

Digital Stepper-Motor Controller

Version 1.00



User Manual

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Safety Information

- The device must be installed and used by authorized and instructed personnel only. Read this manual carefully before installing and using the device. Always follow the safety notes and warnings in this manual.
- The device is designed for inside-use in dry rooms only. Before the device is powered on, its temperature must accommodate to the ambient temperature to avoid moisture condensation. Take this into account when setting up the device after transporting it.
- Do not operate the device if it is damaged or not functioning properly. Never use damaged cables or accessories.
- Do not open the device case, install replacement parts, or modify the device. There are no user-serviceable parts inside.
- To avoid damage, connect the line cord to a properly wired and grounded receptacle only. Be sure that the mains voltage and the fuse rating match the device specification. Never operate the device during thunderstorms.
- Never use corrosive or abrasive cleaning agents or polishes and avoid the usage of organic solvents. If necessary, clean the device with a soft moist cloth. Make sure that the device is completely dry and free from contaminants before powering it on.

! **Warning:** The motor controller is an electronic device that is sensitive to electrostatic electricity. While manipulating with the controller, the ESD (*Electro-Static Discharge*) protection rules must be kept in mind.

! **Warning:** The motor controller may produce electromagnetic radiation if not properly connected or used. Be sure that only the original shielded cables provided with the device are used and that the attached motor is well shielded in a metallic box.

Technical Data

Characteristics

- driver for stepper-motors with nominal currents of up to 5 A
- digital motion controller for precise positioning
- FPGA and microcontroller control for μ s-accuracy
- user interface via keypad, rotary encoder, and LCD
- USB and Ethernet interfaces for outside connections
- 19" case for table-top or rack mounting

Motor Controller

- output connector:
Amphenol Eco-Mate® RM RT0W01419SNH-K
(panel receptacle with 19 female contacts)
- output voltage: 38..50 V, digitally adjustable
- output motor current: 0..5 A, digitally adjustable
- maximum motor speed: >50 RPS (3000 RPM)
- microstepping indexer: 1/256 step ... full step

Motion Controller

- FPGA control based on quartz clock
- linear start and stop speed profile
- operation modes: continuous, burst, automatic repetition
- external synchronization: absolute accuracy <2 μ s

Safety

- interlock loop:
two pins at the output connector
(short circuit enables the motor controller)
- overcurrent protection: output current limiter
- overtemperature protection:
internal temperature sensor
(at the power supply unit and at the motor controller)
external temperature sensor LM35 at the motor
(shutdown and restart temperatures freely programmable)

Trigger

- input switchable between TTL and optical

- TTL input:
 - connector: isolated BNC socket
 - levels: Low < 0.8 V, High > 2.0 V
 - input impedance: 51 k Ω (internal pull-down)
 - precision: better than 50 ns
- optical input:
 - connector according the *Versatile-Link* standard
 - precision: better than 200 ns

Synchronization

- TTL or sine input:
 - connector: isolated BNC socket
(galvanically connected to the TTL trigger input)
 - coupling: AC
 - level: > 250 mV_{pp}, 5 V_{pp} maximum
 - input impedance: 50 Ω or 51 k Ω (internal pull-down, switchable)
 - allowed frequency range: 5..20 MHz

Monitoring

- Indicator LEDs:
 - Power Supply:
 - +48V (motor voltage OK)
 - +12V (fan supply OK)
 - +5V_T (supply of the trigger input OK)
 - Power Stage: Interlock, Activated, Failure
- Continuous monitoring:
 - supply voltages
 - temperatures
 - motor controller
 - fans

User Interface

- monochrome LCD display with 128x64 pixels
 - pixel size: 0.5 mm
 - pixel color: yellow, background: blue
 - background illumination: white LED
- keypad: 5 keys: 4x direction + 1x "enter"
- rotary encoder: 24 positions per revolution, integrated press button
- optional external shutdown button via the interlock loop

Power Supply

- rated voltage: 90-250 V, 50-60 Hz
- power consumption:
 - standby (motor deactivated): <50 VA
 - active (motor activated at 48 V, 4 A): <60 VA
 - active (motor running at 48 V, 4 A and 30 RPS): <70 VA
 - maximum load: 350 VA
- mains fuses: T 6.3 A (slow acting, size \varnothing 5x20 mm)
- mains connection:
 - IEC inlet with EMC filter and integrated fuse holder

General

- 3 U 19" bench-top case:
 - height: 132.5 mm, width: 445 mm, depth: 315.5 mm,
 - total height with case feet: 146 mm,
 - total width with mounting brackets: 483 mm,
 - total depth with fan cover and handles: 358 mm,
 - cover strips, horizontal rails: anthracite gray (RAL 7016),
 - cover, bottom, and side panels: white aluminum (RAL 9006),
 - front and rear panels: clear anodized
- forced cooling:
 - 92-mm 4800-rpm fan at the rear panel,
 - 60-mm 7200-rpm fan in the power stage,
 - 40-mm 9500-rpm fan in the power supply unit,
 - external 12-V fan at the stepper motor,
 - temperature-dependent regulation of the fan speed,
 - monitored fan operation, warning on fan failures
- weight: 8.1 kg
- allowed ambient temperature: 10..40°C
- cleaning: use moist cloth only, avoid use of organic solvents

Shipment Contents

- digital stepper-motor controller DSMC300, Rev.1-00
- line cord (universal IEC mains lead, length 1.8 m)
- output cable with connectors
 - RT0W61419PNH-K and RT0W61419SNH-K
- control and diagnostic software
- user manual in electronic form

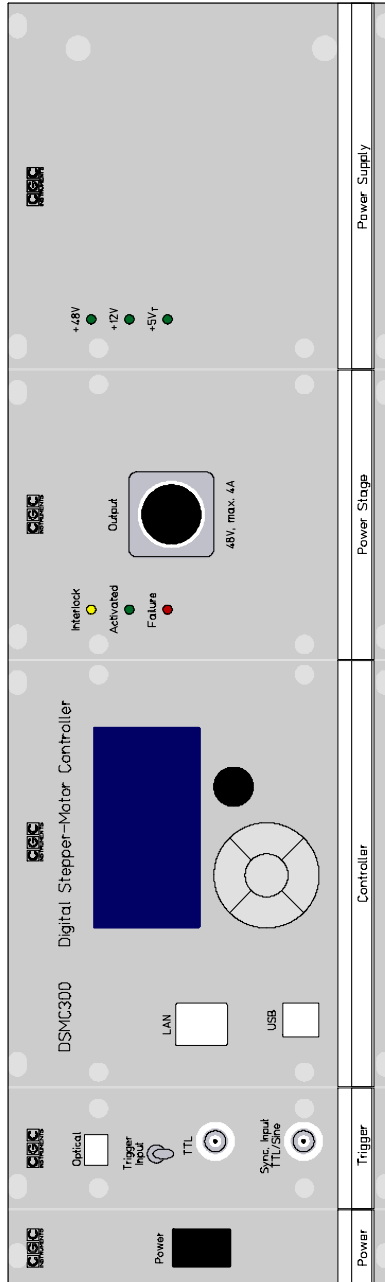


Fig. 1. Front panel of the motor controller.

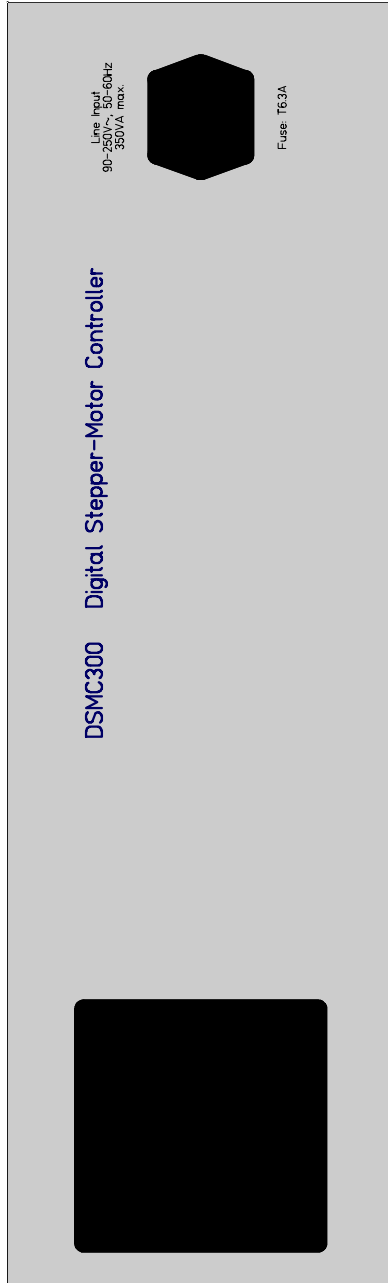


Fig. 2. Rear panel of the motor controller.

Description

General

This document describes the digital stepper-motor controller. The complete measurement system consists of the abovementioned controller, a connection cable, and a stepper-motor in a separate box.

The controller is a combination of a motor controller, a digital motion controller with an external synchronization, and a dedicated power supply unit. It is fit into a metallic 19" case, the front and rear panels are shown in Fig. 1 and Fig. 2. The device uses a modular design consisting of four plug-in modules that can be exchanged to enhance the functionality of modify it for new applications.

The motion controller and the motor box are described in individual manuals, which can be downloaded from the device homepage at www.cgc-instruments.com/Miscellaneous/DSMC300-1). The motion controller also contains control and monitoring circuits of the motor driver. The function of them is briefly described in this document, for more details please consult the manual of the motion controller.

Device Functionality

The block circuit diagram of the device is shown in Fig. 3. The device consists of four plug-in modules: *Trigger*, *Controller*, *Power Stage*, and *Power Supply*, which are symbolized by dashed rectangles. Outside of the modules, several other components are located in the device housing. The external *Motor Box* is connected to the module *Power Stage* via a connection cable.

The module *Power Supply* provides all necessary supply voltages for all remaining modules. It consists of an adjustable high-power switching-mode power supply *PSU1* that generates the motor voltage of typically 48 V with a maximum power of about 300 W. A secondary switching-mode power supply *PSU2* provides the voltages for supplying the fans (+12V), the display (+5V) and the digital circuits (+3V). A galvanically isolated voltage (+5V_{isol.}) is used to supply the trigger and synchronization inputs in the module *Trigger*. The line input is prepared by a *PFC (Power-Factor Correction)* unit ensuring a harmonic current consumption. Several filters reduce the EMI (*Electro-Magnetic Interference*) so that even very sensitive instruments in the proximity of the controller are not disturbed. A fan is used for forced

cooling of the module, a semiconductor sensor measures the temperature of the *PSU1* heatsink and regulates the fan speed (see the module *Controller* for more details).

The module *Trigger* acquires the trigger and synchronization signals. The BNC inputs *Sync* and *TTL* are conditioned in the Schmitt triggers *ST1* and *ST2*. The optical input *Optical* is received by a receiver according to the *Versatile Link* standard. The toggle switch (*Switch*) is used to select the desired trigger input. The output signals are fed via digital isolators to the *FPGA* at the module *Power Stage*.

The module *Power Stage* implements the motor and motion controllers as well as several diagnostic and supervising circuits. The motor controller *MC* directly drives the connected stepper motor in the external box (*Motor Box*). Its power supply is provided by the abovementioned power supply *PSU1*, measured by an *ADC* (*Analog-to-Digital Converter*), and adjusted by a *DAC* (*Digital-to-Analog Converter*). A

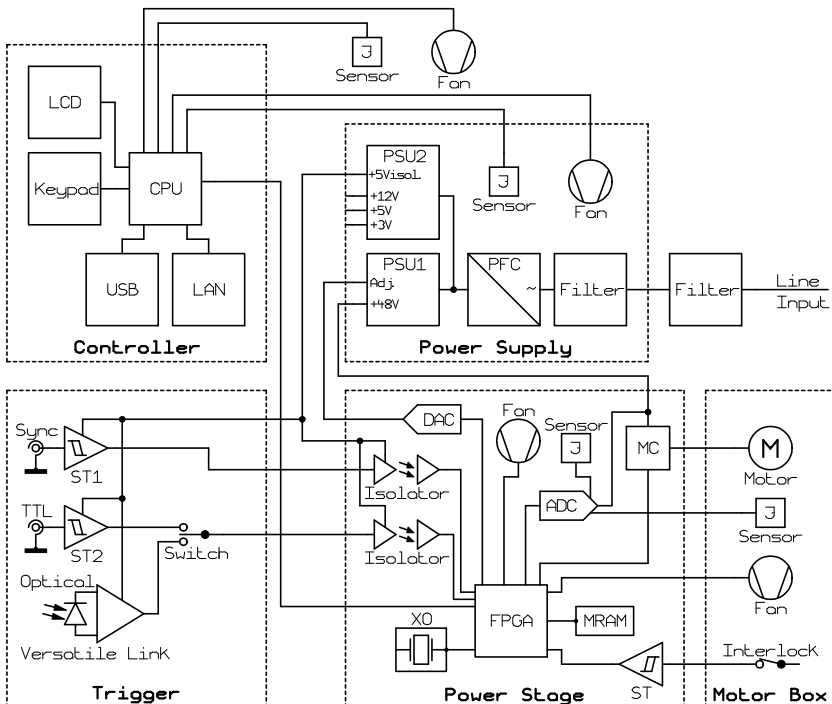


Fig. 3. Block circuit diagram of the device.

semiconductor sensor measures the temperature of the motor controller, this value is also acquired by the *ADC*. The last *ADC* input measures the temperature of the motor by a sensor located in the external motor box. The motor controller is cooled by a fan controlled by the *FPGA* (*Field-Programmable Gate Array*). The *FPGA* also controls both the *ADC* and the *DAC*, scans the interlock loop via the Schmitt trigger *ST*, receives the trigger and synchronization signals via two digital isolators (*Isolator*), and finally produces control signals for the motor controller *MC* and receives its status. The *FPGA* uses for its operation an external clock from a quartz oscillator *XO*. A non-volatile memory *MRAM* (*Magnetoresistive Random-Access Memory*) is used to store measurement and motor settings and other device data. The *FPGA* implements the motion controller, its function is set-up and monitored by the *CPU* (*Central Processing Unit*) in the module *Controller*.

The module *Controller* implements the user interface and most parts of the device monitoring and supervising. The heart of the module is the *CPU*, it is a 16-bit RISC (*Reduced Instruction Set Computer*) microcontroller running at 16 MHz maximum. It controls the display (*LCD*), the keypad with the encoder (*Keypad*) as well as both communication interfaces USB and Ethernet (*LAN*). Furthermore, it monitors the temperatures of the module *Power Supply* and of the device housing and controls the attached fans. The *CPU* communicates with the *FPGA* via a serial link.

Motor Controller

The motor controller is able to drive stepper motors at voltages of up to 50 V and motor currents of up to 5 A. The controller has been excessively tested with the motors part no. 60BYGH401-03 sold by CNC4You, which were run at 38-48 V and 4 A. At lower speeds where lower torque is sufficient, the motor current can be reduced to decrease heat dissipation in the motor coils.

The motor is driven using PWM (*Pulse-Width Modulation*). The controller regulates the duty cycle of the voltage applied to the motor coils and adjusts the motor current precisely. Microstepping, i.e. an enhancement of the angular resolution is reached by a fine distribution of the motor current between the motor coils. The maximum angular resolution of 1/256 step provides an almost perfectly smooth motion even at very low motor speeds. At higher speeds, however, mi-

crostepping leads to a torque reduction. Thus for each particular speed interval, the microstepping setting has to be obtained as a compromise between the available torque and the motion's smoothness.

As the PWM control produces rectangular signals at the motor leads, this may disturb sensitive devices in the proximity of the motor or the controller. The controller integrates EMI (*Electro-Magnetic Interference*) filters that efficiently suppress unwanted radiation from the device. However, the connection cable between the controller and the motor or the motor itself may be a source of disturbing interferences. Be sure that only original shielded cables provided with the device are used and that the motor is well shielded in a metallic box. These measures were verified to be sufficient for reaching low emission levels of electromagnetic radiation.

Embedded Safety Precautions

The system is equipped with an interlock loop that disables the motor output if the loop is opened. The terminals of the interlock loop are located at the output connector. They are typically fed by the output cables to the motor box where they are either short-connected or wired to an emergency push button or switch with a breaking contact. The output is disabled if the output cable is disconnected or broken, or if the emergency push button or switch is activated, i.e. opened. The interlock loop can be deactivated in the system settings (see the manual of the motion controller for more details).

The system is also equipped with a circuitry that scans the temperature measured by an external sensor LM35. This sensor is typically located at the stepper motor that produces most of the heat outside of the motor controller. The controller output is disabled if the measured temperature exceeds a preset value, thereby prevents the overheating of the motor and avoids its permanent damage. The temperature measured by the sensor is further used to control the external 12-V fan that is typically used to cool the motor.

The motor controller and its power supplies are actively cooled by a set of fans built into the device case. The fan speed is adjusted using the temperature measured by multiple sensors inside the device. In the standby state with the output disabled, the device produces only minimal acoustic noise, since the fans are stopped or their rotational speed is rather low. At heavy output loads, the temperature increases

and the fans are set to rotate faster. Under certain conditions, the cooling power of the device is not sufficient and it could overheat. This may happen when the connected stepper motor drives a heavy load, when the ambient temperature is high, or when one of the fans has failed. To prevent overheating, the motor controller is deactivated if the temperatures exceed a preset level.

Control and Indication Elements

All control elements are located at the front panel of the motor controller (see Fig. 1).

The device can be powered on or off using the rocker switch *Power*. When powered on, the three LEDs at the module *Power Supply* (+48V, +12V, and +5V_T) light up green and the display turns on.

The LED *Interlock* shows the state of the interlock loop. It lights up yellow, if the interlock loop is closed, i.e. if the corresponding contacts at the output connector are shorted. When the loop is open, the LED *Interlock* is off and the motor controller cannot be activated, unless the interlock loop is deactivated in the system settings (see the manual of the motion controller for more details).

The LED *Activated* lights up green if the motor controller is active. This indicates that the motor is powered and that no failure occurred. If the device cannot be activated, check the LCD for error messages. The most probable reason is an opened interlock loop or a wrong setting of it. Furthermore, a malfunction of the temperature sensor at the motor or a wrong setting of it may prevent the device from activating. The temperature threshold of all sensors can be modified and the actual temperatures can be monitored on the LCD (see the manual of the motion controller for more details).

The LED *Failure* lights up red if any failure has occurred, i.e. if the device has overheated or a fan has failed. You can identify the reason of the failure via the device-monitoring options (see the manual of the motion controller for more details). On a fan failure, the device continues to operate. However, the fan should be replaced as soon as possible to prevent overheating. This happens if the device reaches the temperature preset in the system settings (see the manual of the motion controller for more details). In this case, the motor controller is deactivated and any output is stopped immediately. The temperature threshold can be modified, you can also check the current tempera-

tures by opening the dialog box for temperature monitoring on the LCD (see the manual of the motion controller for more details).

User Interface

The motor controller is equipped with a graphic liquid crystal display (LCD), a set of keys (keypad), and a rotary encoder. The keys are arranged in a circle symbolizing the key function: there are four direction keys (*left*, *right*, *up*, and *down*) and a middle key for confirmation or selection (*enter*).

The keys are used for navigating in menus, for selecting dialog items, and for change values (see Fig. 4). The function of the keypad in every device state is symbolized on the LCD immediately above the keypad. A text describes the function of the middle key, alternatively just the symbol "⌘" is displayed indicating that the middle key can be used in its default function. Similarly, arrows show which of the keys has an influence on the operation in the current state. When a menu is active, the vertical direction keys are used to change the current selection. The right direction key as well as the middle key open a submenu, provided one is available. The left direction key closes the submenu or the main menu if there was no opened submenu. The middle key selects the menu item and launches the corresponding action.

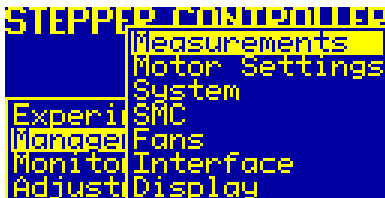


Fig. 4. Main device menu.

The rotary encoder is used to change numerical values or select items. The function of the encoder is symbolized on the LCD immediately above the encoder knob in every device state. In most situations, the encoder uses an enhanced speed control. This enables to precisely set any desired value or rapidly make large changes, since the value steps are proportional to the rotational speed of the encoder. You can change the corresponding value in small steps when you rotate the encoder slowly or make large changes when you spin the en-

coder knob quickly. To set large numbers, the encoder speed can be further increased by pressing the direction key *left*. If this feature is available, the left arrow is shown above the keys. In some situations, the encoder's push button is used to confirm the selected value or to switch the encoder function. In these cases, the symbol "☐" is shown on the LCD above the encoder knob.

For more details about the operation, see the manual of the motion controller.

Terminals

The output terminals are located in the connector *Output* at the module *Power Stage*. The connector is a robust Amphenol Eco-Mate[®] socket with 19 pins, for the pin layout and their assignment, see Fig. 5 and Tab. 1, respectively. The panel receptacle set is the P/N RT0W01419SNH-K, the corresponding cable plug set is the P/N RT0W61419PNH-K.

The outputs for the stepper motor are connected to four pin pairs (OUT1P, OUT1N, OUT2P, and OUT2N) to enhance the current capability of the pins and increase the connection reliability. The next pin is

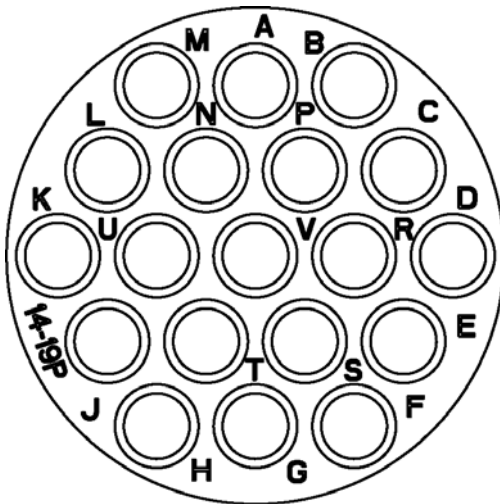


Fig. 5. Pin layout of the output connector.
The figure shows the front view on a cable plug (male) or a back view on a panel socket (female), respectively.

connected to the protection ground of the device (PE). It should be used to ground the transducer, furthermore the cable shielding should be connected to this terminal, too.

Two pins of the output connector are used for the interlock loop (INTERLOCK-POS and INTERLOCK-NEG), they have to be shorted in order to enable the device functionality. Alternatively to shorting the wires INTERLOCK-POS and INTERLOCK-NEG, the positive interlock terminal (INTERLOCK-POS) can be connected to the protection ground (PE), which also enables the device.

Tab. 1. Pin assignment of the output connector.

Pin	Signal	Description
A	OUT2P	Stepper Motor Output 2 Positive
B	FAN-GND	Fan Ground
C	FAN-RPM	Fan Tachometric Output
D	FAN+12V	Fan Supply
E	LM35-OUT	Temperature Sensor Output
F	LM35-GND	Temperature Sensor Ground
G	OUT1N	Stepper Motor Output 1 Negative
H	OUT1N	Stepper Motor Output 1 Negative
J	OUT1P	Stepper Motor Output 1 Positive
K	PE	Protective Ground
L	OUT2N	Stepper Motor Output 2 Negative
M	OUT2P	Stepper Motor Output 2 Positive
N	OUT2N	Stepper Motor Output 2 Negative
P	FAN-PWM	Fan PWM Control Input
R	LM35+5V	Temperature Sensor Supply
S	MOT-SNC	Motor Synchronization Output
T	OUT1P	Stepper Motor Output 1 Positive
U	INTERLOCK-NEG	Interlock Loop - Negative Terminal
V	INTERLOCK-POS	Interlock Loop - Positive Terminal

Tab. 2. Pin assignment of the stepper motor.

Signal	Pins	Wires	Description
OUT1P	J, T	green, orange	Stepper Motor Output 1 Positive
OUT1N	G, H	white, brown	Stepper Motor Output 1 Negative
OUT2P	A, M	yellow, black	Stepper Motor Output 2 Positive
OUT2N	L, N	blue, red	Stepper Motor Output 2 Negative

The next four pins of the output connector are used to connect a fan for the cooling of the motor. The fan is supplied by 12 V (FAN-GND, FAN+12V), controlled by a PWM signal (FAN-PWM), and monitored by its tachometric output (FAN-RPM). The used fan must have all abovementioned features to operate properly. A recommended device is the P/N FFC0912DE-TP04 by Delta Electronics, this is a 92-mm fan with 4800 rpm maximum providing an air flow of up to about 3 m³/min.

The pin pair LM35-OUT and LM35-GND is used to connect the motor temperature sensor. The connection should be made with a coaxial cable, it should be at least shielded from the motor terminals. The power supply of the temperature sensor (LM35+5V) is attached to the next pin.

Optionally, the pin MOT-SNC can be used for motor synchronization. As signal ground, the temperature sensor ground (LM35-GND) should be used. The connection (MOT-SNC and LM35-GND) should be made with a coaxial cable or shielded from the motor terminals. If required, the power supply of the temperature sensor (LM35+5V) can be used to supply the circuit of the motor sensor. Contact the manufacturer of the device for recommended circuits.

The pin assignment of the motor connector is shown in Tab. 2. The wire colors are valid for the stepper motor 60BYGH401-03 sold by CNC4You. Verify that the motor coils are connected in the indicated way to provide the proper direction of the motor rotation. The direction can be changed in the settings of the controller. However, the hardware is not perfectly symmetrical, thus the motors run less perfectly in the reverse direction.

The digital trigger signal can be connected either to the isolated BNC socket as a standard TTL signal or to the optical input according to the

standard *Versatile Link*. The connectors are located at the module *Trigger*. The desired input can be selected using the toggle switch *Trigger Input*. The switch has three positions, in the middle one, both trigger inputs can be used simultaneously - the system is triggered by the currently active one. The optical input provides the best isolation between the trigger source and the motor controller, thus it should be preferably used. However, the BNC trigger input is galvanically isolated from the device too, thus there is no risk of ground loops even with this input.

Similarly to the trigger signal, a digital synchronization signal can be connected to the isolated BNC socket *Sync. Input* at the module *Trigger*. The device expects a rectangular or a sinusoidal signal in the frequency range between 5 and 20 MHz (see the manual of the motion controller for more details).[†] The synchronization input is isolated from the device, but galvanically connected to the TTL trigger input (the BNC socket). This minimizes the risk of ground loops, provided the trigger and the synchronization signals are sourced from the same control device.

Special care has to be taken concerning the proper termination of the connected cables. The device is equipped with an optional termination resistor of 50 Ω at the synchronization input. If enabled, it provides the proper termination, thus ensures clean signal transitions. Since several signal sources are not able to provide a sufficiently high signal amplitude necessary for driving the input impedance of 50 Ω , the termination is disabled by default.[‡] In contrary to that, the TTL trigger input has only a weak pull-down resistor of 51 k Ω , thereby it does not provide any signal termination. When you use longer cables to connect the trigger signal, check the signal quality for overshoots and ringing. If the signal quality is poor, use an external 50- Ω termination resistor and check the signal quality again. Note that especially ringing caused by fast signal transitions with incorrectly terminated cables may prevent the trigger input from functioning properly.

For the mains connection, an IEC inlet with an EMC filter and integrated fuse holder is located at the rear panel. Use a standard line

[†] The present hardware does not evaluate the synchronization input, it is intended for future extensions of the motor controller.

[‡] The corresponding jumper that enables the termination is located in the device housing, contact the manufacturer or the distributor for detailed instructions if you wish to activate it.

cord with the universal IEC mains lead to connect the device to the mains. To replace the mains fuse, remove the line cord and open the fuse holder. Insert the new fuse, close the fuse holder, and connect the line cord back to the IEC inlet. Be sure to use fuses with proper values (see the section "Technical Data").

Installation

! Before powering the system on, read the user manual carefully.

To install the motor controller, a space of at least $49 \times 40 \times 15 \text{ cm}^3$ (width \times depth \times height) on top of a stable surface is required. The device weighs about 8 kg, the supporting surface must guarantee mechanical stability under this load. Optionally, the device can be installed into a standard 19" rack.

The installation area must be kept dry and the temperature within the range specified in the section "Technical Data". Avoid exposing the device to direct sunlight since this may substantially increase the device temperature.

During operation, only the front panel of the motor controller has to be accessible. Before installing the device in its final position, you should attach the line cord; it is connected to the IEC inlet at the rear panel. To power the device, a power mains socket with proper grounding is required. Check the voltage rating at the rear panel before powering the device on.

The air filter at the rear panel must not be covered or obstructed during device operation. It must be provided with sufficiently cool air for the active cooling of the device. Take necessary precautions to ensure a sufficient supply of cool air when installing the device in closed racks. Inspect and clean the fan filter regularly. Furthermore, use a vacuum cleaner or pressurized air to remove dust from the fan at the rear panel and from fans inside the device case. Be sure that the fans cannot rotate during cleaning. Large dust layers lower the cooling power substantially, furthermore the lifetime of the fans can be significantly shortened.

If already connected, disconnect the motor cable and power the device on by toggling the rocker switch *Power*. The three LEDs at the module *Power Supply* (+48V, +12V, and +5V_T) will light up green and the display will turn on. During the startup, the three LEDs at the module *Power Stage* (*Interlock*, *Activated*, and *Failure*) will light up for 1-2 seconds. When the device startup is completed, the LED *Interlock* indicates the state of the interlock loop. The other two LEDs (*Activated* and *Failure*) should be inactive. If the device behaves properly, proceed with the installation the motion controller as described in its manual.

Please consult the manual of the motion controller in case of any discrepancy with the described startup procedure. Should the problem persist, please contact the distributor or the manufacturer.