DTI HIGH POWER INVERTER

User manual for HV-550/HV-850

Version 1.2

Valid for REV. 4 Inverters

Please read the user manual carefully before using the controller. Electrical systems can cause danger to humans, property and nature; therefore, precautions shall be taken to avoid any risk.

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1. HISTORY AND RELATED DOCUMENTS

1.1 Document history

10/2022	**V1.0** Document created; basic specifications added.
12/2022	**V1.2** AC Characteristics table correction

1.2 Related documents

- DTI CAN manual 2.3
- DTI CAN manual 2.4
- DTI Firmware update manual
- DTI Resolver interface manual
- DTI Encoder splitter manual
- DTI COM manual
- SurLok Connector manuals

2. LIABILITY AND SAFE USE OF THIS UNIT

DTI hardware, DTI CAN Tool and the DTI firmware are experimental products designed to develop, evaluate and test electrical systems incorporating electric motors or actuators. Electrical systems can cause danger to humans, property and nature; therefore, precautions shall be taken to avoid any risk. Under no circumstances shall the device be used where humans or property are put to risk without thoroughly validating and testing the whole system. Software and hardware interact in various ways, and developers cannot foresee all possible combinations of hardware used together with software, nor problems that can occur in these different combinations. Can Tool and the DTI firmware are experimental software designed to develop and test. Electrical systems can cause danger to humans, property and nature; therefore, precautions shall be taken to avoid any risk.

Only trained and educated personnel are authorized to configure, integrate and operate the device who know the potential risks, and can act in case of any misbehavior, or fault that occours.

The integrator has the responsibility to select the proper hardware components for the specific use-case. DTI takes no responsibility for any issues, problems, failed examinations, failed registration procedures or evaluations due to inappropriate configuration, system design or general system structure or lacking documents, certifications for the specific area-of use.

Things that can happen, even when using the correct settings, are

- electrical failure
- fire
- electric shock
- hazardous smoke
- overheating motors and actuators
- overloaded power sources, causing fire or explosions (e.g., Lithium-Ion Batteries)
- motors or actuators stopping from spinning/moving
- motors or actuators locking in, acting like a brake (full stop)
- motors or actuators losing control over torque production (uncontrolled acceleration or braking)
- interferences with other systems
- other non-intended or unforeseeable behaviour of the system

DTI CAN Tool and the DTI firmware are developer software that for safety reasons may only be used

- by experts and experienced users, knowing exactly what they do.
- following safety standards applicable in the area of usage.
- under safe conditions where software or hardware malfunction will not lead to death, injuries or severe property damage.
- keeping in mind that software and hardware failures can happen. We can't provide any kinds of warranty because every system is unique and we cannot make sure its safety and integrity. Although we design our products to minimize such issues, you should always operate with the understanding that a failure can occur any time without warning. As such, you shall take the appropriate precautions to minimize danger in case of failure.

Each and every inverter is being tested as a part of the manufacturing progress. DTI assumes no liability in case a customer uses system components for the purposes that they have not been developed for or tested.

DTI reserves the right to change any information within the scope of this whole manual. All connection circuitry described is meant for reference only, are theoretical circuits and not mandatory. DTI does not assume any liability, expressively or inherently, for the information contained in this document, for the functioning of the device or its suitability for any specific application.

2.1 Discharge

Each Controllers are equipped with internal discharge resistors for improved safety. The discharge time for the inverter's internal capacitors is **5 minutes**. The discharge resistance is **188kΩ.**

> The inverter's internal discharge circuit is a safety feature, and it is not meant to replace the system discharge circuitry.

> The minimum wait time before disconnecting the HV cables from the inverters is 5 minutes after powering off the High voltage. In case the safety time frame is not kept correctly, the charged DC capacitor's voltage can be a source of a potential electric shock which can be dangerous or even lethal.

3. WARNING SIGN EXPLAINED

The Warning sign contains the most important safety notices that has to be taken into consideration by everyone who approaches the inverter. The sign cannot be removed or covered off he controller.

In case of the sign is being damaged, or detached from the inverter, please get in touch with DTI as soon as possible at the availability mentioned on the cover page.

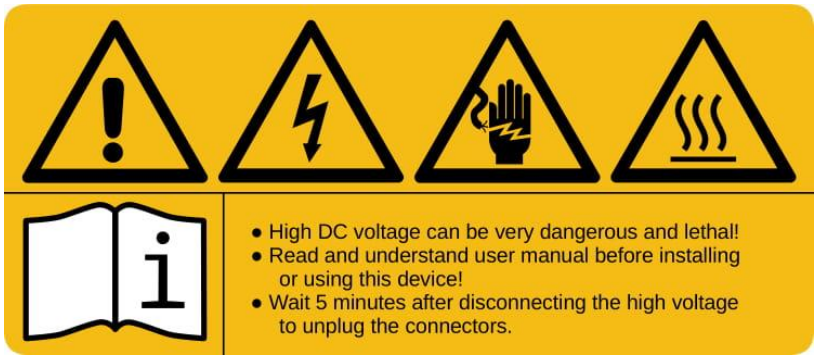
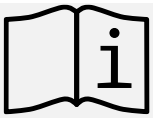


Figure 1. Safety note

Table 1. Safety notes explained

Description	
	Please read this manual carefully, with particular regard to safety notes.
	**Danger of electric shock** Touching HV wires and HV connectors are prohibited without ensuring that the HV is disconnected.
	**Danger of high voltage** The device is attached to high voltage.
	**Danger of hot surfaces** The inverter case, and /or the coolant fluid can get hot during and after operation, touching any of these can cause burn damage.
	**General Warning** Only trained and educated personnel can do integration and maintenance.

4. OVERVIEW

Key Features

- 50-800V power stage input range
- 9-28V logic stage input range
- 388/600 Arms current rating
- Up to 100.000 eRPM motor speed
- Multiple controlling peripherals
- Analog input
- CAN (ISO 11898-2)
- Multiple controlling methods
- Current (Torque) mode
- Speed control mode (eRPM)
- Duty Cycle control mode
- FOC motor control
- 8-14kHz Switching frequency using central aligned PWM
- Regenerative braking, generator mode
- Motor angle positioning
- SSI, ABI, Resolver or HALL Sensor support
- Hardware and software overvoltage, overcurrent protections
- Undervoltage protection and limitation
- Power stage and Motor temperature protection and limitation
- Motor Speed limitation
- Motor Power limitation
- Position sensor error sensing
- AC and DC current limitation
- Configurable APPS/TPS support
- Double redundant APPS/TPS support
- Configurable APPS/TPS characteristics
- Configurable reverse characteristics
- Configurable digital Inputs (i.e., Inverter enable, reverse switch, etc, custom drive mode triggering)
- Configurable digital Outputs (i.e., RPM output for VDO instruments, Error output, limiting feedback)
- Auto-Tune for motor position sensors
- Universal PMSM motor support
- Pre-sets for all EMRAX motors
- Dual inverter configuration support for 2xUVW or TWIN motors using DTI Encoder Splitter

Application

- Prototype cars, motorcycles, vehicles
- Boats, and other watercrafts
- Battery powered machines

Description

The DTI HV-550/HV-850 is a universal PMSM motor controller rated for up to 800Vdc battery voltage and 388/ 600Arms current.

The inverter introduces an easy-to configure lightweight solution for multiple use-cases, for example vehicles, watercraft, and battery-powered machines. Numerous limiting and protection features have been implemented for improved safety.

4.1 Nameplate explained

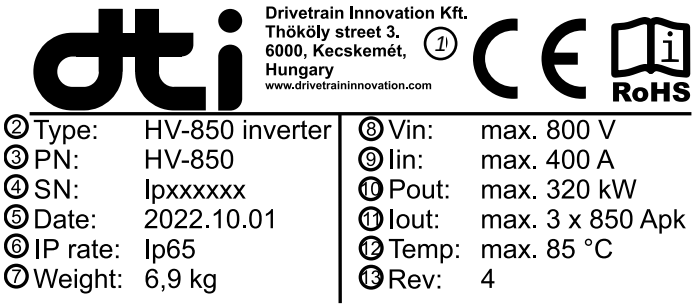


Figure 2. Nameplate

Table 2. HV-550/HV-850 Nameplate explained

No.	Description	No.	Description
1.	Manufacturer information	8.	Input voltage rating
2.	Inverter Type	9.	Input DC current rating
3.	Part Number	10.	Maximum Power output
4.	Serial Number	11.	Maximum Peak Current
5.	Manufacturing date	12.	Maximum working temperature
6.	IP Protection rating	13.	Revision number
7.	Product net weight		

4.2 Technical specifications

4.2.1 DC characteristics

Table 3. DC Characteristics

	HV-550	HV-850	Unit
Low voltage input range	9 – 28		V
Low voltage maximum input current	2		A
Maximum voltage on digital outputs	28		V
Maximum current on digital outputs	240		mA
Maximum input voltage on digital inputs	28		V
Logical LOW voltage on digital inputs	≤ 1		V
Logical HIGH voltage on digital inputs	≥ 2		V
High voltage input range	30 – 800		V
High voltage absolute maximum input voltage	830		V
High voltage maximum input current	280	400	A
DC link capacitor	200		µF
DC link capacitor internal discharge time	5		Min

4.2.2 AC characteristics

Table 4. AC Characteristics

	HV-550	HV-850	Unit
Continuous AC current at $400V_{DC}$[1]	550	850	A_{pk}
Continuous AC current at $800V_{DC}$[2]	516	516	A_{pk}
Maximum AC current for short period (peak current)[3]	550	850	A_{pk}
Maximum AC current for short period (RMS)[4]	390	600	A_{RMS}
Switching frequency	8 – 14		kHz
Maximum power dissipation	4500	5600	W
Maximum electric RPM[5]	100 000		eRPM
Typical efficiency	95		%

Continuous/Peak current measurement conditions:

- 400 Hz output frequency
- 8 kHz switching frequency
- 25°C water inlet temperature
- 25°C ambient temperature
- Peak AC current measurement at $700V_{DC}$ input voltage

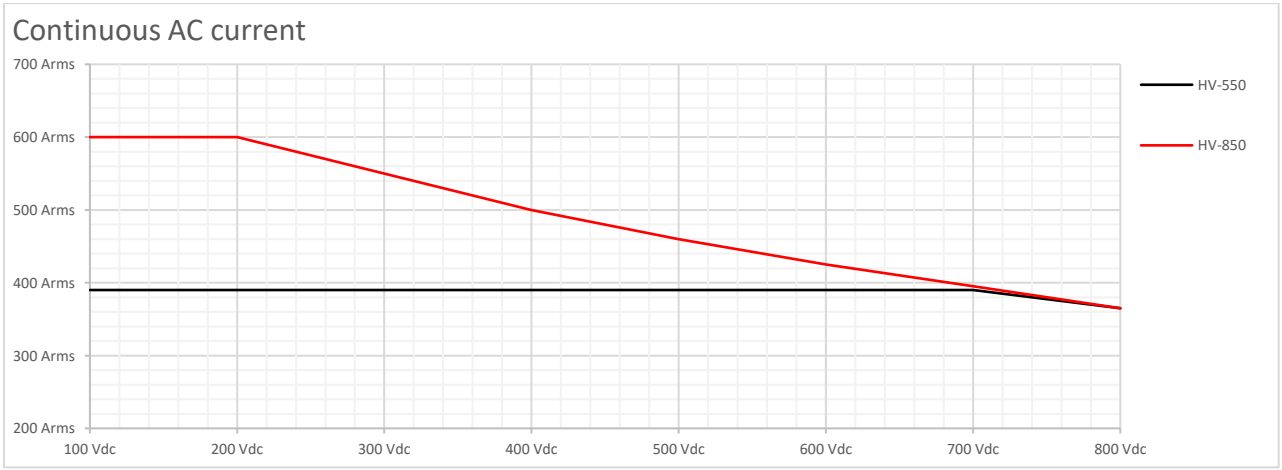


Figure 3 Continuous current measurement

[1] The continuous AC current can only be delivered if the cooling system conditions are match the description of the user manual.
[2] The continuous AC current can only be delivered if the cooling system conditions are match the description of the user manual.
[3] The maximum AC current period is depending on the cooling system.
[4] The maximum AC current period is depending on the cooling system.
[5] 100 000 ERPM means 10 000 RPM on a 10-pole pair motor

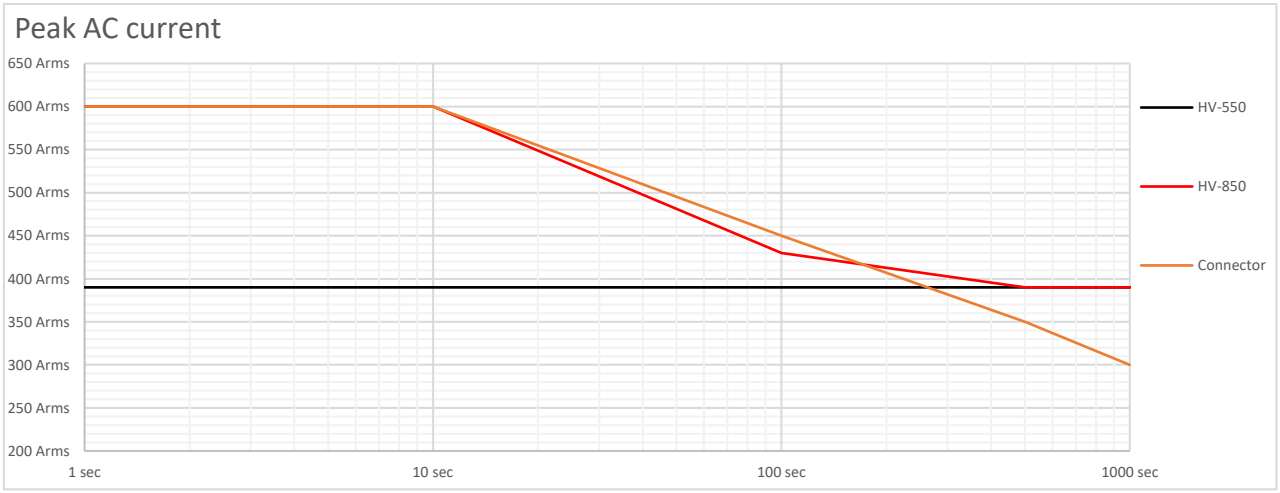


Figure 4. Peak current duration time

Peak current load cycle can be repeated any number of times after a cool-down phase.

5. THERMAL AND MECHANICAL SPECIFICATION

Table 5. Thermal and mechanical specifications

	HV-550/HV-850	Unit
Dimensions (h/w/l)	77/213/420	mm
Weight	6,8	kg
Working temperature	-20-85	°C
Storage temperature	-20-85	°C
IP Protection	IP65	
Coolant quantity in device	0,1	L
Maximum coolant temperature at input	60	°C
Required coolant flow for best continuous current	25,3	L/m
Required coolant pressure for continuous current	1,25	bar
Max coolant pressure	2	bar
Liquid tube connection outer diameter	14	mm

6. LIQUID COOLING PARAMETERS

Table 6. Liquid cooling connection

	Value	Unit
Liquid tube connection outer diameter	**14**	mm
Pipe material	**Aluminium**	
Thermal resistance (at 17,2 L/min)	**0,017**	K/W
Maximum pressure:	**2***	bar
Coolant flow	25,3	Litre/Min
Compatible coolant	**Glycol – Distillate water mixture**	
Coolant dilution ratio	Follow the glycol's directions	
Amount of coolant within the inverter	0,1	Litre

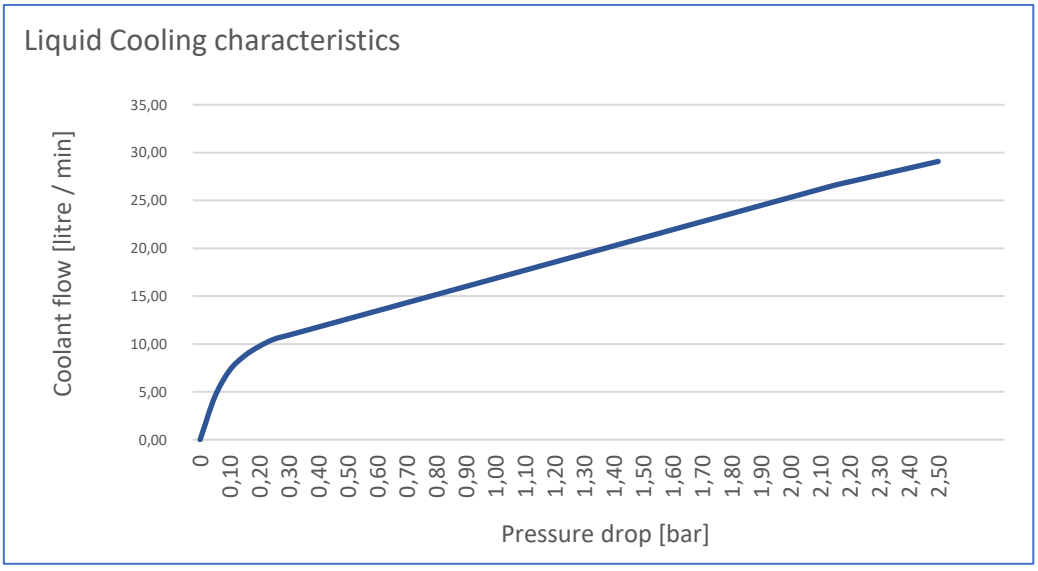


Figure 5. Cooling plate pressure drop per coolant flow ratio

*Cooling plate test pressure: 6 bar.

7. POWER LOSSES

The dissipated power depends on:

- PWM switching frequency
- AC frequency (motor rotation frequency)
- AC current
- DC voltage

The calculation of the total power dissipation is shown here:

Table 7. Power losses

AC current / DC voltage	100 Arms	200 Arms	300 Arms	400 Arms	500 Arms	600 Arms
200 Vdc	261 W	552 W	894 W	1300 W	1740 W	2250 W
400 Vdc	384 W	783 W	1233 W	1750 W	2300 W	2900 W
600 Vdc	513 W	1020 W	1584 W	2200 W	2900 W	3650 W
800 Vdc	642 W	1260 W	1956 W	2740 W	3550 W	4500 W

The values represented by a graph:

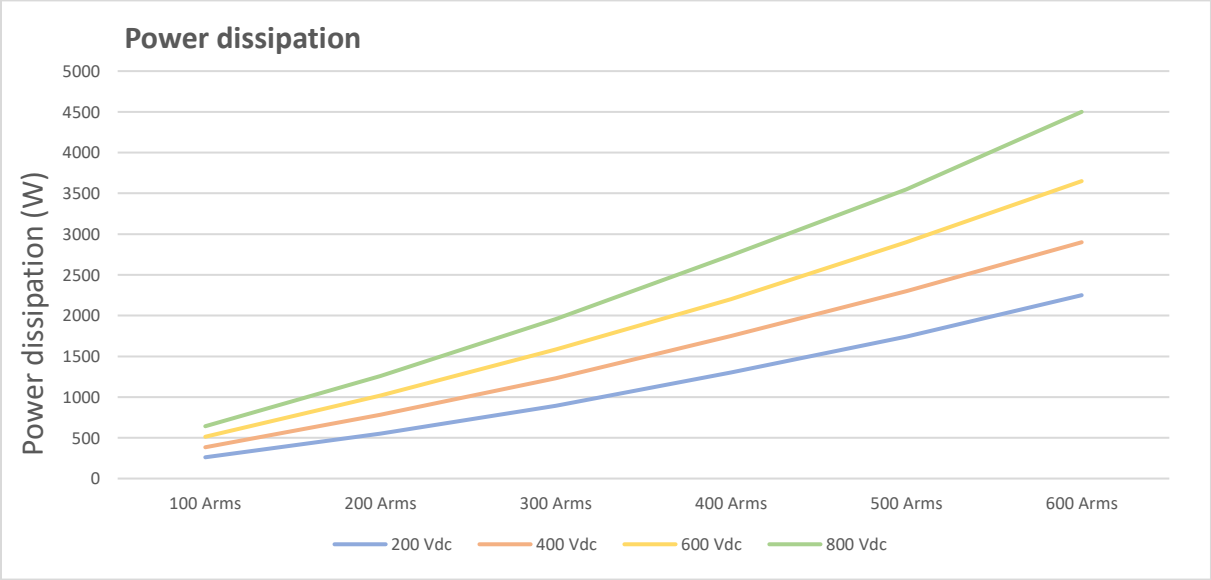


Figure 6. Power dissipation

Calculated at 330 Hz (~2000 RPM with EMRAX) AC frequency and with 10.000 Hz switching frequency. Heatsink temperature is 30°C. The calculation based on the semiconductor manufacturer recommendation

8. MECHANICAL DRAWINGS

Dimensions are shown in mm.

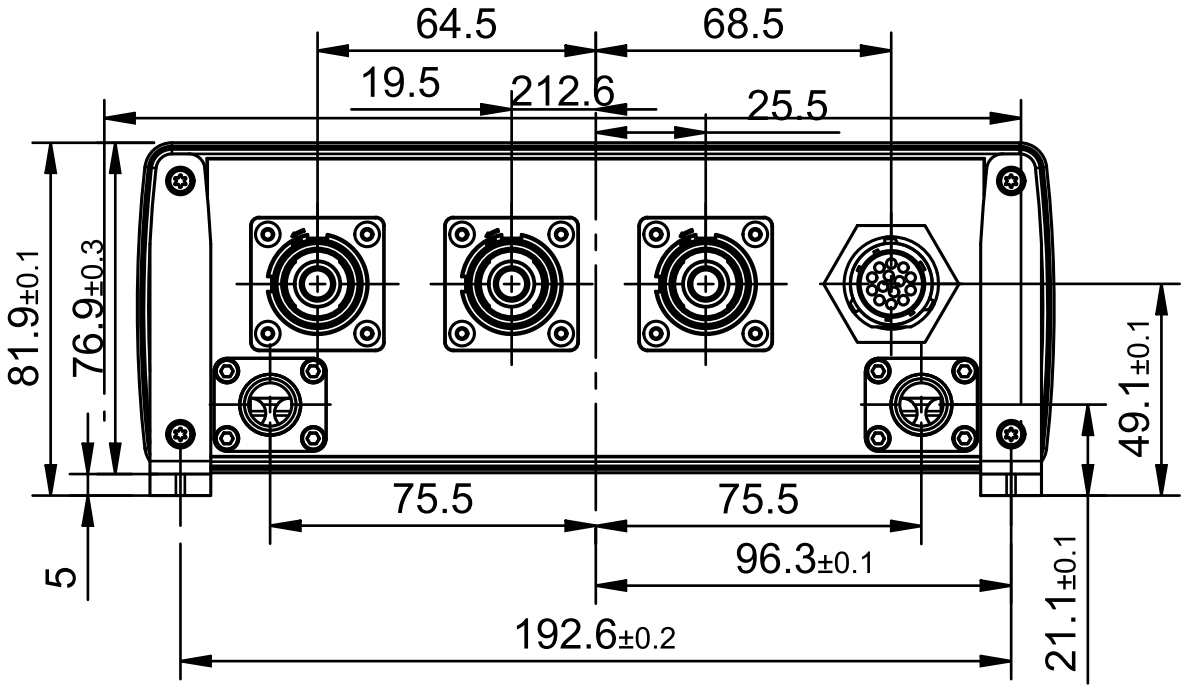


Figure 7. Endplate mechanical drawing

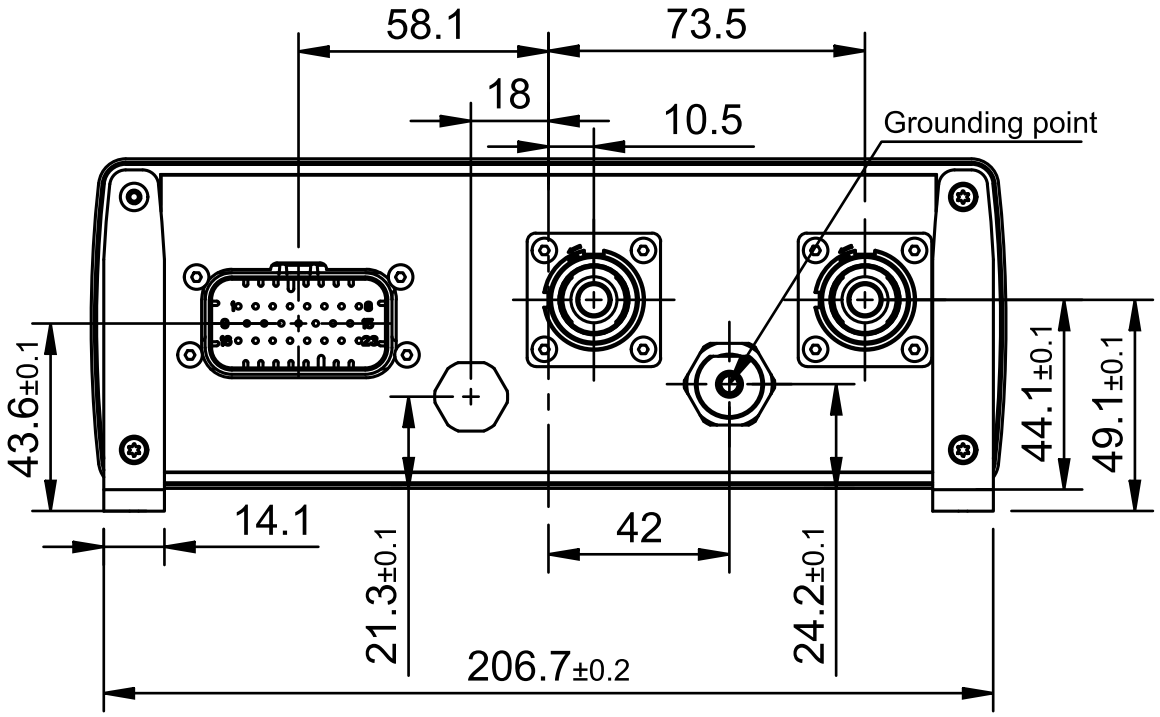


Figure 8. Front plate mechanical drawings

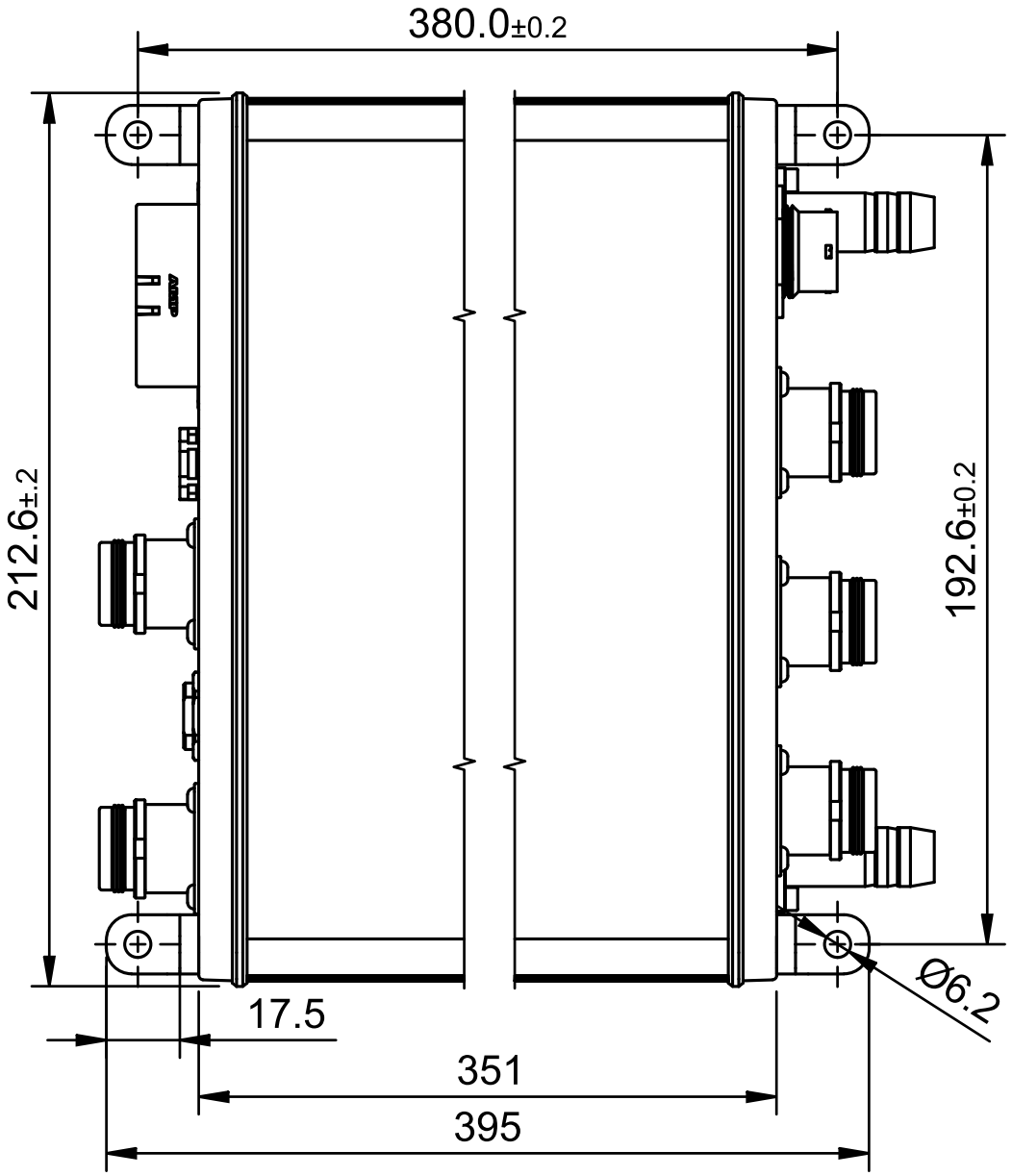


Figure 9. Top side view mechanical drawings

9. COMPATIBLE MOTOR POSITION SENSORS

11.1 Encoders

Supported Encoders: **RLS RM44SI** (SSI + Incremental) 10B,11B,13B resolution variants

- Compatible with normal or differential signals.
- ±15 kV ESD-Protected signals
- Maximum input signal voltage: 5 V
- Maximum encoder resolution: 8192 (counts per revolution)
- Maximum input frequency: 400 kHz

RLS RM44SI is the most recommended way to sense the motor position with the HV-550/HV-850.

9.2 Resolver

The controller is compatible with various 1X-BRX type resolvers, the tested, recommended variant is TAMAGAWA Smartsyn **TS2620N21E11.**

The system requires an intermediate device called DTI Resolver Interface to use any resolver variants. Only 1X-BRX type resolvers are supported at the moment.

11.3 HALL-Sensors

The controller can be configured to use HALL Sensors as a motor position sensor.

- Latching type Hall-effect sensors input
- Maximum input signal voltage: 5 V
- Maximum input frequency: 400 kHz

HALL Sensor is not a recommended motor position sensing method with such relatively large motors. Due to the lack of resolution of sampling, reduced efficiency and power ranges can occur in HALL Sensored operation mode.

10. COMPATIBLE MOTORS

Any 3 phase PMSM motor can be set up for the inverter in case the following parameters are known:

- Number of poles
- Motor inductance
- Motor resistance

Compatible motor temperature sensor:	**kty 81/210**
Maximum ERPM:	100000

11. ELECTRICAL CONNECTIONS

11.1 Harness connector pinout (H) - Inverter side

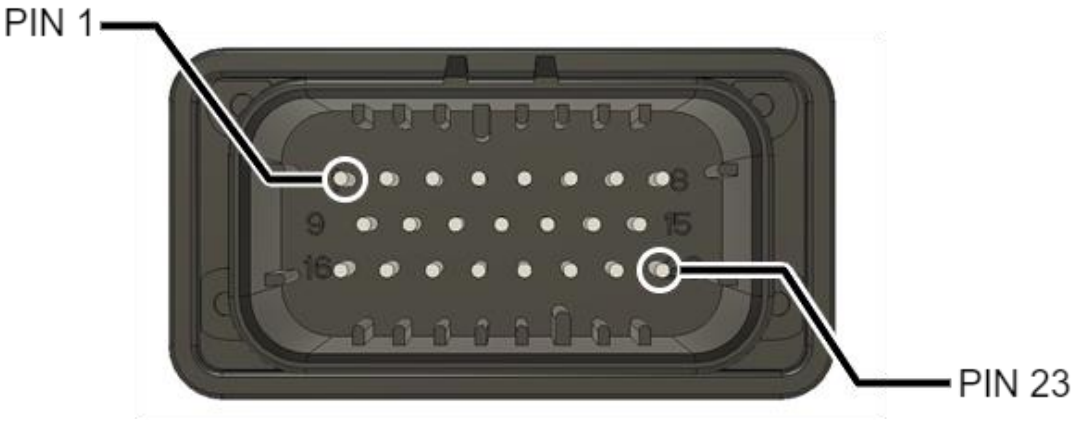


Figure 10. Harness connector

Connector type: TE CONNECTIVITY AMPSEAL **770680-1**

16-20 AWG crimp type: TE CONNECTIVITY AMPSEAL **770520-1**

Table 8. Harness connector pinout description

Id	Pin name	Pin description
1	12_VIN	Auxiliary voltage plus, 9 V – 28 V maximum 30 W
2	D_OUTPUT_1	Open Drain output, maximum 25 V, 240 mA
3	CAN1_L	CAN Low, 24 V suppressor diode
4	CAN2_L	CAN Low, 24 V suppressor diode
5	HVIL_PIN1	High Voltage Interlock Pin 1 (no polarity)
6	D_INPUT_1	Digital input, 12 V input, active high
7	AIN_1	Analog input, maximum 5 V
8	AIN_3	Analog input, maximum 5 V
9	12_VIN	Auxiliary voltage plus, 9 V-28 V maximum 30 W
10	D_OUTPUT_2	Open Drain output, maximum 25 V, 240 mA
11	CAN1_H	CAN High, 24 V suppressor diode
12	CAN2_H	CAN High, 24 V suppressor diode
13	HVIL_PIN2	High Voltage Interlock Pin 2 (no polarity)
14	D_INPUT_2	Digital input, 12 V input, active high
15	AIN_2	Analog input, maximum 5 V
16	GND	Auxiliary voltage minus
17	GND	Auxiliary voltage minus
18	+5 V_OUT	5 V output for sensors, total maximum 500 mA
19	D_OUTPUT_3	Open Drain output, maximum 25 V, 240 mA
20	D_OUTPUT_4	Open Drain output, maximum 25 V, 240 mA
21	D_INPUT_3	Digital input, 12 V input, active high
22	D_INPUT_4	Digital input, 12 V input, active high
23	+5 V_OUT	5 V output for sensors, total maximum 500 mA

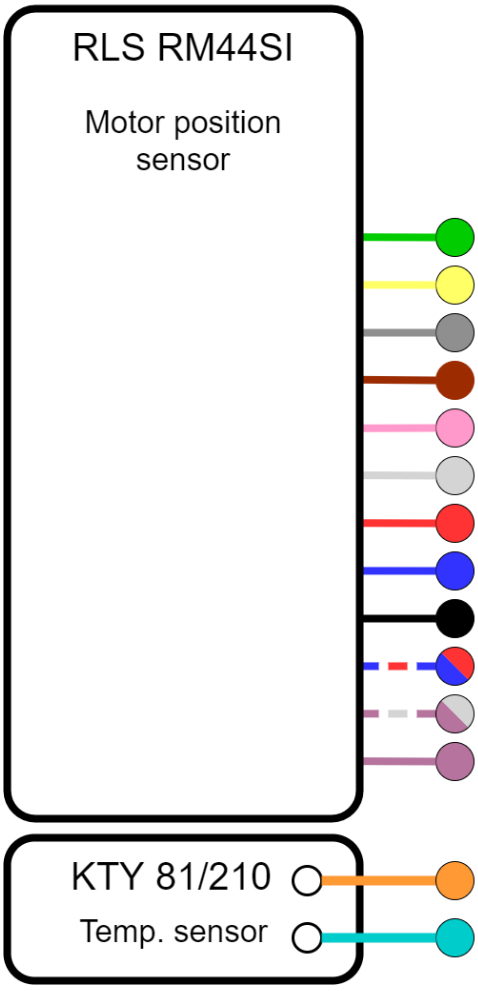
11.2 Motor sensor connector pinout (M)

Required mating part: SOURIAU **UTS6JC12E14P**

11.2.1 RLS RM44SI

Connect the RLS Encoder's coloured wires to the Controller's Motor position sensor connectors according to the chart below.

Make sure to connect the RLS encored shield to one of the GND pins. Without this, the encoder will not work properly.



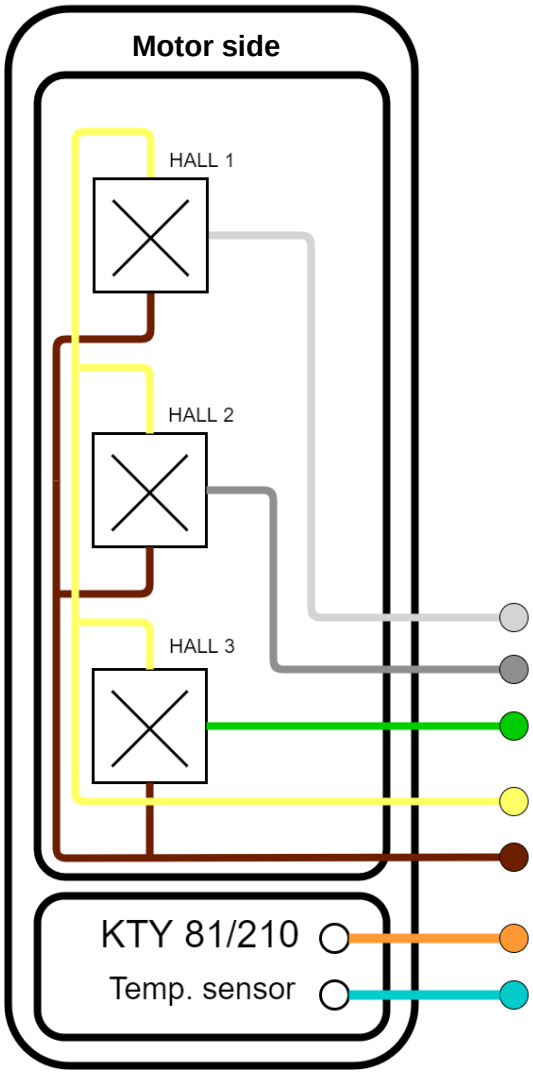
ID	Color	Description
A	Green	ABI B diff. signal +
B	Yellow	ABI B diff. signal -
C	Grey	ABI A diff. signal +
D	Brown	ABI Z diff. signal -
E	Teal	Temperature sensor pin 1
F	Orange	Temperature sensor pin 2
H	Pink	ABI A diff. signal -
J	White	ABI Z diff. signal +
K	Red	Sensor supply V+ (+5V_{DC})
L	Blue	Sensor supply GND
M	Black	ABI SSI CLK +
N	Red/Blue	ABI SSI Data -
P	Grey/Pink	ABI SSI Data +
R	Purple	ABI SSI CLK -

Figure 11. RLS RM44SI sensor wiring diagram

Shrink tubes must be applied during the assembly process to isolate the pins and solder joints of the connector from each other.

14.2.2 HALL effect sensor

Connect only the wires which found in the sensor connection diagram. Leave the other pins free on the connector. The internal circuit contains the hall sensor pull up resistors.



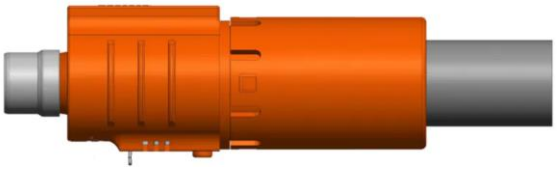
ID	Color	Description
A	White	Sensor A signal output
B	NC	
C	Grey	Sensor B signal output
D	NC	
E	Teal	Temperature sensor pin 2
F	Orange	Temperature sensor pin 1
H	NC	
J	Green	Sensor C signal output
K	Brown	Sensor supply 5V
L	Yellow	Sensor supply GND
M	NC	
N	NC	
P	NC	
R	NC	

Figure 12. HALL sensor wiring diagram

Shrink tubes must be applied during the assembly process to isolate the pins and solder joints of the connector from each other.

14.3 High power connection

Table 9. Compatible high-power connector receptacles.

SurLok Plus™ EMI Plugs			
Part NO.	**Wire dia.**	**Orientation**	
SLPIPB35BSO1EH	35 mm^2	Straight	
SLPIPB50BSO1EH	50 mm^2	Straight	
SLPIPB70BSO1EH	70 mm^2	Straight	
SLPPB35BSO1EH	35 mm^2	Angled	
SLPPB50BSO1EH	50 mm^2	Angled	
SLPPB70BSO1EH	70 mm^2	Angled	

For detailed assembly instructions, please refer to document ***SurLok Plus EMI Right Angle Assembly Instructions***

14.4 Case grounding

The controller casing must be electrically connected to the chassis **which is the potential of the low voltage ground**. The figure below shows the dedicated grounding point of the controller.

Figure 13. Grounding point (M6)

Use the grounding point and connect it to the chassis with at least 6 AWG wire with a short-as-possible distance. In case the inverter is not grounded well, hazardous potential difference can develop causing a risk for electric shock, odd behaviour of the inverter and other potentially other system components connected or on the same bus, increased noise in the commutation and I/O's and other peripherals.

12. PC CONNECTION AND CONTROL

In order to carry out the system integration, the inverter needs to be set-up and configured according the system's specifications. Also, an encoder auto-tune needs to be initiated to calibrate the motor position sensor with the electric motor.

The above tasks can be done via a PC running at least Windows 10 *(for the best user experience at least an Intel i3 or AMD equivalent CPU is recommended)* with an USB 2.0 connector and a DTI-COM Diagnostic tool.

Two applications are available to interface the Controller, offering different features:

- DTI CAN Tool – *For configuring and managing the inverter*
- DTI FWU Tool – *For updating the inverter firmware*

12.1 DTI CAN Tool

The CAN Tool has various additional features for an easier set-up and tuning. Such features are:

- Real time data analysis with plots of various parameters of the inverter
- Visual feedback of the most basic parameters
- Fault code extraction
- Load and save configurations
- Operation by keypad for system evaluation with precautions
- Operation by button for system evaluation with precautions
- One-For-All Tool for multiple CAN based DTI Devices

12.2 DTI FWU Tool

The Firmware Update Tool has a specific purpose to update firmware for all CAN equipped DTI devices. In order to find out more about the firmware update procedure, please refer to ***DTI Firmware upgrade manual*** at our website in the Downloads section.

Additionally, the FWU Tool is able to send specific or custom commands to the Controller's CAN2.

For the OBD-II connector's pinout, please refer to **CAN Wiring**

13. WIRING UP THE CONTROLLER

13.1 Overview

Analog and digital signal inputs and outputs are provided for switches, sensors, contactors, hydraulic valves, CAN communications and SSI communications.

The wiring must be carried out by a qualified person.

Special attention must be paid to the equipotential bonding for components which are connected to the unit and which do not have isolated inputs and outputs (equalizing connection GND). The equalizing currents may damage components and parts permanently.

> The units, the inductive and capacitive accessories as well as the power wiring can generate strong electric and electromagnetic fields. These fields may be dangerous for persons having electronic medical aids or appliances (e.g.: cardiac pacemakers). Sufficient distance to these electrical parts must be observed. The switch cabinet must be labelled accordingly.

Keep all wiring harnesses short and route wiring close to vehicle metalwork. Keep all signal wires clear of power cables and consider the use of screened cable. Keep control wiring clear of power cables when it carries analogue information - for example, accelerator wiring. Tie all wiring securely.

> **Do not apply power until you are certain the controller high power and signal wiring is correct and has been double checked. Wiring faults will damage the controller.**

13.2 Harness connector wiring

You must use TE CONNECTIVITY connector parts. The harness side connector type: **770680-1** and the corresponding crimp pins: **770520-1** for 16-20 AWG wire.

A special hand crimp tool is required for crimping the pins: **58529-1.**

Try to create the simplest and shortest wiring harness as possible. You can involve the harness with cable sleeving polyamide or polypropylene spiral, you can protect it from external influences.

13.2.1 CAN Wiring

CAN is required for firmware updates using the **DTI-COM diagnostic tool**. The tool is not based on OBD-II standard, only the connector.

CAN 1 is used for firmware updates and configuration; CAN 2 is used for interfacing the inverter.

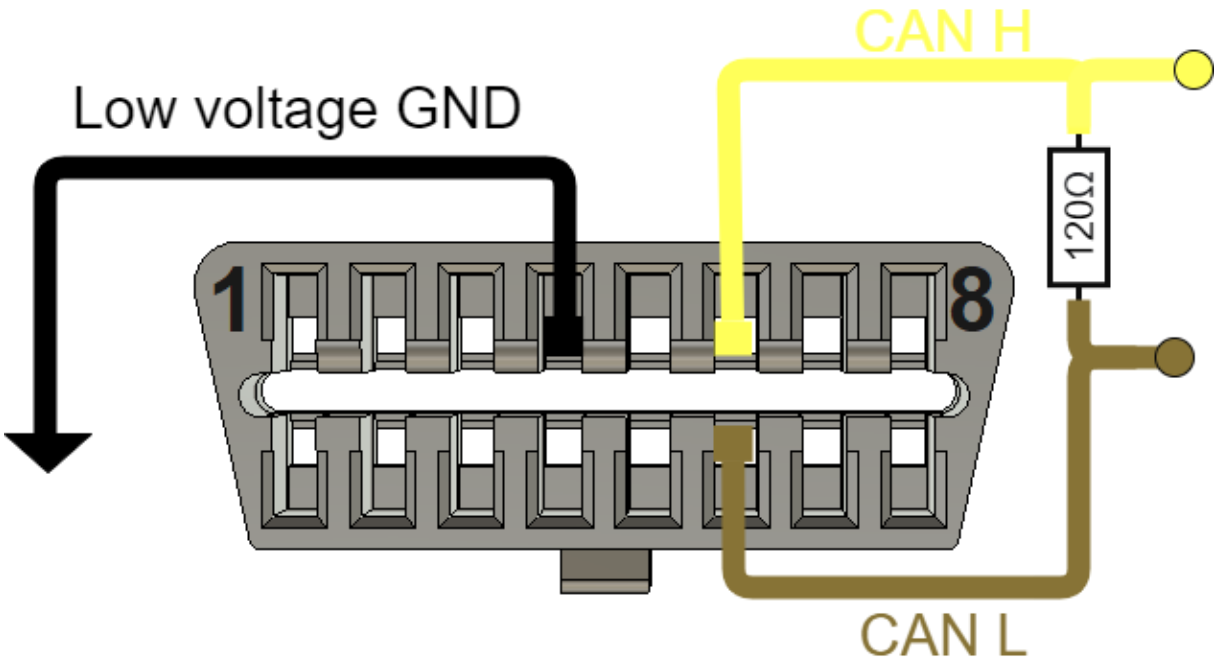


Figure 14. OBD connector pinout for CAN Bus

Adding 120Ω resistors are required for both ends of the CAN bus.

13.2.2 High Voltage InterLock (HVIL)

HV-550 and HV-850 models have integrated HVIL circuit. The inverter itself does not take the HVIL state into account. The governor circuit should be an external device which acts according to the system's requirements.

An example for such use-case is that in case a HVIL fault is detected, it does not affect the behavior until the next power-up sequence for safety reasons. During the power-up process, in case the HVIL fault is present, the main contactors may not be triggered.

All HV connectors including AC and DC are looped into the HVIL system. The following schematic diagram presents the internal HVIL loop:

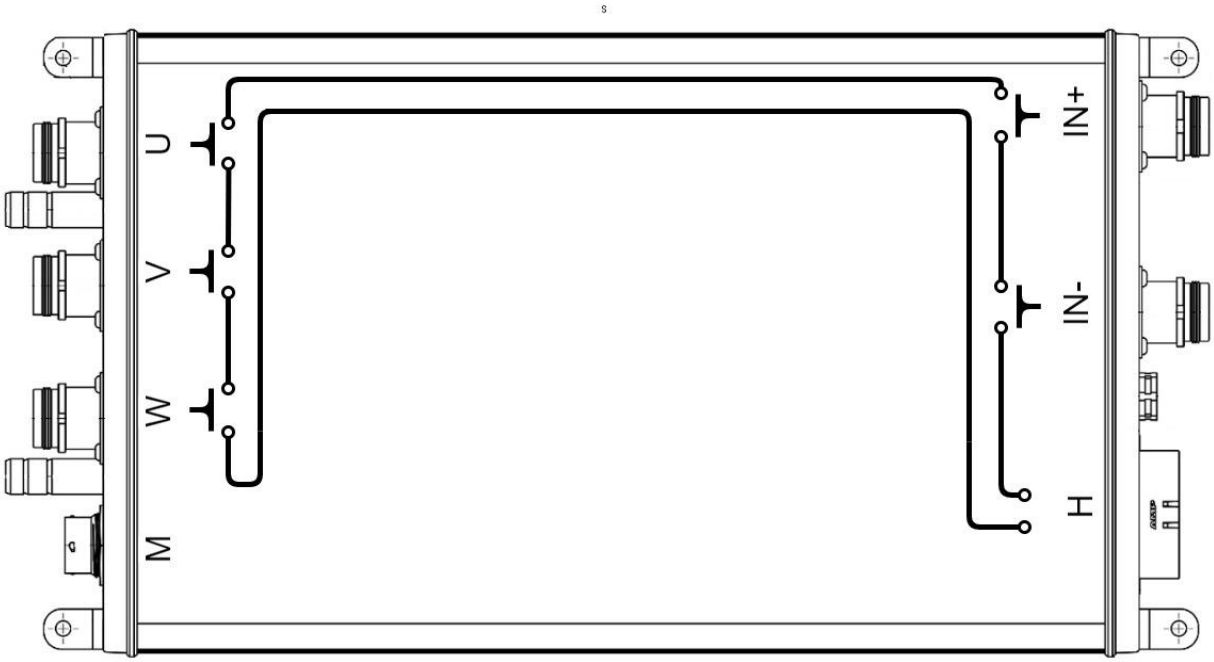


Figure 15. Interlock internal loop equivalent schematic diagram

13.3 System model example

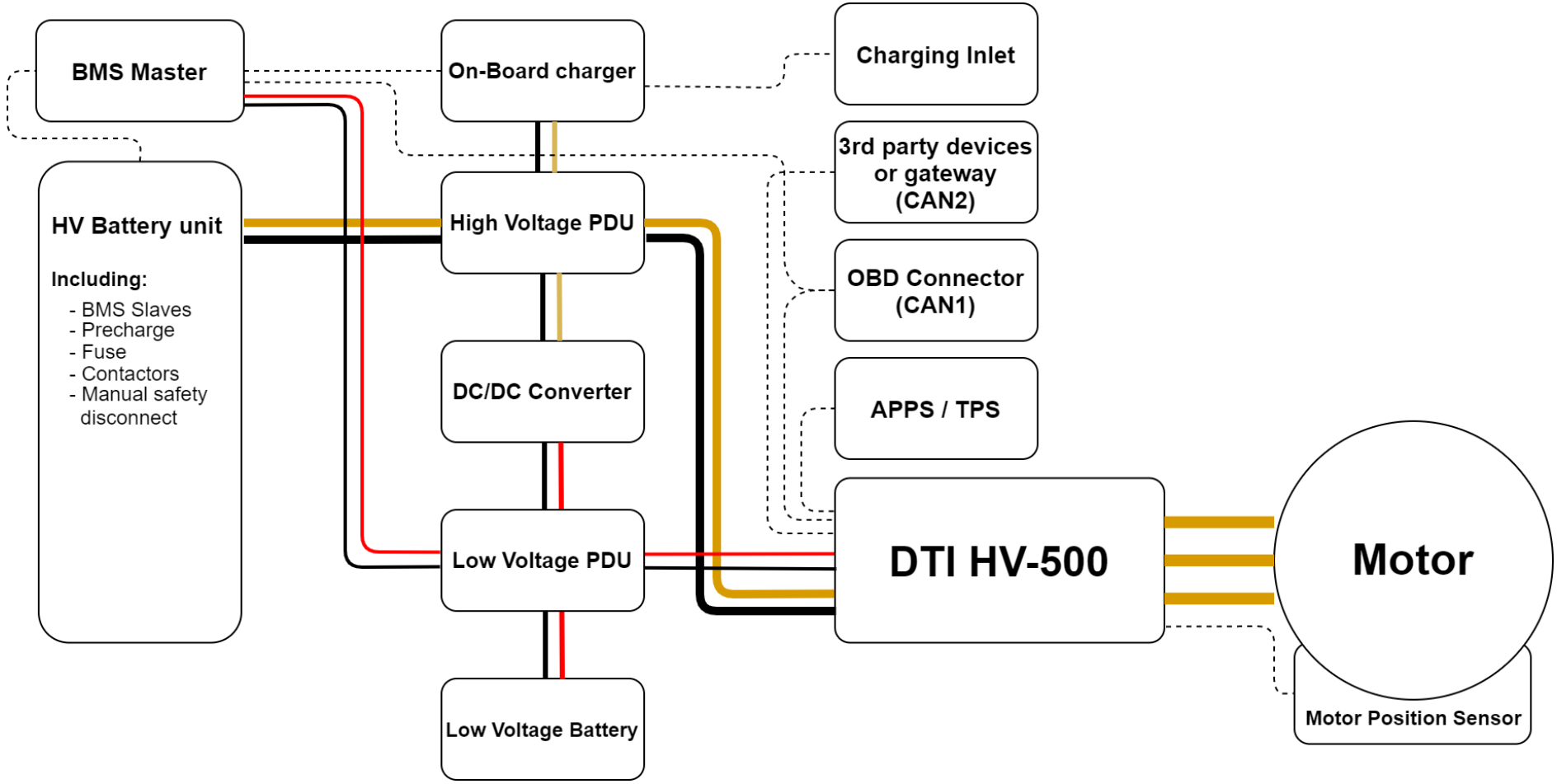


Figure 16. Example system model

14. ELECTRICAL CONNECTION SCHEMATICS

14.1 Input supply

- Reverse polarity protection
- Overvoltage protection
- Resettable overcurrent protection
- Power supply: 9-28V

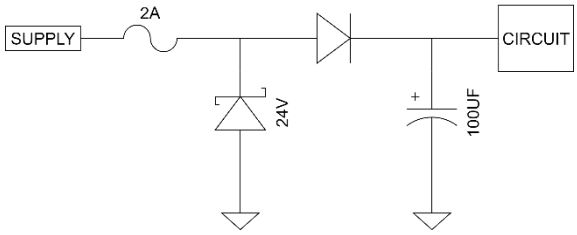


Figure 17. Input supply schematic diagram

14.2 Analog input

- High frequency filter
- Overvoltage protection
- Maximum 5V input

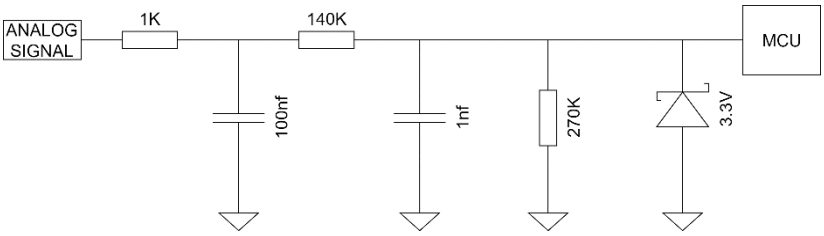


Figure 18. Analog input schematic diagram

14.3 Digital input

- Button debounce
- Overvoltage protection
- Internal pullup resistor

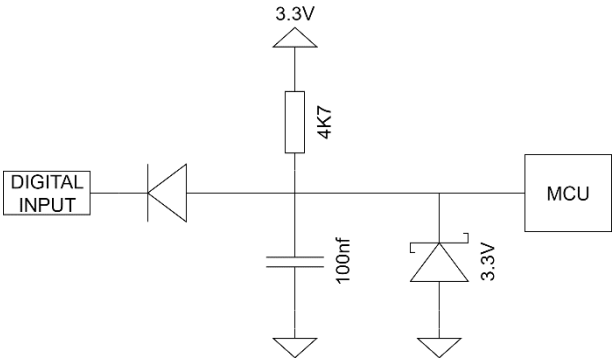


Figure 19. Digital input schematic diagram

14.4 Digital output

- Maximum 24V
- High-Speed resettable fuse
- Maximum 240 mA holding current
- Internal freewheeling diode

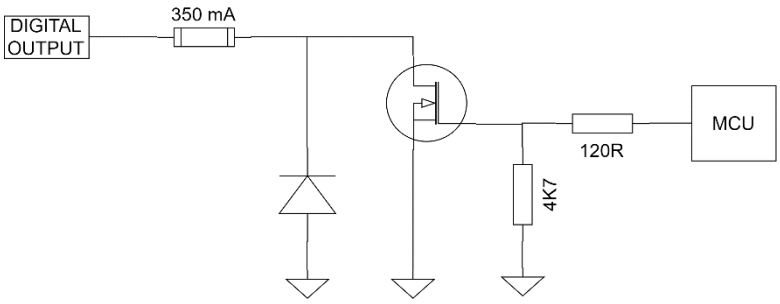


Figure 20. Digital output schematic diagram

14.5 CAN peripheral

- Common mode choke filter
- ESD protection

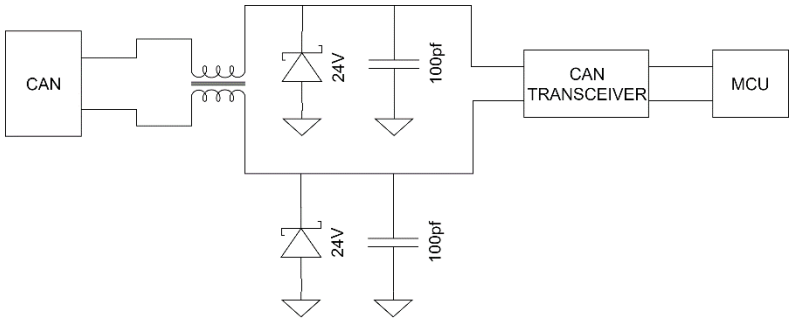


Figure 21. CAN peripheral schematic diagram

15. DUAL CONTROLLER CONNECTION

Two *(or more)* controllers can be connected to one motor if the motor has two *(or more) independent* phase outputs which are completely isolated from each other. The figure below shows a typical layout of a 2xUVW Emrax motor - dual controller configuration.

This layout also can be used for two or more motors on a common shaft mounted together rigidly utilizing a single piece of position sensor and a splitter device.

This layout renders the possibility to double the power achievable on a single motor.

For further information regarding the multi-controller applications please get in touch with us via info@drivetraininnovation.com.

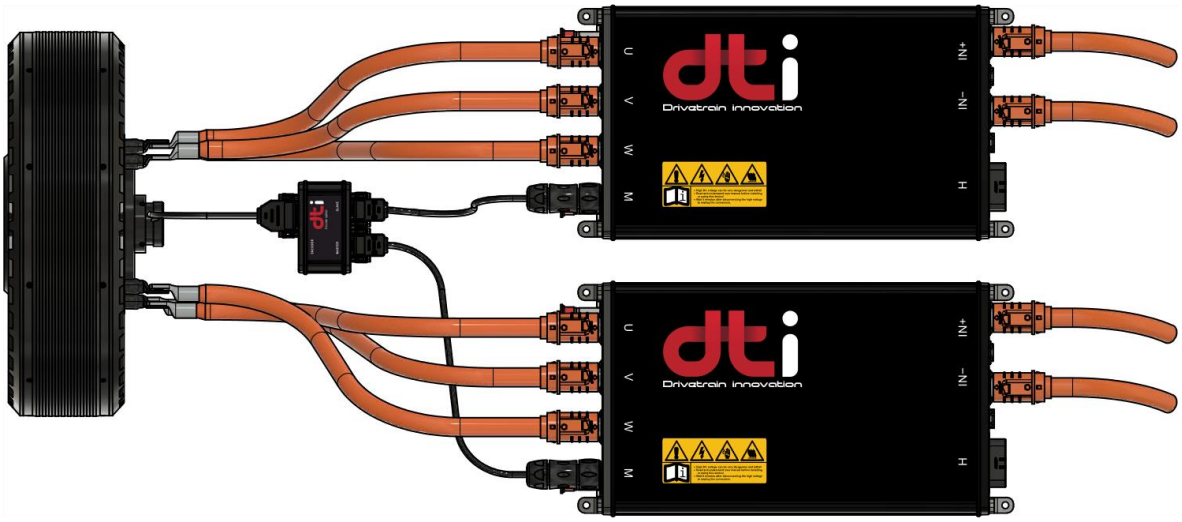


Figure 22. Dual controller system layout

16. LIST OF TABLES

17. LIST OF FIGURES