MC110 Hardware Manual

Release 2.0

Embention

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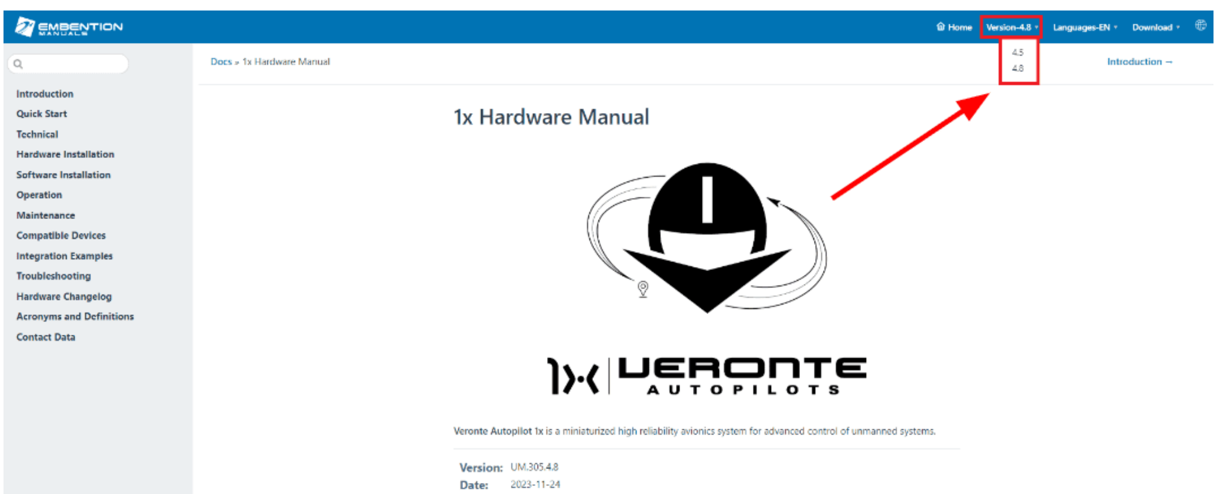
Veronte MC110 is a motor controller designed for aircraft motors up to 110 kW.

Warning: Select your version before reading any user manual. The following image shows where to select a version from any Embention user manual.



CHAPTER ONE

INTRODUCTION

Veronte MC110 speed controller is capable of driving any type of 3-phase PMSM motor. It can be used with a wide variety of UAVs or eVTOL vehicles and also in automotive applications (Bikes, Karts, Cars). **MC110** uses FOC algorithm for motor control together with IGBTs.

CHAPTER

TWO

QUICK START

2.1 First steps

To connect the **MC110** to a PC, use the RS-232 or RS-485 port. If the computer has not a serial port, a RS-232 or RS-485 to USB converter can be employed. The serial pins are explained in the *Pinout* section.

2.2 Warnings

When installing the MC110 speed controller in the vehicle, the following limitations shall be considered:

- The distance between the battery, the controller system and the motor should be as short as possible in order to maximize the efficiency. It is preferable to place the controller system as close to the battery as possible and extend the cables from the controller to the motor. Calibration will be needed depending on the final setup.
- Wire connections between power devices must be crimped not soldered.
- The cold plate is integrated with the **MC110**, but it requires the rest of refrigeration elements. To know how to choose them, read the *Cooling Circuit Sizing section*.
- PID tuning is strongly not recommended, since it nullifies the warranty.
- An unappropriated use of the MC110 exempts Embention from responsabilities related to any damage.
- Embention shall have no responsibility, obligation or liability in any manner for and in respect of any inappropriate use by the client, such as (including but not limited to) not implementing an appropiate *cooling circuit*, applying according to the indications given by Embention.

2.3 Requirements

A *cooling circuit* is required to refrigerate the **MC110**, since the cold plate is integrated, but not the rest of elements.

CHAPTER

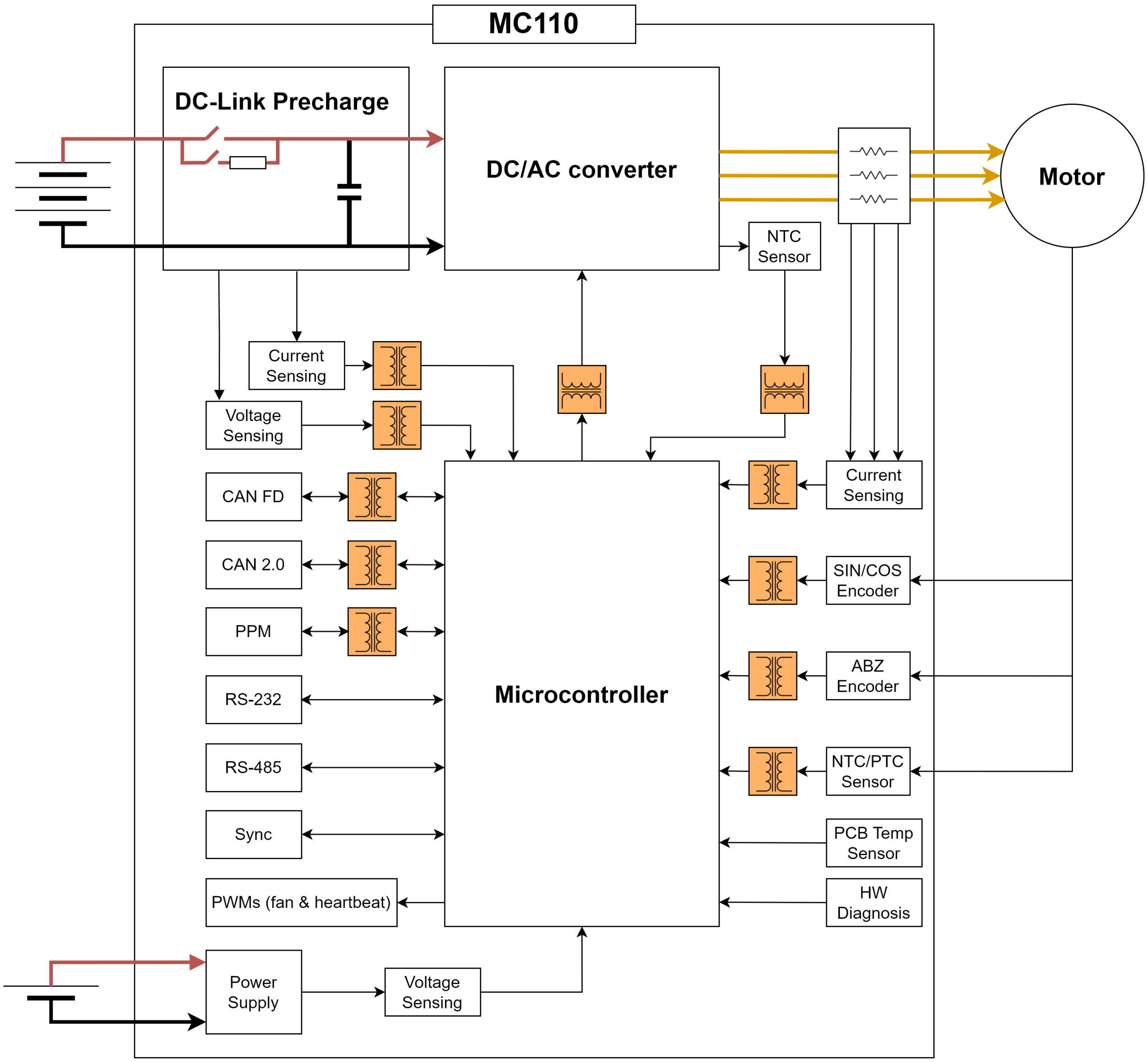
THREE

TECHNICAL

3.1 Main Features

- **Configuration parameters:** for reduced power consumption.

The block diagram of the system is shown below.



Peripheral used for motor control:

- PWM signal, optocupled inside the **MC110**
- CAN bus
- CAN FD bus

Peripheral use for ESC telemetry:

- Serial RS-232
- Serial RS-485

Any of the serial interfaces can be used to configure the internal variables of the **MC110**.

3.2 Mechanical Specifications

- **Weight:** 2680 g
- **Maximum speed (for 1 pair of poles)** 50,000 RPM (depending on the acquisition frequency)
- **Dimensions:**

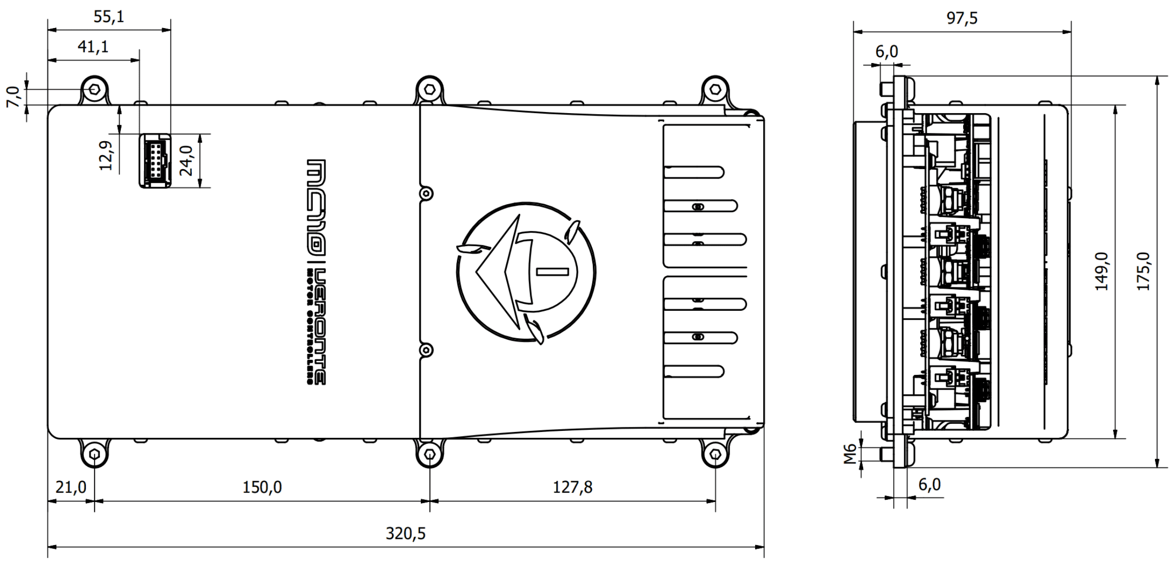


Fig. 1: **Dimensions in mm**

3.3 Electrical Specifications

- **Power:** up to 110 kW *
- **Input current:** 250 A (as long as **MC110** is not overheated by the input power)
- **PWM Frequency:** 5-24 kHz
- **HV range:** 100 V to 800 V
- **LV range:** 8 V to 36 V
- **Minimum temperature:** 30 ºC
- **Maximum temperature:** 150 ºC * (for IGBT module)
- **Regenerative brake:** 60 A maximum
- **Sensorless mode:** MC110 is able to operate with sensorless motors with maximum efficiency.

  The sensorless mode does not require a minimum speed to measure it and operate, as long as **MC110** provides current to the motor phases (since the speed is measured with the current)

> **Note:** Features with * depend on voltage and switching frequency. Read *Maximum continuous current* to know more.

- **Protections:**

  - Protection agains in-rush current when turned on (at low and at high voltage sides)
  - Ground fault detection
  - Protection against overcurrent at power input and phases
- **Sensored motors:**
  - Hall sensors
  - Digital incremental encoders
  - Analog SIN/COS
- **Reverse rotation:** MC110 can operate in any direction of rotation without additional configuration.
- **Configurable:**
  - Type of Observer
  - Programmable acceleration curve
  - Motor direction
  - Overvoltage threshold
  - Overcurrent threshold
  - Overtemperature threshold
  - Max. RPM (limit)
  - Braking force
  - Duty Cycle
- **Communications:**
  - CAN Bus
  - CAN FD Bus
  - PWM optocupled inside the **MC110**
  - RS-232
  - RS-485
- **Redundant control**
- **Telemetry:**
  - Motor & ESC temperature
  - RPM
  - Input voltage
  - Input and output current

3.3.1 Maximum continuous current

The relationship between maximum input current and battery voltage depends on the switching frequency of the DC/AC converter. The following figure shows this relationship for different switching frequencies.

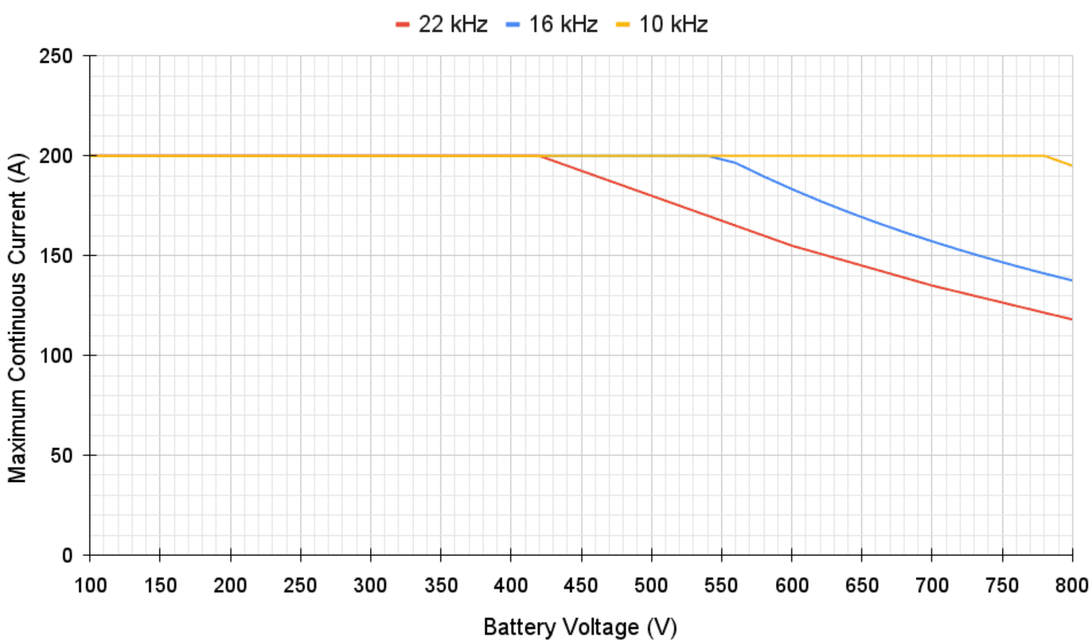


Fig. 2: **Maximum Continuous Current vs Battery Voltage**

3.4 Interfaces

3.4.1 HALL Inputs

Warning: The employed hall sensors must not exceed 5 V.

These inputs are used to add to the system a feedback in sensored mode (incremental type, usually magnetic).

The 3 Hall effect sensors must be placed at 120° (electrical degrees) from each other. The following is a simple formula for obtaining the mechanical degrees of separation when installing the sensors:

$$Electrical\ Degrees = Pole\ Pairs \times Mechanical\ Degrees$$

So the sensors must be placed one of each other at:

$$Mechanical\ Degrees\ () = \frac{120}{Pole\ Pairs}$$

For example, for 10 pole pairs:

$$\frac{120}{Pole\ Pairs} = \frac{120}{10} = 12$$

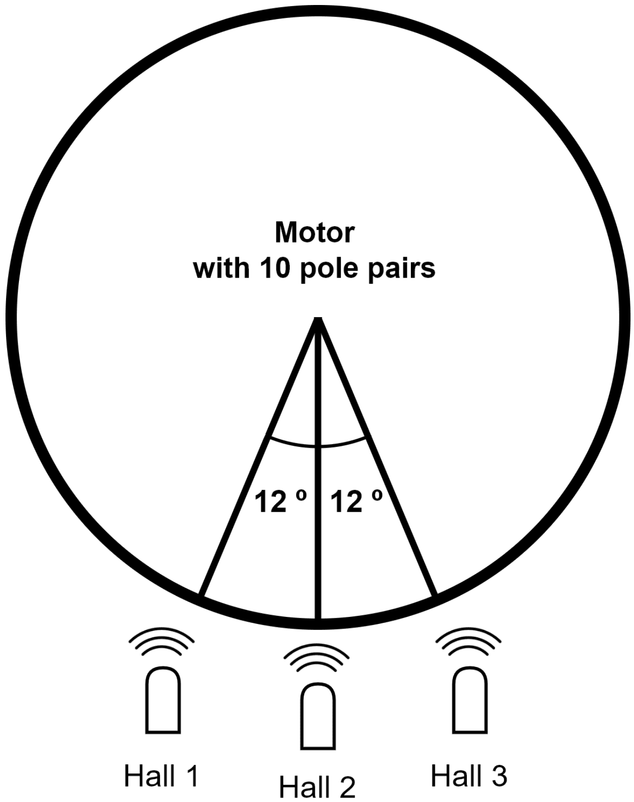


Fig. 3: **Example diagram**

Tip: The arc length between sensors can be calculated as follows:

$$Arc\ Length = \frac{2 \times \pi \times Motor\ Radius \times Mechanical\ Degrees\ ()}{360}$$

3.4.2 FAN_PWM

This Open-Drain output is used to control an external fan if needed. External power for the fan and an aditional pull-up resistor is required. Maximum voltage in this signal is 60 V and 360 mA for maximum sink current. It is important that the GND connection of this supply is the same as the GND connection for the supply of the *control group (user connector)*.

3.4.3 Opto PWM Input

This input is an optocoupled control digital signal.

The input is interpreted as 0-100 % of the maximum RPM. An initial dead band can be configured to prevent the engine from starting.

Table 1: Electrical Characteristics

Type	Specification
Input voltage range	0-5 V
Minimum input current	2.5 mA
Pulse length	1-2 ms
Frequency	40-250 Hz

3.4.4 NTC/PTC Input (External Temperature Sensing)

A PTC or NTC can be integrated.

Warning: The PTC or NTC must not exceed 5 V.

The PTC/NTC should be connected on the low side of an external resistor divider. This is the configuration by default. A high side connection can be used too, but a custom modification is needed.

The isolated Voltage_ref output should be left floating in default mode. The iso_ground is the return path of the NTC/PTC sensor.

3.4.5 SIN/COS_SIGNAL

These signals are those dedicated to the SIN / COS type analog sensor.

Warning: SIN/COS signals must not exceed 5 V.

3.4.6 RS-232

Single ended serial type protocol:

Table 2: Electrical Characteristics

Type	Specification
ESD Protection	±15 kV (HBM)
Requirements	TIA/EIA-232-F and ITU v.28
Speed	Max. 250 kbit/s
Input Voltage	-25 to 25 V
Output Voltage	-13.2 to 13.2 V

3.4.7 RS-485

Differential serial type protocol:

Table 3: Electrical Characteristics

Type	Specification
ESD Protection	±15 kV (HBM)
Requirements	TIA/EIA-485-A
Speed	Max. 25 Mbit/s
Input Voltage(D)	-0.5 to 7 V
Output Voltage (D)	1.5 to 2.4 V

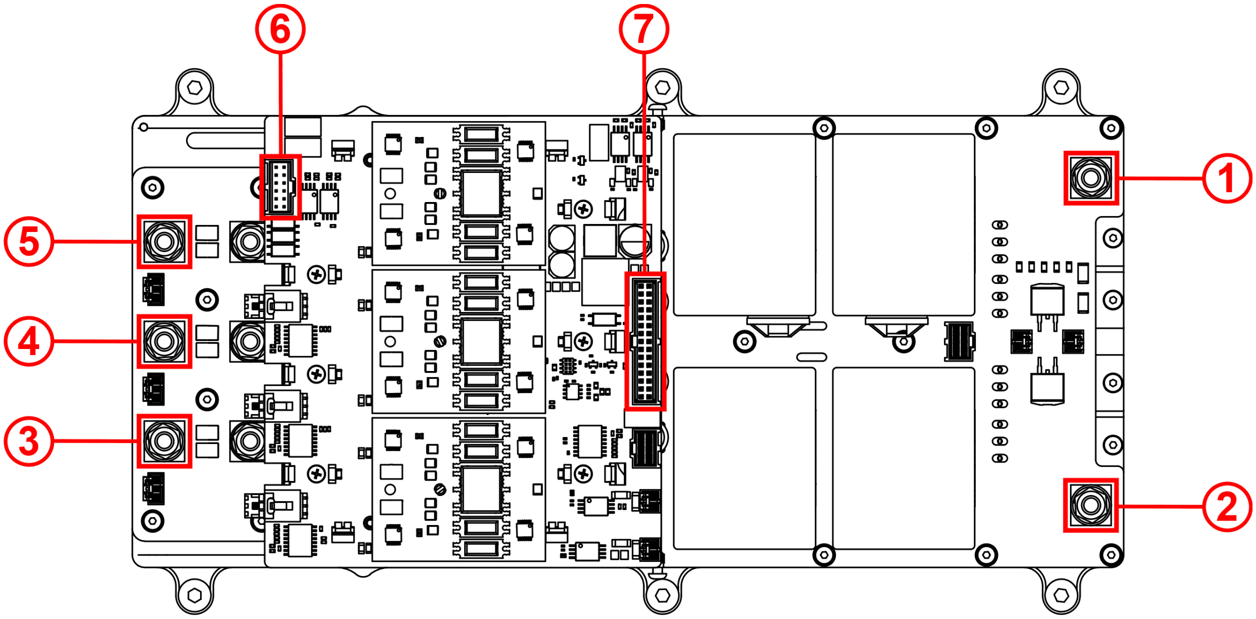
3.4.8 Isolated CAN FD and Isolated CAN 2.0

Differential communication protocol with flexible data rate:

Table 4: Electrical Characteristics

Type	Specification
ESD Protection	±4 kV (HBM)
Requirements	ISO11898-2
Speed	Max. 5 Mbit/s
Max CAN 2.0 Speed	1 Mbit/s
Input Voltage(D)	-12 to 12 V
CAN H Voltage	2.75 to 4.5 V
CAN L Voltage	0.5 to 2.25 V

3.4.9 Mating connectors



Power connectors:

<table>
<tr><th>Number</th><th>Name</th><th>Recommended connector</th></tr>
<tr><td>1</td><td>HV negative</td><td rowspan="5">Tubular cable lugs of Würth with M6.
The recommended reference depends on wire section:
• 10 mm^2: 5580610
• 16 mm^2: 5580616
• 25 mm^2: 5580625
• 35 mm^2: 5580635</td></tr>
<tr><td>2</td><td>HV positive</td></tr>
<tr><td>3</td><td>Phase U</td></tr>
<tr><td>4</td><td>Phase V</td></tr>
<tr><td>5</td><td>Phase W</td></tr>
</table>

Electronic connectors:

<table>
<tr><th>Number</th><th>Name</th><th>Mating connector</th><th>Pin</th><th>Size</th></tr>
<tr><td>6</td><td>Sensor connector</td><td>Molex: 90142-0012</td><td rowspan="2">Molex: 90119-2109</td><td rowspan="2">22AWG to 24AWG</td></tr>
<tr><td>7</td><td>User connector</td><td>Molex: 90142-0030</td></tr>
</table>

CHAPTER

FOUR

HARDWARE INSTALLATION

Danger: The system slowly discharges the voltage on the input terminals when the battery is disconnected. Capacitors may remain charged unless enough time has elapsed.

Note: When working voltage is higher than 60 V, use of insulating gloves are mandatory for installation and the system **must have** a chassis fault detection system.

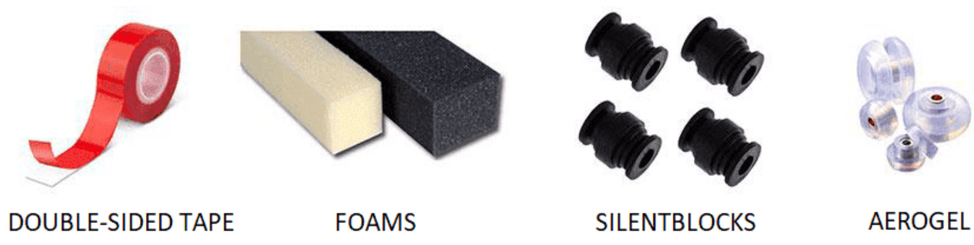
4.1 Mechanical Assembly

To fix the **MC110** to an aircraft frame, take a look to the *dimensions and screws positions*. Screw holes must be deeper than 6 mm with M6.

4.1.1 Vibration Isolation

There might be situations where external isolation components might be needed.

Veronte MC110 can be mounted in different ways in order to reject the airframe vibration. The simplest way CAN be achieved by just using double-sided tape on the bottom side of **MC110**. Other ways may use some external structure which could be rigidly attached to the airframe and softly attached to Veronte (e.g. foam, silent blocks, aerogel, etc).



The user should take into account that wiring should be loose enough so vibrations may not be transmitted to **MC110**.

In cases where mechanical isolation is not viable, it is possible to use soft engine mounts. It is also recommended when there are other sensible payloads like video cameras or for high vibration engines.

4.2 ESC-Motor Wiring

Warning: The polarity connection of the input must be respected, otherwise a short circuit may occur.

The Sensor Connector is easily accesible, but to access the User Connector it is necessary to unscrew the cover from both sides and pull it up.

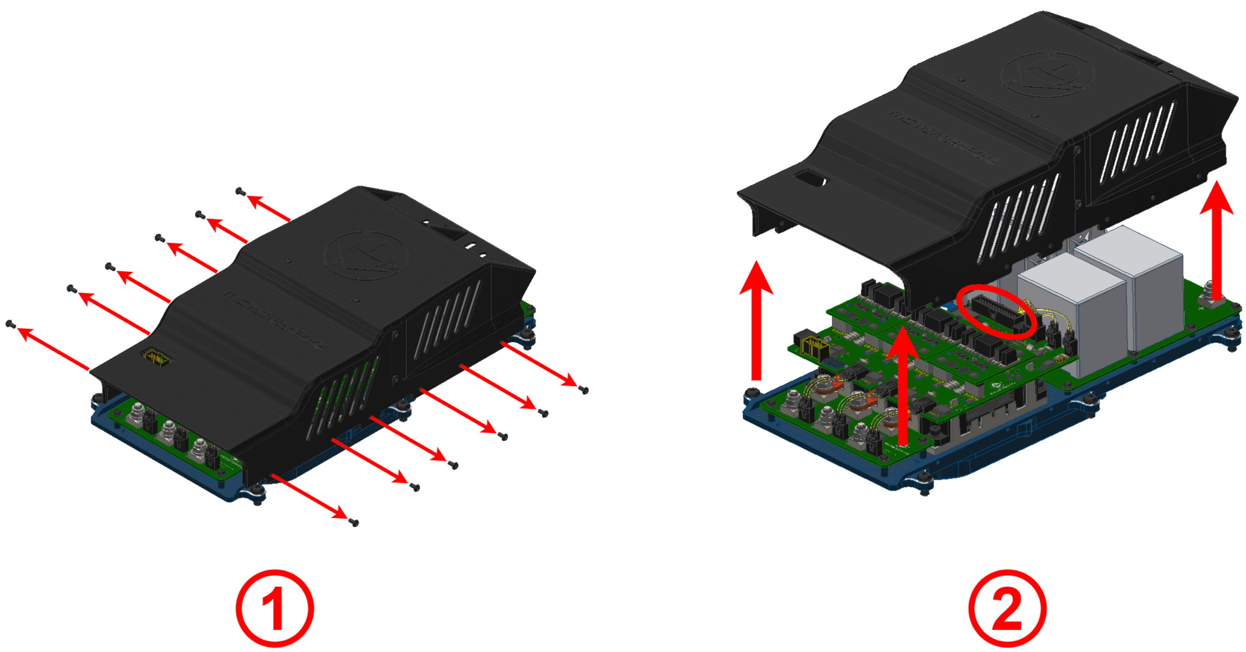
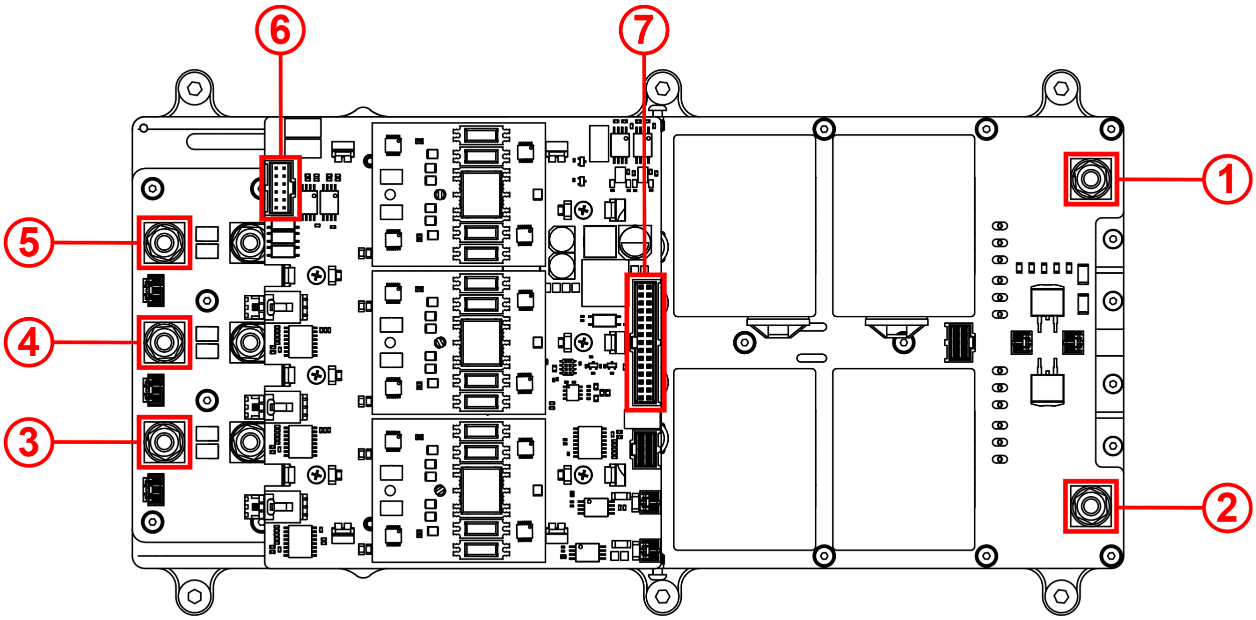


Fig. 1: **How to access the user connector**

The polarity and connections are indicated in the following image and table.



Nº	Name	Description
1	HV negative	Input power from DC current
2	HV positive	100 to 800 V DC
3	Phase U	Output power to motor
4	Phase V	
5	Phase W	
6	Sensor connector	Encoders and sensor temperature signals
7	User connector	Communications, telemetry and control signals

The section of the cables must be dimensioned according to the maximum power that will be used

Battery cables between MC and battery should be as short as possible. If the distance between battery and motor is long, please extend phase cables in order to shorten battery cables.

Tip: Connection of the phases can be done freely, however, it will affect the direction of rotation of the motor. Hence, if the motor is spinning in the opposite direction, switch any 2 phases around.

4.3 Pinouts

4.3.1 User Connector

The user connector pinout is shown in the following figure and table:

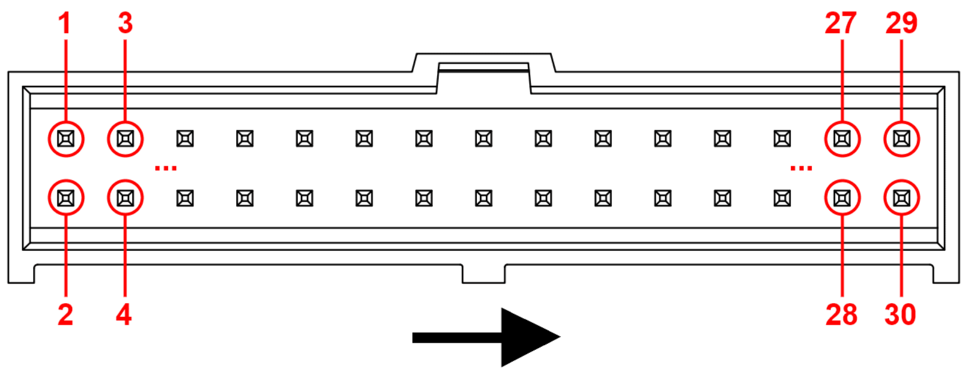


Fig. 2: **Pin numbers of user connector**

User connector					
Nº	Name	Description	Nº	Name	Description
1	SYNC_ID_IN	Input Signal for Sync Identification *	2	SYNC_ID_OUT	Output Signal for Sync Identification *
3	GND	Ground	4	GND	Ground
5	SYNC_OUT *	Output PWM to synchronize multiple MC110 units	6	SYNC_IN *	Input PWM to synchronize multiple MC110 units
7	GND	Ground	8	RS232_TX	RS-232 transmitter
9	OUT_485_P	RS-485 output positive	10	RS232_RX	RS-232 receiver
11	OUT_485_N	RS-485 output negative	12	FAN_PWM	Digital PWM output for fan control
13	IN_485_N	RS-485 input negative	14	HEARTBEAT	Error diagnosis signal
15	IN_485_P	RS-485 input positive	16	GND_485	Ground for RS-485
17	OPTO_PWM	Digital Input for motor speed. Optocupled inside MC110	18	OPTO_RTN	Return of pin 17
19	CANFD_N	CAN FD negative pin	20	CANFD_P	CAN FD positive pin
21			22		
23	GND_CAN **	Isolated ground for CAN	24	GND_CAN **	Isolated ground for CAN
25	CANB_N	CAN B negative pin	26	CANB_P	CAN B positive pin
27			28		
29	GND	Ground	30	VCC	Digital power supply 8 - 36 V

* :Synchronization between MC110s optimizes battery management.

** :Ground for CAN is not necessary, but it can be used in case of having issues with CAN signals.

4.3.2 Sensor Connector

The sensors connector pinout is shown in the following figure and table:

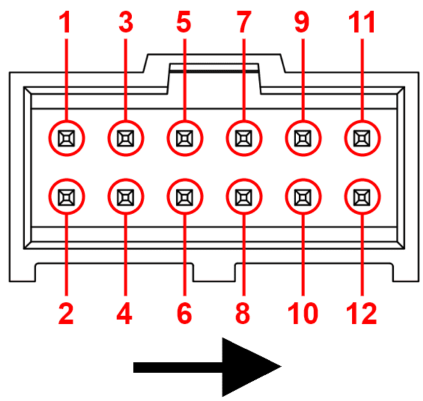
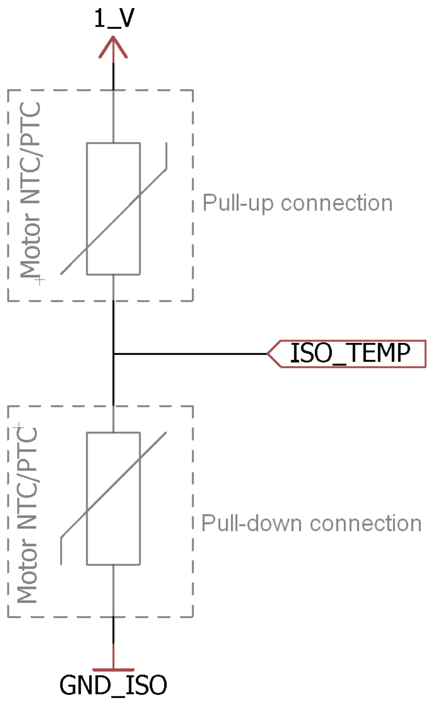


Fig. 3: **Pin numbers of sensor connector**

Sensor connector					
Nº	Name	Description	Nº	Name	Description
1	ENC_SIN	Sine input from encoder	2	ENC_COS	Cosine input from encoder
3	GND_ISO	Isolated ground	4	5_V_HALL	Isolated 5 V
5	ENC_A *	Encoder A	6		
7	ENC_B *	Encoder B	8	ENC_Z *	Encoder Z
9	GND_ISO	Isolated ground	10	ISO_TEMP	External temperature sensor measurement
11			12	1_V	Power supply for external temperature sensor (1 V)

* These inputs are digital, incremental and optocupled inside MC110.

If the temperature sensor is connected as a pull-up resistor, pin `1_V` (12) will be the voltage reference. If the temperature sensor is connected as a pull-down resistor, pin `GND_ISO` (3, 9 or 11) will be the voltage reference.



4.4 How to Turn On and Off

MC110 has two electric circuits: **control** and **power**. To turn on the voltage supply (with devices such as switches, relays or MOSFETs), it is mandatory to do it with the following order: first of all the **control** group, and then the **power** group.

The **control** group is in the user cable. The power circuit is in the negative and positive cables. Then the enabling order is summarized in the following figure:

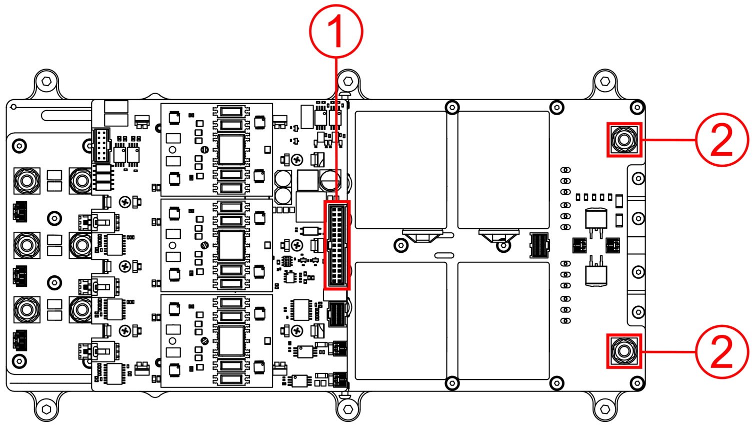


Fig. 4: **Turn on order**

To turn off the **MC110**, the disabling order is reversed: first power circuit (input negative and positive), then the control circuit (user cable).

4.5 Electrical Diagram of CAN Bus

Like any other CAN device, **Veronte MC110** requires a termination resistor to allow the connection of multiple **MC110s** or other CAN bus devices to the same line.

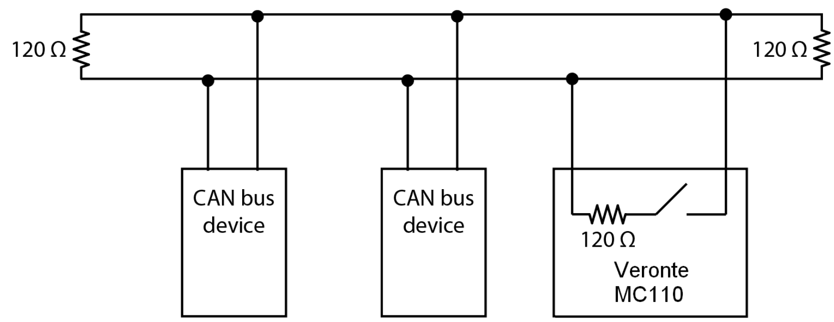


Fig. 5: **Typical CAN diagram**

Considering **Veronte Autopilot** includes one entrance resistor of 120 Ω, a second resistor needs to be placed at the end of the line (120 Ω). This resistor may be placed on the cable or on another PCB.

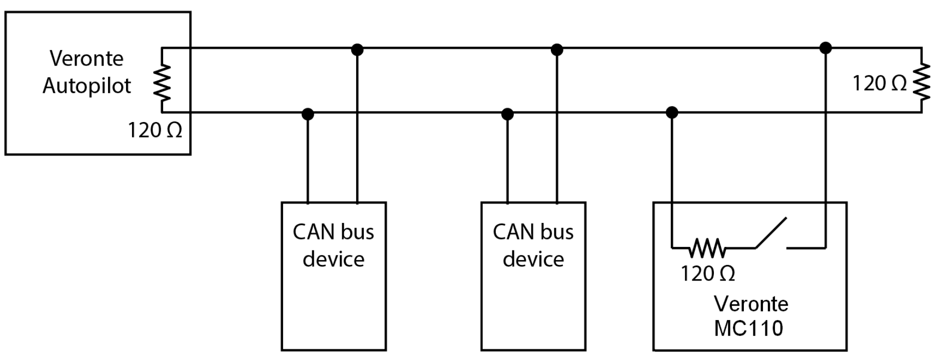


Fig. 6: **CAN diagram with Veronte Autopilot**

MC110 has an internal resistor of 120 Ω, which can be activated by software. Then, another way to connect multiple CAN bus devices lies in connecting a **MC110** to the end of line, then activating its internal CAN resistor. Read Configuration -> Mailboxes section of **MC110 PDI Builder** manual to enable or disable the resistor.

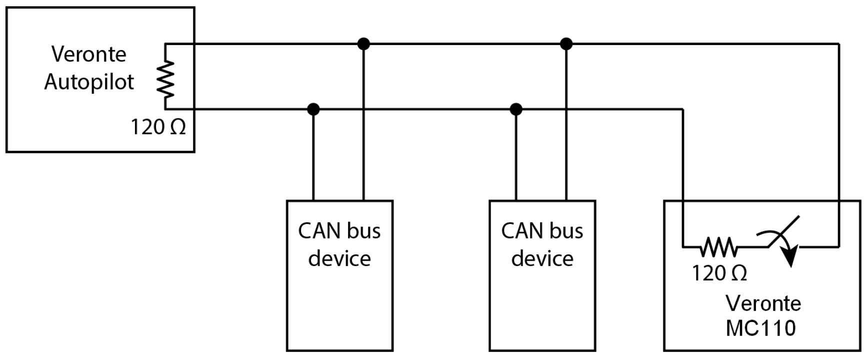


Fig. 7: **Diagram with CAN resistor activated**

4.6 Cooling Circuit Design

Warning: Do not place the **MC110** or its cooling circuit close to another heat source, since it would be counterproductive for the refrigeration, compromising its performance and safety.

Note: The following explanations assume there are not phase changes on the coolant, since it is not necessary to use a refrigeration system with phase changes.

MC110 is able to control motors up to 110 kW due to liquid refrigeration systems. The motor controller only includes the cold plate, requiring the rest of the refrigeration system (pump, pipes, radiator, expansion tank and coolant).

This manual explains two ways to design a cooling circuit, click on the desired one:

- *Simplified*. For one MC110 with a specific type of cooling circuit.
- *Advanced*. Generic indications to design a completely custom application.

4.6.1 Simplified Cooling Circuit Design

This subsection explains how to size a specific layout of cooling design, so the user does not have to calculate any parameters. This layout is intended for one single **MC110**. In case of desiring to use a different layout or to refrigerate multiple controllers with a single circuit, read the *Advanced Cooling Circuit Design*.

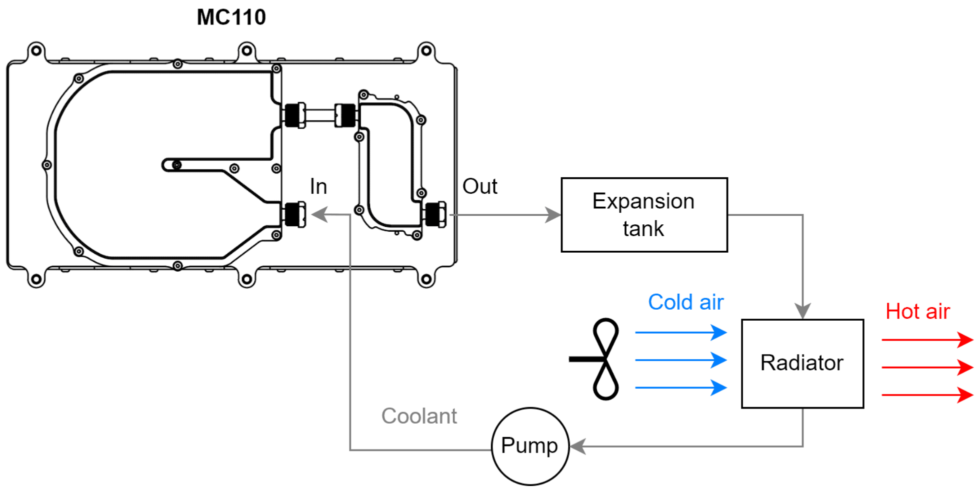


Fig. 8: **Basic diagram of cooling circuit**

Each cooling element must accomplish the following requirements:

- **Pump**
  - Flow rate: 6 l/min.
  - Minimum pressure: 0.5 bar.
  - Activity: always on (while **MC110** is on).
- **Pipes connected to cold plate**
  - Water-glicol resistant
  - Able to join with the following ports:

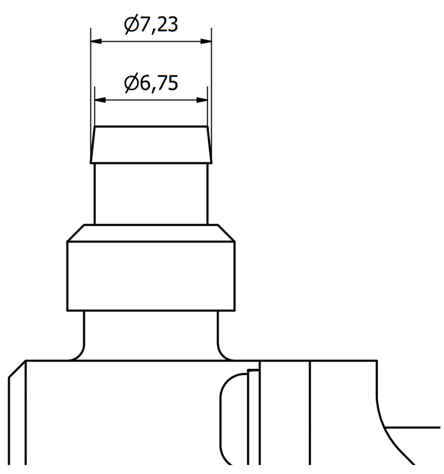


Fig. 9: **Port diamaters (mm)**

Tip: For cold plate connections, it is recommended to use fluoropolymer tubing with 8 mm of outside diameter and 6 mm of internal diameter.

- **Coolant**
  - Mixture water-glycol at 50 %, in order to have a freezing temperature below operating conditions.
- **Radiator**

Radiator thermal conductivity (which is related to size) depends on motor power, switching frequency and battery voltage. Depending on each situation, the following tables show the minimum heat transfer of the required radiator.

Heat transfer for 10 kHz switching frequency (W/ºC)			
Motor power (kW)	Battery voltage		
	800 V	550 V	100 V
15	50	50	150
30	100	100	*
45	100	1050	*
60	150	150	*
75	150	200	*
95	200	200	*
110	200	200	*

Heat transfer for 16 kHz switching frequency (W/ºC)			
Motor power (kW)	Battery voltage		
	800 V	550 V	100 V
15	50	50	150
30	100	100	*
45	150	150	*
60	150	150	*
75	200	200	*
95	200	200	*
110	250	250	*

Heat transfer for 22 kHz switching frequency (W/ºC)			
Motor power (kW)	Battery voltage		
	800 V	550 V	100 V
15	100	100	150
30	100	150	*
45	150	150	*
60	200	200	*
75	200	200	*
95	250	*	*
110	*	*	*

Warning: *: These situations involve an intensity higher to 250 A or overheating.

Tip:

- The generated heat by the **MC110** increases with switching frequency and motor power. But it decreases with battery voltage.
- Be careful with the change of tube sections. If the coolant transitions from a small to a large section, air bubbles may remain.

4.6.2 Advanced Cooling Circuit Design

The power electronics of the **MC110** will produce heat and its temperature will increase. To prevent overheating, the heat will be absorbed by a liquid coolant according to the following equation:

$Q = m \cdot c \cdot (T_{out} - T_{in})$

- Q: heat produced by one single **MC110**.
- m: coolant mass flow.
- c: coolant specific heat.
- T_{out}: temperature of the coolant at the output of the coldplate and at the input of the radiator.
- T_{in}: temperature of the coolant at the input of the coldplate.

Q is assumed to be completely absorbed by the coolant, this assumption is considering the worst case scenario (adiabatic environment, which does not help at all).

The value of Q depends strongly on the switching frequency, input voltage (from battery) and motor power (hence intensity consumption). It can be obtained from the following tables, which assume an input coolant of water at 30 ºC (T_{in}) and 6 l/min:

Q for 10 kHz switching frequency (W)			
Motor power (kW)	Battery voltage		
	800 V	550 V	100 V
15	200	250	950
30	400	450	*
45	600	750	*
60	850	1000	*
75	1100	1350	*
95	1350	1700	*
110	1750	2200	*

Q for 16 kHz switching frequency (W)			
Motor power (kW)	Battery voltage		
	800 V	550 V	100 V
15	300	300	1000
30	550	600	*
45	850	950	*
60	1150	1300	*
75	1500	1750	*
95	2050	2250	*
110	2550	3000	*

Q for 22 kHz switching frequency (W)			
Motor power (kW)	Battery voltage		
	800 V	550 V	100 V
15	350	350	1050
30	700	750	*
45	1100	1200	*
60	1550	1650	*
75	2050	2250	*
95	2650	*	*
110	*	*	*

Warning: *: These situations involve an intensity higher to 250 A or overheating.

Once the heat transfer has been defined, the radiator can be chosen according to the required heat transfer capacity. Considering that each radiator dissipates the heat of several motor controllers.

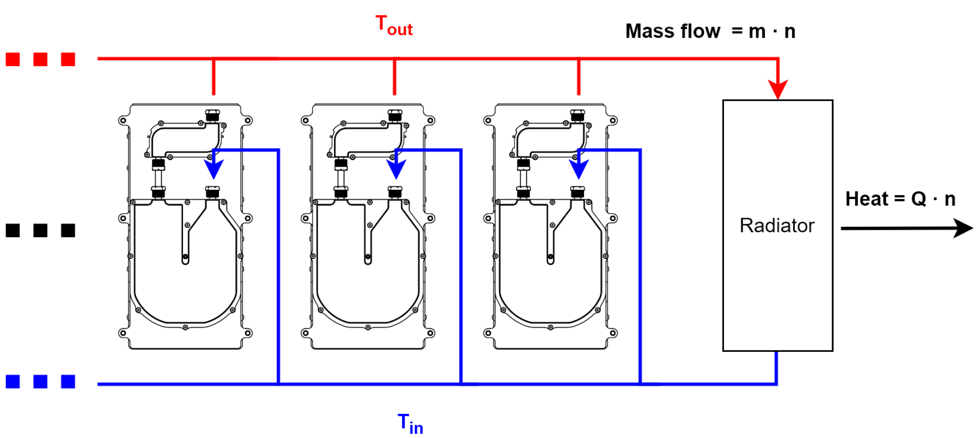


Fig. 10: **Simplified diagram for multiple controllers**

$H = Q \cdot n/(T_{out} - T_{amb})$

- H: heat transfer capacity.
- n: number of motor controllers for the radiator.
- T_{amb}: ambient temperature.

$H = \frac{Q \cdot n}{T_{in} + Q/(m \cdot c) - T_{amb}}$

Applying the previous equation to one **MC110** obtains the tables of the *Simplified Cooling Circuit Design*.

CHAPTER

FIVE

SOFTWARE INSTALLATION

In order to configure **Veronte MC110**, connect it to a computer via USB (through an RS232/485-USB converter) with the harness cable.

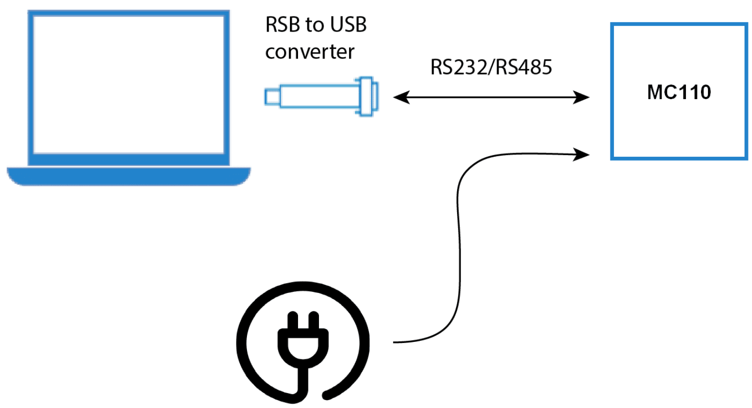


Fig. 1: **Serial connection**

Then, to install the required software and configure **MC110**, read its software manual.

CHAPTER SIX

MAINTENANCE

Once a year, the coolant should be replaced with new one, to ensure it works properly.

In order to clean **Veronte MC110** properly follow the next recommendations.

- Turn off the device before cleaning.
- Use a clean, soft, damp cloth to clean the unit.
- Do not immerse the unit in water to clean it.

CHAPTER

SEVEN

TROUBLESHOOTING

7.1 How to confirm that the MC110 is able to read a PWM signal

Warning: For safety reasons, it is better to do this test without the motor connected or powered.

Power up the controller via user cable, without connecting the motor or the input power. If the input command is higher than the deadband, the MC will start to control (even though there is no motor connected). Then, a noise of 16 kHz will sound due to the PWM switching. If the input command is reduced to below the deadband, the MC and its noise will stop.

CHAPTER

EIGHT

FAQ

8.1 Is it possible to use a standard PWM servo tester to control the MC110?

MC110 is thought to be controlled via CAN. PWM signal should be used for testing purposes. In case to desire using a transmitter, connect a receiver and use just one control channel (just one PWM signal).

CHAPTER

NINE

ACRONYMS AND DEFINITIONS

ATP	Acceptance Test Report
CAN	Controller Area Network
CAN FD	Controller Area Network Flexible Data-Rate
COC	Certificate Of Compliance
COM	COMmunications
ESC	Electronic Speed Control
ESD	ElectroStatic Discharge
ESS	Environmental Stress Screening
eVTOL	electric Vertical Take-Off and Landing
FAQ	Frequently Asked Questions
FOC	Field Oriented Control
GND	Electrical Ground
HBM	Human Body Model
HV	High Voltage Range
IGBT	Insulated Gate Bipolar Transistor
LV	Low Voltage Range
MC	Motor Controller
MTBF	Mean Time Between Failure
NTC	Negative Temperature Coefficient thermistor
OPTO PWM	OPTO-coupled PWM
PMSM	Permanent Magnet Synchronous Motor
PTC	Positive Temperature Coefficient thermistor
PWM	Pulse Width Modulation signal
RPM	Revolutions Per Minute
RS-232	Recommended standard 232
RS-485	Recommended standard 485
SIN/COS	Sine/Cosine
SN	Serial Number
UAV	Unmanned Aerial Vehicle
VCC	Voltage Continuous Current
VDC	Voltage Direct Current

CHAPTER TEN

CONTACT DATA

You can contact Embention if you need further help and support.

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