HV-500 SERIES HIGH POWER INVERTER

User manual for HV-500

Version 2.2

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

07/2018	**V1.0** Document created; basic specifications added.
01/2019	**V1.1** User interface. Digital I/O and low power wiring diagrams added
03/2019	**V1.2** Added efficiency measurement graphs
04/2019	**V1.3** High voltage wiring description
08/2019	**V1.4** Added instructions for Inverter case grounding
11/2019	**V2.0** Updated connectors and raised voltage range
08/2020	**V2.2** Actualization, introducing uniformized datasheets, fixed typos, HV-500 variants diversified Added information about active air-cooled fans.

1.2 Related documents

- DTI HV-500 Interlock manual
- DTI HV-500 CAN manual
- DTI Tool User manual
- DTI Motor setup manual
- DTI Firmware update manual
- DTI Resolver interface manual
- DTI Encoder splitter manual
- SurLok Connector manuals

2. LIABILITY AND SAFE USE OF THIS UNIT

DTI Controller hardware, DTI Tool and the DTI firmware are experimental products designed to develop 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. 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.

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 Tool and the DTI firmware are developer tools 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 give any warranty because every system is unique and we cannot make sure its safety. Although we design our products to minimize such issues, you should always operate with the understanding that a failure can occur at any point of time and without warning. As such, you shall take the appropriate precautions to minimize danger in case of failure.

DTI does not assume any responsibility for difficulties, which are the result of inappropriate configuration, electric system structure and settings that are not in accordance with the latest version of the manual for DTI inverters.

Every inverter is being tested before shipping. DTI assumes no liability in case a customer uses components for the purposes for which they have not been developed or tested.

DTI reserves the right to change any information included this manual. All connection circuitry described is meant for general information purposes and is not mandatory. DTI does not assume any liability, expressively or inherently, for the information contained in this manual, for the functioning of the device or its suitability for any specific application.

2.1 Discharge

The Inverter has internal discharge resistors. The discharge time after powering off the high voltage system is 5 minutes. The resistance is 188kΩ.

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 from the inverter and cannot be covered.

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.

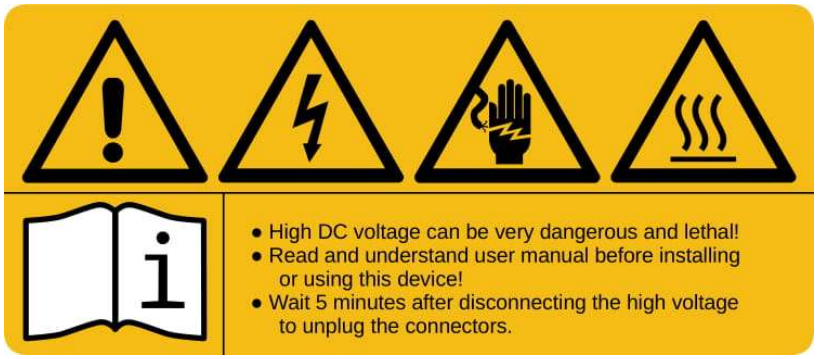
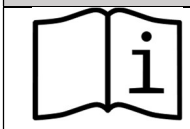


Figure 1. Safety note

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

4.1 Main features of the HV-500

- Sensored FOC motor control
- Analog and digital inputs for control
- CAN (ISO 11898-2)
- UART communication
- Duty-cycle, speed or torque control
- Regenerative braking
- Hand brake function
- Motor angle positioning
- Motor sensors: UVW Hall sensors, SSI, resolver or ABI encoder
- Hardware and Software overcurrent and overvoltage protection
- Undervoltage limitation and protection
- IGBT and motor overtemperature protection
- Encoder wire damage protection
- Maximum motor speed limitation
- Maximum power limitation
- DC and AC current limitation
- Different setup for reverse operation
- Adjustable non-linear or linear analogue input characteristics
- Double redundant throttle input
- Adjustable reverse switch or centralized analogue input for reverse operation
- Simplified motor setup for perfect current control

4.2 Distinction of HV-500 models

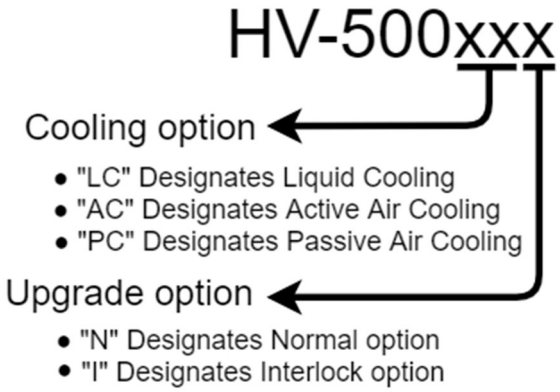


Figure 2. Distinction of HV-500 models

- **Active air-cooled variants** include two high power fans along with a carbon plate for the air conduction through the integrated heatsink.
- **Passive air-cooled** variants include only an integrated heatsink.

4.3 Name plate explained

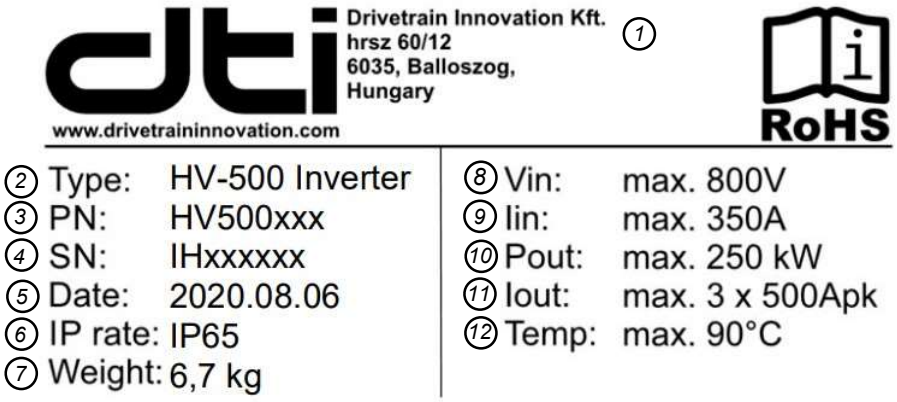


Figure 3. HV-500 Nameplate

Table 2. HV-500 Nameplate explained

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

4.4 Technical specifications

4.4.1 DC characteristics

Table 3. DC Characteristics

	Value	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	200 – 800	V
High voltage absolute maximum input voltage	830	V
High voltage maximum input current	350	A
DC link capacitor	200	µF
DC link capacitor internal discharge time	5	Min

4.4.2 AC characteristics

Table 4. AC Characteristics

	Value	Unit
Continuous AC current (peak-to-peak current)[1]	400	A_{pk-pk}
Maximum AC current for short period (peak-to-peak current)[2]	500	A_{pk-pk}
Maximum AC current for short period (RMS)[3]	350	A_{RMS}
Switching frequency	8 – 14	kHz
Maximum power dissipation	6000	W
Maximum electric RPM[4]	100 000	eRPM
Typical efficiency	95	%

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

5. THERMAL AND MECHANICAL SPECIFICATION

Table 5. Thermal and mechanical specifications

	HV-500LCx	HV-500ACx	HV-500PCx	Unit
Dimensions (h/w/l)	77/213/420	110/213/420	110/213/420	mm
Weight	6,7	7,7	7,2	kg
Working temperature	-20-85			°C
Storage temperature	-20-85			°C
IP Protection	IP65			
Coolant quantity in device	0,38	-		L
Maximum coolant temperature at input	60	-		°C
Required coolant flow for continuous AC current	15,1	-		L/m
Required coolant pressure for continuous AC	0,9	-		bar
Max coolant pressure	4	-		bar
Liquid tube connection outer diameter	12	-		mm

6. HV-500ACX AIR COOLING PARAMETERS

Fan type: **BFM1012UHFF8**

Number of Fans used: **2 pieces**.

Note: The fans need external power source, and its characteristics are the following:

Table 6. HV-500ACx Cooling fan parameters

Parameter	Value	Unit
Rated voltage	12	V
Operation Voltage	10,8-12,6	V
Nominal Input Current	6,96	A
Maximal Input Current	8	A
Nominal Input Power	69,6	W
Maximal Input Power	83,52	W
Fan Speed	8700+- 10%	RPM
MAX. AIR FLOW (AT ZERO STATIC PRESSURE)	1,785(MIN. 1,614)	M3 /MIN
	66,03 (MIN. 56,72)	CFM
MAX. AIR PRESSURE (AT ZERO AIRFLOW)	172,86(MIN. 139,97)	mmH2O
	6,806 (MIN. 5,511)	inchH2O
ACOUSTICAL NOISE (AVG.)	70,5 (MAX. 74,5)	dB-A

Pinout description: (Molex Micro-Fit 441330800):

Table 7. HV-500ACx fan pinout

Pin No.	Colour	Description	Wire AWG
1	Red	V+	20
2	Black	V-	20
3	Yellow	PWM	22
4	Blue	F00	22
5	Red	V+	20
6	Black	V-	20
7	-	NC	-
8	-	NC	-

7. HV-500LCX LIQUID COOLING CONNECTION

Table 8. HV-500LCx Liquid cooling connection

	Value	Unit
Liquid tube connection outer diameter	**12**	mm
Pipe material	**copper**	
Maximum pressure:	**4**	bar
Coolant flow	**15,1**	Litre/Min
Compatible coolant	**Glycol – Distillate water mixture**	
Coolant dilution ratio	Please refer to the coolant manufacturer for the best dilution ratio for the weather conditions where the system is being applied.	

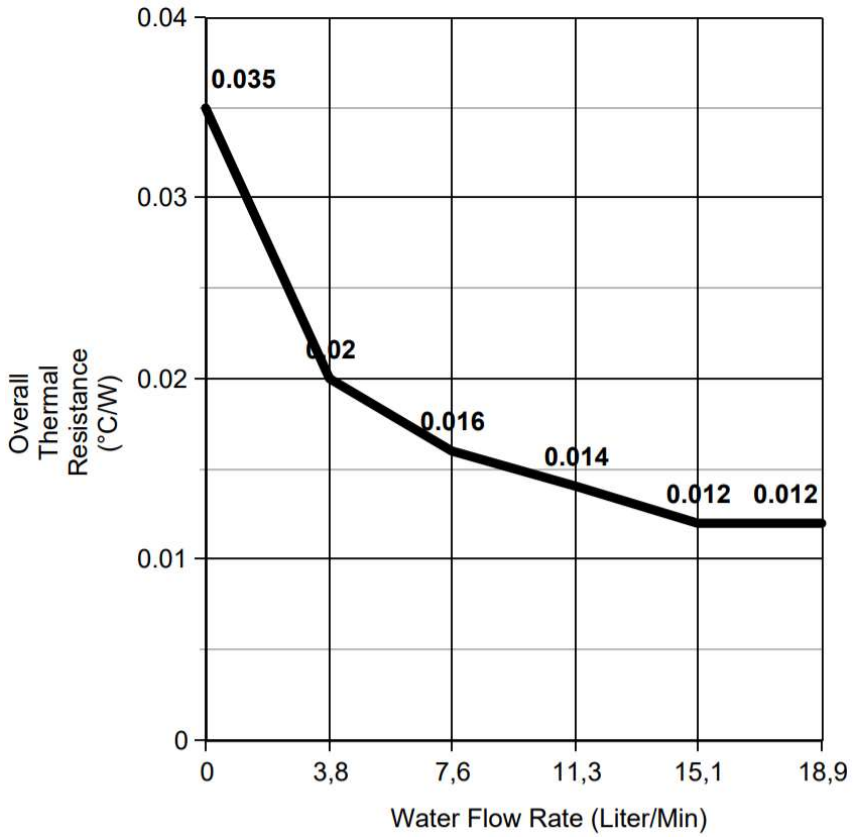


Figure 4. HV-500LCx Thermal resistance and water flow correlation

8. 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 9. Power losses

	AC current	50 Arms	100 Arms	150 Arms	200 Arms	250 Arms	300 Arms	350 Arms
DC voltage								
200 Vdc		129 W	261 W	402 W	552 W	717 W	894 W	1 083 W
400 Vdc		201 W	384 W	579 W	783 W	999 W	1 233 W	1 479 W
600 Vdc		270 W	513 W	759 W	1 020 W	1 290 W	1 584 W	1 899 W
800 Vdc		342 W	642 W	945 W	1 260 W	1 596 W	1 956 W	2 343 W

The values represented by a graph:

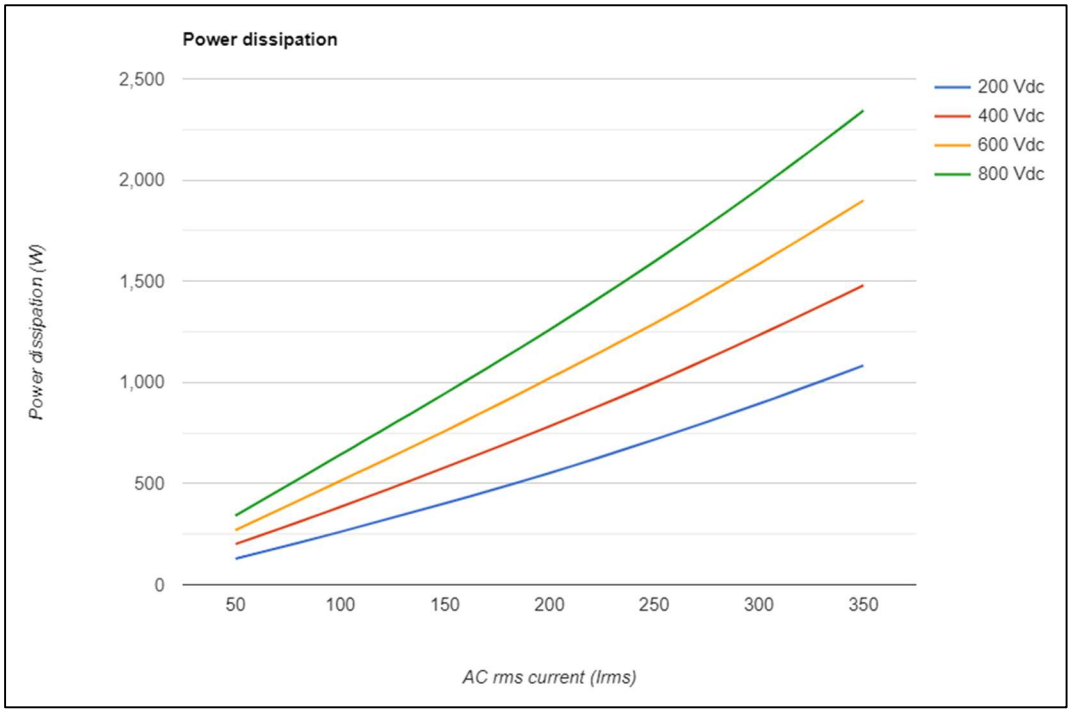


Figure 5. Power dissipation

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

9. SYSTEM EFFICIENCY

The efficiency of the system is influenced by many factors. In order to achieve good efficiency, the voltage difference between inverter AC and DC must be taken into account. Lower voltage difference means better efficiency. The AC voltage is determined by the motor-generated voltage. This value is directly proportional to the motor speed.

In addition, the AC current, the switching frequency, and the AC frequency have a significant effect on efficiency.

We used a **medium voltage EMRAX 228 motor with high 660 Vdc** for efficiency measurement.

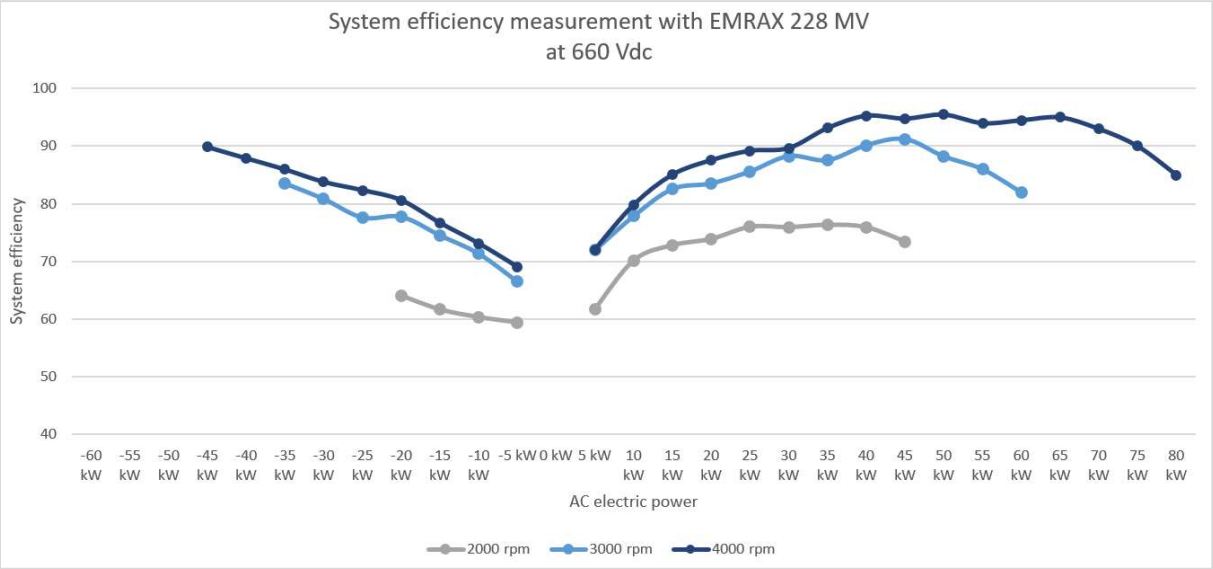


Figure 6. System efficiency graph

10. HV-500LCN-MECHANICAL DRAWINGS

Dimensions are shown in mm.

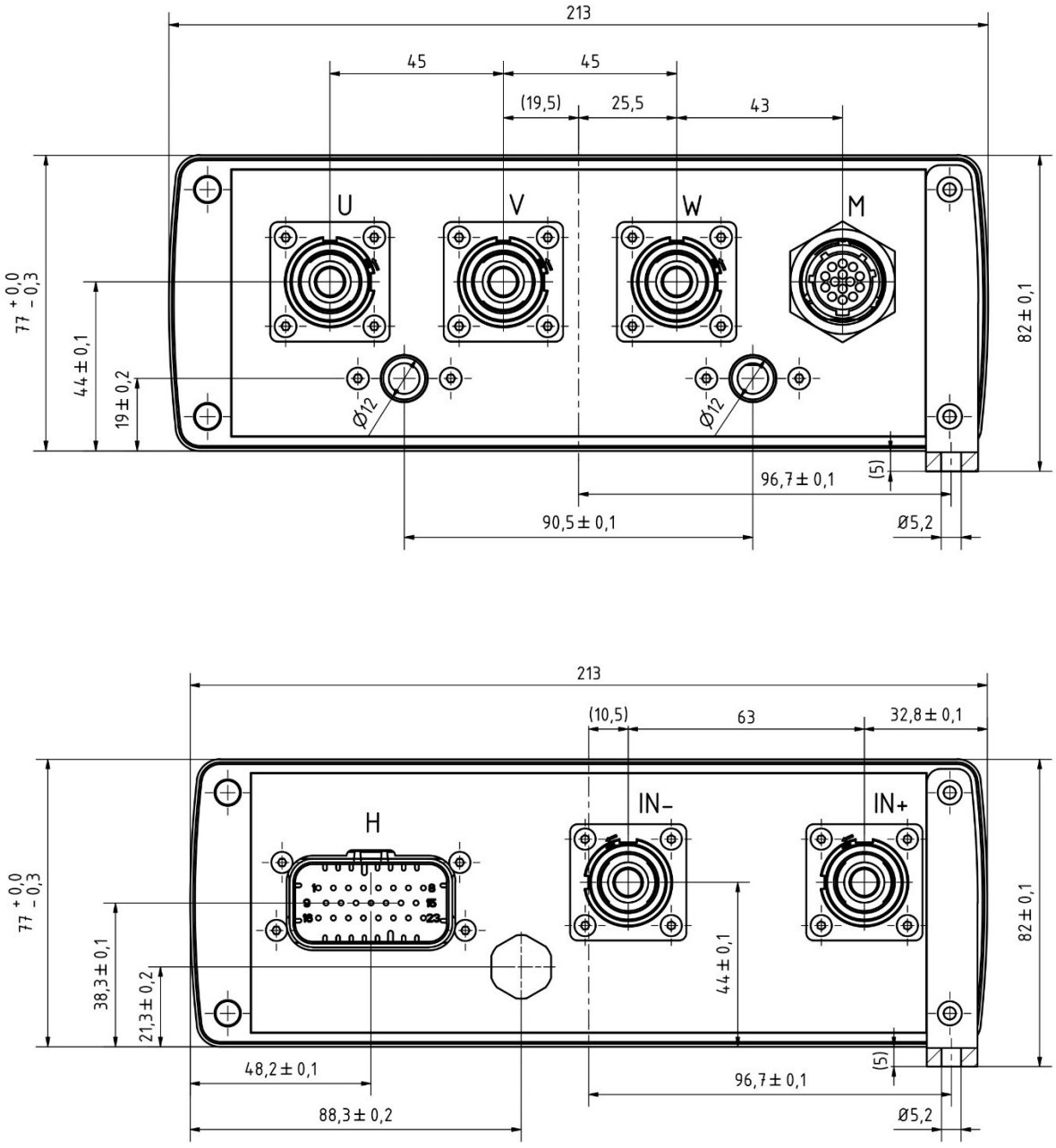


Figure 7. HV-500LCx endplate mechanical drawings

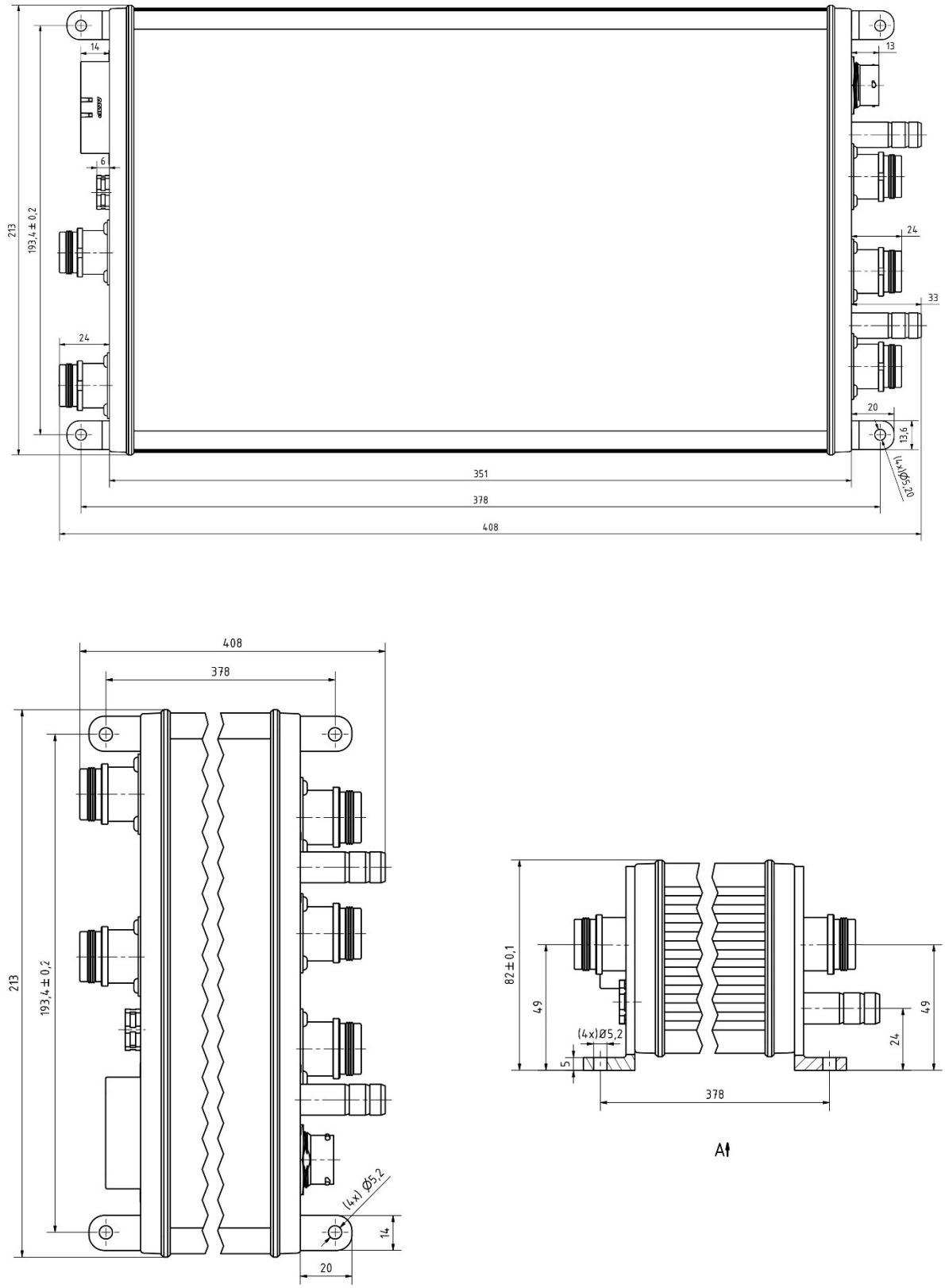


Figure 8. HV-500LCx top and side view mechanical drawings

11. 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

11.2 Resolver

Compatible resolver type: TS2620N21E11

For Resolver support, DTI Resolver Interface is required.

11.3 HALL-Sensors

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

12. COMPATIBLE MOTORS

Any 3 phase PMSM motor can be set up for the inverter knowing the following parameters:

- Number of poles
- Motor inductance
- Motor resistance

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

13. ELECTRICAL CONNECTIONS

13.1 Harness connector pinout (H) (Inverter side)

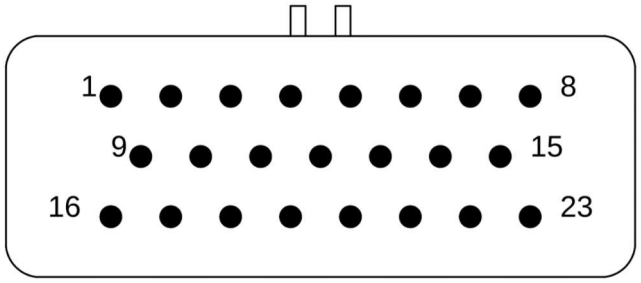


Figure 9. HV-500 Harness connector

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

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

Table 10. HV-500 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	USART_RX	Serial communication, RS232
6	D_INPUT_1	Digital input, 12 V input, active high
7	+5V_OUT	5 V output for sensors, total maximum 500 mA
8	AIN_2	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	USART_TX	Serial communication, RS232
14	D_INPUT_2	Digital input, 12 V input, active high
15	AIN_1	Analog input, maximum 5 V
16	GND	Auxiliary voltage minus
17	GND	Auxiliary voltage minus
18	GND	Auxiliary voltage minus
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	+5 V_OUT	5 V output for sensors, total maximum 500 mA
22	+5 V_OUT	5 V output for sensors, total maximum 500 mA
23	+5 V_OUT	5 V output for sensors, total maximum 500 mA

13.2 Motor sensor connector pinout (M)

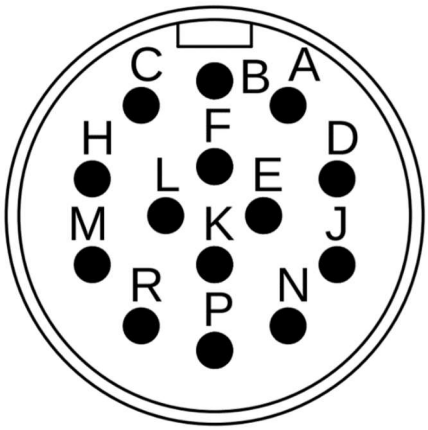


Figure 10. HV-500 Motor sensor connector

Harness side connector type: SOURIAU **UTS6JC12E14P**

Table 11. HV-500 Motor connector pinout description

		RM44	HALL	
A	B+ / Hall U			ABI encoder „B” differential signal positive or A hall sensor
B	B-			ABI encoder „B” differential signal negative
C	A+ / Hall V			ABI encoder „A” differential signal positive or B hall sensor
D	Z-			ABI encoder „Z” differential signal negative
E	TEMP			Temperature sensor
F	GND			Temperature sensor ground
H	A- /			ABI encoder „A” differential signal negative
J	Z+ / Hall W			ABI encoder „Z” differential signal positive or C hall sensor
K	+5 V			Encoder or hall sensor supply output
L	GND			Encoder or hall sensor ground
M	CLK+			ABI encoder SSI „CLK” differential signal positive
N	DATA-			ABI encoder SSI „DATA” differential signal negative
P	DATA+			ABI encoder SSI „DATA” differential signal positive
R	CLK-			ABI encoder SSI „CLK” differential signal negative

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

Shrink tubes must be applied during the assembly process.

13.3 HALL sensor

Only connect 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.

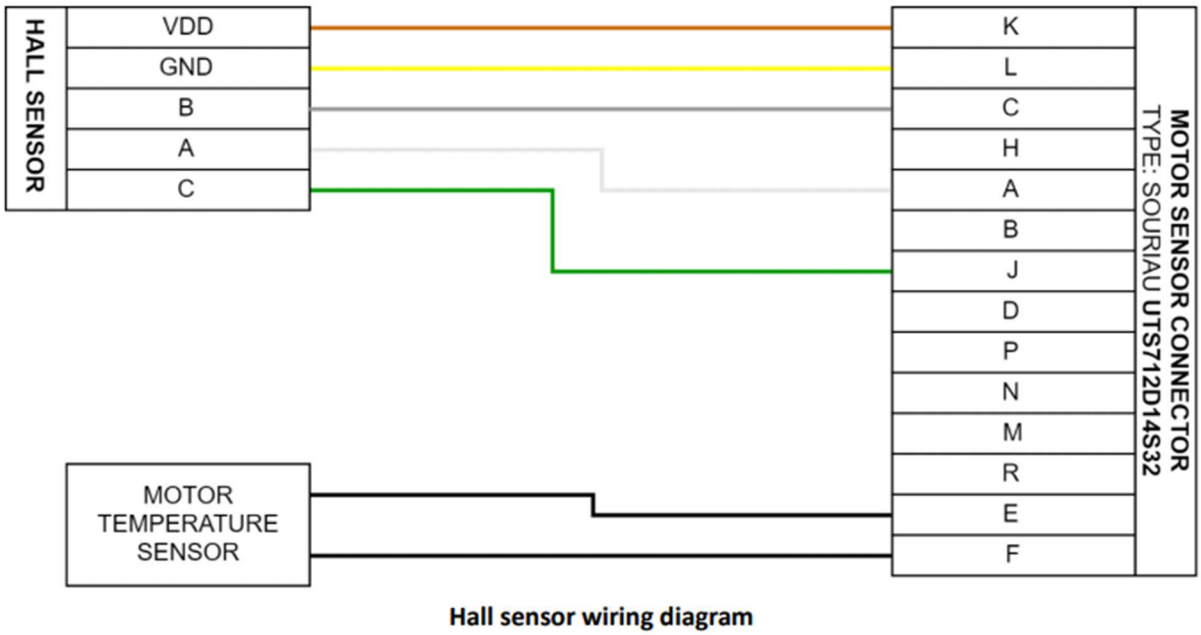


Figure 11. HALL sensor wiring diagram

13.4 High power connection

Table 12. HV-500 compatible high-power connector receptacles.

SurLok Plus™ EMI Plugs		
Part NO.	**Wire size**	**Direction**
SLPIPB35BSO1EH	35 mm2	Straight
SLPIPB50BSO1EH	50 mm2	Straight
SLPIPB70BSO1EH	70 mm2	Straight
SLPPB35BSO1EH	35 mm2	Right angle
SLPPB50BSO1EH	50 mm2	Right angle
SLPPB70BSO1EH	70 mm2	Right angle

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

13.5 Case grounding

The inverter casing must be electrically connected to the chassis **which is the potential of the low voltage ground**.

Use any of the aluminium feet as a grounding point and connect it to the chassis with at least 10 AWG wire with a short-as-possible distance. In chase the inverter is not grounded well, hazardous potential difference can develop causing a risk for electric shock, odd behaviour of the inverter, increased noise in the commutation and I/O's.

14. PC CONNECTION AND CONTROL

14.1 DTI Tool

You can connect the inverter with a USB to RS-232 adapter (*for example: ATEN UC232A*) to the PC, where the inverter can be parameterized. Use the „H" connector 5. and 13. pins and ground to common potential. The DTI Tool software can be run on the PC.

The DTI Tool compatible with windows 10 x86 or x64.

- Real time data analysis
- Online data logging just with DTI Tool
- Error checking and logging
- Motor position sensor setup, inspection
- Online motor control with keypad (very carefully)
- Setting input parameters
- Very detailed query of measured current and voltage (like oscilloscope)

14.2 Firmware update

For firmware update instructions, please refer to DTI Firmware update manual.

15. WIRING THE CONTROLLER

15.1 Overview

Analog and digital signal inputs and outputs are provided for switches, sensors, contactors, hydraulic valves, CAN communications, RS232 communications and SSI communications.

The wiring must be carried out by a qualified person.

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 destroy components and parts.

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.

15.2 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

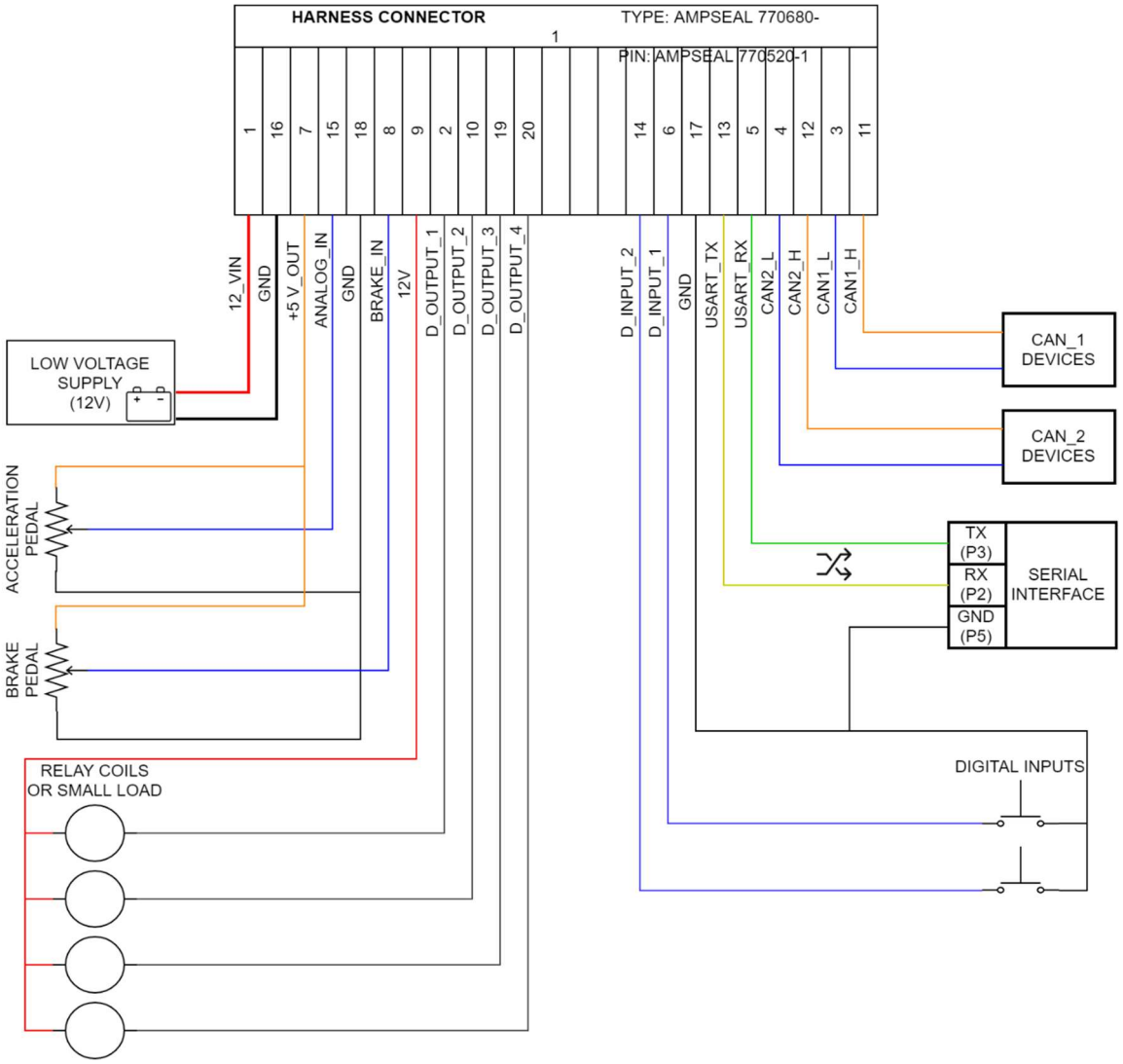


Figure 12. Typical HV-500 wiring scheme

15.2.1 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.

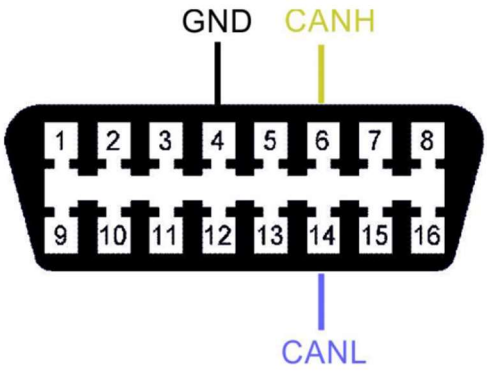


Figure 13. OBD connector pinout for CAN Bus

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

15.3 Electrical connection schematics

15.4.1 Input supply

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

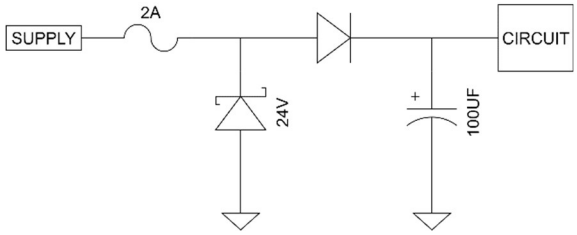


Figure 14. Input supply schematic diagram

15.3.2 Analog input

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

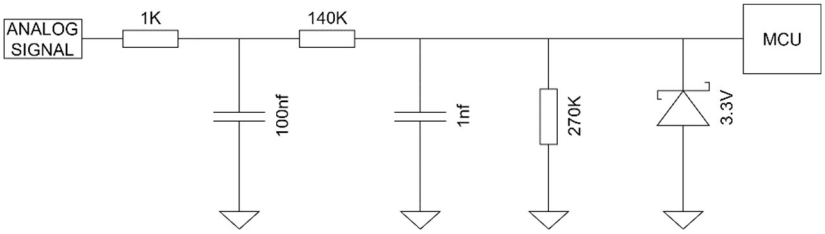


Figure 15. Analog input schematic diagram

15.3.3 Digital input

- Button debounce
- Overvoltage protection
- Internal pullup resistor

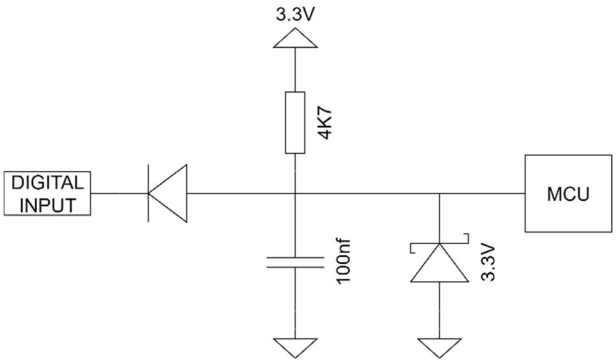


Figure 16. Digital input schematic diagram

15.3.4 Digital output

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

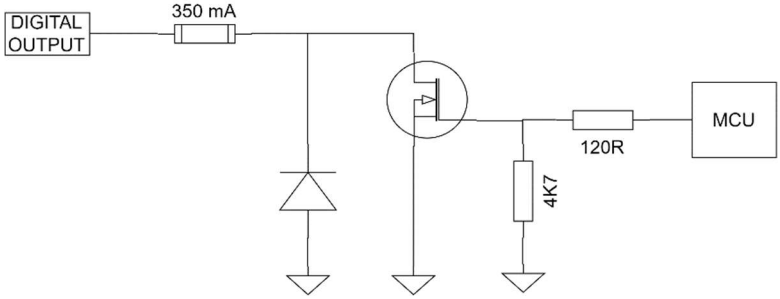


Figure 17. Digital output schematic diagram

15.3.5 CAN peripheral

- Common mode choke filter
- ESD protection

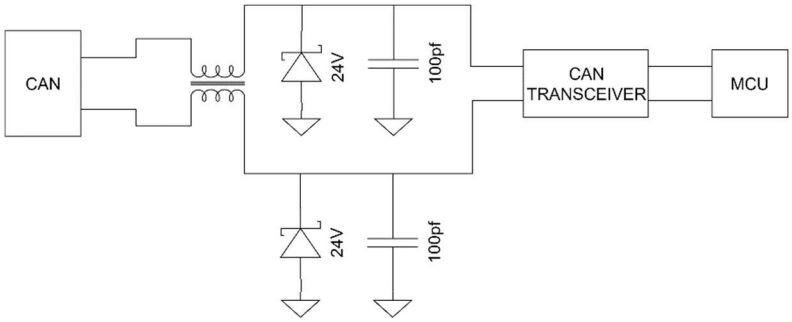


Figure 18. CAN peripheral schematic diagram

15.3.6 RS 232 peripheral

- ESD protection
- Internal serial transceiver

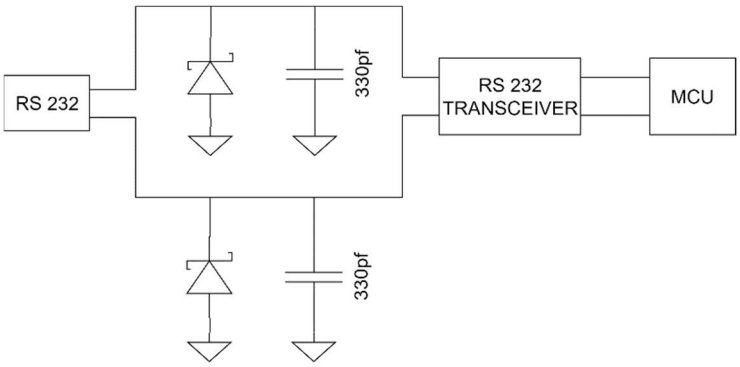


Figure 19. RS-232 peripheral schematic diagram

15.4 Minimal system schematic

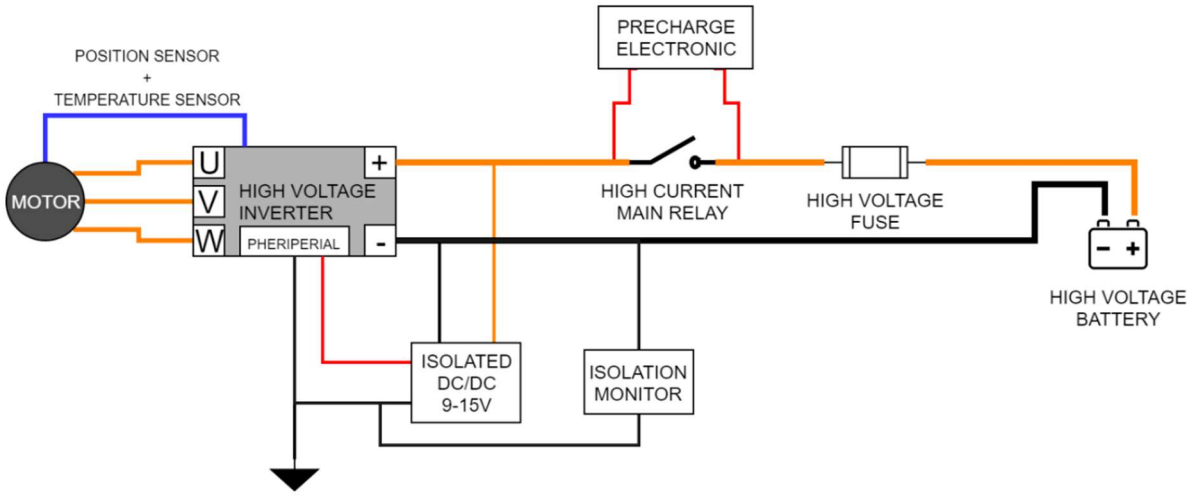


Figure 20. HV-500 minimal system example

Using contactors on both positive and negative side of the high voltage and a fuse are must for safety reasons.

16. LIST OF TABLES

17. LIST OF FIGURES