

**E5X MCS^{T4.1}**

Features

- High-performance 32-bit controller powered by ARM Cortex-M7 processor @ 600 MHz.
- Full 5-Axis control outputs plus a selectable clone axis via on board jumpers - can clone/slave either X, Y, Z, A, or B axis.
- Connectivity via Ethernet, USB and Micro SD Card.
- Reverse polarity and short circuit protection.
- External stepper motor driver support for open/closed loop stepper motor.
- External motor driver support for Servo motors.
- Motor alarm inputs for closed loop stepper motors and servo motors for all axes including slave axis.
- Opto-isolated inputs for DOOR/PROBE/HOLD/START/E-STOP input signals.
- Opto-isolated inputs for all limit switches input signals.
- 4x Auxiliary digital inputs with Schmitt trigger buffer.
- Digital Spindle Enable and Direction outputs.
- 0-10V or 4-20mA spindle speed control outputs.
- 5V PWM laser output.
- 6x 24V Digital Outputs – Mist Coolant, Flood Coolant, Dust Collector, and 3 auxiliary outputs controlled by additional M-codes.
- 24V Mechanical and Inductive limit switch compatible.
- Built-in replaceable over-current and short circuit protection fuses.
- Full range of status indicator LEDs for clear and easy diagnostics, including status LEDs for limit switches, alarm inputs, spindle function, and digital outputs.
- Serial Communication port for pendants and future expansion.
- SD Card enables G-Code files to be stored on the **E5X** and accessed via ioSender.
- All round pluggable 3.81mm pitch screw terminal connectors for I/O. No soldering required.
- Strong metal case - secures electronics.
- Certified Australian Made and Owned (Licensee ID number: 16790)

Applications

- CNC Machines
- 5-Axis Motion Control
- Linear Actuators
- Robotics

Description

The **E5X MCS T4.1** (“**E5X**” for short) is an Ethernet controlled 5 Axis Motion Control System powered by a powerful 32-bit Teensy® 4.1 Microcontroller. It is an easy-to-use and robust motion control system that can drive up to 5-axis (+1 clone/slave) CNC machines.

The **E5X** is designed to run grblHAL firmware, which is increasingly the firmware of choice for CNC control due to its increased functionality and added features. The Teensy® 4.1 paired with grblHAL far surpasses current 8-bit CNC controllers on the standard port of grbl or grbl esp32.

Teensy® 4.1 is ideal as the core controller due to its high processing power and many auxiliary inputs/outputs (which can be used for future expansion). With an ARM Cortex-M7 processor clocked at 600 MHz it is the fastest microcontroller amongst all grbl and grblHAL compatible microcontrollers.

The Name “E5X MCS T4.1”

Ethernet 5 AXis (+1 Slave)

Motion Control System

Powered by **Teensy® 4.1** Microcontroller

E5X

MCS

T4.1

Or “**E5X**” for short.

Specifications

Dimensions	• 229 x 132 x 32 mm
Microcontroller	• High-Performance 32-bit controller powered by ARM Cortex-M7 processor @ 600MHz • Multiple interfaces for plug-and-play capability • Ethernet and USB Support • Micro SD Card support
Outputs	• Full 5 Axis control outputs plus a selectable independent clone/slave axis port • 24V Outputs – Spindle, Mist Coolant, Flood Coolant, Dust Extraction • 3x 24V Auxiliary outputs controlled by additional M-codes • 0-10V or 4-20mA Spindle Control outputs • 5V PWM output suitable for most laser control • Independent stepper motor/servo Enable signal for each axis • Rotary Axis output compatible • External motor driver support for open loop/closed loop stepper motors • External motor driver support for servo motors
Inputs	• Motor alarm inputs for closed loop stepper motors and servo motors for all axes including slave axis • Opto-isolated inputs for DOOR/PROBE/HOLD/START/E-STOP input signals • Opto-isolated inputs for all limit switch input signals • 4x Auxiliary Digital inputs with Schmitt Trigger Buffer • 24V Mechanical and inductive limit switch compatible
Protection	• Built-in replaceable over-current and short circuit protection fuses • Built-in Reverse Polarity protection
Firmware/Software	• Supports grblHAL firmware • Supports ioSender software
Connectivity	• Ethernet • USB Micro • SD Card

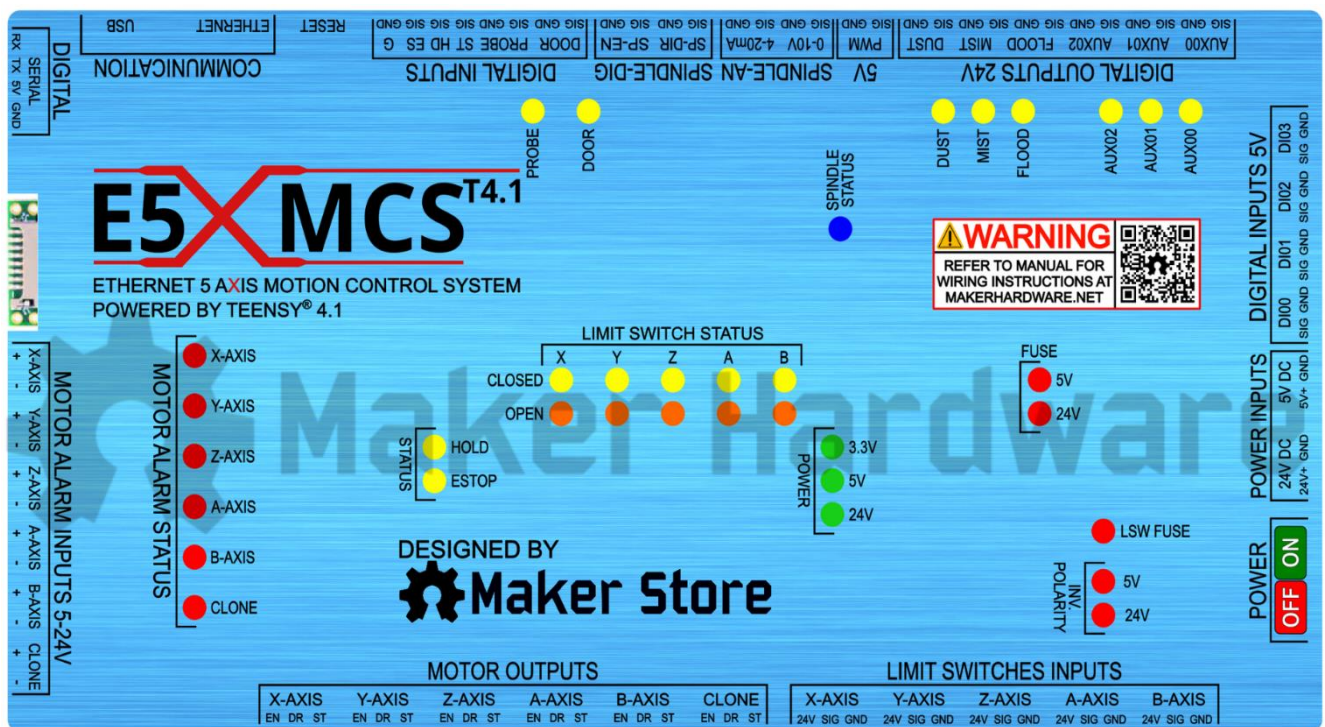
Absolute Maximum Ratings

Item	Rating
Power Input Voltage*	24V (for Limit Switches, Relay outputs, and spindle control signals) 5V (for Teensy® 4.1 microcontroller, LED Lights, and communication devices)
Power Input Current*	2A (for Limit Switches, Relay outputs, and spindle control signals) 2A (for Teensy® 4.1 microcontroller, LED Lights, and communication devices)
External Pull-down resistor (to wire alarm outputs from alarm source) resistance**	For 5V systems: 2kΩ Resistor For 24V systems: 10kΩ Resistor
Digital outputs voltage	24V
Limit Switch input signal voltage	24V
5V PWM toolhead control input voltage	5V
Board Consumption	140mA

* E5X MCS T4.1 needs two power inputs, 5V 2A for the Teensy 4.1, LED Lights and communication devices, and 24V 2A for the limit switches, relay outputs, and spindle control signals.

** See manual for more information and wiring directions.

LEDs, Inputs, and Outputs



LED Indicators

The **E5X** has multiple LED indicators to show controller component status and error reporting (see Figure 1 above). This helps in diagnosing and troubleshooting.

Motor Alarm Status	When a motor alarm is triggered, the associated red LED indicator turns on and the GRBL program is suspended (can resume once alarm is corrected). 6x driver alarms can be connected to the E5X for X, Y Z, A, B, and Clone axes.
Probe and Door Status	The probe status LED indicator glows yellow when the cutting tool makes contact with the probe during the probing process. The door status LED indicator glows yellow when the machine enclosure door is opened and ceases the machine operation.
Digital Outputs 24V	6x 24V 0.5A digital outputs can be used for controlling devices such as relays and solenoids. 3 outputs for Dust extraction, Mist, and Flood. 3 Auxiliary outputs (AUX00, AUX01, AUX02). The digital output LED indicator glows yellow when the output is activated in the G-Code.
Spindle Status	The spindle status LED indicator glows blue when the spindle motor is in use.
Limit Switch Status	The yellow "CLOSED" Limit Switch Status LED indicator glows when the limit switch is activated. Otherwise, the orange "OPEN" LED indicator remains on.
Hold and Estop Status	The Hold Status LED indicator glows yellow when the CNC program is paused. The E-Stop Status LED indicator glows yellow when the E-Stop is activated.
Power Status	The power supply LEDs (3.3V, 5V, or 24V) glow green when power is applied to the associated circuit.
Fuses (5V, 24V, LSW)	3 fuses (5V, 24V, and LSW (Limit Switch)) for protection against over-currents and short circuits. Fuse LEDs are normally OFF. If a fuse blows, the associated LED glows red.

Buttons

Reset	A momentary button that soft resets the E5X. This output is tied to Emergency Stop Switch input logic.
Power	A double pole double throw switch that switches the 5V and 24V power on or off.

Inputs

The **E5X** accepts inputs/switching signals at various voltage levels.

Digital Inputs	5 CNC-specific opto-isolated digital inputs where the signal is at 3.3V. A button interface is used to activate the relevant input. NC (Normally Closed) is the recommended setup.
Digital Inputs 5V	4x 5V tolerant auxiliary digital inputs with a Schmitt trigger buffer. A button interface or digital sensor can be used to trigger the inputs for user-specific applications.
Limit Switches	Accepts 24V switching signals from both mechanical and inductive proximity switches. There are 5 opto-isolated independent limit switch inputs for a 5-Axis + 1 Slave/Clone Axis setup.
Motor Alarm 5/24V	Alarm output signals from closed-loop stepper motors or servo motors can be used to stop a CNC program or cease the motion of the machine. This helps to prevent damage to the system or workpiece.

Outputs

Spindle Digital

Spindle Enable and Spindle Direction outputs are wired directly to the VFD. These signals control the VFD and spindle automatically. Spindle Direction is used to change the spindle direction from clockwise (default) to anti-clockwise. Spindle Enable turns the spindle on or off.

Spindle Analog

Spindle Analog output signals control the spindle speed with an analog 0-10V or 4-20mA depending on user requirements. The 4-20mA output signal provides high resistance to Electromagnetic Interference (EMI).

5V PWM

Drives laser modules or any tool requiring a 5V PWM input signal.

Digital 24V

6x 24V 0.5A digital outputs for controlling 24V devices such as relays and solenoids. Three digital outputs are dedicated to CNC-specific functions such as Dust extraction, Mist, and Flood coolant. The other three are auxiliary outputs that are denoted by AUX00, AUX01, and AUX02. These are activated by grblHAL's additional M-code support.

Motor Outputs

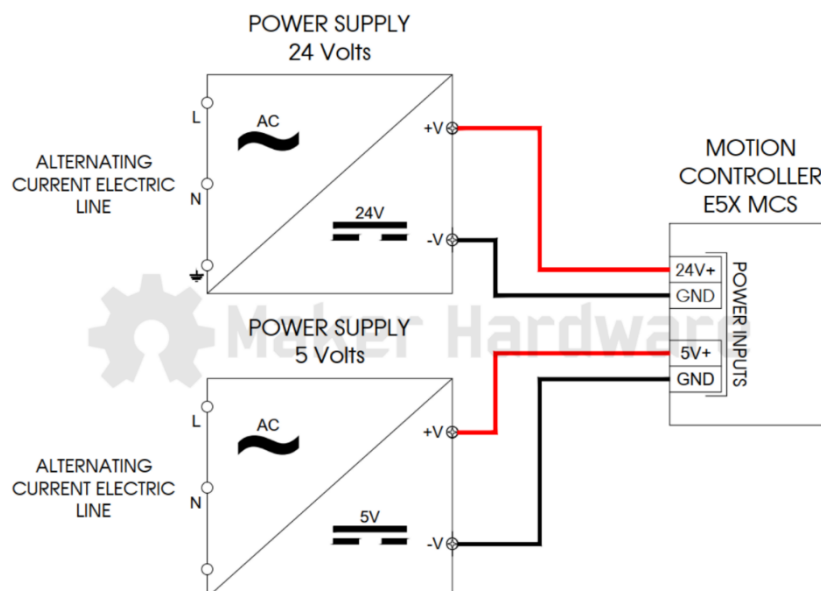
External stepper motor driver/servo support for stepper motors and servo motors with a Step/Direction interface. Each motor can be independently enabled.

Digital

Peripherals such as pendants and Human Machine Interface (HMI) can be added via the serial interface.

Power Inputs

The **E5X MCS T4.1** needs two power inputs, 5V 2A for the Teensy 4.1, LED Lights and communication devices, and 24V 2A for the limit switches, relay outputs, and spindle control signals. A dual-output switching power supply such as the RD-65B is recommended for meeting the power requirements of the **E5X** or alternatively, 2 separate switching power supplies rated at 5V and 24V. The 5V power supply must be connected to the 5V DC terminal and the 24V power supply to the 24V terminal.

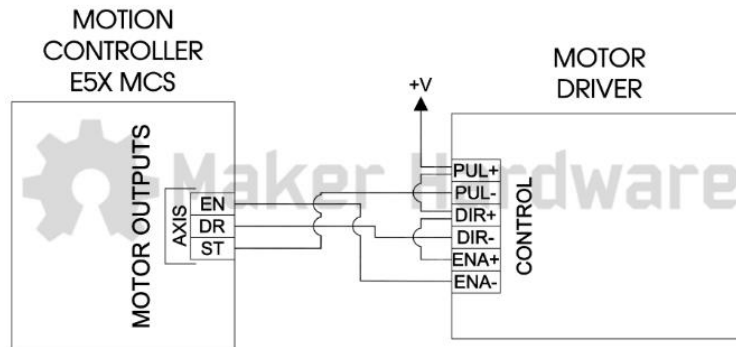


Note: The power inputs must not exceed 24V for the 24V DC input connector and 5V for the 5V DC input connector on the E5X MCS. The onboard circuitry may be irreversibly damaged if the supply voltage exceeds the specified voltage. Prior to connection the power inputs must be checked with a multimeter to ensure that they do not exceed the required ratings.

Motor Wiring

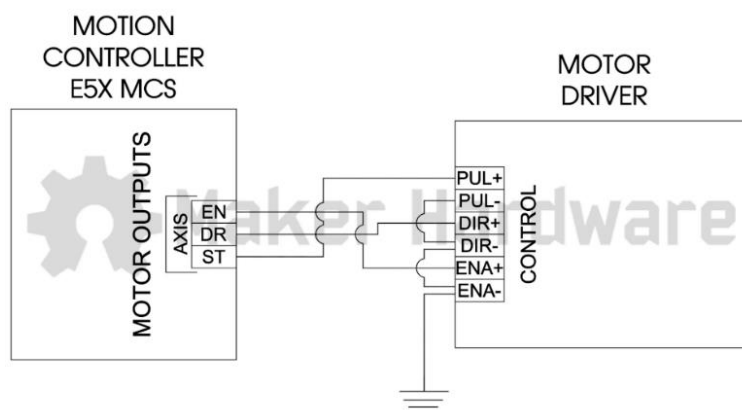
The wiring for all types of motors is nearly identical using the Enable (EN/ENA), Step (ST) or Pulse (PUL), and Direction (DIR/DR) output. There are two methods of wiring; the Common Anode and the Common Cathode method.

Common Cathode Method:



E5X MCS Output	Motor Driver	Description
EN	ENA-	Connects the enable signal EN from E5X to enable pin ENA- on the stepper motor driver.
DR	DIR-	Connects the direction signal DIR from E5X to direction pin DIR- on the stepper motor driver.
ST	PUL-	Connects the pulse signal PUL from E5X to pulse pin PUL- on the stepper motor driver.
NC	ENA+	Connected to +ve on power supply.
NC	DIR+	
NC	PUL+	

Common Anode Method:



E5X MCS Output	Motor Driver	Description
EN	ENA+	Connects the enable signal EN from E5X to enable pin ENA+ on the stepper motor driver
DR	DIR+	Connects the direction signal DIR from E5X to direction pin DIR+ on the stepper motor driver
ST	PUL+	Connects the pulse signal PUL from E5X to pulse pin PUL+ on the stepper motor driver
NC	ENA-	Connected to GND or -ve on power supply
NC	DIR-	
NC	PUL-	

Clone Axis Wiring

The Clone-Axis port and header array clones the output control signals of either the X, Y, Z, A or B axis. This enables both motors to move in sync with one another. The clone Axis can be wired using either common cathode or common anode method as shown above.

The **E5X** comes with the Y-Axis cloned by default, this configuration can be changed by moving the 3 shunts STEP / DIR / EN to the required axis setting.

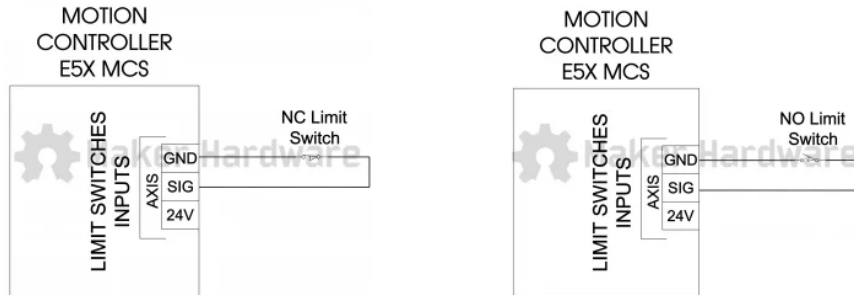


Limit Switch Wiring

The **E5X** controller accepts 24V signal inputs from both mechanical, PNP, and NPN inductive proximity switches. There are 5 independent limit switch inputs for a 5-axis setup; X, Y, Z, A, B. All limit switch inputs are opto-isolated.

Mechanical Limit Switch:

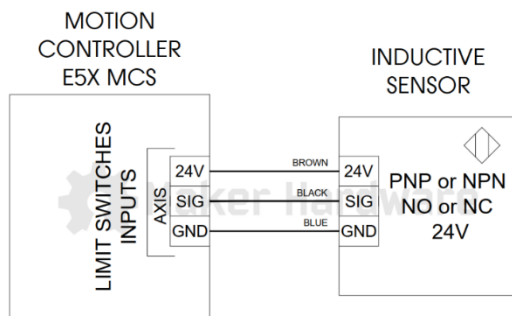
Mechanical switches can be wired into the **E5X** controller using either the Normally Open or Normally Closed configurations. Normally Closed configurations are recommended as the user will be notified when a fault is detected in the wiring, preventing machine axis' collisions. It is recommended to use a shielded 2-core cable to minimise chances of EMI (Electromagnetic Interference) triggering. The shield of the wire must be terminated on one side to GND on the 24V power supply.



Note: Incorrect wiring can blow the fuse and damage the circuitry – follow the above schematic when wiring with special attention to the correct terminals.

Inductive Limit Switch:

Inductive proximity switches trigger when a circuit completes electronically. To complete this electronic circuit, the inductive proximity switch needs to come into contact with a metallic surface such as aluminum or steel. Inductive switches perform best when in contact with ferrous (magnetic) metals such as steel. NPN NC Limit switches are recommended for use with **E5X**. Use a shielded 3-core cable to minimise the chances of EMI triggering. The shield of the wire must be terminated on one side to GND on the 24V power supply.



E5X MCS Controller	Inductive Proximity Switch
24V	24V (Brown)
SIG	SIG (Black)
GND	GND (Blue)

Note: Incorrect wiring can blow the fuse and damage the circuitry – follow the above schematic when wiring with special attention to the correct terminals. Wiring colours above are typical and may change depending on the switch used.

Communication

Communication with the **E5X** controller can be made via Ethernet or USB. The **E5X** uses ioSender to communicate with the CNC machine's components. Communication is via USB connection using USB 2.0 or USB 3.0 A to B cable or via Ethernet connection using a RJ45 cable.

USB Control



Ethernet Control



For future expansion, the E5X MCS controller has a serial interface to add peripherals such as pendants and Human Machine Interface (HMI) devices.

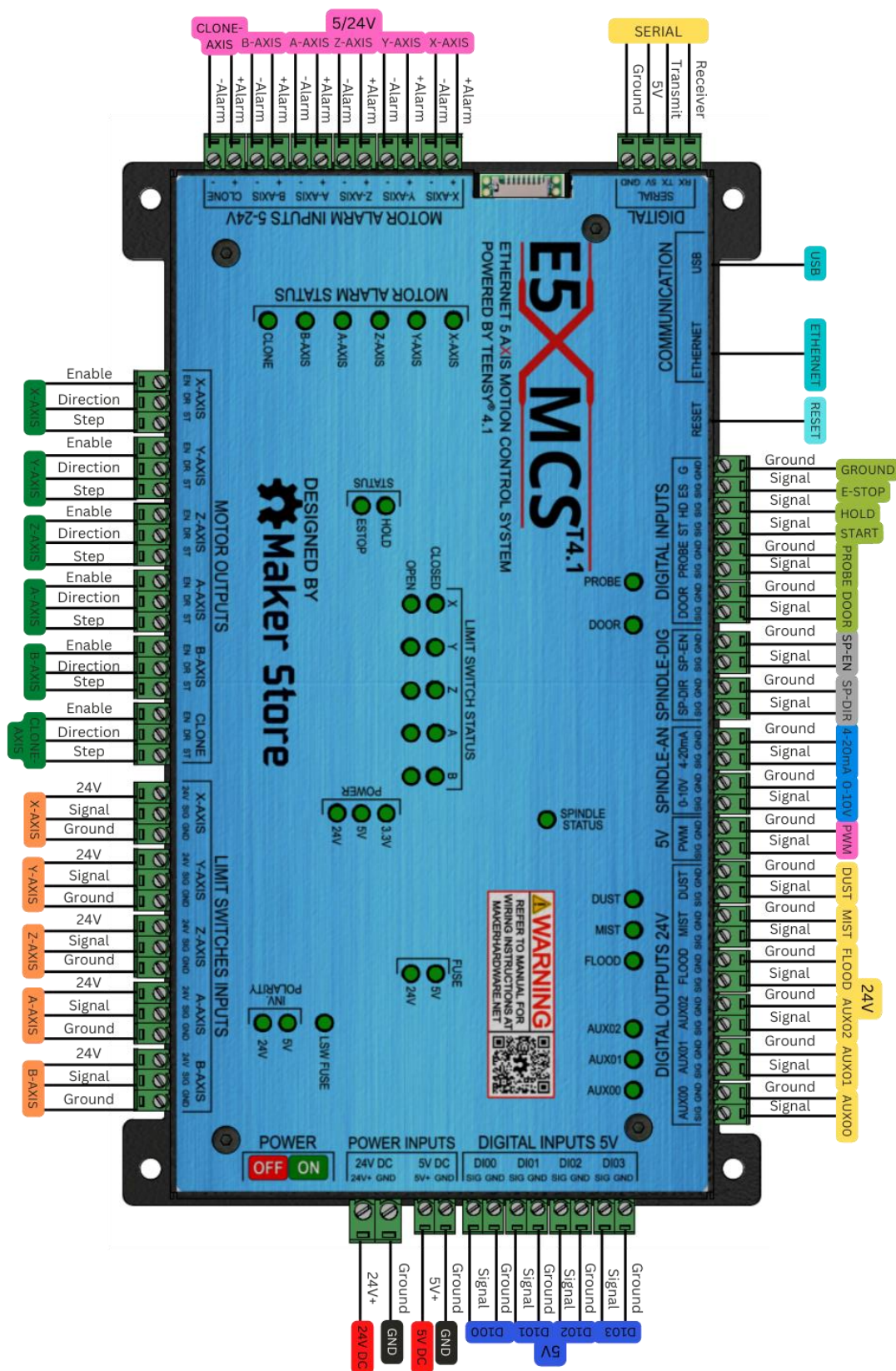
Description	Function
RX	Receiver pin. Receives signal from an external device.
TX	Transmit pin. Transmits signal to an external device.
5V	5V output power to an external device.
GND	Connect to the ground

Software

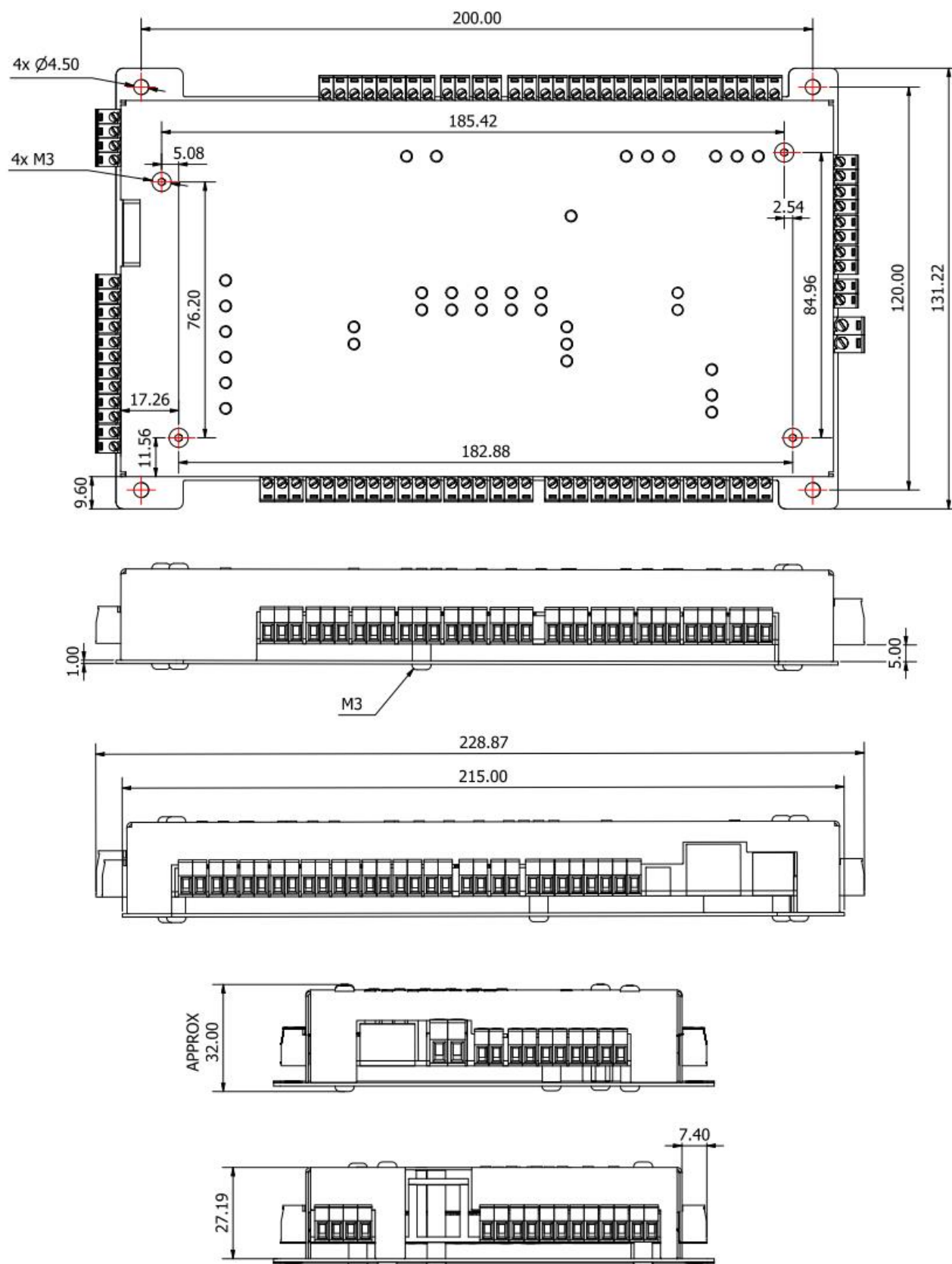
To interface with the **E5X**, a G-Code sending software is required. We highly recommend ioSender because it is a powerful G-Code sender used for CNC control with a feature-rich and easy-to-use interface. It is an ideal CNC G-Code sender for any level of experience and allows all the advanced features of the E5X to be unitized.

ioSender is freely available from the project's GitHub: <https://github.com/terjeio/ioSender/releases>

E5X MCS T4.1 Controller Terminal Pinouts



Mechanical Specifications



Note: All dimensions in mm

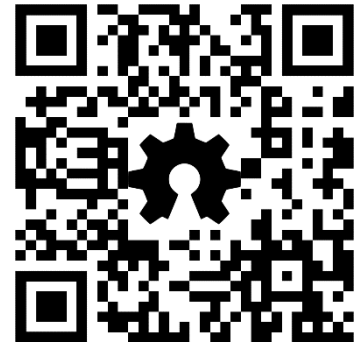
Manual and Resources

The **E5X MCS T4.1** Manual is available at:

<https://makerhardware.net/>

The **E5X MCS T4.1** available for purchase at:

<https://www.makerstore.com.au/product/elec-e5xmcst41/>



Credits

Special thanks to:

PRJC – Teensy

The **E5X Motion Controller** was designed to use the Teensy® 4.1 Development Board as the microcontroller. Maker Store is an authorised distributor of PJRC, the designer and manufacture of the Teensy® 4.1 Development Board. PJRC are the designers, producers and owners of all Teensy brands, trademarks and logos.

PJRC Website: <https://www.pjrc.com/>

Teensy 4.1: <https://www.pjrc.com/store/teensy41.html>

The grblHAL Community

Terjeio ioSender – <https://github.com/terjeio>

grblHAL Core- <https://github.com/grblHAL/core/graphs/contributors>

grblHAL iMXRT1062 Fork – <https://github.com/grblHAL/iMXRT1062/graphs/contributors>

The Maker Community

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