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EN

User Manual

ACE4

FOC version 3

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Contents

1 INTRODUCTION

1.1 About this document

1.1.1 Scope of this manual

This manual provides important information about ACE4 controller featuring **third generation of Zapi field-oriented control algorithm – FOC3**.
It presents instructions, guidelines and diagrams related to installation and maintenance of the controller in an electrically powered vehicle.

1.1.2 Terms and abbreviations

Application..........A customer specific use of Zapi hardware and software.
CAN....................Controller area network.
ESD....................Electrostatic discharge.
EB ....Electromechanical brake.
EV ....Electro-valve.
EVP ....Proportional electro-valve.
FOC....................Field-oriented control.
LC.......................Line contactor.
LED ....Light-emitting diode.
MC......................Main contactor
OEM ....Original equipment manufacturer.
PTC ....Positive temperature coefficient.
PWM ....Pulse-width modulation.
µC ....Microcontroller.

1.1.3 Manual revision

This revision replaces all previous revisions of this document. Zapi has put much effort to ensure that this document is complete and accurate at the time of printing. In accordance with Zapi policy of continuous product improvement, all data in this document are subject to change or correction without prior notice.

1.1.4 Warnings and notes

In this manual special attention must be paid to information presented in warning and information notices.
Definitions of warning and information notices are the following.

This is an information box, useful for anyone is working on the installation, or for a deeper examination of the content.

This is a warning box. Pay special attention to the annotations pointed out within warning boxes. They can describe:
- operations that can lead to a failure of the electronic device or can be dangerous or harmful for the operator;
- items which are important to guarantee system performance and safety.

1.2 About the controller

1.2.1 Operator's safety

Zapi provides this and other manuals to assist manufacturers in using the motor controller in a proper, efficient and safe manner. Manufacturers must ensure that all people responsible for the design and use of equipment employing the motor controller have the proper professional skills and knowledge of equipment.

⚠ ***The high power levels and high torque available from the combination of a motor with a motor controller can cause severe or fatal injuries.***

⚠ ***Before installation, always verify that the motor controller model is correct for the vehicle supply battery voltage. The nominal DC supply voltage of the motor controller is shown on the identification label.***

⚠ ***Before doing any operation, ensure that the battery is disconnected and when the installation is completed start the machine with the driving wheels raised from the ground to ensure that any installation error does not compromise safety.***

⚠ ***After the inverter turn-off, even with the key switch open the internal capacitors may remain charged for some time. For safe operation onto the setup, it is recommended to disconnect the battery and to discharge the capacitors by means of a resistor of about 10 – 100 Ohm between +B and -B terminals of the motor controller for at least 10 seconds.***

1.2.2 OEM's responsibility

Zapi motor controllers are intended for controlling motors in electric vehicles.

These controllers are supplied to original equipment manufacturers (OEMs) for incorporation into their vehicles and vehicle control systems.

Electric vehicles are subject to national and international standards of construction and operation which must be observed. It is responsibility of the vehicle manufacturer to identify the correct standards and to ensure that the vehicle meets these standards. As a major electrical control component, the role of a Zapi motor controller should be carefully considered and relevant safety precautions taken. It has several features which can be configured to help the system integrator meeting vehicle safety standards.

Zapi does not accept responsibility for incorrect application of its products.

⚠ ***Machine manufacturer holds the responsibility for the truck safety and functional safety features and related approval.***

⚠ ***All the motor controller settings and functionalities have to be verified and validated by the OEM prior to use in the field by any end user.***

⚠ ***It is the OEM's responsibility to ensure that the vehicle is configured and set up to conform to applicable safety regulations.***

1.2.3 Regulations

UL certificate	UL 583 compliant (AU3503).
Functional safety	Designed to achieve EN1175-2010 requirements. Design architecture based on CATEGORY 2 according to EN13849; CATEGORY 3 achievable (according to EN13849). Designed to achieve requirements of EN1175-2020 up to PL-d for certain functions (according to EN13849). Designed to achieve requirements of EN280.
EMC	Designed to achieve requirements of EN 12895:2015+A1:2019.
IP code	IP65.

⚠ ***It is the OEM's responsibility to ensure the regulatory compliance of the complete vehicle system where the Zapi controller is installed.***

1.2.4 Technical support

For additional information on any topic covered in this document or application assistance on other Zapi products, contact Zapi sales department.

2 SPECIFICATIONS

2.1 General features

ACE4 inverter is a controller designed to control AC induction and PMSM, SRM and SRPM motors, in the range from 15 kW to 30 kW of continuous power, used in a variety of battery-powered material-handling trucks.
Typical applications include, but are not limited to: counterbalanced trucks with load up to 8 metric tons, HLOP (VNA), GSE, tow tractors and airport ground support vehicles, aerial-access equipment.
Furthermore, it may also be suitable for other markets such as E-mobility and agriculture.

The main inverter features are:

- 16-bit microcontroller for motor control and main functions, 576+ kByte embedded flash memory.
- 16-bit microcontroller for safety functions, 320+ kByte embedded flash memory.
- Third generation Zapi field-oriented motor control.
- Compatible with several types of speed or position sensors:
  - Incremental encoder (default option).
  - Sin/cos sensor.
  - Set of three Hall sensors.
  - Resolver (adding an external interface).
- Low-side driver for a line contactor coil.
- Low-side driver for an electromechanical brake coil.
- Low-side drivers for PWM voltage-controlled valves and for a PWM current-controlled proportional valve.
- Short-circuit and open-load detection.
- Thermal cutback, warnings and automatic shutdown for protection of motor and controller.
- ESD-protected (IEC/EN 61000-4-2 level 4).
- Software downloadable via serial link (internal connector) or CAN bus (external connector).
- Diagnostic provided via CAN bus.
- Rugged sealed housing and connectors meeting IP65 environmental sealing standards for use in harsh environments.

2.2 Technical specifications

Motor type:..ACIM, PMSM, SRM, SRPM
Control mode: ....speed or torque control
Operating frequency: ....8 kHz
Inverter operating frequency:...16 kHz
Ambient operating temperature range: ....-40 °C ÷ 40 °C
Ambient storage temperature range: ....-40 °C ÷ 85 °C
Maximum inverter temperature at full power: ....85 °C
Connector: .... Ampseal 23 or 35 pins
Package Environmental Rating: IP65

2.3 Current ratings

Nominal DC voltage [V]	Maximum rated current [Arms]	Maximum 2' rated current [Arms]	Continuous rated current [Arms]
36 / 48	1000	950	480
	800	800	460
72 / 80	700	630	355
96	700	545	295
120	400	400	200

Custom configurations, featuring current ratings different from those listed above, can be requested too. Please contact Zapi sales for further information.

An internal algorithm automatically reduces the maximum current limit when the controller temperature, measured near the power MOSFETs, exceeds 85 °C (see paragraph 5.6).

Two-minute ratings are referred to an inverter equipped with a base plate. No additional external heat sink or fans are used for the 2-minute rating test. Ratings are based on an initial base plate temperature of 40 °C and a maximum base plate temperature of 85 °C.

The inverter can deliver the rated continuous current only if it is adequately cooled. When it is equipped with its own finned heat sink, a proper dissipation is obtained by applying a 100 m^3/h airflow. In case it is provided with the base plate, it is customer's duty to design an adequate cooling system that can dissipate the heat produced by the inverter, keeping its temperature below 85 °C. Otherwise, the inverter will deliver a continuous RMS current lower than the rated one.

2.4 Voltage ratings

Nominal DC voltage	36 V 48 V	72 V 80 V	96 V
Conventional working voltage range	28.8 V ÷ 43.2 V 38.4 V ÷ 57.6 V	57.6 V ÷ 86.4 V 64 V ÷ 96 V	76.8 V ÷ 115.2 V
Non-operational overvoltage limits	72.5 V	115 V	125 V
Non-operational under-voltage limits	10 V	30 V	30 V

By default, the controller is set to operate without alarm in the range from 80% to 120% of the nominal battery voltage. With a different DC voltage than specified, the controller raises an alarm.

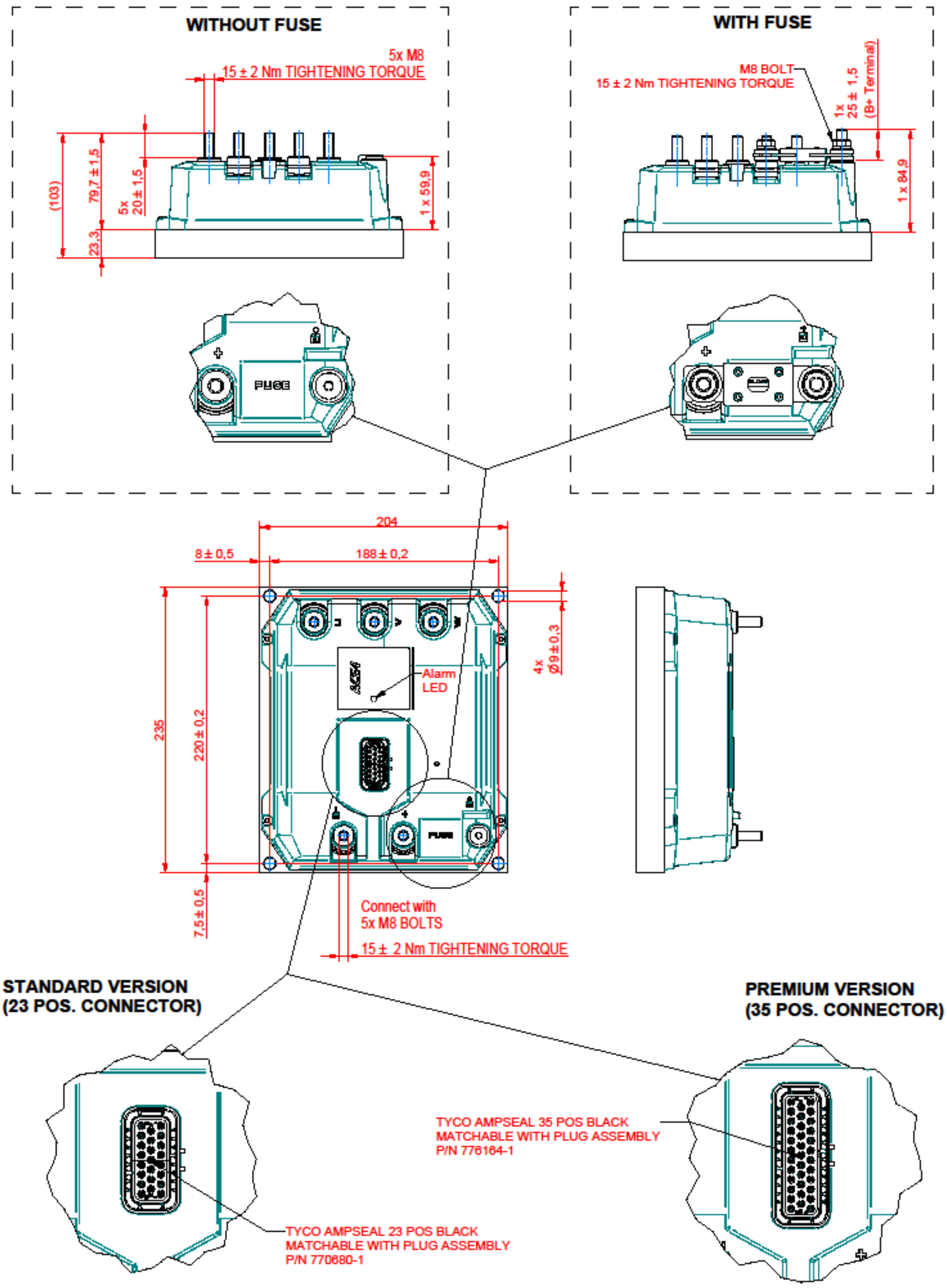
Under-voltage and overvoltage thresholds are defined by hardware. After start-up, the controller is fully operative if the supply voltage stays within the non-operational voltage limits.

Under-voltage is evaluated on the KEY input A3 (A1); overvoltage is evaluated on the positive battery terminal +B.

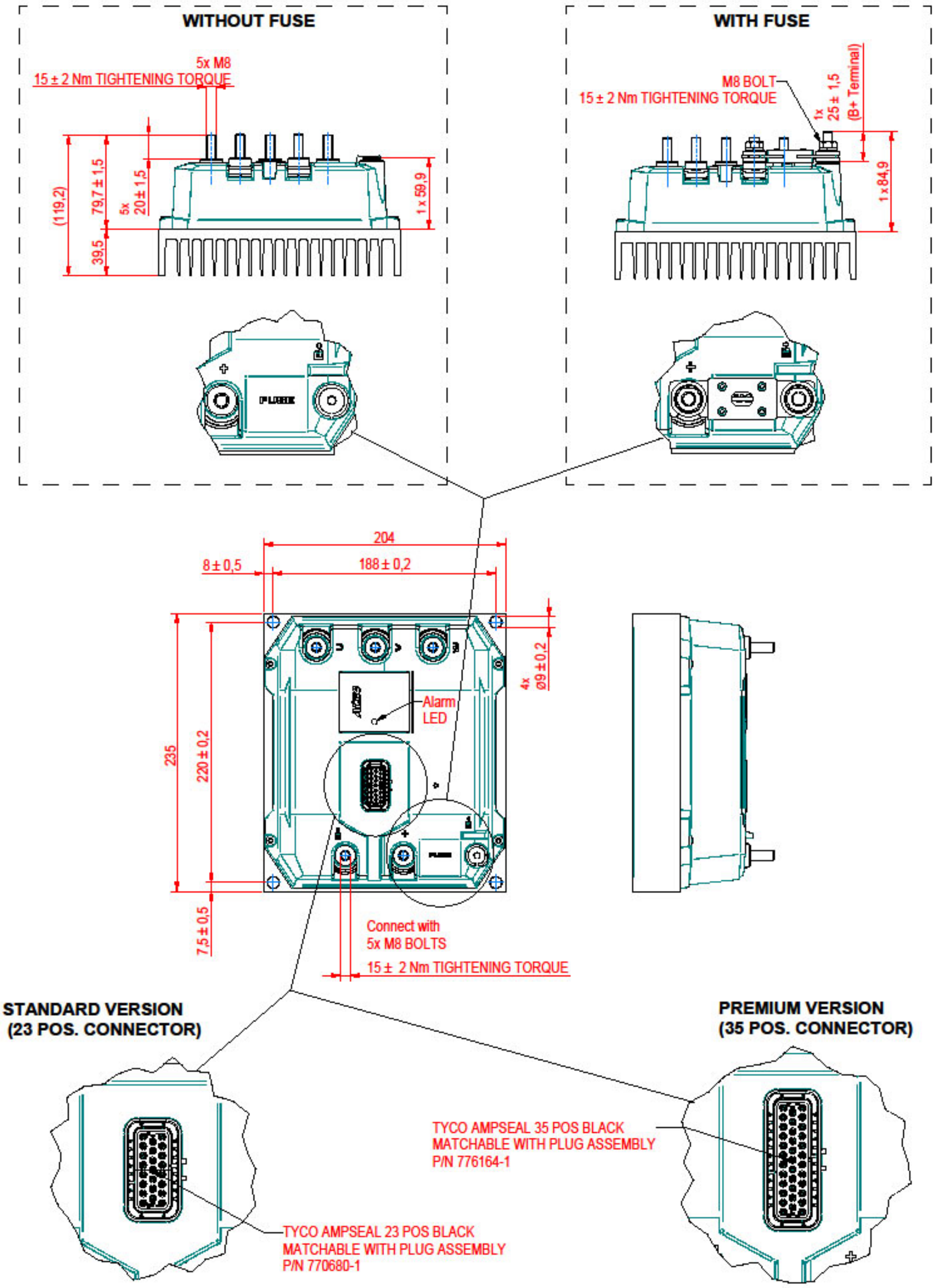
3 DRAWINGS

3.1 Mechanical drawings

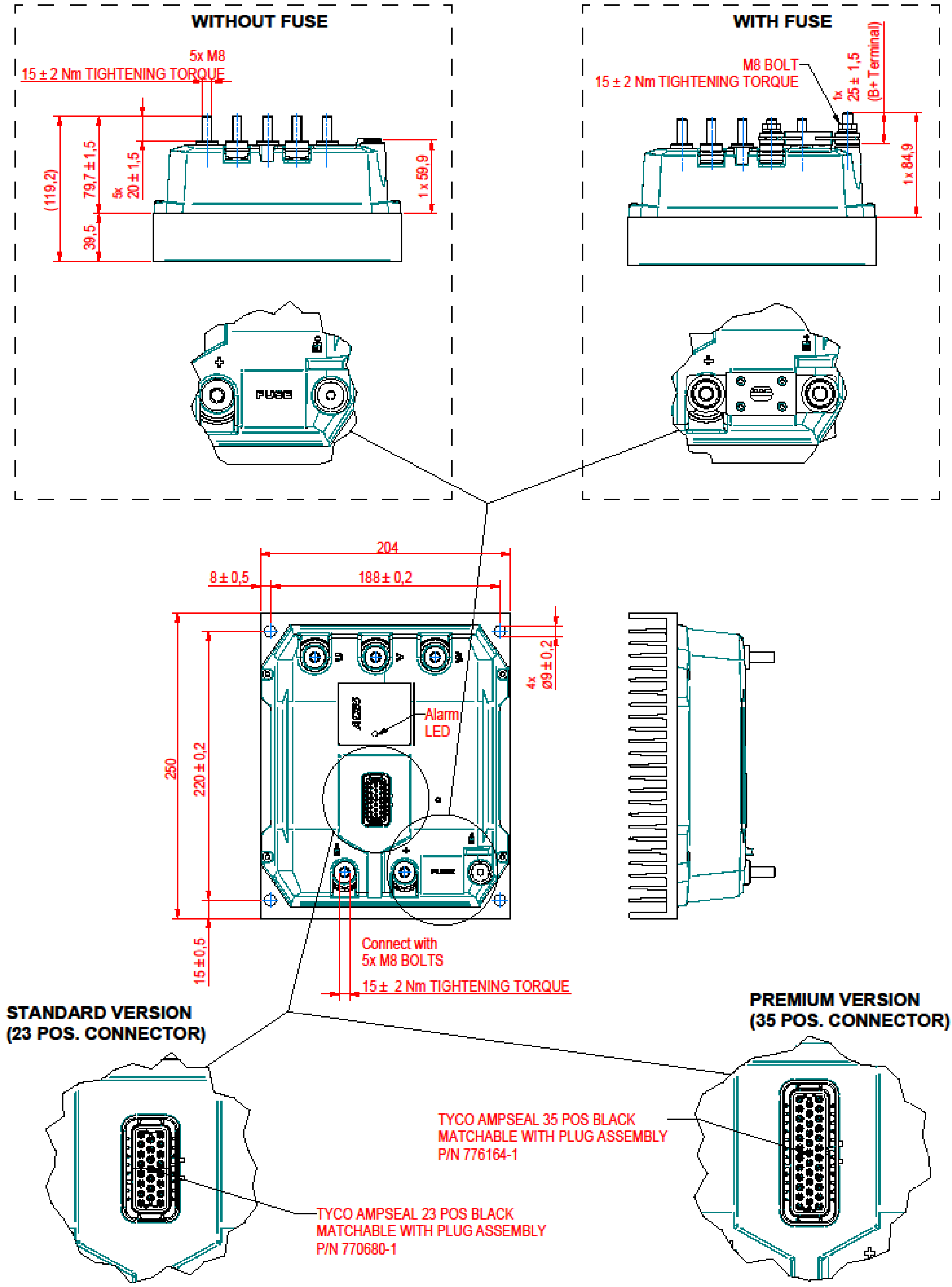
3.1.1 Base plate version



3.1.2 Longitudinal heatsink version

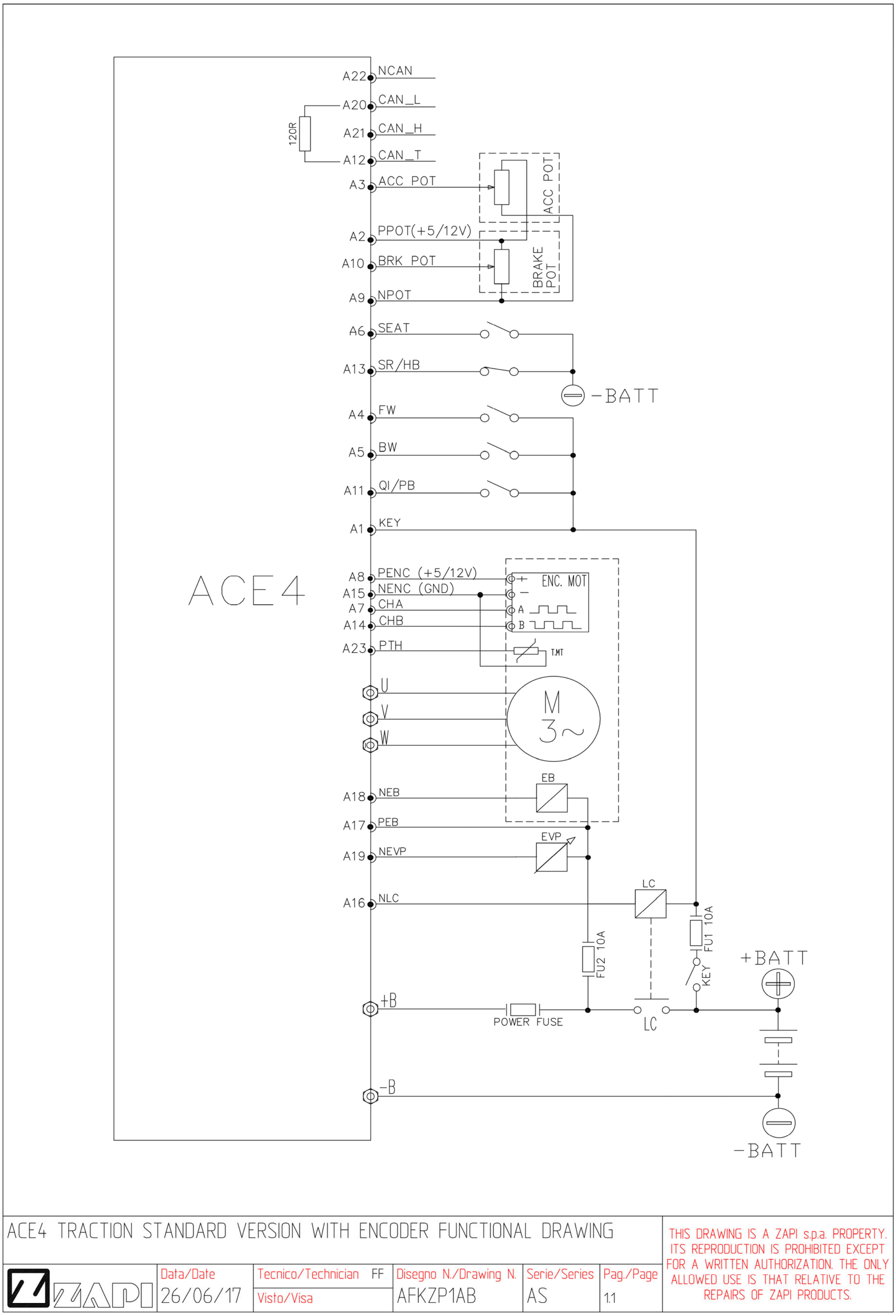


3.1.3 Transversal heatsink version

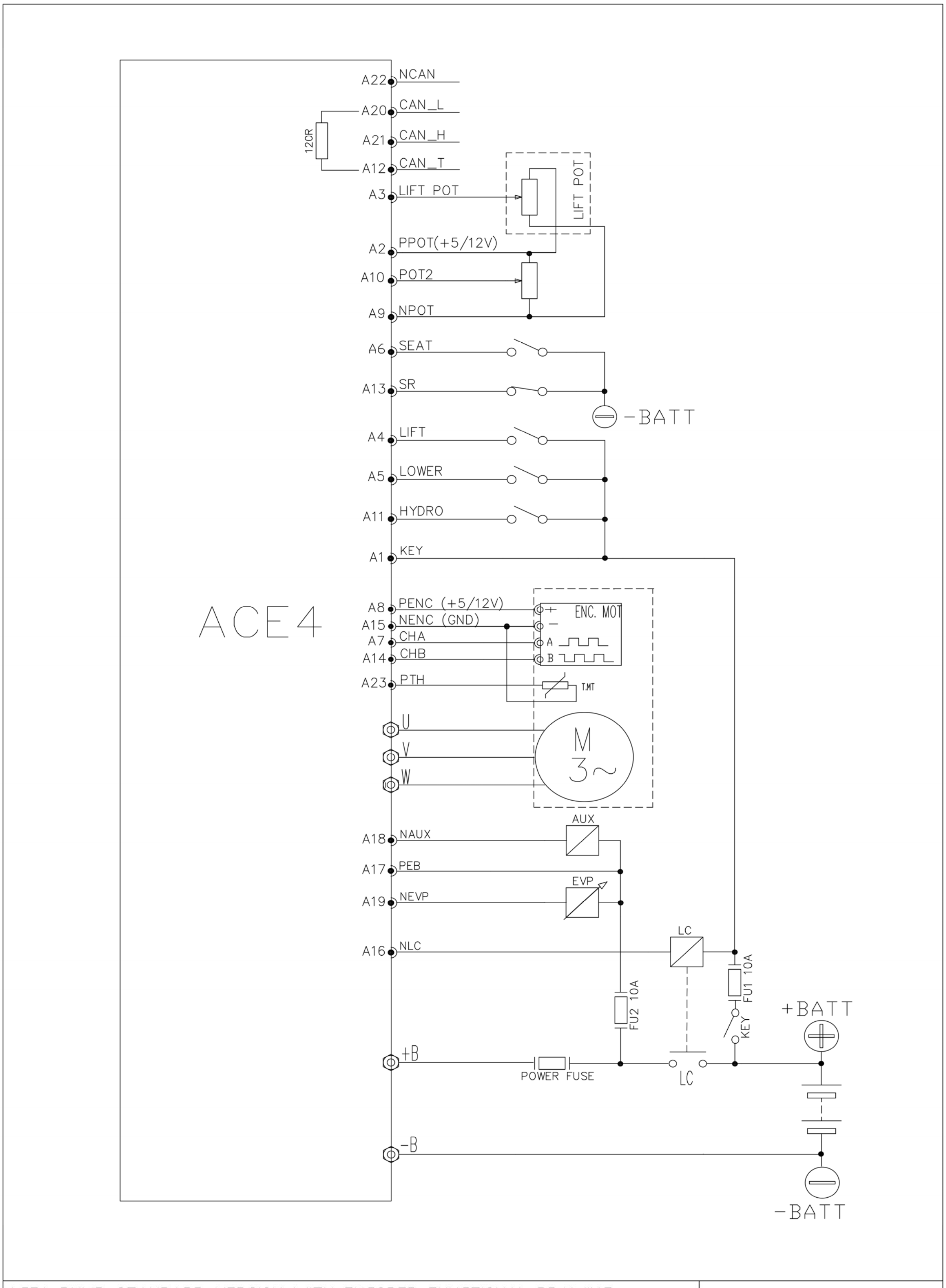


3.2 Connection drawings

3.2.1 Standard version – AC traction

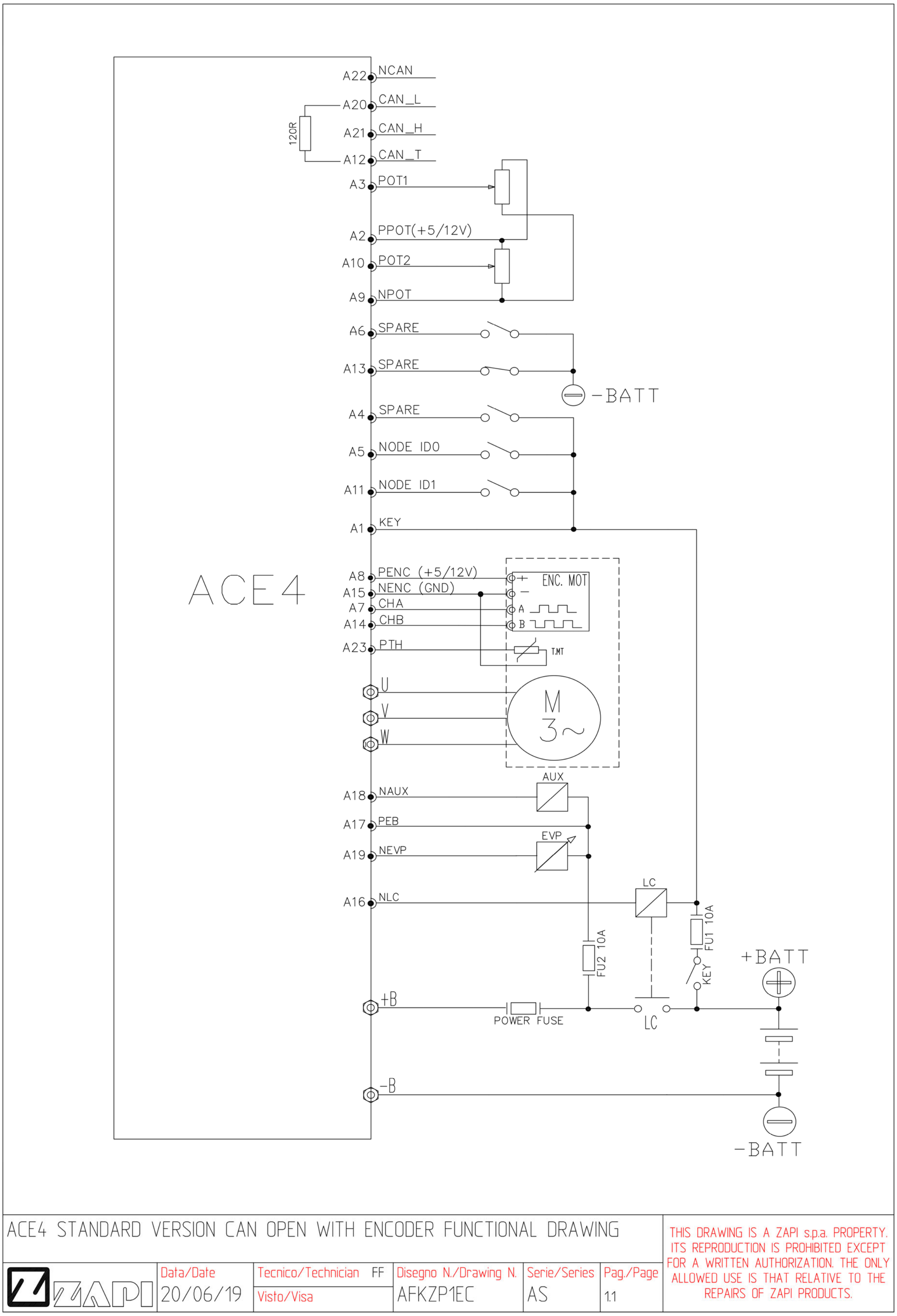


3.2.2 Standard version – AC pump

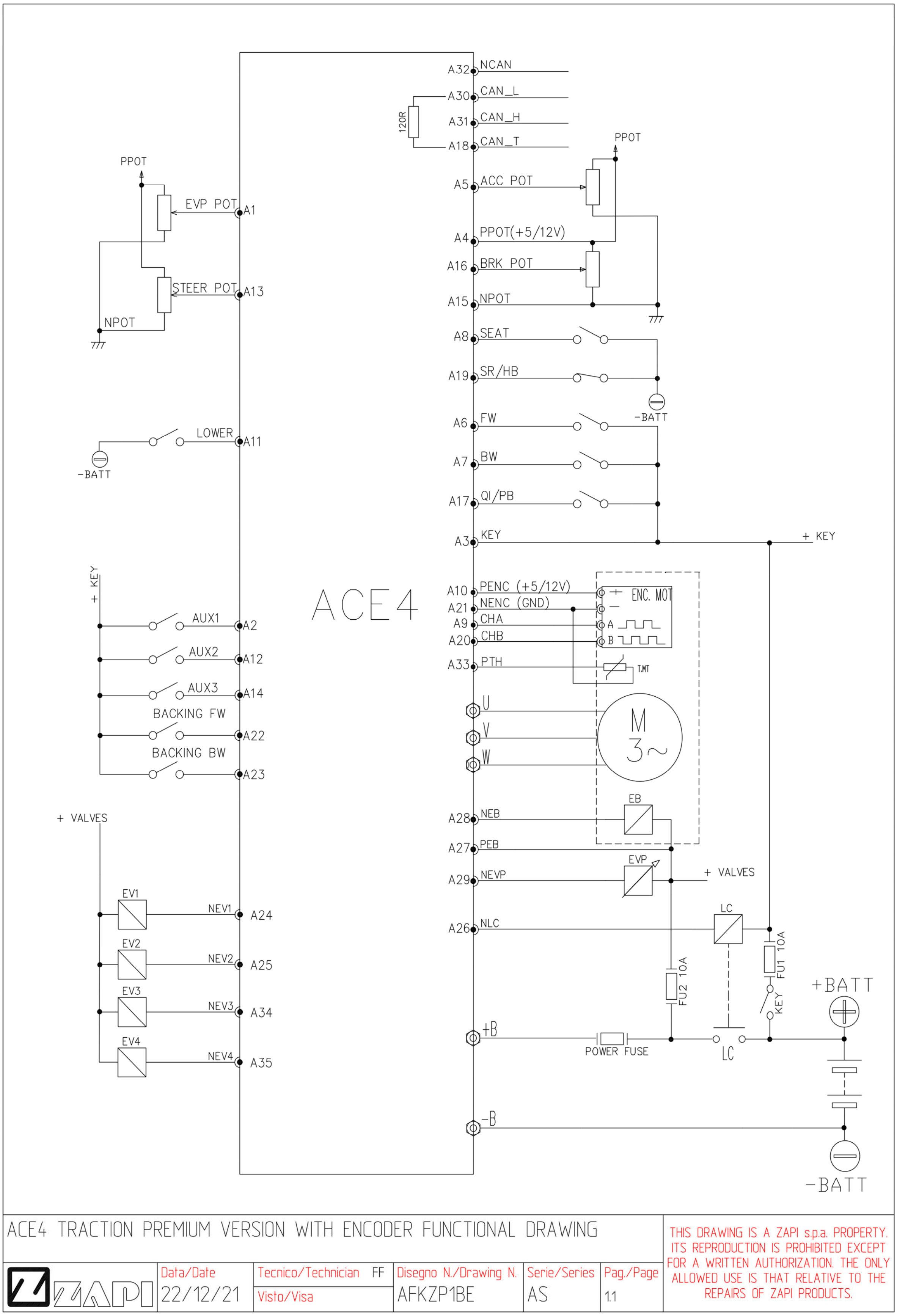


ACE4 PUMP STANDARD VERSION WITH ENCODER FUNCTIONAL DRAWING						THIS DRAWING IS A ZAPI s.p.a. PROPERTY. ITS REPRODUCTION IS PROHIBITED EXCEPT FOR A WRITTEN AUTHORIZATION. THE ONLY ALLOWED USE IS THAT RELATIVE TO THE REPAIRS OF ZAPI PRODUCTS.
ZAPI	Data/Date 26/06/17	Tecnico/Technician FF Visto/Visa	Disegno N./Drawing N. AFKZP1CB	Serie/Series AS	Pag./Page 1.1	

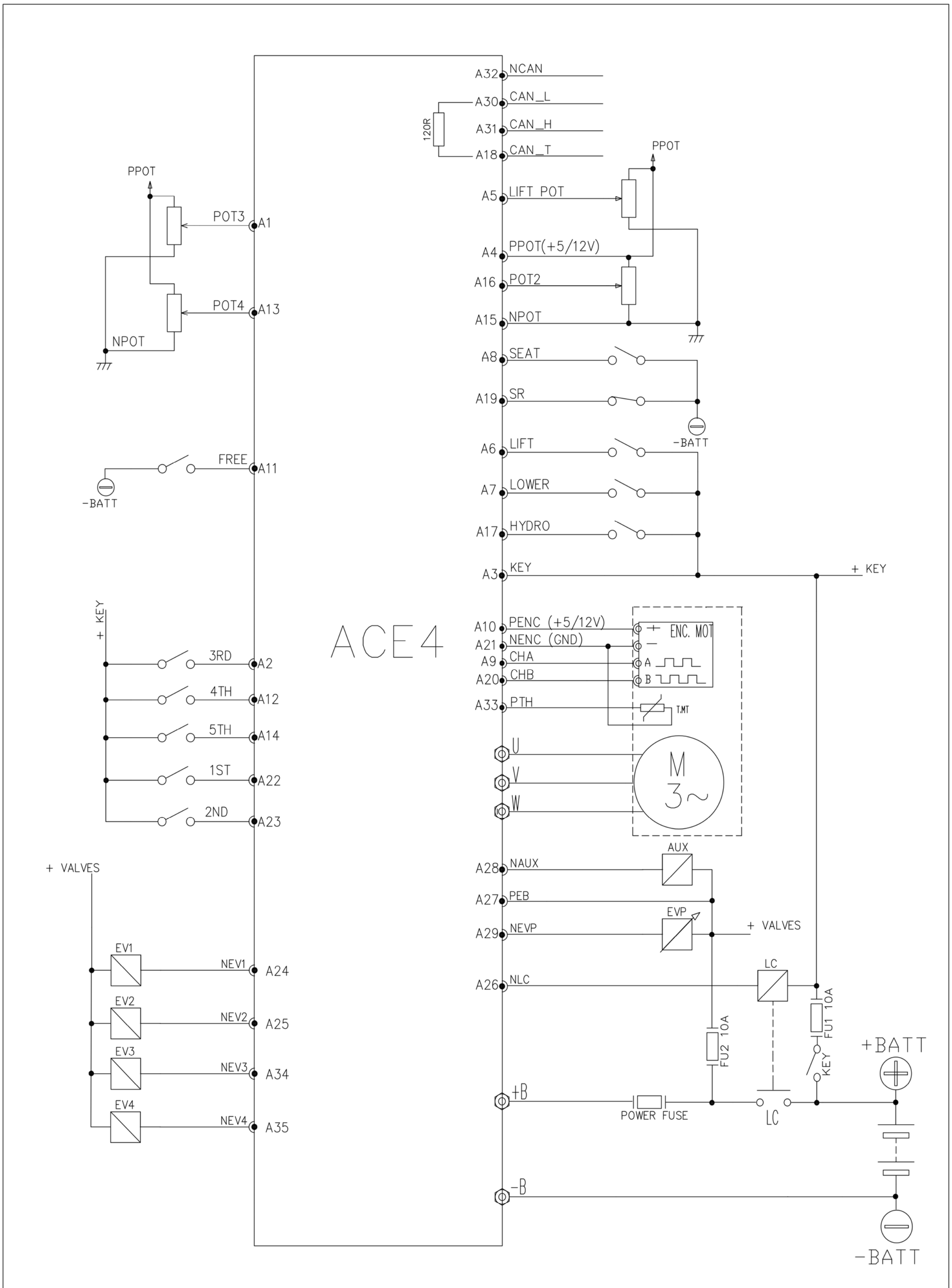
3.2.3 Standard version – AC CAN operated



3.2.4 Premium version – AC traction

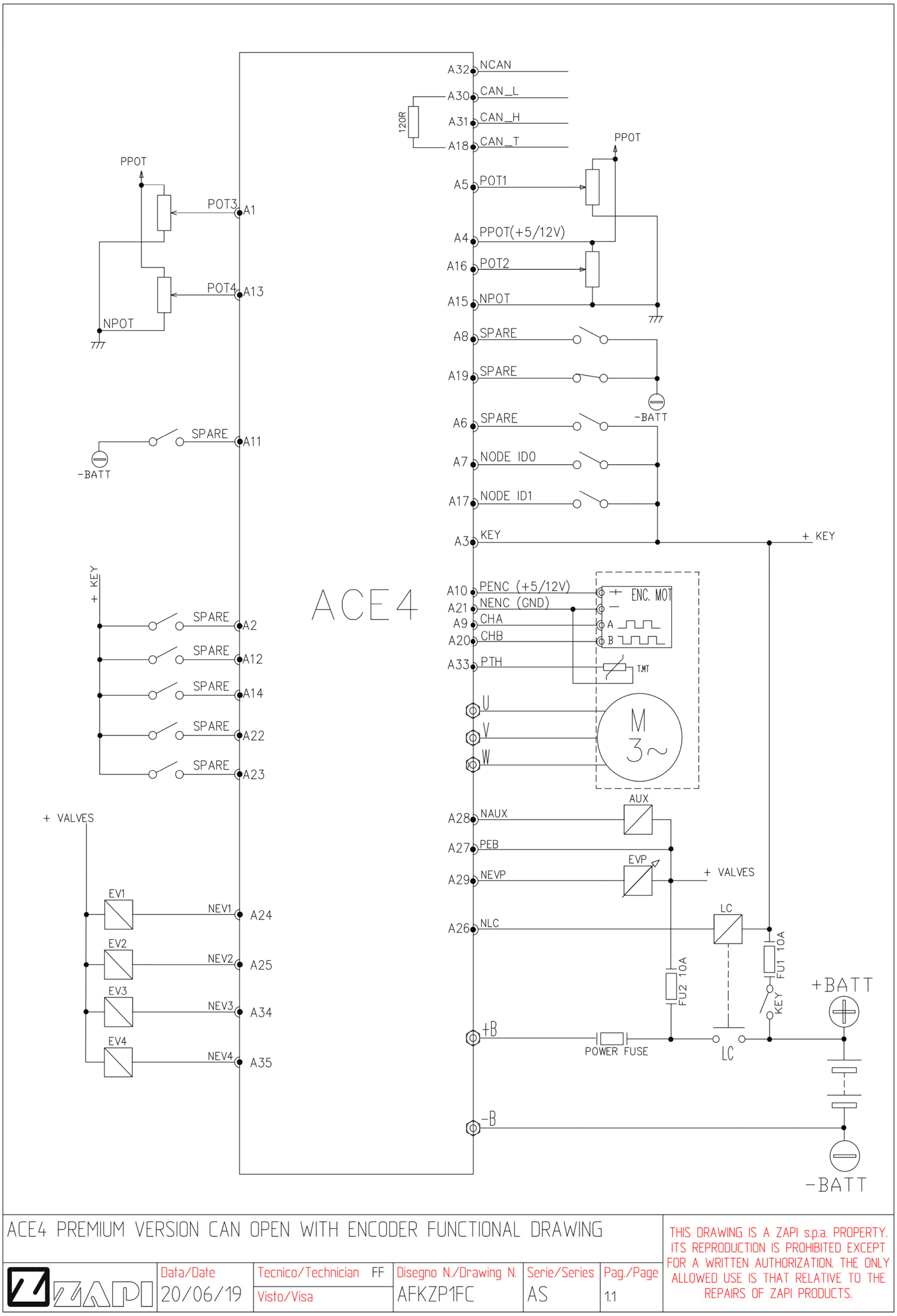


3.2.5 Premium version – AC pump

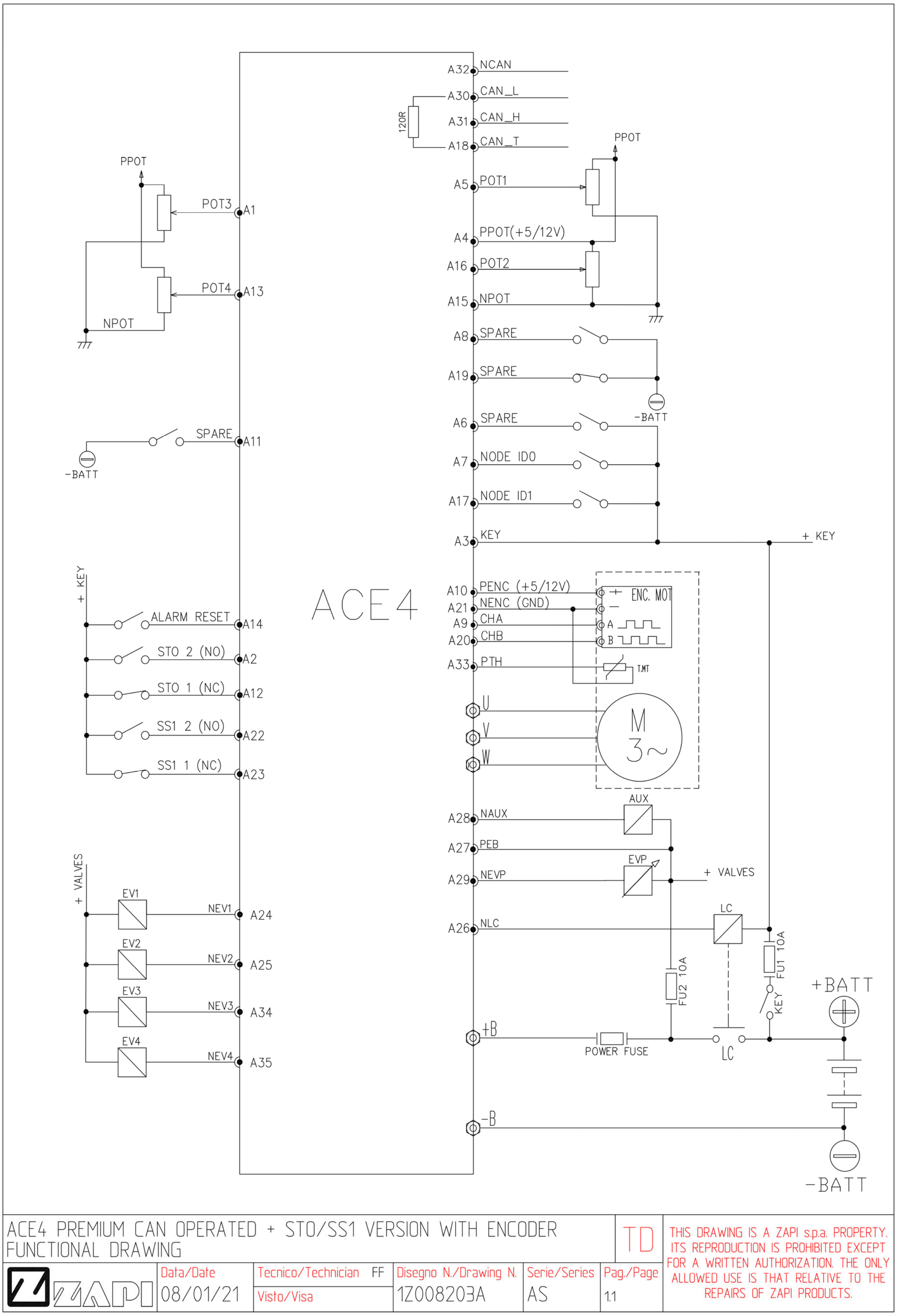


ACE4 PUMP PREMIUM VERSION WITH ENCODER FUNCTIONAL DRAWING						THIS DRAWING IS A ZAPI s.p.a. PROPERTY. ITS REPRODUCTION IS PROHIBITED EXCEPT FOR A WRITTEN AUTHORIZATION. THE ONLY ALLOWED USE IS THAT RELATIVE TO THE REPAIRS OF ZAPI PRODUCTS.
ZAPI	Data/Date 26/06/17	Tecnico/Technician FF Visto/Visa	Disegno N./Drawing N. AFKZP1DB	Serie/Series AS	Pag./Page 1.1	

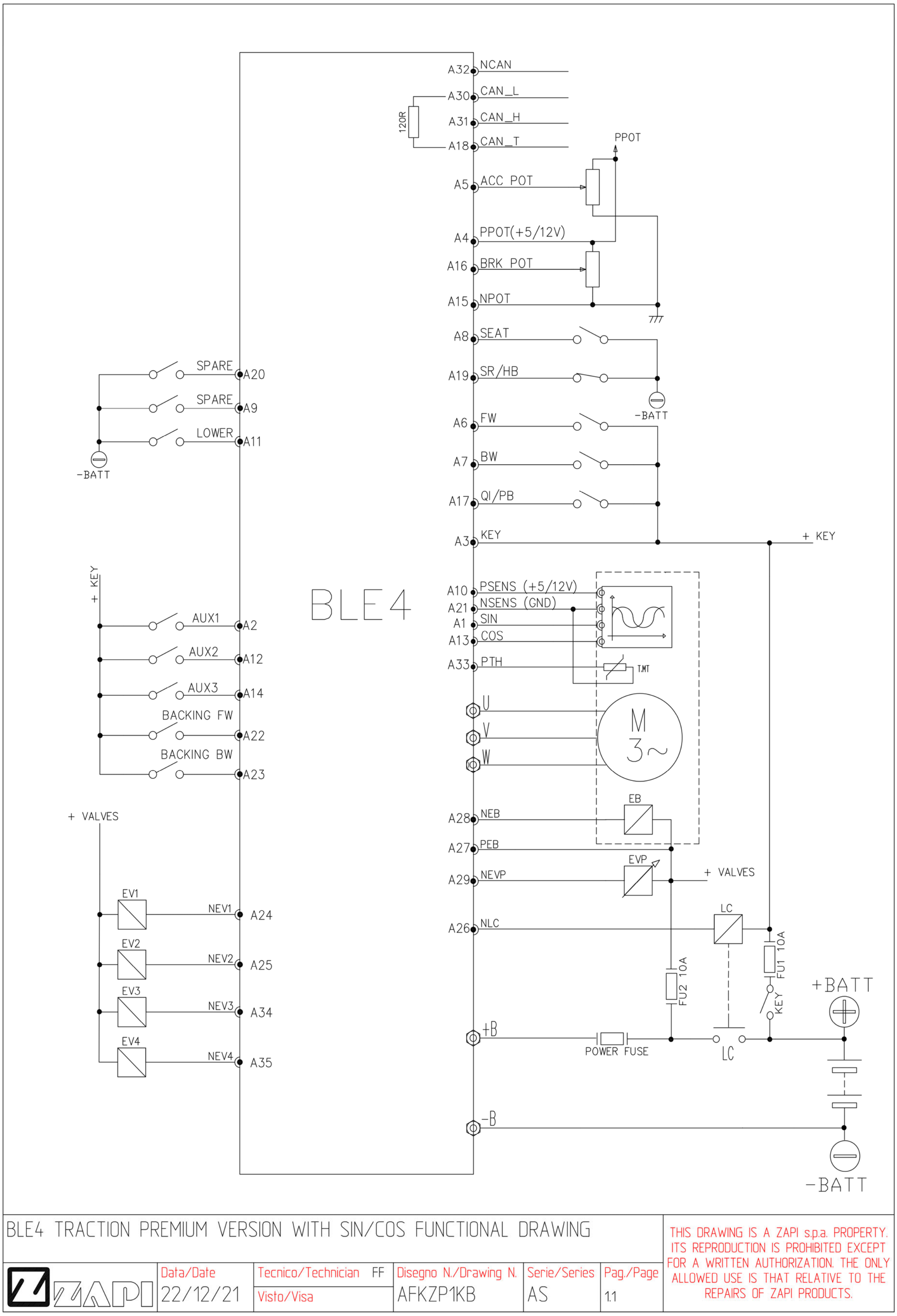
3.2.6 Premium version – AC CAN operated



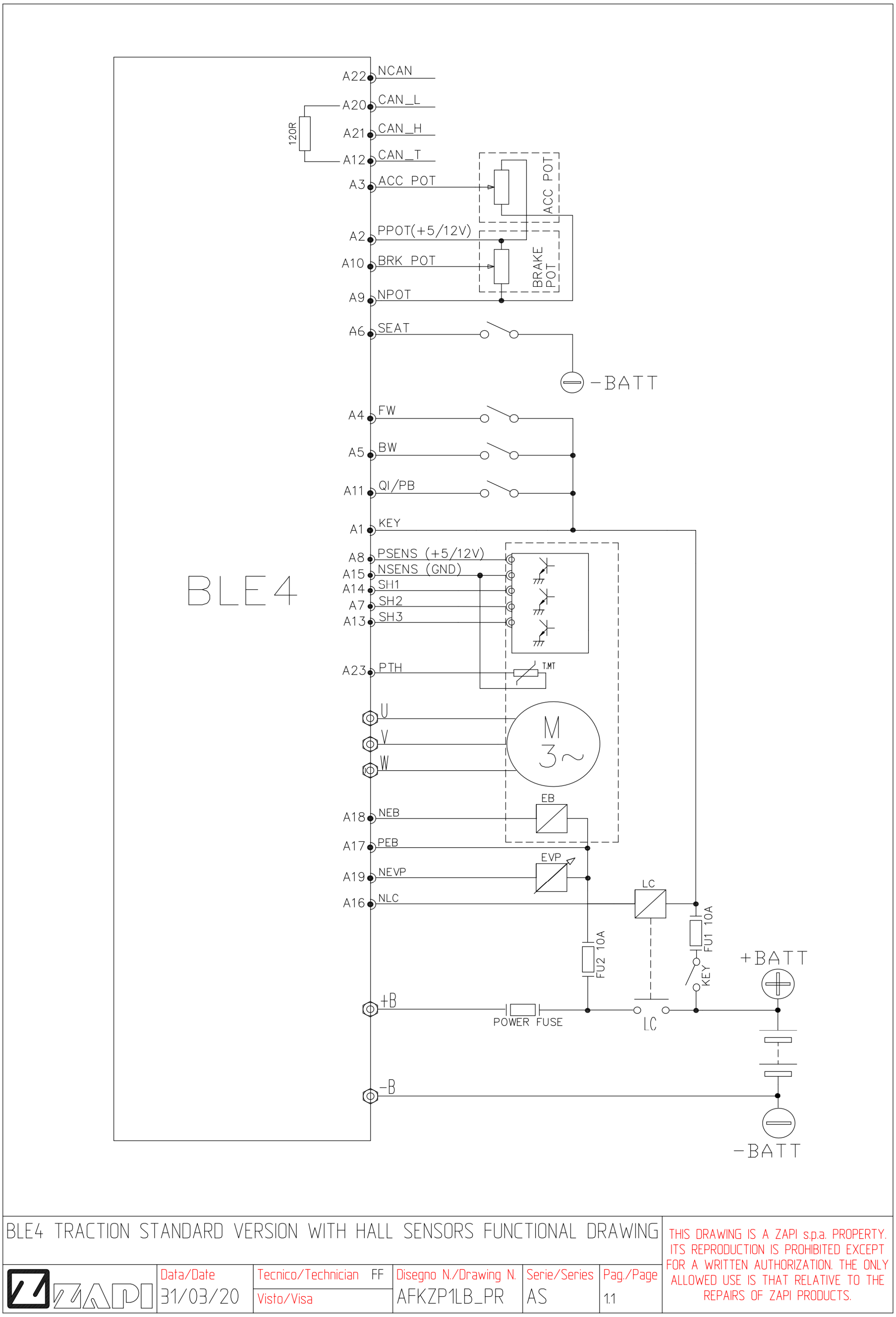
3.2.7 Premium version – AC CAN operated + STO/SS1



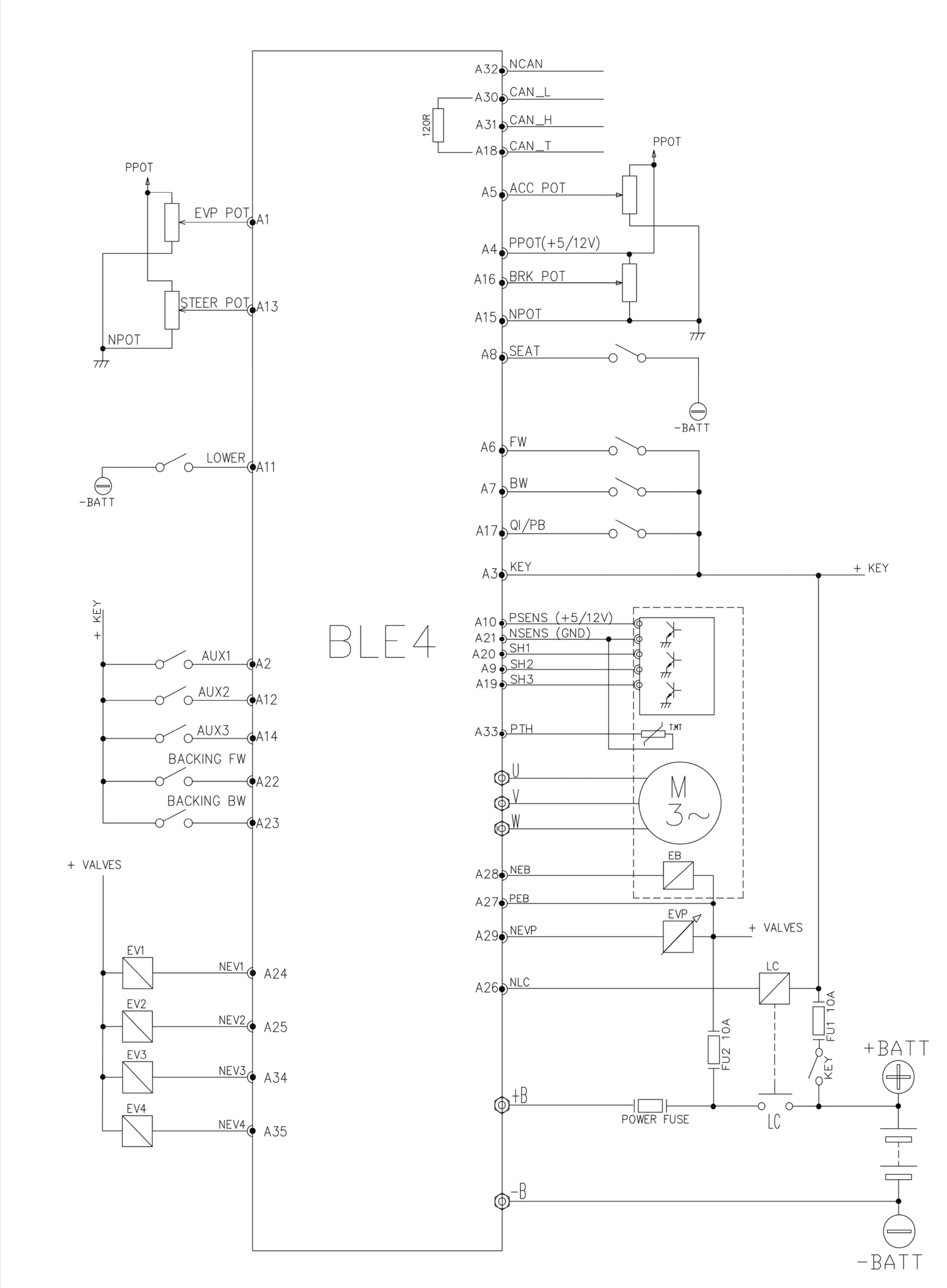
3.2.8 Premium version – BL traction with sin/cos sensor



3.2.9 Standard version – BL traction with 3-Hall sensors

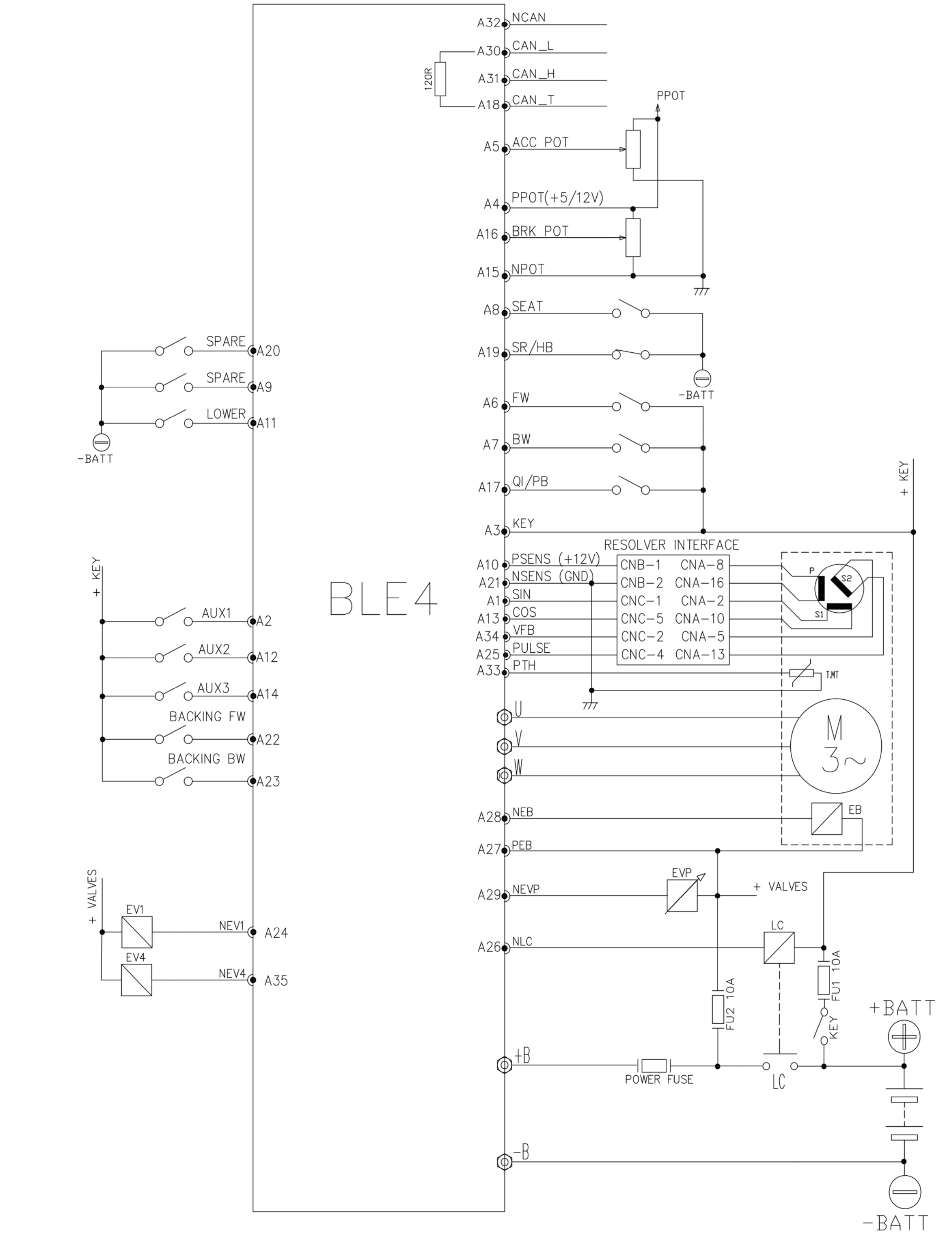


3.2.10 Premium version – BL traction with 3-Hall sensors



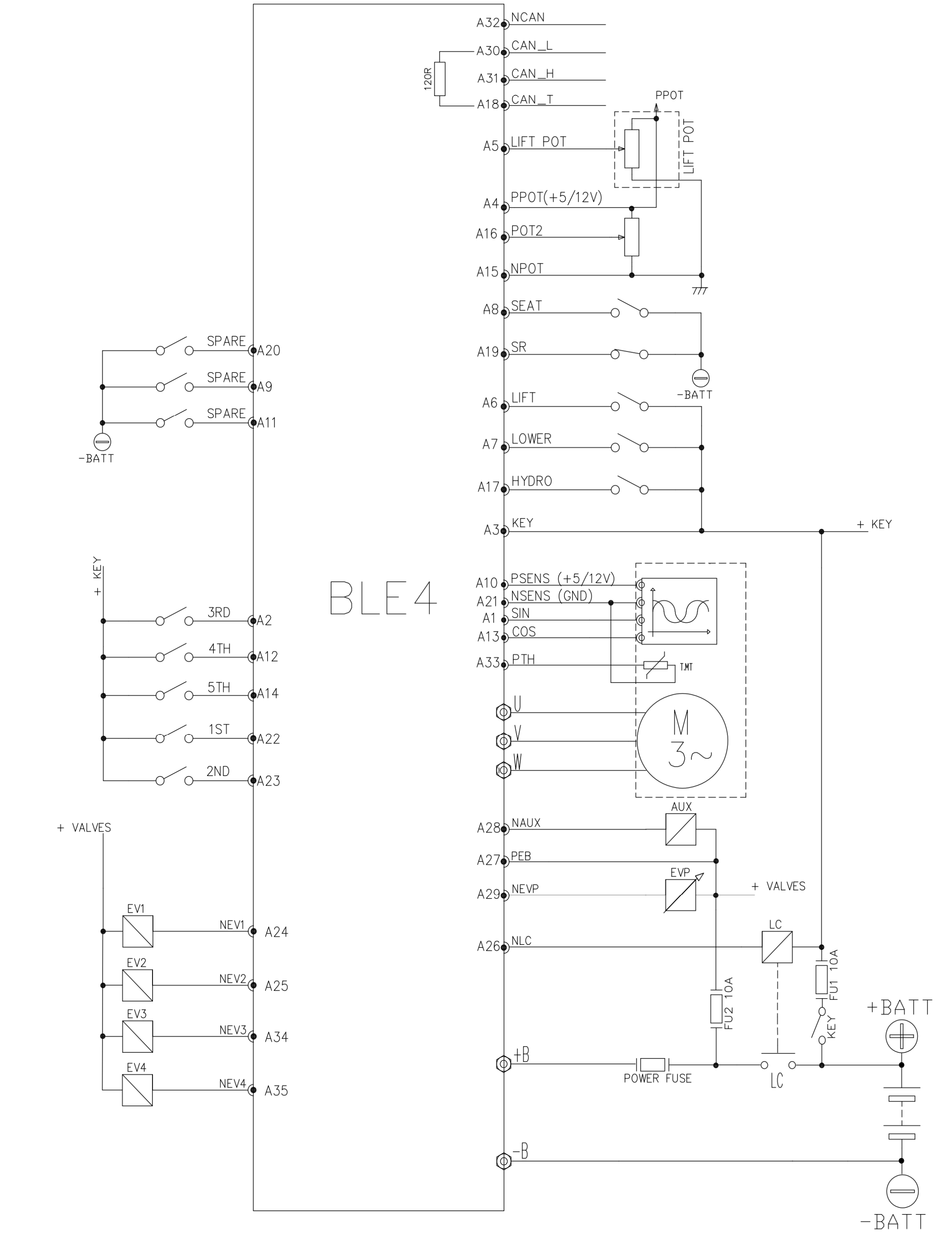
BLE4 TRACTION PREMIUM VERSION WITH HALL SENSORS FUNCTIONAL DRAWING					TD	THIS DRAWING IS A ZAPI s.p.a. PROPERTY. ITS REPRODUCTION IS PROHIBITED EXCEPT FOR A WRITTEN AUTHORIZATION. THE ONLY ALLOWED USE IS THAT RELATIVE TO THE REPAIRS OF ZAPI PRODUCTS.
ZAPI	Data/Date 22/12/21	Tecnico/Technician FF Visto/Visa	Disegno N./Drawing N. 1Z008269A	Serie/Series AS	Pag./Page 1.1	

3.2.11 Premium version – BL traction with resolver interface



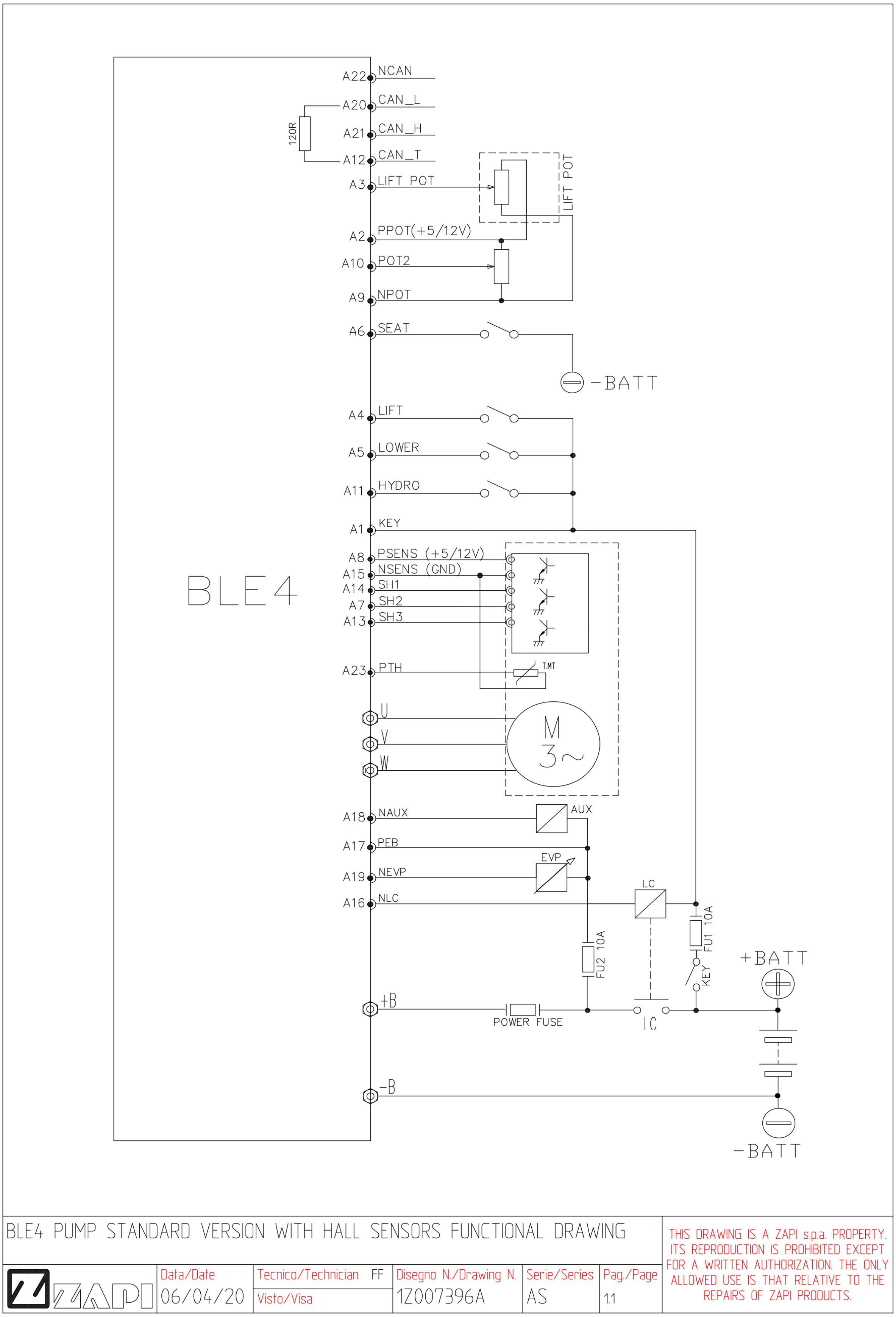
BLE4 TRACTION PREMIUM VERSION WITH RESOLVER INTERFACE FUNCTIONAL DRAWING						TD	THIS DRAWING IS A ZAPI s.p.a. PROPERTY. ITS REPRODUCTION IS PROHIBITED EXCEPT FOR A WRITTEN AUTHORIZATION. THE ONLY ALLOWED USE IS THAT RELATIVE TO THE REPAIRS OF ZAPI PRODUCTS.
ZAPI	Data/Date 22/12/21	Tecnico/Technician FF / Visto/Visa	Disegno N./Drawing N. 1Z008266A	Serie/Series AS	Pag./Page 1.1		

3.2.12 Premium version – BL pump with sin/cos sensor

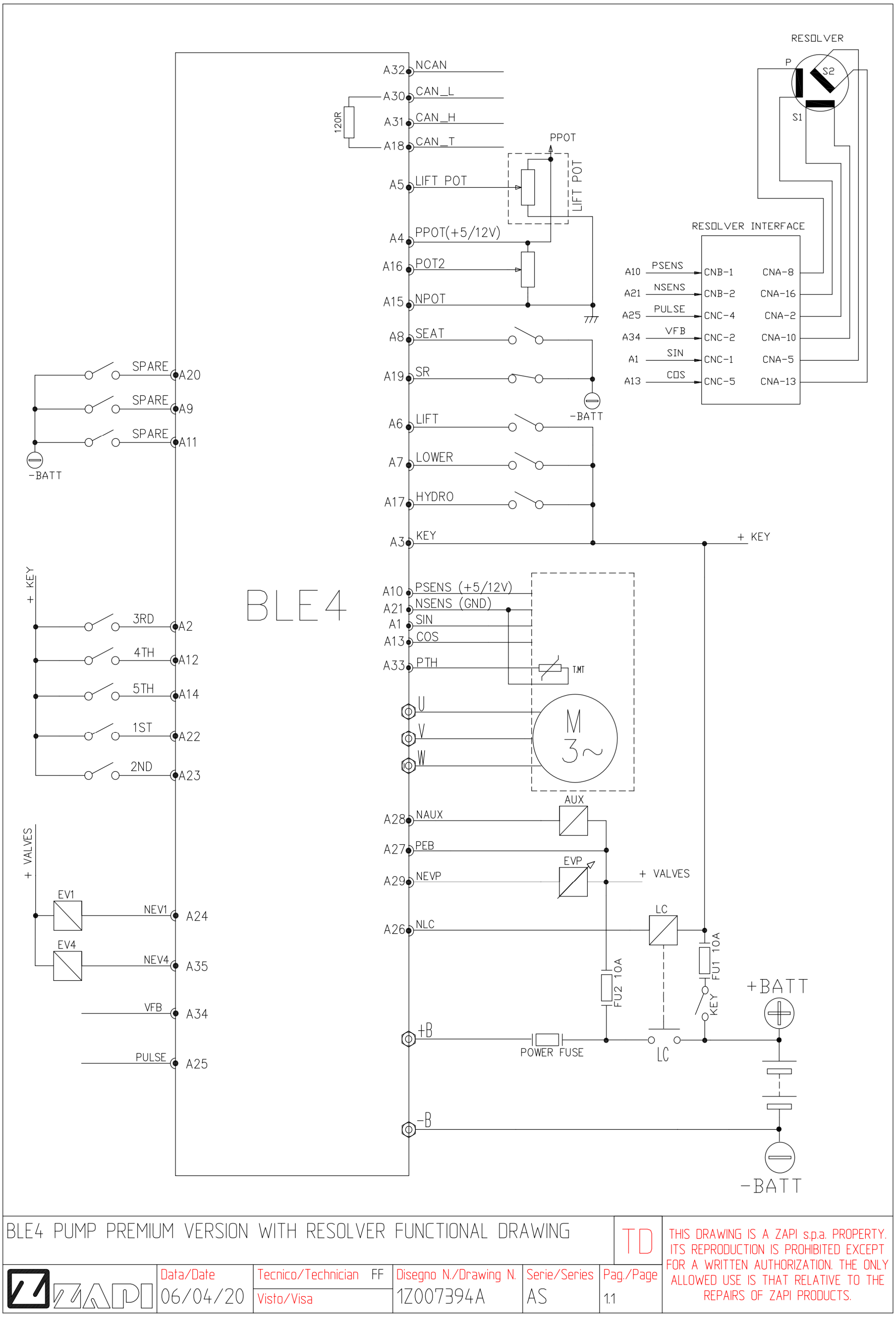


BLE4 PUMP PREMIUM VERSION WITH SIN/COS FUNCTIONAL DRAWING					TD	THIS DRAWING IS A ZAPI s.p.a. PROPERTY. ITS REPRODUCTION IS PROHIBITED EXCEPT FOR A WRITTEN AUTHORIZATION. THE ONLY ALLOWED USE IS THAT RELATIVE TO THE REPAIRS OF ZAPI PRODUCTS.
ZAPI	Data/Date 06/04/20	Tecnico/Technician FF / Visto/Visa	Disegno N./Drawing N. 1Z007395A	Serie/Series AS	Pag./Page 1.1	

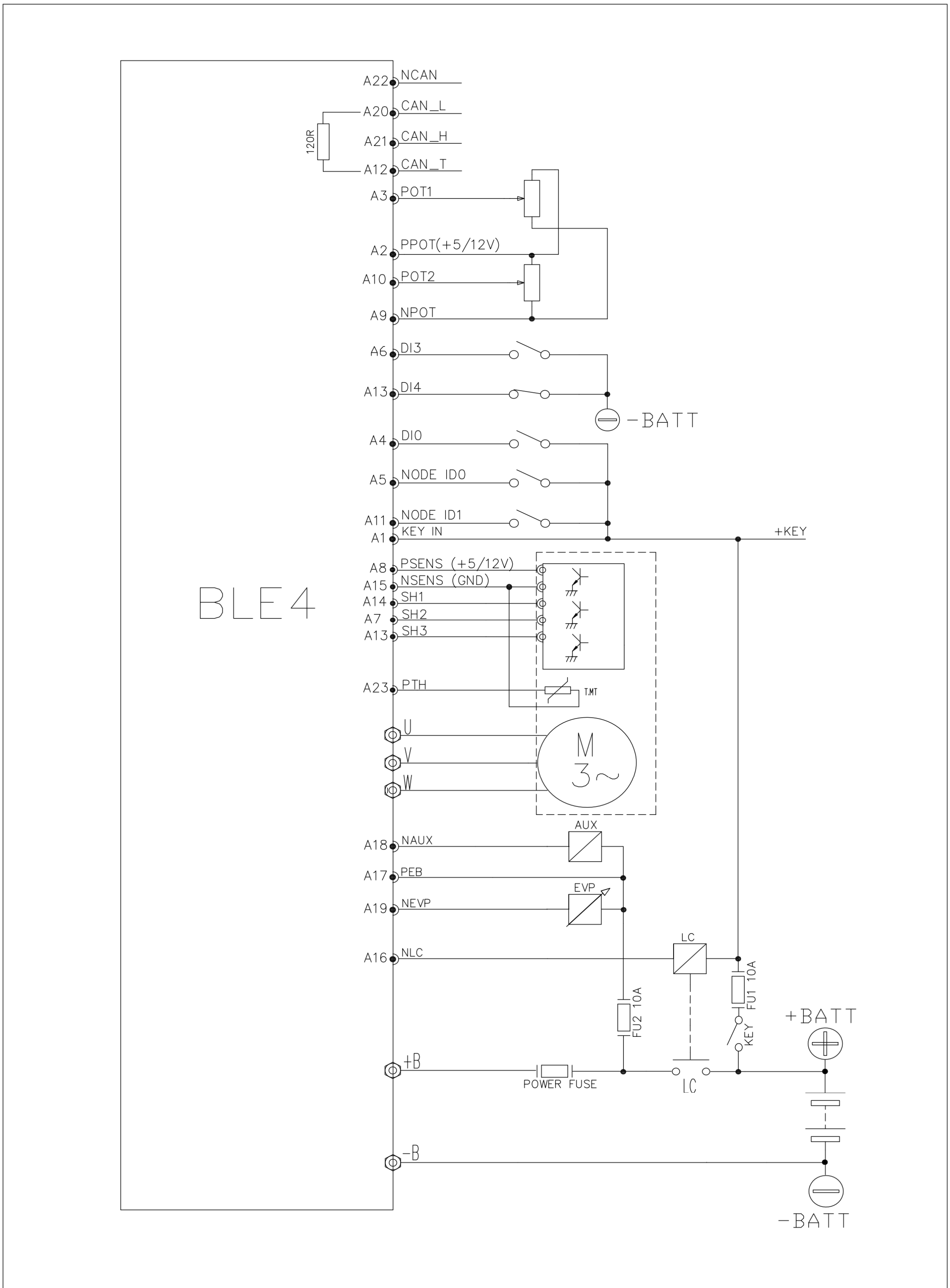
3.2.13 Standard version – BL pump with 3-Hall sensors



3.2.14 Premium version – BL pump with resolver interface



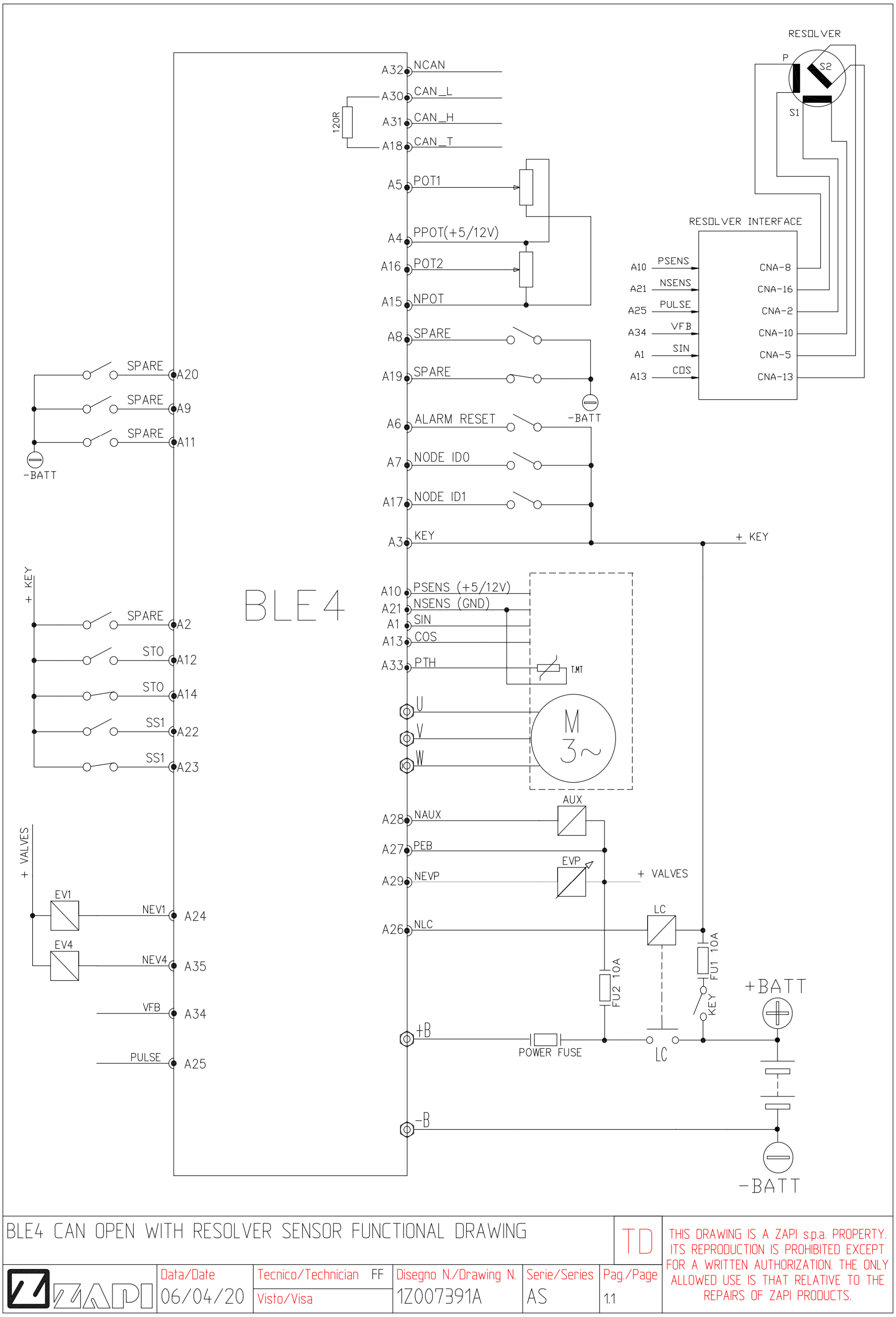
3.2.15 Standard version – BL CAN operated with 3-Hall sensors



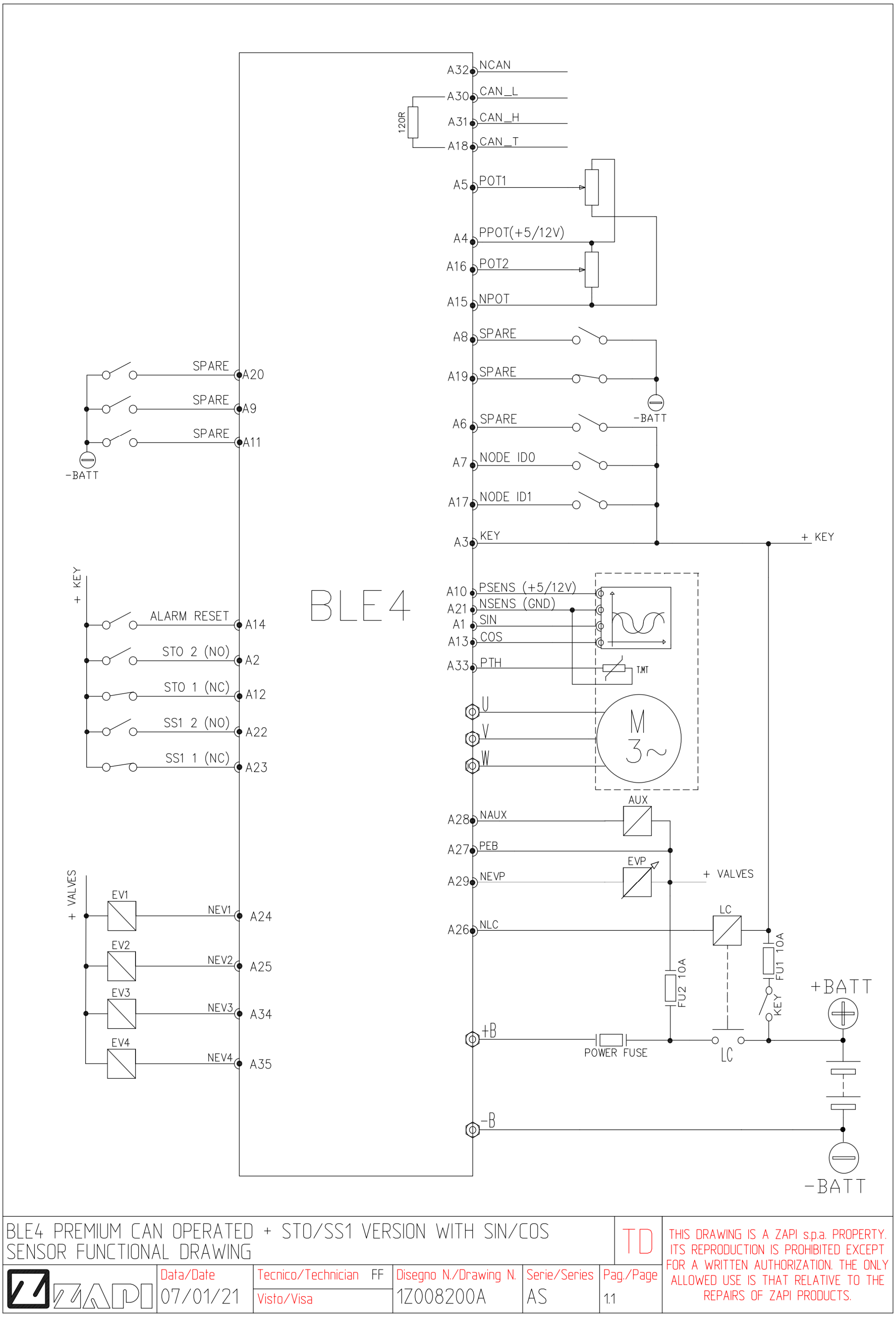
BLE4 STANDARD VERSION CAN OPEN WITH HALL SENSORS FUNCTIONAL DRAW.

ZAPI	Data/Date	Tecnico/Technician FF	Disegno N./Drawing N.	Serie/Series	Pag./Page
	12/09/18	Visto/Visa	AFKZP1JA	AS	1.1

3.2.16 Premium version – BL CAN operated with resolver interface



3.2.17 Premium version – BL CAN operated + STO/SS1 with sin/cos sensor



4 I/O INTERFACE DESCRIPTION

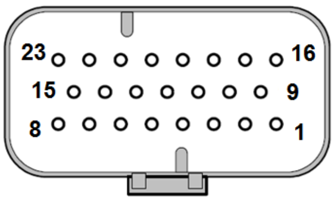
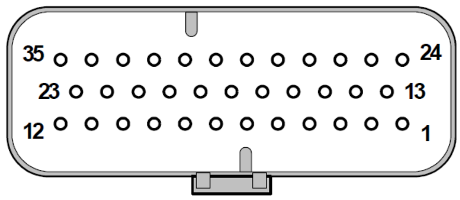
4.1 Power connectors

Power connections reside on vertical posts where to bolt power-cables lugs. On the converter lid, they are labeled as follows.

Terminal name	Description
+B	Positive battery termination, after main contactor
-B	Negative battery termination
U, V, W	Motor phase terminations

4.2 Ampseal connector

ACE4 is equipped with one 35-poles or 23-poles Ampseal connector, depending on the version.

Standard version	***Premium version***
Connector A: 23P	***Connector A: 35P***
	

Throughout this manual, pin references fall under the following color coding depending on the connector size: blue for 35P connector, red for 23P connector.

Each Ampseal pin is referred to as "A#" or "A# (A#)", where "A" denotes the connector name and "#" the pin number.

For each I/O pin, the default Zapi function is indicated. The function of each pin can vary with customized software.

Some I/O pins can have special functionality depending on the controller configuration.

4.2.1 Standard version

ACE4 Standard			
Pin	**Type**	**Name**	**Description**
A1	Input	KEY	Input of the key switch signal.
A2	Output	PPOT	Positive supply for potentiometers (+5 V or +12 V, 200 mA maximum).
A3	Input	ACC POT	Analog input 1. The default function is as accelerator reference (wiper contact of the accelerator potentiometer).
A4	Input	FW	Digital input active when connected to +B. The default function is as forward request; closing this input the truck moves forward.
A5	Input	BW	Digital input active when connected to +B. The default function is as backward request; closing this input the truck moves backward.
A6	Input	SEAT	Digital input active when connected to -B. The default function is as seat (or tiller) input.
A7	Input	CHA	Channel A of the incremental encoder.
A8	Output	PENC	Positive supply for the encoder or for other auxiliary devices like speed transducers, potentiometers, sensors or others (+5 V or +12 V, 200 mA maximum).
A9	Output	NPOT	Negative supply for the potentiometers. It is internally shorted and equivalent to A15.
A10	Input	BRK POT	Analog input 2. The default function is as breaking reference (wiper contact of the brake potentiometer).
A11	Input	QI/PB	Digital input active when connected to +B. The default function is as quick-inversion or brake-pedal input.
A12	Output	CANT	If connected to CANH A21, it introduces the standard 120 Ohm termination resistance between CANL and CANH.
A13	Input	SR/HB	Digital input inactive when connected to -B, active when the external switch is open. The default function is as speed reduction or handbrake request (see parameter HB ON / SR OFF, paragraph 8.2.2).
A14	Input	CHB	Channel B of the incremental encoder.
A15	Output	NENC	Negative supply for the encoder and for the motor thermal sensor. It is internally shorted and equivalent to A9.

ACE4 Standard			
Pin	**Type**	**Name**	**Description**
A16	Output	NLC	Driving output for the line – or main – contactor (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current.
A17	Output	PEB	Connect this pin to the positive terminals of the inductive loads driven by pins NEB A18 and NEVP A19. Take the positive supply for such loads immediately after the main contactor.
A18	Output	NEB	Driving output for the electromechanical brake (driving to -B); PWM controlled; 2 A maximum continuous current.
A19	Output	NEVP	Driving output for the proportional electrovalve (driving to -B); PWM current-controlled; 1.7 A maximum continuous current. Default function is as LOWERING valve.
A20	Output	CANL	Low-level CAN bus line.
A21	Output	CANH	High-level CAN bus line.
A22	Output	NCAN	Negative reference of the CAN bus interface, to be connected to the reference of the CAN bus line.
A23	Input	PTH	Analog input for the motor thermal sensor. Internal pull-up is a 2 mA current source (max 5 V).

4.2.1.1 Pump configuration

When the inverter is configured as pump controller, the pins assignments differ from those of the traction configuration only for the pins listed in the following table. The other ones are unchanged both in name and function.

ACE4 Standard – Pump configuration			
Pin	**Type**	**Name**	**Description**
A3	Input	LIFT POT	Analog input 1. The default function is as lift reference (wiper contact of the lift potentiometer).
A4	Input	LIFT	Digital input, active when connected to +B. The default function is as LIFT request. Closing the switch, the pump lifts the forks.
A5	Input	LOWER	Digital input, active when connected to +B. The default function is as LOWER request. Closing the switch, the pump lowers the forks.
A10	Input	POT2	Analog input 2. By default it is not assigned to any function.
A11	Input	HYDRO	Digital input, active when connected to +B. The default function is as hydraulic steering request.

ACE4 Standard – Pump configuration			
Pin	**Type**	**Name**	**Description**
A18	Output	NAUX	Auxiliary-function output; PWM voltage controlled; 2.5 A maximum continuous current (driving to -B).

4.2.1.2 Three-Hall sensors

When the inverter is configured to drive a BL motor with three-Hall sensors, the pins assignments differ from those of the traction or pump configuration only for the pins listed in the following table. The other ones are unchanged both in name and in function.

BLE4 Standard – Three-Hall sensors			
Pin	**Type**	**Name**	**Description**
A7	Input	SH2	Second Hall sensor.
A8	Input	PENS	Positive supply for the Hall sensors and for potentiometers (+5 V or +12 V, 200 mA maximum).
A13	Input	SH3	Third Hall sensor.
A14	Input	SH1	First Hall sensor.
A15	Input	NSENS	Negative supply for the Hall sensors, the thermal sensor and potentiometers.

4.2.2 Premium version

ACE4 Premium			
Pin	**Type**	**Name**	**Description**
A1	Input	EVP POT	Analog input 3. The default function is as lowering reference (wiper contact of the lowering potentiometer).
A2	Input	AUX1	Digital input, active when connected to +B. By default, closing the switch output NEV1 (A24) is activated.
A3	Input	KEY	Input of the key switch signal.
A4	Output	PPOT	Positive supply for potentiometers (+5 V or +12 V, 200 mA maximum).
A5	Input	ACC POT	Analog input 1. The default function is as accelerator reference (wiper contact of the accelerator potentiometer).

ACE4 Premium			
Pin	**Type**	**Name**	**Description**
A6	Input	FW	Digital input active when connected to +B. The default function is as forward request; closing this input the truck moves forward.
A7	Input	BW	Digital input active when connected to +B. The default function is as backward request; closing this input the truck moves backward.
A8	Input	SEAT	Digital input active when connected to -B. The default function is as seat (or tiller) input.
A9	Input	CHA	Channel A of the incremental encoder.
A10	Output	PENC	Positive supply for the encoder or for another speed transducer (+5 V or +12 V, 200 mA maximum).
A11	Input	LOWER	Digital input, active when connected to -B. The default function is as lowering request. Closing the switch, NEVP output (A29) is activated according to the set-point defined by EVP POT (A1).
A12	Input	AUX2	Digital input, active when connected to +B. By default, closing the switch output NEV2 (A25) is activated.
A13	Input	STEER POT	Analog input 4. The default function is as steering reference (wiper contact of the steering potentiometer).
A14	Input	AUX3	Digital input, active when connected to +B. By default, closing the switch output NEV3 (A34) is activated.
A15	Output	NPOT	Negative supply for the potentiometers. It is internally shorted and equivalent to A21.
A16	Input	BRK POT	Analog input 2. The default function is as breaking reference (wiper contact of the brake potentiometer).
A17	Input	QI/PB	Digital input active when connected to +B. The default function is as quick-inversion or brake-pedal input.
A18	Output	CANT	If connected to CANH A31, it introduces the 120 Ohm termination resistance between CANL and CANH.
A19	Input	SR/HB	Digital input inactive when connected to -B, active when the switch is open. The default function is as speed-reduction or handbrake request (see parameter HB ON / SR OFF, paragraph 8.2.2).
A20	Input	CHB	Channel B of the incremental encoder.

ACE4 Premium			
Pin	**Type**	**Name**	**Description**
A21	Output	NENC	Negative supply for the encoder and for the motor thermal sensor. It is internally shorted and equivalent to A15.
A22	Input	SPARE	Digital input, active when connected to +B. The default function is as forward backing (inching) request.
A23	Input	SPARE	Digital input, active when connected to +B. N The default function is as backward backing (inching) request.
A24	Input	NEV1	Driving output for the on/off electrovalve EV1 (driving to -B); ON/OFF controlled; 1.5 A maximum continuous current. By default, it gets activated by closing the switch AUX1 (A2).
A25	Output	NEV2	Driving output for the on/off electrovalve EV2 (driving to -B); 1.5 A maximum continuous current. By default, it gets activated by closing the switch AUX2 (A12).
A26	Output	NLC	Driving output for the line – or main – contactor (driving to -B); PWM controlled; 1.5 A maximum continuous current.
A27	Output	PEB	Connect this pin to the positive terminals of the inductive loads driven by pins NEB A28 NEV1 A24, NEV2 A25, NEV3 A34, NEV4 A35 and NEVP A29. Take the positive supply for such loads immediately after the main contactor.
A28	Output	NEB	Driving output for the electromechanical brake (driving to -B); PWM controlled; 2 A maximum continuous current.
A29	Output	NEVP	Driving output for the proportional electrovalve (driving to -B); PWM current-controlled; 1.7 A maximum continuous current. Default function is as LOWERING valve.
A30	Output	CANL	Low-level CAN bus line.
A31	Output	CANH	High-level CAN bus line.
A32	Output	NCAN	Negative reference of the CAN bus interface, to be connected to the reference of the CAN bus line.
A33	Input	PTH	Analog input for the thermal sensor of the traction motor. Internal pull-up is a 2 mA current source (max 5 V).
A34	Output	NEV3	Driving output for the on/off electrovalve EV3 (driving to -B); 1.5 A maximum continuous current. By default, it gets activated by closing the switch AUX3 (A14).
A35	Output	NEV4	Driving output for the on/off electrovalve EV4 (driving to -B); 1.5 A maximum continuous current.

4.2.2.1 Sin/cos sensor

When the inverter is configured to drive a BL motor with a sin/cos sensor, the pinout differs from that of the AC configuration only for the pins listed in the following table. The other ones are unchanged both in name and in function. This configuration is available only in combination with the 35-poles connector, available on the Premium version.

BLE4 Premium – Sin/cos			
Pin	**Type**	**Name**	**Description**
A1	Input	SIN	Sine signal of the sin/cos sensor.
A9	Input	CHA	Digital input, active when connected to -B. By default it is not assigned to any function.
A10	Output	PSENS	Positive supply for the sin / cos sensor and for potentiometers (+5 V or +12 V, 200 mA maximum).
A13	Input	COS	Cosine signal of the side sin/cos sensor.
A20	Input	CHB	Digital input, active when connected to -B. By default it is not assigned to any function.
A21	Output	NSENS	Negative supply for sin/cos sensor, thermal sensor and potentiometers.

4.2.2.2 Resolver sensor

When the inverter is configured to drive a BL motor with a resolver, the pins assignments differ from those of the traction or pump sin/cos configuration only for the pins listed in the following table. The other ones are unchanged both in name and in function. This configuration is available only in combination with the 35-poles connector, available on the Premium version.

BLE4 Premium – Resolver			
Pin	**Type**	**Name**	**Description**
A25	Input	VFB	Analog input. Feedback coming from Resolver interface board
A34	Output	PULSE	Command signal for Resolver interface board

4.3 External devices

4.3.1 Key switch

KEY input is generally connected to the vehicle ignition or key switch. The input supplies the logic circuitry with the battery voltage and it also serves as source for the pre-charge of the DC-link capacitors at key-on, while the main contactor is open. The KEY voltage is monitored.

Note: external loads connected to the power terminal +B, such as proximity switches, load the internal PTC resistor along the key input path, with the consequence that the pre-charge voltage may be lower than expected.

Protection

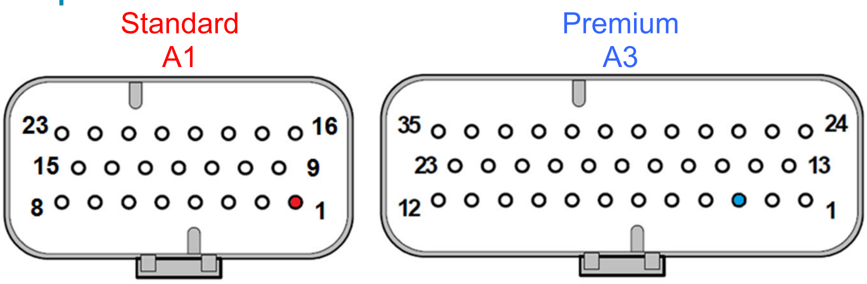
The KEY input is protected against reverse polarity with a diode and it features approximately 470 nF of capacitance to -B for ESD protection and filtering. This capacitance may give a high current spike at the KEY input depending on the external circuit.

Fuse FU1 (see functional drawings, chapter 3.2), should be sized according to the number of motor controllers connected to it (10 A fuse is recommended) and the current absorption of the KEY input (input power below 15 W).

The key switch connected to the KEY input must handle the short inrush current spike to the ESD-protection capacitors. The current peak depends on the external circuit and wires.

Cables from the battery to the KEY input should be as short as possible.

Connector position



4.3.2 Digital inputs

Digital inputs are meant to work in the voltage range from -B to +B. Related command devices (micro-switches) must be connected to the positive voltage (typically to the key line) or to the negative one (typically –B), depending on the input configuration (refer to pin description, paragraph 4.2). Pull-down or pull-up resistors are built-in.

Functional devices (like FW, BW, LOWER, etc.) are normally open, associated functions become active when the micro-switches close. Safety-related devices (by default only SR/HB) must be normally closed, associated functions become active when the micro-switches open.

The nominal voltage figures for the digital inputs in the standard Zapi configuration are listed below. Custom hardware configurations may feature different figures.

Inverter voltage		**24 V**	**36/48 V**	**72/80 V**	**96 V**
Active high	Low threshold	3.6 V	3.6 V	8.2 V	9.8 V
	High threshold	8.5 V	8.5 V	19 V	22.9 V
Active low	Low threshold	3.6 V	2.8 V	3.8 V	3.8 V
	High threshold	8.5 V	6.4 V	8.8 V	8.8 V
Voltage range		0 ÷ 35 V	0 ÷ 72.5 V	0 ÷ 115 V	0 ÷ 125 V

For critical functions, when good diagnostics coverage is necessary, it is recommended to use two digital inputs for plausibility check, for example to use both normally open and normally closed contacts.

Protection

Each digital input features a 10 nF capacitor to -B for ESD protection.

Circuit

Input impedance of active-high digital inputs in standard Zapi configurations are listed below. Custom hardware may feature different impedance values.

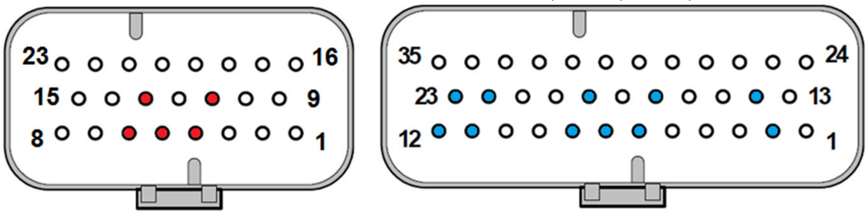
Inverter voltage	**36/48 V**	**72/80 V**	**96 V**
Input impedance	14.5 kΩ	30 kΩ	55 kΩ

Digital inputs on A8 (A6) and A11 are normally configured to be active when closed to -B. Their behavior can be changed by special HW configuration, as to be active when closed to +B.

Connector position

Standard
A4, A5, A6, A11, A13

Premium
A2, A6, A7, A8, A11, A12, A14, A17, A19, A22, A23



Micro-switches

- It is suggested that micro-switches have a contact resistance lower than 0.1 Ω and a leakage current lower than 100 μA.
- In full-load condition, the voltage between the key-switch contacts must be lower than 0.1 V.
- If the micro-switches to be adopted have different specifications, it is suggested to discuss them with Zapi technicians prior to employ them.

4.3.3 Analog inputs

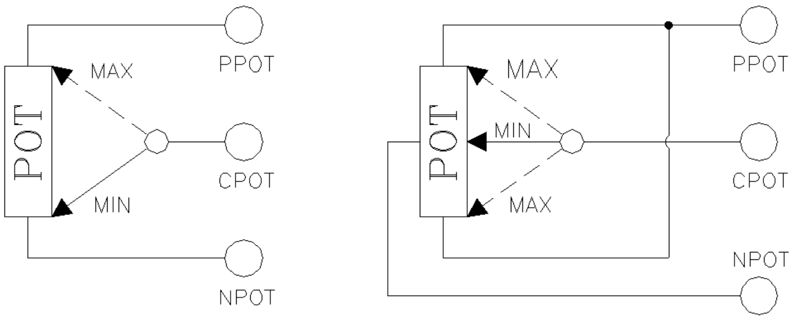
Analog inputs are for functions such as accelerator or brake references and they are acquired through a 10-bit analog-to-digital converter (resolution is given by voltage excursion over 1024 levels).

Circuit

Input impedance and maximum frequency for analog inputs in standard Zapi configurations are listed below. Custom hardware may feature different values.

Inverter voltage	36/48 V	72/80 V	96 V
Input impedance	255 kΩ	255 kΩ	318 kΩ
Maximum frequency	27 Hz	27 Hz	21 Hz

The standard configuration of the potentiometer is that at rest at one end, in combination with a couple of travel-demand switches (left-hand side of the figure). It is also possible to have the configuration at rest in the middle, still in combination with a couple of travel-demand switches. As a general reference, unassigned negative, central and positive terminals are depicted.



Examples of potentiometer configurations.

The negative reference of the potentiometer can be connected to NPOT A15 (A9) or NENC A21 (A15).

Potentiometer resistance should be in the 0.5 – 10 kΩ range; generally, the load should be in the 1.5 mA to 30 mA range.

A procedure for automatic acquisition of all the potentiometers signals can be carried out using the console (see paragraphs 9.1, 9.2 and 9.3).

On demand, analog inputs may also be used as extra digital inputs. In such cases, software based thresholds are implemented.

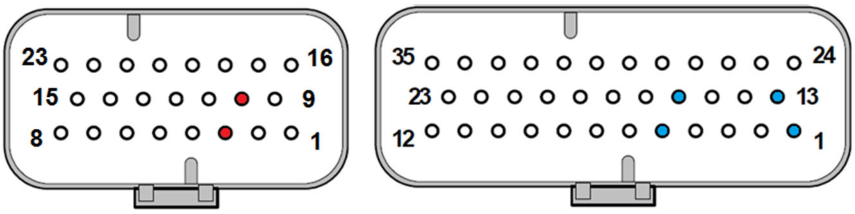
Protection

Analog inputs are protected against short circuits to +B and -B. Each one has a 10 nF capacitor to -B for ESD protection.

Connector position

Standard
A3, A10

Premium
A1, A5, A13, A16



If an analog input is used as a speed reference for the motor controller, a system safety strategy must be defined.

The application software must take care of analog input errors such as VACC OUT OF RANGE or VACC NOT OK.

4.3.4 Encoder input

Inputs for motor-speed feedback (encoder signals) have an internal 1 kΩ pull-up, suited for open collector sensor output.

Threshold levels are:

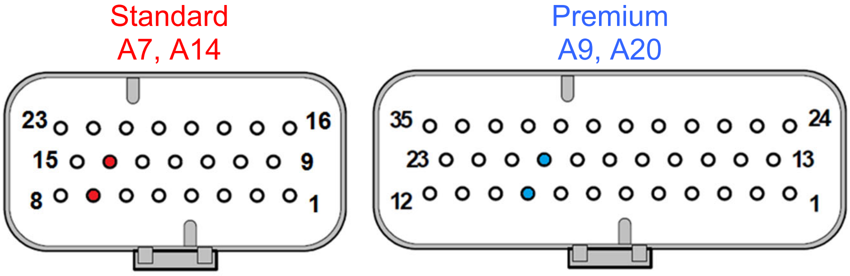
Supply voltage	5 V	12 V
High-to-low	1.4 V	4.3 V
Low-to-high	3.5 V	6.4 V

Encoder signals are acquired through a dedicated quadrature peripheral of the microcontroller.

Protection

Encoder inputs are protected against short circuits to +B and -B and have ESD suppressors to -B for ESD protection.

Connector position



It is important to verify the wiring by ensuring that encoder signals are not disturbed by the motor currents or by the electric motor brake.

For more details about the encoder installation, see paragraph 6.2.6.

The encoder resolution is specified in the PC Zapi Console headline. See paragraph 13.1.2 for the details.

Encoder resolution can be changed through the dedicated parameters. See paragraph 8.2.8.

4.3.5 MC output

The main (or line) contactor is operated through an open-drain PWM voltage-controlled output.

In order to utilize the built-in freewheeling diode, the coil must be supplied by the KEY voltage feeding pin A3 (A1), see chapter 3.2.

A nonstandard hardware configuration can permit to utilize a built-in freewheeling diode connected to pin PEB A27 (A17).

In case the vehicle design does not allow for the usage of the built-in freewheeling diode, i.e. if the return path integrity cannot be guaranteed in all situations, an external diode has to be applied across the coil terminals.

Output features

- Up to 1.5 Arms continuous current (holding).
- Up to 2 A peak (pulling) current for a maximum of 200 ms.
- Individual circuitry for detection of: shorted driver, open driver, open coil.
- 1 kHz default PWM frequency.
- Configurable output voltage, by means of separate parameters for pulling and holding stages.

PWM should only be used for inductive loads such as relays, contactors, motor brakes or hydraulic valves.

PWM frequency can be changed by software. If a different PWM frequency has to be used, it is suggested to discuss it with Zapi technicians.

Protection

Protected against inductive discharge with internal freewheeling diode to pin KEY A3 (A1) or optionally PEB A27 (A17), and ESD protected by means of ESD-suppressing device. Protected against reverse polarity of the battery.

Built-in diagnostics:

- Overcurrent
- Shorted driver
- Open driver
- Open coil

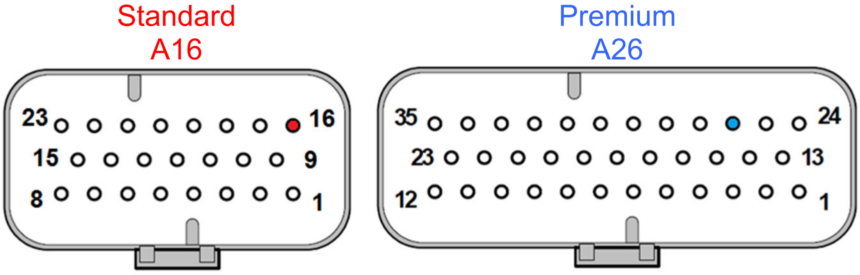
Refer to chapter 10 for a more detailed description.

Overcurrent protection is featured by hardware, shared with EB output.

*MC output can only be a PWM voltage-controlled output. It **cannot** be used as a current-controlled output.*

When driving an inductive load on PWM open-drain output, there must always be a path for the current through a freewheeling diode. Do not connect any switch or fuse in series with the diode.

Connector position



To protect the motor controller from overvoltage due to the inductive nature of the load, freewheeling diode to pin KEY A3 (A1) or optionally PEB A27 (A17) is built-in.

Ensure that the inductive load is connected so that the path through the freewheeling diode is always present; otherwise use an external freewheeling diode.

Using brushless fans or other loads with built-in capacitors may lead to high inrush currents at turn-on, which may eventually bring to overcurrent trips. Inrush current must be below the peak current.

For more details about the main contactor installation, see paragraph 6.2.8.

4.3.6 EB output

The electromechanical brake is operated through an open-drain PWM voltage-controlled output on pin NEB A28 (A18). In order to utilize the built-in freewheeling diode, the coil must be connected to pin PEB A27 (A17), see chapter 3.2.

In case the vehicle design does not allow the usage of the built-in freewheeling diode, i.e. if the return path integrity cannot be guaranteed in all situations, an external freewheeling diode must be applied across the coil terminals.

Output features

- 2 Arms continuous current (holding).
- 3 A peak (pulling) current for a maximum of 200 ms.
- Individual hardware for detection of: shorted driver, open driver, open coil.
- 1 kHz PWM frequencies.
- Configurable output voltage, by means of separate parameters for pulling and holding stages.

PWM shall only be used for inductive loads such as relays, contactors, motor brakes or hydraulic valves.

Protection

Protected against inductive discharge with internal freewheeling diode to pin PEB A27 (A17) and ESD protected.

Not protected against reverse polarity of the battery. A way to avoid a failure caused by the polarity inversion is to activate the contactor only when the voltage across the DC-link capacitors has reached the accepted pre-charge level.

Built-in diagnostics:

- Overcurrent
- Shorted driver
- Open driver
- Open coil

Refer to chapter 10 for more detailed description.

Overcurrent protection is featured by hardware, shared with MC output.

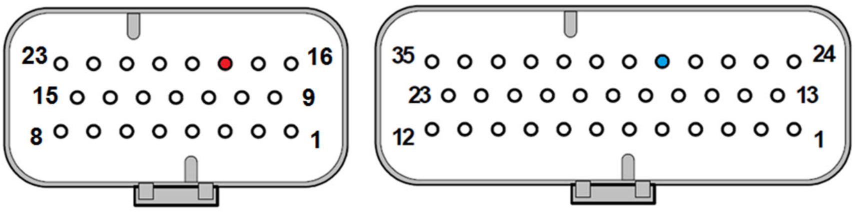
*EB output can be only a PWM voltage-controlled output. It **cannot** be used as current-controlled output.*

Driving an inductive load on a PWM-modulated open-drain output, there is always to be a path for the current through the freewheeling diode. Do not connect any switch or fuse in series with the diode.

Connector position

Standard A18

Premium A28



To protect the motor controller from overvoltage due to the inductive nature of the load, internal freewheeling diode towards pin PEB A27 (A17) is built-in.

Ensure that the inductive load is connected so that the path through the freewheeling diode is always present; otherwise use an external freewheeling diode.

Using brushless fans or other loads with built-in capacitors can give high inrush current at turn-on, which may eventually bring to overcurrent trips. Inrush current must be below the peak current.

4.3.7 Auxiliary outputs

Open-drain outputs can be used for operating auxiliary devices such as relays, hydraulic valves, horns, buzzers, lights, etc.

Three different types of driver are present:

- ON/OFF: EV1 A24, EV4 A35.
- PWM voltage controlled: EV2 A25, EV3 A34.
- PWM current controlled: EVP A29 (A19).

By default, freewheeling diodes to PEB A27 (A17) are built-in. In case the vehicle design does not allow the usage of the built-in freewheeling diodes, i.e. if the return path integrity cannot be guaranteed in all situations, external freewheeling diodes must be applied between the coils terminals.

In order to utilize the built-in freewheeling diode for output EVP and, limited to the premium versions, for outputs EV1 through EV4, the positive terminals of the loads must be connected to PEB A27 (A17).

ON/OFF output: EV1, EV4

- For each output, up to 1.5 Arms continuous (hold) current and up to 2 A peak (pull) current for a maximum duration of 200 ms, provided that EV1, EV2, EV3 and EV4 together do not exceed 3 A.
- Individual detection of shorted driver and open driver.
- By default, EV1 is activated upon input A2; no input is dedicated to activate EV4 by default.
- For configuration options, see parameter EV1 and EV4 under SET OPTION.

PWM voltage-controlled outputs: EV2, EV3

- For each output, up to 1.5 Arms continuous (hold) current and up to 2 A peak (pull) current for a maximum duration of 200 ms, provided that EV1, EV2, EV3 and EV4 together do not exceed 6 A.
- Individual hardware for detection of shorted driver, open driver and open coil.
- Predefined 1 kHz PWM modulation.
- Active-state modulation levels independently configurable.
- By default, EV2 is activated upon input AUX2 A12, EV3 is activated upon input AUX3 A14.
- For configuration options, see parameters EV2 and EV3 under SET OPTIONS.
- For configuring the duty-cycle applied when the output is active, see parameters PWM EV2 and PWM EV3 under ADJUSTMENTS.

PWM current-controlled output: EVP

- Up to 1.5 Arms continuous (hold) current and 1.7 A peak current.
- Individual hardware for detection of shorted driver, open driver and open coil.
- Self-protected against overload condition.
- Dither injection, featuring a low amplitude current modulation at a selectable frequency (see paragraph 8.2.4).
- Dithering is typically used when controlling proportional valves in order to create microscopic movements in the valve, preventing it from sticking in a fixed position. Dithering helps to improve the valve response for small changes.

  Dithering frequency is available in the following values:
  20.8, **22.7**, **25.0**, **27.7**, **31.2**, **35.7**, **41.6**, **50.0**, **62.5**, **83.3**.
- Dithering current amplitude can be adjusted up to 13% of the reference value. The actual amplitude of the dithering current depends on the load inductance.
- By default, EVP is activated upon inputs LOWER A11 and EVP POT A1.
- For configuration options, see parameter EVP TYPE under SET OPTION.

- For other configurations, see parameters MIN EVP, MAX EVP, EVP OPEN DELAY, EVP CLOSE DELAY under PARAMETER CHANGE.

Protection

The auxiliary outputs are protected against inductive discharge with internal freewheeling diodes to pin PEB A27 (A17).

The auxiliary outputs are not directly protected against reverse polarity of the battery. In the event that the battery positive fed –B post or the ground pins A15 and A21 (A9 and A15), while the battery negative fed PEB A27 (A17), a disruptive current would cause a failure in the logic board and potentially in the external circuit as well. Connecting the loads downstream the main contactor, as shown in chapter 3.2, prevents from such an event to occur in the first place. For activating the contactor, the logic board needs to be functioning and the software to pass a number of diagnosis, which would not be possible in case of a polarity inversion.

Built-in diagnostics:

- Overcurrent
- Shorted driver
- Open driver
- Open coil

The overcurrent protection of outputs EV1 through EV4 intervenes for a cumulative current on the four outputs above 9.5 A ± 0.5 A.

Refer to chapter 10 for more details about the alarms.

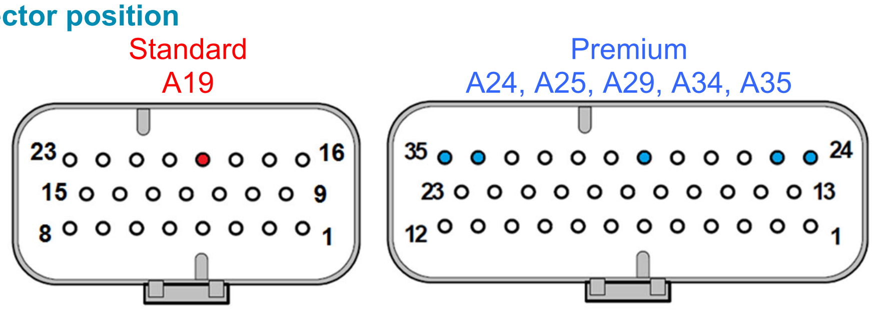
PWM shall only be used for inductive loads such as relays, contactors, motor brakes or hydraulic valves.

The shunt resistor for overcurrent protection is shared among EV1, EV2, EV3 and EV4 outputs. The sum of the four currents is monitored.

The maximum total continuous current when outputs EV1, EV2, EV3 and EV4 are active at the same time is 3 A. The maximum total peak current is 9.5 A.

When driving inductive loads on PWM-modulated open-drain outputs, there must always be a path for the current to the freewheeling diodes. Do not connect any switch or fuse in series with the diode.

Connector position



To protect the motor controller from overvoltage due to the inductive nature of the loads, internal freewheeling diodes towards pin PEB A27 (A17) are built-in.

Ensure that the inductive loads are connected so that the path through the freewheeling diodes is always present; otherwise use external freewheeling diodes.

Using brushless fans or other loads with built-in capacitors can give high inrush current at turn-on, which may eventually bring to overcurrent trips. Inrush current must be below the peak current.

4.3.8 Motor-temperature measurement

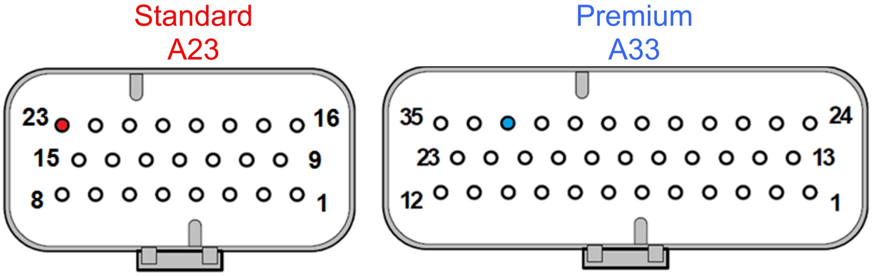
Input for motor-temperature sensor, for measuring the temperature of motor windings, is available on pin PTH A33 (A23).
Compatible temperature sensors are:

- ON/OFF.
- KTY84 with 1000 Ω at 100 °C.
- KTY83 with 1670 Ω at 100 °C.
- PT1000 with 1385 Ω at 100 °C.
- KTY81-110/120 with 1696 Ω at 100 °C.

Protection

PTH input is protected against short circuits to +B and ESD protected. A low-pass filter attenuates the electrical noise from the motor.

Connector position



4.3.9 Auxiliary supplies

Two auxiliary supplies are available for external devices like motor speed sensors, potentiometers, analog sensors, or other auxiliary devices.

The output voltages are configurable at the hardware level to be +12V or +5V.

Actual values for "+12V" and "+5V" are respectively 12 V ± 0.2 V and 5 V ± 0.2 V.

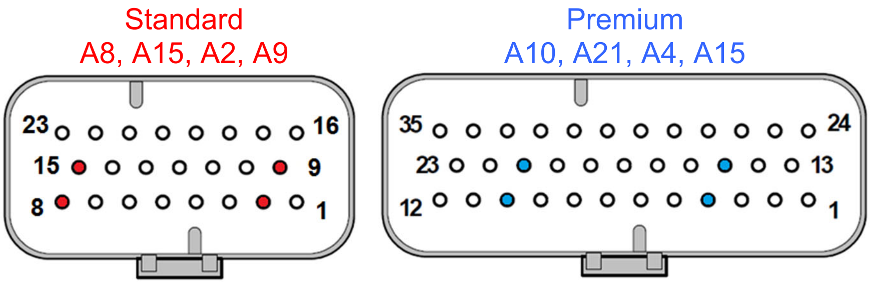
The auxiliary supplies are not isolated with respect to terminal -B.

Protection

The auxiliary supply outputs are protected against overload by a thermal shut down and against accidental connection to +B by output diodes.

Connector position

Positive supplies are on pins PENC/PSENS A10 (A8) and PPOT A4 (A2). Negative references are on pins NENC/NSENS A21 (A15) and NPOT A15 (A9).



Pins NENC/NSENS A21 (A15) and NPOT A15 (A9) are internally shorted and equivalent to each other.

4.3.10 CAN bus interface

A CAN bus interface is available for communication with the controller. It features:

- Physical interface according to ISO 11898-2.
- Data rate can be 20, 50, 125, 250, 500, 800, 1000 kbit/s.
- CAN transceiver is +5 V supplied and provides a rail-to-rail signal on the differential line (CANH – CANL).
- A 120 Ω resistor is built-in between CANL and CANT; by externally coupling pin CANT A18 (A12) with pin CANH A31 (A21), the usual 120 Ω termination between CANH and CANL is obtained. Common-mode filter (resistors and capacitor) is present.
- Negative reference available on pin NCAN A32 (A22).

The CAN bus interface is isolated with opto-couplers and supplied by a dedicated and isolated supply. The CAN bus transceiver gives maximum amplitude on the CANH-CANL differential pair.

Ground reference for the CAN bus, NCAN, must be routed together with CANH and CANL to limit communication problems.

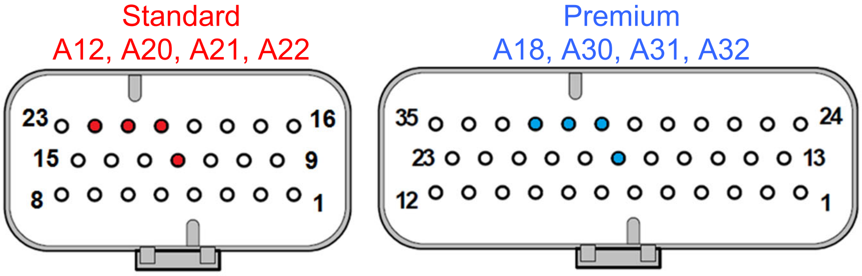
Between NCAN and -B, an internal high-impedance connection and EMC suppression components are present for protection against ESD.

Isolation is featured only for improved immunity to electrical noise; isolation must not be used as a safety countermeasure. NCAN and -B shall be externally connected in a star point of the vehicle wirings.

Protection

The CAN bus interface is protected against accidental connections to +B and –B and ESD protected.

Connector position



The CAN bus wiring shall consists of a pair of twisted wires for CANH and CANL.

The CAN bus wiring shall have a characteristic impedance of 60 Ω; both physical ends of the CAN bus shall be terminated with 120 Ω between CANH and CANL for the best possible noise immunity.

Pin NCAN A32 (A22) is to be connected according to the CAN bus configuration:
- *Isolated line: connect NCAN to the CAN bus reference.*
- *Non-isolated line: connect NCAN to -B (GND).*

5 FEATURES

5.1 Operational features

- Speed control: sensored, sense coil or sensorless.
- Stable speed in every position of the accelerator.
- Regenerative release braking based upon deceleration ramps.
- Direction inversion with regenerative braking based upon deceleration ramp.
- Release braking ramps can be modulated by an analog input, as to feature a proportional brake.
- Electrical stop-on-ramp: the machine is electrically held in place for a programmable time.
- Driver for predefined and generic outputs: main contactor, electromechanical brake, auxiliary loads.
- Hydraulic steering function:
    - ACE4 traction: the traction inverter sends a "hydraulic steering function" request to the pump inverter over the CAN bus line.
    - ACE4 pump: the pump inverter manages a hydraulic steering function, i.e. it drives the pump motor at the programmed speed for the programmed time.
- Dual microcontroller architecture for safety functions.
- Self-diagnosis with faults displayed through the console (Smart Console, PC CAN Console) or Zapi MDI/Display.
- Modification of parameters through the console (Smart Console, PC CAN Console).
- Alarms logbook, with relative hour-count and temperature at the time of the alarm events.
- TESTER function within the console (Smart Console, PC CAN Console) for monitoring of the inverter operation.

5.2 Dual traction

In the case of a dual-traction setup, the steering signal (from a potentiometer or switches) is evaluated in order to generate two different speed demands for the left and right motors, that greatly assists in turning the vehicle and prevents the wheels to scrub. Beyond the generation of two differentiated speed demands, the operation of each motor controller is analogous to the case of a single traction motor.

5.3 Pump

Pump motor control is similar to traction motor control, although motion is requested using a different combination of switches.

5.4 Speed mode

This is the default mode for Zapi motor controllers. In this mode the controller maintains the motor at a constant speed for a given throttle position, as long as sufficient torque is available. The current, and thus the torque applied to the motor, is calculated by the controller based on the requested speed and the actual speed of the vehicle.

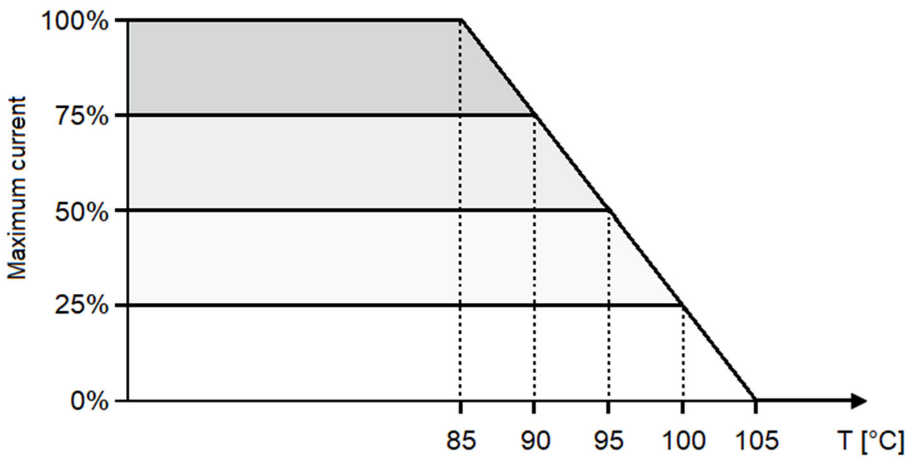
5.5 Torque mode

In this mode the controller maintains the motor torque output at a constant value for a given throttle position. This is similar to the behavior of DC motors (in particular, series wound DC motors) and it provides a driving experience like that of a car. To prevent excessive speed when the load torque is low, for example when driving downhill, a maximum vehicle speed can be set.

5.6 Protection and safety features

ACE4 is protected against:

- **Battery polarity inversion**
  It is necessary to fit a main contactor to protect the inverter against reverse battery polarity and for safety reasons.
- **Connection errors**
  All inputs are protected against connection errors.
- **Wrong supply voltage**
  Protected against battery under-voltage and overvoltage.
- **Over-temperature**
  If the controller temperature exceeds 85 °C, the maximum current will be reduced in proportion to the temperature excess. The temperature can never exceed 105 °C.



Thermal cutback.

- **External agents**
  The inverter is protected against dust and liquid sprays to a degree of protection meeting IP65. Nevertheless, it is suggested to carefully study controller installation and position.
- **Uncontrolled movements**

See safety requirement in clause 5.9.4 of EN1175-1:2010.

The main contactor will not close in the following conditions:
  - The power unit is not working.
  - The logic board does not work perfectly.
  - The output voltage of the accelerator is more than 1 V above the minimum value stored during the calibration procedure.
  - Travel-demand micro-switches are active at startup.

- **Low battery charge**
  When the battery charge is low, the maximum current is reduced to half of the maximum current programmed.
- **Accidental start-up**

See safety requirement in clause 5.9.3 of EN1175-1:2010.

A precise sequence of operations is necessary for the machine to start. Operation cannot begin if these operations are not carried out correctly. Requests for drive must be made after closing the key switch.

The safety of the machine is strongly related to the installation; length, layout and screening of electrical connections have to be carefully designed. ZAPI is always available to cooperate with the customer in order to evaluate installation and connection solutions.

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6 INSTALLATION

This section presents general information about the installation of the motor controller in a vehicle.

The installation of the motor controller in a specific vehicle may vary from what is here presented or include additional steps. It is the responsibility of the vehicle manufacturer to develop detailed instructions for installation and maintenance of the motor controller in the target vehicle.

⚠ ***Wiring errors, improper setup, or other conditions may cause the vehicle to move in the wrong direction or at the wrong speed.***

⚠ ***Take necessary precautions to prevent injury to personnel or damage to equipment prior to applying power for the first time.***

6.1 Material overview

Before starting the inverter, it is necessary to have the required material for a proper installation. Wrong choice of additional parts could lead to failures, misbehaviors or bad performance.

6.1.1 Connection cables

For the auxiliary circuits, use cables of 0.5 mm² section.
For power connections to the motor and from the battery, use cables having proper section. The screwing torque for the controller power connection must be comprised in the range 13 Nm ÷ 17 Nm. For the optimum inverter performance, the cables to the battery should be run side by side and be as short as possible.

6.1.2 Contactors

A main contactor is always to be installed. The output driving the coil is modulated with a 1 kHz PWM basing on parameters MC VOLTAGE and MC VOLTAGE RED. After an initial delay of about 1 second, during which the coil is driven with a percentage of VBATT defined by MC VOLTAGE, PWM reduces the mean voltage by the percentage set in MC VOLTAGE RED. This feature is useful to decrease the power dissipation of the coil and its heating.

⚠ ***Main contactor must be installed to protect the controller against polarity inversion and to permit de-energization of actuators if safety functions require such action.***

6.1.3 Fuses

- Use a 10 A fuse for protection of the auxiliary circuits.
- For the power fuse, the selection of the appropriate fuse rating is a system design issue and falls under the OEMs responsibility. As a rule of thumb, the fuse shall be rated based on the motor controller output power (2-minute rating) listed in chapter 11. Calculate DC input current as follows.

$$I_{DC,in}[A] = \frac{Power\ output\ [VA]}{V_{DC}\ [V]}$$

Select a fuse with rating and time delay characteristics which can carry $I_{DC,in}$ indefinitely and which blows within 2 – 3 seconds with twice the current.

- Chapter 11 shows the maximum allowable values. For special applications or requirements these values can be reduced.
- For safety reasons, Zapi recommend the use of protected fuses in order to prevent the spread of particles in case the fuse blows.

⚠ ***The fuse is not intended to protect the motor controller or the motor against overloads.***

⚠ ***Depending on the application, the fuse may represent a hotspot. It is suggested to check the fuse temperature during the machine operation.***

⚠ ***An excessive temperature of the fuse may cause the surrounding elements to wear.***

6.2 Installation of the hardware

⚠ ***Before doing any operation, ensure that the battery is disconnected.***

⚠ ***The heat sink or the base plate mounting may present machining residues; it is suggested wearing gloves for handling and mounting the motor controller.***

⚠ ***For traction applications, raise up or otherwise disable driving wheels to prevent the possibility of unexpected vehicle motion or motion in the wrong direction during initial commissioning. For hydraulic applications, open the valve to prevent the possibility of excessive pressure (in the event of a malfunction of the pressure-relief valve).***

⚠ ***Take necessary precautions to not compromise safety in order to prevent injuries to personnel and damages to equipment.***

⚠ ***After operation, even with the key switch open, the internal capacitors may remain charged for some time. For safe operation onto the setup, it is recommended to disconnect the battery and to discharge the capacitors by means of a resistor of about 10 Ω – 100 Ω between terminals +B and -B of the inverter.***

⚠ ***After operation of the motor controller, the heat sink may be too hot to touch. Allow it to cool down before performing any maintenance.***

Do not clean the motor controller using high-pressure water.

6.2.1 Positioning and cooling of the controller

- If the controller comes with the base plate mounting:
  - Install it on a flat, clean and unpainted metallic surface.
  - Apply a light layer of thermo-conductive grease between the two surfaces to permit good heat dissipation.
  - Ensure the compartment to be ventilated and the heat-sinking material ample. Abnormal ambient temperatures should be considered.
  - Consider that heat-sinking material should be sized according to the performance requirement of the machine.
  - In situations where either external ventilation is poor or heat exchange is difficult, forced ventilation should be used.
- Ensure that the cable terminals and the connector are correctly connected.

6.2.2 Dust and liquid ingress prevention

The motor controller is protected against the ingress of dust and moisture only when the mating Ampseal connector is inserted and properly assembled with appropriate cable seals.
The motor controller cover provides a measure of protection from liquids and particles dripping, splashing or spraying onto it. The motor controller is not to be subject to liquids under high pressure.

6.2.3 Power cables

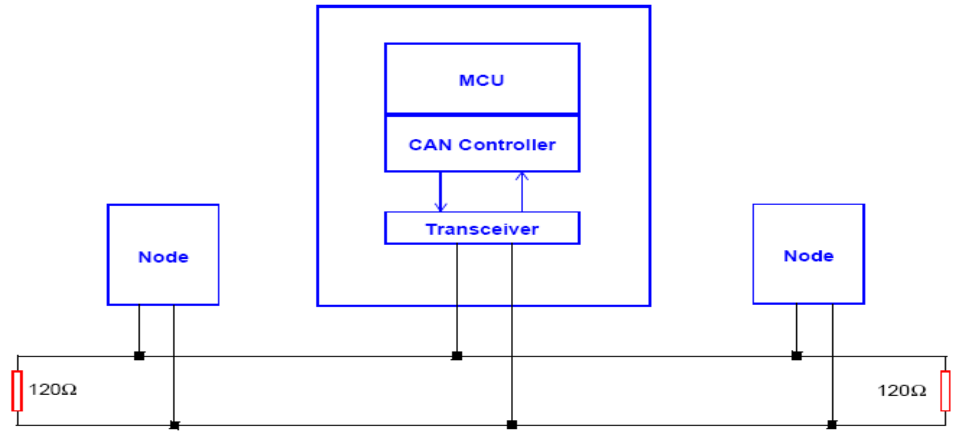
- For the power connections to the motor and from the battery use cables having a proper section.
- Power cables must be as short as possible to minimize power losses.
- Power lugs must be tightened onto the controller power posts with a torque of 13 Nm ÷ 17 Nm.
- Cables from the battery should run side by side.
- The controller should only be connected to a traction battery. Do not use converters outputs or power supplies. For special applications please contact the nearest Zapi service center.

Do not connect the controller to a battery with a nominal voltage different to the nominal value, indicated on the controller label. A higher battery voltage may cause failures in the power section. A lower voltage may not allow the controller to work.

Ring lugs for motor and battery connections must be adequately rated in accordance to the controller and motor ratings. Otherwise, cables and terminal posts may overheat.

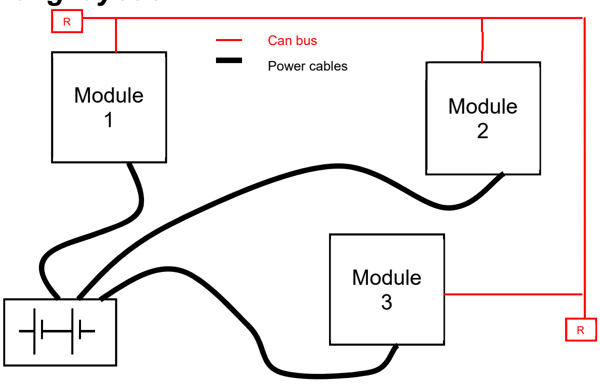
6.2.4 CAN bus

CAN stands for Controller Area Network. CAN bus is a communication protocol for real time control applications. CAN bus operates at data rate of up to 1 Mbit/s. It was invented by the German company Bosch to be used in the automotive industry to permit communication among the various electronic modules of vehicle, connected as illustrated in the following image.



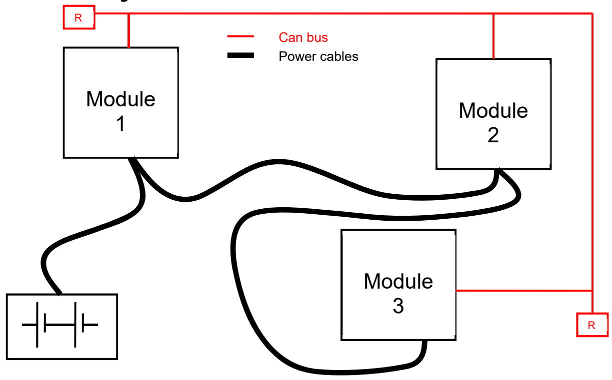
The best type of cables for CAN bus connections is the twisted pair; if it is necessary to increase the immunity of the system to disturbances, a good choice would be to use shielded cables, where the shield is connected to the frame of the truck. Sometimes it is sufficient a not shielded two-wire cable or a duplex cable.
In a system like an industrial truck, where power cables carry currents of hundreds of Ampere, voltage drops due to the impedance of the cables may be considerable, and that could cause errors on the data transmitted through the CAN wires. The following figures show an overview of wrong and right layouts for the routing of CAN connected systems.

Wrong layout:



Red lines are CAN bus wires.
Black boxes are different modules, for example a traction controller, a pump controller and a display connected via CAN bus.
Black lines are the power cables.
This is apparently a good layout, but actually it can bring to errors onto the CAN line. The best solution depends on the type of nodes (modules) connected in the network. If the modules are very different in terms of power, then the preferable connection is the daisy chain.

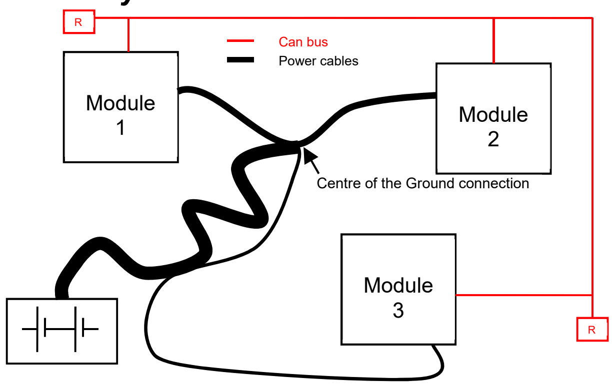
Correct layout:



Note: Module 1 power > Module 2 power > Module 3 power

The chain starts from the -B post of the controller that deals with the highest current, while the other ones are connected in a decreasing order of power. Otherwise, if two controllers are similar in power (for example a traction and a pump motor controller) and a third module works with less current (for example a steering controller), the best way to address this configuration is creating a common ground point (star configuration), as it is in the next figure.

Correct layout:



Note: Module 1 power ≈ Module 2 power > Module 3 power

In this case, the power cables of the two similar controllers must be as short as possible. Of course, the diameter of the cables also concurs in the voltage drops described before; a greater diameter brings to a lower impedance. In this last example the cable between negative battery terminal and the center of the ground connection (pointed by the arrow in the image) must be sized taking into account both thermal and voltage drop problems and considering the current drawn from the battery by the overall system.

The complexity of modern systems needs an increasing amount of data to be exchanged amongst the various nodes. CAN bus is the solution to different problems that arise from this complexity
- simple design (readily available, multi sourced components and tools)
- low costs (less and smaller cables)
- high reliability (fewer connections)
- ease of analysis (easy connection with a pc for sniffing the data being transferred onto the bus).

6.2.5 I/O connections

- Use wires of 0.5 mm² section.
- After crimping the cables, verify that all strands are entrapped in the wire barrel.
- Verify that all the crimped contacts are completely in the connector cavities.
- Where built-in freewheeling diodes cannot be exploited to recirculate the current of inductive loads (solenoids, horns and others), fit external suppression devices before connecting the loads to the controller.
- The motor controller can draw very high currents from the battery. Even if cables are dimensioned correctly, this may lead to a significant voltage drop across the –B connection, between –B post of the motor controller and the negative terminal of the battery. A voltage difference may arise between negative references amongst different units of the application. It is strongly recommended to connect all the auxiliary devices supplied by the motor controller (sensors, input devices, others) directly to the appropriate pin of the Ampseal connector.
- For information about the pins assignment, see chapter 4.
- A cable connected to the wrong pin can lead to short circuits and failures.

Before turning on the truck for the first time, verify the continuity between the ends of each wire.

6.2.6 Motor feedback sensor

Route the motor feedback wires as far as possible from conductors carrying high currents or high current pulses for minimizing the electrical noise affecting the motor feedback signals. Noise immunity may also be improved by using twisted wires.

The motor feedback sensor may be ESD sensitive; see ESD related system design suggestions in paragraph 6.3.

Pay special attention to the feedback sensor pinout.

Contact the motor manufacturer to know the details about the motor feedback behavior and the rotational direction of the motor.

Swapping the channels from the feedback sensor will lead to the improper operation of the system.

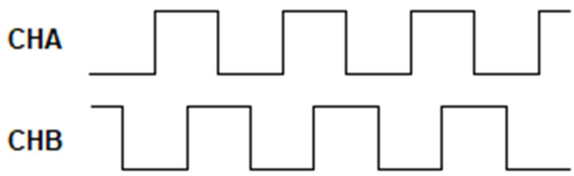
Starting the motor with a wrong pulses/revolution setting may cause dangerous motor movements like uncontrollable accelerations. See paragraph 8.2.8.

Make sure that the encoder signals are not subject to disturbances from electromagnetic noise. The motor cables or the electromechanical brake and its wiring are the most frequent cause of such issues.

Incremental encoder

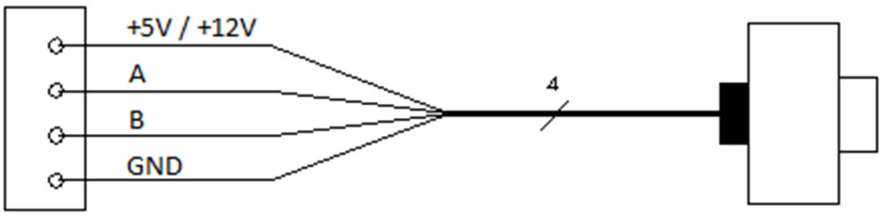
To control an AC motor, a 2-channel quadrature incremental encoder can be employed to provide the speed and direction feedback to the motor controller. Usually, standard encoders switch two open-collector outputs to produce two square-wave signals phase shifted by 90º ± 45º, with a maximum frequency of 20 kHz.

ACE4 can handle different types of encoder. The encoder supply can be 5 V or 12 V. For special applications it is possible to install an incremental encoder with the additional zero-position signal. The sensor signals must have a minimum 6 μs edge separation.

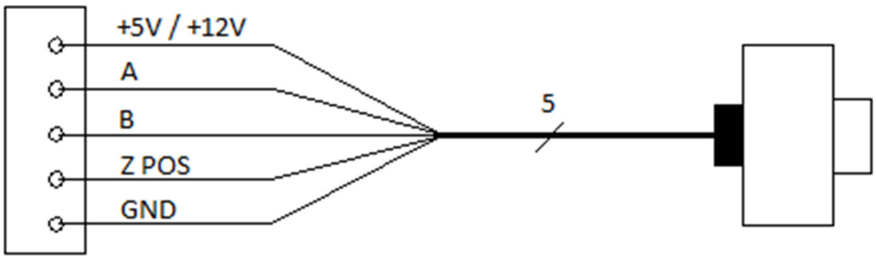


Incremental encoder signals.

A10	(A8)	5 V or 12 V	Positive power supply
A21	(A15)	GND	Negative power supply
A9	(A7)	ENC A	Channel A
A20	(A14)	ENC B	Channel B
A19	(A13)	Z POS	Z-index



Connection of a 2-channel encoder.



Connection of an encoder with zero-position signal.

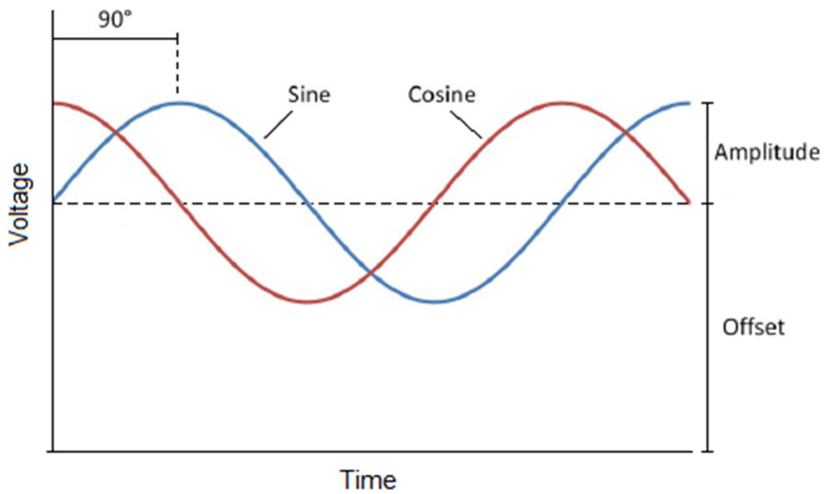
It is suggested to share with Zapi technicians the specifications of the adopted encoder in order to be sure about its full compatibility with the Zapi controller.

The number of pulses/rev can be properly set by dedicated parameters (see paragraph 8.2.8).

Prior to perform any operation with the truck, it is strongly suggested to test the configuration with the wheels off the ground for safety reasons.

Sin/cos sensor

To control BL motors and synchronous motors in general, a sinusoidal sensor can be employed to provide position, speed and direction feedback to the motor controller. The sinusoidal analog sensors usually feature two single-ended sinusoidal outputs, phase shifted by 90° in a sine-cosine fashion.



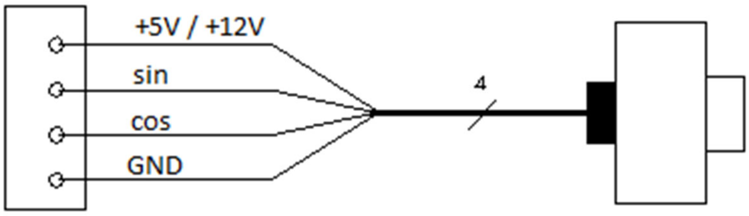
Sinusoidal analog sensor signal.

At the first key-on, an auto-teaching procedure has to be performed so to acquire the sensor signals. Dynamic offset and gain adjustments (individual for each channel) are done in software to compensate for minor changes in sensor characteristics.

The sin/cos interface is available only for BLE4 (Premium version).

Sine and cosine signals from the sensor take the places of the third and fourth analog inputs on pins A1 and A13.

A10	5 V or 12 V	Positive power supply
A21	GND	Negative power supply
A1	SIN	Sine signal
A13	COS	Cosine signal

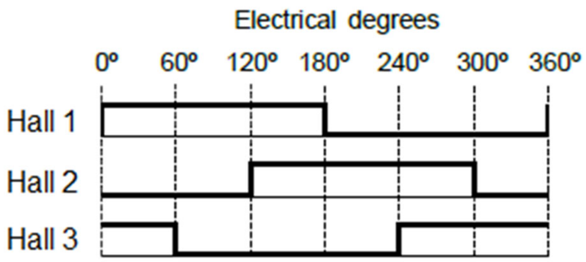


Connections of a sin/cos sensor.

It is suggested to share with Zapi technicians the specifications of the adopted sin/cos sensor in order to be sure about its full compatibility with the Zapi controller.

Three-Hall sensors

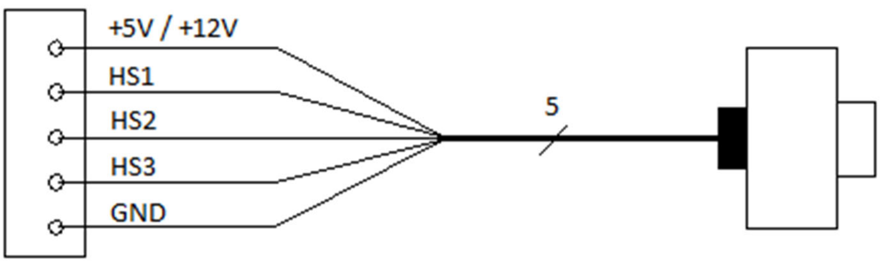
To control BLDC motors, a set of three Hall sensors (also known as six-step encoders) can be employed to provide position, speed and direction feedback to the motor controller. The 3-Hall sensors switch three open-collector outputs to produce a three-phase square wave output, phase shifted 120º ± 15º, ideal for the six-step commutation timing. The maximum allowed frequency is 400 Hz.



Three-Hall sensor signals.

The Hall sensors interface is available only for BLE4 (Premium version).

A10 (A8)	5 V or 12 V	Hall sensor positive supply
A21 (A15)	GND	Hall sensor negative supply
A20 (A14)	HS1	Hall sensor 1
A9 (A7)	HS2	Hall sensor 2
A19 (A13)	HS3	Hall sensor 3



Connection of Hall sensors.

It is suggested to share with Zapi technicians the specifications of the adopted 3-Hall sensor in order to be sure about its full compatibility with the Zapi controller.

6.2.7 Motor temperature sensor

Industrial motors usually feature a temperature sensor with a positive temperature coefficient, embedded close to the motor windings, as a means for the motor controller to monitor the windings temperature. The motor control algorithm makes use of the motor temperature optimizing the control in real time and protecting the motor from overheating.
The motor controller can be configured to operate with different sensors such as KTY 84, KTY 83, KTY 81, PT1000 and similar.

⚠ ***The installation of the motor temperature sensor is done by the motor manufacturer. Contact the motor manufacturer to know how to connect the sensor to the wirings.***

⚠ ***If the temperature sensor cables are connected with the wrong polarity, the sensor readings will not be correct and over-temperature protection of the motor will not work properly.***

6.2.8 Main contactor and key switch

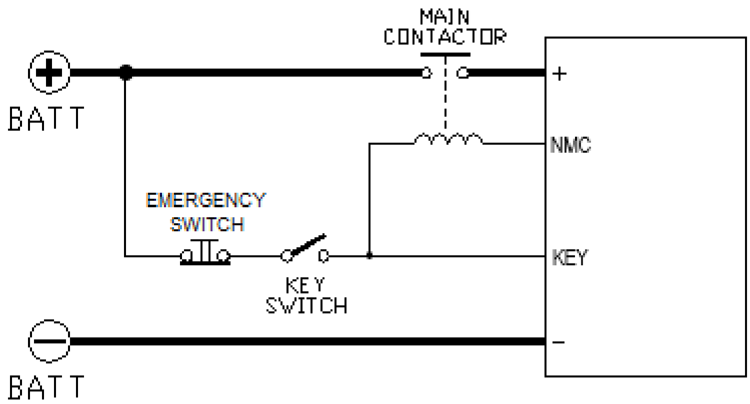
The connection of the battery line switches must be carried out following instructions from Zapi.

⚠ ***Clause 5.13.2 of EN 1175:2010 details how the emergency switching off device shall be installed. In particular it is important to ensure that such device opens the key supply of the inverter together with power battery line.***

At start-up, after voltage has been supplied to the KEY input, while the embedded capacitors bank get charged up by an internal pre-charge protected circuit, the motor controller monitors the voltage across the capacitors bank. When such voltage reaches a pre-defined level, the motor controller closes the main contactor.

Main contactor and key switch can be connected as the following figure.

For safety reasons, an emergency switch should be installed for breaking at the same time the supply to the inverter and to the excitation coil of the main contactor in case of hazard. Supplying the excitation coil as depicted ensures the main contactor will open together with the emergency switch, regardless of the behavior of the motor controller.



Connection of main contactor and key switch.

6.2.9 Insulation of the truck frame

As stated by EN-1175-1:2010, clause 5.7, "there shall be no electrical connection to the truck frame". The truck frame has to be isolated from any electrical potential of the truck power line.

The inverter, with all the power connections open and connector A disconnected, complies with insulation requirements: there is no electrical connection between the mounting element (baseplate or heatsink) and any other electrical conductor.

External connections may alter such insulation. Following the instructions present in this manual is necessary but not sufficient to guarantee that the truck will comply with insulation requirements.

Customer shall take all actions, in particular good wiring practices, to ensure that the inverter installation maintains the required level of insulation.

6.3 EMC

EMC and ESD performances of an electronic system are strongly influenced by the installation. Special attention must be given to lengths, paths and shielding of the electric connections. These aspects are beyond of Zapi control. Zapi can offer assistance and suggestions on EMC related problems, basing on its long experience.
ZAPI declines any responsibility for non-compliance, malfunctions and failures, if correct testing is not made. The machine manufacturer holds the responsibility to carry out machine validation, based on existing norms (EN12895 for industrial truck; EN IEC 61000-6-4 for other applications).

EMC stands for Electromagnetic Compatibility, and it deals with the electromagnetic behavior of an electrical device, both in terms of emission and reception of electromagnetic waves that may cause electromagnetic interference with the surrounding electronics or malfunctions of the device itself.
The matter can be divided into two main branches:

1) The study of the emission problems, the disturbances generated by the device and the possible countermeasures to prevent the propagation of that energy. It is common use to talk about *conduction* issues when guiding structures such as wires and cables are involved, *radiated emissions* issues when the propagation of electromagnetic energy through the open space is involved. Considering the Zapi controller, despite the origin of the disturbances can be found inside the device, where the switching of the MOSFETs at high frequency can generate RF energy, wires have the key role to propagate disturbances given they work as antennas, so a good layout of the power cables and their shielding is to be considered to mitigate the majority of the emission problems.
2) The study of the immunity can be divided into two sub-branches: protection from electromagnetic fields and from electrostatic discharge. The electromagnetic immunity concerns the susceptibility of the controller with regard to electromagnetic fields and their influence on the correct work of the electronic device. There are well defined tests which the machine has to undergo. These tests are carried out at determined levels of electromagnetic fields, simulating external undesired disturbances and verifying the response.

The second type of immunity, against ESD, concerns the prevention of the effects of electric current due to excessive electric charge stored in an object. In fact, when a charge is accumulated on a material, it becomes an electrostatic charge; ESD happens when there is a rapid transfer from one charged object to another. This rapid transfer has, in turn, two important effects:

- This rapid charge transfer can determine, by induction, disturbs on the signal wiring thus causing malfunctions; this effect is particularly critical in modern machines, with communication lines which may carry critical pieces of information.
- In the worst case, when the amount of charge is very high, the discharge process can determine failures in the electronic devices; the type of issue can vary from a temporary malfunction to a definitive failure of the electronic device.

It is always much easier and cheaper to avoid ESD from being generated, rather than increasing the level of immunity of the electronic devices.

There are different solutions to EMC issues, depending on the required level of emission or immunity, the type of controller, materials and position of the wires and electronic components.

1) EMISSIONS. Three ways can be followed to reduce the emissions:
   - SOURCE OF EMISSIONS: finding the main source of disturb and work on it.
   - SHIELDING: enclosing contactor and controller in a shielded box; using shielded cables;
   - LAYOUT: a good layout of the cables can minimize the antenna effect; cables running nearby the truck frame or in iron channels connected to truck frames are generally a suggested not expensive solution to reduce the emission level.
2) ELECTROMAGNETIC IMMUNITY. The considerations made for emissions are valid also for immunity. Additionally, further protection can be achieved with ferrite beads and bypass capacitors.
3) ELECTROSTATIC IMMUNITY. Three ways can be followed to prevent damages from ESD:
   - PREVENTION: when handling ESD-sensitive electronic parts, ensure the operator is grounded; test grounding devices on a daily basis for correct functioning; this precaution is particularly important during controller handling in the storing and installation phase.
   - ISOLATION: use anti-static containers when transferring ESD-sensitive material.
   - GROUNDING: when a complete isolation cannot be achieved, a good grounding can divert the discharge current trough a “safe” path; the frame of a truck can works like a “local earth ground”, absorbing excess charge. So it is strongly suggested to connect to truck frame all the parts of the truck which can be touched by the operator, who is most of the time the source of ESD.

7 START UP

7.1 Check prior to initial power up

⚠ ***For traction applications, raise up or otherwise disable drive wheels to prevent the possibility of unexpected vehicle motion or motion in the wrong direction during initial commissioning. For hydraulic applications, open the valve to prevent the possibility of excessive pressure to build-up (in the event of a malfunction of the pressure-relief valve).***

⚠ ***Do not connect the controller to a battery with a nominal voltage different to the nominal value, indicated on the controller label. A higher battery voltage may cause failures in the power section. A lower voltage may not allow the controller to work.***

⚠ ***All motor controller settings and functionality have to be verified and validated by the OEM prior to use in the field by an end user. The complete range of parameter values that are updated by the truck controller (or any other device) must also be verified and validated prior to use in the field by the end user.***

⚠ ***During the process when the parameter values are established, it is of major importance to take proper safety precautions while testing the system. Incorrect parameter values may jeopardize the operation of the truck safety-critical functions.***

⚠ ***Take necessary precautions to do not compromise safety in order to prevent injury to personnel or damage to equipment***

⚠ ***After operation, even with the key switch open, the internal capacitors may remain charged for some time. For safe operation, we recommend that the battery is disconnected, and a short circuit is made between battery positive and battery negative power terminals of the inverter using a resistor between 10 ohm and 100 ohm.***

Perform the following checks before applying power to the motor controller for the first time:

1. Verify that the proper motor controller for the application has been installed.
2. Verify that the battery voltage matches the motor controller nominal DC supply voltage showed on the product identification label.
3. Verify that the correct software for the application has been loaded.
4. Verify that all power cables and signal wires are correctly connected.
5. Verify that battery and motor terminals are tightened with the appropriate torque.
6. Verify that the I/O plug (Ampseal connector) is properly mated and latched in position on the motor controller.

7. Verify that the motor controller is correctly fused for the application. Refer to paragraph 6.1.3.

7.2 Set-up procedure

Normally, motor controllers shipped for OEM series production are programmed by Zapi lines with the agreed parameters set and do not require any further configuration. Please refer to the OEM documentation for any further setup required during vehicle commissioning.

Setting up a prototype controller for a new vehicle, within a vehicle development program, may require extensive parameterization and possibly re-programming of the motor controller via CAN bus.

The basic set-up procedure for ACE4 is listed below. It can be carried out using the Zapi PC CAN Console or the Zapi Smart Console (see chapter 13).

- In ADJUSTMENTS, set BATTERY VOLTAGE according to the nominal battery voltage (see paragraph 8.2.3).
- Check the wiring and that all commands are functioning. Use the TESTER function to have a real-time feedback about their state.
- Perform the accelerator acquisition using the PROGRAM VACC procedure (see paragraph 9.1).
- Set the current profile for traction and braking by the CURRENT PROFILE parameters (see paragraph 8.2.9).
- Set the motor-related parameters. It is suggested to discuss them with Zapi technicians.
- Set the parameter SET MOT.TEMPERAT according to the type of motor thermal sensor adopted.
- Set the acceleration delay (parameters ACCEL MODULATION and ACCELER. DELAY). Test the behavior in both directions.
- Set the FREQUENCY CREEP starting from 0.3 Hz. The machine should just move when the drive request is active. Increase the level accordingly.
- Set speed reduction as required by your specifications (see parameter HB ON / SR OFF under SET OPTIONS).
- Set the other performance-related parameters such as RELEASE BRAKING, INVERSION BRAKING, DECELERATION BRAKING, PEDAL BRAKING, SPEED LIMIT BRAKING, MAX SPEED FORW, MAX SPEED BACK.
- Set the parameters related to the behavior on a slope (STOP ON RAMP and AUXILIARY TIME parameters).
- Test the truck in all operative conditions (with and without load, on flat and on ramp, etc.).

7.2.1 Acquisition of absolute position sensors

Absolute position sensors (sin/cos, 3-Hall, resolvers) are crucial in the control of synchronous motors. Amplitude and offset of analog signals and the relative angular offset between the sensor orientation and the motor case must be properly set before starting a synchronous motor for the first time.

An automatic acquisition procedure is available. It is to be activated only once at commissioning. Contact a Zapi technician to receive detailed information on how to perform the acquisition procedure.

Once the acquisition has started, the inverter goes down the procedure automatically running the motor in an open-loop fashion forward and backward, in sequence. While the motor spins at a predefined speed, the inverter records the data from the feedback signals.

At the end of the acquisition, feedback related parameters are automatically set in accordance to the acquired data. If the procedure stops with an error, recorded data are discarded and the inverter has to be reset.

8 PROGRAMMING & ADJUSTEMENTS

The ACE4 software makes use of an extensive list of parameters to allow for the configuration of all the functionalities the inverter can perform.

To access and adjust the settings of ACE4, three possibilities are available:

- To use the Zapi PC CAN Console software. The following paragraphs describe the controller configuration in the case the operator is using Zapi PC CAN Console.
- To use the Zapi Smart Console connected to the CAN bus (ask directly to Zapi for the dedicated user manual).
- To connect the Zapi Smart Console (or old hand console) through a remote module, like a Zapi tiller card of a Zapi display. This module is to be connected to the same CAN bus line of the inverter.

Zapi PC CAN Console software and Zapi Smart Console are tools developed to interface with and setup all the Zapi products installed in any application. See Appendix A and Appendix B to have a general overview and basic knowledge about the use of these tools.

The procedure for modifying the parameters is the following.

- Before doing any change, save a copy of the parameters already in place. See section 13.
- As a comment to the saved copy or in any separate format, it is good practice to take note of the context behind the saved set of parameters.
- Change the parameters with full knowledge of what that implies and store the new settings into the controller.
- Cycle the power to ensure the new configuration is put in place (this step is not needed for the low-impact settings, which take place immediately).
- Receive again the parameters values and inspect that all the modifications were properly stored.

Zapi tools permit a deep control over the parameters and behavior of Zapi controllers. Their use is restricted to engineers and well-trained technicians.

All the motor controller settings and functionalities have to be verified and validated by the OEM prior to use in the field by any end user.

The complete range of settings that are updated by the truck controller (or any other device) must also be verified and validated prior to use in the field be the end user.

During the process of defining new settings for the controller, it is of major importance to take proper safety precautions when testing. Wrong settings may jeopardize the operation of the truck safety-critical functions.

It is the OEM's responsibility to ensure that the vehicle is configured and set up to conform to applicable safety regulations.

8.1 Settings overview

PARAMETER CHANGE
ACC. TORQUE DEL.
DEC. TORQUE DEL.
ACCELER. DELAY
RELEASE BRAKING
REL BRK IN CTB
TILLER BRAKING
INVERS. BRAKING
DECEL. BRAKING
PEDAL BRAKING
SPEED LIMIT BRK.
STEER BRAKING
SS1 BRAKING
GSS1 BRK. TIME
ACC. MIN MODUL.
REL. MIN MODUL.
CTB. STEER ALARM
MAX SPEED FORW
MAX SPEED BACK
MAX SPEED LIFT
1ST PUMP SPEED
2ND PUMP SPEED
3RD PUMP SPEED
4TH PUMP SPEED
5TH PUMP SPEED
HYD PUMP SPEED
CUTBACK SPEED 1
CUTBACK SPEED 2
H&S CUTBACK
CURVE SPEED 1
CURVE CUTBACK
FREQUENCY CREEP
TORQUE CREEP
ACC SMOOTH
INV SMOOTH
STOP SMOOTH
BRK SMOOTH
STOP BRK SMOOTH
BACKING SPEED
BACKING TIME
EB. ENGAGE DELAY
AUXILIARY TIME
ROLLING DW SPEED
MIN EVP
MAX EVP
EVP OPEN DELAY
EVP CLOSE DELAY

SET OPTIONS
HM DISPLAY OPT.
HM CUSTOM 1 OPT.
HM CUSTOM 2 OPT.
TILL/SEAT SWITCH
EB ON TILLER BRK
BATTERY CHECK
STOP ON RAMP
PULL IN BRAKING
SOFT LANDING
QUICK INVERSION
PEDAL BRK ANALOG
HARD & SOFT
HB ON / SR OFF
MAIN POT. TYPE
AUX POT. TYPE
SET MOT.TEMPERAT
STEERING TYPE
STEERING POT POS
M.C. FUNCTION
M.C. OUTPUT
EBRAKE ON APPL.
AUX OUT FUNCTION
COMP.VOLT.OUTPUT
EMERGENCY INPUT
SYNCRO
AUTO PARK BRAKE
ACCEL MODULATION
EVP TYPE
EV1
EV2
EV3
EV4
HIGH DYNAMIC
INVERSION MODE
STEER TABLE
WHEELBASE MM
FIXED AXLE MM
STEERING AXLE MM
REAR POT ON LEFT
DISPLAY TYPE
PDO2RX
PDO3TX
PERFORMANCE
BMS FUNCTION
BRK TORQUE BMS
STO
SS1
HEARTBEAT MSG.

ADJUSTMENT
SET BATTERY
ADJUST KEY VOLT.
ADJUST BATTERY
SET POSITIVE PEB
SET PBRK. MIN
SET PBRK. MAX
MIN LOWER
MAX LOWER
THROTTLE 0 ZONE
THROTTLE X1 MAP
THROTTLE Y1 MAP
THROTTLE X2 MAP
THROTTLE Y2 MAP
THROTTLE X3 MAP
THROTTLE Y3 MAP
BAT. MIN ADJ.
BAT. MAX ADJ.
BDI ADJ STARTUP
BDI RESET
BATT.LOW TRESHLD
BAT.ENERGY SAVER
VOLTAGE THR LOW
VOLTAGE THR HIGH
STEER RIGHT VOLT
STEER LEFT VOLT
STEER ZERO VOLT
MAX ANGLE RIGHT
MAX ANGLE LEFT
STEER DEAD ANGLE
STEER ANGLE 1
STEER ANGLE 2
SPEED FACTOR
SPEED ON MDI
LOAD HM FROM MDI
CHECK UP DONE
CHECK UP TYPE
MC VOLTAGE
MC VOLTAGE RED.
EB VOLTAGE
EB VOLTAGE RED.
PWM EV2
PWM EV3
MAX. MOTOR TEMP.
STOP MOTOR TEMP.
MOT.T. T.CUTBACK
IDC BUS SENSOR

SPEC ADJUSTMENT
ADJUSTMENT #01
ADJUSTMENT #02
CURR. SENS. COMP
CURR. FALLBACK
SET CURRENT
SET TEMPERATURE
HW BATTERY RANGE
DUTY PWM CTRAP
PWM AT LOW FREQ
PWM AT HIGH FREQ
FREQ TO SWITCH
DITHER AMPLITUDE
DITHER FREQUENCY
CAN BUS SPEED
DEBUG CANMESSAGE
SAFETY DEBUG
CONTROLLER TYPE
MOTOR TYPE
CONTROLLER SLV1
CONTROLLER SLV2
CONTROLLER SLV3
CONFIG. SLAVES
AGV
SAFETY LEVEL
RS232 CONSOLLE
NODE ID
2ND SDO ID OFST
VDC START UP LIM
VDC UP LIMIT
VDC START DW LIM
VDC DW LIMIT
ADJUSTMENT #01
ADJUSTMENT #02
CURR. SENS. COMP
CURR. FALLBACK
MAX VOLTAGE MOT.

CURRENT PROFILE
P0 IMAX MOT
P0 FREQ. MOT
P1 IMAX MOT
P1 FREQ. MOT
P2 IMAX MOT
P2 FREQ. MOT
P3 IMAX MOT
P3 FREQ. MOT
P0 IMAX BRK
P0 FREQ. BRK
P1 IMAX BRK
P1 FREQ. BRK
P2 IMAX BRK
P2 FREQ. BRK
P3 IMAX BRK
P3 FREQ. BRK
MAX TORQUE REF

HARDWARE SETTING
TOP MAX SPEED
CONF.POSITIVE LC

HYDROSETTING
HYDRO TIME
HYDRO FUNCTION

FEEDBACK SENSOR
ROTATION CW ENC
ROTATION CW POS
ROTATION CW MOT
FEEDBACK SENSOR
FEEDBACK POLES
ENCODER PULSES 1
ENCODER PULSES 2
MOTOR P. PAIRS 1
MOTOR P. PAIRS 2
DIAG.JUMP SENSOR
FILTER SPEED TAU
A.SENS.MAX SE
A.SENS.MIN SE
A.SENS.MAX CE
A.SENS.MIN CE
OFFSET ANGLE
HYST. ANGLE
SENSOR ANGLE DEL
ANGLE IDRMS COMP
RESOLVER PULSE
ABS.SENS. ACQ.ID
ANGLE CORRECTION
FILTER FEEDBACK
KP PLL FEEDBACK
KI PLL FEEDBACK
ABS.SENS.ACQUIRE
COR ANGLE FEEDB.

PERFORM. ECONOMY
ACC.TORQUE DEL.E
ACCELER. DELAY E
MAX SPEED FORW E
MAX SPEED LIFT E
MAX SPEED BACK E
1ST PUMP SPEED E
2ND PUMP SPEED E
3RD PUMP SPEED E
4TH PUMP SPEED E
5TH PUMP SPEED E
HYD PUMP SPEED E
P0 IMAX MOT E
P0 FREQ. MOT E
P1 IMAX MOT E
P1 FREQ. MOT E
P2 IMAX MOT E
P2 FREQ. MOT E
P3 IMAX MOT E
P3 FREQ. MOT E

PERFORM. POWER
ACC.TORQUE DEL.P
ACCELER. DELAY P
MAX SPEED FORW P
MAX SPEED LIFT P
MAX SPEED BACK P
1ST PUMP SPEED P
2ND PUMP SPEED P
3RD PUMP SPEED P
4TH PUMP SPEED P
5TH PUMP SPEED P
HYD PUMP SPEED P
P0 IMAX MOT P
P0 FREQ. MOT P
P1 IMAX MOT P
P1 FREQ. MOT P
P2 IMAX MOT P
P2 FREQ. MOT P
P3 IMAX MOT P
P3 FREQ. MOT P

8.2 Settings description

In the following paragraphs, parameters are presented as follows.

LIST NAME		
Parameter	**Allowable range**	**Description**
Name of the parameter as indicated in the PC CAN Console tool. (Availability)	Allowable range of values that can be set. (Resolution)	Description of the parameter and possibly suggestions on how to set it.

In the "Parameter" column, the availability field (between parentheses) lists the controller types where the parameter is available.

- **A** All controller types.
- **T** Traction controller (single-motor applications).
- **P** Pump controller.
- **CO** CAN-operated controller.
- **TM** Traction master controller (multi-motor applications).
- **TS1** Traction secondary controller number 1 (multi-motor applications).
- **TS23** Traction secondary controller number 2 and 3 (multi-motor applications).
- **G** Hybrid generation set.
- **MCO** Traction master CAN-operated controller (multi-motor applications).
- **SCO** Traction secondary CAN-operated controller (multi-motor applications).

The parameters and the functionalities described in the following paragraphs are referred to Zapi standard software. They could be different in any other customized software releases depending on customer's requests.

8.2.1 PARAMETER CHANGE

PARAMETER CHANGE		
Parameter	**Allowable range**	**Description**
ACC. TORQUE DEL. (T, P, CO, TM, TS23, G, MCO)	0.1 s ÷ 10 s (steps of 0.1 s)	This parameter defines the torque ramp applied during accelerations. It represents the time needed to increase the torque from the minimum value up to the maximum one. In case TORQUE CONTROL is OFF, i.e. when the speed control is active, the speed ramps during accelerations can be subject to limitations given by the torque ramp. With TORQUE CONTROL = OFF, it is suggested to leave this parameter to the default value 0.1 s.
DEC. TORQUE DEL. (T, P, CO, TM, TS23, G, MCO)	0.1 s ÷ 10 s (steps of 0.1 s)	This parameter defines the torque ramp applied during decelerations. It represents the time needed to decrease the torque from the maximum value down to the minimum one. In case TORQUE CONTROL is OFF, i.e. when the speed control is active, the speed ramps during decelerations can be subject to limitations given by the torque ramp. With TORQUE CONTROL = OFF, it is suggested to leave this parameter to the default value 0.1 s.

PARAMETER CHANGE		
Parameter	**Allowable range**	**Description**
ACCELER. DELAY (T, P, CO, TM, G, MCO)	0.1 s ÷ 25.5 s (steps of 0.1 s)	This parameter defines the reference time for the acceleration rate. It represents the time needed to speed up the motor from 0 Hz up to 100 Hz. The acceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.5 Acceleration modulation.
RELEASE BRAKING (T, P, CO, TM, G, MCO)	0.1 s ÷ 25.5 s (steps of 0.1 s)	This parameter defines the reference time for the stopping rate upon the release of the running request. It represents the time needed to stop the motor from a starting speed of 100 Hz. The stopping rate is computed depending on the starting speed, as per the strategy described in paragraph 9.7 Release modulation.
REL BRK IN CTB (T, P, CO, TM, G, MCO)	0.1 s ÷ 25.5 s (steps of 0.1 s)	This parameter defines the reference time for the deceleration rate upon the cutback switch is activated. It represents the time needed to decelerate the motor from 100 Hz down to 0 Hz. The deceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.6 Deceleration modulation.
TILLER BRAKING (T, CO, TM, MCO)	0.1 s ÷ 25.5 s (steps of 0.1 s)	This parameter defines the reference time for the stopping rate upon the release of the tiller/seat switch. It represents the time needed to stop the motor from a starting speed of 100 Hz. The stopping rate is computed depending on the starting speed, as per the strategy described in paragraph 9.7 Release modulation.
INVERS. BRAKING (T, CO, TM, G, MCO)	0.1 s ÷ 25.5 s (steps of 0.1 s)	This parameter defines the reference time for the deceleration rate when the direction switch is toggled during drive. It represents the time needed to decelerate the motor from 100 Hz down to 0 Hz. The deceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.6 Deceleration modulation.
DECEL. BRAKING (T, P, CO, TM, G, MCO)	0.1 s ÷ 25.5 s (steps of 0.1 s)	This parameter defines the reference time for the deceleration rate performed when the accelerator is partially released while the running request keeps being active. It represents the time needed to decelerate the motor from 100 Hz down to 0 Hz. The deceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.6 Deceleration modulation.
PEDAL BRAKING (T, CO, TM, G, MCO)	0.1 s ÷ 25.5 s (steps of 0.1 s)	This parameter defines the deceleration ramp performed when the braking pedal is pressed. It represents the time needed to stop the motor from a starting speed of 100 Hz. The stopping rate is computed depending on the starting speed, as per the strategy described in paragraph 9.7 Release modulation.

PARAMETER CHANGE		
Parameter	**Allowable range**	**Description**
SPEED LIMIT BRK. (T, P, TM)	0.1 s ÷ 25.5 s (steps of 0.1 s)	This parameter defines the deceleration ramp performed upon a speed-reduction request. It represents the time needed to decelerate the motor from 100 Hz down to 0 Hz. The deceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.6 Deceleration modulation.
STEER BRAKING (T, TM)	0.1 s ÷ 25.5 s (steps of 0.1 s)	This parameter defines the deceleration ramp related to the steering angle (see paragraph 9.9 Steering curve). It represents the time needed to decelerate the motor from 100 Hz down to 0 Hz. The deceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.6 Deceleration modulation.
SS1 BRAKING (CO)	0.1 s ÷ 5 s (steps of 0.1 s)	This parameter defines the braking ramp for the safety function SS1 (safe stop 1) featured by the CAN operated versions of the controller. See parameter SS1 under SET OPTIONS.
GSS1 BRK. TIME (CO)	0.1 s ÷ 10 s (steps of 0.1 s)	This parameter defines the maximum braking time for the GSS1 function (guaranteed safe stop 1) featured by the CAN operated versions of the controller. See parameter SS1 under SET OPTIONS.
ACC. MIN MODUL. (T, P, CO, TM, G, MCO)	1% ÷ 100% (steps of 1%)	This parameter defines the minimum speed set-point variation for the acceleration and deceleration modulations to have effect, provided that ACCEL MODULATION = ON. Variations of the speed set-point smaller than ACC. MIN MODUL. result in accelerations or decelerations proportionally shorter than time ACCELER. DELAY. It is expressed as a percentage of 100 Hz, which is the maximum speed set-point variation for the acceleration modulation to have effect. The default value is 8%. For accelerations, see parameters ACCEL MODULATION and ACCELER. DELAY and paragraph 9.5 Acceleration modulation. For decelerations, see parameters ACCEL MODULATION, DECEL. BRAKING, INVER. BRAKING, REL BRK IN CTB, SPEED LIMIT BRK, STEER BRAKING and paragraph 9.6 Deceleration modulation.
REL. MIN MODUL. (T, P, CO, TM, G, MCO)	1% ÷ 100% (steps of 1%)	This parameter defines the minimum speed set-point variation for the release modulation to have effect. Variations of the speed set-point smaller than REL. MIN MODUL. result in decelerations proportionally shorter than time RELEASE BRAKING. It is expressed as a percentage of 100 Hz, which is the maximum speed set-point variation for the braking modulation to have effect. The default value is 30%. See parameter RELEASE BRAKING and paragraph 9.7 Release modulation.

PARAMETER CHANGE		
Parameter	**Allowable range**	**Description**
MAX SPEED FORW (T, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum speed in forward direction as a percentage of TOP MAX SPEED.
MAX SPEED BACK (T, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum speed in backward direction as a percentage of TOP MAX SPEED.
MAX SPEED LIFT (P)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum speed of the pump motor during lift, as a percentage of the maximum voltage applied to the pump motor.
1ST PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor when 1st speed is requested. It represents a percentage of the maximum pump speed.
2ND PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor when 2nd speed is requested. It represents a percentage of the maximum pump speed.
3RD PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor when 3rd speed is requested. It represents a percentage of the maximum pump speed.
4TH PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor when 4th speed is requested. It represents a percentage of the maximum pump speed.
5TH PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor when 5th speed is requested. It represents a percentage of the maximum pump speed.
HYD PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor used for the steering, when HYDRO FUNCTION is ON and the pump controller receives a hydro request. It represents a percentage of the maximum pump speed.
CUTBACK SPEED 1 (T, P, TM)	20% ÷ 100% (steps of 1%)	This parameter defines the maximum speed performed when cutback input 1 is active. It represents a percentage of TOP MAX SPEED.
CUTBACK SPEED 2 (T, P, TM)	20% ÷ 100% (steps of 1%)	This parameter defines the maximum speed performed when cutback input 2 is active. It represents a percentage of TOP MAX SPEED.
H&S CUTBACK (T, TM)	10% ÷ 25% (steps of 1%)	This parameter defines the maximum speed performed when the Hard-and-Soft function is active. It represents a percentage of TOP MAX SPEED.
CTB. STEER ALARM (T, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum traction speed in presence of an alarm from the EPS controller, if the alarm is not safety-related. The parameter represents a percentage of TOP MAX SPEED.
CURVE SPEED 1 (T, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum traction speed when the steering angle is equal to the STEER ANGLE 1 angle. The parameter represents a percentage of TOP MAX SPEED.

PARAMETER CHANGE		
Parameter	**Allowable range**	**Description**
CURVE CUTBACK (T, TM)	1% ÷ 100% (steps of 1%)	This parameter defines the maximum traction speed when the steering angle is equal to the STEER ANGLE 2 angle. The parameter represents a percentage of TOP MAX SPEED.
FREQUENCY CREEP (T, P, TM)	0.6 Hz ÷ 25 Hz (steps of 0.1 Hz)	This parameter defines the minimum speed when the forward- or reverse-request switch is closed, but the accelerator is at its minimum.
TORQUE CREEP (T, P, CO, TM)	0% ÷ 100% (256 steps)	This parameter defines the minimum torque applied when torque control is enabled and the forward- or reverse-request switch is closed, but the accelerator is at its minimum.
ACC SMOOTH (T, P, CO, TM, MCO)	1 ÷ 5 (steps of 0.1)	This parameter defines the acceleration profile: 1 results in a linear ramp, higher values result in smoother parabolic profiles. See parameter 9.8.
INV SMOOTH (T, CO, TM, MCO)	1 ÷ 5 (steps of 0.1)	This parameter defines the acceleration profile performed when the truck changes direction: 1 results in a linear ramp, higher values result in smoother parabolic profiles. See parameter 9.8.
STOP SMOOTH (T, P, CO, TM, MCO)	3 Hz ÷ 100 Hz (steps of 1 Hz)	This parameter defines the frequency at which the smoothing effect of the acceleration profile ends. See parameter 9.8.
BRK SMOOTH (T, CO, TM, MCO)	1 ÷ 5 (steps of 0.1)	This parameter defines the deceleration profile: 1 results in a linear ramp, higher values result in smoother parabolic profiles. See parameter 9.8.
STOP BRK SMOOTH (T, CO, TM, MCO)	3 Hz ÷ 100 Hz (steps of 1 Hz)	This parameter defines the frequency at which the smoothing effect of the deceleration profile ends. See parameter 9.8.
BACKING SPEED (T, TM)	10% ÷ 25% (steps of 1%)	This parameter defines maximum speed performed when the inching function is active. The parameter represents a percentage of TOP MAX SPEED.
BACKING TIME (T, TM)	0 s ÷ 10 s (steps of 0.1 s)	This parameter defines the duration of the inching function. The default value is 0 s, which determines the inching function to be inactive. Set a value higher than 0 s to allow the function to activate upon the associated inputs A22 and A23.
EB. ENGAGE DELAY (T, P, CO, TM, G, MCO)	0 s ÷ 12.75 s (steps of 0.05 s)	This parameter defines the delay introduced between the traction request and the actual activation of the traction motor. This takes into account the delay occurring between the activation of the EB output (i.e. after a traction request) and the effective EB release, so to keep the motor stationary until the electromechanical brake is actually released. The releasing delay of the brake can be measured or it can be found in the technical documentation of the device.

PARAMETER CHANGE		
Parameter	**Allowable range**	**Description**
AUXILIARY TIME (T, P, CO, TM, G, MCO)	0 s ÷ 10 s (steps of 0.1 s)	This parameter defines the timing reference for the stop-on-ramp feature and more in general for the behavior of the controller when the motor comes to a stop. See parameter STOP ON RAMP.
ROLLING DW SPEED (T, P, CO, TM, TS23, G, MCO)	1 Hz ÷ 50 Hz (steps of 1 Hz)	This parameter defines the maximum speed for the rolling-down function.
MIN EVP (A)	0% ÷ 100% (256 steps)	This parameter determines the minimum current applied to the EVP when the potentiometer position is at the minimum. This parameter is not effective if the EVP is programmed like an on/off valve. See paragraph 9.14.
MAX EVP (A)	0% ÷ 100% (256 steps)	This parameter determines the maximum current applied to the EVP when the potentiometer position is at the maximum. This parameter also determines the current value when the EVP is programmed like an ON/OFF valve. See paragraph 9.14.
EVP OPEN DELAY (A)	0 s ÷ 12.75 s (steps of 0.05 s)	It determines the current increase rate on EVP. The parameter sets the time needed to increase the current to the maximum possible value. See paragraph 9.14.
EVP CLOSE DELAY (A)	0 s ÷ 12.75 s (steps of 0.05 s)	It determines the current decrease rate on EVP. The parameter sets the time needed to decrease the current from the maximum possible value down to zero. See paragraph 9.14.

8.2.2 SET OPTIONS

SET OPTIONS		
Parameter	**Allowable range**	**Description**
HM DISPLAY OPT. (T, P, TM)	0 ÷ 6	This parameter defines the configuration for the hour meter shown on a display (i.e. MDI). The possible settings are the same described for parameter HM CUSTOM 1 OPT..

SET OPTIONS		
Parameter	**Allowable range**	**Description**
HM CUSTOM 1 OPT. (T, P, CO, TM, G, MCO)	0 ÷ 6	This parameter decides the configuration for the hour meter number 1 accessible to the customer. The possible settings are: **0:** The hour meter counts since the controller is on. **1:** The hour meter counts when the three-phase power bridge is active. **2:** Not used. **3:** The hour meter counts when one of the valve outputs is active. **4:** Not used. **5:** Same as case 3. **6:** Not used.
HM CUSTOM 2 OPT. (T, P, CO, TM, G, MCO)	0 ÷ 6	This parameter decides the configuration for the hour meter number 2 accessible to the customer. The possible settings are the same of HM CUSTOM 1 OPT. parameter.
TILL/SEAT SWITCH (T, P, TM, G)	List of options	This option handles the input A8 (A6). This input opens when the operator leaves the truck. It is connected to a key voltage when the operator is present. **SEAT** = Input A8 (A6) is managed as seat input (with a delay when released and the de-bouncing function). **HANDLE** = Input A8 (A6) is managed as tiller input (no delay when released). **DEADMAN** = Input A8 (A6) is managed as dead-man input (no delay when released).
EB ON TILLER BRK (T, G)	OFF, ON	This option defines how the electromechanical brake is managed depending on the status of tiller/seat input: **ON** = The electromechanical brake is engaged as soon as the tiller input goes into OFF state. The deceleration ramp defined by TILLER BRAKING parameter has no effect. **OFF** = When the tiller input goes into OFF state, the “tiller braking” ramp is applied before engaging the electromechanical brake.

SET OPTIONS		
Parameter	**Allowable range**	**Description**
BATTERY CHECK (T, P, CO, TM, G, MCO)	0 ÷ 3	This option specifies the management of the low battery charge situation. There are four levels of intervention: **0** = The battery charge level is evaluated but ignored, meaning that no action is taken when the battery runs out. **1** = The BATTERY LOW alarm occurs when the battery level is evaluated to be lower or equal to BATT.LOW TRESHLD. With the BATTERY LOW alarm, the control reduces the maximum speed down to 24% of the full speed and it also reduces the maximum current down to 50% of the full current. **2** = The BATTERY LOW alarm occurs when the battery level is evaluated to be lower or equal to BATT.LOW TRESHLD. **3** = The BATTERY LOW alarm occurs when the battery level is evaluated to be lower or equal to BATT.LOW TRESHLD. With the BATTERY LOW alarm, the control reduces the maximum speed down to 24% of the full speed. See parameter BATT.LOW TRESHLD under ADJUSTMENTS.
STOP ON RAMP (T, P, CO, TM, TS23, G, MCO)	OFF, ON	This parameter enables the stop-on-ramp feature, which holds electrically the truck in place on a slope. **ON** = The stop-on-ramp feature is performed at each stop of the truck. If present, the electromechanical brake activates when the truck stops or when AUXILIARY TIME elapses (starting from when the motor speed falls below 1 Hz), depending on which happens first. As a safety measure against a possible failure of the brake, the power bridge is kept active for twice the AUXILIARY TIME, starting from when the motor speed falls below 1 Hz. **OFF** = The stop-on-ramp feature is not performed. Instead, a controlled rollback is performed at a speed defined by ROLLING DW SPEED (paragraph 8.2.1) until the flat is reached. In this case, AUXILIARY TIME determines the time the control waits before deactivating the power bridge, starting from when the motor speed falls below 1 Hz, as to avoid deactivating the bridge while the truck has not come to a complete stop. Typically, the best configuration is to set STOP ON RAMP = ON in case the electromechanical brake is present, STOP ON RAMP = OFF in case the electromechanical brake is absent. See parameter AUX OUT FUNCTION.

<table>
<tr><th colspan="3">SET OPTIONS</th></tr>
<tr><th>Parameter</th><th>Allowable range</th><th>Description</th></tr>
<tr><td>PULL IN BRAKING
(A)</td><td>OFF, ON</td><td>This parameter enables or disables the functionality that continues to give torque even if the traction (or lift) request has been released.
ON = When the operator releases the traction request, the inverter keeps running the truck, as to oppose the friction that tends to stop it. Similarly, in pump applications, when the operator releases the lift request, the inverter keeps running the pump avoiding the unwanted descent of the forks.
OFF = When the operator releases the traction (or lift) request, the inverter does not power anymore the motor. This setting is useful especially for traction application. When the truck is travelling over a ramp and the driver wants to stop it by gravity, the motor must not be powered anymore, until the truck stops.</td></tr>
<tr><td>SOFT LANDING
(A)</td><td>OFF, ON</td><td>This parameter enables or disables the control of the deceleration rate of the truck when the accelerator is released.
ON = When the accelerator is released, the inverter controls the deceleration rate of the truck through the application of a linearly decreasing torque curve. This is useful when the operator releases the accelerator while the truck is going uphill. If the rise is steep, the truck may stop fast and may also go backwards in short time, possibly leading to a dangerous situation.
OFF = When the accelerator is released, the inverter does not control the deceleration rate of the truck, instead it stops driving the motor.</td></tr>
<tr><td>QUICK INVERSION
(T, P, TM)</td><td>List of options</td><td>This parameter defines the quick-inversion functionality.
NONE = The quick-inversion function is not managed.
BELLY = The quick-inversion function is managed but not timed: upon a QI request the controller drives the motor in the opposite direction until the request is released.
TIMED = The quick-inversion function is timed: upon a QI request the controller drives the motor in the opposite direction for a fixed time (1.5 seconds by default).
BRAKE = Upon a quick-inversion request, the motor is braked.</td></tr>
<tr><td>PEDAL BRK ANALOG
(T, TM)</td><td>OFF, ON</td><td>This parameter defines the kind of brake pedal adopted.
ON = Brake pedal outputs an analog signal, braking is linear.
OFF = Brake pedal outputs a digital signal, braking is on/off.</td></tr>
<tr><td>HARD & SOFT
(T, TM)</td><td>OFF, ON</td><td>This parameter enables or disables the Hard-and-Soft functionality. With H&S, it is possible to start the truck at reduced speed by only activating the H&S switch and the accelerator, without the TILLER input.
OFF = H&S function is disabled (default option).
ON = H&S function is enabled.</td></tr>
</table>

<table>
<tr><th colspan="3">SET OPTIONS</th></tr>
<tr><th>Parameter</th><th>Allowable range</th><th>Description</th></tr>
<tr><td>HB ON / SR OFF
(T, TM)</td><td>OFF, ON</td><td>This parameter defines the function associated with input SR/HB A19 (A13).
ON = Handbrake.
OFF = Speed reduction.</td></tr>
<tr><td>MAIN POT. TYPE
(T, P, TM)</td><td>0 ÷ 14</td><td>This parameter defines the feature of the main potentiometer, connected to pin A5 (A3).
<table>
<tr><th>#</th><th>Pot. type</th><th>Low to High / High to Low</th><th>Direction switches</th><th>Enable switch</th><th>En. dead band</th></tr>
<tr><td>0</td><td rowspan="4">V-type</td><td>L to H</td><td>X</td><td></td><td></td></tr>
<tr><td>1</td><td>L to H</td><td>X</td><td></td><td>X</td></tr>
<tr><td>2</td><td>H to L</td><td>X</td><td></td><td></td></tr>
<tr><td>3</td><td>H to L</td><td>X</td><td></td><td>X</td></tr>
<tr><td>4</td><td rowspan="8">Z-type</td><td>L to H</td><td>X</td><td></td><td></td></tr>
<tr><td>5</td><td>L to H</td><td>X</td><td></td><td>X</td></tr>
<tr><td>6</td><td>L to H</td><td></td><td>X</td><td>X</td></tr>
<tr><td>7</td><td>L to H</td><td></td><td></td><td>X</td></tr>
<tr><td>8</td><td>H to L</td><td>X</td><td></td><td></td></tr>
<tr><td>9</td><td>H to L</td><td>X</td><td></td><td>X</td></tr>
<tr><td>10</td><td>H to L</td><td></td><td>X</td><td>X</td></tr>
<tr><td>11</td><td>H to L</td><td></td><td></td><td>X</td></tr>
<tr><td>12</td><td>V-type*</td><td>L to H</td><td></td><td></td><td>X</td></tr>
<tr><td>13</td><td>No**</td><td>H to L</td><td></td><td>X</td><td></td></tr>
<tr><td>14</td><td>V-type</td><td>L to H</td><td>X</td><td>X</td><td></td></tr>
</table>
* V-type potentiometer without direction switches: the motor spins always in the same direction.
** Only for pump controllers. Only enable is used, without potentiometer. When the rotation is activated, the controller drives the pump motor at the maximum speed.
See paragraph 9.4.</td></tr>
<tr><td>AUX POT. TYPE
(T, P, TM)</td><td>0 ÷ 15</td><td>This parameter defines the feature of the auxiliary potentiometer, connected to pin A16 (A10).
<table>
<tr><th>#</th><th>Pot. type</th><th>Low to High / High to Low</th><th>Direction switches</th><th>Enable switch</th><th>En. dead band</th></tr>
<tr><td>0
÷
11</td><td colspan="5">Same as for MAIN POT. TYPE,
see the previous parameter.</td></tr>
<tr><td>12</td><td>No</td><td>H to L</td><td>X</td><td>X</td><td></td></tr>
<tr><td>13</td><td colspan="5">Crossed twin together with the main potentiometer.</td></tr>
<tr><td>14</td><td colspan="5">Free for future uses.</td></tr>
<tr><td>15</td><td>No</td><td>H to L</td><td>X</td><td></td><td></td></tr>
</table>
See paragraph 9.4.</td></tr>
</table>

SET OPTIONS		
Parameter	**Allowable range**	**Description**
SET MOT.TEMPERAT (T, P, CO, TM, TS23, G, MCO)	List of options	This parameter defines the type of motor temperature sensor connected to A33 (A23). **NONE** = None. **DIGITAL** = Digital (ON/OFF) motor thermal sensor. **KTY84** = KTY84-130. **KTY83** = KTY83-130. **PT1000** = PT1000. **KTY81** = KTY81-110/120. **PT100** = PT100. See paragraph 4.3.8.
STEERING TYPE (T, TM, MCO)	List of options	This parameter defines which type of steering unit is connected to the controller. **NONE** = No steering module is present on the truck, ACE4 does not wait for any CAN message by the EPS and it does not apply EPS and braking steer cutbacks. **ANALOG** = A hydraulic steer is used on the truck and ACE4 reads the wheel rotation by the analog signal coming from a wheel potentiometer on the STEER input. **C.O.** = If the parameter PDO2RX is enabled and CONTROLLER TYPE = C.O., then the ACE4 receives the speed and the steering angle information in PDO2 via a CAN command. **OPTION #1** = EPS Minifit is present, in combination with an encoder and toggles switches. The states of such signals are transmitted to the ACE4 over CAN bus. **OPTION #2** = EPS Minifit is present, in combination with a potentiometer and an encoder. The states of such signals are transmitted to ACE4 over CAN bus. **OPTION #3** = EPS AC0 Ampseal is present, in combination with an encoder and toggles switches. The states of such signals are transmitted to the ACE4 over CAN bus.
STEERING POT POS (TM, MCO)	0 ÷ 3	This parameter defines which controller the steering potentiometer is connected to. It is available in the master unit of a multi-motor application and it is used when STEERING TYPE = ANALOG. **0** = Master controller, on pin A13. **1, 2, 3** = Slave controller 1, 2, 3; on pin A5 (A3).

SET OPTIONS		
Parameter	**Allowable range**	**Description**
M.C. FUNCTION (A)	List of options	This parameter defines the configuration of the NLC output A26 (A16), dedicated to the main – or line – contactor. **OFF** = Main contactor is not present. Diagnoses are masked and MC is not driven. **ON** = Main contactor is in standalone configuration. Diagnoses are performed and MC is closed after key-on only if they have passed. **OPTION #1** = For a traction-and-pump setup, with only one main contactor for both controllers. Diagnoses are performed and MC is closed after key-on only if they have passed. **OPTION #2** = For a traction-and-pump setup, with two main contactors. Each controller drives its own MC. Diagnoses are performed and MCs are closed after key-on only if they have passed.
M.C. OUTPUT (A)	ABSENT, PRESENT	This parameter defines whether a load coil is connected to the NLC output A26 (A16) or not. **ABSENT** = NLC output is not connected to any load coil. **PRESENT** = NLC output is connected to a load coil (by default, that of the main contactor).
EBRAKE ON APPL. (T, P, CO, TM, TS23, G, MCO)	ABSENT, PRESENT	This parameter defines whether the application includes an electromechanical brake or not.
AUX OUT FUNCTION (A)	NONE, BRAKE	This parameter enables or disables the NEB output A28 (A18), dedicated to the electromechanical brake. **NONE** = Diagnoses are masked and E.B. is not driven upon a traction request. **BRAKE** = E.B. is driven upon a traction request if all the related diagnoses pass. The behavior on a slope depends on the STOP ON RAMP setting. **<u>Do not use this setting if the electromechanical brake is not present.</u>** In applications with two controllers driving two traction motors and only one E.B., this parameter has to be set on BRAKE only in the controller that drives the E.B. .
COMP.VOLT.OUTPUT (A)	0 ÷ 3	This parameter defines the voltage compensation for the MC and EB drivers in dependence of the battery voltage. **0** = None. **1** = MC only. **2** = EB only. **3** = MC and EB.

SET OPTIONS		
Parameter	**Allowable range**	**Description**
EMERGENCY INPUT (CO, MCO)	0 ÷ 2	This parameter defines the emergency function, which stops all the active functions, including the power section, upon the activation of input A19 (A13). **0** = Emergency function is disabled. **1** = Emergency function is enabled, plus an alarm is raised at the emergency event. **2** = Emergency function is enabled, without any linked alarm.
SYNCRO (CO, G, MCO, SCO)	OFF, ON	This parameter enables the syncro message. **OFF** = The syncro message is not used **ON** = The syncro message is enabled
AUTO PARK BRAKE (CO, G, MCO, SCO)	OFF, ON	This parameter enables or disables the autonomous management of the brake output. **OFF** = The output is activated or deactivated according to the signal received by CAN bus. **ON** = The output is managed autonomously by the controller itself ignoring any activation/deactivation signal received by CAN bus.
ACCEL MODULATION (T, P, CO, TM, G, MCO)	List of options	This parameter enables or disables the modulation function for accelerations and decelerations. **OFF** = Disabled. **ON** = Enabled. **OPTION #1** = Reserved for future developments. See paragraphs 9.5 and 9.6.
EVP TYPE (A)	List of options	This parameter defines the behavior of output NEVP A29 (A19). **NONE** = Output A29 (A19) is not enabled. **DIGITAL** = Output A29 (A19) manages an on/off valve. By default, on premium versions it is activated by input LOWER A11. **ANALOG** = Output A29 (A19) manages a PWM-modulated current-controlled proportional valve. By default, on premium versions it is activated by input LOWER A11 and EVP POT A1. Note: on standard versions, EVP can only be operated by a CAN command.

SET OPTIONS		
Parameter	**Allowable range**	**Description**
EV1 (A)	List of options	This parameter defines the behavior of output NEV1 A24. **ABSENT** = Output A24 is not enabled. **OPTION #1** = Output A24 manages an ON/OFF valve. By default, it is activated by input AUX1 A2 or by input 1ST A22. **OPTION #2** = Output A24 manages an external pre-charge device. **OPTION #3** = Output A24 manages a horn. **OPTION #4** = Output A24 activates in case any alarm is present.
EV2 (A)	ABSENT, DIGITAL	This parameter defines the behavior of output NEV2 A25. **ABSENT** = Output A25 is not enabled. **DIGITAL** = Output A25 manages a PWM voltage-controlled valve. The PWM frequency is 1 kHz and the duty-cycle when the output is active depends on parameter PWM EV2 (ADJUSTMENTS list, paragraph 8.2.3). By default, it is activated by input AUX2 A12 or by input 2ND A23.
EV3 (A)	ABSENT, DIGITAL	This parameter defines the behavior of output NEV3 A34. **ABSENT** = Output A34 is not enabled. **DIGITAL** = Output A34 manages a PWM voltage-controlled valve. The PWM frequency is 1 kHz and the duty-cycle when the output is active depends on parameter PWM EV3 (ADJUSTMENTS list, paragraph 8.2.3). By default, it is activated by input AUX3 A14 or by input 3RD A2.
EV4 (A)	List of options	This parameter defines the behavior of output NEV4 A35. **ABSENT** = Output A35 is not enabled. **OPTION #1** = Output A35 manages an ON/OFF valve. By default, no input is dedicated to the activation of EV4. Instead, it activates upon driving backwards (traction controllers) or by a CAN command.
HIGH DYNAMIC (T, P, CO, TM, G, MCO)	OFF, ON	This parameter enables or disables the high-dynamic function. **ON** = All acceleration and deceleration profiles set by dedicated parameters are ignored and the controller works always with maximum performance. **OFF** = Standard behavior.
INVERSION MODE (T, TM)	OFF, ON	This parameter sets the behavior of the quick-inversion input A17 (A11): **ON** = The quick-inversion switch is normally closed (the function is active when the switch is open). **OFF** = The quick-inversion switch is normally open (the function is active when the switch is closed).

SET OPTIONS		
Parameter	**Allowable range**	**Description**
STEER TABLE (TM, MCO)	List of options	This parameter defines the steering table. **NONE** = The inverter does not follow any predefined steering table, but it creates a custom table according to parameters WHEELBASE MM, FIXED AXLE MM, STEERING AXLE MM and REAR POT ON LEFT. **OPTION #1** = Three-wheel predefined steering table. **OPTION #2** = Four-wheel predefined steering table. The steering table depends on the truck geometry. The two options available as default may not fit the requirements of your truck. It is advisable to define the geometrical dimensions of the truck in the parameters listed below in order to create a custom table. It is strongly recommended to consult paragraph 9.16 in order to properly understand how to fill the following parameters. If the steering performance of the truck do not match your requirements even if you have defined the right truck geometry, contact a Zapi technician in order to establish if a custom steering table has to be created.
WHEELBASE MM (TM, MCO)	0 ÷ 32000	This parameter defines the wheelbase distance in millimeters, i.e. the distance between the front and back axles of the machine. The setting is discarded if STEER TABLE = OPTION #1 or OPTION #2. See paragraph 9.16.
FIXED AXLE MM (TM, MCO)	0 ÷ 32000	This parameter defines the length in millimeters of the fixed axle, at which the non-steering wheels are connected. The setting is discarded if STEER TABLE = OPTION #1 or OPTION #2. See paragraph 9.16.
STEERING AXLE MM (TM, MCO)	0 ÷ 32000	This parameter defines the length in millimeters of the steering axle, at which the steered wheels [wheel] are [is] connected. The setting is discarded if STEER TABLE = OPTION #1 or OPTION #2. See paragraph 9.16.
REAR POT ON LEFT (TM, MCO)	OFF, ON	This parameter defines the position of the steering potentiometer on a four-wheel machine. **OFF** = The steering potentiometer is placed on the rear-right wheel. **ON** = The steering potentiometer is placed on the rear-left wheel.
DISPLAY TYPE (T, P, TM)	0 ÷ 9	This parameter defines which type of display is connected to the inverter. **0** = None. **1** = MDI PRC. **2** = ECO DISPLAY. **3** = SMART DISPLAY. **4** = MDI CAN. **5 ÷ 9** = Free for future developments.

SET OPTIONS		
Parameter	**Allowable range**	**Description**
PDO2RX (CO, G, MCO, SCO)	ABSENT, PRESENT	This parameter defines whether the message PDO2RX is expected to be received. **ABSENT** = Message PDO2RX is not expected to be received. **PRESENT** = Message PDO2RX is expected to be received. If it is not received, a CAN alarm is raised.
PDO3TX (CO, G, MCO)	0 ÷ 2	This parameter defines whether the controller sends the message PDO3TX over the CAN network. **0** = Message PDO3TX is not sent. **1 ÷ 2 =** Message PDO3TX is sent on the CAN network.
PERFORMANCE (T, P, TM)	OFF, ON	This parameter enables the selection of the performance mode. **OFF** = normal performance level selected and locked. **ON** = the user can change the performance level from normal to economy or power. See paragraph 9.19.
BMS FUNCTION (T, P, CO, TM, G, MCO)	List of options	This parameter defines the battery monitoring strategy and the limitations to the motor speed and current. **OFF** = The controller monitors the battery voltage and the battery state of charge. **ON** = The controller receives information from the BMS about the battery state, its state of charge and the motor speed and current (AC) upper limit. The current limitation is performed both in motoring and regenerative braking if BRK TORQUE BMS = ON, only in motoring otherwise. **OPTION #1** = Like the ON case, but the current limit is referred to the DC battery current and it is applied both in motoring and regenerative braking, without being subject to the setting of BRK TORQUE BMS.
BRK TORQUE BMS (T, P, CO, TM, G, MCO)	OFF, ON	This parameter enables the current, hence torque, limitation during regenerative braking upon a limit received from the BMS over the CAN bus, as per the strategy defined by setting BMS FUNCTION = ON. **OFF** = The current limitation upon a limit received from the BMS is not applied during regenerative braking. **ON** = The current limitation upon a limit received from the BMS is applied also during regenerative braking. This setting has effect only if BMS FUNCTION = ON
STO (CO)	OFF, ON	This parameter enables the STO safety function (safe torque off) featured by the CAN operated versions of the controller.

SET OPTIONS		
Parameter	**Allowable range**	**Description**
SS1 (CO)	List of values	This parameter defines the SS1 safety function (safe stop 1) featured by the CAN operated versions of the controller. **0** = SS1 function is not active. **1** = Monitored. Upon request, inverter brakes with controlled ramp then, when the motor is at standstill, it applies STO. If the desired ramp is not respected, then the controller will raise the related alarm and will apply STO immediately. The desired ramp is defined by parameter SS1 BRAKING. **2** = Time-dependent. In addition to the braking ramp, the controller also checks the total braking time: if one of the two is not respected, then the inverter will raise the related alarm, it will apply STO and it will activate the electromechanical brake. The maximum braking time is defined by parameter GSS1 BRK. TIME.
HEARTBEAT MSG. (CO, G, MCO, SCO)	OFF, ON	This parameter enables the transmission of the heartbeat message, or boot message, over the CAN bus (id 0x700 + node id), providing the NMT state of the node.

8.2.3 ADJUSTMENTS

ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
SET BATTERY (A)	24 V ÷ 120 V (list of values)	This parameter must be set to the nominal battery voltage. The available options are: **24V**, **36V**, **48V**, **72V**, **80V**, **96V**, **120V**
ADJUST KEY VOLT. (A)		Fine adjustment of the key voltage measured by the controller. Calibrated by Zapi production department during the end of line test.
ADJUST BATTERY (A)		Fine adjustment of the battery voltage measured by the controller. Calibrated by Zapi production department during the end of line test.
SET POSITIVE PEB (A)	12 V ÷ 96 V (list of values)	This parameter defines the supply-voltage value connected to PEB A27 (A17). Available values are: **12V**, **24V**, **36V**, **40V**, **48V**, **72V**, **80V**, **96V**
SET PBRK. MIN (T, TM)	0 V ÷ 25.5 V (steps of 0.1 V)	It records the minimum value of brake potentiometer when the brake is analog.
SET PBRK. MAX (T, TM)	0 V ÷ 25.5 V (steps of 0.1 V)	It records the maximum value of brake potentiometer when the brake is analog.
MIN LOWER **(Read Only)** (T, P, TM, TS1)	0 V ÷ 25.5 V (steps of 0.1 V)	It records the minimum value of lower potentiometer when the lower switch is closed. See paragraph 9.2.

ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
MAX LOWER **(Read Only)** (T, P, TM, TS1)	0 V ÷ 25.5 V (steps of 0.1 V)	It records the maximum value of lower potentiometer when the lower switch is closed. See paragraph 9.2.
THROTTLE 0 ZONE (T, P, TM)	0% ÷ 100% (steps of 1%)	This parameter defines a dead band in the accelerator input curve. See paragraph 9.10.
THROTTLE X1 MAP (T, P, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.10.
THROTTLE Y1 MAP (T, P, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.10.
THROTTLE X2 MAP (T, P, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.10.
THROTTLE Y2 MAP (T, P, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.10.
THROTTLE X3 MAP (T, P, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.10.
THROTTLE Y3 MAP (T, P, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.10.
BAT. MIN ADJ. (T, P, CO, TM, G, MCO)	-12.8% ÷ 12.7% (steps of 0.1%)	This parameter defines the full-battery voltage (at state-of-charge = 100%), as the percentage deviation with respect to the nominal voltage. It adjusts the upper level of the battery discharge table. It is used to calibrate the discharge algorithm for the battery used. See paragraph 9.12.
BAT. MAX ADJ. (T, P, CO, TM, G, MCO)	-12.8% ÷ 12.7% (steps of 0.1%)	This parameter defines the full-battery voltage (at state-of-charge = 100%), as the percentage deviation with respect to the nominal voltage. It adjusts the upper level of the battery discharge table. It is used to calibrate the discharge algorithm for the battery used. See paragraph 9.12.
BDI ADJ STARTUP (T, P, CO, TM, G, MCO)	-12.8% ÷ 12.7% (steps of 0.1%)	Adjusts the level of the battery charge table at start-up, in order to calculate the battery charge at key-on. See paragraph 9.12.
BDI RESET (T, P, CO, TM, G, MCO)	0% ÷ 100% (steps of 1%)	It adjusts the minimum variation of the battery discharge table to update the battery % at the start up. It is used to calibrate the discharge algorithm for the battery used. See paragraph 9.12.

ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
BATT.LOW TRESHLD (T, P, CO, TM, G, MCO)	1% ÷ 50% (steps of 1%)	This parameter defines the minimum charge percentage below which the BATTERY LOW alarm rises.
BAT.ENERGY SAVER (T, P, CO, TM, TS23, G, MCO)	0% ÷ 100% (256 steps)	This parameter defines the percentage of the maximum output torque delivered when the battery charge falls below 10%. If the battery-saving feature is not desired, BAT.ENERGY SAVER should be set equal to 100%. See paragraph 9.13.
VOLTAGE THR LOW **VOLTAGE THR HIGH** (A)	0% ÷ 255% (steps of 1%)	These parameters define the voltage thresholds for the working voltage range, expressed as percentages of the nominal voltage. At start-up the controller checks the voltage at the key input and the +B post to be within the range from VOLTAGE THR LOW to VOLTAGE THR HIGH. The default values are respectively 80% and 120%. See paragraph 2.4 for more details. In case the check fails, alarm WRONG KEY VOLT. or WRONG SET BAT. is raised.
STEER RIGHT VOLT (T, TM, MCO)	0 V ÷ 25.5 V (steps of 0.1 V)	This parameter records the maximum steering-control voltage while turning right. See paragraph 9.3.
STEER LEFT VOLT (T, TM, MCO)	0 V ÷ 25.5 V (steps of 0.1 V)	This parameter records the maximum steering-control voltage while turning left. See paragraph 9.3.
STEER ZERO VOLT (T, TM, MCO)	0 V ÷ 25.5 V (steps of 0.1 V)	This parameter records the maximum steering-control voltage when it is in the straight-ahead position. See paragraph 9.3.
MAX ANGLE RIGHT (T, TM, MCO)	0° ÷ 90° (steps of 1°)	This parameter defines the maximum steering-wheel angle while turning right.
MAX ANGLE LEFT (T, TM, MCO)	0° ÷ 90° (steps of 1°)	This parameter defines the maximum steering-wheel angle while turning left.
STEER DEAD ANGLE (T, TM)	1° ÷ 50° (steps of 1°)	This parameter defines the maximum steering-wheel angle up to which the permitted traction speed is 100%. See paragraph 9.9.
STEER ANGLE 1 (T, TM)	1° ÷ 90° (steps of 1°)	This parameter defines the steering-wheel angle at which traction speed is reduced to the value imposed by CURVE SPEED 1. For steering-wheel angles between STEER DEAD ANGLE and STEER ANGLE 1, traction speed is reduced linearly from 100% to CURVE SPEED 1. See paragraph 9.9.

ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
STEER ANGLE 2 (T, TM)	1° ÷ 90° (steps of 1°)	This parameter defines the steering-wheel angle beyond which traction speed is reduced to CURVE CUTBACK. For steering-wheel angles between STEER ANGLE1 and STEER ANGLE 2 traction speed is reduced linearly from CURVE SPEED 1 to CURVE CUTBACK. See paragraph 9.9.
SPEED FACTOR (T, CO, TM, MCO)	0 ÷ 255	This parameter defines the coefficient used for evaluating the truck speed (in km/h) from the motor frequency (in Hz), according to the following formula. $Speed\ [km/h] = 10 \cdot \frac{frequency\ [Hz]}{Speed\ factor}$ This parameter can be derived by the following formula too. $Speed\ factor = \frac{88 \cdot rr \cdot pp}{\emptyset}$ rr: total gearbox reduction ratio. pp: motor poles pair. Ø: traction wheel diameter expressed in cm.
SPEED ON MDI (T, P, TM)	OFF, ON	This parameter enables or disables the speed visualization on MDI display: **ON** = MDI shows traction speed when the truck is moving. In steady-state condition the speed indication is replaced by the hour-meter indication. **OFF** = Standard MDI functionality.
LOAD HM FROM MDI (T, P, TM)	OFF, ON	This parameter is used so to load into the controller the hour-meter count from the MDI CAN connected on the CAN bus network. If no MDI CAN is present on the machine, this parameter has not effect. **OFF** = The controller hour-meter increases over time normally. **ON** = At the next key cycle, the controller will load into its own hour-meter that one stored in the MDI CAN, then the parameter value will automatically be restored to OFF. This can be used to match the controller hour-meter to that of the MDI CAN, for example after the controller has been replaced with a new one.
CHECK UP DONE (T, P, CO, TM, G, MCO)	OFF, ON	This parameter clears the CHECK UP NEEDED warning. Set it ON after the required maintenance service to clear the warning.
CHECK UP TYPE (T, P, CO, TM, G, MCO)	List of options	This parameter defines the CHECK UP NEEDED warning: **NONE** = no CHECK UP NEEDED warning. **OPTION #1** = CHECK UP NEEDED warning shown on the hand-set and MDI after 300 hours. **OPTION #2** = Like OPTION #1, with the addition that the speed reduction intervenes after 340 hours. **OPTION #3** = Like OPTION #2, with the addition that the truck definitively stops after 380 hours.

ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
MC VOLTAGE (A)	0% ÷ 100% (steps of 1%)	This parameter specifies the duty-cycle (t_{ON}/T_{PWM}) of the PWM applied to the main-contactor output A26 (A16) during the first second after the activation signal that causes the main contactor to close.
MC VOLTAGE RED. (A)	0% ÷ 100% (steps of 1%)	This parameter defines a percentage of MC VOLTAGE parameter and it determines the duty-cycle applied after the first second of activation of the contactor. For details and examples see paragraph 9.11.
EB VOLTAGE (A)	0% ÷ 100% (steps of 1%)	This parameter specifies the duty-cycle (t_{ON}/T_{PWM}) of the PWM applied to the electromechanical brake output A28 (A18) during the first second after the activation signal that causes the electromechanical brake to release.
EB VOLTAGE RED. (A)	0% ÷ 100% (steps of 1%)	This parameter defines a percentage of EB VOLTAGE parameter and it determines the duty-cycle applied after the first second since when the electromechanical brake is released. For details and examples see paragraph 9.11.
PWM EV2 (A)	0% ÷ 100% (256 steps)	This parameter defines the on-state duty-cycle of the PWM applied to EV2 output A25 when the output is active.
PWM EV3 (A)	0% ÷ 100% (256 steps)	This parameter defines the duty-cycle of the PWM applied to EV3 output A34 when the output is active.
MAX. MOTOR TEMP. (T, P, CO, TM, TS23, G, MCO)	0 °C ÷ 255 °C	This parameter defines the motor temperature above which a 50% cutback is applied to the maximum current. Cutback is valid only during motoring, while during braking the 100% of the maximum current is always available regardless of the temperature. See paragraph 9.17.
STOP MOTOR TEMP. (T, P, CO, TM, TS23, G, MCO)	0 °C ÷ 255 °C	This parameter defines the maximum motor temperature permitted, above which the controller stops driving the motor. See paragraph 9.17.
MOT.T. T.CUTBACK (T, P, CO, TM, TS23, G, MCO)	0% ÷ 100% (256 steps)	This parameter defines the motor thermal cutback. The control linearly reduces the motor torque basing on the motor temperature. Reference limits of the linear reduction are MAX MOTOR TEMP and TEMP. MOT. STOP. See paragraph 9.17.
IDC BUS SENSOR (G)	OFF, ON	This parameter defines whether an external sensor for the battery current is present on the CAN bus network. **ON** = The controller reads the DC current reading by an external sensor via the CAN bus network. **OFF** = No external current sensor is present, the drive estimates the DC current from the AC power being delivered to or drawn from the motor, also considering estimated internal losses.

8.2.4 SPECIAL ADJUSTMENTS

Note: SPECIAL ADJUST. must only be accessed by skilled people. To change settings in this group of settings, a special procedure is needed. Ask for this procedure directly to a Zapi technician. In SPECIAL ADJUSTMENTS there are factory-adjusted parameters that should be changed by expert technicians only.

SPECIAL ADJUSTMENTS

Parameter	Allowable range	Description
ADJUSTMENT #01 **(Read Only)** (A)	Reserved	Gain of the first traction-motor current-sensing amplifier. NOTE: only Zapi technicians can change this value through a special procedure.
ADJUSTMENT #02 **(Read Only)** (A)	Reserved	Gain of the second traction-motor current-sensing amplifier. NOTE: only Zapi technicians can change this value through a special procedure.
CURR. SENS. COMP (A)	OFF, ON	This parameter enables or disables the linear compensation for the current sensors. NOTE: only Zapi technicians can change this value through a special procedure.
CURR. FALLBACK (A)	OFF, ON	This parameter enables the current reduction after one minute of traction.
SET CURRENT **(Read Only)** (A)	List of values	This parameter defines the maximum RMS current that the inverter can provide to the motor. See paragraph 2.3.
SET TEMPERATURE (A)	0 °C ÷ 255 °C	This parameter calibrates the controller-temperature reading.
HW BATTERY RANGE **(Read Only)** (A)	0 ÷ 4	This parameter defines the range for the nominal controller voltage. **0** = 24 V. **1** = 36 V or 48 V. **2** = 72 V or 80 V. **3** = 96 V. **4** = 120 V. Note: only Zapi technicians can change this value.
DUTY PWM CTRAP **(Read Only)** (A)	0% ÷ 100%	This parameter defines the duty cycle for overcurrent threshold. Reserved.

SPECIAL ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
PWM AT LOW FREQ (A)	Reserved	This parameter defines the power-bridge PWM frequency at low speed. NOTE: only Zapi technicians can change this value through a special procedure.
PWM AT HIGH FREQ (A)	Reserved	This parameter defines the power-bridge PWM frequency at high speed. NOTE: only Zapi technicians can change this value through a special procedure.
FREQ TO SWITCH (A)	5 Hz ÷ 255 Hz (steps of 1 Hz)	This parameter defines the electrical frequency at which the switching frequency is changed from PWM AT LOW FREQ to PWM AT HIGH FREQ.
DITHER AMPLITUDE (A)	0% ÷ 13%	This parameter defines the dither signal amplitude. The dither signal is a square wave added to the proportional-valve set-point. In this way the response to set-point variations results optimized. This parameter is a percentage of the valve maximum current. Setting the parameter to 0% means the dither is not used. The available values are: **0.0%, 1.0%, 2.5%, 4.0%, 5.5%, 7.0%, 8.5%, 10%, 11.5%, 13.0%**
DITHER FREQUENCY (A)	20.8 Hz ÷ 83.3 Hz	This parameter defines the dither frequency, in Hertz. The available values are: **20.8, 22.7, 25, 27.7, 31.2, 35.7, 41.6, 50, 62.5, 83.3**
CAN BUS SPEED (A)	20 kbps ÷ 1000 kbps	This parameter defines the CAN bus data-rate in kbps. **20, 50, 125, 250, 500, 800, 1000**
DEBUG CANMESSAGE (A)	0 ÷ 15	This parameter defines the transmission over the CAN bus of special debug messages. **0** = No debug message transmitted. **1 ÷ 15** = Debug messages transmitted. Ask assistance to Zapi agents or technicians.
SAFETY DEBUG (A)	OFF, ON	This parameter enables or disables special debug messages about the STO and SS1 functions.

SPECIAL ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
CONTROLLER TYPE (A)	List of options	This parameter defines the controller type: **STANDARD TRACT.** = Traction **STANDARD PUMP** = Pump **C.O.** = CAN-operated **MASTER T** = Multi-motor traction (master) **SLAVE1 T** = Multi-motor traction (slave 1) **SLAVE2 T** = Multi-motor traction (slave 2) **SLAVE3 T** = Multi-motor traction (slave 3) **GENSET** = Hybrid generation set **MASTER C** = CAN-operated, multi-motor traction (master) **SLAVE1 C** = CAN-operated, multi-motor traction (slave 1) A mismatch between this parameter and the hardware configuration may lead to a severe malfunctioning of the controller.
MOTOR TYPE (A)	List of options	This parameter defines technology of the controlled motor. **AC MOTOR** = Asynchronous motors (IM). **BL MOTOR** = Brushless synchronous motors (PMSM, BLDC). **SRPM MOTOR** = Synchronous reluctance permanent-magnet motors. A mismatch between this parameter and the motor in use may lead to a severe malfunctioning of the controller.
CONTROLLER SLV1 **CONTROLLER SLV2** **CONTROLLER SLV3** (TM, MCO)	List of options	These parameters define the configuration of up to three slave units in a multi-motor system. **ABSENT** = The first/second/third slave unit is not present. **PRESENT** = The first/second/third slave unit is present, under the same main contactor controlled by the master unit. **OPTION #1** = The first/second/third slave unit is present, under its own main contactor.
CONFIG. SLAVES (TM, MCO)	0, 1	This parameter defines the configuration of the second and third slave units for multi-motor configurations having three to four traction controllers (master, first slave, second slave and, possibly, third slave). **0** = The second and, possibly, third slave units mirror the same speed and torque set-point of the master one. **1** = Four controllers are paired two by two over the two sides of the machine: master and slave number 2 drive the right hand side; slave number 1 and slave number 3 drive the left hand side. The speed set-points of the two pairs of controllers are differentiated as per the steering table, hence performing an electronic differential. To be set equal to 1 in the master drive only. See parameter CONTROLLER TYPE.

SPECIAL ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
AGV (T)	OFF, ON	This parameter enables the automatic guide. **OFF** = The automatic guide is disabled. The controller gets the speed reference from the dedicated analog input. **ON** = The automatic guide is enabled. Upon the reception of the first automatic guide request over the CAN bus, the traction controller and the steering controller are expected to receive the speed set point and the steering angle set point as CAN messages. In case the periodic automatic-guide-request message is missed, then the controller raises an alarm and the traction is stopped.
SAFETY LEVEL (T, P, CO, TM, TS23, G, MCO)	0 ÷ 4	This parameter defines the safety level of the controller, i.e. the functionality of the supervisor microcontroller. **0** = Supervisor microcontroller does not check any signal. **1** = Supervisor microcontroller checks the inputs and the outputs. **2** = Supervisor microcontroller checks the inputs and the motor set-point. **3** = Supervisor microcontroller checks the inputs, the outputs and the motor set-point. **4** = Like level 3, plus safety functions as per regulation EN1175.
RS232 CONSOLLE (A)	OFF, ON	This parameter enables or disables the console to change settings. Only Zapi technicians can change this value.
NODE ID (A)	0 ÷ 126	This parameter defines the ID number of the unit on the system.
2ND SDO ID OFST (A)	0 ÷ 126 (steps of 2)	This parameter defines if another SDO communication channel has to be added. Specify an ID offset different from 0 in order to enable the channel.
VDC START UP LIM (T, P, CO, TM, TS23, G, MCO)	0% ÷ 255% (steps of 1%)	This parameter defines the battery voltage (as percentage of the nominal voltage) above which the regenerative power is reduced in order to avoid an overvoltage condition during braking. See paragraph 9.18.
VDC UP LIMIT (T, P, CO, TM, TS23, G, MCO)	0% ÷ 255% (steps of 1%)	This parameter defines the battery voltage (as a percentage of the nominal voltage) above which the inverter stops the power section in order to avoid a damaging overvoltage condition during braking. See paragraph 9.18.
VDC START DW LIM (T, P, CO, TM, TS23, G, MCO)	0% ÷ 255% (steps of 1%)	This parameter defines the battery voltage (as percentage of nominal voltage) below which the delivered power is reduced in order to avoid an under-voltage condition (typically during accelerations with a low battery). See paragraph 9.18.

SPECIAL ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
VDC DW LIMIT (T, P, CO, TM, TS23, G, MCO)	0% ÷ 255% (steps of 1%)	This parameter defines the battery voltage (as percentage of nominal voltage) below which the inverter stops in order to avoid an uncontrolled shutdown due to an under-voltage condition. See paragraph 9.18.
MAX VOLTAGE MOT. (T, P, CO, TM, TS23, G, MCO)	20% ÷ 180%	This parameter defines the maximum voltage applied to the motor. Consult Zapi technicians before changing this setting.

8.2.5 HARDWARE SETTING

The HARDWARE SETTINGS group includes those parameters related to the motor control.

Only those parameters the user can modify are here described. For descriptions and teaching about missing parameters contact a Zapi technician.

HARDWARE SETTING		
Parameter	**Allowable range**	**Description**
TOP MAX SPEED (T, P, CO, TM, TS23, G, MCO)	0 Hz ÷ 600 Hz (steps of 10 Hz)	This parameter defines the maximum motor speed.
CONF.POSITIVE LC (A)	0 ÷ 2 (steps of 1)	This parameter defines the positive supply configuration for the main-contactor coil. Factory adjusted. **0** = The positive supply of Main Contactor coil is connected to PEB A27 (A17). **1** = The positive supply of Main Contactor coil is connected to KEY A3 (A1). **2** = The positive supply of Main Contactor coil is connected to SEAT A8 (A6). NOTE: only Zapi technicians can change this value through a special procedure.

8.2.6 HYDRO SETTING

HYDRO SETTING		
Parameter	**Allowable range**	**Description**
HYDRO TIME (T, P, TM)	0 s ÷ 20 s (steps of 0.1 s)	This parameter defines the delay time between the release of the hydraulic-function request and the actual stop/release of the associated output, according to the HYDRO FUNCTION setting and the HW configuration.

HYDRO SETTING		
Parameter	**Allowable range**	**Description**
HYDRO FUNCTION (T, TM)	List of options	This parameter defines how the traction controller manages the hydro function, useful to power a hydraulic steering. A separate pump controller is to be dedicated to run the hydro pump motor. The traction controller acts as a master, requiring via CAN the pump unit to run, according to the operative condition and the selected option. At the same time, the traction unit can drive a valve too. The following options are available. **NONE** = The traction controller does not manage any hydro function. **KEYON** = The traction controller commands a separate unit to constantly drive the pump motor as long as the SEAT input A8 (A6) is active. **RUNNING** = The traction controller commands a separate unit to run the pump motor only while travelling. When the traction stops, after a delay defined by the parameter HYDRO TIME the traction controller requires the pump unit to stop. **OPTION #1** = The traction controller commands a separate unit to constantly drive the pump motor as long as the SEAT input A8 (A6) is active. At the same time, the controller activates a valve on output NEVP A29 (A19) at full set point. **OPTION #2** = The traction controller commands a separate unit to run the pump motor only while travelling. At the same time, the controller activates a valve on output NEVP A29 (A19) at full set point. When the traction stops, after a delay defined by the parameter HYDRO TIME the traction controller requires the pump unit to stop and the proportional valve is released.

8.2.7 PERFORM. ECONOMY and PERFORM. POWER

Two analogous sets of parameters put in place by the motor controller depending on the performance mode (economy or power) coming from an external display or a master controlling unit. See paragraph 9.19.

PERFORM. ECONOMY and PERFORM. POWER		
Parameter	**Allowable range**	**Description**
ACC.TORQUE DEL.E **ACC.TORQUE DEL.P** (T, P, CO, TM, TS23, G, MCO)	0.1 s ÷ 10 s (steps of 0.1 s)	These parameters define the acceleration ramps if TORQUE CONTROL is ON, i.e. the times needed to increase the torque from the minimum value up to the maximum one.
ACCELER. DELAY E **ACCELER. DELAY P** (T, P, CO, TM, G, MCO)	0.1 s ÷ 25.5 s (steps of 0.1 s)	These parameters define the reference times for the acceleration rates. They represent the times needed to speed up the motor from 0 Hz up to 100 Hz. The acceleration rates are computed depending on the speed change, as per the strategy described in paragraph 9.4 Acceleration modulation.

PERFORM. ECONOMY and PERFORM. POWER		
Parameter	**Allowable range**	**Description**
MAX SPEED FORW E **MAX SPEED FORW P** (T, TM)	0% ÷ 100% (steps of 1%)	These parameters define the maximum speeds in forward direction, as percentages of TOP MAX SPEED.
MAX SPEED LIFT E **MAX SPEED LIFT P** (P)	0% ÷ 100% (steps of 1%)	These parameters define the maximum speeds of the pump motor during lift, as percentages of TOP MAX SPEED.
MAX SPEED BACK E **MAX SPEED BACK P** (T, TM)	0% ÷ 100% (steps of 1%)	These parameters define the maximum speeds in backward direction, as percentages of TOP MAX SPEED.
1ST PUMP SPEED E/P **2ND PUMP SPEED E/P** **3RD PUMP SPEED E/P** **4TH PUMP SPEED E/P** **5TH PUMP SPEED E/P** (P)	0% ÷ 100% (steps of 1%)	These parameters define the speeds of the pump motor when the corresponding speed is requested, from 1st to 5th, as percentages of TOP MAX SPEED.
HYD PUMP SPEED E **HYD PUMP SPEED P** (P)	0% ÷ 100% (steps of 1%)	These parameters define the speeds of the pump motor used for the steering, when HYDRO FUNCTION is ON, as percentages of TOP MAX SPEED.
P0 IMAX MOT E/P **P1 IMAX MOT E/P** **P2 IMAX MOT E/P** **P3 IMAX MOT E/P** (T, P, CO, TM, TS23, G, MCO)	0% ÷ 100% (steps of 1%)	These parameters define the motor current values for the four points of the current profiles put in place during motoring, as percentages of SET CURRENT.
P0 FREQ. MOT E/P **P1 FREQ. MOT E/P** **P2 FREQ. MOT E/P** **P3 FREQ. MOT E/P** (T, P, CO, TM, TS23, G, MCO)	0 Hz ÷ 1020 Hz (256 steps)	These parameters define the frequency values for the four points of the current profiles put in place during motoring.

8.2.8 FEEDBACK SENSOR

FEEDBACK SENSOR		
Parameter	**Allowable range**	**Description**
ROTATION CW ENC **(Only in combination with encoder)** (A)	OPTION #1, OPTION #2	This parameter defines how the controller expects the encoder signals to be when the motor spins clockwise. **OPTION #1** = Channel B leads channel A. **OPTION #2** = Channel A leads channel B.

FEEDBACK SENSOR		
Parameter	**Allowable range**	**Description**
ROTATION CW MOT (A)	OPTION #1, OPTION #2	This parameter defines the sequence by which the motor phases are powered in case of forward direction. **OPTION #1** = U leads W, W leads V. **OPTION #2** = U leads V, V leads W.
ROTATION CW POS **(Not in combination with encoder)** (A)	OPTION #1, OPTION #2	This parameter defines how the controller expects the sin/cos or 3-Hall signals to be when the motor spins clockwise. Sin/cos case: **OPTION #1** = Sin leads cos. **OPTION #2** = Cos leads sin. 3-Hall case: **OPTION #1** = HS1 leads HS2, HS2 leads HS3. **OPTION #2** = HS3 leads HS2, HS2 leads HS1.
FEEDBACK SENSOR (A)	0 ÷ 7	This parameter defines the type of the adopted speed sensor. Factory adjusted. **0** = Incremental encoder. **1** = Sin/cos sensor. **2** = Incremental encoder + sin/cos sensor. **3** = Incremental encoder + sin/cos sensor + index. **4** = PWM absolute sensor + incremental encoder + index. **5** = Resolver. **6** = 3-Hall sensor (six-step). **7** = Unused.
FEEDBACK POLES (A)	1 ÷ 32	This parameter defines the number of poles per revolution of the motor position sensor. To be ignored in combination with encoders. NOTE: with standard HW, the capability to use position sensors with high number of poles could be limited depending on the maximum motor speed. Ask to Zapi technicians for a feasibility check.
ENCODER PULSES 1 **ENCODER PULSES 2** (A)	32 ÷ 1024	These parameters define the number of encoder pulses per revolution. They must be set equal; otherwise, the controller raises an alarm. The available values are: **32, 48, 64, 80, 96, 107, 124, 128, 143, 177, 256, 500, 512, 1000, 1024** NOTE: with standard HW, the capability to use encoders with high number of pulses could be limited depending on the maximum motor speed. Ask to Zapi technicians for a feasibility check.
MOTOR P. PAIRS 1 **MOTOR P. PAIRS 2** (A)	1 ÷ 28	These parameters define the number of pole pairs of the traction motor. They must be set equal; otherwise, the controller raises an alarm.

FEEDBACK SENSOR		
Parameter	**Allowable range**	**Description**
DIAG.JUMP SENSOR (A)	0 Hz ÷ 255 Hz	This parameter defines the maximum jump the speed feedback can perform within a hard-coded time (few tens of millisecond). In case the motor controller detects a jump of the speed feedback greater than this limit value, it raises the alarm SPEED FB.ERR.
FILTER SPEED TAU (A)	0 ms ÷ 255 ms	This parameter defines the time constant of the software-level filter applied to the speed feedback. See parameter FILTER FEEDBACK.
A.SENS.MAX SE **A.SENS.MIN SE** **(Only in combination with sin/cos sensor or resolver)** (A)	0 ÷ 1023	These parameters record the maximum and minimum voltages of the sine analog input acquired during the auto-teaching procedure (paragraph 7.2.1), expressed as 10-bit digital units over the 0 V through 5 V range.
A.SENS.MAX CE **A.SENS.MIN CE** **(Only in combination with sin/cos sensor or resolver)** (A)	0 ÷ 1023	These parameters record the maximum and minimum voltages of the cosine analog input acquired during the auto-teaching procedure (paragraph 7.2.1), expressed as 10-bit digital units over the 0 V through 5 V range.
OFFSET ANGLE **(Not in combination with incremental encoder)** (A)	-180° ÷ 180° (steps of 0.1°)	This parameter gives the possibility to manually adjust the offset angle present between the absolute position sensor and the PMSM rotor orientation.
HYST. ANGLE **(Only in combination with 3-Hall sensors)** (A)	-180° ÷ 180° (steps of 0.1°)	This parameter defines the angular difference in the commutations of the Hall sensors (position feedback) between one sense of rotation and the other. It is automatically set by the auto-teaching procedure (paragraph 7.2.1).
SENSOR ANGLE DEL (A)	0° ÷ 25.5° (steps of 0.1°)	This parameter defines the position delay introduced by the motor position sensor, as the degrees of delay when the motor spins at 50 Hz of electrical frequency.
ANGLE IDRMS COMP **(Only in combination with 3-Hall sensors)** (A)	0° ÷ 25.5° (steps of 0.1°)	Three-Hall sensors may be affected by a disturbance due to the motor d-current, resulting in an undesired deviation of the returned rotor position. This parameter defines the amount of counteracting compensation put in place by the software.
RESOLVER PULSE **(Only in combination with resolver)** (A)	Reserved	Used for special resolvers. Reserved. Note: only Zapi technicians can change this value.

FEEDBACK SENSOR		
Parameter	**Allowable range**	**Description**
ABS.SENS. ACQ.ID (T, P, CO, TM, TS23, G, MCO)	1% ÷ 100%	This parameters defines the amount of current imposed by the motor controller during the acquisition of the signals from the motor position sensor. It is defined as a percentage of the maximum current defined by parameter SET CURRENT.
ANGLE CORRECTION (A)	OFF, ON	This parameter enables the correction of the position feedback, in case a linearization of the position feedback is needed. The correction map is defined by the COR ANGLE FEEDB table.
FILTER FEEDBACK (A)	OFF, ON	This parameter enables a software-level filter applied to the speed feedback. See parameter FILTER SPEED TAU.
KP PLL FEEDBACK **KI PLL FEEDBACK** (A)	0 ÷ 255	These parameters respectively define the proportional and integral gains for a PLL (phase-locked loop) locked to the feedback position of the right-hand side motor.
ABS.SENS.ACQUIRE (A)	OFF, ON	This parameter activates the acquisition of the signals from the motor position sensor. **Contact Zapi technicians for a detailed description of the acquisition procedure.**
COR ANGLE FEEDB. **(Only in combination with sin/cos sensor or resolver)** (A)	Table	This parameter defines the correction table for the position sensor, in case a linearization of the position feedback is needed. The correction map is acquired automatically by the acquisition procedure of the position sensor. The correction is to be enabled by ANGLE CORRECTION.

8.2.9 CURRENT PROFILE

CURRENT PROFILE		
Parameter	**Allowable range**	**Description**
P0 IMAX MOT **P1 IMAX MOT** **P2 IMAX MOT** **P3 IMAX MOT** (T, P, CO, TM, TS23, G, MCO)	0% ÷ 100% (steps of 1%)	These parameters define the motor current values for the four points of the current profile, which the motor controller puts in place during motoring.

CURRENT PROFILE		
Parameter	**Allowable range**	**Description**
P0 FREQ. MOT **P1 FREQ. MOT** **P2 FREQ. MOT** **P3 FREQ. MOT** (T, P, CO, TM, TS23, G, MCO)	0 Hz ÷ 1020 Hz (255 steps)	These parameters define the frequency values for the four points of the current profile, which the motor controller puts in place during motoring.
P0 IMAX BRK **P1 IMAX BRK** **P2 IMAX BRK** **P3 IMAX BRK** (T, P, CO, TM, TS23, G, MCO)	0% ÷ 100% (steps of 1%)	These parameters define the motor current values for the four points of the current profile, which the motor controller puts in place during braking.
P0 FREQ. BRK **P1 FREQ. BRK** **P2 FREQ. BRK** **P3 FREQ. BRK** (T, P, CO, TM, TS23, G, MCO)	0 Hz ÷ 1020 Hz (255 steps)	These parameters define the frequency values for the four points of the current profile, which the motor controller puts in place during braking.
MAX TORQUE REF (T, P, CO, TM, TS23, G, MCO)	0 Nm ÷ 320 Nm (steps of 2 Nm)	This parameter defines the maximum torque the motor can provide given the current profile defined by the above parameters.

8.3 TESTER function

The TESTER function gives real- time feedbacks about the state of the controller, the motor and command devices. It is possible to know the state (active/inactive, on/off) of the digital I/Os, the voltage value of the analog inputs and the state of the main variables used for the motor and hydraulics control.
In the following tables, “Parameter” columns also report between brackets lists of the controller types where each parameter is available.

- **A** All controller types.
- **T** Traction controller (single-motor applications).
- **P** Pump controller.
- **CO** CAN-operated controller.
- **TM** Traction master controller (multi-motor applications).
- **TS1** Traction secondary controller number 1 (multi-motor applications).
- **TS23** Traction secondary controller number 2 and 3 (multi-motor applications).
- **G** Hybrid generation set.
- **MCO** Traction master CAN-operated controller (multi-motor applications).
- **SCO** Traction secondary CAN-operated controller (multi-motor applications).

8.3.1 TESTER – Master microcontroller

The following table lists the master microcontroller data that can be monitored through the TESTER function.

TESTER (Master microcontroller)		
Parameter	**Unit of measure (resolution)**	**Description**
KEY VOLTAGE (A)	Volt (0.1 V)	KEY voltage A3 (A1) value measured in real time.
BATTERY VOLTAGE (A)	Volt (0.1 V)	Battery voltage measured in real time across the DC-bus.
DC BUS CURRENT (A)	Ampere (1 A)	Estimation of the battery current based on the working point.
BATTERY CHARGE (A)	Percentage (1%)	Estimation of the battery charge based on the battery voltage.
MOTOR VOLTAGE (A)	Percentage (1%)	Theoretical phase-to-phase voltage applied to the motor terminals. The actual voltage delivered to the motor may be over-modulated or under-modulated as per MAX VOLTAGE MOT. Ask to Zapi technicians for more details.
FREQUENCY (A)	Hertz (0.1 Hz)	Frequency of the current sine-wave that the inverter is supplying to the motor.
MEASURED SPEED (A)	Hertz (0.1 Hz)	Motor speed measured through the encoder and expressed in the same unit of FREQUENCY (Hz).
MEASURED SPD SLV (TM, MCO)	Hertz (0.1 Hz)	Motor speed from the slave drive and expressed in the same unit of FREQUENCY (Hz).
SLIP VALUE (A)	Hertz (0.01 Hz)	Motor slip, i.e. difference between the current frequency and the motor speed (in Hz).
CURRENT RMS (A)	Ampere (1 A)	Root-mean-square value of the line current supplied to the motor. $Current\ [Arms] = \sqrt{{I_Q}^2 + {I_D}^2}$
CURRENT RMS SLV (TM, MCO)	Ampere (1 A)	Root-mean-square value of the line current supplied to the motor by the slave drive. $Current\ [Arms] = \sqrt{{I_Q}^2 + {I_D}^2}$
IMAX LIM. TRA **IMAX LIM. BRK** (A)	Ampere (1 A)	Instantaneous values of the maximum current the inverter can apply to the motor to satisfy respectively a traction or braking request. The value is evaluated basing on the real-time conditions (inverter temperature, motor temperature, etc.).

TESTER (Master microcontroller)		
Parameter	**Unit of measure (resolution)**	**Description**
ID FILTERED RMS **IQ FILTERED RMS** (A)	Ampere (1 A)	Projections of the current vector respectively on the d- or q-axis, expressed in root-mean-square Ampere.
FLAGS LIMITATION (A)	ON, OFF	Flag for any current limitation being active, for example thermal current cutback, maximum current reached, etc.
MOT.POWER W.x10 (A)	Watt (10 W)	Estimation of the power supplied to the motor.
STATOR FLUX MWB (A)	10^{-3} Weber (0.1 mWb)	Estimation of the motor magnetic flux.
MOTION TORQUE NM (A)	Nm (0.1 Nm)	Estimation of the motor torque.
STEER ANGLE (T, TM, MCO)	Degrees (1°)	Steering angle from the sensor on the steered wheel or the steered axle. When the steering is straight ahead, STEER ANGLE is zero.
INNER WHEEL RED. (TM, MCO)	Percentage (1%)	Speed reduction of the inner wheel with respect to the turn the machine is making.
TEMPERATURE (A)	Celsius degrees (1 °C)	Temperature measured on the inverter power section.
MOTOR TEMPERAT. (A)	Celsius degrees (1 °C)	Motor-windings temperature.
DI3 TILLER SW (T, TM, TS1, G)	OFF/ON	Status of the TILLER/SEAT input A8 (A6).
DI2 QI/PB SW (T, TM, G)	OFF/ON	Status of the quick-inversion/pedal-brake input A17 (A11).
DI0 FW SW **DI0 ENABLE** (T, TM, G)	OFF/ON	Status of the forward-request input A6 (A4).
DI1 BW SW (T, TM, G)	OFF/ON	Status of the backward-request input A7 (A5).
DI6 LOWER (T, TM, G)	OFF/ON	Status of the lowering-request input A11.
DI8 AUX3 (T, TM, G)	OFF/ON	Status of the AUX3 input A14 that enables output EV3.

TESTER (Master microcontroller)		
Parameter	**Unit of measure (resolution)**	**Description**
DI5 AUX1 (T, TM, G)	OFF/ON	Status of the AUX1 input A2 that enables output EV1.
DI7 AUX2 (T, TM, G)	OFF/ON	Status of the AUX2 input A12 that enables output EV2.
DI4 SR/HB (T, TM, G)	OFF/ON	Status of the speed-reduction/hand-brake input A19 (A13).
DI7 SR2 (T, TM, G)	OFF/ON	Status of the digital input A12.
DI9 FW-INCH (T, TM, G)	OFF/ON	Status of the digital input A22.
DI10 BW-INCH (T, TM, G)	OFF/ON	Status of the digital input A23.
DI0 SEAT SW (P)	OFF/ON	Status of the TILLER/SEAT input A8 (A6).
DI9 SPD1 SW (P)	OFF/ON	Status of the 1ST-speed input A22.
DI2 HYDRO SW (P)	OFF/ON	Status of the hydraulic-steering input A17 (A11).
DI0 LFT/E SW (P)	OFF/ON	Status of the lift-request input A6 (A4).
DI1 LOWER SW (P)	OFF/ON	Status of the lowering-request input A7 (A5).
DI10 SPD2 SW (P)	OFF/ON	Status of the 2ND-speed input A23.
DI6 FREE (P)	OFF/ON	Status of the free input A11.
DI5 SPD3 SW (P)	OFF/ON	Status of the 3RD-speed input A2.
DI7 SPD4 SW **(P)**	OFF/ON	Status of the 4TH-speed input A12.
DI8 SPD5 SW (P)	OFF/ON	Status of the 5TH speed input A14.

TESTER (Master microcontroller)		
Parameter	**Unit of measure (resolution)**	**Description**
DI4 CUTBAC1 (P)	OFF/ON	Status of the speed-reduction input A19 (A13).
NODE ID (CO, MCO, SCO)	Number (1)	Node ID of the controller on the CAN bus network.
STO IN1 (CO)	OFF/ON	Status of the NO safe-torque-off input A12.
STO IN2 (CO)	OFF/ON	Status of the NC safe-torque-off input A14.
SS1 IN1 (CO)	OFF/ON	Status of the NO safe-stop input A22.
SS1 IN2 (CO)	OFF/ON	Status of the NC safe-stop input A23.
RESET SS1-STO AL (CO)	OFF/ON	Status of the SS1-STO alarm reset input A6.
TARGET SPEED (CO, MCO)	Hertz (0.1 Hz)	Speed set-point transmitted over CAN bus. It is expressed in tenths of Hz.
BRAKING REQUEST (CO, MCO)	Number (1)	Braking set-point transmitted over CAN bus.
CONTROL WORD (CO, G, MCO, SCO)	Number (1)	Control word transmitted over CAN bus.
CONTROL WORD 2 (CO, MCO)	Number (1)	Control word transmitted over CAN bus.
STATUS WORD (CO, G, MCO, SCO)	Number (1)	Status word travelling over CAN bus.
WARNING SYSTEM (CO, G, MCO, SCO)	Number (1)	Warning code (in case of warning).
TARGET EVP1 (CO, MCO, SCO)	% (1%)	Set-point of the proportional electrovalve EVP1 transmitted over CAN bus.
TORQUE REQ. (CO, MCO)	% (255 steps)	Torque set-point of the AC motor transmitted over CAN bus, expressed as percentage of the maximum torque.
TORQUE BRK REQ. (CO, MCO)	% (255 steps)	Breaking torque set-point of the AC motor transmitted over CAN bus, expressed as percentage of the maximum torque.

TESTER (Master microcontroller)		
Parameter	**Unit of measure (resolution)**	**Description**
POT#1 (A)	Volt (0.01 V)	Voltage of the analog input 1 A5 (A3).
POT#2 (A)	Volt (0.01 V)	Voltage of the analog input 2 A16 (A10).
POT#3 (A)	Volt (0.01 V)	Voltage of the analog signal on A1.
POT#4 (A)	Volt (0.01 V)	Voltage of the analog signal on A13.
SIN FB. INPUT **COS FB. INPUT** **(Only in combination with sin/cos sensor or resolver)** (A)	Number (1)	Voltage of sine signal on A1. Voltage of cosine signal on A13. Expressed as integer values, from 0 to 1024 over the 0 V to 5 V range at the microcontroller input. Note: the hardware configuration may feature a voltage divider at the inputs, in that case the readouts will be affected by such partition.
SET EVP (A)	% (1%)	Set-point of proportional electrovalve EVP.
OUTPUT EV1 **OUTPUT EV2** **OUTPUT EV3** **OUTPUT EV4** (A)	OFF/ON	Status of the EV1 output A24. Status of the EV2 output A25. Status of the EV3 output A34. Status of the EV4 output A35.
MAIN CONT. (A)	% (1%)	Voltage applied over the main contactor coil. It corresponds to the duty cycle value of PWM applied, expressed as percentage.
ELEC.BRAKE (A)	% (1%)	Voltage applied over the electromechanical brake coil. It corresponds to the duty cycle value of PWM applied, expressed as percentage.
BYTE 4 PDO1TX **BYTE 5 PDO1TX** **BYTE 6 PDO1TX** **BYTE 7 PDO1TX** (CO, MCO)	Number (1)	Bytes 4 through 7 of the PDO1 message transmitted over CAN bus.
BYTE 2 PDO2TX **BYTE 5 PDO2TX** **WORD 6 PDO2TX** (CO, MCO)	Number (1)	Bytes 2 and 5, bytes 6 and 7 of the PDO2 message transmitted over CAN bus.

TESTER (Master microcontroller)		
Parameter	**Unit of measure (resolution)**	**Description**
CTRAP HW (A)	Number (1)	Counter showing the number of occurrences of hardware-overcurrent detection.
CTRAP THRESOLD (A)	Volt (0.01 V)	Threshold voltage of the overcurrent detection circuit.
TRUCK SPEED (T, CO, TM, MCO)	km/h (0.1 km/h)	Speed of the truck (it requires custom software embedding gear ratio and wheels radius).
ODOMETER KM (T, CO, TM, MCO)	km (1 km)	Odometer: overall distance traveled by the truck.
CPU TIME F US **CPU TIME M US** (A)	Number (1)	Reserved Zapi internal use.
RESOLVER PULSE **(Only in combination with resolver)** (A)		Used for special resolvers. Reserved for Zapi technicians use.
SIXSTEP STATE **(Only in combination with 3-Hall sensors)** (A)	Number (1)	Used for six step sensors. Status of the three hall-sensors coded as three binary digits.
PERFORMANCE (T, P, TM)	Number (1)	Performance level: **0** = Economy **1** = Normal **2** = Power

8.3.2 TESTER – Supervisor microcontroller

The following table lists the supervisor microcontroller data that can be monitored through the TESTER function.

TESTER (Supervisor microcontroller)		
Parameter	**Unit of measure (resolution)**	**Description**
MEASURED SPEED (A)	Hertz (0.1 Hz)	Motor speed measured through the encoder and expressed in the same unit of FREQUENCY (Hz).
DI0 (A)	OFF/ON	Status of the digital input on pin A6 (A4).
DI1 (A)	OFF/ON	Status of the digital input on pin A7 (A5).

TESTER (Supervisor microcontroller)		
Parameter	**Unit of measure (resolution)**	**Description**
DI2 (A)	OFF/ON	Status of the digital input on pin A17 (A11).
DI3 (A)	OFF/ON	Status of the digital input on pin A8 (A6).
DI4 (A)	OFF/ON	Status of the digital input on pin A19 (A13).
DI5 (A)	OFF/ON	Status of the digital input on pin A2.
DI6 (A)	OFF/ON	Status of the digital input on pin A11.
DI7 (A)	OFF/ON	Status of the digital input on pin A12.
DI8 (A)	OFF/ON	Status of the digital input on pin A14.
DI9 (A)	OFF/ON	Status of the digital input on pin A22.
DI10 (A)	OFF/ON	Status of the digital input on pin A23.
POT#1 (A)	Volt (0.01 V)	Voltage of the analog signal on pin A5 (A3).
POT#2 (A)	Volt (0.01 V)	Voltage of the analog signal on pin A16 (A10).
POT#3 (A)	Volt (0.01 V)	Voltage of the analog signal on pin A1.
POT#4 (A)	Volt (0.01 V)	Voltage of the analog signal on pin A13.
WARNING SYSTEM (CO, MCO)	Number (1)	Warning code (in case of warning).
SIN FB. INPUT **COS FB. INPUT** **(Only in combination with sin/cos sensor or resolver)** (A)	Number (1)	Voltage of sine signal on A1. Voltage of cosine signal on A13. Expressed as integer values, from 0 to 1024 over the 0 V to 5 V range at the microcontroller input. Note: the hardware configuration may feature a voltage divider at the inputs, in that case the readouts will be affected by such partition.

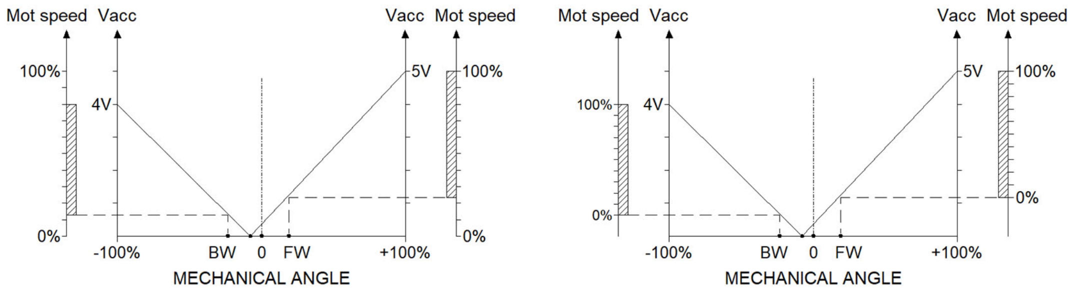
TESTER (Supervisor microcontroller)		
Parameter	**Unit of measure (resolution)**	**Description**
SIXSTEP STATE **(Only in combination with 3-Hall sensors)** (A)	Number (1)	Used for six step sensors. Status of the three hall-sensors coded as three binary digits.
PERFORMANCE (A)	Number (1)	Performance level: **0** = Economy **1** = Normal **2** = Power

9 OTHER FUNCTIONS

9.1 PROGRAM VACC function

This function enables the adjustment of the minimum and maximum useful levels of the voltage from the accelerator potentiometer, in both directions. This function is particularly useful when it is necessary to compensate for asymmetry of mechanical elements associated with the potentiometer, especially relating to the minimum level.

The following two graphs show the output voltage of a potentiometer versus the mechanical angle of the control lever. Angles ‘BW’ and ‘FW’ indicate the points where the direction switches close, while 0 represents the mechanical zero of the lever, i.e. its rest position. In addition, the relationship between motor speed (as a percentage of TOP MAX SPEED) and the potentiometer voltage (Vacc) are shown. Before calibration, the speed percentage maps over the default 0 V – 5 V range; instead, after the adjustment procedure it results mapped over the useful voltage ranges of the potentiometer, for both the travel directions.



PROGRAM VACC procedure can be carried out through Zapi PC CAN Console or through Zapi Smart Console. For the step-by-step procedures of the two cases, refer to paragraphs 13.1.5 or 13.2.7.

9.2 PROGRAM LIFT / LOWER function

This function allows to adjust the minimum and maximum useful signal levels of lift and lowering request. This function is useful when it is necessary to compensate for asymmetry of the mechanical elements associated with the potentiometer, especially relating to the minimum level.

This function looks for and records the minimum and maximum potentiometer wiper voltage over the full mechanical range of the lever.

The values to be acquired are organized in the ADJUSTEMNT list, they are:

- MIN LOWER
- MAX LOWER

See paragraphs 13.1.6 or 13.2.8. for the acquisition procedure.

9.3 PROGRAM STEER function

This enables the adjustment of the minimum and maximum useful signal levels of the steering control. This function is useful when it is necessary to compensate for asymmetry with the mechanical elements associated with the steering.

This function looks for and records the minimum, neutral and maximum voltage over the full mechanical range of the steering. It allows to compensate for dissymmetry of the mechanical system in both directions.

The values to be acquired are organized in the ADJUSTEMNT list, they are:

- STEER RIGHT VOLT
- STEER LEFT VOLT
- STEER ZERO VOLT

See paragraphs 13.1.7 or 13.2.9 for the acquisition procedure.

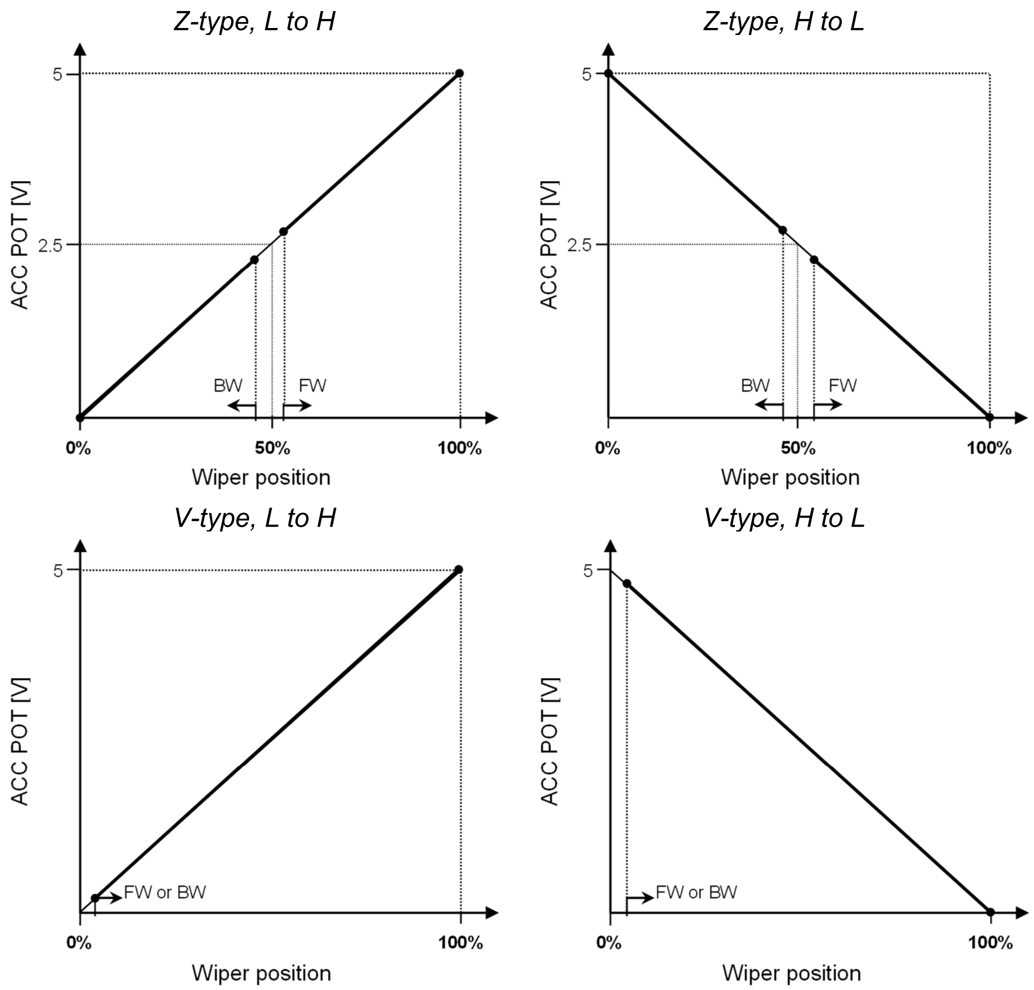
9.4 Potentiometers

The controller can handle different types of potentiometers and, where present, direction and enable switches. Parameters MAIN POT. TYPE and AUX POT. TYPE are to be set accordingly to the configuration of the machine (see paragraph 8.2.2).

The following graphs describe how the mechanical position of the potentiometer wiper and its voltage result in the forward and backward requests. Basing on the application, the voltage excursion may differ from the 0 V through 5 V range shown here.

Adopting a Z-type potentiometer, both the speed setpoint and the travel direction are defined by the potentiometer itself; direction switches are not mandatory.

Adopting a V-type potentiometer, only the speed set-point is defined by the potentiometer; a couple of direction switches are mandatory, except where the application only requires one direction of rotation (for example only lift in pump applications).



Potentiometer configurations.

9.5 Acceleration modulation

Parameters ACCELER. DELAY and ACC. MIN MODUL. allow to define the acceleration rate depending on the speed set-point increase. The feature can be enabled or disabled by parameter ACCEL MODULATION.

– **ACCEL MODULATION = OFF**
  The acceleration time results:

$$\text{ACCELER. DELAY} \cdot \frac{\text{Setpoint step}}{100\text{ Hz}}$$

– **ACCEL MODULATION = ON**
  The acceleration time is evaluated differently by software depending on the extent of the set-point increase.

  <u>Fast response:</u>

  Set-point step < 100 Hz · ACC. MIN MODUL.

  The acceleration time results:

$$\text{ACCELER. DELAY} \cdot \frac{\text{Setpoint step}}{100\text{ Hz} \cdot \text{ACC. MIN MODUL.}}$$

Modulation (grey area):

Set-point step ≥ 100 Hz · ACC. MIN MODUL.
and
Set-point step ≤ 100 Hz

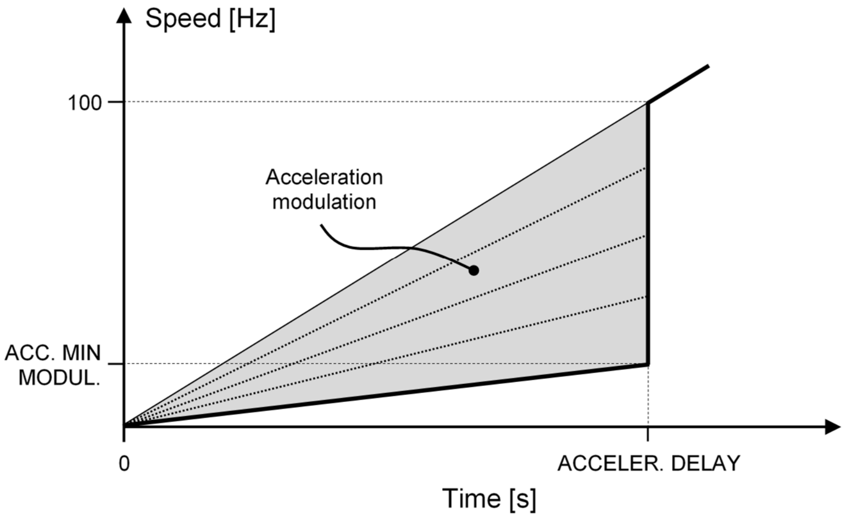
The acceleration rate is re-scaled so that the acceleration time results equal to ACCELER. DELAY.

Wide variation:

Set-point step > 100 Hz

The acceleration time results:

$$\text{ACCELER. DELAY} \cdot \frac{\text{Setpoint step}}{100\ \text{Hz}}$$



Speed evolution during accelerations to positive speeds. The vertical axis represents the speed offset with respect to the starting speed.

9.6 Deceleration modulation

Parameters DECEL. BRAKING and ACC. MIN MODUL. allow to define the deceleration rate depending on the speed set-point variation. The feature can be enabled or disabled by parameter ACCEL MODULATION.

– **ACCEL MODULATION = OFF**
  The deceleration time results:

$$\text{DECEL. BRAKING} \cdot \frac{\text{Setpoint step}}{100\ \text{Hz}}$$

– **ACCEL MODULATION = ON**
  The deceleration time is evaluated differently by software depending on the extent of the set-point variation.

Fast response:

Set-point drop < 100 Hz · ACC. MIN MODUL.

The deceleration time results:

$$\text{DECEL. BRAKING} \cdot \frac{\text{Setpoint drop}}{100\ \text{Hz} \cdot \text{ACC. MIN MODUL.}}$$

Modulation (grey area):

Set-point drop ≥ 100 Hz · ACC. MIN MODUL.
and
Set-point drop ≤ 100 Hz

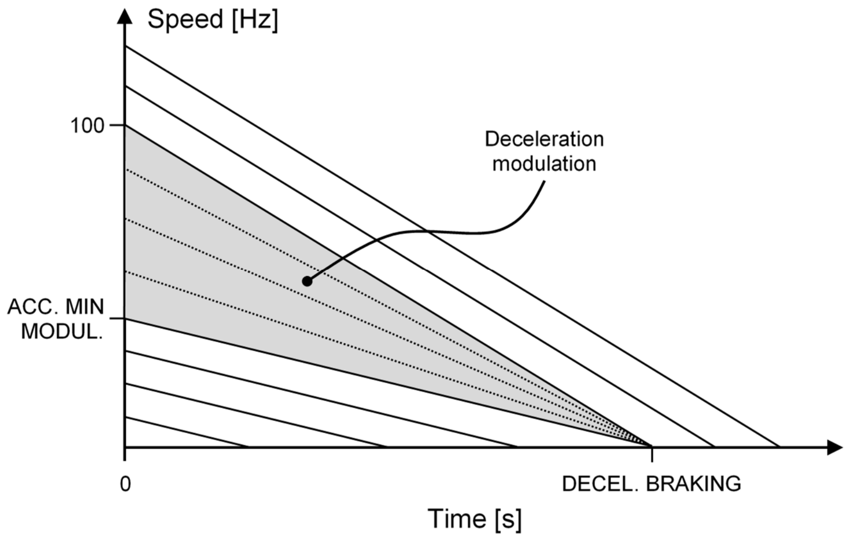
The deceleration rate is re-scaled so that the deceleration time results equal to DECEL. BRAKING.

Wide variation:

Set-point drop > 100 Hz

The deceleration time results:

$$\text{DECEL. BRAKING} \cdot \frac{\text{Setpoint drop}}{100\ \text{Hz}}$$



Speed evolution during decelerations from positive speeds. The vertical axis represents the speed offset with respect to the target speed of the deceleration.

The deceleration modulation is valid for all the deceleration-time parameters: DECEL. BRAKING, INVER. BRAKING, REL BRK IN CTB, SPEED LIMIT BRK, STEER BRAKING.

9.7 Release modulation

Parameters RELEASE BRAKING and REL. MIN MODUL. allow to define the stopping rate depending on the speed set-point variation upon a travel release. The stopping time is evaluated differently by software depending on the extent of the speed variation.

Fast response:

Set-point drop < 100 Hz · REL. MIN MODUL.

The stopping time results:

$$\text{RELEASE BRAKING} \cdot \frac{\text{Setpoint step}}{100\ \text{Hz} \cdot \text{REL. MIN MODUL.}}$$

Modulation (grey area):

Set-point drop ≥ 100 Hz · REL. MIN MODUL.
and
Set-point drop ≤ 100 Hz

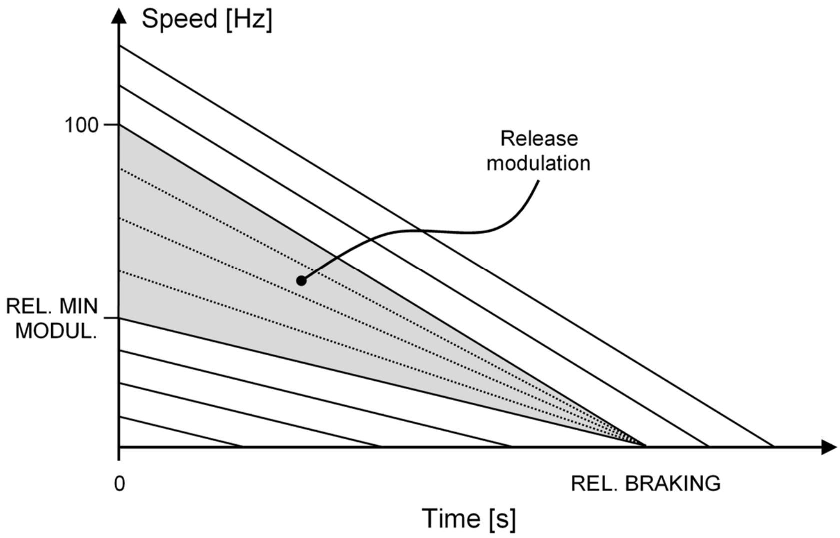
The stopping rate is re-scaled so that the stopping time results equal to RELEASE BRAKING.

Wide variation:

Set-point drop > 100 Hz

The stopping time results:

$$\text{RELEASE BRAKING} \cdot \frac{\text{Setpoint step}}{100\ \text{Hz}}$$

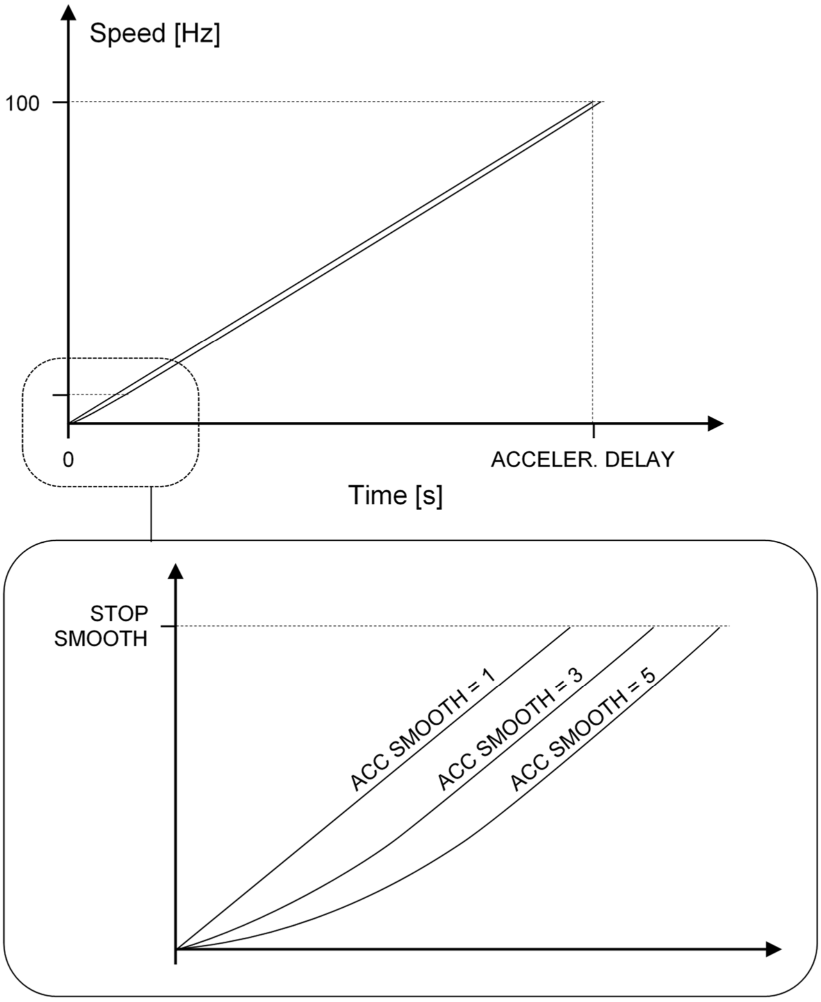


Speed evolution during releases from positive speeds down to stationary.

The release modulation is valid for all the stopping-time parameters: RELEASE BRAKING, TILLER BRAKING, PEDAL BRAKING.

9.8 Acceleration smoothness

Smoothing-related parameters define a parabolic profile for the acceleration or deceleration ramps close to 0 Hz. Values from 1 to 5 define the smoothness effect, without a phisycal meaning: 1 results in a linear ramp, higher values result in smoother acceleration profiles.



Acceleration smoothness.

The smoothing effect is applied to acceleration, braking and inversion as per the settings of parameters ACC SMOOTH, BRK SMOOTH and INV SMOOTH.

The reference speed for the parabolic profile is given by parameters STOP SMOOTH and STOP BRK SMOOTH.

9.9 Steering curve

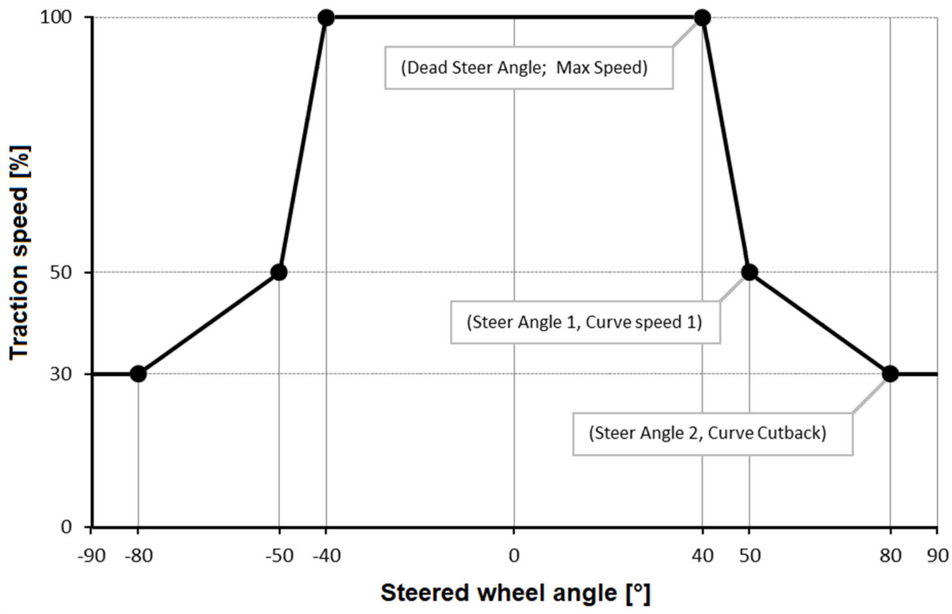
Steering-related parameters (CURVE SPEED 1, CURVE CUTBACK, STEER DEAD ANGLE, STEER ANGLE 1 and STEER ANGLE 2) define a speed-reduction profile dependent on the steering-wheel angle.

The profile is valid both for positive and negative angle values.

Example:

- Three-wheel counterbalanced truck
- Steered wheel excursion = -90° ÷ 90°
- CURVE SPEED 1 = 50%
- CURVE CUTBACK = 30%
- STEER DEAD ANGLE = 40°
- STEER ANGLE 1 = 50°
- STEER ANGLE 2 = 80°

This set of parameters defines the speed profile depicted in the graph below.



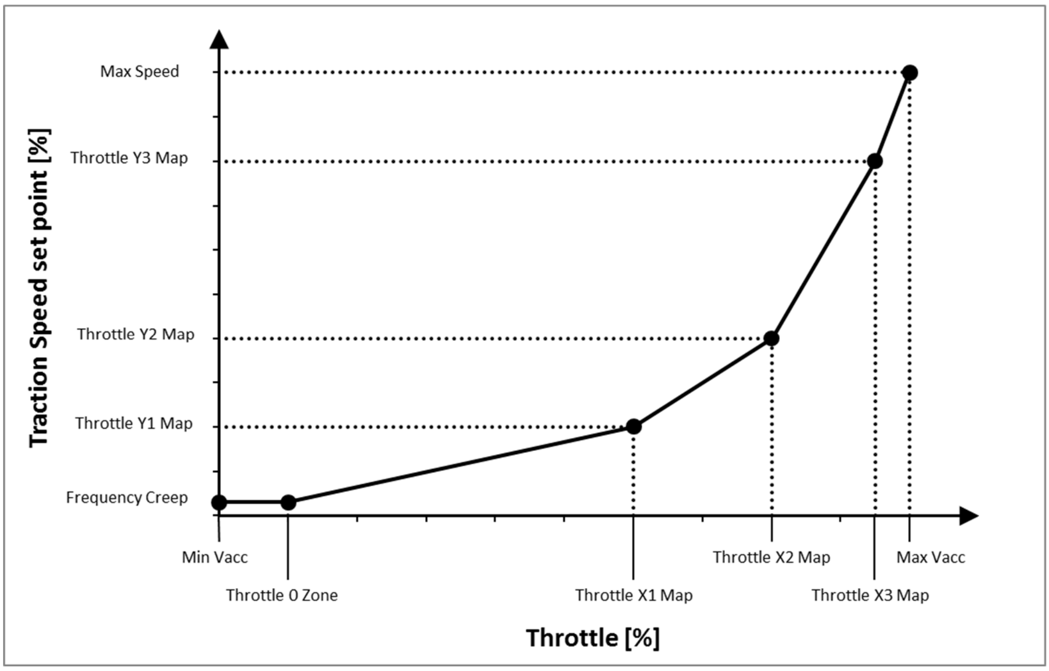
Steering curve.

9.10 Throttle profile

The controller performs the speed control along a non-linear function of the accelerator position, so to provide a better resolution of the speed set-point at low speed. The relationship between the throttle voltage and the speed set-point is defined as a polygonal chain, as per the following table of points.

Throttle signal [% of MAX VACC]	**Speed set-point** [% of TOP MAX SPEED]
0	FREQUENCY CREEP
THROTTLE 0 ZONE	FREQUENCY CREEP
THROTTLE X1 MAP	THROTTLE Y1 MAP
THROTTLE X2 MAP	THROTTLE Y2 MAP
THROTTLE X3 MAP	THROTTLE Y3 MAP
MAX VACC	MAX SPEED FORW MAX SPEED BACK

The speed remains at the FREQUENCY CREEP value as long as the voltage from the accelerator potentiometer is below THROTTLE 0 ZONE. Basically this defines a dead zone close to the neutral position. For higher potentiometer voltages, the speed set-point grows up as a polygonal chain. The following graph better displays the throttle – speed relationship.



Throttle profile.

9.11 MC and EB modulation

The outputs dedicated to drive the main contactor and the electromechanical brake are PWM-modulated in an open loop fashion (voltage controlled).

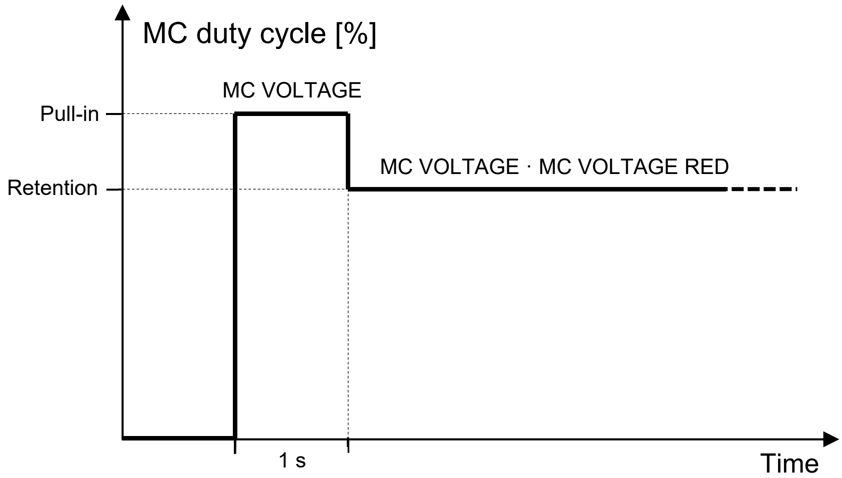
For both the outputs, dedicated parameters (under SET OPTIONS list) define the pull-in duty-cycle and the retention one, the first applied in the first second of actuation, the latter afterwards. The following table summarizes how parameters effect such duty-cycles.

	Pull-in	Retention
MC Duty-cycle [%]	MC VOLTAGE	MC VOLTAGE · MC VOLTAGE RED.
EB Duty-cycle [%]	EB VOLTAGE	EB VOLTAGE · EB VOLTAGE RED.

Example 1:
MC VOLTAGE = 100% ➲ Pull-in duty-cycle = 100%
MC VOLTAGE RED. = 80% ➲ Retention duty-cycle = 80% (100% x 80%).

Example 2:
MC VOLTAGE = 80% ➲ Pull-in duty-cycle = 80%
MC VOLTAGE RED. = 100% ➲ Retention duty-cycle = 80% (80% x 100%).

Example 3:
MC VOLTAGE = 80% ➲ Pull-in duty-cycle = 80%
MC VOLTAGE RED. = 80% ➲ Retention duty-cycle = 64% (80% x 80%).



Main contactor output behavior.

9.12 Battery-charge estimation

During the operating conditions, the battery-charge estimation algorithm makes use of the following parameters.

BAT. MIN ADJ.	Discharged-battery voltage (at state-of-charge = 10%), as the percentage deviation with respect to the nominal voltage.
BAT. MAX ADJ.	Full-battery voltage (at state-of-charge = 100%), as the percentage deviation with respect to the nominal voltage.
BDI ADJ STARTUP	Full-battery voltage (at state-of-charge = 100%) at startup, as the percentage deviation with respect to the nominal voltage. By default, it can be set equal to BAT. MAX ADJ.
BDI RESET	Minimum variation of the battery discharge table needed to update the battery charge estimation at start-up.

Example:

- Nominal voltage: 80 V
- Discharged-battery voltage (SOC = 10%): 72 V
- Full-charge voltage: 87 V
- ➲ BAT. MIN ADJ. = (72 - 80) / 80 = -10%
- ➲ BAT. MAX ADJ = (87 - 80) / 80 = +8.8%

As a hint, if the battery-discharge detection occurs when the battery is not totally discharged, it is necessary to reduce BAT. MIN ADJ.

The battery-charge detection works as follows.

<u>Start-up</u>

1. The battery voltage is read from the key input when the battery current is zero, which is when the output power stage is not driven. It is evaluated as the average value over a window of time.
2. The measured voltage is compared with a threshold value that comes as a function of the actual state of charge and of parameter BDI ADJ STARTUP. By the comparison, a new state of charge is obtained.

3. If the new charge percentage is within the range given by the previous percentage (the last value stored in EEPROM) ± BDI RESET, it is discarded; otherwise the charge percentage is updated by the new value.

Operating condition

The measure of the battery voltage, together with the state of charge at the time of the voltage sampling, gives information about the instantaneous battery current.

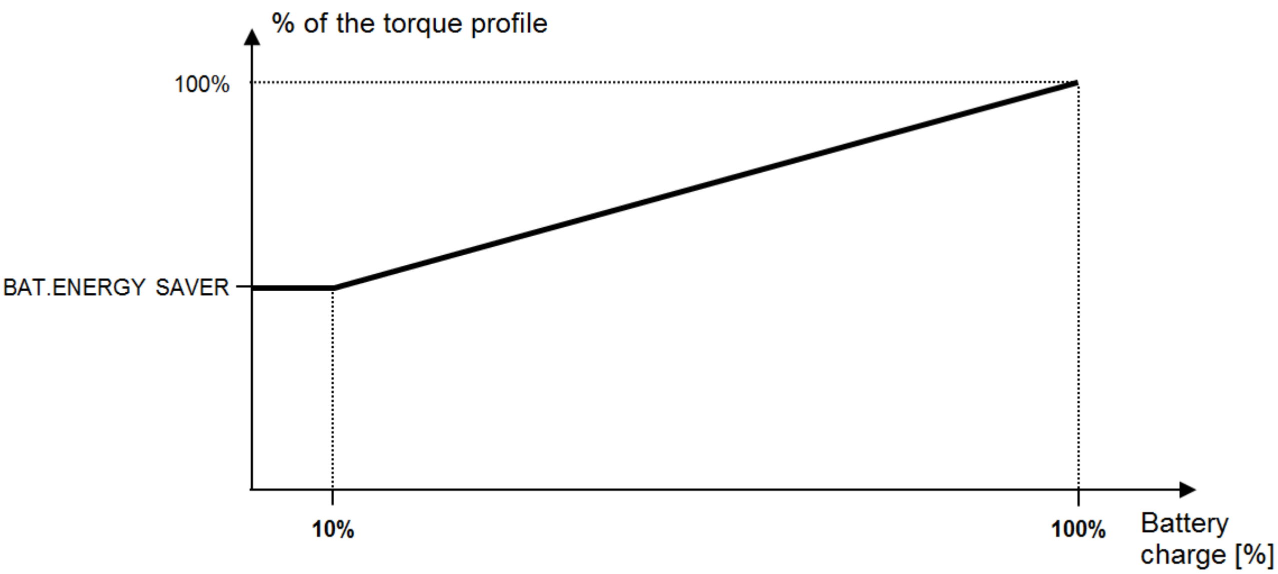
1. The battery voltage is measured when the battery current is not zero, which is when the output power stage is driven. It is evaluated as the average value over a window of time.
2. The measured voltage is compared with a threshold value which comes as a function of the actual state of charge. By the comparison, the current drawn from the battery gets estimated.
3. The current estimation is integrated over time, thus estimating the energy withdrawn from the battery, in Ah.
4. The state of charge is dynamically updated basing on the energy estimation from step 3.

9.13 Saving of the battery

The controller can reduce the battery discharge through a reduction of the output torque profile depending on the charge level.

The battery saving function can be tuned by means of the parameter BAT.ENERGY SAVER under the ADJUSTMENTS list. It represents the percentage of the output torque profile applied when the battery charge falls below 10%.

A linear reduction of the torque profile is performed scaling it down by a percentage from 100% down to BAT.ENERGY SAVER for charge values from 100% down to 10%, as depicted in the graph below. If the saving feature is not desired, BAT.ENERGY SAVER should be set equal to 100%.



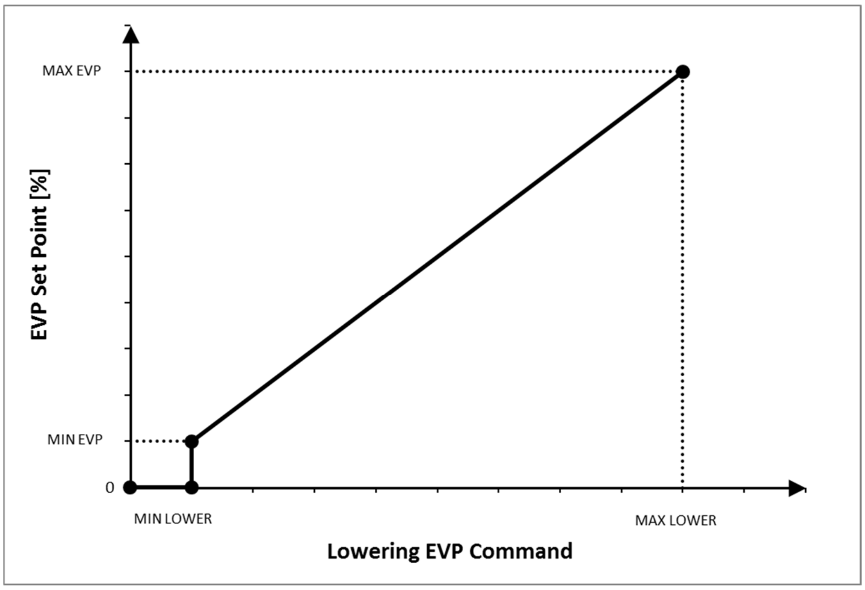
Torque reduction vs. battery charge.

9.14 EVP Setup

When EVP TYPE = ANALOG, the output is managed as explained in the following example.

Considering the case in that the EVP request is concerning the lowering valve, the MIN EVP parameter determines the minimum current set point applied to the valve when the position of the potentiometer is at its minimum (value recorded as MIN LOWER under ADJUSTMENTS).

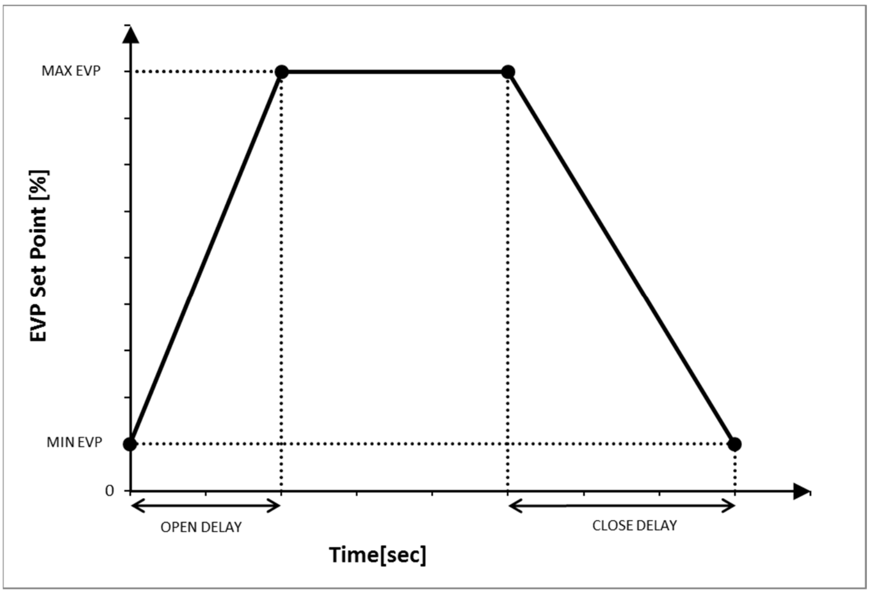
Then, the current set point applied to the valve increases proportionally with the potentiometer voltage up to the maximum defined by MAX EVP, reached when the position of the potentiometer is at its maximum (value recorded as MAX LOWER under ADJUSTMENTS)



EVP management.

If EVP TYPE = DIGITAL, parameter MIN EVP is discarded and the current set point for the valve in on state is defined by MAX EVP.

The dynamic delay seen during the modification of the current set point, in both cases, analog and ON/OFF valve, is dependent by parameters OPEN DELAY and CLOSE DELAY under PARAMETER CHANGE, which define the time needed to increase or decrease the current to and from the maximum.



EVP set point.

Example 1:
EVP TYPE = ANALOG and the descent request consists of a step whose width corresponds to MAX EVP.
The current is immediately set to the MIN EVP and then it is increased up to MAX EVP in the time set by the OPEN DELAY parameter.
In the same way, if the actual set point applied is the maximum and the lowering request is removed all at once, the current is reduced to minimum with a time delay equal to CLOSE DELAY and then is set to zero.

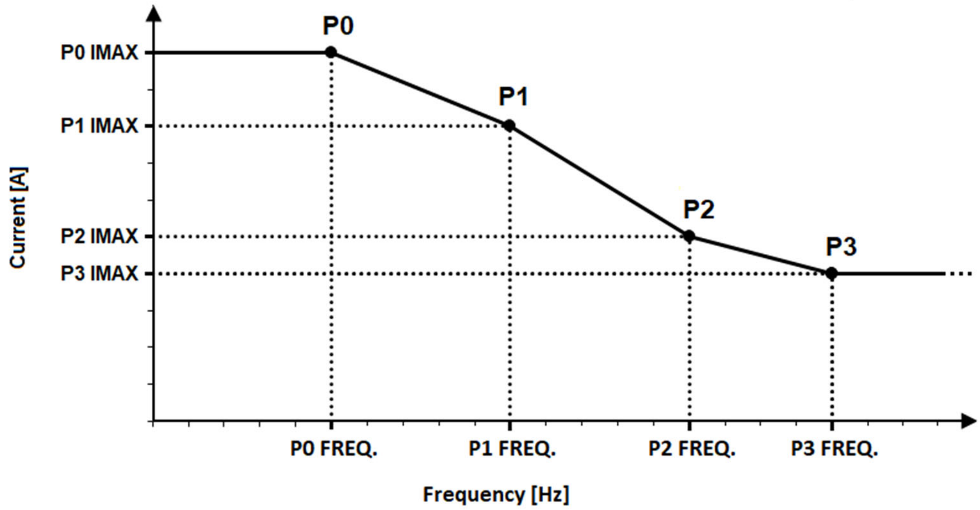
Example 2:
EVP TYPE = DIGITAL.
As soon as the lowering request is applied, the current will increase from zero to MAX EVP in the period correspondent to OPEN DELAY.
In the same way, when the lowering request is removed, the set point current is reduced down to zero in a period equal to CLOSE DELAY.

9.15 Current profile

By setting the proper parameters, it is possible to define a limit for the maximum current demand in the weakening area, for matching two goals:

- Not overtaking the maximum torque profile of the motor.
- Superimposing a limiting profile to the maximum current as to get different drive performances (economy, normal, power).

Under the CURRENT PROFILE list, two maps of four frequency-current points define two different current profiles, for motoring and braking respectively. Points P0 through P3 are expected to describe a descending profile, otherwise alarm CURRENT PROFILE is given.



Generic current profile.

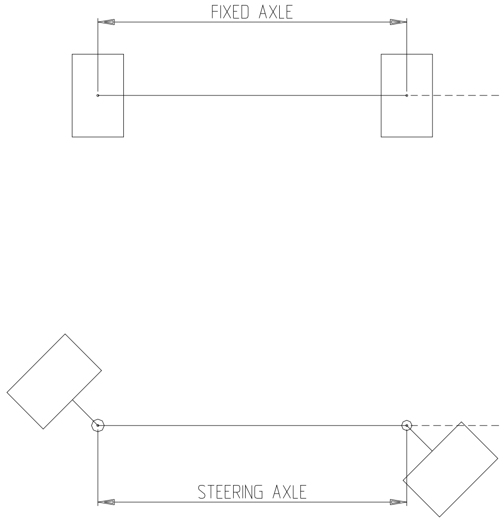
9.16 Steering table

Steering table allows to automatically calibrate the rotation applied to the steering wheels so to obtain the desired steering angle of the truck.

The STEER TABLE parameter defines whether to adopt a custom or predefined steering table:

- **NONE** = custom steering table, according to the following parameters:
  - WHEELBASE MM: distance between the front axle and the rear axle of the truck.
  - FIXED AXLE MM: center-to-center distance between the wheels on the fixed axle.
  - STEERING AXLE MM: distance between the two pivot points of the steered wheels; to be set zero for three-wheeler.

  All three previous parameters must be expressed in millimeters.
- **OPTION #1** = three-wheel predefined steering table.
- **OPTION #2** = four-wheel predefined steering table



Geometrical steering-related parameters.

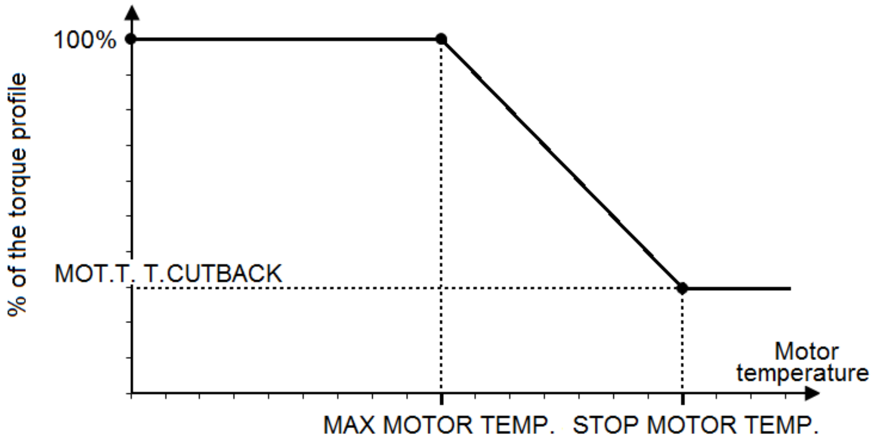
9.17 Motor thermal protection

The controller performs a thermal protection of the driven motor by monitoring its temperature and applying a linear cutback to the maximum current when it becomes excessive.

Thermal protection can be tuned setting parameters MAX. MOTOR TEMP., STOP MOTOR TEMP. and MOT.T. T.CUTBACK in the ADJUSTMENTS list.

A linear reduction is performed for temperatures between MAX. MOTOR TEMP. and STOP MOTOR TEMP. . It acts scaling down the torque profile (see paragraph 9.15) by a percentage from 100% to MOT.T. T.CUTBACK.

When motor temperature reaches STOP MOTOR TEMP., current cutback is fixed to the percentage set in parameter MOT.T. T.CUTBACK.



Torque reduction for motor thermal protection.

Cutback is valid only during motoring, instead during braking the 100% of the maximum current is always available regardless the motor temperature.

If the signal from the motor thermal sensor is out of range (for example due to a problem related to the wiring), a cutback equal to parameter MOT.T. T.CUTBACK is applied.

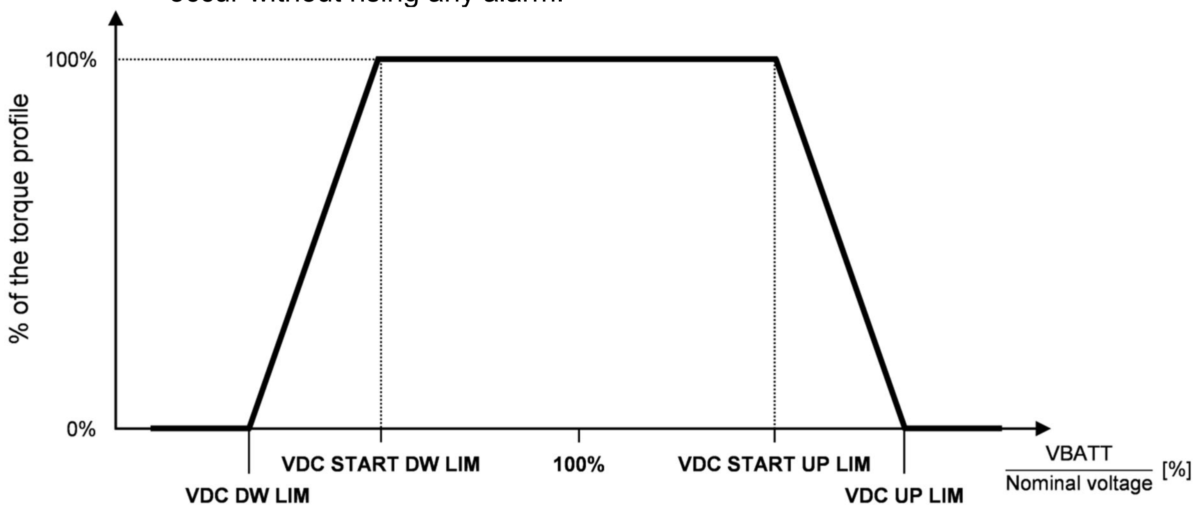
9.18 Overvoltage and under-voltage protection

The controller performs overvoltage and under-voltage protection by monitoring the DC-link voltage and reducing the torque profile when the voltage becomes too high or too low.

Overvoltage and under-voltage limitations can be tuned by setting parameters VDC START UP LIM, VDC UP LIM, VDC START DW LIM and VDC DW LIM in the SPECIAL ADJUSTMENTS list. These parameters represent a percentage of the nominal battery voltage.

A linear reduction of the torque profile is performed scaling it down by a percentage from 100% to 0% depending on the sensed voltage, as depicted in the graph below. Outside the limits defined by VDC UP LIM and VDC DW LIM the torque profile is clamped to zero. Normal operation at full torque profile is automatically restored as soon as the voltage goes back into the range defined by VDC START DW LIM and VDC START UP LIM.

Overvoltage and under-voltage limitations are transparent to the user and they can occur without rising any alarm.



Reduction of the torque profile based on the battery voltage.

9.19 Performance modes

The controller features two performance modes in addition to the normal one.

- Economy
- Power

To enable the selection of such modes, set PERFORMANCE = ON under SET OPTIONS. Parameters under PERFORM. ECONOMY and PERFORM. POWER lists define the economy and power modes settings (see paragraph 8.2.7); they are visible only if PERFORMANCE = ON. Their meanings are the same of the homologous normal parameters; the “E” or “P” suffix helps to discriminate the relative mode.

The controller puts in place either of the two performance modes by the configuration coming from an external display or another master unit on the CAN bus network.

10 DIAGNOSTIC SYSTEM

The diagnostic system of ACE4 provides the operator with information about a wide set of faults or problem that the controller can encounter.

Faults that can be related to hardware failures that forbid to run the motor or safety-related failures are managed by stopping the power bridge and, when possible, opening the main contactor and applying the electromechanical brake.

Instead, when less serious issues occur, which do not require stopping the power section, still allowing driving the motor, the controller keeps controlling the motor. Depending on the nature of the issue, preventive actions are put in place like stopping the machine or reducing the performance.

Paragraphs 10.3 and 10.4 provide comprehensive information about all the alarms from both master and supervisor microcontrollers.

10.1 ALARMS menu

The alarms logbook can be used to revise the history of past-occurred alarms. It has a FIFO (First Input First Output) structure, meaning that the oldest alarm is lost when the database is full and a new alarm is recorded. The following pieces of information are shown.

- The alarm code.
- The number of times the alarm has consecutively occurred.
- The hour-meter value at the last occurrence of the alarm.
- The inverter temperature at the first occurrence of the alarm.

If the same alarm happens consecutively for a number of times, the controller does not create a new logbook record each time; instead, it updates the relative record, increasing the occurrences counter and updating the hour-meter field.

10.2 LED

For simple visual diagnosis of system faults and to monitor the system status, a red LED is visible through a dedicated window on the controller lid.

Alarm LED on the controller lid.

At start-up the LED is turned ON for 2 seconds and then it stays continuously OFF as long as there is no fault.

In case of fault it flashes; the flashing pattern encodes the active faults in a repeating cycle. Each code consists of two decimal digits shown through the following sequence:

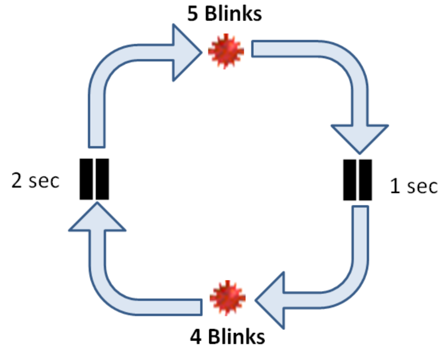
1. It blinks as many times as the first decimal digit.
2. It makes a pause of 1 sec.
3. It blinks as much times as the second decimal digit.

After a pause of 2 seconds, the sequence repeats.

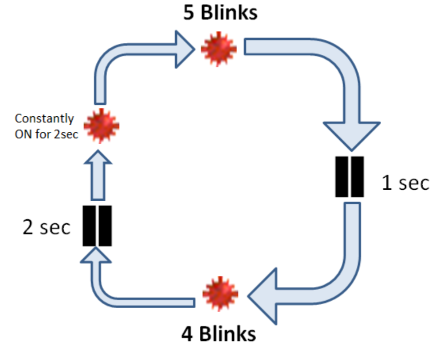
In case of faults from the supervisor microcontroller, the sequence is the same with the only difference that the LED stays ON for 2 sec before flashing the appropriate code.

Examples:

– Alarm 54 on master microcontroller



– Alarm 54 on supervisor microcontroller



10.3 Alarms from master microcontroller

Error code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN CODE	ZAPI CODE
WAITING FOR NODE	MC is opened, EB is applied, Traction/Pump stopped	Start-up, stand-by, running	Key re-cycle	0	0	224
BATTERY LOW	According to parameter BATTERY CHECK (SET OPTIONS list).	Start-up, standby, running	Battery recharge, key re-cycle	0	FF42	66
DATA ACQUISITION	Traction is stopped	Controller calibration	Traction request	0	0	247
CHECK UP NEEDED		Start-up	Check-up done, key re-cycle	0	0	249
RPM HIGH	MC is opened, Traction/Pump stopped	Start-up, standby, running		0	FFA1	161
WRONG PERFORM.	Traction is disabled	Start-up, standby, running	Traction request	0	FF95	149
WARNING SLAVE	It depends on the supervisor microcontroller			1	FF01	244
ACQUIRING A.S.		Sensor Acquiring	Key re-cycle	2	FFAB	171
ACQUIRE END		Sensor Acquiring	Key re-cycle	2	FFAD	173

Error code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN CODE	ZAPI CODE
ACQUIRE ABORT		Sensor Acquiring	Key re-cycle	2	FFAC	172
SPEED FB.ERR. XX	MC is opened , EB is applied, EVP stopped	Running	Valves or Traction/Pump request	3	FFA8	168
OFFSET SPD.SENS.	EB is applied, Traction/Pump, valves stopped.	Start-up	Perform ABS SENS. ACQUIRE	3	FF99	153
EMERGENCY	MC is opened, EB is applied, traction/pump and valves are disabled.	Start-up, standby, running	Valves or Traction/Pump request	3	FFA9	169
IMS ERROR	MC is opened or not closed, EB is applied, Traction/Pump stopped	Start-up, standby, running	Key re-cycle	4	FFA7	167
SHORT CIRCUIT	MC is opened or not closed, EB is applied, Traction/Pump stopped	Start-up, standby, running	Key re-cycle	5	FFA6	166
SHORT CIRCUIT KO	MC is opened or not closed, EB is applied, Traction/Pump stopped	Start-up, standby, running	Key re-cycle	5	FFA5	165
ED SLIP MISMATCH	MC is opened, EB is applied, Traction/Pump stopped	Running	Valves or Traction/Pump request	7	FFA3	163
WATCHDOG	MC is opened, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Key re-cycle	8	6010	8
EVP DRIVER OPEN	MC is opened (the command is released), EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves request	9	FFF8	240
EVP COIL OPEN	Valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	9	5002	214
EVP DRIV. SHORT.	MC is opened , EB is applied, EVP stopped	Start-up, stand-by, running	Traction/Pump request	9	5003	215
STALL ROTOR	Traction/Pump stopped	Start-up, stand-by, running	Valves or Traction/Pump request	11	FFD3	211
CONTROLLER MISM.	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Install the correct software and Key re-cycle	12	FFEF	239
EEPROM KO	Controller works using default parameters	Start-up, stand-by, running		13	3610	208
PARAM RESTORE	No effect	Start-up	Traction/Pump request	14	0	209
SEAT MISMATCH	MC is not closed, EB is applied, Traction/Pump stopped	Start-up, stand-by, running	Valves or Traction/Pump request	15	FFDE	222
HW FAULT EV.	MC is not closed, EB is applied, Traction/Pump stopped	Start-up	Key re-cycle	16	FFEE	238
LOGIC FAILURE #3	MC is opened, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by	Valves or Traction/Pump request	17	FF11	17
LOGIC FAILURE #2	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by,	Valves or Traction/Pump request	18	FF12	18
LOGIC FAILURE #1	MC is not closed, EB is applied, Traction/Pump, valves stopped	Stand-by, running	Valves or Traction/Pump request	19	5114	19
VKEY OFF SHORTED	MC is not closed, EB is applied, Traction/Pump stopped	Start-up	Key re-cycle	20	5101	220
CONT. DRV. EV	Valves stopped	Start-up, stand-by, running	Valves request	21	FFE8	232
DRV. SHOR. EV	Valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	21	FFF9	234
COIL SHOR. EVAUX	MC is opened, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	21	FFf1	241
OPEN COIL EV.	MC remains closed, EB is applied, Traction/Pump, valves stopped (the command is released)	Start-up, Stand-by, running	Valves or Traction/Pump Request	21	FFF2	242
LC COIL OPEN	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	22	FFE6	230
IQ MISMATCHED	Traction is stopped	Running	Valves or Traction/Pump request	24	FFF5	245
PEV NOT OK	Pump motor stopped, valves stopped	Start-up, stand-by, running	Valves request	25	FFDB	217

Error code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN CODE	ZAPI CODE
AUX BATT. SHORT.	None	Start-up, stand-by, running		27	5001	194
INIT VMN LOW	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Valves or Traction/Pump request	30	3121	207
VMN LOW	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Valves or Traction/Pump request	30	3120	30
INIT VMN HIGH	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Valves or Traction/Pump request	31	3111	206
VMN HIGH	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by	Valves or Traction/Pump request	31	3110	31
HW FAULT	MC is not closed, EB is applied, Traction/Pump stopped	Start-up	Key re-cycle	32	FFE3	227
HW FAULT MC	MC is not closed, EB is applied, Traction/Pump and valves are disabled	Start-up	Key re-cycle	32	FFCB	203
HW FAULT EB.	MC is opened, EB is applied, Traction/Pump stopped	Start-up	Key re-cycle	34	FFE5	229
POSITIVE LC OPEN	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	35	FFD5	213
FIELD ORIENT. KO	MC is opened, EB is applied, Traction/Pump, valves stopped	Running	Valves or Traction/Pump request	36	FFFD	253
CONTACTOR CLOSED	MC is not closed (command is not activated), EB is applied, Traction/Pump stopped	Start-up	Valves or Traction/Pump request	37	5442	37
CONTACTOR OPEN	MC is opened, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	38	5441	38
POWER MISMATCH	Traction is stopped, EB is applied, MC is opened	Running	Traction/Pump request	39	FFD4	212
EB. DRIV.SHRT.	MC remains closed, EB is applied (the command is released), Traction/Pump, valves stopped	Stand-by, running	Valves or Traction/Pump Request	40	3222	254
WRONG SET BAT.	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up		41	3100	251
WRONG KEY VOLT.	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up		41	3101	170
EB. DRIV.OPEN	MC remains closed, EB is applied (the command is released), Traction/Pump, valves stopped	Running	Valves or Traction/Pump Request	42	3224	246
EB. COIL OPEN	MC remains closed, EB is applied (the command is released), Traction/Pump, valves stopped	Start-up, Stand-by, running	Valves or Traction/Pump Request	43	FFD8	216
WAIT MOTOR STILL	MC is not closed, EB is applied, Traction/Pump stopped	Start-up		45	FF9B	155
HANDBRAKE	Traction/Pump motor is stopped	Start-up, stand-by, running	Traction/Pump request	46	FFDD	221
MOT.PHASE SH.	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Traction/Pump request	47	FFC4	196
THROTTLE PROG.	MC remains closed, EB is applied (the command is released), Traction stopped	Start-up, Stand-by, running	Valves or Traction/Pump Request	48	FFF3	243
LIFT+LOWER	Pump is stopped	Start-up, stand-by, running	Pump request	49	FFBB	187
TILLER OPEN	LC opens	Start-up, stand-by, running	Valves or Traction/Pump Request	51	0	228
STBY I HIGH	MC is not closed, EB is applied, Traction/Pump stopped	Start-up, stand-by	Valves or Traction/Pump request	53	2311	53
OVERLOAD	MC is not closed, EB is applied, Traction/Pump stopped	Running	Valves or Traction/Pump request	57	FFB4	180
CAPACITOR CHARGE	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Valves or Traction/Pump request	60	3130	60
THERMIC SENS. KO	Maximum current is reduced according to parameter MOT.T.	Start-up, stand-by, running		61	4211	250

Error code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN CODE	ZAPI CODE
	T.CUTBACK and speed is reduced to a fixed value.					
TH. PROTECTION	Traction controller reduces the max current linearly from Imax (85 °C) down to 0 A (105 °C)	Start-up, stand-by, running		**62**	**4210**	**62**
BRAKE RUN OUT	Traction is stopped	Start-up, stand-by, running	Traction/Pump Request	**63**	**FFCC**	**204**
MOTOR TEMPERAT.	Maximum current is linearly reduced (see paragraph 9.14) and speed is reduced to a fixed value.	Start-up, stand-by, running		**65**	**4110**	**65**
MOTOR TEMP. STOP	EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running		**65**	**FFB2**	**178**
NO CAN MSG DISP		Start-up, stand-by, running		**66**	**FF96**	**150**
NO CAN MSG.	MC is opened, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	**67**	**8130**	**248**
SENS MOT TEMP KO	Maximum current is reduced according to parameter MOT.T. T.CUTBACK and speed is reduced to a fixed value.	Start-up, stand-by, running		**68**	**4311**	**218**
SMARTDRIVER KO	MC is not closed, Traction/Pump, valves stopped	Start-up	Key re-cycle	**69**	**3302**	**193**
EPS RELAY OPEN	Traction/Pump motor is stopped	Start-up, stand-by, Running	Valves or Traction/Pump request	**70**	**FFCD**	**205**
WRONG RAM MEM.	MC is opened, EB is applied, Traction/Pump, valves stopped	Stand-by	Key re-cycle	**71**	**FFD2**	**210**
STO-SS1 ALARM XX	EB might be applied (according to the alarm code), power bridge open, traction disabled	Running	Alarm reset input and new traction request	**72**	**FF8E**	**142**
STO-SS1 ACTIVEXX	The warning is shown on the display	Running		**72**	**FF8D**	**141**
DRIVER SHORTED	MC is opened (the command is released), EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	**74**	**3211**	**74**
CONTACTOR DRIVER	MC is opened (the command is released), EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	**75**	**3221**	**75**
MC-EB COIL SHOR.	MC is opened, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	**76**	**2250**	**223**
VDC LINK OVERV.	MC is not closed, EB is applied, Traction/Pump, valves stopped	Stand-by, running	Valves or Traction/Pump request	**77**	**FFCA**	**202**
VACC NOT OK	Traction/Pump motor is stopped	Start-up, stand-by, running	Traction/ request	**78**	**FF4E**	**78**
POT MISMATCH	Traction/Pump motor is disabled	Start-up, stand-by, running	Accelerator at rest	78	FF97	151
INCORRECT START	Traction/Pump motor is stopped	Start-up, stand-by	Traction request	**79**	**FF4F**	**79**
FORW + BACK	Traction is stopped	Start-up, stand-by, running	Traction request	**80**	**FF50**	**80**
FORW + BACK	Traction is stopped	Start-up, stand-by, running	Traction request	**80**	**FF50**	**80**
AGV	Traction is disabled	Start-up, stand-by, running	Traction request	80	FF9A	154
SPEED OVERHEAD	MC is opened, EB is applied, Traction/Pump stopped	Running	Key re-cycle	**81**	**FFAF**	**175**
BMS NOT READY	MC is opened , EB is applied, traction/pump and valves are disabled	Start-up, stand-by, running	Key re-cycle	81	FF94	148
BMS FAULT	MC is opened, EB is applied, traction/pump and valves are disabled	Start-up, stand-by, running	Key re-cycle	82	FF93	147
WRONG FBSENS.SET	MC is not closed, EB applied, Traction/Pump, valves stopped	Start-up	Key re-cycle	**83**	**FF51**	**181**
POS. EB. SHORTED	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Key re-cycle	**84**	**3223**	**195**
VACC OUT RANGE	Traction/Pump motor is stopped	Start-up, Stand-by, Running	Traction/Pump request	**85**	**FFE2**	**226**
SAFETY DIAG. XX	MC is opened, EB is applied, Traction/Pump is disabled	Start-up, standby, running	Key re-cycle	**87**	FF92	**146**
SAFETY WARN. XX	Traction might be disabled (according to alarm code)	Running	Key re-cycle or release all input commands (according to alarm code)	**87**	FF90	**144**

Error code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN CODE	ZAPI CODE
SAFETY SW. XX	MC is opened, EB is applied, Traction/Pump is disabled	Start-up, standby, running	Key re-cycle	87	FF91	145
SAFETY INIT. XX	MC is not closed, EB is applied, Traction/Pump is disabled	Start-up	Key re-cycle	87	FF8F	143
1175 NOT ACTIVE	The warning is shown on the display	Start-up	Key re-cycle	87	FF8C	140
VDC OFF SHORTED	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up, Stand-by, Running	Key re-cycle	88	FFC8	200
POWERMOS SHORTED	MC is opened, EB is applied, traction/pump stopped	Start-up	Key re-cycle	89	FFE9	233
WRONG SLAVE VER.	MC opened, EB is applied, Traction/Pump, valves stopped	Start-up	Key re-cycle	91	FFC5	197
CURRENT GAIN	Controller works, but with low maximum current	Start-up, stand-by		92	6302	236
PARAM TRANSFER	MC stays closed, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Key re-cycle	93	FFC7	199
STEER SENSOR KO	Speed is reduced according to parameter CTB. STEER ALARM (PARAMETER CHANGE list, paragraph 8.2.1)	Start-up, stand-by, running	Return into correct range	95	FFB3	179
ANALOG INPUT	MC is opened, EB is applied, traction/pump stopped	Stand-by, running	Key re-cycle	96	FFFA	237
M/S PAR CHK MISM	MC stays closed, EB is applied, Traction/Pump, valves stopped	Start-up	Save again the parameter and Key re-cycle	97	FFC6	198
CURRENT PROFILE	EB is applied, Traction/Pump motor is stopped	Start-up, stand-by	Valves or Traction/Pump request	98	FFC9	201
CTRAP THRESHOLD	MC is opened, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	99	FFEB	235

10.3.1 Troubleshooting of alarms from master microcontroller

1175 NOT ACTIVE *(MDI/LED code = 87)*
Cause
The safety functions related to EN1175 are active, but the controller is configured as one of the controller types that do not support such safety functions.

Troubleshooting
Under SPECIAL ADJUSTMENTS, set SAFETY LEVEL = 3 to disable the EN1175 safety functions.

ACQUIRE ABORT *(MDI/LED code = 2)*
Cause:
The acquiring procedure relative to the absolute feedback sensor aborted.

ACQUIRE END *(MDI/LED code = 2)*
Cause:
Absolute feedback sensor acquired.

ACQUIRING A.S. *(MDI/LED code = 2)*
Cause:
Controller is acquiring data from the absolute feedback sensor.

Troubleshooting:
The alarm ends when the acquisition is done.

AGV *(MDI/LED code = 80)*
Cause:
The automatic guide is enabled and the periodic automatic-guide-request CAN message is missed (see paragraph 8.2.4).

Troubleshooting:
Check the CAN bus communication.
Verify that the controller receives the periodic automatic-guide-request message.
If necessary, ask for assistance to a Zapi technician in order to record and verify the CAN traces.

ANALOG INPUT *(MDI/LED code = 96)*
Cause
This alarm occurs when the A/D conversion of the analog inputs returns frozen values, on all the converted signals, for more than 400 ms. The goal of this diagnosis is to detect a failure in the A/D converter or a problem in the code flow that skips the refresh of the analog signal conversion.

Troubleshooting
If the problem occurs permanently it is necessary to replace the logic board.

AUX BATT. SHORT. *(MDI/LED code = 27)*
Cause:
The voltage on PEB A27 (A17) is at high value even if it should not.

Troubleshooting:
Verify that the connection of PEB A27 (A17) is correctly connected to +B terminal as expected by default, to terminal +B of the controller.
In case no failures/problems have been found, the problem is in the controller, which has to be replaced.

BATTERY LOW *(MDI/LED code = 0)*
Cause:
Parameter BATTERY CHECK is other than 0 (SET OPTION list, paragraph 8.2.2) and battery charge is evaluated to be lower than BATT.LOW TRESHLD (ADJUSTMENTS list, paragraph 8.2.3).

Troubleshooting:
Check the battery charge and charge it if necessary.
If the battery is actually charged, measure the battery voltage through a voltmeter and compare it with the BATTERY VOLTAGE reading in the TESTER function. If they are different, adjust the ADJUST BATTERY parameter (ADJUSTMENTS list, paragraph 8.2.3) with the value measured through the voltmeter.
If the problem is not solved, replace the logic board.

BMS FAULT *(MDI/LED code = 82)*
Cause:
This alarm occurs if the BMS FUNCTION is enabled and the battery management system is not operative.

Troubleshooting:
Check the battery charge and the battery management system status.
Check the CAN bus communication.
If the BMS is not faulty, ask for assistance to a Zapi technician.

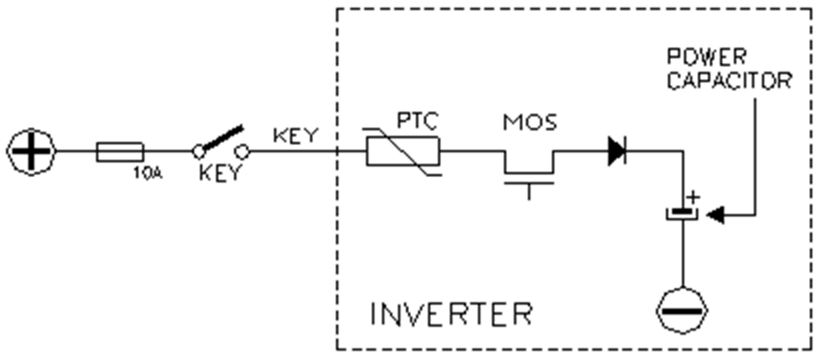
BMS NOT READY *(MDI/LED code = 81)*
Cause:
This alarm occurs if the BMS FUNCTION is enabled and the controller does not receive any information about the battery state of charge; the battery management system is not operative.

Troubleshooting:
Check the battery charge and the battery management system status.
Check the CAN bus communication.

BRAKE RUN OUT *(MDI/LED code = 63)*
Cause:
The CPOT BRAKE input read by the microcontroller is out of the range defined by parameters SET PBRK. MIN and SET PBRK. MAX (ADJUSTMENTS list, paragraph 8.2.3).

Troubleshooting:
Check the mechanical calibration and the functionality of the brake potentiometer.
Acquire the minimum and maximum potentiometer values.
If the alarm is still present, replace the logic board.

CAPACITOR CHARGE *(MDI/LED code = 60)*
Cause
When the key is switched on, the inverter charges the power capacitors through a dedicated pre-charge circuit. The voltage evolution is monitored. If the capacitor bank voltage results less than a certain percentage of the key voltage after a fixed timeout, the alarm is raised and the main contactor is not closed.



Troubleshooting
Check if an external load in parallel to the capacitor bank, which sinks current from the capacitors-charging circuit, thus preventing the caps from charging well. Check if a lamp or a DC/DC converter or an auxiliary load is placed in parallel to the capacitor bank.
The charging resistance or PTC may be broken. Insert a power resistance across line-contactor power terminals; if the alarm disappears, it means that the charging resistance is damaged.
The charging circuit has a failure or there is a problem in the power section. Replace the controller.

CHECK UP NEEDED *(MDI/LED code = 0)*
Cause:
This is a warning to point out that it is time for the programmed maintenance.

Troubleshooting:
Turn on the CHECK UP DONE option after that the maintenance service.

COIL SHOR. EVAUX *(MDI/LED code = 21)*
Cause:
This alarm occurs when there is an overload on any of the auxiliary voltage-controlled outputs: NEV1 A24, NEV2 A25, NEV3 A34 and NEV4 A35.

Troubleshooting:
The typical root cause is in the wiring harness or in the load coil. Check the connections between the controller output and the load.
Collect information about the coil characteristics and ask for assistance to a Zapi technician in order to verify that it complies with the driver specifications.

MC-EB COIL SHOR. *(MDI/LED code = 76)*
Cause:
This alarm occurs when there is an overload on the main contactor or electromechanical brake drivers, on pins NLC A26 (A16) and NEB A28 (A18).

Troubleshooting:
The typical root cause is in the wiring harness or in either of the load coils. Check the connections between the controller outputs and the loads.
Collect information about the coils characteristics and ask for assistance to a Zapi technician in order to verify that it complies with the driver specifications.

CONT. DRV. EV XX *(MDI/LED code = 21)*
Cause:
One or more on/off valve drivers are not able to drive the load. For the meaning of code “XX”, refer to paragraph 10.5.

Troubleshooting:
The device or its driving circuit is damaged. Replace the controller.

CONTACTOR CLOSED *(MDI/LED code = 37)*
Cause
Before driving the LC coil, the controller checks if the contactor is stuck. The controller drives the power bridge for several dozens of milliseconds, trying to discharge the capacitors bank. If the capacitor voltage does not decrease by more than a certain percentage of the key voltage, the alarm is raised.

Troubleshooting
It is suggested to verify the power contacts of LC; if they are stuck, is necessary to replace the LC.

CONTACTOR DRIVER *(MDI/LED code = 75)*
Cause
The LC coil driver is not able to drive the load. The device itself or its driver circuit is damaged.

Troubleshooting
This type of fault is not related to external components; replace the logic board.

CONTACTOR OPEN *(MDI/LED code = 38)*
Cause
The LC coil is driven by the controller, but it seems that the power contacts do not close. In order to detect this condition the controller injects a DC current into the motor and checks the voltage on power capacitor. If the power capacitors get discharged it means that the main contactor is open.

Troubleshooting
LC contacts are not working. Replace the LC.
If LC contacts are working correctly, contact a Zapi technician.

CONTROLLER MISM. *(MDI/LED code = 12)*
Cause
The software is not compatible with the hardware. Each controller produced is “signed” at the end of line test with a specific code mark saved in EEPROM according to the customized part number.
According with this “sign”, only the customized firmware can be uploaded.

Troubleshooting
Upload the correct firmware.
Ask for assistance to a Zapi technician in order to verify that the firmware is correct.

CTRAP THRESHOLD *(MDI/LED code = 99)*
Cause
This alarm occurs when a mismatch is detected between the set-point for the overcurrent detection circuit (dependent on parameter DUTY PWM CTRAP, see paragraph 8.2.4) and the feedback of the actual threshold value.

Troubleshooting
The failure lies in the controller hardware. Replace the logic board.

CURRENT GAIN *(MDI/LED code = 92)*
Cause:
The current gain parameters are at the default values, which means that the maximum current adjustment procedure has not been carried out yet.

Troubleshooting:
Ask for assistance to a Zapi technician in order to do the adjustment procedure of the current gain parameters.

CURRENT PROFILE *(MDI/LED code = 98)*
Cause:
There is an error in the choice of the current profile parameters. Points P0 through P3 are expected to describe a descending profile. See paragraphs 8.2.9 and 9.15.

Troubleshooting:
Check the values under the CURRENT PROFILE list.

DATA ACQUISITION *(MDI/LED code = 0)*
Cause:
Controller in calibration state.

Troubleshooting:
The alarm ends when the acquisition is done.

DRIVER SHORTED *(MDI/LED code = 74)*
Cause
The driver of the LC coil is shorted.

Troubleshooting
Check if there is a short or a low impedance path between NLC A26 (A16) and -B.
The driver circuit is damaged; replace the logic board.

DRV. SHOR. EV XX *(MDI/LED code = 21)*
Cause:
One or more on/off valve drivers are shorted. For the meaning of code "XX", refer to paragraph 10.5.

Troubleshooting:
Check if there is a short circuit or a low impedance path between the negative terminals of the involved coils and -B.
If the problem is not solved, replace the logic board.

EB. COIL OPEN *(MDI/LED code = 43)*
Cause:
An open-load condition is detected on the electromechanical brake output NEB A28 (A18).

Troubleshooting:
Check the EB coil.
Check the wiring.
Check the EB positive terminal, from downstream the main contactor and involving pin PEB A27 (A17).
If the problem is not solved, replace the logic board.

EB. DRIV.OPEN *(MDI/LED code = 42)*
Cause:
The EB driver is not able to drive the load. The device itself or its driving circuit is damaged.

Troubleshooting:
This type of fault is not related to external components. Replace the logic board.

EB. DRIV.SHRT. *(MDI/LED code = 40)*
Cause:
The EB driver is shorted.
The microcontroller detects a mismatch between the set-point and the feedback at the EB output.

Troubleshooting:
Check if there is a short or a low impedance path between the negative coil terminal and -B.
Check if the voltage applied is in accordance with the settings of the EB-related parameters (see paragraph 8.2.5).
If the problem is not solved, replace the controller.

EEPROM KO *(MDI/LED code = 13)*
Cause:
A hardware or software defect of the non-volatile embedded memory storing the controller parameters. This alarm does not inhibit the machine operations, but it makes the truck to work with the default values.

Troubleshooting:
Execute a CLEAR EEPROM procedure (refer to the Console manual). Switch the key off and on to check the result. If the alarm occurs permanently, it is necessary to replace the controller. If the alarm disappears, the previously stored parameters will be replaced by the default parameters.

EMERGENCY *(MDI/LED code = 3)*
Cause:
This alarm occurs when parameter EMERGENCY INPUT is set to 1 (see paragraph 8.2.2) and the emergency input is active.

Troubleshooting:
The emergency input has been activated. Wait until the emergency conditions cease and restore the emergency input.

EPS RELAY OPEN *(MDI/LED code = 70)*
Cause:
The controller receives from EPS information about the safety contacts being open.

Troubleshooting:
Verify the EPS functionality.

EVP COIL OPEN *(MDI/LED code = 9)*
Cause:
An open-load condition is detected on the proportional valve output NEVP A29 (A19).

Troubleshooting:
Check the EVP coil.
Check the wiring.
If the problem is not solved, replace the logic board.

EVP DRIV. SHORT. *(MDI/LED code = 9)*
Cause
The EVP driver, on output NEVP A29 (A19), is shorted to ground. The microcontroller detects a mismatch between the valve set-point and the feedback of the EVP output.

Troubleshooting
Check if there is a short circuit or a low-impedance conduction path between the negative of the coil and -B.
Collect information about:
the voltage applied across the EVP coil,
the current in the coil,
features of the coil.
Ask for assistance to Zapi in order to verify that the software diagnoses are in accordance with the type of coil employed.
If the problem is not solved, it could be necessary to replace the controller.

EVP DRIVER OPEN *(MDI/LED code = 9)*
Cause:
The EVP driver, on output NEVP A29 (A19), is not able to drive the EVP coil. The device itself or its driving circuit is damaged.

Troubleshooting:
This fault is not related to external components. Replace the logic board.

FIELD ORIENT. KO *(MDI/LED code = 36)*
Cause
The error between the estimated Id (d-axis current) and the relative set-point is out of range.

Troubleshooting
Ask for assistance to a Zapi technician in order to do the correct adjustment of the motor parameters.

FORW + BACK *(MDI/LED code = 80)*
Cause:
This alarm occurs when both the travel requests (FW and BW) are active at the same time.

Troubleshooting:
Check that travel requests are not active at the same time.
Check the FW and BW input states through the TESTER function.
Check the wirings relative to the FW and BW inputs.
Check if there are failures in the micro-switches.
If the problem is not solved, replace the logic board.

HANDBRAKE *(MDI/LED code = 46)*
Cause:
Handbrake input is active.

Troubleshooting:
Check that handbrake is not active by mistake.
Check the SR/HB input state through the TESTER function.
Check parameter HB ON / SR OFF under SET OPTIONS.
Check the wirings and the micro-switch.
If the problem is not solved, replace the logic board.

HW FAULT EB. XX *(MDI/LED code = 34)*
Cause:
At start-up, the hardware circuit dedicated to enable and disable the EB driver on output NEB A28 (A18) is found to be faulty. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting:
This type of fault is not related to external components. Replace the logic board.

HW FAULT EV. XX *(MDI/LED code = 16)*
Cause:
At startup, the hardware circuit dedicated to enable and disable the EV drivers is found to be faulty. For the meaning of code "XX", refer to paragraph 10.5.

Troubleshooting:
This type of fault is not related to external components. Replace the logic board.

HW FAULT MC XX *(MDI/LED code = 32)*
Cause:
At start-up, some hardware circuit intended to enable and disable the power bridge or the LC driver on output NLC A26 (A16) is found to be faulty. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting
This type of fault is related to internal components. Replace the logic board.

HW FAULT XX *(MDI/LED code = 32)*
Cause
At start-up, some hardware circuit intended to enable and disable the power bridge is found to be faulty. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting
This type of fault is related to internal components. Replace the logic board.

IMS ERROR *(MDI/LED code = 4)*
Cause
The power section is not properly connected to the logic board.

Troubleshooting
Replace the controller.

INCORRECT START *(MDI/LED code = 79)*
Cause:
Incorrect starting sequence. Possible reasons for this alarm are:
- A travel demand active at key-on.
- Seat or tiller input active at key on.

Troubleshooting:
Check the state of the inputs at key-on.
Check wirings and the micro-switches for failures.
Through the TESTER function, check the states of the inputs are coherent with those of the micro-switches .
If the problem is not solved, replace the logic board.

INIT VMN HIGH XX (*MDI/LED code = 31*)
Cause
Before closing the main contactor and before driving power bridge, one or more motor phases voltage are sensed to be higher than expected. A short circuit or a low-impedance path to the positive rail is affecting the power section. The hexadecimal value "XX" identifies the faulty phase.
81: phase U
82: phase V
83: phase W

Troubleshooting
Check the motor power cables.
Check the impedance between U, V and W terminals and +B terminal of the controller.

If the motor connections are fine and there are no external low-impedance paths, the problem resides inside the controller; replace it.

INIT VMN LOW XX (*MDI/LED code = 30*)
Cause
Before closing the main contactor and before driving power bridge, one or more motor phases voltage are sensed to be lower than expected. A short circuit or a low-impedance path to the negative rail is affecting the power section. The hexadecimal value "XX" identifies the faulty phase.

- 01: phase U
- 02: phase V
- 03: phase W

Troubleshooting
Check the motor power cables.
Check the impedance between U, V and W terminals and -B terminal of the controller.
Check the motor leakage to truck frame.
If the motor connections are OK and there are no external low impedance paths, the problem is inside the controller; replace it.

IQ MISMATCHED *(MDI/LED code = 24)*
Cause
The error between the estimated q-axis current and the related set-point is out of range.

Troubleshooting
Ask for assistance to a Zapi technician in order to do the correct adjustment of the motor parameters.

LC COIL OPEN *(MDI/LED code = 22)*
Cause
An open-load condition is detected on the proportional valve output NLC A26 (A16).

Troubleshooting
Check the LC coil.
Check the wiring.
Check the LC positive terminal, possibly from the key line.
If the problem is not solved, replace the logic board.

LIFT+LOWER *(MDI/LED code = 49)*
Cause:
Both the pump requests (LIFT and LOWER) are active at the same time.

Troubleshooting:
Check that LIFT and LOWER requests are not active at the same time.
Check the LIFT and LOWER states through the TESTER function.
Check the wirings and the micro-switches .
If the problem is not solved, replace the logic board.

LOGIC FAILURE #1 *(MDI/LED code = 19)*
Cause
The controller detects an under-voltage condition at the KEY input A3 (A1). Under-voltage threshold depends on the controller version.

Nominal voltage	24 V, 36 V, 48 V	80 V, 96 V
Under-voltage threshold	10 V	30 V

Troubleshooting (fault at startup or in standby)
Fault can be caused by a key input signal characterized by pulses below the under-voltage threshold, possibly due to external loads like DC/DC converters starting-up, relays or contactors during switching periods, solenoids energizing or de-energizing. Consider to remove such loads.
If no voltage transient is detected on the supply line and the alarm is present every time the key switches on, the failure probably lies in the controller hardware. Replace the logic board.

Troubleshooting (fault displayed during motor driving)
If the alarm occurs during motor acceleration or when there is a hydraulic-related request, check the battery charge, the battery health and power-cable connections.

LOGIC FAILURE #2 *(MDI/LED code = 18)*
Cause
Fault in the hardware section of the logic board which deals with voltage feedbacks of motor phases.

Troubleshooting
The failure lies in the controller hardware. Replace the controller.

LOGIC FAILURE #3 *(MDI/LED code = 17)*
Cause
A hardware problem in the logic board due to high currents (overload). An overcurrent condition is triggered even if the power bridge is not driven.

Troubleshooting
The failure lies in the controller hardware. Replace the controller.

M/S PAR CHK MISM *(MDI/LED code = 97)*
Cause:
At start-up there is a mismatch in the parameter checksum between the master and the supervisor microcontrollers.

Troubleshooting:
Restore and save again the parameters list.

MOT.PHASE SH. XX *(MDI/LED code = 47)*
Cause
A short circuit between two motor phases occurred. The hexadecimal value “XX” identifies the pair of shorted phases.

36: U – V
37: U – W
38: V – W

Troubleshooting
Verify the motor phases connection on the motor and inverters sides.
Check the motor power cables.
Replace the controller.
If the alarm does not disappear, the problem is in the motor; replace it.

MOTOR TEMPERAT. *(MDI/LED code = 65)*
Cause:
This warning occurs when the temperature sensor is open (if digital) or if it exceeds the threshold defined by MAX. MOTOR TEMP. (if analog). See paragraph 8.2.3.

Troubleshooting:
Check the temperature read by the thermal sensor inside the motor through the MOTOR TEMPERATURE reading in the TESTER function.
Check the sensor resistance and the sensor wiring.
If the sensor is OK, improve the cooling of the motor.
If the warning is present when the motor is cool, replace the controller.

NO CAN MSG DISP *(MDI/LED code = 66)*
Cause
CAN bus communication with the display does not work properly. Upon this alarm, economy mode is activated by default.

Troubleshooting
Verify the CAN bus network and the display connected to it.
By a multimeter check the impedance between CANH and CANL; it shall be 60 Ω.
If the alarm persists, replace the logic board.

NO CAN MSG. XX *(MDI/LED code = 67)*
Cause
CAN bus communication does not work properly. The hexadecimal value "XX" identifies the faulty node.

Troubleshooting
Verify the CAN bus network and the devices connected to it.
By a multimeter check the impedance between CANH and CANL; it shall be 60 Ω.
If the alarm persists, replace the logic board.

OFFSET SPD.SENS. *(MDI/LED code = 3)*
Cause:
It is necessary to acquire the offset angle between the stator and the speed sensor, i.e. their mutual angular misalignment. An automatic function is dedicated to this procedure.

Troubleshooting:
Perform the teaching procedure. See paragraph 7.2.1.

OPEN COIL EV. XX *(MDI/LED code = 21)*
Cause:
An open-load condition is detected on one or more EV outputs (NEV1 A24, NEV2 A25, NEV3 A34 or NEV4 A35). Code "XX" identifies the faulty output; see paragraph 10.5.

Troubleshooting:
Check the coils.
Check the wiring.
If the problem is not solved, replace the logic board.

OVERLOAD *(MDI/LED code = 57)*
Cause
The motor current has exceeded the hardware-fixed limit.

Troubleshooting
If the alarm condition occurs again, ask for assistance to a Zapi technician. The fault condition could be affected by wrong adjustments of motor parameters.

PARAM RESTORE *(MDI/LED code = 14)*
Cause:
The controller has restored the default settings. If a CLEAR EEPROM was made before the last key cycle, this warning gives evidence that the settings were correctly restored.

Troubleshooting:
A travel demand or a pump request cancel the alarm.
If the alarm appears at key-on without having performed CLEAR EEPROM before, replace the controller.

PARAM TRANSFER *(MDI/LED code = 93)*
Cause:
Master microcontroller is transferring parameters to the supervisor.

Troubleshooting:
Wait until the end of the procedure. If the alarm remains longer, re-cycle the key.

PEV NOT OK *(MDI/LED code = 25)*
Cause:
Terminal PEB A27 (A17) is not connected or the voltage is different from that defined by parameter SET POSITIVE PEB under ADJUSTMENTS.
This alarm can occur if one output among EVP, EV1, EV2, EV3 and EV4 is present or AUX OUT FUNCTION is active.

Troubleshooting:
Check PEB terminal: by default it must be connected to the battery voltage (after the main contactor).
Set the proper voltage of PEB by parameter SET POSITIVE PEB under ADJUSTMENTS.

POS. EB. SHORTED *(MDI/LED code = 84)*
Cause:
The voltage on terminal PEB A27 (A17) is sensed lower than expected.

Troubleshooting:
Check if PEB A27 (A17) is properly connected to the positive supply or there is an external short or a low impedance path between PEB and any ground reference (-B or GND).
If the issue is not resolved, the problem is in the controller; replaced it.

POSITIVE LC OPEN *(MDI/LED code = 35)*
Cause:
The voltage feedback of the LC driver, output NLC A26 (A16), is different from expected.

Troubleshooting:
Verify LC coil is properly connected.
Verify CONF.POSITIVE LC parameter is set in accordance with the actual coil positive supply (see paragraph 8.2.5).

In case no failures/problems have been found, the problem is in the controller, which has to be replaced.

POT MISMATCH *(MDI/LED code = 78)*
Cause:
This alarm can occur only if the auxiliary potentiometer is of crossed-twin type, in combination with the main potentiometer (see parameter AUX.POT. TYPE under the SET OPTIONS list, paragraph 8.2.2). The sum of main and auxiliary potentiometers is not constant.

Troubleshooting:
Verify that the main and auxiliary potentiometers are properly connected.
Check the mechanical and electrical functionality of the main and auxiliary potentiometers.
Perform the acquisition of the potentiometers; ask for assistance to a Zapi technician if necessary.
If the problem is not solved, replace the logic board.

POWER MISMATCH *(MDI/LED code = 39)*
Cause
The error between the power set-point and the estimated power is out of range.

Troubleshooting
Ask for assistance to a Zapi technician about the correct adjustment of the motor parameters.

POWERMOS SHORTED *(MDI/LED code = 89)*
Cause
The DC-link voltage drops to zero when a high-side or low-side MOSFET is turned on.

Troubleshooting
Check that motor phases are correctly connected.
Check that there is no dispersion to ground for every motor phases.
In case the problem is not solved, replace the controller.

RPM HIGH *(MDI/LED code = 0)*
Cause:
The speed of the hybrid generation set exceeded the maximum one.

SAFETY DIAG. XX *(MDI/LED code = 87)*
Cause
One of the EN1175-related related diagnoses has failed. The hexadecimal value "XX" identifies which one.
- 01: Truck accelerating from standstill.
- 02: Truck moving for longer than 0.5 m from standstill.
- 04: No braking.
- 08: Speed in excess of the maximum allowed speed in the current mode.
- 10: Wrong direction.
- 20: Speed in excess of the maximum speed.
- 40: Setpoint mismatch.
- 80: Too steep braking ramp.

Troubleshooting
Ask for assistance to a Zapi technician

SAFETY SW. XX *(MDI/LED code = 87)*
Cause
One of the safety related modules has reported an error. The hexadecimal value "XX" facilitates Zapi technicians identifying the faulty module.

Troubleshooting
Ask for assistance to a Zapi technician.

SAFETY INIT. XX *(MDI/LED code = 87)*
Cause
One of the safety related modules has reported an error during its initialization. The hexadecimal value "XX" facilitates Zapi technicians identifying the faulty module.

Troubleshooting
Check the parameters, expecially regarding the motor configuration (e.g. ENCODER PULSES 1/2, MOTOR P. PAIRS 1/2, etc…)
If the problem persists, ask for assistance to a Zapi technician.

SAFETY WARN. XX (*MDI/LED code = 87*)
Cause
Mismatch in the setpoint calculation between the Application Layer and the EN1175 SW Layer. The hexadecimal value "XX" identifies the issue.
  01: Application setpoint is greater than the EN1175 setpoint.
  02: Application setpoint is opposite to the EN1175 setpoint

Troubleshooting
Ask for assistance to a Zapi technician.

SEAT MISMATCH *(MDI/LED code = 15)*
Cause
This alarm can appear only in a traction-and-pump configuration or in a multi-motor one. A mismatch is detected between the two TILLER/SEAT inputs A8 (A6) of the two controllers.

Troubleshooting
Check if there are wrong connections in the external wiring.
Using the TESTER function, verify that the seat inputs are in accordance with the actual state of the external switch.
If the issue is not solved, replace the controller.

SENS MOT TEMP KO *(MDI/LED code = 68)*
Cause:
The output of the motor thermal sensor is out of range.

Troubleshooting:
Check if the resistance of the sensor is what expected measuring its resistance.
Check the wiring.
If the problem is not solved, replace the logic board.

SHORT CIRCUIT *(MDI/LED code = 5)*
Cause
The power section of the controller failed to apply the proper PWM pulses as per the driving signals from the logic section.

Troubleshooting
Replace the controller.

SHORT CIRCUIT KO *(MDI/LED code = 5)*
Cause
The circuit monitoring the PWM modulation of the power section is found to be faulty.

Troubleshooting
Replace the controller.

SPEED FB.ERR. XY *(MDI/LED code = 3)*
Cause
An issue with the speed or position feedback sensor is detected. The hexadecimal value “XY” helps to identify the nature of the problem: the first digit “X” encodes the type of feedback sensor, the second digit “Y” encodes the type of issue.

X	Sensor
0	Encoder
1	Sin/cos
3	Encoder + index
5	Resolver
6	3-Hall
7	PWM

Y	Issue
1	Generic error 1
2	Generic error 2
3	Generic error 3
4	Generic error 4
5	Signals off
6	Swapped signals
7	Shorted signals or one is absent
8	Signal amplitude
9	Signal amplitude (supervisor µC)
A	Too large speed step
B	SSL (sensorless speed loop)
C	Signals are filtered out
D	Free
E	Free
F	Free

Troubleshooting
Check both the electric and the mechanical functionality of the sensor.
Check the wires crimping.
Check the mechanical installation of the sensor; the issue may be it slips inside its housing.
The electromagnetic noise on the sensor can be a cause. In this case try to replace the sensor.
For generic errors 1 through 4, contact a Zapi technician for assistance.
If the problem is still present after replacing the sensor, the failure is most likely in the controller; replace it.

SMARTDRIVER KO *(MDI/LED code = 69)*
Cause:
The circuit for the management of the smart driver is found to be faulty. The driver is turned ON but the output voltage remains low.

Troubleshooting:
Verify that the coil is connected correctly between terminals PEB A27 (A17) and NEB A28 (A18). The output of smart driver is in fact evaluated checking the voltage feedback of the low side driver NEB.
Verify that the parameter POSITIVE E.B. is set in accordance with the actual coil positive supply (see paragraph 8.2.5). The software makes a proper diagnosis depending on the parameter; a wrong setting could generate a false fault.
If the issue is not solved, replace the controller.

SPEED OVERHEAD *(MDI/LED code = 81)*
Cause:
The motor speed has exceeded the maximum defined by parameter TOP MAX SPEED (under HARDWARE SETTINGS) by more than a 100 Hz excess.

Troubleshooting:
Check the motor parameters.
Ask for assistance to a Zapi technician.

STALL ROTOR *(MDI/LED code = 11)*
Cause:
The traction rotor is stuck or the controller does not correctly receive the encoder signals.

Troubleshooting:
Check the encoder condition.
Check the wiring.
Through the TESTER function, check if the sign of FREQUENCY and ENCODER are the same and if they are different from zero during a traction request.
If the problem is not solved, replace the logic board.

STBY I HIGH *(MDI/LED code = 53)*
Cause
In standby, the current sensors detect values different from zero. The current sensors or the current feedback circuits are faulty.

Troubleshooting
Replace the controller.

STEER SENSOR KO *(MDI/LED code = 95)*
Cause:
The voltage read by the microcontroller at the steering-sensor input is not within the STEER RIGHT VOLT ÷ STEER LEFT VOLT range, programmed through the STEER ACQUIRING function (see paragraph 9.3).

Troubleshooting:
Acquire the maximum and minimum values coming from the steering potentiometer through the STEER ACQUIRING function. If the alarm is still present, check the mechanical calibration and the functionality of the potentiometer.
If the problem is not solved, replace the logic board.

STO-SS1 ACTIVEXX *(MDI/LED code = 72)*
Cause
This is just a warning to help the user know that the STO and\or SS1 procedure is in progress. It has no effect on the controller. The meaning of the hexadecimal value "XX" is the following.
01: STO in progress.
02: SS1 in progress.
03: Both STO and SS1 in progress.

Troubleshooting
Wait until the ongoing procedure is done.

STO-SS1 ALARM XX *(MDI/LED code = 72)*
Cause
One between the STO and the SS1 procedures has failed. The hexadecimal value "XX" represents a bitmask, where the meaning of each bit is the following:
Bit 0 (XX = 01): STO input timeout.
Bit 1 (XX = 02): SS1 input timeout.
Bit 2 (XX = 04): The braking action did not respect the required ramp (MSS1 only).
Bit 3 (XX = 08): The braking action did not respect the required ramp (GSS1 only).
Bit 4 (XX = 10): The braking action took too long (GSS1 only).

Troubleshooting
If a STO or SS1 timeout happens, be sure to commute both input within the required time. If the problem is about the braking action, increase the value of the required ramp.
If the problem persists, ask for assistance to a Zapi technician.

TH. PROTECTION *(MDI/LED code = 62)*
Cause:
The temperature of the controller base plate exceeds 85 °C. The maximum current is proportionally decreased with the temperature excess from 85 °C up to 105 °C. At 105 °C the current is limited to 0 A. See paragraph 5.6).

Troubleshooting:
It is necessary to improve the controller cooling. To realize an adequate cooling in case of finned heat sink important factors are the air flux and the cooling-air temperature. If the thermal dissipation is realized by applying the controller base plate onto the truck frame, the important factors are the thickness of the frame and the planarity and roughness of its surface.
If the alarm occurs when the controller is cold, the possible reasons are a thermal-sensor failure or a failure in the logic board. In the last case, it is necessary to replace the controller.

THERMIC SENS. KO *(MDI/LED code = 61)*
Cause:
The output of the controller thermal sensor is out of range.

Troubleshooting:
This kind of fault is not related to external components. Replace the controller.

THROTTLE PROG. *(MDI/LED code = 48)*
Cause:
A wrong profile has been set in the throttle profile.

Troubleshooting:
Set properly the throttle-related parameters (see paragraph 9.10).

TILLER OPEN *(MDI/LED code = 51)*
Cause:
Tiller/seat input has been inactive for more than 120 seconds.

Troubleshooting:
Activate the tiller/seat input.
Check the tiller/seat input state through the TESTER function.
Check the wirings.
Check if there are failures in the micro-switches .
If the problem is not solved, replace the logic board.

VACC NOT OK *(MDI/LED code = 78)*
Cause:
The ACC POT input A5 (A3) is sensed above the minimum value acquired by the PROGRAM VACC procedure.

Troubleshooting:
Check the wirings.
Check the mechanical calibration and the functionality of the accelerator potentiometer.
Acquire the maximum and minimum potentiometer value through the PROGRAM VACC function.
If the problem is not solved, replace the logic board.

VACC OUT RANGE *(MDI/LED code = 85)*
Cause:
The ACC POT input A5 (A3) read by the microcontroller is not within the range MIN VACC through MAX VACC, programmed by the PROGRAMM VACC function (see paragraph 9.1). The minimum and maximum acquired values are inconsistent.

Troubleshooting:
Acquire the maximum and minimum potentiometer values by the PROGRAM VACC function. If the alarm is still present, check the mechanical calibration and the functionality of the accelerator potentiometer.
If the problem is not solved, replace the logic board.

VDC LINK OVERV. *(MDI/LED code = 77)*
Cause
This fault is displayed when the controller detects an overvoltage condition. Overvoltage threshold depends on the nominal voltage of the controller.

Nominal voltage	**24 V**	**36 V, 48 V**	**80 V**	**96 V**
Overvoltage threshold	35 V	72.5 V	115 V	125 V

As soon as the fault occurs, power bridge and MC are opened. The condition is triggered using the same HW interrupt used for under-voltage detection, microcontroller discerns between the two evaluating the voltage present across DC-link capacitors:

High voltage → Overvoltage condition
Low/normal voltage → Under-voltage condition

Troubleshooting
If the alarm happens during the brake release, check the line contactor contact and the battery power cable connection.

VDC OFF SHORTED *(MDI/LED code = 88)*
Cause
The logic board measures a voltage value across the DC-link that is constantly out of range, above the maximum allowed value.

Troubleshooting
Check that the battery has the same nominal voltage of the inverter.
Check the battery voltage, if it is out of range replace the battery.
If the battery voltage is ok, replace the logic board.

VKEY OFF SHORTED *(MDI/LED code = 20)*
Cause:
The logic board measures a key voltage value that is constantly under the minimum value allowed.

Troubleshooting:
Check that the battery used as supply for the inverter has the same nominal voltage of the inverter.
Check the battery voltage, if it is out of the allowed range replace the battery.
In case the problem is not solved, the problem is in the logic board, replace it.

VMN HIGH *(MDI/LED code = 31)*
Cause 1:
At start-up, the power bridge is found to be faulty in the sense that one of the three legs is not able to drive the motor phase low.

Troubleshooting 1:
Check the motor internal connections.
Check the motor power cables.
If the issue is not solved, replace the controller.

Cause 2:
At start-up the power bridge works as expected. After the main contactor closes, one of the phase voltages higher than half the battery voltage.

Troubleshooting 2:
Check the motor connections.
Check that the LC power contact closes properly, with a good contact.
If the issue is not solved, replace the controller.

VMN LOW *(MDI/LED code = 30)*
Cause 1:
At start-up, the power bridge is found to be faulty in the sense that one of the three legs is not able to drive the motor phase high.

Troubleshooting 1:
Check the motor internal connections.
Check the motor power-cables connections.

If the issue is not solved, replace the controller.

Cause 2:
While the motor is running, one of the three motor phases is sensed to lower than expected.

Troubleshooting 2:
motor connections.
Check that the LC power contact closes properly, with a good contact.
If the issue is not solved, replace the controller.

WAIT MOTOR STILL *(MDI/LED code = 45)*
Cause:
The controller is waiting for the motor to stop rotating. This warning can only appear in BLE4 for brushless motors.

WAITING FOR NODE *(MDI/LED code = 0)*
Cause:
The controller receives from the CAN bus the message that another controller in the net is in fault condition; as a consequence, the controller itself cannot enter into an operative status, but it has to wait until the other node comes out from the fault status.

Troubleshooting:
Check if any other device on the CAN bus is in fault condition.

WARNING SLAVE *(MDI/LED code = 1)*
Cause:
Warning on supervisor microcontroller.

Troubleshooting:
Connect the Console to the supervisor microcontroller and check which alarm is present.

WATCHDOG *(MDI/LED code = 8)*
Cause
This is a safety related test. It is a self-diagnosis test that involves the logic between master and supervisor microcontrollers.

Troubleshooting
This alarm could be caused by a CAN bus malfunctioning, which blinds master-supervisor communication.

WRONG FBSENS.SET *(MDI/LED code = 83)*
Cause
Mismatch between parameters ENCODER PULSES 1 and ENCODER PULSES 2 (see paragraph 8.2.8).

Troubleshooting
Set the two parameters with the same value, according to the adopted encoder.

WRONG KEY VOLT. *(MDI/LED code = 41)*
Cause
At startup, the controller monitors the key voltage and it verifies that it is within a range defined by parameters VOLTAGE THR LOW and VOLTAGE THR HIGH with respect to the nominal voltage of the controller (parameter SET BATTERY). The default values are respectively 80% and 120%. If the check fails, the alarm raises.

Troubleshooting
Check that the SET BATTERY parameter under ADJUSTMENTS matches with the battery nominal voltage.
If the battery nominal voltage is not available for the SET BATTERY parameter under ADJUSTMENTS, check the value stored as HARDWARE BATTERY RANGE under SPECIAL ADJUST. and contact a Zapi technician.
Check parameters VOLTAGE THR LOW and VOLTAGE THR HIGH.
By the TESTER function, check that the KEY VOLTAGE reading shows the same value as the voltage measured with a voltmeter on the KEY input A3 (A1). If it does not match, then modify the ADJUST KEY VOLT. parameter under ADJUSTMENTS according to the value read by the voltmeter.
In case all the settings are correct, verify the external wiring.
Verify the battery provides the proper voltage to the key input. If not, replace the battery.
Replace the controller.

WRONG PERFORM. *(MDI/LED code = 0)*
Cause
This alarm occurs only if the PERFORMANCE parameter under SET OPTIONS is set to ON. The three performance levels (economy, normal, power) are not set in an ascending order of performance.

Troubleshooting
Check the performance settings under the PERFORM. ECONOMY and PERFORM. POWER lists. The performance related parameters must be set in such a way that the economy mode results in the weakest and the power mode results the highest. Contact a Zapi technician for assistance.

WRONG RAM MEM. *(MDI/LED code = 71)*
Cause
The algorithm implemented to check the main RAM registers finds wrong contents: the registers are corrupted. The machine operations are inhibited.

Troubleshooting
Cycle the key, if the alarm is still present replace the logic board.

WRONG SET BAT. *(MDI/LED code = 41)*
Cause
At start-up, after closing the main contactor, the controller monitors the battery voltage on the +B post and it verifies that it is within a range defined by parameters VOLTAGE THR LOW and VOLTAGE THR HIGH with respect to the nominal voltage of the controller (parameter SET BATTERY). The default values are respectively 80% and 120%. If the check fails, the alarm raises.

Troubleshooting
Check that the SET BATTERY parameter under ADJUSTMENTS matches with the battery nominal voltage.

If the battery nominal voltage is not available for the SET BATTERY parameter under ADJUSTMENTS, check the value stored as HARDWARE BATTERY RANGE under SPECIAL ADJUST. and contact a Zapi technician.
Check parameters VOLTAGE THR LOW and VOLTAGE THR HIGH.
By the TESTER function, check that the BATTERY VOLTAGE reading shows the same value as the voltage measured with a voltmeter on post +B. If it does not match, then modify the ADJUST BATTERY parameter under ADJUSTMENTS according to the value read by the voltmeter.
In case all the settings are correct, verify the battery provides the proper voltage. If not, replace the battery.
Replace the controller.

WRONG SLAVE VER. *(MDI/LED code = 91)*
Cause:
There is a mismatch in the software versions of master and supervisor microcontrollers.

Troubleshooting:
Upload the software to the correct version or ask for assistance to a Zapi technician.

10.4 Alarms from supervisor microcontroller

Error Code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN CODE	ZAPI CODE
SOFTWARE ERROR	MC is not closed, EB is applied, Traction/Pump, valves are disabled	Start-up	Key re-cycle	**0**	**FFE6**	**230**
SPEED FB.ERR. XX	MC is opened , EB is applied, EVP stopped	Running	Valves or Traction/Pump request	**3**	**FFA8**	**221**
WATCHDOG	MC is opened, EB applied, traction/pump stopped	Stand-by, running	Key re-cycle	8	**6010**	8
CONTROLLER MISM.	MC is not closed, EB applied, Traction/Pump, valves stopped	Start-up	Install the correct software and Key re-cycle	12	**FFEF**	239
EEPROM KO	Controller works using default parameters	Start-up, stand-by, running		13	**3610**	208
PARAM RESTORE	No effect	Start-up	Traction/Pump request	14	**3611**	209
SP MISMATCH XX	MC is opened, EB applied, traction/pump stopped	Running	Key re-cycle	15	**FFF2**	242
OUT MISMATCH XX	MC is opened, EB applied, traction/pump stopped	Running	Key re-cycle	16	**FFE3**	227
LOGIC FAILURE #3	MC is opened, EB applied, traction/pump stopped	Stand-by	Valves or Traction/Pump request	17	**FF11**	17
LOGIC FAILURE #1	MC is opened, EB applied, traction/pump stopped	Stand-by, running	Valves or Traction/Pump request	19	**5114**	19
INPUT MISMATCH	MC is opened, EB applied, Traction/Pump stopped	Start-up, standby, running	Key re-cycle	58	**FFD5**	213
W.SET. TG-EB XX	Traction/Pump motor is stopped	Start-up, stand-by, running	Key re-cycle	59	**FFD4**	212
NO CAN MSG.	MC is opened, EB applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	67	**8130**	248
NO CAN MSG DISP		Start-up, stand-by, running		**66**	**FFC5**	**196**
NO CAN WR MSG.XX	No effect	Start-up, stand-by, running		67	**8131**	229

Error Code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN CODE	ZAPI CODE
WRONG RAM MEM.	MC is opened, EB applied, Traction/Pump, valves stopped	Stand-by	Key re-cycle	71	FFD2	210
VDC LINK OVERV.	MC is not closed, EB applied, Traction/Pump, valves stopped	Stand-by, running	Valves or Traction/Pump request	77	FFCA	202
WRONG FBSENS.SET	MC is not closed, EB applied, Traction/Pump, valves stopped	Start-up	Key re-cycle	85	FF51	201
STEER SENSOR KO	EB applied, traction/pump stopped	Start-up, stand-by, running	Key re-cycle	95	FFC3	200
ANALOG INPUT	MC is opened, EB applied, traction/pump stopped	Stand-by, running	Key re-cycle	96	FFFA	237
STO-SS1 ALARM XX	MC is opened, EB is applied, Traction/Pump is disabled	Running	Alarm reset input and new traction request	97	FFF3	199
SAFETY DIAG. XX	MC is opened, EB is applied, Traction/Pump is disabled	Start-up, standby, running	Key re-cycle	98	FFF4	195
SAFETY SW. XX	MC is opened, EB is applied, Traction/Pump is disabled	Start-up, standby, running	Key re-cycle	98	FFF5	194
SAFETY WARN. XX	Traction might be disabled (according to alarm code)	Running	Key re-cycle or release all input commands (according to alarm code)	98	FFF6	193
SAFETY INIT. XX	MC is not closed, EB is applied, Traction/Pump is disabled	Start-up	Key re-cycle	98	FFF7	192

10.4.1 Troubleshooting of alarms from supervisor microcontroller

ANALOG INPUT *(MDI/LED code = 96)*

Cause:

This alarm occurs when the A/D conversion of the analog inputs returns frozen values, on all the converted signals, for more than 400 ms. The goal of this diagnosis is to detect a failure in the A/D converter or a problem in the code flow that skips the refresh of the analog signal conversion.

Troubleshooting

If the problem occurs permanently it is necessary to replace the logic board.

CONTROLLER MISM. *(MDI/LED code = 12)*

Cause:

The software is not compatible with the hardware. Each controller produced is “signed” at the end of line test with a specific code mark saved in EEPROM according to the customized part number.

According with this “sign”, only the customized firmware can be uploaded.

Troubleshooting

Upload the correct firmware.

Ask for assistance to a Zapi technician in order to verify that the firmware is correct.

EEPROM KO *(MDI/LED code = 13)*

Cause:

A HW or SW defect of the non-volatile embedded memory storing the controller parameters. This alarm does not inhibit the machine operations, but it makes the truck to work with the default values.

Troubleshooting:
Execute a CLEAR EEPROM procedure (refer to the Console manual). Switch the key off and on to check the result. If the alarm occurs permanently, it is necessary to replace the controller. If the alarm disappears, the previously stored parameters will be replaced by the default parameters.

INPUT MISMATCH XX *(MDI/LED code = 58)*
Cause:
The supervisor microcontroller records different input values with respect to the master microcontroller. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting:
Compare the values read by master and slave through the TESTER function.
Ask for the assistance to a Zapi technician.
If the problem is not solved, replace the logic board.

LOGIC FAILURE #1 *(MDI/LED code = 19)*
Cause
The controller detects an under-voltage condition at the KEY input A3 (A1). Under-voltage threshold depends on the controller version.

Nominal voltage	**24 V, 36 V, 48 V**	**80 V, 96 V**
Under-voltage threshold	10 V	30 V

Troubleshooting (fault at startup or in standby)
Fault can be caused by a key input signal characterized by pulses below the under-voltage threshold, possibly due to external loads like DC/DC converters starting-up, relays or contactors during switching periods, solenoids energizing or de-energizing. Consider to remove such loads.
If no voltage transient is detected on the supply line and the alarm is present every time the key switches on, the failure probably lies in the controller hardware. Replace the logic board.

Troubleshooting (fault displayed during motor driving)
If the alarm occurs during motor acceleration or when there is a hydraulic-related request, check the battery charge, the battery health and power-cable connections.

LOGIC FAILURE #3 *(MDI/LED code = 17)*
Cause
A hardware problem in the logic board due to high currents (overload). An overcurrent condition is triggered even if the power bridge is not driven.

Troubleshooting
The failure lies in the controller hardware. Replace the controller.

NO CAN MSG DISP *(MDI/LED code = 66)*
Cause
CAN bus communication with the display does not work properly. Upon this alarm, economy mode is activated by default.

Troubleshooting
Verify the CAN bus network and the display connected to it.
By a multimeter check the impedance between CANH and CANL; it shall be 60 Ω.
If the alarm persists, replace the logic board.

NO CAN MSG. XX *(MDI/LED code = 67)*
Cause
CAN bus communication does not work properly. The hexadecimal value "XX" identifies the faulty node.

Troubleshooting
Verify the CAN bus network (external issue).
Replace the logic board (internal issue).

NO CAN WR MSG.XX *(MDI/LED code = 67)*
Cause
CAN bus communication does not work properly. The hexadecimal value "XX" identifies the faulty node.

Troubleshooting
Verify the CAN bus network (external issue).
Replace the logic board (internal issue).

OUT MISMATCH XX *(MDI/LED code = 16)*
Cause:
This is a safety related test. Supervisor microcontroller has detected that master microcontroller is driving traction motor in a wrong way (not corresponding to the operator request). The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting:
Checks the matching of the parameters between Master and Supervisor.
Ask for assistance to a Zapi technician.
If the problem is not solved, replace the logic board.

PARAM RESTORE *(MDI/LED code = 14)*
Cause:
The controller has restored the default settings. If a CLEAR EEPROM has been made before the last key re-cycle, this warning informs you that EEPROM was correctly cleared.

Troubleshooting:
A travel demand or a pump request cancels the alarm.
If the alarm appears at key-on without any CLEAR EEPROM performed, replace the controller.

SAFETY DIAG. XX *(MDI/LED code = 98)*
Cause
One of the EN1175-related related diagnoses has failed. The hexadecimal value "XX" identifies which one.

- 01: Truck accelerating from standstill.
- 02: Truck moving for longer than 0.5 m from standstill.
- 04: No braking.
- 08: Speed in excess of the maximum allowed speed in the current mode.
- 10: Wrong direction.
- 20: Speed in excess of the maximum speed.
- 40: Setpoint mismatch.
- 80: Too steep braking ramp.

Troubleshooting
Ask for assistance to a Zapi technician

SAFETY SW. XX *(MDI/LED code = 98)*
Cause
One of the safety related modules has reported an error. The hexadecimal value "XX" facilitates Zapi technicians identifying the faulty module.

Troubleshooting
Ask for assistance to a Zapi technician.

SAFETY INIT. XX *(MDI/LED code = 98)*
Cause
One of the safety related modules has reported an error during its initialization. The hexadecimal value "XX" facilitates Zapi technicians identifying the faulty module.

Troubleshooting
Check the parameters, especially regarding the motor configuration (e.g. ENCODER PULSES 1/2, MOTOR P. PAIRS 1/2, etc…)
If the problem persists, ask for assistance to a Zapi technician.

SAFETY WARN. XX (*MDI/LED code = 98*)
Cause
Mismatch in the setpoint calculation between the Application Layer and the EN1175 SW Layer. The hexadecimal value "XX" identifies the issue.
01: Application setpoint is greater than the EN1175 setpoint.
02: Application setpoint is opposite to the EN1175 setpoint

Troubleshooting
Ask for assistance to a Zapi technician.

SOFTWARE ERROR *(MDI/LED code = 0)*
Cause:
This alarm can occur only by setting DEBUG CANMESSAGE = 15 under SPECIAL ADJUSTMENTS (paragraph 8.2.3). The alarm returns the code relative to the fail of specific software portions. To be reported to Zapi technicians for dedicated debug of the software.

SP MISMATCH XX *(MDI/LED code = 15)*
Cause:
This is a safety related test. The supervisor microcontroller has detected a mismatch in the speed set-point with respect to the master microcontroller. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting:
Ask for assistance to a Zapi technician.
If the problem is not solved, replace the logic board.

SPEED FB.ERR. XY *(MDI/LED code = 3)*
Cause
An issue with the speed or position feedback sensor is detected. The hexadecimal value "XY" helps to identify the nature of the problem: the first digit "X" encodes the type of feedback sensor, the second digit "Y" encodes the type of issue.

X	Sensor
0	Encoder
1	Sin/cos
3	Encoder + index
5	Resolver
6	3-Hall
7	PWM

Y	Issue
1	Generic error 1
2	Generic error 2
3	Generic error 3
4	Generic error 4
5	Signals off
6	Swapped signals
7	Shorted signals or one is absent
8	Signal amplitude
9	Signal amplitude (supervisor µC)
A	Too large speed step
B	SSL (sensorless speed loop)
C	Signals are filtered out
D	Free
E	Free
F	Free

Troubleshooting
Check both the electric and the mechanical functionality of the sensor.
Check the wires crimping.
Check the mechanical installation of the sensor; the issue may be it slips inside its housing.
The electromagnetic noise on the sensor can be a cause. In this case try to replace the sensor.
If the problem is still present after replacing the sensor, the failure is most likely in the controller; replace it.

STEER SENSOR KO *(MDI/LED code = 95)*
Cause:
The voltage read by the microcontroller at the steering-sensor input is not within the range from STEER RIGHT VOLT to STEER LEFT VOLT, programmed through the STEER ACQUIRING function (see paragraph 9.3).

Troubleshooting:
Acquire the maximum and minimum values from the steering potentiometer through the STEER ACQUIRING function.
Check the mechanical calibration and the functionality of the potentiometer.
If the problem is not solved, replace the logic board.

STO-SS1 ALARM XX *(MDI/LED code = 97)*
Cause
Either the STO or the SS1 procedure has reported an alarm. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting
The fault condition could be due to a timeout of the STO or SS1 procedure; the braking took too long.
Check if the truck follows the imposed braking ramp and ask for assistance to a Zapi technician.
In case the problem is not solved, replace the logic board.

VDC LINK OVERV. *(MDI/LED code = 77)*
Cause
This fault is displayed when the controller detects an overvoltage condition. Overvoltage threshold depends on the nominal voltage of the controller.

Nominal voltage	**24 V**	**36 V, 48 V**	**80 V**	**96 V**
Overvoltage threshold	35 V	72.5 V	115 V	125 V

As soon as the fault occurs, power bridge and MC are opened. The condition is triggered using the same HW interrupt used for under-voltage detection, microcontroller discerns between the two evaluating the voltage present across DC-link capacitors:
High voltage → Overvoltage condition
Low/normal voltage → Under-voltage condition

Troubleshooting
If the alarm happens during the brake release, check the line contactor contact and the battery power-cable connection.

W.SET. TG-EB XX *(MDI/LED code = 59)*
Cause:
Supervisor microcontroller has detected that the master microcontroller has imposed a wrong set-point for the main contactor output or for the electromechanical brake output. The hexadecimal code “XX” helps Zapi technician debugging the problem.

Troubleshooting:
Ask for the assistance of a Zapi technician.
If the problem is not solved, replace the logic board.

WATCHDOG *(MDI/LED code = 8)*
Cause:
This is a safety related test. It is a self-diagnosis test that involves the logic between master and supervisor microcontrollers.

Troubleshooting
This alarm could be caused by a CAN bus malfunctioning, which blinds master - supervisor communication.

WRONG FBSENS.SET *(MDI/LED code = 85)*
Cause
Mismatch between parameters ENCODER PULSES 1 and ENCODER PULSES 2 (see paragraph 8.2.8).

Troubleshooting
Set the two parameters with the same value, according to the adopted encoder.

WRONG RAM MEM. *(MDI/LED code = 71)*
Cause:
The algorithm implemented to check the main RAM registers finds wrong contents: the register is corrupted. This alarm inhibits the machine operations.

Troubleshooting
Try to switch the key off and then on again, if the alarm is still present replace the logic board.

10.5 Info code for electrovalves

Errors related to the EV outputs (CONT. DRV. EV, DRV. SHOR. EV, HW FAULT EV, OPEN COIL EV.) are followed by an info code which helps to spot which EV circuit is faulty.

EV outputs are coded with a decimal number:
- **01:** EV1, pin A24
- **02:** EV2, pin A25
- **03:** EV3, pin A34
- **04:** EV4, pin A35

If the same issue affects more EV outputs, the higher number is shown only.

11 RECOMMENDED SPARE PARTS

Part number	Description	Version
C12532	AMPSEAL CONNECTOR 35 pins Female	Premium
C12531	AMPSEAL CONNECTOR 23 pins Female	Standard
C16520	10 A 20 mm Control Circuit Fuse	All
C16591	FUSE PROT.CNL175 DIN INTERAS60 UL	250 A
C16586	FUSE PROT.CNL250 DIN INTERAS60 UL	300 A, 350 A
C16587	FUSE PROT.CNL300 DIN INTERAS60 UL	400 A, 450 A
C16588	FUSE PROT.CNL350 DIN INTERAS60 UL	500 A, 550 A

12 PERIODIC MAINTENANCE

For the proper and safe operation of the systems where Zapi controllers are employed, all the Zapi controllers and the surrounding elements and devices have always to be in good conditions.

Periodic checks should be carried out on the machines by qualified personnel and any replacement parts used should be original.

Beware of non-original parts.

Zapi is not responsible for any issue due to connections different from information included in this manual.

During periodic checks, if a technician finds any situation that could cause damage or compromise safety, the matter should be brought to the attention of a Zapi agent immediately. The agent will then take the decision regarding the operational safety of the machine.

Never use a vehicle with a faulty electronic controller.

Waste management: this controller has both mechanical parts and high-density electronic parts (printed circuit boards and integrated circuits); if not properly handled during waste processing, this material may become a relevant source of pollution; the disposal and recycling of this controller has to follow the local laws for these kinds of waste materials. Zapi commits itself to update its technology in order to reduce the presence of polluting substances in its products.

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13 APPENDICES

This chapter reports how to use the main Zapi tools for setting and monitoring Zapi controllers: Zapi PC CAN Console and Zapi Smart Console.

Next paragraphs provide the reader with the basic information about how to configure and change the value of the inverter parameters.

Please, contact the Zapi technicians in order to receive more detailed information and dedicated documentation about both the tools described in these appendices.

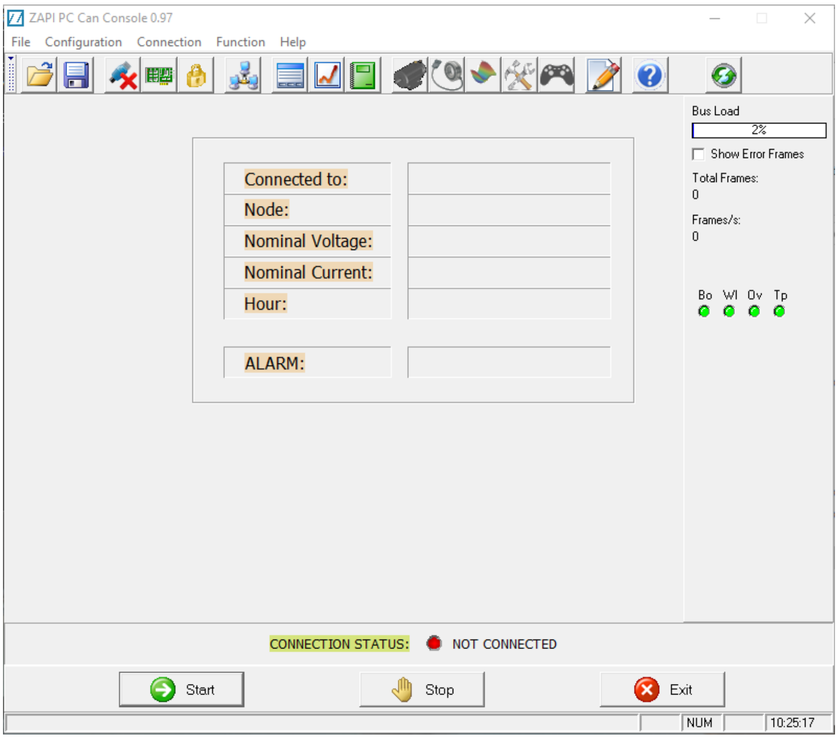
13.1 Appendix A: PC CAN Console user guide

Windows PC CAN Console uses standard Zapi communication protocol to display inverter information. It provides all the standard Zapi Console functions inside the Windows environment. Besides, Pc CAN Console offers the possibility of saving parameter configurations into a file and restoring them onto the control afterwards.

First, PC CAN Console must be installed launching "setup.exe".

13.1.1 PC CAN Console configuration

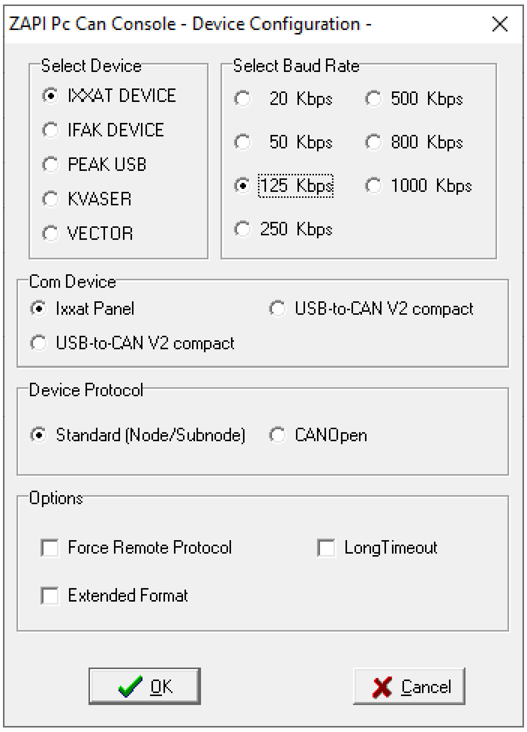
Running the PC Can Console software, the following window appears:



ZAPI PC CAN Console: main screen.

The first step to accomplish is to define the CAN device linked to the PC.

Click on  or “Configuration” → “Can Device” or press CTRL+C to select the USB-to-CAN device, the baud rate and the communication protocol to connect the Zapi PC CAN Console with the Zapi controller.



ZAPI PC CAN Console: device configuration

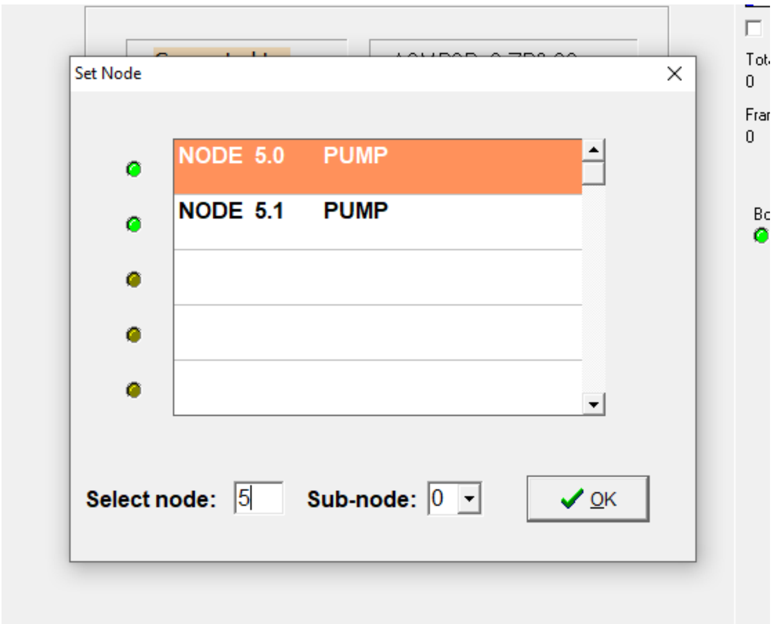
From this form you can define the CAN device in use (IXXAT, IFAK or Peak) and the communication speed.

Once you have defined the CAN interface, you have to choose which CAN device you want to connect to:

Click on  button or "Connection" → "Set Node" to select the wanted Zapi controller.

Controller type	Standard protocol		CAN protocol	
	Master MCU	Slave MCU	Master MCU	Slave MCU
Traction	2.0	2.1	8	9
Pump	5.0	5.1	20	21
CAN operated	2.0	2.1	8 (*)	9 (*)
Multi-motor traction (master)	3.0	3.1	12	13
Multi-motor traction (slave 1)	4.0	4.1	16	17
Multi-motor traction (slave 2)	20.0	20.1	80	81
Multi-motor traction (slave 3)	24.0	24.1	96	97
Generation set	18.0	18.1	72	73
C.O., multi-motor (master)	3.0	3.1	12 (*)	13 (*)
C.O., multi-motor (slave)	4.0	4.1	16 (*)	17 (*)

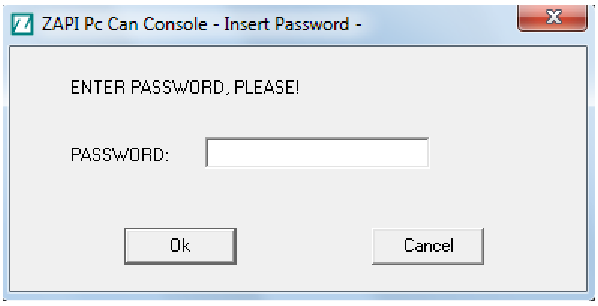
(*) For CAN operated controller types, the node numbers may vary from the default ones depending on the configurations of the ID-related inputs and settings.



ZAPI PC CAN Console: node selection.

Once selected the node and the sub-node, click on the “OK” button.

Once you have chosen the node you want to connect to, start the connection and type in the password in order to have the possibility to change the parameters. Click on  button or “Configuration” → “Enter Password”.



ZAPI PC CAN Console: password window.

Password: “ZAPI”.

Click on 

button in the main window to connect to the selected node.

13.1.2 Headline

The encoder resolution, the motor pole pairs and other pieces of information are specified by means of an head line like the following.

A4MT2B 3 ZP0.56

Where:

A4: ACE4 (B4: BLE4).
M: Master microcontroller (S: Supervisor microcontroller).
T: Traction controller (P: pump controller).
2: Motor poles pair number.

B: 64 pulses/rev encoder.

3: Zapi FOC motor control generation.

ZP0.56: Firmware version.

The encoder resolution is encoded in the last letter of the first batch as:

Code:	A	B	C	D	E	G	H
Pulses/rev:	32	64	80	128	177	256	512

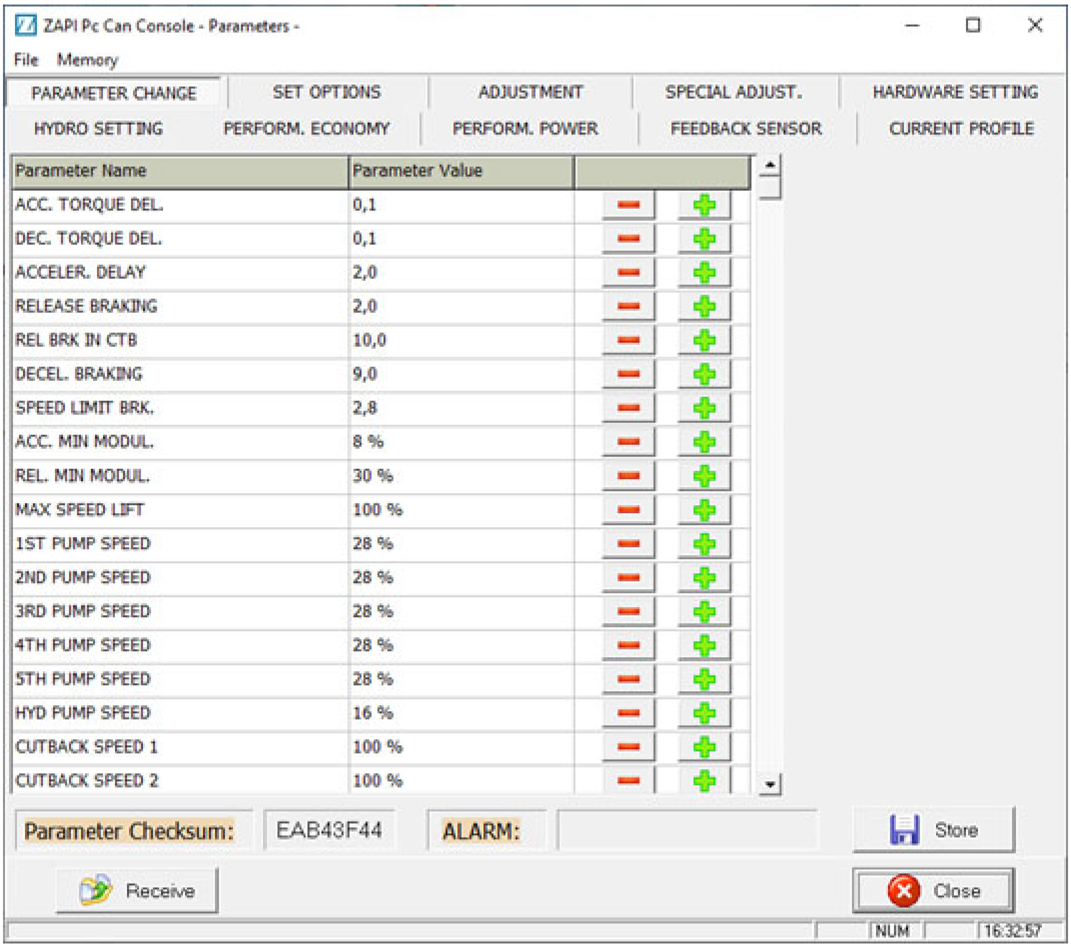
Code:	I	K	L	P	X
Pulses/rev:	1024	48	96	107	124, 143, 500, 1000

13.1.3 Parameter download

Click on  button or “Function” → “Parameters” or press CTRL+P to open the parameters window and on 

button to download the parameters and their settings.

If the password was correct, it will be allowed to change all the parameters.



ZAPI PC CAN Console: parameters window.

13.1.4 How to modify parameters

Before doing any change, save the old parameters set by clicking “File” → “Save” (give the file an understandable name for ease of future use). The complete list of parameters is saved as a csv file.

It is possible to load a previously saved parameters file in case of necessity, for example in order to restore a previous set of parameters and back-up the inverter to a stable and known working condition, or to mirror the settings from another sample of controller.

Moreover, parameters files can be opened by means of a spreadsheet reader. This is useful for debugging or crosschecking the controller settings. Nevertheless, modifications outside the CAN Console tools are not possible; .csv files are protected by checksum and changes are not accepted by the loading function of the Console.

The file contains the whole list of parameters and for each one various data are available, in particular:

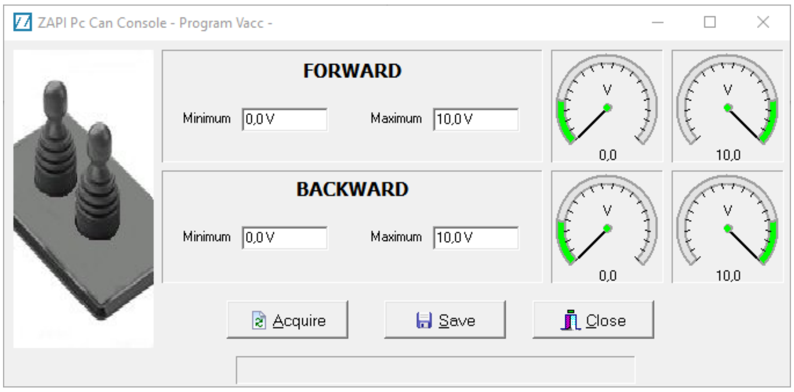
- The values as they are saved within the controller (“Value” column).
- The values as they are shown by the console or similar tools (“Scaled Value” column).
- The name of the menu containing the parameter (“Name menu” column).

From the top tabs of the parameters window of the PC CAN Console, each one dedicated to a specific subset, you can explore all the settings. It is possible to modify the values using the “+” and “–“ buttons or by the dropdown menus, depending on the content.

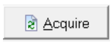
Click on the “Store” button to save the changes on each modified subset.

13.1.5 Program VACC

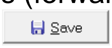
Click “Function” → “Program Vacc” or press CTRL+V to open the accelerator acquisition window.



ZAPI PC CAN Console: Program VACC function.

Click on 

button to start the acquisition procedure. By pressing the accelerator (combined with the direction switch) the referred voltage box follows the accelerator voltage. Depress the accelerator over its full range for both the directions (forward/backward).

Click on 

button to save the values acquired.

Click on 

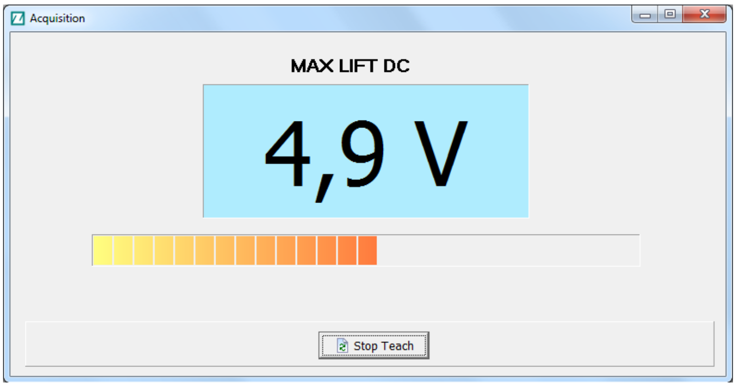
button to close the accelerator acquisition window.

13.1.6 Lift & Lower acquisition

Once you have connected to the inverter, you need to download the parameters; choose "Function" → "Parameters" menu (or press the "Parameter" icon).

Select the "ADJUSTMENT" menu.

Select the value you want to acquire by pressing the "acquiring" button and the acquisition will start:



ZAPI PC CAN Console: acquisition of analog signals

- Activate the Enable switch, if any.
- Activate the control switch (either lift or lower).
- Move the control sensor (lift/lower potentiometer) to the correct position according to what you are acquiring.
- Click "Stop Teach" button.

The procedure is the same for both lift and lower potentiometers.

13.1.7 Steering acquisition

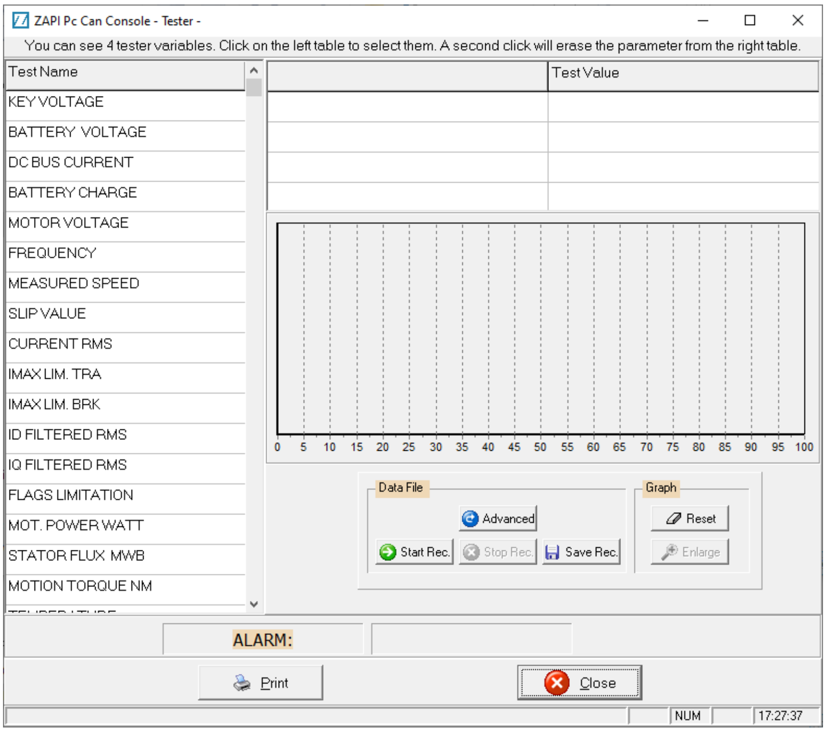
Once you have connected, you need to receive the inverter parameter; choose "Function" → "Parameter" menu (or press the "Parameter" icon).

Select the "ADJUSTMENT" menu.

Select the value to acquire by pressing "acquiring" button, the acquisition will start: the procedure is the same described for Lift & Lower acquisition in the previous paragraph.

13.1.8 Tester Functionality

Click on button or "Function" → "Tester" or press CTRL+T to open the tester window.

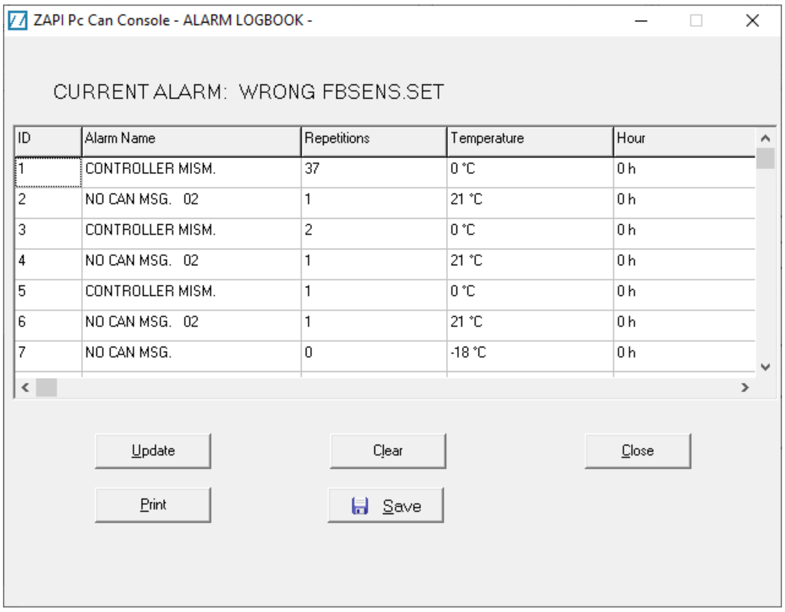


ZAPI PC CAN Console: TESTER window.

Select a variable on the left panel to start monitoring its value in the top table and its evolution on the graph. Click again to stop its monitoring.

13.1.9 Alarm Logbook

Click on  button or "Function" → "Alarm Logbook" or press CTRL+A to open the alarm logbook.



ZAPI PC CAN Console: alarm logbook.

It shows all the alarms occurred since the logbook was cleared. The alarms are recorded along with the number of occurrences, the inverter temperature and the hour-count from when the event occurred.

Click on Update button to refresh the alarms list.

Click on Clear button to clear the alarms list.

Click on Print or Save to print or export the alarms list in *.pdf or *.csv extension.

13.1.10 Monitor CAN bus

The newest versions of the CAN Console embed a function of CAN bus monitoring and trace recording useful for maintenance operations. Contact Zapi technicians to request instructions.

13.2 Appendix B: Zapi Smart Console

13.2.1 Operational Modes

Smart Console has been designed to have multiple ways of operation. Three modes can be identified:

- Serial connection powered by four standard AA size batteries placed in the battery holder of the console.
- CAN bus connection powered by four standard AA size batteries placed in the battery holder of the console.
- CAN bus connection with Smart Console supplied by an external dc source. This source may be a standard battery (lead-acid or other type) or a dc/dc converter

Current-loop serial connection

Smart Console offers the same serial connection as the well-known Console Ultra. Main features of this operational mode are:

- Current-loop serial communication.
- Console is connected to a single controller only (even if Remote Console option is available).
- Selectable baud-rate.
- Zapi can provide the serial cable compatible with Molex SPOX connector used in Console Ultra.

CAN bus connection

The Smart Console can connect to an existing CAN bus and communicate with any Zapi controller inside this bus.

Main features of this operational mode:

- It can be connected to a CAN line composed of any combination of modules, both Zapi ones and non-Zapi ones;
- Supported speeds: 125, 250, 500 kbps;
- It is able to communicate with all the CAN modules connected on the CAN line.

13.2.2 Batteries

Smart Console can operate using four AA batteries. Both rechargeable nickel metal hydride (NiMH) and alkaline batteries are supported.

The default battery type is NiMH. A mismatch with the setting of parameter BATTERY TYPE may result in a SUPPLY VOLTAGE alarm. Make sure the installed batteries and the BATTERY TYPE setting do match.

Refer to the Smart Console manual.

Do not mix different battery types. Install four batteries of the same type and with the same state of charge.

13.2.3 Keyboard

The keyboard is used to navigate through the menus. It features some keys with special functions and a green led.

The foreseen button functions are shown below.

UP and DOWN keys

The menu is a list of items ordered in rows. The selected item is highlighted in light blue.

Up and down keys are used to move the selection up and down (roll or scroll the menu).

LEFT and RIGHT keys

Normally used to increase and decrease the value of the selected item.

OK and ESC keys

OK key is used either to confirm actions or to enter a submenu.

ESC is used either to cancel an action or to exit a menu.

F1, F2, F3 keys

These buttons have a contextual use. The display will show which F button can be used and its function.

ON key

Used while operating with internal batteries.

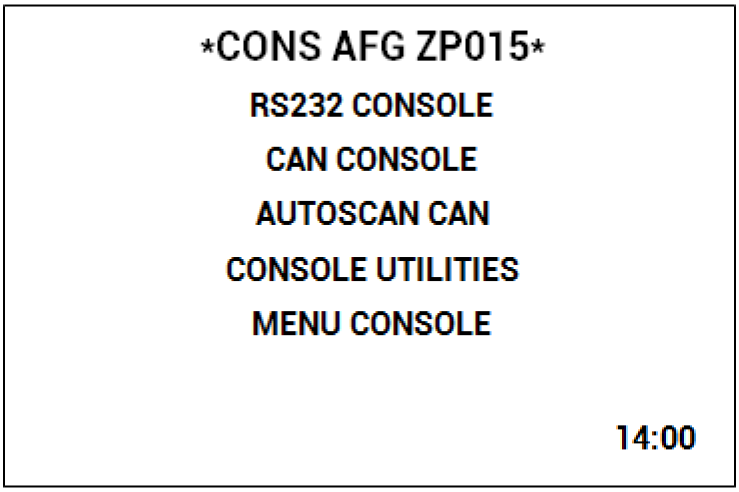
While the Smart Console is powered from external sources on pin CNX8, the ON button is deactivated regardless the presence of the internal batteries.

Green LED

When the console is powered up, the green LED is on.
Green LED can blink in certain cases which will be described better in the following sections.

13.2.4 Home Screen

After showing the Zapi logo, the HOME SCREEN will appear on the display:



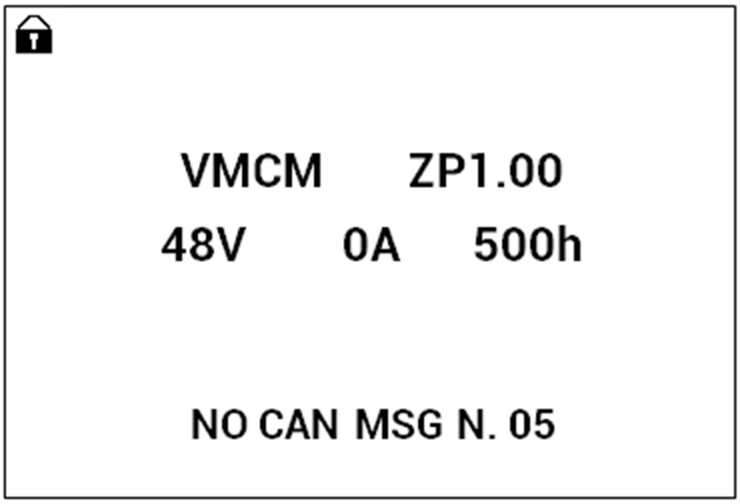
- The first line tells which firmware version is running inside the console, in this case ZP 0.15.
- RS232 Console: enter this menu to start a serial connection as in the Console Ultra.
- CAN Console: enter this menu to establish a CAN connection.
- AUTOSCAN CAN: another way to establish a CAN connection.
- Console Utilities and Menu Console: ignore them at the moment.
- The current time is shown at the bottom right.
- The green LED should be steady on.

The “RS232” console is already highlighted upon start-up. Press the OK key to start a serial connection.
Display prompts a message to inform you that a connection attempt is ongoing.
If serial connection fails a “NO COMMUNICATION” warning will pop up after some seconds: press ESC key and check for what is preventing the connection.

Please notice the red dot appearing on the top right of the display every time you press a button. It indicates that the console has received the command and it is elaborating the request. If the red dot does not appear when a button is pressed, there is probably a failure inside the keyboard or the console has stalled.

13.2.5 Main menu

If the serial or the CAN connection is successful, the display will show the main page.



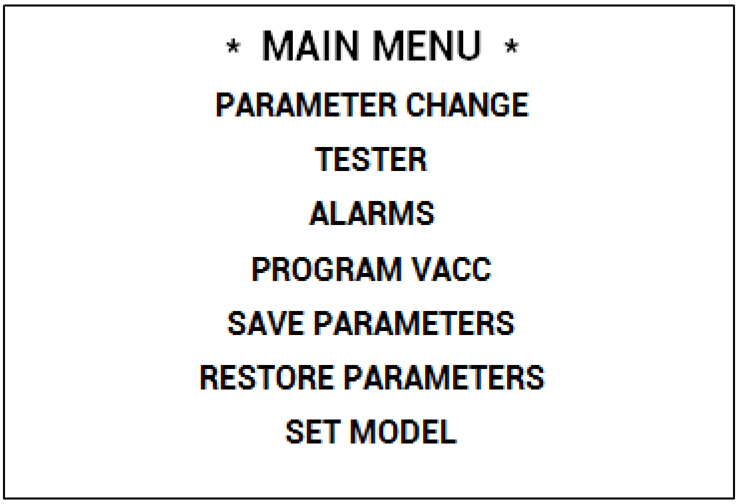
If present, a lock icon on the top left corner of the screen indicates that the console is in read-only mode: only visualization is possible, any modification to the parameters is forbidden.

Refer to the Smart Console manual for more details about the read-only mode.

This menu shows basic information about the controller, in a similar way to the console Ultra.

- First line displays the controller firmware.
- Second line shows controller voltage, controller current and hour meter.
- Last line shows the current alarm code, if any alarm is present.

Press OK to access the MAIN MENU.

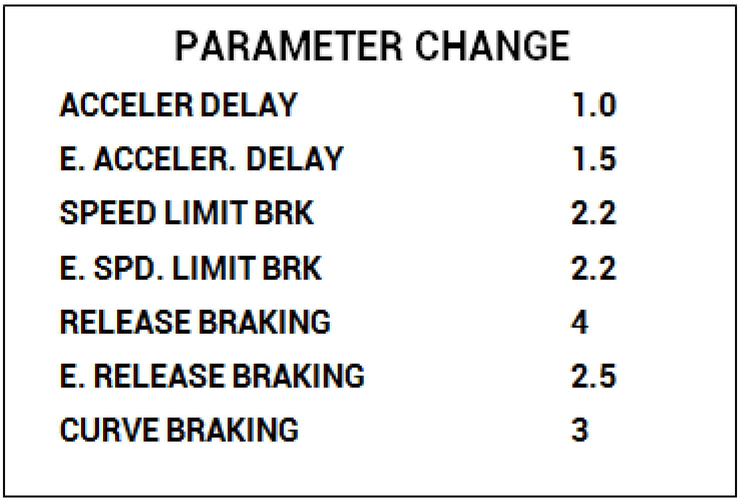


MAIN MENU contains the complete list of submenus available in the controller. Unlike the Console Ultra, here, there are no “hidden” menus which must be reached by some combinations of buttons; all menus are visible.

Use UP and DOWN keys to navigate the list: once you find the desired submenu press OK to enter it.

13.2.6 How to modify a parameter

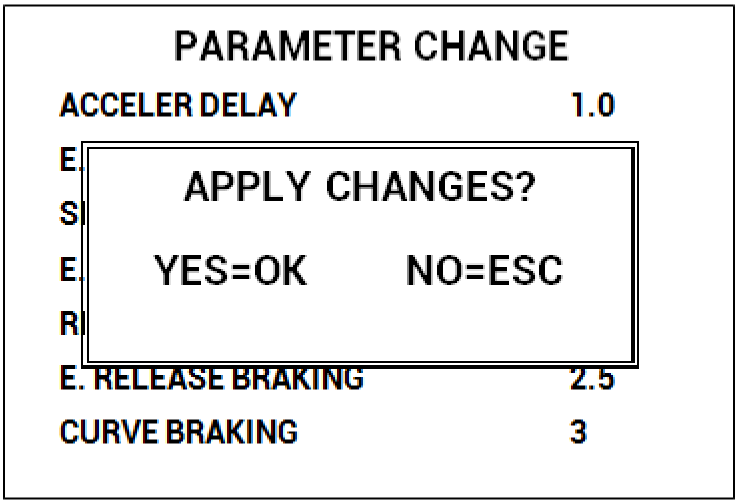
From the MAIN MENU enter the desired submenu (for example the PARAMETER CHANGE menu).



With UP and DOWN keys you can roll/scroll the whole list: once you have highlighted the parameter that you want to modify, use LEFT or RIGHT keys to decrease or increase the parameter value.

Keep the LEFT/RIGHT button pressed to increase/decrease quickly the value ("auto-repeat" function).

You can press ESC to exit the menu at any time. In case some parameter has been modified, the console will prompt a request to confirm/discard changes.



The description above applies to any menu which contains parameters and options like SET OPTIONS, ADJUSTMENTS, HARDWARE SETTINGS, etc.

13.2.7 Program VACC

PROGRAM VACC menu has been slightly modified from old consoles.
Upon entering this menu the console shows the current min and max values.

```
PROGRAM VACC
CURRENT VALUES
MAX          5.0
MIN          0.3

PRESS OK FOR SETUP
```

When OK is pressed, PROGRAM VACC procedure starts. Console invites you:

- to select the enable switch, if any;
- to select the direction switch (either forward or backward);
- to slide/rotate the potentiometer to its maximum excursion. The displayed values change while sliding/rotating the potentiometer.

Sequence above can slightly vary depending on controller firmware. Anyway the logic remains the same: before programming the min/max values, execute any starting sequence which is necessary, then press the pedal or push the joystick.

```
PROGRAM VACC

FORWARD          0.0   4.5
BACKWARD         0.2   4.4

SEL. ENABLE AND DIRECTION
THEN PRESS PEDAL
(ESC TO FINISH)
```

When ESC is pressed, the console asks if programmed values must be saved or discarded.

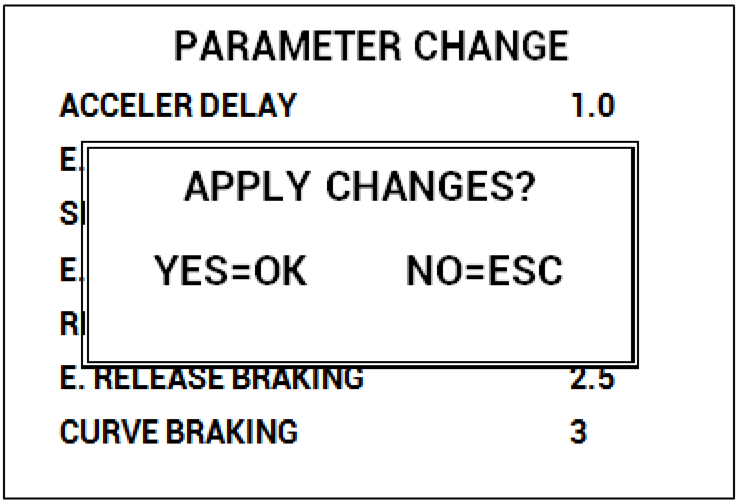
13.2.8 Lift & Lower acquisition

From MAIN MENU go into the Adjustment submenu.
With UP and DOWN keys you can scroll the list: once you have highlighted the value you want to acquire (MIN LIFT, MAX LIFT, MIN LOWER or MAX LOWER), press OK.
By pressing OK, the procedure starts:

- select the enable switch, if any;
- select the control switch, if any (either lift or lower);
- slide the control sensor (lift/lower potentiometer) to the correct position in agreement with the acquisition that you are performing. The displayed values change while sliding/rotating the potentiometer.

The sequence above can slightly vary depending on controller firmware. Anyway the main steps remain the same: before programming the min/max values, execute the starting sequence where foreseen, then press the pedal or push the joystick or slide/rotate the button.

It is possible to acquire all the values in only one session.
At the end, you can press ESC and the console will prompt a request to confirm or discard the changes.



13.2.9 Steer command acquisition

From MAIN MENU go into the ADJUSTMENT submenu.
The procedure to follow is the same described in the previous paragraph.

13.2.10 Tester

Compared to the one of the standard console Ultra, the TESTER menu has been deeply modified. Now it shows four variables at once: use UP/DOWN keys to scroll the list.

TESTER

MOTOR VOLTAGE	0%
FREQUENCY	0
ENCODER	0
BATTERY VOLTAGE	24.5V

13.2.11 Alarms

The Smart Console can visualize on the screen up to 5 alarm codes at a time. To scroll the list use the UP/DOWN keys.

ALARMS

NO CAN MESSAGE	10h
INCORRECT START	2h
NONE	0h
NONE	0h
NONE	0h

F1 TO CLEAR LOGBOOK

Thirty is the maximum number of alarm codes which can be stored inside the controller.

Colors are used to separate recurrent alarm codes from rare events. In order of increasing frequency, alarm names can be:

- White: up to 5 occurrences
- Yellow: up to 20,
- Orange: up to 40,
- Red: more than 40.

Use UP/DOWN to select a certain alarm in the list: if OK is pressed, additional information about that alarm will be displayed.

Press F1 to cancel the alarm logbook of the controller: once pressed, the console will ask for confirmation before to permanently clear the logbook.

13.2.12 Download the parameter list into a USB stick

It is possible to download all the parameters into a USB stick exploiting the Smart Console.
To use this function, connect the Smart Console to the controller and then access the menu SAVE PARAMETER USB from the MAIN MENU.

File format

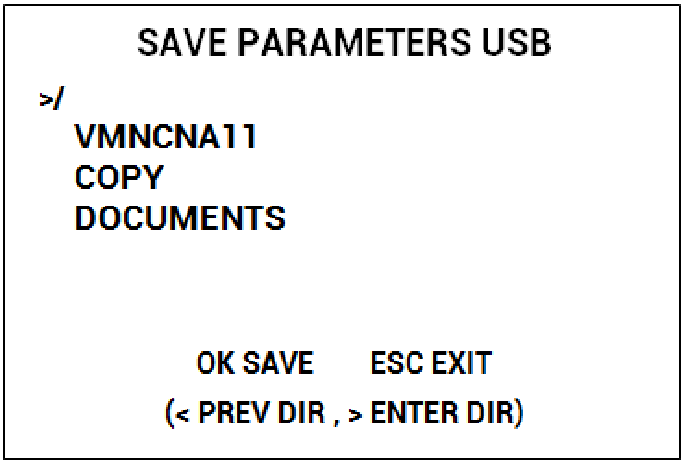
The complete list of parameters is saved as a csv file in order to be opened with Microsoft Excel® or any other spreadsheet tool.
The file is formatted in the same way as with the PC CAN Console. Thus, it contains the whole list of parameter and, for each one, various fields are available, in particular:

- Parameter value as it is saved within controller ("Value" column).
- Parameter value as it is shown by the console or similar tools ("Scaled Value" column).
- Name of the submenu where the parameter is placed ("Name menu" column).

The file name is generated as the hexadecimal code of the time and date of save. This codification prevents any overwrite of previously saved files.

Download procedure

After entering SAVE PARAMETER TO USB, the Smart Console checks the presence of a USB stick. If the stick is not connected, it asks the operator to connect one.
When the stick is present, the display shows the content, starting from the root directory (>/) of the filesystem. The display looks like the following picture.



Worth of notice is that only the directories are shown, not the single files.
While exploring the content, the navigation buttons work in the following way:

- Up/down keys scroll the list.
- Right key explores the highlighted directory: its content (directories only) will be shown immediately.
- Left key returns up one directory level: it does not work in the root directory.
- Esc returns to the HOME SCREEN.
- OK starts download.

When saving files, the console creates a subdirectory whose name consists of eight digits:

- First four digits are controller type.

- Fifth and sixth digits are the customer identification code.
- Seventh and eight digits are the code of the software installed inside the controller.

An example of this code is the first directory name (VMNCNA11) shown in the previous figure.
If parameters are downloaded multiple times from the same controller, or from another controller whose eight digit code is the same, all these parameter files are saved in the same location.
If the directory does not exist, it will be created when the download is carried out for the first time.

To download the parameters, proceed as follows:

- Navigate the directory list and go into the directory where you want to save the parameters.
- If this directory already contains the subdirectory with the correct 8 digits, go to step 3. If it is not present, a new subdirectory will be created automatically. Do not enter the subdirectory manually.
- Press OK to start the parameter download. A progression bar shows the ongoing process.
- When finished, press ESC to return to the MAIN MENU. The USB stick can then be removed safely.

Connect the USB stick to a PC and verify that the new subdirectory with the correct name and containing the csv file has been successfully generated.

During download the led blinks slowly to indicate that the console is running.

When the download is completed, the USB stick can be unplugged safely.

Do not remove USB stick during download or the file will result empty or corrupted.