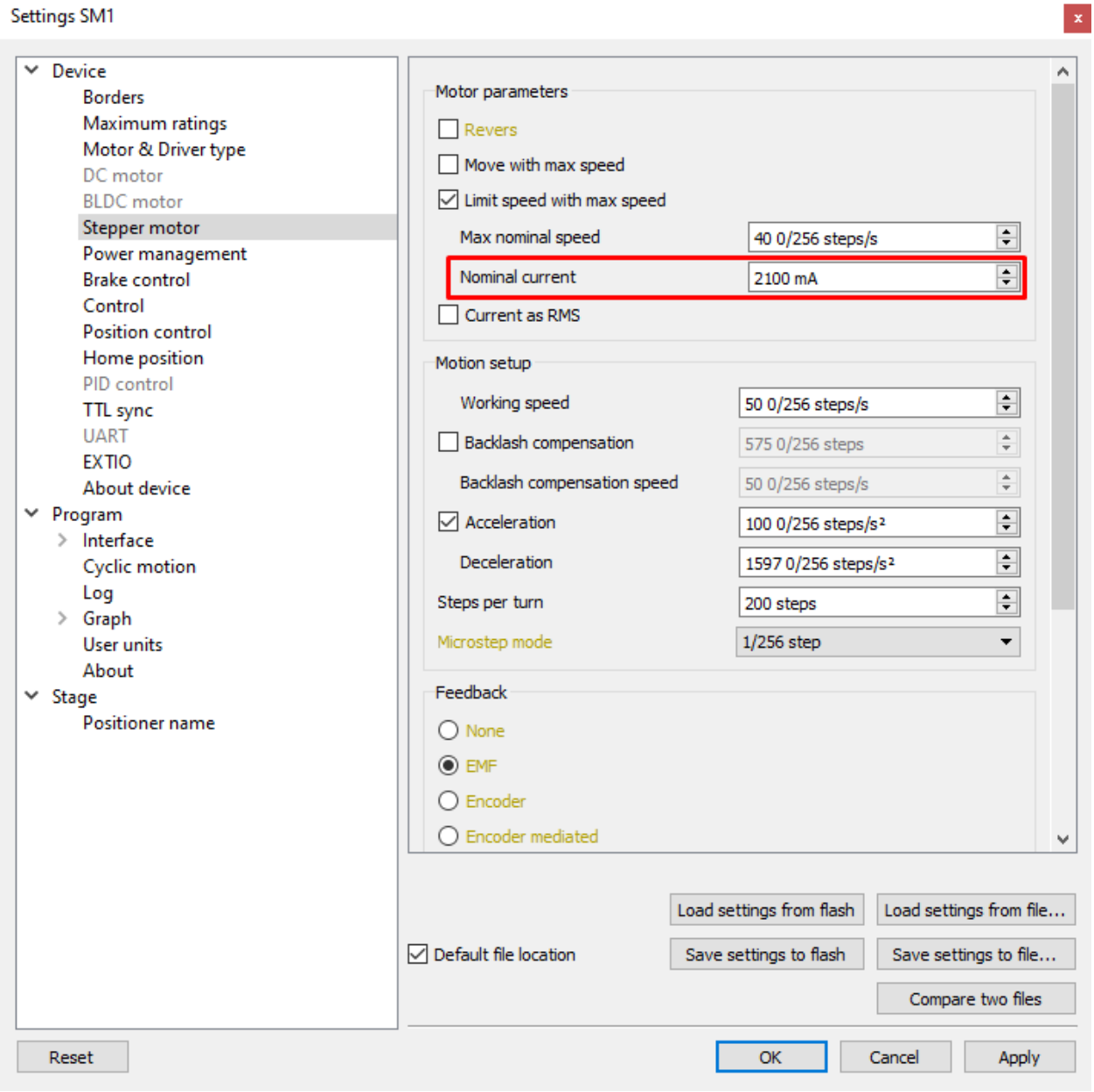
3.3.3 Nominal current setting

Initially, it is needed to set a correct current in motor windings:

- From the specification find the **phase current 2.1 A** - this is the maximum current for the motor in case of **serial** winding connection:

SPECIFICATION \ CONNECTION	UNIPOLAR OR BIPOLAR–1 WINDING	BIPOLAR	
		SERIAL	PARALLEL
VOLTAGE (VDC)	3.0		
AMPS/PHASE	3.0	2.1	4.2
RESISTANCE/PHASE (Ohms)@25°C	1.0±10%	2.0±10%	0.5±10%
INDUCTANCE/PHASE (mH) @1KHz	2.2±20%	8.8±20%	2.2±20%

- Being in the *Settings* window, open *Stepper motor* tab. There are such parameters as rotational speed, acceleration, driving mode, etc. (see *Settings of kinematics (stepper motor)* for additional information). In *Motor parameters-> Nominal current* field you should specify the value of the phase current **not exceeding 2.1 A**:



3.3.4 Basic parameters setting

- In the *Working speed* field we will specify a rotation speed. The recommended speed is not more than **1000 s/sec** at the first start. In the same window you should type *Max Nominal Speed* (**5000 s/sec** is reasonable value for majority of motors and motorized stages) and mark *Limit speed with max speed*. This setting is necessary to limit the motor speed since some mechanical systems can be designed for low speed, and fast rotation can lead to severe wear of motor/stage mechanics.
- In the motor specification we find the number of steps per rotation. For our motor this value is equal to **200 steps**. Specify it in the *Steps per turn* field. Usually, the value of one pitch in degrees is listed in motor description, on the basis of which you can calculate the number of steps per revolution, knowing that one revolution consists of 360 degrees.
- Make sure that movement to the right from the main window of mDrive Direct Control corresponds to the

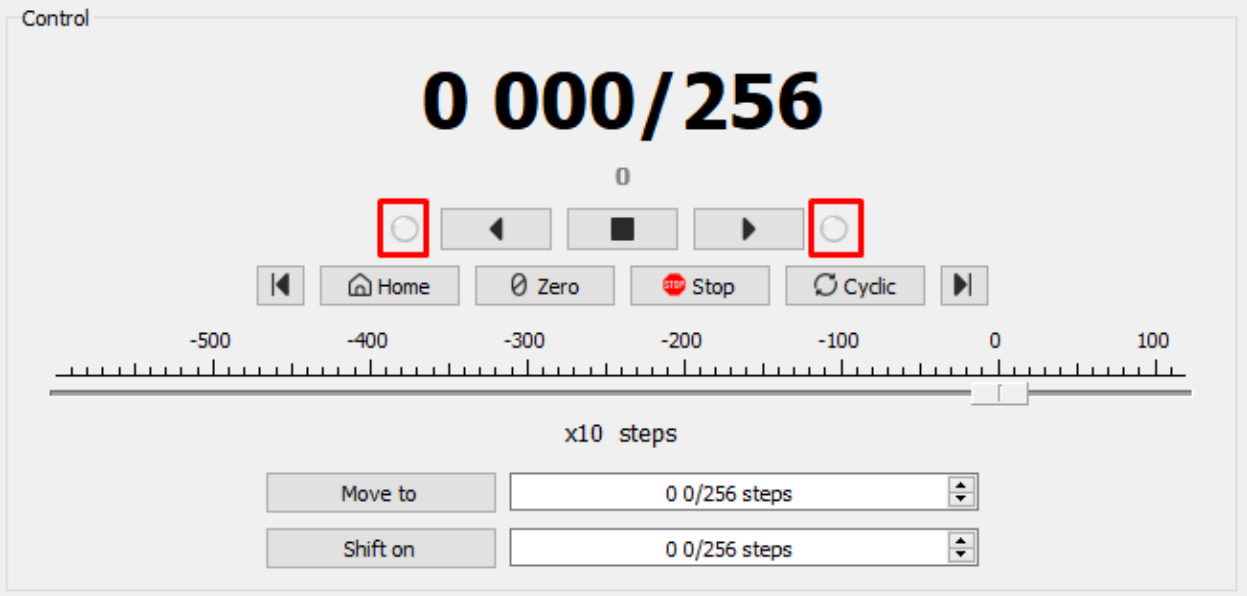
movement to the right of the stage. If not, then check the box *Reverse* field *Stepper motor -> Motor parameters*.

3.3.5 Hardware limit switches setting. Homing.

Note: This section describes the using of motorized stages with hardware *limit switches*. If your system is not provided with hardware limit switches, it is recommended to disable stop by limit switches in settings. To do this, unmark *Stop at right border* and *Stop at left border* in *Borders* tab.

There are stages with limited (translators) and an unlimited range of motion (rotators). The limitation of movement range can be done by position or with limit switches using. When you work with translators if its limit switches are configured incorrectly there exists a risk to break down mechanics, since moving part can try to go out of motion range. Rotators do not have such problem. Moreover, it should be kept in mind that rotator may have only one limit switch.

- To work with limit switches you must specify which one will be left and right. Sometimes it is unknown in advance and we only know that both switches are connected and fire if the corresponding limit of the motion range is reached. The stage jam is possible if the limit switches are configured improperly. Therefore, the controller supports just a simple detection of incorrectly configured limit switches, shutting down the movement on both of them. Please make sure that:
  - The stage is far from limit switches;
  - Switches polarity is configured correctly (limit switches indicators are off in the main window of mDrive Direct Control). In the case of incorrect settings, change their polarity (*Borders -> Pushed position*), indicators should go out.



  - Shutdown mode is activated on both of limit switches (*Stop at right border* and *Stop at left border* are marked in *Borders* tab).
- Mark the flag detecting improper connection of limit switches *Border misset detection* in *Borders* tab.

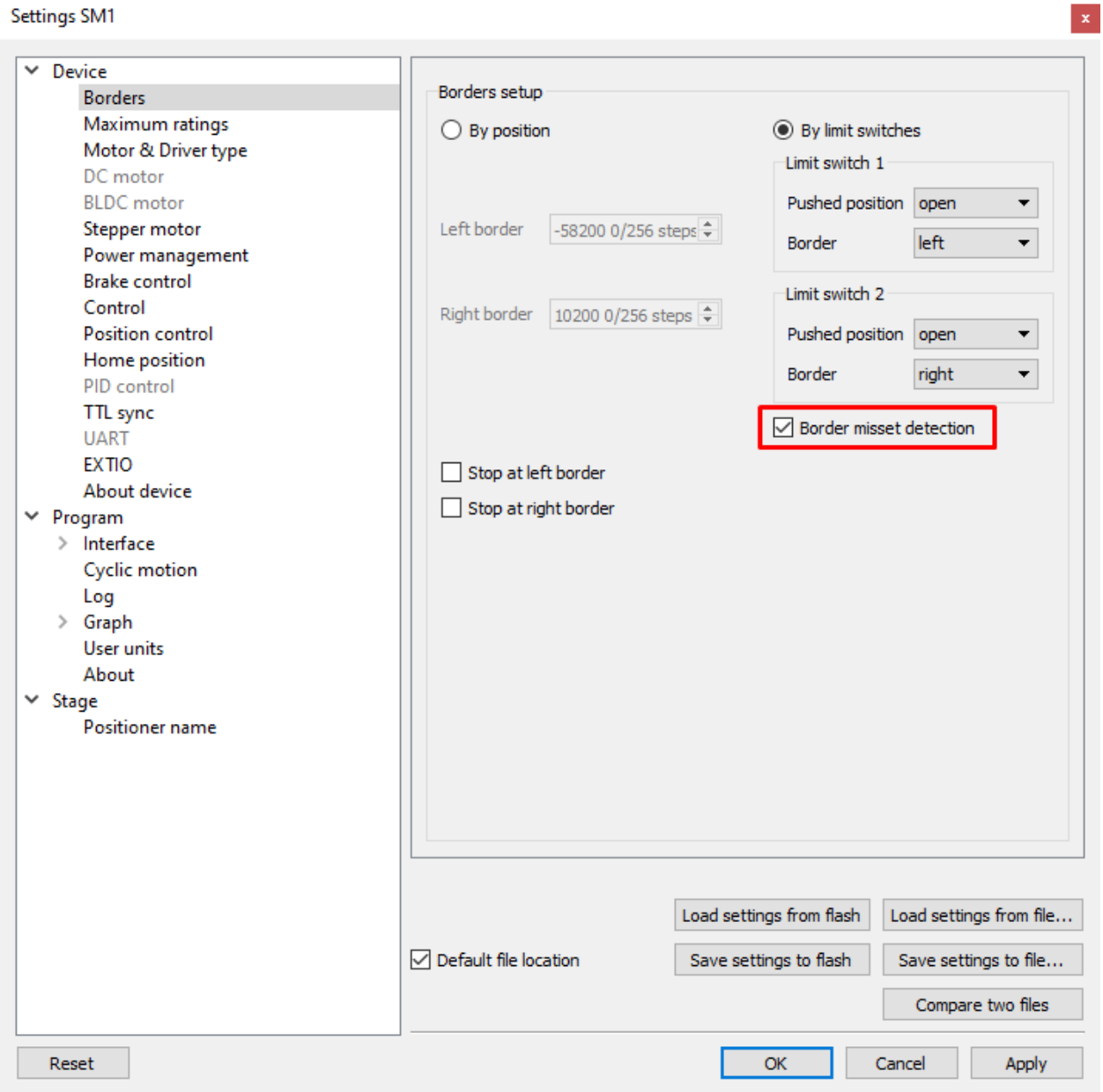


Fig. 3.14: Tab with limit switches settings

- Controller can switch to Alarm state after false limit switch response, if *Enter Alarm state when edge misset is detected* is enabled in *Maximum ratings* tab. It is recommended to enable it. Start the movement in any direction from the *mDrive Direct Control main window* up to Alarm state or stopping by the limit switch. When an Alarm occurs you need to reverse limit switches by changing *Borders->Border* with reversed values in the *Stepper motor* tab.

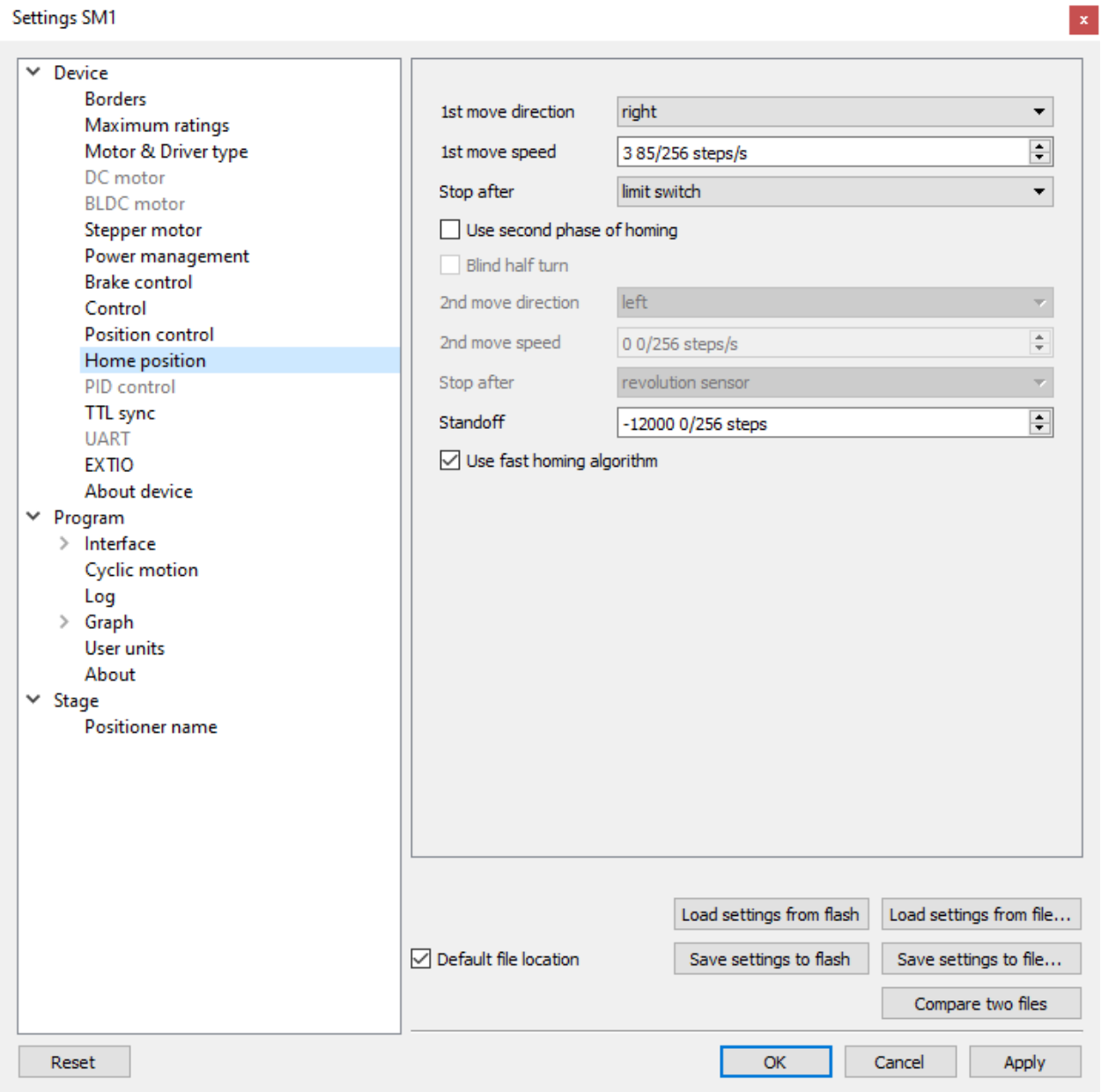
Warning: The protection against mistaken limit switches connection doesn't guarantee the complete solution of the problem, it only makes the initial configuration procedure easier. Don't start the movement with mixed up limit switches if any of them is active, even if the protection is on.

There are still two ways to determine which of the limit switch is right and which is the left:

- You need to know how each of the limit switches is connected to the stage. When loading a profile with the default settings, switch connected to pin 2 of the DVI-I connector is considered as left, while switch connected to pin 3 - as right. Their location relative to the stage is configured in the fields *Limit switch 1* and *Limit switch 2* (see screenshot above). Start the system at the low speed (<100 steps/s) when it is far away from limit switches. If the direction of movement to the switch in a real setting differs from the expected, change *Borders->Border* values with reversed in the *Stepper motor* tab.
- If it is possible to get limit switches activate them and note the correspondence between indicators in mDrive Direct Control and each particular switch. Then start the system at the low speed (<100 steps/s) when it is far away from limit switches and make sure that the system moves to the right switch. Compare this to what you see in the main window of mDrive Direct Control. If the direction of movement to the switch in a real setting and in the main window differs, change *Borders->Border* values with reversed in the *Stepper motor* tab.

For detailed information refer to *motion range and limit switches*.

- Controller has a useful function called *automatic Home position calibration* to set the initial position of the motorized stage.



We will consider the most simple configurations with a single phase only. Start from the setting of the *1st phase speed* which is approximately 5-10 times lower than *Working speed*. It is necessary for higher precision of automatic calibration procedure. In the filed *Stop after* specify the *limit switch* to make the stage reached one of the limit switches during the calibration (direction is selected in the *1st move direction*). In the field *Standoff* specify number in steps, for which stage must be driven away from the limit switch. Click *Ok* or *Apply*.

Note: *Standoff* value is signed. Positive direction is right. That is, if the auto-calibration procedure is set up on the right limit switch, then in order to move stage away to the left you should type negative value in *Standoff* field.

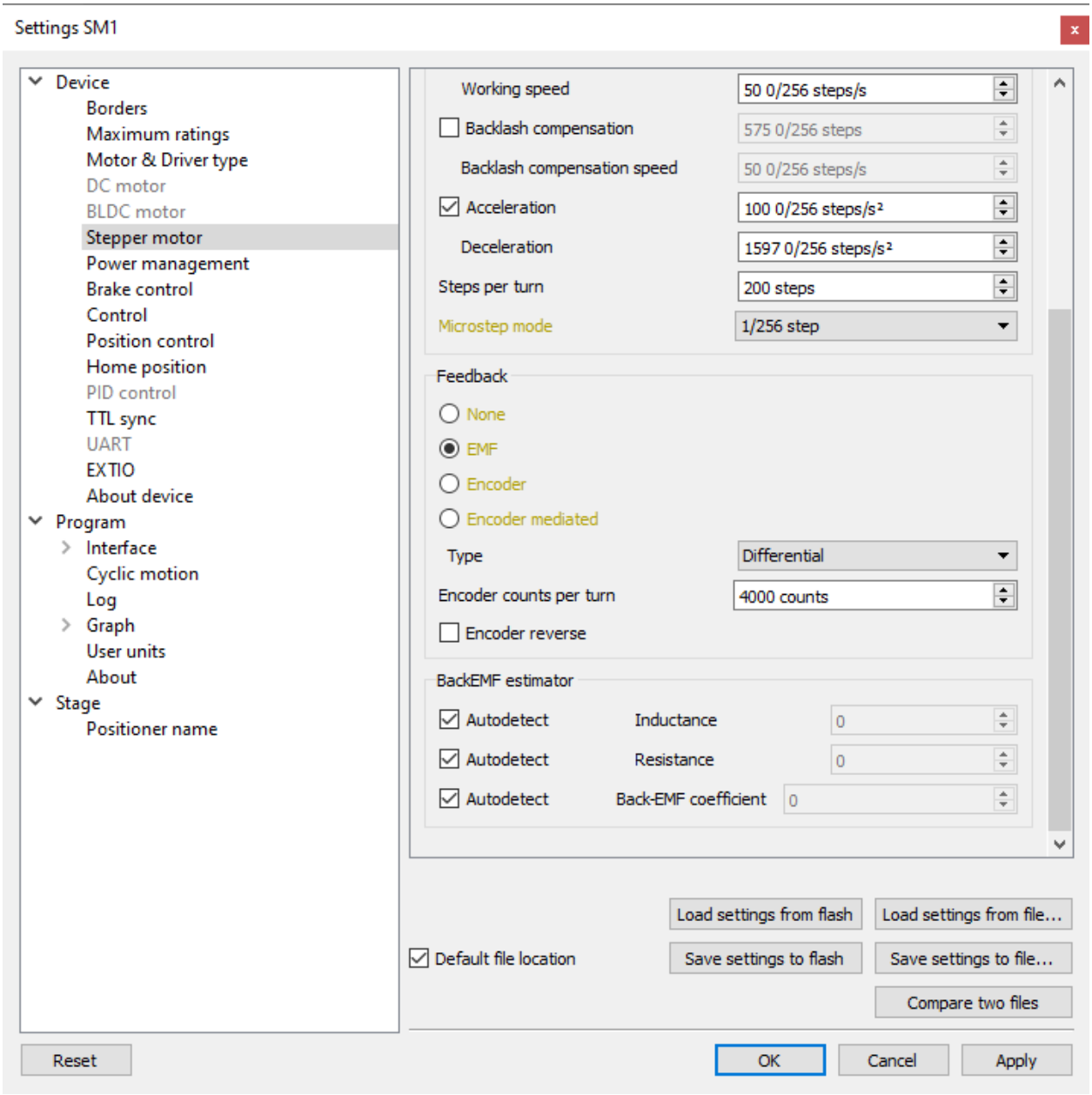
- Start the automatic calibration by clicking *Go home* in the main window of mDrive Direct Control. The result of it is a movement of the stage to the specified limit switch with a relatively low speed and the shift away from him to the value specified in the field *Standoff*.

- After completion of the calibration process, press *ZERO* in mDrive Direct Control to set the origin of coordinate system for your stage.
- Repeat the calibration process again. The stage must return to the ZERO position. Please pay attention that there can be slight deviations from ZERO connected with calibration procedure error.

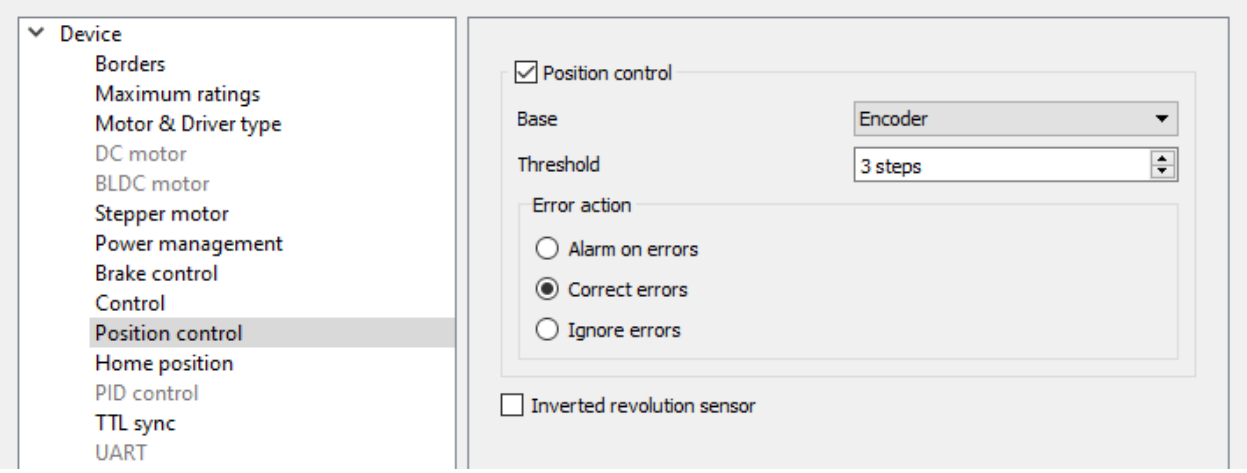
3.3.6 Encoder parameters setting

Note: This section describes the using of motor with encoder. If you motor without an encoder, the parameters described below can be left unchanged.

- Any encoder has **Pulse Per Turn** - **PPT** parameter (sometimes it is called **PPR** - **Pulse Per Rotation**). For correct operation of the encoder with controller you should enter the number of encoder counts per revolution, which is equal to **4xPPT** in the *Encoder counts per turn* field in mDrive Direct Control. For example, if your encoder has **1024** pulses per turn, specify **4096** in the *Counts per turn*:

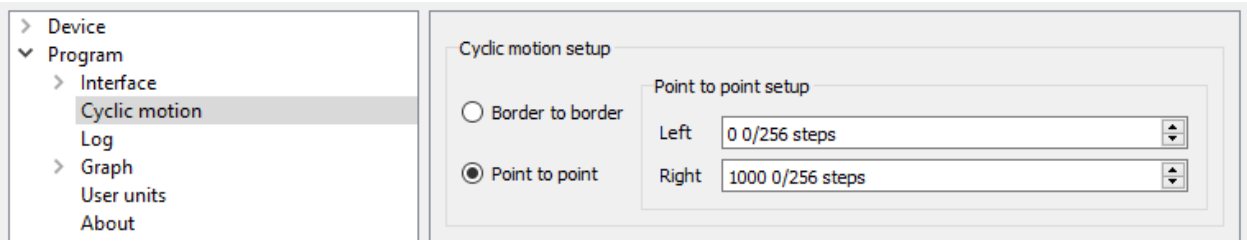


- Start the motor rotation from the *main window of mDrive Direct Control*. If everything is configured correctly, the green indicator ENCD will light in the bottom of window. If ENCD has yellow color, you should mark *Encoder reverse* in the *Stepper motor* tab. Red color of EDCN points to the problem with encoder position recalculation.
- It is possible to activate the position control by encoder. To do this, in the tab *Position control* mark *Position control* and specify allowable error in terms of encoder counts in the *Threshold* field. Then, when a mismatch between position and encoder counts occurs, indicator SLIP will light in the bottom of mDrive Direct Control main window. Beyond this, if *Alarm on errors* is marked, the controller will go to Alarm state. *Correct errors* allows you to start closed loop control, when the difference between real position and encoder position is compensated.



3.3.7 Setting the kinematic characteristics of the controller

- In the *Stepper motor* tab you may specify a necessary acceleration (*Acceleration*) and deceleration (*Deceleration*) for your stepper motor. The process of optimal values selection is the next:
  - Starting from default values make small shifts (start and fast stop) with gradual *Acceleration* increase until the movement become unstable and disrupted sometimes. Take acceleration equal to about **half** of this value.
  - The deceleration can be configured about **1.5 - 2 times higher** than acceleration.
- If in your mechanical system moving to the desired position on the left and on the right is not the same, and there is play, it is possible to eliminate this ambiguity. To do this mark *Backlash compensation* in *Stepper motor* and type number greater than play value. The sign of this setting determines the direction of moving to the position. Positive sign means move from the left while negative - from the right. In *Backlash compensation speed* field set the speed of compensation movement. This value should be low (**50 s/sec** is enough) in order to avoid "drifting" during backlash compensation.
- After the basic configuration of the stage/motor, you can increase working speed. It can be done experimentally like the process of acceleration setting, i.e. you should take its value **about 2 times lower** than value at which there is unstable movement. To test the stability of the rotation it is recommended to use the function *Cyclic* in mDrive Direct Control *main window*. Make sure that you *set* it previously.



- In the *Microstep mode* field we recommend to enter the value **1/256**.

3.3.8 Working with user units

Often it is uncomfortable to work with the steps and microsteps and more convenient units are preferable. For this reason, the controller can recalculate the coordinates in the usual units, for example in millimeters or degrees. It can be done in the tab *User units*, where you should specify the size of the step and the corresponding measurement unit. For more information, refer to *relevant documentation paragraph*.

Configuration of the operating profile complete.

3.4 Calculation of the nominal current

In order to stepper engine gave maximum torque, but it does not overheat, it is important to specify such technical characteristic as the rated current.

The greater a current in the motor winding, the greater the torque at the axis. It is important to remember that with an increase a current flowing through the winding, thermal power released by the motor increases. So the engine could operate for a long time allocated to thermal power (Joule heating) must be less power dissipation. Power dissipation can be calculated on the basis of documentation on the engine.

3.4.1 Calculation based on the parameters of unipolar full step mode

Power dissipation is equal to

$$P = n \cdot R_u I_u^2,$$

where R_u - the resistance of the winding in unipolar mode, I_u - current through the winding in unipolar mode, n - the number of simultaneous windings.

Consider, for example, ST2818M1006. The table in the documentation shows that in full step mode simultaneously running two phase (n = 2) in the unipolar mode, i.e. $P = 2R_u I_u^2$. The motor controllers support only bipolar control mode. To switch from a unipolar to a bipolar mode, connect each phase windings in series, the resistance will increase, $R_b = 2R_u$, where R_b - the resistance of the series-connected windings in the bipolar control mode.

The motor controllers control algorithm is capable of operating in a microstepping mode and maintains the current so that the first winding current varies in function $I_a \sin(\phi)$, in the other winding current varies in function $I_a \cos(\phi)$, where I_a - current amplitude. Thermal power released two windings at any time

$$P = R_b I_a^2 \sin^2(\phi) + R_b I_a^2 \cos^2(\phi) = R_b I_a^2$$

It follows from the foregoing that the $I_a = I_u$.

3.4.2 Calculation based on the parameters of bipolar full step mode

Power dissipation is equal to $P = n \cdot R_b I_b^2$, where R_b - the resistance of the winding in bipolar mode, I_u - current through the winding in bipolar mode, n - the number of simultaneous windings.

Consider, for example, ST2018S0604. The table in the documentation shows that in full step mode simultaneously running two phase (n = 2) in the bipolar mode, i.e. $P = 2R_b I_b^2$.

Thermal power dissipated in the motor windings that managed by motor controller, still is

$$P = R_b I_a^2 \sin^2(\phi) + R_b I_a^2 \cos^2(\phi) = R_b I_a^2$$

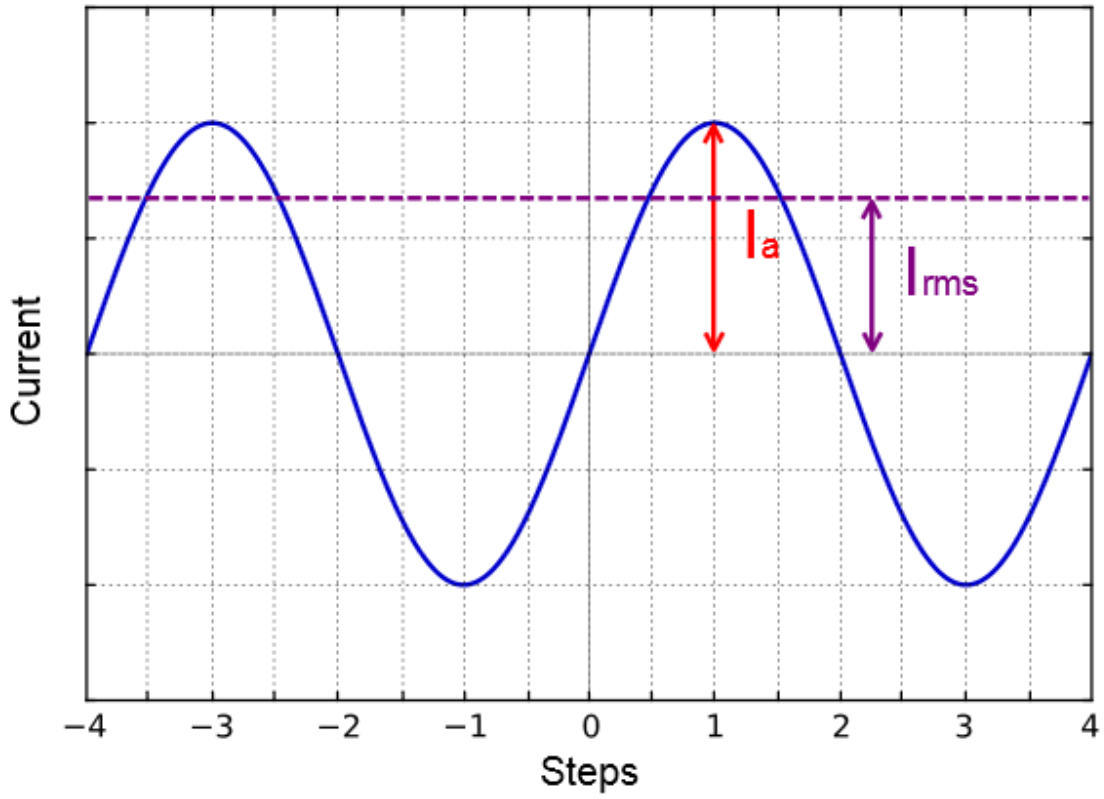
We obtain the equation equating power $2R_b I_b^2 = R_b I_a^2$. We find that $I_a = \sqrt{2} \cdot I_b$.

3.4.3 The relationship with an rms current

Alternating current in each motor winding can be characterized by its rms value in the period

$$I_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} (I_a \sin(\phi))^2 \, \mathrm{d}\phi} = \frac{I_a}{\sqrt{2}}$$

Thermal power of **one** winding is associated with an rms current through it $P_1 = R_b I_{rms}^2$. Both windings are identical $P_1 = P_2$. The total thermal power of the engine that is run by control by motor controller controller $P = P_1 + P_2 = 2R_b I_{rms}^2$.



It follows from the foregoing that $I_{rms} = \frac{I_u}{\sqrt{2}}$, also $I_{rms} = I_b$.

3.4.4 Amplitude and rated current for BLDC

The rated motor current is calculated from the maximum allowable heat dissipation. The rated current written in the documentation is calculated from the power limit allocated when the power supply is connected to the two windings.

Let's write the formula for power with this connection:

$$P_{chop} = 2R_{phase} I_{rate}^2$$

Formula for the power generated by the windings for sinusoidal control:

$$P_{sin} = 3R_{phase} I_{rms}^2$$

The rated motor current is calculated from the maximum allowable heat dissipation. Equate right parts of formulas:

$$I_{rms} = \frac{\sqrt{2}}{\sqrt{3}} I_{rate}$$

So,

$$I_{amp} = \frac{2I_{rate}}{\sqrt{3}}$$

This means that if the documentation on your engine says that the rated current is, for example, 0.88A, then a amplitude current value can be written to the controller:

$$I_{amp} = \frac{2 * 0.88}{\sqrt{3}} = 1A$$

3.4.5 Setting the nominal current

Motor controller are capable of taking the nominal current value as a current amplitude or as rms. The choice of which way to interpret the input value of the nominal current is determined by the absence or presence corresponding flag *ENGINE_CURRENT_AS_RMS* in the *EngineFlags* *engine settings* structure. When *setting the nominal current in mDrive Direct Control* should properly specify how the current is interpreted. Motor controllers in this case will provide the maximum torque without overheating the engine.

The same flag also controls the semantics of the BLDC current.

As for the stepper, there is a special checkbox in the mDrive Direct Control for BLDC, which determines how to interpret the value entered in the Nominal current field. If checkbox “Amplitude current” is checked, the entered current value will be amplitude: maximum the amplitude of the sine will always be less than this value. If checkbox “Amplitude current” is cleared, the verified value will be recalculated by the formula for and the current amplitude will be limited already by this recalculated value

CHAPTER

FOUR

TECHNICAL SPECIFICATION

4.1 Appearance and connectors

mDrive controllers are available in 1-2-3 axial versions. The controller board can be purchased separately, but an mDrive enclosure is required for its operability.

- *Controller board*
- *One axis system*
- *Multi-axes system*

4.1.1 Controller board

4.1.1.1 Dimensions and arrangement

Structurally the controlled is designed as 139.4 x 53 x 22.4 mm board with a power part, the logic controller and control systems mounted on the board. A radiator at the power part is available.

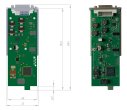


Fig. 4.1: Top view on the controller. The view from power part and radiator side.

Fig. 4.2: Front view on the controller. The view from stage cable side.

Important: If you are mounting the radiator to the power part by yourself, please make sure that there is no contact between heat-conducting surfaces and conductive elements of the unit. Such contact may damage the power circuit!

4.1.1.2 Controller board connectors

4.1.1.2.1 Stage connector

A female DVI-I connector for stage is mounted on the controller board.

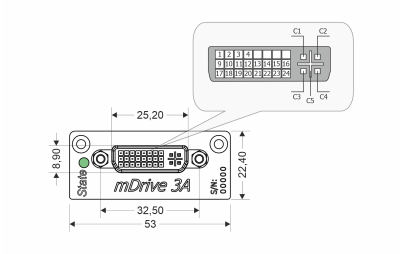


Fig. 4.3: Dimensions and numbers of the pins in DVI-I connector (front view)

Pins functionality:

1. External 5-24 V reference supply voltage for output GPIO, EMBRAKE and SYNC signals (Power, “+”.)
2. 1st limit switch
3. 2nd limit switch
4. Digital output for magnetic brake control, 5-24 V, depending on external power supply (EXT REF SUPPLY)
5. Not connected
6. Not connected
7. Not connected
8. Not connected
9. 5-24 V input GPIO 1 signal
10. 5-24 V input GPIO 2 signal, alternative function moving button
11. 5-24 V input GPIO 3 signal, alternative function moving button
12. Output GPIO signal, 5-24 V, depending on external power supply (EXT REF SUPPLY)
13. Output synchronization signal, 5-24 V, depending on external power supply (EXT REF SUPPLY)
14. Input synchronization signal, 5-24 V, depending on external power supply (EXT REF SUPPLY)
15. An analog 0-3.3 V input used for external joystick connection (JOY)
16. An analog 0-3.3 V input used for general purpose (POT)
17. 5V output, 500 mA - for stabilized output for limit switchers, encoder power supply, etc.
18. Logic GND for limit switchers, encoder, etc.
19. Encoder channel A
20. Inverted Encoder channel A
21. Encoder channel B
22. Inverted Encoder channel B
23. Revolution sensor input
24. Inverted revolution sensor input

C1. Phase A of SM or phase A on BLDC motor C2. Phase B of SM or phase B on BLDC motor C3. Not phase A of SM or phase C on BLDC motor C4. Not phase B of SM C5. Power GND (Power, “-“)

Warning: Plugging in/out the motor to the controller is not recommended while motor windings are under voltage.

4.1.2 One axis system

Single-axis controller model is a *controller board* in a metal case. Case dimensions are 155 x 112 x 59 mm.

Fig. 4.4: Appearance of the one-axis controller mDrive

Front panel of the controller contains *stage connector* and state LED.

Rear panel contains *power supply connector*, *USB type-B data connector* and 2 Ethernet ports.

4.1.2.1 Connectors

4.1.2.1.1 Stage connector

A female DVI-I connector for stage is mounted on the controller board.

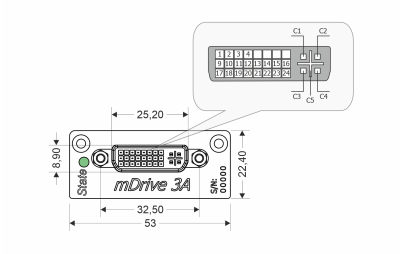


Fig. 4.5: Dimensions and numbers of the pins in DVI-I connector (front view)

Pins functionality:

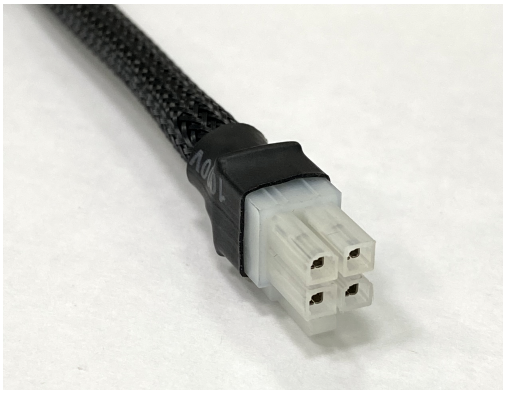
1. External 5-24 V reference supply voltage for output GPIO, EMBRAKE and SYNC signals (Power, “+”.)
2. 1st limit switch
3. 2nd limit switch
4. Digital output for magnetic brake control, 5-24 V, depending on external power supply (EXT REF SUPPLY)
5. Not connected
6. Not connected
7. Not connected
8. Not connected
9. 5-24 V input GPIO 1 signal
10. 5-24 V input GPIO 2 signal, alternative function moving button
11. 5-24 V input GPIO 3 signal, alternative function moving button
12. Output GPIO signal, 5-24 V, depending on external power supply (EXT REF SUPPLY)
13. Output synchronization signal, 5-24 V, depending on external power supply (EXT REF SUPPLY)
14. Input synchronization signal, 5-24 V, depending on external power supply (EXT REF SUPPLY)
15. An analog 0-3.3 V input used for external joystick connection (JOY)
16. An analog 0-3.3 V input used for general purpose (POT)
17. 5V output, 500 mA - for stabilized output for limit switchers, encoder power supply, etc.
18. Logic GND for limit switchers, encoder, etc.
19. Encoder channel A
20. Inverted Encoder channel A
21. Encoder channel B
22. Inverted Encoder channel B
23. Revolution sensor input
24. Inverted revolution sensor input

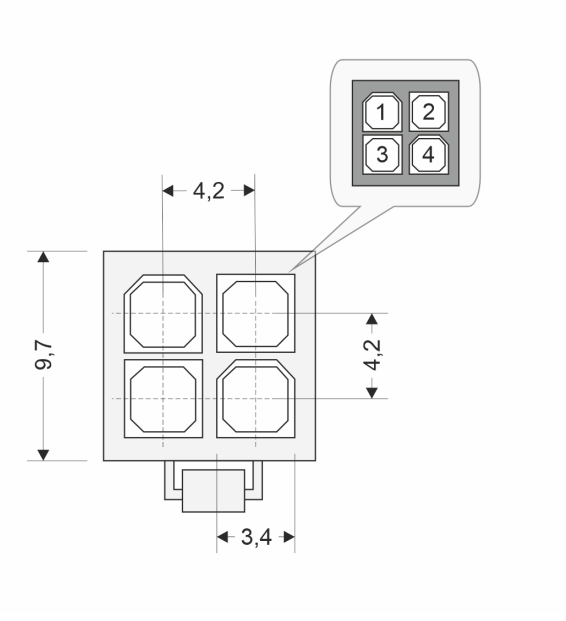
C1. Phase A of SM or phase A on BLDC motor C2. Phase B of SM or phase B on BLDC motor C3. Not phase A of SM or phase C on BLDC motor C4. Not phase B of SM C5. Power GND (Power, "-")

Warning: Plugging in/out the motor to the controller is not recommended while motor windings are under voltage.

4.1.2.1.2 Power supply connector

A male 4-pin Mini-Fit connector with 4.2mm interval (type MF-4MRA) is mounted at the controller board for plugging in to power supply. Its comparable benefits are as following: high 8 A current per pin, a fixation available, a possible coupling with both cable-mounted (type MF-4F, PN 39-01-2040 according to Molex catalogue) and board-mounted counterparts, including vertical (PN 15-24-7041 according to Molex catalogue). All Mini-Fit connectors are available in Molex catalogue at www.molex.com .





Output pin table

Pin	Name
1	“-” power electrode.
2	12–48 V “+” power electrode.
3	“-” power electrode.
4	12–48 V “+” power electrode.

Important: Never supply the power to the controller and do not plug it to power connector if you are not confident that your power supply parameters conform to the requirements. Never attempt to plug the power supply to the controller if you are not sure power supply unit and controller connectors are compatible! The acceptable connection parameters are described in *Safety instructions*.

Important: Hot-swapping or unreliable connection of the power supply connector Mini-Fit may damage the PC and/or the controller. For more details please refer to *Safety instructions*.

4.1.2.1.3 Data connector

Controllers connect via USB type-B or Ethernet connector.

Fig. 4.6: USB type-A - USB type-B cable

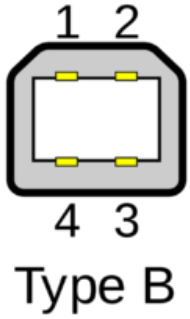


Fig. 4.7: USB type-B connector

Output pin table

Pin #	Name	Wire colour	Description
1	VCC	Red	+5V DC
2	D-	White	Data -
3	D+	Green	Data +
4	GND	Black	Ground

Warning: Use verified USB cables only! Damaged or low-quality USB cable may cause improper controller operation, including motor rotation errors and errors of device recognition by PC operating system. Short cables with thick wires and screening are ideal for sustainable connection.

4.1.2.1.4 Joystick connector

Controller mDrive contain a DVI-I female connector.

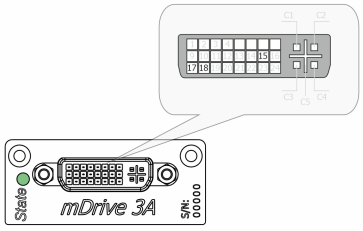


Fig. 4.8: Pinout for joystick connection, front view

Output DVI-I pin table

Pin	Name
15	JOY, an analog 0-3.3 V joystick input.
17	5 V output, 500 mA - for stabilized output for limit switchers, encoder power supply, etc.
18	Logic GND for limit switchers, encoder, etc.

Detailed joystick connection diagrams can be found in the *Joystick control* section.

Note: If you want to connect a 5 V joystick, use a resistor voltage divider. Resistance can be calculated in an online calculator, for example.

Note: Unused pins of the internal connector do not require any additional connection or pullup/pulldown. Simply do not use them.

Important: Analog JOY, POT inputs are designed to work with *less than* 3.3 V voltage. Do not apply higher voltages, including 3.3 V, to these inputs, as it can break all analog controller inputs and lead to the controller or motor failure.

4.1.3 Multi-axes system

4.1.3.1 Enclosure view

Multi-axis controller model consists of two or three *controller boards* in a metal case. Case dimensions are 155 x 112 x 59 mm.

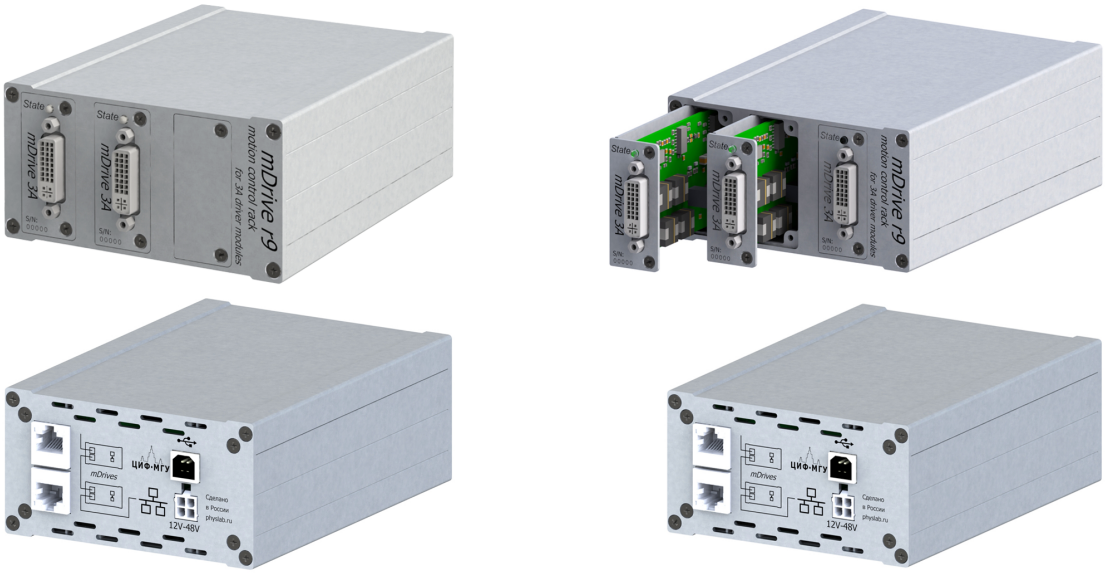


Fig. 4.9: Appearance of the two-axis and three-axis controllers mDrive

Front panel of the controllers contains *stage connector* and state LED.

Rear panel contains *power supply connector*, *USB type-B data connector* and 2 Ethernet ports.

4.1.3.2 Connectors

4.1.3.2.1 Stage connector

A female DVI-I connector for stage is mounted on the controller board.

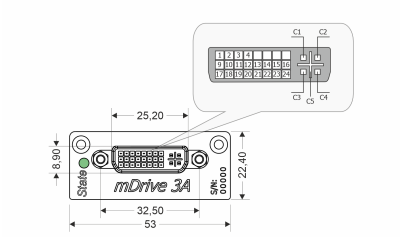


Fig. 4.10: Dimensions and numbers of the pins in DVI-I connector (front view)

Pins functionality:

1. External 5-24 V reference supply voltage for output GPIO, EMBRAKE and SYNC signals (Power, “+”.)
2. 1st limit switch

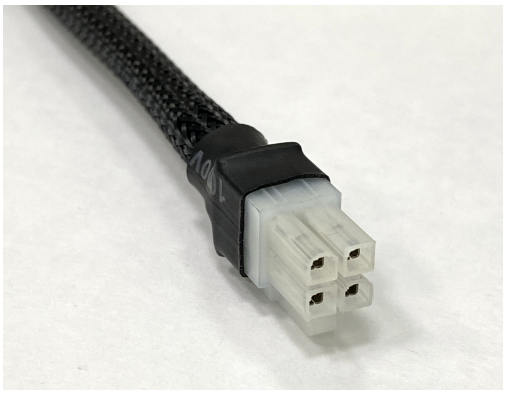
3. 2nd limit switch
4. Digital output for magnetic brake control, 5-24 V, depending on external power supply (EXT REF SUPPLY)
5. Not connected
6. Not connected
7. Not connected
8. Not connected
9. 5-24 V input GPIO 1 signal
10. 5-24 V input GPIO 2 signal, alternative function moving button
11. 5-24 V input GPIO 3 signal, alternative function moving button
12. Output GPIO signal, 5-24 V, depending on external power supply (EXT REF SUPPLY)
13. Output synchronization signal, 5-24 V, depending on external power supply (EXT REF SUPPLY)
14. Input synchronization signal, 5-24 V, depending on external power supply (EXT REF SUPPLY)
15. An analog 0-3.3 V input used for external joystick connection (JOY)
16. An analog 0-3.3 V input used for general purpose (POT)
17. 5V output, 500 mA - for stabilized output for limit switchers, encoder power supply, etc.
18. Logic GND for limit switchers, encoder, etc.
19. Encoder channel A
20. Inverted Encoder channel A
21. Encoder channel B
22. Inverted Encoder channel B
23. Revolution sensor input
24. Inverted revolution sensor input

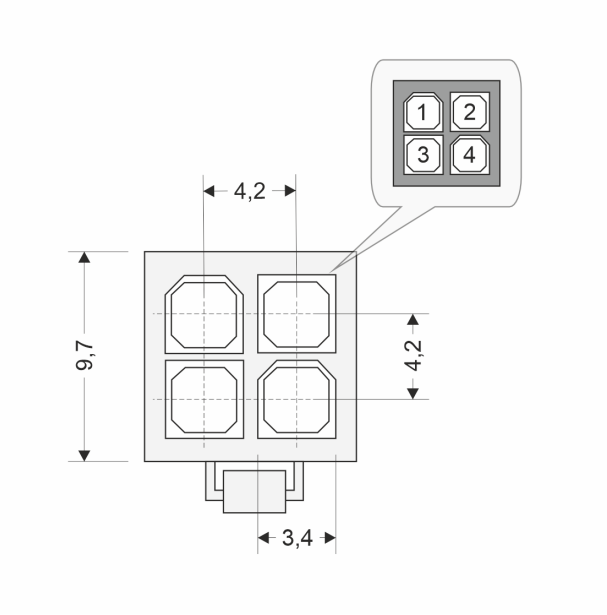
C1. Phase A of SM or phase A on BLDC motor C2. Phase B of SM or phase B on BLDC motor C3. Not phase A of SM or phase C on BLDC motor C4. Not phase B of SM C5. Power GND (Power, "-")

Warning: Plugging in/out the motor to the controller is not recommended while motor windings are under voltage.

4.1.3.2.2 Power supply connector

A male 4-pin Mini-Fit connector with 4.2mm interval (type MF-4MRA) is mounted at the controller board for plugging in to power supply. Its comparable benefits are as following: high 8 A current per pin, a fixation available, a possible coupling with both cable-mounted (type MF-4F, PN 39-01-2040 according to Molex catalogue) and board-mounted counterparts, including vertical (PN 15-24-7041 according to Molex catalogue). All Mini-Fit connectors are available in Molex catalogue at www.molex.com .





Output pin table

Pin	Name
1	“-” power electrode.
2	12–48 V “+” power electrode.
3	“-” power electrode.
4	12–48 V “+” power electrode.

Important: Never supply the power to the controller and do not plug it to power connector if you are not confident that your power supply parameters conform to the requirements. Never attempt to plug the power supply to the controller if you are not sure power supply unit and controller connectors are compatible! The acceptable connection parameters are described in *Safety instructions*.

Important: Hot-swapping or unreliable connection of the power supply connector Mini-Fit may damage the PC and/or the controller. For more details please refer to *Safety instructions*.

4.1.3.2.3 Data connector

Controllers connect via USB type-B or Ethernet connector.

Fig. 4.11: USB type-A - USB type-B cable

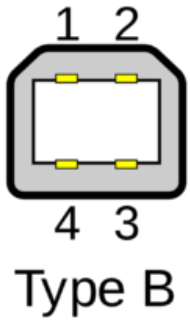


Fig. 4.12: USB type-B connector

Output pin table

Pin #	Name	Wire colour	Description
1	VCC	Red	+5V DC
2	D-	White	Data -
3	D+	Green	Data +
4	GND	Black	Ground

Warning: Use verified USB cables only! Damaged or low-quality USB cable may cause improper controller operation, including motor rotation errors and errors of device recognition by PC operating system. Short cables with thick wires and screening are ideal for sustainable connection.

4.1.3.2.4 Joystick connector

Controller mDrive contain a DVI-I female connector.

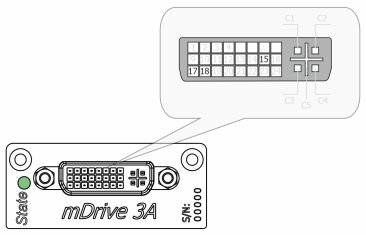


Fig. 4.13: Pinout for joystick connection, front view

Output DVI-I pin table

Pin	Name
15	JOY, an analog 0-3.3 V joystick input.
17	5 V output, 500 mA - for stabilized output for limit switchers, encoder power supply, etc.
18	Logic GND for limit switchers, encoder, etc.

Detailed joystick connection diagrams can be found in the *Joystick control* section.

Note: If you want to connect a 5 V joystick, use a resistor voltage divider. Resistance can be calculated in an online calculator, for example.

Note: Unused pins of the internal connector do not require any additional connection or pullup/pulldown. Simply do not use them.

Important: Analog JOY, POT inputs are designed to work with *less than* 3.3 V voltage. Do not apply higher voltages, including 3.3 V, to these inputs, as it can break all analog controller inputs and lead to the controller or motor failure.

4.2 Kinematics and rotation modes

4.2.1 Predefined speed rotation mode

Predefined speed rotation mode is the main operating mode of the controller for all the motor types. It allows to maintain the predefined rotation speed at a distance from the destination point and is usually used simultaneously with *Rotation for predefined point* or *Predefined displacement* modes. This mode may also get called by left and right motion commands.

Motor steps or *encoder* counts (if the encoder is available) per time unit are used as speed measurement units. Encoders work with all the types of motors.

Turning on the *Acceleration mode* temporarily deactivates the *predefined speed rotation mode*.

After the controller receives the command to start the motion, it rotates the motor with user-defined speed. **The speed adjustment is available** at the *appropriate section of the "Settings..." menu of mDrive Direct Control software* or using the *set_move_settings()* function (refer to *Programming guide* section). For stepper motors the **speed value** may be defined in full steps and microsteps per second, for BLDC motors the speed is defined in revolutions per minute (RPM).

The speed for special motion modes, e.g., for *backlash compensation* or *automatic zero position calibration*, is different from the general rotation speed and is set separately.

The controller allows limitation of the maximum speed if appropriate parameter is defined by user. In that case any rotation that would have happened with the speed over the maximum is performed with the maximum speed. A separate adjustment is available, providing use of the maximum speed for all the ordinary motion modes, except for special ones, e.g., *backlash compensation* or *automatic zero position calibration*. The maximum speed adjustment as well as the adjustment for modes using this speed are available in the *appropriate section of the "Settings..." menu of mDrive Direct Control software*.

The **actual speed** is displayed in *mDrive Direct Control main window*, in the *Speed* field, or on *main operating parameters charts*.

Note: If the **stability of the speed maintenance** seems to be insufficient while the *encoder* is used, please refer to *recommendations for accurate rotation*.

Note: Maximum allowed speed is **100000 steps/s** or **100000 rpm** depending on engine type.

4.2.2 Rotation for predefined point

The *rotation to predefined point* mode is the main operating mode for all the types of motors and is usually used simultaneously with *predefined speed rotation mode*. It provides moving the stage to the defined position with **absolute value** for destination point coordinates which is different from *predefined displacement mode*.

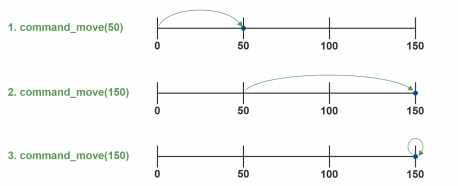


Fig. 4.14: The rotation to predefined point mode

An additional reciprocal motion close to predefined point may be performed at *Backlash compensation* mode.

While using the *encoder*, few barely noticeable "vibrations" are possible before the motor stops in predefined point.

Besides, the movement to a given point, for stepper motors, can be carried out in the feedback mode *encoder mediated*. In this case, the movement is carried out in several iterations with position control at the end of each iteration of the encoder, until it hits a given coordinate with a certain accuracy.

After the starting command is received by the controller, it either switches on the *acceleration mode* (if the appropriate option is on) or immediately starts rotating the shaft of the motor with user-defined speed. After the predefined point is reached, the rotation stops; *deceleration* may be activated if the appropriate option is on. The **destination point** is set in *mDrive Direct Control main window*. The **destination point** may be defined either in full steps and microsteps for stepper motors or in *encoder* counts for all types of motors.

The **actual position** is displayed in *mDrive Direct Control main window*, in the *Control* section, or on *main operating parameters charts*.

Note: If the **positioning accuracy** seems to be insufficient while the *encoder* is used, please refer to *recommendations for accurate rotation*.

4.2.3 Predefined displacement mode

The *predefined displacement mode* provides displacement of the stage for predefined value relative to zero position, if this is a first command since the controller started or relative to position reached by the motor after the previous commands are completed, i.e., the destination point coordinate is a **relative value**.

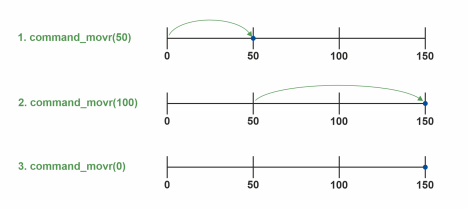


Fig. 4.15: Displacement mode

This mode is useful when the absolute position is unknown or doesn't matter.

Note: The predefined displacement mode is activated either by corresponding command or by incoming synchronization pulse. For more information please refer to *TTL synchronization* chapter.

4.2.4 Acceleration mode

The *acceleration* function is active **by default**. The *acceleration* is used for smooth start or finish of the rotation without shocks that are inevitable when the predefined speed is reached instantly. Moreover, inertia of rotor and the other components of stage usually doesn't allow instant gathering of high speed which results in the loss of steps as well as failure in rotation during the operation without feedback. While operating the motor with feedback via encoder, the speed will increase as quickly as *motor limiters* allow. High acceleration makes the rotation unstable as well as it makes more noise and vibration. That's why the acceleration mode is recommended. The *acceleration* function provides reaching of both maximum speed and sustainable motion even for motors with intermediate torque value.

The *acceleration/deceleration* mode works in the following way: during the speeding-up, while the required speed value is higher than the actual one, a gradual acceleration is performed at the *Acceleration* value which is measured in steps per squared second. After the required speed is reached, the controller switches to *predefined speed rotation* mode. Approaching the destination position, the controller begins to decrease the speed as the speeding-down would equal to *Deceleration* value and the motor would stop exactly at the destination point. Thus, this mode provides a trapezoidal speed profile. If the displacement distance is small, then the acceleration may change directly to deceleration; this will result to triangular speed profile. Turning the acceleration mode on and off, as well as setting of acceleration and deceleration value, is possible using mDrive Direct Control software (see the *Settings of kinematics (stepper motor)* section) or by *set_move_settings()* command described in *Programming guide*.

The *Acceleration* value is adjusted independently from the *Deceleration* value – and there is a reason for it. Usually, due to friction effect resisting acceleration but contributing to deceleration, the maximum acceleration value is less than deceleration one. Therefore, for the fastest response of the stage either preset profiles should be used, or the acceleration/deceleration values should be established experimentally, according to what your stage may provide. For stepper motors working without feedback these are the values that do not lead to the steps loss. For motors with feedback the trapezoidal speed profile should be controlled using *mDrive Direct Control charts*. The acceleration/deceleration values should be taken 1.5–2 times less than those resulting in speed profile distortion or step loss.

Note: Turning the acceleration/deceleration mode off is sometimes useful for multiaxis systems control where, during the motion along multi-dimensional paths, a continuous speed projection on each of the axes is required.

Note: The acceleration value is not displayed in *mDrive Direct Control main window*.

Note: Acceleration/deceleration values should be set as to allow the motor to reach target speed or decelerate from top speed to zero in less than **5 minutes.** If the acceleration/deceleration on *kinematic settings* page is set outside of this range, then the controller will return an "incorrect value" error and accelerarion/deceleration will be changed in controller to applicable value.

4.2.5 Backlash compensation

Backlash occurs in any mechanical device, e.g., in reduction gear or in worm-gear. Backlash results in differences in physical stage position when approaching the same point from different directions, whereas the motor shaft is exactly in the required position.

Backlash compensation mode is used in order to eliminate such ambiquity. Its activation allows user to determine the direction from where the stage would approach the destination point. Further on, the stage will approach the stop point from the defined direction only, eliminating the mechanical backlash. If the natural approaching direction doesn't match the selected one, then the controller drives the motor for some user-defined distance beyond the destination point and after that turns the motor around and completes the approach from the required direction.

While a loaded mechanical system is moving, its dynamic characteristics in the backlash zone do differ from the regular motion mode. Therefore, the rotation in the backlash zone should be performed with user-defined speed.

The following parameters of backlash-compensating system are available for adjustment by user:

- Backlash compensation on/off flag.
- Rotation speed while performing the compensating motion.
- Backlash compensation distance. The plus or minus sign for that parameter is used to determine the approach direction. The plus means the approach from the left side whereas the minus means the approach from the right side.

The controller indicates if the backlash compensation is active using MOVE_STATE_ANTIPLAY flag in the state structure which is also displayed in *mDrive Direct Control main window*.

A forced backlash compensation by using the *LOFT* command may be performed if there is no confidence that the actual position is backlash-free. While carrying out this command, a displacement for backlash compensation distance is performed with subsequent return. Calling this command while driving will lead to a smooth stop of the engine. This command makes sense only when the backlash system is active.

Note: The *backlash compensation mode* presumes no axis position correction, providing the user with just the choice of the direction from where the stage should approach the destination point, sticking to this selected direction.

The backlash compensation adjustment using mDrive Direct Control software is described in *Settings of kinematics (stepper motor)* section. Switching on and backlash compensation parameters detection commands are described in *Programming guide*.

The minimum backlash is reached if the approach to the setpoint is performed with the same movement parameters, so the optimal values of the backlash parameters are: the play speed must be equal to the nominal speed, the backlash compensation distance must be such that the device could reach the nominal speed.

Backlash compensation distance can be calculated from formula:

$$S = \frac{U^2}{2}\left[\frac{1}{Ac} + \frac{1}{Dc}\right] + 0.2U$$

S - backlash compensation, Ac, Dc - acceleration and deceleration, U - nominal speed, 0.2 - even motion time.

4.2.6 Rotation reversal

It is a common agreement that the coordinate increase corresponds to movement to the right, whereas its decrease corresponds to movement to the left. The rotation is to be reversed either if this rule is not satisfied due to physical stage location, or if the stage is supplied with an anchor which is pointed so that it doesn't match coordinate increase.

The rotation reversal may be switched on in the Motor parameters block of *mDrive Direct Control menu*. Switching this feature on will change the current coordinate sign; thus, "left" and "right" terms will get interchanged. For example, the first movement during the *Home position calibration* will perform physically to the opposite direction, the *Left* and *Right* commands in *mDrive Direct Control main window* will interchange, etc.

Warning: Reverse is a setting that affects the whole controller operation if changed. The previously used *mDrive Direct Control scripts* or *your own controlling programs* will work differently.

Particularly, the *limit switches* are adjusted independently from the reverse. Thus, after switching this mode on or off, one must re-adjust them.

4.2.7 Recommendations for accurate rotation

The controller can automatically adjust itself for the required mode, in order to maintain either the speed or the coordinate. However, both the speed and the adjustment property depend on the controller settings. The stepper motor working in steps and microsteps positioning mode can instantly reach the required operating conditions. If the stepper motor is physically unable to provide the required speed or acceleration, the rotation will most likely stop completely. The movement will not fail if a feedback sensor such as quadrature encoder is used as a reference; however, the controller probably won't be able to maintain the required rotation parameters.

The indirect connection of controlling scheme affection with BLDC motor stage displacement results to slowing down of reaching the required coordinate or speed. The following recommendations will help you to accelerate this process and to make it more stable:

- The profile corresponding to the stage being used is normally uploaded to controller and is used by it. Please upload the profile from the the Configuration Files section if you aren't confident that it is proper.
- The motor doesn't enter the limitation mode for one of the operating parameters (refer to *Motor limiters* and *Power control* chapters). Such limitations are displayed by the horizontal bar above the *Current* indicator in either *Power*, *Voltage* or *Speed* blocks in the *Motor* section of *mDrive Direct Control Main window in single-axis control mode*. For more information please refer to *Motor limiters* and *Power control* chapters.
- There are no mechanical impediments for rotation, the axis and stage are not jammed.
- The output power of power supply unit being used is sufficient (see the *Safety instructions*).

4.2.8 PID-algorithm for BLDC engine control

4.2.8.1 PID-algorithm description

BLDC engine is controlled by the PID regulator, with the coordinate as the controlled parameter. The controlled coordinate changes according to motion settings and incoming commands to provide motion capability. We will call controller coordinate the running position. Output current is the control signal of the regulator. The control action is calculated according to the following formula:

$$U(t) = I + P + D = K_p \cdot E(t) + K_i \int E(t)dt + K_d \frac{dE(t)}{dt}, where:$$

$U(t)$ - is the control action

$E(t)$ - is difference between the running coordinate and the current motor coordinate

K_p, K_i, K_d - are proportional, integral and differential coefficients of the regulator. Regulator coefficients are set on *PID settings page* of the mDrive Direct Control program or programmatically by calling set_pid_settings() function of the libximc library (see *Programming guide*).

4.2.8.2 Particular properties of the algorithm

4.2.8.2.1 PID regulator coefficients

User set values are normalized to keep optimal PID regulator coefficients in [0..65535] range.

Let's consider the effects different components have for better understanding. We will assume the supply voltage $U_{supp}(t)$ is constant and equal to the motor nominal voltage U_{nom}. With this assumption PWM fill factor will be equal to 1 in the following cases:

1. $K_p = 1, K_i = 0, K_d = 0$ - if target position is ahead of real position by 256 motor shaft revolutions
2. $K_p = 0, K_i = 1, K_d = 0$ - if integral in the formula above is equal to 52.5 revolutions / second
3. $K_p = 0, K_i = 0, K_d = 1$ - if real motor speed is higher than the required speed by 96000 rpm.

4.2.8.2.2 Reaching target position

Target position is considered to be reached when motor shaft reaches the target position. Some oscillations around target position are possible. Motor will need some time to stop and return to correct position if smooth deceleration is not used and an immediate stop command is received or an emergency stop by limit switch has happened.

Warning: Long time oscillations around the target position while the motion is considered finished are possible if the PID regulator is set up incorrectly.

4.2.8.3 PID regulator manual tuning

We provide a special mDrive Direct Control extension for the manual adjustment of the PID regulator coefficients. The time dependence of the speed of the BLDC engine and the speed retention error is shown in a special window (Settings -> PID control), see the screenshot below.

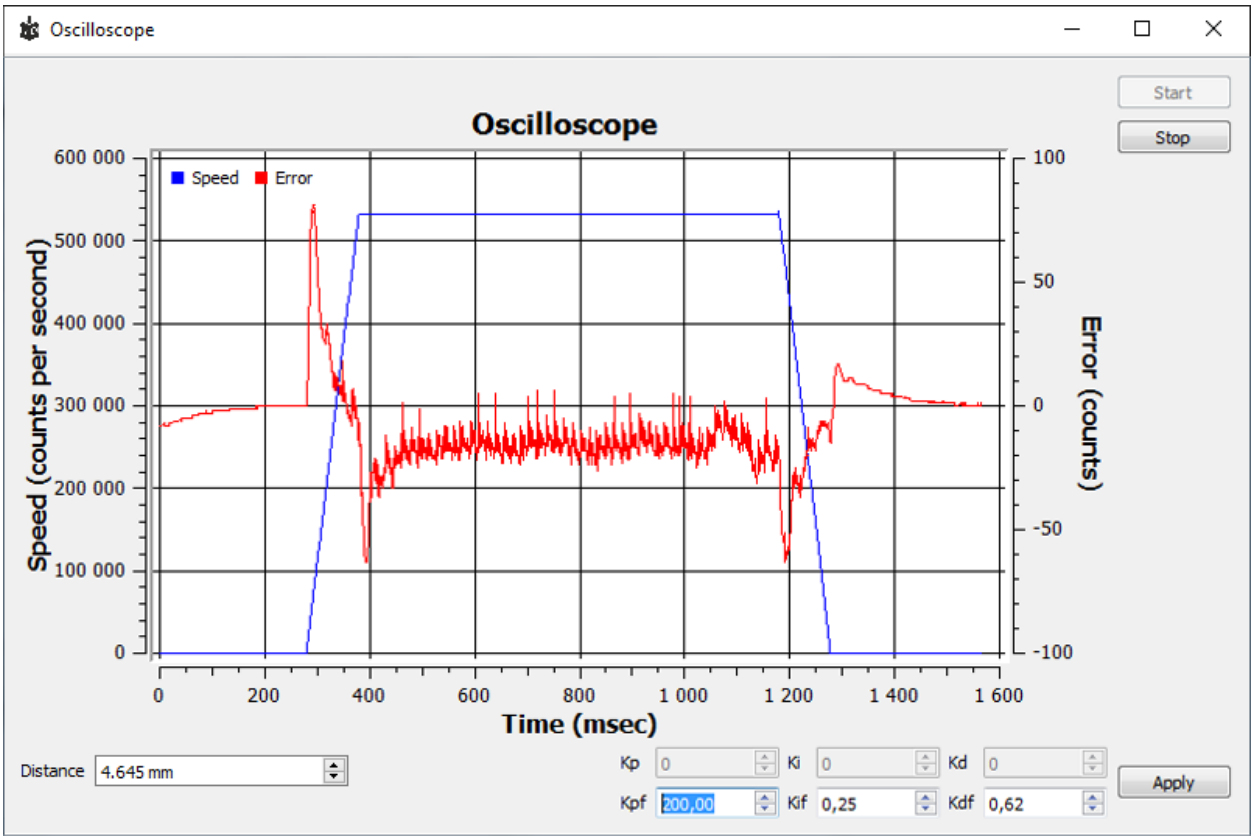


Fig. 4.16: The PID regulator tuning window.

The stable position retention is necessary for the correct engine operation.

4.2.8.3.1 Steps to adjust the coefficients:

1. First, you need to evaluate the PID coefficients. Given the structure of the managed system, they can be calculated from simplified formulas. For this, the parameters from the documentation for the appropriate motor and stage are used.
   - K_m - electromechanical motor coefficient [H / A] (the torque generated by the current strength is 1 A). Can be calculated as the ratio $K_m = \frac{F_n}{I_n}$, where F_n is the nominal (maximum) force generated by the motor, I_n is the rated (maximum) current strength.
   - M - weight of load (kg).
   - $\sigma = \frac{M}{K_m}$.
   - $K_p = 11500\sigma \cdot 1000,\ K_d = 186\sigma \cdot 1000,\ K_d = 12.2\sigma \cdot 1000.$
2. Set the coefficients calculated by formulas, click Apply. Click the Zero button on the *main mDrive Direct Control window*. Set 0 to the Move to field, send the command. The engine should stop. Try to move the position manually, make sure that the response is correct - the engine tries to return to zero position (the encoder reverse is set correctly).
3. Set a small speed in the *motion settings*, click Apply. Start moving in the *main window*. The differential coefficient (Kdf) should be increased if there are vibrations and disruptions.
4. If the vibrations have audio frequencies (the stage emits a loud sound when driving), it may be necessary to reduce the Kd coefficient or all the coefficients proportionally.

5. The integral coefficient (Kif) is responsible for getting into the target position, it is convenient to use the command Shift on for testing.
6. To fine-tune the coefficients use the Oscilloscope window where the speed retention error is displayed for used motion parameters.
7. After the coefficients are adjusted, they need to be proportionally increased/decreased, this corresponds to an increase/decrease in mass, response to the impact becomes more/less powerful, sudden stops will not lead to disruption of movement.

4.2.9 Feedback EMF

4.2.9.1 Advantages

- Always supports sinusoidal current form, which ensures silent operation;
- At high speeds, it can dynamically adapt to external loads, current and voltage restrictions (automatically reduces speed);
- At low speeds, it uses frequency control without rotor position control. When the position of the rotor begins to give correct indicators, it switches to the field control mode with feedback on the rotor position. The switching threshold is individual for each engine, it is determined by the quality of the rotor position assessment issued by the observer;
- Does not use the position sensor (encoder);
- It can operate in three modes:
  - **MTPA** - the most economical mode, characterized by a minimum current, but the voltage increases rapidly with the speed of $I_d = 0$;
  - **FW** - the flux linkage step-down mode is active when the set speed cannot be reached within the current voltage using MTPA $I_d < 0$;
  - **Limit** - saturation mode, when movement at the specified speed is not possible. Occurs when the voltage and current are saturated. In this mode, the drive outputs the maximum torque determined by the current speed and current limits and sets the *PowerLimited flag*.

Important: The algorithm should not be used with the "Position Control" flag enabled. For smooth running in the EMF algorithm, a discrepancy between the actual position and the profile position is implemented. If "Position Control" flag is enabled, false Alarms may be triggered.

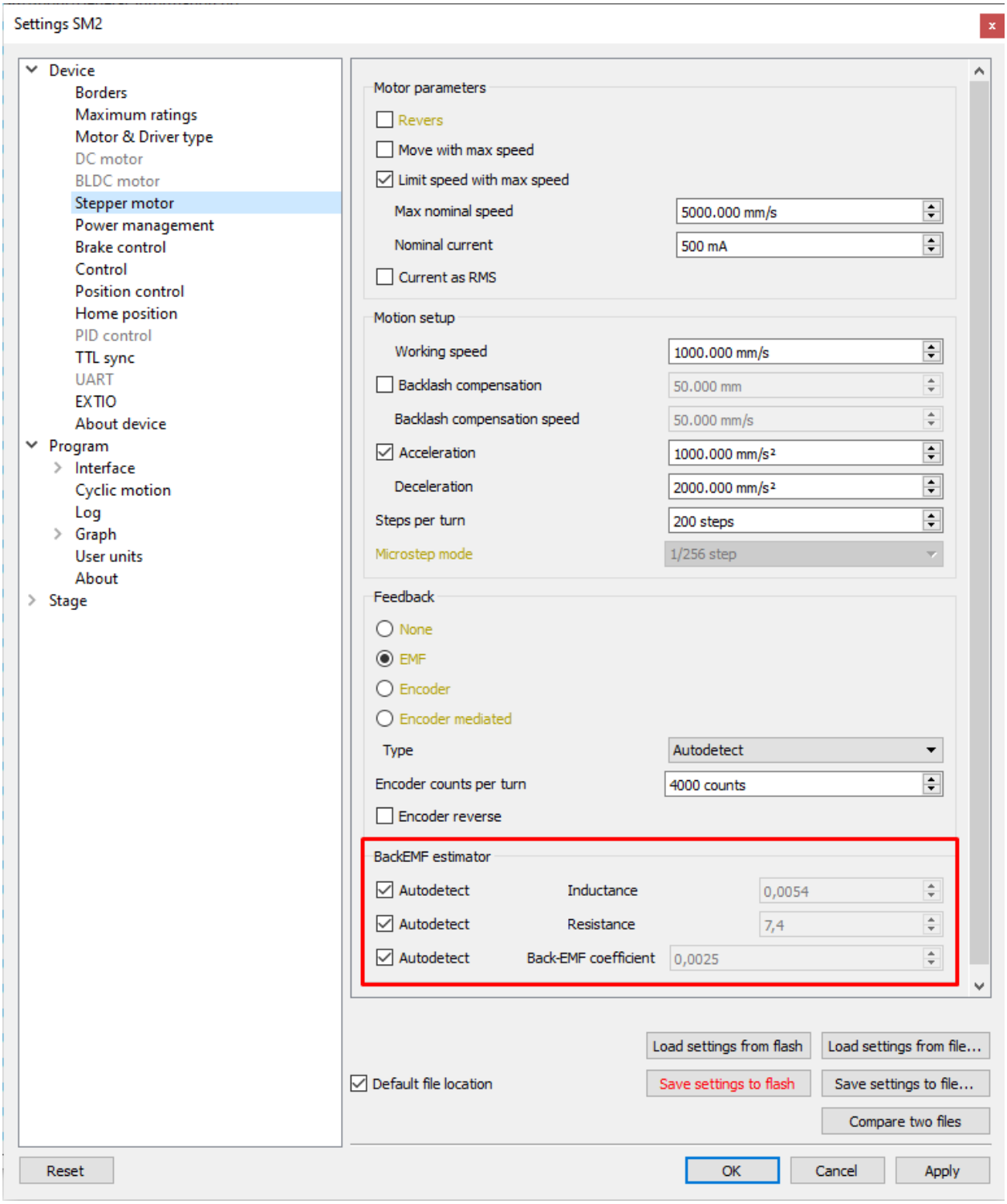
4.2.9.2 Behavior of the engine when exposed to an external force

In frequency control mode: - The rotor position is not controlled, but the current is equal to the nominal value. Only an external force greater than the holding moment can cause the steps to be lost

In field control mode: - If the force can be overcome, then the movement continues at the specified speed; - If the force cannot be overcome, the PowerLimited flag is set, and the set speed value begins to decrease in accordance with the Deceleration value, the position setpoint determined by the logic of the speed profile generator (integral of the speed) is changed accordingly; - If the force is stopped, the misalignment between positions will be compensated by the PID of the position controller; - If the force cannot be overcome by the drive (exceeds the holding force), then at the speed threshold there is a regular switching with subsequent rotor failure and loss of steps.

4.2.9.3 Selecting L, R, and backEMF parameters for EMF algorithm

After turning on the power (switching from the Power: Off state) and before starting to move, the parameters R and L are automatically detected (a short beep is heard). If these parameters are set via the mDrive Direct Control interface, the stage is skipped. To re-evaluate the parameters, the engine must be returned to the Power: off state.



On the *Stepper motor* tab, you can additionally assign the following parameters:

1. Resistance - winding resistance R Ω
2. Inductance - winding inductance L H
3. Back EMF coefficient - the flux linkage of the rotor λ_m Hm/A

4. The value of all these parameters is saved in the engine profile.

Automatic detection of the *back-EMF parameter* works satisfactorily for most engines. However, assigning parameters via a profile provides greater stability of the algorithm.

The values $R\ \Omega$ and L H must be taken directly from the dataset.

The value of the rotor flux linkage λ_m Hm/a can be obtained as follows:

In the datasheet, the value of the motor's Electromechanical coefficient K_m (torque constant, Hm/A) or the counter-EMF coefficient K_{emf} (backEMF constant, Vs), then

$\lambda_m = \frac{4K}{n}$, where K is the value of K_{emf} or K_m, n - number of steps per revolution.

In the datasheet, the rated current i_n (nominal current, A) and the holding torque T_n (holding torque, Hm), then $\lambda_m = \frac{4T_n}{I_n n}$, where n - number of steps per revolution.

4.2.9.4 The choice of PID coefficients for EMF

In field control mode, when the rotor position estimation is available, the position is controlled using a standard PID controller. Its coefficients ensure the stability of the engine in the area of high speeds.

The accuracy of working out a position by profile is determined by many factors:

- In hold mode - the ratio of the hold force to the interference force is the same as for all open-loop algorithms;
- At low speeds - the discrepancy between the actual position and the profile position should not exceed one step;
- At high speeds - the discrepancy can be several steps, due to transients, feedback coefficients, and the presence of external forces.

We suggest using a standard set of coefficients: $K_p = 3.6, \quad K_d = 0.028, \quad K_i = 38$

- K_p increasing the coefficient increases the accuracy (reduces the θ_e error), reduces the adjustment time;
- K_d increasing the coefficient increases the damping of the system and reduces vibrations. A low coefficient can cause instability because the K_d value is too small;
- K_i has little effect on accuracy in transient modes, but it reduces the steady error when moving at a constant speed and acceleration, and also allows you to compensate for constant external forces. In many applications, it can be accepted as null. **If the value is too high, stability is lost**.

4.2.9.4.1 Operation algorithm

The controller **input** is:

- θ_r - desired rotor position (rad), the value of which is generated by the speed profile generator
- ω_r - the desired angular speed of rotation of the rotor (rad/s), the value of which is generated by the speed profile generator
- θ_m, ω_r - rotor position (rad) and speed (rad/c) calculated using the rotor position estimation

Output: I_{qr} - the current value (À) that determines the torque generated by the engine: $M = k_m I_{qr}$, where k_m is the Electromechanical coefficient (torque constant) of the engine

Parameters: K_p, K_i, K_d - feedback coefficients (values set in the *"PID control"* tab).

Control law: 1. Calculation of the control error: $\theta_e = \theta_r - \theta_m, \quad \omega_e = \omega_r - \omega_m$, 2. Calculation of current: $I_{qr} = K_p\theta_e + K_d\omega_e + K_i \int_0^t \theta_e d\tau$

The controller is equipped with an anti-accumulation loop based on the conditional integration algorithm. The growth of the integral part stops if the current saturation occurs ($|I_{qr}| > I_{max} and I_{qr} \cdot \theta_e < 0$)

4.2.10 Feedback encoder

This is the mode when all parameters of the engine including position and velocity are measured directly by the encoder and are denominated basing on counts of encoder. The position is displayed directly in the encoder counts, the speed is denominated in RPM (revolutions per minute). The speed is calculated by the controller basing on the speed alteration data as well as on the number of encoder pulses per one complete revolution of the motor shaft that are displayed in feedback configuration block at the Settings of kinematics (*Stepper motor*), (*BLDC motor*) folder. Note that in the case of BLDC motor the *speed maintaining mode*, the *mode of movement to the predefined point* as well as all their derivations use PID control algorithms and the *appropriate settings* are required. The driving encoder mode optimizes stepper motor control, this leads to noise reducing and facilitates a stable passage of the resonant speeds with no risk of steps loss when the coordinate flounders and the recurrent *calibration* is required.

Set Feedback to Encoder on the Device -> *Stepper motor page*. Note, that position is in encoder counts now.

4.2.11 Feedback encoder mediated

This mode of operation is optimally used in systems with large backlash to get to the desired coordinate in a few iterations, on average from 3 to 10. This mode is used for stepper motors.

For this mode, all motor parameters, including position and speed, are set and displayed directly by the encoder and have dimensions based on the encoder readings. However, in the controller the movement itself is carried out in steps.

Principle of operation: The coordinate values obtained from the external interface are converted into steps and the first iteration of the motion is performed,upon completion of which the position of the encoder is checked. Thereafter the deviation values for the new iteration are determined and a new entrance cycle is carried out. It occurs until the moment when it hits the specified coordinate with a given accuracy.

Use mDrive Direct Control and set Feedback to Encoder mediated on the Device -> *Stepper motor page*.

4.2.12 Stop motion modes

There are two stop motion modes in the controller:

- Immediate stop;
- Stop with deceleration.

4.2.12.1 Immediate stop

Immediate stop is initiated by the command *STOP*. The controller tries to instantly stop the rotation of the motor shaft. This can lead to missed steps in a stepper motor, if no feedback is used. Abrupt cessation of movement can adversely affect the equipment, for example, may shift samples on the microscope stage or require additional adjustment of the optical line after a sudden stop.

Warning: When the controller is configured to trigger a stop on the left/right *limit switch*, it always occurs immediately when the stage reaches the limit switch. This should be avoided.

4.2.12.2 Stop with deceleration

Stop with deceleration is initiated by the command *SSTP*. A smooth stop occurs with deceleration *Deceleration*, if it is not disabled in the *acceleration mode* settings.

Warning: If the *acceleration mode* is disabled, then there is no difference between the immediate stop and the stop with deceleration. An *SSTP* command will then result in an immediate stop.

4.3 Main features

4.3.1 Supported motor types

Currently the controller supports stepper and BLDC motor types. The parameters of supported motors are described in *Specifications* chapter.

4.3.1.1 Stepper motors

Rated current is the main parameter of the stepper motor. The rated current is adjustable at the *Settings of kinematics (stepper motor)* section.

Important: The motor will gradually overheat and get physically damaged if rated current is exceeded. Make sure that the rated current value is set according to the used stage. All the settings are proper in default stage profiles.

Step division mode is another important parameter. In full step operation, the motor moves through its basic step angle (for example, a 1.8° step motor takes 200 steps per motor revolution). Microstepping can divide a motor's basic step up to 256 times. Microstepping improves low speed smoothness and minimizes low speed resonance effects.

The following step division options are available:

- 1 (full) step
- 1/2 of the step
- 1/256 of the step

The microstep mode is set either on *Settings of kinematics (stepper motor)* page or by motor adjustment commands. See the *Communication protocol specification* and the description of the related functions in the *Programming guide* chapter.

Note: The controller always uses the internal step division value equal to 1/256. If the user selects a coarser step division, the software will display only the multiple of the coarser step division positions and both adjustment and transmission are possible only in that coarser step division mode. This is done for compatibility with both obsolete and actual software operating with small multiples of the step division values. On the other hand, operations with the largest step division value provides the most smooth and silent rotation at the smaller speed values.

The number of steps per revolution is the another direct parameter of the stepper motor. This setting does not affect the rotation but is used in *slipping control* block or with motors with the *encoder* feedback.

Note: The controller supports stepper motors with feedback sensor - encoder. The *encoder* can be used as the main position sensor (*more info*) and as the slippage, backlash or steps loss detector (*more info*). Using the encoder facilitates a stable passage of the resonant speeds without movement disruption.

4.3.1.2 BLDC motors

Unlike stepper motors, controlling BLDC motors requires feedback. Currently only *encoder* is supported as a feedback sensor.

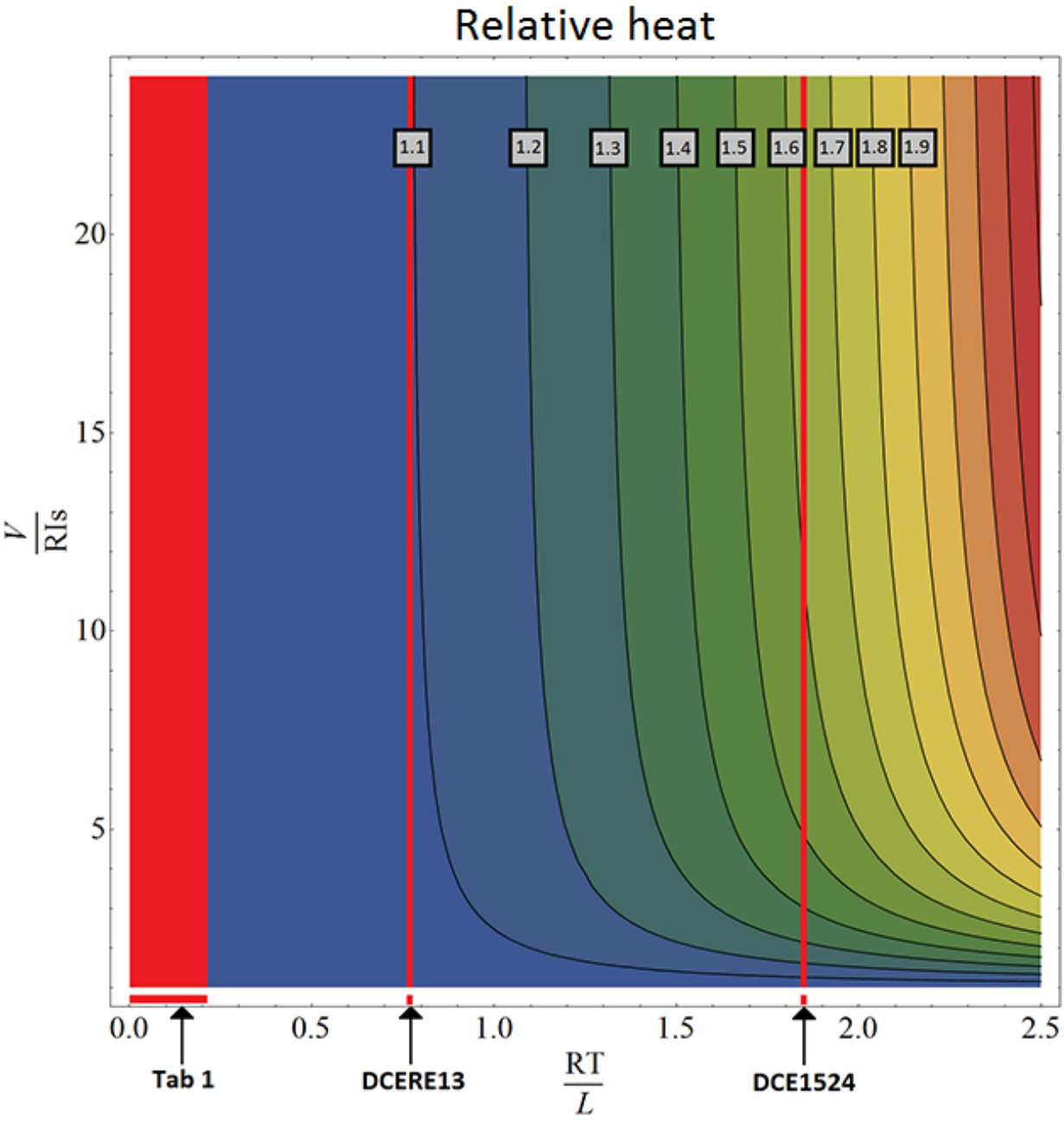
Main BLDC motor parameters are maximum current and number of poles, which can be set on *Settings of kinematics (BLDC motor)*. Main *encoder* parameter is counts per revolution.

Like DC, BLDC engine is controlled by the *PID regulator*. Please carefully read *PID-algorithm for BLDC engine control* before you start working with it.

Important: Wrong PID regulator settings, current and encoder settings might lead to stage failure

4.3.1.3 Engine selection criteria

Pulse-width modulation (PWM) is a widely used way to control winding's current in different motor types. It leads to current oscillations at PWM switching frequency (so-called "current ripple"). Current ripple's amplitude depends on motor characteristics like its winding inductance and resistance. Motor can heat up more than it is expected with nominal current due to current ripple, i.e. $\frac{P_{real}}{RI_s^2} > 1$. There is RI_s^2 - power dissipated by I_s (stabilization current), P_{real} - real power, dissipated in motor. For overheating estimation we recommend to use this graph:



All the major engines and their parameters have been marked in following table:

Table 4.1: RT/L values for some motors

Motor	RT/L
20	0.19576
28	0.07253
28s	0.07168
4118L1804R	0.02715
4118S1404R	0.02844
4247	0.0273
D42.3	0.0223
5618	0.0146
5618R	0.0146
5918	0.0116
5918B	0.012
VSS42	0.029
VSS43	0.0256
ZSS	0.04248

The motor's overheat is determined by this sequence:

- $\frac{RT}{L}$ calculation. There is R, L - resistance and inductance of motor winding (refer to the motor documentation). T - PWM period time. It's value should be 51.2 us for stepper motors and 25.6 us for DC motors.
- $\frac{V}{RI_s}$ calculation. This parameter shows power voltage excess under nominal voltage. There is V - power voltage,:math:*R* - winding resistance, I_s - stabilization current.
- Overheat definition. After first two steps point can be plotted at the graph. Now we should define the region, which corresponds to overheat degree. For example, the region between 1.1 and 1.2 corresponds overheat value between $1.1 * RI_s^2$ and $1.2 * RI_s^2$.

4.3.2 Motor limiters

Motor winding current and voltage limiters and motor shaft revolution speed limiters are provided to ensure safe operation. These limiters, if activated, will lead to gradual power and rotation speed decrease until the parameters being limited are within acceptable range. Motor limiters work with voltage and current values directly on motor windings, unlike *critical parameters*, which work with current and voltage at the controller input. Another distinctive feature of limiters is that they do not stop the motor and let the controller enter **Alarm** state; they merely limit voltage, current and motor revolution speed.

For BLDC motors:

- *Max voltage* is the nominal motor voltage. It defines maximum motor winding woltage. It is usually used to limit voltage growth when the motor or stage is jammed. *Should only be used if maximum motor winding current is unknown.* This parameter is used in *PID regulator*.
- *Max current* defines maximum engine winding current. It is usually used to limit current growth when the stage is jammed. One should set this limit based on maximum current which can be sustained by the motor without damage (primarily by heating).
- *Max RPM* is the maximum motor shaft revolution speed. Is usually used to limit revolution speed when working with reducing gears and other devices which have strict maximum speed limits.

Note: One should be aware of the distinction between maximum motor current and nominal current. In general they may be different because of motor cooling features and operating conditions. Also, one should not mix up maximum

current and starting current with stationary motor shaft.

Important: Changing maximum motor voltage might disrupt PID regulator. For more information see *PID-algorithm for BLDC engine control*.

Important: Maximum motor voltage may exceed nominal voltage, usually by 10-15%. If you are using a motor with low load and you need high motor speed, then you can increase maximum motor voltage.

Current limiter operation.

It is important to note that maximum current limiter does not react immediately when working with BLDC motors. When a higher than maximum current is detected in the motor winding, voltage supplied to the motor is gradually decreased until winding current is less than *Max current*. In the worst case of a rapid jam during high-speed movement motor voltage may decrease for at most 370ms. If the current limit is chosen right, motor should not overheat during this time.

Note: If the *Max current* value is set too low, it is possible that BLDC motor will not be able to move under high load or high friction.

For stepper motors:

- *Max(nominal) Speed* is a maximum motor shaft rotation speed in steps per second. Current stepper motor speed is defined by *Speed* parameter (see *Predefined speed rotation mode*).
- *Nominal current* defines maximum motor winding current. This value cannot be exceeded due to characteristic stepper motor control.

In the mDrive Direct Control software limiter settings are described in sections *Settings of kinematics (BLDC motor)* and *Settings of kinematics (stepper motor)*.

4.3.3 Limit switches

4.3.3.1 Limit switches designation

Limit switches are designed in order either to prevent the stage movement out of permissible physical movement range or to limit its movement range according to user-defined requirements. Incorrect setting of the limit switches may result to stage jam if the controller goes beyond the permissible range.

4.3.3.2 General settings

If the limit switch is active, a corresponding flag is placed in the state structure and the appropriate icon (left or right) is displayed in *mDrive Direct Control Main window*. The controller can either stop any movement in the direction of any active limit switch (left or right) or stop the movement to the single limit witch (left or right) or not to limit the movement. Limit switches settings are performed in mDrive Direct Control software (see the *Motion range and limit switches* section).

4.3.3.3 Programmable motion range limitation

If there are no hardware limit switches for the motion range but the stage requires such limitation, the programmable limiters can be used. For doing that, the limiters should be switched to limitation mode according to position reading (see the *Motion range and limit switches* section). The left and right margin fields are used (the right margin value should be higher than the left one). In this mode, the left limit switch is active if the actual position is less than the left

margin value and the right one is active if the actual position is greater than the right margin value. The operation time is about one millisecond.

Warning: The programmable motion range limitation is reliable only if there is no direct setting of the new position by ZERO or SPOS commands, or if there is no steps loss or encoder malfunction if it is used for positioning, or if there is no frequent power-cut during the rotation. If any of these problems appears, the programmable range should be re-adjusted. The appropriate reference sensor allows the automatic re-adjustment using the *automatic Home position calibration* feature.

4.3.3.4 Hardware limit switches

The controller may operate with limit switches based either on dry contacts, or on optocouplers, or on reed switches, or on any other sensor types generating a 5V TTL-standard "logic one" electric signal in one state and a "logic zero" in the other. Each limit witch may be configured independently. There is also possible to change the position of limit switches or their polarity in software.

Note: Limit switches are also useful for *automatic Zero position calibration*.

4.3.3.5 Limit switches connecting instructions

Limit switches should be connected to *DVI-I connector* pins as it is shown at the diagrams:

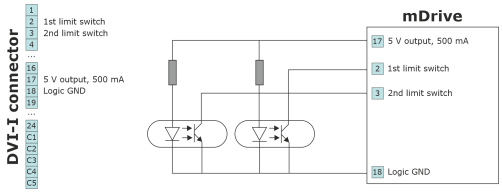


Fig. 4.17: The "optocoupler" limit switches connection diagram

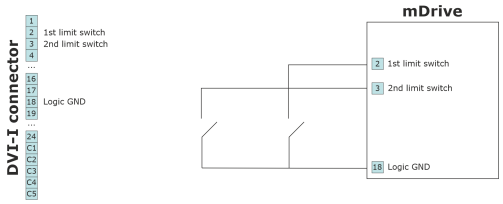


Fig. 4.18: The "dry contact" limit switches connection diagram

4.3.3.6 Limit switches location on translators

The settings of which limit is left or right is required by the controller. Sometimes it is unknown a priori, just it is clear that both limit switches are connected and fire if the corresponding limit of the motion range is reached. The stage jam is possible if the limit switches are configured improperly. Therefore, the controller supports just a simple detection of incorrectly configured limit switches, shutting down the movement on both of them. Please make sure that their polarity is configured correctly and the shutdown mode is activated on both of limit switches. The flag of improper limit switch connection detection should be turned on in corresponding *mDrive Direct Control software menu*. Start the movement to any direction until the limit switch shuts the movement down. If there was right-side movement but the left limit switch became active, or vice versa, the limit switches should be interchanged (see the *Motion range and*

limit switches chapter). If the improper actuation of the limit switch is detected and if the corresponding feature is set in the *Critical parameters* menu, the controller can turn the Alarm mode on.

Warning: The protection against mistaken limit switches connection doesn't guarantee the complete solution of the problem, it only makes the initial configuration procedure easier. Particularly, don't start the movement if any of the limit switches is active, even if the protection is on.

4.3.4 Automatic Home position calibration

Autocalibration (homing) is used for detection and placing the movement to the starting position (it can also be called "home" or "zero" position). Calibration comes to automatic accurate detection of the *limit switch*, the *revolution sensor* signal or moment of getting the *external synchronization pulse* which determines the zero position, and grading from it by a specified offset. This allows one to start working in a situation when the current position of the stage is unknown, but the location of one reference point (initial position) relative to the limit switch or some other signal is known. The homing process does not require programming skills from the user.

The reference point (stop signal) is determined in one of three ways, depending on the settings selected by the user:

- Movement until the *limit switch* is reached - in this case, the current settings of the limit switches (location, polarity) are used. For more details please refer to *Motion range and limit switches* chapter.
- Movement until a signal from the *revolution sensor* is received, in this case the current settings of the revolution sensor are used. For more details please refer to *Position control* chapter.
- Movement until the signal from the *synchronization input* is received, in this case the actual configuration of synchronization input is used. For more details please refer to *Synchronization settings* chapter.

Warning: If the synchronization input is software-disabled in the appropriate settings menu, then the signal from it will never be processed.

4.3.4.1 Standard homing algorithm

Depending on the settings the homing can be processed using three different algorithms. The standard search for a home position is the following: the controller starts moving with the preset parameters of speed and movement direction until a stop signal is received. The speed of homing is usually set lower than the working speed in order to "not miss" the arrival of the stop signal and improve the calibration accuracy. Then an absolute offset is made at a working speed to the preset standoff distance.

The resulting point is called the starting position or "home position". It is important to note that its location on the stage does not depend on the initial position from which calibration started.

4.3.4.2 Accurate additional calibration

After the stop signal is received the position of the controller is already determined. But before making a shift to the home position one can perform the additional movement towards the next stop signal (the second phase of homing). This allows to reach an accuracy in setting a home position of 1/256 steps for stepper motors or 1 encoder count for BLDC motors for some stages. If the corresponding flag is set, the controller rotates the motor in a user-defined direction with the preset speed until a stop signal is received from the source selected by the user. Then, as for the standard algorithm, the offset is made at a working speed to the preset standoff distance.

The parameters of the second phase of homing (speed, movement direction and the source of the stop signal) are set independently of the first phase parameters settings. At the same time it is reasonable to use the signal from the revolution sensor placed on the motor shaft previous to the gear and perform movement at a low speed - this will provide the maximum accuracy. Since the stop signals for the first movement and the second movement can coincide, a special flag is provided in the software to start tracking the stop signal for the second movement only after making

a half turn of the motor shaft. This avoids the ambiguous sequence of receiving stop signals for the first and second movements. As a result of the optional second movement the calibrated position is refined.

Note: In case the second phase of homing is used the first movement can be performed at high speed since it only roughly calibrates the position and accuracy is not required there. The accuracy will not be increased in case the second limit switch is used for the second phase of motion since its physical parameters do not differ from those of the first limit switch.

4.3.4.3 Fast homing algorithm

When the fast homing is enabled the controller starts to rotate the motor towards the preset direction with a working speed in order to quickly find the position of the reference point. After the stop signal is received the controller pulls the motor back for half a turn and starts moving again in the preset direction but takes the speed value specified in the settings of the first phase of homing. After the repeated stop signal is received the offset is made at a working speed to the preset standoff distance. The stop signal source is also set by the standard homing algorithm settings.

The fast homing algorithm is optimal for most motors and positioners.

4.3.4.4 Autocalibration features

Successful completion of home position calibration results in assertion of the STATE_IS_HOMED flag in the *controller state structure*. In case the home position is somehow lost after the calibration (stop on *limit switch*, *immediate stop* while moving, *the detection of loss of steps*, switching to the *alarm mode*), the corresponding flag is dropped and it is necessary to re-calibrate the home position.

Note: The position reached as a result of calibration will slightly depend on the speed of the last motion until the selected sensor responsed. Therefore, don't change the speed parameters for further successful reaching the same position.

Note: If command *immediate stop* or command *power shutdown* are executed while the engine is stopped then it isn't necessary to re-calibrate the home position and the STATE_IS_HOMED flag is not dropped.

The description of the **functions** for auto-calibrating a home position is given in the *Programming guide* chapter.

Autocalibration commands are described in the *Communication protocol specification* chapter.

Autocalibration can be configured by the user in the mDrive Direct Control program on the Device tab -> Home position (see the section *Home position settings*), and started with the **Go home** button in the *mDrive Direct Control main window*.

A **set_zero** *script* is supplied with mDrive Direct Control software pack, providing the automatic home position configuration. This script changes the Standoff setting at *Home position settings* tab, making the actual position as the Home one.

How to use the script:

- place the movement to the desired position,
- launch the script and wait until it's finished.

As a result, the stage will be moved in the same position where the set_zero script was called and all the following calls of homing function will move it there. Make sure to *save the settings* to controller's nonvolatile memory.

4.3.5 Operation with encoders

4.3.5.1 Application of encoders

Encoders are designed for creation of accurate and fast feedback according to the coordinate for all the electric motor types.The feedback is performed by the motor shaft position, by stage's linear position, by the motorized table rotation angle or by any other parameter related to the shaft position and measured by using the two-channel quadrature encoder complying the requirements described in *Specifications* chapter for the appropriate controller type. Controller **mDrive** supports differential encoders and simple (single-ended) encoders..

Warning: Auto-detect works only with 3.3 V and 5 V (with error 0.2 V) encoders.

4.3.5.2 What is quadrature encoder?

Encoder is a mechanical motion sensor. The quadrature encoder is designed for direct detection of the shaft position. The sensor transmits the relative shaft position by using two electric signals at CH A and CH B channels shifted relative to each other at 1/4 of period.

Fig. 4.19: The signals at CH A and CH B outputs of quadrature encoder

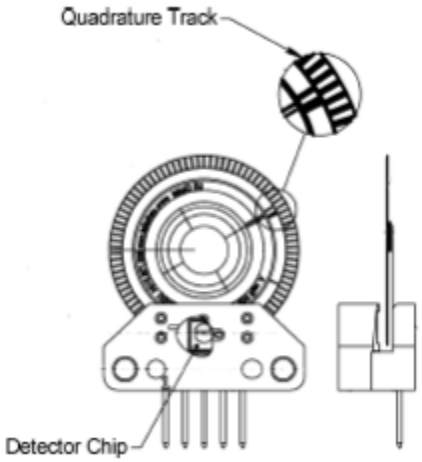


Fig. 4.20: An optical quadrature encoder mechanics

An optical quadrature encoder mechanics is shown at the figure above. There are two optocouplers used. The operational principle of an optocoupler is as following: a LED and a detector are arranged opposite to each other from different sides of a disc. The optocoupler opens when disc's "window" coincides with the detector (the outgoing signal is logic zero). The outgoing signal is logic one if the detector is closed by opaque part of the disc.

Number of steps per revolution (CPR) is the main parameter of the quadrature encoder. The standard resolution values for encoder are from 24 to 1024 CPR. Each period of signal alteration is interpreted by 1, 2 or 4 codes which is corresponding to X1, X2 and X4 operating modes. This controller uses the most accurate X4 mode. The maximum

frequency of each encoder's signal depends on the applied encoder itself, since for 200 kHz in X4 mode the controller can read up to 800,000 encoder counts per second.

4.3.5.3 Controller's features

There are two operating modes with encoder available for the controller:

- the encoder is used as the main position sensor.
- slippage, backlash or steps loss detection (the recommended mode for joint operations with stepper motors, in case the encoder is not used as a primary position sensor, see *more*).

4.3.5.4 Encoder connection

The encoder is connected to the controller via *DVI-I pin* connector, which is in *controller board*, *one-axis* and *multi-axis*.

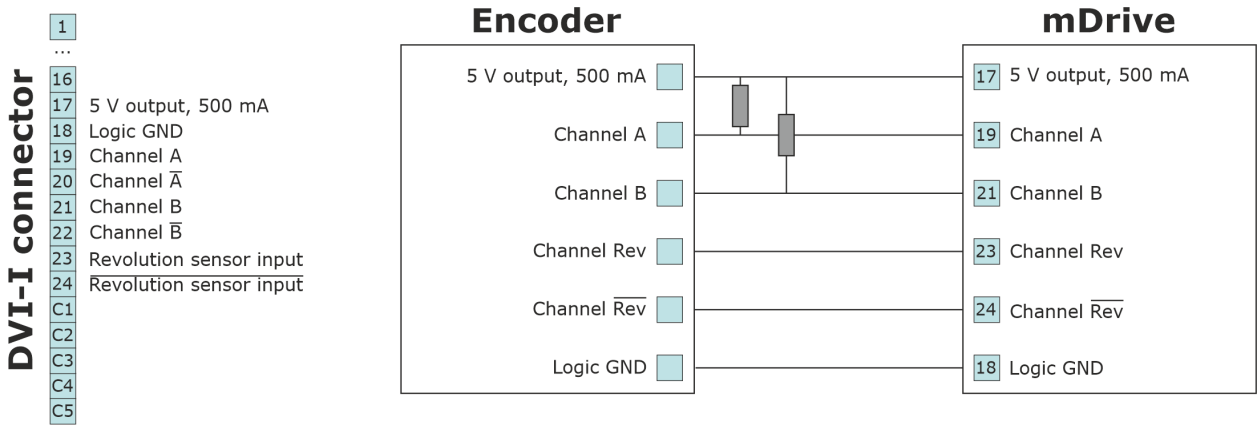


Fig. 4.21: The diagram of single-ended encoder connection using DVI-I connector.

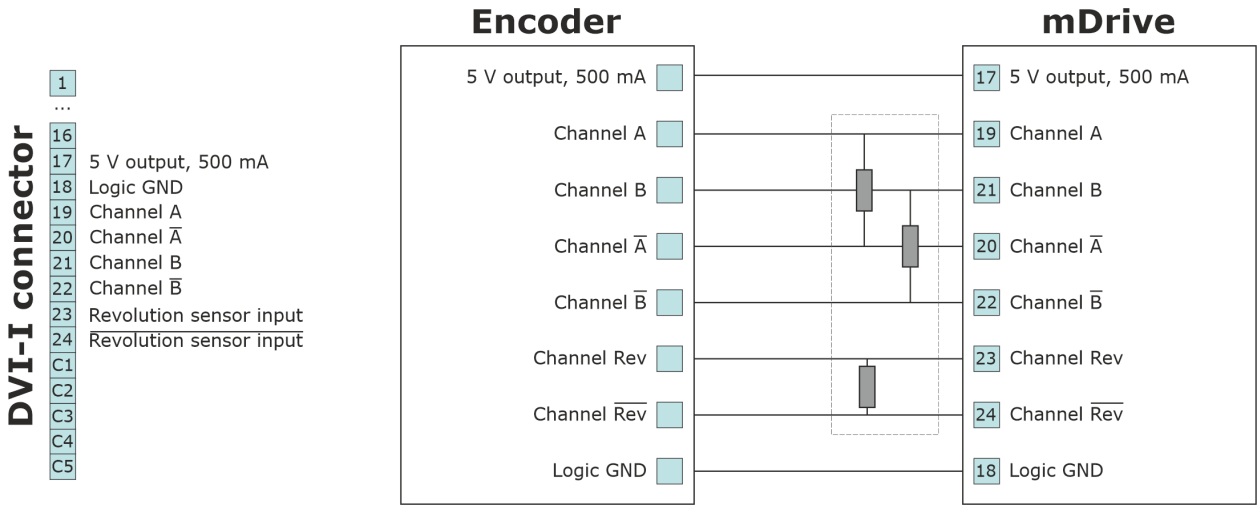


Fig. 4.22: The diagram of differential encoder connection using DVI-I pin connector.

See also the *Example of a motor connection* chapter.

Warning: Encoder inputs of the controller internally pulled up to logic one by using the 5.1kΩ resistors. Frequently encoder outputs are of "open collector" type equipped with internal pull-up resistor. During the data transmission they provide good characteristics while passing from higher logic level to lower. However, the pass from logic 0 to logic 1 is more graduate. It passes through the RC circuit formed by pull-up resistor and cable capacitance. This is the most important thing if the cable is long *(up to 5 meters)*. If the internal pull-up is not sufficient, the pull-up resistor with r=1.5kΩ may be added for every +5V to each output in order to improve the transmission speed parameters; before doing that please check if the open collector of the encoder can transmit 5mA current. The resistors insertion diagram is shown above. The maximum operating speed for quadrature encoder may be increased by adding a push-pull driver with the outgoing current over 10mA to its output, providing quick 0 - 1 and 1 - 0 transmission edges.

4.3.5.4.1 Operation with long cables

For correct encoder operations on cables longer than 5 meters, it is recommended to use an encoder with a differential output (RS-485) to reduce the effect of electromagnetic interference. When using the RS-485, all differential pairs must be terminated with a 120 Ohms resistor in the connector to the controller.

The cable must have an additional internal shield for digital signals (pins 2-4, 9-24) connected to the DGND (pin 18) on the controller side and on the stage side. The external shield must be connected to the metal case of the connector directly on the side of the stage and to the metal case of the connector through a 47 nF capacitor on the side of the stage.

4.3.5.4.2 Automatic encoder type detection

The mDrive controller can automatically detect the type of encoder *if the corresponding option is enabled*. This system is designed to work with standard CAT-5E cables up to 50 meters long and with a conductor resistance about 80 mOhm per meter. Automatic detection may not work well with cables longer than 50 meters or with non-standard cables with high resistance wires. In case of problems with automatic encoder type selection, encoder type can be selected manually in *the feedback settings*.

4.3.6 Revolution sensor

Revolution sensor is designed for *stepper motor shutdown (failure) detection* and for better accuracy of Home position calibration procedure (see *Automatic Home position calibration*).

The controller may receive the actual position data from the external revolution sensor mounted on the stepper motor shaft. The sensor transmits its signals to the controller once or many times per one revolution of the motor.

Usually the revolution sensor is a small disc with precise graduation scale mounted on the motor shaft. A light source (LED) and a sensor of the optocoupler are placed at the opposite sides of the disc. The sensor is open if there is no interrupter between the LED and the sensor (the logic zero is transmitted to optocoupler's output), whereas the logic one is transmitted if the light source is closed by the interrupter.

By default, the lower logic level is interpreted by the controller as the active mode of the revolution sensor. The controller's input is pulled to logic one level, thus, the disconnected revolution sensor means its inactive mode. The controller's input can be inverted if necessary, in that case the logic one level will mean the active mode.

4.3.6.1 Connection diagram

The revolution sensor should be connected to the controller via *DVI-I* connector, which is in all systems (*controller board*, *one-axis* and *multi-axis* in box).

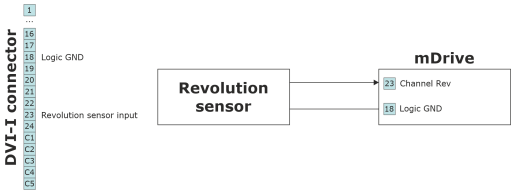


Fig. 4.23: Scheme of revolution sensor connection to the mDrive based system

4.3.7 Steps loss detection

This mode is generally used while operating the stepper motor at full speed or limit loads when the shaft jam resulting to the steps loss is possible. In this case an additional position sensor (*revolution sensor*) or *encoder* allows tracking this moment, informing the user about it. This feature should be applied **with stepper motors only** and it allows detection of the steps loss. Steps and microsteps are the measurement units for all coordinates and shaft positions.

When the encoder is used, the controller stores both number of steps and number of encoder's counts per revolution (see the *Settings of kinematics* folder of mDrive Direct Control program). When the feature is activated, the controller saves the current position in steps of the motor and the current position according to the encoder data. Then, during the motion, the position data according to the encoder converts to steps and if the difference exceeds the predefined value then the slippage is indicated and the *Alarm mode* turns on (if the related option is active). For more information regarding use of encoder as the steps loss detector please refer to *Operation with encoders* chapter.

If the revolution sensor is used, the position is controlled according to it. The controller stores the current position in steps according to active and inactive edges at the sensor's input. Then, at every revolution (number of steps per one full revolution is set by *Steps per turn* parameter, see the *Settings of kinematics (stepper motor)* chapter) the controller checks if the shaft has been displaced and how many steps for. If the mismatch exceeds the predefined *Threshold* value (which is defined in position control settings, see the *Position control* chapter), the slippage is indicated by the state structure flag. If the appropriate flag is set and if the error is detected, the controller turns the *Alarm mode* on and the motor shuts down, otherwise the motion is continued. If the slippage indication flag is active, the controller turns the *Alarm mode* on when the appropriate parameter in the settings is active.

Also you can enable the position correction option in the *position control settings*. If this option is enabled and the steps loss is detected the controller stops the movement, adjust the step position on the basis of the encoder data and try to start the movement again. The flag of the control position error *The position control error flag* is set when the desynchronization of the steps and the encoder position is detected and it will be unset automatically when the position becomes corrected. If the controller is not able to eliminate the desynchronization the controller is set *the position control error flag* and goes to *the Alarm mode*. If the steps loss happens during the movement *the movement command status* will not be changed while the position is correcting. If the steps loss happens during holding a position *the move to position* command will be executed for return the motor axis to the holding position.

Note: For using the position correction function you should have the encoder with the resolution at least two counts per the motor step.

Note: For correct operation of the position correction option you should let the controller to hold the position during 1 second for calibration before moving. It necessary to repeat the calibration after the transition to *the Alarm mode* or after changing the settings.

Note: If the automatically position correction is used it is not recommend to set the *Threshold* value above than 3 steps because in this case not any slippage will be corrected.

Note: *The soft stop* and *the hard stop* commands could be ignored by the controller if it was sent during position correction process. In this case you can send *the soft stop* command twice for power off the motor windings.

Note: If you use *the software limit switches* it is not recommend to use the automatic position correction because the limit switches positions will be changed during position correction process.

Note: A hard STOP launches the the re-calibration process of the revolution sensor position, and the calibration starts after the revolution sensor activates during the motion controlled by the motor. It means that the slippage won't be detected if the shaft has been rotated manually right after the hard stop since the calibration hasn't been performed yet.

Note: If the motor revolution sensor is bouncing (mechanically), the misoperations of the revolution sensor are possible at the very low speeds.

Note: The position control of the revolution sensor can't detect the shaft rotation at the zero speed, i.e., if the motor is shut down and the shaft is rotated manually, it won't be detected.

4.3.8 Power control

4.3.8.1 Current consumption reduction

Controller has an option to set current when idle to reduce power consumption. This mode is active by default. It is widely used to lower stepper motor heating in hold mode while keeping position maintenance accuracy. Hold current is set as a percentage of nominal winding current. A time delay after which current will be reduced is also defined. Current reduction mode can be disabled. To set current reduction see *set_power_settings* function in *Programming guide* or mDrive Direct Control *Power consumption settings* page. Nominal engine current is set by *set_engine_settings* function (see *Programming guide*) or on *Settings of kinematics (stepper motor)* page in mDrive Direct Control.

A reasonable hold current level is 40-70%. This will lower power consumption 2-4 times, while keeping holding force sufficient. A reasonable time to reduce power lies in 50-500 ms range. This is a sufficent time for mechanical oscillations, which might knock the system out of the hold position, to subside.

4.3.8.2 The motor power shutdown

There is also a power shutdown mode to reduce power consumption of a stepper motor. It is mostly used to stop wasting power on position hold, when no movements are performed for a long time. This mode is on by default, but can be disabled by the user. Time from motor stop to power off is set in seconds. A reasonable time is 3600 seconds (one hour). To set power off options see *set_power_settings* function in *Programming guide* or mDrive Direct Control *Power consumption settings* settings page.

4.3.8.3 Time delay calculation specifics

All timeouts work in the follwing way: on each transition to stop state time is saved with millisecond accuracy. After certain set time is elapsed depending on PowerOff/CurrentReduce enabled state a motor will reduce winding current or turn its power off. All settings can be changed online. For example, if you increase PowerOff timeout value after the poweroff has already happened then windings will get powered on and a PowerOff function will activate after the new delay. Timeout countdowns cancel after each movement start.

4.3.8.4 Jerk free function

Sometimes smooth motor winding current changes are required to reduce vibrations of a mechanical system. That's why a *Jerk free* option is provided, which allows one to set current ramp-up time from zero to nominal value with millisecond precision. When this option is turned on all changes to stabilization current or winding powerdown will happen with smooth current increase or decrease. For example, if jerk free time is set to 100ms and the controller needs to reduce current to 50% it will be reduced over the time of 50ms (because 100ms are required to reduce current from full to zero). To setup Jerk free see *set_power_settings* function in *Programming guide* or mDrive Direct Control *Settings of kinematics (stepper motor)* page.

Smooth current change function activates on any change in the amplitude of the winding current, for example on nominal hold current change. In this case current change speed is calculated based both on older and newer hold currents, whichever is higher. If controller needs to turn off the motor windings then current is gradually ramped down, then power output circuits are disconnected. If controller needs to power up the windings, then they are powered with zero current which increases up to nominal current.

There are exceptions to the rule, when the current is immediately reduced to zero even if Jerk free option is active. These are the critical errors/Alarm state (see *Critical parameters*) and controller reset events on firmware update. These events are rare and should not happen during normal stage operation.

A reasonable Jerk free time is 50-200ms, which merely leads to low-energy mechanical oscillations on 3-10 Hz frequencies which are significantly lower than noise from other common sources. Higher Jerk free times will lead to constant delays when current is switched on or off.

4.3.9 Critical parameters

Minimum and maximum values of currents, voltages and temperatures are used for safe controller operation. Any value out of acceptable range leads to the motion stop, windings power-down and Alarm state for the controller. Exiting the Alarm state is possble only after the critical parameter returns to normal and the STOP command is sent to the controller. Critical settings are used for all motor types.

The following parameters are available:

- *Low voltage off* defines the minimum voltage value of the controller power supply (measured in tens of mVs). The *Low voltage protection* flag is used to turn this option on, otherwise the minimum unpowering threshold doesn't work. The 6000 mV to 8000 mV range is sensible for operating power range of 12 V to 48 V. This type of protection helps to determine the power-cut moment due to activation of any sort of power supply unit protection. This may occur if the operating power consumption of the stabilized power supply unit is exceeded.
- *Max current (power)* defines the maximum current of the controller power supply (measured in mAs). The sensible value is twice the maximum operating consumed current registered during the tests. Use the *mDrive Direct Control charts* for registration of the consumed current.
- *Max voltage (power)* defines the maximum voltage value of the controller power supply (measured in tens of mVs). The sensible value is 20% higher than power supply unit voltage.
- *Temperature* defines the maximum temperature of the microprocessor (measured in tenths of degrees Celsius). The microprocessor can operate at the working temperature of up to 75ºC and doesn't overheat by itself. Rise of its temperature indirectly indicates the overheating of the power part of the board. The overheating threshold range from 40ºC to 75ºC is sensible.

Flags:

- *ALARM_ON_DRIVER_OVERHEATING* means entering the Alarm mode if the driver's critical temperature (over 125ºC) is exceeded. The power driver indicates if its temperature is approaching the critical value. If the driver is still working then the further heating will automatically shut it down. It is recommended to set this flag and not to rely on automatic forced shutdown.
- *H_BRIDGE_ALERT* means turning the Alarm mode on if any fault of the power driver due to board overheating or damage is detected. This flag should be set on.

- *ALARM_ON_BORDERS_SWAP_MISSET* means turning the Alarm mode on if the triggering of the wrong limit switch, not corresponding to direction, is detected (see the *Limit switches* chapter). This flag is intended for clear indication of the response of the limit switch swap detection subsystem. The flag is recommended to be set on.
- *ALARM_FLAGS_STICKING* flag activates the sticking of the error indicators in the status structure of the controller, otherwise indicators are active only during the accident that caused the error. If there was a short-time error and its cause was independently removed, then sometimes the reason of Alarm remains uncertain. In that case the sticking is useful and the accident cause can get diagnosed in mDrive Direct Control main window.
- *USB_BREAK_RECONNECT* - This flag configures the operation of an USB break reconnect block. When set, this unit starts to operate and monitor the loss of communication over the USB bus (for example, in case of a static discharge).

Configuration of parameters is described in *Critical board ratings* menu of mDrive Direct Control software. The maximum available value configuration commands are described in *Programming guide*.

4.3.10 Saving the parameters in the controller flash memory

The controller provides an option to save all its parameters into the non-volatile memory. The configuration is restored when the controller is powered on, after that the controller itself is instantly ready for operation. The stage requires no new adjustment every time the power is on. The controller stores its user-defined name which is useful for its further identification.

The non-volatile memory stores all the actual operating parameters of the controller related to *Device* section of mDrive Direct Control settings menu. Either **Save settings to flash** button of mDrive Direct Control program or *command_save_settings* function are used for it (see the *Programming guide* chapter).

All the configuration parameters can get restored to controller's RAM from the non-volatile memory, not only when the power is turned on but also by clicking the **Load setting from flash** button of mDrive Direct Control program which provides the access to the data saved in the flash memory. Internally it uses *command_read_settings* function (see the *Programming guide* chapter). The restored settings become active instantly and all the modules of the controller get re-initialized.

4.3.11 User defined position units

Controller position is set and read in stepper motor steps or encoder counts, if encoder is available and enabled. Is it convenient to set position in mm (in case of translation stages), in degrees (in case of rotator stages) or in any other natural units. Controller software can translate coordinates to user-defined units: user can set a ratio, where a certain amount of controller steps is equal to the certain amount of user-defined units. This enables one to issue movement commands and read controller position in these user units. It applies both to mDrive Direct Control interface and to usage in custom programs or scripts. Speed and acceleration are also set in units derived from user-defined ones (for example mm/s). *Zero position adjustment* can be done the same way in user-defined units as in encoder counts or step motor steps.

You can enable user-defined units in *mDrive Direct Control* on page *User units settings*. You can define the name of the natural units in mDrive Direct Control.

Libximc library functions operating in user defined units have a _calb suffix. They take calibration structure calibration_t as an additional input. For more information see *Programming guide*.

4.3.12 Usage of a coordinate correction table for more accurate positioning

If a shift without a linear encoder is used, the exact position will not always be in correspondence with the indications of the axis coordinates. This is due to the accuracy of the manufacture of mechanical parts, backlashes, temperature expansion. In this case, you can use the correction table for more accurate positioning.

Important: The table is individual for each motion. The table is formed by the manufacturer on a high-precision stand.

Principle of operation:

After certain distances, not necessarily equal, starting with 0, the real position of the motion is measured. The difference between the specified and the actual position is recorded into the table. Based on the obtained values, with the usage of linear interpolation, the coordinates are recalculated with the help of certain _calb functions. As a result when moving, manufacturing inaccuracies and other possible position deviations are compensated.

Example: Suppose the following correction table is set for the stage.

X	0	5	10	15	20	25
dX	0	0.05	0.02	-0.003	0.01	-0.04

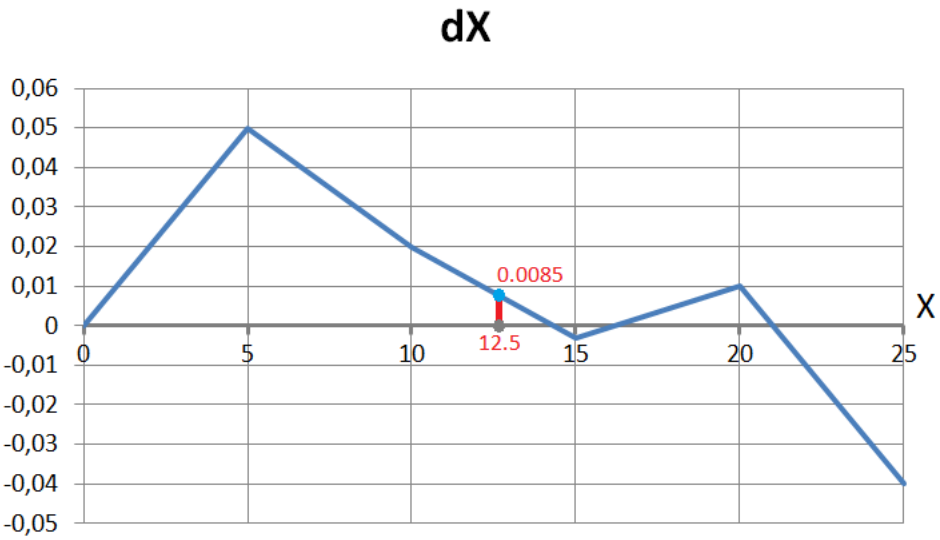


Fig. 4.24: The graph shows the coordinate deviations corresponding to the table

In order to move to position 12.5, the coordinate must be set to 0.0085 greater and that is 12.5085. This is exactly what the algorithms of some _calb commands that use the correction table do.

You can load and clear the coordinate correction table table in *mDrive Direct Control* on page *User units settings*.

To see a list of functions, structures, and parameters that are corrected with the correction table, follow library guide libximc.

4.4 Safe operation

Several controller settings are directly connected with safe operation. If these settings are set wrong it may lead to controller or stage damage. Positioning element can be damaged by exceeded power, rotation speed, or by moving outside the allowed movement range. Usually it is enough to load a preset profile for your stage for safe operation, where all necessary settings are already made.

4.4.1 Movement range bounds and limit switches

Linear stages have limited movement range, unlike circular rotators. Moving outside of the allowed physical movement range is the main reason for stage jamming and damage. To prevent such kinds of breakages the movement range of stages is limited according to user requirements. For this reason *Limit switches* are used, but in some cases when, for example, when stage is not equipped with limit switches or has only one limit switch, movement range can be defined in software (see *Limit switches*). Frequently *limit switches* are reversed. In this case use the mechanism of reversed limit switches detection which is described in *Limit switches* section because otherwise the first motion to the border will lead to stage jamming. *Motion range and limit switches* is described in corresponding section. Settings commands are described in *Programming guide*.

4.4.2 Movement range limiters

Nominal winding current is the main safety setting in stepper motors. This is the main parameter which defines power delivered to the motor. The nominal current should not exceed maximum allowable current for given motor. For more detailed information see *Motor limiters*. For BLDC engines nominal current is a limiting parameter and should be set according to the maximum permissible current through BLDC engine. If maximum current is not known, then maximal voltage delivered to the engine may be limited. This also will prevent engine overheat although voltage limiting is a more coarse mode than current limiting. For more detailed information see chapter *Motor limiters*.

Exceeding the speed limit might damage the stage or lead to faster wearout. It is necessary to set speed limit flag and to set correct maximum speed for the given stage. For more detailed information see chapter *Motor limiters*.

4.4.3 Critical Parameters

Controller tracks voltages and currents which appear in its circuits and can react on their suspicious values. This reaction blocks the engine and prevents any further movement until the source of the problem is eliminated. Due to this it is possible to track winding-winding or winding-ground shortcuts which may happen because of stage cable damage or damage of the stage itself. This reaction also has informational character because it allows to track incorrect values of source voltage or oncoming overheating. That's why you should read *Critical parameters* chapter and set necessary protection. In case of dangerous situation controller will enter Alarm state and the *main window of mDrive Direct Control program* will be colored in red. If this happens, track and eliminate the source of danger before you turn off the Alarm. If you are using your own application for engine control you should pay close attention to Alarm status flag (see *Controller status*).

4.4.4 Operation with Encoder

If during encoder connection sensor channels are swapped, then during engine motion encoder will show direction in reverse. To fix these errors just set *Encoder Reverse* flag in Feedback section on *Settings of kinematics (stepper motor)* page for stepper motors and on *Settings of kinematics (BLDC motor)* page for BLDC motors.

It is also possible that there is no contact with one of encoder channels. In this case during motor motion values of sensor will be oscillating in [-1..1] range around the starting position.

During BLDC engine operation both of these errors will lead to malfunction in control algorithm, which is described in *PID-algorithm for BLDC engine control*. If you have connected new BLDC engine for the first time it is strongly recommended to check encoder connection before starting the operation. To do this you should set corresponding regulation factor values $K_p = 1, K_i = 0, K_d = 0$ and try to make motion to the right or to the left at a low speed. After the motion please check if encoder values are changing in correspondence with chosen directions. Set *Encoder Reverse* flag if it is needed.

4.5 Additional features

4.5.1 Indication

4.5.1.1 Controller status

Indication is provided in mDrive controller. For this purpose, there is one two-color LED on the front panel.

Green Power indicator shows presence of 3.3 V power supply of controller.

Red Status indicator represents controller operating mode. Simultaneous glowing of both lights looks like **yellow glow**.

Table 4.2: Power/Status indicator operation modes

Flicker frequency Hz	Description
LEDs don't glow	the controller is shut down, there is no power supply
Green Power LED is glow	power is supplied to the controller
Green Status LED is glow	the firmware is not loaded
Yellow Status LED is glow	the controller is in an *Alarm state*
Yellow Status LED is flashes, 0,25 Hz	the controller is operating, but there is no connection to the PC via USB
Yellow Status LED is flashes, 1 Hz	the controller is operating, waiting for the movement command
Yellow Status LED is flashes, 4 Hz	the controller is operating, the movement command is executed
Yellow Status LED is flashes, 8 Hz	the controller is in re-flashing mode
Yellow Status LED is flashes, 10 Hz	the controller is in USB bus reconnecting mode

4.5.2 Operations with magnetic brake

There is an output pin on *DVI-I* connector for magnetic brake control, which is installed on the stepper motor shaft. Magnetic brake is used hold motor position in unpowered state.

4.5.2.1 Description of operation

Magnetic brake consists of a magnet and a spring, which performs stops the motor shaft. In case there is no voltage applied to the magnet the spring clamps the shaft in place which allows to keep motor position. When voltage is applied the spring releases the shaft.

4.5.2.1.1 Controller operating sequence during stage shutdown.

Engine shutdown (the time of shutdown is recorded in controller) -> magnet power supply cut off, shaft fixation -> board power supply cut off

During power-on the sequence is reversed.

Since any movement has inertia, the following parameters are set to control magnetic brake and the position fixation process:

- Time between motor power-on and brake deactivation (ms)
- Time between brake deactivation and readiness for movement (ms)
- Time between engine stop and brake activation (ms)
- Time between brake activation and power-off (ms)

If magnetic brake function is turned off then controller will constantly transmit brake release signal. This allows to move engine equipped with magnetic brake without rotor fixation during pauses. If winding poweroff function is turned off then controller will only pause between brake switching and movement start/stop.

All magnetic brake settings can be changed online and brake will be switched to the mode which would be active in case if the setting would have a new value. For example a large increase of brake activation delay when the brake is already active will lead to brake deactivation and countdown to the new delay value. It is also possible to turn on or off magnetic brake itself or winding power function.

Table 4.3: Output electric parameters

Type	TTL
Active condition (brake is released)	5-24 V (depending on EXT REF SUPPLY)
Passive condition (brake is not powered)	0 V
Operational current	no more than 4 mA

Magnetic brake setting in mDrive Direct Control program is described in *Brake settings* section.

4.5.2.2 Magnetic brake connection diagram

To operation with the magnetic brake, a contact pin located on the *DVI-I connector* is used. A connection diagram is shown below.

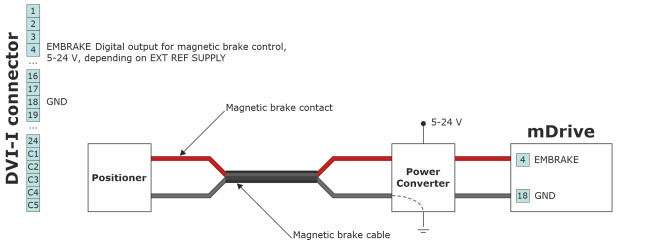


Fig. 4.25: Connection of magnetic brake to mDrive

Power converter is a converter from digital signals to power. If magnetic brake output is high, the magnetic brake of stage has 24 V on its power input. If it is low, the magnetic brake has 0 V on its power input. In the most common case a scheme with transistor and diode is used.

4.5.3 Joystick control

4.5.3.1 General information

Controller accepts an input from an analog joystick with voltage in 0-3.3 V range. Voltage in the equilibrium (central) position and voltage in minimum and maximum position can be set to any value from the working range, if the following condition holds: minimum position < central position < maximum position. Controller uses digital representation of joystick input values: 0 V corresponds to a value of 0 and 3.3 V corresponds to a value of 10000.

To stop movement in the central position a DeadZone option is available, which is counted from the central position and measured in percent. Any joystick position inside deadzone leads to the stopping of the movement by the controller. A larger than deadzone deviation of the stick starts controller movement with the speed which is calculated from the deviation. One can reverse the joystick with a reverse flag which can be useful to keep “right joystick offset means movement to the right” correspondence for any physical orientation of the joystick and the stage.

Movement speed has an exponential dependence on joystick deviation from the center. This enables one to reach high precision through small joystick shifts and high speed through large ones. Nonlinearity parameter (Exp factor) can be varied. If the nonlinearity parameter is zero, then the motor speed will linearly depend on joystick position.

The following graph shows dependence of movement speed on joystick position for the following settings:

Central deviation	4500
Minimum deviation	500
Maximum deviation	9500
Dead zone	10%
Maximum movement speed	100

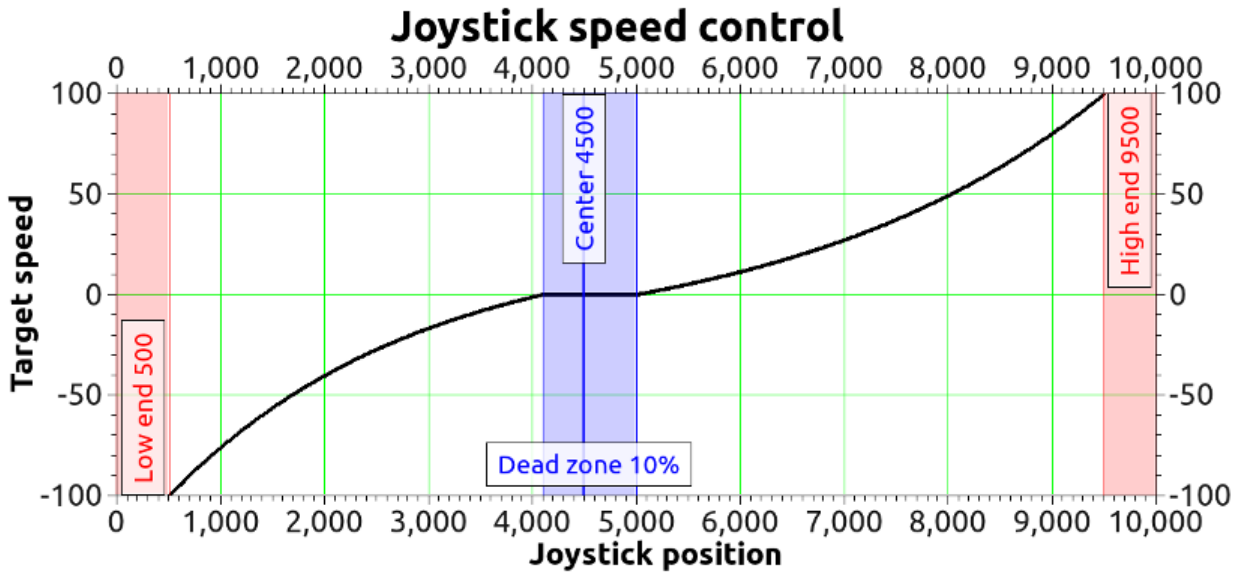


Fig. 4.26: An example of motion speed dependence on joystick deviation

If joystick sits within dead zone for more than 5 seconds it will be logically considered to be out of deadzone only when it has been physically out of deadzone for more than 100 ms. This allows user to release joystick and to be confident that even occasional noise on joystick output won't lead to unnecessary motor motion. While joystick is within *Dead zone* the controller can receive any commands from computer including motion commands, home position calibration commands, etc. If during command execution joystick is brought of *Dead zone* the motion command is canceled and motor is switched to joystick control. This allows the user to turn on joystick control mode and use it only when necessary.

Everything that is related to movement under the control of controller commands is also applicable to joystick movement. This includes acceleration, maximum speed limit, windings poweroff delay, magnetic brake, backlash compensation, etc. For example, if you suddenly release joystick handle and let it return into the deadzone, then, if corresponding modes are on, controller will gradually slow the motor, make a backlash compensation motion, stop the motor, fix the motor shaft with the magnetic brake, smoothly reduce current and switch off windings power.

MaxSpeed[i] and DeadZone parameter change is described in *Settings of external control devices*.

Important: In Joystick control mode, the virtual buttons remain in working order

Warning: Do not disconnect or connect the joystick to the switched on controller! When disconnecting/connecting the joystick to the enabled controller, the joystick or controller will not burn, but the stages connected to the controller will start moving to the limit switches.

4.5.3.2 Connection diagram

A contact for joystick control is located on the *DVI-I connector*.

Important: Analog inputs for joystick connection are designed for a range of 0-3.3 V. Be careful and do not exceed voltage for joystick contacts.

4.5.3.2.1 Connecting a joystick whose voltage does not exceed 3.3 V

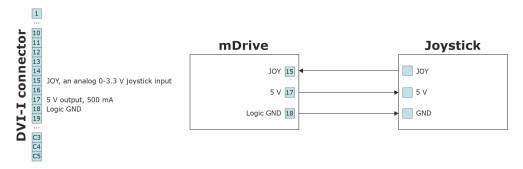


Fig. 4.27: Connection of joystick (up to 3.3 V) to the mDrive via DVI-I connector

4.5.3.2.2 Connecting a 5 V joystick

If you want to connect a 5 V joystick, use a resistor voltage divider. Resistance can be calculated in an an online calculator, for example. Resistors set the sensitivity zone. A connection diagram is shown below.

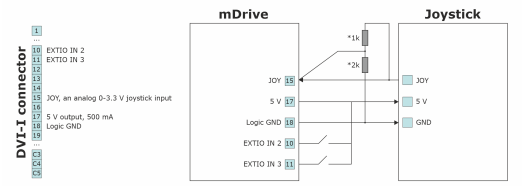


Fig. 4.28: Connection of joystick (up to 5 V) to the mDrive via DVI-I connector ("*" Resistance calculated individually depending on the joystick used)

4.5.4 Left-Right buttons control

For each system it is possible to control the movement of a motor with the buttons. Active button state is programmable and can be logical zero or one. Controller supports a 10-item speed array MaxSpeed[0-9], which is used both for *joystick* and button control.

The buttons control settings are red/written by commands SCTL/GCTL (*set_control_settings*/*get_control_settings*).

- If a left or right button is clicked then motor does a shift on an offset, specified by DeltaPosition and uDeltaPosition.
- If a left or right button is pressed and held for longer than MaxClickTime, then motor starts moving with MaxSpeed[0] and counting down to Timeout[0]. After Timeout[i] microseconds have elapsed speed is changed from MaxSpeed[i] to MaxSpeed[i+1] for any i between 0 and 9 (inclusive).
- If press the two buttons, the controller performs a *stop with deceleration*. Holding both buttons for 3 seconds starts the *automatic calibration of the "home" position*.

Note: You can fill only the upper part of the 10-item speed array if you don't need all of them. Controller changes its speed to the next one only if the target speed is not zero and the timeout is not zero. For example, if MaxSpeed [0] and MaxSpeed[1] are nonzero and MaxSpeed[2] is zero (both step and microstep part), then the controller will start moving with MaxSpeed[0], then change its speed to MaxSpeed[1] after Timeout[0] and will keep moving with MaxSpeed[1] until the button is released. You can also set Timeout[1] to zero and leave MaxSpeed[2] set to any value to achieve the same result. Controller obeys its movement settings (with the exception of target speed). For example, when changing its speed from MaxSpeed[i] to MaxSpeed[i+i] controller will either accelerate with set acceleration value or change its speed instantly if acceleration is disabled.

The default state is set according to the voltage levels of the buttons (*Output parameters*). The state of each button can be software inverted. When active, the button is considered to be down. It does not matter how the condition is active

(after changing the invert states, or when changing the voltage level at the physical impact of a button). The controller uses button contact debouncing. The button is considered pressed if active state lasts for longer than 3 ms.

Table 4.4: Output parameters

Type	TTL
Logic zero level	0 V
Logic one level	3.3 V

Warning: When you turn on or reboot the controller at the input voltage level of the button is present, which is considered to be active, the controller will accept it as a button is pressed, and begin to obey the *rules described above*.

4.5.4.1 Connection diagram

4.5.4.1.1 One-axis and multi-axis systems

"Right" and "Left" control buttons can be connected to the controller board via *DVI-I connector* for a motor motion control.

Connection diagram is shown below.

Fig. 4.29: Scheme of buttons connection to the DVI-I connector

4.5.5 TTL synchronization

4.5.5.1 Principle of operation

TTL-synchronization is used to synchronize controller motion with external devices and/or events. For example, the controller can output synchronization pulse each time it moves a certain distance. Vice versa, controller can shift a certain distance on incoming synchronization pulse, for example from an experimental setup which is ready to move to the next measurement position.

To use mechanical contacts as an input synchronization signal a contact debouncing is provided. One can set minimum input pulse length which is recognized as a valid synchronization signal. An active state is a logical one (see *Input parameters*), and a raising edge is considered to be the start of a signal. However, if for some reason this is undesirable, both options may be inverted independently.

Table 4.5: Input parameters

Type	TTL
Logic zero level	0 V
Logic one level	3.3 V

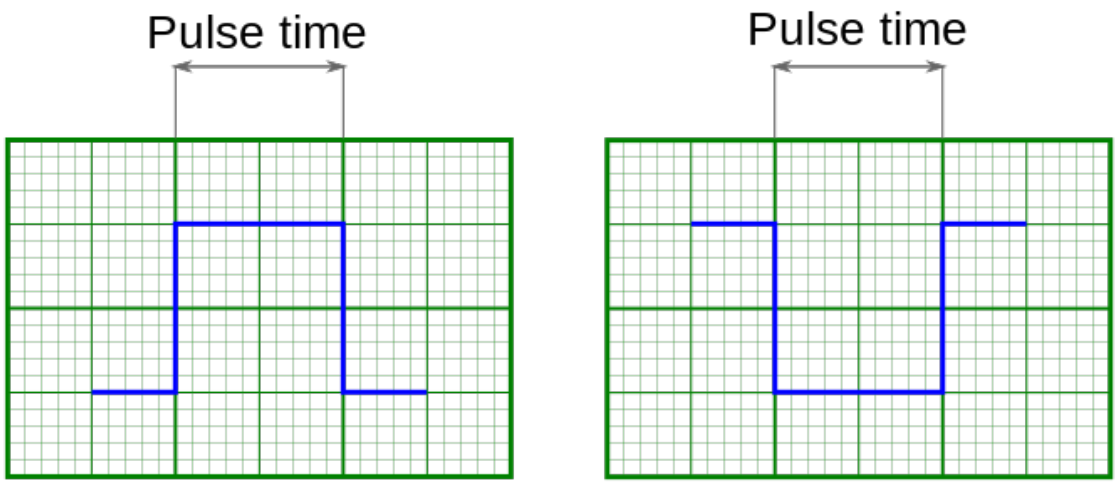


Fig. 4.30: Inversion of input and output syncronization pulse illustrated

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Note: If simultaneous start of several controllers in a multiaxis system is desirable, minimum input pulse length should be the same for all controllers. Contact debouncing should not be used in systems with no mechanical contacts and short noise pulses in synchronization input channel. One should use an RC-circuit which would filter these noise pulses instead.

Synchronization in important in multiaxis systems because it allows one to start movement on several axes simultaneously. To do this all axes are prepared to start the movement, all slave axes are set to start moving on input synchronization pulse, one master axis is set to output a synchronization pulse on the start of the movement. Master axis output is connected to slave axes' input. In this setup any movement of the master axis leads to immediate response of all connected axes.

Note: One should set minimum input sync pulse length to 0 if this kind of connection is used. This disables contact debouncing, but since there are no mechanical contacts it is not needed. If minimum input sync pulse length is not zero then to avoid desynchronization of master and slave axes one should set input sync pulse length the same for all controllers, connect syncout to both master and slave inputs and issue start command by activating input manually.

Synchronization input and output are independent from each other and other means of motion control. Control through *mDrive Direct Control application* or any other user application, *joystick control* and *left-right buttons control* are independent of input/output synchronization state. Last command always takes priority. For example, a movement command sent from mDrive Direct Control will cancel current movement which happened because of input sync pulse, but will not affect output sync state. Next input sync pulse will cancel current movement initiated by user program and will replace it with movement command according to sync in settings.

Note: Sync in settings may be saved in controller flash (non-volatile) memory. In this case everything related to synchronization may also be said about autonomous controller operation. For example, you may set up shift on offset on syncin pulse with syncout pulse on movement stop and connect the controller to a standalone measurement device, which starts measurements on its own input sync pulse and outputs a sync pulse on measurement end. Then you can run such a system without a PC, because after the first sync pulse all measurements and movements will happen automatically.

4.5.5.2 Connection

The controller is supplied with two TTL-sync channels on the *DVI-I connector*.

4.5.5.3 Sync in

Syncronization input has a setting, which defines minimum syncin pulse length which may be registered. This length is measured in microseconds. Use this setting to decrease controller sensitivity to noise. Synchronization input may be turned on or off. If it is on, then a sync in pulse will lead to a situation as if *Predefined displacement mode* command has taken place, which takes its *Position* and *Speed* from syncin settings. If syncin settings are changed during the time the movement takes place it will not change current movement parameters. Movement parameters will change on the next front on syncronization input. This designed deliberately to allow one to set up next shift parameters in multiaxis systems during movement.

Warning: When you turn on or reboot the controller at the input voltage level of the synchronize input is present, which is considered to be active, the controller interprets it as if *Predefined displacement mode* command has taken place.

Note: *Position* and *Speed* are two separate variables which also may be saved in non-volatilve controller memory. They are used only with synchronization input.

Note: Syncin movement obeys acceleration, max speed settings and all other settings which are related to motion. Their incorrect setting may disrupt coordinated movement in multiaxis system.

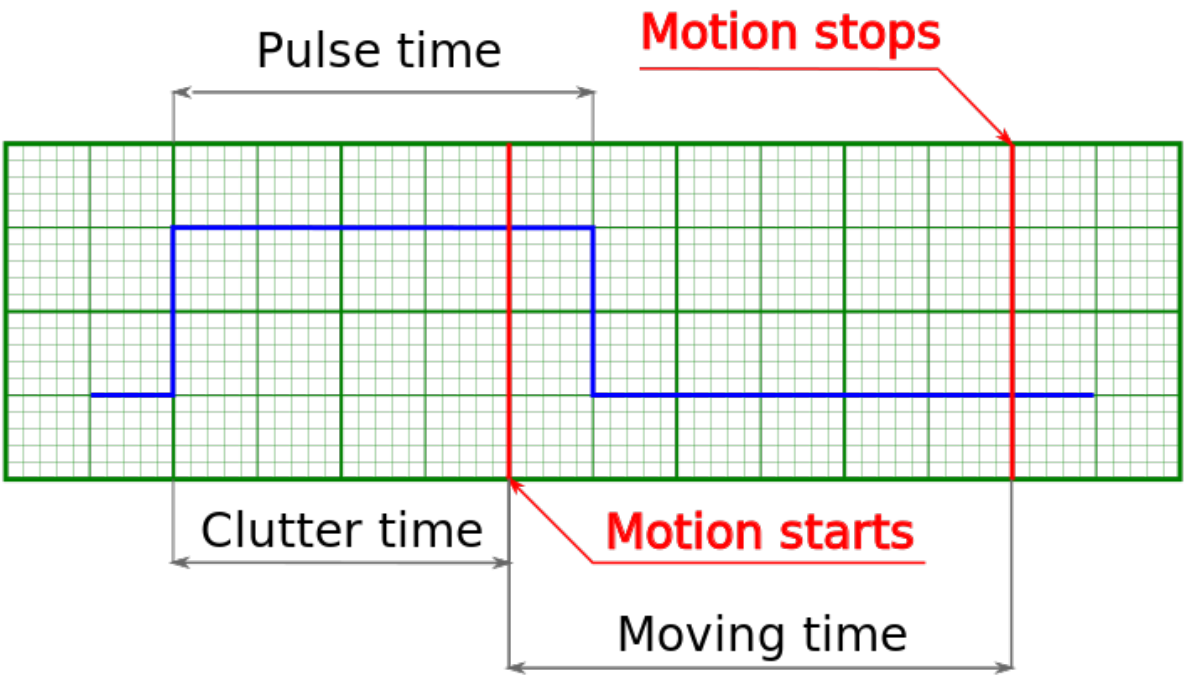


Fig. 4.31: Movement starts becase input pulse is longer than debounce time

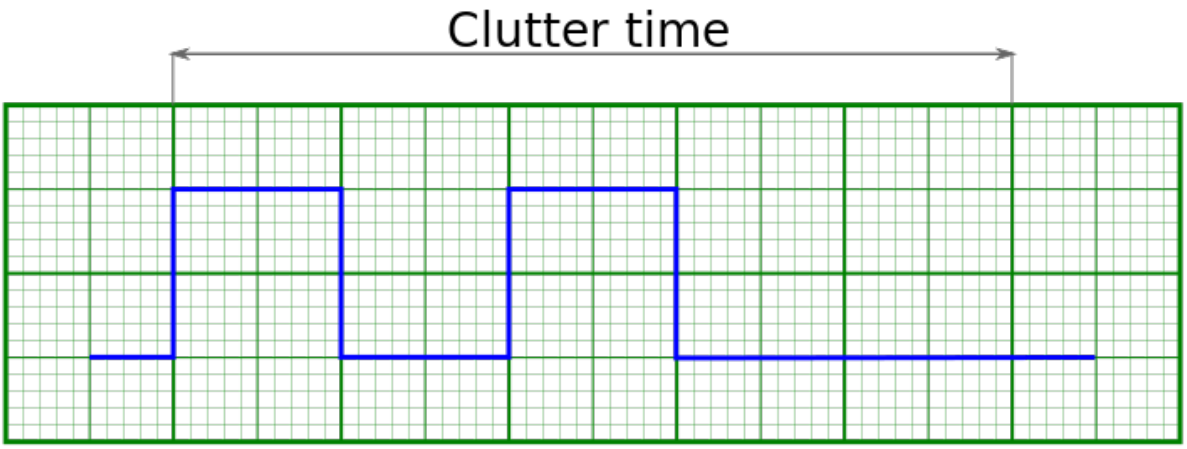


Fig. 4.32: Movement does not start because input pulses are shorter than debounce time

Warning: If a second syncin pulse is received while controller is still moving then the end position will be offset by two times the shift distance from the start, if a third pulse is received, then by three times, etc.

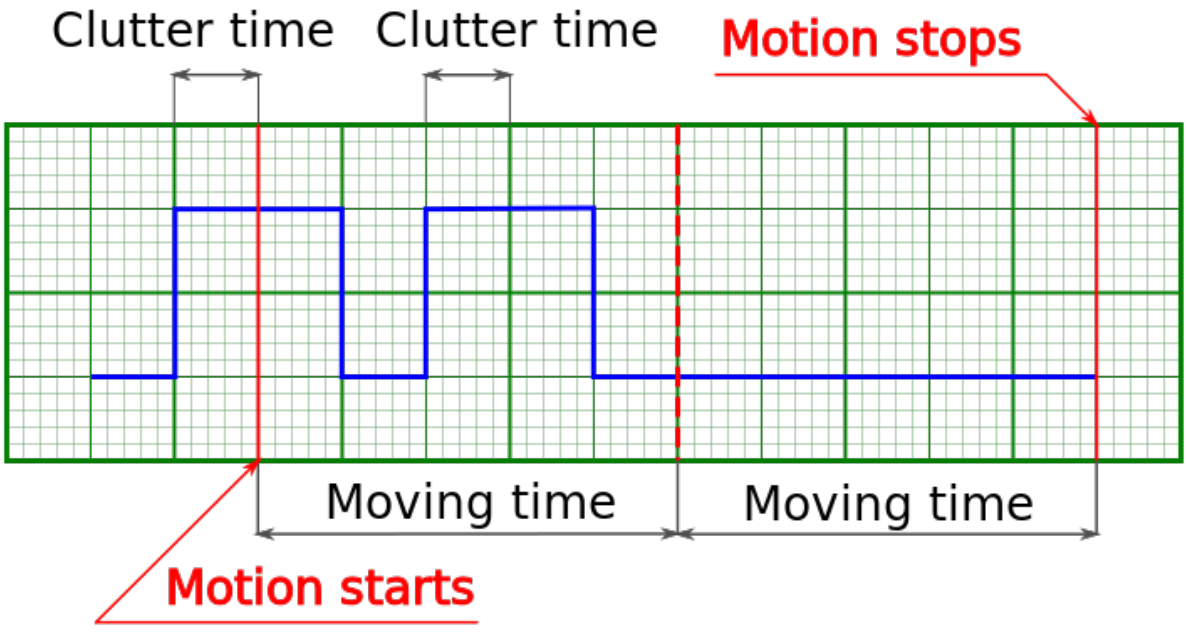


Fig. 4.33: One-time movement with double shift length because second syncin pulse came in before the end of the movement

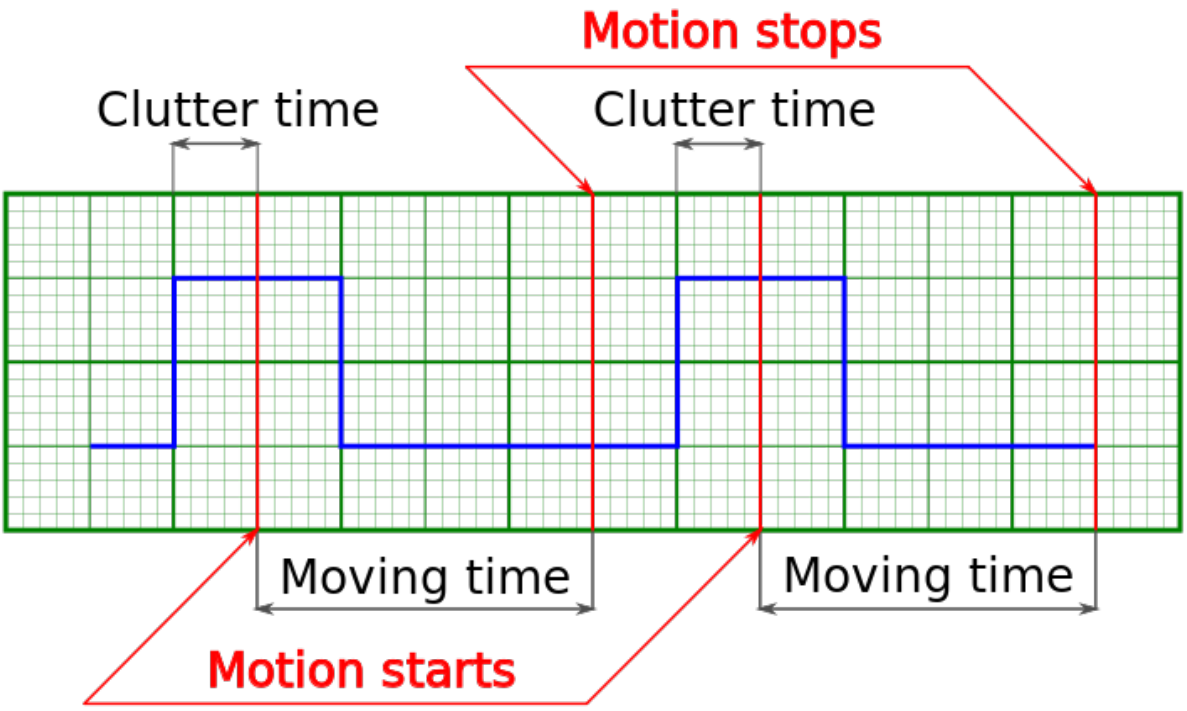


Fig. 4.34: Two separate shifts with two start and two stop phases

Default setting is active state is one, movement on raising edge. Synchronization input may be inverted to the active state is zero, movement on trailing edge.

Note: Inverted synchronization input setting will lead to the change in the definition of active/inactive state which may be seen, for example, in *controller status*. However, programmatical inversion of the syncin state by itself will not lead to the start of the movement, even if the transition happened into the active state.

4.5.5.4 Sync out

Output synchronization is used to control external devices tied to controller movement events. Sync out pulse can be emitted on start and/or stop of the movement, and/or on each shift on the preset distance. *ImpulseTime* setting defines the length of sync pulse, either in microseconds or in distance units. Synchronization output can be switched into general purpose digital output mode. In this mode it is possible to set zero/one output logic level programmatically.

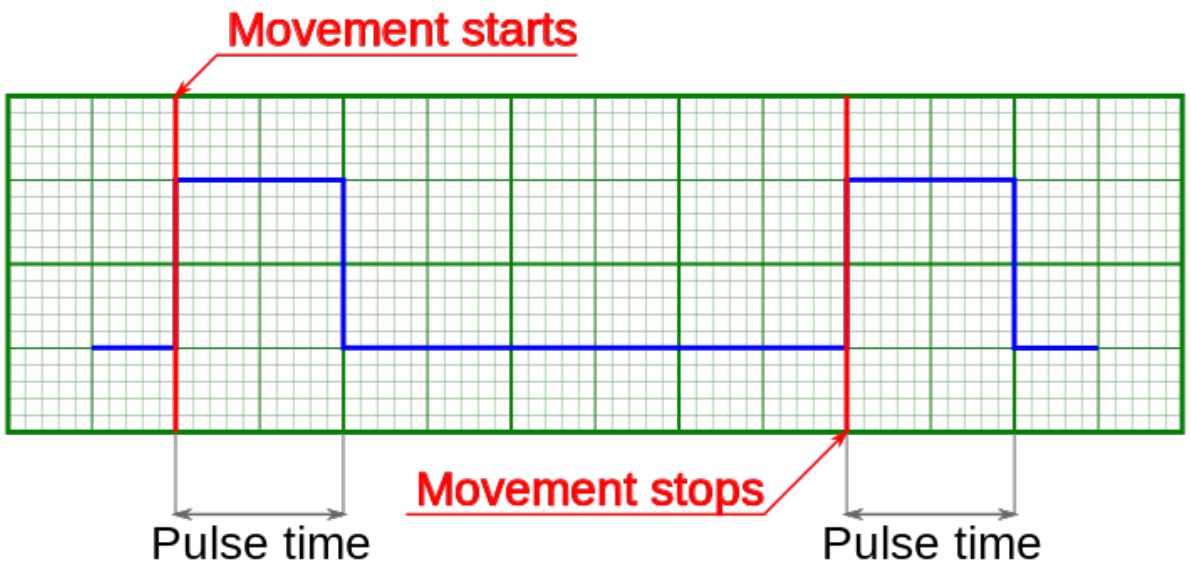


Fig. 4.35: Sync out pulses generated on start and stop of the movement (fixed length pulse)

Note: If syncout pulse length is measured in distance units and, for example, is equal to 10 stepper motor steps and "syncout pulse on stop" mode is active, then the active state on synchronization output will be set on the movement end, but will be cleared only when the motor will move 10 more steps during the next movement.

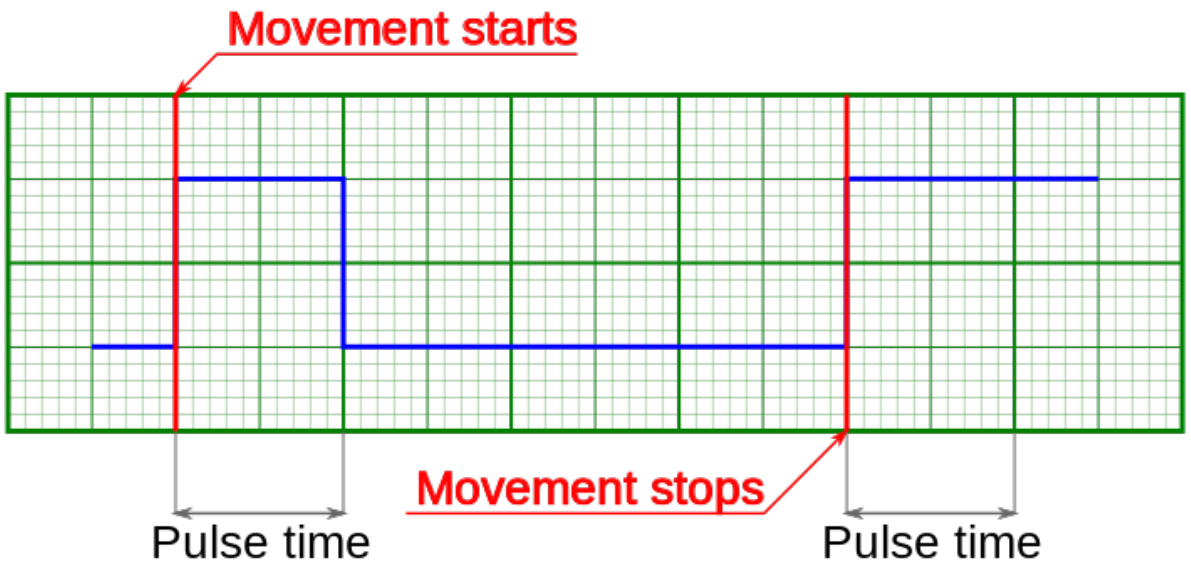


Fig. 4.36: Syncout pulses generated on start and stop of the movement (pulse is measured in distance units)

Note: If you wish to reconfigure synchronization output and are not sure which state is it in, change its state to general purpose output and set the desired logic level.

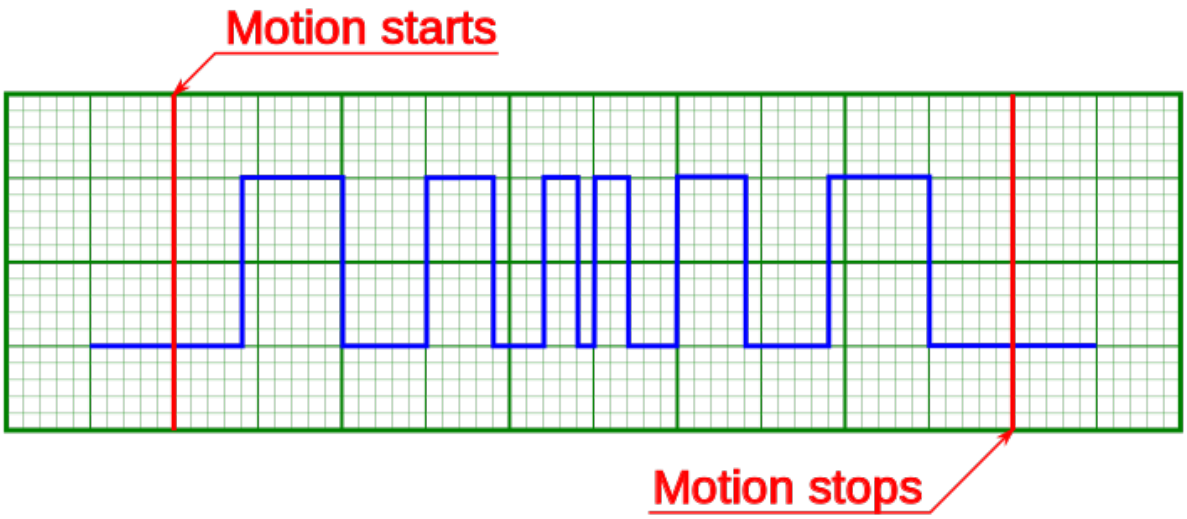


Fig. 4.37: Sync out pulses on movement with acceleration and “generate on shift” mode (pulse length measured in distance units)

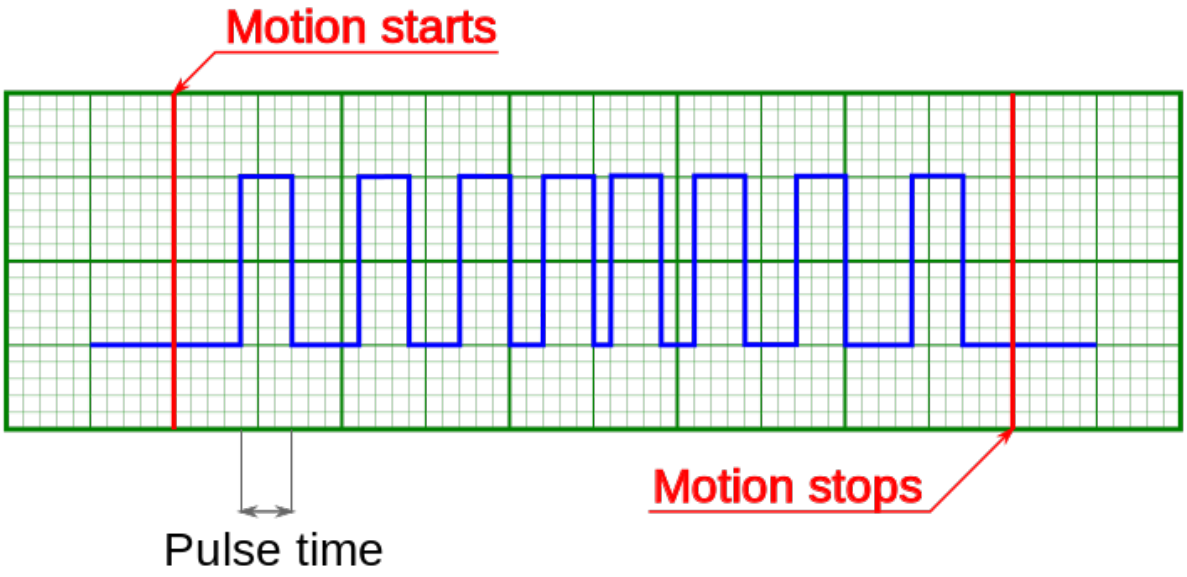


Fig. 4.38: Sync out pulses on movement with acceleration and “generate on shift” mode (pulse length measured in microseconds)

Note: Periodic syncout pulse generation imitates revolution sensor with reducing gear. Coordinates which trigger syncout pulse generation are counted from zero position and not from the position the controller is in at the start of the movement. For example, if synchronization output is set up to generate pulses every 1000 steps then pulses will be generated in positions 0, 1000, 2000, 3000, etc. Pulse generation works when moving in both directions. Pulse is generated when the quotient of current coordinate and pulse generation period changes. That is, pulse is generated when position 1000 is reached when moving in the direction of increasing position and it is generated when position

1000 is left when moving in the direction of decreasing position. Also, syncout pulse is always generated when position 0 is reached from any direction (including the case when position is reset by the ZERO button).

Note: Whenever syncout pulses overlap they are merged into one pulse.

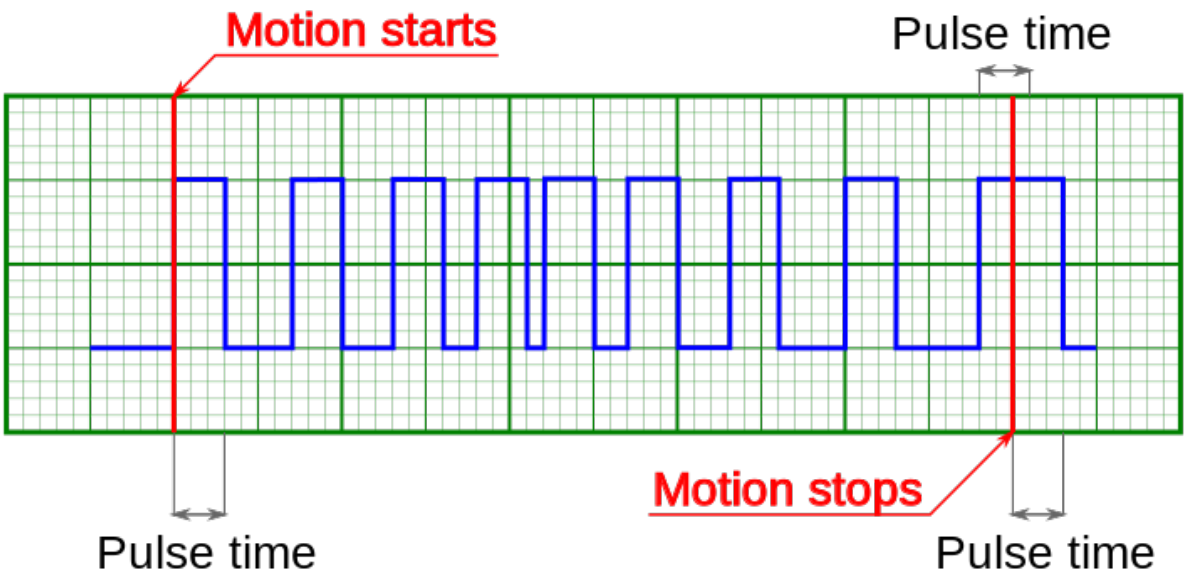


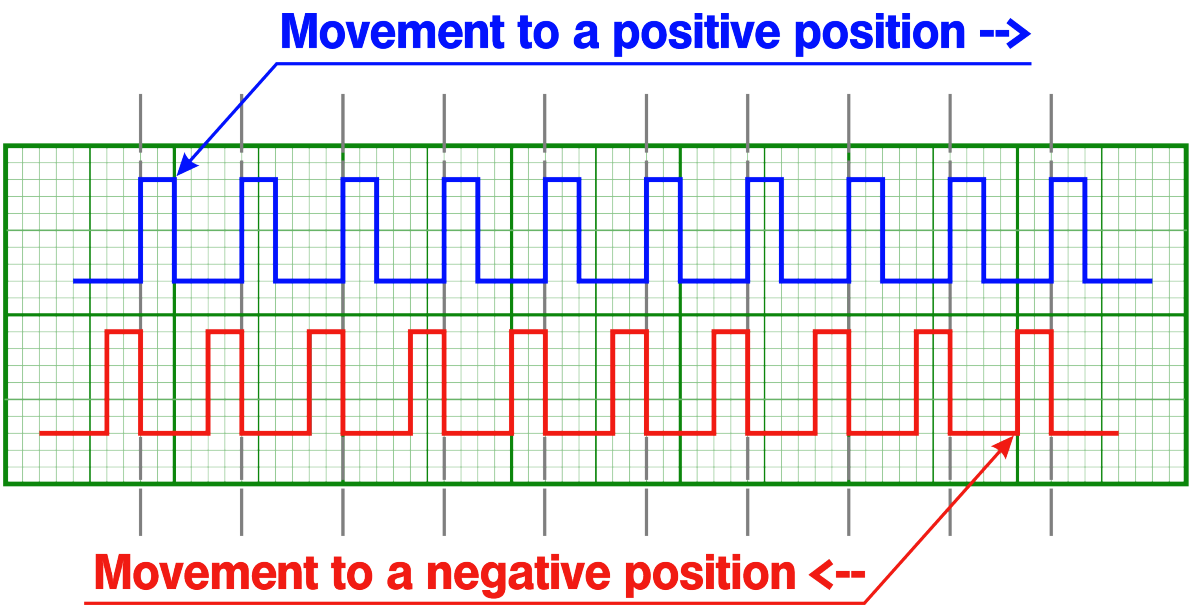
Fig. 4.39: Syncout pulse merge illustrated, pulse generation on start, stop and shift on offset (pulse length measured in microseconds)

The controller will set virtual marks with a specified step that corresponds to the value of the "Every" field starting from zero. The synchronization pulse is always generated after passing the next mark. Therefore, the position of the pulses depends on the direction of movement:

- When moving in a positive direction (position increases, pulses are generated in the direction of movement), that is, they grade the position of the mark
- When moving in a negative direction (position decreases, pulses are generated in the direction of movement), that is, they are smaller than the position of the mark

Example: Pulse width: 100 Every flag: 1000 The controller will set virtual marks: . . . , -2000, 1000, 0, 1000, 2000, . . .

- When moving from -1500 to 1500, the output will be a logical unit when passing the following coordinate ranges: [-1000, -900], [0, 100], [1000, 1100]
- When moving in the opposite direction from 1500 to -1500 logical unit when passing the following coordinate ranges: [1000, 900], [0, -100], [-1000, -1100]



Important: With short movements within the pulse duration around the mark, the output state may not return to zero, so as not to create unnecessary noise switching. The “Every” flag was not designed for single shifts, it was created to generate pulses over long distances

Synchronization settings setup in mDrive Direct Control is described in *Synchronization settings* section.

4.5.5.5 Connection diagram

mDrive contains two TTL-channels of synchronization on the *DVI-I connector*.

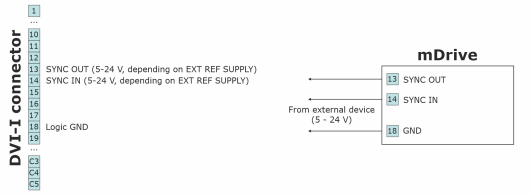


Fig. 4.40: Scheme of connection to the synchronization channels for the controller

4.5.6 Multiaxis system design

Controller axes in multiaxis systems are identified by the controller board serial number. Each controller has its own unique serial number, which may be seen in mDrive Direct Control software on *About controller* page. One can read controller serial number using **get_serial_number** function (see *Programming guide*).

4.5.7 General purpose digital input-output (EXTIO)

Digital input and output are located on *DVI-I connector*. Logical level one is considered to be active (see *Input parameters* table). However it can be inverted so that logical level zero is considered active.

Table 4.6: Input parameters

Type	TTL
Logic zero level	0 V
Logic one level	5-24 V

In input mode you can get information about logical level on input (see *Controller status*), or initiate the following actions during transfer to active state (or during transfer to non-active state if the input is inverted):

- Perform *Command STOP* (quick stop).
- Perform *Command PWOF* command (windings power supply switch off).
- Perform *Command MOVR* command (shift to the given distance with last used settings).
- Perform *Command HOME* command (automatic position calibration).
- Enter *Alarm state* (turn off H-bridges and wait reinitialization).

It does not matter how the state of the input becomes active (after changing the invert states, or when changing the voltage level). The controller uses a software debounce the input. Initiating the action takes place only when the active state of the input buttons lasted for more than 3 ms.

Warning: When you turn on or reboot the controller at the input voltage level of the input is present, which is considered to be active, the controller interprets it as a signal to trigger any of the actions.

Note: Digital input has weak pull down to the ground.

In output mode it is possible to set active or inactive logic level on the following events:

- EXTIO_SETUP_MODE_OUT_MOVING – Active state during motor movement.
- EXTIO_SETUP_MODE_OUT_ALARM – Active state when controller is in Alarm state.
- EXTIO_SETUP_MODE_OUT_MOTOR_ON – Active state while power is supplied to the motor windings.
- EXTIO_SETUP_MODE_OUT_MOTOR_FOUND – Active state while motor is connected.

Table 4.7: Output technical characteristic

Logic type	TTL 5-24 V
Update frequency	1 kHz
Nominal current	5 mA

4.5.7.1 Connection diagram

Digital input and output are located on the *DVI-I connector*

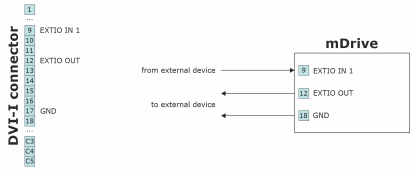


Fig. 4.41: Scheme of connection to digital input/output for the mDrive

4.5.8 General purpose analog input

Analog input may be used for other purpose. For example, it can be used to measure any external signal. Value at the analog input may be read by the *GETC* command and is visible in the *mDrive Direct Control charts*.

This controller represents analog input values as a number in 0..10000 range. Analog input pin is located on *DVI-I connector*.

Important: Analog input voltage should not go outside of 0-3.3 V range. If this voltage is exceeded errors in analog input and other controller subsystems are possible! This may also damage the controller or connected motor.

Table 4.8: Input parameters.

Signal voltage	0-3.3 V
Scanning frequency	1 kHz

4.5.8.1 Connection diagram

4.5.8.1.1 One-axis and multi-axes systems

For the *one-axis* and *multi-axes systems* analog input contact is located on the *DVI-I connector*.

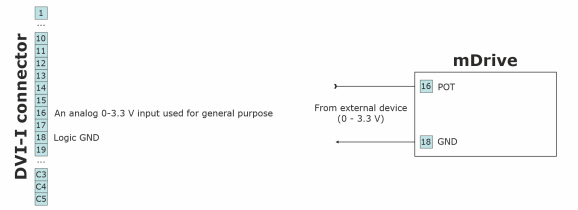


Fig. 4.42: Scheme of connection to analog input for the mDrive systems

4.5.9 Saving the position in FRAM memory

Controller has a function which automatically remembers its last position. This allows one to power-off the controller after it has stopped. On the next power-on the controller will appear in the same motor position, logical position and encoder value. This will work if during the time controller was off the motor shaft was not rotated by external means.

Note: For this function to work one should wait at least 0.5 seconds after the stop before cutting the power. Position is saved even if the controller was powered off during movement, however in this case its saved position will not be exact and a new *calibration* will be needed.

4.6 Secondary features

4.6.1 Zero position adjustment

Controller supports setting of zero position. This function should be used for anchor marked stages, so that anchor position matches logical zero. Also, this function is convenient to use in case there is a single chosen physical position.

To set zero position a *special command* is used. This will zero step/microstep position and encoder count values. Setting of zero position happens simultaneously for all position counters and will not lead to their desynchronization. Current movement command is not affected. If controller was moving to some physical position when logical position

was reset to zero by this command then the movement will still end in that physical position. For example, if the controller moved towards logical position 1000 and set zero position command was sent when it was passing 200, then logical position counter will be decremented by 200 and movement will end in logical position 800.

Note: Setting of zero position when using shift on offset (see *Predefined displacement mode*) will not change target physical position. Next shift will happen towards the same physical position which would have happened without zero position command.

4.6.2 User-defined position adjustment

A SPOS command can be used if it is necessary to set position and/or encoder value to some user-defined position instead of zero. New step/microstep position and encoder count values are passed as parameters to this command. If only one of these counters is needed one should use ignore flags to filter required fields.

This command is different from set zero command in that it doesn't set target position used by MOVE and MOVR commands to zero. During movement and stopping its behavior is the same. If you issue SPOS command during movement the controller will end in the same physical position it would move to if this command was not sent.

4.6.3 Controller status

Controller tracks its own status and can transfer it in the status structure of the *GETS* command. Controller status contains information about performed movement, its result, state of power supply, state of encoder, state of motor windings, digital input-output states, numeric information about position and powering voltage and currents and also error flags.

4.6.3.1 Movement status

MoveSts contains:

- Movement flag which is set when controller changes motor position.
- Target speed reached flag which is set if current speed is equal to the speed controller should be moving with.
- Backlash compensation flag, which is set during backlash compensation in the final stage of the movement (see *Backlash compensation*).

MvCmdSts contains information about the command being executed. All motor movements are initiated by movement commands to the *MOVE* target position, *MOVR* shift relative to the last target position, *RIGT* movement to the right, *LEFT* movement to the left, smooth stop *SSTP* or fast stop *STOP*, *HOME* home position calibration and *LOFT* forced backlash compensation. Control by buttons, joystick, sync in pulses, etc. is also performed by these commands. For example, joystick calls right and left movement commands during deflection or smooth stop command in central position (see *Joystick control*). Current movement command or last command and command status (running/completed) are located in MvCmdSts variable. If the command is completed then another bit shows its result (successful or not). Unsuccessfully completed command means controller could not reach desired position or backlash compensation could not be performed. The reason for this can be a sudden stop due to limit switches or Alarm state. Initial state of this field contains unknown command and successful completion status.

4.6.3.2 Motor power supply status

PWRSts contains information about supply voltage. Windings' status can be:

- Disabled (in this case no voltage is applied).
- Powered by reduced current relative to nominal current (for example if winding current reduction option is used).
- Powered by nominal current.

- Powered by an voltage insufficient to reach nominal current in the windings.

Last status frequently appears with high rotation speeds, because for higher step switching speed one needs higher voltage to ensure current rise in motor winding inductance. Insufficient voltage does not mean the motor won't move, it will merely emit excess noise and its torque will drop (see *Power control*).

4.6.3.3 Encoder status

EncSts contains information about connected encoder if feedback is disabled (for example for stepper motors). Encoder state can be one of the following:

- Not connected.
- Unknown state, when there is not enough data to define encoder state.
- Connected and working.
- Connected and reversed, in this case it is necessary to enable reverse in encoder settings.
- Connected and defective.

The last state is realized when switch signals come to encoder inputs but they don't correspond to the motor rotor movement. State change happens after sufficient statistical data is collected. That's why detection doesn't happen immediately. It is also impossible to define encoder status without movement (see *Operation with encoders*).

4.6.3.4 Motor windings status

WindSts contains information about windings state. State of each of the two windings is shown separately. They can be:

- Disconnected from controller.
- Connected.
- Short-circuited.
- In an unknown state.

A state with very small resistance and inductance is considered to be a short-circuit. A state with very high load resistance is considered to be disconnected.

4.6.3.5 Position status

All data about stage position and speed is reflected in status structure. Fields of primary position (CurPosition, uStep), secondary position (EncPosition), speeds (CurSpeed, uCurSpeed) are used for this. Primary position is counted in steps and microsteps of stepper motor if control without feedback is used. In case of leading encoder mode encoder counts are stored in CurPosition and uStep contains 0. Secondary position contains encoder coordinate if no feedback is used for stepper motor and contains steps if a stepper motor with encoder feedback is used. Speed is always displayed for the primary position and is measured in the same units as the current set speed.

4.6.3.6 Controller power supply status and temperature

Status structure reflects:

- Power current (in mA)
- Power voltage (in tens of mV)
- USB current (in mA)
- USB voltage (in tens of mV)
- Microprocessor temperature (tenths of degrees Celsius)

4.6.3.7 Status flags

There are several types of flags: control command error flags, critical parameter flags, general error flags and state flags.

Note: Many flags do not remove themselves and should be reset by the *STOP* command.

Protocol command errors:

- errc – Unknown protocol command. This error should not appear if the used software corresponds to the used controller protocol version. Flag can't be removed by itself.
- errd – Data integrity command check code is incorrect. This error appears in case of data transfer failure. The flag can't be removed by itself.
- errv – One or more values sent in the command could not be applied. It appears when command was received and successfully recognized but transferred data were incorrect or out of range. This error can also mean that necessary operation is impossible because of hardware failure. For example, this error appears if you set microstep mode which is not in supported list or if you set zero steps per motor revolution. The flag can't be removed by itself. Critical parameter exceeded errors:
- Flag which means that controller is in Alarm state.
- Flag which means that power driver gives overheat signal. The flag is removed by itself depending on *critical parameters settings*.
- Flag which means that microprocessor temperature is out of acceptable range. The flag is removed by itself depending on *critical parameters settings*.
- Flag which means that power supply exceeded acceptable value. The flag is removed by itself depending on *critical parameters settings*.
- Flag which means that power supply voltage is lower than acceptable value. The flag is removed by itself depending on *critical parameters settings*.
- Flag which means that current drawn from the power unit exceeded acceptable value. The flag is removed by itself depending on *critical parameters settings*.
- Flag which means that USB voltage exceeded acceptable value. The flag is removed by itlsef depending on *critical parameters settings*.
- Flag which means that USB voltage is under acceptable value. The flag is removed by itself depending on *critical parameters settings*.
- Flag which means that current drawn from the USB exceeded acceptable value. The flag is removed by itself depending on *critical parameters settings*.
- Flag which means that limit switches are mixed up. The flag can't be removed by itself.

General error flag:

- Flag which means that position control system detected steps counter and position sensor desynchronization. The flag can't be removed by itself (except the case of using position correction).

State flag:

- Presence of external power supply. Otherwise power supply is internal. Is always set.

4.6.3.8 Digital signals status

Controller reflects input and output digital signal status as active state flags or as current logical level. Active state corresponds to one or to zero depending on specific block settings, for example on inverting settings. Flags can be:

- Right limit switch state (one if limit switch is active).
- Left limit switch state (one if limit switch is active).
- Right button state (one if button is pressed).
- Left button state (one if button is pressed).
- 1 if EXTIO pin operates as output. Otherwise - as input.
- EXTIO pin state (1 if state is active on input or on output).
- Hall A sensor state (1 if logical one is on input).
- Hall B sensor state (1 if logical one is on input).
- Hall C sensor state (1 if logical one is on input).
- Magnetic brake state (1 if power supply is applied to brake).
- Complete revolution sensor state (1 if sensor is active).
- Input synchronization pin state (1 if synchronization pin is in active state).
- Output synchronization pin state (1 if synchronization pin is in active state).
- Input encoder A channel state (1 if logical one is on input).
- Input encoder B channel state (1 if logical one is on input).

4.6.4 USB connection autorecovery

This unit is designed to reboot the USB in the event of loss of communication (for example, this may occur in the event of electrostatic discharge or when the USB is disconnected without powering down the controller). The on/off state of this unit is determined by the *USB_BREAK_RECONNECT* flag (see *Critical parameters*). If the unit is turned on, it monitors the connection loss on the USB. In the case of communication loss on the USB after 500 ms the firmware reconnects the device and then checks the state of the USB bus. If for a certain time there is no recovery of connection (i.e. data communication), then this unti reconnects the USB again. Thus, in case USB connection is not restored, the controller will continuously reconnect to the USB bus until connection is restored or until the time between reconnection attempts exceeds 1 minute. So, in the case the USB is disconnected without powering down the controller (for example, in the case of motor control with buttons or joystick) controller will remain in USB reconnection mode for about 5 minutes.

Note: USB reconnection mode does not affect other controller functions (for example movement or winding current maintenance) in any way.

To avoid simultaneous reconnect to the USB bus from both the controller and the computer side, the time between the reconnections changes exponentially (see *Time between USB reconnections*).

Table 4.9: Time between USB reconnections

Restart number	timeout, ms
0 (after communication is lost)	500
1	483
2	622
3	802
4	1034
5	1333
6	1718

The status of the unit can be determined by LED flashing frequency. In the case controller is in reconnection mode the LED will flash with a frequency of 10 Hz (see *Indication*).

Warning: Because of the structure of the program unit, as well as USB bus specification, unit doesn't guarantee 100% recovery of the communication with the computer after a static discharge.

mDrive Direct Control software also tries to reconnect to the controller when it is running. On connection loss, which is defined as "result_nodevice" libximc library call error, mDrive Direct Control waits for 1000 milliseconds, then attempts to reopen device port. On Windows operating systems mDrive Direct Control uses WINAPI functions to check if corresponding COM-port device is present. If it is, then after two unsuccessful attempts to reopen it calls libximc ximc_fix_usbser_sys function, which resets the usbser.sys driver to fix the driver error. On Linux or MacOS mDrive Direct Control simply tries to reopen the device every 1000 ms. After the device is opened mDrive Direct Control sends several commands to read serial number, firmware version and controller settings which are needed to set up user interface.

Libximc library considers device lost (return error code result_nodevice) on critical errors from system calls ReadFile/WriteFile (Windows OS) or read/write (Linux/Mac OS).

CHAPTER

FIVE

MDRIVE DIRECT CONTROL APPLICATION USER'S GUIDE

5.1 About mDrive Direct Control

mDrive Direct Control features a user-friendly graphical interface, which is designed for stages control, diagnostic and fine tuning of the motors driven by the controllers. mDrive Direct Control allows quick adjustment of connected stage by loading of previously prepared configuration files. The control process can be automated with script language that can be used either directly or to speed up the process of customized control program development. mDrive Direct Control supports multiaxial mode and multidimensional control scripts. It is possible to output the data about controller and motor status in form of charts and save them to a file, or export tabular data for external processing. The software is compatible with Windows XP SP3, Windows Vista, Windows 7, Windows 8, Windows 10, Windows 11, Linux, MacOS for intel and Apple Silicon (via Rosetta 2). Depending on the OS of your computer, appearance of some windows may vary.

Here you can find the Quick Installation Guide for the application. This chapter provides a detailed manual for the mDrive Direct Control software.

5.2 Main windows of the mDrive Direct Control application

5.2.1 mDrive Direct Control Start window

When started, mDrive Direct Control opens a controllers detection window. By means of libximc library, mDrive Direct Control queries controllers connected to the system and displays a list of found and successfully identified controllers.

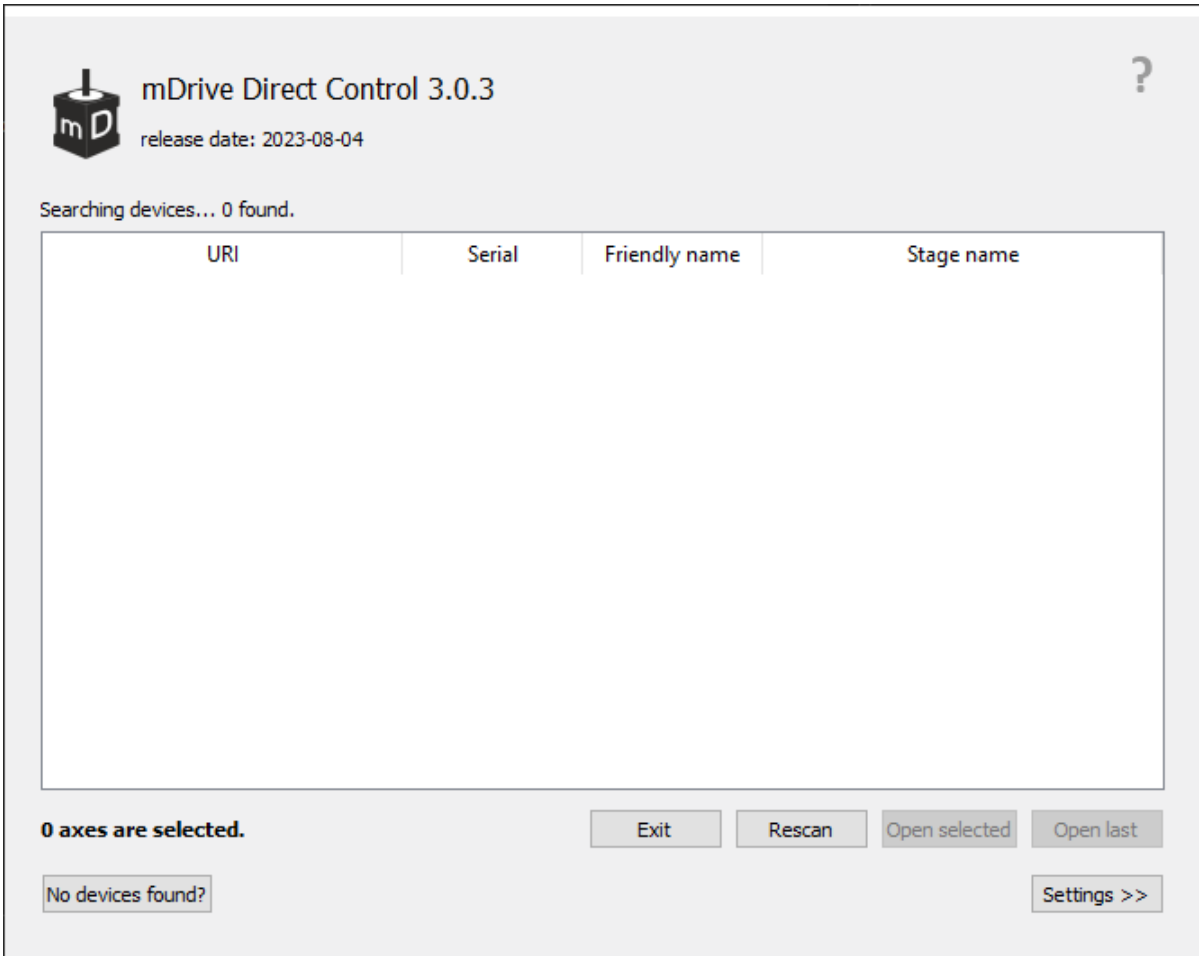


Fig. 5.1: mDrive Direct Control Start Window, 0 controllers found

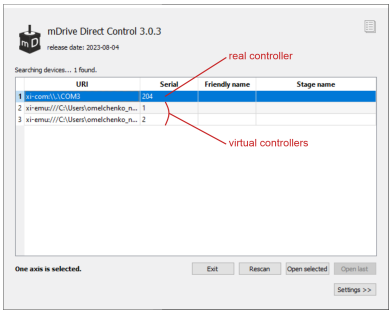


Fig. 5.2: mDrive Direct Control Start Window, 1 real controller and 2 virtual controllers are displayed

The list of found controllers is displayed on the start screen. Here you can select one or more controllers and open them using the *Open selected* button. If one controller is chosen, then *mDrive Direct Control Main window in single-axis control mode* will be opened, if more than one controller is chosen the *mDrive Direct Control Main window in multi-axis control mode* window will be opened. You could repeat the search by clicking the *Rescan* button or exit the program by clicking *Exit*. If the *Open last* button is active it means that all the controllers that had been opened in the previous run of mDrive Direct Control were found. Clicking the *Open last* button will then open the last saved configuration.

mDrive Direct Control can work with virtual controllers, which support the request-response protocol of a real controller. Virtual controllers may be useful for testing and getting used to the mDrive Direct Control interface, if no real hardware controllers are connected to the system.

The *Settings* button opens the new tab that contains the devices detection options.

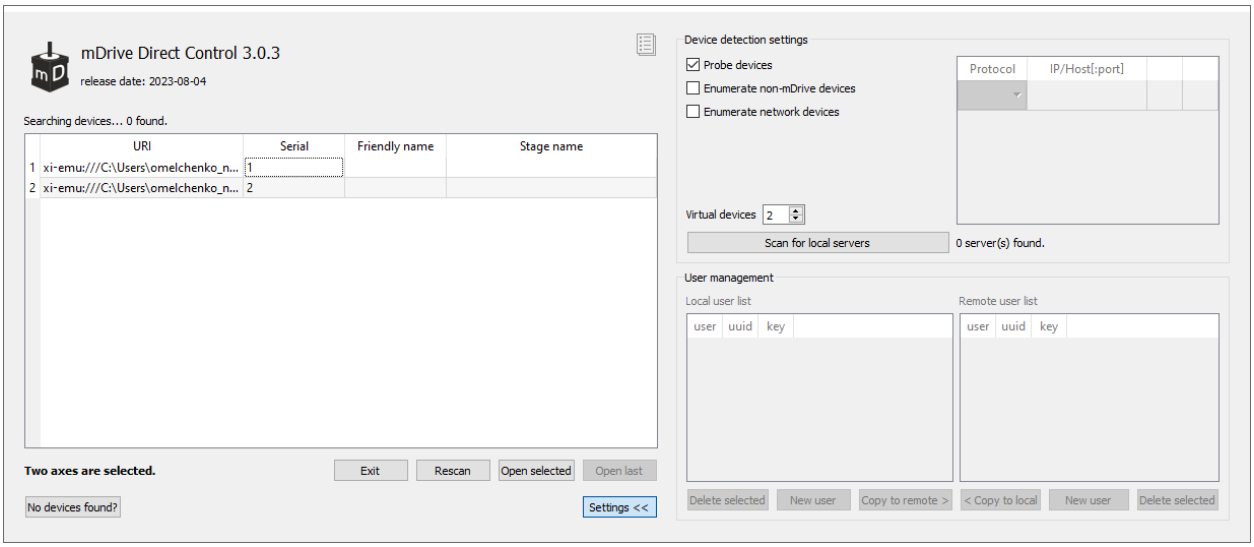


Fig. 5.3: mDrive Direct Control Start Window, the settings tab

Device detection settings group includes device detection settings.

If *Probe devices* option is checked, at the start application tries to identify controllers by sending them commands GETI and GSER.

If *Enumerate non-mDrive devices* option is checked the application queries all COM-port type devices in the system. If the option is disabled, only devices with names matching the mDrive mask ("mDrive Motor Controller" in Windows; /dev/mdrive* and /dev/ttyACM* in Linux/Mac) are queried.

If *Enumerate network devices* option is checked the application queries network-attached devices. A list of domain names and/or IP addesses with mDrive server software is located below. One can add entries to the list manually or use automatic detection by pressing *Scan for local mDrive servers*. Please note that in case of more than one local server automatic scan will pick a random one and it will require several attempts to find them all.

Warning: If both *Probe devices* and *Enumerate non-mDrive devices* options are enabled, on startup mDrive Direct Control will send data to all COM-ports. If the PC has multiple Bluetooth COM-ports, due to the nature of Bluetooth operation, the queries will be conducted sequentially, and connection attempts may take from a few to tens of seconds each.

The *Virtual devices* field contains the number of virtual controllers which will appear in the list of available controllers after you press the *Rescan* button or restart the mDrive Direct Control.

Note: *Note:* Since the libximc library opens mDrive devices in the exclusive access mode, when you start subsequent copies of mDrive Direct Control application, only free controllers will be found and available for selection.

User management panel provides Access Control List management for local and remote servers. This feature enables the end user to selectively grant permisions to connect and control remote mDrive devices. In order to grant permission

you need to create the same user with the same password locally and remotely. Deleting the user (either locally or remotely) revokes permission. By default all mDrive, SDK libraries and mDrive Direct Control have root user preinstalled with default password.

5.2.2 mDrive Direct Control Main window in single-axis control mode

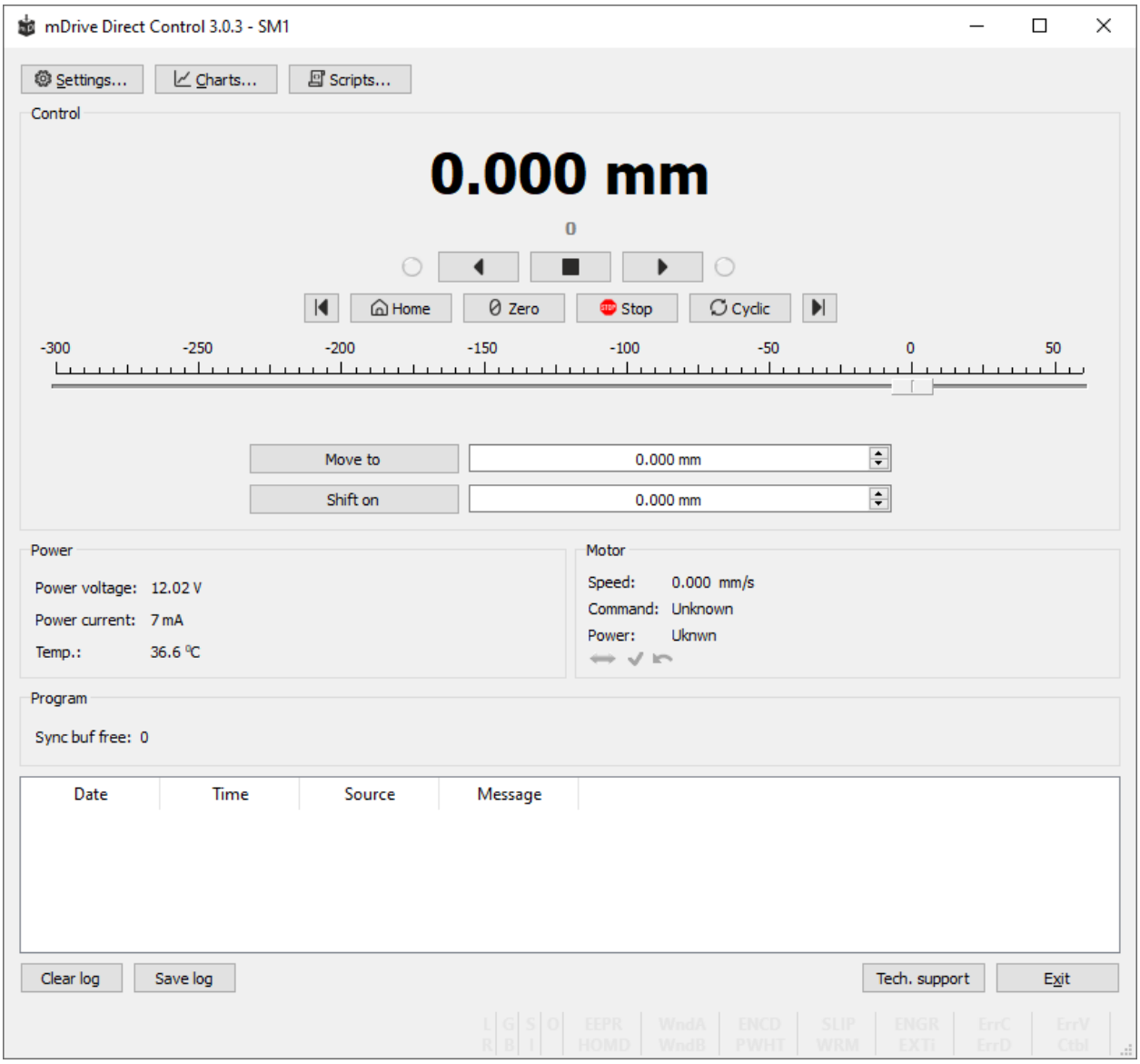


Fig. 5.4: mDrive Direct Control Main Window in General Motor mode

In the left part of the window in **Power** and **Motor** groups of parameters status of the controller and the motor is available. In the central part of the window there is the **Control** group, containing the elements of motor motion control. On the right there is a group of buttons to control the application as a whole. At the bottom there is a *log*, which is hidden as the window is resized to its minimum size and a status bar. Below we consider these groups in more detail.

5.2.2.1 Motion Control Unit

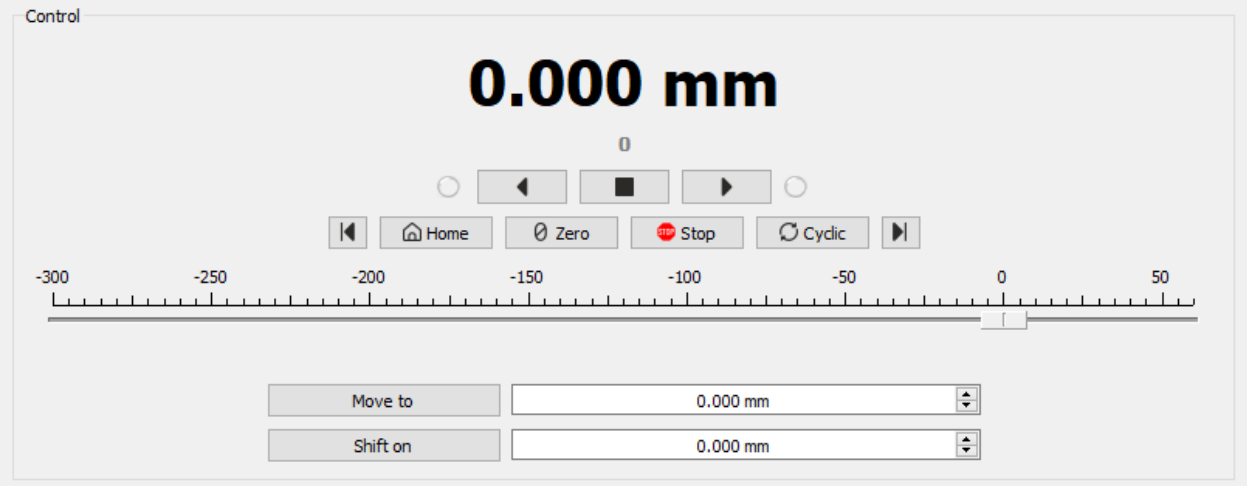


Fig. 5.5: Control Unit

The current position indicator is located in the central part of the block. Below it are the motion control buttons. Even lower, if the encoder is turned on, there is an indicator of the position of the encoder. In the closed loop mode (see *Operation with encoders* section) the main and secondary indicators swap their places.

Below is the **Control** unit, containing the elements of motor motion control. Let us examine them in greater detail:

5.2.2.1.1 Movement without specifying the final position

Fig. 5.6: Movement control buttons

- The buttons *Left*, *Stop* and *Right* trigger movement to the left without specifying the final position, *stop with deceleration* any previously started movement, and start the movement to the right without specifying the final position, respectively.
- Button *Left to the border* will make the motor rotate to the left border of the slider. *Right to the border*, respectively, will do it to the right edge of the slider.
- When you press and hold the keyboard buttons *Right* or *Left* and the slider block has input focus, the movement starts in the direction of increasing or decreasing coordinate. When you release the button the movement stop as if the *Stop* button on the main window have been pressed.

5.2.2.1.2 Movement to the target point

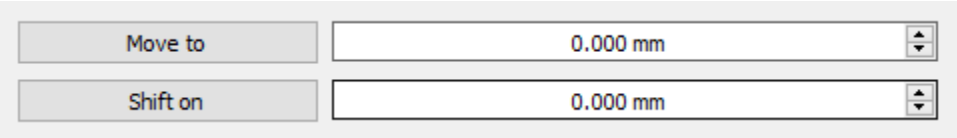


Fig. 5.7: Movement control to the given point

- *Move to* button starts the process of moving to the given position.
- *Shift on* button starts the process of shift to a given distance from the target position.

5.2.2.1.3 Target position for motion commands

Commands *Move to* and *Shift on* use the target position to calculate the movement. The target position is changed by the following commands:

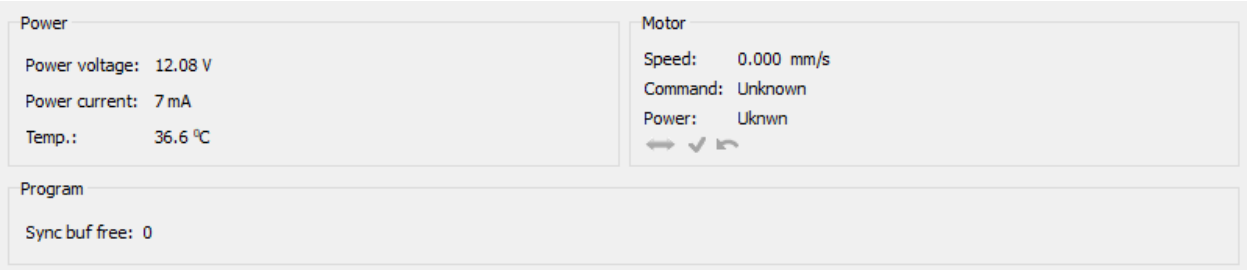
Move to <value>
Target position = <value>

Shift on <offset>
Target position = target position + <offset>

Zero (provided there is no movement at the moment of sending the command)
Target position = 0

Commands *Stop*, *Left*, *Right*, *Left up to the border* and *Right up to the border* do not alter the target position.

5.2.2.2 Controller and motor status



5.2.2.2.1 Controller Power Supply

Power group of parameters contains the following indicators:

- *Power voltage* - voltage supplied to the power module.
- *Power current* - current consumption of the power module.
- *Temp.* - Temperature of the controller processor.

If the color of the indicator *Power voltage* changes to red, it shows that voltage power supply exceeds the allowed value range over the acceptable value. In this case, the controller switches to *Alarm* state. You can change this parameter in the section *Critical board ratings*.

A horizontal bar above the field *Power voltage* indicates that the power voltage exceeds the motor max voltage, you can change this parameter in the section *Settings of kinematics (BLDC motor)*.

If color of the indicator *Power current* turns red, it shows that the current consumed by the controller from the power supply is over the acceptable value. In this case, the controller switches to *Alarm* state. You can change this parameter in the section *Critical board ratings*.

A horizontal bar above the field *Power current* indicates that the power current exceeds the motor max current, you can change this parameter in the section *Settings of kinematics (BLDC motor)*.

If the color of the indicator *Temp* turns red, it shows that the temperature of the controller board exceeds the acceptable value. In this case, the controller switches to *Alarm* state. You can change this parameter in the section *Critical board ratings*.

Important: It is possible to quit the *Alarm* state after terminating of the events that caused Alarm, provided that the flag *Sticky Alarm* is not set. If the flag *Sticky Alarm* is on, use the *Stop* button to quit the Alarm state.

5.2.2.2.2 Motor status

Motor group of parameters contains the following indicators:

- *Speed* - rotation speed of the motor.
- *Command* - the last performing (bold font) or executed (plain font) *controller command*. *Controller command* appears in black if the flag of the motion error MVCMD_ERROR is not set, in red otherwise. Can be one of the following options:
  - *Move to position* - move to the set position
  - *Shift on offset* - offset for a predetermined distance
  - *Move left* - move left
  - *Move right* - move right
  - *Stop* - stop
  - *Homing* - find the home position
  - *Loft* - backlash compensation
  - *Soft stop* - smooth stop
  - *Unknown* - unknown command (it may appear immediately after the controller starts)
- *Power* - state of stepper motor power supply. Can be one of the following options:
  - *Off* - motor winding is disconnected and not controlled by the driver,
  - *Short* - winding is short-circuited through the driver,
  - *Norm* - winding is powered with nominal current,
  - *Reduc* - winding is deliberately powered with reduced current relatively to operational one to reduce the power consumption,
  - *Max* - winding is powered with maximum available current, which a scheme with a given voltage supply can output.

Note: You can use the GPIO flag to detect the connected stage

A horizontal bar above the Speed parameter indicates that the speed has reached the maximum speed, which is defined in the *Settings of kinematics (BLDC motor)*.

5.2.2.2.3 Program status

Program group of parameters contains the following indicators:

- *Sync buf free* - free slots in the syncin command buffer.

5.2.2.3 Group of application control buttons

- *Settings...* button opens controller settings, see *Application settings*.
- *Charts...* button opens a window with charts, see *Charts*.
- *Scripts...* button opens scripting window, see *Scripts*.
- *Home* button searches for the home position, see *Home position settings*.
- *Zero* button resets the current position of the motor and the encoder value.
- *Stop* button sends the command of *immediate stop*, resets the Alarm state, clears the command buffer for synchronous motion and stops a script if it is running.
- *Cyclic* button turns on the cyclic motion, see *Cyclical motion settings*.

Note: The *Cyclic command* is a constituent command: when invoking *Cyclic* in mDrive Direct Control at the controller level the sequence of *Move to* commands is executed.

- *Clear log* button clears the contents of the log.
- *Save log* button saves the contents of the log to a file in CSV format (opens a file selection dialog window).
- *Tech. support* button gives the opportunity to quickly contact us.
- *Exit* button performs safe shutdown, see *Correct shutdown*.

5.2.2.4 Status bar

Status bar contains current controller status indicators. From left to right these are 7 flags:

- **L** - Left button state
- **R** - Right button state
- **G** - State of external GPIO pin
- **B** - State of brake pin
- **S** - State or revolution sensor pin
- **I** - State of sync in pin
- **O** - State of sync out pin

and separate indicators (flags)

- **HOMD** - Lights up after successful execution of home() command meaning that relative position scale is calibrated against a hardware absolute position sensor like a limit switch. Drops after loss of calibration like harsh stop and possibly skipped steps.

- **WndA/WndB** has 1 of 4 statuses: - Winding A/B is disconnected. - Winding A/B state is unknown. - Winding A/B is short-circuited. - Winding A/B is connected and working properly.

Important: Status is determined using statistical data while moving, taking its time, and turning this status rather useless in common applications. Therefore this function have been disabled for the moment.

- **ENCD** - Encoder state has 1 of 5 statuses: - Encoder is absent. - Encoder state is unknown. - Encoder is connected and malfunctioning. - Encoder is connected and operational but counts in other direction. - Encoder is connected and working properly.
- **PWHT** - Power driver overheat. Motor control is disabled until some cooldown. This should not happen in boxed versions of controller. This may happen in bare board version of controller with a custom radiator. Redesign your radiator then.
- **SLIP** - Motor slip detected. Flag is set when encoder position and step position are too far apart. You can disable the "Position control" flag or increase the error in the "threshold" field on the mDrive Direct Control Settings->Position control tab to stop these error from happening.
- **WRM** - Lights up when there is a substantial difference between stepper motor windings resistances. This usually happens with a damaged stepper motor with partially short-circuited windings. You can diagnose the problem according to the instructions *in our manual*

Important: The WRM algorithm was not originally designed to be used for belt-driven stages due to the fact that the belt can stretch and vibrate. Vibration usually occurs at high speeds, which knocks down the work of the WRM algorithm. For belt drive stages, this is normal behavior

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- **ENGR** - Lights up red when the motor control error occurs. Motor control algorithm failure means that it can't define the correct decisions with the feedback data it receives. Single failure may be caused by mechanical problem. A repeating failure can be caused by incorrect motor settings.
- **EXTI** - The error is caused by the external EXTIO input signal set to cause this error in the settings (mDrive Direct Control Settings->EXTIO tab)
- **ErrC** - Command error encountered. The command received is not in the list of controller known commands. Most possible reason is the outdated firmware that can be updated in mDrive Direct Control Settings->About device tab->Autoupdate button.
- **ErrD** - Data integrity error encountered. The data inside command and its CRC code do not correspond, therefore data can't be considered valid. This error may be caused by EMI in RS-232 interface.
- **ErrV** - Value error encountered. The values in the command can't be applied without correction because they fall out the valid range. Corrected values were used instead of the orginal ones.
- **Ctbl** - Loading correction table status.

5.2.3 mDrive Direct Control Main window in multi-axis control mode

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Important: mDrive Direct Control allows you to open up to 32 axes at the same time, but only the first 3 (X/Y/Z axes) will be displayed in the multi-axis interface. However, it is possible to work with other open axes (those that are not visually displayed in mDrive Direct Control), for this you need to use the mDrive Direct Control scripting language. To visually work with a large number of axes (more than three), you will need to launch several mDrive Direct Control windows. For example, you have a 5-axis controller, then in the first mDrive Direct Control window you can open the first three axes, and in the second window the remaining two.

If you need to open more than 3 axes in one window and visually control them, you can use unsupported examples written by *in C* and *Python*

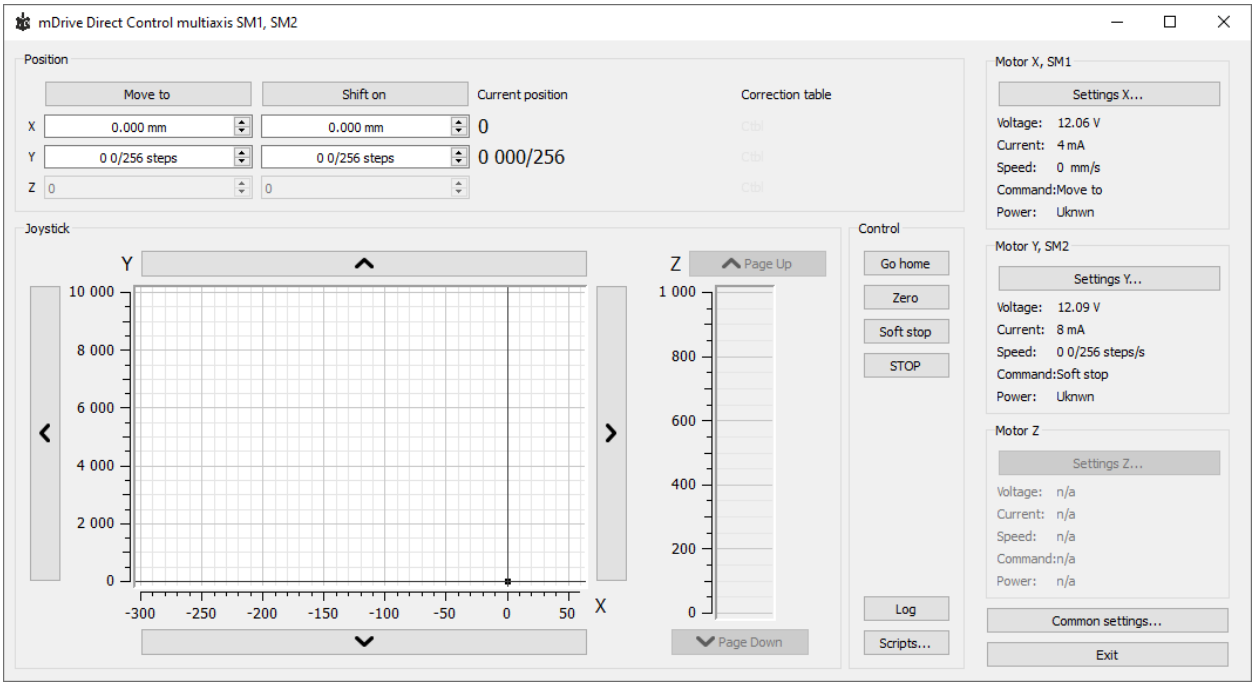


Fig. 5.8: mDrive Direct Control Main window

In the top left part of the screen in the **Position** parameter group there are indicators of the current position. In the bottom left part of the window there is the **Joystick** and **Control** blocks, which are a graphical control element for several axes and a button block respectively. In the top right part, in the **Motor** blocks data on the current status of controllers and connected motors is located. In the bottom right part of the window there is a group of buttons for application control as a whole. Let us consider these groups in more detail.

5.2.3.1 Motion control block

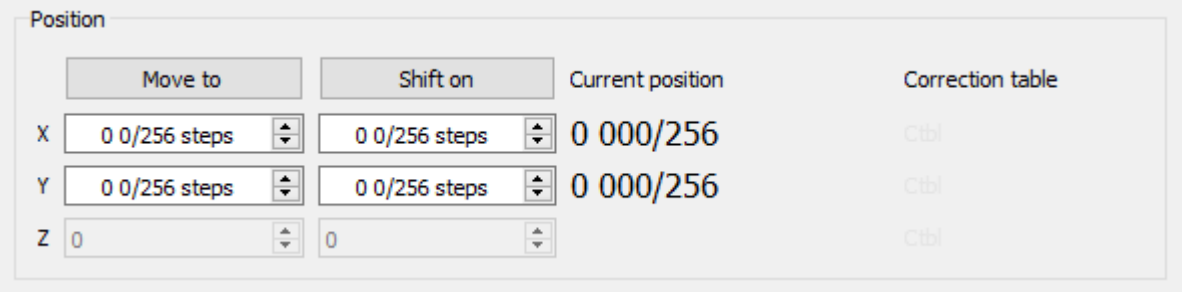


Fig. 5.9: Motion control block

In the *Current position* column indicators of the current position in steps or calibrated units (see below) for the axes X, Y and Z (from left to right) are located. The *Move to* button performs movement to the coordinate given by the controls of its column, and the *Shift on* button performs shift on a specified distance from the current position. If one of the controllers is temporarily absent or disabled, the corresponding line becomes grayed out.

5.2.3.2 Virtual joystick block

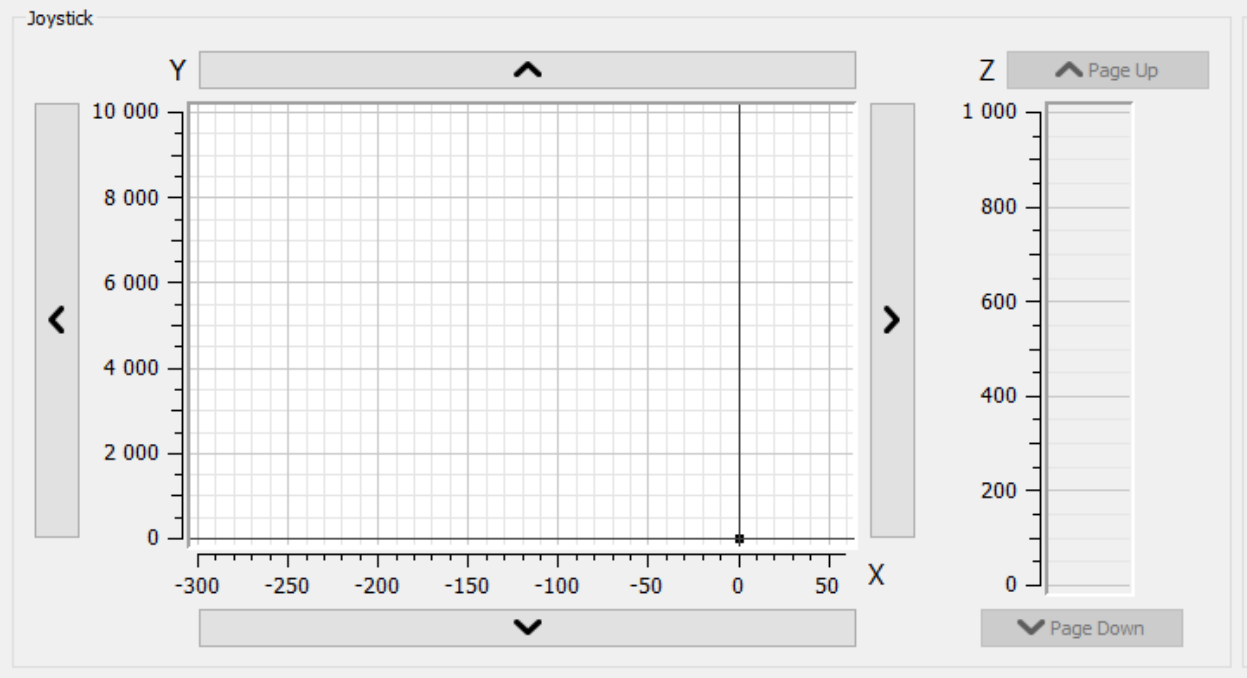


Fig. 5.10: Virtual joystick block

In this block, the current coordinate of the controllers is visualized as a dot with two lines on the plane for X-Y axes and the line for the Z axis.

There are several possible ways to control movement of the controllers:

- When you click anywhere on the X-Y plane or in the Z column, the corresponding controller or controllers start to move to the selected coordinate in accordance to its own movement settings.
- When you press and hold the screen buttons with up, down, left and right arrows, the corresponding axis starts to move in that direction. The movement *stops with deceleration* when you release the button (soft stop command is sent).
- When you press and hold the keyboard buttons Right, Left, Up, Down, PageUp or PageDown when the joystick block has input focus, the axis X, Y or Z, respectively, starts to move in the direction of increasing or decreasing coordinate. The movement *stops with deceleration* when you release the button (soft stop command is sent). On receiving input focus the widget background color changes from white to light-green.

The scales of the axes are set in *Slider settings* block on *General motor* tab in Settings window separately for each controller. If *user units* are being used, then the corresponding axis scale is measured in these units. If the position read from any controller is out of its axis range, then the corresponding indicator will not appear on the screen.

5.2.3.3 Control block

Fig. 5.11: Control block

The *Home* button searches for the home position independently for each of the controllers; see *Home position settings*.

The *Zero* button resets the current position of the motor and value of the encoder for each controller.

The *Soft stop* button executes a soft stop for each of the controllers.

Note: The *STOP* button sends an *immediate stop* command to each controller, resets their Alarm statuses, clears their command buffers for synchronous motion and stops a script if one is running.

The *Log* button opens a window with log information. Here you can find diagnostic information (errors, warnings, informational messages) from mDrive Direct Control, libximc and script sources.

The *Scripts* button opens a scripting window, see *Scripts*.

5.2.3.4 Block of status indicators for controllers and motors

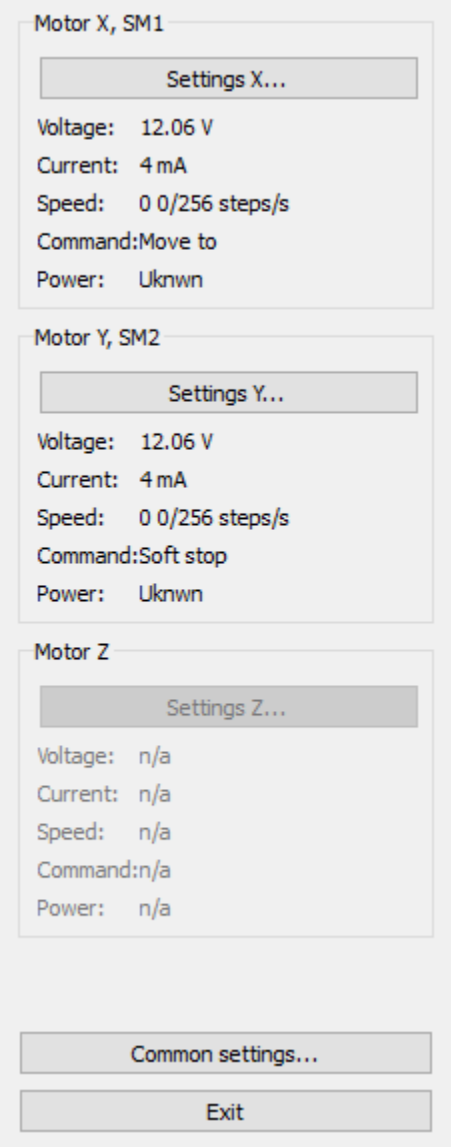


Fig. 5.12: Block of status indicators for controllers and motors

Here are the three blocks of indicators of controllers and motors for axes X, Y and Z. In the title of the block the serial number of corresponding controller is displayed. Each block contains the following indicators:

- Voltage - the voltage at the power section of the motor.
- Current - current power consumption of the motor.
- Speed - current speed of the motor.
- Command - the last command of the controller that was executed, or is being executed.
- Power - the state of the motor power supply.

The buttons Settings X, Y, Z open the configurations of a controller, which corresponds to this axis, see *Application settings*.

Below the indicator blocks *Common settings* and *Exit* buttons are located.

The *Common settings* button opens a dialog window with general settings. Here you can choose which controller serial numbers are considered “X”, “Y” and “Z” axes, also this window contains logging settings.

The *Exit* button performs proper shutdown, see *Correct shutdown*.

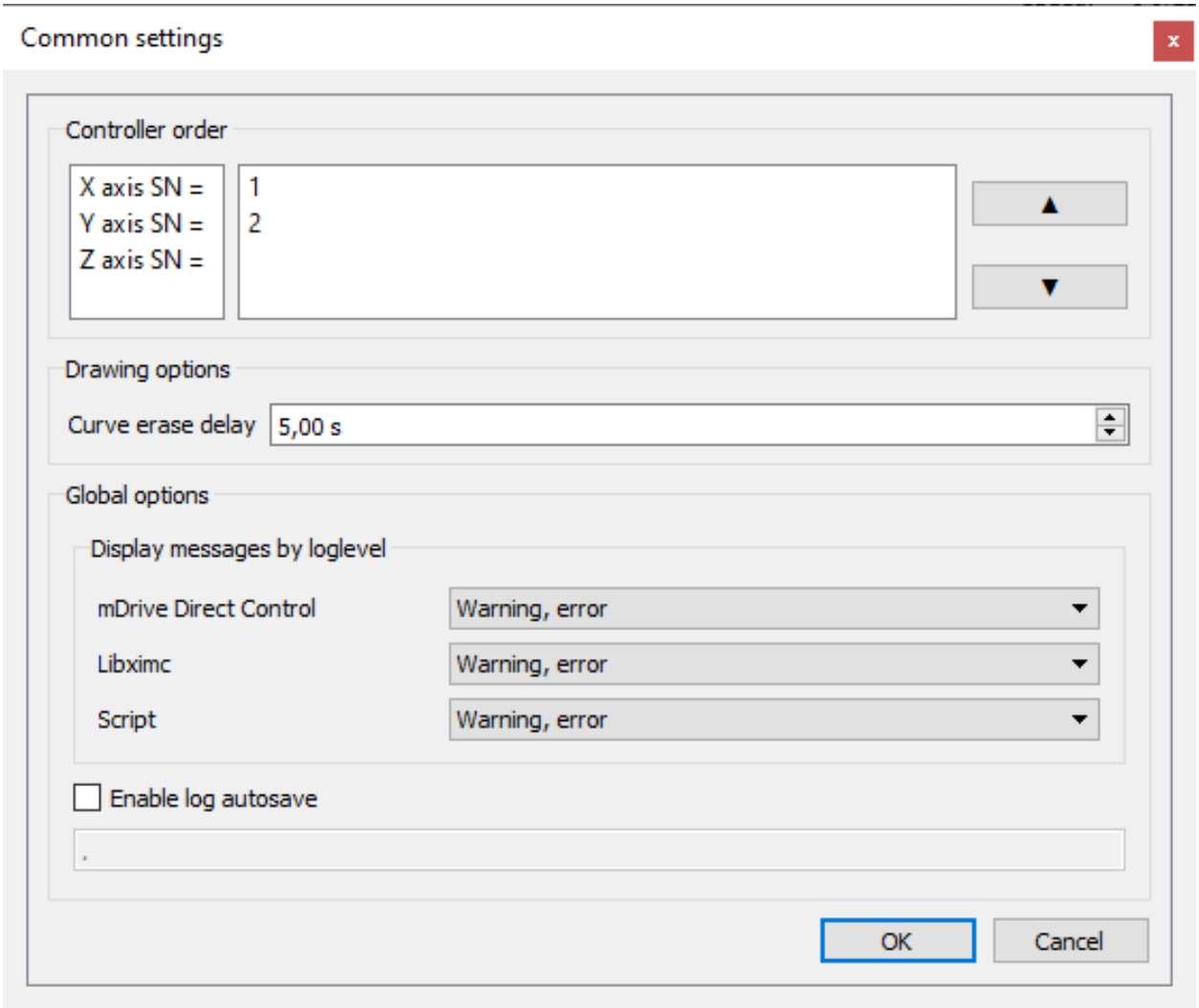


Fig. 5.13: Common settings dialog window

Common settings window contains axis order settings, curve drawing options and logging settings.

You can reorder axes by choosing the axis serial, then pressing “up” or “down” buttons on the right.

First axis in the list, that is, an axis with serial number listed to the right of “X axis SN = ” label will be referred to as “X axis”, the second one as “Y axis”, the third one, if it is available, as “Z axis”.

If you enter a greater than zero value of N seconds in the “curve erase delay” control in the “Drawing options”, then last N seconds of X and Y axis controller motion will be displayed as a trajectory in 2D-space overlaid on the virtual joystick window.

Common logging settings are completely identical to *single-axis version logging settings*.

Here you can configure logging detail (“None” for no logging, “Error” to only log errors, “Error, Warning” to log errors and warnings, “Error, Warning, Info” to log errors, warnings and informational messages) for each source: mDrive Direct Control itself, libximc library and Scripts module.

If the autosave option is enabled the log is saved to the file, which is flushed every 5 seconds. It has a name of type “xilab_log_YYYY.MM.DD.csv”, where YYYY, MM and DD are current year, month and day respectively. The log is saved in CSV format.

5.2.4 Application settings

Settings button from the *main window* opens the Settings window.

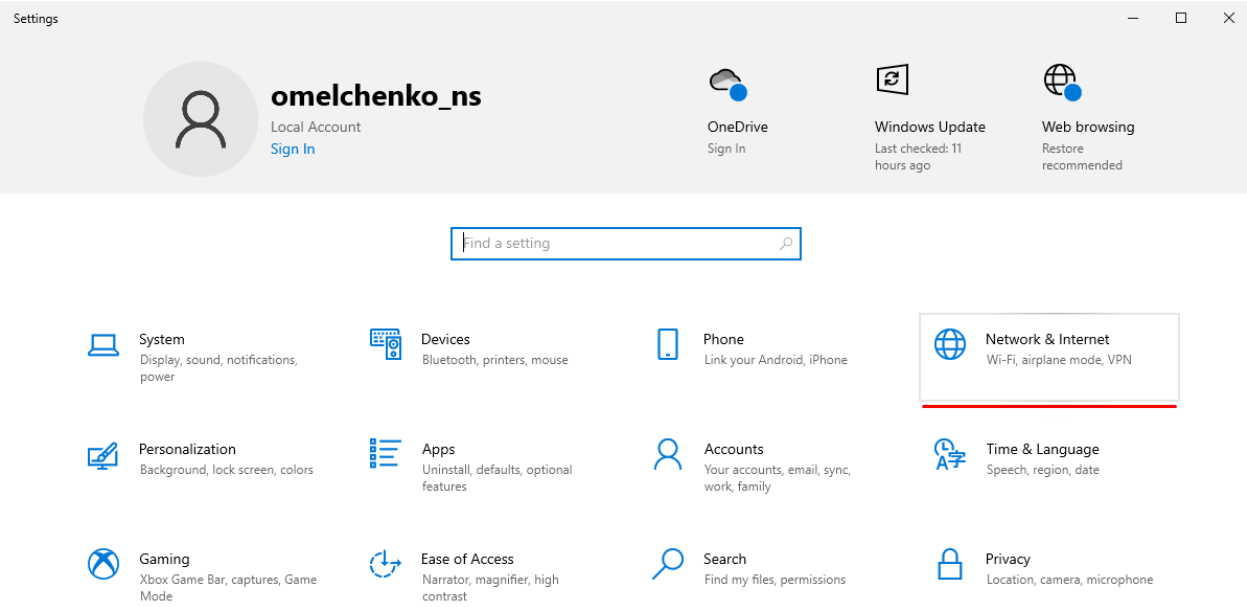


Fig. 5.14: mDrive Direct Control Settings Main Window

Application settings are presented as a hierarchical tree and are divided into three groups: controller settings - “Device”, mDrive Direct Control application settings - “Program”, characteristics of a stage - “Stage”.

The first group *Device* contains the parameters that can be stored directly in the device (in the flash memory or in the RAM of controller).

The second group *Program* contains the mDrive Direct Control application settings, which are not written into the controller, and are used to control the mDrive Direct Control itself.

Important: The information on the *“Stage”* tab temporarily not used

---

Description of **Load setting from flash** and **Save settings to flash** buttons is located in the *Saving the parameters in the controller flash memory*.

All application settings from the first two groups can be saved to an external file when you click **Save settings to file**.

When you click the **Load setting from file...** button you can pick a file with application settings to be loaded into Settings window.

When you click the **Compare two files** button, a dialog window with file selection is opened. If you select two files all their settings are compared and a list of differences is displayed. Missing keys in one of the files are marked in the

table as “<NO KEY>”.

The **OK** Button closes the Settings window and saves all changes to the settings to the controller. The **Cancel** button closes the window without saving. The **Apply** button saves the settings without closing the window.

The **Reset** button resets all setting changes that were made since the **Apply** button was pressed, or after opening the Settings, if the **Apply** button was not pressed.

Note: Only Device configuration settings can be saved into the flash memory of the controller.

5.2.5 Charts

Button **Charts** of the *main window* opens a window for working with charts.

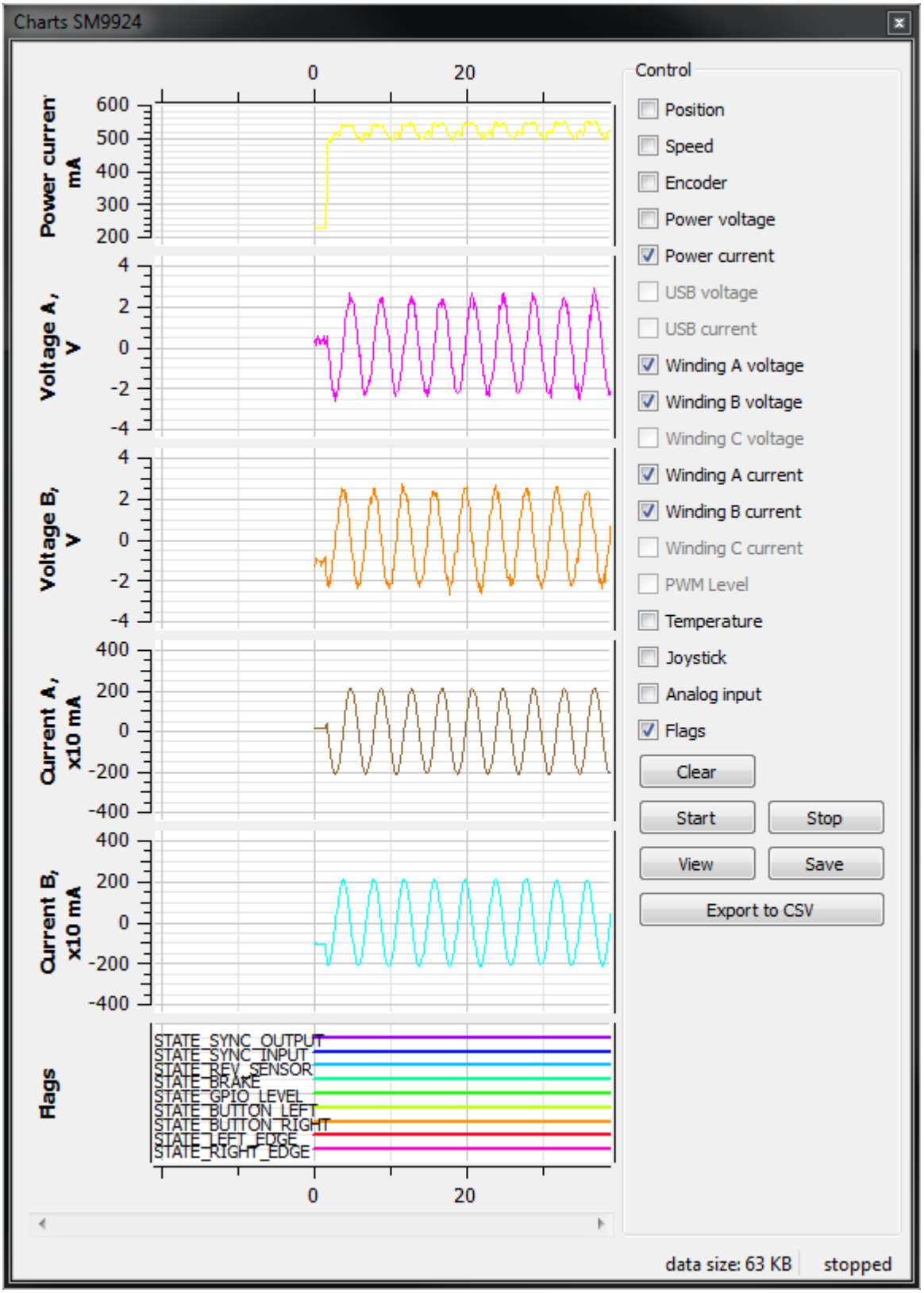


Fig. 5.15: mDrive Direct Control Charts window

In the left part of the window there are Charts of variables, in the right side of the window there is the **Control** block, which contains the charts control elements. Above the **Control** block there are flags which enable different charts, below the **Control** block there is a group of buttons to control the stored charts data.

5.2.5.1 Values displayed on the charts

- *Position* is the primary field in which the current position is stored, no matter how feedback is arranged. In the case of a BLDC-motor this field has the current position according to the encoder, in the case of a SM (stepping motor) this field contains the current position in steps;
- *Speed* is the current speed;
- *Encoder* is the position according to the secondary position sensor;
- *Power voltage* is voltage of the power section;
- *Power current* is current consumption of the power section;
- *USB voltage* is voltage on the USB;
- *USB current* is current consumption by USB;
- *Winding A current* - in the case of stepper motor, the current in winding A; in the case of a BLDC motor, the current in the first winding;
- *Winding B current* - in the case of stepper motor, the current in the winding B; in the case of BLDC motor, the current in the second winding;
- *Winding C current* - in the case of a BLDC motor, the current in the third winding, unused in the case of stepper motor;
- *Winding A voltage* - in the case of stepper motor, the voltage on winding A; in the case of a BLDC motor, the voltage on the first winding;
- *Winding B voltage* - in the case of stepper motor, the voltage on the winding B; in the case of BLDC motor, the voltage on the second winding;
- *Winding C voltage* - in the case of a BLDC motor, the voltage on the third winding, unused in the case of stepper motor;
- *Temperature* is temperature of controller processor;
- *Joystick* is value of input signal from the joystick;
- *Analog input* is value of analog input;
- *Flags* shows the state of the controller flags.

5.2.5.2 Button functions

- *Clear* - clears the stored data and the Charts window;
- *Start* - starts recording the data and displaying charts. If the option “Break data update when motor stopped” in **Program -> Graph** is turned on, no data recording and charts auto-scrolling will occur when the motor is stopped;
- *Stop* - stops data reading;
- *Save* - stores chart data to a file;
- *View* - opens a new window where you can load (using the *Load* button) and view previously saved graphs.
- *Export to CSV* - exports chart data to CSV file

5.2.5.3 Limit value

If a limit is set for speed, power voltage power current, this limitation is displayed on the graph in dotted lines:

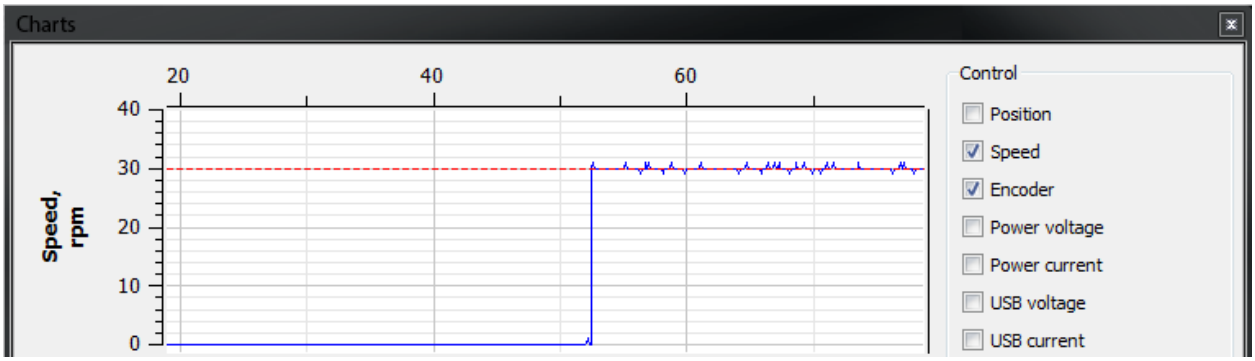


Fig. 5.16: Speed chart in mDrive Direct Control program with speed limitation

5.2.6 Scripts

The “Scripts” button on the *main window* opens a window for working with scripts.

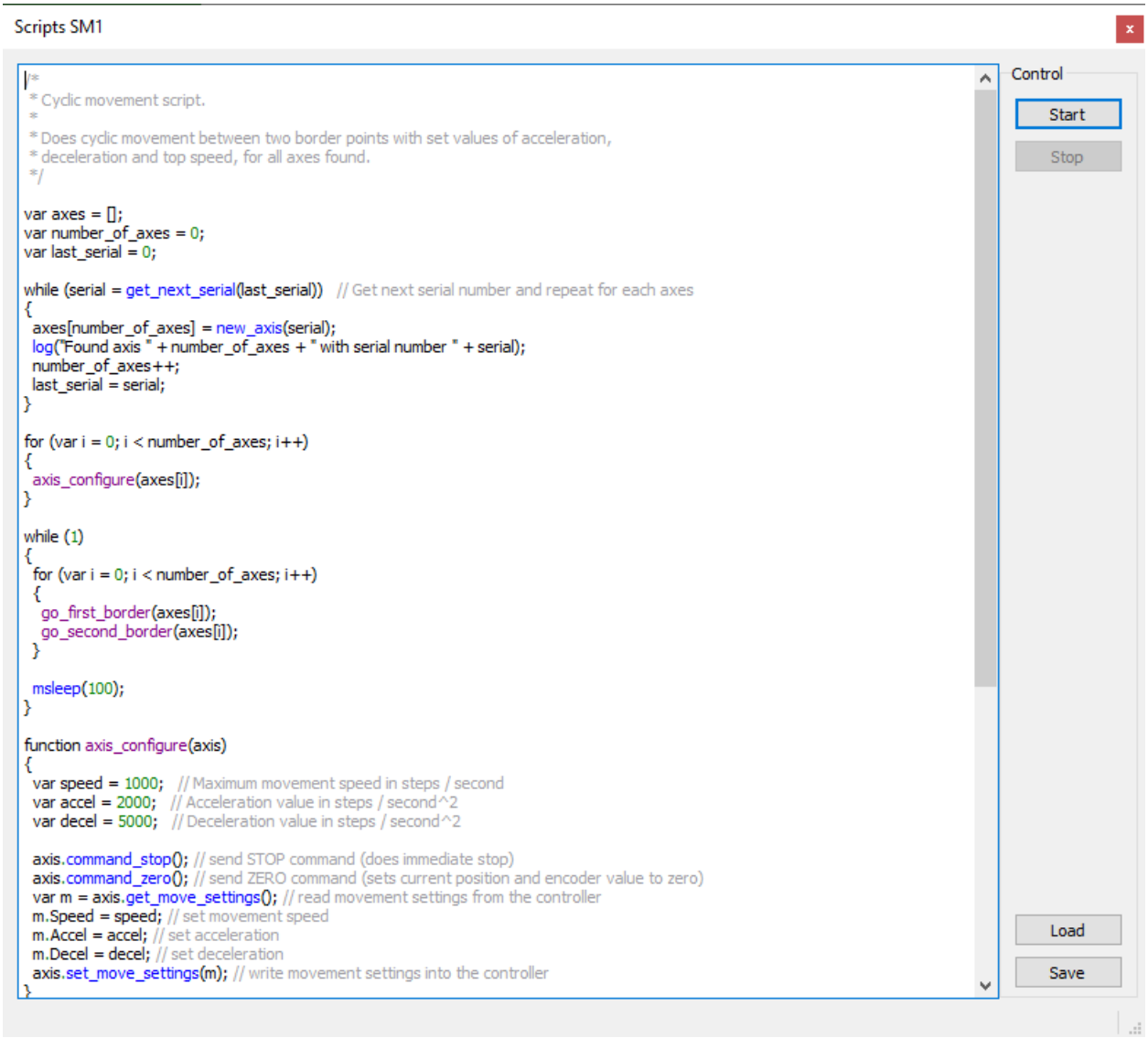


Fig. 5.17: mDrive Direct Control scripting window

On the left side of the window a text edit field is located, on the right side of the window a Control block is located, which contains control buttons.

5.2.6.1 Button functions

- *Start* - launches the script. The button is inactive if the script is already running. Right after the button is pressed and before the script is interpreted the body of the script is autosaved to a temporary file (see below).
- *Stop* - stops the script. Inactive if the script is not running.
- *Save* - opens a file save dialog, prompting the user pick a file to save current script text to. Inactive if the script is running.
- *Load* - opens a file load dialog, prompting the user to pick a file to load into the script window. Inactive if the script is running. Warning! If you load a file all unsaved changes will be lost.

mDrive Direct Control loads last saved script text into the Scripting window on startup. Autosave runs on every script

start and on mDrive Direct Control exit. Autosave file is named “scratch.txt” and is located in user settings directory.

Note: *Stop* button in mDrive Direct Control main window also stops script execution, acting as an emergency stop button.

The *STOP* button sends an *immediate stop* command to each controller, resets their Alarm statuses, clears their command buffers for synchronous motion and stops a script if one is running.

Scripting language description is located in the Programming section of the manual.

5.2.7 mDrive Direct Control log

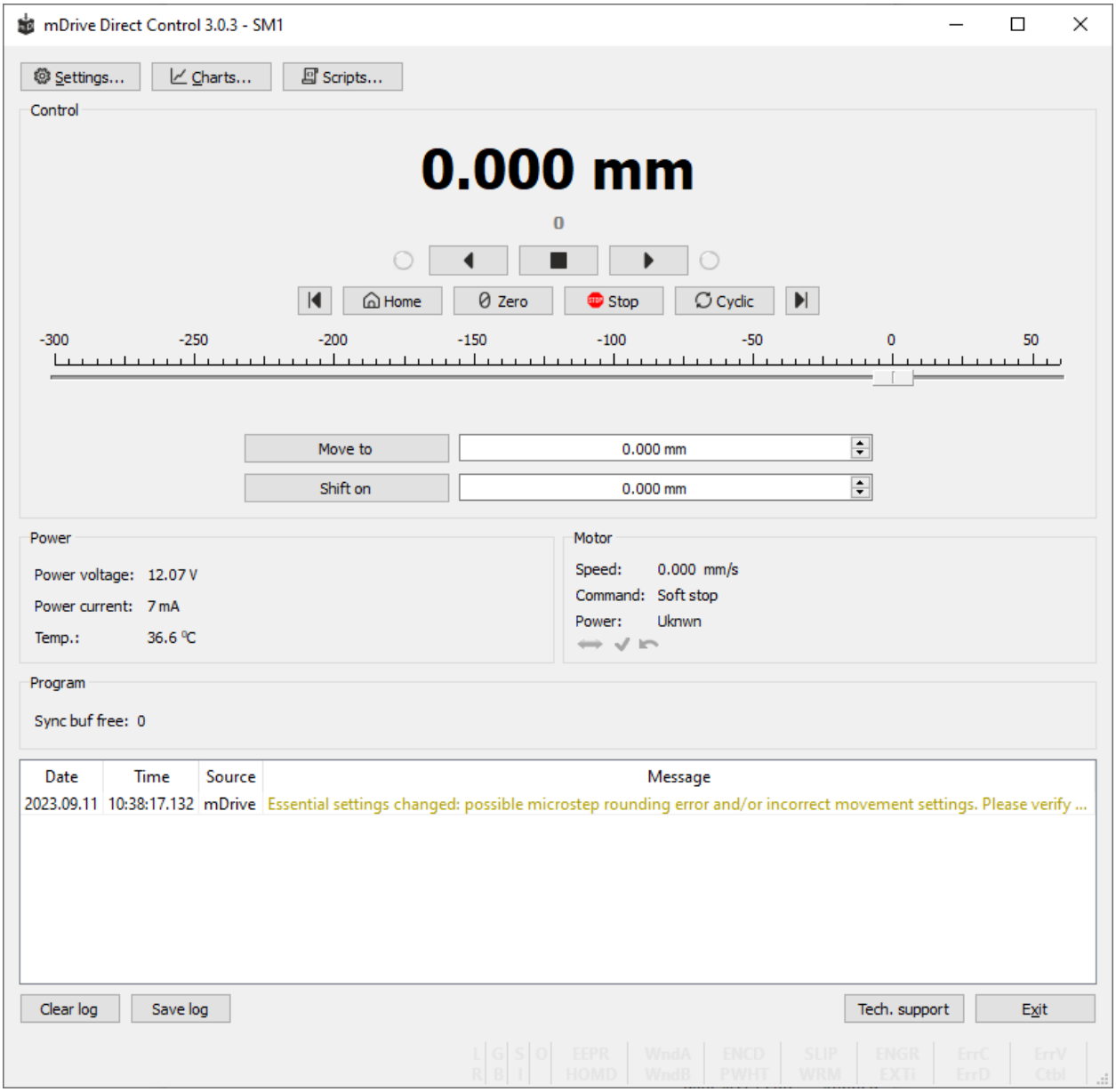


Fig. 5.18: mDrive Direct Control log window

mDrive Direct Control log at the bottom part of the main window shows libximc library messages. It also shows messages from mDrive Direct Control application and *Scripts* interpreter.

Log has 4 columns: date and time of record, the source and the message text.

Messages have a logging level indicating message importance: error, warning and informational message. Error messages are red, warnings are yellow and informational messages are green.

You can set a filter on displayed messages on the *Log settings* page in the Settings window.

5.3 Controller Settings

5.3.1 Settings of kinematics (stepper motor)

In the *Application settings* **Device -> Stepper motor**

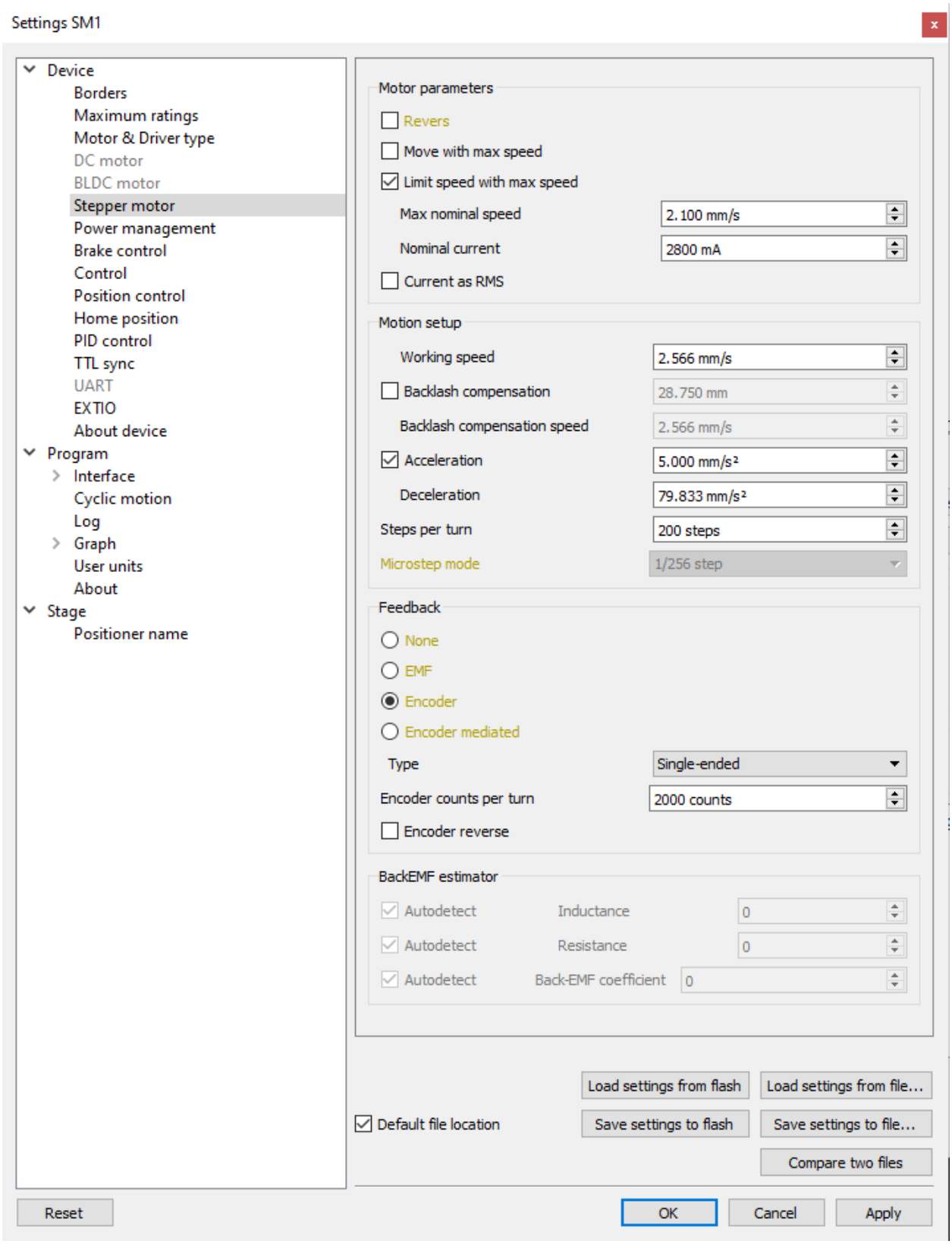


Fig. 5.19: Settings of stepper motor kinematics window

5.3.1.1 Motor parameters - directly related to the electric motor settings

Revers - checking this flag associate the motor rotation direction with the position counting direction. Change the flag if positive motor rotation decreases the value on the position counter. This flag effect is similar to the motor winding reverse polarity.

Move with max speed - if this flag is checked motor ignores the preset speed and rotates at the maximum speed limit.

Limit speed with max speed - if this flag is checked the controller limits maximum speed to the value specified in the *Max nominal speed* field. For example, if the speed exceeds the rated value, controller will reduce output action, until the speed come back to the normal range. However, the controller remains operational and will continue the current task.

Max nominal speed - motor rated speed.

Nominal current - motor rated current. The controller will limit the current with this value.

Current as RMS - if this flag is checked engine current value is interpreted as root mean square current value. If the flag is unset, then engine current value is interpreted as maximum amplitude value. See *Calculation of the nominal current* page for description

5.3.1.2 Motion setup - movement kinematics settings

Working speed - movement speed.

Backlash compensation - backlash compensation. Since the stage mechanics are not ideal there is a difference between approaching a given point from the right and from the left. When the backlash compensation mode is on the stage always approaches the point from one side. The preset value determines the number of steps which the stage takes to pass a given point in order to come back to it from the same side. If the specified number is above zero the stage always approaches the point from the right. If it is below zero the stage always approaches the point from the left.

Backlash compensation speed - speed of backlash compensation. When the backlash compensation mode *Backlash compensation* is on the stage approaches the point from the right or from the left with a preset speed determined in the number of steps per second.

Acceleration - enables the motion in acceleration mode, the numerical value of the field is the acceleration of movement.

Deceleration - movement deceleration.

Steps per turn - determines the number of steps for one complete motor revolution. The parameter is set by user.

Microstep mode - step division mode. 9 modes are available: from a whole step to the 1/256 of a step. Description of modes is in the *Supported motor types*.

5.3.1.3 Feedback settings

An encoder can be used as feedback sensor for stepper motors. Three feedback modes are available for stepper motors.

None - is without feedback. The movement is carried out in steps.

Encoder - mode of motion setting in the encoder reference values. The following encoder types are available: Single-ended, Differential or Autodetect.

Encoder mediated - in this case, the movement is carried out in several iterations with position control at the end of each iteration of the encoder.

Encoder counts per turn - this parameter defines the number of *encoder* pulses per one full motor axis revolution.

Encoder reverse - interpret encoder signal as if it were reversed.

5.3.2 Motion range and limit switches

In the *Application settings* **Device -> Borders**

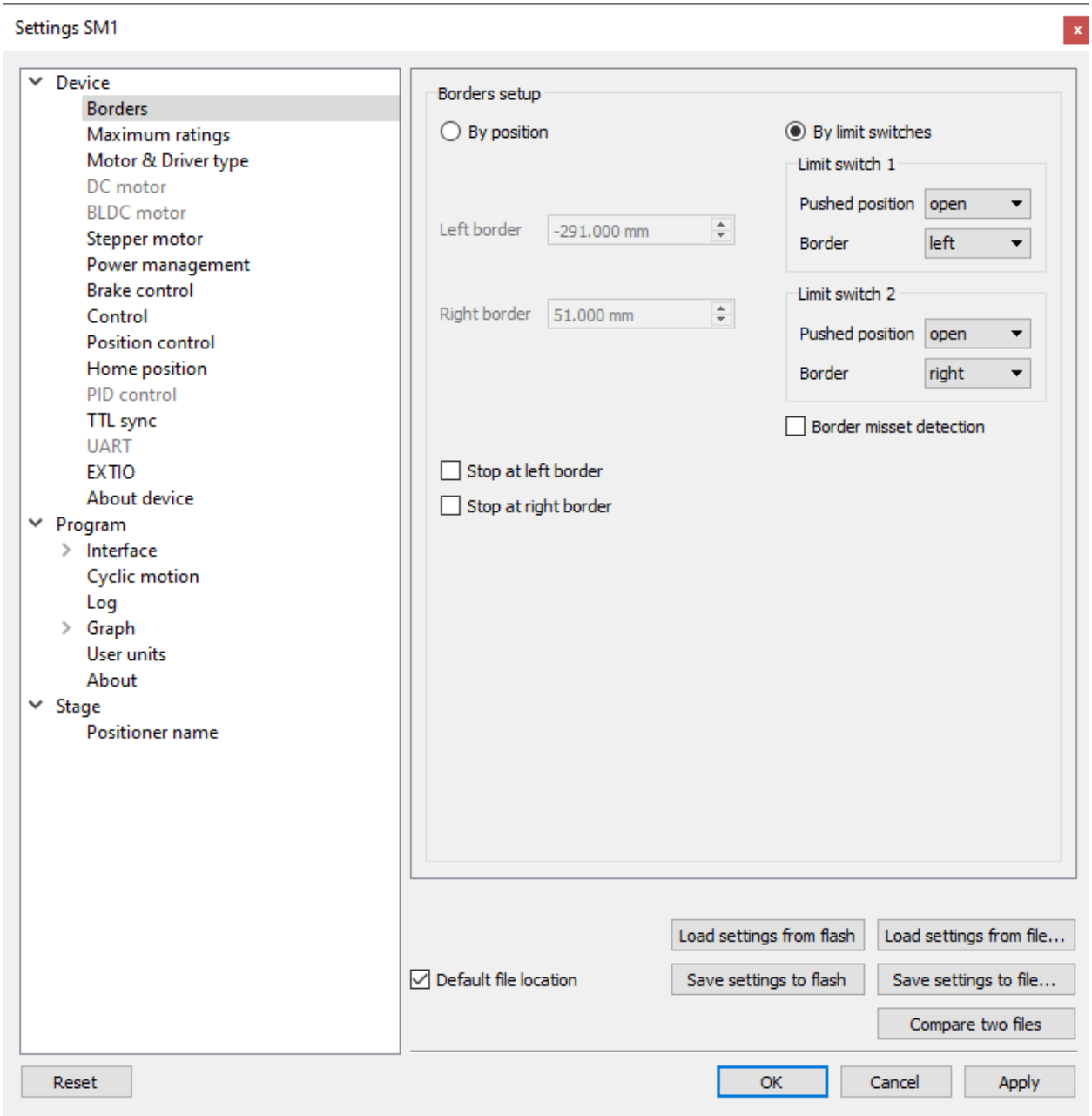


Fig. 5.20: Motion range and limit switches settings window

Borders setup parameter group contains borders and limit switches parameters. These parameters are used to keep the stage in the permissible physical movement limits or motion range limit in accordance with the user requirements. Borders can be set either by position (internal controller step counter) or by *limit switches* located in the stage terminal points.

To set the borders by position select the *By position* and specify the *Left border* and *Right border* values, which correspond to the left and right edge respectively.

To set the borders by the limit switches select *By limit switches* and set up both *Limit switch 1* and *Limit switch 2*.

Pushed position - sets the limit switch condition when it is reached: open or closed.

Border - sets the limit switch position: on the left or on the right of the stage working range.

Check the *Stop at left border* and / or *Stop at right border* for a forced stop of motor when the border is reached. In this case the controller will ignore any commands of movement towards the limit switch if the corresponding limit switch has already been reached.

When the border position is reached the corresponding indicator flashes in the main application window.

If the *Border misset detection* flag is checked, the engine stops upon reaching of each border. This setting is required to prevent engine damage if limit switches appear to be potentially incorrectly configured. Read more about controller operation in this mode in the *limit switches location on stages*.

5.3.3 Critical board ratings

In the *Application settings* **Device -> Maximum ratings**

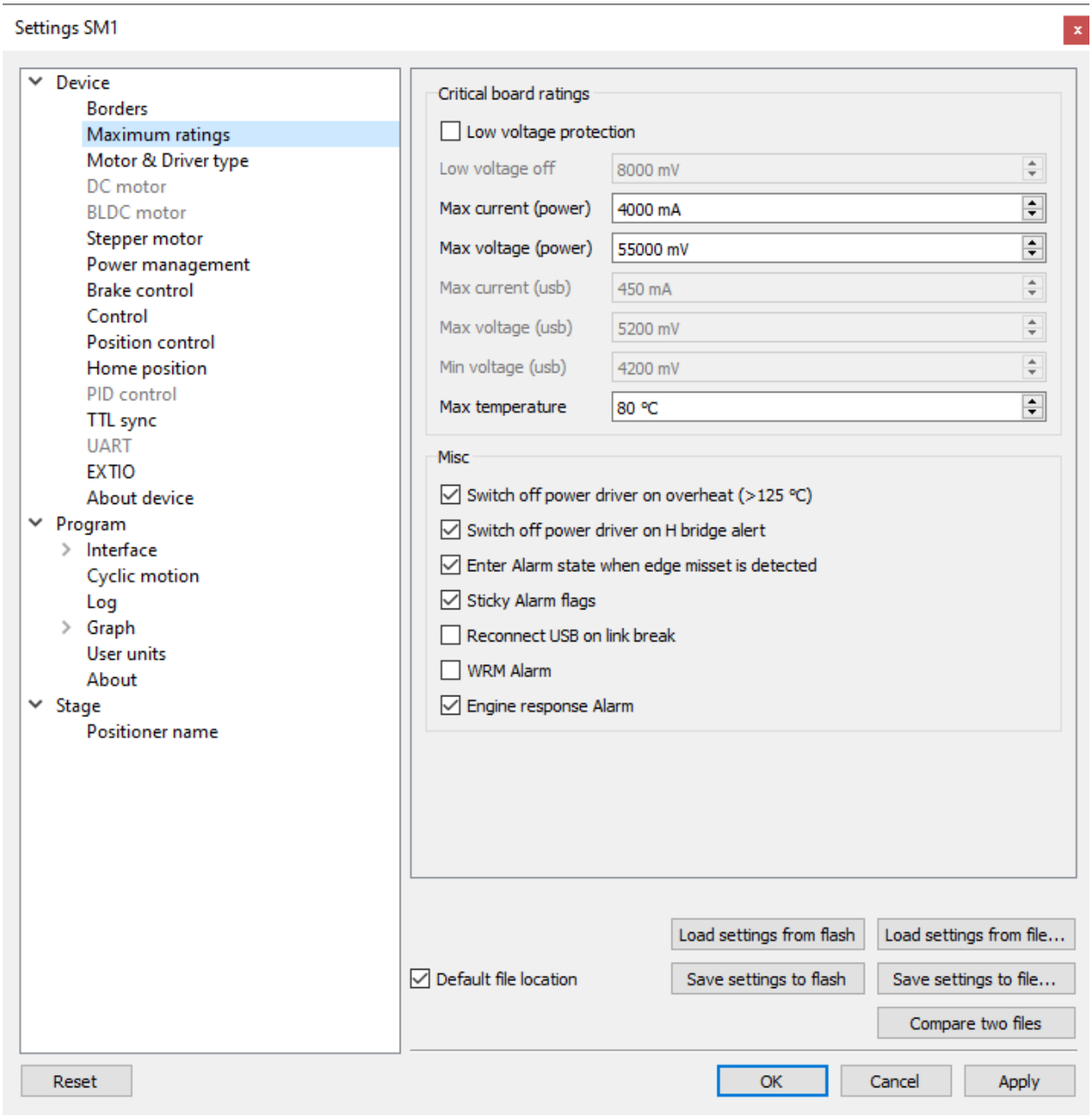


Fig. 5.21: Controller critical parameters settings window

Critical board ratings - This group is responsible for the maximum values of input current *Max current (power)* and voltage *Max voltage (power)* on the controller, the maximum current *Max current (usb)* and voltage *Max voltage (usb)* for USB, the minimum voltage *Min voltage (usb)* for USB, and the board temperature *Temperature* (if the temperature is measured on the given controller version).

If the controller current consumption value, power supply voltage or the temperature goes out of the allowed range defined here then the controller turns off all power outputs and switches to *Alarm* state. At the same time the Alarm state information will appear in the main window (window background will change to red) and the out of range parameter value will be displayed in blue or red (below or above the limit respectively).

If the *Low voltage protection* flag is checked the low voltage supply protection is active. Then *Low voltage off* and

below values of input voltage turns the controller into *Alarm* state.

The group **Misc** includes all other critical parameters settings.

Switch off power driver on overheat (> 125 ° C) - this parameter enables the *Alarm* state in case of power driver overheat.

Switch off power driver on H bridge alert - this parameter enables the *Alarm* state in case of the power driver malfunction signal.

Enter Alarm state when edge misset is detected - this parameter enables the *Alarm* state in case of incorrect boundary detection (activation of right limit switch upon moving to the left, or vice versa).

Sticky Alarm flags - locking of Alarm condition. If the *Sticky Alarm flags* check-box is unchecked the controller removes the Alarm flag as soon as it its cause is removed (e.g. in case of over-current the windings are disconnected, which results in the decreased current). If the *Sticky Alarm flags* is enabled, the Alarm mode cause and the *Alarm* mode are canceled by the *Stop* command only.

Reconnect USB on link break - if this option is enabled, then the controller will reset USB link if the connection breaks.

WRM Alarm - checking for errors related to misalignment of the motor windings.

Engine response Alarm - checking engine response errors to the control action.

5.3.4 Power consumption settings

In the *Application settings* **Device -> Power Management**

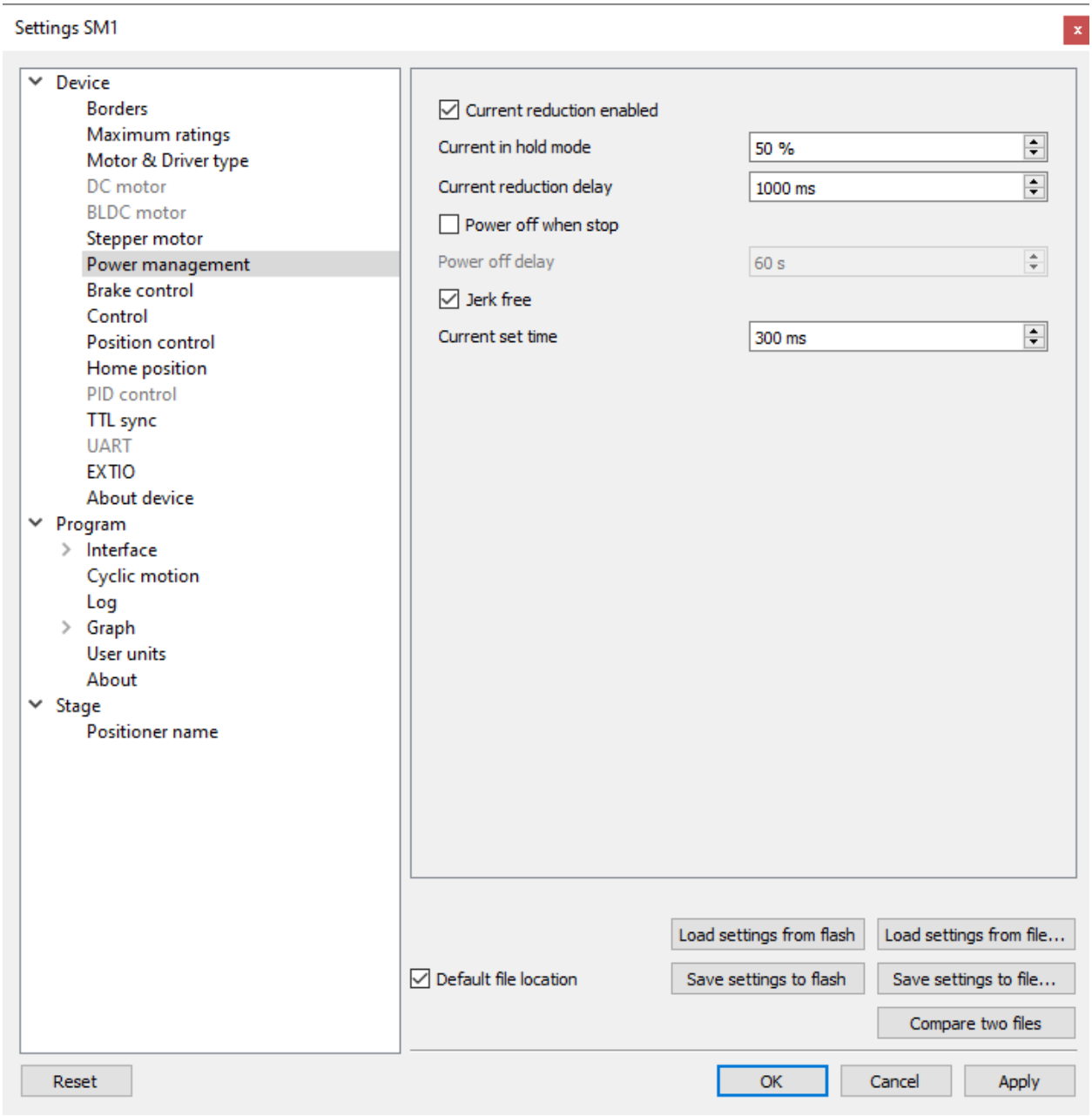


Fig. 5.22: Power consumption settings window

- *Current reduction enabled* - activates the reduced energy consumption mode.
- *Current in hold mode* - it determines the current in the hold mode in % of the nominal value. Value range: 0 .. 100%.
- *Current reduction delay* - parameter determines the delay between switching to the STOP mode and power reduction activation. It is measured in milliseconds. Value range: 0 .. 65535 ms.
- *Power off when stop* - it activates the function that deenergized the motor windings after switching to the STOP state.
- *Power off delay* - parameter determines the delay in seconds between switching to the STOP mode and motor power-off. Value range: 0 .. 65535.

- *Jerk free* - activates the current smoothing function to eliminate the motor vibration.
- *Current set time* - parameter determines the time for jerk free current setting in milliseconds. Value range: 0 .. 65535 ms.

Detailed description of these parameters see in the *Power control* section.

5.3.5 Home position settings

In the *Application settings* **Device -> Home position**

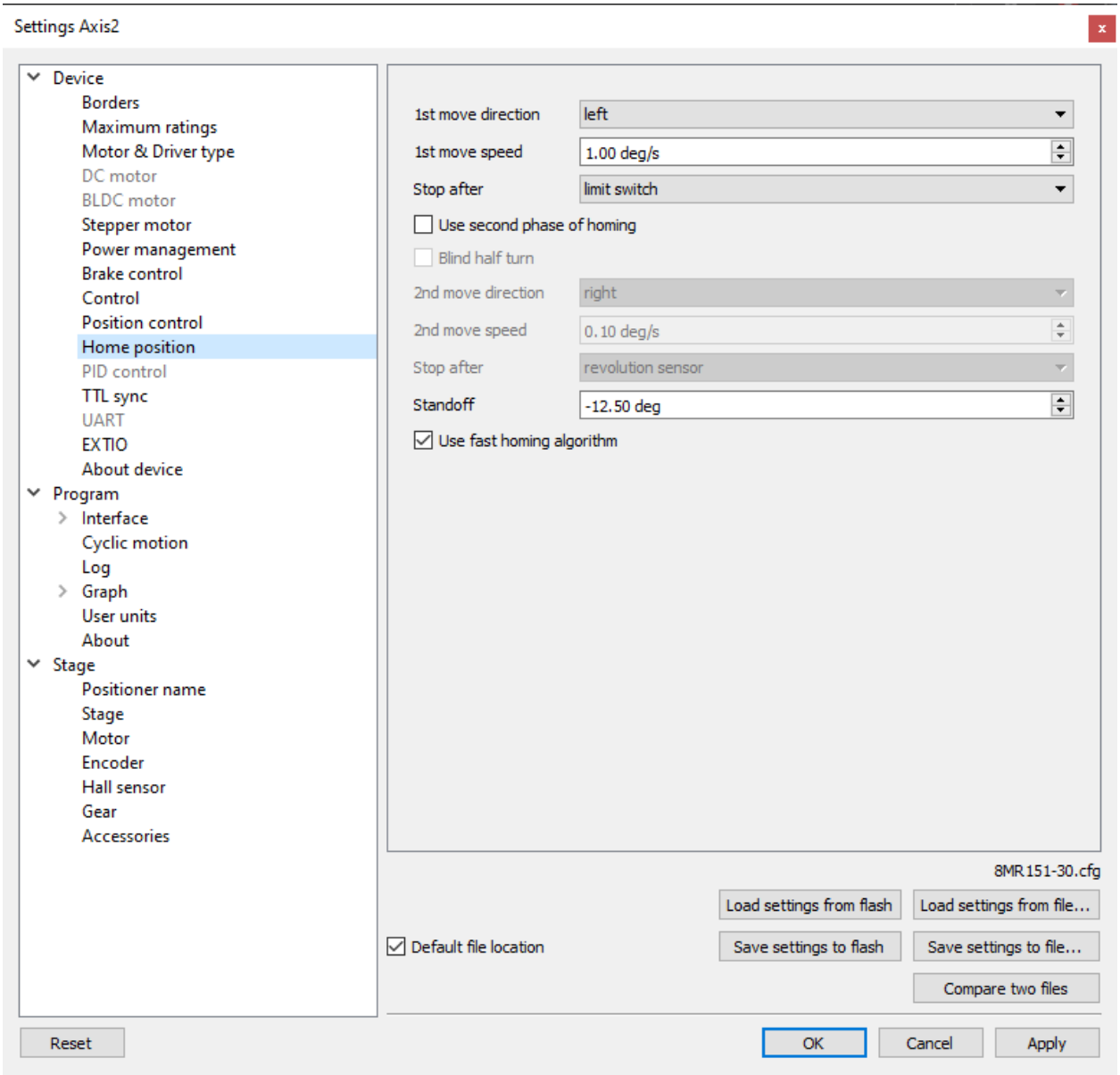


Fig. 5.23: Home position settings window

Tab **Home position** sets the *home position calibration* parameters.

- *1st move direction* - sets the movement direction for the motor to search for a stop signal (right or left) for *standard* and *fast homing algorithms*.

- *1st move speed* - sets the speed for the first phase of the *standard homing algorithm* and the second phase of the *fast homing algorithms*.
- *Stop after* - sets the source of the stop signal (*limit switch*, *revolution sensor* or external *synchronization pulse*).
- *Use second phase of homing* - this flag enables the *accurate additional calibration of the home position* (second phase of the standard calibration algorithm).
- *Blind half turn* - when the flag is set the motor ignores the stop signal for the second phase of homing for half a turn of the motor. This option allows to specify an unambiguous sequence of receiving stop signals for the first and second phases of homing in the case when the sensors are located close enough to each other.
- *2nd move direction* - sets the movement direction for the motor to search for a stop signal (right or left) for the *second phase* of the standard homing algorithm.
- *2nd move speed* - sets the speed for the second phase of the *standard homing algorithm*.
- *Stop after* (in the block of settings for the *second phase of homing*) - sets the source of the stop signal (limit switch, revolution sensor or external synchronization pulse). The signal source may differ from that used for the first phase of homing.
- *Standoff* - sets the distance for the final offset from the reference point. The direction of the offset is given by the sign of the value of this distance (a positive standoff means an offset to the right, a negative standoff - to the left).
- *Use fast homing algorithm* - this flag enables the *fast homing algorithms* to speed up the home calibration procedure.

5.3.6 Synchronization settings

In the *Application settings* **Device -> TTL sync**

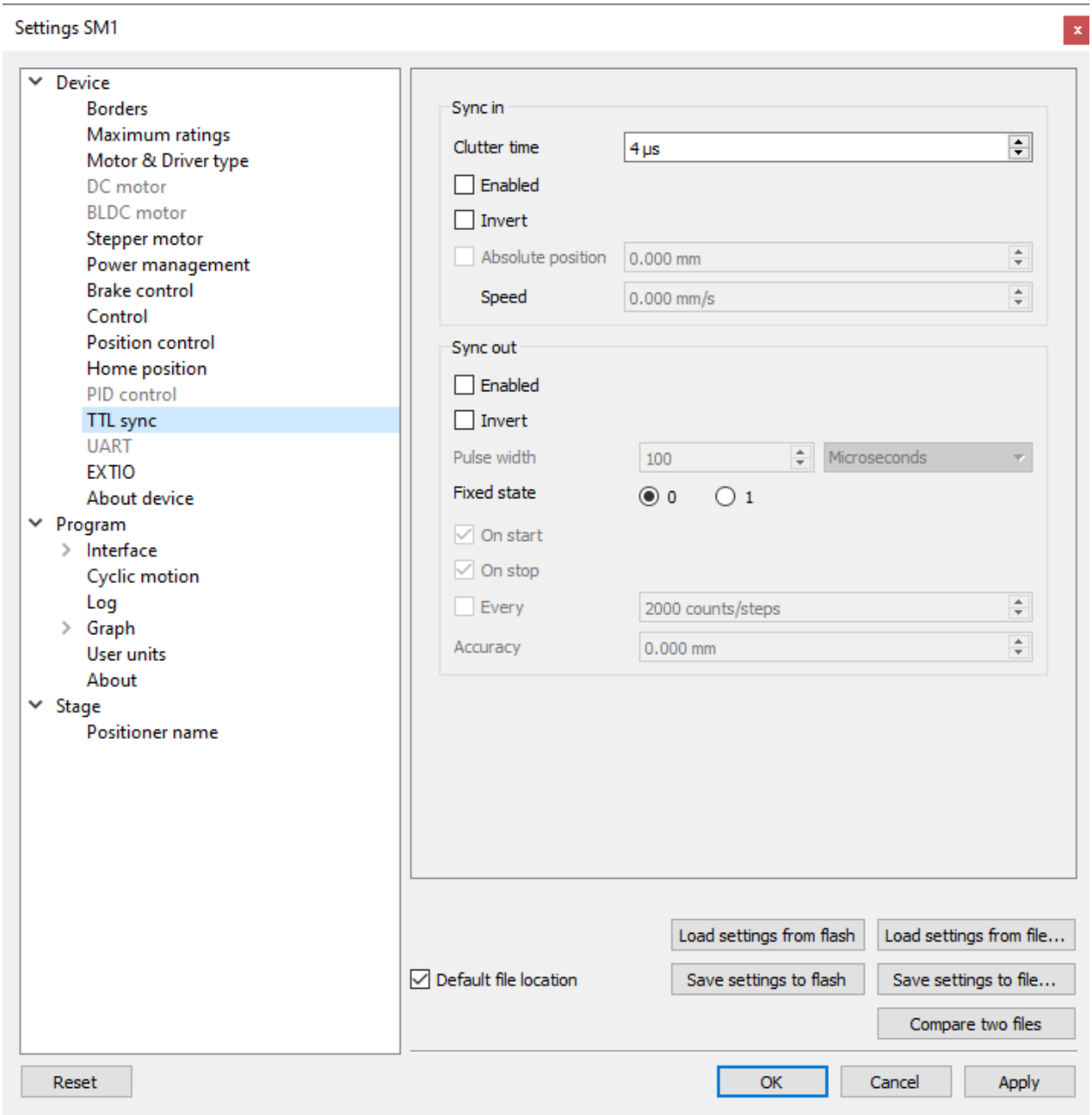


Fig. 5.24: Synchronization settings window

Synchronization is described in details in *TTL synchronization* section.

Sync in:

- *Clutter time* - setting minimum synchronization pulse duration (in microseconds). Defines the minimum duration, which can be detected (anti-chatter).
- *Enabled* - check this box for the sync in mode enable.
- *Invert* - checked flag shows that the operation is triggered by the falling sync pulse edge.
- *Absolute position* - if the flag is checked, upon sync pulse the stage moves into the absolute position specified in the field Step/Micro step. If the flag is unchecked, the shift is relative to the defined destination position.

- *Speed* - the speed to use when moving.

Important: Using the sync input pulse synchronization, to instantly start moving, you need to disable the *jerk free* flag, and it is also recommended to disable the *power off when stop*.

Sync out:

The Synchronization Output can be used as a "General purpose Output signal".

- *Enabled* - if the flag is checked, the sync output functions according to the next settings. If the flag is unchecked, the output value is fixed and equal to the *Fixed state*.
- *Invert* - if the flag is checked the zero logic level is set to active.
- *Pulse width* - specifies the duration of the output signal in microseconds or steps/encoder pulses.
- *Fixed state* - sets the logic level of output to 0 or 1, respectively.
- *On start* - synchronizing pulse is generated at the beginning of movement.
- *On stop* - synchronizing pulse is generated at the end of movement.
- *Every* - synchronizing pulse is generated every n encoder pulses.
- *Accuracy* - distance to the target position. As soon as the distance to target on approach is less than or equal to this distance a synchronizing pulse will be generated if "on stop" option is used.

5.3.7 Brake settings

In the *Application settings* **Device -> Brake control**

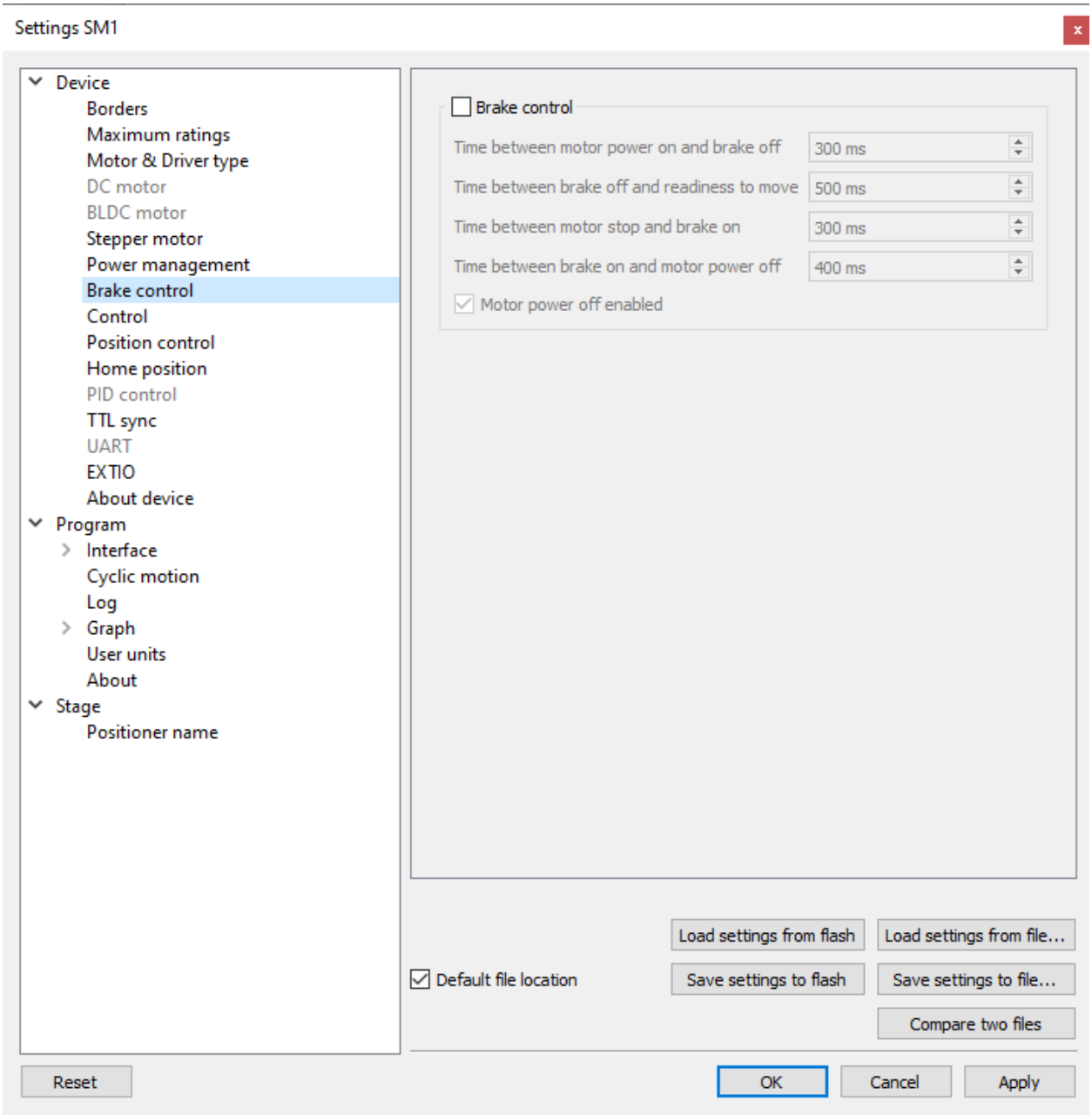


Fig. 5.25: Magnetic brake settings window

Check the *Brake control* flag to enable magnetic brake.

Parameters:

- *Time between motor power on and brake off* - time between switching the motor on and switching off the brake (ms).
- *Time between brake off and readiness to move* - time between switching off the brake and motion readiness (ms). All motion commands will be executed only after this time.
- *Time between motor stop and brake on* - time between stopping the motor and turning on the brake(ms).
- *Time between brake on and motor power off* - time between turning on the brake and motor power-off (ms).

Value range is from 0 to 65535 ms.

- *Motor power off enabled* flag means that when magnetic brake is powered off, the brake turns off motor power supply.

Configuration commands are described in *Communication protocol specification*.

5.3.8 Position control

In the *Application settings* **Device -> Position control**

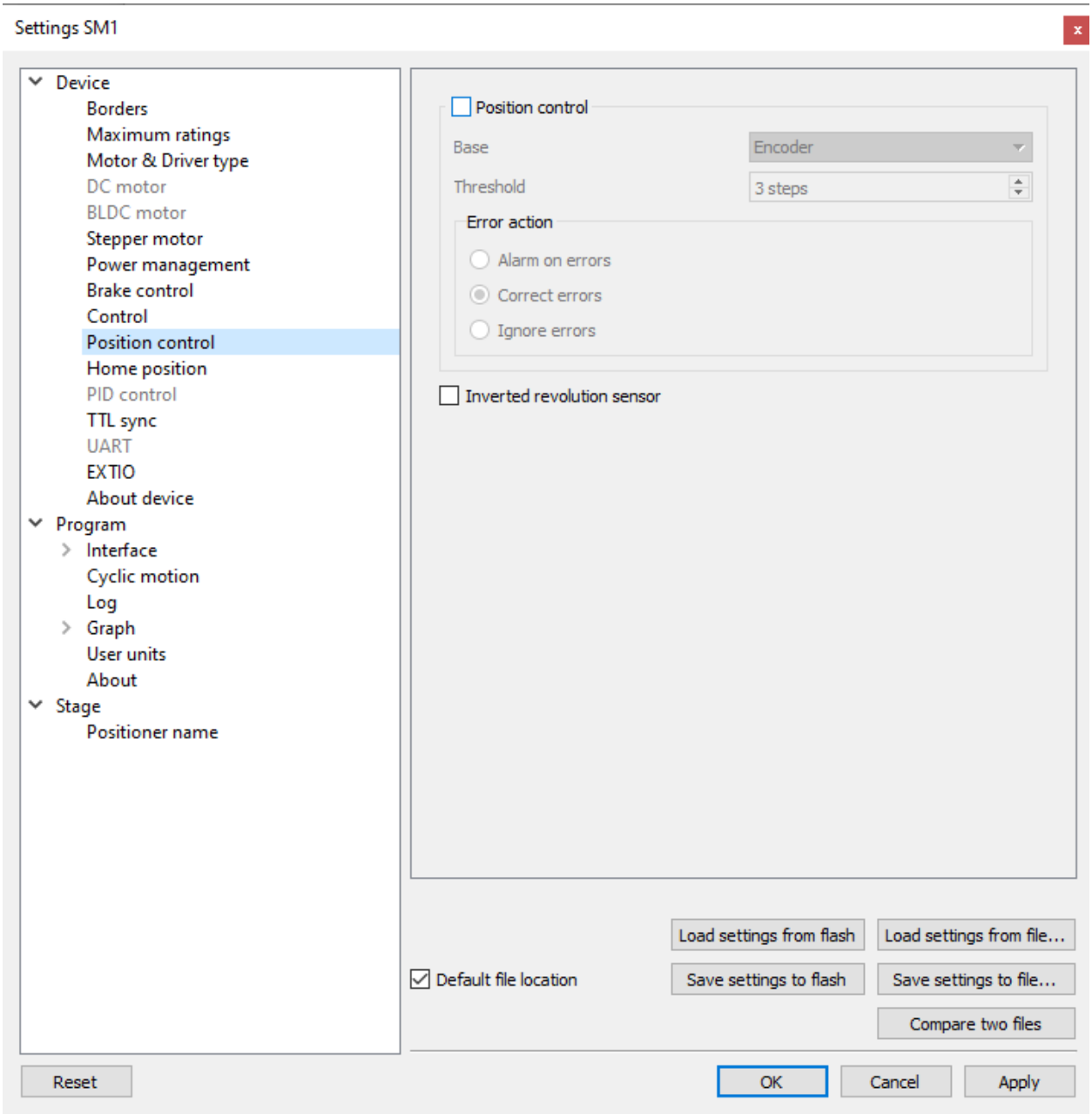


Fig. 5.26: Window of Position control

Check the *Position control* checkbox to activate the position control.

Base - selection of the position control device. You can select an encoder (see *Operation with encoders*) or revolution sensor in the drop-down list.

Threshold - determines the number of missed steps (0 .. 255), which is considered to be an error. If the amount of missed steps exceeds the specified number of steps the SLIP error flag is set. Further actions depend on the *Error action* setting:

If *Alarm on errors* is active then the controller will enter *Alarm state*.

If *Correct errors* is active then the controller will try to correct slip error (see *Steps loss detection*).

If *Ignore errors* is active then the controller will do nothing.

Inverted revolution sensor - if the flag is checked the revolution sensor is triggered by the level 1. Unchecked flag means usual logic is valid - 0 is the trigger/activation/active state.

Configuration commands are described in the *Communication protocol specification*.

Important:

- **Feedback none**: in this mode, "Position control" is useful and should be used. "Position control" compares the position by the encoder/position sensor and recalculates it in steps. If there is a discrepancy between positions, a moving indicator "SLIP" will light up in the bottom of mDrive Direct Control main window. In addition, if "Alarm on errors" is marked, the controller will enter an alarm state.
- **Feedback encoder**: "Position control" does not need to be used because the position is strictly controlled by the encoder.
- **Feedback EMF**: the algorithm should not be used with the "Position Control" flag enabled. For smooth running in the EMF algorithm, a discrepancy between the actual position and the profile position is implemented. If "Position Control" flag is enabled, false Alarms may be triggered.
- **Feedback encoder mediated**: it is not recommended to enable the "Position Control" flag. While driving, the algorithm does not differ from the "none" mode, but when the engine arrives at a position, the actual position is compared to the desired position on the encoder, after which the algorithm compensates for the discrepancy in positions until the position on the encoder becomes desirable. Thus, if the "Position Control" flag is enabled, the SLIP flag and Alarms can be triggered.

5.3.9 Settings of external control devices

In the *Application settings* **Device -> Control**

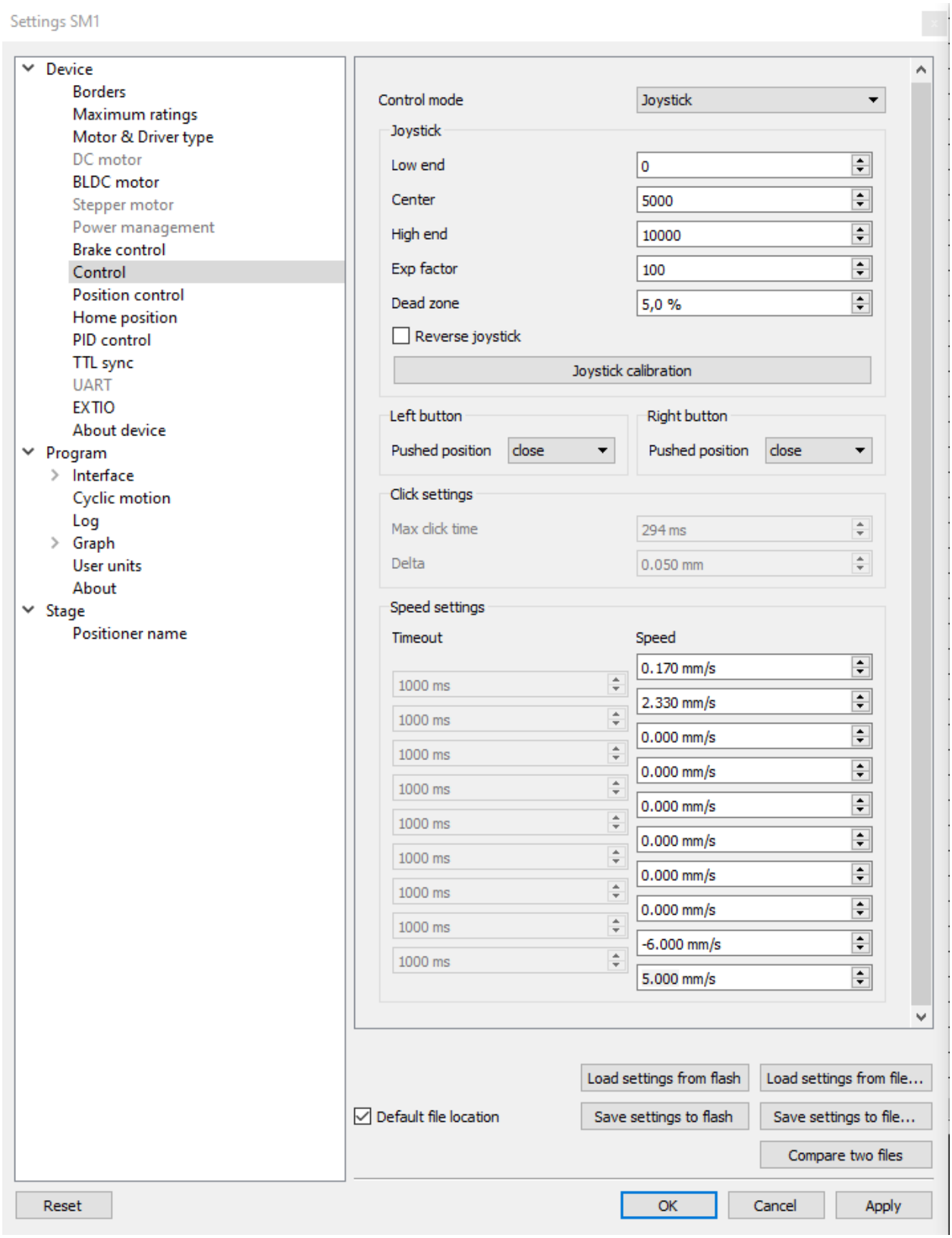


Fig. 5.27: Settings of external control devices window

Control mode - range of external motor control devices.

- *Control disabled* - external devices are not used
- *Joystick* - *joystick* is used
- *Buttons* - *buttons* are used

Important: In Joystick control mode, the physical and virtual buttons remain in working order

---

Joystick block contains joystick settings.

Low end, *Center* and *High end* determine the lower border, the middle and the upper border of joystick range respectively. Hence the joystick ADC normalized value equal to or less than *Low end* corresponds to the maximum joystick deflection towards lower values.

Exp factor - exponential nonlinearity parameter. See *Joystick control*.

Dead zone - dead zone of joystick deviation from the center position. Minimum step of variation: 0.1, the maximum value is 25.5. The joystick deviation from *Center* position by less than *Dead zone* value corresponds to zero speed.

Reverse joystick - reverse the joystick effects. Joystick deviation to large values results in negative speed and vice versa.

Button *Joystick calibration* opens calibration dialog box.

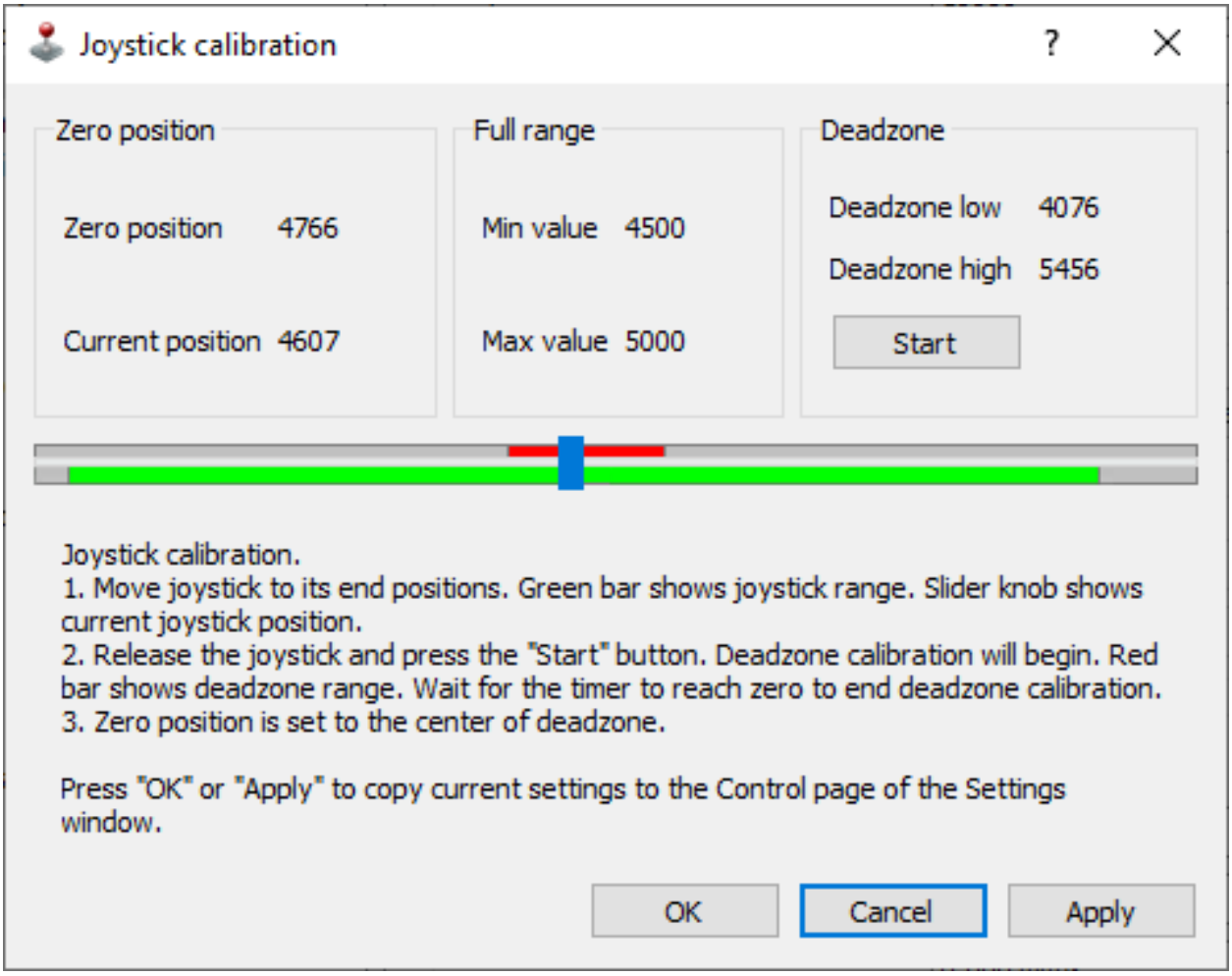


Fig. 5.28: Dialog box of Joystick Calibration

Calibration is automatic border and the dead zone detection. Below is the process description:

Move the joystick to extremes to determine the borders. The range of all measured values is represented in a green line.

Release the joystick and press the Start to initiate detection of the dead zone. Within 5 seconds imitate accidental influences on the joystick, which should not be recognized as deviation from the joystick zero position. The dead zone range is represented in red.

Pressing the Apply button will send the computed values into the Settings window. Pressing OK button will send the values and close the calibration dialog box.

Left button and **Right button** blocks contain the settings of the physical buttons.

Pushed Position - determines the state (pressed or released button) which is considered the motion signal by the controller.

- *Open* - released button is considered to be a motion command.
- *Close* - depressed button is considered to be a motion command.

Click settings block lets one to set up button “click” behaviour. A rapid press of a button is interpreted as a “click”.

Max click time - maximum click time. Until this amount of time is elapsed controller will not start moving with first speed (see below).

Delta - relative position offset. Controller will do a shift on offset with each click.

Speed settings block contains timeout and speed settings.

Timeout [i] - the time after which the speed switches from Speed[i] to Speed[i+1]. If any of the Timeout[i] is equal to zero, no switching to the next speeds will occur.

Speed[i] - speed of the motor after time equal to Timeout[i-1]. If any of the speeds is equal to zero, no switching to this and subsequent speeds will occur.

Configuration commands are described in *Communication protocol specification*.

5.3.10 General purpose input-output settings

In the *Application settings* **Device -> EXTIO**

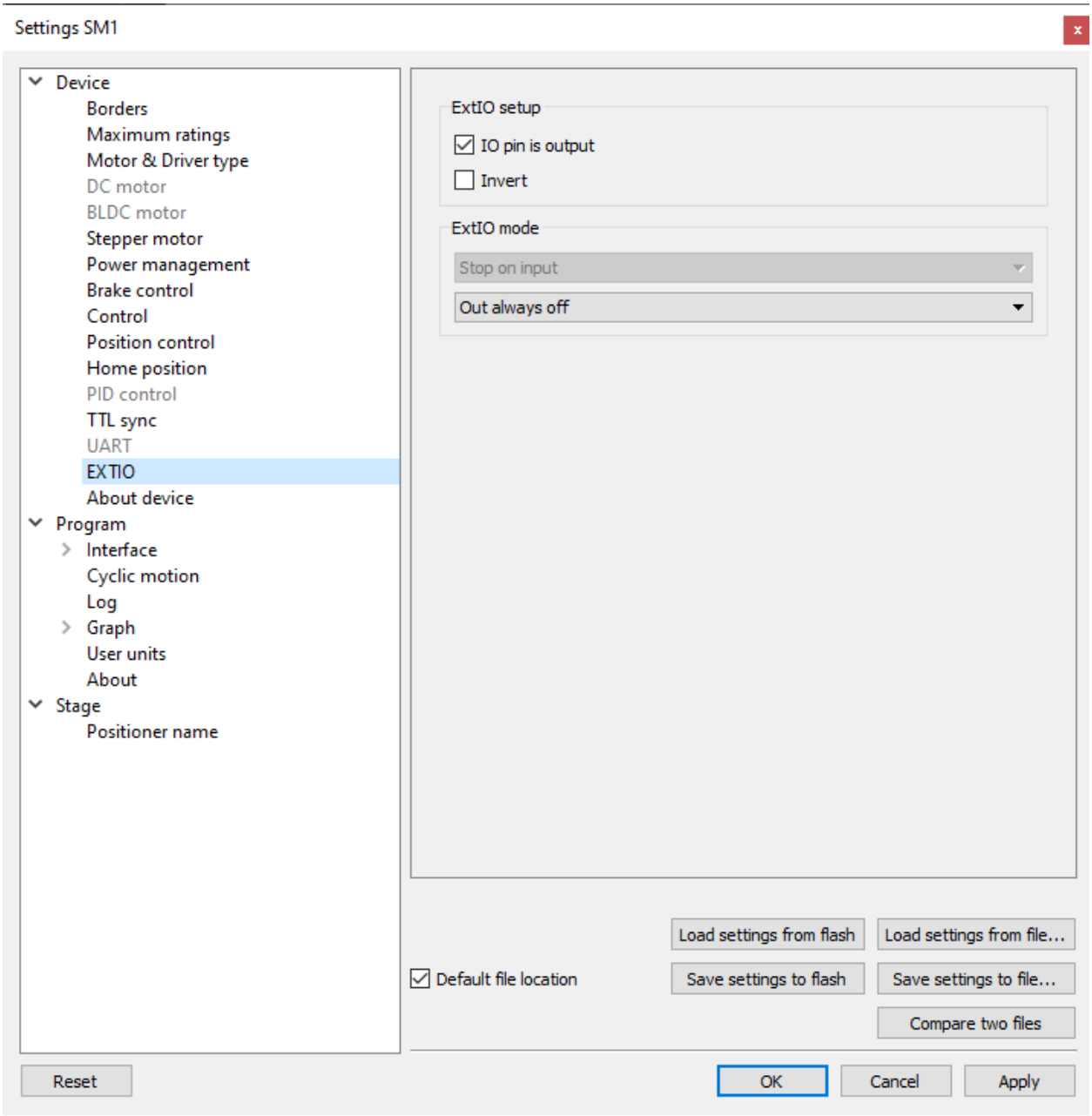


Fig. 5.29: General purpose input-output settings tab

For detailed information, please see *General purpose digital input-output (EXTIO)*.

ExtIO setup

IO pin is output - if the flag is checked the needle of ExtIO works in output mode, otherwise - in the input mode.

Invert - if the flag is checked the rising edge is ignored and the falling edge is active.

ExtIO mode - mode selection

If ExtIO configured for input mode the choice of controller action settings by the input pulse is active:

- *Do nothing* - do nothing.

- *Stop on input* - run *Command STOP*.
- *Power off on input* - run *Command PWOF*.
- *Movr on input* - run *Command MOVR*.
- *Home on input* - run *Command HOME*.
- *Alarm on input* - enter ALARM state.

If ExtIO configured for output mode the choice of the output state depending on the controller status is active:

- *Out always off* - always in inactive state.
- *Out always on* - always in active state.
- *Out active when moving* - in active state during motion.
- *Out active in Alarm* - in active state if the controller is in the Alarm state.
- *Out active when motor is on* - in active state if the motor windings are powered.
- *Out active when motor is found* - in active state if the motor is connected.

5.3.11 Motor type settings

In the *Application settings* **Device -> Motor & Driver type**

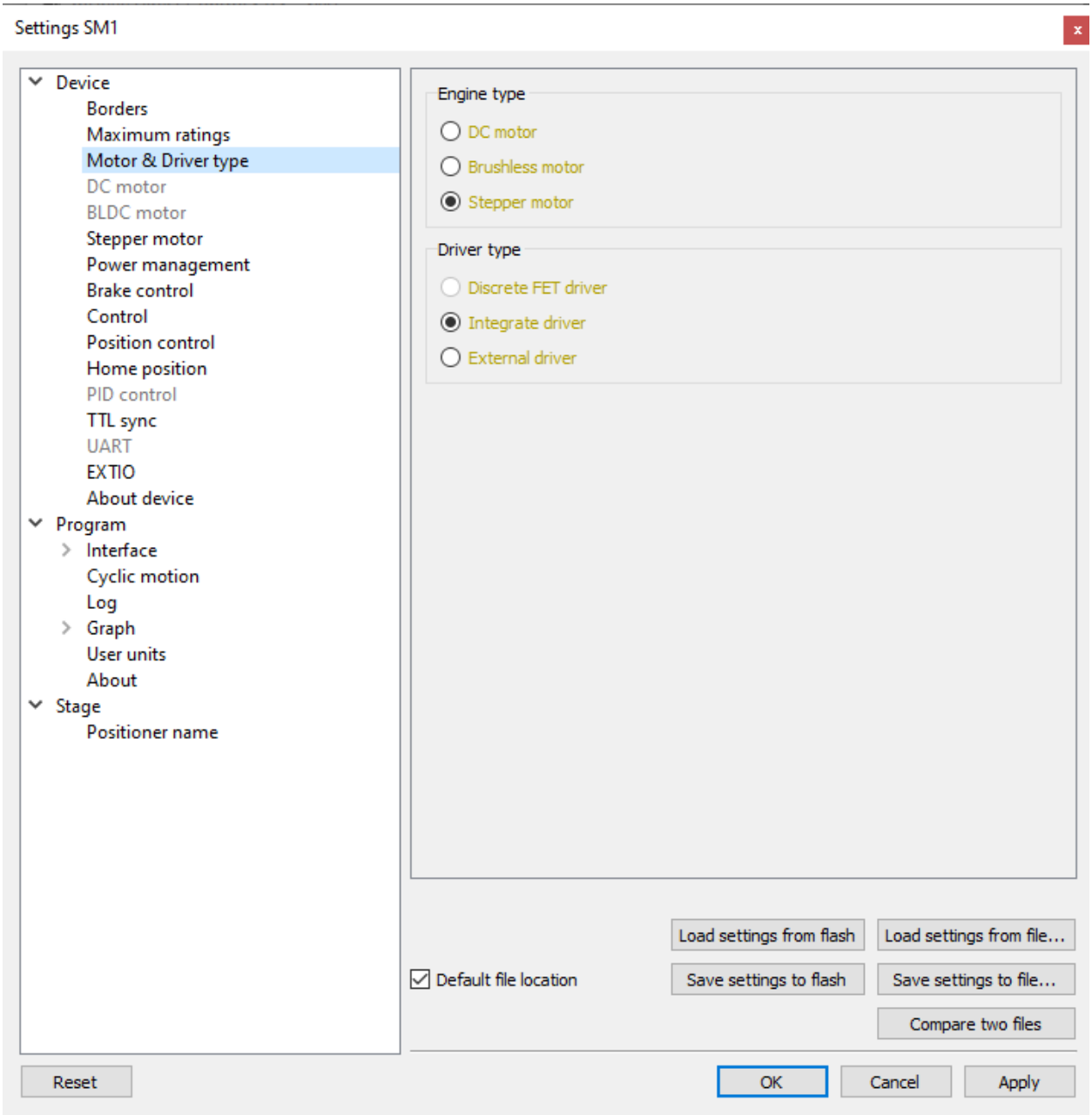


Fig. 5.30: Motor type settings window

Stepper motor or *BLDC-motor* - motor type indication. Control power driver should be selected as well:

- Integrated. This type is used for this controller modification.
- Discrete FET driver. Will be used in future versions.

Warning: Driver type or motor type change is a critical operation that should not be performed while motor rotates. To implement the change correctly the motor winding should be de-energized and turned off, after that motor type can be changed and motor of another type can be connected. The same applies to changing of integrated driver to external one and vice versa.

Note: Available motor types are determined by your firmware upgrade. Available control drivers depend on the controller board type, except for the external driver.

5.3.12 Settings of PID control loops

In the *Application settings* **Device -> PID control**

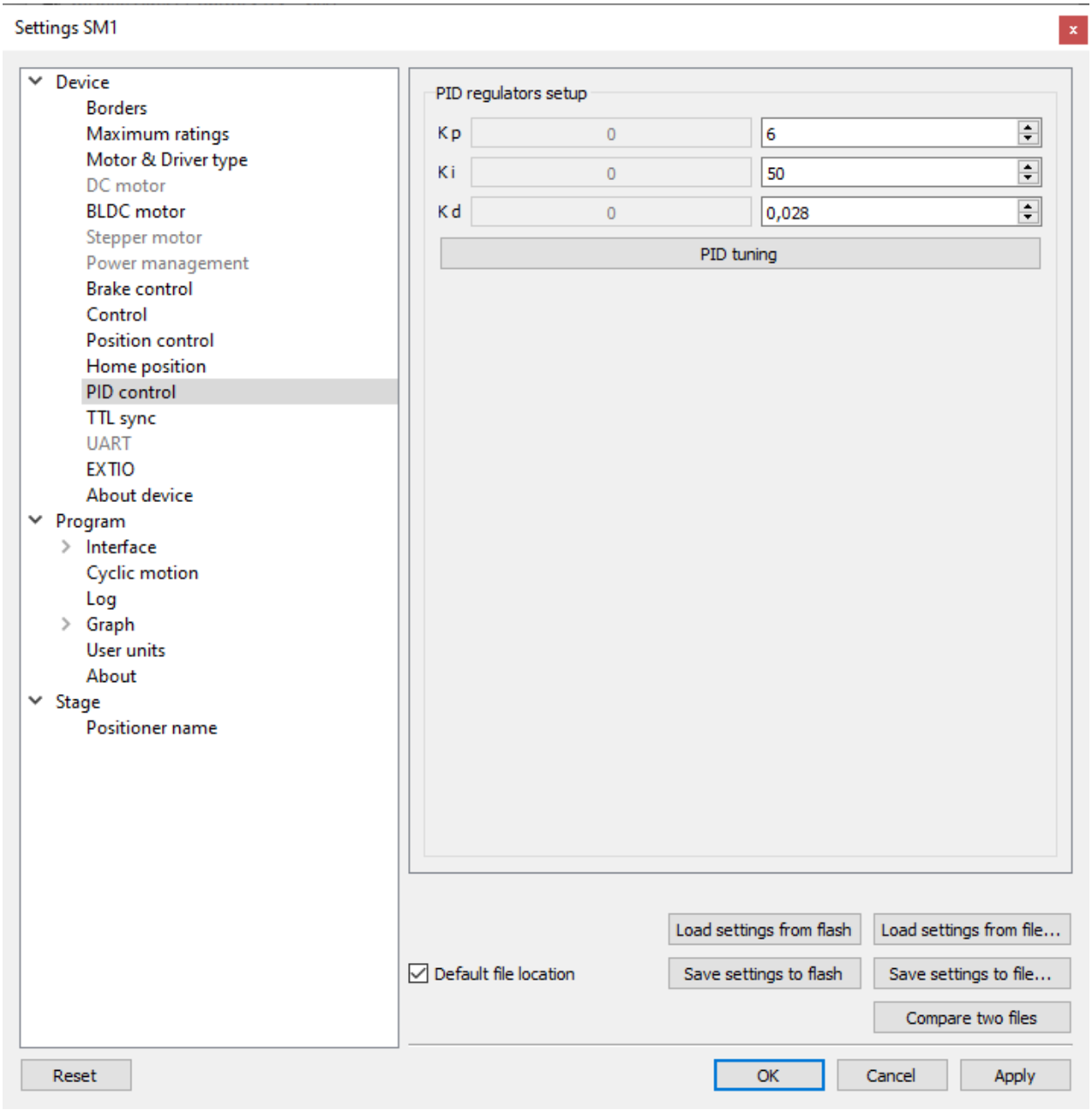


Fig. 5.31: Settings of PID control loops window

In this section, you can change the PID coefficients. A voltage PID is used, K_p, K_i and K_d coefficients can vary in 0..65535 range for BLDC motors.

Fractional PID coefficients (on right) are only for BLDC motor.

Warning: Do not change the settings of PID controllers, if you are not sure you know what you are doing!

Configuration commands are described in the *Communication protocol specification*. PID tuning is described in detail in the *PID-algorithm for BLDC engine control* section.

5.3.13 About controller

In the *Application settings* **Device -> About device**

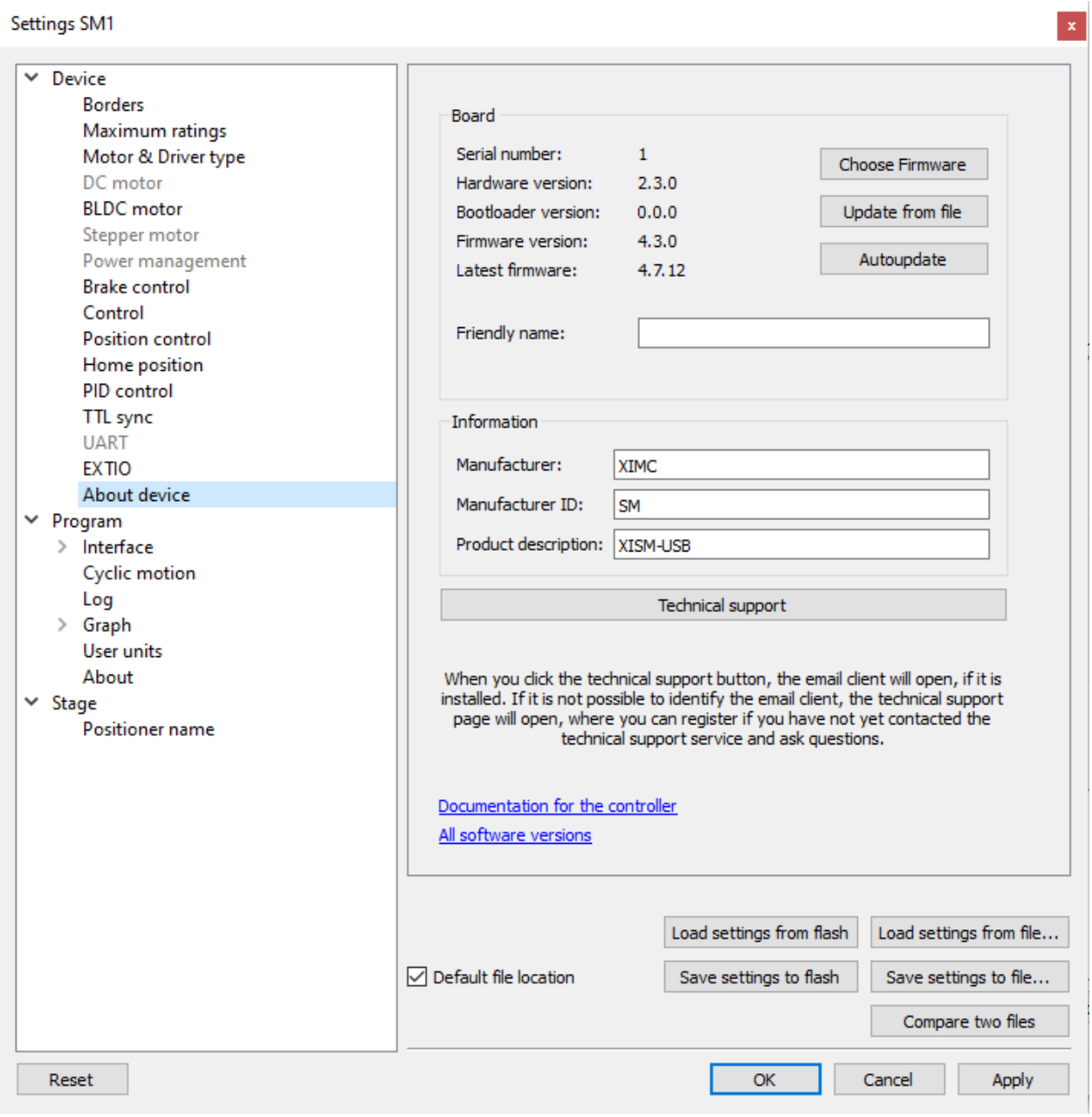


Fig. 5.32: About device tab

The **Board** section displays information about the controller:

- *Serial number* - device serial number.
- *Hardware version* - hardware version.
- *Bootloader version* - bootloader version.
- *Firmware version* - firmware version.
- *Latest firmware* - latest available firmware version for this device (downloaded from the internet if internet connection is available).
- The *Update from file* button opens firmware update dialog box.

Select the firmware file with the .cod extension and click Open. mDrive Direct Control will start the firmware update and will display "Please wait while firmware is updating". Do not power off the controller during the upgrade. Upon completion of the update the "Firmware updated successfully" dialog will be displayed.

The *Choose Firmware* button opens a dialog with firmware version numbers. Pick a number and press "Update firmware" to update to selected version. An appropriate firmware file will be downloaded from the internet and loaded into the controller. This feature requires an active internet connection.

The *Autoupdate* button automatically updates firmware from the internet to the latest available version.

Friendly name - an arbitrary user-defined name for the controller. If this string is not empty, then it will replace device id and serial number in window titles. This is a convenience feature for situations with multiple controllers connected to the same PC.

Information block contains information about the device: the manufacturer, device ID, device type. The data are read from the internal memory of the controller.

All of this data is reported to the mDrive Direct Control application when the device is connected.

5.3.14 Settings of kinematics (BLDC motor)

In the *Application settings* **Device -> BLDC Motor**

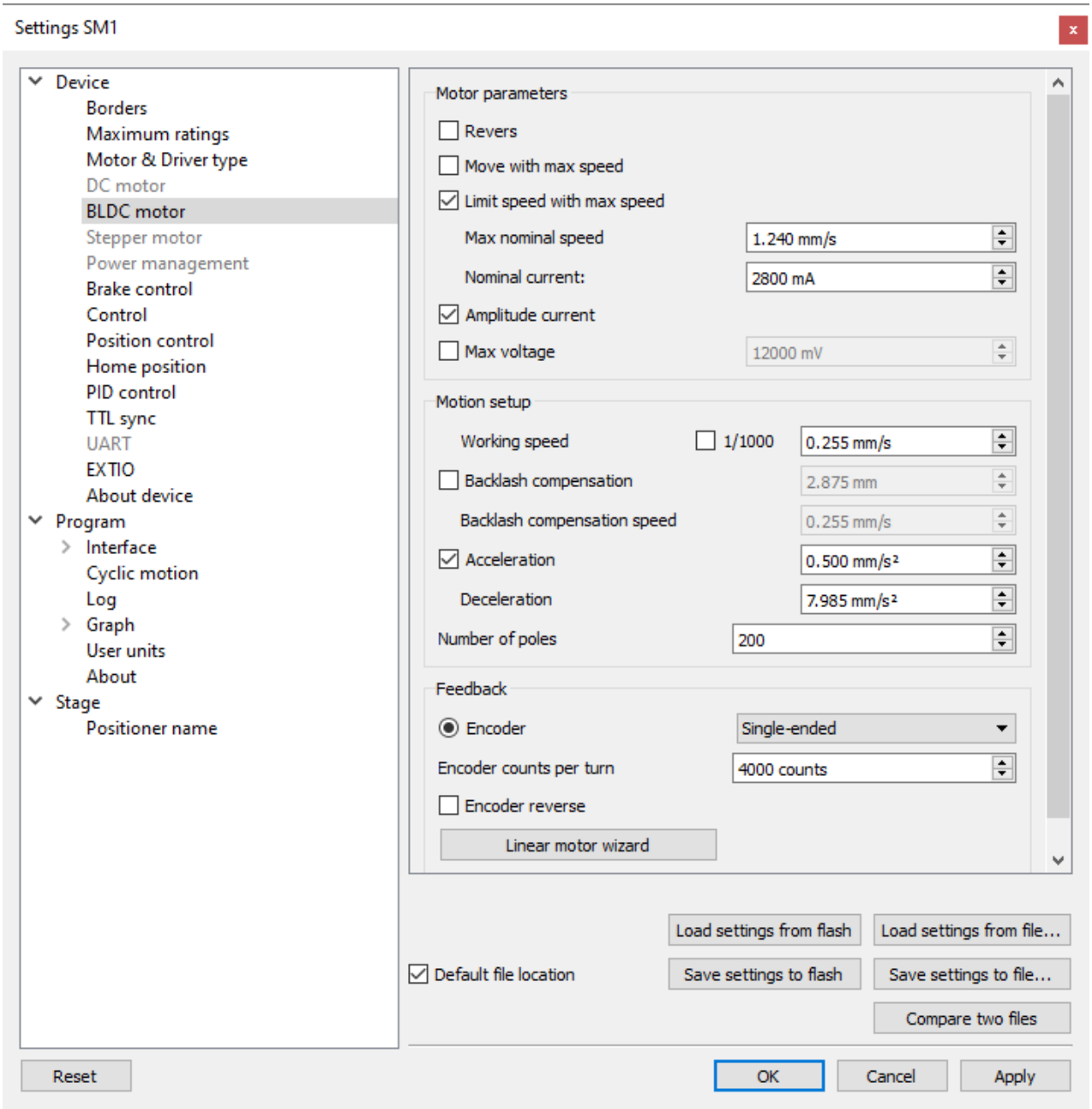


Fig. 5.33: Settings of kinematics (BLDC motor) window

5.3.14.1 Motor parameters - electric motor settings

Revers - checking this flag associate the motor rotation direction with the current position counting direction. Change the status of the flag if positive motor rotation decreases the value on the position counter register. This flag effect is similar to connecting the motor winding to reverse polarity.

Move with max speed - if this flag is checked motor ignores the preset speed and rotates at the maximum speed limit.

Limit speed with max speed - if this flag is checked the controller limits the maximum speed to the number of steps per second, specified in the *Max nominal speed* field.

Max nominal speed, Max voltage - are motor nominal parameters. If they are active and applicable for given type of

motor, the controller limits these parameters within the specified values. For example, if the motor speed and current exceeds the nominal values, the controller will reduce output action until both values are within the normal range. However, the controller remains in operational condition, and will execute the current task.

Important: "Max voltage" is the maximum voltage between any two terminals of the BLDC motor. At the same time, the voltage at each terminal relative to the controller's ground (this voltage is shown on the graphs "Winding A Voltage", "Winding B Voltage") may exceed "Max voltage".

Amplitude current - if this flag is checked engine current value is interpreted as maximum amplitude value. If the flag is unset, then engine current value is interpreted as the current value calculated from the maximum heat dissipation. See *Calculation of the nominal current* page for description

5.3.14.2 Motion setup - settings related to the movement kinematics

Working speed - movement speed.

Flag 1/1000 - allows you to work at ultra-low speeds. If the flag is enabled, the value from the "Working speed" field will be divided by 1000.

Backlash compensation - backlash compensation. Since the stage mechanics are not ideal there is a difference between approaching a given point from the right and from the left. When the backlash compensation mode is on the stage always approaches the point from one side. The preset value determines the number of steps which the stage takes to pass a given point in order to come back to it from the same side. If the specified number is above zero the stage always approaches the point from the right. If it is below zero the stage always approaches the point from the left.

Backlash compensation speed - speed of backlash compensation. When the backlash compensation mode *Backlash compensation* is on the stage approaches the point from the right or from the left with a preset speed determined in the number of steps per second.

Acceleration - enables the motion in acceleration mode, the numerical value of the field is the acceleration of movement.

Deceleration - movement deceleration.

Number of poles - number of poles per revolution.

5.3.14.3 Feedback settings

Encoder - use of *encoder* as a feedback sensor. The following encoder types are available: Single-ended, Differential or Autodetect.

Encoder counts per turn - this parameter defines the number of encoder pulses per one motor axis full rotation.

Linear motor wizard - open dialog for setting linear stages parameters.

5.4 mDrive Direct Control application settings

5.4.1 General motor settings

In the *Application settings* **Program -> Interface -> General motor**

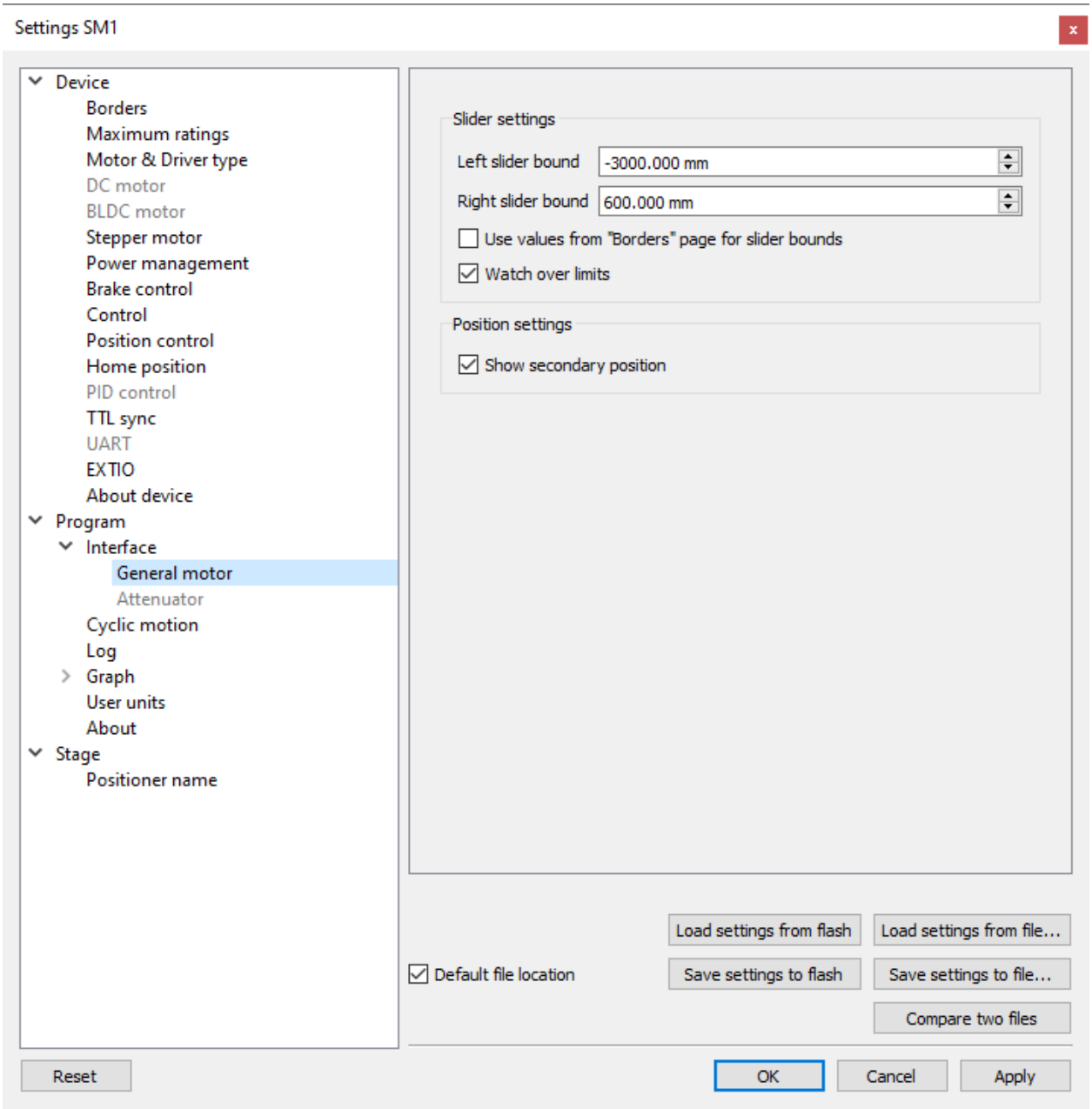


Fig. 5.34: General motor settings tab

This tab configures the slider display settings and secondary position display settings for a general motor device. The position slider is located in the *main window* and visually represents the stage current position relative to the borders.

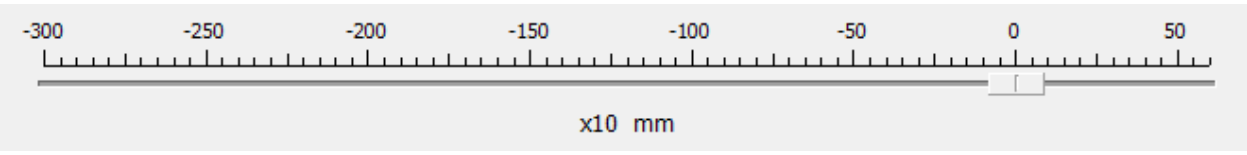


Fig. 5.35: Fragment of Main application window containing slider

Slider settings group contains the following slider settings:

Left slider bound and *Right slider bound* contain the coordinates of the left and right bounds of the slider respectively.

If *Watch over ltimits* is checked then upon moving out of the slider range, the scale shifts to display the current position. However, he total distance displayed on the slider remains unchanged. This option is not used by default. It is useful when you know the stage motion range, but do not know the relation of that position to the values displayed in mDrive Direct Control, e.g. for the calibration purposes. The option is often used together with the settings of the tab *Home position settings*.

Position settings group contains the position display settings.

If *Show secondary position* is checked then a secondary position is shown in the main application window.

5.4.2 Cyclical motion settings

In the *Application settings* **Program -> Cyclic motion**

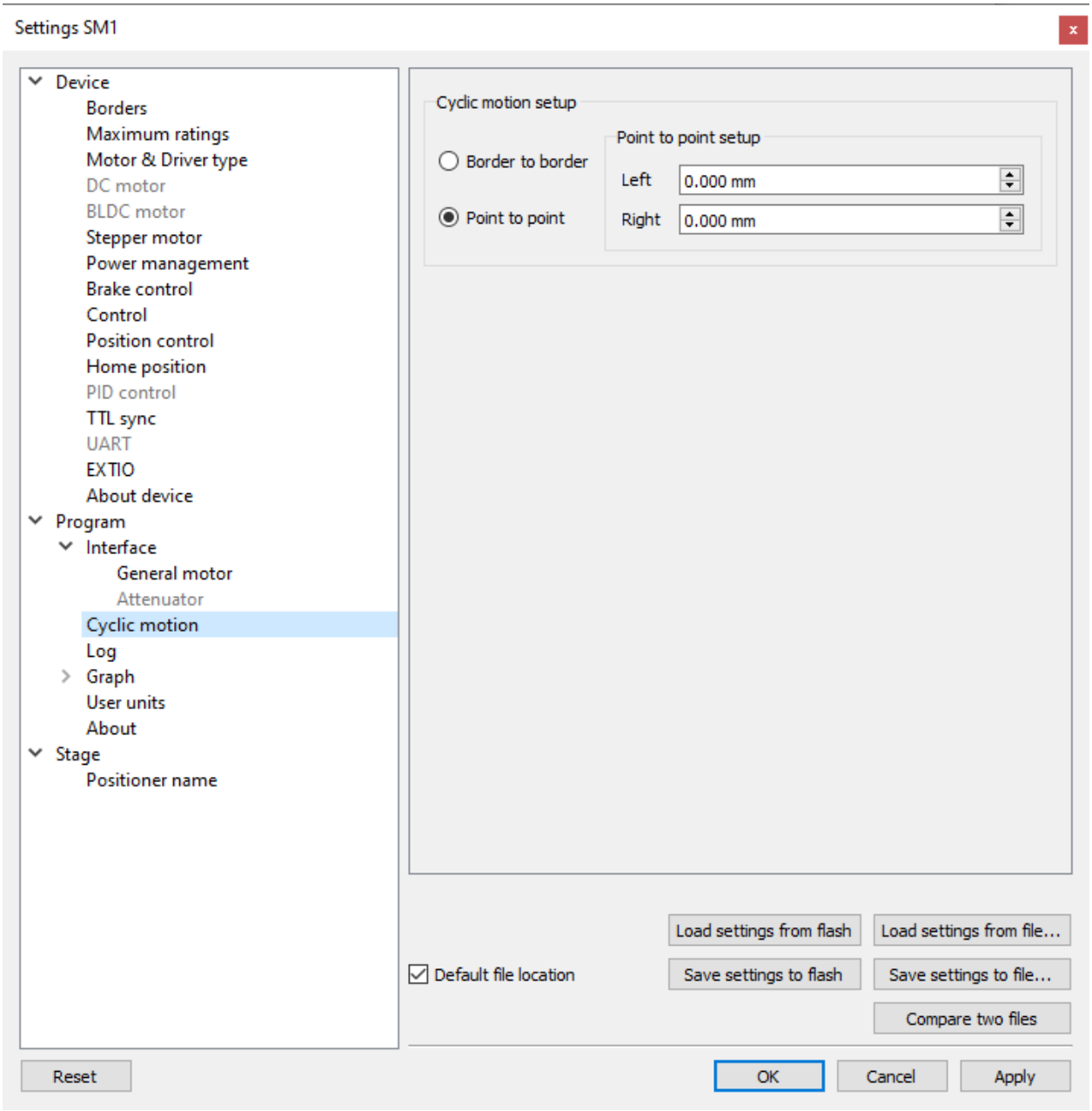


Fig. 5.36: Cyclic motion tab

Use this tab to configure the cyclic motion between two preset positions. It is used mainly for demonstration purposes. This mode is activated by *Cyclic* button in the *main window*, and deactivated by *Stop* button in the *main window*.

Cyclic motion mode settings:

Border to border - cyclical motion between the borders configured in the *Motion range and limit switches*. The motion begins towards the left edge.

Point to point - cyclical motion between points specified in the *Point to point setup* group. The stage moves to the left point, stops, then moves to the right point, stops, and then the cycle repeats.

5.4.3 Log settings

In the *Application settings* **Program -> Log**

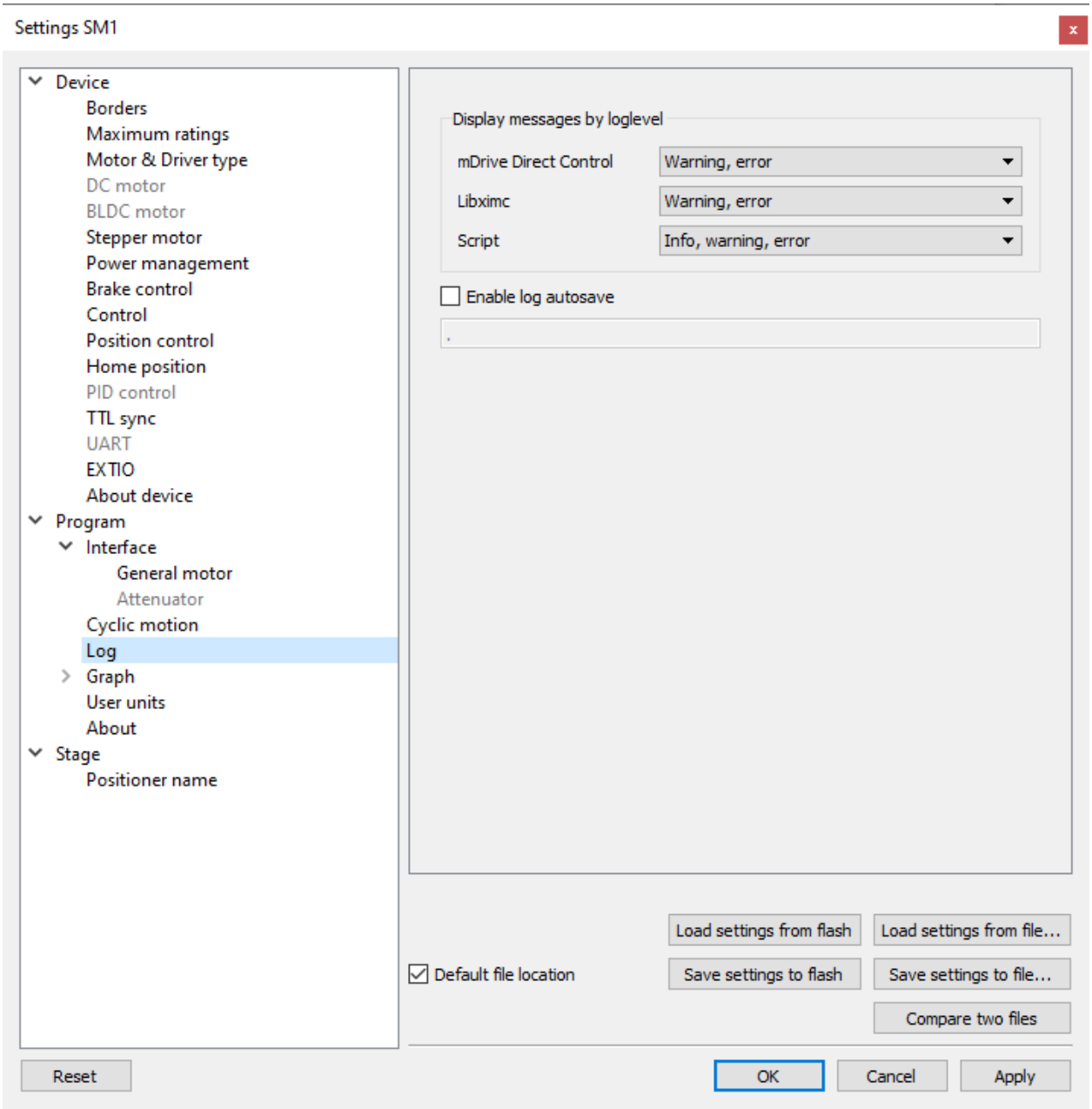


Fig. 5.37: mDrive Direct Control log settings window

On this tab you can configure the logging detail level.

In *Display messages by loglevel* box you can choose an option to log nothing (None), log only errors (Error), errors and warning messages (Error, Warning), errors, warnings and information messages (Error, Warning, Info) for each source: mDrive Direct Control application, libximc library and Scripts module.

If the *Enable log autosave* checkbox is checked then the log is saved into file. Directory where the log file will be saved is set below. Log file is flushed to the disk every 5 seconds.

File has a name of type "xilab_log_YYYY.MM.DD.csv", where YYYY, MM and DD are current year, month and day, respectively. Data is stored in CSV format. Messages that are saved into the log file are not filtered by logging options.

5.4.4 Charts general settings

Program -> Graph in the *Application settings*

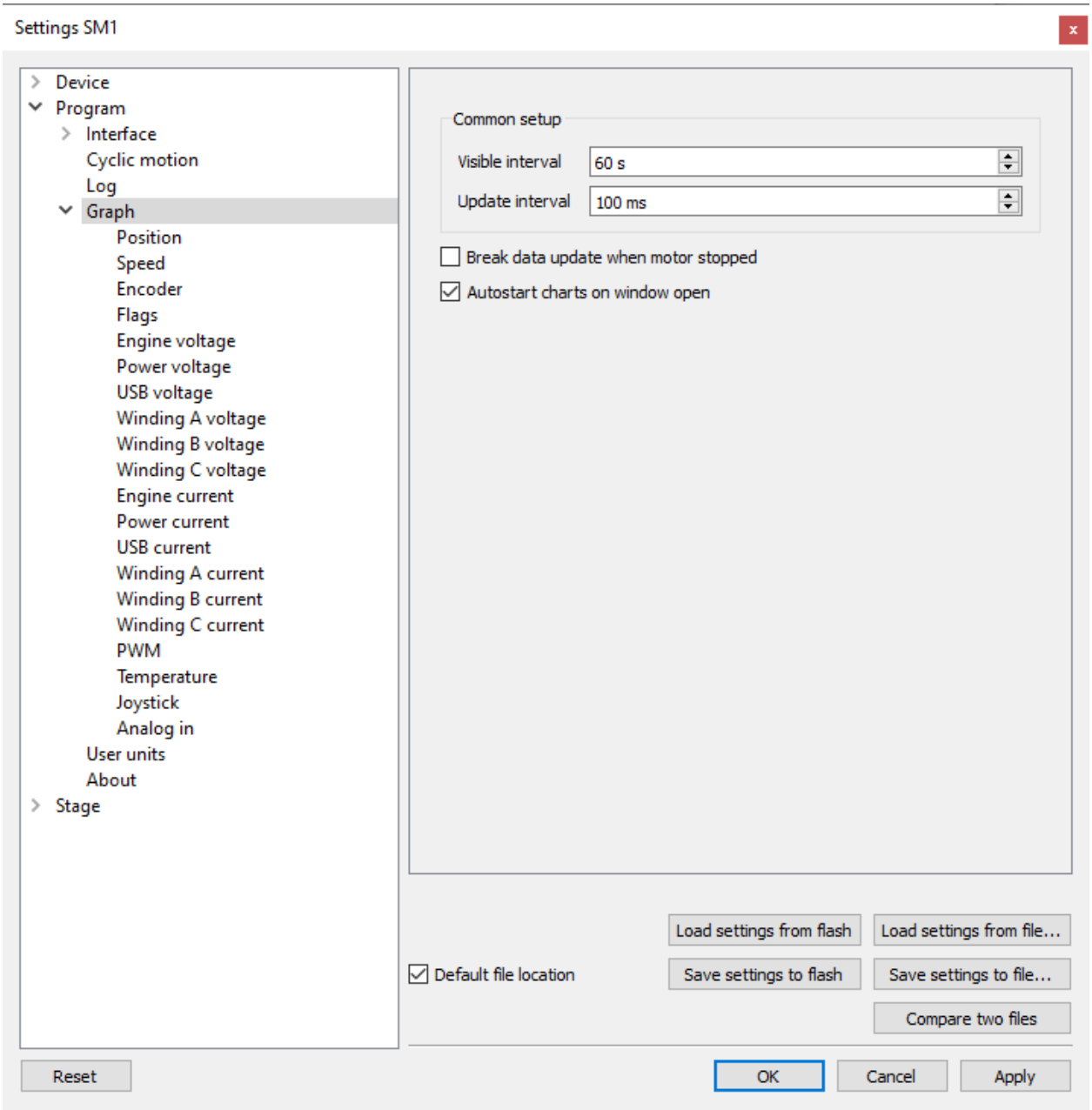


Fig. 5.38: Charts general settings tab

Visible interval - the time interval displayed in charts on the horizontal axis.

Update interval - chart data update interval.

Break data update when motor stopped - stops drawing charts when the motor stops. This option provides the possibility to use the chart space more rationally, removing the areas when there is no motor motion.

Autostart charts on window open - starts displaying chart data automatically on window open. If you wish to start charts update manually, then uncheck this option.

5.4.5 Charts customization

Individual chart display settings are set in the *program settings windows* **Program -> Graph -> ...**

Charts display settings include line style and chart vertical axis scale adjustment.

For example, the Position tab:

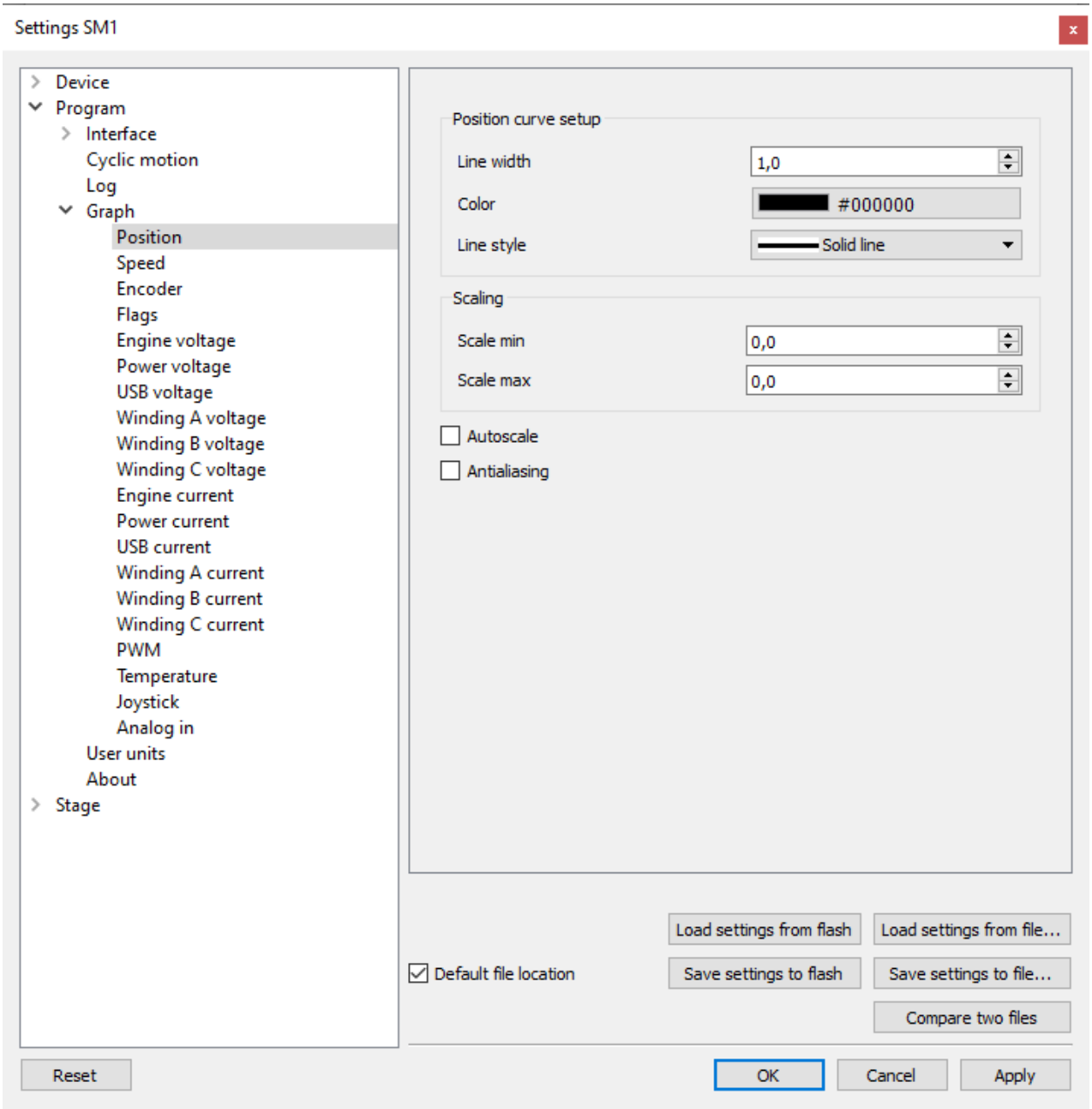


Fig. 5.39: Charts customization on the example of the position chart tab

Position curve setup group changes curve parameters. It includes the *Line width*, *Color* and *Line style*.

Scaling group changes curve display range on the vertical axis by setting values in *Scale min* and *Scale max*.

Checked *Autoscale* flag results in auto-scaling of the scale limits in accordance with the change limits of the variable on the axis Y. In this case, the parameters *Scale min* and *Scale max* are ignored.

Antialiasing flag enables chart lines smoothing, which provides the possibility to achieve a higher-quality display, but it slows a little the chart drawing process.

Similar graph display parameters can be set in the other tabs of the Graph section, such as Speed, Encoder, Flags, Engine voltage and others.

5.4.6 User units settings

In the *Application settings* **Program -> User units**

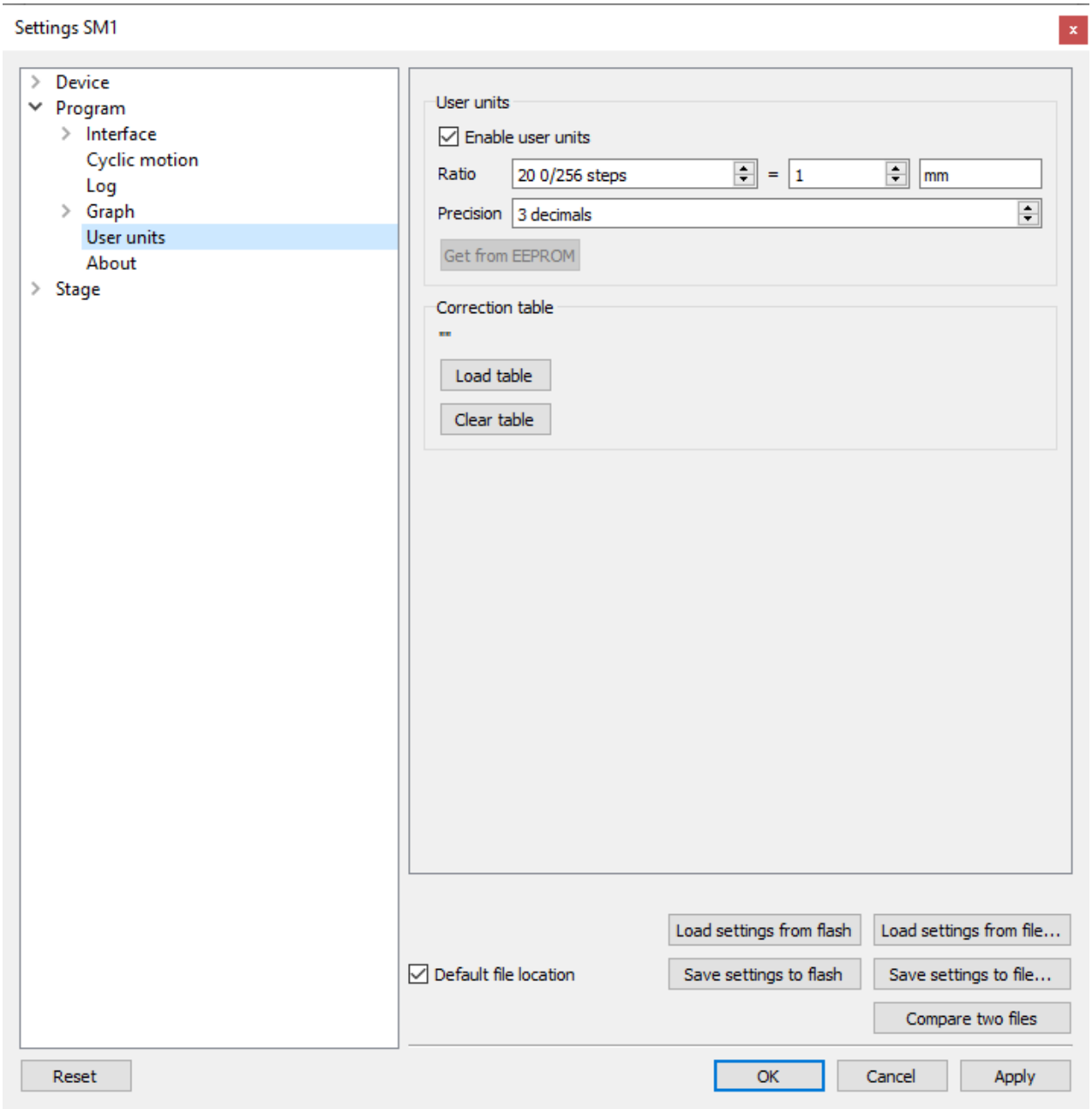


Fig. 5.40: User units tab

Use this tab to configure user units display. Used to replace internal controller coordinates with units familiar to the user. This tab also allows you to use the *coordinate correction table* for user units. The coordinate correction table allows you to significantly improve the positioning accuracy when using custom units.

5.4.6.1 User units

Enable user units - enables user unit display instead of steps (in case of stepper motor) or encoder counts (in case of BLDC motor). User units replace steps(counts) only in the main mDrive Direct Control window and do not affect any of the Settings pages.

Ratio - conversion of controller steps to position units, set as a ratio of two integer values “x steps = y user units”.

Values “x”, “y” and unit name string are set by user.

Precision - displayed precision.

5.4.6.2 Coordinate correction table for more accurate positioning

Some functions for working with user units allow you to use the coordinate correction table for more precise positioning.

Load table - loads the *coordinate correction table*. If it is successfully loaded, the file name of the loaded table appears to the right of the button. From this moment certain _calb functions that perform the re-count procedure of coordinates using the correction table will proceed the recalculation, up to the clearance of the table with *Clear table*.

Clear table - clears the correction table. All _calb functions operate in a normal mode.

5.4.7 About the application

Program -> About in the *Application settings*

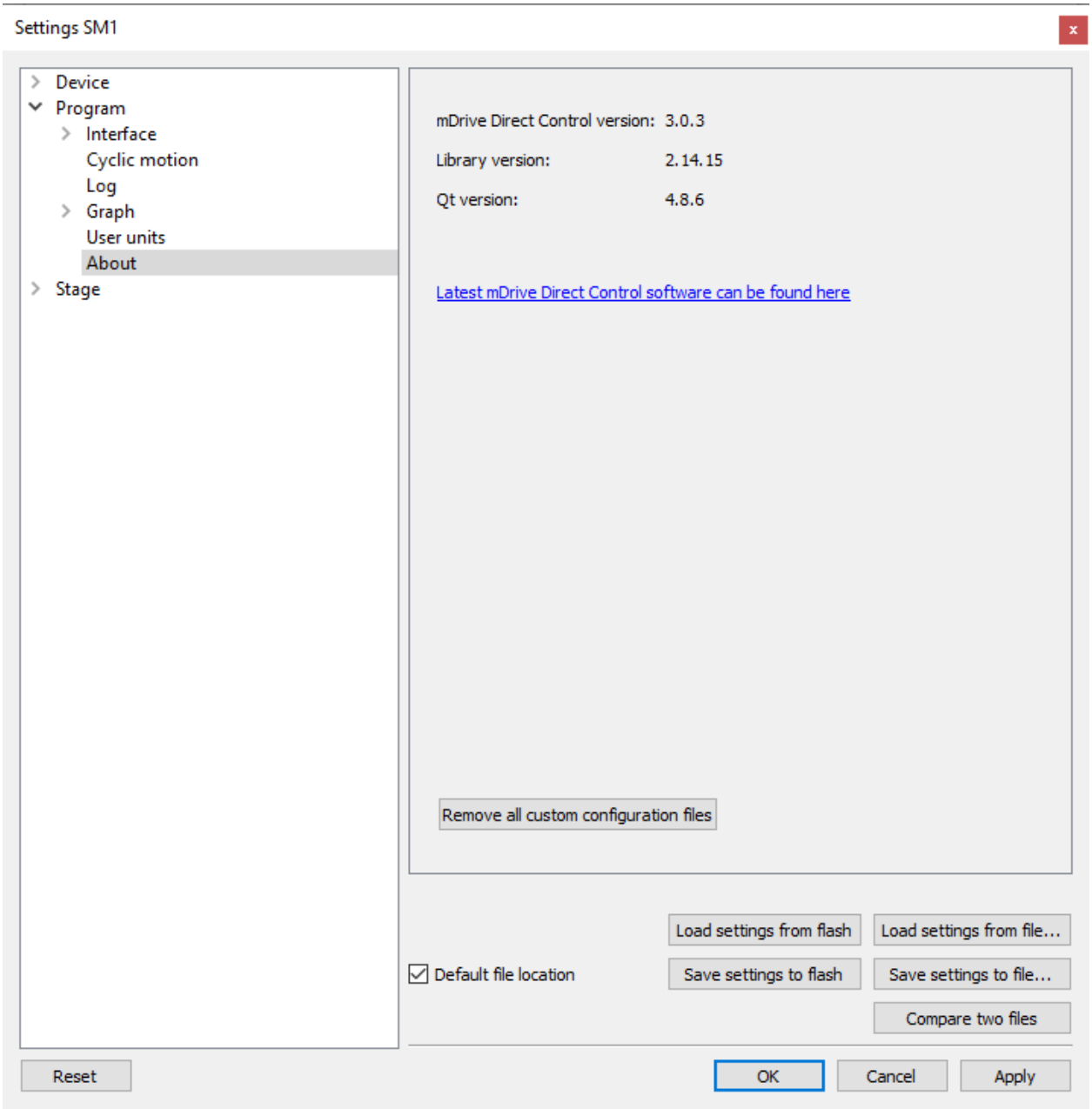


Fig. 5.41: About tab

This section displays the mDrive Direct Control application version. It also contains a link to the page with the latest Software version.

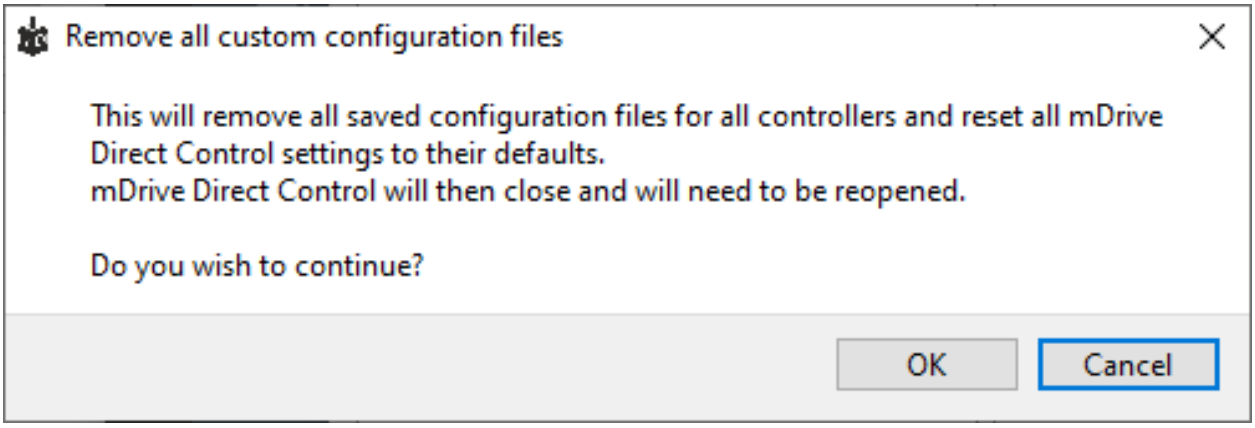


Fig. 5.42: User configuration file cleanup dialog

"Remove all custom configuration files" button displays a dialog prompt to delete all custom configuration files created by mDrive Direct Control. Files to be deleted are located in mDrive Direct Control configuration directory. These files are "settings.ini", which stores common program settings, "SNnnn.cfg", which store per-controller settings, "V_nnn", which store virtual controller internal states, "scratch.txt", which stores last run *script*. Here "nnn" means any number. Pressing OK in this dialog will delete all these files and close mDrive Direct Control, pressing Cancel will abort deletion and close this dialog.

5.5 Correct shutdown

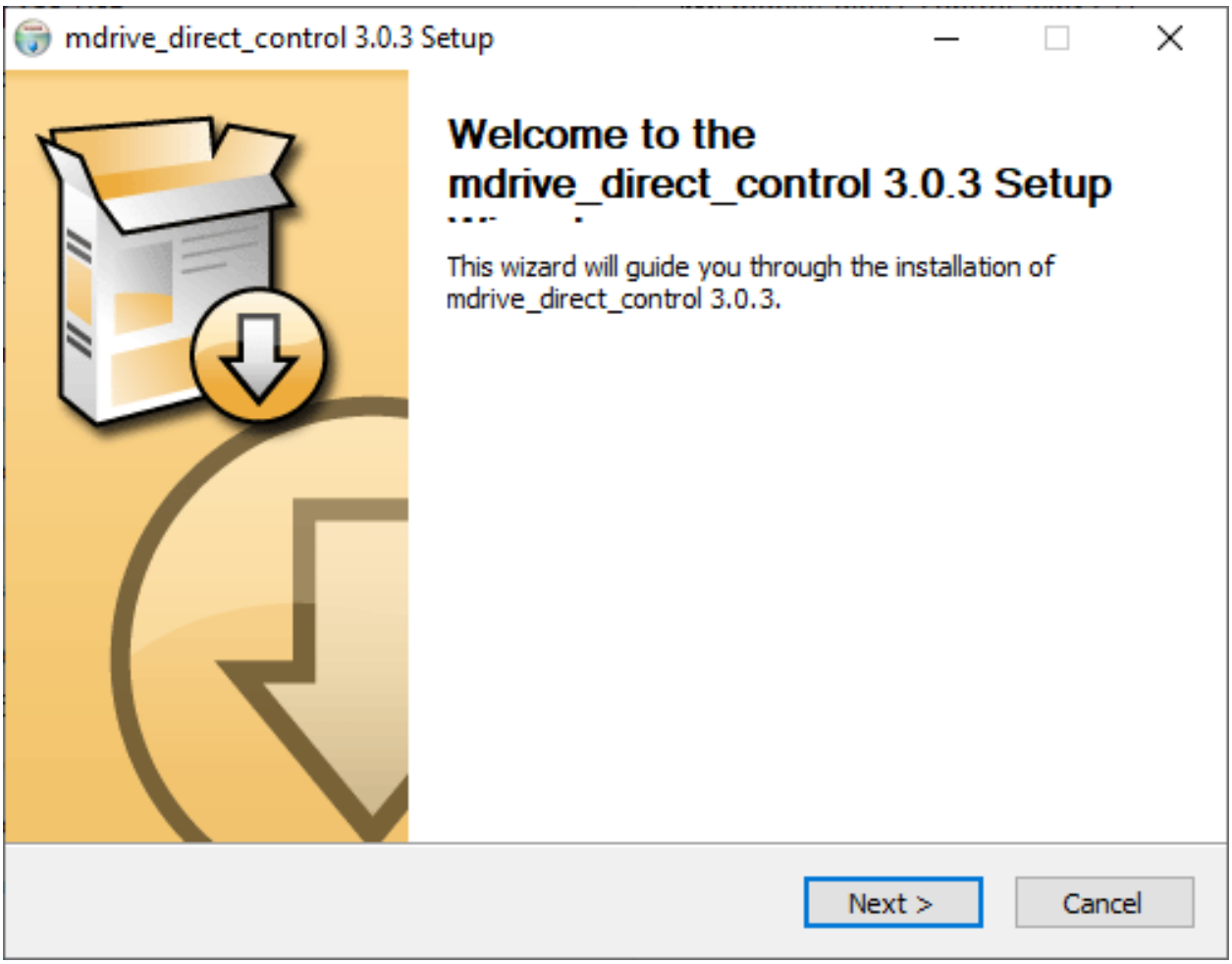
Correct shutdown assumes shutdown of the motor and saving the current position by the controller. The current position is automatically saved, see *Saving the position in FRAM memory*.

Exit button performs correct shutdown and exit. When you click it the application sends a soft stop command to the controller, and after the stop is complete, the application sends command of power-off. If execution of the soft stop command was interrupted by an event like a motion command from the *joystick* or signal of *TTL synchronization*, or if while sending of soft stop command or command of power off to the controller, the library returned an error, the exit will be canceled. In this case you need to check *joystick settings and settings of "right" and "left" buttons* and *Synchronization settings*.

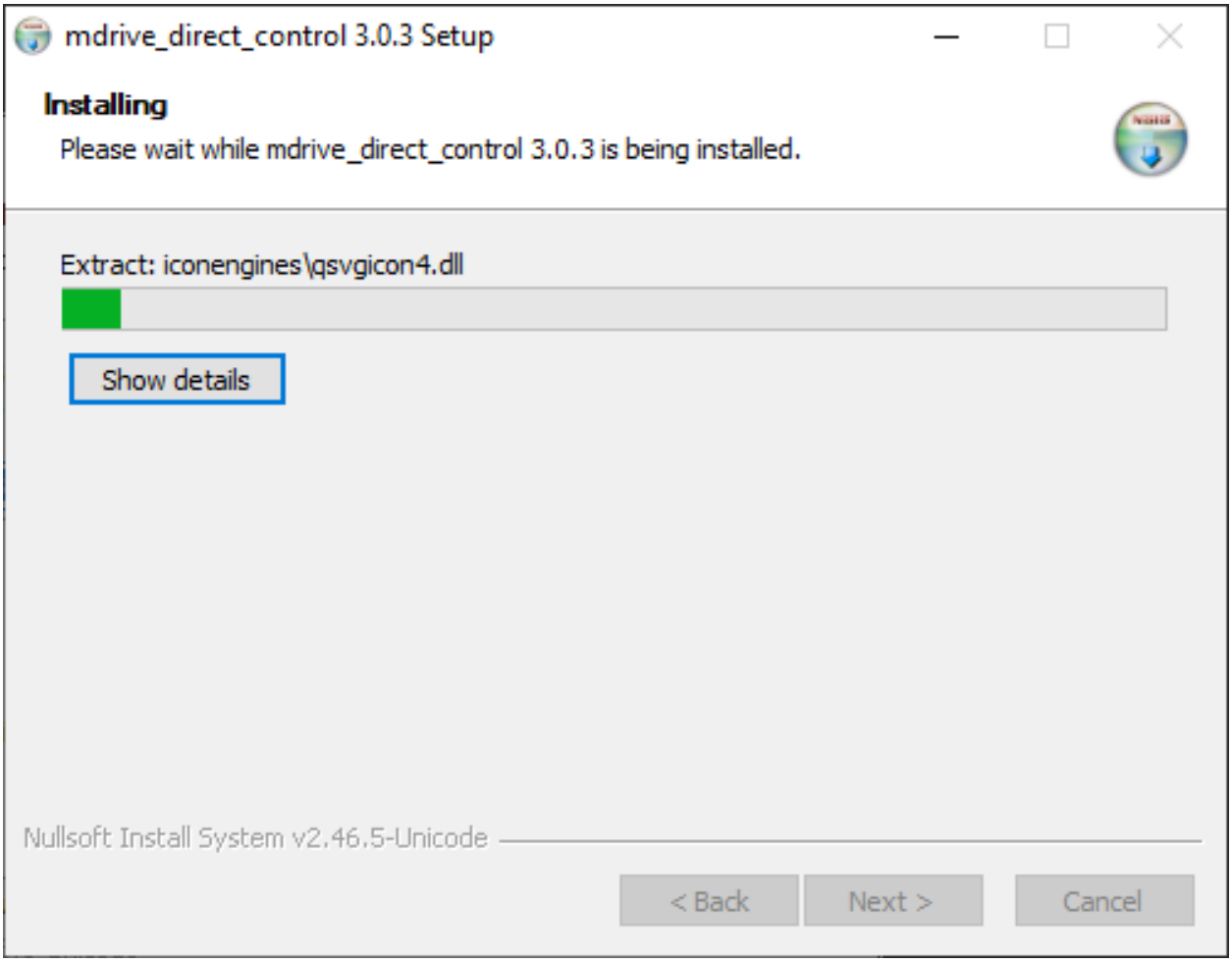
5.6 mDrive Direct Control installation

5.6.1 Installation on Windows

Copy the installer program file to your computer. The installer file name is "mdrive_direct_control-<version_name>-win32_win64.exe". It automatically detects whether it is running on 32-bit or 64-bit version of Windows and installs the appropriate version of mDrive Direct Control.

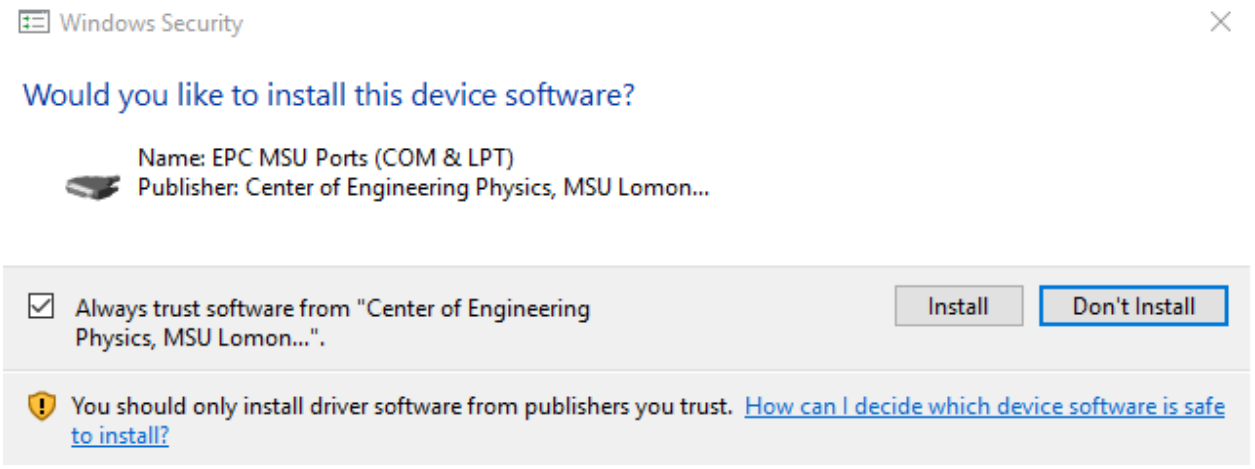


Run the installer and follow the on-screen instructions.

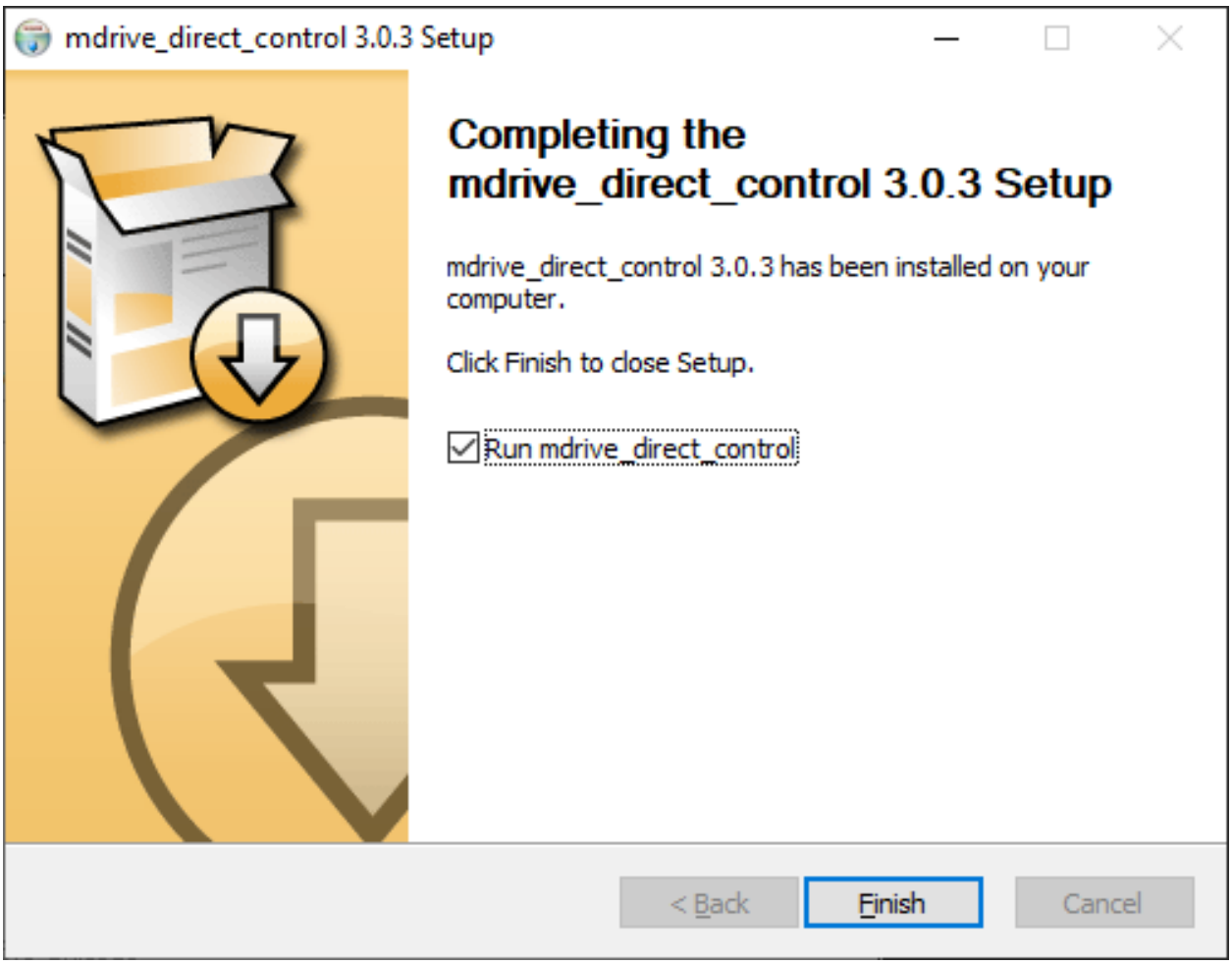


All the necessary software, packages and programs will be installed automatically.

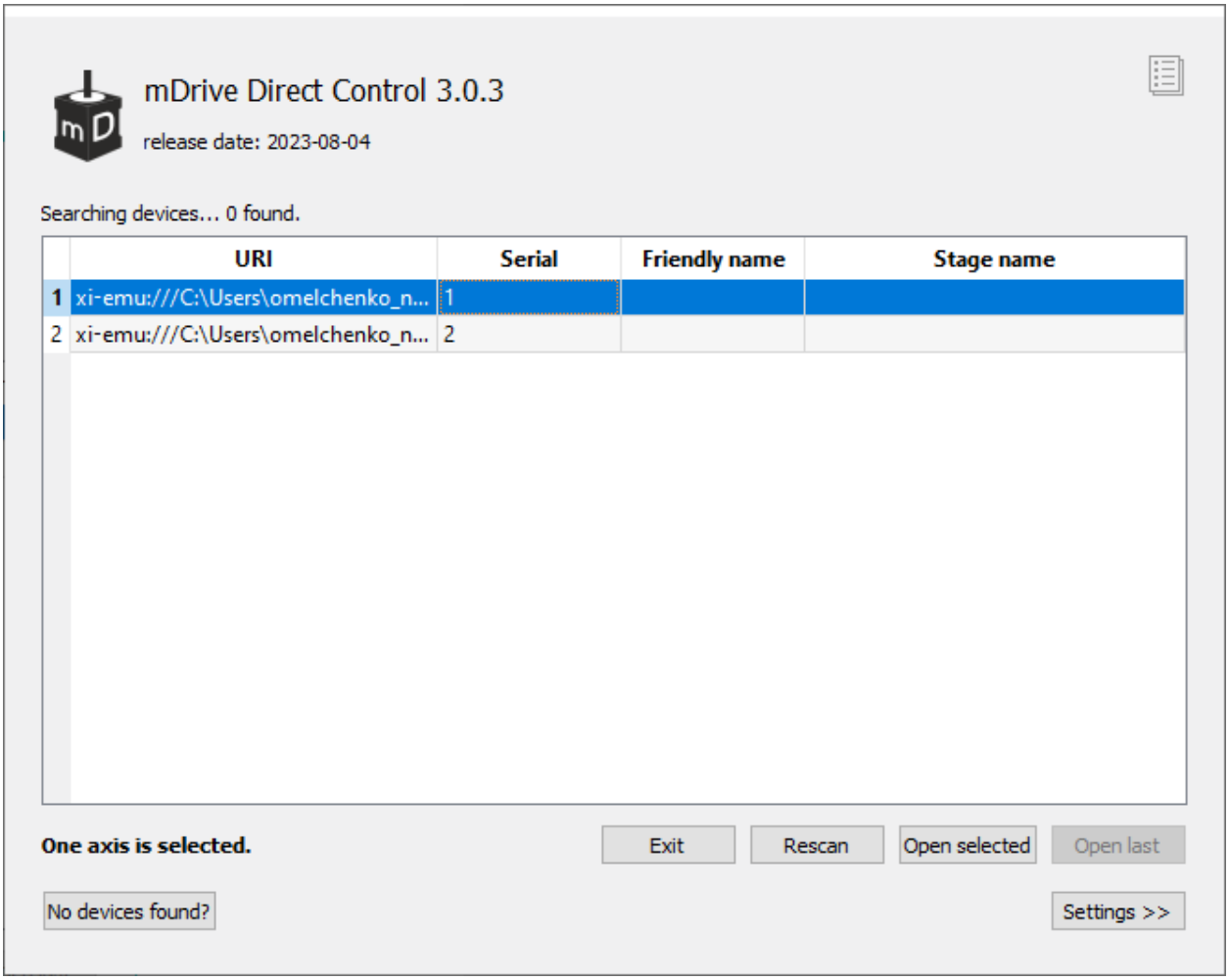
Answer the question of the Windows security service *Install* to get the mDrive conroller driver.



Wait for the installation to complete.



After the installation is complete the mDrive Direct Control application will be started by default.



Connect the stage to the controller. Connect regulated power supply to the controller. Ground the controller or the power supply unit. Connect the controller to the computer using a USB-A - USB-B cable. LED indicator on the controller board will start to flash.

Wait until Windows detects the new device and click *Rescan* or run the mDrive Direct Control application again if it was closed. The system will detect the connected controller and open the main mDrive Direct Control window.

5.6.2 Installation on Linux

mDrive Direct Control package for Linux is distributed in AppImage format - Linux file that contains an application and everything the application needs to run (e.g., libraries, icons, fonts, translations, etc.) To run mDrive Direct Control just download the application, make it executable, and run. No need to install. No system libraries or system preferences are altered.

There are two main ways to make an AppImage executable:

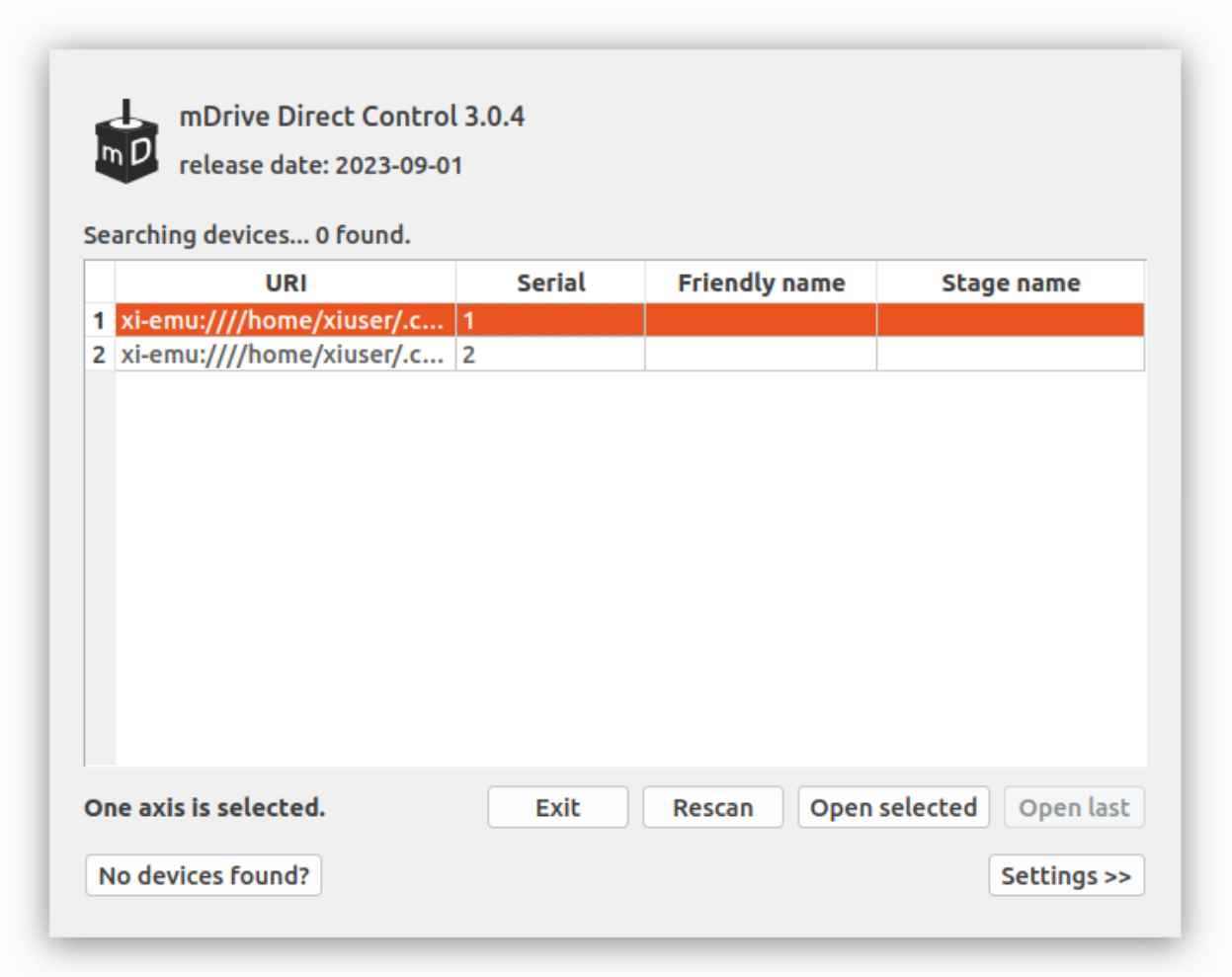
1. With the GUI:

- Open your file manager and browse to the location of the AppImage;
- Right-click on the AppImage and click the “Properties” entry;
- Switch to the “Permissions” tab and click the “Allow executing file as program” checkbox if you are using a Nautilus-based file manager (Files, Nemo, Caja), or click the “Is executable” checkbox if you are using Dolphin, or change the “Execute” drop down list to “Anyone” if you are using PCManFM;

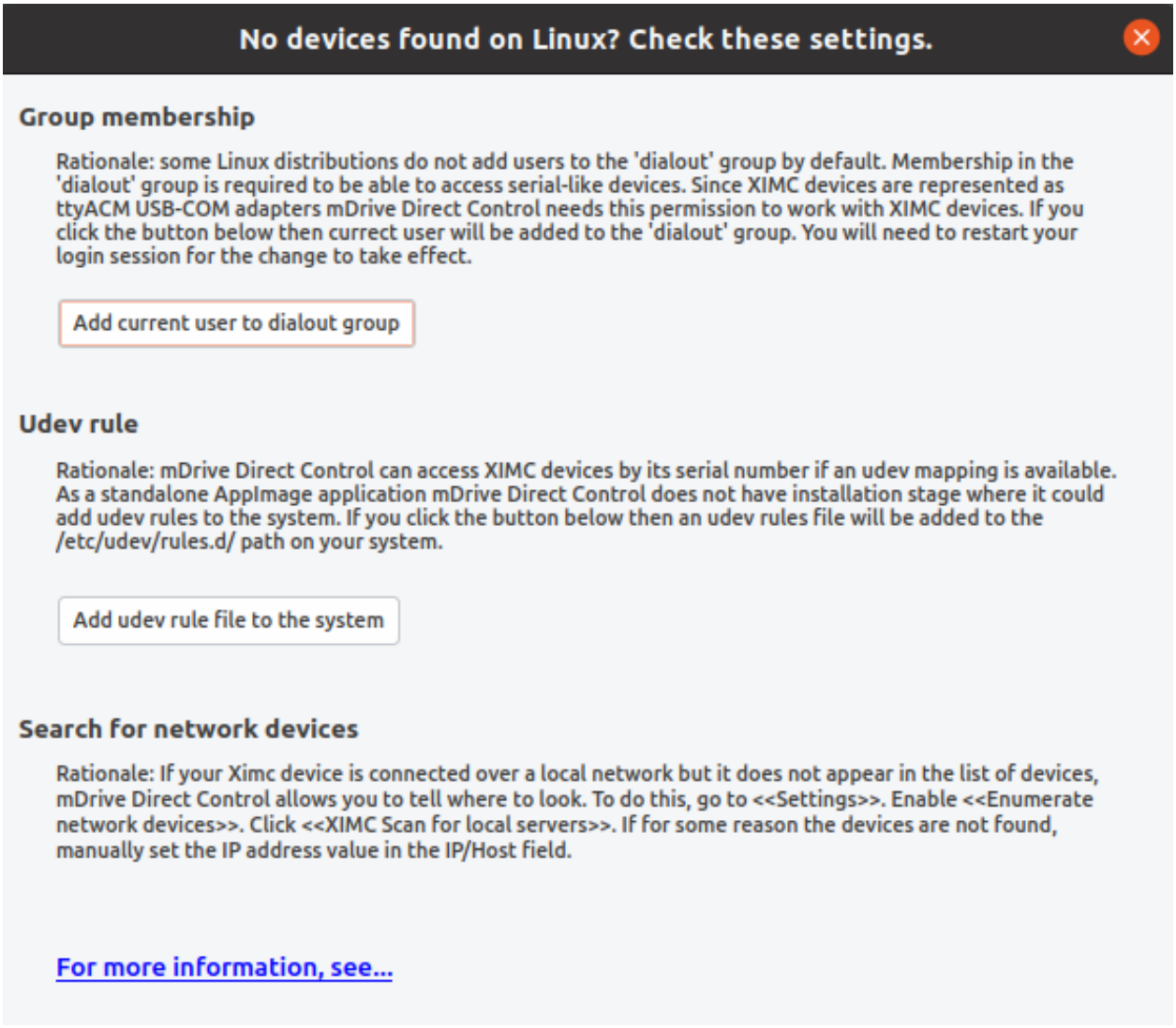
- Close the dialog;
- Double-click on the AppImage file to run.

2. On the command line:

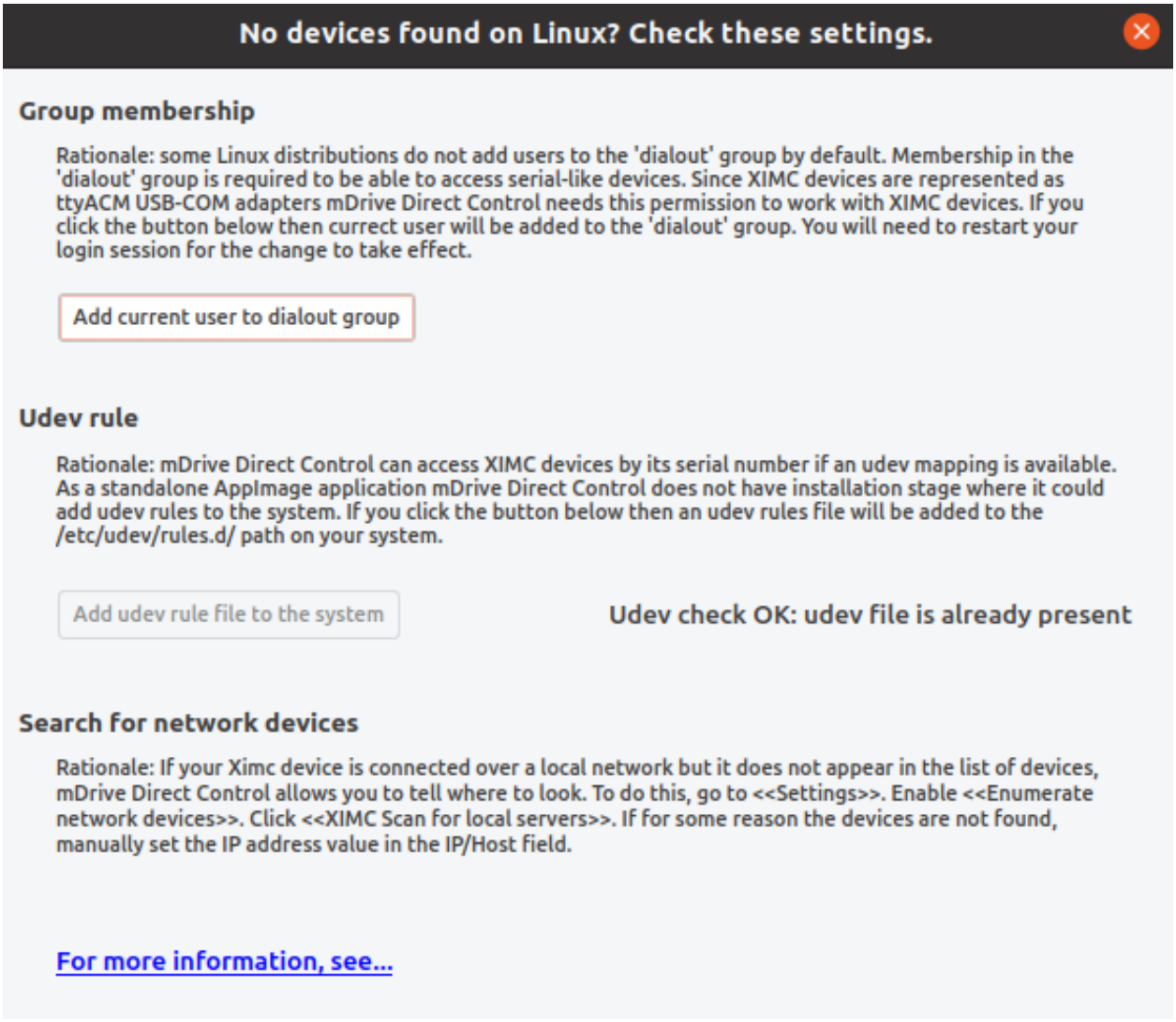
```
chmod a+x mdrive_direct_control-<version>-x86_64.AppImage
./mdrive_direct_control-<version>-x86_64.AppImage
```



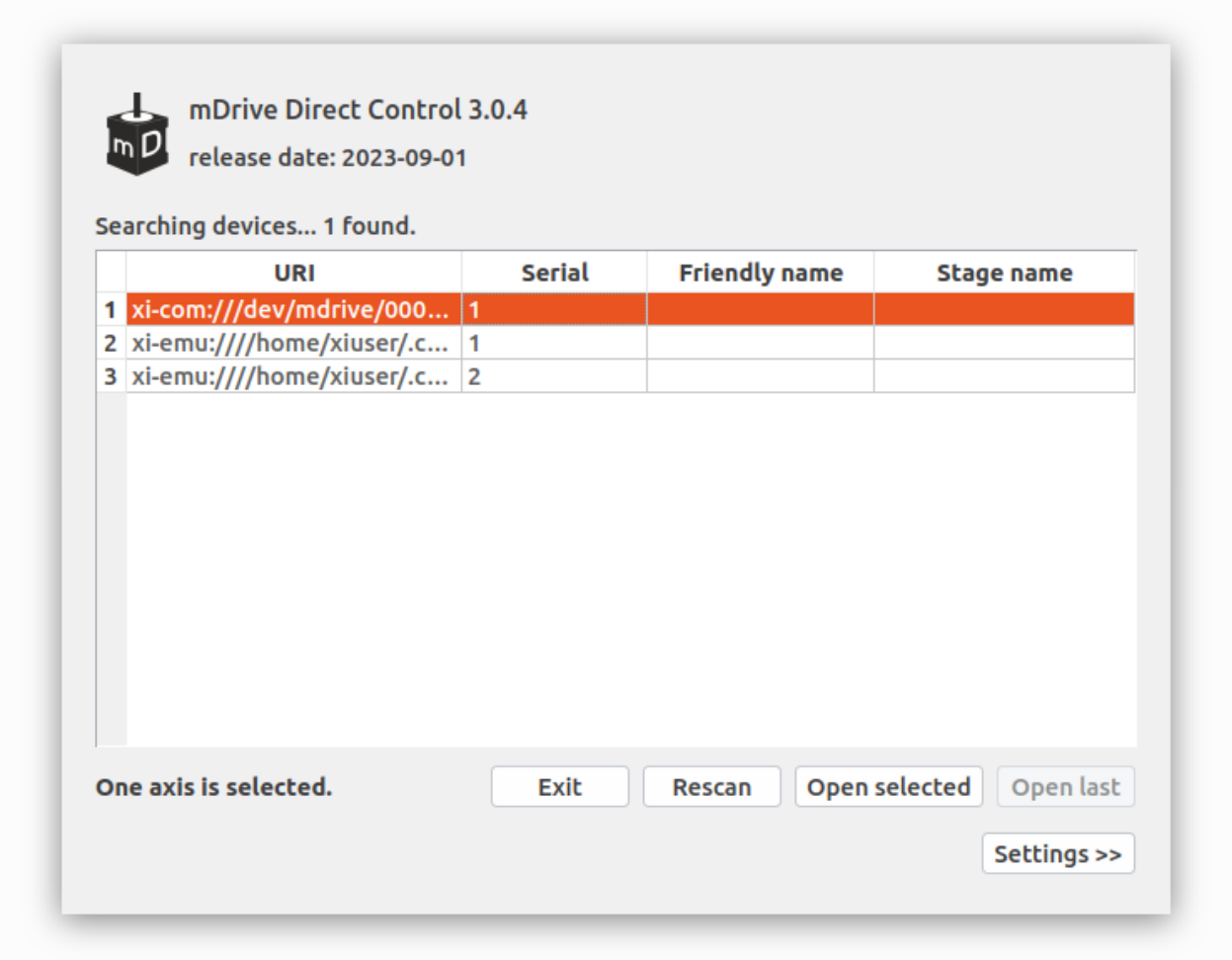
On the first run mDrive Direct Control may not found the usb-connected controllers. To enumerate devices mDrive Direct Control needs the available udev mapping. As a standalone AppImage application mDrive Direct Control doesn't have installation stage which can add the udev rules to the system. Click the *No devices found?* button on the mDrive Direct Control start window then click *Add udev rule file to the system.*



Some Linux distributions do not add users to the “dialout” group by default. Membership in the “dialout” group is required to be able to access serial-like devices. Since devices are represented as ttyACM USB-COM adapters mDrive Direct Control needs this permission to work with XIMC devices. Click *Add current user to the dialout group* button and restert your login session for the chage to take effect.



Important: mDrive Direct Control application requires X-server (graphic mode) for operation.



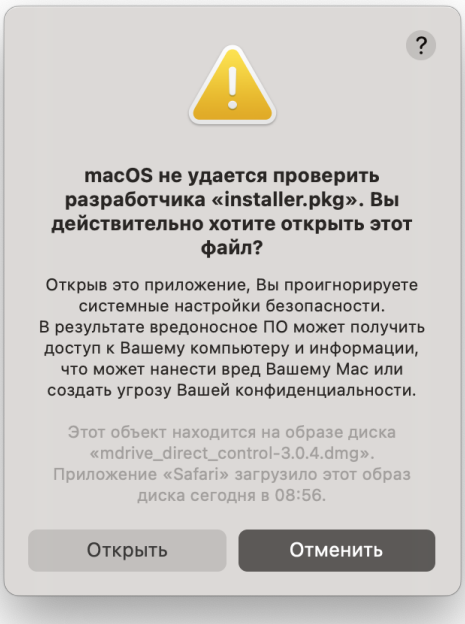
5.6.3 Installation on MacOS

Copy the file with the installer archive to your computer. The archive with the installation program is named "mdrive_direct_control-<version_name>-osx64.tar.gz".

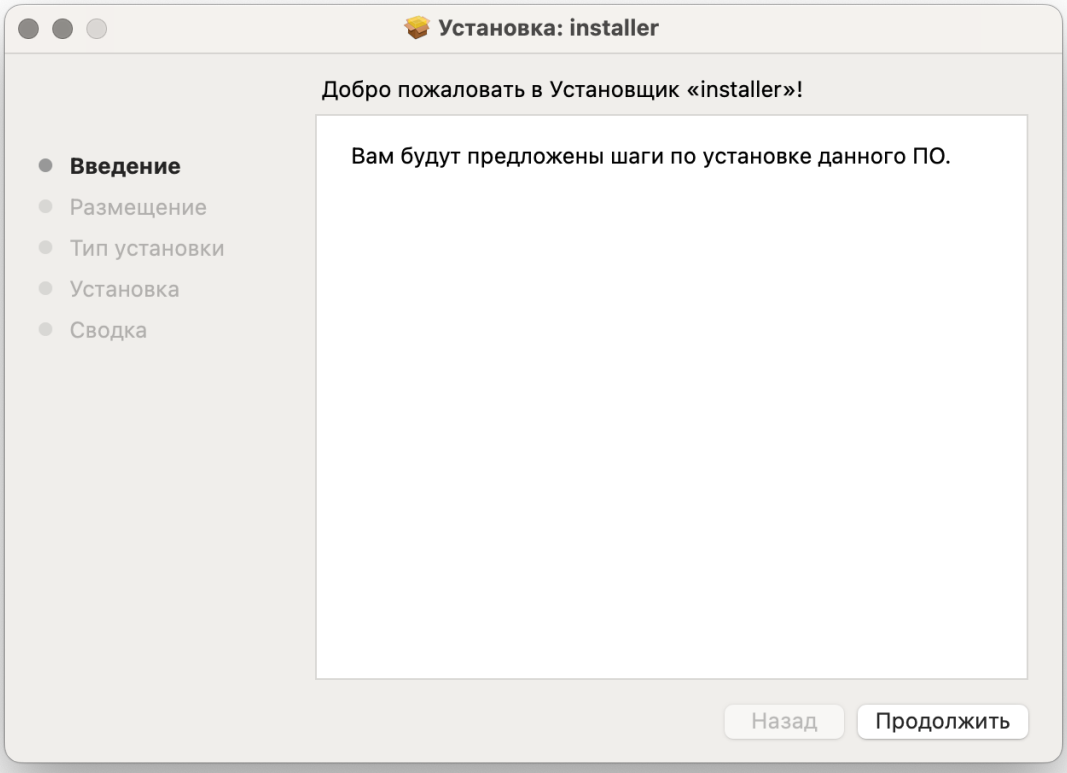
Unpack the archive by a mouse click.

Make right button click on installer.pkg.

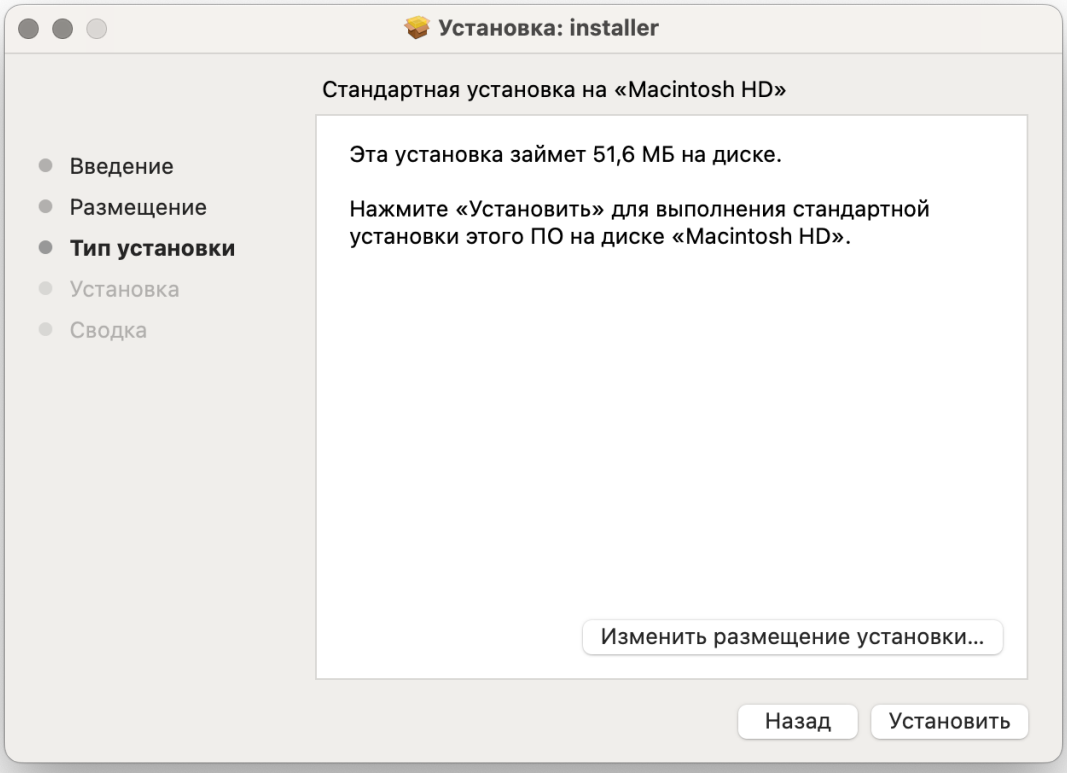
Choose “Open”.


macOS не удается проверить разработчика «installer.pkg». Вы действительно хотите открыть этот файл?
Открыв это приложение, Вы проигнорируете системные настройки безопасности.
В результате вредоносное ПО может получить доступ к Вашему компьютеру и информации, что может нанести вред Вашему Mac или создать угрозу Вашей конфиденциальности.
Этот объект находится на образе диска «mdrive_direct_control-3.0.4.dmg». Приложение «Safari» загрузило этот образ диска сегодня в 08:56.
Открыть
Отменить

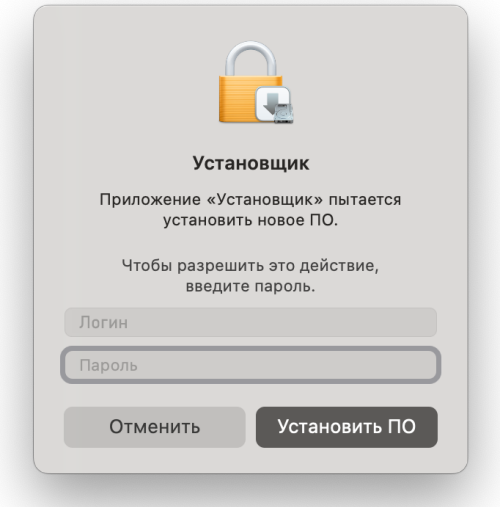
Choose “Open”.



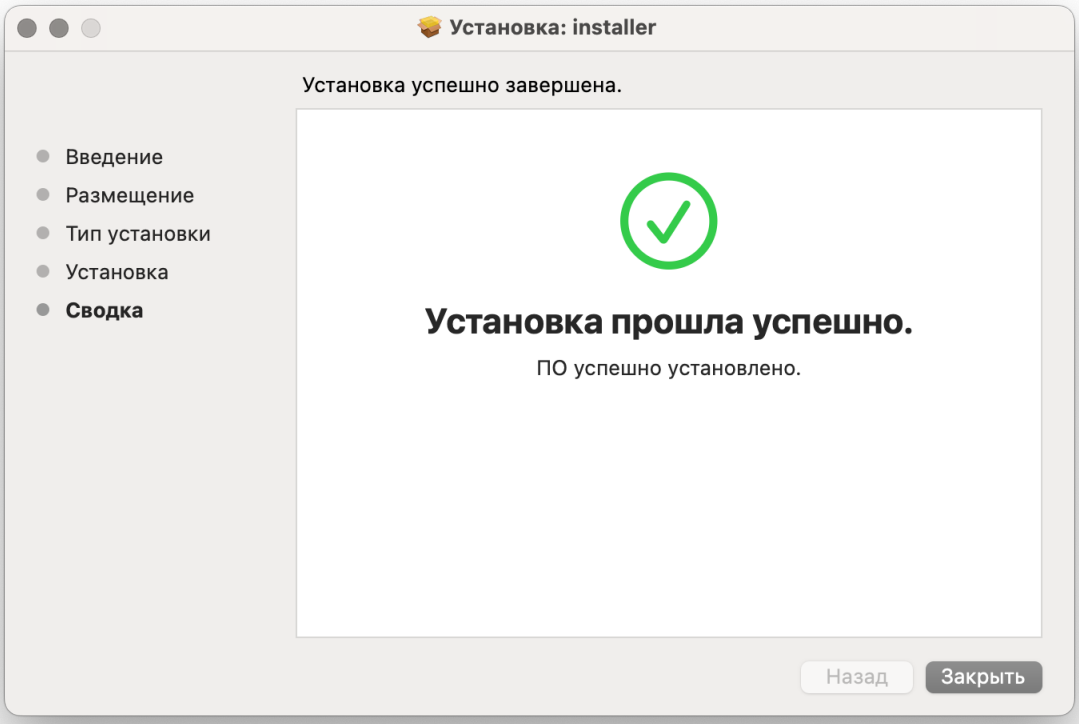
Select “Continue” in the main window of the installer.



Now select “Install.”

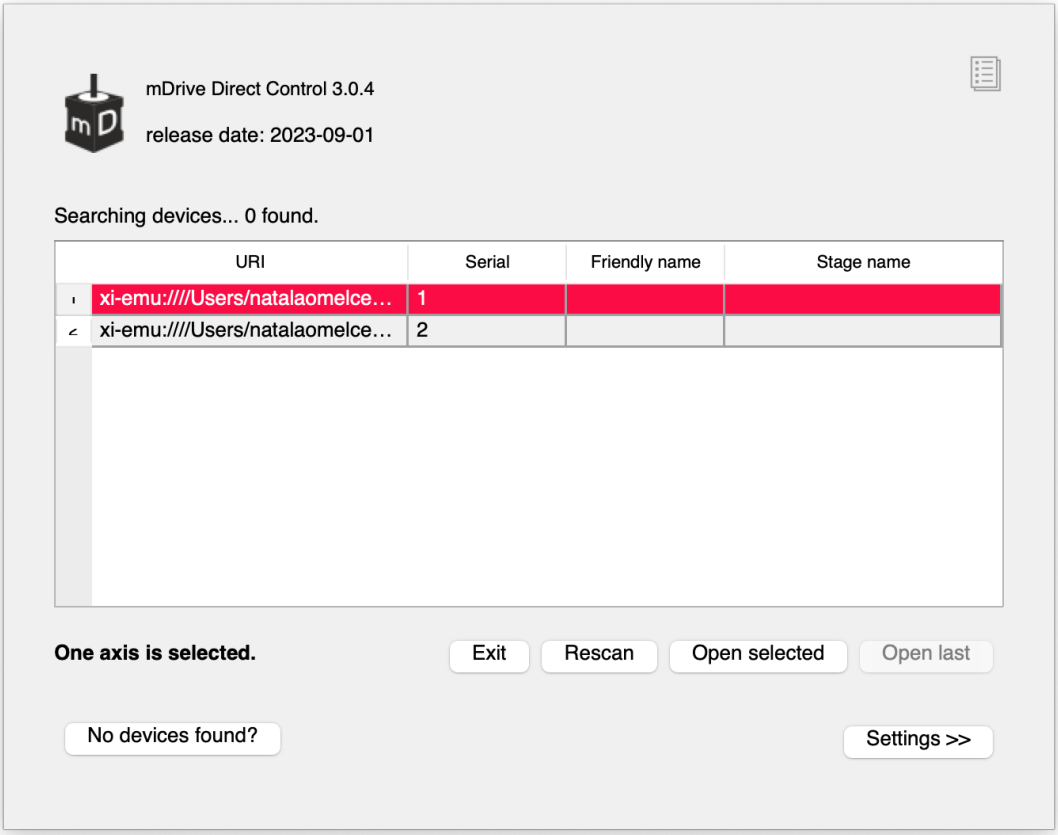


Enter the password.



Wait until the installation is complete.

Select the mDrive Direct Control application in the Programs block.


mDrive Direct Control 3.0.4
release date: 2023-09-01
Searching devices... 0 found.
URI
Serial
Friendly name
Stage name
xi-emu:////Users/natalaomelce…
1
xi-emu:////Users/natalaomelce…
2
One axis is selected.
Exit
Rescan
Open selected
Open last
No devices found?
Settings >>

Start it.

CHAPTER

SIX

PROGRAMMING

6.1 Programming guide

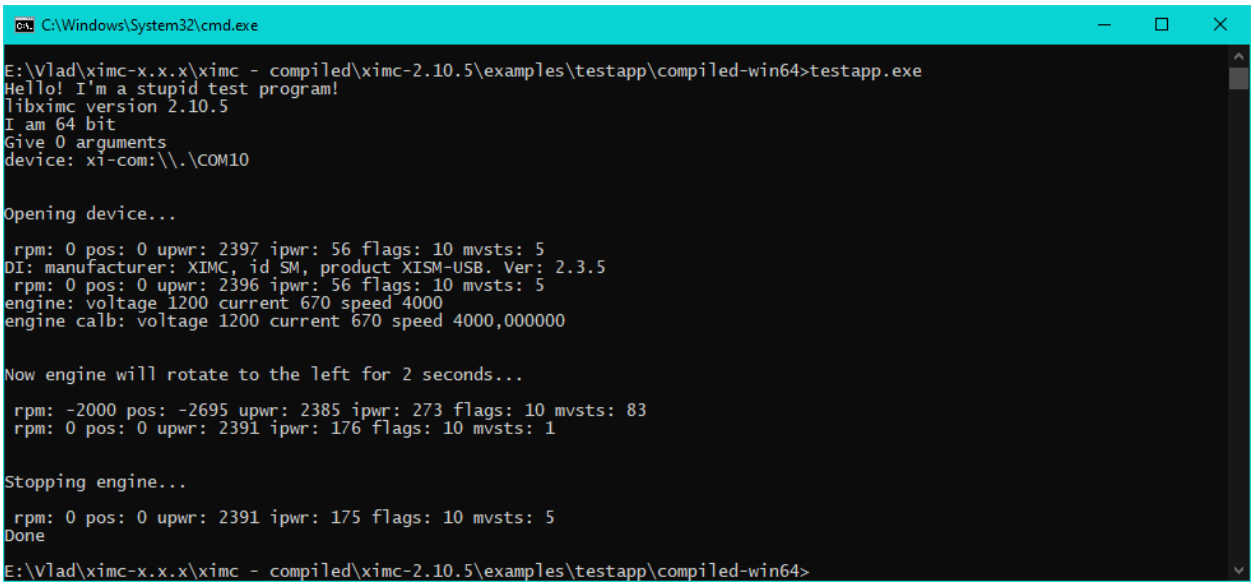
6.1.1 Working with controller in Visual Studio

Download VisualStudio example from the Software page.

Note: Testapp can be built using *testapp.sln*. Library must be compiled with MS Visual C++ too. Make sure that Microsoft Visual C++ Redistributable Package 2013 is installed.

Open solution *examples/testapp/testapp.sln*, build and run from the IDE.

Extract the archive and run *"testapp"* program.



The command prompt opens. You will see a message: "Hello! I'm a stupid test program!"

The program reports the version of the library used, as well as its bit depth. Also *"testapp"* program indicates which port it holds.

After opening the device, the program reads the data fields from the *"status_t"* structure reference.

rpm	int CurSpeed	Motor shaft speed
pos	float CurPosition	Current position
upwr	int Upwr	Power supply voltage, tens of mV
ipwr	int Ipwr	Engine current
flags	unsigned int Flags	Status flags
mvsts	unsigned int MvCmdSts	Move command state

*Function result_t XIMC_API get_device_information (device_t id, device_information_t *device information)* - Return device information

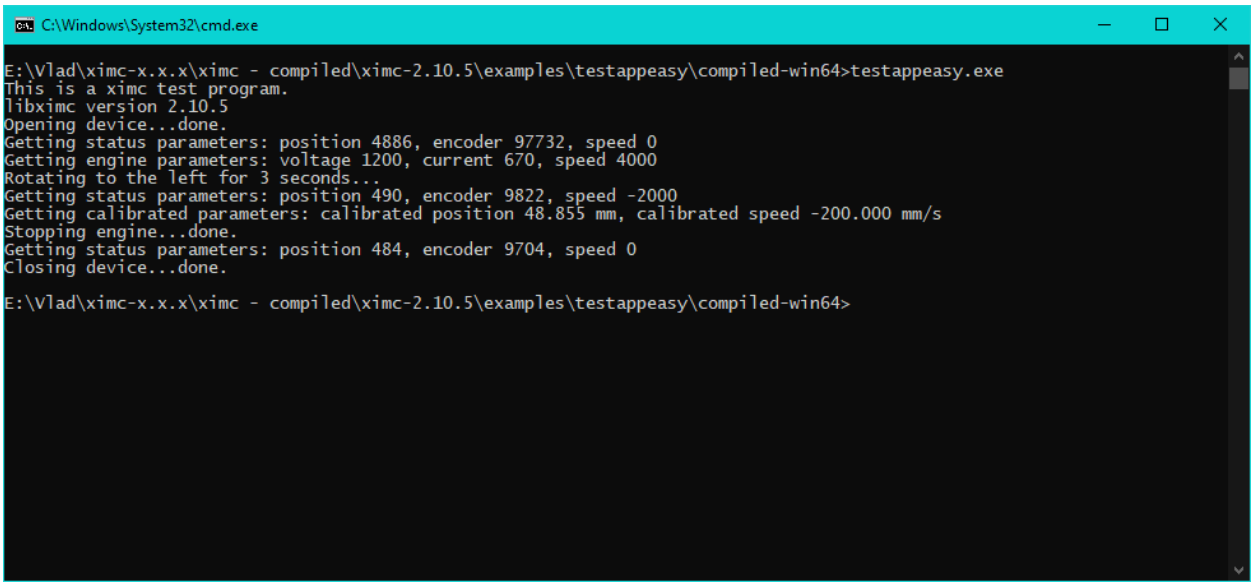
*Function result_t XIMC_API get_engine_settings (device_t id, engine_settings_t *engine settings)* - Read engine settings

engine_settings_calb_t Struct Reference - result_t XIMC_API set_engine_settings_calb (device_t id, const engine_settings_calb_t *engine_settings - calb, const calibration_t *calibration)

After, the *testapp* program executes the command *"command_left"* for 2 seconds. The *"command_left"* command is successfully executed, the *"command_stop"* command is called.

Important: At the end of the program, the command **"close_device"** must be called.

The *"testappeasy"* program isn't so much different from the *"testapp"* program. Open solution *examples/testappeasy/testappeasy.sln*, build and run from the IDE.



The command prompt opens. You will see a message: "This is a ximc test program."

The program reports the version of the library used.

Using the *"open_device"* command, *"testappeasy"* program opens the device in exclusive access mode.

Warning: Libximc library opens the controller in exclusive access mode. Any controller opened with libximc (mDrive Direct Control also uses this library) needs to be closed before it may be used by another process.

After, the *testappeasy* program executes the command *"command_left"* for 3 seconds. The *"command_left"* command is successfully executed, the *"command_stop"* command is called.

The comand *"calibration.A = 0.1;"* - Setting calibration constant to 0.1 (one controller step equals this many units)

The command *"calibration.MicrostepMode = engine_settings.MicrostepMode;"* - To set microstep mode to convert microsteps to calibrated units correctly.

After the *"testappeasy"* program reads calibrated device status from a device.

At the end, a *"command_stop"* command is sent to the device. The *"close_device"* - closes the specified device.

6.1.2 A short description of the work with supported by programming languages

Library usage can be examinated from test application *testapp*. Non-C languages are supported because library supports *stdcall* calling convention and so can be used with a variety of languages.

C test project is located at *"examples/testapp"* directory, C# test project - at *"xamples/testcs"*, for Python - «examples/testpython». Development kit also contains precompiled examples: *testapp* as **32** and **64-bit** applications for **Windows** and **64-bit** application for **OSX**, *testcs* - **32-bit only**, **testpython is runtime-interpreted**. Also the programming guide can be downloaded from this link.

Note: SDK requires Microsoft Visual C++ Redistributable Package 2013 (provided with SDK - vcredist_x86 or vcredist_x64)

6.1.2.1 Visual C++

Testapp can be built using *testapp.sln*. Library must be compiled with MS Visual C++ too. Make sure that Microsoft Visual C++ Redistributable Package 2013 is installed.

Open solution *examples/testapp/testapp.sln*, build and run from the IDE.

6.1.2.2 .NET (C#)

Wrapper assembly for *libximc.dll* is *wrappers/csharp/ximcnet.dll*. It is provided with two different architectures and depends on .NET 2.0.

Test .NET applications for Visual Studio 2013 is located at *testcs* (*for C#*). Open solutions and build.

6.1.2.3 Python

Change current directory to the *examples/testpython*. Before launch:

On OS X: copy library *ximc/macosx/libximc.framework* to the current directory.

On Linux: you may need to set *LD_LIBRARY_PATH* so Python can locate libraries with *RPATH*. For example, you may need:

```
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:`pwd`
```

On Windows before the start nothing needs to be done. Launch Python 2 or Python 3:

```
python testpython.py
```

Note: **Generic logging facility**. If you want to turn on file logging, you should run the program that uses libximc library with the "XILOG" environment variable set to desired file name. This file will be opened for writing on the first log event and will be closed when the program which uses libximc terminates. Data which is sent to/received from the controller is logged along with port open and close events.

Note: **Required permissions**: libximc generally does not require special permissions to work, it only needs read/write access to USB-serial ports on the system. An exception to this rule is a Windows-only "fix_usbser_sys()" function - it needs elevation and will produce null result if run as a regular user.

Note: **C-profiles**. C-profiles are header files distributed with the libximc library. They enable one to set all controller settings for any of the supported stages with a single function call in a C/C++ program. You may see how to use C-profiles in "testcprofile" example directory.

The development kit can be downloaded on the Software page. It contains the compiled libximc library for Windows, Linux and Mac OS systems, the programming guide and the examples. Libximc is a cross-platform library that supports C++, C# and Python languages. The examples included in the library package are intended for quick acquaintance with the programming for mDrive controllers. The Libximc sources are also available for download.

Attention: Programming guide is included in libximc 2.X.X archive, where 2.X.X is the version number. It is located in /ximc-2.X.X/ximc/doc-en/libximc7-en.pdf. Also the libximc manual can be downloaded from this link. The programming guide is Doxygen-based.

6.2 Communication protocol specification

Communication protocol v20.8

6.2.1 Protocol description

Controller can be controlled from the PC using serial connection (COM-port). COM-port parameters are fixed controller-side:

- Speed: 115200 baud
- Frame size: 8 bits
- Stop-bits: 2 bits
- Parity: none
- Flow control: none
- Byte receive timeout: 400 ms
- Bit order: little endian
- Byte order: little endian

6.2.2 Command execution

All data transfers are initiated by the PC, meaning that the controller waits for incoming commands and replies accordingly. Each command is followed by the controller response, with rare exceptions of some service commands. One should not send another command without waiting for the previous command answer.

Commands are split into service, general control and general information types. Commands are executed immediately. Parameters which are set by Sxxx commands are applied no later than 1ms after acknowledgement. Command processing does not affect real-time engine control (PWM, encoder readout, etc).

Both controller and PC have an IO buffer. Received commands and command data are processed once and then removed from buffer. Each command consists of 4-byte identifier and optionally a data section followed by its 2-byte CRC. Data can be transmitted in both directions, from PC to the controller and vice versa. Command is scheduled for

execution if it is a legitimate command and (in case of data) if its CRC matches. After processing a correct command controller replies with 4 bytes - the name of processed command, followed by data and its 2-byte CRC, if the command is supposed to return data.

6.2.3 Controller-side error processing

6.2.3.1 Wrong command or data

If the controller receives a command that cannot be interpreted as a legitimate command, then controller ignores this command, replies with an "errc" string and sets "command error" flag in the current status data structure. If the unreconized command contained additional data, then it can be interpreted as new command(s). In this case resynchronization is required.

If the controller receives a valid command with data and its CRC doesn't match the CRC computed by the controller, then controller ignores this command, replies with an "errd" string and sets "data error" flag in the current status data structure. In this case synchronization is not needed.

6.2.3.2 CRC calculation

CRC is calculated for data only, 4-byte command identifier is not included. CRC algorithm in C is as follows:

```
unsigned short CRC16(INT8U *pbuf, unsigned short n)
{
  unsigned short crc, i, j, carry_flag, a;
  crc = 0xffff;
  for(i = 0; i < n; i++)
  {
    crc = crc ^ pbuf[i];
    for(j = 0; j < 8; j++)
    {
      a = crc;
      carry_flag = a & 0x0001;
      crc = crc >> 1;
      if ( carry_flag == 1 ) crc = crc ^ 0xa001;
    }
  }
  return crc;
}
```

This function receives a pointer to the data array, pbuf, and data length in bytes, n. It returns a two byte CRC code.

The example of CRC calculation:

Command code (CMD): "home" or 0x656D6F68

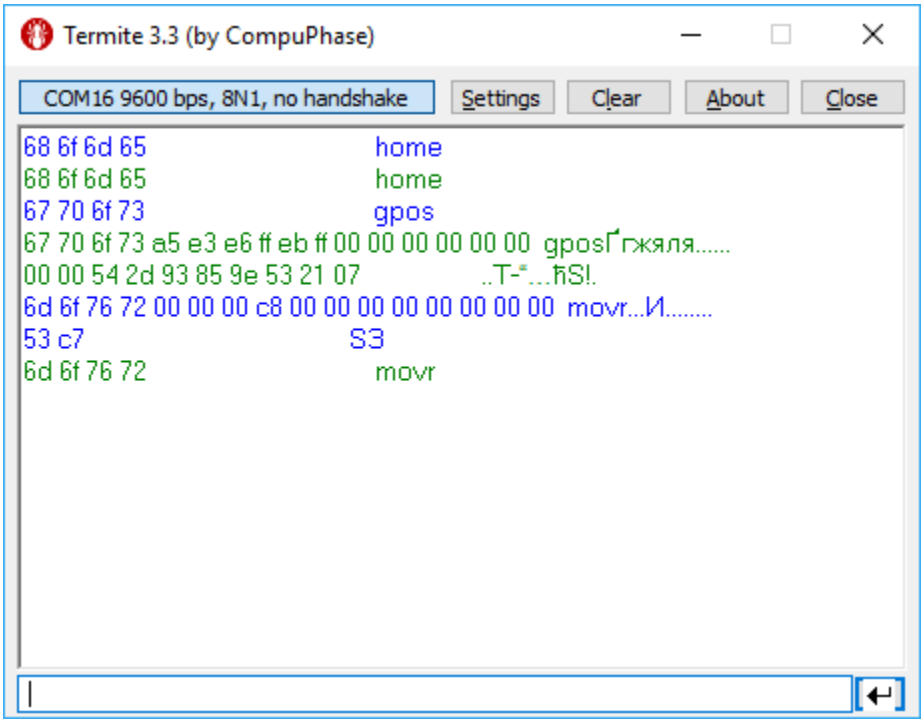
```
0x68 0x6F 0x6D 0x65
CMD
```

Command code (CMD): "gpos" or 0x736F7067

```
0x67 0x70 0x6F 0x73
CMD
```

Command code (CMD): "movr" or 0x72766F6D

```
0x6D 0x6F 0x76 0x72  0x00 0x00 0x00 0xC8  0x00 0x00  0x00 0x00 0x00 0x00 0x00 0x00
↪0x53 0xc7
CMD                  DeltaPosition        uDPos      Reserved
↪CRC
```



6.2.3.3 Transmission errors

Most probable transmission errors are missing, extra or altered byte. In usual settings transmission errors happen rarely, if at all.

Frequent errors are possible when using low-quality or broken USB-cable or board interconnection cable. Protocol is not designed for use in noisy environments and in rare cases an error may match a valid command code and get executed.

Missing byte, controller side “

A missing byte on the controller side leads to a timeout on the PC side. Command is considered to be sent unsuccessfully by the PC. Synchronization is momentarily disrupted and restored after a timeout.

Missing byte, PC side

A missing byte on the PC side leads to a timeout on PC side. Synchronization is maintained.

Extra byte, controller side

An extra byte received by the controller leads to one or several “errc” or “errd” responses. Command is considered to be sent unsuccessfully by the PC. Receive buffer may also contain one or several “errc” or “errd” responses. Synchronization is disrupted.

Extra byte, PC side

An extra byte received by the PC leads to an incorrectly interpreted command or CRC and an extra byte in the receive buffer. Synchronization is disrupted.

Altered byte, controller side

An altered byte received by the controller leads to one or several “errc” or “errd” responses. Command is considered to be sent unsuccessfully by the PC. Receive buffer may also contain one or several “errc” or “errd” responses. Synchronization can rarely be disrupted, but is generally maintained.

Altered byte, PC side

An altered byte received by the PC leads to an incorrectly interpreted command or CRC. Synchronization is maintained.

6.2.3.4 Timeout resynchronization

If during packet reception next byte wait time exceeds timeout value, then partially received command is ignored and receive buffer is cleared. Controller timeout should be less than PC timeout, taking into account time it takes to transmit the data.

6.2.3.5 Zero byte resynchronization

There are no command codes that start with a zero byte ('\0'). This allows for a following synchronization procedure: controller always answers with a zero byte if the first command byte is zero, PC ignores first response byte if it is a zero byte. Then, if synchronization is disrupted on either side the following algorithm is used:

In case PC receives "errc", "errd" or a wrong command answer code, then PC sends 4 to 250 zeroes to the controller (250 byte limit is caused by input buffer length and usage of I2C protocol, less than 4 zeroes do not guarantee successful resynchronization). During this time PC continuously reads incoming bytes from the controller until the first zero is received and stops sending and receiving right after that.

Received zero byte is likely not a part of a response to a previous command because on error PC receives "errc"/"errd" response. It is possible in rare cases, then synchronization procedure will start again. Therefore first zero byte received by the PC means that controller input buffer is already empty and will remain so until any command is sent. Right after receiving first zero byte from the controller PC is ready to transmit next command code. The rest of zero bytes in transit will be ignored because they will be received before controller response.

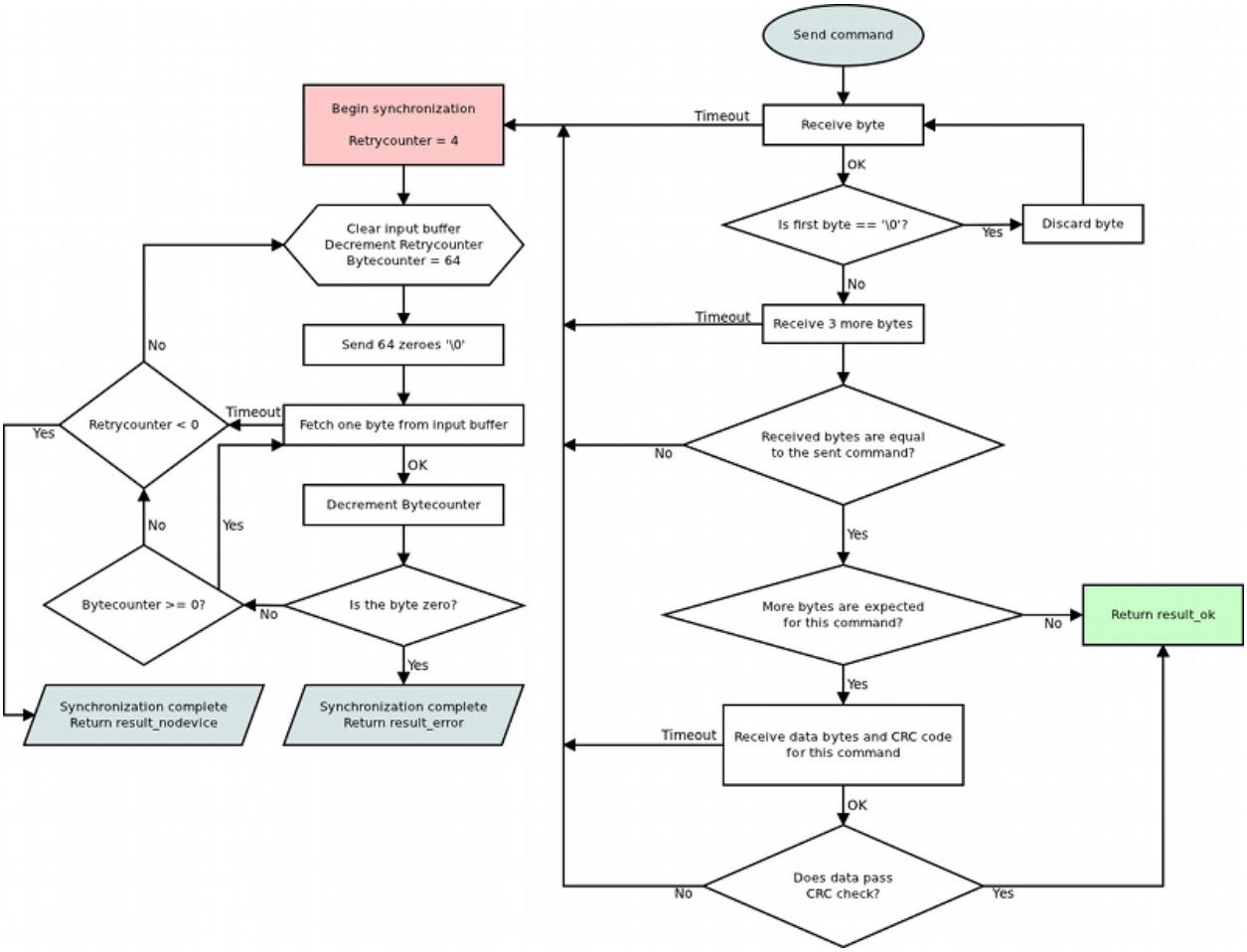
This completes the zero byte synchronization procedure.

6.2.4 Library-side error processing

Nearly every library function has a return status of type *result_t*.

After sending command to the controller library reads incoming bytes until a non-zero byte is received. All zero bytes are ignored. Library reads first 4 bytes and compares them to the command code. It then waits for data section and CRC, if needed. If first 4 received bytes do not match the sent command identifier, then zero byte synchronization procedure is launched, command is considered to be sent unsuccessfully. If first 4 received bytes match the sent command identifier and command has data section, but the received CRC doesn't match CRC calculated from the received data, then zero byte synchronization procedure is launched, command is considered to be sent unsuccessfully. If a timeout is reached while the library is waiting for the controller response, then zero byte synchronization procedure is launched, command is considered to be sent unsuccessfully.

If no errors were detected, then command is considered to be successfully completed and *result_ok* is returned.



6.2.4.1 Library return codes

- *result_ok*. No errors detected.
- *result_error*. Generic error. Can happen because of hardware problems, empty port buffer, timeout or successfull synchronization after an error. Another common reason for this error is protocol version mismatch between controller firmware and PC library.
- *result_nodevice*. Error opening device, lost connection or failed synchronization. Device reopen and/or user action is required.

If a function returns an error values of all parameters it writes to are undefined. Error code may be accompanied by detailed error description output to system log (Unix-like OS) or standard error (Windows-like OS).

6.2.4.2 Zero byte synchronization procedure

Synchronization is performed by means of sending zero ('\0') bytes and reading bytes until a zero byte is received. Optionally one may clear port buffer at the end of synchronization procedure. Initially 64 zero bytes are sent. If there were no zero bytes received during the timeout, then a string of 64 bytes is sent 3 more times. After 4 unsuccessful attempts and no zero bytes received device is considered lost. In this case library should return *result_nodevice* error code. In case of successful syncronization library returns *result_error*.

6.2.5 Controller error response types

6.2.5.1 ERRC

Answer: (4 bytes)

Code: "errc" or 0x63727265

uint32_t	errc	Command error

Description:

Controller answers with "errc" if the command is either not recognized or cannot be processed and sets the correspoding bit in status data structure.

6.2.5.2 ERRD

Answer: (4 bytes)

Code: "errd" or 0x64727265

uint32_t	errd	Data error

Description:

Controller answers with "errd" if the CRC of the data section computed by the controller doesn't match the received CRC field and sets the correspoding bit in status data structure.

6.2.5.3 ERRV

Answer: (4 bytes)

Code: "errv" or 0x76727265

uint32_t	errv	Value error

Description:

Controller answers with "errv" if any of the values in the command are out of acceptable range and can not be applied. Inacceptable value is replaced by a rounded, truncated or default value. Controller also sets the correspoding bit in status data structure.

6.2.6 All controller commands

6.2.6.1 Command GACC

Command code (CMD): "gacc" or 0x63636167.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (114 bytes)

uint32_t	CMD	Command

Continued on next page

Table 6.6 – continued from previous page

int8_t	MagneticBrakeInfo	The manufacturer and the part number of magnetic brake, the maximum string length is 24 characters.
float	MBRatedVoltage	Rated voltage for controlling the magnetic brake (V). Data type: float.
float	MBRatedCurrent	Rated current for controlling the magnetic brake (A). Data type: float.
float	MBTorque	Retention moment (mN m). Data type: float.
uint32_t	MBSettings	Flags of magnetic brake settings. This is a bit mask for bitwise operations.
	0x1 - MB_AVAILABLE	If the flag is set, the magnetic brake is available
	0x2 - MB_POWERED_HOLD	If this flag is set, the magnetic brake is on when powered
int8_t	TemperatureSensorInfo	The manufacturer and the part number of the temperature sensor, the maximum string length: 24 characters.
float	TSMin	The minimum measured temperature (degrees Celsius) Data type: float.
float	TSMax	The maximum measured temperature (degrees Celsius) Data type: float.
float	TSGrad	The temperature gradient (V/degrees Celsius). Data type: float.
uint32_t	TSSettings	Flags of temperature sensor settings. This is a bit mask for bitwise operations.
	0x7 - TS_TYPE_BITS	Bits of the temperature sensor type
	0x0 - TS_TYPE_UNKNOWN	Unknown type of sensor
	0x1 - TS_TYPE_THERMOCOUPLE	Thermocouple
	0x2 - TS_TYPE_SEMICONDUCTOR	The semiconductor temperature sensor
	0x8 - TS_AVAILABLE	If the flag is set, the temperature sensor is available
uint32_t	LimitSwitchesSettings	Flags of limit switches settings. This is a bit mask for bitwise operations.
	0x1 - LS_ON_SW1_AVAILABLE	If the flag is set, the limit switch connected to pin SW1 is available
	0x2 - LS_ON_SW2_AVAILABLE	If the flag is set, the limit switch connected to pin SW2 is available
	0x4 - LS_SW1_ACTIVE_LOW	If the flag is set, the limit switch connected to pin SW1 is triggered by a low level on the pin
	0x8 - LS_SW2_ACTIVE_LOW	If the flag is set, the limit switch connected to pin SW2 is triggered by a low level on pin
	0x10 - LS_SHORTED	If the flag is set, the limit switches are shorted
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read additional accessory information from the EEPROM.

6.2.6.2 Command GBRK

Command code (CMD): “gbrk” or 0x6B726267.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (25 bytes)

uint32_t	CMD	Command
uint16_t	t1	Time in ms between turning on motor power and turning off the brake.
uint16_t	t2	Time in ms between the brake turning off and moving readiness. All moving commands will execute after this interval.
uint16_t	t3	Time in ms between motor stop and the brake turning on.
uint16_t	t4	Time in ms between turning on the brake and turning off motor power.
uint8_t	BrakeFlags	Flags. This is a bit mask for bitwise operations.
	0x1 - BRAKE_ENABLED	Brake control is enabled if this flag is set.
	0x2 - BRAKE_ENG_PWROFF	Brake turns the stepper motor power off if this flag is set.
uint8_t	Reserved [10]	Reserved (10 bytes)
uint16_t	CRC	Checksum

Description: Read break control settings.

6.2.6.3 Command GCAL

Command code (CMD): “gcal” or 0x6C616367.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (118 bytes)

uint32_t	CMD	Command
float	CSS1_A	Scaling factor for the analog measurements of the A winding current.
float	CSS1_B	Offset for the analog measurements of the A winding current.
float	CSS2_A	Scaling factor for the analog measurements of the B winding current.
float	CSS2_B	Offset for the analog measurements of the B winding current.
float	FullCurrent_A	Scaling factor for the analog measurements of the full current.

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float	FullCurrent_B	Offset for the analog measurements of the full current.
uint8_t	Reserved [88]	Reserved (88 bytes)
uint16_t	CRC	Checksum

Description: Read calibration settings. Manufacturer only. This function reads the structure with calibration settings. These settings are used to convert bare ADC values to winding currents in mA and the full current in mA. Parameters are grouped into pairs, XXX_A and XXX_B, representing linear equation coefficients. The first one is the slope, the second one is the constant term. Thus, XXX_Current[mA] = XXX_A[mA/ADC]XXX_ADC_CODE[ADC] + XXX_B[mA].

6.2.6.4 Command GCTL

Command code (CMD): "gctl" or 0x6C746367.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (93 bytes)

uint32_t	CMD	Command
uint32_t	MaxSpeed	Array of speeds (full step) used with the joystick and the button control. Range: 0..100000.
uint8_t	uMaxSpeed	Array of speeds (in microsteps) used with the joystick and the button control. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint16_t	Timeout	Timeout[i] is timeout in ms. After that, max_speed[i+1] is applied. It's used with the button control only.
uint16_t	MaxClickTime	Maximum click time (in ms). Until the expiration of this time, the first speed isn't applied.
uint16_t	Flags	Control flags. This is a bit mask for bitwise operations.
	0x3 - CONTROL_MODE_BITS	Bits to control the engine by joystick or buttons.
	0x0 - CONTROL_MODE_OFF	Control is disabled.
	0x1 - CONTROL_MODE_JOY	Control by joystick.
	0x2 - CONTROL_MODE_LR	Control by left/right buttons.
	0x4 - CONTROL_BTN_LEFT_PUSHED_OPEN	Pushed left button corresponds to the open contact if this flag is set.
	0x8 - CONTROL_BTN_RIGHT_PUSHED_OPEN	Pushed right button corresponds to open contact if this flag is set.
int32_t	DeltaPosition	Position Shift (delta) (full step)

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int16_t	uDeltaPosition	Fractional part of the shift in micro steps. It's used with a stepper motor only. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint8_t	Reserved [9]	Reserved (9 bytes)
uint16_t	CRC	Checksum

Description: Read motor control settings. In case of CTL_MODE=1, joystick motor control is enabled. In this mode, while the joystick is maximally displaced, the engine tends to move at MaxSpeed[i]. i=0 if another value hasn't been set at the previous usage. To change the speed index 'i', use the buttons. In case of CTL_MODE=2, the motor is controlled by the left/right buttons. When you click on the button, the motor starts moving in the appropriate direction at a speed MaxSpeed[0]. After Timeout[i], motor moves at speed MaxSpeed[i+1]. At the transition between MaxSpeed[i] and MaxSpeed[i+1] the motor just accelerates/decelerates as usual.

6.2.6.5 Command GCTP

Command code (CMD): "gctp" or 0x70746367.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (18 bytes)

uint32_t	CMD	Command
uint8_t	CTPMinError	The minimum difference between the SM position in steps and the encoder position that causes the setting of the STATE_CTP_ERROR flag. Measured in steps.
uint8_t	CTPFlags	This is a bit mask for bitwise operations.
	0x1 - CTP_ENABLED	The position control is enabled if the flag is set.
	0x2 - CTP_BASE	The position control is based on the revolution sensor if this flag is set; otherwise, it is based on the encoder.
	0x4 - CTP_ALARM_ON_ERROR	Set ALARM on mismatch if the flag is set.
	0x8 - REV_SENS_INV	Typically, the sensor is active when it is at 0, and inversion makes active at 1. That is, if you do not invert, it is normal logic - 0 is the activation.
	0x10 - CTP_ERROR_CORRECTION	Correct errors that appear when slippage occurs if the flag is set. It works only with the encoder. Incompatible with the flag CTP_ALARM_ON_ERROR.
uint8_t	Reserved [10]	Reserved (10 bytes)
uint16_t	CRC	Checksum

Description: Read control position settings (used with stepper motor only). When controlling the step motor with an encoder (CTP_BASE=0), it is possible to detect the loss of steps. The controller knows the number of steps per revolution (GENG::StepsPerRev) and the encoder resolution (GFBS::IPT). When the control is enabled (CTP_ENABLED is set), the controller stores the current position in the steps of SM and the current position of the encoder. Next, the encoder position is converted into steps at each step, and if the difference between the current position in steps and the encoder position is greater than CTPMinError, the flag STATE_CTP_ERROR is set. Alternatively, the stepper motor may be controlled with the speed sensor (CTP_BASE 1). In this mode, at the active edges of the input clock, the controller stores the current value of steps. Then, at each revolution, the controller checks how many steps have been passed. When the difference is over the CTPMinError, the STATE_CTP_ERROR flag is set.

6.2.6.6 Command GEAS

Command code (CMD): "geas" or 0x73616567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (54 bytes)

uint32_t	CMD	Command
uint16_t	stepcloseloop_Kw	Mixing ratio of the actual and set speed, range [0, 100], default value 50.
uint16_t	stepcloseloop_Kp_low	Position feedback in the low-speed zone, range [0, 65535], default value 1000.
uint16_t	stepcloseloop_Kp_high	Position feedback in the high-speed zone, range [0, 65535], default value 33.
uint8_t	Reserved [42]	Reserved (42 bytes)
uint16_t	CRC	Checksum

Description: Read engine advanced settings.

6.2.6.7 Command GEDS

Command code (CMD): "geds" or 0x73646567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (26 bytes)

uint32_t	CMD	Command
uint8_t	BorderFlags	Border flags, specify types of borders and motor behavior at borders. This is a bit mask for bitwise operations.
	0x1 - BORDER_IS_ENCODER	Borders are fixed by predetermined encoder values, if set; borders are placed on limit switches, if not set.
	0x2 - BORDER_STOP_LEFT	The motor should stop on the left border.

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	0x4 - BORDER_STOP_RIGHT	Motor should stop on right border.
	0x8 - BORDERS_SWAP_MISSET_DETECTION	Motor should stop on both borders. Need to save motor then wrong border settings is set
uint8_t	EnderFlags	Flags specify electrical behavior of limit switches like order and pulled positions. This is a bit mask for bitwise operations.
	0x1 - ENDER_SWAP	First limit switch on the right side, if set; otherwise on the left side.
	0x2 - ENDER_SW1_ACTIVE_LOW	1 - Limit switch connected to pin SW1 is triggered by a low level on pin.
	0x4 - ENDER_SW2_ACTIVE_LOW	1 - Limit switch connected to pin SW2 is triggered by a low level on pin.
int32_t	LeftBorder	Left border position, used if BORDER_IS_ENCODER flag is set.
int16_t	uLeftBorder	Left border position in microsteps (used with stepper motor only). The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
int32_t	RightBorder	Right border position, used if BORDER_IS_ENCODER flag is set.
int16_t	uRightBorder	Right border position in microsteps. Used with a stepper motor only. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Description: Read border and limit switches settings.

6.2.6.8 Command GEIO

Command code (CMD): “geio” or 0x6F696567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (18 bytes)

uint32_t	CMD	Command
uint8_t	EXTIOSetupFlags	Configuration flags of the external I-O. This is a bit mask for bitwise operations.
	0x1 - EXTIO_SETUP_OUTPUT	EXTIO works as output if the flag is set, works as input otherwise.

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	0x2 - EXTIO_SETUP_INVERT	Interpret EXTIO state inverted if the flag is set. A falling front is treated as an input event and a low logic level as an active state.
uint8_t	EXTIOModeFlags	Flags mode settings external I-O. This is a bit mask for bitwise operations.
	0xf - EXTIO_SETUP_MODE_IN_BITS	Bits of the behavior selector when the signal on input goes to the active state.
	0x0 - EXTIO_SETUP_MODE_IN_NOP	Do nothing.
	0x1 - EXTIO_SETUP_MODE_IN_STOP	Issue STOP command, ceasing the engine movement.
	0x2 - EXTIO_SETUP_MODE_IN_PWOF	Issue PWOF command, powering off all engine windings.
	0x3 - EXTIO_SETUP_MODE_IN_MOVR	Issue MOVR command with last used settings.
	0x4 - EXTIO_SETUP_MODE_IN_HOME	Issue HOME command.
	0x5 - EXTIO_SETUP_MODE_IN_ALARM	Set Alarm when the signal goes to the active state.
	0xf0 - EXTIO_SETUP_MODE_OUT_BITS	Bits of the output behavior selection.
	0x0 - EXTIO_SETUP_MODE_OUT_OFF	EXTIO pin always set in inactive state.
	0x10 - EXTIO_SETUP_MODE_OUT_ON	EXTIO pin always set in active state.
	0x20 - EXTIO_SETUP_MODE_OUT_MOVING	EXTIO pin stays active during moving state.
	0x30 - EXTIO_SETUP_MODE_OUT_ALARM	EXTIO pin stays active during the alarm state.
	0x40 - EXTIO_SETUP_MODE_OUT_MOTOR_ON	EXTIO pin stays active when windings are powered.
uint8_t	Reserved [10]	Reserved (10 bytes)
uint16_t	CRC	Checksum

Description: Read EXTIO settings. This function reads a structure with a set of EXTIO settings from the controller's memory.

6.2.6.9 Command GEMF

Command code (CMD): "gemf" or 0x666D6567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (48 bytes)

uint32_t	CMD	Command
float	L	Motor winding inductance.
float	R	Motor winding resistance.
float	Km	Electromechanical ratio of the motor.
uint8_t	BackEMFFlags	Auto-settings stepper motor flags. This is a bit mask for bitwise operations.
	0x1 - BACK_EMF_INDUCTANCE_AUTO	Flag of auto-detection of inductance of windings of the engine.

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	0x2 - BACK_EMF_RESISTANCE_AUTO	Flag of auto-detection of resistance of windings of the engine.
	0x4 - BACK_EMF_KM_AUTO	Flag of auto-detection of electromechanical coefficient of the engine.
uint8_t	Reserved [29]	Reserved (29 bytes)
uint16_t	CRC	Checksum

Description: Read electromechanical settings. The settings are different for different stepper motors.

6.2.6.10 Command GENG

Command code (CMD): "geng" or 0x676E6567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (34 bytes)

uint32_t	CMD	Command
uint16_t	NomVoltage	Rated voltage in tens of mV. Controller will keep the voltage drop on motor below this value if ENGINE_LIMIT_VOLT flag is set (used with DC only).
uint16_t	NomCurrent	Rated current (in mA). Controller will keep current consumed by motor below this value if ENGINE_LIMIT_CURR flag is set. Range: 15..8000
uint32_t	NomSpeed	Nominal (maximum) speed (in whole steps/s or rpm for DC and stepper motor as a master encoder). Controller will keep motor shaft RPM below this value if ENGINE_LIMIT_RPM flag is set. Range: 1..100000.
uint8_t	uNomSpeed	The fractional part of a nominal speed in microsteps (is only used with stepper motor). Microstep size and the range of valid values for this field depend on selected step division mode (see MicrostepMode field in engine_settings).
uint16_t	EngineFlags	Set of flags specify motor shaft movement algorithm and a list of limitations. This is a bit mask for bitwise operations.

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	0x1 - ENGINE_REVERSE	Reverse flag. It determines motor shaft rotation direction that corresponds to feedback counts increasing. If not set (default), motor shaft rotation direction under positive voltage corresponds to feedback counts increasing and vice versa. Change it if you see that positive directions on motor and feedback are opposite.
	0x2 - ENGINE_CURRENT_AS_RMS	Engine current meaning flag. If the flag is unset, then the engine's current value is interpreted as the maximum amplitude value. If the flag is set, then the engine current value is interpreted as the root-mean-square current value (for stepper) or as the current value calculated from the maximum heat dissipation (BLDC).
	0x4 - ENGINE_MAX_SPEED	Max speed flag. If it is set, the engine uses the maximum speed achievable with the present engine settings as its nominal speed.
	0x8 - ENGINE_ANTIPLAY	Play compensation flag. If it is set, the engine makes backlash (play) compensation and reaches the predetermined position accurately at low speed.
	0x10 - ENGINE_ACCEL_ON	Acceleration enable flag. If it set, motion begins with acceleration and ends with deceleration.
	0x20 - ENGINE_LIMIT_VOLT	Maximum motor voltage limit enable flag (is only used with DC motor).
	0x40 - ENGINE_LIMIT_CURR	Maximum motor current limit enable flag (is only used with DC motor).
	0x80 - ENGINE_LIMIT_RPM	Maximum motor speed limit enable flag.
int16_t	Antiplay	Number of pulses or steps for backlash (play) compensation procedure. Used if ENGINE_ANTIPLAY flag is set.
uint8_t	MicrostepMode	Settings of microstep mode (Used with stepper motor only). the microstep size and the range of valid values for this field depend on the selected step division mode (see MicrostepMode field in engine_settings). This is a bit mask for bitwise operations.
	0x1 - MICROSTEP_MODE_FULL	Full step mode.
	0x2 - MICROSTEP_MODE_FRAC_2	1/2-step mode.
	0x3 - MICROSTEP_MODE_FRAC_4	1/4-step mode.
	0x4 - MICROSTEP_MODE_FRAC_8	1/8-step mode.
	0x5 - MICROSTEP_MODE_FRAC_16	1/16-step mode.
	0x6 - MICROSTEP_MODE_FRAC_32	1/32-step mode.
	0x7 - MICROSTEP_MODE_FRAC_64	1/64-step mode.
	0x8 - MICROSTEP_MODE_FRAC_128	1/128-step mode.

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	0x9 - MICROSTEP_MODE_FRAC_256	1/256-step mode.
uint16_t	StepsPerRev	Number of full steps per revolution (Used with stepper motor only). Range: 1..65535.
uint8_t	Reserved [12]	Reserved (12 bytes)
uint16_t	CRC	Checksum

Description: Read engine settings. This function reads the structure containing a set of useful motor settings stored in the controller's memory. These settings specify motor shaft movement algorithm, list of limitations and rated characteristics.

6.2.6.11 Command GENI

Command code (CMD): "geni" or 0x696E6567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (70 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer. Max string length: 16 chars.
int8_t	PartNumber	Series and PartNumber. Max string length: 24 chars.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read encoder information from the EEPROM.

6.2.6.12 Command GENS

Command code (CMD): "gens" or 0x736E6567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (54 bytes)

uint32_t	CMD	Command
float	MaxOperatingFrequency	Maximum operation frequency (kHz). Data type: float.
float	SupplyVoltageMin	Minimum supply voltage (V). Data type: float.
float	SupplyVoltageMax	Maximum supply voltage (V). Data type: float.
float	MaxCurrentConsumption	Max current consumption (mA). Data type: float.
uint32_t	PPR	The number of counts per revolution

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uint32_t	EncoderSettings	Encoder settings flags. This is a bit mask for bitwise operations.
	0x1 - ENCSET_DIFFERENTIAL_OUTPUT	If the flag is set, the encoder has differential output, otherwise single-ended output
	0x4 - ENCSET_PUSHPULL_OUTPUT	If the flag is set the encoder has push-pull output, otherwise open drain output
	0x10 - ENCSET_INDEXCHANNEL_PRESENT	If the flag is set, the encoder has an extra indexed channel
	0x40 - ENCSET_REVOLUTIONSENSOR_PRESENT	If the flag is set, the encoder has the revolution sensor
	0x100 - ENCSET_REVOLUTIONSENSOR_ACTIVE_HIGH	If the flag is set, the revolution sensor's active state is high logic state; otherwise, the active state is low logic state
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read encoder settings from the EEPROM.

6.2.6.13 Command GENT

Command code (CMD): "gent" or 0x746E6567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (14 bytes)

uint32_t	CMD	Command
uint8_t	EngineType	Engine type. This is a bit mask for bitwise operations.
	0x0 - ENGINE_TYPE_NONE	A value that shouldn't be used.
	0x1 - ENGINE_TYPE_DC	DC motor.
	0x2 - ENGINE_TYPE_2DC	2 DC motors.
	0x3 - ENGINE_TYPE_STEP	Step motor.
	0x4 - ENGINE_TYPE_TEST	Duty cycle are fixed. Used only manufacturer.
	0x5 - ENGINE_TYPE_BRUSHLESS	Brushless motor.
uint8_t	DriverType	Driver type. This is a bit mask for bitwise operations.
	0x1 - DRIVER_TYPE_DISCRETE_FET	Driver with discrete FET keys. Default option.
	0x2 - DRIVER_TYPE_INTEGRATE	Driver with integrated IC.
	0x3 - DRIVER_TYPE_EXTERNAL	External driver.
uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Description: Return engine type and driver type.

6.2.6.14 Command GEST

Command code (CMD): “gest” or 0x74736567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (46 bytes)

uint32_t	CMD	Command
uint16_t	Param1	
uint8_t	Reserved [38]	Reserved (38 bytes)
uint16_t	CRC	Checksum

Description: Read extended settings. Currently, it is not in use.

6.2.6.15 Command GFBS

Command code (CMD): “gfbs” or 0x73626667.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (18 bytes)

uint32_t	CMD	Command
uint16_t	IPS	The number of encoder counts per shaft revolution. Range: 1..655535. The field is obsolete, it is recommended to write 0 to IPS and use the extended CountsPerTurn field. You may need to update the controller firmware to the latest version.
uint8_t	FeedbackType	Type of feedback. This is a bit mask for bitwise operations.
	0x1 - FEEDBACK_ENCODER	Feedback by encoder.
	0x4 - FEEDBACK_EMF	Feedback by EMF.
	0x5 - FEEDBACK_NONE	Feedback is absent.
	0x6 - FEEDBACK_ENCODER_MEDIATED	Feedback by encoder mediated by mechanical transmission (for example leadscrew).
uint8_t	FeedbackFlags	Flags. This is a bit mask for bitwise operations.
	0x1 - FEEDBACK_ENC_REVERSE	Reverse count of encoder.
	0xc0 - FEEDBACK_ENC_TYPE_BITS	Bits of the encoder type.
	0x0 - FEEDBACK_ENC_TYPE_AUTO	Auto detect encoder type.
	0x40 - FEEDBACK_ENC_TYPE_SINGLE_ENDED	Single-ended encoder.
	0x80 - FEEDBACK_ENC_TYPE_DIFFERENTIAL	Differential encoder.

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uint32_t	CountsPerTurn	The number of encoder counts per shaft revolution. Range: 1..4294967295. To use the CountsPerTurn field, write 0 in the IPS field, otherwise the value from the IPS field will be used.
uint8_t	Reserved [4]	Reserved (4 bytes)
uint16_t	CRC	Checksum

Description: Feedback settings.

6.2.6.16 Command GGRI

Command code (CMD): "ggri" or 0x69726767.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (70 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer. Max string length: 16 chars.
int8_t	PartNumber	Series and PartNumber. Max string length: 24 chars.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read gear information from the EEPROM.

6.2.6.17 Command GGRS

Command code (CMD): "ggrs" or 0x73726767.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (58 bytes)

uint32_t	CMD	Command
float	ReductionIn	Input reduction coefficient. (Output = (ReductionOut / ReductionIn) Input) Data type: float.
float	ReductionOut	Output reduction coefficient. (Output = (ReductionOut / ReductionIn) Input) Data type: float.
float	RatedInputTorque	Maximum continuous torque (N m). Data type: float.
float	RatedInputSpeed	Maximum speed on the input shaft (rpm). Data type: float.

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float	MaxOutputBacklash	Output backlash of the reduction gear (degree). Data type: float.
float	InputInertia	Equivalent input gear inertia (g cm2). Data type: float.
float	Efficiency	Reduction gear efficiency (%). Data type: float.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read gear settings from the EEPROM.

6.2.6.18 Command GHOM

Command code (CMD): "ghom" or 0x6D6F6867.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (33 bytes)

uint32_t	CMD	Command
uint32_t	FastHome	Speed used for first motion (full steps). Range: 0..100000.
uint8_t	uFastHome	Fractional part of the speed for first motion, microsteps. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint32_t	SlowHome	Speed used for second motion (full steps). Range: 0..100000.
uint8_t	uSlowHome	Part of the speed for second motion, microsteps. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
int32_t	HomeDelta	Distance from break point (full steps).
int16_t	uHomeDelta	Fractional part of the delta distance, microsteps. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint16_t	HomeFlags	Set of flags specifies the direction and stopping conditions. This is a bit mask for bitwise operations.

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	0x1 - HOME_DIR_FIRST	The flag defines the direction of the 1st motion after execution of the home command. The direction is to the right if the flag is set, and to the left otherwise.
	0x2 - HOME_DIR_SECOND	The flag defines the direction of the 2nd motion. The direction is to the right if the flag is set, and to the left otherwise.
	0x4 - HOME_MV_SEC_EN	Use the second phase of calibration to the home position, if set; otherwise the second phase is skipped.
	0x8 - HOME_HALF_MV	If the flag is set, the stop signals are ignored during the first half-turn of the second movement.
	0x30 - HOME_STOP_FIRST_BITS	Bits of the first stop selector.
	0x10 - HOME_STOP_FIRST_REV	First motion stops by revolution sensor.
	0x20 - HOME_STOP_FIRST_SYN	First motion stops by synchronization input.
	0x30 - HOME_STOP_FIRST_LIM	First motion stops by limit switch.
	0xc0 - HOME_STOP_SECOND_BITS	Bits of the second stop selector.
	0x40 - HOME_STOP_SECOND_REV	Second motion stops by revolution sensor.
	0x80 - HOME_STOP_SECOND_SYN	Second motion stops by synchronization input.
	0xc0 - HOME_STOP_SECOND_LIM	Second motion stops by limit switch.
	0x100 - HOME_USE_FAST	Use the fast algorithm of calibration to the home position, if set; otherwise the traditional algorithm.
uint8_t	Reserved [9]	Reserved (9 bytes)
uint16_t	CRC	Checksum

Description: Read home settings. This function reads the structure with home position settings.

6.2.6.19 Command GHSI

Command code (CMD): “ghsi” or 0x69736867.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (70 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer. Max string length: 16 chars.
int8_t	PartNumber	Series and PartNumber. Max string length: 24 chars.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read hall sensor information from the EEPROM.

6.2.6.20 Command GHSS

Command code (CMD): “ghss” or 0x73736867.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (50 bytes)

uint32_t	CMD	Command
float	MaxOperatingFrequency	Maximum operation frequency (kHz). Data type: float.
float	SupplyVoltageMin	Minimum supply voltage (V). Data type: float.
float	SupplyVoltageMax	Maximum supply voltage (V). Data type: float.
float	MaxCurrentConsumption	Maximum current consumption (mA). Data type: float.
uint32_t	PPR	The number of counts per revolution
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read hall sensor settings from the EEPROM.

6.2.6.21 Command GJOY

Command code (CMD): “gjoy” or 0x796F6A67.

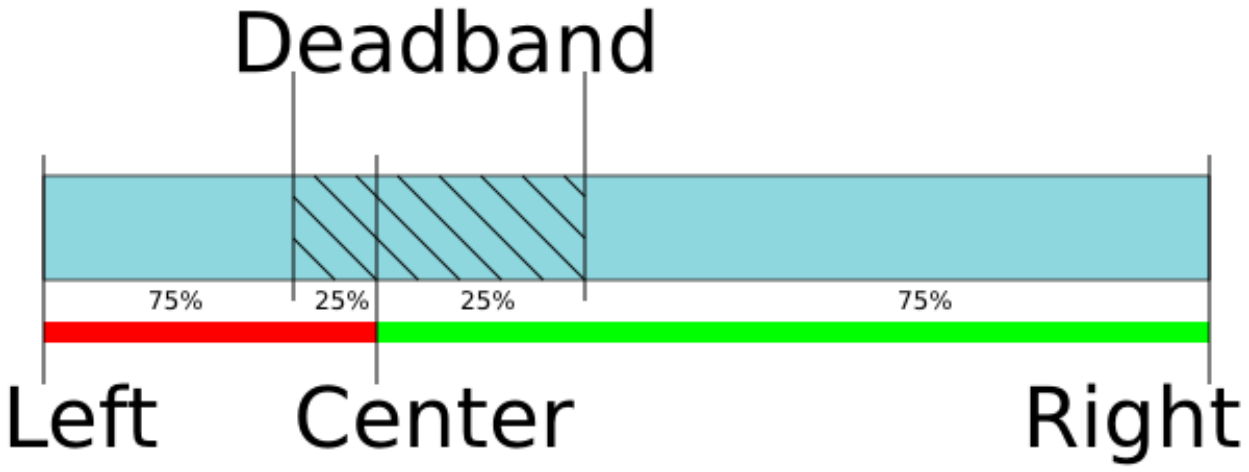
Request: (4 bytes)

uint32_t	CMD	Command

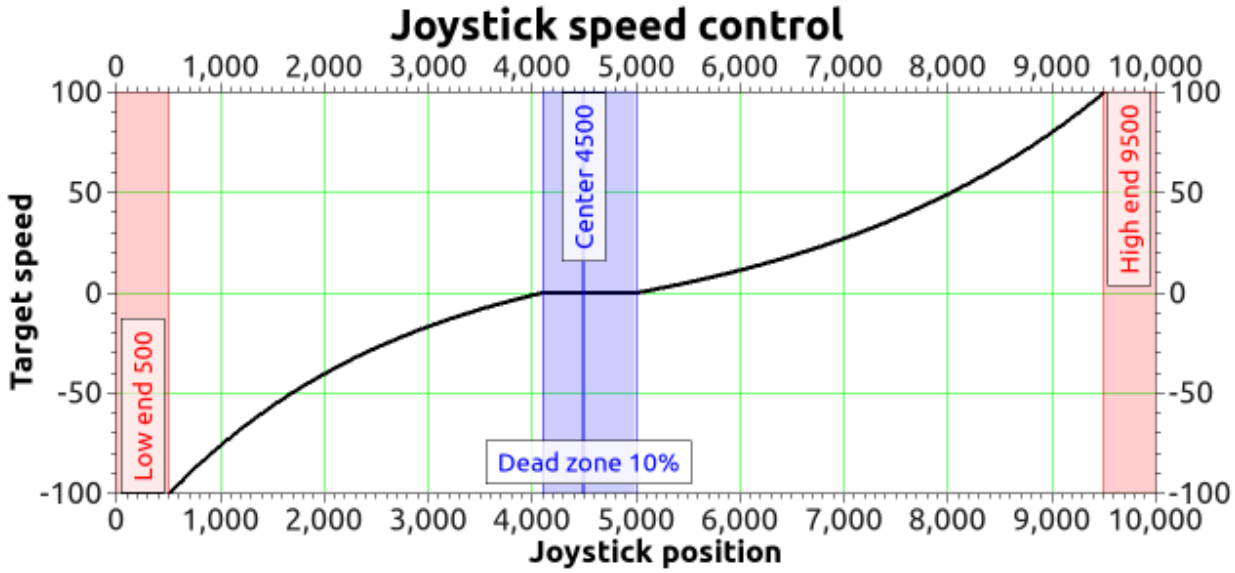
Answer: (22 bytes)

uint32_t	CMD	Command
uint16_t	JoyLowEnd	Joystick lower end position. Range: 0..10000.
uint16_t	JoyCenter	Joystick center position. Range: 0..10000.
uint16_t	JoyHighEnd	Joystick upper end position. Range: 0..10000.
uint8_t	ExpFactor	Exponential nonlinearity factor.
uint8_t	DeadZone	Joystick dead zone.
uint8_t	JoyFlags	Joystick control flags. This is a bit mask for bitwise operations.
	0x1 - JOY_REVERSE	Joystick action is reversed. The joystick deviation to the upper values corresponds to negative speed and vice versa.
uint8_t	Reserved [7]	Reserved (7 bytes)
uint16_t	CRC	Checksum

Description: Read joystick settings. If joystick position falls outside DeadZone limits, a movement begins. The speed is defined by the joystick's position in the range of the DeadZone limit to the maximum deviation. Joystick positions inside DeadZone limits correspond to zero speed (a soft stop of the motion), and positions beyond Low and High limits correspond to MaxSpeed[i] or -MaxSpeed[i] (see command SCTL), where i = 0 by default and can be changed with the left/right buttons (see command SCTL). If the next speed in the list is zero (both integer and microstep parts), the button press is ignored. The first speed in the list shouldn't be zero. The DeadZone ranges are illustrated on the following picture.



The relationship between the deviation and the rate is exponential, allowing no switching speed combine high mobility and accuracy. The following picture illustrates this:



The nonlinearity parameter is adjustable. Setting it to zero makes deviation/speed relation linear.

6.2.6.22 Command GMOV

Command code (CMD): "gmov" or 0x766F6D67.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (30 bytes)

uint32_t	CMD	Command
uint32_t	Speed	Target speed (for stepper motor: steps/s, for DC: rpm). Range: 0..100000.
uint8_t	uSpeed	Target speed in microstep fractions/s. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings). Used with a stepper motor only.
uint16_t	Accel	Motor shaft acceleration, steps/s^2 (stepper motor) or RPM/s (DC). Range: 1..65535.
uint16_t	Decel	Motor shaft deceleration, steps/s^2 (stepper motor) or RPM/s (DC). Range: 1..65535.
uint32_t	AntiplaySpeed	Speed in antiplay mode, full steps/s (stepper motor) or RPM (DC). Range: 0..100000.
uint8_t	uAntiplaySpeed	Speed in antiplay mode, microsteps/s. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings). Used with a stepper motor only.
uint8_t	MoveFlags	Flags that control movement settings. This is a bit mask for bitwise operations.
	0x1 - RPM_DIV_1000	This flag indicates that the operating speed specified in the command is set in milliRPM. Applicable only for ENCODER feedback mode and only for BLDC motors.
uint8_t	Reserved [9]	Reserved (9 bytes)
uint16_t	CRC	Checksum

Description: Movement settings read command (speed, acceleration, threshold, etc.).

6.2.6.23 Command GMTI

Command code (CMD): “gmti” or 0x69746D67.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (70 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer. Max string length: 16 chars.
int8_t	PartNumber	Series and PartNumber. Max string length: 24 chars.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read motor information from the EEPROM.

6.2.6.24 Command GMTS

Command code (CMD): "gmts" or 0x73746D67.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (112 bytes)

uint32_t	CMD	Command
uint8_t	MotorType	Motor type. This is a bit mask for bitwise operations.
	0x0 - MOTOR_TYPE_UNKNOWN	Unknown type of engine
	0x1 - MOTOR_TYPE_STEP	Step engine
	0x2 - MOTOR_TYPE_DC	DC engine
	0x3 - MOTOR_TYPE_BLDC	BLDC engine
uint8_t	ReservedField	Reserved
uint16_t	Poles	Number of pole pairs for DC or BLDC motors or number of steps per rotation for stepper motors.
uint16_t	Phases	Number of phases for BLDC motors.
float	NominalVoltage	Nominal voltage on winding (B). Data type: float
float	NominalCurrent	Maximum direct current in winding for DC and BLDC engines, nominal current in windings for stepper motors (A). Data type: float.
float	NominalSpeed	Not used. Nominal speed (rpm). Used for DC and BLDC engines. Data type: float.
float	NominalTorque	Nominal torque (mN m). Used for DC and BLDC engines. Data type: float.
float	NominalPower	Nominal power (W). Used for DC and BLDC engines. Data type: float.
float	WindingResistance	Resistance of windings for DC engines, of each of two windings for stepper motors, or of each of three windings for BLDC engines (Ohm). Data type: float.

Continued on next page

Table 6.52 – continued from previous page

float	WindingInductance	Inductance of windings for DC engines, inductance of each of two windings for stepper motors, or inductance of each of three windings for BLDC engines (mH). Data type: float.
float	RotorInertia	Rotor inertia (g cm2). Data type: float.
float	StallTorque	Torque hold position for a stepper motor or torque at a motionless rotor for other types of engines (mN m). Data type: float.
float	DetentTorque	Holding torque position with unpowered windings (mN m). Data type: float.
float	TorqueConstant	Torque constant that determines the proportionality constant between the maximum rotor torque and current flowing in the winding (mN m / A). Used mainly for DC motors. Data type: float.
float	SpeedConstant	Velocity constant, which determines the value or the amplitude of the induced voltage on the motion of DC or BLDC motors (rpm / V) or stepper motors (steps/s / V). Data type: float.
float	SpeedTorqueGradient	Speed torque gradient (rpm / mN m). Data type: float.
float	MechanicalTimeConstant	Mechanical time constant (ms). Data type: float.
float	MaxSpeed	The maximum speed for stepper motors (steps/s) or DC and BLDC motors (rmp). Data type: float.
float	MaxCurrent	The maximum current in the winding (A). Data type: float.
float	MaxCurrentTime	Safe duration of overcurrent in the winding (ms). Data type: float.
float	NoLoadCurrent	The current consumption in idle mode (A). Used for DC and BLDC motors. Data type: float.
float	NoLoadSpeed	Idle speed (rpm). Used for DC and BLDC motors. Data type: float.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read motor settings from the EEPROM.

6.2.6.25 Command GNET

Command code (CMD): “gnet” or 0x74656E67.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (38 bytes)

uint32_t	CMD	Command
uint8_t	DHCPEnabled	Indicates the method to get the IP-address. It can be either 0 (static) or 1 (DHCP).
uint8_t	IPv4Address	IP-address of the device in format x.x.x.x.
uint8_t	SubnetMask	The mask of the subnet in format x.x.x.x.
uint8_t	DefaultGateway	Default value of the gateway in format x.x.x.x.
uint8_t	Reserved [19]	Reserved (19 bytes)
uint16_t	CRC	Checksum

Description: Read network settings. Manufacturer only. This function returns the current network settings.

6.2.6.26 Command GNME

Command code (CMD): "gnme" or 0x656D6E67.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (30 bytes)

uint32_t	CMD	Command
int8_t	PositionerName	User's positioner name. It can be set by a user. Max string length: 16 characters.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Description: Read the user's stage name from the EEPROM.

6.2.6.27 Command GNMF

Command code (CMD): "gnmf" or 0x666D6E67.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (30 bytes)

uint32_t	CMD	Command
int8_t	ControllerName	User controller name. It may be set by the user. Max string length: 16 characters.
uint8_t	CtrlFlags	Internal controller settings. This is a bit mask for bitwise operations.
	0x1 - EEPROM_PRECEDENCE	If the flag is set, settings from external EEPROM override controller settings.
uint8_t	Reserved [7]	Reserved (7 bytes)

Continued on next page

Table 6.58 – continued from previous page

uint16_t	CRC	Checksum

Description: Read user's controller name and internal settings from the FRAM.

6.2.6.28 Command GNVM

Command code (CMD): "gnvm" or 0x6D766E67.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (36 bytes)

uint32_t	CMD	Command
uint32_t	UserData	User data. It may be set by the user. Each element of the array stores only 32 bits of user data. This is important on systems where an int type contains more than 4 bytes. For example, on all amd64 systems.
uint8_t	Reserved [2]	Reserved (2 bytes)
uint16_t	CRC	Checksum

Description: Read user data from FRAM.

6.2.6.29 Command GPID

Command code (CMD): "gpid" or 0x64697067.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (48 bytes)

uint32_t	CMD	Command
uint16_t	KpU	Proportional gain for voltage PID routine
uint16_t	KiU	Integral gain for voltage PID routine
uint16_t	KdU	Differential gain for voltage PID routine
float	Kpf	Proportional gain for BLDC position PID routine
float	Kif	Integral gain for BLDC position PID routine
float	Kdf	Differential gain for BLDC position PID routine
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Read PID settings. This function reads the structure containing a set of motor PID settings stored in the controller's memory. These settings specify the behavior of the PID routine for the positioner. These factors

are slightly different for different positioners. All boards are supplied with the standard set of PID settings in the controller's flash memory.

6.2.6.30 Command GPWD

Command code (CMD): "gpwd" or 0x64777067.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (36 bytes)

uint32_t	CMD	Command
int8_t	UserPassword	Password for the web-page that the user can change with a USB command or via web-page.
uint8_t	Reserved [10]	Reserved (10 bytes)
uint16_t	CRC	Checksum

Description: Read the password. Manufacturer only. This function reads the user password for the device's web-page.

6.2.6.31 Command GPWR

Command code (CMD): "gpwr" or 0x72777067.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (20 bytes)

uint32_t	CMD	Command
uint8_t	HoldCurrent	Holding current, as percent of the nominal current. Range: 0..100.
uint16_t	CurrReductDelay	Time in ms from going to STOP state to the end of current reduction.
uint16_t	PowerOffDelay	Time in s from going to STOP state to turning power off.
uint16_t	CurrentSetTime	Time in ms to reach the nominal current.
uint8_t	PowerFlags	Flags with parameters of power control. This is a bit mask for bitwise operations.
	0x1 - POWER_REDUCT_ENABLED	Current reduction is enabled after CurrReductDelay if this flag is set.
	0x2 - POWER_OFF_ENABLED	Power off is enabled after PowerOffDelay if this flag is set.
	0x4 - POWER_SMOOTH_CURRENT	Current ramp-up/down are performed smoothly during current_set_time if this flag is set.
uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Description: Read settings of step motor power control. Used with a stepper motor only.

6.2.6.32 Command GSEC

Command code (CMD): “gsec” or 0x63657367.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (28 bytes)

uint32_t	CMD	Command
uint16_t	LowUpwrOff	Lower voltage limit to turn off the motor, in tens of mV.
uint16_t	CriticalIpwr	Maximum motor current which triggers ALARM state, in mA.
uint16_t	CriticalUpwr	Maximum motor voltage which triggers ALARM state, in tens of mV.
uint16_t	CriticalT	Maximum temperature, which triggers ALARM state, in tenths of degrees Celsius.
uint16_t	CriticalIusb	Maximum USB current which triggers ALARM state, in mA.
uint16_t	CriticalUusb	Maximum USB voltage which triggers ALARM state, in tens of mV.
uint16_t	MinimumUusb	Minimum USB voltage which triggers ALARM state, in tens of mV.
uint8_t	Flags	Critical parameter flags. This is a bit mask for bitwise operations.
	0x1 - ALARM_ON_DRIVER_OVERHEATING	If this flag is set, enter the alarm state on the driver overheat signal.
	0x2 - LOW_UPWR_PROTECTION	If this flag is set, turn off the motor when the voltage is lower than LowUpwrOff.
	0x4 - H_BRIDGE_ALERT	If this flag is set then turn off the power unit with a signal problem in one of the transistor bridge.
	0x8 - ALARM_ON_BORDERS_SWAP_MISSET	If this flag is set, enter Alarm state on borders swap misset
	0x10 - ALARM_FLAGS_STICKING	If this flag is set, only a STOP command can turn all alarms to 0
	0x20 - USB_BREAK_RECONNECT	If this flag is set, the USB brake reconnect module will be enabled
	0x40 - ALARM_WINDING_MISMATCH	If this flag is set, enter Alarm state when windings mismatch
	0x80 - ALARM_ENGINE_RESPONSE	If this flag is set, enter the Alarm state on response of the engine control action
uint8_t	Reserved [7]	Reserved (7 bytes)
uint16_t	CRC	Checksum

Description: Read protection settings.

6.2.6.33 Command GSNI

Command code (CMD): “gsni” or 0x696E7367.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (28 bytes)

uint32_t	CMD	Command
uint8_t	SyncInFlags	Input synchronization flags. This is a bit mask for bitwise operations.
	0x1 - SYNCIN_ENABLED	Synchronization in mode is enabled if this flag is set.
	0x2 - SYNCIN_INVERT	Trigger on falling edge if flag is set, on rising edge otherwise.
	0x4 - SYNCIN_GOTOPOSITION	The engine is going to the position specified in Position and uPosition if this flag is set. And it is shifting on the Position and uPosition if this flag is unset
uint16_t	ClutterTime	Input synchronization pulse dead time (us).
int32_t	Position	Desired position or shift (full steps)
int16_t	uPosition	The fractional part of a position or shift in microsteps. It is used with a stepper motor. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint32_t	Speed	Target speed (for stepper motor: steps/s, for DC: rpm). Range: 0..100000.
uint8_t	uSpeed	Target speed in microsteps/s. Microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings). Used a stepper motor only.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Description: Read input synchronization settings. This function reads the structure with a set of input synchronization settings, modes, periods and flags that specify the behavior of input synchronization. All boards are supplied with the standard set of these settings.

6.2.6.34 Command GSNO

Command code (CMD): “gsno” or 0x6F6E7367.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (16 bytes)

uint32_t	CMD	Command
uint8_t	SyncOutFlags	Output synchronization flags. This is a bit mask for bitwise operations.
	0x1 - SYNCOUT_ENABLED	The synchronization out pin follows the synchronization logic if the flag is set. Otherwise, it is governed by the SYNCOUT_STATE flag.
	0x2 - SYNCOUT_STATE	When the output state is fixed by the negative SYNCOUT_ENABLED flag, the pin state is in accordance with this flag state.
	0x4 - SYNCOUT_INVERT	The low level is active if the flag is set. Otherwise, the high level is active.
	0x8 - SYNCOUT_IN_STEPS	Use motor steps or encoder pulses instead of milliseconds for output pulse generation if the flag is set.
	0x10 - SYNCOUT_ONSTART	Generate a synchronization pulse when movement starts.
	0x20 - SYNCOUT_ONSTOP	Generate a synchronization pulse when movement stops.
	0x40 - SYNCOUT_ONPERIOD	Generate a synchronization pulse every SyncOutPeriod encoder pulses.
uint16_t	SyncOutPulseSteps	This value specifies the duration of output pulse. It is measured microseconds when SYNCOUT_IN_STEPS flag is cleared or in encoder pulses or motor steps when SYNCOUT_IN_STEPS is set.
uint16_t	SyncOutPeriod	This value specifies the number of encoder pulses or steps between two output synchronization pulses when SYNCOUT_ONPERIOD is set.
uint32_t	Accuracy	This is the neighborhood around the target coordinates, every point in which is treated as the target position. Getting in these points cause the stop impulse.
uint8_t	uAccuracy	This is the neighborhood around the target coordinates in microsteps (used with a stepper motor only). The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint16_t	CRC	Checksum

Description: Read output synchronization settings. This function reads the structure containing a set of output synchronization settings, modes, periods and flags that specify the behavior of output synchronization. All boards are supplied with the standard set of these settings.

6.2.6.35 Command GSTI

Command code (CMD): “gsti” or 0x69747367.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (70 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer. Max string length: 16 chars.
int8_t	PartNumber	Series and PartNumber. Max string length: 24 chars.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read stage information from the EEPROM.

6.2.6.36 Command GSTS

Command code (CMD): "gsts" or 0x73747367.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (70 bytes)

uint32_t	CMD	Command
float	LeadScrewPitch	Lead screw pitch (mm). Data type: float.
int8_t	Units	Units for MaxSpeed and TravelRange fields of the structure (steps, degrees, mm, . . .). Max string length: 8 chars.
float	MaxSpeed	Maximum speed (Units/c). Data type: float.
float	TravelRange	Travel range (Units). Data type: float.
float	SupplyVoltageMin	Minimum supply voltage (V). Data type: float.
float	SupplyVoltageMax	Maximum supply voltage (V). Data type: float.
float	MaxCurrentConsumption	Maximum current consumption (A). Data type: float.
float	HorizontalLoadCapacity	Horizontal load capacity (kg). Data type: float.
float	VerticalLoadCapacity	Vertical load capacity (kg). Data type: float.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Description: Deprecated. Read stage settings from the EEPROM.

6.2.6.37 Command GURT

Command code (CMD): "gurt" or 0x74727567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (16 bytes)

uint32_t	CMD	Command
uint32_t	Speed	UART baudrate (in bauds)
uint16_t	UARTSetupFlags	UART setup flags. This is a bit mask for bitwise operations.
	0x3 - UART_PARITY_BITS	Bits of the parity.
	0x0 - UART_PARITY_BIT_EVEN	Parity bit 1, if even
	0x1 - UART_PARITY_BIT_ODD	Parity bit 1, if odd
	0x2 - UART_PARITY_BIT_SPACE	Parity bit always 0
	0x3 - UART_PARITY_BIT_MARK	Parity bit always 1
	0x4 - UART_PARITY_BIT_USE	None parity
	0x8 - UART_STOP_BIT	If set - one stop bit, else two stop bit
uint8_t	Reserved [4]	Reserved (4 bytes)
uint16_t	CRC	Checksum

Description: Read UART settings. This function reads the structure containing UART settings.

6.2.6.38 Command SACC

Command code (CMD): “sacc” or 0x63636173.

Request: (114 bytes)

uint32_t	CMD	Command
int8_t	MagneticBrakeInfo	The manufacturer and the part number of magnetic brake, the maximum string length is 24 characters.
float	MBRatedVoltage	Rated voltage for controlling the magnetic brake (V). Data type: float.
float	MBRatedCurrent	Rated current for controlling the magnetic brake (A). Data type: float.
float	MBTorque	Retention moment (mN m). Data type: float.
uint32_t	MBSettings	Flags of magnetic brake settings. This is a bit mask for bitwise operations.
	0x1 - MB_AVAILABLE	If the flag is set, the magnetic brake is available
	0x2 - MB_POWERED_HOLD	If this flag is set, the magnetic brake is on when powered
int8_t	TemperatureSensorInfo	The manufacturer and the part number of the temperature sensor, the maximum string length: 24 characters.
float	TSMin	The minimum measured temperature (degrees Celsius) Data type: float.
float	TSMax	The maximum measured temperature (degrees Celsius) Data type: float.

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float	TSGrad	The temperature gradient (V/degrees Celsius). Data type: float.
uint32_t	TSSettings	Flags of temperature sensor settings. This is a bit mask for bitwise operations.
	0x7 - TS_TYPE_BITS	Bits of the temperature sensor type
	0x0 - TS_TYPE_UNKNOWN	Unknown type of sensor
	0x1 - TS_TYPE_THERMOCOUPLE	Thermocouple
	0x2 - TS_TYPE_SEMICONDUCTOR	The semiconductor temperature sensor
	0x8 - TS_AVAILABLE	If the flag is set, the temperature sensor is available
uint32_t	LimitSwitchesSettings	Flags of limit switches settings. This is a bit mask for bitwise operations.
	0x1 - LS_ON_SW1_AVAILABLE	If the flag is set, the limit switch connected to pin SW1 is available
	0x2 - LS_ON_SW2_AVAILABLE	If the flag is set, the limit switch connected to pin SW2 is available
	0x4 - LS_SW1_ACTIVE_LOW	If the flag is set, the limit switch connected to pin SW1 is triggered by a low level on the pin
	0x8 - LS_SW2_ACTIVE_LOW	If the flag is set, the limit switch connected to pin SW2 is triggered by a low level on pin
	0x10 - LS_SHORTED	If the flag is set, the limit switches are shorted
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set additional accessories' information to the EEPROM. Can be used by the manufacturer only.

6.2.6.39 Command SBRK

Command code (CMD): "sbrk" or 0x6B726273.

Request: (25 bytes)

uint32_t	CMD	Command
uint16_t	t1	Time in ms between turning on motor power and turning off the brake.
uint16_t	t2	Time in ms between the brake turning off and moving readiness. All moving commands will execute after this interval.
uint16_t	t3	Time in ms between motor stop and the brake turning on.
uint16_t	t4	Time in ms between turning on the brake and turning off motor power.

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uint8_t	BrakeFlags	Flags. This is a bit mask for bitwise operations.
	0x1 - BRAKE_ENABLED	Brake control is enabled if this flag is set.
	0x2 - BRAKE_ENG_PWROFF	Brake turns the stepper motor power off if this flag is set.
uint8_t	Reserved [10]	Reserved (10 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set brake control settings.

6.2.6.40 Command SCAL

Command code (CMD): "scal" or 0x6C616373.

Request: (118 bytes)

uint32_t	CMD	Command
float	CSS1_A	Scaling factor for the analog measurements of the A winding current.
float	CSS1_B	Offset for the analog measurements of the A winding current.
float	CSS2_A	Scaling factor for the analog measurements of the B winding current.
float	CSS2_B	Offset for the analog measurements of the B winding current.
float	FullCurrent_A	Scaling factor for the analog measurements of the full current.
float	FullCurrent_B	Offset for the analog measurements of the full current.
uint8_t	Reserved [88]	Reserved (88 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set calibration settings. Manufacturer only. This function sends the structure with calibration settings to the controller's memory. These settings are used to convert bare ADC values to winding currents in mA and the full current in mA. Parameters are grouped into pairs, XXX_A and XXX_B, representing linear equation coefficients. The first one is the slope, the second one is the constant term. Thus, XXX_Current[mA] = XXX_A[mA/ADC]XXX_ADC_CODE[ADC] + XXX_B[mA].

6.2.6.41 Command SCTL

Command code (CMD): "sctl" or 0x6C746373.

Request: (93 bytes)

uint32_t	CMD	Command
uint32_t	MaxSpeed	Array of speeds (full step) used with the joystick and the button control. Range: 0..100000.
uint8_t	uMaxSpeed	Array of speeds (in microsteps) used with the joystick and the button control. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint16_t	Timeout	Timeout[i] is timeout in ms. After that, max_speed[i+1] is applied. It's used with the button control only.
uint16_t	MaxClickTime	Maximum click time (in ms). Until the expiration of this time, the first speed isn't applied.
uint16_t	Flags	Control flags. This is a bit mask for bitwise operations.
	0x3 - CONTROL_MODE_BITS	Bits to control the engine by joystick or buttons.
	0x0 - CONTROL_MODE_OFF	Control is disabled.
	0x1 - CONTROL_MODE_JOY	Control by joystick.
	0x2 - CONTROL_MODE_LR	Control by left/right buttons.
	0x4 - CONTROL_BTN_LEFT_PUSHED_OPEN	Pushed left button corresponds to the open contact if this flag is set.
	0x8 - CONTROL_BTN_RIGHT_PUSHED_OPEN	Pushed right button corresponds to open contact if this flag is set.
int32_t	DeltaPosition	Position Shift (delta) (full step)
int16_t	uDeltaPosition	Fractional part of the shift in micro steps. It's used with a stepper motor only. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint8_t	Reserved [9]	Reserved (9 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Read motor control settings. In case of CTL_MODE=1, joystick motor control is enabled. In this mode, the joystick is maximally displaced, the engine tends to move at MaxSpeed[i]. i=0 if another value hasn't been set at the previous usage. To change the speed index 'i', use the buttons. In case of CTL_MODE=2, the motor is controlled by the left/right buttons. When you click on the button, the motor starts moving in the appropriate direction at a speed MaxSpeed[0]. After Timeout[i], motor moves at speed MaxSpeed[i+1]. At the transition between MaxSpeed[i] and MaxSpeed[i+1] the motor just accelerates/decelerates as usual.

6.2.6.42 Command SCTP

Command code (CMD): "sctp" or 0x70746373.

Request: (18 bytes)

uint32_t	CMD	Command
uint8_t	CTPMinError	The minimum difference between the SM position in steps and the encoder position that causes the setting of the STATE_CTP_ERROR flag. Measured in steps.
uint8_t	CTPFlags	This is a bit mask for bitwise operations.
	0x1 - CTP_ENABLED	The position control is enabled if the flag is set.
	0x2 - CTP_BASE	The position control is based on the revolution sensor if this flag is set; otherwise, it is based on the encoder.
	0x4 - CTP_ALARM_ON_ERROR	Set ALARM on mismatch if the flag is set.
	0x8 - REV_SENS_INV	Typically, the sensor is active when it is at 0, and inversion makes active at 1. That is, if you do not invert, it is normal logic - 0 is the activation.
	0x10 - CTP_ERROR_CORRECTION	Correct errors that appear when slippage occurs if the flag is set. It works only with the encoder. Incompatible with the flag CTP_ALARM_ON_ERROR.
uint8_t	Reserved [10]	Reserved (10 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set control position settings (used with stepper motor only). When controlling the step motor with the encoder (CTP_BASE=0), it is possible to detect the loss of steps. The controller knows the number of steps per revolution (GENG::StepsPerRev) and the encoder resolution (GFBS::IPT). When the control is enabled (CTP_ENABLED is set), the controller stores the current position in the steps of SM and the current position of the encoder. Next, the encoder position is converted into steps at each step, and if the difference between the current position in steps and the encoder position is greater than CTPMinError, the flag STATE_CTP_ERROR is set. Alternatively, the stepper motor may be controlled with the speed sensor (CTP_BASE 1). In this mode, at the active edges of the input clock, the controller stores the current value of steps. Then, at each revolution, the controller checks how many steps have been passed. When the difference is over the CTPMinError, the STATE_CTP_ERROR flag is set.

6.2.6.43 Command SEAS

Command code (CMD): "seas" or 0x73616573.

Request: (54 bytes)

uint32_t	CMD	Command
uint16_t	stepcloseloop_Kw	Mixing ratio of the actual and set speed, range [0, 100], default value 50.
uint16_t	stepcloseloop_Kp_low	Position feedback in the low-speed zone, range [0, 65535], default value 1000.

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uint16_t	stepcloseloop_Kp_high	Position feedback in the high-speed zone, range [0, 65535], default value 33.
uint8_t	Reserved [42]	Reserved (42 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set engine advanced settings.

6.2.6.44 Command SEDS

Command code (CMD): "seds" or 0x73646573.

Request: (26 bytes)

uint32_t	CMD	Command
uint8_t	BorderFlags	Border flags, specify types of borders and motor behavior at borders. This is a bit mask for bitwise operations.
	0x1 - BORDER_IS_ENCODER	Borders are fixed by predetermined encoder values, if set; borders are placed on limit switches, if not set.
	0x2 - BORDER_STOP_LEFT	The motor should stop on the left border.
	0x4 - BORDER_STOP_RIGHT	Motor should stop on right border.
	0x8 - BORDERS_SWAP_MISSET_DETECTION	Motor should stop on both borders. Need to save motor then wrong border settings is set
uint8_t	EnderFlags	Flags specify electrical behavior of limit switches like order and pulled positions. This is a bit mask for bitwise operations.
	0x1 - ENDER_SWAP	First limit switch on the right side, if set; otherwise on the left side.
	0x2 - ENDER_SW1_ACTIVE_LOW	1 - Limit switch connected to pin SW1 is triggered by a low level on pin.
	0x4 - ENDER_SW2_ACTIVE_LOW	1 - Limit switch connected to pin SW2 is triggered by a low level on pin.
int32_t	LeftBorder	Left border position, used if BORDER_IS_ENCODER flag is set.
int16_t	uLeftBorder	Left border position in microsteps (used with stepper motor only). The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
int32_t	RightBorder	Right border position, used if BORDER_IS_ENCODER flag is set.

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int16_t	uRightBorder	Right border position in microsteps. Used with a stepper motor only. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set border and limit switches settings.

6.2.6.45 Command SEIO

Command code (CMD): "seio" or 0x6F696573.

Request: (18 bytes)

uint32_t	CMD	Command
uint8_t	EXTIOSetupFlags	Configuration flags of the external I-O. This is a bit mask for bitwise operations.
	0x1 - EXTIO_SETUP_OUTPUT	EXTIO works as output if the flag is set, works as input otherwise.
	0x2 - EXTIO_SETUP_INVERT	Interpret EXTIO state inverted if the flag is set. A falling front is treated as an input event and a low logic level as an active state.
uint8_t	EXTIOModeFlags	Flags mode settings external I-O. This is a bit mask for bitwise operations.
	0xf - EXTIO_SETUP_MODE_IN_BITS	Bits of the behavior selector when the signal on input goes to the active state.
	0x0 - EXTIO_SETUP_MODE_IN_NOP	Do nothing.
	0x1 - EXTIO_SETUP_MODE_IN_STOP	Issue STOP command, ceasing the engine movement.
	0x2 - EXTIO_SETUP_MODE_IN_PWOF	Issue PWOF command, powering off all engine windings.
	0x3 - EXTIO_SETUP_MODE_IN_MOVR	Issue MOVR command with last used settings.
	0x4 - EXTIO_SETUP_MODE_IN_HOME	Issue HOME command.
	0x5 - EXTIO_SETUP_MODE_IN_ALARM	Set Alarm when the signal goes to the active state.
	0xf0 - EXTIO_SETUP_MODE_OUT_BITS	Bits of the output behavior selection.
	0x0 - EXTIO_SETUP_MODE_OUT_OFF	EXTIO pin always set in inactive state.
	0x10 - EXTIO_SETUP_MODE_OUT_ON	EXTIO pin always set in active state.
	0x20 - EXTIO_SETUP_MODE_OUT_MOVING	EXTIO pin stays active during moving state.
	0x30 - EXTIO_SETUP_MODE_OUT_ALARM	EXTIO pin stays active during the alarm state.

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	0x40 - EXTIO_SETUP_MODE_OUT_MOTOR_ON	EXTIO pin stays active when windings are powered.
uint8_t	Reserved [10]	Reserved (10 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set EXTIO settings. This function sends the structure with a set of EXTIO settings to the controller's memory. By default, input events are signaled through a rising front, and output states are signaled by a high logic state.

6.2.6.46 Command SEMF

Command code (CMD): "semf" or 0x666D6573.

Request: (48 bytes)

uint32_t	CMD	Command
float	L	Motor winding inductance.
float	R	Motor winding resistance.
float	Km	Electromechanical ratio of the motor.
uint8_t	BackEMFFlags	Auto-settings stepper motor flags. This is a bit mask for bitwise operations.
	0x1 - BACK_EMF_INDUCTANCE_AUTO	Flag of auto-detection of inductance of windings of the engine.
	0x2 - BACK_EMF_RESISTANCE_AUTO	Flag of auto-detection of resistance of windings of the engine.
	0x4 - BACK_EMF_KM_AUTO	Flag of auto-detection of electromechanical coefficient of the engine.
uint8_t	Reserved [29]	Reserved (29 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set electromechanical coefficients. The settings are different for different stepper motors. Please set new settings when you change the motor.

6.2.6.47 Command SENG

Command code (CMD): "seng" or 0x676E6573.

Request: (34 bytes)

uint32_t	CMD	Command

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uint16_t	NomVoltage	Rated voltage in tens of mV. Controller will keep the voltage drop on motor below this value if ENGINE_LIMIT_VOLT flag is set (used with DC only).
uint16_t	NomCurrent	Rated current (in mA). Controller will keep current consumed by motor below this value if ENGINE_LIMIT_CURR flag is set. Range: 15..8000
uint32_t	NomSpeed	Nominal (maximum) speed (in whole steps/s or rpm for DC and stepper motor as a master encoder). Controller will keep motor shaft RPM below this value if ENGINE_LIMIT_RPM flag is set. Range: 1..100000.
uint8_t	uNomSpeed	The fractional part of a nominal speed in microsteps (is only used with stepper motor). Microstep size and the range of valid values for this field depend on selected step division mode (see MicrostepMode field in engine_settings).
uint16_t	EngineFlags	Set of flags specify motor shaft movement algorithm and a list of limitations. This is a bit mask for bitwise operations.
	0x1 - ENGINE_REVERSE	Reverse flag. It determines motor shaft rotation direction that corresponds to feedback counts increasing. If not set (default), motor shaft rotation direction under positive voltage corresponds to feedback counts increasing and vice versa. Change it if you see that positive directions on motor and feedback are opposite.
	0x2 - ENGINE_CURRENT_AS_RMS	Engine current meaning flag. If the flag is unset, then the engine's current value is interpreted as the maximum amplitude value. If the flag is set, then the engine current value is interpreted as the root-mean-square current value (for stepper) or as the current value calculated from the maximum heat dissipation (BLDC).
	0x4 - ENGINE_MAX_SPEED	Max speed flag. If it is set, the engine uses the maximum speed achievable with the present engine settings as its nominal speed.
	0x8 - ENGINE_ANTIPLAY	Play compensation flag. If it is set, the engine makes backlash (play) compensation and reaches the predetermined position accurately at low speed.
	0x10 - ENGINE_ACCEL_ON	Acceleration enable flag. If it set, motion begins with acceleration and ends with deceleration.

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	0x20 - ENGINE_LIMIT_VOLT	Maximum motor voltage limit enable flag (is only used with DC motor).
	0x40 - ENGINE_LIMIT_CURR	Maximum motor current limit enable flag (is only used with DC motor).
	0x80 - ENGINE_LIMIT_RPM	Maximum motor speed limit enable flag.
int16_t	Antiplay	Number of pulses or steps for backlash (play) compensation procedure. Used if ENGINE_ANTIPLAY flag is set.
uint8_t	MicrostepMode	Settings of microstep mode (Used with stepper motor only). the microstep size and the range of valid values for this field depend on the selected step division mode (see MicrostepMode field in engine_settings). This is a bit mask for bitwise operations.
	0x1 - MICROSTEP_MODE_FULL	Full step mode.
	0x2 - MICROSTEP_MODE_FRAC_2	1/2-step mode.
	0x3 - MICROSTEP_MODE_FRAC_4	1/4-step mode.
	0x4 - MICROSTEP_MODE_FRAC_8	1/8-step mode.
	0x5 - MICROSTEP_MODE_FRAC_16	1/16-step mode.
	0x6 - MICROSTEP_MODE_FRAC_32	1/32-step mode.
	0x7 - MICROSTEP_MODE_FRAC_64	1/64-step mode.
	0x8 - MICROSTEP_MODE_FRAC_128	1/128-step mode.
	0x9 - MICROSTEP_MODE_FRAC_256	1/256-step mode.
uint16_t	StepsPerRev	Number of full steps per revolution (Used with stepper motor only). Range: 1..65535.
uint8_t	Reserved [12]	Reserved (12 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set engine settings. This function sends a structure with a set of engine settings to the controller's memory. These settings specify the motor shaft movement algorithm, list of limitations and rated characteristics. Use it when you change the motor, encoder, positioner, etc. Please note that wrong engine settings may lead to device malfunction, which can cause irreversible damage to the board.

6.2.6.48 Command SENI

Command code (CMD): "seni" or 0x696E6573.

Request: (70 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer. Max string length: 16 chars.
int8_t	PartNumber	Series and PartNumber. Max string length: 24 chars.
uint8_t	Reserved [24]	Reserved (24 bytes)

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uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set encoder information to the EEPROM. Can be used by the manufacturer only.

6.2.6.49 Command SENS

Command code (CMD): "sens" or 0x736E6573.

Request: (54 bytes)

uint32_t	CMD	Command
float	MaxOperatingFrequency	Maximum operation frequency (kHz). Data type: float.
float	SupplyVoltageMin	Minimum supply voltage (V). Data type: float.
float	SupplyVoltageMax	Maximum supply voltage (V). Data type: float.
float	MaxCurrentConsumption	Max current consumption (mA). Data type: float.
uint32_t	PPR	The number of counts per revolution
uint32_t	EncoderSettings	Encoder settings flags. This is a bit mask for bitwise operations.
	0x1 - ENCSET_DIFFERENTIAL_OUTPUT	If the flag is set, the encoder has differential output, otherwise single-ended output
	0x4 - ENCSET_PUSHPULL_OUTPUT	If the flag is set the encoder has push-pull output, otherwise open drain output
	0x10 - ENCSET_INDEXCHANNEL_PRESENT	If the flag is set, the encoder has an extra indexed channel
	0x40 - ENCSET_REVOLUTIONSENSOR_PRESENT	If the flag is set, the encoder has the revolution sensor
	0x100 - ENCSET_REVOLUTIONSENSOR_ACTIVE_HIGH	If the flag is set, the revolution sensor's active state is high logic state; otherwise, the active state is low logic state
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set encoder settings to the EEPROM. Can be used by the manufacturer only.

6.2.6.50 Command SENT

Command code (CMD): "sent" or 0x746E6573.

Request: (14 bytes)

uint32_t	CMD	Command
uint8_t	EngineType	Engine type. This is a bit mask for bitwise operations.
	0x0 - ENGINE_TYPE_NONE	A value that shouldn't be used.
	0x1 - ENGINE_TYPE_DC	DC motor.
	0x2 - ENGINE_TYPE_2DC	2 DC motors.
	0x3 - ENGINE_TYPE_STEP	Step motor.
	0x4 - ENGINE_TYPE_TEST	Duty cycle are fixed. Used only manufacturer.
	0x5 - ENGINE_TYPE_BRUSHLESS	Brushless motor.
uint8_t	DriverType	Driver type. This is a bit mask for bitwise operations.
	0x1 - DRIVER_TYPE_DISCRETE_FET	Driver with discrete FET keys. Default option.
	0x2 - DRIVER_TYPE_INTEGRATE	Driver with integrated IC.
	0x3 - DRIVER_TYPE_EXTERNAL	External driver.
uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set engine type and driver type.

6.2.6.51 Command SEST

Command code (CMD): "sest" or 0x74736573.

Request: (46 bytes)

uint32_t	CMD	Command
uint16_t	Param1	
uint8_t	Reserved [38]	Reserved (38 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set extended settings. Currently, it is not in use.

6.2.6.52 Command SFBS

Command code (CMD): "sfbs" or 0x73626673.

Request: (18 bytes)

uint32_t	CMD	Command

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uint16_t	IPS	The number of encoder counts per shaft revolution. Range: 1..655535. The field is obsolete, it is recommended to write 0 to IPS and use the extended CountsPerTurn field. You may need to update the controller firmware to the latest version.
uint8_t	FeedbackType	Type of feedback. This is a bit mask for bitwise operations.
	0x1 - FEEDBACK_ENCODER	Feedback by encoder.
	0x4 - FEEDBACK_EMF	Feedback by EMF.
	0x5 - FEEDBACK_NONE	Feedback is absent.
	0x6 - FEEDBACK_ENCODER_MEDIATED	Feedback by encoder mediated by mechanical transmission (for example leadscrew).
uint8_t	FeedbackFlags	Flags. This is a bit mask for bitwise operations.
	0x1 - FEEDBACK_ENC_REVERSE	Reverse count of encoder.
	0xc0 - FEEDBACK_ENC_TYPE_BITS	Bits of the encoder type.
	0x0 - FEEDBACK_ENC_TYPE_AUTO	Auto detect encoder type.
	0x40 - FEEDBACK_ENC_TYPE_SINGLE_ENDED	Single-ended encoder.
	0x80 - FEEDBACK_ENC_TYPE_DIFFERENTIAL	Differential encoder.
uint32_t	CountsPerTurn	The number of encoder counts per shaft revolution. Range: 1..4294967295. To use the CountsPerTurn field, write 0 in the IPS field, otherwise the value from the IPS field will be used.
uint8_t	Reserved [4]	Reserved (4 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Feedback settings.

6.2.6.53 Command SGRI

Command code (CMD): “sgri” or 0x69726773.

Request: (70 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer. Max string length: 16 chars.
int8_t	PartNumber	Series and PartNumber. Max string length: 24 chars.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set gear information to the EEPROM. Can be used by the manufacturer only.

6.2.6.54 Command SGRS

Command code (CMD): "sgrs" or 0x73726773.

Request: (58 bytes)

uint32_t	CMD	Command
float	ReductionIn	Input reduction coefficient. (Output = (ReductionOut / ReductionIn) Input) Data type: float.
float	ReductionOut	Output reduction coefficient. (Output = (ReductionOut / ReductionIn) Input) Data type: float.
float	RatedInputTorque	Maximum continuous torque (N m). Data type: float.
float	RatedInputSpeed	Maximum speed on the input shaft (rpm). Data type: float.
float	MaxOutputBacklash	Output backlash of the reduction gear (degree). Data type: float.
float	InputInertia	Equivalent input gear inertia (g cm2). Data type: float.
float	Efficiency	Reduction gear efficiency (%). Data type: float.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set gear settings to the EEPROM. Can be used by the manufacturer only.

6.2.6.55 Command SHOM

Command code (CMD): "shom" or 0x6D6F6873.

Request: (33 bytes)

uint32_t	CMD	Command
uint32_t	FastHome	Speed used for first motion (full steps). Range: 0..100000.
uint8_t	uFastHome	Fractional part of the speed for first motion, microsteps. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).

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uint32_t	SlowHome	Speed used for second motion (full steps). Range: 0..100000.
uint8_t	uSlowHome	Part of the speed for second motion, microsteps. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
int32_t	HomeDelta	Distance from break point (full steps).
int16_t	uHomeDelta	Fractional part of the delta distance, microsteps. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint16_t	HomeFlags	Set of flags specifies the direction and stopping conditions. This is a bit mask for bitwise operations.
	0x1 - HOME_DIR_FIRST	The flag defines the direction of the 1st motion after execution of the home command. The direction is to the right if the flag is set, and to the left otherwise.
	0x2 - HOME_DIR_SECOND	The flag defines the direction of the 2nd motion. The direction is to the right if the flag is set, and to the left otherwise.
	0x4 - HOME_MV_SEC_EN	Use the second phase of calibration to the home position, if set; otherwise the second phase is skipped.
	0x8 - HOME_HALF_MV	If the flag is set, the stop signals are ignored during the first half-turn of the second movement.
	0x30 - HOME_STOP_FIRST_BITS	Bits of the first stop selector.
	0x10 - HOME_STOP_FIRST_REV	First motion stops by revolution sensor.
	0x20 - HOME_STOP_FIRST_SYN	First motion stops by synchronization input.
	0x30 - HOME_STOP_FIRST_LIM	First motion stops by limit switch.
	0xc0 - HOME_STOP_SECOND_BITS	Bits of the second stop selector.
	0x40 - HOME_STOP_SECOND_REV	Second motion stops by revolution sensor.
	0x80 - HOME_STOP_SECOND_SYN	Second motion stops by synchronization input.
	0xc0 - HOME_STOP_SECOND_LIM	Second motion stops by limit switch.
	0x100 - HOME_USE_FAST	Use the fast algorithm of calibration to the home position, if set; otherwise the traditional algorithm.
uint8_t	Reserved [9]	Reserved (9 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set home settings. This function sends home position structure to the controller's memory.

6.2.6.56 Command SHSI

Command code (CMD): "shsi" or 0x69736873.

Request: (70 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer. Max string length: 16 chars.
int8_t	PartNumber	Series and PartNumber. Max string length: 24 chars.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set hall sensor information to the EEPROM. Can be used by the manufacturer only.

6.2.6.57 Command SHSS

Command code (CMD): "shss" or 0x73736873.

Request: (50 bytes)

uint32_t	CMD	Command
float	MaxOperatingFrequency	Maximum operation frequency (kHz). Data type: float.
float	SupplyVoltageMin	Minimum supply voltage (V). Data type: float.
float	SupplyVoltageMax	Maximum supply voltage (V). Data type: float.
float	MaxCurrentConsumption	Maximum current consumption (mA). Data type: float.
uint32_t	PPR	The number of counts per revolution
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set hall sensor settings to the EEPROM. Can be used by the manufacturer only.

6.2.6.58 Command SJOY

Command code (CMD): "sjoy" or 0x796F6A73.

Request: (22 bytes)

uint32_t	CMD	Command
uint16_t	JoyLowEnd	Joystick lower end position. Range: 0..10000.
uint16_t	JoyCenter	Joystick center position. Range: 0..10000.
uint16_t	JoyHighEnd	Joystick upper end position. Range: 0..10000.
uint8_t	ExpFactor	Exponential nonlinearity factor.
uint8_t	DeadZone	Joystick dead zone.
uint8_t	JoyFlags	Joystick control flags. This is a bit mask for bitwise operations.
	0x1 - JOY_REVERSE	Joystick action is reversed. The joystick deviation to the upper values corresponds to negative speed and vice versa.
uint8_t	Reserved [7]	Reserved (7 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set joystick position. If joystick position falls outside DeadZone limits, a movement begins. The speed is defined by the joystick's position in the range of the DeadZone limit to the maximum deviation. Joystick positions inside DeadZone limits correspond to zero speed (a soft stop of motion), and positions beyond Low and High limits correspond to MaxSpeed[i] or -MaxSpeed[i] (see command SCTL), where i = 0 by default and can be changed with the left/right buttons (see command SCTL). If the next speed in the list is zero (both integer and microstep parts), the button press is ignored. The first speed in the list shouldn't be zero. See the Joystick control section on https://doc.xisupport.com for more information.

6.2.6.59 Command SMOV

Command code (CMD): "smov" or 0x766F6D73.

Request: (30 bytes)

uint32_t	CMD	Command
uint32_t	Speed	Target speed (for stepper motor: steps/s, for DC: rpm). Range: 0..100000.
uint8_t	uSpeed	Target speed in microstep fractions/s. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings). Used with a stepper motor only.
uint16_t	Accel	Motor shaft acceleration, steps/s^2 (stepper motor) or RPM/s (DC). Range: 1..65535.

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uint16_t	Decel	Motor shaft deceleration, steps/s^2 (stepper motor) or RPM/s (DC). Range: 1..65535.
uint32_t	AntiplaySpeed	Speed in antiplay mode, full steps/s (stepper motor) or RPM (DC). Range: 0..100000.
uint8_t	uAntiplaySpeed	Speed in antiplay mode, microsteps/s. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings). Used with a stepper motor only.
uint8_t	MoveFlags	Flags that control movement settings. This is a bit mask for bitwise operations.
	0x1 - RPM_DIV_1000	This flag indicates that the operating speed specified in the command is set in milliRPM. Applicable only for ENCODER feedback mode and only for BLDC motors.
uint8_t	Reserved [9]	Reserved (9 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Movement settings set command (speed, acceleration, threshold, etc.).

6.2.6.60 Command SMTI

Command code (CMD): “smti” or 0x69746D73.

Request: (70 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer. Max string length: 16 chars.
int8_t	PartNumber	Series and PartNumber. Max string length: 24 chars.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set motor information to the EEPROM. Can be used by the manufacturer only.

6.2.6.61 Command SMTS

Command code (CMD): “smts” or 0x73746D73.

Request: (112 bytes)

uint32_t	CMD	Command
uint8_t	MotorType	Motor type. This is a bit mask for bitwise operations.
	0x0 - MOTOR_TYPE_UNKNOWN	Unknown type of engine
	0x1 - MOTOR_TYPE_STEP	Step engine
	0x2 - MOTOR_TYPE_DC	DC engine
	0x3 - MOTOR_TYPE_BLDC	BLDC engine
uint8_t	ReservedField	Reserved
uint16_t	Poles	Number of pole pairs for DC or BLDC motors or number of steps per rotation for stepper motors.
uint16_t	Phases	Number of phases for BLDC motors.
float	NominalVoltage	Nominal voltage on winding (B). Data type: float
float	NominalCurrent	Maximum direct current in winding for DC and BLDC engines, nominal current in windings for stepper motors (A). Data type: float.
float	NominalSpeed	Not used. Nominal speed (rpm). Used for DC and BLDC engines. Data type: float.
float	NominalTorque	Nominal torque (mN m). Used for DC and BLDC engines. Data type: float.
float	NominalPower	Nominal power (W). Used for DC and BLDC engines. Data type: float.
float	WindingResistance	Resistance of windings for DC engines, of each of two windings for stepper motors, or of each of three windings for BLDC engines (Ohm). Data type: float.
float	WindingInductance	Inductance of windings for DC engines, inductance of each of two windings for stepper motors, or inductance of each of three windings for BLDC engines (mH). Data type: float.
float	RotorInertia	Rotor inertia (g cm2). Data type: float.
float	StallTorque	Torque hold position for a stepper motor or torque at a motionless rotor for other types of engines (mN m). Data type: float.
float	DetentTorque	Holding torque position with unpowered windings (mN m). Data type: float.
float	TorqueConstant	Torque constant that determines the proportionality constant between the maximum rotor torque and current flowing in the winding (mN m / A). Used mainly for DC motors. Data type: float.

Continued on next page

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float	SpeedConstant	Velocity constant, which determines the value or the amplitude of the induced voltage on the motion of DC or BLDC motors (rpm / V) or stepper motors (steps/s / V). Data type: float.
float	SpeedTorqueGradient	Speed torque gradient (rpm / mN m). Data type: float.
float	MechanicalTimeConstant	Mechanical time constant (ms). Data type: float.
float	MaxSpeed	The maximum speed for stepper motors (steps/s) or DC and BLDC motors (rmp). Data type: float.
float	MaxCurrent	The maximum current in the winding (A). Data type: float.
float	MaxCurrentTime	Safe duration of overcurrent in the winding (ms). Data type: float.
float	NoLoadCurrent	The current consumption in idle mode (A). Used for DC and BLDC motors. Data type: float.
float	NoLoadSpeed	Idle speed (rpm). Used for DC and BLDC motors. Data type: float.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set motor settings to the EEPROM. Can be used by the manufacturer only.

6.2.6.62 Command SNET

Command code (CMD): “snet” or 0x74656E73.

Request: (38 bytes)

uint32_t	CMD	Command
uint8_t	DHCPEnabled	Indicates the method to get the IP-address. It can be either 0 (static) or 1 (DHCP).
uint8_t	IPv4Address	IP-address of the device in format x.x.x.x.
uint8_t	SubnetMask	The mask of the subnet in format x.x.x.x.
uint8_t	DefaultGateway	Default value of the gateway in format x.x.x.x.
uint8_t	Reserved [19]	Reserved (19 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set network settings. Manufacturer only. This function sets the desired network settings.

6.2.6.63 Command SNME

Command code (CMD): "snme" or 0x656D6E73.

Request: (30 bytes)

uint32_t	CMD	Command
int8_t	PositionerName	User's positioner name. It can be set by a user. Max string length: 16 characters.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Write the user's stage name to EEPROM.

6.2.6.64 Command SNMF

Command code (CMD): "snmf" or 0x666D6E73.

Request: (30 bytes)

uint32_t	CMD	Command
int8_t	ControllerName	User controller name. It may be set by the user. Max string length: 16 characters.
uint8_t	CtrlFlags	Internal controller settings. This is a bit mask for bitwise operations.
	0x1 - EEPROM_PRECEDENCE	If the flag is set, settings from external EEPROM override controller settings.
uint8_t	Reserved [7]	Reserved (7 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Write user's controller name and internal settings to the FRAM.

6.2.6.65 Command SNVM

Command code (CMD): "snvm" or 0x6D766E73.

Request: (36 bytes)

uint32_t	CMD	Command
uint32_t	UserData	User data. It may be set by the user. Each element of the array stores only 32 bits of user data. This is important on systems where an int type contains more than 4 bytes. For example, on all amd64 systems.
uint8_t	Reserved [2]	Reserved (2 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Write user data into the FRAM.

6.2.6.66 Command SPID

Command code (CMD): "spid" or 0x64697073.

Request: (48 bytes)

uint32_t	CMD	Command
uint16_t	KpU	Proportional gain for voltage PID routine
uint16_t	KiU	Integral gain for voltage PID routine
uint16_t	KdU	Differential gain for voltage PID routine
float	Kpf	Proportional gain for BLDC position PID routine
float	Kif	Integral gain for BLDC position PID routine
float	Kdf	Differential gain for BLDC position PID routine
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set PID settings. This function sends the structure with a set of PID factors to the controller's memory. These settings specify the behavior of the PID routine for the positioner. These factors are slightly different for different positioners. All boards are supplied with the standard set of PID settings in the controller's flash memory. Please use it for loading new PID settings when you change positioner. Please note that wrong PID settings lead to device malfunction.

6.2.6.67 Command SPWD

Command code (CMD): "spwd" or 0x64777073.

Request: (36 bytes)

uint32_t	CMD	Command
int8_t	UserPassword	Password for the web-page that the user can change with a USB command or via web-page.
uint8_t	Reserved [10]	Reserved (10 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Sets the password. Manufacturer only. This function sets the user password for the device's web-page.

6.2.6.68 Command SPWR

Command code (CMD): "spwr" or 0x72777073.

Request: (20 bytes)

uint32_t	CMD	Command
uint8_t	HoldCurrent	Holding current, as percent of the nominal current. Range: 0..100.
uint16_t	CurrReductDelay	Time in ms from going to STOP state to the end of current reduction.
uint16_t	PowerOffDelay	Time in s from going to STOP state to turning power off.
uint16_t	CurrentSetTime	Time in ms to reach the nominal current.
uint8_t	PowerFlags	Flags with parameters of power control. This is a bit mask for bitwise operations.
	0x1 - POWER_REDUCT_ENABLED	Current reduction is enabled after CurrReductDelay if this flag is set.
	0x2 - POWER_OFF_ENABLED	Power off is enabled after PowerOffDelay if this flag is set.
	0x4 - POWER_SMOOTH_CURRENT	Current ramp-up/down are performed smoothly during current_set_time if this flag is set.
uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set settings of step motor power control. Used with a stepper motor only.

6.2.6.69 Command SSEC

Command code (CMD): "ssec" or 0x63657373.

Request: (28 bytes)

uint32_t	CMD	Command
uint16_t	LowUpwrOff	Lower voltage limit to turn off the motor, in tens of mV.
uint16_t	CriticalIpwr	Maximum motor current which triggers ALARM state, in mA.
uint16_t	CriticalUpwr	Maximum motor voltage which triggers ALARM state, in tens of mV.
uint16_t	CriticalT	Maximum temperature, which triggers ALARM state, in tenths of degrees Celsius.
uint16_t	CriticalIusb	Maximum USB current which triggers ALARM state, in mA.
uint16_t	CriticalUusb	Maximum USB voltage which triggers ALARM state, in tens of mV.
uint16_t	MinimumUusb	Minimum USB voltage which triggers ALARM state, in tens of mV.
uint8_t	Flags	Critical parameter flags. This is a bit mask for bitwise operations.
	0x1 - ALARM_ON_DRIVER_OVERHEATING	If this flag is set, enter the alarm state on the driver overheat signal.
	0x2 - LOW_UPWR_PROTECTION	If this flag is set, turn off the motor when the voltage is lower than LowUpwrOff.
	0x4 - H_BRIDGE_ALERT	If this flag is set then turn off the power unit with a signal problem in one of the transistor bridge.
	0x8 - ALARM_ON_BORDERS_SWAP_MISSET	If this flag is set, enter Alarm state on borders swap misset
	0x10 - ALARM_FLAGS_STICKING	If this flag is set, only a STOP command can turn all alarms to 0
	0x20 - USB_BREAK_RECONNECT	If this flag is set, the USB brake reconnect module will be enabled
	0x40 - ALARM_WINDING_MISMATCH	If this flag is set, enter Alarm state when windings mismatch
	0x80 - ALARM_ENGINE_RESPONSE	If this flag is set, enter the Alarm state on response of the engine control action
uint8_t	Reserved [7]	Reserved (7 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set protection settings.

6.2.6.70 Command SSNI

Command code (CMD): “ssni” or 0x696E7373.

Request: (28 bytes)

uint32_t	CMD	Command

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uint8_t	SyncInFlags	Input synchronization flags. This is a bit mask for bitwise operations.
	0x1 - SYNCIN_ENABLED	Synchronization in mode is enabled if this flag is set.
	0x2 - SYNCIN_INVERT	Trigger on falling edge if flag is set, on rising edge otherwise.
	0x4 - SYNCIN_GOTOPOSITION	The engine is going to the position specified in Position and uPosition if this flag is set. And it is shifting on the Position and uPosition if this flag is unset
uint16_t	ClutterTime	Input synchronization pulse dead time (us).
int32_t	Position	Desired position or shift (full steps)
int16_t	uPosition	The fractional part of a position or shift in microsteps. It is used with a stepper motor. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint32_t	Speed	Target speed (for stepper motor: steps/s, for DC: rpm). Range: 0..100000.
uint8_t	uSpeed	Target speed in microsteps/s. Microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings). Used a stepper motor only.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set input synchronization settings. This function sends the structure with a set of input synchronization settings that specify the behavior of input synchronization to the controller's memory. All boards are supplied with the standard set of these settings.

6.2.6.71 Command SSNO

Command code (CMD): "ssno" or 0x6F6E7373.

Request: (16 bytes)

uint32_t	CMD	Command
uint8_t	SyncOutFlags	Output synchronization flags. This is a bit mask for bitwise operations.
	0x1 - SYNCOUT_ENABLED	The synchronization out pin follows the synchronization logic if the flag is set. Otherwise, it is governed by the SYNCOUT_STATE flag.

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	0x2 - SYNCOUT_STATE	When the output state is fixed by the negative SYNCOUT_ENABLED flag, the pin state is in accordance with this flag state.
	0x4 - SYNCOUT_INVERT	The low level is active if the flag is set. Otherwise, the high level is active.
	0x8 - SYNCOUT_IN_STEPS	Use motor steps or encoder pulses instead of milliseconds for output pulse generation if the flag is set.
	0x10 - SYNCOUT_ONSTART	Generate a synchronization pulse when movement starts.
	0x20 - SYNCOUT_ONSTOP	Generate a synchronization pulse when movement stops.
	0x40 - SYNCOUT_ONPERIOD	Generate a synchronization pulse every SyncOutPeriod encoder pulses.
uint16_t	SyncOutPulseSteps	This value specifies the duration of output pulse. It is measured microseconds when SYNCOUT_IN_STEPS flag is cleared or in encoder pulses or motor steps when SYNCOUT_IN_STEPS is set.
uint16_t	SyncOutPeriod	This value specifies the number of encoder pulses or steps between two output synchronization pulses when SYNCOUT_ONPERIOD is set.
uint32_t	Accuracy	This is the neighborhood around the target coordinates, every point in which is treated as the target position. Getting in these points cause the stop impulse.
uint8_t	uAccuracy	This is the neighborhood around the target coordinates in microsteps (used with a stepper motor only). The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set output synchronization settings. This function sends the structure with a set of output synchronization settings that specify the behavior of output synchronization to the controller's memory. All boards are supplied with the standard set of these settings.

6.2.6.72 Command SSTI

Command code (CMD): "ssti" or 0x69747373.

Request: (70 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer. Max string length: 16 chars.
int8_t	PartNumber	Series and PartNumber. Max string length: 24 chars.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set stage information to the EEPROM. Can be used by the manufacturer only.

6.2.6.73 Command SSTS

Command code (CMD): "ssts" or 0x73747373.

Request: (70 bytes)

uint32_t	CMD	Command
float	LeadScrewPitch	Lead screw pitch (mm). Data type: float.
int8_t	Units	Units for MaxSpeed and TravelRange fields of the structure (steps, degrees, mm, . . .). Max string length: 8 chars.
float	MaxSpeed	Maximum speed (Units/c). Data type: float.
float	TravelRange	Travel range (Units). Data type: float.
float	SupplyVoltageMin	Minimum supply voltage (V). Data type: float.
float	SupplyVoltageMax	Maximum supply voltage (V). Data type: float.
float	MaxCurrentConsumption	Maximum current consumption (A). Data type: float.
float	HorizontalLoadCapacity	Horizontal load capacity (kg). Data type: float.
float	VerticalLoadCapacity	Vertical load capacity (kg). Data type: float.
uint8_t	Reserved [24]	Reserved (24 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Deprecated. Set stage settings to the EEPROM. Can be used by the manufacturer only

6.2.6.74 Command SURT

Command code (CMD): "surt" or 0x74727573.

Request: (16 bytes)

uint32_t	CMD	Command
uint32_t	Speed	UART baudrate (in bauds)
uint16_t	UARTSetupFlags	UART setup flags. This is a bit mask for bitwise operations.
	0x3 - UART_PARITY_BITS	Bits of the parity.
	0x0 - UART_PARITY_BIT_EVEN	Parity bit 1, if even
	0x1 - UART_PARITY_BIT_ODD	Parity bit 1, if odd
	0x2 - UART_PARITY_BIT_SPACE	Parity bit always 0
	0x3 - UART_PARITY_BIT_MARK	Parity bit always 1
	0x4 - UART_PARITY_BIT_USE	None parity
	0x8 - UART_STOP_BIT	If set - one stop bit, else two stop bit
uint8_t	Reserved [4]	Reserved (4 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Set UART settings. This function sends the structure with UART settings to the controller's memory.

6.2.6.75 Command ASIA

Command code (CMD): "asia" or 0x61697361.

Request: (22 bytes)

uint32_t	CMD	Command
int32_t	Position	Desired position or shift (full steps)
int16_t	uPosition	The fractional part of a position or shift in microsteps. Used with stepper motor only. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint32_t	Time	Time period in which you want to achieve the desired position in microseconds.
uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: This command adds one element to the FIFO command buffer. Commands are executed at an input clock pulse. Each synchronization pulse launches the action described in SSNI if the buffer is empty. Otherwise, the pulse launches the first command from the FIFO. In the latter case, the command is erased from the buffer. The number of remaining empty buffer elements can be found in the GETS.

6.2.6.76 Command CLFR

Command code (CMD): "clfr" or 0x72666C63.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: The command to clear the controller's FRAM. The memory is cleared by filling the whole memory bytes with 0x00. After cleaning, the controller restarts. There is no response to this command.

6.2.6.77 Command CONN

Command code (CMD): "conn" or 0x6E6E6F63.

Request: (14 bytes)

uint32_t	CMD	Command
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Answer: (15 bytes)

uint32_t	CMD	Command
uint8_t	sresult	Command result.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Description: Command to open a ISP session (in-system programming) when downloading the firmware. Result = RESULT_OK if the command loader. Result = RESULT_SOFT_ERROR if an error occurred at the time of the command. The Result is not available through the library command_update_firmware(). The function processes it internally.

6.2.6.78 Command DBGR

Command code (CMD): "dbgr" or 0x72676264.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (142 bytes)

uint32_t	CMD	Command
uint8_t	DebugData	Arbitrary debug data.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Description: Read data from firmware for debug purpose. Manufacturer only. Its use depends on context, firmware version and previous history.

6.2.6.79 Command DBGW

Command code (CMD): “dbgw” or 0x77676264.

Request: (142 bytes)

uint32_t	CMD	Command
uint8_t	DebugData	Arbitrary debug data.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Write data to firmware for debug purpose. Manufacturer only.

6.2.6.80 Command DISC

Command code (CMD): “disc” or 0x63736964.

Request: (14 bytes)

uint32_t	CMD	Command
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Answer: (15 bytes)

uint32_t	CMD	Command
uint8_t	sresult	Command result.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Description: Command to close the ISP session (in-system programming) when loading firmware. Result = RESULT_OK if the command loader. Result = RESULT_HARD_ERROR if a hardware error occurred at the time of the command. Result = RESULT_SOFT_ERROR if a software error occurred at the time of the command. The Result is not available through the library command_update_firmware(). The function processes it internally.

6.2.6.81 Command EERD

Command code (CMD): “eerd” or 0x64726565.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Read settings from the stage’s EEPROM to the controller’s RAM. This operation is performed automatically at the connection of the stage with an EEPROM to the controller. Can be used by the manufacturer only.

6.2.6.82 Command EESV

Command code (CMD): “eesv” or 0x76736565.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Save settings from the controller’s RAM to the stage’s EEPROM. Can be used by the manufacturer only.

6.2.6.83 Command GBLV

Command code (CMD): “gblv” or 0x766C6267.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (10 bytes)

uint32_t	CMD	Command
uint8_t	Major	Bootloader major version number
uint8_t	Minor	Bootloader minor version number
uint16_t	Release	Bootloader release version number
uint16_t	CRC	Checksum

Description: Read the controller’s bootloader version.

6.2.6.84 Command GETC

Command code (CMD): “getc” or 0x63746567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (38 bytes)

uint32_t	CMD	Command
int16_t	WindingVoltageA	In case of a step motor, it contains the voltage across the winding A (in tens of mV); in case of a brushless motor, it contains the voltage on the first coil; in case of a DC motor, it contains the only winding current.

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int16_t	WindingVoltageB	In case of a step motor, it contains the voltage across the winding B (in tens of mV); in case of a brushless motor, it contains the voltage on the second winding; and in case of a DC motor, this field is not used.
int16_t	WindingVoltageC	In case of a brushless motor, it contains the voltage on the third winding (in tens of mV); in the case of a step motor and a DC motor, the field is not used.
int16_t	WindingCurrentA	In case of a step motor, it contains the current in the winding A (in mA); in case of a brushless motor, it contains the current in the winding A; and in case of a DC motor, it contains the only winding current.
int16_t	WindingCurrentB	In case of a step motor, it contains the current in the winding B (in mA); in case of a brushless motor, it contains the current in the winding B; and in case of a DC motor, the field is not used.
int16_t	WindingCurrentC	In case of a brushless motor, it contains the current in the winding C (in mA); in case of a step motor and a DC motor, the field is not used.
uint16_t	Pot	Analog input value, dimensionless. Range: 0..10000
uint16_t	Joy	The joystick position, dimensionless. Range: 0..10000
int16_t	DutyCycle	PWM duty cycle.
uint8_t	Reserved [14]	Reserved (14 bytes)
uint16_t	CRC	Checksum

Description: Return device electrical parameters, useful for charts. A useful function that fills the structure with a snapshot of the controller voltages and currents.

6.2.6.85 Command GETI

Command code (CMD): “geti” or 0x69746567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (36 bytes)

uint32_t	CMD	Command
int8_t	Manufacturer	Manufacturer
int8_t	ManufacturerId	Manufacturer id
int8_t	ProductDescription	Product description

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uint8_t	Major	The major number of the hardware version.
uint8_t	Minor	The minor number of the hardware version.
uint16_t	Release	Release version.
uint8_t	Reserved [12]	Reserved (12 bytes)
uint16_t	CRC	Checksum

Description: Return device information. It's available in the firmware and the bootloader.

6.2.6.86 Command GETM

Command code (CMD): "getm" or 0x6D746567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (216 bytes)

uint32_t	CMD	Command
int32_t	Speed	Current speed in microsteps per second (whole steps are recalculated considering the current step division mode) or encoder counts per second.
int32_t	Error	Current error in microsteps per second (whole steps are recalculated considering the current step division mode) or encoder counts per second.
uint32_t	Length	Length of actual data in buffer.
uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Description: A command to read the data buffer to build a speed graph and a speed error graph. Filling the buffer starts with the command 'start_measurements'. The buffer holds 25 points; the points are taken with a period of 1 ms. To create a robust system, read data every 20 ms. If the buffer is full, it is recommended to repeat the readings every 5 ms until the buffer again becomes filled with 20 points. To stop measurements just stop reading data. After buffer overflow measurements will stop automatically.

6.2.6.87 Command GETS

Command code (CMD): "gets" or 0x73746567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (54 bytes)

uint32_t	CMD	Command

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uint8_t	MoveSts	Move state. This is a bit mask for bitwise operations.
	0x1 - MOVE_STATE_MOVING	This flag indicates that the controller is trying to move the motor. Don't use this flag to wait for the completion of the movement command. Use the MVCMD_RUNNING flag from the MvCmdSts field instead.
	0x2 - MOVE_STATE_TARGET_SPEED	Target speed is reached, if flag set.
	0x4 - MOVE_STATE_ANTIPLAY	Motor is playing compensation, if flag set.
uint8_t	MvCmdSts	Move command state. This is a bit mask for bitwise operations.
	0x3f - MVCMD_NAME_BITS	Move command bit mask.
	0x0 - MVCMD_UKNWN	Unknown command.
	0x1 - MVCMD_MOVE	Command move.
	0x2 - MVCMD_MOVR	Command movr.
	0x3 - MVCMD_LEFT	Command left.
	0x4 - MVCMD_RIGHT	Command rigt.
	0x5 - MVCMD_STOP	Command stop.
	0x6 - MVCMD_HOME	Command home.
	0x7 - MVCMD_LOFT	Command loft.
	0x8 - MVCMD_SSTP	Command soft stop.
	0x40 - MVCMD_ERROR	Finish state (1 - move command has finished with an error, 0 - move command has finished correctly). This flag makes sense when MVCMD_RUNNING signals movement completion.
	0x80 - MVCMD_RUNNING	Move command state (0 - move command has finished, 1 - move command is being executed).
uint8_t	PWRSts	Power state of the stepper motor (used with stepper motor only). This is a bit mask for bitwise operations.
	0x0 - PWR_STATE_UNKNOWN	Unknown state, should never happen.
	0x1 - PWR_STATE_OFF	Motor windings are disconnected from the driver.
	0x3 - PWR_STATE_NORM	Motor windings are powered by nominal current.
	0x4 - PWR_STATE_REDUCT	Motor windings are powered by reduced current to lower power consumption.
	0x5 - PWR_STATE_MAX	Motor windings are powered by the maximum current driver can provide at this voltage.
uint8_t	EncSts	Encoder state. This is a bit mask for bitwise operations.
	0x0 - ENC_STATE_ABSENT	Encoder is absent.
	0x1 - ENC_STATE_UNKNOWN	Encoder state is unknown.
	0x2 - ENC_STATE_MALFUNC	Encoder is connected and malfunctioning.

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	0x3 - ENC_STATE_REVERS	Encoder is connected and operational but counts in other direction.
	0x4 - ENC_STATE_OK	Encoder is connected and working properly.
uint8_t	WindSts	Windings state. This is a bit mask for bitwise operations.
	0x0 - WIND_A_STATE_ABSENT	Winding A is disconnected.
	0x1 - WIND_A_STATE_UNKNOWN	Winding A state is unknown.
	0x2 - WIND_A_STATE_MALFUNC	Winding A is short-circuited.
	0x3 - WIND_A_STATE_OK	Winding A is connected and working properly.
	0x0 - WIND_B_STATE_ABSENT	Winding B is disconnected.
	0x10 - WIND_B_STATE_UNKNOWN	Winding B state is unknown.
	0x20 - WIND_B_STATE_MALFUNC	Winding B is short-circuited.
	0x30 - WIND_B_STATE_OK	Winding B is connected and working properly.
int32_t	CurPosition	Current position.
int16_t	uCurPosition	Step motor shaft position in microsteps. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings). Used with stepper motors only.
int64_t	EncPosition	Current encoder position.
int32_t	CurSpeed	Motor shaft speed in steps/s or rpm.
int16_t	uCurSpeed	Fractional part of motor shaft speed in microsteps. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings). Used with stepper motors only.
int16_t	Ipwr	Engine current, mA.
int16_t	Upwr	Power supply voltage, tens of mV.
int16_t	Iusb	USB current, mA.
int16_t	Uusb	USB voltage, tens of mV.
int16_t	CurT	Temperature, tenths of degrees Celsius.
uint32_t	Flags	A set of flags specifies the motor shaft movement algorithm and a list of limitations. This is a bit mask for bitwise operations.
	0x3f - STATE_CONTR	Flags of controller states.
	0x1 - STATE_ERRC	Command error encountered. The command received is not in the list of controller known commands. The most possible reason is the outdated firmware.

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	0x2 - STATE_ERRD	Data integrity error encountered. The data inside the command and its CRC code do not correspond. Therefore, the data can't be considered valid. This error may be caused by EMI in the UART/RS232 interface.
	0x4 - STATE_ERRV	Value error encountered. The values in the command can't be applied without correction because they fall outside the valid range. Corrected values were used instead of the original ones.
	0x10 - STATE_EEPROM_CONNECTED	EEPROM with settings is connected. The built-in stage profile is uploaded from the EEPROM memory chip if the EEPROM_PRECEDENCE flag is set, allowing you to connect various stages to the controller with automatic setup.
	0x20 - STATE_IS_HOMED	Calibration performed. This means that the relative position scale is calibrated against a hardware absolute position sensor, like a limit switch. Drops after loss of calibration, like harsh stops and possibly skipped steps.
	0x1b3ffc0 - STATE_SECUR	Security flags.
	0x40 - STATE_ALARM	The controller is in an alarm state, indicating that something dangerous has happened. Most commands are ignored in this state. To reset the flag, a STOP command must be issued.
	0x80 - STATE_CTP_ERROR	Control position error (is only used with stepper motor). The flag is set when the encoder position and step position are too far apart.
	0x100 - STATE_POWER_OVERHEAT	Power driver overheat. Motor control is disabled until some cooldown occurs. This should not happen with boxed versions of the controller. This may happen with the bare-board version of the controller with a custom radiator. Redesign your radiator.
	0x200 - STATE_CONTROLLER_OVERHEAT	Controller overheat.
	0x400 - STATE_OVERLOAD_POWER_VOLTAGE	Power voltage exceeds safe limit.
	0x800 - STATE_OVERLOAD_POWER_CURRENT	Power current exceeds safe limit.
	0x1000 - STATE_OVERLOAD_USB_VOLTAGE	USB voltage exceeds safe limit.
	0x2000 - STATE_LOW_USB_VOLTAGE	USB voltage is insufficient for normal operation.
	0x4000 - STATE_OVERLOAD_USB_CURRENT	USB current exceeds safe limit.
	0x8000 - STATE_BORDERS_SWAP_MISSET	Engine stuck at the wrong edge.
	0x10000 - STATE_LOW_POWER_VOLTAGE	Power voltage is lower than Low Voltage Protection limit

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	0x20000 - STATE_H_BRIDGE_FAULT	Signal from the driver that fault happened
	0x100000 - STATE_WINDING_RES_MISMATCH	The difference between winding resistances is too large. This usually happens with a damaged stepper motor with partially short-circuited windings.
	0x200000 - STATE_ENCODER_FAULT	Signal from the encoder that fault happened
	0x800000 - STATE_ENGINE_RESPONSE_ERROR	Error response of the engine control action. Motor control algorithm failure means that it can't make the correct decisions with the feedback data it receives. A single failure may be caused by a mechanical problem. A repeating failure can be caused by incorrect motor settings.
	0x1000000 - STATE_EXTIO_ALARM	The error is caused by the external EXTIO input signal.
uint32_t	GPIOFlags	A set of flags of GPIO states. This is a bit mask for bitwise operations.
	0xffff - STATE_DIG_SIGNAL	Flags of digital signals.
	0x1 - STATE_RIGHT_EDGE	Engine stuck at the right edge.
	0x2 - STATE_LEFT_EDGE	Engine stuck at the left edge.
	0x4 - STATE_BUTTON_RIGHT	Button 'right' state (1 if pressed).
	0x8 - STATE_BUTTON_LEFT	Button 'left' state (1 if pressed).
	0x10 - STATE_GPIO_PINOUT	External GPIO works as out if the flag is set; otherwise, it works as in.
	0x20 - STATE_GPIO_LEVEL	State of external GPIO pin.
	0x200 - STATE_BRAKE	State of Brake pin. Flag '1' - if the pin state brake is not powered (brake is clamped), '0' - if the pin state brake is powered (brake is unclamped).
	0x400 - STATE_REV_SENSOR	State of Revolution sensor pin.
	0x800 - STATE_SYNC_INPUT	State of Sync input pin.
	0x1000 - STATE_SYNC_OUTPUT	State of Sync output pin.
	0x2000 - STATE_ENC_A	State of encoder A pin.
	0x4000 - STATE_ENC_B	State of encoder B pin.
uint8_t	CmdBufFreeSpace	This field is a service field. It shows the number of free synchronization chain buffer cells.
uint8_t	Reserved [4]	Reserved (4 bytes)
uint16_t	CRC	Checksum

Description: Return device state. A useful function that fills the structure with a snapshot of the controller state, including speed, position, and boolean flags.

6.2.6.88 Command GFWV

Command code (CMD): "gfwv" or 0x76776667.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (10 bytes)

uint32_t	CMD	Command
uint8_t	Major	Firmware major version number
uint8_t	Minor	Firmware minor version number
uint16_t	Release	Firmware release version number
uint16_t	CRC	Checksum

Description: Read the controller's firmware version.

6.2.6.89 Command GOFW

Command code (CMD): "gofw" or 0x77666F67.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (15 bytes)

uint32_t	CMD	Command
uint8_t	sresult	Result of the command.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Description: Command initiates the transfer of control to firmware. This command is also available in the firmware for compatibility. Manufacturer only. Result = RESULT_OK, if the transition from the loader to the firmware is possible. After the response to this command, the transition is executed. Result = RESULT_NO_FIRMWARE if the firmware is not found. Result = RESULT_ALREADY_IN_FIRMWARE if this command is called from the firmware.

6.2.6.90 Command GPOS

Command code (CMD): "gpos" or 0x736F7067.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (26 bytes)

uint32_t	CMD	Command
int32_t	Position	The position of the whole steps in the engine
int16_t	uPosition	Microstep position is only used with stepper motors. Microstep size and the range of valid values for this field depend on the selected step division mode (see MicrostepMode field in engine_settings).
int64_t	EncPosition	Encoder position.

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uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Description: Reads the value position in steps and microsteps for stepper motor and encoder steps for all engines.

6.2.6.91 Command GSER

Command code (CMD): "gser" or 0x72657367.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (10 bytes)

uint32_t	CMD	Command
uint32_t	SerialNumber	Board serial number.
uint16_t	CRC	Checksum

Description: Read device serial number.

6.2.6.92 Command GUID

Command code (CMD): "guid" or 0x64697567.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (40 bytes)

uint32_t	CMD	Command
uint32_t	UniqueID0	Unique ID 0.
uint32_t	UniqueID1	Unique ID 1.
uint32_t	UniqueID2	Unique ID 2.
uint32_t	UniqueID3	Unique ID 3.
uint8_t	Reserved [18]	Reserved (18 bytes)
uint16_t	CRC	Checksum

Description: This value is unique to each individual device, but is not a random value. Manufacturer only. This unique device identifier can be used to initiate secure boot processes or as a serial number for USB or other end applications.

6.2.6.93 Command HASF

Command code (CMD): "hasf" or 0x66736168.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (15 bytes)

uint32_t	CMD	Command
uint8_t	sresult	Result of command.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Description: Check for firmware on device. Manufacturer only. Result = RESULT_NO_FIRMWARE if the firmware is not found. Result = RESULT_HAS_FIRMWARE if the firmware has been found.

6.2.6.94 Command HOME

Command code (CMD): "home" or 0x656D6F68.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Moving to home position. Moving algorithm: 1) Moves the motor according to the speed FastHome, uFastHome and flag HOME_DIR_FAST until the limit switch if the HOME_STOP_ENDS flag is set. Or moves the motor until the input synchronization signal occurs if the flag HOME_STOP_SYNC is set. Or moves until the revolution sensor signal occurs if the flag HOME_STOP_REV_SN is set. 2) Then moves according to the speed SlowHome, uSlowHome and flag HOME_DIR_SLOW until the input clock signal occurs if the flag HOME_MV_SEC is set. If the flag HOME_MV_SEC is reset, skip this step. 3) Then shifts the motor according to the speed FastHome, uFastHome and the flag HOME_DIR_SLOW by HomeDelta distance, uHomeDelta. See GHOM/SHOM commands' description for details on home flags. Moving settings can be set by set_home_settings/set_home_settings_calb.

6.2.6.95 Command IRND

Command code (CMD): "irnd" or 0x646E7269.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (24 bytes)

uint32_t	CMD	Command
uint8_t	key	Random key.
uint8_t	Reserved [2]	Reserved (2 bytes)
uint16_t	CRC	Checksum

Description: Read a random number from the controller. Manufacturer only.

6.2.6.96 Command LEFT

Command code (CMD): “left” or 0x7466656C.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Start continuous moving to the left.

6.2.6.97 Command LOFT

Command code (CMD): “loft” or 0x74666F6C.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Upon receiving the command ‘loft’, the engine is shifted from the current position to a distance Antiplay defined in engine settings. Then moves to the initial position.

6.2.6.98 Command MOVE

Command code (CMD): “move” or 0x65766F6D.

Request: (18 bytes)

uint32_t	CMD	Command
int32_t	Position	Desired position (full steps or encoder counts).
int16_t	uPosition	The fractional part of a position in microsteps. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings). Used with stepper motor only.
uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Move to position. Upon receiving the command 'move' the engine starts to move with pre-set parameters (speed, acceleration, retention), to the point specified by Position and uPosition. uPosition sets the microstep position of a stepper motor. In the case of DC motor, this field is ignored.

6.2.6.99 Command MOVR

Command code (CMD): "movr" or 0x72766F6D.

Request: (18 bytes)

uint32_t	CMD	Command
int32_t	DeltaPosition	Position shift (delta) (full steps or encoder counts)
int16_t	uDeltaPosition	Fractional part of the shift in microsteps. Used with stepper motor only. The microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
uint8_t	Reserved [6]	Reserved (6 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Shift by a set offset. Upon receiving the command 'movr', the engine starts to move with preset parameters (speed, acceleration, hold) left or right (depending on the sign of DeltaPosition). It moves by the number of steps specified in the fields DeltaPosition and uDeltaPosition. uDeltaPosition sets the microstep offset for a stepper motor. In the case of a DC motor, this field is ignored.

6.2.6.100 Command PWOF

Command code (CMD): "pwof" or 0x666F7770.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Immediately power off the motor regardless its state. Shouldn't be used during motion as the motor could be powered on again automatically to continue movement. The command is designed to manually power off the motor. When automatic power off after stop is required, use the power management system.

6.2.6.101 Command RDAN

Command code (CMD): "rdan" or 0x6E616472.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (76 bytes)

uint32_t	CMD	Command
uint16_t	A1Voltage_ADC	'Voltage on pin 1 winding A' raw data from ADC.
uint16_t	A2Voltage_ADC	'Voltage on pin 2 winding A' raw data from ADC.
uint16_t	B1Voltage_ADC	'Voltage on pin 1 winding B' raw data from ADC.
uint16_t	B2Voltage_ADC	'Voltage on pin 2 winding B' raw data from ADC.
uint16_t	SupVoltage_ADC	'Supply voltage of H-bridge's MOSFETs' raw data from ADC.
uint16_t	ACurrent_ADC	'Winding A current' raw data from ADC.
uint16_t	BCurrent_ADC	'Winding B current' raw data from ADC.
uint16_t	FullCurrent_ADC	'Full current' raw data from ADC.
uint16_t	Temp_ADC	Voltage from temperature sensor, raw data from ADC.
uint16_t	Joy_ADC	Joystick raw data from ADC.
uint16_t	Pot_ADC	Voltage on analog input, raw data from ADC
uint16_t	L5_ADC	USB supply voltage after the current sense resistor, raw data from ADC.
uint16_t	H5_ADC	USB Power supply from ADC
int16_t	A1Voltage	'Voltage on pin 1 winding A' calibrated data (in tens of mV).
int16_t	A2Voltage	'Voltage on pin 2 winding A' calibrated data (in tens of mV).
int16_t	B1Voltage	'Voltage on pin 1 winding B' calibrated data (in tens of mV).
int16_t	B2Voltage	'Voltage on pin 2 winding B' calibrated data (in tens of mV).
int16_t	SupVoltage	'Supply voltage on the top of H-bridge's MOSFETs' calibrated data (in tens of mV).
int16_t	ACurrent	'Winding A current' calibrated data (in mA).
int16_t	BCurrent	'Winding B current' calibrated data (in mA).
int16_t	FullCurrent	'Full current' calibrated data (in mA).
int16_t	Temp	Temperature, calibrated data (in tenths of degrees Celsius).
int16_t	Joy	Joystick, calibrated data. Range: 0..10000
int16_t	Pot	Analog input, calibrated data. Range: 0..10000
int16_t	L5	USB supply voltage after the current sense resistor (in tens of mV).
int16_t	H5	USB power supply (in tens of mV).

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uint16_t	deprecated	
int32_t	R	Motor winding resistance in mOhms (is only used with stepper motors).
int32_t	L	Motor winding pseudo inductance in uH (is only used with stepper motors).
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Description: Read the analog data structure that contains raw analog data from the embedded ADC. This function is used for device testing and deep recalibration by the manufacturer only.

6.2.6.102 Command READ

Command code (CMD): "read" or 0x64616572.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Read all settings from the controller's flash memory to the controller's RAM, replacing previous data in the RAM.

6.2.6.103 Command RERS

Command code (CMD): "rers" or 0x73726572.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Read important settings (calibration coefficients, etc.) from the controller's flash memory to the controller's RAM, replacing previous data in the RAM. Manufacturer only.

6.2.6.104 Command REST

Command code (CMD): "rest" or 0x74736572.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: The controller reset command. After the reset, the controller goes into bootloader mode. The command is added for compatibility with the loader exchange protocol. There is no response to this command.

6.2.6.105 Command RIGT

Command code (CMD): "rigt" or 0x74676972.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Start continuous moving to the right.

6.2.6.106 Command SARS

Command code (CMD): "sars" or 0x73726173.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Save important settings (calibration coefficients, etc.) from the controller's RAM to the controller's flash memory, replacing previous data in the flash memory. Manufacturer only.

6.2.6.107 Command SAVE

Command code (CMD): "save" or 0x65766173.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Save all settings from the controller's RAM to the controller's flash memory, replacing previous data in the flash memory.

6.2.6.108 Command SPOS

Command code (CMD): “spos” or 0x736F7073.

Request: (26 bytes)

uint32_t	CMD	Command
int32_t	Position	The position of the whole steps in the engine
int16_t	uPosition	Microstep position is only used with stepper motors. Microstep size and the range of valid values for this field depend on the selected step division mode (see the MicrostepMode field in engine_settings).
int64_t	EncPosition	Encoder position.
uint8_t	PosFlags	Position flags. This is a bit mask for bitwise operations.
	0x1 - SETPOS_IGNORE_POSITION	Will not reload position in steps/microsteps if this flag is set.
	0x2 - SETPOS_IGNORE_ENCODER	Will not reload encoder state if this flag is set.
uint8_t	Reserved [5]	Reserved (5 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Sets position in steps and microsteps for stepper motor. Sets encoder position for all engines.

6.2.6.109 Command SSER

Command code (CMD): “sser” or 0x72657373.

Request: (50 bytes)

uint32_t	CMD	Command
uint32_t	SN	New board serial number.
uint8_t	Key	Protection key (256 bit).
uint8_t	Major	The major number of the hardware version.
uint8_t	Minor	The minor number of the hardware version.
uint16_t	Release	Number of edits this release of hardware.
uint8_t	Reserved [4]	Reserved (4 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Write device serial number and hardware version to the controller's flash memory. Along with the new serial number and hardware version, a 'Key' is transmitted. The SN and hardware version are changed and saved when keys match. Can be used by the manufacturer only.

6.2.6.110 Command SSTP

Command code (CMD): "sstp" or 0x70747373.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Soft stop the engine. The motor is slowing down with the deceleration specified in move_settings.

6.2.6.111 Command STMS

Command code (CMD): "stms" or 0x736D7473.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Start measurements and buffering of speed and the speed error (target speed minus real speed).

6.2.6.112 Command STOP

Command code (CMD): "stop" or 0x706F7473.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Immediately stops the engine, moves it to the STOP state, and sets switches to BREAK mode (windings are short-circuited). The holding regime is deactivated for DC motors, keeping current in the windings for stepper motors (to control it, see Power management settings). When this command is called, the ALARM flag is reset.

6.2.6.113 Command UPDF

Command code (CMD): “updf” or 0x66647075.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: The command switches the controller to update the firmware state. Manufacturer only. After receiving this command, the firmware board sets a flag (for loader), sends an echo reply, and restarts the controller.

6.2.6.114 Command WDAT

Command code (CMD): “wdat” or 0x74616477.

Request: (142 bytes)

uint32_t	CMD	Command
uint8_t	Data	Encoded firmware.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Writes encoded firmware to the controller’s flash memory. The result of each packet write is not available. The overall result is available when the firmware upload is finished.

6.2.6.115 Command WKEY

Command code (CMD): “wkey” or 0x79656B77.

Request: (46 bytes)

uint32_t	CMD	Command
uint8_t	Key	Protection key (256 bit).
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Answer: (15 bytes)

uint32_t	CMD	Command
uint8_t	sresult	Command result.
uint8_t	Reserved [8]	Reserved (8 bytes)
uint16_t	CRC	Checksum

Description: Write command key to decrypt the firmware. Result = RESULT_OK, if the command loader. Result = RESULT_HARD_ERROR if there was a mistake at the time of the command. The Result is not available through the library write_key(). The function processes it internally. Can be used by the manufacturer only.

6.2.6.116 Command ZERO

Command code (CMD): “zero” or 0x6F72657A.

Request: (4 bytes)

uint32_t	CMD	Command

Answer: (4 bytes)

uint32_t	CMD	Command

Description: Sets the current position to 0. Sets the target position of the move command and the movr command to zero for all cases except for movement to the target position. In the latter case, the target position is calculated so that the absolute position of the destination stays the same. For example, if we were at 400 and moved to 500, then the command Zero makes the current position 0 and the position of the destination 100. It does not change the mode of movement. If the motion is carried, it continues, and if the engine is in the ‘hold’, the type of retention remains.

About this document

6.3 Libximc library timeouts

A number of timeouts and wait times are used when working with *mDrive Direct Control* program or your own application using *libximc library* to detect errors and support robust controller operation. A list of times is provided below, together with reasons. Times are optimized for the USB connection on a modern PC. It is important to take delays into account when designing your own signal transmission lines to avoid erroneous timeouts.

Condition	Name	Time in milliseconds
Enumeration timeout. Happens if device type cannot be determined.	ENUMERATE_TIMEOUT_TIME	100
Port open timeout. Happens if library cannot open port.	DEFAULT_TIMEOUT_TIME	5000
Wait time when no data is received from device.	DEFAULT_TIMEOUT_TIME	5000
Wait time on device open.	RESET_TIME/2	50
Wait time from controller reset to device reappearance on firmware reflash.	RESET_TIME * 1.2 + DEFAULT_TIMEOUT_TIME	5120
Wait time on flash sector write.	FLASH_SECTIONWRITE_TIME	100
Reconnect timeout on flash update .	XISM_PORT_DETECT_TIME	60000

6.4 mDrive Direct Control scripts

– *Sync bug test script*

mDrive Direct Control scripting language is implemented using QtScript, which in turn is based on ECMAScript.

ECMAScript is the scripting language standardized by Ecma International in the ECMA-262 specification and ISO/IEC 16262.

QtScript (and, by extension, mDrive Direct Control) uses third edition of the ECMAScript standard.

6.4.1 Brief description of the language

6.4.1.1 Data Types

ECMAScript supports nine primitive data types. Values of type Reference, List, and Completion are used only as intermediate results of expression evaluation and cannot be stored as properties of objects. The rest of the types are:

- Undefined,
- Null,
- Boolean,
- String,
- Number,
- Object.

6.4.1.2 Statements

Most common ECMAScript language statements are summarized below:

Name	Usage	Description
Block	{[<statement list>]}	Several statements may be grouped into a block using braces.
Variable declaration	var <varialble declaration list>	Variables are declared using "var" keyword.
Empty statement	;	Semicolon denotes an empty instruction. It is not required to end a line with a semicolon.
Conditional execution	if (<condition>) <instruction> [else <instruction>]	Conditional execution is done using "if … else" keywords. If a condition is true, then "if"-block instruction is executed, else an "else"-block instruction is executed.
Loop	do <loop body> while (<condition>) while (<condition>) <loop body> for ([<initialization>]; [<condition>]; [<iterative statement>]) <loop body>	Loops have several forms. A "do … while …" loop executes loop body and then checks if condition is true or false to see whether it should stop or continue running. A "while … do …" loop repeatedly checks the condition and executes loop body if it is true. A "for …" loop executes an initialization statement once, then executes an iterative statement and loop body while the condition is true.
Return	return [<expression>]	Stops function execution and returns expression as a result.

Continued on next page

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Name	Usage	Description
Exception	throw <expression>	Generates or "throws" an exception, which may be processed by the "try" statement (see below).
Try-catch block	try <block> catch (<identifier>) <block> try <block> finally <block> try <block> catch (<identifier>) <block> finally <block>	Used together with exceptions. This statement tries to execute its "try"-block. If an exception is thrown in it, then a "catch"-block is executed. Finally a "finally"-block is executed unconditionally. Either a "catch" or a "finally" block may be omitted.

6.4.1.3 Variable statements

Variables are declared using *var* keyword. A declared variable is placed within visibility scope that corresponds to the function in which it is declared. If the variable is declared outside of functions, it is placed in the global visibility scope. Variable is created when the function within which it was declared, or, if the variable is global, at the start of the application. When a variable is created it is initialized with *Undefined* value. If a variable is created with initialization, the initialization does not occur in the moment of variable creation, it happens when the string with the var statement executes.

6.4.1.4 Reserved words

The following words are the reserved keywords in the language and may not be used as identifiers:

```
break     else        new     var
case      finally     return  void
catch     for         switch  while
continue  function    this    with
default   if          throw
delete    in          try
do        instanceof  typeof
```

The following words are used as keywords in proposed extensions and are therefore reserved to allow for the possibility of future adoption of those extensions:

```
abstract  enum        int         short
boolean   export      interface   static
byte      extends     long        super
char      final       native      synchronized
class     float       package     throws
const     goto        private     transient
debugger  implements  protected   volatile
double    import      public
```

6.4.1.5 Functions

Functions are objects in ECMAScript. Functions like any other objects can be stored in variables, objects and arrays, can be passed as arguments to other functions and can be returned by functions. Functions, like any other objects may have properties. Essential specific feature of functions is that they can be invoked.

In the application text, the most common way to define a function is:

```
function sum(arg1, arg2) { // a function which takes two parameters
    return arg1 + arg2;    // and returns their sum
}
```

6.4.2 Syntax highlighting

Script window text has syntax highlighting. Its colors are:

Statement type	*color*	*text example*
Arbitrary functions	purple	my_function();
mDrive Direct Control functions	blue	get_status();
Positive numbers	green	a = 100;
Negative numbers	red	b = -200;
Comments	grey	// a comment
The rest of the text	black	var s = "a string";

During the script execution the background of line with the last executed command is changed to dark gray with update rate of once in every 20 ms.

6.4.3 Additional mDrive Direct Control functions

This image shows mDrive Direct Control functions which are available from scripts, aside from standard built-in language functions.

```
var s = "a string";
```

- log(string text [, int loglevel]) – save text to the mDrive Direct Control log
- msleep(int ms) - delay script execution
- new_axis(int serial_number) - create new axis object
- new_file(string filename) - create new file object
- new_calibration(int A, int Microstep) - create calibration structure to pass to calibrated functions
- get_next_serial(int serial) - get next serial out of an ordered list of opened controller serials
- command_wait_for_stop(int refresh_period) - wait until controller stops moving
- and all libximc library functions (see *Programming guide*)

Also, all constant values from the communication protocol are defined and can be used in scripts. *Usage example*.

6.4.3.1 mDrive Direct Control log

Logging is done by calling log(string text [, int loglevel]) function. This function adds the *text* line to the mDrive Direct Control log. If the second *loglevel* parameter is passed the message receives the appropriate logging level and is displayed in corresponding color.

Loglevel	Type
1	Error
2	Warning
3	Info

Example:

```
var x = 5;
log("x = " + x);
```

Function usage example

Note: It is not recommended to invoke functions that interact with mDrive Direct Control user interface (i.e. logging function) with a frequency of more than once in 20 ms.

6.4.3.2 Script execution delay

Script is paused by calling the msleep(int ms) function, which suspends script execution for *ms* milliseconds.

Example:

```
msleep(200);
```

Function usage example.

6.4.3.3 New axis object creation

mDrive Direct Control multi-axis interface provides the ability to manage controllers via scripts. The difference from the single-axis case is that you should specify the controller which receives the command. An "axis" object is introduced to abstract this concept. It has methods which match the *libximc library* function names. Controllers are identified by their serial numbers.

Example:

```
var x = new_axis(123);
x.command_move(50);
```

In this example first line of the script creates an axis-type object with the variable name "x", which tries to use controller with the serial number "123". If this controller is not connected, then the script will return an error and terminate. The second line of the script sends a "move to position 50" command to this controller.

Function usage example.

6.4.3.4 New file object creation

mDrive Direct Control scripts can read from and write to files. To do this you need to create a "file" object, passing desired filename in its constructor. File object has the following functions:

return_type Function_name	Description
bool open()	Opens the file. File is opened in read-write mode if possible, in read-only mode otherwise.
void close()	Closes the file.
Number size()	Returns file size in bytes.
bool seek(Number pos)	Sets current position in file to *pos* bytes[1].
bool resize(Number size)	Resizes the file to *size* bytes. If *size* is less than current file size, then the file is truncated, if it is greater than current file size, then the file is padded with zero bytes.
bool remove()	Removes the file.
String read(Number maxsize)	Reads up to *maxsize* bytes from the file and returns result as a string. Data is read in utf-8 Unicode encoding.
Number write(String s, Number maxsize)	Writes up to *maxsize* btyes to the file from the string. Data is written in utf-8 unicode encoding, end-of-line character should be set by user. Returns amount of written bytes or -1 if an error occurred.

All file functions which return *bool* type, return "true" on success and "false" on failure.

Use "/" symbol as path separator, this works on all systems (Windows/Linux/Mac).

[1] Seeking beyond the end of a file: If the position is beyond the end of a file, then seek() shall not immediately extend the file. If a write is performed at this position, then the file shall be extended. The content of the file between the previous end of file and the newly written data is UNDEFINED and varies between platforms and file systems.

Example:

```
var winf = new_file("C:/file.txt"); // An example of file name and path on Windows
var linf = new_file("/home/user/Desktop/file.txt"); // An example of file name and␣
↪path on Linux
var macf = new_file("/Users/macuser/file.txt"); // An example of file name and path␣
↪on Mac

var f = winf; // Pick a file name
if (f.open()) { // Try to open the file
  f.write( "some text" ); // If successful, then write desired data to the file
  f.close(); // Close the file
} else { // If file open failed for some reason
  log( "Failed opening file" ); // Log an error
}
```

Function usage example.

6.4.3.5 Creation of calibration structure

new_calibration(double A, int Microstep) function takes as a parameter a floating point number A, which sets the ratio of user units to motor steps, and microstep division mode, which was either read earlier from MicrostepMode field of get_engine_settings() return type, or set by a *MICROSTEP_MODE_* constant. This function returns calibration_t structure, which should be passed to calibrated get_/set* functions to get or set values in user units. The following two forms are functionally equivalent:

```
// create calibration: type 1
var calb = new_calibration(c1, c2);
```

```
// create calibration: type 2
var calb = new Object();
calb.A = c1;
calb.MicrostepMode = c2;
```

Function usage example.

6.4.3.6 Get next serial

get_next_serial(int serial) function takes as a parameter an integer number and returns the smallest serial from a sorted list of opened controller serials which is strictly greater than the parameter. If there are no such serials a zero is returned. This function is a convenient shortcut for automatic creation of "axis" type objects without hardcoded serial numbers.

Example:

```
var first_serial = get_next_serial(0);
var x = new_axis(first_serial);
var y = new_axis(get_next_serial(first_serial));
```

In this example in the first line we obtain a serial, in the second line an axis-type object is created, in the third line we get the next serial and create an axis for it.

Function usage example.

6.4.3.7 Wait for stop

The command_wait_for_stop(int refresh period) script function waits until the controller stops movement, that is, until the MVCMD_RUNNING bit in the MvCmdSts member of the structure returned by the get_status() function

becomes unset. command_wait_for_stop script function uses command_wait_for_stop libximc function and takes as a paramater an integer denoting time delay in milliseconds between successive queries of controller state.

This function is also present as a method of an "axis"-type object.

Function usage example.

6.4.3.8 libximc library functions

Libximc library functions with "get*" prefix read settings from the controller and return the corresponding settings structure. Libximc library functions with "set*" prefix take as a parameter a settings data structure and write these settings to the controller. There are two ways to set data structure contents:

1. call the corresponding get-function and modify required fields

```
// set settings: type 1
var m = get_move_settings();
m.Speed = 100;
set_move_settings(m);
```

2. create an *Object* and set all of its *properties* that are present as members of the data structure (case-sensitive).

```
// set settings: type 2
var m = new Object;
m.Speed = 100;
m.uSpeed = 0;
m.Accel = 300;
m.Decel = 500;
m.AntiplaySpeed = 10;
m.uAntiplaySpeed = 0;
set_move_settings(m);
```

Please note, that in the first case controller receives an additional command (sent by the get-function before the set-). In the second case one should initialize all object properties corresponding to structure members. Any missing property will be initialized with zero. Any property that does not match a structure member name will be ignored. Any property with non-matching type will be typecast according to EcmaScript rules. All data structures are described in *Communication protocol specification* chapter of the manual.

Function usage example.

6.4.4 Examples

This section contains examples of typical tasks which can be easily automated by mDrive Direct Control scripts.

6.4.4.1 Bit mask example script

```
/*
* Bit mask example script
*
* Description of the script:
*  This script clearly shows how to work with bit masks.
*  This script or part of it may be needed when working with any of our other␣
↪commands that use bit masks. For example, the  «set_home_settings» command
*
* To run the script, upload it to the mDrive Direct Control software
*/

var a = new_axis(get_next_serial(0)); // take first found axis
var gets = a.get_status(); // read status once and reuse it
```

```
var gpio = gets.GPIOflags;
var left = STATE_LEFT_EDGE;
var right = STATE_RIGHT_EDGE;
var mask = left | right;
var result = gpio & mask;
log( to_binary(left) + " = left limit switch flag" );
log( to_binary(right) + " = right limit switch flag" );
log( to_binary(mask) + " = OR operation on flags gives the mask" );
log( to_binary(gpio) + " = gpio state" );
log( to_binary(result) + " = AND operation on state and mask gives result" );
if ( result ) {
  log("At least one limit switch is on");
} else {
  log("Both limit switches are off");
}

// Binary representation function
function to_binary(i)
{
  bits = 32;
  x = i >>> 0; // coerce to unsigned in case we need to print negative ints
  str = x.toString(2); // the binary representation string
  return (repeat("0", bits) + str).slice (-bits); // pad with zeroes and return
}

// String repeat function
function repeat(str, times)
{
  var result="";
  var pattern=str;
  while (times > 0) {
    if (times&1) {
      result+=pattern;
    }
    times>>=1;
    pattern+=pattern;
  }
  return result;
}
```

6.4.4.2 A script which scans and writes data to the file

```
/*
* A script which scans and writes data to the file
*
* Description of the script:
*  This script scans and writes the data to a .csv file.
*  The script can be useful if you are using the system to scan an area and/or
↪capture frames
*
* To run the script, upload it to the mDrive Direct Control software
*/

var start = 0; // Starting coordinate in steps
var step = 10; // Shift amount in steps
var end = 100; // Ending coordinate in steps
```

```
var speed = 300; // maximum movement speed in steps / second
var accel = 100; // acceleration value in steps / second^2
var decel = 100; // deceleration value in steps / second^2
var delay = 100;

var m = get_move_settings(); // read movement settings from the controller
m.Speed = speed; // set movement speed
m.Accel = accel; // set acceleration
m.Decel = decel; // set deceleration
set_move_settings(m); // write movement settings into the controller

var f = new_file("C:/a.csv"); // Choose a file name and path
f.open(); // Open a file
f.seek( 0 ); // Seek to the beginning of the file

command_move(start); // Move to the starting position
command_wait_for_stop(delay); // Wait until controller stops moving

while (get_status().CurPosition < end) {
  f.write( get_status().CurPosition + "," + get_chart_data().Pot + "," + Date.now() +
↪"\n" ); // Get current position, potentiometer value and date and write them to file
  command_movr(step); // Move to the next position
  command_wait_for_stop(delay); // Wait until controller stops moving
}
f.close(); // Close the file
```

move_and_sleep.csv

- a sample file for use with the above example

6.4.4.3 Multi axis cyclic movement script

```
/*
* Multi axis cyclic movement script
*
* Description of the script:
*  Does cyclic movement between two border points with set values of acceleration,
*  deceleration and top speed, for all axes found. The script is similar to the
↪"Cyclic"
*  button in mDrive Direct Control
*
* To run the script, upload it to the mDrive Direct Control software
*/

var axes = [];
var number_of_axes = 0;
var last_serial = 0;

while (serial = get_next_serial(last_serial))   // Get next serial number and repeat␣
↪for each axes
{
  axes[number_of_axes] = new_axis(serial);
  log("Found axis " + number_of_axes + " with serial number " + serial);
  number_of_axes++;
  last_serial = serial;
}
```

```
for (var i = 0; i < number_of_axes; i++)
{
  axis_configure(axes[i]);
}

while (1)
{
  for (var i = 0; i < number_of_axes; i++)
  {
    go_first_border(axes[i]);
    go_second_border(axes[i]);
  }

  msleep(100);
}

function axis_configure(axis)
{
  var speed = 1000;   // Maximum movement speed in steps / second
  var accel = 2000;   // Acceleration value in steps / second^2
  var decel = 5000;   // Deceleration value in steps / second^2

  axis.command_stop(); // send STOP command (does immediate stop)
  axis.command_zero(); // send ZERO command (sets current position and encoder value
↪to zero)
  var m = axis.get_move_settings(); // read movement settings from the controller
  m.Speed = speed; // set movement speed
  m.Accel = accel; // set acceleration
  m.Decel = decel; // set deceleration
  axis.set_move_settings(m); // write movement settings into the controller
}

function go_first_border(axis)
{
  var first_border = 0; // first border coordinate in steps
  var GETS = axis.get_status();

  if (!(GETS.MvCmdSts & MVCMD_RUNNING) && (GETS.CurPosition != first_border))
  {
    axis.command_move(first_border);  // move towards one border
  }
}

function go_second_border(axis)
{
  var second_border = 25000; // second border coordinate in steps
  var GETS = axis.get_status();

  if (!(GETS.MvCmdSts & MVCMD_RUNNING) && (GETS.CurPosition != second_border))
  {
    axis.command_move(second_border);   // move towards another border
  }
}
```

6.4.4.4 Single axis cyclic movement script

```
/*
* Single axis cyclic movement script
*
* Description of the script:
*  Does cyclic movement between two border points with set values of acceleration,
*  deceleration and top speed. The script is similar to the "Cyclic" button in mDrive␣
↪Direct Control
*
* To run the script, upload it to the mDrive Direct Control software
*/

var first_border = -10; // first border coordinate in mm
var second_border = 10; // second border coordinate in mm
var mm_per_step = 0.005; // steps to distance translation coefficient
var delay = 100; // delay in milliseconds
var calb = new_calibration(mm_per_step, get_engine_settings().MicrostepMode); //␣
↪create calibration structure
command_stop(); // send STOP command (does immediate stop)
command_zero(); // send ZERO command (sets current position and encoder value to zero)
while (1) { // infinite loop
  command_move_calb(first_border, calb); // move towards one border
  command_wait_for_stop(delay); // wait until controller stops moving
  command_move_calb(second_border, calb); // move towards another border
  command_wait_for_stop(delay); // wait until controller stops moving
}
```

6.4.4.5 Homing test script

```
/*
* Homing test script
*
* Description of the script:
*  This script tests homing function by repeatedly moving to a random position,
*  doing quick stop and then homing, for all axes found. The script is similar to the␣
↪GO
*  Home button in mDrive Direct Control
*
* To run the script, upload it to the mDrive Direct Control software
*/

var axes = [];
var number_of_axes = 0;
var last_serial = 0;
while (serial = get_next_serial(last_serial)) // get next serial number and repeat␣
↪for each axes.
{
    axes[number_of_axes] = new_axis(serial);
   log("Found axis " + number_of_axes + " with serial number " + serial);
   number_of_axes++;
   last_serial = serial;
}

while (1) { // infinite loop
    for (var i = 0; i < number_of_axes; i++)
   {
        homing_test(axes[i]);
```

```
    }
}

function homing_test(axis)
{
    var shift_low = 0; // minimum shift distance in steps
   var shift_high = 10000; // maximum shift distance in steps
   var speed_low = 100; // minimum movement speed in steps / second
   var speed_high = 5000; // maximum movement speed in steps / second
   var time_low = 1; // minimum wait time in seconds
   var time_high = 10; // maximum wait time in seconds

    axis.command_home(); // send HOME command (find home position)
    axis.command_wait_for_stop(100); // wait until controller stops moving
    var m = axis.get_move_settings(); // read movement settings from the controller
    m.Speed = rnd(speed_low, speed_high); // set random speed from a range of speeds␣
↪between "speed_low" and "speed_high"
    axis.set_move_settings(m); // write movement settings into the controller
    var shift = rnd(shift_low, shift_high); // pick random shift value from a range␣
↪of distances between "shift_low" and "shift_high"
    if (Math.random() < 0.5) { // pick random direction
       shift = -shift;
    }
    axis.command_movr(shift); // send MOVR command (does a relative shift)
    msleep( rnd(time_low*1000, time_high*1000) ); // pause for a random time from a␣
↪range between "time_low" and "time_high"
    axis.command_stop(); // send STOP command (does immediate stop)
}

function rnd(min,max) { // "rnd" is a helper function which uses Math.random() and␣
↪returns a uniformly distributed integer random value between "min" and "max"
 var r = Math.random()*(max-min)+min;
 return Math.round(r);
}
```

6.4.4.6 List axis serials script

```
/*
* List axis serials script
*
* Description of the script:
*  An example of a script that searches for all the serial numbers of controllers
*  and outputs them to the log.
*
* To run the script, upload it to the mDrive Direct Control software
*/

var i = 0; // Declare loop iteration variable
var serial = 0; // Declare serial number variable
var axes = Array(); // Declare axes array
while (true) { // The loop
 serial = get_next_serial(serial); // Get next serial
 if (serial == 0) // If there are no more controllers then...
     break; // ...break out of the loop
 var a = new Object(); // Create an object
 a.serial = serial; // Assign serial number to its "serial" property
 a.handle = new_axis(serial); // Assign new axis object to its "handle" property
```

```
 axes[i] = a; // Add it to the array
 i++; // Increment counter
}
for (var k=0; k < axes.length; k++) { // Iterate through array elements
  log ( "Axis with S/N " + axes[k].serial + " is in position " + axes[k].handle.get_
↪status().CurPosition ); // For each element print saved axis serial and call a get_
↪status() function
}
```

6.4.4.7 Move and wait script

```
/*
* Move and wait script
*
* Description of the script:
*  The script reads the next coordinate and the delay time from the csv file,
*  after which it moves to the specified coordinate with a subsequent delay,
*  and so on until the end of reading the entire file.
*     The script can be useful if you are using the system to scan an area and/or␣
↪capture frames
* To run the script, upload it to the mDrive Direct Control software
*/

var axis = new_axis(get_next_serial(0)); // Use first available controller
var x; // A helper variable, represents coordinate
var ms; // A helper variable, represents wait time in milliseconds
var f = new_file("./move_and_sleep.csv"); // Choose a file name and path; this script␣
↪uses a file from examples in the installation directory
f.open(); // Open a file
while ( str = f.read(4096) ) { // Read file contents string by string, assuming each␣
↪string is less than 4 KiB long
  var ar = str.split(","); // Split the string into substrings with comma as a␣
↪separator; the result is an array of strings
  x = ar[0]; // Variable assignment
  ms = ar[1]; // Variable assignment
  log( "Moving to coordinate " + x ); // Log the event
  axis.command_move(x); // Move to the position
  axis.command_wait_for_stop(100); // Wait until the movement is complete
  log( "Waiting for " + ms + " ms" ); // Log the event
  msleep(ms); // Wait for the specified amount of time
}
log ( "The end." );
f.close(); // Close the file
```

6.4.4.8 Random shift script

```
/*
* Random shift script
*
* Description of the script:
*  This script does shifts on random offset from a specified range of distances
*  with a random speed from a chosen range of speeds.

* To run the script, upload it to the mDrive Direct Control software
*/

var axes = [];
```

```
var number_of_axes = 0;
var last_serial = 0;
while (serial = get_next_serial(last_serial)) // get next serial number and repeat␣
↪for each axes.
{
   axes[number_of_axes] = new_axis(serial);
   log("Found axis " + number_of_axes + " with serial number " + serial);
   number_of_axes++;
    last_serial = serial;
}

while (1) { // infinite loop
   for (var i = 0; i < number_of_axes; i++)
   {
       go_to_random_shift(axes[i]);
    }
}

function go_to_random_shift(axis)
{
   var shift_low = 0; // minimum shift distance in steps
   var shift_high = 10000; // maximum shift distance in steps
   var speed_low = 100; // minimum movement speed in steps / second
   var speed_high = 5000; // maximum movement speed in steps / second

   var m = axis.get_move_settings(); // read movement settings from the controller
   m.Speed = rnd(speed_low, speed_high); // set random speed from a range of speeds␣
↪between "speed_low" and "speed_high"
   axis.set_move_settings(m); // write movement settings into the controller
   var shift = rnd(shift_low, shift_high); // pick random shift value from a range of␣
↪distances between "shift_low" and "shift_high"
   if (Math.random() < 0.5) { // pick random direction
       shift = -shift;
   }
   axis.command_movr(shift); // send MOVR command (does a relative shift)
    axis.command_wait_for_stop(100); // wait until controller stops moving
}

function rnd(min,max) { // "rnd" is a helper function which uses Math.random() and␣
↪returns a uniformly distributed integer random value between "min" and "max"
  var r = Math.random()*(max-min)+min;
  return Math.round(r);
}
```

6.4.4.9 Set zero scrip

```
/*
* Set zero script
*
* Description of the script:
*  This script changes "standoff" setting (found on "Home position" page in the␣
↪mDrive Direct Control "Settings") so that the current position becomes the home␣
↪position.
*  The script is very convenient for calibrating and configuring new stages, as well␣
↪as for changing the zero position
*
* How to use:
```

```
*  - manually move your positioner to a desired position
*  - launch this script and wait for completion
*  As a result your positioner will return to the starting position and all␣
↪subsequent calls to "homing" function will bring it there.
*
* Note: homing settings are saved into RAM and will be lost when controller is␣
↪powered down. If you wish to save these settings to non-volatile memory you should␣
↪either pick "Save settings to flash" on the XILab main Settings page or call
↪"command_save_settings()" at the end of the script.
*
* To run the script, upload it to the mDrive Direct Control software
*/

var axes = [];
var number_of_axes = 0;
var last_serial = 0;
while (serial = get_next_serial(last_serial)) // get next serial number and repeat␣
↪for each axes.
{
    axes[number_of_axes] = new_axis(serial);
   log("Found axis " + number_of_axes + " with serial number " + serial);
   number_of_axes++;
   last_serial = serial;
}

for (var i = 0; i < number_of_axes; i++)
{
   set_zero(axes[i]);
}

function set_zero(axis)
{
    axis.command_stop(); // send STOP command (does immediate stop)

   var h = axis.get_home_settings(); // read homing settings from the controller
   h.HomeDelta = 0; // set "HomeDelta" parameter in "home_position" structure to 0
   h.uHomeDelta = 0; // set "uHomeDelta" parameter in "home_position" structure to 0
   var saved_fast = h.FastHome; // save "FastHome" parameter from "home_position"␣
↪structure to a variable
   var saved_ufast = h.uFastHome; // save "uFastHome" parameter from "home_position"␣
↪structure to a variable
   if (h.HomeFlags & HOME_MV_SEC_EN != 0) // if homing settings have two homing␣
↪phases turned on
   {
        h.FastHome = 100; // set "FastHome" parameter in "home_position" structure␣
↪(first movement speed) to 100 steps/s: this is required to avoid slip at the end of␣
↪the first phase
       h.uFastHome = 0; // set "uFastHome" parameter in "home_position" structure to 0
    }
    axis.set_home_settings(h); // write homing settings into the controller

    var old_pos = axis.get_status().CurPosition; // save whole step part of the␣
↪initial position into a variable
    var old_upos = axis.get_status().uCurPosition; // save microstep part of the␣
↪initial position into a variable
    axis.command_home(); // send HOME command (find home position)
    do { msleep(100); } while (axis.get_status().MvCmdSts == (MVCMD_HOME | MVCMD_
↪RUNNING)); // query controller state every 100 ms while movement state is "homing␣
↪command is being executed"
```

```
    if (axis.get_status().MvCmdSts != MVCMD_HOME)  // if current state is not "homing␣
↪completed successfully" (MVCMD_RUNNING unset, MVCMD_ERROR unset, last command MVCMD_
↪HOME) then homing was interrupted
    {
        h.FastHome = saved_fast; // set "FastHome" parameter in "home_position"␣
↪structure to a saved value
       h.uFastHome = saved_ufast; // set "uFastHome" parameter in "home_position"␣
↪structure to a saved value
       axis.set_home_settings(h); // write movement settings into the controller␣
↪(this restores the initial settings)
       throw "Script aborted: homing failed."; // throw an exception and terminate
    }

    var new_pos = axis.get_status().CurPosition; // read whole part of new position␣
↪into "new_pos" variable
    var new_upos = axis.get_status().uCurPosition; // read microstep part of new␣
↪position into "new_upos" variable
    h.HomeDelta = old_pos-new_pos; // set "HomeDelta" parameter in "home_position"␣
↪structure to this value
    h.uHomeDelta = old_upos-new_upos; // set "uHomeDelta" parameter in "home_position
↪" structure to this value
    h.FastHome = saved_fast; // set "FastHome" parameter in "home_position" structure␣
↪to a saved value
    h.uFastHome = saved_ufast; // set "uFastHome" parameter in "home_position"␣
↪structure to a saved value
    axis.set_home_settings(h); // write movement settings into the controller
    axis.command_move(old_pos, old_upos); // move to initial position
    do { msleep(100); } while (axis.get_status().MvCmdSts == (MVCMD_MOVE | MVCMD_
↪RUNNING)); // query controller state every 100 ms while movement state is "movement␣
↪command is being executed"
    if (axis.get_status().MvCmdSts != MVCMD_MOVE)  // if current state is not
↪"movements completed successfully" (MVCMD_RUNNING unset, MVCMD_ERROR unset, last␣
↪command MVCMD_MOVE) then movement was interrupted
    {
        throw "Script aborted: return to position failed."; // throw an exception and␣
↪terminate
    }
    axis.command_zero(); // send ZERO command (sets current position and encoder␣
↪value to zero)
}

log("Done."); // log success
```

6.4.4.10 Autotester script

```
/*
* Autotester script
*
* Description of the script:
*  The script tests the controller with a stage using a set of tests.
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/
```

View the full code

6.4.4.11 Border crossing test

```
/*
* Border crossing test
*
* Description of the script:
*  The script checks the correct operation of the connected external limit switch
*
* How to connect wires?
*  You must connect the limit switch to the DSub-15 connector (pins 8 and 9 on the
↪controller connector).
*
* Note: This is a rather difficult script to learn, since it uses a large number of
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

const MVCMD_ERROR = 0x40;
const MVCMD_RUNNING = 0x80;

var axis = new_axis(get_next_serial(0));
var m = axis.get_extio_settings();
var s = axis.get_status();

var count_error = 0;
var count_good = 0;

function BorderOff()
{
  m.EXTIOSetupFlags = 0x01;
  m.EXTIOModeFlags = 0x10;

  axis.set_extio_settings(m);
}

function BorderOn()
{
  m.EXTIOSetupFlags = 0x01;
  m.EXTIOModeFlags = 0x00;

  axis.set_extio_settings(m);
}

function BorderCycle()
{
  BorderOn();
  msleep(50);

  BorderOff();
  msleep(100);
}

log("You have to connect the common",2);
log("input/output pin on the backplane connector to",2);
log("the 2nd limit switch pin on the stage connector", 2);
```

```
log("Also its recommended to load the profile for your stage", 2);

log(">>> Start testing", 3);

while (1)
{
  axis.command_left();
  msleep(200);
  BorderOn();
  msleep(200);
  s = axis.get_status();

  if (s.MvCmdSts & MVCMD_RUNNING)
  {
    count_error++;

    log(">>> ALARM ! Crossing through the limit switch !" ,1);
  }
  else
  {
    count_good++;

    if (!(count_good % 50))
      log(">>> " + count_good + " cycles were done correct, " + count_error + "␣
↪cycles were done incorrect", 3);
  }

  BorderOff();
}
```

6.4.4.12 Closed loop tuning test

```
/*
* Closed loop tuning test
*
* Description of the script:
*  The script checks the parameters of a closed loop
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

var global_axis;

global_axis = new_axis(get_next_serial(0));
global_axis.command_stop();

const DEBUG = 1;
const MICROSTEPS = 256;
const SKIP_ENCODER_COUNT = 7;
const STORE_COUNT_MICROSTEPS = 19;
const TRUST_INDEX = 15;      // Always TRUST_INDEX < STORE_COUNT_MICROSTEPS

/*
* Save and overwrite settings
```

```
*/
var SFBS = global_axis.get_feedback_settings(); // Save information about encoder␣
↪(IPS)
SFBS.FeedbackType = FEEDBACK_NONE;              // Overwrite feedback type, because␣
↪in profile feedback is encoder

var SENG = global_axis.get_engine_settings();   // Save information about engine␣
↪(nominal current, steps per revolution)

var SENT = global_axis.get_entype_settings();   // Save information about engine type

var SEDS = global_axis.get_edges_settings();    // Save information about edges

/*
* Clear FRAM for synchronization
* real full step with full step of firmware
*/
log("Clearing FRAM", 1);
global_axis.command_clear_fram();
msleep(4000);

/*
* Restore controller settings
*/
global_axis.set_feedback_settings(SFBS);
msleep(100);

global_axis.set_engine_settings(SENG);
msleep(100);

global_axis.set_entype_settings(SENT);
msleep(100);

global_axis.set_edges_settings(SEDS);
msleep(100);

/*
* Prepare and apply move settings
*/
var SMOV = global_axis.get_move_settings();
SMOV.Speed = 0;
SMOV.uSpeed = 16;
global_axis.set_move_settings(SMOV);
msleep(100);

/*
* Going to the full step and waiting 3 seconds for equilibration
*/
global_axis.command_move(0, 0);
msleep(3000);

/*
* Arrays for measurements and structure for GPOS
*/
var MicroStepsToRight = [];
var MicroStepsToLeft = [];
var EncToRight = [];
var EncToLeft = [];
```

```
var GPOS;

/*
* Start moving
*/
global_axis.command_right();

/*
* Skipping a some first counts for the stable experiment
*/
for (var i = 0; i < SKIP_ENCODER_COUNT; i++)
{
  GPOS = global_axis.get_position();
  var EncPos = GPOS.EncPosition;

  while (EncPos == GPOS.EncPosition)
  {
    msleep(40);
    GPOS = global_axis.get_position();
  }

  EncPos = GPOS.EncPosition;
}

/*
* Start measurements
*/
for (var i = 0; i < STORE_COUNT_MICROSTEPS; i++)
{
  GPOS = global_axis.get_position();
  var EncPos = GPOS.EncPosition;

  while (EncPos == GPOS.EncPosition)
  {
    msleep(40);
    GPOS = global_axis.get_position();
  }

  EncPos = GPOS.EncPosition;

  MicroStepsToRight[i] = GPOS.Position * MICROSTEPS + GPOS.uPosition;
  EncToRight[i] = GPOS.EncPosition;
}

/*
* Stop moving
*/
global_axis.command_stop();

/*
*  Start moving and measurements
*/
global_axis.command_left();

for (var i = 0; i < STORE_COUNT_MICROSTEPS; i++)
{
  GPOS = global_axis.get_position();
  var EncPos = GPOS.EncPosition;
```

```
  while (EncPos == GPOS.EncPosition)
  {
    msleep(40);
    GPOS = global_axis.get_position();
  }

  EncPos = GPOS.EncPosition;

  MicroStepsToLeft[STORE_COUNT_MICROSTEPS - 1 - i] = GPOS.Position * MICROSTEPS +␣
↪GPOS.uPosition;
  EncToLeft[STORE_COUNT_MICROSTEPS - 1 - i] = GPOS.EncPosition;
}

/*
* Stop moving
*/
global_axis.command_stop();

/*
* Check all values
*/
for (var i = 0; i < STORE_COUNT_MICROSTEPS; i++)
{
  var diffMicrosteps = MicroStepsToRight[i] - MicroStepsToLeft[i];
  var diffConts = EncToRight[i] - EncToLeft[i];

  if (DEBUG)
  {
    log(MicroStepsToRight[i] + " - " + MicroStepsToLeft[i] + " = " + diffMicrosteps +
↪" microstep(s)\t" +
      EncToRight[i] + " - " + EncToLeft[i] + " = " + diffConts + " count(s)", 3);
  }

  if (diffConts != 1)
  {
    log("Script error! Try again", 1);
  }
}

var RightB = (MicroStepsToRight[TRUST_INDEX] * EncToRight[0] - MicroStepsToRight[0] *␣
↪EncToRight[TRUST_INDEX]) / (EncToRight[0] - EncToRight[TRUST_INDEX]);
var LeftB = (MicroStepsToLeft[TRUST_INDEX] * EncToLeft[0] - MicroStepsToLeft[0] *␣
↪EncToLeft[TRUST_INDEX]) / (EncToLeft[0] - EncToLeft[TRUST_INDEX]);

log("Right counts show B = " + RightB, 2);
log("Left counts show B = " + LeftB, 2);
log("Aver B = " + ((RightB + LeftB) / 2), 3);
```

6.4.4.13 Discrete motion script

```
/*
* Discrete motion script
*
* Description of the script:
*  The script opens two axes by serial numbers. Moves along the X axis to a certain␣
↪coordinate. Then it begins to shift discretely along the Y axis, with a␣
↪programmable pause after each offset.
```

```
*  The script can be useful if you are using the system to scan an area and/or␣
↪capture frames
*
* Warning: enter the serial numbers of your axes!
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

// Enter the serial numbers of your axes.
serial_number_x = 14889;
serial_number_y = 14888;

var x = new_axis(serial_number_x);
var y = new_axis(serial_number_y);

// Installing the source data
var x_target_coordinate = 5000; // first border coordinate
var delay = 100; // delay in milliseconds

var y_first_border = 0; // first border coordinate
var y_second_border = 5000; // second border coordinate
var y_step = 100
var y_direct = 1

// Calibration and positioning of the axes to their original positions.
x.command_stop(); // send STOP command (does immediate stop)
x.command_zero(); // send ZERO command (sets current position and encoder value to␣
↪zero)
y.command_stop(); // send STOP command (does immediate stop)
y.command_zero(); // send ZERO command (sets current position and encoder value to␣
↪zero)

x.command_move(x_target_coordinate); // move to wards one border
x.command_wait_for_stop(10); // wait until controller stops moving
y.command_move(y_first_border); // move towards one border
y.command_wait_for_stop(10); // wait until controller stops moving

// Movement in discrete samples along one axis from the end to the end
// with a delay after each movement.
while (1) { // infinite loop

// Choosing the direction of travel
if (y.get_position() >= y_second_border)
{
  y_direct = -1
}
if (y.get_status().CurPosition <= y_first_border)
{
  y_direct = 1
}

// Movement in a given direction
y.command_movr(y_step*y_direct); // move towards another border
y.command_wait_for_stop(10); // wait until controller stops moving
msleep(delay);
```

```
}
```

6.4.4.14 Exponential position change in user units script

```
/*
* Exponential position change in user units script
*
* Description of the script:
*  The script performs discrete control of movement according to a certain law of␣
↪motion. The amplitude and the law of displacement are given. A correction speed is␣
↪used to maintain the positioning accuracy.
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

// Main characteristics
var time_discre = 10; // Discreteness of movement control(ms)
var end_err = 0.01; // The accuracy of reaching the final coordinate of the movement.

var full_move = 6; // Total movement in mm

// If you change the equation of motion, you will need to change the equation for the␣
↪correction velocity, since this change is not linear.
var K = 0.4;
var Glob_err = 0;

// Advanced setting.
var mm_per_step = 0.00125; // Distance in gr for 1 completed step.
var calb = new_calibration(mm_per_step, get_engine_settings().MicrostepMode); //␣
↪create calibration structure

// Setting the starting position.
command_stop(); // send STOP command (does immediate stop)
command_wait_for_stop(10); // wait until controller stops moving
command_zero(); // send ZERO command (sets current position and encoder value to zero)


log("Start:");
// Setting 0 speeds and accelerations.
zero_movesettings();

//
go_position(full_move, time_discre)


// Function for calculating the set speed and acceleration
function set_movesettings(time, corr_speed)
{
  // Speed, Accel, Decel setting.
  var m = get_move_settings_calb(calb); // read movement settings from the controller

  // The equation of speed is equal to the derivative of the equation of motion.
  m.Speed =  K*Math.exp(K*time/1000 )+ corr_speed;
```

```
  set_move_settings_calb(m, calb); // write movement settings into the controller

log("Speed = " +m.Speed);
log("corr_speed = " +corr_speed);
}

// Set the initial parameters of motion
function zero_movesettings()
{
  var m = get_move_settings_calb(calb); // read movement settings from the controller
  m.Speed = 0.1; // set movement speed

  set_move_settings_calb(m, calb); // write movement settings into the controller
}

// A function of calculating target coordinates from time
function current_target_coordinate(time)
{
  // The equation of motion. The time is set in milliseconds. The position at the␣
↪initial time is 0.
  return (Math.exp(K*time/1000) - 1);
}

// The calculation of the correction speed
function speed_corr(err_pos)
{
  Glob_err = Glob_err + err_pos*0.35;
  return  Glob_err;
}

// The main moving
function go_position(full_time, time_discre)
{
  Glob_err = 0;
  var end_position = full_move;

  // Setting the movement to the desired coordinate.
  command_move_calb(end_position, calb);

  // Pause before starting to move, to turn on the power button.
  msleep(300);
  var mas = 1;
  var basetime = new Date();
  var curr_time = new Date();
  var err_pos = 0;
  var pos = 0;
  var pos1 = 0;
  var i = time_discre;
  do {
    // If you do not need position feedback, you can instead speed_corr(err_pos)␣
↪write 0
    set_movesettings(i+1, speed_corr(err_pos));

    // Waiting for the end of a discrete time interval
    do {
      curr_time = new Date - basetime;
      msleep(1);
    }
```

```
    while ((curr_time) < i); //

    // Reading the actual and calculating the planned coordinate if used.
    pos =  get_position_calb(calb).Position;
    pos1 =  current_target_coordinate(i);

    // Calculation of the position error.
    err_pos =  (pos1 -  pos);

    log("time = " + i);
    log("err_pos = " + err_pos);

    i = i + time_discre
  }
  while (Math.abs(pos - end_position) > end_err); // Completion when the end of the␣
↪movement is reached with the specified accuracy.
}
```

6.4.4.15 For calb step script

```
/*
* For calb step script
*
* Description of the script:
*  In the script, the user units are configured, after which there is a departure to␣
↪the leftmost position and then a certain number of shifts occur until the right␣
↪position is reached. Each position is recorded in a .csv file.
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

command_home(); // send HOME command (find home position)
command_wait_for_stop(100);
command_zero();
command_wait_for_stop(100);

// Setting the value to convert to user unit
var mm_per_step = 0.00125; // steps to distance translation coefficient
var calb = new_calibration(mm_per_step, get_engine_settings().MicrostepMode); //␣
↪create calibration structure

// Setting boundaries and movement step
// Boundaries can be set manually or taken from limit constraints
var edge = get_edges_settings_calb(calb);
var first_border = edge.LeftBorder; //0;
var second_board = edge.RightBorder;//23;
var shift = 5;//step move;
var delay = 2000;// The delay of movement

var f = new_file("file.csv"); // Choose a file name and path
f.open(); // Open a file
f.resize(0);
f.seek( 0 ); // Seek to the beginning of the file
```

```
command_move_calb(first_border, calb); // Move to the starting position
command_wait_for_stop(delay); // Wait until controller stops moving
var i = 1;
var time = 0;
var step = (second_board - first_border)/shift;
f.write(0+ "," + get_status().CurPosition + "," + get_status().uCurPosition+ "," +
↪"\n" ); // Get current position, potentiometer value and date and write them to file
do {
  time = i*delay;
  command_movr_calb(shift, calb); // Move to the next position
  command_wait_for_stop(delay); // Wait until controller stops moving
  f.write(time + "," + get_position_calb(calb).Position + "," + get_position_
↪calb(calb).EncPosition+ "," + "\n" ); // Get current position, potentiometer value␣
↪and date and write them to file
  i = i+1;
} while ( get_position_calb(calb).Position+shift < second_board )
f.close(); // Close the file
```

6.4.4.16 Step script

```
/*
* Step script
*
* Description of the script:
*  In the script, there is a departure to the leftmost position and then a certain␣
↪number of shifts occur until the right position is reached. Each position is␣
↪recorded in a .csv file.
*
* Note: The script is similar to the "for_calb_step" script, only in this script the␣
↪offset occurs at the step mode
*
* To run the script, upload it to the mDrive Direct Control software
*/

command_home(); // send HOME command (find home position)
command_wait_for_stop(100);
command_zero();
command_wait_for_stop(100);
var edge = get_edges_settings();
var first_border = edge.LeftBorder;
var second_board = edge.RightBorder;
var count = 10;
var f = new_file("E:/a.csv"); // Choose a file name and path
f.open(); // Open a file
f.seek( 0 ); // Seek to the beginning of the file

var delay = 2000;
command_move(first_border); // Move to the starting position
command_wait_for_stop(delay); // Wait until controller stops moving
var i = 1;
var time = 0;
var shift = 6;
var step = (second_board - first_border)/shift;
f.write(0+ "," + get_status().CurPosition + "," + get_status().uCurPosition+ "," +
↪"\n" ); // Get current position, potentiometer value and date and write them to file
do {
  time = i*delay;
```

```
  command_movr(step, 0); // Move to the next position
  command_wait_for_stop(delay); // Wait until controller stops moving
  f.write(time + "," + get_status().CurPosition + "," + get_status().uCurPosition+
↪"," + "\n" ); // Get current position, potentiometer value and date and write them␣
↪to file
  i = i+1;
} while (i < shift )
f.close(); // Close the file
```

6.4.4.17 Homing test with extio

```
/*
* Homing test with extio
*
* Description of the script:
*  The script starts calibration when a signal is received from a general purpose␣
↪digital input/output (extio)
*
* How to connect wires?
*  You must connect to the HDB-26 connector (pin 25 on the controller).
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

const MVCMD_ERROR = 0x40;
const MVCMD_RUNNING = 0x80;

var axis = new_axis(get_next_serial(0));
var m = axis.get_extio_settings();
var s = axis.get_status();

var count_error = 0;
var count_good = 0;

function BorderOff()
{
  m.EXTIOSetupFlags = 0x01;
  m.EXTIOModeFlags = 0x10;

  axis.set_extio_settings(m);
}

function BorderOn()
{
  m.EXTIOSetupFlags = 0x01;
  m.EXTIOModeFlags = 0x00;

  axis.set_extio_settings(m);
}

function BorderCycle()
{
  BorderOn();
  msleep(50);
```

```
  BorderOff();
  msleep(2500);
}

log(">>> Start testing", 3);

while (1)
{
  axis.command_home();
  msleep(1500);

  BorderCycle();
  BorderCycle();

  command_wait_for_stop(100);

  s = axis.get_status();

  if (s.MvCmdSts & MVCMD_ERROR)
  {
    count_error++;

    log(">>> Alarm! Homing broken", 1);
  }
  else
  {
    count_good++;

    if (!(count_good % 50))
      log(">>> " + count_good + " cycles were done correct, " + count_error + "␣
↪cycles were done incorrect", 3);
  }
}
```

6.4.4.18 Motion by sin function

```
/*
*  Motion by sin function
*
* Description of the script:
*  A script for moving with a change in speed according to the trigonometric law.
*  The script can be useful for precise positioning of a laser or motorized mirror
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

var delay = 100;

/* Definition of delta and initial phase*/
var df = 0.05;
var f = 0;

/* Definition of package */
```

```
var GETS = new Object();

// Initial installations
var move_set = get_move_settings();
var speed = 3000;
var amplitude = 1000;
var nomber = 100;
var time = 1000;
var pos = 0;
var Pi = 3.1415;
df = Pi/nomber;

command_zero();

var pos_read = new Object();
while (1)
{
    pos_read = get_position();

    // Movement to a point with an increase in the velocity amplitude
    for (i = 1; i <= nomber-1; i++)
    {
      f = df*i;

      move_set.Speed = speed * Math.sin(f);
      pos =  amplitude*i /nomber;

      set_move_settings(move_set);
      command_move(pos);
      while (Math.abs(pos_read.Position - pos)>move_set.Speed/10)
      {
        pos_read = get_position();
      }

    }

    // Movement to a point with a decrease in the velocity amplitude
    for (i = nomber-1; i >= 1; i--)
    {
      f = df*i;

      move_set.Speed = speed * Math.sin(f);
      pos =  amplitude*i /nomber;

      set_move_settings(move_set);
      command_move(pos);
      while (Math.abs(pos_read.Position - pos)>move_set.Speed/10)
      {
        pos_read = get_position();
      }

    }

  msleep(1000);

}
```

6.4.4.19 Move EXTIO calb script

```
/*
* Move EXTIO calb script
*
* Description of the script:
*  The script moves to one of the 2 specified points, depending on the state of the␣
↪EXTIO input. The movement is carried out in user units.
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

// Main characteristics
var time_discre = 10; // Discreteness of movement control(ms)
var nomspeed = 5;
var end_err = 0.015;

var low_position = 0; // Move to position for low EXTIO
var high_position = 180; // Move to position for high EXTIO

// Advanced setting.
var gr_per_step = 0.015; // Distance in gr for 1 completed step.
var calb = new_calibration(gr_per_step, get_engine_settings().MicrostepMode); //␣
↪create calibration structure

// Setting the starting position.
command_stop(); // send STOP command (does immediate stop)
command_wait_for_stop(10); // wait until controller stops moving
command_home();
command_zero(); // send ZERO command (sets current position and encoder value to zero)


log("Start:");
// Setting 0 speeds and accelerations.
movesettings();

extiosettings();
//
go_position(time_discre)

function extiosettings()
{
  var extsettings = get_extio_settings();
  extsettings.EXTIOSetupFlags = 0x00;
  extsettings.EXTIOModeFlags = 0x00;
  set_extio_settings(extsettings);
}

// Set the initial parameters of motion
function movesettings()
{
  var m = get_move_settings_calb(calb); // read movement settings from the controller
  m.Speed = nomspeed; // set movement speed

  set_move_settings_calb(m, calb); // write movement settings into the controller
}
```

```
// The main moving
function go_position(time_discre)
{
  var oldstate = 0;
  var maskstate = 32;

  // Setting the movement to the desired coordinate.
  command_move_calb(low_position, calb);

  // Pause before starting to move, to turn on the power button.
  msleep(300);

  while(1) {

  //
  var status = get_status_calb(calb);
  if ((status.GPIOFlags & maskstate) != oldstate)
  {
    log(status.GPIOFlags);
    if (oldstate)
      command_move_calb(high_position, calb);
    else
      command_move_calb(low_position, calb);

    oldstate = status.GPIOFlags & maskstate;
  }
  // Waiting for the end of a discrete time interval
  msleep(time_discre);
  }
}
```

6.4.4.20 Probabilistic tests

```
/*
* Probabilistic tests
*
* Description of the script:
*  The script runs a set of repeatable tests a certain number of times and is␣
↪expected to fail.
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/
```

View the full code

6.4.4.21 Several shifts with calibration script

```
/*
* Several shifts with calibration script
*
* Description of the script:
*  This program makes shifts given number of times to the specified distance, and␣
↪stands the appointed time after every shift. First it goes left, then it returns␣
↪back to the origin and repeats all movements to right.
```

```
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

const LEFT = -1;
const RIGHT = 1;

var axes = [];
var number_of_axes = 0;
var last_serial = 0;
while (serial = get_next_serial(last_serial)) // get next serial number and repeat␣
↪for each axes.
{
    axes[number_of_axes] = new_axis(serial);
    log("Found axis " + number_of_axes + " with serial number " + serial);
    number_of_axes++;
    last_serial = serial;
}

// Start the main function for all avaliable axes
for (var i = 0; i < number_of_axes; i++)
{
    main(axes[i]);
}


function main(axis)
{
    axis.command_move(0,0); // Go back to the origin.
    msleep(500);

/* Creating and filling the calibration structure for specifying distances in um */
    var calibration = new Object;
    calibration.A = 5; // 1 step correspond to 5 um for 8MT50-100BS1
    calibration.MicrostepMode = axis.get_engine_settings().MicrostepMode; // Get␣
↪MicrostepMode from controller settings
/*********************************************************/

/* Main cycle */

    var N = 10; // Number of shifts
    var stand_time  = 3000; // Stand time in ms
    var shift = 10; // Distance of shift in um

    MakeShifts(axis, LEFT,   shift, N, stand_time, calibration); // Make 10 shifts to␣
↪the left
    MakeShifts(axis, RIGHT, shift, N, stand_time, calibration); // Make 10 shifts to␣
↪the right
    MakeShifts(axis, RIGHT, shift, N, stand_time, calibration); // Make 10 shifts to␣
↪the right again
    MakeShifts(axis, LEFT,   shift, N, stand_time, calibration); // Make 10 shifts to␣
↪the left
}

function MakeShifts(axis, Direction, ShiftDistance, ShiftsQuantity, StandTime,␣
↪Calibration)
```

```
{
/**
    This function makes shifts which number is specified by ShiftQuantity and length␣
↪is specified by ShiftDistance. After every shift it stands StandTime miliseconds.␣
↪Calibration parameter is a structure for convertation between steps and micrometers.
*/
    for (var i = 0; i < ShiftsQuantity; i++)
    {
        axis.command_movr_calb(Direction*ShiftDistance, Calibration);
        axis.command_wait_for_stop(100);
        msleep(StandTime);
    }
}
```

6.4.4.22 Steps loss test

```
/*
* Steps loss test
*
* Description of the script:
*  The script was written to check for skipping steps
*  It can be useful for diagnosing problematic stages
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

function abs(x)
{
    return ((x > 0) ? x : -x);
}

/*
* Set home settings
*/
var SHOM = get_home_settings()
SHOM.FastHome = 500;
SHOM.uFastHome = 0;
SHOM.SlowHome = 20;
SHOM.uSlowHome = 0;
SHOM.HomeDelta = 300;
SHOM.uHomeDelta = 0;
SHOM.HomeFlags = HOME_STOP_FIRST_LIM;
set_home_settings(SHOM);

/*
* Check for encoder
*/
var encoder = 1
command_zero()
var first = get_status().EncPosition
command_movr(100)
command_wait_for_stop(300)
var second = get_status().EncPosition
if(abs(second - first) < 2)
```

```
{
  encoder = 0
  log("It seems like here are no encoder", 2)
}

command_home();
command_wait_for_stop(300);
command_zero();
msleep(200);
// Store old move settings
var MOV = get_move_settings();

// Set fast speed and accel\decel
var MOV2 =get_move_settings();
MOV2.Speed = MOV.Speed * 2;
MOV2.Accel = MOV.Accel * 2;
MOV2.Decel = MOV.Decel * 2;

for(var i=0; i < 1; i++) // Set default settings first
{
  set_move_settings(MOV2);

  // Move long...
  command_move(20000);
  command_wait_for_stop(300);

  // Set prev settings back
  set_move_settings(MOV);

  // Move back
  command_move(0);
  command_wait_for_stop(300);
}

if (encoder > 0)
{
  var lost = get_status().EncPosition
  if (abs(lost) > 1)
  {
    log("Lost " + lost + " pulses", 1)
  }
  else
  {
    log("All is OK");
  }
}
else
{
  log("Do final homing...")
  command_home()
  command_wait_for_stop(300)
  var  lost = get_status().CurPosition
  if (abs(lost) > 2)
  {
    log("Lost " + lost + " steps", 1)
  }
  else
  {
```

```
    log("All is OK");
  }
}
```

6.4.4.23 Sync test script

```
/*
* Sync test script
*
* Description of the script:
*  The script is written to demonstrate the work of synchronization, and also checks its operability
*
* For test you must short special pins on the controller. Pin 5 (sync in) and pin 6 (sync out). See https://doc.xisupport.com/en/8smc5-usb/8SMCn-USB/Technical_specification/Appearance_and_connectors/One_axis_system.html
*
* Note: This is a rather difficult script to learn, since it uses a large number of commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

const dX = 4.5;
const dot_num = 5;
const micro2mili = 1000;

var ASIA = [];

for (var i = 0; i < dot_num; i++)
  ASIA[i] = new Object();

var calb = new_calibration(1, MICROSTEP_MODE_FRAC_256);

function abs(x)
{
  return (x > 0) ? x : -x;
}

function set_default()
{
  // SSNI settings
  var SSNI = get_sync_in_settings_calb(calb);
  SSNI.SyncInFlags = SYNCIN_ENABLED | SYNCIN_GOTOPOSITION;
  set_sync_in_settings_calb(SSNI, calb);

  // SSNO settings
  var SSNO = get_sync_out_settings(calb);
  SSNO.SyncOutFlags = SYNCOUT_ENABLED;
  SSNO.Accuracy = 0.5;
  set_sync_out_settings(SSNO, calb);

  // SMOV settings
  var SMOV = get_move_settings_calb(calb);
  SMOV.Speed = 1000;
  SMOV.Accel = 500;
  SMOV.Decel = 1000;
```

```
  SMOV.AntiplaySpeed = 50;
  set_move_settings_calb(SMOV, calb);

  // SENG settings
  var SENG = get_engine_settings();
  SENG.NomSpeed = 5000;
  SENG.EngineFlags = ENGINE_ACCEL_ON | ENGINE_LIMIT_VOLT | ENGINE_LIMIT_CURR;
  SENG.Antiplay = 50;
  SENG.MicrostepMode = MICROSTEP_MODE_FRAC_256;
  SENG.StepsPerRev = 200;
  set_engine_settings(SENG);
}

function send_all_asia()
{
  for (var i = 0; i < dot_num; i++)
    command_add_sync_in_action_calb(ASIA[i], calb);
}

function check_all_asia()
{
  var GETS;

  for (var i = 0; i < dot_num; i++)
  {
    log("> Checking movement ASIA[" + i + "]", 3);
    msleep(ASIA[i].Time / micro2mili);
    GETS = get_status_calb(calb);
    if (abs(GETS.CurPosition - ASIA[i].Position) < dX)
      log(">>> OK! GETS.CurSpeed = " + GETS.CurSpeed, 3);
    else
      log(">>> Error! GETS.CurPosition = " + GETS.CurPosition + ", ASIA[" + i + "].
↪Position = " + ASIA[i].Position, 1);
    }
}

function test1()
{
  ASIA[0].Position = 22.5;
  ASIA[0].Time = 300000;

  ASIA[1].Position = 45.0;
  ASIA[1].Time = 300000;

  ASIA[2].Position = 32.5;
  ASIA[2].Time =300000;

  ASIA[3].Position = 10;
  ASIA[3].Time = 300000;

  ASIA[4].Position = -11.5;
  ASIA[4].Time = 300000;
}

function test2()
{
  ASIA[0].Position = -22.5;
  ASIA[0].Time = 300000;
```

```
  ASIA[1].Position = -45.0;
  ASIA[1].Time = 300000;

  ASIA[2].Position = -32.5;
  ASIA[2].Time =300000;

  ASIA[3].Position = -10;
  ASIA[3].Time = 300000;

  ASIA[4].Position = 11.5;
  ASIA[4].Time = 300000;
}

function test3()
{
  ASIA[0].Position = -6;
  ASIA[0].Time = 300000;

  ASIA[1].Position = 6;
  ASIA[1].Time = 300000;

  ASIA[2].Position = -6;
  ASIA[2].Time =300000;

  ASIA[3].Position = 6;
  ASIA[3].Time = 300000;

  ASIA[4].Position = -6;
  ASIA[4].Time = 300000;
}

command_zero();
set_default();
log(">>> Function test1() started", 3)
test1();
send_all_asia();
check_all_asia();
msleep(500);

command_zero();
set_default();
log(">>> Function test2() started", 3)
test2();
send_all_asia();
check_all_asia();
msleep(500);

command_zero();
set_default();
log(">>> Function test3() started", 3)
test3();
send_all_asia();
check_all_asia();
msleep(500);
```

6.4.4.24 Sync bug test script

```
/*
* Sync bug test script
*
* Description of the script:
*  This script does synchronization test to find sync bug in firmware 3.9.9, 3.8.7, 3.
↪9.10.
*  This test only for hardware from ver. 2.2.0 to ver. 2.2.4.
*  To begin the test, the first what you need to do is connect synchronization pin 15␣
↪to pin 16 on CN1 jack.
*  The scripts automatically set all necessary settings for test, and automatically␣
↪beginning the test.
*  As a result you will see a log message with current position of motor and text OK!␣
↪(green text) or ERROR! (red text).
*
* Note: This is a rather difficult script to learn, since it uses a large number of␣
↪commands and structures.
*
* To run the script, upload it to the mDrive Direct Control software
*/

var axes = [];
var number_of_axes = 0;
var last_serial = 0;

while (serial = get_next_serial(last_serial)) // get next serial number and repeat␣
↪for each axes.
{
  axes[number_of_axes] = new_axis(serial);
  number_of_axes++;
  last_serial = serial;
  log("Found axis " + number_of_axes + " with serial number " + serial);
}

// SSNI settings
var SSNI = get_sync_in_settings;
SSNI.SyncInFlags = SYNCIN_ENABLED | SYNCIN_GOTOPOSITION; //set flags for␣
↪synchronization in for enabled and absolute position
SSNI.ClutterTime = 4;// set sync in Clutter Time
SSNI.Position = 0;// set sync in absolute position
SSNI.Speed = 500;// set sync in speed
set_sync_in_settings(SSNI);// set synchronization in settings

// GSNO settings
var GSNO = get_sync_out_settings;
GSNO.SyncOutFlags = SYNCOUT_ENABLED | SYNCOUT_ONPERIOD;  // set flags for␣
↪synchronization out for enabled out and period
GSNO.SyncOutPeriod = 200;// set sync out period
GSNO.SyncOutPulseSteps = 2000;// set sync out Pusle width
set_sync_out_settings(GSNO);  // set synchronization out settings

for (i = 0; i < 10; i++)  // testing cycle
{
  GETS = get_status();// get information about device
  command_movr(201, 0);  // shifting position for 201 steps
  command_wait_for_stop(100); // Wait until the movement is complete

  if (GETS.CurPosition != 0)// get device current position and compare it with 0
```

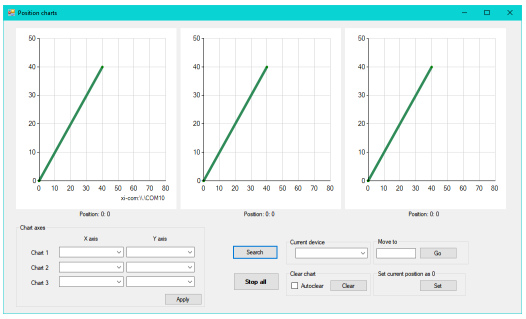
```
  {
    log(">>> Error! GETS.CurPosition = " + GETS.CurPosition, 1);// log ERROR, bug is␣
↪exist
  }
  else
  {
    log(">>> OK! GETS.CurPosition = " + GETS.CurPosition, 3); // log OK, bug does not␣
↪exist
  }
}
```

6.5 Community examples

- *Example of six-axis mDrive Direct Control*
- *The multi-axis interface in Python*

Important: Below there are examples found on the open source Internet The developer is responsible for executing the examples

6.5.1 Example of six-axis mDrive Direct Control



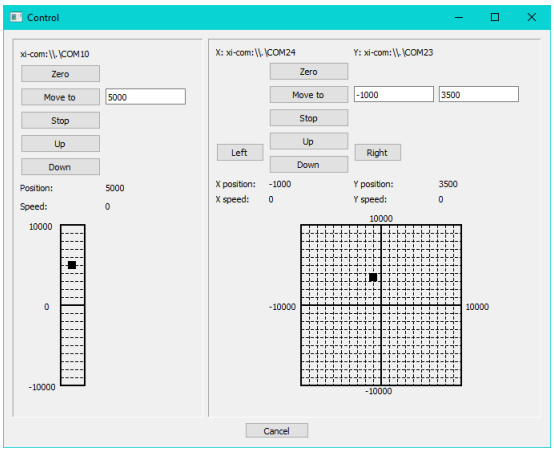
The program allows to operate with up to 6 devices in real time on 3 charts **The precompiled examples were build with Visual Studio 2013**.

Example and guide posted on GitHub: https://github.com/sushchev/testwfa.

6.5.2 The multi-axis interface in Python

An example of a program with GUI, designed to work with multiple servo controllers (up to six inclusive, it is easy to increase this number if necessary) by means of mDrive protocol. GUI was created through PyQt5 package.

Example and guide posted on GitHub: https://github.com/Negrebetskiy/MultiAxleGUI.


Control
xi-com:\\.\COM10
Zero
Move to
5000
Stop
Up
Down
Position:
5000
Speed:
0
10000
0
-10000
X: xi-com:\\.\COM24
Y: xi-com:\\.\COM23
Zero
Move to
-1000
3500
Stop
Up
Left
Right
Down
X position:
-1000
Y position:
3500
X speed:
0
Y speed:
0
10000
-10000
10000
-10000
Cancel

CHAPTER

SEVEN

CONTROL VIA ETHERNET

7.1 Network configuration

Connecting the controller via a local network:

By default, to obtain the device's IP address, use DHCP. But if necessary, you can use a static IP address. **The controller and your PC must be on the same subnet!**

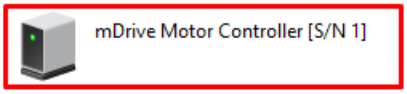
- Your DHCP server must supports an automatic distribution of ip addresses.
- Server and your computer must support IPv4 protocol.

mDrive can also be used when directly connected to a PC with a working DHCP server.

If the DHCP server is unavailable, mDrive independently **assigns itself an IP address in the range 169.254.1.0 - 169.254.254.255**.

7.1.1 mDrive controller detection on the network with a DHCP server

In Windows Explorer, go to the "Network" tab and find mDrive controller.



Go to the web interface of the device by double-clicking on it with the left mouse button.

7.1.2 Automatic device detection

As a convenience we provide a small dedicated utility called "Revealer" in order to help you instantly identify all the mDrive controller connected to your local network. You can download it from our software page .

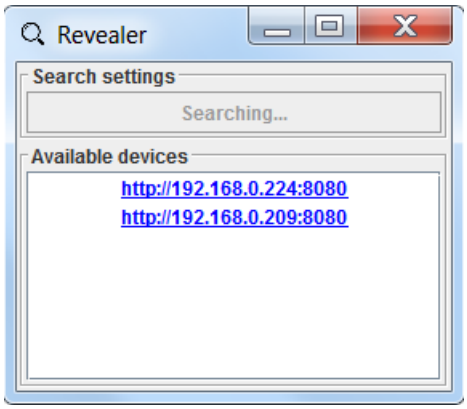


Fig. 7.1: "Revealer" utility interface

The Graphical User Interface of the "Revealer" is a simple one. In order to start search click Search button on Search settings panel - the scan takes approximately 3 seconds. After that all mDrive devices found in your local network will be listed on Available devices panel as clickable links. When clicked, the link opens your defaul system browser and redirects it to Administartion interface web page.

The utility requires Java Runtime Environment (or simply JRE) version 6 or greater to work. There are high chances that you already have it installed on your PC as it's the requirement for a great number of popular software packages and so you just need to double-click the "revealer-j_0.1.0.jar" file to launch the utility.

Otherwise it means that you don't have JRE installed and have two options:

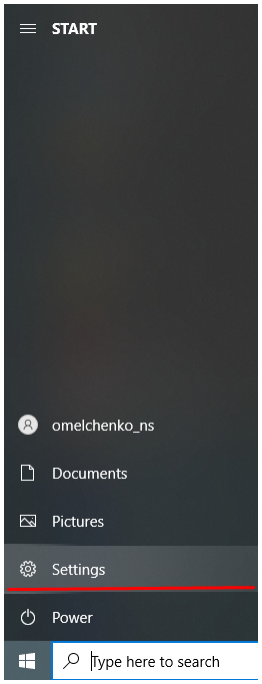
1. Download our ready-made packages for your operating system containing the "Revealer" utility and all the stuff necessary to make it work. In this case you just need to launch "Revealer" executable.
2. Install JRE. A good candidate is Oracle JRE which you can install following the official instructions.

Warning: "Revealer" uses UDP broadcasts to reach all mDrive devices in your LAN so it might be unusable in the environments where UDP broadcasts are forbidden or unwanted.

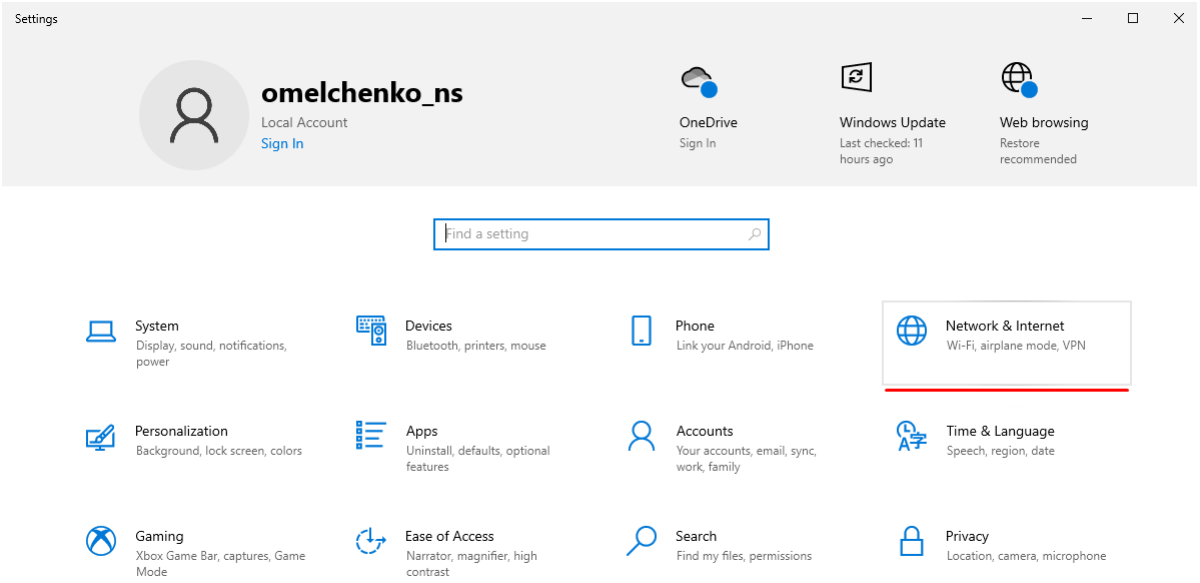
7.1.3 mDrive controller detection on the network with a static IP address

To discover a device and change its IP address, change the network connection settings by following the steps:

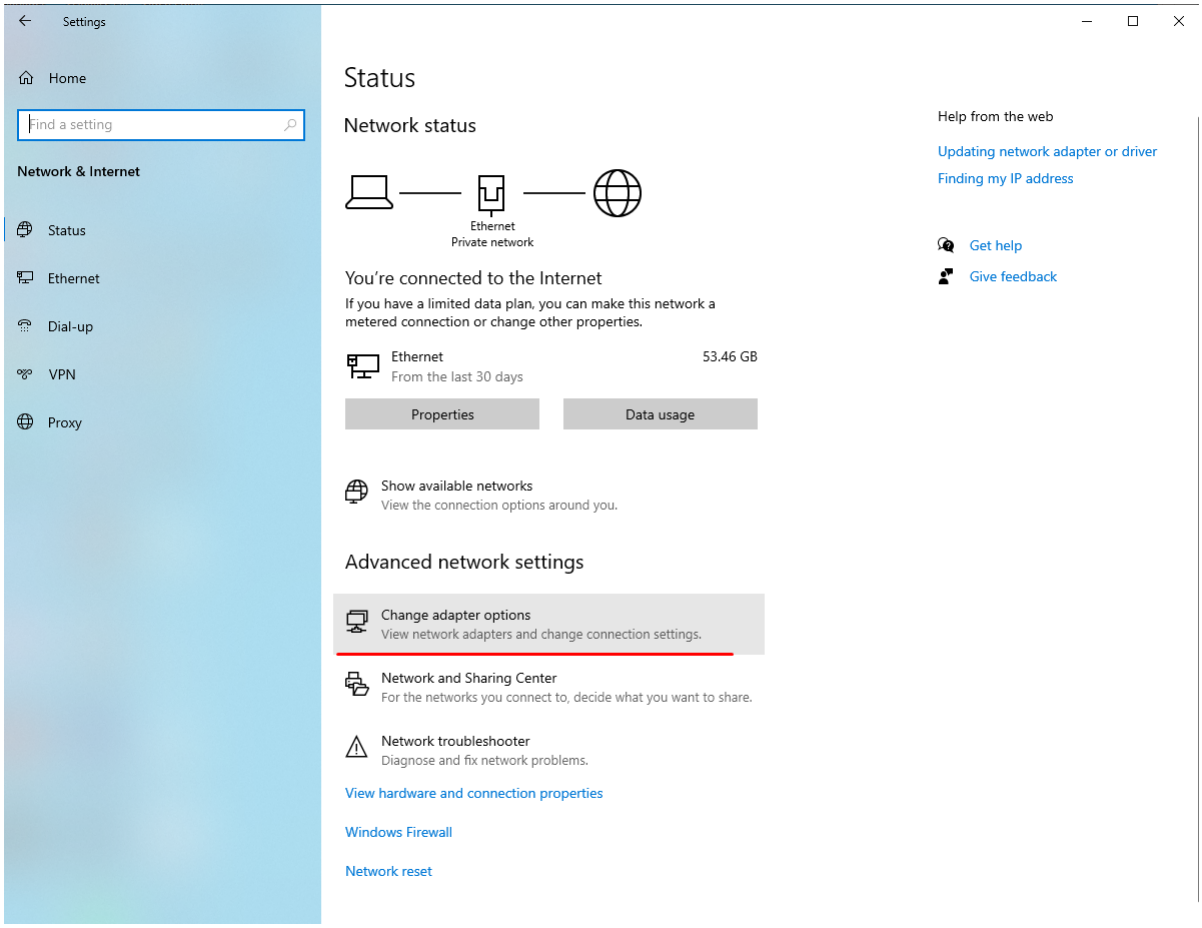
1. Go Start -> Settings



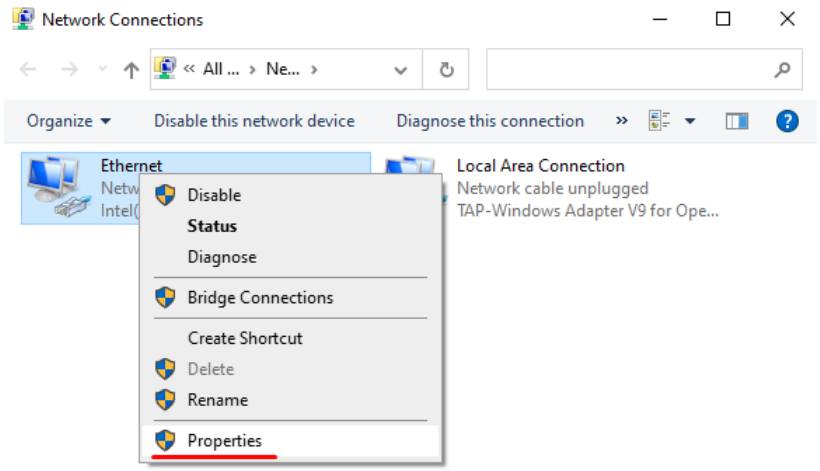
2. Select “Network & Internet” in the Settings window



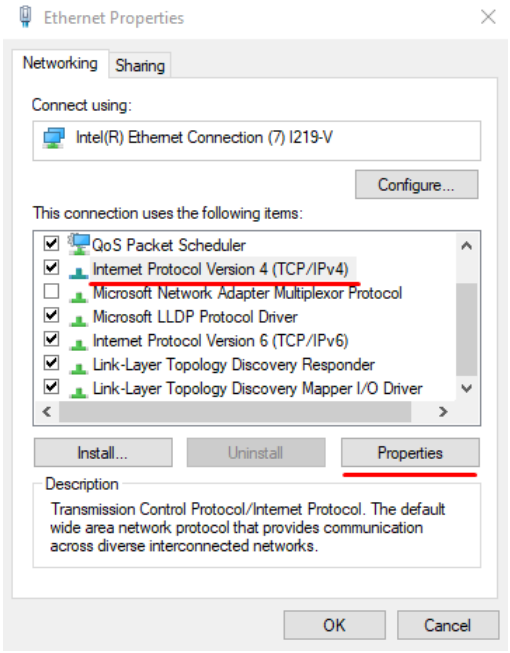
3. Click “Change adapter options”



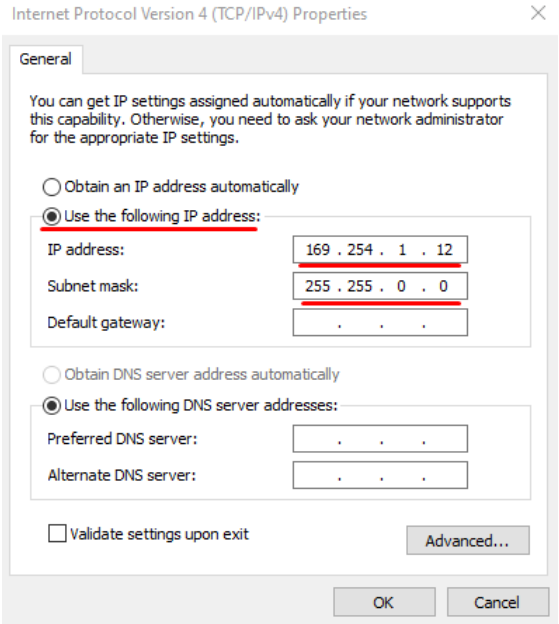
4. Right-click on the active local connection and click “Properties”



5. In the Network connection properties window, select the “Internet Protocol version 4 (TCP/IPv4)” component and click the “Properties” button

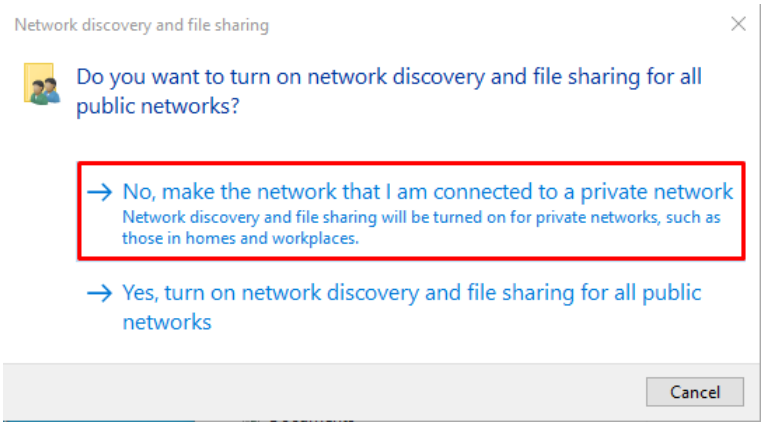


6. In the “Use the following IP address” item, find the IP address and subnet mask. Remember their current values so that you can return to them later.

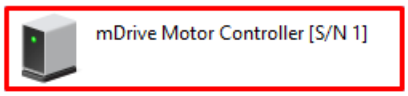


7. Change your IP address to any other from the range 169.254.1.0 - 169.254.254.255, set the subnet mask value to 255.255.0.0. Click “OK”.
8. Find mDrive and change its IP address by following the steps:

1. In Windows Explorer, go to the “Network” tab. Right-click on the alert, then select “Enable Network discovery and File sharing” then select “No, make the network to which this computer is connected private”



2. Update the “Network” tab. Make sure that the device named “mDrive Motor Controller [S/N #]” (where # is the serial number of the device) is displayed.



9. Go to the web interface of the device by double-clicking on it with the left mouse button.

10. In the “Network settings” block, enter the IP address and subnet mask in which the device should be located. Click “Apply”

11. Confirm the actions in the warnings that open.

12. Return the original network connection settings by following steps 1 - 6 of this instruction. Note that in step 6 the IP address and subnet mask must be set in accordance with the original values.

7.2 mDrive web interface

The web interface contains information about the mDrive network settings, general information about the device and a brief table of characteristics.

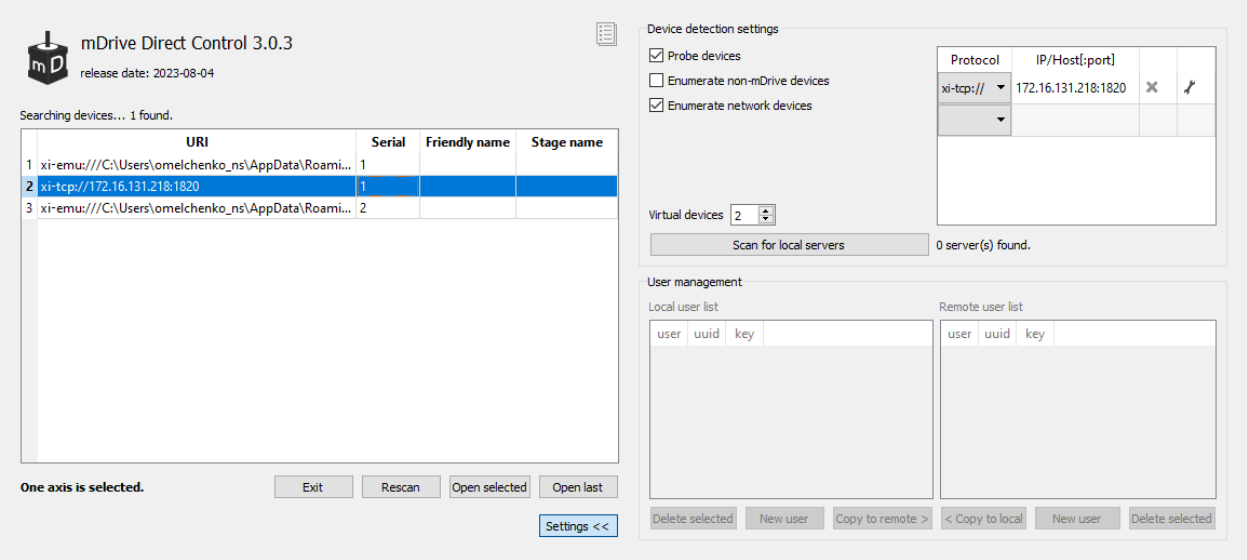
Fig. 7.2: mDrive web interface

7.3 Getting started with mDrive Direct Control

Launch mDrive Direct Control and make the following. *It is assumed that the connection and configuration instructions have been followed.*

At first start, mDrive Direct Control opens controller detection window with two virtual devices.

Click *Settings*, check *Enumerate network devices* in the right tab. Enter the IP address of the mDrive Motor Controller and **do not forget to specify the port**. Select the "xi-tcp://" protocol.Then click *Rescan* button in the left tap, mDrive Direct Control will find connected controller.



In controller detection window choose an axis you need. You can control it in *single-axis mode* or in *multi-axis mode* if more than one axis was chosen. For additional information please refer to *Getting started with mDrive_Direct_Control software* and *mDrive Direct Control application User's guide*.

Note: Once the device IP address has been found, it should be understood that moving the device to another location may lead to a change in its IP.

CHAPTER

EIGHT

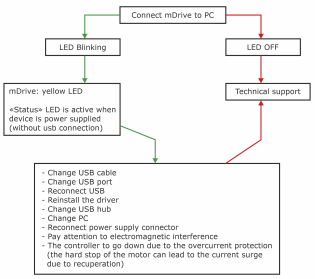
FAQ

8.1 No device found / Can't open device

8.1.1 Connect via USB

mDrive Direct Control or other software can not find the controller.

- The PC does not detect the controller via USB:



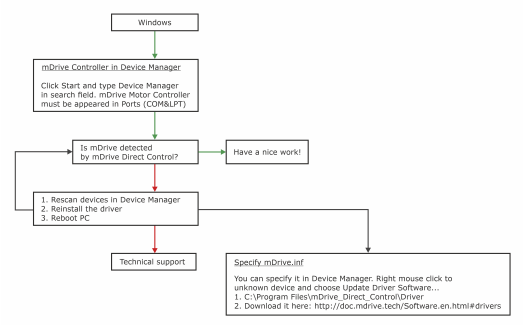
Comment to the scheme:

The most common cause for such type of problem is bad work of the usb-hub, cables or the virtual COM-port identification problem of the operation system on the used PC. Try to reproduce the problem on the another PC or another usb-hub if it is used.

Warning: **"Can't open device" error or "open_device()" function returns -1**. Libximc library opens the controller in exclusive access mode. Any controller opened with libximc (mDrive Direct Control also uses this library) needs to be closed before it may be used by another process. So at first check that you have closed mDrive Direct Control or other software dealing with the controller before trying to reopen the controller.

Below are the action maps for the not found controller.

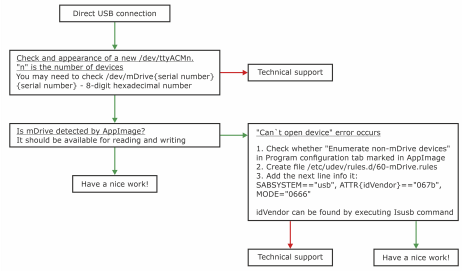
Windows:

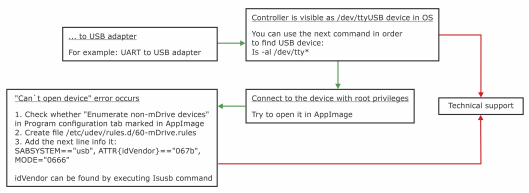


Comments to the scheme:

- Check whether the COM-port corresponding to your controller presents in the Device manager. It should be displayed as “mDrive Motor Controller (COMn)”. In case the controller has not been recognized, try to reinstall the driver for the controller manually.
- Try to open the COM-port of the controller in any simple serial emulator (Putty for example) and just send the simple command to the controller (like “stop”, “sstp”, “zero”, *“GETS”*, *“GETI”*). The connection parameters are described *here*. The absence of errors means that the controller is operating correctly and the problem should be caused by the used software.

Linux:





Comment to “Can’t open device” problem solution:

When working with USB-UART converter (as well as USB-Ethernet, USB-Bluetooth etc.) in **Linux** it appears as **/dev/ttyUSB** device. mDrive Direct Control shows it in a list, but when you try to open it, an error “can’t open device” occurs due to the lack of permissions to the device.

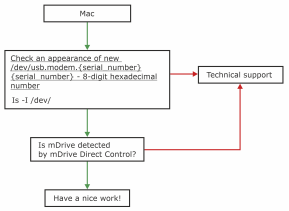
To solve this problem, create a file: /etc/udev/rules.d/60-mdrive.rules and add the next line into it:

```
SUBSYSTEM=="usb", ATTR{idVendor}=="067b", MODE="0666"
```

idVendor identifier can be found by executing *lsusb* command.

Note: One possible solution to the "**device not found**" problem is to add a user to the dialuot group. **Important**: after adding it, you must restart your computer.

Mac OS:



8.1.2 Connect via ETHERNET

Note: When performing the steps described below, it is assumed that the controller is turned on and running. The controller connected via Ethernet can be opened via tcp/udp protocol.

- **Is your controller visible in the "Revealer" program?**

  If yes:

  - To access the administration panel, click on the IP address. If the control panel opens (by default, use "0000" as the password), your controller works fine!

  If no:

  - **Connect the controller to your computer via USB**:
    - Make sure that the USB-connected controller is working correctly. To do this, upload the profile and perform any movements. *We recommend using mDrive Direct Control for verification*
  - Disable "Windows Defender Firewall"
  - **Connect the controller to the computer using an Ethernet cable**:
    - Check that the controller is visible in an isolated network using revealer.
    - Use revealer to change the IP address of your controller. To change the settings in the revealer window, click on the gears. For example, you can set a static IP address for your controller.

- **Is a DHCP server installed on your network?**

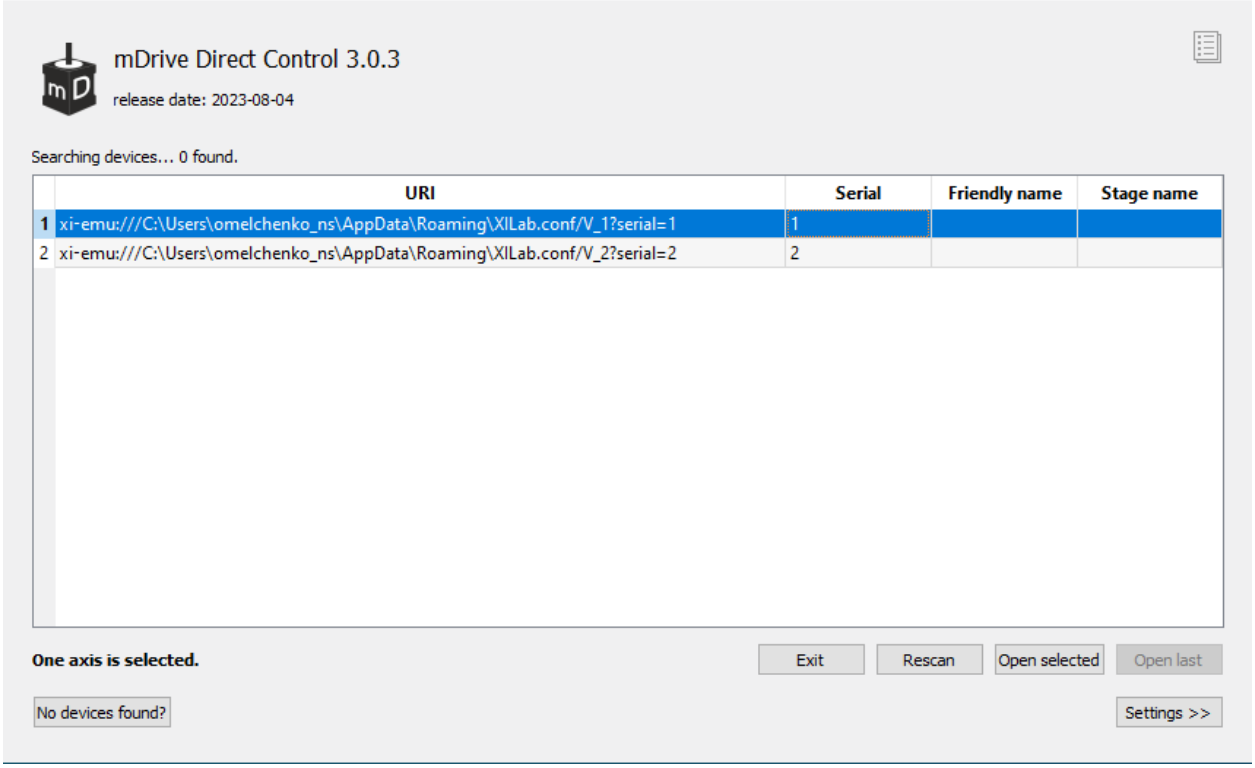
  If yes:

  - Make sure that the controller is assigned an IP address.
  - Make sure that the controller is on the same subnet as your computer.

  If no:

  - You can install a DHCP server.
  - Use revealer to set the static IP address of your controller. To change the settings in the revealer window, click on the gears.

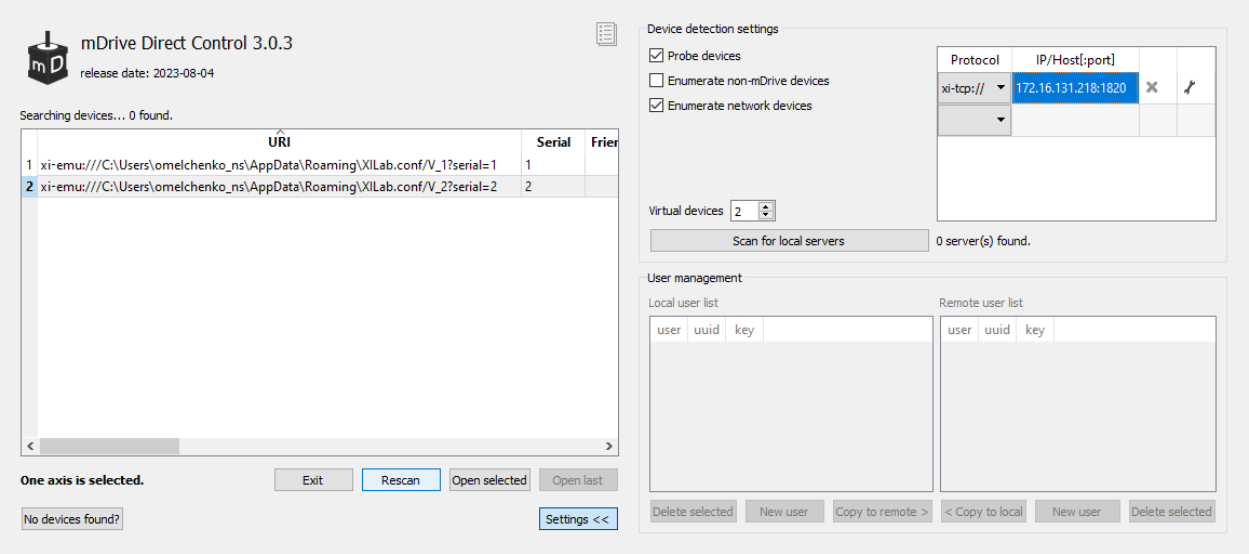
8.1.2.1 If the mDrive is not found on the local network



Disable "Windows Defender Firewall" and click the "Search/Restart" button in mDrive Direct Control program. In order to get access to the Administration panel, navigate your browser to *http:///[address]* URL (where *[address]* should be replaced with IP address of the device in your local network and can be found in Revealer or in the network tab of windows Explorer). If you are doing this for the first time (or you've disabled cookies/password storage in your browser) **you'll need to authenticate yourself using "0000" as password**.

If the control panel opens, your mDrive works fine.

Go to drive Direct Control, click Settings, check the Enumerate network devices box on the right side of the window, enter the IP address and click Rescan. Your device should be displayed in mDrive Direct Control.



After that, don't forget enable firewall.

8.2 Unable to rotate the motor by the controller

8.2.1 Controller has Alarm state

Note: Click *Stop* in the main window of mDrive Direct Control. Controller must return to its normal state.

If this approach was not helpful and Alarm state emerged again, do the following:

- Being in mDrive Direct Control go to the *Maximum ratings* tab.
- Mark *Sticky Alarm flags* option. Click *Ok*.
- Press *Stop* in the main window of mDrive Direct Control, it will temporary return controller to its normal state. Repeat the sequence of actions leading to Alarm state.
- Make the screenshot of mDrive Direct Control main window and send it to the technical support with detailed description of your problem.

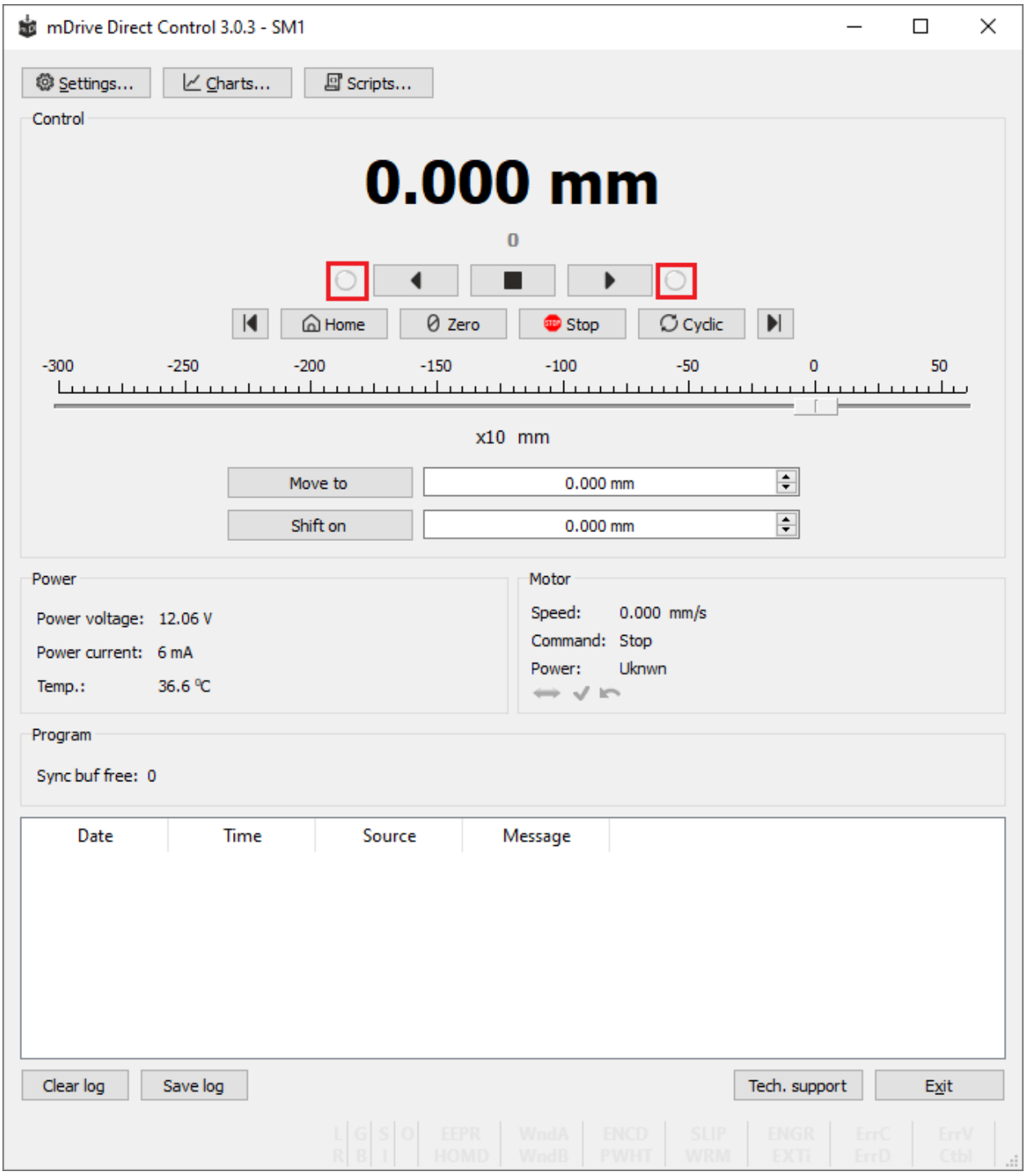
8.2.2 Motor vibrates without rotation

This problem has several reasons:

- Installed **incorrect profile** for your motor/stage.

  - Search for a better match for the title of profile used by your motorized stage in mDrive Direct Control folder.
  - It is recommended to save your current configuration to file. To do this, in the *Settings* window of mDrive Direct Control click *Save settings to file* (see *mDrive Direct Control settings*), choose path where you want to save the settings. Then send this file in technical support with detailed description of the problem.

- **Incorrect configuration of limit switches**, as result the stage rests the limit switch. This can usually be seen by the indicator lights in mDrive Direct Control.



The main reason for the incorrect setting of limit switches is incorrect configuration file for your stage (see previous item). Information about manual setting is located in *manual profile setting*. When such problem is emerged it is recommended to contact the technical support for further assistance.

  - It is also one of the consequences of problems with limit switches can be **mechanical jamming** (see the next item).

- **Broken winding** of the motor, problems with bad **contact in connector** etc. It is possible to diagnose this kind of problems independently. For this purpose, we recommend to get mDrive Direct Control graphs of voltage and current during the operation of motor. The proper motor current in the winding varies according to a sine or cosine. In the broken motor much stronger differences of the current from harmonic form can be noticed.

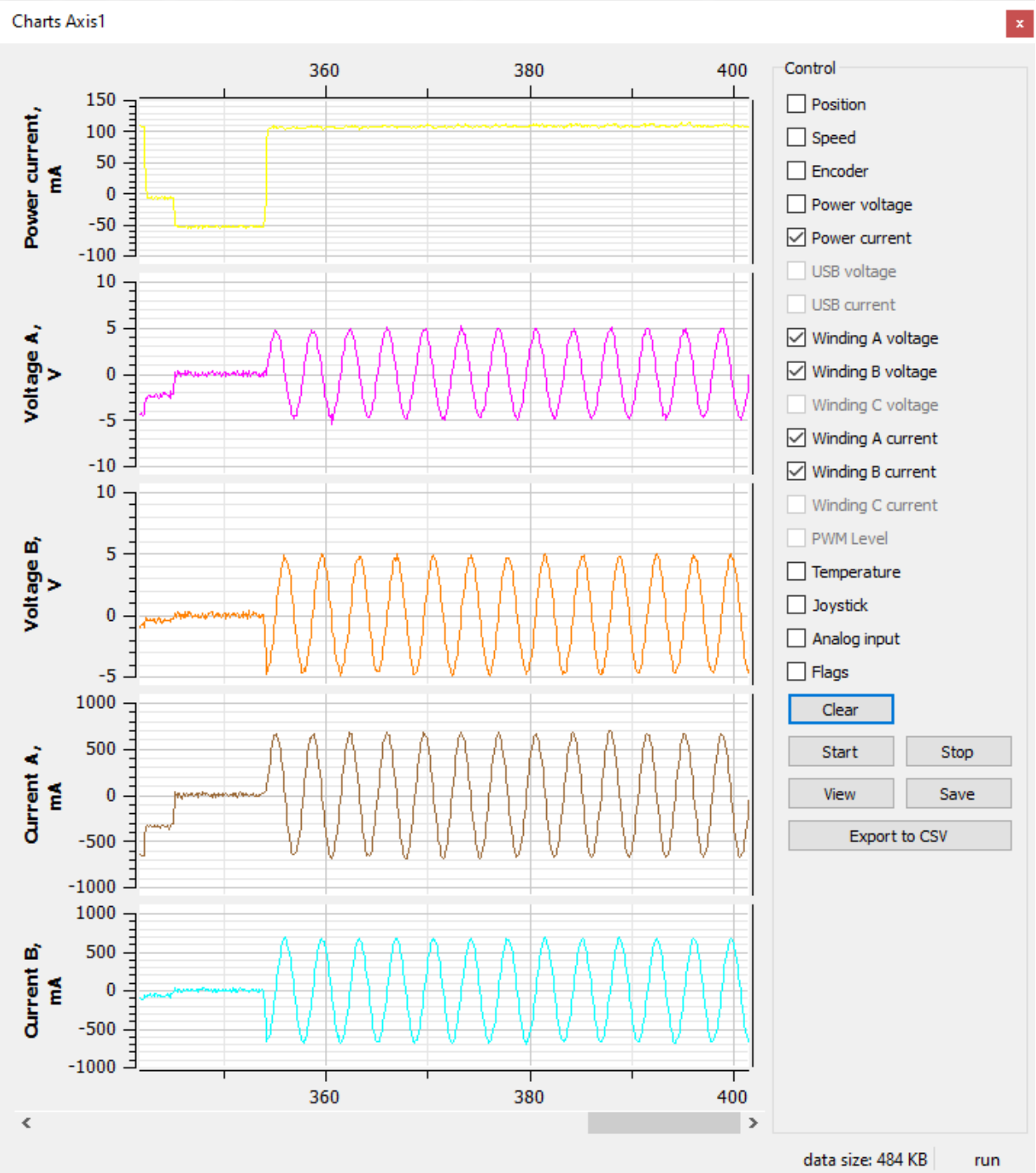


Fig. 8.1: Working case

In the charts below you can see the problems. For example, winding B is open circuit. Probably it is broken. Also, voltage and current forms are distorted.

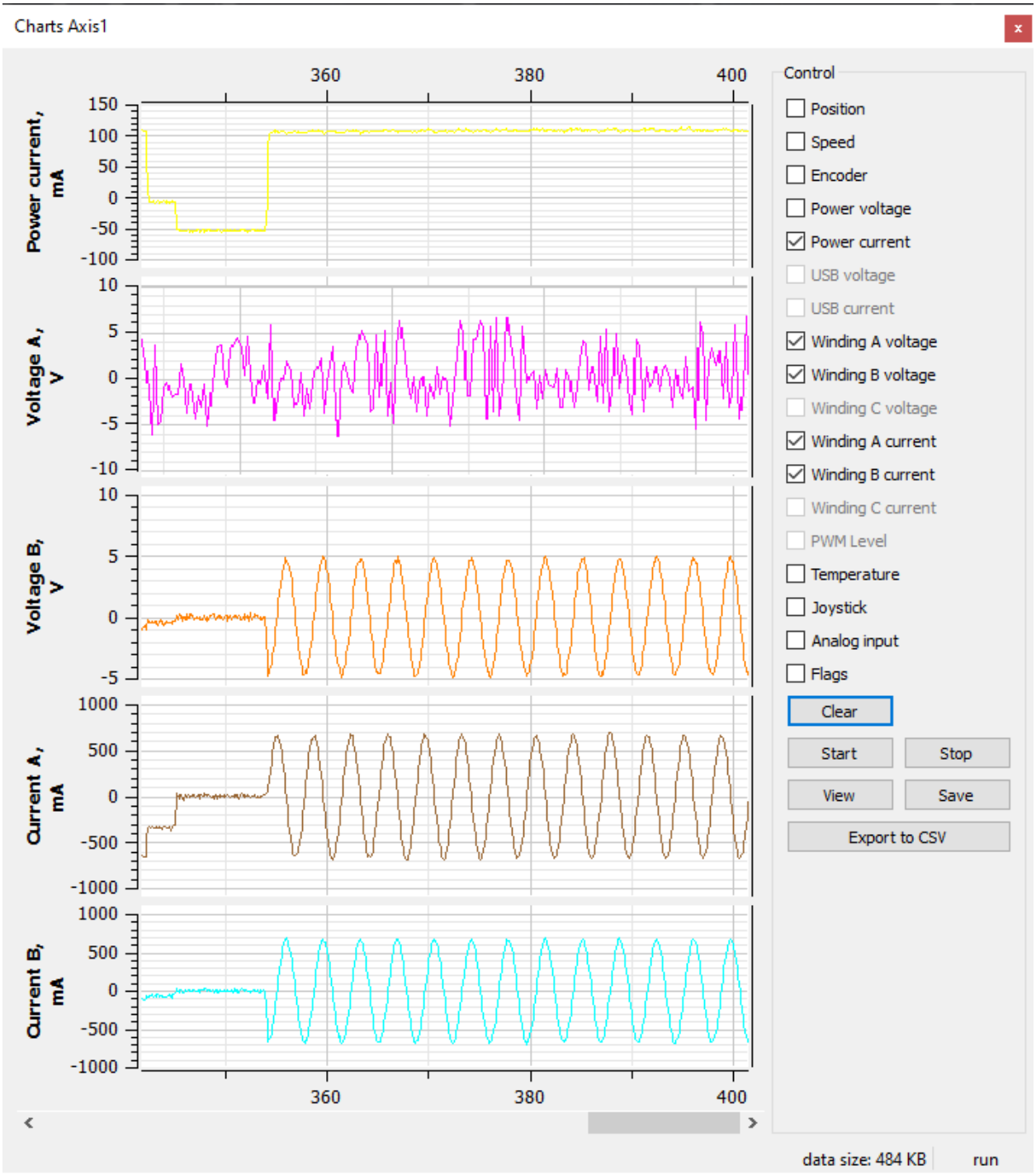


Fig. 8.2: There are problems with motor

To diagnose the problem set very low speed (**1 s/sec** is optimal) and send movement command. Then turn on graphs of current and voltage for windings A and B in mDrive Direct Control and the Power current (button *Charts*, then mark correspond fields). Wait for a while until the graphs are built. Then it is recommended to send them (Click *Save* in the same window with graphs) in technical support with a detailed description of the problem. Sometimes, when winding is broken, it is impossible to use mDrive Direct Control due to permanent loss of device. In this case also contact technical support with description of the problem.

8.2.3 Mechanical jamming

There are two ways to deal with jamming:

- Turn the motorized stage by hands if it is possible.
- Increase the winding current 2-3 times for a short time (about 5-10 seconds) and send movement command to the stage in the right direction at the low speed (about **50-100 s/sec** will be enough). A few seconds after rotation, press stop button (small black square) until *power off* status appears in the main window of mDrive Direct Control in order to prevent motor overheating. **After this do not forget to return the settings back!**

8.2.4 The motor does not react on move commands

The controller looks OK but the motor does not move, leaving error messages in the log, the controller reboots. This bug can arise due to extremely wrong calibration setting of the controller. This happen when the predicted values of the electrical parameters of the motor differ for several orders from the right ones. The wrong calibration sometimes could be caused by the mechanical load on the motor or by differ of mechanical friction in both directions of moving that affects the calibration. So the controller tryes to make a little movement to calibrate the motor (the calibration is performed before the motor power on) and goes down due to the overcurrent protection.

If you encounter this problem just do the following:

- Open mDrive Direct Control, load the profile for used motor.
- On the *Stepper motor* tab of *Settings* menu change the nominal current to **200 mA**, change the working speed to **1 step/s**, click *Apply* and *Save settings to flash*.
- Try to start moving, watch the current parameters of the motor via *Charts* like it was described above.
- If the charts look OK, then load the normal setting for used motor and work with it as usual.

8.3 When using the libximc library and Linux with kernel version less than 3.16, there are possible hanging of the operating system

Comment: above-mentioned problem stems from the error in serial port driver cdc-acm. It is observed with frequent sequential opening and closing of some devices. Operation system hanging was shown on Debian 7 (3.2 kernel version) and worked correctly on Debian 8 (3.16 kernel version). For additional information about problem please refer to the next link.

Solution: update your current version of Linux.

8.4 USB connection loss

The most common cause of this kind of problem lies in grounding. To find out the reason for the permanent loss of the USB connection, you should:

- If the controller and/or stage is fasten to a metal table, temporarily put something dielectric under it or transfer it to a dialectric surface;
- Ground the computer;
- Ground the controller;
- Ground stage;

Note: If the above steps eliminated the problem of losing the USB connection, then the problem was the grounding of your metal table. There were fluctuations of electrical potential on it.

- Change USB cable. *Use verified USB cables only!* Damaged or low-quality USB cable may cause improper controller operation, including motor rotation errors and errors of device recognition by PC operating system. **Super short cables with thick wires and screening** are ideal for sustainable connection;
- Change USB port;
- Change PC.

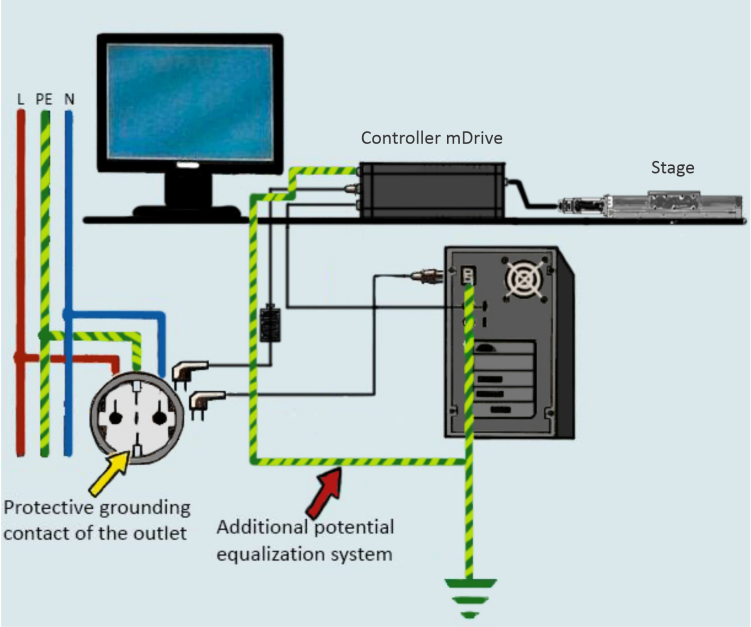


Fig. 8.3: Example of correct grounding

8.5 *probe_flag* - what is it?

```
probe_flags = 1 + 4; % ENUMERATE_PROBE and ENUMERATE_NETWORK
```

"probe_flag" is a parameter passed to the libximc library *"enumerate_devices"* function. It controls how *libximc.dll* does search for devices.

```
define ENUMERATE PROBE 0x01
```

Check if a device with OS name is mDrive device. **Be carefuly with this flag because it sends some data to the device!**

```
define ENUMERATE NETWORK 0x04
```

Check network devices.

Note: Depending on the type of controller connection, you can remove this or that flag

8.6 Virtual controller as in mDrive Direct Control Software

You can use the virtual controller in your programs. To do this, use the function:

```
device_t XIMC_API open_device (const char *uri)
```

Open a device with OS uri and return identifier of the device which can be used in calls.

Parameters **uri**- a device uri. Device uri has form:

```
"xi-com:port"                - # Serial port
"xi-udp://<ip/host>:<port>" - # Raw UDP connection
"xi-tcp://<ip/host>:<port>" - # Raw TCP connection
"xi-emu:///file"             - # Virtual device
```

For example:

```
"xi-com:\\.\COM3        # in Windows
"xi-com:/dev/tty.s123"` # in Linux/Mac
```

In case of network device the "host" is an IPv4 address or fully qualified domain uri (FQDN), "serial" is the device serial number in hexadecimal system.

In case of UDP/TCP protocol, use *"xi-udp://<ip/host>:<port>" "xi-tcp://<ip/host>:<port>"*.

For example:

```
"xi-udp://192.168.0.1:1818"
"xi-tcp://192.168.0.1:1820"
```

In case of virtual device the *"file"* is the full filename with device memory state, if it doesn't exist then it is initialized with default values.

For example:

```
"xi-emu:///C:/dir/file.bin"      # in Windows
"xi-emu:///home/user/file.bin"   # in Linux/Mac
```

You can also use a virtual controller from mDrive Direct Control with a loaded profile. To do this, select and open the virtual controller in mDrive Direct Control. After loading the required profile ("*Settings*" -> "*Load setting from file...*" button) or just set the necessary parameters and click "*Apply*". Then the file will be saved to the directory *C:\Users\user\AppData\Roaming\XILab.conf/V_x*, where x - is the number of the virtual controller.

In your program you can open this virtual controller by specifying the full path to the file. **For example:**

```
device_name = "xi-emu:///C:\Users\"user"\AppData\Roaming\XILab.conf/V_1";
device = open_device(device_name);
```

Attention: The profile loading function is only implemented in the mDrive Direct Control interface. If you need to change the stage settings during code execution, you can use an alternative option. You can upload the profile to the controller flash memory. Open mDrive Direct Control->Settings->Load setting from file...->choose your profile->OK->Apply->Save settings to flash. Then you can change the settings in your program. As soon as you want to return all the default settings, execute the *Command READ*.

8.7 Python CRC algorithm

Below is an example of our **CRC-16/MODBUS** algorithm, which is written in Python.

```
def crc16(data: bytes):
 crc = 0xffff
 for cur_byte in data:
   crc = crc ^ cur_byte
   for _ in range(8):
      a = crc
      carry_flag = a & 0x0001
      crc = crc >> 1
      if carry_flag == 1:
         crc = crc ^ 0xa001
   return bytes([crc % 256, crc >> 8 % 256])


data = b"\x00\x00\x00\xC8\x00\x00\x00\x00\x00\x00\x00\x00"
crc = crc16(data)

crc_str = " ".join("{:02x}".format(x) for x in crc)
print(crc_str)
```

Note: At this link you can find the CRC-16/MODBUS algorithm written in *C#*, *Java* and *PHP*, found on the open source Internet.

The developer is responsible for executing the code.

8.8 Where can I find the programming manual for the mDrive controller?

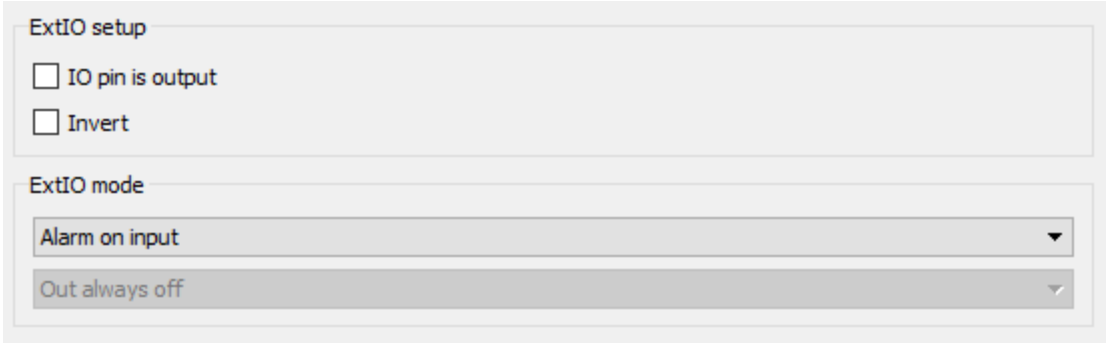
Programming guide is included in libximc 2.X.X archive, where 2.X.X is the version number. It is located in /ximc-2.X.X/ximc/doc-en/libximc7-en.pdf. The programming guide can be found on our second site libximc.xisupport.com or you can download a PDF version of it. The programming guide is Doxygen-based.

8.9 How do I implement an emergency stop button?

To implement an emergency stop button you will need to use a *General purpose digital input/output*, (pins **9. EXTIO IN 1** and **18. DGND, digital ground**) located on the *DVI-I connector*.

Using the libximc library, you will need to set the **0x5 - EXTIO_SETUP_MODE_IN_ALARM** flag (see *Command SEIO*).

If you using mDrive Direct Control, you need to uncheck the “IO pin is output” in the *EXTIO settiongs* and then select “Alarm on input” from the drop-down list.



Important: It is recommended to use an ALARM for the emergency stop button, because the ALARM will not allow you to perform any actions until it is reset (reset occurs using the stop button or when calling the stop command). If another command is used instead of an ALARM, for example "stop" or "power off", then when any move command (MOVE/MOVR/LEFT/RIGT) is called, the movement will continue, despite the fact that the button is pressed.

The emergency button function does not provide a smooth stop!

8.10 How to get a mDrive Direct Control window that has disappeared off the screen?

All data from installed programs is stored in a hidden *AppData* folder (settings, bookmarks, history, saves, etc). One of the following steps will help you recover your lost mDrive Direct Control window:

Default mDrive Direct Control settings Go to the directory *C:\Users\<your_user>\AppData\Roaming* -> find the *xilab.conf* folder -> rename it or delete it. After that, the mDrive Direct Control settings will be restored to default and all lost windows should return.

You can also manually change the window size. To do this, in the *xilab.conf* folder, find the file with the serial number of your controller, *for example: SM123.cfg*, open it with any text editor and change the fields:

```
[settingsWindow_params]
position = @ Point (411 1057)
size = @ Size (722 286)
```

Arrange the windows in a cascade Click the right mouse button on the taskbar. Select "cascade windows". All open programs will appear in front of you and you can sort them.

Enable display detection Right - click on the desktop and select "screen settings". Then click the Open button. Windows will return the missing Windows to the screen. This helps if the problem occurs due to the presence of multiple monitors.

Change the screen resolution Right - click on the desktop and select "screen settings". In the window that opens, change the permission to another one that is available to you. Windows will move all Windows that go off the screen back to the display. After that, you can return the permission that you had by default.

Use the keyboard shortcut First of all, make the "escaped" program window active. In other words, select it with the mouse on the taskbar, or use Alt+Tab to switch to it. Press Alt+space. It opens a special system menu of the active window. Then click the down arrow on your keyboard and select the second item — **Move**. Press Enter. Now, after pressing Enter, the window is ready to move. Press the left or right key on your keyboard and start moving the window. Continue holding the arrow key until the entire outline is on the visible desktop. Then press Enter.

8.11 How to check if the connection to mDrive is established and still active during my session using the libximc library?

To constantly check for a connection between the controller and the libximc library, send the get_status command at regular intervals in the loop.

```
result_t XIMC_API get_status (device_t id, status_t *status)
```

The method described above can be implemented in any program that uses the libximc library.

Note: A similar connection verification method is implemented in mDrive Direct Control

8.12 Raspberry Pi control

Important: Almost all ARM single-board computers are supported (Raspberry Pi 1/2/3/4/..., NanoPi, Cubieboard, and so on). The only limitation is that the ARM core must be version 7 or higher

8.12.1 Working with mDrive Direct Control software on ARM processor

Warning: mDrive Direct Control will not run on ARM processor!

If your linux has a graphical shell, you can use *unsupported examples*, among which there are examples that resemble mDrive Direct Control.

8.12.2 Working with libximc library on an ARM processor

On Linux both the *libximc7_x.x.x* and *libximc7-dev_x.x.x* target architecture **in the specified order**. For install packages, you can use the .deb command: `dpkg -i filename.deb`, where "filename.deb" is the name of the package (packages in Debian have the extension .deb). You must run dpkg with superuser privileges (root).

In a Linux-based OS, mDrive controllers must be recognized as a **ttyACMn** device and have a symbolic link in **/dev/mdrive/**

The controller may not be found in the system due to lack of access rights to the device. To solve this problem, create a file: `/etc/udev/rules.d/60-mdrive.rules` and add the following line to it: `SUBSYSTEM=="usb", ATTRS{idVendor}=="067b", MODE="0666"`

The ID *idVendor* can be found by running the command `lsusb`. Also, one of the possible solutions to the "no device found" problem is to add a user to the **dialout** group. **Important**: After adding a user to the group, you need to restart the computer.

The development kit can be downloaded on the Software page. It contains the compiled libximc library for Windows, Linux and Mac OS systems, the programming guide and the examples. Libximc is a cross-platform library that supports C++, C#, Delphi, Visual Basic, Matlab, Java and Python languages. The examples included in the library package are intended for quick acquaintance with the programming for mDrive controllers. The Libximc sources are also available for download.